SEDAR

Southeast Data, Assessment, and Review

SEDAR 77

Stock Assessment Report

HMS Hammerhead Sharks

January 2024

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

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SECTION I: Introduction

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Introduction

SEDAR 77 addressed the stock assessments for HMS Hammerhead Sharks, including great, smooth, and scalloped hammerhead sharks. The process consisted of a Stock ID Process, conducted via webinars, and in-person Data Workshop, a series of assessment webinars, and an in-person Review Workshop.

The Stock Assessment Report is organized into 6 sections. Section I – Introduction contains a brief description of the SEDAR Process, Assessment and Management Histories for the species of interest, and the management specifications requested by the Cooperator. The results of the Stock Identification Process are presented in Section II. The Data Workshop Report can be found in Section III. It documents the discussions and data recommendations from the Data Workshop Panel. Section IV contains the Assessment Process reports. This section details the assessment model, as well as documents any changes to the data recommendations that may have occurred after the data workshop. Consolidated Research Recommendations from all stages of the process can be found in Section V for easy reference. Finally, Section VI documents the discussions and findings of the Review Workshop (RW).

The final Stock Assessment Reports (SAR) for HMS Hammerhead Sharks were disseminated to the public in January 2024.

1. SEDAR Process Description

SouthEast Data, Assessment, and Review (SEDAR) is a cooperative Fishery Management Council process initiated in 2002 to improve the quality and reliability of fishery stock assessments in the South Atlantic, Gulf of Mexico, and US Caribbean. The improved stock assessments from the SEDAR process provide higher quality information to address fishery management issues. SEDAR emphasizes constituent and stakeholder participation in assessment development, transparency in the assessment process, and a rigorous and independent scientific review of completed stock assessments.

SEDAR is managed by the Caribbean, Gulf of Mexico, and South Atlantic Regional Fishery Management Councils in coordination with NOAA Fisheries and the Atlantic and Gulf States Marine Fisheries Commissions. Oversight is provided by a Steering Committee composed of NOAA Fisheries representatives: Southeast Fisheries Science Center Director and the Southeast Regional Administrator Regional Council representatives: Executive Directors and Chairs of the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; a representative from the Highly Migratory Species Division of NOAA Fisheries; and Interstate Commission representatives: Executive Directors of the Atlantic States and Gulf States Marine Fisheries Commissions.

SEDAR is typically organized around four stages. First is the Stock ID stage where meetings are held to determine the geographic biological and management boundaries of the relevant species. Second is the Data Stage, where a workshop is held during which fisheries, monitoring, and life history data are reviewed and compiled. Third is the Assessment Stage, which is conducted via a workshop and/or series of webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. The final stage is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products. The completed assessment, including the reports of all 4 stages and all supporting documentation, is then forwarded to the Cooperator foor use in management decisions.

SEDAR workshops are public meetings organized by SEDAR staff and the lead Council. Workshop participants are drawn from state and federal agencies, non-government organizations, Council members, Council advisors, and the fishing industry with a goal of including a broad range of disciplines and perspectives. All participants are expected to contribute to the process by preparing working papers, contributing, providing assessment analyses, and completing the workshop report.

2 Summary of the Management of HMS Hammerhead Sharks through 2020

Purpose of this document

This document provides a summary of the management and stock status determinations of the hammerhead sharks (great, smooth, and scalloped) in U.S. federal waters from Maine through Texas and in the Caribbean through 2020. The Carolina hammerhead shark species has only recently been defined genetically and continues to be managed under the same regulations as the other hammerhead species. This summary is provided to help the assessment scientists who are conducting the hammerhead shark stock assessment (SEDAR 77). Specific information can be found in the Federal Register notices and fishery management plans and amendments referenced throughout this document. Because management has not always been specific to hammerhead shark species, much of the history is not specific to hammerhead sharks. The following summary, to the extent possible, focuses only on those management actions that likely affected hammerhead sharks. The management measures implemented under fishery management plans and amendments are also summarized in Table 1.

Preliminary Fishery Management Plan (PMP) for Atlantic Billfish and Sharks

The U.S. Atlantic shark fisheries developed rapidly in the late 1970s due to increased demand for their meat, fins, and cartilage worldwide. At the time, sharks were perceived to be underutilized as a fishery resource. The high commercial value of shark fins led to the controversial practice of "finning," or removing the valuable fins from sharks and discarding the carcasses. Growing demand for shark products encouraged expansion of the commercial fishery throughout the late 1970s and the 1980s. Tuna and swordfish vessels began to retain a greater proportion of their shark incidental catch and some directed fishery effort expanded as well.

In January 1978, NOAA Fisheries published the Preliminary Fishery Management Plan (PMP) for Atlantic Billfish and Sharks (43 FR 3818), which was supported by an Environmental Impact Statement (EIS) (42 FR 57716). This PMP was a Secretarial effort (not conducted by the Regional Fishery Management Councils). The management measures contained in the plan were designed to:

1. Minimize conflict between domestic and foreign users of billfish and shark resources;
2. Encourage development of an international management regime; and
3. Maintain availability of billfishes and sharks to the expanding U.S. fisheries.

Primary shark management measures in the Atlantic Billfish and Shark PMP included:

- Mandatory data reporting requirements for foreign vessels;
- A hard cap on the catch of sharks by foreign vessels, which when achieved would prohibit further landings of sharks by foreign vessels;
- Permit requirements for foreign vessels to fish in an established 200-mile Fishery Conservation Zone (FCZ) of the United States (later amended and the geographical area of coverage was changed to the Exclusive Economic Zone);
- Required radio checks by foreign vessels upon entering and leaving the FCZ;
- Boarding and inspection privileges for U.S. observers; and
- Prohibition on intentional discarding of fishing gears by foreign fishing vessels within the FCZ that may pose environmental or navigational hazards.

Fishery Management Plans and Amendments

1993 Fishery Management Plan for Sharks of the Atlantic Ocean (1993 FMP)

In the 1980s, the Regional Fishery Management Councils were responsible for the management of Atlantic highly migratory species (HMS), including sharks. As catches accelerated through the 1980s, shark stocks started to show signs of decline. Peak commercial landings of large coastal and pelagic sharks were reported in 1989. In 1989, the five Atlantic Fishery Management Councils asked the Secretary of Commerce (Secretary) to develop a Shark Fishery Management Plan (FMP). The Councils were concerned about the late maturity and low fecundity of sharks, the increase in fishing mortality, and the possibility of the resource being overfished. The Councils requested that the FMP cap commercial fishing effort, establish a recreational bag limit, prohibit finning, and begin a data collection system.

On November 28, 1990, the President of the United States signed into law the Fishery Conservation Amendments of 1990 (Pub. L. 101-627). This law amended the Magnuson Fishery Conservation and Management Act (later renamed the Magnuson-Stevens Fishery Conservation and Management Act or Magnuson-Stevens Act) and gave the Secretary the authority (effective January 1, 1992) to manage HMS, including sharks, in the exclusive economic zone (EEZ) of the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea under authority of the Magnuson-Stevens

Act (16 U.S.C. §1811). This law also transferred from the Fishery Management Councils to the Secretary, effective November 28, 1990, the management authority for HMS, including sharks, in the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea (16 U.S.C. §1854(f)(3)). At this time, the Secretary delegated authority to manage Atlantic HMS to NOAA Fisheries.

After this, NOAA Fisheries in consultation with the Councils and interested parties conducted a shark stock assessment and began the process to develop a shark fishery management plan. This plan was completed and implemented in 1993. The plan was for all Atlantic sharks from Maine through Texas including the Caribbean. The management measures in the 1993 FMP included:

- Establishing a fishery management unit (FMU) consisting of 39 frequently caught species of Atlantic sharks, separated into three groups for assessment and regulatory purposes (Large Coastal Sharks (LCS); which included all hammerhead shark species, Small Coastal Sharks (SCS), and pelagic sharks)[1];
- Establishing calendar year commercial quotas for the LCS and pelagic sharks and dividing the annual quota into two equal half-year quotas that applied to the following two fishing periods – January 1 through June 30 and July 1 through December 31;
- Establishing a recreational trip limit of four sharks per vessel for LCS or pelagic shark species groups;
- Requiring that all sharks not taken as part of a commercial or recreational fishery be released uninjured;
- Establishing a framework procedure for adjusting commercial quotas, recreational bag limits, species size limits, management unit, fishing year, species groups, estimates of maximum sustainable yield (MSY), and permitting and reporting requirements;
- Prohibiting finning by requiring that the ratio between wet fins/dressed carcass weight not exceed five percent;
- Prohibiting the sale by recreational fishermen of sharks or shark products caught in the EEZ;
- Requiring annual commercial permits for fishermen who harvest and sell shark products (meat products and fins);
- Establishing a permit eligibility requirement that the owner or operator (including charter vessel and headboat owners/operators who intend to sell their catch) must show proof that at least 50 percent of earned income has been derived from that sale of fish or fish products or charter vessel and headboat operations or at least $20,000 from the sale of fish during one of three years preceding the permit request;
- Requiring trip reports by permitted fishermen and persons conducting shark tournaments and requiring fishermen to provide information to NOAA Fisheries under the Trip Interview Program; and,
- Requiring NOAA Fisheries observers on selected shark fishing vessels to document mortality of marine mammals and endangered species.

At that time, NOAA Fisheries identified LCS as overfished and established the commercial quota at 2,436 metric tons (mt) dressed weight (dw) based on a 1992 stock assessment. Under the rebuilding plan established in the 1993 FMP, the LCS quota was expected to increase in 1994 and 1995 up to the MSY estimated in the 1992 stock assessment (3,800 mt dw).

In 1994, under the rebuilding plan implemented in the 1993 FMP, the LCS quota was increased to 2,570 mt dw. Additionally, a new stock assessment was completed in March 1994. This stock assessment focused on LCS, suggested that recovery to the levels of the 1970s could take as long as 30 years, and concluded that "increases in the [Total Allowable Catch (TAC)] for

[1] At that time, hammerhead sharks were managed within the large coastal shark complex.

sharks [are] considered risk-prone with respect to promoting stock recovery." A final rule that capped quotas for LCS at the 1994 levels was published on May 2, 1995 (60 FR 21468).

1999 Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks (1999 FMP)

In June 1996, NOAA Fisheries convened another stock assessment to examine the status of LCS stocks. The 1996 stock assessment found no clear evidence that LCS stocks were rebuilding and concluded that "[a]nalyses indicate that recovery is more likely to occur with reductions in effective fishing mortality rate of 50 [percent] or more." In addition, in 1996, amendments to the Magnuson-Stevens Act modified the definition of overfishing and established new provisions to halt overfishing and rebuild overfished stocks, minimize bycatch and bycatch mortality to the extent practicable, and identify and protect essential fish habitat. Accordingly, in 1997, NOAA Fisheries began the process of creating a rebuilding plan for overfished HMS, including LCS, consistent with the new provisions. In addition, in 1995 and 1997, new quotas were established for LCS and SCS.

In June 1998, NOAA Fisheries held another LCS stock assessment. The 1998 stock assessment found that LCS were overfished and would not rebuild under 1997 harvest levels. Based in part on the results of the 1998 stock assessment, in April 1999, NOAA Fisheries published the final 1999 FMP, NOAA Fisheries had issued two separate FMPs in April 1999 for the Atlantic HMS fisheries. The 1999 Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks combined, amended, and replaced previous management plans for swordfish and sharks(1993 FMP), and was the first FMP for tunas. Amendment 1 to the Billfish Management Plan updated and amended the 1988 Billfish FMP. Management measures related to sharks that changed in the 1999 FMP included:

- Reducing commercial LCS quotas;
- Establishing ridgeback (e.g., sandbar; *Carcharhinus plumbeus*) and non-ridgeback (e.g., hammerhead species; family *Sphyrnidae*) categories of LCS;
- Implementing a commercial minimum size of 4.5 feet fork length for ridgeback LCS;
- Reducing recreational retention limits for all sharks to 1 shark/vessel/trip;
- Establishing a recreational minimum size of 54" fork length for all sharks except Atlantic sharpnose;
- Establishing essential fish habitat (EFH) for 39 species of sharks;
- Implementing HMS limited access permits (LAPs) in commercial fisheries;
- Establishing a shark public display quota;
- Establishing new procedures for counting dead discards as well as state landings of sharks after Federal fishing season closures against Federal quotas; and,
- Establishing season-specific over- and underharvest adjustment procedures.

The implementing regulations were published on May 28, 1999 (64 FR 29090). However, in 1999, a court enjoined implementation of the 1999 regulations as they related to the ongoing litigation on the 1997 quotas. As such, many of the regulations in the 1999 FMP had a delayed implementation or were never implemented. These changes are explained below under Section 2.0.

2003: Amendment 1 to the 1999 FMP for Atlantic Tunas, Swordfish, and Sharks (Amendment 1)

In 2002, additional LCS stock assessments were conducted. Based on these assessments, NOAA Fisheries re-examined many of the shark management measures in the 1999 FMP for Atlantic Tunas, Swordfish, and Sharks. The changes in Amendment 1 affected all aspects of shark management. The final management measures (December 24, 2003, 68 FR 74746) selected in Amendment 1 included, among other things:

- Re-aggregating the large coastal shark complex;
- Dividing LCS and SCS between three regions: South Atlantic, North Atlantic, and Gulf of Mexico. The South Atlantic region included all waters east of the Gulf of Mexico region north to the border between North Carolina and Virginia roughly 36°30’ N. lat. including the waters surrounding the Caribbean. The North Atlantic region included all waters north of the North Carolina and Virginia border at roughly 36°30’ N. lat. The Gulf of Mexico region included all waters of the U.S. EEZ west and north of the boundary stipulated at 50 CFR 600.105(c);
- Using maximum sustainable yield as a basis for setting commercial quotas;
- Eliminating the commercial minimum size;
- Establishing regional commercial quotas and trimester commercial fishing seasons, adjusting the recreational bag and size limits, and establishing gear restrictions to reduce bycatch or reduce bycatch mortality;
- Establishing a time/area closure off the coast of North Carolina to reduce fishing mortality of dusky sharks and juvenile sandbar sharks;
- Updating EFH identifications for sandbar, blacktip, finetooth, dusky, and nurse sharks; and,
- Changing the administration for issuing permits for display purposes.

2006 Consolidated HMS FMP

The 2006 Consolidated HMS FMP consolidated the management of all Atlantic HMS into one comprehensive FMP, adjusted the regulatory framework measures, continued the process for updating HMS EFH, and combined and simplified the objectives of the previous FMPs.

In 2005, NOAA Fisheries released the draft Consolidated HMS FMP. In July 2006, the final Consolidated HMS FMP was completed and the implementing regulations were published on October 2, 2006 (71 FR 58058). Measures that were specific to the shark fisheries included:

- Mandatory workshops and certifications for all vessel owners and operators that have pelagic longline or bottom longline gear on their vessels and that had been issued or were required to be issued any of the LAPs to participate in HMS longline and gillnet fisheries. These workshops provide information and ensure proficiency with using required equipment to handle release and disentangle sea turtles, smalltooth sawfish, and other non-target species;
- Mandatory Atlantic shark identification workshops for all federally permitted shark dealers to train shark dealers to properly identify shark carcasses;
- Differentiation between pelagic longline and bottom longline gear based upon the species composition of the catch onboard or landed;
- The requirement that the 2nd dorsal fin and the anal fin remain on all sharks through landing; and,
- Prohibition on the sale or purchase of any HMS that was offloaded from an individual vessel in excess of the retention limits specified in §§ 635.23 and 635.24.

2008: Amendment 2 to the 2006 Consolidated HMS FMP

In 2005/2006, new stock assessments were conducted on the LCS complex, sandbar, blacktip, porbeagle, and dusky sharks. On April 10, 2008, NOAA Fisheries released the Final EIS for Amendment 2 to the 2006 Consolidated HMS FMP, which implemented management measures based on the results of those assessments. The implementing regulations were published on June 24, 2008 (73 FR 35778; corrected version published July 15, 2008; 73 FR 40658). Management measures implemented in Amendment 2 included:

- Establishing a boundary between the Gulf of Mexico region and the Atlantic region, defined as a line beginning on the east coast of Florida at the mainland at 25°20.4' N. lat., proceeding due east. Any water and land to the south and west of that boundary was considered within the Gulf of Mexico. Any water and land to the north and east of that boundary line was considered within the Atlantic region.
- Implementing commercial quotas of 188.3 mt dw for Atlantic non-sandbar LCS and 493.5 mt dw for Gulf of Mexico non-sandbar LCS (non-sandbar LCS includes hammerhead shark species along with other LCS);
- Establishing a 33 non-sandbar LCS per trip retention limit for directed permit holders and a 3 non-sandbar LCS per trip retention limit for incidental permit holders;
- Requiring that all Atlantic sharks be offloaded with fins naturally attached;
- Collecting shark life history information via the implementation of a shark research fishery and establishing a non-sandbar LCS quota (including hammerhead shark species) of 50 mt dw for the shark research fishery; and
- Prohibiting the retention of sandbar sharks in the recreational fisheries and in the commercial fisheries unless participants were part of the shark research fishery.

2010: Amendment 3 to the 2006 Consolidated HMS FMP (Amendment 3)

On June 1, 2010 (75 FR 30484), NOAA Fisheries published the final rule for Amendment 3 to the 2006 Consolidated HMS FMP. This Amendment focused on management for small coastal sharks, porbeagle sharks, and smoothhound sharks. While the measures were not specific to hammerhead shark species, some of them may have resulted in fishermen changing fishing practices, particularly those fishermen who used gillnet gear. The major measures that might have affected hammerhead shark fishing were:

- Establishing new SCS commercial complexes and quotas (Non-blacknose SCS: 221.6 mt dw and blacknose shark: 19.9 mt dw);
- Linking the non-blacknose SCS and blacknose shark fisheries so that both fisheries close when landings of either reaches 80 percent of its quota; and
- Maintain all currently authorized gear types for the Atlantic shark fishery including gillnet gear (prohibiting gillnet gear from South Carolina south had been proposed).

2010: Amendment 5a to the 2006 Consolidated HMS FMP (Amendment 5a)

On July 3, 2013 (78 FR 40318), NOAA Fisheries published the final rule for Amendment 5a to the 2006 Consolidated HMS FMP. This Amendment focused on management for hammerhead sharks, Gulf of Mexico blacktip sharks, and blacknose sharks. In October 2009, Hayes et al. (2009) published in the North American Journal of Fisheries Management a stock assessment of the Atlantic population of scalloped hammerhead sharks in U.S. waters. NOAA Fisheries reviewed this paper and concluded that: the assessment was complete; the assessment was an improvement over a 2008 aggregated species assessment for hammerhead sharks; and the assessment was appropriate for U.S. management decisions (76 FR 23794; April 28, 2011). Based on the results of this paper, NOAA Fisheries determined on April 28, 2011 that scalloped hammerhead sharks were overfished and experiencing overfishing (76 FR 23794). Due to difficulties in species identification, NOAA Fisheries implemented management measures consistent with the scalloped hammerhead shark stock assessment for all hammerhead shark species (great, smooth, scalloped, and Carolina). The major measures that might have affected hammerhead shark fishing were:

- In the Atlantic region, removed hammerhead sharks from the non-sandbar LCS management group quota, which became renamed the Atlantic aggregated LCS management group (included Atlantic blacktip, bull, lemon, nurse, silky, spinner, and tiger sharks), and established separate quota for hammerhead sharks;
- Established the Atlantic hammerhead shark (great, smooth, scalloped, and Carolina) commercial quota at 27.1 mt dw;
- In the Gulf of Mexico, removed hammerhead and blacktip sharks from the non-sandbar LCS management group quota, and established separate Gulf of Mexico quotas for blacktip and hammerhead sharks;
- Established the Gulf of Mexico hammerhead shark (great, smooth, scalloped, and Carolina) commercial quota at 25.3 mt dw;
- Implemented regional quota linkages between management groups whose species are often caught together in the same fisheries to prevent exceeding the new established quotas through discarded bycatch;
- Established a new recreational minimum size limit for the large hammerhead shark species (great, smooth, scalloped, and Carolina) of 78 inches (6.5 feet) fork length; and
- Maintained the size and retention limits for other shark species.

2015: Amendment 6 to the 2006 Consolidated HMS FMP (Amendment 6)

On September 16, 2011 (76 FR 57709), NOAA Fisheries published a notice of intent (NOI) that announced NOAA Fisheries' intent to prepare an EIS and FMP Amendment that would consider catch shares for the Atlantic shark fisheries. The NOI also established a control date for eligibility to participate in an Atlantic shark catch share program, announced the availability of a white paper describing design elements of catch share programs in general and issues specific to the Atlantic shark fisheries, and requested public comment on the implementation of catch shares in the Atlantic shark fisheries. NOAA Fisheries received comments on a variety of modifications to the existing management structure for the Atlantic shark fisheries, including programs such as catch shares, limited access privilege programs (LAPPs), individual fishing quotas (IFQs), and/or sectors. In addition, for allocation purposes, fishermen requested that sandbar sharks landings be included when determining the landings history of fishermen. Fishermen also requested, if an IFQ allocation was implemented, that the sandbar research quota be equally distributed to all qualified shark fishermen and that they would be allowed to land all sandbar sharks caught in the research fishery.

On August 18, 2015 (80 FR 50074), NOAA Fisheries published the final rule for Amendment 6 to the 2006 Consolidated HMS FMP. In the final rule, NOAA Fisheries did not implement any catch share program. While the measures that were finalized were not specific to hammerhead sharks, some of them may have resulted in fishermen changing fishing practices, particularly for fishermen using gillnet. The major measures that might have affected hammerhead shark fishing were:

- Increasing the LCS retention limit for directed permit holders to a maximum of 55 LCS other than sandbar sharks per trip (including hammerhead sharks) and setting the default LCS retention limit for directed permit holders to 45 LCS other than sandbar sharks per trip;
- Modifying quota linkages between blacknose and non-blacknose SCS in both the Atlantic and Gulf of Mexico regions;
- Modifying the TACs and commercial quotas for non-blacknose SCS in both the Atlantic and Gulf of Mexico regions;
- Establishing a management boundary in the Atlantic region along 34° 00’ N. lat. (approximately at Wilmington, North Carolina) for the SCS fishery;
- Maintaining SCS quota linkages south of the 34° 00 N. lat. management boundary; and prohibiting the harvest and landings of blacknose sharks north of the 34° 00’ N. lat. management boundary;
- Apportioning the Gulf of Mexico regional commercial quotas for aggregated LCS, blacktip, and hammerhead sharks into western and eastern sub-regional quotas along 88° 00’ W. long.;
- Establishing the western Gulf of Mexico sub-region hammerhead shark (great, smooth, scalloped, and Carolina) commercial quota at 11.9 mt dw;
- Establishing the eastern Gulf of Mexico sub-region hammerhead shark (great, smooth, scalloped, and Carolina) commercial quota at 13.4 mt dw; and
- Removing the upgrading restrictions for shark LAP holders.

2015: Amendment 9 to the 2006 Consolidated HMS FMP (Amendment 9)

On November 24, 2015 (80 FR 73128), NOAA Fisheries published the final rule for Amendment 9 to the 2006 Consolidated HMS FMP. This Amendment focused on management for smoothhound sharks. While the measures were not specific to hammerhead shark species, some of them may have resulted in fishermen changing fishing practices, particularly those fishermen who used gillnet gear. The major measures that might have affected hammerhead shark fishing were:

- Modifying the TACs and commercial quotas for smoothhound sharks in both the Atlantic and Gulf of Mexico regions;
- Establishing a soak time limits for the sink and drift gillnet gear in the Atlantic shark and smoothhound shark fisheries;
- Requiring Federal directed shark permit holders with gillnet gear on board to use VMS only in the Southeast U.S. Monitoring Area, pursuant to Atlantic Large Whale Take Reduction Plan requirements; and
- Implementing the smooth dogfish-specific measures in the Shark Conservation Act of 2010. The Shark Conservation Act amended the MSA to prohibit shark finning and require all sharks in the

United States, except for smooth dogfish, to be brought to shore with their fins naturally attached. Amendment 9 established an allowance for the removal of smooth dogfish fins while at sea.

2017 Amendment 5b to the 2006 Consolidated HMS FMP (Amendment 5b)

On April 4, 2017 (82 FR 16478), NOAA Fisheries published the final rule for Amendment 5b to the 2006 Consolidated HMS FMP. While the measures were not specific to hammerhead shark species, some of them may have resulted in fishermen changing fishing practices, particularly those fishermen using recreational gear or longline gear. The major measures that might have affected hammerhead shark fishing were:

- Requiring all HMS recreational permit holders to obtain a “shark endorsement” to fish for, retain, possess, or land sharks;
- Establishing a circle hook requirement for anglers fishing recreationally for sharks south of 41°43’ N. latitude;
- Requiring Atlantic shark LAP holders fishing with pelagic longline gear to release all sharks that are not being boarded or retained by using a dehooker or by cutting the gangion less than three feet (91.4 cm) from the hook as safely as practicable; and
- Establishing a circle hook requirement in the directed shark bottom longline fishery.

2019: Amendment 11 to the 2006 Consolidated HMS FMP (Amendment 11)

In 2018, NOAA Fisheries published an emergency rule in response to ICCAT Recommendation 17-08 (83 FR 8946). The emergency measures included in this rulemaking included commercial measures for fishermen using pelagic longline gear to release all live shortfin mako sharks and retain a shortfin mako shark only if the shark is dead at haulback. Fishermen using bottom longline and gillnet gear were required to release all shortfin mako sharks alive or dead. Additionally, the minimum size of shortfin mako sharks was increased to 83 inches (210 cm) FL.

On February 21, 2019 (84 FR 5358), NOAA Fisheries published the final rule for Amendment 5b to the 2006 Consolidated HMS FMP. This Amendment focused on management for shortfin mako sharks. While the measures were not specific to hammerhead shark species, some of them may have resulted in fishermen changing fishing practices, particularly those fishermen who used gillnet gear. The major measures that might have affected hammerhead shark fishing were:

- Allowing the retention of shortfin mako sharks caught with longline or gillnet gear by persons issued a Directed or Incidental shark LAP only if the shark is dead at haulback. Retention of dead shortfin mako sharks with pelagic longline gear is allowed only if there is a functional electronic monitoring system on board the vessel; and
- Establishing the foundation for developing an international rebuilding plan for shortfin mako sharks.

2020: Amendment 14 to the 2006 Consolidated HMS FMP (Amendment 14)

On September 24, 2020 (85 FR 60132), NOAA Fisheries published a notice of availability for draft Amendment 14 to the 2006 Consolidated HMS FMP. While the potential framework management measures are not specific to hammerhead shark species, some of them could result in fishermen changing fishing practices. The potential measures that could affect hammerhead shark fishing are:

- Create a tiered Acceptable Biological Catch (ABC) control rule;
- Allow consideration of phase-in ABC control rules for any modifications in ABC;
- Actively manage all sector ACLs (commercial and recreational);
- Establish an ACL for each Atlantic shark management group, without commercial ACL quota linkages;
- Allow carry-over, and only for underharvest of the commercial quotas (landings only) under certain conditions; and
- Compare a three-year average of fishing mortality estimates to the overfishing limit to determine overfishing status.

Table 1. FMP Amendments and their implementing regulations affecting hammerhead shark species

Effective Date	FMP/Amendment	Description of Action
January 1978	Preliminary Fishery Management Plan (PMP) for Atlantic Billfish and Sharks	• Mandatory data reporting requirements for foreign vessels; and, • Established a hard cap on the catch of sharks by foreign vessels, which when achieved would prohibit further landings of sharks by foreign vessels
Most parts effective April 26, 1993, such as quotas, complexes, etc. Finning prohibition effective May 26, 1993. Need to have permit, report landings, and carry observers effective July 1, 1993.	FMP for Sharks of the Atlantic Ocean	• Established a fishery management unit (FMU) consisting of 39 frequently caught species of Atlantic sharks, separated into three groups for assessment and regulatory purposes (LCS, SCS, and pelagic sharks); • Established calendar year commercial quotas for the LCS (2,436 mt dw) and pelagic sharks (580 mt dw) and divided the annual quota into two equal half-year quotas that apply to the following two fishing periods – January 1 through June 30 and July 1 through December 31; • Established a recreational trip limit of 4 LCS & pelagic sharks/vessel ; • Prohibited finning by requiring that the ratio between wet fins/dressed carcass weight not exceed five percent; • Prohibited the sale by recreational fishermen of sharks or shark products caught in the Economic Exclusive Zone (EEZ); • Required annual commercial permits for fishermen who harvest and sell shark (meat products and fins); and, • Required trip reports by permitted fishermen and persons conducting shark tournaments and requiring fishermen to provide information to NOAA Fisheries under the Trip Interview Program. Other management measures included: establishing a framework procedure for adjusting commercial quotas, recreational bag limits, species size limits, management unit, fishing year, species groups, estimates of maximum sustainable yield (MSY), and permitting and reporting requirements; establishing a permit eligibility requirement that the owner or operator (including charter vessel and headboat owners/operators who intend to sell their catch); and requiring NOAA Fisheries observers on selected shark fishing vessels to document mortality of marine mammals and endangered species.
July 1, 1999 -Limited access permits issued immediately; application and appeals processed over the next year	FMP for Atlantic Tunas, Swordfish and Sharks	• Implemented limited access in commercial fisheries; • Reduced commercial LCS to 1,285 mt dw; • Reduced recreational retention limits for all sharks to 1 shark/vessel/trip except for Atlantic sharpnose (1 Atlantic sharpnose/person/trip); • Established a recreational minimum size for all sharks except Atlantic sharpnose (4.5 feet); • Established a shark public display quota (60 mt ww); • Established new procedures for counting dead discards and state landings of sharks after Federal fishing season closures against Federal quotas; and

Effective Date	FMP/Amendment	Description of Action
(measures in italics were delayed)		established season-specific over- and underharvest adjustment procedures *(effective January 1, 2003)*; • Established ridgeback and non-ridgeback categories of LCS (annual quotas of 783 mt dw for non-ridgeback LCS & 931 mt dw for ridgeback LCS; *effective January 1, 2003; suspended after 2003 fishing year*); and, • Implemented a commercial minimum size for ridgeback LCS (*suspended*).
February 1, 2004, except LCS and SCS quotas, and recreational retention and size limits, which were delayed	Amendment 1 to the FMP for Atlantic Tunas, Swordfish and Sharks	• Re-aggregated the large coastal shark complex; • Dividing LCS and SCS between three regions. The South Atlantic, North Atlantic, and Gulf of Mexico. The South Atlantic region included all waters east of the Gulf of Mexico region north to the border between North Carolina and Virginia roughly 36°30’ N. lat. including the waters surrounding the Caribbean. The North Atlantic region included all waters north of the North Carolina and Virginia border at roughly 36°30’ N. lat. The Gulf of Mexico region included all waters of the U.S. EEZ west and north of the boundary stipulated at 50 CFR 600.105(c); • Eliminated the commercial minimum size; • Established gear restrictions to reduce bycatch or reduce bycatch mortality (allowed only handline and rod and reel in recreational shark fishery); • Used maximum sustainable yield as a basis for setting commercial quotas (LCS quota=1,017 mt dw) (*effective December 30, 2003*); • Adjusted the recreational bag and size limits (allowed 1 bonnethead/person/trip in addition to 1 Atlantic sharpnose/person/trip with no size limit for bonnethead or Atlantic sharpnose) (*effective December 30, 2003*); • Established regional commercial quotas and trimester commercial fishing seasons (*trimesters not implemented until January 1, 2005; 69 FR 6964*); and, • Established a time/area closure off the coast of North Carolina (*effective January 1, 2005*). Other management measures included: establishing a mechanism for changing the species on the prohibited species list; updating essential fish habitat identifications for five species of sharks; requiring the use of non-stainless steel corrodible hooks and the possession of line cutters, dipnets, and approved dehooking device on bottom longline vessels; requiring vessel monitoring systems (VMS) for fishermen operating near the time/area closures off North Carolina and on gillnet vessels operating during the right whale calving season and, changing the administration for issuing display permits.
November 1, 2006, except for workshops	2006 Consolidated HMS FMP	• Differentiated between pelagic longline and bottom longline gear based upon the species composition of the catch onboard or landed; • Required that the 2nd dorsal fin and the anal fin remain on all sharks through landing; • Required mandatory workshops and certifications for all vessel owners and operators that have pelagic longline or bottom longline gear on their vessels for fishermen with HMS LAPs (*effective January 1, 2007*); and • Required mandatory Atlantic shark identification workshops for all Federally permitted shark dealers (*effective January 1, 2007*).
July 24, 2008	Amendment 2 to the 2006 Consolidated HMS FMP	• Implemented commercial quotas for Atlantic and Gulf of Mexico non-sandbar LCS of 188.3 mt dw and 439.5 mt dw, (non-sandbar LCS includes hammerhead shark species along with other LCS); • Established the Gulf of Mexico region and the Atlantic region, defined as a line beginning on the east coast of Florida at the mainland at 25°20.4’ N. lat., proceeding due east. Any water and land to the south and west of that boundary was considered within the Gulf of Mexico. Any water and land to the north and east of that boundary line was considered within the Atlantic region;

Effective Date	FMP/Amendment	Description of Action
		• Established a 33 non-sandbar LCS per trip retention limit for directed permit holders and a 3 non-sandbar LCS per trip retention limit for incidental permit holders; • Established a non-sandbar LCS quota of 50 mt dw for the shark research fishery which collects shark life history information; • Required that all Atlantic sharks be offloaded with fins naturally attached; and, • Implemented bottom longline time/area closures recommended by the South Atlantic Fishery Management Council. • Other management measures included modifying reporting requirements (dealer reports must be received by NOAA Fisheries within 10 days of the reporting period). • Prohibited the retention of sandbar sharks in the recreational fisheries and in the commercial fisheries unless participants were part of the shark research fishery
July 3, 2013	Amendment 5a to the 2006 Consolidated HMS FMP	• In the Atlantic region, removed hammerhead sharks from the non-sandbar LCS management group quota, which became renamed the Atlantic Aggregated LCS management group (included Atlantic blacktip, bull, lemon, nurse, silky, spinner, and tiger sharks) and established separate quota for hammerhead sharks; • Established the Atlantic hammerhead shark commercial quota at 27.1 mt dw; • In the Gulf of Mexico, removed hammerhead and blacktip sharks from the non-sandbar LCS management group quota, and established separate Gulf of Mexico quotas from blacktip and hammerhead sharks; • Established the Gulf of Mexico hammerhead shark commercial quota at 25.3 mt dw; • Implemented regional quota linkages between management groups whose species are often caught together in the same fisheries to prevent exceeding the new established quotas through discarded bycatch; • Established a new recreational minimum size limit for the large hammerhead shark species of 78 inches (6.5 feet) fork length; and • The size and retention limits for other shark species remained the same.
August 18, 2015	Amendment 6 to the 2006 Consolidated HMS FMP	• Modified retention limits for LCS; • Created a new management boundary for SCS in the Atlantic region; • Modified quota linkages between blacknose and non-blacknose SCS in both the Atlantic and Gulf of Mexico regions; • Modified the TACs and commercial quotas for non-blacknose SCS in both the Atlantic and Gulf of Mexico regions; • Apportioned the Gulf of Mexico regional commercial quotas for aggregated LCS, blacktip, and hammerhead sharks into western and eastern sub-regional quotas along 88° 00’ W. long.; • Established the western Gulf of Mexico sub-region hammerhead shark commercial quota at 11.9 mt dw; • Established the eastern Gulf of Mexico sub-region hammerhead shark commercial quota at 13.4 mt dw; and • Removed the upgrading restrictions for shark limited access permit holders.
November 24, 2015	Amendment 9 to the 2006 Consolidated HMS FMP	• Modified the TACs and commercial quotas for smoothhound sharks in both the Atlantic and Gulf of Mexico regions; • Established a soak time limits for the sink and drift gillnet gear in the Atlantic shark and smoothhound shark fisheries;

Effective Date	FMP/Amendment	Description of Action
		• Required Federal directed shark permit holders with gillnet gear on board to use VMS only in the Southeast U.S. Monitoring Area, pursuant to Atlantic Large Whale Take Reduction Plan requirements; and • Implemented the smooth dogfish-specific measures in the Shark Conservation Act of 2010 to establish an allowance for the removal of smooth dogfish fins while at sea.
April 4, 2017	Amendment 5b to the 2006 Consolidated HMS FMP	• Required all HMS recreational permit holders to obtain a "shark endorsement" to fish for, retain, possess, or land sharks. • Establish a circle hook requirement for anglers fishing recreationally for sharks south of 41°43' N latitude. • Required Atlantic shark limited access permit holders fishing with pelagic longline gear to release all sharks that are not being boarded or retained by using a dehooker or by cutting the gangion less than three feet (91.4 cm) from the hook as safely as practicable. • Established a circle hook requirement in the directed shark bottom longline fishery.
February 21, 2019	Amendment 11 to the 2006 Consolidated HMS FMP	• Allowed the retention of shortfin mako sharks caught with longline or gillnet gear by persons issued a Directed or Incidental shark LAP only if the shark is dead at haulback. Retention of dead shortfin mako sharks with pelagic longline gear is allowed only if there is a functional electronic monitoring system on board the vessel; and • Established the foundation for developing an international rebuilding plan for shortfin mako sharks.
September 24, 2020	Draft Amendment 14 to the 2006 Consolidated HMS FMP	• Created a tiered Acceptable Biological Catch (ABC) control rule; • Allow consideration of phase-in ABC control rules for any modifications in ABC; • Actively managed all sector ACLs (commercial and recreational); • Established an ACL for each Atlantic shark management group, without commercial ACL quota linkages; • Allowed carry-over, and only for underharvest of the commercial quotas (landings only) under certain conditions; and • Compared a three-year average of fishing mortality estimates to the overfishing limit to determine overfishing status.

Emergency and Other Major Rules

Rules in Relation to 1993 FMP

A number of difficulties arose in the initial year of implementation of the 1993 FMP that resulted in a short season and low ex-vessel prices. First, the January to June semi-annual LCS quota was exceeded shortly after implementation of the FMP, and that portion of the commercial fishery was closed on May 10, 1993. The LCS fishery reopened on July 1, 1993, with an adjusted quota of 875 mt dw (see Table 3 below). Derby-style fishing, coupled with what some participants observed to be an unusual abundance or availability of sharks, led to an intense and short fishing season for LCS, with the fishery closing within one month. Although fin prices remained strong throughout the brief season, the oversupply of shark carcasses led to reports of record low prices. The closure was significantly earlier than expected, and a number of commercial fishermen and dealers indicated that they were adversely affected. The intense season also complicated the task of monitoring the LCS quota and closing the season with the required advance notice.

To address these problems, a commercial trip limit of 4,000 lb for permitted vessels for LCS was implemented on December 28, 1993 (58 FR 68556), and a control date for the Atlantic shark fishery was established on February 22, 1994 (59 FR 8457). A final rule to implement additional measures authorized by the 1993 FMP published on October 18, 1994 (59 FR 52453), which:

- Clarified operation of vessels with a Federal commercial permit;
- Established the fishing year;
- Consolidated the regulations for drift gillnets;
- Required dealers to obtain a permit to purchase sharks;
- Required dealer reports;
- Established recreational bag limits;
- Established quotas for commercial landings; and
- Provided for commercial fishery closures when quotas were reached.

A final rule that capped quotas for LCS (2,570 mt dw) at the 1994 levels was published on May 2, 1995 (60 FR 21468).

In response to a 1996 LCS stock assessment, in 1997, NOAA Fisheries reduced the LCS commercial quota by 50 percent to 1,285 mt dw and the recreational retention limit to two LCS, SCS, and pelagic sharks combined per trip with an additional allowance of two Atlantic sharpnose sharks per person per trip (62 FR 16648, April 2, 1997). On May 2, 1997, the Southern Offshore Fishing Association (SOFA) and other commercial fishermen and dealers sued the Secretary of Commerce (Secretary) on the April 1997 regulations.

In May 1998, NOAA Fisheries completed its consideration of the economic effects of the 1997 LCS quotas on fishermen and submitted the analysis to the court. NOAA Fisheries concluded that the 1997 LCS quotas may have had a significant economic impact on a substantial number of small entities and that there were no other available alternatives that would both mitigate those economic impacts and ensure the viability of the LCS stocks. Based on these findings, the court allowed NOAA Fisheries to maintain those quotas while the case was settled in combination with litigation mentioned below regarding the 1999 FMP.

Rules in Relation to the 1999 FMP

The implementing regulations for the 1999 FMP were published on May 28, 1999 (64 FR 29090). At the end of June 1999, NOAA Fisheries was sued several times by several different entities regarding the commercial and recreational management measures in the 1999 FMP. Due to the overlap of one of those lawsuits with the 1997 litigation, on June 30, 1999, NOAA Fisheries received a court order enjoining it from enforcing the 1999 regulations with respect to Atlantic shark commercial catch quotas and fish-counting methods (including the counting of dead discards and state commercial landings after Federal closures), which were different from the quotas and fish counting methods prescribed by the 1997 Atlantic shark regulations. Due to the injunction, NOAA Fisheries was unable to implement measures that would have established limited access in commercial fisheries, ridgeback and non-ridgeback categories of LCS, with sandbar sharks being placed in the ridgeback category, a commercial minimum size of 4.5 ft (54 inches) fork length for ridgeback LCS, including sandbar sharks, and a reduced commercial LCS annual quota of 1,285 mt dw.

On September 25, 2000, the United States District Court for the District of Columbia ruled against the plaintiffs regarding the commercial pelagic shark management measures, stating that the regulations were consistent with the Magnuson-Stevens Act and the Regulatory Flexibility Act. On September 20, 2001, the same court ruled against different plaintiffs regarding the recreational shark retention limits in the 1999 FMP, again stating that the regulations were consistent with the Magnuson-Stevens Act. This recreational shark retention limits established a recreational minimum size for all sharks of 4.5 ft (54 inches) fork length for all sharks, including sandbar sharks, except Atlantic sharpnose.

On November 21, 2000, SOFA *et al*. and NOAA Fisheries reached a settlement agreement for the May 1997 and June 1999 lawsuits. On December 7, 2000, the United States District Court for the Middle District of Florida entered an order approving the settlement agreement and lifting the injunction. The settlement agreement required, among other things, an independent (*i.e*., non-NOAA Fisheries) review of the 1998 LCS stock assessment. The settlement agreement did not address any regulations affecting recreational shark fisheries, which included establishing a recreational minimum size of 4.5 ft fork length for all sharks, including sandbar sharks, except Atlantic sharpnose. The injunction was lifted, on January 1, 2001 (66 FR 55) and on March 6, 2001, NOAA Fisheries published an emergency rule implementing the settlement agreement (66 FR 13441). This emergency rule expired on September 4, 2001, and established the LCS annual quota (including sandbar sharks) (1,285 mt dw) at 1997 levels.

In late 2001, the Agency received the results of the independent peer review of the 1998 LCS stock assessment. These peer reviews found that the 1998 LCS stock assessment was not the best available science for LCS. Taking into consideration the settlement agreement, the results of the peer reviews of the 1998 LCS stock assessment, current catch rates, and the best available scientific information (not including the 1998 stock assessment projections), NOAA Fisheries implemented another emergency rule for the 2002 fishing year that suspended certain measures. Under the 1999 regulations pending completion of new LCS and SCS stock assessments and a peer review of the new LCS stock assessment (66 FR 67118, December 28, 2001; extended 67 FR 37354, May 29, 2002). Specifically, NOAA Fisheries maintained the 1997 LCS commercial quota (1,285 mt dw), suspended the commercial ridgeback LCS minimum size, suspended counting dead discards and state landings after a Federal closure against the quota, and replaced season-specific quota accounting methods with subsequent-season quota accounting methods. That emergency rule expired on December 30, 2002.

On May 28, 2002 (67 FR 36858), NOAA Fisheries announced the availability of a modeling document that explored the suggestions of the CIE and NRC peer reviews on LCS. Then NOAA Fisheries held a 2002 LCS stock assessment workshop in June 2002. On October 17, 2002, NOAA Fisheries announced the availability of the 2002 LCS stock assessment and the workshop meeting report (67 FR 64098). The results of this stock assessment indicated that the

LCS complex was still overfished and overfishing was occurring. Additionally, the 2002 LCS stock assessment found that sandbar sharks were overfished, but that overfishing was not occurring.

Based on the results of the 2002 LCS stock assessment, NOAA Fisheries implemented an emergency rule to ensure that the commercial management measures in place for the 2003 fishing year were based on the best available science (67 FR 78990, December 27, 2002; extended 68 FR 31987, May 29, 2003). Specifically, the emergency rule implemented the LCS ridgeback/non-ridgeback split established in the 1999 FMP (the ridgeback quota was set at 783 mt dw and the non-ridgeback quota was set at 931 mt dw), suspended the commercial ridgeback LCS minimum size, and allowed both the season-specific quota adjustments and the counting of all mortality measures to go into place. Additionally, NOAA Fisheries announced its intent to conduct an EIS and amend the 1999 FMP (67 FR 69180, November 15, 2002).

The emergency rule was an interim measure to maintain the status of LCS pending the re-evaluation of management measures in the context of the rebuilding plan through the amendment to the 1999 FMP. The emergency rule for the 2003 fishing year implemented for the first and only time the classification system (ridgeback/non-ridgeback LCS) finalized in the 1999 FMP. Table 5 indicates which LCS were considered ridgeback and which non-ridgeback. NOAA Fisheries also implemented for the first time a provision to count state landings after a Federal closure and to count dead discards against the quota. To calculate the commercial quotas for these groups, NOAA Fisheries took the average landings for individual species from 1999 through 2001 and either increased them or decreased them by certain percentages, as suggested by scenarios presented in the stock assessment. Because the stock assessment scenarios suggested that an increase in catch for blacktip sharks would not cause overfishing and that maintaining the sandbar sharks would not increase overfishing (the two primary species in the LCS fishery), this method resulted in an increase in the overall quota for the length of the emergency rule. During the comment period on the emergency rule and scoping for this amendment, NOAA Fisheries received comments regarding, among other things, the quota levels under the rule, concern over secondary species and discards, the ability of fishermen to target certain species, and impacts of the different season length for ridgeback and non-ridgeback LCS. NOAA Fisheries responded to these comments when extending the emergency rule and further considered these comments when examining the alternatives presented in the Amendment to the 1999 FMP.

NOAA Fisheries received the results of the peer review of the 2002 LCS stock assessment in December 2002. These reviews were generally positive.

Rules in Relation to 2003 Amendment 1

Based on the 2002 LCS stock assessment, NOAA Fisheries re-examined many of the shark management measures in the 1999 FMP for Atlantic Tunas, Swordfish, and Sharks. The changes in Amendment 1 affected all aspects of shark management, including management of sandbar sharks which were part of the LCS complex. Shortly after the final rule for Amendment 1 was published, NOAA Fisheries conducted a rulemaking that adjusted the percent quota of LCS for each region, changed the seasonal split for the North Atlantic based on historical landing patterns of LCS, and finalized a method of changing the split between regions and/or seasons as necessary to account for changes in the fishery over time, and established a method to adjust from semi-annual to trimester seasons (69 FR 6954, November 30, 2004,).

Shark Rules that could affect hammerhead shark fishing after the 2006 Consolidated HMS FMP

In 2007, NOAA Fisheries expanded the equipment required for the safe handling, release, and disentanglement of sea turtles caught in the Atlantic shark bottom longline fishery (72 FR 5633, February 7, 2007). As a result, the equipment required for bottom longline vessels is now consistent with the requirements for the pelagic longline fishery (e.g., vessels must carry dehookers and line cutters). Furthermore, this action implemented several year-round bottom longline closures to protect EFH to maintain consistency with the Caribbean Fishery Management Council.

On August 29, 2011, NOAA Fisheries published a final rule (76 FR 53652) that implemented ICCAT recommendations 10-07 and 10-08, which prohibited the retention, transshipping, landing, storing, or selling of hammerhead sharks in the family Sphyrnidae (except for *Sphyrna tiburo*) and oceanic whitetip sharks (*Carcharhinus longimanus*) caught in association with ICCAT fisheries. This rule affected the commercial HMS pelagic longline fishery and recreational fisheries for tunas, swordfish, and billfish in the Atlantic Ocean, including the Caribbean Sea and Gulf of Mexico.

On July 9, 2018, NOAA Fisheries published a final rule (83 FR 31677) that revised the closure regulations for commercial shark fisheries to remain open after the fishery's landings have reached or are projected to reach 80 percent of the available overall, regional, and/or sub-regional quota, if the fishery's landings are not projected to reach 100 percent of the applicable quota before the end of the season. This final action also changed the minimum notice time between filing of the closure notice with the Office of the Federal Register and the closure going into effect from five days to four days.

Petition to list scalloped hammerhead sharks under the Endangered Species Act (ESA)

On August 14, 2011, NOAA Fisheries received a petition from WildEarth Guardians and Friends of Animals to list the scalloped hammerhead shark as threatened or endangered under the ESA throughout its entire range, or as an alternative, to delineate the species into distinct population segments. On November 28, 2011, NOAA Fisheries published a notice that listing may be warranted (76 FR 72891). NOAA Fisheries published the proposed rule (78 FR 20717) to list under the ESA and status review of the species on April 5, 2013. On July 3, 2014 (79 FR 38213), NOAA Fisheries issued a final determination to list the Central and Southwest (SW) Atlantic Distinct Population Segment (DPS) and the Indo-West Pacific DPS of scalloped hammerhead shark as threatened species under ESA. In addition, NOAA Fisheries determined to list the Eastern Atlantic DPS and Eastern Pacific DPS of scalloped hammerhead sharks as endangered species under the ESA.

On November 17, 2015, NOAA Fisheries published a notice announcing that there are no marine areas within the jurisdiction of the United States that meet the definition of critical habitat for the Central and SW Atlantic DPS, Indo-West Pacific DPS, or Eastern Pacific DPS of scalloped hammerhead shark (80 FR 71774). On September 6, 2019, NOAA Fisheries announced its intent to conduct a 5-year review for the four DPSs of the scalloped hammerhead shark: Eastern Atlantic DPS, Eastern Pacific DPS, Central & Southwest Atlantic DPS, and Indo-West Pacific

DPS (84 FR 46938). NOAA Fisheries is required under ESA to conduct 5-year reviews to ensure that listing classifications of species are accurate.

Table 2. Chronological list of most of the Federal Register publications relating to Atlantic large coastal sharks, when appropriate, specific to hammerhead sharks. NOA=Notice of Availability; ANPR=Advanced Notice of Proposed Rulemaking; NOI=Notice of Intent.

Federal Register Cite	Date	Rule or Notice
Pre 1993		
48 FR 3371	1/25/1983	Preliminary management plan with optimum yield and total allowable level of foreign fishing for sharks
56 FR 20410	5/3/1991	NOA of draft Fishery Management Plan (FMP); 8 hearings
57 FR 1250	1/13/1992	NOA of Secretarial FMP
57 FR 24222	6/8/1992	Proposed rule to implement FMP
57 FR 29859	7/7/1992	Correction to 57 FR 24222
1993		
58 FR 21931	4/26/1993	Final rule and interim final rule implementing FMP
58 FR 27336	5/7/1993	Correction to 58 FR 21931
58 FR 27482	5/10/1993	Large Coastal Shark (LCS) commercial fishery closure announcement
58 FR 40075	7/27/1993	Adjusts 1993 second semi-annual quotas
58 FR 40076	7/27/1993	LCS commercial fishery closure announcement
58 FR 46153	9/1/1993	Notice of 13 public scoping meetings
58 FR 59008	11/5/1993	Extension of comment period for 58 FR 46153
58 FR 68556	12/28/1993	Interim final rule implementing trip limits
1994		
59 FR 3321	1/21/1994	Extension of comment period for 58 FR 68556
59 FR 8457	2/22/1994	Notice of control date for entry
59 FR 25350	5/16/1994	LCS commercial fishery closure announcement
59 FR 33450	6/29/1994	Adjusts second semi-annual 1994 quota
59 FR 38943	8/1/1994	LCS commercial fishery closure announcement
59 FR 44644	8/30/1994	Reopens LCS fishery with new closure date
59 FR 48847	9/23/1994	Notice of public scoping meetings
59 FR 51388	10/11/1994	Rescission of LCS closure
59 FR 52277	10/17/1994	Notice of additional scoping meetings
59 FR 52453	10/18/1994	Final rule implementing interim final rule in 1993 FMP
59 FR 55066	11/3/1994	LCS commercial fishery closure announcement
1995		
60 FR 2071	1/6/1995	Proposed rule to adjust quotas
60 FR 21468	5/2/1995	Final rule indefinitely establishes LCS quota at 1994 level
60 FR 27042	5/22/1995	LCS commercial fishery closure announcement
60 FR 30068	6/7/1995	Announcement of Shark Operations Team meeting
60 FR 37023	7/19/1995	Adjusts second semi-annual 1995 quota
60 FR 38785	7/28/1995	ANPR - Options for Permit Moratoria
60 FR 44824	8/29/1995	Extension of ANPR comment period
60 FR 49235	9/22/1995	LCS commercial fishery closure announcement
60 FR 61243	11/29/1995	Announces Limited Access Workshop

Federal Register Cite	Date	Rule or Notice
1996		
61 FR 21978	5/13/1996	LCS commercial fishery closure announcement
61 FR 37721	7/19/1996	Announcement of Shark Operations Team meeting.
61 FR 39099	7/26/1996	Adjusts second semi-annual 1996 quota
61 FR 43185	8/21/1996	LCS commercial fishery closure announcement
61 FR 67295	12/20/1996	Proposed rule to reduce Quotas/Bag Limits
61 FR 68202	12/27/1996	Proposed rule to establish limited entry (Draft Amendment 1 to 1993 FMP)
1997		
62 FR 724	1/6/1997	NOA of Draft Amendment 1 to 1993 FMP
62 FR 1705	1/13/1997	Notice of 11 public hearings for Amendment 1
62 FR 1872	1/14/1997	Extension of comment period and notice of public hearings for proposed rule on quotas
62 FR 4239	1/29/1997	Extension of comment period for proposed rule on quotas
62 FR 8679	2/26/1997	Extension of comment period for Amendment 1 to 1993 FMP
62 FR 16647	4/7/1997	Final rule reducing quotas/bag limits
62 FR 16656	4/7/1997	LCS commercial fishery closure announcement
62 FR 26475	5/14/1997	Announcement of Shark Operations Team meeting
62 FR 26428	5/14/1997	Adjusts second semi-annual 1997 LCS quota
62 FR 27586	5/20/1997	Notice of Intent to prepare an supplemental environmental impact statement
62 FR 27703	5/21/1997	Technical Amendment regarding bag limits
62 FR 38942	7/21/1997	LCS commercial fishery closure announcement
1998		
63 FR 14837	3/27/1998	LCS commercial fishery closure announcement
63 FR 19239	4/17/1998	NOA of draft consideration of economic effects of 1997 quotas
63 FR 27708	5/20/1998	NOA of final consideration of economic effects of 1997 quotas
63 FR 29355	5/29/1998	Adjusts second semi-annual 1998 LCS quota
63 FR 41736	8/5/1998	LCS commercial fishery closure announcement
63 FR 57093	10/26/1998	NOA of draft 1999 FMP
1999		
64 FR 3154	1/20/1999	Proposed rule for draft 1999 FMP
64 FR 14154	3/24/1999	LCS commercial fishery closure announcement
64 FR 29090	5/28/1999	Final rule for 1999 FMP
64 FR 30248	6/7/1999	Fishing season notification
64 FR 37700	7/13/1999	Technical amendment to 1999 FMP final rule
64 FR 37883	7/14/1999	Fishing season change notification
64 FR 47713	9/1/1999	LCS fishery reopening
64 FR 52772	9/30/1999	Notice of Availability of outline for National Plan of Action for sharks
64 FR 53949	10/5/1999	LCS closure postponement
64 FR 66114	11/24/1999	Fishing season notification
2000		
65 FR 16186	3/27/2000	Revised timeline for National Plan of Action for sharks
65 FR 35855	6/6/2000	Fishing season notification and 2nd semi-annual LCS quota adjustment
65 FR 47214	8/1/2000	Final rule closing Desoto Canyon, Florida East Coast, and Charleston Bump and requiring live bait for Pelagic Longline (PLL) gear in Gulf of Mexico

Federal Register Cite	Date	Rule or Notice
65 FR 47986	8/4/2000	Notice of Availability of National Plan of Action for sharks
65 FR 38440	6/21/2000	Implementation of prohibited species provisions and closure change
65 FR 60889	10/13/2000	Final rule closed Northeast Distant (NED) and required dipnets and line clippers for Pelagic Longline (PLL) vessels
65 FR 75867	12/5/2000	Fishing season notification
2001		
66 FR 10484	2/15/2001	NOA of Final National Plan of Action for the Conservation and Management of Sharks
66 FR 13441	3/6/2001	Emergency rule to implement settlement agreement
66 FR 33918	6/26/2001	Fishing season notification and 2nd semi-annual LCS quota adjustment
66 FR 34401	6/28/2001	Proposed rule to implement national finning ban
66 FR 36711	7/13/2001	Emergency rule implementing 2001 Biological Opinion (BiOp) requirements
66 FR 46401	9/5/2001	LCS fishing season extension
66 FR 48812	9/24/2001	Amendment to emergency rule (66 FR 13441) to incorporate change in requirement for handling and release guidelines
66 FR 67118	12/28/2001	Emergency rule to implement measures based on results of peer review and fishing season notification
2002		
67 FR 6194	2/11/2002	Final rule implementing national shark finning ban
67 FR 8211	2/22/2002	Correction to fishing season notification 66 FR 67118
67 FR 36858	5/28/2002	Notice of availability of LCS sensitivity document and announcement of stock evaluation workshop in June
67 FR 37354	5/29/2002	Extension of emergency rule and fishing season announcement
67 FR 45393	7/9/2002	Final rule to implement measures under 2001 BiOp (gangion placement measure not implemented), including HMS shark gillnet measures
67 FR 64098	10/17/2002	Notice of availability of LCS stock assessment and final meeting report
67 FR 69180	11/15/2002	Notice of intent to conduct an environmental impact assessment and amend the 1999 FMP
67 FR 72629	12/6/2002	Proposed rule regarding Exempted Fishing Permits (EFPs)
67 FR 78990	12/27/2002	Emergency rule to implement measures based on stock assessments and fishing season notification
2003		
68 FR 1024	1/8/2003	Announcement of 4 public hearings on emergency rule
68 FR 1430	1/10/2003	Extension of comment period for proposed rule on EFPs
68 FR 3853	1/27/2003	Announcement of 7 scoping meetings and notice of availability of Issues and Options paper
68 FR 31983	5/29/2003	Emergency rule extension and fishing season notification
68 FR 45196	8/1/2003	Proposed rule and NOA for draft Amendment 1 to 1999 FMP
68 FR 47904	8/12/2003	Public hearing announcement for draft Amendment 1 to 1999 FMP
68 FR 51560	8/27/2003	Announcement of HMS AP meeting on draft Amendment 1 to 1999 FMP
68 FR 54885	9/19/2003	Rescheduling of public hearings and extending comment period for draft Amendment 1 to 1999 FMP
68 FR 64621	11/14/2003	NOA of availability of Amendment 1
68 FR 66783	11/28/2003	NOI for Supplemental Environmental Impact Statement (SEIS)
68 FR 74746	12/24/2003	Final Rule for Amendment 1

Federal Register Cite	**Date**	**Rule or Notice**
2004		
69 FR 6621	2/11/2004	Proposed rule for PLL fishery
69 FR 19979	4/15/2004	VMS type approval notice
69 FR 26540	5/13/2004	N. Atlantic Quota Split Proposed Rule
69 FR 28106	5/18/2004	VMS effective date proposed rule
69 FR 30837	6/1/2004	Fishing season notice
69 FR 33321	6/15/2004	N. Atlantic Quota Split Final Rule
69 FR 44513	7/26/04	Notice of sea turtle release/protocol workshops
69 FR 47797	8/6/2004	Technical amendment correcting changes to Bottom Longline (BLL) gear requirements
69 FR 49858	8/12/2004	Advanced notice of proposed rulemaking; reducing sea turtle interactions with fishing gear
69 FR 51010	8/17/2004	Vessel Monitoring System (VMS) effective date final rule
69 FR 56024	9/17/2004	Regional quota split proposed rule
69 FR 6954	11/30/2004	Regional quota split final rule and season announcement
69 FR 71735	12/10/2004	Correction notice for 69 FR 6954
2005		
70 FR 11922	3/10/2005	2nd and 3rd season proposed rule
70 FR 21673	4/27/2005	2nd and 3rd season final rule
70 FR 24494	5/10/2005	North Carolina Petition for Rulemaking
70 FR 29285	5/20/2005	Notice of handling and release workshops for BLL fishermen
70 FR 48804	8/19/2005	Proposed rule Draft Consolidated HMS FMP
70 FR 48704	8/19/2005	NOA of Draft EIS for Draft Consolidated HMS FMP
70 FR 52380	9/2/2005	Correction to 70 FR 48704
70 FR 53146	9/7/2005	Cancellation of hearings due to Hurricane Katrina
70 FR 54537	9/15/2005	Notice of LCS data workshop
70 FR 55814	9/23/2005	Cancellation of Key West Public hearing due to Hurricane Rita
70 FR 58190	10/5/2005	Correction to 70 FR 54537
70 FR 58177	10/5/2005	Extension of comment period for Draft Consolidated HMS FMP
70 FR 58366	10/6/2005	1st season proposed rule
70 FR 72080	12/1/2005	1st season final rule, fishing season notification
70 FR 73980	12/14/2005	Final Agency decision on petition for rulemaking to amend mid-Atlantic closed area
70 FR 76031	12/22/2005	Notice for Large Coastal Shark 2005/2006 Stock Assessment Workshop
70 FR 76441	12/27/2005	Rescheduling and addition of public hearings for Consolidated HMS FMP
2006		
71 FR 8223	2/16/2006	Temporary rule prohibiting gillnet gear in areas around the Southeast U.S. Restricted Area
71 FR 8557	2/17/2006	Proposed Rule for third and second trimester seasons
71 FR 12185	3/9/2006	Notice for Large Costal Shark Review Workshop
71 FR 15680	3/29/2006	Proposed rule for gear operation and deployment for BLL and gillnet fishery and complementary closure
71 FR 16243	3/31/2006	Final rule for second and third trimester seasons
71 FR 26351	5/4/2006	Scientific research permit for pelagic shark research
71 FR 41774	7/24/2006	Notice of availability of final stock assessment for Large Costal Sharks
71 FR 58058	10/2/2006	Final Rule for the HMS Consolidated Fishery Management Plan
71 FR 58058	10/2/2006	1st season proposed rule

Federal Register Cite	**Date**	**Rule or Notice**
71 FR 62095	10/23/2006	Notice of shark dealer identification workshops and protected species safe handling and release workshops
71FR 64213	11/1/2006	Extension of comment period regarding the 2007 first trimester season proposed rule
71 FR 65086	11/7/2006	Notice of Intent to prepare Amendment 2 to the 2006 Consolidated HMS FMP and status determination for sandbar, blacktip, dusky, the LCS complex, and porbeagle sharks based on the latest stock assessments
71 FR 65087	11/7/2006	Notice of Intent to prepare Amendment 1 to the 2006 Consolidated HMS FMP for Essential Fish Habitat for Some Atlantic Highly Migratory Species
71 FR 66154	11/13/2006	Extension of comment period regarding the 2007 first trimester season proposed rule
71 FR 68561	11/27/2006	Notice of shark dealer identification workshops and protected species safe handling and release workshops
71 FR 75122	12/14/2006	Final Rule and Temporary Rule for the 2007 first trimester season and south Atlantic quota modification
71 FR 75714	12/18/2006	Notice of shark dealer identification workshops and protected species safe handling and release workshops
2007		
72 FR 123	1/3/2007	Notice of public hearings for scoping for Amendment 2 to the 2006 Consolidated HMS FMP
72 FR 5633	2/7/2007	Final rule for gear operation and deployment for bottom longline and gillnet fishery and complementary closures
72 FR 7417	2/15/2007	Revised list of equipment models for careful release of sea turtles in the pelagic longline and bottom longline fisheries
72 FR 8695	2/27/2007	Notice of new VMS type approval for HMS fisheries and other programs
72 FR 10480	3/8/2007	Proposed rule for second and third trimester seasons
72 FR 11335	3/13/2007	Schedule of public protected resources dehooking workshops and Atlantic shark identification workshops
72 FR 19701	4/19/2007	Notice of Small Costal Shark stock assessment workshop
72 FR 20765	4/26/2007	Final rule for second and third trimester season
72 FR 32836	6/14/2007	Schedule of public protected resources dehooking workshops and Atlantic shark identification workshops
72 FR 34632	6/25/2007	Final rule prohibiting gillnet gear from November 15-April 15 between NC/SC border and 29°00’N.
72 FR 39606	7/18/2007	Notice of Small Costal Shark 2007 peer review workshop
72 FR 41392	7/27/2007	Proposed rule for Amendment 2 to the Consolidated Atlantic Highly Migratory Species Fishery Management Plan
72 FR 52552	9/14/2007	Schedules for Atlantic shark identification workshops and protected species safe handling, release, and identification workshops
72 FR 55729	10/1/2007	Proposed rule for 2008 first trimester quotas
72 FR 56330	10/3/2007	Amendment 2 to the Consolidated FMP – extension of comment period
72 FR 57104	10/5/2007	Final rule amending restriction in the Southeast U.S. Monitoring Area
72 FR 63888	11/13/2007	Notice of Small Coastal Shark Stock Assessment - notice of availability
72 FR 67580	11/29/2007	Final rule for 2008 first trimester quotas
2008		
73 FR 11621	3/4/2008	Notice of Atlantic shark identification workshops and protected species safe handling, release, and identification workshops
73 FR 19795	4/11/2008	Proposed rule for renewal of Atlantic tunas longline limited access permits; and, Atlantic shark dealer workshop attendance requirements

Federal Register Cite	Date	Rule or Notice
73 FR 25665	5/7/2008	Stock Status Determinations; Notice of Intent (NOI) to prepare an Environmental Impact Statement (EIS) for Amendment 3 to the 2006 Consolidated HMS FMP
73 FR 32309	6/6/2008	Notice of Atlantic shark identification workshops and protected species safe handling, release, and identification workshops
73 FR 35778	6/24/2008	Final rule for Amendment 2 to the 2006 Consolidated HMS FMP and fishing season notification
73 FR 35834	6/24/2008	Shark research fishery; Notice of intent; request for applications
73 FR 38144	7/3/2008	Final rule for renewal of Atlantic tunas longline limited access permits; and, Atlantic shark dealer workshop attendance requirements
73 FR 40658	7/15/2008	Final rule for Amendment 2 to the 2006 Consolidated HMS FMP and fishing season notification; correction/republication
73 FR 47851	8/15/2008	Effectiveness of collection-of-information requirements to implement fins-on check box on Southeast dealer form
73 FR 51448	9/3/2008	Notice of Atlantic shark identification workshops and protected species safe handling, release, and identification workshops
73 FR 53851	9/17/2008	Atlantic Shark Management Measures; Changing the time and location of a scoping meeting
73 FR 63668	10/27/2008	Proposed rule for 2009 shark fishing season
73 FR 64307	10/29/2008	Extension of scoping comment period for Amendment 3 to the 2006 Consolidated HMS FMP
73 FR 79005	12/24/2008	NOAA Fisheries establishes the annual quotas for the 2009 shark fishing season
2009		
74 FR 8913	2/27/2009	Notice of Atlantic shark identification workshops and protected species safe handling, release, and identification workshops
74 FR26803	6/4/2009	Inseason action to close the commercial Gulf of Mexico non-sandbar large coastal shark fishery
74 FR 27506	6/10/2009	Notice of Atlantic shark identification workshops and protected species safe handling, release, and identification workshops
74 FR 30479	6/26/2009	Inseason action to close the commercial non–sandbar large coastal shark fisheries in the shark research fishery and Atlantic region
74 FR 39914	8/10/2009	Extension of Comment Period for Amendment 3 to the 2006 Consolidated HMS FMP
74 FR 46572	9/10/2009	Notice of Atlantic shark identification workshops and protected species safe handling, release, and identification workshops
74 FR 55526	10/28/2009	Proposed rule for 2010 shark fishing season
74 FR 56177	10/30/2009	Notice of intent for 2010 shark research fishery; request for applications
2010		
75 FR 250	1/5/2010	Final rule for the 2010 Commercial Quotas and Opening Dates for the Atlantic Shark Fisheries
75 FR 12700	3/12/2010	Closure of the Gulf of Mexico Large Coastal Shark Fishery
75 FR 29991	5/28/2010	Notice of Schedules for Atlantic Shark Identification Workshops and Protected Species Safe Handling Release, and Identification Workshops
75 FR 22103	4/27/2010	Atlantic Coastal Fisheries Cooperative Management Act Provisions; Atlantic Coastal Shark Fishery
75 FR 44938	7/30/2010	Atlantic Coastal Fisheries Cooperative Management Act Provisions; Atlantic Coastal Shark Fishery
75 FR 30484	6/1/2010	Final Rule for Amendment 3 to the Consolidated HMS FMP

Federal Register Cite	Date	Rule or Notice
75 FR 52510	8/26/2010	Notice for Fisheries of the Gulf of Mexico and South Atlantic; Southeast Data, Assessment, and Review for Highly Migratory Species Fisheries; Sandbar, Dusky, and Blacknose Sharks
75 FR 53665	9/1/2010	Notice of Schedules for Atlantic Shark Identification Workshops and Protected Species Safe Handling Release, and Identification Workshops
75 FR 54598	9/8/2010	Notice of Schedules for Atlantic Shark Identification Workshops and Protected Species Safe Handling, Release, and Identifications Workshops; Correction
75 FR 57235	9/20/2010	Advance Notice of Proposed Rulemaking for Atlantic Shark Management Measures
75 FR 57240	9/20/2010	Proposed Rule for 2011 Commercial Fishing Season and Adaptive Management Measures for the Atlantic Shark Fishery
75 FR 57259	9/20/2010	Notice of Intent for Atlantic Shark Management Measures: 2011 Research Fishery
75 FR 62690	10/8/2010	Closure of the Commercial Non-Sandbar Large Coastal Shark Research Fishery
75 FR 62506	10/12/2010	Notice of Southeast Data Assessment and Review (SEDAR) 21 Assessment Webinar
75 FR 62690	10/13/2010	Inseason Action to Close the Commercial Non-sandbar Large Coastal Shark Research Fishery
75 FR 70216	11/17/2010	Fisheries of the Gulf of Mexico and South Atlantic; Southeast Data, Assessment, and Review (SEDAR); Assessment Process Webinar for Highly Migratory Species (HMS) Fisheries Sandbar, Dusky, and Blacknose Sharks
75 FR 74693	12/1/2010	Notice of Schedules for Atlantic Shark Identification Workshops and Protected Species Safe Handling, Release, and Identification Workshop
75 FR 75416	12/2/2010	Closure of the Commercial Non-Sandbar Large Coastal Shark Fishery in the Atlantic Region
75 FR 75416	12/3/2010	Inseason Action to Close the Commercial Non-Sandbar Large Coastal Shark Fishery in the Atlantic Region
75 FR 76302	12/8/2010	Final rule for the 2011 Commercial Quotas and Opening Dates for the Atlantic Shark Fisheries
2011		
76 FR 5340	1/31/2011	Notice of Schedules for Atlantic Shark Identification Workshops and Protected Species Safe Handling, Release and Identification Workshops, Correction
76 FR 13985	3/15/2011	Notice of Public Meeting for the Fisheries of the Gulf of Mexico and South Atlantic; Southeast Data, Assessment, and Review (SEDAR)
76 FR 14884	3/18/2011	Proposed rule for Atlantic Highly Migratory Species; Modification of the Retention of Incidentally-Caught Highly Migratory Species in Atlantic Trawl Fisheries
76 FR 23794	4/28/2011	Notice of Stock Status Determination for Atlantic highly Migratory scalloped Hammerhead Shark
76 FR 23935	4/29/2011	Proposed Rule to Implement the 2010 International Commission for the Conservation of Atlantic Tunas (ICCAT) Recommendations on Sharks
76 FR 34209	6/13/2011	Notice of Schedules for Atlantic Shark Identification Workshops and Protected Species Safe Handling, Release, and Identification Workshops
76 FR 36071	6/21/2011	Proposed rule for Atlantic Highly Migratory Species; Vessel Monitoring Systems
76 FR 37750	6/28/2011	Proposed Rule for Atlantic Highly Migratory Species; Electronic Dealer Reporting Requirement
76 FR 38107	6/29/2011	Correction on Proposed Rule for Atlantic Highly Migratory Species; Electronic Dealer Reporting Requirement

Federal Register Cite	Date	Rule or Notice
76 FR 41723	7/15/2011	Inseason Action to Close the Commercial Gulf of Mexico Non-Sandbar Large Coastal Shark Fishery
76 FR 44501	7/26/2011	Inseason Action To Close the Commercial Non-Sandbar Large Coastal Shark Research Fishery
76 FR 49368	8/10/2011	Final rule for Atlantic Highly Migratory Species; Modification of the Retention of Incidentally-Caught Highly Migratory Species in Atlantic Trawl Fisheries
76 FR 53652	8/29/2011	Final Rule to Implement the 2010 International Commission for the Conservation of Atlantic Tunas (ICCAT) Recommendations on Sharks
76 FR 57709	9/16/2011	Notice of Intent for Catch Shares in the Atlantic Shark Fisheries
76 FR 59661	9/27/2011	Notice of Schedules for Atlantic Shark Identification Workshops and Protected Species Safe Handling, Release, and Identification Workshop
76 FR 61092	10/3/2011	Notice of Availability of Stock Assessment Reports for Dusky, Sandbar, and Blacknose Sharks in the U.S. Atlantic and Gulf of Mexico
76 FR 62331	10/7/2011	Notice of Stock Status Determinations
76 FR 64074	10/17/2011	Notice of Schedules for Atlantic Shark Identification Workshops and Protected Species Safe Handling, Release, and Identification Workshops; Correction
76 FR 65673	10/24/2011	Notice of Stock Status Determinations
76 FR 67149	10/31/2011	Notice of Intent for 2012 Research Fishery Participants
76 FR 67121	10/31/2011	Proposed Rule for 2012 Atlantic Shark Commercial Fishing Season
76 FR 69139	11/8/2011	Inseason Action to Close the Commercial Atlantic Non-Sandbar Large Coastal Shark Fishery
76 FR 72383	11/23/2011	Atlantic Highly Migratory Species; Atlantic Shark Management Measures; Notice of Workshops
76 FR 72678	11/25/2011	Notice of Intent to Issue Exempted Fishing, Scientific Research, Display, and Chartering Permits; Letters of Acknowledgements
2012		
77 FR 3393	1/24/2012	Final Rule to Establish the Quotas and Opening Dates for the 2012 Atlantic Shark Commercial Fishing Season
77 FR 8218	2/14/2012	NOAA Fisheries Announces a Public Meeting for Selected Participants of the 2012 Shark Research Fishery
77 FR 15701	3/16/2012	Proposed rule for Amendment 4 to the 2006 Consolidated HMS FMP
77 FR 31562	5/29/2012	NMFS Considers Adding Gulf of Mexico Sharks to Amendment 5 to the 2006 Consolidated HMS FMP
77 FR 35357	6/13/2012	NOAA Fisheries Announces the Opening Date of the Commercial Atlantic Region Non-Sandbar Large Coastal Fishery
77 FR 39648	7/5/2012	Inseason Action to Close the Commercial Non-Sandbar Large Coastal Shark Fishery in the Gulf of Mexico Region
77 FR 59842	10/1/2012	Final Rule for Amendment 4 to the 2006 Consolidated HMS FMP
77 FR 61562	10/10/2012	Proposed Rule to Establish the Quotas and Opening Dates for the 2013 Atlantic Shark Commercial Fishing Season
77 FR 67631	10/13/2012	Notice of Intent for Applications to the 2013 Shark Research Fishery
77 FR 70552	10/26/2012	Proposed Rule for Amendment 5 to the 2006 Consolidated HMS FMP
77 FR 73608	12/11/2012	Public Hearings for Draft Amendment 5 to the 2006 Consolidated HMS FMP
77 FR 75896	12/26/2012	Final Rule Regarding the 2013 Atlantic Shark Commercial Fishing Season
2013		
78 FR 279	1/3/2013	Two Additional Public Hearings and a Change in Date of One Public Hearing for Draft Amendment 5 to the 2006 Consolidated HMS FMP
78 FR 14515	3/6/2013	Public Meeting for Selected Participants of the 2013 Shark Research Fishery

Federal Register Cite	**Date**	**Rule or Notice**
78 FR 20718	4/5/2013	Proposed Rule for Endangered, Threatened, and Not Warranted Listing Determinations for Six Distinct Population Segments of Scalloped Hammerhead Sharks
78 FR 24148	4/24/2013	Notice of Intent to Prepare an Environmental impact Statement and Associated Rulemaking for Dusky Shark Management Measures
78 FR 24701	4/26/2013	90-Day Finding on Petitions to List the Great Hammerhead Sharks as Threatened or Endangered under the Endangered Species Act
78 FR 24743	4/26/2013	Availability of the Final EIS for Amendment 5a to the 2006 Consolidated HMS FMP
78 FR 25685	5/2/2013	Proposed Rule to Implement Provisions of the Shark Conservation Act of 2010
78 FR 29100	5/17/2013	90-Day Finding on Petitions to List Dusky Shark as Threatened or Endangered Under the Endangered Species Act
78 FR 40318	7/3/2013	Final Rule for Amendment 5a to the 2006 Consolidated HMS FMP and Closure of the Gulf of Mexico Blacktip Shark Management Group
78 FR 42021	7/15/2013	Final Rule for Amendment 5a to the 2006 Consolidated HMS FMP and Closure of the Gulf of Mexico Blacktip Shark Management Group NOAA Fisheries Closes the Gulf of Mexico Aggregated LCS and Hammerhead Shark Management Groups
78 FR 52487	8/23/2013	Proposed Rule to Establish the Quotas and Opening Dates for the 2014 Atlantic Shark Commercial Fishing Season
78 FR 70018	11/22/2013	Notice of Intent for Applications to the 2014 Shark Research Fishery
78 FR 70500	11/26/2013	Final Rule Regarding the 2014 Atlantic Shark Commercial Fishing Season
2014		
79 FR 12155	3/4/2014	Public Meeting for Selected Participants of the 2014 Shark Research Fishery
79 FR 15959	3/24/2014	Initiation of 5-Year EFH Review
79 FR 28849	5/20/2014	NMFS Closes the Gulf of Mexico Aggregated LCS and Hammerhead Shark Management Groups
79 FR 30064	5/27/2014	Notice of Intent to Prepare an EA for Amendment 6 to the 2006 Consolidated HMS FMP
79 FR 31227	6/2/2014	NMFS Closes the Gulf of Mexico Blacktip Shark Management Group
79 FR 33509	6/11/2014	12-Month Finding on Petitions to List the Great Hammerhead Sharks as Threatened or Endangered under the Endangered Species Act
79 FR 38214	7/3/2014	Final Rule to List Four Distinct Segments of Scalloped Hammerhead Shark as under the Endangered Species Act
79 FR 54252	9/11/2014	Proposed Rule to Establish the Quotas and Opening Dates for the 2015 Atlantic Shark Commercial Fishing Season
79 FR 64750	10/31/2014	Notice of Intent for Applications to the 2014 Shark Research Fishery
79 FR 71029	12/1/2014	Closure of the Commercial Aggregated LCS and Hammerhead Shark Management Groups in the Atlantic Region
79 FR 71331	12/2/2014	Final Rule to Establish the Quotas and Opening Dates for the 2015 Atlantic Shark Commercial Fishing Season
79 FR 74684	12/16/2014	12-Month Finding on Petition to List the Northwest Atlantic Population of the Dusky Shark Under the Endangered Species Act
2015		
80 FR 2648	1/20/2015	Proposed Rule for Amendment 6 to the 2006 Consolidated Atlantic HMS FMP
80 FR 2916	1/21/2015	Notice of Intent for Applications from the Gulf of Mexico Region to the 2015 Shark Research Fishery
80 FR 3221	1/22/2015	Public Meeting for Selected Participants of the 2015 Shark Research Fishery

Federal Register Cite	Date	Rule or Notice
80 FR 12394	3/9/2015	Notice to Reschedule the Manteo, NC Public Hearing for Draft Amendment 6 to the 2006 Consolidated HMS FMP
80 FR 16356	3/27/2015	90-Day Finding on Petition to List the Porbeagle Shark as Threatened or Endangered Under the Endangered Species Act
80 FR 48053	8/11/2015	90-Day Finding on Petition to List the Smooth Hammerhead Shark as Threatened or Endangered Under the Endangered Species Act
80 FR 50074	8/18/2015	Final Rule for Amendment 6 to the 2006 Consolidated Atlantic HMS FMP
80 FR 49974	8/18/2015	Proposed Rule to Establish the Quotas and Opening Dates for the 2016 Atlantic Shark Commercial Fishing Season
80 FR 68513	11/5/2015	Notice of Intent for Applications to the 2016 Shark Research Fishery
80 FR 74999	12/1/2015	Final Rule to Establish the Quotas and Opening Dates for the 2016 Atlantic Shark Commercial Fishing Season
2016		
81 FR 1941	1/14/2016	Notice of Public Meeting for Selected Participants of the 2016 Shark Research Fishery
81 FR 12602	3/10/2016	Closure of the Commercial Blacktip Shark, Aggregated Large Coastal Sharks, and Hammerhead Shark Groups in the Western Gulf of Mexico Sub-Region
81 FR 18541	3/31/2016	Retention Limit of Commercial Aggregated Large Coastal Shark and Hammerhead Shark Management Groups: Atlantic Region Reduced to 3 Sharks per Trip
81 FR 44798	7/11/2016	Retention Limit of Commercial Aggregated Large Coastal Shark and Hammerhead Shark Management Groups: Atlantic Region Increased to 45 Sharks per Trip
81 FR 59167	8/29/2016	Proposed Rule to Establish Quotas, Opening Dates, and Retention Limits for the 2017 Atlantic Shark Commercial Fishing Season
81 FR 62100	9/8/2016	Notice of Availability of Draft Amendment 10 to the 2006 Consolidated Atlantic HMS Fishery Management Plan: Essential Fish Habitat
81 FR 69043	10/5/2016	Notice of Determination that Atlantic Dusky Sharks are Overfished and Subject to Overfishing
81 FR 71076	10/14/2016	Notice of Public Hearings for Draft Amendment 10 to the 2006 Consolidated Atlantic HMS Fishery Management Plan: Essential Fish Habitat
81 FR 71672	10/18/2016	Proposed Rule to Implement Amendment 5b to the 2006 Consolidated Atlantic HMS FMP: Atlantic Shark Management Measures
81 FR 72007	10/19/2016	Retention Limit of Commercial Aggregated Large Coastal Shark and Hammerhead Shark Management Groups: Atlantic Region Reduced to 25 Sharks per Trip
81 FR 79409	11/14/2016	Notice of Change in Location of Public Hearing for Amendment 5b to the 2006 Consolidated Atlantic HMS FMP
81 FR 83206	11/21/2016	Request for Applications for Participation in the Atlantic HMS 2017 Shark Research Fishery
81 FR 84491	11/23/2016	Final Rule to Establish Quotas, Opening Dates, and Retention Limits for the 2017 Atlantic Shark Commercial Fishing Season
2017		
82 FR 16478	4/4/2017	Final Rule to Implement Amendment 5b to the 2006 Consolidated Atlantic HMS Fishery Management Plan
82 FR 17765	4/13/2017	Atlantic Region Commercial Aggregated Large Coastal Shark and Hammerhead Shark Management Groups Retention Limit Adjustment
82 FR 20447	5/2/2017	Closure of Commercial Blacktip Shark, Aggregated Large Coastal Sharks, and Hammerhead Shark Management Groups in the Western Gulf of Mexico Sub-Region

Federal Register Cite	Date	Rule or Notice
82 FR 32490	7/14/2017	Atlantic Region Commercial Aggregated Large Coastal Shark and Hammerhead Shark Management Groups Retention Limit Adjustment July 16 – December 31
82 FR 39735	8/22/2017	Proposed Rule to Establish Quotas, Opening Dates, and Retention Limits for the 2018 Atlantic Shark Commercial Fishing Season
82 FR 42329	9/7/2017	Notice of Availability of Final Amendment 10 to the 2006 Consolidated Atlantic HMS Fishery Management Plan: Essential Fish Habitat
82 FR 51218	11/3/2017	Request for Applications for Participation in the Atlantic HMS 2018 Shark Research Fishery
82 FR 55512	11/22/2017	Final Rule to Establish Quotas, Opening Dates, and Retention Limits for the 2018 Atlantic Shark Commercial Fishing Season
2018		
83 FR 5061	2/5/2018	Notice of Public Meeting for Selected Participants of the 2018 Shark Research Fishery
83 FR 8037	2/23/2018	Proposed Rule to Revise Atlantic Shark Fishery Closure Regulations
83 FR 10802	3/13/2018	Closure of Commercial Blacktip Shark, Aggregated Large Coastal Sharks, and Hammerhead Shark Management Groups in the Western Gulf of Mexico Sub-Region
83 FR 21744	5/10/2018	Atlantic Region Commercial Aggregated Large Coastal Shark and Hammerhead Shark Management Groups Retention Limit Adjustment
83 FR 31677	7/9/2018	Final Rule to Revise Atlantic Shark Fishery Closure Regulations
83 FR 33870	7/18/2018	Atlantic Region Commercial Aggregated Large Coastal Shark and Hammerhead Shark Management Groups Retention Limit Adjustment
83 FR 45866	9/11/2018	Proposed Rule to Establish Quotas, Opening Dates, and Retention Limits for the 2019 Atlantic Shark Commercial Fishing Season
83 FR 54917	11/1/2018	Request for Applications for Participation in the Atlantic HMS 2019 Shark Research Fishery
83 FR 55638	11/7/2018	Atlantic Region Commercial Aggregated Large Coastal Shark and Hammerhead Shark Management Groups Retention Limit Adjustment
83 FR 60777	11/27/2018	Final Rule to Establish Quotas, Opening Dates, and Retention Limits for the 2019 Atlantic Shark Commercial Fishing Season
83 FR 60777	11/27/2018	Final Rule to Establish Quotas, Opening Dates, and Retention Limits for the 2019 Atlantic Shark Commercial Fishing Season
2019		
84 FR 12524	4/02/2019	Adjustment of commercial aggregated large coastal shark and hammerhead shark management group retention limit
84 FR 22112	5/16/2019	Notice of intent to prepare a draft environmental impact analysis related to research and data collection in support of spatial fisheries management
84 FR 23014	5/21/2019	Notice of Intent to prepare an environmental impact statement related to implementation of new National Standard 1 Guidelines as they relate to annual catch limits for sharks (Amendment 14)
84 FR 23519	5/22/2019	Notice of scoping meetings for three actions to evaluate possible revisions to measures implemented under the 2006 Consolidated Atlantic Highly Migratory Species Fishery Management Plan (Amendments 12, 13, 14)
84 FR 29808	6/25/2019	Adjustment of commercial aggregated large coastal shark and hammerhead shark management group retention limit
84 FR 39774	8/12/2019	Adjustment of commercial aggregated large coastal shark retention limit in the Gulf of Mexico
84 FR 42827	8/19/2019	Adjustment of commercial aggregated large coastal shark retention limit in the Atlantic
84 FR 48791	9/17/2019	Transfer of large coastal shark quota in the Gulf of Mexico

Federal Register Cite	Date	Rule or Notice
84 FR 49236	9/19/2019	Proposed rule to adjust quotas and retention limits for Atlantic commercial shark fisheries
84 FR 54522	10/10/2019	Adjustment of commercial aggregated large coastal shark and hammerhead shark retention limits in the Atlantic region
84 FR 65690	11/29/2019	**Final rule to establish quotas, opening dates, and retention limits for the 2020 Atlantic shark commercial fishing season**
2020		
85 FR 14802	3/16/2020	Closure of commercial aggregated large coastal shark and hammerhead shark management group in the western Gulf of Mexico
85 FR 37390	6/22/2020	Adjustment of commercial aggregated large coastal shark and hammerhead shark management group retention limit
85 FR 60132	9/24/2020	Notice of Availability of Draft Amendment 14 to implement new National Standard 1 Guidelines as they relate to annual catch limits for sharks
85 FR 60947	9/29/2020	Proposed rule to adjust quotas and retention limits for Atlantic commercial shark fisheries
85 FR 76533	11/30/2020	Notice to solicit applications for the 2021 shark research fishery
85 FR 77007	12/1/2020	Final rule to establish quotas, opening dates, and retention limits for the 2020 Atlantic shark commercial fishing season

Table 3. List of Large Coastal or Hammerhead Shark Seasons, 1993-2020

Note: SB=sandbar shark; NSB=non-sandbar LCS; NSB Research=non-sandbar LCS research; N.Atl=North Atlantic LCS, all waters north of 36°30' N. lat.; S. Atl=South Atlantic LCS, all waters east of the Gulf of Mexico north to 36°30' N lat., including the Caribbean; ATL Agg LCS= Atlantic Aggregated LCS; GOM = Gulf of Mexico; WGOM = Western Gulf of Mexico, all waters of the Gulf of Mexico westward of 88°00' W. long.; EGOM = Eastern Gulf of Mexico, all waters of the Gulf of Mexico eastward of 88°00' W. long., including the Caribbean. "Quota" is how much fishermen was allowed to harvest, not how much was actually harvested.

Year	Open dates	Quota (mt dw)
1993 (LCS combined)	Jan. 1 - May 15	1,218
	July 1 - July 31	875
1994 (LCS combined)	Jan. 1 - May 17	1,285
	July 1 - Aug 10 Sept. 1 - Nov. 4	1,318
1995 (LCS combined)	Jan. 1 - May 31	1,285
	July 1 - Sept. 30	968
1996 (LCS combined)	Jan. 1 - May 17	1,285
	July 1 - Aug 31	1,168
1997 (LCS combined)	Jan. 1 - April 7	642
	July 1 - July 21	326
1998 (LCS combined)	Jan. 1 - Mar. 31	642
	July 1 - Aug. 4	600
1999 (LCS combined)	Jan. 1 - Mar. 31	642
	July 1 - July 28 Sept. 1 - Oct. 15	585
2000 (LCS combined)	Jan. 1 - Mar. 31	642
	July 1 - Aug. 15	542
2001	Jan. 1 - Mar. 24	642

Year	Open dates	Quota (mt dw)
(LCS combined)	July 1 - Sept. 4	697
2002 (LCS combined)	Jan. 1 - April 15	735.5
	July 1 - Sept. 15	655.5
2003 (LCS combined)	Jan. 1 - April 15 (Ridgeback LCS, e.g., sandbar) Jan. 1 - May 15 (Non-ridgeback LCS, e.g. hammerhead)	391.5 (Ridgeback LCS) 465.5 (Non-ridgeback LCS)
	July 1 - Sept. 15 (All LCS)	424 (Ridgeback LCS) 498 (Non-ridgeback LCS)
2004 (LCS combined)	GOM: Jan. 1 - Feb 29 S. Atl: Jan 1 - Feb 15 N. Atl: Jan 1 - April 15	190.3 244.7 18.1
	GOM: July 1 - Aug 15 S. Atl: July 1 - Sept 30 N. Atl: July 1 - July 15	287.4 369.5 39.6
2005 (LCS combined)	GOM: Jan 1 - Feb 28 S. Atl: Jan 1 - Feb 15 N. Atl: Jan. 1 - April 30	156.3 133.3 6.3
	GOM: July 6 - July 23 S. Atl: July 6 - Aug 31 N. Atl: July 21 - Aug 31	147.8 182 65.2
	GOM: Sept. 1 - Oct. 31 S. Atl: Sept 1 - Nov 15 N. Atl: Sept 1 - Sept 15	167.7 187.5 4.9
2006 (LCS combined)	GOM: Jan 1 - April 15 S. Atl: Jan 1 - Mar. 15 N. Atl: Jan 1 - April 30	222.8 141.3 5.3
	GOM: July 6 – July 31 S. Atl: July 6 – Aug 16 N. Atl: July 6 – Aug 6	180 151.7 66.3
	GOM: Sept.1 – Nov 7 S. Atl: Sept1 – Oct 3 N. Atl: Closed	225.6 50.3 Closed
2007 (LCS combined)	GOM: Jan 1 – Jan 15 S. Atl: Closed N. Atl: Jan 1 – April 30	62.3 Closed (-112.9) 7.9
	GOM: Sep 1 – Sep 22 S. Atl: July 15 – Aug 15 N. Atl: July 6 – July 31	83.1 163.1 69.0
	GOM: merged with 2nd season S. Atl: merged with 2nd season N. Atl: CLOSED	
2008 (LCS combined except no sandbar allowed)	GOM: CLOSED to July 23 S. Atl: CLOSED to July 23 N. Atl: CLOSED to July 23	Closed (51) Closed (16.3) Closed (10.7)
	NSB GOM: July 24 - Dec. 31 NSB Atlantic: July 24 - Dec. 31 NSB Research: July 24 - Dec. 31 SB Research: July 24 - Dec. 31	390.5 187.5 37.5 87.9
2009 (LCS combined except no sandbar allowed)	NSB GOM: Jan 23 - June 6 NSB Atl: Jan 23 - July 1 NSB Research: Jan 23 - July 1	390.5 187.8 37.5
2010 (LCS combined except no sandbar allowed)	NSB GOM: Feb 4 – Mar 17 NSB Atl: July 15 – Dec 5 NSB Research: Jan 5 – Oct 12	390.5 169.7 37.5
2011 (LCS combined except no sandbar allowed)	NSB GOM: Mar 1 – July 17 NSB Atl: July 15 – Nov 15 NSB Research: Jan 1 – July 26	351.9 190.4 37.5

Year	Open dates	Quota (mt dw)
2012 All SHKs except LCS opened Jan 24; Porbeagle closed May 31	NSB GOM: Feb 15 – July 6 NSB Atl: July 15 – Dec 31 NSB Research: Jan 24 – Dec 31	392.8 183.2 37.5
2013 All SHKS opened Jan 1 Porbeagle sharks closed for entire year; ATL SCS and BN closed Sept 30	GOM Hammerhead: Jan 1 – July 17 ATL Hammerhead: Jan 1 – Sept 30 Research Agg LCS: Jan 1 – Dec 31	25.3 27.1 50.0
2014 Porbeagle closed Dec 17	GOM Hammerhead: Jan 1 - May 20 Atl Hammerhead: June 1 - Nov 30 Research Agg LCS: Jan 1 – Dec 31	25.3 27.1 50.0
2015 All SHKs except ATL LCS opened Jan 1; Porbeagle closed all year; GOM and ATL NBN SCS reopened on Aug 18 with new quotas	GOM Hammerhead: Jan 1 – May 3 Atl Hammerhead: July 1 – Dec 31 Research Agg LCS: Jan 1 – Dec 31	25.3 27.1 50.0
2016 All SHKs opened Jan 1; Only allow 20% of ATL Agg LCS quota at the beginning of the year	EGOM Hammerhead: Jan 1 – Dec 31 WGOM Hammerhead: Jan 1 – Mar 12 Atl Hammerhead: Jan 1 – Dec 31 Research Agg LCS: Jan 1 – Dec 31	13.4 11.9 27.1 50.0
2017 All SHKs except wGOM LCS opened Jan 1; Only allow 20% of ATL Agg LCS quota at the beginning of the year	EGOM Hammerhead: Jan 1 – Dec 31 WGOM Hammerhead: Jan 1 – May 2 Atl Hammerhead: Jan 1 – Dec 31 Research Agg LCS: Jan 1 – Dec 31	13.4 11.9 27.1 50.0
2018 All SHKs opened Jan 1; Only allow 20% of ATL Agg LCS quota at the beginning of the year	EGOM Hammerhead: Jan 1 – Dec 31 WGOM Hammerhead: Jan 1 – March 13 Atl Hammerhead: Jan 1 – Dec 31 Research Agg LCS: Jan 1 – Dec 31	13.4 11.9 27.1 50.0
2019 All SHKs opened Jan 1; Only allow 20% of ATL Agg LCS quota at the beginning of the year. *Transferred quota from the western Gulf of Mexico to the eastern Gulf of Mexico: 8 mt dw hammerhead	EGOM Hammerhead: Jan 1 – Dec 31 WGOM Hammerhead: Jan 1 – Dec 31 Atl Hammerhead: Jan 1 – Dec 31 Research Agg LCS: Jan 1 – Dec 31	13.4 (21.4*) 11.9 (3.9*) 27.1 50.0
2020 All SHKs opened Jan 1; Only allow 35% of ATL Agg LCS quota at the beginning of the year	EGOM Hammerhead: Jan 1 – Dec 31 WGOM Hammerhead: Jan 1 – Mar 14 Atl Hammerhead: Jan 1 – Dec 31 Research Agg LCS: Jan 1 – Dec 31	13.4 11.9 27.1 50.0

Table 4. List of current LCS species and LCS that later became prohibited species

Common name	Species name	Notes
Current LCS		
Ridgeback Species		
Sandbar	*Carcharhinus plumbeus*	
Silky	*Carcharhinus falciformis*	
Tiger	*Galeocerdo cuvier*	
Non-Ridgeback Species		
Blacktip	*Carcharhinus limbatus*	
Spinner	*Carcharhinus brevipinna*	
Bull	*Carcharhinus leucas*	
Lemon	*Negaprion brevirostris*	
Nurse	*Ginglymostoma cirratum*	
Scalloped hammerhead	*Sphyrna lewini*	
Great hammerhead	*Sphyrna mokarran*	
Smooth hammerhead	*Sphyrna zygaena*	
Former LCS that are now Prohibited Species		
Sand tiger	*Odontaspis taurus*	Part of LCS complex until 1997
Bigeye sand tiger	*Odontaspis noronhai*	Part of LCS complex until 1997
Whale	*Rhincodon typus*	Part of LCS complex until 1997
Basking	*Cetorhinus maximus*	Part of LCS complex until 1997
White	*Carcharodon carcharias*	Part of LCS complex until 1997
Dusky	*Carcharhinus obscurus*	Part of LCS complex until 1999
Bignose	*Carcharhinus altimus*	Part of LCS complex until 1999
Galapagos	*Carcharhinus galapagensis*	Part of LCS complex until 1999
Night	*Carcharhinus signatus*	Part of LCS complex until 1999
Caribbean reef	*Carcharhinus perezi*	Part of LCS complex until 1999
Narrowtooth	*Carcharhinus brachyurus*	Part of LCS complex until 1999

Table 5. Summary of 2020 shark regulations affecting hammerhead sharks

Requirement for Specific Fishery	**Retention Limits**	**Quotas**	**Other Requirements**
Inside the Commercial Shark Research Fishery	Trip limit is specific to each vessel and owner(s) combination and is listed on the Shark Research Permit. **Non-sandbar LCS:** Trip limit is specific to each vessel and owner (s) combination and is listed on the Shark Research Permit.	**Non-sandbar LCS:** <u>Quota as of Jan 1, 2020</u>: 50 mt dw	- Need Shark Research Fishery Permit -100 percent observer coverage when participating in research fishery - Adjusted quotas may be further adjusted based on future overharvests, if any.
Outside the Commercial Shark Research Fishery	**Non-sandbar LCS:** <u>Directed Permit:</u> • Gulf of Mexico region: 45 non-sandbar LCS/vessel/trip • Atlantic Region: 36 non-sandbar LCS/vessel/trip (Jan 1-June 18); 55 non-sandbar LCS/vessel/trip (June 19-Dec 31) <u>Incidental Permit</u>: • Atlantic and Gulf of Mexico: 3 non-sandbar LCS/vessel/trip	**Hammerhead shark Atlantic Region:** <u>Quota as of Jan 1, 2020</u>: 27.1 mt dw **Hammerhead shark Gulf of Mexico Region:** <u>Quota as of Jan 1, 2020</u>: Western sub-region:11.9 mt dw Eastern sub-region:13.4 mt dw	-Vessels subject to observer coverage, if selected - Adjusted quotas may be further adjusted based on future overharvests, if any. - Trips limits were adjusted inseason
All Commercial Shark Fisheries	**Gears Allowed:** Gillnet; Bottom/Pelagic Longline; Rod and Reel; Handline; Bandit Gear		
	Authorized Species: Non-sandbar LCS (silky (not authorized for PLL), blacktip, spinner, bull, lemon, nurse, great hammerhead (not authorized for pelagic longline), scalloped hammerhead (not authorized for pelagic longline), smooth hammerhead (not authorized for pelagic longline), and tiger sharks), pelagic sharks (porbeagle, common thresher, shortfin mako, oceanic whitetip (not authorized for pelagic longline), and blue sharks), and SCS (bonnethead, finetooth, blacknose, and Atlantic sharpnose sharks)		
	Landings condition: All sharks must have *fins naturally attached* through offloading; fins can be cut slightly for storage but must remain attached to the carcass via at least a small amount of uncut skin; shark carcasses must remain in whole or log form through offloading. Sharks can have the heads removed but the tails must remain naturally attached.		
	Permits Required: Commercial Directed or Incidental Shark Permit		
	Reporting Requirements: All commercial fishermen must submit commercial logbooks; all dealers must report weekly		
All Recreational Shark Fisheries	**Gears Allowed:** Rod and Reel; Handline		
	Authorized Species: Non-ridgeback LCS (blacktip, spinner, bull, lemon, nurse, great hammerhead, scalloped hammerhead, smooth hammerhead); tiger sharks; pelagic sharks (porbeagle, common thresher, shortfin mako, oceanic whitetip, and blue sharks); and SCS (bonnethead, finetooth, blacknose, and Atlantic sharpnose sharks)		
	Landing condition: Sharks must be landed with head, fins, and tail naturally attached		
	Retention limits: 1 shark vessel/trip for most sharks, plus 1 Atlantic sharpnose and 1 bonnethead per person/trip, plus no limit on smoothhound sharks		
	Minimum size: For most sharks, including blacktip, 54” straight fork length. 78” straight fork length for great, smooth, and scalloped hammerhead. 71” straight fork length for males and 83” straight fork length for female shortfin mako. No minimum size for Atlantic sharpnose, bonnethead, or smoothhound sharks.		
	Permits Required: HMS Angling; HMS Charter/Headboat; General Category Permit Holders and General Commercial Swordfish Permit Holders (only when fishing in a shark tournament)		
	Reporting Requirements: Participate in MRIP and LPS if contacted		

<u>Definitions of Acronyms in Table 1</u>: Fork Length (FL); Highly Migratory Species (HMS); Large Coastal Sharks (LCS); Large Pelagic Survey (LPS); Marine Recreational Information Program (MRIP); Small Coastal Sharks (SCS)

Control Date Notices

February 22, 1994 (59 FR 8457), September 16, 2011 (76 FR 57709)

Management Program Specifications

Table 6. General management information for the hammerhead shark species

Species	Great hammerhead shark (*Sphyrna mokarran*) Smooth hammerhead shark (*Sphyrna zygaena*) Scalloped hammerhead shark (*Sphyrna lewini*) Carolina hammerhead shark (*Sphyrna gilberti*) - no specific management
Management Unit	Atlantic Ocean and Gulf of Mexico
Management Unit Definition	All federal waters within U.S. EEZ of the western north Atlantic Ocean, including the Gulf of Mexico and the Caribbean Sea.
Management Entity	NOAA Fisheries, Highly Migratory Species Management Division
Management Contacts **SERO / Council**	Karyl Brewster-Geisz N/A
Current stock exploitation status	Unknown
Current stock biomass status	Unknown

Table 7. Specific management criteria for the hammerhead shark

Criteria	Value
Current Relative Biomass Level	N_{2005}/N_{MSY} = 0.45
Domestic Minimum Stock Size Threshold	$(1\text{-M})B_{MSY}$
Years to Rebuild	10
Current Relative Fishing Mortality	F_{2005}/F_{MSY} =1.29
Maximum Fishing Mortality Threshold	F_{MSY} = 0.11
B_{MSY}	N_{MSY} = 62,000 (numbers of sharks)

Stock Projection Information for the Hammerhead Sharks:

NOAA Fisheries only has a rebuilding plan for scalloped hammerhead sharks, which was a 10-year rebuilding plan that will end in 2023.

Quota Calculations

Table 8. Quota calculation details for hammerhead sharks.

Current Commercial Landings Quota Value	Annual 52.4 mt dw
Next Scheduled Quota Change	NA
Annual or averaged quota ?	Annual
If averaged, number of years to average	NA
Does the quota include bycatch/discard ?	No

How is the quota calculated - conditioned upon exploitation or average landings?

The quota was determined based on the TAC calculated for the scalloped hammerhead shark TAC of 79.6 mt dw provided by Hayes et al. (2009). Based on that TAC, the HMS Management Division subtracted average annual recreational landings from 2008-2011 (4.9 mt dw), discards from 2008-2011 (22.0 mt dw), and research set-aside mortality from 2008-2011 (0.3 mt dw), resulting in an overall commercial quota of 52.4 mt dw, which applies across both the Atlantic and Gulf of Mexico regions and to all three hammerhead shark species. This total commercial hammerhead shark quota is divided between these two regions using the average percentage of total hammerhead shark landings in each region. Between 2008 and 2011, hammerhead shark landings in the Atlantic region accounted for 51.7 percent of the total hammerhead shark landings and hammerhead shark landings in the Gulf of Mexico region accounted for 48.3 percent of the total hammerhead shark landings. Thus, the Atlantic hammerhead shark commercial quota is 27.1 mt dw and the Gulf of Mexico hammerhead shark commercial quota is 25.3 mt dw. The boundary between the Gulf of Mexico region and the Atlantic region is defined as a line beginning on the east coast of Florida at the mainland at 25°20.4′ N. lat., proceeding due east. Any water and land to the south and west of that boundary is considered, for the purposes of quota monitoring and setting of quotas, to be within the Gulf of Mexico region. Any water and land to the north and east of that boundary, for the purposes of quota monitoring and setting of quotas, is considered to be within the Atlantic region.

Under Amendment 6, the Gulf of Mexico regional commercial quotas for hammerhead sharks was split for management purposes into western and eastern sub-regional quotas. Based on landings from 2014, the eastern Gulf of Mexico sub-region receives 52.8 percent of the Gulf of Mexico hammerhead shark base annual quota (13.4 mt dw), and the western Gulf of Mexico sub-region receives 47.2 percent of the Gulf of Mexico hammerhead shark base annual quota (11.9 mt dw). The boundary between the sub-regions is drawn along 88°00′ W. long.. All sharks harvested within the Gulf of Mexico region in fishing catch areas in waters westward of 88°00′ W. long. are considered to be from the western Gulf of Mexico sub-region, and all sharks harvested within the Gulf of Mexico region in fishing catch areas in waters east of 88°00′ W. long., including within the Caribbean Sea, are considered to be from the eastern Gulf of Mexico sub-region.

Does the quota include bycatch/discard estimates? If so, what is the source of the bycatch/discard values? What are the bycatch/discard allowances?

The commercial quota does not include bycatch/discards estimates. While the quota does not include bycatch/discards estimates, the ACL does.

Are there additional details of which the analysts should be aware to properly determine quotas for this stock?

The quota is adjusted each year through a season rule. Overharvests are deducted from the following year. No overharvests have been experienced for the hammerhead shark species since implementation of Amendment 5a in 2013. Table 3 shows the history of shark quotas adjusted for under and overharvest. Underharvests are not applied to the hammerhead shark management group because the stock status is unknown.

Management and Regulatory Timeline

The following tables provide a timeline of Federal management actions by fishery. It should be noted that federally permitted fishermen must follow federal regulations unless state regulations are more restrictive.

Table 9. Annual commercial hammerhead shark regulatory summary (managed in the LCS complex in 2003 where it was managed as a ridgeback).

		Fishing Year			**Possession Limit**
Year	*Base Quota (LCS complex)*	*N. Atlantic*	*S. Atlantic*	*Gulf*	*All regions*
1993	2,436 mt dw	One region; calendar year with two fishing periods			No trip limit
1994	2,346 mt dw	One region; calendar year with two fishing periods			4,000 lb dw LCS combined/trip
1995	2,570 mt dw	One region; calendar year with two fishing periods			4,000 lb dw LCS combined/trip
1996	2,570 mt dw	One region; calendar year with two fishing periods			4,000 lb dw LCS combined/trip
1997	1,285 mt dw	One region; calendar year with two fishing periods			4,000 lb dw LCS combined/trip
1998	1,285 mt dw	One region; calendar year with two fishing periods			4,000 lb dw LCS combined/trip
1999	1,285 mt dw	One region; calendar year with two fishing periods (but fishing season open and closed twice during 2nd season-see Table 3)			4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders*
2000	1,285 mt dw	One region; calendar year with two fishing periods			4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders
2001	1,285 mt dw	One region; calendar year with two fishing periods			4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders
2002	1,285 mt dw	One region; calendar year with two fishing periods			4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders
2003	783 mt dw	One region; calendar year with two fishing periods but ridgeback and non-ridgeback split-see Table 3)			4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders
2004	1,107 mt dw	Regions† with two fishing seasons	Regions† with two fishing seasons	Regions† with two fishing seasons	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders
2005	1,107 mt dw	Trimesters/Regions†	Trimesters/Regions†	Trimesters/Regions†	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders
2006	1,107 mt dw	Trimesters/Regions†	Trimesters/Regions†	Trimesters/Regions†	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders
2007	1,107 mt dw	Trimesters/Regions†	Trimesters/Regions†	Trimesters/Regions†	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders
2008**	677.8 mt dw***	Atlantic region; calendar year		Gulf of Mexico region; calendar year	33 non-sandbar LCS/vessel/trip; 3 non-sandbar LCS/vessel/trip for incidental permit holders

Table 9 cont.		**Fishing Year**			**Possession Limit**
Year	*Base Quota (LCS complex)*	*N. Atlantic*	*S. Atlantic*	*Gulf*	*All regions*
2010**	677.8 mt dw***	Atlantic region; calendar year		Gulf of Mexico region; calendar year	33 non-sandbar LCS/vessel/trip; 3 non-sandbar LCS/vessel/trip for incidental permit holders
2011**	677.8 mt dw***	Atlantic region; calendar year		Gulf of Mexico region; calendar year	33 non-sandbar LCS/vessel/trip; 3 non-sandbar LCS/vessel/trip for incidental permit holders
2012**	677.8 mt dw***	Atlantic region; calendar year		Gulf of Mexico region; calendar year	33 non-sandbar LCS/vessel/trip; 3 non-sandbar LCS/vessel/trip for incidental permit holders
2013**	52.4 mt dw****	Atlantic region; calendar year		Gulf of Mexico region; calendar year	36 non-sandbar LCS/vessel/trip; 3 non-sandbar LCS/vessel/trip for incidental permit holders
2014**	52.4 mt dw****	Atlantic region; calendar year		Gulf of Mexico region; calendar year	36 non-sandbar LCS/vessel/trip; 3 non-sandbar LCS/vessel/trip for incidental permit holders
2015*****	52.4 mt dw****	Atlantic region; calendar year		Gulf of Mexico region; calendar year	45 non-sandbar LCS/vessel/trip; 3 non-sandbar LCS/vessel/trip for incidental permit holders
2016*****	52.4 mt dw****	Atlantic region; calendar year		Gulf of Mexico region; calendar year	45 non-sandbar LCS/vessel/trip; 3 non-sandbar LCS/vessel/trip for incidental permit holders
2017*****	52.4 mt dw****	Atlantic region; calendar year		Gulf of Mexico region; calendar year	45 non-sandbar LCS/vessel/trip; 3 non-sandbar LCS/vessel/trip for incidental permit holders
2018*****	52.4 mt dw****	Atlantic region; calendar year		Gulf of Mexico region; calendar year	45 non-sandbar LCS/vessel/trip; 3 non-sandbar LCS/vessel/trip for incidental permit holders
2019*****	52.4 mt dw****	Atlantic region; calendar year		Gulf of Mexico region; calendar year	45 non-sandbar LCS/vessel/trip; 3 non-sandbar LCS/vessel/trip for incidental permit holders
2020*****	52.4 mt dw****	Atlantic region; calendar year		Gulf of Mexico region; calendar year	45 non-sandbar LCS/vessel/trip; 3 non-sandbar LCS/vessel/trip for incidental permit holders

*Limited Access Permits (LAPs) were implemented for the shark and swordfish fisheries under 1999 FMP; †Regions = Gulf of Mexico, South Atlantic, and North Atlantic.
**Under Amendment 2, the base quota for the LCS complex was reduced, two regions were formed (Atlantic and Gulf of Mexico), and sharks are required to be offloaded with all fins naturally attached.
***The total base quota for non-sandbar LCS (including hammerhead sharks) was 677.8 mt dw. This base quota was split between the two regions and the shark research fishery as follows: Gulf of Mexico = 439.5 mt dw; Atlantic = 188.3 mt dw; and Shark Research Fishery = 50 mt dw. However, from July 24, 2008 through December 31, 2012, to account for overharvests that occurred in 2007, the total adjusted base quota is 615.8 mt dw. This adjusted base quota is split between the regions and the shark research fishery as follows: Gulf of Mexico = 390.5 mt dw; Atlantic = 187.8 mt dw;
****Under Amendment 5a, hammerhead sharks were removed from the aggregated LCS complex and was split into regional quotas. This base quota split between the two regions are as follows: Gulf of Mexico= 25.3 mt dw; Atlantic= 27.1 mt dw. Under Amendment 6, the Gulf of Mexico regional commercial quotas for hammerhead sharks was split into western and eastern sub-regional quotas as follows: Western Gulf of Mexico sub-regional quota= 11.9 mt dw; Eastern Gulf of Mexico sub-regional quota= 13.4 mt dw.
*****The default retention limit for LCS could be adjusted during the fishing year from zero to 55 non-sandbar LCS/vessel/trip.

Table 10. Annual recreational hammerhead shark species regulatory summary

Year	**Fishing Year**	**Size Limit (straight line fork length)**	**Bag Limit**
1993	Calendar Year	No size limit	4 LCS or pelagic sharks/vessel
1994	Calendar Year	No size limit	4 LCS or pelagic sharks/vessel
1995	Calendar Year	No size limit	4 LCS or pelagic sharks/vessel
1996	Calendar Year	No size limit	4 LCS or pelagic sharks/vessel
1997	Calendar Year	No size limit	2 LCS/SCS/pelagic sharks combined/vessel
1998	Calendar Year	No size limit	2 LCS/SCS/pelagic sharks combined/vessel
1999	Calendar Year	No size limit	2 LCS/SCS/pelagic sharks combined/vessel
2000	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2001	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2002	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2003	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2004	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2005	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2006	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2007	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2008	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2009	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2010	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2011	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2012	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2013	Calendar Year	Minimum size =6.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2014	Calendar Year	Minimum size =6.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2015	Calendar Year	Minimum size =6.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2016	Calendar Year	Minimum size =6.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2017	Calendar Year	Minimum size =6.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2018	Calendar Year	Minimum size =6.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2019	Calendar Year	Minimum size =6.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2020	Calendar Year	Minimum size =6.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip

Table 11: Atlantic Blacktip Recreational Regulatory History
prepared by: Larry Redd, Jr.

Year	Quota (units)	ACL (units)	Days Open	Fishing Season	season start date (first day implemented)	season end date (last day effective)	reason for closure	Minimum Size limit (Fork length, inches)	size limit start date	size limit end date	Retention Limit (# fish)	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit1 (# fish)	Aggregate Retention Limit Start Date	Aggregate Retention Limit End Date
1993	NA	NA	184	Open	7/1/1993	12/31/1993	NA	None	NA	NA	NA	NA	NA	4 LCS or pelagic sharks/vessel A	7/1/1993	12/31/1993
1994	NA	NA	365	Open	1/1/1994	12/31/1994	NA	None	NA	NA	NA	NA	NA	4 LCS or pelagic sharks/vessel A	1/1/1994	12/31/1994
1995	NA	NA	365	Open	1/1/1995	12/31/1995	NA	None	NA	NA	NA	NA	NA	4 LCS or pelagic sharks/vessel A	1/1/1995	12/31/1995
1996	NA	NA	366	Open	1/1/1996	12/31/1996	NA	None	NA	NA	NA	NA	NA	4 LCS or pelagic sharks/vessel A	1/1/1996	12/31/1996
1997	NA	NA	365	Open	1/1/1997	12/31/1997	NA	None	NA	NA	NA	NA	NA	4 LCS or pelagic sharks/vessel A	1/1/1997	4/1/1997
														2 LCS/SCS/pelagic sharks combined/vessel B	4/2/1997	12/31/1997
1998	NA	NA	365	Open	1/1/1998	12/31/1998	NA	None	NA	NA	NA	NA	NA	2 LCS/SCS/pelagic sharks combined/vessel B	1/1/1998	12/31/1998
1999	NA	NA	365	Open	1/1/1999	12/31/1999	NA	None	NA	NA	NA	NA	NA	2 LCS/SCS/pelagic sharks combined/vessel B	1/1/1999	6/30/1999
														1 LCS/SCS/pelagic shark combined/vessel/trip C	7/1/1999	12/31/1999
2000	NA	NA	366	Open	1/1/2000	12/31/2000	NA	54 C	1/1/2000	12/31/2000	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C	1/1/2000	12/31/2000
2001	NA	NA	365	Open	1/1/2001	12/31/2001	NA	54 C	1/1/2001	12/31/2001	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C	1/1/2001	12/31/2001
2002	NA	NA	365	Open	1/1/2002	12/31/2002	NA	54 C	1/1/2002	12/31/2002	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C	1/1/2002	12/31/2002
2003	NA	NA	365	Open	1/1/2003	12/31/2003	NA	54 C	1/1/2003	12/31/2003	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C	1/1/2003	12/29/2003
														1 LCS/SCS/pelagic shark combined/vessel/trip C, D	12/30/2003	12/31/2003
2004	NA	NA	366	Open	1/1/2004	12/31/2004	NA	54 C,D	1/1/2004	12/31/2004	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D	1/1/2004	12/31/2004
2005	NA	NA	365	Open	1/1/2005	12/31/2005	NA	54 C,D	1/1/2005	12/31/2005	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D	1/1/2005	12/31/2005
2006	NA	NA	365	Open	1/1/2006	12/31/2006	NA	54 C,D	1/1/2006	12/31/2006	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D	1/1/2006	12/31/2006
2007	NA	NA	365	Open	1/1/2007	12/31/2007	NA	54 C,D	1/1/2007	12/31/2007	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D	1/1/2007	12/31/2007
2008	NA	NA	366	Open	1/1/2008	12/31/2008	NA	54 C,D	1/1/2008	12/31/2008	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D, E	1/1/2008	12/31/2008
2009	NA	NA	365	Open	1/1/2009	12/31/2009	NA	54 C,D	1/1/2009	12/31/2009	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D, E	1/1/2009	12/31/2009
2010	NA	NA	365	Open	1/1/2010	12/31/2010	NA	54 C,D	1/1/2010	12/31/2010	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D, E	1/1/2010	12/31/2010
2011	NA	NA	365	Open	1/1/2011	12/31/2011	NA	54 C,D	1/1/2011	12/31/2011	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D, E	1/1/2011	12/31/2011
2012	NA	NA	366	Open	1/1/2012	12/31/2012	NA	54 C,D	1/1/2012	12/31/2012	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D, E	1/1/2012	12/31/2012
2013	NA	NA	365	Open	1/1/2013	12/31/2013	NA	78 C,D,F	1/1/2013	12/31/2013	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D, E	1/1/2013	12/31/2013
2014	NA	NA	365	Open	1/1/2014	12/31/2014	NA	78 C,D,F	1/1/2014	12/31/2014	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D, E	1/1/2014	12/31/2014
2015	NA	NA	365	Open	1/1/2015	12/31/2015	NA	78 C,D,F	1/1/2015	12/31/2015	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D, E	1/1/2015	12/31/2015
2016	NA	NA	366	Open	1/1/2016	12/31/2016	NA	78 C,D,F	1/1/2016	12/31/2016	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D, E	1/1/2016	12/31/2016
2017	NA	NA	365	Open	1/1/2017	12/31/2017	NA	78 C,D,F,	1/1/2017	12/31/2017	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D, E	1/1/2017	12/31/2017
2018	NA	NA	365	Open	1/1/2018	12/31/2018	NA	78 C,D,F,	1/1/2018	12/31/2018	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D, E, G,H	1/1/2018	12/31/2018
2019	NA	NA	365	Open	1/1/2018	12/31/2018	NA	78 C,D,F,	1/1/2019	12/31/2019	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip C, D, E, G, H	1/1/2019	12/31/2019

1 = The aggregate recreational bag limit includes several species(LCS: including sandbar, silky, tiger, blacktip, spinner, bull, lemon, nurse, scalloped hammerhead, great hammerhead, and smooth hammerhead; SCS: including bonnethead, Atlantic sharpnose, finetooth, and blacknose; Pelagic sharks: including porbeagle, thresher, shortfin mako, blue, and oceanic whitetip) that change within the aggregate bag limit throughout the time series.
A = Established a recreational trip limit of 4 LCS or pelagic sharks per vessel (1993 FMP for Sharks of the Atlantic Ocean; effective April 26, 1993);
B= Reduced recreational retention limit for all sharks to 2 LCS/SCS/pelagic sharks combined per trip (effective April 2, 1997)
C = Reduced recreational retention limits for all sharks to 1 shark per vessel per trip except for Atlantic sharpnose (1 Atlantic sharpnose/person/trip) and established a recreational minimum size for all sharks except Atlantic sharpnose (4.5 feet) (1999 FMP for Atlantic Tunas, Swordfish and Sharks; effective date July 1, 1999);
D= Adjusted the recreational bag and size limits (allowed 1 bonnethead/person/trip in addition to 1 Atlantic sharpnose/person/trip with no size limit for bonnethead or Atlantic sharpnose) (Amendment 1 to the FMP for Atlantic Tunas, Swordfish and Sharks ; effective December 30, 2003);
E = Retention of sandbar sharks prohibited in recreational fishery (Amendment 2, effective July 24, 2008).
F = Increased recreational minimum size for hammerhead sharks to 78 inches fork length (Amendment 5a, effective July 3, 2013)
G= Required the use of non-offset, non-stainless steel circle hooks by all HMS permit holders with a shark endorsement when fishing for sharks recreationally south of 41° 43' N latitude, except when fishing with flies or artificial lures (Amendment 5b, effective June 5, 2017)
H = Retention of oceanic whitetip sharks and scalloped, smooth, and great hammerhead sharks prohibited by recreational fishermen fishing with a General Category permit participating in an HMS tournament or those fishing under an HMS Angling or Charter/ Headboat permit when tuna or tuna-like species are also retained (rulemaking 76 FR 53652, effective September 28, 2011)

Table 12: Hammerhead Shark Commercial Regulatory History
prepared by: Delisse Ortiz and Karyl Brewster-Geisz

Year	Annual Quota (mt dw)	Seasonal Quota (mt dw)	ACL (units)	Days Open/ Close	Fishing Season	Reason for Closure	season start date (first day implemented)	season end date (last day effective)	Size limit (units and length type, indicate maximum or natural length)	size limit start date	size limit end date	Retention Limit (units)	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit (units)	Aggregate Retention Limit Start Date	Aggregate Retention Limit End Date
1993 A,B, C	2436	1218	NA	135	Open		1/1/1993	5/15/1993	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	46	Closed	Met seasonal quota	5/16/1993	6/30/1993	NA	NA	NA	NA	NA	NA	NA		
		875	NA	31	Open		7/1/1993	7/31/1993	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	153	Closed	Met seasonal quota	8/1/1993	12/31/1993	NA	NA	NA	NA	NA	NA	NA	NA	NA
1994 A,B,C	2,436	1,285	NA	137	Open		1/1/1994	5/17/1994	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip L	1/1/1994	5/17/1994
			NA	44	Closed	Met seasonal quota	5/18/1994	6/30/1994	NA	NA	NA	NA	NA	NA	NA	NA	NA
		1,318	NA	41	Open		7/1/1994	8/10/1994	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip L	7/1/1994	8/10/1994
			NA	21	Closed	Met seasonal quota	8/11/1994	8/31/1994	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	65	Open		9/1/1994	11/4/1994	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip L	9/1/1994	11/4/1994
			NA	57	Closed	Met seasonal quota	11/5/1994	12/31/1994	NA	NA	NA	NA	NA	NA	NA	NA	NA
1995 A,C, J	2,570	1,285	NA	151	Open		1/1/1995	5/31/1995	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip L	1/1/1995	5/31/1995
			NA	30	Closed	Met seasonal quota	6/1/1995	6/30/1995	NA	NA	NA	NA	NA	NA	NA	NA	NA
		968	NA	92	Open		7/1/1995	9/30/1995	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip L	7/1/1995	8/31/1994
			NA	92	Closed	Met seasonal quota	10/1/1995	12/31/1995	NA	NA	NA	NA	NA	NA	NA	NA	NA
1996 A,C, J	2,570	1,285	NA	138	Open		1/1/1996	5/17/1996	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip L	1/1/1996	5/17/1996
			NA	44	Closed	Met seasonal quota	5/18/1996	6/30/1996	NA	NA	NA	NA	NA	NA	NA	NA	NA
		1,168	NA	62	Open		7/1/1996	8/31/1996	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip L	7/1/1996	8/31/1996
			NA	122	Closed	Met seasonal quota	9/1/1996	12/31/1996	NA	NA	NA	NA	NA	NA	NA	NA	NA
1997 A, C,E	1,285	642	NA	97	Open		1/1/1997	4/7/1997	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip L	1/1/1997	4/7/1997
			NA	84	Closed	Met seasonal quota	4/8/1997	6/30/1997	NA	NA	NA	NA	NA	NA	NA	NA	NA
		326	NA	21	Open		7/1/1997	7/21/1997	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip L	7/1/1997	7/21/1997
			NA	163	Closed	Met seasonal quota	7/22/1997	12/31/1997	NA	NA	NA	NA	NA	NA	NA	NA	NA
1998 A,C,E	1,285	642	NA	90	Open		1/1/1998	3/31/1998	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip L	1/1/1998	3/31/1998
			NA	91	Closed	Met seasonal quota	4/1/1998	6/30/1998	NA	NA	NA	NA	NA	NA	NA	NA	NA
		600	NA	35	Open		7/1/1998	8/4/1998	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip L	7/1/1998	8/4/1998
			NA	148	Closed	Met seasonal quota	8/5/1998	12/30/1998	NA	NA	NA	NA	NA	NA	NA	NA	NA
1999 A,C,D,E	1,285	642	NA	90	Open		1/1/1999	3/31/1999	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/1999	3/31/1999
			NA	91	Closed	Met seasonal quota	4/1/1999	6/30/1999	NA	NA	NA	NA	NA	NA	NA	NA	NA
		585	NA	28	Open		7/1/1999	7/28/1999	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/1/1999	7/28/1999
			NA	34	Closed	Met seasonal quota	7/29/1999	8/31/1999	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	45	Open		9/1/1999	10/15/1999	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders	9/1/1999	10/15/1999
			NA	77	Closed	Met seasonal quota	10/16/1999	12/31/1999	NA	NA	NA	NA	NA	NA	NA	NA	NA
2000 A,C,D,E	1,285	642	NA	91	Open		1/1/2000	3/31/2000	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/2000	3/31/2000
			NA	91	Closed	Met seasonal quota	4/1/2000	6/30/2000	NA	NA	NA	NA	NA	NA	NA	NA	NA
		542	NA	46	Open		7/1/2000	8/15/2000	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/1/2000	8/15/2000
			NA	138	Closed	Met seasonal quota	8/16/2000	12/31/2000	NA	NA	NA	NA	NA	NA	NA	NA	NA
2001 A,C,D,E	1,285	642	NA	83	Open		1/1/2001	3/24/2001	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/2001	3/24/2001
			NA	98	Closed	Met seasonal quota	3/25/2001	6/30/2001	NA	NA	NA	NA	NA	NA	NA	NA	NA
		697	NA	66	Open		7/1/2001	9/4/2001	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/1/2001	9/4/2001
			NA	118	Closed	Met seasonal quota	9/5/2001	12/31/2001	NA	NA	NA	NA	NA	NA	NA	NA	NA
2002 A,C,D,E	1,285	735.5	NA	105	Open		1/1/2002	4/15/2002	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/2002	4/15/2002
			NA	76	Closed	Met seasonal quota	4/16/2002	6/30/2002	NA	NA	NA	NA	NA	NA	NA	NA	NA
		655.5	NA	77	Open		7/1/2002	9/15/2002	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/1/2002	9/15/2002

Table 12: Hammerhead Shark Commercial Regulatory History Continued

Year	Annual Quota (mt dw)	Seasonal Quota (mt dw)	ACL (units)	Days Open/ Close	Fishing Season	Reason for Closure	season start date (first day implemented)	season end date (last day effective)	Size limit (units and length type, indicate maximum or natural length)	size limit start date	size limit end date	Retention Limit (units)	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit (units)	Aggregate Retention Limit Start Date	Aggregate Retention Limit End Date
			NA	107	Closed	Met seasonal quota	9/16/2002	12/31/2002	NA	NA	NA	NA	NA	NA	NA	NA	NA
2003 A,C,D,F	783	391.5	NA	105	Open - Ridgeback LCS		1/1/2003	4/15/2003	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/2003	4/15/2003
		424	NA	76	Closed - Ridgeback LCS	Met seasonal quota	4/16/2003	6/30/2003	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	77	Open - Ridgeback LCS		7/1/2003	9/15/2003	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/1/2003	9/15/2003
		465.5	NA	107	Closed - Ridgeback LCS	Met seasonal quota	9/16/2003	12/31/2003	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	135	Open - Non-ridgeback LCS		1/1/2003	5/15/2003	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/2003	5/15/2003
		498	NA	46	Closed- Non-ridgeback LCS	Met seasonal quota	5/16/2003	6/30/2003	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	77	Open - Non-ridgeback LCS		7/1/2003	9/15/2003	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/1/2003	9/15/2003
2004 A,C,D,G,H	1,107	244.7	NA	107	Closed - Non-ridgeback LCS	Met seasonal quota	9/16/2003	12/31/2003	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	46	Open - SATL		1/1/2004	2/15/2004	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/2004	2/15/2004
		369.5	NA	136	Closed - SATL	Met seasonal quota	2/16/2004	6/30/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	92	Open - SATL		7/1/2004	9/30/2004	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/1/2004	9/30/2004
		18.1	NA	92	Closed - SATL	Met seasonal quota	10/1/2004	12/31/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	106	Open - NATL		1/1/2004	4/15/2004	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/2004	4/15/2004
		39.6	NA	76	Closed - NATL	Met seasonal quota	4/16/2004	6/30/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	15	Open - NATL		7/1/2004	7/15/2004	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/1/2004	7/15/2004
2005 A,C,D,G,H	1,107	133.3	NA	169	Closed - NATL	Met seasonal quota	7/16/2004	12/31/2004	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	46	Open - SATL		1/1/2005	2/15/2005	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/2005	2/15/2005
			NA	140	Closed - SATL	Met seasonal quota	2/16/2005	7/5/2005	NA	NA	NA	NA	NA	NA	NA	NA	NA
		182 187.5	NA	57	Open - SATL		7/6/2005	8/31/2005	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/6/2005	8/31/2005
			NA	76	Open - SATL		9/1/2005	11/15/2005	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	9/1/2005	11/15/2005
		6.3	NA	46	Closed - SATL	Met seasonal quota	11/16/2005	12/31/2005	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	120	Open - NATL		1/1/2005	4/30/2005	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/2005	4/30/2005
			NA	81	Closed - NATL	Met seasonal quota	5/1/2005	7/20/2005	NA	NA	NA	NA	NA	NA	NA	NA	NA
		65.2 4.9	NA	42	Open - NATL		7/21/2005	8/31/2005	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/21/2005	8/31/2005
			NA	15	Open - NATL		9/1/2005	9/15/2005	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	9/1/2005	9/15/2005

Table 12: Hammerhead Shark Commercial Regulatory History Continued

Year	Annual Quota (mt dw)	Seasonal Quota (mt dw)	ACL (units)	Days Open/ Close	Fishing Season	Reason for Closure	season start date (first day implemented)	season end date (last day effective)	Size limit (units and length type, indicate maximum or natural length)	size limit start date	size limit end date	Retention Limit (units)	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit (units)	Aggregate Retention Limit Start Date	Aggregate Retention Limit End Date
			NA	107	Closed -NATL	Met seasonal quota	9/16/2005	12/31/2005	NA	NA	NA	NA	NA	NA	NA	NA	NA
2006 A,C,D,G,H	1,107	141.3	NA	74	Open - SATL		1/1/2006	3/15/2006	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/2006	3/15/2006
			NA	112	Closed - SATL	Met seasonal/regional quota; quota exceeded by 136.7%	3/16/2006	7/5/2006	NA	NA	NA	NA	NA	NA	NA	NA	NA
		151.7 50.3	NA	42	Open - SATL		7/6/2006	8/16/2006	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/6/2006	8/16/2006
			NA	33	Open - SATL		9/1/2006	10/3/2006	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	9/1/2006	10/3/2006
		5.3	NA	89	Closed _SATL	Met seasonal/regional quota	10/4/2006	12/31/2006	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	120	Open - NATL		1/1/2006	4/30/2006	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/2006	4/30/2006
		66.3	NA	66	Closed - NATL	Met seasonal/regional quota	5/1/2006	7/5/2006	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	32	Open - NATL		7/6/2006	8/6/2006	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/6/2006	8/6/2006
2007 A,C,D,G,H	1,107		NA	147	Closed -NATL	Met seasonal/regional quota	8/7/2006	12/31/2006	NA	NA	NA	NA	NA	NA	NA	NA	NA
		0 163.1	NA	195	SATL - Closed	Met seasonal/regional quota	1/1/2007	7/14/2007	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	32	Open - SATL		7/15/2007	8/15/2007	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/15/2007	8/15/2007
		7.9	NA	138	Closed - SATL	Met seasonal/regional quota	8/16/2007	12/31/2007	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	120	NATL - Open		1/1/2007	4/30/2007	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	1/1/2007	4/30/2007
		69	NA	66	Closed - NATL	Met seasonal/regional quota	5/1/2007	7/5/2007	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	26	Open - NATL		7/6/2007	7/31/2007	NA	NA	NA	NA	NA	NA	4,000 lb dw LCS combined/trip; 5 LCS for incidental permit holders L,D	7/6/2007	7/31/2007
2008I	1,107		NA	153	Closed -NATL	Met seasonal/regional quota	8/1/2007	12/31/2007	NA	NA	NA	NA	NA	NA	NA	NA	NA
		0	NA	205	Closed - SATL	delayed opening for management reasons	1/1/2008	7/23/2008	NA	NA	NA	NA	NA	NA	NA	NA	NA
		0	NA	205	Closed - NATL	delayed opening for management reasons	1/1/2008	7/23/2008	NA	NA	NA	NA	NA	NA	NA	NA	NA
	187.8	187.8	NA	161	Non Sandbar ATL- Open		7/24/2008	12/31/2008	NA	NA	NA	NA	NA	NA	33 non-sandbar LCS per vessel per trip for directed permit holders	7/24/2008	12/31/2008
			NA						NA	NA	NA	NA	NA	NA	3 non sandbar LCS per vessel per trip for incidental permit holders.	7/24/2008	12/31/2008

Table 12: Hammerhead Shark Commercial Regulatory History Continued

Year	Annual Quota (mt dw)	Seasonal Quota (mt dw)	ACL (units)	Days Open/ Close	Fishing Season	Reason for Closure	season start date (first day implemented)	season end date (last day effective)	Size limit (units and length type, indicate maximum or natural length)	size limit start date	size limit end date	Retention Limit (units)	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit (units)	Aggregate Retention Limit Start Date	Aggregate Retention Limit End Date
2009 I	37.5 187.8	37.5	NA	161	Non Sandbar Research- Open		7/24/2008	12/31/2008	NA	NA	NA	NA	NA	NA	NA	7/24/2008	12/31/2008
		0	NA	22	Non Sandbar ATL-Closed	delayed opening for management reasons	1/1/2009	1/22/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA
		187.8	NA	160	Non Sandbar ATL- Open		1/23/2009	7/1/2009	NA	NA	NA	NA	NA	NA	33 non-sandbar LCS per vessel per trip for directed permit holders	1/23/2009	7/1/2009
			NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/23/2009	7/1/2009
	37.5		NA	183	Non Sandbar ATL-Closed		7/2/2009	12/31/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA
		0 37.5	NA	22	Non- Sandbar Research- Closed	delayed opening for management reasons	1/1/2009	1/22/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	160	Non Sandbar Research- Open		1/23/2009	7/1/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA
2010 I	187.8		NA	183	Non Sandbar Research- Closed		7/2/2009	12/31/2009	NA	NA	NA	NA	NA	NA	NA	NA	NA
		0	NA	195	Non Sandbar ATL - Closed	delayed opening for management reasons	1/1/2010	7/14/2010	NA	NA	NA	NA	NA	NA	NA	NA	NA
		169.7	NA	144	Non Sandbar ATL- Open		7/15/2010	12/5/2010	NA	NA	NA	NA	NA	NA	33 non-sandbar LCS per vessel per trip for directed permit holders	7/15/2010	12/5/2010
			NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	7/15/2010	12/5/2010
	390.5		NA	26	Non Sandbar ATL- Closed	Met seasonal/regional quota	12/6/2010	12/31/2010	NA	NA	NA	NA	NA	NA	NA	NA	NA
		0	NA	34	Non Sandbar GOM - Closed	delayed opening for management reasons	1/1/2010	2/3/2010	NA	NA	NA	NA	NA	NA	NA	NA	NA
		390.5		42	Non Sandbar GOM - Open		2/4/2010	3/17/2010	NA	NA	NA	NA	NA	NA	33 non-sandbar LCS per vessel per trip for directed permit holders	2/4/2010	3/17/2010
			NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	2/4/2010	3/17/2010
	37.5		NA	289	Non Sandbar GOM - Closed	Met seasonal/regional quota	3/18/2010	12/31/2010	NA	NA	NA	NA	NA	NA	NA	NA	NA
		0 37.5	NA	4	Non Sandbar Research - Closed	delayed opening for management reasons	1/1/2010	1/4/2010	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	281	Non Sandbar Research- Open		1/5/2010	10/12/2010	NA	NA	NA	NA	NA	NA	NA	1/5/2010	10/12/2010
2011 I	187.8		NA	80	Non Sandbar Research- Closed	Met seasonal/regional quota	10/13/2010	12/31/2010	NA	NA	NA	NA	NA	NA	NA	NA	NA
		0	NA	195	Non Sandbar ATL - Closed	delayed opening for management reasons	1/1/2011	7/14/2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
		190.4	NA	124	Non Sandbar ATL- Open		7/15/2011	11/15/2011	NA	NA	NA	NA	NA	NA	33 non-sandbar LCS per vessel per trip for directed permit holders	7/15/2011	11/15/2011
			NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	7/15/2011	11/15/2011
	351.9		NA	46	Non Sandbar ATL - Closed	Met seasonal/regional quota	11/16/2011	12/31/2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
		0	NA	59	Non Sandbar GOM - Closed	delayed opening for management reasons	1/1/2011	2/28/2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
		351.9	NA	139	Non Sandbar GOM - Open		3/1/2011	7/17/2011	NA	NA	NA	NA	NA	NA	33 non-sandbar LCS per vessel per trip for directed permit holders	3/1/2011	7/17/2011
			NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	3/1/2011	7/17/2011
	37.5	37.5	NA	167	Non Sandbar GOM - Closed	Met seasonal/regional quota	7/18/2011	12/31/2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	207	Non Sandbar Research - Open		1/1/2011	7/26/2011	NA	NA	NA	NA	NA	NA	NA	1/1/2011	7/26/2011

Table 12: Hammerhead Shark Commercial Regulatory History Continued

Year	Annual Quota (mt dw)	Seasonal Quota (mt dw)	ACL (units)	Days Open/ Close	Fishing Season	Reason for Closure	season start date (first day implemented)	season end date (last day effective)	Size limit (units and length type, indicate maximum or natural length)	size limit start date	size limit end date	Retention Limit (units)	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit (units)	Aggregate Retention Limit Start Date	Aggregate Retention Limit End Date
2012 I	187.8		NA	158	Non Sandbar Research - Closed	Met seasonal/regional quota	7/27/2011	12/31/2011	NA	NA	NA	NA	NA	NA	NA	NA	NA
		0	NA	196	Non Sandbar ATL- Closed	delayed opening for management reasons	1/1/2012	7/14/2012	NA	NA	NA	NA	NA	NA	NA	NA	NA
		183.2	NA	170	Non Sandbar ATL- Open		7/15/2012	12/31/2012	NA	NA	NA	NA	NA	NA	33 non-sandbar LCS per vessel per trip for directed permit holders	7/15/2012	12/31/2012
	392.8		NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	7/15/2012	12/31/2012
		0	NA	45	Non Sandbar GOM - Closed	delayed opening for management reasons	1/1/2012	2/14/2012	NA	NA	NA	NA	NA	NA	NA	NA	NA
		392.8	NA	143	Non Sandbar GOM -Open		2/15/2012	7/6/2012	NA	NA	NA	NA	NA	NA	33 non-sandbar LCS per vessel per trip for directed permit holders	2/15/2012	7/6/2012
			NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	2/15/2012	7/6/2012
	37.5		NA	178	Non Sandbar GOM - Closed	Met seasonal/regional quota	7/7/2012	12/31/2012	NA	NA	NA	NA	NA	NA	NA	NA	NA
		0	NA	23	Non Sandbar Research- Closed	delayed opening for management reasons	1/1/2012	1/23/2012	NA	NA	NA	NA	NA	NA	NA	NA	NA
2013 I, N,O	27.1	37.5	NA	342	Non Sandbar Research- Open		1/24/2012	12/31/2012	NA	NA	NA	NA	NA	NA	NA	1/24/2012	12/31/2012
			NA	273	ATL Hammerhead Sharks- Open		1/1/2013	9/30/2013	NA	NA	NA	NA	NA	NA	36 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2013	9/30/2013
			NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2013	9/30/2013
	25.3		NA	92	ATL Hammerhead Sharks- Closed	Met seasonal/regional quota	10/1/2013	12/31/2013	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	188	GOM Hammerhead Sharks - Open		1/1/2013	7/7/2013	NA	NA	NA	NA	NA	NA	36 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2013	7/7/2013
			NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2013	7/7/2013
				177	GOM Hammerhead Sharks - Closed		7/8/2013	12/31/2013	NA	NA	NA	NA	NA	NA	NA	NA	NA
2014 I, N, O	50 27.1	50	NA	365	Research Aggregated LCS- Open		1/1/2013	12/31/2013	NA	NA	NA	NA	NA	NA	NA	1/1/2013	12/31/2013
		0			ATL Hammerhead Shark - Closed	delayed opening for management reasons	1/1/2014	5/31/2014	NA	NA	NA	NA	NA	NA	NA	NA	NA
		27.1	NA	183	ATL Hammerhead Sharks- Open		6/1/2014	11/30/2014	NA	NA	NA	NA	NA	NA	36 non-sandbar LCS per vessel per trip for directed permit holders	6/1/2014	11/30/2014
			NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2014	11/30/2014
	25.3	25.3	NA	31	ATL Hammerhead Sharks - Closed	Met seasonal/regional quota	12/1/2014	12/31/2014	NA	NA	NA	NA	NA	NA	NA	NA	NA
			NA	140	GOM Hammerhead Sharks - Open		1/1/2014	5/20/2014	NA	NA	NA	NA	NA	NA	36 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2014	5/20/2014
			NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2014	5/20/2014
			NA	225	GOM Hammerhead Sharks - Closed	Met seasonal/regional quota	5/21/2014	12/31/2014	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 12: Hammerhead Shark Commercial Regulatory History Continued

Year	Annual Quota (mt dw)	Seasonal Quota (mt dw)	ACL (units)	Days Open/ Close	Fishing Season	Reason for Closure	season start date (first day implemented)	season end date (last day effective)	Size limit (units and length type, indicate maximum or natural length)	size limit start date	size limit end date	Retention Limit (units)	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit (units)	Aggregate Retention Limit Start Date	Aggregate Retention Limit End Date
2015 I, K, N, O	50 27.1	50	NA	365	Research Aggregated LCS-Open		1/1/2014	12/31/2014	NA	NA	NA	NA	NA	NA	NA	1/1/2014	12/31/2014
		0	NA	184	ATL Hammerhead Shark - Closed	delayed opening for management reasons	1/1/2015	6/30/2015	NA	NA	NA	NA	NA	NA	NA	NA	NA
		27.1	NA		ATL Hammerhead Sharks- Open		7/1/2015	12/31/2015	NA	NA	NA	NA	NA	NA	45 non-sandbar LCS per trip per vessel for directed permit holders	7/1/2015	12/31/2015
	13.4	13.4	NA	123	Eastern GOM Hammerhead Sharks - Open		1/1/2015	5/3/2015	NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	7/1/2015	12/31/2015
			NA						NA	NA	NA	NA	NA	NA	45 non-sandbar LCS per trip per vessel for directed permit holders	1/1/2015	6/30/2015
	11.9	11.9	NA	123	Western GOM Hammerhead Sharks - Open		1/1/2015	5/3/2015	NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	7/1/2015	12/31/2015
			NA						NA	NA	NA	NA	NA	NA	45 non-sandbar LCS per trip per vessel for directed permit holders	1/1/2015	6/30/2015
			NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	7/1/2015	12/31/2015
			NA	241	Eastern and Western GOM Hammerhead Sharks - Closed	Met seasonal/regional quota	5/4/2015	12/31/2015	NA	NA	NA	NA	NA	NA	NA	NA	NA
2016 I, K N, O	50	50	NA	365	Research Aggregated LCS-Open		1/1/2015	12/31/2015	NA	NA	NA	NA	NA	NA	NA	1/1/2015	12/31/2015
	27.1	27.1	NA	365	ATL Hammerhead Sharks- Open		1/1/2016	12/31/2016	NA	NA	NA	NA	NA	NA	36 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2016	4/4/2016
			NA									NA	NA	NA	3 non-sandbar LCS per vessel per trip for directed permit holders	4/4/2016	7/14/2016
			NA									NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holder	7/15/2016	10/18/2016
			NA									NA	NA	NA	25 non-sandbar LCS per vessel per trip for directed permit holders	10/19/2016	12/31/2016
	13.4	13.4	NA	365	Eastern GOM Hammerhead Sharks - Open		1/1/2016	12/31/2016	NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2016	12/31/2016
			NA									NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2016	12/31/2016
	11.9	11.9	NA	71	Western GOM Hammerhead Sharks - Open		1/1/2016	3/12/2016	NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2016	12/31/2016
			NA									NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2016	12/31/2016
			NA									NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2016	12/31/2016
				293	Western GOM Hammerhead Sharks - Closed	Met seasonal/regional quota	3/13/2016	12/31/2016	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 12: Hammerhead Shark Commercial Regulatory History Continued

Year	Annual Quota (mt dw)	Seasonal Quota (mt dw)	ACL (units)	Days Open/ Close	Fishing Season	Reason for Closure	season start date (first day implemented)	season end date (last day effective)	Size limit (units and length type, indicate maximum or natural length)	size limit start date	size limit end date	Retention Limit (units)	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit (units)	Aggregate Retention Limit Start Date	Aggregate Retention Limit End Date
	50	50	NA	365	Research		1/1/2016	12/31/2016	NA	NA	NA	NA	NA	NA	NA	1/1/2016	12/31/2016
2017 I, K, N, O	27.1	27.1	NA	365	Aggregated LCS- Open ATL Hammerhead Sharks- Open		1/1/2017	12/31/2017	NA	NA	NA	NA	NA	NA	25 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2017	4/14/2017
			NA									NA	NA	NA	3 non-sandbar LCS per vessel per trip for directed permit holders	4/15/2017	7/15/2017
			NA									NA	NA	NA	36 non-sandbar LCS per vessel per trip for directed permit holders	7/16/2017	12/31/2017
	13.4	13.4	NA	365	Eastern GOM Hammerhead Sharks- Open		1/1/2017	12/31/2017	NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2017	12/31/2017
			NA									NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2017	12/31/2017
	11.9		NA									NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2017	12/31/2017
		0			Western GOM Hammerhead Sharks - Closed	delayed opening for management reasons	1/1/2017	1/31/2017	NA	NA	NA	NA	NA	NA			
		11.9	NA	91	Western GOM Hammerhead Sharks- Open		2/1/2017	5/3/2017	NA	NA	NA	NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holders	2/1/2017	12/31/2017
			NA									NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	2/1/2017	12/31/2017
			NA	242	Western GOM Hammerhead Sharks - Closed	Met seasonal/regional quota	5/3/2017	12/31/2017	NA	NA	NA	NA	NA	NA	NA		
	50	50	NA	365	Research		1/1/2017	12/31/2017	NA	NA	NA	NA	NA	NA	NA	1/1/2017	12/31/2017
2018 I, K, N, O	27.1	27.1	NA	365	Aggregated LCS- Open ATL Hammerhead Sharks- Open		1/1/2018	12/31/2018	NA	NA	NA	NA	NA	NA	25 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2018	5/11/2018
			NA						NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for directed permit holders	5/12/2018	7/17/2018
			NA						NA	NA	NA	NA	NA	NA	36 non-sandbar LCS per vessel per trip for directed permit holders	7/18/2018	11/5/2018
									NA	NA	NA	NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holders	11/6/2018	12/31/2018
			NA		Eastern GOM Hammerhead Shark - Open		1/1/2018	12/31/2018	NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2018	12/31/2018
	13.4	13.4	NA						NA	NA	NA	NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2018	12/31/2018
					Western GOM Hammerhead Shark - Open		1/1/2018	3/14/2018	NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2018	12/31/2018
	11.9	11.9	NA						NA	NA	NA	NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2018	12/31/2018
									NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2018	12/31/2018
			NA		Western GOM Hammerhead Shark - Closed	Met regional/seasonal quota	3/15/2018	12/31/2018	NA	NA	NA	NA	NA	NA	NA	NA	NA
	50	50	NA	365	Research		1/1/2018	12/31/2018	NA	NA	NA	NA	NA	NA	NA	1/1/2018	12/31/2018
2019 I, K, N, O,P	27.1	27.1	NA	365	Aggregated LCS- Open ATL Hammerhead Sharks- Open		1/1/2019	12/31/2019	NA	NA	NA	NA	NA	NA	25 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2019	6/24/2019
			NA						NA	NA	NA	NA	NA	NA	36 non-sandbar LCS per vessel per trip for directed permit holders	6/25/2019	8/18/2019
									NA	NA	NA	NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holders	8/19/2019	10/8/2019
			NA						NA	NA	NA	NA	NA	NA	55 non-sandbar LCS per vessel per trip for directed permit holders	10/9/2019	12/31/2019
			NA		Eastern GOM Hammerhead Shark - Open		1/1/2019	12/31/2019	NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2019	12/31/2019
	13.4	13.4	NA						NA	NA	NA	NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2019	12/31/2019
					Western GOM Hammerhead Shark - Open		1/1/2019	12/31/2019	NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2019	12/31/2018
	11.9	11.9	NA						NA	NA	NA	NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2019	12/31/2019
									NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2019	12/31/2019

Table 12: Hammerhead Shark Commercial Regulatory History Continued

Year	Annual Quota (mt dw)	Seasonal Quota (mt dw)	ACL (units)	Days Open/ Close	Fishing Season	Reason for Closure	season start date (first day implemented)	season end date (last day effective)	Size limit (units and length type, indicate maximum or natural length)	size limit start date	size limit end date	Retention Limit (units)	Retention Limit Start Date	Retention Limit End Date	Aggregate Retention Limit (units)	Aggregate Retention Limit Start Date	Aggregate Retention Limit End Date
2020I, K, N, O	50	50	NA	365	Research		1/1/2019	12/31/2019	NA	NA	NA	NA	NA	NA	NA	1/1/2019	12/31/2019
	27.1	27.1	NA	366	Aggregated LCS- Open		1/1/2020	12/31/2020	NA	NA	NA	NA	NA	NA	36 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2020	6/18/2020
			NA		ATL Hammerhead Sharks- Open				NA	NA	NA	NA	NA	NA	55 non-sandbar LCS per vessel per trip for directed permit holders	6/19/2020	12/31/2020
			NA		Eastern GOM Hammerhead Shark - Open		1/1/2020	12/31/2020	NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2020	12/31/2020
	13.4	13.4	NA						NA	NA	NA	NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2020	12/31/2020
					Western GOM Hammerhead Shark - Open		1/1/2020	3/14/2020	NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2020	12/31/2020
	11.9	11.9	NA						NA	NA	NA	NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holders	1/1/2020	12/31/2020
									NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2020	12/31/2020
			NA		Western GOM Hammerhead Shark - Closed	Met regional/seasonal quota	3/15/2020	12/31/2020	NA	NA	NA	NA	NA	NA	NA	NA	NA

A= Established a fishery management unit consisting of 39 frequently caught species of Atlantic sharks, separated into three groups for assessment and regulatory purposes (LCS, SCS, and pelagic sharks), with sandbar sharks managed as part of the LCS complex (1993 FMP, effective date April 26, 1993)

B= Established calendar year commercial quotas for the LCS (2,436 mt dw) (1993 FMP, effective date April 26, 1993)

C = Divided the annual quota into two equal half-year quotas that apply to the following two fishing periods – January 1 through June 30 and July 1 through December 31 (1993 FMP, effective date April 26, 1993)

D= Implemented limited access in commercial shark fisheries and reduced the annual LCS quota to 1,285 mt dw (1999 FMP, effective date July 1, 1999)

E = Reduced the LCS commercial quota by 50 percent to 1,285 mt dw (Rulemaking:62 FR 16648, effective April 2, 1997).

F= Established ridgeback and non-ridgeback categories of LCS and managed sandbar sharks as part of the ridgeback shark complex (annual quotas of 783 mt dw for non-ridgeback LCS and 931 mt dw for ridgeback LCS) (1999 FMP, but not implemented until an emergency rulemaking, effective May 29, 2003)

G = Established commercial shark quotas using maximum sustainable yield as a basis for setting commercial shark quotas (LCS quota=1,017 mt dw) (Amendment 1, effective December 30, 2003);

H = Established regional commercial quotas and trimester commercial fishing seasons (Amendment 1; trimesters not implemented until January 1, 2005, 69 FR 6964);

I= All Atlantic sharks required to be offloaded with fins naturally attached and a sandbar specific commercial research quota (sandbar research annual quota = 87.9 mt dw) was implemented with the retention of sandbar sharks prohibited outside of the research fishery (Amendment 2; effective date July 24, 2008)

J= Increased LCS quota to 2,570 mt dw (Rulemaking 60 FR 21468, effective May 2, 1995)

K = Reduced commercial sandbar research quota to 90.7 mt dw; increased the LCS retention limit to 55 LCS per trip, with a default limit of 45 LCS per trip; established sub-regional regional commercial hammerhead quotas (13.4 mt dw in the western Gulf of Mexico and to 11.9 mt dw in the eastern Gulf of Mexico region) (Amendment 6, effective date August 18, 2015)

L= A commercial trip limit of 4,000 lb for permitted vessels for LCS was implemented (58 FR 68556, effective December 28, 1993),

M = Under Amendment 2, trip limits within sandbar research fishery are set annually. Trips limits are as follows: 2008-2,750 lb dw per trip of LCS of which no more than 2,000 lb dw could be sandbar sharks; 2009-45 lb dw per trip of LCS; 2010 to 2011- 33 sandbar sharks per trip; and 2012-2016 - no trip limit.

N= Established 2013 quotas for new management groups, including hammerhead sharks (Amendment 5a, effective July 3, 2013).

O = Retention of oceanic whitetip sharks and scalloped, smooth, and great hammerhead sharks on Atlantic HMS commercially-permitted vessels that have PLL gear on board are prohibited when tuna or tuna-like species are also retained (rulemaking 76 FR 53652, effective September 28, 2011).

P = Transferred quota from the western Gulf of Mexico to the eastern Gulf of Mexico to the eastern Gulf of Mexico: 50 mt dw aggregated large coastal sharks (84 FR 48791; effective September 17, 2019)

Table 13: Atlantic States Regulatory history pre 1995-1998

State	Confirmed for the SEDAR 77 2021 Hammerhead assessment through information collected for Atlantic HMS SAFE Report	pre-1995	1996	1997	1998
Atlantic Region					
Connecticut	Y	No shark regulations	No shark regulations	No shark regulations	No shark regulations
Delaware	Y	No shark regulations	No shark regulations	No shark regulations	Commercial shark fishermen must hold a federal shark permit even when fishing in state waters, therefore, state regulations match federal regulations; sharks must be landed with meat and fins intact, but head can be removed; any shark not kept must be released in a manner that maximizes survival; taking of basking, white, whale, sand tiger, and bigeye sand tiger prohibited; seasonal gillnet restrictions. Recreational regulations: no more than two sharks per vessel except that 2 sharpnose can also be landed; prohibition on finning and filleting or taking of the 5 prohibited species
Florida	Y	1992: first shark-specific regulations: must hold federal shark permit; commercial and recreational possession limit of 1 shark per person per day or 2 sharks per vessel per day, whichever is less (virtually no commercial shark fishery in state waters); prohibition on landing fins withour corresponding carcass; released sharks should be released in a manner that maximizes survival; recreationally caught sharks cannot be transerred at sea; recreatioanlly cuagth sharks cannot be sold; prohibition on harvest, landing and sale of basking and whale sharks; state shark fishery closes with federal shark fishery; 1994: prior to landing, fins cannot be removed from a shark harvested in state waters; fishermen returning from federal waters with sharks or shark parts harvested in federal waters, cannot fish in state waters; 1995: ban on the use of entanglement nets larger than 500 square feet	No new shark regulations	No new shark regulations	By 1998: ban on longlines; 1998: Added sand tiger, bigeye sandtiger, and white sharks to prohibited species list; prohibition on filleting sharks at sea.
Georgia	Y	1950s: ban on gillnets and longlines; All finfish spp. must be landed with head and fins intact	No new shark regulations	No new shark regulations	First shark regulation: prohibition on taking sand tiger sharks; Small Shark Composite (Atl. Sharpnose, bonnethead, spiny dogfish) 30"TL min. size; Creel: 2/person/day **Hammerhead** and all other sharks 2/person/day or 2 /boat/day, whichever is less. 54"TL min. size, only one shark over 84" TL
Maine	Y	No shark regulations	No shark regulations	No shark regulations	By 1998: large state water closures to gillnets resulting in virtually no gillnet fishery; 1998: no shark regulations
Maryland	Y	No shark regulations	4,000 lb shark limit per person per day; fins must accompany carcass and not exceed 5% fin-to-carcass ratio, state shark fishery closes with federal shark fishery	No new shark regulations	Size limit of 58" FL or a carcass less than 31"; recreational bag limit of one shark per person per day; by 1998: maximum gillnet mesh size of 6"; no longlining in tidal waters.
Massachusetts	Y	No shark regulations	No shark regulations	No shark regulations	No shark regulations
New Hampshire	Y	No shark regulations	No shark regulations	No shark regulations	No shark regulations
New Jersey	Y	No shark regulations	No shark regulations	No shark regulations	No shark-specific regulations; by 1998: no longline fishing; restrictions on the use of gillnets
New York	Y	No shark regulations	No shark regulations	No shark regulations	By 1998: prohibition on finning sharks; no other shark regulations
North Carolina	Y	1990: prohibition on finning 1990 – 7,500 lbs per trip, dogfish exempt; unlawful to land fins without carcass; fins no more than 10%; unlawful to land dried fins; required record keeping; Recreational - bag limit is 2 per day 1992 – Reduced fins to no more than 7%	No new shark regulations	No sharks, except Atlantic sharpnose and pelagic sharks, can be taken by commercial gear in state waters; fins must be landed with the carcass; maximum 5% fin-to-carcass ratio; fishers cannot posses or land dried shark fins	No new shark regulations
Rhode Island	Y	No shark regulations	No shark regulations	No shark regulations	No shark regulations
South Carolina	Y				By 1998: federal regs adopted by reference; use of gillnets prohibited in the shark fishery
Virginia	Y	1991: no longlines in state waters; recreational bag limit of 1 shark per person per day; established a commercial trip limit of___; 1993: mandatory reporting of all shark landings	No new shark regulations	7,500 lb commercial trip limit; minimum size of 58" FL or 31" carcass length (but can keep up to 200 lbs dw of sharks per day less than 31" carcass length); prohibition on finning; recreational: possession limit of 1 shark per person per day	By 1998: no longlining in state waters

Table 13 continued: Atlantic States Regulatory history 1999 - 2003					
State	**1999**	**2000**	**2001**	**2002**	**2003**
Atlantic Region					
Connecticut	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations
Delaware	No new shark regulations	Creel limit on regulated sharks of 1 shark per vessel per day; creel limit for sharpnose is 2 sharks per day; minimum size on regulated sharks is 54 inches FL; fins must be naturally attached; 14 prohibited species added (Atlantic angel shark, bigeye sixgill shark, bigeye thresher, bignose shark, Caribbean reef shark, Caribbean sharpnose shark, dusky shark, Galapagos shark, longfin mako, narrowtooth shark, night shark, sevengill shark, sixgill shark, smalltail shark)	No new shark regulations	No new shark regulations	No new shark regulations
Florida	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Georgia	No new shark regulations	Sharks may not be landed in Georgia if harvested using gillnets	No new shark regulations	No new shark regulations	No new shark regulations
Maine	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations
Maryland	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Massachusetts	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations
New Hampshire	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations
New Jersey	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations
New York	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
North Carolina	No new shark regulations	One shark per vessel per day with commercial gear (except Atlantic sharpnose and dogfish) while federal waters are open for species group; 84" maximum size limit (except for tiger, thresher, bigeye thresher, shortfin mako and **hammerhead species**); must be landed with head, tail and fins intact; Recreational – bag limit is 1 per person per day with a minimum size of 54" (none on Atlantic sharpnose) and a maximum of 84" (except for tiger, thresher, bigeye thresher, shortfin mako and **hammerhead species**); Prohibited species – basking, white, sand tiger and whale sharks	No new shark regulations	No new shark regulations	April: Prohibited ridgebacks (sandbar, silky, and tiger sharks) from Large Coastal Group
Rhode Island	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations
South Carolina	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Virginia	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations

Table 13 continued: Atlantic States Regulatory history 2004 - 2008					
State	**2004**	**2005**	**2006**	**2007**	**2008**
Atlantic Region					
Connecticut	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations
Delaware	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Florida	No new shark regulations	No new shark regulations	March: Same prohibited species as federal regulations, except Caribbean sharpnose is not included	No new shark regulations	No new shark regulations
Georgia	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Maine	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations
Maryland	By Feb 2004: minimum FL reduced to 54", carcass length the same (31"); recreational catch limit of 1 shark per person per day; reference to federal regs 50 CFR 635.	ASMFC Coastal Shark Plan	No new shark regulations	No new shark regulations	No new shark regulations
Massachusetts	No shark regulations	Regulations apply to Spiny dogfish; Prohibition on harvest, catch, take, possession, transportation, selling or offer to sell any basking, dusky, sand tiger, or white sharks.	By May 2006: Prohibition on harvest, catch, take, possession, transportation, selling or offer to sell any basking, dusky, sand tiger, or white sharks.	No new shark regulations	By Oct 2008: Regulations apply to Spiny and Smooth dogfish; Prohibition on harvest, catch, take, possession, transportation, selling or offer to sell any basking, dusky, sand tiger, or white sharks (unchanged).
New Hampshire	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations
New Jersey	By Feb 2004: commercial/recreational possession limit of 2 sharks per vessel; prohibition on finning; dorsal fin to pre-caudal pit must be at least 23 inches in length; total length must be 48 inches in length	No new shark regulations	By May 2006: no sale during federal closures; Finning prohibited; Prohibited Species: basking, bigeye sand tiger, sand tiger, whale and white sharks	No new shark regulations	No new shark regulations
New York	By Feb 2004: reference to federal regs 50 CFR part 635; prohibited sharks listed	No new shark regulations	By May 2006: no new shark regulations	No new shark regulations	No new shark regulations
North Carolina	No new shark regulations	No new shark regulations	Open seasons and species groups same as federal; 4,000 lb trip limit for LCS; retain fins with carcass through point of landing; longline shall only be used to harvest LCS during open season, shall not exceed 500 yds or have more than 50 hooks (state waters reopened to commercial fishing); Recreational: **LCS** (54” FL min size) - no more than 1 shark/vessel/day or 1 shark/person/day, SCS (no min size) – no more than 1 finetooth or blacknose shark/vessel/day and no more than 1 Atlantic sharpnose and 1 bonnethead/person/day, pelagics (no min size) -1 shark/vessel/day; Same prohibited shark species as federal regulations	No new shark regulations	July: Adopted federal regulations of 33 Large Coastal sharks per trip and fins must be naturally attached to carcass
Rhode Island	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations
South Carolina	By Feb 2004: retention limit of 2 Atlantic sharpnose per person per day and 1 bonnethead per person per day; no min size for recreationally caught bonnethead sharks; reference to federal commercial regulations and closures	No new shark regulations	By May 2006: non-Atlantic sharpnose/bonnethead sharks – 1 shark/boat/trip, min size – 54” FL	No new shark regulations	No new shark regulations
Virginia	No new shark regulations	No new shark regulations	By May 2006: Recreational: bag limit – 1 LCS, SCS, or pelagic shark/vessel/day with a min size of 54” FL or 30” CL; 1 Atlantic sharpnose and bonnethead/person/day with no min size; Commercial: possession limit - 4000 lb dw/day, min size - 58" FL or 31" CL west of the COLREGS line and no min size limit east of the COLREGS line; Prohibitions: fillet at sea, finning, longlining, same prohibited shark species as federal regulations	No new shark regulations	No new shark regulations

Table 13 continued: Atlantic States Regulatory history 2009-2013					
State	**2009**	**2010**	**2011**	**2012**	**2013**
Atlantic Region					
Connecticut	July: No possession or landing of large coastal shark species by any commercial fishing gear or for commercial purposes.	Feb: Commercial possession of prohibited Small Coastal Sharks: Atlantic sharpnose, finetooth, blacknose, bonnethead until a 2010 quota is set by NMFS; Sandbar shark take prohibited in the commercial and recreational fisheries per ASMFC FMP except under Scientific Collection Permit	Prohibited species same as federal regulations; No commercial fishing for large coastal sharks; No commercial small coastal shark fishing until further notice	No new shark regulations	No new shark regulations
Delaware	ASMFC Plan	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Florida	No new shark regulations	Jan: Commercial/recreational min size – 54" except no min. size on blacknose, blacktip, bonnethead, smooth dogfish, finetooth, Atlantic sharpnose; Allowable gear – hook and line only; prohibition on the removal of shark heads and tails in state waters; prohibition on harvest of sandbar, silky, and Caribbean sharpnose sharks in state waters; March: prohibition on all harvest of lemon sharks in state waters.	Commercial/recreational possession limit – 1 shark/person/day, max. 2 sharks/vessel on any vessel with 2 or more persons on board; State waters close to commercial harvest when adjacent federal waters close; Federal permit required for commercial harvest, so federal regulations apply in state waters unless state regulations are more restrictive; Finning, removing heads and tails, and filleting prohibited; Direct and continuous transit through state waters to place of landing of lemon sharks and sandbar sharks legally caught in federal waters is allowed; Prohibited species same as federal regulations plus prohibition on harvest of lemon and sandbar sharks in state waters.	Effective January 1, 2012: Prohibition species same as federal regulations plus harvest of lemon, sandbar, tiger sharks and **Hammerheads (Great, smooth, scalloped)** from state waters.	No new shark regulations
Georgia	Recreational: 1 shark from the Small Shark Composite (bonnethead, sharpnose, and spiny dogfish, min size 30" FL; **Hammerhead** and all other sharks - 1 shark/person or boat, whichever is less, min size 54" FL, Prohibited Species: sand tiger sharks, sandbar, silky, bigeye sandtiger, whale, basking, white, dusky, bignose, Galapagos, night, reef, narrowtooth, Caribbean sharpnose, smalltail, Atlantic angel, longfin mako, bigeye thresher, sharpnose sevengill, bluntnose sixgill, and bigeye sixgill.	Commercial/Recreational: 1 shark from the Small Shark Composite (bonnethead, sharpnose, and spiny dogfish), min size 30" FL; **Hammerhead** and all other sharks - 1 shark/person or boat, whichever is less, min size 54" FL (unchanged from previous); Prohibited Species unchanged; All species must be landed head and fins intact; Sharks may not be landed in Georgia if harvested using gill nets.	Commercial/Recreational: 2/person/boat for sharks from the Small Shark Composite (bonnethead, sharpnose, and spiny dogfish), min size 30" FL; **Hammerhead** and all other sharks - 2 shark/person or boat, whichever is less, min size 48" FL; unlawful to have in possession more than one shark greater than eighty-four inches (84") total length; Prohibited Species: same as federal, plus silky sharks; All species must be landed head and fins intact (unchanged); Sharks may not be landed in Georgia if harvested using gillnets (unchanged).	Commercial/Recreational: 1/person/boat for sharks from the Small Shark Composite (bonnethead, sharpnose, and spiny dogfish), min size 30" FL; **Hammerhead** and all other sharks - 1 shark/person or boat, whichever is less, min size 54" FL. Prohibited Species: unchanged (same as federal, plus silky sharks); All species must be landed head and fins intact (unchanged); Sharks may not be landed in Georgia if harvested using gillnets (unchanged); ASMFC Coastal Shark Plan	No new shark regulations
Maine	Maximum 5 % fin-to-carcass ratio	– Fins of coastal sharks can be removed at sea, but fin weight may not exceed 5% of the carcass weight	Prohibited species same as federal, plus silky and sandbar; Commercial harvest of porbeagle sharks prohibited in state waters, porbeagle cannot be landed after federal quota closes; sharks must be landed with head, fins, and tail naturally attached to the carcass	Commercial harvest of sharks (except spiny dogfish) in state waters prohibited; Finning prohibited; Sharks harvested elsewhere but landed in Maine, or sharks landed recreationally, must be landed with head, fins, and tail naturally attached to the carcass; Porbeagle cannot be landed commercially after federal quota closes; Dealers who purchase sharks must obtain a federal dealer permit; Recreational anglers must possess a federal HMS angling permits	No new shark regulations
Maryland	Regulations for those Squaliformes listed in need of conservation in ASMFC Coastal Shark Plan added to state regulations.	No new shark regulations	No new shark regulations	No new shark regulations	Recreational catch required to be tagged
Massachusetts	No new shark regulations	ASMFC Coastal Shark Plan except that the tails and fins of smooth dogfish must remain attached through landing (322 CMR 6.37(3)(d))	No new shark regulations	No new shark regulations	No new shark regulations
New Hampshire	No commercial take of porbeagle	Prohibited sharks same as Federal; Federal Dealer permit required for all shark dealers; Porbeagle sharks can only be taken by recreational fishing; Head, fins and tail must remain attached to all shark species through landing	No new shark regulations	No take, landings, or possession of prohibited shark species on list (http://gencourt.state.nh.us/rules/state_agencies/fis600.html); Porbeagle sharks can only be taken by recreational fishing (unchaged); Head, fins and tail must remain attached to all shark species through landing (unchanged); NH Wholesale Marine Species License and a Federal Dealer permit required for all dealers purchasing listed sharks.	no new shark regulations
New Jersey	No new shark regulations	ASMFC Coastal Shark Plan	No new shark regulations	No new shark regulations	No new shark regulations
New York	No new shark regulations	ASMFC Coastal Shark Plan	No new shark regulations	No new shark regulations	No new shark regulations
North Carolina	Fins must be naturally attached to shark carcass	Director may impose restrictions for size, seasons, areas, quantity, etc. via proclamation; Commercial: open seasons and species groups same as federal; 33 non-sandbar LCS retention limit; no retention of sandbar sharks; fins naturally attached to shark carcass, except for smooth dogfish; LL shall only be used to harvest LCS during open season, shall not exceed 500 yds or have more than 50 hooks; Recreational: LCS (54" FL min size) - no more than 1 shark/vessel/day or 1 shark/person/day, SCS (no min size) – no more than 1 finetooth or blacknose shark/vessel/day and no more than 1 Atlantic sharpnose and 1 bonnethead/person/day, pelagics (no min size) -1 shark/vessel/day; Same prohibited shark species as federal regulations	Director may impose restrictions for size, seasons, areas, quantity, etc. via proclamation; ASMFC Coastal Shark IFMP; additionally: LL in the shark fishery shall not exceed 500 yds or have more than 50 hooks	No new shark regulations	No new shark regulations
Rhode Island	No shark regulations	ASMFC Coastal Shark Plan	No new shark regulations	No new shark regulations	Sharks - RIMFC Regulations part VII 7.24
South Carolina	No new shark regulations	Defer to federal regulations; Gillnets may not be used in the shark fishery in state waters; State permit required for shark fishing in state waters	No new shark regulations	No new shark regulations	No new shark regulations
Virginia	ASMFC Coastal Shark Plan	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations

Table 13 continued: Atlantic States Regulatory history 2014-2018					
State	**2014**	**2015**	**2016**	**2017**	**2018**
Atlantic Region					
Connecticut	**Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL	Prohibited species same as federal regulations; Possession of sandbar shark (Carcharhinus plumbeus) prohibited except by permit for research and display purposes	Prohibited species same as federal regulations; Possession of sandbar sharks prohibited except by permit for research and display purposes. No commercial fishing for large coastal sharks; No commercial small coastal shark fishing until further notice	No new shark regulations	No new shark regulations
Delaware	**Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Florida	**Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL	Direct and continuous transit through state waters to place of landing for spiny dogfish, lemon, sandbar, silky, tiger, **great hammerhead, smooth hammerhead, and scalloped hammerhead** sharks legally caught in federal waters is allowed; Prohibited species same as federal regulations plus prohibition on harvest of spiny dogfish, lemon, sandbar, silky, tiger, great hammerhead, smooth hammerhead, and scalloped hammerhead sharks.	It is unlawful to harvest any shark with the use of any multiple hook in conjunction with live or dead natural bait and unlawful to harvest shark by snagging (snatch hooking)	No new shark regulations	No new shark regulations
Georgia	Commercial/Recreational: **Hammerheads** (great, scalloped and smooth)- 1/person, minimum size – 78" FL. All other sharks - 1 shark/person or boat, whichever is less, min size 54" FL (unchanged).	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Maine	**Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Maryland	Recreational catch required to be tagged (unchanged); ASMFC Coastal Shark Plan (unchanged); all recreationally harvested sharks must have heads, tails, and fins attached naturally to the carcass through landing; all commercially harvested sharks other than smoothhounds must have tails and fins attached naturally to carcass through landing; smoothhound sharks harvested commercially may have dorsal, pectoral and caudal fins removed (caudal fins may not exceed 4% of total dressed weight of smoothhound shark carcasses on board; dorsal and pectoral fins may not exceed 8% of total dressed weight of smoothhound shark carcasses on board); **Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL	No new shark regulations	"Commercial - During the period of May 15-July 15 an individual may not harvest the species listed in §A(6) and (7) of this regulation from State waters or transport the species listed in §A(6) and (7) of this regulation in State waters, unless the shark was harvested from federal waters provided: (i) The vessel does not engage in fishing within the closed area while possessing the species listed in §A(6) and (7) of this regulation; (ii) The sharks possessed were not caught in the closed area; and (iii) All fishing gear is stowed as described in §D(4) of this regulation and not available for immediate use.	Closure for certain species from May 15-July 15 unless the shark was legally harvested from federal waters and gear is stowed; closed to harvest when federal waters are closed.	No new shark regulations
Massachusetts	**Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL. "...exempt from the possession limit and closures of the aggregated large coastal and **hammerhead** shark fisheries"	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
New Hampshire	**Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
New Jersey	**Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
New York	**Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL	No person shall possess, sell, offer for sale, trade, or distribute a shark fin; provided, however, that this prohibition shall not apply to any shark fin that was taken from a spiny dogfish (Squalus acanthias) or a smooth dogfish (Mustelus canis) lawfully caught by a licensed commercial fisherman; a shark fin may be possessed by any person if the shark was lawfully caught and the person has a recreational marine fishing registration or a license or permit from the department for bona fide scientific research or educational purposes.	Non-stainless, non-offset circle hooks must be used when taking sharks.	No new shark regulations	Commercial fishermen must attend NOAA Fisheries' Safe Handling, Release, and Identification Worskhop.
North Carolina	**Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Rhode Island	**Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL	RI commercial fishing license or landing permit required to harvest or land HMS	No person fishing recreationally shall possess a shark with a fork length less than 54 inches, with the exception of Atlantic sharpnose, bonnethead, and smoothhound, which have no minimum size limit; No person shall possess a sandbar shark.	No new shark regulations	No new shark regulations
South Carolina	**Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Virginia	**Hammerhead (Great, smooth, scalloped)** recreational minimum size of 78" FL	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations

Table 13 continued: Atlantic States Regulatory history 2019-2020		
State	**2019**	**2020**
Atlantic Region		
Connecticut	No new shark regulations	No new shark regulations
Delaware	No new shark regulations	Shark fins may be possessed, but cannot be sold.
Florida	Hook and line only; A no-cost, annual shore-based shark fishing permit is mandatory for all shore-based shark fishing anglers ages 16 and up; Shore anglers are prohibited from chumming and delaying the release of prohibited sharks; All shore-and vessel-based shark fishermen are required to keep prohibited sharks in the waters, use circle hooks in state waters, and possess/use appropriate cutters.	Effective January 1, 2020: minimum size of 83" for shortfin mako. Effective Jan 1, 2021, the possession, import, export, and sale of shark fins are prohibited with the following 2 exceptions: 1) shark fins may be sold by commercial fishermen who harvested sharks from a vessel holding a valid federal shark fishing permit on January 1, 2020 and 2) shark fins may be exported and sold by any wholesale dealer holding a valid federal Atlantic shark dealer permit on January 1, 2020.
Georgia	No new shark regulations	Prohibited Species: same as federal plus Oceanic Whitetip
Maine	Commercial harvest of coastal sharks in state waters is prohibited; Unlawful to harvest, land or posess more than 5,000 lb of spiny dogfish per calendar day or 24-hour period commercially; one dogfish per day for personal use; Recreational harvest of porbeagle sharks shall only be taken from state waters when open; Finning prohibited (unchanged); coastal sharks, porbeagle or spiny dogfish harvested elsewhere but landed in Maine, or sharks landed recreationally, must have the head, fins and tail attached naturally to the carcass through landing; Dealers who purchase sharks must obtain a federal dealer permit (unchanged); Recreational anglers must possess a federal HMS angling permit (unchanged).	No new shark regulations
Maryland	ASMFC Coastal Shark Plan, with additional measures to complement HMS regulations. Recreational: Except when fishing with artificial flies or artificial lures, an angler must use corrodible, non-offset circle hooks and have in possession at least one device capable of quickly cutting either leader or hook; any shark, except smooth dogfish, not being kept must be released in water; for any shark that will be released, an individual may not (a) sit on shark, (b) hold shark's mouth open, (c) put shark on dry sand, (d) the shark on a boat deck, or (e) use a gaff; catch must be tagged and reported using catch cards; all recreationally harvested sharks must have heads, tails, and fins attached naturally to carcass through landing. Commercial: If smoothhound fins are removed, the total wet weight of caudal fins may not exceed 4 percent of total dw of smoothhound carcasses landed or found on board vessel, and dorsal and pectoral fins may not exceed 8 percent of the total dw of smoothhound carcasses landed or found on board a vessel.	Shark fin prohibition: no person shall possess, sell, offer for sale, trade or distribute a shark fin, excluding spiny dogfish and smooth dogfish. Commercial fishermen with a license and permit issued by the State to take or land sharks for commercial purposes may possess or distribute, but not sell within Delaware. Recreational fishermen may possess shark fins for personal use.
Massachusetts	No new shark regulations	No new shark regulations
New Hampshire	Persons recreationally fishing for sharks must use non-offset, corrodible circle hooks; recreational minimum size limit for North Atlantic shortfin mako of 71" FL for males and 83" FL for females.	No new shark regulations
New Jersey	No new shark regulations	Sharks recreationally harvested only by angling with a handline or rod and reel. Sharks commercially harvested only by gillnets, trawl nets, and pound nets. State waters are closed to possession of species belonging to the aggregated large coastal shark and **hammerhead groups** from May 15 through July 15. A shark or dogfish may be eviscerated prior to landing. The fins may not be removed from a shark or spiny dogfish until fishing has ceased and such shark or spiny dogfish has been landed, except that commercial fishermen may completely remove the fins of any of the species in the smoothhound shark group prior to landing if the total wet weight of the fins does not exceed 12 percent of the dressed weight of the carcasses and at least 25 percent of the total retained catch of all marine species, by weight, is comprised of smooth dogfish. Effective January 1, 2021 the possession and sale of shark fins is prohibited.
New York	No new shark regulations.	No new shark regulations.
North Carolina	No new shark regulations	No new shark regulations
Rhode Island	ASMFC Coastal Shark Plan, with additional measures to complement HMS regulations; commercial fishing license or landing permit required to harvest or land sharks (unchanged); no person fishing commercially shall possess shortfin mako or species listed in the prohibited or research commercial species groups; no person fishing recreationally shall possess a shark listed in prohibited or research species groups (unchanged); **Hammerhead (Great, smooth, scalloped)** minimum FL size of 78", shortfin mako minimum FL size 83", no minimum FL sizes for Atlantic sharpnose, bonnethead, and smoothhound; all other sharks minimum FL size of 54"; any person fishing recreationally for sharks with rod and reel must use corrodible circle hooks and maximize gear removal as safely as possible when releasing sharks.	no new shark regulations
South Carolina	No new shark regulations	No new shark regulations
Virginia	No new shark regulations	No new shark regulations

Table 14: Gulf of Mexico state regulatory history pre 1995 - 1998

State	Confirmed for the SEDAR 77 2021 Hammerhead assessment through information collected for Atlantic HMS SAFE Report	pre-1995	1996	1997	1998
Gulf of Mexico Region					
Alabama	Y	No shark regulations	First shark regulations implemented: state shark fishery closes with the federal shark fishery	No new shark regulations	By 1998: only short lines in state waters; time/area and size restrictions on the recreational use of gillnets
Louisiana	Y	No shark regulations	No shark regulations	Ban on entanglement nets	No new shark regulations
Mississippi	Y	No shark regulations	No shark regulations	Prohibit taking and possession of sand tiger, bigeye sand tiger, whale, basking, and white sharks; Recreational: bag limit of 4 small coastal sharks (Atlantic sharpnose, Caribbean sharpnose, finetooth, blacknose, smalltail, bonnethead and Atlantic angel shark) per person per day; limit of 3 large coastal and pelagic sharks, in aggregate per vessel per day, same prohibited species as commercial fishers; minimum size of 25" total length for small coastal sharks and 37" total length for large coastal sharks.	
Texas	Y	Sept. 1989: Bag limit set at five sharks per day for both rec and commercial anglers; Sept 1992: Bag limit increased to ten sharks per day. Trotlines were added as allowable gear for sharks.	No new shark regulations	1997: Commercial bag limit of 5 sharks; possession limit of 10 sharks; no min or max size. Recreational bag, possession, and lack of size restrictions same as commercial	1998: commercial fishing for sharks can only be done with rod and reel; no entanglement nets
Puerto Rico	Y	No shark regulations	No shark regulations	No shark regulations	No shark regulations
U.S. Virgin Islands	Y	No shark regulations	No shark regulations	No shark regulations	No shark regulations

Table 14 Continued: Gulf of Mexico state regulatory history 1999 - 2003

State	1999	2000	2001	2002	2003
Gulf of Mexico Region					
Alabama	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Louisiana	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Mississippi	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Texas	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Puerto Rico	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations
U.S. Virgin Islands	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations

Table 14 Continued: Gulf of Mexico state regulatory history 2004 - 2008

State	2004	2005	2006	2007	2008
Gulf of Mexico Region					
Alabama	By Feb 2004: Recreational daily bag limit - 2 sharpnose/person/day; all other species - 1fish/person/day; Recreational minimum size all sharks (except sharpnose) - 54" FL	No new shark regulations	By May 2006: Recreational & Commercial: bag limit – 2 sharpnose/person/day; no min size; all other sharks – 1/person/day; min size – 54" FL or 30" dressed; state waters close when Federal season closes; Prohibition: Atlantic angel, bigeye thresher, dusky, longfin mako, sand tiger, basking, whale, white, and nurse sharks.	No new shark regulations	No new shark regulations
Louisiana	By Feb 2004: Minimum size - 54" except sharpnose; Possession limit - 1 fish/vessel/trip; Trip limit 4,000 lbs dw LCS; Reference to federal regulations; State waters closed to rec/commercial April 1 through June 30	No new shark regulations	By May 2006: Recreational: min size – 54" FL, except Atlantic sharpnose and bonnethead; bag limit - 1 sharpnose/person/day; all other sharks – 1 fish/person/day; Commercial: 4,000 lb LCS trip limit, no min size; Com & Rec Harvest Prohibited: 4/1-6/30; Prohibition: same as federal regulations	No new shark regulations	By Oct 2008: Commercial: 33 per vessel per trip limit, no min size
Mississippi	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	By Oct 2008: Recreational bag limit - LCS/Pelagics 1/person up to 3/vessel; SCS 4/person; Commercial & Prohibited Species - Reference to federal regulations
Texas	Sept: Commercial/Recreational retention limit 1 fish/person/day; Commercial/Recreational possession limit is twice the daily bag limit (i.e., 1 fish/person/day); Commercial/Recreational minimum size 24 in TL	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Puerto Rico	Year-round closed season on nurse sharks Shark "finning" is prohibited. PR regulations indicate the need for compliance by local fishers with federal shark regulations.	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
U.S. Virgin Islands	Federal regulations and federal permit requirements apply in territorial waters.	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations

State	2009	2010	2011	2012	2013
Gulf of Mexico Region					
Alabama	Recreational & commercial sharpnose bag limit dropped to 1 sharpnose per person per day; no shark fishing on weekends, Memorial Day, Independence Day, or Labor Day	Recreational & commercial: bag limit – 1 sharpnose/person/day and 1 bonnethead/person/day; no min size; all other sharks – 1/person/day; min size – 54" FL or 30" dressed (HH Unchanged); Prohibited species: dusky, sand tiger, bigeye sand tiger, basking, whale, and white sharks; Restrictions of chumming and shore-based angling if creating unsafe bathing conditions; Regardless of open or closed season, gillnet fishermen targeting other fish may retain sharks with a dressed weight not exceeding 10% of total catch	No new shark regulations	Commercial-state waters close when federal season closes; Prohibited species: Atlantic angel, basking, bigeye sand tiger, bigeye sixgill, bigeye thresher, bignose, Caribbean reef, Caribbean sharpnose, dusky, Galapagos, largetooth sawfish, longfin mako, narrowtooth,night, sandtiger, smalltooth sawfish, smalltail, sevengill, sixgill, spotted eagle ray, whale, white	No new shark regulations
Louisiana	No new shark regulations	Recreational: min size – 54" FL, except Atlantic sharpnose and bonnethead; bag limit - 1 sharpnose/person/trip, all other sharks – 1 fish/person/day; Commercial: 33 per vessel per trip limit; no min size; Com & rec harvest prohibited: 4/1- 6/30; Prohibited species: same as federal regulations; Fins must remain naturally attached to carcass though off-loading	Commercial shark fishing requires annual state shark permit. Owners/operators of vessels other than those taking sharks in compliance with state or federal commercial permits are restricted to no more than one shark from either the large coastal, small coastal, or pelagic group per vessel per trip within or without Louisiana waters.	No new shark regulations	No new shark regulations
Mississippi	No new shark regulations	Recreational: min size - LCS/Pelagics 37" TL; SCS 25" TL; Prohibition on finning.	No new shark regulations	No new shark regulations	No new shark regulations
Texas	Sept: Min size 24" TL for Atlantic sharpnose, blacktip, and bonnethead sharks and 64" TL for all other lawful sharks. Prohibited species: same as federal regulations	Commercial/recreational: bag limit - 1 shark/person/day; Commercial/recreational possession limit is twice the daily bag limit (i.e., 2 sharks/person/day); min size 24" TL for Atlantic sharpnose, blacktip, and bonnethead sharks and 64" TL for all other lawful sharks.	No new shark regulations	No new shark regulations	No new shark regulations
Puerto Rico	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
U.S. Virgin Islands	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations

Table 14 Continued: Gulf of Mexico state regulatory history 2014 - 2018

State	2014	2015	2016	2017	2018
Gulf of Mexico Region					
Alabama	**<u>Hammerheads (Great smooth, scalloped)</u>** 1/person/day - 78" FL; all other sharks – 1/person/day; min size – 54" FL or 30" dressed; Commercial - no size limit and no possession limit on any non-prohibited species.	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
Louisiana	Commercial: 33/vessel/day limit (36/vessel/day by mid-2013); no min size; Com & rec harvest prohibited: Apr 1 - Jun 30	Commercial: 36/vessel/day limit; no min size; Com & rec harvest prohibited: Apr 1 - Jun 30; Prohibited species: same as federal regulations; Fins must remain naturally attached to carcass though offloading.	Commercial: 45/vessel/day limit; no min size; Com & rec prohibited: Apr 1 - Jun 30; Prohibited species: same as federal regulations; Fins must remain naturally attached to carcass though off-loading. Commercial shark fishing requires annual state shark permit. Owners/operators of vessels other than those taking sharks in compliance with state or federal commercial permits are restricted to no more than one shark from either the large coastal, small coastal, or pelagic group per vessel per trip within or without Louisiana waters, except Atlantic sharpnose and bonnethead which are allowed at one/person/day.	No new shark regulations	No new shark regulations
Mississippi	No new shark regulations	No new shark regulations	It is unlawful for commercial fishermen to possess sandbar sharks.	No new shark regulations	No new shark regulations
Texas	No new shark regulations	No new shark regulations	Buying, selling, offering to buy or sell, or possessing a for the purpose of sale, transport, or shipment a shark fin is prohibited.	Minimum size for **<u>Hammerheads (Great, smooth, scalloped)</u>** is 99" TL. Prohib species: all federally prohibited species and sandbar sharks.	No new shark regulations
Puerto Rico	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations
U.S. Virgin Islands	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations

Table 14 Continued: Gulf of Mexico state regulatory history 2019-2020

State	2019	2020
Gulf of Mexico Region		
Alabama	Male shortfin mako bag limit of one/person/day with 71" FL minimum size; female shortfin mako bag limit of one/person/day with 83" FL minimum size; When using natural bait in state waters to fish for sharks, anglers must use non-offset non-stainless-steel circle hooks.	No new shark regulations
Louisiana	No new shark regulations	No new shark regulations
Mississippi	Commercial fishery developed in 2019 with identical size regulations to the recreational fishery (See 2008 and 2010).	Bag limit is 25 small and large coastal sharks in aggregate per endorsed individual per day; Seasons are set to run concurrently with the federal shark fisheries; To qualify for a Commercial Shark Endorsement, anglers must attend an ID and Safe Handling Course and pass an exam.
Texas	Non-offset, non-stainless steel circle hooks must be used when fishing for sharks in state waters.	no new shark regulations
Puerto Rico	No new shark regulations	No new shark regulations
U.S. Virgin Islands	No new shark regulations	No new shark regulations

Atlantic States Marine Fisheries Commission Regulatory history

The measures in the Interstate FMP for Coastal Sharks in regards to Hammerhead species, as summarized from the ASMFC Coastal Shark FMP Executive Summary, are listed below. These were to be implemented by January 1, 2010 by ASMFC member states.

Recreational Measures:

1) Recreational anglers are prohibited from possessing silky, tiger, blacktip, spinner, bull, lemon, nurse, scalloped hammerhead, great hammerhead, and smooth hammerhead in the state waters of Virginia, Maryland, Delaware and New Jersey from May 15 through July 15—regardless of where the shark was caught;
2) Recreational anglers may only use handlines and rod and reel;
3) Sharks caught in the recreational fishery must have a fork length of at least 4.5 feet (except Atlantic sharpnose, blacknose, finetooth, bonnethead, and smooth dogfish);
4) Recreational anglers may only use handlines and rod and reel;
5) Each recreational shore-angler is allowed max harvest of 1 shark from the federal recreationally permitted species, plus 1 addtl bonnethead, and 1 addtl Atlantic sharpnose, /calendar day.
6) Recreational fishing vessels are allowed max harvest of 1 shark from the federal recreationally permitted species plus 1 addtl bonnethead, and 1 Atlantic sharpnose, /trip, regardless of the number of people on board the vessel. Smooth dogfish excluded from retention limit.

Commercial Measures:

7) All commercial fishermen are prohibited from possessing silky, tiger, blacktip, spinner, bull, lemon, nurse, scalloped hammerhead, great hammerhead, and smooth hammerhead in the state waters of Virginia, Maryland, Delaware and New Jersey from May 15 through July 15.
8) States will close the fishery for any shark species when NMFS closes the fishery in federal waters.
9) States will implement possession limits as annually specified.
10) Commercial shark fishermen must hold a state commercial license or permit in order to commercially catch and sell sharks in state waters.
11) States may grant exemptions from the seasonal closure, quota, possession limit, size limit, gear restrictions, and prohibited species restrictions contained in this plan through a state display or research permit system.
12) A federal Commercial Shark Dealer Permit is required to buy and sell any shark caught in state waters.
13) Prohibits the use of any gear type other than rod and reel, handlines, small mesh gillnets, large mesh gillnets, trawl nets, shortlines, pound nets/fish traps, or weirs.
14) States must implement shortline and gillnet bycatch reduction measures
15) All sharks caught by commercial fishermen must have tails and fins attached naturally to the carcass through landing, except for smooth dogfish. Commercial fishermen may completely remove the fins of smooth dogfish from March through June of each year. If fins are removed, the total wet weight of the shark fins may not exceed 5 percent of the total dressed weight of smooth dogfish carcasses. From July through February each year, commercial fishermen may completely remove the head, tail, pectoral fins, pelvic (ventral) fins, anal fin, and second dorsal fin, but must keep the dorsal fin attached naturally to the carcass through landing.
16) A state can request permission to implement an alternative to any mandatory compliance measure only if that state can show to the Board's satisfaction that its alternative proposal will have the same conservation value as the measure contained in this management plan or any addenda prepared under Adaptive Management.

2 Assessment History & Review

This is the first hammerhead assessment conducted by the Southeast Fisheries Science Center (SEFSC) for individual stocks of scalloped hammerhead, great hammerhead, and smooth hammerhead sharks. Previously, the SEFSC assessed hammerhead sharks together within the Large Coastal Shark species complex, which consisted of multiple shark stocks with the number of stocks in the complex changing over time. The Large Coastal Shark complex was first assessed by the SEFSC externally to the SEDAR process in 1991 (Parrack 1990-1991) and subsequently in 1994 (NMFS 1994), 1996 (NMFS 1996), 1998 (NMFS 1998) and 2002 (Cortés et al. 2002).

The Large Coastal Shark complex was subsequently assessed by the SEFSC within the SEDAR process in 2006 (NMFS 2006; SEDAR 11). However, because of mismatching information from various species components within the catch and abundance index data, the SEDAR 11 CIE review panel determined that it was not possible to support use of the Large Coastal Shark complex assessment results for management of the complex. In addition, the SEDAR 11 CIE review panel noted that any assessment of the Large Coastal Shark complex, which used the same approach and similar data, would suffer from the same concerns. Consequently, the SEDAR 11 CIE review panel recommended prioritizing research, data analysis, and model development to permit species-specific assessments for the main components of the complex.

Subsequently, the scalloped hammerhead stock in the Western North Atlantic and Gulf of Mexico was assessed externally to the SEFSC and to the SEDAR process (Hayes et al. 2009). In response to the external assessment, the NOAA, NMFS, Office of Sustainable Fisheries (OSF), requested that the SEFSC review the Hayes et al (2009) publication for its potential use as the basis of U.S. Management Decisions. A subsequent SEFSC review memo (SEFSC 2010) noted, among other things, that several recommendations from NMFS (2006; SEDAR 11) were addressed, including the use of observer data rather than logbook data. The SEFSC review memo (SEFSC 2010) also noted that the removal of the fishery-dependent CPUE time series made for a more optimistic assessment.

Similarly, the hammerhead species complex was also assessed externally to the SEFSC and to the SEDAR process (Jiao et al. 2009). In addition, scalloped, great, and smooth hammerhead sharks were subsequently assessed externally using hierarchical Bayesian state-space surplus production models (Jiao et al. 2011). However, the assessments by Jiao et al. (2009, 2011) were not reviewed by SEFSC for potential use in U.S. Management Decisions.

References

Cortés, E., Brooks, L., and G. Scott. 2002. Stock assessment of large coastal sharks in the U.S. Atlantic and Gulf of Mexico. Sustainable Fisheries Division Contribution SFD-02/03-177. 222 pp. [Ref Doc pdf available 8/23/2023]

Hayes, C. G., Jiao Y., and E. Cortés. 2009. Stock assessment of scalloped hammerheads in the Western North Atlantic Ocean and Gulf of Mexico. North American Journal of Fisheries Management 29:1406-1417. [SEDAR 77 Reference Document 49]

Jiao Y., Cortés, E., Andrews, K., and F. Guo. 2011. Poor-data and data-poor species stock assessment using a Bayesian hierarchical approach. Ecological Applications 21:2691-2708. [SEDAR 77 Reference Document 50]

Jiao, Y., Hayes, C., and E. Cortés. 2009. Hierarchical Bayesian approach for population dynamics modeling of fish complexes without species-specific data. ICES Journal of Marine Science 66: 367-377[SEDAR 77 Reference Document 51]

NMFS (National Marine Fisheries Service). 1994. 1994 Report of the Shark Evaluation Workshop. 17 pp. [Ref Doc pdf available 8/23/2023]

NMFS (National Marine Fisheries Service). 1996. 1996 Report of the Shark Evaluation Workshop. 80 pp. [Ref Doc pdf available 8/23/2023]

NMFS (National Marine Fisheries Service). 1998. 1998 Report of the Shark Evaluation Workshop. 109pp. [Ref Doc pdf available 8/23/2023]

NMFS (National Marine Fisheries Service). 2006. Southeast Data, Assessment and Review (SEDAR) 11. Large Coastal Shark complex, blacktip and sandbar shark stock assessment report. NOAA/NMFS Highly Migratory Species Division, Silver Spring, MD. [Available from SEDAR]

SEFSC (Southeast Fisheries Science Center) 2010. SEFSC Review Memorandum Regarding Hayes et al 2009 North American Journal of Fisheries Management. 8 pp. [Ref Doc pdf available 8/23/2023]

Parrack, M. L. 1990-1991. A preliminary study of shark exploitation during 1986-1989 in the U.S. FCZ. Contribution MIA-90-493. NMFS, SEFSC, 75 Virginia Beach Drive, Miami, FL 33149. 23pp. [Ref Doc pdf available 8/23/2023]

4. Regional Maps

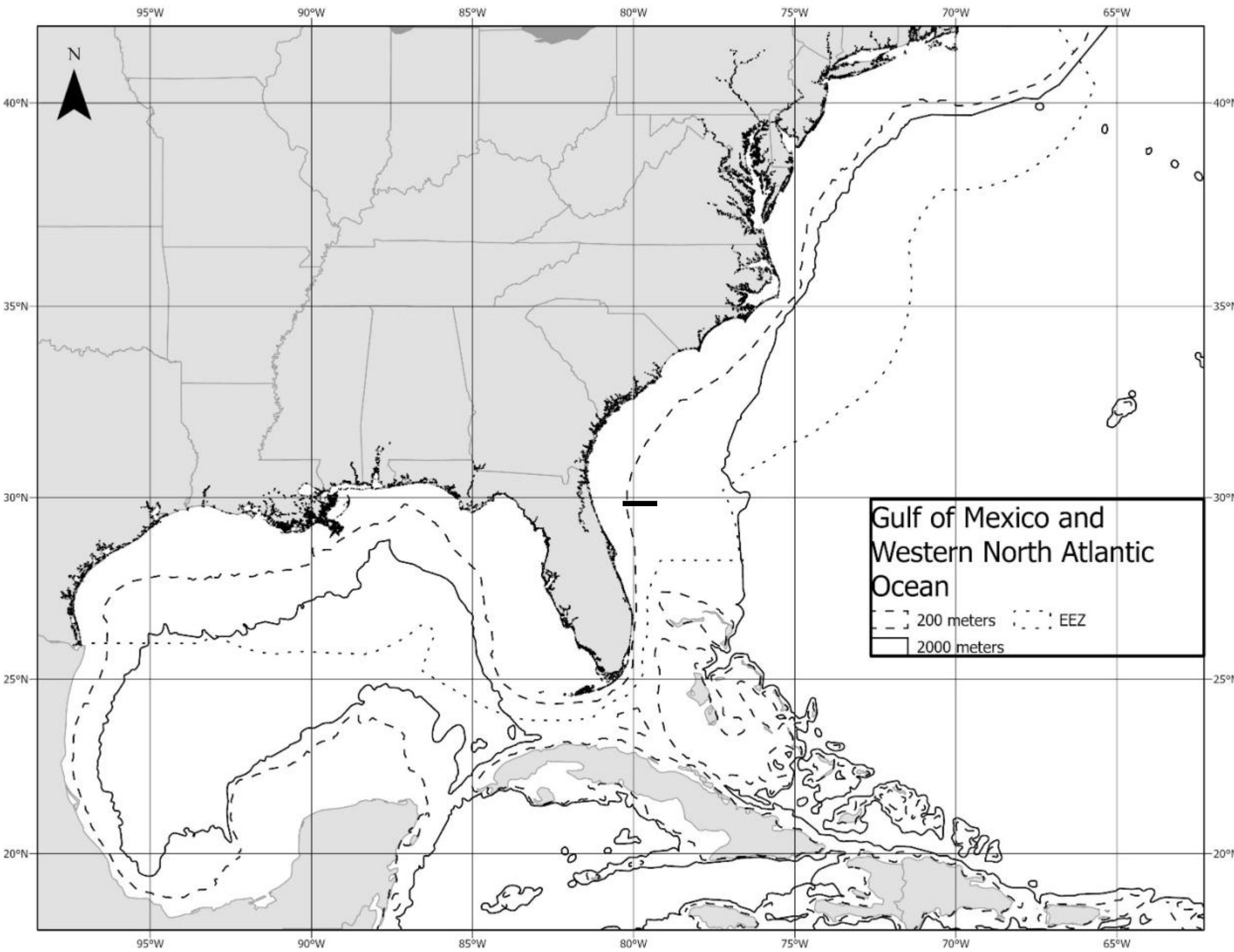

Figure 4.1. Regional map of Gulf of Mexico and Western North Atlantic Ocean off the east coast of the United States. The 200 and 2000 m isobaths are indicated along with the U.S. Exclusive Economic Zone. The horizontal black line at 25°20.4' latitude (Miami-Dade County line) indicates the boundary between the Atlantic region and the Gulf of Mexico region for the management purposes.

2. SEDAR Abbreviations

APAIS	Access Point Angler Intercept Survey
ABC	Allowable Biological Catch
ACCSP	Atlantic Coastal Cooperative Statistics Program
ADMB	AD Model Builder software program
ALS	Accumulated Landings System; SEFSC fisheries data collection program
AMRD	Alabama Marine Resources Division
ASMFC	Atlantic States Marine Fisheries Commission
ASPIC	a stock production model incorporating covariates
ASPM	age-structured production model
B	stock biomass level
BAM	Beaufort Assessment Model
BMSY	value of B capable of producing MSY on a continuing basis
CFMC	Caribbean Fishery Management Council
CIE	Center for Independent Experts
CPUE	catch per unit of effort
EEZ	exclusive economic zone
F	fishing mortality (instantaneous)
FMSY	fishing mortality to produce MSY under equilibrium conditions
FOY	fishing mortality rate to produce Optimum Yield under equilibrium
FXX% SPR	fishing mortality rate that will result in retaining XX% of the maximum spawning production under equilibrium conditions
FMAX	fishing mortality that maximizes the average weight yield per fish recruited to the fishery
F0	a fishing mortality close to, but slightly less than, Fmax
FL FWCC	Florida Fish and Wildlife Conservation Commission
FWRI	(State of) Florida Fish and Wildlife Research Institute
GA DNR	Georgia Department of Natural Resources
GLM	general linear model
GMFMC	Gulf of Mexico Fishery Management Council

GSMFC	Gulf States Marine Fisheries Commission
GULF FIN	GSMFC Fisheries Information Network
HMS	Highly Migratory Species
LDWF	Louisiana Department of Wildlife and Fisheries
M	natural mortality (instantaneous)
MAFMC	Mid-Atlantic Fishery Management Council
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MDMR	Mississippi Department of Marine Resources
MFMT	maximum fishing mortality threshold, a value of F above which overfishing is deemed to be occurring
MRFSS	Marine Recreational Fisheries Statistics Survey; combines a telephone survey of households to estimate number of trips with creel surveys to estimate catch and effort per trip
MRIP	Marine Recreational Information Program
MSST	minimum stock size threshold, a value of B below which the stock is deemed to be overfished
MSY	maximum sustainable yield
NC DMF	North Carolina Division of Marine Fisheries
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
OY	optimum yield
SAFMC	South Atlantic Fishery Management Council
SAS	Statistical Analysis Software, SAS Corporation
SC DNR	South Carolina Department of Natural Resources
SEAMAP	Southeast Area Monitoring and Assessment Program
SEDAR	Southeast Data, Assessment and Review
SEFIS	Southeast Fishery-Independent Survey
SEFSC	Fisheries Southeast Fisheries Science Center, National Marine Fisheries Service
SERO	Fisheries Southeast Regional Office, National Marine Fisheries Service
SPR	spawning potential ratio, stock biomass relative to an unfished state of the stock
SSB	Spawning Stock Biomass
SSC	Science and Statistics Committee
TIP	Trip Incident Program; biological data collection program of the SEFSC and Southeast States.
TPWD	Texas Parks and Wildlife Department
Z	total mortality, the sum of M and F

SEDAR

Southeast Data, Assessment, and Review

SEDAR 77

HMS Hammerhead Sharks

Stock ID Process Final Report

October 2021

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

Table of Contents

1. Introduction

1.1 Stock ID Process Summary

The Stock ID Workshop for the four species of Hammerhead shark was held as a series of three webinars, including a data scoping webinar (6/11/2021) and two webinars to discuss data analysis (7/20/2021, 8/10/2021). In an effort to follow best practices in stock identification, an interdisciplinary approach was used to synthesize all available information and determine the most plausible hypotheses of population structure. To that end, information from different approaches (life history, genetics, tagging and movement) was considered and integrated. Most workshop participants volunteered to join one of three designated working groups (WGs): life history, genetics, or spatial distribution/movement. These WGs also met individually outside of the three official Stock ID webinars. Recommendations of the Workshop were formed based on the review and analysis of life history characteristics, genetics, and archival satellite, SPOT (smart position and temperature) transmitting tags, and conventional tagging data. The primary findings of the Stock ID Workshop were as follows.

Regarding Great Hammerhead, the Life History WG determined it was not possible to conclude whether regional differences in life history exist. The Genetics WG found no significant genetic differentiation between the Gulf of Mexico and U.S. Atlantic, and the Spatial Distribution/Movement WG concluded Great Hammerhead comprise a single biological stock based on movements of individuals between regions. The Stock ID Workshop recommended that one stock assessment be conducted for Great Hammerhead.

There were limited data available for assessing the stock identification of Smooth Hammerhead. There are no applicable life history data available and no population genetic studies of Smooth Hammerhead testing for differentiation between locations within U.S. waters. However, both the Life History and Genetics WGs recommended assessing Smooth Hammerheads as a single stock in the U.S. Atlantic and Gulf of Mexico. The Spatial Distribution/Movement WG also agreed that Smooth Hammerheads comprise a single biological stock in the U.S. Atlantic Ocean and Gulf of Mexico based on the fact that they are a wide-ranging species with the ability to move long distances (> 6,600 km; Santos and Coelho, 2018) and it is not inconceivable that this species could occasionally move among regions. The Stock ID Workshop recommended that one stock assessment be conducted for Smooth Hammerhead.

The Carolina Hammerhead is very difficult to distinguish from Scalloped Hammerhead, even for trained biologists, and thus much of the catch data will likely represent both species in unknown overall proportions. There are also very limited data on life history and movements for this species. Based on genetic analysis, Carolina Hammerhead made up 27% of a mixed species sample of these two species in the U.S. Atlantic but was not recorded in a sample from the Gulf of Mexico (Barker et al. 2021). Thus, it is highly likely that Carolina Hammerhead is only found in the U.S. Atlantic. Regarding Scalloped Hammerhead, the Life History WG determined it was not possible to conclude whether regional differences in life history exist. The Genetics WG found no significant genetic differentiation between the Gulf of Mexico and U.S. Atlantic, and the Spatial Distribution/Movement WG concluded Scalloped Hammerheads comprise a single biological stock based on movements of individuals between regions. Considering all of the available information for Carolina and Scalloped Hammerhead, the Stock ID Workshop recommended that two stock assessments be conducted, if sufficient data are available. Carolina and Scalloped Hammerhead should be assessed as one stock in the U.S. Atlantic and another assessment should be conducted for the Scalloped Hammerhead in the Gulf of Mexico. If it is determined that sufficient data are not available to conduct separate assessments, then a single stock assessment should be conducted for the combined Carolina and Scalloped Hammerhead for all areas in the Northwest Atlantic.

1.2 Workshop Time And Place

The SEDAR 77 HMS Hammerheads Stock ID Process was conducted via a series of webinars, including a data scoping webinar (5/26/2021) and two webinars to discuss data analysis (7/20/2021, 8/10/2021).

1.3 Terms Of Reference

1. Review relevant information on stock structure for all Sphyrna species located in U.S. Atlantic, Gulf of Mexico, and Caribbean, with the exception of S. tiburo, S. tudes, and S. media Potential sources include genetic studies, growth patterns, movement and migration, existing stock definitions, vertebral chemistry, oceanographic and habitat characteristics, and hotspot maps of landings or catch per unit effort (CPUE).

2. Make recommendations on biological stock structure and the assessment unit stock or stocks to be addressed through SEDAR 77, and document the rationale behind the recommendations. The boundaries for the species assessments will be determined after examination of the current stock boundaries used in management and conservation under the ESA and additional analysis of biological and genetic stock structure.

3. Discuss the strength of evidence in support of stock ID recommendations with particular attention paid to recommendations if they result in a mismatch of biological stock structure, assessment unit stock, and existing management or conservation boundaries.

4. Provide recommendations for future research on stock structure.

5. Prepare a report providing complete documentation of workshop recommendations and decisions.

1.4 List Of Participants

Appointee	Affiliation
Stock ID Panel	
Enric Cortes, analyst	SEFSC Panama City Laboratory
Dean Courtney, analyst	SEFSC Panama City Laboratory
Xinsheng Zhang, analyst	SEFSC Panama City Laboratory
John Carlson, Lead	SEFSC Panama City Laboratory
Heather Baertlein	HMS
Alyssa Mathers	SEFSC Panama City Laboratory
Andrea Kroetz	SEFSC Panama City Laboratory
Cliff Hutt	HMS
Adam Pollack	SEFSC Mississippi Laboratories
Eric Hoffmayer	SEFSC Mississippi Laboratories
Cami McCandless	NEFSC Narragansett Laboratory
Trey Driggers	SEFSC Mississippi Laboratories
Heather Cox	SEFSC Panama City Laboratory
David Wells	Department of Biology Texas A&M University
David Portnoy	Department of Biology Texas A&M University
Bryan Frazier	SC Department of Natural Resources
Robert Latour	Virginia Institute of Marine Science College of William and Mary
R. Dean Grubbs	Florida State University Coastal and Marine Laboratory
Marcus Drymon	Mississippi State University
Bradley Wetherbee	University of Rhode Island
Mahmood Shivji	NOVA Southeastern University - Halmos College of Natural Sciences and Oceanography
Russell Hudson	Directed Shark Fisheries, Inc.
Beth Babcock	RSMAS U. Of Miami
Neil Hammerschlag	RSMAS U. Of Miami
Juan Carlos Perez-Jimenez	El Colegio de la Frontera Sur (ECOSUR)
J. Leonardo Castillo-Geniz	Centro Regional de Investigación Acuícola y Pesquera de Ensenada, BC (CRIAP-Ensenada) del Instituto Nacional de Pesca y Acuacultura (INAPESCA)
Demian Chapman	Mote Marine Laboratory and Aquarium
James Gelsleichter	University of North Florida

List of Participants Cont.	
Other	
Name	**Affiliation**
Michelle Passerotti	NMFS
Kesley Banks	Texas A&M
Steve Durkee	NMFS
Kristin Hannan	NMFS
Mariah Pfleger	Oceana
Bradley Smith	NMFS
Derek Kraft	NMFS
Jayne Gardiner	New College
Gregory Stuntz	Texas A&M Corpus Christi
STAFF Kathleen Howington	SEDAR
Karyl Brewster-Geisz	HMS Management
Margaret Miller	NMFS
Adam Brame	NMFS

1.5 Stock Id Process Working Papers And Reference Documents

Document #	Title	Authors	Received
Documents Prepared for SEDAR 77 Stock ID process			
SEDAR77-SID01	Regional movements of great, *Sphyrna mokarran,* and scalloped, *Sphyrna lewini,* hammerhead sharks in the US Atlantic, Gulf of Mexico and the 2 Bahamas: preliminary results	Vital Heim, Dean Grubbs, Bryan Frazier, Matthew J. Smukall, Tristan L. Guttridge	6/28/2021
SEDAR77-SID02	Catches of Hammerhead Sharks from the Congressional Supplemental Sampling Program (CSSP) in the Northern Gulf of Mexico	Adam G. Pollack and David S. Hanisko	6/29/2021
SEDAR77-SID03	Supplementary Material: Regional movements of great, Sphyrna mokarran, 1 and scalloped, Sphyrna lewini, hammerhead sharks in the US Atlantic,Gulf 2 of Mexico and the Bahamas: preliminary results	Vital Heim, Dean Grubbs, Bryan Frazier, Matthew J. Smukall, Tristan L. Guttridge	6/29/2021
SEDAR77-SID04	Tag and recapture data for Great Hammerhead, *Sphyrna mokarran*, and Scalloped Hammerhead, *Sphyrna lewini*, sharks caught in the western Gulf of Mexico from 2014-2021	Kesley G. Banks, and Gregory W. Stunz	7/2/2021
SEDAR77-SID05	Residency and movements of juvenile great hammerheads, *Sphyrna mokarran*, in the Tampa Bay area: preliminary results	Jayne M. Gardiner, Tonya R. Wiley, Susan K. Lowerre-Barbieri, Kim Bassos-Hull, and Krystan Wilkinson	7/2/2021
SEDAR77-SID06	Directed Sustainable Fisheries, Inc. A Saltwater Fisheries Consulting Company: Some Large Hammerhead shark information based on shark fin business knowledge from the mid-1980's through to September 1997 from Rusty Hudson.	Rusty Hudson	7/5/2021
SEDAR77-SID07	Report on spatial movements of great and scalloped hammerhead sharks in the US Atlantic and Gulf of Mexico using Satellite tags	Neil Hammerschlag	7/14/2021

Document #	Title	Authors	Received
Reference Documents			
SEDAR77-RD01	Movement, Behavior, and Habitat Use of a Marine Apex Predator, the Scalloped Hammerhead	R. J. David Wells, Thomas C. TinHan, Michael A. Dance, J. Marcus Drymon, Brett, Falterman, Matthew J. Ajemian, Gregory W. Stunz, John A. Mohan, Eric R. Hoffmayer, William B. Driggers III and Jennifer A. McKinney	5/27/2021
SEDAR77-RD02	First Verified Record of the Smooth Hammerhead (Sphyrna zygaena) in Coastal Waters of the Northern Gulf of Mexico with a Review of their Occurrence in the Western North Atlantic Ocean	Bethany M. Deacy, Heather E. Moncrief-Cox, and John K. Carlson	5/27/2021
SEDAR77-RD03	Use of marine protected areas and exclusive economic zones in the subtropical western North Atlantic Ocean by large highly mobile sharks	Fiona Graham, Patrick Rynne, Maria Estevanez, Jiangang Luo, Jerald S. Ault and Neil Hammerschlag	5/27/2021
SEDAR77-RD04	Overlap between highly suitable habitats and longline gear management areas reveals vulnerable and protected regions for highly migratory sharks	Hannah Calich, Maria Estevanez, Neil Hammerschlag	5/27/2021

Document #	Title	Authors	Received
Reference Documents Cont.			
SEDAR77-RD05	Regional-scale variability in the movement ecology of marine fishes revealed by an integrative acoustic tracking network	Claudia Friess, Susan K. Lowerre-Barbieri, Gregg R. Poulakis, Neil Hammerschlag, Jayne M. Gardiner, Andrea M. Kroetz, Kim Bassos-Hull, Joel Bickford, Erin C. Bohaboy, Robert D. Ellis, Hayden Menendez, William F. Patterson III, Melissa E. Price, Jennifer S. Rehage, Colin P. Shea, Matthew J. Smukall, Sarah Walters Burnsed, Krystan A. Wilkinson, Joy Young, Angela B. Collins, Breanna C. DeGroot, Cheston T. Peterson, Caleb Purtlebaugh, Michael Randall, Rachel M. Scharer, Ryan W. Schloesser, Tonya R. Wiley, Gina A. Alvarez, Andy J. Danylchuk, Adam G. Fox, R. Dean Grubbs, Ashley Hill, James V. Locascio, Patrick M. O'Donnell, Gregory B. Skomal, Fred G. Whoriskey, Lucas P. Griffin	5/27/2021
SEDAR77-RD06	Restricted connectivity and population genetic fragility in a globally endangered Hammerhead Shark	Danillo Pinhal, Rodrigo R. Domingues, Christine C. Bruels, Bruno L. S. Ferrette, Otto B. F. Gadig, Mahmood S. Shivji, Cesar Martins	5/27/2021

Document #	Title	Authors	Received
Reference Documents Cont.			
SEDAR77-RD07	Tracking the Fin Trade: Genetic Stock Identification in western Atlantic scalloped hammerhead sharks *Sphyrna lewini*	Demian D. Chapman, Danillo Pinhal, Mahmood S. Shivji	5/27/2021
SEDAR77-RD08	Seasonal Movements and Habitat Use of Juvenile Smooth Hammerhead Sharks in the Western North Atlantic Ocean and Significance for Management	Ryan K. Logan, Jeremy J. Vaudo, Lara L. Sousa, Mark Sampson, Bradley M. Wetherbee and Mahmood S. Shivji	5/27/2021
SEDAR77-RD09	The complete mitochondrial genome of the endangered great hammerhead shark, *Sphyrna mokarran*	Cassandra L. Ruck, Nicholas Marra, Mahmood S. Shivji & Michael J. Stanhope	6/18/2021
SEDAR77-RD10	New insights into the migration patterns of the scalloped hammerhead shark *Sphyrna lewini* based on vertebral microchemistry	Claire Coiraton · Felipe Amezcua · James T. Ketchum	6/18/2021
SEDAR77-RD11	Global Phylogeography with Mixed-Marker Analysis Reveals Male-Mediated Dispersal in the Endangered Scalloped Hammerhead Shark (Sphyrna lewini)	Toby S. Daly-Engel, Kanesa D. Seraphin, Kim N. Holland, John P. Coffey, Holly A. Nance, Robert J. Toonen, Brian W. Bowen	6/18/2021
SEDAR77-RD12	Species composition of the largest shark fin retail-market in mainland China	Diego Cardeños, Andrew T. Fields, Elizabeth A. Babcock, Stanley K. H. Shea, Kevin A. Feldheim & Demian D. Chapman	6/18/2021
SEDAR77-RD13	Identification of young-of-the-year great hammerhead shark *Sphyrna mokarran* in northern Florida and South Carolina	A. M. Barker, B. S. Frazier, D. M. Bethea, J. R. Gold and D. S. Portnoy	6/18/2021
SEDAR77-RD14	Sphyrna gilberti sp. nov., a new hammerhead shark (Carcharhiniformes, Sphyrnidae) from the western Atlantic Ocean	Joseph M. Quattro, William B. Driggers Iii, James M. Grady, Glenn F. Ulrich & Mark A. Roberts	6/18/2021

Document #	Title	Authors	Received
Reference Documents Cont.			
SEDAR77-RD16	Philopatry and Regional Connectivity of the Great Hammerhead Shark, Sphyrna mokarran in the U.S. and Bahamas	Tristan L. Guttridge, Maurits P. M. Van Zinnicq Bergmann, Chris Bolte, Lucy A. Howey, Jean S. Finger, Steven T. Kessel, Jill L. Brooks, William Winram, Mark E. Bond, Lance K. B. Jordan, Rachael C. Cashman, Emily R. Tolentino, R. Dean Grubbs and Samuel H. Gruber	6/18/2021
SEDARE77-RD17	Potential distribution of critically endangered hammerhead sharks and overlap with the small-scale fishing fleet in the southern Gulf of Mexico	Mercedes Yamily Chi Chan, Oscar Sosa-Nishizaki, Juan Carlos Pérez-Jiménez	6/23/2021 Revised: 6/29/2021
SEDAR77-RD18	Complete mitogenome sequences of smooth hammerhead sharks, *Sphyrna zygaena*, from the eastern and western Atlantic	Derek S. Guy, Cassandra L. Ruck, Jose V. Lopez & Mahmood S. Shivji	6/18/2021
SEDAR77-RD19	Cryptic hammerhead shark lineage occurrence in the western South Atlantic revealed by DNA analysis	D. Pinhal · M. S. Shivji · M. Vallinoto · D. D. Chapman · O. B. F. Gadig · C. Martins	6/18/2021
SEDAR77-RD20	Double tagging clarifies post-release fate of great hammerheads (Sphyrna mokarran)	J. Marcus Drymon and R. J. David Wells	6/22/2021
SEDAR77-RD21	Defining Sex-Specific Habitat Suitability for a Northern Gulf of Mexico Shark Assemblage	J. M. Drymon, S. Dedman, J. T. Froeschke, E. A. Seubert, A. E. Jefferson, A. M. Kroetz, J. F. Mareska and S. P. Powers	6/22/2021

Document #	Title	Authors	Received
	Reference Documents Cont.		
SEDAR77-RD22	Distribution and relative abundance of scalloped (*Sphyrna lewini)* and Carolina (*S. gilberti*) hammerheads in the western North Atlantic Ocean	Amanda M. Barker Bryan S. Frazier, Douglas H. Adams, Christine N. Bedore, Carolyn N. Belcher, William B. Driggers III, Ashley S. Galloway, James Gelsleichter, R. Dean Grubbs, Eric A. Reyier, David S. Portnoy	6/23/2021
SEDAR77-RD23	Distributions and Movements of Atlantic Shark Species: A 52-Year Retrospective Atlas of Mark and Recapture Data	Nancy E. Kohler And Patricia A. Turner	7/6/2021
SEDAR77-RD24	First identification of probable nursery habitat for critically endangered great hammerhead Sphyrna mokarran on the Atlantic Coast of the United States	Catherine Macdonald, Jacob Jerome, Christian Pankow, Nicholas Perni, Kristina Black, David Shiffman, Julia Wester	7/12/2021
SEDAR77-RD25	Characterization of a scalloped hammerhead (Sphyrna lewini) nursery habitat in portions of the Atlantic Intracoastal Waterway	Bryanna N. Wargat	7/15/2021

2. Stock Id Panel Reports

2.1 Life History Working Group

2.1.1 Life History Working Group participants:

William Driggers (National Marine Fisheries Service)
Bryan Frazier (South Carolina Department of Marine Resources)
James Gelsleichter (University of North Florida)
Kristin Hannan (National Marine Fisheries Service)
Heather Moncrief-Cox (National Marine Fisheries Service)
Michelle Passerotti (National Marine Fisheries Service)
Juan Carlos Perez-Jimenez (El Colegio de la Frontera Sur)

2.1.2 Carolina Hammerhead (*Sphyrna gilberti*)

A total of 76 vertebrae (Table 1) were available for construction of growth curves for Carolina hammerheads (all from the Atlantic). Unfortunately, insufficient samples are available to generate robust estimates of growth in this species. The majority of collected specimens to date are young-of-the-year or juvenile animals (Figure 1). Only one mature specimen, a male, was present in the dataset, so reproductive analysis was not conducted on this species. To date, no Carolina hammerheads have been documented in the Gulf of Mexico (Barker et al. 2021). Discussions largely revolved around how the presence of Carolina hammerheads could affect life history data for scalloped hammerheads as Carolina hammerhead specimens are likely present within the available dataset for Atlantic scalloped hammerheads due to the cryptic nature of the species. All specimens used for life history analyses were identified to species using the methods of Barker et al. (2021). Length data from young-of-the-year Carolina and scalloped hammerheads in SC nursery areas suggest Carolina hammerheads are born at a smaller length than scalloped hammerheads (SCDNR unpublished); however, how this difference in length-at-birth impacts species-specific life histories (e.g. growth and fecundity) remains unknown.

2.1.3 Great hammerhead (*Sphyrna mokarran*)

Vertebrae were available from 283 great hammerheads to generate von Bertalanffy growth models to assess if differences existed in growth parameter estimates between individuals collected in United States waters off the east coast (Atlantic) and in the northern Gulf of Mexico (Gulf) (Table 2). The size of sampled great hammerheads ranged from 40.4-357.0 cm fork length (FL) (Table 3).

Ages were obtained using the methods of Piercy et al. (2010) with the exception of no stain (i.e. crystal violet) being used to elucidate growth bands. Band counts were similar between readers with 84% of counts being in agreement. In those cases when counts differed (96% of counts within one year and 100% within two years) consensus was reached on all samples aged. Age and length data were then utilized to generate growth models by sex and region. Likelihood ratio tests (LRT) were used to determine if there were significant differences in growth parameters for great hammerheads among models generated for the Atlantic and Gulf (Cerrato 1990).

Growth parameter estimates and models are presented in Table 4 and Figures 2-4, respectively. There were significant differences between females (X^2 = 18.79, $p < 0.01$), males (X^2= 22.18, $p < 0.01$) and combined sexes (X^2 = 28.31, $p < 0.01$) between regions (Table 4). As expected, females had higher asymptotic lengths (L_∞) and lower growth constants (k) than males in both regions. However, L_∞ was higher and k was lower in the Gulf than in the Atlantic for both sexes: a general trend not seen in similar species of coastal sharks within the order Carcharhiniformes (e.g. Loefer and Sedberry 2003; Driggers et al. 2004; Frazier et al. 2014). Inspection of the length-at-age data presented in Figures 2 and 3 indicate that smaller size classes (i.e. < 200 cm FL) are underrepresented for both sexes collected in the Atlantic and large individuals are limited, particularly among Gulf samples.

Maturity status information was available for a total of 835 great hammerheads to evaluate length at maturity (Table 5). Of these, the majority of specimens came from the Gulf of Mexico (n=700). No males under 100 cm were available for the Atlantic region, and no females below 200 cm were available (Table 5). Generalized linear models with a logit link and binomial distribution (binary logistic regression models) were fit to the data, and 95% confidence intervals were used to test for significant differences between regions. There was no significant difference in length at 50% maturity (L_{50}) between the Atlantic and Gulf of Mexico, both with sexes combined or independent from one another (Table 6, Figure 5). For age-at-maturity, only 61 had associated ages (Table 7), with no Age-0 individuals present in the dataset, and a higher proportion coming from the Gulf of Mexico. Therefore, additional samples are needed in order to increase confidence in the results presented in Table 8.

While significant differences were found among growth parameters estimated between regions, the Life History Group determined that because data gaps were evident, resulting region-specific growth models need to be further developed through the inclusion of additional samples before it can be reliably determined if regional differences in growth truly exist. As a result, it was concluded that, for the purposes of this assessment, potential differences in the growth of great hammerheads between the Atlantic and Gulf should not be considered when determining stock structure of the species in the western North Atlantic Ocean.

2.1.4 **Scalloped Hammerhead (*Sphyrna lewini*)**

Vertebrae from 945 scalloped hammerheads from fishery dependent and independent sources were available to assess stock structure based on potential life history differences. A total of 631 samples were available from the Atlantic and 286 samples from the Gulf of Mexico, with larger individuals only being represented among Atlantic samples (Table 9). Ages were estimated following the methods of Frazier et al. (2014); however, due to the last-minute inclusion of additional vertebrae, only single-reader age estimates were available at the time of the stock ID workshop.

Estimated age and measured fork lengths (cm) were used to model growth using the von Bertalanffy growth model by sex and region as well as with sexes combined, and sexes and region combined. Likelihood ratio tests (Kimura 1980) were used to test for significant differences between growth models for sexes and regions. Growth parameter estimates and models are presented in Table 10 and Figures 6-8, respectively. There were significant differences in growth between females and males (X^2 = 33.94, $p < 0.01$), therefore, sexes were modeled independently. There were no significant differences in growth for females from the Atlantic and Gulf (X^2 = 2.24, $p < 0.52$); however, given the small sample size from the Gulf (n=105), and lack of samples from large mature female scalloped hammerheads in this region, we do not have confidence that these results reflect true population parameters. Significant differences in growth were detected for males between regions (X^2 = 36.83, $p < 0.01$), with scalloped hammerheads in the Atlantic reaching a larger asymptotic length and having a lower growth constant and older age (Figure 8), similar to trends seen in other coastal sharks (Frazier et al. 2014, Loefer et al. 2003, Vinyard et al. 2020). Despite these differences, it must be noted that there were almost certainly vertebral samples from both Carolina and scalloped hammerheads present in the specimens used to generate growth models for scalloped hammerheads in the Atlantic. Therefore, the growth data generated for the Atlantic could be biased due to potential differences in growth between the two species.

Maturity status information was available for 1,525 scalloped hammerhead specimens, of which 1,038 were captured in the Gulf of Mexico (Table 11). Ages were available for 523 animals to estimate age-at-maturity (Table 13). Generalized linear models with a logit link and binomial distribution (binary logistic regression models) fit to the data showed a significant difference in L_{50} between the Atlantic and Gulf of Mexico with sexes combined, due to a significant difference in males ($L_{50} = 145.87 \pm 1.41$, $p < 0.01$; Table 12, Figure 9). This is likely due to the higher number of immature males in the dataset, primarily from the Atlantic. No significant difference was detected for females between regions ($L_{50} = 178.83 \pm 3.87$, $p < 0.72$). A significant difference between regions was also present for A_{50} with sexes combined ($A_{50} = 12.90 \pm 0.40$, $p < 0.01$; Table 14), again likely due to immature male prevalence in the dataset. No significant difference was detected for females ($A_{50} = 17.44 \pm 1.27$, $p < 0.95$).

Given uncertainties due to sampling (low sample sizes in the GOM, and lack of mature females in both regions), as well as the potentially confounding presence of the Carolina hammerhead, the Life History Group recommended using other data sources (genetic, conventional and electronic tagging data) as primary methods for determining stock structure for scalloped hammerheads. Based on discussions among Life History Working Group members revolving around the presence of Carolina hammerheads in the Atlantic scalloped hammerhead life history samples, it was recommended that the Atlantic and Gulf stocks be assessed separately with the understanding that species-specific life history data is not available for the Carolina Hammerhead.

2.1.5 Smooth hammerhead (*Sphyrna zygaena*)

There were no applicable life history data available to determine the stock structure of smooth hammerheads.

2.1.6 **Literature cited**

Barker, A. M., Frazier, B. S., Adams, D. H., Bedore, C. N., Belcher, C. N., Driggers, W. B. III, Galloway, A. S., Gelsleichter, J., Grubbs, R. D., Reyier, E.A., & Portnoy, D. S. 2021. Distribution and relative abundance of scalloped (*Sphyrna lewini*) and Carolina (*S. gilberti*) hammerheads in the western North Atlantic Ocean. Fisheries Research 242.

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2.1.7 **Tables**

Table 1: Sample size and minimum/maximum fork lengths by sex for Carolina hammerheads (*Sphyrna gilberti*) collected off the U.S. east coast (Atlantic).

Sex	n	Min FL (cm)	Max FL (cm)
Female	39	27.0	104.1
Male	37	27.6	192.5
Combined	76	27.0	192.5

Table 2: Sex and capture location of great hammerheads (*Sphyrna mokarran*) specimens used to examine potential growth differences between individuals collected off the U.S. east coast (Atlantic) and in the northern Gulf of Mexico (Gulf).

	Atlantic	Gulf	Areas combined
Female	62	106	168
Male	53	59	112
Sexes combined	115	168	283

Table 3. Fork length (cm) and sex of great hammerheads (*Sphyrna mokarran*) whose vertebrae were utilized to determine if growth differences are present between individuals collected off the east coast (Atlantic) and in the northern Gulf of Mexico (Gulf).

	Atlantic	Gulf
Female	41.7-357.0	54.0-322.0
Male	40.4-296.7	60.0-274.0
Sexes combined	40.4-357.0	55.0-322.0

Table 4. Sex-specific, combined sexes and region-specific von Bertalanffy growth parameter estimates for great hammerheads (*Sphyrna mokarran*) collected off the east coast of the U.S. (Atlantic) and in the northern Gulf of Mexico (Gulf). L_∞ = asymptotic length, k = growth constant, t_o = theoretical age at size zero, MOA = maximum observed age.

Area	Sex	L_∞ (cm)	k	t_o (years)	n	r^2	MOA (years)
Atlantic	Female	316.78	0.13	-1.37	62	0.95	35
	Male	250.84	0.22	-0.86	53	0.96	38
	Combined	281.76	0.17	-1.10	115	0.93	
Gulf	Female	357.37	0.07	-3.50	106	0.92	30
	Male	251.56	0.16	-2.11	59	0.92	34
	Combined	298.00	0.11	-2.80	168	0.90	
Combined	Female	327.42	0.10	-2.12	168	0.93	
	Male	250.29	0.19	-1.34	112	0.93	
	Combined	286.99	0.14	-1.74	283	0.91	
Piercy et al. (2010)	Female	307.8	0.11	-2.86	105	0.85	44
	Male	264.2	0.16	-1.99	111	0.92	42
	Combined	286.9	0.13	-2.51	216	0.89	

Table 5. Sex, capture location, maturity status and fork lengths used to evaluate potential differences in length-at-maturity for great hammerhead (*Sphyrna mokarran*) individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

		Atlantic			Gulf of Mexico			Areas Combined		
Sex	Maturity Status	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)
Female	Immature	2	207.0	214.5	222	48.0	222.0	224	48.0	222.0
	Mature	11	228.0	309.0	107	118.7	360.0	118	118.7	360.0
	Combined	13	207.0	309.0	329	48.0	360.0	342	48.0	360.0
Male	Immature	31	100.0	225.0	255	50.0	221.0	286	50.0	225.0
	Mature	91	117.0	291.0	116	108.0	340.4	207	108.0	340.4
	Combined	122	100.0	291.0	371	50.0	340.4	493	50.0	340.4
Combined	Immature	33	100.0	225.0	477	48.0	222.0	510	48.0	225.0
	Mature	102	117.0	309.0	223	108.0	360.0	325	108.0	360.0
	Combined	135	100.0	309.0	700	48.0	360.0	835	48.0	360.0

Table 6. Great hammerhead (*Sphyrna mokarran*) sex-specific, combined sex and region-specific lengths at which 50% of the specimens were mature (L_{50}), with minimum and maximum fork lengths (FL) reported.

	Sex	L_{50}	Min FL (cm)	Max FL (cm)
Atlantic	Female	209.63	207.0	309.0
	Male	189.52	100.0	291.0
	Combined	188.70	100.0	309.0
Gulf of Mexico	Female	196.21	48.0	360.0
	Male	201.74	50.0	340.4
	Combined	199.64	48.0	360.0
Combined	Female	196.79	48.0	360.0
	Male	198.57	50.0	340.4
	Combined	197.58	48.0	360.0

Table 7. Sex, capture location, maturity status and estimated ages used to evaluate potential differences in age-at-maturity for great hammerhead (*Sphyrna mokarran*) individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

		Atlantic			Gulf of Mexico			Areas Combined		
Sex	Maturity Status	n	Min Age (yr)	Max Age (yr)	n	Min Age (yr)	Max Age (yr)	n	Min Age (yr)	Max Age (yr)
Female	Immature	2	7	9	10	2	9	12	2	9
	Mature	4	11	32	14	4	17	18	4	32
	Combined	6	7	32	24	2	17	30	2	32
Male	Immature	4	6	9	15	3	14	19	3	14
	Mature	7	10	20	5	10	25	12	10	25
	Combined	11	6	20	20	3	25	31	3	25
Combined	Immature	6	6	9	25	2	14	31	2	14
	Mature	11	10	32	19	4	25	30	4	32
	Combined	17	6	32	44	2	25	61	2	32

Table 8. Great hammerhead (*Sphyrna mokarran*) sex-specific, combined sex and region-specific ages at which 50% of the specimens were mature (A_{50}), along with minimum and maximum ages observed for individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

	Sex	A_{50}	Min Age (yr)	Max Age (yr)
Atlantic	Female	10.2	7	32
	Male	9.4	6	20
	Combined	9.6	6	32
Gulf of Mexico	Female	6.5	2	17
	Male	12.3	3	25
	Combined	8.9	2	25
Combined	Female	7.1	2	32
	Male	11.0	3	25
	Combined	9.1	2	32

Table 9. Sex and capture location of scalloped hammerhead (*Sphyrna lewini*) specimens used to examine potential growth differences between individuals collected off the U.S. east coast (Atlantic) and in the northern Gulf of Mexico. A limited number of individuals (n=11 Female, n=17 Male) had no known region and are included in the areas combined only.

	Atlantic			Gulf of Mexico			Areas Combined		
Sex	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)
Female	243	31.6	245.0	105	30.0	235.0	359	30.0	245.0
Male	388	30.8	287.0	181	35.0	223.0	586	30.8	287.0
Combined	631	30.8	287.0	286	30.0	235.0	945	30.0	287.0

Table 10. Sex-specific, combined sexes and region-specific von Bertalanffy growth parameter estimates for scalloped hammerheads (*Sphyrna lewini*) collected off the east coast of the U.S. (Atlantic) and in the northern Gulf of Mexico (Gulf). L_∞ = asymptotic length, k = growth constant, t_o = theoretical age at size zero, MOA = maximum observed age.

Region	Sex	L_∞ (cm)	k	t_0 (years)	n	MOA
Atlantic	Female	277.2	0.05	-3.31	243	31.0
	Male	247.4	0.07	-2.48	388	41.9
	Combined	256.4	0.06	-2.78	631	41.9
Gulf	Female	263.8	0.06	-2.97	105	29.7
	Male	212.8	0.10	-1. 90	181	34.1
	Combined	223.9	0.09	-2.19	286	34.1
Combined	Female	280.5	0.05	-3.21	359	31.0
	Male	234.6	0.08	-2.28	586	41.9
	Combined	246.0	0.07	-2.88	945	41.9
Piercy	Female	233.1	0.09	-1.62	116	30.5
	Male	214.8	0.13	-2.22	191	30.5
	Combined	219.8	0.12	-1.84	307	30.5

Table 11. Sex, capture location, maturity status and fork lengths used to evaluate potential differences in length-at-maturity for scalloped hammerhead (*Sphyrna lewini*) individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

		Atlantic			Gulf of Mexico			Areas Combined		
Sex	Maturity Status	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)	n	Min FL (cm)	Max FL (cm)
Female	Immature	99	31.6	196.0	288	31.0	182.9	387	31.0	196.0
	Mature	336	188.0	243.0	35	177.0	255.0	68	177.0	255.0
	Combined	132	31.6	243.0	323	31.0	255.0	455	31.0	255.0
Male	Immature	156	31.8	183.0	392	28.0	192.0	548	28.0	192.0
	Mature	199	149.3	250.0	323	110.0	289.0	522	110.0	289.0
	Combined	355	31.8	250.0	715	28.0	289.0	1070	28.0	289.0
Combined	Immature	255	31.6	196.0	680	28.0	192.0	935	28.0	196.0
	Mature	232	149.3	250.0	358	110.0	289.0	590	110.0	289.0
	Combined	487	31.6	250.0	1038	28.0	289.0	1525	28.0	289.0

Table 12. Scalloped hammerhead (*Sphyrna lewini*) sex-specific, combined sex and region-specific lengths at which 50% of the specimens were mature (L_{50}), with minimum and maximum fork lengths (FL) reported.

	Sex	L_{50}	Min FL (cm)	Max FL (cm)
Atlantic	Female	177.59	31.6	243.0
	Male	157.11	31.8	250.0
	Combined	159.85	31.6	250.0
Gulf of Mexico	Female	180.43	31.0	255.0
	Male	141.76	28.0	289.0
	Combined	145.22	28.0	289.0
Combined	Female	178.83	31.0	255.0
	Male	145.87	28.0	289.0
	Combined	149.66	28.0	289.0

Table 13. Sex, capture location, maturity status and estimated ages used to evaluate potential differences in age-at-maturity for scalloped hammerhead (*Sphyrna lewini*) individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

		Atlantic			Gulf of Mexico			Areas Combined		
Sex	Maturity Status	n	Min Age (yr)	Max Age (yr)	n	Min Age (yr)	Max Age (yr)	n	Min Age (yr)	Max Age (yr)
Female	Immature	99	0	22	53	0	20	152	0	22
	Mature	13	7	24	1	10	10	14	7	24
	Combined	112	0	24	54	0	20	166	0	24
Male	Immature	138	0	17	52	0	21	190	0	21
	Mature	104	9	42	63	8	34	167	8	42
	Combined	242	0	42	115	0	34	357	0	42
Combined	Immature	237	0	22	105	0	21	342	0	22
	Mature	117	7	42	64	8	34	181	7	42
	Combined	354	0	42	169	0	34	523	0	42

Table 14. Scalloped hammerhead (*Sphyrna lewini*) sex-specific, combined sex and region-specific ages at which 50% of the specimens were mature (A_{50}), along with minimum and maximum ages observed for individuals collected off the U.S. east coast (Atlantic) and in the Gulf of Mexico.

	Sex	A_{50}	Min Age (yr)	Max Age (yr)
Atlantic	Female	17.4	0	24
	Male	12.7	0	42
	Combined	13.7	0	42
Gulf of Mexico	Female	17.7	0	20
	Male	10.2	0	34
	Combined	10.7	0	34
Combined	Female	17.4	0	24
	Male	11.9	0	42
	Combined	12.9	0	42

2.1.8 **Figures**

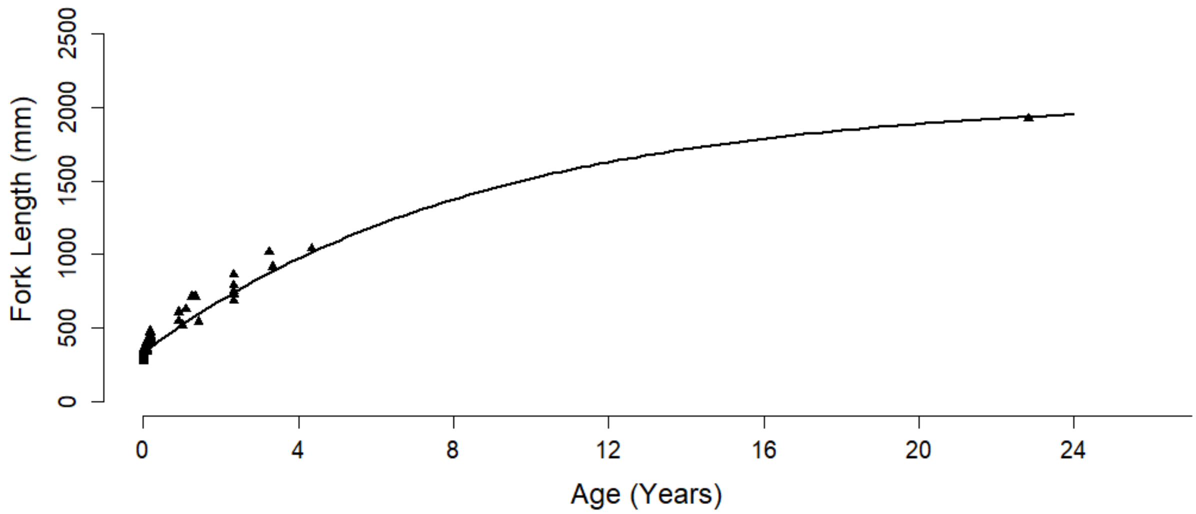


Figure 1. von Bertalanffy growth curve for combined male and female Carolina hammerheads (*Sphyrna gilberti*) sampled off the east coast of the U.S. (Atlantic).

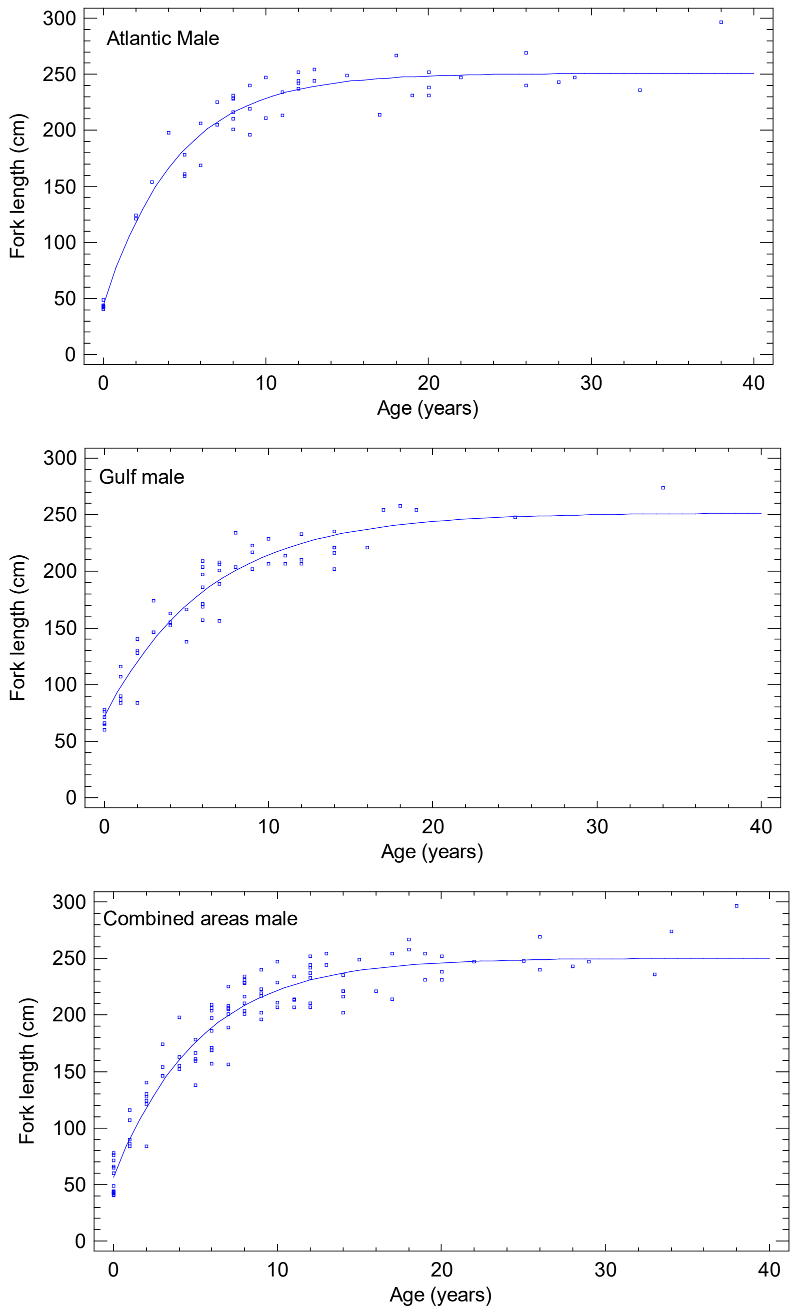


Figure 2. von Bertalanffy growth curves for male great hammerheads (*Sphyrna mokarran*) sampled off the east coast of the U.S. (Atlantic), the northern Gulf of Mexico (Gulf), and regions combined.

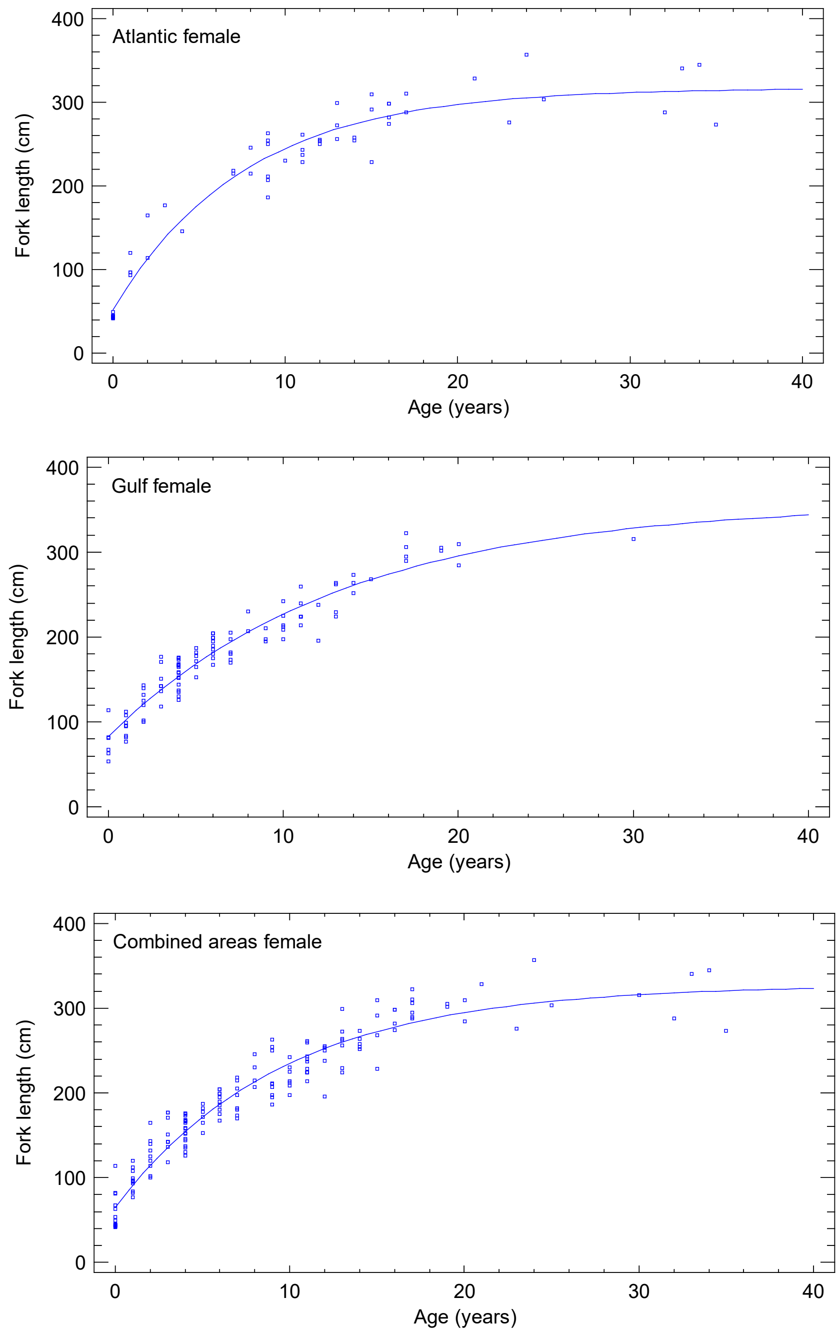


Figure 3. von Bertalanffy growth curves for female great hammerheads (*Sphyrna mokarran*) sampled off the east coast of the U.S. (Atlantic) and the northern Gulf of Mexico (Gulf), and regions combined.

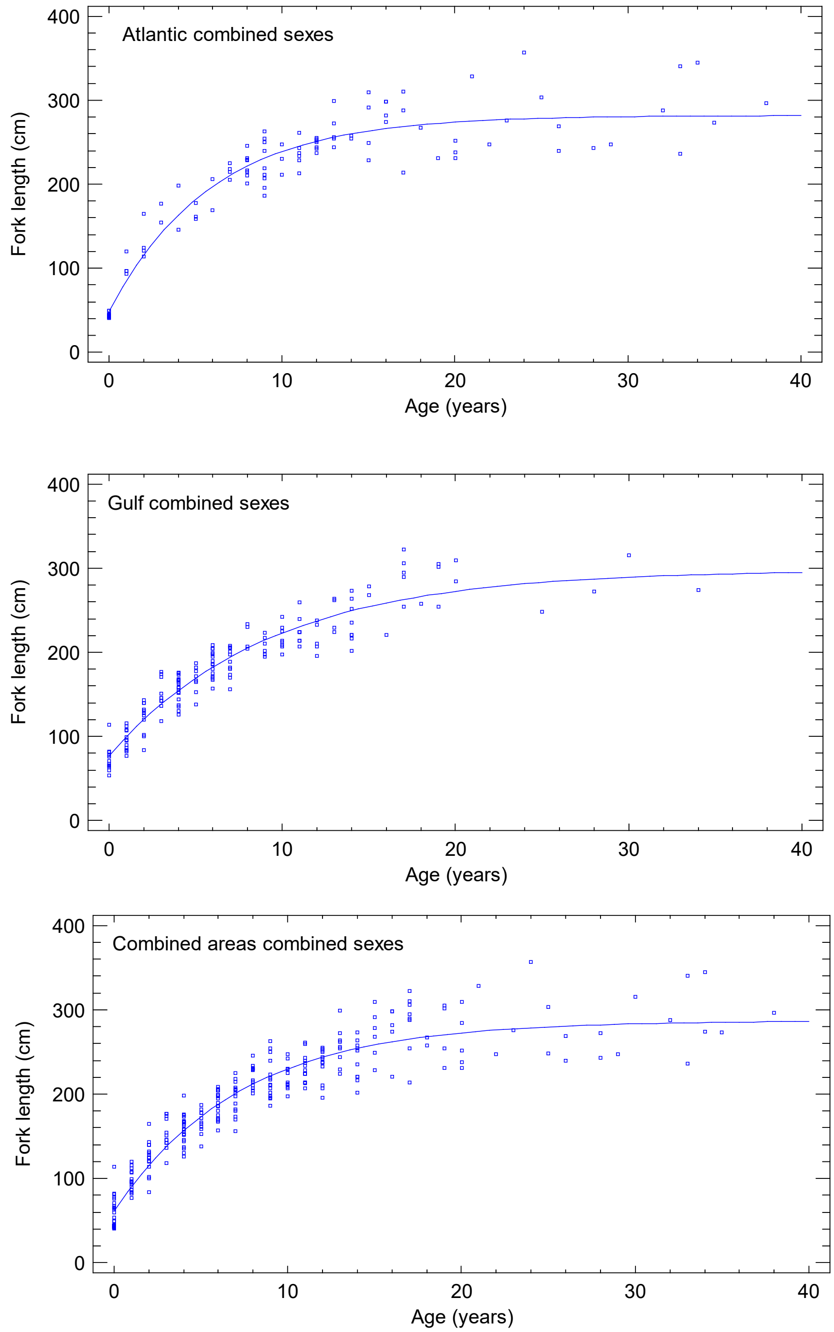


Figure 4. von Bertalanffy growth curves for male and female great hammerheads (*Sphyrna mokarran*) combined sampled off the east coast of the U.S. (Atlantic) and the northern Gulf of Mexico (Gulf), as well as regions combined.

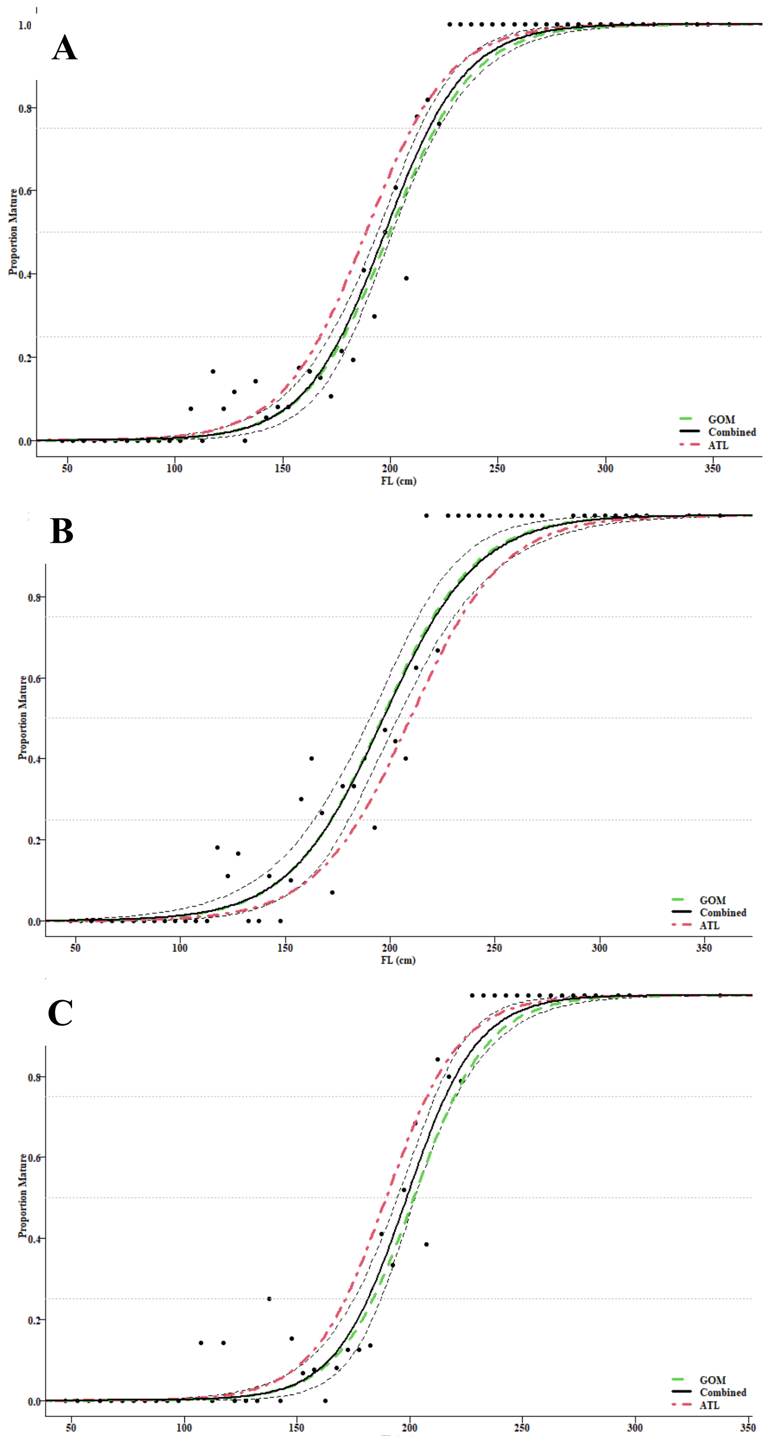


Figure 5. Proportion mature at length for great hammerhead (*Sphyrna mokarran*) maturity data for A) sexes combined, B) females, C) males. Combined region analysis is represented by the solid black line, Gulf of Mexico (GOM) as green dashed line, and Atlantic (ATL) as red dashed line. Black dashed lines represent 95% confidence intervals from bootstrap analysis.

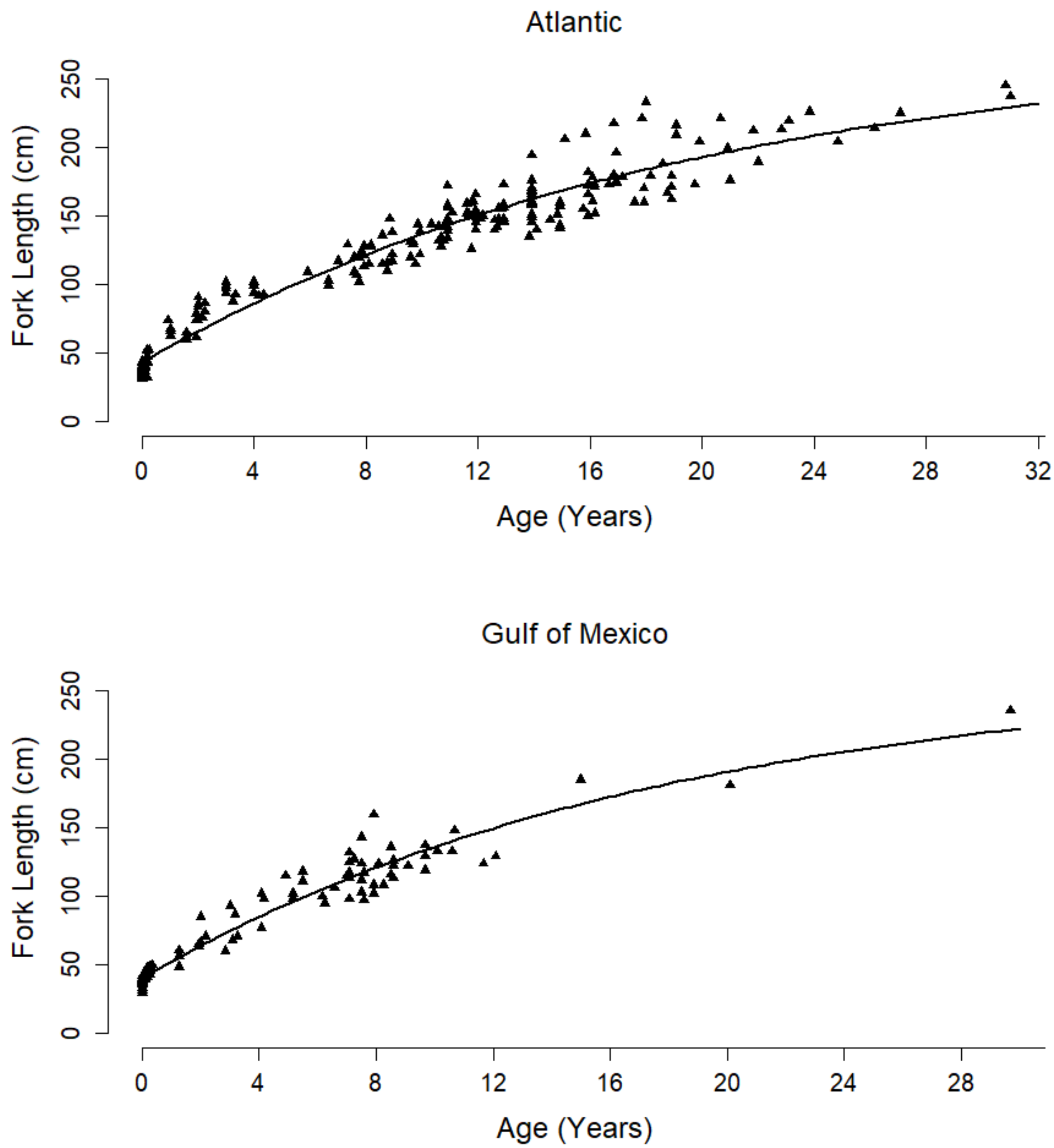


Figure 6. von Bertalanffy growth curve for female scalloped hammerheads (*Sphyrna lewini*) sampled off the east coast of the U.S. (Atlantic) and the northern Gulf of Mexico.

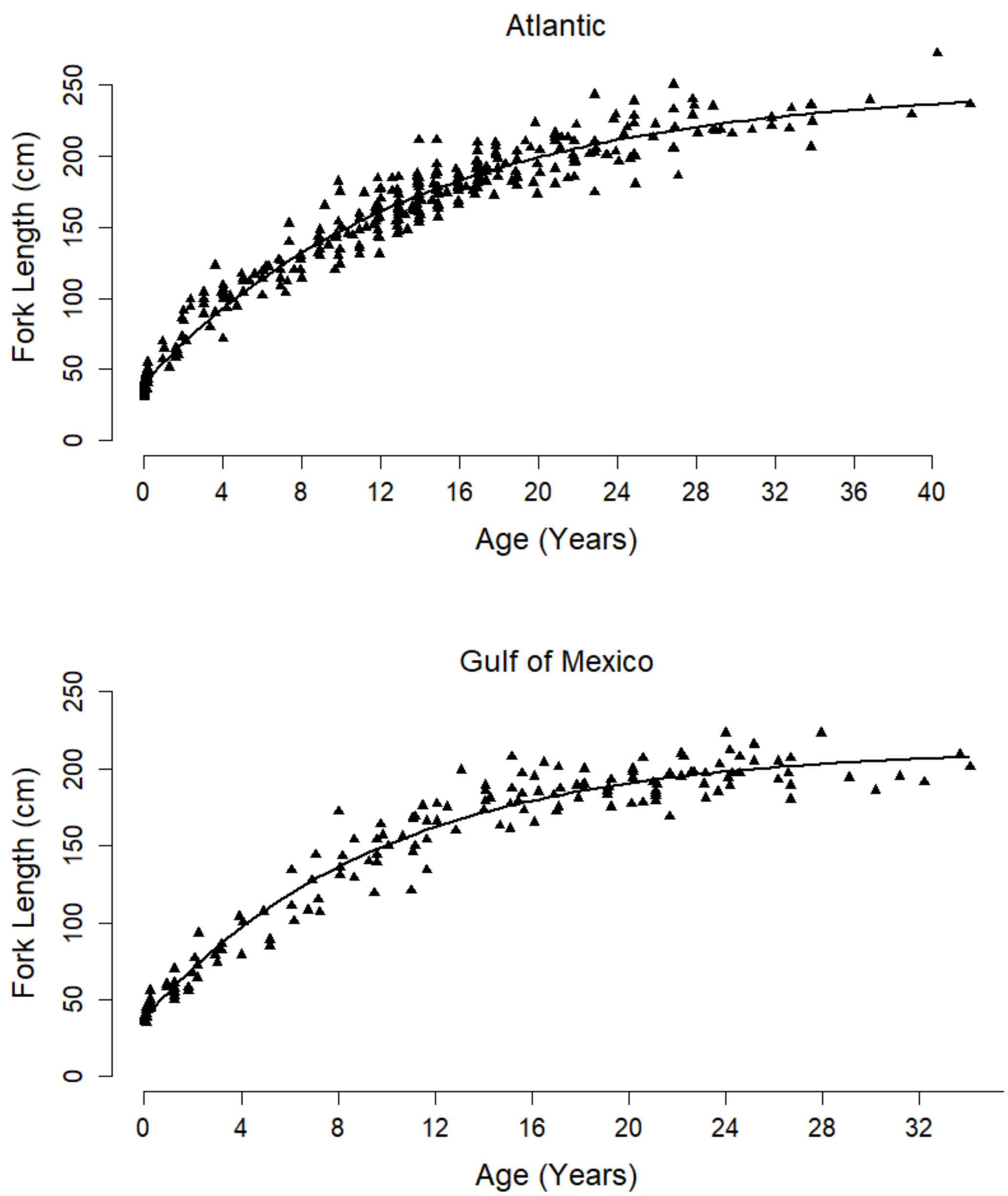


Figure 7. von Bertalanffy growth curves for male scalloped hammerheads (*Sphyrna lewini*) sampled off the east coast of the U.S. (Atlantic) and the northern Gulf of Mexico.

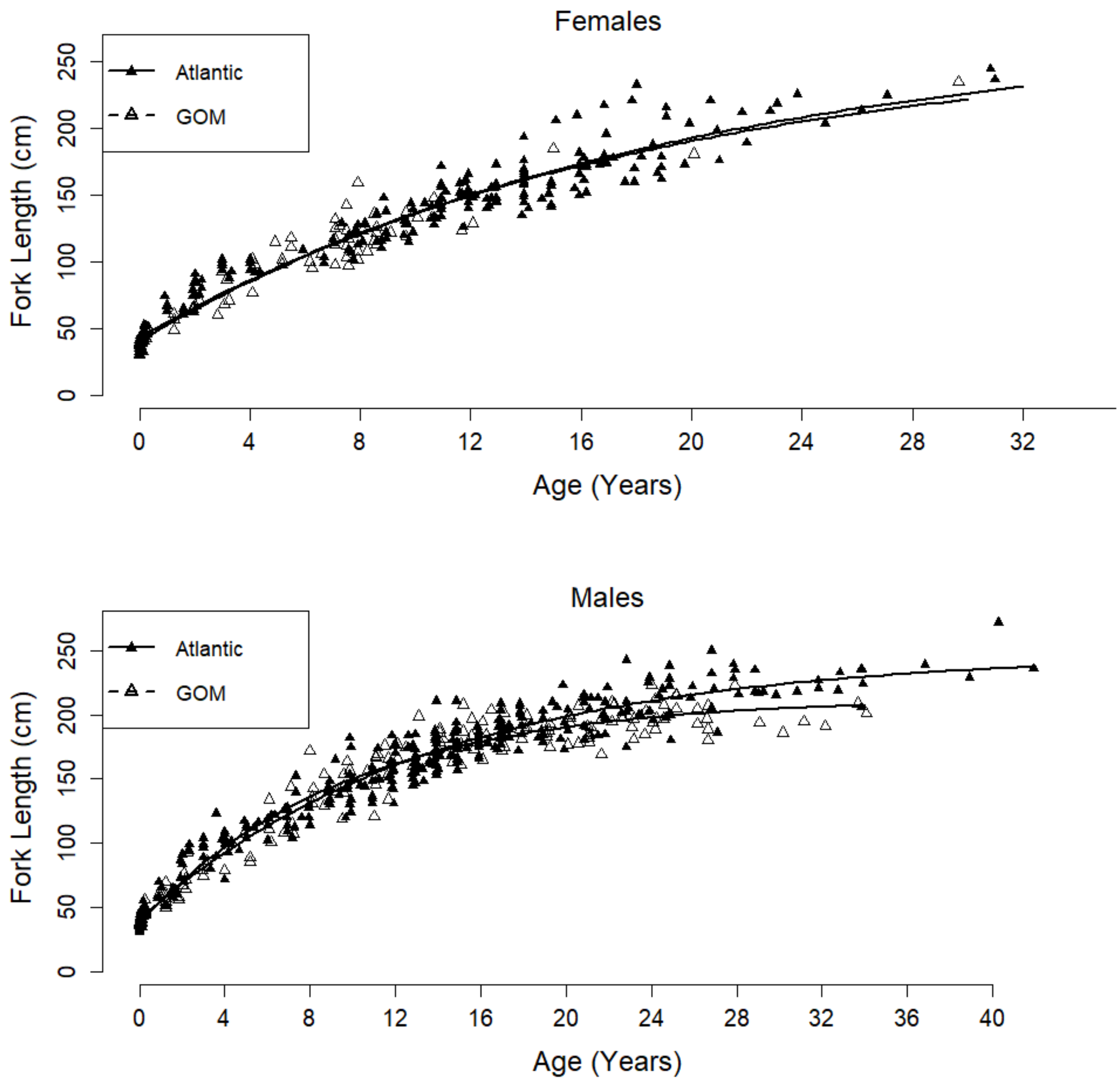


Figure 8. Comparison von Bertalanffy growth curves for female and male scalloped hammerheads (*Sphyrna lewini*) sampled off the east coast of the U.S. (Atlantic) and the northern Gulf of Mexico (GOM).

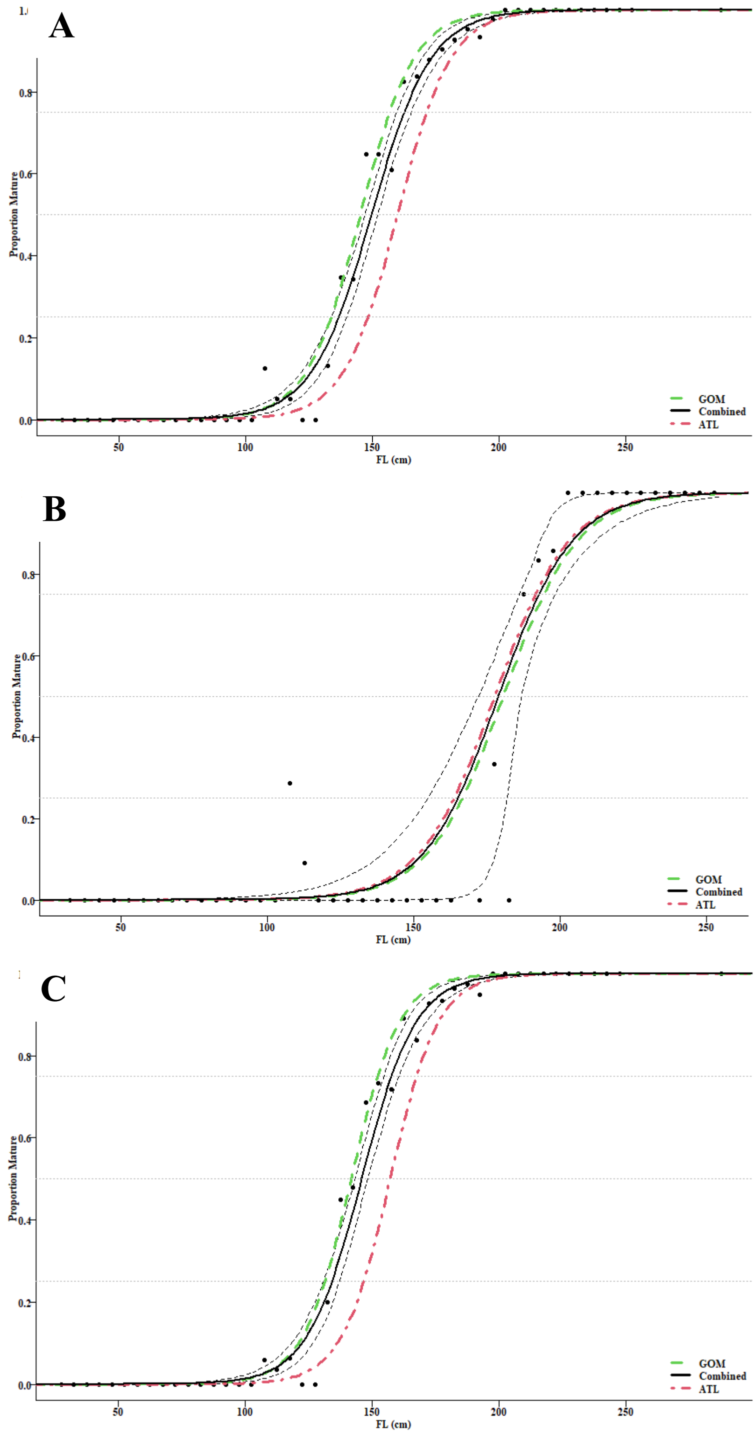


Figure 9. Proportion mature at length for scalloped hammerhead (*Sphyrna lewini*) maturity data for A) sexes combined, B) females, C) males. Combined region analysis is represented by the solid black line, Gulf of Mexico (GOM) as green dashed line, and Atlantic (ATL) as red dashed line. Black dashed lines represent 95% confidence intervals from bootstrap analysis.

2.2 Genetics Working Group

2.2.1 **Review relevant information on stock structure.**

Genetics Workgroup Appointed Participants: Demian Chapman (Mote Marine Laboratory & Aquarium), Mahmood Shivji (Nova Southeastern University), Derek Kraft (NOAA Fisheries), David Portnoy (Texas A & M University).

Literature and Data Review and Evaluation: The genetics working group reviewed published literature relevant to the genetic population structure of four species of hammerhead sharks in U.S. Atlantic, U.S. Gulf of Mexico and U.S. Caribbean jurisdictions during a Zoom videoconference and via email. They also discussed some unpublished data that were relevant.

Working documents that were reviewed by the workgroup included the following publications and theses (in chronological order by publication date):

- Duncan, K.M., Martin, A.P., Bowen, B.W. and De Couet, H.G., 2006. Global phylogeography of the scalloped hammerhead shark (*Sphyrna lewini*). Molecular ecology, 15(8), pp.2239-2251.
- Chapman, D.D., Pinhal, D. and Shivji, M.S., 2009. Tracking the fin trade: genetic stock identification in western Atlantic scalloped hammerhead sharks *Sphyrna lewini*. Endangered Species Research, 9(3), pp.221-228.
- Pinhal, D., Shivji, M.S., Vallinoto, M., Chapman, D.D., Gadig, O.B.F. and Martins, C., 2012. Cryptic hammerhead shark lineage occurrence in the western South Atlantic revealed by DNA analysis. Marine Biology, 159(4), pp.829-836.
- Daly-Engel, T.S., Seraphin, K.D., Holland, K.N., Coffey, J.P., Nance, H.A., Toonen, R.J. and Bowen, B.W., 2012. Global phylogeography with mixed-marker analysis reveals male-mediated dispersal in the endangered scalloped hammerhead shark (*Sphyrna lewini*). PLoS One, 7(1), p.e29986.
- Testerman, C.B., 2014. Molecular Ecology of Globally Distributed Sharks. Doctoral dissertation. Nova Southeastern University. Retrieved from NSUWorks, Oceanographic Center. https://nsuworks.nova.edu/occ_stuetd/6.
- Barker, A.M., Adams, D.H., Driggers III, W.B., Frazier, B.S. and Portnoy, D.S., 2019. Hybridization between sympatric hammerhead sharks in the western North Atlantic Ocean. Biology letters, 15(4), p.20190004.
- Pinhal, D., Domingues, R.R., Bruels, C.C., Ferrette, B.L., Gadig, O.B., Shivji, M.S. and Martins, C., 2020. Restricted connectivity and population genetic fragility in a globally endangered Hammerhead Shark. Reviews in Fish Biology and Fisheries, 30, pp.501-517.
- Barker, A.M., Frazier, B.S., Adams, D.H., Bedore, C.N., Belcher, C.N., Driggers III, W.B., Galloway, A.S., Gelsleichter, J., Grubbs, R.D., Reyier, E.A. and Portnoy, D.S., 2021. Distribution and relative abundance of scalloped (*Sphyrna lewini*) and Carolina (*S. gilberti*) hammerheads in the western North Atlantic Ocean. Fisheries Research, 242, p.106039.

2.2.2 **Smooth Hammerhead (*Sphyrna zygaena*)**

There are no population genetic studies of Smooth Hammerhead sharks testing for differentiation between locations within U.S. jurisdictions. This species exhibits an anti-tropical distribution in the Atlantic and the species core U.S. distribution appears to be at higher latitudes in the U.S. Atlantic with rare records in the Gulf of Mexico and the U.S. Caribbean (Rigby, C.L. *et al*. 2019. *Sphyrna zygaena*. The IUCN Red List of Threatened Species 2019: e.T39388A2921825. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T39388A2921825.en). The U.S. Atlantic population is differentiated from populations in the Southwest Atlantic based on complete mt control region sequences (U.S. Atlantic (n=21) and Southwest Atlantic (Brazil, n=55; pairwise Φ_{ST} = 0.1116, $P < 0.0001$) but not microsatellites (Testerman 2014).

Recommendation: The working group recommends assessing Smooth Hammerheads as one stock in the U.S. Atlantic (core U.S. range) and U.S. Gulf of Mexico. We caution that no sampling or analyses included U.S. Caribbean jurisdictions (Puerto Rico and U.S. Virgin Islands). We also recommend sampling efforts to determine if Smooth Hammerheads occur in the U.S. Caribbean jurisdictions and, if so, determine whether or not they are genetically differentiated from the core U.S. Atlantic population.

2.2.3**Great Hammerhead (*Sphyrna mokarran*)**

A large sample of mostly large juvenile and adult Great Hammerheads from the U.S. Atlantic, U.S. Gulf of Mexico, Bahamas, and Belize has been tested with multiple genetic markers (mitochondrial control region, microsatellites, and SNPs) by Nova Southeastern University and Texas A & M University. There was no significant differentiation observed in any comparison (Testerman 2014;, 3,873 SNP-containing loci in examined in a U.S. Atlantic sample [N=24] and U.S. Gulf of Mexico sample [N=218] exhibited non-significant F_{ST} [0.0003, P=0.1568]).

Recommendation: The working group recommends assessing Great Hammerheads as one stock in the U.S. Atlantic, U.S. Gulf of Mexico and broader Caribbean region, although we caution that no sampling or analyses included U.S. Caribbean jurisdictions. We recommend sampling and genetic analyses from the U.S. Caribbean jurisdictions. We also recommend sampling and genetic analysis of young-of-the year and small juvenile (< 110 cm total length) individuals because the current sample is dominated by individuals in the mobile phase of their life-cycle, which could mask structure based on reproductive philopatry.

2.2.4 **Carolina Hammerhead (*Sphyrna gilberti*)**

The Carolina Hammerhead occurs in sympatry with its morphologically indistinguishable sister species the Scalloped Hammerhead in the U.S. Atlantic, with a core distribution around Bulls Bay, South Carolina (Barker et al. 2021). Carolina Hammerheads made up 27% of a mixed species sample of these two species in the U.S. Atlantic but was not recorded in a sample from the Gulf of Mexico (Barker et al. 2021). The species has also been recorded in the Caribbean (Trinidad and Tobago, Portnoy unpublished data) and Southwest Atlantic (Brazil; Pinhal et al. 2012) but these specimens have not been genetically compared to U.S. specimens. The species has not yet been recorded in U.S. Caribbean jurisdictions.

Recommendation: The working group recommends assessing Carolina Hammerheads as one stock in the U.S. Atlantic (core U.S. range). We caution that no sampling or analyses included U.S. Caribbean jurisdictions. We recommend sampling efforts to determine if Carolina Hammerheads occur in the U.S. Caribbean jurisdictions and, if so, determine whether or not they are genetically differentiated from the core U.S. Atlantic population.

2.2.5 **Scalloped Hammerhead (*Sphyrna lewini*)**

A large sample of Scalloped Hammerheads from the U.S. Atlantic, U.S. Gulf of Mexico, Belize and Brazil has been tested with multiple genetic markers (mitochondrial control region and 10 microsatellites [N=308], or SNPs [N=679]) (Duncan et al. 2006, Chapman et al. 2009, Daly-Engel et al. 2012, Pinhal et al. 2020, Portnoy unpublished data). Mitochondrial control region sequences and 10 microsatellite loci separate at least three differentiated stocks across this range, with the U.S. Atlantic and U.S. Gulf of Mexico forming one stock and Belize and Brazil each comprising separate stocks with unclear boundaries due to a lack of samples from elsewhere (Chapman et al. 2009, Pinhal et al. 2020; mitochondrial control $\Phi_{ST} = 0.60$; $P < 0.001$, microsatellites: D_{EST} 0.0794, $P < 0.001$). Daly-Engel et al. 2012 recorded differentiation between Scalloped Hammerhead samples from the U.S. Atlantic (N= 29) and U.S. Gulf of Mexico (N=43) using 13 microsatellite loci ($F_{ST} = 0.07$, $P < 0.001$) but subsequent SNP analyses with a larger sample size (N= 679), more markers (4,415 SNP-containing loci) and after filtering out within-sample siblings, found no evidence of population differentiation ($F_{ST} = 0.0000$, $P = 0.5144$).

Recommendation: The working group recommends assessing Scalloped Hammerheads as one stock in the U.S. Atlantic and U.S. Gulf of Mexico. We cautiously recommend assessing Scalloped Hammerheads in U.S. Caribbean jurisdictions separately. Although a sample exists from Puerto Rico (N=7 individuals) it has not yet been analyzed. The Scalloped Hammerheads in the Western Caribbean (Belize) are differentiated from U.S. Atlantic and U.S. Gulf of Mexico and we think the same is likely to be true for Eastern Caribbean populations. We recommend genetic analyses of U.S. Caribbean Scalloped Hammerheads as a matter of urgency given that the Central & Southwest Atlantic Distinct Population Segment (DPS) of this species is listed under the Endangered Species Act (https://www.federalregister.gov/documents/2014/07/03/2014-15710/endangered-and-threatened-wildlife-and-plants-threatened-and-endangered-status-for-distinct).
The working group also recommends that if the Scalloped and Carolina hammerheads cannot be separately assessed that they should be assessed as a complex, recognizing that catches of the complex in the U.S. Atlantic are more likely to contain both species than catches of the complex in the U.S. Gulf of Mexico (which will be comprised solely or primarily of scalloped hammerheads). This could entail managing the Scalloped hammerhead/Carolina hammerhead as a complex in the U.S. Atlantic and the Scalloped hammerhead in the U.S. Gulf of Mexico.

2.3 Spatial-Movements and Catches Working Group

. Introduction

2.3.1 **Workshop Time And Place**
The SEDAR 77 HMS Atlantic Hammerhead Stock ID Process was conducted via a series of webinars, including a Data Scoping webinar (May 26, 2021) and two Stock ID webinars (July 20, 2021; August 10, 2021).

2.3.2 **Terms Of Reference**

Process Goal: Review hammerhead shark species stock structure and unit stock definitions, and consider appropriate stock definitions. The Spatial-Movements Working Group was responsible for evaluating the spatial distribution in the South Atlantic and Gulf of Mexico, and to evaluate any studies that indicated movement across the proposed boundary.

1. Review relevant information on stock structure for all *Sphyrna* species located in the U.S. Atlantic, Gulf of Mexico, and Caribbean Sea, with the exception of *S. tiburo*, *S. tudes*, and *S. media.* Potential data sources include genetic studies, growth patterns, movement and migration, existing stock definitions, vertebral chemistry, oceanographic and habitat characteristics, and hotspot maps of landings or catch per unit effort (CPUE).

2. Make recommendations on biological stock structure and the assessment unit stock or stocks to be addressed through SEDAR 77, and document the rationale behind the recommendations. The boundaries for the species assessments will be determined after examination of the current stock boundaries used in management and conservation under the ESA and additional analysis of biological and genetic stock structure.

3. Discuss the strength of evidence in support of stock ID recommendations with particular attention paid to recommendations if they result in a mismatch of biological stock structure, assessment unit stock, and existing management or conservation boundaries.

4. Provide recommendations for future research on stock structure.

5. Prepare a report providing complete documentation of workshop recommendations and decisions.

2.3.3 **Spatial Working Group Participants**

Panelists	**Affiliation**
Andrea Kroetz (Co-Chair, Movements/Satellite tagging)	CIMAS/SEFSC Panama City
Eric Hoffmayer (Co-Chair, Movements/Satellite tagging)	SEFSC Pascagoula
Cami McCandless (Co-Chair, Movements/Conventional tagging)	NEFSC Narragansett
Enric Cortes (Co-Chair, Catches)	SEFSC Panama City
Heather Baertlein	ECS/HMS
Marcus Drymon	Mississippi State University
R. Dean Grubbs	Florida State University
Neil Hammerschlag	University of Miami
Cliff Hutt	HMS
Adam Pollack	SEFSC Pascagoula
David Wells	Texas A&M Galveston
Bradley Wetherbee	University of Rhode Island

Contributors	**Affiliation**
Kesley Banks	Texas A&M Corpus Christi
Jayne Gardiner	New College
Juan Carlos Pérez Jiménez	El Colegio de la Frontera Sur
Gregory Stunz	Texas A&M Corpus Christi

2.3.4 **Spatial Movements And Catches Working Papers And Reference Documents**

Document #	**Title**	**Authors**
Spatial Working Documents Prepared for the Stock ID Workshop (SID)		
SEDAR77-SID01	Regional movements of great, *Sphyrna mokarran*, and scalloped, *Sphyrna lewini*, hammerhead sharks in the US Atlantic, Gulf of Mexico and the Bahamas: preliminary results	V Heim, RD Grubbs, B Frazier, MJ Smukall, and TL Guttridge
SEDAR77-SID02	Catches of hammerhead sharks from the Congressional Supplemental Sampling Program (CSSP) in the northern Gulf of Mexico	AG Pollack and DS Hanisko
SEDAR77-SID03	Supplementary Material: Regional movements of great, *Sphyrna mokarran*, and scalloped, *Sphyrna lewini*, hammerhead sharks in the US Atlantic,Gulf of Mexico and the Bahamas preliminary results	V Heim, RD Grubbs, B Frazier, MJ Smukall, and TL Guttridge
SEDAR77-SID04	Tag and recapture data for great hammerhead, *Sphyrna mokarran*, and scalloped hammerhead, *Sphyrna lewini*, sharks caught in the western Gulf of Mexico from 2014-2021	KG Banks, and G W Stunz
SEDAR77-SID05	Residency and movements of juvenile great hammerheads, *Sphyrna mokarran*, in the Tampa Bay area preliminary results	JM Gardiner, TR Wiley, SK Lowerre-Barbieri, K Bassos-Hull, and K Wilkinson
SEDAR77-SID06	Some large hammerhead shark information based on shark fin business knowledge from the mid-1980’s through to September 1997	R Hudson
SEDAR77-SID07	Report on spatial movements of great and scalloped hammerhead sharks in the US Atlantic and Gulf of Mexico using satellite tags	N Hammerschlag

Spatial Reference Documents (RD)		
SEDAR77-RD01	Movement, behavior, and habitat use of a marine apex predator, the scalloped hammerhead	RJD Wells, TC TinHan, MA Dance, JM Drymon, B Falterman, MJ Ajemian, GW Stunz, JA Mohan, ER Hoffmayer, WB Driggers III and JA McKinney
SEDAR77-RD02	First verified record of the smooth hammerhead (*Sphyrna zygaena*) in coastal waters of the northern Gulf of Mexico with a review of their occurrence in the western North Atlantic Ocean	BM Deacy, HE Moncrief-Cox, and JK Carlson
SEDAR77-RD03	Use of marine protected areas and exclusive economic zones in the subtropical western North Atlantic Ocean by large highly mobile sharks	F Graham, P Rynne, M Estevanez, J Luo, JS Ault1 and N Hammerschlag
SEDAR77-RD04	Overlap between highly suitable habitats and longline gear management areas reveals vulnerable and protected regions for highly migratory sharks	H Calich, M Estevanez, and N Hammerschlag
SEDAR77-RD05	Regional-scale variability in the movement ecology of marine fishes revealed by an integrative acoustic tracking network	C Friess, SK Lowerre-Barbieri, GR Poulakis, N Hammerschlag, JM Gardiner, AM Kroetz, K Bassos-Hull, et al.
SEDAR77-RD08	Seasonal movements and habitat use of juvenile smooth hammerhead sharks in the western North Atlantic Ocean and significance for management	RK Logan, JJ Vaudo, LL Sousa, M Sampson, B M Wetherbee and MS Shivji
SEDAR77-RD13	Identification of young-of-the-year great hammerhead shark *Sphyrna mokarran* in northern Florida and South Carolina	AM Barker, BS Frazier, DM Bethea, JR Gold, and DS Portnoy

SEDAR77-RD16	Philopatry and regional connectivity of the great hammerhead shark in the US and Bahamas	TL Guttridge, MPM Van Zinnicq Bergmann, C Bolte, LA Howey, JS Finger, ST Kessel, JL Brooks, W Winram, ME Bond, LKB Jordan, RC Cashman, ER Tolentino, RD Grubbs and SH Gruber
SEDAR77-RD17	Potential distribution of critically endangered hammerhead sharks and overlap with the small-scale fishing fleet in the southern Gulf of Mexico	MY Chi Chan, O Sosa-Nishizaki, JC Pérez-Jiménez
SEDAR77-RD20	Double tagging clarifies post-release fate of great hammerheads	JM Drymon and RJD Wells
SEDAR77-RD21	Defining sex-specific habitat suitability for a northern Gulf of Mexico shark assemblage	JM Drymon, S Dedman, JT Froeschke, EA Seubert, AE Jefferson, AM Kroetz, JF Mareska, and SP Powers
SEDAR77-RD22	Distribution and relative abundance of scalloped (*Sphyrna lewini*) and Carolina (*S. gilberti*) hammerheads in the western North Atlantic Ocean	AM Barker BS Frazier, DH Adams, CN Bedore, CN Belcher, WB Driggers III, AS Galloway, J Gelsleichter, RD Grubbs, EA Reyier, DS Portnoy
SEDAR77-RD23	Distributions and movements of Atlantic shark species: A 52-year retrospective atlas of mark and recapture data	NE Kohler and PA Turner
SEDAR77-RD24	First identification of probable nursery habitat for critically endangered great hammerhead *Sphyrna mokarran* on the Atlantic Coast of the United States	C Macdonald, J Jerome, C Pankow, N Perni, K Black, D Shiffman, J Wester
SEDAR77-RD25	Characterization of a scalloped hammerhead (*Sphyrna lewini*) nursery habitat in portions of the Atlantic Intracoastal Waterway	BN Wargat

2.3.5 **Literature And Data Evaluation**

The Spatial-Movements Working Group reviewed 22 relevant working papers and reference documents that described movements and distributions of great (*Sphyrna mokarran*), scalloped (*S. lewini*), Carolina (*S. gilberti*), and smooth (*S. zygaena*) hammerheads. Extensive review of the literature was conducted to locate information regarding movements from satellite, acoustic, and mark-recapture tagging. Limited information was available for all species. A recommendation for stock boundary based on these documents is provided.

SEDAR77-SID01 and SEDAR77-SID03 (supplementary to SID01)
Titles: Regional movements of great, *Sphyrna mokarran*, and scalloped, *Sphyrna lewini*, hammerhead sharks in the US Atlantic; Gulf of Mexico and the Bahamas: preliminary results
Synopsis: In this study, 15 great hammerhead (*Sphyrna mokarran*) and 10 scalloped hammerhead (*Sphyrna lewini*) sharks were tagged with fin-mounted Smart Position and Temperature tags (SPOT, Wildlife Computers) between January 2019 and June 2021 to track their large-scale movements. Tagging efforts were in the Bahamas (Bimini and Andros Island), Florida Keys (FL, USA), South Carolina (USA), and Tampa (FL, USA) and the estimated battery duration ranged from 171 to 300 days. Fourteen great hammerheads generated data and days at liberty ranged from 37 to 286 days. The sharks showed a high degree of individual variation in their regional movements and migrations. While some sharks migrated up and down the US Atlantic coast, others swam into the Gulf of Mexico, and two males tagged in the Bahamas predominantly spent time in the Bahamas EEZ. Eight scalloped hammerheads generated regional movement data and days at liberty ranged from 10 to 404 days. Individual sharks tagged in South Carolina showed relatively similar movement patterns spatially and timing-wise with movement further north during the summer months and movements back down south towards South Carolina in autumn. One female that was pregnant at the time of capture showed a large-scale movement from the Florida Keys to Louisiana, back to the Florida Keys and then north along the US Atlantic coast to South Carolina. This study provides useful data on the large-scale movements of both great and scalloped hammerheads, although the sample sizes are small and these data are preliminary. These data indicate exchange between the Gulf of Mexico and Atlantic in both species.

SEDAR77-SID02
Title: Catches of hammerhead sharks from the Congressional Supplemental Sampling Program (CSSP) in the northern Gulf of Mexico
Synopsis: The Congressional Supplemental Sampling Program (CSSP), also referred to as Expanded Annual Stock Assessment (EASA) program in previous SEDAR documents, was a single year, highly extensive survey that sampled the northern Gulf of Mexico (GOM). The CSSP was intended to provide additional information on key fisheries in the GOM, create a truly synoptic survey, increase precision of relative abundance estimates, and to evaluate selectivity issues between gears and hook sizes. Four longline and two vertical line vessels simultaneously fished randomly selected sites in the northern GOM from April 7 – October 25, 2011. For this document, all stations from the CSSP, along with the catches of great hammerhead (*Sphyrna mokarran*) and scalloped hammerhead (*Sphyrna lewini*) were extracted from the Mississippi Laboratories Oracle Database. Overall, 1,172 bottom longline stations were sampled from April through October. Scalloped

hammerheads were more prevalent in the sampling than great hammerheads, with 140 and 24 individuals being captured, respectively. Higher catches of great hammerheads occurred off the Texas and Louisiana coastlines whereas scalloped hammerheads had higher catches offshore of Texas, Louisiana, Mississippi, and Alabama. Although for only one year (2011), these data are useful in showing distribution for great and scalloped hammerheads throughout the Gulf of Mexico.

SEDAR77-SID04
Title: Tag and recapture data for great hammerhead, *Sphyrna mokarran*, and scalloped hammerhead, *Sphyrna lewini*, sharks caught in the western Gulf of Mexico from 2014-2021.
Synopsis: In partnership with the Center for Sportfish Science and Conservation, anglers participating in the Texas Shark Rodeo (TSR) target sharks from shore using large reels and baits. The anglers practice catch-photo-release with an "emphasis on tagging and collecting data for the conservation of sharks". From 2014 - June 2021, 46 great hammerheads and 39 scalloped hammerheads were tagged and released. Of the 46 great hammerhead sharks tagged, there were three reported recaptured, one of which was recaptured twice within a month. Of the 39 scalloped tagged, two recaptures were reported. All movements were considered short distance (4 out of 5 sharks moved >85 km), except for one scalloped hammerhead that was recaptured and landed in Carbajal, Mexico (~400 km).

SEDAR77-SID05
Title: Residency and movements of juvenile great hammerheads, *Sphyrna mokarran*, in the Tampa Bay area preliminary results
Synopsis: This pilot study was carried out to examine the spatiotemporal patterns of habitat use in the Tampa Bay estuary by juvenile great hammerheads (*Sphyrna mokarran*). Four juveniles captured via longline gear were tagged with surgically-implanted acoustic transmitters (V16-4L and V9-2L, Innovasea), two in 2019 and two in 2020. Upon release, their movements within the Tampa Bay and Sarasota Bay areas were tracked by arrays of passive acoustic receivers maintained by the authors. Detection data from receivers in other areas were obtained via collaborative telemetry networks, Integrated Tracking of Aquatic Animals in the Gulf of Mexico (iTAG) and the FACT Network. Detection data are current through spring (May/June) 2021 for the New College of Florida/Havenworth Coastal Conservation and Sarasota Coast Acoustic Network arrays and through summer 2020 for the Florida Fish and Wildlife Conservation Commission arrays. Detection data were filtered to remove false detections and residency indices at the regional (Tampa Bay, Sarasota Bay, Gulf of Mexico) level were computed. All four great hammerheads displayed residency in Tampa Bay. The smallest individual, a 1.3m male, also exhibited residency in Sarasota Bay. All individuals were seasonally present in the Tampa Bay estuary (or Sarasota Bay estuary) during spring/summer and moved out into the Gulf of Mexico during late fall to winter, returning inshore in spring. Movement maps indicate that the smallest individual was detected primarily in inshore areas, while larger individuals were detected in deeper offshore areas, with the largest individual venturing the furthest from Tampa Bay. All four individual great hammerheads were found to use the Tampa Bay estuary for extended periods and to return to the same areas across multiple years. These data are preliminary, as tags are still active and data for movements within and outside the Tampa Bay area continue to be received as arrays are downloaded, but they provide further evidence of a potential nursery area in lower Tampa Bay.

SEDAR77-SID06
Title: Some large hammerhead shark information based on shark fin business knowledge from the mid-1980's through to September 1997
Synopsis: Rusty Hudson provided a summary of hammerhead shark information on catch composition and identification he gained from buying, and/or selling shark fins from various commercial fishing fleets located from New York to Texas during the mid-1980's through 1997. With respect to catches he reports that the frequency of encounter for primary shark fins was greatest for the scalloped hammerhead, followed by the great hammerhead, though the weight of the set of primary shark fins for the great hammerhead are much larger than any other adult hammerhead. Additionally, the smooth hammerhead was third by number with catch generally coming from commercial shark fishing fleets of different sorts between NC and Florida east coasts, and adult catch coming from offshore where the pelagic longline fleets operated off the US east coast. He also reports rare encounters with Carolina hammerhead fins that he thinks were from sharks caught offshore.

SEDAR77-SID07
Title: Report on spatial movements of great and scalloped hammerhead sharks in the US Atlantic and Gulf of Mexico using satellite tags
Synopsis: This report plots SPOT tag movement data on great and scalloped hammerheads showing movement between the Gulf of Mexico and Atlantic. These plots were not shown in the publications associated with this work, which are included as reference documents for this Stock ID Workshop (SEDAR77-RD03 and SEDAR77-RD04).

SEDAR77-RD01
Title: Movement, behavior, and habitat use of a marine apex predator, the scalloped hammerhead
Synopsis: The goal of this study was to better understand the movement dynamics of this species in the Gulf of Mexico. The scalloped hammerhead (Sphyrna lewini) was the first shark species to be protected under the U.S. Endangered Species Act and has life history characteristics that make this species particularly at risk for local depletion. A total of 33 scalloped hammerheads were tagged with fin mounted smart position and temperature transmitting (SPOT) tags and tracked for an average of 146 days (ranging from 5 to 479 days) to examine horizontal movements and quantify space use. Scalloped hammerheads showed a wide range of movements throughout the Gulf of Mexico continental shelf with limited long-distance dispersal. No individuals left the Gulf of Mexico. Habitat suitability for scalloped hammerheads was predicted to be high on the mid to outer continental shelf inside the 200 m isobath. Findings from this study provide important information on movement of this species in the Gulf of Mexico and highlight their restricted use of continental shelf habitat and resident behavior that will need to be incorporated in future stock assessments and extinction risk analyses.

SEDAR77-RD02
Title: First verified record of the smooth hammerhead (*Sphyrna zygaena*) in coastal waters of the northern Gulf of Mexico with a review of their occurrence in the western North Atlantic Ocean
Synopsis: This study documents a confirmed record of smooth hammerhead (*Sphyrna zygaena*) in the northern Gulf of Mexico. Smooth hammerheads are considered a wide-ranging species, though its distribution throughout its range is not well known. The occurrence of this species in the northern Gulf of Mexico is largely unknown, with only limited unverified records in this region. In

September of 2017, a smooth hammerhead was collected from Florida coastal waters in the northern Gulf of Mexico, representing a confirmed record of this species in this region. To further understand the range of smooth hammerhead, available occurrence data throughout the western North Atlantic Ocean was reviewed. At-sea observer data from 1996–2018 in the pelagic longline fishery that targets swordfish *(Xiphias gladius)* and tuna (*Thunnus* sp.) contained 8 records of smooth hammerheads in deep offshore waters, mostly in the southern Gulf of Mexico. Additionally, data collected by observers from the commercial shark bottom longline fishery since 1994 reported 6 smooth hammerhead captures in the Straits of Florida. In the western North Atlantic Ocean, the smooth hammerheads' distribution is not well known. A review of available records showed that sightings are limited, and available data comes generally from commercial fishery catch data, recreational fishing reports, historical reports, and reports through citizen science organizations. The majority of these records occurred in the deep offshore waters beyond the continental shelf, and there appears to be a trend of habitat usage that suggests this species tends to occur in offshore pelagic waters along the continental shelf. The occurrences from observer data in the Gulf of Mexico suggest this species may follow the deep waters of the shelf in this region as well. Given the highly migratory nature of other closely related hammerhead shark species, these reports could suggest that the Smooth Hammerhead migrates along the edge of the continental shelf off the east coast of the United States and into the Gulf of Mexico and occasionally ventures into coastal waters. These few records are helpful in adding to the current knowledge of this species' range.

SEDAR77-RD03
Title: Use of marine protected areas and exclusive economic zones in the subtropical western North Atlantic Ocean by large highly mobile sharks.
Synopsis: To fill in knowledge gaps on the effectiveness of marine protected areas (MPA) to large shark species, bull, great hammerhead, and tiger sharks were satellite tagged to examine core habitat use areas in relation to established MPAs in the western North Atlantic Ocean. Eighteen great hammerhead sharks were tagged with smart position and temperature transmitting (SPOT) tags from 2010-2013 and tracked for 2 to 154 days with a total of 833 tracking days. The core habitat use area (85,061 km^2) for great hammerheads was primarily in the south Florida region encompassing both the Gulf of Mexico and South Atlantic Bight. Only 27% of the great hammerhead core use area was found to be protected from exploitation. The authors only presented a single representative track for great hammerheads, so it is not clear how many individuals moved to and from the Gulf of Mexico and South Atlantic Bight.

SEDAR77-RD04
Title: Overlap between highly suitable habitats and longline gear management areas reveals vulnerable and protected regions for highly migratory sharks
Synopsis: Maximum entropy habitat suitability models were developed for great hammerhead sharks *Sphyrna mokarran*, tiger sharks *Galeocerdo cuvier*, and bull sharks *Carcharhinus leucas* within the southeast region based on satellite tag (n = 96) and remotely sensed environmental data for comparison to longline gear management areas. Using data from 23 great hammerheads, habitat with the greatest probability of presence in the southeast region of the US EEZ from May-October was located in the Gulf of Mexico in the coastal waters from off Port Aransas, Texas down to the Mexican border, southwest of the Mississippi River Delta in Louisiana, southwest of Cape San Blas and around the Dry Tortugas and western Keys in Florida, and in the Atlantic off Florida around the Keys and throughout the continental shelf, but only offshore at the shelf edge off the northern part of the state. During November through April, habitat with the greatest probability of great hammerhead

presence in the southeast region of the US EEZ was off Florida in the Gulf of Mexico around the Keys, Dry Tortugas, and further west near this longitude. In the Atlantic, likelihood of greatest presence was found around the Keys and out along the shelf edge and slope up the coast from Florida through Georgia.

SEDAR77-RD05
Title: Regional-scale variability in the movement ecology of marine fishes revealed by an integrative acoustic tracking network
Synopsis: The goal of this study was to evaluate how an integrative acoustic telemetry tracking approach can provide multi-species movement data to improve our understanding of movement ecology and ecosystem processes, with a specific focus on the seasonal movements of predators off the west coast of Florida (WCF), USA. Three years of data (2016–2018) for 29 species (889 transmitters), ranging from large top predators to small consumers, from 21 acoustic telemetry arrays within the iTAG network in the eastern Gulf of Mexico were analyzed. Included in this synthesis were five great hammerheads (*Sphyrna mokarran*; 50 detection days). For analysis purposes, great hammerheads were grouped with tiger (*Galeocerdo cuvier*), lemon (*Negaprion brevirostris*), and sandbar (*Carcharhinus plumbeus*) sharks due to limited data on each species and similarities in life history, movement ecology, and shared taxonomy. Data indicated that great hammerheads exhibited northbound movements in spring and were southbound during the fall and were characterized as low-detection, long distance movers.

SEDAR77-RD08
Title: Seasonal movements and habitat use of juvenile smooth hammerhead sharks in the western North Atlantic Ocean and significance for management
Synopsis: This study used fin-mounted satellite tags to examine the movements and habitat use of juvenile smooth hammerheads, *Sphyrna zygaena*, a demographic segment particularly threatened by exploitation. Six sharks were tagged off the US mid-Atlantic region and tracked for 49–441 days (mean 187 ±136 days). Sharks consistently showed area-restricted movements within a summer core area in waters of the New York Bight and a winter core area off Cape Hatteras, North Carolina, with directed movements between those areas in autumn. There was high overlap of shark winter core area use and the Mid-Atlantic Shark Area (MASA) – a 7 month per year, bottom-longline fishery closure indicating that this area closure offers seasonal reduction in fishing pressure for this species. Generalized additive mixed models revealed that area-restricted movements of sharks in their summer and winter core areas coincided with high primary productivity, and elevated sea surface temperature. Consistency in use of summer and winter core areas suggests that the coastal waters of the New York Bight and Cape Hatteras, North Carolina could be considered for Essential Fish Habitat designation for this species. This study reveals the first high-resolution movements and habitat use for smooth hammerheads in the western North Atlantic to inform management planning for this population.

SEDAR77-RD13
Title: Identification of young-of-the-year great hammerhead shark *Sphyrna mokarran* in northern

Florida and South Carolina
Synopsis: Two sharks, visually identified in the field as young-of-the-year (YOY) scalloped hammerhead *Sphyrna lewin*i, were identified as great hammerhead *Sphyrna mokarran* based on nuclear-encoded single nucleotide polymorphisms (SNP) and sequences of mtDNA. Individuals were captured and released in Bulls Bay, SC, and Saint Joseph Bay, FL, in 2013 and 2014, respectively. The observation of two *S. mokarran* neonates in nearshore habitat of South Carolina and the northern Gulf of Mexico coast of Florida indicates that *S. mokarran* may use nursery habitat further north and further inshore than known previously.

SEDAR77-RD16
Title: Philopatry and regional connectivity of the great hammerhead shark, *Sphyrna mokarran* in the U.S. and Bahamas
Synopsis: Biotelemetry techniques (acoustic and satellite), conventional tagging, laser-photogrammetry, and photo-identification were used to investigate the level of site fidelity/residency for great hammerheads to coastal areas in the Bahamas and U.S., and the extent of movements and connectivity of great hammerheads between the U.S. and Bahamas. Results revealed large-scale return migrations (3030 km), seasonal residency to local areas (some for 5 months), site fidelity (annual return to Bimini and Jupiter for many individuals) and numerous international movements. Regional movements were shown between Jupiter, Florida and off Grand Bahama, Andros, and South Carolina. Additionally movements occurred between Bimini and Jupiter, off Grand Bahama, Georgia and South Carolina, and the slope waters off Virginia.

SEDAR77-RD17
Title: Potential distribution of critically endangered hammerhead sharks and overlap with the small-scale fishing fleet in the southern Gulf of Mexico
Synopsis: Ecological niche models were used to estimate the distribution of bonnethead, great, and scalloped hammerhead sharks within the Gulf of Mexico and determine their overlap with the small-scale fishing fleet based out of the San Francisco de Campeche port. Areas with a relatively high environmental suitability for the bonnethead shark were located in coastal areas <30 m depth. Scalloped hammerhead areas with a relatively high environmental suitability were located on the continental shelf from >10 m up to the 200 m isobath. Great hammerhead's potential distribution within the GOM was generally observed throughout the continental shelf with highest environmental suitability predicted in coastal and intermediate areas < 30 m depth.

SEDAR77-RD20
Title: Double tagging clarifies post-release fate of great hammerheads
Synopsis: This study used a combination of tags to examine horizontal movements and verify post-release fate of great hammerheads in the northern Gulf of Mexico. Three individuals (one male and two females) were equipped with both fin-mounted smart position and temperature transmitting (SPOT) tags and survivorship pop-off archival tags (sPAT). Tagged sharks measured 187 (F), 203 (M), and 250 (M) cm total length. A single fin-mounted SPOT tag, attached to the smallest of the three sharks, reported position estimates over an 81-day period and moved a straight-line distance of approximately 400 km; however, the other two fin-mounted SPOT tags failed to generate position estimates. All three sPAT tags indicated post-release survival. Final positions of the sPAT tags from the two largest sharks suggested restricted horizontal movements (< 35 km).

SEDAR77-RD21

Title: Defining sex-specific habitat suitability for a northern Gulf of Mexico shark assemblage
Synopsis: The authors used survey catch data and a suite of environmental variables to predict habitat suitability for small coastal, large coastal, and shelf associated sharks. Scalloped hammerheads were the most abundant shelf-associated species; males were encountered across a wider range of sizes than females. Males and females were encountered broadly across the continental shelf. Females were much less common than males (0.36:1. Female scalloped hammerhead abundance was influenced by distance from shore, depth, and bottom salinity, with little seasonal variation. Female scalloped hammerheads were encountered 75–85 km offshore, at depths between 50 and 100 m. Suitable habitat for female scalloped hammerheads was restricted to a small core area directly south of Mobile Bay, Alabama. Male scalloped hammerhead abundance was influenced by distance from shore, as well as bottom salinity and bottom velocity. Male scalloped hammerheads were encountered closer to shore (15–75 km offshore) relative to females, at depths between 25 and 100 m.

SEDAR77-RD22
Title: Distribution and relative abundance of scalloped (*Sphyrna lewini*) and Carolina (*S. gilberti*) hammerheads in the western North Atlantic Ocean
Synopsis: In this study, the distribution of Carolina hammerheads (*Sphyrna gilberti*) in waters of the United States off the east coast (U.S. Atlantic) and Gulf of Mexico (Gulf) was examined and their abundance relative to scalloped hammerheads (*S. lewini*) assessed by genetically identifying 1,231 individuals using diagnostic single nucleotide polymorphisms. Both species were found in the U.S. Atlantic, where 27 % of individuals were Carolina hammerheads, but only scalloped hammerheads were identified in the Gulf. In Bulls Bay, SC, a well-known hammerhead nursery, assessment of relative abundance from May to September showed scalloped hammerheads were more abundant May-June and Carolina hammerheads more abundant July-September. Results of this study suggest Carolina hammerheads have a spatially limited distribution in the western North Atlantic and highlight the importance of Bulls Bay as a nursery for the species. In addition, the results suggest Carolina hammerheads may comprise a non-trivial proportion of what is considered the U.S. Atlantic scalloped hammerhead stock and should be considered in future decisions regarding management of the hammerhead complex.

SEDAR77-RD23
Title: Distributions and movements of Atlantic shark species: A 52-year retrospective atlas of mark and recapture data
Synopsis: This document shows distribution and movement data obtained using mark and recapture data from NOAA Fisheries Cooperative Shark Tagging Program between 1962 and 2013 and includes data on three of the hammerhead species included in the Stock ID process for SEDAR 77. Tag and recapture data shows great hammerhead distribution throughout the shelf waters of the Gulf of Mexico and US Atlantic up off New Jersey. Winter distribution is constricted to shelf waters off Florida, primarily at the shelf edge, in the Atlantic and Gulf. Mark-recapture data for the great hammerhead shows no exchange between the Gulf and Atlantic, but does show exchange between the US and Mexican Gulf waters. Scalloped hammerhead distribution based on tag and recapture data also occurs throughout the shelf waters of the Gulf and US Atlantic up off New York. Winter distribution for scalloped hammerheads is primarily located along the shelf edge and only extends north off North Carolina in the US Atlantic. Mark-recapture data for scalloped hammerheads shows exchange between the US and Mexican Gulf and between the Gulf and the Atlantic. Smooth hammerhead distribution based on tag and recapture data only occurs in the US Atlantic excluding

the Gulf of Mexico. In the Atlantic, distribution extend from off Florida to southern New England with the majority of records north of North Carolina, similar to what is seen in the summer distribution. Fall smooth hammerhead distribution was only recorded from North Carolina and north. Winter had very few records (n=6) only located off Florida's east coast and spring only had records off North Carolina and south. Mark-recapture data only showed movements along the US east coast ranging from New Jersey to Florida.

SEDAR77-RD24
Title: First identification of probable nursery habitat for critically endangered great hammerhead *Sphyrna mokarran* on the Atlantic Coast of the United States
Synopsis: Identification of potential nursery habitat within Biscayne Bay near Miami, Florida. Small juveniles <100 cm total length (TL) were captured at this site between June 2018 and January 2020 TL. Species identification was confirmed through genetic analysis.

SEDAR77-RD25
Title: Characterization of a scalloped hammerhead (*Sphyrna lewini*) nursery habitat in portions of the Atlantic Intracoastal Waterway
Synopsis: The Tolomato River in northeastern Florida provides important nursery habitat for scalloped hammerhead sharks. Fishery-independent survey, mark-recapture, and acoustic tracking data show that this area within the Intracoastal Waterway hosts high consistent numbers of young-of-the-year scalloped hammerheads annually (2009-2019) for extended periods of time (May through August).

2.3.6 **Great Hammerhead**

Terms of Reference: The goal of the Stock ID workshop was to review great hammerhead stock structure and unit stock definitions, and consider appropriate stock definitions. The Spatial-Movements Working Group was responsible for evaluating the spatial distribution and movements in the Atlantic and Gulf of Mexico, and to evaluate any studies that indicated movement across the proposed boundary.

Selected portions of the Terms of Reference (TORs) specifically related to the spatial distribution of great hammerheads used by this group are as follows:

TOR 1. Review relevant information on stock structure. Potential data sources include … movement and migration, existing stock definitions, … and hotspot maps of landings or catch per unit effort (CPUE).

Response: All relevant information on stock structure of great hammerheads in relation to distributions, movements, and migrations were reviewed and discussed by the Spatial-Movements Workgroup.

TOR 2. The boundaries for the species assessments will be determined after examination of the current stock boundaries used in management and conservation under the ESA and additional analysis of biological and genetic stock structure.

Response: After reviewing the working papers and reference documents and discussions within the working group, the recommendation is to retain the HMS management boundary for the Gulf of Mexico and the Atlantic Ocean used to separate landings data, as there were no data reviewed during this workshop that suggest an alternate boundary should be used. This boundary starts at 25°20.4'N and extends due east out to the US EEZ boundary. Above the Miami-Dade line in the Keys is considered the Atlantic Ocean and below is the Gulf of Mexico.

TOR 3. Discuss the strength of evidence in support of stock ID recommendations with particular attention paid to recommendations if they result in a mismatch of biological stock structure, assessment unit stock, and existing management or conservation boundaries.

Response: The Spatial-Movement Workgroup agreed that great hammerheads comprise a single biological stock in the Atlantic Ocean and Gulf of Mexico and should be assessed as a single stock. Although conventional tag data (SEDAR77-RD23) did not show exchange between the Atlantic and Gulf, satellite telemetry data did verify the movement of individuals across the proposed boundary between regions (SEDAR77-SID01, SEDAR77-SID07).

TOR 4. Provide recommendations for future research on stock structure.

Response: Overall, the movement/migration data available for great hammerheads from the Gulf of Mexico and Atlantic Ocean is limited and the Spatial-Movement Workgroup recommends additional tagging (conventional, acoustic, and satellite) studies to better elucidate their movement patterns within the region.

TOR 5. Prepare a report providing complete documentation of workshop recommendations and decisions.

Response: This report satisfies this requirement.

Movement Summary: Great hammerheads are the largest of the hammerhead species and are widely distributed in warm temperate and tropical waters (Compagno 1984). They are considered highly migratory with the ability to move long distances over short periods of time (i.e. over 1,200 km in a 30-day period; Hammerschlag et al. 2011). Conventional tagging data shows that both sexes of this species are present in continental shelf waters throughout the Gulf of Mexico and U.S. Atlantic Ocean to up off New Jersey with winter distribution constricted to shelf and slope waters off Florida (SEDAR77-RD23, Figures 1 and 2). This distribution range is supported by additional working and reference documents reviewed during the Stock ID process for SEDAR 77. In 52-years of NOAA Fisheries Cooperative Shark Tagging Program, there were five recaptures showing exchange between the U.S. and Mexican Gulf of Mexico, but not between the Gulf of Mexico and Atlantic Ocean (SEDAR77-RD23; Figure 3). Similarly, though data are limited, satellite and acoustic telemetry studies reviewed also revealed localized movements within the Gulf of Mexico and the U.S. Atlantic Ocean. However, animals tagged in the Florida Keys have been shown to use either body of water and exchange between the Gulf of Mexico and Atlantic Ocean is evident (SEDAR77-SID01, SEDAR77-SID07, Figures 4, 5). These data are preliminary and tagging studies are ongoing.

Recommendation for Stock ID:

<u>Great hammerhead (*Sphyrna mokarran*):</u> Great hammerheads in the Gulf of Mexico and Atlantic

Ocean are a single biological stock and should be assessed as one management stock.

2.3.7 Smooth Hammerhead

Terms of Reference: The goal of the Stock ID workshop was to review smooth hammerhead stock structure and unit stock definitions, and consider appropriate stock definitions. The Spatial-Movements Working Group was responsible for evaluating the spatial distribution in the Atlantic and Gulf of Mexico, and to evaluate any studies that indicated movement across the proposed boundary.

Selected portions of the Terms of Reference (TORs) specifically related to the spatial distribution of smooth hammerheads used by this group are as follows:

TOR 1. Review relevant information on stock structure. Potential data sources include … movement and migration, existing stock definitions, … and hotspot maps of landings or catch per unit effort (CPUE).

Response: All relevant information on stock structure of smooth hammerheads in relation to distributions, movements, and migrations were reviewed and discussed by the Spatial-Movements workgroup.

TOR 2. The boundaries for the species assessments will be determined after examination of the current stock boundaries used in management and conservation under the ESA and additional analysis of biological and genetic stock structure.

Response: After reviewing the working papers and reference documents and discussions within the working group, the recommendation is to retain the HMS management boundary for the Gulf of Mexico and the Atlantic Ocean used to separate landings data, as there were no data reviewed during this workshop that suggest an alternate boundary should be used. This boundary starts at 25°20.4’N and extends due east out to the US EEZ boundary. Above the Miami-Dade line in the Keys is considered the Atlantic Ocean and below is the Gulf of Mexico.

TOR 3. Discuss the strength of evidence in support of stock ID recommendations with particular attention paid to recommendations if they result in a mismatch of biological stock structure, assessment unit stock, and existing management or conservation boundaries.

Response: The Spatial-Movement Workgroup agreed that smooth hammerheads comprise a single biological stock in the Atlantic Ocean and Gulf of Mexico and should be assessed as a single management stock. Although conventional tag data (SEDAR77-RD23) did not show any records in the Gulf of Mexico or any exchange between the Atlantic and Gulf, there are a few accounts of smooth hammerheads observed in the Gulf (SEDAR77-RD02). Regardless, they are a wide-ranging species with the ability to move long distances (> 6,600 km; Santos and Coelho, 2018) and it is not inconceivable that this species could occasionally enter the Gulf.

TOR 4. Provide recommendations for future research on stock structure.

Response: Overall, spatial data, especially with respect to movements and migrations, available for smooth hammerhead from the Gulf of Mexico and Atlantic Ocean is scant at best and the Spatial-Movement workgroup recommends additional tagging (conventional, acoustic, and satellite) studies to better elucidate their movement patterns within the region.

TOR 5. Prepare a report providing complete documentation of workshop recommendations and decisions.

Response: This report satisfies this requirement.

Movement Summary: The smooth hammerhead is a circumglobal, semi-pelagic species found in amphitemperate and tropical waters (Compagno, 1984). Conventional tagging data shows that both sexes of this species are present off the east coast of the U.S. in the Atlantic Ocean from off Florida to southern New England (SEDAR77-RD23, Figure 6). Seasonal distribution during the summer is similar to the overall distribution, but records were only present off North Carolina and further north in the fall, off North Carolina and further south in the spring, and there were limited records (n=6) during the winter located off Florida (SEDAR77-RD23, Figure 7). In 52-years of the NOAA Fisheries Cooperative Shark Tagging Program, there were seven recaptures and no exchange between the Gulf of Mexico and Atlantic Ocean (SEDAR77-RD23, Figure 8). To date, there is only a single satellite telemetry study where six tagged juvenile smooth hammerheads showed area restricted movements in the U.S. mid-Atlantic region; no individuals entered the Gulf of Mexico (SEDAR77-RD08, Figure 9). Given the known range of the smooth hammerhead extends south to the Caribbean Sea and beyond, there is no barrier keeping this species from entering the Gulf of Mexico (SEDAR77-RD02). Until recently, there were no reliable records for the Gulf of Mexico. A single individual smooth hammerhead was found dead in the shallow waters off the northeast Gulf of Mexico, and a dozen or so other observations from the NOAA NMFS Observer Program highlights their presence in this region (SEDAR77-RD08). Their occurrence in the Gulf of Mexico is not inconceivable as they are a wide-ranging species with the ability to move long distances (> 6,600 km; Santos and Coelho, 2018).

Recommendation for Stock ID:
Smooth hammerhead (*Sphyrna zygaena*): Smooth hammerheads are likely one biological stock in the Gulf of Mexico and Atlantic Ocean and should be assessed as one management stock.

2.3.8 **Scalloped Hammerhead**

Terms of Reference: The goal of the Stock ID workshop was to review scalloped hammerhead stock structure and unit stock definitions, and consider appropriate stock definitions. The Spatial-Movements Working Group was responsible for evaluating the spatial distribution in the South Atlantic and Gulf of Mexico, and to evaluate any studies that indicated movement across the proposed boundary.

Selected portions of the Terms of Reference (TORs) specifically related to the spatial distribution of scalloped hammerheads used by this group are as follows:

TOR 1. Review relevant information on stock structure. Potential data sources include … movement and migration, existing stock definitions, … and hotspot maps of landings or catch per unit effort (CPUE).

Response: All relevant information on stock structure of scalloped hammerheads in relation to distributions, movements, and migrations were reviewed and discussed by the Spatial-Movements workgroup.

TOR 2. The boundaries for the species assessments will be determined after examination of the current stock boundaries used in management and conservation under the ESA and additional analysis of biological and genetic stock structure.

Response: After reviewing the working papers and reference documents and discussions within the working group, the recommendation is to retain the HMS management boundary for the Gulf of Mexico and the Atlantic Ocean used to separate landings data, as there were no data reviewed during this workshop that suggest an alternate boundary should be used. This boundary starts at 25°20.4'N and extends due east out to the US EEZ boundary. Above the Miami-Dade line in the Keys is considered the Atlantic Ocean and below is the Gulf of Mexico.

TOR 3. Discuss the strength of evidence in support of stock ID recommendations with particular attention paid to recommendations if they result in a mismatch of biological stock structure, assessment unit stock, and existing management or conservation boundaries.

Response: The Spatial-Movement Workgroup agreed that scalloped hammerheads comprise a single biological stock in the Atlantic Ocean and Gulf of Mexico. Conventional tag data (SEDAR77-RD23) and satellite telemetry data (SEDAR77-SID01, SEDAR77-SID07) do show exchange between the Atlantic and Gulf for the scalloped hammerhead. However, the Carolina hammerhead overlaps in distribution in the Atlantic, is not found in the Gulf, and is externally indistinguishable from the scalloped hammerhead (SEDAR77-RD22). For these reasons, the Spatial-Movement workgroup agreed on two options:

1) Scalloped hammerheads should be assessed as two management stocks,
    a. Atlantic Ocean – scalloped and Carolina hammerhead complex
    b. Gulf of Mexico – scalloped hammerhead
2) If scalloped hammerhead data cannot support a separate assessments in the Atlantic and Gulf or if new data becomes available through the Data Workshop process then it may be necessary to assess scalloped hammerheads as a single management stock with Carolina hammerheads in the Atlantic and Gulf combined

TOR 4. Provide recommendations for future research on stock structure.

Response: Overall, the movement/migration data available for scalloped hammerhead from the Gulf of Mexico and Atlantic Ocean is limited and the Spatial-Movement workgroup recommends additional tagging (conventional, acoustic, and satellite) studies to better elucidate their movement patterns within the region.

TOR 5. Prepare a report providing complete documentation of workshop recommendations and decisions.

Response: This report satisfies this requirement.

Movement Summary: Scalloped hammerheads are a large, semi-coastal species with a circumtropical range (Compagno 1984). Conventional tagging data shows that both sexes of this species are present throughout the Gulf of Mexico and U.S. Atlantic Ocean up off New York (SEDAR77-RD23, Figure 10). Seasonal distribution is similar throughout the year except during winter when the distribution is primarily located along the shelf edge and only extends north in the Atlantic to off North Carolina (SEDAR77-RD23, Figures 11). This distribution range is supported by additional working and reference documents reviewed during the Stock ID process for SEDAR 77. In 52-years of NOAA Fisheries Cooperative Shark Tagging Program, there were 62 recaptures showing exchange between the Gulf of Mexico and Atlantic Ocean and between the U.S. and Mexican Gulf of Mexico (SEDAR77-RD23, Figure 12). Similarly, though data are limited, satellite telemetry data show that there is exchange between the Gulf of Mexico and Atlantic Ocean and animals tagged in the Florida Keys have been shown to use either body of water (SEDAR77-SID01, SEDAR-SID07, Figures 13, 14).

Recommendation for Stock ID:

Scalloped hammerhead (*Sphyrna lewini*): Scalloped hammerheads comprise a single biological stock in the Atlantic Ocean and Gulf of Mexico, but the Carolina hammerhead overlaps in distribution in the Atlantic, is not found in the Gulf, and is externally indistinguishable from the scalloped hammerhead, therefore:

Scalloped hammerheads should be assessed as two management stocks,

1. Atlantic Ocean – scalloped and Carolina hammerhead complex
2. Gulf of Mexico – scalloped hammerhead

Secondary recommendation: If scalloped hammerhead data cannot support separate assessments in the Atlantic and Gulf or if new data becomes available through the Data Workshop process then it may be necessary to assess scalloped hammerheads as a single management stock (scalloped and Carolina hammerhead complex) in the Atlantic and Gulf combined

2.3.9 **Carolina Hammerhead**

Terms of Reference: The goal of the Stock ID workshop was to review Carolina hammerhead stock structure and unit stock definitions, and consider appropriate stock definitions. The Spatial-Movements Working Group was responsible for evaluating the spatial distribution in the South Atlantic, and to evaluate any studies that indicated movement across the proposed boundary.

Selected portions of the Terms of Reference (TORs) specifically related to the spatial distribution of Carolina hammerheads used by this group are as follows:

TOR 1. Review relevant information on stock structure. Potential data sources include … movement and migration, existing stock definitions, … and hotspot maps of landings or catch per unit effort (CPUE).

Response: All relevant information on stock structure of Carolina hammerheads in relation to distributions, movements, and migrations were reviewed and discussed by the Spatial-Movements workgroup.

TOR 2. The boundaries for the species assessments will be determined after examination of the current stock boundaries used in management and conservation under the ESA and additional analysis of biological and genetic stock structure.

Response: After reviewing the working papers and reference documents and discussions within the working group, the recommendation is to retain the HMS management boundary for the Gulf of Mexico and the Atlantic Ocean used to separate landings data, as there were no data reviewed during this workshop that suggest an alternate boundary should be used. This boundary starts at 25°20.4'N and extends due east out to the US EEZ boundary. Above the Miami-Dade line in the Keys is considered the Atlantic Ocean and below is the Gulf of Mexico.

TOR 3. Discuss the strength of evidence in support of stock ID recommendations with particular attention paid to recommendations if they result in a mismatch of biological stock structure, assessment unit stock, and existing management or conservation boundaries.

Response: The Spatial-Movement Workgroup agreed that Carolina hammerheads comprise a single biological stock in the Atlantic Ocean. There are no movement data available for this species and limited distribution data has it ranging from North Carolina to Florida (SEDAR77-RD22) However, the Carolina hammerhead overlaps in distribution with the scalloped hammerhead in the Atlantic and is externally indistinguishable from the scalloped hammerhead (SEDAR77-RD22). For these reasons, the Spatial-Movement workgroup agreed on two options:

1) Carolina hammerheads should be assessed as a single management stock in the Atlantic (scalloped and Carolina hammerhead complex)
2) If scalloped hammerhead data cannot support separate assessments in the Atlantic and Gulf or if new data becomes available through the Data Workshop process then it may be necessary to assess Carolina hammerheads as a single management stock in the Atlantic and Gulf (scalloped and Carolina hammerhead complex)

TOR 4. Provide recommendations for future research on stock structure.

Response: Overall, the movement/migration data available for Carolina hammerhead from the Atlantic Ocean is non-existent and the Spatial-Movement workgroup recommends tagging (conventional, acoustic, and satellite) studies to better elucidate their movement patterns within the region.

TOR 5. Prepare a report providing complete documentation of workshop recommendations and decisions.

Response: This report satisfies this requirement.

Movement Summary: There is a paucity of data for Carolina hammerheads. Limited available data suggest this species has a spatially limited distribution in the Atlantic Ocean, primarily occurring from North Carolina to Florida (SEDAR77-RD22, Figure 15). As this is a cryptic species and indistinguishable from scalloped hammerheads using external morphology, it is difficult to obtain verifiable records of this species. Since field identification is nearly impossible, no tagging studies have been performed to date. A recent genetics study of Carolina and scalloped hammerheads revealed that Carolina hammerheads accounted for 27% of the population in the Atlantic Ocean and only scalloped hammerheads were observed in the Gulf of Mexico (SEDAR77-RD22).

Recommendation for Stock ID:

Carolina hammerhead (*Sphyrna gilberti*): Carolina hammerheads comprise a single biological stock in the Atlantic Ocean, but the Carolina hammerhead overlaps in distribution with the scalloped hammerhead in the Atlantic and is externally indistinguishable from the scalloped hammerhead, therefore:

Carolina hammerheads should be assessed as a single management stock in the Atlantic (scalloped and Carolina hammerhead complex)

Secondary recommendation: If scalloped hammerhead data cannot support separate assessments in the Atlantic and Gulf or if new data becomes available through the Data Workshop process then it may be necessary to assess Carolina hammerheads as a single management stock (scalloped and Carolina hammerhead complex) in the Atlantic and Gulf combined

2.3.10 **Catches Working Group**

BACKGROUND

The spatial distribution of commercial landings and recreational catches was investigated as a potential surrogate for movement to help identify stocks of the three hammerhead shark species.

2.3.10.1 COMMERCIAL LANDINGS

Commercial landings of scalloped, great, and smooth hammerheads in 1991-2020 were extracted from the FINS database, which includes landings from the Atlantic Coastal Cooperative Statistics Program (ACCSP) and the Gulf Fisheries Information Network (GulfFIN) for the Atlantic and Gulf of Mexico (GOM) regions, respectively. Commercial landings aggregated over the entire period by state of landing showed that scalloped hammerheads were mostly landed on both coasts of Florida, followed by North Carolina on the Atlantic coast and Louisiana in the GOM (Figure 16 top). Great hammerheads were mostly caught on Florida’s GOM coast and North Carolina (Figure 16 middle), whereas smooth hammerheads were exclusively landed in the Atlantic coast, in New York, Virginia, and North Carolina (Figure 16 bottom).

Since the state where sharks are landed may differ from the state where they are caught we examined the location of commercial catches as reported in the FINS database for the same period. Except for catches off Louisiana, most of the catches of scalloped hammerheads in the GOM occurred on the west coast of Florida; those in the Atlantic were from the east coast of Florida, in the Florida Keys and off Central Florida, with the highest catches occurring in the mid-Atlantic region off North Carolina. Catches occurred during most months of the year, especially in the Atlantic region (Figure 17). Most catches of great hammerheads occurred off North Carolina and the Florida Keys, also during most months of the year (Figure 18). Catch location of smooth hammerheads was not reported in most cases; of those reported most were off North Carolina with some off Virginia, but none in the GOM (Figure 19).

2.3.10.2 RECREATIONAL CATCHES

Almost all the recreational catches of the three hammerhead shark species during 1981-2020 came from the Marine Recreational Information Program (MRIP) and therefore only state of landing/catch is available. The MRIP estimates include Access Point Angler Intercept Survey (APAIS) and Fishing Effort Survey (FES) calibrations and the estimates reported here are the sum of type A (number of fish killed or kept seen by the interviewer) and type B1 (number of fish killed or kept reported to the interviewer by the angler) in number of animals.

Most scalloped hammerhead catches in 1981-2020 occurred in the Atlantic, from Florida's east coast to North Carolina, with lower catches in the GOM coming from Florida's west coast and Mississippi (Figure 20 top). Most catches occurred in waves 3 (May-June) and 4 (July-August) (Figure 20 middle) in most states where they were reported (Figure 20 bottom).

The vast majority of great hammerhead catches occurred in Florida, with about 20% more catches in the Atlantic than the GOM coast (Figure 21 top). Although higher catches also occurred in waves 3 and 4, unlike for scalloped hammerheads, great hammerheads were also caught significantly in waves 1 (January-February), 2 (March-April), and 5 (September-October) (Figure 21 middle). Interestingly, while great hammerheads on the east coast of Florida were caught mainly in waves 2, 3, and 4 (March through August), they were caught mostly in waves 1 (January-February) and 5 (Sept-October) on the west coast of Florida (Figure 21 bottom).

With the only exception of Florida's west coast (where there were estimated catches in 1982, 1987, and 1988), smooth hammerheads were caught exclusively in the Atlantic, from the east coast of Florida to Maryland (Figure 22 top). They were caught in waves 3 (May-June) and 6 (November-December), but also in waves 4 (July-August) and 5 (September-October) (Figure 22 middle). A large amount of smooth hammerheads were estimated to have been caught off Florida's east coast in wave 6 (November-December) (Figure 22 bottom).

2.3.10.3. DISCUSSION

Commercial landings and recreational catches were aggregated over the entire time periods available for this analysis. No patterns that could be used to discern different stocks of the three species were identified. One interesting result is the differential recreational catch of great hammerheads on the east coast of Florida during spring and summer compared to the west coast of Florida in winter and fall, which could potentially be attributed to movement of the same stock from one region to another. However, in the absence of detailed fishing effort information no conclusions can be drawn. A more in depth analysis than was possible for this stock ID workshop could be undertaken in the future as a research topic to help differentiate between stocks using catch and effort data and considering the effect of mis-identification, especially for recreational fisheries.

2.3.11 **Literature Cited**

Compagno, L.J.V. 1984. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 2: Carcharhiniformes. FAO Fish. Synop. 4 (125): 251–655.

Hammerschlag, N., Gallagher, A.J., Lazarre, D.M., Slonim, C. 2011. Range extension of the endangered great hammerhead shark *Sphyrna mokarran* in the northwest Atlantic: preliminary data and significance for conservation. Endangered Species Research 13: 111-116. doi: 10.3354/esr00332.

Santos C.C., Coelho, R. 2018. Migrations and habitat use of the smooth hammerhead shark (*Sphyrna zygaena*) in the Atlantic Ocean. PLoS ONE 13(6): e0198664. doi: 10.1371/ journal.pone.0198664.

2.3.12 **Figures**

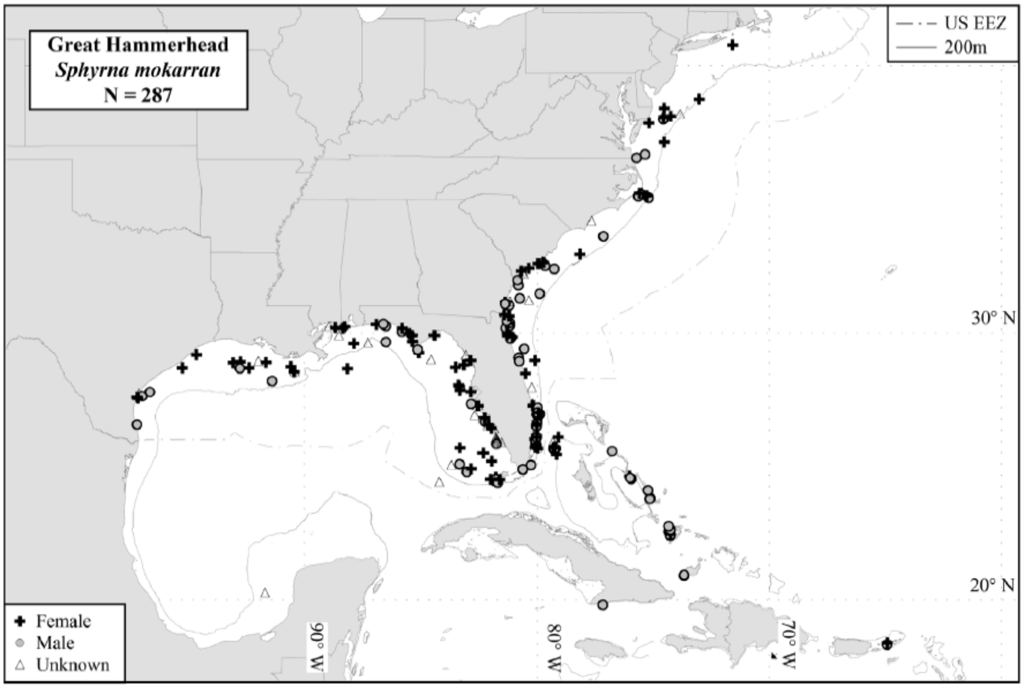


Figure 1. Cooperative Shark Tagging Program distribution of tag and recapture locations for great hammerheads from 1962-2013 (SEDAR77-RD23).

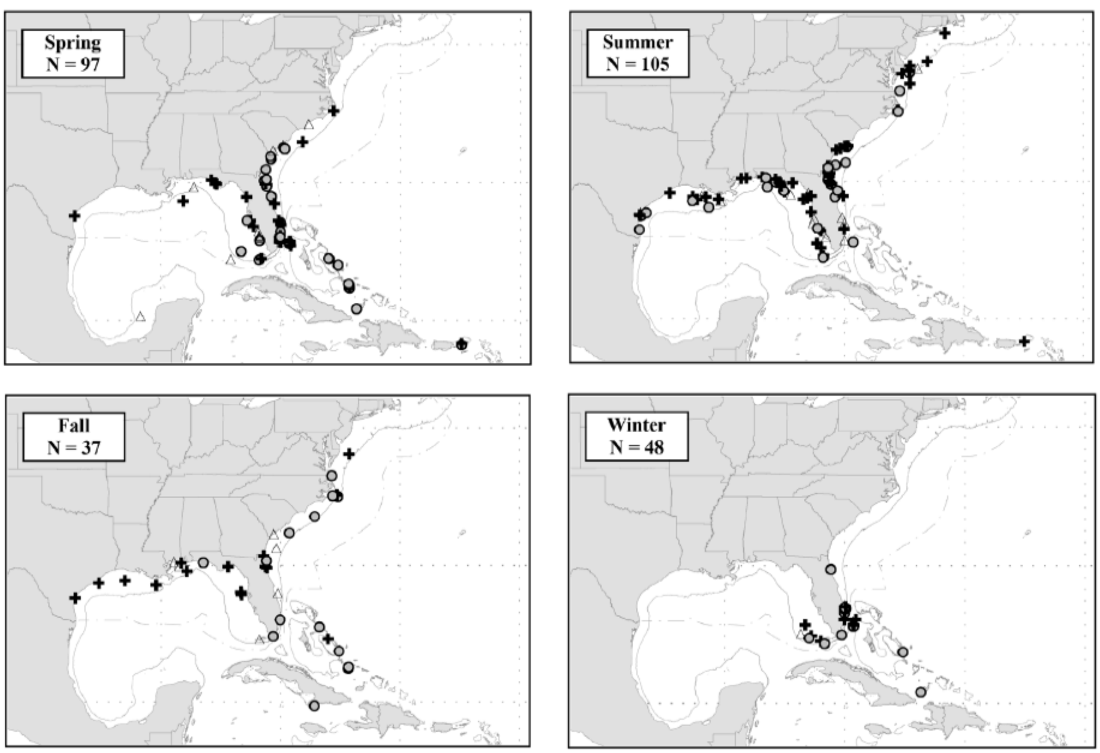


Figure 2. Cooperative Shark Tagging Program seasonal distribution of tag and recapture data for the great hammerhead from 1962-2013 (SEDAR77-RD23).

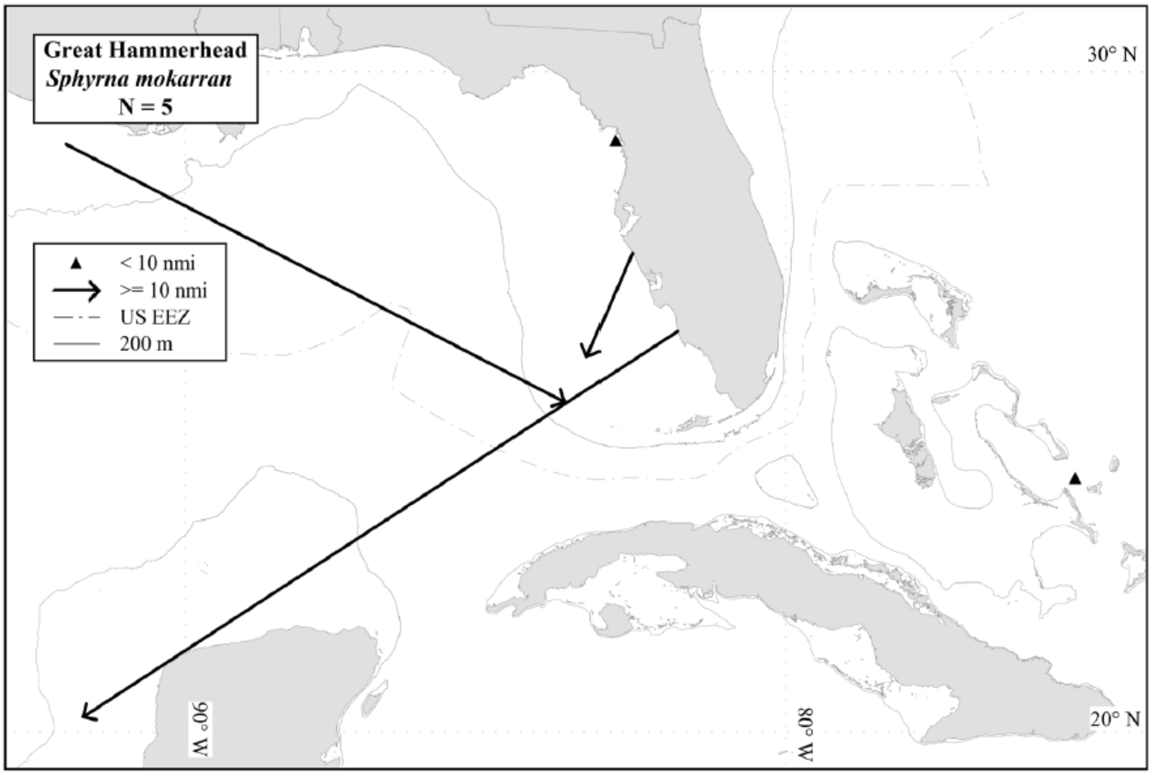


Figure 3. Cooperative Shark Tagging Program mark-recapture data for great hammerhead from 1962-2013. Data indicates exchange between the US and Mexican Gulf of Mexico (SEDAR77-RD23).

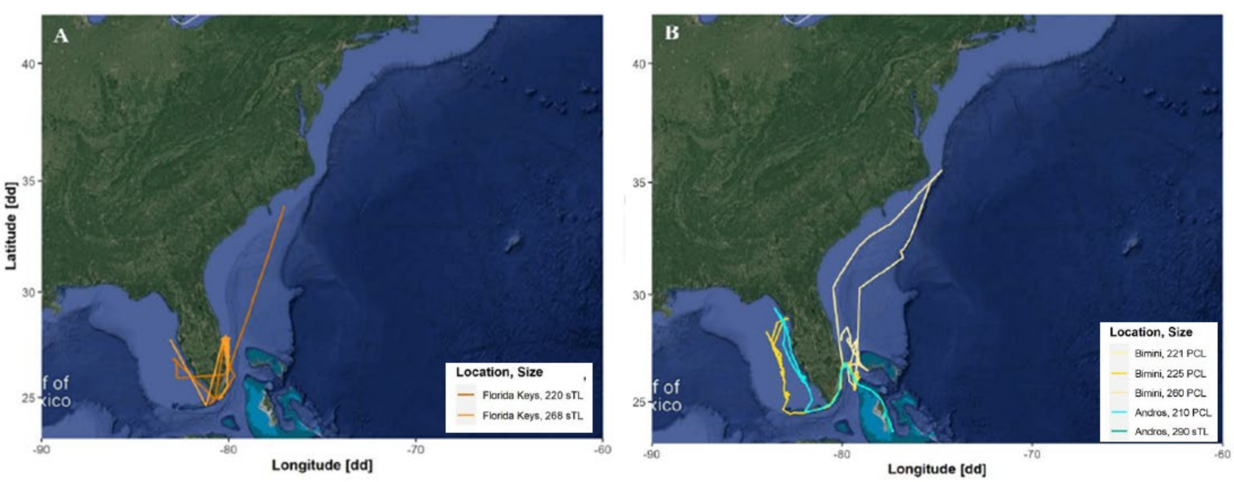


Figure 4. Regional movements of sexually immature female (A) and mature female (B) satellite tagged great hammerheads 2019-2021 (SEDAR77-SID01). Tracks indicate exchange between the Gulf of Mexico and Atlantic Ocean.

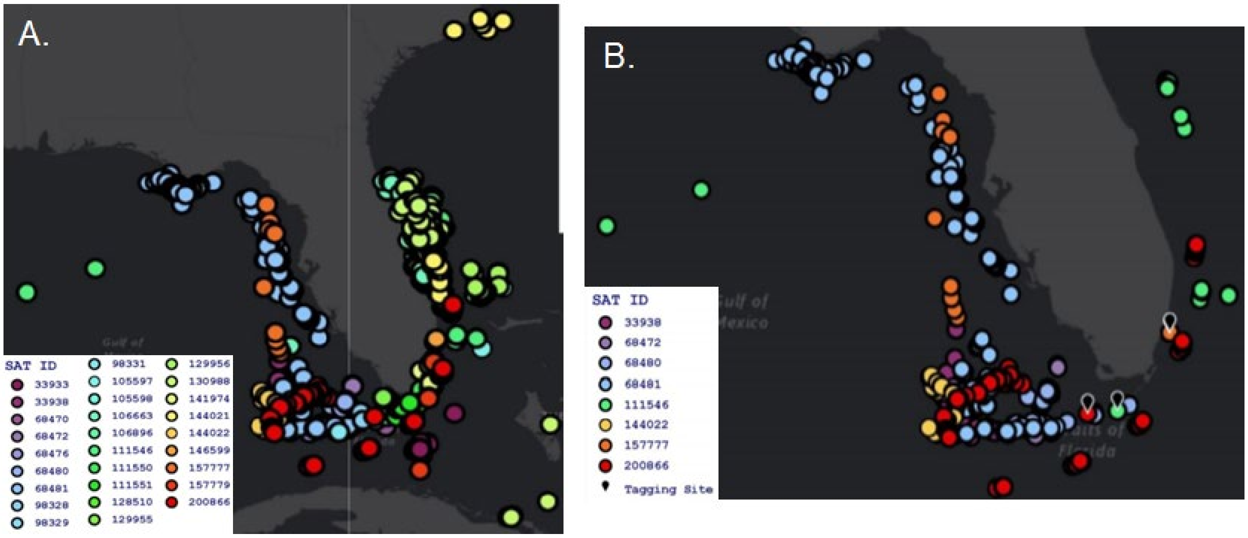


Figure 5. (A) Raw positions received from ARGOS for satellite tagged great hammerheads (n=28) and (B) the same plot restricted to animals that showed exchange between the Gulf of Mexico and Atlantic Ocean (n=8; SEDAR77-SID07).

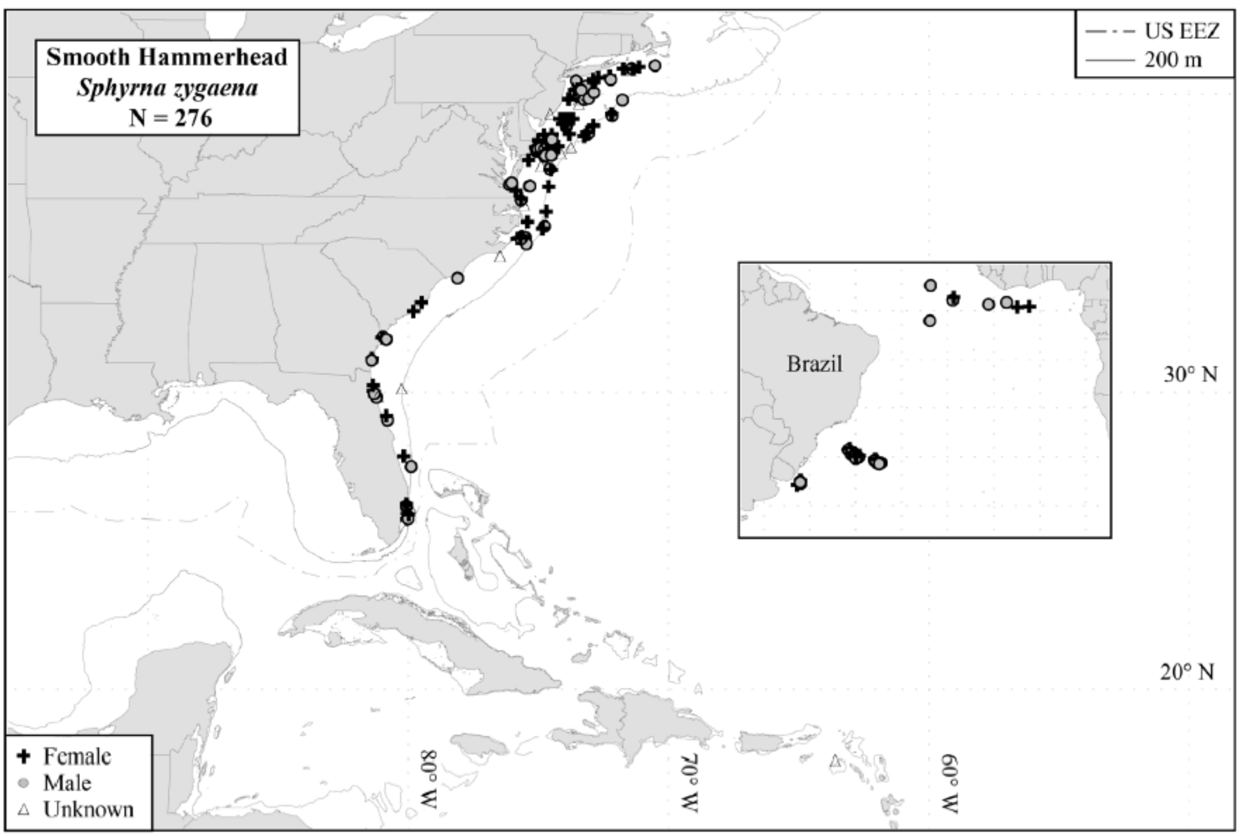


Figure 6. Cooperative Shark Tagging Program distribution of tag and recapture locations for smooth hammerheads from 1962-2013 (SEDAR77-RD23).

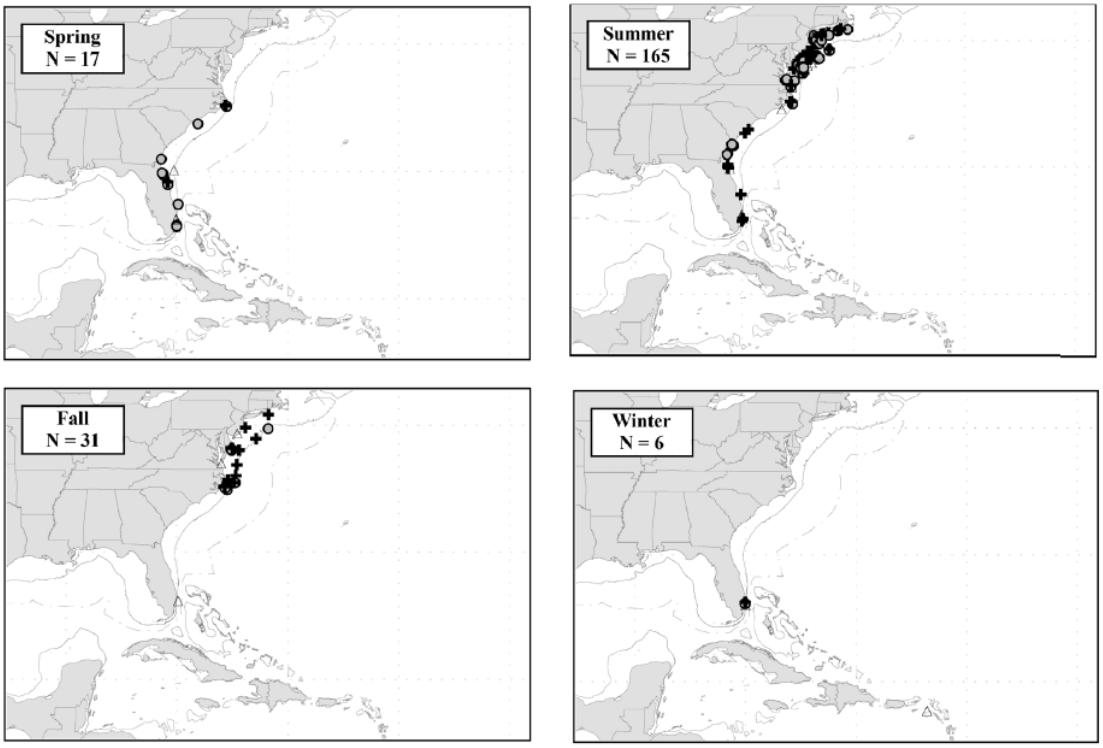


Figure 7. Cooperative Shark Tagging Program seasonal distribution of tag and recapture data for the smooth hammerhead from 1962-2013 (SEDAR77-RD23).

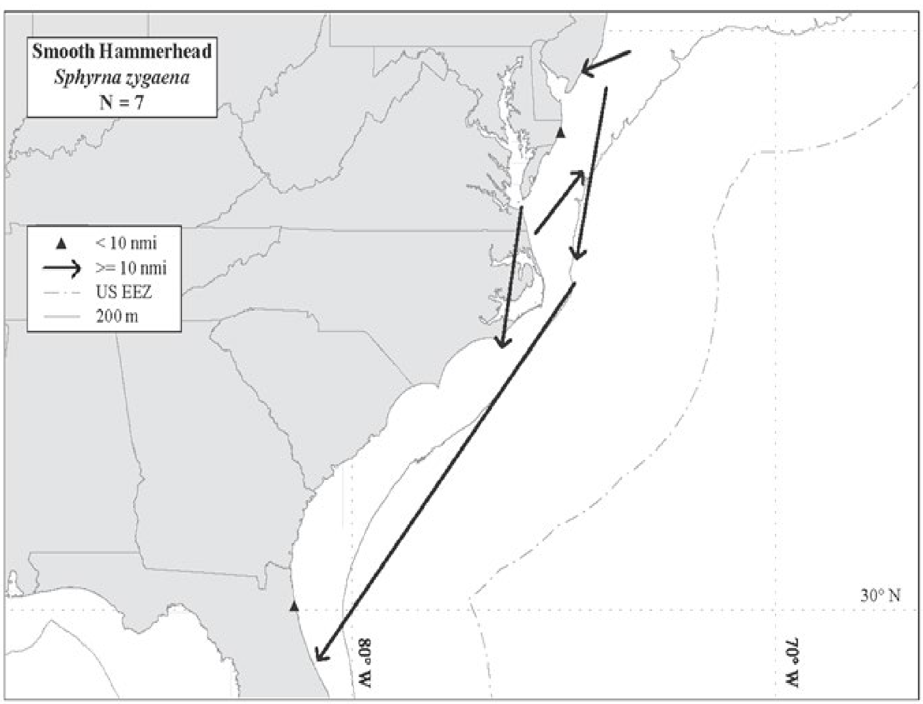


Figure 8. Cooperative Shark Tagging Program mark-recapture data for smooth hammerhead from 1962-2013 (SEDAR77-RD23). No exchange is apparent between the Gulf of Mexico and the Atlantic Ocean.

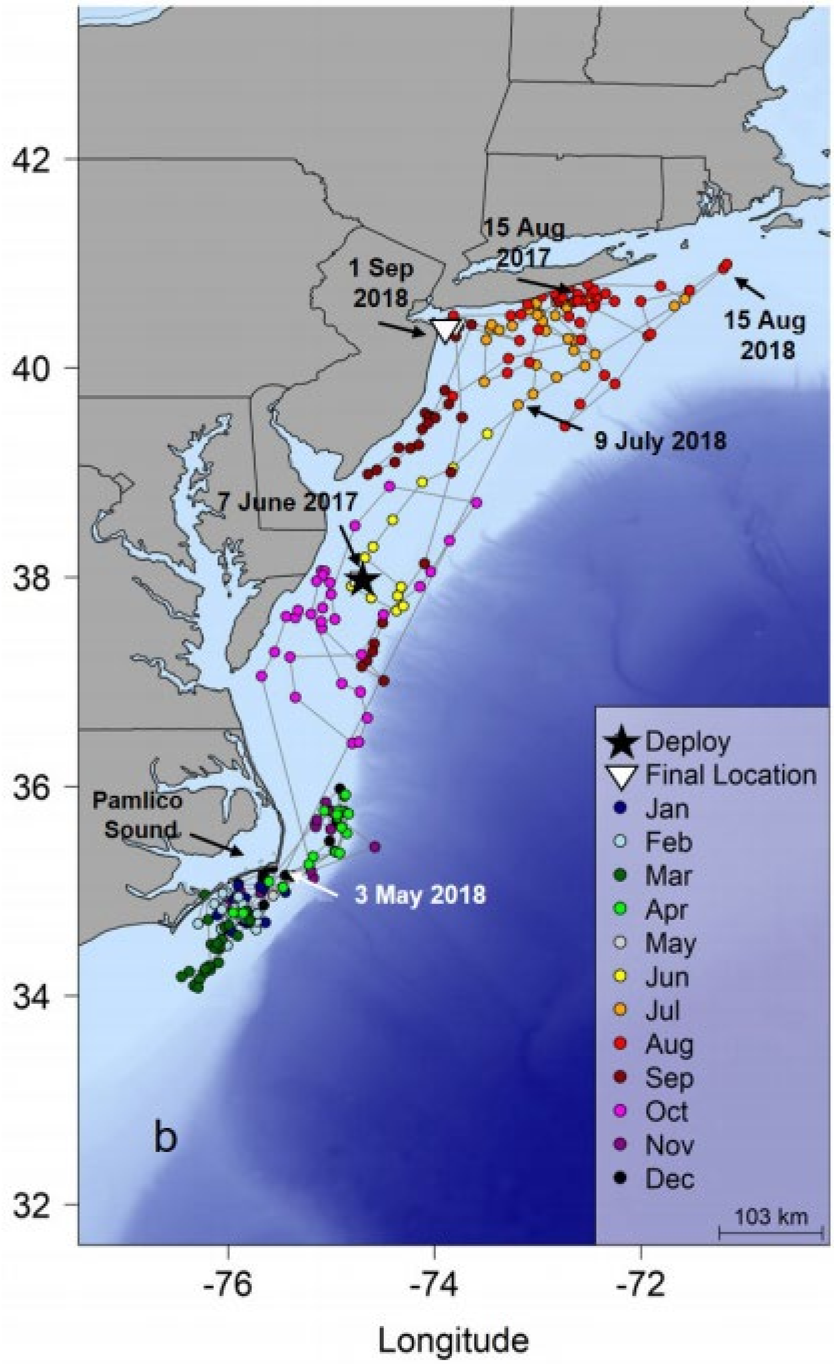


Figure 9. Satellite tag tracks of a juvenile smooth hammerhead from 2017-2018. No exchange between the Gulf of Mexico and Atlantic Ocean (SEDAR77-RD08).

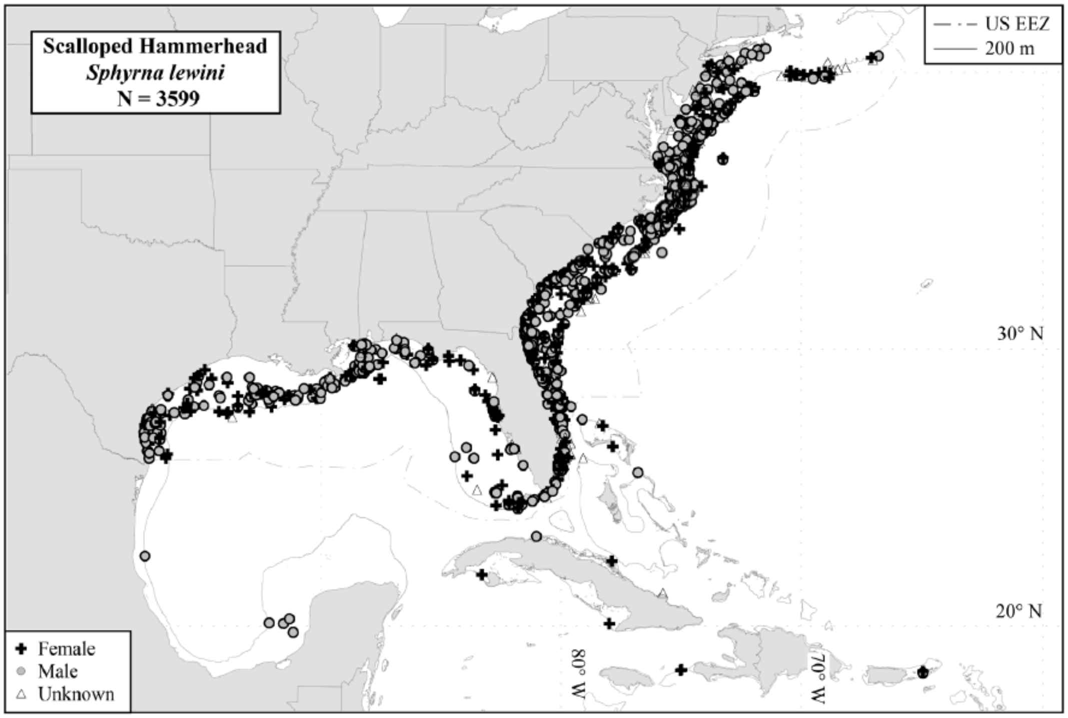


Figure 10. Cooperative Shark Tagging Program distribution of tag and recapture locations for scalloped hammerheads from 1962-2013 (SEDAR77-RD23).

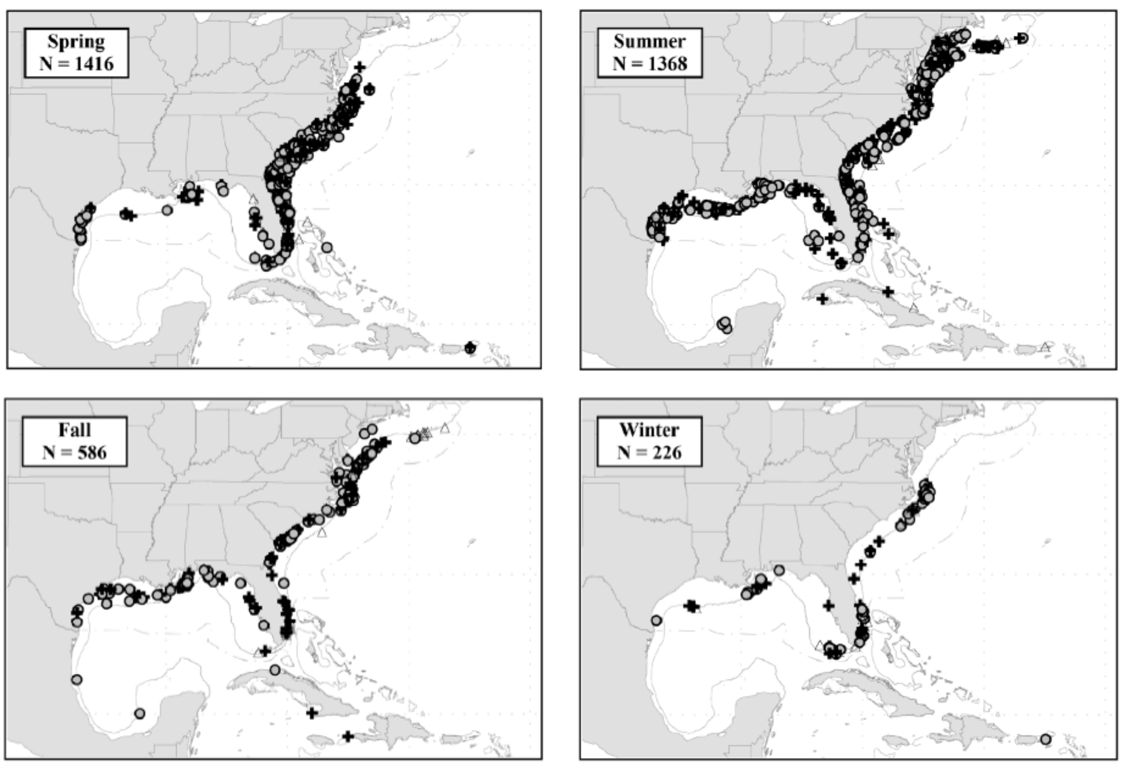


Figure 11. Cooperative Shark Tagging Program seasonal distribution of tag and recapture data for the scalloped hammerhead from 1962-2013 (SEDAR77-RD23).

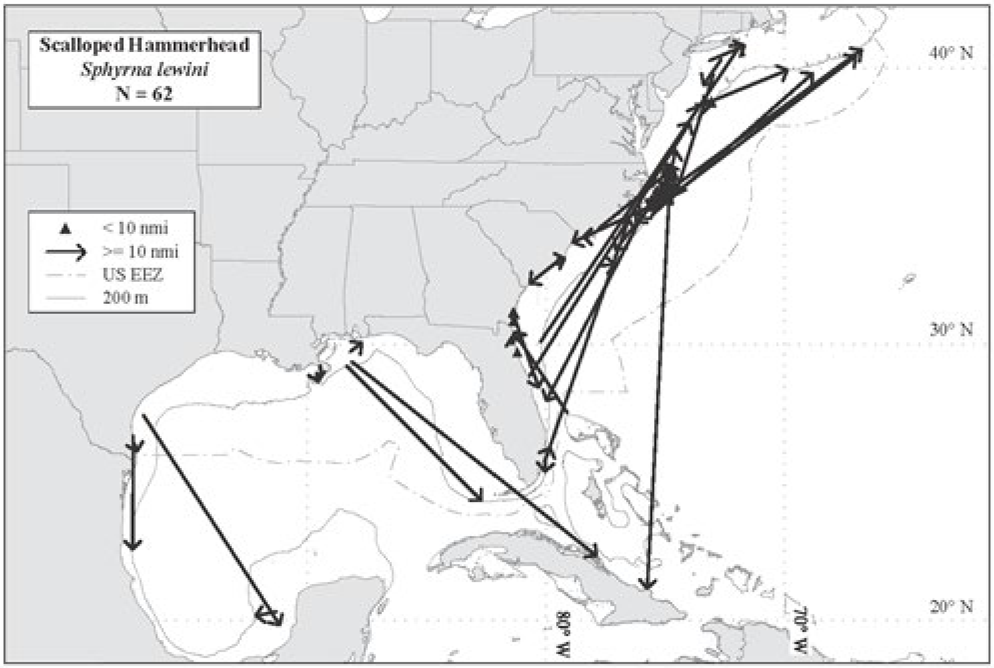


Figure 12. Cooperative Shark Tagging Program mark-recapture data for scalloped hammerhead from 1962-2013 (SEDAR77-RD23). Exchange is apparent between the Gulf of Mexico and the Atlantic Ocean and between the US and Mexican Gulf of Mexico.

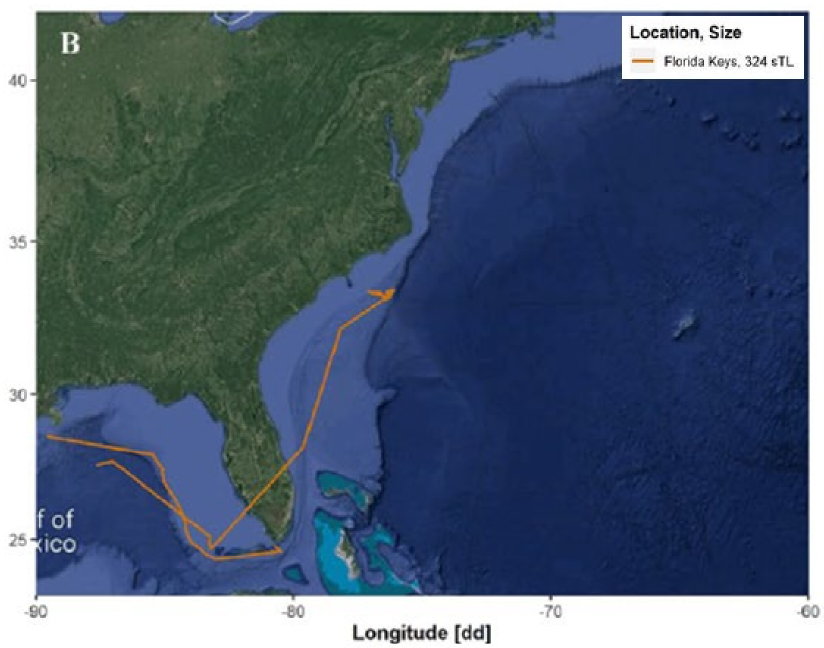


Figure 13. Regional movement track of a satellite tagged mature male scalloped hammerhead 2019-2021 (SEDAR77-SID01). The track indicates exchange between the Gulf of Mexico and Atlantic Ocean.

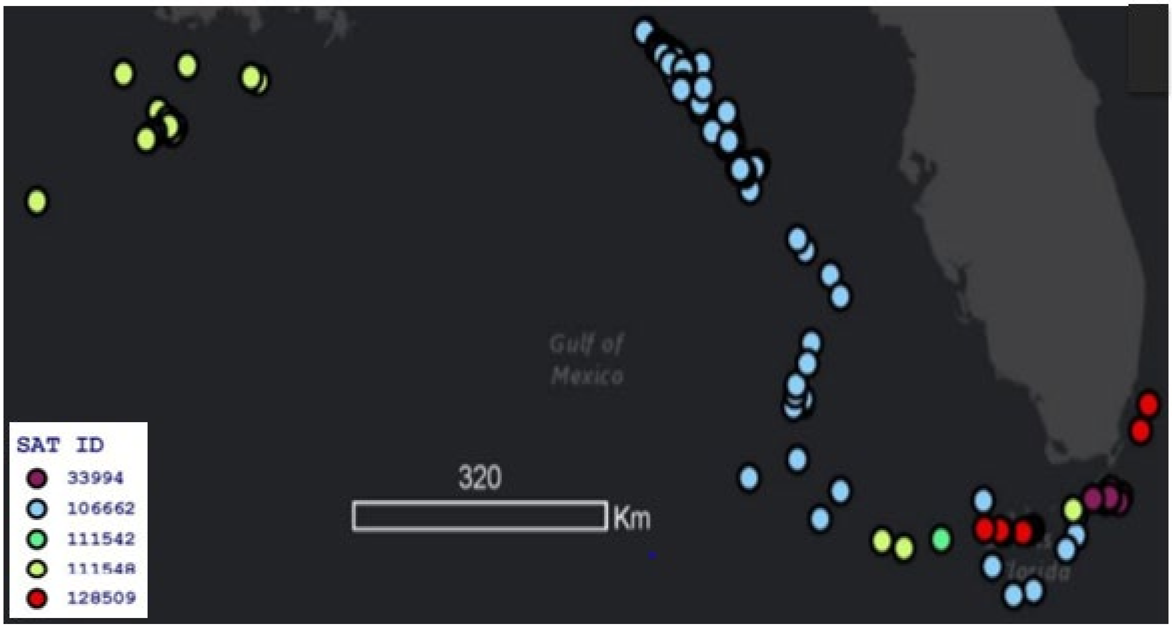


Figure 14. Raw positions received from ARGOS for satellite tagged scalloped hammerheads (n=5). Positions indicate exchange between the Gulf of Mexico and Atlantic Ocean (SEDAR77-SID07).

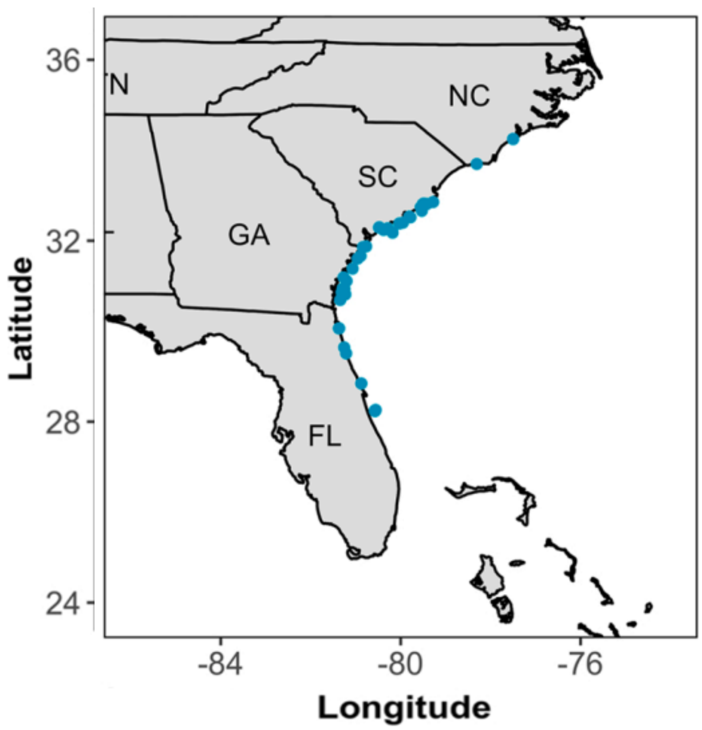
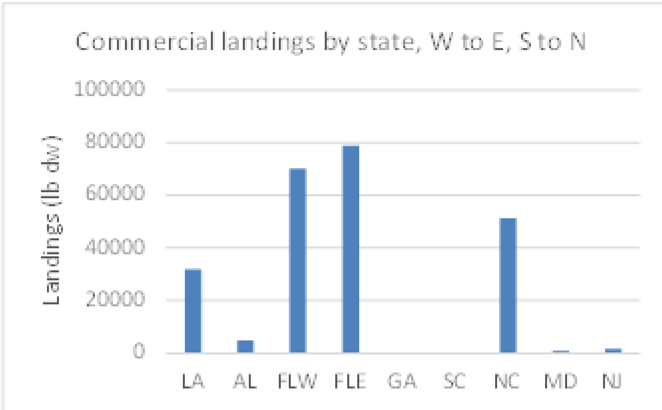
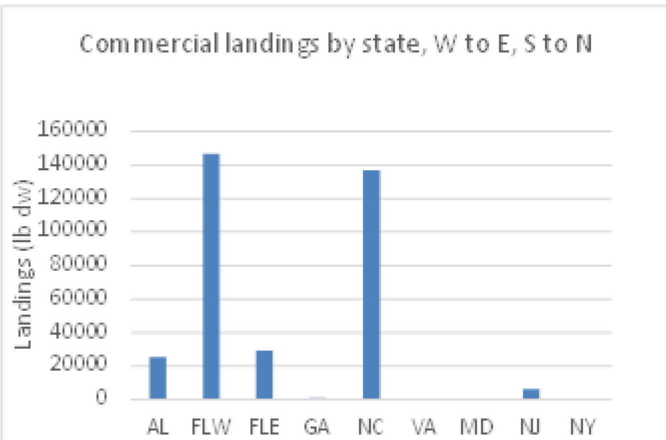


Figure 15. Sampling locations of Carolina hammerheads 2010-2019 (SEDAR77-RD22). No exchange between the Gulf of Mexico and Atlantic Ocean.





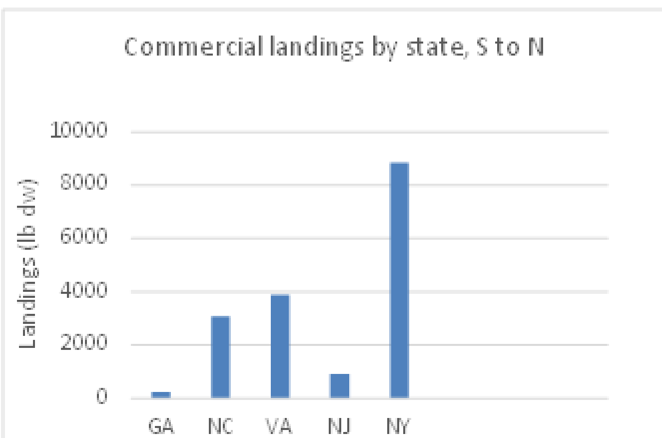


Figure 16. Total landed pounds (dressed weight) of scalloped (top), great (middle), and smooth (bottom) hammerhead sharks for 1991-2020 by state of landing reported in the FINS database. States are listed from west to east in the Gulf of Mexico and from south to north in the Atlantic. Note the different scales on the vertical axis.

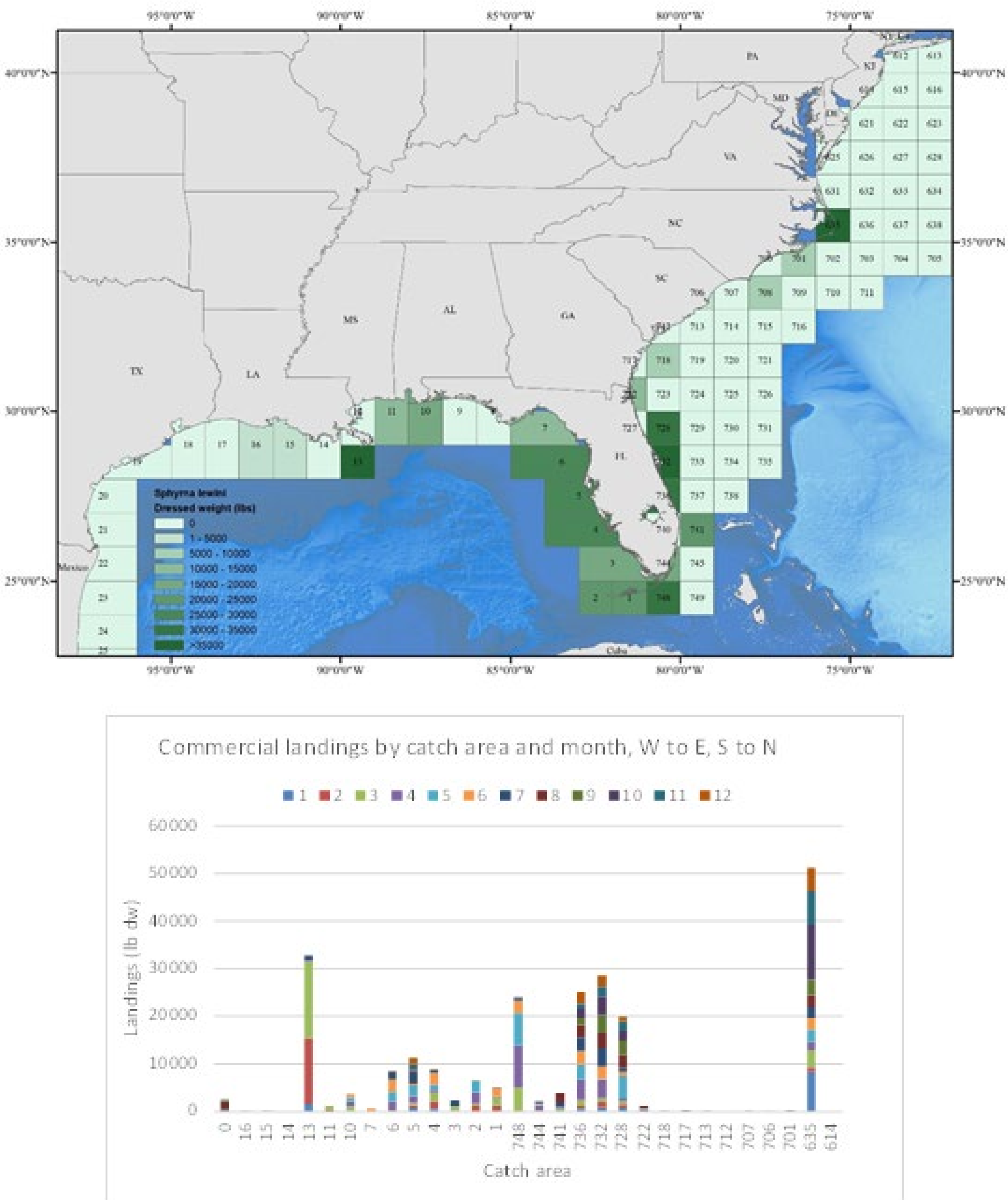


Figure 17. Total landed pounds (dressed weight) of scalloped hammerhead sharks for 1991-2020 by catch area reported in the FINS database. The bottom panel shows the catch areas from west to east in the Gulf of Mexico and from south to north in the Atlantic.

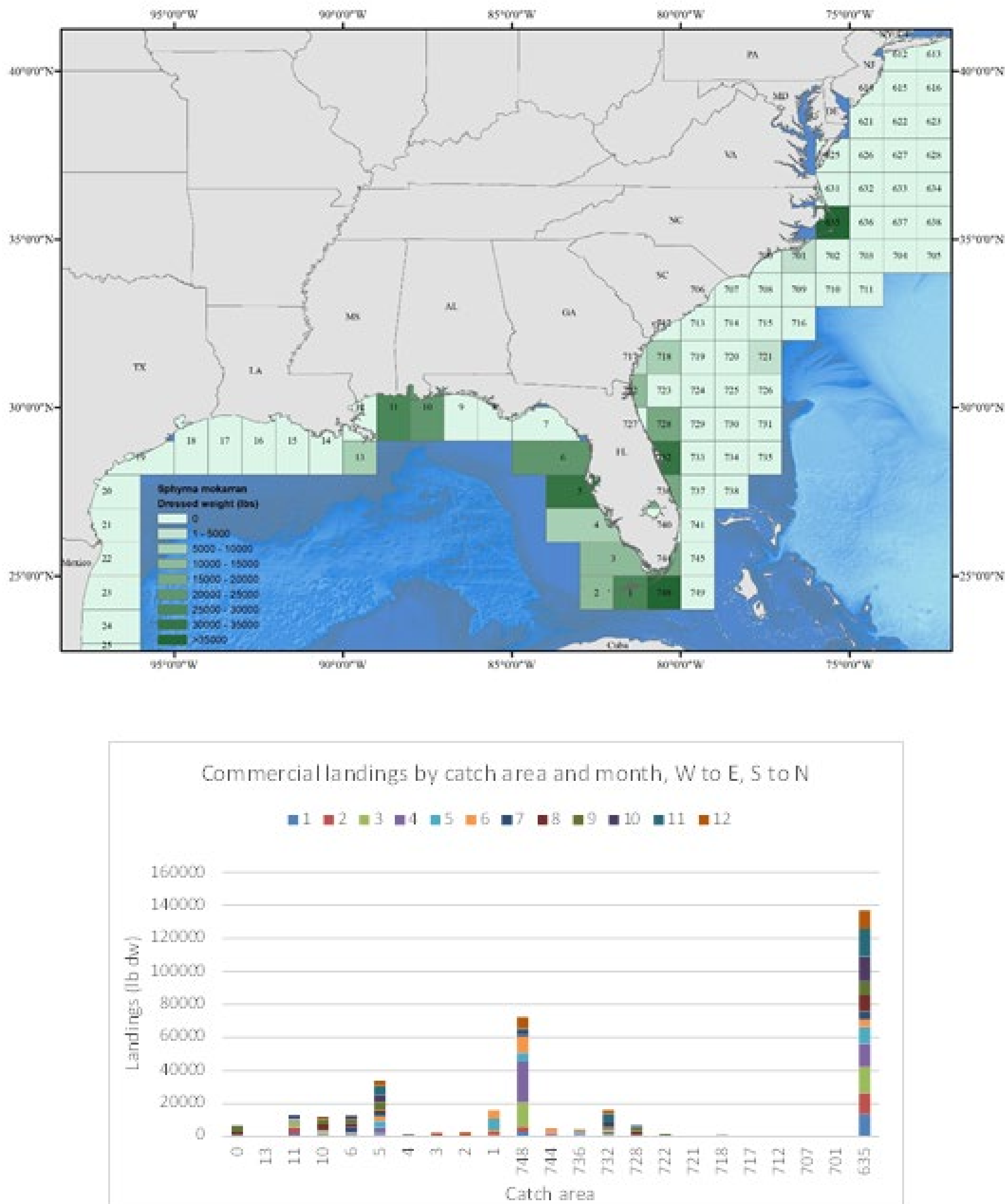


Figure 18. Total landed pounds (dressed weight) of great hammerhead sharks for 1991-2020 by catch area reported in the FINS database. The bottom panel shows the catch areas from west to east in the Gulf of Mexico and from south to north in the Atlantic.

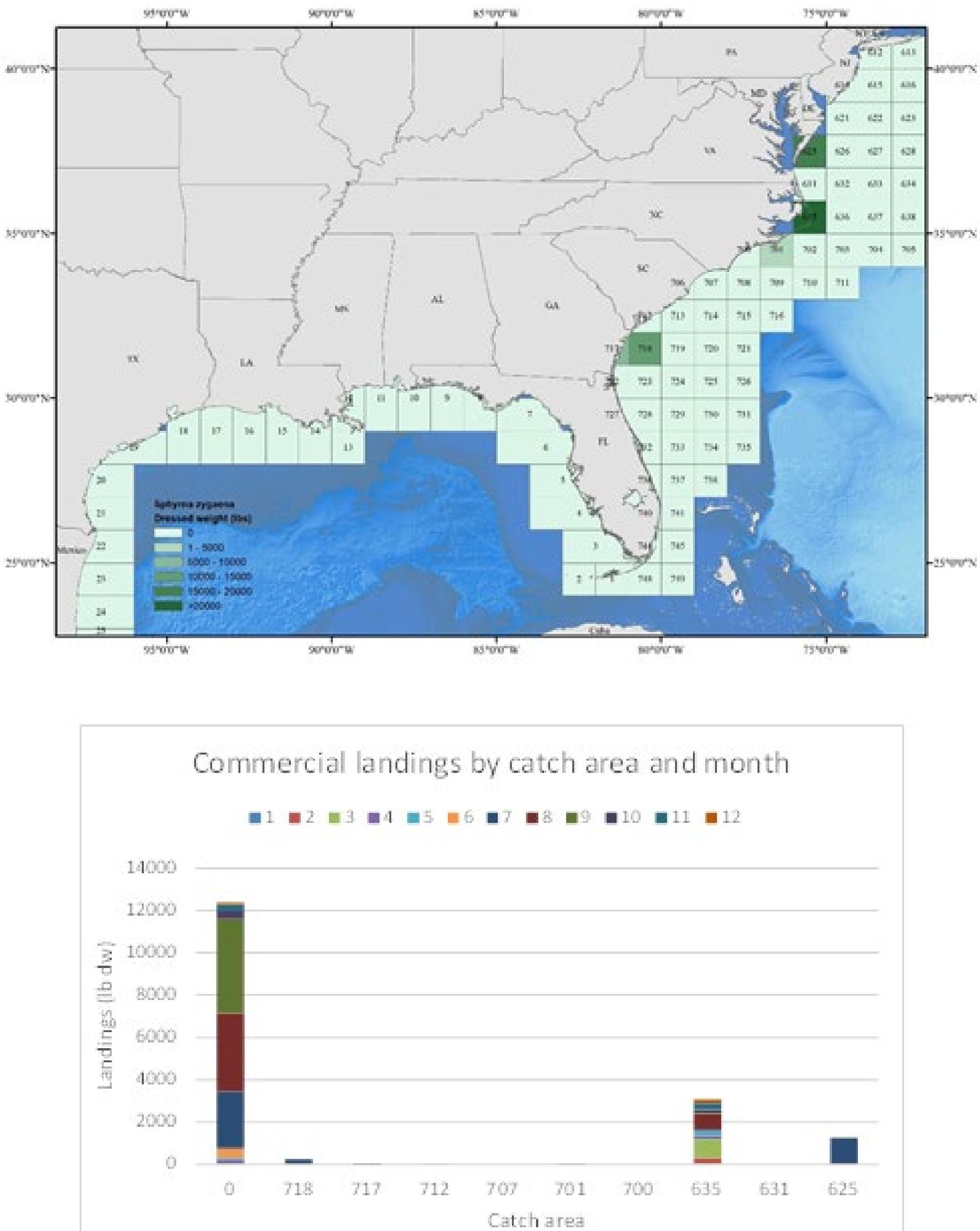


Figure 19. Total landed pounds (dressed weight) of smooth hammerhead sharks for 1991-2020 by catch area reported in the FINS database. The bottom panel shows the catch areas from west to east in the Gulf of Mexico and from south to north in the Atlantic.

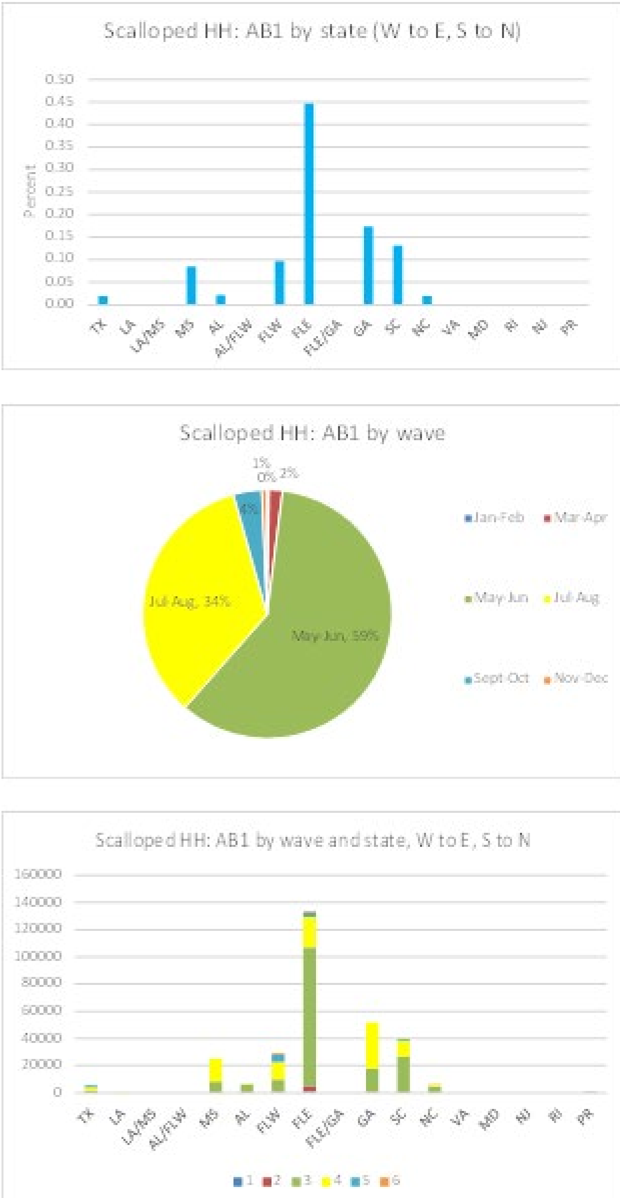


Figure 20. Catches (A+B1) of scalloped hammerhead sharks for 1981-2020 by state (from west to east in the Gulf of Mexico and from south to north in the Atlantic) (top), wave (middle), and state/wave (bottom).

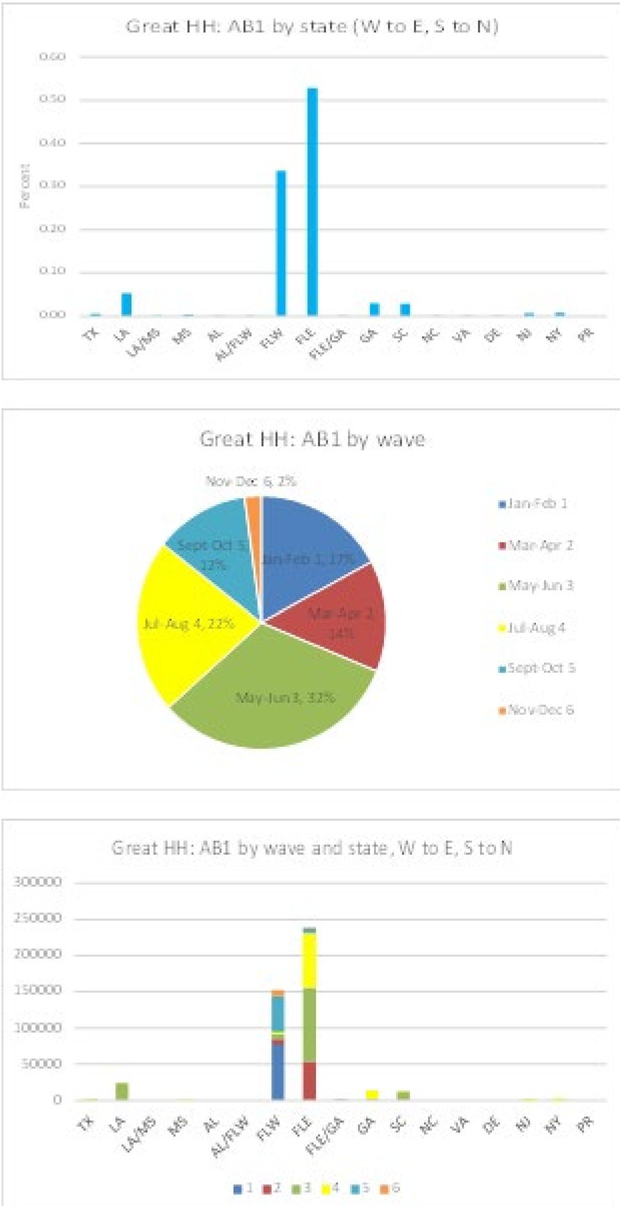


Figure 21. Catches (A+B1) of great hammerhead sharks for 1981-2020 by state (from west to east in the Gulf of Mexico and from south to north in the Atlantic) (top), wave (middle), and state/wave (bottom).

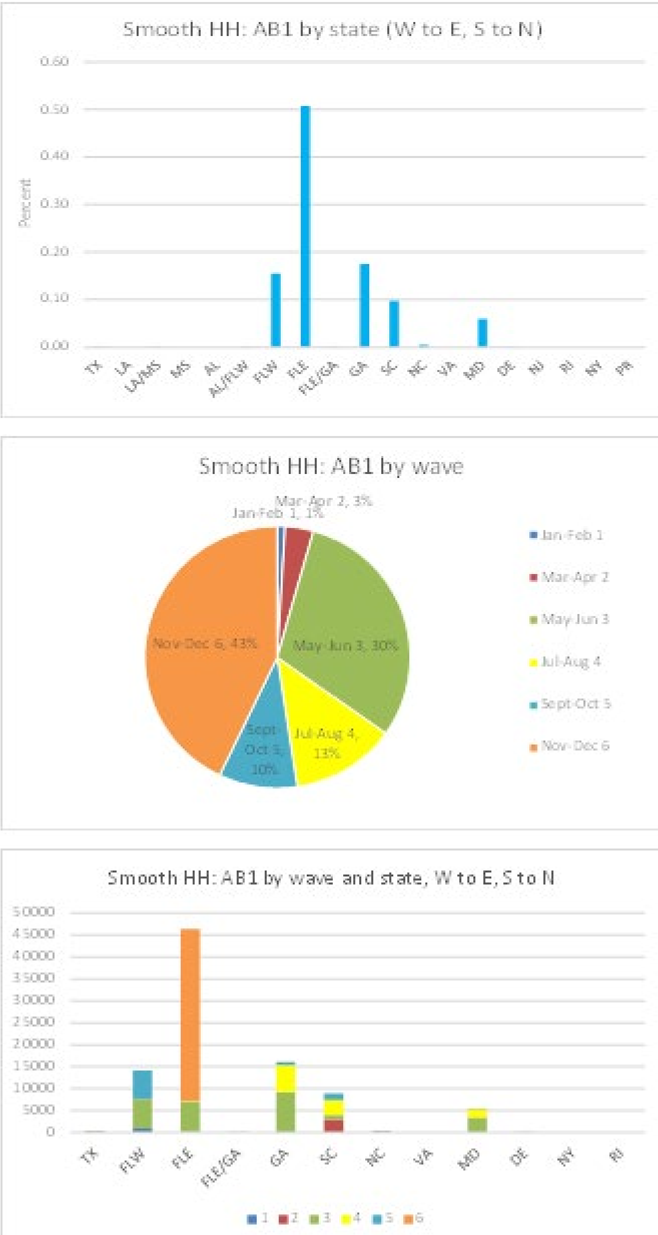


Figure 22. Catches (A+B1) of smooth hammerhead sharks for 1981-2020 by state (from west to east in the Gulf of Mexico and from south to north in the Atlantic) (top), wave (middle), and state/wave (bottom).

SEDAR

Southeast Data, Assessment, and Review

SEDAR 77

HMS Hammerhead Sharks

Data Workshop Final Report

April 2022

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

Table of Contents

1. Introduction

1.1 Workshop Time and Place

The SEDAR 77 Data Workshop meeting was held December 13-17, 2021 via webinar. Three data webinars were held prior to the workshop on September 23, October 20th and November 9th, 2021. Two additional webinars were held post the Data workshop on January 13 and January 31, 2022.

1.2 Terms of Reference

1. Definition of assessment unit stock will be developed through the Hammerhead Sharks Stock ID process and will be added to TORs once that process is complete.
2. Review, discuss, and tabulate available life history information for each stock being assessed.
    a. Evaluate age, growth, natural mortality, and reproductive characteristics
    b. Provide appropriate models to describe population- and area-specific (if warranted) growth, maturation, and fecundity by age, sex, or length as applicable.
    c. Evaluate the adequacy of available life history information for conducting stock assessments and recommend life history information for use in population modeling.
    d. Evaluate and discuss the sources of uncertainty and error and data limitations (such as temporal and spatial coverage) for each data source. Provide estimates or ranges of uncertainty for all life history information, where applicable.
3. Provide measures of population relative abundance that are appropriate for these stock assessments.
    a. Consider all available and relevant fishery-dependent and fishery-independent data sources
    b. Document all programs evaluated; address program objectives, methods, coverage, sampling intensity, and other relevant characteristics.
    c. Provide maps of fishery-dependent and fishery independent survey coverage.
    d. Develop fishery and survey CPUE indices by appropriate strata (e.g., age, size, area, and fishery) and include measures of precision and accuracy.
    e. Document pros and cons of available indices regarding their ability to represent abundance.
        i. Consider potential species identification issues between hammerhead shark species and, if present, whether the issue was adequately addressed during index development.
    f. Categorize the available indices into Recommended and Not Recommended; provide justifications for the categorization.
    g. For recommended indices, document any known or suspected spatial or temporal patterns not accounted for by standardization.
    h. Provide appropriate measures of uncertainty for the abundance indices to be used in stock assessment models.
4. Provide commercial catch statistics for each stock being assessed, including landings, dead discards, live discards, and potential post-release mortality in both weight and number. Consider species identification issues between hammerhead shark species and correct for these instances as appropriate.
    a. Evaluate and discuss the adequacy of available data for accurately characterizing

landings and discards by fishery sector or gear.

b. Provide length and age distributions for both landings and discards if feasible.
c. Provide maps of fishery effort and harvest by fishery sector or gear.
d. Provide estimates of uncertainty around each set of commercial landings (if possible) and discard estimates.
e. Provide estimates of discard mortality rate by gear.

5. Provide recreational catch statistics for each stock being assessed, including landings, dead discards, live discards, and potential post-release mortality in both weight and number. Consider species identification issues between hammerhead shark species and correct for these instances as appropriate.
    a. Evaluate and discuss the adequacy of available data for accurately characterizing landings and discards by fishery sector or gear.
    b. Provide length and age distributions for both landings and discards if feasible.
    c. Provide maps of fishery effort and harvest by fishery sector or gear.
    d. Provide estimates of uncertainty around each set of recreational landings and discard estimates.
    e. Provide estimates of discard mortality rate by gear.
6. Identify and describe ecosystem, climate, species interactions, habitat considerations, and/or episodic events that would be reasonably expected to affect population dynamics.
    a. Report and summarize species that frequently co-occur or are associated with hammerhead sharks from survey data, if possible.
    b. Report and summarize species envelopes used for CPUE standardization, i.e. minimum and maximum values of environmental boundaries (e.g. depth, temperature, substrate, relief).
    c. Review and summarize available diet composition with respect to ontogeny, seasonality, and habitat, where available.
7. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Include specific guidance on sampling intensity (number of length samples) and appropriate strata and coverage.
8. Prepare a Data Workshop report providing complete documentation of workshop actions and decisions in accordance with project schedule deadlines.

1.3 List of Participants

Participants	Affiliation
Assessment Development Team (ADT)	
Rob Latour	Virginia Institute of Marine Science College of William and Mary
Beth Babcock	RSMAS U. Of Miami
John Carlson	HMS
Trey Driggers	SEFSC Mississippi Laboratory
Panelists	
Eric Hoffmayer	SEFSC Mississippi laboratory
Enric Cortes	SEFSC Panama City laboratory
Xinsheng Zhang	SEFSC Panama City laboratory
Dean Courtney	SEFSC Panama City laboratory
Xinsheng Zhang	SEFSC Panama City laboratory
Heather Baertlein	HMS
Alyssa Mathers	SEFSC Panama City laboratory
Andrea Kroetz	SEFSC Panama City laboratory
Cliff Hutt	HMS
Adam Pollack	SEFSC Mississippi laboratory
Cami McCandless	NEFSC Narragansett Laboratory
Heather Moncrief-Cox	SEFSC Panama City Laboratory
Michelle Passerotti	NEFSC Narragansett Laboratory
David Wells	Department of Biology Texas A&M University
David Portnoy	Department of Biology Texas A&M University
Bryan Frazier	SC Department of Natural Resources
R. Dean Grubbs	Florida State University Coastal and Marine Laboratory
Marcus Drymon	Mississippi State
Bradley Wetherbee	University of Rhode Island
Mahmood Shivji	NOVA Southeastern University - Halmos College of Natural Sciences and Oceanography
Russell Hudson	Directed Shark Fisheries, Inc.
Neil Hammerschlag	RSMAS U. Of Miami
Juan Carlos Perez-Jimenez	El Colegio de la Frontera Sur (ECOSUR)
Demian Chapman	Florida International University
James Gelsleichter	University of North Florida
Mark Sampson	Recreational fisherman
STAFF	
Kathleen Howington	SEDAR
Cindy Chaya	SAFMC
Julie Neer	SEDAR
Suzanna Thomas	SAFMC
Karyl Brewster-Geisz	HMS Management

Margaret Miller	NMFS
Adam Brame	NMFS

Appointed Data providers

Vivian Matter	SEFSC Miami
Kevin McCarthy	SEFSC Miami
Larry Beerkircher	SEFSC Miami
Graciela Garcia-Moliner	CMFC
Hannah Medd	Shark conservancy
Jayne Gardiner	New College
Max lee	MOTE

Other

Simon Gulak	Sea Leucas LLC
Bradley Smith	NMFS
Carole Neidig	MOTE
Cassandra Scott	
Chip Collier	SAFMC
Dalyan Lopez	CFMC
Delisse Ortiz	NMFS
Derek Kraft	NMFS
Genevieve Patrick	MOTE
Ian Miller	NMFS
Kesley Banks	Texas A&M
Leann Bosarge	GMFMC
Liajay Riviera	CFMC
Sascha Cushner	NMFS
Steve Durkee	NMFS
Tobey Curtis	NMFS
Kristin Hannah	NMFS
Matthew Streich	Texas A&M
Dan Crear	NMFS
Daniel Roberts	Water Interface EM

1.4 Document List

Document #	Title	Authors	Received
Documents Prepared for SEDAR 77 Data process			
SEDAR77-DW01	Hammerhead Shark Catches from Bottom Longline and Pelagic Longline Surveys conducted by Mississippi Laboratories	Adam G. Pollack and David S. Hanisko	9/7/2021
SEDAR77-DW02	Report on spatial movements of great and scalloped hammerhead sharks in the US Atlantic and Gulf of Mexico using Satellite tags	Neil Hammerschlag	9/8/2021
SEDAR77-DW03	Morphometric conversions for great hammerhead *Sphyrna mokarran* and scalloped hammerhead *Sphyrna lewini* from the western North Atlantic Ocean and Gulf of Mexico	Lisa J. Natanson, Camilla T. McCandless William B. Driggers III, Eric R. Hoffmayer, Bryan S. Frazier, Carolyn N. Belcher, James Gelsleichter, Michelle S. Passerotti	11/8/2021
SEDAR77-DW04	Preliminary catches of hammerhead sharks in the U.S. Atlantic, Gulf of Mexico, and Caribbean	Enric Cortes	11/28/2021
SEDAR77-DW05	Hammerhead Shark (*Sphyrna spp.*) Electronic Monitoring Data Review from the Gulf of Mexico Bottom Longline Reef Fish Fishery	Max Lee, B.S., Genevieve Patrick, M.S., Carole Neidig, M.S., and Ryan Schloesser, Ph.D.	11/17/2021
SEDAR77-DW06	Size distribution and trends in relative abundance of scalloped hammerheads (*Sphyrna lewini*) in the northern Gulf of Mexico, 2006-2021	M. B. Jargowsky, S. P. Powers, and J. M. Drymon	11/29/2021 Revised: 12/16/21
SEDAR77-DW07	Post-release mortality and behavior of sharks in shore-based recreational fisheries using citizen scientists and low-cost tags	John A. Mohan , R.J. David Wells, Marcus Drymon, Gregory Stunz, and Matthew Streich	11/29/2021 Revised: 12/16/21
SEDAR77-DW08	Standardized abundance indices for scalloped hammerhead shark from the Pelagic Longline Observer Program, 1992-2019	John K. Carlson, Sasha Cushner, and Lawrence Beerkircher	11/28/2021

SEDAR77-DW09	Stress physiology of scalloped and great hammerhead sharks from a bottom longline fishery	Bianca K. Prohaska, Heather Marshall, R. Dean Grubbs, Bryan S. Frazier, John J. Morris, Alyssa Andres, Karissa Lear, Robert E Hueter, Bryan A Keller, Nicholas M Whitney	11/29/2021
SEDAR77-DW10	Stress physiology of scalloped and great hammerhead sharks from a bottom longline fishery: Supplemental Tables	Bianca K. Prohaska, Heather Marshall, R. Dean Grubbs, Bryan S. Frazier, John J. Morris, Alyssa Andres, Karissa Lear, Robert E Hueter, Bryan A Keller, Nicholas M Whitney	11/29/2021
SEDAR77-DW11	Age and growth of the great hammerhead, *Sphyrna mokarran*, in the western North Atlantic Ocean.	William B. Driggers III, Christian M. Jones, Kristin M. Hannan, Andrew Piercy, and Bryan S. Frazier	11/29/2021
SEDAR77-DW12	Standardized abundance indices from scalloped and great hammerhead from the Shark Bottom Longline Observer Program, 1994-2019	John K. Carlson and Alyssa N. Mathers	11/30/2021
SEDAR77-DW13	Standardized Abundance Indices for Scalloped Hammerhead from the Southeast Coastal Gillnet Fishery	John Carlson and Alyssa Mathers	11/30/2021
SEDAR77-DW14	Standardized Abundance Indices for Great Hammerhead from the Florida State University Longline Survey	John Carlson and R. Dean Grubbs	11/30/2021

SEDAR77-DW15	Standardized Abundance Index for Great Hammerhead from the Rosenstiel School of Marine and Atmospheric Science Drumline Survey	John Carlson, Neil Hammerschlag and Robert J. Latour	11/30/2021 Revised: 2/9/2022
SEDAR77-DW16	Relative abundance index for young-of-the-year scalloped hammerhead shark based on a fishery-independent gillnet survey off Texas, 1982-2019	John K. Carlson and Mark Fisher	12/1/2021
SEDAR77-DW17	Relative abundance index for young-of-the-year scalloped hammerhead shark from the northeastern Gulf of Mexico	John K. Carlson, Jill Hendon, Jeremy Higgs, Dana M. Bethea, Bethany Deacy, Heather Moncrief-Cox, and Andrea Kroetz	12/1/2021
SEDAR77-DW18	Reproductive parameters of great hammerhead sharks (*Sphyrna mokarran*) and scalloped hammerhead sharks (*Sphyrna lewini*) from the western North Atlantic Ocean	Heather E. Moncrief-Cox, Kristin M. Hannan, Michelle S. Passerotti, William B. Driggers III and Bryan S. Frazier	12/1/2021
SEDAR77-DW19	Age and growth of scalloped (*Sphyrna lewini*) and Carolina (*Sphyrna gilberti*) hammerheads in the western North Atlantic Ocean	Bryan S. Frazier, Ashley S. Galloway, Lisa J. Natanson, Andrew N. Piercy, and William B. Driggers III	12/2/2021
SEDAR77-DW20	Bycatch estimates of scalloped and great hammerhead shark in the shark bottom longline fishery	John Carlson, Alyssa Mathers, Heather Moncrief-Cox, Kevin McCarthy	12/8/2021

SEDAR77-DW21	Bycatch Estimates of Scalloped and Great Hammerhead Shark in the Southeast Coastal Gillnet Fishery	John Carlson, Alyssa Mathers and Kevin McCarthy	12/8/2021
SEDAR77-DW22	Report on the post-release mortality rates of great hammerhead sharks *Sphyrna mokarran* in the recreational, catch and release, shore-based fishery in Florida, USA.	Hannah B. Medd and Jill L. Brooks	12/6/2021
SEDAR77-DW23	Relative abundance of scalloped hammerhead*, Sphyrna lewini*, and Carolina hammerhead, *Sphyrna gilberti*, along the southern U.S east coast.	David S, Portnoy, Amanda M. Barker, and Bryan S. Frazier	12/8/2021
SEDAR77-DW24	Scalloped and Great Hammerheads Abundance Indices from NMFS Bottom Longline Surveys in the Northern Gulf of Mexico and Western North Atlantic	Adam G. Pollack and David S. Hanisko	12/9/2021
SEDAR77-DW25	Standardized Catch Rates Of Great Hammerheads (*Sphyrna Mokarran*) Collected During Bottom Longline Surveys In Coastal Waters Of The Northern Gulf Of Mexico, 2006-2019	Eric Hoffmayer, Adam Pollack, Jill Hendon, Marcus Drymon, and Sean Powers	12/10/21
SEDAR77-DW26	An Updated Literature Review of Post-Release Live-Discard Mortality Rate Estimates in Sharks for use in SEDAR 77	Dean Courtney, Alyssa Mathers, and Andrea Kroetz	12/13/21
SEDAR77-DW27	Estimation of scalloped and smooth hammerhead discards in the northeast gillnet fishery using data collected by the NOAA Northeast Fisheries Observer Program	Camilla T. McCandless and Joseph J. Mello	1/24/22 Revised: 1/29/2022

SEDAR77-DW28	Standardized index of abundance for scalloped hammerhead sharks from the NOAA Northeast Fisheries Science Center coastal shark bottom longline survey	Camilla T. McCandless and Lisa J. Natanson.	1/7/22
SEDAR77-DW29	Standardized indices of abundance for scalloped hammerhead sharks from the South Carolina Department of Natural Resources red drum and Southeast Area Monitoring and Assessment Program longline surveys	Camilla T. McCandless and Bryan S. Frazier	1/7/22
SEDAR77-DW30	Standardized index of abundance for scalloped hammerhead sharks from the South Carolina Department of Natural Resources, Cooperative Atlantic States Shark Pupping and Nursery long-gillnet survey	Camilla T. McCandless, Bryan S. Frazier, James Gelsleichter, and Carolyn N. Belcher.	1/7/22
SEDAR77-DW31	Standardized index of abundance for scalloped hammerhead sharks from the South Carolina Department of Natural Resources, Cooperative Atlantic States Shark Pupping and Nursery long-gillnet survey	Camilla T. McCandless and Bryan S. Frazier	1/7/22
SEDAR77-DW32	Standardized index of abundance for scalloped hammerhead sharks from the South Carolina Department of Natural Resources, Cooperative Atlantic States Shark Pupping and Nursery short-gillnet survey	Camilla T. McCandless and Bryan S. Frazier	1/7/22
SEDAR77-DW33	Standardized index of abundance for scalloped hammerhead sharks from the University of North Carolina shark longline survey south of Shakleford Banks	Camilla T. McCandless and Joel Fodrie	1/7/22
SEDAR77-DW34	Movement and post-release mortality data for great hammerheads, *Sphyrna mokarran*, tagged during research bottom longline surveys in the northern Gulf of Mexico from 2012-2014	Eric R. Hoffmayer, Jill M. Hendon, Jennifer A. McKinney, Brett Falterman, William B. Driggers III	12/16/21

SEDAR77-DW35	Hammerhead post-release mortality data summary for SEDAR	N.M. Whitney, K.O. Lear, H.M. Marshall, J. Morris, A.M. Andres, C.F. White, T. Driggers, B. Prohaska, J. Gelsleichter, B. Frazier, R.D. Grubbs	12/17/2021
SEDAR77-DW36	Report on post-release mortality of scalloped hammerhead, *Sphyrna lewini*, and great hammerhead, *Sphyrna mokarran*	Jayne M. Gardiner, Tonya R. Wiley, Jorge Brenner	1/24/2022
SEDAR77-DW37	Revised bycatch estimates of scalloped and great hammerhead shark in the shark bottom longline fishery	Xinsheng Zhang, John Carlson, Enric Cortés, Elizabeth Babcock, Robert Latour	1/31/22
SEDAR77-DW38	Revised Bycatch Estimates of Scalloped and Great Hammerhead Shark in the Southeast Coastal Gillnet Fishery	Xinsheng Zhang, John Carlson, Enric Cortés, Elizabeth Babcock, Robert Latour	1/31/22
Document #	Title	Authors	Received
Reference Documents for the SEDAR 77 Data process			
SEDAR77-RD26	Age and growth of the great hammerhead shark, Sphyrna mokarran, in the north-western Atlantic Ocean and Gulf of Mexico	Andrew N. Piercy, John K. Carlson and Michelle S. Passerotti	9/8/2021
SEDAR77-RD27	Status Review Report: Great Hammerhead Shark *(Sphyrna mokarran)*	Margaret Miller, John Carlson, LeAnn Hogan, and Donald Kobayashi	9/8/2021
SEDAR77-RD28	Hammerhead Sharks of the Northwest Atlantic and Gulf of Mexico (2014 – 2020)	Lisa Clarke, Librarian, NOAA Central Library	9/8/2021

SEDAR77-RD29	Age validation of great hammerhead shark (*Sphyrna mokarran*), determined by bomb radiocarbon analysis	Michelle S. Passerotti John K. Carlson Andrew N. Piercy Steven E. Campana	9/8/2021
SEDAR77-RD30	Age and growth of the smooth hammerhead, Sphyrna zygaena, in the Atlantic Ocean: comparison with other hammerhead species	Daniela Rosa, Rui Coelho, Joana Fernandez-Carvalho & Miguel N. Santos	9/8/2021
SEDAR77-RD31	Status Review Report: Scalloped Hammerhead Shark (*Sphyrna lewini*)	Margaret H. Miller, Dr. John Carlson, Peter Cooper, Dr. Donald Kobayashi, Marta Nammack, and Jackie Wilson	9/8/2021
SEDAR77-RD32	Age and growth of the scalloped hammerhead shark, *Sphyrna lewini*, in the north-west Atlantic Ocean and Gulf of Mexico	Andrew N. Piercy, John K. Carlson, James A. Sulikowski and George H. Burgess	9/8/2021
SEDAR77-RD33	Scalloped hammerhead shark (Sphyrna lewini) 2014-2019	Trevor Riley, Head of Public Services, NOAA Central Library	9/8/2021
SEDAR77-RD34	The biology and conservation status of the large hammerhead shark complex: the great, scalloped, and smooth hammerheads	Austin J. Gallagher and A. Peter Klimley	9/8/2021
SEDAR77-RD35	Hooking mortality of scalloped hammerhead Sphyrna lewini and great hammerhead Sphyrna mokarran sharks caught on bottom longlines	SJB Gulak, AJ de Ron Santiago & JK Carlson	9/8/2021
SEDAR77-RD36	ENDANGERED SPECIES ACT STATUS REVIEW REPORT Smooth Hammerhead Shark (*Sphyrna zygaena*)	M.H. Miller	9/8/2021
SEDAR77-RD37	Scalloped Hammerhead Shark *(Sphyrna lewini)* 5-Year Review: Summary and Evaluation	National Marine Fisheries Service Office of Protected Resources Silver Spring, MD	9/8/2021

SEDAR77-RD38	Periodicity of the growth-band formation in vertebrae of juvenile scalloped hammerhead shark *Sphyrna lewini* from the Mexican Pacific Ocean	C. Coiraton,| J. Tovar-Ávila, K. C. Garcés-García, J. A. Rodríguez-Madrigal, R. Gallegos-Camacho, D. A. Chávez-Arrenquín, F. Amezcua	9/8/2021
SEDAR77-RD39	Range extension of the Endangered great hammerhead shark *Sphyrna mokarran* in the Northwest Atlantic: preliminary data and significance for conservation	Neil Hammerschlag, Austin J. Gallagher, Dominique M. Lazarre, and Curt Slonim	9/8/2021
SEDAR77-RD40	Identification of a nursery area for the critically endangered hammerhead shark (Sphyrna lewini) amid intense fisheries in the southern Gulf of Mexico	Gabriela Alejandra Cuevas-Gómez, Juan Carlos Pérez-Jiménez, Iván Méndez-Loeza, Maribel Carrera-Fernández, and José Leonardo Castillo-Géniz	9/8/2021
SEDAR77-RD41	SEDAR65-RD20 - An Updated Literature Review of Post-release Live-discard Mortality Rate Estimates in Sharks for use in SEDAR 65	Dean Courtney and Alyssa Mathers	9/23/2021
SEDAR77-RD42	Physiological stress response, reflex impairment, and survival of five sympatric shark species following experimental capture and release	A. J. Gallagher, J. E. Serafy, S. J. Cooke, N. Hammerschlag,	9/23/2021
SEDAR77-RD43	Integrating reflexes with physiological measures to evaluate coastal shark stress response to capture	J. M. Jerome, A. J. Gallagher, S. J. Cooke, and N. Hammerschlag	9/23/2021
SEDAR77-RD44	SEDAR29-WP17- A preliminary review of post-release live-discard mortality estimates for sharks.	Dean Courtney	12/14/21
SEDAR77-RD45	SEDAR34-WP08- A preliminary review of post-release live-discard mortality rate estimates in sharks for use in SEDAR 34	Dean Courtney	12/14/21

SEDAR77-RD46	SEDAR39-DW21 - A preliminary review of post-release live-discard mortality rate estimates in sharks for use in SEDAR 39.	Dean Courtney	12/14/21
SEDAR77-RD47	Updated Post-release Live-discard Mortality Rate and Range of Uncertainty Developed for Blacktip Sharks Captured in Hook and Line Recreational Fisheries for use in the SEDAR 29-Update	Dean Courtney	12/14/2021
SEDAR77-RD48	Meta-analysis of post-release fishing mortality in apex predatory pelagic sharks and white marlin	Michael K. Musyl and Eric L. Gilman	1/31/2022

2. Life History

Life History Workgroup participants

William Driggers, Co-Leader	National Marine Fisheries Service, Pascagoula, MS
Bryan Frazier, Co-leader	South Carolina Department of Natural Resources
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Michelle Passerotti	National Marine Fisheries Service, Narragansett, RI
David Portnoy	Texas A&M University, Corpus Christi, TX

2.1 Summary of Life History Documents

SEDAR77-DW03: Morphometric conversions for great hammerhead *Sphyrna mokarran* and scalloped hammerhead *Sphyrna lewini* from the western North Atlantic Ocean and Gulf of Mexico.
Lisa J. Natanson, Camilla T. McCandless, William B. Driggers III, Eric R. Hoffmayer, Bryan S. Frazier, Carolyn N. Belcher, James Gelsleichter, and Michelle S. Passerotti

Morphometric conversion equations were presented for great and scalloped hammerheads collected from United States waters of the western North Atlantic Ocean. Equations were given for each species relating fork length (FL), pre-caudal length, total length, stretched total length and whole weight. These data were derived from measurements of sharks sampled during research activities from 1961-2018. All FL – length relationships were pooled across sexes whereas FL – weight relationships were calculated separately for each sex and for sexes combined.

SEDAR77-DW11: Age and growth of the great hammerhead, *Sphyrna mokarran*, in the western North Atlantic Ocean.
William B. Driggers III, Christian M. Jones, Kristin M. Hannan, Andrew Piercy, and Bryan S. Frazier

Vertebrae were collected from 388 great hammerheads off the east coast of the United States and within the northern Gulf of Mexico, including 204 females, 179 males and five individuals of unknown sex, to assess the age and growth of the species. Female sharks ranged in size from 42-357 cm FL and males ranged in size from 40-297 cm FL. As the current study was an update to growth models presented by Piercy et al. (2010), we employed the identical standard ageing methods described in that study with the exception that no stain (i.e., crystal violet) was used to elucidate growth bands as bands were readily visible in non-stained vertebra.

Three parameter von Bertalanffy growth models were fitted to age and length data from both sexes and sexes combined using parameters reported by Piercy et al. (2010) as initial estimates. As expected, females (L_∞ = 323.9 mm FL, k = 0.11, t_o = -2.06 years) had a higher asymptotic length and lower growth constant than males (L_∞ = 249.4 mm FL, k = 0.20, t_o = -1.37 years) and there was a significant difference among VBGF parameter estimates between the sexes (χ^2 = 113.21, $p < 0.01$). The maximum observed ages for females and males were 35 years and 38 years, respectively. These maximum observed ages were lower than those found by Piercy et al. (2010) who reported maximum observed ages of 44 years for females and 42 years for males.

SEDAR77-DW18: Reproductive parameters of great hammerhead sharks (*Sphyrna mokarran*) and scalloped hammerhead sharks (*Sphyrna lewini*) from the western North Atlantic Ocean.
Heather E. Moncrief-Cox, Kristin M. Hannan, Michelle S. Passerotti, William B. Driggers III and Bryan S. Frazier

Maturity at length and at age was evaluated for great and scalloped hammerheads from the east coast of the United States (hereafter Atlantic) and Gulf of Mexico. Binomial maturity data were fit to length and age maturity ogives using generalized linear models with a logit link, following the methods of Natanson et al. (2019). Ages for great hammerheads were provided by Driggers et al. (SEDAR77-DW11) and scalloped hammerhead age data were provided by Frazier et al. (SEDAR77-DW19).

Maturity data were available for 751 great hammerheads, of which 86 had associated ages. Most individuals evaluated were captured in the Gulf Mexico (n = 617 and n = 55 for length and age data, respectively). Males ranged in size from 50.0 – 298.0 cm FL, with the median length at maturity (L_{50}) being 200.56 cm FL (L_{50} SE = 1.63, a = -19.144, b = 0.095) for both regions combined. Minimum and maximum observed sizes for females in the Atlantic and Gulf of Mexico were 48.0 cm and 360.0 cm FL, respectively, with L_{50} estimated to be 206.83 cm FL (L_{50} SE = 2.89; a = -21.286, b = 0.103). The age at which 50% of males were mature (A_{50}) for both regions combined was 7.8 years (A_{50} SE = 0.49, a = -8.876, b = 1.137), and 8.1 years for females (A_{50} SE = 0.70, a = -7.569, b = 0.937); however, additional age data are needed to improve confidence in these values.

A total of 1,537 scalloped hammerheads had maturity status information available to evaluate median length at maturity, with fork lengths ranging from 27.0 – 289.0 cm FL. Age information was available for 459 individuals from the Atlantic and 174 from the Gulf of Mexico. Due to the presence of Carolina hammerheads and Carolina-scalloped hammerhead hybrids in the Atlantic, the regions were analyzed separately. In the Atlantic, male L_{50} and A_{50} were 158.31 cm FL (L_{50} SE = 1.99, a = -21.937, b = 0.139) and 12.4 years (A_{50} SE = 0.44, a = -7.670, b = 0.619), respectively. In the Gulf of Mexico, L_{50} was estimated at 142.94 cm (L_{50} SE = 1.55, a = -17.544, b = 0.123) and A_{50} was 8.6 years (A_{50} SE = 0.57, a = -8.080, b = 2.84). There was a significant difference in both L_{50} and A_{50} for males between the regions ($p < 0.001$ in both analyses). Females in the Atlantic had L_{50} estimated at 187.54 cm FL (L_{50} SE = 3.13, a = -45.626, b = 0.243), and A_{50} was 16.2 years (A_{50} SE = 0.78, a = -11.652, b = 0.721). Within the Gulf of Mexico, 50% of females matured at 176.50 cm FL (L_{50} SE = 16.80, a = -4941.910, b = 28.000) and 13.9 years (A_{50} SE = 6797.88, a = -55.677, b = 4.009). Females did not show a significant difference between regions, possibly due to the low sample size in the Atlantic (n = 8).

SEDAR77-DW19: Age and growth of scalloped (*Sphyrna lewini*) and Carolina (*Sphyrna gilberti*) hammerheads in the western North Atlantic Ocean.
Bryan S. Frazier, Ashley S. Galloway, Lisa J. Natanson, Andrew N. Piercy, and William B. Driggers III

Scalloped hammerhead

Vertebrae from scalloped hammerheads were collected from a variety of fishery dependent and independent sources, including archived samples used by Piercy et al. (2007). Because Carolina and scalloped hammerheads are sympatric in at least a portion of their known ranges (i.e., off the east coast) and are indistinguishable relying solely on their external morphologies, fin clips were taken when possible and samples were identified to species level using genomic techniques (Barker et al. 2021). As fin clips were not available for archived specimens, we could not determine if Carolina hammerhead samples were present. Despite extensive sampling, the Carolina hammerhead has not been detected in the Gulf of Mexico but is known to occur along the U.S. east coast (hereafter, Atlantic) (Barker et al. 2021). Therefore, samples from the Atlantic were assumed to include both scalloped and Carolina hammerheads while samples from the Gulf of Mexico were assumed to be solely scalloped hammerheads. Standard techniques were used to section vertebrae and estimate ages and were similar to those used by Piercy et al. (2010).

Atlantic and Gulf of Mexico combined

A total of 1,026 vertebrae were available for analysis. Of these, 403 were females (27-245 cm FL range), and 623 were males (27.6-287 cm FL). Three parameter von Bertalanffy growth models were fit to females, males, and sexes combined. Model results indicate females (L_∞ = 229.2 cm FL, k = 0.086, t_o = -2.35 years) and males (L_∞ = 230.1 cm FL, k = 0.092, t_o = -2.17 years) had similar estimates of average asymptotic length and growth coefficient, although there was a significant difference among VBGF parameter estimates between the sexes (χ^2 = 19.00, p < 0.001). However, it should be noted samples from presumed mature females were lacking compared to those available for males. Maximum estimated ages were 29.5 for females, and 39.5 for males. Previous age and growth work by Piercy et al. (2007) found maximum estimated ages of 30.5 for both sexes. Region-specific growth models were significantly different (χ^2 = 48.15, p < 0.001) with scalloped hammerheads in the Atlantic reaching a larger asymptotic length and lower growth constant compared to individuals from the Gulf of Mexico.

Gulf of Mexico

A total of 291 vertebrae from scalloped hammerheads collected in the Gulf of Mexico were available for age analysis. Vertebrae from 107 females and 184 males were available for growth modeling. Female sharks ranged in size from 30-235 cm FL and males ranged in size from 35-223 cm FL. Sample sizes were lower for the Gulf of Mexico compared to the Atlantic and samples of mature female scalloped hammerheads were limited. Three parameter von Bertalanffy growth models were fit to length and age data for females, males, and sexes combined. Model results indicate females (L_∞ = 234.5 cm FL, k = 0.084, t_o = -2.41 years) had a higher asymptotic length and lower growth constant than males (L_∞ = 210.5 cm FL, k = 0.122, t_o = -1.82 years). Maximum estimated ages were 24.5 for females, and 37.5 for males.

Vertebral sample were available for 708 scalloped hammerheads from the Atlantic, of which 285 were females and 423 were males. Female sharks ranged in size from 27-245 cm FL and males ranged in size from 28-287 cm FL. Three parameter von Bertalanffy growth models were fit to sex-specific and combined sexes length and age data. Model results indicated females (L_∞ = 225.8 cm FL, k = 0.089, t_o = -2.29 years) had a lower asymptotic length and slightly higher growth constant than males (L_∞ = 242.1 cm FL, k = 0.081, t_o = -2.33 years) and there was a significant difference among VBGF parameter estimates between the sexes (X^2 = 19.00, $p < 0.001$). Maximum estimated ages were 29.5 for females, and 39.5 for males.

Carolina hammerhead

A total of 76 vertebrae were available for construction of growth curves for Carolina hammerheads (all from the Atlantic). Unfortunately, insufficient samples were available to generate robust estimates of growth in this species. Further, all but one of the vertebral samples from genetically verified Carolina hammerheads were from individuals 4 years of age or less.

2.2 Life History Information Summary and Consensus

2.2.1 Age and Growth Datasets and Decisions

Scalloped hammerhead

Age estimates for 1,026 scalloped hammerheads (403 females and 623 males) were used to generate region and sex-specific growth curves as well as growth curves for combined regions and sexes. Age estimates reported in Frazier et al. (SEDAR77-DW19) were considered accurate and reliable as between reader agreement was high (70.8%) and 92.8% of age estimates were within ± 1 band. This conclusion was supported by a low inter-reader index of average percentage error (5.5%) and coefficient of variation (7.6%). Three parameter von Bertalanffy growth models were fit to age and length data for female, male, and combined sexes age for the combined Atlantic and Gulf of Mexico areas. While results indicated females and males had similar asymptotic length and growth coefficient estimates, there was a significant difference among VBGF parameter estimates between the sexes (χ^2 = 19.00, $p < 0.001$). Further, region-specific (i.e. Atlantic vs. Gulf of Mexico) growth models were significantly different (χ^2 = 48.15, $p < 0.001$) with scalloped hammerheads in the Atlantic reaching a larger asymptotic length and lower growth constant compared to individuals from the Gulf of Mexico. The regional differences in growth coupled with the inclusion of an unknown number of samples from the cryptic Carolina hammerhead among Atlantic samples led the Life History Group to agree that region-specific growth model parameter estimates should be used for scalloped hammerheads.

When comparing region and sex-specific growth models, there was no significant difference in the growth of females between regions (χ^2 = 1.02, p = 0.796) while VBGF parameter estimates were significantly different between regions for males (χ^2 = 48.15, $p < 0.001$). Frazier et al. (SEDAR77-DW19) suggested that VBGF parameter estimates for the Gulf of Mexico were based on the inclusion of a limited number of samples from large, mature females and thus possibly do not reflect true population parameters in this region. Regardless, the Life History Group concluded that these are the best available estimates of sex and region-specific growth for the species. Among all vertebral samples aged, the oldest observed individual in the Atlantic was a 39.5 year old male while the oldest individual collected from the Gulf of Mexico was a 37.5 year old male: the previous maximum observed age for the species was 30.5 years. This individual was 9 years older than the oldest aged specimen from Piercy et al. (2007).

Decision: Use region and sex-specific growth model parameters estimates and a maximum age of 39.5 years for both regions as presented in SEDAR77-DW19.

Carolina hammerhead

Limited life history data were available for the Carolina hammerhead. Frazier et al. (SEDAR77-DW19) produced a growth model using the available data, however, there was a paucity of large juvenile and adult samples. Therefore, the Life History Working Group had no confidence that model results were representative of Carolina hammerhead population life history.

Decision: Combine Carolina hammerhead age and growth samples with Atlantic scalloped hammerhead samples to produce sex-specific growth models containing both species.

Great hammerhead

Age and growth information was presented by Driggers et al. (SEDAR77-DW-11) based on analyses of vertebral centra from 388 great hammerheads collected from fishery dependent and independent sources in United States waters of the western North Atlantic Ocean. Included among these samples were 92 vertebrae included in the growth model presented by Piercy et al. (2010); however, not all samples utilized by Piercy et al. (2010) were available for reanalysis. Sharks aged by Driggers et al. (SEDAR77-DW-11) ranged in size from 42-357 cm FL and 40-297 cm FL for females and males, respectively. Based on high between-reader agreement (84% of counts in agreement, 96% of counts within one year, 100% of counts within 2 years), and low inter-reader index of average percentage error (0.92%) and coefficient of variation (1.30%), ages were considered accurate and reliable. Three parameter von Bertalanffy growth models were generated and models for females and males were significantly different from one another. The maximum observed ages by Driggers et al. (SEDAR77-DW-11) for females and males were 35 years and 38 years, respectively. These maximum observed ages were lower than those found by Piercy et al. (2010) who reported maximum observed ages of 44 years for females and 42 years for males. Based on direct observation and bomb radiocarbon analysis, Passerotti et al. (2010) validated an age of 42 years for a great hammerhead collected off the east coast of the United States.

Decision: Use sex-specific growth model parameters from SEDAR77-DW-11 and a maximum age of 42 years from Passerotti et al. (2010).

Smooth hammerhead

No age and growth information or data for smooth hammerheads were available for the US waters of the western North Atlantic Ocean. Therefore, the Life History Working Group reviewed the available literature to determine the most appropriate age and growth data to use for smooth hammerheads. After review, von Bertalanffy parameters from Rosa et al. (2017) were deemed most appropriate as this study contained samples from the northern and southern hemispheres in the Atlantic Ocean.

Decision: Use sex-specific growth model parameters and maximum ages from Rosa et al. (2017).

2.2.2 Reproduction Datasets and Decisions

Scalloped hammerhead

Age and size at maturity ogives for scalloped hammerheads were presented in SEDAR77-DW18. These were based on data collected from fishery dependent and independent sources, including the SEFSC, NEFSC, South Carolina Department of Natural Resources, Mote Marine Laboratory, University of Florida, Dauphin Island Sea Lab, and the Gulf of Mexico Shark Pupping and Nursery Project. The resulting region and sex-specific ogives were based on a robust sample size and larger sample size than previously available.

Decision: Use region-specific age and size at maturity ogives reported for scalloped hammerheads in SEDAR77-DW18 and summarized in Table 1 and maturity schedules listed in Tables 5 and 6.

Despite the common occurrence and frequent capture of scalloped hammerheads, surprisingly few studies have examined their reproductive biology in United States waters of the western North Atlantic Ocean with none being notable or examining the species in detail. Based on the concurrent presence of vitellogenic ovarian follicles and developing embryos, Castro (2009) demonstrated that scalloped hammerheads off the southeastern United States have an annual reproductive cycle. This finding is in agreement with other studies examining the reproductive cycle of the species in other regions (e.g., Hazin et al., 2001; Torres-Huerta et al., 2008). The Life History Group determined the mean fecundity of scalloped hammerheads to be 18 pups per brood (S.D. = 7.67) based on data obtained from various unpublished sources (NEFSC, SEFSC, SCDNR, Florida State University, University of Florida). Based on these data, and in agreement with Hazin et al. (2001), there was no relationship between maternal length and brood size. The gestation period of scalloped hammerheads is considered to be 10-11 months based on a limited number of observations reported in Castro (2011); an estimate similar to gestation times suggested in other parts of the species' range (e.g., Branstetter, 1987; Chen et al., 1988; Stevens and Lyle, 1989; Hazin et al., 2001). Parturition in the southeastern United States occurs during May through June (Ulrich et al. 2007). Data from 351 individuals with an open umbilicus collected in South Carolina waters during May and June indicated that the mean size at birth for scalloped hammerheads is 352 mm FL (S.D. = 31.8).

Decision: Use reproductive characteristics summarized above and in Tables 1.

Carolina hammerhead

Because the Carolina hammerhead was only recently described (i.e., 2013) and that, externally, it is morphologically indistinguishable from the scalloped hammerhead, there has been very limited targeted sampling of the species and almost nothing is known about its basic biology. The only aspect of the species' reproductive biology that are known are that parturition occurs during June and the mean size at birth is 315.3 mm FL (S.D. = 18.5)(B. Frazier, unpublished data). What limited information that is available for Carolina hammerheads is summarized in Table 2.

Decision: Insufficient data to describe the basic reproductive biology of the Carolina hammerhead.

Great hammerhead

Age and size at maturity ogives were presented in SEDAR77-DW18 and based on length and maturity data taken from 751 individuals collected by a number of sources, including the SEFSC, NEFSC, Florida State University, Gulf Coast Research Laboratory and the University of Florida. The resulting sex-specific ogives were based on a robust sample size and larger sample size than previously available.

Decision: Use sex-specific age and size at maturity ogives reported for great hammerheads in SEDAR77-DW18 and summarized in Table 3. and maturity schedules listed in Tables 7 and 8.

Stevens and Lyle (1989) examined the reproductive system of great hammerheads collected off northern Australia and noted the lack of ovarian activity in pregnant females. Thus, they concluded the species reproduces on a biennial cycle. This finding was supported by Castro (2011), who reported observing females nearing parturition with inactive ovaries. Fecundity data were very limited in the primary literature, therefore, the Life History Group compiled information from all available published records (e.g., Springer, 1938, 1940; Baughman and Springer, 1950; Clark and von Schmidt, 1965; Dodrill, 1977; Castro, 2011) and supplemented those data with unpublished records from the NEFSC and E. Hoffmayer. The mean brood size of great hammerheads was determined to be 30.93 pups per brood (S.D. = 10.74). Gestation was determined to be 11-12 months by Cadenat and Blache (1981), Stevens and Lyle (1989) and Castro (2011) based primarily on the development of embryos and comparisons of months associated with mating times and presence of postpartum females. Parturition occurs in late spring/ early summer (Clark and von Schmidt, 1965) off the west coast of Florida. As location of pupping grounds are currently unknown for great hammerheads in the western North Atlantic Ocean, the Life History Group determined the time of parturition observed off western Florida was likely representative of what occurs in the western North Atlantic in general. There was a significant relationship between maternal length and brood size (provided in Table 3) based on data reported in Springer (1938), Clark and von Schmidt (1965), Dodrill (1977) and Castro (2011) in addition to unpublished data from the NEFSC and E. Hoffmayer. Piercy et al. (2010) reported that the size at birth for great hammerheads is 50 cm FL; a size similar to the range of sizes (46-54 cm FL) of free swimming, presumed neonates observed in South Corlina waters (B. Frazier, unpublished data).

Decision: Use reproductive characteristics summarized above and in Table 3.

Smooth hammerhead

No new data related to the reproductive biology of smooth hammerheads were presented or available from fisheries dependent or independent sources in the western North Atlantic Ocean. Therefore, the Life History Group relied on published information to determine which of the available data were most appropriate to describe the reproductive biology of the species in United States waters of the western North Atlantic Ocean. Size at 50% maturity for females (200 cm FL) and males (193.7 cm FL) were obtained from Nava Nava and Marquez-Farias (2014), who examined

1,041 individuals collected in the Gulf of California from 1995-2000. Unfortunately, no *a* and *b* parameter estimates were reported for the presented ogives and age at maturity was not assessed. To provide an estimate for age at 50% maturity we back transformed the age at the reported sizes at 50% maturity reported by Nava Nava and Marquez-Farias (2014) for females and males, which were 10.5 years and 10.4, respectively, using the VBGF parameter estimates provided by Rosa et al. (2017).

There are very limited data available to describe the basic reproductive biology of the smooth hammerhead and, as a result, the Life History Group had to rely on information from a number of published sources, most based on studies conducted outside of the western North Atlantic Ocean. Based on the examination of 21 gravid females collected from a commercial longline fishery operating in the Gulf of Guinea, Castro and Mejuto (1995) reported that the mean brood size for smooth hammerheads is 33.5, which was consistent with the brood size range of 29-37 reported by Bigelow and Schroeder (1948) and 20-50 reported by Ebert and Stehmann (2013). The only information the Life History Group could locate regarding the reproductive periodicity for female smooth hammerheads was Castro (2011) who reports having examined two gravid females with inactive ovaries indicating these females were reproducing on a biennial cycle. Castro (2011) also stated that he observed no appendiculae on the umbilical cords of these gravid females. This is consistent with a biennial cycle among placentally viviparous sharks within the order Carcharhiniformes as species with an exclusively annual reproductive cycle have appendiculae present on their umbilical cords (e.g. Atlantic sharpnose sharks (*Rhizoprionodon terraenovae*), bonnetheads (*Sphyrna tiburo*) and scalloped hammerheads). A gestation time of 10-11 months was suggested by White et al. (2006), however, there was no supporting information. No relationship between maternal length and fecundity was available. The size at birth for smooth hammerheads is 50.3 cm FL based on conversion of the reported TL at birth of 55 cm TL from Coelho et al. (2011) and Rosa et al. (2017).

Decision: Use reproductive characteristics described above and summarized in Table 4.

2.3 Research recommendations:

- Increase data and sample collection in all forms necessary for informing age related parameters for all hammerhead species, with particular attention to Carolina and smooth hammerheads of both sexes and female scalloped hammerheads.
- Investigate alternative methods for non-lethal estimation of age and/or maturity status (e.g., epigenetic ageing). Conduct age validation studies on scalloped hammerheads to reduce uncertainty in band counting methodology.
- Increased reproductive sampling for all species throughout their range, especially with regard to brood size, gestation period, and reproductive cycle.
- Improve standardization of reproductive measurements and sampling techniques across research groups to facilitate better estimates of reproductive parameters.
- Increase genetic surveillance of scalloped and Carolina hammerheads in the Atlantic in order to further delineate species-specific life history traits and important habitats
- Continued genetic monitoring of Carolina and scalloped hammerheads within nurseries to track the relative abundance of the two species.

- Determine life-stage specific movement patterns and habitat utilization for all hammerhead species using electronic tagging, with particular attention to identifying pupping areas for great and smooth hammerheads.
- Assess stock structure and movement between Caribbean and U.S. waters for scalloped and great hammerheads.
- Identify species-specific abiotic characteristics driving distributions and how environmental changes could impact the life history and distribution of hammerheads in the western North Atlantic Ocean.

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2.4 Tables

Table 1 Summary of life history parameters for scalloped hammerheads (*Sphyrna lewini*) in the western North Atlantic Ocean.

Life History Workgroup	Region	Summary of scalloped hammerhead biological inputs for 2022 assessment	Reference
Growth parameters		Female / Male / Combined	
L_∞ (cm FL)	Combined	229.2 (5.44)/ 230.1 (2.77)/ 232.2 (2.47)	SEDAR77-DW-19
k	Combined	0.086 (0.005)/ 0.092 (0.003)/ 0.088 (0.002)	SEDAR77-DW-19
t_o (years)	Combined	-2.352 (0.11)/ -2.166 (0.10)/ -2.262 (0.07)	SEDAR77-DW-19
Maximum observed age (years)	Combined	29.5 / 39.5	SEDAR77-DW-19
Sample size	Combined	403 / 623 / 1026	SEDAR77-DW-19
L_∞ (cm FL)	GOM	234.5 (12.89)/ 210.5 (3.90)/ 216.0 (3.61)	SEDAR77-DW-19
k	GOM	0.084 (0.009)(/ 0.122 (0.008)/ 0.108 (0.005)	SEDAR77-DW-19
t_o (years)	GOM	-2.407 (0.17)/ -1.818 (0.18)/ -1.998 (0.13)	SEDAR77-DW-19
Maximum observed age (years)	GOM	24.5 / 37.5	SEDAR77-DW-19
Sample size	GOM	107 / 184 / 291	SEDAR77-DW-19
L_∞ (cm FL)	Atlantic	225.8 (6.33)/ 242.1 (3.65)/ 241.0 (3.28)	SEDAR77-DW-19
K	Atlantic	0.089 (0.006)/ 0.081 (0.003)/ 0.080 (0.003)	SEDAR77-DW-19
t_o (years)	Atlantic	-2.29 (0.14)/ -2.33 (0.11)/ -2.38 (0.09)	SEDAR77-DW-19
Maximum observed age (years)	Atlantic	29.5/ 39.5*	SEDAR77-DW-19
Sample size	Atlantic	285 / 423 / 708	SEDAR77-DW-19
Length-weight relationships			
PCL in cm		PCL= (0.909)FL-0.265	SEDAR77-DW03
TL in cm		TL = (1.281)FL+0.218	SEDAR77-DW03
STL in cm		STL = (1.305)FL+0.596	SEDAR77-DW03
WT in kg Combined		WT=(1.161e-5)$FL^{2.988}$	SEDAR77-DW03
WT in kg Female		WT=(5.774e-6)$FL^{3.128}$	SEDAR77-DW03
WT in kg Male		WT=(1.778e-5)$FL^{2.905}$	SEDAR77-DW03
Age at 50% maturity ogive			
Female (n =220)	Combined	t_{mat} = 16.11 years *a* = -11.979 (3.80), *b* = 0.744 (0.24)	SEDAR77-DW18
Male (n= 413)	Combined	t_{mat} = 11.31 years *a* = -6.317 (0.82), *b* = 0.559 (0.07)	SEDAR77-DW18
Size at 50% maturity ogive			
Female (n= 473)	Combined	FL_{mat} = 183.93 cm FL *a* = -35.342 (10.57), *b* = 0.192 (0.06)	SEDAR77-DW18
Male (n= 1064)	Combined	FL_{mat} = 147.48 cm FL *a* = -16.127 (1.30), *b* = 0.109 (0.01)	SEDAR77-DW18
Age at 50% maturity ogive			
Female (n= 56)	GOM	t_{mat} = 13.89 years *a* = -55.677 (62741.45), *b* = 4.009 (4967.34)	SEDAR77-DW18
Male (n= 118	GOM	t_{mat} = 8.60 years *a* = -8.08 (2.84), *b* = 0.94 (0.32)	SEDAR77-DW18
Size at 50% maturity ogive			
Female (n= 289)	GOM	FL_{mat} = 176.50 cm FL *a* = -4941.9 (166040.49), *b* = 28.0 (940.67)	SEDAR77-DW18
Male (n= 656)	GOM	FL_{mat} = 142.94 cm FL *a* = -17.544 (1.81), *b* = 0.123 (0.01)	SEDAR77-DW18
Age at 50% maturity ogive			
Female (n= 164)	Atlantic	t_{mat} = 16.16 years *a* = -11.652 (3.84), *b* = 0.721 (0.25)	SEDAR77-DW18
Male (n= 295)	Atlantic	t_{mat} = 12.39 years *a* = -7.670 (1.31), *b* = 0.619 (0.10)	SEDAR77-DW18
Size at 50% maturity ogive			
Female (n= 184)	Atlantic	FL_{mat} = 187.54 cm FL *a* = -45.626 (19.93), *b* = 0.243 (0.10)	SEDAR77-DW18
Male (n= 408)	Atlantic	FL_{mat} = 158.31 cm FL *a* = -21.937 (3.24), *b* = 0.139 (0.042)	SEDAR77-DW18
Reproductive cycle		Annual	Castro 2009
Fecundity		18 (SD = 7.67); range 7-30 (n=11)	NMFS unpublished, Castro 2011
Size at birth		352.0 m FL (S.D. = 31.8) (n = 351)	Frazier, unpublished
Gestation		10-12 months	Castro 2011
Pupping month		May – June	Ulrich et al. 2007
Fecundity-maternal size relationship		No relationship	NFMS unpublished, Castro 2011
*Recommended use of male maximum age for species			

*All values in parentheses are standard error unless indicated otherwise

Table 2. Summary of life history parameters for Carolina hammerheads (*Sphyrna gilberti*) in the western North Atlantic Ocean.

Life History Workgroup	Summary of Carolina hammerhead biological inputs for 2022 assessment	Reference
Growth parameters	Combined	
L_∞ (cm FL)	192*	SEDAR77-DW19
k	0.21*	SEDAR77-DW19
t_o (years)	-0.99*	SEDAR77-DW19
Maximum observed age (years)	21.5*	SEDAR77-DW19
Sample size	78	SEDAR77-DW19
Length-weight relationships**		
PCL in cm	PCL= (0.909)FL-0.265	SEDAR77-DW03
TL in cm	TL = (1.281)FL+0.218	SEDAR77-DW03
STL in cm	STL = (1.305)FL+0.596	SEDAR77-DW03
WT in kg Combined	$WT=(1.161e\text{-}5)FL^{2.988}$	SEDAR77-DW03
WT in kg Males	$WT=(5.774e\text{-}6)FL^{3.128}$	SEDAR77-DW03
WT in kg Females	$WT=(1.778e\text{-}5)FL^{2.905}$	SEDAR77-DW03
Age at 50% maturity ogive		
Female	Unknown	
Male	Unknown	
Size at 50% maturity ogive		
Female	Unknown	
Male	Unknown	
Reproductive cycle		
Fecundity	Unknown	
Size at birth	315.3 mm FL (S.D. = 18.5)	Frazier, unpublished
Gestation		
Pupping month	June	Frazier, unpublished
Fecundity-maternal size relationship	Unknown	

*Limited samples did not yield robust growth curves
**Recommended use of length-weight relationships from scalloped hammerhead

Table 3. Summary of life history parameters for great hammerheads (*Sphyrna mokarran*) in the western North Atlantic Ocean.

Life History Workgroup	Summary of great hammerhead biological inputs for 2022 assessment	Reference
Growth parameters	Female / Male / Combined	
L_∞ (cm FL)	323.9 (7.49)/ 249.4 (3.36)/ 283.8 (3.96)	SEDAR77-DW11
k	0.11 (0.011)/ 0.20 (0.010)/ 0.15 (0.010)	SEDAR77-DW11
t_o (years)	-2.06 (0.20)/ -1.37 (0.14)/ -1.72 (0.14)	SEDAR77-DW11
Maximum observed age (years)	35 / 38 / 42*	SEDAR77-DW11, *recommended per SEDAR77-RD29
Sample size	204 / 179 / 388	SEDAR77-DW11
Length-weight relationships		
PCL in cm	PCL= (0.895)FL+1.652	SEDAR77-DW03
TL in cm	TL = (1.226)FL+9.139	SEDAR77-DW03
STL in cm	STL = (1.227)FL+14.13	SEDAR77-DW03
WT in kg Combined	$WT=(1.691e\text{-}5)FL^{2.912}$	SEDAR77-DW03
WT in kg Female	$WT=(9.275e\text{-}6)FL^{3.028}$	SEDAR77-DW03
WT in kg Male	$WT=(2.482e\text{-}5)FL^{2.836}$	SEDAR77-DW03
Age at 50% maturity ogive		
Female (n= 34)	t_{mat} = 8.1 years a = -7.569 (2.67), b = 0.937 (0.32)	SEDAR77-DW18
Male (n= 52)	t_{mat} = 7.8 years a = -8.876 (2.61), b = 1.137 (0.34)	SEDAR77-DW18
Size at 50% maturity ogive		
Female (n= 273)	FL_{mat} = 206.83 cm FL a = -21.286 (3.53), b = 0.103 (0.02)	SEDAR77-DW18
Male (n= 478)	FL_{mat} = 200.56 cm FL a = -19.144 (1.89), b = 0.095 (0.01)	SEDAR77-DW18
Reproductive cycle	Biennial	Stevens and Lyle 1989, Cortes et al. 2015
Fecundity	30.93 (SD = 10.74), range 13-56	Springer 1938, Springer 1940, Baughman and Springer, 1950, Clark and von Schmidt, 1965, Dodrill 1977, Castro 2011, NEFSC unpublished data, Hoffmayer unpublished data
Size at birth	500 mm FL	Piercy et al. 2010, Frazier unpublished
Gestation	11-12 months	Cadenat and Blache 1981,Stevens and Lyle 1989, Castro 2011
Pupping month	late spring/summer	Clark and von Schmidt 1965
Fecundity-maternal size relationship	Brood size = -67.9565 + 0.345301*FL, ($p < 0.01$, $r^2 = 0.90$)	Springer 1938, Baughman and Springer 1950, Clark and von Schmidt 1965, Dodrill 1977, Castro 2011, NEFSC unpublished data, Hoffmayer unpublished data

*All values in parentheses are standard error unless indicated otherwise

Table 4. Summary of life history parameters for smooth hammerheads (*Sphyrna zygaena*) in the western North Atlantic Ocean.

Life History Workgroup	Summary of smooth hammerhead biological inputs for 2022 assessment	Reference
Growth parameters	Female / Male / Combined	
L_∞ (cm FL)	293.9 / 284.6 / 288.2	Rosa et al. 2017
k	0.09 / 0.09 / 0.09	Rosa et al. 2017
L_0 (cm)	52.7 / 52.2 / 52.4	Rosa et al. 2017
Maximum observed age (years)	25 / 24 / 25	Rosa et al. 2017
Sample size	287	Rosa et al. 2017
Length-weight relationships		
FL in cm	TL = 12.72 + 0.84 FL	Coelho et al. 2011*
WT in kg Combined	$WT=(2.00e\text{-}6)FL^{3.329}$	Coelho (IPMA) unpublished data
Age at 50% maturity ogive		
Female	t_{mat} = 10.5 years	Nava Nava and Marquez-Farias (2014)**
Male	t_{mat} = 10.4 years	
Size at 50% maturity ogive		
Female	FL_{mat} = 200 cm FL	Nava Nava and Marquez-Farias 2014
Male	FL_{mat} = 193.7 cm FL	Nava Nava and Marquez-Farias 2014
Reproductive cycle	Biennial	Castro, 2011
Fecundity	33.5	Bigelow and Schroder, 1948, Castro and Mejuto 1995
Size at birth	50.3 cm FL	Coelho et al. 2011, Rosa et al. 2017.
Gestation	10-11 months	White et al. 2006
Pupping month	summer (January-March, NSW Australia)	Stevens 1984
Fecundity-maternal size relationship		

* Relationship misstated in publication as FL=12.72+0.84*TL. This results in FL>TL.
**Estimates at age at 50% maturity based on length at 50% maturity transformed using recommended von Bertalanffy growth parameters from Rosa et al. 2017.

Table 5. Proportion of mature scalloped hammerheads (*Sphyrna lewini*) in 5 cm size classes by sex and region.

	Sexes combined			Females			Males		
Fork length (cm)	Areas combined	Gulf of Mexico	Atlantic	Areas combined	Gulf of Mexico	Atlantic	Areas combined	Gulf of Mexico	Atlantic
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
105	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
110	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.02	0.00
115	0.02	0.01	0.00	0.00	0.00	0.00	0.03	0.03	0.00
120	0.03	0.03	0.01	0.00	0.00	0.00	0.05	0.06	0.01
125	0.04	0.05	0.01	0.00	0.00	0.00	0.08	0.10	0.01
130	0.07	0.08	0.02	0.00	0.00	0.00	0.12	0.17	0.02
135	0.11	0.14	0.03	0.00	0.00	0.00	0.20	0.28	0.04
140	0.17	0.22	0.05	0.00	0.00	0.00	0.30	0.42	0.08
145	0.25	0.34	0.09	0.00	0.00	0.00	0.42	0.57	0.14
150	0.35	0.49	0.16	0.00	0.00	0.00	0.56	0.71	0.25
155	0.48	0.63	0.26	0.00	0.00	0.00	0.68	0.82	0.40
160	0.60	0.76	0.39	0.01	0.00	0.00	0.79	0.89	0.58
165	0.71	0.85	0.53	0.03	0.00	0.00	0.87	0.94	0.73
170	0.80	0.91	0.68	0.06	0.00	0.01	0.92	0.97	0.84
175	0.87	0.95	0.79	0.15	0.00	0.04	0.95	0.98	0.92
180	0.92	0.97	0.87	0.31	1.00	0.13	0.97	0.99	0.96
185	0.95	0.98	0.93	0.54	1.00	0.34	0.98	0.99	0.98
190	0.97	0.99	0.96	0.76	1.00	0.63	0.99	1.00	0.99
195	0.98	1.00	0.98	0.89	1.00	0.85	0.99	1.00	0.99
200	0.99	1.00	0.99	0.96	1.00	0.95	1.00	1.00	1.00
205	0.99	1.00	0.99	0.98	-	0.99	1.00	1.00	1.00
210	1.00	1.00	1.00	0.99	-	1.00	1.00	1.00	1.00
215	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
220	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
225	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
230	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
235	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
240	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
245	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
250	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
255	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
260	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
265	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
270	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
275	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
280	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
285	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
290	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
295	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00
300	1.00	1.00	1.00	1.00	-	1.00	1.00	1.00	1.00

Table 6. Proportion of mature scalloped hammerheads (*Sphyrna lewini*) in 1 year age classes by sex.

	Sexes Combined			Females			Males		
Age (years)	Areas combined	Gulf of Mexico	Atlantic	Areas combined	Gulf of Mexico	Atlantic	Areas combined	Gulf of Mexico	Atlantic
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.00
3	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.61	0.00
4	0.01	0.01	0.00	0.00	0.00	0.00	0.02	0.96	0.01
5	0.02	0.02	0.01	0.00	0.00	0.00	0.03	1.00	0.01
6	0.03	0.05	0.01	0.00	0.00	0.00	0.05	1.00	0.02
7	0.06	0.12	0.03	0.00	0.00	0.00	0.08	1.00	0.03
8	0.09	0.28	0.05	0.00	0.00	0.00	0.14	1.00	0.06
9	0.15	0.52	0.08	0.01	0.00	0.01	0.22	1.00	0.11
10	0.23	0.75	0.13	0.01	0.00	0.01	0.33	1.00	0.19
11	0.34	0.89	0.21	0.02	0.00	0.02	0.46	1.00	0.30
12	0.46	0.96	0.33	0.05	0.00	0.05	0.60	1.00	0.44
13	0.59	0.98	0.47	0.09	0.03	0.09	0.72	1.00	0.59
14	0.71	0.99	0.61	0.17	0.61	0.17	0.82	1.00	0.73
15	0.81	1.00	0.73	0.31	0.99	0.30	0.89	1.00	0.83
16	0.88	1.00	0.83	0.48	1.00	0.47	0.93	1.00	0.90
17	0.92	1.00	0.90	0.66	1.00	0.65	0.96	1.00	0.95
18	0.95	1.00	0.94	0.80	1.00	0.79	0.98	1.00	0.97
19	0.97	1.00	0.97	0.90	1.00	0.89	0.99	1.00	0.98
20	0.98	1.00	0.98	0.95	1.00	0.94	0.99	1.00	0.99
21	0.99	1.00	0.99	0.97	1.00	0.97	1.00	1.00	1.00
22	0.99	1.00	0.99	0.99	1.00	0.99	1.00	1.00	1.00
23	1.00	1.00	1.00	0.99	1.00	0.99	1.00	1.00	1.00
24	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
28	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
29	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
30	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
31	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
32	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
34	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
35	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
36	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
37	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
38	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
39	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
40	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 7. Proportion of mature great hammerheads (*Sphyrna mokarran*) in 5 cm size classes by sex.

Fork length (cm)	Sexes Combined	Females	Males
40	0.00	0.00	0.00
45	0.00	0.00	0.00
50	0.00	0.00	0.00
55	0.00	0.00	0.00
60	0.00	0.00	0.00
65	0.00	0.00	0.00
70	0.00	0.00	0.00
75	0.00	0.00	0.00
80	0.00	0.00	0.00
85	0.00	0.00	0.00
90	0.00	0.00	0.00
95	0.00	0.00	0.00
100	0.00	0.00	0.00
105	0.00	0.00	0.00
110	0.00	0.00	0.00
115	0.00	0.00	0.00
120	0.00	0.00	0.00
125	0.00	0.00	0.00
130	0.00	0.00	0.00
135	0.00	0.00	0.00
140	0.00	0.00	0.00
145	0.01	0.00	0.00
150	0.01	0.00	0.01
155	0.02	0.00	0.01
160	0.03	0.01	0.02
165	0.04	0.01	0.03
170	0.07	0.02	0.05
175	0.11	0.04	0.07
180	0.16	0.06	0.11
185	0.24	0.10	0.17
190	0.35	0.15	0.25
195	0.47	0.23	0.35
200	0.59	0.33	0.46
205	0.70	0.46	0.58
210	0.80	0.59	0.69
215	0.87	0.70	0.78
220	0.91	0.80	0.85
225	0.95	0.87	0.90
230	0.97	0.92	0.94
235	0.98	0.95	0.96
240	0.99	0.97	0.97
245	0.99	0.98	0.98
250	1.00	0.99	0.99
255	1.00	0.99	0.99
260	1.00	1.00	1.00
265	1.00	1.00	1.00
270	1.00	1.00	1.00
275	1.00	1.00	1.00
280	1.00	1.00	1.00
285	1.00	1.00	1.00
290	1.00	1.00	1.00
295	1.00	1.00	1.00
300	1.00	1.00	1.00
305	1.00	1.00	1.00
310	1.00	1.00	1.00
315	1.00	1.00	1.00
320	1.00	1.00	1.00
325	1.00	1.00	1.00
330	1.00	1.00	1.00
335	1.00	1.00	1.00
340	1.00	1.00	1.00
345	1.00	1.00	1.00
350	1.00	1.00	1.00
355	1.00	1.00	1.00
360	1.00	1.00	1.00

Table 8. Proportion of mature great hammerheads (*Sphyrna mokarran*) in 1 year age classes by sex.

Age (years)	Sexes Combined	Females	Males
0	0.00	0.00	0.00
1	0.00	0.00	0.00
2	0.00	0.00	0.00
3	0.01	0.01	0.00
4	0.02	0.02	0.01
5	0.05	0.05	0.04
6	0.12	0.12	0.11
7	0.28	0.27	0.29
8	0.53	0.48	0.55
9	0.76	0.70	0.80
10	0.90	0.86	0.92
11	0.96	0.94	0.97
12	0.99	0.98	0.99
13	1.00	0.99	1.00
14	1.00	1.00	1.00
15	1.00	1.00	1.00
16	1.00	1.00	1.00
17	1.00	1.00	1.00
18	1.00	1.00	1.00
19	1.00	1.00	1.00
20	1.00	1.00	1.00
21	1.00	1.00	1.00
22	1.00	1.00	1.00
23	1.00	1.00	1.00
24	1.00	1.00	1.00
25	1.00	1.00	1.00
26	1.00	1.00	1.00
27	1.00	1.00	1.00
28	1.00	1.00	1.00
29	1.00	1.00	1.00
30	1.00	1.00	1.00
31	1.00	1.00	1.00
32	1.00	1.00	1.00
33	1.00	1.00	1.00
34	1.00	1.00	1.00
35	1.00	1.00	1.00
36	1.00	1.00	1.00
37	1.00	1.00	1.00
38	1.00	1.00	1.00
39	1.00	1.00	1.00
40	1.00	1.00	1.00
41	1.00	1.00	1.00
42	1.00	1.00	1.00

3. Catches

Catches Panel

Heather Baertlein, co-Leader.………… .…………………………..………NMFS HMS Division
Enric Cortés, Leader…………………………………………………….....NMFS Panama City
Cliff Hutt…………………………………………………………...….NMFS HMS Division
Alyssa Mathers……………………………………………………………. NMFS Panama City
Vivian Matter, *not present*………………………………………………….. NMFS Miami
Xinsheng Zhang, Commercial Bycatch Leader.…………………..…….… NMFS Panama City

Ad-hoc working group on Post-Release Live Discard Mortality (PRLDM)

SEDAR Pool members:

Banks, Kesley…………………………………………………….....… Texas A&M University
Courtney, Dean, Ad-Hoc WG Leader…….…………………………………..NMFS Panama City
Drymon, Marcus……………………………………………...………Mississippi State University
Frazier, Bryan…………………………………………………………...…South Carolina DNR
Gardiner, Jayne…………………………………………………….…...New College of Florida
Gelsleichter, Jim……………………………………………………………………....UNF
Grubbs, Dean………………………………………………………………………..FSU
Hammerschlag, Neil……………………………………………...………RSMAS, U. of Miami
Hoffmayer, Eric……………………………………………...……………NMFS Pascagoula
Hutt, Cliff……………………………………………………..…………….NMFS HMS Division
Medd, Hannah…………………………………………………………American Shark Conservancy
Wells, David……………………………..………………...…………Texas A&M University
.
Working paper or data providers who participated in PRLDM ad-hoc WG discussions but were not part of SEDAR pool:

Gulak, Simon…………………………………………………………..………Mar Alliance
Whitney, Nick…………………………………………………………New England Aquarium

List of Working and Reference Papers

Documents Prepared for the Data Workshop Process		
SEDAR77-DW4	Preliminary catches of hammerhead sharks in the U.S. Atlantic, Gulf of Mexico, and Caribbean	Enric Cortés and Heather Baertlein
SEDAR77-DW7	Preliminary post-release mortality estimates for the shore-based recreational shark fishery in Texas	John A. Mohan , R. J. David Wells, Marcus Drymon, Gregory Stunz, and Matthew Streich
SEDAR77-DW9	Stress physiology of scalloped and great hammerhead sharks from a bottom longline fishery	Bianca K. Prohaska, Heather Marshall, R. Dean Grubbs, Bryan S. Frazier, John J. Morris, Alyssa Andres, Karissa Lear, Robert E. Hueter, Bryan A. Keller, and Nicholas M. Whitney
SEDAR77-DW10	Stress physiology of scalloped and great hammerhead sharks from a bottom longline fishery: Supplemental Tables	Bianca K. Prohaska, Heather Marshall, R. Dean Grubbs, Bryan S. Frazier, John J. Morris, Alyssa Andres, Karissa Lear, Robert E. Hueter, Bryan A. Keller, and Nicholas M Whitney
SEDAR77-DW20	Bycatch estimates of scalloped and great hammerhead shark in the shark bottom longline fishery	John Carlson, Alyssa Mathers, Heather Moncrief-Cox, and Kevin McCarthy
SEDAR77-DW21	Bycatch estimates of scalloped and great hammerhead shark in the southeast coastal gillnet fishery	John Carlson, Alyssa Mathers, and Kevin McCarthy
SEDAR77-DW22	Report on the post-release mortality rates of great hammerhead sharks *Sphyrna mokarran* in the recreational, catch and release, shore-based fishery in Florida, USA	Hannah B. Medd and Jill L. Brooks
SEDAR77-DW26	An updated literature review of post-release live-discard mortality rate estimates in sharks for use in SEDAR 77	Dean Courtney, Alyssa Mathers, and Andrea Kroetz
SEDAR77-DW27	Estimation of scalloped and smooth hammerhead discards in the northeast gillnet	Camilla T. McCandless and Joseph J. Mello

	fishery using data collected by the NOAA Northeast Fisheries Observer Program	
SEDAR77-DW34	Movement and post-release mortality data for great hammerheads, *Sphyrna mokarran*, tagged during research bottom longline surveys in the northern Gulf of Mexico from 2012-2014	Eric Hoffmayer, Jill Hendon, Jennifer McKinney, Brett Falterman, and William B. Driggers III
SEDAR77-DW35	Hammerhead post-release mortality data summary for SEDAR	N. M. Whitney, K. O. Lear, H. M. Marshall, J. Morris, A. M. Andres, C. F. White, T. Driggers, B. Prohaska, J. Gelsleichter, B. Frazier, and R. D. Grubbs
SEDAR77-DW36	Report on post-release mortality of scalloped hammerhead, *Sphyrna lewini*, and great hammerhead, *Sphyrna mokarran*	Jayne M. Gardiner, Tonya R. Wiley, and Jorge Brenner
SEDAR77-DW37	Revised bycatch estimates of scalloped and great hammerhead shark in the shark bottom longline fishery	Xinsheng Zhang, John Carlson, Enric Cortés, Elizabeth Babcock, and Robert Latour
SEDAR77-DW38	Revised bycatch estimates of scalloped and great hammerhead shark in the southeast coastal gillnet fishery	Xinsheng Zhang, John Carlson, Enric Cortés, Elizabeth Babcock, and Robert Latour
	Reference Documents	
SEDAR77-RD20	Double tagging clarifies post-release fate of great hammerheads (*Sphyrna mokarran*)	J. M. Drymon and R. J. D. Wells
SEDAR77-RD35	Hooking mortality of scalloped hammerhead *Sphyrna lewini* and great hammerhead *Sphyrna mokarran* sharks caught on bottom longlines	S. J. B. Gulak, A. J. de Ron Santiago, and J. K. Carlson
SEDAR77-RD41	An updated literature review of post-release live-discard mortality rate estimates in sharks for use in SEDAR 65	Dean Courtney and Alyssa Mathers
SEDAR77-RD42	Physiological stress response, reflex impairment, and survival of five sympatric shark species following experimental capture and release	A. J. Gallagher, J. E. Serafy, S. J. Cooke, and N. Hammerschlag
SEDAR77-RD43	Integrating reflexes with physiological measures to evaluate coastal shark stress response to capture	J. M. Jerome, A. J. Gallagher, S. J. Cooke, and N. Hammerschlag
SEDAR77-RD44	SEDAR29-WP17- A preliminary review of post-release live-discard mortality estimates for sharks	Dean Courtney

SEDAR77-RD45	SEDAR34-WP08- A preliminary review of post-release live-discard mortality rate estimates in sharks for use in SEDAR 34	Dean Courtney
SEDAR77-RD46	SEDAR39-DW21 - A preliminary review of post-release live-discard mortality rate estimates in sharks for use in SEDAR 39	Dean Courtney
SEDAR77-RD47	Updated post-release live-discard mortality rate and range of uncertainty developed for blacktip sharks captured in hook and line recreational fisheries for use in the SEDAR 29-Update	Dean Courtney
SEDAR77-RD48	Meta-analysis of post-release fishing mortality in apex predatory pelagic sharks and white marlin	Michael K. Musyl and Eric L. Gilman

RELEVANT TERMS OF REFERENCE

Term of Reference 4

Provide commercial catch statistics for each stock being assessed, including landings, dead discards, live discards, and potential post-release mortality in both weight and number. Consider species identification issues among hammerhead shark species and correct for these instances as appropriate.

a. Evaluate and discuss the adequacy of available data for accurately characterizing landings and discards by fishery sector or gear.

b. Provide length and age distributions for both landings and discards if feasible.

c. Provide maps of fishery effort and harvest by fishery sector or gear.

d. Provide estimates of uncertainty around each set of commercial landings (if possible) and discard estimates.

e. Provide estimates of discard mortality rate by gear.

Term of Reference 5

Provide recreational catch statistics for each stock being assessed, including landings, dead discards, live discards, and potential post-release mortality in both weight and number. Consider species identification issues among hammerhead shark species and correct for these instances as appropriate.

a. Evaluate and discuss the adequacy of available data for accurately characterizing landings and discards by fishery sector or gear.

b. Provide length and age distributions for both landings and discards if feasible.

c. Provide maps of fishery effort and harvest by fishery sector or gear.

d. Provide estimates of uncertainty around each set of recreational landings and discard estimates.

e. Provide estimates of discard mortality rate by gear.

Term of Reference 7

Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Include specific guidance on sampling intensity (number of length samples) and appropriate strata and coverage.

Term of Reference 8

Prepare a Data Workshop report providing complete documentation of workshop actions and decisions in accordance with project schedule deadlines.

3.1 Data Review - Catch Statistics

3.1.1 Commercial catches

Review of working papers

SEDAR77-DW4: Preliminary catches of hammerhead sharks in the U.S. Atlantic, Gulf of Mexico, and Caribbean
E. Cortes and H. Baertlein

This document presents commercial landings and recreational catch estimates of hammerhead sharks (*Sphyrna lewini, S. mokarran, S. zygaena, and Sphyrna* spp.) along the U.S. Atlantic and Gulf of Mexico coasts for 1981-2020. Commercial dead discards from the pelagic longline fishery are also presented along with Mexican landings from the Gulf of Mexico and available landings from Puerto Rico and the U.S. Virgin Islands. Information on the geographical distribution of both commercial landings and recreational catches is presented along with gear-specific information of commercial landings and information on recreational catches by fishing mode and fishing area. Length composition information from recreational sources is also presented.

SEDAR77-DW7: Preliminary post-release mortality estimates for the shore-based recreational shark fishery in Texas
J.A. Mohan, R.J. David Wells, M. Drymon, G. Stunz, and M. Streich

Recreational shark fishing has become increasingly popular in recent decades, especially shore-based fishing that has provided access to a broad demographic of anglers. Catch and release (CR) shark fishing has become best practice to limit deleterious effects on overall stocks, but species-specific stress levels and post-release mortality in shore-based fisheries are unclear. Advances in electronic tagging technology, including acceleration data loggers (ADLs) and pop-up satellite archival transmitting tags (PSATs), now provide unprecedented insight into fine scale (e.g. seconds to minutes with ADLs) and long term (e.g. daily to monthly with PSAT) behavior of sharks post-release. Using electronic tags, researchers have demonstrated that the physical and physiological stress inflicted upon sharks caught and released contributes directly to post-release mortality (PRM), which can occur immediately or as a result of cumulative sub-lethal effects causing fitness losses over time. Currently, PRM estimates from boat-based shark fisheries are primarily used to inform management strategies and research into the contribution of shore-based shark fishing to overall PRM rates is lacking. This project cooperatively engaged recreational shore-based shark anglers to deploy ADLs and PSATs on blacktip, bull, tiger and scalloped hammerhead sharks to estimate post-release behavior and mortality rates. These species vary in physiological sensitivity to capture from highly sensitive (hammerhead species) to less sensitive (tiger) and ensures increased tag deployment rates in unpredictable but diverse catches to explore species specific mortality rates. The objectives of the study were: 1) Characterize both fine and broad-scale post-release behavior and mortality of beach-caught sharks in Texas using ADLs and PSATs deployed by experienced recreational fishermen; 2) Compare behavioral capture responses among diverse shark species with variable capture-sensitivities (blacktip, bull, tiger, and scalloped hammerhead sharks) and seasonal environmental variables; 3) Host both pre- and post-tagging shark angler workshops to train anglers in shark identification, disseminate tagging results and discuss how results can be applied to shark conservation efforts. Sharks were captured by recreational shore-based anglers from August 2018 to October 2021. For each captured shark, fight time, handling time, and biological metrics including length and sex were recorded, and release condition was scored as good, fair, poor, or dead.

Of the 21 PSATs deployed, 5 PSAT tags were recovered by researchers and provided high-resolution data for temperature, light level, and depth: 4 sharks survived and 1 shark experienced mortality 1.25 hours after release. Eleven tags transmitted limited data, but the data were sufficient to determine shark status based on high-resolution depth data for the final 5 days of deployment and daily summaries for minimum and maximum depths, temperature, and light levels: 8 sharks survived, and 3 sharks exhibited mortality immediately. One tag on a shark that experienced mortality less than 10 min after release returned light level, depth, and temperature data that were sufficient to determine the shark was ingested by a predator. Five tags did not transmit any data after deployment and thus we cannot determine the post-release fate of those sharks. Post release mortality rates across all the PSAT tags was 25% (4/16). ADLs were deployed on 20 different sharks and were recovered for analysis: 14 sharks survived, 2 sharks exhibited mortality immediately, and 4 sharks displayed mortality from 45 min to 5 hours post release. Post-release mortality across all the ADL tags was 30% (6/20). A total of 20 bull sharks were caught and tagged: 2 sharks experienced mortality, 14 sharks survived, and 4 tags did not transmit data. The mortality rate for bull sharks was therefore found to be 12.5% (2/16). A total of 13 blacktip sharks were caught and tagged: 5 sharks exhibited mortality, 6 sharks survived, and 2 tags did not transmit any data. The mortality rate for blacktip sharks was estimated to be 45.5% (5/11). **Although scalloped hammerheads were originally targeted, 2 great hammerheads were caught and tagged: 1 experienced immediate mortality and was ingested and 1 experienced delayed mortality five days after release. The mortality rate for great hammerheads was estimated at 100% (2/2) if both mortalities can be attributed to the capture event, or 50% if the delayed mortality five days post release is considered a natural mortality**. A total of 4 tiger sharks were caught and tagged and all survived, suggesting 0% mortality. However, one tiger shark exhibited mortality 41 days after tagging that was categorized as a natural mortality and not due to capture stress.

Understanding how fishing mortality rates may differ between shore-based and boat-based recreational fleets and across different species is essential for accurately assigning gear type and mortality estimates in stock assessment models. Angler outreach and education was achieved by PIs attending the Sharkathon shore-based fishing tournament in October 2021, reaching hundreds of participating anglers, even though 2020 survey ambitions were delayed due to COVID19. Follow-up angler surveys will occur in 2022 to generate reference data on angler attitude and response to research results. In summary, this collaborative project combined cooperative angler citizen scientists and advanced electronic tags to provide an empirically derived post-release mortality rate estimate across different species in a recreational shore-based fishery for use in management protocols.

SEDAR77-DW9: Stress physiology of scalloped and great hammerhead sharks from a bottom longline fishery
B.K. Prohaska, H. Marshall, R.D. Grubbs, B.S. Frazier, J.J. Morris, A. Andres, K. Lear, R.E. Hueter, B.A. Keller, and N.M. Whitney

The scalloped hammerhead *Sphyrna lewini* and the great hammerhead *Sphyrna mokarran* are large, coastal to semi-oceanic shark species common to waters of the U.S. east coast where they are regularly taken in commercial and recreational fisheries, particularly the bottom longline fishery. High rates of hooking mortality and low rates of population growth are believed to have caused severe declines in the U.S. Atlantic populations of these species. The objective of this study was to determine the physiological stress induced by bottom longline capture in both *S. lewini* and *S. mokarran*. Physiological stress was quantified using the blood biochemical indicators glucose, lactate, pH, hematocrit, sodium, potassium, calcium, chloride, and magnesium, which have been demonstrated to indicate physiological stress in elasmobranchs. Each shark captured was assigned a condition factor, which was compared with the stress parameters and time on hook to quantify stress induced by different longline hook times. The physiological stress parameters lactate and pH were found to scale negatively with hook time and condition factor in both species. For both species, possible predictors of mortality include hook time, lactate, potassium, and pH. These data will be useful for estimating post-release mortality of *S. mokarran* from measurements taken at the time of capture and the physiological stress response to longline capture in both species to the Atlantic bottom longline fishery.

SEDAR77-DW20: Bycatch estimates of scalloped and great hammerhead shark in the shark bottom longline fishery.
J. Carlson, A. Mathers, H. Moncrief-Cox, and K. McCarthy

This document presents calculated scalloped and great hammerhead shark dead and live discards (in numbers of sharks) from the commercial shark bottom longline fishery (1993–2019) and the shark research fishery (2008–2019). The authors followed the approach of Garrison (2007) by employing a simple ratio estimator to represent bycatch rates. An estimate of uncertainty in these estimates was derived from bootstrap resampling of the calculated CPUE data set. Estimates of dead and live discards were reported separately for the shark research fishery and the shark bottom longline fishery. As vessels in the shark research fishery are monitored 100%, no extrapolations of the dead discards were needed.

SEDAR77-DW21: Bycatch estimates of scalloped and great hammerhead shark in the southeast coastal gillnet fishery
J. Carlson, A. Mathers, and K. McCarthy

This document presents calculated scalloped and great hammerhead shark dead and live discards (in numbers of sharks) from the commercial gillnet fishery from 1998–2019. The authors followed the approach of Garrison (2007) by employing a simple ratio estimator to represent bycatch rates. An estimate of uncertainty in these estimates was derived from bootstrap resampling of the calculated CPUE data set. Total discards were calculated as the product of observer reported yearly mean dead and live discard rates by set and the yearly total fishing effort (gillnet sets) reported to the coastal logbook program.

SEDAR77-DW22: Report on the post-release mortality rates of great hammerhead sharks *Sphyrna mokarran* in the recreational, catch and release, shore-based fishery in Florida, USA.
H.B. Medd and J.L. Brooks

Great hammerhead sharks (*Sphyrna mokarran)* are targeted by recreational anglers along the coast of Florida. We estimated the post-release mortality rates for those great hammerhead sharks captured by rod and reel shore-based recreational anglers using short-term, pop-off satellite archival tags (PSATs). All sharks were tagged within the normal release procedures by anglers, and the handling time was not extended to collect other data. One of 13 sharks with reporting tags (7.7%) died post-release.

SEDAR77-DW26: An updated literature review of post-release live-discard mortality rate estimates in sharks for use in SEDAR 77
D. Courtney, A. Mathers, and A. Kroetz

This working paper summarizes a literature database reviewed for post-release live-discard mortality (PRLDM) rates in sharks. The literature database was reviewed for estimates of delayed discard-mortality rates (MD) and immediate (i.e. at-vessel or acute) discard-mortality rates (MA) for hammerhead sharks (Sphyrnidae). Previous SEDAR Assessment Process (AP) and Data Workshop (DW) PRLDM rate decisions for sharks were also summarized.

SEDAR77-DW27: Estimation of scalloped and smooth hammerhead discards in the northeast gillnet fishery using data collected by the NOAA Northeast Fisheries Observer Program
C.T. McCandless and J.J. Mello

Dead and live discards of scalloped and smooth hammerhead sharks from the Northeast Region's Mid-Atlantic sink-gillnet fishing fleet were estimated in numbers and weight using data collected by the Northeast Fisheries Observer Program from 1995 to 2019 and were back-calculated to 1981. Block averaging of the discard rates was also used to create estimates in numbers of individuals and weight. Additionally, based on panel recommendations considering all bycatch data available for use during this assessment, discard estimates for the northeast gillnet fishery were created using the grand mean of the discard ratios.

SEDAR77-DW34: Movement and post-release mortality data for great hammerheads, *Sphyrna mokarran*, tagged during research bottom longline surveys in the northern Gulf of Mexico from 2012-2014
E.R. Hoffmayer, J.M. Hendon, J.A. McKinney, B. Falterman, and W.B. Driggers III

Great hammerheads, *Sphyrna mokarran*, were targeted using 1.8 km bottom longline with 100 3m gangions baited with Atlantic mackerel, *Scomber scomber* set in northern Gulf of Mexico waters from 9 – 366m. The bottom longlines were soaked for one hour and retrieved, and sharks were identified, measured, weighed and then tagged and released. Nine great hammerheads (male n=1: 155 cm FL; female n=8: 85.5-214 cm FL) were fitted with smart position and temperature transmitting (SPOT) tags. Four SPOT tags (range 19 to 101 days, mean: 53.3 ± 20.0 days) reported data with five of the tags not transmitting data to the satellite after the tags were deployed, suggesting those sharks succumbed to the capture stress. All surviving four great hammerheads remained in relatively coastal, nearshore waters with only two locations occurring in waters deeper than 50m. Two of the sharks remained in the general localized area where they were tagged, whereas the other two sharks moved across the Mississippi River Delta from MS to LA and vice versa. The post-release mortality rate was estimated to be 55.5% with a 95% binomial confidence interval of 21.2 to 86.3%.

SEDAR77-DW35: Hammerhead post-release mortality data summary for SEDAR
N.M. Whitney, K.O. Lear, H.M. Marshall, J. Morris, A.M. Andres, C.F. White, T. Driggers, B. Prohaska, J. Gelsleichter, B. Frazier, and R.D. Grubbs

Between 2014 and 2019 Scalloped and Great Hammerhead sharks (*Sphyrna lewini* and *Sphyrna mokarran*) were tagged with a combination of acceleration data-loggers (ADLs; model G6A+, Cefas, Inc., Lowestoft UK) and Pop-up Satellite Archival Tags (PSATs; model PSATLIFE, Lotek, Ontario, CAN) to determine their post-release survival from commercial longline fisheries. Sharks were caught on longlines in collaboration with commercial fishermen in the Gulf of Mexico near Madeira Beach, FL, Naples, FL, and Galveston, TX, and in Florida Bay near Key West, FL. In most cases (excluding sets fished near Galveston, TX), hook timers were deployed on the gangions with each hook, so that the actual time each shark was hooked before capture was known. Relatively short soak times were used in order to land live animals for tagging, with the result that the majority of hook times are under three hours.

SEDAR77-DW36: Report on post-release mortality of scalloped hammerhead, *Sphyrna lewini*, and great hammerhead, *Sphyrna mokarran*
J.M. Gardiner, T.R. Wiley, and J. Brenner

This was a data summary and there was no abstract available.

SEDAR77-DW37: Revised bycatch estimates of scalloped and great hammerhead shark in the shark bottom longline fishery
X. Zhang, J.Carlson, E. Cortés, E. Babcock, and R. Latour

This document details the use of the delta-lognormal method (Pennington, 1983) to calculate discard rates to produce discard estimates and associated uncertainty to use in the SEDAR 77 assessment of hammerhead sharks. The ratio method was used in SEDAR77-DW20 to calculate discard estimates and associated uncertainty. However, the estimated standard deviations (or CVs) obtained through bootstrap resampling reported in SEDAR77-DW20 are extremely high. The panel recommended to use the delta-lognormal method as an alternative method to estimate dead discards and live discards with the same data sets. The discard estimates from the delta-lognormal are similar to those of the ratio method, but the estimated standard deviations (or CVs) from the delta-lognormal method are much smaller than the ratio method and are within a very reasonable range. Consequently, the panel recommended to use discard estimates and associated uncertainty estimates from the delta-lognormal method in the SEDAR 77 stock assessment. Given the very small number of sets in which a non-zero bycatch was observed (positive sets), the panel recommended to use the grand mean of discard rates based on the pooled observed sets for all years and the annual logbook effort to produce annual discard estimates. With this recommendation, the trend of the discard estimates is solely driven by the logbook effort. The estimated discard estimates, upper 95% CI and lower 95% CI were recommended to be used in the base, and high and low catch scenarios, respectively.

SEDAR77-DW38: Revised Bycatch Estimates of Scalloped and Great Hammerhead Shark in the Southeast Coastal Gillnet Fishery
X. Zhang, , J. Carlson, E. Cortés, E. Babcock, and R. Latour

This document details the use of the delta-lognormal method (Pennington, 1983) to calculate discard rates to produce discard estimates and associated uncertainty from US southeast commercial gillnet fishery to use in the SEDAR 77 assessment of hammerhead sharks. The ratio method was used in SEDAR77-DW21 to calculate discard estimates and associated uncertainty. However, the estimated standard deviations (or CVs) obtained through bootstrap resampling reported in SEDAR77-DW21 are extremely high. The panel recommended to use the delta-lognormal method as an alternative method to estimate dead discards and live discards with the same data sets. The discard estimates from the delta-lognormal are similar to those of the ratio method, but the estimated standard deviations (or CVs) from the delta-lognormal method are much smaller than the ratio method and are within a very reasonable range. Consequently, the panel recommended to use discard estimates and associated uncertainty estimates from the delta-lognormal method in the SEDAR 77 stock assessment. Given the very small number of sets in which a non-zero bycatch was observed (positive sets), the panel recommended to use the grand mean of discard rates based on the pooled observed sets for all years and the annual logbook effort to produce annual discard estimates. With this recommendation, the trend of the discard estimates is solely driven by the logbook effort. The estimated discard estimates, upper 95% CI and lower 95% CI were recommended to be used in the base and high and low catch scenarios, respectively.

3.1.2 Commercial Datasets and Decisions

Commercial landings

U.S. commercial landings in weight (lb dw) were available for the period 1991-2020. These data were gathered from two different sources over the time series. Commercial landings for 1991-2013 come from the FINS database, which includes Atlantic Coastal Cooperative Statistics Program (ACCSP) and Gulf Fisheries Information Network (GulfFIN) landings, from the Atlantic and Gulf of Mexico regions, respectively. Landings for 2014-2020 come from the NOAA Fisheries Highly Migratory Species commercial landings (eDealer) database.

In addition to the above databases, landings for Puerto Rico and the U.S. Virgin Islands were also gathered from the Accumulated Landings System (ALS) database for 1987-2011 and the Caribbean Commercial Vessel Logbook database for 2012-2020. Mexican landings of hammerhead sharks in the Gulf of Mexico were reconstructed based on a near-census of landings at fishing camps in the states of Tamaulipas, Veracruz, Tabasco, and Campeche conducted during approximately one year from November 1993 to December 1994 (see section below).

Reported landings of unclassified sharks were apportioned to scalloped, great, smooth, and unclassified hammerheads based on year, state, gear, and area fished whenever possible; year, state and gear; year and state; or only state depending on data availability. Unclassified hammerheads were then apportioned to the different species (scalloped, great, or smooth hammerhead) based on the proportions of these three species in the FINS database during 1991-2020 (the average proportion for the entire period was used because proportions fluctuated widely from year to year and some years had no observations). For gear-specific landings, unclassified hammerheads were apportioned to the different species based on the average proportions of the three species in the main gears (bottom longlines, gillnets, and lines) during the same period.

Commercial landings in numbers were calculated by dividing annual landings in weight (lb dw) by average weights (lb dw) obtained from the Southeast Gillnet Observer Program (GNOP) and the Reef Fish and Shark Bottom Longline Observer Programs (collectively referred to as BLLOP henceforth) as appropriate. All weights from the GNOP and BLLOP were predicted from fork length measurements taken by observers in gillnet and longline fisheries, respectively, using weight-length regressions given in SEDAR77-DW03. Since there were no observations of sharks caught on hook and line/hand line fisheries, average weights for hook and line/hand line gears were assumed equal to those from the bottom longline fishery. Since the native form of commercial catches is weight (lb dw, with lb dw = lb whole weight/1.39) it is more appropriate to use catch in weight in models where catches can be entered either in numbers or in weight (e.g., Stock Synthesis).

<u>Scalloped hammerhead, all regions</u>—Total commercial landings of scalloped hammerheads (with added pelagic longline dead discards; see section below) peaked during the early to mid-1990s and decreased thereafter generally remaining below 100,000 pounds dressed weight (lb dw) after 1996 (**Figure 1**).

Commercial landings by gear from FINS for 1991-2020 (accounting only for unclassified sharks apportioned to be scalloped hammerheads) were dominated by longlines (60%) and gillnets (26%), with hook & line accounting for 10% of the total (**Figure 2, top**). The relative importance of longlines and gillnets alternated through time but was generally higher for longlines (**Figure 2, bottom**).

Landings by state were dominated by Florida (62%; 29% on the west coast, 33% on the east coast), followed by North Carolina (21%) and Louisiana (13%) (**Figure 3, top**), with Florida dominating through time during most of 1991-2015 and North Carolina and Louisiana becoming more important thereafter (**Figure 3, bottom**).

Average weights were available for 2002-2020 from the GNOP and for 1993-2020 from the BLLOP. For the GNOP, the average weight for 1981-2001 was taken as the mean for the entire time series of data (2002-2020); for the BLLOP, the average weight for 1981-1992 was taken as the average for the entire time series of data (1993-2020) owing to high interannual variability in average weights in both cases. Individual weights were obtained from individual fork lengths using the sex-specific weight-to-length regressions given in SEDAR77-DW03.

Scalloped hammerhead GOM—Total commercial landings of scalloped hammerheads in the Gulf of Mexico (with added pelagic longline dead discards; see section below) were rather choppy throughout the time series but never exceeded 41,000 lb dw (**Figure 4**).

Commercial landings by gear from FINS for 1991-2020 (accounting only for unclassified sharks apportioned to be GOM scalloped hammerheads) were dominated by longlines (76%) and hand lines (23%), with gillnets accounting for less than 1% (**Figure 5, top**). Longlines were the dominant gear in all years except for 2018 and 2020 when hand lines had a higher contribution (**Figure 5, bottom**).

Landings by state were dominated by Florida (66%), followed by Louisiana (30%) and Alabama to a lesser extent (4%) (**Figure 6, top**), with Florida dominating throughout the entire time series with the exception of higher landings in Louisiana in 2018 and 2020 (**Figure 6, bottom**).

Average weights were available for 2002-2020 from the GNOP and for 1994-2020 from the BLLOP. For the GNOP, the average weight for 1981-2001 was taken as the mean for the entire time series of data (2002-2020); for the BLLOP, the average weight for 1981-1993 was taken as the average for the entire time series of data (1994-2020) owing to high interannual variability in average weights in both cases. Individual weights were obtained from individual fork lengths using the sex-specific weight-to-length regressions given in SEDAR77-DW03 (for GOM and ATL combined).

Scalloped hammerhead ATL— Total commercial landings of scalloped hammerheads (with added pelagic longline dead discards; see section below) peaked during the early to mid-1990s and decreased thereafter generally remaining below 100,000 pounds dressed weight (lb dw) after 1996 (**Figure 7**).

Commercial landings by gear from FINS for 1991-2020 (accounting only for unclassified sharks apportioned to be ATL scalloped hammerheads) were almost equally represented by longlines (46%) and gillnets (47%), with hook and line accounting for the remaining 7% (**Figure 8, top**). Longlines and gillnets alternated in importance throughout the time series (**Figure 8, bottom**).
Landings by state were dominated by Florida (59%) and North Carolina (39%) (**Figure 9, top**), with Florida being the main state of landings in most years up to 2015 after which North Carolina became the main sate of landings (**Figure 9, bottom**).

Average weights were available for 2002-2020 from the GNOP and for 1993-2020 from the BLLOP. For the GNOP, the average weight for 1981-2001 was taken as the mean for the entire time series of data (2002-2020); for the BLLOP, the average weight for 1981-1992 was taken as the average for the entire time series of data (1993-2020) owing to high interannual variability in average weights in both cases. Individual weights were obtained from individual fork lengths using the sex-specific weight-to-length regressions given in SEDAR77-DW03 (for GOM and ATL combined).

Great hammerhead—Total commercial landings of great hammerheads (with added pelagic longline dead discards; see section below) peaked at over 550,000 lb dw in 1994, but rapidly decreased thereafter remaining under 90,000 lb dw since 1997 (**Figure 10**).

Commercial landings by gear from FINS for 1991-2020 (accounting only for unclassified sharks apportioned to be great hammerheads) were dominated by longlines (57%), followed by gillnets (42%), with hook and line making up the remaining 1% (**Figure 11, top**). The relative importance of longlines and gillnets varied slightly through time (**Figure 11, bottom**).

Landings by state were dominated by Florida (50%; 42% on the west coast, 8% on the east coast), closely followed by North Carolina (40%), with some landings from Alabama (7%) (**Figure 12, top**). Alabama accounted for all landings in 2005-2011 and Florida and North Carolina consistently dominated the landings since 2012 (**Figure 12, bottom**).

Average weights were only available for 2002, 2003, and 2020 from the GNOP and for 1993-2020 from the BLLOP. For the GNOP, the average weight for all remaining years was taken as the average of the three available years (2002, 2003, 2020); for the BLLOP, the average weight for 1981-1992 was taken as the average for the entire time series of data (1993-2020) owing to high interannual variability in average weights. Individual weights were obtained from individual fork lengths using the sex-specific weight-to-length regressions given in SEDAR77-DW03.

Smooth hammerhead—Total commercial landings of smooth hammerheads (with added pelagic longline dead discards; see section below) were of small magnitude and never exceeded 10,000 lb dw during the entire time series (**Figure 13**).

Almost half of all commercial landings from FINS for 1991-2020 (accounting only for unclassified sharks apportioned to be smooth hammerheads) were not identified to gear, gillnets made up the majority of the identified gears (41%), followed by longlines (5%) (**Figure 14, top**). The majority of unidentified gear occurred in 2009 and 2010, after which gillnets were generally the most dominant gear (**Figure 14, bottom**).

All landings occurred in the Atlantic, with New York (52%), Virginia (23%), and North Carolina (18%) being the main states of landing (**Figure 15, top**). New York landings dominated in 2009-2011, Virginia landings in 2012, and North Carolina landings in 2013-2014 and since 2016 (**Figure 15, bottom**).

There were very few available average weights: for 2009 and 2010 from the GNOP and for 1994, 1995, 1997, 2000, 2002, 2005, 2008, 2010, and 2018 from the BLLOP, but sample sizes were very low for most years. For the GNOP, the average weight for all remaining years was taken as the average of the two available years (2009-2010); for the BLLOP, the average weight for 1981-1993 and all other years without samples was taken as the average of the years with samples (1994, 1995, 1997, 2000, 2002, 2005, 2008, 2010, and 2018). Individual weights were obtained from individual fork lengths using a weight-to-length regression for sexes combined given in Coelho et al. (2011).

Carolina hammerhead—There were no commercial landings identified as Carolina hammerheads, but an unknown portion of the scalloped hammerhead landings in the Atlantic could be attributed to this cryptic species.

Discussion and decisions

Although recreational catch statistics are available since 1981, commercial landings by species only start in 1991. Based on previous input from the commercial shark fishing industry provided for SEDAR 65, there was very little commercial shark fishing effort in the early 1980s so it was proposed that to reconstruct the commercial landings series back to 1981, a linear decrease from the average of the first three years of data (1991-1993) be assumed from 1990 back to 1981. This back-calculation methodology should also be applied to the discard series available.

Decision: ***Assume a linear increase of landings from 0 in 1981 to 90% of the mean of 1991-1993 in 1990 to represent growing market for shark products. Apply this increase to the three fleets considered for each stock (longlines, gillnets, and hook and line/unknown gear)***

Commercial dead and live discards

Working papers SEDAR77-DW20 and SEDAR77-DW21 provided estimates of dead and live discards of scalloped and great hammerheads for the bottom longline fishery and the gillnet fishery for the southeast region, respectively, based on observer reports and commercial logbook data. Working Paper SEDAR77-DW27 provided estimates of live and dead discards in the northeast gillnet fishery based on observer reports from the Northeast Fishery Observer Program and Vessel Trip Report (VTR) landings data. SEDAR77-DW20 and SEDAR77-DW21 were replaced by SEDAR77-DW37 and SEDAR77-DW38 after the data workshop for the bottom longline fishery and the gillnet fishery for the southeast region, respectively.

Discussion and decisions

Estimates of dead and live discards were generated for 1993-2019 for longlines and 1998-2019 for gillnets for the southeast region, and 1995-2019 for gillnets in the northeast region. For consistency with the landings, which started in 1981, it was also proposed that the longline and gillnet dead and live discards be back-calculated to 1981.

The Group discussed that the ratio method used to estimate discards in the three working papers was a reasonable approach, but that the estimated standard deviations (or CVs) obtained from bootstrapping were extremely high in working papers SEDAR77-DW20 and SEDAR77-DW21. It was decided to form a small bycatch working group to use an alternative discard estimation method based on the delta-lognormal approach (Pennington, 1983) using the same data sets with the expectation that this alternative method can provide reasonable estimated standard deviations (or CVs).

The delta-lognormal method (Pennington, 1983) assumes a lognormal distribution of the positive bycatch rate observations. Effectively, the estimates are constructed as a product of the proportion of successful occurrences of an event and the average rate at which the event occurs for those successful events. The variance is a function of the variability of the positive bycatch rates as well the number of successful and unsuccessful sets. The delta estimator is more appropriate than the simple ratio estimate because catch rates are generally log-normally distributed and bycatch events (i.e., positive sets) are rare. The unit of effort in this analysis is the number of hooks (bottom longlines) or sets (gillnets). Due to small number of sets in which a non-zero bycatch of the species group was observed (positive sets), observed sets are pooled by each observed year and all observed years, respectively. The annual mean discard rate is based on the pooled observed sets for each observed year. The grand mean discard rate is based on the pooled observed sets for all observed years.

When number of sets in which a non-zero bycatch was observed (positive sets) is greater than 1, the mean discard rate, *C*, is calculated as:

$$C = \frac{m}{n} e^{L} G_m(\frac{s^2}{2}) \qquad (1)$$

m is number of sets in which a non-zero bycatch was observed (positive sets),
n is total number of sets observed,
L is the mean of the log-transformed number of animals taken per 1000 hooks (bottom longlines) or per set (gillnets) for the positive sets,
s^2 is the variance of the log-transformed number of animals taken per 1000 hooks (bottom longlines) or per set (gillnets) for the positive sets, and
$G_m(\frac{1}{2}s^2)$ is the cumulative probability function from the Poisson distribution given as:

$$G_m(\frac{1}{2}s^2) = 1 + \frac{m-1}{m}(\frac{1}{2}s^2) + \sum_{j=2}^{\infty} \frac{(m-1)^{2j-1}}{m^j (m+1)(m+3)...(m+2j-3)} \text{x} \frac{(\frac{1}{2}s^2)^j}{j!} \qquad (2)$$

The series was computed numerically over *j* terms until meeting a convergence criterion of a change in the function value of < 0.001 with additional terms (j). The variance of the delta estimator is:

$$\text{var}(C) = \frac{m}{n}(e^{2L})\left[\frac{m}{n} G_m^2(\frac{s^2}{2}) - \frac{m-1}{n-1} G_m(\frac{m-2}{m-1}s^2)\right] \qquad (3)$$

When number of sets in which a non-zero bycatch was observed (positive sets) is equal to 1, the mean discard rate reduces to the simple mean rate where:

$$C = \frac{e^{L}}{n} \qquad (4)$$

and the variance of the delta estimator is:

$$\text{var}(C) = (\frac{e^L}{n})^2 \quad (5)$$

When number of sets in which a non-zero bycatch was observed (positive sets) is equal to 0, the mean discard is:

$$C = 0 \quad (6)$$

and the variance of the delta estimator is:

$$\text{var}(C) = 0 \quad (7)$$

When number of sets in which a non-zero bycatch was observed (positive sets) is greater than or equal to 1, the coefficient of variation for the mean discard rate is taken as:

$$CV = \frac{\sqrt{\text{var}(C)}}{C} \quad (8)$$

The *C* calculated above gives either the annual mean or the grand mean number of animals caught per 1000 hooks (bottom longlines) or per set (gillnets) for the observed sets. To estimate annual discards, *N*, these rates are multiplied by the annual total number of logbook hooks (in thousands, bottom longlines) or logbook sets (gillnets). With an assumption of effort (*number of logbook hooks or logbook sets*) being a known constant, the coefficient of variation for the annual (or grand) mean discard rate is the same as the coefficient of variation for the annual discards. Approximate 95% confidence intervals (95% CI) were calculated assuming a log-normal distribution of annual discards as *Nk* and *N/k* for the upper and lower confidence bounds respectively where:

$$k = e^{\left[1.96\sqrt{\ln(1+\text{CV}^2)}\right]} \quad (9)$$

The discard estimates from the delta-lognormal method are similar to those of the ratio method, but the estimated standard deviations (or CVs) from the delta-lognormal method are much smaller than those from the ratio method and are within a very reasonable range. Consequently, the panel recommended to use discard estimates and associated uncertainty estimates from the delta-lognormal method (Pennington, 1983) in the SEDAR 77 stock assessment. The panel recommended to include the number of reported logbook hooks/sets, number of observed hooks/sets, number of observed positive hooks/sets, and number of animals caught in the Tables if they are available. Given the very small number of sets in which a non-zero bycatch was observed (positive sets), the panel recommended to use the grand mean of discard rates based on the pooled observed sets for all years and the annual logbook effort to produce annual discard estimates. With this recommendation, the trend of the discard estimates is solely driven by the logbook effort. The estimated discard estimates, upper 95% CI and lower 95% CI were recommended to be used in the base, and high and low catch scenarios, respectively. The discard estimates from the delta-lognormal method were presented in working papers SEDAR77-DW37 and SEDAR77-DW38 after the data workshop for the bottom longline fishery and the gillnet fishery for the southeast region, respectively.

<u>Decision:</u> Include the number of reported logbook hooks/sets, number of observed hooks/sets, number of observed positive hooks/sets, and number of animals caught in the Tables if they are available.

<u>Decision:</u> Back-calculate dead and live discards to 1981 for the southeast bottom longlines and southeast gillnets (1993 – 2019 for southeast bottom longlines; 1998-2019 for southeast gillnets). Assume a linear increase in discards from 0 in 1981 to 90% of the mean of the entire time series in the year preceding the first year of bycatch estimates for southeast bottom longlines and southeast gillnets to parallel the approach used for back-calculating landings.

<u>Decision</u>: Back-calculate dead and live discards to 1981 for northeast gillnets. The average discard ratio for the entire time series (1995-2019 for northeast gillnets) across all strata (grand mean) for live and dead discards by number and weight were applied to the annual total landings for the Mid-Atlantic statistical areas identified in the dealer database for northeast gillnets.

<u>Decision:</u> Use the delta-lognormal method to replace the ratio method for southeast bottom longline and southeast gillnet discard estimates.

<u>Decision:</u> Include the dead and live discard estimates obtained with the delta-lognormal method and the grand mean CPUE in the base run for southeast bottom longline and southeast gillnet; include the dead and live discard estimates obtained with the ratio method and the grand mean CPUE in the base run for northeast gillnet. Use the estimated lower 95%CI and upper 95%CI in low and high catch sensitivity scenarios, respectively.

<u>Shark bottom longline for areas combined</u>

<u>Great hammerhead</u> — Yearly calculated dead discards of great hammerhead sharks for the shark bottom longline fishery were a couple of hundred during 1993 to the mid-2000s and less than 50 after 2006 (**Table 1**). Yearly observed dead discards of great hammerhead sharks for the shark research bottom longline fishery (2008-2019) were small and were less than 10 after 2011 (**Table 2**). Yearly calculated live discards of great hammerhead sharks for the shark bottom longline fishery were a couple of hundred during 1993 to the mid-2000s and less than 100 after 2006 (**Table 3**). Yearly observed live discards of great hammerhead sharks for the shark research bottom longline fishery (2008-2019) were less than 30 (**Table 4**).

<u>Scalloped hammerhead</u> — Yearly calculated dead discards of scalloped hammerhead sharks for the shark bottom longline fishery were generally a few hundred during 1993 to the mid-2000s except for a peak in 1996 and were about 100 after 2007 (**Table 5**). Yearly observed dead discards of scalloped hammerhead sharks for the shark research bottom longline fishery (2008-2019) were small and were less than 10 after 2011 (**Table 6**). Yearly calculated live discards of scalloped hammerhead sharks for the shark bottom

longline fishery were a few hundred during 1993 to the mid-2000s except for a peak in 1996 and were about 100 after 2006 (**Table 7**). Yearly observed live discards of scalloped hammerhead sharks for the shark research bottom longline fishery (2008-2019) were less than 50 (**Table 8**).

Shark bottom longline for the Atlantic

Scalloped hammerhead — Yearly calculated dead discards of scalloped hammerhead sharks for the shark bottom longline fishery were generally a couple of hundred during 1993 to the mid-2000s and below 100 after 2006 (**Table 9**). Yearly observed dead discards of scalloped hammerhead sharks for the shark research bottom longline fishery (2008-2019) were small and were less than 5 after 2011 (**Table 10**). Yearly calculated live discards of scalloped hammerhead sharks for the shark bottom longline fishery were generally a couple of hundred during 1993 to the mid-2000s and less than 100 after 2006 (**Table 11**). Yearly observed live discards of scalloped hammerhead sharks for the shark research bottom longline fishery (2008-2019) were less than 20 (**Table 12**).

Shark bottom longline for the Gulf of Mexico

Scalloped hammerhead — Yearly calculated dead discards of scalloped hammerhead sharks for the shark bottom longline fishery were generally a couple of hundred during 1993 to the mid-2000s with peaks in 1995 and 1996 and were less than 100 after 2007 (**Table 13**). Yearly observed dead discards of scalloped hammerhead sharks for the shark research bottom longline fishery (2008-2019) were small and were less than 10 after 2011 (**Table 14**). Yearly calculated live discards of scalloped hammerhead sharks for the shark bottom longline fishery were a couple of hundred during 1993 to the mid-2000s with peaks in 1995 and 1996 and were less than 100 after 2006 (**Table 15**). Yearly observed live discards of scalloped hammerhead sharks for the shark research bottom longline fishery (2008-2019) were less than 30 (**Table 16**).

US southeast commercial gillnet for areas combined

Great hammerhead — Yearly calculated dead discards of great hammerhead sharks for the US southeast commercial gillnet fishery (1998-2019) ranged from 28 to 77 (**Table 17**). Yearly calculated live discards of great hammerhead sharks for the US southeast commercial gillnet fishery (1998-2019) ranged from 4 to 10 (**Table 18**).

Scalloped hammerhead — Yearly calculated dead discards of scalloped hammerhead sharks for the US southeast commercial gillnet fishery (1998-2019) ranged from 183 to 504 (**Table 19**). Yearly calculated live discards of scalloped hammerhead sharks for the US southeast commercial gillnet fishery (1998-2019) ranged from 75 to 208 (**Table 20**).

US southeast commercial gillnet for the Atlantic

Scalloped hammerhead — Yearly calculated dead discards of scalloped hammerhead sharks for the US southeast commercial gillnet fishery (1998-2019) ranged from 173 to 459 (**Table 21**). Yearly calculated live discards of scalloped hammerhead sharks for the US southeast commercial gillnet fishery (1998-2019) ranged from 75 to 200 (**Table 22**).

US southeast commercial gillnet for the Gulf of Mexico

Scalloped hammerhead — Yearly calculated dead discards of scalloped hammerhead sharks for the US southeast commercial gillnet fishery (1998-2019) ranged from 9 to 120 (**Table 23**). Yearly calculated live discards of scalloped hammerhead sharks for the US southeast commercial gillnet fishery (1998-2019) ranged from 1 to 12 (**Table 24**).

US northeast commercial gillnet for the Mid-Atlantic

Scalloped hammerhead — Yearly back-calculated dead discards of scalloped hammerhead sharks for the US northeast commercial gillnet fishery (1981-1994) ranged from 4 to 110 and
yearly calculated dead discards of scalloped hammerhead sharks for the US northeast commercial gillnet fishery (1995-2019) ranged from 70 to 618 (**Table 25**). Yearly back-calculated live discards of scalloped hammerhead sharks for the US northeast commercial gillnet fishery (1981-1994) ranged from 3 to 86 and yearly calculated dead discards of scalloped hammerhead sharks for the US northeast commercial gillnet fishery (1995-2019) ranged from 55 to 483 (**Table 25**).

Smooth hammerhead — Yearly back-calculated dead discards of smooth hammerhead sharks for the US northeast commercial gillnet fishery (1981-1994) ranged from 4 to 111 and
yearly calculated dead discards of smooth hammerhead sharks for the US northeast commercial gillnet fishery (1995-2019) ranged from 71 to 628 (**Table 26**). Yearly back-calculated live discards of smooth hammerhead sharks for the US northeast commercial gillnet fishery (1981-1994) ranged from 2 to 58 and yearly calculated dead discards of smooth hammerhead sharks for the US northeast commercial gillnet fishery (1995-2019) ranged from 37 to 328 (**Table 26**).

Commercial post-release live discard mortality

Discussion and decisions

SEDAR77-DW09 and SEDAR77-DW10

The Post-release delayed mortality (PRLDM) Ad-hoc Working Group discussed SEDAR77-DW09 and SEDAR77-DW10 (Prohaska et al. 2021a, 2021b), which provided evidence from the evaluation of blood biochemical indicators and capture condition that scalloped and great hammerheads captured with bottom longlines and on the hook for longer than about 3 hr are likely to be in either poor condition or dead at release. SEDAR77-DW09 and SEDAR77-DW10 evaluated the physiological stress induced by bottom longline capture for scalloped and great hammerheads. Each captured shark was assigned a capture condition factor at release, which was compared with physiological stress quantified using the blood biochemical indicators and with time on hook to quantify stress induced by different longline hook times. SEDAR77-DW09 and SEDAR77-DW10 indicated that after about 3 hr of hook time, there were no scalloped hammerhead assigned to either excellent, good, or fair condition at release (**Figure 16**). SEDAR77-DW09 and SEDAR77-DW10 indicated that after about 2 hr of hook time, there were no great hammerhead assigned to either excellent, good, or fair capture condition at release (**Figure 16**). SEDAR77-DW09 and SEDAR77-DW10 indicated that scalloped and great hammerheads released in fair condition had lactate levels of about 6 and 12 mmol l^{-1}, respectively, which corresponded to about 80 and 100 minutes of time on the hook, respectively (**Figure 17**). SEDAR77-DW09 and SEDAR77-DW10 indicated that lactate levels of scalloped and great hammerheads released in poor condition were about 12 and 19 mmol l^{-1}, respectively, which corresponded to about 180 and 200 minutes of time on the hook, respectively (**Figure 18**).

SEDAR77-RD35

The PRLDM Ad-hoc Working Group discussed SEDAR77-RD35 (Gulak et al. 2015; Simon Gulak, Pers. Comm. December 14, 2022), which provided evidence from fisheries research conducted employing hook timers on contracted commercial bottom-longline vessels in the U.S. Highly Migratory Species Shark Research Fishery to determine that the proportion of total number captured by hour for scalloped and great hammerheads on the hook <= 3 hr was 33.54 and 33.80%, respectively (**Tables 27 and 28**).

SEDAR77-RD20, SEDAR77-RD42, SEDAR77-DW34, and SEDAR77-DW35

The PRLDM Ad-hoc Working Group discussed SEDAR77-RD20 (Drymon and Wells 2017), SEDAR77-RD42 (Gallagher et al. 2014), SEDAR77-DW34 (Hoffmayer et al. 2021), and SEDAR77-DW35 (Whitney et al. 2021), which provided evidence from electronically tagged sharks to estimate PRLDM of great hammerheads captured on drumline and bottom longline gear soaked for between about 1 – 3 hr that ranged from 0 % (N tagged = 3, n dead post-release = 0) to 56% (N tagged = 9, n dead post-release = 5) with a pooled estimate of 45% (N tagged = 60, n dead post-release = 27; **Table 29**). The PRLDM Ad-hoc Working Group also discussed that SEDAR77-DW35 (Whitney et al. 2021) provided evidence from electronically tagged sharks to estimate PRLDM of scalloped hammerheads captured on bottom longline gear soaked for between about 1 – 3 hr (post-release mortality = 8% obtained from N tagged = 25 and n dead post-release = 2; **Table 29**).

The PRLDM Ad-hoc Working Group discussed using the proportion of total number captured by hour for scalloped hammerheads on bottom longline hook-timers for <=3 hr and > 3 hr to compute the PRLDM rate for scalloped hammerheads captured in commercial bottom longline gear. The estimate of PRLDM rate obtained from electronically tagged scalloped hammerheads captured on bottom longlines with hook or soak times about 1 – 3 hr (8%; **Table 29**) was applied to the proportion of scalloped hammerheads on hook-timers for <=3 hr (33.54%, n = 55; **Tables 27 and 30**). The PRLDM Ad-hoc Working Group discussed that the PRLDM rate of scalloped hammerheads on hook timers > 3hr (66.46%, n = 109; **Tables 27 and 30**) was assumed to be 100% because live scalloped hammerheads were likely to be in poor condition at release and unlikely to survive post-release. The PRLDM mortality rate calculated for scalloped hammerheads released from commercial bottom longline gear using this approach was 69.15% (**Table 30**).

Decision: ***Use a PRLDM mortality rate of 69.15% as the best estimate of PRLDM for scalloped hammerheads released alive from commercial bottom longline gear.***

A binomial confidence interval was used to calculate a range of uncertainty for PRLDM in a recent SEDAR blacktip shark stock assessment (NMFS 2020). Consequently, the PRLDM Ad-hoc Working Group also discussed using a binomial 95% confidence interval (CI, 0.0098 – 0.2603) calculated in R version 4.0.5 (R Development Core Team, 2021) with the library "binom" (Dorai-Raj 2014): binom.confint(x = 2, n = 25, method = "exact") as the minimum and maximum estimate of PRLDM obtained from electronic tag data for scalloped hammerheads captured on bottom longline gear soaked for between about 1 – 3 hr. Applying this range of uncertainty obtained from the binomial CI to the equations in **Table 30** resulted in a 95% CI of 66.79 – 75.19% PRLDM for scalloped hammerheads captured on bottom longline gear.

Decision: ***Use a 95% CI of 66.79 – 75.19% PRLDM as the minimum and maximum estimate of PRLDM for scalloped hammerheads released alive from commercial bottom longline gear.***

Similarly, the PRLDM Ad-hoc Working Group discussed using proportions of great hammerheads on bottom longline hook-timers for <=3 hr and > 3hr to compute the PRLDM for great hammerheads captured in commercial bottom longline gear. The estimate of PRLDM rate obtained from electronically tagged great hammerheads captured on drumlines and bottom longlines with soak times about 1 – 3 hr (45%; **Table 29**) was applied to the proportion of great hammerheads on hook-timers for <=3 hr (33.80%, n = 24; **Tables 28 and 31**). The PRLDM Ad-hoc Working Group discussed that the PRLDM rate of great hammerheads on hook timers > 3hr (66.20%, n = 47; **Tables 28 and 31**) was assumed to be 100% because live great hammerheads were likely to be in poor condition at release and unlikely to survive post-release. The PRLDM rate calculated for great hammerheads released from commercial bottom longline gear using this approach was 81.41% (**Table 31**).

Decision: ***Use a PRLDM rate of 81.41% for great hammerheads released alive from commercial bottom longline gear.***

Similarly, the PRLDM Ad-hoc Working Group discussed using a binomial 95% confidence interval (CI, 0.3212 – 0.5839) calculated in R version 4.0.5 (R Development Core Team, 2021) with the library "binom" (Dorai-Raj 2014): binom.confint(x = 27, n = 60, method = "exact") as the minimum and maximum estimate of PRLDM obtained from electronic tag data for great hammerheads captured on bottom longline gear soaked for between about 1 – 3 hr. Applying this range of uncertainty obtained from the binomial CI to the equations in **Table 31** resulted in a 95% CI of 77.05 – 85.93% PRLDM for great hammerheads captured on bottom longline gear.

<u>Decision:</u> Use a 95% CI of 77.05 – 85.93% PRLDM as the minimum and maximum estimate of PRLDM for great hammerheads released alive from commercial bottom longline gear.

Other methods have also been used to obtain a 95% confidence interval for post-release mortality estimates for demersal longlines (Whitney 2019 citing methods in Goodyear 2002), however these methods were not reviewed by the PRLDM Ad-hoc Working Group during the data process workshops.

The PRLDM Ad-hoc Working Group discussed that PRLDM rates obtained for hammerheads captured with bottom longline gear may also be the best available estimates of PRLDM for hammerheads captured in commercial gillnet gear.

<u>Decision:</u> Use PRLDM rates obtained for hammerheads captured with bottom longline gear as the best available estimates of PRLDM for hammerheads captured in commercial gillnet gear.

The PRLDM Ad-hoc Working Group discussed that smooth and scalloped hammerheads are physiologically more similar than smooth and great hammerheads. Consequently, the PRLDM Ad-hoc Working Group discussed that PRLDM rates obtained for scalloped hammerheads captured with bottom longline gear may be the best available estimates of PRLDM for smooth hammerheads captured with both bottom longline gear and commercial gillnet gear.

<u>Decision:</u> Use PRLDM rates obtained for scalloped hammerheads captured with bottom longline gear as the best available estimates of PRLDM for smooth hammerheads captured with both bottom longline gear and commercial gillnet gear.

<u>Commercial length compositions</u>

The data sources for lengths of commercially caught sharks are the observer programs (BLLOP, GNOP, NEFOP, and PLLOP in this case). Length composition information from these programs is provided in the length composition section of this DW report.

<u>Mexican landings</u>

An intensive monitoring of the artisanal shark fisheries in the coastal waters of the Mexican Gulf of Mexico was carried out from November 1993 to December 1994 with the aim of characterizing the shark fisheries prosecuted in the region (Castillo et al., 1998). Twelve of the most important fishing ports from the States of Tamaulipas, Veracruz, Tabasco and Campeche were sampled on a daily basis (**Figure 19**). The shark fishing operations of 901 artisanal boats were monitored. Most of the sampled boats (97%) were small boats (“pangas”) with fiberglass and wood hulls, 7.5–10.0 m long and 1.0–2.5 m wide, with an outboard motor and an operational range of 1–3 days, whereas the remaining 3% were larger boats with hulls of wood and metal, > 10 m long and >2.6 m wide, with an inboard motor and an operational range of 4–15 days. The two types of boats combined accounted for 9964 trips, with Campeche having the highest number of boats, fishing trips, and shark landings overall. Biological information collected included length, sex, and reproductive stage of individual animals. It must be noted that in some of the sites visited sampling was not systematic throughout the year owing to logistic and funding issues.

The Castillo et al. (1998) study thus provided a snapshot of the landings, sex, and lengths of sharks captured in four of the six Mexican states in the GOM for one year spanning 1993-1994. Based on this information it was possible to reconstruct the catches of the different hammerhead shark species using the following procedure. First, the proportion that hammerhead shark species made up of the total sharks landed was computed for each of the four states sampled (**Figure 20**). Second, for each species of hammerhead represented in the landings (i.e., scalloped and great hammerhead) length-frequency distributions (cm TL) by sex by state were computed (**Figures 21, 22**) and the proportion of landings of sharks <150 cm TL were assigned to a "*cazones*" category and those >=150 cm TL to a "*tiburones*" category. These two categories are those reported in the Mexican official fishery statistics from the Comisión Nacional de Acuacultura y Pesca (Conapesca) available for the period 1976-2019 (J.L. Castillo, pers. comm. to Enric Cortés). We then calculated the percentage of "cazones" and "tiburones" for sexes combined as a weighted average (by sample size for each sex) for each state (**Figures 21, 22**). Third, for each species, we took the landings of "cazones" and "tiburones" reported for each state by Conapesca (**Table 32**) and multiplied it by the proportion that scalloped and great hammerhead make up of the entire catches (step 1) and by the proportion of "cazones" and "tiburones" attributed to each species (step 2) to obtain the total estimated number of hammerheads of each species caught in each state (**Table 33**; **Figure 23**). This assumed that the species composition of the landings observed in 1993-1994 remained the same throughout the entire time series. Fourth, these total estimated landings could further be disaggregated into gear-specific landings for each state by assigning landings to three major gear types (longlines, nets, and hook and line) based on gear composition observed by state. Gear-specific landings by state were then added to provide total landings by gear type (**Table 34**; **Figures 24, 25**).

An additional source of information on Mexican shark landings was also examined in SEDAR77-DW04. This sample, based in part on Pérez-Jiménez and Méndez-Loeza (2015), monitored the small-scale artisanal shark gillnet fishery in the states of Tabasco and Campeche during 2011-2016. However, the proportion that hammerhead shark species (scalloped and great hammerheads) made up of the total sharks landed was only available for the state of Campeche and therefore it was decided not to use this source of data.

Discussion ensued about these sources of Mexican landings. It was noted that while the Castillo et al. (1998) study was almost a census, reconstruction of catches for the 1981-2019 period assumed that the species composition had remained the same throughout this time period. Since there was no additional information available to determine whether/how species composition may have changed through time and that the entire reconstructed series was based on a single year of data, the Panel decided that Mexican landings should be used only in a high catch sensitivity scenario. It was also noted that the U.S. has no management authority in Mexico and therefore inclusion of this series in the base run could be problematic.

<u>Decision:</u> Include the reconstructed Mexican landings based on one year of data from Castillo et al. (1998) in a high catch sensitivity scenario only; exclude from the base run.

Puerto Rico/U.S. Virgin Islands landings

There were no commercial landings of hammerhead sharks from Puerto Rico (PR) or the U.S. Virgin Islands (USVI) reported in the FINS or eDealer databases. The Caribbean Commercial Vessel Logbook database included some reports, but of very small magnitude. For scalloped hammerhead in PR, weights ranged from 14 to 116 lb dw during 2012-2020 and in the USVI, weights were less than 1 lb dw. For great hammerhead in PR, weights ranged from 81 to 676 lb dw during 2012-2020, and in the USVI, from 57 to 662 lb dw. Additional information obtained from the Accumulated Landings System (ALS) database showed that most sharks in PR are reported as unclassified and those reported as "hammerhead" never exceeded 80 lb whole weight (ww) in any year during 1987-2011. **Figure 26** shows the landings of scalloped and great hammerheads after apportioning the unclassified sharks to the different hammerhead species and then apportioning the unclassified hammerheads to scalloped or great hammerhead. Scalloped hammerhead landings ranged from 31 to 323 lb dw during 1987-2011 and great hammerhead landings ranged from 261 to 2,694 lb dw during the same period.

These low reported landings reflect the fact that few longliners dock and offload in PR ports and that they do not fish in more coastal waters (R. Espinoza, Conservación Conciencia, pers. comm. to Enric Cortés). As part of a Shark Research and Conservation Program Conservación Conciencia has been conducting fishery-dependent surveys at fishing ports and villages from 2019 to 2021 as well as fishery-independent surveys since 2017 with the aim to characterize Puerto Rico's shark fishery through a marine conservation agreement with PR fishers who report and provide details on their catch. Scalloped hammerheads were the second most observed species during fishery-dependent surveys conducted from February 2019-August 2021 (n = 46; all immature) and only 10 (90% immature) great hammerheads were observed. While this information may become important in future stock assessments, there are currently no data/estimates of coastal shark landings in PR that could be used to raise these observations to total estimates of hammerhead sharks landed.

The Panel noted the small magnitude of the PR/USVI landings available, that inclusion of potentially available hammerhead catch data from the rest of Caribbean nations was outside the scope of this assessment and should be addressed in the future through a Regional Fisheries Management Organization (RFMO) such as the WECAFC (Western Central Atlantic Fishery Commission), and that the current assessment represented a good-faith effort to include catches from U.S. territories (and Mexico) only.

Decision:* *Although the magnitude is almost insignificant, do not include Puerto Rico and U.S. Virgin Islands landings in the base run; include them only in a high catch sensitivity scenario

Pelagic longline dead discards and live post-release mortality

Dead discard estimates of scalloped, great, and smooth hammerhead sharks in the pelagic longline fishery for the period 1987-2020 (based on the Pelagic Longline Observer Program and fishing effort reported in pelagic longline logbooks) were obtained from the International Commission for the Conservation of Atlantic Tunas (ICCAT) Task 1 statistics (**Figures 1, 4, 7, 10, and 13**). Estimates of animals released alive were not available. To convert weights into numbers, weights in tons ww were first converted to weights in lb dw by applying a conversion ratio of 2.02 (ww = 2.02 dw) and then obtaining average weights from fork lengths reported in the Pelagic Longline Observer Program for 1992-2017. Average weight for all remaining years was taken as the average for the entire time series of data available (1992-2017). Individual weights were obtained from individual fork lengths using the sex-specific weight-to-length regressions given in SEDAR77-DW03. Unclassified hammerheads were apportioned to the different species based on the proportions of the three species for years with data or based on the average proportions for the entire period in the years for which there were no species-specific data. Years with no data at all (i.e., 2002-2006) were set equal to the mean unclassified hammerheads for the entire period multiplied by the average proportion of the three species for the entire period.

It was noted that the dead discard estimates from the pelagic longline fishery are available in the ICCAT Task I database and should thus be used, but that no estimates of live release discards have been generated to date.

Decision: ***There are no uncertainty estimates associated with published ICCAT pelagic longline dead discards and no live discard estimates. CVs are calculated by area/quarter but not overall, and are not included in the Task 1 data reported to ICCAT. The DW panel recommended using ICCAT pelagic longline dead discards in the base run (and low catch and high catch scenarios).***

Decision: ***Assume a linear increase in discards from 0 in 1981 to 83.4% of the mean of the entire time series in the year preceding the first year of bycatch estimates (1987) to parallel the approach used for back-calculating landings and other commercial discard series***

3.1.3 Recreational Catch Datasets and Decisions

Recreational catches

Recreational catches of hammerhead sharks reported herein are the sum of estimates from the Marine Recreational Information Program (MRIP), the Southeast Region Headboat Survey (SRHS) operated by the SEFSC Beaufort Laboratory, and the Texas Parks and Wildlife Department (TPWD) Survey. There were no hammerhead sharks reported from the Louisiana Creel survey and only insignificant amounts in the Large Pelagic Survey (LPS). The MRIP estimates include Access Point Angler Intercept Survey (APAIS) and Fishing Effort Survey (FES) calibrations. Annual recreational catch estimates of hammerhead sharks were computed as the sum of type A (number of fish killed or kept seen by the interviewer), type B1 (number of fish killed or kept reported to the interviewer by the angler), and type B2 (number of fish released alive reported by the fisher) estimated to have died from post-release live-discard mortality. MRIP catches are reported in both numbers and weight for types A and B1, but only in numbers for type B2. SRHS catch estimates for types A and B1 are also provided in both numbers and weight, but B2 estimates are not available. TPWD catch estimates for types A and B1 are only provided in numbers and B2 estimates are not available. Annual weight estimates for MRIP type B2 were computed by multiplying B2 catches in numbers by an average weight obtained from MRIP AB1 catches. Since the native form of recreational catches is numbers, it is more appropriate to use catch in numbers in models where catches can be entered either in numbers or in weight (e.g., Stock Synthesis).

To account for sharks identified only as Sphyrnidae or *Sphyrna* spp., unclassified sphyrnid sharks were initially allocated to each of the three hammerhead species (*S. lewini*, *S. mokarran* or *S. zygaena*) based on the annual contribution of these three species and the bonnethead shark (*Sphyrna tiburo*) to the sphyrnid shark catch. On average throughout the time series (1981-2020) bonnethead, scalloped hammerhead, great hammerhead, and smooth hammerhead sharks accounted for 82%, 7%, 9%, and 2% of sphyrnid AB1 catches and 83%, 5%, 9%, and 3% of sphyrnid B2 catches, respectively.

It was noted that it would be better to use the species composition of A catches only (observed by the interviewer) rather than AB1 or B2 catches to apportion the unclassified hammerheads into the three species. It was thus recommended to use the annual proportions based on A catches for 1981-2000, and to use the 1981-2000 average proportions of A catches for 2001-2020 to account for management measures implemented during that period.

As in other SEDARs, in initial discussions the Panel expressed concerns over the inter-annual variability and high uncertainty of the recreational catch estimates. To account for the large interannual variability in recreational catch estimates, the A+B1 and B2 catch series were smoothed using a three-year moving geometric average, as most recently done for SEDAR 65 [(NMFS 2020), while preserving the average trend. It was noted that despite smoothing the series with the three-year moving geometric average there were still some large peaks apparent. Thus, individual years with noticeable peaks were identified for each of the stocks and smoothed:

		Stock				
		Scalloped all	Scalloped GOM	Scalloped ATL	Great	Smooth
AB1	Numbers	1982, 1993	1984, 1985	1982, 1993	1982	1991
	Weight	1993	1984, 1985	1993	1982	1991

The individual smoothing applied is described below for each stock.

<u>Decision:</u> Apportion the AB1 and B2 unclassified sphyrnid sharks as follows: 1) for 1981-2000, use annual proportions based on A catches (observed by interviewer) and 2) for 2001-2020, use average proportion during 1981-2000 based on the A catches to account for management measures implemented

<u>Decision:</u> Smooth the AB1 and B2 recreational catch series with a three-year geometric moving average

<u>Decision:</u> Smooth individual years with noticeable peaks by setting them equal to the geometric mean of the 3 preceding and ensuing years (as available)

Recreational post-release live discard mortality

The PRLDM Ad-hoc Working Group discussed that direct estimates of PRLDM were not available for hammerheads from a review of the scientific literature reviewed in SEDAR77-DW25 (Courtney et al. 2021, their Tables A.1 and A.2). Consequently, a minimum estimate of recreational PRLDM for hammerheads was developed by the PRLDM Ad-hoc Working Group from great hammerheads captured and released alive in three directed electronic tagging studies of recreational fishing gear reported and reviewed during the SEDAR 77 Data Workshop (SEDAR77-DW07, SEDAR77-DW22, and a SEDAR 77 Data Workshop presentation) as summarized below. The PRLDM rate estimate was obtained primarily from great hammerheads captured and released alive by experienced recreational anglers targeting sharks. As a result, the PRLDM estimate obtained from these studies was assumed to represent a plausible minimum estimate of the PRLDM of all hammerheads released alive from recreational gear, which are primarily captured incidentally, as discussed below. In contrast, a best estimate of hammerhead shark recreational PRLDM was obtained during the SEDAR 77 Data Workshop from a previously published meta-analysis of pelagic shark PRLDM rates captured and released alive from multiple gear types (Musyl and Gilman 2019). It was noted during the SEDAR 77 Data Workshop that meta-analysis may provide a relatively more robust (stable) PRLDM estimate than those obtained from individual directed studies, which can fluctuate based on individual study design and sample size, as discussed below. Similarly, a maximum estimate of hammerhead shark recreational PRLDM was obtained during the SEDAR 77 Data Workshop as the 95% upper confidence interval (UCI) of pelagic shark PRLDM (Musyl and Gilman 2019).

***Decision:* Use the pooled PRLDM rate of 11.8% obtained from three directed electronic tagging studies of great hammerheads released alive from recreational gear as a minimum estimate of the PRLDM rate for hammerheads captured and released alive with recreational gear.**

The PRLDM Ad-hoc Working Group discussed, and the SEDAR 77 Data Workshop panel accepted, using a pooled PRLDM rate of 11.8% obtained from great hammerheads released alive from recreational gear as a minimum estimate of the PRLDM rate of hammerheads captured and released alive with recreational gear.

Source	Tags	PRLDM	(%)
SEDAR77-DW07	2	1	50.0%
SEDAR77-DW22	13	1	7.7%
SEDAR 77 Data Workshop Presentation[1]	2	0	0.0%
Total (pooled data)	17	2	11.8%

[1](Bryan Frazier – Tag Data)

The PRLDM Ad-hoc Working Group noted that two of the directed studies (SEDAR77-DW07 and SEDAR77-DW22) which reported PRLDM from electronic tagging involved anglers experienced at targeting sharks, and that experienced anglers may reflect best practices associated with maximizing post-release survival (for example, reduced fight and handling time associated with heavy tackle designed to catch sharks). The PRLDM Ad-hoc Working Group also noted that the post-release mortality rate of 11.8% obtained from great hammerheads released alive from recreational gear is lower than that obtained for Atlantic blacktip sharks (18.5%; range 10.8–28.7%) during the SEDAR 65 Atlantic blacktip shark stock assessment (NMFS 2020; e.g., Courtney et al. 2021, their Table B.1) and also lower than that obtained from meta-analysis of pelagic sharks captured and released alive from longline, purse-seine and rod & reel gear combined (Musyl and Gilman 2019). Consequently, the PRLDM Ad-hoc Working Group discussed that the post-release mortality rate of 11.8% obtained from the three directed studies evaluated here may represent a plausible minimum estimate of the PRLDM rate of hammerheads captured and released alive with recreational gear.

Decision: ***Use the PRLDM obtained from meta-analysis for pelagic sharks (26.8%, Musyl and Gilman 2019) as the best estimate of the PRLDM rate for hammerheads captured and released alive with recreational gear.***

Decision: ***Use the 95% upper confidence interval (UCI) of PRLDM obtained from meta-analysis for pelagic sharks (36.0%, Musyl and Gilman 2019) as the maximum estimate of the PRLDM rate for hammerheads captured and released alive with recreational gear.***

The PRLDM Ad-hoc Working Group discussed the meta-analysis of pelagic shark post-release mortality rates captured and released alive from multiple gear types (Musyl and Gilman 2019) during the SEDAR 77 Data Workshop. The PRLDM Ad-hoc Working Group discussed, and the SEDAR 77 Data Workshop panel accepted, that the PRLDM rate obtained from meta-analysis (Musyl and Gilman, 2019) is likely to be more robust (stable) compared to the PRLDM estimated from the three directed studies evaluated here because of low sample size in the directed studies.

SEDAR77-DW07

The PRLDM Ad-hoc Working Group discussed SEDAR77-DW07 (Mohan et al. 2021), which provided evidence to estimate post release mortality from electronically tagged great hammerheads captured and released alive during Texas shore based angling. Two great hammerheads were caught, tagged, released alive, and provided electronic tag data that indicated the animal’s fate (alive or dead) after live release. One experienced immediate mortality (light level, depth, and temperature data were sufficient to determine the shark was ingested by a predator) and one survived up to 16 days following release. The mortality rate for great hammerheads obtained from these data was estimated at 50%. The study included highly experienced Texas shore-based anglers who were trained during the study in shark identification, data collection, and tag deployment. No further input was provided by investigators during the study in order to ensure the preservation of normal techniques utilized by shore-based recreational fishermen.

SEDAR77-DW22

The PRLDM Ad-hoc Working Group discussed SEDAR77-DW22 (Medd et al. 2021), which provided evidence to estimate post release mortality from electronically tagged great hammerheads captured and released alive during Florida shore based recreational angling. Thirteen great hammerheads were caught, tagged, released alive, and provided electronic tag data that indicated the animal's fate (alive or dead) after live release. One experienced constant depth associated with mortality. None of the pressure profiles of the other 13 tags indicated a detachment due to constant depth release. The mortality rate for great hammerheads obtained from these data was estimated at 7.7%. The anglers that caught the sharks in the tagging study were experienced (i.e., more than 1- 5 years of shark fishing) and generally used heavy gear types capable of reeling in sharks to shore relatively more quickly than would have been possible with lighter tackle.

SEDAR 77 Data Workshop presentation (Bryan Frazier – PRLDM in South Carolina charter vessel based recreational angling)

The PRLDM Ad-hoc Working Group discussed the SEDAR 77 Data Workshop presentation by Bryan Frazier, which provided evidence to estimate post-release mortality from electronically tagged great hammerheads captured and released alive during South Carolina charter vessel based recreational angling. Two great hammerheads were caught, tagged, released alive, and provided electronic tag data that indicated the animal's fate (alive or dead) after live release. None experienced constant depth assumed to be associated with mortality. The mortality rate for great hammerheads obtained from these data was estimated at 0%. One additional great hammerhead was tagged, but electronic tag data was not available at the Data Workshop to determine the animal's fate after live release.

A summary of the information provided during the SEDAR 77 Data Workshop presentation by Bryan Frazier is provided below and in **Figures 27** and **28**. One great hammerhead was a 245 cm fork length pregnant female (confirmed via ultrasound) captured after a 32 minute fight time and at a water temperature of 30.7° C. The shark was tagged with standard-rate X-tag on 8/24/17. The tag was shed after 122 days at liberty. An example of the temperature and depth profile is provided in **Figure 27**. The other great hammerhead was a 286 cm fork length female captured after a 47 minute fight time and at a water temperature of 29.4° C. The shark was tagged with a PSATLife tag on 6/28/17. After 9 days at liberty, the tag shed prematurely, but indicated post-release survival based on light intensity and depth data. An example of light intensity and pressure (depth) of the great hammerhead tagged with a PSATLife tag is provided in **Figure 28**.

SEDAR 77 Data Workshop presentation (Kesley Banks - Fight and handling times in a Texas shore-based recreational shark fishery)

The PRLDM Ad-hoc Working Group discussed the SEDAR 77 Data Workshop presentation by Kesley Banks, which summarized fight and handling times in a shore-based recreational shark fishery. It was noted that anglers generally used heavy gear, and that fight times for great hammerheads were generally longer than those for scalloped hammerhead because the size of great hammerheads was generally larger than the size of scalloped hammerheads in the shore based fishery.

A summary of the information provided during the SEDAR 77 Data Workshop presentation by Kesley Banks is provided below. The Texas Shark Rodeo (TSR) is an annual 9-month long land-based shark fishing tournament that advocates for catch-photo-release with an "emphasis on tagging and collecting data for the conservation of sharks" (texassharkrodeo.com). There is no entry fee for the tournament, with winners receiving trophies and recognition, but no monetary incentive. Anglers participating in the TSR tag and submit a photograph of their catch for it to be counted, allowing for confirmation of the species submitted. Date of capture, location, stretched total length (measured from the tip of the snout to the tip of the stretched upper caudal lobe), sex, species, and tag number, along with photographs were then submitted via online form. Although variation in recreational gear types exists amongst individual anglers, the general strategy for land-based fishing in Texas involves the use of large reels spooled with 800–1,000 m of 50-lb (22.68-kg) to 100-lb (45.36-kg) test line (monofilament or braided) with approximately 100 m of monofilament top shot of increased strength. A wire or monofilament leader, consisting of a weight and a line with a circle or J-hook ranging in size from 13/0 to 24/0, is connected to the top-shot line. The hook is baited with large sections of stingray *Rhinoptera* spp. or *Dasyatis* spp., crevalle jack *Caranx hippos*, or striped mullet *Mugil cephalus* and is either surf cast or kayaked out 100–400 m offshore. Anglers participating in the TSR span the entire Texas coast and were permitted to target sharks from shore (e.g., beach, jetty, channel), excluding piers or vessels of any type.

Beginning in 2020, time of hook, time at landing, and time at release were asked during the tournaments. This allowed for 62 hammerheads (great: n = 43, scalloped: n = 19) to be sampled for fight and handling times. Anglers typically spent longer fighting great hammerheads (mean ± SD: 30 ± 21 min) than scalloped hammerheads (5 ± 4 min). The maximum fight time was 90 minutes to land a great hammerhead and the shortest time was 1 minute for a scalloped hammerhead. Handling times were also longer for great hammerheads (5 ± 2.5 min) than scalloped hammerheads (3 ± 1.6 min) with the longest being 15 minutes for a great hammerhead and shortest at 0 minutes for a great hammerhead. Length data was also available for hammerheads from 2014 – 2021. Scalloped hammerheads were typically smaller in length than great hammerheads. The reported number of pups captured is larger for scalloped hammerheads (n = 43 smaller than 70 cm FL) than great hammerheads (n = 2 smaller than 80 cm FL), which could help explain the shorter fight and handling times for scalloped hammerheads.

SEDAR 77 Data Workshop presentation (Cliff Hutt – Proportion of shark targeted recreational fishing trips in the MRIP data base that captured or harvested hammerheads)

The PRLDM Ad-hoc Working Group discussed the SEDAR 77 Data Workshop presentation by Cliff Hutt, which reported the proportion of shark targeted recreational fishing trips in the MRIP data base that captured or harvested hammerheads. It was noted that the majority of trips which reported either catching or harvesting hammerheads, did not report targeting sharks.

A summary of the information provided during the SEDAR 77 Data Workshop presentation by Cliff Hutt is provided below and in **Figures 29** to **32**. The MRIP data base was queried for the number of MRIP trips: (1) targeting sharks (excluding pelagic, small coastals, and dogfish); (2) catching hammerheads, including generic hammerheads; (3) catching hammerheads identified to species; and 4) harvesting hammerheads identified to species. 17.7% of trips that reported catch of hammerheads reported targeting sharks (excluding pelagics or small coastals). 33.1% of trips that reported harvesting hammerheads reported targeting sharks (excluding pelagics or small coastals). Trips targeting sharks account for approximately 3.5% of all MRIP estimated recreational trips that reported catching sharks. The patterns of available data used to calculate these proportions has also changed over time, possibly in response to changes in management, for example limiting harvest of hammerheads (e.g., see **Figures 29 to 32**).

SEDAR77-RD48 (Musyl and Gilman 2019)

The PRLDM Ad-hoc Working Group discussed the published meta-analysis of pelagic shark post-release mortality rates captured and released alive from multiple gear types (Musyl and Gilman 2019) during the SEDAR 77 Data Workshop. The PRLDM Ad-hoc Working Group noted that the post-release mortality rate obtained from the published meta-analysis (Musyl and Gilman, 2019) is likely to be more robust (stable) compared to the PRLDM estimated from the three directed studies identified above because of low sample size in the directed studies. PRLDM obtained from meta-analysis for all pelagic sharks combined (33 studies) was 26.8% (Musyl and Gilman 2019, 19.3% LCI, 36.0% UCI, obtained from longline, purse-seine, rod and reel combined, Dead = 95, Tagged = 401). In comparison, PRLDM obtained from meta-analysis for scalloped hammerhead captured and released alive from purse-seine gear (One study) was 87.5% (Musyl and Gilman 2019, 26.6% LCI, 99.3% UCI, Dead = 3, Tagged = 3). The PRLDM Ad-hoc Working Group discussed that the post-release mortality rate of 26.8% obtained from meta-analysis for all pelagic sharks combined (Musyl and Gilman 2019) along with the 95% UCI (36.0%) may represent plausible robust (stable) estimates of the best available and maximum, respectively, PRLDM rate of hammerheads captured and released alive with recreational gear.

SEDAR77-DW36

The PRLDM Ad-hoc Working Group discussed SEDAR77-DW36 (Gardiner et al. 2022), which provided evidence of post-release mortality for great and scalloped hammerheads fitted with surgically implanted acoustic transmitters and/or satellite tags after being captured during fishery-independent surveys or directed sampling efforts using gillnet, bottom longline, or drum line gear. One great hammerhead was also incidentally captured using rod and reel gear, with light monofilament terminating in a 6/0 circle hook. Only individuals that appeared healthy and in robust condition were selected for tagging. Upon release, animal movements were tracked by arrays of passive acoustic receivers (e.g., SEDAR 77-SID05, Gardiner et al. 2021). Animals were classified as either survivals (individuals that maintained continuous movement for a period ≥ 14 days) or mortalities (individuals that ceased movement within 14 days or individuals that disappeared within a gated array after 6 months had elapsed).

Post-release outcomes were determined for scalloped and great hammerheads from multiple release locations in Florida west coast estuaries and bays adjacent to the Gulf of Mexico as described in Gardiner et al. (2022, their Tables 1 and 2) and summarized below in **Table 35**. The PRLDM Ad-hoc Working Group discussed that many of the acoustic array locations provided complete coverage across all entry/exit points (Gardiner et al. 2022), such that acoustically tagged sharks were unlikely to emigrate from the tag location undetected. Consequently, the PRLDM Ad-hoc Working Group discussed that the resulting post-release mortality rate estimates obtained from the acoustic tagging data (**Table 35**) could be useful to inform stock assessment. However, the PRLDM rates obtained from the study were not adopted for use in the current assessment because the data were not reviewed by the PRLDM Ad-hoc Working Group in detail. The PRLDM Ad-hoc Working Group discussed that the post-release mortality of the one great hammerhead incidentally captured using rod and reel gear, with light monofilament terminating in a 6/0 circle hook, was consistent with the possibility that hammerheads captured incidentally may experience higher post-release mortality rates than hammerheads captured by anglers targeting sharks, as discussed above.

SEDAR77-SID01

The PRLDM Ad-hoc Working Group discussed SEDAR77-SID01 (Heim et al. 2021), which provided evidence of post-release mortality for 15 great hammerhead (1 post-release mortality) and 10 scalloped hammerheads (1 post release mortality). Sharks were tagged in the Bahamas, Florida and South Carolina using various capture methods including hand line and bottom longline. The data collection for the project was still ongoing and therefore the data analysis was preliminary. The PRLDM rates obtained from the study were not adopted for use in the current assessment because the data were not reviewed by the PRLDM Ad-hoc Working Group in detail.

Catches by species/stock

Scalloped hammerhead, all regions—The vast majority of scalloped hammerhead catches were from MRIP. Catches were highest at the beginning of the time series and showed a decreasing trend punctuated by some peaks, notably in 1982 and 1993 for the AB1 series. Upon further examination, it was found that the A estimate for 1982 was influenced by a large value of 22,010 sharks for South Carolina (Wave 3, Private, Inland), which was based on one observed trip that harvested 20 sharks, all measuring only 11 inches. Since this was unrealistic, the recommendation was to remove this SC estimate entirely. Thus, 22,010 was subtracted from the original A estimate of 39,739. The original AB1 estimate for 1993 was 60,926 sharks, including an A estimate of 5,559 sharks (east coast of FL, Wave 3, Shore, State Ocean) and a B1 estimate of 38,913 sharks (east coast of FL, W3, Shore, State Ocean). The A estimate corresponded to 1 angler reporting 1 harvested shark and the B1 estimate to 3 anglers reporting harvests of 1, 2, and 4 sharks each, all legal in 1993). Based on this the recommendation was to smooth the 1993 data point. **Figure 33** shows the recreational catches before (top) and after (bottom) smoothing the individual points and the general smoothing.

Most AB1 catches by state corresponded to the southeast region in the Atlantic with Florida-East coast (45%), Georgia (17%), and South Carolina (13%) accounting for 75% of all scalloped hammerhead catches (**Figure 34, top**). By fishing mode, most AB1 catches were from shore (48%) and by private boats (47%), with charter boats and headboats contributing very little (**Figure 34, middle**). By fishing area, most AB1 catches occurred less than 3 miles from shore (45%) and in inshore waters (37%), with the remaining catches occurring in waters over three miles from shore (9%) or less than 10 miles from shore (8%; **Figure 34, bottom**).

Decision: ***Remove the South Carolina A estimate of 22,010 sharks from the original A estimate of 39,739 for the 1982 AB1 estimate in numbers; smooth the 1993 AB1 estimate (in numbers and weight) by setting it equal to the geometric mean of the 3 preceding and ensuing years***

Scalloped hammerhead GOM—The vast majority of scalloped hammerhead catches were from MRIP. Catches showed a decreasing trend punctuated by some peaks, notably in 1985 for the AB1 series. Upon further examination, it was found that of the original AB1 estimate of 27,387 sharks for 1985, 19,977 sharks corresponded to A estimates of 5,408 sharks (MS, W3, Private, Inland), 7,600 sharks (West coast of FL, W4, Private, Fed Ocean), and 4,814 sharks (MS, W4, Private, Inland). The 5,408 estimate was based on 2 anglers reporting 1 shark each, the 7,600 estimate was based on 1 angler reporting 1 shark, and the 4,814 estimate was based on 2 anglers reporting 1 shark each, and 1 angler reporting 2 sharks. Based on this the recommendation was to smooth the 1985 estimate. The 1984 AB1 estimate of 10,416 was influenced by a B1 estimate of 10,001 sharks (MS, Wave 4, Private, Fed Ocean), which was based on an extrapolation from 2 trips reporting 1 shark harvested each. Based on this the recommendation was also to smooth this estimate. **Figure 35** shows the recreational catches before (top) and after (bottom) smoothing the individual points and the general smoothing.

Most AB1 catches by state corresponded to Florida-west coast (43%), Mississippi (38%), Alabama (10%), and Texas (9%) (**Figure 36, top**). By fishing mode, most AB1 catches were from private boats (72%) and from shore (19%), with charter boats and headboats contributing the remaining 9% (**Figure 36, middle**). By fishing area, most AB1 catches occurred in waters over three miles from shore (21%) and less than 10 miles from shore (33%) with catches in less than 3 miles from shore and in inshore waters accounting for 40% of the total catches (**Figure 36, bottom**).

Decision: ***Smooth the 1984 and 1985 AB1 estimates (in numbers and weight) by setting them equal to the geometric mean of the 3 preceding and ensuing years***

Scalloped hammerhead ATL—Almost all scalloped hammerhead catches were from MRIP. Catches showed a decreasing trend punctuated by some peaks, notably in 1982 and 1993 for the AB1 series. As for the scalloped hammerhead with all regions combined, the A estimate for 1982 was influenced by a large value of 22,010 sharks for SC (Wave 3, Private, Inland), which was based on one observed trip that harvested 20 sharks, all measuring only 11 inches. Since this was unrealistic, the recommendation was to remove this SC estimate entirely. Thus, 22,010 was subtracted from the original A estimate of 39,066. The original AB1 estimate for 1993 was 56,720 sharks, including an A estimate of 5,559 sharks (east coast of FL, Wave 3, Shore, State Ocean) and a B1 estimate of 38,913 sharks (east coast of FL, W3, Shore, State Ocean). The A estimate corresponded to 1 angler reporting 1 harvested shark and the B1 estimate to 3 anglers reporting harvests of 1, 2, and 4 sharks each, all legal in 1993). Based on this the recommendation was to smooth the 1993 data point. **Figure 37** shows the recreational catches before (top) and after (bottom) smoothing the individual points and the general smoothing.

Most AB1 catches by state corresponded to Florida-east coast (58%), Georgia (22%), South Carolina (17%), and North Carolina (3%) (**Figure 38, top**). By fishing mode, most AB1 catches were from shore (57%) and from private boats (39%), with charter boats contributing the remaining 4% (**Figure 38, middle**). By fishing area, most AB1 catches occurred in waters less than 3 miles from shore (55%) and in inshore waters (39%), with catches in waters over three miles from shore accounting for 6% of the total (**Figure 38, bottom**).

<u>Decision:</u> Remove the South Carolina A estimate of 22,010 sharks from the original A estimate of 39,066 for the 1982 AB1 estimate in numbers; smooth the 1993 AB1 estimates (in numbers and weight) by setting them equal to the geometric mean of the 3 preceding and ensuing years

<u>Great hammerhead</u>—The vast majority of great hammerhead catches were from MRIP. Catches showed a decreasing trend punctuated by some peaks, notably in 1982 for the AB1 series. Upon further examination, it was found that of the original AB1 estimate of 105,497 sharks for 1982, 87,791 sharks corresponded to an A estimate of 19,282 sharks (LA, W3, Shore, Ocean), an A estimate of 10,865 sharks (east coast of FL, W4, Shore, Ocean), a B1 estimate of 42,876 sharks (East coast of FL, W2, Shore, Ocean), and a B1 estimate of 14,768 sharks (east coast of FL, W4, Shore, Ocean). The 19,282 estimate was based on 1 angler reporting 1 shark, the 10,865 estimate was based on 1 angler reporting 1 shark, the 42,876 estimate was based on 1 angler reporting 1 shark (which was an unusually large effort extrapolation), and the 14,768 estimate on 1 angler reporting 1 shark. Based on this the recommendation was to remove the 42,876 B1 estimate and to further smooth the 1982 estimate. **Figure 39** shows the recreational catches before (top) and after (bottom) smoothing the individual points and the general smoothing.

Most AB1 catches by state corresponded to the southeast region with Florida-east coast (53%) and Florida-west coast (34%) accounting for 87% of all great hammerhead catches, followed by Louisiana (5%), and Georgia and South Carolina (3% each) (**Figure 40, top**). By fishing mode, almost all AB1 catches were from shore (76%) and by private boats (32%), with charter boats and headboats contributing only 2% (**Figure 40, middle**). By fishing area, most AB1 catches occurred less than 3 miles from shore (48%) and in inshore waters (28%), with the remaining catches occurring in waters over three from shore (3%), less than 10 miles from shore (18%), or in waters over 10 miles from shore (3%) (**Figure 40, bottom**).

<u>Decision:</u> Remove the Florida east coast B1 estimate of 42,876 sharks from the original AB1 estimate of 105,497 for the 1982 AB1 estimate in numbers and smooth that 1982 AB1 estimate (in numbers and weight) by setting it equal to the geometric mean of the 3 ensuing years (1981 value was 0)

<u>Smooth hammerhead</u>—Almost all smooth hammerhead catches were from MRIP. Catches showed a generally decreasing trend punctuated by a very large peak in 1991 for the AB1 series. Upon further examination, it was found that the A estimate for 1991 was influenced by a large value of 39,148 sharks (east coast of FL, W6, Shore, Ocean), which was based on 1 angler reporting 1 shark (an unusually large effort extrapolation). Since this was unrealistic, the recommendation was to remove this FL estimate

entirely. Thus, 39,148 was subtracted from the original A estimate of 39,284. **Figure 41** shows the recreational catches before (top) and after (bottom) smoothing the individual points and the general smoothing.

Most AB1 catches by state corresponded to the southeast region with Florida-East coast (51%) and Florida-west coast (16%) accounting for 67% of all smooth hammerhead catches, followed by Georgia (17%), South Carolina (10%), and Maryland (6%) (**Figure 42, top**). By fishing mode, almost all AB1 catches were from shore (60%) and by private boats (38%), with charter boats and headboats contributing only 2% (**Figure 42, middle**). By fishing area, most AB1 catches occurred less than 3 miles from shore (53%) and in inshore waters (27%), with the remaining catches occurring in waters over three miles from shore (4%) and less than 10 miles from shore (16%) (**Figure 42, bottom**).

***Decision:* Remove the Florida east coast A estimate of 39,148 sharks from the original A estimate of 39,284 for the 1991 AB1 estimate in numbers; smooth that 1991 AB1 estimate in weight by setting it equal to the geometric mean of the 3 preceding and ensuing years**

Carolina hammerhead— There were no recreational catches identified as Carolina hammerheads, but an unknown portion of the scalloped hammerhead catches in the Atlantic could be attributed to this cryptic species.

Recreational length compositions

Lengths available from the MRIP and the SRHS surveys were reported and analyzed in SEDAR77-DW04. See that working document for details and section on length compositions of this DW report. We only provide a synopsis by stock here.

Scalloped hammerhead, all regions—Lengths of scalloped hammerheads were available from the MRIP (cm FL; n=227) and the SRHS (mm TL; n=63). Total lengths in the SRHS were converted to fork lengths with the equation for combined sexes given in SEDAR77-DW03. Length-frequency distributions show that more immature than mature sharks are caught based on the median sizes at maturity for males and females listed in the SEDAR 77 Stock ID report (146 cm FL for males; 179 cm FL for females) (**Figure 43**).

Scalloped hammerhead GOM—Lengths of GOM scalloped hammerheads were available from the MRIP (cm FL; n=53) and the SRHS (mm TL; n=59). Total lengths in the SRHS were converted to fork lengths with the equation for combined sexes given in SEDAR77-DW03 for scalloped hammerheads (GOM and ATL combined). Length-frequency distributions show that more immature than mature sharks are caught based on the median sizes at maturity for males and females listed in the SEDAR 77 Stock ID report (142 cm FL for males; 180 cm FL for females) (**Figure 44**).

Scalloped hammerhead ATL—Lengths of ATL scalloped hammerheads were available from the MRIP (cm FL; n=174) while very few were available from the SRHS (mm TL; n=4). Total lengths in the SRHS were converted to fork lengths with the equation for combined sexes given in SEDAR77-DW03 for scalloped hammerheads (GOM and ATL combined). Length-frequency distributions show that more immature than mature sharks are caught in the MRIP based on the median sizes at maturity for males and females listed in the SEDAR 77 Stock ID report (157 cm FL for males; 178 cm FL for females) (**Figure 45).**

Great hammerhead—Lengths of great hammerheads were available from the MRIP (cm FL; n=89) while very few were available from the SRHS (mm TL; n=8). Total lengths in the SRHS were converted to fork lengths with the equation for combined sexes given in SEDAR77-DW03. Length-frequency distributions show that more immature than mature sharks are caught based on the median sizes at maturity for males and females listed in the SEDAR 77 Stock ID report (197 cm FL for males; 199 cm FL for females) (**Figure 46**).

Smooth hammerhead—Lengths of smooth hammerheads were only available from the MRIP (cm FL; n=47). The length-frequency distribution shows that most sharks caught were immature based on median sizes at maturity for males and females given in Stevens (1984) (255 cm TL for males; 265 cm TL for females; when transformed into fork lengths using the regression equation FL=12.72+0.84TL from Coelho et al. (2011) they become 227 cm FL for males and 235 cm FL for females) (**Figure 47**).

Carolina hammerhead— There were no recreational lengths identified as Carolina hammerheads, but an unknown portion of the scalloped hammerhead lengths in the Atlantic could be attributed to this cryptic species.

3.1.4 Combined commercial and recreational catches

Scalloped hammerhead, all regions—Total catches of scalloped hammerheads in weight peaked during the early 1990s and again in the early 2000s and showed a decreasing trend thereafter. Recreational catches were generally the most important, except for years with higher commercial catches in the late 1980s and mid-1990s (**Figure 48**).

Tables 36 and **37** show commercial catches by gear, dead discard estimates from the pelagic longline (PLL) fishery, recreational catches (AB1, LPRM=Live post-release mortality=B2 dead), and total catch. Total catch was computed as the sum of recreational catches (AB1+LPRM) and the maximum of the sum of commercial catches by gear (bottom longline+gillnets+hand lines/hook and line+PLL discards) and the total combined commercial catches not disaggregated by gear, in weight (lb dw) and numbers, respectively.

Scalloped hammerhead GOM— Total catches of GOM scalloped hammerheads in weight peaked during the mid-1990s and again in the mid-2000s and showed a decreasing trend thereafter. Recreational catches were generally the most important, except for years with higher commercial catches in the mid-1990s, late 2000s, and mid-2010s (**Figure 49**).

Tables 38 and **39** show commercial catches by gear, dead discard estimates from the pelagic longline (PLL) fishery, recreational catches (A+B1, LPRM=Live post-release mortality), and total catch. Total catch was computed as the sum of recreational catches (AB1+LPRM) and the maximum of the sum of commercial catches by gear (bottom longline+gillnets+hand lines/hook and line+PLL discards) and the total combined commercial catches not disaggregated by gear, in weight (lb dw) and numbers, respectively.

Scalloped hammerhead ATL—Total catches of ATL scalloped hammerheads in weight generally mirrored those for the scalloped hammerheads for regions combined because catches in the Atlantic accounted for the majority of scalloped hammerhead catches (**Figure 50**).

Tables 40 and **41** show commercial catches by gear, dead discard estimates from the pelagic longline (PLL) fishery, recreational catches (AB1, LPRM=Live post-release mortality), and total catch. Total catch was computed as the sum of recreational catches (AB1+LPRM) and the maximum of the sum of commercial catches by gear (bottom longline+gillnets+hand lines/hook and line+PLL discards) and the total combined commercial catches not disaggregated by gear, in weight (lb dw) and numbers, respectively.

Great hammerhead—Total catches of great hammerheads in weight were overwhelmingly dominated by recreational catches until the late 1990s and remained at low levels thereafter. Recreational catches showed a steep decline from the early 1980s to the late 1990s (**Figure 51**).

Tables 42 and **43** show commercial catches by gear, dead discard estimates from the pelagic longline (PLL) fishery, recreational catches (AB1, LPRM=Live post-release mortality), and total catch. Total catch was computed as the sum of recreational catches (AB1+LPRM) and the maximum of the sum of commercial catches by gear (bottom longline+gillnets+hand lines/hook and line+PLL discards) and the total combined commercial catches not disaggregated by gear, in weight (lb dw) and numbers, respectively.

Smooth hammerhead—The vast majority of catches of smooth hammerheads in weight were reported as recreational during the entire time series (**Figure 52**).

Tables 44 and **45** show commercial catches by gear, dead discard estimates from the pelagic longline (PLL) fishery, recreational catches (AB1, LPRM=Live post-release mortality), and total catch. Total catch was computed as the sum of recreational catches (AB1+LPRM) and the maximum of the sum of commercial catches by gear (bottom longline+gillnets+unknown gear+PLL discards) and the total combined commercial catches not disaggregated by gear, in weight (lb dw) and numbers, respectively.

Carolina hammerhead—There were no commercial or recreational catches reported as Carolina hammerheads, but an unknown portion of the scalloped hammerhead catches in the Atlantic could be attributed to this cryptic species.

3.2 Research Recommendations

- Increase public education outreach activities for species identification in the recreational fishery. This is important because there are no species identification training workshops for recreational fishers, and it is difficult to distinguish among different species, especially juveniles, by non-trained individuals.

- Improve the MRIP process to filter biased sampling that leads to unreal, extreme fluctuations in catch data for sharks, through a QA step that is applied with an objective, non-arbitrary procedure.

- Promote that the next stock assessment of hammerhead shark species/stocks be conducted under the auspices of an RFMO (e.g., WECAFC) so that all sources of removals and abundance indices and length compositions (if available) from Caribbean nations where the species/stock is distributed can be accounted for.

- Pooling observed sets for all areas by either each observed year or all observed years without considering variance of areas and seasons, along with an assumption of effort (*number of logbook hooks*) being a known constant, may cause the actual variance of discard estimates to be underestimated. This in turn will produce a narrower confidence interval, which may have a confidence level lower than desired. The pooling methods may need to be further evaluated in the future.
- Given the very small number of sets in which a non-zero bycatch was observed (positive sets), the panel recommended to use the grand mean of discard rates based on the pooled observed sets for all years and the annual logbook effort to produce annual discard estimates. Assuming the grand mean of discard rate based on all the pooled observed sets is a constant for the entire time series, and the trend of the discard estimates is solely driven by the logbook effort, which may need to be further evaluated in the future.
- The discard estimates and associated uncertainty estimates using the delta-lognormal method (SEDAR77-DW37 and SEDAR77-DW38) are regarded as an improvement over the discard estimates and associated uncertainty estimates using the ratio method reported in SEDAR77-DW20 and SEDAR77-DW21. More discard methods should be further explored in the future.

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3.4 Tables

Table 1. Yearly calculated dead discards of great hammerhead sharks for the shark bottom longline fishery for the areas combined. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Hooks	Positive Hooks	Observed Animals	Mean CPUE (Per 1000 Hooks)	Standard Deviation	CV	Logbook Year	Logbook Hooks	Estimated Discards	Upper 95% CI	Lower 95% CI
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	1993	1101380	102	252	41
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	1994	1941435	180	444	73
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	1995	2417653	224	553	91
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	1996	3435583	319	787	129
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	1997	1471463	137	338	56
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	1998	1579283	147	363	60
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	1999	1529138	142	350	58
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2000	1387950	129	318	52
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2001	1358879	126	311	51
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2002	1662874	154	380	62
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2003	1652615	153	378	62
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2004	1227075	114	281	46
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2005	1388406	129	318	52
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2006	1579548	147	363	60
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2007	495758	46	114	19
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2008	258546	24	59	10
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2009	290442	27	67	11
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2010	230152	21	52	9
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2011	209477	19	47	8
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2012	193178	18	44	7
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2013	231876	22	54	9
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2014	329424	31	76	13
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2015	300820	28	69	11
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2016	187493	17	42	7
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2017	210155	20	49	8
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2018	196449	18	44	7
2005-2019	649	6	249305	1327	12	0.093	0.045	0.490	2019	130975	12	30	5

Table 2. Yearly observed dead discards of great hammerhead sharks from the shark research fishery for the areas combined. Discards are reported as number of individuals.

Year	Number Observed Sets	Total Dead Discards
2008	62	3
2009	111	3
2010	185	27
2011	236	37
2012	85	2
2013	93	6
2014	104	1
2015	99	1
2016	81	1
2017	104	2
2018	108	0
2019	100	3

Table 3. Yearly calculated live discards of great hammerhead sharks for the shark bottom longline fishery for the areas combined. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Hooks	Positive Hooks	Observed Animals	Mean CPUE (Per 1000 Hooks)	Standard Deviation	CV	Logbook Year	Logbook Hooks	Estimated Discards	Upper 95% CI	Lower 95% CI
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	1993	1101380	155	289	83
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	1994	1941435	272	507	146
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	1995	2417653	339	631	182
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	1996	3435583	482	898	259
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	1997	1471463	206	384	111
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	1998	1579283	222	413	119
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	1999	1529138	215	400	115
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2000	1387950	195	363	105
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2001	1358879	191	356	103
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2002	1662874	233	434	125
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2003	1652615	232	432	125
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2004	1227075	172	320	92
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2005	1388406	195	363	105
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2006	1579548	222	413	119
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2007	495758	70	130	38
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2008	258546	36	67	19
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2009	290442	41	76	22
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2010	230152	32	60	17
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2011	209477	29	54	16
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2012	193178	27	50	14
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2013	231876	33	61	18
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2014	329424	46	86	25
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2015	300820	42	78	23
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2016	187493	26	48	14
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2017	210155	29	54	16
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2018	196449	28	52	15
2005-2019	649	15	249305	4608	20	0.140	0.046	0.330	2019	130975	18	34	10

Table 4. Yearly observed live discards of great hammerhead sharks from the shark research fishery for the areas combined. Discards are reported as number of individuals.

Year	Number Observed Sets	Total Live Discards
2008	62	2
2009	111	4
2010	185	0
2011	236	8
2012	85	3
2013	93	15
2014	104	4
2015	99	12
2016	81	5
2017	104	26
2018	108	5
2019	100	14

Table 5. Yearly calculated dead discards of scalloped hammerhead sharks for the shark bottom longline fishery for the areas combined. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Hooks	Positive Hooks	Observed Animals	Mean CPUE (Per 1000 Hooks)	Standard Deviation	CV	Logbook Year	Logbook Hooks	Estimated Discards	Upper 95% CI	Lower 95% CI
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	1993	1101380	362	615	213
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	1994	1941435	637	1083	375
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	1995	2417653	794	1349	467
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	1996	3435583	1128	1917	664
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	1997	1471463	483	821	284
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	1998	1579283	518	880	305
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	1999	1529138	502	853	295
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2000	1387950	456	775	268
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2001	1358879	446	758	262
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2002	1662874	546	928	321
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2003	1652615	543	923	320
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2004	1227075	403	685	237
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2005	1388406	456	775	268
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2006	1579548	519	882	305
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2007	495758	163	277	96
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2008	258546	85	144	50
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2009	290442	95	161	56
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2010	230152	76	129	45
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2011	209477	69	117	41
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2012	193178	63	107	37
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2013	231876	76	129	45
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2014	329424	108	184	64
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2015	300820	99	168	58
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2016	187493	62	105	36
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2017	210155	69	117	41
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2018	196449	64	109	38
2005-2019	649	25	249305	7203	44	0.328	0.090	0.280	2019	130975	43	73	25

Table 6. Yearly observed dead discards of scalloped hammerhead sharks from the shark research fishery for the areas combined. Discards are reported as number of individuals.

Year	Number Observed Sets	Total Dead Discards
2008	62	1
2009	111	41
2010	185	23
2011	236	37
2012	85	6
2013	93	3
2014	104	4
2015	99	4
2016	81	6
2017	104	8
2018	108	4
2019	100	3

Table 7. Yearly calculated live discards of scalloped hammerhead sharks for the shark bottom longline fishery for the areas combined. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Hooks	Positive Hooks	Observed Animals	Mean CPUE (Per 1000 Hooks)	Standard Deviation	CV	Logbook Year	Logbook Hooks	Estimated Discards	Upper 95% CI	Lower 95% CI
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	1993	1101380	347	670	180
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	1994	1941435	611	1179	317
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	1995	2417653	761	1468	394
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	1996	3435583	1081	2086	560
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	1997	1471463	463	893	240
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	1998	1579283	497	959	258
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	1999	1529138	481	928	249
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2000	1387950	437	843	226
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2001	1358879	428	826	222
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2002	1662874	523	1009	271
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2003	1652615	520	1003	269
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2004	1227075	386	745	200
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2005	1388406	437	843	226
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2006	1579548	497	959	258
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2007	495758	156	301	81
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2008	258546	81	156	42
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2009	290442	91	176	47
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2010	230152	72	139	37
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2011	209477	66	127	34
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2012	193178	61	118	32
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2013	231876	73	141	38
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2014	329424	104	201	54
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2015	300820	95	183	49
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2016	187493	59	114	31
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2017	210155	66	127	34
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2018	196449	62	120	32
2005-2019	649	18	249305	5196	40	0.315	0.109	0.350	2019	130975	41	79	21

Table 8. Yearly observed live discards of scalloped hammerhead sharks from the shark research fishery for the areas combined. Discards are reported as number of individuals.

Year	Number Observed Sets	Total Live Discards
2008	62	2
2009	111	16
2010	185	13
2011	236	19
2012	85	5
2013	93	7
2014	104	10
2015	99	13
2016	81	23
2017	104	42
2018	108	14
2019	100	17

Table 9. Yearly calculated dead discards of scalloped hammerhead sharks for the shark bottom longline fishery for the Atlantic. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Hooks	Positive Hooks	Observed Animals	Mean CPUE (Per 1000 Hooks)	Standard Deviation	CV	Logbook Year	Logbook Hooks	Estimated Discards	Upper 95% CI	Lower 95% CI
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	1993	373270	99	208	47
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	1994	767570	204	429	97
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	1995	293603	78	164	37
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	1996	853758	226	475	108
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	1997	393413	104	219	49
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	1998	458687	122	256	58
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	1999	420234	111	233	53
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2000	398160	106	223	50
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2001	432662	115	242	55
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2002	586165	155	326	74
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2003	586888	156	328	74
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2004	455745	121	254	58
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2005	386396	103	217	49
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2006	386212	102	214	49
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2007	207548	55	116	26
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2008	112946	30	63	14
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2009	252278	67	141	32
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2010	209491	56	118	27
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2011	150252	40	84	19
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2012	88786	24	50	11
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2013	126843	34	71	16
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2014	173177	46	97	22
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2015	155914	41	86	20
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2016	92890	25	53	12
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2017	97453	26	55	12
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2018	72317	19	40	9
2005-2019	251	11	94607	3721	21	0.265	0.104	0.39	2019	22476	6	13	3

Table 10. Yearly observed dead discards of scalloped hammerhead sharks from the shark research fishery for the Atlantic. Discards are reported as number of individuals.

Year	Number Observed Sets	Total Dead Discards
2008	21	0
2009	40	0
2010	127	10
2011	141	17
2012	58	3
2013	47	1
2014	88	2
2015	60	2
2016	52	1
2017	49	1
2018	57	4
2019	51	0

Table 11. Yearly calculated live discards of scalloped hammerhead sharks for the shark bottom longline fishery for the Atlantic. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Hooks	Positive Hooks	Observed Animals	Mean CPUE (Per 1000 Hooks)	Standard Deviation	CV	Logbook Year	Logbook Hooks	Estimated Discards	Upper 95% CI	Lower 95% CI
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	1993	373270	118	298	47
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	1994	767570	243	613	96
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	1995	293603	93	235	37
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	1996	853758	270	681	107
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	1997	393413	124	313	49
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	1998	458687	145	366	57
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	1999	420234	133	335	53
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2000	398160	126	318	50
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2001	432662	137	346	54
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2002	586165	185	467	73
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2003	586888	186	469	74
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2004	455745	144	363	57
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2005	386396	122	308	48
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2006	386212	122	308	48
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2007	207548	66	166	26
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2008	112946	36	91	14
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2009	252278	80	202	32
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2010	209491	66	166	26
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2011	150252	48	121	19
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2012	88786	28	71	11
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2013	126843	40	101	16
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2014	173177	55	139	22
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2015	155914	49	124	19
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2016	92890	29	73	11
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2017	97453	31	78	12
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2018	72317	23	58	9
2005-2019	251	8	94607	2263	10	0.316	0.158	0.500	2019	22476	7	18	3

Table 12. Yearly observed live discards of scalloped hammerhead sharks from the shark research fishery for the Atlantic. Discards are reported as number of individuals.

Year	Number Observed Sets	Total Live Discards
2008	21	0
2009	40	0
2010	127	9
2011	141	4
2012	58	0
2013	47	7
2014	88	7
2015	60	6
2016	52	17
2017	49	19
2018	57	9
2019	51	1

Table 13. Yearly calculated dead discards of scalloped hammerhead sharks for the shark bottom longline fishery for the Gulf of Mexico. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Hooks	Positive Hooks	Observed Animals	Mean CPUE (Per 1000 Hooks)	Standard Deviation	CV	Logbook Year	Logbook Hooks	Estimated Discards	Upper 95% CI	Lower 95% CI
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	1993	728110	267	525	136
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	1994	1173865	431	848	219
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	1995	2124050	780	1534	397
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	1996	2581825	948	1864	482
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	1997	1078050	396	779	201
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	1998	1120596	411	808	209
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	1999	1108904	407	800	207
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2000	989790	363	714	185
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2001	926217	340	669	173
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2002	1076709	395	777	201
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2003	1065727	391	769	199
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2004	771330	283	557	144
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2005	1002010	368	724	187
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2006	1193336	438	861	223
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2007	288210	106	208	54
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2008	137903	51	100	26
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2009	29846	11	22	6
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2010	24177	9	18	5
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2011	26370	10	20	5
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2012	95264	35	69	18
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2013	95401	35	69	18
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2014	135732	50	98	25
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2015	130594	48	94	24
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2016	82828	30	59	15
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2017	100869	37	73	19
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2018	111142	41	81	21
2005-2019	398	14	154698	3482	23	0.367	0.131	0.360	2019	96685	35	69	18

Table 14. Yearly observed dead discards of scalloped hammerhead sharks from the shark research fishery for the Gulf of Mexico. Discards are reported as number of individuals.

Year	Number Observed Sets	Total Dead Discards
2008	41	1
2009	71	41
2010	58	13
2011	95	20
2012	27	3
2013	46	2
2014	16	2
2015	39	2
2016	29	5
2017	55	7
2018	49	0
2019	49	3

Table 15. Yearly calculated live discards of scalloped hammerhead sharks for the shark bottom longline fishery for the Gulf of Mexico. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Hooks	Positive Hooks	Observed Animals	Mean CPUE (Per 1000 Hooks)	Standard Deviation	CV	Logbook Year	Logbook Hooks	Estimated Discards	Upper 95% CI	Lower 95% CI
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	1993	728110	224	514	98
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	1994	1173865	362	830	158
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	1995	2124050	655	1502	286
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	1996	2581825	796	1825	347
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	1997	1078050	332	761	145
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	1998	1120596	345	791	150
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	1999	1108904	342	784	149
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2000	989790	305	699	133
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2001	926217	285	653	124
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2002	1076709	332	761	145
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2003	1065727	328	752	143
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2004	771330	238	546	104
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2005	1002010	309	708	135
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2006	1193336	368	844	161
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2007	288210	89	204	39
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2008	137903	42	96	18
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2009	29846	9	21	4
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2010	24177	7	16	3
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2011	26370	8	18	3
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2012	95264	29	66	13
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2013	95401	29	66	13
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2014	135732	42	96	18
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2015	130594	40	92	17
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2016	82828	26	60	11
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2017	100869	31	71	14
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2018	111142	34	78	15
2005-2019	398	10	154698	2933	30	0.308	0.137	0.440	2019	96685	30	69	13

Table 16. Yearly observed live discards of scalloped hammerhead sharks from the shark research fishery for the Gulf of Mexico. Discards are reported as number of individuals.

Year	Number Observed Sets	Total Live Discards
2008	41	2
2009	71	16
2010	58	4
2011	95	15
2012	27	5
2013	46	0
2014	16	3
2015	39	7
2016	29	6
2017	55	23
2018	49	5
2019	49	16

Table 17. Yearly calculated dead discards of great hammerhead sharks from the US southeast commercial gillnet fishery for the areas combined. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	3790	25	68	0.018	0.004	0.250	1998	2515	44	71	27
1998-2019	3790	25	68	0.018	0.004	0.250	1999	2077	36	58	22
1998-2019	3790	25	68	0.018	0.004	0.250	2000	2097	37	60	23
1998-2019	3790	25	68	0.018	0.004	0.250	2001	2034	36	58	22
1998-2019	3790	25	68	0.018	0.004	0.250	2002	1953	34	55	21
1998-2019	3790	25	68	0.018	0.004	0.250	2003	1633	29	47	18
1998-2019	3790	25	68	0.018	0.004	0.250	2004	1602	28	45	17
1998-2019	3790	25	68	0.018	0.004	0.250	2005	1879	33	54	20
1998-2019	3790	25	68	0.018	0.004	0.250	2006	2471	43	70	27
1998-2019	3790	25	68	0.018	0.004	0.250	2007	3748	66	107	41
1998-2019	3790	25	68	0.018	0.004	0.250	2008	3756	66	107	41
1998-2019	3790	25	68	0.018	0.004	0.250	2009	4422	77	125	47
1998-2019	3790	25	68	0.018	0.004	0.250	2010	2801	49	80	30
1998-2019	3790	25	68	0.018	0.004	0.250	2011	3825	67	109	41
1998-2019	3790	25	68	0.018	0.004	0.250	2012	3773	66	107	41
1998-2019	3790	25	68	0.018	0.004	0.250	2013	2173	38	62	23
1998-2019	3790	25	68	0.018	0.004	0.250	2014	3932	69	112	43
1998-2019	3790	25	68	0.018	0.004	0.250	2015	3871	68	110	42
1998-2019	3790	25	68	0.018	0.004	0.250	2016	3221	56	91	35
1998-2019	3790	25	68	0.018	0.004	0.250	2017	2351	41	67	25
1998-2019	3790	25	68	0.018	0.004	0.250	2018	3227	56	91	35
1998-2019	3790	25	68	0.018	0.004	0.250	2019	3635	64	104	39

Table 18. Yearly calculated live discards of great hammerhead sharks from the US southeast commercial gillnet fishery for the areas combined. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	3790	8	9	0.002	0.001	0.360	1998	2515	6	12	3
1998-2019	3790	8	9	0.002	0.001	0.360	1999	2077	5	10	3
1998-2019	3790	8	9	0.002	0.001	0.360	2000	2097	5	10	3
1998-2019	3790	8	9	0.002	0.001	0.360	2001	2034	5	10	3
1998-2019	3790	8	9	0.002	0.001	0.360	2002	1953	5	10	3
1998-2019	3790	8	9	0.002	0.001	0.360	2003	1633	4	8	2
1998-2019	3790	8	9	0.002	0.001	0.360	2004	1602	4	8	2
1998-2019	3790	8	9	0.002	0.001	0.360	2005	1879	4	8	2
1998-2019	3790	8	9	0.002	0.001	0.360	2006	2471	6	12	3
1998-2019	3790	8	9	0.002	0.001	0.360	2007	3748	9	18	5
1998-2019	3790	8	9	0.002	0.001	0.360	2008	3756	9	18	5
1998-2019	3790	8	9	0.002	0.001	0.360	2009	4422	10	20	5
1998-2019	3790	8	9	0.002	0.001	0.360	2010	2801	7	14	4
1998-2019	3790	8	9	0.002	0.001	0.360	2011	3825	9	18	5
1998-2019	3790	8	9	0.002	0.001	0.360	2012	3773	9	18	5
1998-2019	3790	8	9	0.002	0.001	0.360	2013	2173	5	10	3
1998-2019	3790	8	9	0.002	0.001	0.360	2014	3932	9	18	5
1998-2019	3790	8	9	0.002	0.001	0.360	2015	3871	9	18	5
1998-2019	3790	8	9	0.002	0.001	0.360	2016	3221	8	16	4
1998-2019	3790	8	9	0.002	0.001	0.360	2017	2351	6	12	3
1998-2019	3790	8	9	0.002	0.001	0.360	2018	3227	8	16	4
1998-2019	3790	8	9	0.002	0.001	0.360	2019	3635	9	18	5

Table 19. Yearly calculated dead discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the areas combined. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	3790	115	558	0.114	0.017	0.150	1998	2515	287	386	213
1998-2019	3790	115	558	0.114	0.017	0.150	1999	2077	237	319	176
1998-2019	3790	115	558	0.114	0.017	0.150	2000	2097	239	321	178
1998-2019	3790	115	558	0.114	0.017	0.150	2001	2034	232	312	173
1998-2019	3790	115	558	0.114	0.017	0.150	2002	1953	223	300	166
1998-2019	3790	115	558	0.114	0.017	0.150	2003	1633	186	250	138
1998-2019	3790	115	558	0.114	0.017	0.150	2004	1602	183	246	136
1998-2019	3790	115	558	0.114	0.017	0.150	2005	1879	214	288	159
1998-2019	3790	115	558	0.114	0.017	0.150	2006	2471	282	379	210
1998-2019	3790	115	558	0.114	0.017	0.150	2007	3748	427	574	318
1998-2019	3790	115	558	0.114	0.017	0.150	2008	3756	428	575	318
1998-2019	3790	115	558	0.114	0.017	0.150	2009	4422	504	678	375
1998-2019	3790	115	558	0.114	0.017	0.150	2010	2801	319	429	237
1998-2019	3790	115	558	0.114	0.017	0.150	2011	3825	436	586	324
1998-2019	3790	115	558	0.114	0.017	0.150	2012	3773	430	578	320
1998-2019	3790	115	558	0.114	0.017	0.150	2013	2173	248	333	184
1998-2019	3790	115	558	0.114	0.017	0.150	2014	3932	448	602	333
1998-2019	3790	115	558	0.114	0.017	0.150	2015	3871	441	593	328
1998-2019	3790	115	558	0.114	0.017	0.150	2016	3221	367	493	273
1998-2019	3790	115	558	0.114	0.017	0.150	2017	2351	268	360	199
1998-2019	3790	115	558	0.114	0.017	0.150	2018	3227	368	495	274
1998-2019	3790	115	558	0.114	0.017	0.150	2019	3635	414	557	308

Table 20. Yearly calculated live discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the areas combined. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	3790	106	194	0.047	0.005	0.11	1998	2515	118	147	95
1998-2019	3790	106	194	0.047	0.005	0.11	1999	2077	98	122	79
1998-2019	3790	106	194	0.047	0.005	0.11	2000	2097	99	123	79
1998-2019	3790	106	194	0.047	0.005	0.11	2001	2034	96	120	77
1998-2019	3790	106	194	0.047	0.005	0.11	2002	1953	92	115	74
1998-2019	3790	106	194	0.047	0.005	0.11	2003	1633	77	96	62
1998-2019	3790	106	194	0.047	0.005	0.11	2004	1602	75	93	60
1998-2019	3790	106	194	0.047	0.005	0.11	2005	1879	88	110	71
1998-2019	3790	106	194	0.047	0.005	0.11	2006	2471	116	145	93
1998-2019	3790	106	194	0.047	0.005	0.11	2007	3748	176	219	141
1998-2019	3790	106	194	0.047	0.005	0.11	2008	3756	177	221	142
1998-2019	3790	106	194	0.047	0.005	0.11	2009	4422	208	259	167
1998-2019	3790	106	194	0.047	0.005	0.11	2010	2801	132	164	106
1998-2019	3790	106	194	0.047	0.005	0.11	2011	3825	180	224	144
1998-2019	3790	106	194	0.047	0.005	0.11	2012	3773	178	222	143
1998-2019	3790	106	194	0.047	0.005	0.11	2013	2173	102	127	82
1998-2019	3790	106	194	0.047	0.005	0.11	2014	3932	185	230	148
1998-2019	3790	106	194	0.047	0.005	0.11	2015	3871	182	227	146
1998-2019	3790	106	194	0.047	0.005	0.11	2016	3221	152	189	122
1998-2019	3790	106	194	0.047	0.005	0.11	2017	2351	111	138	89
1998-2019	3790	106	194	0.047	0.005	0.11	2018	3227	152	189	122
1998-2019	3790	106	194	0.047	0.005	0.11	2019	3635	171	213	137

Table 21. Yearly calculated dead discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the Atlantic. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	3598	111	511	0.112	0.017	0.15	1998	2403	269	361	200
1998-2019	3598	111	511	0.112	0.017	0.15	1999	1855	207	278	154
1998-2019	3598	111	511	0.112	0.017	0.15	2000	1945	218	293	162
1998-2019	3598	111	511	0.112	0.017	0.15	2001	1872	209	281	156
1998-2019	3598	111	511	0.112	0.017	0.15	2002	1874	210	282	156
1998-2019	3598	111	511	0.112	0.017	0.15	2003	1558	174	234	130
1998-2019	3598	111	511	0.112	0.017	0.15	2004	1547	173	232	129
1998-2019	3598	111	511	0.112	0.017	0.15	2005	1812	203	273	151
1998-2019	3598	111	511	0.112	0.017	0.15	2006	2379	266	357	198
1998-2019	3598	111	511	0.112	0.017	0.15	2007	3658	409	549	305
1998-2019	3598	111	511	0.112	0.017	0.15	2008	3602	403	541	300
1998-2019	3598	111	511	0.112	0.017	0.15	2009	4108	459	616	342
1998-2019	3598	111	511	0.112	0.017	0.15	2010	2714	304	408	226
1998-2019	3598	111	511	0.112	0.017	0.15	2011	3467	388	521	289
1998-2019	3598	111	511	0.112	0.017	0.15	2012	3540	396	532	295
1998-2019	3598	111	511	0.112	0.017	0.15	2013	1876	210	282	156
1998-2019	3598	111	511	0.112	0.017	0.15	2014	3354	375	504	279
1998-2019	3598	111	511	0.112	0.017	0.15	2015	3125	350	470	261
1998-2019	3598	111	511	0.112	0.017	0.15	2016	2851	319	428	238
1998-2019	3598	111	511	0.112	0.017	0.15	2017	2151	241	324	179
1998-2019	3598	111	511	0.112	0.017	0.15	2018	3063	343	461	255
1998-2019	3598	111	511	0.112	0.017	0.15	2019	3370	377	506	281

Table 22. Yearly calculated live discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the Atlantic. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	3598	104	191	0.049	0.006	0.110	1998	2403	117	146	94
1998-2019	3598	104	191	0.049	0.006	0.110	1999	1855	90	112	72
1998-2019	3598	104	191	0.049	0.006	0.110	2000	1945	95	119	76
1998-2019	3598	104	191	0.049	0.006	0.110	2001	1872	91	114	73
1998-2019	3598	104	191	0.049	0.006	0.110	2002	1874	91	114	73
1998-2019	3598	104	191	0.049	0.006	0.110	2003	1558	76	95	61
1998-2019	3598	104	191	0.049	0.006	0.110	2004	1547	75	94	60
1998-2019	3598	104	191	0.049	0.006	0.110	2005	1812	88	110	70
1998-2019	3598	104	191	0.049	0.006	0.110	2006	2379	116	145	93
1998-2019	3598	104	191	0.049	0.006	0.110	2007	3658	178	222	143
1998-2019	3598	104	191	0.049	0.006	0.110	2008	3602	176	220	141
1998-2019	3598	104	191	0.049	0.006	0.110	2009	4108	200	250	160
1998-2019	3598	104	191	0.049	0.006	0.110	2010	2714	132	165	106
1998-2019	3598	104	191	0.049	0.006	0.110	2011	3467	169	211	135
1998-2019	3598	104	191	0.049	0.006	0.110	2012	3540	173	216	139
1998-2019	3598	104	191	0.049	0.006	0.110	2013	1876	91	114	73
1998-2019	3598	104	191	0.049	0.006	0.110	2014	3354	164	205	131
1998-2019	3598	104	191	0.049	0.006	0.110	2015	3125	152	190	122
1998-2019	3598	104	191	0.049	0.006	0.110	2016	2851	139	174	111
1998-2019	3598	104	191	0.049	0.006	0.110	2017	2151	105	131	84
1998-2019	3598	104	191	0.049	0.006	0.110	2018	3063	149	186	119
1998-2019	3598	104	191	0.049	0.006	0.110	2019	3370	164	205	131

Table 23. Yearly calculated dead discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the Gulf of Mexico. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	192	4	47	0.161	0.131	0.810	1998	112	18	73	4
1998-2019	192	4	47	0.161	0.131	0.810	1999	222	36	146	9
1998-2019	192	4	47	0.161	0.131	0.810	2000	152	24	97	6
1998-2019	192	4	47	0.161	0.131	0.810	2001	162	26	105	6
1998-2019	192	4	47	0.161	0.131	0.810	2002	79	13	53	3
1998-2019	192	4	47	0.161	0.131	0.810	2003	75	12	49	3
1998-2019	192	4	47	0.161	0.131	0.810	2004	55	9	36	2
1998-2019	192	4	47	0.161	0.131	0.810	2005	67	11	44	3
1998-2019	192	4	47	0.161	0.131	0.810	2006	92	15	61	4
1998-2019	192	4	47	0.161	0.131	0.810	2007	90	14	57	3
1998-2019	192	4	47	0.161	0.131	0.810	2008	154	25	101	6
1998-2019	192	4	47	0.161	0.131	0.810	2009	314	51	206	13
1998-2019	192	4	47	0.161	0.131	0.810	2010	87	14	57	3
1998-2019	192	4	47	0.161	0.131	0.810	2011	358	58	234	14
1998-2019	192	4	47	0.161	0.131	0.810	2012	233	37	150	9
1998-2019	192	4	47	0.161	0.131	0.810	2013	297	48	194	12
1998-2019	192	4	47	0.161	0.131	0.810	2014	578	93	376	23
1998-2019	192	4	47	0.161	0.131	0.810	2015	746	120	485	30
1998-2019	192	4	47	0.161	0.131	0.810	2016	370	60	243	15
1998-2019	192	4	47	0.161	0.131	0.810	2017	200	32	129	8
1998-2019	192	4	47	0.161	0.131	0.810	2018	164	26	105	6
1998-2019	192	4	47	0.161	0.131	0.810	2019	265	43	174	11

Table 24. Yearly calculated live discards of scalloped hammerhead sharks from the US southeast commercial gillnet fishery for the Gulf of Mexico. Discards are reported as number of individuals. Due to small number of observed positive sets, all years of observed data are combined.

Observed Year	Observed Sets	Positive Sets	Observed Animals	Mean CPUE (Per Set)	Standard Deviation	CV	Logbook Year	Logbook Sets	Estimated Discards	Upper 95% CI	Lower 95% CI
1998-2019	192	2	3	0.016	0.012	0.740	1998	112	2	7	1
1998-2019	192	2	3	0.016	0.012	0.740	1999	222	3	11	1
1998-2019	192	2	3	0.016	0.012	0.740	2000	152	2	7	1
1998-2019	192	2	3	0.016	0.012	0.740	2001	162	3	11	1
1998-2019	192	2	3	0.016	0.012	0.740	2002	79	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2003	75	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2004	55	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2005	67	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2006	92	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2007	90	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2008	154	2	7	1
1998-2019	192	2	3	0.016	0.012	0.740	2009	314	5	18	1
1998-2019	192	2	3	0.016	0.012	0.740	2010	87	1	4	0
1998-2019	192	2	3	0.016	0.012	0.740	2011	358	6	22	2
1998-2019	192	2	3	0.016	0.012	0.740	2012	233	4	15	1
1998-2019	192	2	3	0.016	0.012	0.740	2013	297	5	18	1
1998-2019	192	2	3	0.016	0.012	0.740	2014	578	9	33	2
1998-2019	192	2	3	0.016	0.012	0.740	2015	746	12	44	3
1998-2019	192	2	3	0.016	0.012	0.740	2016	370	6	22	2
1998-2019	192	2	3	0.016	0.012	0.740	2017	200	3	11	1
1998-2019	192	2	3	0.016	0.012	0.740	2018	164	3	11	1
1998-2019	192	2	3	0.016	0.012	0.740	2019	265	4	15	1

Table 25. Scalloped hammerhead final discard estimates from the Northeast Region's Mid-Atlantic sink-gillnet fishing fleet created using the grand mean discard ratio for use in the SEDAR 77 assessment for this species.

year	total landings (lbs)	ave num live d/k	est num live disc	95% LCL	95% UCL	ave wgt live d/k	est wgt (lbs) live disc	95% LCL	95% UCL	ave num dead d/k	est num dead disc	95% LCL	95% UCL	ave wgt dead d/k	est wgt (lbs) dead disc	95% LCL	95% UCL
1981	952070	0.0000040	4	2	6	0.0002151	205	40	369	0.0000051	5	3	7	0.0003480	331	143	520
1982	800479	0.0000040	3	1	5	0.0002151	172	34	311	0.0000051	4	2	6	0.0003480	279	120	437
1983	1633356	0.0000040	7	3	10	0.0002151	351	69	634	0.0000051	8	4	12	0.0003480	568	245	891
1984	1109970	0.0000040	4	2	7	0.0002151	239	47	431	0.0000051	6	3	8	0.0003480	386	167	606
1985	1393009	0.0000040	6	2	9	0.0002151	300	59	540	0.0000051	7	4	10	0.0003480	485	209	760
1986	1665998	0.0000040	7	3	11	0.0002151	358	70	646	0.0000051	9	5	12	0.0003480	580	250	909
1987	2535339	0.0000040	10	4	16	0.0002151	545	107	984	0.0000051	13	7	19	0.0003480	882	381	1384
1988	2641003	0.0000040	11	4	17	0.0002151	568	111	1025	0.0000051	14	7	20	0.0003480	919	397	1441
1989	7681371	0.0000040	31	13	49	0.0002151	1652	324	2980	0.0000051	39	21	58	0.0003480	2673	1154	4192
1990	8883032	0.0000040	36	15	56	0.0002151	1911	375	3446	0.0000051	45	24	67	0.0003480	3091	1334	4848
1991	14004376	0.0000040	56	23	89	0.0002151	3012	591	5433	0.0000051	72	39	105	0.0003480	4873	2103	7643
1992	14803957	0.0000040	59	25	94	0.0002151	3184	625	5743	0.0000051	76	41	111	0.0003480	5151	2224	8079
1993	21398090	0.0000040	86	36	136	0.0002151	4602	903	8301	0.0000051	110	59	160	0.0003480	7446	3214	11678
1994	20856487	0.0000040	83	35	132	0.0002151	4486	880	8091	0.0000051	107	57	156	0.0003480	7257	3133	11382
1995	18574803	0.0000040	74	31	118	0.0002151	3995	784	7206	0.0000051	95	51	139	0.0003480	6463	2790	10137
1996	26013961	0.0000040	104	43	165	0.0002151	5595	1098	10092	0.0000051	133	72	195	0.0003480	9052	3907	14197
1997	33567487	0.0000040	134	56	213	0.0002151	7220	1417	13022	0.0000051	172	92	251	0.0003480	11680	5042	18319
1998	37990099	0.0000040	152	63	241	0.0002151	8171	1604	14738	0.0000051	195	105	285	0.0003480	13219	5706	20733
1999	35233873	0.0000040	141	59	223	0.0002151	7578	1487	13669	0.0000051	180	97	264	0.0003480	12260	5292	19228
2000	29740831	0.0000040	119	49	188	0.0002151	6397	1255	11538	0.0000051	152	82	223	0.0003480	10349	4467	16231
2001	25990262	0.0000040	104	43	165	0.0002151	5590	1097	10083	0.0000051	133	71	195	0.0003480	9044	3904	14184
2002	22966222	0.0000040	92	38	146	0.0002151	4940	970	8910	0.0000051	118	63	172	0.0003480	7991	3449	12533
2003	28133639	0.0000040	113	47	178	0.0002151	6051	1188	10914	0.0000051	144	77	211	0.0003480	9790	4226	15354
2004	22495571	0.0000040	90	37	143	0.0002151	4838	950	8727	0.0000051	115	62	168	0.0003480	7828	3379	12277
2005	20886990	0.0000040	84	35	132	0.0002151	4492	882	8103	0.0000051	107	57	156	0.0003480	7268	3137	11399
2006	13680048	0.0000040	55	23	87	0.0002151	2942	577	5307	0.0000051	70	38	102	0.0003480	4760	2055	7466
2007	25248342	0.0000040	101	42	160	0.0002151	5430	1066	9795	0.0000051	129	69	189	0.0003480	8786	3792	13779
2008	20668902	0.0000040	83	34	131	0.0002151	4445	873	8018	0.0000051	106	57	155	0.0003480	7192	3104	11280
2009	27306265	0.0000040	109	45	173	0.0002151	5873	1153	10593	0.0000051	140	75	205	0.0003480	9502	4101	14902
2010	14664473	0.0000040	59	24	93	0.0002151	3154	619	5689	0.0000051	75	40	110	0.0003480	5103	2203	8003
2011	30295460	0.0000040	121	50	192	0.0002151	6516	1279	11753	0.0000051	155	83	227	0.0003480	10542	4550	16533
2012	24959012	0.0000040	100	41	158	0.0002151	5368	1054	9683	0.0000051	128	69	187	0.0003480	8685	3749	13621
2013	23562221	0.0000040	94	39	149	0.0002151	5068	995	9141	0.0000051	121	65	176	0.0003480	8199	3539	12859
2014	31582469	0.0000040	126	53	200	0.0002151	6793	1333	12252	0.0000051	162	87	237	0.0003480	10990	4744	17236
2015	120724151	0.0000040	483	201	765	0.0002151	25965	5096	46834	0.0000051	618	332	904	0.0003480	42008	18132	65883
2016	19271696	0.0000040	77	32	122	0.0002151	4145	814	7476	0.0000051	99	53	144	0.0003480	6706	2895	10517
2017	18009161	0.0000040	72	30	114	0.0002151	3873	760	6987	0.0000051	92	50	135	0.0003480	6267	2705	9828
2018	16100672	0.0000040	64	27	102	0.0002151	3463	680	6246	0.0000051	82	44	121	0.0003480	5602	2418	8787
2019	18502297	0.0000040	74	31	117	0.0002151	3979	781	7178	0.0000051	95	51	139	0.0003480	6438	2779	10097

Table 26. Smooth hammerhead final discard estimates from the Northeast Region's Mid-Atlantic sink-gillnet fishing fleet created using the grand mean discard ratio for use in the SEDAR 77 assessment for this species.

year	total landings (lbs)	ave num live d/k	est num live disc	95% LCL	95% UCL	ave wgt live d/k	est wgt (lbs) live disc	95% LCL	95% UCL	ave num dead d/k	est num dead disc	95% LCL	95% UCL	ave wgt dead d/k	est wgt (lbs) dead disc	95% LCL	95% UCL
1981	952070	0.0000027	3	2	3	0.0000386	37	26	47	0.0000052	5	4	6	0.0001878	179	92	266
1982	800479	0.0000027	2	1	3	0.0000386	31	22	40	0.0000052	4	3	5	0.0001878	150	77	223
1983	1633356	0.0000027	4	3	6	0.0000386	63	45	81	0.0000052	8	6	11	0.0001878	307	158	456
1984	1109970	0.0000027	3	2	4	0.0000386	43	31	55	0.0000052	6	4	7	0.0001878	208	107	310
1985	1393009	0.0000027	4	3	5	0.0000386	54	39	69	0.0000052	7	5	9	0.0001878	262	134	389
1986	1665998	0.0000027	5	3	6	0.0000386	64	46	82	0.0000052	9	6	11	0.0001878	313	161	465
1987	2535339	0.0000027	7	5	9	0.0000386	98	70	125	0.0000052	13	10	17	0.0001878	476	245	707
1988	2641003	0.0000027	7	5	9	0.0000386	102	73	131	0.0000052	14	10	17	0.0001878	496	255	737
1989	7681371	0.0000027	21	14	27	0.0000386	296	213	380	0.0000052	40	29	51	0.0001878	1443	742	2143
1990	8883032	0.0000027	24	17	32	0.0000386	343	246	439	0.0000052	46	34	59	0.0001878	1668	858	2479
1991	14004376	0.0000027	38	26	50	0.0000386	540	388	693	0.0000052	73	53	93	0.0001878	2630	1352	3908
1992	14803957	0.0000027	40	28	53	0.0000386	571	410	732	0.0000052	77	56	98	0.0001878	2780	1429	4131
1993	21398090	0.0000027	58	40	77	0.0000386	826	593	1059	0.0000052	111	81	141	0.0001878	4019	2066	5971
1994	20856487	0.0000027	57	39	75	0.0000386	805	578	1032	0.0000052	108	79	138	0.0001878	3917	2014	5820
1995	18574803	0.0000027	51	35	66	0.0000386	717	514	919	0.0000052	97	70	123	0.0001878	3488	1793	5183
1996	26013961	0.0000027	71	49	93	0.0000386	1004	720	1287	0.0000052	135	99	172	0.0001878	4885	2512	7259
1997	33567487	0.0000027	91	63	120	0.0000386	1295	930	1661	0.0000052	175	127	222	0.0001878	6304	3241	9367
1998	37990099	0.0000027	103	71	136	0.0000386	1466	1052	1879	0.0000052	198	144	251	0.0001878	7134	3668	10601
1999	35233873	0.0000027	96	66	126	0.0000386	1359	976	1743	0.0000052	183	134	233	0.0001878	6617	3402	9832
2000	29740831	0.0000027	81	56	106	0.0000386	1147	824	1471	0.0000052	155	113	197	0.0001878	5585	2871	8299
2001	25990262	0.0000027	71	49	93	0.0000386	1003	720	1286	0.0000052	135	99	172	0.0001878	4881	2509	7253
2002	22966222	0.0000027	62	43	82	0.0000386	886	636	1136	0.0000052	119	87	152	0.0001878	4313	2217	6409
2003	28133639	0.0000027	77	53	101	0.0000386	1085	779	1392	0.0000052	146	107	186	0.0001878	5283	2716	7851
2004	22495571	0.0000027	61	42	80	0.0000386	868	623	1113	0.0000052	117	85	149	0.0001878	4225	2172	6277
2005	20886990	0.0000027	57	39	75	0.0000386	806	578	1033	0.0000052	109	79	138	0.0001878	3923	2017	5828
2006	13680048	0.0000027	37	26	49	0.0000386	528	379	677	0.0000052	71	52	90	0.0001878	2569	1321	3817
2007	25248342	0.0000027	69	47	90	0.0000386	974	699	1249	0.0000052	131	96	167	0.0001878	4742	2438	7045
2008	20668902	0.0000027	56	39	74	0.0000386	797	572	1022	0.0000052	108	78	137	0.0001878	3882	1996	5768
2009	27306265	0.0000027	74	51	98	0.0000386	1054	756	1351	0.0000052	142	104	181	0.0001878	5128	2636	7620
2010	14664473	0.0000027	40	27	52	0.0000386	566	406	725	0.0000052	76	56	97	0.0001878	2754	1416	4092
2011	30295460	0.0000027	82	57	108	0.0000386	1169	839	1499	0.0000052	158	115	200	0.0001878	5689	2925	8454
2012	24959012	0.0000027	68	47	89	0.0000386	963	691	1235	0.0000052	130	95	165	0.0001878	4687	2410	6965
2013	23562221	0.0000027	64	44	84	0.0000386	909	653	1166	0.0000052	123	89	156	0.0001878	4425	2275	6575
2014	31582469	0.0000027	86	59	113	0.0000386	1219	875	1562	0.0000052	164	120	209	0.0001878	5931	3049	8813
2015	120724151	0.0000027	328	225	432	0.0000386	4658	3343	5972	0.0000052	628	458	798	0.0001878	22672	11656	33688
2016	19271696	0.0000027	52	36	69	0.0000386	744	534	953	0.0000052	100	73	127	0.0001878	3619	1861	5378
2017	18009161	0.0000027	49	34	64	0.0000386	695	499	891	0.0000052	94	68	119	0.0001878	3382	1739	5025
2018	16100672	0.0000027	44	30	58	0.0000386	621	446	796	0.0000052	84	61	106	0.0001878	3024	1555	4493
2019	18502297	0.0000027	50	35	66	0.0000386	714	512	915	0.0000052	96	70	122	0.0001878	3475	1786	5163

Table 27. Capture of scalloped hammerheads (n = 164) by hour during fisheries research conducted employing hook timers on contracted commercial bottom-longline vessels in the U.S. Highly Migratory Species Shark Research Fishery (Gulak et al. 2015; Simon Gulak, Pers. Comm. December 14, 2022)[1].

Hours	Alive	Dead	Total	% Alive	% Dead	Proportion of total captured each hour	Running tally	Running proportion of total captured by hour
0-1	14		14	100.0%	0.0%	8.54%	14	8.54%
1-2	22	6	28	78.6%	21.4%	17.07%	42	25.61%
2-3	7	6	13	53.8%	46.2%	7.93%	55	33.54%
3-4	9	10	19	47.4%	52.6%	11.59%	74	45.12%
4-5	7	8	15	46.7%	53.3%	9.15%	89	54.27%
5-6	1	13	14	7.1%	92.9%	8.54%	103	62.80%
6-7	1	4	5	20.0%	80.0%	3.05%	108	65.85%
7-8	1	14	15	6.7%	93.3%	9.15%	123	75.00%
8-9		13	13	0.0%	100.0%	7.93%	136	82.93%
9-10		1	1	0.0%	100.0%	0.61%	137	83.54%
10-11	1	3	4	25.0%	75.0%	2.44%	141	85.98%
11-12		6	6	0.0%	100.0%	3.66%	147	89.63%
12-13		3	3	0.0%	100.0%	1.83%	150	91.46%
13-14		4	4	0.0%	100.0%	2.44%	154	93.90%
14-15		3	3	0.0%	100.0%	1.83%	157	95.73%
15-16		1	1	0.0%	100.0%	0.61%	158	96.34%
16-17		3	3	0.0%	100.0%	1.83%	161	98.17%
17-18		1	1	0.0%	100.0%	0.61%	162	98.78%
18-19		1	1	0.0%	100.0%	0.61%	163	99.39%
19-20		1	1	0.0%	100.0%	0.61%	164	100.00%

[1] Data provided by Simon Gulak (Pers. Comm. December 14, 2022) were not filtered to include covariates used in the original study and, consequently, differ slightly from those presented in the original study.

Table 28. Capture of great hammerheads (n = 71) by hour during fisheries research conducted employing hook timers on contracted commercial bottom-longline vessels in the U.S. Highly Migratory Species Shark Research Fishery (Gulak et al. 2015; Simon Gulak, Pers. Comm. December 14, 2022)[1].

Hours	Alive	Dead	Total	% Alive	% Dead	Proportion of total captured each hour	Running tally	Running proportion of total captured by hour
0-1	10		10	100.0%	0.0%	14.08%	10	14.08%
1-2	9		9	100.0%	0.0%	12.68%	19	26.76%
2-3	4	1	5	80.0%	20.0%	7.04%	24	33.80%
3-4	5	3	8	62.5%	37.5%	11.27%	32	45.07%
4-5	2	5	7	28.6%	71.4%	9.86%	39	54.93%
5-6		8	8	0.0%	100.0%	11.27%	47	66.20%
6-7	1	6	7	14.3%	85.7%	9.86%	54	76.06%
7-8		2	2	0.0%	100.0%	2.82%	56	78.87%
8-9		6	6	0.0%	100.0%	8.45%	62	87.32%
9-10		1	1	0.0%	100.0%	1.41%	63	88.73%
10-11		1	1	0.0%	100.0%	1.41%	64	90.14%
12-13		1	1	0.0%	100.0%	1.41%	65	91.55%
14-15		2	2	0.0%	100.0%	2.82%	67	94.37%
15-16		1	1	0.0%	100.0%	1.41%	68	95.77%
16-17		1	1	0.0%	100.0%	1.41%	69	97.18%
18-19		1	1	0.0%	100.0%	1.41%	70	98.59%
19-20		1	1	0.0%	100.0%	1.41%	71	100.00%

[1] Data provided by Simon Gulak (Pers. Comm. December 14, 2022) were not filtered to include covariates used in the original study and, consequently, differ slightly from those presented in the original study.

Table 29. Post release mortality of electronically tagged great and scalloped hammerheads captured on bottom longline gear (SEDAR77-RD20; SEDAR77-RD42; SEDAR77-DW34; SEDAR77-DW35).

A. Great Hammerhead

Source	Tagged (N)	Post-release mortality (n)	Proportion (n/N)	Post-release mortality (%)
SEDAR77-RD20[1]	3	0	0.00	0
SEDAR77-RD42[2]	28	13	0.46	46
SEDAR77-DW34[3]	9	5	0.56	56
SEDAR77-DW35[4]	20	9	0.45	45
Pooled	60	27	0.45	45

B. Scalloped Hammerhead

Source	Tagged (N)	Post-release mortality (n)	Proportion (n/N)	Post-release mortality (%)
SEDAR77-DW35[4]	25	2	0.08	8

[1] SEDAR77-RD20 (Drymon and Wells 2017) captured sharks in northern Gulf of Mexico with research longlines set for about one hour; Post-release mortality was estimated with double tagging from SPOT and survivorship pop-off archival transmitting tags (sPAT, Wildlife Computers).

[2] SEDAR77-RD42 (Gallagher et al. 2014) captured sharks in subtropical locations with baited drum-lines soaked for about one hour; Post-release mortality was estimated with Smart Position or Temperature Transmitting (SPOT) satellite tags (SPOTS, Wildlife Computers) reporting rates after 4 weeks.

[3] SEDAR77-DW34 (Hoffmayer et al. 2021) captured sharks in the northern Gulf of Mexico with research longlines set for about one hour; Post-release mortality was estimated with SPOT tag reporting rates (n = 4 reporting tags ranged 19 to 101 days, mean: 53.3 ± 20.0 days). Five tags did not transmit data to the satellite after the tags were deployed, suggesting those sharks succumbed to the capture stress.

[4] SEDAR77-DW35 (Whitney et al. 2021) captured sharks in the Gulf of Mexico with commercial longlines using a combination of relatively short soak times and (or) hook-timers in order to land live animals for tagging, with the result that the majority of hook times were under three hours; Post-release mortality was estimated with a combination of acceleration data-loggers (ADLs; model G6A+, Cefas, Inc., Lowestoft UK) and Pop-up Satellite Archival Tags (PSATs; model PSATLIFE, Lotek, Ontario, CAN).

Table 30. Post-release live-discard mortality rate calculations for scalloped hammerheads released from commercial bottom longline gear (69.15%).

M_A = Minimum PRLDM	0.0800	
S_A = 1 - M_A	0.9200	
Cumulative percentage on hook timers		
Hook time	Scalloped	n
1hr	8.54%	14
2hr	25.61%	42
3hr	33.54%	55
Total	100.00%	164
Proportion not at poor condition (<= 3hr)		
<= 3hr	0.3354	55
Proportion at poor condition (> 3hr)		
> 3hr	0.6646	109
Proportion that survive post-release		Calculations
<= 3hr	0.3085	[(1-0.0800)*0.3354]
> 3hr	0	[0*0.6646]
Total	0.3085	
Proportion that die post-release		Calculations
1-Total	0.6915	[1-0.3085]
Check proportion that die		Calculations
<= 3hr	0.0268	[0.0800*0.3354]
> 3hr	0.6646	[">3 hr"]
Total	0.6915	["<=3hr" + ">3 hr"]
PRLDM – Scalloped hammerhead	69.15%	

Table 31. Post-release live-discard mortality rate calculations for great hammerheads released from commercial bottom longline gear (81.41%).

M_A = Minimum PRLDM	0.4500	
S_A = 1 - M_A	0.5500	
Cumulative percentage on hook timers		
Hook time	Great	n
1hr	14.08%	10
2hr	26.76%	19
3hr	33.80%	24
Total	100.00%	71
Proportion not at poor condition (<= 3hr)		
<= 3hr	0.3380	24
Proportion at poor condition (> 3hr)		
> 3hr	0.6620	47
Proportion that survive post-release		Calculations
<= 3hr	0.1859	[(1-0.4500)*0.3380]
> 3hr	0	[0*0.6620]
Total	0.1859	
Proportion that die post-release		Calculations
1-Total	0.8141	[1-0.1859]
Check proportion that die		Calculations
<= 3hr	0.1521	[0.4500*0.3380]
> 3hr	0.6620	[">3 hr"]
Total	0.8141	["<=3hr" + ">3 hr"]
PRLDM – Great hammerhead	81.41%	

Table 32. Mexican landings of “cazones “ (sharks less than 150 cm TL) and “tiburones” (sharks greater than 150 cm TL) by state reported by the Comisión Nacional de Acuacultura y Pesca (Conapesca; tons ww).

	Landings of cazones				Landings of tiburones			
Year	Tamaulipas	Veracruz	Tabasco	Campeche	Tamaulipas	Veracruz	Tabasco	Campeche
1976	266	474	169	627	75	234	92	468
1977	575	654	189	544	155	190	358	817
1978	439	358	204	377	133	667	309	1037
1979	733	627	228	429	203	738	193	640
1980	889	706	274	491	371	1351	182	391
1981	2486	1036	407	441	703	3676	181	758
1982	1044	1309	392	847	286	3461	148	706
1983	1019	1493	311	2013	423	2719	374	1741
1984	1291	2433	500	2005	466	3133	397	1839
1985	1479	1144	442	1582	378	1239	414	1249
1986	1382	991	438	1174	372	1935	812	1754
1987	1583	777	467	1390	494	1425	669	2671
1988	1744	838	477	1363	631	2283	372	2573
1989	1917	1254	410	1128	573	1617	252	1400
1990	2352	1254	667	1209	666	1823	380	2022
1991	1692	1137	802	1003	551	1670	400	1802
1992	1907	1135	678	2414	622	1823	482	2163
1993	2154	1464	571	1745	593	1731	326	1785
1994	2052	1266	489	1273	707	1685	438	1808
1995	1655	1162	449	1115	1136	1683	325	1543
1996	1775	1355	515	1066	1044	2047	328	1637
1997	825	1739	331	489	697	2381	148	615
1998	1229	972	421	821	981	1519	136	641
1999	882	736	419	738	784	1414	188	483
2000	928	532	372	851	729	1652	199	519
2001	973	653	357	901	814	1738	147	548
2002	1156	586	344	757	698	1314	101	398
2003	1036	389	360	778	751	974	226	277
2004	1325	354	254	824	776	933	165	200
2005	676	23	1243	309	220	336	593	229
2006	618	400	316	432	562	1155	227	140
2007	624	631	321	405	775	842	236	101
2008	698	286	309	379	647	503	310	118
2009	847	336	266	542	520	505	208	140
2010	1256	351	260	507	807	550	307	260
2011	774	153	197	329	531	282	605	105
2012	883	224	113	409	507	545	449	148
2013	1060	344	138	269	1060	344	138	269
2014	911	392	133	345	654	652	727	291
2015	1058	621	141	391	662	904	841	318
2016	1297	861	159	435	874	1405	756	1375
2017	1775	838	215	344	1046	2209	739	163
2018	2131	974	230	312	1912	1990	751	215

Table 33. Estimated Mexican landings of scalloped and great hammerheads by state (lb dw).

	Scalloped hammerhead landings				Great hammerhead landings			
Year	Tamaulipas	Veracruz	Tabasco	Campeche	Tamaulipas	Veracruz	Tabasco	Campeche
1976	45408	11841	55386	26946	4803	3562	974	10556
1977	98119	15818	64931	25701	10294	4806	1413	12719
1978	74988	10862	69177	20471	8041	3093	1427	12894
1979	125109	17340	75529	20244	13190	5063	1402	9993
1980	152388	21560	90182	21240	17545	6128	1622	8479
1981	424387	38264	132910	21375	44915	10382	2295	11140
1982	178174	43715	127703	36818	18748	12146	2177	14899
1983	174660	45053	104323	87859	20083	12846	2053	35956
1984	220916	68339	165327	88103	24577	19869	3041	36722
1985	252271	31217	146888	68374	26222	9150	2769	27224
1986	235824	30414	150268	55413	24736	8633	3253	27369
1987	270478	23486	157911	68965	29175	6693	3219	37554
1988	298441	28249	157643	67365	33219	7831	2893	36425
1989	327415	35232	134706	51630	35018	10242	2401	23825
1990	401517	36038	218793	58283	42505	10411	3867	30054
1991	289222	32742	262409	49056	31469	9454	4578	26012
1992	325979	33295	223523	105786	35480	9565	4053	43770
1993	367627	40518	187310	77720	38717	11829	3312	33558
1994	350962	35774	162273	59555	38646	10383	3038	28864
1995	286023	33369	148094	51934	38186	9642	2691	24929
1996	305849	39242	169338	50566	38792	11313	3030	25236
1997	143263	49400	108101	22428	20657	14317	1868	10399
1998	213119	28348	136881	35443	30061	8157	2309	14066
1999	153365	22498	136848	31333	22566	6393	2365	11837
2000	160862	18727	121874	35917	22553	5138	2141	13320
2001	168922	21852	116444	38019	24263	6069	1998	14090
2002	199284	18649	111727	31590	25488	5244	1874	11297
2003	179254	12778	118334	31720	24399	3565	2114	10467
2004	228292	11810	83556	33068	28916	3282	1498	10276
2005	115551	1845	406385	13271	12571	439	7061	5188
2006	107526	13739	104207	17535	15968	3792	1892	5692
2007	109656	17839	105919	16268	18698	5177	1929	5074
2008	121509	8560	102930	15357	18187	2446	1962	4952
2009	146060	9721	87916	21799	18782	2803	1614	6833
2010	216778	10243	87149	21120	28296	2947	1709	7509
2011	133764	4630	70397	13345	17855	1319	1767	4321
2012	152084	7296	41576	16689	19145	2040	1143	5523
2013	184933	9275	45964	11946	28580	2728	875	5120
2014	157592	11587	51261	15016	21376	3322	1597	6098
2015	182511	17851	55168	16952	23615	5157	1783	6809
2016	224067	25344	59956	24628	29724	7274	1766	16423
2017	305859	27960	77752	14254	38817	7770	2029	4979
2018	370638	30237	82713	13308	54741	8558	2120	5098

Table 34. Estimated Mexican landings of scalloped and great hammerheads by major gear type (lb dw).

	Scalloped hammerhead landings by gear			Great hammerhead landings by gear		
Year	Longlines	Nets	Lines	Longlines	Nets	Lines
1976	53650	79756	6176	3751	14663	1481
1977	63181	132424	8964	5207	21734	2291
1978	61723	106680	7095	4028	19844	1583
1979	70765	157048	10408	5349	21705	2594
1980	84416	188218	12736	6314	24198	3262
1981	127923	463111	25902	10684	51354	6694
1982	129164	236590	20656	11034	31704	5232
1983	124504	267029	20362	12301	53083	5553
1984	183601	329285	29800	17920	58199	8089
1985	142512	336371	19868	10322	50172	4872
1986	141427	311219	19273	10348	49047	4596
1987	145756	356519	18565	9613	62696	4333
1988	148473	382614	20612	10171	65197	4999
1989	133213	393180	22589	10878	54719	5889
1990	196146	491174	27310	12728	67592	6518
1991	222432	386344	24653	12168	53975	5370
1992	207713	456088	24782	12663	74491	5714
1993	180446	465987	26743	13210	67537	6669
1994	155289	429069	24207	11835	62883	6212
1995	141378	356681	21361	10879	58624	5946
1996	160236	380629	24131	12293	59564	6514
1997	115268	187265	20660	12075	29109	6056
1998	125899	270243	17650	8867	40869	4857
1999	120759	208859	14426	7418	32012	3730
2000	108671	215546	13162	6466	33348	3338
2001	107299	223858	14080	7045	35615	3760
2002	100679	246707	13863	6325	33982	3597
2003	101542	228634	11910	5355	32200	2989
2004	76638	268152	11938	4792	35933	3248
2005	296766	224606	15680	6863	17292	1104
2006	88314	144903	9790	4842	20091	2411
2007	91901	146763	11019	5846	21978	3054
2008	83715	155939	8703	4060	21325	2162
2009	75296	180948	9253	4099	23613	2319
2010	75480	248534	11275	4615	32751	3096
2011	57497	157653	6987	3121	20357	1785
2012	39393	170886	7366	3160	22582	2109
2013	43015	200191	8911	3680	30574	3050
2014	48762	177721	8973	4481	25232	2681
2015	56195	204805	11482	5944	27995	3425
2016	66445	252734	14816	7917	42715	4556
2017	79236	328353	18236	8291	39894	5410
2018	84550	391598	20748	9414	54222	6881

Table 35. Post-release live discard mortality (PRLDM) rate (%) outcomes for electronically tagged scalloped and great hammerheads from multiple release locations in Florida west coast estuaries and bays adjacent to the Gulf of Mexico adapted from Gardiner et al. (2022, their Tables 1 and 2).

Scalloped hammerhead				
	Gear type	Tags reporting	PRLDM	(%)
	GN	2	2	100%
	DL	1	0	0%
Great hammerhead				
	Source	Tags reporting	PRLDM	(%)
	RR	1	1	100%
	BLL	7	1	14%

Gear type (GN = gillnet, DL = drumline, BLL = bottom longline, RR = rod and reel).

Table 36. Catches of scalloped hammerheads for areas combined in weight (lb dw). Total commercial catch is the maximum of the sum of commercial catches by gear and total commercial catches not disaggregated by gear; total recreational catch is the sum of total recreational AB1 catch and LPRM (live post-release mortality=B2 dead); total catch is the sum of total recreational and total commercial catch. See text for additional definitions of terms.

Year	Total Bottom longline catch	Total Gillnet catch	Total hook and line + hand line catch	Pelagic longline dead discards	Total commercial catch	Total AB1 recreational catch	Total recreational LPRM	Total recreational catch	Total catch
1981	0	0	0	0	0	344834	120621	465454	465454
1982	20095	4641	88	11446	49453	344834	120621	465454	514907
1983	40189	9342	175	23168	98906	262674	105935	368609	467515
1984	60284	13957	263	34615	148359	201196	78254	279450	427809
1985	80379	18649	351	46061	197812	192528	75544	268072	465884
1986	100474	23360	438	57507	247264	156621	57171	213792	461056
1987	120568	28219	526	84513	296717	157274	57747	215021	511738
1988	140663	32948	614	275099	449324	210126	61440	271566	720890
1989	160758	39096	701	127729	395623	322442	75539	397981	793604
1990	180853	44369	789	163350	445076	460766	85443	546209	991285
1991	79321	76921	121	111360	325196	471572	128370	599941	925137
1992	229490	50096	912	405737	737447	483904	222049	705953	1443400
1993	298117	29300	1597	44761	420944	296889	364756	661645	1082589
1994	508601	25247	43129	46221	676082	186186	231260	417446	1093528
1995	324146	22070	10393	89767	471014	135787	60918	196705	667719
1996	276803	30681	10758	15546	351177	141401	30676	172078	523255
1997	86146	28089	235	48258	171746	159323	29690	189013	360760
1998	95459	29054	1272	47384	186198	176826	84581	261407	447605
1999	108111	23392	9704	40433	187294	195243	193419	388662	575956
2000	69798	21011	388	46364	157837	212856	407217	620073	777911
2001	63314	19710	1182	55740	180295	185014	707696	892710	1073005
2002	97532	10098	2759	44239	205088	158624	702714	861338	1066426
2003	122966	47533	726	44239	234996	192135	646678	838812	1073808
2004	92665	26383	2690	44239	181461	231956	459143	691099	872560
2005	88680	9887	2346	44239	221448	291251	344016	635267	856715
2006	92643	15402	216	44239	205937	125684	234518	360202	566140
2007	22132	11526	83	96855	151883	68720	199444	268164	420047
2008	29237	77323	789	63284	177781	30799	194339	225138	402919
2009	77151	21045	13711	51367	168913	30665	226045	256710	425622
2010	44546	13458	1825	2401	68776	17743	308583	326326	395102
2011	65256	26130	1404	4092	103357	19021	414648	433670	537026
2012	57039	22371	9490	1900	90806	35643	483193	518836	609642
2013	31547	21145	1989	3240	58167	100491	336837	437328	495496
2014	36165	23388	409	34086	94048	177288	191907	369195	463243
2015	34149	57050	70	31145	122414	37735	139812	177547	299961
2016	18757	21741	17225	52595	114598	7026	125625	132651	247249
2017	27670	49017	3147	80614	160680	1288	133651	134939	295619
2018	20848	13266	17713	22552	74379	1288	133651	134939	209318
2019	12350	16214	205	10805	39574	1288	133651	134939	174513
2020	3682	8704	3172	66025	81799	1288	133651	134939	216738

Table 37. Catches of scalloped hammerheads for areas combined in numbers. Total commercial catch is the maximum of the sum of commercial catches by gear and total commercial catches not disaggregated by gear; total recreational catch is the sum of total recreational AB1 catch and LPRM; total catch is the sum of total recreational and total commercial catch. See text for additional definitions of terms.

Year	Total Bottom longline catch	Total Gillnet catch	Total hook and line + hand line catch	Pelagic longline dead discards	Total commercial catch	Total AB1 recreational catch	Total recreational LPRM	Total recreational catch	Total catch
1981	0	0	0	0	0	23641	22898	46539	46539
1982	227	138	1	163	829	23641	22898	46539	47368
1983	454	277	2	329	1659	19641	14312	33954	35612
1984	681	414	3	492	2488	16353	7444	23797	26285
1985	908	552	4	655	3318	13812	5644	19456	22774
1986	1135	692	5	817	4147	8373	2008	10380	14527
1987	1362	834	6	1201	4977	6134	1384	7518	12494
1988	1588	974	7	3909	6478	5822	1209	7031	13509
1989	1815	1144	8	1815	6635	8374	2501	10875	17510
1990	2042	1296	9	2321	7465	11299	4041	15341	22805
1991	896	2247	1	1583	5033	11283	7022	18305	23338
1992	2592	1448	10	7839	13220	11498	12474	23972	37192
1993	3367	812	18	536	6630	7262	16393	23655	30285
1994	4732	693	401	695	9320	4680	8397	13078	22398
1995	2761	605	89	803	5388	3404	4247	7651	13039
1996	2727	840	106	339	4612	3413	2335	5748	10360
1997	1291	743	4	680	3003	3670	2344	6014	9016
1998	1045	759	14	376	2409	3992	2296	6288	8697
1999	1003	599	90	505	2363	4449	2727	7176	9539
2000	788	543	4	434	2083	4937	3551	8488	10571
2001	860	515	16	1154	3314	4656	4925	9581	12895
2002	1056	625	30	423	3172	4272	5189	9461	12633
2003	1716	467	10	571	2764	5267	5736	11004	13767
2004	1417	420	41	783	2797	5868	5873	11741	14539
2005	1050	449	28	553	3949	6827	7049	13876	17825
2006	1391	509	3	877	4131	2909	6718	9627	13758
2007	482	750	2	1345	3568	1616	6933	8549	12117
2008	590	734	16	1269	2609	740	6085	6825	9434
2009	804	1142	143	1313	3830	746	5844	6590	10420
2010	511	807	21	55	1581	466	5359	5825	7406
2011	593	912	13	57	1855	511	4858	5369	7223
2012	507	1062	84	30	1781	939	4873	5812	7593
2013	301	2924	19	68	3311	2436	4543	6979	10290
2014	485	2011	5	506	3007	4132	4423	8555	11562
2015	294	1939	1	372	2605	890	3689	4579	7185
2016	232	1955	173	770	3130	193	2988	3181	6311
2017	267	532	30	1287	2115	39	2495	2534	4649
2018	236	1288	202	320	2047	39	2495	2534	4581
2019	133	1095	2	154	1384	39	2495	2534	3918
2020	55	361	43	938	1397	39	2495	2534	3931

Table 38. Catches of GOM scalloped hammerheads in weight (lb dw). Total commercial catch is the maximum of the sum of commercial catches by gear and total commercial catches not disaggregated by gear; total recreational catch is the sum of total recreational AB1 catch and LPRM; total catch is the sum of total recreational and total commercial catch. See text for additional definitions of terms.

Year	Total Bottom longline catch	Total Gillnet catch	Total hook and line + hand line catch	Pelagic longline dead discards	Total commercial catch	Total AB1 recreational catch	Total recreational LPRM	Total recreational catch	Total catch
1981	0	0	0	0	0	46365	1692	48057	48057
1982	3388	128	46	928	4489	46365	1692	48057	52546
1983	6775	256	91	1878	9001	36701	5334	42035	51036
1984	10163	385	137	2806	13490	27874	16796	44670	58160
1985	13550	513	182	3734	17979	24832	52889	77721	95700
1986	16938	641	228	4661	22468	26475	35971	62446	84914
1987	20326	769	273	6496	27865	33016	27198	60215	88079
1988	23713	898	319	20239	45169	47588	20565	68153	113322
1989	27101	1026	364	13441	41932	44311	14755	59065	100997
1990	30488	1154	410	19083	51135	24420	2934	27355	78490
1991	34507	1282	0	8821	45823	20770	2238	23008	68831
1992	33534	1284	875	4303	39995	22191	2652	24843	64838
1993	35449	1282	492	4303	41525	34473	10241	44714	86239
1994	91367	1286	30561	4303	127516	14113	3452	17564	145080
1995	157845	1283	1573	2292	169212	5516	1064	6581	175792
1996	187200	1296	7549	1519	204227	5368	694	6062	210289
1997	29529	1282	116	1598	35744	12613	1351	13965	49709
1998	43693	653	106	223	51577	31079	4167	35246	86823
1999	16130	1282	1	610	23758	20573	8261	28834	52592
2000	48215	855	127	14236	76088	14283	25179	39462	115550
2001	37548	945	0	3641	58358	14494	54993	69487	127845
2002	50598	58	0	4303	86592	22891	87083	109974	196566
2003	81602	1939	678	4303	101798	35027	66668	101695	203493
2004	57839	759	446	4303	76034	24324	40765	65089	141123
2005	106403	100	0	4303	167223	14485	18180	32666	199889
2006	53300	412	0	4303	90319	6421	7940	14360	104679
2007	11045	67	0	2013	24361	4290	4241	8531	32892
2008	16644	3232	372	13995	39822	3500	4476	7976	47798
2009	37790	663	2854	5784	55251	3394	9958	13352	68604
2010	16037	175	290	149	20739	3196	23312	26509	47248
2011	32795	1414	575	2301	43018	3662	38825	42487	85506
2012	39373	701	5827	386	46287	4786	30962	35748	82035
2013	6838	239	0	1315	8392	6301	20616	26917	35310
2014	9154	705	80	14028	23967	4397	10723	15120	39087
2015	13352	1808	70	4353	20443	2852	12887	15738	36181
2016	10010	594	17068	10937	42889	1627	16539	18165	61054
2017	19890	3725	3147	378	27371	1283	26573	27856	55228
2018	13953	177	17584	1346	33060	1283	26573	27856	60917
2019	9061	458	0	832	10452	1283	26573	27856	38308
2020	868	0	2882	0	3750	1283	26573	27856	31606

Table 39. Catches of GOM scalloped hammerheads in numbers. Total commercial catch is the maximum of the sum of commercial catches by gear and total commercial catches not disaggregated by gear; total recreational catch is the sum of total recreational AB1 catch and LPRM; total catch is the sum of total recreational and total commercial catch. See text for additional definitions of terms.

Year	Total Bottom longline catch	Total Gillnet catch	Total hook and line + hand line catch	Pelagic longline dead discards	Total commercial catch	Total AB1 recreational catch	Total recreational LPRM	Total recreational catch	Total catch
1981	0	0	0	0	0	2102	255	2357	2357
1982	40	35	1	13	89	2102	255	2357	2446
1983	81	8	1	27	116	1658	655	2313	2429
1984	121	11	2	40	174	1301	1678	2979	3153
1985	162	15	2	53	232	1217	4302	5519	5751
1986	202	19	3	66	290	1279	1302	2581	2872
1987	243	23	3	92	361	1501	649	2150	2512
1988	283	27	4	288	601	1997	324	2321	2922
1989	324	30	4	191	550	1864	489	2352	2902
1990	364	34	5	271	675	1043	190	1233	1907
1991	412	38	0	125	602	931	180	1111	1713
1992	401	38	10	83	532	1044	185	1230	1762
1993	424	38	6	52	519	1698	476	2174	2694
1994	766	38	256	65	1141	993	295	1288	2430
1995	1440	38	14	20	1717	465	184	650	2367
1996	1747	38	70	33	2150	341	95	435	2585
1997	729	38	3	23	889	418	82	500	1389
1998	668	19	2	2	836	622	87	709	1545
1999	696	38	0	8	934	467	116	583	1516
2000	576	25	2	133	953	383	240	623	1577
2001	560	28	0	75	994	509	415	925	1919
2002	689	14	0	41	1615	875	686	1561	3176
2003	825	13	7	55	960	1385	619	2004	2964
2004	748	10	6	76	1009	629	512	1141	2150
2005	620	12	0	54	1346	261	338	599	1945
2006	1043	16	0	85	2092	110	183	293	2384
2007	286	15	0	28	944	100	110	210	1154
2008	336	26	8	281	651	107	118	225	876
2009	402	54	30	148	1068	104	212	317	1385
2010	201	15	4	3	442	88	376	465	906
2011	274	62	5	32	616	98	407	505	1121
2012	373	45	55	6	732	125	337	461	1193
2013	68	51	0	27	157	179	277	456	613
2014	190	110	2	208	585	114	234	348	933
2015	147	128	1	52	376	66	307	373	749
2016	166	72	198	160	843	38	378	416	1259
2017	202	34	32	6	273	34	496	530	804
2018	186	28	238	19	771	34	496	530	1301
2019	97	46	0	12	176	34	496	530	707
2020	10	0	34	0	69	34	496	530	600

Table 40. Catches of ATL scalloped hammerheads in weight (lb dw). Total commercial catch is the maximum of the sum of commercial catches by gear and total commercial catches not disaggregated by gear; total recreational catch is the sum of total recreational AB1 catch and LPRM; total catch is the sum of total recreational and total commercial catch. See text for additional definitions of terms.

Year	Total Bottom longline catch	Total Gillnet catch	Total hook and line + hand line catch	Pelagic longline dead discards	Total commercial catch	Total AB1 recreational catch	Total recreational LPRM	Total recreational catch	Total catch
1981	0	0	0	0	0	276251	131889	408141	408141
1982	25469	4581	36	11430	45878	276251	131889	408141	454018
1983	50939	9224	72	23135	91755	101772	90553	192325	284080
1984	76408	13777	109	34565	137633	42156	39460	81616	219249
1985	101878	18412	145	45995	183510	35340	25687	61027	244537
1986	127347	23067	181	57425	229388	53448	25314	78763	308151
1987	152817	27876	217	84365	275265	93025	42987	136012	411277
1988	178286	32550	253	274617	485706	155373	68581	223954	709660
1989	203756	38713	290	127505	370264	264983	80331	345314	715578
1990	229225	43959	326	163064	436574	411972	88192	500164	936737
1991	61349	77022	98	111165	288394	456615	124943	581559	869953
1992	300448	49709	73	405737	755966	483664	215320	698984	1454950
1993	404694	28642	915	44761	479012	332019	357630	689649	1168661
1994	642570	24472	11626	46221	724889	228407	264168	492575	1217464
1995	238160	21234	7189	89767	356349	178347	81827	260174	616524
1996	123325	29966	2956	15519	171766	156319	40409	196727	368493
1997	64557	27553	101	48174	140385	147599	35457	183056	323442
1998	47850	21650	945	47302	117746	139307	80513	219820	337566
1999	48962	15872	7825	40363	113021	156589	181451	338040	451061
2000	23499	14865	216	46283	89408	174074	358662	532736	622144
2001	33454	14148	953	55642	122422	154092	680480	834573	956995
2002	33591	5921	2225	44162	96515	127903	724912	852815	949331
2003	74692	40553	72	44162	159479	157940	735427	893367	1052846
2004	43913	21356	2100	44162	111530	203163	528941	732104	843634
2005	38508	6038	2170	44162	94731	276442	398066	674508	769239
2006	41773	12534	174	44162	110770	120339	276395	396734	507504
2007	12772	6912	67	96686	123451	65195	232965	298160	421611
2008	15217	67869	354	63284	146725	27673	234543	262217	408941
2009	41909	12100	8895	51367	114272	27260	263510	290770	405042
2010	34463	8834	1252	2396	46946	14016	358975	372991	419936
2011	25181	15582	696	4085	46171	14806	446550	461356	507526
2012	8805	13392	3778	1897	36720	28437	507748	536185	572905
2013	7263	17607	1989	3234	46708	91072	372331	463404	510112
2014	8302	18293	329	34086	76999	172400	240253	412653	489653
2015	10719	38407	0	31145	87544	3060	186026	189086	276630
2016	6654	18481	157	52595	79161	54	161446	161500	240661
2017	8407	43066	0	80614	132116	2	152373	152376	284492
2018	4884	10818	129	22552	39656	2	152373	152376	192031
2019	961	13180	205	9825	25908	2	152373	152376	178284
2020	0	8704	290	66025	78049	2	152373	152376	230425

Table 41. Catches of ATL scalloped hammerheads in numbers. Total commercial catch is the maximum of the sum of commercial catches by gear and total commercial catches not disaggregated by gear; total recreational catch is the sum of total recreational AB1 catch and LPRM; total catch is the sum of total recreational and total commercial catch. See text for additional definitions of terms.

Year	Total Bottom longline catch	Total Gillnet catch	Total hook and line + hand line catch	Pelagic longline dead discards	Total commercial catch	Total AB1 recreational catch	Total recreational LPRM	Total recreational catch	Total catch
1981	0	0	0	0	0	25249	26004	51253	51253
1982	250	136	0	162	744	25249	26004	51253	51997
1983	500	272	1	329	1488	8248	12283	20530	22018
1984	750	408	1	491	2231	2872	3544	6416	8648
1985	1000	544	1	654	2975	1226	1503	2729	5704
1986	1251	681	2	816	3719	1474	771	2245	5964
1987	1501	821	2	1199	4463	2152	887	3039	7502
1988	1751	958	2	3903	6614	3593	1376	4969	11584
1989	2001	1122	3	1812	5950	6125	2475	8600	14551
1990	2251	1269	3	2317	6694	9522	3971	13493	20187
1991	602	2224	1	1580	4407	10554	6703	17258	21665
1992	2950	1409	1	7839	12340	11180	11538	22718	35058
1993	3974	753	9	536	5662	7674	15898	23573	29235
1994	6036	632	109	695	8188	5279	10730	16009	24197
1995	2006	546	61	803	3678	4122	6790	10912	14590
1996	1256	771	30	338	2425	3613	3663	7276	9701
1997	567	665	1	679	1919	3411	2837	6248	8167
1998	448	752	9	375	1584	3219	2138	5358	6942
1999	436	572	70	504	1596	3619	2429	6048	7644
2000	231	527	2	433	1259	4023	3065	7088	8347
2001	313	495	9	1152	2261	3632	4617	8249	10510
2002	463	620	31	422	1841	3082	5208	8290	10130
2003	903	462	1	570	1935	3834	6214	10048	11983
2004	692	412	33	781	1919	4836	6445	11281	13200
2005	563	443	32	552	1986	6436	7694	14131	16117
2006	350	497	1	876	1960	2781	7415	10197	12157
2007	190	740	1	1343	2530	1508	7527	9035	11564
2008	149	683	3	1269	2106	640	7084	7724	9830
2009	343	1063	73	1313	2791	640	7121	7761	10552
2010	301	779	11	55	1147	374	6947	7321	8468
2011	261	820	7	57	1198	408	5769	6176	7374
2012	68	947	29	30	1074	774	5397	6170	7245
2013	68	2970	18	68	3123	2183	4922	7104	10228
2014	274	2034	4	506	2818	4000	5121	9120	11938
2015	136	2290	0	372	2799	595	4548	5143	7942
2016	69	1964	1	770	2804	89	3630	3719	6523
2017	62	570	0	1287	1918	4	2845	2849	4767
2018	59	1323	1	320	1703	4	2845	2849	4552
2019	34	1124	2	140	1300	4	2845	2849	4149
2020	45	361	4	938	1348	4	2845	2849	4197

Table 42. Catches of great hammerheads in weight (lb dw). Total commercial catch is the maximum of the sum of commercial catches by gear and total commercial catches not disaggregated by gear; total recreational catch is the sum of total recreational AB1 catch and LPRM; total catch is the sum of total recreational and total commercial catch. See text for additional definitions of terms.

Year	Total Bottom longline catch	Total Gillnet catch	Total hook and line + hand line catch	Pelagic longline dead discards	Total commercial catch	Total AB1 recreational catch	Total recreational LPRM	Total recreational catch	Total catch
1981	0	0	0	0	0	1805080	1188771	2993851	2993851
1982	22580	14157	11	651	37399	1805080	1188771	2993851	3031250
1983	45160	28314	22	1317	74814	2353810	1304552	3658362	3733176
1984	67740	42471	34	1967	112213	3183814	1311445	4495258	4607471
1985	90321	56628	45	2618	149612	2908133	1037763	3945896	4095508
1986	112901	70786	56	3268	187011	2271091	819635	3090726	3277737
1987	135481	84943	67	4981	225471	1338955	509558	1848514	2073985
1988	158061	99100	78	16212	273452	844899	388267	1233167	1506618
1989	180641	113257	90	7527	301515	812657	303680	1116336	1417851
1990	203221	127414	101	9627	340363	1048784	276710	1325494	1665857
1991	61870	196477	18	6563	264927	1463934	248883	1712818	1977745
1992	264261	138762	117	21665	424804	987133	231498	1218631	1643435
1993	356276	89475	204	7157	453111	528352	256239	784591	1237702
1994	587130	81260	5509	5686	679585	356835	468713	825548	1505133
1995	258843	76231	1328	546	336947	337131	807241	1144372	1481319
1996	167915	88904	1374	916	259110	343424	1423679	1767103	2026212
1997	69717	77641	30	2844	150231	126380	604849	731229	881460
1998	51265	6534	162	2793	60753	70612	287768	358380	419133
1999	54675	131366	1240	2383	191344	54553	92722	147275	338619
2000	45394	166852	50	2732	231201	92000	74440	166440	397641
2001	46811	21478	151	3285	101137	95213	35302	130515	231653
2002	50113	47304	352	2607	137360	18356	27932	46287	183647
2003	111826	217562	93	2607	332088	4467	18973	23440	355527
2004	90940	555945	166	2607	649658	1475	22487	23962	673619
2005	33432	18622	116	2607	105650	4330	18655	22985	128635
2006	51387	82006	28	2607	163848	10089	17552	27642	191489
2007	13105	15248	12	5708	41031	20751	20335	41086	82117
2008	30756	29847	101	44	60749	9787	30417	40203	100952
2009	79516	30854	1752	118	112239	5741	44041	49782	162022
2010	53510	29465	252	141	83368	3001	37014	40015	123383
2011	56229	17707	179	241	74356	3342	27663	31005	105362
2012	8954	81235	1179	112	91480	2067	22230	24297	115777
2013	52403	58553	512	191	116661	1387	21111	22499	139159
2014	22930	14279	2094	5422	55782	898	31575	32473	88255
2015	37554	47992	13941	4554	105630	840	47013	47853	153483
2016	20987	39573	15198	2218	77976	272	69717	69989	147965
2017	29105	17743	966	1449	49938	72	53188	53260	103198
2018	60761	127112	1612	688	190174	72	53188	53260	243434
2019	42343	52325	1224	0	96042	72	53188	53260	149302
2020	9995	27773	409	0	38282	72	53188	53260	91542

Table 43. Catches of great hammerheads in numbers. Total commercial catch is the maximum of the sum of commercial catches by gear and total commercial catches not disaggregated by gear; total recreational catch is the sum of total recreational AB1 catch and LPRM; total catch is the sum of total recreational and total commercial catch. See text for additional definitions of terms.

Year	Total Bottom longline catch	Total Gillnet catch	Total hook and line + hand line catch	Pelagic longline dead discards	Total commercial catch	Total AB1 recreational catch	Total recreational LPRM	Total recreational catch	Total catch
1981	0	0	0	0	0	30549	39786	70335	70335
1982	133	136	0	5	274	30549	39786	70335	70609
1983	267	271	0	10	548	38694	41373	80067	80615
1984	400	407	0	15	822	51047	32318	83365	84187
1985	534	543	0	20	1096	47728	19483	67211	68307
1986	667	678	0	25	1370	38331	12598	50929	52300
1987	801	814	0	38	1652	22539	7978	30517	32169
1988	934	999	0	122	2055	14205	6536	20740	22796
1989	1067	1085	1	57	2210	14079	4412	18491	20701
1990	1201	1221	1	73	2495	19278	4844	24121	26616
1991	366	1882	0	49	2298	28009	5285	33294	35591
1992	1562	1330	1	254	3145	18896	7211	26107	29252
1993	2105	857	1	41	3005	9996	8054	18050	21055
1994	3110	779	29	24	3942	6592	9652	16243	20185
1995	2164	730	11	3	2908	6097	10140	16237	19145
1996	1422	852	12	11	2297	6086	10473	16559	18857
1997	515	744	0	24	1283	2299	5563	7862	9145
1998	378	63	1	16	457	1273	3204	4476	4934
1999	361	1259	8	17	1644	998	2186	3184	4829
2000	200	1599	0	21	1820	1650	2598	4247	6067
2001	242	206	1	31	479	1765	2950	4715	5194
2002	345	686	2	20	1053	377	1534	1910	2964
2003	769	1521	1	38	2328	97	705	803	3131
2004	642	5327	1	30	6000	33	408	442	6442
2005	132	178	0	24	335	87	389	477	812
2006	301	786	0	17	1104	188	419	606	1710
2007	94	146	0	18	258	358	449	808	1066
2008	191	286	1	0	478	182	585	767	1245
2009	476	296	10	1	783	111	741	852	1635
2010	302	282	1	1	587	58	622	679	1266
2011	326	170	1	3	500	60	464	524	1024
2012	53	778	7	1	839	36	373	410	1249
2013	271	561	3	2	837	26	354	381	1218
2014	176	132	10	65	383	19	530	549	932
2015	237	449	77	39	802	19	789	808	1610
2016	108	368	79	16	571	7	1171	1178	1749
2017	194	170	6	16	387	2	893	895	1282
2018	385	1214	10	5	1614	2	893	895	2509
2019	256	501	7	0	764	2	893	895	1659
2020	49	274	2	0	325	2	893	895	1220

Table 44. Catches of smooth hammerheads in weight (lb dw). Total commercial catch is the maximum of the sum of commercial catches by gear and total commercial catches not disaggregated by gear; total recreational catch is the sum of total recreational AB1 catch and LPRM; total catch is the sum of total recreational and total commercial catch. See text for additional definitions of terms.

Year	Total Bottom longline catch	Total Gillnet catch	Total unknown gear	Pelagic longline dead discards	Total commercial catch	Total AB1 recreational catch	Total recreational LPRM	Total recreational catch	Total catch
1981	0	3651	0	0	3651	18232	28852	47084	50735
1982	102	406	0	220	5360	18232	28852	47084	52443
1983	204	0	0	446	10719	11145	52243	63387	74107
1984	307	1217	0	666	16079	15779	138388	154167	170246
1985	409	1623	0	886	21439	24491	226635	251127	272565
1986	511	2028	0	1107	26799	70365	386063	456429	483227
1987	613	2434	0	1800	32158	83958	372880	456838	488997
1988	715	2840	0	5858	37518	87102	191568	278670	316188
1989	818	3245	0	2720	42878	83726	142396	226121	268999
1990	920	3651	0	3479	48238	89834	131028	220861	269099
1991	204	7326	0	2371	33827	150086	204139	354225	388052
1992	1214	3889	0	4329	61201	243597	119783	363379	424580
1993	1649	954	0	668	65763	360474	60555	421029	486792
1994	2658	465	2	220	107102	255864	27648	283512	390614
1995	1139	165	0	742	45160	170017	33746	203762	248922
1996	582	920	0	331	26667	120077	48187	168265	194932
1997	219	249	0	1028	10492	110034	75232	185266	195758
1998	113	389	0	1009	8388	85937	50033	135970	144358
1999	122	69	0	861	8215	52694	23790	76483	84699
2000	18	4	0	987	6036	34985	6157	41141	47178
2001	53	5	0	1187	11864	28578	3774	32352	44216
2002	77	148	0	942	15128	3439	3335	6774	21901
2003	386	116	0	942	17911	287	5531	5818	23729
2004	327	139	0	942	15251	30	5954	5984	21235
2005	166	7	0	942	23022	26	10693	10719	33741
2006	237	128	0	942	20587	33	18790	18823	39410
2007	65	2	0	2063	8775	10	32852	32863	41637
2008	507	317	0	63	7463	3	21964	21967	29430
2009	384	565	2540	43	20311	1	14322	14323	34634
2010	207	424	5607	51	14844	1	9551	9552	24396
2011	242	179	65	87	9949	28	6116	6144	16093
2012	41	4141	70	40	7244	801	4357	5158	12402
2013	0	179	0	69	329	22690	4430	27120	27449
2014	312	257	32	58	659	801	7304	8106	8765
2015	264	40	0	562	866	28	11334	11363	12229
2016	0	125	0	1385	1510	1	8707	8708	10219
2017	0	1127	0	6446	7639	1	6719	6720	14359
2018	0	530	0	286	816	1	6719	6720	7536
2019	0	13	0	1306	1346	1	6719	6720	8066
2020	0	0	0	361	361	1	6719	6720	7081

Table 45. Catches of smooth hammerheads in numbers. Total commercial catch is the maximum of the sum of commercial catches by gear and total commercial catches not disaggregated by gear; total recreational catch is the sum of total recreational AB1 catch and LPRM; total catch is the sum of total recreational and total commercial catch. See text for additional definitions of terms.

Year	Total Bottom longline catch	Total Gillnet catch	Total unknown gear	Pelagic longline dead discards	Total commercial catch	Total AB1 recreational catch	Total recreational LPRM	Total recreational catch	Total catch
1981	0	309	0	0	309	4095	872	4966	5276
1982	1	34	0	3	118	4095	872	4966	5085
1983	3	0	0	6	237	1198	1312	2511	2748
1984	4	103	0	9	355	810	2446	3256	3611
1985	5	138	0	12	473	624	3616	4240	4713
1986	7	172	0	14	592	2135	5820	7956	8547
1987	8	206	0	24	710	3071	6992	10064	10774
1988	9	241	0	77	828	3696	4020	7716	8544
1989	11	275	0	36	947	3943	2900	6844	7790
1990	12	309	0	46	1065	4414	2501	6916	7981
1991	3	621	0	31	739	6412	4698	11110	11849
1992	16	330	0	56	1336	7248	6468	13716	15053
1993	21	81	0	9	1474	7877	8661	16538	18013
1994	37	39	0	3	2584	4927	7000	11927	14511
1995	11	14	0	10	770	3273	5290	8563	9333
1996	8	78	0	1	594	2310	2032	4341	4935
1997	18	21	0	13	795	2114	1031	3144	3940
1998	1	33	0	26	192	1651	431	2082	2273
1999	2	6	0	11	177	1013	295	1308	1484
2000	1	0	0	13	327	675	112	788	1114
2001	1	0	0	16	256	554	84	638	894
2002	35	13	0	10	2031	135	73	208	2239
2003	5	10	0	14	396	26	113	139	535
2004	4	12	0	10	332	5	120	125	457
2005	2	1	0	22	498	5	215	220	718
2006	3	11	0	15	457	4	378	382	839
2007	1	0	0	44	195	3	660	663	858
2008	2	27	0	1	68	2	441	443	511
2009	5	34	33	0	433	1	288	289	722
2010	1	62	33	1	166	1	192	193	359
2011	3	15	1	3	225	8	175	184	408
2012	1	351	1	1	353	68	170	238	590
2013	0	15	0	3	19	559	198	757	776
2014	4	22	0	1	27	55	228	283	310
2015	3	3	0	7	14	5	261	266	281
2016	0	11	0	41	51	1	175	175	227
2017	0	96	0	148	243	1	135	136	379
2018	0	45	0	4	49	1	135	136	184
2019	0	1	0	17	18	1	135	136	154
2020	0	0	0	5	5	1	135	136	140

3.5 Figures

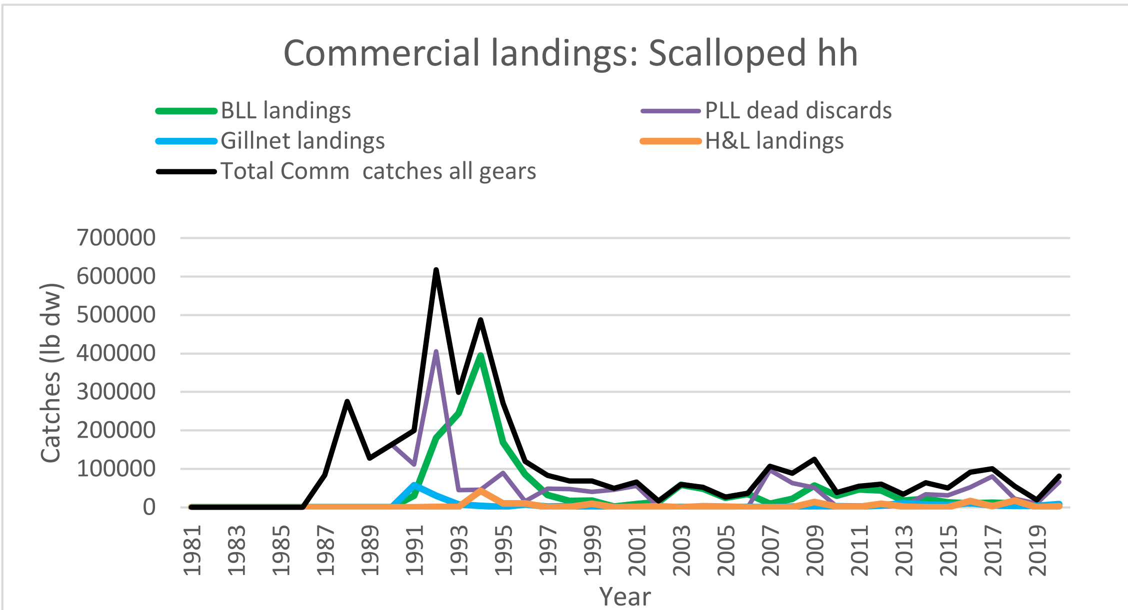
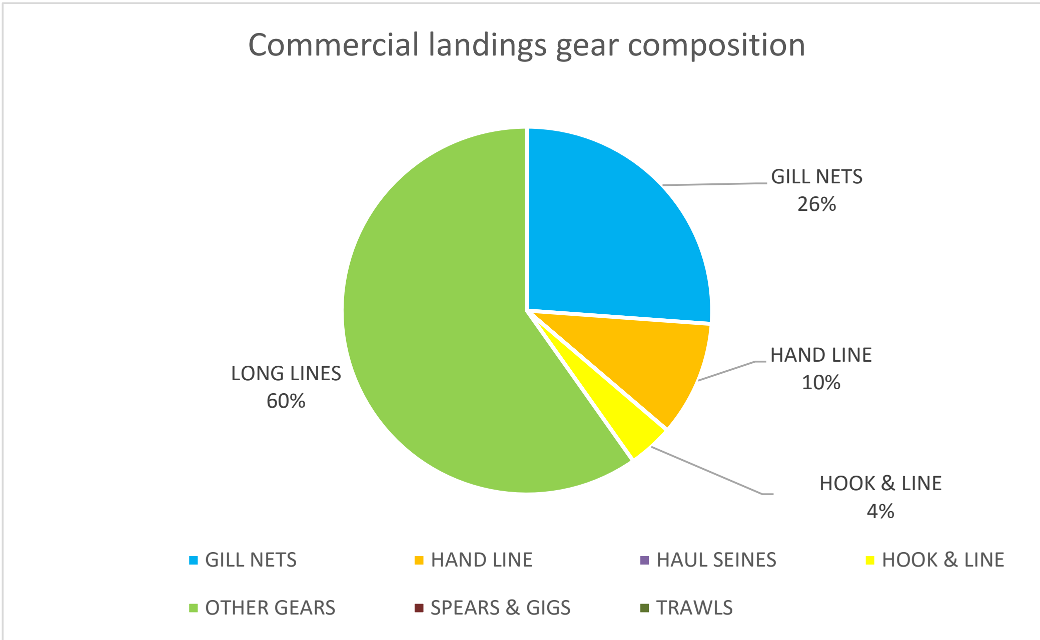


Figure 1. Commercial landings (lb dw) of scalloped hammerheads (all regions) by gear, including dead discards from the pelagic longline fishery. BLL=bottom longline; PLL=pelagic longline; H&L=hook and line.



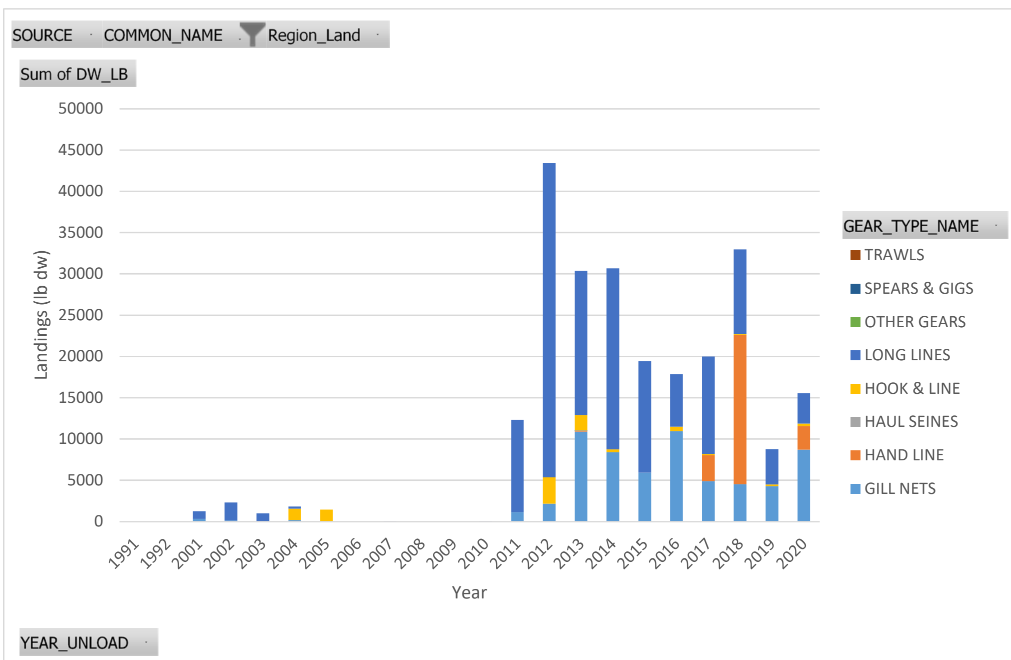
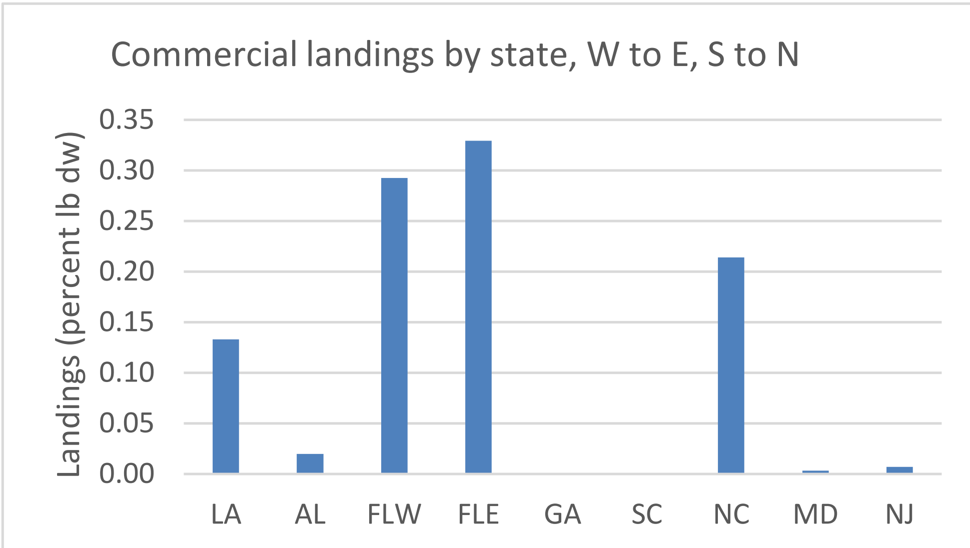


Figure 2. Commercial landings (lb dw) of scalloped hammerheads (all regions) by gear type from FINS for 1991-2020. Top panel: relative contribution for the entire time period; bottom panel: annual composition of the main gears by year.



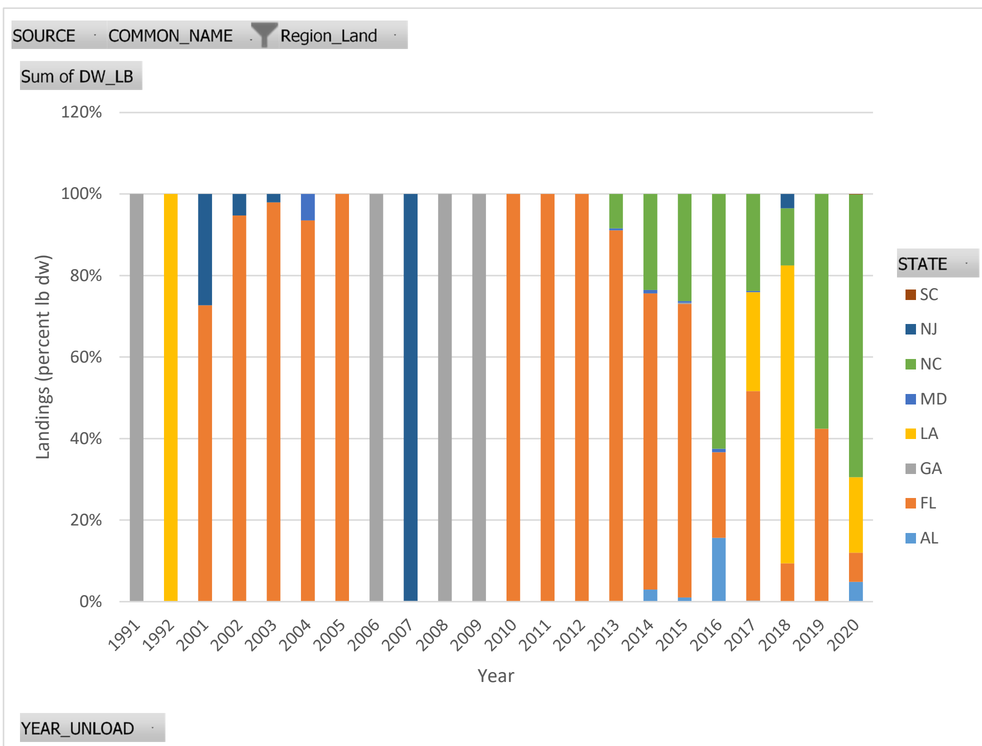


Figure 3. Commercial landings (lb dw) of scalloped hammerheads (all regions) by state of landing from FINS for 1991-2020. Top panel: relative contribution for the entire time period; bottom panel: composition of states by year

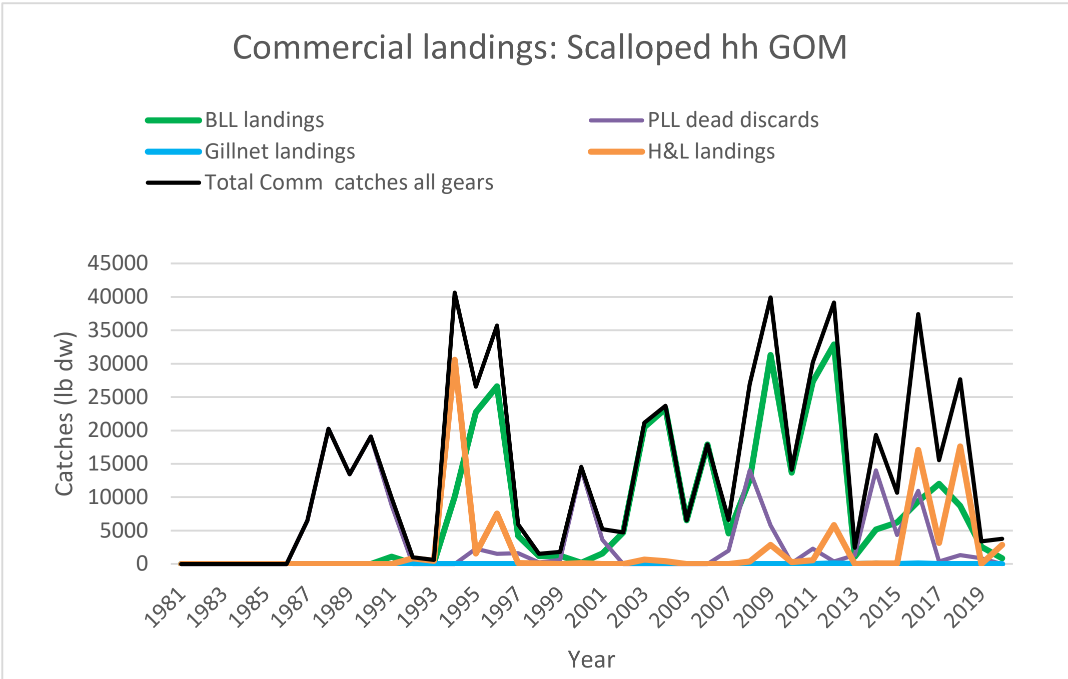
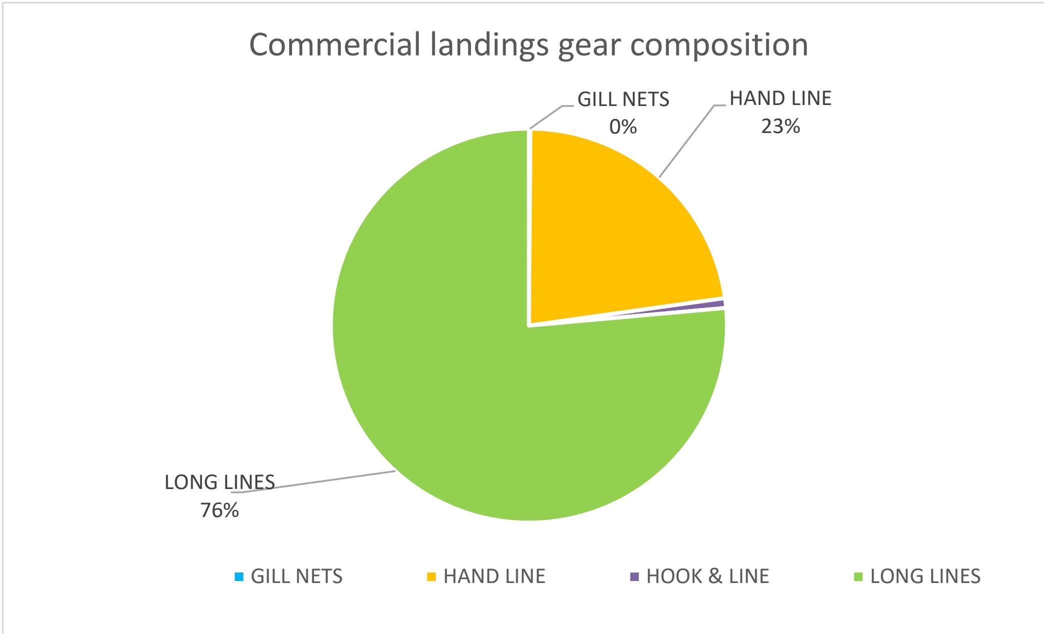


Figure 4. Commercial landings (lb dw) of scalloped hammerheads in the GOM by gear, including dead discards from the pelagic longline fishery. BLL=bottom longline; PLL=pelagic longline; H&L=hook and line.



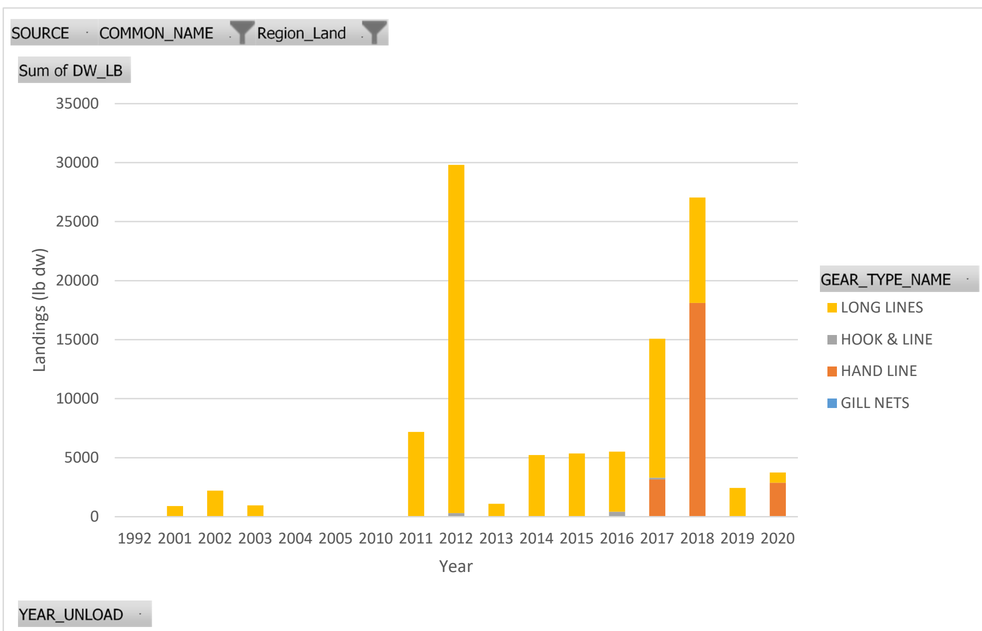
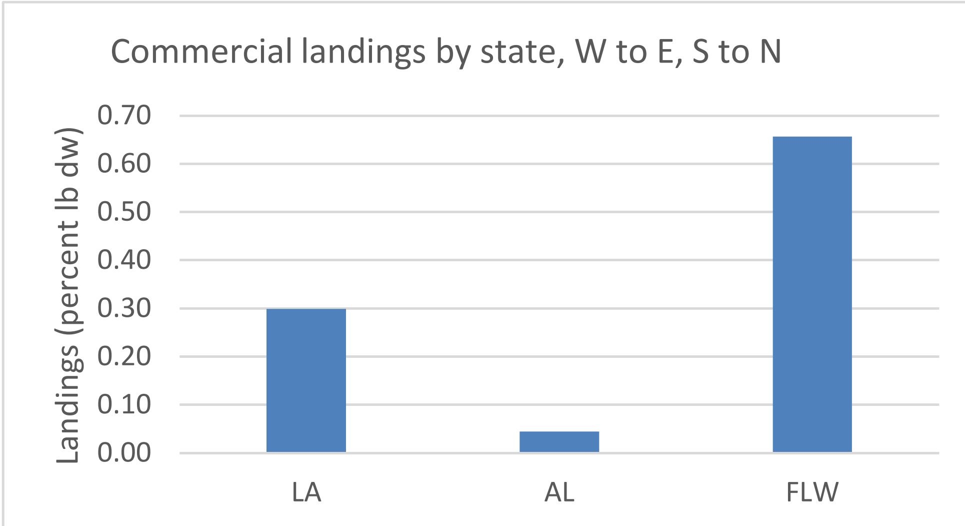


Figure 4. Commercial landings (lb dw) of scalloped hammerheads in the GOM by gear type from FINS for 1991-2020. Top panel: relative contribution for the entire time period; bottom panel: annual composition of the main gears by year.



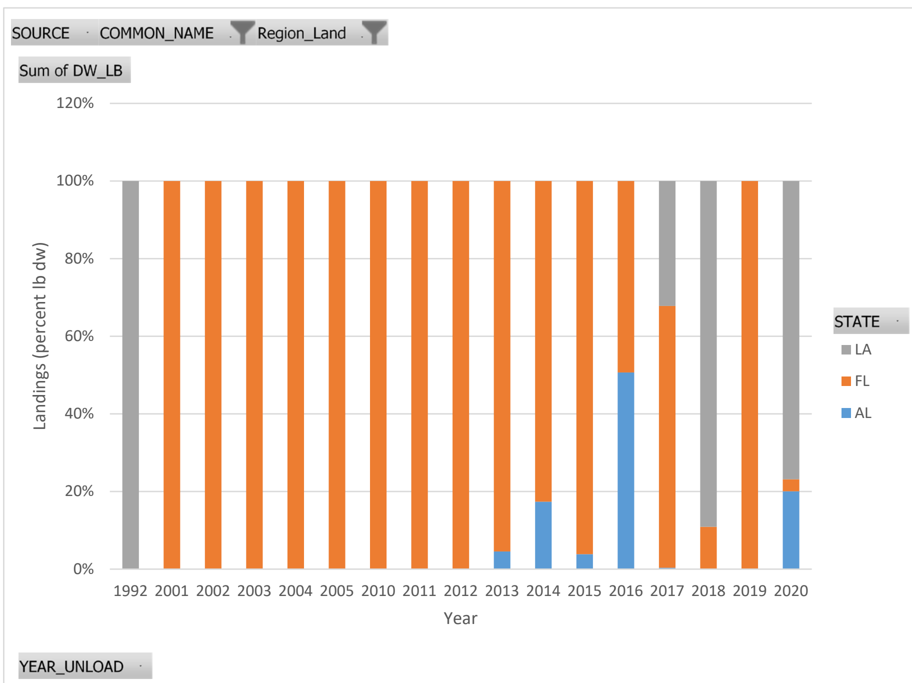


Figure 6. Commercial landings (lb dw) of scalloped hammerheads in the GOM by state of landing from FINS for 1991-2020. Top panel: relative contribution for the entire time period; bottom panel: composition of states by year.

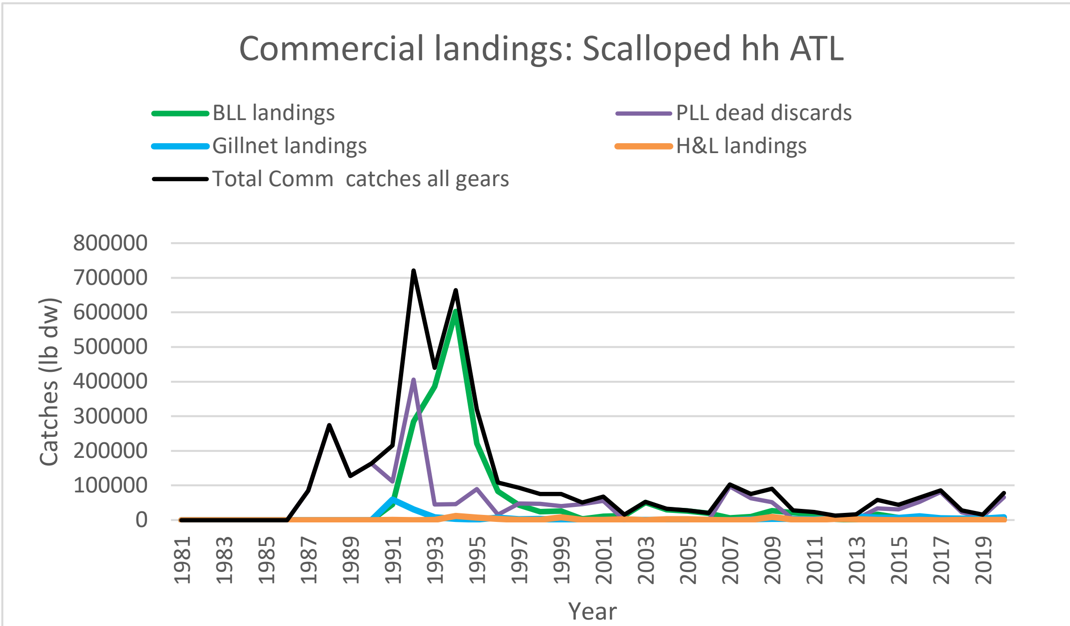
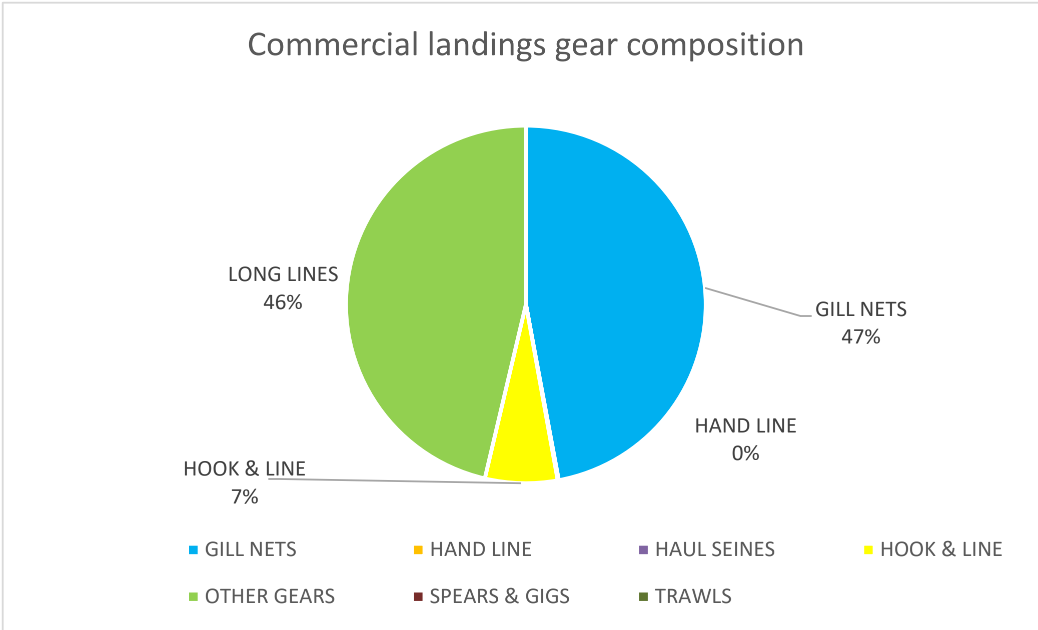


Figure 7. Commercial landings (lb dw) of scalloped hammerheads in the ATL by gear, including dead discards from the pelagic longline fishery. BLL=bottom longline; PLL=pelagic longline; H&L=hook and line.



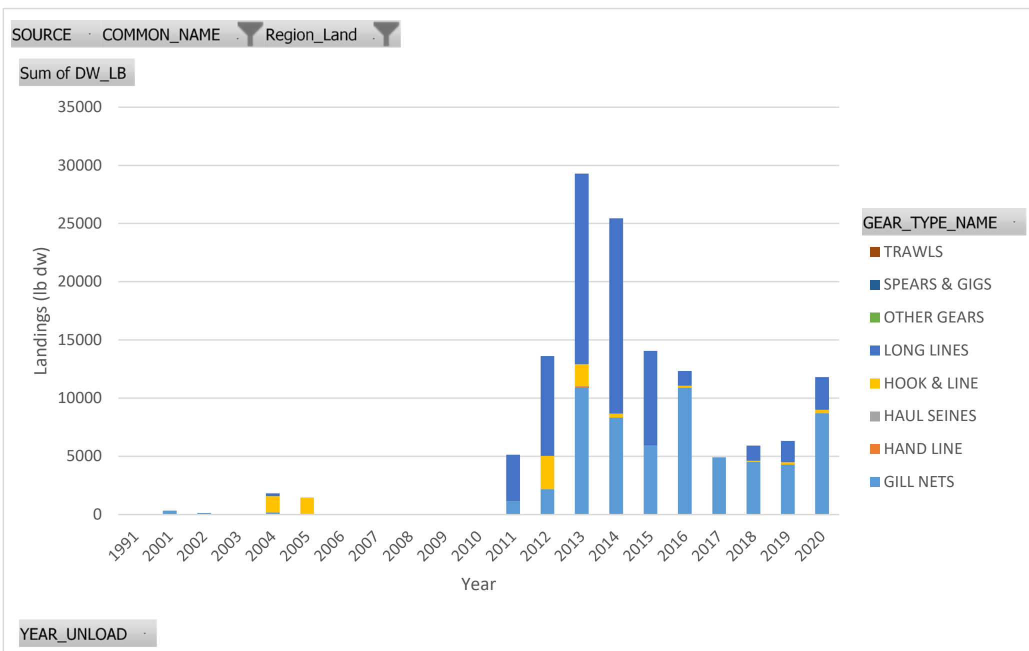


Figure 8. Commercial landings (lb dw) of scalloped hammerheads in the ATL by gear type from FINS for 1991-2020. Top panel: relative contribution for the entire time period; bottom panel: annual composition of the main gears by year.

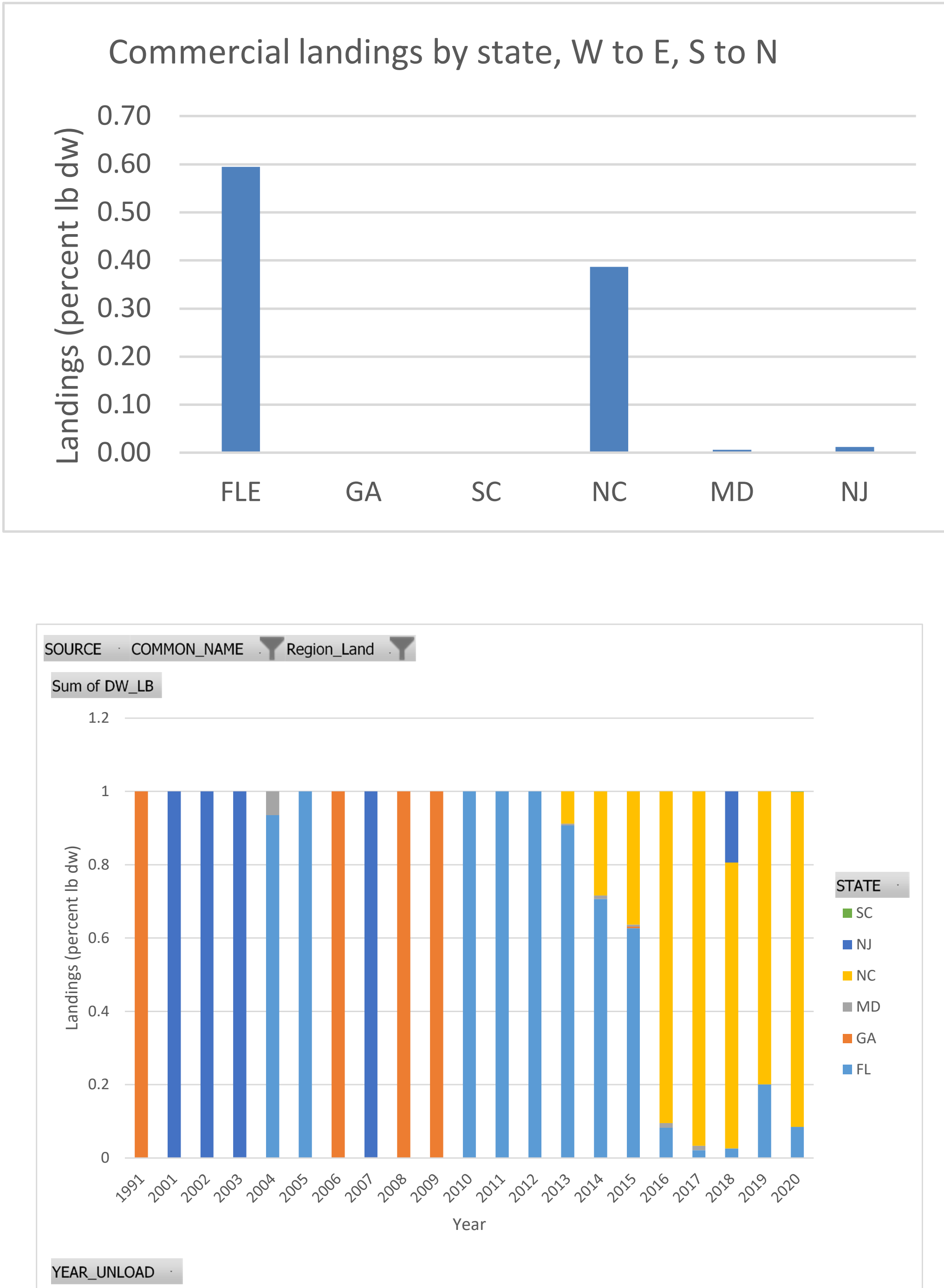


Figure 9. Commercial landings (lb dw) of scalloped hammerheads in the ATL by state of landing from FINS for 1991-2020. Top panel: relative contribution for the entire time period; bottom panel: composition of states by year.

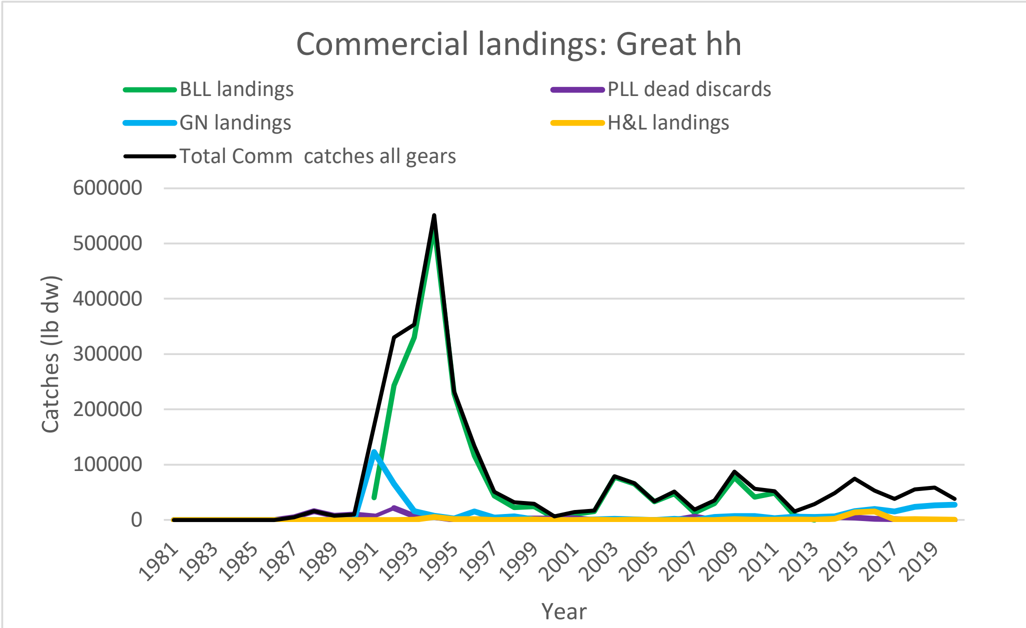
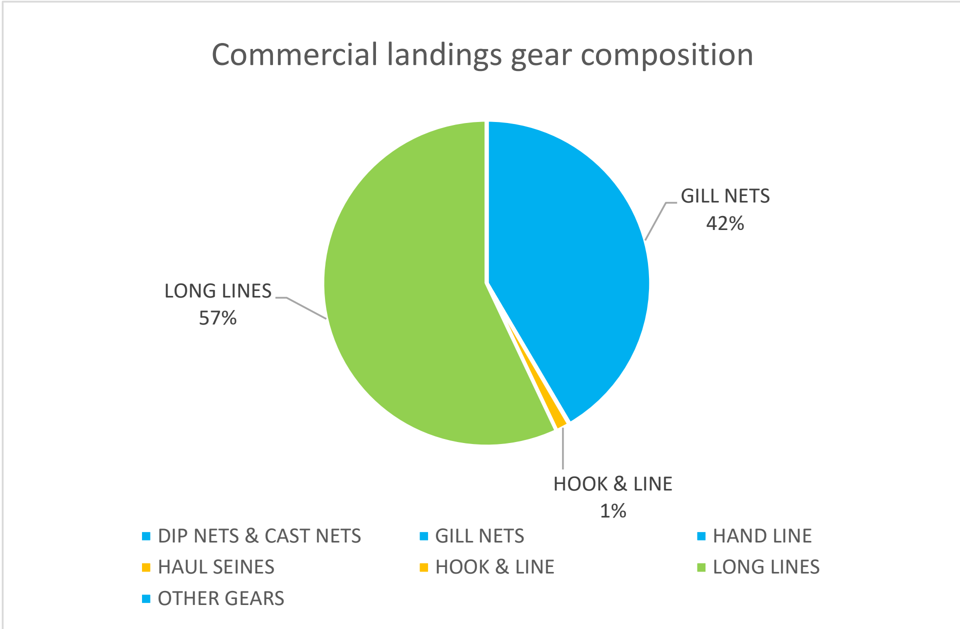


Figure 10. Commercial landings (lb dw) of great hammerheads by gear, including dead discards from the pelagic longline fishery. BLL=bottom longline; PLL=pelagic longline; H&L=hook and line.



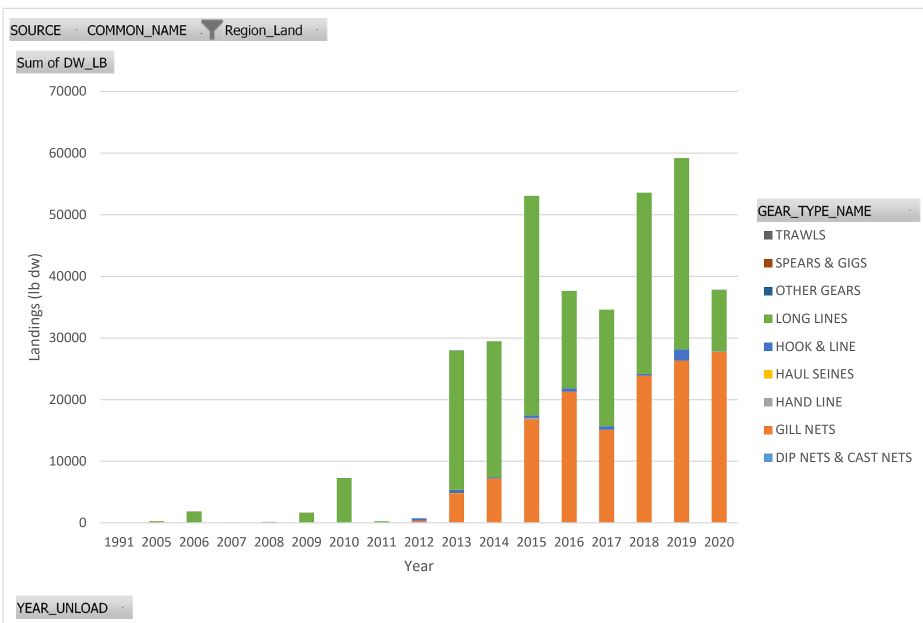
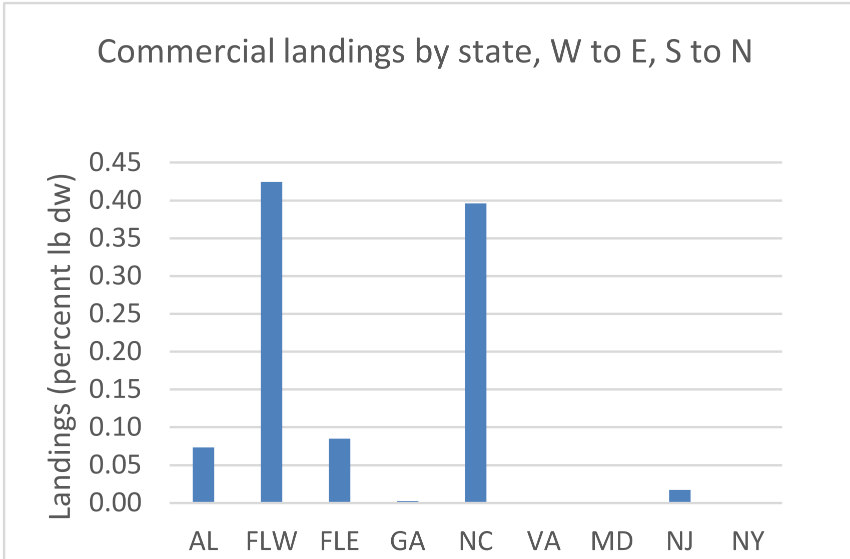


Figure 11. Commercial landings (lb dw) of great hammerheads by gear type from FINS for 1991-2020. Top panel: relative contribution for the entire time period; bottom panel: annual composition of the main gears by year.



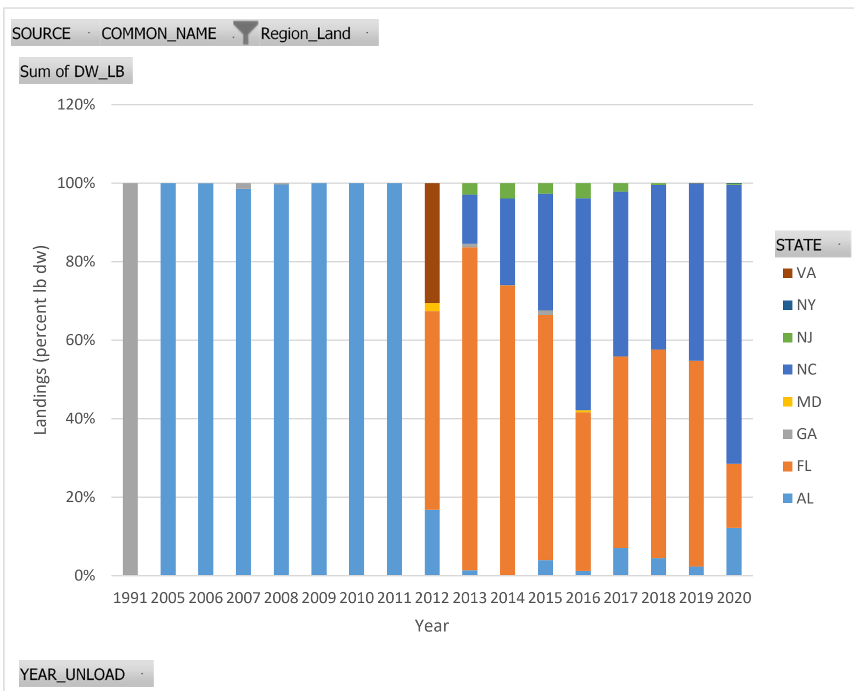


Figure 12. Commercial landings (lb dw) of great hammerheads by state of landing from FINS for 1991-2020.Top panel: relative contribution for the entire time period; bottom panel: composition of states by year.

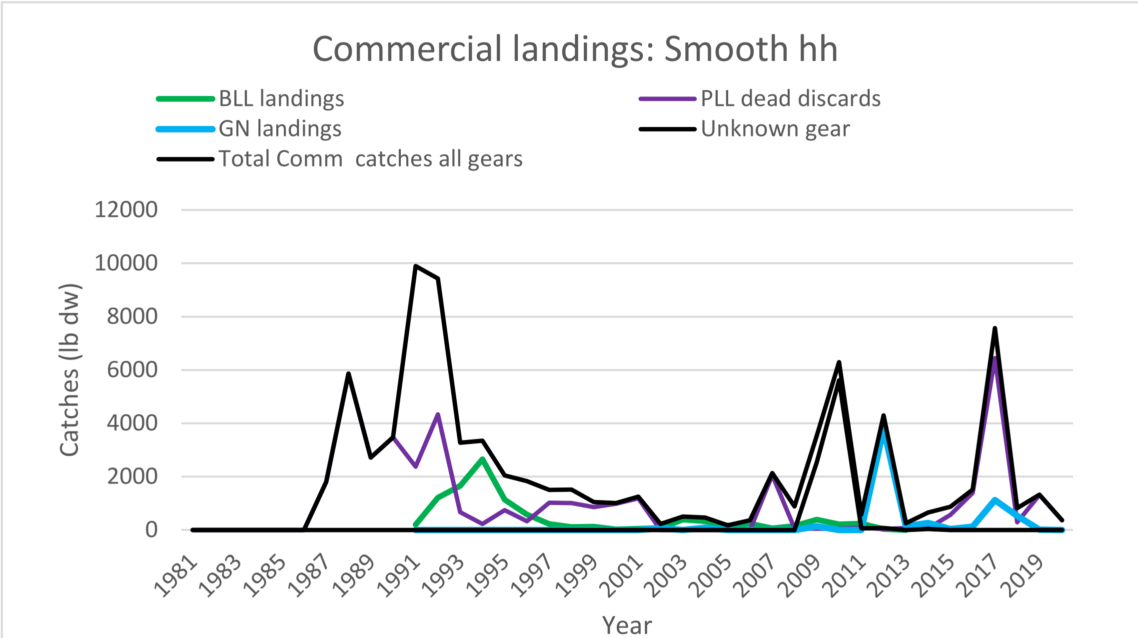


Figure 13. Commercial landings (lb dw) of smooth hammerheads by gear, including dead discards from the pelagic longline fishery. BLL=bottom longline; PLL=pelagic longline; H&L=hook and line.

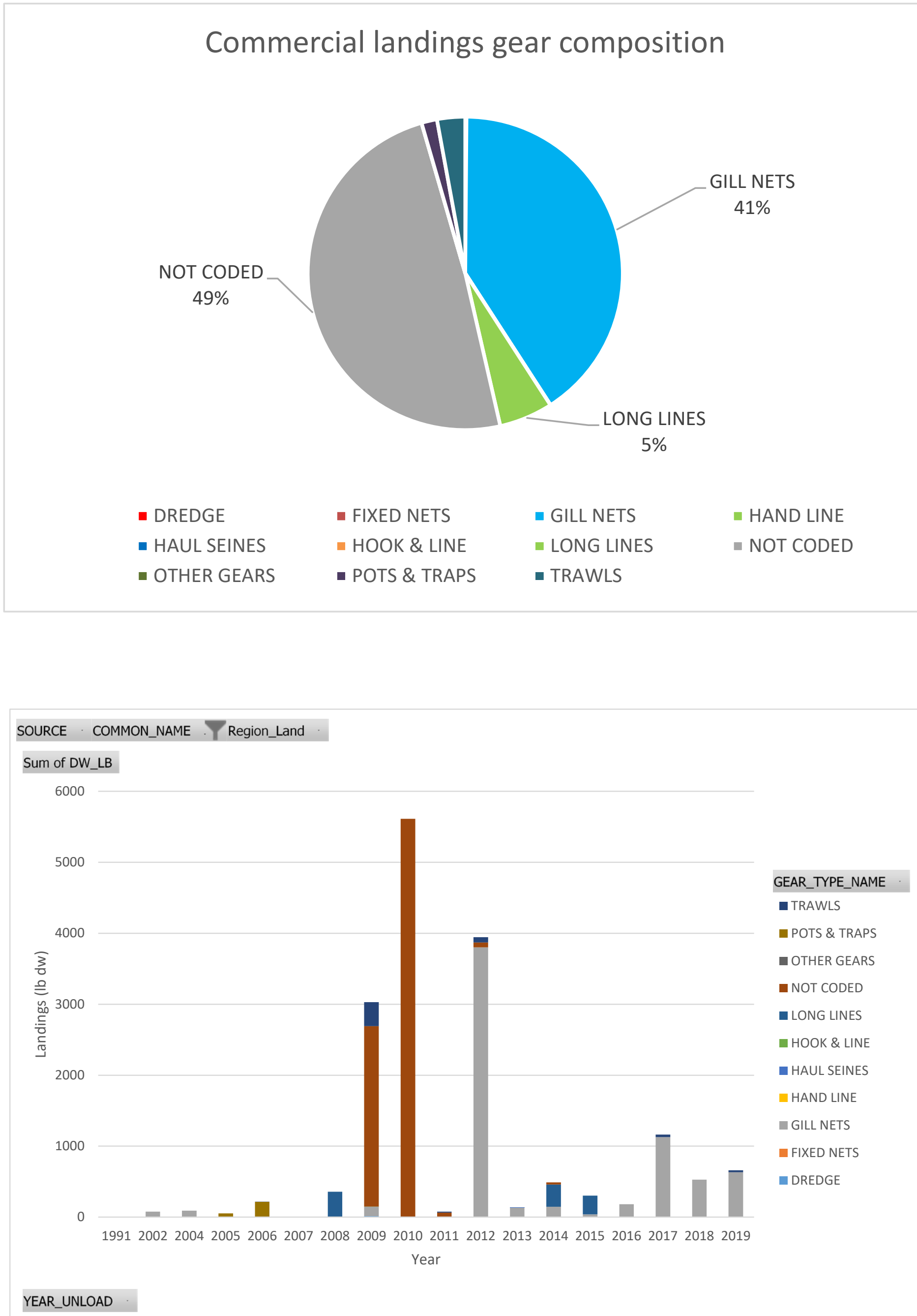
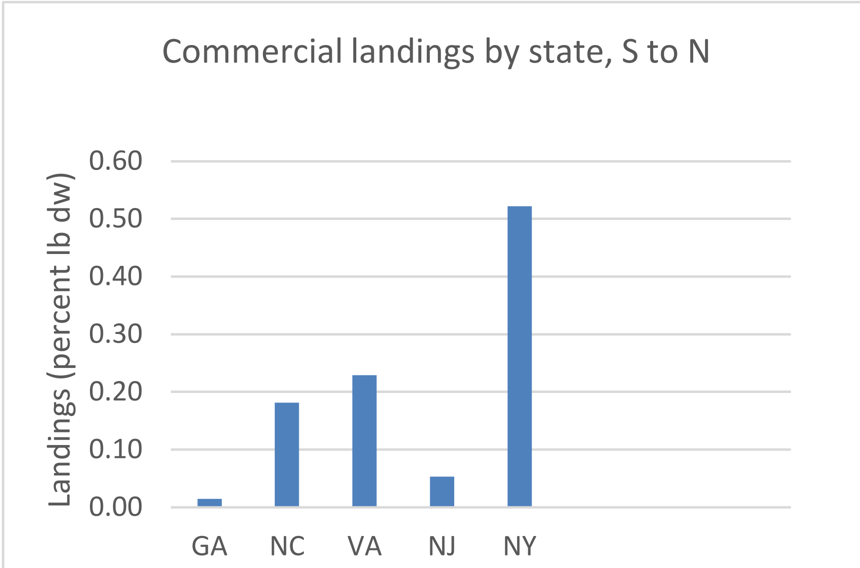


Figure 14. Commercial landings (lb dw) of smooth hammerheads by gear type from FINS for 1991-2020. Top panel: relative contribution for the entire time period; bottom panel: annual composition of the main gears by year.



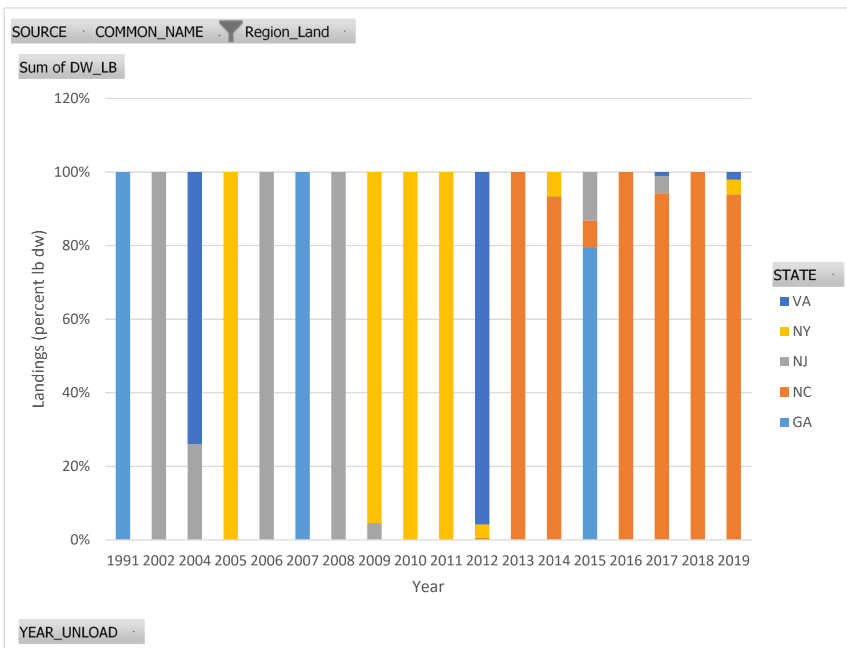
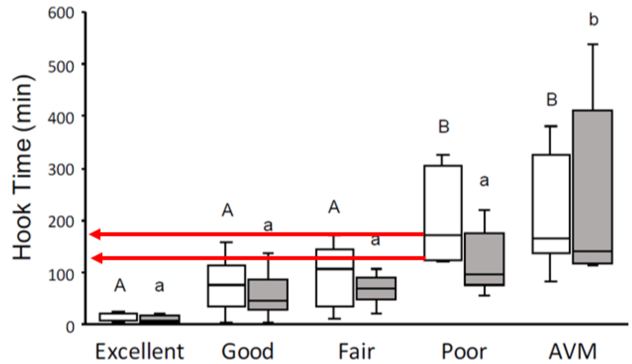


Figure 15. Commercial landings (lb dw) of smooth hammerheads by state of landing from FINS for 1991-2020.Top panel: relative contribution for the entire time period; bottom panel: composition of states by year.

A. Scalloped hammerheads in poor condition at release.



B. Great hammerheads in poor condition at release.

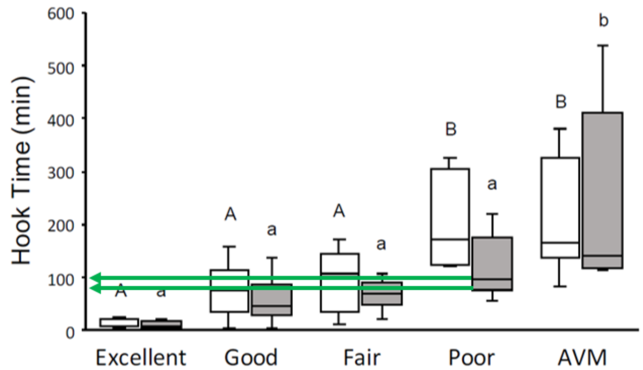
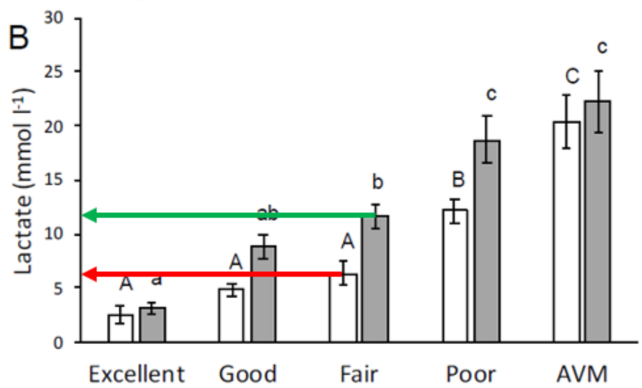


Figure 16. Box plots (quartiles) of scalloped (white, N = 86) and great (grey, N = 85) hammerheads release condition by hook time (min) (adapted from SEDAR77-DW09, their Figure 1); Scalloped hammerheads reached poor condition after about 120 – 180 minutes on hook (Panel A); Great hammerheads reached poor condition after about 80 – 100 minutes on hook (Panel B).

A. Lactate levels of scalloped and great hammerheads in fair condition.



B. Hook time of scalloped and great hammerheads with lactate levels associated with fair condition.

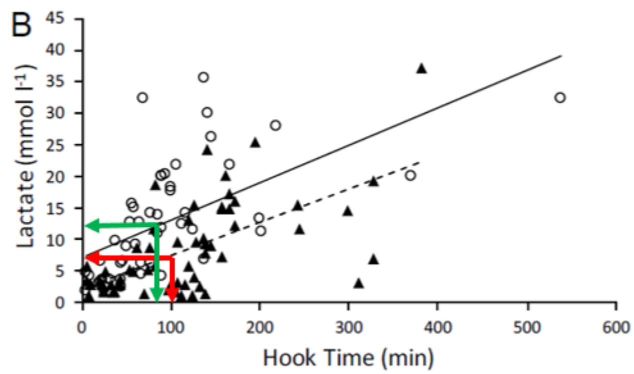
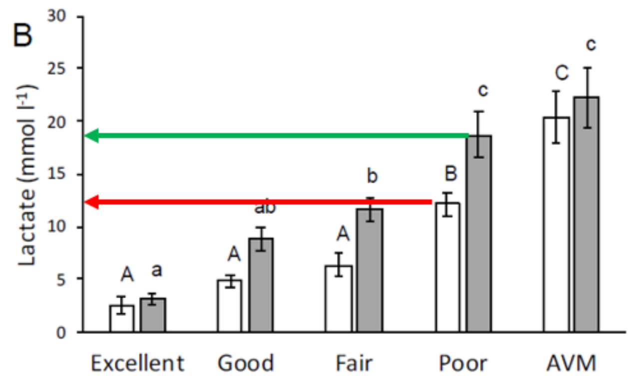


Figure 17. Lactate levels of scalloped (white bars) and great (grey bars) hammerheads released in fair condition were about 6 and 12 mmol l^{-1}, respectively (Panel A; Adapted from SEDAR77-DW09, their Figure 4), which corresponded to about 80 and 100 minutes of time on the hook for scalloped (closed triangles, dashed line) and great (open circles, solid line) hammerheads, respectively (Panel B; Adapted from SEDAR77-DW09, their Figure 2).

A. Lactate levels of scalloped and great hammerheads in poor condition.



B. Hook time of scalloped and great hammerheads with lactate levels associated with poor condition.

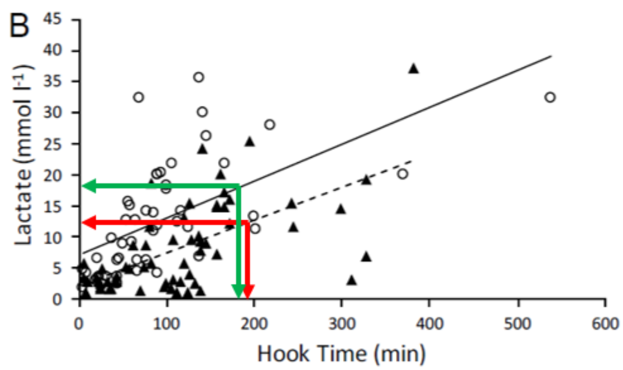
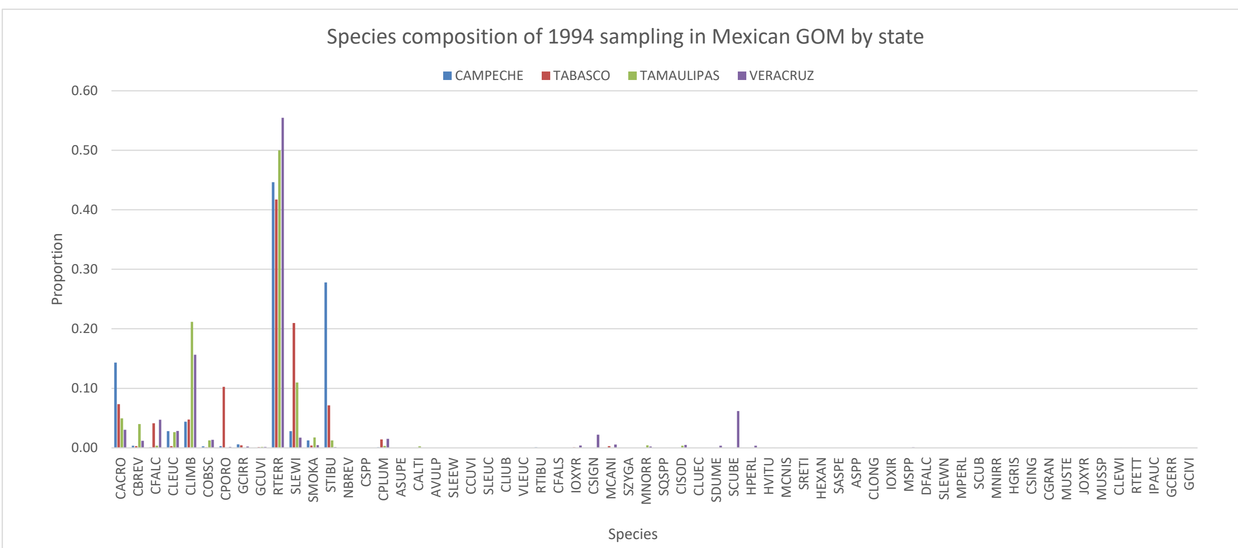


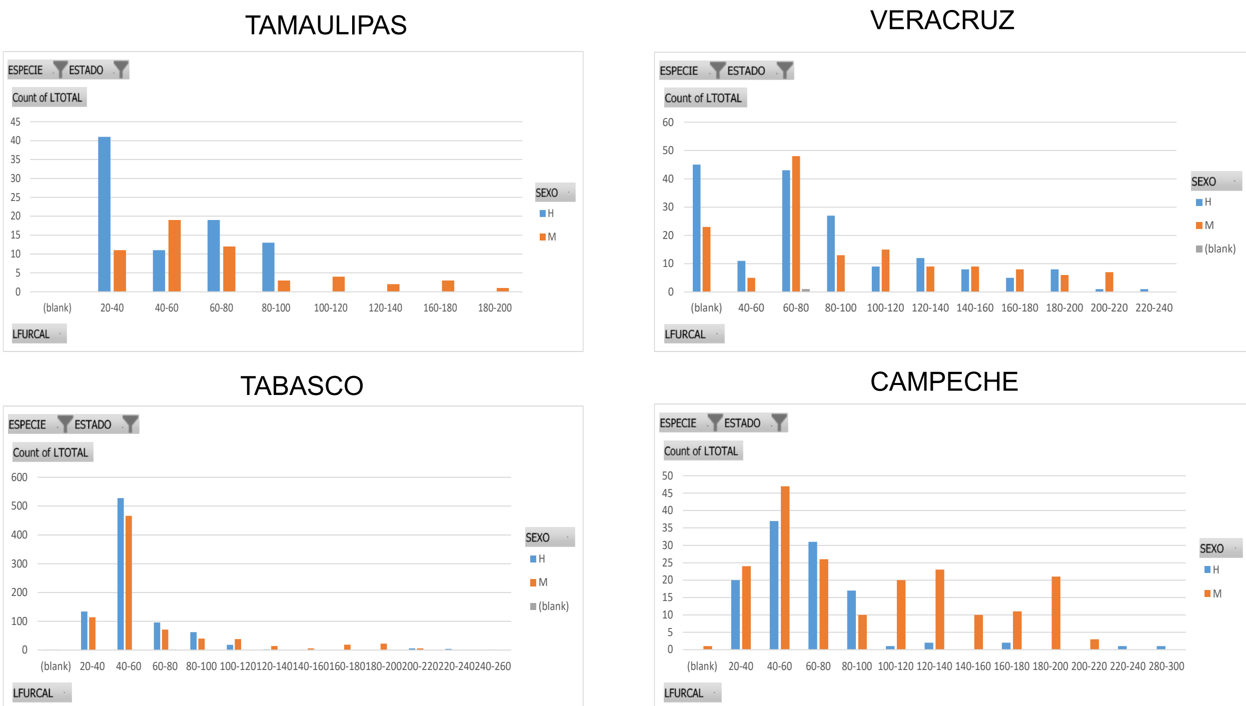
Figure 18. Lactate levels of scalloped (white bars) and great (grey bars) hammerheads released in poor condition were about 12 and 19 mmol l^{-1}, respectively (Panel A; Adapted from SEDAR77-DW09, their Figure 4), which corresponded to about 180 and 200 minutes of time on the hook for scalloped (closed triangles, dashed line) and great (open circles, solid line) hammerheads, respectively (Panel B; Adapted from SEDAR77-DW09, their Figure 2).

Figure 19. Map of Mexico showing the Gulf of Mexico states of Tamaulipas, Veracruz, Tabasco, and Campeche sampled during the 1993-1994 Castillo et al. (1998) monitoring study.



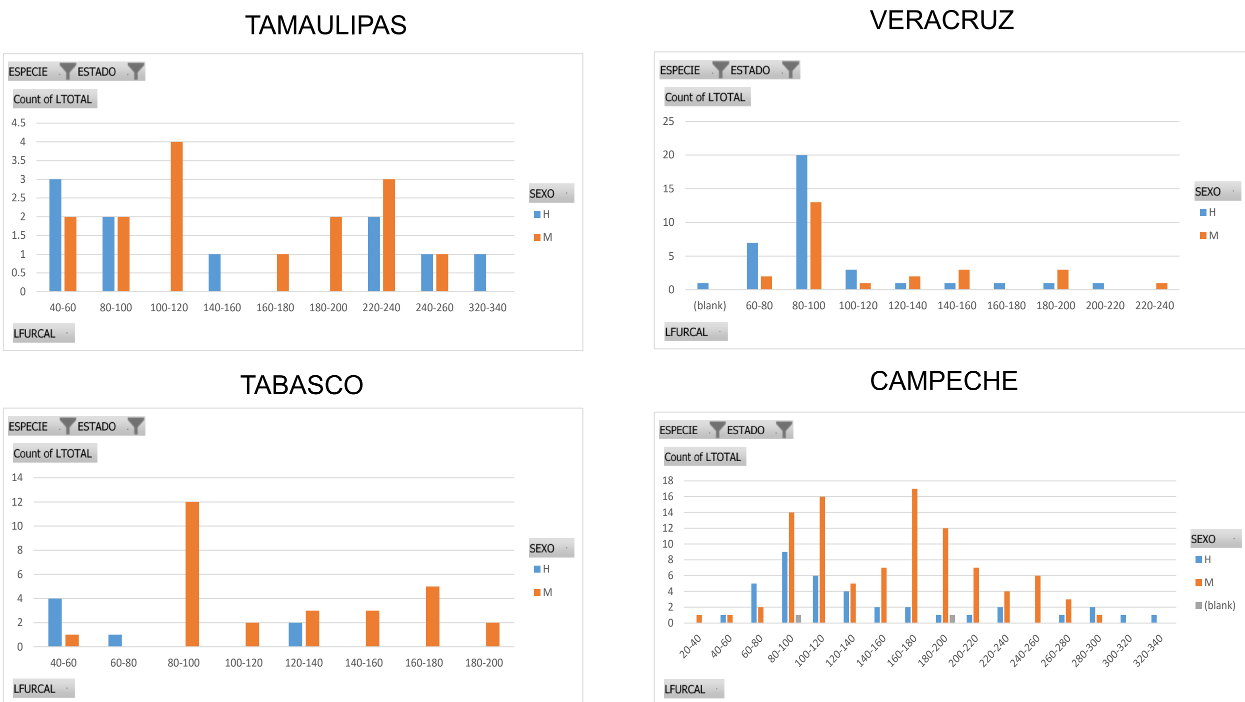
	TAMAULIPAS	VERACRUZ	TABASCO	CAMPECHE	ALL
SLEWI	0.110	0.017	0.210	0.028	0.054
SMOKA	0.017	0.005	0.004	0.012	0.009
SZYGA	0	3.64511E-05	0	0	1E-05

Figure 20. Species composition of sharks landed in the Mexico states of Tamaulipas, Veracruz, Tabasco, and Campeche observed in the 1993-1994 Castillo et al. (1998) monitoring study. The table shows scalloped hammerheads (SLEWI) were the main hammerhead species landed in each state, with smooth hammerhead (SZYGA) landings being negligible (SMOKA=great hammerhead).



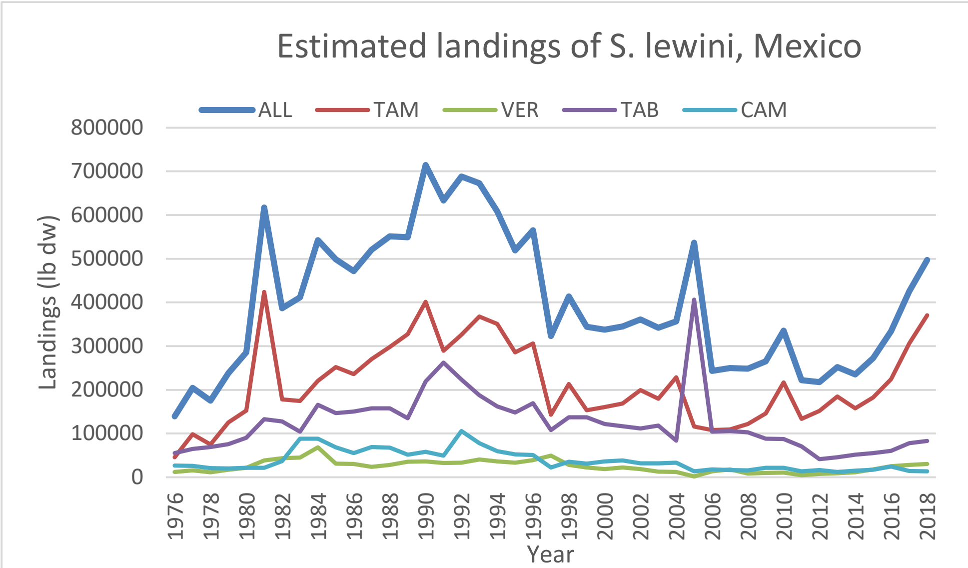
	ALL both sexes		TAM both sexes		VER both sexes		TAB both sexes		CAM both sexes	
% Cazon	0.94		0.97		0.85		0.96		0.87	
% Tiburon	0.06		0.03		0.15		0.04		0.13	

Figure 21. Length-frequency distributions of scalloped hammerheads landed in Mexico states by sex (H=Hembra=Female; Macho=M=Male), and state observed in the 1993-1994 Castillo et al. (1998) monitoring study (upper panels). The table shows the proportion of scalloped hammerhead landings that were <150 cm TL (“cazones”) and >=150 cm TL (“tiburones”) for sexes combined computed as a weighted average (weighted by sample size for each sex). Most animals observed were immature and assigned to the “cazones” category.



	ALL both sexes	TAM both sexes	VER both sexes	TAB both sexes	CAM both sexes
% Cazon	0.66	0.56	0.88	0.80	0.54
% Tiburon	0.34	0.44	0.12	0.20	0.46

Figure 22. Length-frequency distributions of great hammerheads landed in Mexico states by sex (H=Hembra=Female; Macho=M=Male) and state observed in the 1993-1994 Castillo et al. (1998) monitoring study (upper panels). The table shows the proportion of great hammerhead landings that were <150 cm TL ("cazones") and >=150 cm TL ("tiburones") for sexes combined computed as a weighted average (weighted by sample size for each sex). Although a larger proportion of animals observed were assigned to the "tiburones" category, most animals were immature.



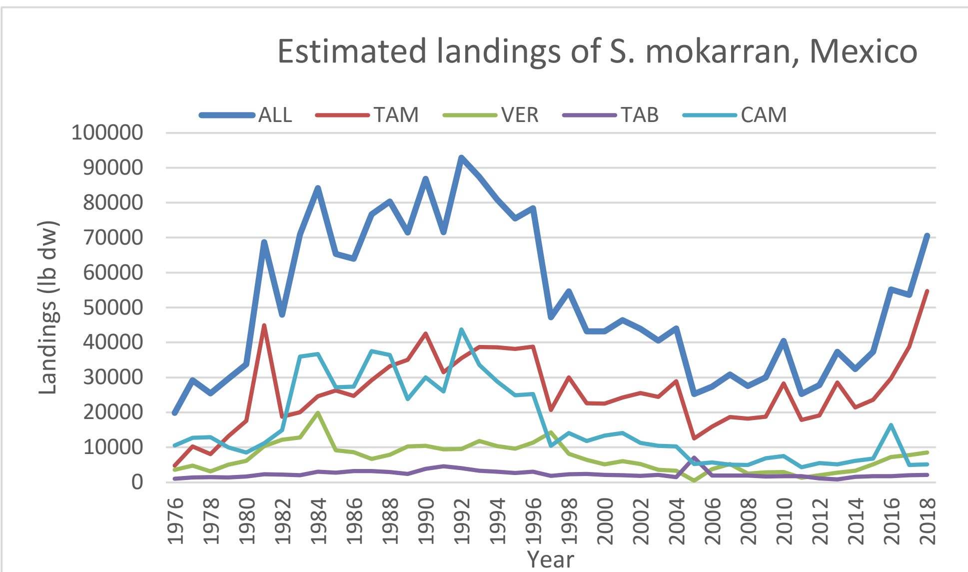
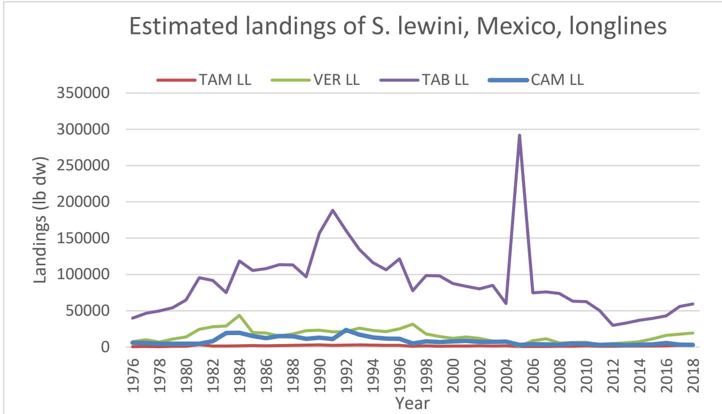
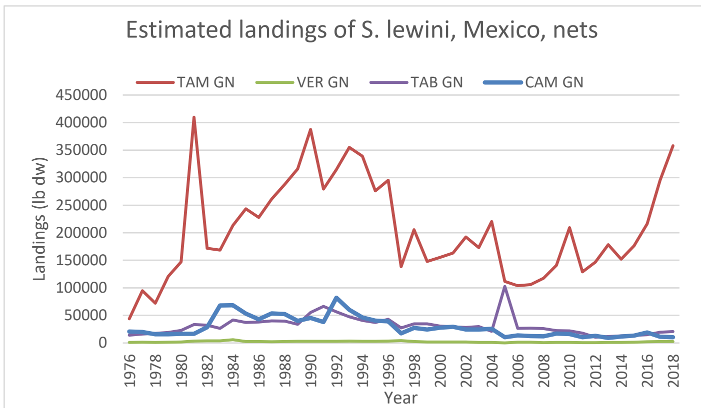
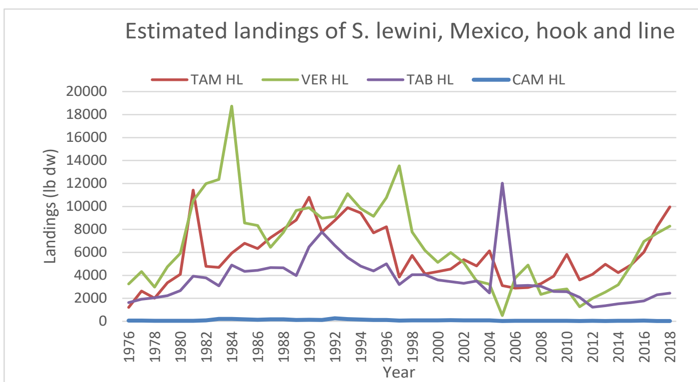


Figure 23. Estimated landings of scalloped (top) and great (bottom) hammerheads by Mexico state. Landings of "cazones" (<150 cm TL) and "tiburones" (>=150 cm TL) by state reported by the Comisión Nacional de Acuacultura y Pesca (Conapesca) were multiplied by the proportion that scalloped and great hammerheads make up of the entire catches and by the proportion of "cazones" and "tiburones" attributed to each species to obtain total estimates.

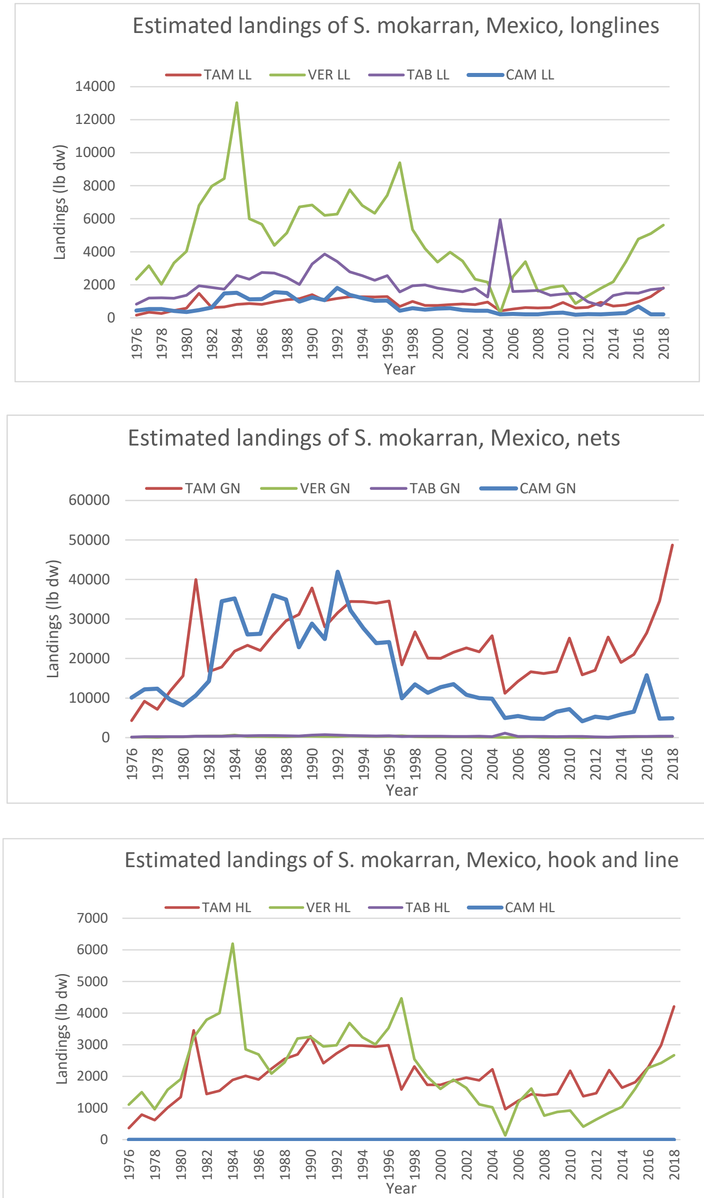






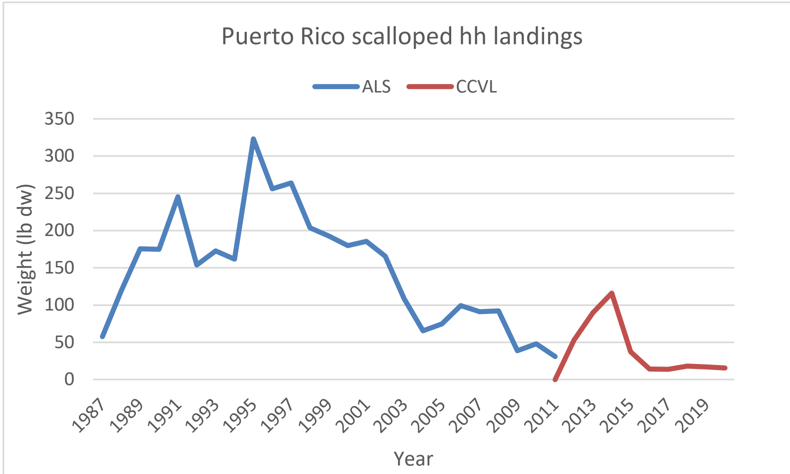
	TAM	VER	TAB	CAM
LONGLINES	0.01	0.64	0.72	0.22
NETS	0.97	0.09	0.25	0.78
HOOK&LINE	0.03	0.27	0.03	0.00

Figure 24. Estimated landings of scalloped hammerheads by gear and Mexico state. The table shows the percentage composition of gears that scalloped hammerheads were caught by state.



	TAM	VER	TAB	CAM
LONGLINES	0.03	0.66	0.84	0.04
NETS	0.89	0.03	0.16	0.96
HOOK&LINE	0.08	0.31	0.00	0.00

Figure 25. Estimated landings of great hammerheads by gear and Mexico state. The table shows the percentage composition of gears that great hammerheads were caught by state.



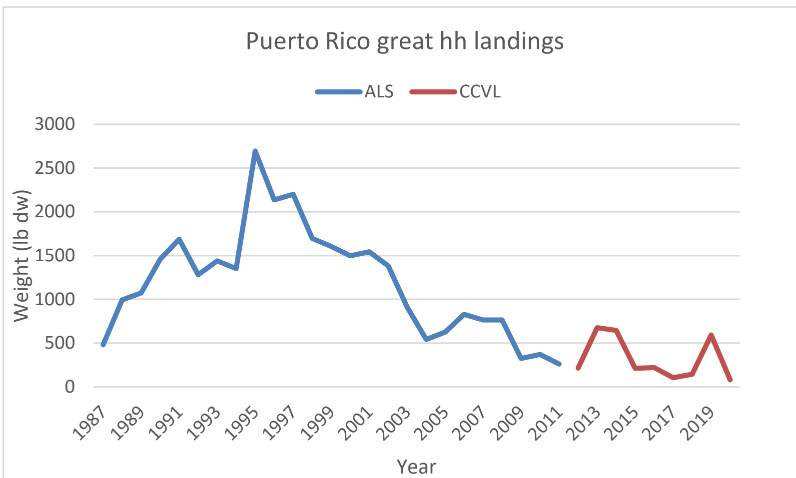


Figure 26. Landings of scalloped (top) and great (bottom) hammerheads from the Caribbean Commercial Vessel Logbook (CCVL) in 2011-2020 and from the Accumulated Landings System (ALS) for 1987-2011.

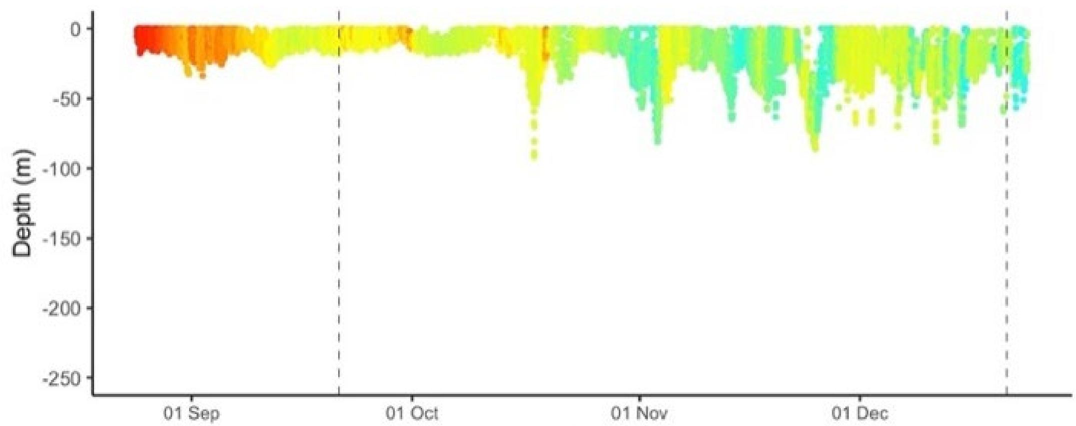


Figure 27. Vertical and thermal habitat use of a great hammerhead, *Sphyrna mokarran,* tagged with a PSAT using recreational fishing gear during South Carolina charter vessel based recreational angling, as described above. Red to blue color scale indicates warmer to cooler temperature. Adapted from SEDAR 77 Data Workshop presentation by Bryan Frazier – PRLDM in South Carolina charter vessel based recreational angling.

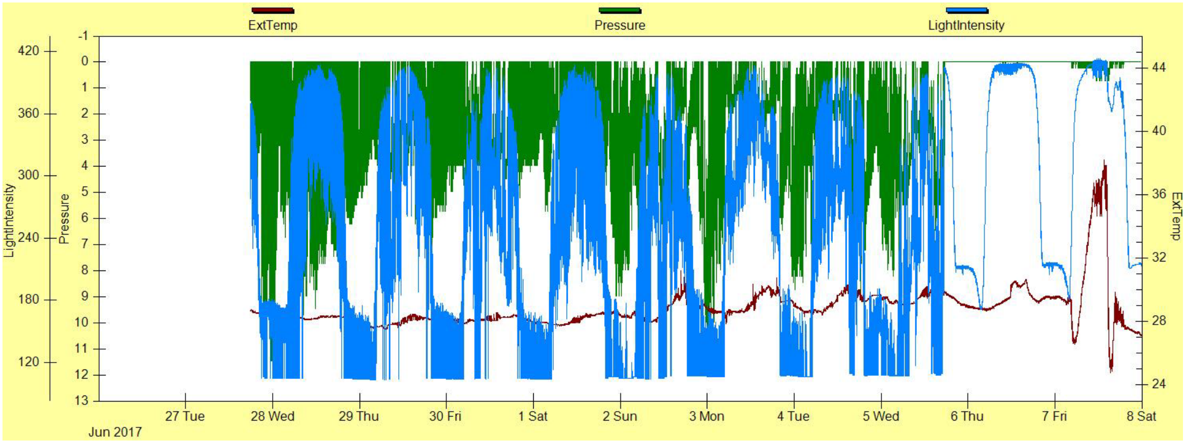


Figure 28. Depth, light intensity, and pressure (depth) of a great hammerhead, *Sphyrna mokarran* tagged with a PSATLife captured using recreational fishing gear during South Carolina charter vessel based recreational angling, as described above. Adapted from SEDAR 77 Data Workshop presentation by Bryan Frazier – PRLDM in South Carolina charter vessel based recreational angling.

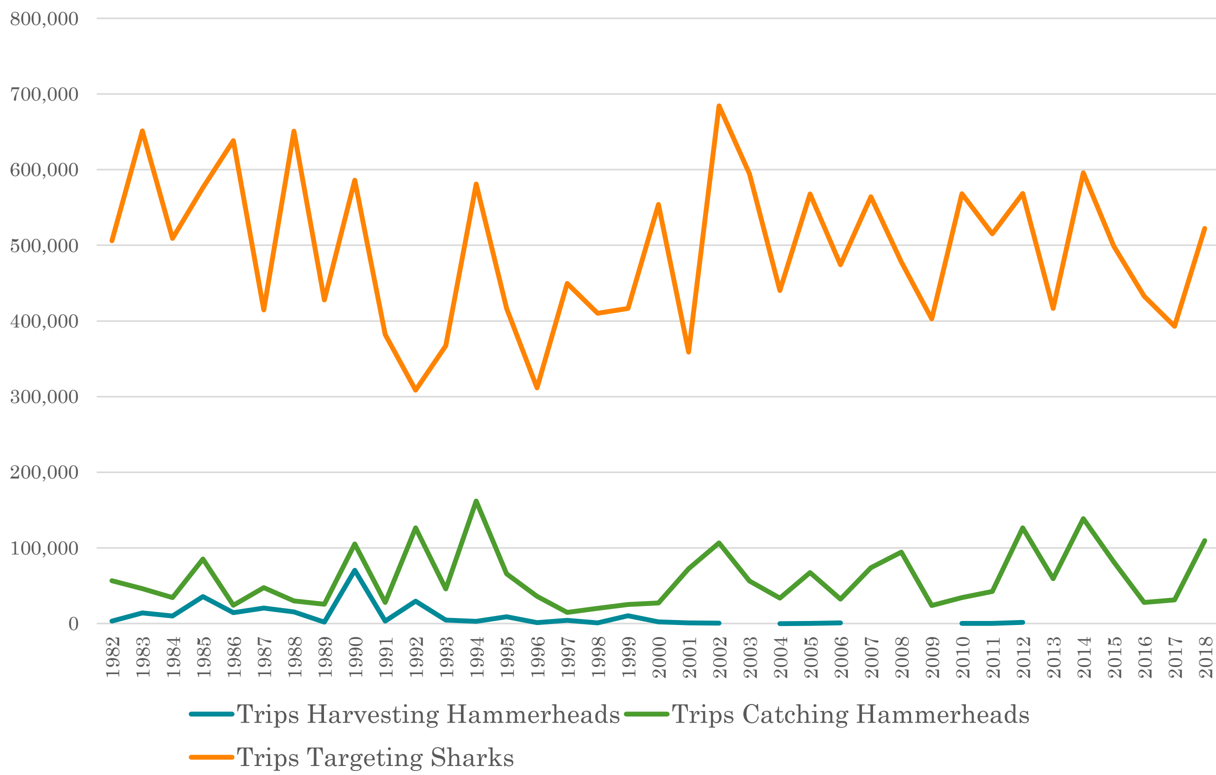


Figure 29. Summary of data used to calculate the proportion of shark targeted recreational fishing trips in the MRIP data base that captured or harvested hammerheads, as described above. The MRIP data base was queried for the number of MRIP trips: (1) targeting sharks (excluding pelagic, small coastals, and dogfish); (2) catching hammerheads, including generic hammerheads; (3) catching hammerheads identified to species; and (4) harvesting hammerheads identified to species. Adapted from SEDAR 77 Data Workshop presentation by Cliff Hutt – Proportion of shark targeted recreational fishing trips in the MRIP data base that captured or harvested hammerheads.

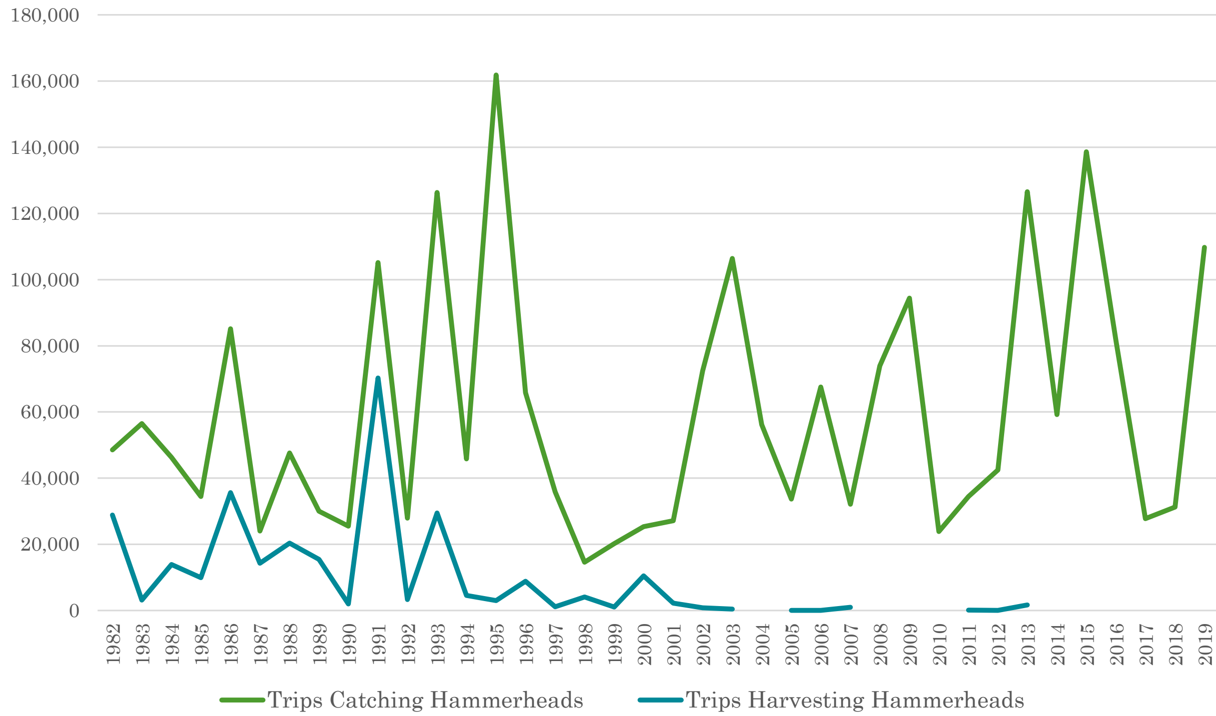


Figure 30. Summary of data used to calculate the proportion of shark targeted recreational fishing trips in the MRIP data base that captured or harvested hammerheads, as described above. The MRIP data base was queried as described in Figure 29. Adapted from SEDAR 77 Data Workshop presentation by Cliff Hutt – Proportion of shark targeted recreational fishing trips in the MRIP data base that captured or harvested hammerheads.

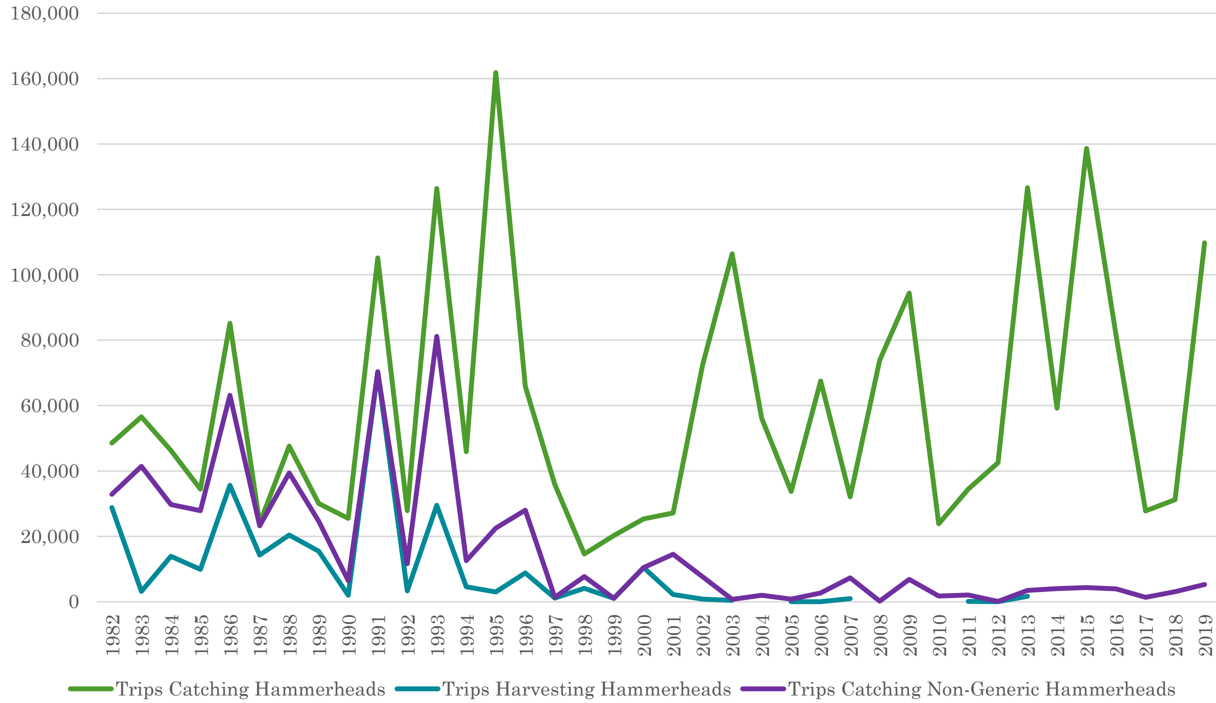


Figure 31. Summary of data used to calculate the proportion of shark targeted recreational fishing trips in the MRIP data base that captured or harvested hammerheads, as described above. The MRIP data base was queried as described in Figure 29. Adapted from SEDAR 77 Data Workshop presentation by Cliff Hutt – Proportion of shark targeted recreational fishing trips in the MRIP data base that captured or harvested hammerheads.

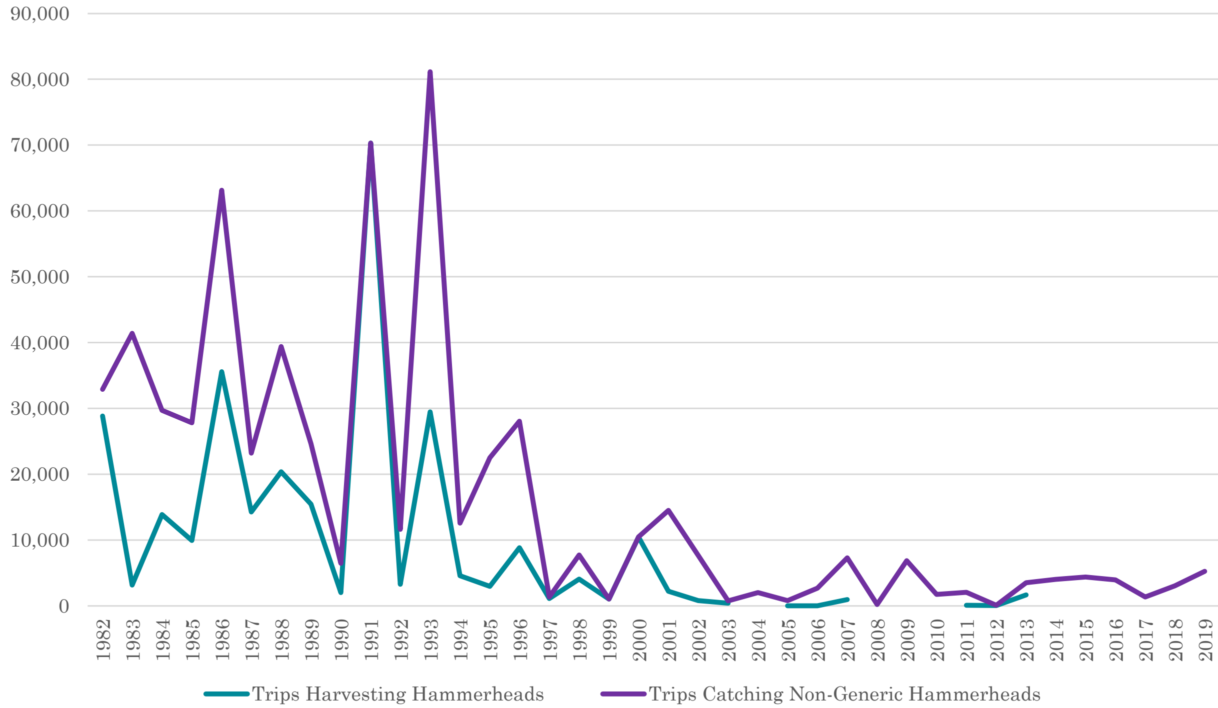
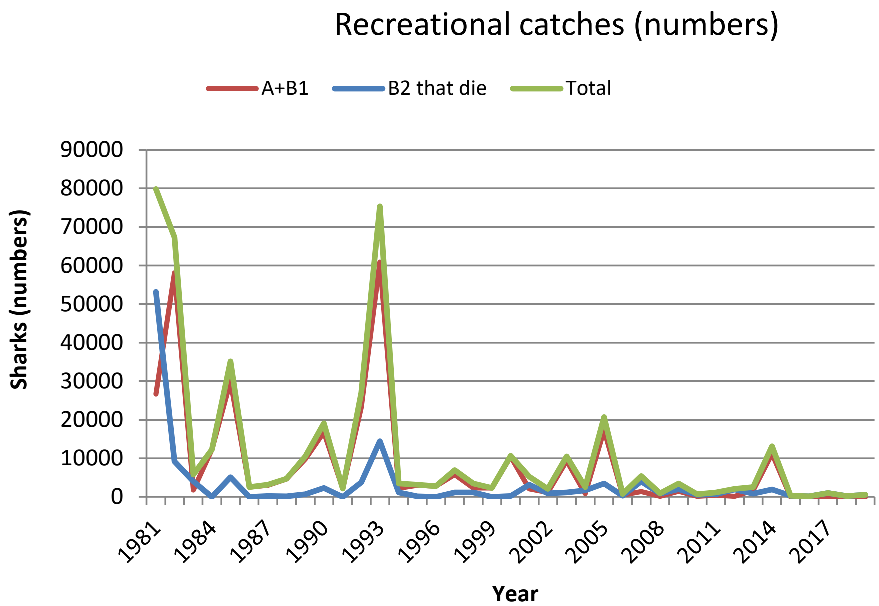


Figure 32. Summary of data used to calculate the proportion of shark targeted recreational fishing trips in the MRIP data base that captured or harvested hammerheads, as described above. The MRIP data base was queried as described in Figure 29. Adapted from SEDAR 77 Data Workshop presentation by Cliff Hutt – Proportion of shark targeted recreational fishing trips in the MRIP data base that captured or harvested hammerheads.



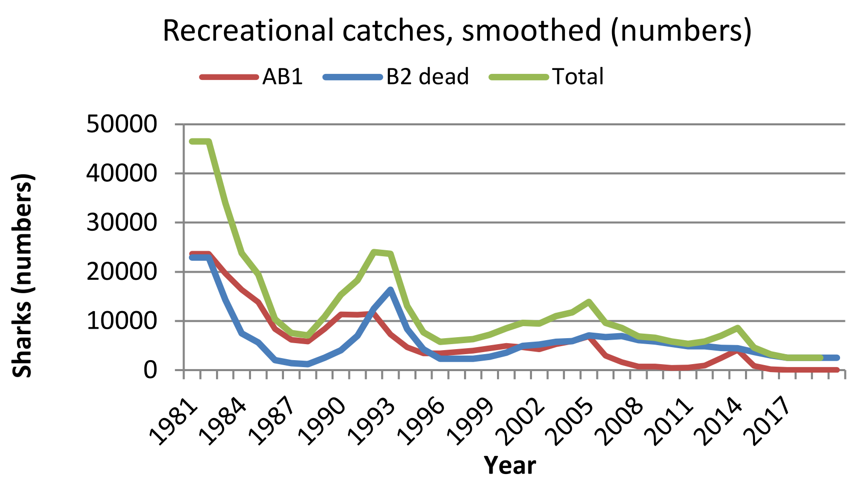
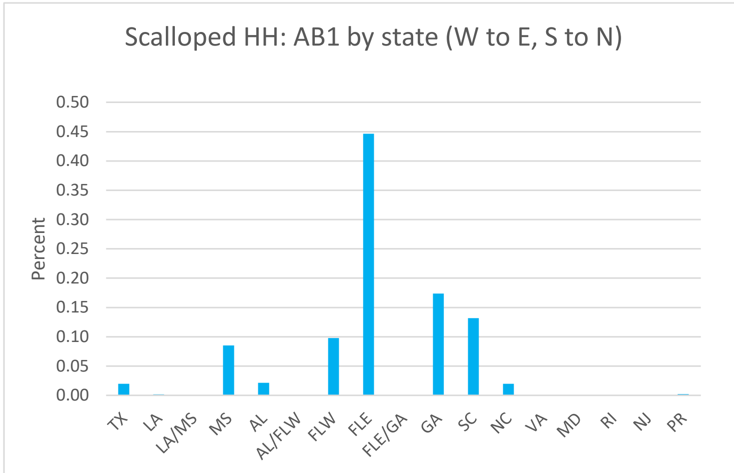
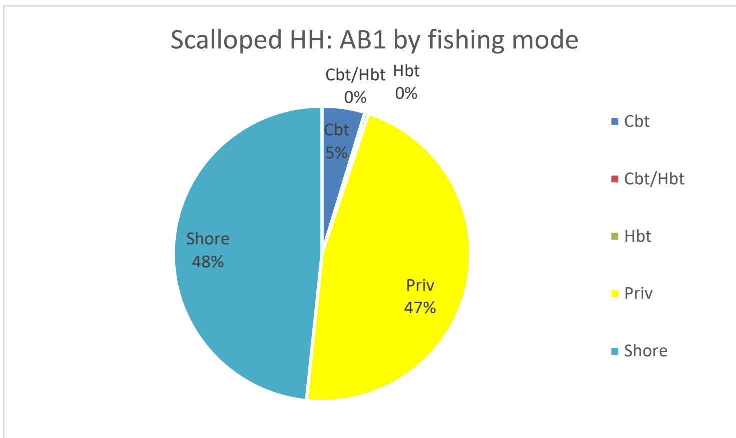


Figure 33. Recreational catches in numbers (AB1 and B2s that die assuming an initial arbitrary post-release mortality rate of 10%) of scalloped hammerheads (all regions) before smoothing (top) and after adjusting the 1982 AB1 estimate, smoothing the 1993 AB1 estimate, smoothing the entire series using a three-year moving geometric average, and using the recommended post-release mortality rate of 26.81% (bottom).





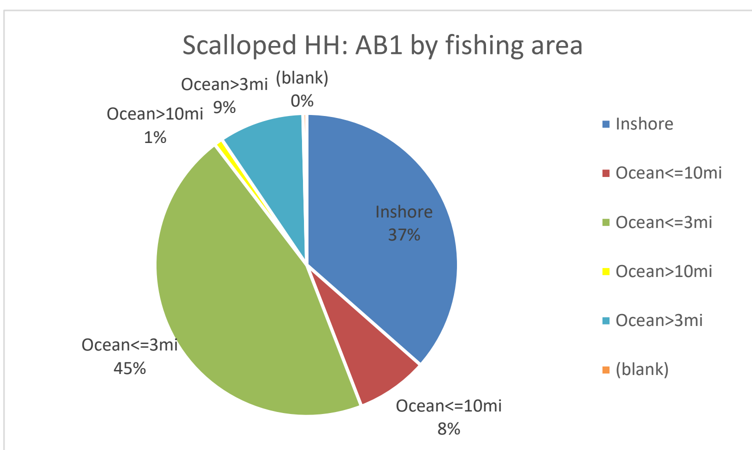


Figure 34. Recreational catches (AB1, numbers) of scalloped hammerhead by state (top), fishing mode (middle), and fishing area (bottom), 1981-2020. Note: "Blank" fishing area indicates catches reported in the Southeast Region Headboat Survey (SRHS).

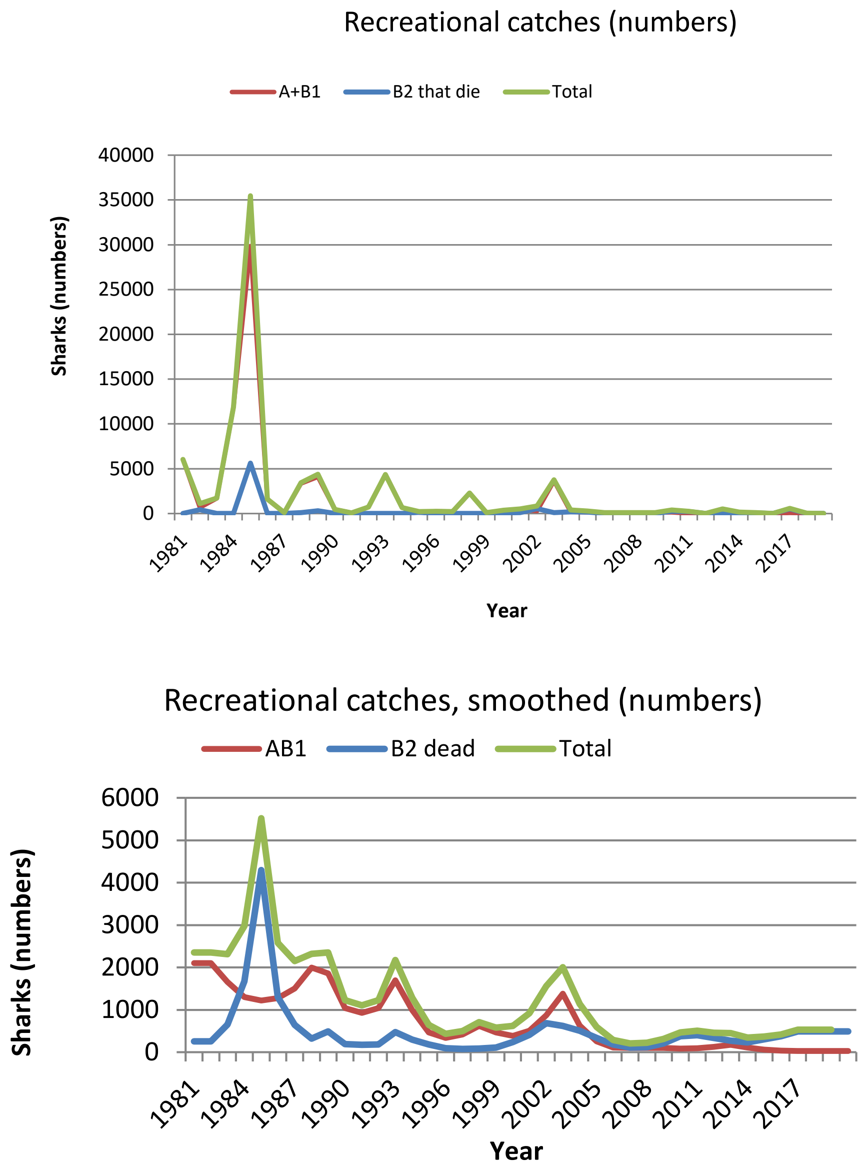
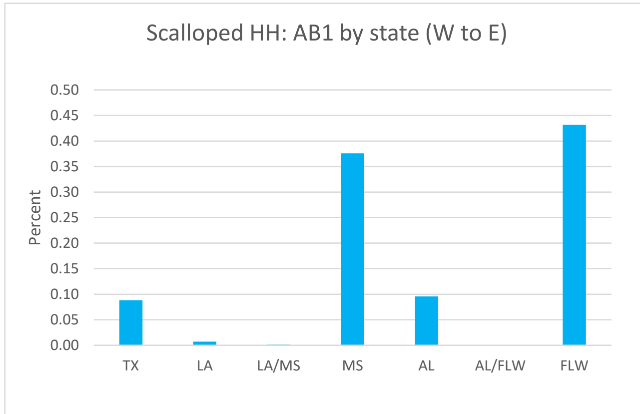
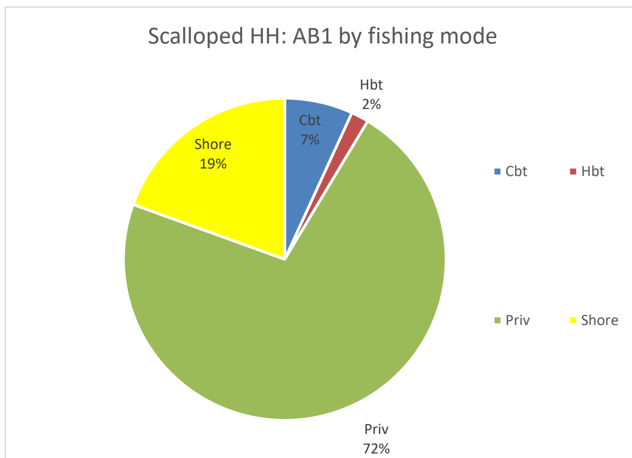


Figure 35. Recreational catches in numbers (AB1 and B2s that die assuming an initial arbitrary post-release mortality rate of 10%) of scalloped hammerheads in the GOM before smoothing (top) and after smoothing the 1984 and 1985 AB1 estimates, smoothing the entire series using a three-year moving geometric average, and using the recommended post-release mortality rate of 26.81% (bottom).





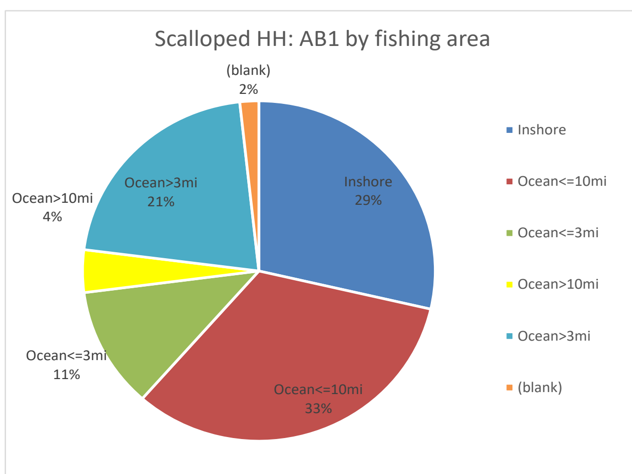
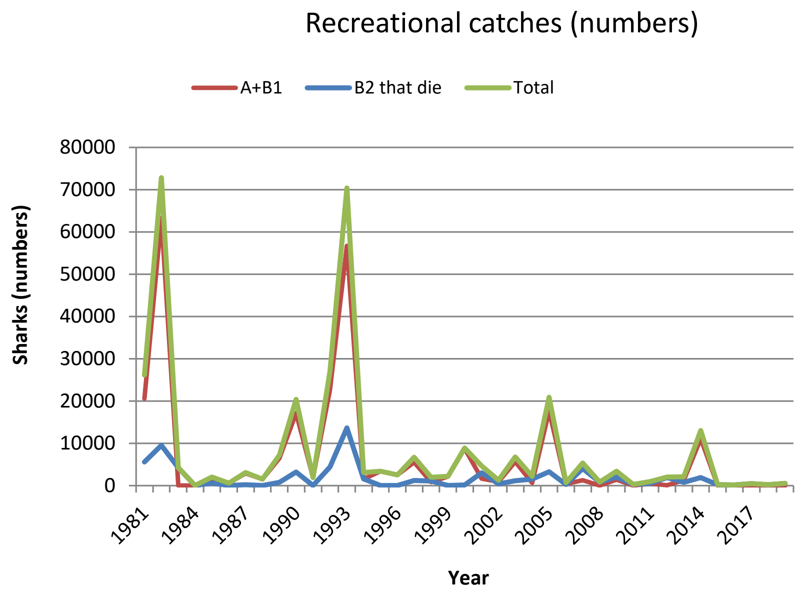


Figure 36. Recreational catches (AB1, numbers) of scalloped hammerheads in the GOM by state (top), fishing mode (middle), and fishing area (bottom), 1981-2020. Note: "Blank" fishing area indicates catches reported in the Southeast Region Headboat Survey (SRHS).



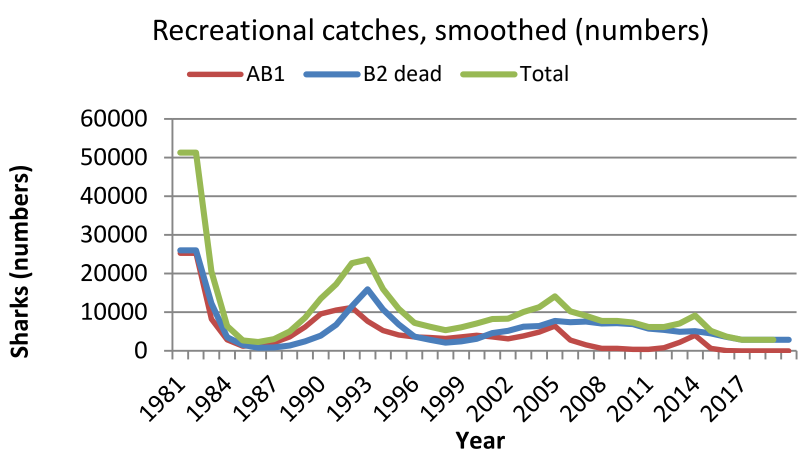
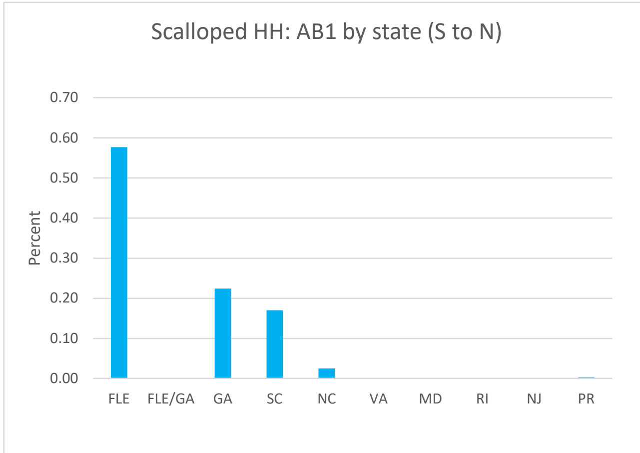
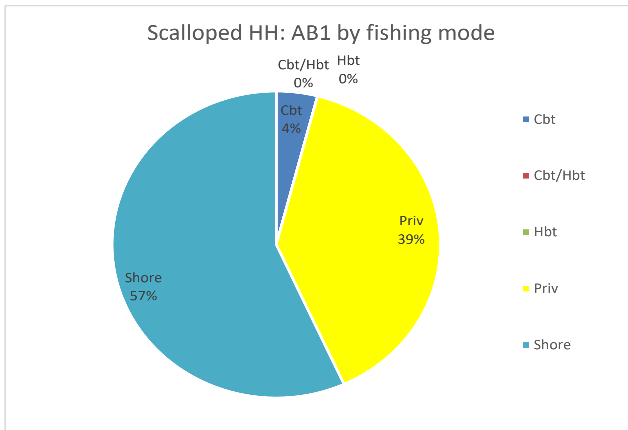


Figure 37. Recreational catches in numbers (AB1 and B2s that die assuming an initial arbitrary post-release mortality rate of 10%) of scalloped hammerheads in the ATL before smoothing (top) and after adjusting the 1982 AB1 estimate, smoothing the 1993 AB1 estimate, smoothing the entire series using a three-year moving geometric average, and using the recommended post-release mortality rate of 26.81% (bottom).





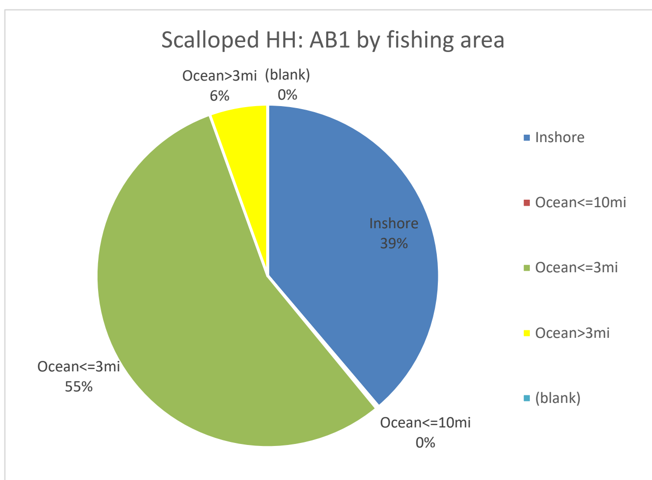
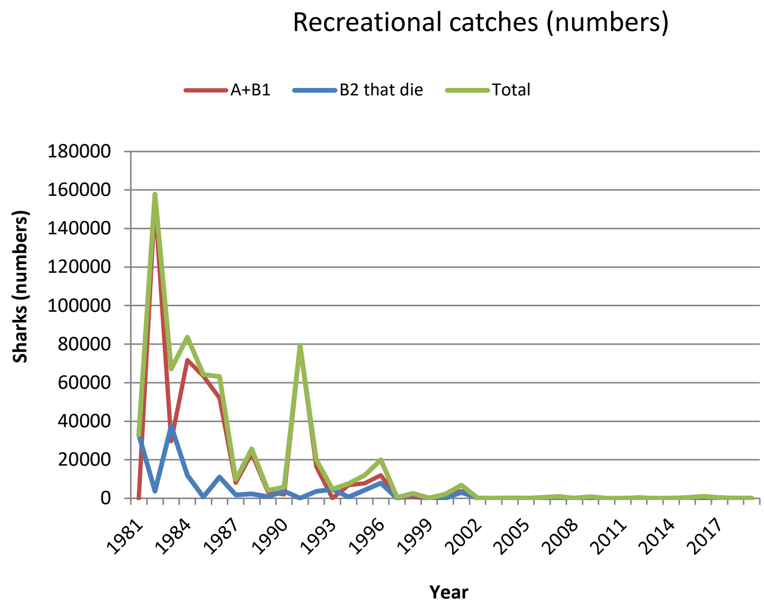


Figure 38. Recreational catches (AB1, numbers) of scalloped hammerheads in the ATL by state (top), fishing mode (middle), and fishing area (bottom), 1981-2020. Note: “Blank” fishing area indicates catches reported in the Southeast Region Headboat Survey (SRHS).



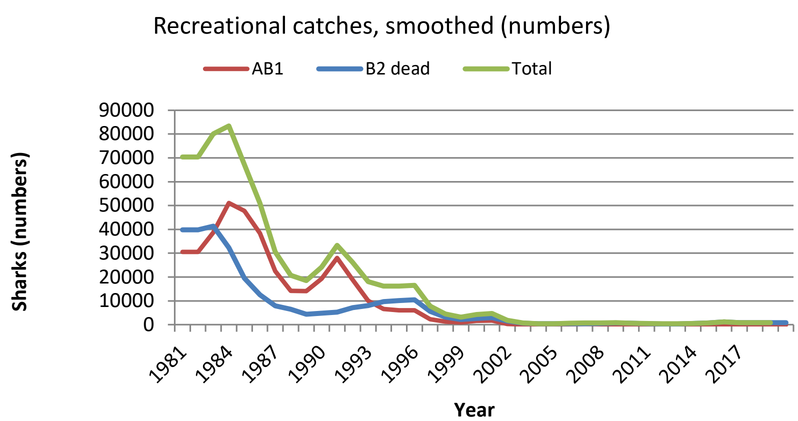
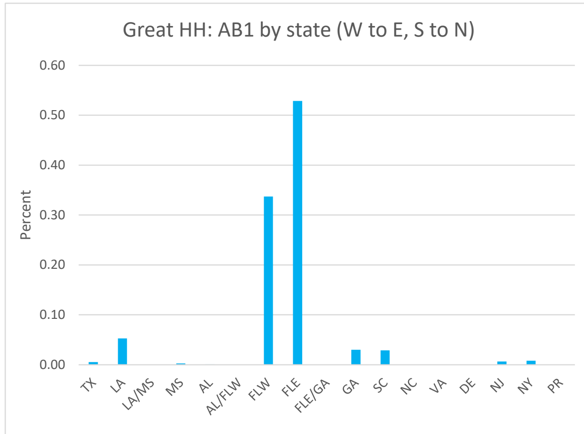
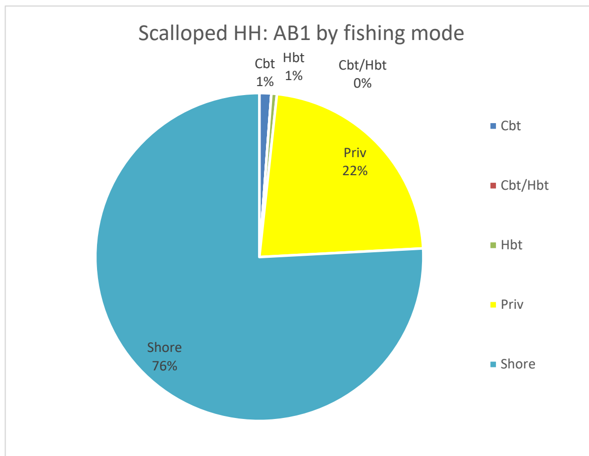


Figure 39. Recreational catches in numbers (AB1 and B2s that die assuming an initial arbitrary post-release mortality rate of 10%) of great hammerheads before smoothing (top) and after adjusting and smoothing the 1982 AB1 estimate, smoothing the entire series using a three-year moving geometric average, and using the recommended post-release mortality rate of 26.81% (bottom).





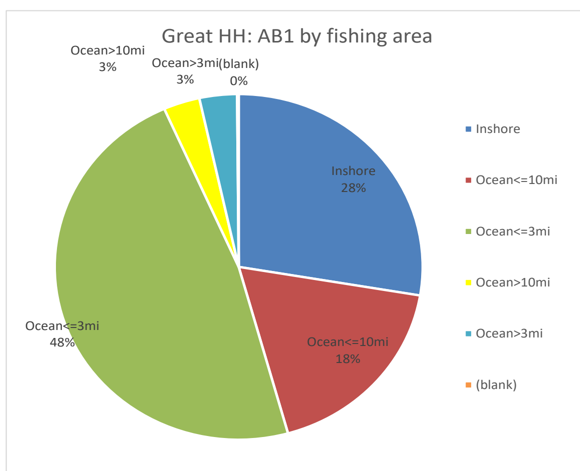
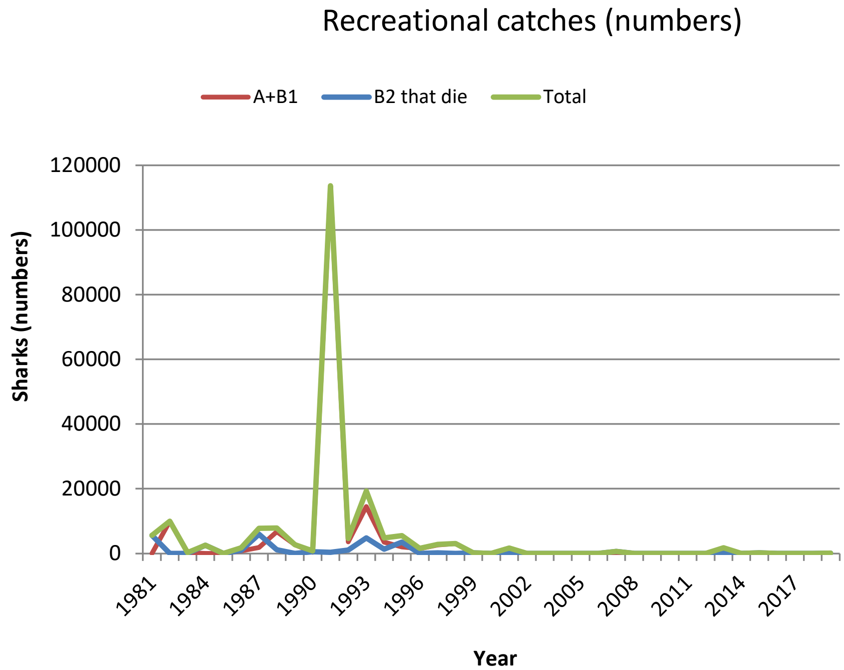


Figure 40. Recreational catches (AB1, numbers) of great hammerheads by state (top), fishing mode (middle), and fishing area (bottom), 1981-2020. Note: "Blank" fishing area indicates catches reported in the Southeast Region Headboat Survey (SRHS).



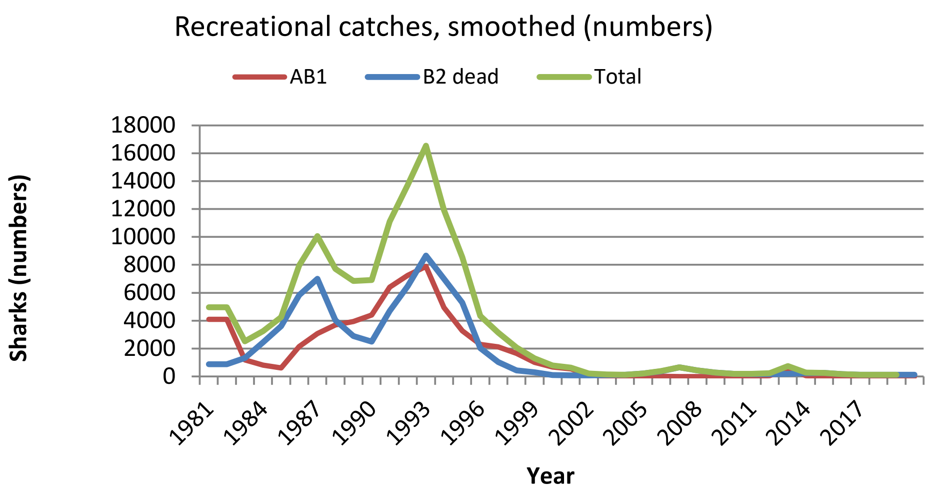


Figure 41. Recreational catches in numbers (AB1 and B2s that die assuming an initial arbitrary post-release mortality rate of 10%) of smooth hammerheads before smoothing (top) and after adjusting the 1991 AB1 estimate, smoothing the entire series using a three-year moving geometric average, and using the recommended post-release mortality rate of 26.81% (bottom).

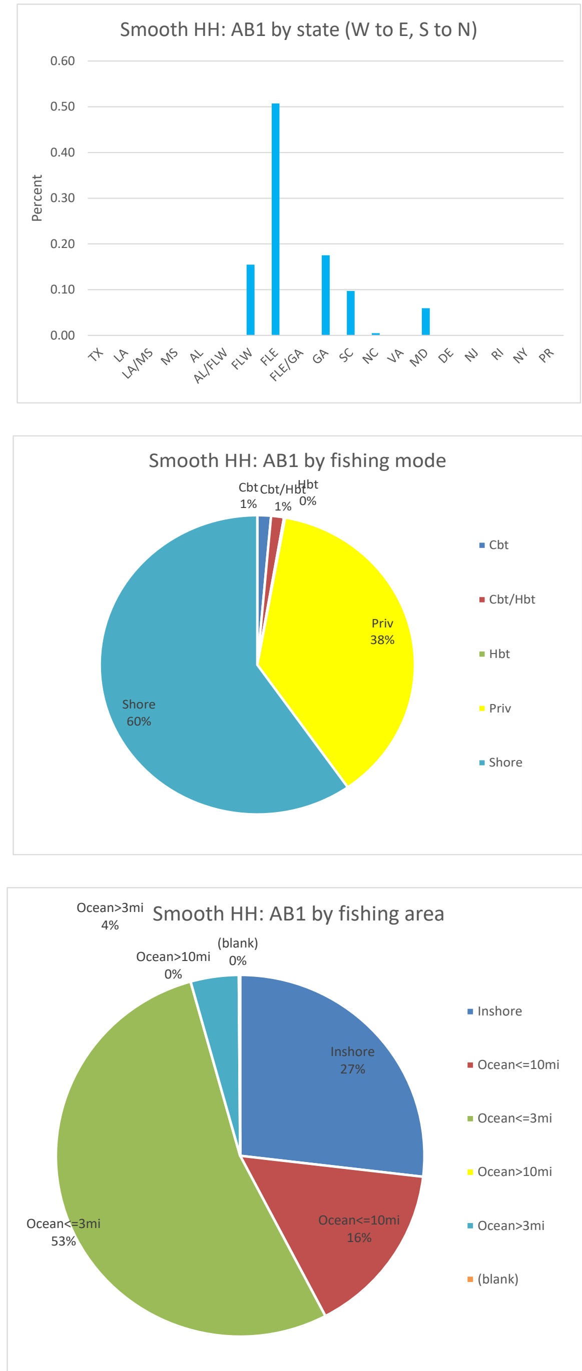


Figure 42. Recreational catches (AB1, numbers) of smooth hammerheads by state (top), fishing mode (middle), and fishing area (bottom), 1981-2020. Note: "Blank" fishing area indicates catches reported in the Southeast Region Headboat Survey (SRHS).

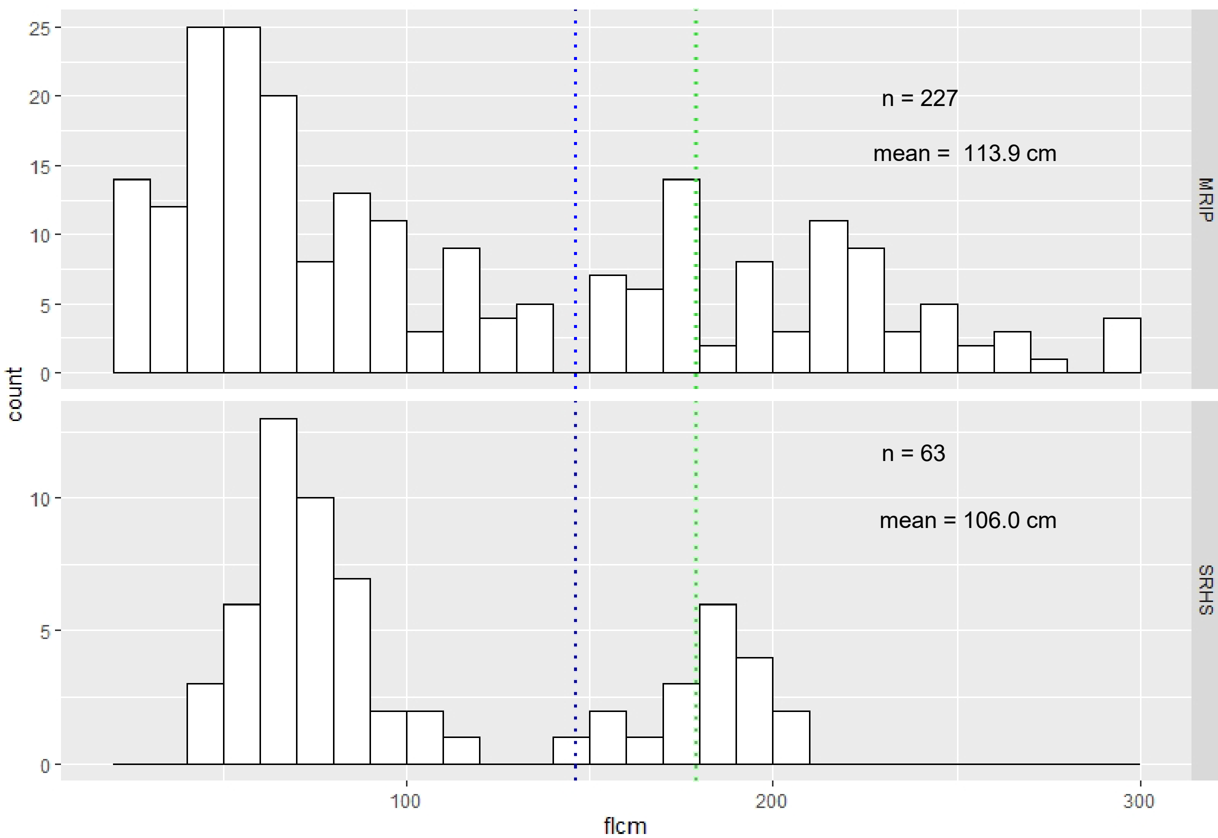


Figure 43. Length-frequency histograms of scalloped hammerheads in all regions caught in the MRIP and SRHS recreational surveys. The dotted blue and green lines denote the median length at maturity for males and females, respectively. MRIP= Marine Recreational Information Program (MRIP). SRHS=Southeast Region Headboat Survey.

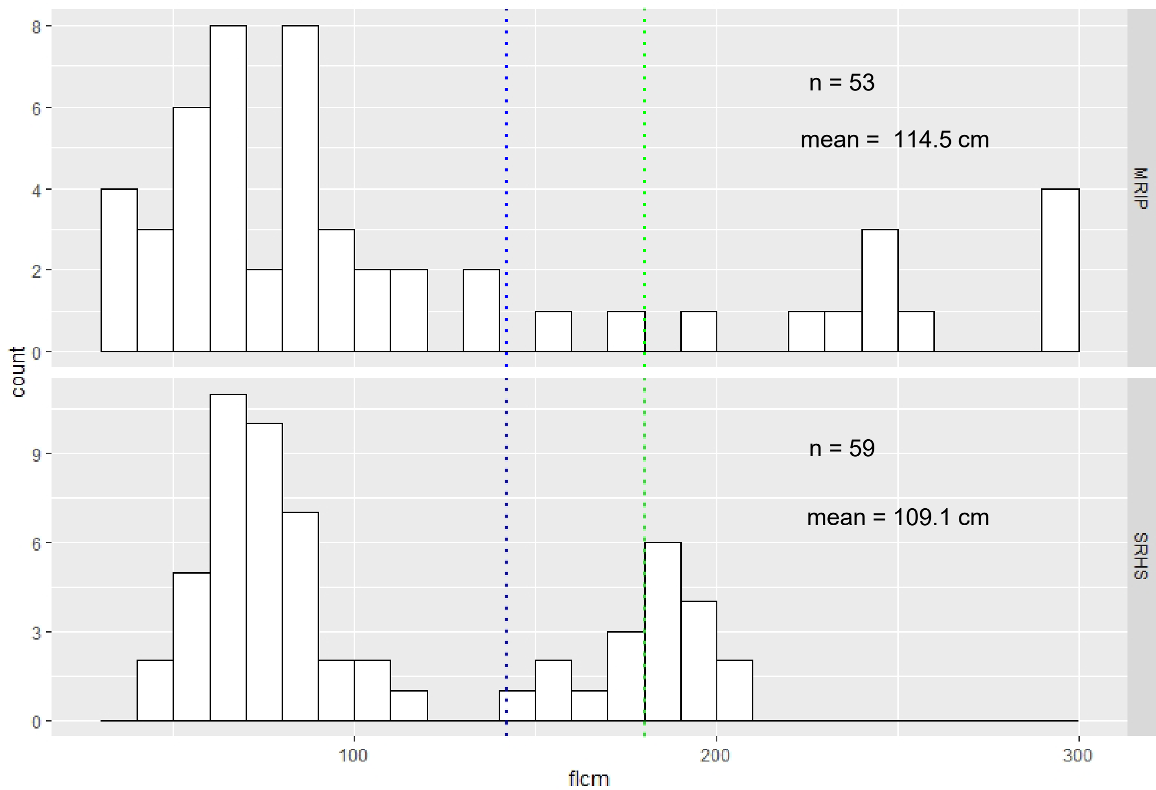


Figure 44. Length-frequency histograms of GOM scalloped hammerheads caught in the MRIP and SRHS recreational surveys. The dotted blue and green lines denote the median length at maturity for males and females, respectively. MRIP= Marine Recreational Information Program (MRIP). SRHS=Southeast Region Headboat Survey.

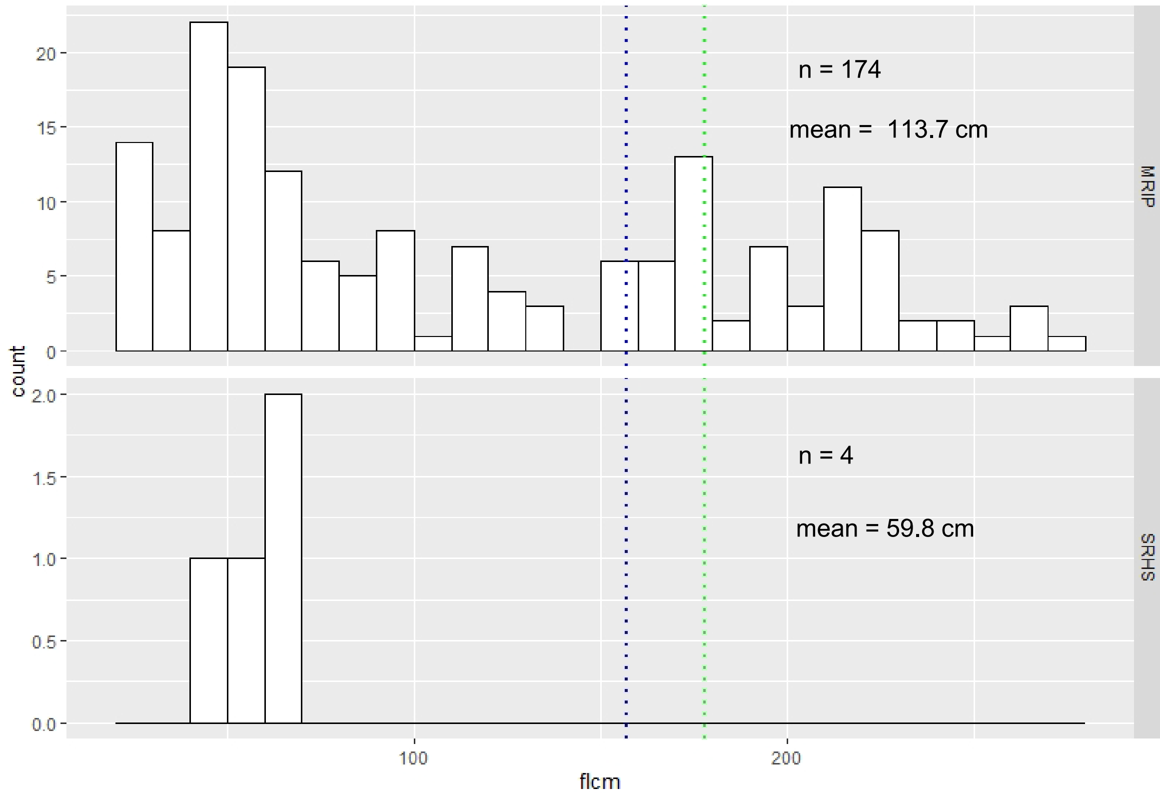


Figure 45. Length-frequency histograms of ATL scalloped hammerheads caught in the MRIP and SRHS recreational surveys. The dotted blue and green lines denote the median length at maturity for males and females, respectively. MRIP= Marine Recreational Information Program (MRIP). SRHS=Southeast Region Headboat Survey.

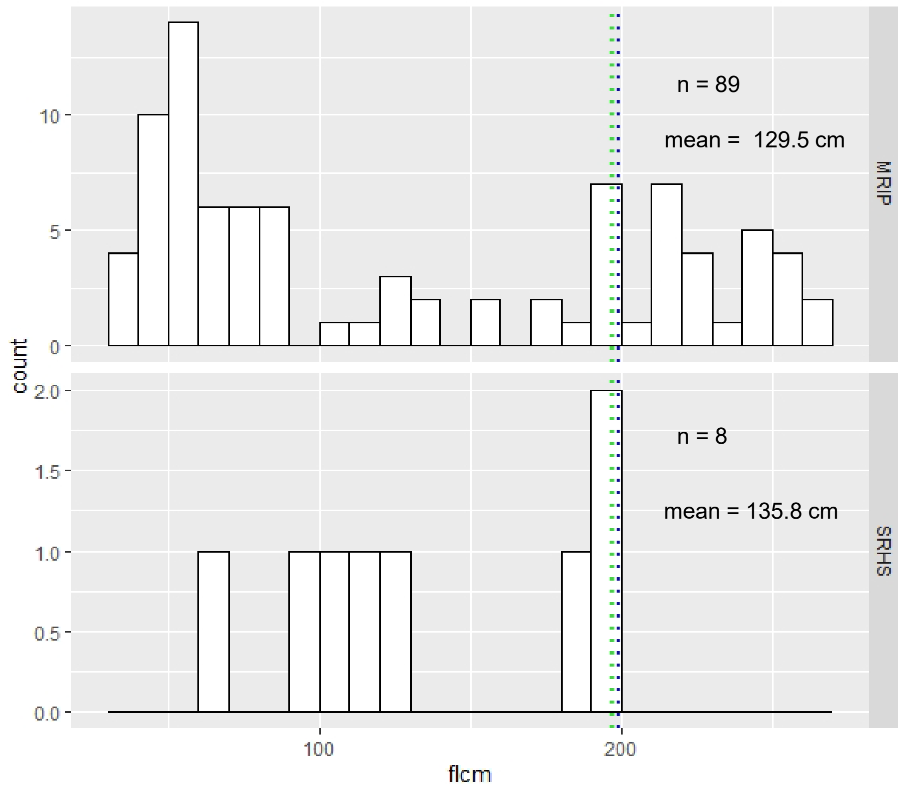


Figure 46. Length-frequency histograms of great hammerheads caught in the MRIP and SRHS recreational surveys. The dotted blue and green lines denote the median length at maturity for males and females, respectively. MRIP= Marine Recreational Information Program (MRIP). SRHS=Southeast Region Headboat Survey.

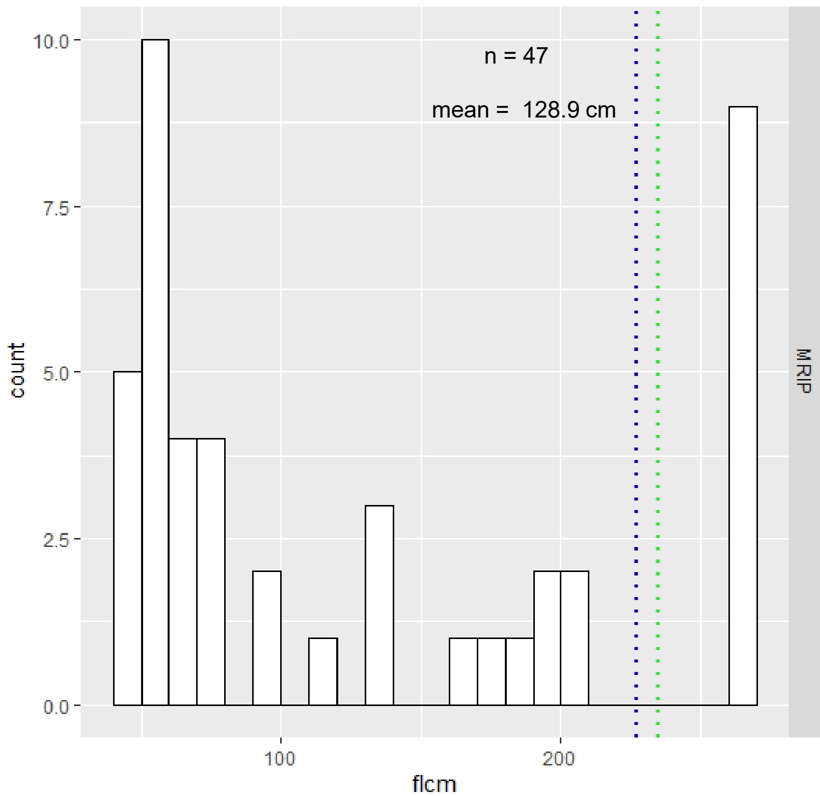
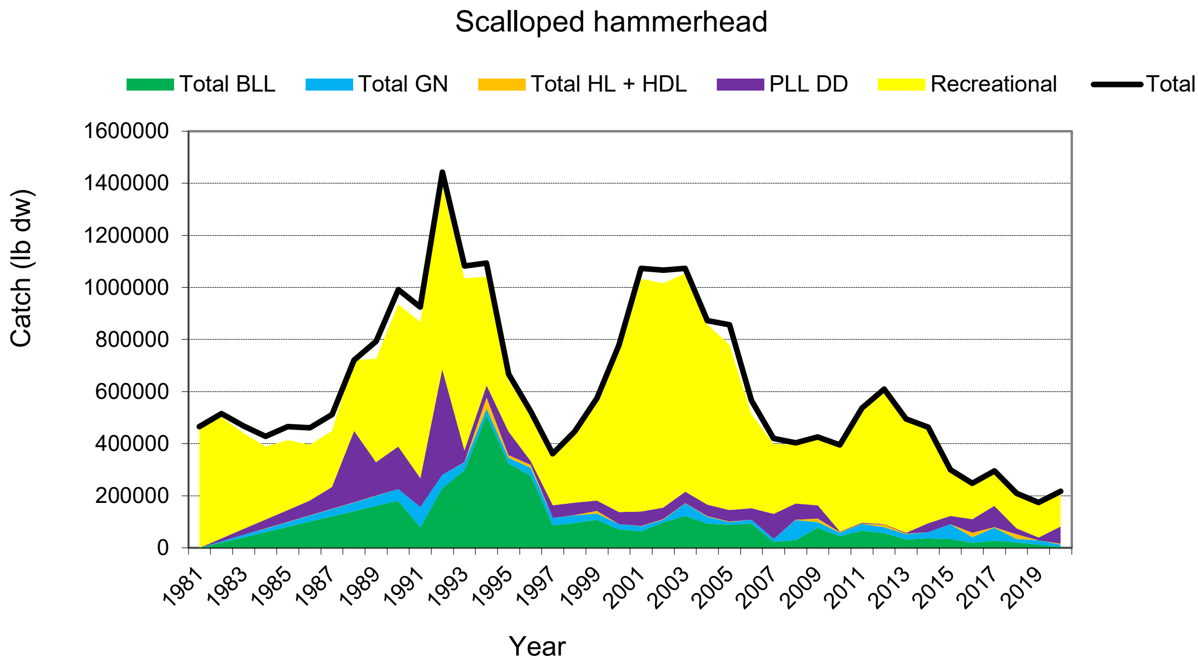


Figure 47. Length-frequency histograms of smooth hammerheads caught in the MRIP and SRHS recreational surveys. The dotted blue and green lines denote the median length at maturity for males and females, respectively. MRIP= Marine Recreational Information Program (MRIP). SRHS=Southeast Region Headboat Survey.



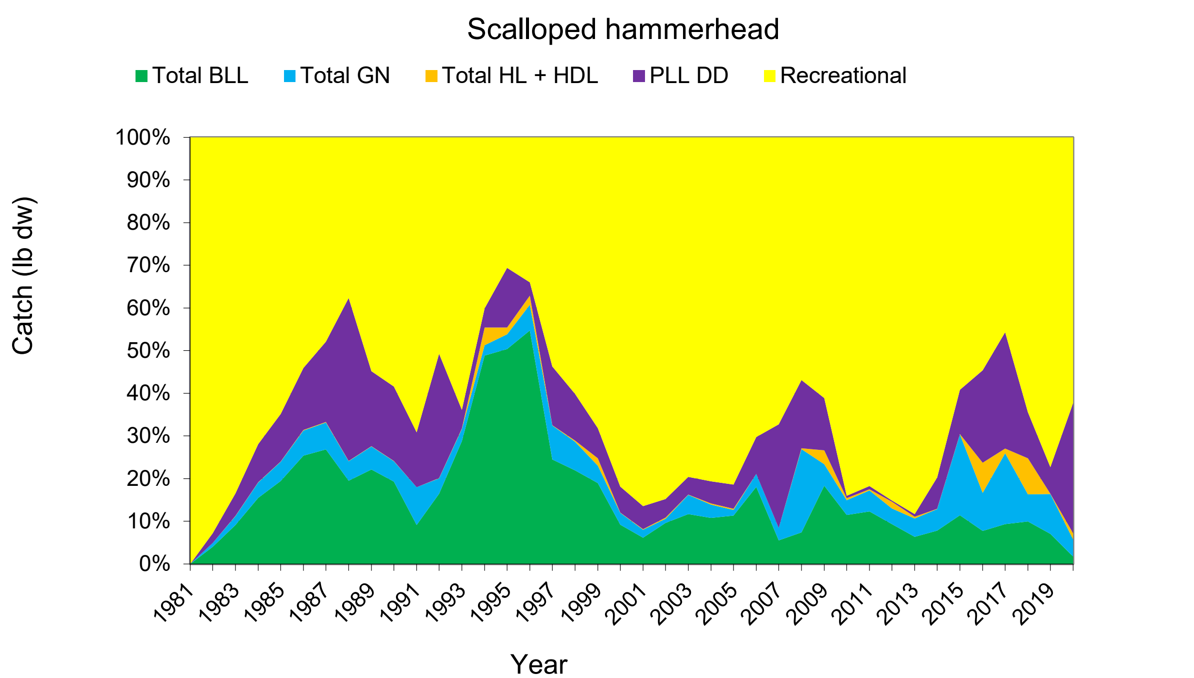
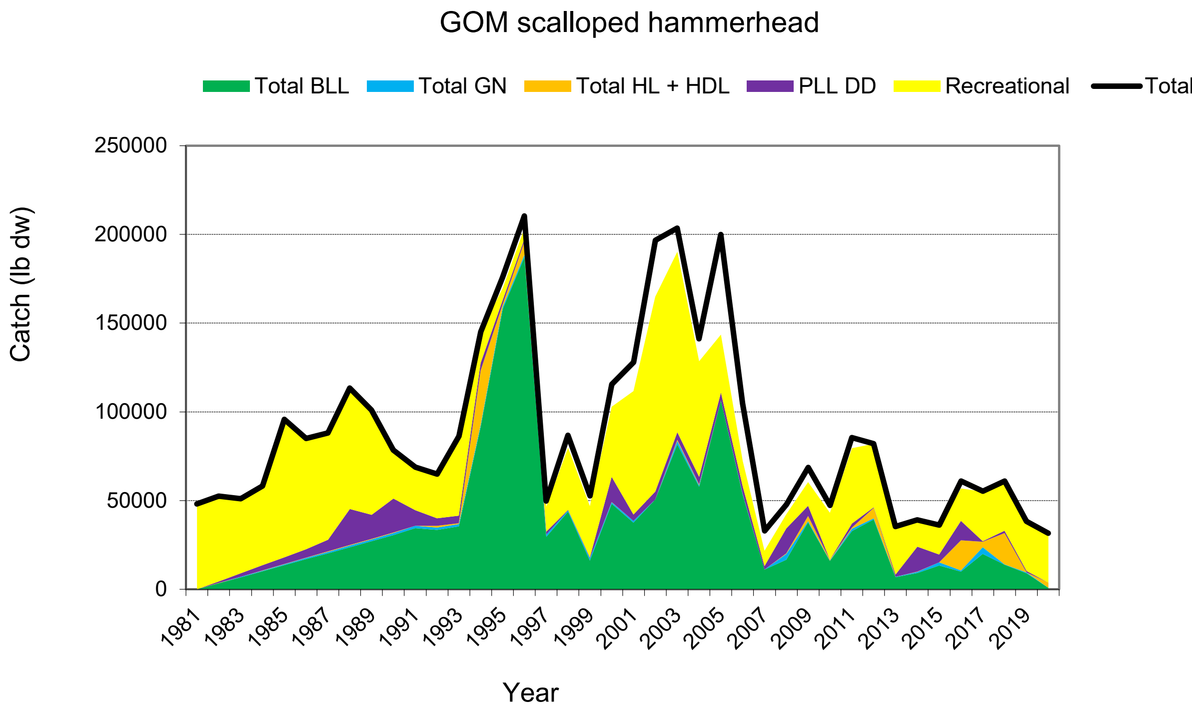


Figure 48. Commercial catches by gear and smoothed recreational catches of scalloped hammerheads in weight (lb dw), 1981-2020. Top panel: stacked catches by year; bottom panel: proportions by year.



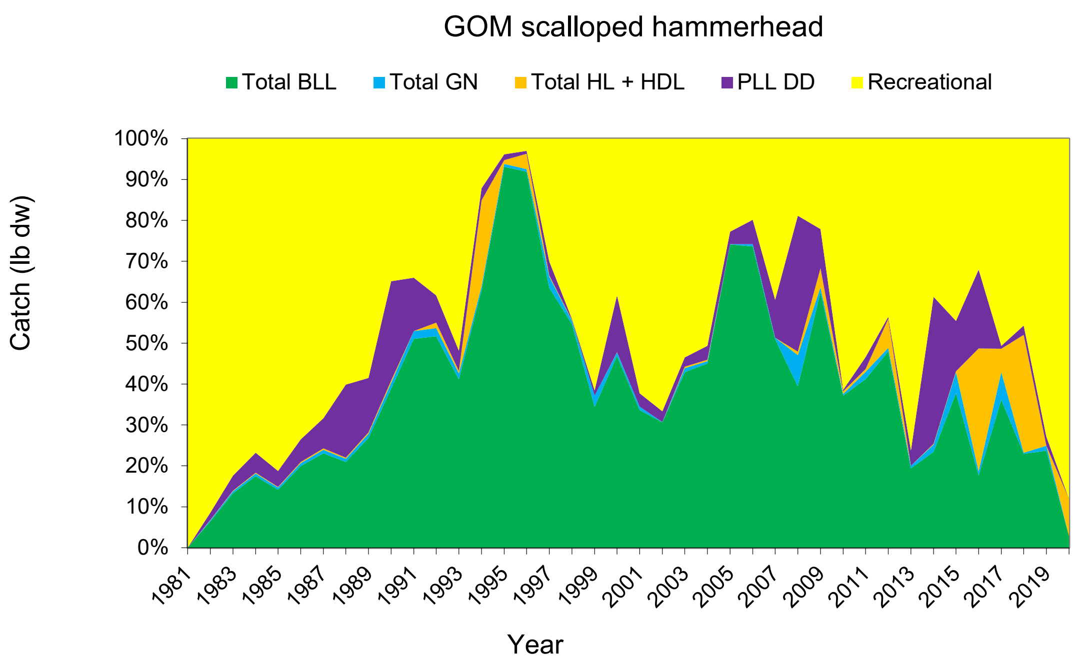


Figure 49. Commercial catches and smoothed recreational catches of GOM scalloped hammerheads in weight (lb dw), 1981-2020. Top panel: stacked catches by year; bottom panel: proportions by year.

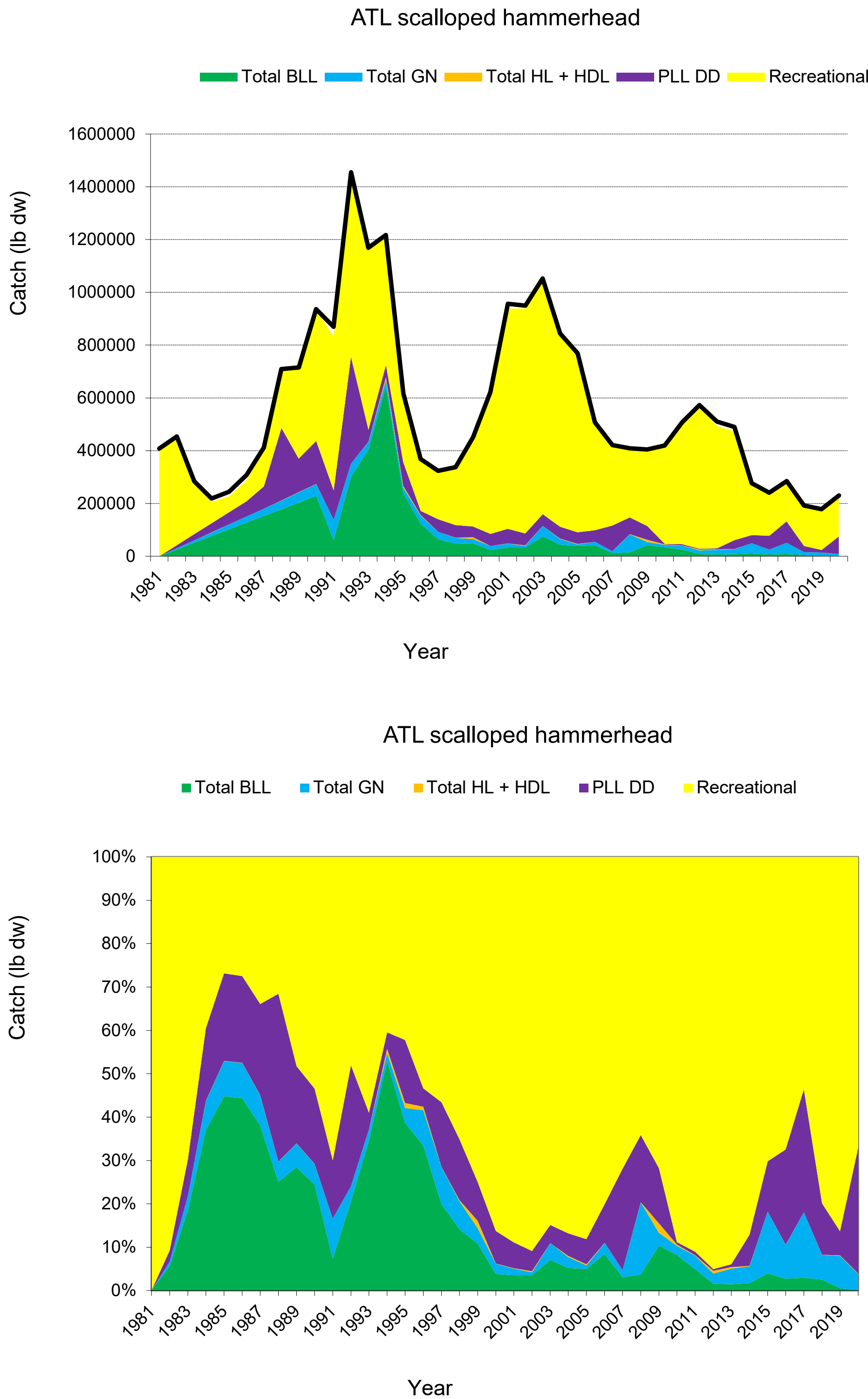


Figure 50. Commercial catches and smoothed recreational catches of ATL scalloped hammerheads in weight (lb dw), 1981-2020. Top panel: stacked catches by year; bottom panel: proportions by year.

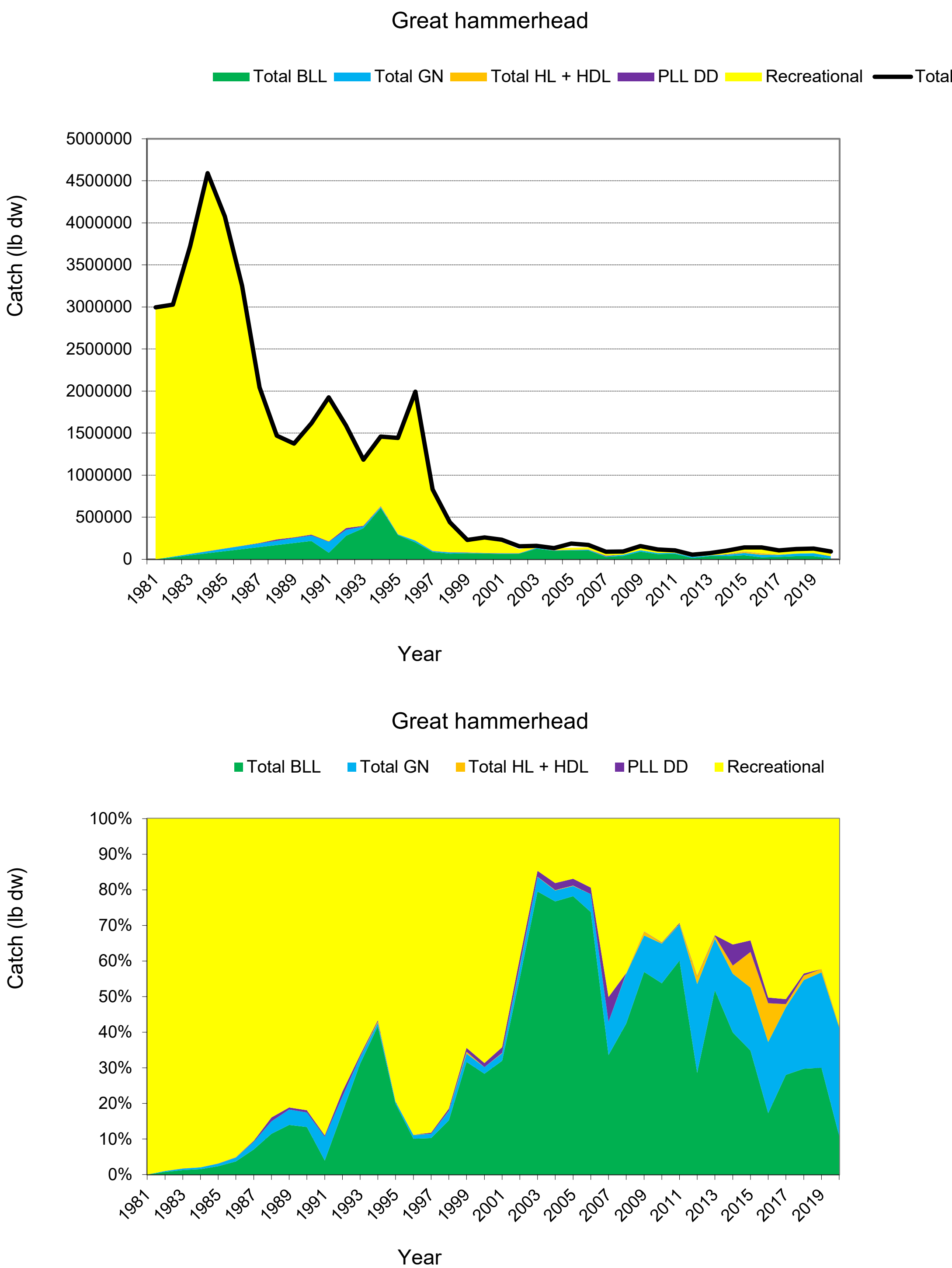


Figure 51. Commercial catches and smoothed recreational catches of great hammerheads in weight (lb dw), 1981-2020. Top panel: stacked catches by year; bottom panel: proportions by year.

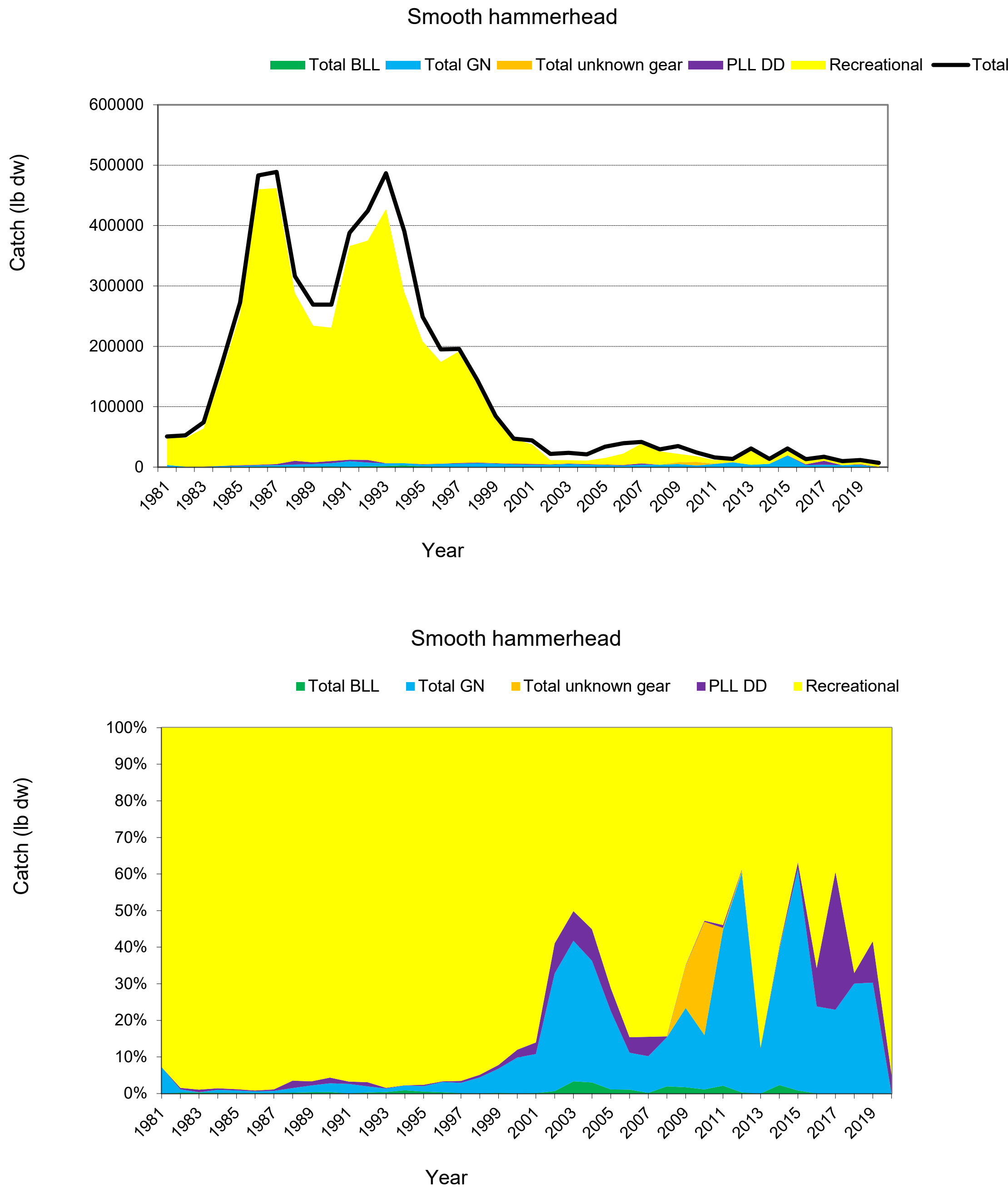


Figure 52. Commercial catches and smoothed recreational catches of smooth hammerheads in weight (lb dw), 1981-2020. Top panel: stacked catches by year; bottom panel: proportions by year

4. Indices of Population Abundance

4.1 Overview

During the initial webinars for SEDAR77, data sources were preliminary examined in terms of their usefulness in developing an index of abundance. Thirty-one (31) data sources were initially considered for use in developing indices of abundance (Table 1). No data sources were considered for Carolina hammerhead due to the difficulty in differentiating the species in the field without genetic analysis. Indices were constructed using both scientific survey and fishery-dependent data. The Working Group (referred to as “Group” henceforth) assessed the appropriateness of each time series by modifying guidelines developed by the International Commission for the Conservation of Atlantic Tunas (ICCAT) Scientific Committee on Research and Statistics (SCRS; ICCAT Doc. No. SCI-033 / 2012). In almost all data series, regardless of whether the data were fishery-dependent or from a scientific survey, the data were standardized using a form of the generalized linear model (Aitchison, 1955). In some cases, scalloped hammerhead datasets were subset to create an Age 0 complex (61 cm FL, young-of-the-year, SEDAR77-DW) and an Age 1+ complex (62 cm FL and greater, juvenile to adult, SEDAR77-DW) to facilitate the creation of recruitment indices (Age 0). The delta-lognormal modeling methods were the most often used to estimate relative abundance indices for great and scalloped hammerheads (Pennington, 1983; Bradu and Mundlak, 1970). The main advantage of using this method is allowance for the probability of zero catch (Ortiz et al., 2000). Elements considered for each data series ranged from the statistical diagnostics of the analysis to the temporal and spatial coverage of the index (Table 2). The Group also used a flowchart developed by ICCAT in its decision-making process (Figure 1). In previous SEDARs for sharks, the indices working group ranked indices on a scale of 1-5 as a means of attributing relative weights for the stock assessment. As was done at SEDAR65, the Group discussed that there is likely little difference among several of the categorical designations and decided to drop that method and to simply recommend the retention of the index or recommend it be not utilized for the assessment. While all indices reviewed were judged to be appropriately constructed, in some cases revisions were recommended.

Group Membership

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4.2 Review Of Indices –Scalloped Hammerhead-

4.2.1 Fishery-Dependent Indices

Pelagic Longline Observer Program (SEDAR77-DW08)

In 1992, the National Marine Fisheries Service (NMFS) initiated scientific sampling of the U.S. large pelagic fisheries longline fleet, as mandated by the U.S. Swordfish Fisheries Management Plan and subsequently the Atlantic Highly Migratory Species Fishery Management Plan (1998). Scientific observers were placed aboard vessels participating in the Atlantic pelagic longline fishery. Relative abundance indices from data collected by observers have been previously developed and used in a variety of assessments of pelagic species primarily under the auspices of the International Commission for the Conservation of Atlantic Tunas (ICCAT). A data set was developed based on the observer programs as described in Beerkircher et al. (2002) and Cortés et al. (2007). Following recommendations of the stock identification workshop, separate indices were evaluated for the three putative scalloped hammerhead stocks defined in the stock identification workshop by the geographic region: (1) the Atlantic Ocean and Gulf of Mexico regions combined (base); (2) the Atlantic Ocean region alone (sensitivity); and (3) the Gulf of Mexico region alone (sensitivity). However, it was not possible to develop and index for the Gulf of Mexico region alone because the model would not converge with only Year as a covariate. For the Atlantic Ocean and Gulf of Mexico regions combined (base) and the Atlantic Ocean region alone (sensitivity) the CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution (Lo et al. 1992).

Decision: The Group determined that because this series is stock wide and used in previous stock assessments for other pelagic species, the series should be retained for use in the scalloped hammerhead stock assessment base model. The recommendation is for Age 1+ scalloped hammerhead stocks in the Atlantic Ocean and Gulf of Mexico regions combined (Base; Tables 3 and 5) and the Atlantic Ocean region (Sensitivity; Tables 3 and 6). There was discussion relative to the initial abundance in 1992 being much higher than the remainder of the series. It was noted that this high value was also found for other species (e.g. shortfin mako) and as there was no obvious explanation, the data point was retained in the time series.

Shark Bottom Longline Observer Program and Shark Research Fishery (SEDAR77-DW12)

Observations by at-sea observers of the shark-directed bottom longline fishery in the Atlantic Ocean and Gulf of Mexico have been conducted since 1994 (e.g. Morgan et al. 2009, Mathers et al. 2018 and references therein). A combined data set was developed based on observer programs from Morgan et al. (2009) and Mathers et al. (2018). Historically, vessels in this fishery primarily targeted sandbar shark. With the introduction of the shark research fishery in 2008, vessels outside the research fishery were not permitted to target or land sandbar sharks. This change in management regulations likely influences the time series of abundance for sharks such that vessels fishing in the research fishery should be modeled separately from those outside the research fishery. Therefore, two indices of abundance were created from this data series; 1994-2007 for all vessels and 2008-2019 for vessels in the research fishery. The time series covers a broad area (North Carolina to eastern Gulf of Mexico) over a long temporal period (1993-2019). Following recommendations of the stock identification workshop, separate indices were evaluated for the three putative scalloped hammerhead stocks defined in the stock identification workshop by the geographic region: (1) the Atlantic Ocean and Gulf of Mexico regions combined (base); (2) the Atlantic Ocean region alone (sensitivity); and (3) the Gulf of Mexico region alone (sensitivity). For each region, the CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution (Lo et al. 1992).

Decision: The Group determined that because this series is stock wide and used in previous stock assessments for sharks, the series should be retained for use in the scalloped hammerhead stock assessment base model. The recommendation is for Age 1+ scalloped hammerhead stocks in the Atlantic Ocean and Gulf of Mexico regions combined (Base; Tables 3 and 5), the Atlantic Ocean region (Sensitivity; Tables 3 and 6), and the Gulf of Mexico region (Sensitivity; Tables 3 and 7) including both the non-research (≤ year 2007) and the research (≥ year 2008) time series in each region.

Southeast Coastal Gillnet Observer Program (SEDAR77-DW13)

Observer coverage of the Florida-Georgia shark gillnet fishery began in 1992, and has since documented the many changes to effort, gear characteristics, and target species the fishery has undergone following the implementation of multiple fisheries regulations. In 2005, the gillnet observer program was expanded to include all vessels that have an active directed shark permit and fish with sink gillnet gear. These vessels were not previously subject to observer coverage because they either were targeting non-highly migratory species or were not fishing gillnets in a drift or strike fashion. In 2006, the National Marine Fisheries Service Southeast Regional Office requested further expansion of the scope of the gillnet observer program to include all vessels fishing gillnets regardless of target, and for coverage to be extended to cover the full geographic range of gillnet fishing effort in the southeast United States. Based on these regulations and on current funding levels, the gillnet observer program now covers all anchored (sink, stab, set), strike, or drift gillnet fishing by vessels that fish from Florida to North Carolina and the Gulf of Mexico year-round. Following recommendations of the stock identification workshop, separate indices were evaluated for the three putative scalloped hammerhead stocks defined in the stock identification workshop by the geographic region: (1) the Atlantic Ocean and Gulf of Mexico regions combined (base); (2) the Atlantic Ocean region alone (sensitivity); and (3) the Gulf of Mexico region alone (sensitivity). However, abundance trends were not developed specific to the Gulf of Mexico due to low proportion positives. For the Atlantic Ocean and Gulf of Mexico regions combined (base) and the Atlantic Ocean region alone (sensitivity) the CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution (Lo et al. 1992).

Decision: The Group determined that because this series is stock wide and used in previous stock assessments for sharks, the series should be retained for use in the scalloped hammerhead stock

assessment. However, given the higher CVs and the presence of other indices it was recommended this time series be used as a sensitivity. The recommendation is for use as an additional sensitivity analysis of Age 1+ scalloped hammerhead stocks in the Atlantic Ocean and Gulf of Mexico regions combined (Sensitivity; Tables 3 and 8), and the Atlantic Ocean region alone (Sensitivity; Tables 3 and 8).

4.2.2 Scientific Survey Indices

Dauphin Island Sea Laboratory Bottom Longline Survey (SEDAR77-DW06)

Scalloped hammerheads (*Sphyrna lewini*) are a common shelf-associated shark off the coast of Alabama. From May 2006 to October 2019, 230 scalloped hammerheads were captured during 1311 fisheries-independent bottom longline sets. Trends in catch by sex were examined and catch data were standardized using a negative binomial generalized linear model to create a standardized index of relative abundance. Males were significantly larger and more abundant than females and few females larger than 175 cm stretch total length were caught. The standardized index of relative abundance indicated that the relative abundance of scalloped hammerheads in the sampling region has remained relatively stable over the past 14 years.

Decision: The Group determined that because this series covers a relatively long time period, the series should be retained for use in the scalloped hammerhead stock assessment. However, given that the time series is limited spatially (only off the coast of Alabama) and it overlaps with the SEFSC bottom longline survey (SEDAR77-DW24), it was recommended that this time series be used as a sensitivity. The recommendation is for Age 1+ scalloped hammerhead stocks in the Gulf of Mexico region alone (Tables 3 and 8).

Florida State University Bottom Longline Survey (SEDAR77-DW14)

The Florida State University longline survey was expanded in 2011 to include regular sampling in southwest Florida in an effort to capture smalltooth sawfish for research directed at promoting recovery of this endangered species. This work is concentrated in two areas, in Everglades National Park, mostly in northern Florida Bay, along the middle to lower Florida Keys, primarily along the shelf break. Along the Florida Keys, scalloped and great hammerhead sharks are among the most frequently encountered species in this survey. The FSU survey targets coastal sharks and smalltooth sawfish using fishery-independent longlines consisting of a 4.0 mm monofilament main line that is anchored on each end and marked with a surface buoy bearing the permit numbers. Each mainline set was approximately 750 m long. A standard set included 50 or 100 gangions consisting of a stainless-steel tuna clip with an 8/0 stainless steel swivel attached to 2.5 m of 300 kg monofilament that was doubled in the terminal 25 cm and attached to 16/0 non-offset circle hook. Hooks were baited with ladyfish *Elops saurus* or Spanish mackerel *Scomberomorus maculatus*. Depth (m), turbidity (cm), water temperature (°C), salinity, and dissolved oxygen (mg l^{-1}) were recorded from the surface to the bottom for all sets made in depths of less than 10 m, and bottom water temperature (°C) was recorded for those greater than 10 m deep. Targeted soak times were 1 h to minimize mortality, and all lines were set during daylight hours. The line was hauled in the order and direction it was set and teleosts and elasmobranchs were sampled as they were caught during retrieval. Areas sampled included the Atlantic side of the Florida Keys from Key West to Islamorada and inside ENP from Florida Bay north to Ponce de Leon Bay. The CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution (Lo et al. 1992).

Decision: The series covers a proportion of the stock not sampled by other surveys. The initial analysis of these data resulted in high CVs and a low proportion positive. The Group decided that a post-analysis be conducted on a subset of data based on habitat. Data were refined and post-analysis conducted on a subset of data to reduce true zeros from areas where hammerheads would never or rarely be available. The revised indices were recommended for use in the scalloped hammerhead stock assessment base model. The recommendation is for Age 1+ scalloped hammerhead stocks in the Atlantic Ocean and Gulf of Mexico regions combined (Base; Tables 3 and 5) and the Gulf of Mexico region alone (Sensitivity; Tables 3 and 7).

NOAA Fisheries-Southeast Fisheries Science Center- Bottom Longline Survey (SEDAR77-DW24)

The Southeast Fisheries Science Center Mississippi Laboratories (MSLABS) has conducted standardized bottom longline surveys in the Gulf of Mexico (GOM), Caribbean, and Western North Atlantic Ocean (Atlantic) since 1995. Additionally, in 2011 the Congressional Supplemental Sampling Program (CSSP) was conducted, where high levels of standardized bottom longline survey effort were maintained from April through October. Data from the MSLABS Bottom Longline Survey and the CSSP Survey were used to produce a relative abundance index for scalloped hammerhead (*Sphyrna lewini*) and great hammerhead (*Sphyrna mokarran*). One abundance index was calculated for great hammerhead that included data from both the GOM and Atlantic. Following recommendations of the stock identification workshop, separate indices were evaluated for the three putative scalloped hammerhead stocks defined in the stock identification workshop by the geographic region: (1) the Atlantic Ocean and Gulf of Mexico regions combined (base); (2) the Atlantic Ocean region alone (sensitivity); and (3) the Gulf of Mexico region alone (sensitivity). Delta-lognormal modeling methods were used to estimate relative abundance indices for great and scalloped hammerheads. All age 0 scalloped hammerhead (FL < 61 cm) were removed when building the dataset for the abundance indices.

Decision: The Group determined that because this series is stock wide and used in previous stock assessments for sharks, the series should be retained for use in the scalloped hammerhead stock assessment base model. The recommendation is for Age 1+ scalloped hammerhead stocks in the Atlantic Ocean and Gulf of Mexico regions combined (Base; Tables 3 and 5), the Atlantic Ocean region alone (Sensitivity; Tables 3 and 6), and the Gulf of Mexico region alone (Sensitivity; Tables 3 and 7).

NOAA Northeast Fisheries Science Center coastal shark bottom longline survey (SEDAR77-DW28)

This document details scalloped hammerhead shark catches from the Northeast Fisheries Science Center (NEFSC) coastal shark bottom longline survey conducted by the Apex Predators Program from 1996-2018. Data from this survey were used to examine the trends in relative abundance in the waters off the east coast of the United States. Catch per unit effort (CPUE) in number of sharks per 100 hook hours were examined for each year of the bottom longline survey, 1996, 1998, 2001, 2004, 2007, 2009, 2012, 2015, and 2018. The CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The standardized

CPUE results from the NEFSC longline survey show an increasing trend in scalloped hammerhead shark relative abundance across the survey years from 1996 to 2018.

Decision: The initial standardized CPUE results showed an increasing trend in scalloped hammerhead shark relative abundance across the survey years from 1996 to 2018. This result is not supported by the life history of the species, particularly the large increase in the final years of the survey. Following SEDAR 77 panel feedback, additional analyses were undertaken that modified the spatial coverage of the survey (excluding non-repeated stations and excluding areas), modified model development (excluding year until all covariates were incorporated), and incorporating habitat suitability. Although some improvements were seen in model fit, diagnostics, and estimated trends, these models still seemed to be driven by the year effect and/or overinflated some estimates (habitat suitability weighting). Therefore, resulting indices from these analyses for the NEFSC coastal shark bottom longline survey are not recommended for use in the SEDAR 77 assessment for scalloped hammerhead sharks at this time. However, during the final post- Data Workshop webinar it was decided that spatiotemporal modelling should be investigated and results reviewed during the first Assessment Workshop webinar for potential incorporation into the assessment as a recommended index or in a sensitivity run if recommended for inclusion by the Assessment Workshop panel.

Texas Parks and Wildlife Gillnet Survey (SEDAR77-DW16)

This paper determines a relative abundance index for young-of-the-year scalloped hammerhead sharks utilizing a scientific survey gillnet survey by the Texas Parks and Wildlife Department, Coastal Fisheries Division. The protocol for the survey, as it is constituted today, has been standardized since 1982 with the purpose of monitoring relative abundance and size of organisms, their spatial and temporal distribution, and species composition of the community and selected environmental parameters known to influence their distribution and abundance. Surveys were conducted in 10 major bay systems along the Texas coast in the northwestern Gulf of Mexico from 1982 to 2019. The CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution (Lo et al. 1992).

Decision: Although the proportion positive was low for scalloped hammerhead, the Group noted the temporal and spatial coverage of the series (1982-2019; entire Texas coast). As the survey

largely catches only juveniles, the series was recommended for use in the scalloped hammerhead stock assessment base model as a potential recruitment series (Age 0). The recommendation is for Age 0 scalloped hammerhead stocks in the Atlantic Ocean and Gulf of Mexico regions combined (Base; Tables 3 and 9) and Gulf of Mexico region alone (Sensitivity; Tables 3 and 9).

Northeast Gulf of Mexico (GULFSPAN) Gillnet Survey (SEDAR77-DW17)

Fishery-independent surveys of coastal shark populations have taken place since 1994 in the eastern and northern Gulf of Mexico. The cooperative Gulf of Mexico Shark Pupping and Nursery (GULFSPAN) survey began in 1996 to examine the distribution and abundance of juvenile sharks in coastal areas. The ultimate intent of this survey is to continue to describe and further refine shark essential fish habitat as mandated by the Magnuson-Steven Fishery Conservation and Management Act. NOAA Fisheries Panama City Laboratory oversees the survey. In 2003, Gulf Coast Research Laboratory at the University of Southern Mississippi was added to the survey. In 2007, additional participants included the Florida Natural History Museum at the University of Florida and Dauphin Island Sea Laboratory at the University of South Alabama. In 2008, the Florida State University Coastal and Marine Laboratory became a collaborator. In 2016 and 2017, New College of Florida and Havenworth Coastal Conservation became collaborators in the GULFSPAN project, respectively. Preliminary examination of the data indicated the occurrence of scalloped hammerhead was highest in the northern Gulf of Mexico for the NOAA and University of Southern Mississippi surveys. While the other surveys did capture scalloped hammerhead, the frequency of capture (<1%) was too low to develop a reliable index and these surveys were excluded. The CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution (Lo et al. 1992).

Decision: The survey has been used in previous shark assessments. As the survey largely catches only juveniles, the series was recommended for use in the scalloped hammerhead stock assessment base model as a potential recruitment series (Age 0). The recommendation is for Age 0 scalloped hammerhead stocks in the Atlantic Ocean and Gulf of Mexico regions combined (Base; Tables 3 and 9) and Gulf of Mexico region alone (Sensitivity; Tables 3 and 9).

Cooperative Atlantic States Shark Pupping and Nursery longline survey (SEDAR77-DW30)

This document details the shark catches from the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) longline surveys conducted in estuarine and nearshore waters from South Carolina to northern Florida. Catch per unit effort (CPUE) in number of sharks per 100 hook hours were used to examine young-of-the-year scalloped hammerhead shark relative abundance from 2005-2019. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The standardized index of abundance from the COASTSPAN longline survey shows an overall decreasing trend in in relative abundance for YOY scalloped hammerhead across survey years.

Decision: The survey has been used in previous shark assessments. As the survey largely catches only juveniles, the series was recommended for use in the scalloped hammerhead stock assessment base model as a potential recruitment series (Age 0). The recommendation is for Age 0 scalloped hammerhead stocks in the in the Atlantic Ocean and Gulf of Mexico regions combined (Base; Tables 3 and 9) and Atlantic region alone (Sensitivity; Tables 3 and 9).

South Carolina Department of Natural Resources, Cooperative Atlantic States Shark Pupping and Nursery long-gillnet survey (SEDAR77-DW31)

This document details scalloped hammerhead shark catches from the South Carolina Department of Natural Resources (SCDNR), Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) long-gillnet survey (2001-2019). Catch per unit effort (CPUE) in number of sharks per net hour were used to examine young-of-the-year (YOY) scalloped hammerhead shark relative abundance in South Carolina's estuarine waters. The CPUE was standardized using generalized linear models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. Nominal and standardized CPUE results from the COASTSPAN long-gillnet survey indicate a slight increasing trend in YOY scalloped hammerhead relative abundance across survey years.

Decision: Although the survey is limited spatially, it has been used in previous shark assessments. As the survey largely catches only juveniles, the series was recommended for use in the scalloped hammerhead stock assessment base model as a potential recruitment series (Age 0). The recommendation is for Age 0 scalloped hammerhead stocks in the Atlantic Ocean and Gulf of Mexico regions combined (Base; Tables 3 and 9) and Atlantic region alone (Sensitivity; Tables 3 and 9).

South Carolina Department of Natural Resources, Cooperative Atlantic States Shark Pupping and Nursery short-gillnet survey (SEDAR77-DW32)

This document details scalloped hammerhead shark catches from the South Carolina Department of Natural Resources (SCDNR), Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) short-gillnet survey (2007-2019). Catch per unit effort (CPUE) in number of sharks per net hour were used to examine the young-of-year (YOY) scalloped hammerhead sharks trend in South Carolina estuaries for use as a recruitment index in the SEDAR 77 stock assessment. The CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. Nominal and standardized CPUE results from the COASTSPAN short-gillnet survey indicate an overall decreasing trend in YOY scalloped hammerhead shark relative abundance during the survey years.

Decision: Although the survey is limited spatially and contained missing years, it has been used in previous shark assessments. As the survey largely catches only juveniles, the series was recommended for use in the scalloped hammerhead stock assessment base model as a potential recruitment series (Age 0). The recommendation is for Age 0 scalloped hammerhead stocks in the Atlantic Ocean and Gulf of Mexico regions combined (Base; Tables 3 and 9) and Atlantic region alone (Sensitivity; Tables 3 and 9).

Standardized index of abundance for scalloped hammerhead sharks from the University of North Carolina shark longline survey south of Shakleford Banks (SEDAR77-DW33)

This document details the scalloped hammerhead catch from April-November, 1981-2019, at two fixed stations in Onslow Bay south of Shackleford Banks, North Carolina. Catch per unit effort (CPUE) by set in number of sharks per number of set hooks were examined by year. The CPUE was standardized using a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The majority of catches occurred during April and early May (82%), which were not consistently sampled across years due to weather and logistical constraints. The standardized relative abundance for scalloped hammerhead sharks shows a variable but overall decreasing trend through the early 1990s followed by an increasing trend throughout the remainder of the time series.

Decision: The survey is limited spatially but is long term and began in 1981. However, in many years the catches are very low (0-3) which suggests it may not be a good survey for tracking abundance. However, the time series has been used in previous shark assessments (blacknose shark) and the Group agreed that the series should be retained for use in the scalloped hammerhead stock assessment, but it was recommended that this time series be used as a sensitivity. The recommendation is for Age 1+ scalloped hammerhead Atlantic Ocean and Gulf of Mexico regions combined and in the Atlantic region (Table 6).

4.2.3 Summary-Scalloped Hammmerhead

The geographic coverage of the abundance indices for scalloped hammerhead shark are in Figures 2-6 and plots of the relative indices (index/mean index of the time series) by year are in Figures 7-11. The Indices Working Group recommends compiling indices for use in stock assessment consistent with scalloped hammerhead Stock ID Workshop recommendations to separate indices for the three putative scalloped hammerhead stocks defined in the stock identification workshop by the geographic region: (1) the Atlantic Ocean and Gulf of Mexico regions combined (base); (2) the Atlantic Ocean region alone (sensitivity); and (3) the Gulf of Mexico region alone (sensitivity):

1. Compile indices for a base model in the Atlantic Ocean and Gulf of Mexico regions combined from the recommended scalloped hammerhead stock assessment indices as follows:

   a. Include each recommended stock wide Age 1+ index (Tables 3 and 5); and

   b. Include each recommended regional Age 0 index (Tables 3 and 9) as a potential recruitment index within the base model.

2. Compile indices for an Atlantic region sensitivity model from the recommended scalloped hammerhead stock assessment indices as follows:

a. Include each recommended regional Age 1+ index (Tables 3 and 6), from the Atlantic region within the Atlantic region model; and

b. Include each recommended regional Age 0 index from the Atlantic region (Tables 3 and 9) as a potential recruitment index within the Atlantic region model.

3. Compile indices for a Gulf of Mexico region sensitivity model from the recommended scalloped hammerhead stock assessment indices as follows:

a. Include each recommended regional Age 1+ index (Tables 3 and 7), from the Gulf of Mexico region within the Gulf of Mexico region model; and

b. Include each recommended regional Age 0 index from the Gulf of Mexico region (Tables 3 and 9) as a potential recruitment index within the Gulf of Mexico region model.

4. Compile additional recommended indices of abundance for Age 1+ scalloped hammerhead sensitivity analysis as described in Tables 3 and 8.

4.3 Review Of Indices –Great Hammerhead

4.3.1 Fishery-Dependent Indices

Shark Bottom Longline Observer Program (SEDAR77-DW12)

Observations by at-sea observers of the shark-directed bottom longline fishery in the Atlantic Ocean and Gulf of Mexico have been conducted since 1994 (e.g. Morgan et al. 2009, Mathers et al. 2018 and references therein). A combined data set was developed based on observer programs from Morgan et al. (2009) and Mathers et al. (2018). Historically, vessels in this fishery primarily targeted sandbar shark. With the introduction of the shark research fishery in 2008, vessels outside the research fishery were not permitted to target or land sandbar sharks. This change in management regulations likely influences the time series of abundance for sharks such that vessels fishing in the research fishery should be modeled separately from those outside the research fishery. Therefore, two indices of abundance were created from this data series; 1994-2007 for all vessels and 2008-2019 for vessels in the research fishery. While observations of vessels outside the research fishery were made from 2008-2018, the low sample size in some years precluded including those data, as the model would have difficulty converging. The time series covers a broad area (North Carolina to eastern Gulf of Mexico) over a long temporal period (1993-2019). The CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution (Lo et al. 1992).

Decision: The Group determined that because this series is stock wide and used in previous stock assessments for sharks, the series should be retained for use in the stock assessment. The recommendation is for the stock wide great hammerhead stock assessment base run (Table 10), including both the non-research (≤ year 2007) and the research (≥ year 2008) time series.

4.3.2 Scientific Survey Indices

Florida State University Bottom Longline Survey (SEDAR77-DW14)

The Florida State University longline survey was expanded in 2011 to include regular sampling in southwest Florida in an effort to capture smalltooth sawfish for research directed at promoting recovery of this endangered species. This work is concentrated in two areas, in Everglades National Park, mostly in northern Florida Bay, along the middle to lower Florida Keys, primarily along the shelf break. Along the Florida Keys, scalloped and great hammerhead sharks are among the most frequently encountered species in this survey. The FSU survey targets coastal sharks and smalltooth sawfish using fishery-independent longlines consisting of a 4.0 mm monofilament main line that is anchored on each end and marked with a surface buoy bearing the permit numbers. Each mainline set was approximately 750 m long. A standard set included 50 or 100 gangions consisting of a stainless steel tuna clip with an 8/0 stainless steel swivel attached to 2.5 m of 300 kg monofilament that was doubled in the terminal 25 cm and attached to 16/0 non-offset circle hook. Hooks were baited with ladyfish *Elops saurus* or Spanish mackerel *Scomberomorus maculatus*. Depth (m), turbidity (cm), water temperature (°C), salinity, and dissolved oxygen (mg l^{-1}) were recorded from the surface to the bottom for all sets made in depths of less than 10 m, and bottom water temperature (°C) was recorded for those greater than 10 m deep. Targeted soak times were 1 h to minimize mortality, and all lines were set during daylight hours. The line was hauled in the order and direction it was set and teleosts and elasmobranchs were sampled as they were caught during retrieval. Areas sampled included the Atlantic side of the Florida Keys from Key West to Islamorada and inside ENP from Florida Bay north to Ponce de Leon Bay. The CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution (Lo et al. 1992).

Decision: The initial analysis of these data resulted in high CVs and a low proportion positive. The Group decided that a post-analysis be conducted on a subset of data based on habitat (i.e. samples were only included if they represented habitat where great hammerheads would be expected to be found) to reduce true zeros from areas where hammerheads are not available. The revised indices were recommended for use in the stock wide great hammerhead stock assessment base run (Table 10).

Rosenstiel School of Marine and Atmospheric Science Drumline Survey (SEDAR65-DW15)

Shark surveys were conducted year-round, encompassing Florida's wet season (May-October) and dry season (November – April). Shark surveys in the Keys region predominately occurred between January 2009 and December 2013, whereas surveys in the Miami region primarily occurred between April 2014 and February 2021. Daily sampling locations were selected randomly within inshore or offshore habitats. Sharks were surveyed using a standardized and minimally invasive drumline fishing method as described in Gallagher et al. (2014). The fishing gear consisted of a submerged 20-kg weight tied to a line running to the surface by means of an attached inflatable buoy. A 23-m monofilament ganglion line (~400 kg test) was attached to the submerged weight by a swivel, which terminated at a baited 16/0 5°-offset circle hook. Two sets of five baited drumlines were deployed and hooks were baited with a standardized type of cut fish, primarily great barracuda (*Sphyrna barracuda*) and false albacore (*Euthynnus alletteratus*), and to a lesser degree ladyfish (*Elops saurus*), greater amberjack (*Seriola dumerili*) and jack crevalle (*Caranx hippos*). Each drumline within a set was separated by ~100 m. Catch per unit effort were calculated by dividing the number of hammerheads captured by the total soak time of the 10 drumlines deployed at a specific site on a given day. Data were analyzed using the gamlss R package with a negative binomial distribution. Model covariates including month, region (Keys vs Miami), Habitat (Bay vs Ocean), Season (Wet vs Dry) and Latitude and Longitude. Soak Time was included as an offset in the model

Decision: Similar to the Florida State University longline series, the initial analysis of these data resulted in high CVs and a low proportion positive. The Group decided that a post-analysis be

conducted on subset of data based on habitat (i.e. samples were only included if they represented habitat where great hammerheads would be expected to be found) to reduce true zeros from areas where hammerheads are not available. The revised indices were recommended use in the for stock wide great hammerhead stock assessment base run (Table 10).

NOAA Fisheries-Southeast Fisheries Science Center- Bottom Longline Survey (SEDAR77-DW24)

The Southeast Fisheries Science Center Mississippi Laboratories (MSLABS) has conducted standardized bottom longline surveys in the Gulf of Mexico (GOM), Caribbean, and Western North Atlantic Ocean (Atlantic) since 1995. Additionally, in 2011, the Congressional Supplemental Sampling Program (CSSP) was conducted, where high levels of standardized bottom longline survey effort were maintained from April through October. Data from the MSLABS Bottom Longline Survey and the CSSP Survey were used to produce a relative abundance index for scalloped hammerhead (*Sphyrna lewini*) and great hammerhead (*Sphyrna mokarran*). One abundance index was calculated for great hammerhead that included data from both the GOM and Atlantic. Three abundance indices were calculated for scalloped hammerhead, with one covering both the GOM and Atlantic, and with the other two covering the GOM and Atlantic separately. The CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution (Lo et al. 1992).

Decision: The Group determined that because this series is stock wide and used in previous stock assessments for sharks, the series should be retained for use in the stock assessment. The recommendation is for use in the stock wide great hammerhead stock assessment base run (Table 10).

SEAMAP Bottom Longline Survey (SEDAR77-DW25)

A combined index of great hammerhead abundance from scientific survey bottom longline (BLL) surveys conducted in coastal waters of the northern Gulf of Mexico was generated using Southeast Area Monitoring and Assessment Program (SEAMAP) BLL (AL-TX, 2008-2019) and Dauphin Island Sea Lab BLL (2006-2019) data. Both BLL surveys used the same gear, bait, and identical deployment protocols. Due to a change in survey design of the SEAMAP BLL survey, which started sampling exclusively in waters between 3-10m in 2015 to complement the NMFS bottom longline survey and the fact that the majority of the great hammerhead sharks were caught in shallow waters (<15m), the datasets were truncated to include only stations that occurred in less than 15 m of water. The index extends from 2006 to 2019, and resulted in 85 great hammerheads captured during 1,279 BLL sets. Standardized catch rates were estimated using a delta-lognormal modeling method. Nominal and standardized great hammerhead catch rates remained relatively stable throughout the survey period.

Decision: The Group recommended that this series be retained for use in the assessment. It was noted that the time series represents sampling with the spatial distribution of great hammerhead where there are few indices. The recommendation is for use in the stock wide great hammerhead stock assessment base run (Table 9).

4.3.3 Summary-Great Hammerhead

The geographic coverage of the abundance indices for great hammerhead shark are in Figure 12 and plots of the relative indices (index/mean index of the time series) by year are in Figures 13. The Indices Working Group recommends compiling indices for use in stock assessment consistent with great hammerhead Stock ID Workshop recommendations:

1. Compile indices for a base model from the recommended great hammerhead stock assessment indices as follows:

    a. Include each recommended stock wide Age 1+ index (Table 10) within the base model.

4.4 Review Of Indices –Smooth Hammerhead

During the initial webinars for SEDAR77, data sources were preliminary examined in terms of their usefulness in developing an index of abundance for smooth hammerhead. Two data sources were identified; the pelagic longline observer program and the personal logbooks of a recreational charter Captain, Mark Sampson, which are being archived in a database at Maryland Department of Natural Resources. While data from the pelagic longline observer program was previously analyzed in Jiao et al. (2011), the initial analysis noted a very low proportion positive (<1%) and many years with no (0) catches of smooth hammerhead. Therefore, the data were deemed not to be useful for describing the abundance of smooth hammerhead. The initial examination of the data provided by Maryland Department of Natural Resources was incomplete due to issues related to COVID. The data that were provided had covariates with multiply levels (e.g trip type had over 70 levels) that would be difficult to refine without considerable work. While the data series has great promise, it will require much more time and resources to understand the data. It was suggested this data source be examined in the future as a potential thesis project for a student.

4.5 Review Of Indices –Carolina Hammerhead

During the initial webinars for SEDAR77, it was determined that without genetic verification it would not be possible to separate catches of Carolina hammerhead from scalloped hammerhead when trying to derive indices of abundance. Therefore, no indices are currently available for Carolina hammerhead.

4.6 Research Recommendations

1. During the assessment process, explore the utility of combining multiple indices into one scalloped hammerhead index using the Bayesian hierarchical model (Conn, 2009) or Dynamic Factor Analysis (Peterson et al., 2017). The data series that could potentially be combined as a recruitment index are Texas Parks and Wildlife gillnet series, Gulfspan gillnet series, South Carolina Coastspan Gillnet Long and Short Series and the Coastspan Longline Series.

2. Examine the utility of spatiotemporal modelling as a way to improve the indices of abundance for the NEFSC longline survey.

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4.8 Tables

Table 1. Data sources initially examined as potential indices of abundance for hammerhead sharks. Area(s)=the area the data source covered following recommendations from the stock identification process for all hammerheads.

Data source	Area(s)	Hammerhead Species Considered	Further develop as an index	Factors for not developing as an index
Shark bottom longline observer program and shark research fishery	All	Scalloped/Great	Yes	
Southeast gillnet observer program	All	Scalloped	Yes	
	Gulf of Mexico	Scalloped	No	Low catches
	Atlantic	Scalloped	Yes	
	All	Great	No	Low catches
Pelagic longline observer program	All	Scalloped	Yes	
	All	Smooth	No	Low proportion positive, No catches in many years
SEFSC Bottom Longline Survey	All	Great/Scalloped	Yes	
Texas Parks and Wildlife Gillnet	All/Gulf of Mexico	Scalloped	Yes	
Everglades National Park Creel Census	Gulf of Mexico	Scalloped	No	Low catches, species identification
Mote Marine Laboratory Longline	Gulf of Mexico	Great/Scalloped	No	Low catches
Mote Drumline Survey	Gulf of Mexico	Great	No	Low catches

Table 1 Continued: Data sources initially examined as potential indices of abundance for hammerhead sharks. Area(s)=the area the data source covered following recommendations from the stock identification process for all hammerheads.

Dauphin Island Sea Laboratory Longline Survey	All/Gulf of Mexico	Scalloped	Yes	
GULFSPAN Gillnet Series	All/Gulf of Mexico			
NMFS-Panama City		Scalloped	Yes	
Mote Marine Laboratory		Great/Scalloped	No	Low catches; Limited temporally
Havenworth Consulting		Scalloped	No	Low catches; Limited temporally
Florida State University		Scalloped	No	Low catches
New College		Scalloped	No	Low catches; Limited temporally
Gulf Coast Research Laboratory		Scalloped	Yes	
Virginia Institute of Marine Science Longline	Atlantic	Scalloped	No	Low catches
SEAMAP Coastal Bottom Longline	Gulf of Mexico	Scalloped	No	Low catches/Survey(s) already present in the area
	All	Great	Yes	
SEAMAP Trawl	Atlantic	Scalloped	No	Low catches
Florida State University Longline Sawfish	All/Gulf of Mexico	Great/Scalloped	Yes	
Mark Sampson Logbook Recreational Series	Atlantic	Scalloped/Smooth	No	Database not complete
Rosenstiel School of Marine and Atmospheric Science Drumline	All	Great	Yes	

Table 1 Continued: Data sources initially examined as potential indices of abundance for hammerhead sharks. Area(s)=the area the data source covered following recommendations from the stock identification process for all hammerheads.

Electronic Monitoring of Gulf of Mexico reeffish fishery	Gulf of Mexico	Scalloped	No	Data was preliminary
NEFSC-Bottom Longline Survey	All/Atlantic	Scalloped	Yes	
		Great	No	Low catches
South Carolina SEAMAP longline	Atlantic	Scalloped	No	Low proportion positive, No catches in many years
COASTSPAN Series				
Bottom Longline	All/Atlantic	Scalloped	Yes	
South Carolina Large Gillnet	All/Atlantic	Scalloped	Yes	
South Carolina Small Gillnet	All/Atlantic	Scalloped	Yes	
South Carolina Red Drum Survey	Atlantic	Scalloped	No	Low proportion positive, No catches in many years
University North Carolina Longline	All/Atlantic	Scalloped	Yes	
GA Seamap Longline	Atlantic	Scalloped	No	Low proportion positive, No catches in many years
NEFSC Observer Gillnet	Atlantic	Smooth	No	Low catches

Table 2. Elements used to evaluate the adequacy and retention of CPUE series as an input to the stock assessment model.

ELEMENT	DESCRIPTION	ACTIONS AND REASONING
1	Diagnostics	Apply defendable model validations (i.e., Q-Q plots, residuals, etc.) and consider overdispersion
2	Appropriateness of data exclusions and classifications (e.g., to identify targeted trips).	How were trips identified and was this a shark directed survey
3	Geographical coverage	How does the series compare with the range of the stock (i.e. Miami , FL to Long Island, NY)
4	Catch fraction	Change to mean proportion positives through time series
5	Length of time series relative to the history of exploitation.	The length of catch series for assessment is 1981-2018. For inclusion, survey must be established for minimum of 10 years but consideration will be given to shorter time series if they satisfy other important criteria
6	Are other indices available for the same time period?	Evaluate and pick best survey or combine them at the data level (if methods are similar)
7	Does the index standardization account for known factors that influence catchability/selectivity?	Is there an attempt to account for catchability and are the appropriate factors being considered
8	Are there conflicts between the catch history and the CPUE response?	Does the trend follow the expected performance based on management
9	Is the interannual variability outside biologically plausible bounds	Look at interannual variability: Is the trend of increase biologically plausible?
10	Are biologically implausible interannual deviations severe?	Covariates appropriate or accurate, change in design or stations appropriate
11	Assessment of data quality and adequacy of data for standardization purposes (e.g., sampling design, sample size, factors considered)	Are the covariates appropriate that were used in standardizing the data?
12	Is this CPUE time series continuous?	If not continuous, were there big changes in survey?
13	Characterization of Index uncertainty	Method of characterization (e.g., bootstrap, delta method), magnitude of uncertainty (e.g., CV)

Table 3. Scalloped hammerhead indices recommended by the Indices Working Group, including the corresponding SEDAR document number, the area covered, age class sampled and index type (fishery dependent or scientific survey).

Index Name	SEDAR Document Number	Area(s)	Age Class	Index Type	Base/Sensitivity
Pelagic Longline Observer Program	SEDAR77-DW08	All/Atlantic	Age 1+	Fishery Dependent	Base/Sensitivity
SEFSC Shark Bottom Longline Observer Program	SEDAR77-DW12	All/Atlantic/Gulf of Mexico	Age 1+	Fishery Dependent	Base/Sensitivity/Sensitivity
Florida State University Longline Survey	SEDAR77-DW14	All/Gulf of Mexico	Age 1+	Scientific Survey	Base/Sensitivity
Gulfspan Gillnet Survey	SEDAR77-DW17	All/Gulf of Mexico	Age 0	Scientific Survey	Base/Sensitivity
Texas Parks and Wildlife Gillnet Survey	SEDAR77-DW16	All/Gulf of Mexico	Age 0	Scientific Survey	Base/Sensitivity
SEFSC Bottom Longline Survey	SEDAR77-DW24	All/Atlantic/Gulf of Mexico	Age 1+	Scientific Survey	Base/Sensitivity/Sensitivity
COASTSPAN Longline	SEDAR77-DW30	All/Atlantic	Age 0	Scientific Survey	Base/Sensitivity
SC COASTSPAN Long and Short Gillnet Survey	SEDAR77-DW31 and 32	All/Atlantic	Age 0	Scientific Survey	Base/Sensitivity
SEFSC Southeast Gillnet Observer Program	SEDAR77-DW13	All/Atlantic	Age 1+	Fishery Dependent	Sensitivity/Sensitivity
Dauphin Island Sea Laboratory Longline Survey	SEDAR77-DW06	Gulf of Mexico	Age 1+	Scientific Survey	Sensitivity
University of North Carolina Longline Survey	SEDAR77-DW33	All/Atlantic	Age 1+	Scientific Survey	Sensitivity/Sensitivity

Table 4. Great hammerhead indices recommended by the Indices Working Group, including the corresponding SEDAR document number, the area covered, age class sampled and index type (fishery dependent or scientific survey).

Index Name	SEDAR Document Number	Area(s)	Age Class	Index Type	Base/Sensitivity
SEFSC Shark Bottom Longline Observer Program	SEDAR77-DW12	All/	Age 1+	Fishery Dependent	Base
Florida State University Longline Survey	SEDAR77-DW14	All	Age 1+	Scientific Survey	Base
SEAMAP Bottom Longline Survey	SEDAR77-DW25	All	Age 1+	Scientific Survey	Base
Rosenstiel School of Marine and Atmospheric Science Drumline	SEDAR77-DW15	All/	Age 1+	Scientific Survey	Base
SEFSC Bottom Longline Survey	SEDAR77-DW24	All	Age 1+	Scientific Survey	Base

Table 5. Recommended base stock wide indices of abundance for Age 1+ scalloped hammerhead including index name, the value of catch per unit effort, and SEDAR document number. CV is the coefficient of variation for the annual index value. Missing values in a given year correspond to zero catches (index value of 0 and no CV), where no sampling occurred (ns), or when the model did not converge (nc).

	Pelagic Longline SEDAR77-DW08 sharks per 1000 hooks		Shark Bottom Longline SEDAR77-DW12 sharks per 10000 hooks		Shark Research Fishery SEDAR77-DW12 sharks per 10000 hooks		FSU Longline SEDAR77-DW14 sharks per 100 hook hour		SEFSC MS Bottom Longline SEDAR77-DW24 number sharks per hook-hour	
year	index	CV	index	CV	index	CV	index	CV	index	CV
1992	0.174	0.741								
1993	0.062	0.565								
1994	0.045	0.645	5.867	0.430						
1995	0.039	0.629	8.990	0.419					0.081	0.337
1996	0.014	1.231	9.030	0.398					0.052	0.438
1997	0.070	0.729	9.015	0.503					0.063	0.310
1998	0.077	0.880	12.811	0.452					ns	
1999	0.018	1.066	3.266	0.714					0.050	0.339
2000	0.017	0.772	0.281	1.596					0.071	0.247
2001	0.052	0.807	12.125	0.447					0.115	0.219
2002	0.017	1.319	16.468	0.390					0.093	0.177
2003	0.038	0.785	20.271	0.343					0.154	0.209
2004	0.035	0.772	16.563	0.378					0.056	0.312
2005	0.040	0.642	6.975	0.509					0.112	0.475
2006	0.050	0.777	25.205	0.405					0.060	0.358
2007	0.049	0.591	15.530	0.562					0.088	0.327
2008	0.073	0.497			4.129	0.773			0.095	0.372
2009	0.101	0.449			65.590	0.331			0.129	0.268
2010	0.084	0.488			46.926	0.328			0.142	0.242
2011	0.054	0.481			58.507	0.325	0.003	0.333	0.066	0.269
2012	0.101	0.471			90.500	0.374	ns		0.060	0.358
2013	0.046	0.458			53.035	0.396	ns		0.061	0.312
2014	0.038	0.551			68.047	0.358	0.001	1.147	0.079	0.337
2015	0.039	0.516			99.944	0.371	0.006	0.468	0.157	0.219
2016	0.041	0.521			68.444	0.360	0.004	0.777	0.094	0.295
2017	0.073	0.523			89.840	0.361	0.009	0.271	0.126	0.243
2018	0.033	0.688			42.589	0.395	0.003	0.656	0.094	0.275
2019	0.015	0.918			44.341	0.387	0.002	0.796	0.118	0.294

Table 6. Recommended indices of abundance for the Atlantic Ocean region of Age 1+ scalloped hammerhead sensitivity analysis including index name, the value of catch per unit effort and SEDAR document number. CV is the coefficient of variation for the annual index value. Missing values in a given year correspond to zero catches (index value of 0 and no CV), where no sampling occurred (ns), or when the model did not converge (nc).

	Pelagic Longline		Shark Bottom Longline		Shark Research Fishery		SEFSC MS Bottom Longline	
	SEDAR77-DW08		SEDAR77-DW12		SEDAR77-DW12		SEDAR77-DW24	
	sharks per 1000 hooks		sharks per 10000 hooks		sharks per 10000 hooks		number sharks per hook-hour	
year	index	CV	index	CV	index	CV	index	CV
1992	0.232	0.571						
1993	0.100	0.459						
1994	0.087	0.517	9.514	0.350				
1995	0.085	0.486	11.957	0.351			0.068	0.624
1996	0.022	0.842	12.727	0.330			0.034	1.108
1997	0.145	0.538	6.067	0.553			ns	
1998	0.130	0.608	17.577	0.308			ns	
1999	0.038	0.761	5.929	0.744			ns	
2000	0.059	0.553	0.229	1.482			0.016	0.781
2001	0.122	0.596	16.904	0.377			ns	
2002	0.041	0.884	17.461	0.366			0.074	0.310
2003	0.069	0.632	12.811	0.333			ns	
2004	0.068	0.617	7.867	0.421			ns	
2005	0.116	0.530	11.620	0.674			0.031	1.104
2006	0.122	0.594	63.093	0.375			0.105	0.646
2007	0.189	0.492	21.511	0.593			ns	
2008	0.095	0.543			0.000		0.149	0.527
2009	0.174	0.456			63.443	0.427	0.194	0.623
2010	0.144	0.406			46.747	0.255	0.229	0.408
2011	0.097	0.462			37.435	0.271	0.135	0.492
2012	0.201	0.437			91.472	0.304	0.064	0.783
2013	0.025	0.578			64.498	0.438	0.100	0.636
2014	0.047	0.513			53.727	0.287	0.060	0.665
2015	0.097	0.432			63.541	0.348	0.236	0.370
2016	0.092	0.432			56.871	0.315	0.036	0.777
2017	0.152	0.402			40.475	0.368	0.091	0.549
2018	0.070	0.536			41.877	0.368	0.055	0.642
2019	0.035	0.658			22.889	0.504	0.120	0.552

Table 7. Recommended indices of abundance for the Gulf of Mexico region of Age 1+ scalloped hammerhead sensitivity analysis including index name, the value of catch per unit effort and SEDAR document number. Missing values in a given year correspond to zero catches (index value of 0 and no CV), where no sampling occurred (ns), or when the model did not converge (nc).

	Shark Bottom Longline Observer		Shark Research Fishery		FSU Longline		SEFSC MS Bottom Longline	
	SEDAR77-DW12		SEDAR77-DW12		SEDAR77-DW14		SEDAR77-DW24	
	sharks per 10000 hooks		sharks per 10000 hooks		sharks per 100 hook hour		number sharks per hook-hour	
year	index	CV	index	CV	index	CV	index	CV
1994	0.727	1.100						
1995	4.445	0.801					0.090	0.402
1996	6.603	0.621					0.057	0.476
1997	23.542	0.632					0.086	0.306
1998	6.604	0.665					ns	
1999	0.399	1.511					0.048	0.332
2000	ns						0.111	0.259
2001	11.066	0.628					0.109	0.211
2002	14.561	0.459					0.080	0.241
2003	24.324	0.353					0.147	0.200
2004	24.302	0.344					0.062	0.307
2005	3.808	0.642					0.145	0.525
2006	6.982	0.774					0.042	0.435
2007	19.646	0.796					0.084	0.319
2008			11.196	0.878			0.082	0.522
2009			84.325	0.260			0.095	0.305
2010			41.180	0.339			0.110	0.302
2011			50.887	0.311	0.003	0.333	0.047	0.320
2012			64.255	0.544	ns		0.055	0.402
2013			67.233	0.397	ns		0.050	0.356
2014			61.826	0.556	0.001	1.147	0.070	0.400
2015			216.816	0.366	0.006	0.468	0.131	0.271
2016			78.541	0.452	0.004	0.777	0.111	0.317
2017			260.287	0.321	0.009	0.271	0.120	0.281
2018			31.181	0.472	0.003	0.656	0.099	0.305
2019			71.195	0.352	0.002	0.796	0.109	0.350

Table 8. Additional recommended indices of abundance for Age 1+ scalloped hammerhead sensitivity analysis including index name, the value of catch per unit effort, the area sampled and SEDAR document number (See Table 3 for the regions recommended for sensitivity analysis with each index). Missing values in a given year correspond to zero catches (index value of 0 and no CV), where no sampling occurred (ns), or when the model did not converge (nc).

	Dauphin Island Sea Lab		Southeast Gillnet Observer		Univ North Carolina		Southeast Gillnet	
	SEDAR77-DW-06		SEDAR77-DW13		SEDAR77-DW-33		SEDAR77-DW13	
	Gulf of Mexico		Stock wide		Stockwide/Atlantic		Atlantic	
	shark 100 hook/hour		sharks/(net length*net depth*soak time/10000000))		shark per hook		sharks/(net length*net depth*soak time/10000000))	
year	**index**	**CV**	**index**	**CV**	**index**	**CV**	**index**	**CV**
1981					0.008	0.350		
1982					0.005	0.286		
1983					0.007	0.246		
1984					0.007	0.299		
1985					0.001	0.447		
1986					0.006	0.307		
1987					0.005	0.339		
1988					0.007	0.301		
1989					0.001	0.735		
1990					0.000	1.045		
1991					0.000	1.042		
1992					0.000	1.042		
1993					0.002	0.576		
1994					0.001	1.038		
1995					0.000			
1996					0.001	1.051		
1997					0.000	1.087		
1998			28.901	1.149	0.001	0.736	17.261	1.235
1999			3.901	0.806	0.005	0.725	3.358	0.779
2000			24.642	0.718	0.002	0.581	13.957	0.758
2001			6.986	0.714	0.001	1.054	10.132	0.680
2002			6.308	0.765	0.001	0.739	7.090	0.771
2003			3.667	0.917	0.001	1.042	4.840	0.877
2004			23.651	0.723	0.001	1.043	27.603	0.670
2005			22.095	0.575	0.002	0.760	31.277	0.552
2006	0.127	0.531	37.384	0.596	0.006	0.399	36.875	0.608
2007	0.068	0.515	11.077	0.922	0.006	0.385	7.145	0.901
2008	0.103	0.387	11.252	0.695	0.003	0.730	19.188	0.696
2009	nc		18.625	0.662	0.000		26.397	0.604
2010	0.047	1.038	18.804	0.829	0.001	1.043	21.259	0.834
2011	0.073	0.474	23.339	0.808	0.005	0.367	29.713	0.739
2012	0.175	0.458	27.013	0.682	0.002	1.049	22.212	0.618
2013	0.480	0.495	41.607	0.798	0.009	0.358	50.386	0.770
2014	0.097	0.322	25.509	1.037	0.001	1.039	42.718	0.976
2015	0.090	0.310	18.620	0.968	0.004	0.576	13.233	0.900
2016	0.118	0.284	21.464	0.877	0.002	0.755	25.716	0.805
2017	0.104	0.308	0.702	1.450	0.004	0.710	0.462	1.928
2018	0.204	0.271	124.260	0.775	0.003	0.575	83.657	0.781
2019	0.040	0.430	54.626	0.822	0.006	0.479	33.383	0.885

Table 9. Recommended base indices of abundance for the Age 0 scalloped hammerhead including index name, the value of catch per unit effort, the area sampled and SEDAR document number (See Table 3 for the regions recommended for base model and sensitivity analysis with each index). CV is the coefficient of variation for the annual index value. Missing values in a given year correspond to zero catches (index value of 0 and no CV), where no sampling occurred (ns), or when the model did not converge (nc).

	TXPWD-Gillnet		GULFSPAN		COASTSPAN - LL		SCCOASTGN - LONG		SCCOASTGN - SHORT	
	SEDAR77 DW-16		SEDAR77 DW-17		SEDAR77-DW-30		SEDAR77-DW-31		SEDAR77 DW-32	
	Stockwide/Gulf of Mexico		Stockwide/Gulf of Mexico		Stockwide/Atlantic		Stockwide/Atlantic		Stockwide/Atlantic	
	sharks per net per hour		sharks per net per hour		sharks per 100 hook hours		sharks per net hour		sharks per net hour	
year	index	CV	index	CV	index	CV	index	CV	index	CV
1982	0.00033									
1983	0.00042	0.912								
1984	0.00000									
1985	0.00015									
1986	0.00035	0.732								
1987	0.00000									
1988	0.00050	0.618								
1989	0.00012									
1990	0.00090	0.603								
1991	0.00053	0.749								
1992	0.00000									
1993	0.00032	0.819								
1994	0.00027	0.848								
1995	0.00010	1.165								
1996	0.00093	0.536	0.009	0.294						
1997	0.00172	0.666	0.016	0.461						
1998	0.00031	0.842	0.002	0.548						
1999	0.00021	0.781	0.091	0.312						
2000	0.00048	0.589	0.156	0.253						
2001	0.00150	0.603	0.148	0.302			1.250	0.479		
2002	0.00033	0.822	0.15	0.166			0.788	0.518		
2003	0.00183	0.577	0.102	0.181			2.742	0.450		
2004	0.00075	0.689	0.07	0.227			0.541	1.432		
2005	0.00254	0.517	0.048	0.373	5.464	0.529	0.625	0.538		
2006	0.00069	0.630	0.079	0.22	8.119	0.416	0.981	1.018		
2007	0.00079	0.778	0.168	0.171	1.976	1.128	1.952	0.533	0.171	0.423
2008	0.00075	0.703	0.172	0.189	1.730	1.165	1.384	0.707	0.286	0.581
2009	0.00095	0.560	0.163	0.2	3.482	0.654	7.298	1.383	0.000	
2010	0.00213	0.598	0.208	0.211	9.376	0.327	2.297	0.854	0.114	0.581
2011	0.00091	0.563	0.159	0.201	3.876	0.372	1.487	0.540	0.113	0.307
2012	0.00124	0.540	0.093	0.217	1.907	0.469	8.180	0.527	0.116	0.307
2013	0.00484	0.428	0.129	0.215	2.052	0.427	4.058	0.451	0.090	0.423
2014	0.00198	0.477	0.141	0.207	2.443	0.548	2.204	0.695	0.000	
2015	0.00283	0.565	0.068	0.252	1.158	0.554	0.969	0.616	0.020	0.581
2016	0.00191	0.590	0.124	0.235	1.899	0.419	1.675	0.538	0.098	0.351
2017	0.00041	0.775	0.184	0.2	1.123	0.519	6.808	0.341	0.000	
2018	0.00482	0.499	0.21	0.225	0.738	0.565	3.725	0.547	0.000	
2019	0.00248	0.514	0.176	0.265	1.029	1.175	3.305	0.423	0.021	0.581

Table 10. Recommended base stock wide indices of abundance for great hammerhead shark including index name and SEDAR document number CV is the coefficient of variation for the annual index value. Missing values in a given year correspond to zero catches (index value of 0 and no CV), where no sampling occurred (ns), or when the model did not converge (nc).

	Shark Bottom Longline		Shark Research		FSU Longline		RSMAS Drumline		SEFSC MS Bottom Longline		SEAMAP BLL survey	
	SEDAR77-DW12		SEDAR77-DW12		SEDAR77-DW14		SEDAR77-DW15		SEDAR77-DW24		SEDAR77-DW25	
	sharks per 10000 hooks		sharks per 10000 hooks		sharks per 100 hook hour		number of sharks per 10 drumlines per hour		number sharks per hook-hour		number sharks per hook-hour	
year	index	CV	index	CV	index	CV	index	CV	index	CV	index	CV
1994	1.071	0.478										
1995	5.908	0.206							0.016	0.518		
1996	6.749	0.229							0.018	0.556		
1997	9.424	0.303							0.007	0.497		
1998	10.140	0.246							ns			
1999	7.511	0.270							0.002	1.081		
2000	3.207	0.473							0.002	0.784		
2001	3.674	0.371							0.009	0.482		
2002	11.726	0.212							0.003	0.648		
2003	9.966	0.207							0.012	0.454		
2004	7.873	0.226							0.009	0.486		
2005	6.425	0.293							0.004	1.074		
2006	5.261	0.300							0.006	0.650	0.013	1.062
2007	9.718	0.272							0.006	0.782	0.045	0.525
2008			40.370	0.226					0.008	0.655	0.109	0.344
2009			29.215	0.244			0.027	0.707	0.011	0.519	0.039	0.728
2010			18.072	0.221			0.055	0.297	0.021	0.477	0.050	0.716
2011			26.748	0.190	0.001	0.291	0.053	0.265	0.004	0.648	0.000	.
2012			43.110	0.308	ns		0.036	0.317	0.017	0.479	0.064	0.532
2013			52.307	0.199	0.001	0.734	0.039	0.268	0.006	0.651	0.142	0.456
2014			40.176	0.218	0.002	0.729	0.053	0.241	0.012	0.650	0.173	0.323
2015			57.252	0.174	0.002	0.598	0.048	0.255	0.011	0.489	0.051	0.421
2016			26.352	0.294	0.003	0.296	0.074	0.194	0.014	0.485	0.089	0.335
2017			47.025	0.193	0.004	0.293	0.055	0.180	0.023	0.414	0.081	0.451
2018			26.739	0.250	0.003	0.302	0.053	0.197	0.020	0.416	0.043	0.521
2019			43.489	0.220	0.002	0.519	0.053	0.184	0.036	0.372	0.088	0.449

4.9 Figures

Figure 1. Flowchart developed by ICCAT and used as a method to evaluate indices of abundance as an input to the stock assessment model

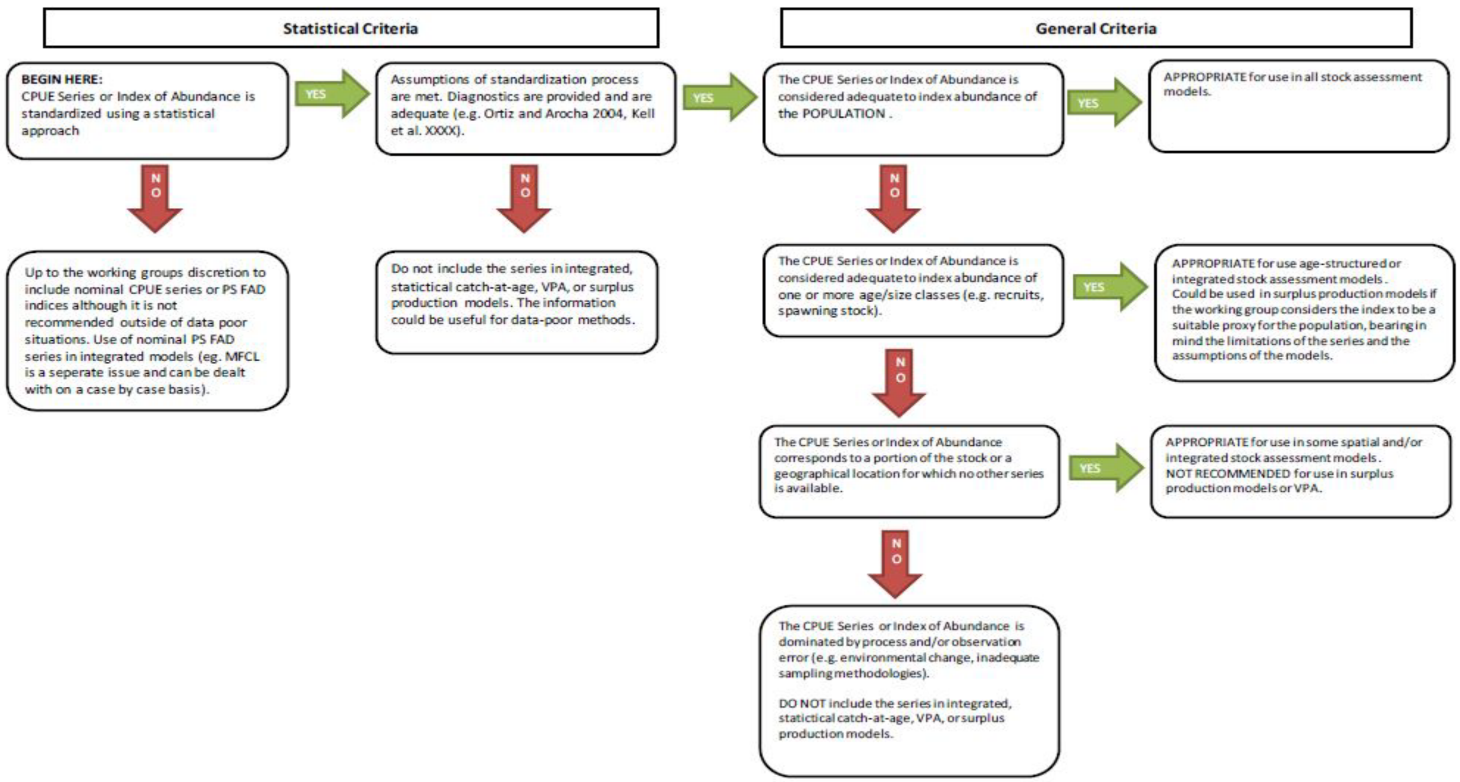


Figure 2. Approximate linear coverage of the stock wide base abundance indices for the Age 1+ scalloped hammerhead shark. Colors of the labeled abundance series correspond to the linear coverage.

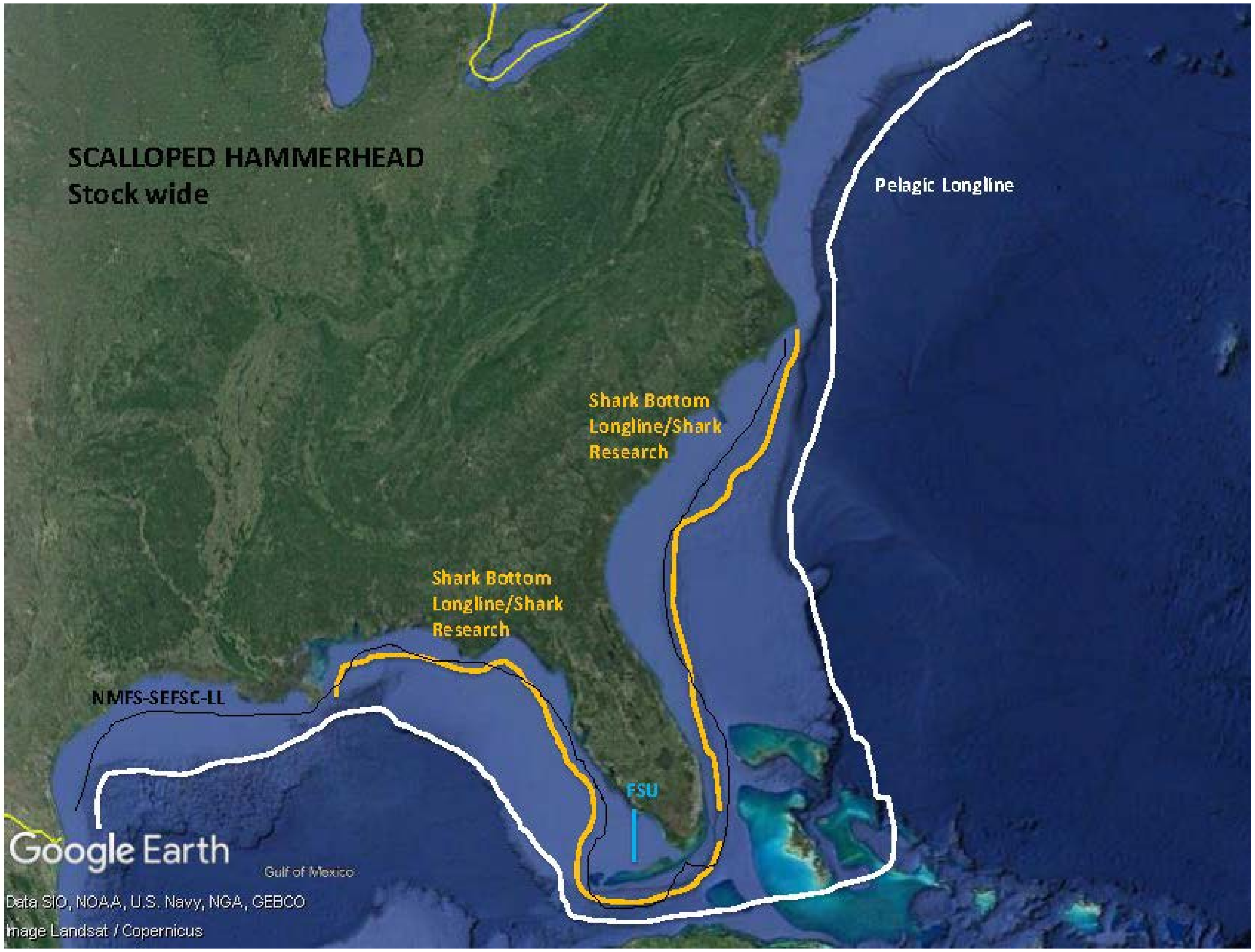


Figure 3. Approximate linear coverage of the Atlantic Ocean base abundance indices for the Age 1+ scalloped hammerhead shark**.** Colors of the labeled abundance series correspond to the linear coverage.

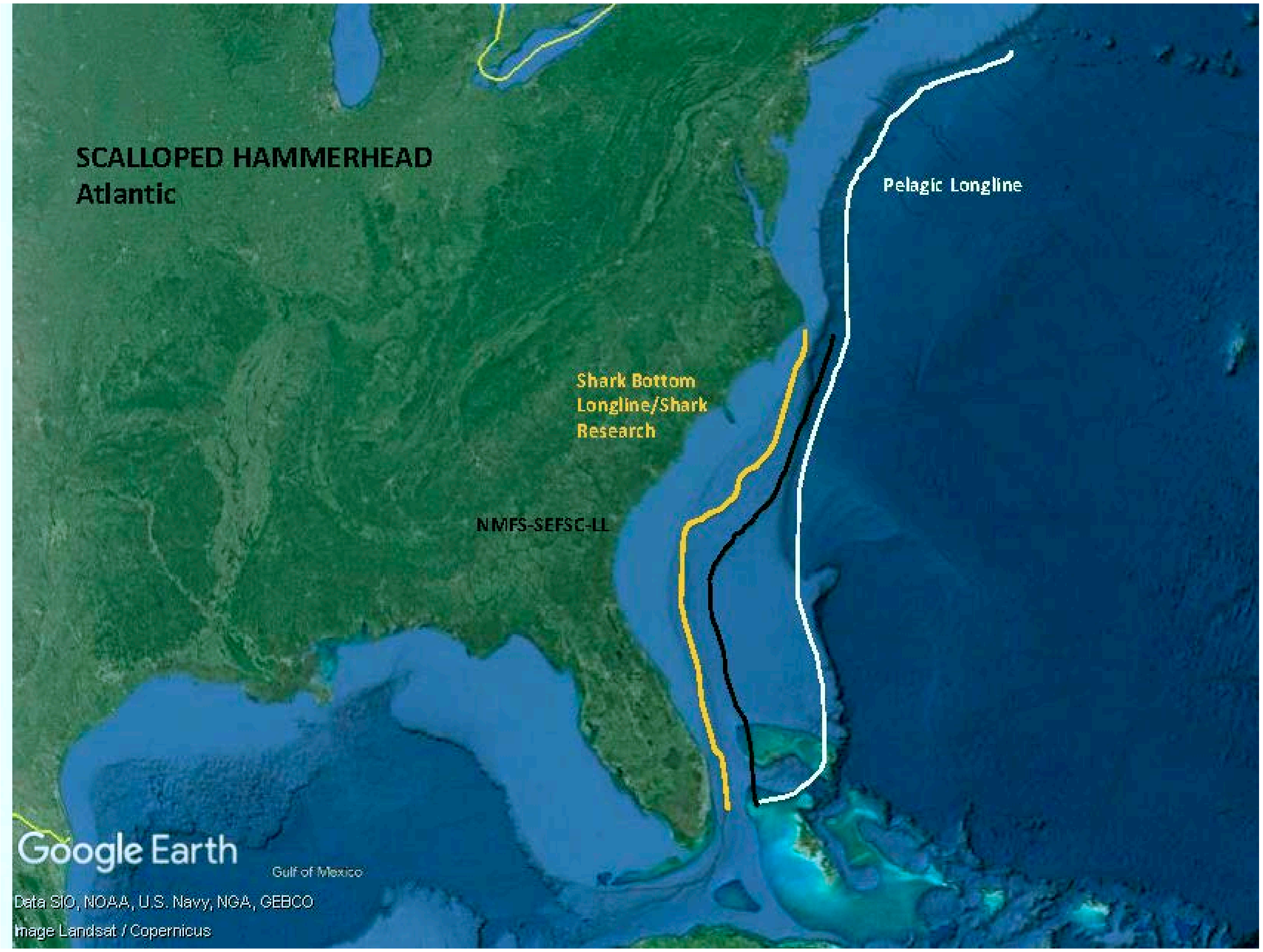


Figure 4. Approximate linear coverage of the Gulf of Mexico base abundance indices for the Age 1+ scalloped hammerhead shark. Colors of the labeled abundance series correspond to the linear coverage.

Figure 5. Approximate linear coverage of the sensitivity abundance indices for the Age 1+ scalloped hammerhead shark. Colors of the labeled abundance series correspond to the linear coverage.

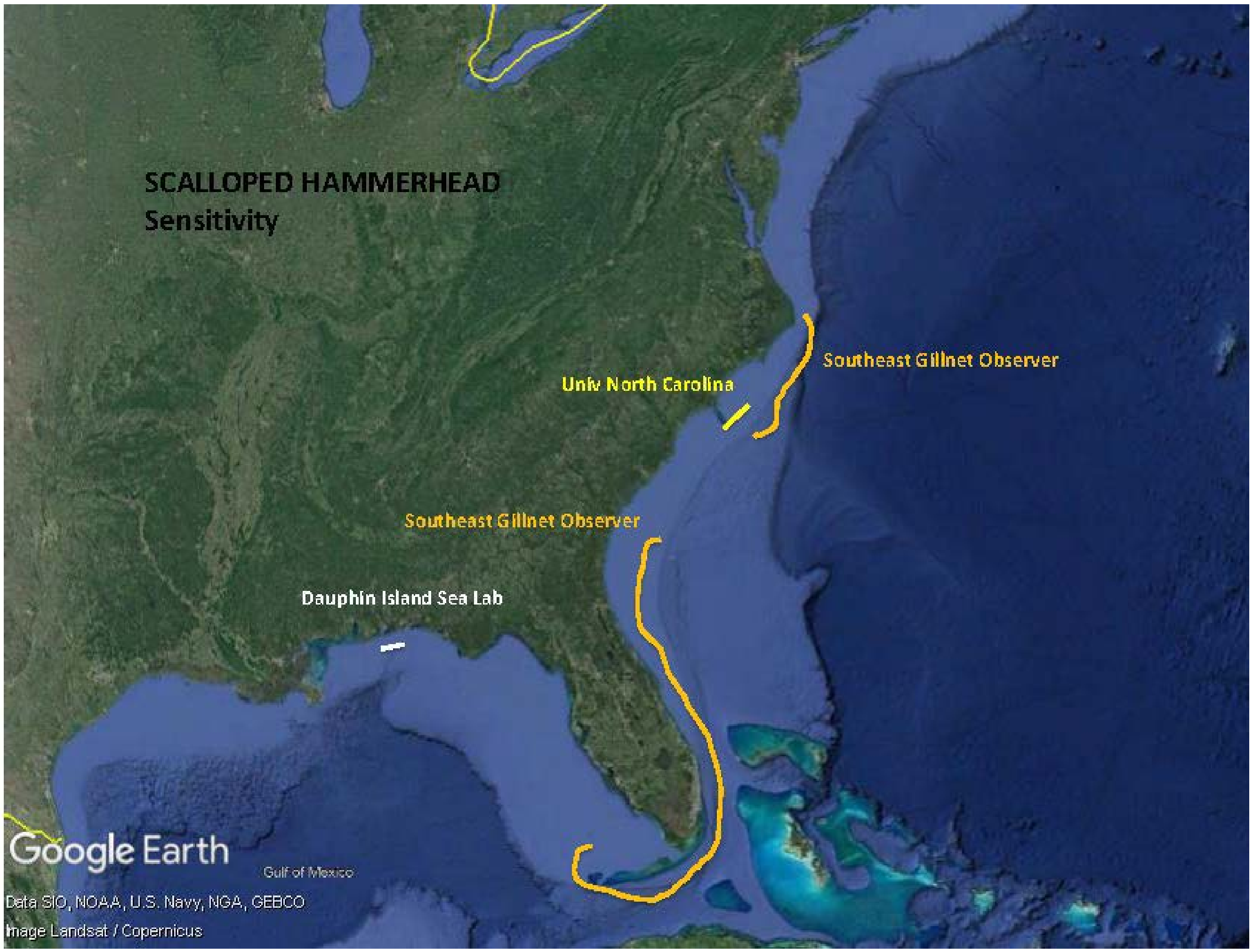


Figure 6. Approximate linear coverage of the recruitment (Age 0) abundance indices for the scalloped hammerhead shark. Colors of the labeled abundance series correspond to the linear coverage.

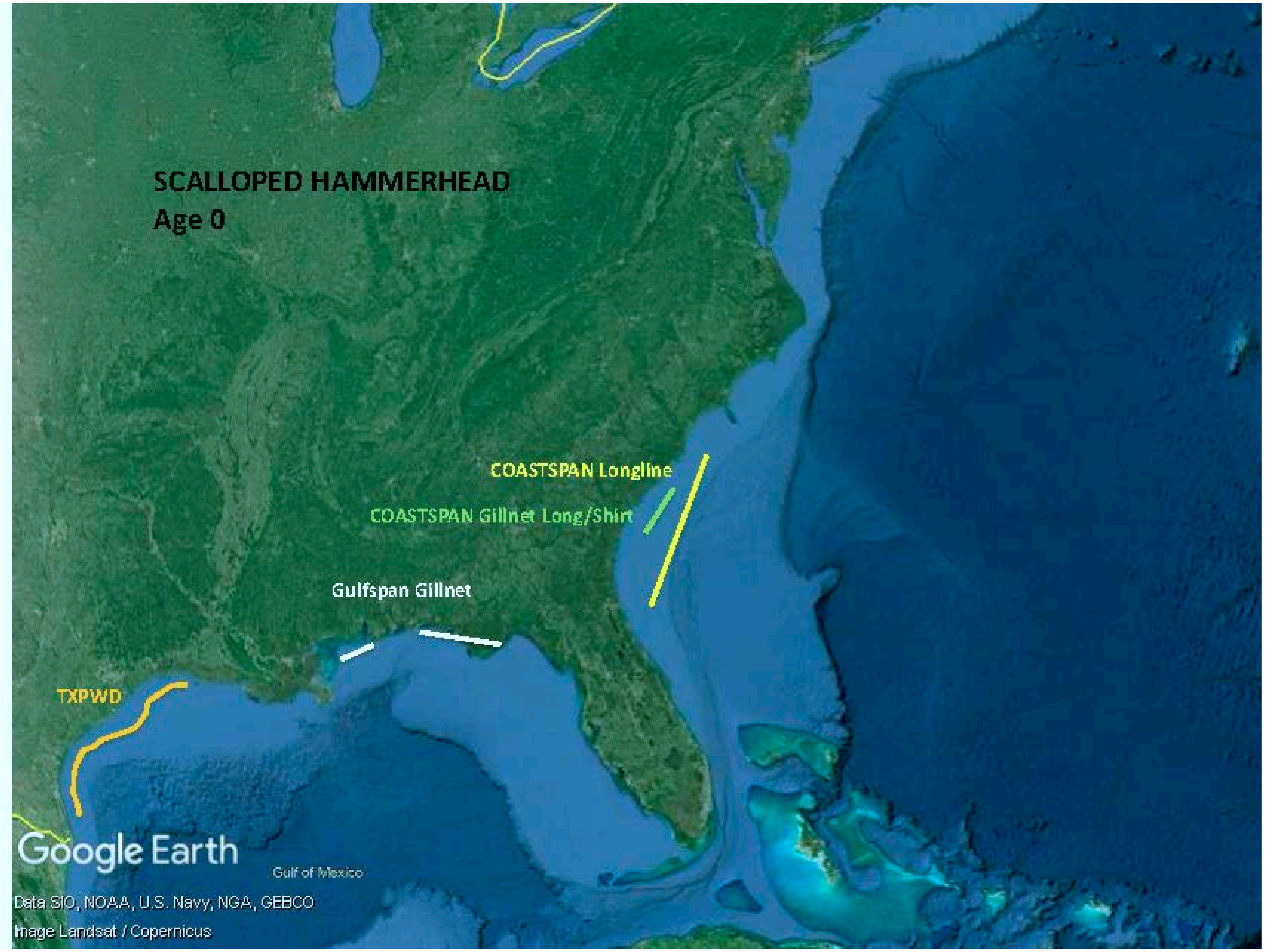


Figure 7. Plot of mean annual values of relative abundance for each stock wide base time series recommended for the Age 1+ scalloped hammerhead shark base run by the Indices Working Group. For each index, values were converted to a common scale for plotting purposes by dividing mean annual values for a time series by the average of all mean annual values for that specific time series.

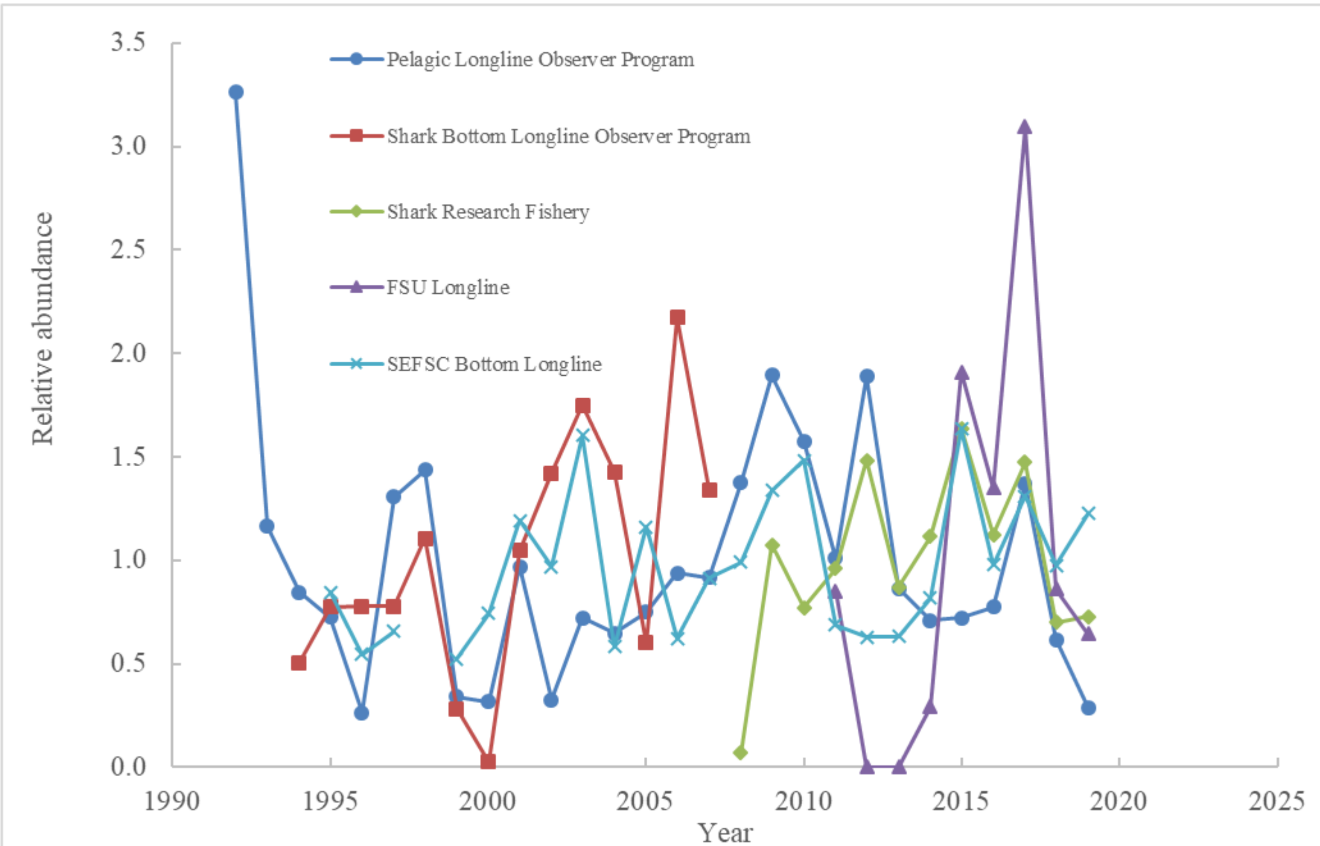


Figure 8. Plot of mean annual values of relative abundance for each Atlantic Ocean base time series recommended for the Age 1+ scalloped hammerhead shark base run by the Indices Working Group. For each index, values were converted to a common scale for plotting purposes by dividing mean annual values for a time series by the average of all mean annual values for that specific time series.

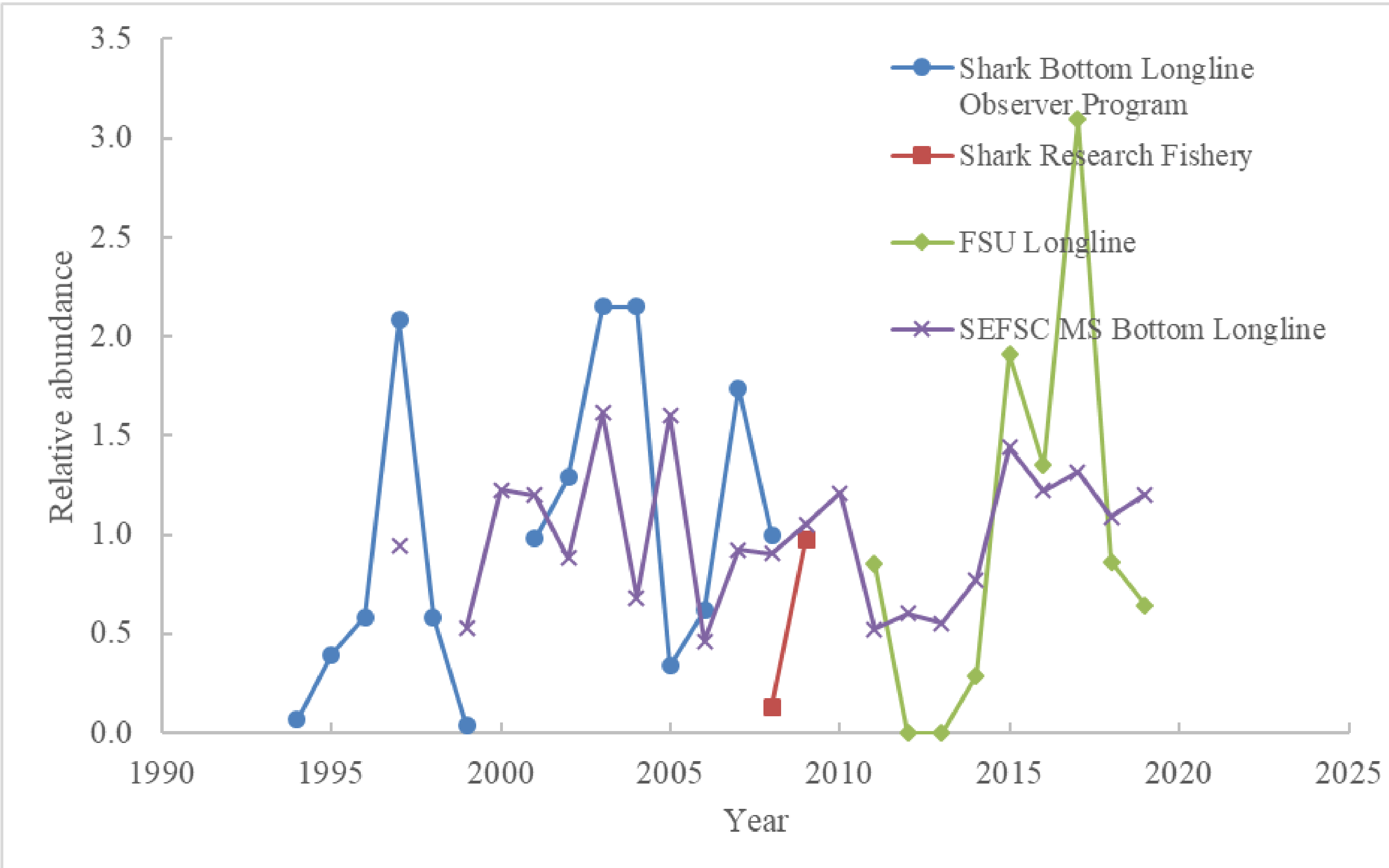


Figure 9. Plot of mean annual values of relative abundance for each Gulf of Mexico base time series recommended for the Age 1+ scalloped hammerhead shark base run by the Indices Working Group. For each index, values were converted to a common scale for plotting purposes by dividing mean annual values for a time series by the average of all mean annual values for that specific time series.

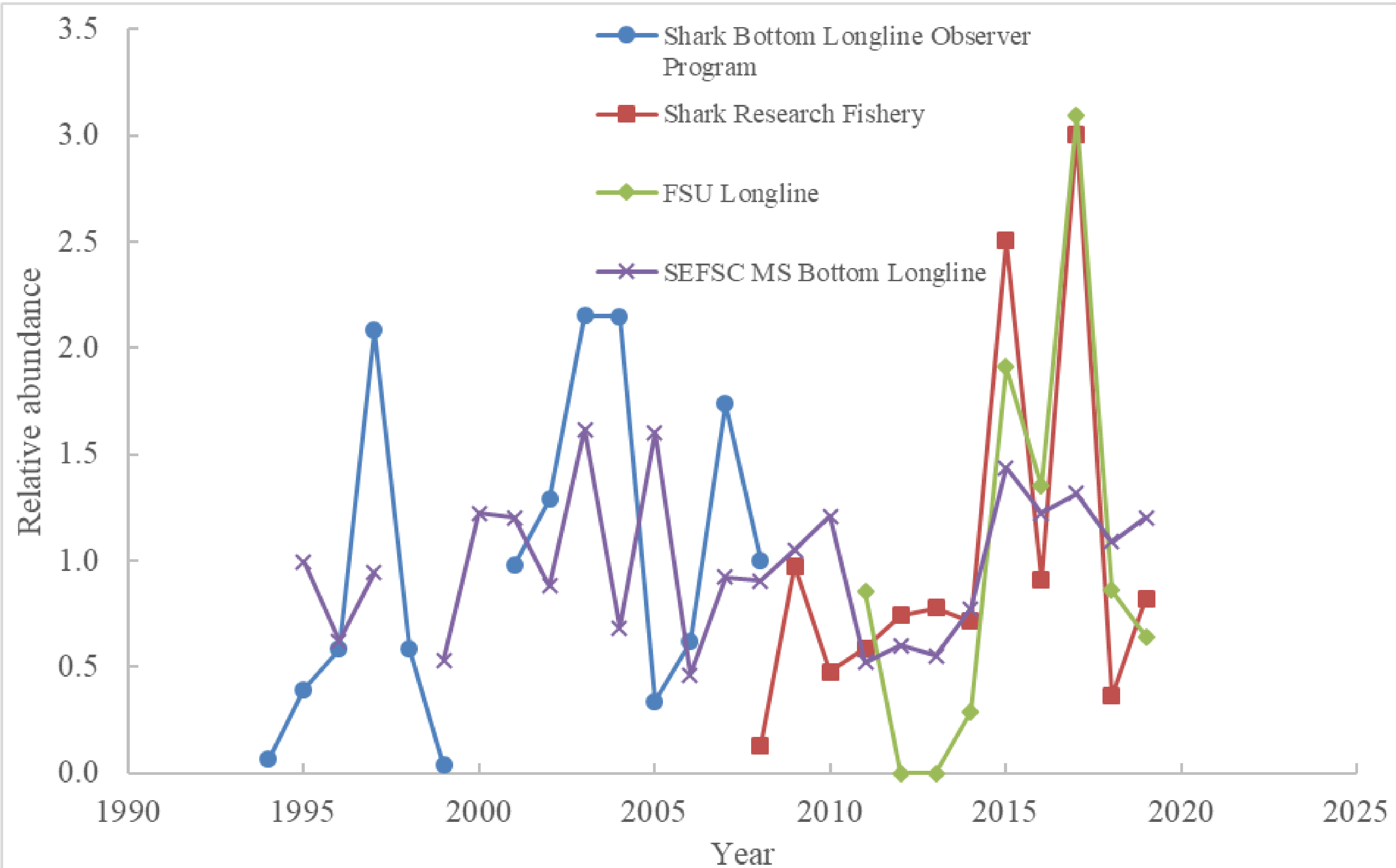


Figure 10. Plot of mean annual values of relative abundance for each sensitivity time series recommended for the Age 1+ scalloped hammerhead shark base run by the Indices Working Group. For each index, values were converted to a common scale for plotting purposes by dividing mean annual values for a time series by the average of all mean annual values for that specific time series.

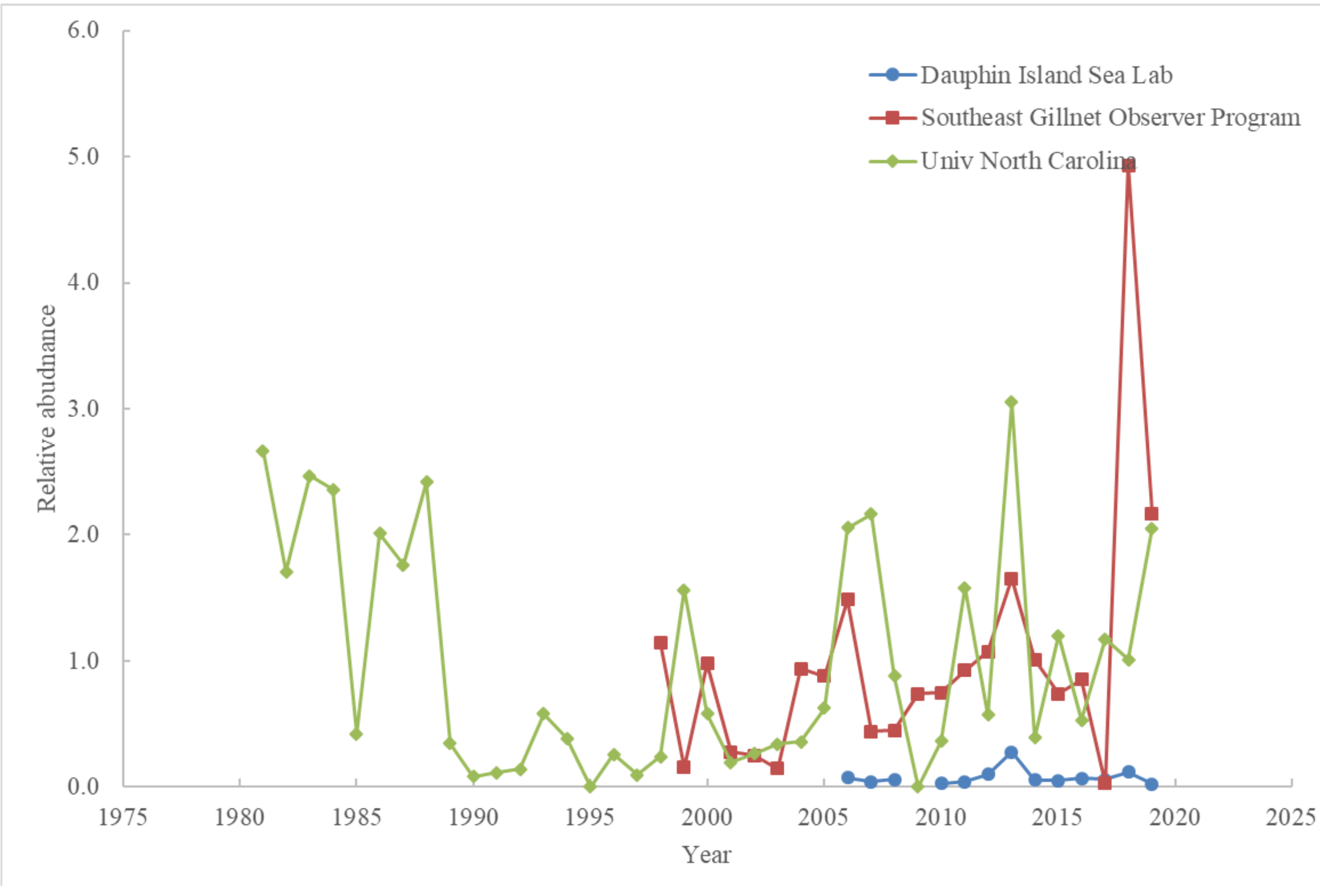


Figure 11. Plot of mean annual values of relative abundance for the recruitment (Age 0) time series recommended for the scalloped hammerhead shark base run by the Indices Working Group. For each index, values were converted to a common scale for plotting purposes by dividing mean annual values for a time series by the average of all mean annual values for that specific time series.

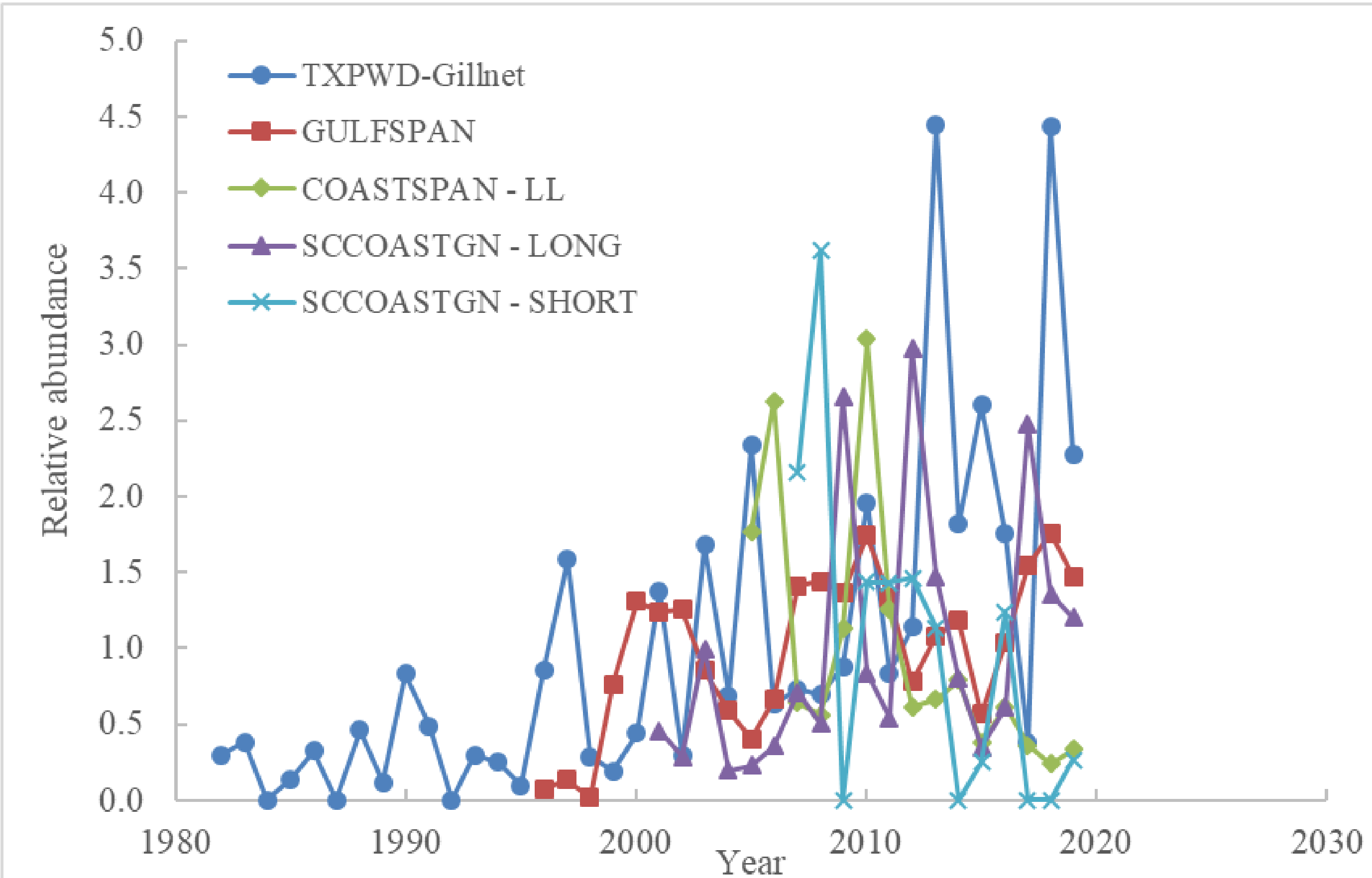


Figure 12. Approximate linear coverage of the stock wide abundance indices for the great hammerhead shark. Colors of the labeled abundance series correspond to the linear coverage.

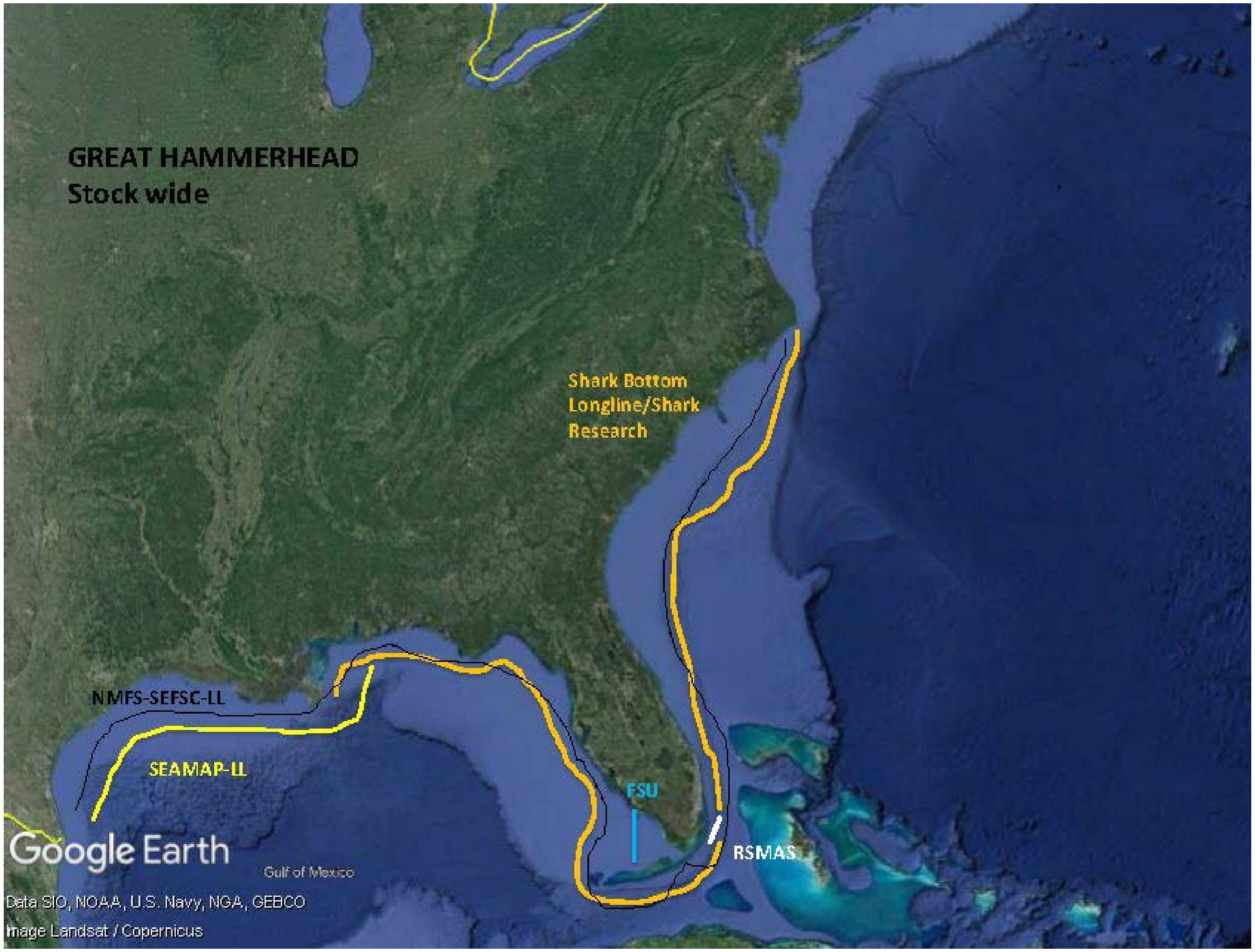
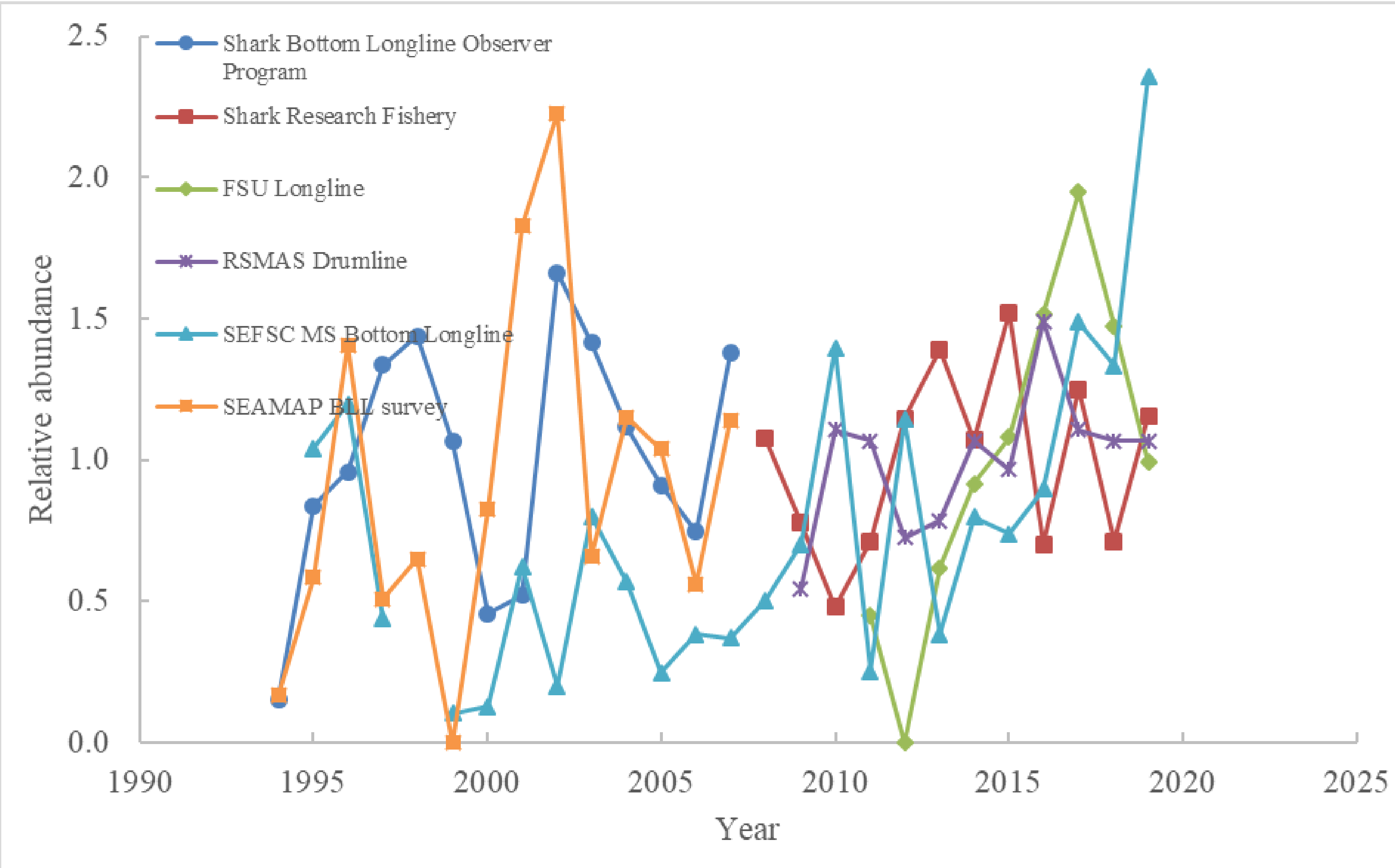


Figure 13. Plot of mean annual values of relative abundance for time series recommended for the great hammerhead shark base run by the Indices Working Group. For each index, values were converted to a common scale for plotting purposes by dividing mean annual values for a time series by the average of all mean annual values for that specific time series.



4.10 Length Frequency

Summary

A complete overview of the length-frequency data is summarized in Kroetz and Courtney (2022).

Twenty-seven data sources were submitted for possible use in the assessment, many with multiple surveys for multiple gear types. Fishery-dependent (commercial and recreational surveys) contributed 13,084 records whereas fishery-independent surveys contributed 9,024 records of all four species. Scalloped hammerheads had the highest frequency of catches compared to the other species in commercial and recreational gears and Carolina hammerheads were captured the least. Bottom longline gear was the primary gear that captured hammerheads, and other gears included gillnets, pelagic longlines, hook and line/rod and reel, and trawls. Age 0 (young-of-the-year) scalloped hammerheads were primarily captured in fishery-independent gillnets, followed by bottom longlines whereas Age 1+ (juveniles to adults) scalloped hammerheads were primarily captured in bottom longline gear followed by gillnets. Great hammerheads were primarily captured in bottom longlines and drumlines, while smooth hammerheads were captured primarily in bottom longlines. The few Carolina hammerheads captured were in gillnets and trawls.

5. Ecological Factors

Ecosystem Workgroup participants

Michelle Passerotti-Leader	National Marine Fisheries Service, Narragansett, RI
William Driggers	National Marine Fisheries Service, Pascagoula, MS
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David Portnoy	Texas A&M University, Corpus Christi, TX

Scalloped *Sphyrna lewini*, Carolina *Sphyrna gilberti*, great *Sphyrna mokarran* and smooth hammerheads *Sphyrna zygaena* are long-lived, highly migratory species that inhabit both coastal and oceanic environments. As such, throughout their ranges in the western North Atlantic Ocean and the Gulf of Mexico, they are subject to a wide range of environmental and ecological variables with the potential to affect their populations. Herein, we summarize available information to address the directives of Terms of Reference (TOR) #7, specifically, providing a general overview of known habitat, diet, species associations, and environmental envelopes for developing habitat suitability projections for each species, where available. We also provide broad considerations of ecological factors with the potential to affect these species and, hence, to affect ecosystem-based management of these species. Lists of co-occurring species from survey data are not provided, but an effort should be made in future assessments to develop a standardized way to capture this information. We also provide a list of research recommendations, in no particular order of importance, to address knowledge gaps with regard to the ecology of these species toward the development of an ecosystem based management approach.

5.1 Habitat

Established Essential Fish Habitat (EFH)

As documented most recently in Amendment 10 to the Consolidated Atlantic Highly Migratory Species Fishery Management Plan (NMFS 2017), essential fish habitat (EFH) was established for scalloped and great hammerheads in the Gulf of Mexico and western North Atlantic Ocean (Figures 1 and 2) based upon data available through 2015 in published scientific literature and from unpublished sources, such as scientific surveys and fisheries monitoring programs. Available environmental parameters associated with the occurrence of hammerheads, including, depth, dissolved oxygen, salinity and temperature ranges, were incorporated into the published EFH identification models (NMFS 2017) and are summarized here in Table 1 based on documentation in Amendment 10. There is currently no designated EFH for smooth or Carolina hammerheads due to limited data for these two species. Updated environmental parameters available since 2015 are also provided herein, described below. Broad categorization of known habitat preferences for each species are provided in Table 6 from existing literature and unpublished sources.

5.2 Environmental envelopes

As an update and supplement to the data utilized for the Amendment 10 EFH designation (NMFS 2017), environmental parameters associated with catches of all four hammerhead species from fishery-independent and –dependent surveys that were submitted for use in the current assessment are provided in Tables 2-5. It is important to note that not all surveys were used to produce indices of abundance for inclusion in assessment models. For those that were used, associated environmental parameters may or may not have been found to influence abundance. Indices for which any environmental parameter was determined to be a significant factor are indicated in each table.

5.3 Diet

Broad categorization of known diet characteristics for each species are summarized in Table 6 from existing literature and unpublished sources.

5.4 Factors with potential to affect ecology and population dynamics of hammerheads

Climate:

- changes in oceanographic conditions and trends (e.g. current/circulation patterns, salinity, dissolved oxygen, pH, etc.)
- species distribution effects due to changing climate and resulting range shifts, expansions or contractions
- phenology
- prey distribution and abundance
- understanding potential for changes in life history characteristics (e.g. growth rate, age at maturity) as a result of climate change

Persistent environmental disturbances:

- anthropogenic sources, such as contaminants (e.g. industrial/agricultural runoff), with higher potential to impact nursery areas

Episodic events:

- harmful algal blooms (HABs)
- hypoxia events
- oil spills
- extreme weather events (e.g. hurricanes)

Habitat disruption:

- coastal development
- dredging
- energy production structures
- loss of seagrass or salt marsh (prey habitat)

5.5 Research recommendations

- Improve understanding of all aspects of biology of hammerheads, particularly with regard to smooth and Carolina hammerhead occurrence, life history, and diet
- Investigate Bulls Bay, SC as a Habitat Area of Particular Concern for Carolina hammerhead
- Increase genetic surveillance to not only identify Carolina hammerhead individuals in the Atlantic, but also as a means to study use of nursery habitats and potential philopatry among all four species, potentially using close-kin mark-recapture techniques.
- Improve understanding of sex- and life stage-critical habitat for all species, particularly with regard to identification of essential habitat for data-poor species and life stages (Carolina and smooth hammerhead as well as young-of-year great hammerhead).
- Investigate impacts of environmental changes on life history characteristics, such as growth and reproduction
- Increase efforts in tagging and tracking to evaluate potential climate-induced range shifts
- Develop habitat suitability models for projecting climate-induced shifts in species distributions over time
- Increase effort for collecting environmental/oceanographic data with occurrence and movement data to identify linkages
- Assess the levels of environmental contaminants in hammerhead species and how those impact physiology and reproductive success
- Study the response of hammerhead species to harmful algal blooms and how those phenomena affect behavior and physiology

5.6 Figures

Figure 1. Essential Fish Habitat for scalloped hammerhead *Sphyrna lewini* by life stage as designated by Amendment 10 to the HMS FMP (NMFS 2017). Map courtesy of J. Cudney, NOAA Fisheries.

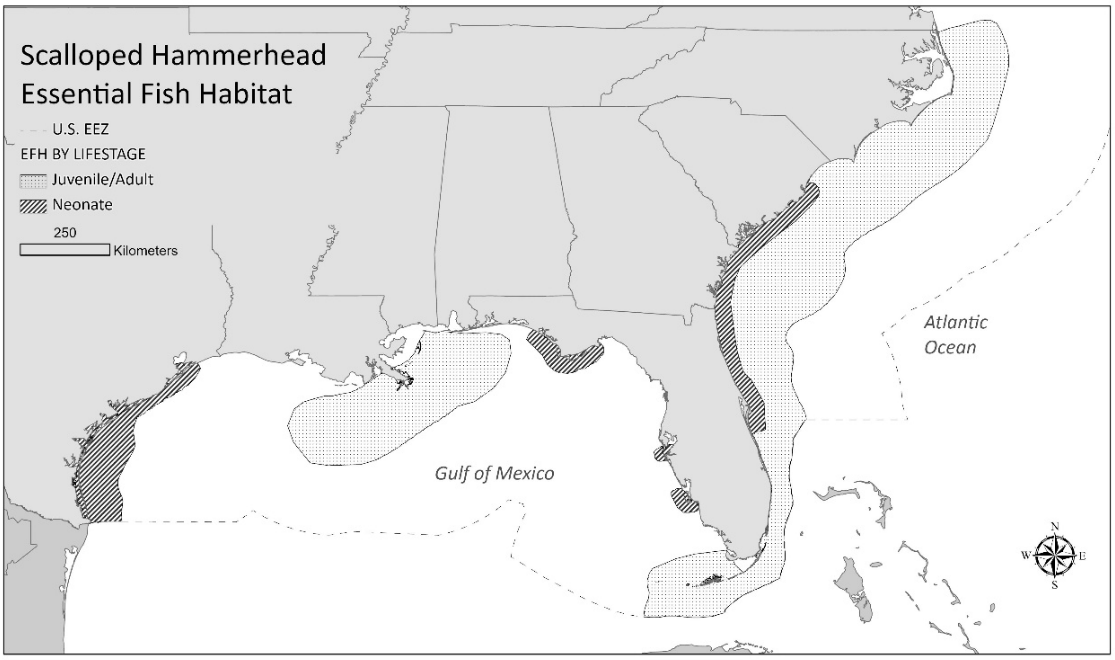
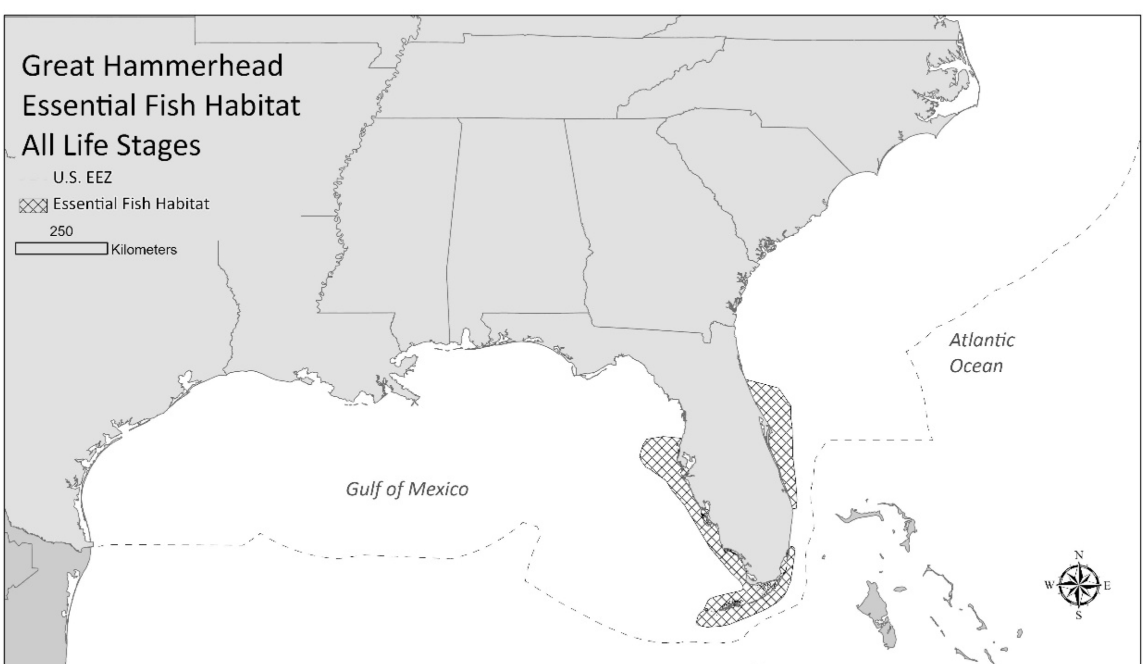


Figure 2. Essential Fish Habitat for great hammerhead *Sphyrna mokarran* as designated by Amendment 10 to the HMS FMP (NMFS 2017). Map courtesy of J. Cudney, NOAA Fisheries.



5.7 Tables

Table 1. Environmental parameters associated with NMFS Essential Fish Habitat (EFH) delineation for scalloped hammerhead *Sphyrna lewini* and great hammerhead *Sphyrna mokarran* by species and life stage, as specified in the most recent EFH report (NMFS 2017). YOY=young of the year (age 1).

Species	Lifestage	Temp	Salinity	DO	Depth
Sphyrna lewini	Neonate/YOY (≤ 45 cm TL)	23.2-30.2°C	27.6-36.3 ppt	5.1-5.5 mL/L	5.0-6.0 m
Sphyrna mokarran	Neonate/YOY Juveniles (< 224 cm FL) Adults (≥ 224 cm FL)	23.9-31.5°C	20.8-34.2 ppt	5.3-7.6 mg/L	1.8-5.5 m

Table 2. Environmental variable ranges associated with positive catches of scalloped hammerhead *Sphyrna lewini* from fishery-dependent and –independent sources in the Gulf of Mexico (GOM) and western North Atlantic (ATL). Variable values in parentheses represent the observed range of each variable measured across all sets. For sources that were used to generate abundance indices for this assessment (in bold), an asterisk (*) denotes variables that were found to be significant factors for at least one final index model. LL = longline, GN = gillnet, 1+ = catches modeled for ages ≥1, 0+ = catches modeled for ages ≥0, YOY = catches modeled for young of the year (age 1) only.

Source (Ages modeled)	Region	Year range	Temperature (°C)	Salinity (psu)	DO (mg/L)	Depth (m)	Contact/Reference
SEFSC Bottom LL (1+)	**GOM**	**1995-2019***	**11.1-31.8 (6.8-31.9)**	**26.4-36.8 (17.9-26.4)**	**0.1-7.71 (0-10.6)**	**14.0-295.0 (7.0-375.0)***	**W. Driggers/SEDAR 77-DW24**
FSUCML Keys LL (0+)	**GOM**	**2011-2021**	**18.5-30.9 (17.1-33.9)**	**35.3-36.8 (5.56-45.3)**	**5.2-7.36 (0.2-10.19)**	**11.3-75.0 (0.9-75.1)**	**R.D. Grubbs/SEDAR 77-DW14**
GULFSPAN GN (YOY)	**GOM**	**1996-2019**	**20.9-33.4 (9.8-34.2)**	**16.6-38.0 (0.19-40.0)**	**1.0-8.2 (0.0-14.0)**	**0.0-10.0 (0.0-21.0)**	**J. Carlson/SEDAR 77-DW17**
Pelagic LL Observer Program (1+)	**GOM/ATL**	**1992-2019**	**10.7-30.7 (-1.1-35.4)**			**10.1-960.1 (5.6-2520.1)**	**J. Carlson/SEDAR 77-DW8**
Texas Parks & Wildlife GN (YOY)	**GOM**	**1982-2019***	**18.5-37.0 (6.0-38.0)**	**11.1-43.2 (0.0-70.8)**	**2.6-11.6 (0.0-26.0)**		**J. Carlson/SEDAR 77-DW16**
Shark Bottom LL Observer Program (0+)	**GOM/ATL**	**1994-2019***	**7.8-33.8 (7.8-33.8)**			**2.9-110.0 (1.6-490.8)***	**J. Carlson/SEDAR 77-DW12**
SCDNR Red Drum LL (0+)	**ATL**	**1997-2006***	**20.0-31.0 (19.0-37.0)**	**25.0-34.0 (23.0-35.0)**		**3.4-16.2 (3.4-17.1)**	**C. McCandless/SEDAR 77-DW29**
SCDNR SEAMAP LL (0+)	**ATL**	**2008-2019***	**18.7-30.2 (13.1-31.8)**	**24.4-36.7 (0.10-39.0)***		**4.6-17.7 (3.0-22.4)**	**C. McCandless/SEDAR 77-DW29**
SCDNR COASTSPAN Long GN (YOY)	**ATL**	**2001-2018***	**22.5-31.2 (20.4-31.3)**	**1.05-37.4 (15-38)**		**0.6-4.6 (0.6-5.4)**	**C. McCandless/SEDAR 77-DW31**
SCDNR COASTSPAN Short GN (YOY)	**ATL**	**2007-2019***	**20.9-30.4 (18.9-31.2)**	**16.0-35.0 (16-37.2)**		**1.2-3.7 (1.2-3.7)**	**C. McCandless/SEDAR 77-DW32**
COASTSPAN LL (YOY)	**ATL**	**2005-2019***	**20.2-38.2 (6.7-39.1)**	**14.6-37.3 (1.2-38.1)***		**1.2-15.5 (1.1-17.2)***	**C. McCandless/SEDAR 77-DW30**
NEFSC LL (1+)	**ATL**	**1996-2018***	**17.7-26.2 (13.1-26.2)***	**31.1-36.7 (29.2-37)**		**10.5-67.8 (10.4-67.8)***	**C. McCandless/SEDAR 77-DW28**
UNC LL (1+)	**ATL**	**1981-2019***	**16.1-31.0 (8.6-31.5)***				**C. McCandless/SEDAR 77-DW33**
New College of Florida LL	GOM	2015-2021	23.5-32.4 (14.5-33.2)	24.0-36.7 (14.5-37.4)	4.68-8.06 (3.12-10.3)	1.68-3.30 (0.48-8.40)	J. Gardiner/SEDAR 77-SID-05
GOM SEAMAP Bottom LL	GOM	2008-2021	13.2-30.7 (12.2-32.1)	24.0-37.4 (4.9-38)	1.2-7.8 (0.1-12.3)	5.5-332.2 (1.4-332.2)	E. Hoffmayer
FSUCML Deep Sea LL	GOM	2011-2018	7.93-15.04 (4.12-19.6)			195-504 (90-2646)	R.D. Grubbs

Table 2 Continued							
Source (Ages modeled)	**Region**	**Year range**	**Temperature (°C)**	**Salinity (psu)**	**DO (mg/L)**	**Depth (m)**	**Contact/Reference**
FSUCML Big Bend GN/LL	GOM	2009-2021	16.4-31.4	27.4-34.4	2.5-7.92	2.3-5.9	R.D. Grubbs
Texas A&M Marine Genomics GN	GOM	2015-2021	26.5-32.8 (21.9-32.8)	21.8-38.5 (10-39.9)	4.55-10.5 (1.55-10.5)	4.29-4.65 (2.33-4.74)	D. Portnoy
Dauphin Island Sea Lab LL	GOM	2006-2019	17.2-30.1 (12.7-32.0)	23.9-37.6 (0.03-38.0)	1.2-7.4 (0.2-10.6)	2.7-104.0 (1.5-111.0)	M. Drymon/SEDAR 77-DW06

Table 3. Environmental variable ranges associated with positive catches of Carolina hammerhead *Sphyrna gilberti* from South Carolina Department of Natural Resources fishery-independent surveys in the western North Atlantic (ATL). Values in parentheses represent the observed range of each variable measured across all sets for each source. Indices of abundance were not compiled due to lack of data.

Source	**Region**	**Year range**	**Temperature (°C)**	**Salinity (psu)**	**DO (mg/L)**	**Depth (m)**	**Contact/Reference**
SCDNR (all surveys)	ATL	1994-2021	19.0-30.4 (9.7-35.0)	22.7-36.3 (0.0-38.9)	4.3-7.1 (2.4-10.8)	1.5-15.8 (0.5-700)	B. Frazier

Table 4. Environmental variable ranges associated with positive catches of great hammerhead *Sphyrna mokarran* from fishery-dependent and –independent sources in the Gulf of Mexico (GOM) and western North Atlantic (ATL). Values in parentheses represent the observed range of each variable measured across all sets for each source. For sources that were used to generate abundance indices for this assessment (in bold), an asterisk (*) denotes variables that were found to be significant factors for indices modeling. LL = longline, GN = gillnet, 1+ = catches modeled for ages ≥1, 0+ = catches modeled for ages ≥0, YOY = catches modeled for young of the year (age 1) only.

Source (Ages modeled)	Region	Year range	Temperature (°C)	Salinity (ppt)	DO (mg/L)	Depth (m)	Contact/Reference
SEFSC Bottom LL (Age 1+)	**GOM**	**1995-2019***	**14.0-30.8 (6.8-31.9)**	**31.8-36.7 (17.9-26.4)**	**0.1-7.71 (0-10.6)**	**11.4-138.3 (7-375)***	**W. Driggers/SEDAR 77-DW24**
GOM SEAMAP Bottom LL (Age 1+)	**GOM**	**2008-2021***	**21.3-31 (12.2-32.1)**	**22.3-38.2 (4.9-38)***	**1.4-8.2 (0.1-12.3)***	**3.7-14.9 (1.4-332.2)**	**E. Hoffmayer/SEDAR77-DW25**
Shark Bottom LL Observer Program (0+)	**GOM/ATL**	**1994-2019***	**14.8-32.7 (7.8-33.8)**			**2.0-66.7 (1.6-490.8)***	**J. Carlson/SEDAR 77-DW12**
FSUCML Keys LL (0+)	**GOM**	**2011-2021***	**18.5-31.2 (17.1-33.9)**	**32.5-39.7 (5.56-45.3)***	**3.82-7.36 (0.2-10.19)**	**2.1-72.0 (0.9-75.1)***	**R.D. Grubbs/SEDAR 77-DW14**
New College of Florida LL	GOM	2015-2021	24.9-31.3 (14.5-33.2)	21.8-36.6 (0.30-37.4)	5.25-7.42 (3.12-10.3)	1.91-6.53 (0.48-8.4)	J. Gardiner/SEDAR 77-SID-05
SCDNR (all surveys)	ATL	1994-2021	20.7-30.7 (9.7-35.0)	27.8-35 (0.0-38.9)	4.2-7.7 (2.4-10.8)	2.1-21.0 (0.5-700)	B. Frazier
NEFSC LL	ATL	1996-2018	21.3-24.1 (6.1-26.0)	36.0-36.6 (29.2-37.0)		15.0-43.9 (6.6-67.8)	C. McCandless
FSUCML Deep Sea LL	GOM	2011-2018	11.49 (4.12-19.61)			297 (90-2646)	R.D. Grubbs
FSUCML Big Bend GN/LL	GOM	2009-2021	21.7-31.1	27.3-34.7	4.67-8.88	2.0-6.7	R.D. Grubbs

Table 5. Environmental ranges associated with positive catches of smooth hammerhead *Sphyrna zygaena* from South Carolina Department of Natural Resources fishery-independent surveys in the western North Atlantic (ATL). Values in parentheses represent the full range of each variable measured across all sets for each source. Indices of abundance were not compiled due to lack of data.

Source	Region	Year range	Temperature (°C)	Salinity (ppt)	DO (mg/L)	Depth (m)	Contact/Reference
SCDNR (all surveys)	ATL	1994-2021	23.2 (9.7-35.0)	35 (0.0-38.9)	6.8 (2.4-10.8)	91.2 (0.5-700)	B. Frazier

Table 6. General habitat and diet information for scalloped *Sphyrna lewini*, Carolina *Sphyrna gilberti*, great *Sphyrna mokarran*, and smooth *Sphyrna zygaena* hammerheads. References for studies outside the western North Atlantic/Gulf of Mexico were included when region-specific data were lacking.

Species	Habitat	Trophic level/Diet
Sphyrna lewini	• Depth: shallow to ~275m, although documented to 1045m (Moore and Gates 2015) • Exploit shallow estuaries for use as nursery grounds, with juveniles migrating offshore near adulthood (Stevens and Lyle 1989). • Sub-adults/adults known to occupy deep waters potentially for foraging purposes, while also exploiting the mixed layer and shallower shelf habitats depending on location. Some evidence for preference for high relief/bottom structure (Wells et al. 2018) • Vertical diel migrations are apparent, likely for foraging (Hoffmayer et al. 2013).	4.1 (Cortés 1999); • YOY: Broad diet in comparison to other non-hammerhead species (SCDNR, unpublished) • Juvenile prey items: mix of fish and crustaceans • Adult prey items: larger/higher level prey (squid, teleosts); sexual segregation may lead to dietary differences (Klimley 1987)
Sphyrna gilberti	• Depth: unknown • Center of young juvenile abundance in US waters: Bulls Bay, SC (nursery area; Quattro 2006; Barker et al. 2021); documented occurrences in Trinidad (D. Portnoy, TAMU, unpublished)	4.1 (from *S. lewini*, Cortés 1999; likely the same due to species similarities) • YOY: Broad diet in comparison to other non-hammerhead species – similar to scalloped hammerhead (SCDNR, unpublished) • Juvenile prey items: mix of fish and crustaceans (A. Galloway, SCDNR, unpublished)
Sphyrna mokarran	• Depth: near-surface to 300m (Ebert et al. 2013; Weigmann 2016) • Shallow coastal waters, but migrate offshore to pelagic habitats; habitat use can be seasonal (Calich et al. 2018; Gardiner et al. 2021) and/or related to prey availability (Calich et al. 2021) • Some evidence of philopatry to coastal habitats (Hammerschlag et al. 2011a, b; Graham et al. 2016; Guttridge et al. 2017; Gardiner et al. 2021) • Evidence of pupping grounds off South Carolina and western Florida (Barker et al. 2017; Heuter & Tyminski 2007); young juvenile habitat off Miami, Florida (MacDonald et al. 2021)	4.3 (Cortés 1999); • Prey items: teleost fishes, sharks and rays • cephalopods are notably less prevalent in diet than in other hammerhead species (Smale & Cliff 1993; Raoult et al. 2019)
Sphyrna zygaena	• Depth: near-surface to 260m; in southern Atlantic, prefer < 50m (Kotas 2004; Vooren et al. 2005; Santos & Coelho 2018) • Coastal, pelagic, and semi-oceanic waters off and on continental shelves (Compagno 2005) • Salinity may play a role in habitat selection, especially in estuarine waters (Burgess, unpublished; Doño 2008; González Pestana 2018)	4.2 (Cortés 1999); • Prey items: primarily cephalopods, but bony fishes, crustaceans, small elasmobranchs also documented (Bornatowski et al. 2014). • Some evidence of ontogenetic diet shift (Gonzalez-Pestana et al. 2017) • Low overlap with co-occurring scalloped hammerhead (Loor-Andrade et al. 2015)

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6. Length Composition Section

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6.1 Length Composition Submitted For Use In The Assessment Workshop

Overview

This document details length composition data sources submitted for four species of hammerhead sharks during the SEDAR 77 Data Workshop for possible use in the SEDAR 77 HMS Hammerhead Sharks stock assessment. Great (*Sphyrna mokarran*), scalloped (*S. lewini*), smooth (*S. zygaena*), and Carolina (*S. gilberti*) hammerheads length composition data were submitted from commercial, recreational, and scientific surveys and summarized here. The goal for all of the data is to provide numbers of available length data (and their distribution) by species so that the assessment team can decide which stock assessment software to use for each species. Data were binned into 5 cm fork length increments by year (terminal year 2019) and matrices extracted for stock assessment model input. Length compositions were plotted for each species to show length-frequency histograms. Twenty-seven data sources (several with multiple surveys) were submitted for a total of 22,108 records collected for the four hammerhead species between 1973 and 2019. Variability in years of data available, species, and the size distributions of recorded specimens was present among the different data sources. Fishery-dependent (commercial and recreational surveys) contributed 13,084 records of the four species whereas fishery-independent surveys contributed 9,024 records.

Introduction

The proposed analytical approach to be implemented in this assessment with these data is a length-based, age-structured statistical model (Stock Synthesis; Methot and Wetzel 2013; e.g., Wetzel and Punt 2011a, 2011b). Stock Synthesis utilizes an integrated modeling approach (Maunder and Punt 2013) to take advantage of the many data sources available, including length composition data. Once data are organized into 'fleets' based on similar length compositions, selectivity for each fleet can be estimated in the Stock Synthesis model from the time series of binned length data. Similarly, available length composition time series obtained for accepted CPUE indices will be reviewed during subsequent assessment webinars in order to determine if there are sufficient length data to represent the length composition distributions of each accepted CPUE index. Length-based selectivity for CPUE indices with representative length composition distributions will be estimated in the Stock Synthesis model from the time series of binned length data. Length-based selectivity for CPUE indices without representative length composition distributions will be set equal to (mirror) CPUE indices with representative length composition distributions.

Methods

Length composition data for great, scalloped, smooth, and Carolina hammerheads were submitted during the SEDAR 77 Data Workshop, which occurred from December 13-17, 2021. The goal for all of the data is to provide numbers of available length data (and their distribution) by species so that the assessment team can decide which stock assessment software to use for each species. The available length composition time series data were obtained from fisheries-independent scientific surveys as well as from fishery-dependent sources from commercial and recreational catch data and were available from 1973-2019 (Table 1), depending on the data source. Data were recorded by fisheries research biologists, scientific observers, commercial, and recreational fishers from various surveys and fishing events. Length data from each dataset were omitted from analyses if it exceeded biologically plausible measurements for the species reported in SEDAR77-DW18. Fork length measurements (cm FL) were used if available and data were converted to cm FL from other measured length units with the equation for combined sexes given in SEDAR 77-DW03. Data were subset into three regions: Gulf of Mexico, Atlantic Ocean, and combined Gulf of Mexico and Atlantic Ocean. Recommendations from the Stock ID Final Report (SEDAR 2022) were followed as to how to treat each stock. Thus, scalloped hammerhead data were separated out into each of the three regions if data were available whereas great, smooth, and Carolina hammerheads were grouped into the combined regions only. Data were further subset into males, females, unknown sex, and combined sex for each species and region. Scalloped hammerheads were further subset to create an Age 0 complex (≤ 61 cm FL, young-of-the-year) and an Age 1+ complex (≥ 62 cm FL, juvenile to adult) to match that of the Indices Working Group, as described in SEDAR77-DW24, which is consistent with the interpretation of the size at Age 0 of scalloped hammerheads among the various data sources. Length data were then binned by year into 5 cm FL increments and the matrices extracted for stock assessment model input (i.e., Stock Synthesis). Length-frequency histograms were created for each species and sex matrix with length at 50% maturity (L_{50}) denoted in each plot obtained from SEDAR77-DW18.

6.2 Fishery-Dependent Data Sources

Recreational Catches: Marine Recreational Information Program (MRIP) and the Southeast Region Head Boat Survey (SRHS)

Length composition data for hammerheads were available via the Marine Recreational Information Program (MRIP) and the Southeast Region Headboat Survey (SRHS) operated by the Southeast Fisheries Science Center (SEFSC) Beaufort Laboratory as described in the Catches Section of this report and in SEDAR77-DW04. MRIP and SRHS were combined to create one Recreational Survey category (n=430). Data were split into three regions: Gulf of Mexico, Atlantic Ocean, and combined Gulf of Mexico and Atlantic Ocean. Provided data ranged from 1981-2015 for Age 0 (n=85) and Age 1+ (n=203) scalloped hammerheads, combined ages of great (n=97) hammerheads, and for smooth hammerheads (n=45) (Table 2). No sex was recorded for these surveys so single matrices were created for each species in the Gulf of Mexico, Atlantic Ocean, and combined regions.

South Carolina Department of Natural Resources (SCDNR)

Commercial trawl and gillnet data were available through the South Carolina Department of Natural Resources (n=85) ranging from 2006-2019 for the Atlantic Ocean. Length data were provided for Age 0 (n=37) and Age 1+ (n=10) scalloped hammerheads and for Carolina hammerheads (n=13) collected using trawl gear. Age 1+ (n=12) scalloped hammerheads were collected in gillnet gear along with Carolina hammerheads (n=13) (Table 2).

Mexican Gulf of Mexico Artisanal Shark Fisheries

Intensive monitoring of the artisanal shark fisheries in the coastal waters of the Mexican Gulf of Mexico provided length data from 1982-2019 (n=1,637) to be considered for use in the assessment (Table 2; see SEDAR77-DW04 for further details). Artisanal gillnet and bottom longline gears provided length composition data in the Gulf of Mexico for Age 0 (n=778) and Age 1+ (n=797) scalloped hammerheads, and combined ages of great hammerheads (n=62).

NOAA Fisheries Northeast Fishery Science Center (NEFSC) Cooperative Shark Tagging Program (CSTP)

The Cooperative Shark Tagging Program, launched in 1962, is a collaborative effort among recreational anglers, the commercial fishing industry, and NOAA Fisheries to learn more about the life history of Atlantic Sharks. Most CSTP participants tag the sharks they catch with a rod and reel while fishing recreationally. Other participants include commercial anglers using longline and net gear, biologists, and NOAA fisheries observers. Length composition data were available from 1962-2019 (n=2,576) (Table 2). A large amount of data included estimated fork lengths, thus matrices were made for both measured and estimated lengths for the Gulf of Mexico, Atlantic Ocean, and combined regions. Gears included were commercial and recreational trawl, gillnet, bottom longline, rod and reel, and handline. Age 0 scalloped hammerheads were caught by trawl (n=6), gillnet (n=2), longline (n=1), and rod and reel (n=322) gears. Age 1+ scalloped hammerheads were caught by trawl (n=393), gillnet (n=18), longline (n=248), and rod and reel (n=1035) gears. Combined ages of great hammerheads were captured by longline (n=17) and rod and reel gears (n=276), smooth hammerheads by longline (n=34) and rod and reel gears (n=218).

Texas Shark Rodeo

Data collected from anglers targeting sharks participating in the Texas Shark Rodeo were available from 2014-2019 for the Gulf of Mexico (n=146). Age 0 (n=31) and Age 1+ (n=50) scalloped hammerheads and all ages combined of great (n=65) had length information (Table 2).

Recreational Logbook

Personal logbooks of recreational charter Captain, Mark Sampson, are being archived in a database at Maryland Department of Natural Resources. These data were available from 2007-2019 (n=88) and provided length compositions for Age 1+ (n=30) scalloped hammerheads and for smooth hammerheads (n=58) in the Atlantic Ocean (Table 2).

Southeast Coastal Gillnet Observer Program (GNOP)

Observer coverage of the Florida-Georgia shark gillnet fishery began in 1992, and has since documented the many changes to effort, gear characteristics, and target species the fishery has undergone following the implementation of multiple fisheries regulations as described in SEDAR77-DW13. A large amount of data included estimated fork lengths, thus matrices were made for both measured and estimated lengths for the Gulf of Mexico, Atlantic Ocean, and combined regions (n=303). Length composition data were available from 1999-2019 and provided information for Age 0 (n=32) and Age 1+ (n=213) scalloped hammerheads, combined ages of great hammerheads (n=44), and for smooth hammerheads (n=14) (Table 2).

Shark Bottom Longline Observer Program (BLLOP)

Observations by at-sea observers of the shark-directed bottom longline fishery in the Atlantic Ocean and Gulf of Mexico have been conducted since 1994 as described in SEDAR77-DW12. Length composition data were available from 1994-2019 (n=4,219) and include data prior to the Shark Research Fishery that was run by the University of Florida. Length data were provided for Age 0 (n=13) and Age 1+ (n=2,782) scalloped hammerheads, all ages combined of great hammerheads (n=1,409), and for smooth hammerheads (n=15) (Table 2). Matrices were created for the Gulf of Mexico, Atlantic Ocean, and combined regions.

Pelagic Longline Observer Program (PLLOP)

In 1992, the National Marine Fisheries Service (NMFS) initiated scientific sampling of the U.S. large pelagic fisheries longline fleet, as mandated by the U.S. Swordfish Fisheries Management Plan and subsequently the Atlantic Highly Migratory Species Fishery Management Plan (1998). Scientific observers were placed aboard vessels participating in the Atlantic pelagic longline fishery as described in SEDAR77-DW08. Length composition data were available from 1992-2019 (n=3,600). A large amount of data included estimated fork lengths, thus matrices were made for both measured and estimated lengths for the Gulf of Mexico, Atlantic Ocean, and combined regions. Length data for Age 1+ (n=3,195) scalloped hammerheads, combined ages of great hammerheads (n=297), and for smooth hammerheads (n=108) (Table 2).

6.3 Fishery-Independent Data Sources

Northeast Gulf of Mexico (GULFSPAN) Gillnet Survey

Fishery-independent surveys of coastal shark populations have taken place since 1994 in the eastern and northern Gulf of Mexico. The cooperative GULFSPAN gillnet survey began in 1996 to examine the distribution and abundance of juvenile sharks in coastal areas as described in SEDAR77-DW17 and data were available from 1994-2019 (n=1,742). Length data were provided for Age 0 (n=1,530) and Age 1+ (n=187) scalloped hammerheads and combined ages of great hammerheads (n=25) in the Gulf of Mexico (Table 3).

Texas Parks and Wildlife Gillnet Survey

The Texas Parks and Wildlife Department, Coastal Fisheries Division runs a fishery-independent gillnet survey to monitor the relative abundance and size of organisms, their spatial and temporal distribution, species composition of the community, and selected environmental parameters known to influence their distribution and abundance. Surveys were conducted in 10 major bay systems along the Texas coast in the northwestern Gulf of Mexico from 1982 to 2019 as described in SEDAR77-DW16. Length composition data were provided for 662 animals consisting of Age 0 (n=569) and Age 1+ (n=81) scalloped hammerheads and combined ages of great hammerheads (n=25) (Table 3).

Florida State University Bottom Longline Survey

The Florida State University bottom longline survey was expanded in 2011 to include regular sampling in southwest Florida in an effort to capture smalltooth sawfish, *Pristis pectinata*, for research directed at promoting recovery of this endangered species. This work is concentrated in two areas, in Everglades National Park, mostly in northern Florida Bay, along the middle to lower Florida Keys, primarily along the shelf break as described in SEDAR77-DW14. Length composition data (n=219) were available from 2011-2019 for Age 1+ scalloped hammerheads (n=76) and combined ages of great hammerheads (n=143) in the Gulf of Mexico (Table 3).

NOAA Fisheries Southeast Fisheries Science Center Bottom Longline Survey

NOAA Fisheries SEFSC Mississippi Laboratories has conducted standardized bottom longline surveys in the western North Atlantic Ocean since 1995 as described in SEDAR77-DW24. Length compositions were provided for 703 animals from 1995-2019 consisting of Age 0 (n=9) and Age 1+ (n=598) scalloped hammerheads and combined ages of great hammerheads (n=96) (Table 3). Matrices were created for the Gulf of Mexico, Atlantic Ocean, and combined regions.

NOAA Northeast Fisheries Science Center Coastal Shark Bottom Longline Survey

The NOAA Fisheries NEFSC Apex Predators Program has conducted coastal shark bottom longline surveys from 1996-2018 along the Atlantic coast of the United States as described in SEDAR77-DW28. Length compositions were available for 259 animals consisting of Age 1+ (n=251) scalloped hammerheads and combined ages of great hammerheads (n=8) (Table 3).

Southeast Area Monitoring and Assessment Program Bottom Longline Survey

Fishery-independent bottom longline surveys have been conducted in coastal waters of the northern Gulf of Mexico by the Southeast Area Monitoring and Assessment Program (SEAMAP) via NOAA Fisheries SEFSC Mississippi Labs, the Dauphin Island Sea Lab, Gulf Coast Research Laboratory, Louisiana Department of Wildlife and Fisheries, and Texas Parks and Wildlife Department as described in SEDAR77-DW25. Surveys spanned from Texas to Alabama providing length compositions for 153 animals from 2008-2019: Age 0 (n=3) and Age 1+ (n=86) scalloped hammerheads and combined ages of great hammerheads (n=64) (Table 3).

NOAA Fisheries Cooperative Atlantic States Shark Pupping and Nursery Longline Survey

In an effort to examine the use of South Carolina’s, Georgia’s and northern Florida’s estuarine and nearshore waters as nursery areas for coastal shark species, personnel from SCDNR, Georgia Department of Natural Resources (GADNR), and the University of North Florida (UNF) in collaboration with NMFS Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) program began sampling for sharks using longline and gillnet methods in several of their state’s estuaries and nearshore waters as described in SEDAR77-DW30. Length composition from longline surveys were available from 2000-2019, providing data for 477 animals. Age 0 (n=439) and Age 1+ (n=37) scalloped hammerheads and one Carolina hammerhead were captured by longline gear on the Atlantic coast (Table 3).

South Carolina Department of Natural Resources, Cooperative Atlantic States Shark Pupping and Nursery Long-Gillnet Survey

In an effort to examine the use of South Carolina's estuarine waters as nursery areas for coastal shark species the SCDNR Marine Resources Division, in collaboration with NMFS COASTSPAN Survey began sampling for sharks using longline and gillnet methods in several estuaries within South Carolina as described in SEDAR77-DW31. Length composition data from long gillnet were available from 2001-2019 for 1,060 animals in the Atlantic Ocean. Age 0 (n=1,017) and Age 1+ (n=8) scalloped hammerheads and combined ages of Carolina (n=35) hammerheads were captured by gillnet gear (Table 3).

South Carolina Department of Natural Resources, Cooperative Atlantic States Shark Pupping and Nursery Short-Gillnet Survey

In an effort to increase sampling effort in South Carolina's estuarine waters SCDNR Marine Resources Division, in collaboration with NMFS COASTSPAN Survey added an additional survey gear (short gillnet) in 2006 to the established longline and gillnet methods that had been ongoing in several estuaries within South Carolina since 1998 as described in SEDAR77-DW32. Length composition data were available for short gillnet gear from 2007-2019 for Age 0 scalloped hammerheads (n=34) in the Atlantic Ocean (Table 3).

South Carolina Department of Natural Resources Red Drum Bottom longline

The SCDNR runs a long-term monitoring program for adult red drum, *Sciaenops ocellatus*, in the coastal waters of South Carolina as described in SEDAR77-DW29. Length composition data were available from 1995-2006 for Age 0 (n=52) and Age 1+ (n=34) scalloped hammerheads in the Atlantic Ocean (Table 3).

South Carolina Department of Natural Resources SEAMAP Bottom Longline

Under SEAMAP, the SCDNR red drum longline survey was modified from a fixed-station survey to a random stratified multispecies survey in 2007 in response to the needs of stock assessment biologists and to increase coverage along the coast as described in SEDAR77-DW29. Length composition data were available from 2007-2019 for 53 animals. Age 0 (n=34) and Age 1+ (n=12) scalloped hammerheads and combined ages of great (n=7) hammerheads were captured by longlines in the Atlantic Ocean (Table 3).

South Carolina Department of Natural Resources Scientific Trawl

The SCDNR runs a scientific trawl survey that provided length composition data for 122 animals from 2006-2019. Age 0 (n=68) and Age 1+ (n=21) scalloped hammerheads, combined ages of great (n=5), and for Carolina (n=28) hammerheads were captured by trawl gear in the Atlantic Ocean (Table 3).

<u>Texas A&M University Corpus Christi Gillnet and Longline Surveys</u>

Texas A&M University Corpus Christi runs a longline and gillnet program in Corpus Christi Bay to sample shark assemblages within the bay. Length composition data were available for 12 Age 0 scalloped hammerhead collected between 2017-2018. Nine (n=9) were captured by gillnet gear and three were captured by longline gear for the Gulf of Mexico region (Table 3).

<u>University of North Carolina Shark Longline Survey</u>

A bi-weekly longline survey has been conducted at two fixed stations south of Shackleford Banks in Onslow Bay, North Carolina by the University of North Carolina (UNC), Institute of Marine Sciences starting in 1972 as described in SEDAR77-DW33. Length composition data were available for 506 scalloped hammerheads from 1972-2019. Eight Age 0 and 498 Age 1+ scalloped hammerheads were captured by longline gear in the Atlantic Ocean during this survey (Table 3).

<u>Rosenstiel School of Marine and Atmospheric Science Drumline Survey</u>

Shark drumline surveys have been conducted by the Rosenstiel School of Marine and Atmospheric Science from Miami through the middle Florida Keys to examine spatial, seasonal, and environmental patterns in shark occurrence, catch per unit effort, composition, and demographic structure as described in SEDAR65-DW15. Length composition data were available for 220 animals from 2008-2019. Age 1+ (n=17) scalloped hammerheads and combined ages of great (n=203) hammerheads were captured by drumline gear (Table 3). Matrices were created for the Gulf of Mexico, Atlantic Ocean, and combined regions.

<u>Mote Marine Laboratory Surveys</u>

Mote Marine Laboratory has conducted long-term sampling of shark assemblages in the eastern Gulf of Mexico utilizing longline, drumline, and gillnet gears. Length composition data were available for 337 animals from 1992-2019. Longline gear captured 79 animals comprised of Age 1+ (n=20) scalloped hammerheads and combined ages of great (n=59) hammerheads. Drumline gear captured 78 animals consisting of Age 1+ (n=8) scalloped hammerheads and combined ages of great (n=70) hammerheads. Gillnet gear captured 180 animals consisting of Age 0 (n=76) and Age 1+ (n=5) scalloped hammerheads and combined ages of great (n=99) hammerheads (Table 3). Matrices for each gear type were created for the Gulf of Mexico.

<u>Dauphin Island Sea Lab (DISL) Bottom Longline Survey</u>

Fishery-independent bottom longline surveys have been conducted out of the Dauphin Island Sea Lab by the University of South Alabama since 2006 as described in SEDAR77-DW06 and under

SEAMAP as described in SEDAR77-DW25. Length composition data were available for 250 animals from 2006-2019. Age 1+ (n=182) scalloped and combined ages of great (n=68) hammerheads were captured in the Gulf of Mexico (Table 3). ***Note: there are 31 animals (n=21 great hammerhead, n= 10 scalloped hammerhead) that were captured under the SEAMAP survey. These lengths were also included in the SEAMAP length composition summary described here to match the index development for SEAMAP, which included some of the DISL stations.***

Georgia Department of Natural Resources, SEAMAP Bottom Longline Survey

Under SEAMAP, the GADNR conducts a bottom longline survey off the Georgia coast in the Atlantic Ocean. Length composition data were available for 38 scalloped hammerheads from 2007-2019. Age 0 (n=31) and Age 1+ (n=7) animals were captured (Table 3).

NOAA Fisheries Cooperative Shark Tagging Program

The CSTP provided length composition data for 2,122 animals from 1962-2019 from six scientific gear types: trawl, gillnet, longline, rod and reel, drumline, and handline. A large amount of data included estimated fork lengths, thus matrices were made for both measured and estimated lengths for the Gulf of Mexico, Atlantic Ocean, and combined regions. Trawl gear captured Age 0 (n=5) and Age 1+ (n=7) scalloped hammerheads; gillnet gear captured Age 0 (n=173) and Age 1+ (n=19) scalloped hammerheads; longline gear captured Age 0 (n=168) and Age 1+ (n=1499) scalloped hammerheads, combined ages of great (n=72) and smooth (n=27) hammerheads; rod and reel gear captured Age 0 (n=6) and Age 1+ (n=13) scalloped hammerheads, combined ages of great (n=7) and smooth (n=5) hammerheads; drumline gear captured 97 great hammerheads (combined ages); and handline gear captured 24 great hammerheads (combined ages) (Table 3).

6.4 Summary

Twenty-seven data sources were submitted for possible use in the assessment, many with multiple surveys for multiple gear types. Fishery-dependent (commercial and recreational surveys) contributed 13,084 records (Figure 1) whereas fishery-independent surveys contributed 9,024 records of all four species (Figure 2). Scalloped hammerheads had the highest frequency of catches compared to the other species in commercial and recreational gears and Carolina hammerheads were captured the least. Bottom longline gear was the primary gear that captured hammerheads, and other gears included gillnets, pelagic longlines, hook and line/rod and reel, and trawls (Figure 1). Age 0 (young-of-the-year) scalloped hammerheads were primarily captured in fishery-independent gillnets, followed by bottom longlines (Figure 2) whereas Age 1+ (juveniles to adults) scalloped hammerheads were primarily captured in bottom longline gear followed by gillnets (Figure 2). Great hammerheads were primarily captured in bottom longlines and drumlines, while smooth hammerheads were captured primarily in bottom longlines. The few Carolina hammerheads captured were in gillnets and trawls (Figure 2).

Length composition for Age 0 scalloped hammerheads ranged from 21-61 cm FL (Figure 3) and from 62-400 cm FL for Age 1+ (Figure 4). Great hammerheads length composition ranged from 26-365 cm FL (Figure 5) and smooth hammerheads from 29-350 cm FL (Figure 6). Carolina hammerhead length composition ranged from 27-104 cm FL (Figure 7). Length compositions of each data source of males and females of each species were plotted to provide visualization of available data. Example plots of one fishery-dependent and one fishery-independent survey can are provided below.

Example length-frequency compositions for HMS hammerhead sharks submitted during the SEDAR 77 Data Workshop for possible inclusion in the SEDAR 77 stock assessment

1. Length composition data for hammerheads were available via the Marine Recreational Information Program (MRIP) and the Southeast Region Headboat Survey (SRHS) operated by the Southeast Fisheries Science Center (SEFSC) Beaufort Laboratory (as described in the methods section of the main text and summarized in Table 2 above; Figures 8-10). MRIP and SRHS were combined to create one Recreational Survey (n=430) that includes all fishery-dependent recreational catches. Data were split into three regions: Gulf of Mexico, Atlantic Ocean, and combined Gulf of Mexico and Atlantic Ocean. Female length at 50% maturity are denoted by a red dashed line and males length at 50% maturity are denoted by solid blue lines for each region as described in SEDAR77-DW18.

2. Length compositions for hammerheads were available from NOAA Fisheries Southeast Fisheries Science Center (SEFSC) Mississippi Laboratories standardized fishery-independent bottom longline survey (n=703, NMFS Longline; as described in the methods section of the main text and summarized in Table 3 above; Figures 11-16). Data were split into three regions: Gulf of Mexico, Atlantic Ocean, and combined Gulf of Mexico and Atlantic Ocean. Female length at 50% maturity are denoted by a red dashed line and males length at 50% maturity are denoted by solid blue lines for each region as described in SEDAR77-DW18.

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Maunder, M. N. and A. E. Punt. 2013. A review of integrated analysis in fisheries stock assessment. Fisheries Research 142:61–74.

Methot R. D. and C. R. Wetzel. 2013. Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142:86–99.

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Wetzel, C. R., and A. E. Punt. 2011a. Model performance for the determination of appropriate harvest levels in the case of data-poor stocks. Fisheries Research 110:342–355.

Wetzel, C. R., and A. E. Punt. 2011b. Performance of a fisheries catch-at-age model (Stock Synthesis) in data-limited situations. Marine and Freshwater Research 62: 927–936.

6.5 Tables

Table 1. Summary of available length composition data for scalloped (*S. lewini*), great (*S. mokarran*), smooth (*S. zygaena*), and Carolina (*S. gilberti*) hammerheads from 1973-2019. Data were broken into fishery-independent and fishery-dependent data sources and 'estimated' refers to fork lengths (FL cm) that were estimated and thus not exact measurements. Age 0 refers to scalloped hammerheads (<61 cm FL) and Age 1+ scalloped hammerheads refers to (>61 cm FL). If not noted, ages are combined for species. Abbreviations are as follows: SHH = scalloped hammerheads, GHH = great hammerheads, SMH = smooth hammerheads, and CHH = Carolina hammerheads.

Data Sources	Age 0 SHH	Age 1+ SHH	All GHH	All SMH	All CHH	Total
Fishery-Independent	4234	2216	981	30	64	7525
Estimated Fishery-Independent	0	1440	57	2	-	1499
Total	4234	3656	1038	32	64	9024
Fishery-Dependent	1191	5172	1820	269	26	8478
Estimated Fishery-Dependent	116	3814	453	223	-	4606
Total	1307	8986	2273	492	26	13084
Grand Total	5541	12642	3311	524	90	**22108**

Table 2. Fishery-dependent data sources from commercial and recreational catches for possible use in the assessment. Age 0 refers to scalloped hammerheads (≤61 cm FL) and Age 1+ scalloped hammerheads refers to (≥62 cm FL). If not noted, ages are combined for species. Abbreviations are as follows: SHH = scalloped hammerheads, GHH = great hammerheads, SMH = smooth hammerheads, and CHH = Carolina hammerheads.

Data Source	**Years of Coverage**	**Age 0 SHH**	**Age 1+ SHH**	**GHH**	**SMH**	**CHH**
Recreational Catches						
MRIP, SRHS	1981-2015	85	203	97	45	0
South Carolina Department of Natural Resources						
Commercial trawl	2006-2019	37	10	0	0	13
Commercial gillnet	2006-2019	0	12	0	0	13
Mexican Gulf of Mexico Artisanal fisheries						
Gillnet	1982-2019	122	408	44	0	0
Longline	1982-2019	656	389	18	0	0
Cooperative Shark Tagging Program						
Commercial/recreational trawl	1962-2019	6	393	0	0	0
Commercial/recreational gillnet	1962-2019	2	18	0	0	0
Commercial/recreational longline	1962-2019	1	248	17	34	0
Commercial/recreational rod and reel	1962-2019	322	1035	276	218	0
Commercial/recreational handline	1962-2019	0	0	6	0	0
Texas Shark Rodeo	2014-2019	31	50	65	0	0
Recreational Logbook (Mark Sampson)	2007-2019	0	30	0	58	0
Southeast Coastal Gillnet Observer Program	1999-2019	32	213	44	14	0
Shark Bottom Longline Observer Program						
All vessels (includes UF BLL)	1994-2005	13	1056	418	8	0
Shark Research Fishery	2005-2019	0	1726	991	7	0
Pelagic Longline Observer Program	1992-2019	0	3195	297	108	0
	TOTAL	**1307**	**8986**	**2273**	**492**	**26**

Table 3. Fishery-independent data for possible use in the assessment. Age 0 refers to scalloped hammerheads (≤61 cm FL) and Age 1+ scalloped hammerheads refers to (≥62 cm FL). If not noted, ages are combined for species. Abbreviations are as follows: SHH = scalloped hammerheads, GHH = great hammerheads, SMH = smooth hammerheads, and CHH = Carolina hammerheads.

Data Source	Years of Coverage	Age 0 SHH	Age 1+ SHH	GHH	SMH	CHH
Northeast Gulf of Mexico (GULFSPAN) Gillnet Survey	1994-2019	1530	187	25	0	0
Texas Park and Wildlife Gillnet Survey	1982-2019	569	81	12	0	0
NOAA Fisheries						
Southeast Area Monitoring and Assessment Program (SEAMAP) Bottom Longline Survey	2008-2019	3	86	64	0	0
Northeast Fisheries Science Center (NEFSC) coastal shark bottom longline survey	1996-2018	0	251	8	0	0
Southeast Fisheries Science Center (SEFSC) Bottom Longline Survey	1995-2019	9	598	96	0	0
Cooperative Shark Tagging Program scientific trawl	1962-2019	5	7	0	0	0
Cooperative Shark Tagging Program scientific gillnet	1962-2019	173	19	0	0	0
Cooperative Shark Tagging Program scientific longline	1962-2019	168	1499	72	27	0
Cooperative Shark Tagging Program scientific rod and reel	1962-2019	6	13	7	5	0
Cooperative Shark Tagging Program scientific drumline	1962-2019	0	0	97	0	0
Cooperative Shark Tagging Program scientific handline	1962-2019	0	0	24	0	0
Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN)						
Long gillnet	2001-2019	1017	8	0	0	35
Short gillnet	2007-2019	34	0	0	0	0
Bottom longline	2000-2019	439	37	0	0	1
Georgia Department of Natural Resources (GADNR) SEAMAP	2007-2019	31	7	0	0	0
South Carolina Department of Natural Resources (SCDNR)						
Red drum longline	1995-2006	52	34	0	0	0
SEAMAP longline	2007-2019	34	12	7	0	0
Scientific Trawl	2006-2019	68	21	5	0	28
University of North Carolina Longline survey	1973-2019	8	498	0	0	0

Table 3. Continued.

Data Source	Years of Coverage	Age 0 SHH	Age 1+ SHH	GHH	SMH	CHH
Texas A&M University Corpus Christi						
Gillnet	2017-2018	9	0	0	0	0
Longline	2017-2018	3	0	0	0	0
Dauphin Island Sea Lab (DISL) Bottom Longline Survey	2006-2019	0	182*	68*	0	0
Florida State University Bottom Longline Survey	2011-2019	0	76	143	0	0
Rosenstiel School of Marine and Atmospheric Science Drumline Survey	2008-2019	0	17	203	0	0
Mote Marine Lab						
Longline	1992-2019	0	20	59	0	0
Drumline	1992-2019	0	8	70	0	0
Gillnet	1992-2019	76	5	99	0	0
	TOTAL	**4234**	**3656**	**1038**	**32**	**64**

Asterisk (*) indicates that 10 SHH and 21 GHH lengths from DISL were included in SEAMAP length composition summary to match the index development for SEAMAP, which included some DISL stations. Totals do not include these 31 animals.

6.6 Figures

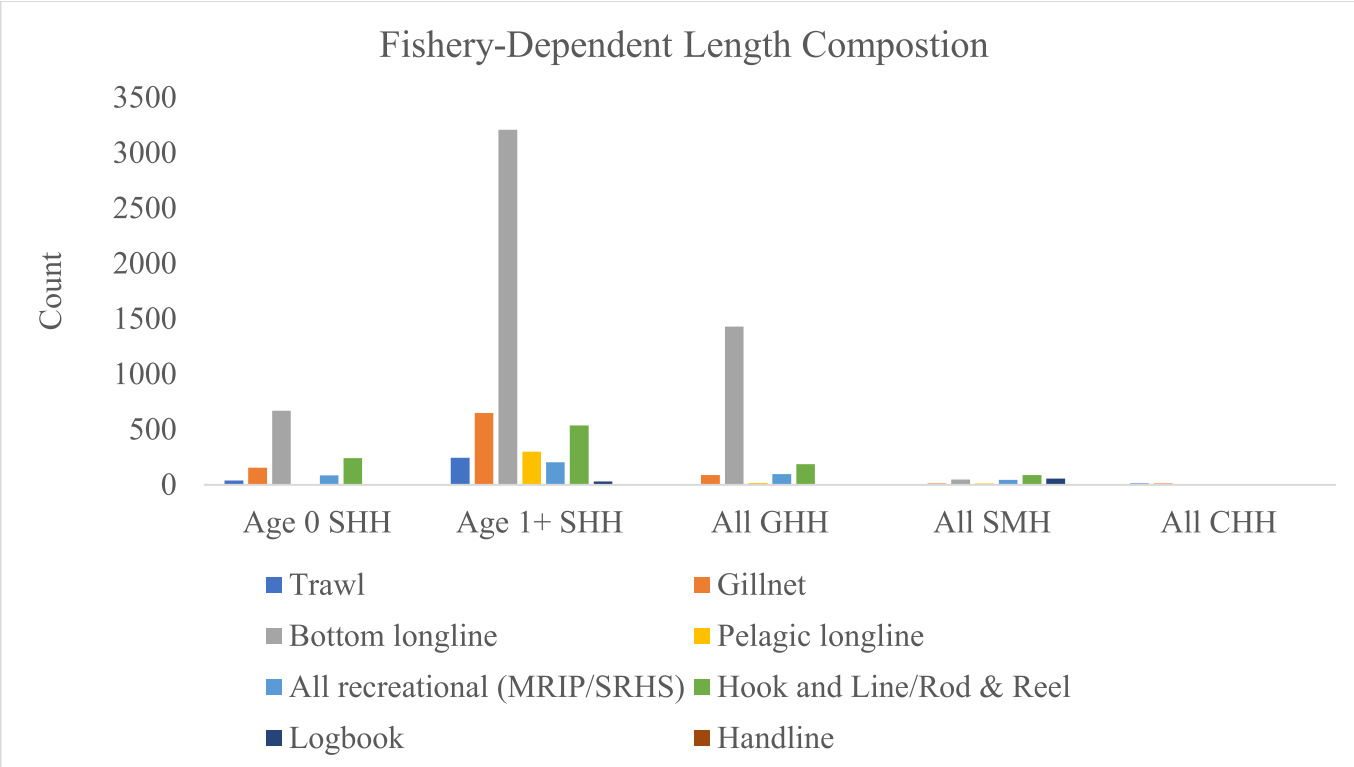

Figure 5. Length compositions for scalloped (SHH), great (GHH), smooth (SMH), and Carolina (CHH) hammerheads from fishery-dependent data sources. Gear types are summarized for combined Gulf of Mexico and Atlantic Ocean regions for each species. Ages are combined for GHH, SMH, and CHH.

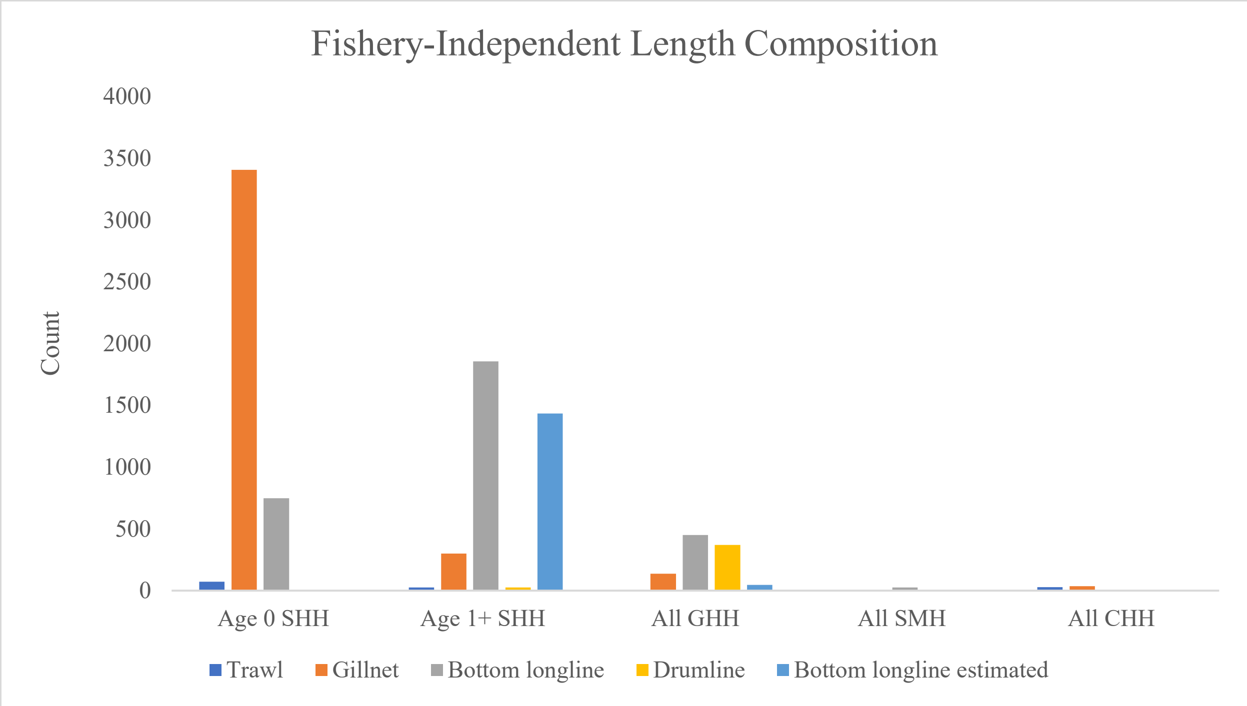

Figure 6. Length compositions for scalloped (SHH), great (GHH), smooth (SMH), and Carolina (CHH) hammerheads from fishery-independent data sources. Gear types are summarized for combined Gulf of Mexico and Atlantic Ocean regions for each species. Ages are combined for GHH, SMH, and CHH.

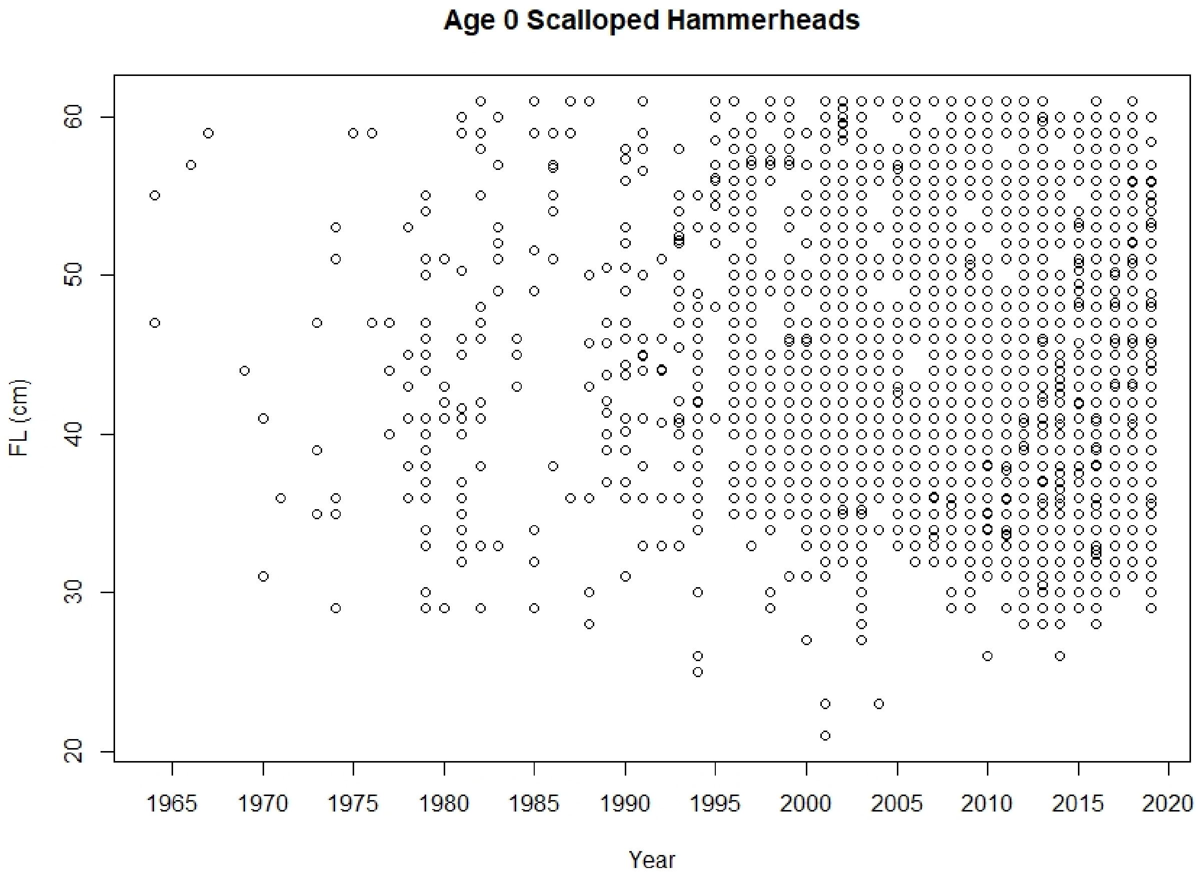

Figure 7. Length composition of Age 0 scalloped hammerheads across available years for potential use in the assessment. Fishery-dependent and independent data are combined.

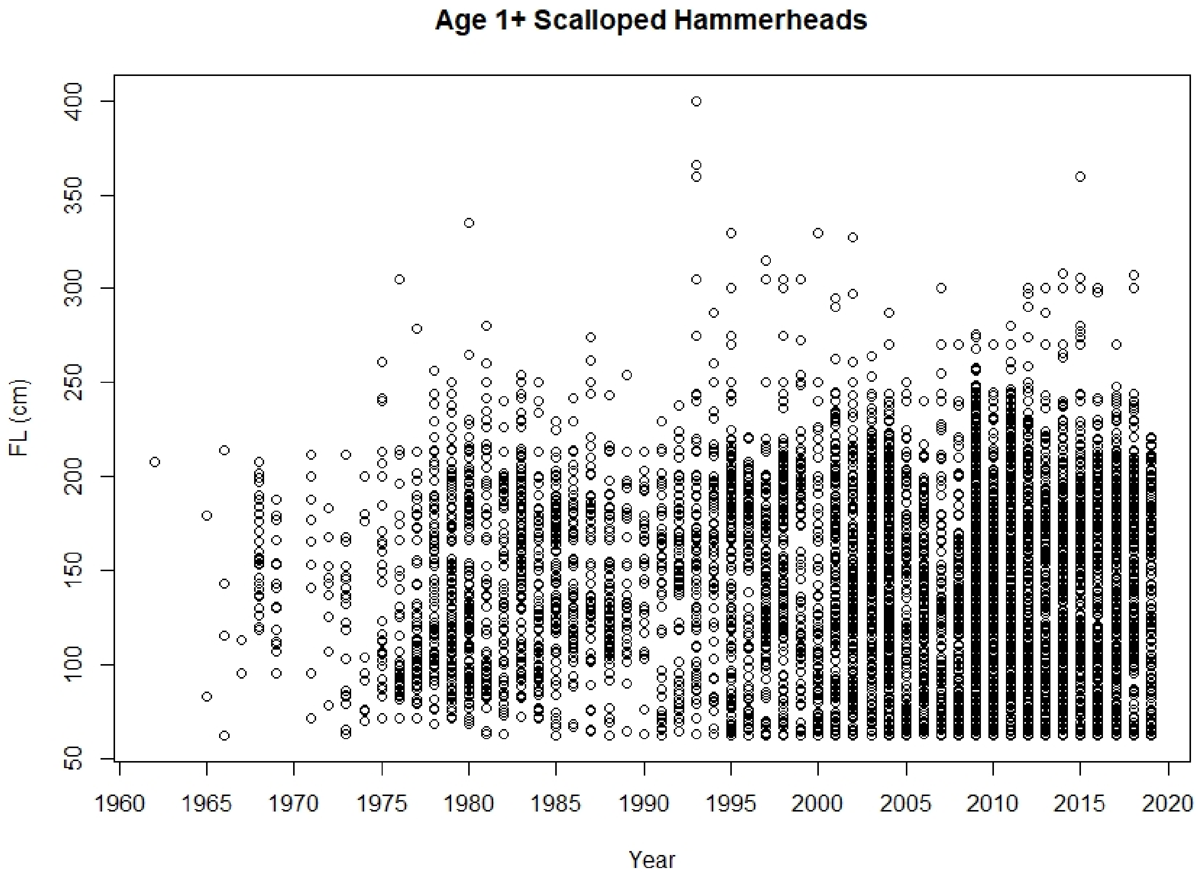

Figure 8. Length composition of Age 1+ scalloped hammerheads across available years for potential use in the assessment. Fishery-dependent and independent data are combined.

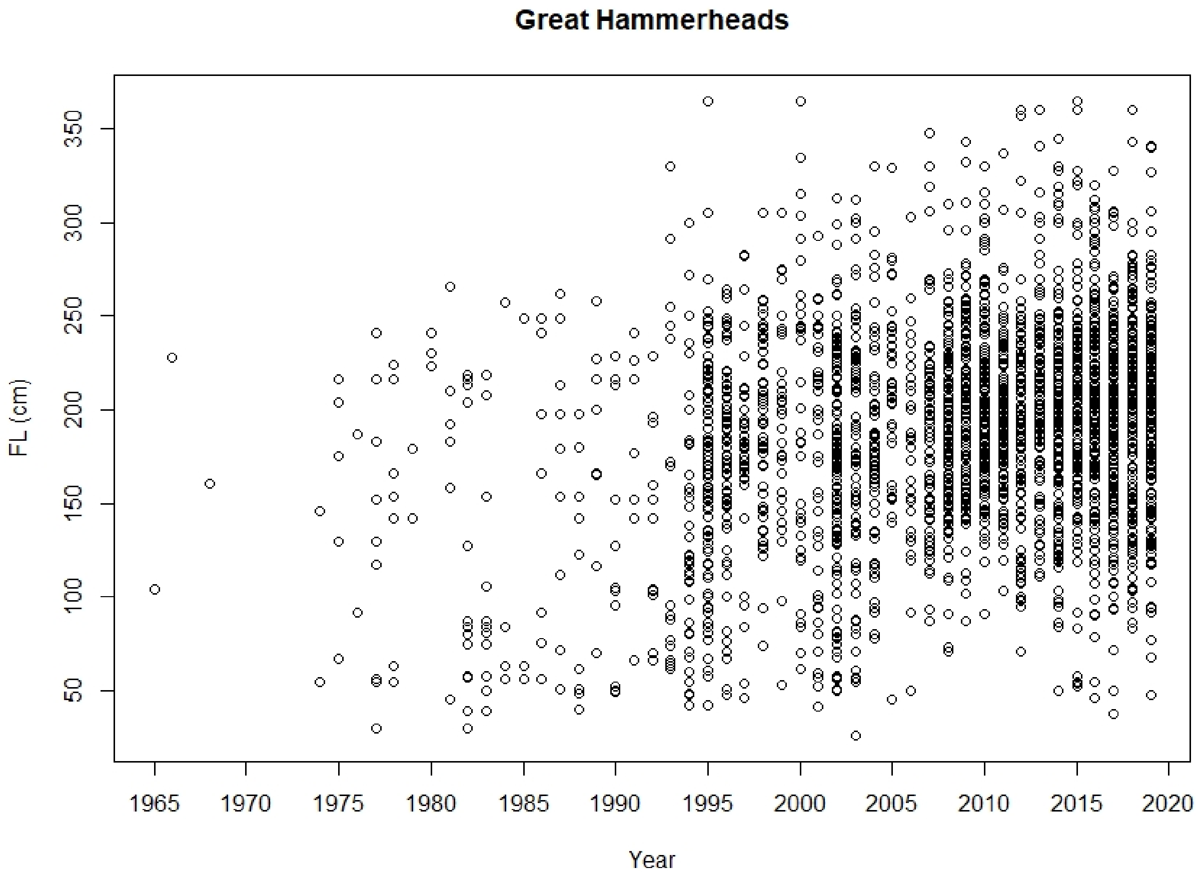

Figure 9. Length composition of combined ages of great hammerheads across available years for potential use in the assessment. Fishery-dependent and independent data are combined.

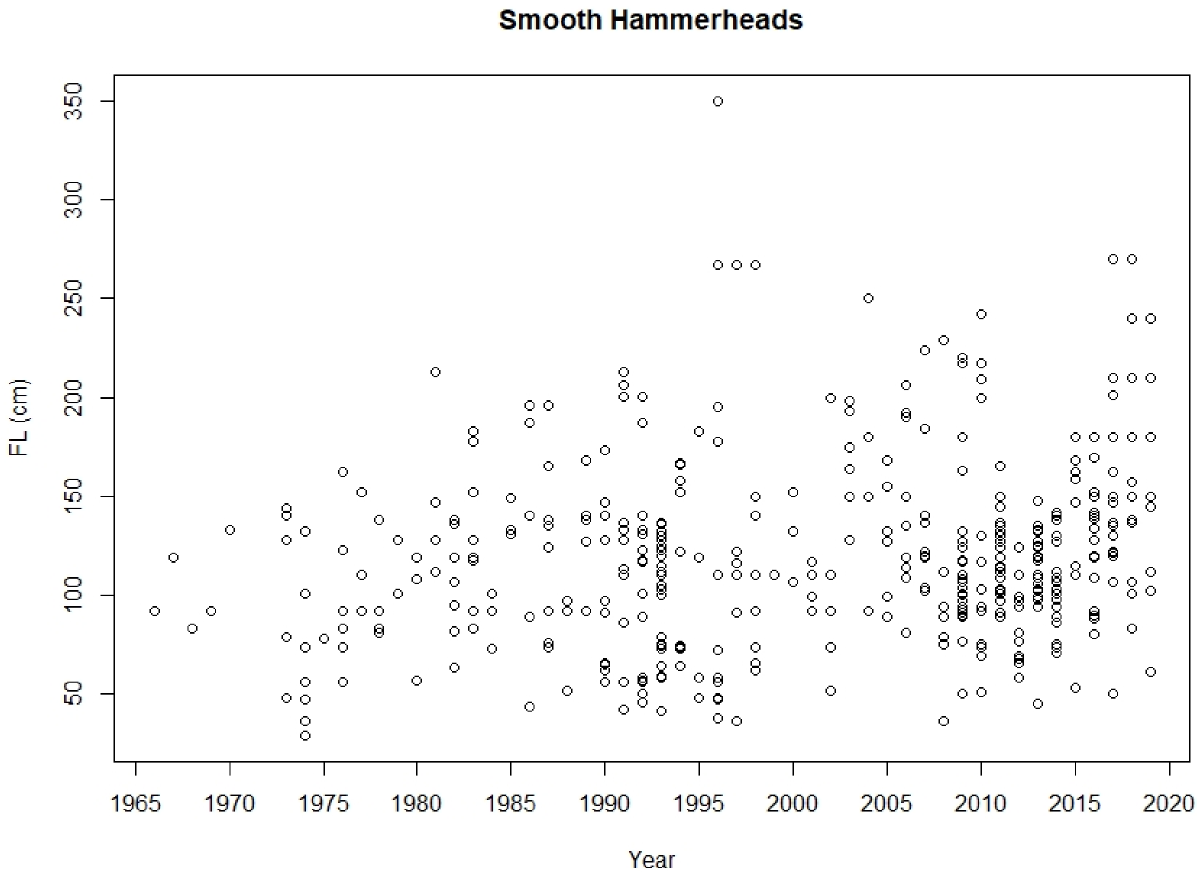

Figure 10. Length composition of combined ages of smooth hammerheads across available years for potential use in the assessment. Fishery-dependent and independent data are combined.

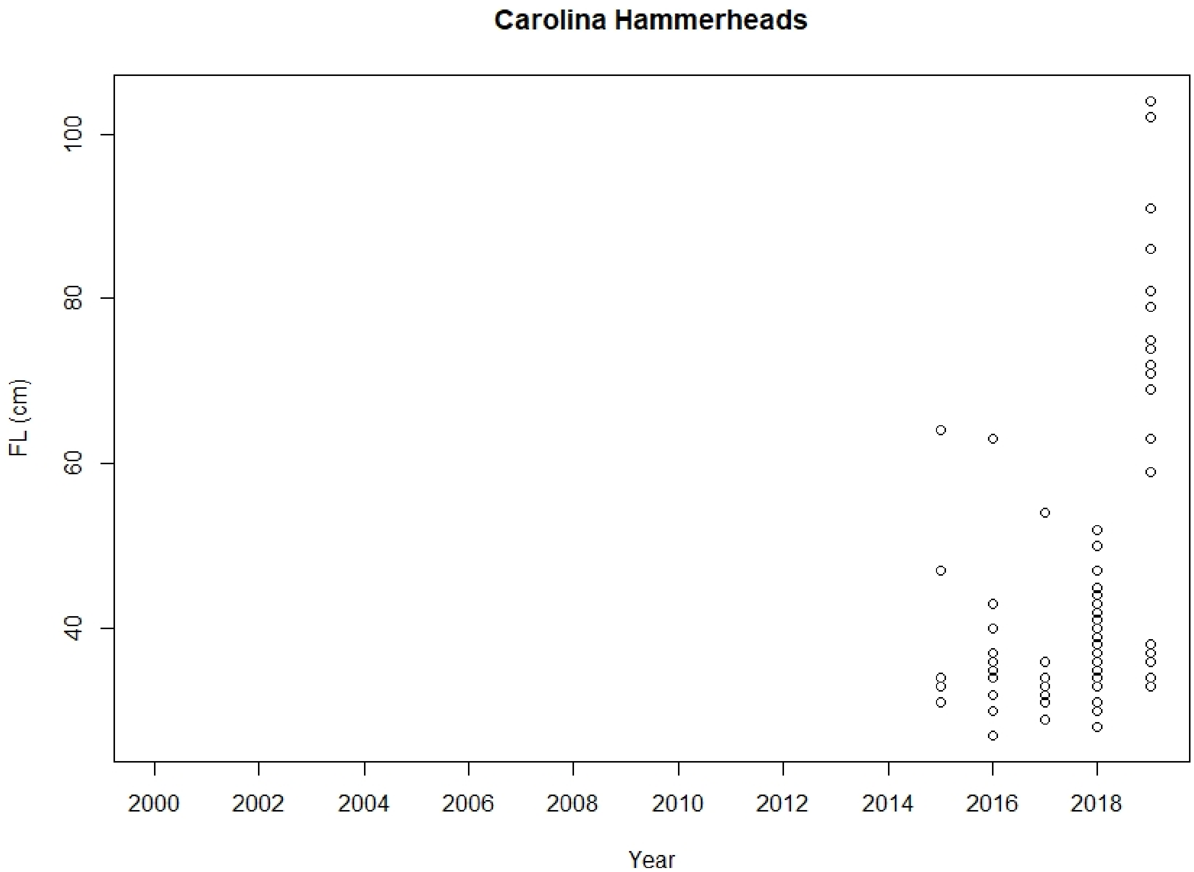

Figure 11. Length composition of combined ages of Carolina hammerheads across available years for potential use in the assessment. Fishery-dependent and independent data are combined.

Combined Gulf of Mexico and Atlantic Ocean Regions

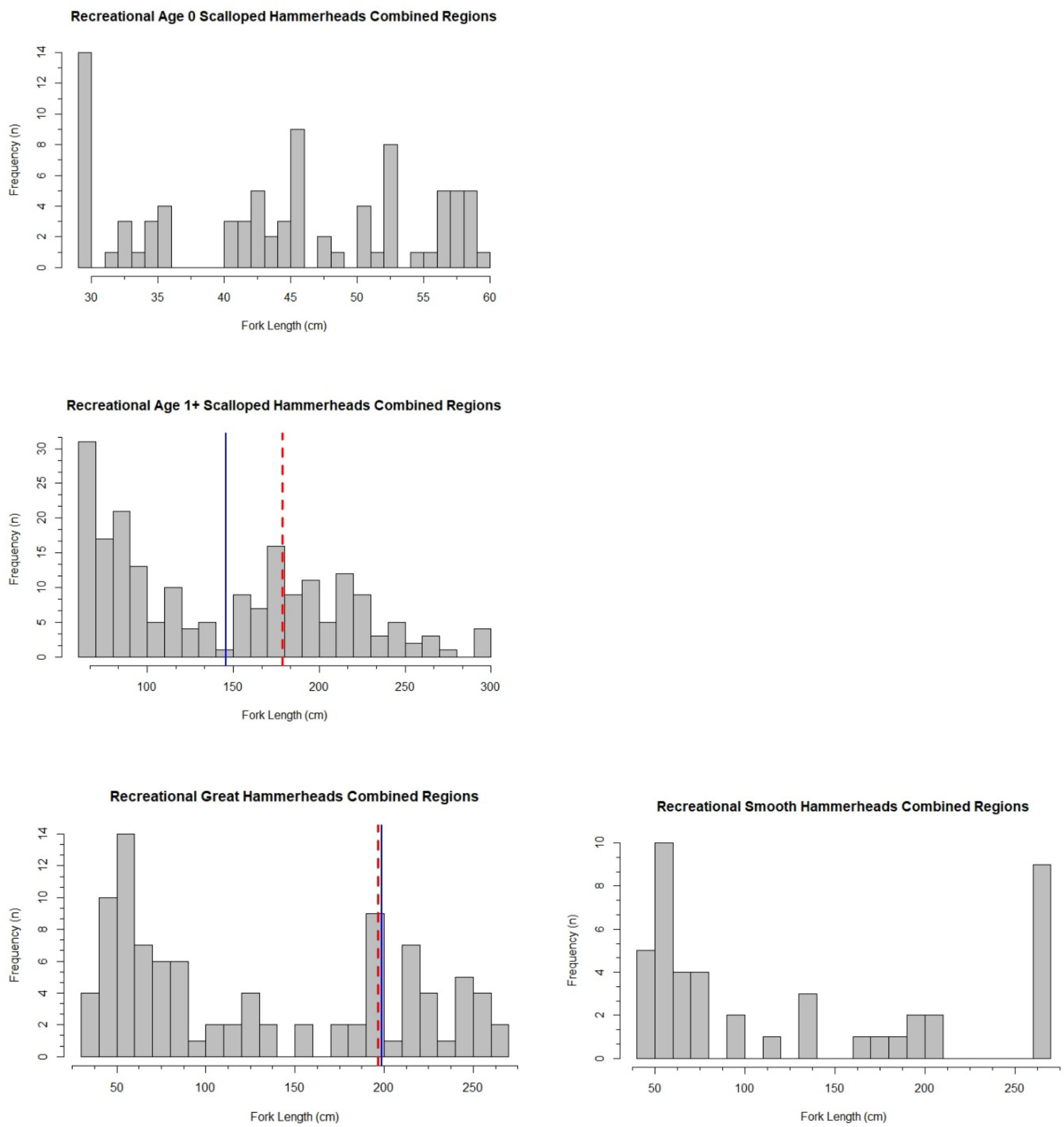

Figure 8. Recreational length composition data for hammerheads for the combined Gulf of Mexico and Atlantic Ocean regions.

Atlantic Ocean Region

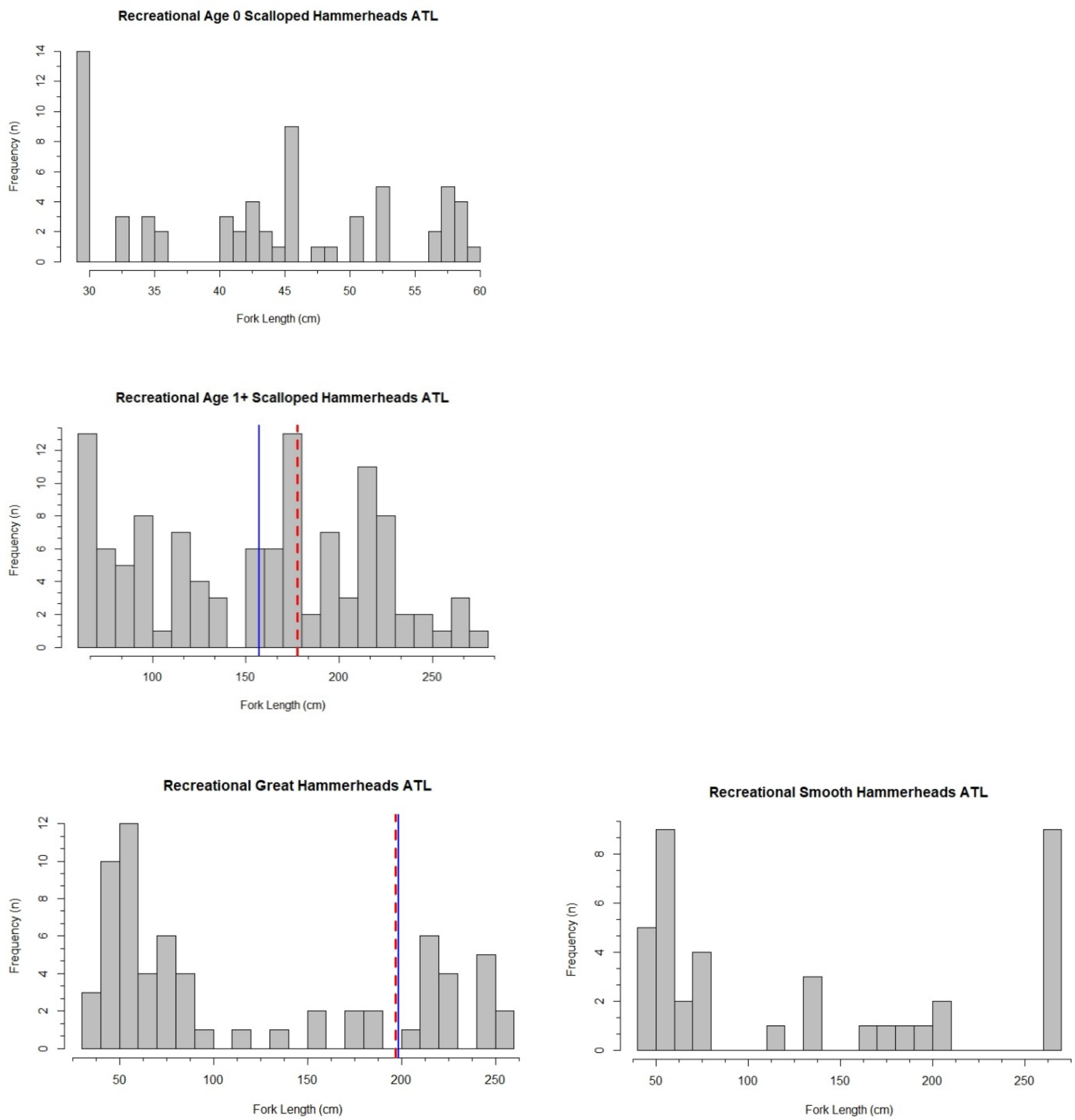

Figure 9. Recreational length composition data for hammerheads for the Atlantic Ocean region.

Gulf of Mexico Region

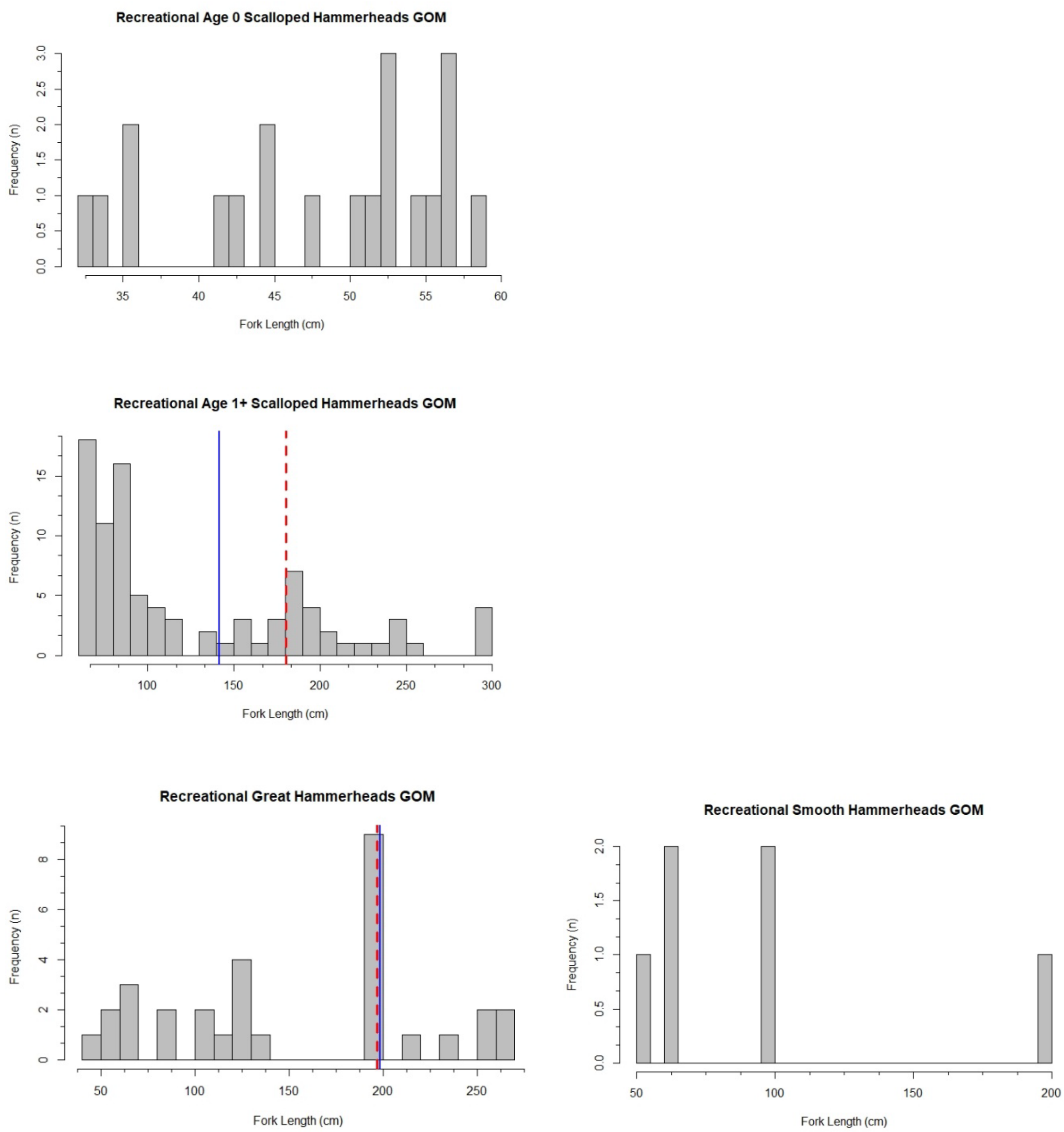

Figure 10. Recreational length composition data for hammerheads for the Gulf of Mexico region.

Combined Gulf of Mexico and Atlantic Ocean Regions

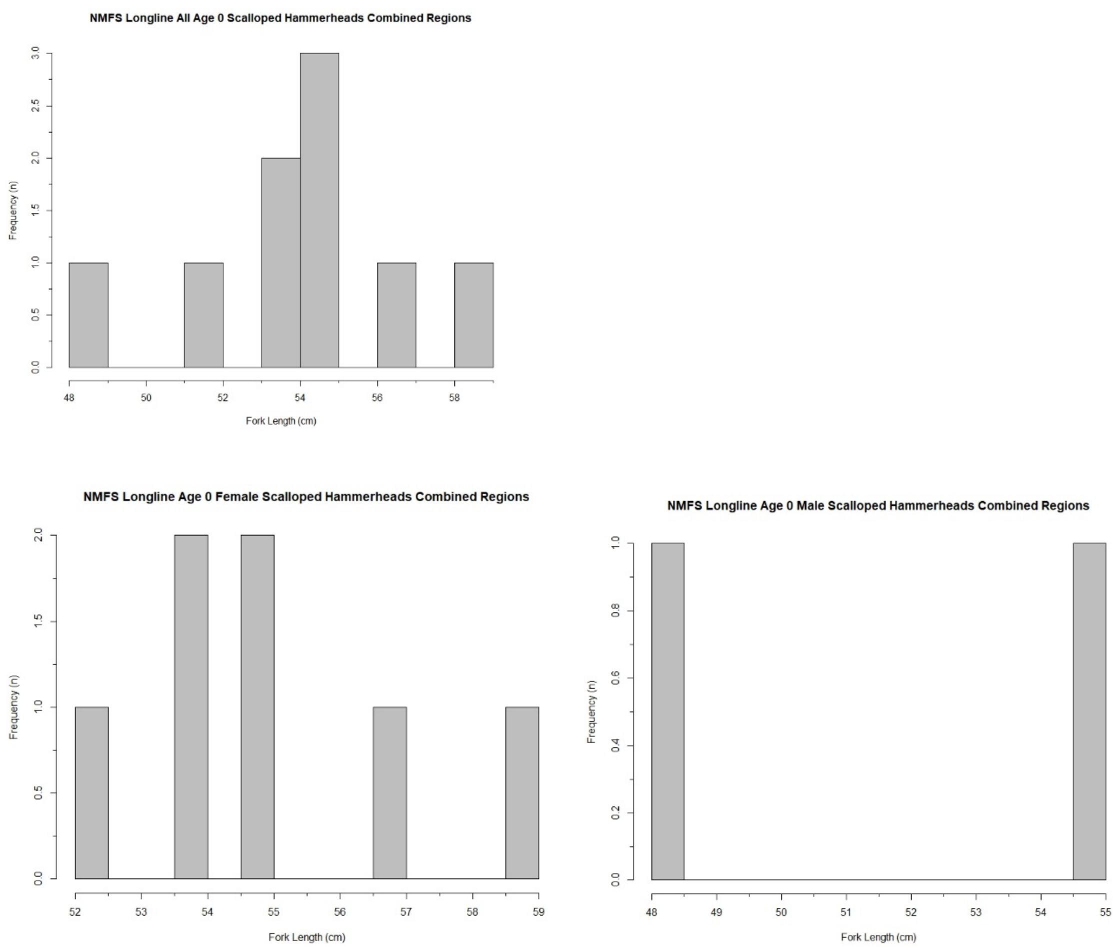

Figure 11. Fishery-independent bottom longline survey length composition data for Age 0 scalloped hammerheads for the combined Gulf of Mexico and Atlantic Ocean regions.

Combined Gulf of Mexico and Atlantic Ocean Regions

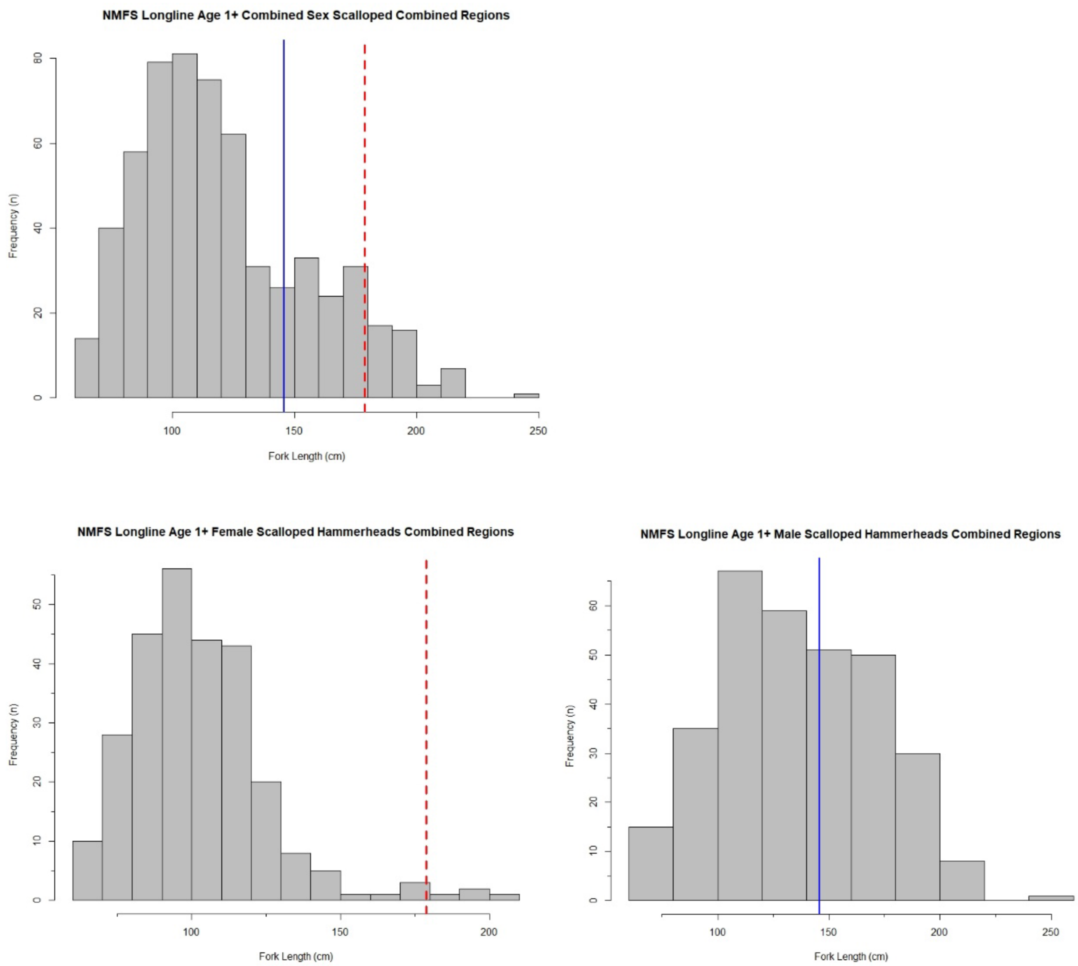

Figure 12. Fishery-independent bottom longline survey length composition data for Age 1+ scalloped hammerheads for the combined Gulf of Mexico and Atlantic Ocean regions.

Combined Gulf of Mexico and Atlantic Ocean Regions

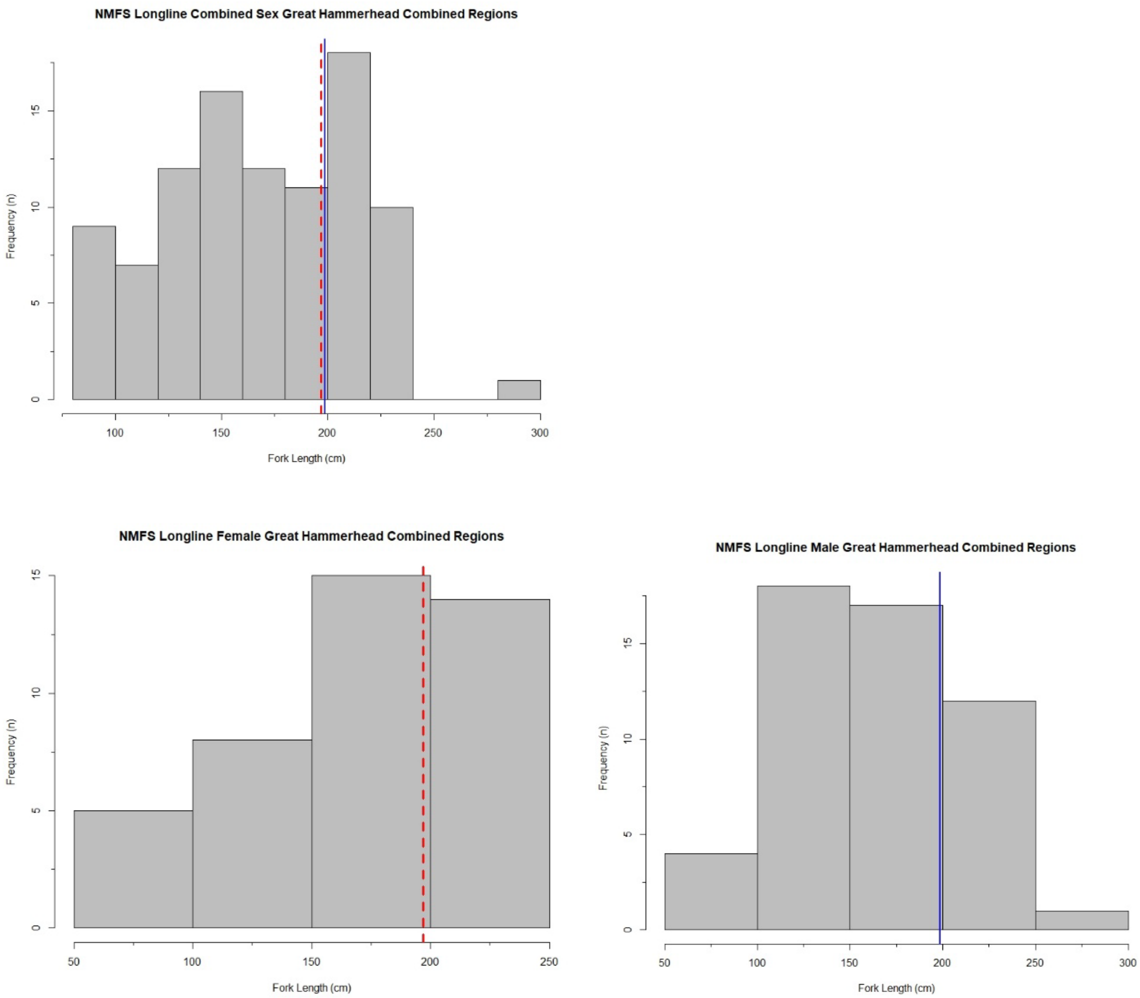

Figure 13. Fishery-independent bottom longline survey length composition data for great hammerheads for the combined Gulf of Mexico and Atlantic Ocean regions.

Atlantic Ocean Region

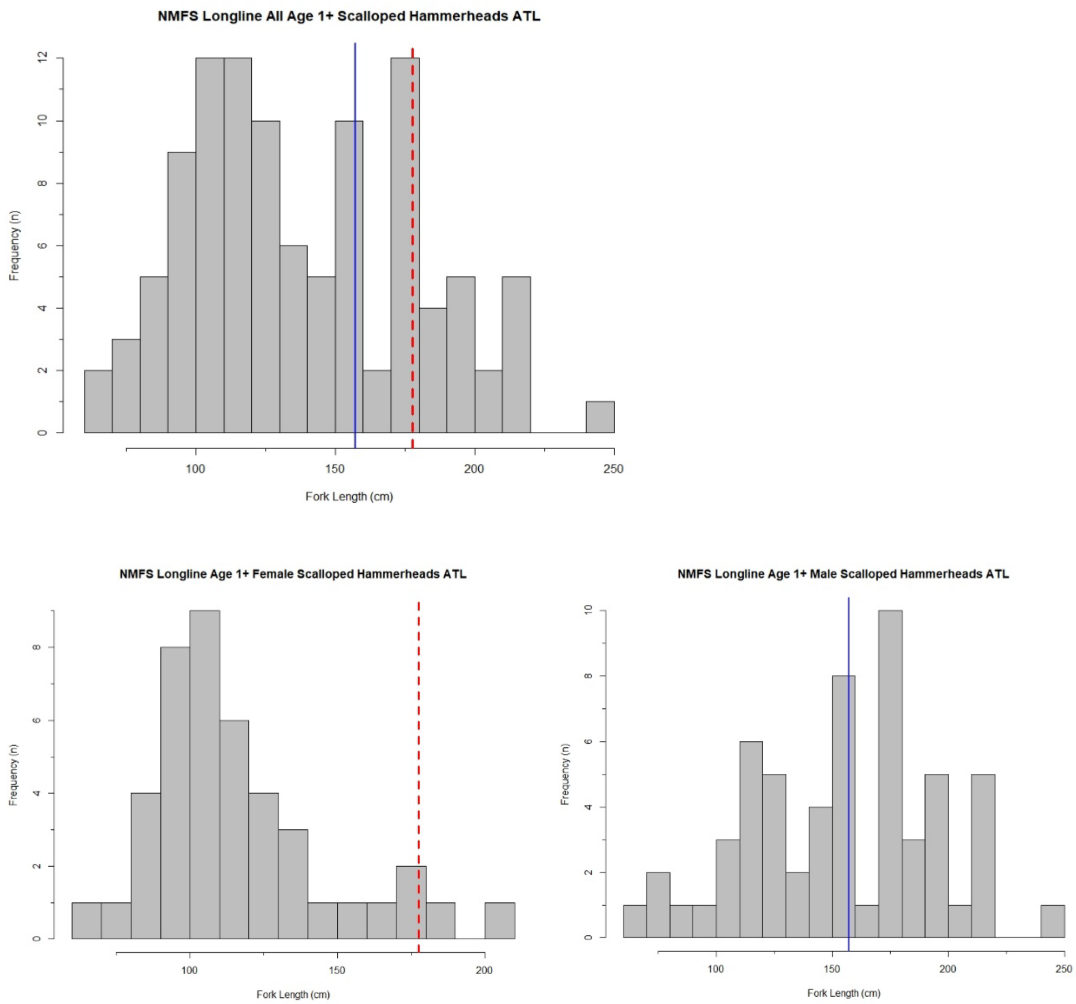

Figure 14. Fishery-independent bottom longline survey length composition data for Age 1+ scalloped hammerheads for the Atlantic Ocean region.

Gulf of Mexico Region

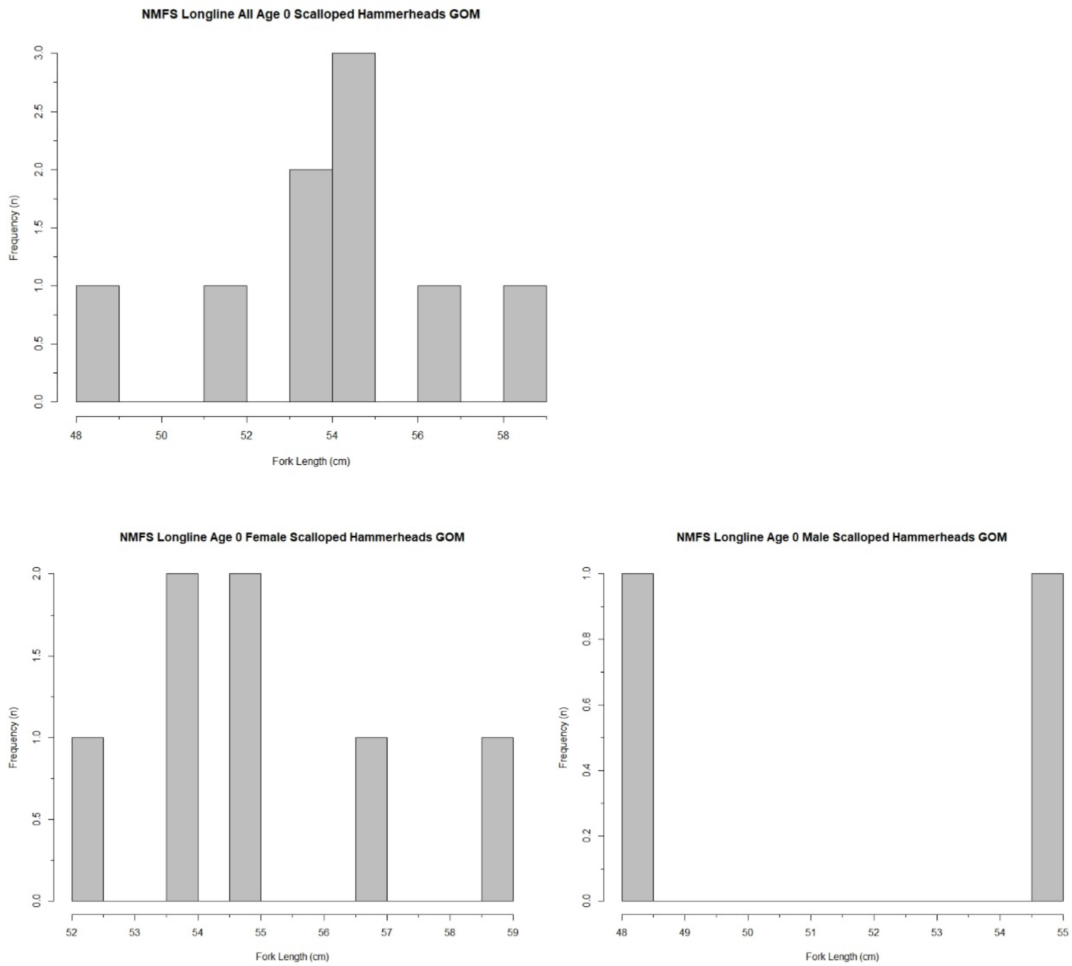

Figure 15. Fishery-independent bottom longline survey length composition data for Age 0 scalloped hammerheads for the Gulf of Mexico region.

Gulf of Mexico Region

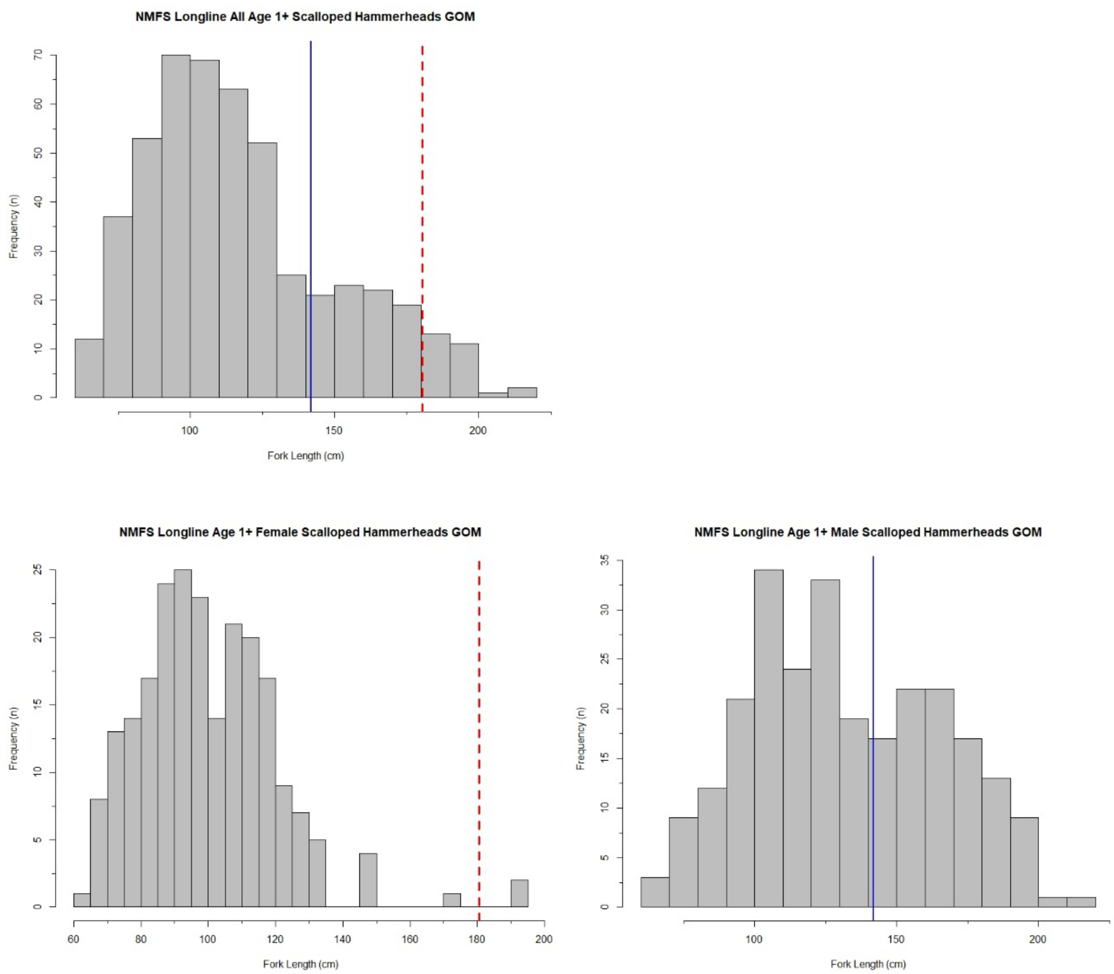

Figure 16. Fishery-independent bottom longline survey length composition data for Age 1+ scalloped hammerheads for the Gulf of Mexico region.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 77

HMS Hammerhead Sharks: Scalloped Hammerhead Shark

Section IVa: Assessment Report

June 2023

SEDAR

4055 Faber Place Drive, Suite 201 North Charleston, SC 29405

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1. INTRODUCTION

1.1 Workshop Time and Place

The SEDAR 77 Assessment Workshop was held via a series of webinars from May 2022 – March, 2023.

1.2 Terms of Reference

1. Review any changes in data or analyses following the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.
2. Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations (if necessary) for each model considered.
3. Identify preferred model approach if applicable.
4. Provide preliminary estimates of stock population parameters:
    a. Include fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship (if applicable), and other parameters as necessary to describe the population.
    b. Include appropriate measures of precision for parameter estimates.
5. Characterize uncertainty in the assessment and estimated values, if possible.
    a. Consider uncertainty in input data, modeling approach, and model configuration.
    b. Consider and include other sources of uncertainty as appropriate for this assessment.
    c. Provide appropriate measures of model performance, reliability, and 'goodness of fit'.
6. Provide preliminary estimates of population benchmarks or management criteria consistent with available FMPs and amendments, proposed FMPs and amendments, other ongoing or proposed management programs, and the National Standards.
    a. Evaluate existing or proposed management criteria as specified in the management summary.
    b. Recommend and define proxy values when necessary, and provide appropriate justification.
7. Recommend preliminary stock status relative to management benchmarks or alternative data-poor approaches if necessary.
8. Provide uncertainty distributions of proposed reference points and stock status metrics that provide the values indicated in the management specifications. Include probability

density functions for reference point estimates and population metrics (e.g., biomass and exploitation) used to evaluate stock status.

9. Project future stock conditions and develop rebuilding schedules, if warranted. Provide the estimated generation time for the stock. Stock projections shall be developed in accordance with the following:
    a. If the preliminary stock status is overfished, then utilize projections to determine:
        i. Year in which F=0 results in a 70% probability of rebuilding (Year $F=0_{p70}$).
        ii. Target rebuilding year ($Year_{rebuild}$).
            1. Year $F=0_{p70}$ if Year $F=0_{p70} \leq 10$ years, or
            2. Year $F=0_{p70}$ + 1 generation time if Year $F=0_{p70} > 10$ years.
        iii. F resulting in 50% and 70% probability of rebuilding by $Year_{rebuild}$.
        iv. Fixed level of removals allowing rebuilding of stock with 50% and 70% probability.
    b. If the preliminary stock status is determined to be undergoing overfishing, then utilize projections to determine:
        i. $F=F_{reduce}$ (different reductions in F that should end overfishing with a 50% and 70% probability).
    c. If the preliminary stock status is determined to be neither overfished nor undergoing overfishing, then utilize projections to determine:
        i. The F needed and corresponding removals associated with a 70% probability of overfishing not occurring (analogous to a P* = 0.3 approach), and/or
        ii. The constant catch associated with a 70% probability of overfishing not occurring and the stock not being overfished.
    d. If data limitations and/or model limitations preclude classic projections (i.e. a, b, and c above), explore alternate projection models.
10. Provide ABCs in accordance with HMS management needs.
11. Provide recommendations for future research and data collection. Emphasize items that will improve future assessment capabilities and reliability. Consider data, monitoring, and assessment needs.
12. Complete an Assessment Workshop Report in accordance with project schedule deadlines.

1.3 List of Participants

Participants	Affiliation
ADT	
Rob Latour	Virginia Institute of Marine Science, College of William And Mary
Beth Babcock	RSMAS University of Miami
John Carlson	SEFSC Panama City Laboratory
Trey Driggers	SEFSC Mississippi Laboratory
Dean Courtney	SEFSC Panama City Laboratory
Xinsheng Zhang	SEFSC Panama City Laboratory
Enric Cortés *	SEFSC Panama City Laboratory
Additional Panelists	
Eric Hoffmayer	SEFSC Mississippi Laboratory
Henning Winker	JRC European Commission
Felipe Carvalho	NOAA PIFSC
Joel Rice	Rice Marine Analytics
Staff	
Kathleen Howington	SEDAR
Karyl Brewster-Geisz	NMFS: HMS Management
Margaret Miller	NMFS
Adam Brame	NMFS
Other	
Adam Pollack	SEFSC Mississippi Laboratory
Andrea Kroetz	SEFSC Panama City Laboratory
Ann Williamson	NMFS
Becky Curtis	NMFS
Blaise Rohan	RSMAS University Of Miami
Cami Mccandless	NEFSC Narragansett Laboratory
Christina Vaeth	
Clifford Hutt	NMFS: HMS Management
Dean Grubbs	Florida State University Coastal and Marine Laboratory
Delisse Ortiz	NMFS
Hannah Medd	Shark Conservancy
Heather Baertlein	NMFS: HMS Management
Heather Moncrief-Cox	SEFSC Panama City Laboratory
Jason Cope	NMFS
Juan Carlos Pérez-Jiménez	El Colegio de la Frontera Sur (ECOSUR)
Leann Bosarge	GMFMC
Marcus Drymon	Mississippi State University
Max Lee	Mote Marine Laboratory
Michelle Passerotti	NEFSC Narragansett Laboratory
Neil Hammerschlag	RSMAS University of Miami
Orian Tzadik	NMFS
Tobey Curtis	NMFS
Willow Patten	NCDMF

*Enric Cortés retired on December 31, 2022

1.4 Document List

Working Papers			
SEDAR77-AW01	Exploratory analysis of U.S Atlantic and Gulf of Mexico scalloped hammerhead recruitment indices	Henning Winker	5/27/2022
SEDAR77-AW02	Hierarchical analyses of U.S. Atlantic and Gulf of Mexico scalloped hammerhead recruitment indices	Camilla T. McCandless and John K. Carlson	5/31/2022
SEDAR77-AW03		Cami McCandless	Not Received
SEDAR77-AW04	Estimates of vital rates and population dynamics parameters of interest for hammerhead sharks (*Sphyrna lewini, S. mokarran, and S. zygaena*) in the western North Atlantic Ocean	Enric Cortés	6/17/2022
SEDAR77-AW05	Reconciling age-0 indices of relative abundance of the U.S. Atlantic and Gulf of Mexico scalloped hammerhead (*Sphyrna lewini*)	Dean Courtney, Robert J. Latour, and Cassidy D. Peterson	6/20/2022
SEDAR77-AW06	Fishpath Questions	Enric Cortés	9/21/2022
SEDAR77-AW07	Selected FishPath Results for Smooth hammerhead shark, U.S. Atlantic and Gulf of Mexico	Enric Cortés	9/21/2022
SEDAR77-AW08	Selected FishPath Results for Smooth hammerhead shark, U.S. Atlantic and Gulf of Mexico: Narrowed	Enric Cortés	9/21/2022

Reference Documents			
SEDAR77-RD49	Stock Assessment of Scalloped Hammerheads in the Western North Atlantic Ocean and Gulf of Mexico	Christopher G. Hayes, Yan Jiao, and Enric Cortés	11/30/2020
SEDAR77-RD50	Poor-data and data-poor species stock assessment using a Bayesian hierarchical approach	Yan Jiao, Enric Cortés, Kate Andrews, And Feng Guo	11/30/2020
SEDAR77-RD51	Hierarchical Bayesian approach for population dynamics modelling of fish complexes without species-specific data	Yan Jiao, Christopher Hayes, and Enric Cortés	11/30/2020
SEDAR77-RD52	Highly migratory species predictive spatial modeling (PRiSM): an analytical framework for assessing the performance of spatial fisheries management	Daniel P. Crear, Tobey H. Curtis, Stephen J. Durkee, John K. Carlson	5/26/2022
SEDAR77-RD53	Dynamic factor analysis to reconcile conflicting survey indices of abundance	Cassidy D. Peterson, Michael J. Wilberg, Enric Cortés, and Robert J. Latour	5/26/2022
SEDAR77-RD54	SEDAR 65 - AW03: Reconciling indices of relative abundance of the Atlantic blacktip shark (*Carcharhinus limbatus*)	Robert J. Latour and Cassidy D. Peterson	5/31/2022

1.5 Statement addressing each term of reference

1. *Review any changes in data or analyses following the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.*

The data used in the assessment are summarized in Section 2 (Data Review and Update). Vital rates (steepness and natural mortality) are obtained from SEDAR77-AW04 (Cortés 2022) developed from life history data provided in the Data Workshop.

2. *Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations (if necessary) for each model considered.*

Stock Synthesis is implemented as the population assessment model based on its compatibility with the available data and its use in several previous shark stock assessments as summarized in Section 3.1. Input data are provided in Section 3.2 (Data Sources). Model configuration is described in Section 3.3 (Model Configuration and Equations).

3. *Identify preferred model approach if applicable.*

See the statement addressing TOR 2.

4. *Provide preliminary estimates of stock population parameters:*
    a. *Include fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship (if applicable), and other parameters as necessary to describe the population.*
    b. *Include appropriate measures of precision for parameter estimates.*

Preliminary stock population parameters are provided in Section 4 (Results).

Precision of estimated and derived parameters is obtained from Stock Synthesis AD-Model Builder (ADMB) output as the asymptotic parameter standard deviations (SD) at the converged solution (Fournier et al. 2011) as described in Section 3.3.1.11 (Uncertainty and Measures of Precision).

5. *Characterize uncertainty in the assessment and estimated values, if possible.*
    a. *Consider uncertainty in input data, modeling approach, and model configuration.*

Two sensitivity analyses were completed, one for the Gulf of Mexico (GOM) and the other for the Atlantic (ATL). In response to the presence of a cryptic hammerhead species in the Atlantic region (Carolina hammerhead), the Stock ID Process recommended conducting sensitivity analyses to the scalloped hammerhead assessment for data inputs separately by geographic region for the GOM and the ATL. Consequently, Stock Synthesis models were fit to data inputs provided separately in the GOM and ATL regions for catch (see Section 2.1.4 Sensitivity Analyses and see Section 3.2.1.4 Sensitivity Analyses for Catches), indices of abundance (see Section 2.2.2 Sensitivity Analyses and see Section 3.2.1 Indices of Abundance Sensitivity Analyses), length composition (see Section 2.4.1 Sensitivity Analyses and see Section 3.2.4.1 Length Composition Sensitivity Analyses), and life history (see Section 2.3.2 Sensitivity Analyses and Section 3.2.3.1 Life History Analyses).

Results of the GOM and ATL sensitivity analyses are provided in Section 3.4.4 Sensitivity Analyses (see Section 3.11 **Appendix 3.B** and see Section 3.12 **Appendix 3.C**). However, both sensitivity analysis model configurations failed to pass multiple convergence criteria. A hypothesis provided for the lack of model convergence is that the limited data in both the GOM or the ATL model configurations may not be sufficiently informative to estimate the absolute scale (size) of the population, catchability, and selectivity simultaneously.

b. *Consider and include other sources of uncertainty as appropriate for this assessment.*

Other sensitivity analyses were not conducted due to time constraints.

c. *Provide appropriate measures of model performance, reliability, and 'goodness of fit'.*

Diagnostic results implemented for the Stock Synthesis GOM+ATL continuity analysis model configuration are provided in Section 3.4.5 Diagnostics (see Section 3.14 **Appendix 3.D)**.

6. *Provide preliminary estimates of population benchmarks or management criteria consistent with available FMPs and amendments, proposed FMPs and amendments, other ongoing or proposed management programs, and the National Standards.*

a. *Evaluate existing or proposed management criteria as specified in the management summary.*
b. *Recommend and define proxy values when necessary, and provide appropriate justification.*

Preliminary estimates of population benchmarks are provided in Section 3.4.6 (Benchmarks and Reference Points).

7. *Recommend preliminary stock status relative to management benchmarks or alternative data-poor approaches if necessary.*

The Stock Synthesis reference case (GOM + ATL) model configuration, defined here as a provisional base model configuration, predicted that the stock was not overfished (SSF_{2019} > MSST) and that the stock was not experiencing overfishing ($F_{2019} > F_{MSY}$) in the terminal year of the assessment (see Section 3.4.6 Benchmarks and Reference Points; see **Tables 3.10** and **3.11**; and see **Figures 3.9** and **3.10**).

8. *Provide uncertainty distributions of proposed reference points and stock status metrics that provide the values indicated in the management specifications. Include probability density functions for reference point estimates and population metrics (e.g., biomass and exploitation) used to evaluate stock status.*

A multivariate log-normal Monte-Carlo approach (MVLN; Winker et al 2019; e.g., Walter and Winker 2020) was applied to the Stock Synthesis (GOM + ATL) continuity analysis model configuration to estimate uncertainty about the stock status as described in Section 3.13 (**Appendix 3.D)**.

9. *Project future stock conditions and develop rebuilding schedules, if warranted. Provide the estimated generation time for the stock. Stock projections shall be developed in accordance with the following:*
   a. *If the preliminary stock status is overfished, then utilize projections to determine:*
      i. *Year in which F=0 results in a 70% probability of rebuilding (Year $F=0_{p70}$).*
      ii. *Target rebuilding year ($Year_{rebuild}$).*
         1. *Year $F=0_{p70}$ if Year $F=0_{p70} \leq 10$ years, or*
         2. *Year $F=0_{p70}$ + 1 generation time if Year $F=0_{p70}$ > 10 years.*
      iii. *F resulting in 50% and 70% probability of rebuilding by $Year_{rebuild}$.*
      iv. *Fixed level of removals allowing rebuilding of stock with 50% and 70% probability.*

- *b. If the preliminary stock status is determined to be undergoing overfishing, then utilize projections to determine:*
  - *i. $F=F_{reduce}$ (different reductions in F that should end overfishing with a 50% and 70% probability).*
- *c. If the preliminary stock status is determined to be neither overfished nor undergoing overfishing, then utilize projections to determine:*
  - *i. The F needed and corresponding removals associated with a 70% probability of overfishing not occurring (analogous to a P* = 0.3 approach), and/or*
  - *ii. The constant catch associated with a 70% probability of overfishing not occurring and the stock not being overfished.*
- *d. If data limitations and/or model limitations preclude classic projections (i.e. a, b, and c above), explore alternate projection models.*

Examples of projected fishery removals at the overfishing limit (OFL) were obtained for the Stock Synthesis reference case (GOM + ATL) model configuration as described in Sections 3.3.1.14, 3.4.7, and 3.14 (**Appendix 3.E)**. Examples of projected OFL during the years 2020 – 2025 were obtained from Stock Synthesis projections at F_{MSY} based on the underlying population dynamics assumed during the projection period as described in Sections 3.4.7 and 3.14.

10. Provide ABCs in accordance with HMS management needs.

Examples of ABC reductions from OFL were obtained for the Stock Synthesis reference case (GOM + ATL) model configuration and are described in Sections 3.3.1.14 and 3.14 (**Appendix 3.E)**. Examples of average annual ABC during the years 2023, 2024, and 2025 were obtained by using an ABC/OFL map (ABC = 80.4% of average OFL; Courtney and Rice 2023), where average OFL was computed as the average of projected annual OFL obtained during the years 2023, 2024, and 2025, as described in Sections 3.4.7 and 3.14.

11. Provide recommendations for future research and data collection. Emphasize items that will improve future assessment capabilities and reliability. Consider data, monitoring, and assessment needs.

See Section 3.6 (Recommendations for Future Research and Data Collection).

12. Complete an Assessment Workshop Report in accordance with project schedule *deadlines.*

This document is the Assessment Workshop Report completed in accordance with project schedule deadlines.

2. DATA REVIEW AND UPDATE

2.1 Catches

2.1.1 Total Commercial Catch

Total commercial catches of scalloped hammerheads were obtained for the period 1981 – 2019 from the SEDAR 77 DW Report (their section 3, Tables 36, 38, and 40) in pounds dressed weight (lb dw), converted to kilograms whole weight (kg ww) using conversion ratios obtained from the DW for each data source (Pers. Comm. E. Cortés, July 2022; **Table 2.1**) and entered in Stock Synthesis in units of metric tons (where one mt = 1,000 kg; **Table 2.1**).

2.1.2 Total Recreational Catch

Total recreational catches of scalloped hammerheads were obtained for the period 1981 – 2019 from the SEDAR 77 DW Report (their section 3, Tables 37, 39, and 41) in numbers (thousands; **Table 2.2**). Recreational catches were obtained as the sum of type A (number of fish killed or kept seen by the interviewer) plus type B1 (number of fish killed or kept reported to the interviewer by the angler). Recreational live post-release mortality (LPRM) was obtained as type B2 (number of fish released alive reported by the fisher) multiplied by the assumed post-release mortality rate.

2.1.3 Commercial Discards

Commercial discards were included in the reference case total commercial catches of scalloped hammerheads obtained for the period 1981 – 2019 from the SEDAR 77 DW Report (their section 3, Tables 36, 38, and 40) and reported here in (**Table 2.1**).

2.1.4 Sensitivity Analyses

Gulf of Mexico and Atlantic

In response to the presence of a cryptic hammerhead species in the Atlantic region (Carolina hammerhead), the Stock ID Process recommended conducting sensitivity analyses to the scalloped hammerhead assessment for data inputs separately by geographic region for the GOM and the ATL. Consequently, separate data inputs were provided in the DW for catch in the Gulf of Mexico (**Table 2.1**, Panel B) and Atlantic (**Table 2.1**, Panel C) regions.

2.2 Indices of Abundance

2.2.1 Indices of Abundance Recommended by the DW

All indices of abundance recommended by the DW for use in the stock assessment model are described in the DW report and the associated DW working papers and are summarized here in **Tables 2.3** and **2.4**. Unless noted otherwise below, all indices were standardized using generalized linear models in a two-step delta-lognormal approach that modeled the proportion of positive catch with a binomial error distribution separately from the positive catch, which was modeled using a lognormal distribution as described in the associated DW working papers identified below. The SEDAR77 DW papers identified **Tables 2.3** and **2.4** are referenced in the first section of the DW (List of Data Workshop Working Papers).

2.2.2 Sensitivity Analyses

Gulf of Mexico and Atlantic

Separate data inputs were provided in the DW for indices of abundance in the GOM (**Table 2.3**, Panel B; **Table 2.4**) and the ATL (**Table 2.3**, Panel C; **Table 2.4**) regions.

2.3 Life History Inputs

Life history data used in the stock assessment model were obtained directly from the DW report (Data Workshop Report Section 2 Life History, their Tables 1 and 6) and were unchanged for use in the scalloped hammerhead stock assessment unless noted otherwise below.

2.3.1 Estimates of Vital Rates

Assessment document SEDAR77-AW04 (Cortés 2022) developed vital rates and population dynamics parameters including Beverton-Holt stock-recruitment steepness (*h*) and natural mortality based on biological information provided in the Data Workshop Report. For the combined regions (GOM + ATL), the median steepness value (0.69), along with approximate lower and upper confidence limits computed as the 2.5th and 97.5th percentiles (LCL = 0.44 and UCL = 0.87) obtained from Monte Carlo simulation of vital rates with a Leslie matrix approach were recommended by the author for use in the Stock Synthesis base, low, and high productivity states of nature sensitivity analyses, respectively (Cortés 2022, his Table 8, Panel A; Pers. Comm. E. Cortés, July 2022).

Mean estimates of instantaneous natural mortality rates (yr^{-1}) were obtained from six life-history invariant estimators (Cortés 2022, his Tables 1 – 3 and 6; Pers. Comm. E. Cortés, July 2022) for use in the reference case Stock Synthesis model (areas combined GOM+ATL; **Table 2.5 Panel A**).

2.3.2 Sensitivity Analyses

Gulf of Mexico and Atlantic Stock Recruit Steepness

Median steepness values of 0.71 (Cortés 2022, his Table 8, Panel B) and 0.67 (Cortés 2022, his Table 8, Panel C) were obtained for use in the Stock Synthesis GOM and ATL sensitivity analyses, respectively, along with approximate lower and upper confidence limits for the GOM (LCL = 0.37 and UCL = 0.89) and ATL (LCL = 0.41 and UCL = 0.86).

Gulf of Mexico and Atlantic Natural Mortality

Mean estimates of instantaneous natural mortality rates (yr^{-1}) obtained with six life-history invariant estimators used in the Euler-Lotka and Leslie matrix approaches (Cortés 2022, his Tables 1 – 3 and 6; Pers. Comm. E. Cortés, July 2022) were obtained separately for use in the GOM and ATL regional sensitivity analyses (**Table 2.5** Panels B and C).

Deterministic Natural Mortality

Additionally, estimates of instantaneous natural mortality rates (yr^{-1}) obtained with the Dureuil et al. (2021) length-based method (Cortés 2022, his Tables 1 – 3 and 6; Pers. Comm. E. Cortés, July 2022) were obtained for use in an areas combined sensitivity analysis (GOM+ATL; **Table 2.5** Panel A) and in separate GOM and ATL regional sensitivity analyses (**Table 2.5** Panels B and C).

Low and High Productivity

Low and high productivity states of nature sensitivity analyses were not evaluated due to time constraints.

Natural Mortality

Estimates of instantaneous natural mortality rates (yr^{-1}) obtained with the Dureuil et al. (2021) method, as described below, were not evaluated with sensitivity analysis due to time constraints.

2.4 Length Composition Data

A review of the available length composition data is provided in the Data Workshop Report (Section 6. Length Composition). Length composition data sets used in the Stock Synthesis stock assessment model(s) are discussed in more detail below in Section 3.

2.4.1 Sensitivity Analyses

Separate Gulf of Mexico and Atlantic Stocks

Length composition data sets associated with separate GOM and ATL stocks were obtained from the review of available length composition data provided in the Data Workshop Report (Section 6. Length Composition). Length composition data sets used in the GOM and ATL Stock Synthesis regional sensitivity analyses model runs are discussed in more detail below in Section 3.

2.5 Tables

Table 2.1. Total commercial catches of scalloped hammerheads in weight (mt ww) adapted from SEDAR 77 DW Report (their section 3, Tables 36, 38, and 40) using conversion ratios obtained from the DW for each data source (Pers. Comm. E. Cortés, July 2022).

A. Areas Combined (GOM + ATL)

Year	Bottom longline (total catch)	Gillnet (total catch)	Hook and line + hand line (total catch)	Pelagic longline (dead discards)
1981	0.0000	0.0000	0.0000	0.0000
1982	12.6696	2.9262	0.0553	10.4877
1983	25.3392	5.8899	0.1106	21.2282
1984	38.0088	8.7995	0.1658	31.7159
1985	50.6784	11.7582	0.2211	42.2036
1986	63.3480	14.7285	0.2764	52.6914
1987	76.0176	17.7917	0.3317	77.4356
1988	88.6871	20.7736	0.3870	252.0608
1989	101.3567	24.6498	0.4422	117.0324
1990	114.0263	27.9747	0.4975	149.6706
1991	50.0113	48.4981	0.0763	102.0339
1992	144.6921	31.5849	0.5751	371.7588
1993	187.9606	18.4732	1.0070	41.0122
1994	320.6698	15.9182	27.1928	42.3501
1995	204.3716	13.9147	6.5526	82.2492
1996	174.5224	19.3441	6.7826	14.2441
1997	54.3142	17.7101	0.1479	44.2171
1998	60.1862	18.3182	0.8017	43.4163
1999	68.1631	14.7485	6.1180	37.0474
2000	44.0074	13.2471	0.2444	42.4813
2001	39.9188	12.4268	0.7454	51.0720
2002	61.4934	6.3666	1.7396	40.5345
2003	77.5295	29.9690	0.4577	40.5345
2004	58.4247	16.6344	1.6960	40.5345
2005	55.9120	6.2334	1.4789	40.5345
2006	58.4108	9.7109	0.1359	40.5345
2007	13.9540	7.2669	0.0526	88.7442
2008	18.4335	48.7514	0.4973	57.9844
2009	48.6432	13.2687	8.6450	47.0655
2010	28.0862	8.4853	1.1505	2.1995
2011	41.1434	16.4746	0.8849	3.7492
2012	35.9625	14.1050	5.9831	1.7413
2013	19.8901	13.3315	1.2541	2.9688
2014	22.8020	14.7457	0.2579	31.2313
2015	21.5305	35.9696	0.0441	28.5372
2016	11.8260	13.7074	10.8603	48.1910
2017	17.4460	30.9052	1.9842	73.8634
2018	13.1444	8.3638	11.1679	20.6635
2019	7.7864	10.2231	0.1293	9.9001
lb ww : lb dw	1.39	1.39	1.39	2.02

Table 2.1. Continued.

B. Gulf of Mexico (GOM)

Year	Bottom longline (total catch)	Gillnet (total catch)	Hook and line + hand line (total catch)	Pelagic longline (dead discards)
1981	0.0000	0.0000	0.0000	0.0000
1982	2.1359	0.0809	0.0287	0.8501
1983	4.2717	0.1617	0.0574	1.7207
1984	6.4076	0.2426	0.0862	2.5708
1985	8.5434	0.3234	0.1149	3.4209
1986	10.6793	0.4043	0.1436	4.2710
1987	12.8151	0.4851	0.1723	5.9522
1988	14.9510	0.5660	0.2011	18.5444
1989	17.0868	0.6469	0.2298	12.3153
1990	19.2227	0.7277	0.2585	17.4849
1991	21.7563	0.8081	0.0000	8.0827
1992	21.1428	0.8095	0.5516	3.9424
1993	22.3502	0.8081	0.3101	3.9424
1994	57.6062	0.8107	19.2684	3.9424
1995	99.5205	0.8092	0.9920	2.1000
1996	118.0286	0.8172	4.7593	1.3922
1997	18.6176	0.8081	0.0733	1.4641
1998	27.5484	0.4115	0.0669	0.2041
1999	10.1699	0.8082	0.0005	0.5590
2000	30.3991	0.5388	0.0803	13.0438
2001	23.6739	0.5959	0.0000	3.3364
2002	31.9019	0.0367	0.0000	3.9424
2003	51.4496	1.2223	0.4275	3.9424
2004	36.4668	0.4785	0.2813	3.9424
2005	67.0866	0.0630	0.0000	3.9424
2006	33.6053	0.2600	0.0000	3.9424
2007	6.9640	0.0421	0.0000	1.8448
2008	10.4940	2.0380	0.2346	12.8233
2009	23.8260	0.4183	1.7993	5.2999
2010	10.1113	0.1101	0.1829	0.1366
2011	20.6768	0.8916	0.3623	2.1083
2012	24.8247	0.4418	3.6736	0.3540
2013	4.3114	0.1508	0.0000	1.2050
2014	5.7716	0.4444	0.0504	12.8536
2015	8.4182	1.1396	0.0441	3.9887
2016	6.3111	0.3743	10.7613	10.0209
2017	12.5407	2.3488	1.9842	0.3461
2018	8.7974	0.1117	11.0866	1.2333
2019	5.7128	0.2885	0.0000	0.7620
lb ww : lb dw	1.39	1.39	1.39	2.02

Table 2.1. Continued.

C. Atlantic (ATL)

Year	Bottom longline (total catch)	Gillnet (total catch)	Hook and line + hand line (total catch)	Pelagic longline (dead discards)
1981	0.0000	0.0000	0.0000	0.0000
1982	16.0583	2.8882	0.0228	10.4728
1983	32.1166	5.8158	0.0456	21.1980
1984	48.1750	8.6865	0.0685	31.6708
1985	64.2333	11.6089	0.0913	42.1436
1986	80.2916	14.5434	0.1141	52.6164
1987	96.3499	17.5755	0.1369	77.3001
1988	112.4083	20.5223	0.1597	251.6197
1989	128.4666	24.4086	0.1825	116.8276
1990	144.5249	27.7157	0.2054	149.4086
1991	38.6803	48.5621	0.0615	101.8553
1992	189.4303	31.3415	0.0458	371.7588
1993	255.1568	18.0585	0.5771	41.0122
1994	405.1362	15.4297	7.3300	42.3501
1995	150.1582	13.3881	4.5325	82.2492
1996	77.7556	18.8933	1.8637	14.2191
1997	40.7029	17.3720	0.0637	44.1397
1998	30.1692	13.6500	0.5958	43.3403
1999	30.8701	10.0069	4.9333	36.9825
2000	14.8162	9.3722	0.1362	42.4070
2001	21.0926	8.9199	0.6011	50.9826
2002	21.1789	3.7330	1.4028	40.4636
2003	47.0931	25.5683	0.0452	40.4636
2004	27.6868	13.4645	1.3238	40.4636
2005	24.2793	3.8072	1.3679	40.4636
2006	26.3378	7.9029	0.1096	40.4636
2007	8.0526	4.3579	0.0424	88.5889
2008	9.5945	42.7912	0.2233	57.9844
2009	26.4234	7.6292	5.6082	47.0655
2010	21.7289	5.5698	0.7892	2.1957
2011	15.8765	9.8244	0.4391	3.7426
2012	5.5517	8.4435	2.3820	1.7382
2013	4.5795	11.1013	1.2541	2.9636
2014	5.2343	11.5335	0.2074	31.2313
2015	6.7585	24.2156	0.0000	28.5372
2016	4.1953	11.6524	0.0991	48.1910
2017	5.3007	27.1527	0.0000	73.8634
2018	3.0795	6.8209	0.0813	20.6635
2019	0.6060	8.3100	0.1293	9.0026
lb ww : lb dw	1.39	1.39	1.39	2.02

Table 2.2. Total recreational catches of scalloped hammerheads in numbers (thousands of individuals) adapted from SEDAR 77 DW Report (their section 3, Tables 37, 39, and 41). Recreational catch (AB1) is type A (number of fish killed or kept seen by the interviewer) plus type B1 (number of fish killed or kept reported to the interviewer by the angler). Recreational LPRM is type B2 (number of fish released alive reported by the fisher) multiplied by the assumed post-release mortality rate.

	Areas combined (GOM + ATL)		Gulf of Mexico (GOM)		Atlantic (ATL)	
Year	Recreational AB1 (1000s)	Recreational LPRM (1000s)	Recreational AB1 (1000s)	Recreational LPRM (1000s)	Recreational AB1 (1000s)	Recreational LPRM (1000s)
1981	23.6410	22.8979	2.1019	0.2551	25.2492	26.0038
1982	23.6410	22.8979	2.1019	0.2551	25.2492	26.0038
1983	19.6412	14.3124	1.6583	0.6547	8.2477	12.2826
1984	16.3525	7.4442	1.3009	1.6782	2.8722	3.5442
1985	13.8120	5.6438	1.2172	4.3017	1.2258	1.5032
1986	8.3727	2.0075	1.2792	1.3022	1.4744	0.7708
1987	6.1343	1.3837	1.5014	0.6491	2.1519	0.8870
1988	5.8216	1.2090	1.9975	0.3235	3.5929	1.3765
1989	8.3740	2.5009	1.8637	0.4888	6.1254	2.4749
1990	11.2992	4.0414	1.0431	0.1898	9.5219	3.9714
1991	11.2828	7.0222	0.9311	0.1797	10.5541	6.7034
1992	11.4982	12.4739	1.0443	0.1854	11.1797	11.5382
1993	7.2617	16.3933	1.6980	0.4763	7.6743	15.8982
1994	4.6804	8.3971	0.9929	0.2953	5.2792	10.7296
1995	3.4040	4.2473	0.4653	0.1843	4.1221	6.7899
1996	3.4133	2.3350	0.3409	0.0945	3.6128	3.6628
1997	3.6700	2.3439	0.4178	0.0823	3.4111	2.8371
1998	3.9919	2.2961	0.6222	0.0870	3.2193	2.1383
1999	4.4489	2.7271	0.4667	0.1158	3.6188	2.4293
2000	4.9371	3.5506	0.3833	0.2401	4.0231	3.0647
2001	4.6564	4.9247	0.5092	0.4155	3.6318	4.6169
2002	4.2724	5.1887	0.8745	0.6865	3.0820	5.2076
2003	5.2674	5.7362	1.3852	0.6188	3.8340	6.2142
2004	5.8682	5.8732	0.6290	0.5120	4.8362	6.4449
2005	6.8268	7.0494	0.2613	0.3380	6.4364	7.6943
2006	2.9087	6.7183	0.1100	0.1827	2.7814	7.4154
2007	1.6160	6.9328	0.1004	0.1098	1.5075	7.5270
2008	0.7403	6.0848	0.1074	0.1179	0.6405	7.0835
2009	0.7460	5.8441	0.1041	0.2124	0.6404	7.1210
2010	0.4662	5.3589	0.0882	0.3764	0.3737	6.9474
2011	0.5107	4.8578	0.0980	0.4069	0.4079	5.7686
2012	0.9389	4.8733	0.1245	0.3366	0.7738	5.3967
2013	2.4363	4.5427	0.1787	0.2771	2.1825	4.9219
2014	4.1317	4.4232	0.1140	0.2341	3.9998	5.1207
2015	0.8902	3.6891	0.0661	0.3072	0.5949	4.5480
2016	0.1932	2.9880	0.0384	0.3775	0.0887	3.6302
2017	0.0389	2.4954	0.0342	0.4962	0.0040	2.8450
2018	0.0389	2.4954	0.0342	0.4962	0.0040	2.8450
2019	0.0389	2.4954	0.0342	0.4962	0.0040	2.8450

Table 2.3. Recommended indices of abundance for Age 1+ scalloped hammerhead including index name, the value of catch per unit effort, and SEDAR document number (adapted from SEDAR 77 DW Report, their section 4, Tables 5, 6, and 7); CV is the coefficient of variation for the annual index value; Years with missing values (corresponding to either zero catches, no CV, or no sampling, ns) were excluded from the assessment.

A. Areas Combined (GOM+ATL)

	Pelagic Longline Observer Program SEDAR77-DW08 Sharks per 1000 hooks		**Shark Bottom Longline Observer Program SEDAR77-DW12 Sharks per 10000 hooks**		**Shark Research Fishery SEDAR77-DW12 Sharks per 10000 hooks**		**FSU Longline SEDAR77-DW14 Sharks per 100 hook-hrs**		**SEFSC MS Bottom Longline SEDAR77-DW24 Sharks per 100 hook-hrs**	
Year	**Index**	**CV**	**Index**	**CV**	**Index**	**CV**	**Index**	**CV**	**Index**	**CV**
1992	0.174	0.741								
1993	0.062	0.565								
1994	0.045	0.645	5.867	0.430						
1995	0.039	0.629	8.990	0.419					0.081	0.337
1996	0.014	1.231	9.030	0.398					0.052	0.438
1997	0.070	0.729	9.015	0.503					0.063	0.310
1998	0.077	0.880	12.811	0.452					ns	
1999	0.018	1.066	3.266	0.714					0.050	0.339
2000	0.017	0.772	0.281	1.596					0.071	0.247
2001	0.052	0.807	12.125	0.447					0.115	0.219
2002	0.017	1.319	16.468	0.390					0.093	0.177
2003	0.038	0.785	20.271	0.343					0.154	0.209
2004	0.035	0.772	16.563	0.378					0.056	0.312
2005	0.040	0.642	6.975	0.509					0.112	0.475
2006	0.050	0.777	25.205	0.405					0.060	0.358
2007	0.049	0.591	15.530	0.562					0.088	0.327
2008	0.073	0.497			4.129	0.773			0.095	0.372
2009	0.101	0.449			65.590	0.331			0.129	0.268
2010	0.084	0.488			46.926	0.328			0.142	0.242
2011	0.054	0.481			58.507	0.325	0.003	0.333	0.066	0.269
2012	0.101	0.471			90.500	0.374	ns		0.060	0.358
2013	0.046	0.458			53.035	0.396	ns		0.061	0.312
2014	0.038	0.551			68.047	0.358	0.001	1.147	0.079	0.337
2015	0.039	0.516			99.944	0.371	0.006	0.468	0.157	0.219
2016	0.041	0.521			68.444	0.360	0.004	0.777	0.094	0.295
2017	0.073	0.523			89.840	0.361	0.009	0.271	0.126	0.243
2018	0.033	0.688			42.589	0.395	0.003	0.656	0.094	0.275
2019	0.015	0.918			44.341	0.387	0.002	0.796	0.118	0.294

Table 2.3. Continued.

B. Gulf of Mexico (GOM)

	Shark Bottom Longline Observer Program SEDAR77-DW12 Sharks per 10000 hooks		Shark Research Fishery SEDAR77-DW12 Sharks per 10000 hooks		FSU Longline SEDAR77-DW14 Sharks per 100 hook-hrs		SEFSC MS Bottom Longline SEDAR77-DW24 Sharks per 100 hook-hrs	
Year	**Index**	**CV**	**Index**	**CV**	**Index**	**CV**	**Index**	**CV**
1994	0.727	1.100						
1995	4.445	0.801					0.090	0.402
1996	6.603	0.621					0.057	0.476
1997	23.542	0.632					0.086	0.306
1998	6.604	0.665					ns	
1999	0.399	1.511					0.048	0.332
2000	ns						0.111	0.259
2001	11.066	0.628					0.109	0.211
2002	14.561	0.459					0.080	0.241
2003	24.324	0.353					0.147	0.200
2004	24.302	0.344					0.062	0.307
2005	3.808	0.642					0.145	0.525
2006	6.982	0.774					0.042	0.435
2007	19.646	0.796					0.084	0.319
2008			11.196	0.878			0.082	0.522
2009			84.325	0.260			0.095	0.305
2010			41.180	0.339			0.110	0.302
2011			50.887	0.311	0.003	0.333	0.047	0.320
2012			64.255	0.544	ns		0.055	0.402
2013			67.233	0.397	ns		0.050	0.356
2014			61.826	0.556	0.001	1.147	0.070	0.400
2015			216.816	0.366	0.006	0.468	0.131	0.271
2016			78.541	0.452	0.004	0.777	0.111	0.317
2017			260.287	0.321	0.009	0.271	0.120	0.281
2018			31.181	0.472	0.003	0.656	0.099	0.305
2019			71.195	0.352	0.002	0.796	0.109	0.350

Table 2.3. Continued.

C. Atlantic (ATL)

	Pelagic Longline Observer Program SEDAR77-DW08 Sharks per 1000 hooks		Shark Bottom Longline Observer Program SEDAR77-DW12 Sharks per 10000 hooks		Shark Research Fishery SEDAR77-DW12 Sharks per 10000 hooks		SEFSC MS Bottom Longline SEDAR77-DW24 Sharks per 100 hook-hrs	
Year	**Index**	**CV**	**Index**	**CV**	**Index**	**CV**	**Index**	**CV**
1992	0.232	0.571						
1993	0.100	0.459						
1994	0.087	0.517	9.514	0.350				
1995	0.085	0.486	11.957	0.351			0.068	0.624
1996	0.022	0.842	12.727	0.330			0.034	1.108
1997	0.145	0.538	6.067	0.553			ns	
1998	0.130	0.608	17.577	0.308			ns	
1999	0.038	0.761	5.929	0.744			ns	
2000	0.059	0.553	0.229	1.482			0.016	0.781
2001	0.122	0.596	16.904	0.377			ns	
2002	0.041	0.884	17.461	0.366			0.074	0.310
2003	0.069	0.632	12.811	0.333			ns	
2004	0.068	0.617	7.867	0.421			ns	
2005	0.116	0.530	11.620	0.674			0.031	1.104
2006	0.122	0.594	63.093	0.375			0.105	0.646
2007	0.189	0.492	21.511	0.593			ns	
2008	0.095	0.543			0.000		0.149	0.527
2009	0.174	0.456			63.443	0.427	0.194	0.623
2010	0.144	0.406			46.747	0.255	0.229	0.408
2011	0.097	0.462			37.435	0.271	0.135	0.492
2012	0.201	0.437			91.472	0.304	0.064	0.783
2013	0.025	0.578			64.498	0.438	0.100	0.636
2014	0.047	0.513			53.727	0.287	0.060	0.665
2015	0.097	0.432			63.541	0.348	0.236	0.370
2016	0.092	0.432			56.871	0.315	0.036	0.777
2017	0.152	0.402			40.475	0.368	0.091	0.549
2018	0.070	0.536			41.877	0.368	0.055	0.642
2019	0.035	0.658			22.889	0.504	0.120	0.552

Table 2.4. Recommended indices of abundance for Age 0 scalloped hammerhead including index name, the value of catch per unit effort, and SEDAR document number (adapted from SEDAR 77 DW Report, their section 4, Table 9). Years with missing values (corresponding to either zero catches, no CV, or no sampling, ns) were excluded from the assessment.

	TXPWD-Gillnet SEDAR77 DW-16 Gulf of Mexico Sharks per net per hour		GULFSPAN SEDAR77 DW-17 Gulf of Mexico Sharks per net per hour		COASTSPAN - LL SEDAR77-DW-30 Atlantic Sharks per 100 hook hours		SCCOASTGN - LONG SEDAR77-DW-31 Atlantic Sharks per net hour		SCCOASTGN - SHORT SEDAR77 DW-32 Atlantic Sharks per net hour	
Year	**Index**	**CV**	**Index**	**CV**	**Index**	**CV**	**Index**	**CV**	**Index**	**CV**
1982	0.00033									
1983	0.00042	0.912								
1984	0.00000									
1985	0.00015									
1986	0.00035	0.732								
1987	0.00000									
1988	0.00050	0.618								
1989	0.00012									
1990	0.00090	0.603								
1991	0.00053	0.749								
1992	0.00000									
1993	0.00032	0.819								
1994	0.00027	0.848								
1995	0.00010	1.165								
1996	0.00093	0.536	0.009	0.294						
1997	0.00172	0.666	0.016	0.461						
1998	0.00031	0.842	0.002	0.548						
1999	0.00021	0.781	0.091	0.312						
2000	0.00048	0.589	0.156	0.253						
2001	0.00150	0.603	0.148	0.302			1.2498	0.4793		
2002	0.00033	0.822	0.15	0.166			0.7881	0.5178		
2003	0.00183	0.577	0.102	0.181			2.7417	0.4496		
2004	0.00075	0.689	0.07	0.227			0.5413	1.4316		
2005	0.00254	0.517	0.048	0.373	5.464	0.529	0.6254	0.5384		
2006	0.00069	0.630	0.079	0.22	8.119	0.416	0.9807	1.0179		
2007	0.00079	0.778	0.168	0.171	1.976	1.128	1.9521	0.5328	0.1709	0.4233
2008	0.00075	0.703	0.172	0.189	1.730	1.165	1.3839	0.7066	0.2857	0.5813
2009	0.00095	0.560	0.163	0.2	3.482	0.654	7.2980	1.3825	0.0000	
2010	0.00213	0.598	0.208	0.211	9.376	0.327	2.2974	0.8537	0.1135	0.5813
2011	0.00091	0.563	0.159	0.201	3.876	0.372	1.4874	0.5401	0.1129	0.3072
2012	0.00124	0.540	0.093	0.217	1.907	0.469	8.1799	0.5273	0.1155	0.3072
2013	0.00484	0.428	0.129	0.215	2.052	0.427	4.0580	0.4515	0.0897	0.4233
2014	0.00198	0.477	0.141	0.207	2.443	0.548	2.2039	0.6955	0.0000	
2015	0.00283	0.565	0.068	0.252	1.158	0.554	0.9686	0.6158	0.0199	0.5813
2016	0.00191	0.590	0.124	0.235	1.899	0.419	1.6754	0.5384	0.0978	0.3507
2017	0.00041	0.775	0.184	0.2	1.123	0.519	6.8082	0.3406	0.0000	
2018	0.00482	0.499	0.21	0.225	0.738	0.565	3.7252	0.5473	0.0000	
2019	0.00248	0.514	0.176	0.265	1.029	1.175	3.3050	0.4230	0.0208	0.5813

Table 2.5. Mean estimates of instantaneous natural mortality rates (yr^{-1}) for use in the reference case Stock Synthesis model obtained with six life-history invariant estimators used in the Euler-Lotka and Leslie matrix approaches, and estimates for use in sensitivity analyses obtained with the Dureuil et al. (2021) method; Adapted from the estimation of vital rates for scalloped hammerhead in the assessment document SEDAR77-AW04 (Cortés 2022, his Tables 1 – 3 and 6; Pers. Comm. E. Cortés, July 2022).

A. Areas Combined (GOM+ATL)

	Mean of 6 life-history invariant methods		Dureuil et al. (2021) length-based method	
Age	Female (Mean of 6)	Male (Mean of 6)	Female (Dureuil et al. 2021)	Male (Dureuil et al. 2021)
0	0.184	0.193	0.353	0.385
1	0.164	0.171	0.258	0.275
2	0.152	0.159	0.207	0.218
3	0.145	0.152	0.175	0.184
4	0.140	0.146	0.154	0.161
5	0.136	0.143	0.138	0.144
6	0.133	0.140	0.126	0.132
7	0.130	0.137	0.117	0.122
8	0.128	0.135	0.110	0.114
9	0.127	0.134	0.104	0.108
10	0.125	0.133	0.099	0.103
11	0.124	0.131	0.095	0.099
12	0.123	0.131	0.091	0.095
13	0.122	0.130	0.088	0.092
14	0.122	0.129	0.086	0.090
15	0.121	0.129	0.084	0.088
16	0.120	0.128	0.082	0.086
17	0.120	0.128	0.080	0.084
18	0.120	0.127	0.078	0.082
19	0.119	0.127	0.077	0.081
20	0.119	0.126	0.076	0.080
21	0.119	0.126	0.075	0.079
22	0.118	0.126	0.074	0.078
23	0.118	0.126	0.073	0.077
24	0.118	0.126	0.072	0.076
25	0.118	0.125	0.072	0.076
26	0.117	0.125	0.071	0.075
27	0.117	0.125	0.070	0.075
28	0.117	0.125	0.070	0.074
29	0.117	0.125	0.069	0.074
30	0.117	0.125	0.069	0.073
31	0.117	0.125	0.069	0.073
32	0.117	0.124	0.068	0.073
33	0.117	0.124	0.068	0.072
34	0.116	0.124	0.068	0.072
35	0.116	0.124	0.067	0.072
36	0.116	0.124	0.067	0.072
37	0.116	0.124	0.067	0.071
38	0.116	0.124	0.067	0.071
39	0.116	0.124	0.067	0.071
40	0.116	0.124	0.066	0.071
41	0.116	0.124	0.066	0.071
42	0.116	0.124	0.066	0.071
43	0.116	0.124	0.066	0.071
44	0.116	0.124	0.066	0.070
45	0.116	0.124	0.066	0.070
46	0.116	0.124	0.066	0.070
47	0.116	0.124	0.066	0.070
48	0.116	0.124	0.066	0.070
49	0.116		0.066	
50	0.116		0.065	
Average	0.123		0.093	

Table 2.5. Continued.

B. Gulf of Mexico (GOM)

	Mean of 6 life-history invariant methods		Dureuil et al. (2021) length-based method	
	Female (Mean of 6)	Male (Mean of 6)	Female (Dureuil et al. 2021)	Male (Dureuil et al. 2021)
0	0.184	0.203	0.345	0.475
1	0.164	0.179	0.254	0.325
2	0.153	0.167	0.204	0.254
3	0.145	0.159	0.173	0.213
4	0.140	0.154	0.152	0.186
5	0.136	0.151	0.136	0.167
6	0.133	0.148	0.125	0.154
7	0.131	0.146	0.116	0.143
8	0.129	0.145	0.108	0.135
9	0.127	0.143	0.102	0.129
10	0.126	0.142	0.098	0.124
11	0.125	0.141	0.093	0.120
12	0.124	0.141	0.090	0.116
13	0.123	0.140	0.087	0.113
14	0.122	0.139	0.084	0.111
15	0.122	0.139	0.082	0.108
16	0.121	0.139	0.080	0.107
17	0.121	0.138	0.078	0.105
18	0.120	0.138	0.077	0.104
19	0.120	0.138	0.076	0.103
20	0.119	0.138	0.074	0.102
21	0.119	0.137	0.073	0.101
22	0.119	0.137	0.072	0.100
23	0.119	0.137	0.072	0.099
24	0.118	0.137	0.071	0.099
25	0.118	0.137	0.070	0.098
26	0.118	0.137	0.070	0.098
27	0.118	0.137	0.069	0.097
28	0.118	0.137	0.068	0.097
29	0.118	0.137	0.068	0.097
30	0.117	0.136	0.068	0.096
31	0.117	0.136	0.067	0.096
32	0.117	0.136	0.067	0.096
33	0.117	0.136	0.067	0.096
34	0.117	0.136	0.066	0.096
35	0.117	0.136	0.066	0.096
36	0.117	0.136	0.066	0.095
37	0.117		0.066	
38	0.117		0.065	
39	0.117		0.065	
40	0.117		0.065	
41	0.117		0.065	
42	0.117		0.065	
43	0.117		0.065	
44	0.116		0.064	
45	0.116		0.064	
46	0.116		0.064	
47	0.116		0.064	
48	0.116		0.064	
49	0.116		0.064	
50	0.116		0.064	
Average	0.124		0.091	

Table 2.5. Continued.

C. Atlantic (ATL)

	Mean of 6 life-history invariant methods		Dureuil et al. (2021) length-based method	
	Female (Mean of 6)	Male (Mean of 6)	Female (Mean of 6)	Male (Mean of 6)
0	0.187	0.191	0.364	0.352
1	0.166	0.171	0.265	0.256
2	0.155	0.159	0.212	0.204
3	0.147	0.151	0.179	0.173
4	0.142	0.146	0.157	0.151
5	0.138	0.142	0.141	0.135
6	0.135	0.139	0.129	0.123
7	0.133	0.136	0.119	0.114
8	0.131	0.134	0.112	0.107
9	0.129	0.133	0.106	0.101
10	0.128	0.131	0.101	0.096
11	0.127	0.130	0.097	0.092
12	0.126	0.129	0.093	0.088
13	0.125	0.128	0.090	0.085
14	0.124	0.127	0.088	0.082
15	0.124	0.127	0.086	0.080
16	0.123	0.126	0.084	0.078
17	0.123	0.126	0.082	0.076
18	0.122	0.125	0.080	0.075
19	0.122	0.125	0.079	0.074
20	0.121	0.125	0.078	0.072
21	0.121	0.124	0.077	0.071
22	0.121	0.124	0.076	0.070
23	0.121	0.124	0.075	0.069
24	0.120	0.123	0.074	0.069
25	0.120	0.123	0.074	0.068
26	0.120	0.123	0.073	0.067
27	0.120	0.123	0.073	0.067
28	0.120	0.123	0.072	0.066
29	0.120	0.123	0.072	0.066
30	0.120	0.122	0.071	0.065
31	0.119	0.122	0.071	0.065
32	0.119	0.122	0.070	0.064
33	0.119	0.122	0.070	0.064
34	0.119	0.122	0.070	0.064
35	0.119	0.122	0.070	0.064
36	0.119	0.122	0.069	0.063
37	0.119	0.122	0.069	0.063
38	0.119	0.122	0.069	0.063
39	0.119	0.122	0.069	0.063
40	0.119	0.122	0.069	0.063
41	0.119	0.122	0.069	0.062
42	0.119	0.121	0.068	0.062
43	0.119	0.121	0.068	0.062
44	0.119	0.121	0.068	0.062
45	0.119	0.121	0.068	0.062
46	0.119	0.121	0.068	0.062
47	0.119	0.121	0.068	0.062
48	0.119	0.121	0.068	0.062
49	0.119	0.121	0.068	0.061
50	0.119	0.121	0.068	0.061
Average	0.126		0.095	

3. STOCK ASSESSMENT MODELS AND RESULTS

The analytical approach implemented in this assessment is a length-based age-structured statistical model implemented within Stock Synthesis (Methot and Wetzel 2013; e.g., Wetzel and Punt 2011a, 2011b). Stock Synthesis utilizes an integrated modeling approach (Maunder and Punt 2013) to take advantage of the many data sources available.

3.1 Overview

Stock Synthesis (version 3.30.15.00; Methot et al. 2020) was implemented here using an areas as fleets approach by including multiple fleets within a spatially-aggregated assessment model (e.g., Hurtado-Ferro et al. 2014; Punt et al. 2014). In the areas as fleets approach, each fleet is assigned its own size selectivity pattern. Size selectivity is the probability of a fleet capturing a shark of a given size relative to the probability of that fleet capturing a shark of a different size (here the size at which the probability of capture is highest). Size selectivity for each fleet is either fixed or estimated within the assessment model based on the available size composition data. The resulting size selectivity for each fleet is interpreted as the combined effect of availability to the fishing gear (i.e., a shark of a given size is in the fishing area when fishing occurs and is available to be captured) and size selectivity of the fishing gear. Stock Synthesis has previously been implemented utilizing the areas as fleets approach for Atlantic HMS domestic shark stock assessments conducted within the SEDAR process (Anon. 2015, 2017a, 2018, 2020) and for Atlantic HMS international shark stock assessments conducted within the ICCAT process (Anon. 2016, 2017b; Courtney 2016; Courtney et al. 2017a, 2017b).

3.2 Data Sources

Total commercial catch, total recreational catch, indices of abundance, life history, and length composition were obtained as described in Section 2 above and summarized here in **Table 3.1**.

3.2.1 Catch

3.2.1.1. Total Commercial Catch

Total commercial catches during the years 1981 – 2019 were obtained from **Table 2.1** above. Commercial catches were entered in Stock Synthesis in metric tons (one mt = 1,000 kg) aggregated into “fleets” (F1 – F3, and F6) as described in **Table 3.1**:

F1 (Com-BLL) = Bottom longline (1981 – 2019);
F2 (Com-GN) = Gillnet (1981 – 2019);
F3 (Com-PLL) = Pelagic longline discard (1981 – 2019); and
F6 (Com-Other-Kept) = Hook and line plus hand line (1981 – 2019) as described below.

3.2.1.2. Total Recreational Catch

Total recreational catches during the years 1981 – 2019 were obtained from **Table 2.2 above**. Recreational catch and recreational post-release mortality, PRM, were entered in Stock Synthesis in numbers (thousands) aggregated into “fleets" (F4 and F5) described in **Table 3.1**:

F4 (Recreational catch) = Recreational (A+B1) (1981 – 2019); and
F5 (Recreational PRM) = Recreational (B2 PRM) (1981 – 2019), as described below.

3.2.1.3. Commercial Discards

Commercial discards were included in the total commercial catches of scalloped hammerheads obtained for the period 1981 – 2019 from the SEDAR 77 DW Report (their section 3, Tables 36, 38, and 40) as described above and in **Table 2.1**.

3.2.1.4. Sensitivity Analyses for Catches

Gulf of Mexico (GOM) and Atlantic (ATL)

In response to the presence of a cryptic hammerhead species in the Atlantic region (Carolina hammerhead), the Stock ID Process recommended conducting sensitivity analyses to the scalloped hammerhead assessment for data inputs separately by geographic region for the Gulf of Mexico (GOM) and the Atlantic (ATL). Consequently, separate data inputs were obtained from the DW for catch in the Gulf of Mexico (**Table 2.1**, Panel B) and Atlantic (**Table 2.1**, Panel C) regions, as described above.

Low and High Catch Scenarios

Low and high catch scenarios were not implemented due to time constraints.

3.2.2 Indices of Abundance and Catchability

Indices of relative abundance during the years 1982 – 2019 were obtained from **Tables 2.3** and **2.4** above. Indices of relative abundance were input in Stock Synthesis (**Table 3.1**) as either population "surveys" (S1 – S5; all-ages in the sampled population, generally obtained offshore and generally not including age-0 individuals) or surveys of "recruits" (R1 – R5; age-0 in the sampled population, generally obtained from near-shore bays or estuaries and further limited within analyses to include only age-0 data):
S1 (PLL-Obs) = Pelagic longline observer program (1992 – 2019);
S2 (Shark-BLL-Obs) = Bottom longline fishery observer program (1994 – 2007);
S3 (Shark-BLL-Res) = Shark bottom longline research fishery (2008 – 2019);
S4 (FSU-BLLS) = FSU bottom longline survey (2011 – 2019);
S5 (SEFSC-BLLS) = NMFS SEFSC bottom longline survey (1995 – 2019);
R1 (TXPWD-GNS) = Texas Parks and Wild. Dep. gillnet survey (age-0, 1982 – 2019);
R2 (GULFSPAN-GNS) = GULFSPAN gillnet survey (age-0, 1996 – 2019);
R3 (COASTSPAN-BLLS) = (COASTSPAN) bottom longline survey (age-0, 2005 – 2019);
R4 (COASTSPAN-LGNS) = COASTSPAN long-gillnet survey (age-0, 2001-2019); and
R5 (COASTSPAN-SGNS) = COASTSPAN short-gillnet survey (age-0, 2007 – 2019) as described below.

The ten indices of relative abundance were recommended by the Index Working Group of the Data Workshop for use in a base model configuration. The annual indices of relative abundance and their associated annual coefficients of variation (CVs) were obtained from both fisheries-dependent observer programs (S1 – S3) and fisheries-independent scientific surveys (S4, S5, R1 – R5) as described in **Tables 2.3 and 2.4** above.

All "surveys" were input in Stock Synthesis as indices of relative abundance and assumed to have log-normally distributed annual error input as sqrt(ln(1+CV^2)), which is approximated by the annual CVs provided for each index as described in **Tables 2.3 and 2.4** above and then modified by data weighting described below.

Indices of relative abundance were assumed to be proportional to available biomass at the middle of the calendar year, with constant catchability (q) (Methot and Wetzel 2013). Catchability, q, was estimated for index S2 with time blocks (1981 – 1996, 1997 – 2004 [main years], and 2005 – 2007) and for index S3 with time blocks (2008, 2009 – 2017 [main years], and 2018 – 2019). The time blocks implemented in SEDAR 77 for length composition data were adapted from those previously implemented in the relatively more data rich SEDAR 65 Atlantic blacktip shark stock assessment (Anonymous. 2020). An assumption made in SEDAR 77 was that time blocks implemented for fits to length composition data in SEDAR 65 resulted from poor fits to length data over time caused by factors not accounted for directly in the modelled population dynamics (e.g., management changes or other external factors not accounted for in the population dynamics model). Another assumption made in SEDAR 77 was that similar factors probably affected length composition data collected in both SEDAR 65 and SEDAR 77 and, consequently, that time blocks developed fits to length composition data in the relatively more data rich SEDAR 65 stock assessment could be adapted here for use in the relatively more data poor SEDAR 77 stock assessment (E.g., Punt et al. 2011, 2020). For indices without time blocks, the median unbiased analytical solution for *q* was obtained from Stock Synthesis by setting *q* equal to a constant scaling factor (Methot et al. 2020).

3.2.2.1. Indices of Abundance Sensitivity Analyses

Gulf of Mexico and Atlantic

In response to the presence of a cryptic hammerhead species in the Atlantic region (Carolina hammerhead), the Stock ID Process recommended conducting sensitivity analyses to the scalloped hammerhead assessment for data inputs separately by geographic region for the GOM and the ATL. Consequently, separate data inputs were obtained from the DW for indices of abundance in the Gulf of Mexico (**Table 2.3**, Panel B; **Table 2.4**) and Atlantic (**Table 2.3**, Panel C; **Table 2.4**) regions, as described above.

3.2.3 Life History Data

Life history data were obtained from the Data Workshop Report (Their Section 2 Life History Table 1) for use in the reference case Stock Synthesis model (areas combined GOM+ATL). In addition, the assessment document SEDAR77-AW04 (Cortés 2022) developed vital rates and population dynamics parameters including Beverton-Holt stock-recruitment steepness (*h*) and natural mortality based on biological information provided in the Data Workshop Report. The median steepness value (0.69), along with approximate lower and upper confidence limits computed as the 2.5th and 97.5th percentiles (LCL = 0.44 and UCL = 0.87) obtained from Monte Carlo simulation of vital rates with a Leslie matrix approach (Cortés 2022, his Table 8 Panel A GOM+ATL combined; Pers. Comm. E. Cortés, July 2022) were used as a Stock Synthesis productivity reference case, low productivity state of nature sensitivity analysis, and high productivity state of nature sensitivity analysis, respectively.

Mean estimates of instantaneous natural mortality rates (yr^{-1}) were obtained from six life-history invariant estimators (Cortés 2022, his Tables 1 – 3 and 6; Pers. Comm. E. Cortés, July 2022) for use in the reference case Stock Synthesis model (areas combined GOM+ATL; **Table 2.5 Panel A**).

3.2.3.1. Life History Sensitivity Analyses

Gulf of Mexico and Atlantic Stock Recruit Steepness

Median steepness values of 0.71 (Cortés 2022, his Table 8, Panel B) and 0.67 (Cortés 2022, his Table 8, Panel C) were obtained for use in the Stock Synthesis GOM and ATL sensitivity analyses, respectively, along with approximate lower and upper confidence limits for the GOM (LCL = 0.37 and UCL = 0.89) and ATL (LCL = 0.41 and UCL = 0.86).

Gulf of Mexico and Atlantic Natural Mortality

Mean estimates of instantaneous natural mortality rates (yr^{-1}) obtained with six life-history invariant estimators used in the Euler-Lotka and Leslie matrix approaches (Cortés 2022, his Tables 1 – 3 and 6; Pers. Comm. E. Cortés, July 2022) were obtained separately for use in the GOM and ATL regional sensitivity analyses (**Table 2.5** Panels B and C).

Deterministic Natural Mortality

Additionally, estimates of instantaneous natural mortality rates (yr^{-1}) obtained with the Dureuil et al. (2021) length-based method (Cortés 2022, his Tables 1 – 3 and 6; Pers. Comm. E. Cortés, July 2022) were obtained for use in an areas combined sensitivity analysis (GOM+ATL; **Table 2.5** Panel A) and in separate GOM and ATL regional sensitivity analyses (**Table 2.5** Panels B and C).

3.2.4 Length Composition Data

The available length composition data are summarized in the Data Workshop Report (Their Section 6. Length Composition). For use in Stock Synthesis, the commercial and recreational gear types were aggregated into six ‘fleets’ (F1 – F6) with similar length composition as described in **Tables 3.1** and **3.2**. This approach is consistent with previous Atlantic HMS SEDAR stock assessments conducted in Stock Synthesis for both the Atlantic smooth dogfish shark (Anon. 2015) and the Atlantic blacktip shark (Anon. 2020). Fishery-independent length composition data were also provided for several fishery independent scientific surveys as described in **Tables 3.1** and **3.2**.

A minimum annual sample size of 20 to 30 measured individuals was implemented for the Stock Synthesis reference case (GOM + ATL) model configuration (**Table 3.2**). A minimum sample size was implemented in an effort to insure that the annual length composition data entered in the stock assessment model were representative of the annual distributions in length captured by each fleet and survey. This approach is also consistent with previous Atlantic HMS SEDAR stock assessments conducted in Stock Synthesis for both the Atlantic smooth dogfish shark (Anon. 2015) and the Atlantic blacktip shark (Anon. 2020). Total sample size differs in some cases between the Data Workshop Report (Their Section 6. Length Composition) and **Table 3.2** because length data in **Table 3.2** were limited to the years with catch and survey data included for the Stock Synthesis reference case (GOM + ATL) model configuration (**Table 3.1)**. Fits to length composition data by fleet and survey are provided below in the assessment model results section.

3.2.4.1. Length Composition Sensitivity Analyses

Gulf of Mexico and Atlantic

Length composition data sets associated with each separate GOM and ATL catch and index data set were obtained from the review of the available length composition data provided in the Data Workshop Report (Section 6. Length Composition). Length composition data sets used in the GOM and ATL Stock Synthesis sensitivity analyses were entered into Stock Synthesis analogously to the reference case model (GOM +ATL) as described above.

3.3 Model Configuration and Equations

The Stock Synthesis model for the GOM + ATL combined regions, defined here as the provisional base model configuration, is a single stock that encompasses the U.S. Gulf of Mexico and East Coast Atlantic waters combined, as defined in the Stock ID Process Report and the Data Workshop Report. Based on the Data Workshop Report recommendations, the end year of the assessment data included in the model was 2019, and the start year was 1981, based on the availability of catch data.

3.3.1 Provisional Base Model Configuration

The Stock Synthesis reference case (GOM + ATL) model configuration is defined here as the provisional base model configuration. The model included two sexes to account for disparities in growth parameters between sexes identified in the Data Workshop Report (Their Section 2 Life History Table 1). Recruitment was assumed to occur at age-0 in order to accommodate the high proportion of sharks captured at small sizes in many of the length composition data sources (e.g., as described in the Data Workshop Report Section 6. Length Composition, and summarized here in **Tables 3.1** and **3.2)**. The maximum age in Stock Synthesis is modeled as a “plus” group that accumulates ages greater than or equal to the maximum age by assuming constant natural mortality at age and constant fishing mortality at age above the maximum age (Methot and Wetzel 2013; Methot et al. 2020). The maximum age was set equal to 50 years for both sexes (**Table 3.3**), which is consistent with the theoretical maximum age of females (51 years) and males (48 years) obtained from the estimation of vital rates for scalloped hammerhead in the assessment document SEDAR77-AW04 (Cortés 2022, his Tables 1 and 6 GOM + ATL combined; Pers. Comm. E. Cortés, July 2022). The theoretical maximum ages are well above the observed maximum age for females (29.5 yr) and males (39.5 yr) (e.g., as described in the Data Workshop Report Section 2. Life History, their Table 1).

3.3.1.1. Length at Age and Weight at Length

Growth in length at age for the Stock Synthesis reference case (GOM + ATL) model configuration was assumed to follow the separate von Bertalanffy growth (VBG) relationships recommended in the DW report for females and males as described in the Data Workshop Report (Their Section 2. Life History, Table 1). The VBG length at Amin was set equal to length at age-0 (LAmin = L_0 cm FL). VBG asymptotic length was set equal to the length at age-infinity (LAmax = L_{inf} cm FL). L_{inf}, the VBG growth coefficient (k), and the VBG parameter (t_0) were then input as fixed parameters separately for males and females (**Table 3.3**). The parameter for LAmin, defined here as the length at age-0, was fixed at 42.0 and 41.6 cm FL for females and males, respectively, following the VBG relationships described above (**Table 3.3**). The parameter for LAmax, defined here as the length at age-infinity (L_{inf}), was set equal to 229.2 and 230.1 cm FL for females and males, respectively, following the VBG relationships described above (**Table 3.3**).

In Stock Synthesis (version 3.30.15.00; Methot et al. 2020), fish recruit at the real age of 0.0 with a body size equal to the lower edge of the first population size bin. Fish then grow linearly until they reach the real age associated with LAmin and have a size equal to the parameter value for LAmin. As fish continue to age, they grow according to the VBG relationship. The growth curve is calibrated to go through the size equal to the parameter value for LAmax when they reach the age associated with LAmax.

The implementation of the VBG relationship resulted in a slightly larger length at age-0 (LAmin) for females and males than the approximate size at birth (c. 35 cm FL; e.g., as described in the Data Workshop Report Section 2. Life History, their Table 1). Consequently, an attempt was made to account for growth from the approximate observed size at birth by fixing the lower edge of the first population size bin equal to the approximate size at birth (35 cm FL). This approach is also consistent with previous Atlantic HMS SEDAR stock assessments conducted in Stock

Synthesis for both the Atlantic smooth dogfish shark (Anon. 2015) and the Atlantic blacktip shark (Anon. 2020).

Uncertainty, in the distribution of mean length at each age was modeled as a normal distribution and the CV in mean length at age was modeled as a linear function of length. The CVs for LAmin and LAmax were fixed at 0.1 for both females and males (**Figure 3.1**). The CV values were obtained from a Stock Synthesis assessment model developed for North Atlantic shortfin mako (Courtney et al. 2017a; Anon. 2017b). In that assessment, the CV values in length for each observed age were approximated from the sample distribution of the pooled length-at-age data. Consequently, the uncertainty in length at each age was assumed to be equal to that of North Atlantic shortfin mako and was not analyzed further because of time constraints and the limited sex specific length composition data available in this assessment. This approach is also consistent with a previous Atlantic HMS SEDAR stock assessment conducted in Stock Synthesis for the Atlantic blacktip shark (Anon. 2020), where stock assessment model sensitivity to the assumed uncertainty in length at age could was evaluated by estimating the CVs for L_{Amin} and L_{Amax} within their logistic sensitivity analysis.

Sex-specific weight (kg) at length (cm FL) was assumed to follow the sex-specific weight-at-length relationships recommended for females $Wt = (5.77x10^{-6})FL^{3.128}$ and males $Wt = (1.78x10^{-5})FL^{2.905}$ (e.g., as described in the Data Workshop Report Section 2. Life History, their Table 1). The weight-at-length relationship parameters were input as fixed parameters separately for males and females.

3.3.1.2. Annual Pup Production at Age

Annual pup production at age for the Stock Synthesis reference case (GOM + ATL) model configuration (**Table 3.4**) was calculated as follows based on life history data obtained from the Data Workshop Report Section 2. Life History, their Tables 1 and 6, unless noted otherwise below. Litter size (LS) was obtained as 18 pups with no relationship between fecundity and maternal size or age. Female fraction mature at age was obtained from a logistic relationship for females in the GOM + ATL regions combined where tmat = 16.11 years, a = -11.979, and b = 0.744. Female fraction maternal at age was obtained from the fraction mature at age by assuming an 10 – 12 month gestation period, approximated here by 1-year from maturity to maternity. Pup production at age was then calculated here as (LS at age)* (Fraction Maternal at age). Annual pup production at age was obtained by assuming an annual reproductive cycle and then calculated here as [(LS at age)* (Fraction Maternal at age)]/one.

3.3.1.3. Stock Recruit Model and Steepness (*h*)

A Beverton-Holt (BH) stock-recruitment relationship was assumed and implemented for the Stock Synthesis reference case (GOM + ATL) model configuration. In Stock Synthesis, (version 3.30.15.00; Methot et al. 2020), the BH stock-recruitment model is parameterized with three parameters, the natural log (ln) of unexploited equilibrium recruitment (R_0), the steepness parameter (h) and a parameter representing the standard deviation in annual recruitment deviation (σ_R) (Methot and Wetzel 2013; e.g., Wetzel and Punt 2011a, 2011b). Parameter estimation for ln(R_0) utilized a normal prior with a large standard deviation (Pr_SD) along with independent minimum and maximum boundary conditions (Min, Max). Implementation of a normal prior is described in the manual for Stock Synthesis (version 3.30.15.00; Methot et al. 2020). The steepness parameter, *h*, describes the fraction of the unexploited recruits produced at 20% of the equilibrium spawning stock size. The stock-recruit steepness parameter was fixed at a value obtained analytically based on life history, h = 0.69, obtained from the assessment document SEDAR77-AW04 (Cortés 2022), as described in Sections 2.3 and 3.2.7 above. The parameter representing the standard deviation in annual recruitment, σ_R, was fixed initially at a value of 0.283 obtained from a recent Stock Synthesis assessment model developed for North Atlantic shortfin mako (Courtney et al. 2017a). In that assessment, the σ_R value was adjusted one time from an initial value of 0.4 to the value of 0.28 in order match the RMSE of recruitment variability obtained during the main recruitment deviation period (1990 – 2012) from the assessment model (Courtney et al. 2017a). The same uncertainty in annual recruitment deviation was assumed for this assessment. The minimum (-10) and maximum (10) recruitment deviation bounds were set at relatively large values in an effort not to restrict the estimated recruitment deviation beyond that imposed by the standard deviation in annual recruitment, σ_R. This approach is also consistent with a previous Atlantic HMS SEDAR stock assessment conducted in Stock Synthesis for the Atlantic blacktip shark (Anon. 2020).

Spawning stock size within the stock-recruitment relationship was modeled as spawning stock fecundity (SSF), and calculated as the sum of female numbers at age (1000s of individuals) multiplied by annual pup production at age at the beginning of each calendar year assuming a 1:1 ratio of male to female pups. This approach is also consistent with previous Atlantic HMS SEDAR stock assessments conducted in Stock Synthesis for both the Atlantic smooth dogfish shark (Anon. 2015) and the Atlantic blacktip shark (Anon. 2020), and consistent with earlier implementations in the State Space Age Structured Production Model (SSASPM) previously used by the SEFSC to conduct Atlantic HMS domestic shark stock assessments (e.g., Anon. 2012, 2013a, 2013b).

An examination of the Stock Synthesis reference case (GOM + ATL) model configuration output with the program r4ss (Taylor et al. 2020) indicated that there was little recruitment information in the data prior to the 1990s. There was also a ramp up in recruitment information in the data from about the year 1988 until about the year 2000 consistent with the increasing availability of length composition data during that time period (**Table 3.2**). Consequently, main recruitment deviations were estimated during the years 1998 – 2017, with early recruitment deviations beginning 10 years prior to the main recruitment period (1988 – 1997) and late recruitment deviations estimated for the years 2018 and 2019. Main recruitment deviations are zero centered. The use of recruitment deviations periods allows the estimation of early and late recruitment deviations without biasing the zero centered estimation of main recruitment deviations.

In Stock Synthesis (version 3.30.15.00; Methot et al. 2020), recruitment deviations are estimated on the natural log scale. Consequently, the expected recruitments require a bias adjustment so that the resulting recruitment level on the standard scale provides an unbiased estimate of the mean (i.e., is mean unbiased). The years chosen for bias adjustment, and the maximum bias adjustment parameter value, were obtained from Stock Synthesis output with the program r4ss, as described below in the data weighting section. Both the recruitment deviation approach and the bias correction approach are consistent with a previous Atlantic HMS SEDAR stock assessment conducted in Stock Synthesis for the Atlantic blacktip shark (Anon. 2020).

3.3.1.4. Reproductive Output Timing

In Stock Synthesis version 3.30 (version 3.30.15.00; Methot et al. 2020), reproductive output has a specified “spawning” (parturition) timing within the calendar year and an explicit elapsed time between spawning (parturition) and recruitment. Spawning (parturition) timing was defined in the Stock Synthesis reference case (GOM + ATL) model configuration as January 1 and recruitment timing was defined as July 1 (month 7) approximately one month after pupping, which occurs for scalloped hammerhead sharks in late May and June (e.g., see the Data Workshop Report Section 2. Life History, their Table 1). The timing of reproductive output is consistent with the previous Atlantic HMS SEDAR stock assessment for the Atlantic blacktip shark conducted in Stock Synthesis version 3.30 (version 3.30.15.00; Anon. 2020) and with the earlier Atlantic HMS SEDAR benchmark stock assessment conducted in Stock Synthesis v3.24U for Atlantic smooth dogfish (Anon. 2015), which included one spawning season and recruitment event on January 1.

3.3.1.5. Natural Mortality (*M*)

The sex-specific natural mortality rate at each age (M_a) was fixed in the Stock Synthesis reference case (GOM + ATL) model configuration at age-specific values, separately for females and males, obtained externally to the model, as described above in Section 2.3 Life History Inputs and provided in **Table 2.5**. Natural mortality was assumed to occur beginning at age-0 consistent with the previous Atlantic HMS SEDAR stock assessment for the Atlantic blacktip shark conducted in Stock Synthesis version 3.30 (version 3.30.15.00; Anon. 2020) and with the earlier Atlantic HMS SEDAR benchmark stock assessment conducted in Stock Synthesis v3.24U for Atlantic smooth dogfish (Anon. 2015). In contrast, natural mortality was assumed to occur beginning at age-1 in the State Space Age Structured Production Model, SSASPM, previously used by the NMFS SEFSC to conduct Atlantic HMS domestic shark stock assessments (e.g., Anon. 2012, 2013a, 2013b).

3.3.1.6. Selectivity

The Stock Synthesis double normal selectivity function (Stock Synthesis selectivity pattern 24; Methot et al. 2020) was implemented (**Table 3.5**) in the Stock Synthesis reference case (GOM + ATL) model configuration and fit to the available length composition data (35 – 250+ cm FL with a 10 cm data bin width) based on a review of the available length composition data described in the Data Workshop Report Section 6 Length Composition, and summarized here in **Tables 3.1** and **3.2)**. The double normal selectivity function includes six parameters: p1 - Peak value, p2 - Top logistic, p3 - Ascending width, p4 - Descending width, p5 - Selectivity at initial size bin, and p6 - Selectivity at final size bin. Initial selectivity parameter values were obtained by fitting the double normal selectivity curve by eye to the available length composition data separately for each fleet with the SELEX24 helper spreadsheet.[1] If any individual selectivity parameter could not be estimated in Stock Synthesis, e.g., based on poor model diagnostics, then the electivity parameter was fixed at the value obtained externally with the SELEX24 helper spreadsheet by setting initial values equal to those obtained with the SELEX24 helper spreadsheet. This approach allowed for either asymptotic selectivity (logistic) or dome-shaped selectivity to be implemented consistent with selectivity parameter values obtained externally to the model with the SELEX24 helper spreadsheet while allowing a limited number of selectivity parameters to be estimated for each data set base on the limited available length composition data and the resulting model diagnostics for fit to data. Parameter estimation for double normal selectivity parameters utilized a diffuse symmetric beta prior (Pr_SD = 0.05) scaled between minimum and maximum parameter bounds (Min, Max). The diffuse symmetric beta prior imposes a relative large penalty near parameter bounds, but is otherwise uninformative (Methot et al. 2020). The symmetric beta prior does not utilize the prior mean (Methot et al. 2020). However, a value for the prior mean is still required and reported, as a placeholder. Because there was no prior information – other than the fit obtained externally to the model with the SELEX24 helper spreadsheet, the prior means for the double normal selectivity function were set equal to estimated values obtained from preliminary model runs.

[1] (SELEX24 helper spreadsheet available: https://vlab.ncep.noaa.gov/web/stock-synthesis; accessed August 2020)

Sex-specific selectivity was implemented for fleets with sufficient sex-specific length composition data (F1, F3, S4, and S5; **Tables 3.2 and 3.5**). Sex-specific selectivity was implemented as a parameter offset to the double normal selectivity (Methot et al. 2020) and included the estimation of five additional parameters per fleet: p1-offset (peak), p3-offset (ascending width), p4-offset (descending width), p6-offset (selectivity at final size bin), and a scaling parameter representing the sex specific offset (as a fraction) of apical selectivity. Estimation of parameter offsets to double normal selectivity utilized a normal prior with a large standard deviation (Pr_SD) along with independent minimum and maximum parameter offset bounds (Min, Max). Prior mean values were set to zero for parameter offsets and to one for the offset scaling parameter. For each fleet with sex-specific selectivity, both male (option 3) and female (option 4) selectivity were evaluated as the offset parameters. The offset option which resulted in maximum selectivity equal to one and the offset scaling parameter as a fraction less than one was chosen. Following this approach, the resulting apical fishing mortality, the maximum continuous F obtained for each fleet when multiplied by maximum selectivity (equal to one), was comparable among fleets. Initial values for selectivity offset parameters along with their minimum and maximum parameter offset bounds were adjusted by trial and error in preliminary model runs to insure that parameter estimates were not hitting upper or lower bounds. Both the double normal selectivity approach and sex-specific offset approach are consistent with a previous Atlantic HMS SEDAR stock assessment conducted in Stock Synthesis for the Atlantic blacktip shark (Anon. 2020).

Asymptotic (logistic) selectivity was proposed during the Assessment Process webinars for fleets that capture the largest sharks F1 (Com-BLL), F3 (Com-PLL), S4 (FSU-BLL), and S5 (SEFSC-BLLS) (**Table 3.5**). An examination of the available fishery-dependent length composition data obtained from observer programs identified a high proportion of large **male** sharks (> size at maturity) in both F1 and F3. Similarly, an examination of the available fishery-independent length composition data identified a high proportion of large **male** sharks (> size at maturity) in both S4 and S5 (e.g., as described in the Data Workshop Report, their Section 6 Length Composition and their Figure 12). In contrast, the only data set which captured a high proportion of both large **female** and large **male** sharks (> size at maturity) was the NOAA Northeast Fisheries Science Center coastal shark bottom longline survey (NMFS-NE-LLS) provided in Data Workshop Report SEDAR77-DW28 (McCandless and Natanson 2021). This data set was recommended for use as a sensitivity analysis of the provisional base model configuration, because of ongoing work needed to standardize the index with a spatially explicit model. The remaining fleets and surveys all captured a high proportion of relatively smaller sharks (< size at maturity).

Asymptotic selectivity was implemented with a logistic selectivity curve for the previous Atlantic HMS SEDAR stock assessment conducted in Stock Synthesis for the Atlantic blacktip shark (Anon. 2020). The logistic selectivity function was implemented in Stock Synthesis with selectivity pattern 1 (Methot et al. 2020):

(Eq. 3.1) $$S(l) = \frac{1}{1 + e^{\left(\frac{-\ln(19)(L_l - p1)}{p2}\right)}}$$ (Methot et al. 2020, their equation 21).

The value for L_l is the length bin, p1 is the size at inflection, and p2 is width for 95% selection. A negative width causes a descending curve. However, logistic selectivity resulted in poor fits to length composition data at the largest size bins (not shown). Consequently, the double normal selectivity function was implemented in the Stock Synthesis base model configuration for the Atlantic blacktip shark (Anon. 2020) logistic fleets with final selectivity at the largest size bins estimated in the model based on fit to the length composition data. In contrast, because of generally low length composition sample size in SEDAR 77, the double normal selectivity function was implemented in Stock Synthesis for logistic fleets with fully asymptotic (logistic) selectivity at the largest size bins obtained based on the fit to length composition data obtained externally to the model with the SELEX24 helper spreadsheet.

The SEDAR 65 Atlantic blacktip shark stock assessment in Stock Synthesis implemented time blocks in selectivity for fleets F1 (Com-BLL-Kept 1981 – 1996, 1997 – 2004, 2005 – 2007, 2008 – 2017, and 2018), F2 (Com-GN-Kept 1981 – 2006, and 2007 – 2018), and F4 (Recreational 1981 – 1989, 1990 – 1999, and 2000 – 2018). Time blocks were implemented in SEDAR 65 to improve model fits to the available length composition data (Anon. 2020; their Table 3.5).

The same fleets F1 (Com-BLL), F2 (Com-GN) and F4 (Rec) are modelled in both the SEDAR 65 and SEDAR 77. However, the SEDAR 77 scalloped hammerhead stock assessment has much lower length composition sample size for fleets with time blocks (F1 ♀ 1206, ♂ 1560; F2 ♀ + ♂ 245; and F4 ♀ + ♂ 290; **Table 3.2**) compared to the same fleets in SEDAR 65 (F1 ♀ 2993, ♂ 2382; F2 ♀ + ♂ 1476; and F4 ♀ + ♂ 822; Anon. 2020; their Table 3.2). Consequently, a decision was made during early SEDAR 77 model development to inform the selectivity time blocks for fleets F1, F2 and F4 based on the time blocks previously obtained for those same fleets in SEDAR 65. This approach informs the relatively data poor SEDAR 77 assessment model time blocks from model fits to data obtained in the relatively data rich(er) SEDAR 65 assessment model (e,g., similar to the “Robin Hood” approach, Punt et al 2011). An assumption made here is that the fleet characteristics for F1, F2, and F4 are similar between SEDAR 65 and SEDAR 77.

This process resulted in time blocks added to the estimation of selectivity (**Table 3.5**) for F1 (Com-BLL 1981 – 1996, 1997 – 2004, 2005 – 2008, 2009 – 2017 [main years], and 2018 –

2019), F2 (Com-GN 1981 – 2006, and 2007 – 2019 [main years]), and F4 (Recreational 1981 – 1999, and 2000 – 2019 [main years]). Corresponding time blocks were also added to the estimation of catchability, *q*, for surveys S2 and S3 because the surveys S1 and S2 are fit using the length based selectivity obtained for F1 (Mirror F1; **Table 3.5**).

Preliminary model runs resulted in a large number of poorly estimated selectivity parameters (i.e., large gradient $>1.00*10^{-04}$ or CV > 50%, highly correlated > 0.95 or un-correlated < 0.01, or estimated at a boundary condition). Consequently, the number of estimated selectivity parameters was reduced by identifying and removing (or reformulating) poorly estimated selectivity parameters. Poorly estimated selectivity time block parameters were fixed to their values obtained during the time block with the most data [main years]. Similarly, poorly estimated sex-specific offset parameter values were fixed to their estimated values obtained for the other sex in the same fleet. If neither of these options were available, poorly estimated selectivity parameters were fixed at their initial values obtained from the fit to length composition data obtained externally to the model with the SELEX24 helper spreadsheet, as described above.

3.3.1.7. Data Weighting

A Francis (2011) two-stage data weighting approach was implemented in the Stock Synthesis reference case (GOM + ATL) model configuration. In stage one, a minimum average standard error, SE on the natural log scale, was imposed in Stock Synthesis for each CPUE series. The minimum SE was based on the residual variance obtained from a simple smoother fit to each CPUE series, on the natural log scale, outside the model (Francis 2011; Lee et al. 2014a, 2014b). In stage two, the effective sample size (Effn) of each length composition data set was obtained from the residuals of the Stock Synthesis model fit to each length composition data set using either the Francis (2011) or the McAllister and Ianelli (1997) harmonic mean data weighting methods. The Francis (2011) and McAllister and Ianelli (1997) data weighting methods are reviewed in Francis (2017) and Punt (2017). Data weighting philosophies in fisheries stock assessment models are discussed in Punt et al. (2014).

Stage 1

A LOESS smoother was fit to each CPUE data on the log scale (**Appendix 3.A**). The square root of the residual variance was calculated for each CPUE series based on the fit of the simple smoother to the CPUE series on the log scale as

(Eq. 3.2)
$$\mathrm{RMSE}_{smoother} = \sqrt{\left(\frac{1}{N}\right)\sum_{t=1}^{N}\left(Y_t - \hat{Y}_t\right)^2} \quad .$$

The value for Y_t is the observed CPUE in year *t* on the log scale, $\hat{Y}_t$ is the predicted CPUE in year *t* obtained from the smoother fit to the data on the log scale, and *N* is the number of CPUE observations (Francis 2011; Lee et al. 2014a, 2014b; e.g., Courtney et al. 2017b). The average annual CV input (SE.in) for each CPUE series in the Stock Synthesis was assumed to be equal to the average SE on the log scale. The SE was then adjusted based on the expectation that the stock assessment model would fit each CPUE time series **at best** as well as a LOESS smoother (Francis 2011; Lee et al. 2014a, 2014b; e.g., Courtney et al. 2017b).

On one hand, if SE.in for a CPUE series was less than $\mathrm{RMSE}_{smoother}$ for that CPUE series, then the input SE for the CPUE series was adjusted (SE.adj) in Stock Synthesis before running the model so that the new average SE was equal to $\mathrm{RMSE}_{smoother}$ (SE.in + SE.adj $= \mathrm{RMSE}_{smoother}$). On the other hand, if SE.in for a CPUE series was greater than or equal to the $\mathrm{RMSE}_{smoother}$ for that CPUE series, then the SE of the CPUE series was not adjusted in the Stock Synthesis model. All calculations were implemented in R (R Core Team 2020). The resulting variance adjustments for surveys are provided in **Table 3.6**.

Stage 2

Effn for each length composition data set was estimated using the Francis method (Punt 2017, his equation 1.C "Francis tuning method") for length composition data sets with more than ten years of data. Otherwise, Effn was estimated using the McAllister and Ianelli harmonic mean method (Punt 2017, his equation 1.B "McAllister-Ianelli-2 tuning method"). Sample size for the Francis method is based on the number of years with length composition data (Punt 2017, his Table 2). In contrast, sample size for the McAllister and Ianelli harmonic mean method is based on the number of lengths measured each year (Punt 2017, his Table 2). In preliminary model runs, Effn estimates obtained using the Francis method were larger than those obtained using the McAllister and Ianelli harmonic mean method for data sets with less than 11 years of length composition. Consequently, the McAllister and Ianelli harmonic mean was used for these length composition data. Effn estimates were obtained from the R package r4ss (Taylor et al. 2020) for the Francis method, and from Stock Synthesis output (Methot and Wetzel 2013; Methot et al. 2020) for the McAllister and Ianelli harmonic mean method. The resulting variance adjustments for length composition are provided in **Table 3.6**.

3.3.1.8. Recruitment Deviation Bias Adjustment Ramp

The parameter representing the standard deviation in recruitment, σ_R, was not adjusted from the initial value of 0.28, and was also consistent with the RMSE of recruitment variability obtained from the Stock Synthesis report file for the main recruitment deviation period (0.19, 1998 – 2017).

The expected recruitments require a bias adjustment so that the resulting recruitment level on the standard scale is mean unbiased (Methot and Taylor 2011). The years chosen for bias adjustment, and the maximum bias adjustment parameter value were obtained from Stock Synthesis output with the program r4ss from the R package r4ss (Taylor et al. 2020):

```
1982.5   #_last_yr_nobias_adj_in_MPD; begin of ramp
2000.9   #_first_yr_fullbias_adj_in_MPD; begin of plateau
2018.8   #_last_yr_fullbias_adj_in_MPD
  2020   #_end_yr_for_ramp_in_MPD
0.6718   #_max_bias_adj_in_MPD
```

3.3.1.9. Initial Population State

The population was assumed to be in an unfished state of equilibrium at the start of the model (1981). The population age structure and overall size in the first year was determined as a function of the parameter estimate of the first year recruitment on the natural log scale, $\ln(R_0)$, and the initial equilibrium catch (set to 0.0 mt).

3.3.1.10. Model Convergence and Diagnostics

Model convergence was based on whether or not the Hessian matrix inverted (i.e., the matrix of second derivatives of the likelihood with respect to the parameters, from which the asymptotic standard error of the parameter estimates is derived). Other convergence diagnostics were also evaluated. Excessive CVs on estimated quantities (>> 50 %) or a large final gradient ($>1.00*10^{-04}$) were indicative of poorly estimated parameters. The correlation matrix was also examined for highly correlated (> 0.95) and un-correlated (< 0.01) parameters, which were assumed to be non-informative and an indication of over parameterization. Parameters estimated at a bound were a diagnostic for poorly estimated parameters (or poorly specified model structure). Poor fits to CPUE or length composition data along with patterns in Pearson's residuals of fits to CPUE or length composition data were diagnostics for problems with fitting the available data resulting from poorly estimated parameters or poorly specified model structure.

3.3.1.11. Uncertainty and Measures of Precision

Precision in estimated and derived parameters was obtained from Stock Synthesis AD-Model Builder (ADMB) output as the asymptotic parameter standard deviations (SD) at the converged solution (Fournier et al. 2011).

A multivariate log-normal Monte-Carlo approach (MVLN; Winker et al 2019; e.g., Walter and Winker 2020) was applied to the Stock Synthesis (GOM + ATL) continuity analysis model configuration to estimate uncertainty about the stock status as described in Section 3.13 **Appendix 3.D.**

An estimate of within assessment uncertainty was obtained here from median OFL catch in 2020 (325.381 mt) and its StdDev (53.58) for the Stock Synthesis reference case (GOM + ATL) model configurationa. A log normal standard error for OFL catch in 2020 was assumed, and a log normal sigma (0.164) was calculated here obtained as sqrt(ln(1+CV^2)), where CV = StdDev/(Median OFL catch). The estimate of within assessment uncertainty obtained for the Stock Synthesis reference case (GOM + ATL) model configuration (sigma = 0.164) is relatively smaller than a minimum estimate of among assessment uncertainty (log normal standard error, sigma_min = 0.415) obtained from meta-analysis of previously completed age-structured shark stock assessments within SEDAR (Courtney and Rice 2023) as described in Section 3.14 **Appendix E**.

3.3.1.12. Sensitivity Analyses

Gulf of Mexico and Atlantic

In response to the presence of a cryptic hammerhead species in the Atlantic region (Carolina hammerhead), the Stock ID Process recommended conducting sensitivity analyses to the scalloped hammerhead assessment for data inputs separately by geographic region for the Gulf of Mexico (GOM) and the Atlantic (ATL). Consequently, Stock Synthesis models were fit to data inputs provided by the DW separately for catch in the GOM (**Table 2.1**, Panel B) and the ATL (**Table 2.1**, Panel C) regions, as well as for indices of abundance in the GOM (**Table 2.3**, Panel B; **Table 2.4**) and the ATL (**Table 2.3**, Panel C; **Table 2.4**) regions, along with the length composition, life history, and natural mortality separated by region (Table 2.5), as described above.

3.3.1.13. Benchmarks and Reference Points

Benchmarks are provided in this assessment for spawning stock fecundity, SSF, and fishing mortality, *F*, in the terminal year of the assessment, 2019 (SSF_{2019}, and F_{2019}). Benchmarks are reported relative to equilibrium MSY reference points (SSF_{MSY}, and F_{MSY}). Depletion estimates are provided relative to unfished equilibrium levels estimated at the start year of the assessment (1981) for SSF, *F* and recruitment (SSF_0, F_0, R_0). Trajectories and phase plots are provided for F_Y/F_{MSY} and SSF_Y/SSF_{MSY}.

Stock status definitions are based on recent Atlantic HMS stock status criteria (e.g., NMFS (2019, their Section 2 Status of Stocks) and summarized here: "… a stock is considered "overfished" when the current biomass (B) is less than the biomass for the minimum stock size threshold ($B < B_{MSST}$). The minimum stock size threshold (MSST) is determined based on the natural mortality of the stock and the biomass at maximum sustainable yield (B_{MSY}). Maximum sustainable yield (MSY) is the maximum long-term average yield that can be produced by a stock on a continuing basis. The biomass can fall below the B_{MSY} without causing the stock to be declared "overfished" as long as the biomass is above B_{MSST}."

Similarly, stock status determinations are based on the recent Atlantic HMS stock status reference point thresholds (e.g., NMFS 2019, their Section 2 Status of Stocks) and summarized here:

> "Maximum Fishing Mortality Threshold (MFMT) = $F_{limit} = F_{MSY}$;
> Overfishing is occurring when $F_{year} > F_{MSY}$;
> Minimum Stock Size Threshold (MSST) = $B_{limit} = (1\text{-}M)B_{MSY}$ when $M < 0.5$ or MSST = $0.5B_{MSY}$ when $M \geq 0.5$, M = natural mortality.
> An overfished status is defined as B_{year} relative to B_{MSST}."

Consequently, for the purposes of this assessment, the scalloped hammerhead stock in the combined GOM + ATL regions was defined to be in an overfishing condition in year *y* if $F_Y > F_{MSY}$. The fishing mortality rate, *F*, was calculated in Stock Synthesis as the total annual fishing mortality rate experienced by the population ($F=Z-M$) (Methot et al. 2020). The stock was defined to be in an overfished condition in year *y* if $SSF_Y < \left(1-\bar{M}_a\right)*SSF_{MSY}$. Spawning stock fecundity, SSF, was used as a proxy for female biomass, *B*, and $\bar{M}_a$ was calculated as the average natural mortality rate at age used in the assessment model configuration. For the Stock

Synthesis reference case (GOM + ATL) model configuration, $\bar{M}_a$ was calculated as the arithmetic mean of the female age-specific values of *M* used for the baseline run (0.123; **Table 2.5**, Panel A). Consequently, for the Stock Synthesis reference case (GOM + ATL) model configuration $\bar{M}_a < 0.5$ and MSST was defined as $\left(1-\bar{M}_a\right)*SSF_{MSY}$. The MSST reference point threshold defined in NMFS (2019, their Section 2 Status of Stocks) is consistent with recommendations from Restrepo et al. (1998) and Restrepo and Powers (1999).

3.3.1.14. Projection Methods

Stock Synthesis projections for the scalloped hammerhead stock in the combined GOM + ATL regions are provided separately as an appendix. Projections methods were adapted from the SEDAR 57 U.S. Caribbean spiny lobster stock assessment as implemented under the Caribbean Fishery Management Council (CFMC) ABC Control Rule (Anon. 2019). Projections are implemented here as an example application of methods available for obtaining ABC from OFL projections in a manner that is consistent with Stock Synthesis projection methods previously implemented in SEDAR 57.

3.4 Results

3.4.1 Measures of Overall Model Fit

3.4.1.1. Model Convergence and Diagnostics

The Hessian matrix inverted and, consequently, was assumed to be positive definite. However, the maximum gradient ($3.61*10^{-4}$, Late_RecrDev_2019; **Table 3.7**) along with the gradients of several other estimated parameters (**Table 3.7**) were relatively larger than expected at a converged solution ($>1.00*10^{-04}$). Similarly, CVs of several estimated catchability and selectivity parameters were also relatively larger than expected at a converged solution (> 50 %; **Table 3.7**), and the CV of one estimated selectivity parameter was much larger (>> 50 %; **Table 3.7**) than expected at a converged solution. However, the very large CV resulted from division with a value near zero (-0.02), which highlights the limited utility of evaluating parameters CVs as a convergence diagnostic. No parameters were estimated above the maximum correlation threshold *(cormax = 0.95)* or below the minimum correlation threshold (*cormin* = 0.01), and no parameters were estimated on a boundary condition.

3.4.1.2. Indices of Abundance and Catchability

Model fits to indices of abundance for the Stock Synthesis reference case (GOM + ATL) model configuration are provided in **Figure 3.2**. Fits are provided on the nominal scale and on the log scale along with residuals on the log scale. Catchability, *q*, is estimated for indices with time blocks (S2 and S3), and the median unbiased analytical solution for *q*, calculated in Stock Synthesis, is provided for the remaining indices S1, S3 – S5, R1 – R5 (**Table 3.8; Figure 3.2**). Fits to population "surveys" (S1 – S5; all-ages in the sampled population, generally obtained offshore and generally not including age-0 individuals) and one survey of "recruits" (R4; age-0 in the sampled population, generally obtained from near-shore bays or estuaries and further limited within analyses to include only age-0 data) were generally poor, with resulting estimated trends in abundance either being flat or slightly increasing (**Figure 3.2**). In contrast, the fits to the remaining surveys of "recruits" (R1 – R3, R5; age-0 in the sampled population) had obvious trends or autocorrelation in their residuals, indicating a general lack of fit to these surveys. In addition a negative trend in residuals was apparent for fits to R3 and R5 (trend from positive to negative residuals over time; **Figure 3.2**). In contrast, a positive trend in residuals was apparent for R1, R2, and R4 (trend form negative residuals to positive residuals over time; **Figure 3.2**). The contrasting trends in residuals among indices provides evidence of conflicting information content about trends in relative abundance of "recruits" (age-0 in the sampled population) among these indices.

3.4.1.3. Length Composition

Fits to length composition for the Stock Synthesis reference case (GOM + ATL) model configuration are provided in **Figure 3.3**. Observed and predicted annual length compositions are provided along with Pearson residuals. Years with annual length composition sample size less than the minimum input sample size (Min; **Table 3.2)** were excluded from the model fit, and are not plotted. The value "N adj" is the input effective sample size obtained using either the Francis method or the McAllister and Ianelli harmonic mean, as described above. The value "N eff" is an alternative effective sample size estimate (McAllister and Ianelli 1997; Punt 2017, his McAllister-Ianelli-1 in equation 1.A:) that is not implemented in this assessment. The diameter of Pearson residuals indicates relative error; predicted < observed (solid), predicted > observed (transparent) within the length composition data set. The maximum diameter of Pearson residuals indicates relative error among length composition data sets.

Fits to available length composition data obtained from fishery dependent data (F1 – F4) and from fishery independent population "surveys" (S4, and S5) were generally poor (**Figure 3.3**).

As described above, time blocks were added to the estimation of selectivity for F1 (Com-BLL 1981 – 1996, 1997 – 2004, 2005 – 2008, 2009 – 2017 [main years], and 2018 – 2019), F2 (Com-GN 1981 – 2006, and 2007 – 2019 [main years]), and F4 (Recreational 1981 –1999, and 2000 – 2019 [main years]; **Table 3.5**). As described above, corresponding time blocks were also added to the estimation of catchability, *q*, for surveys S2 and S3 because the surveys S1 and S2 are fit using the length based selectivity obtained for F1 (Mirror F1; **Table 3.5**). As described above, sex-specific selectivity was also implemented for fleets with sufficient sex-specific length composition data (F1, F3, S4, and S5; **Tables 3.2 and 3.5**). After the addition of time-blocks and sex specific selectivity there were few remaining obvious systematic patterns observed in the residuals (e.g., patterns of positive or negative residuals), making it difficult to objectively determine how to improve the fits.

In contrast, fits to available length composition data obtained from fishery independent surveys of "recruits" (R1 – R4; age-0 in the sampled population, were reasonable (**Figure 3.3**). However, the maximum diameter of Pearson residuals was relatively large (> 8) for F3, F4, S5 as well as R2 and R4 indicating a relatively poorer fit to these length composition data sets than to the others.

In comparison, fits to aggregate length compositions (**Figure 3.4**) for some fishery dependent data (F1, F2, and F4) and some fishery independent population "surveys" (S5) also appeared to be reasonably accurate, indicating that the estimated selectivity curves removed sharks from the modeled population in aggregate at comparable length to that observed in the data for each of these fleets and surveys. In contrast, fits to aggregate length compositions (**Figure 3.4**) for other fishery dependent data (F3) and other fishery independent population "surveys" (S4) appeared to be poor.

3.4.1.4. Parameter Estimates and Associated Measures of Uncertainty

Parameter estimates along with their priors, asymptotic standard errors, and resulting CVs are provided in **Table 3.7**, as described above. Parameters with a negative phase were fixed at their initial value. CVs are calculated as the asymptotic standard error (Parm_StDev) divided by the estimated value (Value), which may have limited utility for parameters with estimated values near zero, as described above.

3.4.1.5. Length Based Selectivity

Estimated selectivity at length (cm FL) obtained for the Stock Synthesis reference case (GOM + ATL) model configuration is provided in **Figure 3.5.** Selectivity was estimated by implementing the selectivity functions identified in **Table 3.5**. Selectivity parameter estimates and their associated asymptotic standard errors and CVs are provided in **Table 3.7**.

3.4.1.6. Recruitment

The annual numbers of age-0 recruits obtained for the Stock Synthesis reference case (GOM + ATL) model configuration are provided in **Table 3.9** and **Figure 3.6**. Log recruitment deviations were estimated for early (1988 – 1997), main (1998 – 2017), late (2018 – 2019), and forecast (2020) recruitment periods and are plotted with associated 95% asymptotic confidence intervals. Estimated annual age-0 recruits are also plotted with 95% asymptotic confidence intervals. Age-0 recruits follow the assumed stock recruitment relationship exactly in years prior to 1988 and after 2019. Expected recruitment from the stock-recruitment relationship and the bias adjustment applied to the stock-recruitment relationship (Methot and Taylor 2011) are provided in **Figure 3.7**.

3.4.2 Fishing Mortality

Two calculations of fishing mortality rate were obtained from Stock Synthesis model output for the Stock Synthesis reference case (GOM + ATL) model configuration. First, the instantaneous annual fishing mortality rate (continuous *F*) was obtained from Stock Synthesis output separately for each fleet F1 – F6 (**Figure 3.8**). A plot of total commercial and recreational catch (mt) by fleet is also provided (**Figure 3.8)** for comparison. Total catch includes both total commercial catch entered in Stock Synthesis in weight (mt) and total recreational catch (A + B1 + LPRM) entered in Stock Synthesis in numbers (thousands), as described above, and then converted internally within Stock Synthesis to weight (mt).

Second, the summary fishing mortality rate across all fleets was obtained from Stock Synthesis output as the total fishing mortality rate experienced by the population ($F=Z-M$) on an annual basis (**Table 3.9**). The summary fishing mortality rate across all fleets is also provided relative to F_{MSY} (F/F_{MSY}; **Figure 3.8**, panel B; **Table 3.10)**. Approximate 95% confidence intervals, ± 1.96*SE, were plotted using the asymptotic standard errors (SE) of the derived quantity, F/F_{MSY}, obtained from Stock Synthesis output (**Figure 3.9,** upper panel**)**.

3.4.3 Stock Biomass (Total and Spawning Stock)

Annual total biomass, *B*, and annual spawning stock fecundity, SSF, obtained for the Stock Synthesis reference case (GOM + ATL) model configuration are provided in **Table 3.9**. Annual SSF is provided relative to SSF_{MSY}, SSF/SSF_{MSY}, along with the asymptotic standard error of the derived quantity obtained from Stock Synthesis output (**Table 3.10)**. Annual SSF is also provided relative to MSST, SSF/MSST, in **Table 3.10.** However, SSF/MSST is not a standard derived quantity in Stock Synthesis. Consequently, the asymptotic standard error of the derived quantity SSF/MSST is not available from Stock Synthesis output. Annual SSF is plotted along with its asymptotic standard error obtained from Stock Synthesis and then compared to MSST in **Figure 3.9**.

3.4.4 Sensitivity Analyses

3.4.4.1. Stock Synthesis Gulf of Mexico Sensitivity Analysis Model Configuration

Results of the Stock Synthesis GOM regional sensitivity analysis model configuration are provided in Section 3.11 **Appendix 3.B**. The Stock Synthesis GOM model configuration failed to pass multiple convergence criteria including parameters estimates for $\ln(R_0)$, catchability, and selectivity with excessively large final gradients ($>1.00\text{x}10^{-04}$), excessively high (> 0.95) or low (< 0.01) correlations, and estimated parameter values hitting an upper or lower boundary condition previously imposed for the parameter. Multiple iterative model simplifications including the removal of time blocks and implementation of fixed selectivity parameters at values obtained from relatively more data rich fleets or time periods failed to improve the model's ability to estimate $\ln(R_0)$ along with multiple selectivity parameters simultaneously. The final parameter estimate for $\ln(R_0)$ was equal to the mean of the lower and upper boundary conditions previously established for the parameter. Similarly, the asymptotic uncertainty of the estimated $\ln(R_0)$ parameter was equal to the range of the previously established lower and upper boundary conditions for the parameter.

For these reasons, as discussed during Assessment Webinar 8, it was determined that the Stock Synthesis GOM model configuration failed to converge to reasonable parameter estimates. A hypothesis for the lack of model convergence discussed during Assessment Webinar 8 was the relatively limited data available for use in the GOM. The limited data may not have been sufficiently informative within the Stock Synthesis GOM model configuration to estimate $\ln(R_0)$, catchability, and selectivity simultaneously.

3.4.4.2. Stock Synthesis Atlantic Sensitivity Analysis Model Configuration

Results of the Stock Synthesis ATL regional sensitivity analysis model configuration are provided in Section 3.12 **Appendix 3.C**. The Stock Synthesis ATL model configuration also failed to pass multiple convergence criteria including parameters estimates for ln(R_0), catchability, and selectivity with excessively large final gradients (>$1.00x10^{-04}$), excessively high (> 0.95) or low (< 0.01) correlations, and estimated parameter values hitting an upper or lower boundary previously imposed for the parameter. Multiple iterative model simplifications including the removal of time blocks and implementation of fixed selectivity parameters at values obtained from relatively more data rich fleets or time periods also failed to improve the model's ability to estimate ln(R_0) along with multiple selectivity parameters simultaneously. The final model configuration in Stock Synthesis was implemented with a simplified model structure, which fixed multiple selectivity parameters at externally estimated values, because of problems estimating multiple selectivity parameters with the limited length composition data. The final model failed to pass multiple convergence criteria including the ln(R_0) parameter estimated at and upper boundary condition and multiple parameters, including ln(R_0), estimated below the correlation threshold (0.01).

For these reasons, as discussed during Assessment Webinar 8, it was also determined that the Stock Synthesis ATL model configuration failed to converge to reasonable parameter estimates. A hypothesis for the lack of model convergence discussed during Assessment Webinar 8 was the relatively limited data available for use in the ATL. Similar to the hypothesis proposed for the GOM, the limited data available in the ATL may not have been sufficiently informative to estimate ln(R_0), catchability, and selectivity simultaneously within the Stock Synthesis ATL model configuration.

3.4.5 Diagnostics

Diagnostic results implemented for the Stock Synthesis GOM+ATL continuity analysis model configuration are provided and discussed in Section 3.14 **Appendix 3.D**. Diagnostic analyses were not implemented for either the Stock Synthesis GOM or the Stock Synthesis ATL sensitivity analyses because both sensitivity analysis model configurations failed multiple convergence criteria.

3.4.6 Benchmarks and Reference Points

Results obtained for the Stock Synthesis reference case (GOM + ATL) model configuration predicted that the combined GOM + ATL stock was not overfished (SSF_{2019} > MSST) and that the stock was not experiencing overfishing ($F_{2019} > F_{MSY}$) in the terminal year of the assessment (**Tables 3.10** and **3.11; Figures 3.9** and **3.10**). In contrast, results obtained for the Stock Synthesis reference case (GOM + ATL) model configuration predicted that the combined GOM

+ ATL stock had experienced overfishing, annual total $F > F_{MSY}$, during some years of the assessment: 1981 – 1985, 1990 – 1995, and 2003 – 2005 (**Table 3.10**; **Figures 3.9** and **3.10**).

3.4.7 Projections

Examples of projected fishery removals at the overfishing limit (OFL) were obtained for the Stock Synthesis reference case (GOM + ATL) model configuration as described in Section 3.14 (**Appendix 3.E)**. Examples of projected OFL during the years 2020 – 2025 were obtained from Stock Synthesis projections at F_{MSY} based on the underlying population dynamics assumed during the projection period as described in **Appendix 3.E**.

Examples of ABC reductions from OFL were obtained for the Stock Synthesis reference case (GOM + ATL) model configuration and are described in Sections 3.3.1.14 and 3.14 (**Appendix 3.E)**. Examples of average annual ABC during the years 2023, 2024, and 2025 were obtained by using an ABC/OFL map (ABC = 80.4% of average OFL; Courtney and Rice 2023), where average OFL was computed as the average of projected annual OFL obtained during the years 2023, 2024, and 2025, as described in **Appendix 3.E**.

OFL Projections in Biomass

Examples of projected fishery removals in biomass (mt) at the overfishing limit (OFL) were obtained during the years 2020 – 2025 for commercial and recreational catch plus PRM (**Figure 3.E.1** and **Table 3.E.3**). Projected OFL (mt) was adjusted for expected average annual fishery removals during the gap years 2020, 2021, and 2022 (OFL Adj-1; **Figure 3.E.1** and Table **3.E.3**).

OFL Projections in Numbers

Examples of projected fishery removals in numbers (1000s of individuals) at the overfishing limit (OFL) were obtained during the years 2020 – 2025 for commercial and recreational catch plus PRM (**Figure 3.E.2** and **Table 3.E.4**). Projected OFL (mt) was adjusted for expected average annual fishery removals during the gap years 2020, 2021, and 2022 (OFL Adj-1; **Figure 3.E.2** and **Table 3.E.4**).

Example ABC Reduction from OFL Projections in Biomass

An example of the average annual ABC (mt) during the years 2023, 2024, and 2025 (273.13 mt) was obtained for the Stock Synthesis reference case (GOM + ATL) model configuration using the ABC/OFL map (ABC = 80.4% of average OFL), where average OFL in biomass was computed as the average of projected annual OFL obtained during the years 2023, 2024, and 2025 (Avg. OFL 2023 – 2025 = 339.54 mt).

Example ABC Reduction from OFL Projections in Numbers

An example of the average annual ABC (1000s of individuals) during the years 2023, 2024, and 2025 (14.74, 1000s) was obtained for the Stock Synthesis reference case (GOM + ATL) model configuration using the ABC/OFL map (ABC = 80.4% of average OFL), where average OFL in numbers was computed as the average of projected annual OFL obtained during the years 2023, 2024, and 2025 (Avg. OFL 2023 – 2025 = 18.33, 1000s).

3.5 Discussion

Multiple sensitivity analyses were recommended during the scalloped hammerhead Stock ID and assessment processes, including low and high productivity, low and high catch and others such as the use of super years in Stock Synthesis for length composition data sets with low sample size. Unfortunately, due to time constraints, only two model sensitivity analyses were evaluated as discussed below.

In response to the presence of a cryptic hammerhead species in the Atlantic region (Carolina hammerhead), the Stock ID process recommended conducting sensitivity analyses to the combined region scalloped hammerhead stock assessment for data inputs separately by geographic region for the GOM and the ATL. Consequently, separate Stock Synthesis data inputs were obtained from the DW for catch, indices of abundance, and life history in the GOM and the ATL regions, and separate Stock Synthesis model configurations were evaluated for scalloped hammerhead in the GOM (**Appendix 3.B**) and ATL (**Appendix 3.C**) regions as described above. unfortunately, as discussed above, both the Stock Synthesis GOM sensitivity analysis model configuration and the Stock Synthesis ATL sensitivity analysis model configuration failed to converge to reasonable parameter estimates, putatively as a result of data limitations within each separate region compared to the GOM+ATL regions combined.

A full set of model diagnostics was implemented for a preliminary version of the Stock Synthesis reference case (GOM + ATL) model configuration (**Appendix 3.D**). The preliminary version of the Stock Synthesis (GOM+ATL) model configuration was defined here as a “continuity” analysis model because it was obtained from previously developed Stock Synthesis models. Specifically, continuity was obtained here by adapting the preliminary Stock Synthesis (GOM+ATL) model configuration directly from the final SEDAR 65 Stock Synthesis model configuration, updated with data for SEDAR 77.

In contrast, example ABC reduction from OFL projections were obtained for the Stock Synthesis reference case (GOM + ATL) model configuration (**Appendix 3.E.**), defined here as the “provisional base” model configuration. The Stock Synthesis reference case (GOM + ATL) model configuration was obtained from the continuity analysis model configuration by making minor corrections including the implementation of several fixed sex specific selectivity parameters, which more accurately matched the available sex specific length composition data. An assumption was that the model diagnostics evaluated for the continuity analysis model configuration (**Appendix 3.D**) also applied to the provisional base model configuration, although this was not evaluated.

An effort was also made during this assessment to develop methods for obtaining ABC from OFL projections in a manner that is consistent with Stock Synthesis projection methods previously implemented in SEDAR 57 as documented within Courtney and Rice (2023).

Regarding current stock assessment good practices for model diagnostics and model sensitivity analyses, Punt (2023) notes:

> “Overall, the ideal is to apply as many diagnostic analyses as possible, along with running sensitivity analyses to explore sensitivity even within a model that exhibits no obvious problems, recognizing that currently available diagnostics are not guaranteed to identify all problems or uncertainties.”

Regarding model diagnostics, a full set of model diagnostics was evaluated and summarized above. However, regarding sensitivity analyses, while multiple sensitivity analyses were identified, most were not implemented due to time constraints. Sensitivity analyses identified included states of nature such as low and high productivity, and low and high catch, among others. Additional sensitivity analyses identified included evaluating the use of super years in Stock Synthesis for length composition data sets with low sample size, and the use of a spatially standardized index, among others. Consequently, in future research track assessments it may be important to rank model sensitives recommended (or identified) during the Stock ID, Data, and Assessment Processes objectively based upon which sensitivities (or states of nature) are either most likely to improve our understanding of model performance or are needed to provide robust management advice.

Additional research may be needed evaluate the effect of federal and state management actions, such as size restrictions and bag limits, on CPUE and length composition of recreational catch available for use in stock assessment. For example, the SEDAR 65 Atlantic Blacktip Stock Assessment Report recommended future research on the variable effects of federal and state recreational management actions on the annual length composition of Atlantic blacktip shark recreational catch. The SEDAR 65 Atlantic Blacktip Stock Assessment Report noted that federal management actions include implementation of a minimum size limit (54 inches straight FL; measured in a straight line from tip nose to fork in tail) in federal waters during calendar years 2000 – 2018 and the implementation of federal bag limits of four LCS (Large Coastal Sharks; 1993), two LCS (1997) and one LCS (2000 – 2018). It was also noted that most Atlantic blacktip sharks are captured recreationally within state waters, and that the federal management actions identified above may not have been implemented uniformly within state waters. These federal management actions, or others, may also apply to scalloped hammerheads. In particular, time blocks used to fit to length composition data were adapted from SEDAR 65 for use in the SEDAR 77 continuity analysis and carried forward to the SEDAR 77 provisional base model configuration.

As noted in the SEDAR 65 Atlantic Blacktip Stock Assessment Report Recommendations for Future Research section, the selectivity parameterization approach implemented here estimated selectivity parameters where possible and fixed (or reformulated) poorly estimated selectivity parameters where necessary. An assumption was that poor quality annual length composition data sets (e.g., either because of low sample size and observation error, or because of sampling bias) were not necessarily representative of annual changes in the length composition sampled in that year. Consequently a poor fit to some annual length composition data sets was accepted. In contrast, aggregate length composition data were assumed to be representative of the length composition because of higher sample size and reduced observation error in aggregate. Consequently and effort was made to fit all aggregate length composition data well. We note that this approach does not address sampling bias. This pragmatic approach was implemented here in order to remove sharks from the modeled population at approximately the correct size sampled in aggregate, while allowing relatively poorer fits to poor quality annual length composition data. This pragmatic selectivity parameterization approach is consistent with regularization to reduce over-parameterization in Bayesian stock assessments implemented in AD Model Builder, ADMB, by adding priors and turning off estimation for poorly informed parameters (Monnahan et al. 2019). Future research could investigate trade-offs in model fit and uncertainty by evaluating selectivity functions with fewer parameters and developing informed priors for the selectivity parameters, or investigate the use of super years for length composition data sets with low sample size, as noted above.

As noted in the SEDAR 65 Atlantic Blacktip Stock Assessment Report Recommendations for Future Research section, the observation of proportionally few large sharks in the sampled length composition data compared to that expected based on life history may result from multiple reasons. For example, the spatial distribution of fishing effort for an exploited population that is not well mixed (Sampson 2014) and selection of individuals with relatively faster growth rates (Taylor and Methot 2013) can produce apparent dome-shaped selectivity patterns if not explicitly accounted for. Alternative modelling approaches for dealing with apparent dome-shaped selectivity can result in different underlying population numbers at age predicted over time within the stock assessment model. The approach taken in this assessment was to implement logistic selectivity for length composition data sets with the largest sizes. This is consistent with use of an areas as fleets approach including multiple fleets within a spatially-aggregated assessment model (e.g., Hurtado-Ferro et al. 2014; Punt et al. 2014).

As noted in the SEDAR 65 Atlantic Blacktip Stock Assessment Report Recommendations for Future Research section, the reproductive output timing within the Stock Synthesis assessment model is an active area of investigation within the SEFSC PCL stock assessment enterprise. In older versions of Stock Synthesis (< v3.30), implemented for Atlantic HMS SEDAR shark stock assessments, spawning stock size was calculated annually at the beginning of one specified spawning season and this spawning stock size produced one annual total recruitment value. Our intent in Stock Synthesis version 3.30 had been to change both the spawning timing (to June) and recruitment timing (to July). However, preliminary model runs with spawning timing defined as June (month 6) and recruitment timing defined as July (month 7) crashed, and require further evaluation before this setup can be implemented. In addition, recruitment is assumed to occur at age-0 in Stock Synthesis, consistent with previous Atlantic HMS SEDAR domestic shark stock assessments conducted with Stock Synthesis (Anon. 2015, 2017a, 2018). In contrast, recruitment was assumed to occur at age-1 in Atlantic HMS SEDAR domestic shark stock assessments previously conducted with SSASPM (Anon. 2012, 2013a, 2013b).

However, the implementation of recruitment timing in SEDAR 77 was unchanged from that in SEDAR 65, due to time constraints. Consequently, model sensitivity to reproductive output timing could be investigated in the future assessments. For example, defining the real age associated with L_{Amin} as age-1 and the size at the parameter value for L_{Amin} based on the VBG length at age-1 might be more consistent with previous SSASPM implementations. However, in the length-based Stock Synthesis model implemented here, the recruitment timing and the resulting body size at recruitment also interact with other parameters within the Stock Synthesis model such as the CV in L_{Amin}, as well as with natural mortality and fishing mortality, which occur annually within the calendar year of recruitment.

3.6 Recommendations for Future Research and Data Collection

Support research to objectively rank (and prioritize) model sensitivities typically conducted during an Atlantic HMS domestic shark SEDAR stock assessment based on likely improvement for understanding model performance and providing robust management advice.

Support research to evaluate the effect of federal and state management actions, such as size restrictions and bag limits, on CPUE standardization and length composition of recreational catch available for use in stock assessment.

Support research to investigate trade-offs in model fit and uncertainty resulting from the use of selectivity functions with fewer parameters and informed priors.

Investigate the use of super years for length composition data with low sample size that result in poor quality annual length composition distributions.

Investigate the use of logistic selectivity vs dome-shaped selectivity for length composition data sets with the largest sizes. For example, asymptotic selectivity is typically implemented for fleets with the largest length size within an areas as fleets approach including multiple fleets within a spatially-aggregated assessment model (e.g., Hurtado-Ferro et al. 2014; Punt et al. 2014). However, this approach contrasts with evidence that asymptotic selectivity curves for length size are unlikely under equilibrium conditions (Waterhouse et al 2014).

Investigate the effect of reproductive output timing implemented within the Stock Synthesis for Atlantic HMS domestic shark stock assessment models on the resulting model fit and population dynamics.

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3.8 Tables

Table 3.1 Time series of total commercial catch, recreational catch, relative abundance, and length composition data used in the Stock Synthesis reference case (GOM + ATL) model configuration.

Time series	Symbol	Commercial catch, recreational catch (A+B1+B2PRM) and relative abundance	Name	Definition	Length composition
1	F1	Commercial catch (t)	Com-BLL	Bottom longline Kept + PRM (1981 – 2019)	UF [1] + SBLOP[2] (1993 – 2019)
2	F2	Commercial catch (t)	Com-GN	Gillnet Kept + PRM (1981 – 2019)	GNOP[3] (2002 – 2019)
3	F3	Commercial catch (t)	Com-PLL	Pelagic longline discard PRM (1981 – 2019)	(1992 – 2019)
4	F4	Recreational catch (thousands)	Rec	Recreational (A+B1) (1981 – 2019)	MRIP [4]+ SRHS[5] (1981 – 2019)
5	F5	Recreational PRM (thousands)	Rec-PRM	Recreational (B2 PRM) (1981 – 2019)	Mirror F4
6	F6	Commercial catch (t)	Com-Other-Kept	Hook and line plus hand line (1981 – 2019)	Mirror F4
7	S1	Relative abundance (numbers of individuals)	PLL-Obs	Pelagic longline observer program (1992 – 2019)	Mirror F3
8	S2	Relative abundance (numbers)	Shark-BLL-Obs	Bottom longline fishery observer program (1994 – 2007)	Mirror F1
9	S3	Relative abundance (numbers)	Shark-BLL-Res	Shark bottom longline research fishery (2008 – 2019)	Mirror F1
10	S4	Relative abundance (numbers)	FSU-BLLS	FSU bottom longline survey (2011 – 2019)	2011 – 2019
11	S5	Relative abundance (numbers)	SEFSC-BLLS	NMFS SEFSC bottom longline survey (1995 – 2019)	1995 – 2019
12	R1	Relative abundance (numbers)	TXPWD-GNS	Texas Parks and Wildlife Dep. gillnet survey (age-0, 1982 – 2019)	1982 – 2019
13	R2	Relative abundance (numbers)	GULFSPAN-GNS	GULFSPAN gillnet survey (age-0, 1996 – 2019)	1994 – 2019
14	R3	Relative abundance (numbers)	COASTSPAN-BLLS	(COASTSPAN) bottom longline survey (age-0, 2005 – 2019)	2000 – 2019
15	R4	Relative abundance (numbers)	COASTSPAN-LGNS	COASTSPAN long-gillnet survey (age-0, 2001-2019)	2001 – 2019
16	R5	Relative abundance (numbers)	COASTSPAN-SGNS	COASTSPAN short-gillnet survey (age-0, 2007 – 2019)	Mirror R4[6]

[1] University of Florida (UF) Longline 1993 – 2005.
[2] Southeast Fisheries Science Center (SEFSC) Panama City Lab Shark Bottom Longline Observer Program (SBLOP) 2005 – 2019.
[3] Southeast Fisheries Science Center (SEFSC) Panama City Lab Gillnet Observer Program (GNOP).
[4] Marine Recreational Information Program (MRIP).
[5] Southeast Region Head Boat Survey (SRHS).
[6] Total length composition sample size for COASTSPAN-SGNS (n = 34) was too small to fit in Stock Synthesis.

Table 3.2 Length composition sample size (number of sharks measured) for fleets (F) surveys (S), and age-0 recruitment indices (R) fit in the Stock Synthesis reference case (GOM + ATL) model configuration, as defined in **Table 3.1**.

	F1		F2	F3		F4	S4		S5	
	(Com-BLL)		(Com-GN)	(Com-PLL)		(Rec)	(FSU-BLLS)		(SEFSC-BLL)	
	1993 – 2019		2002 – 2019	1992 – 2019		1981-2018	2011 – 2019		1995 – 2019	
	Min.[1] 30		Min. 30	Min. 20		Min. 20	Min. 20		Min. 20	
Year	(♀)	(♂)	(♀,♂,Unknown)[2]	(♀)	(♂)	(♀,♂,Unknown)[3]	(♀)	(♂)	(♀)	(♂)
1981						4				
1982						21				
1983						4				
1984						4				
1985						20				
1986						3				
1987						9				
1988						7				
1989						8				
1990						11				
1991						9				
1992				16	17	9				
1993	0	1		11	3	25				
1994	7	17		6	5	7				
1995	10	46		6	8	22			1	10
1996	9	55		4	1	8			2	5
1997	43	17		16	10	9			2	13
1998	55	78		2	3	8			0	0
1999	7	24		1	0	6			12	7
2000	1	2		0	2	8			23	22
2001	67	42		9	0	8			12	14
2002	75	56	12	0	0	14			22	22
2003	68	195	9	1	2	6			14	16
2004	79	97	39	1	1	8			7	7
2005	10	14	15	15	4	13			4	6
2006	39	28	15	14	15	6			8	9
2007	27	9	1	2	0	7			4	8
2008	33	7	3	24	11	0			3	6
2009	239	191	62	40	15	4			17	11
2010	91	121	12	6	2	1			12	13
2011	142	111	6	3	2	3	9	16	70	71
2012	36	46	16	1	2	3	0	0	4	7
2013	19	36	30	3	1	13	8	0	6	3
2014	51	66	5	1	0	1	1	0	5	7
2015	24	76	6	2	3	1	6	2	15	31
2016	15	50	2	1	2	0	0	3	9	18
2017	44	88	1	0	0	0	15	5	42	79
2018	7	55	9	0	0	0	1	2	16	20
2019	8	32	2	0	1	0	3	4	2	17
Total	1206	1560	245	185	110	290	43	32	312	422
Proportion (♀,♂)	99%		95%	99%		NA	99%		94%	

[1] Years with less than minimum sample size were excluded from the fit in the model likelihood.
[2] Sex-combined length composition data (♀, ♂, Unknown) were input for fleet F2 following SEDAR 65 blacktip
[3] Sex specific length composition data date were not available for fleet F4.

Table 3.2 Continued.

	R1	R2	R3	R4
	(TXPWD-GNS)	(GULFSPAN-GNS)	(COASTSPAN-BLLS)	(COASTSPAN-LGNS)
	1982– 2019	1994 – 2019	2000 – 2019	2001 – 2019
	Min. 20	Min. 30	Min. 20	Min. 30
Year	(♀,♂,Unknown)[4]	(♀,♂,Unknown)[4]	(♀,♂,Unknown)[4]	(♀,♂,Unknown)[4]
1981				
1982	4			
1983	8			
1984	2			
1985	2			
1986	5			
1987	0			
1988	7			
1989	3			
1990	12			
1991	4			
1992	1			
1993	3			
1994	3	46		
1995	1	0		
1996	23	23		
1997	13	99		
1998	3	35		
1999	6	41		
2000	11	38	18	
2001	31	75	7	34
2002	3	123	0	21
2003	15	68	4	90
2004	7	32	6	3
2005	22	18	14	18
2006	13	29	19	18
2007	3	95	3	36
2008	11	74	5	10
2009	20	87	34	59
2010	20	97	98	14
2011	40	59	65	2
2012	23	65	19	127
2013	96	73	25	152
2014	35	67	5	77
2015	14	39	10	36
2016	17	46	26	50
2017	3	66	24	93
2018	69	62	19	98
2019	16	73	38	79
Total	569	1530	439	1017
Proportion (♀,♂)	NA	NA	NA	NA

[4] Sex-combined length composition data (♀, ♂, Unknown) were input for recruitment indices.

Table 3.3 The von Bertalanffy growth (VBG) size at age implemented separately for females and males in the Stock Synthesis reference case (GOM + ATL) model configuration.

Age (yr.)	Female cm FL predicted from the VBG parameters below	Male cm FL predicted from VBG parameters below
0	42.0	41.6
1	57.4	58.1
2	71.6	73.3
3	84.5	87.0
4	96.5	99.6
5	107.4	111.1
6	117.4	121.5
7	126.7	131.1
8	135.1	139.8
9	142.9	147.7
10	150.0	155.0
11	156.5	161.6
12	162.5	167.6
13	168.0	173.1
14	173.0	178.1
15	177.7	182.7
16	181.9	186.8
17	185.8	190.6
18	189.4	194.1
19	192.7	197.3
20	195.7	200.2
21	198.4	202.8
22	201.0	205.2
23	203.3	207.4
24	205.4	209.4
25	207.4	211.2
26	209.2	212.9
27	210.8	214.4
28	212.4	215.8
29	213.7	217.0
30[1]	215.0	218.2
31	216.2	219.2
32	217.3	220.2
33	218.2	221.0
34	219.1	221.8
35	220.0	222.6
36	220.7	223.2
37	221.4	223.8
38	222.1	224.4
39	222.7	224.9
40[1]	223.2	225.3
41	223.7	225.8
42	224.1	226.1
43	224.6	226.5
44	224.9	226.8
45	225.3	227.1
46	225.6	227.4
47	225.9	227.6
48	226.2	227.8
49	226.4	228.0
50[2]	226.7	228.2

VBG parameters	Female	Male
L_{inf}	229.2	230.1
k	0.086	0.092
t_0	-2.35	-2.166
CV implemented for L_{Amin}	0.093	0.097
CV implemented for L_{inf}	0.090	0.082

[1] Observed Tmax (♀) = 29.5 yr and Tmax (♂) = 39.5 yr (Data Workshop Report Section 2. Life History, their Table 1).
[2] Theoretical Tmax (♀) = 51 yr and Tmax (♂) = 48 yr (Cortés 2022, his Tables 1 and 6; Pers. Comm. E . Cortés July 2022).

Table 3.4 Annual pup production at age used in the Stock Synthesis reference case (GOM + ATL) model configuration.

Age (yr.)	Litter size (LS) [1]	Fraction mature [2]	Fraction maternal [3]	Pup production [4]	Annual pup production [5]
0	18.00	0.00	0.00	0.0	0.00
1	18.00	0.00	0.00	0.0	0.00
2	18.00	0.00	0.00	0.0	0.00
3	18.00	0.00	0.00	0.0	0.00
4	18.00	0.00	0.00	0.0	0.00
5	18.00	0.00	0.00	0.0	0.00
6	18.00	0.00	0.00	0.0	0.00
7	18.00	0.00	0.00	0.0	0.00
8	18.00	0.00	0.00	0.0	0.00
9	18.00	0.01	0.00	0.0	0.00
10	18.00	0.01	0.01	0.2	0.18
11	18.00	0.02	0.01	0.2	0.18
12	18.00	0.05	0.02	0.4	0.36
13	18.00	0.09	0.05	0.9	0.90
14	18.00	0.17	0.09	1.6	1.62
15	18.00	0.31	0.17	3.1	3.06
16	18.00	0.48	0.31	5.6	5.58
17	18.00	0.66	0.48	8.6	8.64
18	18.00	0.80	0.66	11.9	11.88
19	18.00	0.90	0.80	14.4	14.40
20	18.00	0.95	0.90	16.2	16.20
21	18.00	0.97	0.95	17.1	17.10
22	18.00	0.99	0.97	17.5	17.46
23	18.00	0.99	0.99	17.8	17.82
24	18.00	1.00	0.99	17.8	17.82
25	18.00	1.00	1.00	18.0	18.00
26	18.00	1.00	1.00	18.0	18.00
27	18.00	1.00	1.00	18.0	18.00
28	18.00	1.00	1.00	18.0	18.00
29	18.00	1.00	1.00	18.0	18.00
30	18.00	1.00	1.00	18.0	18.00
31	18.00	1.00	1.00	18.0	18.00
32	18.00	1.00	1.00	18.0	18.00
33	18.00	1.00	1.00	18.0	18.00
34	18.00	1.00	1.00	18.0	18.00
35	18.00	1.00	1.00	18.0	18.00
36	18.00	1.00	1.00	18.0	18.00
37	18.00	1.00	1.00	18.0	18.00
38	18.00	1.00	1.00	18.0	18.00
39	18.00	1.00	1.00	18.0	18.00
40	18.00	1.00	1.00	18.0	18.00
41	18.00	1.00	1.00	18.0	18.00
42	18.00	1.00	1.00	18.0	18.00
43	18.00	1.00	1.00	18.0	18.00
44	18.00	1.00	1.00	18.0	18.00
45	18.00	1.00	1.00	18.0	18.00
46	18.00	1.00	1.00	18.0	18.00
47	18.00	1.00	1.00	18.0	18.00
48	18.00	1.00	1.00	18.0	18.00
49	18.00	1.00	1.00	18.0	18.00
50	18.00	1.00	1.00	18.0	18.00

[1] Brood size = 18; range 7 – 30 (Data Workshop Report Section 2. Life History, their Table 1).
[2] Fraction mature at age "tmat = 16.11 years, a = -11.979, b = 0.744" (DW Section 2.4, their Tables 1 and 6).
[3] Fraction maternal assumed an 10 – 12 month gestation period (DW Section 2.4, their Table 1), approximated here by a one year offset from maturity to maternity, e.g., see outlined boxes above at ages 9 and 23.
[4] Pup production was obtained as (LS at age)* (Fraction maternal at age).
[5] Annual pup production was obtained by assuming an annual reproductive cycle (DW Section 2.4, their Table 1) and calculated as [(LS at age)* (Fraction maternal at age)]/1 .

Table 3.5 Number of estimated parameters (numbers within parentheses) in the Stock Synthesis reference case (GOM + ATL) model configuration.

Fleet	Fleet name	Proposed selectivity pattern	Implemented selectivity pattern	Sex	Time block(s)	Number of selectivity parameters	Number of catchability parameters	Sub-total of parameters	Sub-total of estimated parameters
1	F1 (Com-BLL)	Logistic	Logistic	Sex specific	Sel. (peak, ascend)[1]	19 (6)	0 (0)	19	(6)
2	F2 (Com-GN)	Double normal	Double normal	Combined sex	Sel. (peak)[2]	7 (3)	0 (0)	7	(3)
3	F3 (Com-PLL)	Logistic	Logistic	Sex specific		11(3)	0 (0)	11	(3)
4	F4 (Rec)	Double normal	Double normal	Combined sex	Sel. (end)[3]	7 (1)	0 (0)	7	(1)
5	F5 (Rec-RPM)		Mirror F4	Mirror F4	Mirror F4	0 (0)	0 (0)	0	(0)
6	F6 (Com-Other-Kept)		Mirror F4	Mirror F4	Mirror F4	0 (0)	0 (0)	0	(0)
7	S1 (PLL-Obs)		Mirror F3	Mirror F3		0 (0)	1 (0)	1	(0)
8	S2 (Shark-BLL-Obs)		Mirror F1	Mirror F1	Catchability[4]	0 (0)	3 (3)	3	(3)
9	S3 (Shark-BLL-Res)		Mirror F1	Mirror F1	Catchability[5]	0 (0)	3 (3)	3	(3)
10	S4 (FSU-BLLS)	Logistic	Logistic	Sex specific		11(2)	1 (0)	12	(2)
11	S5 (SEFSC-BLLS)	Logistic	Logistic	Sex specific		11(3)	1 (0)	12	(3)
12	R1 (TXPWD-GNS)	Double normal	Double normal	Combined sex		6 (2)	1 (0)	7	(2)
13	R2 (GULFSPAN-GNS)	Double normal	Double normal	Combined sex		6 (1)	1 (0)	7	(1)
14	R3 (COASTSPAN-BLLS)	Double normal	Double normal	Combined sex		6 (1)	1 (0)	7	(1)
15	R4 (COASTSPAN-LGNS)	Double normal	Double normal	Combined sex		6 (1)	1 (0)	7	(1)
16	R5 (COASTSPAN-SGNS)	Double normal	Mirror R4	Mirror R4		0 (0)	1 (0)	1	(0)
						Total (selectivity, catchability)		104	(29)
	Other estimated parameters								
	ln(R_0)								(1)
	Recruitment deviations					1988 – 2019			(32)
	Forecast rec. dev.					2020 – 2029			(10)
						Grand total			(72)

[1] Time blocks in selectivity for F1 (1981 – 1996, 1997 – 2004, 2005 – 2008, 2009 – 2017 [main years], and 2018 – 2019; adapted from SEDAR 65 blacktip).
[2] Time blocks in selectivity for F2 (1981 – 2006, and 2007 – 2019 [main years]; adapted from SEDAR 65 blacktip).
[3] Time blocks in selectivity for F4 (1981 – 1999, and 2000 – 2019 [main years]; adapted from SEDAR 65 blacktip).
[4] Time blocks in catchability for S2 (1981 – 1996, 1997 – 2004 [main years], and 2005 – 2007; adapted from SEDAR 65 blacktip).
[5] Time blocks in catchability for S3 (2008, 2009 – 2017 [main years], and 2018 – 2019; adapted from SEDAR 65 blacktip).

Table 3.6 Two stage data weighting used in the Stock Synthesis reference case (GOM + ATL) model configuration, as described in the main text above; The stage-1 CPUE (survey) variance adjustments are provided along with the mean of input CV and the resulting mean of adjusted input CV obtained after adding the variance adjustment (**Panel A**); The stage-2 length composition effective sample size (Effn) adjustments are provided along with the mean input sample size (n) and the resulting mean of the adjusted input sample size, n, obtained after multiplying by the Effn adjustment (**Panel B**).

Panel A

Survey	Mean of input CV	Variance adjustment	Mean of adjusted input CV
S1 (PLL-Obs)	0.6968	0.0000	0.6968
S2 (Shark-BLL-Obs)	0.5390	0.2530	0.7920
S3 (Shark-BLL-Res)	0.3967	0.0000	0.3967
S4 (FSU-BLLS)	0.6352	0.0000	0.6352
S5 (SEFSC-BLLS)	0.3013	0.0097	0.3110
R1 (TXPWD-GNS)	0.6652	0.0318	0.6970
R2 (GULFSPAN-GNS)	0.2552	0.4318	0.6870
R3 (COASTSPAN-BLLS)	0.6178	0.0000	0.6178
R4 (COASTSPAN-LGNS)	0.6626	0.0000	0.6626
R5 (COASTSPAN-SGNS)	0.4597	0.0000	0.4597

Panel B

Length composition data source	Mean of input n	Adjustment method	Sample size adjustment	Mean of adjusted input n
F1 (Com-BLL)	118.0	Francis Effn	0.092	10.8
F2 (Com-GN)	43.7	Harmonic Mean Effn	0.130	5.7
F3 (Com-PLL)	35.6	Harmonic Mean Effn	0.505	18.0
F4 (Rec)	22.0	Harmonic Mean Effn	0.240	5.3
S4 (FSU-BLLS)	22.5	Harmonic Mean Effn	1.120	25.2
S5 (SEFSC-BLLS)	51.7	Francis Effn	1.384	71.6
R1 (TXPWD-GNS)	37.9	Harmonic Mean Effn	0.186	7.0
R2 (GULFSPAN-GNS)	66.4	Francis Effn	0.695	46.1
R3 (COASTSPAN-BLLS)	44.3	Harmonic Mean Effn	0.063	2.8
R4 (COASTSPAN-LGNS)	77.6	Francis Effn	0.603	46.8

Table 3.7 Parameters in the Stock Synthesis reference case (GOM + ATL) model configuration; Parameter value, phase, minimum bound, maximum bound, initial value, standard deviation (StDev), gradient, prior type, prior value, prior standard deviation, and parameter CV calculated as the parameter StDev (asymptotic standard error) divided by the parameter estimated value; Parameters with a negative phase were fixed at their initial value.

Label	Value	Par.	Ph.	Min.	Max.	Init.	StDev	Grad.	Pr_type	Prior	Pr_SD	CV
L_at_Amin_Fem_GP_1	41.97	_	-3	5	100	41.97	_	_	Normal	41.97	1000	NA
L_at_Amax_Fem_GP_1	229.20	_	-4	50	600	229.20	_	_	Normal	229.20	1000	NA
VonBert_K_Fem_GP_1	0.09	_	-5	0.01	0.65	0.09	_	_	Normal	0.06	0.2	NA
CV_young_Fem_GP_1	0.09	_	-2	0.01	0.3	0.09	_	_	Normal	0.09	0.01	NA
CV_old_Fem_GP_1	0.09	_	-3	0.01	0.3	0.09	_	_	Normal	0.09	0.01	NA
Wtlen_1_Fem_GP_1	0.00	_	-3	-3	3	0.00	_	_	Normal	0.00	0.8	NA
Wtlen_2_Fem_GP_1	3.13	_	-3	-3	5	3.13	_	_	Normal	3.00	0.8	NA
Mat50%_Fem_GP_1	199.10	_	-3	1	300	199.10	_	_	Normal	199.10	0.8	NA
Mat_slope_Fem_GP_1	-0.19	_	-3	-200	3	-0.19	_	_	Normal	-0.19	0.8	NA
Eggs_scalar_Fem_GP_1	18.00	_	-3	-3	50	18.00	_	_	Normal	18.00	0.8	NA
Eggs_exp_len_Fem_GP_1	0.00	_	-3	-3	3	0.00	_	_	Normal	0.00	0.8	NA
L_at_Amin_Mal_GP_1	41.57	_	-3	5	100	41.57	_	_	Normal	41.57	1000	NA
L_at_Amax_Mal_GP_1	230.10	_	-4	50	600	230.10	_	_	Normal	230.10	1000	NA
VonBert_K_Mal_GP_1	0.09	_	-5	0.01	0.65	0.09	_	_	Normal	0.09	0.2	NA
CV_young_Mal_GP_1	0.10	_	-2	0.01	0.3	0.10	_	_	Normal	0.10	0.01	NA
CV_old_Mal_GP_1	0.08	_	-3	0.01	0.3	0.08	_	_	Normal	0.08	0.01	NA
Wtlen_1_Mal_GP_1	0.00	_	-3	-3	3	0.00	_	_	Normal	0.00	0.8	NA
Wtlen_2_Mal_GP_1	2.91	_	-3	-3	5	2.91	_	_	Normal	3.00	0.8	NA
CohortGrowDev	1.00	_	-1	0.1	10	1.00	_	_	Normal	1.00	1	NA
FracFemale_GP_1	0.50	_	-99	0.000001	0.999999	0.50	_	_	No_prior			NA
SR_LN(R0)	4.29	1	1	2.0685	8.742	4.14	0.09	1.18E-06	Normal	7.04	1000	2%
SR_BH_steep	0.69	_	-2	0.2	0.99	0.69	_	_	Normal	0.69	1000	NA
SR_sigmaR	0.28	_	-4	0.2	1.9	0.28	_	_	Normal	0.28	1000	NA
SR_regime	0.00	_	-4	-5	5	0.00	_	_	Normal	0.00	1	NA
SR_autocorr	0.00	_	-4	-5	5	0.00	_	_	Normal	0.00	1	NA

Table 3.7 Continued.

Label	Value	Par.	Ph.	Min.	Max.	Init.	StDev	Grad.	Pr_type	Prior	Pr_SD	CV
Early_RecrDev_1988	-0.21	2	4	-10	10	0.00	0.25	4.28E-05	dev			
Early_RecrDev_1989	-0.15	3	4	-10	10	0.00	0.25	1.84E-05	dev			
Early_RecrDev_1990	-0.19	4	4	-10	10	0.00	0.24	3.03E-05	dev			
Early_RecrDev_1991	-0.22	5	4	-10	10	0.00	0.24	4.38E-05	dev			
Early_RecrDev_1992	-0.19	6	4	-10	10	0.00	0.23	-4.77E-06	dev			
Early_RecrDev_1993	-0.49	7	4	-10	10	0.00	0.22	-4.08E-05	dev			
Early_RecrDev_1994	-0.11	8	4	-10	10	0.00	0.20	7.22E-06	dev			
Early_RecrDev_1995	-0.28	9	4	-10	10	0.00	0.22	-8.98E-06	dev			
Early_RecrDev_1996	0.08	10	4	-10	10	0.00	0.17	-2.72E-05	dev			
Early_RecrDev_1997	-0.81	11	4	-10	10	0.00	0.19	4.06E-06	dev			
Main_RecrDev_1998	-0.27	12	3	-10	10	0.00	0.20	-3.33E-05	dev			
Main_RecrDev_1999	0.09	13	3	-10	10	0.00	0.19	1.63E-05	dev			
Main_RecrDev_2000	0.12	14	3	-10	10	0.00	0.17	-2.20E-06	dev			
Main_RecrDev_2001	-0.42	15	3	-10	10	0.00	0.16	-6.58E-06	dev			
Main_RecrDev_2002	0.05	16	3	-10	10	0.00	0.16	9.08E-06	dev			
Main_RecrDev_2003	-0.27	17	3	-10	10	0.00	0.18	5.53E-06	dev			
Main_RecrDev_2004	0.03	18	3	-10	10	0.00	0.21	1.03E-05	dev			
Main_RecrDev_2005	-0.03	19	3	-10	10	0.00	0.21	-3.95E-05	dev			
Main_RecrDev_2006	0.10	20	3	-10	10	0.00	0.17	3.51E-05	dev			
Main_RecrDev_2007	0.18	21	3	-10	10	0.00	0.14	-1.07E-05	dev			
Main_RecrDev_2008	-0.10	22	3	-10	10	0.00	0.14	3.58E-05	dev			
Main_RecrDev_2009	-0.14	23	3	-10	10	0.00	0.15	-7.35E-06	dev			
Main_RecrDev_2010	0.30	24	3	-10	10	0.00	0.14	-2.99E-05	dev			
Main_RecrDev_2011	0.34	25	3	-10	10	0.00	0.13	1.51E-05	dev			
Main_RecrDev_2012	0.19	26	3	-10	10	0.00	0.13	-6.02E-05	dev			
Main_RecrDev_2013	0.07	27	3	-10	10	0.00	0.13	-1.71E-05	dev			
Main_RecrDev_2014	-0.05	28	3	-10	10	0.00	0.15	3.80E-07	dev			
Main_RecrDev_2015	-0.15	29	3	-10	10	0.00	0.17	1.25E-05	dev			
Main_RecrDev_2016	-0.14	30	3	-10	10	0.00	0.16	-9.93E-06	dev			
Main_RecrDev_2017	0.11	31	3	-10	10	0.00	0.16	5.87E-05	dev			
Late_RecrDev_2018	-0.06	32	6	-10	10	0.00	0.18	-1.98E-04	dev			
Late_RecrDev_2019	0.19	33	6	-10	10	0.00	0.19	3.61E-04	dev			
ForeRecr_2020	0.00	34	6	-10	10	0.00	0.28	0.00E+00	dev			
ForeRecr_2021	0.00	35	6	-10	10	0.00	0.28	0.00E+00	dev			
ForeRecr_2022	0.00	36	6	-10	10	0.00	0.28	0.00E+00	dev			
ForeRecr_2023	0.00	37	6	-10	10	0.00	0.28	0.00E+00	dev			
ForeRecr_2024	0.00	38	6	-10	10	0.00	0.28	0.00E+00	dev			
ForeRecr_2025	0.00	39	6	-10	10	0.00	0.28	0.00E+00	dev			
ForeRecr_2026	0.00	40	6	-10	10	0.00	0.28	0.00E+00	dev			
ForeRecr_2027	0.00	41	6	-10	10	0.00	0.28	0.00E+00	dev			
ForeRecr_2028	0.00	42	6	-10	10	0.00	0.28	0.00E+00	dev			
ForeRecr_2029	0.00	43	6	-10	10	0.00	0.28	0.00E+00	dev			

Table 3.7 Continued.

Label	Value	Par.	Ph.	Min.	Max.	Init.	StDev	Grad.	Pr_type	Prior	Pr_SD	CV
LnQ_base_S1_PLL_Obs(7)	-7.57	_	-1	-25	25	0.00	_	_	No_prior			NA
LnQ_base_S2_Shark_BLL_Obs(8)	-1.41	44	1	-10	10	0.00	0.35	4.95E-05	Sym_Beta	0.00	0.05	25%
LnQ_base_S3_Shark_BLL_Res(9)	0.37	45	1	-10	10	0.00	0.27	8.20E-05	Sym_Beta	0.00	0.05	73%
LnQ_base_S4_FSU_BLLS(10)	-10.49	_	-1	-25	25	0.00	_	_	No_prior			NA
LnQ_base_S5_SEFSC_BLLS(11)	-7.61	_	-1	-25	25	0.00	_	_	No_prior			NA
LnQ_base_R1_TXPWD_GNS(12)	-11.13	_	-1	-25	25	0.00	_	_	No_prior			NA
LnQ_base_R2_GULFSPAN_GNS(13)	-6.56	_	-1	-25	25	0.00	_	_	No_prior			NA
LnQ_base_R3_COASTSPAN_BLLS(14)	-2.99	_	-1	-25	25	0.00	_	_	No_prior			NA
LnQ_base_R4_COASTSPAN_LGNS(15)	-3.12	_	-1	-25	25	0.00	_	_	No_prior			NA
LnQ_base_R5_COASTSPAN_SGNS(16)	-6.41	_	-1	-25	25	0.00	_	_	No_prior			NA
LnQ_base_S2_Shark_BLL_Obs(8)_BLK3repl_1981	-1.99	46	1	-10	10	0.00	0.43	-1.19E-04	Sym_Beta	0.00	0.05	21%
LnQ_base_S2_Shark_BLL_Obs(8)_BLK3repl_2005	-1.27	47	1	-10	10	0.00	0.47	1.87E-04	Sym_Beta	0.00	0.05	37%
LnQ_base_S3_Shark_BLL_Res(9)_BLK4repl_2008	-2.55	48	1	-10	10	0.00	0.80	-1.88E-04	Sym_Beta	0.00	0.05	31%
LnQ_base_S3_Shark_BLL_Res(9)_BLK4repl_2018	-0.42	49	1	-10	10	0.00	0.33	1.48E-04	Sym_Beta	0.00	0.05	80%
Size_DblN_peak_F1_COM_BLL(1)	206.32	50	2	55.6	247.5	195.90	10.73	-3.12E-05	Sym_Beta	186.10	0.05	5%
Size_DblN_top_logit_F1_COM_BLL(1)	4.00	_	-3	-6	4	4.00	_	_	Sym_Beta	4.00	0.05	NA
Size_DblN_ascend_se_F1_COM_BLL(1)	7.84	51	3	-1	9	7.80	0.31	-1.11E-05	Sym_Beta	8.70	0.05	4%
Size_DblN_descend_se_F1_COM_BLL(1)	-1.00	_	-3	-1	9	-1.00	_	_	Sym_Beta	-1.00	0.05	NA
Size_DblN_start_logit_F1_COM_BLL(1)	-5.50	_	-2	-15	9	-5.50	_	_	Sym_Beta	-5.50	0.05	NA
Size_DblN_end_logit_F1_COM_BLL(1)	9.00	_	-2	-15	9	9.00	_	_	Sym_Beta	9.00	0.05	NA
SzSel_Fem_Peak_F1_COM_BLL(1)	-72.52	52	4	-100	100	-79.35	6.31	-1.17E-04	Normal	0.00	1000	9%
SzSel_Fem_Ascend_F1_COM_BLL(1)	-1.37	_	-4	-15	15	-1.37	_	_	Normal	0.00	1000	NA
SzSel_Fem_Descend_F1_COM_BLL(1)	0.00	_	-4	-15	15	0.00	_	_	Normal	0.00	1000	NA
SzSel_Fem_Final_F1_COM_BLL(1)	0.00	_	-4	-15	15	0.00	_	_	Normal	0.00	1000	NA
SzSel_Fem_Scale_F1_COM_BLL(1)	0.34	53	5	0	1	1.00	0.06	7.83E-05	Normal	1.00	1000	18%
Size_DblN_peak_F2_Com_GN(2)	66.72	54	2	42.5	247.5	73.10	4.76	5.97E-05	Sym_Beta	73.10	0.05	7%
Size_DblN_top_logit_F2_Com_GN(2)	-2.90	_	-3	-6	4	-2.90	_	_	Sym_Beta	-2.90	0.05	NA
Size_DblN_ascend_se_F2_Com_GN(2)	4.75	_	-3	-1	9	4.75	_	_	Sym_Beta	5.30	0.05	NA
Size_DblN_descend_se_F2_Com_GN(2)	6.38	_	-3	-1	9	6.38	_	_	Sym_Beta	7.80	0.05	NA
Size_DblN_start_logit_F2_Com_GN(2)	-15.00	_	-2	-15	9	-15.00	_	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_F2_Com_GN(2)	-1.24	55	2	-15	9	-2.30	0.90	3.65E-06	Sym_Beta	-2.30	0.05	73%
Size_DblN_peak_F3_Com_PLL(3)	135.29	56	2	55.6	247.5	143.40	9.03	1.19E-05	Sym_Beta	143.40	0.05	7%
Size_DblN_top_logit_F3_Com_PLL(3)	-6.00	_	-3	-6	4	-6.00	_	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_F3_Com_PLL(3)	6.27	57	3	-1	9	6.50	0.75	-2.14E-05	Sym_Beta	6.50	0.05	12%
Size_DblN_descend_se_F3_Com_PLL(3)	9.00	_	-3	-1	9	9.00	_	_	Sym_Beta	9.00	0.05	NA
Size_DblN_start_logit_F3_Com_PLL(3)	-15.00	_	-2	-15	9	-15.00	_	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_F3_Com_PLL(3)	9.00	_	-2	-15	9	9.00	_	_	Sym_Beta	9.00	0.05	NA
SzSel_Male_Peak_F3_Com_PLL(3)	14.04	58	4	-100	100	0.00	6.84	-4.68E-05	Normal	0.00	1000	49%
SzSel_Male_Ascend_F3_Com_PLL(3)	0.00	_	-4	-15	15	0.00	_	_	Normal	0.00	1000	NA
SzSel_Male_Descend_F3_Com_PLL(3)	0.00	_	-4	-15	15	0.00	_	_	Normal	0.00	1000	NA
SzSel_Male_Final_F3_Com_PLL(3)	0.00	_	-4	-15	15	0.00	_	_	Normal	0.00	1000	NA
SzSel_Male_Scale_F3_Com_PLL(3)	1.00	_	-5	0	1	1.00	_	_	Normal	1.00	1000	NA

Table 3.7 Continued.

Label	Value	Par.	Ph.	Min.	Max.	Init.	StDev	Grad.	Pr_type	Prior	Pr_SD	CV
Size_DblN_peak_F4_Rec(4)	61.80	_	-2	42.5	247.5	61.80	_	_	Sym_Beta	61.80	0.05	NA
Size_DblN_top_logit_F4_Rec(4)	-6.00	_	-3	-6	4	-6.00	_	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_F4_Rec(4)	9.00	_	-3	-1	9	9.00	_	_	Sym_Beta	9.00	0.05	NA
Size_DblN_descend_se_F4_Rec(4)	7.60	_	-3	-1	9	7.60	_	_	Sym_Beta	7.60	0.05	NA
Size_DblN_start_logit_F4_Rec(4)	1.00	_	-2	-15	9	1.00	_	_	Sym_Beta	1.00	0.05	NA
Size_DblN_end_logit_F4_Rec(4)	-1.00	_	-2	-15	9	-1.00	_	_	Sym_Beta	-1.00	0.05	NA
SizeSel_P1_F5_Rec_PRM(5)	1.00	_	-99	0	10	1.00	_	_	Normal	1.00	25	NA
SizeSel_P2_F5_Rec_PRM(5)	44.00	_	-99	10	100	44.00	_	_	Normal	44.00	25	NA
SizeSel_P1_F6_Com_Other_Kept(6)	1.00	_	-99	0	10	1.00	_	_	Normal	1.00	25	NA
SizeSel_P2_F6_Com_Other_Kept(6)	44.00	_	-99	10	100	44.00	_	_	Normal	44.00	25	NA
SizeSel_P1_S1_PLL_Obs(7)	1.00	_	-99	0	10	1.00	_	_	Normal	1.00	25	NA
SizeSel_P2_S1_PLL_Obs(7)	44.00	_	-99	10	100	44.00	_	_	Normal	44.00	25	NA
SizeSel_P1_S2_Shark_BLL_Obs(8)	1.00	_	-99	0	10	1.00	_	_	Normal	1.00	25	NA
SizeSel_P2_S2_Shark_BLL_Obs(8)	44.00	_	-99	10	100	44.00	_	_	Normal	44.00	25	NA
SizeSel_P1_S3_Shark_BLL_Res(9)	1.00	_	-99	0	10	1.00	_	_	Normal	1.00	25	NA
SizeSel_P2_S3_Shark_BLL_Res(9)	44.00	_	-99	10	100	44.00	_	_	Normal	44.00	25	NA
Size_DblN_peak_S4_FSU_BLLS(10)	110.76	59	2	55.6	247.5	113.20	11.24	1.18E-04	Sym_Beta	113.20	0.05	10%
Size_DblN_top_logit_S4_FSU_BLLS(10)	4.00	_	-3	-6	4	4.00	_	_	Sym_Beta	4.00	0.05	NA
Size_DblN_ascend_se_S4_FSU_BLLS(10)	6.33	60	3	-1	9	5.90	0.76	-7.81E-05	Sym_Beta	5.90	0.05	12%
Size_DblN_descend_se_S4_FSU_BLLS(10)	-1.00	_	-3	-1	9	-1.00	_	_	Sym_Beta	-1.00	0.05	NA
Size_DblN_start_logit_S4_FSU_BLLS(10)	-5.50	_	-2	-15	9	-5.50	_	_	Sym_Beta	-5.50	0.05	NA
Size_DblN_end_logit_S4_FSU_BLLS(10)	9.00	_	-2	-15	9	9.00	_	_	Sym_Beta	9.00	0.05	NA
SzSel_Fem_Peak_S4_FSU_BLLS(10)	18.11	_	-4	-100	100	18.11	_	_	Normal	0.00	1000	NA
SzSel_Fem_Ascend_S4_FSU_BLLS(10)	0.00	_	-4	-15	15	0.00	_	_	Normal	0.00	1000	NA
SzSel_Fem_Descend_S4_FSU_BLLS(10)	0.00	_	-4	-15	15	0.00	_	_	Normal	0.00	1000	NA
SzSel_Fem_Final_S4_FSU_BLLS(10)	0.00	_	-4	-15	15	0.00	_	_	Normal	0.00	1000	NA
SzSel_Fem_Scale_S4_FSU_BLLS(10)	1.00	_	-5	0	1	1.00	_	_	Normal	1.00	1000	NA
Size_DblN_peak_S5_SEFSC_BLLS(11)	102.15	61	2	55.6	247.5	144.50	4.31	-7.12E-05	Sym_Beta	117.60	0.05	4%
Size_DblN_top_logit_S5_SEFSC_BLLS(11)	4.00	_	-3	-6	4	4.00	_	_	Sym_Beta	4.00	0.05	NA
Size_DblN_ascend_se_S5_SEFSC_BLLS(11)	5.95	62	3	-1	9	9.00	0.28	-1.71E-05	Sym_Beta	9.00	0.05	5%
Size_DblN_descend_se_S5_SEFSC_BLLS(11)	-1.00	_	-3	-1	9	-1.00	_	_	Sym_Beta	-1.00	0.05	NA
Size_DblN_start_logit_S5_SEFSC_BLLS(11)	-15.00	_	-2	-15	9	-15.00	_	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_S5_SEFSC_BLLS(11)	9.00	_	-2	-15	9	9.00	_	_	Sym_Beta	9.00	0.05	NA
SzSel_Fem_Peak_S5_SEFSC_BLLS(11)	-11.53	63	4	-100	100	-42.53	2.39	8.37E-05	Normal	0.00	1000	21%
SzSel_Fem_Ascend_S5_SEFSC_BLLS(11)	0.00	_	-4	-15	15	0.00	_	_	Normal	0.00	1000	NA
SzSel_Fem_Descend_S5_SEFSC_BLLS(11)	0.00	_	-4	-15	15	0.00	_	_	Normal	0.00	1000	NA
SzSel_Fem_Final_S5_SEFSC_BLLS(11)	0.00	_	-4	-15	15	0.00	_	_	Normal	0.00	1000	NA
SzSel_Fem_Scale_S5_SEFSC_BLLS(11)	1.00	_	-5	0	1	1.00	_	_	Normal	1.00	1000	NA

Table 3.7 Continued.

Label	Value	Par.	Ph.	Min.	Max.	Init.	StDev	Grad.	Pr_type	Prior	Pr_SD	CV
Size_DblN_peak_R1_TXPWD_GNS(12)	54.07	64	2	42.5	77.5	55.30	1.02	1.11E-04	Sym_Beta	55.30	0.05	2%
Size_DblN_top_logit_R1_TXPWD_GNS(12)	-5.90	_	-3	-6	4	-5.90	_	_	Sym_Beta	-5.90	0.05	NA
Size_DblN_ascend_se_R1_TXPWD_GNS(12)	4.80	_	-3	-1	9	4.80	_	_	Sym_Beta	4.80	0.05	NA
Size_DblN_descend_se_R1_TXPWD_GNS(12)	2.90	_	-3	-1	9	2.90	_	_	Sym_Beta	2.90	0.05	NA
Size_DblN_start_logit_R1_TXPWD_GNS(12)	-0.02	65	2	-15	9	-1.10	0.62	7.04E-05	Sym_Beta	-1.10	0.05	2886%
Size_DblN_end_logit_R1_TXPWD_GNS(12)	-15.00	_	-2	-15	9	-15.00	_	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_peak_R2_GULFSPAN_GNS(13)	42.50	_	-2	42.5	77.5	42.50	_	_	Sym_Beta	43.00	0.05	NA
Size_DblN_top_logit_R2_GULFSPAN_GNS(13)	-6.00	_	-3	-6	4	-6.00	_	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_R2_GULFSPAN_GNS(13)	9.00	_	-3	-1	9	9.00	_	_	Sym_Beta	9.00	0.05	NA
Size_DblN_descend_se_R2_GULFSPAN_GNS(13)	3.96	66	3	-1	9	3.90	0.08	4.19E-05	Sym_Beta	3.90	0.05	2%
Size_DblN_start_logit_R2_GULFSPAN_GNS(13)	9.00	_	-2	-15	9	9.00	_	_	Sym_Beta	0.60	0.05	NA
Size_DblN_end_logit_R2_GULFSPAN_GNS(13)	-15.00	_	-2	-15	9	-15.00	_	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_peak_R3_COASTSPAN_BLLS(14)	37.90	_	-2	37.9	250	37.90	_	_	Sym_Beta	37.90	0.05	NA
Size_DblN_top_logit_R3_COASTSPAN_BLLS(14)	-6.00	_	-3	-6	4	-6.00	_	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_R3_COASTSPAN_BLLS(14)	-1.00	_	-3	-1	9	-1.00	_	_	Sym_Beta	-1.00	0.05	NA
Size_DblN_descend_se_R3_COASTSPAN_BLLS(14)	3.39	67	3	-1	9	4.30	0.67	2.72E-04	Sym_Beta	4.30	0.05	20%
Size_DblN_start_logit_R3_COASTSPAN_BLLS(14)	9.00	_	-2	-15	9	9.00	_	_	Sym_Beta	9.00	0.05	NA
Size_DblN_end_logit_R3_COASTSPAN_BLLS(14)	-15.00	_	-2	-15	9	-15.00	_	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_peak_R4_COASTSPAN_LGNS(15)	37.90	_	-2	37.9	250	37.90	_	_	Sym_Beta	37.90	0.05	NA
Size_DblN_top_logit_R4_COASTSPAN_LGNS(15)	-6.00	_	-3	-6	4	-6.00	_	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_R4_COASTSPAN_LGNS(15)	-1.00	_	-3	-1	9	-1.00	_	_	Sym_Beta	-1.00	0.05	NA
Size_DblN_descend_se_R4_COASTSPAN_LGNS(15)	3.07	68	3	-1	9	3.60	0.13	2.50E-05	Sym_Beta	3.60	0.05	4%
Size_DblN_start_logit_R4_COASTSPAN_LGNS(15)	9.00	_	-2	-15	9	9.00	_	_	Sym_Beta	9.00	0.05	NA
Size_DblN_end_logit_R4_COASTSPAN_LGNS(15)	-15.00	_	-2	-15	9	-15.00	_	_	Sym_Beta	-15.00	0.05	NA
SizeSel_P1_R5_COASTSPAN_SGNS(16)	1.00	_	-99	0	10	1.00	_	_	Normal	1.00	25	NA
SizeSel_P2_R5_COASTSPAN_SGNS(16)	44.00	_	-99	10	100	44.00	_	_	Normal	44.00	25	NA
Size_DblN_peak_F1_COM_BLL(1)_BLK2repl_1981	207.56	_	-2	55.6	247.5	207.56	_	_	Sym_Beta	176.25	0.05	NA
Size_DblN_peak_F1_COM_BLL(1)_BLK2repl_1997	198.07	69	2	55.6	247.5	207.56	8.91	-9.23E-05	Sym_Beta	176.25	0.05	5%
Size_DblN_peak_F1_COM_BLL(1)_BLK2repl_2005	207.56	_	-2	55.6	247.5	207.56	_	_	Sym_Beta	176.25	0.05	NA
Size_DblN_peak_F1_COM_BLL(1)_BLK2repl_2018	195.94	_	-2	55.6	247.5	195.94	_	_	Sym_Beta	186.09	0.05	NA
Size_DblN_ascend_se_F1_COM_BLL(1)_BLK2repl_1981	8.42	_	-3	-1	9	8.42	_	_	Sym_Beta	8.16	0.05	NA
Size_DblN_ascend_se_F1_COM_BLL(1)_BLK2repl_1997	7.87	70	3	-1	9	8.42	0.29	5.51E-05	Sym_Beta	8.16	0.05	4%
Size_DblN_ascend_se_F1_COM_BLL(1)_BLK2repl_2005	8.42	_	-3	-1	9	8.42	_	_	Sym_Beta	8.16	0.05	NA
Size_DblN_ascend_se_F1_COM_BLL(1)_BLK2repl_2018	7.76	_	-3	-1	9	7.76	_	_	Sym_Beta	8.66	0.05	NA
Size_DblN_peak_F2_Com_GN(2)_BLK5repl_1981	84.91	71	2	42.5	247.5	73.10	9.15	4.25E-05	Sym_Beta	73.10	0.05	11%
Size_DblN_end_logit_F4_Rec(4)_BLK6repl_1981	-0.57	72	2	-15	9	-1.00	0.79	-2.03E-05	Sym_Beta	-1.00	0.05	138%

Table 3.8. Catchability (*q*) in the Stock Synthesis reference case (GOM + ATL) model configuration; Catchability, *q*, is estimated in Stock Synthesis for indices with time blocks (S2 and S3) and is calculated as the median unbiased analytical solution obtained from Stock Synthesis for the remaining indices.

Index name and years	ln(*q*)	*q*
Main years		
S1 (PLL-Obs; 1992 – 2019)	-7.571	5.15E-04
S2 (Shark-BLL-Obs; 1997 - 2004)	-1.405	2.45E-01
S3 (Shark-BLL-Res; 2009 - 2017)	0.370	1.45E+00
S4 (FSU-BLLS; 2011 - 2019)	-10.491	2.78E-05
S5 (SEFSC-BLLS; 1995 - 2019)	-7.611	4.95E-04
R1 (TXPWD-GNS; 1983 - 2019)	-11.127	1.47E-05
R2 (GULFSPAN-GNS; 1996 - 2019)	-6.558	1.42E-03
R3 (COASTSPAN-BLLS; 2005 - 2019)	-2.987	5.05E-02
R4 (COASTSPAN-LGNS; 2001 - 2019)	-3.116	4.43E-02
R5 (COASTSPAN-SGNS; 2007 - 2019)	-6.414	1.64E-03
Time block years		
S2 (Shark-BLL-Obs; block years 1981 – 1996)	-1.986	1.37E-01
S2 (Shark-BLL-Obs; block years 2005 – 2007)	-1.266	2.82E-01
S3 (Shark-BLL-Res; block year 2008)	-2.554	7.77E-02
S3 (Shark-BLL-Res; block years 2018 – 2019)	-0.419	6.58E-01

Table 3.9 Total biomass (*B*), spawning stock fecundity (SSF), recruits (*R*), and total fishing mortality (*F=Z-M*) obtained for the Stock Synthesis reference case (GOM + ATL) model configuration.

	Total biomass *B* (Total, mt)	Female spawning stock fecundity SSF (1,000s pups)	Recruits *R* (1,000s pups)	Total fishing mortality *F=Z-M*
Virg		617	73	
Init		617	73	
1981	14472	617	73	0.090
1982	13633	587	73	0.099
1983	12727	555	72	0.078
1984	12012	530	72	0.059
1985	11465	511	72	0.051
1986	10994	494	71	0.031
1987	10678	481	71	0.026
1988	10391	469	57	0.034
1989	9959	447	60	0.040
1990	9605	428	57	0.055
1991	9145	405	55	0.064
1992	8731	383	56	0.101
1993	7886	341	41	0.093
1994	7349	315	58	0.074
1995	6832	290	48	0.048
1996	6535	271	68	0.035
1997	6349	258	28	0.031
1998	6285	249	47	0.033
1999	6226	241	67	0.034
2000	6170	235	68	0.034
2001	6142	231	39	0.040
2002	6129	227	63	0.038
2003	6102	224	45	0.050
2004	6037	220	61	0.048
2005	5993	215	57	0.053
2006	5952	210	65	0.039
2007	5970	206	69	0.034
2008	6004	202	52	0.038
2009	6050	199	50	0.032
2010	6131	197	78	0.021
2011	6310	199	81	0.020
2012	6491	202	70	0.022
2013	6690	205	63	0.023
2014	6901	208	56	0.029
2015	7053	211	51	0.023
2016	7213	215	51	0.018
2017	7384	219	66	0.018
2018	7502	222	56	0.013
2019	7697	228	73	0.009

Table 3.10 Total annual fishing mortality (*F=Z-M*) relative to MSY (F/F_{MSY}), annual spawning stock fecundity relative to MSY (SSF/SSF_{MSY}), and annual SSF relative to MSST (SSF/MSST) obtained for the Stock Synthesis reference case (GOM + ATL) model configuration.

Year	F/F_{MSY}	SE	SSF/SSF_{MSY}	SE	SSF/MSST
1981	1.87	0.206	3.41	NA	3.89
1982	2.05	0.241	3.25	0.062	3.70
1983	1.62	0.200	3.07	0.112	3.50
1984	1.22	0.154	2.93	0.147	3.34
1985	1.06	0.134	2.82	0.171	3.22
1986	0.64	0.080	2.73	0.189	3.11
1987	0.54	0.065	2.66	0.197	3.03
1988	0.70	0.085	2.59	0.201	2.96
1989	0.82	0.103	2.47	0.202	2.82
1990	1.15	0.146	2.37	0.206	2.70
1991	1.32	0.170	2.24	0.212	2.55
1992	2.10	0.284	2.12	0.219	2.41
1993	1.93	0.280	1.88	0.226	2.15
1994	1.53	0.239	1.74	0.232	1.99
1995	1.00	0.160	1.60	0.229	1.83
1996	0.72	0.117	1.50	0.222	1.71
1997	0.64	0.102	1.43	0.214	1.63
1998	0.68	0.108	1.38	0.207	1.57
1999	0.71	0.114	1.33	0.202	1.52
2000	0.71	0.110	1.30	0.198	1.48
2001	0.83	0.130	1.28	0.192	1.45
2002	0.79	0.126	1.26	0.186	1.43
2003	1.03	0.166	1.24	0.182	1.41
2004	1.00	0.164	1.21	0.178	1.38
2005	1.10	0.185	1.19	0.174	1.36
2006	0.80	0.135	1.16	0.170	1.32
2007	0.70	0.118	1.14	0.166	1.30
2008	0.79	0.142	1.12	0.164	1.27
2009	0.67	0.114	1.10	0.162	1.26
2010	0.43	0.072	1.09	0.161	1.24
2011	0.42	0.071	1.10	0.160	1.26
2012	0.45	0.075	1.12	0.161	1.27
2013	0.47	0.077	1.13	0.161	1.29
2014	0.60	0.098	1.15	0.161	1.31
2015	0.47	0.083	1.17	0.161	1.33
2016	0.37	0.061	1.19	0.162	1.35
2017	0.38	0.066	1.21	0.163	1.38
2018	0.27	0.044	1.23	0.164	1.40
2019	0.19	0.032	1.26	0.164	1.44

Table 3.11 Summary of benchmark and reference point results obtained for the Stock Synthesis reference case (GOM + ATL) model configuration. Benchmarks are provided for spawning stock fecundity, SSF, and the summary fishing mortality, *F*, calculated as the total fishing mortality rate experienced by the population ($F=Z-M$) for the terminal year of the assessment (SSF_{2019}, and F_{2019}). Benchmarks are reported relative to equilibrium MSY reference points (SSF_{MSY}, and F_{MSY}) and to the Minimum Stock Size Threshold, MSST = $(1-\bar{M}_a)$*SSF_{MSY}, with $\bar{M}_a$ calculated as the arithmetic mean of the female age-specific values of *M* used in the assessment model configuration (**Table 2.5**). Unfished equilibrium levels for SSF and recruitment (SSF_0, R_0) are estimated at the start year of the assessment (1981). Stock and fishery status are summarized relative to the benchmarks and reference points as described above in Sections 3.3.1.13 and 3.4.6.

	Provisional base model configuration	
Parameters	72	
Objective function	894.3	
Gradient	3.61E-04	
$\bar{M}_a$	0.123	
$(1-\bar{M}_a)$	0.877	
Steepness	0.69	
	Est	CV
SSF_{2019}	228	21%
F_{2019}	0.009	---
R_{2019}	73	22%
SSF_0	617	9%
R_0	73	9%
MSY	244	9%
SSF_{MSY}	181	9%
F_{MSY}	0.048	4%
SSF_{2019}/SSF_{MSY}	1.259	13%
F_{2019}/F_{MSY}	0.194	16%
MSST	159	---
SSF_{2019}/MSST	1.436	---
Stock status	SSF_{2019} > MSST	
Fishery status	$F_{2019} < F_{MSY}$	

3.9 Figures

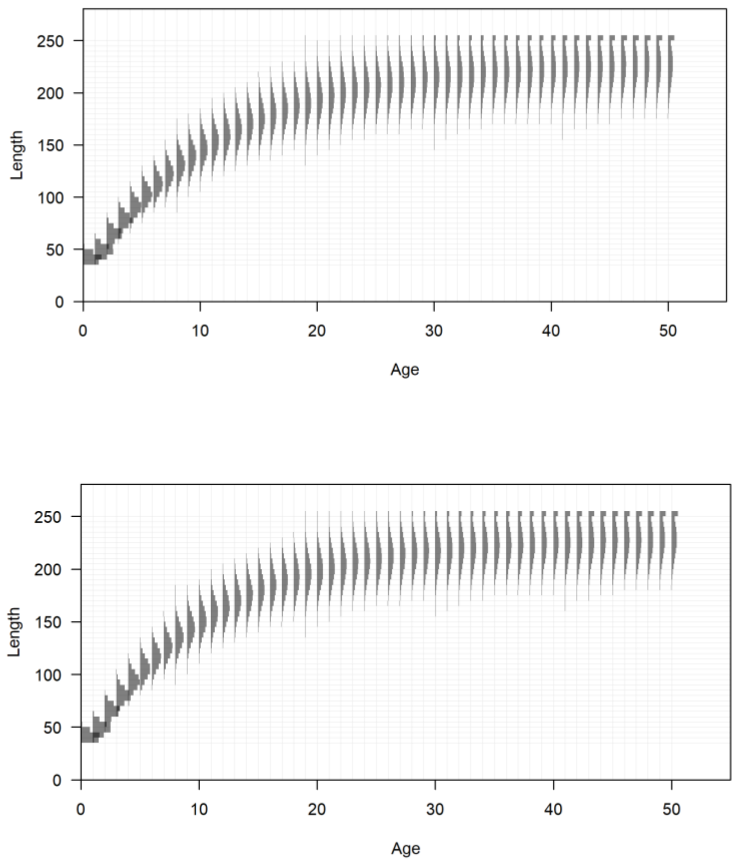


Figure 3.1 Distribution of mean length (cm FL) at each age implemented separately for females (upper panel) and males (lower panel) in the Stock Synthesis reference case (GOM + ATL) model configuration.

A. S1 (PLL-Obs)

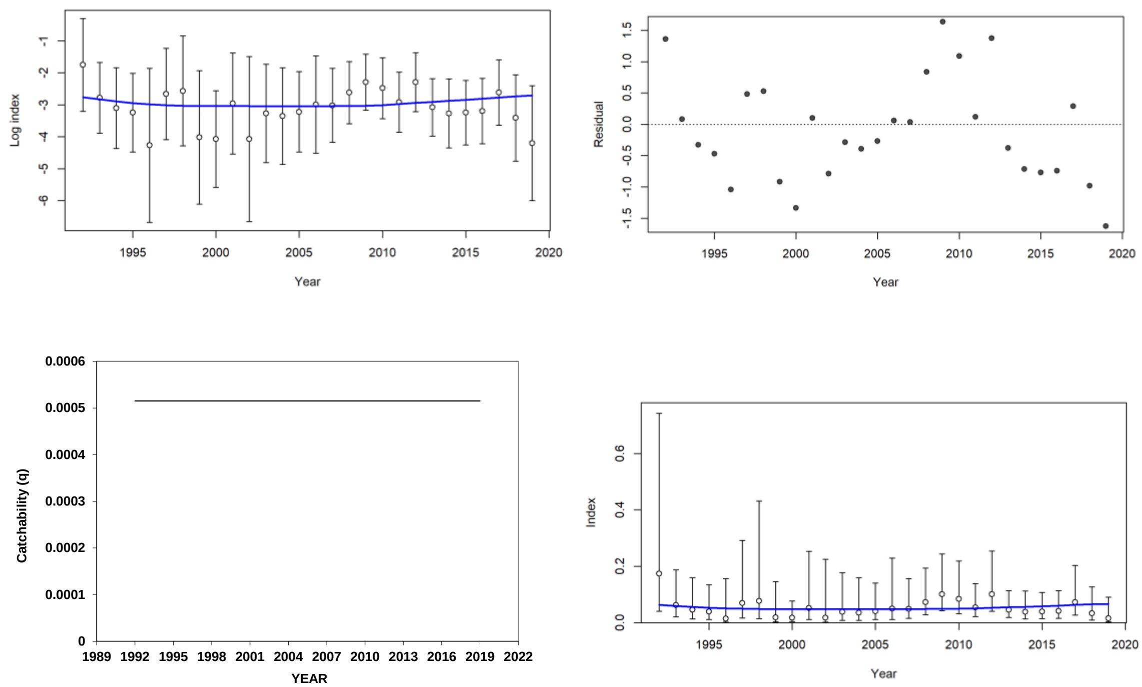


Figure 3.2 Fits to abundance indices obtained for the Stock Synthesis reference case (GOM + ATL) model configuration; Upper left panel is predicted (blue line) and observed (open circles with approximate 95% confidence intervals based on the input standard error, SE) on the natural log scale; Upper right panel is residuals on the natural log scale (ln(Obs) - ln(Exp))/(observed SE); Lower left panel is estimated catchability; Lower right panel is observed and predicted on the nominal scale.

B. S2 (Shark-BLL-Obs)

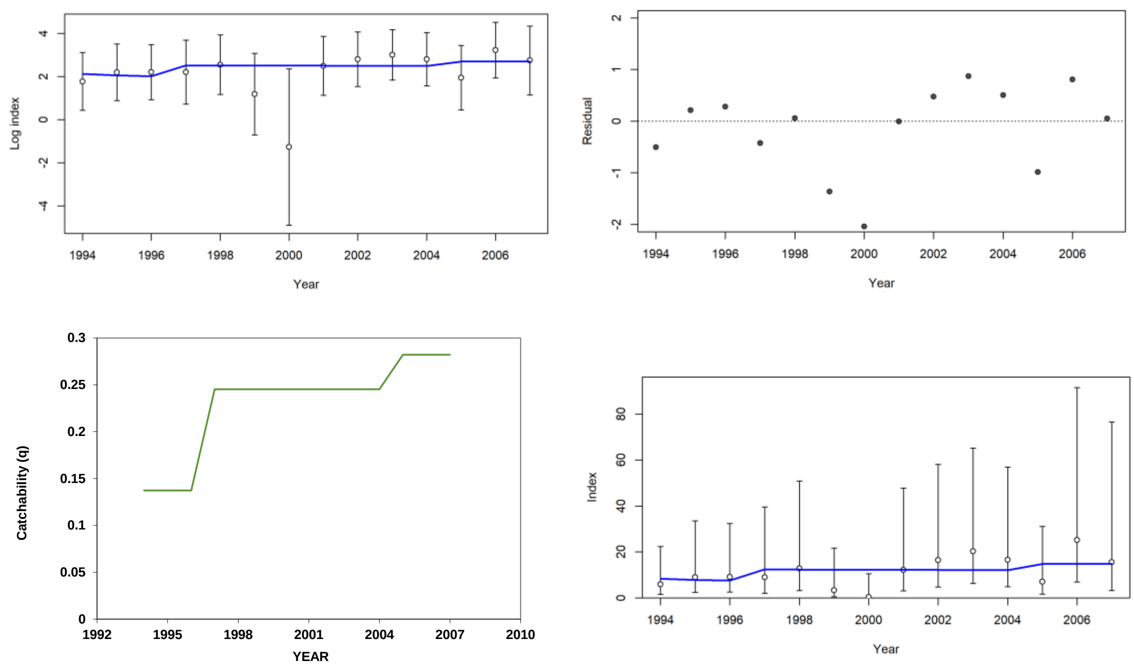


Figure 3.2 Continued.

C. S3 (Shark-BLL-Res)

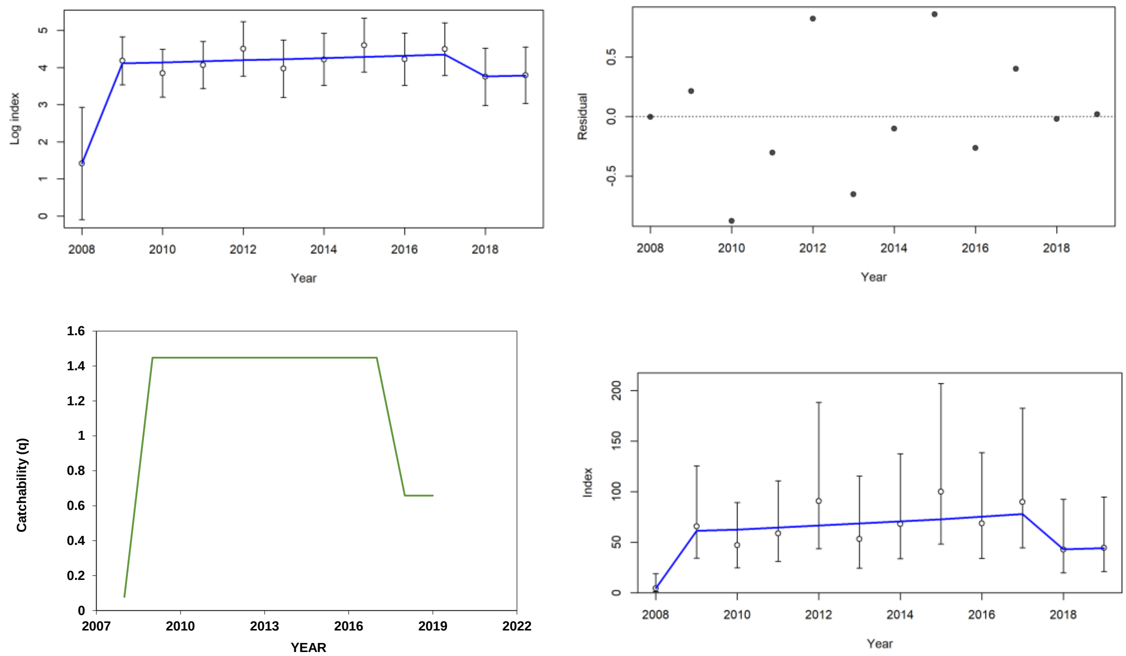


Figure 3.2 Continued.

D. S4 (FSU-BLLS)

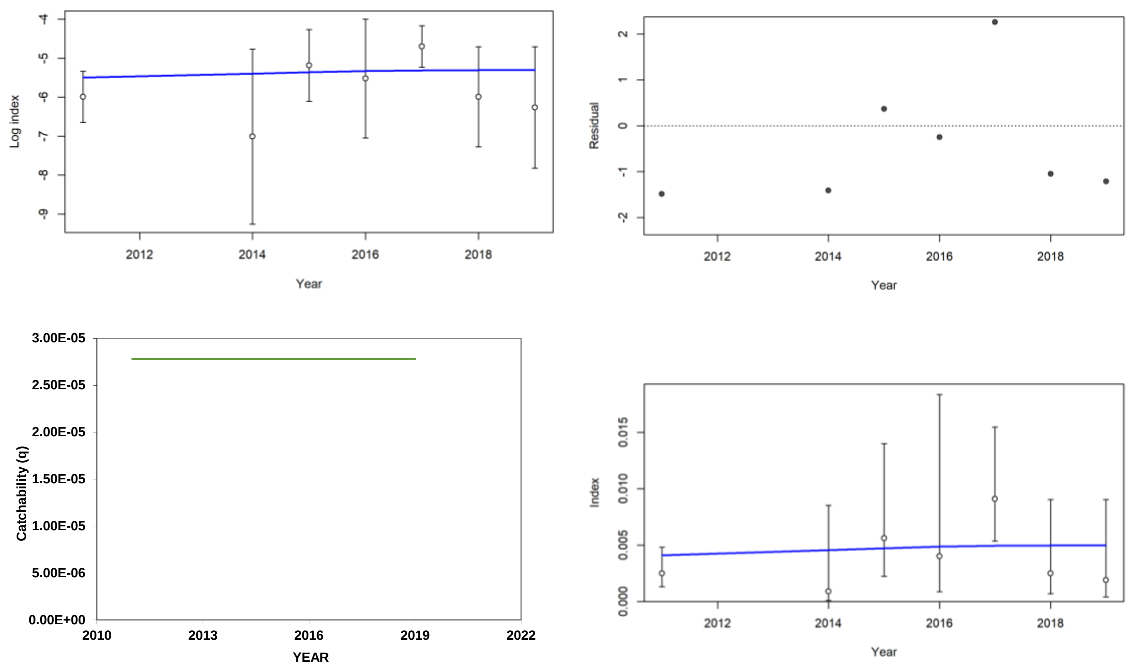


Figure 3.2 Continued.

E. S5 (SEFSC-BLLS)

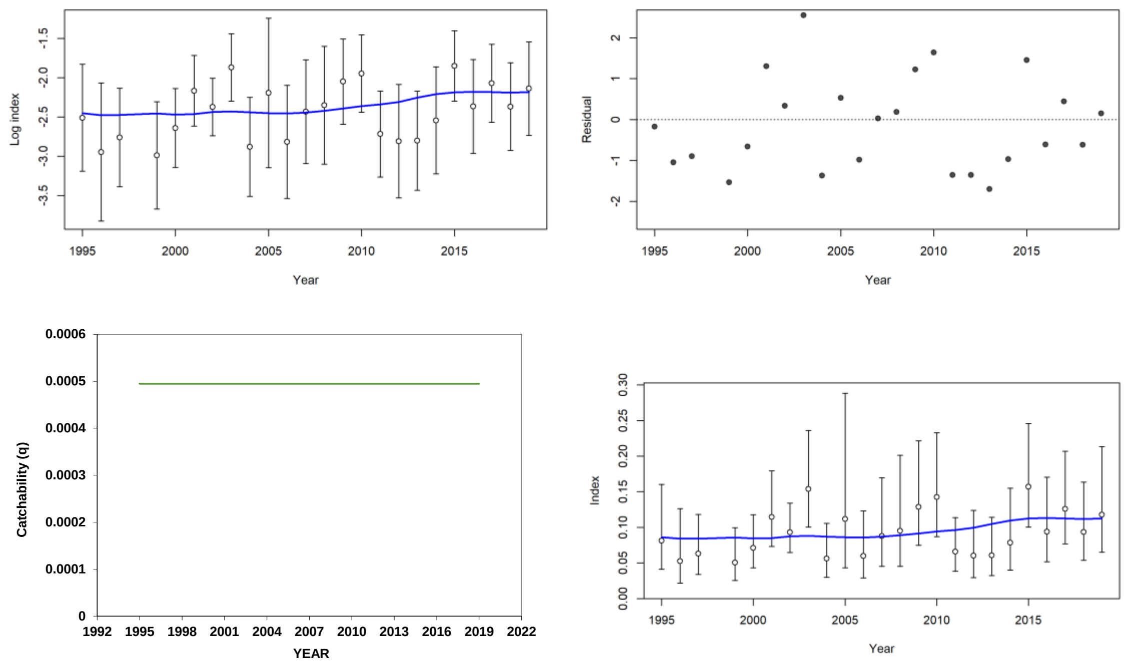


Figure 3.2 Continued.

F. R1 (TXPWD-GNS)

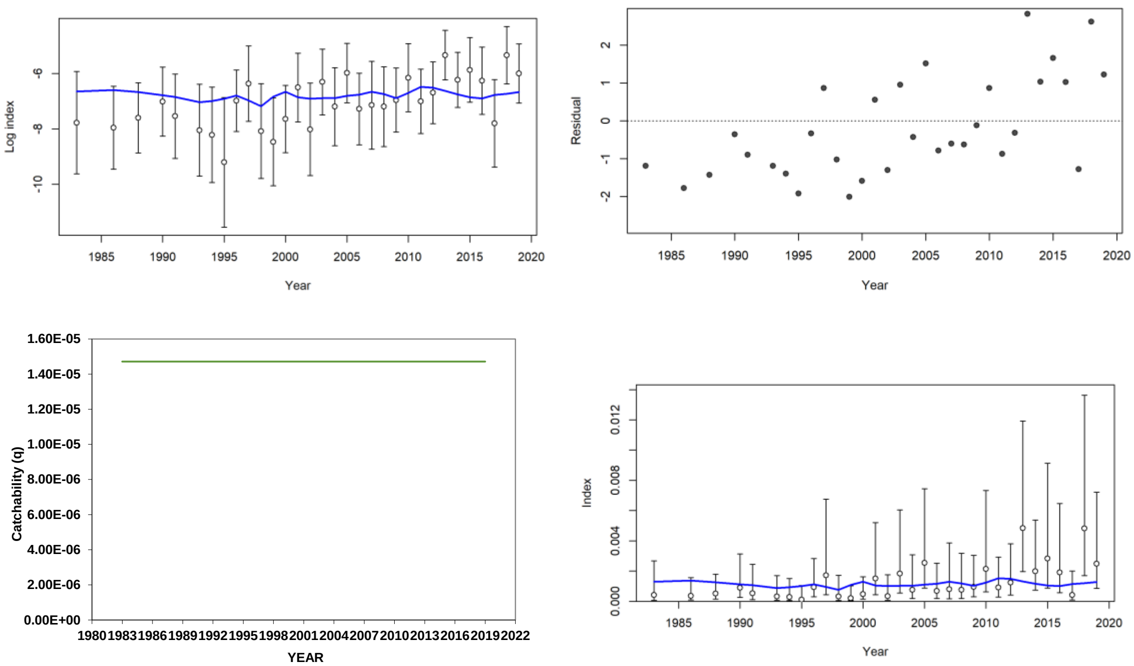


Figure 3.2 Continued.

G. R2 (GULFSPAN-GNS)

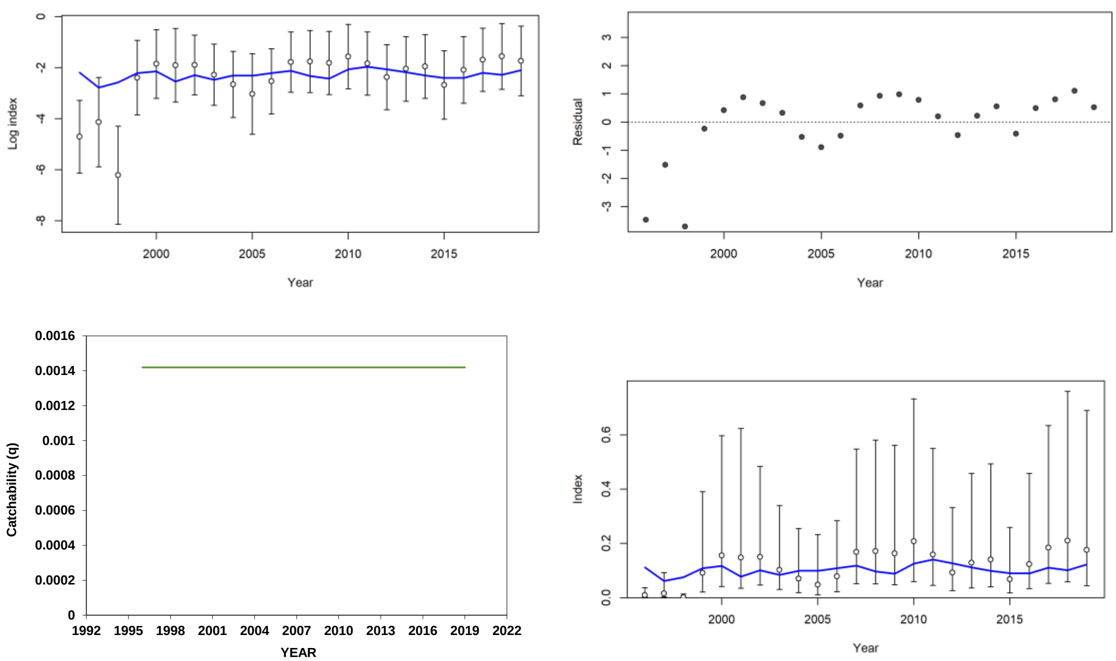


Figure 3.2 Continued.

H. R3 (COASTSPAN-BLLS)

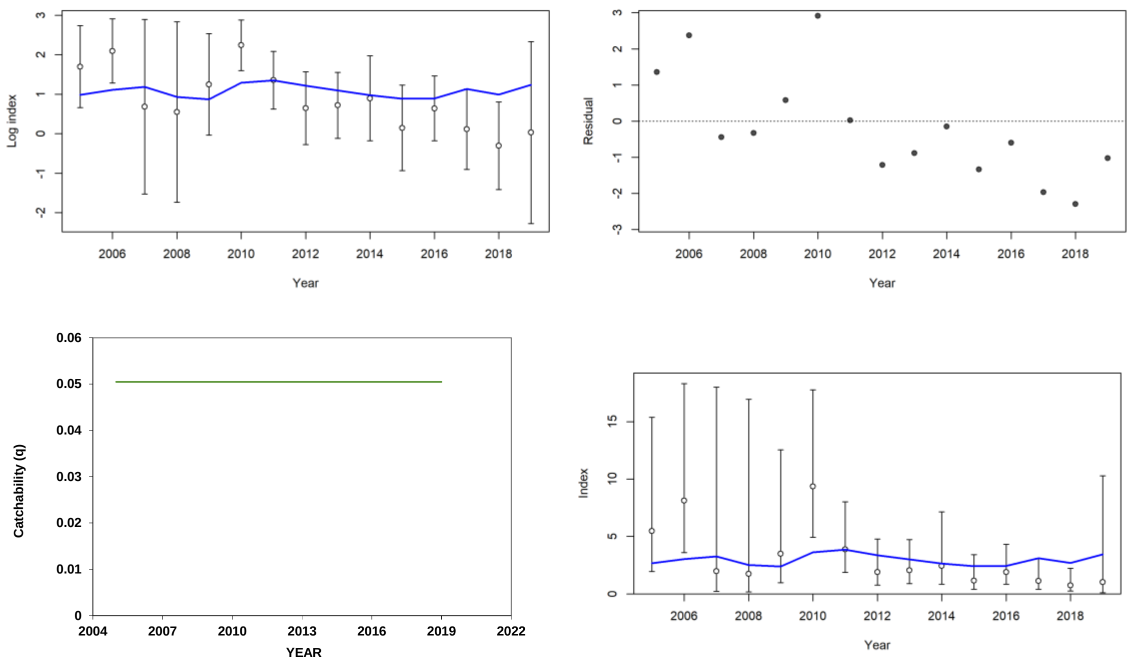


Figure 3.2 Continued.

I. R4 (COASTSPAN-LGNS)

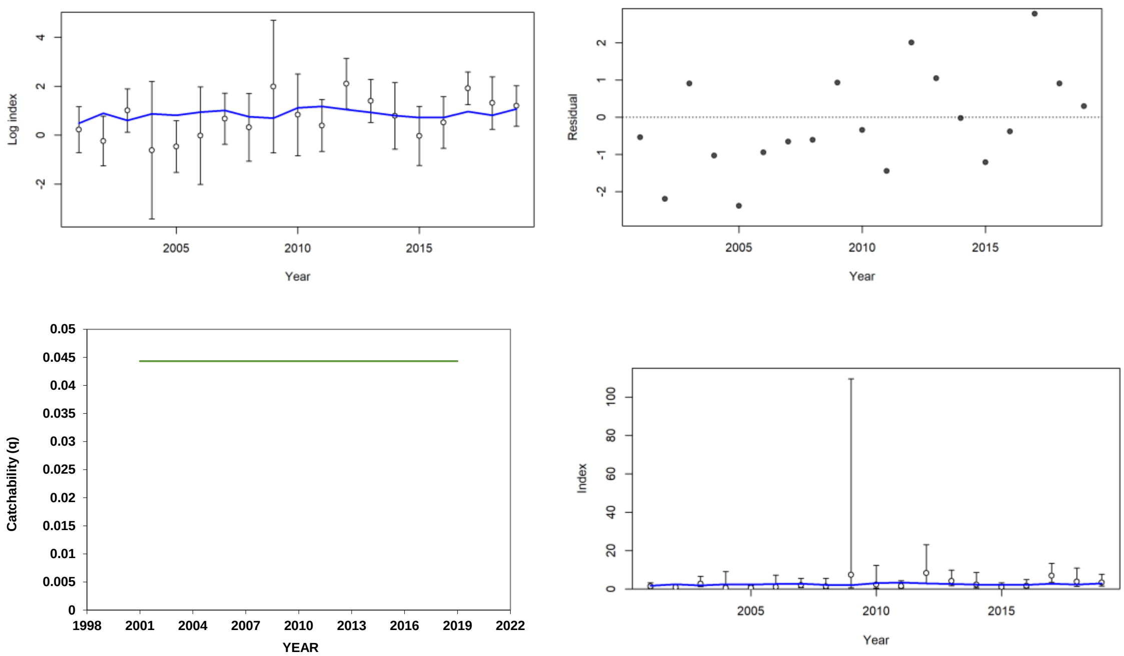


Figure 3.2 Continued.

J. R5 (COASTSPAN-SGNS)

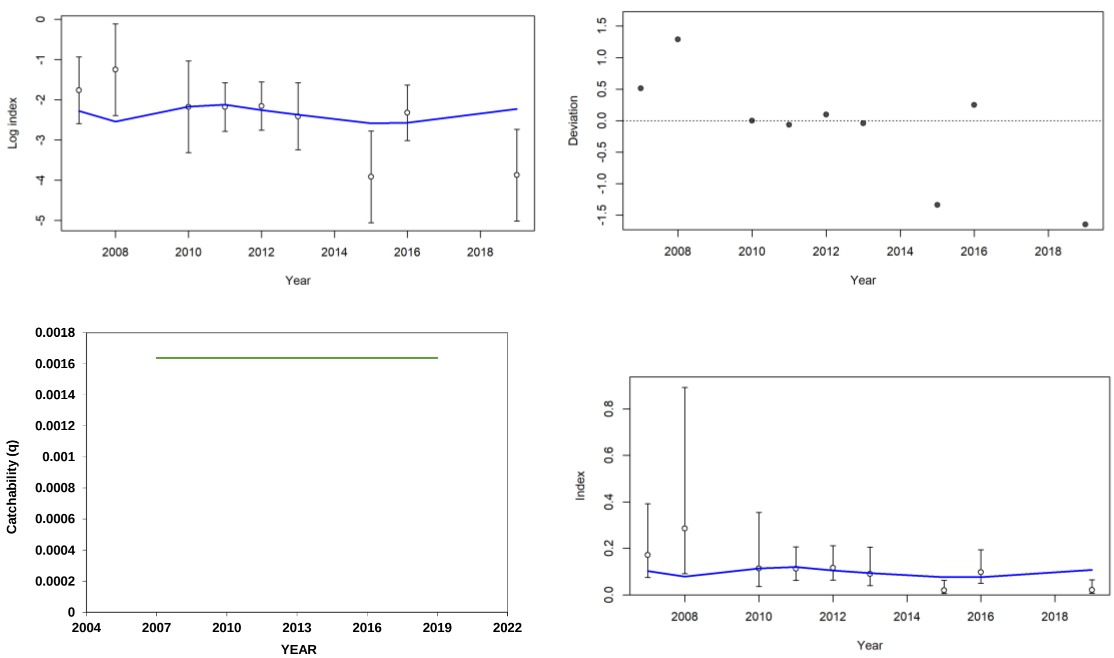
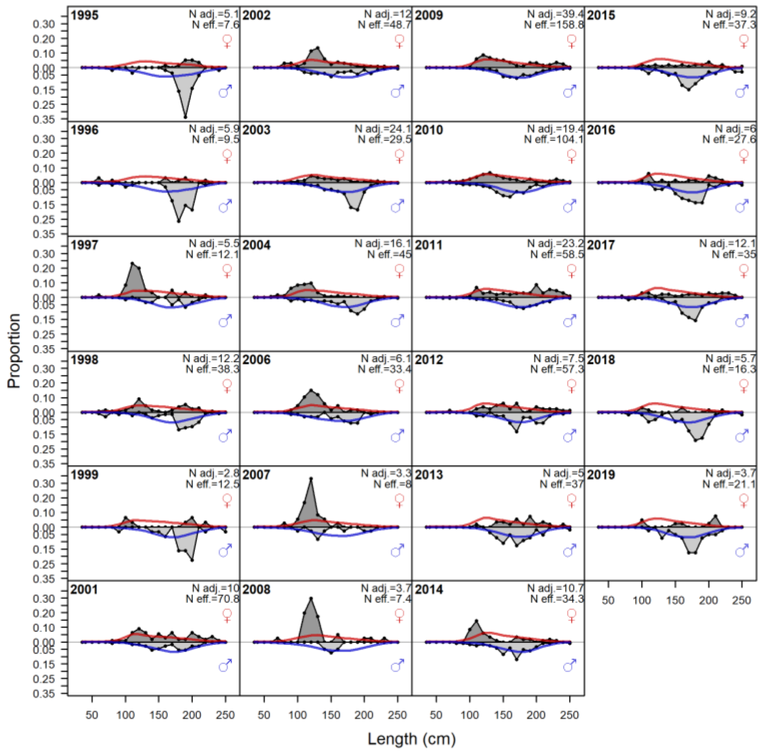


Figure 3.2 Continued.

Figure 3.3 Observed and predicted annual length compositions (upper panel) and Pearson residuals (lower panel) obtained for the Stock Synthesis reference case (GOM + ATL) model configuration; Years with annual length composition sample size less than the minimum input sample size (Min; **Table 3.2)** were excluded from the model fit, and are not plotted; The value "N adj" is the input effective sample size obtained using either the Francis method or the McAllister and Ianelli harmonic mean, as described above (**Table 3.6**); The value "N eff" is an alternative effective sample size estimate (McAllister and Ianelli 1997; e.g., see Punt 2017, his McAllister-Ianelli-1 in his equation 1.A) that is not implemented in this assessment; The diameter of Pearson residuals indicates relative error for predicted < observed (solid) and predicted > observed (transparent) within the length composition data set; The maximum diameter of Pearson residuals indicates relative error among length composition data sets.

A. F1 (Com-BLL)



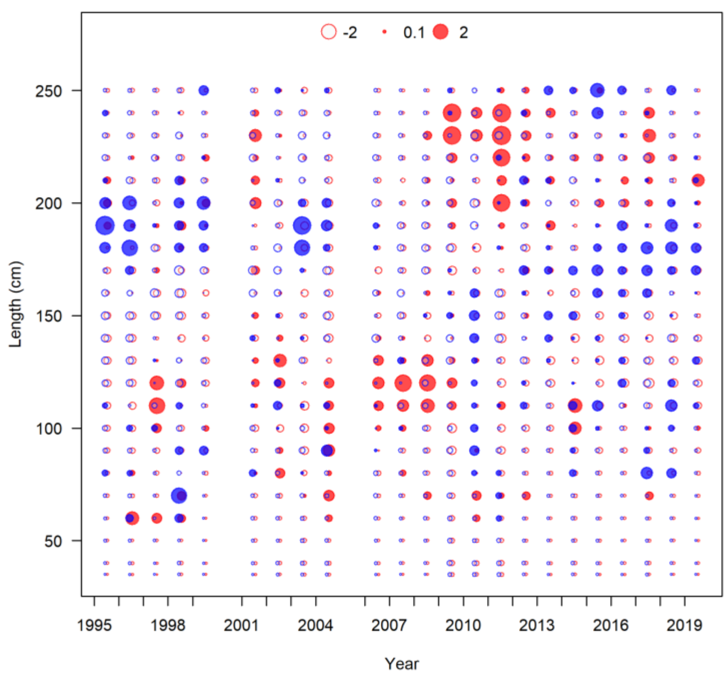
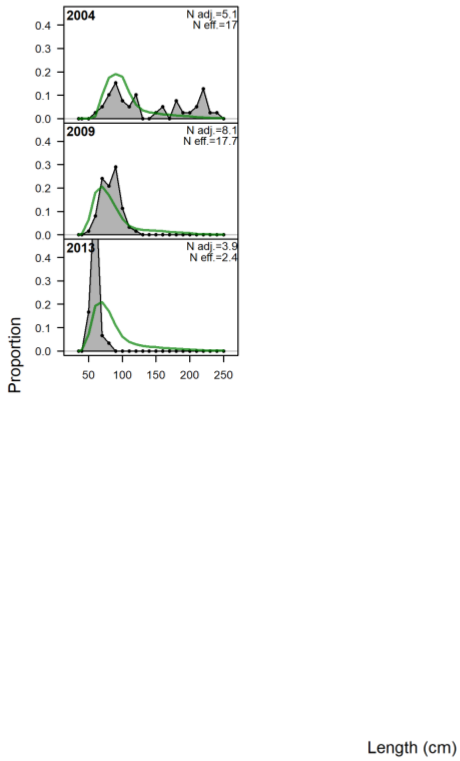


Figure 3.3 Continued.

B. F2 (Com-GN)



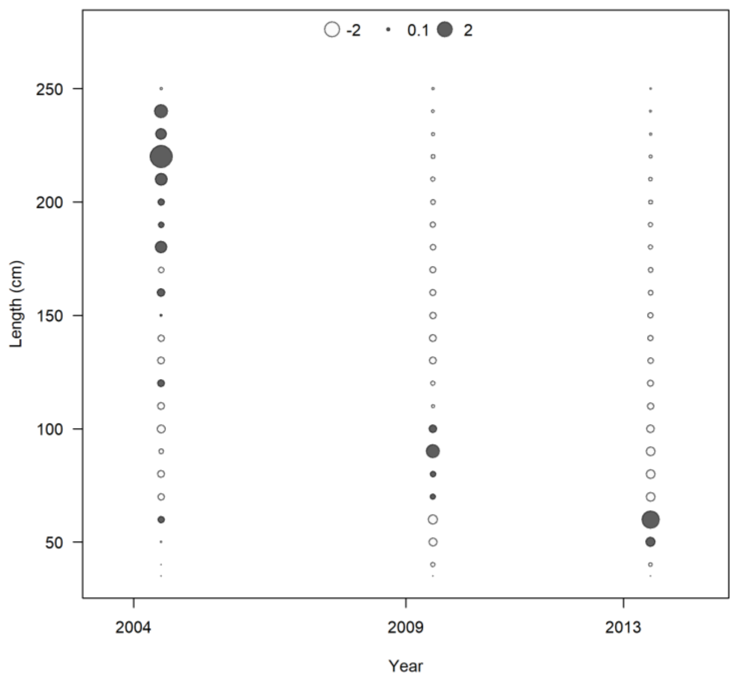
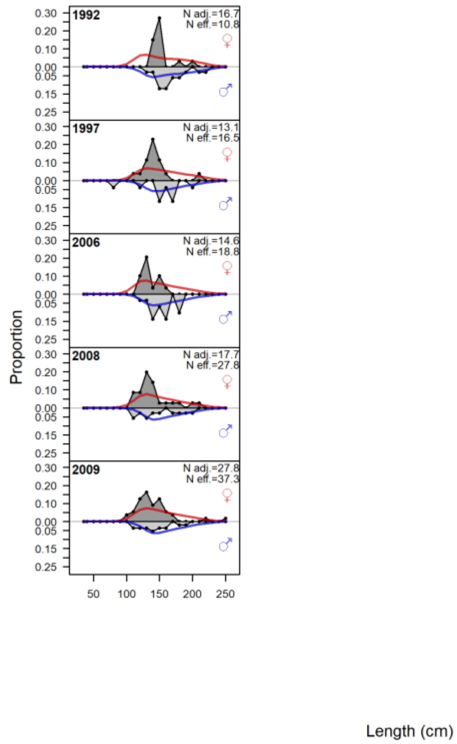


Figure 3.3 Continued.

C. F3 (Com-PLL)



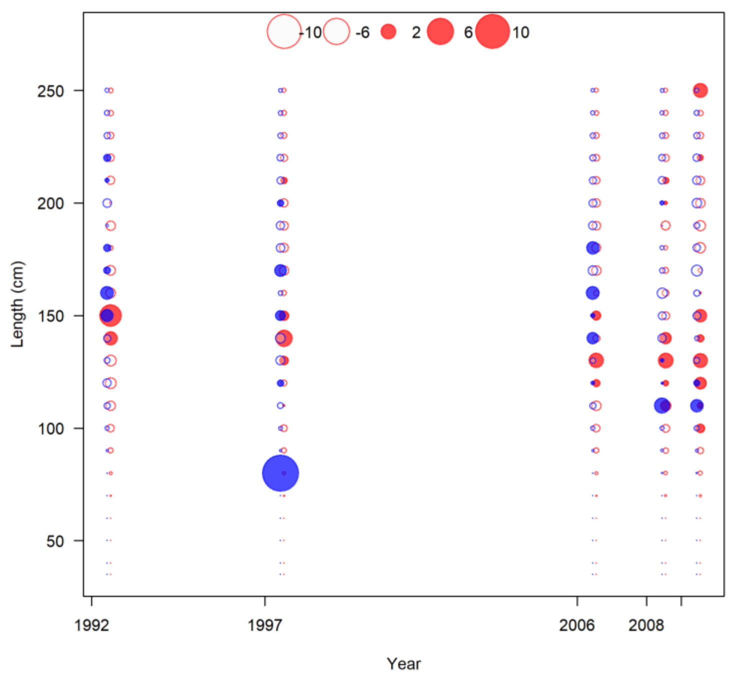
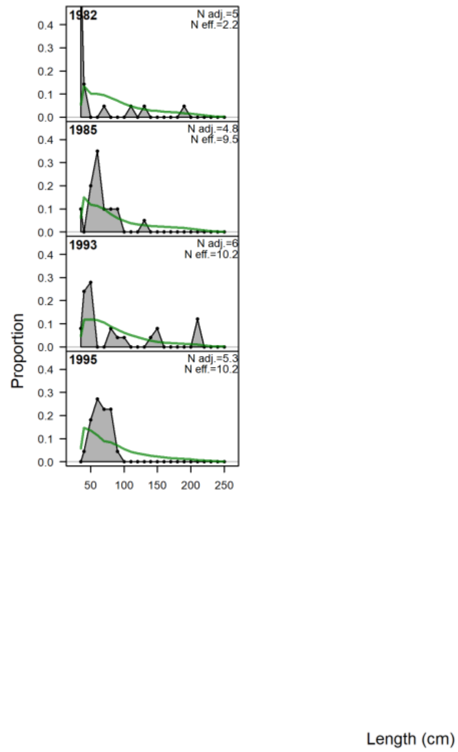


Figure 3.3 Continued.

D. F4 (Rec)



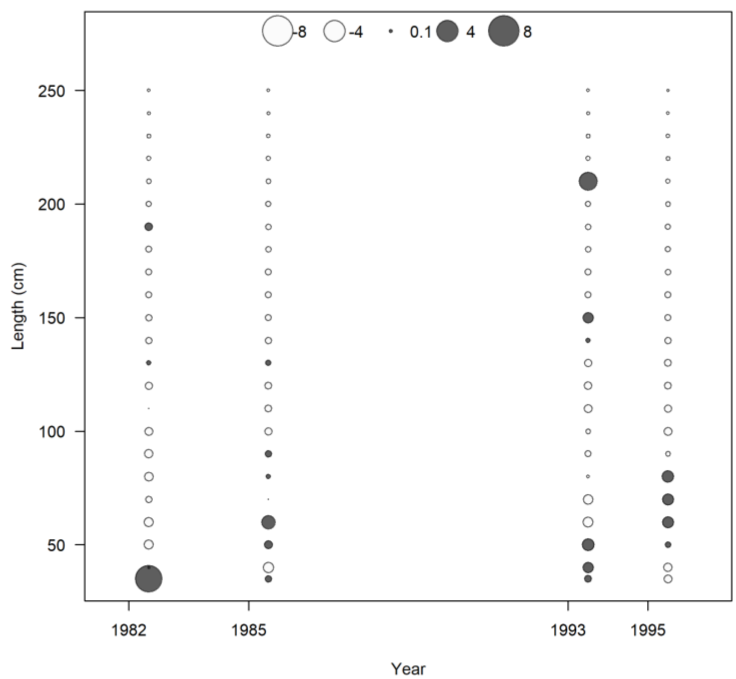
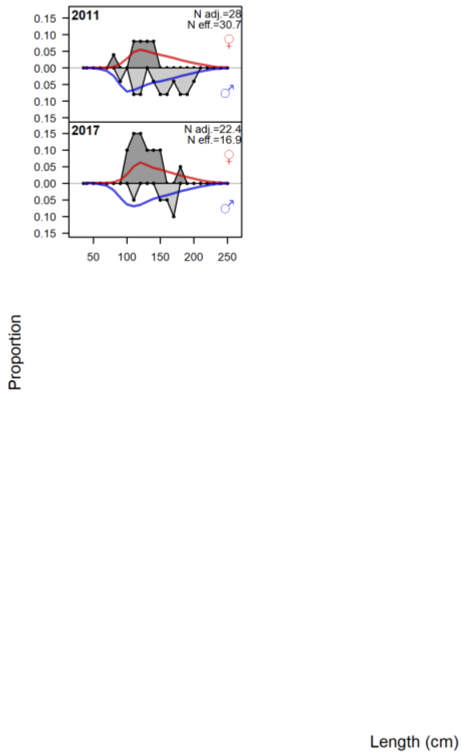


Figure 3.3 Continued.

E. S4 (FSU-BLLS)



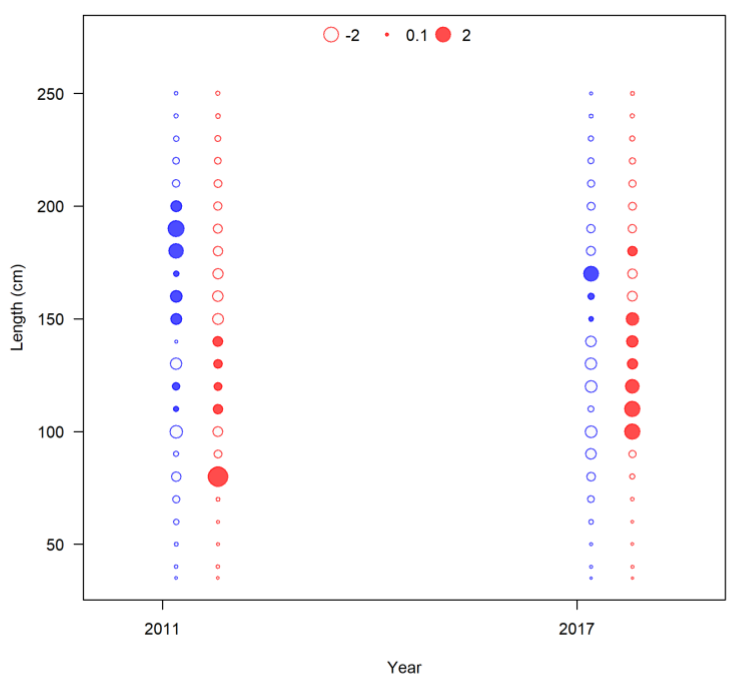
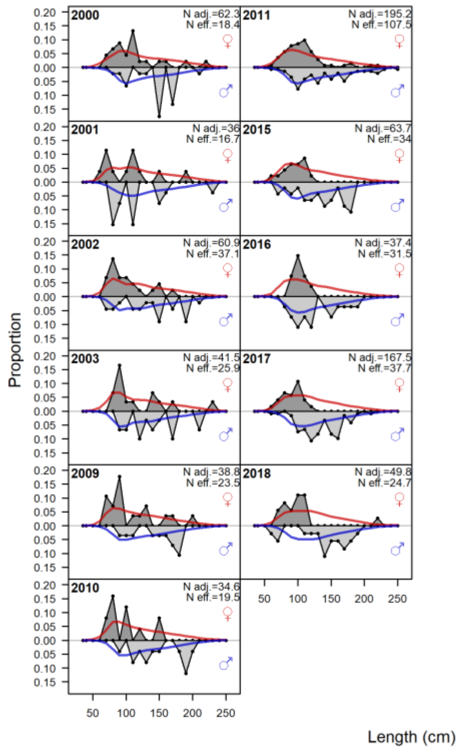


Figure 3.3 Continued.

F. S5 (SEFSC-BLLS)



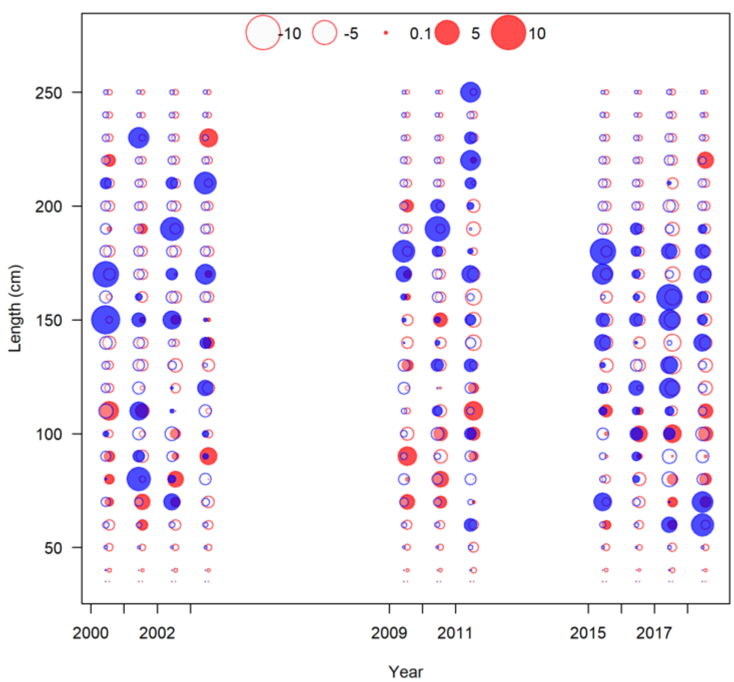
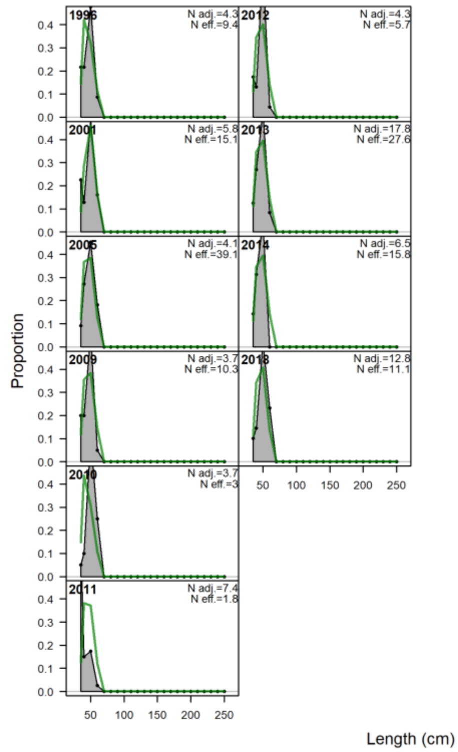


Figure 3.3 Continued.

G. R1 (TXPWD-GNS)



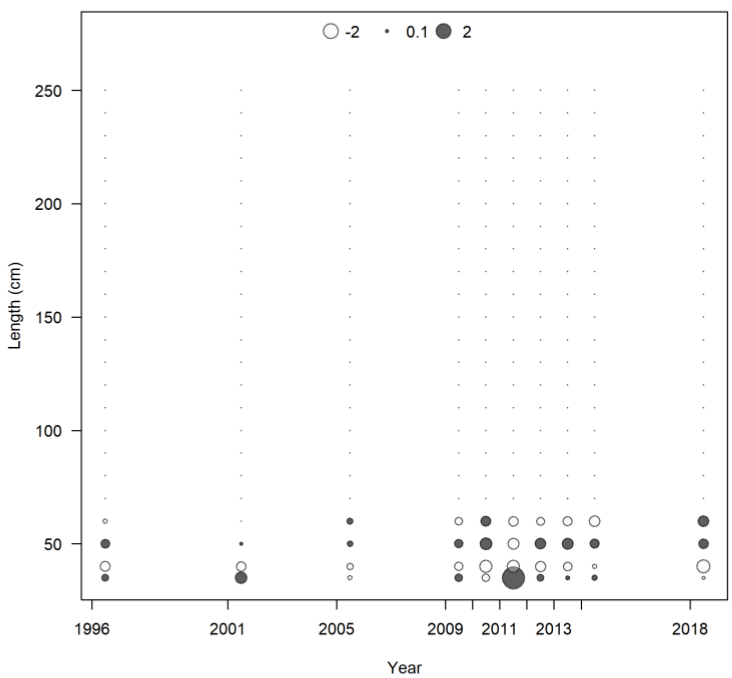
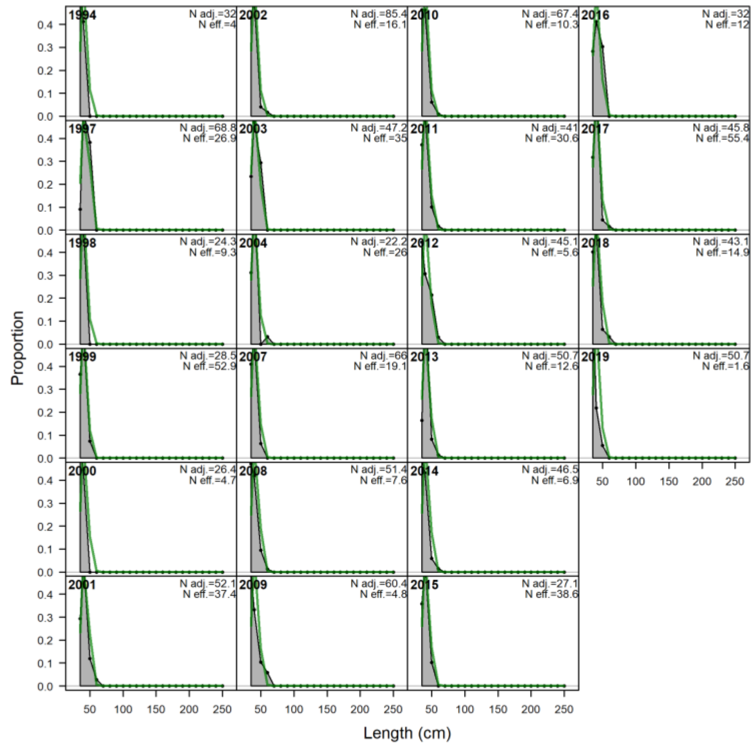


Figure 3.3 Continued.

H. R2 (GULFSPAN-GNS)



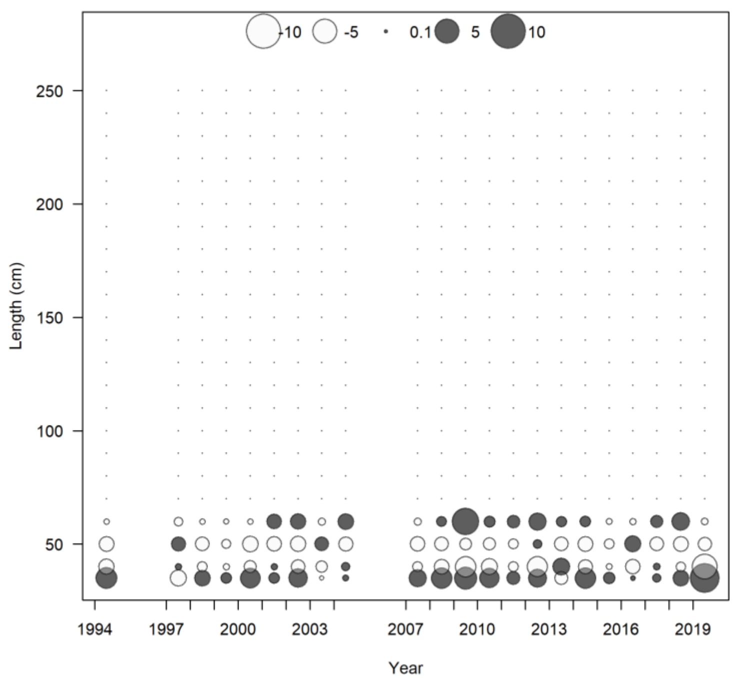
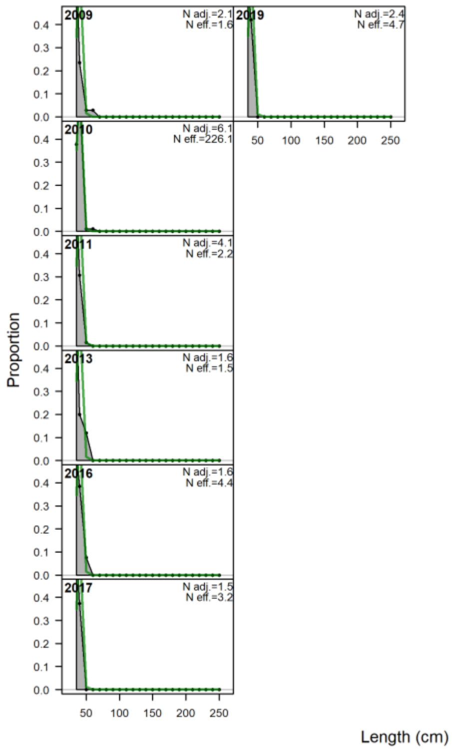


Figure 3.3 Continued.

I. R3 (COASTSPAN-BLLS)



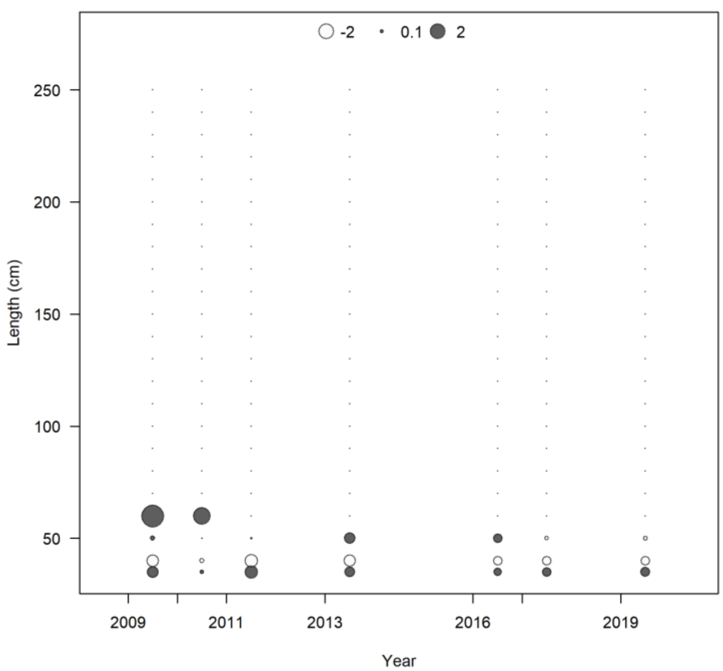
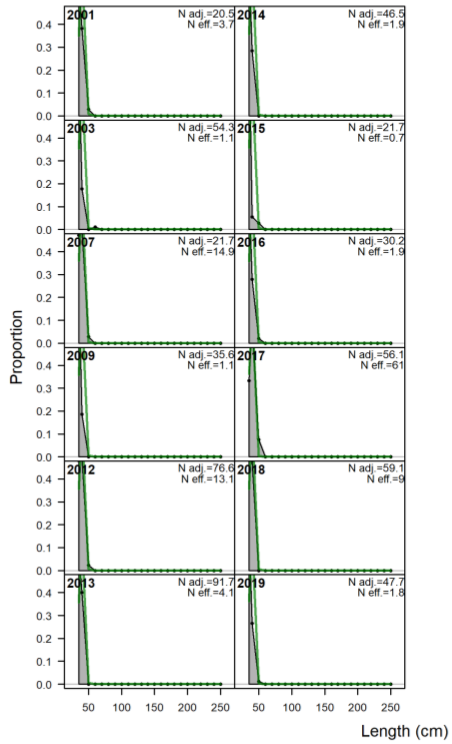


Figure 3.3 Continued.

J. R4 (COASTSPAN-LGNS)



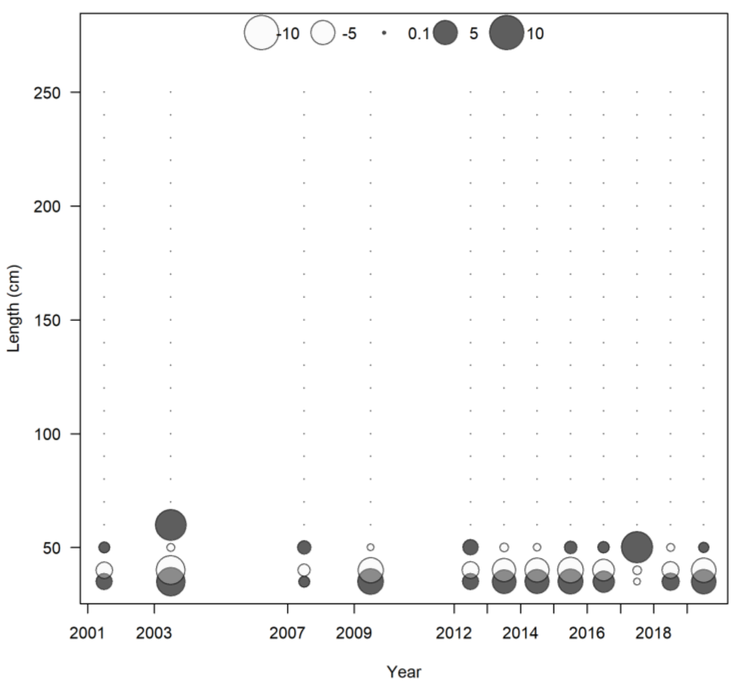


Figure 3.3 Continued.

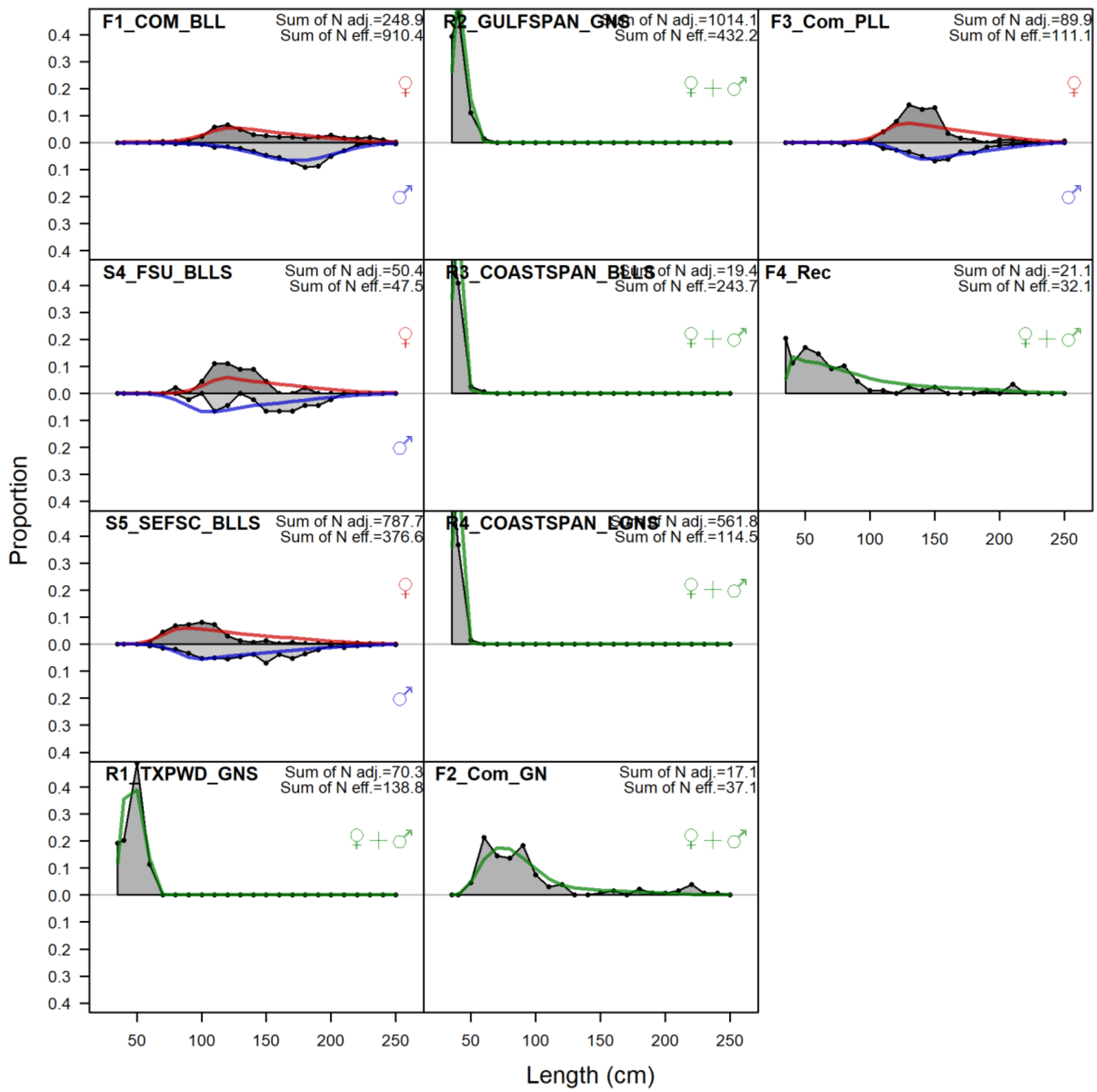
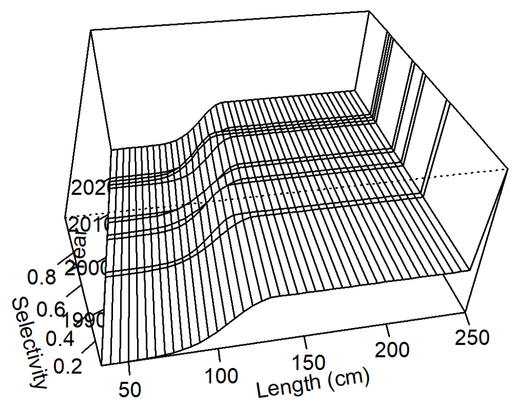


Figure 3.4 Predicted (line) and observed (shaded) aggregated length compositions obtained for the Stock Synthesis reference case (GOM + ATL) model configuration; Years with annual length composition sample size less than the minimum input sample size (Min; **Table 3.2)** were excluded from the model fit, and are not plotted; The value "N adj" is the input effective sample size obtained using either the Francis method or the McAllister and Ianelli harmonic mean, as described above; The value "N eff" is an alternative effective sample size estimate (McAllister and Ianelli 1997; Punt 2017, his McAllister-Ianelli-1 in his equation 1.A) that is not implemented in this assessment.

A. F1 (Com-BLL)



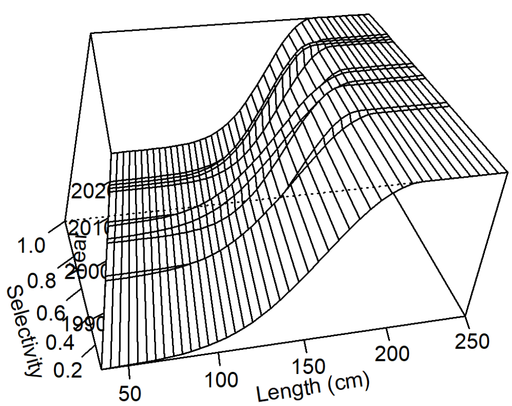


Figure 3.5 Estimated selectivity at length (cm FL) obtained for the Stock Synthesis reference case (GOM + ATL) model configuration (**Table 3.5**); Upper panel is female selectivity; Lower panel is male selectivity, if different from female selectivity; Otherwise female and male selectivity are the same.

B. F2 (Com-GN)

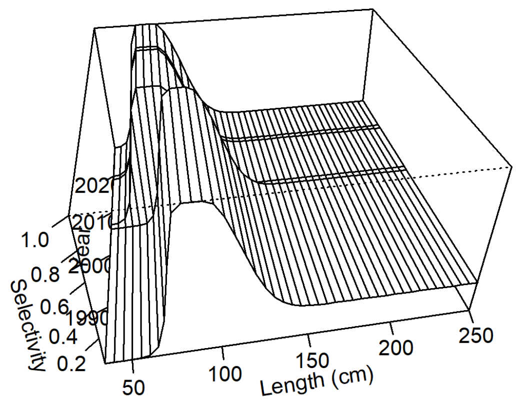
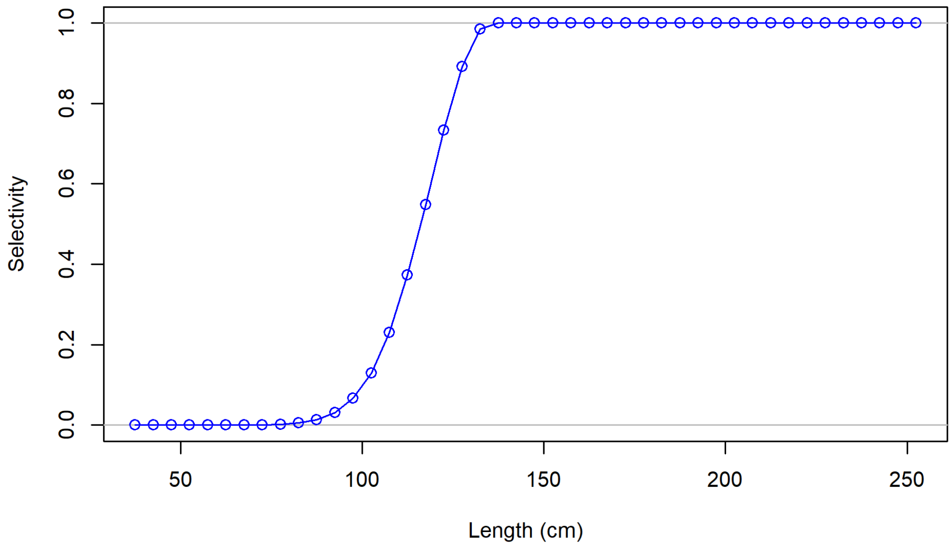


Figure 3.5 Continued.

C. F3 (Com-PLL)



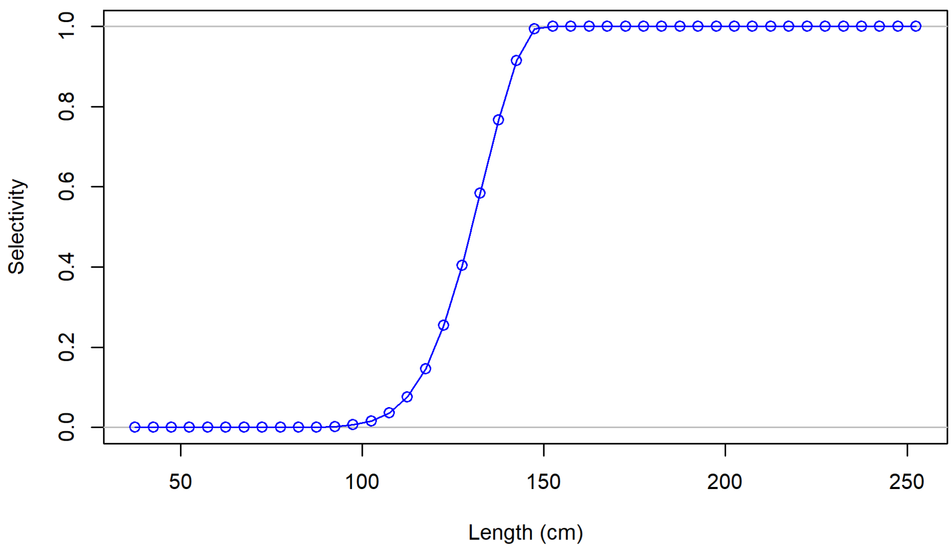


Figure 3.5 Continued.

D. F4 (Rec)

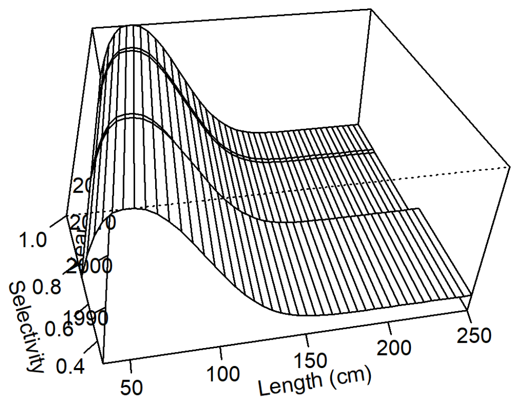
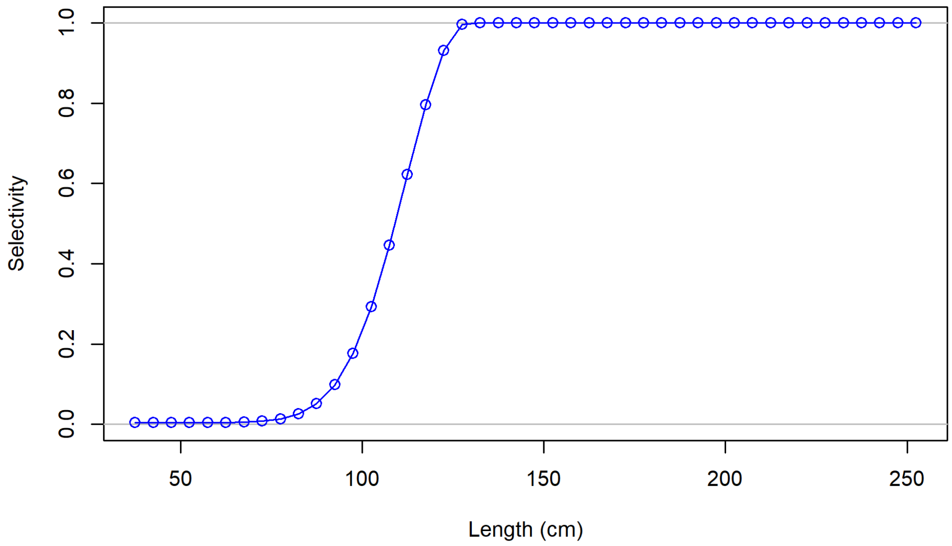


Figure 3.5 Continued.

E. S4 (FSU-BLLS)



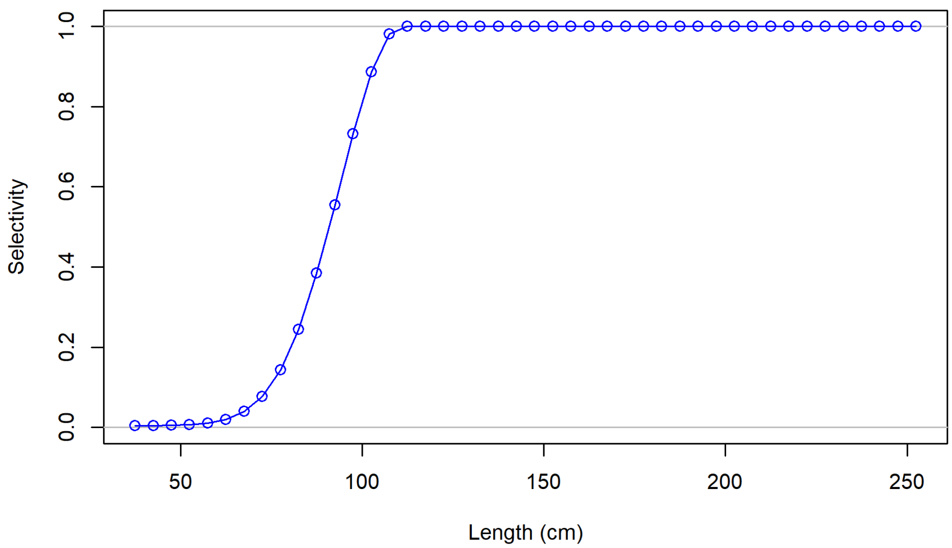
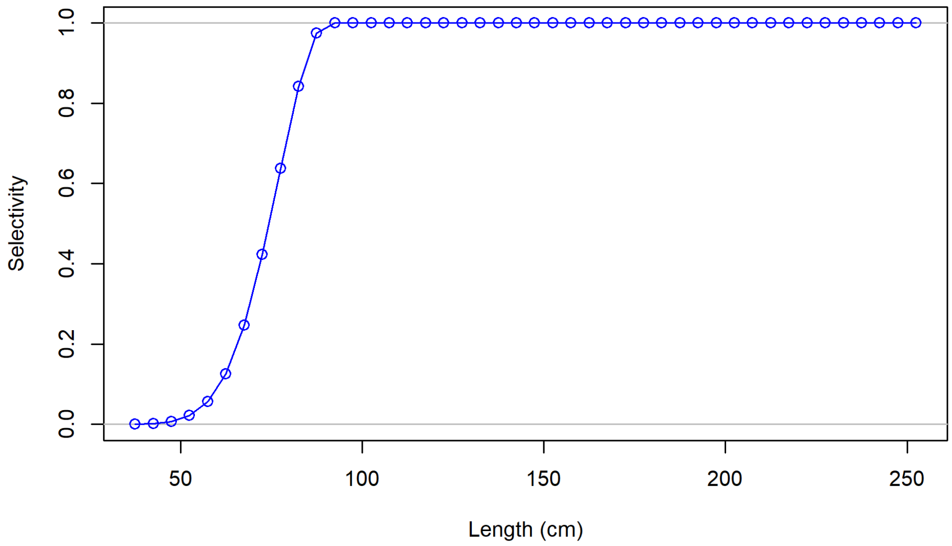


Figure 3.5 Continued.

F. S5 (SEFSC-BLLS)



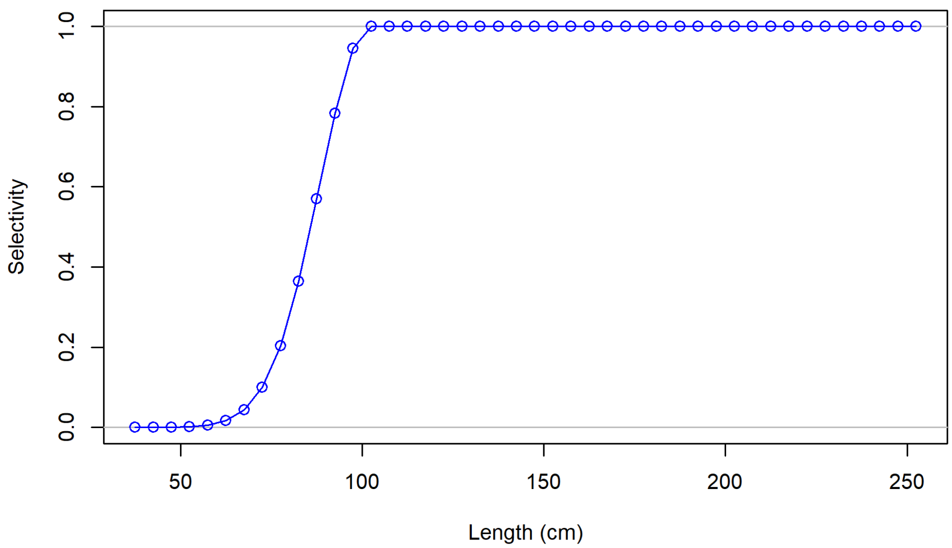
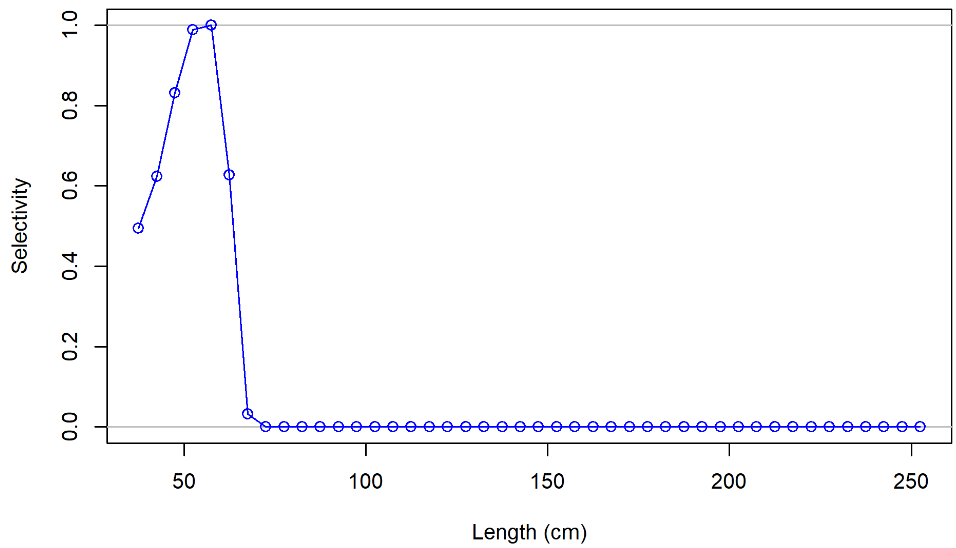


Figure 3.5 Continued.

G. R1 (TXPWD-GNS)



H. R2 (GULFSPAN-GNS)

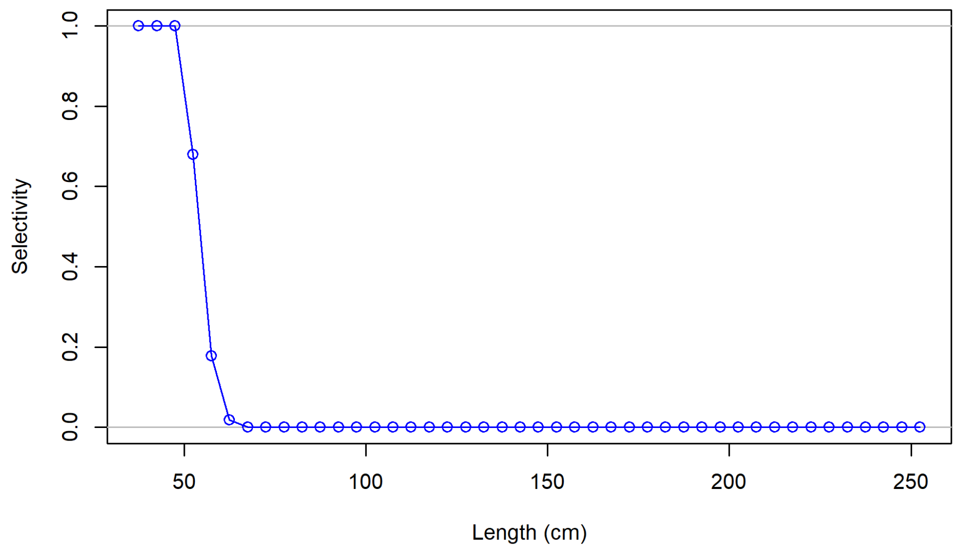
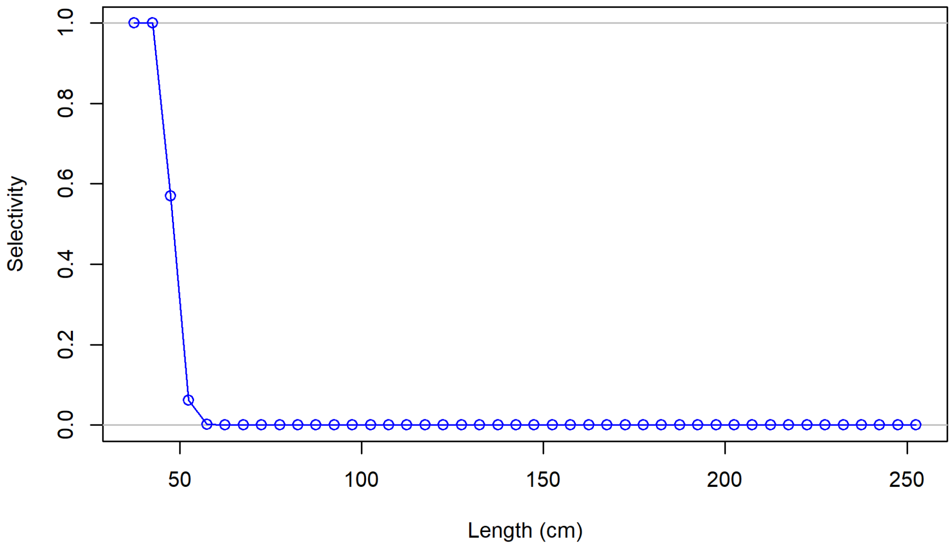


Figure 3.5 Continued.

I. R3 (COASTSPAN-BLLS)



J. R4 (COASTSPAN-LGNS)

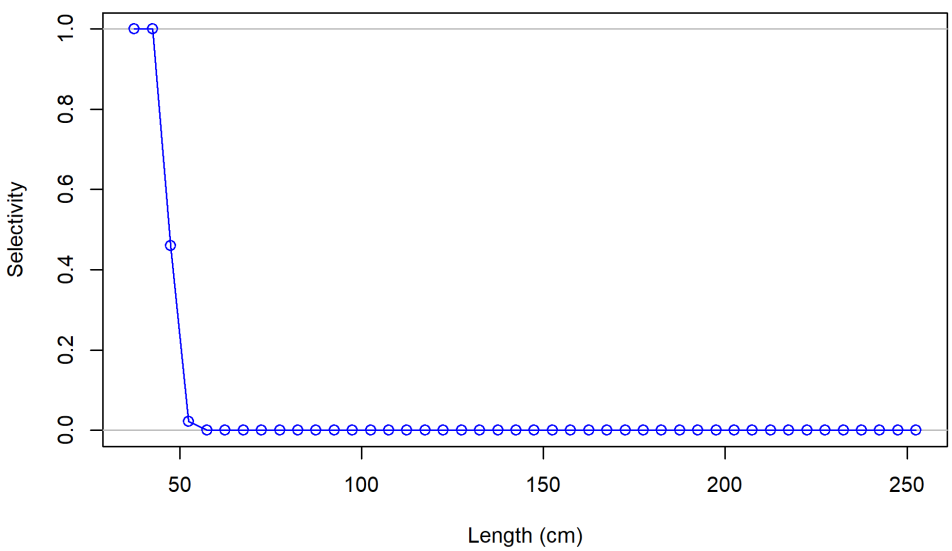


Figure 3.5 Continued.

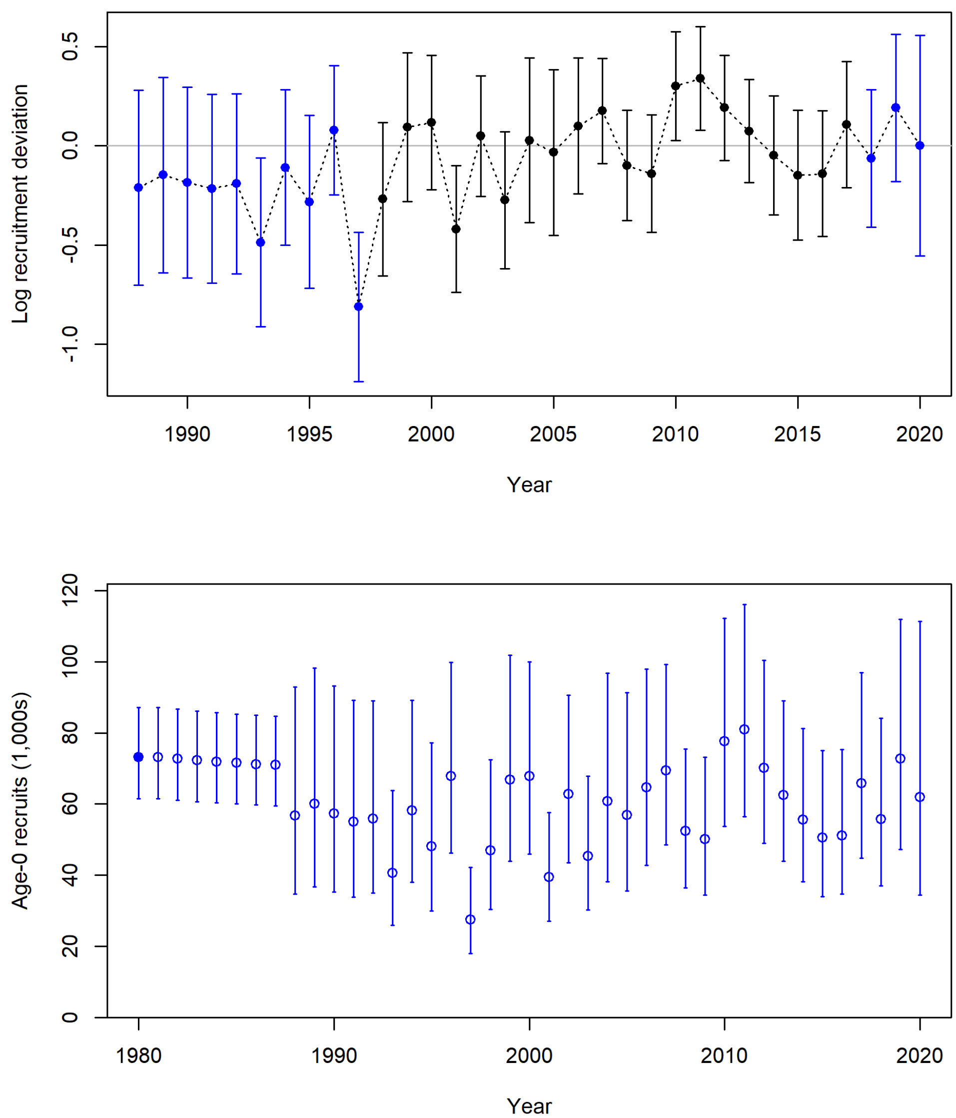


Figure 3.6 Recruitment time series obtained for the Stock Synthesis reference case (GOM + ATL) model configuration; Upper panel is the estimated log recruitment deviations for the early (1988 – 1997, blue), main (1998 – 2017, black), late (2018 – 2019, blue), and forecast (2020, blue) recruitment periods with associated 95% asymptotic confidence intervals; Lower panel is the estimated annual age-0 recruits (circles) with 95% asymptotic confidence intervals; Age-0 recruits follow the assumed stock recruitment relationship exactly in years prior to 1988 and after 2019.

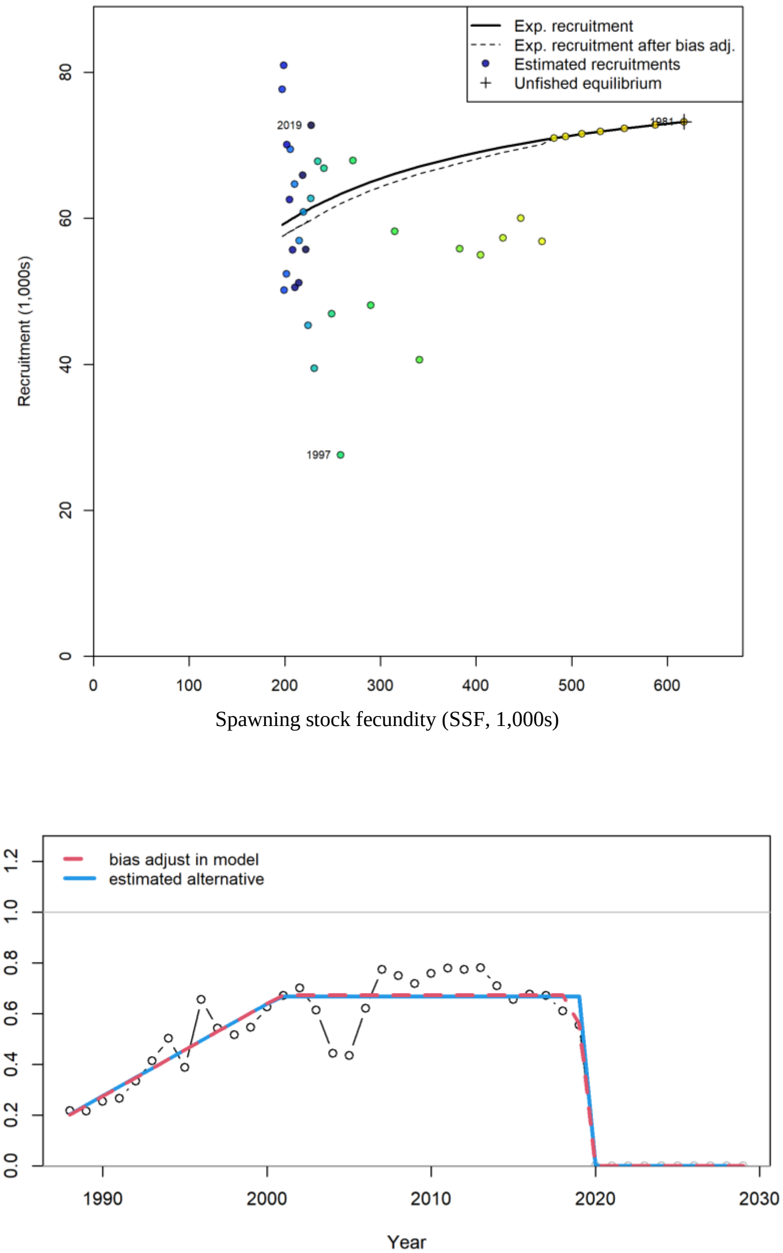
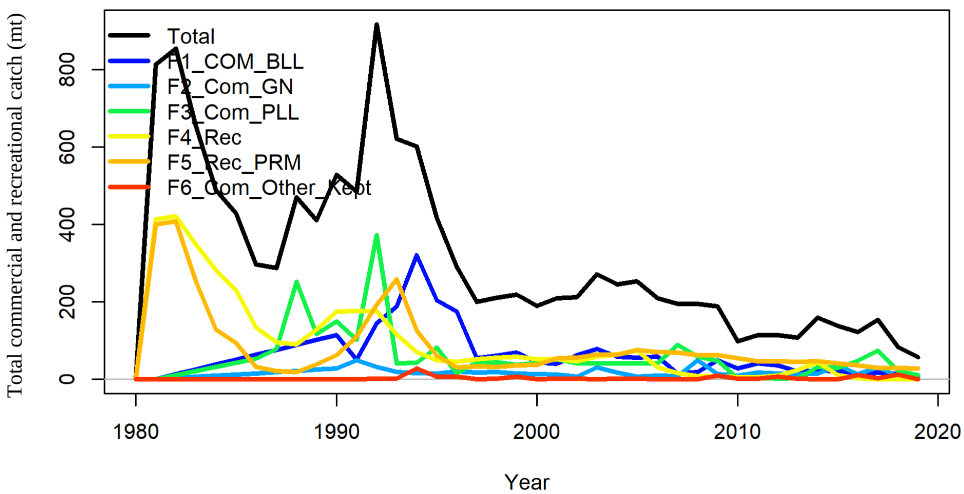


Figure 3.7 Expected recruitment (upper panel) from the stock-recruitment relationship (solid line), expected recruitment after implementing the bias adjustment correction (dashed line), estimated annual recruitments (circles), unfished equilibrium (plus), and first (1981) and last (2019) years along with years with log deviations > 0.5 (1997) obtained for the Stock Synthesis reference case (GOM + ATL) model configuration; Bias adjustment ramp (lower panel) applied to the stock-recruitment relationship (red stippled line) and the estimated alternative (blue line); The y-axis of the lower panel is the bias adjustment fraction (Methot and Taylor 2011).

A.



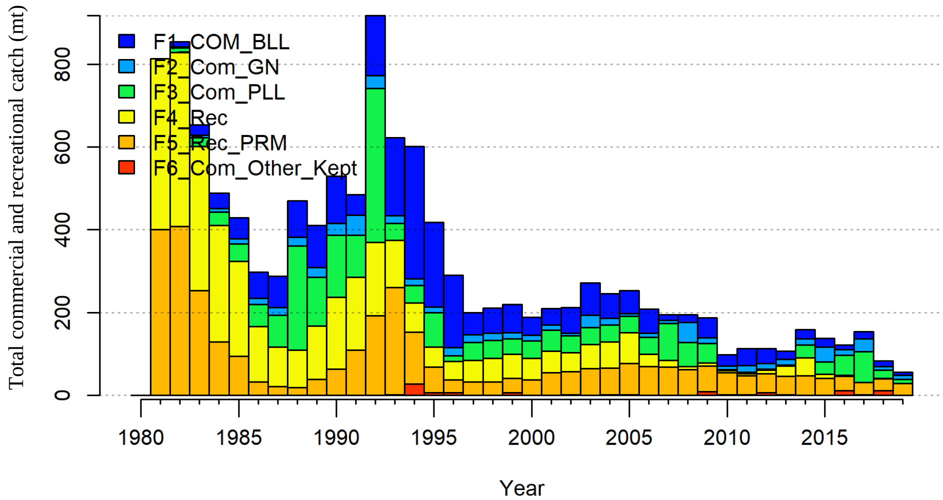
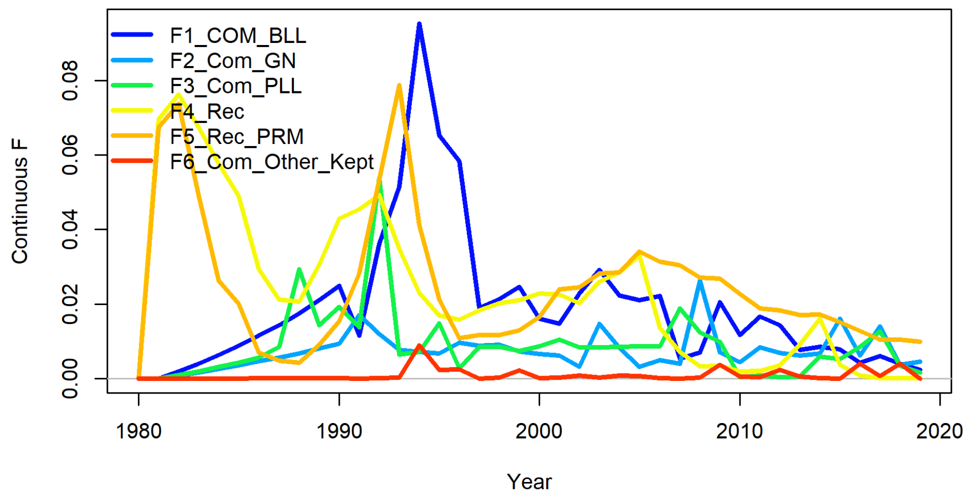


Figure 3.8 Total commercial and recreational catch (panel A), continuous fishing mortality by fleet (continuous *F* by fleet; panel B upper plot), and the summary fishing mortality of all fleets combined (panel B lower plot) obtained for the Stock Synthesis reference case (GOM + ATL) model configuration; The summary fishing mortality is plotted as a ratio calculated as the total fishing mortality rate experienced by the population ($F=Z\text{-}M$) relative to F_{MSY} (F/F_{MSY}); Error bars are the 95% asymptotic standard errors, ± 1.96*SE, obtained from Stock Synthesis output; Total catch includes both total commercial catch entered in Stock Synthesis in weight (mt) and total recreational catch (A + B1 + LPRM) entered in Stock Synthesis in numbers (thousands), as described above, and then converted internally within Stock Synthesis to weight (mt).

B.



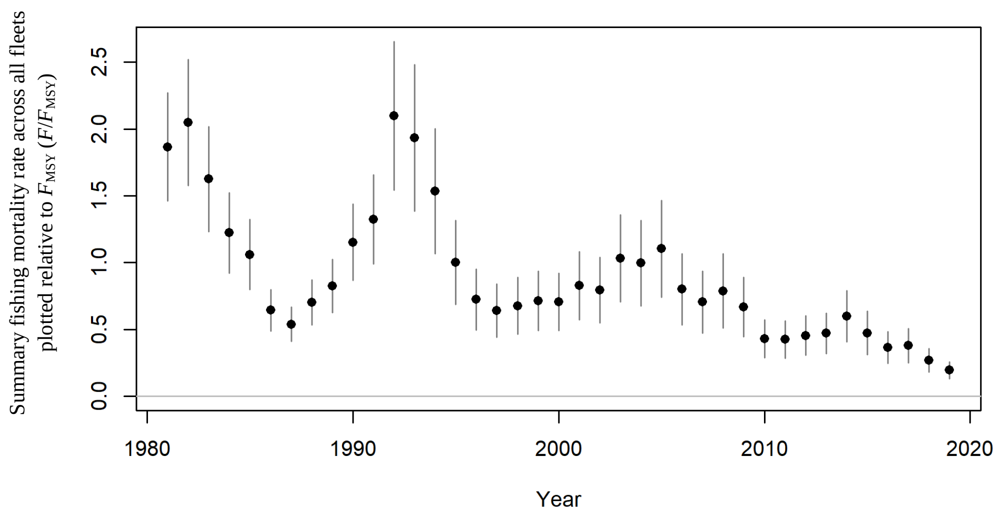
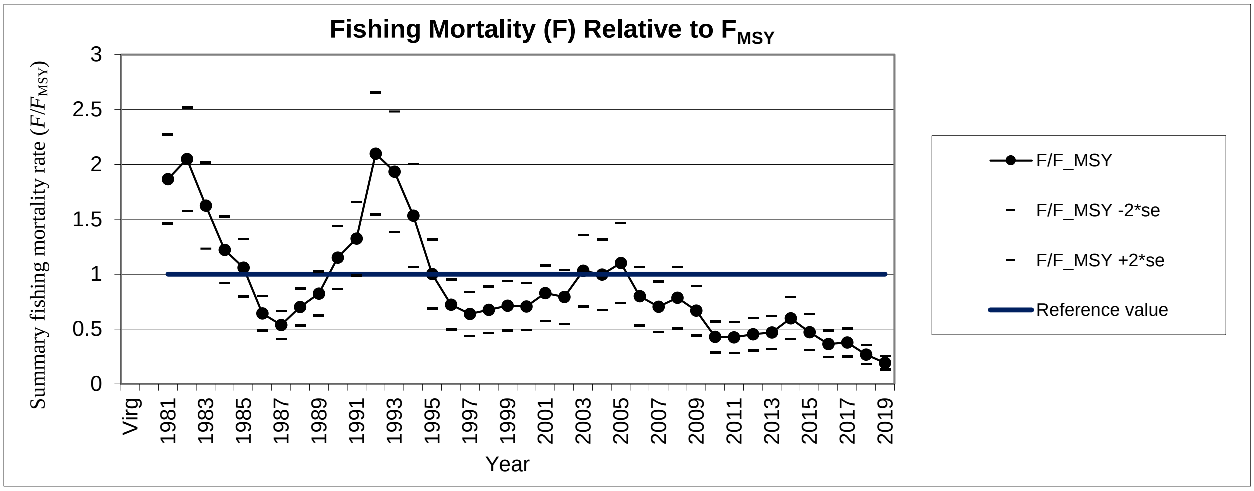


Figure 3.8 Continued.



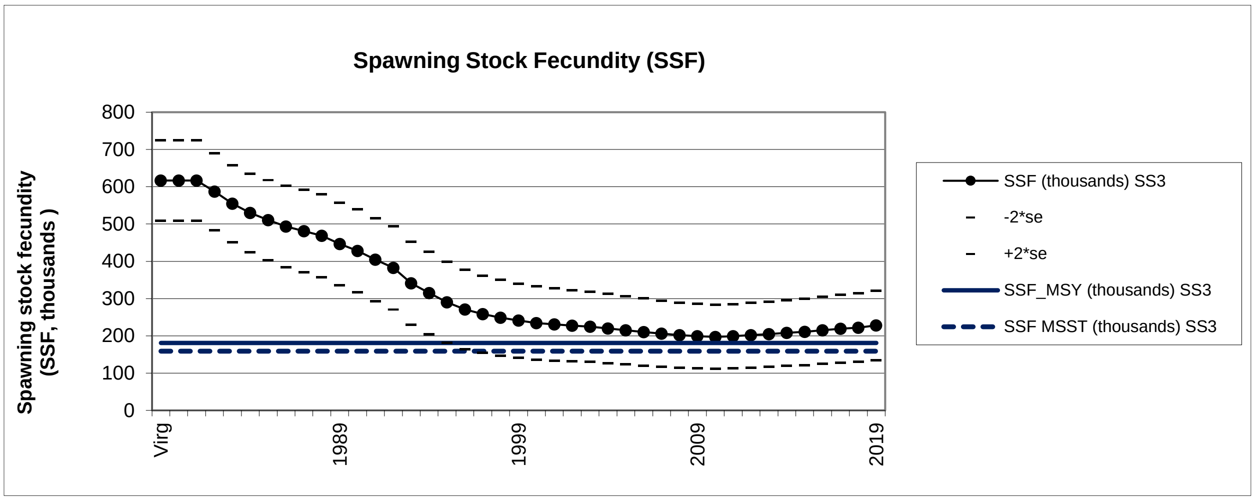


Figure 3.9. Summary fishing mortality (F) relative to F_{MSY} (upper panel) and spawning stock fecundity (SSF) (lower panel) obtained for the Stock Synthesis reference case (GOM + ATL) model configuration; Summary fishing mortality, F, is calculated as the total fishing mortality rate experienced by the population (F=Z-M) obtained from Stock Synthesis output on an annual basis; Error bars are the 95% asymptotic standard errors, ± 1.96*SE, for F_Y/F_{MSY} and SSF_Y obtained from Stock Synthesis output. MSST (lower Panel) is $(1-\bar{M}_a)$ *SSF_{MSY}, with $\bar{M}_a$ calculated as the arithmetic mean of the female age-specific values of M used in the provisional base model configuration (0.123, **Table 2.5**, panel A).

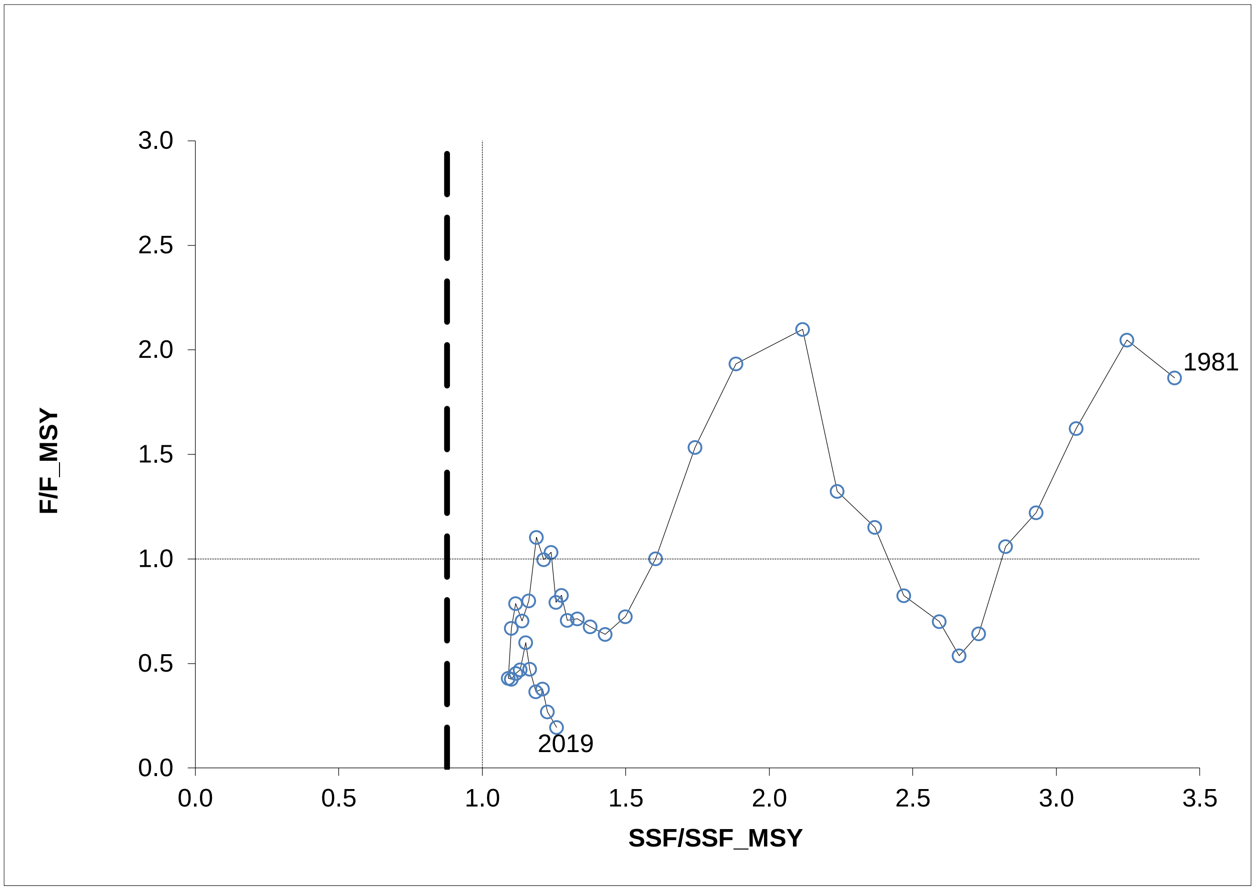


Figure 3.10. Phase plot of the relative spawning stock fecundity (SSF) and relative fishing mortality (*F*) trajectories by year from 1981 to 2019 obtained for the Stock Synthesis reference case (GOM + ATL) model configuration; The dotted horizontal and vertical lines indicate F_{MSY} and SSF_{MSY}. The dashed vertical line indicates MSST $= \left(1 - \bar{M}_a\right)$ *SSF_{MSY}, with $\bar{M}_a$ calculated as the arithmetic mean of the female age-specific values of *M* used in the provisional base model configuration (**Tables 2.5 and 3.11**).

3.10 Appendix 3.A. CPUE Variance Adjustments

A. S1 (PLL-Obs)

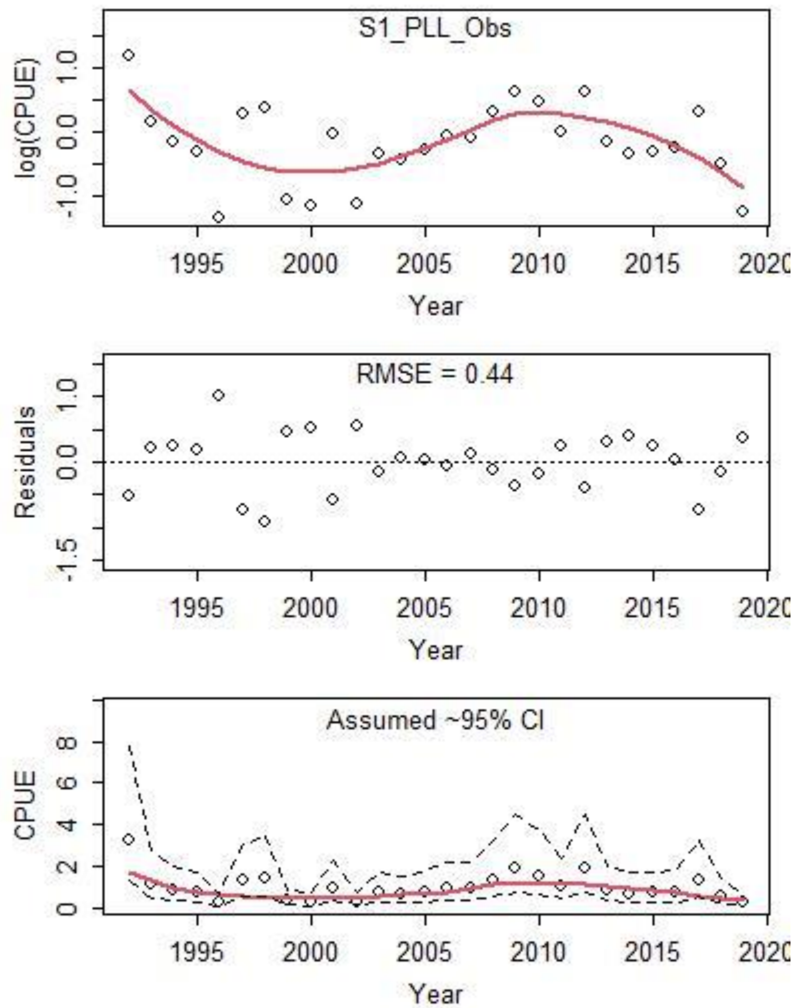


Figure 3.A.1. LOESS smoother fits used to estimate the RMSEsmoother for each CPUE series; Upper panel: Smoother fits to log (CPUE) data; Middle panel: Residual plots and estimated RMSE for each CPUE series; Lower panel: LOESS smoother fits illustrated for CPUE indices along with approximate 95% confidence intervals after applying the variance adjustment.

B. S2 (Shark-BLL-Obs)

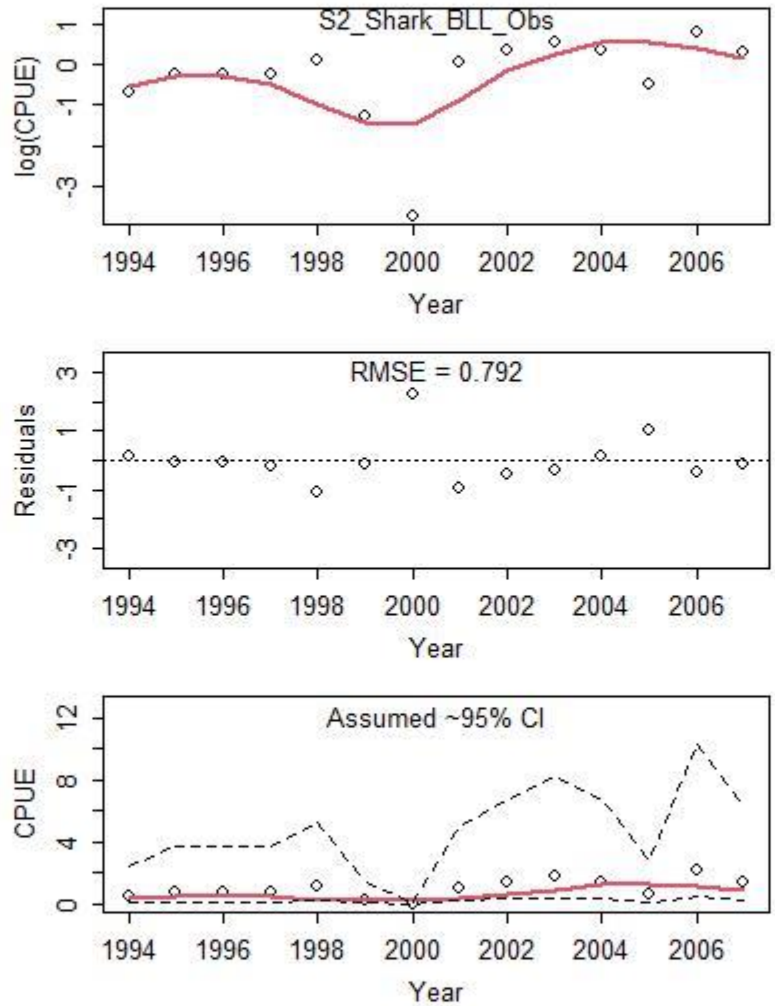


Figure 3.A.1 Continued.

C. S3 (Shark-BLL-Res)

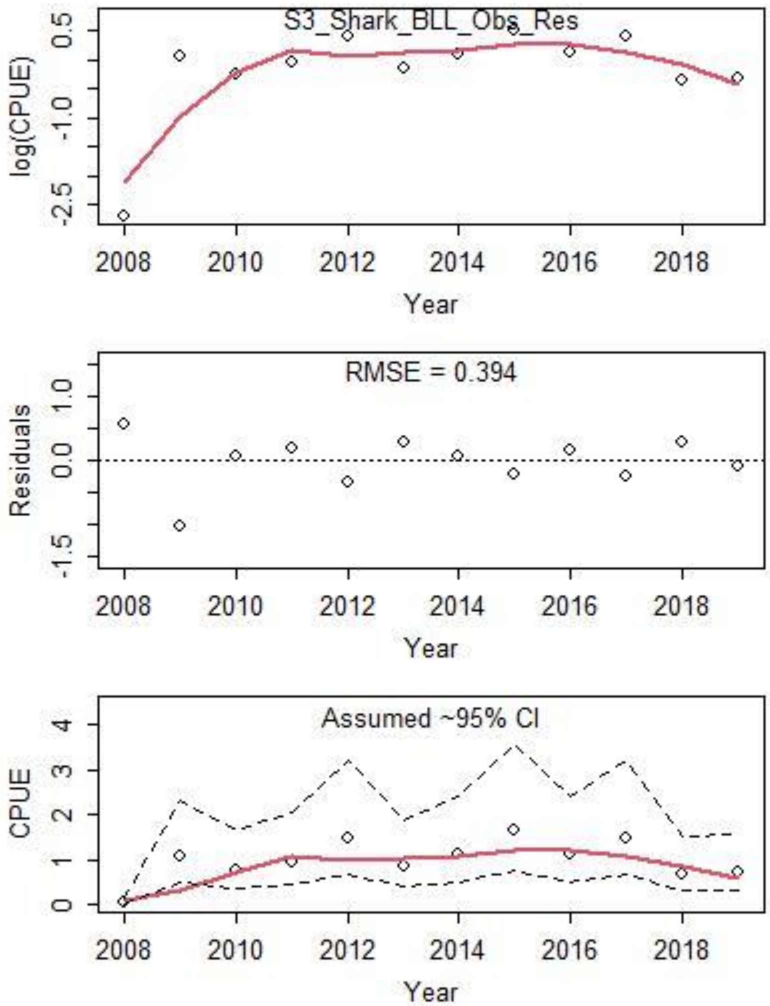


Figure 3.A.1 Continued.

D. S4 (FSU-BLLS)

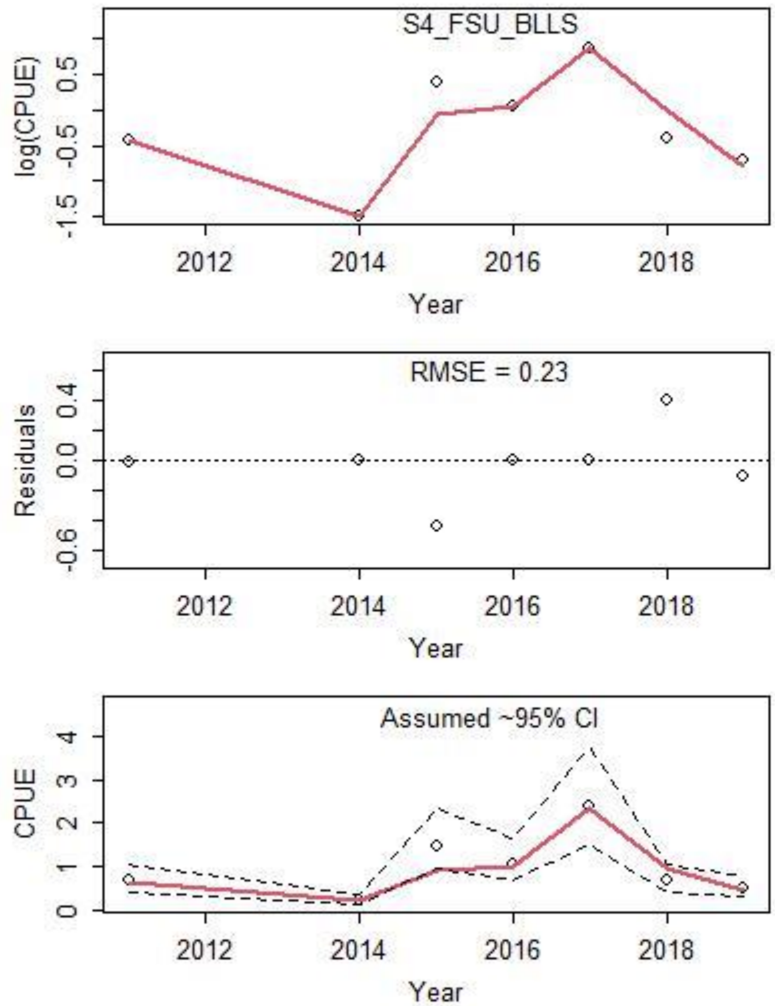


Figure 3.A.1 Continued.

E. S5 (SEFSC-BLLS)

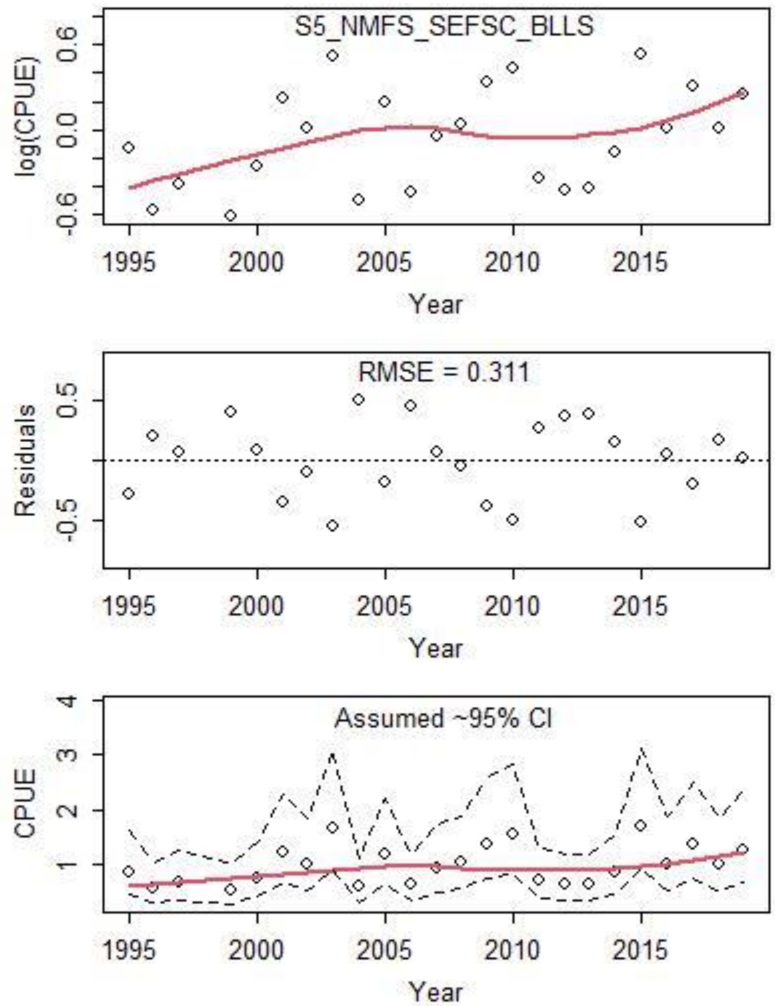


Figure 3.A.1 Continued.

F. R1 (TXPWD-GNS)

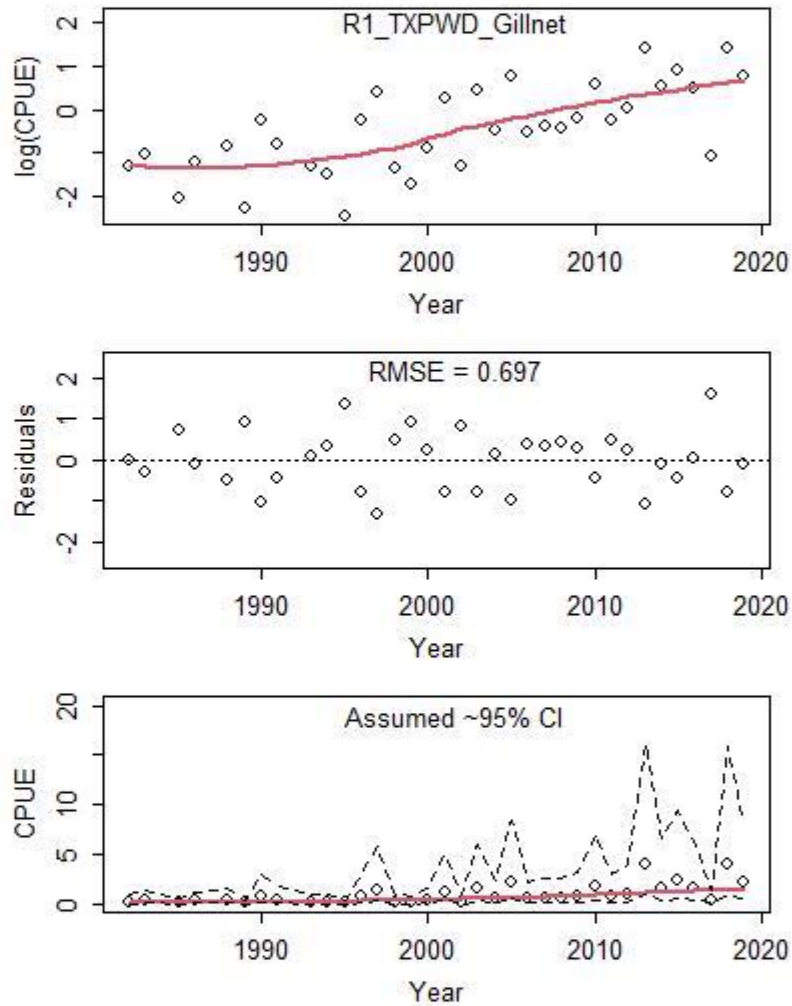


Figure 3.A.1 Continued.

G. R2 (GULFSPAN-GNS)

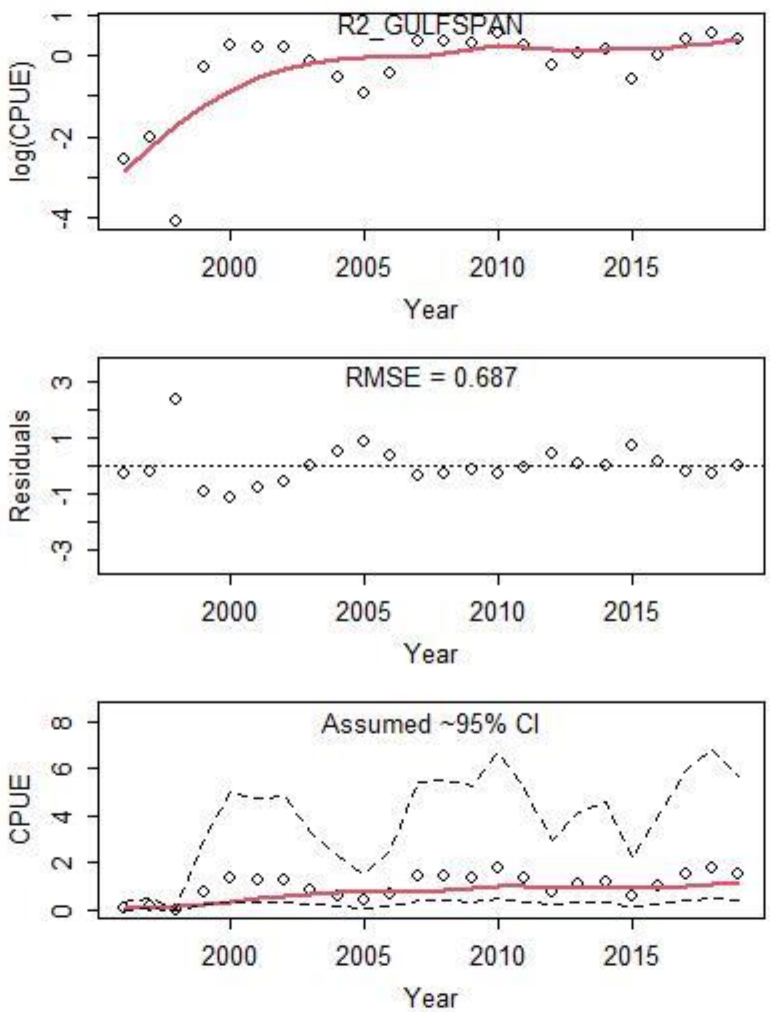


Figure 3.A.1 Continued.

H. R3 (COASTSPAN-BLLS)

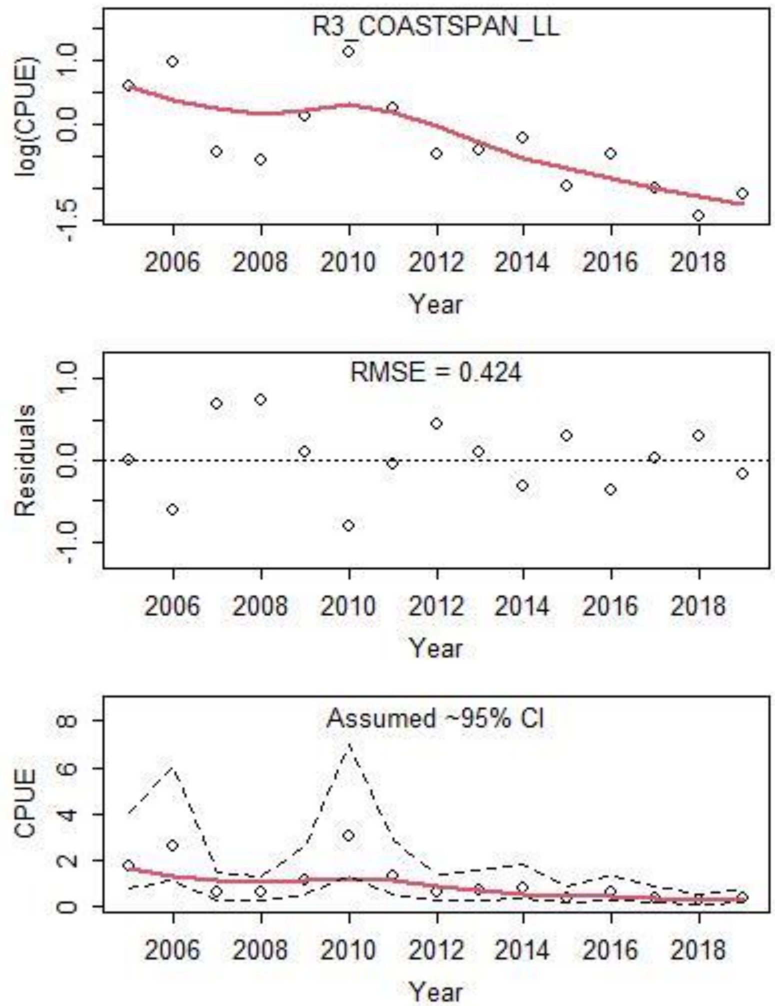


Figure 3.A.1 Continued.

I. R4 (COASTSPAN-LGNS)

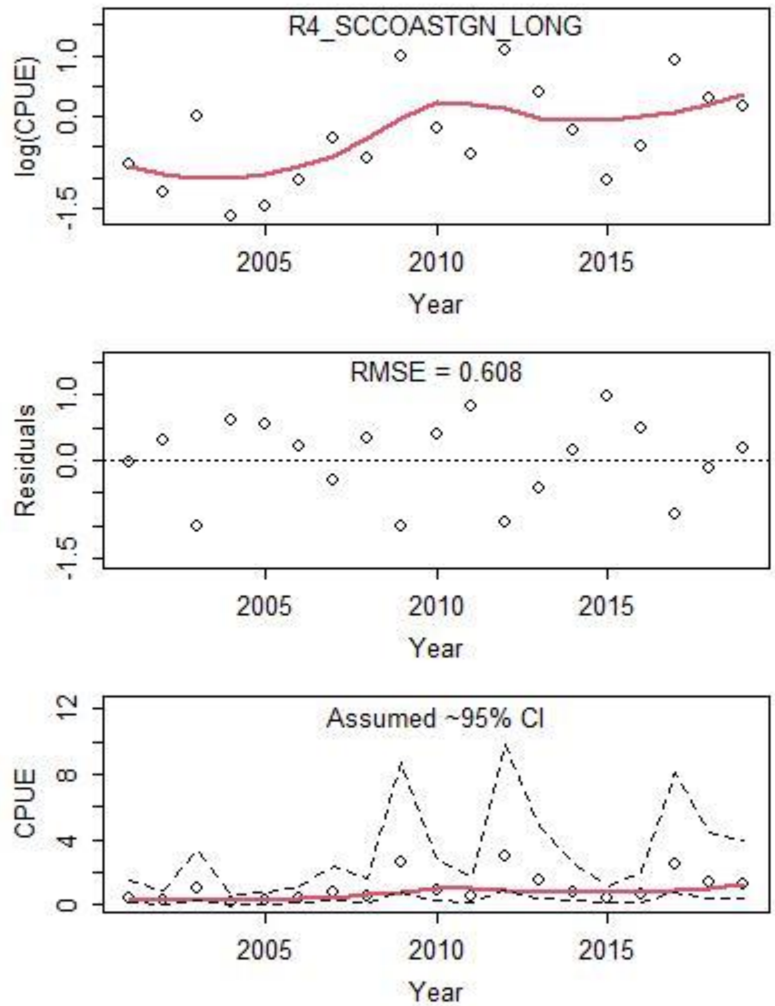


Figure 3.A.1 Continued.

J. R5 (COASTSPAN-SGNS)

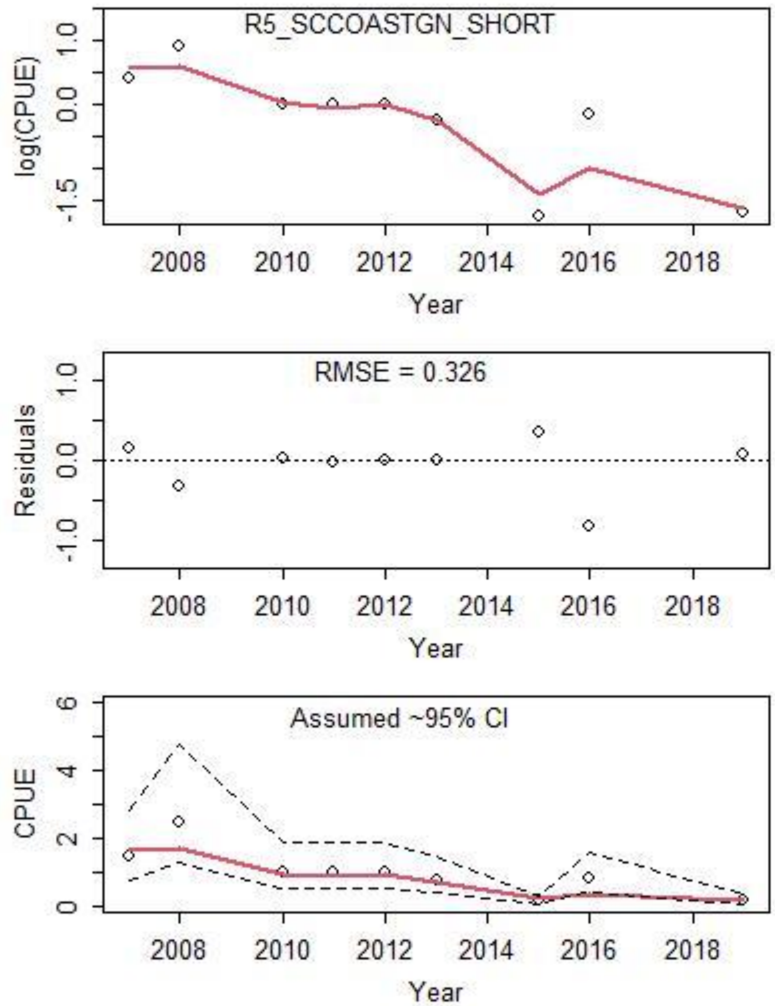


Figure 3.A.1 Continued.

3.11 Appendix 3.B. Stock Synthesis GOM Sensitivity Analysis Model Configuration and Model Fits

Tables

Table 3.B.1. Time series of total commercial catch, total recreational catch, relative abundance, and length composition data used in the Stock Synthesis GOM sensitivity analysis model configuration; The symbol "…" indicates time series that were removed from the GOM sensitivity analysis relative to the GOM+ATL continuity analysis.

Time series	Symbol	Commercial catch, recreational catch (A+B1+B2PRM) and relative abundance	Name	Definition	Length composition
1	F1	Commercial catch (t)	Com-BLL-GOM-Sens	Bottom longlines Kept + PRM (1981 – 2019)	UF [1] + SBLOP[2] (1993 – 2019)
2	F2	Commercial catch (t)	Com-GN-GOM-Sens	Gillnets Kept + PRM (1981 – 2019)	GNOP[3] (NA)
3	F3	Commercial catch (t)	Com-PLL-GOM-Sens	Pelagic longline discard PRM (1981 – 2019)	(1992 – 2019)
4	F4	Recreational catch (thousands)	Rec-GOM-Sens	Recreational (A+B1) (1981 – 2019)	MRIP [4]+ SRHS[5] (1981 – 2019)
5	F5	Recreational PRM (thousands)	Rec-PRM-GOM-Sens	Recreational (B2 PRM) (1981 – 2019)	Mirror F4
6	F6	Commercial catch (t)	Com-Other-Kept-GOM-Sens	Hook and line plus hand line (1981 – 2019)	Mirror F4
	…				
7	S2	Relative abundance (numbers of individuals)	Shark-BLL-Obs-GOM-Sens	Bottom longline fishery observer program (1994 – 2007)	Mirror F1
8	S3	Relative abundance (numbers)	Shark-BLL-Res-GOM-Sens	Shark bottom longline research fishery (2008 – 2019)	Mirror F1
9	S4	Relative abundance (numbers)	FSU-BLLS-GOM-Sens	FSU bottom longline survey (2011 – 2019)	2011 – 2019
10	S5	Relative abundance (numbers)	SEFSC-BLLS-GOM-Sens	NMFS SEFSC bottom longline survey (1995 – 2019)	1995 – 2019
11	R1	Relative abundance (numbers)	TXPWD-GNS-GOM-Sens	Texas Parks and Wildlife Dep. gillnet survey (age-0, 1982 – 2019)	1982 – 2019
12	R2	Relative abundance (numbers)	GULFSPAN-GNS-GOM-Sens	GULFSPAN gillnet survey (age-0, 1996 – 2019)	1994 – 2019
	…				
	…				
	…				

[1] University of Florida (UF) Longline 1993 – 2005.
[2] Southeast Fisheries Science Center (SEFSC) Panama City Lab Shark Bottom Longline Observer Program (SBLOP) 2005 – 2019.
[3] Southeast Fisheries Science Center (SEFSC) Panama City Lab Gillnet Observer Program (GNOP); NA (only 5 measured lengths in GOM-Sens).
[4] Marine Recreational Information Program (MRIP).
[5] Southeast Region Head Boat Survey (SRHS).

Table 3.B.2. Length composition sample size (number of sharks measured) for fleets (F) surveys (S), and age-0 recruitment indices (R) fit in the Stock Synthesis GOM sensitivity analysis model configuration, as defined in **Table 3.B.1**; The symbol "…" indicates time series that were removed from the sensitivity analysis.

	F1		…	F3		F4	S4		S5	
	(Com-BLL)			(Com-PLL)		(Rec)	(FSU-BLLS)		(SEFSC-BLL)	
	1993 – 2019			1992 – 2019		1981-2018	2011 – 2019		1995 – 2019	
	Min.[1] 20			Min. 20		Min. 17	Min. 20		Min. 20	
Year	(♀)	(♂)		(♀)	(♂)	(♀,♂,Unknown)[2]	(♀)	(♂)	(♀)	(♂)
1981						1				
1982						1				
1983						4				
1984						4				
1985						17				
1986						2				
1987						2				
1988						4				
1989						2				
1990						2				
1991						4				
1992				0	1	4				
1993	0	0		5	1	5				
1994	0	2		1	3	2				
1995	0	8		3	0	21			1	7
1996	1	19		2	1	7			2	4
1997	40	6		1	0	2			2	13
1998	37	14		0	0	4			0	0
1999	3	0		0	0	0			9	6
2000	0	0		0	0	1			21	22
2001	41	13		0	0	2			12	14
2002	44	23		0	0	4			15	9
2003	17	137		0	0	1			14	16
2004	45	73		0	0	3			7	7
2005	3	3		0	1	2			4	5
2006	30	20		0	0	0			3	3
2007	21	7		1	0	0			4	8
2008	33	7		24	11	0			2	3
2009	235	176		22	6	0			9	8
2010	80	110		2	0	0			7	9
2011	114	83		3	1	0	9	16	67	66
2012	23	30		0	0	2	0	0	2	5
2013	10	25		3	1	8	8	0	4	2
2014	35	13		1	0	0	1	0	4	5
2015	19	44		0	0	1	6	2	13	25
2016	15	28		0	0	0	0	3	8	17
2017	43	84		0	0	0	15	5	41	75
2018	5	30		0	0	0	1	2	13	18
2019	5	25		0	0	0	3	4	2	11
Total	899	980		68	26	112	43	32	266	358
Proportion (♀,♂)	99%			97%		NA	99%		94%	

[1] Years with less than minimum sample size were excluded from the fit in the model likelihood.
[2] Sex specific length composition data date were not available for fleet F4.

Table B.2. Continued.

	R1	R2	…	…
	(TXPWD-GNS)	(GULFSPAN-GNS)		
	1982– 2019	1994 – 2019		
	Min. 20	Min. 30		
Year	(♀,♂,Unknown)[3]	(♀,♂,Unknown)[3]		
1981				
1982	4			
1983	8			
1984	2			
1985	2			
1986	5			
1987	0			
1988	7			
1989	3			
1990	12			
1991	4			
1992	1			
1993	3			
1994	3	46		
1995	1	0		
1996	23	23		
1997	13	99		
1998	3	35		
1999	6	41		
2000	11	38		
2001	31	75		
2002	3	123		
2003	15	68		
2004	7	32		
2005	22	18		
2006	13	29		
2007	3	95		
2008	11	74		
2009	20	87		
2010	20	97		
2011	40	59		
2012	23	65		
2013	96	73		
2014	35	67		
2015	14	39		
2016	17	46		
2017	3	66		
2018	69	62		
2019	16	73		
Total	569	1530		
Proportion (♀,♂)	NA	NA		

[3] Sex-combined length composition data (♀, ♂, Unknown) were input for recruitment indices.

Table 3.B.3. The von Bertalanffy growth (VBG) size at age implemented separately for females and males in the Stock Synthesis GOM sensitivity analysis model configuration.

Age (yr.)	Female cm FL predicted from the VBG parameters below	Male cm FL predicted from VBG parameters below
0	42.9	41.9
1	58.4	61.2
2	72.6	78.4
3	85.6	93.6
4	97.6	107.0
5	108.6	118.9
6	118.8	129.4
7	128.1	138.7
8	136.7	147.0
9	144.5	154.3
10	151.8	160.7
11	158.5	166.4
12	164.6	171.5
13	170.2	176.0
14	175.4	179.9
15	180.2	183.4
16	184.5	186.6
17	188.6	189.3
18	192.3	191.7
19	195.7	193.9
20	198.8	195.8
21	201.7	197.5
22	204.3	199.0
23	206.7	200.3
24[1]	209.0	201.5
25	211.0	202.5
26	212.9	203.4
27	214.7	204.2
28	216.3	205.0
29	217.7	205.6
30	219.1	206.2
31	220.3	206.7
32	221.5	207.1
33	222.5	207.5
34	223.5	207.8
35	224.4	208.1
36	225.2	208.4
37[1]	225.9	208.7
38	226.6	208.9
39	227.3	209.1
40	227.8	209.2
41	228.4	209.4
42	228.9	209.5
43	229.3	209.6
44	229.7	209.7
45	230.1	209.8
46	230.5	209.9
47	230.8	210.0
48	231.1	210.0
49	231.4	210.1
50[2]	231.6	210.1

VBG parameters	Female	Male
L_{inf}	234.5	210.5
k	0.084	0.122
t_0	-2.407	-1.818
CV implemented for L_{Amin}	0.093	0.097
CV implemented for L_{inf}	0.090	0.082

[1] Observed Tmax (♀) = 24.5 yr and Tmax (♂) = 37.5 yr (Data Workshop Section 2.4 Life History Report, their Table 1).
[2] Theoretical Tmax (♀) = 52 yr and Tmax (♂) = 36 yr (SEDAR77AW04, their Table 2; Pers. Comm. E . Cortés).

Table 3.B.4. Annual pup production at age used in the Stock Synthesis GOM sensitivity analysis model configuration.

Age (yr.)	Litter size (LS) [1]	Fraction mature [2]	Fraction maternal [3]	Pup production [4]	Annual pup production [5]
0	18.00	0.00	0.00	0.0	0.00
1	18.00	0.00	0.00	0.0	0.00
2	18.00	0.00	0.00	0.0	0.00
3	18.00	0.00	0.00	0.0	0.00
4	18.00	0.00	0.00	0.0	0.00
5	18.00	0.00	0.00	0.0	0.00
6	18.00	0.00	0.00	0.0	0.00
7	18.00	0.00	0.00	0.0	0.00
8	18.00	0.00	0.00	0.0	0.00
9	18.00	0.01	0.00	0.0	0.00
10	18.00	0.01	0.01	0.2	0.18
11	18.00	0.02	0.01	0.2	0.18
12	18.00	0.05	0.02	0.4	0.36
13	18.00	0.09	0.05	0.9	0.90
14	18.00	0.17	0.09	1.6	1.62
15	18.00	0.31	0.17	3.1	3.06
16	18.00	0.48	0.31	5.6	5.58
17	18.00	0.66	0.48	8.6	8.64
18	18.00	0.80	0.66	11.9	11.88
19	18.00	0.90	0.80	14.4	14.40
20	18.00	0.95	0.90	16.2	16.20
21	18.00	0.97	0.95	17.1	17.10
22	18.00	0.99	0.97	17.5	17.46
23	18.00	0.99	0.99	17.8	17.82
24	18.00	1.00	0.99	17.8	17.82
25	18.00	1.00	1.00	18.0	18.00
26	18.00	1.00	1.00	18.0	18.00
27	18.00	1.00	1.00	18.0	18.00
28	18.00	1.00	1.00	18.0	18.00
29	18.00	1.00	1.00	18.0	18.00
30	18.00	1.00	1.00	18.0	18.00
31	18.00	1.00	1.00	18.0	18.00
32	18.00	1.00	1.00	18.0	18.00
33	18.00	1.00	1.00	18.0	18.00
34	18.00	1.00	1.00	18.0	18.00
35	18.00	1.00	1.00	18.0	18.00
36	18.00	1.00	1.00	18.0	18.00
37	18.00	1.00	1.00	18.0	18.00
38	18.00	1.00	1.00	18.0	18.00
39	18.00	1.00	1.00	18.0	18.00
40	18.00	1.00	1.00	18.0	18.00
41	18.00	1.00	1.00	18.0	18.00
42	18.00	1.00	1.00	18.0	18.00
43	18.00	1.00	1.00	18.0	18.00
44	18.00	1.00	1.00	18.0	18.00
45	18.00	1.00	1.00	18.0	18.00
46	18.00	1.00	1.00	18.0	18.00
47	18.00	1.00	1.00	18.0	18.00
48	18.00	1.00	1.00	18.0	18.00
49	18.00	1.00	1.00	18.0	18.00
50	18.00	1.00	1.00	18.0	18.00

[1] Brood size = 18; range 7 – 30 (Data Workshop Section 2.4 Life History Report, their Table 1).
[2] Fraction mature at age obtained from GOM+ATL "tmat = 16.11 years, a = -11.979, b = 0.744" (DW Section 2.4, their Tables 1 and 6); The values of the SEs of the intercept and slope of the age-based maturity ogive for GOM were extremely high (SE(a)=62741.45 and SE(b)=4967.34; DW Section 2.4, their Table 1); Consequently, the maturity ogive from GOM+ATL was used here (See SEDAR77AW04, their Tables 1 and 2; Pers. Comm. E . Cortés).
[3] Fraction maternal assumed an 10 – 12 month gestation period (DW Section 2.4, their Table 1), approximated here by a one year offset from maturity to maternity, e.g., see outlined boxes above at ages 9 and 23.
[4] Pup production was obtained as (LS at age)* (Fraction maternal at age).
[5] Annual pup production was obtained by assuming an annual reproductive cycle (DW Section 2.4, their Table 1) and calculated as [(LS at age)* (Fraction maternal at age)]/1 .

Table 3.B.5. Number of estimated parameters (numbers within parentheses) in the Stock Synthesis GOM sensitivity analysis model configuration; The symbol "…" indicates time series that were removed from the sensitivity analysis.

Fleet	Fleet name	Proposed selectivity pattern	Implemented selectivity pattern	Sex	Time block(s)	Number of selectivity parameters	Number of catchability parameters	Sub-total of parameters	Sub-total of estimated parameters
1	F1 (Com-BLL-GOM)	Logistic	Logistic	Sex specific	Sel. (peak, ascend)[1]	13 (5)[4]	0 (0)	13	(5)
2	F2 (Com-GN-GOM)	Double normal	Double normal	Combined sex	Sel. (peak)[2]	7 (0)[5]	0 (0)	7	(0)
3	F3 (Com-PLL-GOM)	Logistic	Logistic	Sex specific		11(1)[6]	0 (0)	11	(1)
4	F4 (Rec-GOM)	Double normal	Double normal	Combined sex	Sel. (end)[3]	7 (0)[7]	0 (0)	7	(0)
5	F5 (Rec-RPM-GOM)		Mirror F4	Mirror F4	Mirror F4	0 (0)	0 (0)	0	(0)
6	F6 (Com-Other-Kept-GOM)		Mirror F4	Mirror F4	Mirror F4	0 (0)	0 (0)	0	(0)
	…								
7	S2 (Shark-BLL-Obs-GOM)		Mirror F1	Mirror F1		0 (0)	1 (0)	1	(0)
8	S3 (Shark-BLL-Res-GOM)		Mirror F1	Mirror F1		0 (0)	1 (0)	1	(0)
9	S4 (FSU-BLLS-GOM)	Logistic	Logistic	Sex specific		11(2)[4]	1 (0)	12	(2)
10	S5 (SEFSC-BLLS-GOM)	Logistic	Logistic	Sex specific		11(1)[6]	1 (0)	12	(1)
11	R1 (TXPWD-GNS-GOM)	Double normal	Double normal	Combined sex		6 (2)[8]	1 (0)	7	(2)
12	R2 (GULFSPAN-GNS-GOM)	Double normal	Double normal	Combined sex		6 (1)[9]	1 (0)	7	(1)
	…								
	…								
	…								
						Subtotal (selectivity, catchability)		78	(12)
	Other estimated parameters								
	ln(R_0)								(1)
	Recruitment deviations					1988 – 2019			(32)
						Grand total			(45)

[1] Time blocks in selectivity for F1 (1981 – 2007, 2008 – 2019 [main years]) were adapted from the GOM +ATL continuity analysis.
[2] Time blocks in selectivity for F2 (1981 – 2006, 2007 – 2019 [main years]) were adapted from the GOM +ATL continuity analysis.
[3] Time blocks in selectivity for F4 (1981 – 1999, 2000 – 2019 [main years]) were adapted from the GOM +ATL continuity analysis.
[4] Selectivity parameters for the location of the peak and the ascending width were estimated; The remaining selectivity parameters were fixed at their initial values obtained externally from a selectivity gamer fit to the GOM length data set.
[5] All selectivity parameters were fixed at their initial values obtained externally from the GOM +ATL continuity analysis.
[6] Only selectivity parameters for the location of the peak were estimated; The remaining selectivity parameters were fixed at their initial values obtained externally from either a selectivity gamer fit to the GOM length data set or from the GOM +ATL continuity analysis.
[7] All selectivity parameters were fixed at their initial values obtained externally from either a selectivity gamer fit to the GOM length data set or from the GOM +ATL continuity analysis.
[8] Only selectivity parameters for the location of the peak and the initial selectivity were estimated; The remaining selectivity parameters were fixed at their initial values obtained externally from the GOM +ATL continuity analysis.
[9] Only selectivity parameters for the descending slope were estimated; The remaining selectivity parameters were fixed at their initial values obtained externally from the GOM +ATL continuity analysis.

Table 3.B.6. Two stage data weighting used in the Stock Synthesis GOM sensitivity analysis model configuration; The stage-1 CPUE (survey) variance adjustments are provided along with the mean of input CV and the resulting mean of adjusted input CV obtained after adding the variance adjustment (**Panel A**); The stage-2 length composition effective sample size (Effn) adjustments are provided along with the mean input sample size (n) and the resulting mean of the adjusted input sample size, n, obtained after multiplying by the Effn adjustment (**Panel B**); The symbol "…" indicates time series that were removed from the sensitivity analysis.

Panel A

Survey	Mean of input CV	Variance adjustment	Mean of adjusted input CV
…			
S2 (Shark-BLL-Obs-GOM)	0.7173	0.1147	0.8320
S3 (Shark-BLL-Res-GOM)	0.4373	0.1167	0.5540
S4 (FSU-BLLS-GOM)	0.4941	0.0000	0.4941
S5 (SEFSC-BLLS-GOM)	0.3393	0.0000	0.3393
R1 (TXPWD-GNS-GOM)	0.6652	0.0318	0.6970
R2 (GULFSPAN-GNS-GOM)	0.2552	0.4318	0.6870
…			
…			
…			

Panel B

Length composition data source	Mean of input n	Adjustment method	Sample size adjustment	Mean of adjusted input n
F1 (Com-BLL-GOM)	88.6	Francis Effn	0.067	5.9
…				
F3 (Com-PLL-GOM)	31.5	Harmonic Mean Effn	0.797	25.1
F4 (Rec-GOM)	19.0	Harmonic Mean Effn	0.452	8.6
S4 (FSU-BLLS-GOM)	22.5	Harmonic Mean Effn	0.984	22.1
S5 (SEFSC-BLLS-GOM)	51.8	Francis Effn	0.452	23.4
R1 (TXPWD-GNS)	37.9	Harmonic Mean Effn	0.156	5.9
R2 (GULFSPAN-GNS)	66.4	Francis Effn	0.744	49.4
…				
…				

Table 3.B.7. Parameters in the Stock Synthesis GOM sensitivity analysis model configuration; Parameters with a negative phase were fixed at their initial value; CV is calculated as the asymptotic standard error (Parm_StDev) divided by the estimated value (Value).

Label	Value	Active	Phase	Min	Max	Init	StDev	Pr_type	Prior	Pr_SD	CV
L_at_Amin_Fem_GP_1	42.93	_	-3	5	100	42.93	_	Normal	42.93	1000	NA
L_at_Amax_Fem_GP_1	234.50	_	-4	50	600	234.50	_	Normal	234.50	1000	NA
VonBert_K_Fem_GP_1	0.08	_	-5	0.01	0.65	0.08	_	Normal	0.06	0.2	NA
CV_young_Fem_GP_1	0.09	_	-2	0.01	0.3	0.09	_	Normal	0.09	0.01	NA
CV_old_Fem_GP_1	0.09	_	-3	0.01	0.3	0.09	_	Normal	0.09	0.01	NA
Wtlen_1_Fem_GP_1	0.00	_	-3	-3	3	0.00	_	Normal	0.00	0.8	NA
Wtlen_2_Fem_GP_1	3.13	_	-3	-3	5	3.13	_	Normal	3.00	0.8	NA
Mat50%_Fem_GP_1	199.10	_	-3	1	300	199.10	_	Normal	199.10	0.8	NA
Mat_slope_Fem_GP_1	-0.19	_	-3	-200	3	-0.19	_	Normal	-0.19	0.8	NA
Eggs_scalar_Fem_GP_1	18.00	_	-3	-3	50	18.00	_	Normal	18.00	0.8	NA
Eggs_exp_len_Fem_GP_1	0.00	_	-3	-3	3	0.00	_	Normal	0.00	0.8	NA
L_at_Amin_Mal_GP_1	41.87	_	-3	5	100	41.87	_	Normal	41.87	1000	NA
L_at_Amax_Mal_GP_1	210.50	_	-4	50	600	210.50	_	Normal	210.50	1000	NA
VonBert_K_Mal_GP_1	0.12	_	-5	0.01	0.65	0.12	_	Normal	0.12	0.2	NA
CV_young_Mal_GP_1	0.10	_	-2	0.01	0.3	0.10	_	Normal	0.10	0.01	NA
CV_old_Mal_GP_1	0.08	_	-3	0.01	0.3	0.08	_	Normal	0.08	0.01	NA
Wtlen_1_Mal_GP_1	0.00	_	-3	-3	3	0.00	_	Normal	<0.001	0.8	NA
Wtlen_2_Mal_GP_1	2.91	_	-3	-3	5	2.91	_	Normal	3.00	0.8	NA
CohortGrowDev	1.00	_	-1	0.1	10	1.00	_	Normal	1.00	1	NA
FracFemale_GP_1	0.50	_	-99	0.00	0.99	0.50	_	No_prior			NA
SR_LN(R0)	5.49	1	1	2.0685	8.742	4.14	1.08	Normal	7.04	1000	75%
SR_BH_steep	0.71	_	-2	0.2	0.99	0.71	_	Normal	0.71	1000	NA
SR_sigmaR	0.28	_	-4	0.2	1.9	0.28	_	Normal	0.28	1000	NA
SR_regime	0.00	_	-4	-5	5	0.00	_	Normal	0.00	1	NA
SR_autocorr	0.00	_	-4	-5	5	0.00	_	Normal	0.00	1	NA

Table 3.B.7. Continued.

Label	Value	Active	Phase	Min	Max	Init	StDev	Pr_type	Prior	Pr_SD	CV
Early_RecrDev_1988	-0.19	2	4	-10	10	0.00	0.26	dev			
Early_RecrDev_1989	-0.14	3	4	-10	10	0.00	0.26	dev			
Early_RecrDev_1990	-0.16	4	4	-10	10	0.00	0.25	dev			
Early_RecrDev_1991	-0.13	5	4	-10	10	0.00	0.26	dev			
Early_RecrDev_1992	-0.09	6	4	-10	10	0.00	0.26	dev			
Early_RecrDev_1993	-0.34	7	4	-10	10	0.00	0.24	dev			
Early_RecrDev_1994	0.08	8	4	-10	10	0.00	0.22	dev			
Early_RecrDev_1995	-0.19	9	4	-10	10	0.00	0.24	dev			
Early_RecrDev_1996	0.10	10	4	-10	10	0.00	0.19	dev			
Early_RecrDev_1997	-0.85	11	4	-10	10	0.00	0.20	dev			
Main_RecrDev_1998	-0.36	12	3	-10	10	0.00	0.21	dev			
Main_RecrDev_1999	-0.11	13	3	-10	10	0.00	0.21	dev			
Main_RecrDev_2000	0.15	14	3	-10	10	0.00	0.19	dev			
Main_RecrDev_2001	-0.24	15	3	-10	10	0.00	0.18	dev			
Main_RecrDev_2002	0.28	16	3	-10	10	0.00	0.17	dev			
Main_RecrDev_2003	-0.42	17	3	-10	10	0.00	0.20	dev			
Main_RecrDev_2004	-0.03	18	3	-10	10	0.00	0.22	dev			
Main_RecrDev_2005	-0.11	19	3	-10	10	0.00	0.24	dev			
Main_RecrDev_2006	-0.27	20	3	-10	10	0.00	0.22	dev			
Main_RecrDev_2007	0.15	21	3	-10	10	0.00	0.18	dev			
Main_RecrDev_2008	0.06	22	3	-10	10	0.00	0.17	dev			
Main_RecrDev_2009	-0.14	23	3	-10	10	0.00	0.17	dev			
Main_RecrDev_2010	0.14	24	3	-10	10	0.00	0.18	dev			
Main_RecrDev_2011	0.42	25	3	-10	10	0.00	0.18	dev			
Main_RecrDev_2012	0.15	26	3	-10	10	0.00	0.19	dev			
Main_RecrDev_2013	0.21	27	3	-10	10	0.00	0.18	dev			
Main_RecrDev_2014	0.14	28	3	-10	10	0.00	0.18	dev			
Main_RecrDev_2015	0.15	29	3	-10	10	0.00	0.19	dev			
Main_RecrDev_2016	-0.35	30	3	-10	10	0.00	0.21	dev			
Main_RecrDev_2017	0.17	31	3	-10	10	0.00	0.20	dev			
Late_RecrDev_2018	0.08	32	5	-10	10	0.00	0.20	dev			
Late_RecrDev_2019	0.41	33	5	-10	10	0.00	0.23	dev			

Table 3.B.7. Continued.

Label	Value	Active	Phase	Min	Max	Init	StDev	Pr_type	Prior	Pr_SD	CV
LnQ_base_S2_Shark_BLL_Obs_GOM_Sens(7)	-4.11	_	-1	-25	25	0.00	_	No_prior			NA
LnQ_base_S3_Shark_BLL_Res_GOM_Sens(8)	-2.14	_	-1	-25	25	0.00	_	No_prior			NA
LnQ_base_S4_FSU_BLLS(9)	-12.23	_	-1	-25	25	0.00	_	No_prior			NA
LnQ_base_S5_SEFSC_BLLS_GOM_Sens(10)	-9.40	_	-1	-25	25	0.00	_	No_prior			NA
LnQ_base_R1_TXPWD_GNS(11)	-12.45	_	-1	-25	25	0.00	_	No_prior			NA
LnQ_base_R2_GULFSPAN_GNS(12)	-7.92	_	-1	-25	25	0.00	_	No_prior			NA
Size_DblN_peak_F1_COM_BLL_GOM_Sens(1)	172.25	44	2	55.6	247.5	184.70	12.58	Sym_Beta	172.9	0.05	107%
Size_DblN_top_logit_F1_COM_BLL_GOM_Sens(1)	4.00	_	-3	-6	4	4.00	_	Sym_Beta	4	0.05	NA
Size_DblN_ascend_se_F1_COM_BLL_GOM_Sens(1)	7.26	45	3	-1	9	7.40	0.56	Sym_Beta	8.7	0.05	102%
Size_DblN_descend_se_F1_COM_BLL_GOM_Sens(1)	-1.00	_	-3	-1	9	-1.00	_	Sym_Beta	-1	0.05	NA
Size_DblN_start_logit_F1_COM_BLL_GOM_Sens(1)	-4.70	_	-2	-15	9	-4.70	_	Sym_Beta	-4.9	0.05	NA
Size_DblN_end_logit_F1_COM_BLL_GOM_Sens(1)	9.00	_	-2	-15	9	9.00	_	Sym_Beta	9	0.05	NA
SzSel_Fem_Peak_F1_COM_BLL_GOM_Sens(1)	-47.80	46	4	-100	100	-64.39	8.79	Normal	0	1000	135%
SzSel_Fem_Ascend_F1_COM_BLL_GOM_Sens(1)	-1.56	_	-4	-15	15	-1.56	_	Normal	0	1000	NA
SzSel_Fem_Descend_F1_COM_BLL_GOM_Sens(1)	0.00	_	-4	-15	15	0.00	_	Normal	0	1000	NA
SzSel_Fem_Final_F1_COM_BLL_GOM_Sens(1)	0.00	_	-4	-15	15	0.00	_	Normal	0	1000	NA
SzSel_Fem_Scale_F1_COM_BLL_GOM_Sens(1)	1.00	_	-5	-15	15	1.00	_	Normal	1	1000	NA
Size_DblN_peak_F2_Com_GN_GOM_Sens(2)	66.72	_	-2	42.50	247.50	66.72	_	Sym_Beta	73.1	0.05	NA
Size_DblN_top_logit_F2_Com_GN_GOM_Sens(2)	-2.86	_	-3	-6.00	4.00	-2.86	_	Sym_Beta	-2.9	0.05	NA
Size_DblN_ascend_se_F2_Com_GN_GOM_Sens(2)	4.75	_	-3	-1.00	9.00	4.75	_	Sym_Beta	5.3	0.05	NA
Size_DblN_descend_se_F2_Com_GN_GOM_Sens(2)	6.38	_	-3	-1.00	9.00	6.38	_	Sym_Beta	7.8	0.05	NA
Size_DblN_start_logit_F2_Com_GN_GOM_Sens(2)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15	0.05	NA
Size_DblN_end_logit_F2_Com_GN_GOM_Sens(2)	-1.24	_	-2	-15.00	9.00	-1.24	_	Sym_Beta	-2.3	0.05	NA
Size_DblN_peak_F3_Com_PLL_GOM_Sens(3)	125.90	47	2	55.60	247.50	143.40	4.87	Sym_Beta	143.4	0.05	114%
Size_DblN_top_logit_F3_Com_PLL_GOM_Sens(3)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6	0.05	NA
Size_DblN_ascend_se_F3_Com_PLL_GOM_Sens(3)	6.27	_	-3	-1.00	9.00	6.27	_	Sym_Beta	6.5	0.05	NA
Size_DblN_descend_se_F3_Com_PLL_GOM_Sens(3)	9.00	_	-3	-1.00	9.00	9.00	_	Sym_Beta	9	0.05	NA
Size_DblN_start_logit_F3_Com_PLL_GOM_Sens(3)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15	0.05	NA
Size_DblN_end_logit_F3_Com_PLL_GOM_Sens(3)	9.00	_	-2	-15.00	9.00	9.00	_	Sym_Beta	9	0.05	NA
SzSel_Male_Peak_F3_Com_PLL_GOM_Sens(3)	14.04	_	-4	-50.00	50.00	14.04	_	Normal	0	1000	NA
SzSel_Male_Ascend_F3_Com_PLL_GOM_Sens(3)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0	1000	NA
SzSel_Male_Descend_F3_Com_PLL_GOM_Sens(3)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0	1000	NA
SzSel_Male_Final_F3_Com_PLL_GOM_Sens(3)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0	1000	NA
SzSel_Male_Scale_F3_Com_PLL_GOM_Sens(3)	1.00	_	-5	-15.00	15.00	1.00	_	Normal	1	1000	NA

Table 3.B.7. Continued.

Label	Value	Active	Phase	Min	Max	Init	StDev	Pr_type	Prior	Pr_SD	CV
Size_DblN_peak_F4_Rec_GOM_Sens(4)	69.90	_	-2	42.50	247.50	69.90	_	Sym_Beta	61.8	0.05	NA
Size_DblN_top_logit_F4_Rec_GOM_Sens(4)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6	0.05	NA
Size_DblN_ascend_se_F4_Rec_GOM_Sens(4)	7.00	_	-3	-1.00	9.00	7.00	_	Sym_Beta	9	0.05	NA
Size_DblN_descend_se_F4_Rec_GOM_Sens(4)	7.60	_	-3	-1.00	9.00	7.60	_	Sym_Beta	7.6	0.05	NA
Size_DblN_start_logit_F4_Rec_GOM_Sens(4)	-2.00	_	-2	-15.00	9.00	-2.00	_	Sym_Beta	1	0.05	NA
Size_DblN_end_logit_F4_Rec_GOM_Sens(4)	-1.10	_	-2	-15.00	9.00	-1.10	_	Sym_Beta	-1	0.05	NA
SizeSel_P1_F5_Rec_PRM_GOM_Sens(5)	1.00	_	-99	0.00	10.00	1.00	_	Normal	1	25	NA
SizeSel_P2_F5_Rec_PRM_GOM_Sens(5)	44.00	_	-99	10.00	100.00	44.00	_	Normal	44	25	NA
SizeSel_P1_F6_Com_Other_Kept_GOM_Sens(6)	1.00	_	-99	0.00	10.00	1.00	_	Normal	1	25	NA
SizeSel_P2_F6_Com_Other_Kept_GOM_Sens(6)	44.00	_	-99	10.00	100.00	44.00	_	Normal	44	25	NA
SizeSel_P1_S2_Shark_BLL_Obs_GOM_Sens(7)	1.00	_	-99	0.00	10.00	1.00	_	Normal	1	25	NA
SizeSel_P2_S2_Shark_BLL_Obs_GOM_Sens(7)	44.00	_	-99	10.00	100.00	44.00	_	Normal	44	25	NA
SizeSel_P1_S3_Shark_BLL_Res_GOM_Sens(8)	1.00	_	-99	0.00	10.00	1.00	_	Normal	1	25	NA
SizeSel_P2_S3_Shark_BLL_Res_GOM_Sens(8)	44.00	_	-99	10.00	100.00	44.00	_	Normal	44	25	NA
Size_DblN_peak_S4_FSU_BLLS(9)	105.02	48	2	55.60	247.50	113.20	9.61	Sym_Beta	113.2	0.05	108%
Size_DblN_top_logit_S4_FSU_BLLS(9)	4.00	_	-3	-6.00	4.00	4.00	_	Sym_Beta	4	0.05	NA
Size_DblN_ascend_se_S4_FSU_BLLS(9)	6.15	49	3	-1.00	9.00	5.90	0.78	Sym_Beta	5.9	0.05	96%
Size_DblN_descend_se_S4_FSU_BLLS(9)	-1.00	_	-3	-1.00	9.00	-1.00	_	Sym_Beta	-1	0.05	NA
Size_DblN_start_logit_S4_FSU_BLLS(9)	-5.50	_	-2	-15.00	9.00	-5.50	_	Sym_Beta	-5.5	0.05	NA
Size_DblN_end_logit_S4_FSU_BLLS(9)	9.00	_	-2	-15.00	9.00	9.00	_	Sym_Beta	9	0.05	NA
SzSel_Fem_Peak_S4_FSU_BLLS(9)	18.11	_	-4	-50.00	50.00	18.11	_	Normal	0	1000	NA
SzSel_Fem_Ascend_S4_FSU_BLLS(9)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0	1000	NA
SzSel_Fem_Descend_S4_FSU_BLLS(9)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0	1000	NA
SzSel_Fem_Final_S4_FSU_BLLS(9)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0	1000	NA
SzSel_Fem_Scale_S4_FSU_BLLS(9)	1.00	_	-5	-15.00	15.00	1.00	_	Normal	1	1000	NA
Size_DblN_peak_S5_SEFSC_BLLS_GOM_Sens(10)	98.65	50	2	55.60	247.50	133.70	2.54	Sym_Beta	117.6	0.05	136%
Size_DblN_top_logit_S5_SEFSC_BLLS_GOM_Sens(10)	4.00	_	-3	-6.00	4.00	4.00	_	Sym_Beta	4	0.05	NA
Size_DblN_ascend_se_S5_SEFSC_BLLS_GOM_Sens(10)	5.95	_	-3	-1.00	9.00	5.95	_	Sym_Beta	9	0.05	NA
Size_DblN_descend_se_S5_SEFSC_BLLS_GOM_Sens(10)	-1.00	_	-3	-1.00	9.00	-1.00	_	Sym_Beta	-1	0.05	NA
Size_DblN_start_logit_S5_SEFSC_BLLS_GOM_Sens(10)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15	0.05	NA
Size_DblN_end_logit_S5_SEFSC_BLLS_GOM_Sens(10)	9.00	_	-2	-15.00	9.00	9.00	_	Sym_Beta	9	0.05	NA
SzSel_Fem_Peak_S5_SEFSC_BLLS_GOM_Sens(10)	-11.53	_	-4	-100.0	100.0	-11.53	_	Normal	0	1000	NA
SzSel_Fem_Ascend_S5_SEFSC_BLLS_GOM_Sens(10)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0	1000	NA
SzSel_Fem_Descend_S5_SEFSC_BLLS_GOM_Sens(10)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0	1000	NA
SzSel_Fem_Final_S5_SEFSC_BLLS_GOM_Sens(10)	0.00	_	-4	-15	15	0.00	_	Normal	0	1000	NA
SzSel_Fem_Scale_S5_SEFSC_BLLS_GOM_Sens(10)	1.00	_	-5	-15.00	15.00	1.00	_	Normal	1	1000	NA

Table 3.B.7. Continued.

Label	Value	Active	Phase	Min	Max	Init	StDev	Pr_type	Prior	Pr_SD	CV
Size_DblN_peak_R1_TXPWD_GNS(11)	53.90	51	2	42.50	77.50	55.30	1.04	Sym_Beta	55.3	0.05	103%
Size_DblN_top_logit_R1_TXPWD_GNS(11)	-5.90	_	-3	-6.00	4.00	-5.90	_	Sym_Beta	-5.9	0.05	NA
Size_DblN_ascend_se_R1_TXPWD_GNS(11)	4.80	_	-3	-1.00	9.00	4.80	_	Sym_Beta	4.8	0.05	NA
Size_DblN_descend_se_R1_TXPWD_GNS(11)	2.90	_	-3	-1.00	9.00	2.90	_	Sym_Beta	2.9	0.05	NA
Size_DblN_start_logit_R1_TXPWD_GNS(11)	-0.16	52	2	-15.00	9.00	-1.10	0.63	Sym_Beta	-1.1	0.05	679%
Size_DblN_end_logit_R1_TXPWD_GNS(11)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15	0.05	NA
Size_DblN_peak_R2_GULFSPAN_GNS(12)	42.50	_	-2	42.50	77.50	42.50	_	Sym_Beta	43	0.05	NA
Size_DblN_top_logit_R2_GULFSPAN_GNS(12)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6	0.05	NA
Size_DblN_ascend_se_R2_GULFSPAN_GNS(12)	9.00	_	-3	-1.00	9.00	9.00	_	Sym_Beta	9	0.05	NA
Size_DblN_descend_se_R2_GULFSPAN_GNS(12)	4.04	53	3	-1.00	9.00	3.90	0.08	Sym_Beta	3.9	0.05	97%
Size_DblN_start_logit_R2_GULFSPAN_GNS(12)	9.00	_	-2	-15.00	9.00	9.00	_	Sym_Beta	0.6	0.05	NA
Size_DblN_end_logit_R2_GULFSPAN_GNS(12)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15	0.05	NA
Size_DblN_peak_F1_COM_BLL_GOM_ Sens(1)_BLK2repl_1981	161.42	54	2	55.6	247.5	207.56	14.61	Sym_Beta	176.2	0.05	129%
Size_DblN_ascend_se_F1_COM_BLL_GOM_ Sens(1)_BLK2repl_1981	7.30	55	3	-1	9	8.42	0.71	Sym_Beta	8.2	0.05	115%
Size_DblN_peak_F2_Com_GN_GOM_ Sens(2)_BLK3repl_1981	84.91	_	-2	42.5	247.5	84.91	_	Sym_Beta	73.1	0.05	NA
Size_DblN_end_logit_F4_Rec_GOM_ Sens(4)_BLK4repl_1981	-0.57	_	-2	-15	9	-0.572	_	Sym_Beta	-1	0.05	NA

Table 3.B.8. Catchability (*q*) in the Stock Synthesis GOM sensitivity model configuration; Catchability is calculated as the median unbiased analytical solution obtained from Stock Synthesis; The symbol "…" indicates time series that were removed from the sensitivity analysis.

Index name and years	ln(*q*)	*q*
Main years		
…		
S2 (Shark-BLL-Obs-GOM; 1994 – 2007)	-4.109	1.64E-02
S3 (Shark-BLL-Res-GOM; 2008 – 2019)	-2.141	1.18E-01
S4 (FSU-BLLS; 2011 – 2019)	-12.234	4.86E-06
S5 (SEFSC-BLLS-GOM; 1995 – 2019)	-9.396	8.30E-05
R1 (TXPWD-GNS; 1983 – 2019)	-12.450	3.92E-06
R2 (GULFSPAN-GNS; 1996 – 2019)	-7.921	3.63E-04
…		
…		
…		
Time block years		
...		
…		
…		
…		

Figures

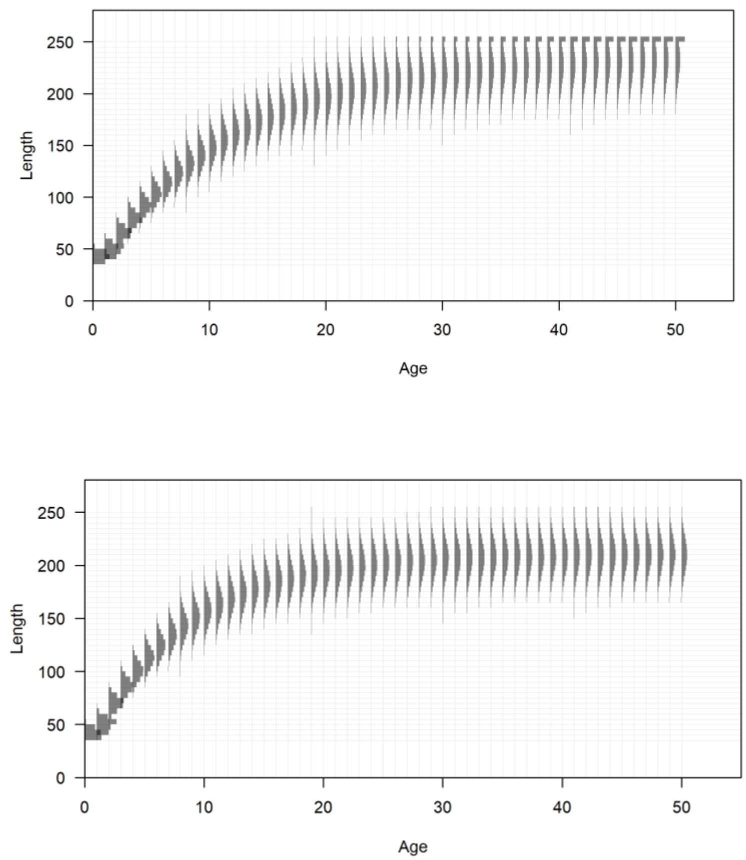


Figure 3.B.1. Distribution of mean length (cm FL) at each age implemented separately for females (upper panel) and males (lower panel) in the Stock Synthesis GOM sensitivity model configuration.

A. S2 (Shark-BLL-Obs-GOM)

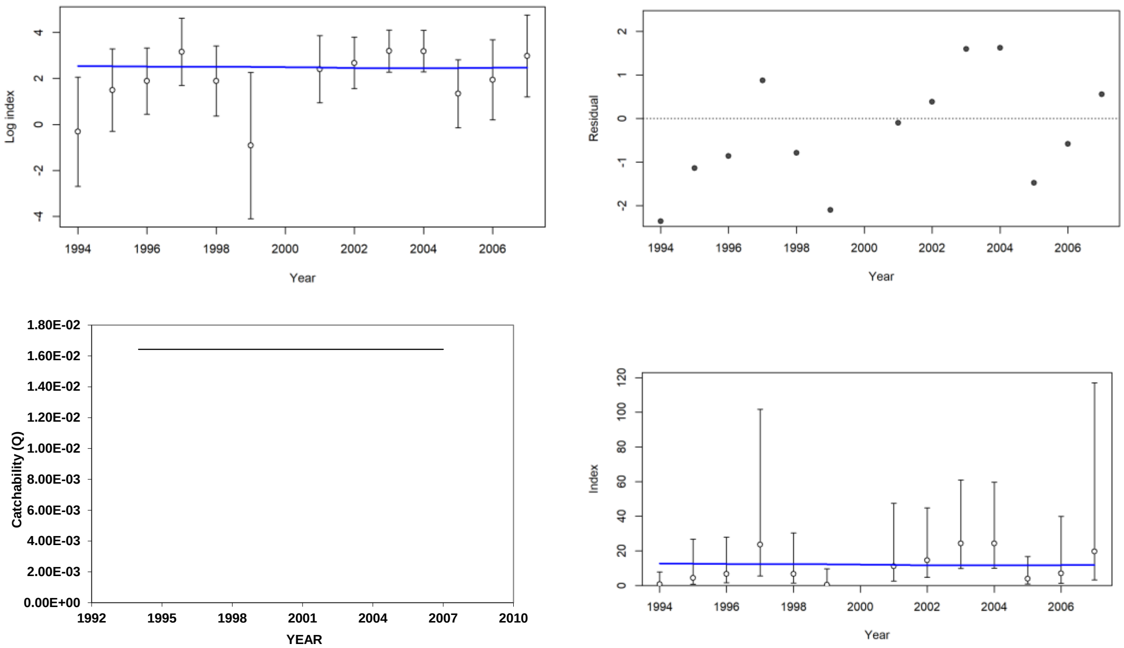


Figure 3.B.2. Fits to abundance indices in the Stock Synthesis GOM sensitivity model configuration; Upper left panel is predicted (blue line) and observed (open circles with approximate 95% confidence intervals based on the input standard error, SE) on the natural log scale; Upper right panel is residuals on the natural log scale (ln(Obs) - ln(Exp))/(observed SE); Lower left panel is estimated catchability; Lower right panel is observed and predicted on the nominal scale.

B. S3 (Shark-BLL-Res-GOM)

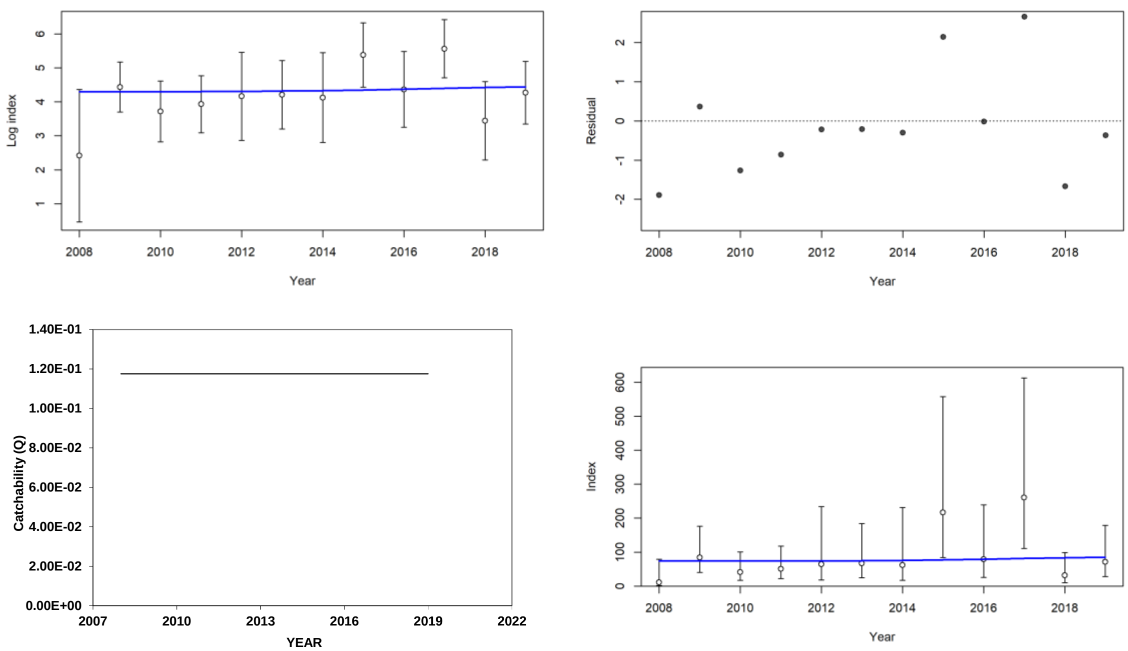


Figure 3.B.2. Continued.

C. S4 (FSU-BLLS)

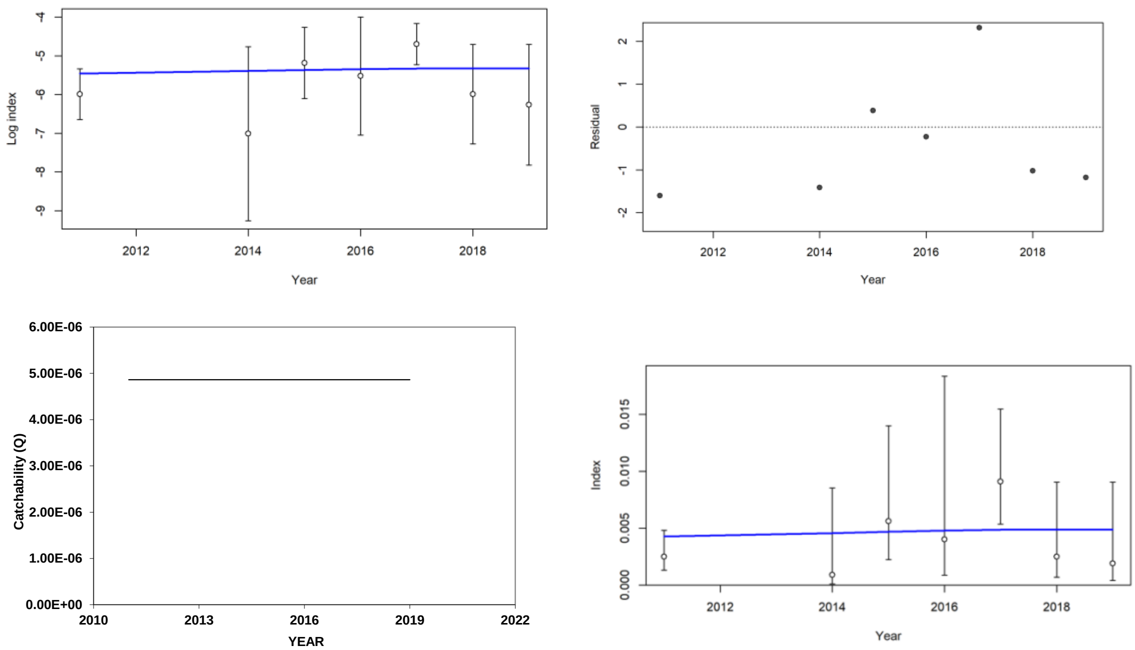


Figure 3.B.2. Continued.

D. S5 (SEFSC-BLLS-GOM)

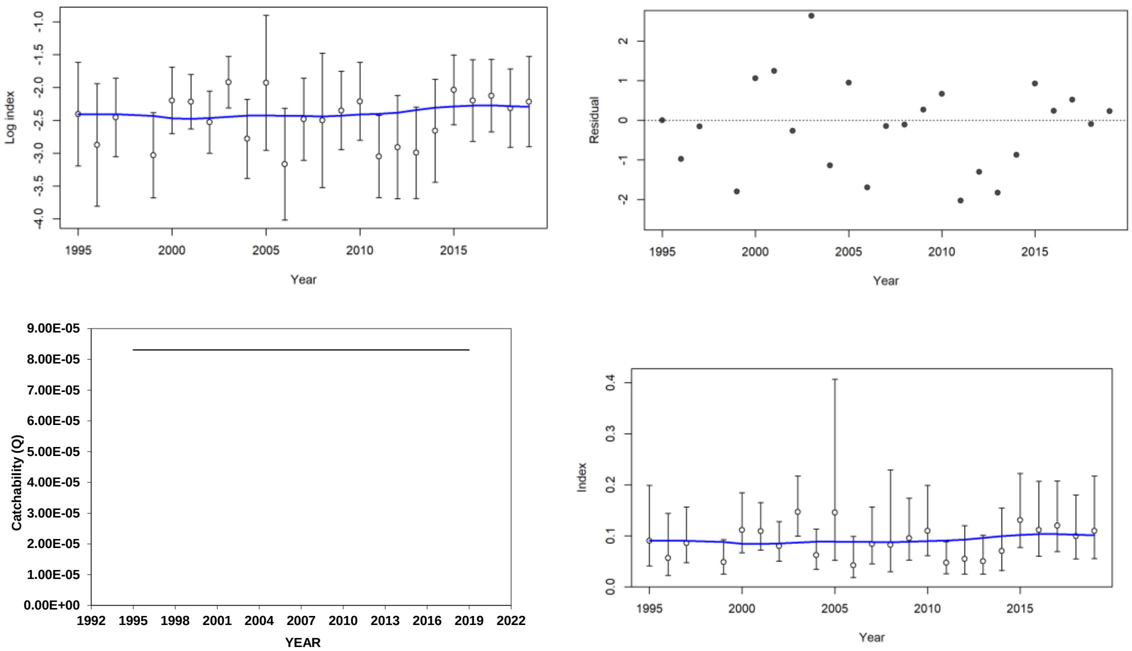


Figure 3.B.2. Continued.

E. R1 (TXPWD-GNS)

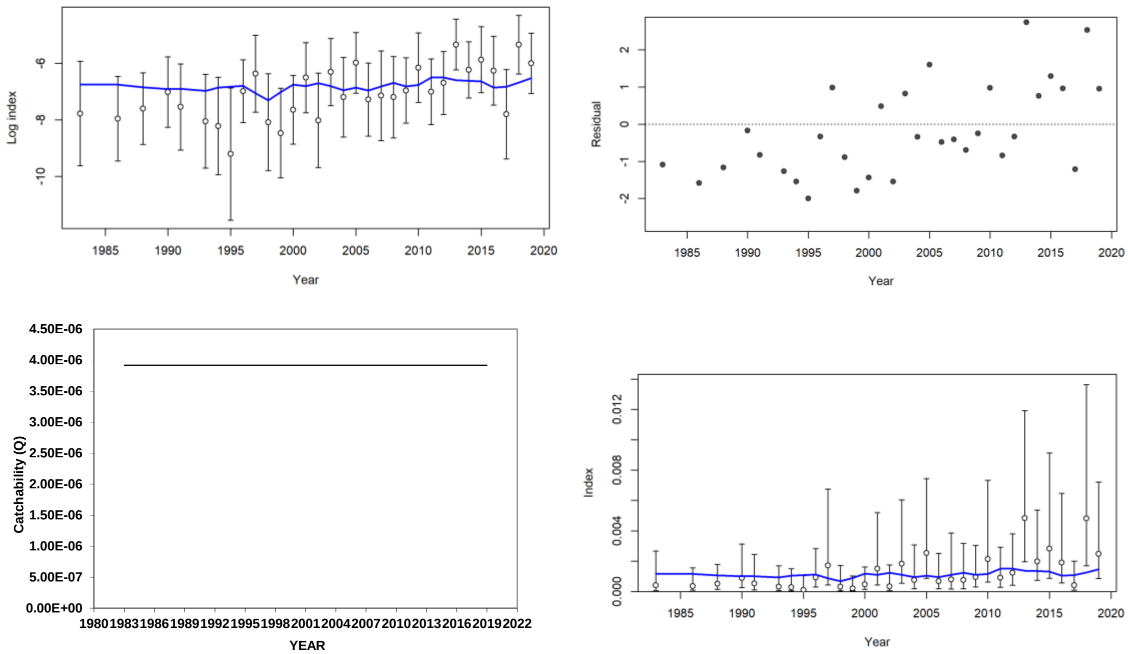


Figure 3.B.2. Continued.

F. R2 (GULFSPAN-GNS)

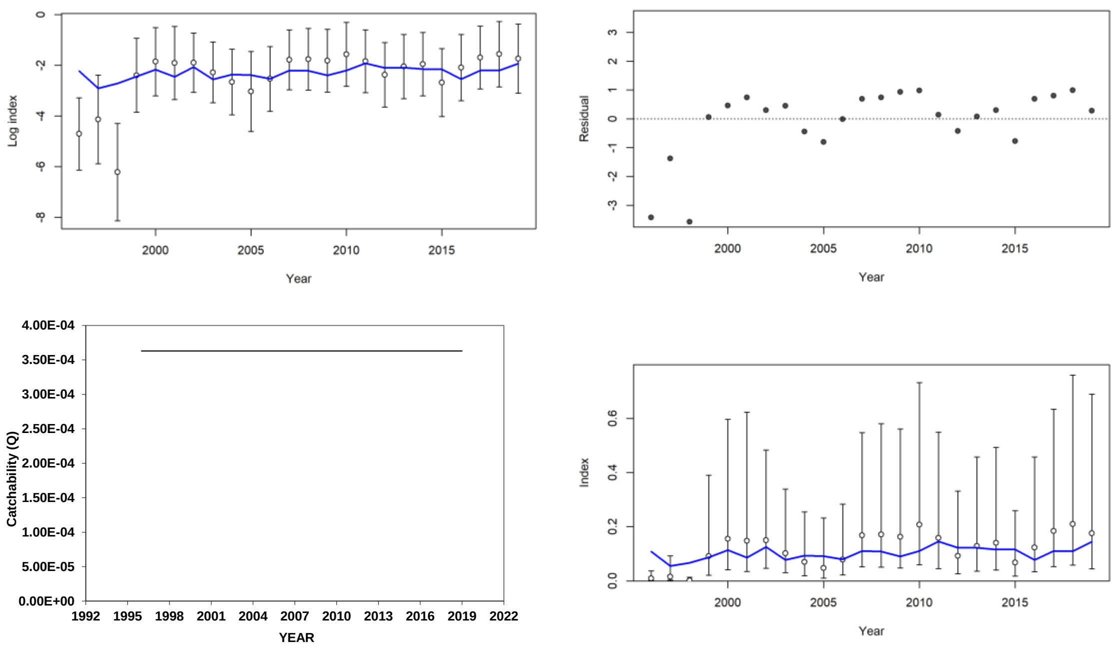
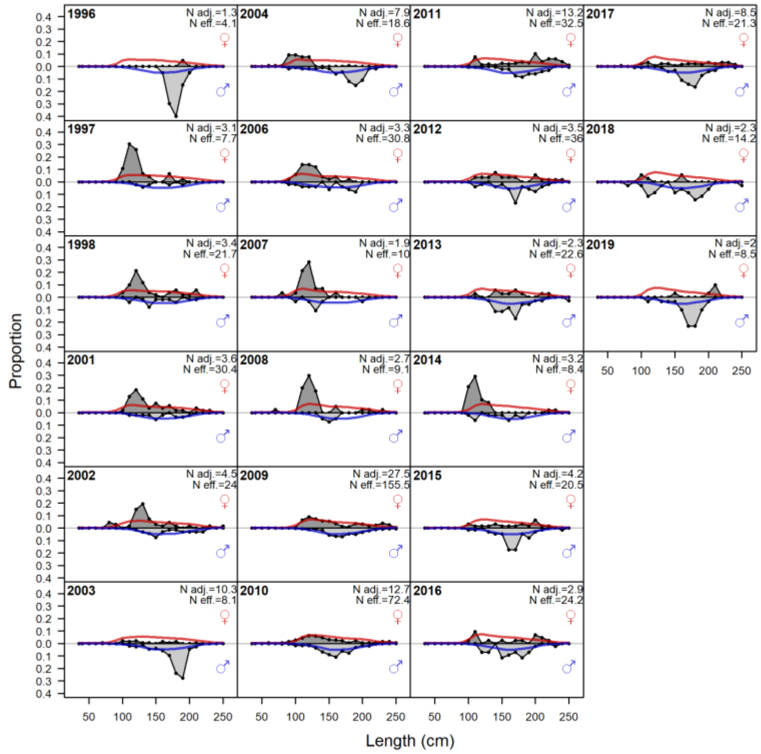


Figure 3.B.2. Continued.

Figure 3.B.3. Observed and predicted annual length compositions (upper panel) and Pearson residuals (lower panel) in the Stock Synthesis GOM sensitivity model configuration; Years with annual length composition sample size less than the minimum input sample size (Min; **Table 3.B.2)** were excluded from the model fit, and are not plotted; The value “N adj” is the input effective sample size obtained using either the Francis method or the McAllister and Ianelli harmonic mean, as described above; The value “N eff” is an alternative effective sample size estimate (McAllister and Ianelli 1997; Punt 2017, his McAllister-Ianelli-1 in his equation 1.A) that is not implemented in this assessment; The diameter of Pearson residuals indicates relative error for predicted < observed (solid) and predicted > observed (transparent) within the length composition data set; The maximum diameter of Pearson residuals indicates relative error among length composition data sets.

A. F1 (Com-BLL-GOM)



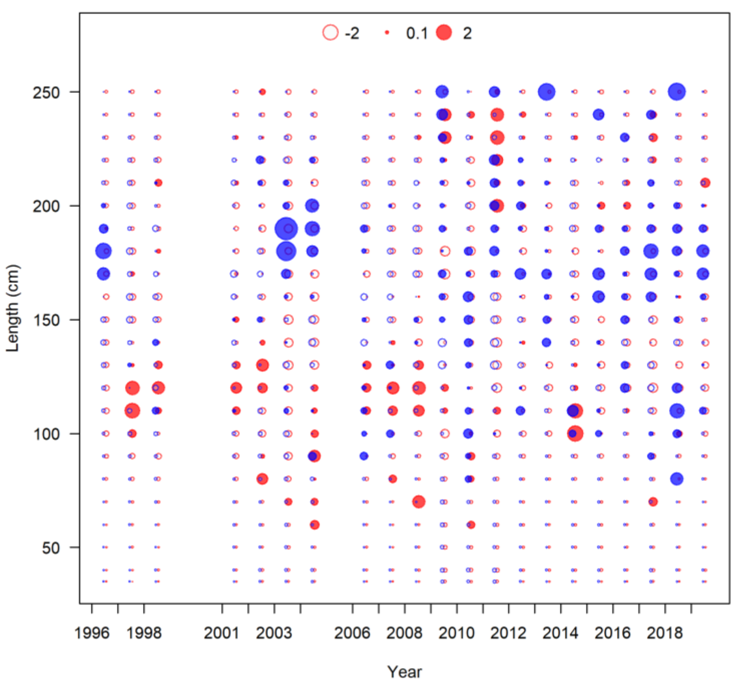
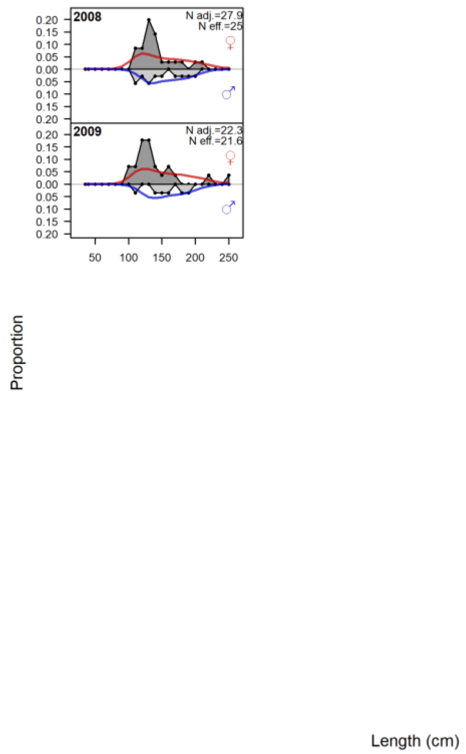


Figure 3.B.3. Continued.

B. F3 (Com-PLL-GOM)



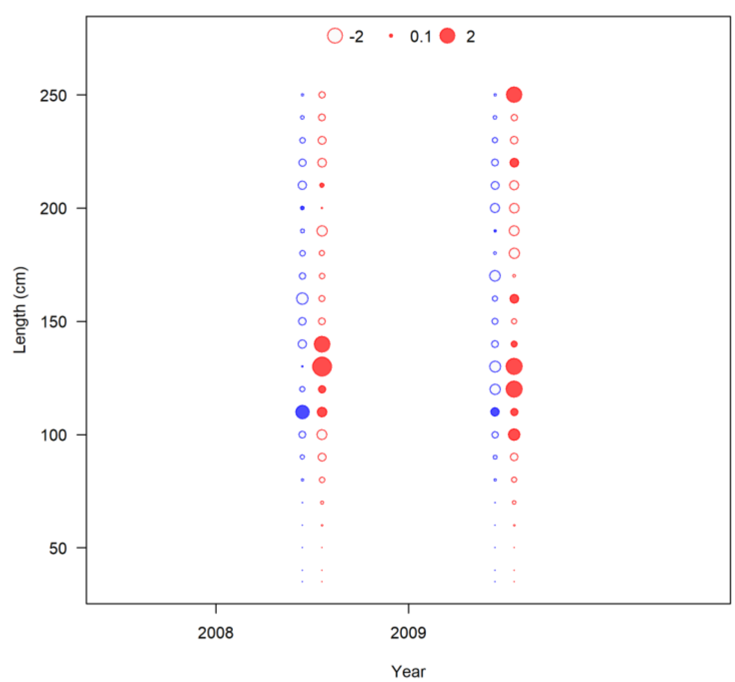
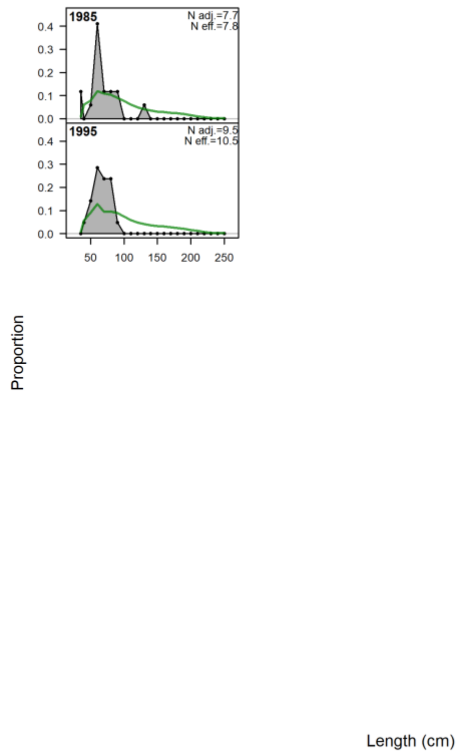


Figure 3.B.3. Continued.

C. F4 (Rec-GOM)



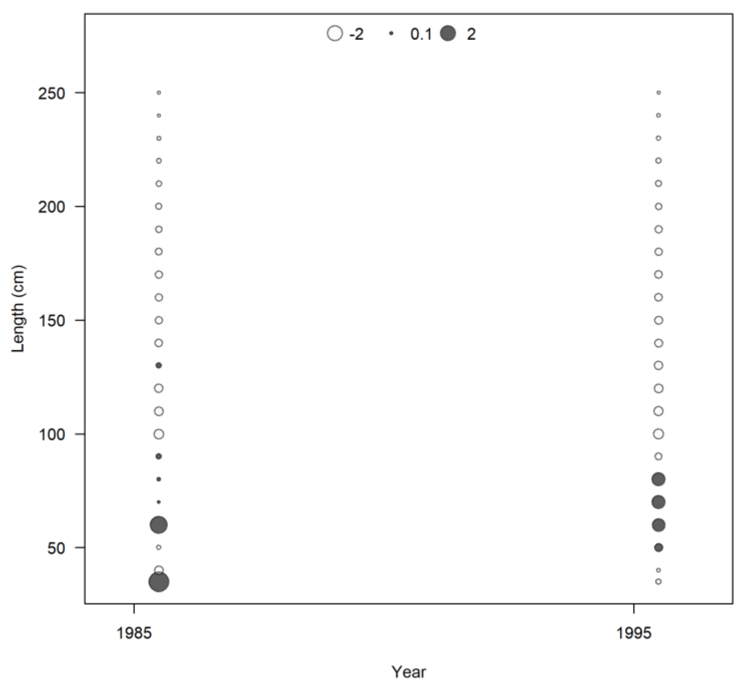
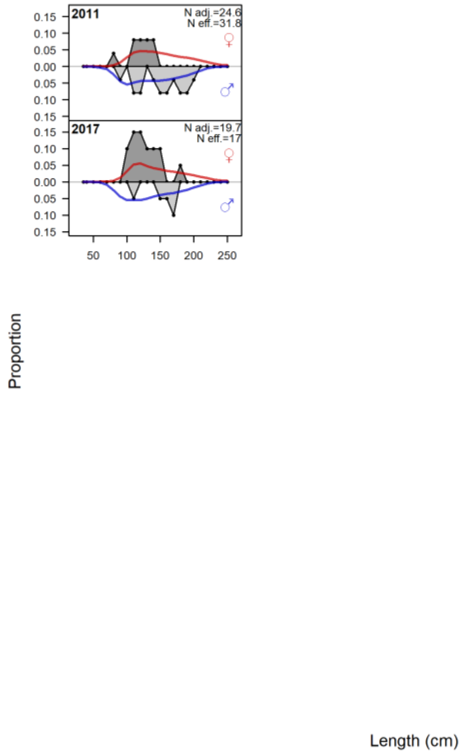


Figure 3.B.3. Continued.

D. S4 (FSU-BLLS)



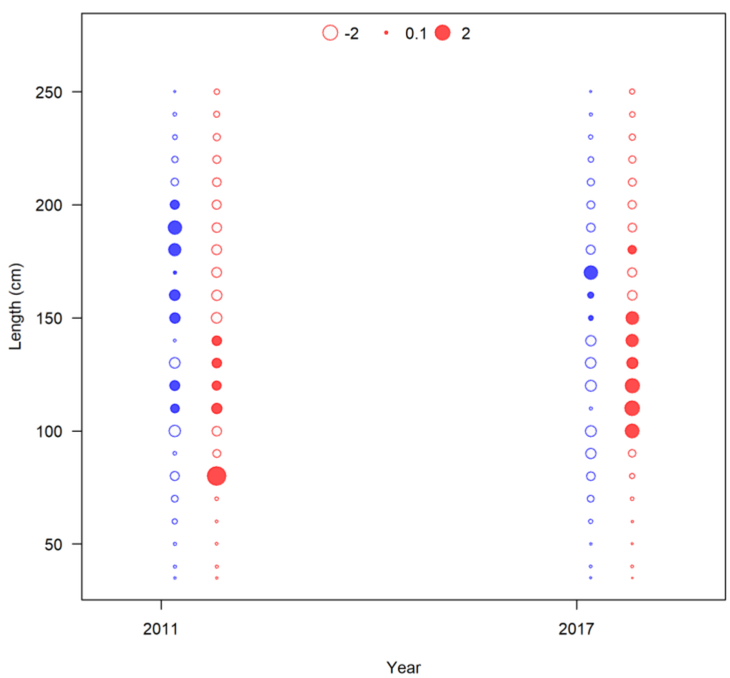
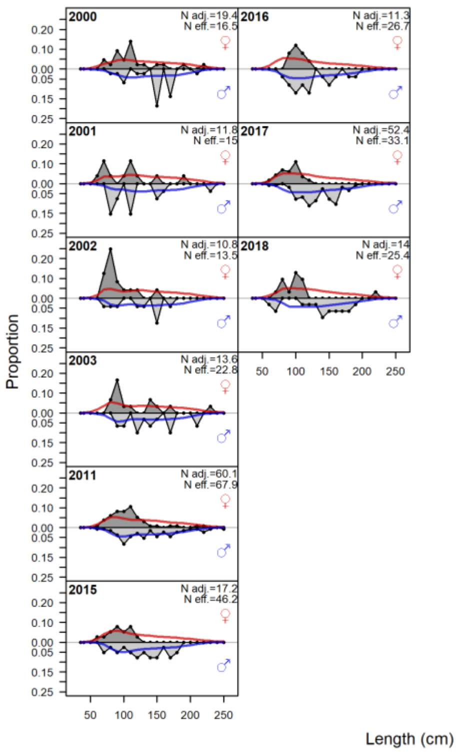


Figure 3.B.3. Continued.

E. S5 (SEFSC-BLLS-GOM)



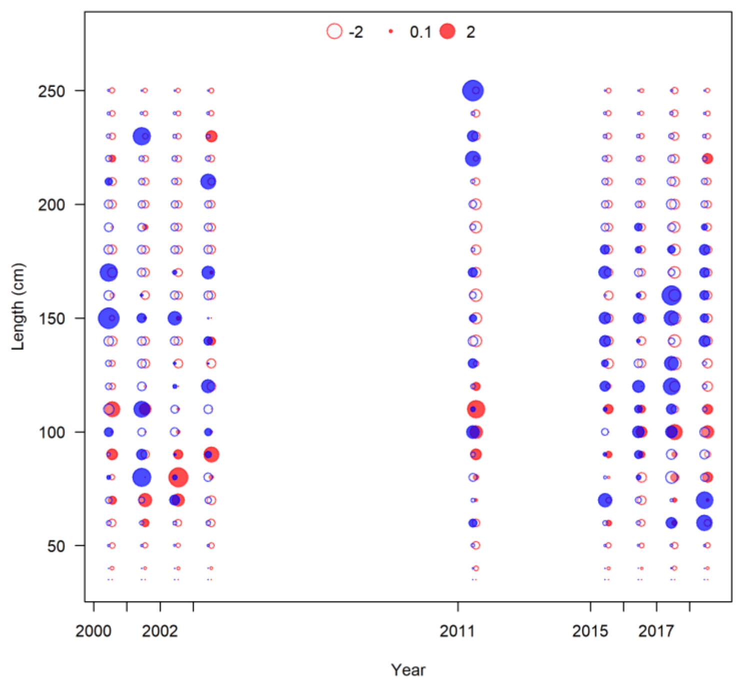
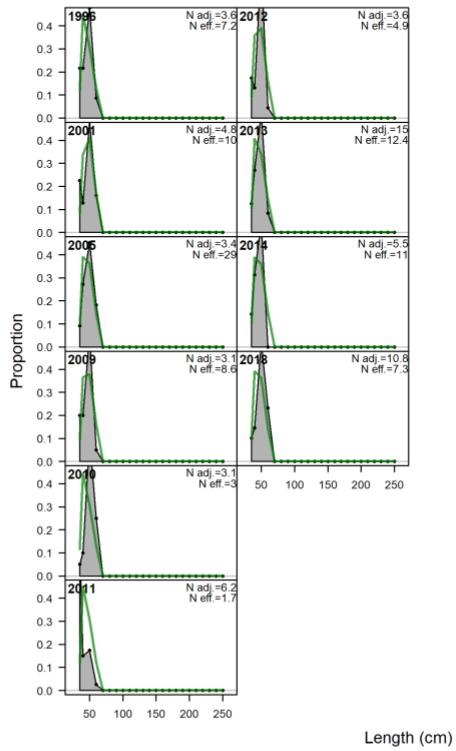


Figure 3.B.3. Continued.

F. R1 (TXPWD-GNS)



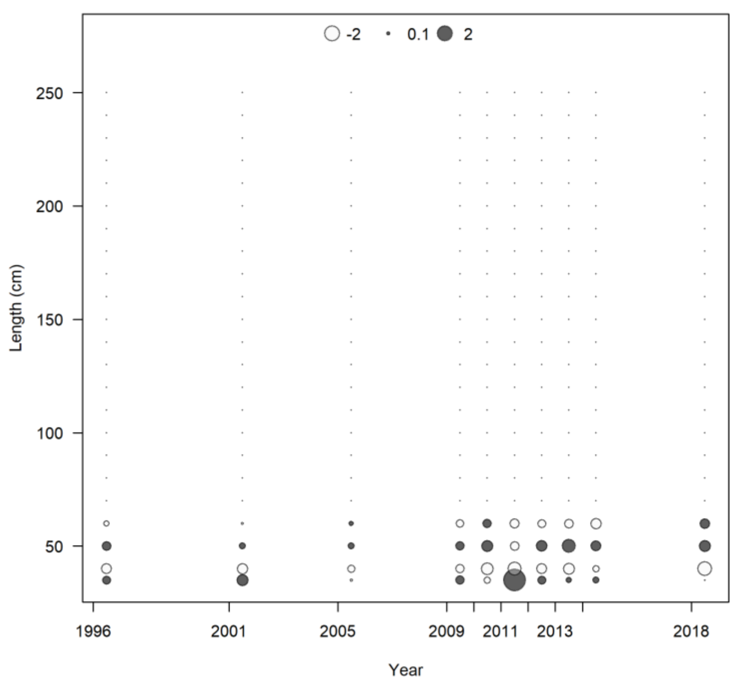
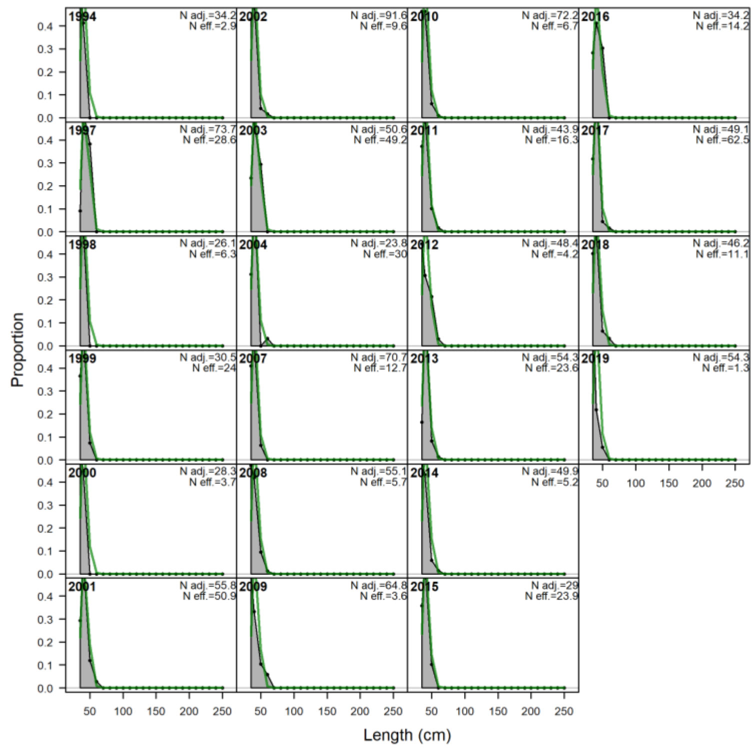


Figure 3.B.3. Continued.

G. R2 (GULFSPAN-GNS)



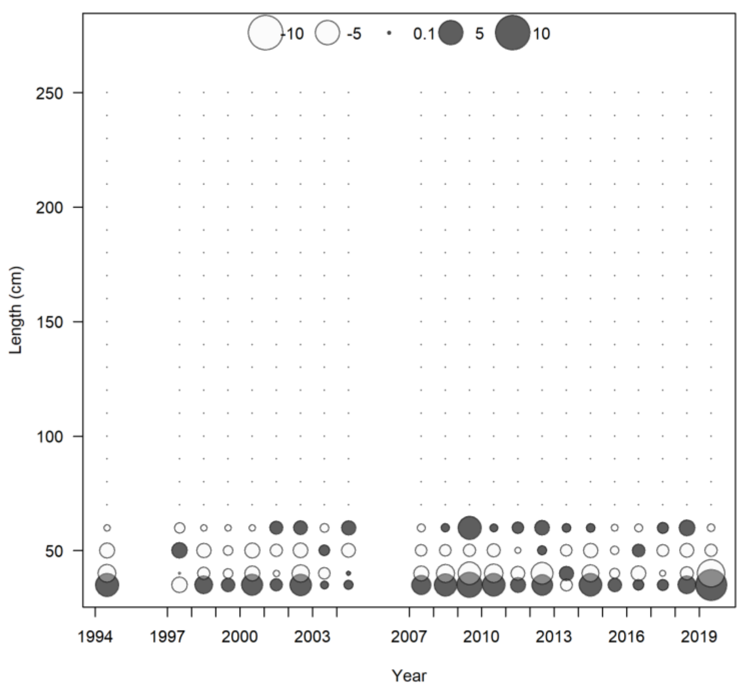


Figure 3.B.3. Continued.

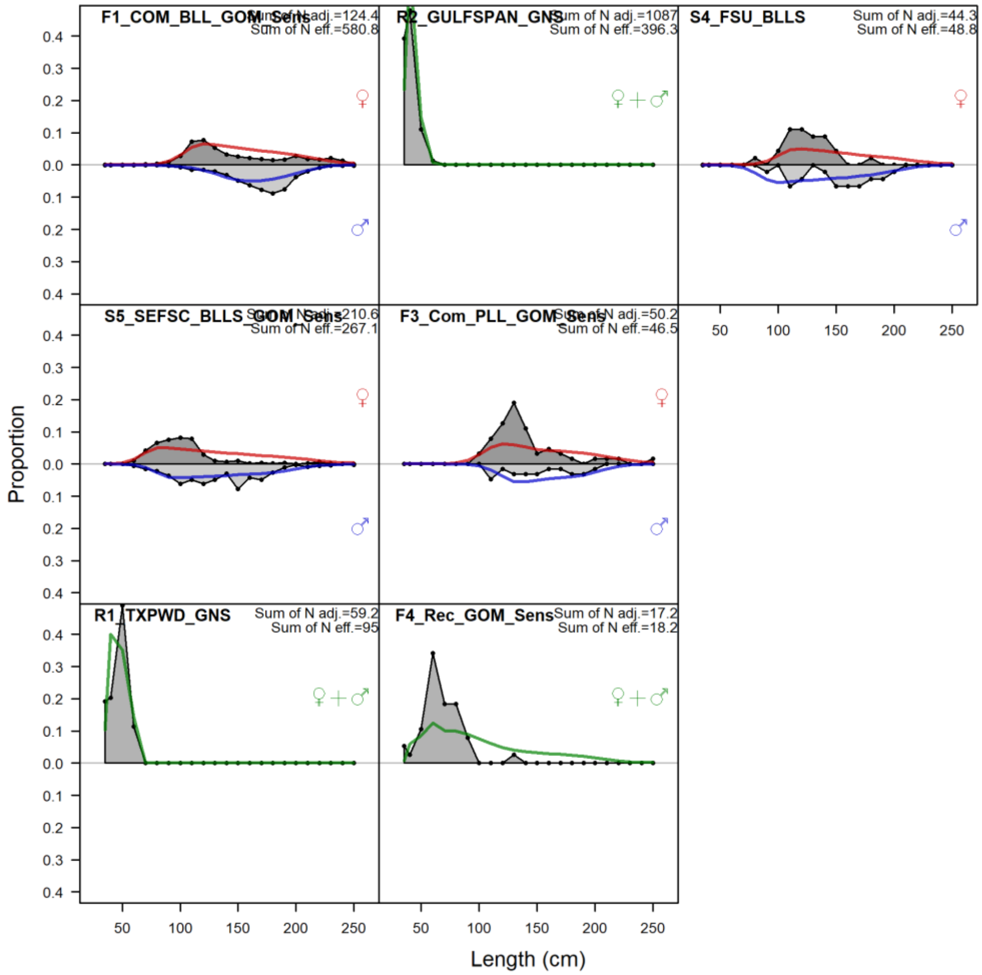
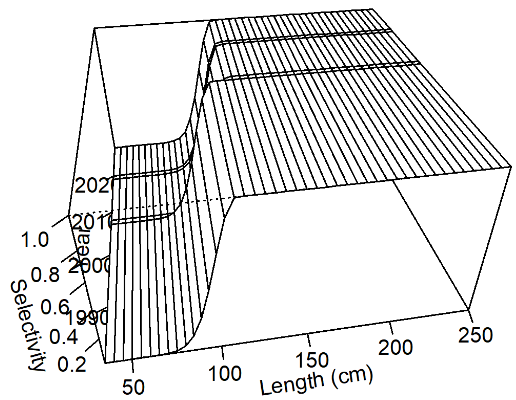


Figure 3.B.4. Predicted (line) and observed (shaded) aggregated length compositions in the Stock Synthesis GOM sensitivity model configuration; Years with annual length composition sample size less than the minimum input sample size (Min; **Table 3.B.2)** were excluded from the model fit, and are not plotted; The value “N adj” is the input effective sample size obtained using either the Francis method or the McAllister and Ianelli harmonic mean, as described above; The value “N eff” is an alternative effective sample size estimate (McAllister and Ianelli 1997; Punt 2017, his McAllister-Ianelli-1 in his equation 1.A) that is not implemented in this assessment.

A. F1 (Com-BLL-GOM)



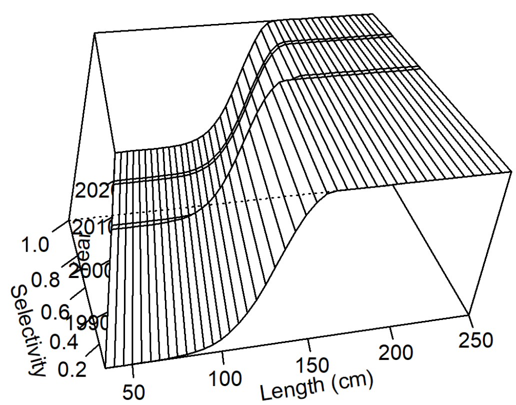


Figure 3.B.5. Estimated selectivity at length (cm FL) obtained in the Stock Synthesis GOM sensitivity model configuration (**Table 3.B.5**); Upper panel is female selectivity; Lower panel is male selectivity, if different from female selectivity; Otherwise female and male selectivity are the same.

B. F2 (Com-GN -GOM)

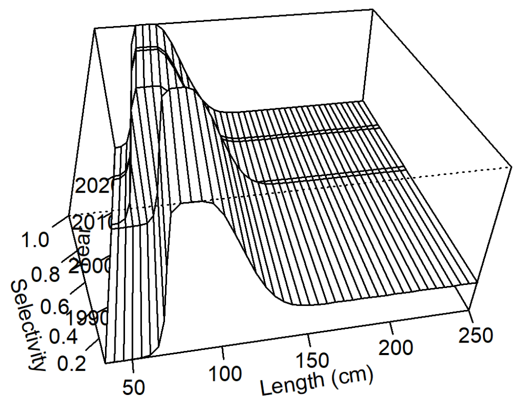
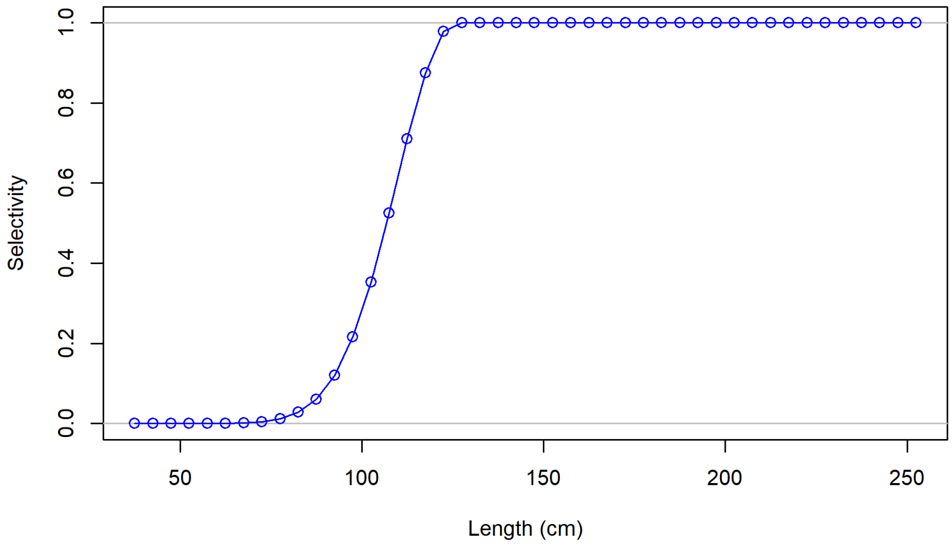


Figure 3.B.5. Continued.

C. F3 (Com-PLL-GOM)



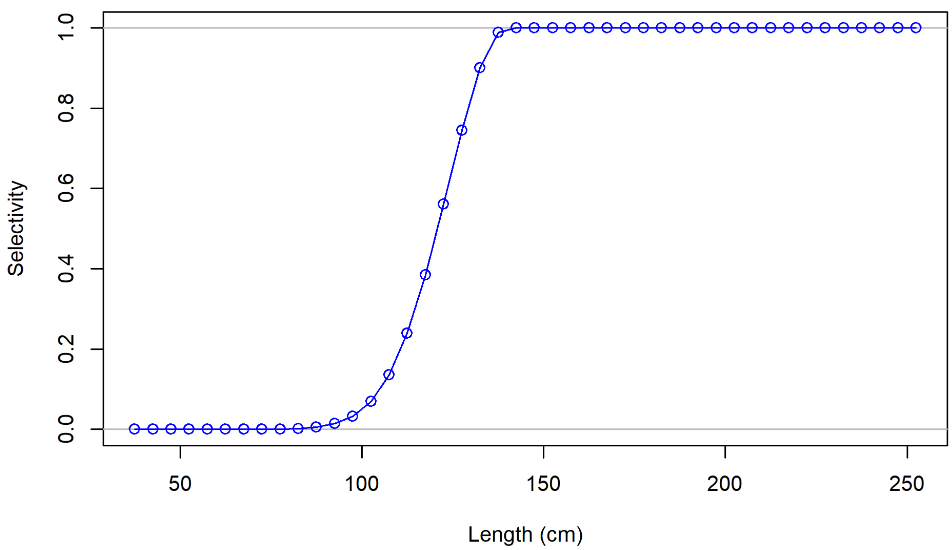


Figure 3.B.5. Continued.

D. F4 (Rec-GOM)

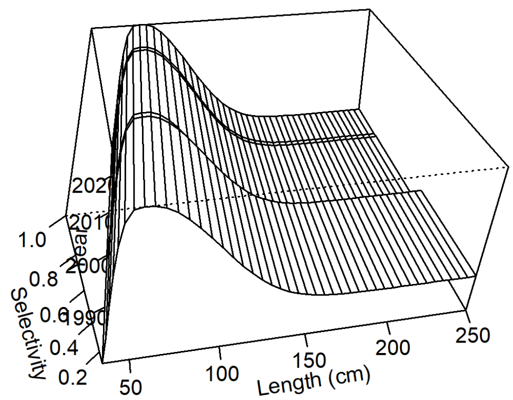
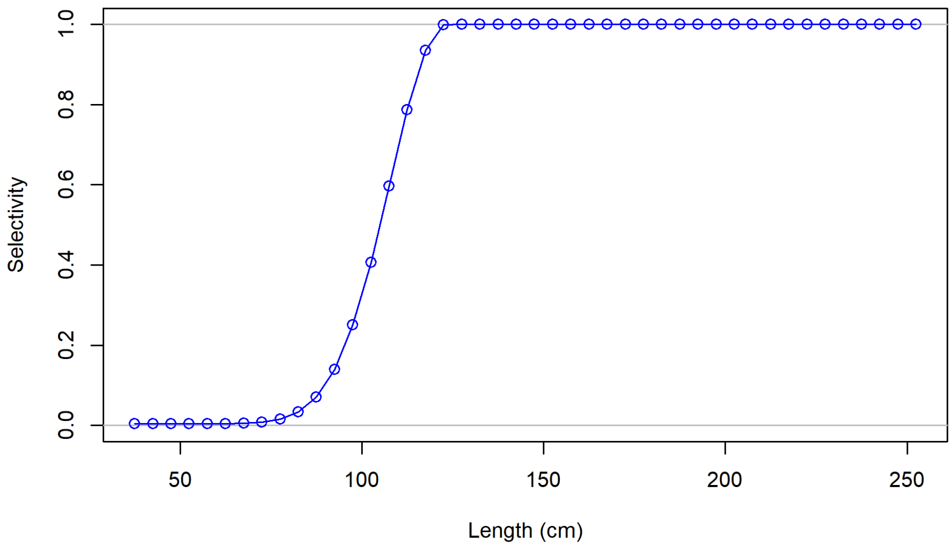


Figure 3.B.5. Continued.

E. S4 (FSU-BLLS)



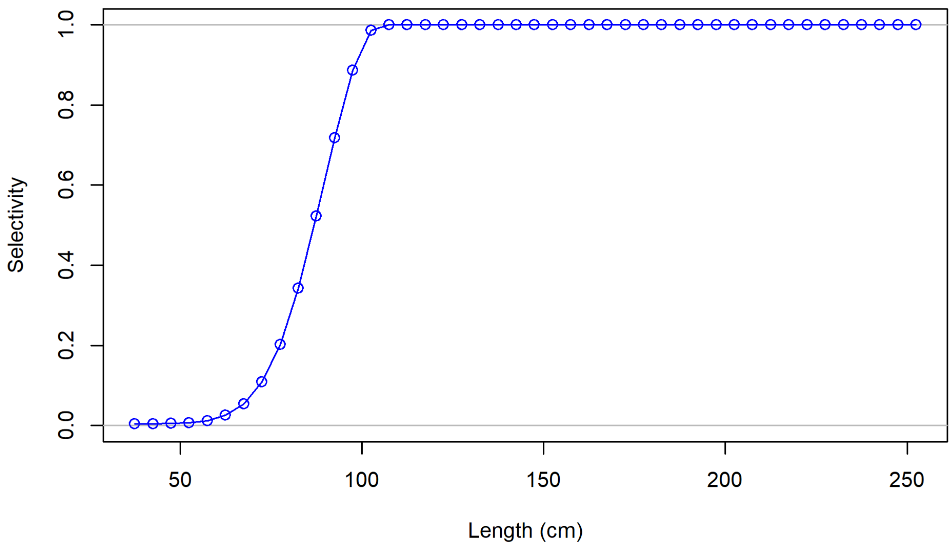
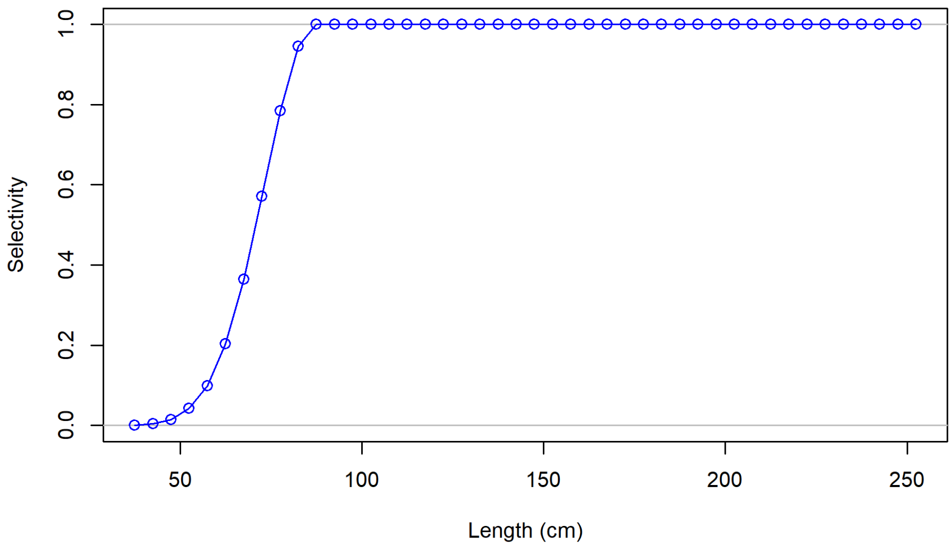


Figure 3.B.5. Continued.

F. S5 (SEFSC-BLLS-GOM)



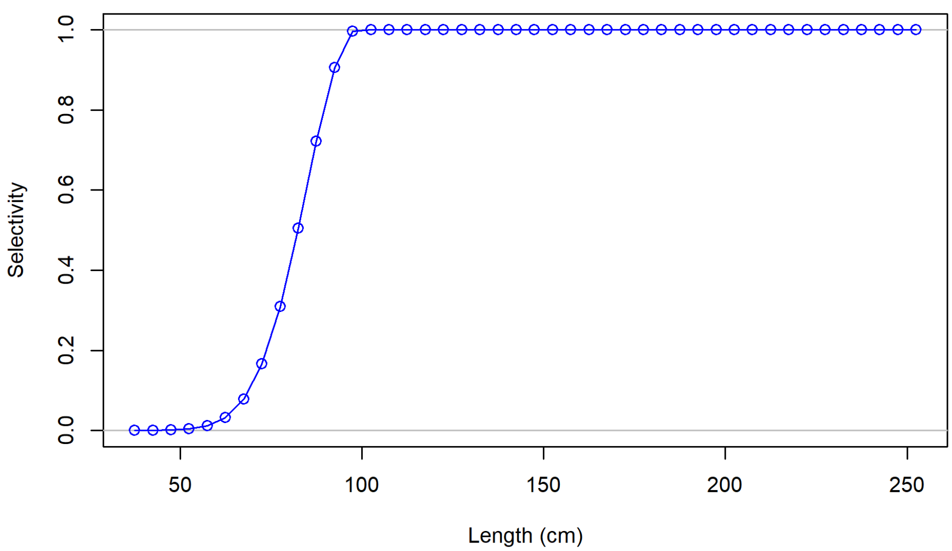


Figure 3.B.5. Continued.

G. R1 (TXPWD-GNS)

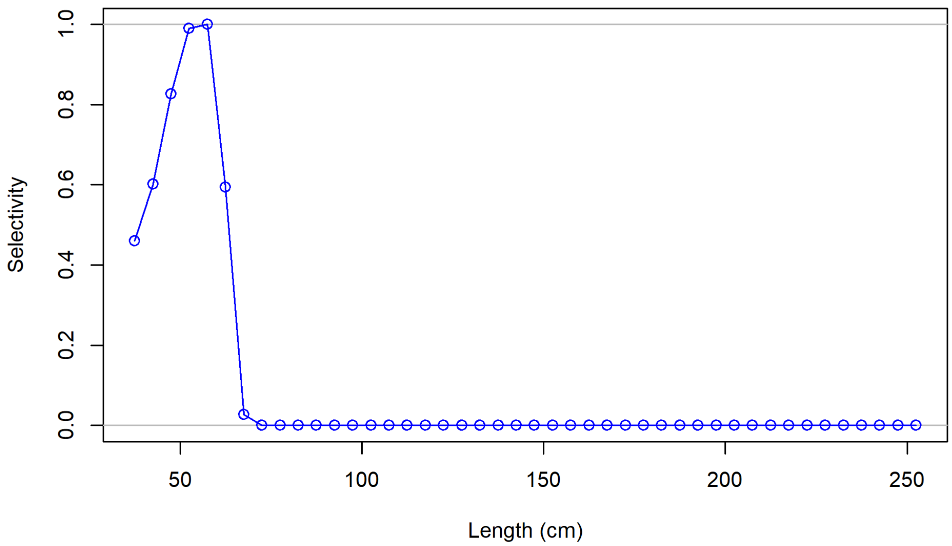


Figure 3.B.5. Continued.

H. R2 (GULFSPAN-GNS)

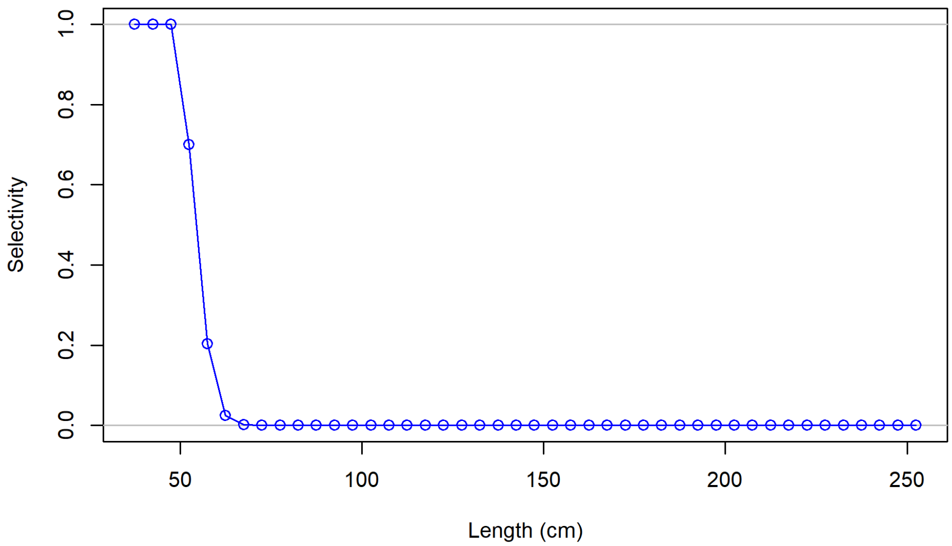
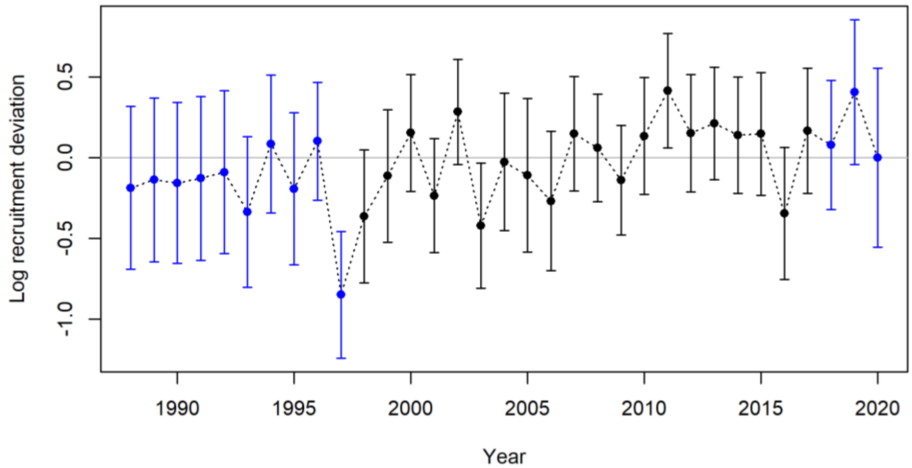


Figure 3.B.5. Continued.



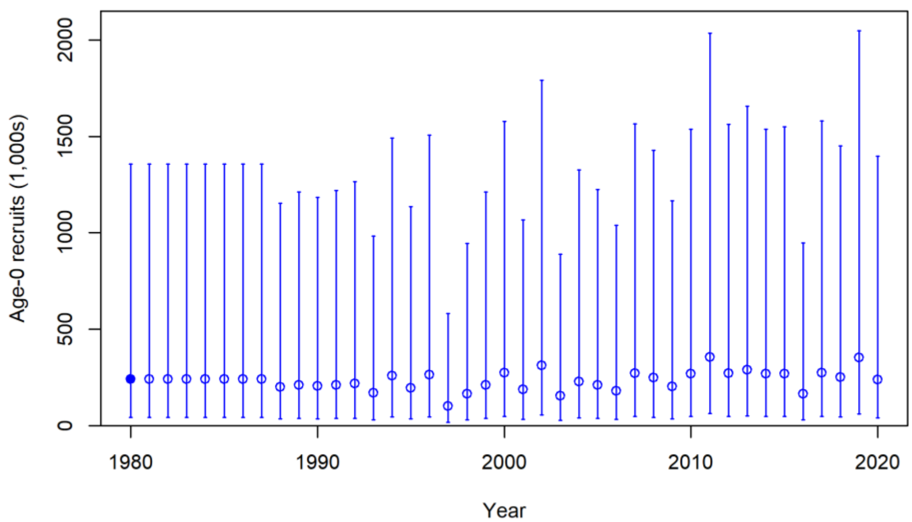


Figure 3.B.6. Upper panel is the estimated log recruitment deviations for the early (1988 – 1997, blue), main (1998 – 2017, black), late (2018 – 2019, blue), and forecast (2020, blue) recruitment periods with associated 95% asymptotic confidence intervals in the Stock Synthesis GOM sensitivity model configuration; Lower panel is the estimated annual age-0 recruits (circles) with 95% asymptotic confidence intervals; Age-0 recruits follow the assumed stock recruitment relationship exactly in years prior to 1988 and after 2019.

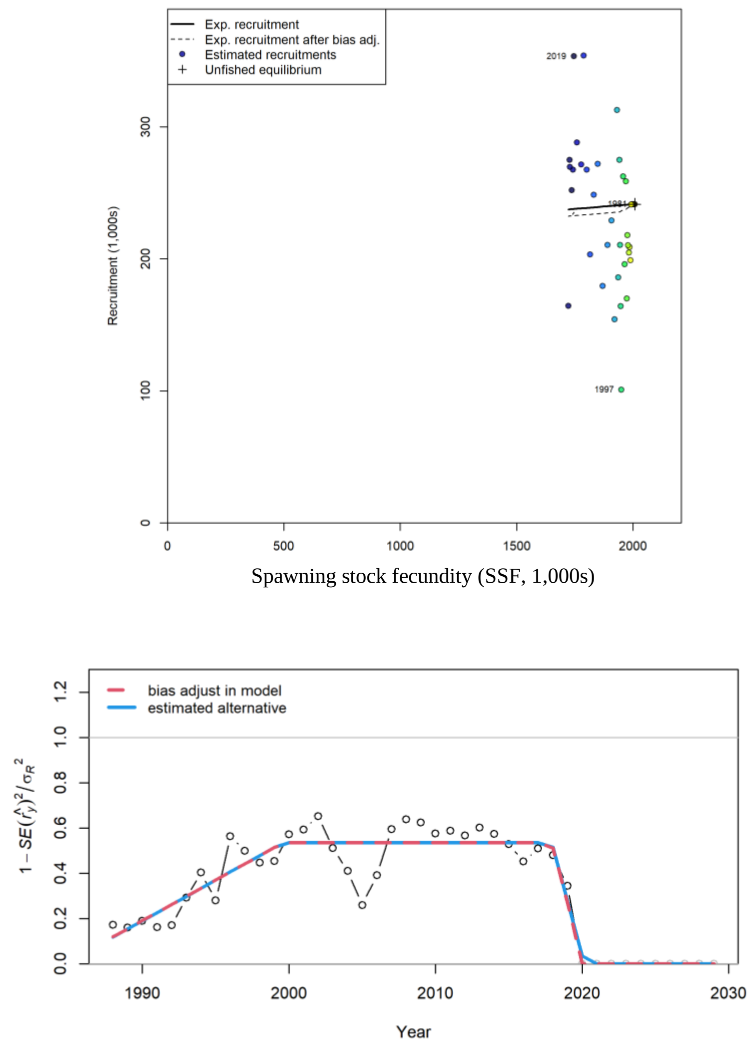
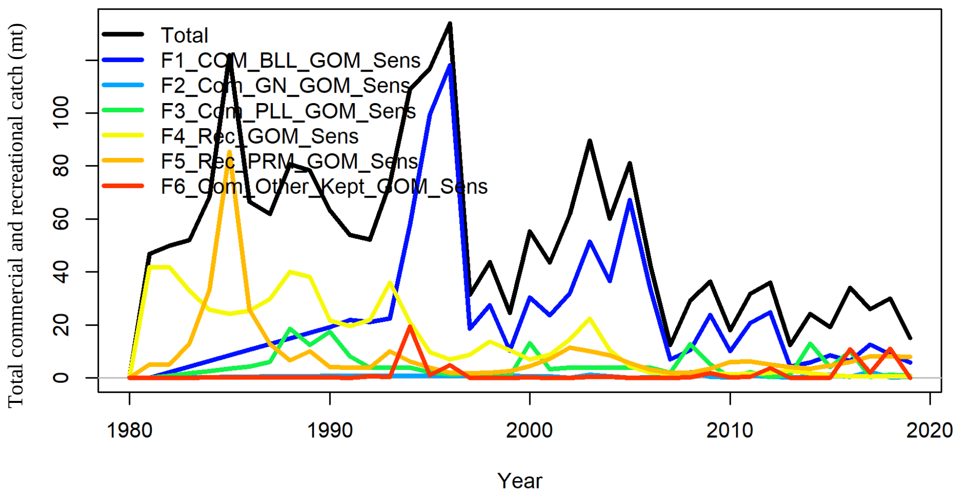


Figure 3.B.7. Expected recruitment (upper panel) from the stock-recruitment relationship (solid line), expected recruitment after implementing the bias adjustment correction (dashed line), estimated annual recruitments (circles), unfished equilibrium (plus), and first (1981) and last (2019) years along with years with log deviations > 0.5 (1997, 2019) in the Stock Synthesis GOM sensitivity model configuration; Bias adjustment ramp (Lower panel) applied to the stock-recruitment relationship (red stippled line) and the estimated alternative (blue line); The y-axis of the lower panel is the bias adjustment fraction (Methot and Taylor 2011) in the model configuration.

Figure 3.B.8. Total commercial and recreational catch (panel A), continuous fishing mortality by fleet (continuous *F* by fleet; panel B upper plot), and the summary fishing mortality of all fleets combined (panel B lower plot) in the Stock Synthesis GOM sensitivity analysis model configuration; The summary fishing mortality is plotted as a ratio calculated as the total fishing mortality rate experienced by the population ($F=Z-M$) relative to F_{MSY} (F/F_{MSY}); Error bars are the 95% asymptotic standard errors, ± 1.96*SE, obtained from Stock Synthesis output; Total catch includes both total commercial catch entered in Stock Synthesis in weight (mt) and total recreational catch (A + B1 + LPRM) entered in Stock Synthesis in numbers (thousands), as described above, and then converted internally within Stock Synthesis to weight (mt).

A.



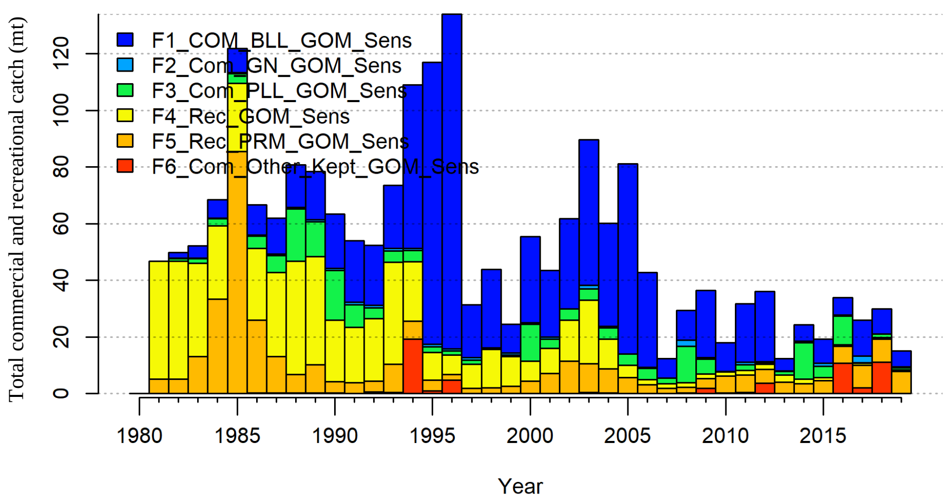


Figure 3.B.8. Continued.

B.

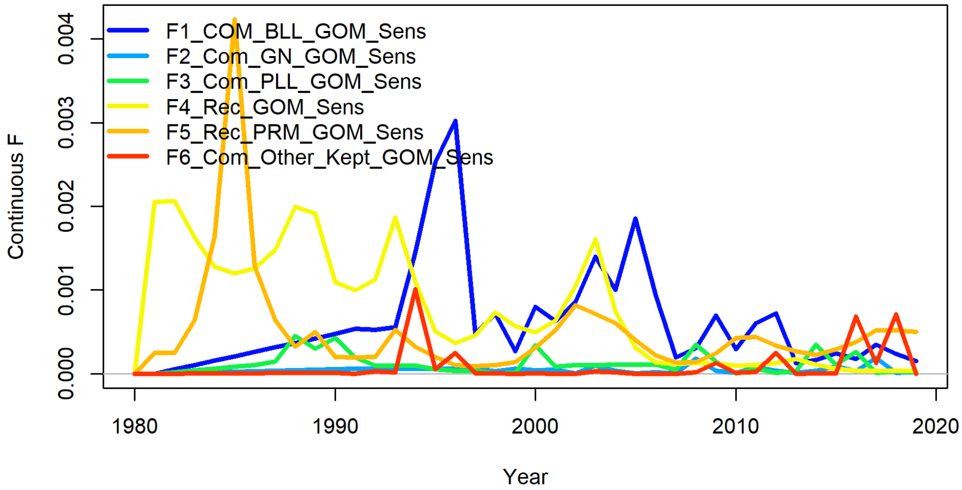


Figure 3.B.8. Continued.

3.12 Appendix 3.C. Stock Synthesis ATL Sensitivity Analysis Model Configuration and Model Fits

Tables

Table 3.C.1. Time series of total commercial catch, recreational catch, relative abundance, and length composition data used in the Stock Synthesis ATL sensitivity analysis model configuration; The symbol "…" indicates time series that were removed from the ATL sensitivity analysis, relative to the GOM+ATL continuity analysis.

Time series	Symbol	Commercial catch, recreational catch (A+B1+B2PRM) and relative abundance	Name	Definition	Length composition
1	F1	Commercial catch (t)	Com-BLL-ATL-Sens	Bottom longlines Kept + PRM (1981 – 2019)	UF [1] + SBLOP[2] (1993 – 2019)
2	F2	Commercial catch (t)	Com-GN-ATL-Sens	Gillnets Kept + PRM (1981 – 2019)	GNOP[3] (2002 – 2019)
3	F3	Commercial catch (t)	Com-PLL-ATL-Sens	Pelagic longline discard PRM (1981 – 2019)	(1992 – 2019)
4	F4	Recreational catch (thousands)	Rec-ATL-Sens	Recreational (A+B1) (1981 – 2019)	MRIP [4]+ SRHS[5] (1981 – 2019)
5	F5	Recreational PRM (thousands)	Rec-PRM-ATL-Sens	Recreational (B2 PRM) (1981 – 2019)	Mirror F4
6	F6	Commercial catch (t)	Com-Other-Kept-ATL-Sens	Hook and line plus hand line (1981 – 2019)	Mirror F4
7	S1	Relative abundance (numbers of individuals)	PLL-Obs-ATL-Sens	Pelagic longline observer program (1992 – 2019)	Mirror F3
8	S2	Relative abundance (numbers)	Shark-BLL-Obs-ATL-Sens	Bottom longline fishery observer program (1994 – 2007)	Mirror F1
9	S3	Relative abundance (numbers)	Shark-BLL-Res-ATL-Sens	Shark bottom longline research fishery (2008 – 2019)	Mirror F1
	…		…		
10	S5	Relative abundance (numbers)	SEFSC-BLLS-ATL-Sens	NMFS SEFSC bottom longline survey (1995 – 2019)	1995 – 2019
	…		…		
	…				
11	R3	Relative abundance (numbers)	COASTSPAN-BLLS	(COASTSPAN) bottom longline survey (age-0, 2005 – 2019)	2000 – 2019
12	R4	Relative abundance (numbers)	COASTSPAN-LGNS	COASTSPAN long-gillnet survey (age-0, 2001-2019)	2001 – 2019
13	R5	Relative abundance (numbers)	COASTSPAN-SGNS	COASTSPAN short-gillnet survey (age-0, 2007 – 2019)	Mirror R4[6]

[1] University of Florida (UF) Longline 1993 – 2005.
[2] Southeast Fisheries Science Center (SEFSC) Panama City Lab Shark Bottom Longline Observer Program (SBLOP) 2005 – 2019.
[3] Southeast Fisheries Science Center (SEFSC) Panama City Lab Gillnet Observer Program (GNOP).
[4] Marine Recreational Information Program (MRIP).
[5] Southeast Region Head Boat Survey (SRHS).
[6] Total length composition sample size for COASTSPAN-SGNS (n = 34) was too small to fit in Stock Synthesis.

Table 3.C.2. Length composition sample size (number of sharks measured) for fleets (F) surveys (S), and age-0 recruitment indices (R) fit in the Stock Synthesis ATL sensitivity analysis model configuration, as defined in **Table 3.C.1**; The symbol "…" indicates time series that were removed from the ATL sensitivity analysis, relative to the GOM+ATL continuity analysis.

	F1		F2	F3		F4	…		S5	
	ATL-Sens		ATL-Sens	ATL-Sens		ATL-Sens			ATL-Sens	
	(Com-BLL)		(Com-GN)	(Com-PLL)		(Rec)			(SEFSC-BLL)	
	1993 – 2019		2002 – 2019	1992 – 2019		1981 – 2018			1995 – 2019	
	Min.[1] 20		Min. 30	Min. 20		Min. 20			Min. 20	
Year	(♀)	(♂)	(♀,♂,Unknown)[2]	(♀)	(♂)	(♀,♂,Unknown)[3]			(♀)	(♂)
1981						3				
1982						20				
1983						0				
1984						0				
1985						3				
1986						1				
1987						7				
1988						3				
1989						6				
1990						9				
1991						5				
1992				16	16	5				
1993	0	1		6	2	20				
1994	7	15		5	2	5				
1995	10	38		3	8	1			0	3
1996	8	36		2	0	1			0	1
1997	3	11		15	10	7			0	0
1998	18	64		2	3	4			0	0
1999	4	24		1	0	6			3	1
2000	1	2		0	2	7			2	0
2001	26	29		9	0	6			0	0
2002	31	33	12	0	0	10			7	13
2003	51	58	9	1	2	5			0	0
2004	34	24	39	1	1	5			0	0
2005	7	11	15	15	3	11			0	1
2006	9	8	15	14	15	6			5	6
2007	6	2	1	1	0	7			0	0
2008	0	0	3	0	0	0			1	3
2009	4	15	62	18	9	4			8	3
2010	11	11	12	4	2	1			5	4
2011	28	28	6	0	1	3			3	5
2012	13	16	16	1	2	1			2	2
2013	9	11	30	0	0	5			2	1
2014	16	53	5	0	0	1			1	2
2015	5	32	6	2	3	0			2	6
2016	0	22	2	1	2	0			1	1
2017	1	4	1	0	0	0			1	4
2018	2	25	9	0	0	0			3	2
2019	3	7	2	0	1	0			0	6
Total	307	580	245	117	84	178			46	64
Proportion (♀,♂)	99%		95%	100%		NA			92%	

[1] Years with less than minimum sample size were excluded from the fit in the model likelihood.
[2] Sex-combined length composition data (♀, ♂, Unknown) were input for fleet F2 following SEDAR 65 blacktip.
[3] Sex specific length composition data date were not available for fleet F4.

Table 3.C.2. Continued.

	…	…	R3	R4
			ATL-Sens	ATL-Sens
			(COASTSPAN-BLLS)	(COASTSPAN-LGNS)
			2000 – 2019	2001 – 2019
			Min. 20	Min. 30
Year			(♀,♂,Unknown)[4]	(♀,♂,Unknown)[4]
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989				
1990				
1991				
1992				
1993				
1994				
1995				
1996				
1997				
1998				
1999				
2000			18	
2001			7	34
2002			0	21
2003			4	90
2004			6	3
2005			14	18
2006			19	18
2007			3	36
2008			5	10
2009			34	59
2010			98	14
2011			65	2
2012			19	127
2013			25	152
2014			5	77
2015			10	36
2016			26	50
2017			24	93
2018			19	98
2019			38	79
Total			439	1017
Proportion (♀,♂)			NA	NA

[4] Sex-combined length composition data (♀, ♂, Unknown) were input for recruitment indices.

Table 3.C.3. The von Bertalanffy growth (VBG) size at age relationship implemented separately for females and males in the Stock Synthesis ATL sensitivity analysis model configuration.

Age (yr.)	Female cm FL predicted from the VBG parameters below	Male cm FL predicted from VBG parameters below
0	41.6	41.6
1	57.3	57.2
2	71.7	71.6
3	84.8	84.9
4	96.8	97.1
5	107.8	108.4
6	117.8	118.8
7	127.0	128.4
8	135.4	137.2
9	143.1	145.4
10	150.2	152.9
11	156.6	159.9
12	162.5	166.3
13	167.9	172.2
14	172.8	177.6
15	177.3	182.6
16	181.5	187.2
17	185.2	191.5
18	188.7	195.5
19	191.9	199.1
20	194.7	202.4
21	197.4	205.5
22	199.8	208.4
23	202.0	211.0
24	204.0	213.4
25	205.9	215.6
26	207.6	217.7
27	209.1	219.6
28	210.6	221.3
29	211.9	223.0
30[1]	213.0	224.5
31	214.1	225.8
32	215.1	227.1
33	216.0	228.3
34	216.9	229.3
35	217.6	230.3
36	218.3	231.2
37	219.0	232.1
38	219.5	232.9
39	220.1	233.6
40[1]	220.6	234.2
41	221.0	234.9
42	221.4	235.4
43	221.8	235.9
44	222.1	236.4
45	222.4	236.9
46	222.7	237.3
47	223.0	237.6
48	223.2	238.0
49	223.4	238.3
50[2]	223.6	238.6

VBG parameters	Female	Male
L_{inf}	225.8	242.1
k	0.089	0.081
t_0	-2.29	-2.33
CV implemented for L_{Amin}	0.093	0.097
CV implemented for L_{inf}	0.090	0.082

[1] Observed Tmax (♀) = 29.5 yr and Tmax (♂) = 39.5 yr (Data Workshop Section 2.4 Life History Report, their Table 1).
[2] Theoretical Tmax (♀) = 49.5 yr and Tmax (♂) = 54 yr (SEDAR77AW04, their Table 3; Pers. Comm. E . Cortés).

Table 3.C.4. Annual pup production at age used in the Stock Synthesis ATL sensitivity analysis model configuration.

Age (yr.)	Litter size (LS) [1]	Fraction mature [2]	Fraction maternal [3]	Pup production [4]	Annual pup production [5]
0	18.00	0.00	0.00	0.0	0.00
1	18.00	0.00	0.00	0.0	0.00
2	18.00	0.00	0.00	0.0	0.00
3	18.00	0.00	0.00	0.0	0.00
4	18.00	0.00	0.00	0.0	0.00
5	18.00	0.00	0.00	0.0	0.00
6	18.00	0.00	0.00	0.0	0.00
7	18.00	0.00	0.00	0.0	0.00
8	18.00	0.00	0.00	0.0	0.00
9	18.00	0.01	0.00	0.0	0.00
10	18.00	0.01	0.01	0.2	0.18
11	18.00	0.02	0.01	0.2	0.18
12	18.00	0.05	0.02	0.4	0.36
13	18.00	0.09	0.05	0.9	0.90
14	18.00	0.17	0.09	1.6	1.62
15	18.00	0.30	0.17	3.1	3.06
16	18.00	0.47	0.30	5.4	5.40
17	18.00	0.65	0.47	8.5	8.46
18	18.00	0.79	0.65	11.7	11.70
19	18.00	0.89	0.79	14.2	14.22
20	18.00	0.94	0.89	16.0	16.02
21	18.00	0.97	0.94	16.9	16.92
22	18.00	0.99	0.97	17.5	17.46
23	18.00	0.99	0.99	17.8	17.82
24	18.00	1.00	0.99	17.8	17.82
25	18.00	1.00	1.00	18.0	18.00
26	18.00	1.00	1.00	18.0	18.00
27	18.00	1.00	1.00	18.0	18.00
28	18.00	1.00	1.00	18.0	18.00
29	18.00	1.00	1.00	18.0	18.00
30	18.00	1.00	1.00	18.0	18.00
31	18.00	1.00	1.00	18.0	18.00
32	18.00	1.00	1.00	18.0	18.00
33	18.00	1.00	1.00	18.0	18.00
34	18.00	1.00	1.00	18.0	18.00
35	18.00	1.00	1.00	18.0	18.00
36	18.00	1.00	1.00	18.0	18.00
37	18.00	1.00	1.00	18.0	18.00
38	18.00	1.00	1.00	18.0	18.00
39	18.00	1.00	1.00	18.0	18.00
40	18.00	1.00	1.00	18.0	18.00
41	18.00	1.00	1.00	18.0	18.00
42	18.00	1.00	1.00	18.0	18.00
43	18.00	1.00	1.00	18.0	18.00
44	18.00	1.00	1.00	18.0	18.00
45	18.00	1.00	1.00	18.0	18.00
46	18.00	1.00	1.00	18.0	18.00
47	18.00	1.00	1.00	18.0	18.00
48	18.00	1.00	1.00	18.0	18.00
49	18.00	1.00	1.00	18.0	18.00
50	18.00	1.00	1.00	18.0	18.00

[1] Brood size = 18; range 7 – 30 (Data Workshop Section 2.4 Life History Report, their Table 1).
[2] Fraction mature at age (ATL) "tmat = 16.16 years, a = -11.652, b = 0.721" (DW Section 2.4, their Tables 1 and 6).
[3] Fraction maternal assumed an 10 – 12 month gestation period (DW Section 2.4, their Table 1), approximated here by a one year offset from maturity to maternity, e.g., see outlined boxes above at ages 9 and 23.
[4] Pup production was obtained as (LS at age)* (Fraction maternal at age).
[5] Annual pup production was obtained by assuming an annual reproductive cycle (DW Section 2.4, their Table 1) and calculated as [(LS at age)* (Fraction maternal at age)]/1 .

Table 3.C.5. Number of estimated parameters (numbers within parentheses) in the Stock Synthesis ATL sensitivity analysis model configuration; The symbol "…" indicates time series that were removed from the sensitivity analysis.

Fleet	Fleet name	Proposed selectivity pattern	Implemented selectivity pattern	Sex	Time block(s)	Number of selectivity parameters	Number of catchability parameters	Sub-total of parameters	Sub-total of estimated parameters
1	F1 (Com-BLL-ATL)	Logistic	Logistic	Sex specific	Sel. (peak, ascend)[1]	13 (3) [4]	0 (0)	13	(3)
2	F2 (Com-GN-ATL)	Double normal	Double normal	Combined sex	Sel. (peak)[2]	7 (3) [5]	0 (0)	7	(3)
3	F3 (Com-PLL-ATL)	Logistic	Logistic	Sex specific		11(1) [4]	0 (0)	11	(1)
4	F4 (Rec-ATL)	Double normal	Double normal	Combined sex	Sel. (end)[3]	7 (0) [6]	0 (0)	7	(0)
5	F5 (Rec-RPM-ATL)		Mirror F4	Mirror F4	Mirror F4	0 (0)	0 (0)	0	(0)
6	F6 (Com-Other-Kept-ATL)		Mirror F4	Mirror F4	Mirror F4	0 (0)	0 (0)	0	(0)
7	S1 (PLL-Obs-ATL)		Mirror F3	Mirror F3		0 (0)	1 (0)	1	(0)
8	S2 (Shark-BLL-Obs-ATL)		Mirror F1	Mirror F1		0 (0)	1 (0)	1	(0)
9	S3 (Shark-BLL-Res-ATL)		Mirror F1	Mirror F1		0 (0)	1 (0)	1	(0)
	…								
10	S5 (SEFSC-BLLS-ATL)	Logistic	Logistic	Sex specific		11(1) [4]	1 (0)	12	(1)
	…								
	…								
11	R3 (COASTSPAN-BLLS)	Double normal	Double normal	Combined sex		6 (1) [7]	1 (0)	7	(1)
12	R4 (COASTSPAN-LGNS)	Double normal	Double normal	Combined sex		6 (1) [7]	1 (0)	7	(1)
13	R5 (COASTSPAN-SGNS)	Double normal	Mirror R4	Mirror R4		0 (0)	1 (0)	1	0
						Subtotal (selectivity, catchability)		68	(10)
	Other estimated parameters								
	ln(R_0)							1	(1)
	Recruitment deviations					1988 – 2019			(32)
						Grand total			(43)

[1] Time blocks in selectivity for F1 (1981 – 2007, 2008 – 2019 [main years]; reduced from GOM + ATL).
[2] Time blocks in selectivity for F2 (1981 – 2006, 2007 – 2019 [main years]; adapted from GOM + ATL).
[3] Time blocks in selectivity for F4 (1981 – 1999, 2000 – 2019 [main years]; adapted from GOM + ATL).
[4] Only selectivity parameters for the location of the peak were estimated; The remaining selectivity parameters were fixed at their initial values obtained externally from either a selectivity gamer fit to the ATL length data set or from the GOM +ATL continuity analysis.
[5] Only selectivity parameters for the peak and descending slope were estimated; The remaining selectivity parameters were fixed at their initial values obtained externally from the GOM +ATL continuity analysis.
[6] All selectivity parameters were fixed at their initial values obtained externally from the GOM +ATL continuity analysis.
[7] Only selectivity parameters for the descending slope were estimated; The remaining selectivity parameters were fixed at their initial values obtained externally from the GOM +ATL continuity analysis.

Table 3.C.6. Two stage data weighting used in the Stock Synthesis ATL sensitivity analysis model configuration; The stage-1 CPUE (survey) variance adjustments are provided along with the mean of input CV and the resulting mean of adjusted input CV obtained after adding the variance adjustment (**Panel A**); The stage-2 length composition effective sample size (Effn) adjustments are provided along with the mean input sample size (n) and the resulting mean of the adjusted input sample size, n, obtained after multiplying by the Effn adjustment (**Panel B**); The symbol "…" indicates time series that were removed from the sensitivity analysis.

Panel A

Survey	Mean of input CV	Variance adjustment	Mean of adjusted input CV
S1 (PLL-Obs-ATL)	0.5547	0.0000	0.5547
S2 (Shark-BLL-Obs-ATL)	0.5184	0.4606	0.9790
S3 (Shark-BLL-Res-ATL)	0.3532	0.0000	0.3532
…			
S5 (SEFSC-BLLS-ATL)	0.6442	0.0000	0.6442
…			
…			
R3 (COASTSPAN-BLLS)	0.6178	0.0000	0.6178
R4 (COASTSPAN-LGNS)	0.6626	0.0000	0.6626
R5 (COASTSPAN-SGNS)	0.4597	0.0000	0.4597

Panel B

Length composition data source	Mean of input n	Adjustment method	Sample size adjustment	Mean of adjusted input n
F1 (Com-BLL-ATL)	46.6	Francis Effn	0.185	8.6
F2 (Com-GN-ATL)	43.7	Harmonic Mean Effn	0.143	6.2
F3 (Com-PLL-ATL)	28.3	Harmonic Mean Effn	0.520	14.7
F4 (Rec-ATL)	20.0	Harmonic Mean Effn	0.174	3.5
…				
S5 (SEFSC-BLLS-ATL)	20.0	Harmonic Mean Effn	0.791	15.8
…				
…				
R3 (COASTSPAN-BLLS)	44.3	Harmonic Mean Effn	0.067	2.9
R4 (COASTSPAN-LGNS)	77.6	Francis Effn	0.638	49.5

Table 3.C.7. Parameters in the Stock Synthesis ATL sensitivity model configuration; Parameters with a negative phase were fixed at their initial value; CV is calculated as the asymptotic standard error (Parm_StDev) divided by the estimated value (Value).

Label	Value	Active	Phase	Min	Max	Init	StDev	Pr_type	Prior	Pr_SD	CV
L_at_Amin_Fem_GP_1	41.63	_	-3	5	100	41.63	_	Normal	41.63	1000	NA
L_at_Amax_Fem_GP_1	225.80	_	-4	50	600	225.80	_	Normal	225.80	1000	NA
VonBert_K_Fem_GP_1	0.09	_	-5	0.01	0.65	0.09	_	Normal	0.06	0.2	NA
CV_young_Fem_GP_1	0.09	_	-2	0.01	0.3	0.09	_	Normal	0.09	0.01	NA
CV_old_Fem_GP_1	0.09	_	-3	0.01	0.3	0.09	_	Normal	0.09	0.01	NA
Wtlen_1_Fem_GP_1	0.00	_	-3	-3	3	0.00	_	Normal	0.00	0.8	NA
Wtlen_2_Fem_GP_1	3.13	_	-3	-3	5	3.13	_	Normal	3.00	0.8	NA
Mat50%_Fem_GP_1	202.80	_	-3	1	300	202.80	_	Normal	202.80	0.8	NA
Mat_slope_Fem_GP_1	-0.24	_	-3	-200	3	-0.24	_	Normal	-0.24	0.8	NA
Eggs_scalar_Fem_GP_1	18.00	_	-3	-3	50	18.00	_	Normal	18.00	0.8	NA
Eggs_exp_len_Fem_GP_1	0.00	_	-3	-3	3	0.00	_	Normal	0.00	0.8	NA
L_at_Amin_Mal_GP_1	41.64	_	-3	5	100	41.64	_	Normal	41.64	1000	NA
L_at_Amax_Mal_GP_1	242.10	_	-4	50	600	242.10	_	Normal	242.10	1000	NA
VonBert_K_Mal_GP_1	0.08	_	-5	0.01	0.65	0.08	_	Normal	0.08	0.2	NA
CV_young_Mal_GP_1	0.10	_	-2	0.01	0.3	0.10	_	Normal	0.10	0.01	NA
CV_old_Mal_GP_1	0.08	_	-3	0.01	0.3	0.08	_	Normal	0.08	0.01	NA
Wtlen_1_Mal_GP_1	0.00	_	-3	-3	3	0.00	_	Normal	<0.001	0.8	NA
Wtlen_2_Mal_GP_1	2.91	_	-3	-3	5	2.91	_	Normal	3.00	0.8	NA
CohortGrowDev	1.00	_	-1	0.1	10	1.00	_	Normal	1.00	1	NA
FracFemale_GP_1	0.50	_	-99	0.00	0.99	0.50	_	No_prior			NA
SR_LN(R0)[1]	8.74[1]	1	1	2.0685	8.742[1]	4.14	0.60	Normal	7.04	1000	47%
SR_BH_steep	0.67	_	-2	0.2	0.99	0.67	_	Normal	0.67	1000	NA
SR_sigmaR	0.28	_	-4	0.2	1.9	0.28	_	Normal	0.28	1000	NA
SR_regime	0.00	_	-4	-5	5	0.00	_	Normal	0.00	1	NA
SR_autocorr	0.00	_	-4	-5	5	0.00	_	Normal	0.00	1	NA

[1] Parameter estimated at upper bound.

Table 3.C.7. Continued.

Label	Value	Active	Phase	Min	Max	Init	StDev	Pr_type	Prior	Pr_SD	CV
Early_RecrDev_1988	-0.19	2	4	-10	10	0.00	0.26	dev			
Early_RecrDev_1989	-0.19	3	4	-10	10	0.00	0.26	dev			
Early_RecrDev_1990	-0.18	4	4	-10	10	0.00	0.26	dev			
Early_RecrDev_1991	-0.19	5	4	-10	10	0.00	0.26	dev			
Early_RecrDev_1992	-0.13	6	4	-10	10	0.00	0.26	dev			
Early_RecrDev_1993	-0.08	7	4	-10	10	0.00	0.26	dev			
Early_RecrDev_1994	-0.06	8	4	-10	10	0.00	0.27	dev			
Early_RecrDev_1995	0.02	9	4	-10	10	0.00	0.28	dev			
Early_RecrDev_1996	0.11	10	4	-10	10	0.00	0.28	dev			
Early_RecrDev_1997	0.13	11	4	-10	10	0.00	0.29	dev			
Main_RecrDev_1998	0.08	12	3	-10	10	0.00	0.28	dev			
Main_RecrDev_1999	0.11	13	3	-10	10	0.00	0.29	dev			
Main_RecrDev_2000	0.11	14	3	-10	10	0.00	0.28	dev			
Main_RecrDev_2001	-0.14	15	3	-10	10	0.00	0.24	dev			
Main_RecrDev_2002	-0.28	16	3	-10	10	0.00	0.25	dev			
Main_RecrDev_2003	0.20	17	3	-10	10	0.00	0.24	dev			
Main_RecrDev_2004	0.01	18	3	-10	10	0.00	0.28	dev			
Main_RecrDev_2005	-0.10	19	3	-10	10	0.00	0.23	dev			
Main_RecrDev_2006	0.27	20	3	-10	10	0.00	0.22	dev			
Main_RecrDev_2007	0.00	21	3	-10	10	0.00	0.21	dev			
Main_RecrDev_2008	-0.09	22	3	-10	10	0.00	0.22	dev			
Main_RecrDev_2009	0.05	23	3	-10	10	0.00	0.23	dev			
Main_RecrDev_2010	0.34	24	3	-10	10	0.00	0.19	dev			
Main_RecrDev_2011	0.05	25	3	-10	10	0.00	0.18	dev			
Main_RecrDev_2012	0.05	26	3	-10	10	0.00	0.18	dev			
Main_RecrDev_2013	-0.03	27	3	-10	10	0.00	0.18	dev			
Main_RecrDev_2014	-0.09	28	3	-10	10	0.00	0.21	dev			
Main_RecrDev_2015	-0.47	29	3	-10	10	0.00	0.21	dev			
Main_RecrDev_2016	-0.02	30	3	-10	10	0.00	0.19	dev			
Main_RecrDev_2017	-0.02	31	3	-10	10	0.00	0.20	dev			
Late_RecrDev_2018	-0.15	32	5	-10	10	0.00	0.22	dev			
Late_RecrDev_2019	-0.13	33	5	-10	10	0.00	0.22	dev			

Table 3.C.7. Continued.

Label	Value	Active	Phase	Min	Max	Init	StDev	Pr_type	Prior	Pr_SD	CV
LnQ_base_S1_PLL_Obs_ATL_Sens(7)	-12.08	_	-1	-25	25	0.00	_	No_prior			NA
LnQ_base_S2_Shark_BLL_Obs_ATL_Sens(8)	-7.24	_	-1	-25	25	0.00	_	No_prior			NA
LnQ_base_S3_Shark_BLL_Res_ATL_Sens(9)	-5.74	_	-1	-25	25	0.00	_	No_prior			NA
LnQ_base_S5_SEFSC_BLLS_ATL_Sens(10)	-12.57	_	-1	-25	25	0.00	_	No_prior			NA
LnQ_base_R3_COASTSPAN_BLLS(11)	-7.61	_	-1	-25	25	0.00	_	No_prior			NA
LnQ_base_R4_COASTSPAN_LGNS(12)	-7.73	_	-1	-25	25	0.00	_	No_prior			NA
LnQ_base_R5_COASTSPAN_SGNS(13)	-10.96	_	-1	-25	25	0.00	_	No_prior			NA
Size_DblN_peak_F1_COM_BLL_ATL_Sens(1)	180.86	44	2	55.6	247.5	195.90	7.90	Sym_Beta	186.10	0.05	108%
Size_DblN_top_logit_F1_COM_BLL_ATL_Sens(1)	4.00	_	-3	-6	4	4.00	_	Sym_Beta	4.00	0.05	NA
Size_DblN_ascend_se_F1_COM_BLL_ATL_Sens(1)	7.84	_	-3	-1	9	7.84	_	Sym_Beta	8.70	0.05	NA
Size_DblN_descend_se_F1_COM_BLL_ATL_Sens(1)	-1.00	_	-3	-1	9	-1.00	_	Sym_Beta	-1.00	0.05	NA
Size_DblN_start_logit_F1_COM_BLL_ATL_Sens(1)	-5.50	_	-2	-15	9	-5.50	_	Sym_Beta	-5.50	0.05	NA
Size_DblN_end_logit_F1_COM_BLL_ATL_Sens(1)	9.00	_	-2	-15	9	9.00	_	Sym_Beta	9.00	0.05	NA
SzSel_Fem_Peak_F1_COM_BLL_ATL_Sens(1)	-29.79	45	4	-100	100	-79.35	7.54	Normal	0.00	1000	266%
SzSel_Fem_Ascend_F1_COM_BLL_ATL_Sens(1)	-1.37	_	-4	-15	15	-1.37	_	Normal	0.00	1000	NA
SzSel_Fem_Descend_F1_COM_BLL_ATL_Sens(1)	0.00	_	-4	-15	15	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Final_F1_COM_BLL_ATL_Sens(1)	0.00	_	-4	-15	15	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Scale_F1_COM_BLL_ATL_Sens(1)	1.00	_	-5	-15.00	15.00	1.00	_	Normal	1.00	1000	NA
Size_DblN_peak_F2_Com_GN_ATL_Sens(2)	66.88	46	2	42.50	247.50	73.10	4.69	Sym_Beta	73.10	0.05	109%
Size_DblN_top_logit_F2_Com_GN_ATL_Sens(2)	-2.90	_	-3	-6.00	4.00	-2.90	_	Sym_Beta	-2.90	0.05	NA
Size_DblN_ascend_se_F2_Com_GN_ATL_Sens(2)	4.75	_	-3	-1.00	9.00	4.75	_	Sym_Beta	5.30	0.05	NA
Size_DblN_descend_se_F2_Com_GN_ATL_Sens(2)	6.23	47	3	-1.00	9.00	7.80	0.77	Sym_Beta	7.80	0.05	125%
Size_DblN_start_logit_F2_Com_GN_ATL_Sens(2)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_F2_Com_GN_ATL_Sens(2)	-2.30	_	-2	-15.00	9.00	-2.30	_	Sym_Beta	-2.30	0.05	NA
Size_DblN_peak_F3_Com_PLL_ATL_Sens(3)	137.00	48	2	55.60	247.50	154.80	4.47	Sym_Beta	160.10	0.05	113%
Size_DblN_top_logit_F3_Com_PLL_ATL_Sens(3)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_F3_Com_PLL_ATL_Sens(3)	6.27	_	-3	-1.00	9.00	6.27	_	Sym_Beta	7.10	0.05	NA
Size_DblN_descend_se_F3_Com_PLL_ATL_Sens(3)	9.00	_	-3	-1.00	9.00	9.00	_	Sym_Beta	9.00	0.05	NA
Size_DblN_start_logit_F3_Com_PLL_ATL_Sens(3)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_F3_Com_PLL_ATL_Sens(3)	9.00	_	-2	-15.00	9.00	9.00	_	Sym_Beta	9.00	0.05	NA
SzSel_Male_Peak_F3_Com_PLL_ATL_Sens(3)	14.04	_	-4	-50.00	50.00	14.04	_	Normal	0.00	1000	NA
SzSel_Male_Ascend_F3_Com_PLL_ATL_Sens(3)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Descend_F3_Com_PLL_ATL_Sens(3)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Final_F3_Com_PLL_ATL_Sens(3)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Scale_F3_Com_PLL_ATL_Sens(3)	1.00	_	-5	-15.00	15.00	1.00	_	Normal	1.00	1000	NA

Table 3.C.7. Continued.

Label	Value	Active	Phase	Min	Max	Init	StDev	Pr_type	Prior	Pr_SD	CV
Size_DblN_peak_F4_Rec_ATL_Sens(4)	46.00	_	-2	42.50	247.50	46.00	_	Sym_Beta	61.80	0.05	NA
Size_DblN_top_logit_F4_Rec_ATL_Sens(4)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_F4_Rec_ATL_Sens(4)	5.80	_	-3	-1.00	9.00	5.80	_	Sym_Beta	9.00	0.05	NA
Size_DblN_descend_se_F4_Rec_ATL_Sens(4)	7.60	_	-3	-1.00	9.00	7.60	_	Sym_Beta	7.60	0.05	NA
Size_DblN_start_logit_F4_Rec_ATL_Sens(4)	2.20	_	-2	-15.00	9.00	2.20	_	Sym_Beta	1.00	0.05	NA
Size_DblN_end_logit_F4_Rec_ATL_Sens(4)	-1.00	_	-2	-15.00	9.00	-1.00	_	Sym_Beta	-1.00	0.05	NA
SizeSel_P1_F5_Rec_PRM_ATL_Sens(5)	1.00	_	-99	0.00	10.00	1.00	_	Normal	1.00	25	NA
SizeSel_P2_F5_Rec_PRM_ATL_Sens(5)	44.00	_	-99	10.00	100.00	44.00	_	Normal	44.00	25	NA
SizeSel_P1_F6_Com_Other_Kept_ATL_Sens(6)	1.00	_	-99	0.00	10.00	1.00	_	Normal	1.00	25	NA
SizeSel_P2_F6_Com_Other_Kept_ATL_Sens(6)	44.00	_	-99	10.00	100.00	44.00	_	Normal	44.00	25	NA
SizeSel_P1_S1_PLL_Obs_ATL_Sens(7)	1.00	_	-99	0.00	10.00	1.00	_	Normal	1.00	25	NA
SizeSel_P2_S1_PLL_Obs_ATL_Sens(7)	44.00	_	-99	10.00	100.00	44.00	_	Normal	44.00	25	NA
SizeSel_P1_S2_Shark_BLL_Obs_ATL_Sens(8)	1.00	_	-99	0.00	10.00	1.00	_	Normal	1.00	25	NA
SizeSel_P2_S2_Shark_BLL_Obs_ATL_Sens(8)	44.00	_	-99	10.00	100.00	44.00	_	Normal	44.00	25	NA
SizeSel_P1_S3_Shark_BLL_Res_ATL_Sens(9)	1.00	_	-99	0.00	10.00	1.00	_	Normal	1.00	25	NA
SizeSel_P2_S3_Shark_BLL_Res_ATL_Sens(9)	44.00	_	-99	10.00	100.00	44.00	_	Normal	44.00	25	NA
Size_DblN_peak_S5_SEFSC_BLLS_ATL_Sens(10)	102.31	49	2	55.60	247.50	150.10	12.00	Sym_Beta	117.60	0.05	147%
Size_DblN_top_logit_S5_SEFSC_BLLS_ATL_Sens(10)	4.00	_	-3	-6.00	4.00	4.00	_	Sym_Beta	4.00	0.05	NA
Size_DblN_ascend_se_S5_SEFSC_BLLS_ATL_Sens(10)	5.95	_	-3	-1.00	9.00	5.95	_	Sym_Beta	9.00	0.05	NA
Size_DblN_descend_se_S5_SEFSC_BLLS_ATL_Sens(10)	-1.00	_	-3	-1.00	9.00	-1.00	_	Sym_Beta	-1.00	0.05	NA
Size_DblN_start_logit_S5_SEFSC_BLLS_ATL_Sens(10)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_S5_SEFSC_BLLS_ATL_Sens(10)	9.00	_	-2	-15.00	9.00	9.00	_	Sym_Beta	9.00	0.05	NA
SzSel_Fem_Peak_S5_SEFSC_BLLS_ATL_Sens(10)	-11.53	_	-4	-50.00	50.00	-11.53	_	Normal	0.00	1000	NA
SzSel_Fem_Ascend_S5_SEFSC_BLLS_ATL_Sens(10)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Descend_S5_SEFSC_BLLS_ATL_Sens(10)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Final_S5_SEFSC_BLLS_ATL_Sens(10)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Scale_S5_SEFSC_BLLS_ATL_Sens(10)	1.00	_	-5	-15.00	15.00	1.00	_	Normal	1.00	1000	NA
Size_DblN_peak_R3_COASTSPAN_BLLS(11)	37.90	_	-2	37.90	250.00	37.90	_	Sym_Beta	37.90	0.05	NA
Size_DblN_top_logit_R3_COASTSPAN_BLLS(11)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_R3_COASTSPAN_BLLS(11)	-1.00	_	-3	-1.00	9.00	-1.00	_	Sym_Beta	-1.00	0.05	NA
Size_DblN_descend_se_R3_COASTSPAN_BLLS(11)	3.37	50	3	-1.00	9.00	4.30	0.62	Sym_Beta	4.30	0.05	128%
Size_DblN_start_logit_R3_COASTSPAN_BLLS(11)	9.00	_	-2	-15.00	9.00	9.00	_	Sym_Beta	9.00	0.05	NA
Size_DblN_end_logit_R3_COASTSPAN_BLLS(11)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15.00	0.05	NA

Table 3.C.7. Continued.

Label	Value	Active	Phase	Min	Max	Init	StDev	Pr_type	Prior	Pr_SD	CV
Size_DblN_peak_R4_COASTSPAN_LGNS(12)	37.90	_	-2	37.9	250	37.90	_	Sym_Beta	37.90	0.05	NA
Size_DblN_top_logit_R4_COASTSPAN_LGNS(12)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_R4_COASTSPAN_LGNS(12)	-1.00	_	-3	-1.00	9.00	-1.00	_	Sym_Beta	-1.00	0.05	NA
Size_DblN_descend_se_R4_COASTSPAN_LGNS(12)	3.09	51	3	-1.00	9.00	3.60	0.13	Sym_Beta	3.60	0.05	116%
Size_DblN_start_logit_R4_COASTSPAN_LGNS(12)	9.00	_	-2	-15.00	9.00	9.00	_	Sym_Beta	9.00	0.05	NA
Size_DblN_end_logit_R4_COASTSPAN_LGNS(12)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15.00	0.05	NA
SizeSel_P1_R5_COASTSPAN_SGNS(13)	1.00	_	-99	0.00	10.00	1.00	_	Normal	1.00	25	NA
SizeSel_P2_R5_COASTSPAN_SGNS(13)	44.00	_	-99	10.00	100.00	44.00	_	Normal	44.00	25	NA
Size_DblN_peak_F1_COM_BLL_ATL_Sens(1) _BLK2repl_1981	167.72	52	2	55.60	247.50	207.56	8.24	Sym_Beta	176.20	0.05	124%
Size_DblN_ascend_se_F1_COM_BLL_ATL_Sens(1) _BLK2repl_1981	7.87	_	-3	-1.00	9.00	7.87	_	Sym_Beta	8.20	0.05	NA
Size_DblN_peak_F2_Com_GN_ATL_Sens(2) _BLK3repl_1981	83.11	53	2	42.50	247.50	73.10	10.14	Sym_Beta	73.10	0.05	88%
Size_DblN_end_logit_F4_Rec_ATL_Sens(4) _BLK4repl_1981	-0.57	_	-2	-15.00	9.00	-0.57	_	Sym_Beta	-1.00	0.05	NA

Table 3.C.8. Catchability (q) in the Stock Synthesis ATL sensitivity model configuration; Catchability is calculated as the median unbiased analytical solution obtained from Stock Synthesis; The symbol "…" indicates time series that were removed from the sensitivity analysis.

Index name and years	ln(q)	q
Main years		
S1 (PLL-Obs-ATL; 1992 – 2019)	-12.083	5.66E-06
S2 (Shark-BLL-Obs-ATL; 1994 – 2007)	-7.235	7.21E-04
S3 (Shark-BLL-Res-ATL; 2009 – 2019)	-5.737	3.22E-03
…		
S5 (SEFSC-BLLS-ATL; 1995 – 2019)	-12.568	3.48E-06
…		
…		
R3 (COASTSPAN-BLLS; 2005 – 2019)	-7.605	4.98E-04
R4 (COASTSPAN-LGNS; 2001 – 2019)	-7.729	4.40E-04
R5 (COASTSPAN-SGNS; 2007 – 2019)	-10.963	1.73E-05
Time block years		
...		
…		
…		
…		

Figures

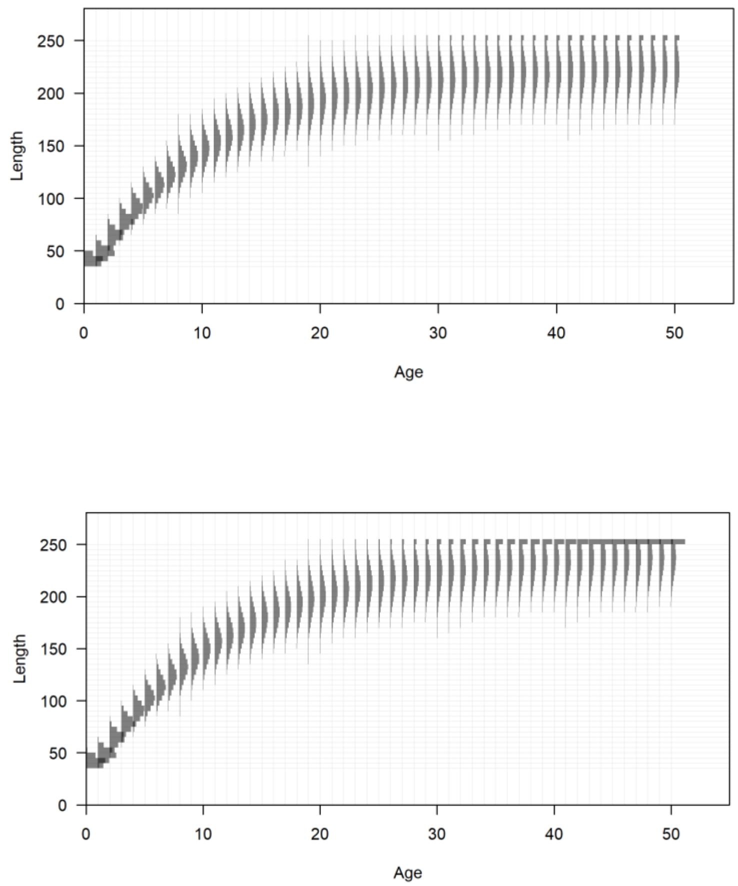


Figure 3.C.1. Distribution of mean length (cm FL) at each age implemented separately for females (upper panel) and males (lower panel) in the Stock Synthesis ATL sensitivity model configuration.

A. S1 (PLL-Obs-ATL)

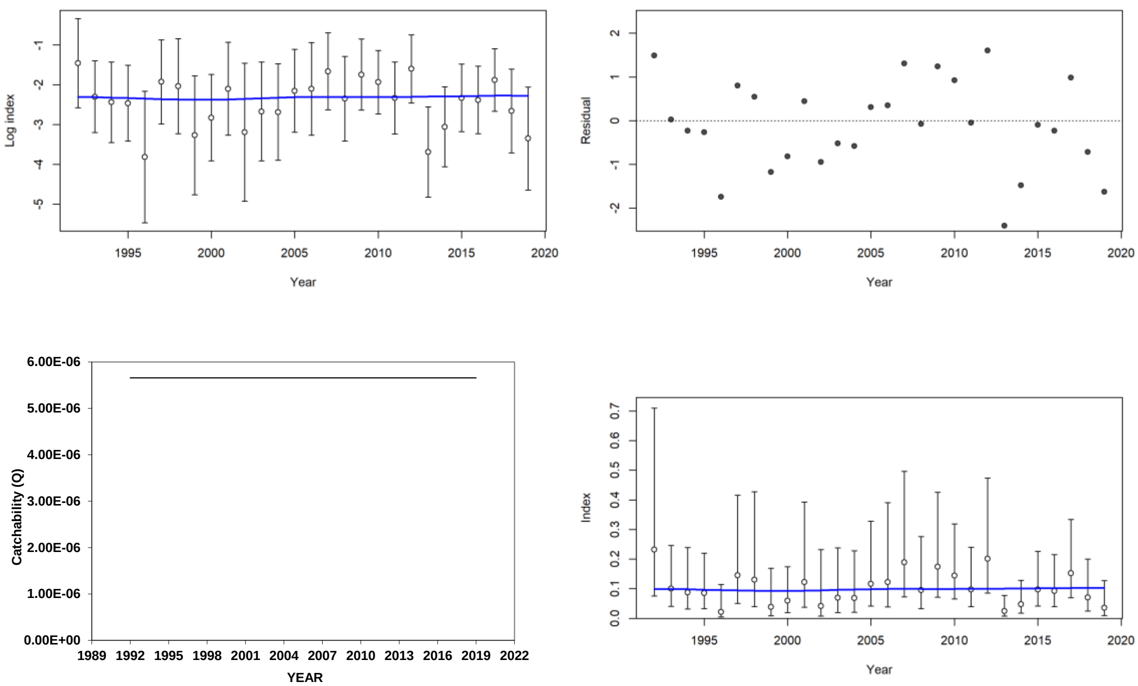


Figure 3.C.2. Fits to abundance indices in the Stock Synthesis ATL sensitivity model configuration; Upper left panel is predicted (blue line) and observed (open circles with approximate 95% confidence intervals based on the input standard error, SE) on the natural log scale; Upper right panel is residuals on the natural log scale (ln(Obs) - ln(Exp))/(observed SE); Lower left panel is estimated catchability; Lower right panel is observed and predicted on the nominal scale.

B. S2 (Shark-BLL-Obs-ATL)

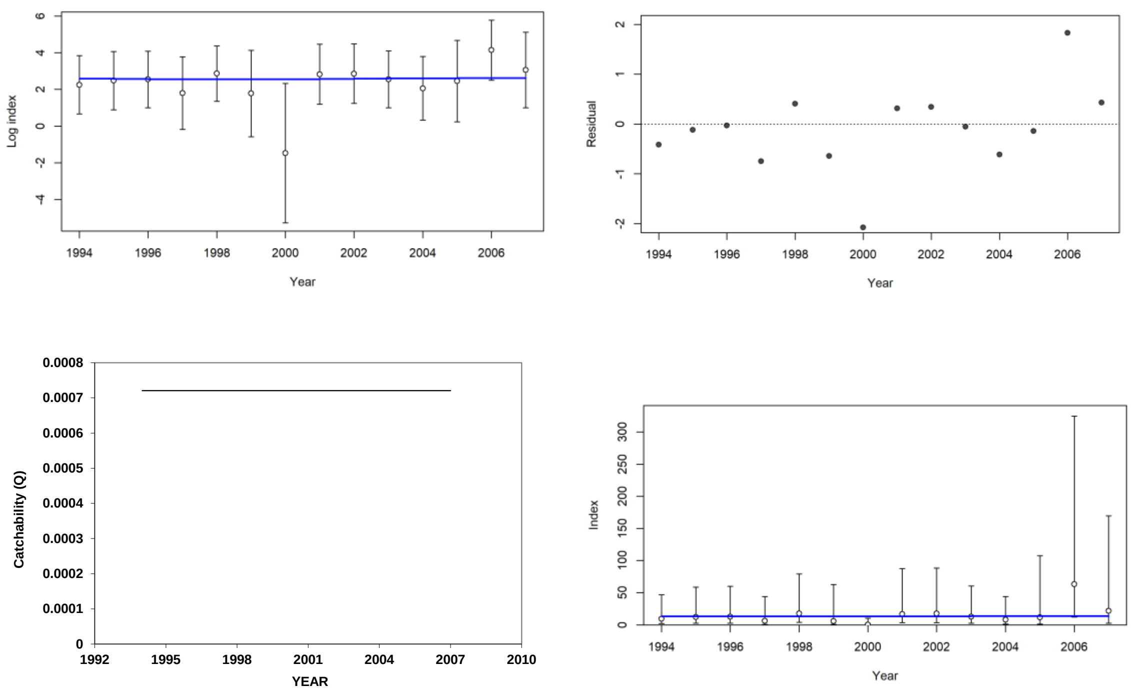


Figure 3.C.2. Continued.

C. S3 (Shark-BLL-Res-ATL)

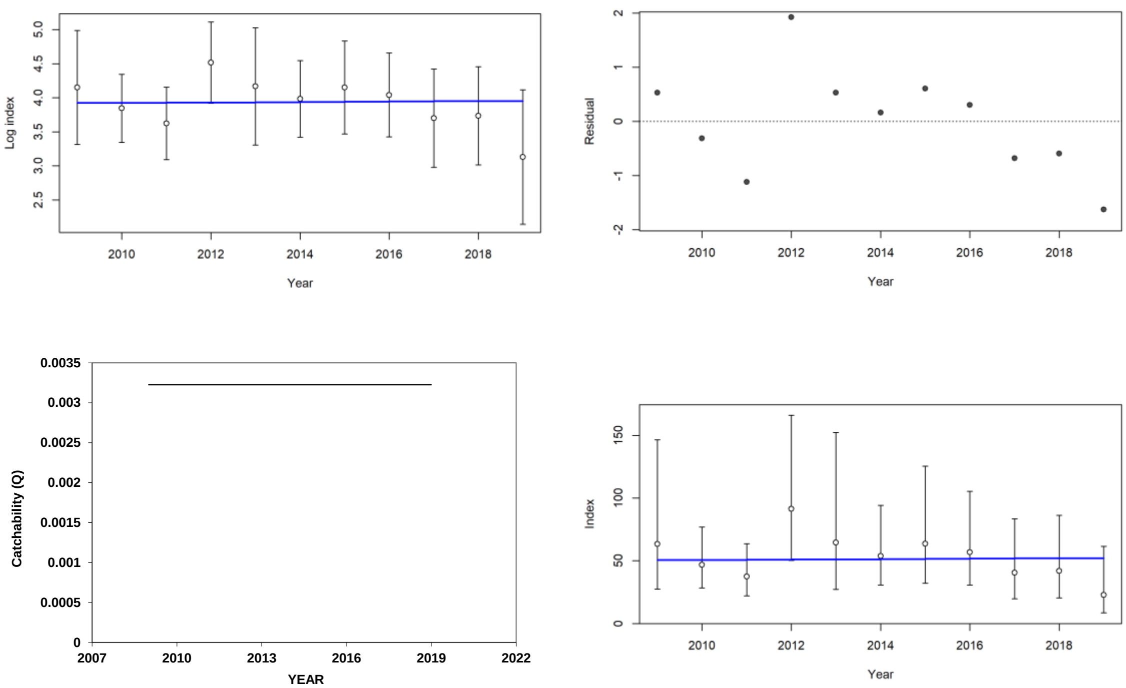


Figure 3.C.2. Continued.

D. S5 (SEFSC-BLLS-ATL)

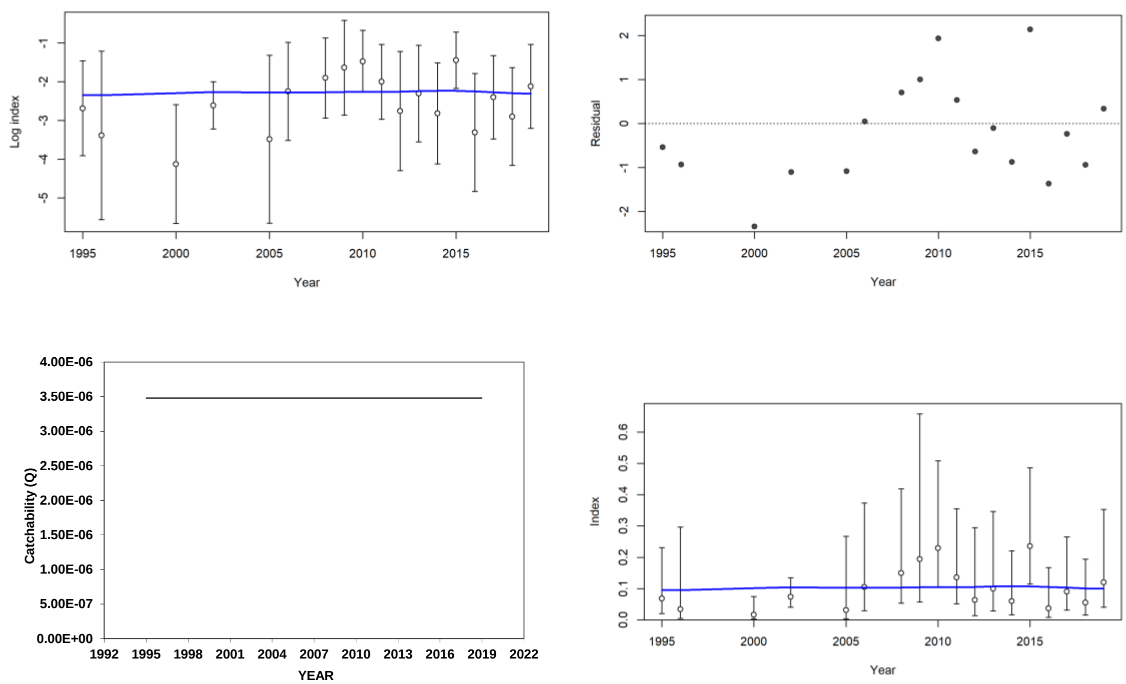


Figure 3.C.2. Continued.

E. R3 (COASTSPAN-BLLS)

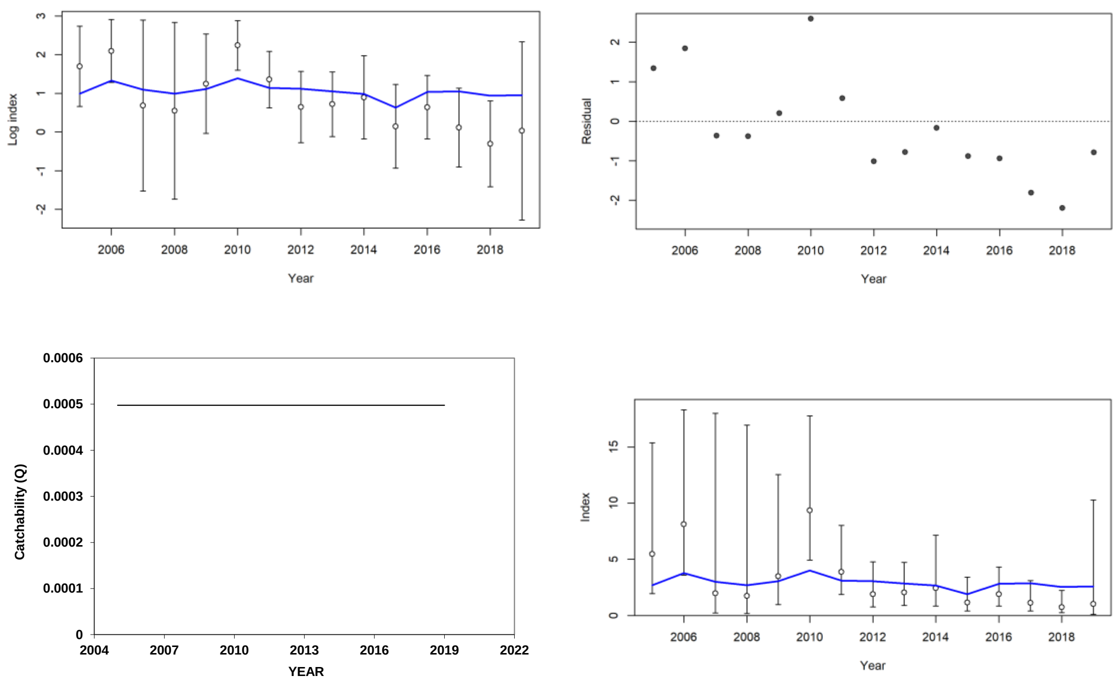


Figure 3.C.2. Continued.

F. R4 (COASTSPAN-LGNS)

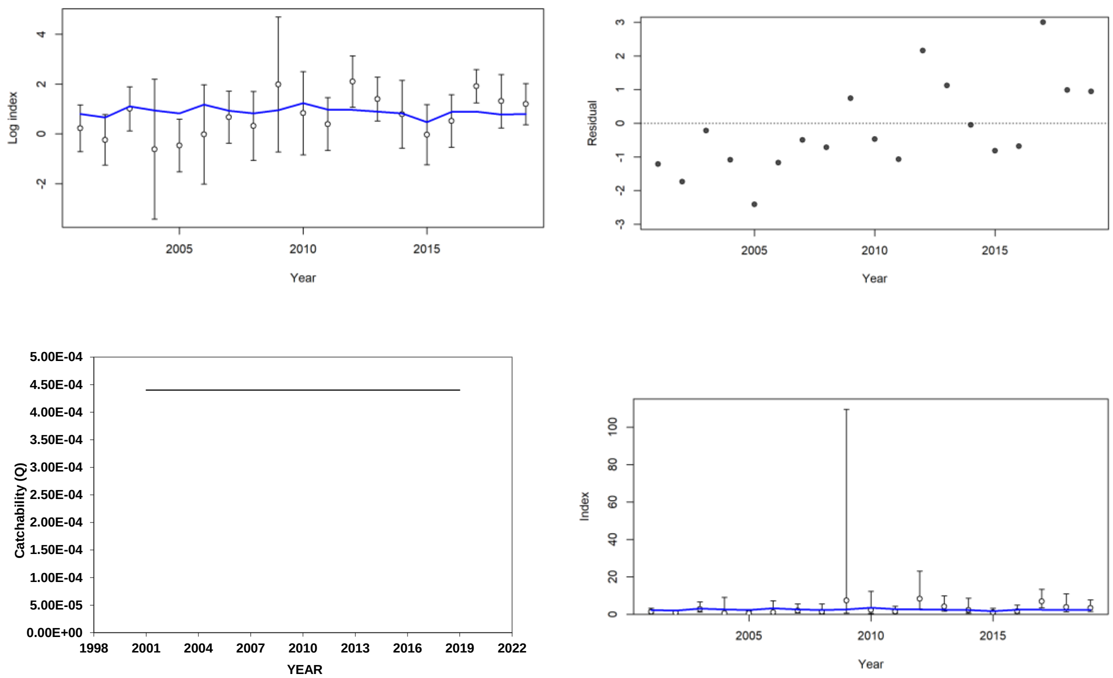


Figure 3.C.2. Continued.

G. R5 (COASTSPAN-SGNS)

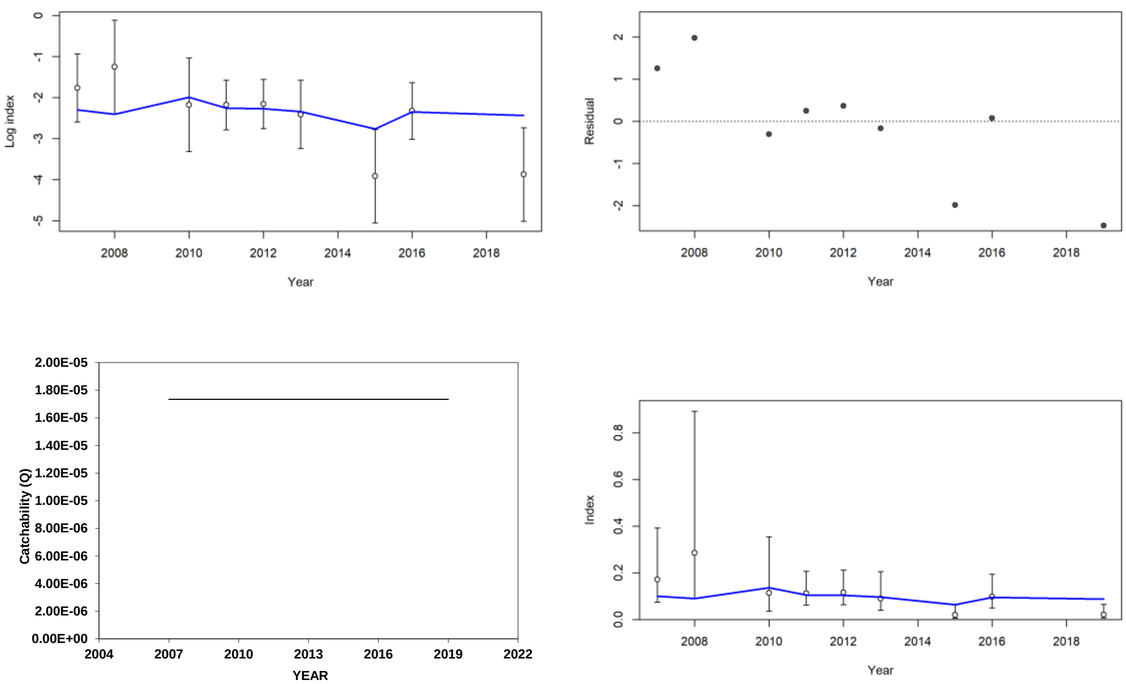
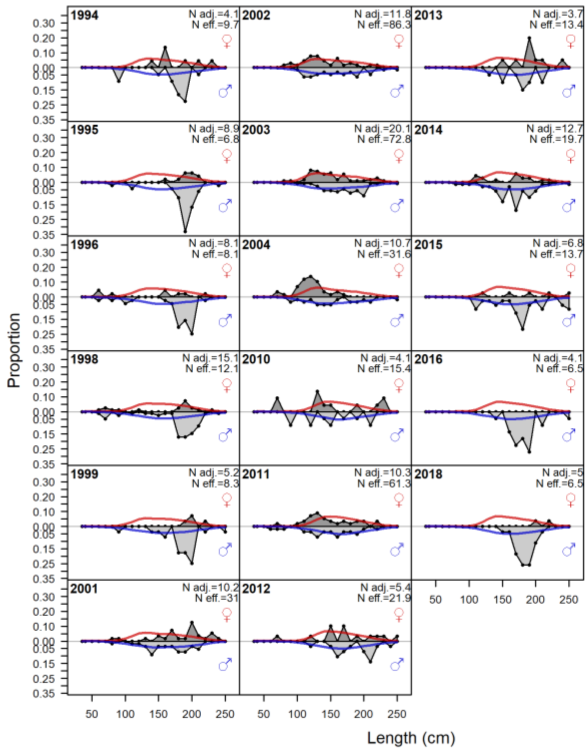


Figure 3.C.2. Continued.

Figure 3.C.3. Observed and predicted annual length compositions (upper panel) and Pearson residuals (lower panel) in the Stock Synthesis ATL sensitivity model configuration; Years with annual length composition sample size less than the minimum input sample size (Min; **Table 3.C.2)** were excluded from the model fit, and are not plotted; The value “N adj” is the input effective sample size obtained using either the Francis method or the McAllister and Ianelli harmonic mean, as described above; The value “N eff” is an alternative effective sample size estimate (McAllister and Ianelli 1997; Punt 2017, his McAllister-Ianelli-1 in his equation 1.A) that is not implemented in this assessment; The diameter of Pearson residuals indicates relative error for predicted < observed (solid) and predicted > observed (transparent) within the length composition data set; The maximum diameter of Pearson residuals indicates relative error among length composition data sets.

A. F1 (Com-BLL-ATL)



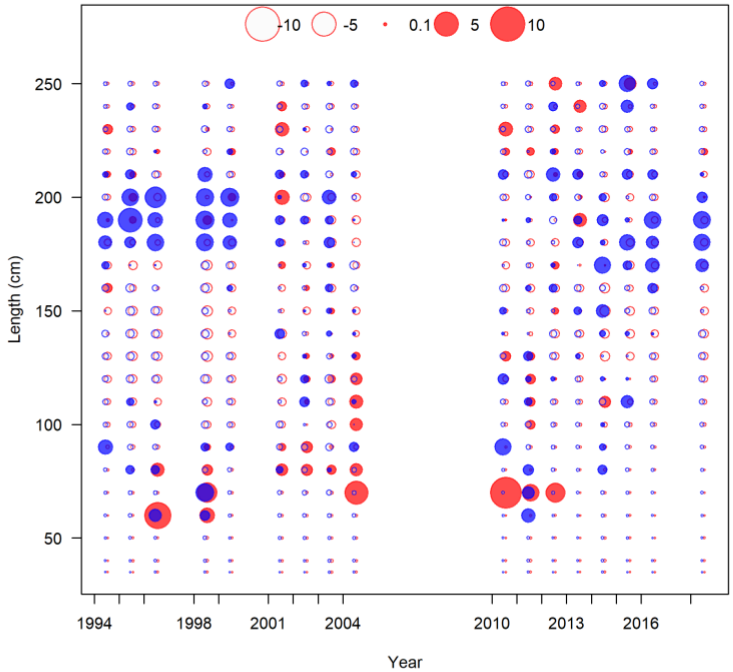
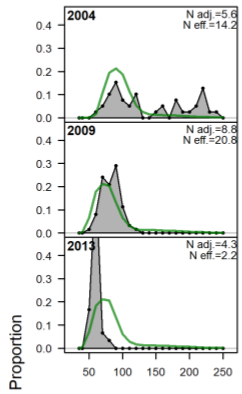


Figure 3.C.3. Continued.

B. F2 (Com-GN-ATL)



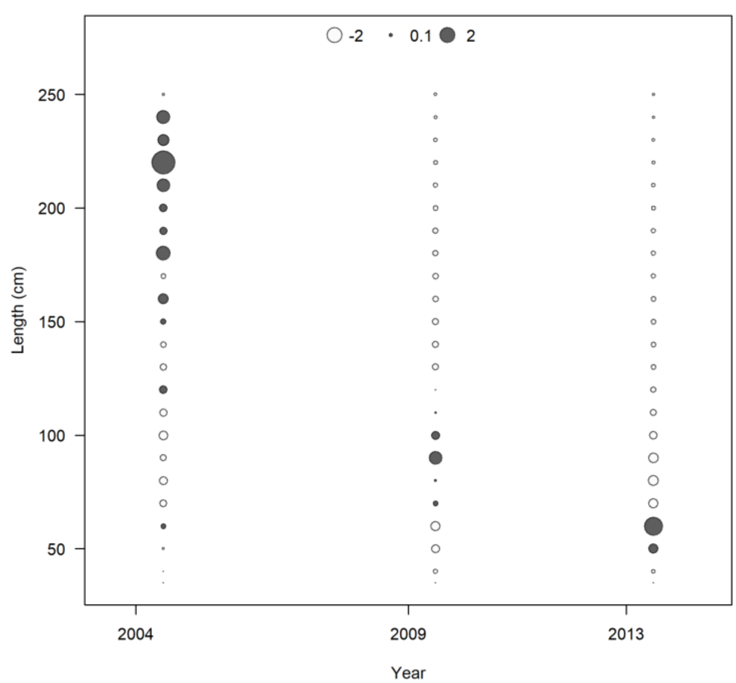
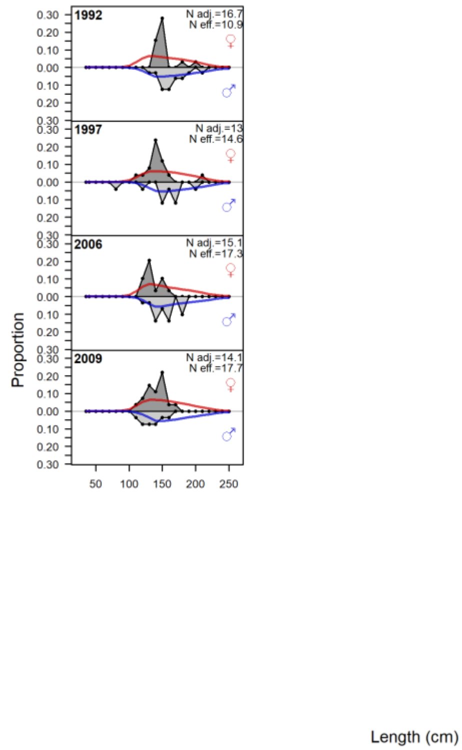


Figure 3.C.3. Continued.

C. F3 (Com-PLL-ATL)



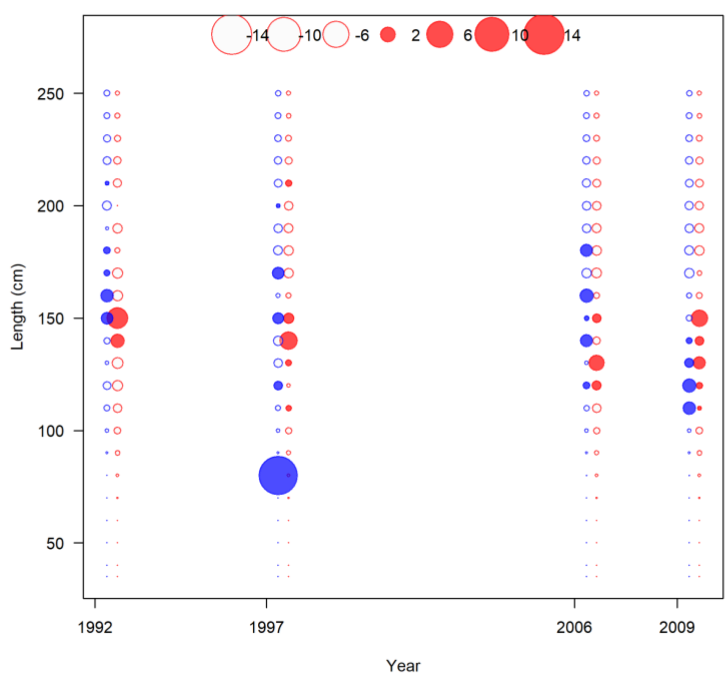
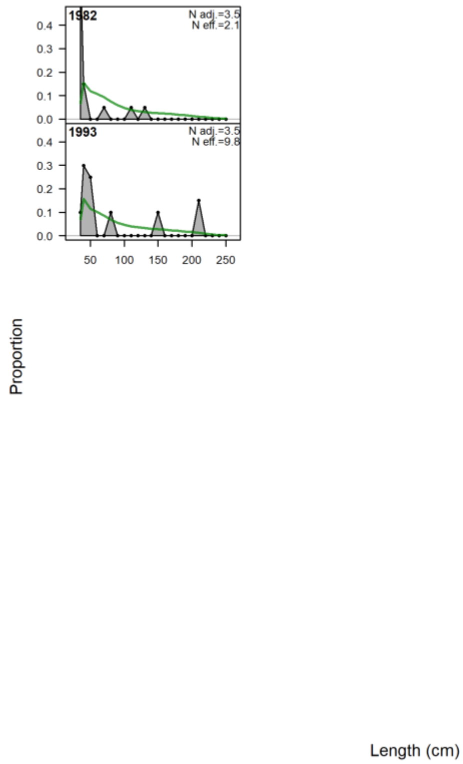


Figure 3.C.3. Continued.

D. F4 (Rec-ATL)



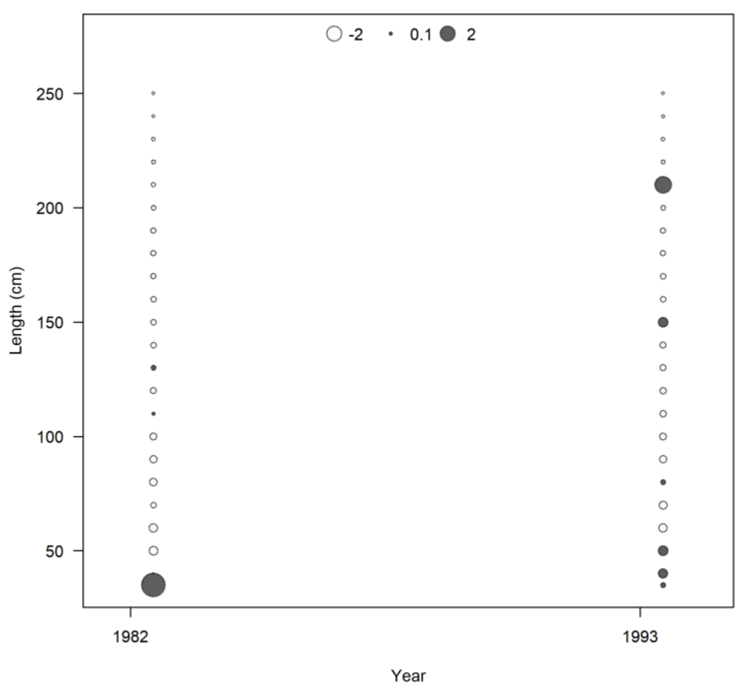
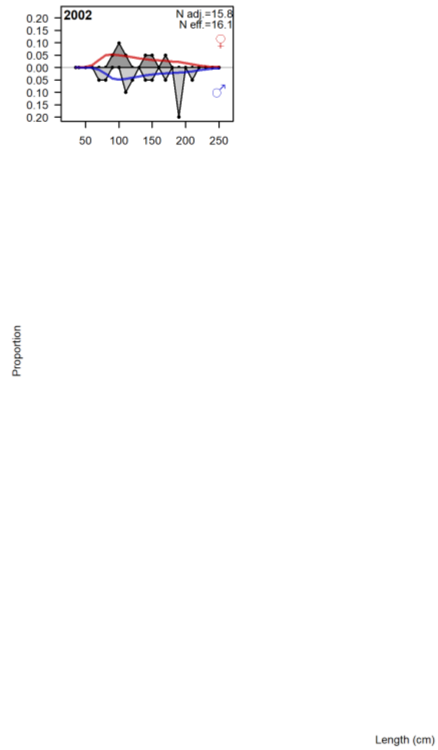


Figure 3.C.3. Continued.

E. S5 (SEFSC-BLLS-ATL)



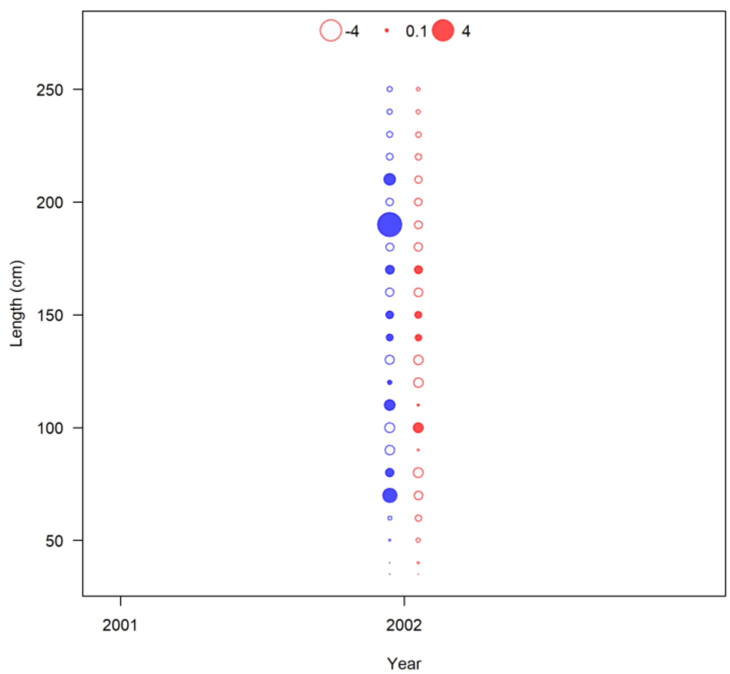
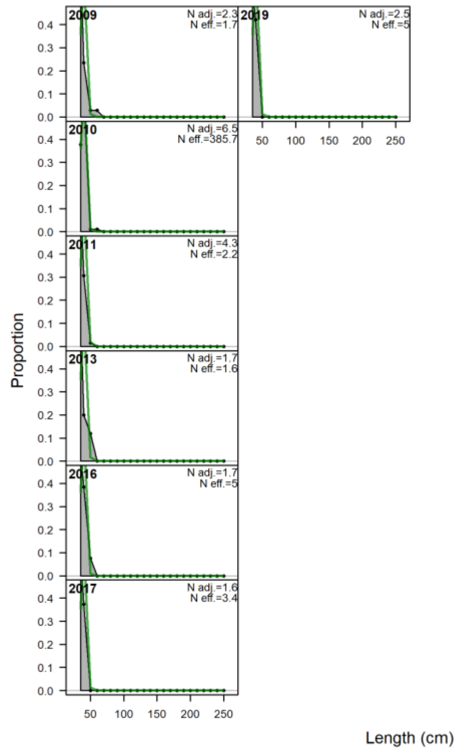


Figure 3.C.3. Continued.

F. R3 (COASTSPAN-BLLS)



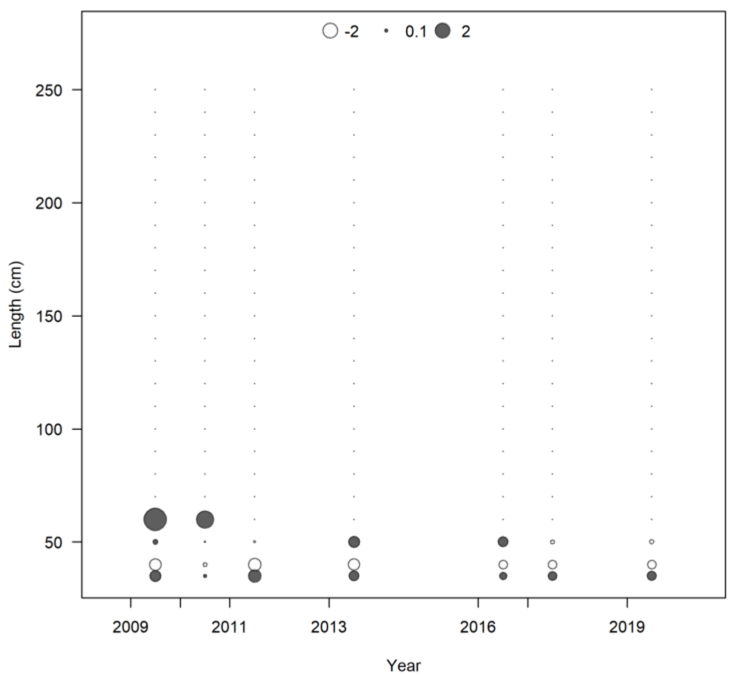
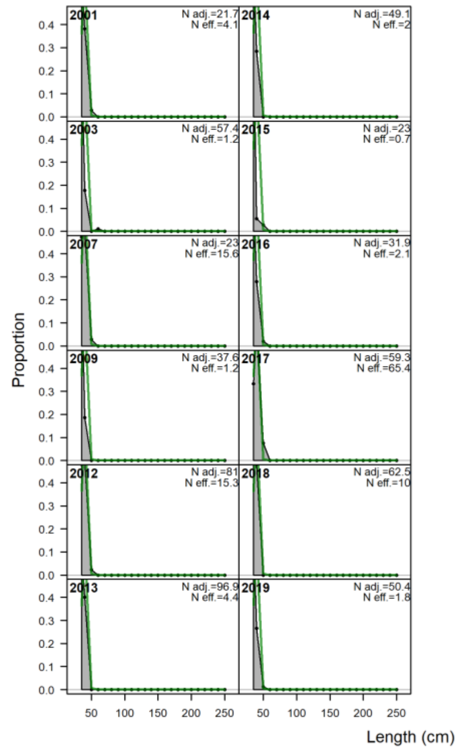


Figure 3.C.3. Continued.

G. R4 (COASTSPAN-LGNS)



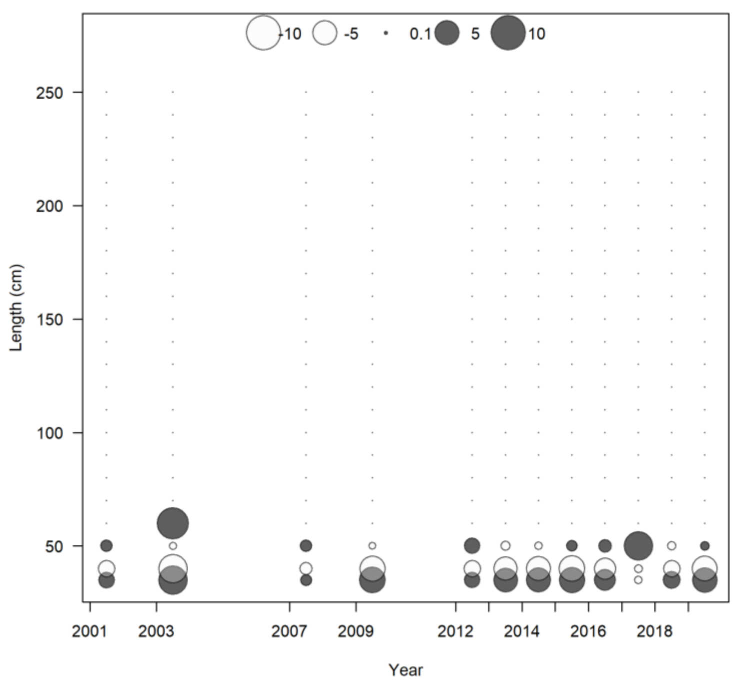


Figure 3.C.3. Continued.

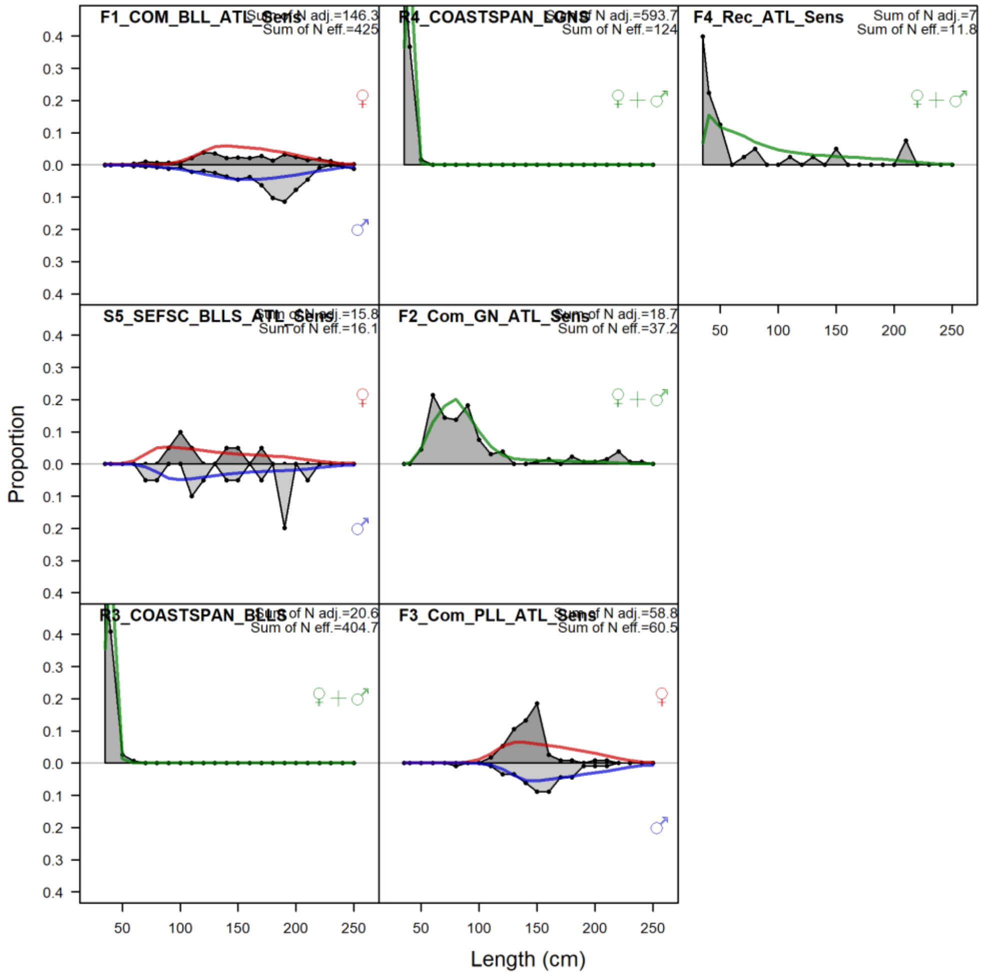


Figure 3.C.4. Predicted (line) and observed (shaded) aggregated length compositions in the Stock Synthesis ATL sensitivity model configuration; Years with annual length composition sample size less than the minimum input sample size (Min; **Table 3.C.2)** were excluded from the model fit, and are not plotted; The value "N adj" is the input effective sample size obtained using either the Francis method or the McAllister and Ianelli harmonic mean, as described above; The value "N eff" is an alternative effective sample size estimate (McAllister and Ianelli 1997; Punt 2017, his McAllister-Ianelli-1 in his equation 1.A) that is not implemented in this assessment.

A. F1 (Com-BLL-ATL)

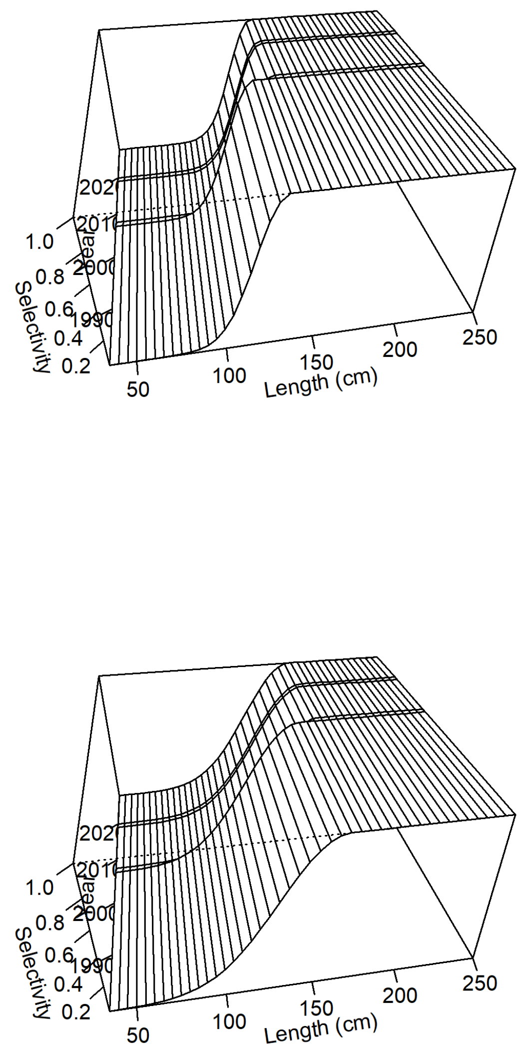


Figure 3.C.5. Estimated selectivity at length (cm FL) obtained in the Stock Synthesis ATL sensitivity model configuration (**Table 3.C.5**); Upper panel is female selectivity; Lower panel is male selectivity, if different from female selectivity; Otherwise female and male selectivity are the same.

B. F2 (Com-GN-ATL)

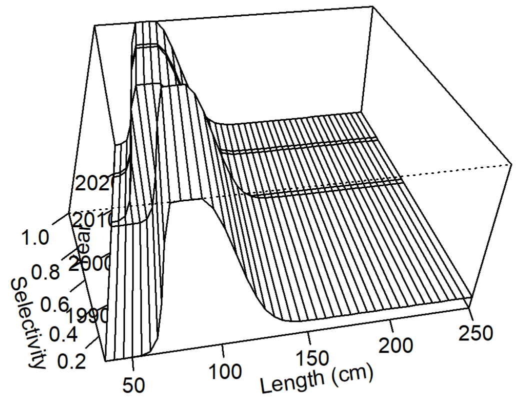
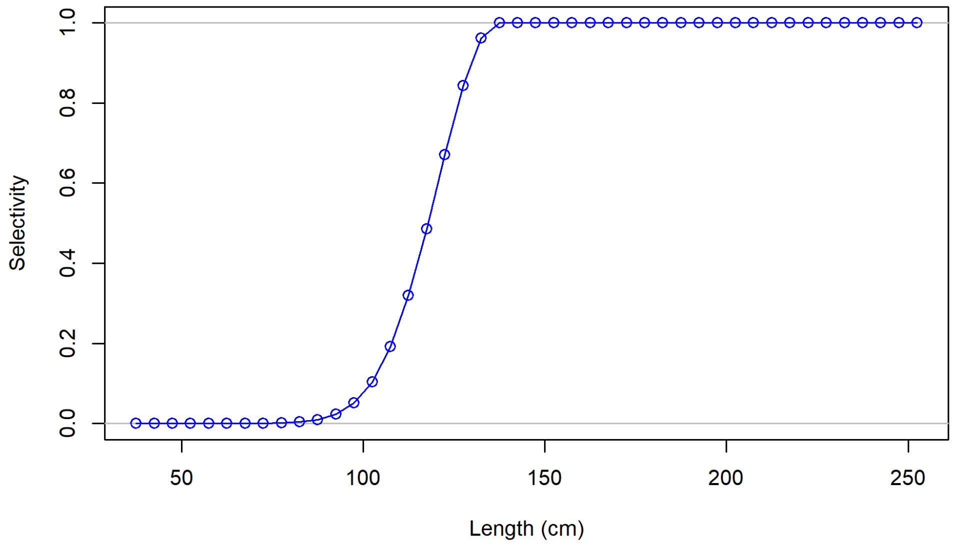


Figure 3.C.5. Continued.

C. F3 (Com-PLL-ATL)



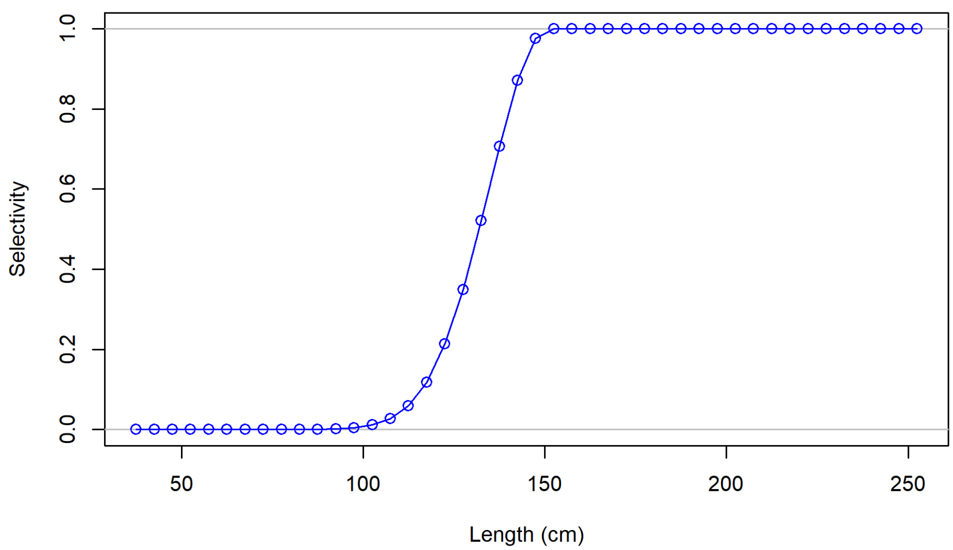


Figure 3.C.5. Continued.

D. F4 (Rec-ATL)

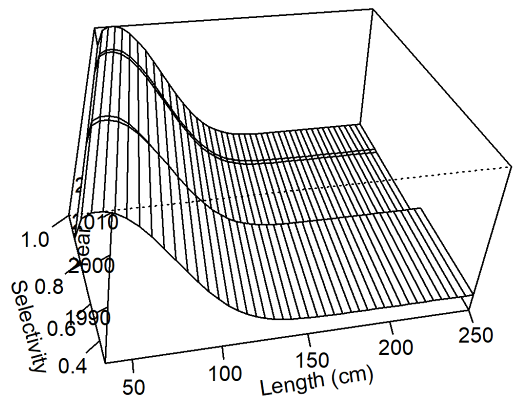
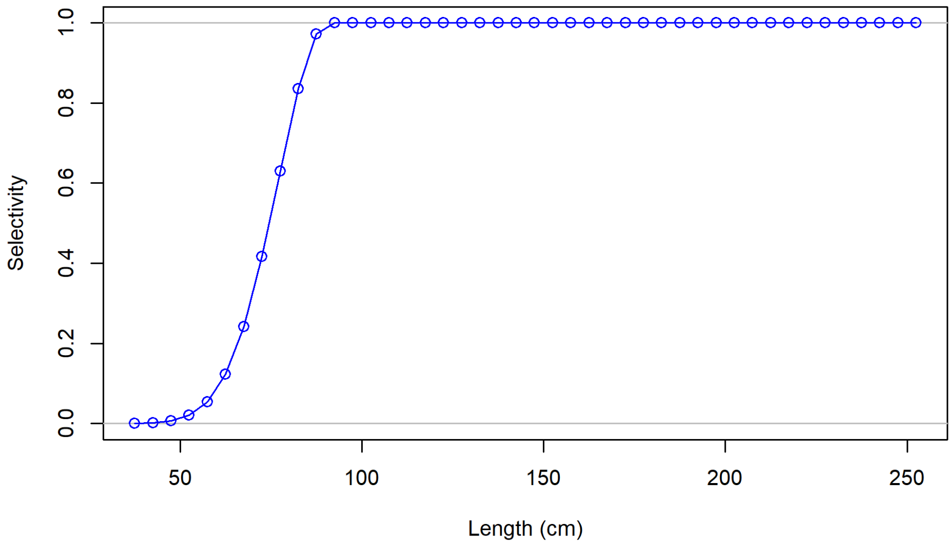


Figure 3.C.5. Continued.

E. S5 (SEFSC-BLLS)



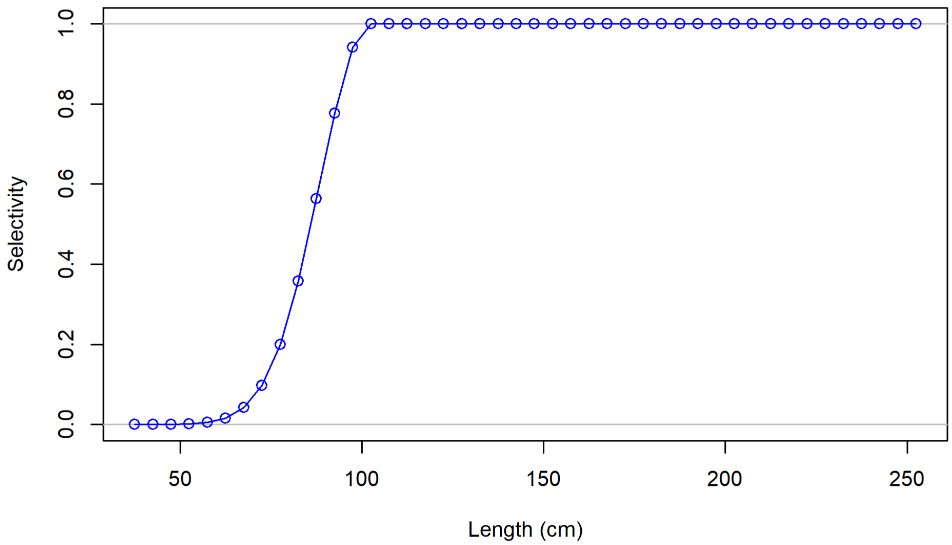


Figure 3.C.5. Continued.

F. R3 (COASTSPAN-BLLS)

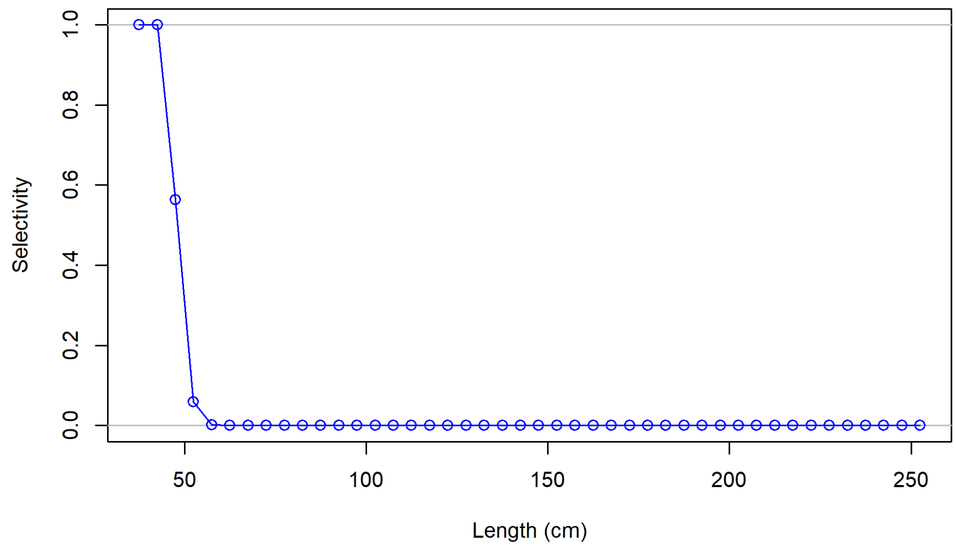


Figure 3.C.5. Continued.

G. R4 (COASTSPAN-LGNS)

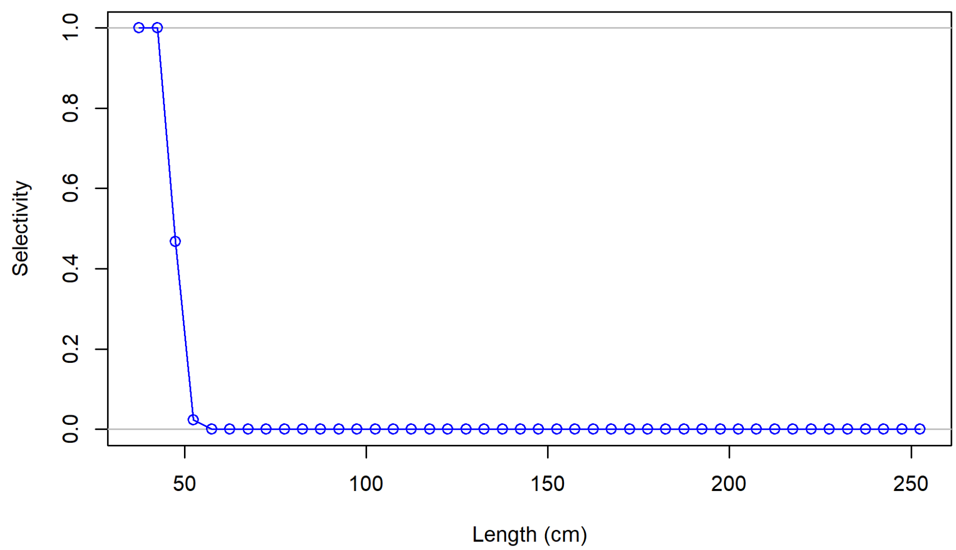


Figure 3.C.5. Continued.

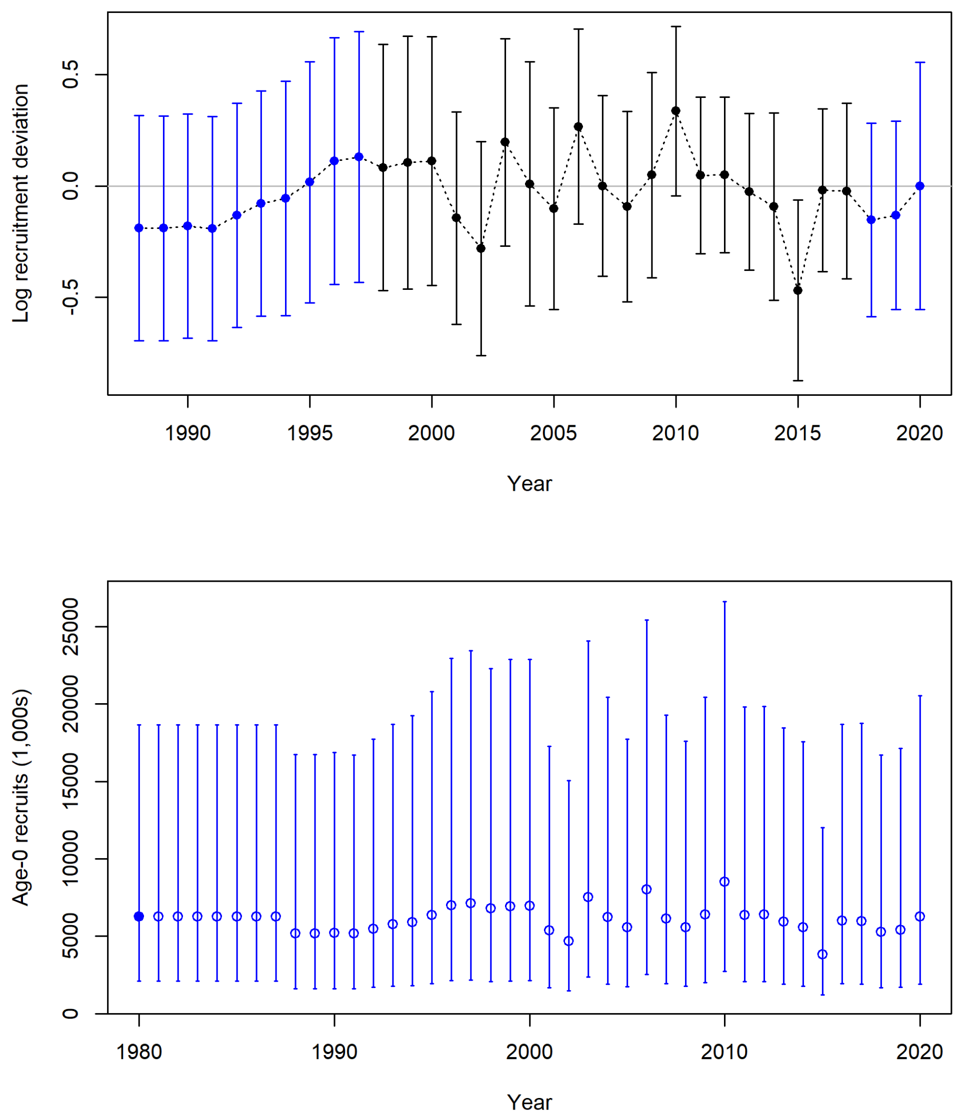
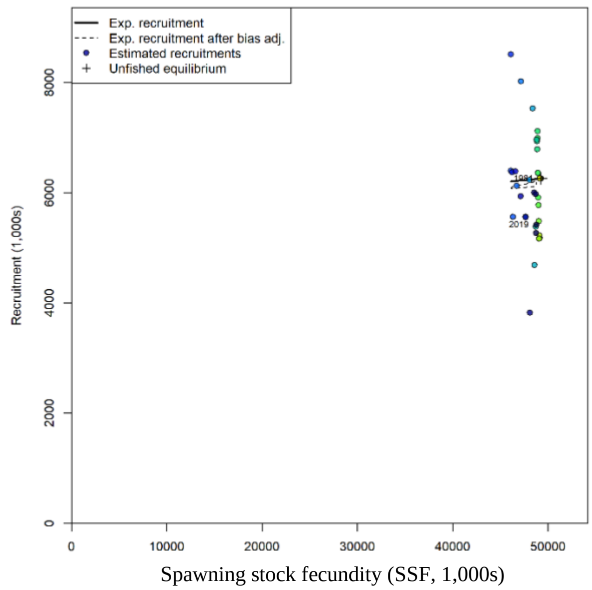


Figure 3.C.6. Upper panel is the estimated log recruitment deviations for the early (1988 – 1997, blue), main (1998 – 2017, black), late (2018 – 2019, blue), and forecast (2020, blue) recruitment periods with associated 95% asymptotic confidence intervals in the Stock Synthesis ATL sensitivity model configuration; Lower panel is the estimated annual age-0 recruits (circles) with 95% asymptotic confidence intervals; Age-0 recruits follow the assumed stock recruitment relationship exactly in years prior to 1988 and after 2019.



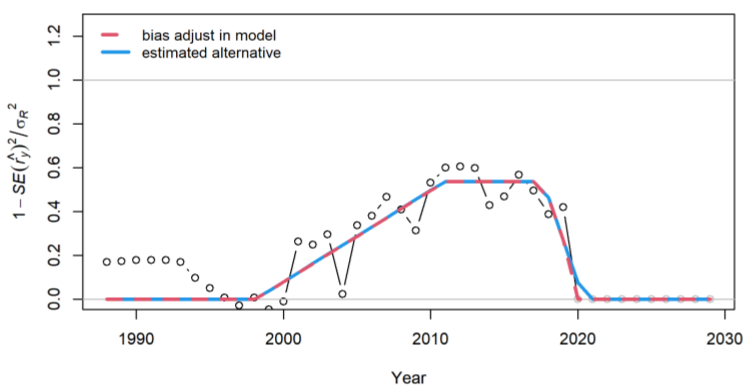
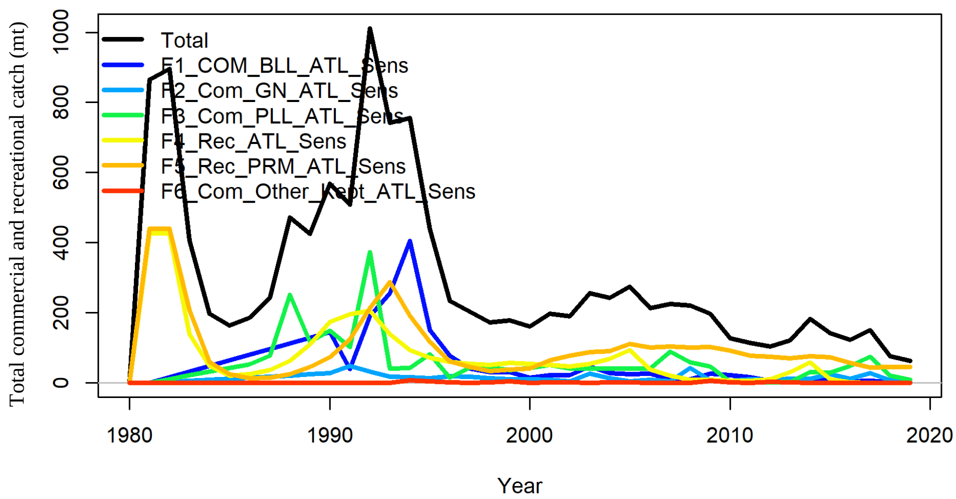


Figure 3.C.7. Expected recruitment (upper panel) from the stock-recruitment relationship (solid line), expected recruitment after implementing the bias adjustment correction (dashed line), estimated annual recruitments (circles), unfished equilibrium (plus), and first (1981) and last (2019) in the Stock Synthesis ATL sensitivity model configuration; Bias adjustment ramp (lower panel) applied to the stock-recruitment relationship (red stippled line) and the estimated alternative (blue line); The y-axis of the lower panel is the bias adjustment fraction (Methot and Taylor 2011) in the model configuration.

Figure 3.C.8. Total commercial and recreational catch (panel A), continuous fishing mortality by fleet (continuous *F* by fleet; panel B upper plot), and the summary fishing mortality of all fleets combined (panel B lower plot) in the Stock Synthesis ATL sensitivity analysis model configuration; The summary fishing mortality is plotted as a ratio calculated as the total fishing mortality rate experienced by the population (F=Z-M) relative to F_{MSY} (F/ F_{MSY}); Error bars are the 95% asymptotic standard errors, ± 1.96*SE, obtained from Stock Synthesis output; Total catch includes both total commercial catch entered in Stock Synthesis in weight (mt) and total recreational catch (A + B1 + LPRM) entered in Stock Synthesis in numbers (thousands), as described above, and then converted internally within Stock Synthesis to weight (mt).

A.



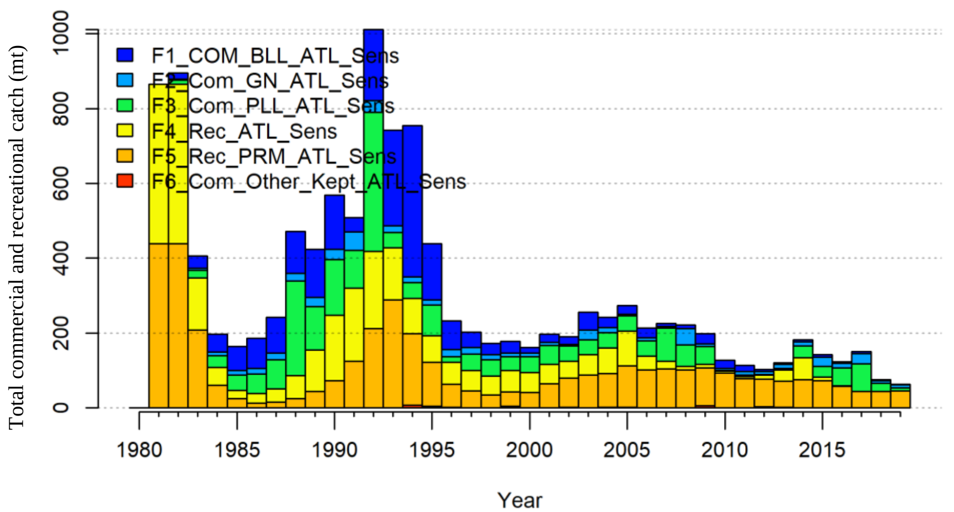


Figure 3.C.8. Continued.

B.

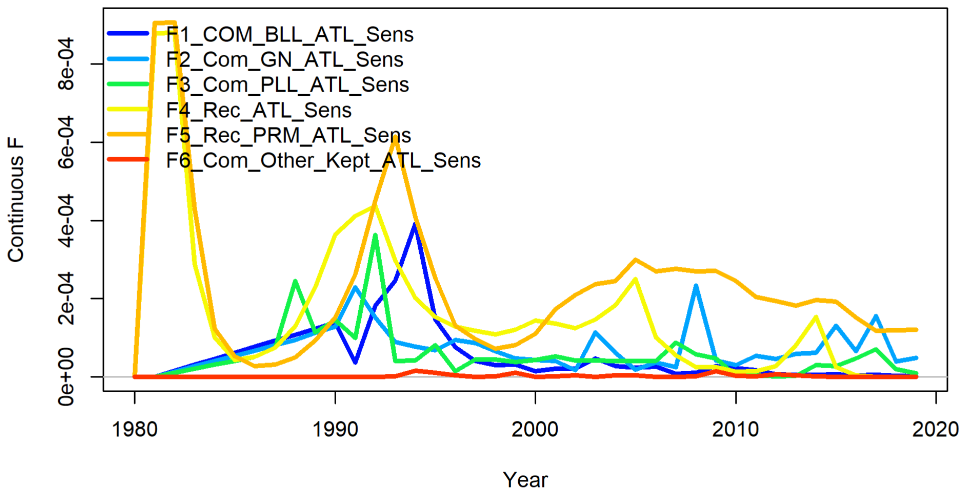


Figure 3.C.8. Continued.

3.13 Appendix 3.D Diagnostics Implemented for the Stock Synthesis (GOM + ATL) Continuity Analysis Model Configuration

3.D.1. Introduction

Multiple diagnostics (Carvalho et al. 2021; **Tables 3.D.1** and **Table 3.D.2;** e.g., Courtney et al. 2020) were implemented for the Stock Synthesis (GOM + ATL) continuity analysis model configuration, as described below.

3.D.2. Methods

3.D.2.1 Diagnostic-1 (Jitter)

A jitter test for global convergence (100 iterations) was implemented for the Stock Synthesis (GOM + ATL) continuity analysis model configuration. The jitter test for global convergence was implemented in Stock Synthesis (Methot and Wetzel 2013) utilizing the jitter feature described in detail within the Stock Synthesis manual (version 3.30.15; Methot et al. 2020) using a jitter fraction of 10% (0.1). The jitter feature was implemented in R (version 4.0.5; R Core Team 2021) using the r4ss function SS_RunJitter (r4ss version 1.42.1; Taylor et al. 2021a, 2021b).

3.D.2.2 Diagnostic-2 (Runs test of CPUE and mean length residuals)

A runs test (Carvalho et al. 2017, 2021) was applied to the residuals of each CPUE index fit in the Stock Synthesis model in order to quantitatively evaluate the randomness of the time-series of CPUE residuals by fleet. The diagnostic was implemented in R with functions available in ss3diags (Carvalho et al. 2021).

The runs test implemented in ss3diags (Carvalho et al. 2021) utilizes a nonparametric hypothesis test for randomness that calculates the 2-sided p-value of the Wald-Wolfowitz runs test. Additionally, time series data points further than three standard deviations away from the expected residual process average of zero (the ‘three-sigma limit’ for that series) are assumed to be unlikely given a random process error in the observed residual distribution (Anhøj and Olesen, 2014).

Runs test plots provided in ss3diags (Carvalho et al. 2021) utilize green shading to indicate no evidence ($p \geq 0.05$) and red shading to indicate evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. The shaded (green/red) area spans three residual standard deviations to either side from zero, and red points outside of the shading violate the ‘three-sigma limit’ for that series.

The runs test was also applied to the standardized residuals of the fit to length composition by fleet and year in order to quantitatively evaluate the randomness of the time-series of length composition residuals by fleet (Carvalho et al. 2017). Standardized residuals were obtained for each fleet using the Francis method (Carvalho et al. 2017, citing Punt 2017 their Table 2 equation 1.C; e.g., see Francis 2011, 2017). The diagnostic was implemented in R with functions available in ss3diags as applied to “mean length” (Carvalho et al. 2021).

3.D.2.3 Diagnostic-3 (Joint residual plots and RMSE of CPUE and mean length)

A joint residual plot (Winker et al. 2018; Carvalho et al. 2021) was applied to the Stock Synthesis (GOM + ATL) continuity analysis model configuration fits to time series of both CPUE indices and mean length. The diagnostic was adapted for Stock Synthesis and implemented in R with functions available in ss3diags (Carvalho et al. 2021).

The diagnostic includes several features (Winker et al. 2018; Carvalho et al. 2021): 1) Color coded lognormal residuals of observed versus predicted time series by fleet; 2) boxplots indicating the median and quantiles of all residuals available for any given year, with the area of each box indicating the strength of the discrepancy between time series (larger boxes indicate a higher degree of conflicting information); 3) a loess smoother through all residuals, which highlights systematically auto-correlated residual patterns; and 4) the root mean square error of all residuals combined (RMSEr; Carvalho et al. 2021), which describes the standard deviation of residuals and can be interpreted analogously to a standard error. A relatively small RMSEr ($\leq$ 0.3) is an indication of a relatively precise model fit to time series data (Winker et al. 2018). However, Carvalho et al. (2021) caution that observation error assumptions within an integrated assessment model can affect the resulting RMSEr and argue that, consequently, the RMSEr is not suitable to judge the goodness-of-fit across different time series in integrated assessments and should not be used for model selection purposes in isolation.

3.D.2.4 Diagnostic-4 (Log-likelihood component profiles for R_0)

An R_0 likelihood component profile (e.g., Carvalho et al. 2017, 2021) was applied to the Stock Synthesis (GOM + ATL) continuity analysis model configuration. The diagnostic was implemented by sequentially fixing the equilibrium recruitment parameter, R_0, on the natural log scale, log(R_0), to a range of values (3.5 to 5.0, step size of 0.1). This range included the parameter estimate obtained for log(R_0) from the original Stock Synthesis model run (4.29). The maximum likelihood estimates of all other model parameters in the R_0 likelihood component profile were obtained from Stock Synthesis output in the usual way by minimizing the negative of the log likelihood in AD Model Builder (ADMB; Fournier et al. 2011).

The relative change in negative log-likelihood units over the range of fixed values for log(R_0) (the R_0 profile) was compared among the Stock Synthesis model likelihood components for indices of relative abundance, length-compositions, and recruitment deviations using two diagnostic tests. First, a relatively large change in negative log-likelihood units along the R_0 profile was diagnostic of a relatively informative data source for that particular model. Second, a difference in the location of the minimum negative log-likelihood along the R_0 profile among data sources was diagnostic of either conflict in the data or model misspecification (or both).

The R_0 likelihood component profile utilized Stock Synthesis (Methot and Wetzel 2013) and the r4ss functions “SS_profile”, “SSplotProfile”, and “PinerPlot” (r4ss version 1.42.1; Taylor et al. 2021a, 2021b) implemented in R (version 4.0.5; R Core Team 2021; **Table 3.D.2**).

3.D.2.5 Diagnostic-5 (ASPM)

An age-structured production model (ASPM; Maunder and Piner 2015) was applied to the Stock Synthesis (GOM + ATL) continuity analysis model configuration. The ASPM was also applied with the recruitment deviates estimated (ASPMdev; Minte-Vera et al. 2017, 2021). The ASPM was implemented in R (**Table 3.D.2**) using the following workflow adapted from Carvalho et al. (2021) and Minte-Vera et al. (2017): (1) run the original full integrated Stock Synthesis model, (2) fix the selectivity parameters at the maximum likelihood estimates, MLEs, (3) fix the recruitment deviates equal to zero, (4) fit the resulting ASPM to the indices of abundance only, (5) repeat steps 1 – 4 but with recruitment deviates estimated (ASPMdev) and with the bias-correction factor for estimated recruitment deviations adjusted appropriately (Methot and Taylor 2011).

Trends in relative spawning stock size and 95% asymptotic confidence intervals were compared for the full integrated stock assessment model (reference model) and the ASPMs (ASPM and ASPMdev). On the one hand, Carvalho et al. (2017, 2021) note that if the ASPM is able to fit well to the indices of abundance that have good contrast (i.e. those that have declining and/or increasing trends), then this is evidence of the existence of a production function, and the indices will likely provide information about absolute abundance. On the other hand, Carvalho et al. (2017, 2021) note that if there is not a good fit to the indices, then the catch data alone cannot explain the trajectories depicted in the indices of relative abundance. This can have several causes: (i) the stock is recruitment-driven; (ii) the stock has not yet declined to the point at which catch is a major factor influencing abundance; (iii) the base-case model is incorrect; or (iv) the indices of relative abundance are not proportional to abundance.

3.D.2.6 Diagnostic-6 (Retrospective patterns and Mohn’s rho test)

The diagnostic was implemented here by sequentially eliminating the five most recent years of data from the full stock assessment model (a 5 year “peel”) and then re-estimating all stock assessment model parameters from each peel and from the full model. The Mohn’s rho statistic (Hurtado-Ferro et al. 2014; Carvalho et al. 2017) was calculated for ending year spawning stock size obtained from each peel relative to that obtained from the full model. Determining whether a given value of Mohn’s rho indicates that an assessment exhibits a retrospective pattern is subjective. We followed the rule of thumb proposed by Hurtado-Ferro et al. (2014), i.e., values of Mohn’s rho that fall outside the range (-0.15 to 0.20) can be interpreted as an indication of a retrospective pattern for long-lived species. In addition, the asymptotic 95% confidence intervals obtained for relative spawning stock size from each peel were compared to that of the full model.

3.D.2.7 Diagnostic-7 (Hindcasting cross validation)

In addition to determining if the model fits the historical data, it is important to evaluate whether the model can replicate the future dynamics of the system, which is required to provide management advice. One diagnostic for this is model prediction skill. Model prediction skill was diagnosed here with hindcasting precision (Kell et al. 2016). Prediction skill of the stock assessment model was evaluated using a hindcast (Kell et al. 2016), where each assessment model was retrospectively re-run by tail cutting, i.e. removing recent years' data and the biomass trajectories projected up to the most recent year.

The hindcasting cross-validation technique (HCXval; Kell et al. 2016) was implemented in ss3diags (Carvalho et al. 2021). In ss3diags, the HCXval implementation utilizes the same procedure of peeling the observations and refitting the model to the truncated data series as in retrospective analysis. Then, like retrospective forecasting, HCXval involves the additional steps of projecting forward (hindcasting), except that HCXval cross-validates the forecasts using the observations that were left out of the fit to the truncated time series in order to assess the model's prediction skill. The retrospective diagnostic, and consequently the HCXval diagnostic, were implemented here by sequentially eliminating the five most recent years of data from the full stock assessment model.

Hindcast results were summarized using the Mean Absolute Scaled Error (MASE, as described in Carvalho et al. 2021) which compares forecast accuracy to a "naïve" forecast equal to the last observation, i.e. a random walk. Values greater than one indicate that the average one-step ahead forecasts from the naïve method (a random walk) perform better than the average forecast values under consideration. MASE also penalizes positive and negative errors and errors in large forecasts and small forecasts equally.

3.D.2.8 Diagnostic-8 (MVLN Uncertainty for Stock Status)

A multivariate log-normal Monte-Carlo approach (MVLN; Winker et al 2019; e.g., Walter and Winker 2020) was applied to the Stock Synthesis (GOM + ATL) continuity analysis model configuration to estimate uncertainty about the stock status. The MVLN technique was implemented in ss3diags (Carvalho et al. 2021).

3.D.3. Results

3.D.3.1 Diagnostic-1 (Jitter)

The model passed this diagnostic. A total of 100 iterations of the jitter test for global convergence resulted in 79 jittered model runs with the same total likelihood value as the continuity analysis model configuration (894.3, reported as the negative natural log of the penalized likelihood), four jittered model runs with a lower total likelihood value (894.2), and 17 jittered model runs with a higher total likelihood value (895.0 to 911.2 likelihood units) (**Table 3.D.3** and **Figure 3.D.1**). The four jittered model runs with a lower total likelihood value (894.2) were similar to the continuity analysis model configuration total likelihood value (894.3) within rounding error. Similarly, the four jittered model runs with a lower total likelihood value and the continuity analysis model configuration resulted in similar model results for estimated parameters and their derived quantities (within rounding error) such as spawning output, fishing mortality, and age-0 recruits (**Figure 3.D.2**). Given that all model runs implemented within the jitter test for global convergence resulted in total likelihood values equal to or greater than the continuity analysis model configuration (894 likelihood units within rounding error), the jitter test did not provide evidence to reject the hypothesis that the continuity analysis model configuration parameter optimization converged to the global solution.

3.D.3.2 Diagnostic-2 (Runs test of CPUE and mean length residuals)

The results for this diagnostic were mixed. Runs test results applied to residuals from each CPUE index fit in the Stock Synthesis model are provided in **Table 3.D.4** (panel A) and **Figure 3.D.3**. There was evidence ($p < 0.05$) to reject the hypothesis of randomly distributed residuals for one survey CPUE index (S1_PLL_Obs) and two age-0 recruitment CPUE indices (R2_GULFSPAN_GNS, R3_COASTSPAN_BLLS). The remaining CPUE indices passed the diagnostic.

Runs test results applied to standardized residuals of the fit to length composition data by fleet are provided in **Table 3.D.4** (panel B) and **Figure 3.D.4**. There was evidence ($p < 0.05$) to reject the hypothesis of randomly distributed residuals for two time series (F3_Com_PLL and F4_Rec). The remaining length compostion data sets passed the diagnostic.

3.D.3.3 Diagnostic-3 (Joint residual plots and RMSE of CPUE and mean length)

The results for this diagnostic were mixed. Joint residual diagnostic plot results are provided for fits to CPUE and mean length in **Figures 3.D.5** and **3.D.6**, respectively. The overall model fit to CPUE was relatively imprecise (root mean square error of all residuals combined, RMSEr >> 0.3). In contrast, the overall model fit to mean length was relatively more precise (RMSEr < 0.3). There were also trends in overall residuals for fits to CPUE and mean length, indicated by a loess smoother through all residuals, except for age-0 mean length time series.

3.D.3.4 Diagnostic-4 (Log-likelihood component profiles for R_0)

The results for this diagnostic were mixed. R_0 likelihood component profile results are provided in **Figure 3.D.7**. First, there were similar changes in magnitude of the R_0 profiles for estimated recruitment deviations (Recruitment likelihood) compared to the data likelihood components for length composition (Length likelihood) and CPUE (Index likelihood). This result indicated that the estimation of the recruitment deviations, length composition, and CPUE were about equally informative within the likelihood. Additionally, there were relatively large changes in the magnitude of the R_0 profiles for two CPUE time series (S5_SEFSC_BLLS, R1_TXPED_GNS) and two length compositions (F1_COM_BLL, S5_SEFSC_BLLS) (surveys and fleets as defined in in the original Stock Synthesis model). This result indicated that these data sources were relatively more informative than the other data components included in the R_0 profile.

Second, differences in the location of the minimum value along the R_0 profile were observed among likelihood components for estimated recruitment deviations and the data likelihood components for indices of relative abundance and length-compositions. The location of the minimum negative log-likelihood along the R_0 profile for length composition and recruitment were similar (about 4.0). However, a minimum value was not identified for indices of relative abundance and the parameter estimate obtained for log(R_0) from the original Stock Synthesis model run (4.29) differed from the minimum log-likelihood R_0 profile for length composition and recruitment. These results indicate that there was conflict among the different components of the likelihood in the best estimate of R_0.

3.D.3.5 Diagnostic-5 (ASPM)

The results of this diagnostic were mixed. ASPM results are provided in **Figures 3.D.8 – 3.D.10**. The reference model and ASPM showed similar trends in total and relative spawning output. However the ASPM showed a larger total spawning stock size, a less steep decline in relative spawning stock size, and an earlier recovery in relative spawning stock (beginning in the early 2000s) compared to the full integrated stock assessment model. This result indicated that there was not enough information in catch and CPUE data alone (ASPM) to estimate the absolute scale and relative trend in spawning stock output.

The ASPM and ASPMdev showed similar trends in total and relative spawning output. However, the ASPMdev showed a later recovery in relative spawning stock (beginning between 2010 and 2015) and somewhat improved fits to important CPUE, consistent with the full integrated stock assessment model. This result indicated that recruitment estimates are driven, at least in part, by fits to CPUE.

3.D.3.6 Diagnostic-6 (Retrospective patterns and Mohn's rho test)

The model failed this diagnostic. Mohn's rho was calculated for spawning biomass peels (**Figure 3.D.11**). Severity of the retrospective pattern was based on the range provided by Hurtado-Ferro et al. (2015), with values higher than 0.20 and lower than -0.15 used as an indication for problematic retrospective patterns. Mohn's rho for the Stock Synthesis (GOM + ATL) continuity analysis model configuration (**Figure 3.D.11**) exhibited a retrospective pattern in recent years, with Mohn's rho values for spawning biomass 2.5. This result indicates that there is an apparent tendency to overestimate spawning biomass in recent years 2014, 2015, and 2016, but not 2017, and 2018.

3.D.3.7 Diagnostic-7 (Hindcasting cross validation)

The results of this diagnostic were mixed for CPUE time series. **Table 3.D.5** provides the mean absolute scaled error, MASE, score obtained from the HCXval diagnostic implemented by sequentially eliminating the five most recent years of data from the full stock assessment model (n_eval), if available, for each CPUE (panel A) and size composition (panel B) time series. Fits to CPUE and size composition 'pass' the HCXval diagnostic with a MASE or MASE.adj < 1. Predictions for CPUE time series (**Table 3.D.5** panel A and **Figure 3.D.12**) were all relatively flat (neither increasing nor decreasing within the hindcast evaluation period 2014 – 2018. Four CPUE indices failed the diagnostic and four CPUE indices passed the diagnostic. The most accurate CPUE index predictions were observed for S5_SEFSC_BLLS (MASE 0.5). Two CPUE series had insufficient observations (n < 5) within the hindcast evaluation period 2014 – 2018 to complete the diagnostic.

The model passed this diagnostic for mean length time series. Three length composition time series with complete observations (n = 5) within the hindcast evaluation period 2014 – 2018 passed the HCXval diagnostic (**Table 3.D.5** panel B and **Figure 3.D.13**). Predictions for length composition time series were also all relatively flat (neither increasing nor decreasing within the hindcast evaluation period 2014 – 2018. The most accurate length composition time series predictions were observed for R2_GULFSPAN_GNS and R4_COASTSPAN_LGNS (MASE.adj 0.4). Seven length composition time series had insufficient observations (n < 5) within the hindcast evaluation period 2014 – 2018 to complete the diagnostic.

3.D.3.8 Diagnostic-8 (MVLN Uncertainty for Stock Status)

The results for this diagnostic were mixed for stock status. A Kobe 2 plot obtained with multivariate log-normal Monte-Carlo, MVLN, indicated a narrow band of uncertainty characteristic of highly correlated derived paramters representing stock status (**Figure 3.D.14)**. Uncertianty obtained with MVLN for time series of derived paramters **Figure 3.D.15** was consistent with the 95% asymptotic standard errors, ± 1.96*SE, obtained from the original Stock Synthesis model output in the main document (**Section III Figures 3.8 and 3.9**).

3.D.4. Discussion

Selected model diagnostic results for the Stock Synthesis (GOM + ATL) continuity analysis model configuration are discussed below. Carvalho et al. (2017, 2021), Karp et al. (2022), and Punt (2023) review common diagnostics and their application. Carvalho et al. (2017) found that applying multiple diagnostics within a simulation study increased the likelihood of identifying model misspecification without a major increase in 'Type I error', i.e., incorrectly rejecting a correctly specified model. Consequently, Punt (2023) notes that it is generally best practice to apply a range of diagnostics. Punt (2023) also notes:

> "overall, a model would be considered adequate for providing management advice if the optimization was successful, the model fits the data adequately (e.g., based on residual analysis), the model provides reliable estimates of trends and scale, the results of the model are consistent when updated with new data (e.g., retrospective analysis), and the model is able to make adequate future predictions (e.g., hindcasting) (Carvalho et al., 2021)."

3.D.4.1 Diagnostic-4(Log-likelihood component profiles for R_0)

The R_0 profile is designed to identify conflict among likelihood components fit within an integrated stock assessment model relative to all of the assumptions made within that particular model. The equilibrium recruitment parameter, R_0, determines the absolute size (scale) of the population. Consequently, conflicts among likelihood components in the estimation of R_0 can have a large effect on model results depending upon the data weighting applied among the conflicting likelihood components in the model. If the data are assumed to be valid, then the expectation is that model development should continue until there are no data conflicts identified by the R_0 profile diagnostic. However, in practice this can be difficult to accomplish, in which case the diagnostic can be used to identify conflict among likelihood components and the possible implications of alternative data weighting applied among the conflicting likelihood components in the model.

A minimum value was not identified in the R_0 likelihood profile results for any of the indices of relative abundance (**Figure 3.D.7**). The lack of a minimum value in the R0 profile may have resulted from both the generally poor fit to indices of relative abundance and the time blocks imposed for some indices of relative abundance in the original Stock Synthesis model. A flat profile likelihood or a profile likelihood with its minimum value occurring at a bound (e.g., **Figure 3.D.7**, indices of relative abundance) suggests that there is an inability to estimate the parameter from any of the data sets and that the parameter should potentially be fixed (Karp et al. 2022). However, fixing the R_0 parameter in Stock Synthesis would be more appropriately implemented within a data poor modelling approach, e.g., Stock Synthesis Simple. Another approach may be to investigate alternative data sources or model configurations, for example with sensitivity analyses, to determine if either alternative model configurations or alternative data sources, result in a minimum value in the R_0 likelihood profile results for any of the indices of relative abundance.

The R_0 likelihood component profile results (**Figure 3.D.7**) indicate that there was conflict among the different data components of the likelihood (length composition and indices of relative abundance) in the best estimate of R_0. Data conflict in the model indicates that data weighting applied among the conflicting likelihood components may have a large effect on model results and, consequently, should be evaluated carefully (e.g., see Punt 2017). Data conflict was addressed in this assessment by "right weighting" the data following a Francis (2011) two-stage data weighting approach implemented in the original Stock Synthesis model configuration. The two-stage Francis approach implemented in the original Stock Synthesis model appeared to balance between the conflicting data components. However, the weighting approach did not eliminate the data conflict (**Figure 3.D.7**). In addition, the lack of a minimum value in the R_0 likelihood profile for any of the indices of relative abundance (**Figure 3.D.7**), combined with the generally poor model fit to indices of relative abundance, is inconsistent the "right weighting" data weighting philosophy, namely "do not let other data stop the model from fitting abundance data well" (e.g., see Francis 2011, 2017).

It is important to note that correctly specified stock assessment models generally require data that is typically lacking for most data poor species, such as sharks. For example, many of the relative abundance indices and size composition data available for this stock assessment had variably incomplete geographic coverage across fisheries and surveys, and the time series themselves suffered from low sample sizes and temporal inconsistencies in sampling design. However, diagnosing which of many confounded model processes lead to the data conflicts is difficult even for stock assessments of targeted species. In particular, the R_0 likelihood component profile by itself performed poorly as a diagnostic to identify model misspecification in a simulation study (Carvalho et al. 2017; e.g., Punt 2023). In contrast, Carvalho et al. (2017) note from the results of their simulation study that applying multiple carefully selected model diagnostics can increase the power to identify model misspecification without substantially increasing the probability of falsely concluding there is misspecification when the model is correctly specified.

3.D.4.2 Diagnostic-5 (ASPM)

The large asymptotic 95% confidence intervals of relative spawning stock size obtained for the ASPMs did not overlap the median relative spawning stock size obtained from the full integrated stock assessment model in recent years, indicating highly divergent results between the reference model and the ASPMs (**Figure 3.D.8**, lower panel). Consequently, the ASPM results indicate that the observed catches alone could not explain the trend in the indices of abundance and hence that the data available to the ASPM (i.e., the indices of abundance and the catch) did not provide enough information to estimate the scale of the population (e.g., see Punt 2023). The large asymptotic 95% confidence intervals of total and relative spawning output in the APSM results (**Figure 3.D.8**, lower and upper panels, respectively) also indicate that the ASPMs by themselves are not suitable for use in management.

The differences observed between the full integrated stock assessment model compared to the ASPMs (**Figure 3.D.8)** indicate that the fit to length composition data inform the estimated stock size. Consequently, as discussed in Minta-Vera et al. (2017), there is a trade-off within the fully integrated model between the fit to composition data (in general used to estimate recruitment) and the influence of fits to length composition on absolute abundance through a catch-curve type process. The tradeoff was addressed in this assessment by right weighting the data following A Francis (2011) two-stage data weighting approach implemented in the model configuration. However, results of the ASPM diagnostic, together with the results of the log-likelihood component profiles for R_0, as discussed above, are consistent and both indicate that the "right weighting" data weighting philosophy may not have been achieved, namely "do not let other data stop the model from fitting abundance data well" (e.g., see Francis 2011, 2017).

3.D.4.3 Diagnostic-7 (Hindcasting cross validation)

The hind-cast cross-validation diagnostic, HCXval, identified that four CPUE indices (S1_PLL_Obs, S3_Shark_BLL_Res, R2_GULFSPAN_GNS, and R3_COASTSPAN_BLLS) failed the diagnostic and four CPUE indices (S4_FSU_BLLS, S5_SEFSC_BLLS, R1_TXPWD_GNS, R4_COASTSPAN_LGNS) passed the diagnostic (**Table 3.D.4** panel A**, Figure 3.D.12**). As discussed above, fits to CPUE and size composition 'pass' the HCXval diagnostic with a MASE or MASE.adj < 1. The most accurate CPUE index predictions were observed for S5_SEFSC_BLLS (MASE 0.5).

In contrast, the HCXval diagnostic identified that three length composition data sets (F1_COM_BLL, R2_GULFSPAN_GNS, and R4_COASTSPAN_LGNS) passed the diagnostic (**Table 3.D.4** panel B**, Figure 3.D.13**). The most accurate length composition time series predictions were observed for R2_GULFSPAN_GNS and R4_COASTSPAN_LGNS (MASE.adj 0.4).

CPUE indices which failed the diagnostic had poor prediction skill. An explanation for poor prediction skill may be that either the indices are not proportional to relative abundance or that there are processes that are not being accounted for in the model structure. For example, in the latter case, fits to length composition may be driving trends in abundance. This interpretation is consistent with the R_0 likelihood component profile, which indicated that the minimum R_0

profile of the population is driven by fit to fit to length composition data and that there is conflict in the minimum likelihood for the R_0 profile between data components. This interpretation is also consistent with the ASPM results, which indicate that the observed catches alone could not explain the trend in the indices of abundance and hence that the data available to the ASPM (i.e., the indices of abundance and the catch) did not provide enough information to estimate the scale of the population. This interpretation could be investigated further by considering a range of scenarios based on alternative datasets and model structures. Hindcasting could then be used to identify the best performing scenarios (e.g., choice of models and data which inform abundance from CPUE data and inform recruitment from length composition data) by comparing predictions with observations in the updated models with updated hind-cast cross-validation.

Tables

Table 3.D.1. Summary of diagnostics results for the Stock Synthesis (GOM + ATL) continuity analysis model configuration: 1) green, model passed diagnostic; 2) yellow, model diagnostic provided mixed results; and 3) red, model failed diagnostic.

Diagnostic-1 (Jitter)
The model passed this diagnostic.

Diagnostic-2 (Runs test of CPUE and mean length residuals)
The results for this diagnostic were mixed.

Diagnostic-3 (Joint residual plots and RMSE of CPUE and mean length)
The results for this diagnostic were mixed.

Diagnostic-4 (Log-likelihood component profiles for R_0)
The results for this diagnostic were mixed.

Diagnostic-5 (ASPM)
The results of this diagnostic were mixed.

Diagnostic-6 (Retrospective patterns and Mohn's Rho test)
The model failed this diagnostic.

Diagnostic-7 (Hindcasting cross validation)
The results for this diagnostic were mixed for CPIE indices.
The model passed this diagnostic for mean length time series.

Diagnostic-8 (MVLN Uncertainty for Stock Status)
The results for this diagnostic were mixed for stock status.

Table 3.D.2. Software (and versions) used for diagnostics.

Diagnostic	R[1]	Repository-code[2]	r4ss[3]	Stock Synthesis[4]
Diagnostics 1-4,9	R (version 4.0.5)	ss3diags	version 1.42.0	(version 3.30.15)
Diagnostic 5-8	R (version 4.0.5)	r4ss	version 1.42.0	(version 3.30.15)

[1] R (R Core Team 2021). Available: https://www.R-project.org (Version 4.0.5).
[2] R code for Stock Synthesis version 3 diagnostics (ss3diags; Carvalho et al. 2021). Available https://github.com/PIFSCstockassessments/ss3diags (Accessed ~2/16/2022);
See http://www.capamresearch.org/content/diagnostics-workshop-presentations
"The value of diagnostics in stock assessment, Felipe Carvalho and Henning Winker" www.capamresearch.org/sites/default/files/IATTC_Workshop_Final_Felipe.pdf.
[3] R code for Stock Synthesis (r4ss; Taylor et al. 2021a, 2021b). Available: https://github.com/r4ss/r4ss (Version 1.42.0).
[4] Stock Synthesis (Methot and Wetzel 2013; Methot et al. 2020). Available: https://github.com/nmfs-stock-synthesis/stock-synthesis/releases (Version 3.30.15).

Table 3.D.3. Jitter results for global convergence (100 iterations) obtained as described above for the Stock Synthesis (GOM + ATL) continuity analysis model configuration.

	Likelihood	Frequency
1	894.2[1]	4
2	894.3[2]	79
3	895.0	3
4	895.3	2
5	895.4	10
6	900.5	1
7	911.2	1
	Total	100

[1]Min 894.2
[2]Continuity analysis model configuration 894.3

Table 3.D.4. Runs tests results for the Stock Synthesis (GOM + ATL) continuity analysis model configuration CPUE index fit residuals and mean length standardized residuals; P-values indicate no evidence ($p \geq 0.05$; Passed) and evidence ($p < 0.05$; Failed), respectively, to reject the hypothesis of a randomly distributed time-series of residuals. Points outside three residual standard deviations to either side from zero, sigma3.lo and sigma3.hi, violate the 'three-sigma limit' for that series.

A. CPUE indices

Index	p-value	test	sigma3.lo	sigma3.hi	type
S1_PLL_Obs	0.028	Failed	-1.40326291	1.40326291	cpue
S2_Shark_BLL_Obs	0.532	Passed	-1.94279929	1.94279929	cpue
S3_Shark_BLL_Res	0.5	Passed	-0.89411324	0.89411324	cpue
S4_FSU_BLLS	0.888	Passed	-2.51109178	2.51109178	cpue
S5_SEFSC_BLLS	0.35	Passed	-1.00081145	1.00081145	cpue
R1_TXPWD_GNS	0.283	Passed	-2.35734546	2.35734546	cpue
R2_GULFSPAN_GNS	0.029	Failed	-1.0455668	1.0455668	cpue
R3_COASTSPAN_BLLS	0.013	Failed	-1.42317283	1.42317283	cpue
R4_COASTSPAN_LGNS	0.174	Passed	-2.28860875	2.28860875	cpue
R5_COASTSPAN_SGNS	0.656	Passed	-2.3921328	2.3921328	cpue

B. Length composition

Index	P-value	test	sigma3.lo	sigma3.hi	type
F1_COM_BLL	0.419	Passed	-0.24363421	0.24363421	len
F2_Com_GN	NA	Excluded	NA	NA	len
F3_Com_PLL	0.001	Failed	-0.07536178	0.07536178	len
F4_Rec	0.001	Failed	-0.59935541	0.59935541	len
S4_FSU_BLLS	NA	Excluded	NA	NA	len
S5_SEFSC_BLLS	0.8	Passed	-0.11246806	0.11246806	len
R1_TXPWD_GNS	0.978	Passed	-0.25291126	0.25291126	len
R2_GULFSPAN_GNS	0.79	Passed	-0.09893599	0.09893599	len
R3_COASTSPAN_BLLS	0.736	Passed	-0.06498071	0.06498071	len
R4_COASTSPAN_LGNS	0.673	Passed	-0.09657717	0.09657717	len

Table 3.D.5. The mean absolute scaled error (MASE) score obtained from the HCXval diagnostic implemented by sequentially eliminating the five most recent years of data from the full Stock Synthesis (GOM + ATL) continuity analysis model configuration (n_eval), if available, for each CPUE (panel A) and size composition (panel B) time series; The MASE score scales the mean absolute error (MAE) of forecasts (i.e., prediction residuals, MAE.PR) to the MAE of a naïve in-sample prediction MAE.base, log(y[t+1])-log(y[t]), such that MASE = MAE.PR/MAE.base; The MASE score was adjusted in ss3diags for series which showed very little inter-annual variation among observations (baseline MAE for the naïve predictions < 0.1) by setting MAE.base.adj = 0.1 and calculating MASE.adj = MAE.PR/MAE.base.adj. The rational for this adjustment was that less variable and thus more informative indices required higher prediction accuracy than noisy and less influential CPUE indices to 'pass' with a MASE < 1.

A. CPUE indices

CPUE index		MASE	MAE.PR	MAE.base	MASE.adj	n.eval
S1_PLL_Obs	Fail	1.460	0.653	0.447	1.460	5
S2_Shark_BLL_Obs	n < 5	NA	NA	NA	NA	0
S3_Shark_BLL_Res	Fail	1.022	0.372	0.364	1.022	5
S4_FSU_BLLS	Pass	0.838	0.763	0.911	0.838	5
S5_SEFSC_BLLS*	Pass	0.488	0.197	0.405	0.488	5
R1_TXPWD_GNS	Pass	0.884	0.957	1.084	0.884	5
R2_GULFSPAN_GNS	Fail	1.293	0.526	0.407	1.293	5
R3_COASTSPAN_BLLS	Fail	2.205	1.111	0.504	2.205	5
R4_COASTSPAN_LGNS	Pass	0.838	0.586	0.699	0.838	5
R5_COASTSPAN_SGNS	n < 5	0.735	1.154	1.570	0.735	2

*The most accurate CPUE index predictions were observed for S5_SEFSC_BLLS (MASE 0.5).

B. Length composition

Length composition		MASE	MAE.PR	MAE.base	MASE.adj	n.eval
F1_COM_BLL	Pass (adj)	1.494	0.066	0.044	0.664	5
F2_Com_GN	n < 5	NA	NA	NA	NA	0
F3_Com_PLL	n < 5	NA	NA	NA	NA	0
F4_Rec	n < 5	NA	NA	NA	NA	0
S4_FSU_BLLS	n < 5	NA	NA	NA	NA	0
S5_SEFSC_BLLS	n < 5	2.442	0.053	0.022	0.532	3
R1_TXPWD_GNS	n < 5	0.866	0.085	0.098	0.848	1
R2_GULFSPAN_GNS*	Pass (adj)	1.069	0.044	0.041	0.436	5
R3_COASTSPAN_BLLS	n < 5	1.476	0.028	0.019	0.280	2
R4_COASTSPAN_LGNS*	Pass (adj)	1.110	0.039	0.036	0.394	5

*The most accurate length composition time series predictions were observed for R2_GULFSPAN_GNS and R4_COASTSPAN_LGNS (MASE.adj 0.4).

Figures

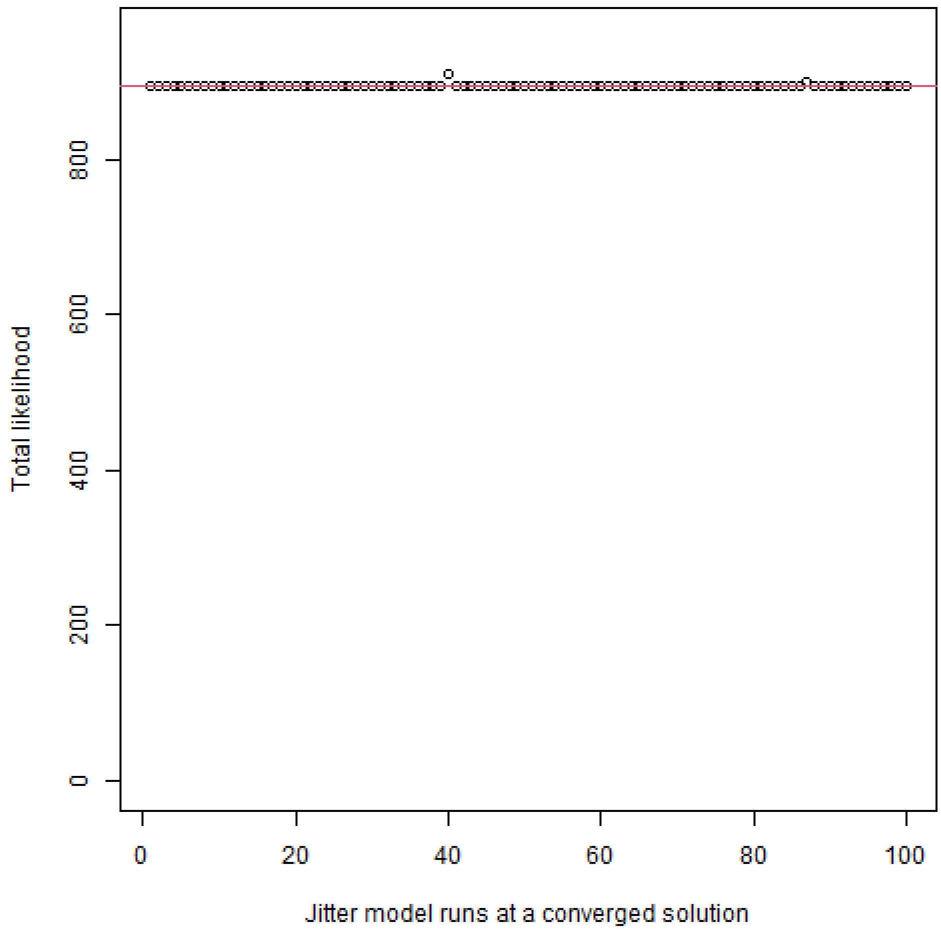


Figure 3.D.1. Total likelihood results of a jitter test for global convergence (100 iterations) implemented for the Stock Synthesis (GOM + ATL) continuity analysis model configuration; The horizontal line represents the total likelihood of the continuity analysis model configuration as described above (894.3, likelihood units are the negative natural log of the penalized likelihood); Open circles represent the 79 jittered model runs with the same total likelihood value as the continuity analysis model configuration (894.3), the 4 jittered model runs with a lower total likelihood value (894.2) and the 17 jittered model runs with a higher total likelihood value (895.0 to 911.2 likelihood units).

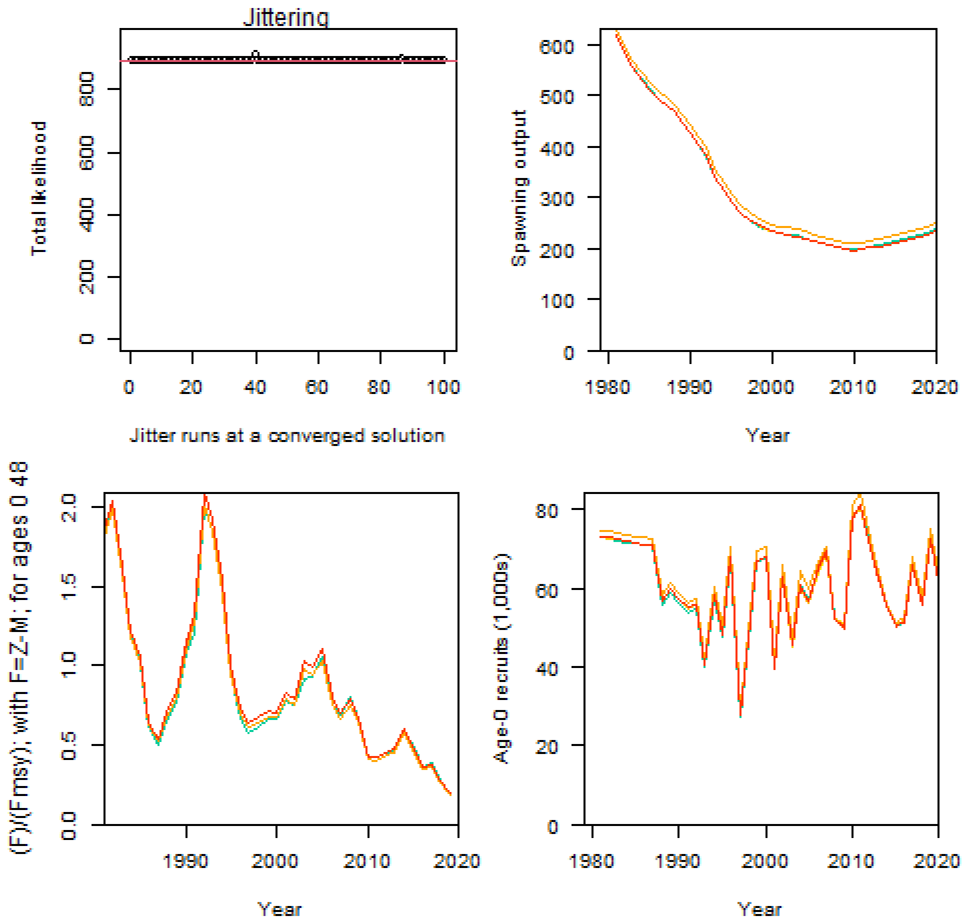


Figure 3.D.2. Total likelihood results of a jitter test for global convergence (100 iterations) implemented for the Stock Synthesis (GOM + ATL) continuity analysis model configuration (upper left) along with spawning output (spawning stock fecundity thousands, upper right), *F* ratio (lower left panel), and age-0 recruits (thousands, lower right panel).

A.

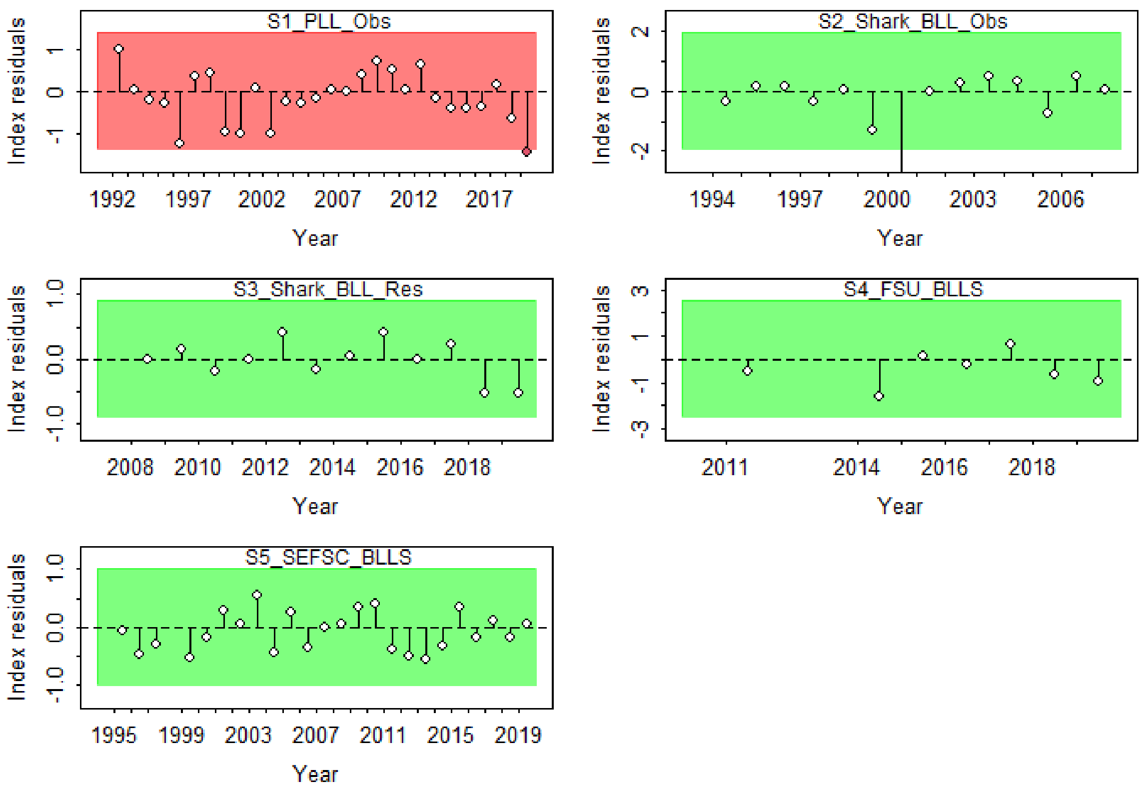


Figure 3.D.3. Runs tests for the Stock Synthesis (GOM + ATL) continuity analysis model configuration fits to CPUE indices (panel A) and age-0 recruitment CPUE indices (panel B); Fleets as defined in the (GOM + ATL) continuity analysis model configuration; Green shading indicates no evidence ($p \geq 0.05$) and red shading to indicate evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. The shaded (green/red) area spans three residual standard deviations to either side from zero, and red points outside of the shading violate the 'three-sigma limit' for that series.

B.

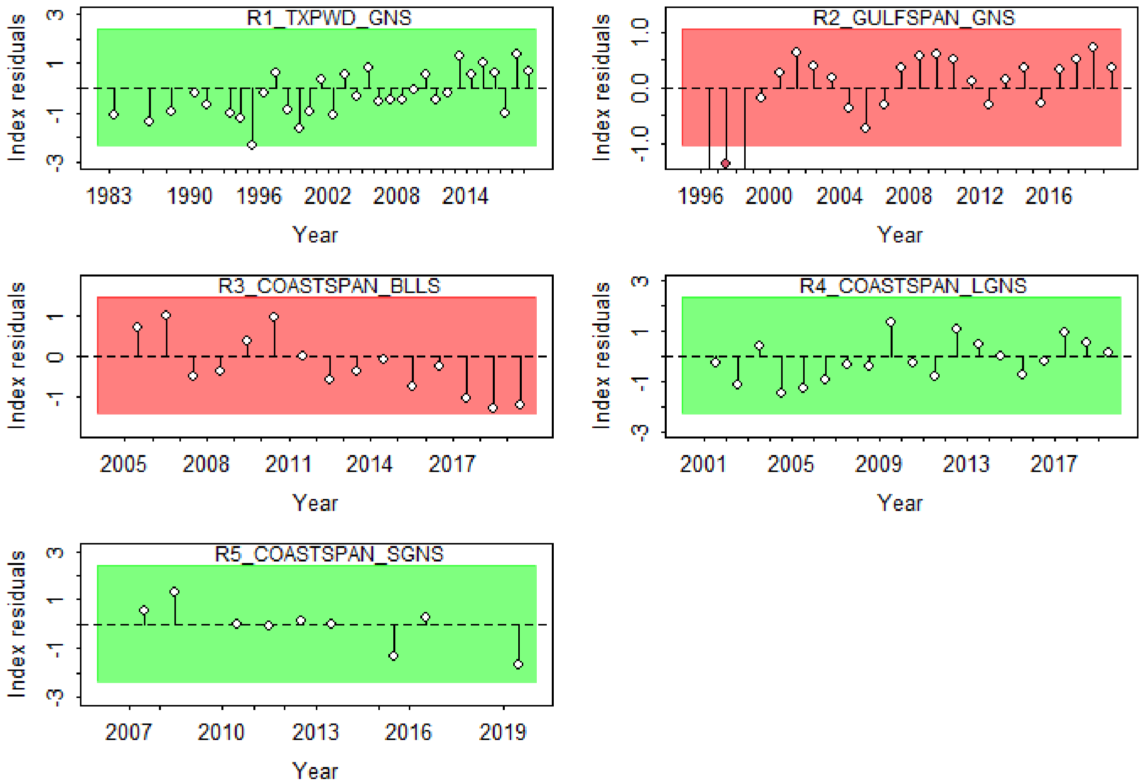


Figure 3.D.3. Continued.

A.

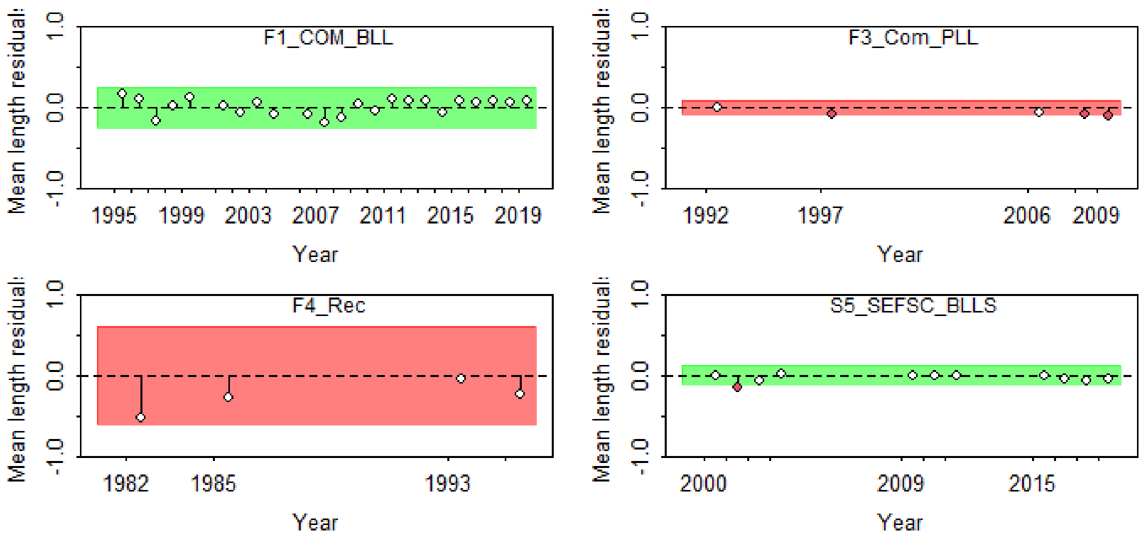


Figure 3.D.4. Runs tests for the Stock Synthesis (GOM + ATL) continuity analysis model configuration mean length standardized residuals (panel A) and age-0 recruitment mean length standardized residuals (panel B); Fleets as defined in the (GOM + ATL) continuity analysis model configuration; Green shading indicates no evidence ($p \geq 0.05$) and red shading to indicate evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. The shaded (green/red) area spans three residual standard deviations to either side from zero, and red points outside of the shading violate the 'three-sigma limit' for that series.

B.

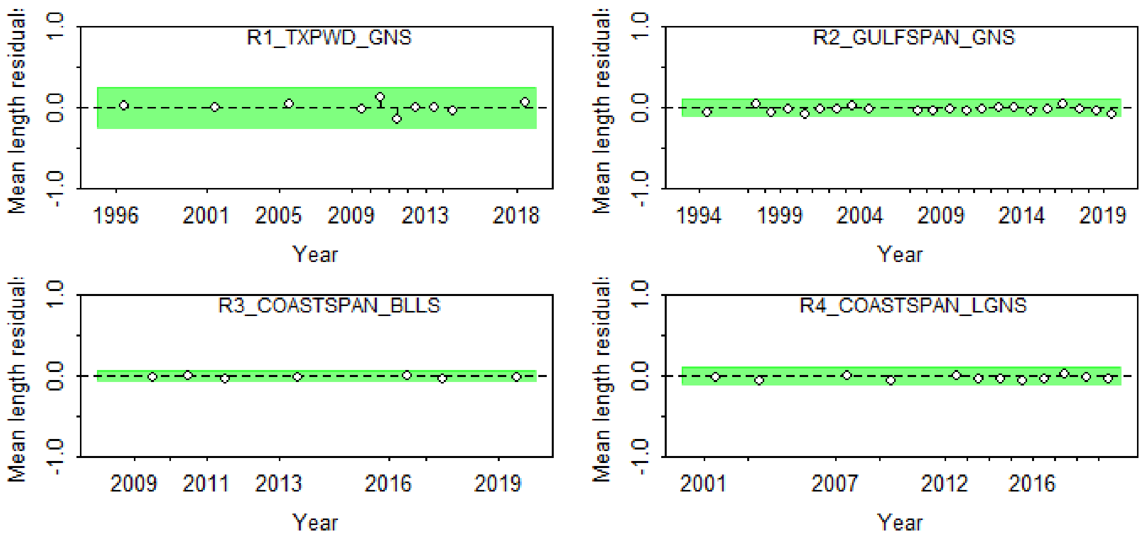


Figure 3.D.4. Continued.

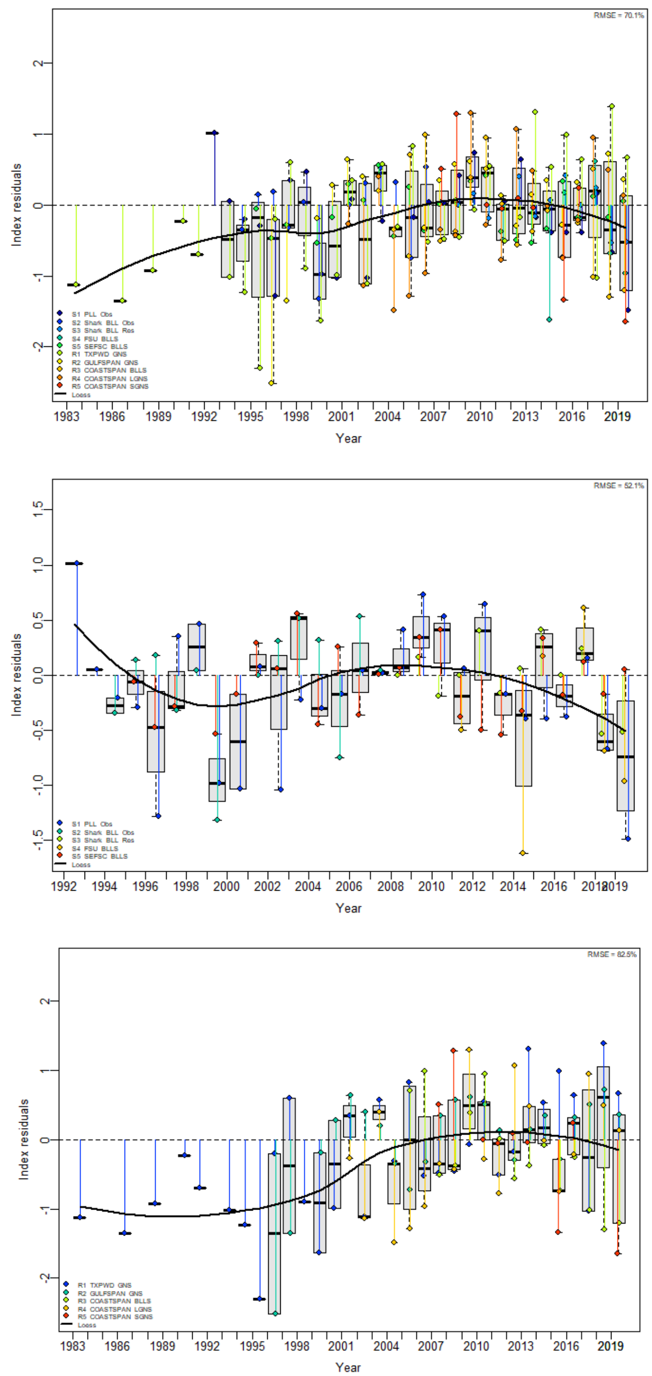


Figure 3.D.5. Joint residual diagnostic plots for the Stock Synthesis (GOM + ATL) continuity analysis model configuration fits to all CPUE time series (upper panel), age 1+ CPUE time series (middle panel), and age-0 CPUE time series (lower panel); Surveys as defined in the (GOM + ATL) continuity analysis model configuration; Boxplots and RMSE as described in the methods section above.

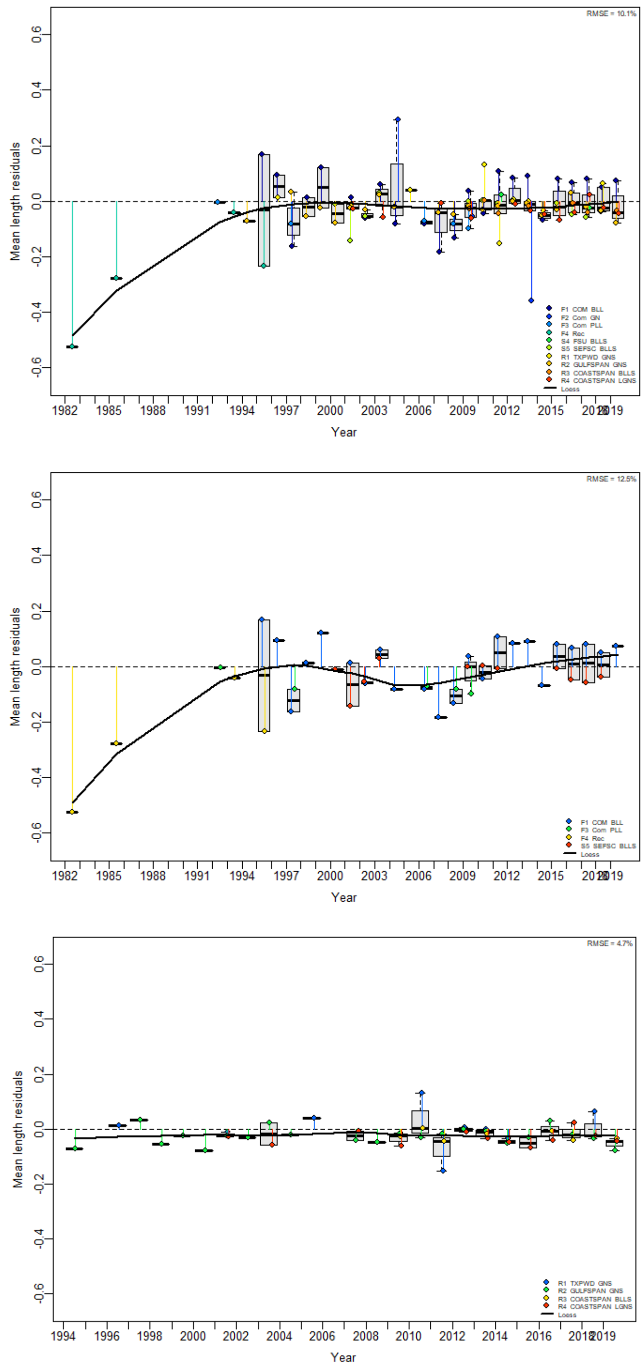


Figure 3.D.6. Joint residual diagnostic plots for the Stock Synthesis (GOM + ATL) continuity analysis model configuration fits to all mean length time series (upper panel), age 1+ mean length time series (middle panel), and age-0 mean length time series (lower panel); Length composition time series as defined in assessment; Boxplots and RMSE as described in the methods section above.

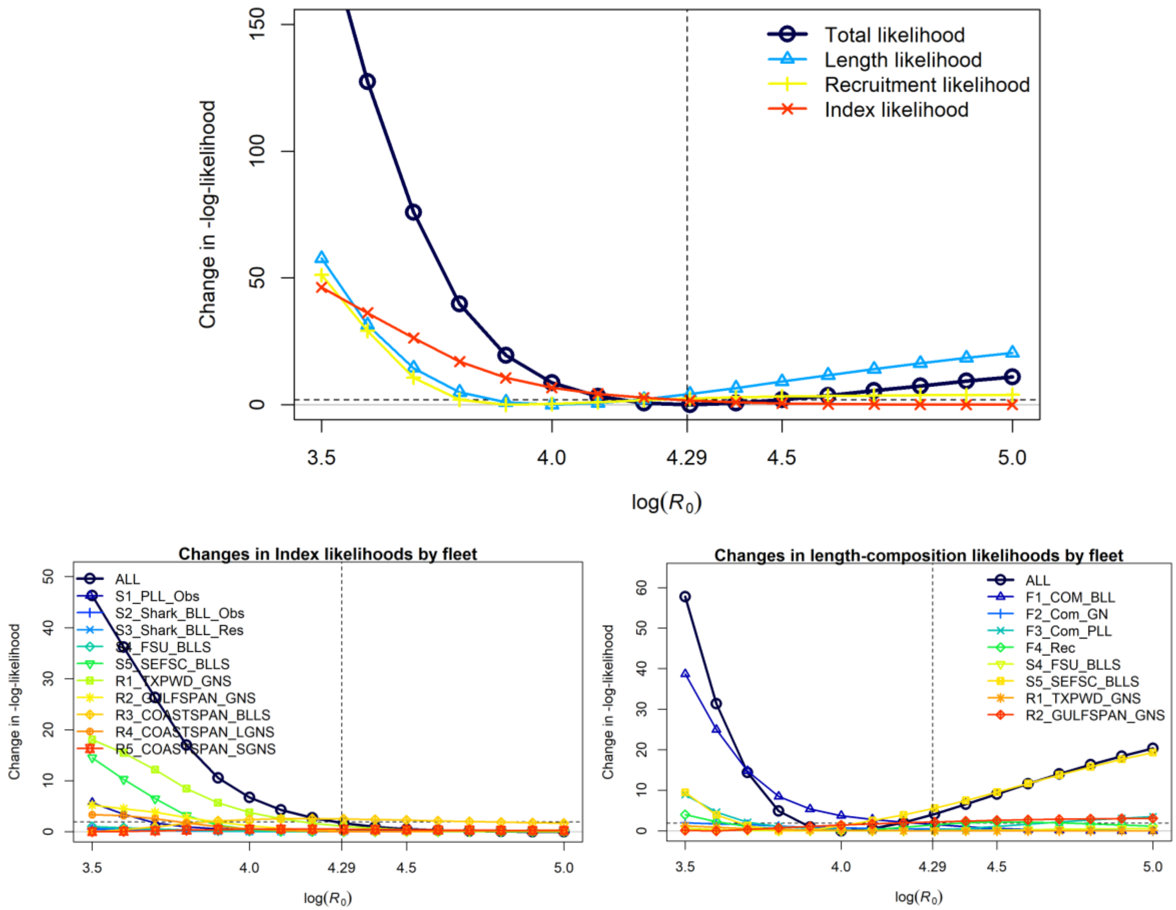


Figure 3.D.7. R_0 likelihood component profiles applied to the Stock Synthesis (GOM + ATL) continuity analysis model configuration results; Fleets as defined in original model; Vertical dashed line is the parameter estimate obtained for $\log(R_0)$ from the original Stock Synthesis model run (4.29); Values that fall within the 95% confidence interval (chi-square, horizontal dashed line) are considered supported by the data (Karp et al. 2022).

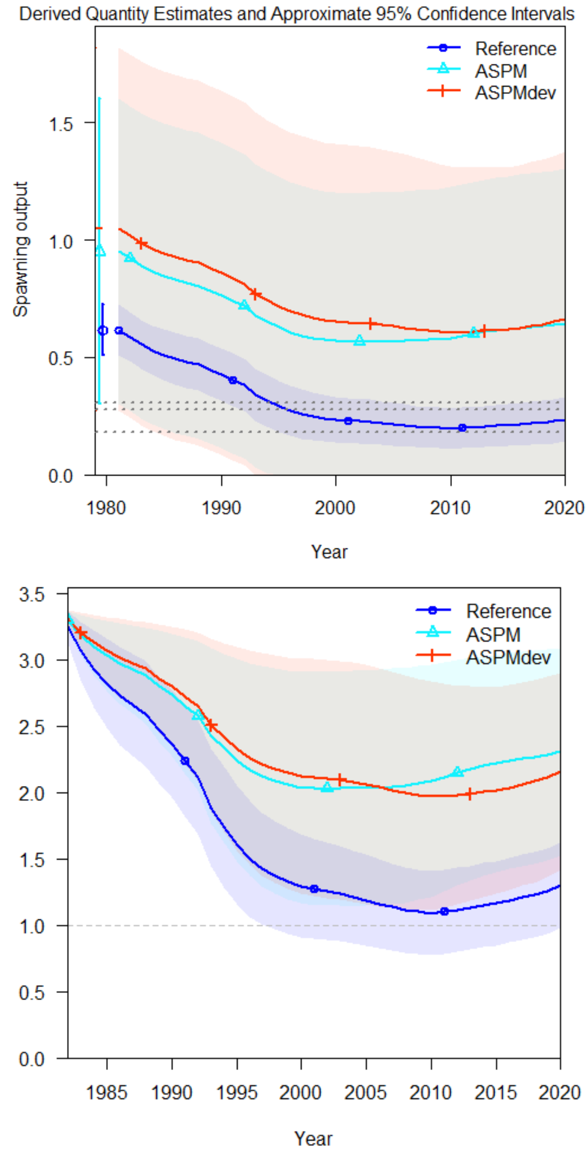


Figure 3.D.8. Trends in total (upper panel) and relative (lower panel) spawning output and 95% asymptotic confidence intervals for the Stock Synthesis (GOM + ATL) continuity analysis model configuration (reference model) and the ASPMs (ASPM and ASPMdev); Spawning output is pups produced per female (spawning stock fecundity, SSF in millions) relative to SSF at equilibrium MSY (stippled lines).

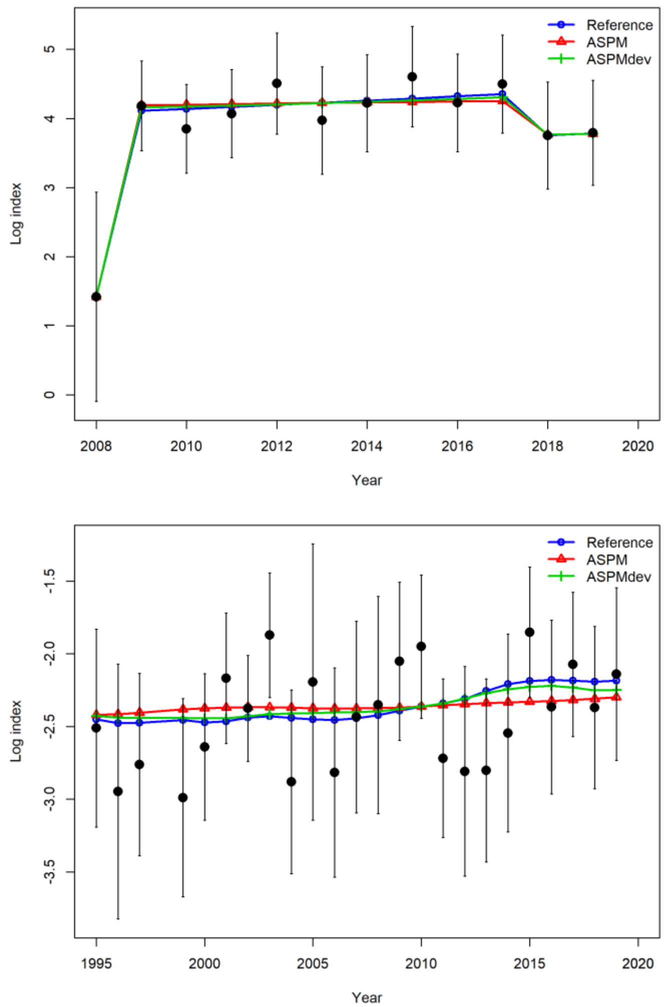


Figure 3.D.9. Observed (black circles with error bars) and predicted values for S3 Shark BLL Res CPUE (upper panel) and S5 SEFSC BLLS CPUE (lower panel) for the Stock Synthesis (GOM + ATL) continuity analysis model configuration (reference model) and the ASPMs (ASPM and ASPMdev); Indices are plotted (and fit) on the natural log scale.

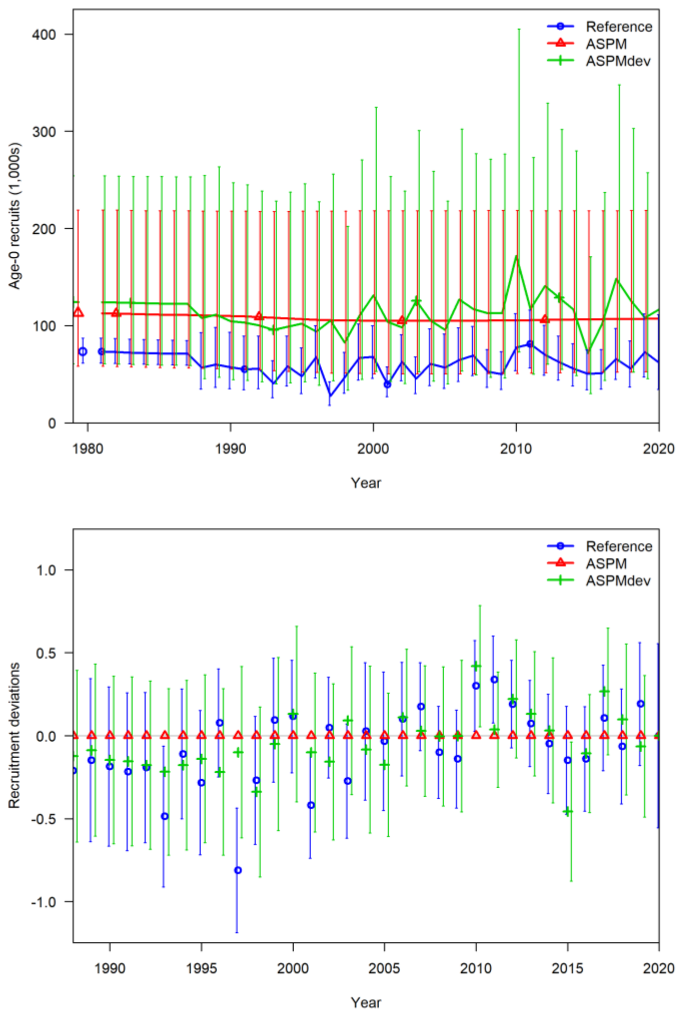


Figure 3.D.10. Age-0 recruitment (upper panel), recruitment deviations (lower panel) and 95% asymptotic confidence intervals for the Stock Synthesis (GOM + ATL) continuity analysis model configuration (reference model) and the ASPMs (ASPM and ASPMdev).

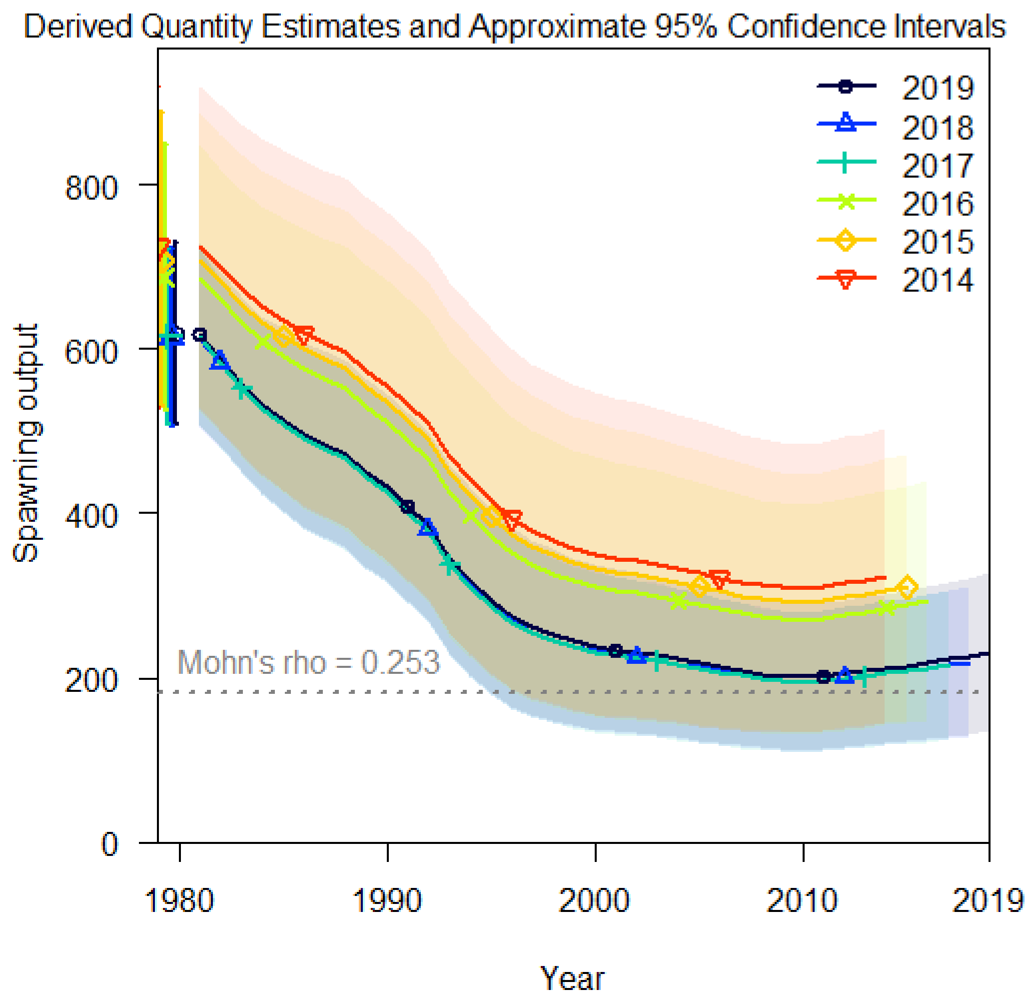


Figure 3.D.11. Retrospective analysis of spawning output for the Stock Synthesis (GOM + ATL) continuity analysis model configuration; Spawning output is spawning stock fecundity (SSF) in units of millions of pups produced; The stippled line is SSF at MSY; The Mohn's rho statistic is provided for the five year peel.

A.

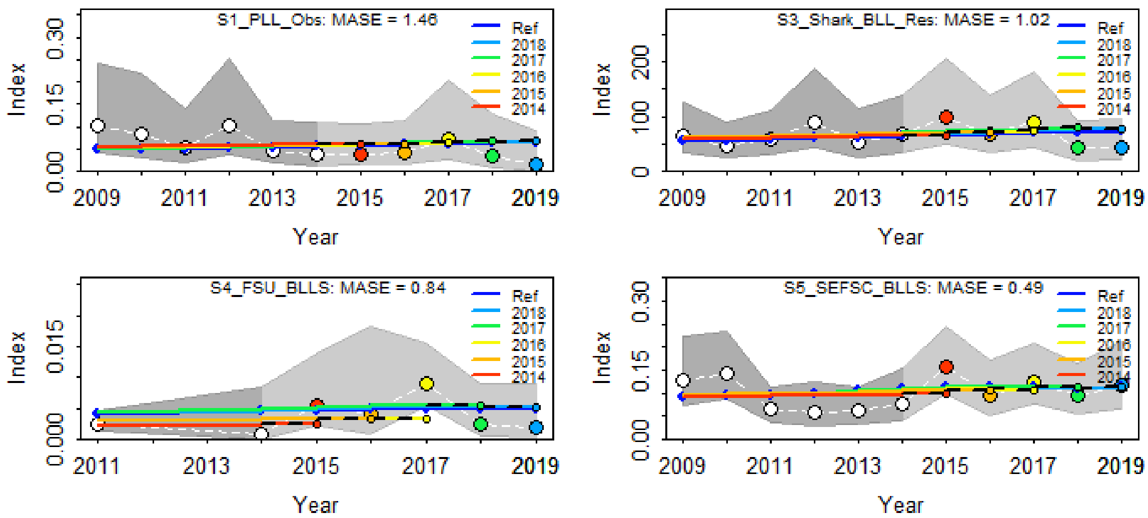


Figure 3.D.12. Hindcasting cross-validation (HCxval) results for the Stock Synthesis (GOM + ATL) continuity analysis model configuration fits to all age (panel A) and age 0 (panel B) CPUE indices; Fleets as defined in the (GOM + ATL) continuity analysis model configuration; Plots show observed (large points connected with dashed line), fitted (solid lines) and one-year ahead forecast values (small terminal points); HCxval was performed using one reference model (Ref) and five hindcast model runs (solid lines) relative to the expected catch-per-unit effort (CPUE) [or size composition time series]. The observations used for cross validation are highlighted as color-coded solid circles with associated 95 % confidence intervals (light-gray shading). The model reference year refers to the endpoints of each one-year-ahead forecast and the corresponding observation (i.e., year of peel + 1); The mean absolute scaled error (MASE) score associated with each CPUE [or size composition time series] is denoted in each panel.

B.

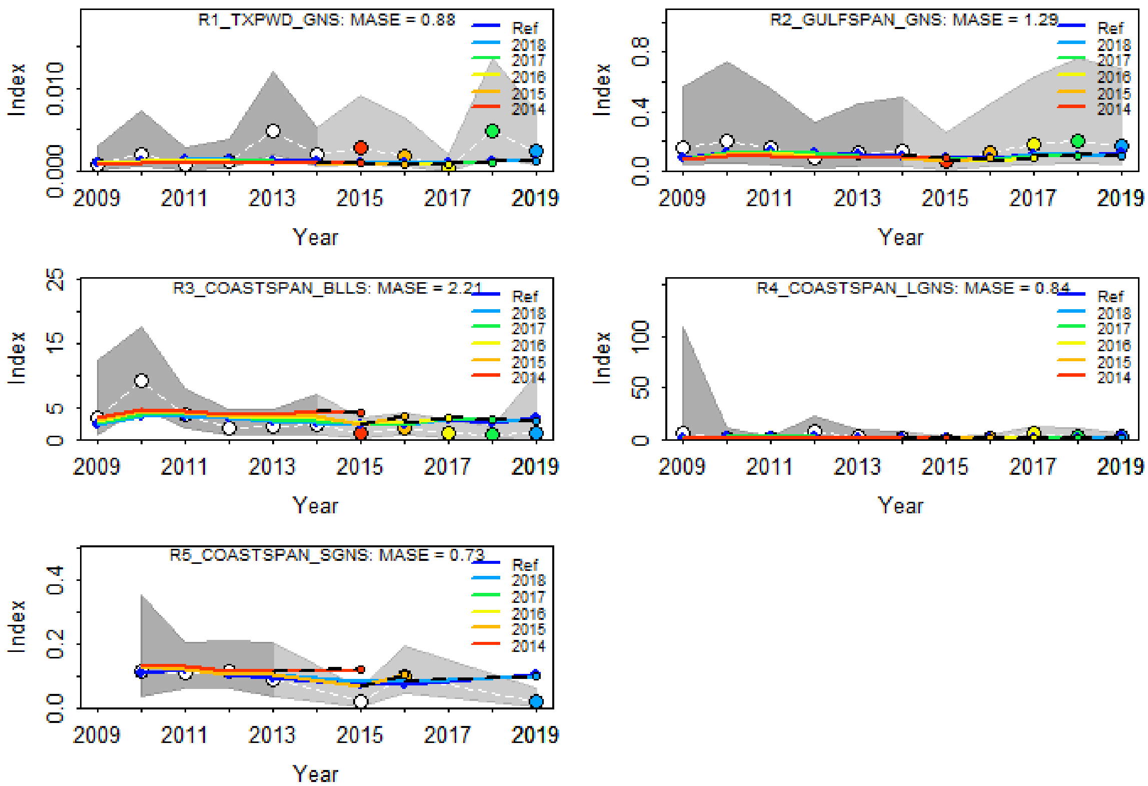


Figure 3.D.12. Continued.

A.

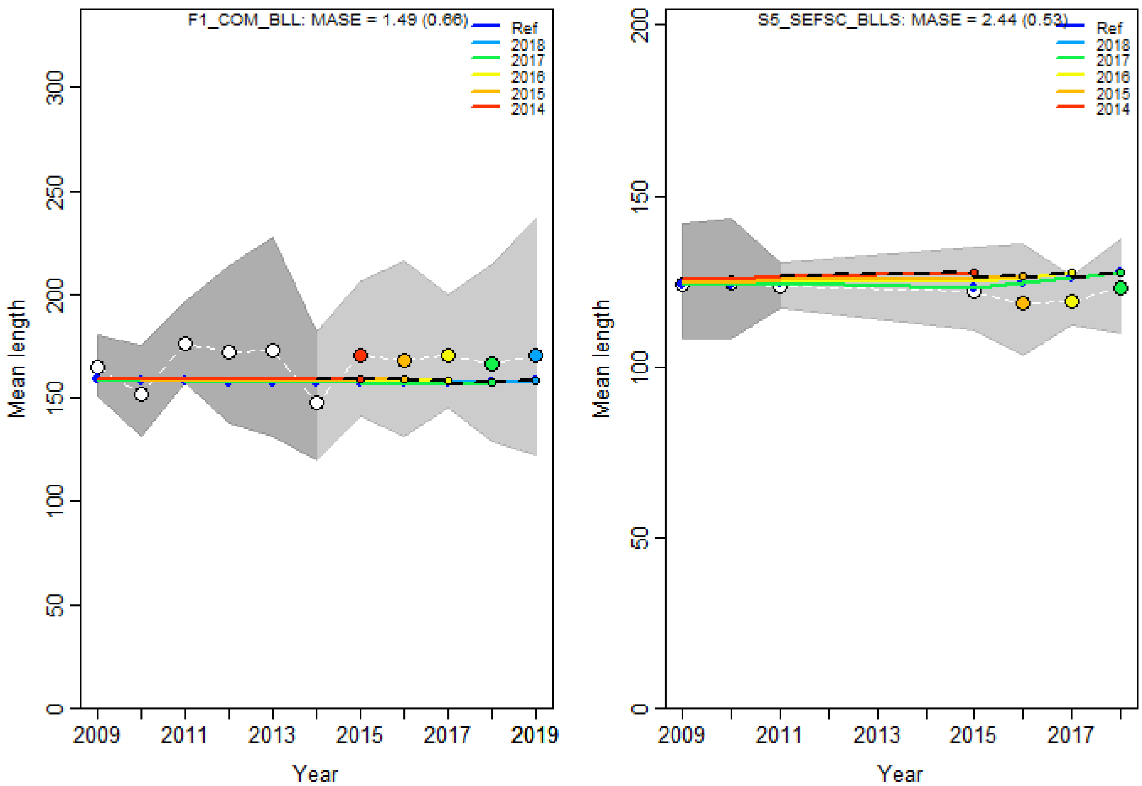


Figure 3.D.13. Hindcasting cross-validation (HCxval) results for the Stock Synthesis (GOM + ATL) continuity analysis model configuration fits to all age (panel A) and age 0 (panels B and C) size composition time series; Fleets as defined in the (GOM + ATL) continuity analysis model configuration; Plots show observed (large points connected with dashed line), fitted (solid lines) and one-year ahead forecast values (small terminal points); HCxval was performed using one reference model (Ref) and five hindcast model runs (solid lines) relative to the expected size composition time series. The observations used for cross validation are highlighted as color-coded solid circles with associated 95 % confidence intervals (light-gray shading). The model reference year refers to the endpoints of each one-year-ahead forecast and the corresponding observation (i.e., year of peel + 1); The mean absolute scaled error (MASE) score and the adjusted MASE score (in parentheses if provided) associated with each size composition time series is denoted in each panel.

B.

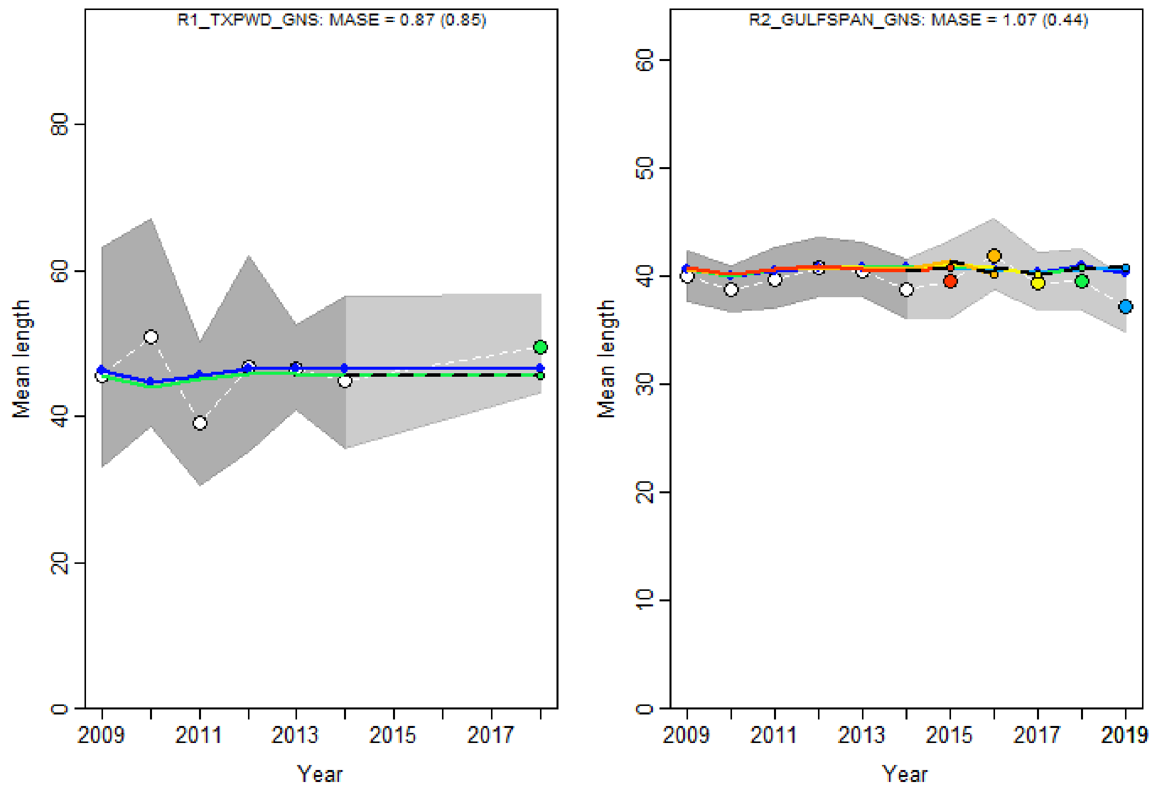


Figure 3.D.13. Continued.

C.

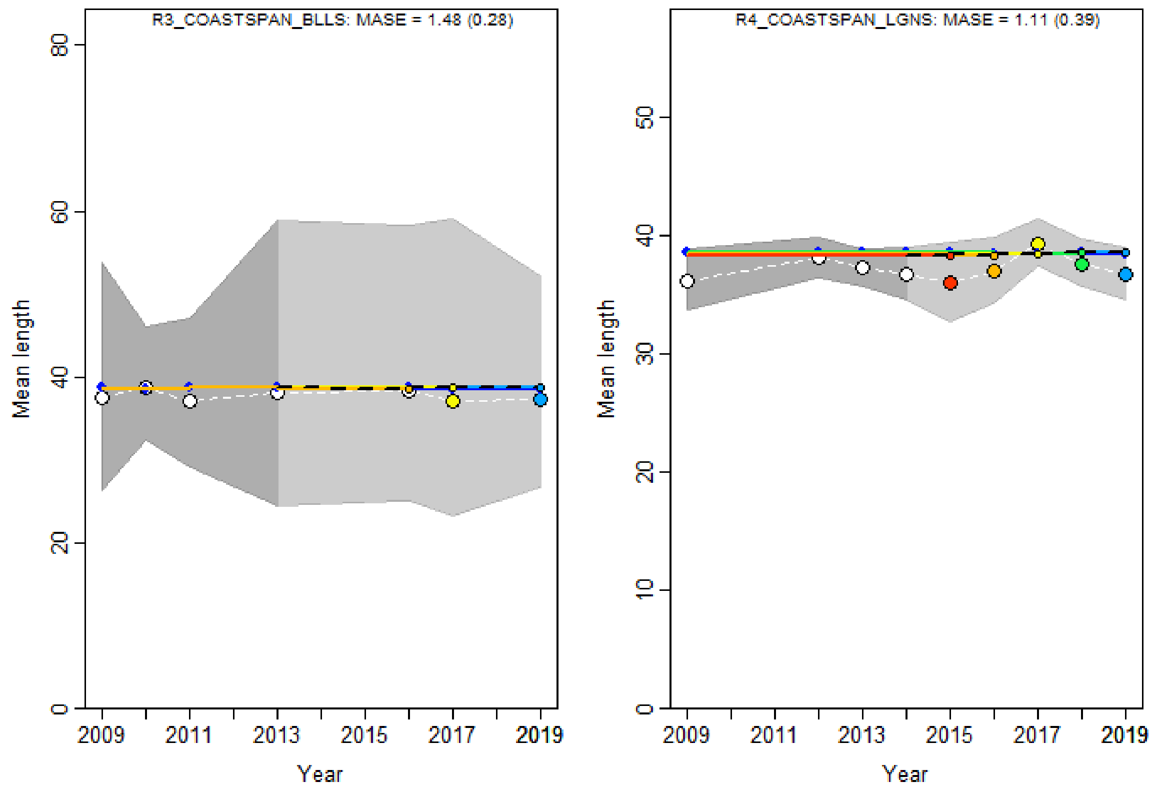


Figure 3.D.13. Continued.

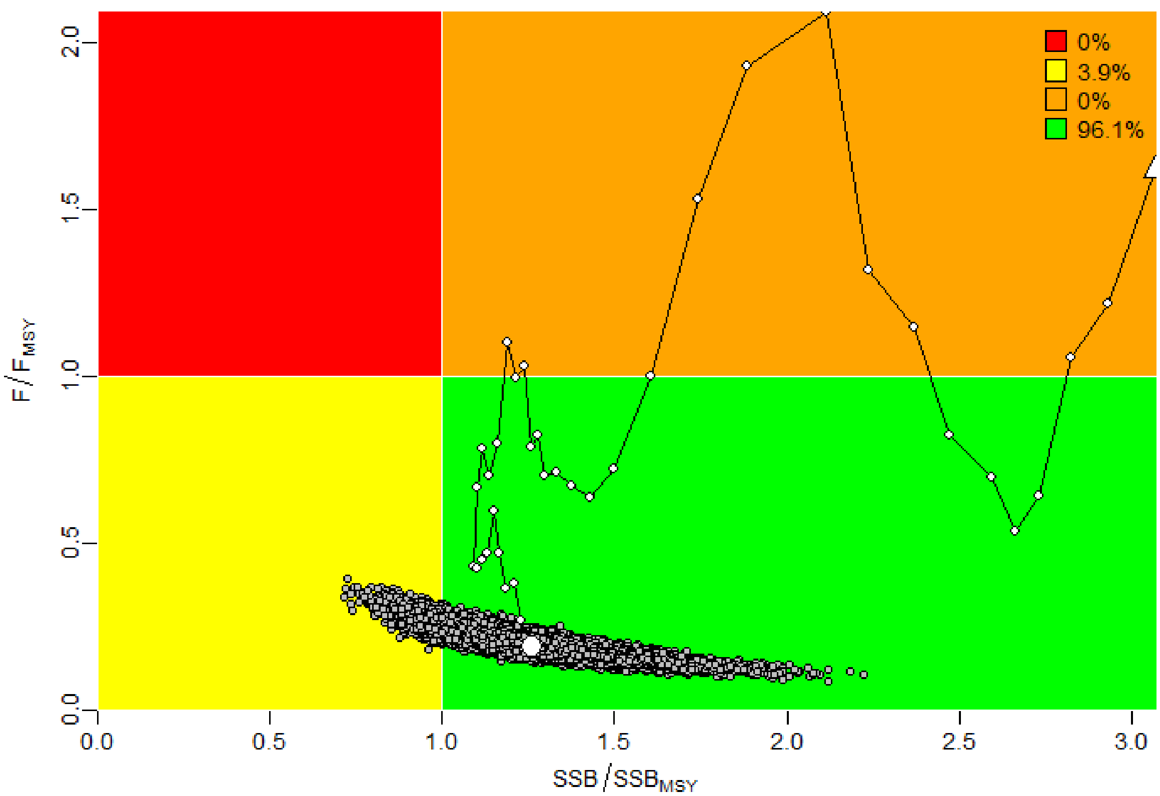


Figure 3.D.14. Kobe 2 plot with multivariate log-normal Monte-Carlo, MVLN, estimated uncertainty for the derived paramters representing stock status applied to the Stock Synthesis (GOM + ATL) continuity analysis model configuration.

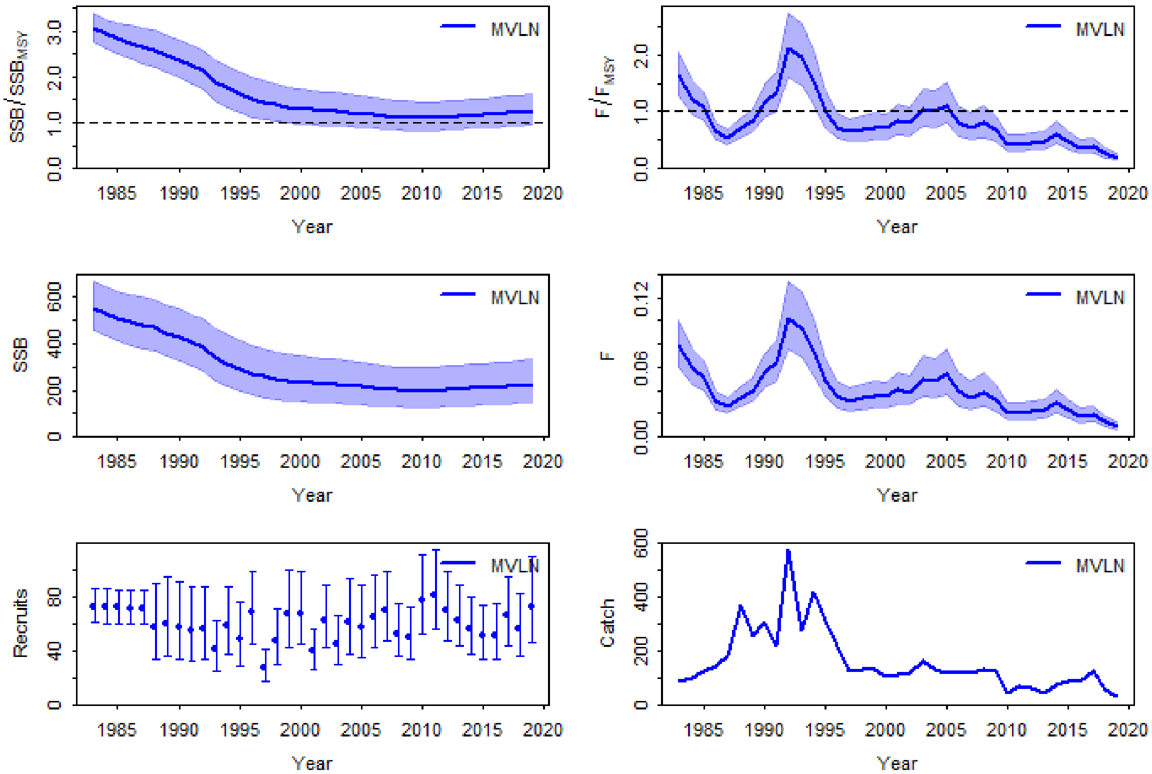


Figure 3.D.15. Multivariate log-normal Monte-Carlo, MVLN, estimated uncertainty for time series of derived paramters applied to the Stock Synthesis (GOM + ATL) continuity analysis model configuration.

3.14 Appendix 3.E. Example ABC Reduction from OFL Projections Applied to the Stock Synthesis (GOM + ATL) Provisional Base Model Configuration

3.E.1. Executive Summary

Stock Synthesis projections were implemented for the years 2020-2025 of the Stock Synthesis (GOM + ATL) provisional base model configuration. The Stock Synthesis (GOM + ATL) provisional base model configuration projected fishery removals at the overfishing limit, OFL, for the years 2020 to 2025. OFL projections methods were adapted from the SEDAR 57 U.S. Caribbean spiny lobster stock assessment as implemented under the Caribbean Fishery Management Council, CFMC, Acceptable Biological Catch, ABC, Control Rule. Projected fishery removals at OFL obtained from the Stock Synthesis (GOM + ATL) provisional base model configuration were adjusted (OFL-Adj-1) for the average total commercial and average total recreational catch (including recreational post release mortality. PRM) implemented for the projection gap years (2020 to 2022). A minimum estimate of the log-scale standard error in OFL (lognormal sigma_min equal to 0.415) was obtained from Atlantic HMS domestic shark stock assessment uncertainty (Courtney and Rice 2023) following the methods in Ralston et al. (2011). An acceptable risk of overfishing (P*) equal to 0.3 was assumed, consistent with projections under previous Atlantic HMS rebuilding plans. Projected fishery removals at ABC were obtained from adjusted OFL using a map from the acceptable risk of overfishing (P* equal to 0.3; sigma_min equal to 0.415) to the reduction in ABC (ABC/OFL = 80.4%). An example of a three year constant catch, CC, ABC in biomass (mt) and numbers (1000s) is provided based on the three-year average adjusted OFL obtained for the years 2023, 2024, and 2025. The example follows methods adapted from the SEDAR 57 U.S. Caribbean spiny lobster stock assessment as implemented under the CFMC ABC Control Rule.

3.E.2. Introduction

Ralston et al. (2011) illustrate how an estimate of log-scale standard error can be used to form the basis of an ABC control rule. The median of a lognormal distribution with a mean equal to zero and a standard error equal to sigma_min is assumed to be indicative of the best risk-neutral point estimate of scientific uncertainty in the OFL. The value for sigma_min is obtained from meta-analysis of historical stock assessment uncertainty. Selecting a cumulative lognormal probability less than 0.50 provides a buffer from the median OFL, which can then be used to map the acceptable risk of overfishing (P*) to the ratio of ABC to OFL (ABC/OFL) based on both the historical stock assessment uncertainty in the OFL and the risk of exceeding the OFL.

3.E.3 Methods

3.E.3.1 OFL Projections

Stock Synthesis projections were implemented for the years 2020 – 2025. Projection methods followed the SEDAR 77 provisional base model run. The forecast file of the provisional base model run projected fishery removals at the OFL for the years 2020 to 2025. OFL projections were implemented in Stock Synthesis at the fishing mortality rate, *F*, that achieved maximum sustainable yield, MSY, from the assessment. Projection selectivity, catchability by gear type, and recruitment deviations were obtained from the assessment time block 2008 – 2018.

Projections were implemented with average total commercial catch and with average total recreational catch (including recreational PRM) implemented for the projection "gap" years between the end year of the assessment and the year 2023 (2020 – 2022). Average total commercial catches by fleet during the years 2015 – 2019 (**Table 3.E.1**) were obtained from commercial catch in metric tons whole weight (mt ww) used in the assessment (e.g., see section 2 of main document, their Data Review and Update **Table 2.1** panel A). Similarly, average recreational catches and PRM by fleet during the years 2015 – 2019 (**Table 3.E.2**) were obtained from recreational catch estimates in numbers (1000s) used in the assessment. (e.g., see section 2 of main document, their Data Review and Update **Table 2.2**).

Projected fishery removals at OFL were adjusted, OFL-Adj-1, for the average commercial landings and average recreational catches plus recreational PRM implemented for the projection gap years.

3.E.3.2 Historical Stock Assessment Uncertainty

A minimum estimate of stock assessment uncertainty was assumed to be log-normally distributed and was obtained here from among assessment variability calculated from previously completed Atlantic HMS domestic shark stock assessments (Courtney and Rice 2023) following methods adapted from Ralston et al. (2011).

3.E.3.3 Acceptable Risk of Overfishing

A provisional acceptable risk of overfishing (P*) equal to 0.3 was assumed, consistent with projections under previous Atlantic HMS rebuilding plans (Courtney and Rice 2023).

3.E.3.4 Example ABC Reduction from OFL Projections

Example fishery removals at ABC were obtained from projected OFL adjusted, OFL-Adj-1, for the average commercial landings and average recreational catches plus recreational PRM implemented for the projection gap years.

3.E.4 Results

3.E.4.1 OFL Projections

Projected OFL during the years 2020 – 2025 was obtained from Stock Synthesis projections at F_{MSY} based on the underlying population dynamics assumed during the projection period, as described above.

OFL Projections in Biomass

Projected fishery removals in biomass (mt) at the OFL were obtained during the years 2020 – 2025 for commercial and recreational catch plus PRM (**Figure 3.E.1** and **Table 3.E.3**). Projected OFL (mt) was adjusted for expected average annual fishery removals during the gap years 2020, 2021, and 2022 (OFL Adj-1; **Figure 3.E.1** and Table **3.E.3**).

OFL Projections in Numbers

Projected fishery removals in numbers (1000s) at the OFL were obtained during the years 2020 – 2025 for commercial and recreational catch plus PRM (**Figure 3.E.2** and **Table 3.E.4**). Projected OFL (1000s) was adjusted for expected average annual fishery removals during the gap years 2020, 2021, and 2022 (OFL Adj-1; **Figure 3.E.2** and **Table 3.E.4**).

3.E.4.2 Historical Stock Assessment Uncertainty

A provisional minimum estimate of the log-scale standard error in OFL (lognormal sigma_min equal to 0.415) was obtained from Atlantic HMS domestic shark stock assessment uncertainty (Courtney and Rice 2023) following the methods adapted from Ralston et al. (2011).

In comparison, the provisional minimum estimate of the log-scale standard error in OFL (lognormal sigma_min equal to 0.415) obtained from Atlantic HMS domestic shark stock assessment uncertainty (Courtney and Rice 2023) is larger than an estimate of within assessment uncertainty for the Stock Synthesis (GOM + ATL) provisional base model configuration (sigma = 0.164) obtained as described above (section 3.3.1.11 Uncertainty and Measures of Precision).

3.E.4.3 Acceptable Risk of Overfishing

Selecting a 30% cumulative lognormal probability (P* equal to 0.3) provides a buffer from the median OFL at the 30% acceptable risk of overfishing.

3.E.3.4 Example ABC Reduction from OFL Projections

ABC/OFL Map

Given a provisional minimum estimate scientific uncertainty in OFL (sigma_min equal to 0.415; Courtney and Rice 2023), the 30% cumulative lognormal probability density is found at values ≤ 0.804. The value of 0.804 is then defined as the map from the acceptable risk of overfishing (P* equal to 0.3; sigma_min equal to 0.415) to the reduction in ABC from OFL (ABC/OFL = 80.4%; **Tables 3.E.5** and **3.E.6**).

Example ABC Reduction from OFL Projections in Biomass

Examples of annual ABC (mt) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM (**Figure 3.E.1** and Table **3.E.5**) from projected annual OFL adjusted for fishery removals during the gap years, OFL Adj-1, using the ABC/OFL map (ABC = 80.4% of adjusted OFL). Average annual OFL (mt) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM (**Figure 3.E.1** and **Table 3.E.5**) from projected annual OFL adjusted for fishery removals during the gap years (Avg. 2023-2025 = 339.54 mt). An example of the average annual ABC (mt) during the years 2023, 2024, and 2025 (273.13 mt) was obtained using the ABC/OFL map (ABC = 80.4% of average OFL).

Example ABC Reduction from OFL Projections in Numbers

Examples of annual ABC (1000s) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM (**Figure 3.E.2** and **Table 3.E.6)** from projected annual OFL adjusted for fishery removals during the gap years, OFL Adj-1, using the ABC/OFL map (ABC = 80.4% of adjusted OFL). Average annual OFL (1000s) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM (**Figure 3.E.2** and **Table 3.E.6**) from projected annual OFL adjusted for fishery removals during the gap years (Avg. 2023-2025 = 18.33, 1000s). An example of the average annual ABC (1000s) during the years 2023, 2024, and 2025 (14.74, 1000s) was obtained using the ABC/OFL map (ABC = 80.4% of average OFL).

3.E.5 Discussion

A 30% probability of overfishing is consistent with the Atlantic HMS domestic shark projection TORs for SEDAR 65: "If stock is neither overfished nor undergoing overfishing, then utilize projections to determine: i. The F needed and corresponding removals associated with a 70% probability of overfishing not occurring (analogous to a P* = 0.3 approach)." A 30% probability of overfishing is also consistent with previously implemented Atlantic HMS domestic shark rebuilding plans, which utilized projections to determine the constant catch associated with a 70% probability of rebuilding.

In the SEDAR 77 provisional base model run, total commercial catches in weight (mt; 1000s kg whole weight) were obtained from assumed conversion ratios for dressed weight (dw) to whole weight (ww) of dw = 1.39 ww for three fleets (Bottom longline catch, Gillnet catch, and hook and line + hand line catch). In contrast, a conversion ratio of dw = 2.02 ww was used for Pelagic longline dead discards. For example, see section 2 of main document, their Data Review and Update **Table 2.1** panel A.

Tables

Table 3.E.1. Expected average total annual commercial catches of scalloped hammerheads in weight (mt) in the U.S. Atlantic and Gulf of Mexico obtained for the years 2015-2019 for the Stock Synthesis (GOM + ATL) provisional base model configuration (see section 2 of main document, their Data Review and Update **Table 2.1** panel A).

Year	F1_COM_BLL	F2_Com_GN	F3_Com_PLL	F6_Com_Other_Kept
2015	21.530	35.970	28.537	0.044
2016	11.826	13.707	48.191	10.860
2017	17.446	30.905	73.863	1.984
2018	13.144	8.364	20.664	11.168
2019	7.786	10.223	9.900	0.129
Average	14.347	19.834	36.231	4.837

Table 3.E.2. Expected average total annual recreational catch (including recreational post release mortality PRM) of scalloped hammerheads in numbers (1000s) in the U.S. Atlantic and Gulf of Mexico obtained for the years 2015-2019 for the Stock Synthesis (GOM + ATL) provisional base model configuration (see section 2 of main document, their Data Review and Update **Table 2.2**).

Year	F4_Rec	F5_Rec_PRM
2015	0.890	3.689
2016	0.193	2.988
2017	0.039	2.495
2018	0.039	2.495
2019	0.039	2.495
Average	0.240	2.833

Table 3.E.3. Preliminary projected fishery removals in weight (mt) at the overfishing limit (OFL) obtained during the years 2020 – 2025 for commercial and recreational catch plus PRM; Projected OFL (mt) was adjusted (OFL Adj-1) for the expected average annual fishery removals input in projections during gap years 2020, 2021, and 2022 (Tables **3.E.1** and **3.E.2**).

Year	OFL Catch (B, mt)	OFL Catch Adj 1 (B, mt)	ForeCatch (B, mt)
2020	325.380	325.380	109.944
2021	323.063	332.501	110.379
2022	319.868	338.830	110.842
2023	316.120	344.448	344.448
2024	312.249	339.543	339.543
2025	308.489	334.626	334.626
2026	304.854	329.852	329.852
2027	301.321	325.217	325.216
2028	297.915	320.697	320.697
2029	294.675	316.299	316.299

Color Code

Blue	Blue: Projected fishery removals in biomass (mt) obtained from Stock Synthesis (forecast_report.ss loop 3) based on the commercial removal (mt) and recreational catch plus PRM (1000s) input in Stock Synthesis projections during the gap years 2020, 2021, 2022 (forecast.ss).
Yellow	Yellow: Projected fishery removals in biomass (mt) for commercial and recreational catch plus PRM obtained from Stock Synthesis projections (forecast_report.ss loop 1) at F_MSY based on the underlying population dynamics assumed during the projection period.
Orange	Orange: Projected OFL (mt) adjusted for input commercial landings (mt) and input recreational catch plus PRM (1000s) during the years 2020, 2021, 2022 obtained from Stock Synthesis projections (forecast_report.ss loop 1) (forecast_report.ss loop 1). [Projected OFL Adj-1 (B, mt) is provided as OFLCatch in the report.ss management quantities section along with the standard error of the estimates obtained from the Hessian].
Green	Green: Projected fishery removals in biomass (mt) include both the removals input in Stock Synthesis projections during the years 2020, 2021, 2022 (blue), and OFL adjusted for the input removals during the years 2023+ (orange). [Projected Fishery Removals (B, mt) is provided as ForeCatch in the report.ss management quantities section along with the standard error of the estimates obtained from the Hessian].

Table 3.E.4. Preliminary projected fishery removals in numbers (1000s) at the overfishing limit (OFL) obtained during the years 2020 – 2025 for commercial and recreational catch plus PRM; Projected OFL (1000s) was adjusted (OFL Adj-1) for the expected average annual fishery removals input in projections during gap years 2020, 2021, and 2022 (**Tables 3.E.1** and **3.E.2**); Color code as described in **Table 3.E.3**.

Year	OFL Catch (N,1000s)	OFL Catch Adj 1 (N,1000s)	Forecast Catch (N,1000s)
2020	18.33	18.33	5.90
2021	18.00	18.55	5.89
2022	17.64	18.65	5.86
2023	17.36	18.74	18.74
2024	17.16	18.28	18.28
2025	17.03	17.96	17.96
2026	16.94	17.74	17.74
2027	16.87	17.58	17.58
2028	16.81	17.46	17.46
2029	16.77	17.36	17.36

Table 3.E.5. Preliminary annual ABC (mt) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (OFL Adj catch) using the ABC/OFL map (ABC = 80.4% of OFL); Average annual OFL (mt) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (Avg. OFL 2023-2025 = 339.54 mt); Average annual ABC (mt) during the years 2023, 2024, and 2025 (Avg. ABC 2023-2025 = 273.13 mt) was obtained using the ABC/OFL map (ABC = 80.4% of OFL); Color code as described in **Table 3.E.3**.

A. Example ABC/OFL Ratio

Parameter	Value
P*	0.3
Lognormal sigma_min	0.415
Map	ABC (P*,sigma_min)
Example ABC/OFL Ratio[1]	0.804

[1]Where, 0.804 = LOGNORM.INV(0.3,0,0.415)

B. Example ABC Reduction from OFL Projections in Biomass

Year	OFL Adj catch (mt)	ABC (mt)	Map (ABC/OFL)
2023	344.45	277.08	0.804
2024	339.54	273.14	0.804
2025	334.63	269.18	0.804
Avg. 2023-2025	339.54	273.13	0.804

Table 3.E.6. Preliminary annual ABC (1000s) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (OFL Adj catch) using the ABC/OFL map (ABC = 80.4% of OFL); Average annual OFL (1000s) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (Avg. OFL 2023-2025 = 18.33, 1000s); Average annual ABC (1000s) during the years 2023, 2024, and 2025 (Avg. ABC 2023-2025 = 14.71, 1000s) was obtained using the ABC/OFL map (ABC = 80.4% of OFL); Color code as described in **Table 3.E.3**.

A. Example ABC/OFL Ratio

Parameter	Value
P*	0.3
Lognormal sigma_min	0.415
Map	ABC (P*,sigma_min)
Example ABC/OFL Ratio[1]	0.804

[1]Where, 0.804 = LOGNORM.INV(0.3,0,0.415)

B. Example ABC Reduction from OFL Projections in Numbers

Year	OFL Adj catch (1000s)	ABC (1000s)	Map (ABC/OFL)
2023	18.74	15.07	0.80
2024	18.28	14.71	0.80
2025	17.96	14.45	0.80
Avg. 2023-2025	18.33	14.74	0.80

Figures

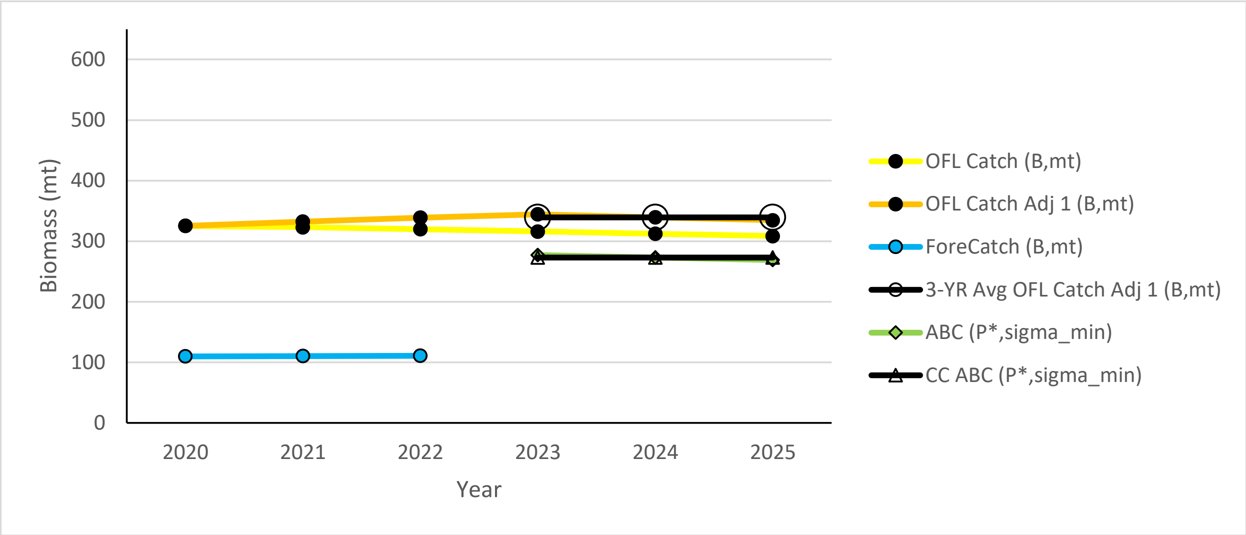


Figure 3.E.1. Preliminary annual ABC (mt) during the years 2023, 2024, and 2025 (green line with diamond markers) was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (OFL Adj catch) using the ABC/OFL map (ABC = 80.4% of OFL); Average annual OFL (mt) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (Avg. OFL 2023-2025 = 339.54 mt); CC ABC is the average annual ABC (mt) during the years 2023, 2024, and 2025 (Avg. ABC 2023-2025 = 273.13 mt) was obtained using the ABC/OFL map (ABC = 80.4% of OFL); P* and sigma_min as described above and in **Table 3.E.5**.

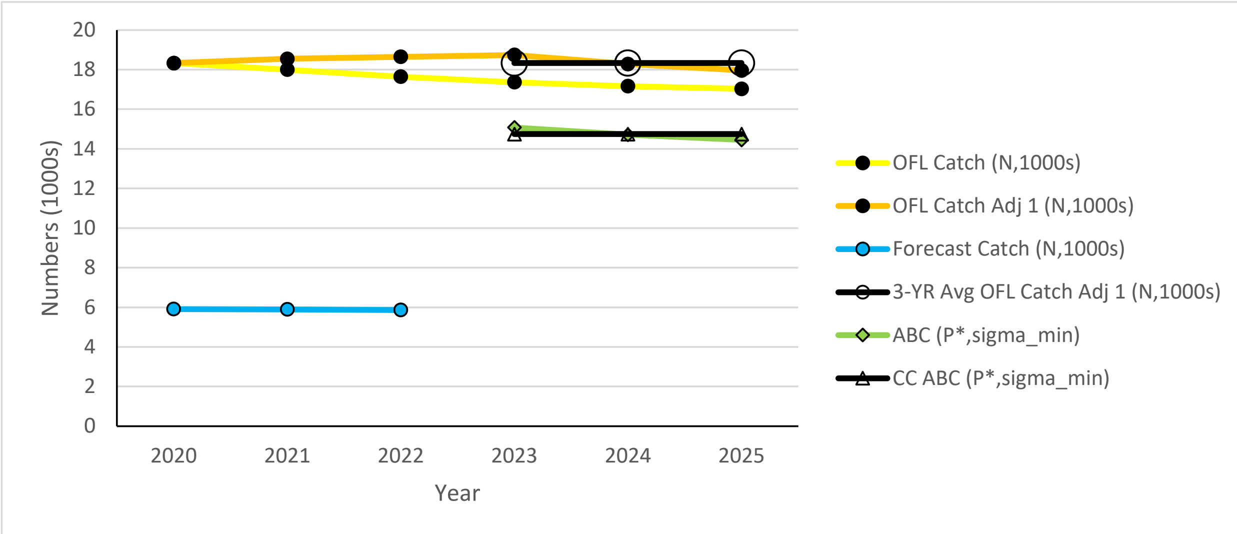


Figure 3.E.2. Preliminary annual ABC (1000s) during the years 2023, 2024, and 2025 (green line with diamond markers) was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (OFL Adj catch) using the ABC/OFL map (ABC = 80.4% of OFL); Average annual OFL (1000s) during the years 2023, 2024, and 2025 was obtained for commercial and recreational catch plus PRM from projected annual OFL adjusted for fishery removals during the gap years (Avg. OFL 2023-2025 = 18.33, 1000s, black line with open black circle markers); Average annual ABC (1000s) during the years 2023, 2024, and 2025 (Avg. ABC 2023-2025 = 14.71, 1000s, black line with open black triangle markers) was obtained using the ABC/OFL map (ABC = 80.4% of OFL); OFL Catch Adj, ForeCatch, P*, and sigma_min as described above and in **Table 3.E.6**.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 77
HMS Hammerhead Sharks: Smooth Hammerhead Shark

Section III: Assessment Report

June 2023

SEDAR

4055 Faber Place Drive, Suite 201 North Charleston, SC 29405

1. INTRODUCTION

1.1 WORKSHOP TIME AND PLACE

The SEDAR 77 Assessment Workshop held via a series of webinars from May 2022 – March, 2023.

1.2 TERMS OF REFERENCE

1. Review any changes in data or analyses following the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.
2. Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations (if necessary) for each model considered.
3. Identify preferred model approach if applicable.
4. Provide preliminary estimates of stock population parameters:
    a. Include fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship (if applicable), and other parameters as necessary to describe the population.
    b. Include appropriate measures of precision for parameter estimates.
5. Characterize uncertainty in the assessment and estimated values, if possible.
    a. Consider uncertainty in input data, modeling approach, and model configuration.
    b. Consider and include other sources of uncertainty as appropriate for this assessment.
    c. Provide appropriate measures of model performance, reliability, and 'goodness of fit'.
6. Provide preliminary estimates of population benchmarks or management criteria consistent with available FMPs and amendments, proposed FMPs and amendments, other ongoing or proposed management programs, and the National Standards.
    a. Evaluate existing or proposed management criteria as specified in the management summary.
    b. Recommend and define proxy values when necessary, and provide appropriate justification.
7. Recommend preliminary stock status relative to management benchmarks or alternative data-poor approaches if necessary.
8. Provide uncertainty distributions of proposed reference points and stock status metrics that provide the values indicated in the management specifications. Include probability density functions for reference point estimates and population metrics (e.g., biomass and exploitation) used to evaluate stock status.

9. Project future stock conditions and develop rebuilding schedules, if warranted. Provide the estimated generation time for the stock. Stock projections shall be developed in accordance with the following:
    a. If the preliminary stock status is overfished, then utilize projections to determine:
        i. Year in which F=0 results in a 70% probability of rebuilding (Year $F=0_{p70}$).
        ii. Target rebuilding year ($Year_{rebuild}$).
            1. Year $F=0_{p70}$ if Year $F=0_{p70} \leq 10$ years, or
            2. Year $F=0_{p70}$ + 1 generation time if Year $F=0_{p70} > 10$ years.
        iii. F resulting in 50% and 70% probability of rebuilding by $Year_{rebuild}$.
        iv. Fixed level of removals allowing rebuilding of stock with 50% and 70% probability.
    b. If the preliminary stock status is determined to be undergoing overfishing, then utilize projections to determine:
        i. $F=F_{reduce}$ (different reductions in F that should end overfishing with a 50% and 70% probability).
    c. If the preliminary stock status is determined to be neither overfished nor undergoing overfishing, then utilize projections to determine:
        i. The F needed and corresponding removals associated with a 70% probability of overfishing not occurring (analogous to a P* = 0.3 approach), and/or
        ii. The constant catch associated with a 70% probability of overfishing not occurring and the stock not being overfished.
    d. If data limitations and/or model limitations preclude classic projections (i.e. a, b, and c above), explore alternate projection models.
10. Provide ABCs in accordance with HMS management needs.
11. Provide recommendations for future research and data collection. Emphasize items that will improve future assessment capabilities and reliability. Consider data, monitoring, and assessment needs.
12. Complete an Assessment Workshop Report in accordance with project schedule deadlines.

1.3 LIST OF PARTICIPANTS

Participants	Affiliation
ADT	
Rob Latour	Virginia Institute of Marine Science, College of William And Mary
Beth Babcock	RSMAS University of Miami
John Carlson	SEFSC Panama City Laboratory
Trey Driggers	SEFSC Mississippi Laboratory
Dean Courtney	SEFSC Panama City Laboratory
Xinsheng Zhang	SEFSC Panama City Laboratory
Enric Cortés *	SEFSC Panama City Laboratory
	Additional Panelists
Eric Hoffmayer	SEFSC Mississippi Laboratory
Henning Winker	JRC European Commission
Felipe Carvalho	NOAA PIFSC
Joel Rice	Rice Marine Analytics
	Staff
Kathleen Howington	SEDAR
Karyl Brewster-Geisz	NMFS: HMS Management
Margaret Miller	NMFS
Adam Brame	NMFS
Other	
Adam Pollack	SEFSC Mississippi Laboratory
Andrea Kroetz	SEFSC Panama City Laboratory
Ann Williamson	NMFS
Becky Curtis	NMFS
Blaise Rohan	RSMAS University Of Miami
Cami Mccandless	NEFSC Narragansett Laboratory
Christina Vaeth	
Clifford Hutt	NMFS: HMS Management
Dean Grubbs	Florida State University Coastal and Marine Laboratory
Delisse Ortiz	NMFS
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Heather Moncrief-Cox	SEFSC Panama City Laboratory
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Leann Bosarge	GMFMC
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Max Lee	Mote Marine Laboratory
Michelle Passerotti	NEFSC Narragansett Laboratory
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Orian Tzadik	NMFS
Tobey Curtis	NMFS
Willow Patten	NCDMF

*Enric Cortés retired on December 31, 2022

1.4 DOCUMENT LIST

Working Papers			
SEDAR77-AW01	Exploratory analysis of U.S Atlantic and Gulf of Mexico scalloped hammerhead recruitment indices	Henning Winker	5/27/2022
SEDAR77-AW02	Hierarchical analyses of U.S. Atlantic and Gulf of Mexico scalloped hammerhead recruitment indices	Camilla T. McCandless and John K. Carlson	5/31/2022
SEDAR77-AW03		Cami McCandless	Not Received
SEDAR77-AW04	Estimates of vital rates and population dynamics parameters of interest for hammerhead sharks (*Sphyrna lewini, S. mokarran, and S. zygaena*) in the western North Atlantic Ocean	Enric Cortés	6/17/2022
SEDAR77-AW05	Reconciling age-0 indices of relative abundance of the U.S. Atlantic and Gulf of Mexico scalloped hammerhead (*Sphyrna lewini*)	Dean Courtney, Robert J. Latour, and Cassidy D. Peterson	6/20/2022
SEDAR77-AW06	Fishpath Questions	Enric Cortés	9/21/2022
SEDAR77-AW07	Selected FishPath Results for Smooth hammerhead shark, U.S. Atlantic and Gulf of Mexico	Enric Cortés	9/21/2022
SEDAR77-AW08	Selected FishPath Results for Smooth hammerhead shark, U.S. Atlantic and Gulf of Mexico: Narrowed	Enric Cortés	9/21/2022

Reference Documents			
SEDAR77-RD49	Stock Assessment of Scalloped Hammerheads in the Western North Atlantic Ocean and Gulf of Mexico	Christopher G. Hayes, Yan Jiao, and Enric Cortés	11/30/2020
SEDAR77-RD50	Poor-data and data-poor species stock assessment using a Bayesian hierarchical approach	Yan Jiao, Enric Cortés, Kate Andrews, And Feng Guo	11/30/2020
SEDAR77-RD51	Hierarchical Bayesian approach for population dynamics modelling of fish complexes without species-specific data	Yan Jiao, Christopher Hayes, and Enric Cortés	11/30/2020
SEDAR77-RD52	Highly migratory species predictive spatial modeling (PRiSM): an analytical framework for assessing the performance of spatial fisheries management	Daniel P. Crear, Tobey H. Curtis, Stephen J. Durkee, John K. Carlson	5/26/2022
SEDAR77-RD53	Dynamic factor analysis to reconcile conflicting survey indices of abundance	Cassidy D. Peterson, Michael J. Wilberg, Enric Cortés, and Robert J. Latour	5/26/2022
SEDAR77-RD54	SEDAR 65 - AW03: Reconciling indices of relative abundance of the Atlantic blacktip shark (*Carcharhinus limbatus*)	Robert J. Latour and Cassidy D. Peterson	5/31/2022

1.5 PANEL RECOMMENDATIONS AND COMMENTS

1.5.1. Term of Reference 1

Review any changes in data or analyses following the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.

Commercial catch was entered in Simple Stock Synthesis (SSS) in metric tons whole weight as per recommendation of SSS creator, Jason Cope. The SEDAR 77 DW Report approved total commercial catch and total recreational catch in pounds dressed weight (lb dw), which were converted to metric tons whole weight (mt ww) using a conversion ratio for dressed weight (dw) to whole weight (ww) of dw=ww/1.39 (default used by the NMFS; Pers. Comm. E. Cortés) and one lb=0.0004536 mt. These are summarized in **Section 2**.

1.5.2. Term of Reference 2

Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations (if necessary) for each model considered.

All analyses were conducted with SSS. SSS is one application of the Stock Synthesis Data-limited tool (SS-DL tool) for application to data-limited stocks that estimates catch limits (i.e. overfishing limit (*OFL*)). SSS needs the stock status on the value of depletion in a given year (i.e. a proxy of overfished stock status) as an input, so SSS should not be used to determine if the stock is overfished. It is an age-structured version of other catch-only methods such as Depletion-Based Stock Reduction Analysis (DBSRA) (Cope 2013). The underlying population dynamics in SSS are fully age-structured. Age and growth estimates are needed in SSS to define age structure and remove catch according to age/length-based selectivity patterns. Biomass (*B*) is measured as sex-combined biomass of mature individuals. The model and its configuration are fully described in **Section 3.1**.

1.5.3. Term of Reference 3

Identify preferred model approach if applicable.

All analyses were conducted with SSS as the assessment Panel recommended.

1.5.4. Term of Reference 4

Provide preliminary estimates of stock population parameters:

a) *Include fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship (if applicable), and other parameters as necessary to describe the population.*

b) *Include appropriate measures of precision for parameter estimates.*

Estimates of assessment model parameters and their associated uncertainties are reported in **Sections 3.2.1** to **3.2.5**. Since this is a data limited catch-only method, only lnR_0, stock depletion, *OFL* and Acceptable Biological Catch (*ABC*) were estimated and reported.

1.5.5. Term of Reference 5

Characterize uncertainty in the assessment and estimated values, if possible.

a) *Consider uncertainty in input data, modeling approach, and model configuration.*

b) *Consider and include other sources of uncertainty as appropriate for this assessment.*

c) *Provide appropriate measures of model performance, reliability, and 'goodness of fit'.*

Uncertainty in the assessment and estimated values is characterized at length with the Panel-approved reference run and sensitivity runs in **Sections 3.2.1** to **3.2.5**.

1.5.6. Term of Reference 6.

Provide preliminary estimates of population benchmarks or management criteria consistent with available FMPs and amendments, proposed FMPs and amendments, other ongoing or proposed management programs, and the National Standards.

a) *Evaluate existing or proposed management criteria as specified in the management summary.*

b) *Recommend and define proxy values when necessary, and provide appropriate justification.*

SSS needs the stock status on the value of depletion in a given year (i.e. a proxy of overfished stock status) as an input, so SSS should not be used to determine if the stock is overfished. Since this is a data limited catch-only method, only stock depletion, *OFL* and *ABC* are provided in **Sections 3.2.2** to **3.2.5**.

1.5.7. Term of Reference 7

Recommend preliminary stock status relative to management benchmarks or alternative data-poor approaches if necessary.

SSS needs the stock status on the value of depletion in a given year (i.e. a proxy of overfished stock status) as an input, so SSS should not be used to determine if the stock is overfished. Since this is a data limited catch-only method, only stock depletion, *OFL* and *ABC* are provided in **Sections 3.2.2** to **3.2.5**.

1.5.8. Term of Reference 8

Provide uncertainty distributions of proposed reference points and stock status metrics that provide the values indicated in the management specifications. Include probability density functions for reference point estimates and population metrics (e.g., biomass and exploitation) used to evaluate stock status.

As this is a data limited catch-only method, only *OFL*-associated uncertainties are provided in **Sections 3.2.3** and **3.2.4**.

1.5.9. Term of Reference 9

Project future stock conditions and develop rebuilding schedules, if warranted. Provide the estimated generation time for the stock. Stock projections shall be developed in accordance with the following:

- a) *If the preliminary stock status is overfished, then utilize projections to determine:*
  - i) *Year in which F=0 results in a 70% probability of rebuilding (Year $F=0_{p70}$).*
  - ii) *Target rebuilding year ($Year_{rebuild}$).*
    - (1) *Year $F=0_{p70}$ if Year $F=0_{p70} \leq 10$ years, or*

(2) Year $F=0_{p70}$ + 1 generation time if Year $F=0_{p70}$ > 10 years.

iii) F resulting in 50% and 70% probability of rebuilding by $Year_{rebuild}$.

iv) Fixed level of removals allowing rebuilding of stock with 50% and 70% probability.

b) If the preliminary stock status is determined to be undergoing overfishing, then utilize projections to determine:

i) $F=F_{reduce}$ (different reductions in F that should end overfishing with a 50% and 70% probability).

c) If the preliminary stock status is determined to be neither overfished nor undergoing overfishing, then utilize projections to determine:

i) The F needed and corresponding removals associated with a 70% probability of overfishing not occurring (analogous to a P = 0.3 approach), and/or*

ii) The constant catch associated with a 70% probability of overfishing not occurring and the stock not being overfished.

d) *If data limitations and/or model limitations preclude classic projections (i.e. a, b, and c above), explore alternate projection models.*

SSS is one application of the SS-DL tool for application to data-limited stocks that estimates catch limits (i.e. *OFL*). SSS needs the stock status on the value of depletion in a given year (i.e. a proxy of overfished stock status) as an input, so SSS should not be used to determine if the stock is overfished. In accordance with Term of Reference 9(d) *If data limitations and/or model limitations preclude classic projections (i.e. a, b, and c above), explore alternate projection models.* OFL_{2021} was estimated with the SSS inbuilt terminal year plus one projection. Longer terms of catch-based and fishing mortality-based (*F*-based) projections were not carried out due to the limitations of this catch-only method. *OFL*-associated uncertainties are provided in **Sections 3.2.3** and **3.2.4**.

1.5.10. Term of Reference 10

Provide ABCs in accordance with HMS management needs.

In accordance with Term of Reference 10, two approaches were used to calculate *ABC* from *OFL* (see **Section 3.1.8** and **Section 3.2.5**).

1.5.11. Term of Reference 11

Provide recommendations for future research and data collection. Emphasize items that will improve future assessment capabilities and reliability. Consider data, monitoring, and assessment needs.

Recommendations for future research and data collection are provided in **Section 3.4**.

1.5.12. Term of Reference 12

Complete an Assessment Workshop Report in accordance with project schedule deadlines.

This document is **Section III** of the SEDAR Stock Assessment Report.

2. DATA REVIEW AND UPDATE

2.1. CATCHES

The SEDAR 77 DW Report approved total commercial catch and total recreational catch in pounds dressed weight (lb dw), which were converted to metric tons whole weight (mt ww) obtained using a conversion ratio for dressed weight (dw) to whole weight (ww) of dw=ww/1.39 (default used by NMFS, Pers. Comm. E. Cortés) and one lb=0.0004536 mt. The vast majority of smooth hammerhead catches were from the recreational sector (**Tables 2.5.1** and **2.5.2**; **Figures 2.6.1** and **2.6.2**). Fishing pressure showed an initial increasing trend from 1981 to high values during a period ranging from 1985 to 1995, followed by a decreasing trend to a low value in 2000, and very reduced values during the last 20 years (**Figure 2.6.2**).

2.2. LIFE HISTORY INPUTS

Biological input values for females used to compute maximum population growth rate (r_{max}), proportion of unfished recruits produced when the stock is at 20% of the unfished population size (steepness), and other parameters of interest for smooth hammerheads in **Table 2.5.3** are as reported in SEDAR77-AW04 (Cortés 2022). For the computation of stochastic estimates of steepness, natural mortality rate at age was obtained through six alternative life history-invariant estimators: Jensen's (1996) *K*-based and age at maturity estimators, a modified growth-based Pauly (1980) estimator (Then et al. 2015), a modified longevity-based Hoenig (1983) estimator (Then et al. 2015), Chen and Yuan's (2006) estimator, and the mass-based estimator of Peterson and Wroblewski (1984) (see **Appendix 1** of Cortés 2022 for details). The median estimates of the average (age 1 to maximum age) natural mortality rate (0.129 yr^{-1}) and steepness (0.78) obtained in the Leslie matrix stochastic analyses were used as fixed inputs for SSS (see **Section 3.1.4** and SEDAR77-AW04 (Cortés 2022) for details). Life history inputs for SSS are summarized in **Table 2.5.4.**

2.3. LENGTH COMPOSITION DATA

There were 524 observations over an approximately 55-year period (1966-2016) (225 of those measurements were estimated; only 7 years had more than 20 observations) (**Table 2.5.5**) (presented at Assessment Webinar 8 on February 21, 2023 based on Length Composition Section of the DW report and Pers. Comm. E. Cortés). The sample size of these length composition data is very small and very likely unrepresentative of the real length composition of the catches. Therefore, it is not advisable to fully use them at this stage. SSS requires to associate length selectivity to each catch series. Rather than assuming a selectivity pattern for each catch series, we examined the length-frequency distribution of the entire composition data (**Figure 2.6.3)** and approximated by eye the lengths at 50% and 95% selectivity assuming a logistic pattern, being 120 and 200 cm fork length (FL), respectively.

2.4. REFERENCES

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2.5. TABLES

Table 2.5.1. Stock wide catches of smooth hammerheads in weight (lb dw). Total commercial catch is the maximum of the sum of commercial catches by gear and total commercial catches not disaggregated by gear; total recreational catch is the sum of total recreational AB1 catch and LPRM; total catch is the sum of total recreational and total commercial catch. Abbreviations for recreational catches are as follows: AB1=fish killed or kept either seen by the interviewer or reported to the interviewer by the angler; LPRM=live post-release mortality.

Year	Total Bottom longline catch	Total Gillnet catch	Total unknown gear	Pelagic longline dead discards	Total commercial catch	Total AB1 recreational catch	Total recreational LPRM	Total recreational catch	Total catch
1981	0	3651	0	0	3651	18232	28852	47084	50735
1982	102	406	0	220	5360	18232	28852	47084	52443
1983	204	0	0	446	10719	11145	52243	63387	74107
1984	307	1217	0	666	16079	15779	138388	154167	170246
1985	409	1623	0	886	21439	24491	226635	251127	272565
1986	511	2028	0	1107	26799	70365	386063	456429	483227
1987	613	2434	0	1800	32158	83958	372880	456838	488997
1988	715	2840	0	5858	37518	87102	191568	278670	316188
1989	818	3245	0	2720	42878	83726	142396	226121	268999
1990	920	3651	0	3479	48238	89834	131028	220861	269099
1991	204	7326	0	2371	33827	150086	204139	354225	388052
1992	1214	3889	0	4329	61201	243597	119783	363379	424580
1993	1649	954	0	668	65763	360474	60555	421029	486792
1994	2658	465	2	220	107102	255864	27648	283512	390614
1995	1139	165	0	742	45160	170017	33746	203762	248922
1996	582	920	0	331	26667	120077	48187	168265	194932
1997	219	249	0	1028	10492	110034	75232	185266	195758
1998	113	389	0	1009	8388	85937	50033	135970	144358
1999	122	69	0	861	8215	52694	23790	76483	84699
2000	18	4	0	987	6036	34985	6157	41141	47178
2001	53	5	0	1187	11864	28578	3774	32352	44216
2002	77	148	0	942	15128	3439	3335	6774	21901
2003	386	116	0	942	17911	287	5531	5818	23729
2004	327	139	0	942	15251	30	5954	5984	21235
2005	166	7	0	942	23022	26	10693	10719	33741
2006	237	128	0	942	20587	33	18790	18823	39410
2007	65	2	0	2063	8775	10	32852	32863	41637
2008	507	317	0	63	7463	3	21964	21967	29430
2009	384	565	2540	43	20311	1	14322	14323	34634
2010	207	424	5607	51	14844	1	9551	9552	24396
2011	242	179	65	87	9949	28	6116	6144	16093
2012	41	4141	70	40	7244	801	4357	5158	12402
2013	0	179	0	69	329	22690	4430	27120	27449
2014	312	257	32	58	659	801	7304	8106	8765
2015	264	40	0	562	866	28	11334	11363	12229
2016	0	125	0	1385	1510	1	8707	8708	10219
2017	0	1127	0	6446	7639	1	6719	6720	14359
2018	0	530	0	286	816	1	6719	6720	7536
2019	0	13	0	1306	1346	1	6719	6720	8066
2020	0	0	0	361	361	1	6719	6720	7081

Table 2.5.2. Total commercial catch and total recreational catch of smooth hammerheads in weight (mt ww) used in SSS. A conversion ratio for dressed weight (dw) to whole weight

(ww) of dw=ww/1.39 (default used by NMFS; Pers. Comm. E. Cortés) and one lb=0.0004536 mt was used.

Year	Commercial	Recreational
1981	2.300	29.700
1982	3.400	29.700
1983	6.800	40.000
1984	10.100	97.200
1985	13.500	158.300
1986	16.900	287.800
1987	20.300	288.000
1988	23.700	175.700
1989	27.000	142.600
1990	30.400	139.300
1991	21.300	223.300
1992	38.600	229.100
1993	41.500	265.500
1994	67.500	178.800
1995	28.500	128.500
1996	16.800	106.100
1997	6.600	116.800
1998	5.300	85.700
1999	5.200	48.200
2000	3.800	25.900
2001	7.500	20.400
2002	9.500	4.300
2003	11.300	3.700
2004	9.600	3.800
2005	14.500	6.800
2006	13.000	11.900
2007	5.500	20.700
2008	4.700	13.900
2009	12.800	9.000
2010	9.400	6.000
2011	6.300	3.900
2012	4.600	3.300
2013	0.200	17.100
2014	0.400	5.100
2015	0.500	7.200
2016	1.000	5.500
2017	4.800	4.200
2018	0.500	4.200
2019	0.800	4.200
2020	0.200	4.200

Table 2.5.3. Biological input values for females used to compute maximum population growth rate (r_{max}), proportion of unfished recruits produced when the stock is at 20% of the unfished population size (steepness), and other parameters of interest for smooth hammerheads.

Parameter	Definition	Value	Unit	References
L_∞	Theoretical maximum length	293.9	cm FL	DW report life history section
K	Brody growth coefficient	0.09	yr^{-1}	DW report life history section
t_0	Theoretical age at zero length	-2.195*	yr	DW report life history section
a	Intercept of maturity ogive	n/a	dimensionless	DW report life history section
b	Slope of maturity ogive	n/a	dimensionless	DW report life history section
c	Scalar coefficient of weight on length	2.000E-06	dimensionless	DW report life history section
d	Power coefficient of weight on length	3.329	dimensionless	DW report life history section
w	Observed lifespan	25	yr	DW report life history section
	Theoretical lifespan (99% of Linf)	49	yr	DW report life history section
	Sex ratio at birth	1:1	dimensionless	DW report life history section
	Reproductive cycle	biennial	yr	DW report life history section
mx	Constant litter size	33.5	pups per litter	DW report life history section
e	Intercept of maternal length vs. fecundity	n/a	dimensionless	DW report life history section
f	Slope of maternal length vs. fecundity	n/a	dimensionless	DW report life history section
GP	Gestation period	11	months	DW report life history section

* Obtained from an L_0 of 52.7 cm FL.

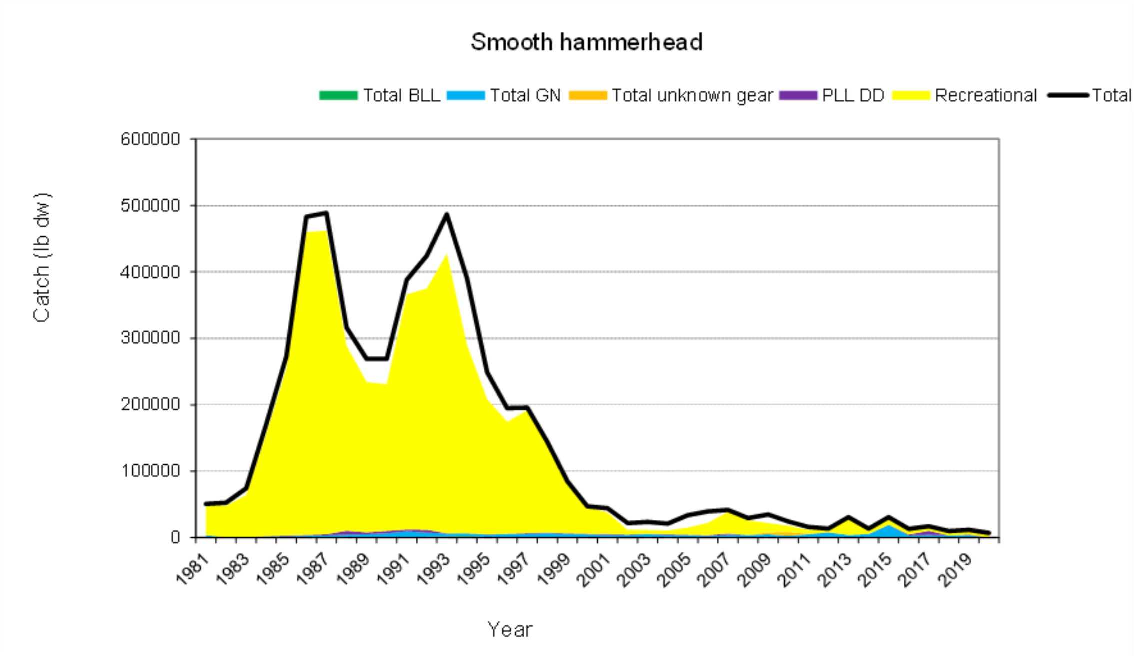
Table 2.5.4. Life history inputs for smooth hammerheads for SSS.

Female	Mean	SD	Prior type
Natural Mortality (M)	0.129	0.024	Lognormal
Asymptotic size (Linf)	293.9	0	Fixed
Growth coefficient (k)	0.09	0	Fixed
Correlation between Linf and k	0.96		Fixed
Age at length 0 (t_0)	-2.195	0	Fixed
CV at length(young then old)	0.1,0.1	0,0	Fixed
Length at 50% maturity	200		Fixed
Length at 95% maturity	227		Fixed
Reproductive cycle	biennial		Fixed
Constant litter size	33.5 pups per litter		Fixed
Fecundity-length relationship: Coefficient a	16.75		Fixed
Fecundity-length relationship: Exponent b	1E-10		Fixed
Steepness	0.78	0.15	Symmeric Beta
Weight (kg)-Length (cm) relationship: Coefficient a	0.000002		Fixed
Weight (kg)-Length (cm) relationship: Exponent b	3.329		Fixed
Male			
Natural Mortality (M)	0.129	0.024	Lognormal
Asymptotic size (Linf)	284.6	0	Fixed
Growth coefficient (k)	0.09	0	Fixed
Age at length 0 (t_0)	-2.25	0	Fixed
CV at length(young then old)	0.1,0.1	0,0	Fixed
Weight (kg)-Length (cm) relationship: Coefficient a	0.000002		Fixed
Weight (kg)-Length (cm) relationship: Exponent b	3.329		Fixed

Table 2.5.5. Length composition data of smooth hammerheads in years 1966-2019 (presented at Assessment Webinar 8 on February 21, 2023 based on Length Composition Section of the DW report and Pers. Comm. E. Cortés). Note: 524 samples over an approximately a 55-year period; 225 of those measurements were estimated; only 7 years with more than 20 samples. The sample size of these length composition data is very small and very likely unrepresentative of the real length-composition of the catches.

Year	Sample Size	Year	Sample Size
1966	1	1994	9
1967	1	1995	5
1968	1	1996	12
1969	1	1997	11
1970	1	1998	9
1973	5	1999	1
1974	7	2000	4
1975	1	2001	5
1976	6	2002	5
1977	3	2003	6
1978	4	2004	4
1979	4	2005	7
1980	3	2006	9
1981	4	2007	12
1982	9	2008	7
1983	10	2009	29
1984	4	2010	13
1985	3	2011	27
1986	5	2012	11
1987	9	2013	23
1988	3	2014	22
1989	8	2015	8
1990	14	2016	27
1991	15	2017	47
1992	15	2018	13
1993	38	2019	23
	Grand Total		**524**

2.6. FIGURES



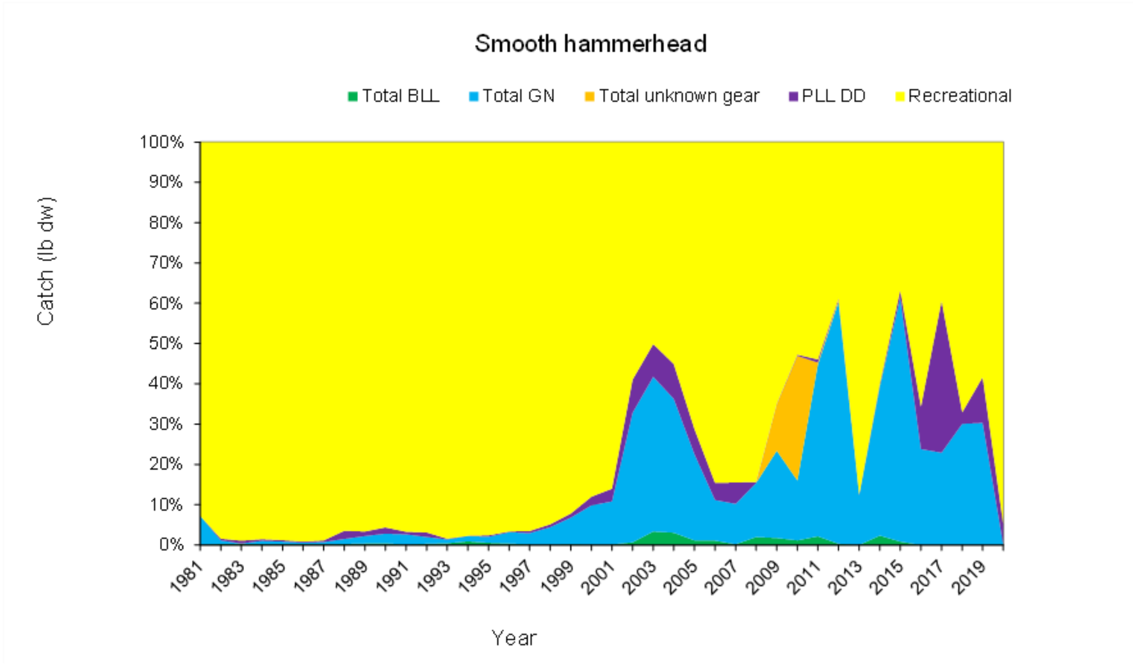


Figure 2.6.1. Commercial catches and smoothed recreational catches of smooth hammerheads in weight (lb dw), 1981-2020. Top panel: stacked catches by year; bottom panel: proportions by year. Abbreviations are as follows: BLL=Bottom longline; GN=Gillnet; PLL DD=Pelagic longline dead discards.

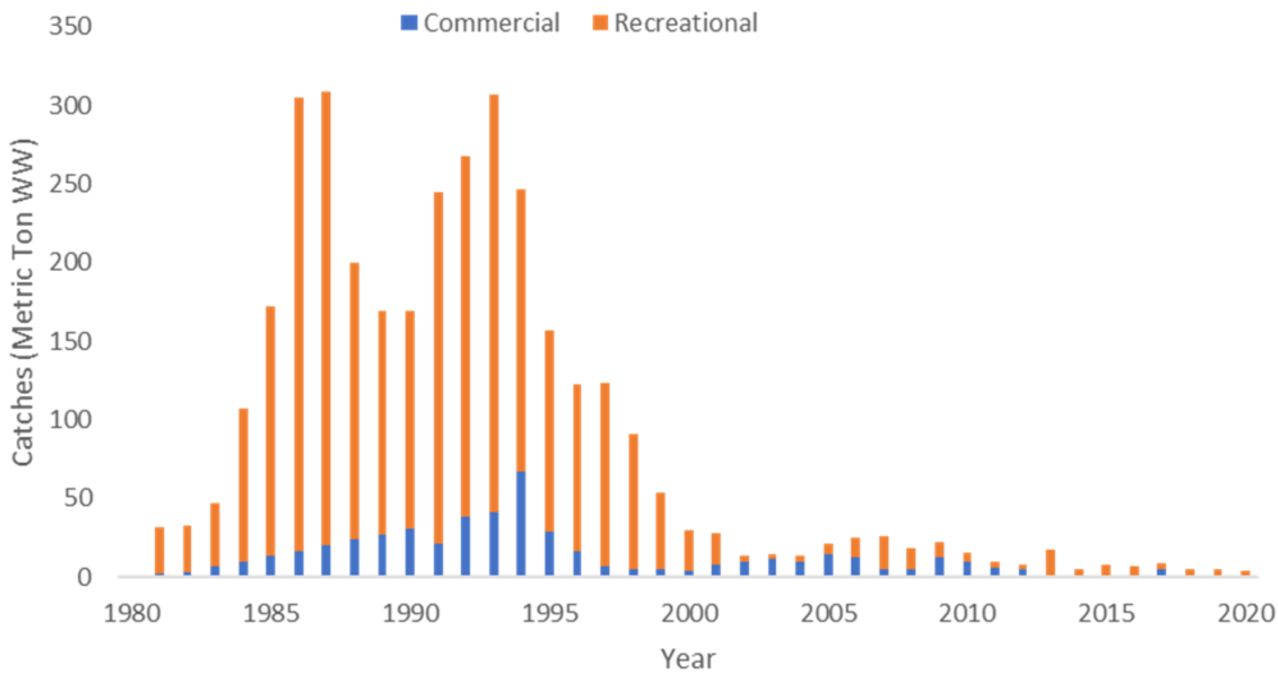


Figure 2.6.2. Commercial catches and smoothed recreational catches of smooth hammerheads in weight (mt ww) used in SSS. Total catch is the sum of total recreational and total commercial catch. A conversion ratio for dressed weight (dw) to whole weight (ww) of dw=ww/1.39 (default used by NMFS; Pers. Comm. E. Cortés) and one lb=0.0004536 mt were used.

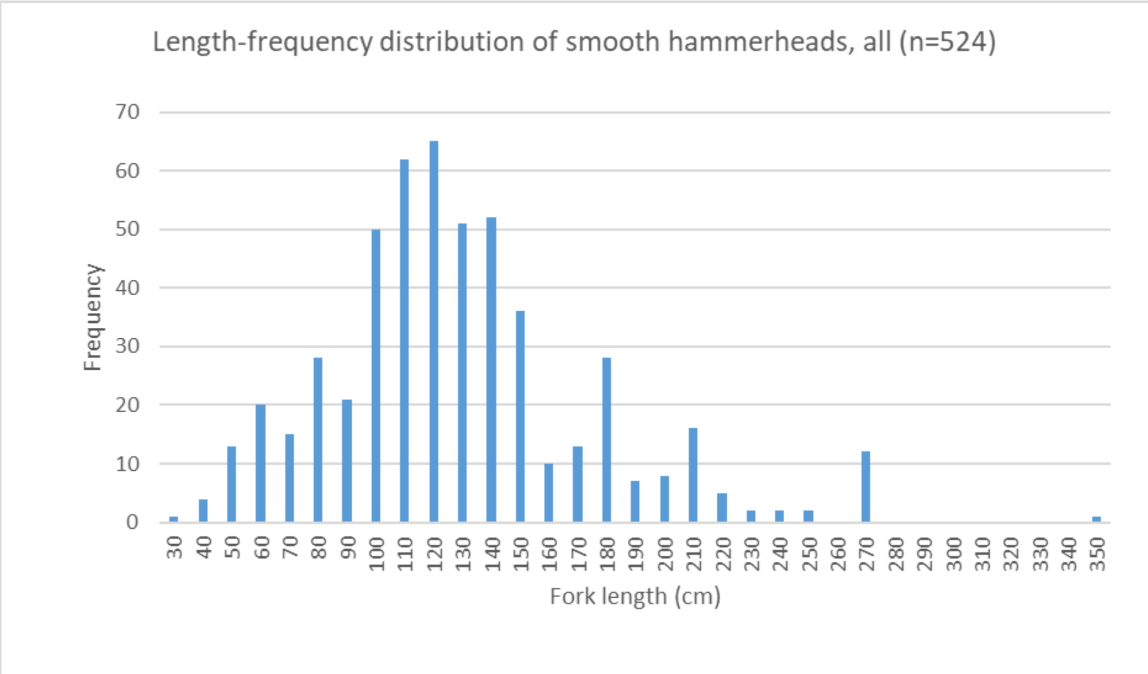


Figure 2.6.3. Length-frequency distribution of smooth hammerheads (sample size: total=524, measured 299, and estimated =225) in years 1966-2019 (presented at Assessment Webinar 8 on February 21, 2023 based on Length Composition Section of the DW report and Pers. Comm. E. Cortés). Note: the sample size of these composition data is very small and very likely unrepresentative of the real length-composition of the catches.

3. STOCK ASSESSMENT MODEL AND RESULTS

While there was a 40-year time series of catches for this smooth hammerhead stock, the life history information was extracted from a number of published sources, most based on studies conducted outside of the western North Atlantic Ocean, and the length-composition data were very limited and very likely unrepresentative of the real length-composition of the catches. Given this data-poor situation, it was initially decided to explore FishPath (https://www.fishpath.org; Dowling et al., 2016), which is a decision support tool intended to justify and document the best way forward to find the right-fit models in data- and resource-limited situations. In addition to data collection and management modules, FishPath contains a stock assessment module meant to match stock assessment options against prevailing conditions. The matchmaking is done via a questionnaire that asks questions regarding life history, data availability and quality, operational characteristics of the fishery(ies), and governance. Matches are expressed based on data criteria of each method, the quality of the criteria matches, and the assumptions for each assessment option based on inherent method structure (static caveats) and questionnaire answers (question-based caveats). This approach also highlights the important distinction between being technically able to do a method and deciding to do it when weighed against data quality, assumptions and resource constraints. The tool transparently lays out each option, and guides the user through the process of identifying a short list of what the user deems the most viable options. This process can also be done with any number of stakeholders in order to raise transparency and encourage dialogue in the process. After going through FishPath (SEDAR77-AW06, SEDAR77-AW07, and SEDAR77-AW08), the Panel recommended using SSS instead. The model is described below.

3.1. SSS ASSESSMENT MODEL

3.1.1. Overview

The SS-DL tool (Cope 2013) uses Stock Synthesis (Methot and Wetzel 2013) to implement several common data-limited assessment methods all in one modelling framework. Under a unified modelling framework, additional data can be added as they become available. The SS-DL tool builds Stock Synthesis files for provided data and life history information. It produces full plots and tables for each model run via the r4ss package, as well as additional screen output for easy interpretation. The SS-DL tool is an open-source modelling framework and is available at github.com/shcaba/SS-DL-tool. SSS is one application of the SS-DL tool for use with data-limited stocks that estimates catch limits (i.e. *OFL*). SSS needs the stock status on the value of depletion in a given year (i.e. a proxy of overfished stock status) as an input, so SSS should not be used to determine if the stock is overfished. It is an age-structured version of other catch-only methods such as DBSRA (Cope 2013). The underlying population dynamics in SSS are fully age-structured. Age and growth estimates are needed in SSS to define age structure and remove catch according to age/length-based selectivity patterns. Biomass (*B*) is measured as sex-combined biomass of mature individuals.

3.1.2. Data sources

Total commercial catch, total recreational catch, and life history inputs used in the application of SSS are described in **Section 2**.

3.1.3. Catch

Total commercial catch

Total commercial catch (in metric tons whole weight) was available from 1981 to 2020 (**Table 2.5.2**). Commercial catch was entered in SSS in metric tons whole weight.

Total recreational catches

Total recreational catch (in metric tons whole weight) was available from 1981 to 2020 (**Table 2.5.2**). Recreational catch was entered in SSS in metric tons whole weight.

3.1.4. Life history

Natural mortality

A mean natural mortality rate (*M*) of 0.129 yr^{-1} and lognormal standard deviation of 0.024 were used to form a distribution from which *M* values are drawn for both females and males (**Table 2.5.4**). Natural mortality curves/functions were implemented in SSS based on these input values (**Figure 3.1**).

Growth parameters

Growth parameters (asymptotic size (*Linf*: female=293.9 cm FL, male=284.6 cm FL), growth coefficient (*K*: female=male=0.09 yr^{-1}), correlation between *Linf* and *K* (female=male=0.96), age at length 0 (t_0: female=-2.195 years; male=-2.25 years), and *CV* at length (young and old: all cases=0.1) were assumed to be fixed (**Table 2.5.4**). Growth curves/functions were implemented in SSS based on these input values **(Figure 3.2**).

Maturity parameters

Length at 50% maturity (200 cm FL) and length at 95% maturity (227 cm FL) for females were assumed to be fixed (**Table 2.5.4**). The maturity curve/function for females was implemented in SSS based on these input values **(Figure 3.3**).

Fecundity-length relationship

There are very limited data available to describe the basic reproductive biology of the smooth hammerheads and, as a result, the Life History Group had to rely on information from a number of published sources, most based on studies conducted outside of the western North Atlantic Ocean. The limited data suggested that mean brood size of the smooth hammerheads was 33.5 pups per brood with a biennial reproductive cycle. No relationship between maternal length and fecundity was available. Because of the biennial reproductive cycle, the annual length-invariant fecundity is 16.75 pups per year. A coefficient a=16.75 and exponent b=1.00E-10 were used to implement the length-invariant fecundity(F)-length (L) relationship, $F=a*L^b$, in SSS (**Figure 3.4**). As the exponent b=0 is not defined for L=0, a very small number (1.00E-10) was used instead.

Spawning output-length relationship

To derive the spawning output-length relationship, the length-invariant fecundity relationship was scaled (i.e. multiplied) with the logistic maturity-length relationship in SSS (**Figure 3.5**). This scaling procedure has been used in previous HMS shark assessments.

Weight-length relationship

The weight(W)-length (L) relationship was assumed to be same for both sexes and fixed (**Table 2.5.4**). A coefficient a=0.000002 and exponent b=3.329 were used to implement the weight-length relationship, $W=a*L^b$, in SSS.

Steepness

Two values of steepness (0.78 and 0.58) were explored. The model results are not sensitive to the changes of steepness. The Panel recommended to use steepness=0.78 for the reference model run (**Table 2.5.4**).

Selectivity

Rather than assuming a selectivity pattern for each catch series, we examined the length-frequency distribution of composition data (**Figure 2.6.3)** and approximated by eye the lengths of 50% and 95% selectivity assuming a logistic pattern, being 120 and 200 cm FL, respectively (**Figure 3.6**).

Relative stock status (stock depletion)

This input represents the prior belief on the status of the stock in a given year, measured as stock depletion. Fishing pressure showed an initial increasing trend from 1981 to high values during a period ranging from 1985 to 1995, followed by a decreasing trend to a low value in 2000, and very reduced values during the last 20 years (**Figure 2.6.2**). The Panel recommended to use a relative stock status in 2000 (depletion mean=0.1 and beta standard deviation=0.2) as the best educated guess for the reference model run. This recommendation was mainly based on 1) year 2000 is the starting point of low fishing pressure during the last 20 years, and 2) the preliminary assessment results of SEDAR 77 suggest that stock depletion is about 0.1 for great hammerheads in 2000 (i.e. the assumption about the relative stock status in 2000 (depletion mean=0.1) for the Panel-approved reference run was in line with results for the great hammerheads). Due to the large uncertainty associated with this catch-only method and the assumed status of the stock in 2000, the Panel is only able to recommend a reference model instead of a base model.

Log value of initial recruitment (lnR_0)

The population model underlying SSS is sex- and age-structured with a Beverton-Holt stock-recruitment relationship, though recruitment is assumed deterministic. The only estimated parameter is lnR_0. Two values of lnR_0 (12 and 2) were explored (see **Appendix**). The model results are not sensitive to the changes of lnR_0. However, models run much faster with lnR_0=2. Therefore, the Panel recommended to use lnR_0=2 for the reference model run.

3.1.5. Parameter estimation

Only one parameter, lnR_0, is estimated in SSS. SSS estimates a lnR_0 value which results in a population that meets the assumed depletion value, based on the other fixed model parameters. 1000 Monte Carlo draws were used for SSS to define the probability distributions. It takes 10-20 hours to complete each model run (laptop computer with a processor: 11th Gen Intel(R) Core (TM) i9-11950H@2.60GHz).

3.1.6. Sensitivity to stock depletion assumptions and steepness

The Panel approved to use the relative stock status in 2000 (depletion mean=0.1 and beta standard deviation=0.2) as the best educated guess for the reference model run. The uncertainty in the assumed stock depletion was examined through the use of sensitivity scenarios with depletion mean=0.2, 0.3, 0.5, and 0.7 (**Table 3.2**).
In addition to the Panel-approved relative stock status in 2000, additional sensitivity scenarios were carried out assuming the relative stock status in 1990, 2010, 2020 using the same levels of stock depletion (0.1, 0.2, 0.3 0.5, and 0.7) (**Table 3.3**). Sensitivity scenarios assuming the relative stock status in 2020 using the same levels of stock depletion (0.1, 0.2, 0.3 0.5, and 0.7) with a lower steepness (0.58 instead of 0.78) were also carried out (**Table 3.3**). No continuity analysis was conducted because this is the first time this stock has been assessed.

We now specifically describe how each of the sensitivity runs was implemented:
The Panel-approved reference run and sensitivity runs assuming a relative stock status in 2000
Fishing pressure showed an initial increasing trend from 1981 to high values during a period ranging from 1985 to 1995, followed by a decreasing trend to a low value in 2000, and very reduced values during the last 20 years.
Scenario 1-1: *E_B3*—This is the Panel-approved reference run, a relative stock status (depletion=0.1) in 2000.
Scenario 1-2: *E02_B3*—This is the Panel-approved sensitivity run, same as the reference run, but a relative stock status (depletion=0.2) in 2000.
Scenario 1-3: *E1_B3*—This is the Panel-approved sensitivity run, same as the reference run, but a relative stock status (depletion=0.3) in 2000.
Scenario 1-4: *E2_B3*—This is the Panel-approved sensitivity run, same as the reference run, but a relative stock status (depletion =0.5) in 2000.

Scenario 1-5: *E3_B3*—This is the Panel-approved sensitivity run, same as the reference run, but a relative stock status (depletion=0.7) in 2000.

Additional sensitivity runs assuming a relative stock status in 1990

Fishing pressure showed an initial increasing trend from 1981 to high values during a period ranging from 1985 to 1995.

Scenario 2-1: *F_B3*—Same as the reference run, but a relative stock status (depletion=0.1) in 1990.

Scenario 2-2: *F02_B3*—Same as the reference run, but a relative stock status (depletion=0.2) in 1990.

Scenario 2-3: *F1_B3*—Same as the reference run, but a relative stock status (depletion=0.3) in 1990.

Scenario 2-4: *F2_B3*—Same as the reference run, but a relative stock status (depletion=0.5) in 1990.

Scenario 2-5: *F3_B3*—Same as the reference run, but a relative stock status (depletion=0.7) in 1990.

Additional sensitivity runs assuming a relative stock status in 2010

2010 is the end point of the first 10 years of the low fishing pressure during the last 20 years.

Scenario 3-1: *D_B3*—Same as the reference run, but a relative stock status (depletion=0.1) in 2010.

Scenario 3-2: *D02_B3*—Same as the reference run, but a relative stock status (depletion=0.2) in 2010.

Scenario 3-3: *D1_B3*—Same as the reference run, but a relative stock status (depletion=0.3) in 2010.

Scenario 3-4: *D2_B3*—Same as the reference run, but a relative stock status (depletion=0.5) in 2010.

Scenario 3-5: *D3_B3*—Same as the reference run, but a relative stock status (depletion=0.7) in 2010.

Additional sensitivity runs assuming a relative stock status in 2020

2020 is the terminal year and the end of the second 10 years of the low pressure during the last 20 years.

Scenario 4-1: *C_B3*—Same as the reference run, but a relative stock status (depletion=0.1) in 2020.
Scenario 4-2: *C02_B3*—Same as the reference run, but a relative stock status (depletion=0.2) in 2020.
Scenario 4-3: *C1_B3*—Same as the base run, but a relative stock status (depletion=0.3) in 2020.
Scenario 4-4: *C2_B3*—Same as the base run, but a relative stock status (depletion=0.5) in 2020.
Scenario 4-5: *C3_B3*—Same as the reference run, but a relative stock status (depletion=0.7) in 2020.

Additional sensitivity runs assuming a relative stock status in 2020, but with a lower steepness
2020 is the terminal year and the end of the second 10 years of the low pressure during the last 20 years.
Scenario 5-1: *C_B3_C2*—Same as the reference run, but a relative stock status (depletion=0.1, steepness=0.58 instead of 0.78) in 2020.
Scenario 5-2: *C02_B3_C2*—Same as the reference run, but a relative stock status (depletion=0.2, steepness=0.58 instead of 0.78) in 2020.
Scenario 5-3: *C1_B3_C2*—Same as the reference run, but a relative stock status (depletion=0.3, steepness=0.58 instead of 0.78) in 2020.
Scenario 5-4: *C2_B3_C2*—Same as the reference run, but a relative stock status (depletion=0.5, steepness=0.58 instead of 0.78) in 2020.
Scenario 5-5: *C3_B3_C2*—Same as the reference run, but a relative stock status (depletion=0.7, steepness=0.58 instead of 0.78) in 2020.

3.1.7. Projection methods

SSS is one application of the SS-DL tool for application to data-limited stocks that estimates catch limits (i.e. *OFL*). SSS needs the stock status on the value of depletion in a given year (i.e. a proxy of overfished stock status) as an input, so SSS should not be used to determine if the stock is overfished. In accordance with Term of Reference 9(d) *If data limitations and/or model limitations preclude classic projections (i.e. a, b, and c above), explore alternate projection models.* OFL_{2021} was estimated with the SSS inbuilt terminal year plus one projection. Longer terms of catch-based and *F*-based projections were not carried out due to the limitations of this catch-only method.

3.1.8. *ABC* calculations

This assessment can be considered data limited. Catch and life history data were available to be used in this stock assessment, but there were no time series data to develop indices of abundance or to fully parameterize catch-at-age or catch-at-length population dynamics. Therefore, this assessment falls under tier 3 of the *ABC* control rule in Final Amendment 14 to the 2006 Consolidated Atlantic Highly Migratory Species Fishery Management Plan (2023). In accordance with Term of Reference 10 *Provide ABCs in accordance with HMS management needs*, two approaches were used to calculate *ABC* from *OFL*.

1) Calculating *ABC* as 30th percentile of *OFL*
2) Calculating *ABC* by using an *ABC*/*OFL* ratio of 0.647 for tier 3 stocks with a P^*=0.3 following Courtney and Rice (2023)

3.2. MODEL RESULTS

3.2.1. Priors and posteriors of the estimated lnR_0

Only one parameter, lnR_0, is estimated in SSS. Priors and posteriors for lnR_0 for the Panel-approved reference run (depletion=0.1 in the year 2000) and sensitivity runs (depletion = 0.2, 0.3, 0.5, and 0.7 in the year 2000) are shown in **Figure 3.7**. Prior medians for lnR_0 were almost identical to the input value (lnR_0=2) as expected for all runs. The posterior medians for lnR_0 showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 2000. The posterior medians for lnR_0 were slightly less than 2 for the runs with depletion=0.1, 0.2, and 0.3, whereas the posterior medians for lnR_0 were slightly greater than 2 for the runs with depletion=0.5 and 0.7.

3.2.2. Terminal year depletion

The terminal year (2020) depletion for the Panel-approved reference run (depletion=0.1 in the year 2000) and sensitivity runs (depletion=0.2, 0.3, 0.5, and 0.7 in the year 2000) was sensitive to the assumed values of depletion in the year 2000 (**Table 3.4** and **Figure 3.8**). The posterior medians for the terminal year depletion showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 2000 (**Figure 3.8 upper panel**). Among the 5 runs, the distribution of the terminal year depletion for the Panel-approved reference run is the most similar to a bell shape (**Figure 3.8 lower panel**). The median (0.48) and mean (0.49) of the terminal year depletion were very similar for the Panel- approved reference run (**Table 3.4** and **Figure 3.8**). The medians of the terminal year depletion for the Panel-approved reference run and sensitivity runs were in a range between 0.48 and 0.94 (**Table 3.4**). The median of the terminal year depletion for each of the 5 Panel-approved reference run and sensitivity runs was larger than the assumed depletion in the year 2000 (i.e. 0.48 vs 0.1, 0.67 vs 0.2, 0.77 vs 0.3, 0.87 vs 0.5, 0.94 vs 0.7) (**Table 3.4**).

3.2.3. Projections

OFL_{2021} was estimated with the SSS inbuilt terminal year plus one projection. Longer term catch-based and *F*-based projections were not carried out due to the limitations of this catch-only method. Similar to the terminal year depletion, OFL_{2021} for the Panel-approved reference run (depletion=0.1 in the year 2000) and sensitivity runs (depletion 0.2, 0.3, 0.5, and 0.7 in the year 2000) was sensitive to the assumed values of depletion in the year 2000 (**Table 3.5** and **Figure 3.9**). The posterior medians for OFL_{2021} showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 2000 (**Figure 3.9 upper panel**). Among these 5 runs, the distribution of OFL_{2021} for the Panel-approved sensitivity run E1_B3 (depletion=0.3 in the year 2000) is the most similar to a bell shape (**Figure 3.9 lower panel**). However, the distribution of OFL_{2021} for the Panel-approved reference run E_B3 (depletion=0.1 in the year 2000) is skewed to the right (**Figure 3.9 lower**). Consequently, the median OFL_{2021} (71.208 mt ww) was much smaller than the mean OFL_{2021} (126.307 mt ww) for the Panel-approved reference run (**Table 3.5**). The medians of OFL_{2021} for the Panel-approved reference run and sensitivity runs were in a range between 71.208 and 406.480 mt ww (**Table 3.5**).

3.2.4. Additional sensitivity scenarios

In addition to the Panel-approved relative stock status in 2000, additional sensitivity scenarios were carried out assuming the relative stock status in 1990, 2010, and 2020 using the same levels of stock depletion (0.1, 0.2, 0.3 0.5, and 0.7). Sensitivity scenarios assuming the relative stock status in 2020 using the same levels of stock depletion (0.1, 0.2, 0.3 0.5, and 0.7) with a lower steepness (0.58 instead of 0.78) were also carried out.

Additional sensitivity runs assuming a relative stock status in 1990

The priors and posteriors for lnR_0 were similar to the Panel-approved reference run and sensitivity runs (**Figure 3.10**). Prior medians for lnR_0 were almost identical to the input value (lnR_0=2) as expected for all runs. The posterior medians for lnR_0 showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 1990. The posterior medians for lnR_0 were slightly smaller than 2 for the runs with depletion=0.1, 0.2, 0.3, and 0.5 whereas the posterior median for lnR_0 was slightly greater than 2 for the run with depletion = 0.7.

The posterior medians for the terminal year depletion showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 1990 (**Figure 3.11 upper panel**). However, the terminal year depletion reached zero for three runs with the assumed input depletion=0.1, 0.2, and 0.3 in the year 1990 (**Table 3.6** and **Figure 3.11 lower panel**). The medians of the terminal year depletion for these 5 sensitivity runs were in a range between 0 to 0.87 (**Table 3.6**). The median of the terminal year depletion for each of these 5 sensitivity runs was smaller than its counterpart run of the Panel-approved reference run and sensitivity runs (**Table 3.6**).

The posterior medians for OFL_{2021} showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 1990 (**Figure 3.12 upper panel**). However, OFL_{2021} was practically zero for three runs with the assumed input depletion=0.1, 0.2 and 0.3 in the year 1990 (**Table 3.7** and **Figure 3.12 lower panel**). The medians of OFL_{2021} for these 5 sensitivity runs were in a range between 0.013 and 224.440 mt ww (**Table 3.7**). The median of OFL_{2021} for each of these 5 sensitivity runs was smaller than its counterpart run of the Panel-approved reference run and sensitivity runs (**Table 3.7**).

Additional sensitivity runs assuming a relative stock status in 2010

The priors and posteriors for lnR_0 were similar to the Panel-approved reference run and sensitivity runs (**Figure 3.13**). Prior medians for lnR_0 were almost identical to the input value (lnR_0=2) as expected for all runs. The posterior medians for lnR_0 showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 2010. The posterior medians for lnR_0 were slightly smaller than 2 for the runs with the assumed depletion=0.1, 0.2, 0.3 and 0.5 whereas the posterior median for lnR_0 was slightly greater than 2 for the run with depletion=0.7.

The posterior medians for the terminal year depletion showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 2010 (**Figure 3.14 upper panel**). The medians of the terminal year depletion for these 5 sensitivity runs were in a range between 0.23 to 0.87 (**Table 3.6**). The median of the terminal year depletion for each of these 5 sensitivity runs was smaller than its counterpart run of the Panel-approved reference run and sensitivity runs (**Table 3.6**).

The posterior medians for OFL_{2021} showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 2010 (**Figure 3.15 upper panel**). The medians of OFL_{2021} for these 5 sensitivity runs were in a range between 41.340 and 225.990 mt ww (**Table 3.7**). The median of OFL_{2021} for each of these 5 sensitivity runs was smaller than its counterpart run of the Panel-approved reference run and sensitivity runs (**Table 3.7**).

Additional sensitivity runs assuming a relative stock status in 2020

The priors and posteriors for lnR_0 were similar to the Panel-approved reference run and sensitivity runs (**Figure 3.16**). Prior medians for lnR_0 were almost identical to the input value (lnR_0=2) as expected for all runs. The posterior medians for lnR_0 showed a slightly increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 2020. The posterior medians for lnR_0 were slightly smaller than 2 for all 5 runs.

The posterior medians for the terminal year depletion showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 2020 (**Figure 3.17 upper panel**). The medians of the terminal year depletion for these 5 sensitivity runs were in a range between 0.05 to 0.73 (**Table 3.6**). The median of the terminal year depletion for each of these 5 sensitivity runs was smaller than its counterpart run of the Panel-approved reference run and sensitivity runs. (**Table 3.6**).

The posterior medians for OFL_{2021} showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 2020 (**Figure 3.18 upper panel**). The medians of OFL_{2021} for these 5 sensitivity runs were in a range between 11.809 and 124.680 mt ww (**Table 3.7**). The median of OFL_{2021} for each of these 5 additional sensitivity runs was smaller than its counterpart run of both the Panel-approved reference run and sensitivity runs and the additional sensitivity runs assuming a relative stock status in 2010 (**Table 3.7**).

Additional sensitivity runs assuming a relative stock status in 2020 with a lower steepness
The priors and posteriors for lnR_0 were similar to the Panel-approved reference run and sensitivity runs (**Figure 3.19**). Prior medians for lnR_0 were almost identical to the input value (lnR_0=2) as expected for all runs. The posterior medians for lnR_0 did not show a consistent increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 2020 with a lower steepness (0.58). The posterior medians for lnR_0 were very similar and slightly smaller than 2 for the runs with depletion=0.1, 0.2 and 0.3 whereas the posterior medians for lnR_0 were slightly greater than 2 for the runs with depletion=0.5 and 0.7. The posterior median for lnR_0 was the largest for the run with depletion=0.5 among these 5 runs.

The posterior medians for the terminal year depletion showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 2020 with a lower steepness (0.58) (**Figure 3.20 upper panel**). The medians of the terminal year depletion for these 5 sensitivity runs were in a range between 0.05 to 0.73 (**Table 3.6**). The median of the terminal year depletion for each of these 5 sensitivity runs was very similar to its counterpart run of the additional sensitivity runs assuming a relative stock status in 2020 (**Table 3.6**). The median of the terminal year depletion for each of these 5 sensitivity runs was smaller than its counterpart run of the Panel-approved reference run and sensitivity runs (**Table 3.6**).

The posterior medians for OFL_{2021} showed an increasing trend from the assumed input depletion=0.1 to depletion=0.7 in the year 2020 with a lower steepness (0.58) (**Figure 3.21 upper panel**). The medians of OFL_{2021} for these 5 sensitivity runs were in a range between 9.536 and 158.020 mt ww (**Table 3.7**). The median of OFL_{2021} for each of these 5 additional sensitivity runs was smaller than its counterpart run of both the Panel-approved reference run and sensitivity runs and the additional sensitivity runs assuming a relative stock status in 2010 (**Table 3.7**).

3.2.5. ABC

The values of ABC_{2021} calculated from approach 1 for the Panel-approved reference run and sensitivity runs were in a range between 50.178 and 287.747 mt ww (**Table 3.8**). The values of ABC_{2021} calculated from approach 2 for the Panel-approved reference run and sensitivity runs were in a range between 46.072 and 262.993 mt ww (**Table 3.9**). ABC_{2021} calculated from approach 1 was slightly larger than its counterpart from approach 2. ABC_{2021} was 50.178 and 46.072 mt ww calculated from approach 1 and 2 for the Panel-approved reference run, respectively (**Table 3.8** and **Table 3.9**).

3.3. DISCUSSION

Two values of lnR_0 (12 and 2) were explored. The model results are not sensitive to the changes of the assumed lnR_0. However, models run much faster with lnR_0=2. Therefore, the Panel recommended to use lnR_0=2 for the reference model run. As the exploratory runs with lnR_0=12 have been presented and discussed during assessment webinars, the results of these runs were included as an **Appendix** for reference and completeness.

Providing a most reliable depletion level input in SSS is a major part of this assessment. The *OFL* estimates were sensitive to the stock status on the value of depletion in a given year (i.e. a proxy of overfished stock status) as an input and it is a common criticism how one would know what stock status is in order to use it as an input (Carruthers et al., 2014). Defining the relative stock status prior earlier in the time-series allows subsequent removals to inform terminal stock status (e.g. relative stock status in 1990, 2000 and 2010). By setting stock status at the terminal year (i.e. relative stock status in 2020), one has pre-determined status and disqualified any opportunity to inform current stock status. The Panel-approved to use the relative stock status in 2000 (depletion mean=0.1) as the best educated guess for the reference model run. The uncertainty in the assumed stock depletion was examined through the use of sensitivity scenarios with depletion mean=0.2, 0.3, 0.5, and 0.7.

Here is some supporting evidence to justify the Panel's recommendation:

1) Fishing pressure showed an initial increasing trend from 1981 to high values during a period ranging from 1985 to 1995, followed by a decreasing trend to a low value in 2000, and very reduced values during the last 20 years (i.e. 2001-2020). Therefore, 2000 should be the most depleted (i.e. value of depletion is small) period for this stock. The preliminary SEDAR 77 great hammerhead stock assessment suggested that the value of depletion was about 0.1 in 2000. Therefore, the assumption about the relative stock status in 2000 (depletion mean=0.1) for the Panel-approved reference run was in line with results for the great hammerheads.

2) Representative length composition data can be added to SSS as they become available to eliminate the need of the stock status on the value of depletion in a given year (i.e. a proxy of overfished stock status) as an input. The sample size of the length composition data is very small and very likely unrepresentative of the real length composition of the catch (524 observations for an approximately 55-year period; 225 of those measurements were estimated; only 7 years with more than 20 observations) (**Table 2.5.5**). Therefore, it is not advisable to fully use them for this assessment at this stage. For a proof of concept, all 2016-2019 length composition data were aggregated using a bin size of either 10 cm FL or 20 cm FL, and then assigned to either the year 2019 or 2016 (i.e. a "super year"). There are some spikes in the fit of the length composition (**Figure 3.22**), but the medians of OFL_{2021} estimated from SSS including super year 2019 based on aggregated 2016-2019 length composition data (37.682 mt ww using a bin size=10 cm FL; 55.137 mt ww using a bin size=20 cm FL) (**Figure 3.23**) were in the same ballpark as in the Panel-approved reference run (71.208 mt ww). Similarly, there are some spikes in the fit of the length composition (**Figure 3.24**), but the medians of OFL_{2021} estimated from SSS including super year 2016 based on aggregated 2016-2019 length composition data (48.49 mt ww using a bin size=10 cm FL; 66.96 mt ww using a bin size=20 cm FL) (**Figure 3.25**) were in the same ballpark as in the Panel-approved reference run (71.208 mt ww). Although not conclusive, the results of these proof-of-concept model runs provide some evidence to support the assumption about the relative stock status in 2000 (depletion mean=0.1) for the Panel-approved reference run.

This assessment can be considered data limited. Catch and life history data were available to be used in this stock assessment, but there were no time series data to develop indices of abundance or to fully parameterize catch-at-age or catch-at-length population dynamics. Therefore, this assessment falls under tier 3 of the *ABC* control rule in Final Amendment 14 to the 2006 Consolidated Atlantic Highly Migratory Species Fishery Management Plan (2023). *ABC* was calculated from two approaches provided here for management consideration.

SSS needs the stock status on the value of depletion in a given year (i.e. a proxy of overfished stock status) as an input, so SSS should not be used to determine if the stock is overfished. As total catch (4.400 mt ww) in the terminal year (**Table 2.5.2**) is much less than the estimated OFL_{2021} for the Panel-approved reference run and scenario runs (**Table 3.5**), overfishing most likely is not occurring. The uncertainty (*SD* and *CV*) associated with the OFL_{2021} for all Panel-approved runs was large, especially the Panel-approved reference run (**Table 3.5**). Since SSS provides highly uncertain estimates of *OFL*, the catch recommendations should be interpreted with caution. Longer terms of catch-based and *F*-based projections were not carried out due to the limitations of this catch-only method. In addition, longer term projections would be highly unreliable. Regardless, SSS offers a foothold in the path toward more fully realized stock assessments in SS, while providing catch limit information to advise resource managers along the way. It is more desirable for management to carry out data-limited assessments with SSS and provide some catch recommendations than delaying science-based management until there are sufficient data for a data-rich assessment (i.e. doing something is better than doing nothing). The median of the terminal year depletion for each of the Panel-approved reference run and sensitivity runs was larger than the assumed depletion in the year 2000 (i.e. 0.48 vs 0.1, 0.67 vs 0.2, 0.77 vs 0.3, 0.87 vs 0.5, 0.94 vs 0.7) (**Table 3.4**), which suggested the stock has been rebuilding since 2000 due to the low fishing pressure during the last 20 years or so. Therefore, the stock is very likely continuously rebuilding under the current management regulations.

3.4. RECOMMENDATIONS FOR DATA COLLECTION AND FUTURE RESEARCH

We list below research recommendations that are more feasible and would allow improvement of future stock assessments of this stock:

- Since catches are dominated by recreational catches, decreasing the uncertainty associated with the recreational catches will be critical for improvement of future stock assessments of this stock.
- Since representative length composition data can be added to SSS as they become available to free the input requirement of the stock status on the value of depletion in a given year (i.e. a proxy of overfished stock status), programs to collect length data to allow their incorporation into SSS in future assessments should be developed.
- Since there are insufficient time series data to develop indices of abundance, programs to collect relative abundance data to allow their incorporation into SSS in future assessments should also be developed.

- Since some of the life history data were borrowed from other stocks, programs to obtain representative biological information for this stock should also be developed.

3.5. ACKNOWLEDGMENTS

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3.7. TABLES

Table 3.1. Life history inputs for smooth hammerheads for SSS.

Female	Mean	SD	Prior type
Natural Mortality (M)	0.129	0.024	Lognormal
Asymptotic size (Linf)	293.9	0	Fixed
Growth coefficient (k)	0.09	0	Fixed
Correlation between Linf and k	0.96		Fixed
Age at length 0 (t_0)	-2.195	0	Fixed
CV at length(young then old)	0.1,0.1	0,0	Fixed
Length at 50% maturity	200		Fixed
Length at 95% maturity	227		Fixed
Reproductive cycle	biennial		Fixed
Constant litter size	33.5 pups per litter		Fixed
Fecundity-length relationship: Coefficient a	16.75		Fixed
Fecundity-length relationship: Exponent b	1E-10		Fixed
Steepness	0.78	0.15	Symmeric Beta
Weight (kg)-Length (cm) relationship: Coefficient a	0.000002		Fixed
Weight (kg)-Length (cm) relationship: Exponent b	3.329		Fixed
Male			
Natural Mortality (M)	0.129	0.024	Lognormal
Asymptotic size (Linf)	284.6	0	Fixed
Growth coefficient (k)	0.09	0	Fixed
Age at length 0 (t_0)	-2.25	0	Fixed
CV at length(young then old)	0.1,0.1	0,0	Fixed
Weight (kg)-Length (cm) relationship: Coefficient a	0.000002		Fixed
Weight (kg)-Length (cm) relationship: Exponent b	3.329		Fixed

Table 3.2. The Panel-approved reference run (highlighted in green) and sensitivity runs (see **Section 3.1.6** for details).

Scenario runs
The Panel-approved reference run and sensitivity runs
1-1) Dep=0.1 in 2000, lnR0=2, steepness=0.78 (E_B3)
1-2) Dep=0.2 in 2000, lnR0=2, steepness=0.78 (E02_B3)
1-3) Dep=0.3 in 2000, lnR0=2, steepness=0.78 (E1_B3)
1-4) Dep=0.5 in 2000, lnR0=2, steepness=0.78 (E2_B3)
1-5) Dep=0.7 in 2000, lnR0=2, steepness=0.78 (E3_B3)

Table 3.3. The Panel-approved reference run and sensitivity runs, and additional sensitivity runs. The settings of additional sensitivity runs are the same as the Panel-approved reference run and sensitivity runs, but assuming a relative stock status in 1990, 2010, 2020, and 2020 with a lower steepness (see **Section 3.1.6** for details).

Scenario runs
The Panel-approved reference run and sensitivity runs
1-1) Dep=0.1 in 2000, lnR0=2, steepness=0.78 (E_B3)
1-2) Dep=0.2 in 2000, lnR0=2, steepness=0.78 (E02_B3)
1-3) Dep=0.3 in 2000, lnR0=2, steepness=0.78 (E1_B3)
1-4) Dep=0.5 in 2000, lnR0=2, steepness=0.78 (E2_B3)
1-5) Dep=0.7 in 2000, lnR0=2, steepness=0.78 (E3_B3)
Additional sensitivity runs assuming a relative stock status in 1990
2-1) Dep=0.1 in 1990, lnR0=2, steepness=0.78 (F_B3)
2-2) Dep=0.2 in 1990, lnR0=2, steepness=0.78 (F02_B3)
2-3) Dep=0.3 in 1990, lnR0=2, steepness=0.78 (F1_B3)
2-4) Dep=0.5 in 1990, lnR0=2, steepness=0.78 (F2_B3)
2-5) Dep=0.7 in 1990, lnR0=2, steepness=0.78 (F3_B3)
Additional sensitivity runs assuming a relative stock status in 2010
3-1) Dep=0.1 in 2010, lnR0=2, steepness=0.78 (D_B3)
3-2) Dep=0.2 in 2010, lnR0=2, steepness=0.78 (D02_B3)
3-3) Dep=0.3 in 2010, lnR0=2, steepness=0.78 (D1_B3)
3-4) Dep=0.5 in 2010, lnR0=2, steepness=0.78 (D2_B3)
3-5) Dep=0.7 in 2010, lnR0=2, steepness=0.78 (D3_B3)
Additional sensitivity runs assuming a relative stock status in 2020
4-1) Dep=0.1 in 2020, lnR0=2, steepness=0.78 (C_B3)
4-2) Dep=0.2 in 2020, lnR0=2, steepness=0.78 (C02_B3)
4-3) Dep=0.3 in 2020, lnR0=2, steepness=0.78 (C1_B3)
4-4) Dep=0.5 in 2020, lnR0=2, steepness=0.78 (C2_B3)
4-5) Dep=0.7 in 2020, lnR0=2, steepness=0.78 (C3_B3)
Additional sensitivity runs assuming a relative stock status in 2020 with a lower steepness
5-1) Dep=0.1 in 2020, lnR0=2, steepness=0.58 (C_B3_C2)
5-2) Dep=0.2 in 2020, lnR0=2, steepness=0.58 (C02_B3_C2)
5-3) Dep=0.3 in 2020, lnR0=2, steepness=0.58 (C1_B3_C2)
5-4) Dep=0.5 in 2020, lnR0=2, steepness=0.58 (C2_B3_C2)
5-5) Dep=0.7 in 2020, lnR0=2, steepness=0.58 (C3_B3_C2)

Table 3.4. Values of the terminal year (2020) depletion for the Panel-approved reference run (depletion=0.1 in the year 2000) and sensitivity runs (depletion=0.2, 0.3, 0.5, and 0.7 in the year 2000).

Scenario runs	Dep (median)	Dep (mean)
The Panel-approved reference run and sensitivity runs		
1-1) Dep=0.1 in 2000, lnR0=2, steepness=0.78 (E_B3)	0.48	0.49
1-2) Dep=0.2 in 2000, lnR0=2, steepness=0.78 (E02_B3)	0.67	0.64
1-3) Dep=0.3 in 2000, lnR0=2, steepness=0.78 (E1_B3)	0.77	0.73
1-4) Dep=0.5 in 2000, lnR0=2, steepness=0.78 (E2_B3)	0.87	0.84
1-5) Dep=0.7 in 2000, lnR0=2, steepness=0.78 (E3_B3)	0.94	0.91

Table 3.5. Overfishing limits in the year 2021 (OFL_{2021}) for the Panel-approved reference run (depletion=0.1 in the year 2000) and sensitivity runs (depletion=0.2, 0.3, 0.5, and 0.7 in the year 2000).

Scenario runs	OFL (median)	OFL (mean)	SD	CV
The Panel-approved reference run and sensitivity runs				
1-1) Dep=0.1 in 2000, lnR0=2, steepness=0.78 (E_B3)	71.208	126.307	309.533	2.451
1-2) Dep=0.2 in 2000, lnR0=2, steepness=0.78 (E02_B3)	104.280	124.813	87.984	0.705
1-3) Dep=0.3 in 2000, lnR0=2, steepness=0.78 (E1_B3)	136.120	156.070	110.623	0.709
1-4) Dep=0.5 in 2000, lnR0=2, steepness=0.78 (E2_B3)	214.380	251.820	148.484	0.590
1-5) Dep=0.7 in 2000, lnR0=2, steepness=0.78 (E3_B3)	406.480	556.360	428.517	0.770

Table 3.6. Values of the terminal year (2020) depletion for the Panel-approved reference run and sensitivity runs, and additional sensitivity runs. The settings of additional sensitivity runs are the same as the Panel-approved reference run and sensitivity runs, but assuming a relative stock status in 1990, 2010, 2020, and 2020 with a lower steepness (see **Section 3.1.6** for details).

Scenario runs	Dep (median)	Dep (mean)
The Panel-approved reference run and sensitivity runs		
1-1) Dep=0.1 in 2000, lnR0=2, steepness=0.78 (E_B3)	0.48	0.49
1-2) Dep=0.2 in 2000, lnR0=2, steepness=0.78 (E02_B3)	0.67	0.64
1-3) Dep=0.3 in 2000, lnR0=2, steepness=0.78 (E1_B3)	0.77	0.73
1-4) Dep=0.5 in 2000, lnR0=2, steepness=0.78 (E2_B3)	0.87	0.84
1-5) Dep=0.7 in 2000, lnR0=2, steepness=0.78 (E3_B3)	0.94	0.91
Additional sensitivity runs assuming a relative stock status in 1990		
2-1) Dep=0.1 in 1990, lnR0=2, steepness=0.78 (F_B3)	0.00	0.05
2-2) Dep=0.2 in 1990, lnR0=2, steepness=0.78 (F02_B3)	0.00	0.08
2-3) Dep=0.3 in 1990, lnR0=2, steepness=0.78 (F1_B3)	0.00	0.12
2-4) Dep=0.5 in 1990, lnR0=2, steepness=0.78 (F2_B3)	0.43	0.40
2-5) Dep=0.7 in 1990, lnR0=2, steepness=0.78 (F3_B3)	0.87	0.73
Additional sensitivity runs assuming a relative stock status in 2010		
3-1) Dep=0.1 in 2010, lnR0=2, steepness=0.78 (D_B3)	0.23	0.27
3-2) Dep=0.2 in 2010, lnR0=2, steepness=0.78 (D02_B3)	0.40	0.44
3-3) Dep=0.3 in 2010, lnR0=2, steepness=0.78 (D1_B3)	0.57	0.56
3-4) Dep=0.5 in 2010, lnR0=2, steepness=0.78 (D2_B3)	0.75	0.72
3-5) Dep=0.7 in 2010, lnR0=2, steepness=0.78 (D3_B3)	0.87	0.85
Additional sensitivity runs assuming a relative stock status in 2020		
4-1) Dep=0.1 in 2020, lnR0=2, steepness=0.78 (C_B3)	0.05	0.10
4-2) Dep=0.2 in 2020, lnR0=2, steepness=0.78 (C02_B3)	0.14	0.22
4-3) Dep=0.3 in 2020, lnR0=2, steepness=0.78 (C1_B3)	0.27	0.30
4-4) Dep=0.5 in 2020, lnR0=2, steepness=0.78 (C2_B3)	0.51	0.51
4-5) Dep=0.7 in 2020, lnR0=2, steepness=0.78 (C3_B3)	0.73	0.70
Additional sensitivity runs assuming a relative stock status in 2020 with a lower steepness		
5-1) Dep=0.1 in 2020, lnR0=2, steepness=0.58 (C_B3_C2)	0.05	0.10
5-2) Dep=0.2 in 2020, lnR0=2, steepness=0.58 (C02_B3_C2)	0.12	0.20
5-3) Dep=0.3 in 2020, lnR0=2, steepness=0.58 (C1_B3_C2)	0.27	0.31
5-4) Dep=0.5 in 2020, lnR0=2, steepness=0.58 (C2_B3_C2)	0.50	0.50
5-5) Dep=0.7 in 2020, lnR0=2, steepness=0.58 (C3_B3_C2)	0.73	0.85

Table 3.7. Overfishing limits in the year 2021 (OFL_{2021}) for the Panel-approved reference run and sensitivity runs, and additional sensitivity runs. The settings of additional sensitivity runs are the same as the Panel-approved reference run and sensitivity runs, but assuming a relative stock status in 1990, 2010, 2020, and 2020 with a lower steepness (see **Section 3.1.6** for details).

Scenario runs	OFL (median)	OFL (mean)	SD	CV
The Panel-approved reference run and sensitivity runs				
1-1) Dep=0.1 in 2000, lnR0=2, steepness=0.78 (E_B3)	71.208	126.307	309.533	2.451
1-2) Dep=0.2 in 2000, lnR0=2, steepness=0.78 (E02_B3)	104.280	124.813	87.984	0.705
1-3) Dep=0.3 in 2000, lnR0=2, steepness=0.78 (E1_B3)	136.120	156.070	110.623	0.709
1-4) Dep=0.5 in 2000, lnR0=2, steepness=0.78 (E2_B3)	214.380	251.820	148.484	0.590
1-5) Dep=0.7 in 2000, lnR0=2, steepness=0.78 (E3_B3)	406.480	556.360	428.517	0.770
Additional sensitivity runs assuming a relative stock status in 1990				
2-1) Dep=0.1 in 1990, lnR0=2, steepness=0.78 (F_B3)	0.013	36.688	200.595	5.468
2-2) Dep=0.2 in 1990, lnR0=2, steepness=0.78 (F02_B3)	0.013	17.734	57.637	3.250
2-3) Dep=0.3 in 1990, lnR0=2, steepness=0.78 (F1_B3)	0.016	25.895	79.645	3.076
2-4) Dep=0.5 in 1990, lnR0=2, steepness=0.78 (F2_B3)	57.720	95.659	122.418	1.280
2-5) Dep=0.7 in 1990, lnR0=2, steepness=0.78 (F3_B3)	224.440	314.650	314.650	1.000
Additional sensitivity runs assuming a relative stock status in 2010				
3-1) Dep=0.1 in 2010, lnR0=2, steepness=0.78 (D_B3)	41.340	69.830	155.561	2.228
3-2) Dep=0.2 in 2010, lnR0=2, steepness=0.78 (D02_B3)	64.540	77.330	46.555	0.602
3-3) Dep=0.3 in 2010, lnR0=2, steepness=0.78 (D1_B3)	89.740	98.230	54.918	0.559
3-4) Dep=0.5 in 2010, lnR0=2, steepness=0.78 (D2_B3)	131.750	149.760	71.412	0.477
3-5) Dep=0.7 in 2010, lnR0=2, steepness=0.78 (D3_B3)	225.990	302.880	213.153	0.704
Additional sensitivity runs assuming a relative stock status in 2020				
4-1) Dep=0.1 in 2020, lnR0=2, steepness=0.78 (C_B3)	11.809	29.927	81.847	2.735
4-2) Dep=0.2 in 2020, lnR0=2, steepness=0.78 (C02_B3)	28.022	39.386	30.920	0.785
4-3) Dep=0.3 in 2020, lnR0=2, steepness=0.78 (C1_B3)	47.777	53.242	32.935	0.619
4-4) Dep=0.5 in 2020, lnR0=2, steepness=0.78 (C2_B3)	81.280	86.730	38.413	0.443
4-5) Dep=0.7 in 2020, lnR0=2, steepness=0.78 (C3_B3)	124.680	156.520	100.546	0.642
Additional sensitivity runs assuming a relative stock status in 2020 with a lower steepness				
5-1) Dep=0.1 in 2020, lnR0=2, steepness=0.58 (C_B3_C2)	9.536	32.039	109.602	3.421
5-2) Dep=0.2 in 2020, lnR0=2, steepness=0.58 (C02_B3_C2)	22.446	36.103	35.114	0.973
5-3) Dep=0.3 in 2020, lnR0=2, steepness=0.58 (C1_B3_C2)	46.515	56.243	40.703	0.724
5-4) Dep=0.5 in 2020, lnR0=2, steepness=0.58 (C2_B3_C2)	88.550	88.550	56.657	0.640
5-5) Dep=0.7 in 2020, lnR0=2, steepness=0.58 (C3_B3_C2)	158.020	214.170	214.170	1.000

Table 3.8. Acceptable biological catch in the year 2021 (ABC_{2021}) calculated as 30th percentile of OFL_{2021} (Approach 1, see **Section 3.1.8**) for the Panel-approved reference run (depletion=0.1 in the year 2000) and sensitivity runs (depletion=0.2, 0.3, 0.5, and 0.7 in the year 2000).

Scenario runs	OFL (median)	OFL (mean)	SD	CV	ABC (30th percentile of OFL)	ABC/OFL ratio
The Panel-approved reference run and sensitivity runs						
1-1) Dep=0.1 in 2000, lnR0=2, steepness=0.78 (E_B3)	71.208	126.307	309.533	2.451	50.178	0.705
1-2) Dep=0.2 in 2000, lnR0=2, steepness=0.78 (E02_B3)	104.280	124.813	87.984	0.705	77.107	0.739
1-3) Dep=0.3 in 2000, lnR0=2, steepness=0.78 (E1_B3)	136.120	156.070	110.623	0.709	109.147	0.802
1-4) Dep=0.5 in 2000, lnR0=2, steepness=0.78 (E2_B3)	214.380	251.820	148.484	0.590	166.356	0.776
1-5) Dep=0.7 in 2000, lnR0=2, steepness=0.78 (E3_B3)	406.480	556.360	428.517	0.770	287.747	0.708

Table 3.9. Acceptable biological catch in the year 2021 (ABC_{2021}) calculated by using an *ABC/OFL* ratio of 0.647 for tier 3 stocks with a *P**=0.3 following Courtney and Rice (2023) (Approach 2, see **Section 3.1.8**) for the Panel-approved reference run (depletion=0.1 in the year 2000) and sensitivity runs (depletion=0.2, 0.3, 0.5, and 0.7 in the year 2000).

Scenario runs	OFL (median)	OFL (mean)	SD	CV	ABC (median)	ABC/OFL ratio
The Panel-approved reference run and sensitivity runs						
1-1) Dep=0.1 in 2000, lnR0=2, steepness=0.78 (E_B3)	71.208	126.307	309.533	2.451	46.072	0.647
1-2) Dep=0.2 in 2000, lnR0=2, steepness=0.78 (E02_B3)	104.280	124.813	87.984	0.705	67.469	0.647
1-3) Dep=0.3 in 2000, lnR0=2, steepness=0.78 (E1_B3)	136.120	156.070	110.623	0.709	88.070	0.647
1-4) Dep=0.5 in 2000, lnR0=2, steepness=0.78 (E2_B3)	214.380	251.820	148.484	0.590	138.704	0.647
1-5) Dep=0.7 in 2000, lnR0=2, steepness=0.78 (E3_B3)	406.480	556.360	428.517	0.770	262.993	0.647

3.8. FIGURES

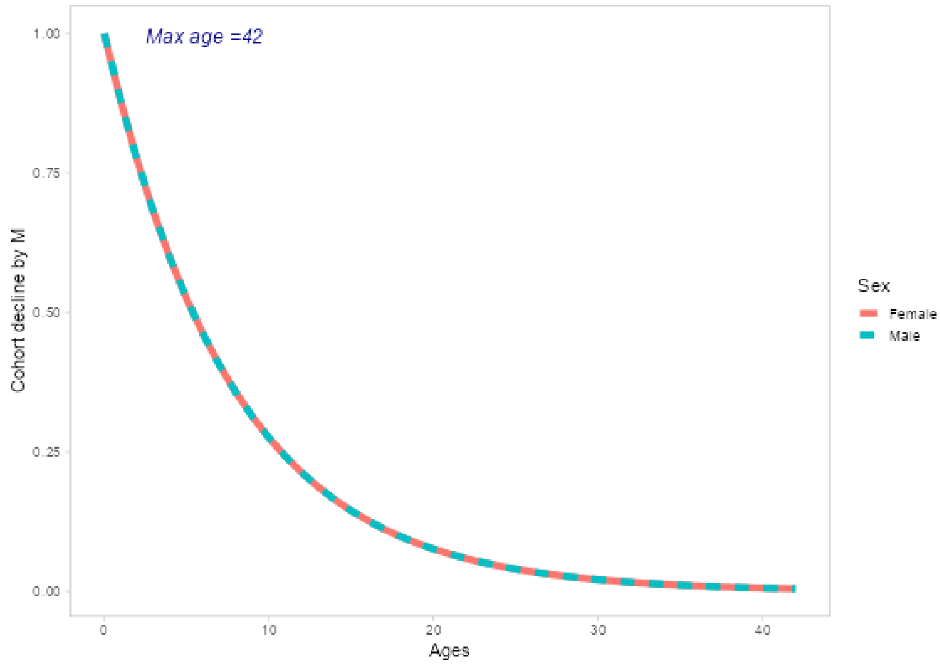

Figure 3.1. Natural mortality curves/functions were implemented in SSS based on the input value for the reference run.

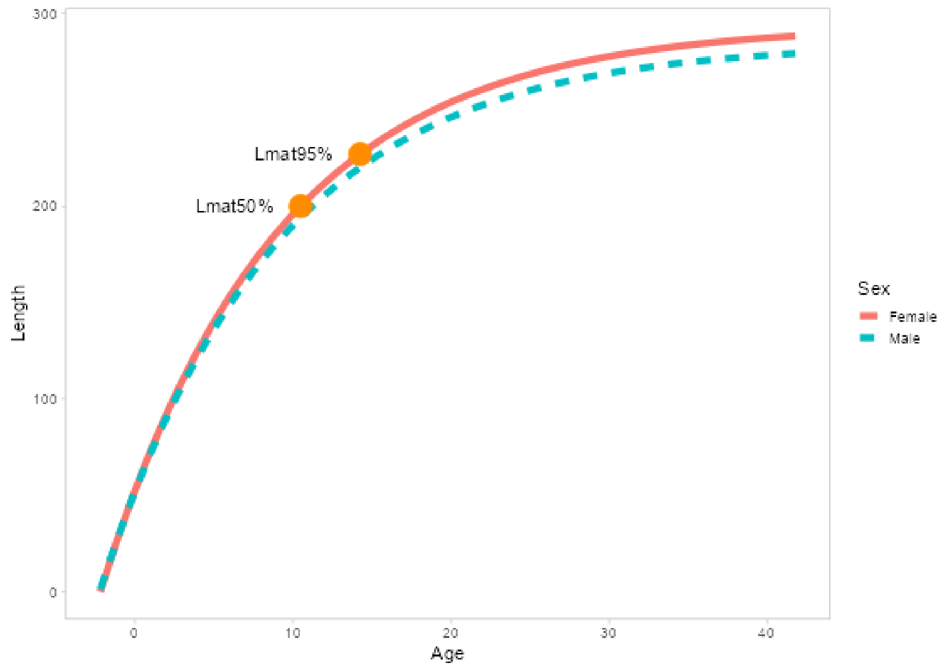

Figure 3.2. Growth curves/functions were implemented in SSS based on the input values for the reference run. Length is in cm fork length.

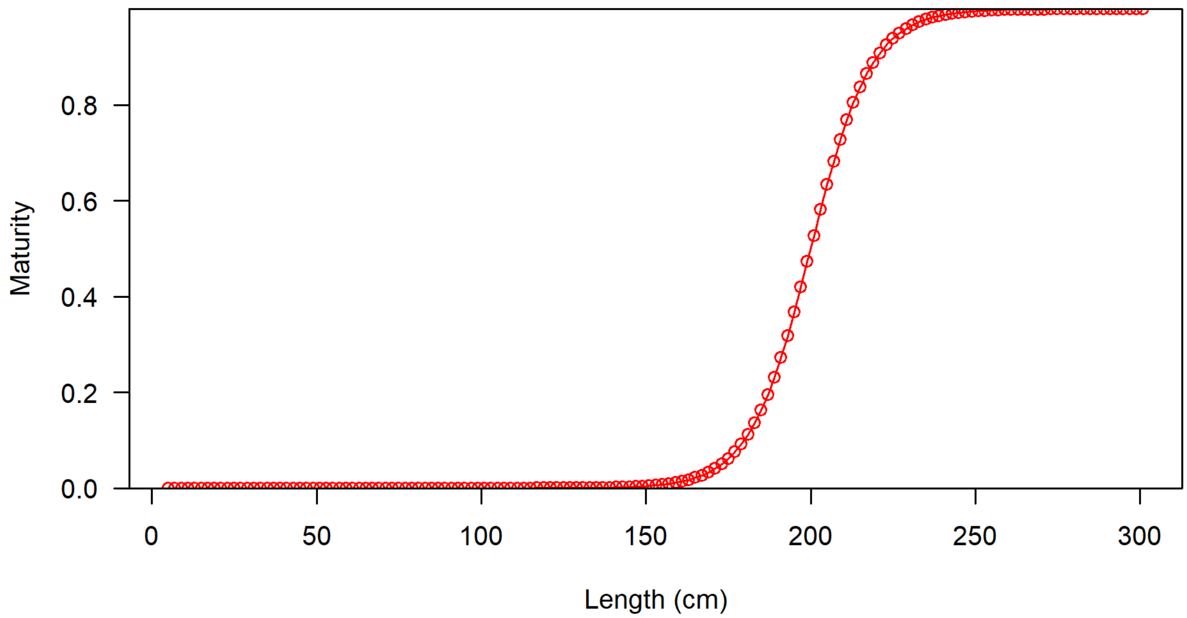

Figure 3.3. Maturity curve/function for females was implemented in SSS based on the input values for the reference run. Length is in cm fork length.

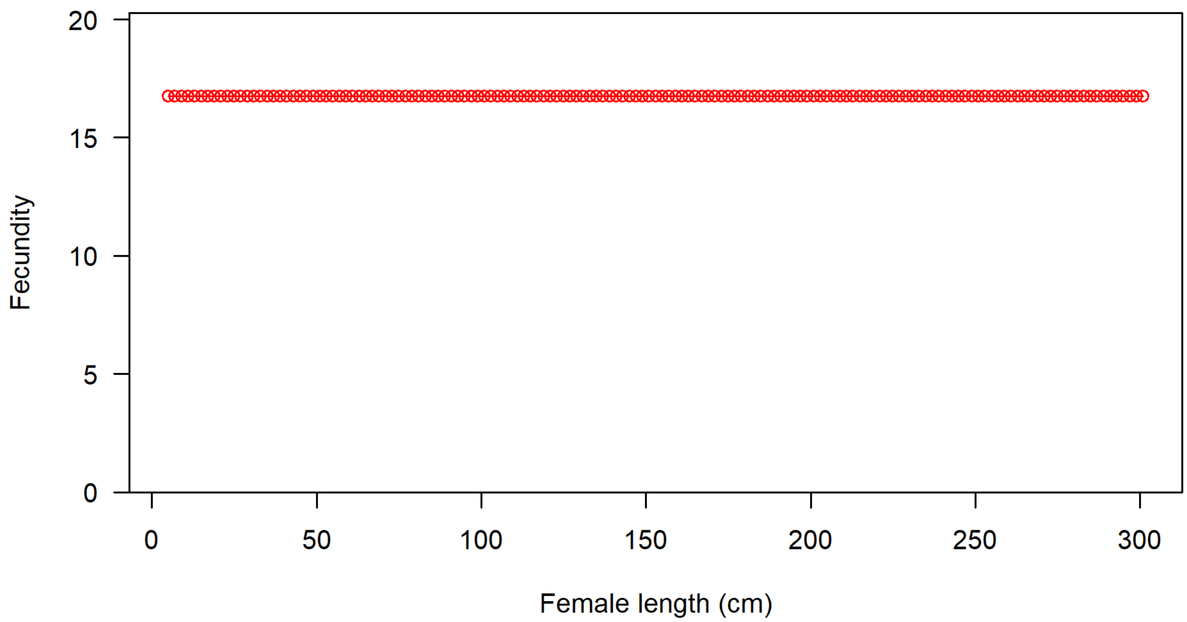

Figure 3.4. Length-invariant fecundity-length relationship was implemented in SSS based on the input values for the reference run. Length is in cm fork length.

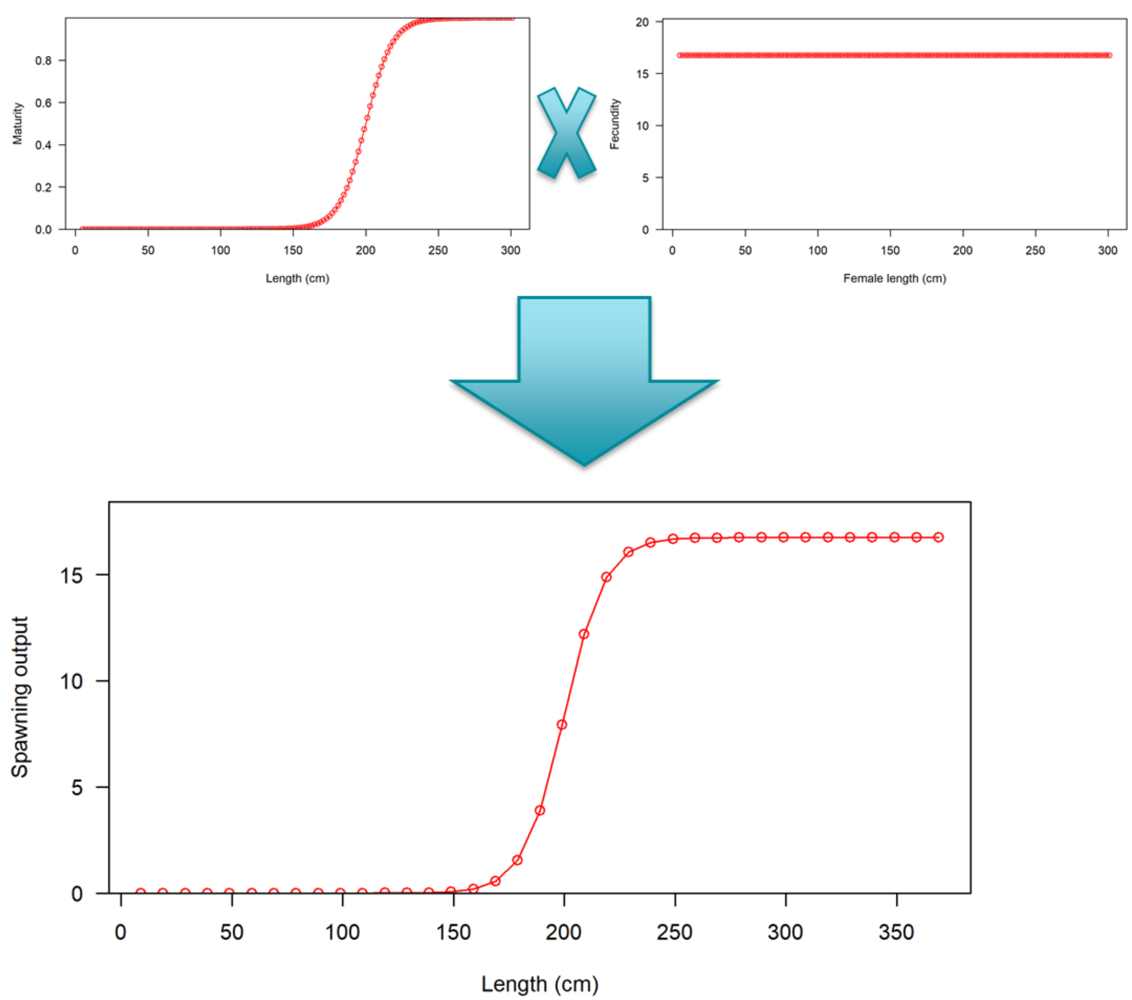

Figure 3.5. Spawning output-length relationship derived from the length-invariant fecundity relationship scaled (i.e. multiplied) with the logistic maturity-length relationship in SSS for the reference run. Length is in cm fork length.

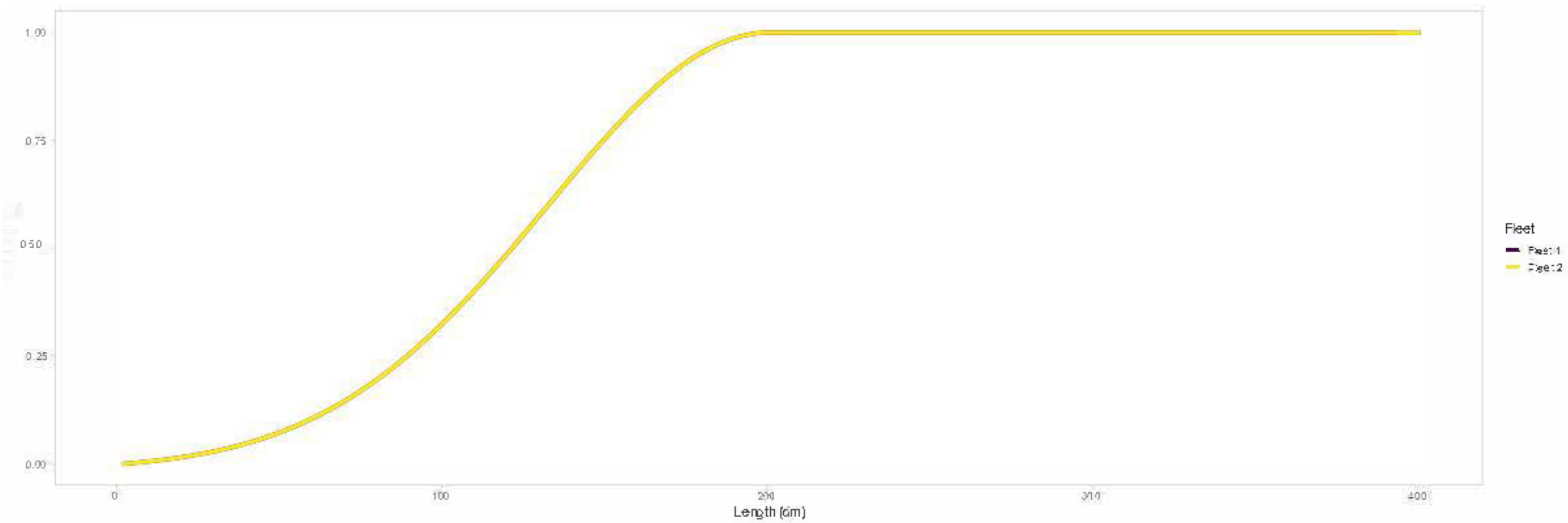

Figure 3.6. Logistic selectivity curve with 50% and 95% selectivity lengths (120 cm FL and 200 cm FL) was implemented in SSS for the reference run.

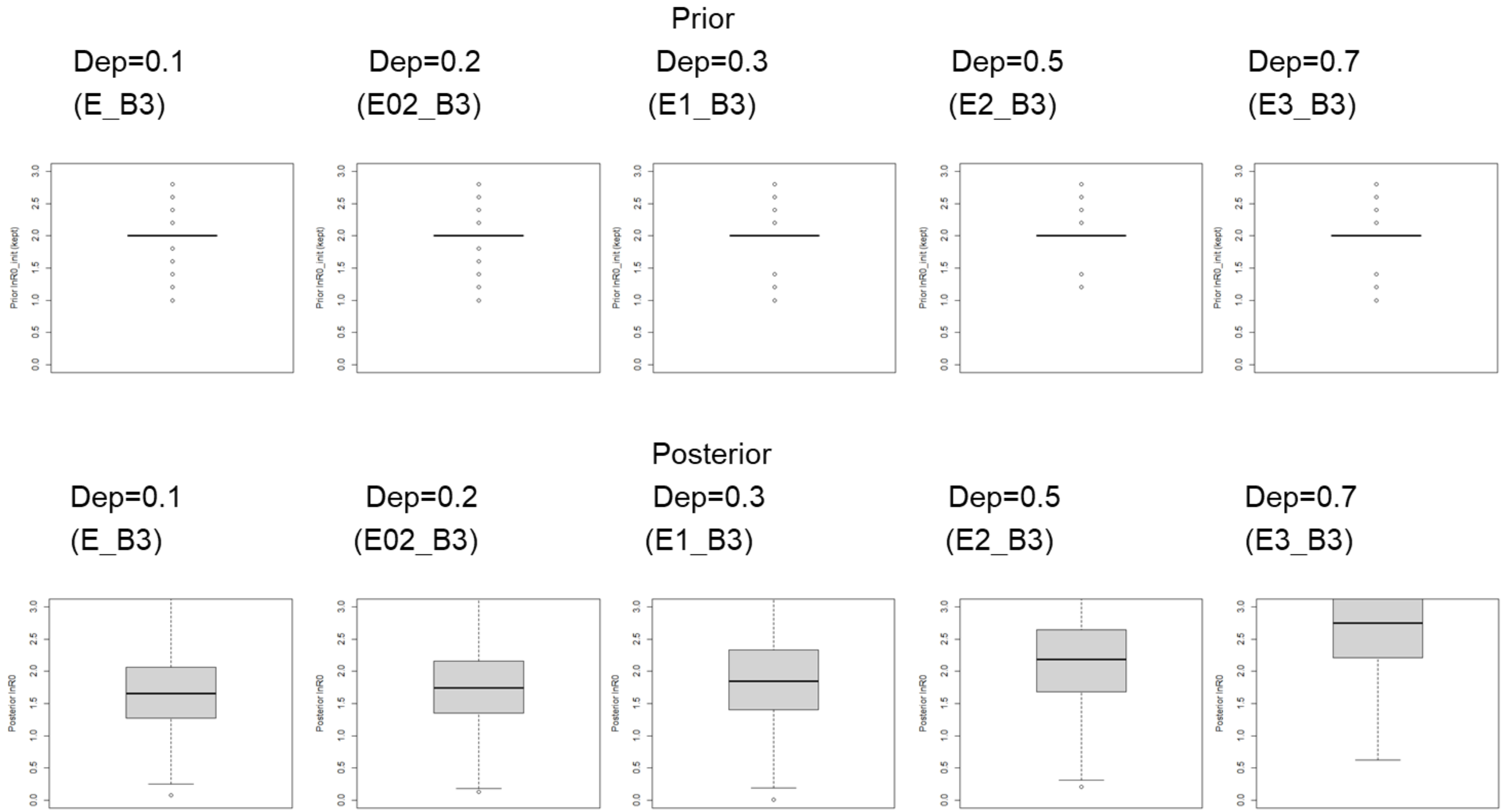

Figure 3.7. Priors and posteriors for *lnR₀* for the Panel-approved reference run (depletion=0.1 (E_B3) in the year 2000) and sensitivity runs (depletion=0.2 (E02_B3), 0.3 (E1_B3), 0.5 (E2_B3), and 0.7 (E3_B3) in the year 2000).

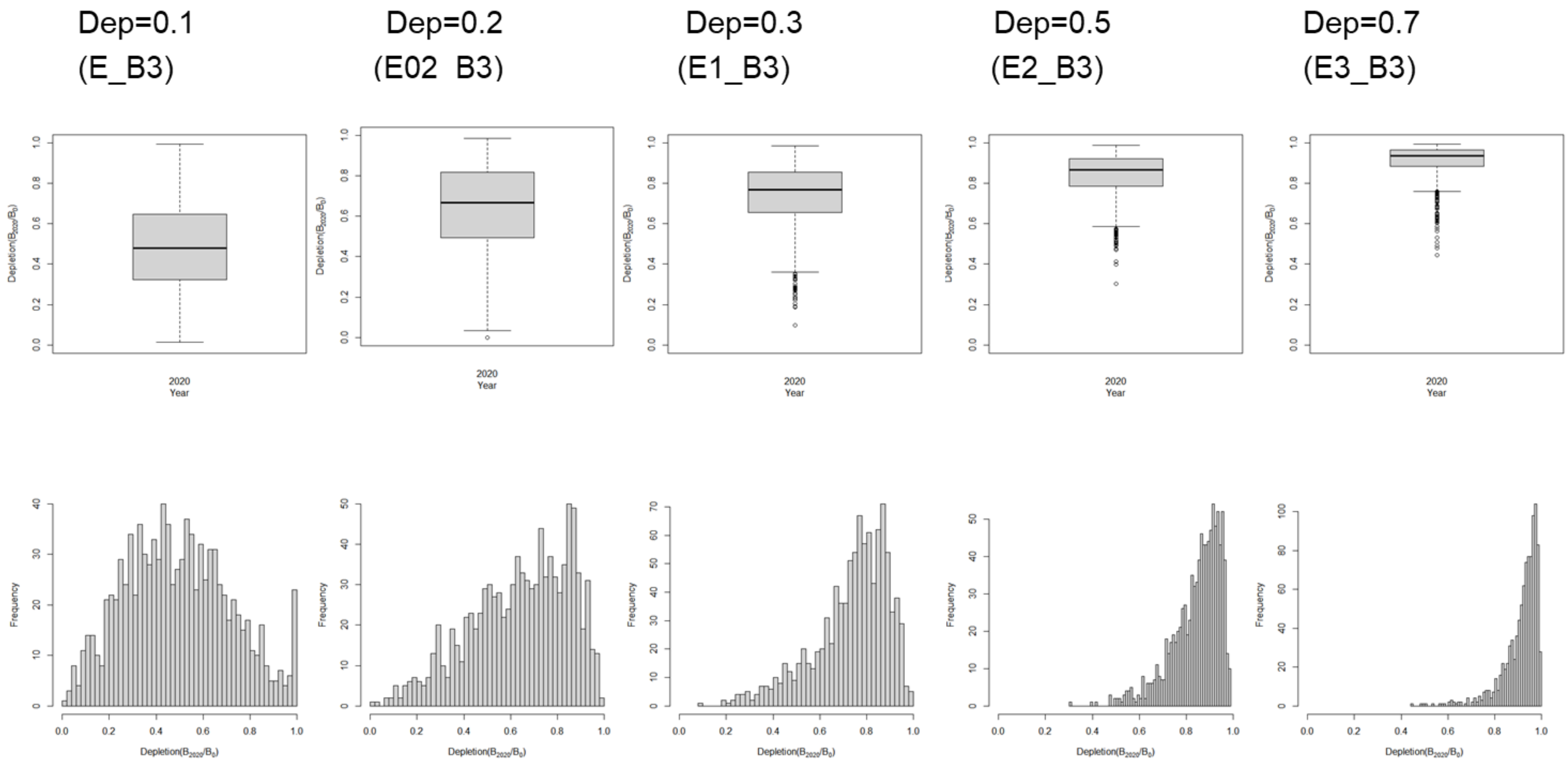

Figure 3.8. Terminal year (2020) depletion for the Panel-approved reference run (depletion=0.1 (E_B3) in the year 2000) and sensitivity runs (depletion=0.2 (E02_B3), 0.3 (E1_B3), 0.5 (E2_B3), and 0.7 (E3_B3) in the year 2000).

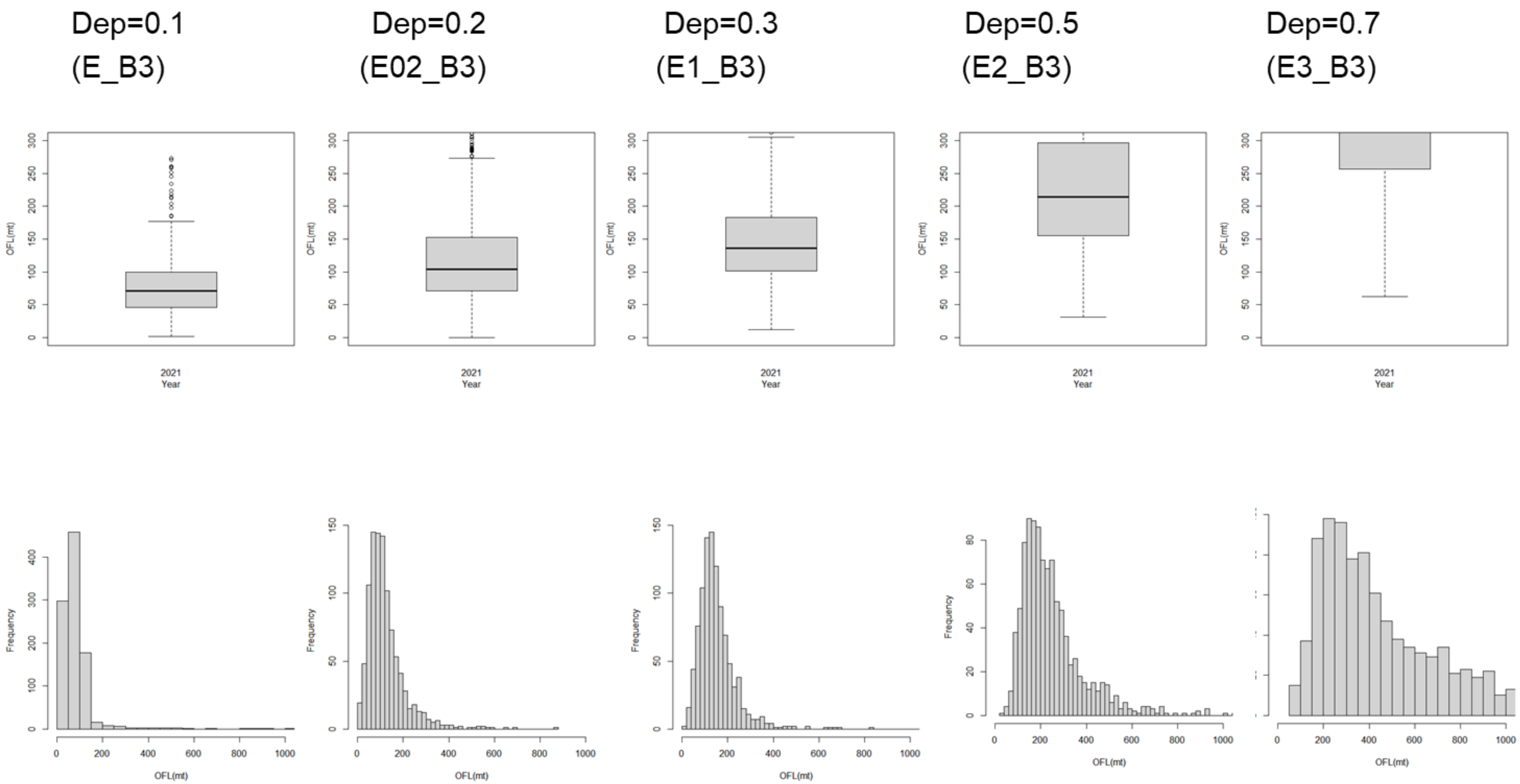

Figure 3.9. *OFL* in 2021 (terminal year plus one) for the Panel-approved reference run (depletion=0.1 (E_B3) in the year 2000) and sensitivity runs (depletion=0.2 (E02_B3), 0.3 (E1_B3), 0.5 (E2_B3), and 0.7 (E3_B3) in the year 2000).

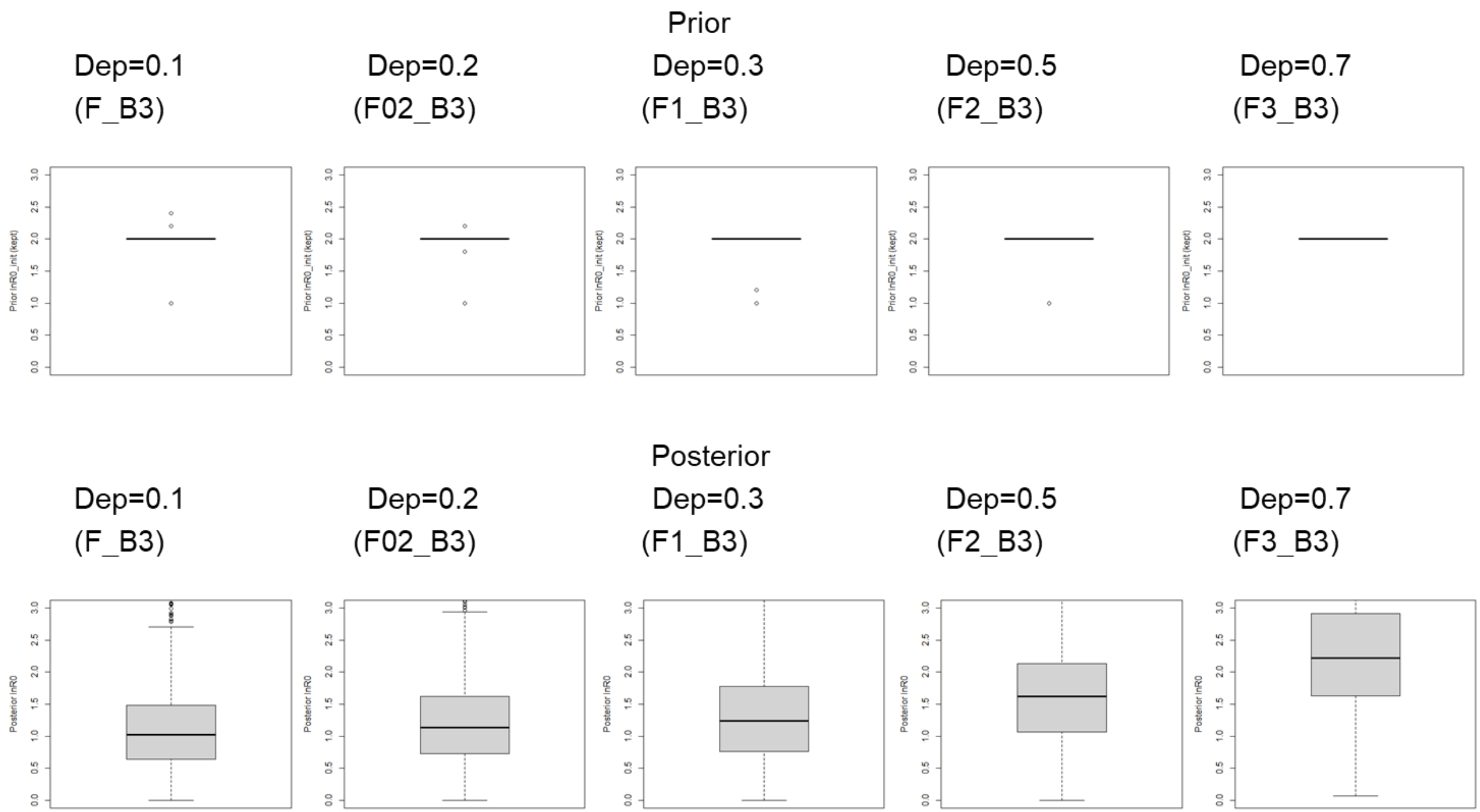

Figure 3.10. Priors and posteriors for lnR_0 for additional sensitivity runs (depletion=0.1 (F_B3), 0.2 (F02_B3), 0.3 (F1_B3), 0.5 (F2_B3), and 0.7 (F3_B3) in the year 1990) (see **Section 3.1.6**).

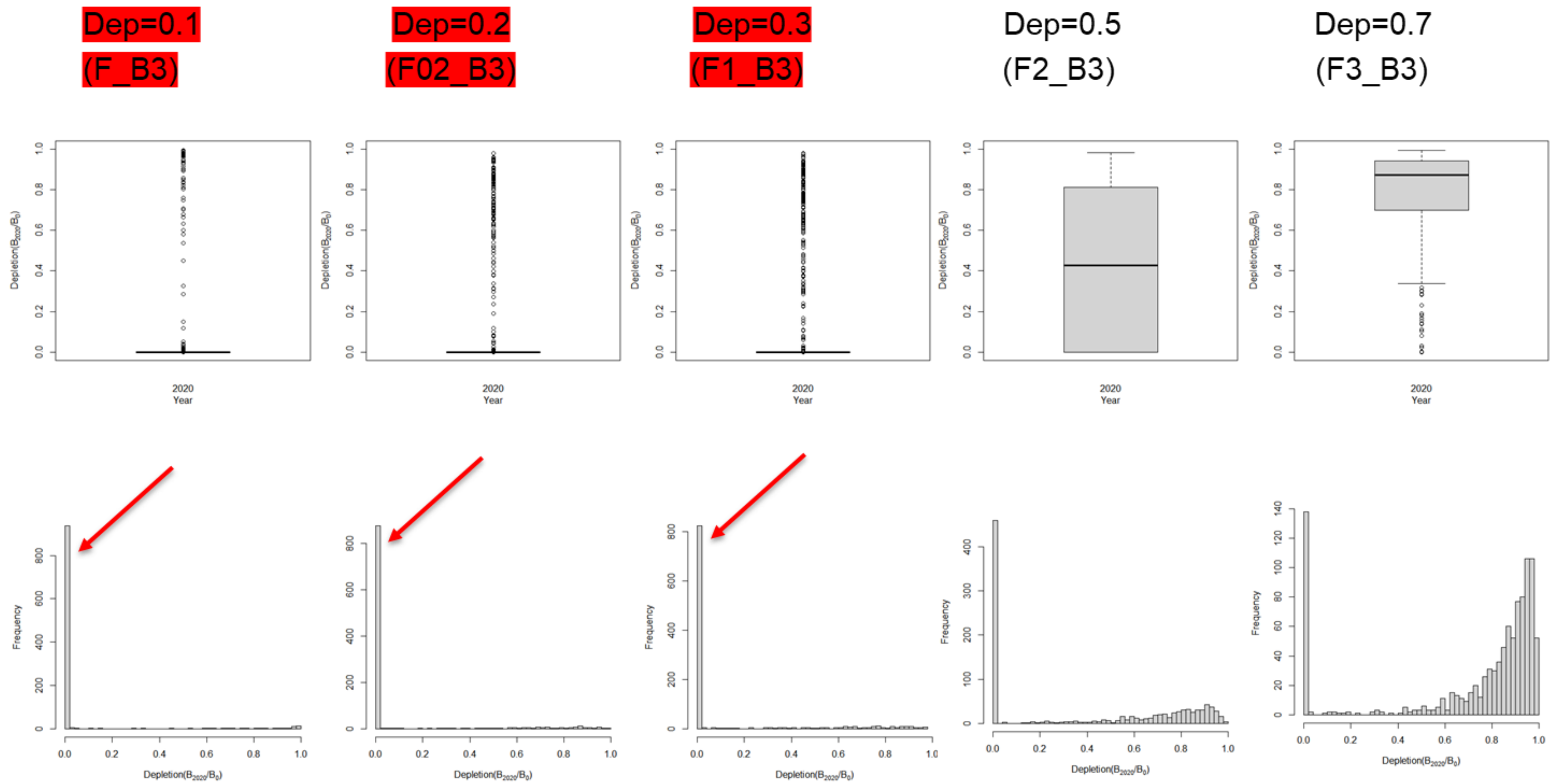

Figure 3.11. Terminal year (2020) depletion for additional sensitivity runs (depletion=0.1 (F_B3), 0.2 (F02_B3), 0.3 (F1_B3), 0.5 (F2_B3), and 0.7 (F3_B3) in the year 1990) (see **Section 3.1.6**).

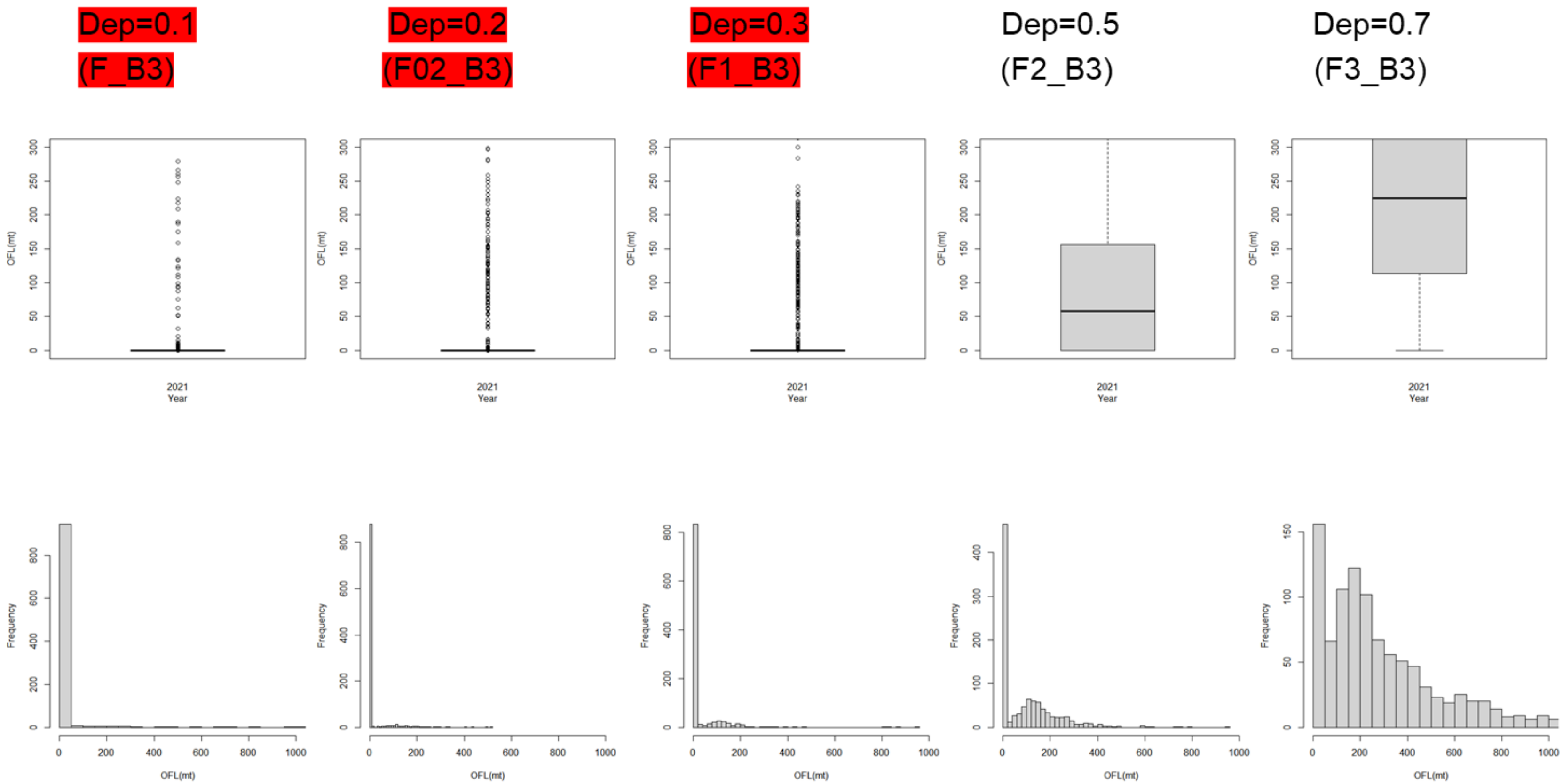

Figure 3.12. *OFL* in 2021 (terminal year plus one) for additional sensitivity runs (depletion=0.1 (F_B3), 0.2 (F02_B3), 0.3 (F1_B3), 0.5 (F2_B3), and 0.7 (F3_B3) in the year 1990) (see **Section 3.1.6**).

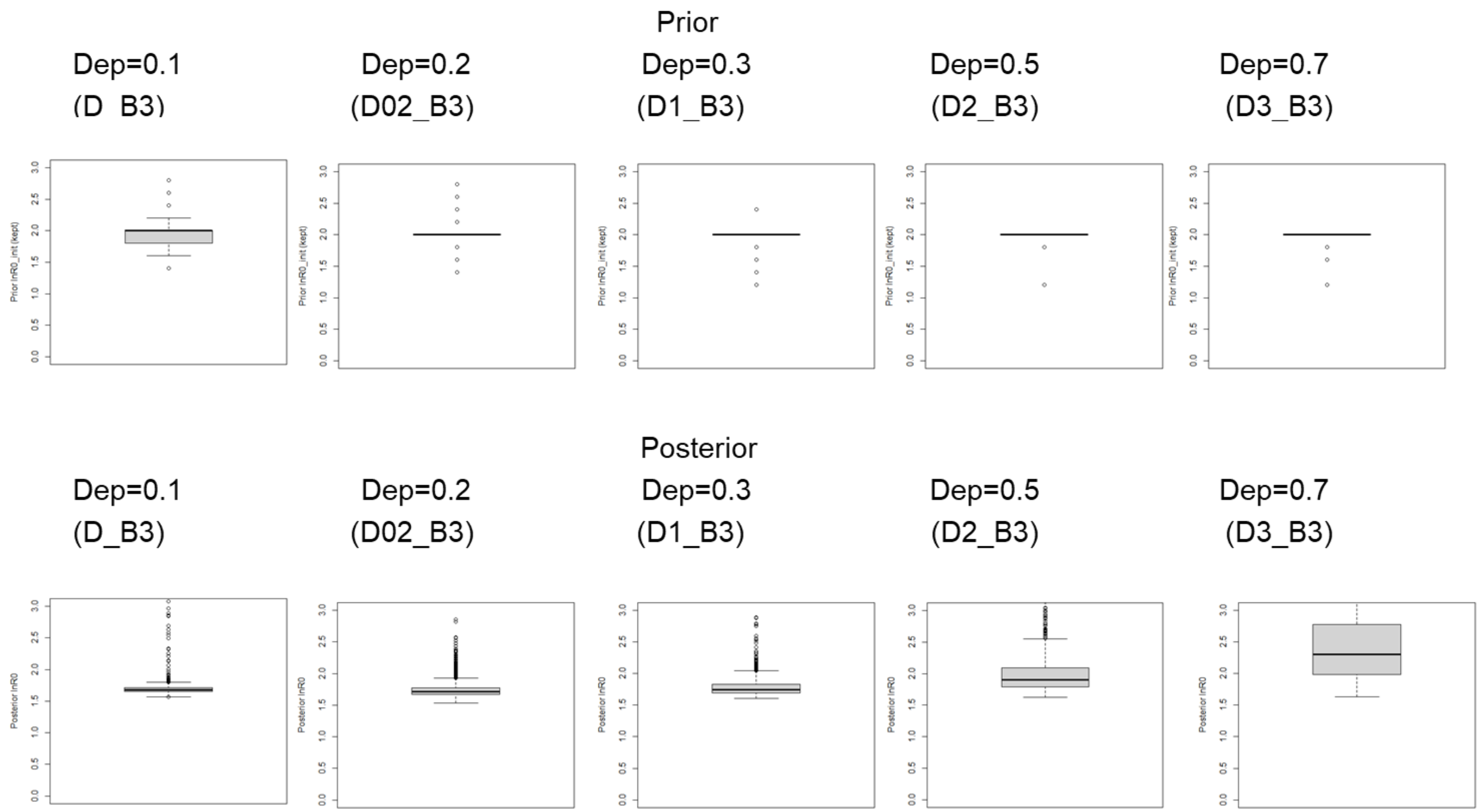

Figure 3.13. Priors and posteriors for *lnR₀* for additional sensitivity runs (depletion=0.1 (D_B3), 0.2 (D02_B3), 0.3 (D1_B3), 0.5 (D2_B3), and 0.7 (D3_B3) in the year 2010) (see **Section 3.1.6**).

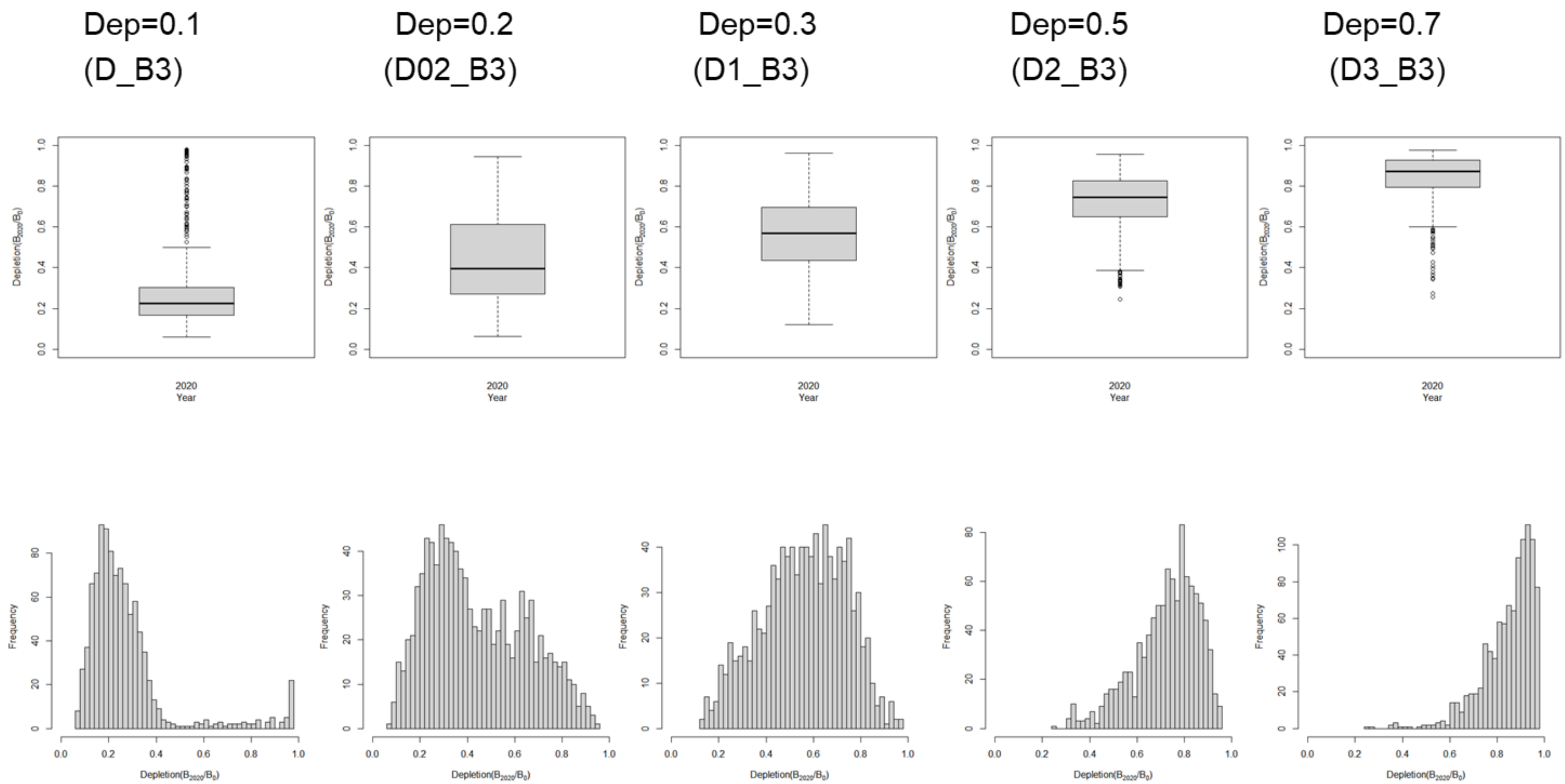

Figure 3.14. Terminal year (2020) depletion for additional sensitivity runs (depletion=0.1 (D_B3), 0.2 (D02_B3), 0.3 (D1_B3), 0.5 (D2_B3), and 0.7 (D3_B3) in the year 2010) (see **Section 3.1.6**).

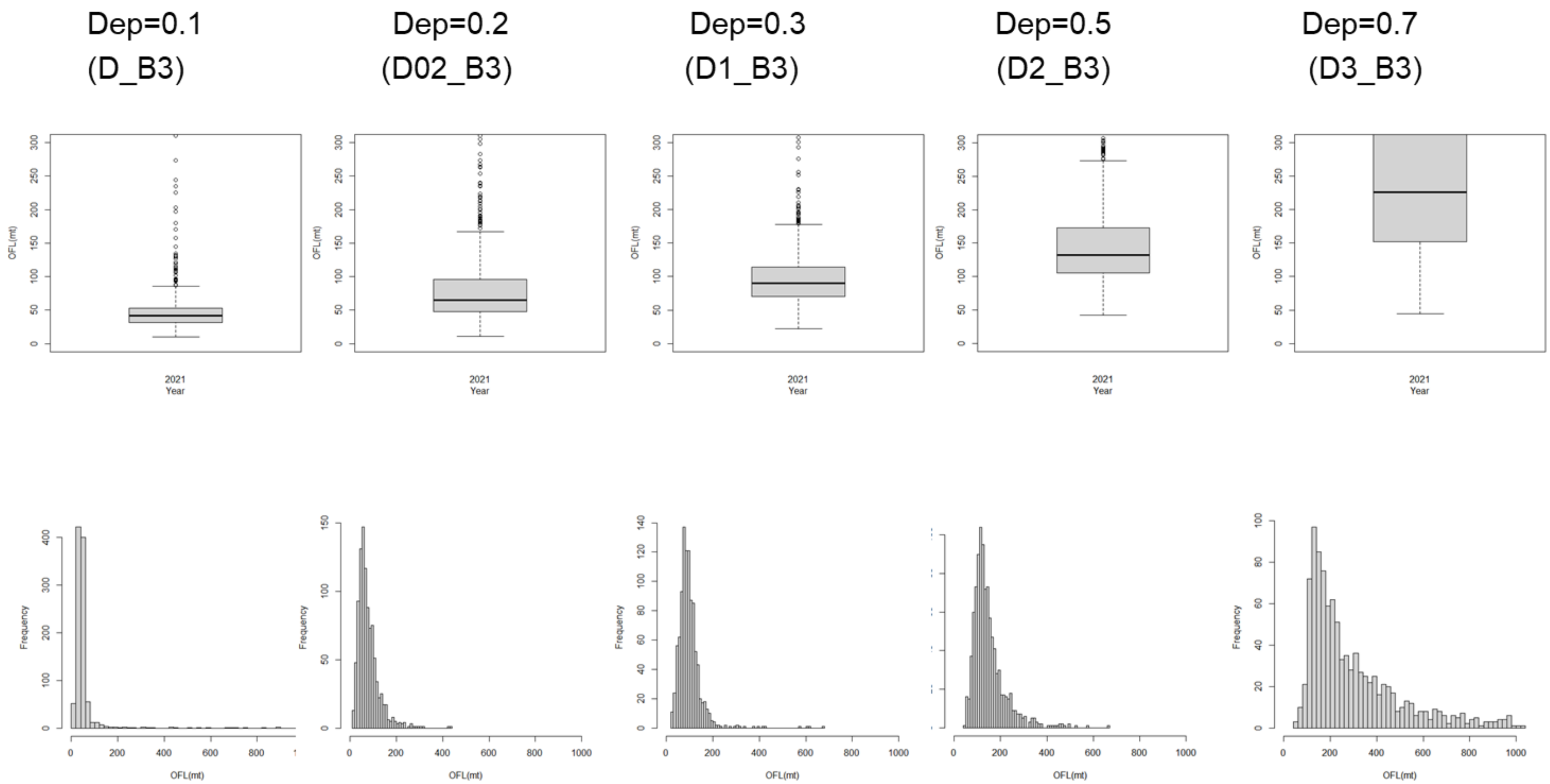

Figure 3.15. *OFL* in 2021 (terminal year plus one) for additional sensitivity runs (depletion=0.1 (D_B3), 0.2 (D02_B3), 0.3 (D1_B3), 0.5 (D2_B3), and 0.7 (D3_B3) in the year 2010) (see **Section 3.1.6**).

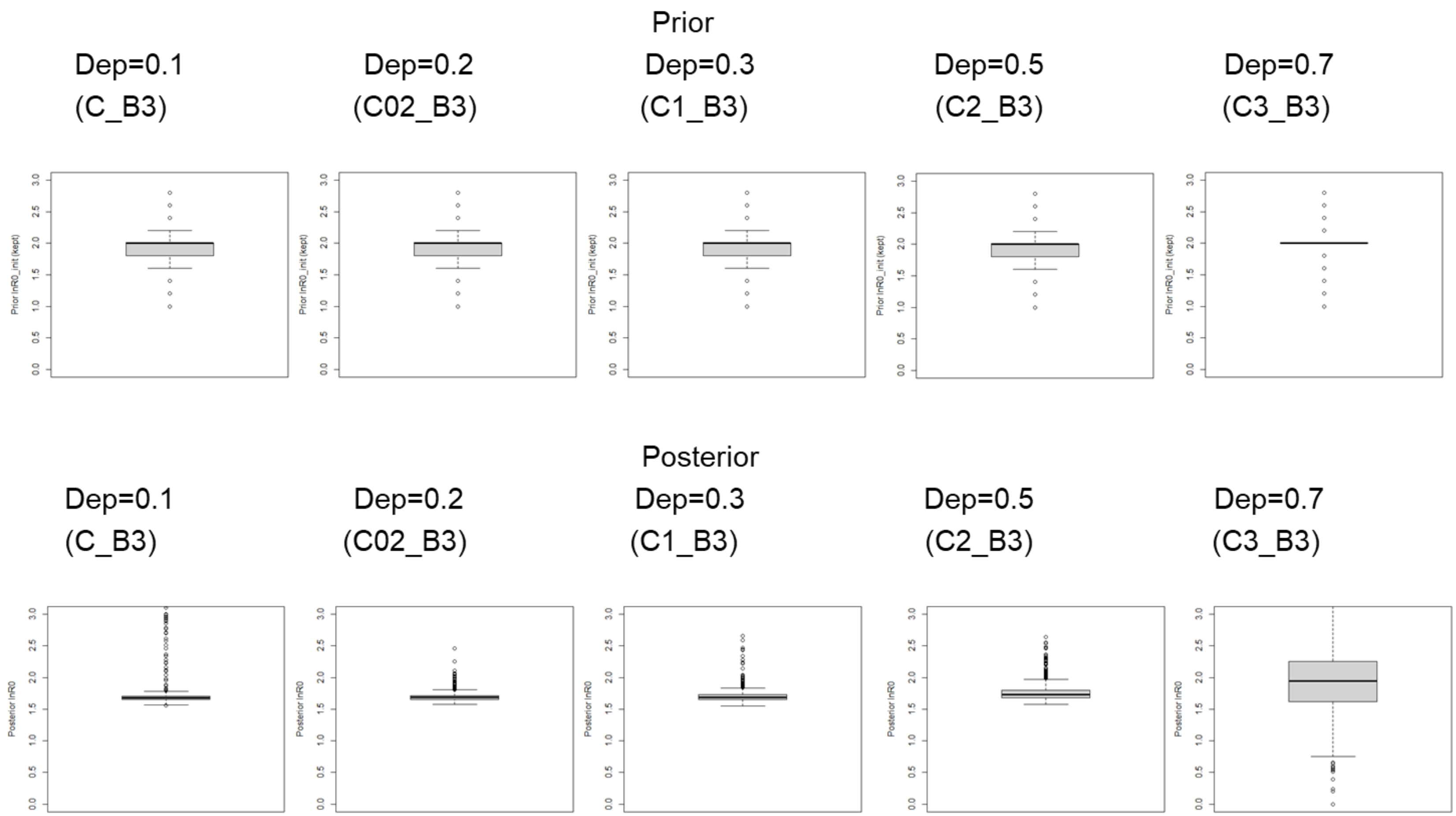

Figure 3.16. Priors and posteriors for lnR_0 for additional sensitivity runs (depletion 0.1 (C_B3), 0.2 (C02_B3), 0.3 (C1_B3), 0.5 (C2_B3), and 0.7 (C3_B3) in the year 2020) (see **Section 3.1.6**).

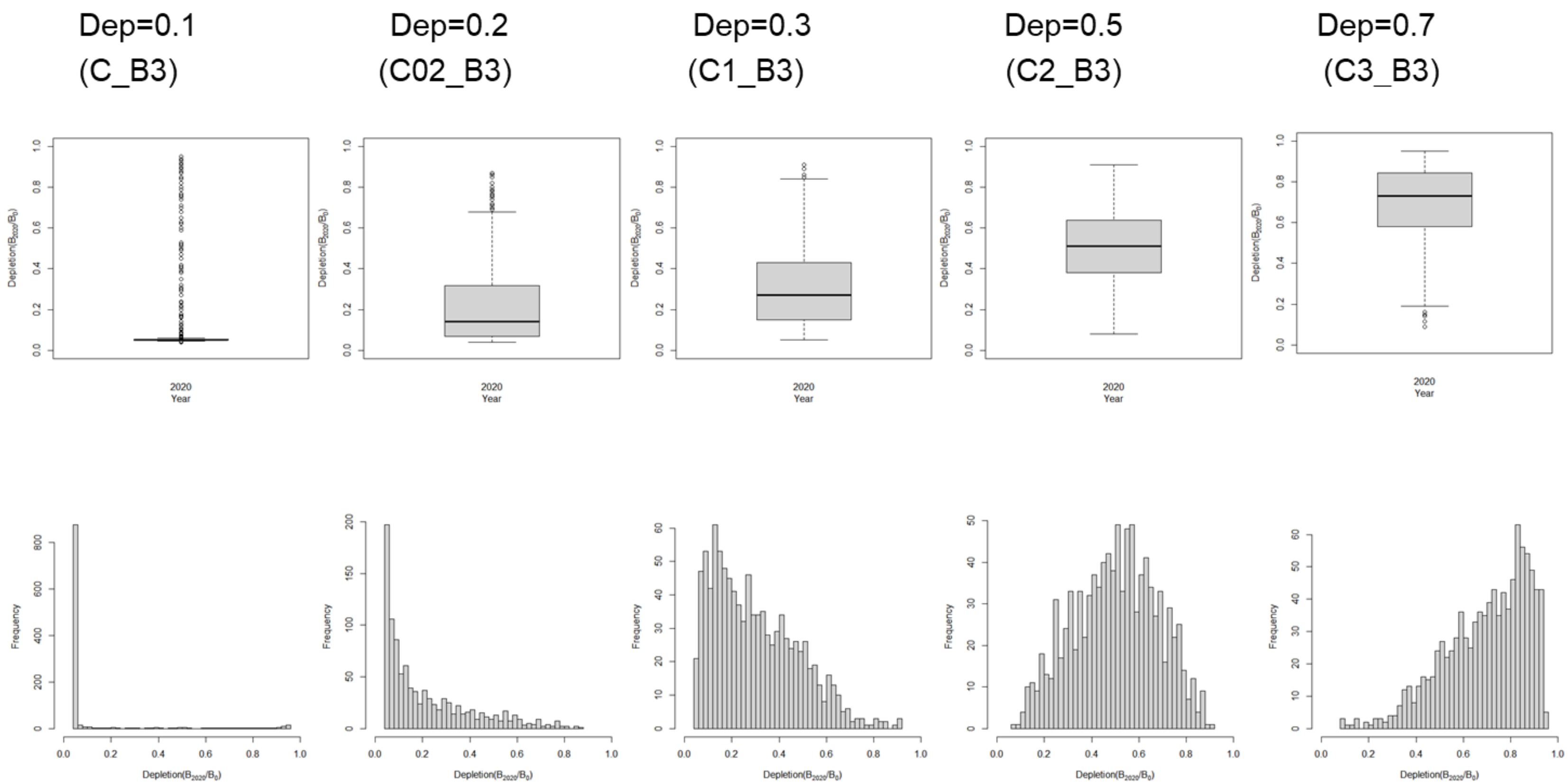

Figure 3.17. Terminal year (2020) depletion for additional sensitivity runs (depletion=0.1 (C_B3), 0.2 (C02_B3), 0.3 (C1_B3), 0.5 (C2_B3), and 0.7 (C3_B3) in the year 2020) (see **Section 3.1.6**).

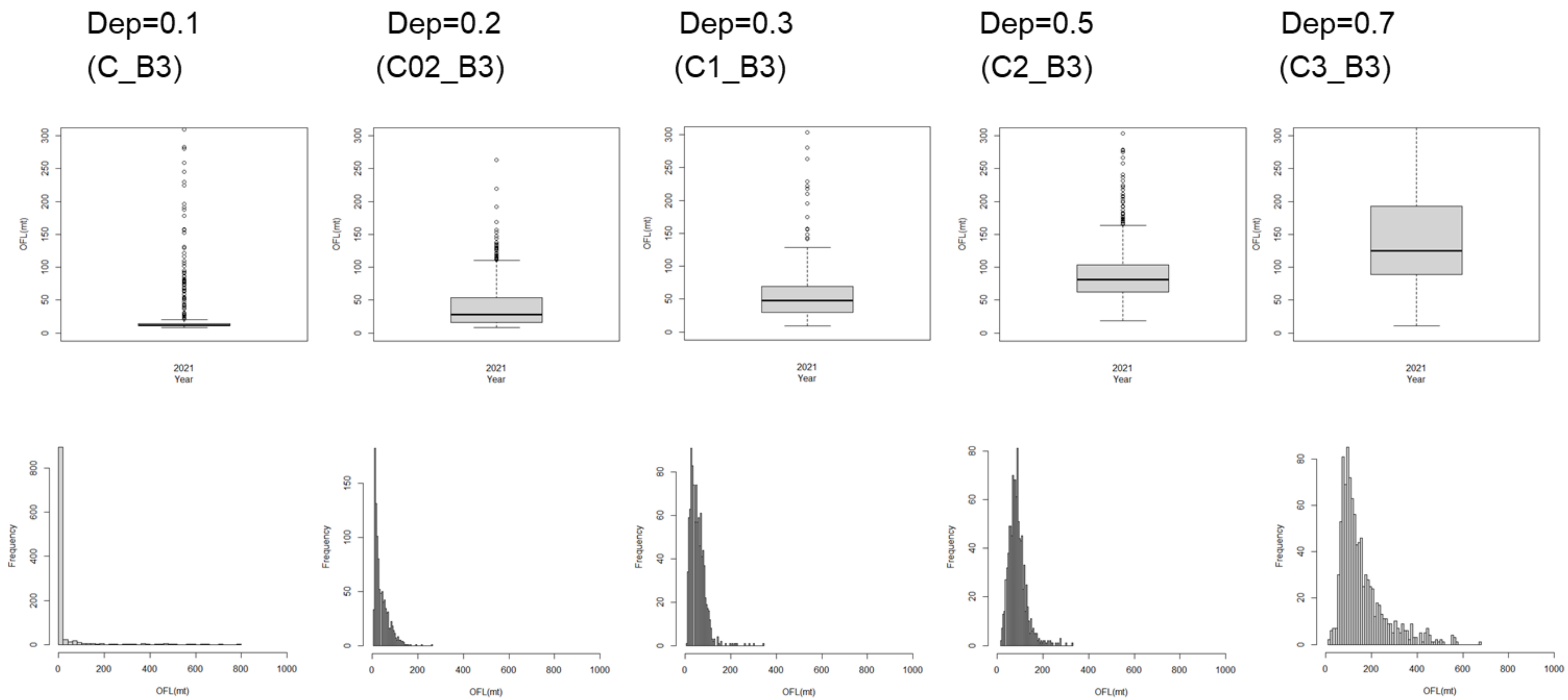

Figure 3.18. *OFL* in 2021 (terminal year plus one) for additional sensitivity runs (depletion=0.1 (C_B3), 0.2 (C02_B3), 0.3 (C1_B3), 0.5 (C2_B3), and 0.7 (C3_B3) in the year 2020) (see **Section 3.1.6**).

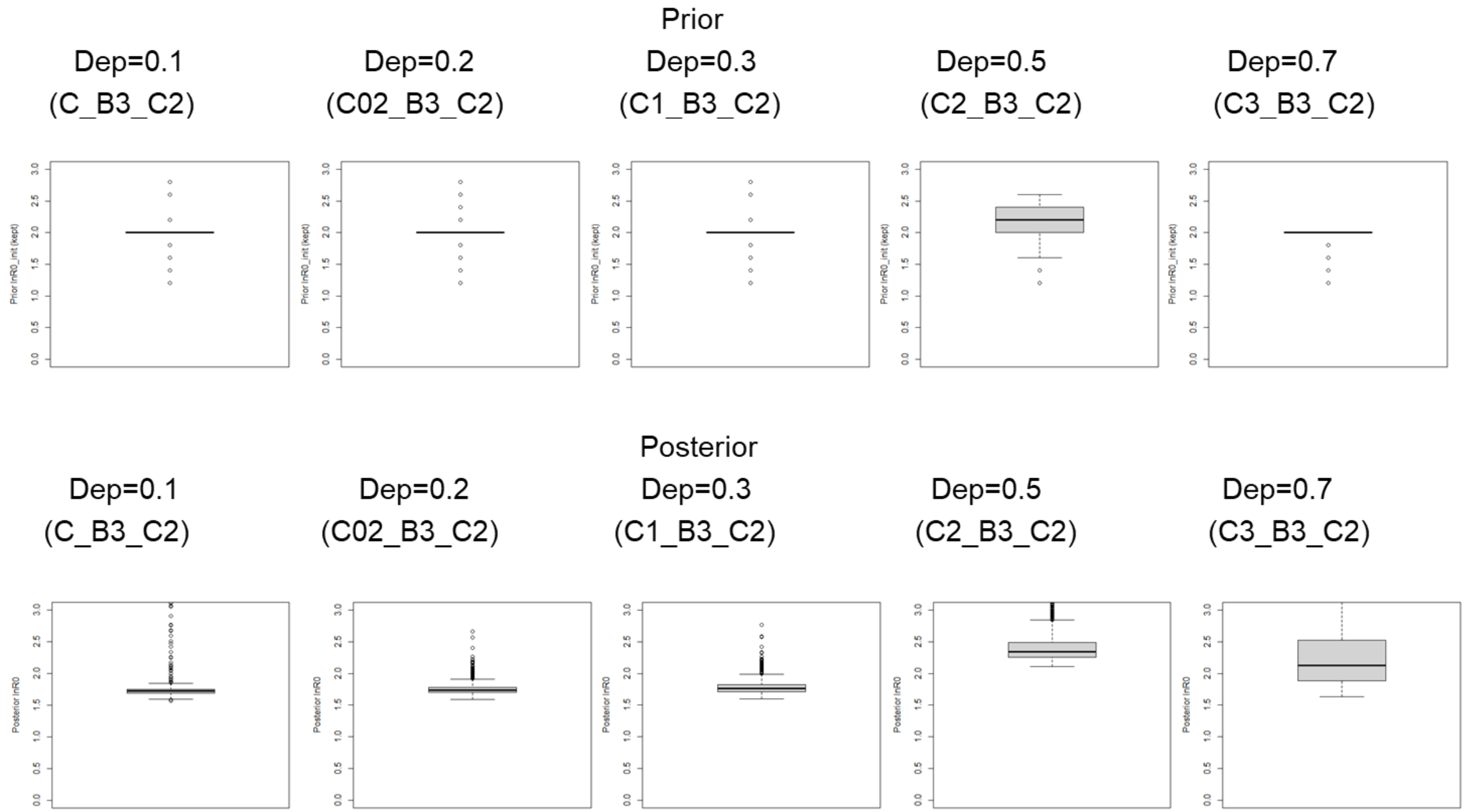

Figure 3.19. Priors and posteriors for lnR_0 for additional sensitivity runs (depletion=0.1 (C_B3_C2), 0.2 (C02_B3_C2), 0.3 (C1_B3_C2), 0.5 (C2_B3_C2), and 0.7 (C3_B3_C2) in the year 2020 with a lower steepness=0.58 instead of 0.78) (see **Section 3.1.6**).

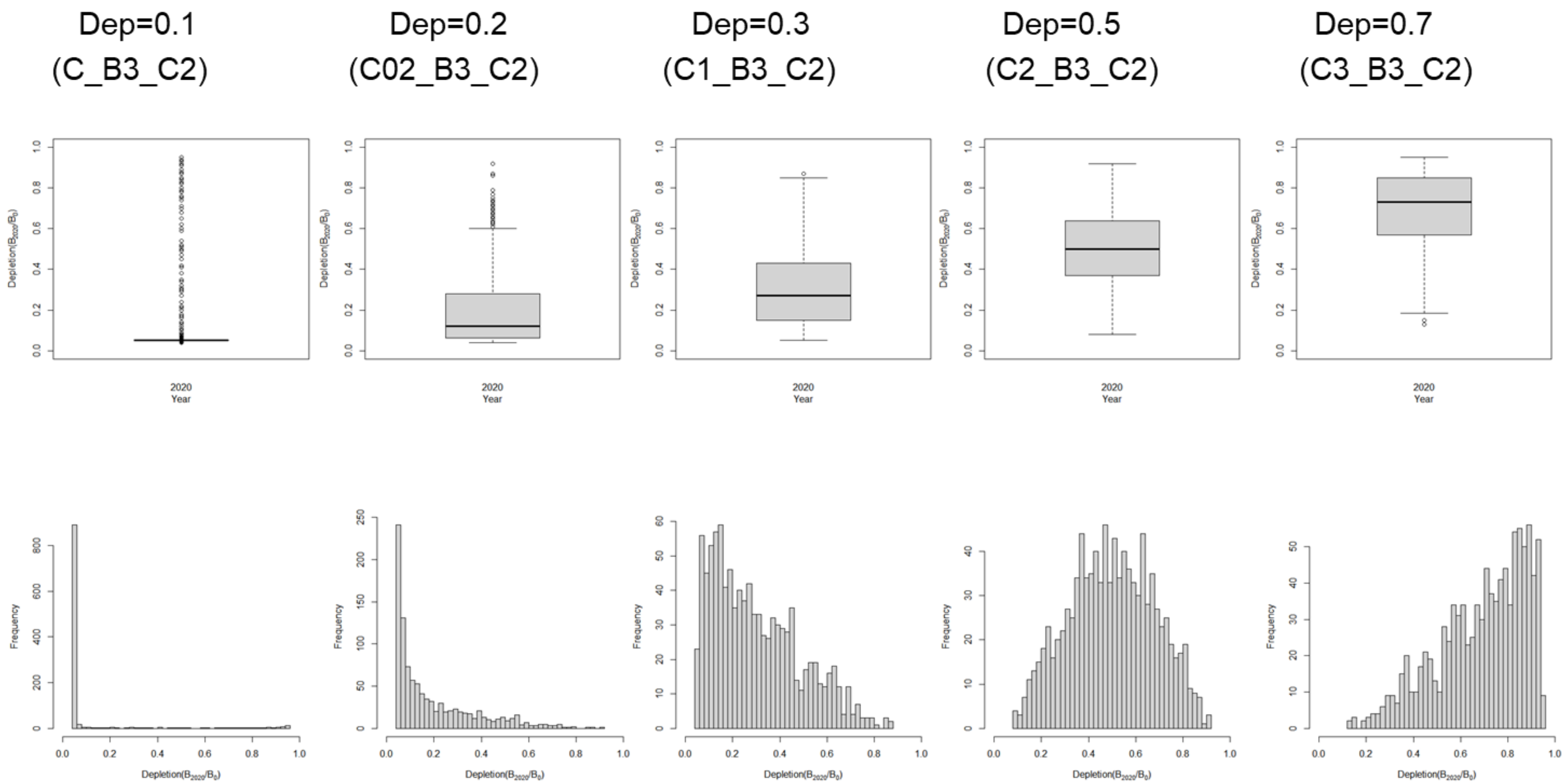

Figure 3.20. Terminal year (2020) depletion for additional sensitivity runs (depletion=0.1 (C_B3_C2), 0.2 (C02_B3_C2), 0.3 (C1_B3_C2), 0.5 (C2_B3_C2), and 0.7 (C3_B3_C2) in the year 2020 with a lower steepness=0.58 instead of 0.78) (see **Section 3.1.6**).

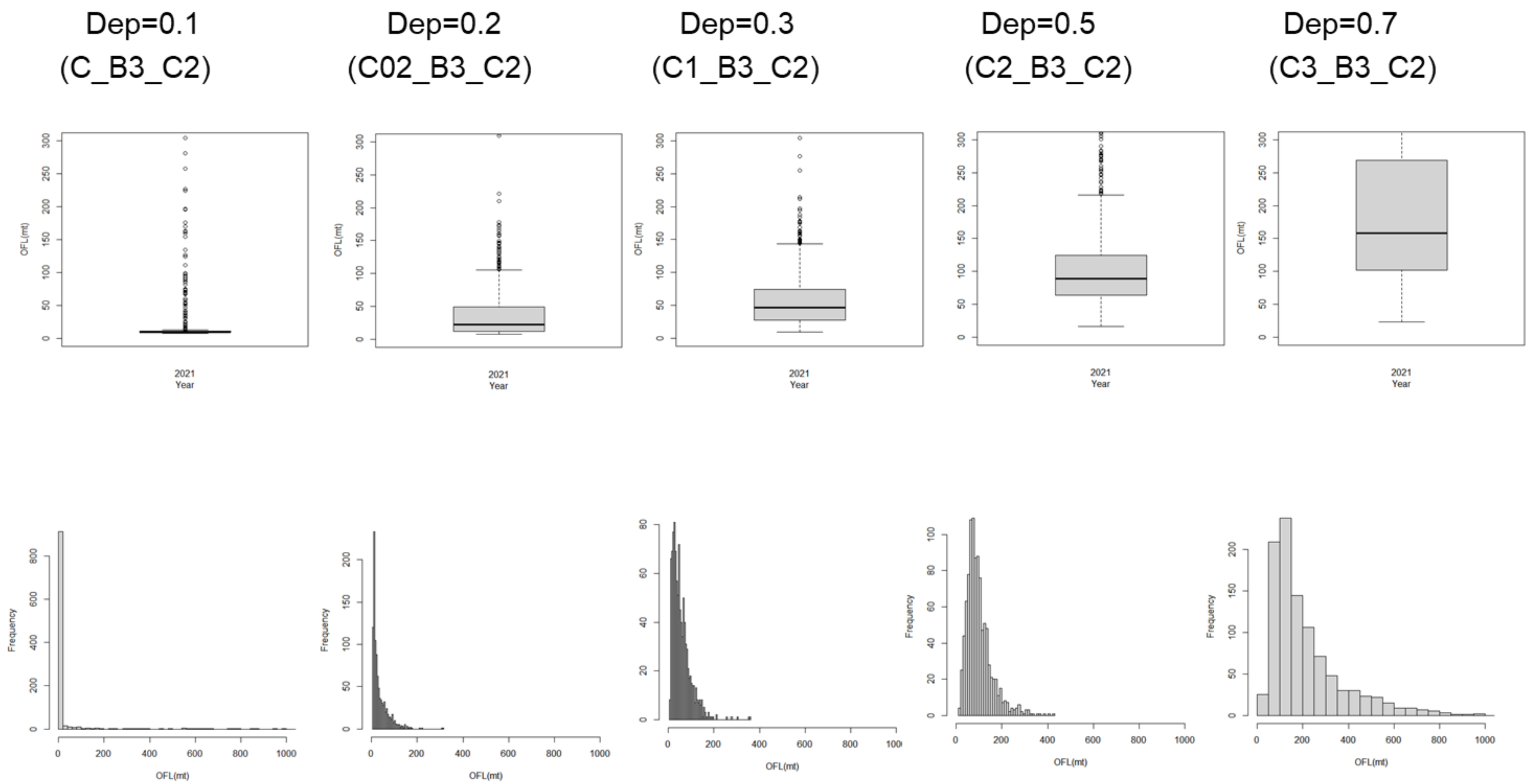

Figure 3.21. *OFL* in 2021 (terminal year plus one) for additional sensitivity runs (depletion=0.1 (C_B3_C2), 0.2 (C02_B3_C2), 0.3 (C1_B3_C2), 0.5 (C2_B3_C2), and 0.7 (C3_B3_C2) in the year 2020 with a lower steepness=0.58 instead of 0.78) (see **Section 3.1.6**).

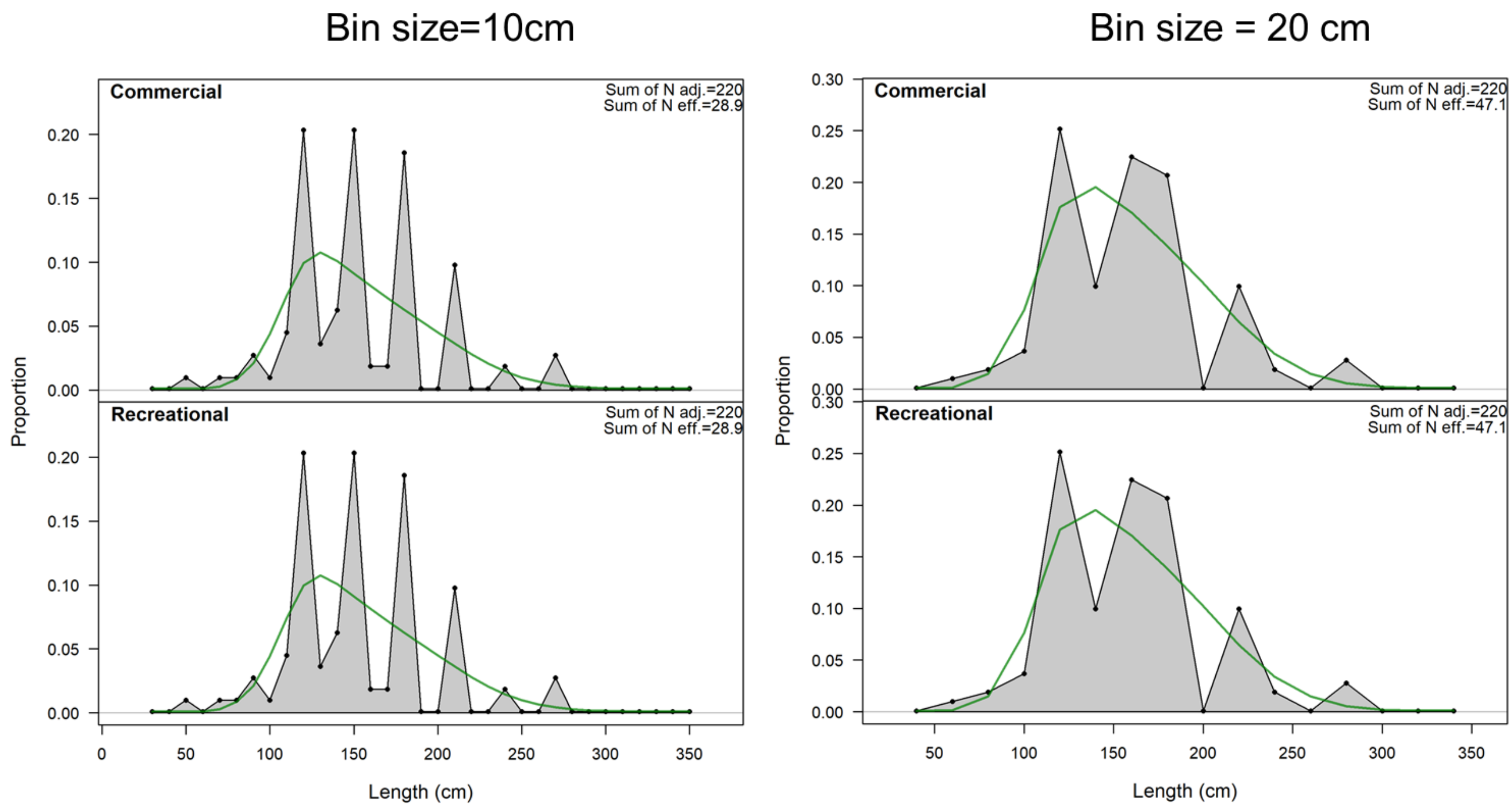

Figure 3.22. Fit of length composition data of super year 2019 based on aggregated 2016-2019 data. Length is in cm fork length.

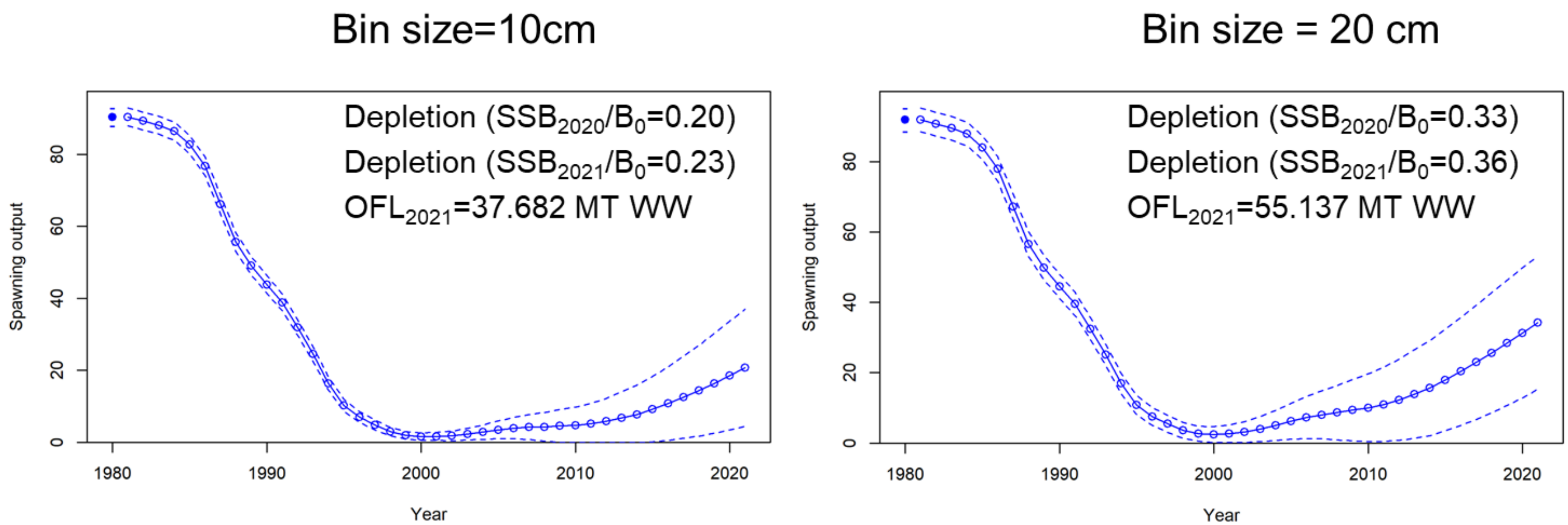

Figure 3.23. Depletion and OFL_{2021} estimated from SSS including super year 2019 based on aggregated 2016-2019 data. Length is in cm fork length.

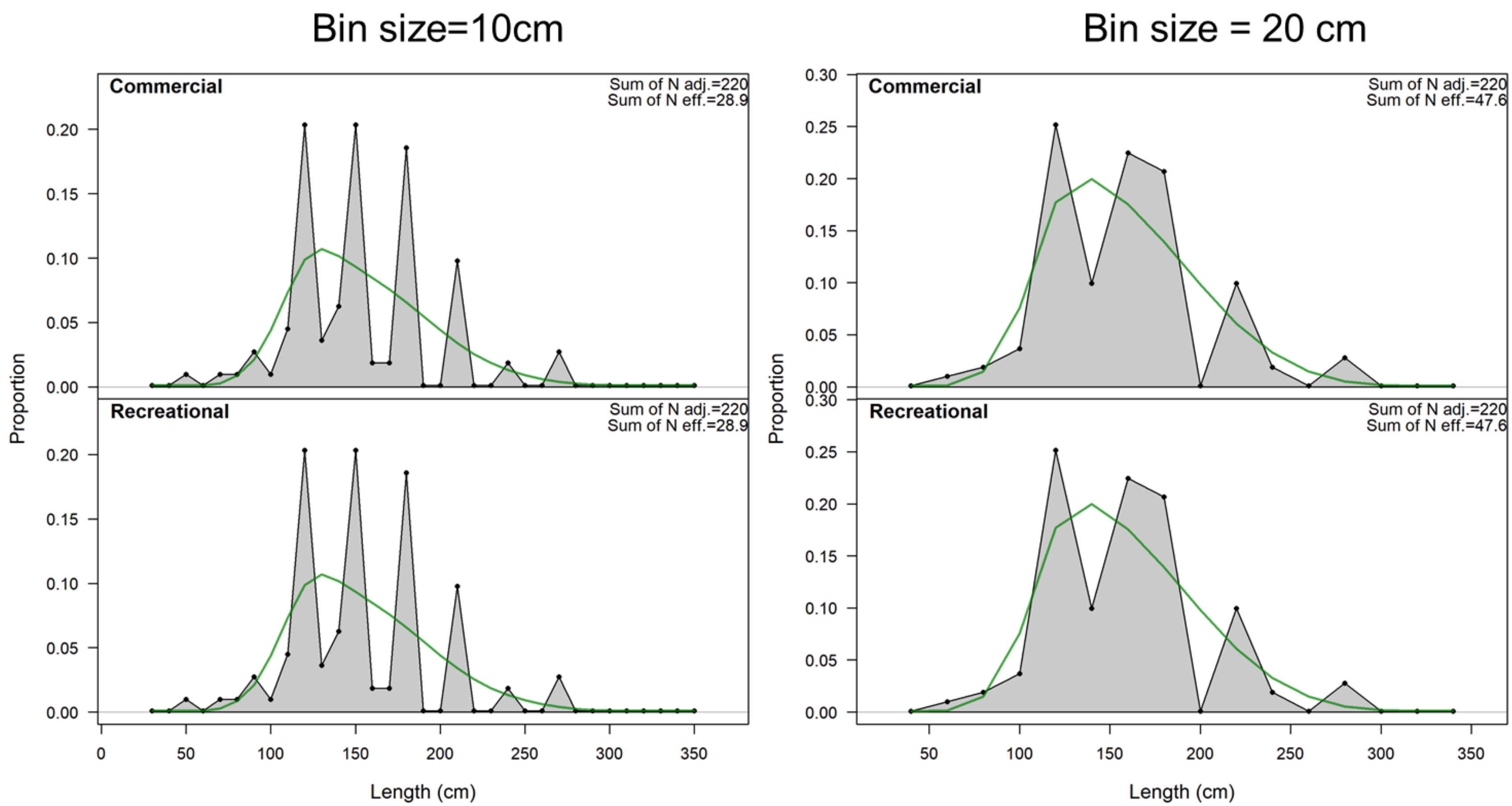

Figure 3.24. Fit of length composition data of super year 2016 based on aggregated 2016-2019 data. Length is in cm fork length.

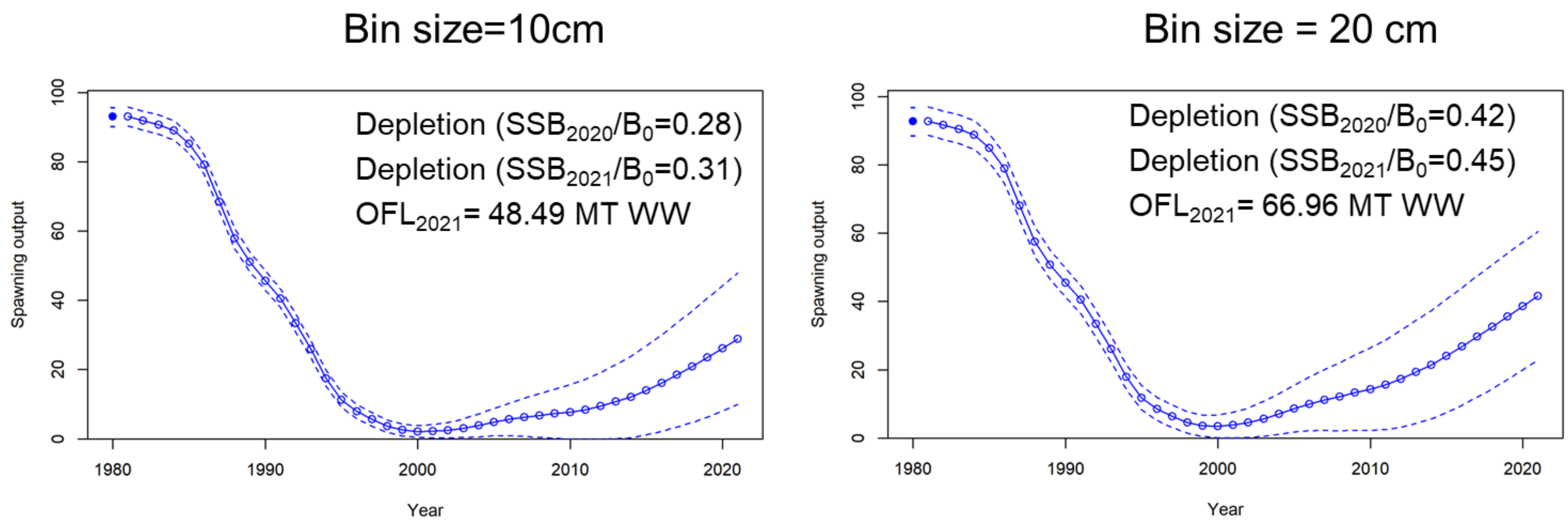

Figure 3.25. Depletion and OFL_{2021} estimated from SSS including super year 2016 based on aggregated 2016-2019 data. Length is in cm fork length.

3.9. APPENDIX

Table 3.9.1. Overfishing limits in the year 2021 (OFL_{2021}) for the initial exploratory runs. The settings of the initial exploratory runs are the same as in the Panel-approved reference run and sensitivity runs, but assuming lnR_0=12.

Scenario runs	OFL (median)	OFL (mean)	SD	CV
Exploratory runs assuming a relative stock status in 2020 , lnR0=12, steepness=0.78				
Dep=0.1 in 2020, lnR0=12, steepness=0.78 (C)	10.982	47.366	114.020	2.407
Dep=0.2 in 2020, lnR0=12, steepness=0.78 (C02)	36.336	47.375	37.682	0.795
Dep=0.3 in 2020, lnR0=12, steepness=0.78 (C1)	56.174	60.699	35.385	0.583
Dep=0.5 in 2020, lnR0=12, steepness=0.78 (C2)	86.270	101.017	40.213	0.398
Dep=0.7 in 2020, lnR0=12, steepness=0.78 (C3)	129.150	161.530	101.017	0.625
Exploratory runs assuming a relative stock status in 2010 , lnR0=12, steepness=0.78				
Dep=0.1 in 2010, lnR0=12, steepness=0.78 (D)	38.044	71.907	166.720	2.319
Dep=0.2 in 2010, lnR0=12, steepness=0.78 (D02)	66.740	66.740	48.690	0.730
Dep=0.3 in 2010, lnR0=12, steepness=0.78 (D1)	87.770	96.060	55.150	0.574
Dep=0.5 in 2010, lnR0=12, steepness=0.78 (D2)	127.800	146.200	71.572	0.490
Dep=0.7 in 2010, lnR0=12, steepness=0.78 (D3)	222.870	299.950	213.265	0.711
Exploratory runs assuming a relative stock status in 2020 , lnR0=12, steepness=0.58				
Dep=0.1 in 2020, lnR0=12, steepness=0.58 (C_C2)	9.423	41.955	133.9063	3.192
Dep=0.2 in 2020, lnR0=12, steepness=0.58 (C02_C2)	26.064	39.928	37.697	0.944
Dep=0.3 in 2020, lnR0=12, steepness=0.58 (C1_C2)	49.666	59.949	42.392	0.707
Dep=0.5 in 2020, lnR0=12, steepness=0.58 (C2_C2)	89.140	101.900	56.758	0.557
Dep=0.7 in 2020, lnR0=12, steepness=0.58 (C3_C2)	161.130	217.360	165.936	0.763

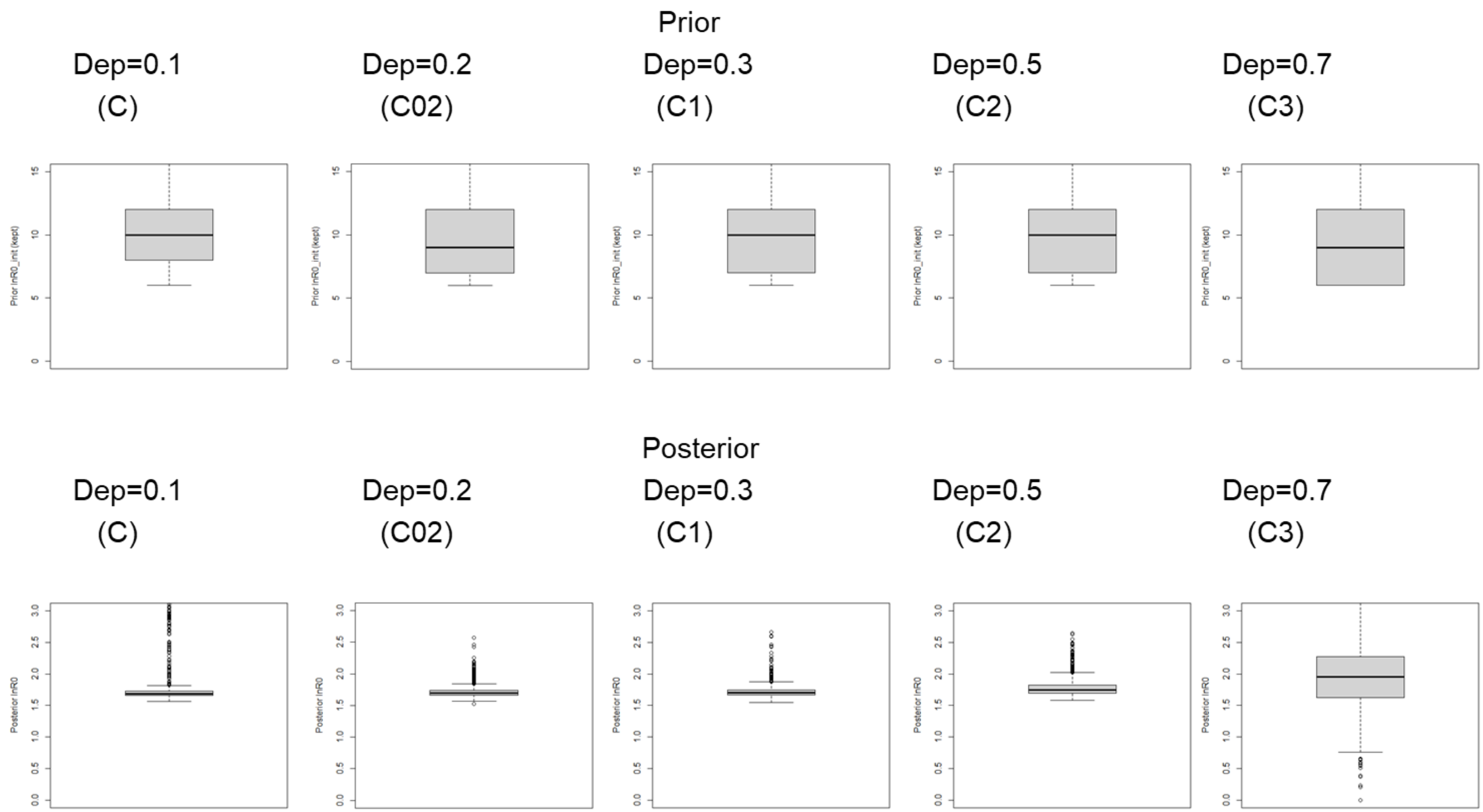

Figure 3.9.1. Priors and posteriors for lnR_0 for the exploratory runs (depletion=0.1 (C), 0.2 (C02), 0.3 (C1), 0.5 (C2), and 0.7 (C3) in the year 2020), lnR_0=12, steepness=0.78.

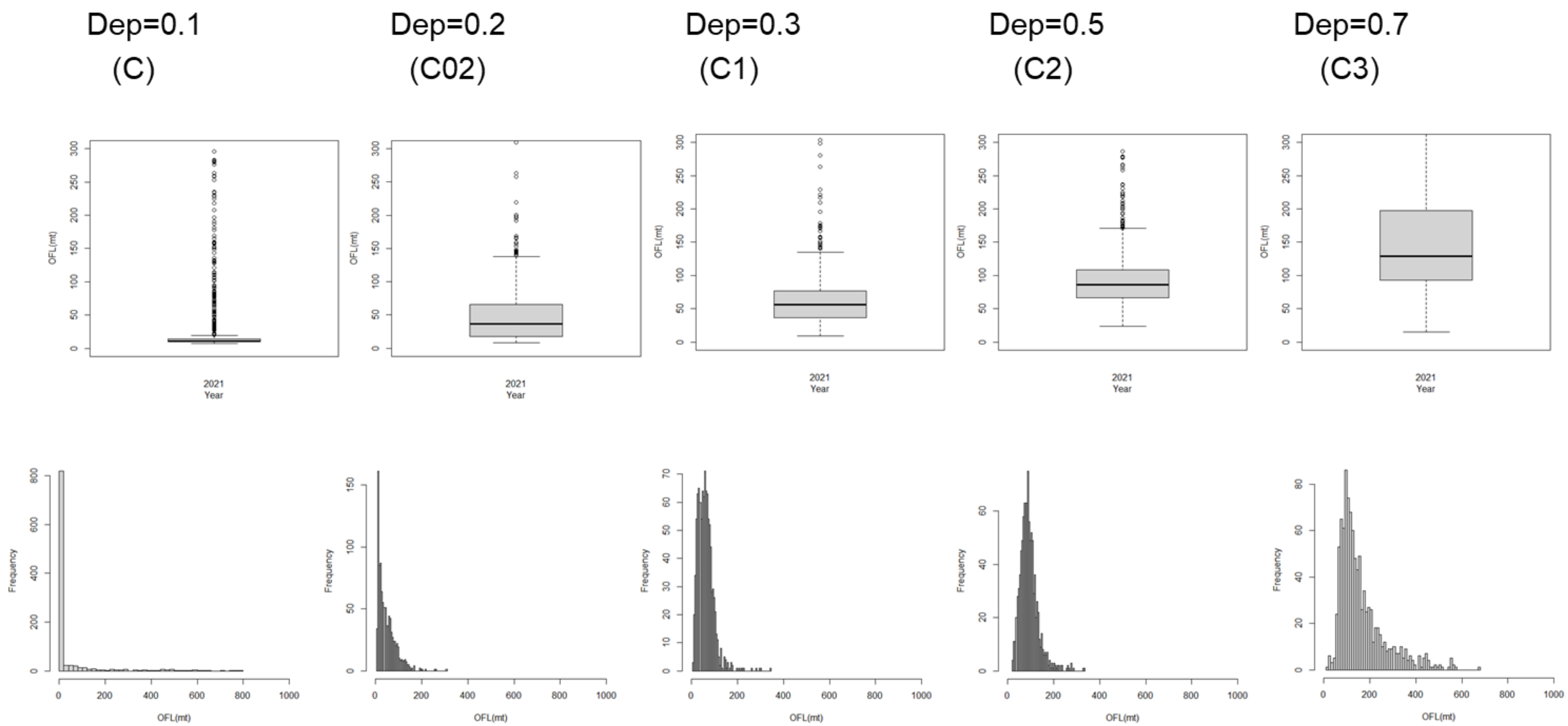

Figure 3.9.2. *OFL* in 2021 (terminal year plus one) for the exploratory runs (depletion=0.1 (C), 0.2 (C02), 0.3 (C1), 0.5 (C2), and 0.7 (C3) in the year 2020), lnR_0=12, steepness=0.78.

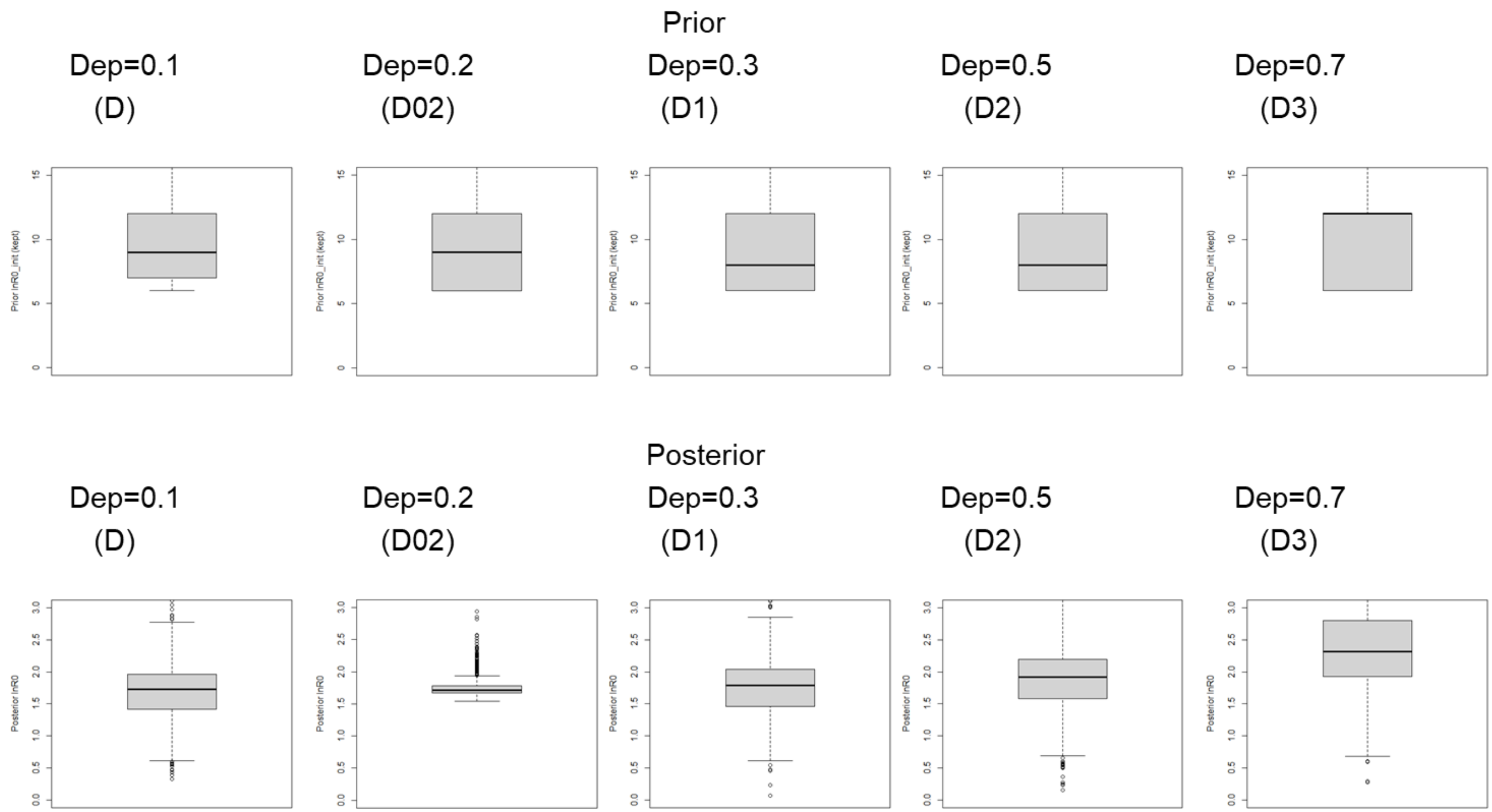

Figure 3.9.3. Priors and posteriors for lnR_0 for the exploratory runs (depletion=0.1 (D), 0.2 (D02), 0.3 (D1), 0.5 (D2), and 0.7 (D3) in the year 2010), lnR_0=12, steepness=0.78.

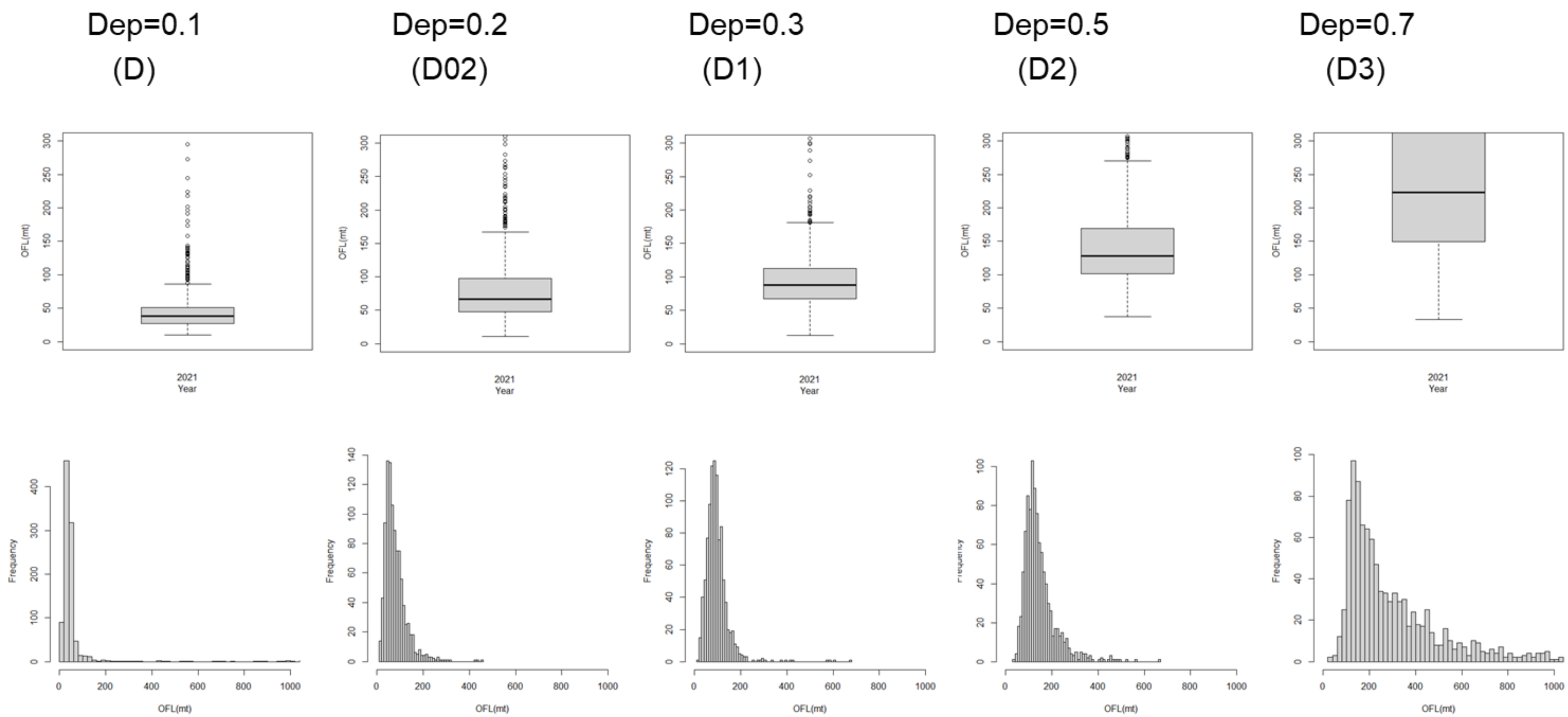

Figure 3.9.4. *OFL* in 2021 (terminal year plus one) for the exploratory runs (depletion=0.1 (D), 0.2 (D02), 0.3 (D1), 0.5 (D2), and 0.7 (D3) in the year 2010), lnR_0=12, steepness=0.78.

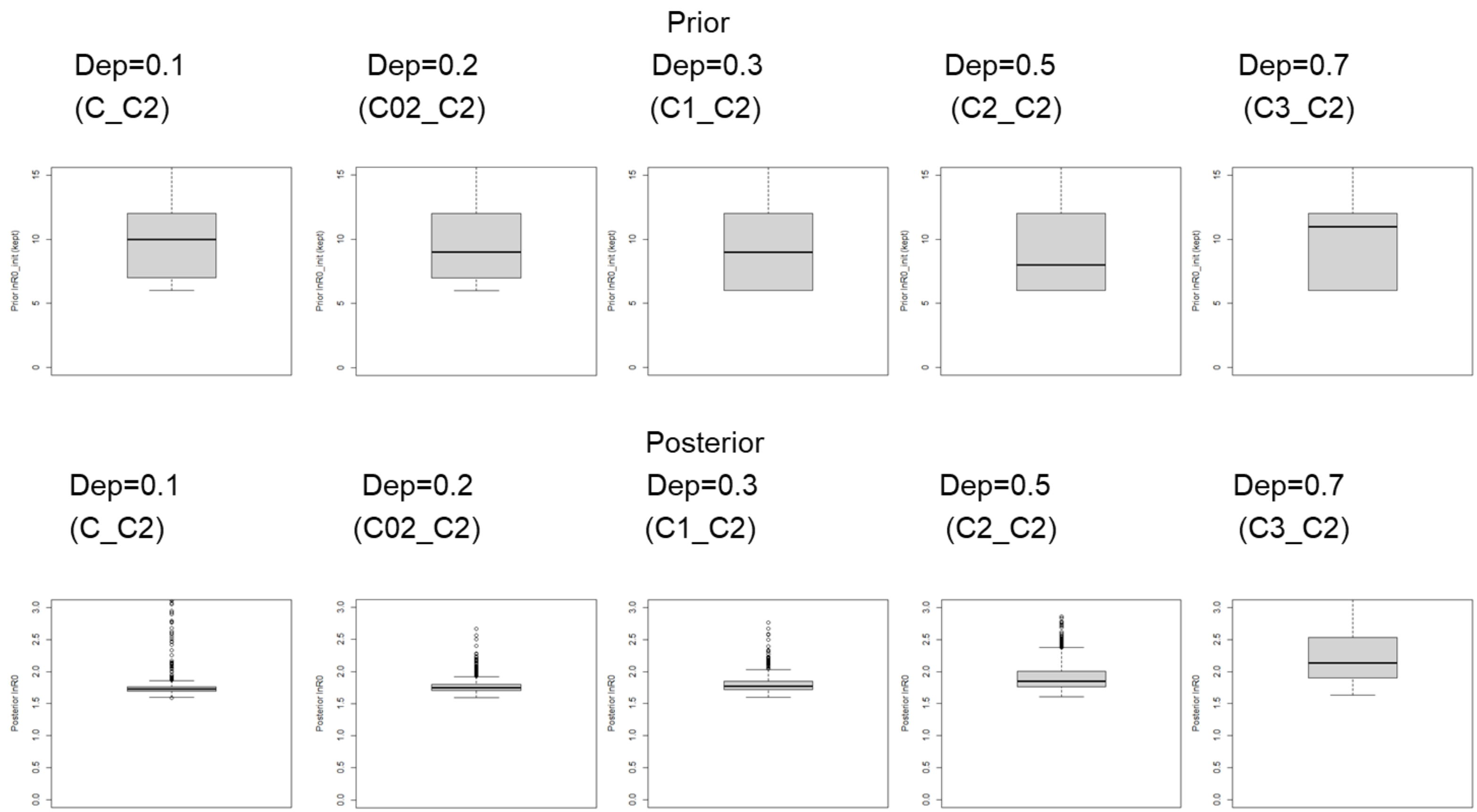

Figure 3.9.5. Priors and posteriors for lnR_0 for the exploratory runs (depletion=0.1 (C_C2), 0.2 (C02_C2), 0.3 (C1_C2), 0.5 (C2_C2), and 0.7 (C3_C2) in the year 2020), lnR_0=12, steepness=0.58.

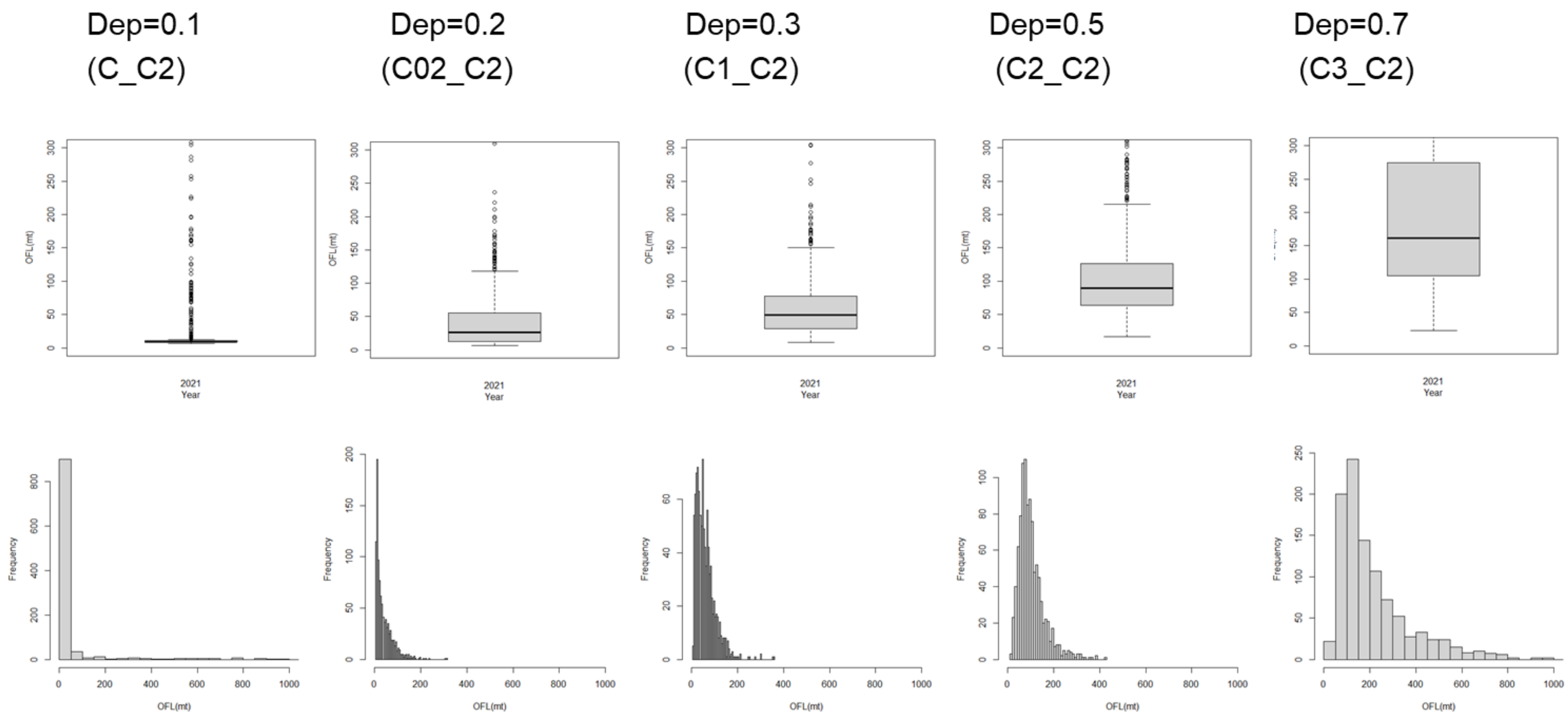

Figure 3.9.6. *OFL* in 2021 (terminal year plus one) for the exploratory runs (depletion=0.1 (C_C2), 0.2 (C02_C2), 0.3 (C1_C2), 0.5 (C2_C2), and 0.7 (C3_C2) in the year 2020), lnR_0=12, steepness=0.58.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 77
HMS Hammerhead Sharks:
Great Hammerhead Shark
Section IVc: Assessment Report

June 2023

SEDAR

4055 Faber Place Drive, Suite 201 North Charleston, SC 29405

1. INTRODUCTION

1.1 Workshop Time and Place

The SEDAR 77 Assessment Workshop held via a series of webinars from May 2022 – March, 2023.

1.2 Terms of Reference

1. Review any changes in data or analyses following the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.
2. Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations (if necessary) for each model considered.
3. Identify preferred model approach if applicable.
4. Provide preliminary estimates of stock population parameters:
    a. Include fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship (if applicable), and other parameters as necessary to describe the population.
    b. Include appropriate measures of precision for parameter estimates.
5. Characterize uncertainty in the assessment and estimated values, if possible.
    a. Consider uncertainty in input data, modeling approach, and model configuration.
    b. Consider and include other sources of uncertainty as appropriate for this assessment.
    c. Provide appropriate measures of model performance, reliability, and 'goodness of fit'.
6. Provide preliminary estimates of population benchmarks or management criteria consistent with available FMPs and amendments, proposed FMPs and amendments, other ongoing or proposed management programs, and the National Standards.
    a. Evaluate existing or proposed management criteria as specified in the management summary.
    b. Recommend and define proxy values when necessary, and provide appropriate justification.
7. Recommend preliminary stock status relative to management benchmarks or alternative data-poor approaches if necessary.
8. Provide uncertainty distributions of proposed reference points and stock status metrics that provide the values indicated in the management specifications. Include probability density functions for reference point estimates and population metrics (e.g., biomass and exploitation) used to evaluate stock status.

9. Project future stock conditions and develop rebuilding schedules, if warranted. Provide the estimated generation time for the stock. Stock projections shall be developed in accordance with the following:
   a. If the preliminary stock status is overfished, then utilize projections to determine:
      i. Year in which F=0 results in a 70% probability of rebuilding (Year $F=0_{p70}$).
      ii. Target rebuilding year ($Year_{rebuild}$).
         1. Year $F=0_{p70}$ if Year $F=0_{p70} \leq 10$ years, or
         2. Year $F=0_{p70}$ + 1 generation time if Year $F=0_{p70} > 10$ years.
      iii. F resulting in 50% and 70% probability of rebuilding by $Year_{rebuild}$.
      iv. Fixed level of removals allowing rebuilding of stock with 50% and 70% probability.
   b. If the preliminary stock status is determined to be undergoing overfishing, then utilize projections to determine:
      i. $F=F_{reduce}$ (different reductions in F that should end overfishing with a 50% and 70% probability).
   c. If the preliminary stock status is determined to be neither overfished nor undergoing overfishing, then utilize projections to determine:
      i. The F needed and corresponding removals associated with a 70% probability of overfishing not occurring (analogous to a P* = 0.3 approach), and/or
      ii. The constant catch associated with a 70% probability of overfishing not occurring and the stock not being overfished.
   d. If data limitations and/or model limitations preclude classic projections (i.e. a, b, and c above), explore alternate projection models.
10. Provide ABCs in accordance with HMS management needs.
11. Provide recommendations for future research and data collection. Emphasize items that will improve future assessment capabilities and reliability. Consider data, monitoring, and assessment needs.
12. Complete an Assessment Workshop Report in accordance with project schedule deadlines.

1.3 List of Participants

Participants	Affiliation
ADT	
Rob Latour	Virginia Institute of Marine Science, College of William And Mary
Beth Babcock	RSMAS University of Miami
John Carlson	SEFSC Panama City Laboratory
Trey Driggers	SEFSC Mississippi Laboratory
Dean Courtney	SEFSC Panama City Laboratory
Xinsheng Zhang	SEFSC Panama City Laboratory
Enric Cortés *	SEFSC Panama City Laboratory
Additional Panelists	
Eric Hoffmayer	SEFSC Mississippi Laboratory
Henning Winker	JRC European Commission
Felipe Carvalho	NOAA PIFSC
Joel Rice	Rice Marine Analytics
Staff	
Kathleen Howington	SEDAR
Karyl Brewster-Geisz	NMFS: HMS Management
Margaret Miller	NMFS
Adam Brame	NMFS
Other	
Adam Pollack	SEFSC Mississippi Laboratory
Andrea Kroetz	SEFSC Panama City Laboratory
Ann Williamson	NMFS
Becky Curtis	NMFS
Blaise Rohan	RSMAS University Of Miami
Cami Mccandless	NEFSC Narragansett Laboratory
Christina Vaeth	
Clifford Hutt	NMFS: HMS Management
Dean Grubbs	Florida State University Coastal and Marine Laboratory
Delisse Ortiz	NMFS
Hannah Medd	Shark Conservancy
Heather Baertlein	NMFS: HMS Management
Heather Moncrief-Cox	SEFSC Panama City Laboratory
Jason Cope	NMFS
Juan Carlos Pérez-Jiménez	El Colegio de la Frontera Sur (ECOSUR)
Leann Bosarge	GMFMC
Marcus Drymon	Mississippi State University
Max Lee	Mote Marine Laboratory
Michelle Passerotti	NEFSC Narragansett Laboratory
Neil Hammerschlag	RSMAS University of Miami
Orian Tzadik	NMFS
Tobey Curtis	NMFS
Willow Patten	NCDMF

*Enric Cortés retired on December 31, 2022

1.4 Document List

Working Papers			
SEDAR77-AW01	Exploratory analysis of U.S Atlantic and Gulf of Mexico scalloped hammerhead recruitment indices	Henning Winker	5/27/2022
SEDAR77-AW02	Hierarchical analyses of U.S. Atlantic and Gulf of Mexico scalloped hammerhead recruitment indices	Camilla T. McCandless and John K. Carlson	5/31/2022
SEDAR77-AW03		Cami McCandless	Not Received
SEDAR77-AW04	Estimates of vital rates and population dynamics parameters of interest for hammerhead sharks (*Sphyrna lewini, S. mokarran, and S. zygaena*) in the western North Atlantic Ocean	Enric Cortés	6/17/2022
SEDAR77-AW05	Reconciling age-0 indices of relative abundance of the U.S. Atlantic and Gulf of Mexico scalloped hammerhead (*Sphyrna lewini*)	Dean Courtney, Robert J. Latour, and Cassidy D. Peterson	6/20/2022
SEDAR77-AW06	Fishpath Questions	Enric Cortés	9/21/2022
SEDAR77-AW07	Selected FishPath Results for Smooth hammerhead shark, U.S. Atlantic and Gulf of Mexico	Enric Cortés	9/21/2022
SEDAR77-AW08	Selected FishPath Results for Smooth hammerhead shark, U.S. Atlantic and Gulf of Mexico: Narrowed	Enric Cortés	9/21/2022

Reference Documents			
SEDAR77-RD49	Stock Assessment of Scalloped Hammerheads in the Western North Atlantic Ocean and Gulf of Mexico	Christopher G. Hayes, Yan Jiao, and Enric Cortés	11/30/2020
SEDAR77-RD50	Poor-data and data-poor species stock assessment using a Bayesian hierarchical approach	Yan Jiao, Enric Cortés, Kate Andrews, And Feng Guo	11/30/2020
SEDAR77-RD51	Hierarchical Bayesian approach for population dynamics modelling of fish complexes without species-specific data	Yan Jiao, Christopher Hayes, and Enric Cortés	11/30/2020
SEDAR77-RD52	Highly migratory species predictive spatial modeling (PRiSM): an analytical framework for assessing the performance of spatial fisheries management	Daniel P. Crear, Tobey H. Curtis, Stephen J. Durkee, John K. Carlson	5/26/2022
SEDAR77-RD53	Dynamic factor analysis to reconcile conflicting survey indices of abundance	Cassidy D. Peterson, Michael J. Wilberg, Enric Cortés, and Robert J. Latour	5/26/2022
SEDAR77-RD54	SEDAR 65 - AW03: Reconciling indices of relative abundance of the Atlantic blacktip shark (*Carcharhinus limbatus*)	Robert J. Latour and Cassidy D. Peterson	5/31/2022

1.5 Statement addressing each term of reference

1.5.1. Term of Reference 1

Review any changes in data or analyses following the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.

There were no changes in the catch series and indices of abundance recommended by the Data Workshop (DW), which are summarized in **Section 2**.

1.5.2. Term of Reference 2

Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations (if necessary) for each model considered.

All analyses were conducted with the Bayesian state-space surplus production model framework JABBA (Winker *et al.*, 2018) version v.2.2.8. JABBA is an open-source modelling software and is available as an 'R package' that can be installed from github.com/jabbamodel/JABBA. The model and its configuration are fully described in **Section 3.1.3**.

1.5.3. Term of Reference 3

Identify preferred model approach if applicable.

All analyses were conducted with the Bayesian state-space surplus production model framework JABBA as planned.

1.5.4. Term of Reference 4

Provide preliminary estimates of stock population parameters:

- *a) Include fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship (if applicable), and other parameters as necessary to describe the population.*
- *b) Include appropriate measures of precision for parameter estimates.*

Estimates of assessment model parameters and their associated uncertainties are reported in **Sections 3.2.6** and **3.2.7**. We estimated abundance (exploitable numbers) because input catches were in numbers and the model estimates fishing mortality (harvest rates). Since this is a production model, no selectivity or stock-recruit relationship were estimated.

1.5.5. Term of Reference 5

Characterize uncertainty in the assessment and estimated values, if possible.

- *a) Consider uncertainty in input data, modeling approach, and model configuration.*
- *b) Consider and include other sources of uncertainty as appropriate for this assessment.*
- *c) Provide appropriate measures of model performance, reliability, and 'goodness of fit'.*

Uncertainty in the assessment and estimated values is characterized at length in **Sections 3.2.6** and **3.2.7**. Fits to abundance indices, residual plots, runs test plots, prediction skill (via hindcasting) plots and process error deviate plots are provided in **Sections 3.2.2** to **3.2.5**.

1.5.6. Term of Reference 6

Provide preliminary estimates of population benchmarks or management criteria consistent with available FMPs and amendments, proposed FMPs and amendments, other ongoing or proposed management programs, and the National Standards.

a) *Evaluate existing or proposed management criteria as specified in the management summary.*
b) *Recommend and define proxy values when necessary, and provide appropriate justification.*

Estimates of benchmark and biological reference points (MSY, $MSST$, F_{MSY}, B_{MSY}, F/F_{MSY}, and B/B_{MSY}) are provided in **Sections 3.2.6** and **3.2.7**.

1.5.7. Term of Reference 7

Recommend preliminary stock status relative to management benchmarks or alternative data-poor approaches if necessary.

Stock status based on the status determination criteria is reported in **Section 3.2.6**.

1.5.8. Term of Reference 8

Provide uncertainty distributions of proposed reference points and stock status metrics that provide the values indicated in the management specifications. Include probability density functions for reference point estimates and population metrics (e.g., biomass and exploitation) used to evaluate stock status.

Main model parameters and stock status metrics (B/B_{MSY} and F/F_{MSY}) and associated uncertainties are reported in **Sections 3.2.6** and **3.2.7**.

1.5.9. Term of Reference 9

Project future stock conditions and develop rebuilding schedules, if warranted. Provide the estimated generation time for the stock. Stock projections shall be developed in accordance with the following:

- a) *If the preliminary stock status is overfished, then utilize projections to determine:*
  - i) *Year in which F=0 results in a 70% probability of rebuilding (Year $F=0_{p70}$).*
  - ii) *Target rebuilding year ($Year_{rebuild}$).*
    - (1) *Year $F=0_{p70}$ if Year $F=0_{p70} \leq 10$ years, or*
    - (2) *Year $F=0_{p70}$ + 1 generation time if Year $F=0_{p70} > 10$ years.*
  - iii) *F resulting in 50% and 70% probability of rebuilding by $Year_{rebuild}$.*
  - iv) *Fixed level of removals allowing rebuilding of stock with 50% and 70% probability.*
- b) *If the preliminary stock status is determined to be undergoing overfishing, then utilize projections to determine:*
  - i) *$F=F_{reduce}$ (different reductions in F that should end overfishing with a 50% and 70% probability).*
- c) *If the preliminary stock status is determined to be neither overfished nor undergoing overfishing, then utilize projections to determine:*
  - i) *The F needed and corresponding removals associated with a 70% probability of overfishing not occurring (analogous to a P* = 0.3 approach), and/or*
  - ii) *The constant catch associated with a 70% probability of overfishing not occurring and the stock not being overfished.*
- d) *If data limitations and/or model limitations preclude classic projections (i.e. a, b, and c above), explore alternate projection models.*

The preliminary stock status is overfished. Therefore, projections were carried out in accordance with Term of Reference 9(a). A detailed description of the projection methodology, along with estimated generation time, is provided in **Section 3.1.9** and projection results are provided in **Section 3.2.8**.

1.5.10. Term of Reference 10

Provide ABCs in accordance with HMS management needs.

The preliminary stock status is overfished. Therefore, projections were carried out in accordance with Term of Reference 9(a) for rebuilding and there is no need to provide *ABCs*.

1.5.11. Term of Reference 11

Provide recommendations for future research and data collection. Emphasize items that will improve future assessment capabilities and reliability. Consider data, monitoring, and assessment needs.

Recommendations for future research and data collection are provided in **Section 3.4**.

1.5.12. Term of Reference 12

Complete an Assessment Workshop Report in accordance with project schedule deadlines.

This document is **Section III** of the SEDAR Stock Assessment Report.

2. DATA REVIEW AND UPDATE

2.1 CATCHES

No changes were introduced to the catch streams presented and approved at the DW. The vast majority of great hammerhead catches were recreational catches (**Table 2.5.1**; **Figure 2.6.1**).

2.2 INDICES OF ABUNDANCE

The six standardized indices of abundance used in the assessment are presented in **Table 2.5.2** and **Figure 2.6.2**. These indices cover Atlantic and Gulf of Mexico GOM. All these indices were standardized by the respective authors through general linear model (GLM) techniques (see SEDAR 77 DW Report). The coefficients of variation (*CV*) associated with the standardized indices are also listed in **Table 2.5.2**.

2.3 LIFE HISTORY INPUTS

The life history inputs used to compute productivity (i.e. maximum population growth rate r_{max}), natural mortality at age, generation time, and the inflection point of the surplus production curve (B_{MSY}/K) for great hammerheads in **Table 2.5.3** are as reported in SEDAR77-AW04 (Cortés 2022). For the computation of deterministic estimates of r_{max}, annual natural mortality at age was obtained from a method developed by Dureuil *et al.* (2021) based on Lorenzen (2000). For the computation of stochastic estimates of r_{max}, annual survival at age (obtained from the instantaneous natural mortality rate at age as e^{-M}) was obtained through six alternative life history invariant estimators: Jensen's (1996) *K*-based and age at maturity estimators, a modified growth-based Pauly (1980) estimator (Then *et al*. 2015), a modified longevity-based Hoenig (1983) estimator (Then *et al*. 2015), Chen and Yuan's (2006) estimator, and the mass-based estimator of Peterson and Wroblewski (1984) (see **Appendix 1** of Cortés 2022 for details). The mean estimate of r_{max} (0.144 yr^{-1}), obtained from fitting a normal distribution to the values of r_{max} obtained from the stochastic simulation of a Leslie matrix, was used to develop the prior for the base run (see **Section 3.1.4**). The median estimates of the average (age 1 to maximum age) natural mortality rate (M=0.156 yr^{-1}) from the six mortality estimators, generation time (14.5 years), and the inflection point of the surplus production curve (B_{MSY}/K=0.48) obtained in the Leslie matrix stochastic analyses were used to develop the prior of B_{MSY}/K for the base run (see **Section 3.1.4**), to calculate *MSST* to assess stock status (see **Section 3.1.7**), and to use in projections (generation time; see **Section 3.1.9**).

2.4 REFERENCES

Chen, P. and W. Yuan. 2006. Demographic analysis based on the growth parameter of sharks. Fish Res. 78: 374-379.

Cortés, E. 2022. Estimates of vital rates and population dynamics parameters of interest for hammerhead sharks (*Sphyrna lewini, S. mokarran, and S. zygaena*) in the western North Atlantic Ocean. SEDAR77-AW04. SEDAR, North Charleston, SC. 14 pp.

Dureuil, M., W.H. Aeberhard, K.A. Burnett, R.E. Hueter, J.P. Tyminski, and B. Worm. 2021. Unified natural mortality estimation for teleosts and elasmobranchs. Mar. Ecol. Prog. Ser. 667: 113-129.

Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 81: 898–903.

Jensen, A.L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Can. J. Fish. Aquat. Sci. 53: 820–822.

Lorenzen, K. 2000. Allometry of natural mortality as a basis for assessing optimal release size in fish-stocking programmes. Can. J. Fish. Aquat. Sci. 57: 2374-2381.

Pauly, D. 1980. On the interrelationship between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer 39: 175–192.

Peterson, I. and J.S. Wroblewski. 1984. Mortality rates of fishes in the pelagic ecosystem. Can. J. Fish. Aquat. Sci. 41: 1117-1120.

Then, A.Y., J.M. Hoenig, N.G. Hall, and D.A. Hewitt. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES J. Mar. Sci. 72: 82-92.

2.5 TABLES

Table 2.5.1. Stock wide catches of great hammerheads in numbers used for the base run. Total commercial catch is the maximum of the sum of commercial catches by gear and total commercial catches not disaggregated by gear; total recreational catch is the sum of total recreational AB1 catch and LPRM; total catch is the sum of total recreational and total commercial catch. Abbreviations for recreational catches are as follows: AB1=fish killed or kept either seen by the interviewer or reported to the interviewer by the angler; LPRM=live post-release mortality.

Year	Total Bottom longline catch	Total Gillnet catch	Total hook and line + hand line catch	Pelagic longline dead discards	Total commercial catch	Total AB1 recreational catch	Total recreational LPRM	Total recreational catch	Total catch
1981	0	0	0	0	0	30549	39786	70335	70335
1982	133	136	0	5	274	30549	39786	70335	70609
1983	267	271	0	10	548	38694	41373	80067	80615
1984	400	407	0	15	822	51047	32318	83365	84187
1985	534	543	0	20	1096	47728	19483	67211	68307
1986	667	678	0	25	1370	38331	12598	50929	52300
1987	801	814	0	38	1652	22539	7978	30517	32169
1988	934	999	0	122	2055	14205	6536	20740	22796
1989	1067	1085	1	57	2210	14079	4412	18491	20701
1990	1201	1221	1	73	2495	19278	4844	24121	26616
1991	366	1882	0	49	2298	28009	5285	33294	35591
1992	1562	1330	1	254	3145	18896	7211	26107	29252
1993	2105	857	1	41	3005	9996	8054	18050	21055
1994	3110	779	29	24	3942	6592	9652	16243	20185
1995	2164	730	11	3	2908	6097	10140	16237	19145
1996	1422	852	12	11	2297	6086	10473	16559	18857
1997	515	744	0	24	1283	2299	5563	7862	9145
1998	378	63	1	16	457	1273	3204	4476	4934
1999	361	1259	8	17	1644	998	2186	3184	4829
2000	200	1599	0	21	1820	1650	2598	4247	6067
2001	242	206	1	31	479	1765	2950	4715	5194
2002	345	686	2	20	1053	377	1534	1910	2964
2003	769	1521	1	38	2328	97	705	803	3131
2004	642	5327	1	30	6000	33	408	442	6442
2005	132	178	0	24	335	87	389	477	812
2006	301	786	0	17	1104	188	419	606	1710
2007	94	146	0	18	258	358	449	808	1066
2008	191	286	1	0	478	182	585	767	1245
2009	476	296	10	1	783	111	741	852	1635
2010	302	282	1	1	587	58	622	679	1266
2011	326	170	1	3	500	60	464	524	1024
2012	53	778	7	1	839	36	373	410	1249
2013	271	561	3	2	837	26	354	381	1218
2014	176	132	10	65	383	19	530	549	932
2015	237	449	77	39	802	19	789	808	1610
2016	108	368	79	16	571	7	1171	1178	1749
2017	194	170	6	16	387	2	893	895	1282
2018	385	1214	10	5	1614	2	893	895	2509
2019	256	501	7	0	764	2	893	895	1659

Table 2.5.2. Stock wide indices of abundance for great hammerheads used for the base run including index name and SEDAR document number. *CV* is the coefficient of variation for the annual index value. Missing values in a given year correspond to zero catches (index value of 0 and no *CV*), where no sampling occurred (ns), or when the model did not converge (nc).

	Shark Bottom Longline		Shark Research		FSU Longline		RSMAS Drumline		SEFSC MS Bottom Longline		SEAMAP BLL survey	
	SEDAR77-DW12		SEDAR77-DW12		SEDAR77-DW14		SEDAR77-DW15		SEDAR77-DW24		SEDAR77-DW25	
	sharks per 10000 hooks		sharks per 10000 hooks		sharks per 100 hook hour		number of sharks per 10 drumlines per hour		number sharks per hook-hour		number sharks per hook-hour	
year	index	CV	index	CV	index	CV	index	CV	index	CV	index	CV
1994	1.071	0.478										
1995	5.908	0.206							0.016	0.518		
1996	6.749	0.229							0.018	0.556		
1997	9.424	0.303							0.007	0.497		
1998	10.140	0.246							ns			
1999	7.511	0.270							0.002	1.081		
2000	3.207	0.473							0.002	0.784		
2001	3.674	0.371							0.009	0.482		
2002	11.726	0.212							0.003	0.648		
2003	9.966	0.207							0.012	0.454		
2004	7.873	0.226							0.009	0.486		
2005	6.425	0.293							0.004	1.074		
2006	5.261	0.300							0.006	0.650	0.013	1.062
2007	9.718	0.272							0.006	0.782	0.045	0.525
2008			40.370	0.226					0.008	0.655	0.109	0.344
2009			29.215	0.244			0.027	0.707	0.011	0.519	0.039	0.728
2010			18.072	0.221			0.055	0.297	0.021	0.477	0.050	0.716
2011			26.748	0.190	0.001	0.291	0.053	0.265	0.004	0.648	0.000	.
2012			43.110	0.308	ns		0.036	0.317	0.017	0.479	0.064	0.532
2013			52.307	0.199	0.001	0.734	0.039	0.268	0.006	0.651	0.142	0.456
2014			40.176	0.218	0.002	0.729	0.053	0.241	0.012	0.650	0.173	0.323
2015			57.252	0.174	0.002	0.598	0.048	0.255	0.011	0.489	0.051	0.421
2016			26.352	0.294	0.003	0.296	0.074	0.194	0.014	0.485	0.089	0.335
2017			47.025	0.193	0.004	0.293	0.055	0.180	0.023	0.414	0.081	0.451
2018			26.739	0.250	0.003	0.302	0.053	0.197	0.020	0.416	0.043	0.521
2019			43.489	0.220	0.002	0.519	0.053	0.184	0.036	0.372	0.088	0.449

Table 2.5.3. Life history inputs used to compute productivity (i.e. maximum population growth rate r_{max}), natural mortality at age, generation time, and the inflection point of the surplus production curve (B_{MSY}/K) for great hammerheads for the base run.

Parameter	Definition	Value	Unit	References
L_∞	Theoretical maximum length	323.9 (7.49)	cm FL	DW report life history section
K	Brody growth coefficient	0.11 (0.011)	yr^{-1}	DW report life history section
t_0	Theoretical age at zero length	-2.06 (0.20)	yr	DW report life history section
a	Intercept of maturity ogive	-7.569 (2.67)	dimensionless	DW report life history section
b	Slope of maturity ogive	0.937 (0.32)	dimensionless	DW report life history section
c	Scalar coefficient of weight on length	9.275E-06	dimensionless	DW report life history section
d	Power coefficient of weight on length	3.028	dimensionless	DW report life history section
w	Observed lifespan	35	yr	DW report life history section
	Theoretical lifespan (99% of Linf)	40	yr	DW report life history section
	Sex ratio at birth	1:1	dimensionless	DW report life history section
	Reproductive cycle	biennial	yr	DW report life history section
mx	Constant litter size	30.93 (SD=10.74; 13-56)	pups per litter	DW report life history section
e	Intercept of maternal length vs. fecundity	-67.9565	dimensionless	DW report life history section
f	Slope of maternal length vs. fecundity	0.3453	dimensionless	DW report life history section
GP	Gestation period	12	months	DW report life history section

Values in parentheses are SEs.

2.6 FIGURES

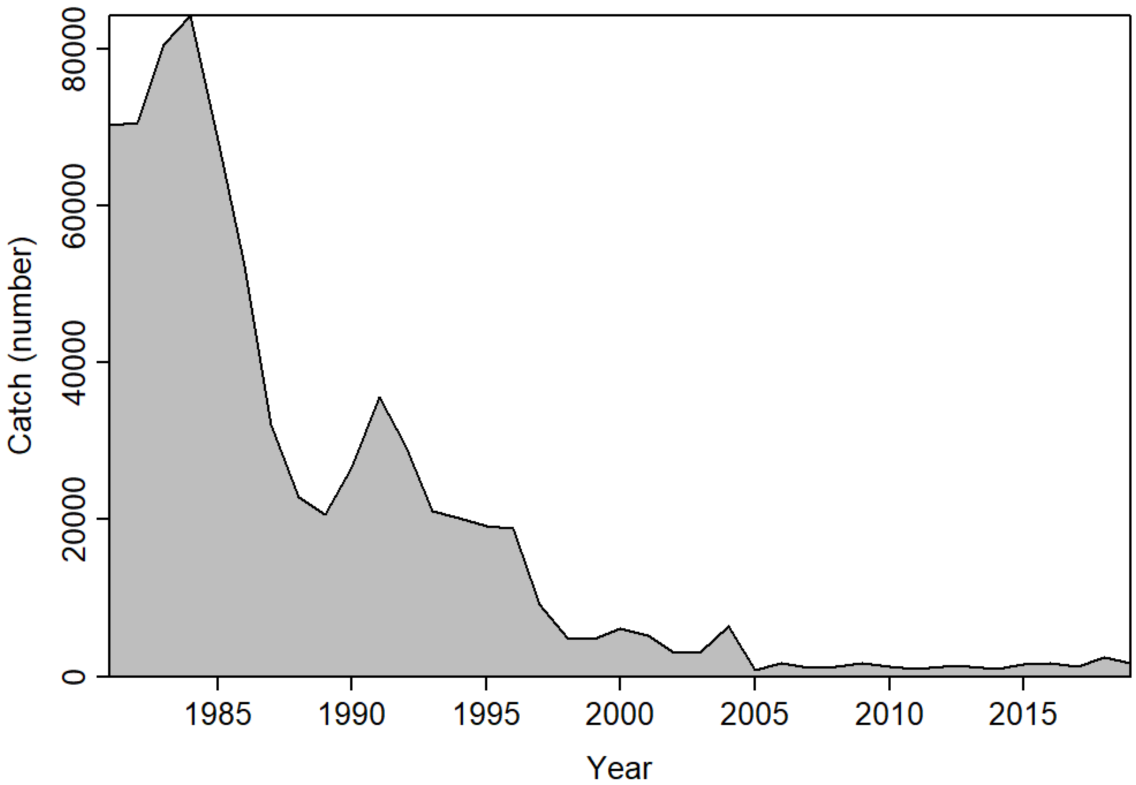

Figure 2.6.1. Stock wide total catch of great hammerheads in numbers used for the base run. Total catch is the sum of total recreational and total commercial catch.

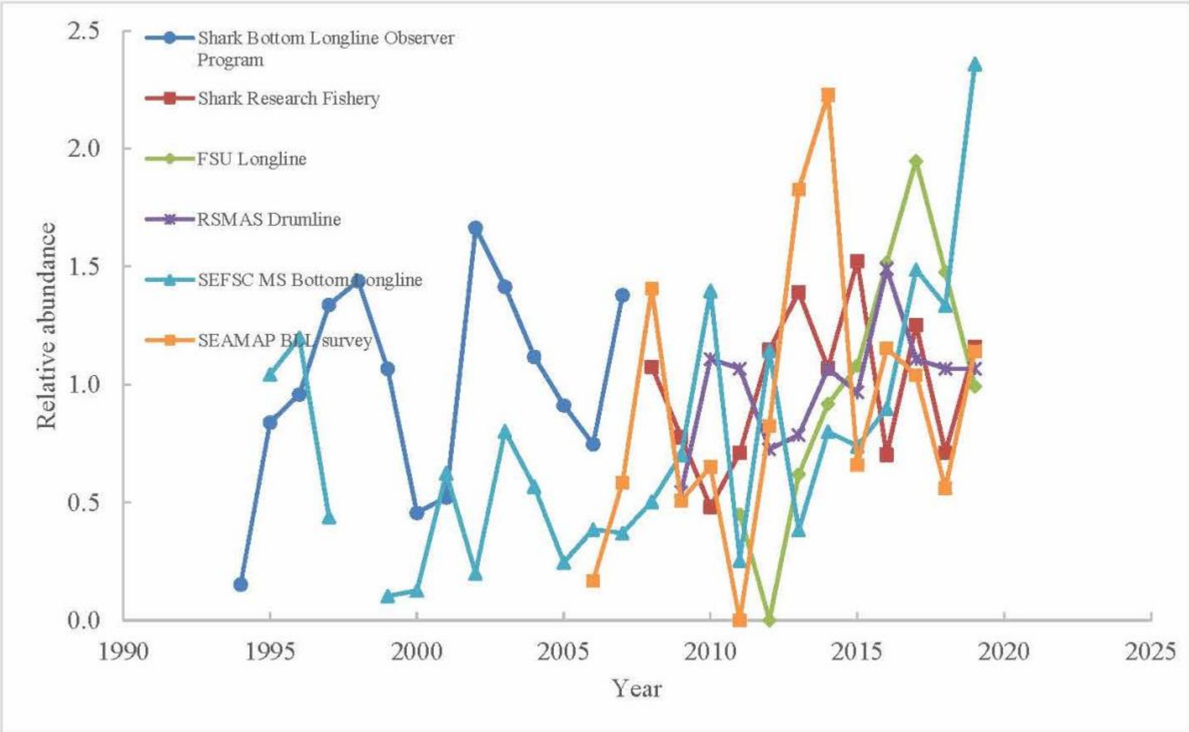

Figure 2.6.2. Indices of abundance used for the base run. All indices are statistically standardized and scaled (divided by the average of all annual values for that specific time series for plotting purposes).

3. STOCK ASSESSMENT MODEL AND RESULTS

The model is described below.

3.1 JABBA ASSESMENT MODEL

3.1.1 Overview

This stock assessment is implemented with the Bayesian state-space surplus production model framework JABBA (Winker *et al.*, 2018) version v.2.2.8. JABBA has been widely applied in a number of recent ICCAT stock assessments, including South Atlantic blue shark (ICCAT, 2016), Mediterranean albacore (ICCAT, 2017c), South Atlantic swordfish (ICCAT, 2017a; Winker *et al*., 2018), Atlantic shortfin mako shark stocks (south and north) (ICCAT, 2017d; Winker *et al*., 2017, 2019a), Atlantic blue marlin (Mourato *et al.*, 2019), Atlantic bigeye tuna (Winker *et al.*, 2019b), Atlantic white marlin (Mourato *et al*., 2020), Atlantic yellowfin tuna (Sant'Ana *et al.*, 2020), and Mediterranean swordfish (Winker *et al.* 2020; ICCAT, 2017b).

JABBA is formulated on the Bayesian state-space estimation framework proposed by Meyer and Millar (Meyer and Millar, 1999a). It estimates both process error variance and observation error variance. JABBA is an open-source modelling software and is available as an 'R package' that can be installed from github.com/jabbamodel/JABBA. JABBA uses R (R Foundation for Statistical Computing, Vienna, 2011) to set up the model and call up the software program JAGS (Just Another Gibbs Sampler, Plummer, (2003)) using the R package 'rjags' (Plummer, 2016). JABBA estimates Bayesian posterior distributions of model outputs by means of a Markov Chain Monte Carlo (MCMC) simulation. JABBA's inbuilt options include: (1) automatic fitting of multiple abundance time-series and associated standard errors; (2) estimating or fixing the process variance, (3) optional estimation of additional observation variance for individual or grouped abundance time-series, (4) specifying a Fox, Schaefer or Pella-Tomlinson production function by setting the inflection point B_{MSY}/K and converting this ratio into the shape parameter m, (5) extensive diagnostic procedures and associated plots (e.g. residual runs test and recently added posterior predictive check), (6) a routine to conduct hindcasting and retrospective analysis, and (7) catch-based and F-based projections. A full description of the JABBA model, including formation and state-space implementation, prior specification options and diagnostic tools is available in Winker *et al.* (2018).

3.1.2 Data sources

The catch stream, indices of abundance and associated *CVs*, and biological inputs used to derive productivity in the application of JABBA are described in **Section 2**. Catch data (in numbers) were available from 1981 to 2019 (**Table 2.5.1**) and of the six CPUE series used in the base run, the earliest year represented was 1994 (**Table 2.5.2**). Due to remaining uncertainty about the catch time series we admitted catch observation error with a *CV*=0.1. Here are name abbreviations for the six CPUE series used in this report:
Shark Bottom Longline Observer Program (BLLOP.NR)
Shark Research Fishery (BLLOP.R)
FSU Longline (FSU.LL)
RSMAS Drumline (RSMAS.DL)
SEFSC MS Bottom Longline (SEFSC.BLL)
SEAMAP BLL survey (SEAMAP.BLL)

3.1.3 Model configuration

Fox, Schaefer, and Pella-Tomlinson production functions were explored. Pella-Tomlinson production function was recommended by the assessment Panel to be used for this assessment. The model started in 1981 and ended in 2019. The first year in which both CPUE and catch data were available was 1994. Estimated parameters were r, K, the abundance (in numbers) in 1981 relative to K (B_{81}/K or initial depletion at the beginning of the model *psi*), process and observation error variances, the time series of proportions of carrying capacity (P_t terms; see eq. 1 below), catchability coefficient associated with each CPUE time series and shape parameter (m). JABBA provides a generalized Bayesian state-space estimation framework for surplus production models (SPMs) by building on previous formulations by Pella and Tomlinson (1969). Surplus production models are frequently implemented to estimate sustainable levels of harvest (biomass removals) at corresponding levels of stock biomass. Maximum sustainable yield (*MSY*) is the maximum level of catch that can be removed from a stock over time while maintaining biomass at B_{MSY}, the biomass to produce *MSY*.

$$P_t = \left(P_{t-1} + \frac{r}{(m-1)} P_{t-1}(1 - P_{t-1}{}^{(m-1)}) - \frac{C_{t-1}}{K} \right) e^{P\varepsilon_t} \quad (1)$$

where $P_t = B_t/K$, B_t is the abundance (number) in year t, K is the carrying capacity (number), r is the intrinsic rate of population growth (yr^{-1}), C_{t-1} is the catch (number) in year t-1, and m is a shape parameter that determines where maximum surplus production is attained. If the shape parameter m=2, the model reduces to the Schaefer form, with the surplus production attaining maximum surplus production, or *MSY* at exactly a stock biomass level corresponding to K/2. If $0 < m < 2$, *MSY* occurs when biomass values are smaller than K/2; when m > 2, *MSY* occurs when biomass values are greater than K/2.

The model is a state-space model, which relates the observed catch rates (I_t) to unobserved states (P_t) through a stochastic observation model for I_t given P_t (Millar and Meyer 1999a, Meyer and Millar 1999b):

$$I_{i,t} = q_i K P_t e^{O\varepsilon_{t,i}} \quad (2)$$

The model assumes lognormal error structures for both process and observation errors ($e^{P\varepsilon}$ and $e^{O\varepsilon}$), with $P\varepsilon_t \sim N(0,\sigma^2)$ and $O\varepsilon_{t,i} \sim N(0,\tau^2)$. The process error model relates the dynamics of exploitable biomass (abundance) to natural variability in biological and environmental processes affecting the stock. Thus, the population dynamics are subject to natural variation (eq. 1), which is expressed in the form of independent and lognormally distributed random variables ($e^{P\varepsilon}$). The observation error model relates the observed indices of abundance (indistinctly also referred to here as CPUE) to the exploitable biomass (abundance) of the stock. The CPUE dynamics are subject in this case to sampling or observation variability (eq. 2), which is expressed in the form of independent and lognormally distributed random variables ($e^{O\varepsilon}$). In the present implementation, the catchability coefficient for each index of abundance (q_i) is estimated within the model.

3.1.4 Parameter estimation

Prior distributions

Prior distributions were used to quantify the degree of existing knowledge on each of the model parameters to be estimated under the Bayesian approach. Here are the key priors required to be specified in JABBA.

Carrying capacity—Vaguely informative lognormal priors with a mean of 400, 40, and 6 times the maximum observed catch (33,670,000, 3,367,000, and 505,000 sharks), and the JABBA default prior *K* setting (*K* was assumed to equal the unfished biomass B_0) were explored. The JABBA default prior *K* setting was recommended by the Panel to be used for the base run.

Intrinsic rate of population growth—An informative, lognormally distributed prior (mean=0.144 yr^{-1}, *CV*=0.244) was used for *r* to take advantage of the available biological information reported in **Section 2.3** for the base run (see **Section 2.3** and SEDAR77-AW04 (Cortés 2022) for details).

Initial depletion—An informative prior was also used for B_{81}/K *(i.e. psi)* defined with a beta distribution with the mean=0.9 and *CV*=0.1 to reflect some depletion with respect to virgin levels. Considering initial depletion in 1981 is justified because previous input from the commercial shark fishing industry provided for SEDAR 65 stated that “there was very little commercial shark fishing effort in the early 1980s".

Inflection point of the surplus production curve—An informative prior for the inflection point of the surplus production curve (B_{MSY}/K =0.48) was used for the base run. This prior was derived from the Leslie matrix stochastic analyses (see **Section 2.3** and SEDAR77-AW04 (Cortés 2022) for details).

Priors for error variances—Priors for both the observation error variance (τ^2) and process error variance (σ^2) were used in JABBA. The observation variance consists of both an assumed minimum fixed observation error component (0.001) and an estimable “additional” observation variance component (Winker *et al.* 2018). Both the estimable “additional” observation variance and the process error variance were specified as inverse-gamma distributions (shape k = 0.001 and rate λ = 0.001), assuming fairly low stochastic biomass variation considering the long generation length (Winker, 2018).

3.1.5 Model execution

JABBA is implemented in R (R Development Core Team, https://www.r-project.org/) with the JAGS interface (Plummer, 2003) to estimate the Bayesian posterior distributions of all quantities of interest by means of a MCMC simulation. The JAGS model is executed from R using wrapper function jsgs() from the library r2jags (Su and Yajima, 2012), which depends on rjags. In this study, three MCMC chains were used. Each model was run for 30,000 iterations, sampled with a burn-in period of 5,000 iterations for each chain and thinning rate of five iterations. JABBA inbuilt functions used to fit the model are build_jabba() and fit_jabba().

3.1.6 Model performance diagnostics

Here is a brief description of JABBA's inbuilt options of diagnostic procedures and associated plots that were used in this assessment.

Goodness of CPUE fits—To evaluate CPUE fits, the model predicted CPUE indices were compared to the observed CPUE. R plots were developed in JABBA as an aid to visualize results.

Posterior predictive check—Posterior predictive check of CPUE fits was compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of each of the six indices of abundance and the combined six indices of abundance. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process. R plots were developed in JABBA as an aid to visualize results.

Runs test—Runs test was applied to the residuals of each abundance index fit to quantitatively evaluate the randomness of the time-series of abundance residuals by index (Carvalho *et al*. 2017). R plots were developed in JABBA as an aid to visualize results obtained from residuals runs tests. The plots identify individual time-series data points farther than three standard deviations away from the mean (the three-sigma rule), which is a test used to detect non-random time series (e.g., see Anhøj and Olesen 2014).

Hindcasting cross-validation — Hindcasting cross-validation (HCXval) was carried out with a JABBA inbuilt function (hindcast_jabba()) to check the model prediction skill. The HCXval technique was developed by Kell *et al.* (2016). The HCXval algorithm has in common with retrospective analysis that it requires the same two routine procedures of sequential removal of the observations and re-fitting the model to the so truncated data series, but HCXval involves the additional steps of projecting ahead over the missing years and then cross-validating these forecasts against observations to assess the model's prediction skill. A robust statistic for evaluating prediction skill is the Mean Absolute Scaled Error (*MASE*) proposed by Hyndman and Koehler (2006), which scales the mean absolute error of prediction residuals to a naive baseline prediction, where a 'prediction' is said to have 'skill' if it improves the model forecast when compared to the naive baseline. A widely used baseline forecast for time series is the 'persistence algorithm' that takes the value at the previous time step to predict the expected outcome at the next time step as a naive in-sample prediction, e.g., tomorrow's weather will be the same as today's. The *MASE* score scales the mean absolute error of the prediction residuals to the mean absolute error of a naive in-sample prediction. A *MASE* score higher than one can then be interpreted such that the average model forecasts are no better than a random walk. Conversely, a *MASE* score of 0.5 indicates that the model forecasts twice as accurately as a naive baseline prediction; thus, the model has prediction skill. R plots were developed in JABBA as an aid to visualize results.

Retrospective analysis—A retrospective analysis was conducted with a JABBA inbuilt function (hindcast_jabba()) to assess whether there are consistent patterns in model-estimated outputs based on increasing periods of data (Mohn, 1999). A retrospective analysis is conducted by sequentially removing the terminal year of data and re-estimating model results. Each subsequent year removal is called a 'peel.' A retrospective analysis was conducted going back to 2011 by successively deleting the catch and CPUE data for years 2018 through 2012 in seven 1-year 'peels,' refitting the assessment model, and comparing the results to the base case model with terminal data and estimates in 2019. The magnitude of the retrospective pattern was assessed using Mohn's rho (ρ; Mohn, 1999), which computes relative patterns of deviations with respect to a base model. R plots were developed in JABBA as an aid to visualize results. A 'rule of thumb', proposed by Hurtado-Ferro *et al*. (2015), suggests values of Mohn's rho that fall outside (-0.15 to 0.20) for *SSB* for longer-lived species, or outside (-0.22 to 0.30) for shorter-lived species indicates an undesirable retrospective pattern.

3.1.7 Stock status

Reference points for this assessment are based on *MSY* (F_{MSY}, B_{MSY}), and current status relative to *MSY* levels. In addition, trajectories for predicted abundance (B_{year}) and harvest rate (F_{year}), B_{year}/B_{MSY}, and F_{year}/F_{MSY} were produced and plotted. Phase plots of stock status, including *MSST* (Minimum Stock Size Threshold) were also included. The average (age 1 to maximum age) natural mortality rate (M=0.156 yr^{-1}) was used for the base run. Because M<0.5, *MSST* is computed as (1-M)B_{MSY} (Restrepo *et al.* 1998). Phase plots depicting the combined F_{year}/F_{MSY} and B_{year}/B_{MSY} trajectories were also produced for every year considered in the base model.

3.1.8 Uncertainty analysis

Uncertainty in data inputs and model configuration was examined through the use of sensitivity scenarios (**Table 3.1**). The summary of each of the Panel-approved nine sensitivity runs in total is included in this report in addition to the base run (**Tables 3.4** and **3.5**, **Figures 3.12a, 3.12b, 3.13a** and **3.13b**). No continuity analysis was conducted because this is the first time this stock has been assessed.

We now specifically describe how each of the Panel-approved nine sensitivity runs was implemented:

Scenario 1: *ref2B (400x*C_{MAX}*, CV=2)*—Same as the base run, but a vaguely informative lognormal prior with a very large mean of 400 times the maximum observed catch (33,670,000 sharks) and a *CV* of 2 was used as a *K* prior.

Scenario 2: *ref3B (40x*C_{MAX}*, CV=2)*—Same as the base run, but a vaguely informative lognormal prior with a large mean of 40 times the maximum observed catch (3,367,000 sharks) and a *CV* of 2 was used as a *K* prior.

Scenario 3: *ref1_1B (6xC_{MAX}, CV=2)*—Same as the base run, but a vaguely informative lognormal prior with a best-guessed mean of 6 times the maximum observed catch (505,000 sharks) and a *CV* of 2 was used as a *K* prior.

Scenario 4: *ref1_2B (6xC_{MAX}, CV=200)*—Same as the base run, but a vaguely informative lognormal prior with a best guessed mean of 6 times the maximum observed catch (505,000 sharks) and a very large *CV* of 200 was used as a *K* prior.

Scenario 5: *ref12BB (High r)*—Same as the base run, but increasing *r* from 0.144 yr^{-1} to 0.199 yr^{-1} (i.e. high productivity estimate).

Scenario 6: *ref13BB (Low r)*—Same as the base run, but decreasing *r* from 0.144 yr^{-1} to 0.099 yr^{-1} (i.e. low productivity estimate).

Scenario 7: *ref3_2BB (High CV)*—Same as the base run, but increasing the *CV* of *r* from 0.244 to 0.488 (i.e. increasing the uncertainty of the informative *r* estimate).

Scenario 8: *ref12_2BB (High r & High CV)*—Same as the base run, but increasing both *r* and the *CV* of *r* from 0.144 yr^{-1} to 0.199 yr^{-1} and from 0.244 to 0.488, respectively.

Scenario 9: *ref13_2BB (low r & High CV)*—Same as the base run, but decreasing *r* from 0.144 yr^{-1} to 0.099 yr^{-1} and increasing the CV of *r* from 0.244 to 0.488.

3.1.9 Projection methods

Projections were governed by the same population dynamics (eq. 1) used to fit the model during 1981-2019. Both catch-based and *F*-based projections were carried out with the JABBA inbuilt function (fw_jabba()). OFL_{2020} (i.e. catch in 2020 that corresponds to the estimate of 100% F_{MSY} applied to the stock biomass in 2020) was estimated with the *F*-based the terminal year plus one projection in JABBA for the base run. For projections with lengths of projections > 3 years, projections were set up with 3 intermediate years under current catch (here mean of recent 3 years), then a fixed level of catch or *F* during the rest of the projection period. A new JABBA inbuilt fw_jabba() option in the form of probability risk plots was used, which produces plots to show the risk of *B* falling below B_{MSY} (or *MSST*) and *F* rising above F_{MSY} for fixed catch levels with various lengths of projection periods. The preliminary results suggest the stock is overfished. Therefore, projections were carried out in accordance with Term of Reference 9(a) for rebuilding (there is no *ABC* calculation was needed). This new JABBA inbuilt option was used in this assessment to estimate the Year in which F=0 results in a 70% probability of rebuilding (Year F=0_{p70}), and fixed levels of catch allowing rebuilding of the stock with 50% and 70% probability by $Year_{rebuild}$ (Note: for Year F=0_{p70} > 10 years, target rebuilding year ($Year_{rebuild}$) is Year F=0_{p70} plus one generation time) for the base run. In addition, *F*-based projections were used to estimate the fixed levels of *F* allowing rebuilding of stock with 50% and 70% probability by $Year_{rebuild}$ for the base run.

3.2 MODEL RESULTS

3.2.1 Posteriors for model parameters

Posteriors for model parameters including carrying capacity (*K*), intrinsic population growth rate (*r*), shape parameter (*m*), initial proportion of carrying capacity (*psi*), catchability for each of six indices of abundance (q_1, q_2, q_3, q_4, q_5, q_6), and process error variance (*sigma2*) for the base run are depicted as distributions in **Figure 3.1**.

The posterior median for carrying capacity *K* was estimated to be 592,637 sharks, the posterior median for intrinsic population growth *r* was 0.126 yr^{-1}, the posterior median for the shape parameter *m* was 2.17, the initial year proportion of biomass to carrying capacity (i.e. initial depletion, *psi*) was 0.93, and the posterior median for process error deviate (*sigma*) was 0.073. The values estimated for posterior to prior median (*PPMR*) and variance (*PPVR*) ratio for *K* indicate that this parameter has been informed by the data; the values of *PPMR* and *PPVR* estimated for *r* and *m,* in general, showed that the priors used have defined the behavior of the posteriors as expected; and the *psi* marginal posterior for the base run was largely informed by the prior distribution.

3.2.2 Measures of model fit

The catch series was fit very well as expected (**Figure 3.2**). All six indices of abundance were fit reasonably well, with the exception of large interannual fluctuations, but in all cases (5 indices except for BLLOP.NR which ended in 2007) the recent increasing trend of the observed series was captured by the model fit (**Figure 3.3**). The fit to the BLLOP.NR index was satisfactory, except for the very low value in 1994. According to the posterior predictive check of CPUE fits compared to the posterior predictive distribution of both each of the six indices of abundance and the combined six indices of abundance, all six indices of abundance fit reasonably well (ρ=0.5 is ideal and a range 0.2-0.8 is acceptable (**Figures 3.4** and **3.5**). The results of the log-residuals runs test for each CPUE series are shown in **Figure 3.6**. All six indices of abundance passed the runs test with no evidence of a non-random residual pattern ($p > 0.05$).

3.2.3 Hindcasting cross-validation

The estimated *MASE* was above the reference level (*MASE* > 1) for only 2 of 5 indices of abundance evaluated (**Section 3.1.6** Hindcasting cross-validation, **Figure 3.7**), which indicates that the average model forecasts are not better than a naive baseline prediction for these 2 indices of abundance (RSMAS.DL and FSU.LL). However, the joint *MASE* is 0.89 and is below the reference level (*MASE* < 1).

3.2.4 Trajectory for process error deviates

Process error deviates are within a couple of percent for most years. However, there is a persistent negative process error during the last 10 years or so (**Figure 3.8**).

3.2.5 Retrospective analysis

Retrospective analyses for median annual biomass, fishing mortality, biomass relative to B_{MSY}, fishing mortality relative to F_{MSY}, process deviations and surplus production curve for the base run showed no major or consistent retrospective pattern for seven annual retrospective peels (**Section 3.1.6** Retrospective analysis, **Figure 3.9**). The estimated Mohn's rho for all stock quantities fell within the acceptable range of -0.15 and 0.20 (Hurtado-Ferro *et al.*, 2014).

3.2.6 Biomass, fishing mortality and stock status

Table 3.2 lists summaries of posterior quantiles presented in the form of marginal posterior medians and the associated 95% credibility intervals of parameters for the base run. **Table 3.3** lists the time series values for biomass (B) and fishing mortality (F), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}). The predicted biomass trajectory showed a sharp decreasing trend from 1981 to 2002, followed by a slow increasing trend (**Table 3.3** and **Figure 3.10 top**). The predicted fishing mortality fluctuated, and showed an increasing trend from 1981 to 1996, followed by a decreasing trend to 2004, and then a low flat trend thereafter (**Table 3.3** and **Figure 3.10 top**). The model predicted that the stock had not been overfished ($B>MSST$) from 1981 to 1985 only, but had been overfished thereafter (**Table 3.2** and **Figure 3.10 middle, Figure 11**). The model predicted that the stock had been undergoing overfishing ($F>F_{MSY}$) from 1981 to 2004, but had not been experiencing overfishing thereafter (**Table 3.2** and **Figure 3.10 middle, Figure 11**). The predicted biomass relative to B_0 (B/B_0) showed the same pattern as the predicted biomass (**Figure 3.10 bottom**). The predicted surplus production curve is left skewed (**Figure 3.10 bottom**). The predicted inflection point of the surplus production curve (B_{MSY}/K) is 0.516 (**Table 3.2)**, which is larger than the informative prior (0.48).

3.2.7 Evaluation of uncertainty

The base run predicted the stock had not been overfished ($B>MSST$) from 1981 to 1985 only, but had been overfished thereafter (**Table 3.2** and **Figure 3.10 middle, Figure 3.11**). The model predicted that the stock had been undergoing overfishing ($F>F_{MSY}$) from 1981 to 2004, but had not been experiencing overfishing thereafter (**Table 3.2** and **Figure 3.10 middle, Figure 3.11**). Results of all sensitivity runs explored agreed with the prediction of an overfished/no overfishing status (**Tables 3.4** and **3.5, Figures 3.12a 3.12b, 3.13a** and **3.13b**). In general, all scenarios showed similar trends for the trajectories of B/B_{MSY} and F/F_{MSY} over time (**Figures 3.12a 3.12b, 3.13a** and **3.13b**).

3.2.8 Projections

OFL_{2020} estimated with the terminal year plus one projection in JABBA for the base run is 5900 sharks per year for the base run **(Table 3.6** and **Figure 3.14).** The preliminary results suggest the stock is overfished. Therefore, projections were carried out in accordance with Term of Reference 9(a) for rebuilding (there is no *ABC* calculation was needed).

Various lengths of projections were carried out for the base run. The year in which F=0 results in a 70% probability of rebuilding (Year F=0_{p70}) is 2041 (**Figure 3.15**). Since the year F=0_{p70} > 10 years, the target rebuilding year ($Year_{rebuild}$) becomes 2056 (2041 plus one generation time).

Various catch-based projections were carried out to the $Year_{rebuild}$ (2056) for the base run. A fixed level of catch (7264 sharks yr^{-1}) allows rebuilding of the stock with 50% probability by $Year_{rebuild}$ ($B < B_{MSY} <$ 50%) (**Figure 3.16**). A fixed level of catch (4994 sharks yr^{-1}) allows rebuilding of the stock with 70% probability by $Year_{rebuild}$ ($B < B_{MSY} <$ 30%) (**Figure 3.16**).

Various *F*-based projections were carried out for $Year_{rebuild}$ (2056) for the base run. A fixed level of *F* (72% F_{MSY}=0.042 yr^{-1}) allows rebuilding of the stock with 50% probability by $Year_{rebuild}$ (**Figure 3.17**). A fixed level of *F* (53% F_{MSY}=0.031 yr^{-1}) allows rebuilding of the stock with 70% probability by $Year_{rebuild}$ (**Figure 3.18**).

3.3 DISCUSSION

This assessment can be considered data moderate. Catch, indices of abundance, and life history data were used in this stock assessment. However, there are insufficient time series data to fully parameterize catch-at-age or catch-at-length population dynamics. Therefore, this assessment falls under tier 2 of the *ABC* control rule in Final Amendment 14 to the 2006 Consolidated Atlantic Highly Migratory Species Fishery Management Plan (2023).

Six indices of abundance were available. These indices cover Atlantic and Gulf of Mexico. All indices of abundance were standardized through GLM techniques. All indices of abundance were fit reasonably well, with the exception of large interannual fluctuations, but in all cases (5 indices except for BLLOP.NR which ended in 2007) the recent increasing trend of the observed series was captured by the model fit. Posterior predictive check suggests that model error assumptions are consistent with the underlying data generation process. Runs test indicates no evidence of lack of randomness of time-series residuals. The estimated *MASE* was above the reference level (*MASE* > 1) for 2 of 5 indices of abundance evaluated (RSMAS.DL and FSU.LL). In an ideal world one would have a scientific survey index that represents the vulnerable portion of the population. Then the model would indeed have prediction skill for such an index. However, considering we are working with standardized CPUE indices that are representative of different areas and CPUE standardization may not result independent year-effects due to overfitting and other issues, which to some extent violates the "random walk" assumption. Since only 2 of 5 indices failed the hindcast cross-validation, these results are reasonable. As a matter of fact, this prediction skill is a better performance than exhibited by many tuna and billfish assessments and the data conflict is not severe (Winker per comm).

Process error deviates are within a couple of percent for most years, which is consistent with the biology of long-lived sharks. A persistent negative process error during the last 10 years or so is a concern, but this is also common for long-lived sharks. Retrospective analyses for the base run showed no major or consistent retrospective pattern for seven annual retrospective peels, indicating the model performance is very robust. The uncertainty analysis conducted revealed that stock status results relative to *MSY*-based reference points were rather insensitive to assumptions about *K* and *r* priors. Results of all runs explored agreed with the prediction of an overfished/no overfishing status. The JABBA inbuilt catch-based and *F*-based projections save analysts a great deal of time to carry out different catch-based and *F*-based strategies for setting quotas and rebuilding schedules for management recommendations. Despite the limitations of the data available, the known life-history characteristics of this stock, in combination with the indicators of relative abundance, suggest that this stock has been rebuilding during the last decade or so.

3.4 RECOMMENDATIONS FOR DATA COLLECTION AND FUTURE RESEARCH

We list below research recommendations that are more feasible and would allow improvement of future stock assessments of this stock:

- Since catches are dominated by recreational catches, decreasing the uncertainty associated with the recreational catches will be critical for improvement of future stock assessments of this stock.
- Since there are insufficient length composition data, programs to collect lengths to allow for a length-based, age-structured assessment in the future assessments should be developed.

3.5 ACKNOWLEDGMENTS

Thanks to Henning Winker for his guidance and availability to answer JABBA questions. He has continually been supportive of this assessment with the JABBA application.

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3.7 TABLES

Table 3.1. *K* and *r* priors of each of the Panel-approved sensitivity runs.

Run	*K*	*r*
refB(Base)	Default in JABBA ($K=B_0$)	Lognormal (0.144, 0.244)
1) ref2B (400xC_{MAX}, CV=2)	Lognormal (33670000, 2)	Lognormal (0.144, 0.244)
2) ref3B (40xC_{MAX}, CV=2)	Lognormal (3367000, 2)	Lognormal (0.144, 0.244)
3) ref1_1B (6xC_{MAX}, CV=2)	Lognormal (505000, 2)	Lognormal (0.144, 0.244)
4) ref1_2B (6xC_{MAX}, CV=200)	Lognormal (505000, 200)	Lognormal (0.144, 0.244)
5) ref12BB (High r)	Default in JABBA ($K=B_0$)	Lognormal (0.199, 0.244)
6) ref13BB (Low r)	Default in JABBA ($K=B_0$)	Lognormal (0.099, 0.244)
7) ref3_2BB (High CV)	Default in JABBA ($K=B_0$)	Lognormal (0.144, 0.488)
8) ref12_2BB (High r & High CV)	Default in JABBA ($K=B_0$)	Lognormal (0.199, 0.488)
9) ref13_2BB (Low r & High CV)	Default in JABBA ($K=B_0$)	Lognormal (0.099, 0.488)

Table 3.2. Summary of posterior quantiles presented in the form of marginal posterior medians and associated the 95% credibility intervals of parameters for the base run. All abundance metrics refer to exploitable number. *K* is carrying capacity, *r* is intrinsic rate of population growth, *psi* is initial depletion (B_{81}/K), sigma.proc is process error deviate, *m* is the shape parameter of the Pella-Tomlinson production model, *MSST* is the minimum stock size threshold. *M* is the average (age 1 to maximum age) natural mortality rate. Overfishing limit (OFL_{2020}) is the amount of catch in 2020 that corresponds to the estimate of F_{MSY} applied to the stock biomass in 2020 estimated with the terminal year plus one projection in JABBA for the base run.

Run	**refB(Base)**		
Estimates	Median	LCI	UCI
K	592637	437837	853215
r	0.126	0.081	0.195
psi	0.931	0.689	0.997
sigma.proc	0.073	0.025	0.184
m	2.173	1.447	3.350
F_{MSY}	0.058	0.037	0.088
B_{MSY}	307024	209347	456490
MSY	17559	12161	27253
B_{MSY}/K	0.516	0.438	0.598
B_{2019}/B_{MSY}	0.284	0.112	0.652
F_{2019}/F_{MSY}	0.338	0.141	0.807
M	0.156		
MSST((1 -M)*B_{MSY})	259128		
OFL_{2020}	5900	2096	13118

Table 3.3. Model-estimated biomass (*B*) and fishing mortality (*F*), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) by year for the base run.

refB (Base)				
Year	B	F	B/B_{MSY}	F/F_{MSY}
1981	541273	0.130	1.772	2.270
1982	476666	0.148	1.554	2.587
1983	416582	0.194	1.360	3.379
1984	350360	0.240	1.143	4.201
1985	282043	0.242	0.921	4.239
1986	229254	0.228	0.750	3.998
1987	192024	0.168	0.629	2.940
1988	173646	0.131	0.568	2.302
1989	163731	0.126	0.536	2.216
1990	155124	0.172	0.508	2.999
1991	139935	0.254	0.460	4.426
1992	115061	0.254	0.379	4.410
1993	94959	0.222	0.313	3.844
1994	81791	0.247	0.271	4.277
1995	70321	0.272	0.233	4.710
1996	59012	0.320	0.195	5.548
1997	46250	0.198	0.153	3.453
1998	41941	0.118	0.138	2.053
1999	41096	0.118	0.136	2.055
2000	40410	0.150	0.133	2.629
2001	39274	0.132	0.129	2.318
2002	38772	0.076	0.127	1.342
2003	40452	0.077	0.132	1.362
2004	41400	0.156	0.135	2.740
2005	38865	0.021	0.127	0.369
2006	41960	0.041	0.137	0.722
2007	45177	0.024	0.147	0.419
2008	49368	0.025	0.161	0.447
2009	51162	0.032	0.167	0.566
2010	53116	0.024	0.174	0.422
2011	55595	0.018	0.182	0.327
2012	60805	0.021	0.199	0.365
2013	66123	0.018	0.216	0.328
2014	71043	0.013	0.232	0.232
2015	74696	0.022	0.244	0.383
2016	78279	0.022	0.256	0.397
2017	80931	0.016	0.265	0.280
2018	82102	0.031	0.269	0.541
2019	86743	0.019	0.284	0.338

Table 3.4. Summary of posterior quantiles presented in the form of marginal posterior medians and associated the 95% credibility intervals of parameters for the base run and the Panel-approved sensitivity runs with various *K* priors. All abundance metrics refer to exploitable number. *K* is carrying capacity, *r* is intrinsic rate of population growth, *psi* is initial depletion (B_{81}/K), sigma.proc is process error deviate, *m* is the shape parameter of Pella-Tomlinson production model, *MSST* is the minimum stock size threshold. *M* is the average (age 1to maximum age) natural mortality rate.

Run	**refB(Base)**			**ref2B (400xC_{MAX}, CV=2)**			**ref3B (40xC_{MAX}, CV=2)**			**ref1_1B (6xC_{MAX}, CV=2)**			**ref1_2B (6xC_{MAX}, CV=200)**		
Estimates	Median	LCI	UCI	Median	LCI	UCI	Median	LCI	UCI	Median	LCI	UCI	Median	LCI	UCI
K	592637	437837	853215	637182	466748	1062049	604499	441853	948605	586529	428261	829888	588478	420672	843341
r	0.126	0.081	0.195	0.124	0.080	0.191	0.125	0.080	0.194	0.125	0.081	0.195	0.125	0.081	0.191
psi	0.931	0.689	0.997	0.913	0.618	0.996	0.927	0.669	0.997	0.933	0.688	0.998	0.934	0.699	0.997
sigma.proc	0.073	0.025	0.184	0.077	0.028	0.188	0.074	0.025	0.186	0.072	0.022	0.183	0.071	0.023	0.182
m	2.173	1.447	3.350	2.182	1.470	3.337	2.185	1.450	3.368	2.182	1.447	3.363	2.179	1.430	3.311
F_{MSY}	0.058	0.037	0.088	0.057	0.036	0.086	0.057	0.036	0.087	0.057	0.037	0.089	0.057	0.037	0.088
B_{MSY}	307024	209347	456490	330668	224608	571386	314003	210951	499815	304443	202659	450012	305100	201104	458104
MSY	17559	12161	27253	18668	12634	32678	17706	12172	30061	17282	12006	26541	17261	11829	26863
B_{MSY}/K	0.516	0.438	0.598	0.517	0.441	0.597	0.517	0.438	0.599	0.517	0.437	0.599	0.516	0.435	0.596
B_{2019}/B_{MSY}	0.284	0.112	0.652	0.246	0.094	0.734	0.288	0.115	0.640	0.301	0.112	0.704	0.329	0.129	0.887
F_{2019}/F_{MSY}	0.338	0.141	0.807	0.359	0.118	0.837	0.327	0.144	0.733	0.320	0.131	0.795	0.295	0.104	0.697
M	0.156			0.156			0.156			0.156			0.156		
MSST($(1-M)*B_{MSY}$)	259128			279084			265019			256950			257505		

Table 3.5. Summary of posterior quantiles presented in the form of marginal posterior medians and associated the 95% credibility intervals of parameters for the base run and the Panel-approved sensitivity runs with various *r* priors. All abundance metrics refer to exploitable number. *K* is carrying capacity, *r* is intrinsic rate of population growth, psi is initial depletion (B_{81}/K), sigma.proc is process error deviate, *m* is the shape parameter of Pella-Tomlinson production model, *MSST* is the minimum stock size threshold. *M* is the average (age 1 to maximum age) natural mortality rate.

Run	refB(Base)			ref12BB (High r)			ref13BB (Low r)			ref3_2BB (High CV)			ref12_2BB (High r & High CV)			ref13_2BB (Low r & High CV)		
Estimates	Median	LCI	UCI	Median	LCI	UCI	Median	LCI	UCI	Median	LCI	UCI	Median	LCI	UCI	Median	LCI	UCI
K	592637	437837	853215	572326	404103	810238	615371	466633	853216	617722	442276	924793	600028	426589	888346	630619	450420	945830
r	0.126	0.081	0.195	0.163	0.106	0.253	0.091	0.059	0.140	0.099	0.049	0.200	0.121	0.060	0.249	0.081	0.040	0.168
psi	0.931	0.689	0.997	0.930	0.684	0.997	0.935	0.706	0.997	0.929	0.670	0.997	0.926	0.678	0.997	0.929	0.661	0.997
sigma.proc	0.073	0.025	0.184	0.080	0.025	0.190	0.064	0.021	0.176	0.071	0.023	0.182	0.076	0.024	0.186	0.066	0.023	0.178
m	2.173	1.447	3.350	2.495	1.652	3.800	1.862	1.234	2.847	1.938	1.185	3.166	2.091	1.267	3.394	1.776	1.082	2.943
F_{MSY}	0.058	0.037	0.088	0.065	0.042	0.103	0.049	0.031	0.074	0.051	0.030	0.087	0.058	0.035	0.098	0.046	0.026	0.077
B_{MSY}	307024	209347	456490	312171	204573	455667	300031	209194	438970	304301	204590	477503	304589	203686	469280	300813	200450	472847
MSY	17559	12161	27253	20035	13933	31709	14600	10040	22202	15559	9284	27476	17662	11073	30084	13835	8016	24016
B_{MSY}/K	0.516	0.438	0.598	0.542	0.463	0.621	0.486	0.407	0.568	0.494	0.400	0.587	0.509	0.412	0.600	0.477	0.382	0.574
B_{2019}/B_{MSY}	0.284	0.112	0.652	0.262	0.106	0.785	0.308	0.127	0.928	0.282	0.111	0.732	0.255	0.106	1.085	0.313	0.113	0.821
F_{2019}/F_{MSY}	0.338	0.141	0.807	0.313	0.108	0.717	0.373	0.115	0.893	0.375	0.143	0.928	0.363	0.088	0.872	0.390	0.133	1.048
M	0.156			0.080			0.182			0.156			0.080			0.182		
MSST((1 -M)*B_{MSY})	259128			287197			245425			256830			280222			246065		

Table 3.6. Summary of the posterior medians of parameters for the projections in JABBA for the base run. OFL_{2020} is the amount of catch in 2020 that corresponds to the estimate of F_{MSY} applied to the stock biomass in 2020. Year in which F=0 results in a 70% probability of rebuilding (Year $F=0_{p70}$). For Year $F=0_{p70}$ > 10 years, target rebuilding year ($Year_{rebuild}$) is 2056 (2041 plus one generation time).

refB (Base)	
Estimates	Median
OFL_{2020} (number)	5900
Generation time (years)	14.5
Year $F=0_{p70}$	2041
Year rebuild	2056
Fixed level of annaul catch allowing rebuilding of stock with 50% probability by year rebuild (number)	7264
Fixed level of annual catch allowing rebuilding of stock with 70% probability by year rebuild (number)	4994
Fixed level of F allows rebuilding of stock with 50% probability by year rebuild	72% F_{MSY}=0.042
Fixed level of F allows rebuilding of stock with 70% probability by year rebuild	53% F_{MSY}=0.031

3.8 FIGURES

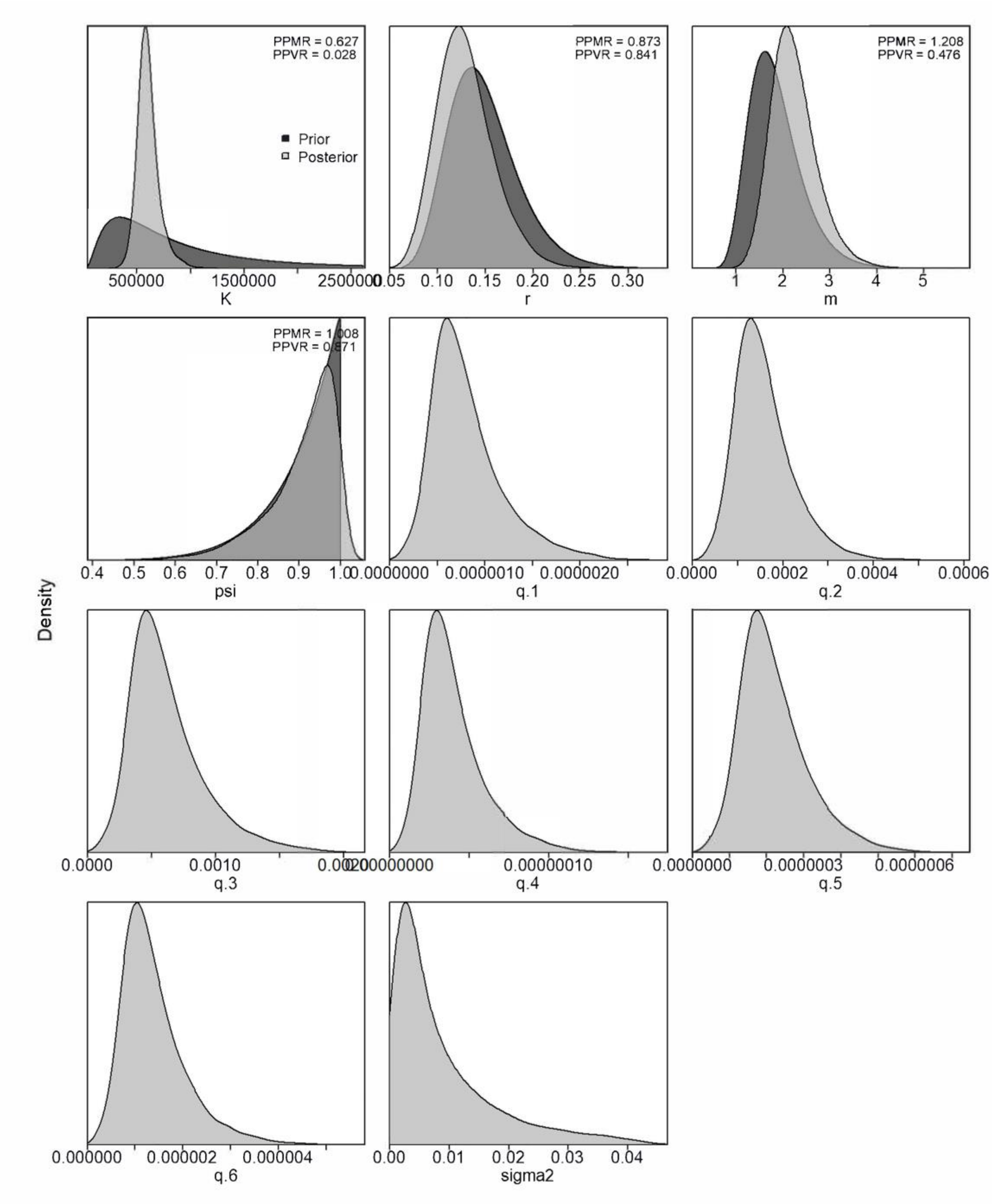


Figure 3.1. Prior and posterior distribution of various model parameters for the base run. *PPRM*: Posterior to Prior Ratio of Medians; *PPRV*: Posterior to Prior Ratio of Variances.

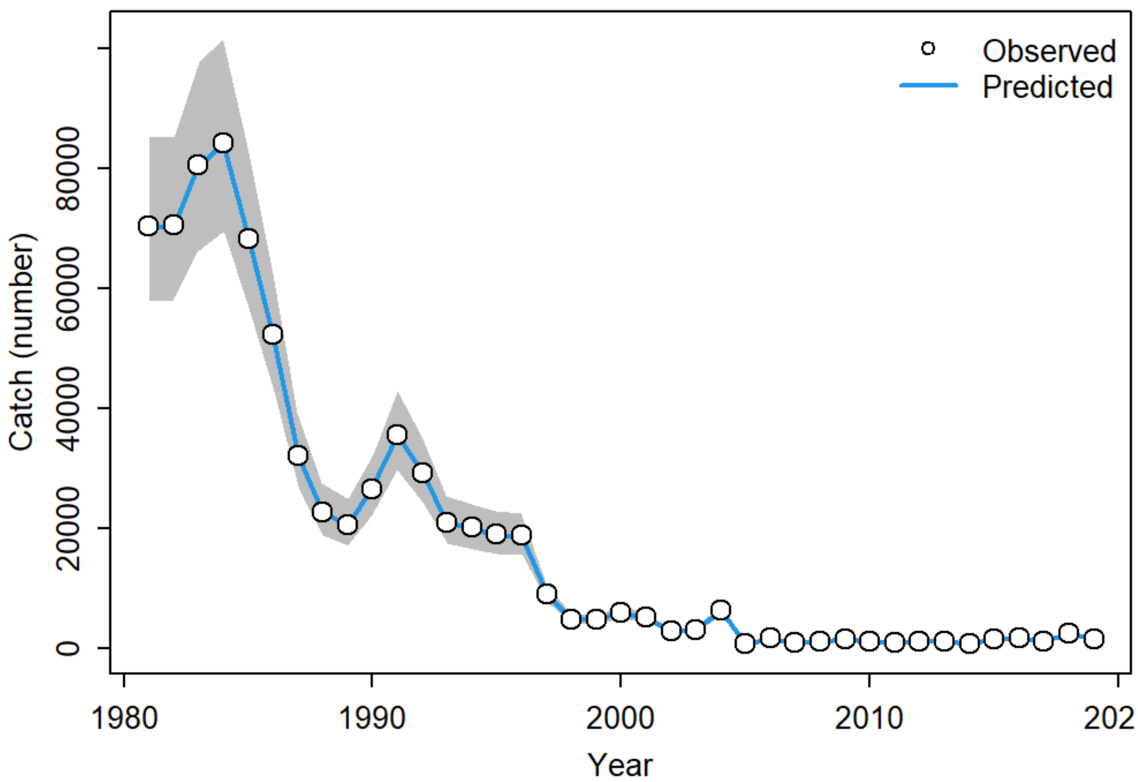


Figure 3.2. Catches of great hammerheads in numbers (1981-2019) for the base run.

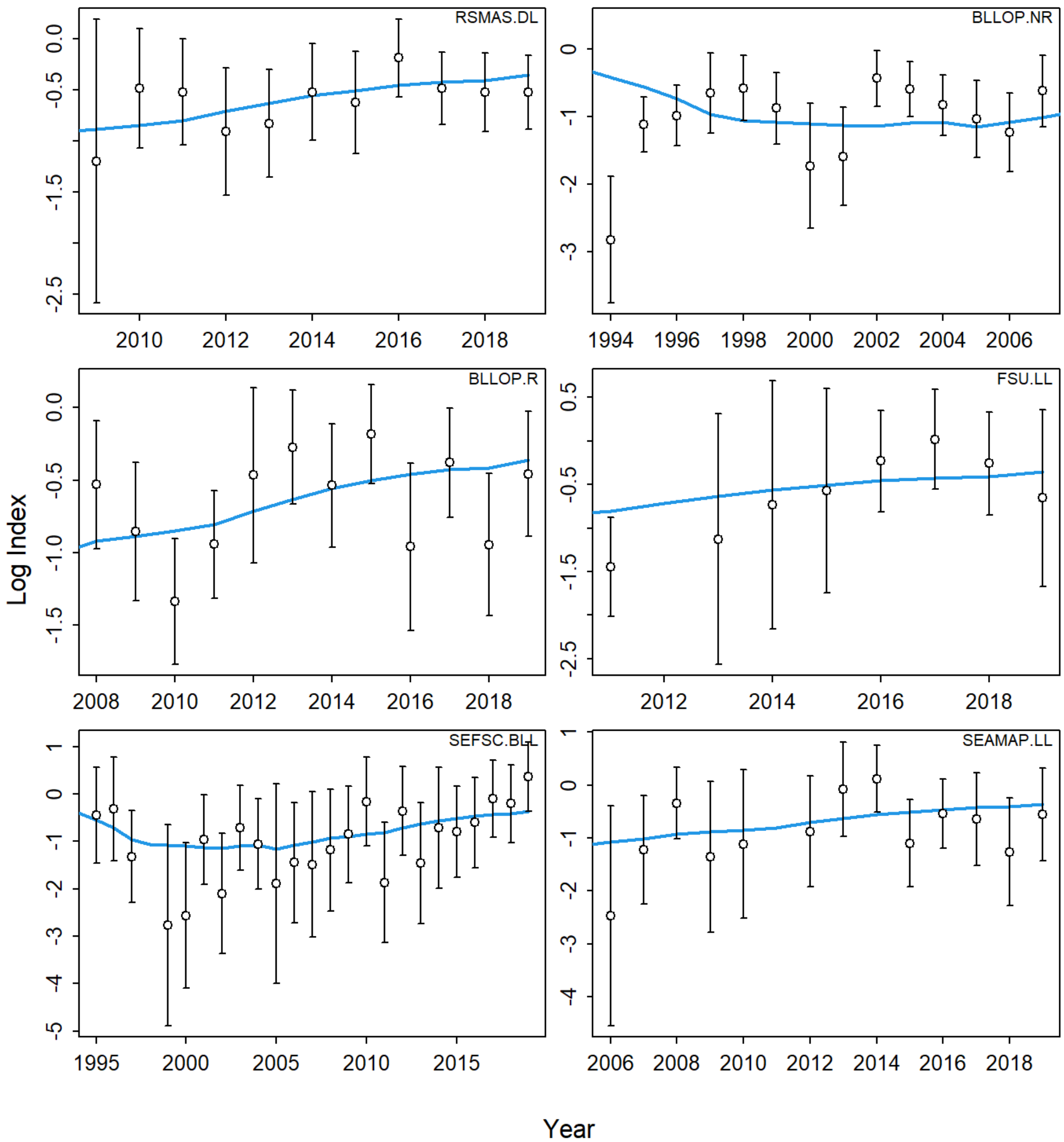


Figure 3.3. JABBA fits to the standardized catch-per-unit-effort (CPUE) (in log scale) data sets from the six indices of abundance for the base run. The solid line is the model-predicted value and the circles are observed data values. Vertical lines represent the estimated 95% confidence intervals around the CPUE values.

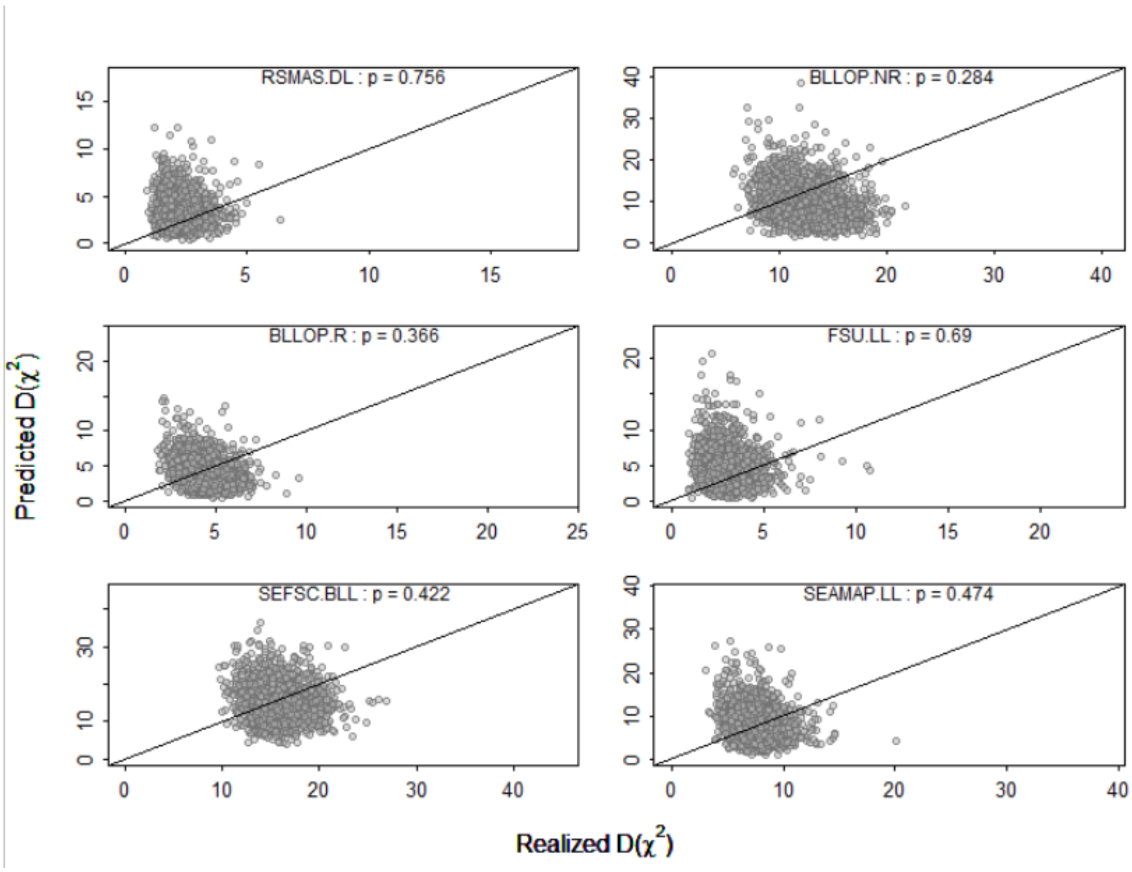


Figure 3.4. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of each of the six indices of abundance for the base run. A general rule of thumb is that ρ=0.5 is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

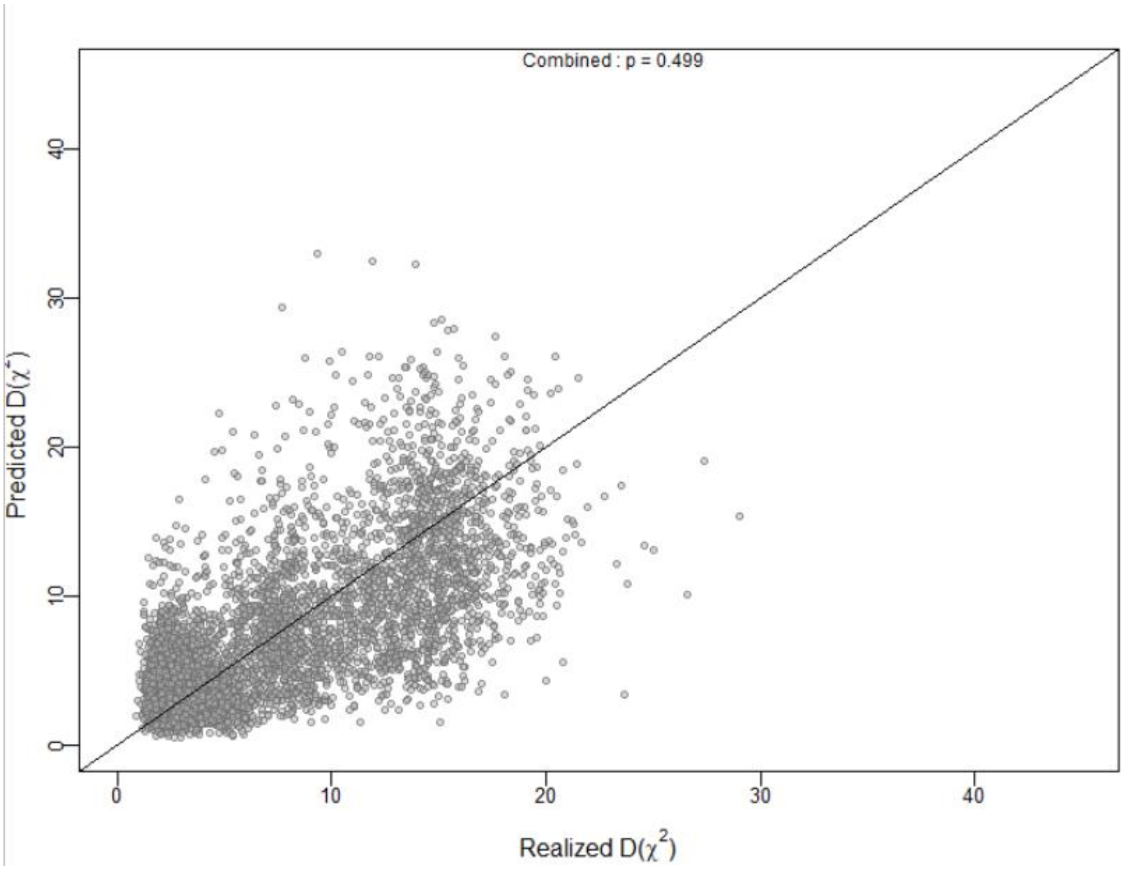


Figure 3.5. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of the combined CPUE for the base run. A general rule of thumb is that ρ=0.5 is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

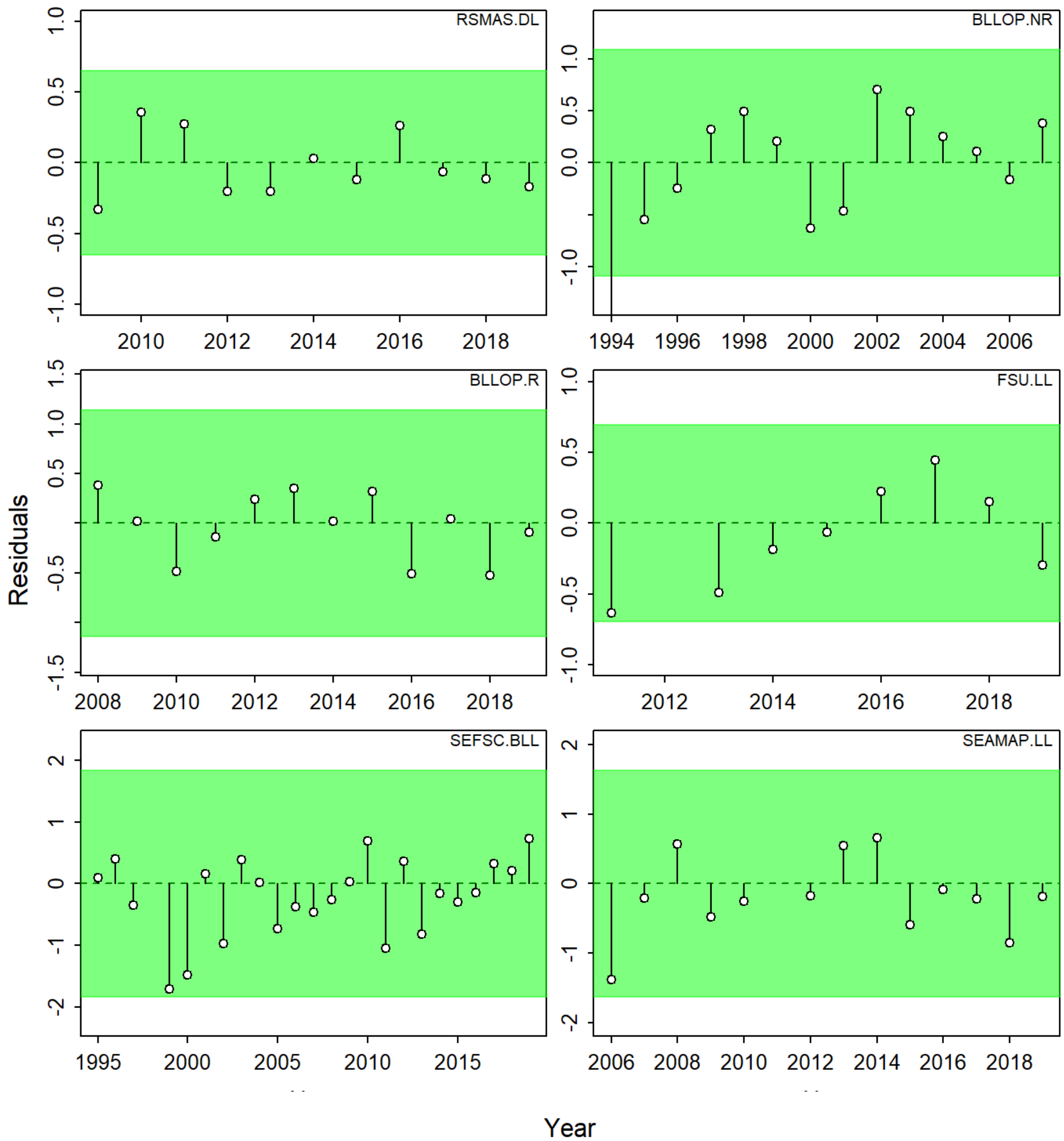


Figure 3.6. Runs test to quantitatively evaluate the randomness of the time series of CPUE residuals for each of the six indices of abundance for the base run. Green panels indicate no evidence of lack of randomness of time-series residuals ($p>0.05$) while red panels indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

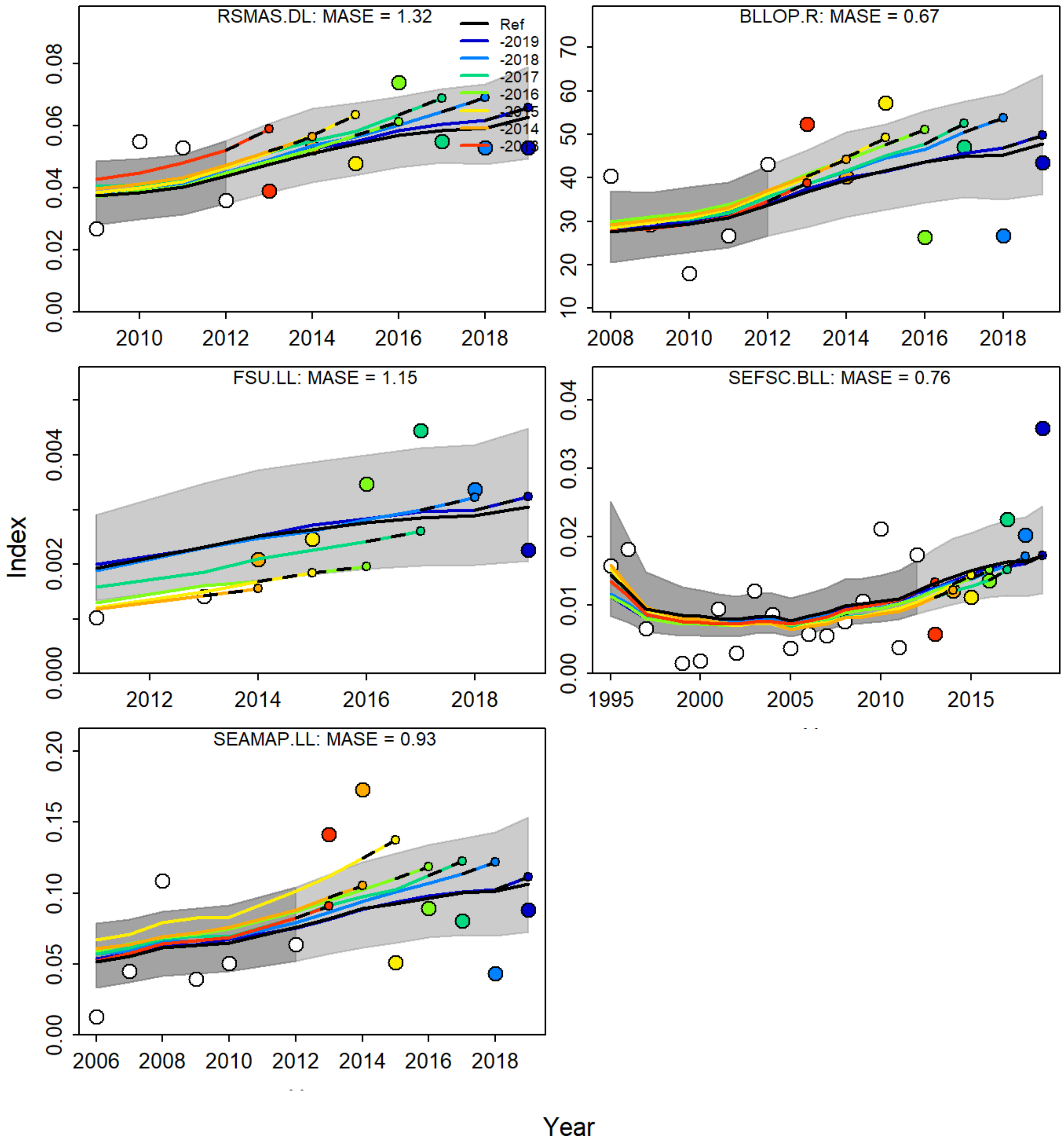


Figure 3.7. Hindcasting cross-validation results (HCxval) for the base run, showing one-year-ahead forecasts of CPUE values, performed with seven hindcast model runs relative to the expected CPUE. The CPUE observations, used for cross-validation, are highlighted as color-coded solid circles with associated light-grey shaded 95% confidence interval. The model reference year refers to the end points of each one-year-ahead forecast and the corresponding observation (i.e. year of peel + 1). The joint *MASE* value is 0.89.

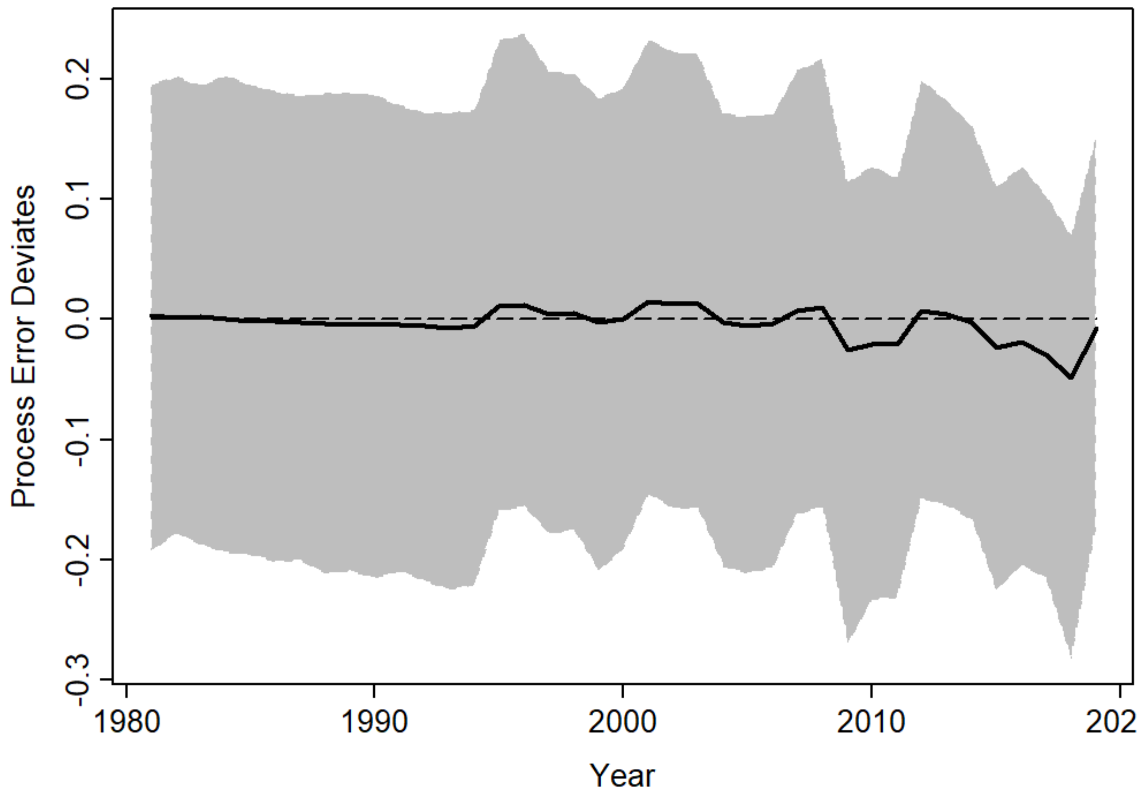


Figure 3.8. Process error deviates (median: solid line) with shaded gray area indicating 95% credibility intervals for the base run.

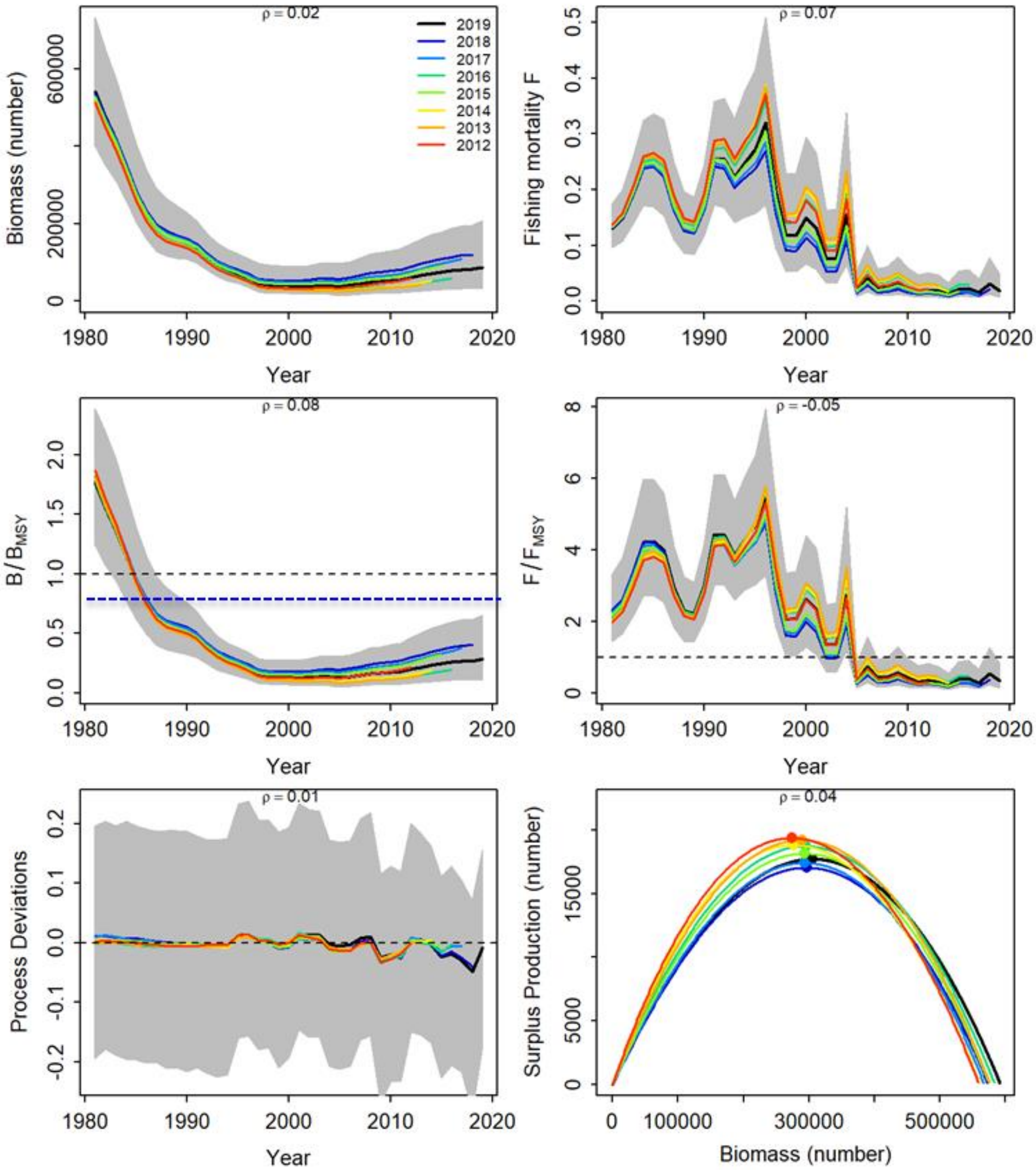


Figure 3.9. Retrospective analysis conducted by removing one year at a time sequentially (n=7) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}, blue dash line is the Minimum Stock Size Threshold ((1-M)B_{MSY}) reference line) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and process deviations and surplus production curve (bottom panels) for the base run.

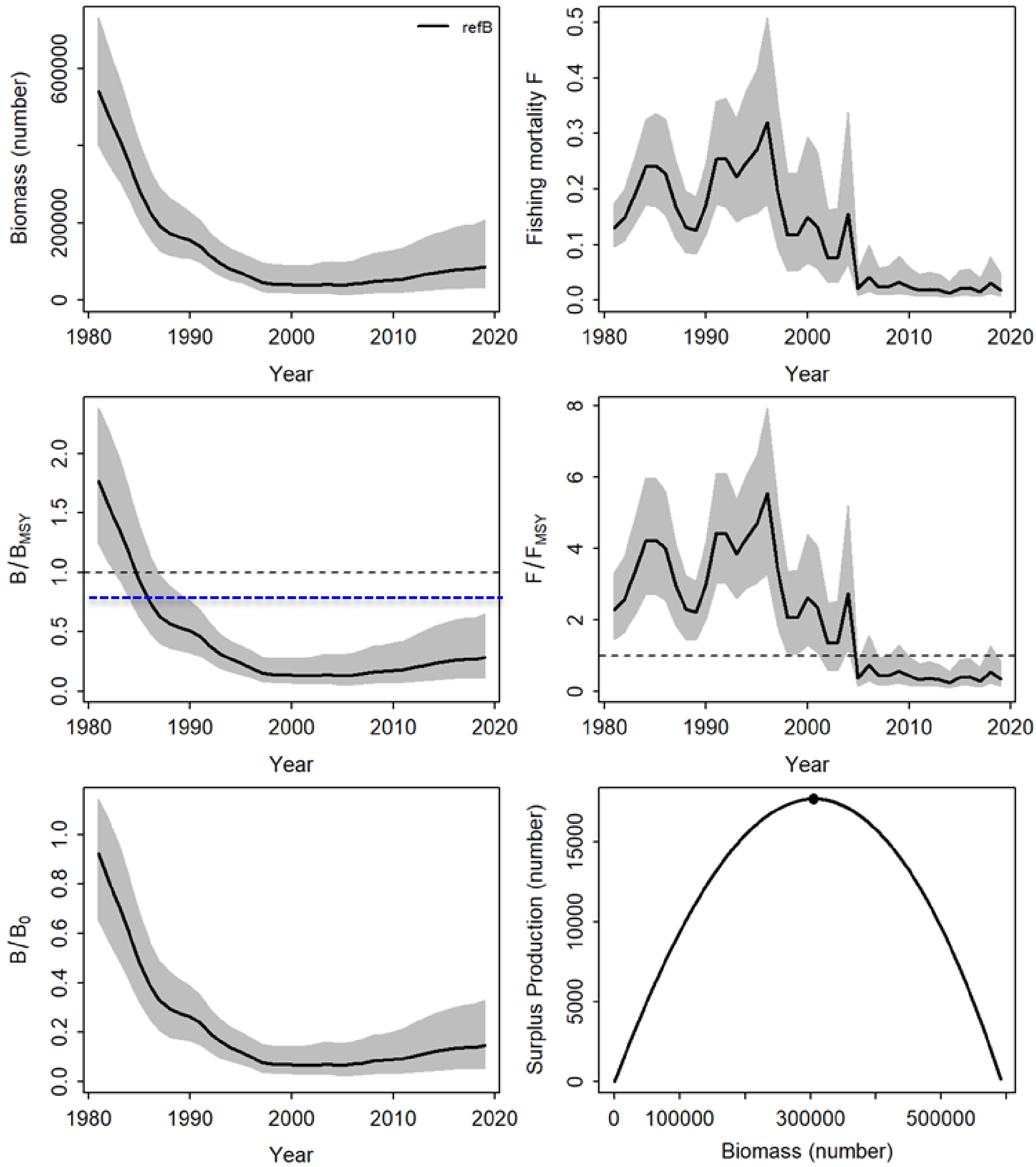


Figure 3.10. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}, blue dash line is the Minimum Stock Size Threshold ((1-M)B_{MSY}) reference line) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to B_0 (B/B_0) and surplus production curve (bottom panels) for the base run.

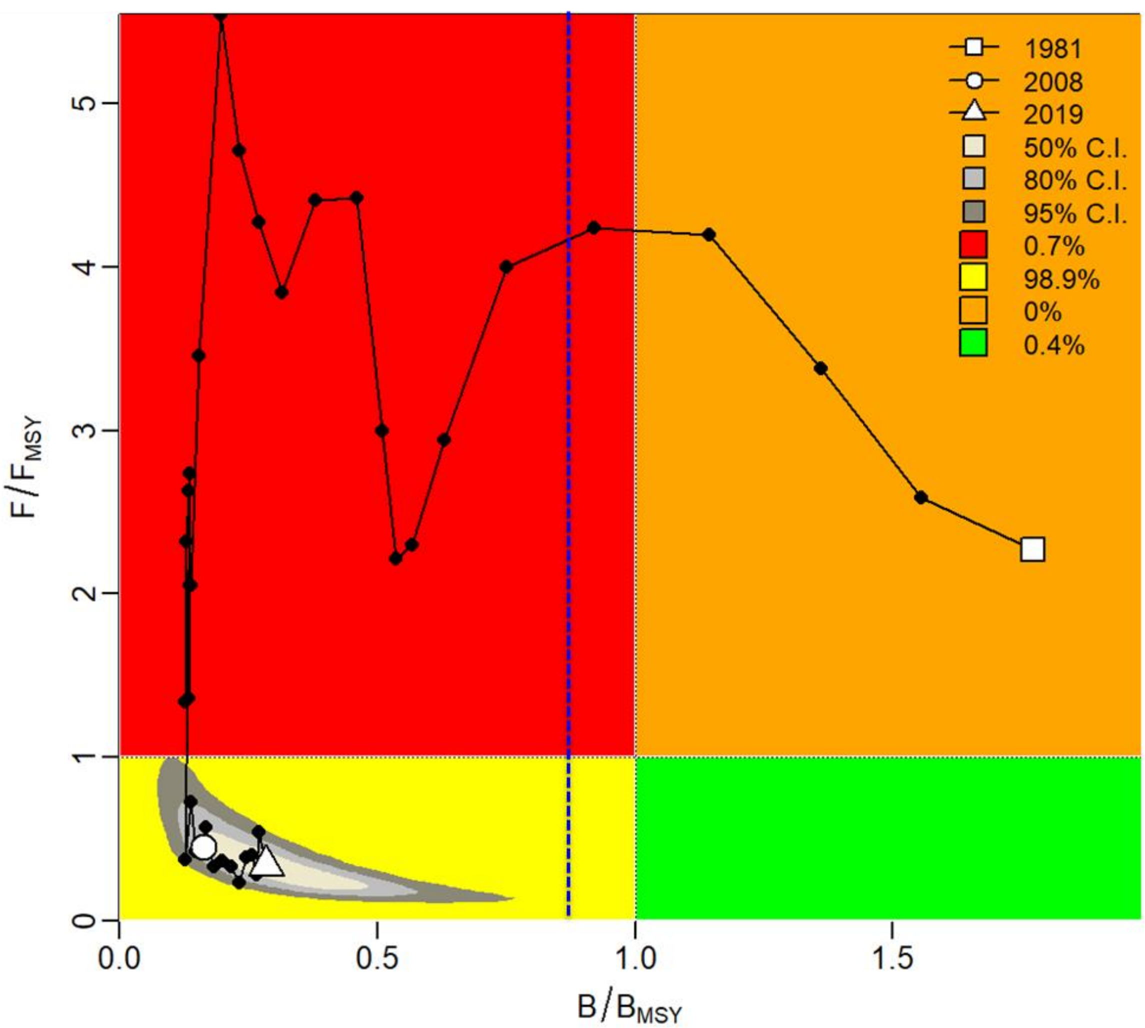


Figure 3.11. Kobe phase plot showing estimated trajectories (1981-2019) of B/B_{MSY} and F/F_{MSY} for the base run. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend. The blue dash line is the Minimum Stock Size Threshold ($(1-M)B_{MSY}$) reference line.

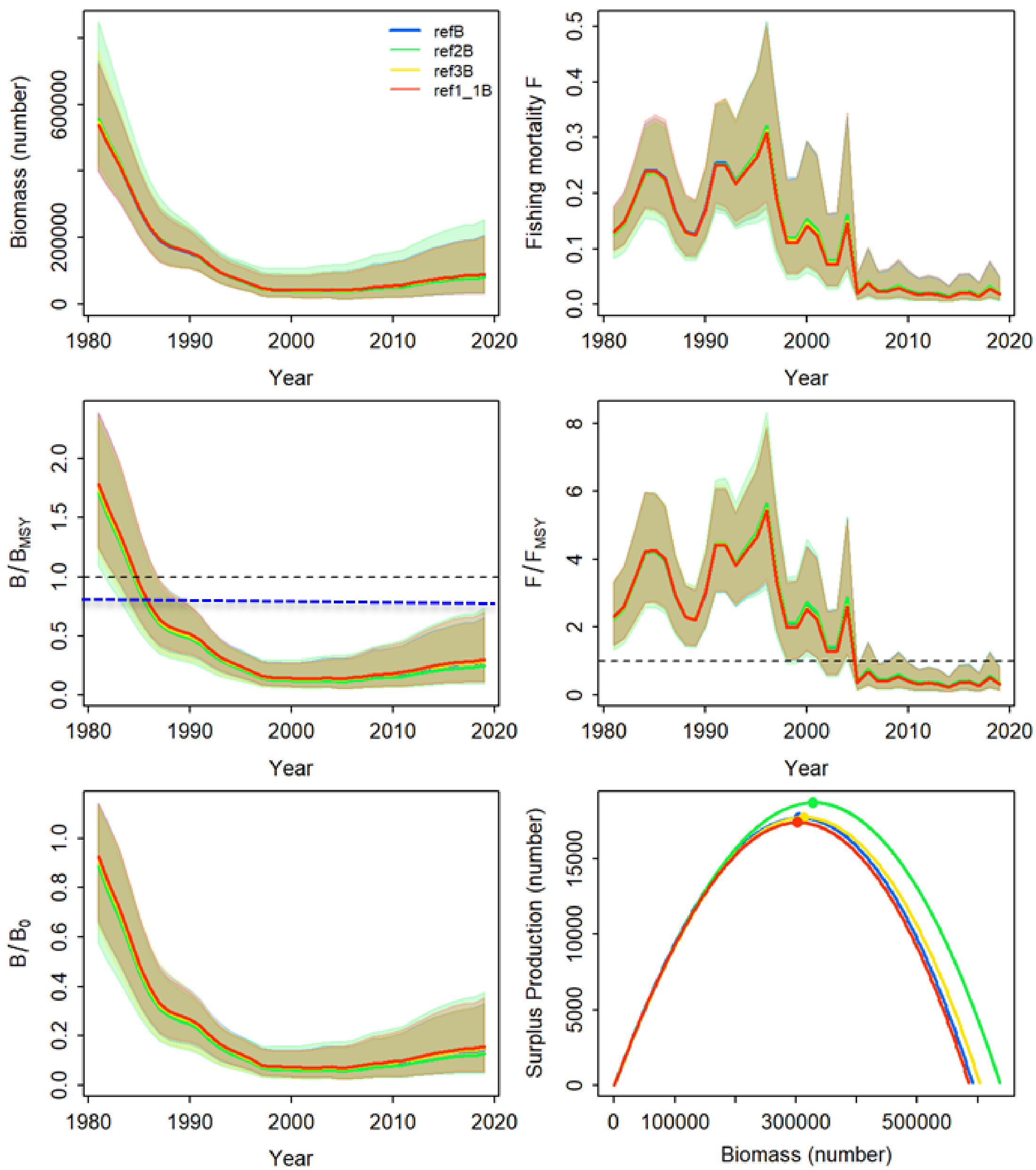


Figure 3.12a. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}, blue dash line is the Minimum Stock Size Threshold ($(1\text{-}M)B_{MSY}$) reference line for the base run) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to B_0 (B/B_0) and surplus production curve (bottom panels) for the base run and the Panel-approved sensitivity runs with various values of *K* priors (see **Section 3.1.8** Uncertainty analysis for a description of each sensitivity run).

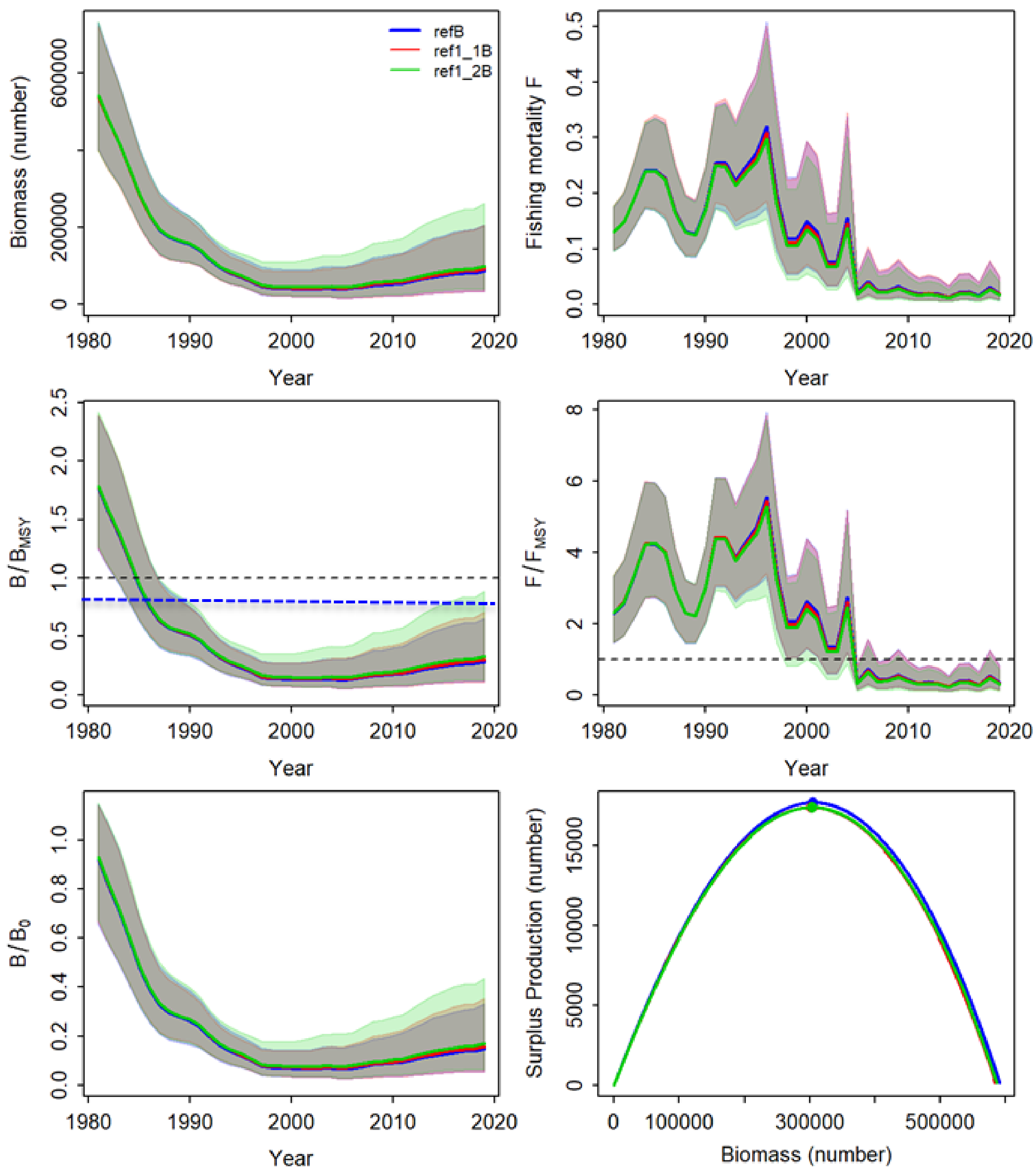


Figure 3.12b. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}, blue dash line is the Minimum Stock Size Threshold ($(1\text{-}M)B_{MSY}$) reference line for the base run) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to B_0 (B/B_0) and surplus production curve (bottom panels) for the base run and the Panel-approved sensitivity runs with a best-guess mean of 6 times the maximum observed catch (505,000) with the base *CV* and a high *CV* values of *K* priors (see **Section 3.1.8** Uncertainty analysis for a description of each sensitivity run).

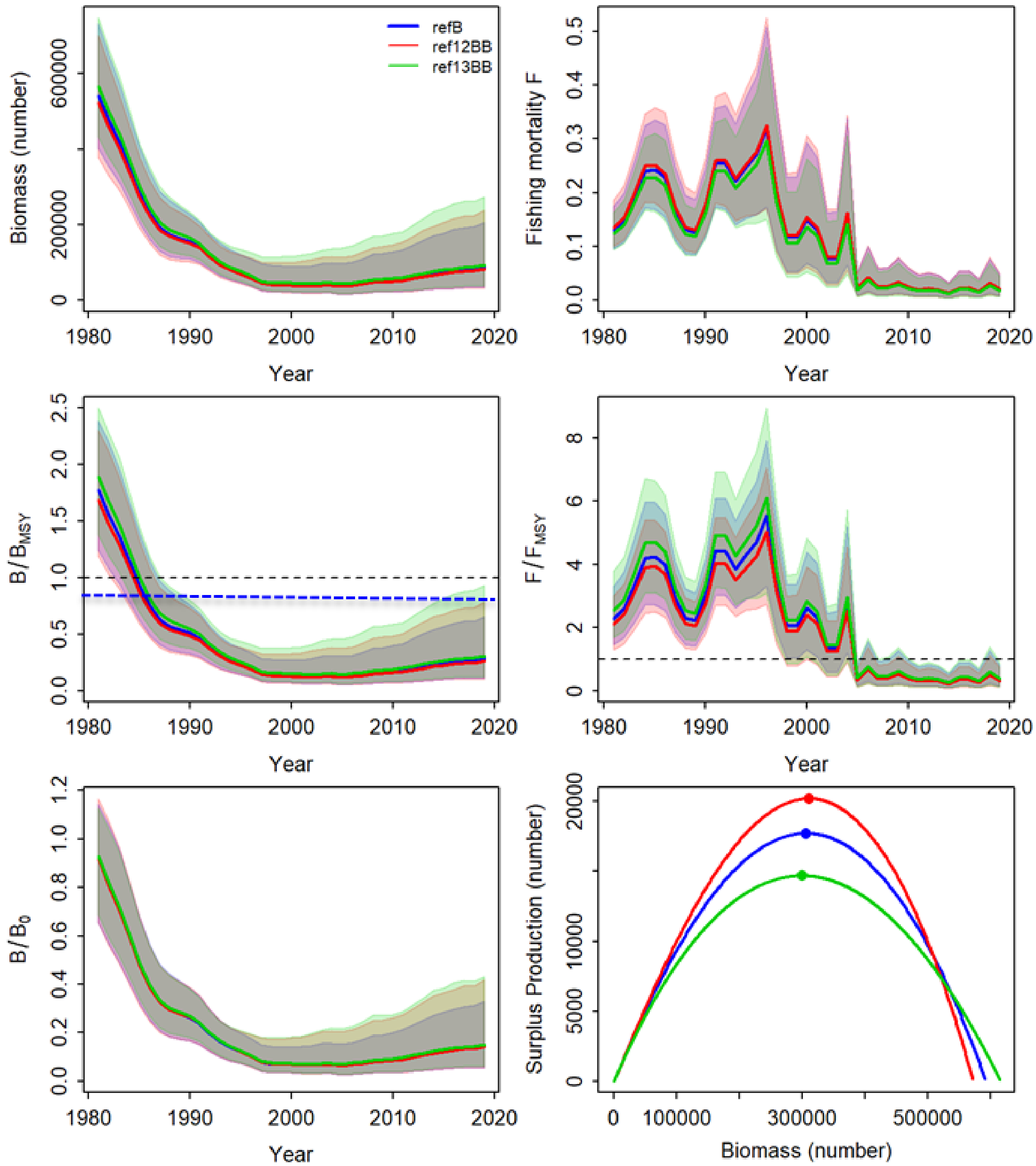


Figure 3.13a. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}, blue dash line is the Minimum Stock Size Threshold ($(1\text{-}M)B_{MSY}$) reference line for the base run) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to B_0 (B/B_0) and surplus production curve (bottom panels) for the base run and the Panel-approved sensitivity runs with high and low mean values of *r* priors (see **Section 3.1.8** Uncertainty analysis for a description of each sensitivity run).

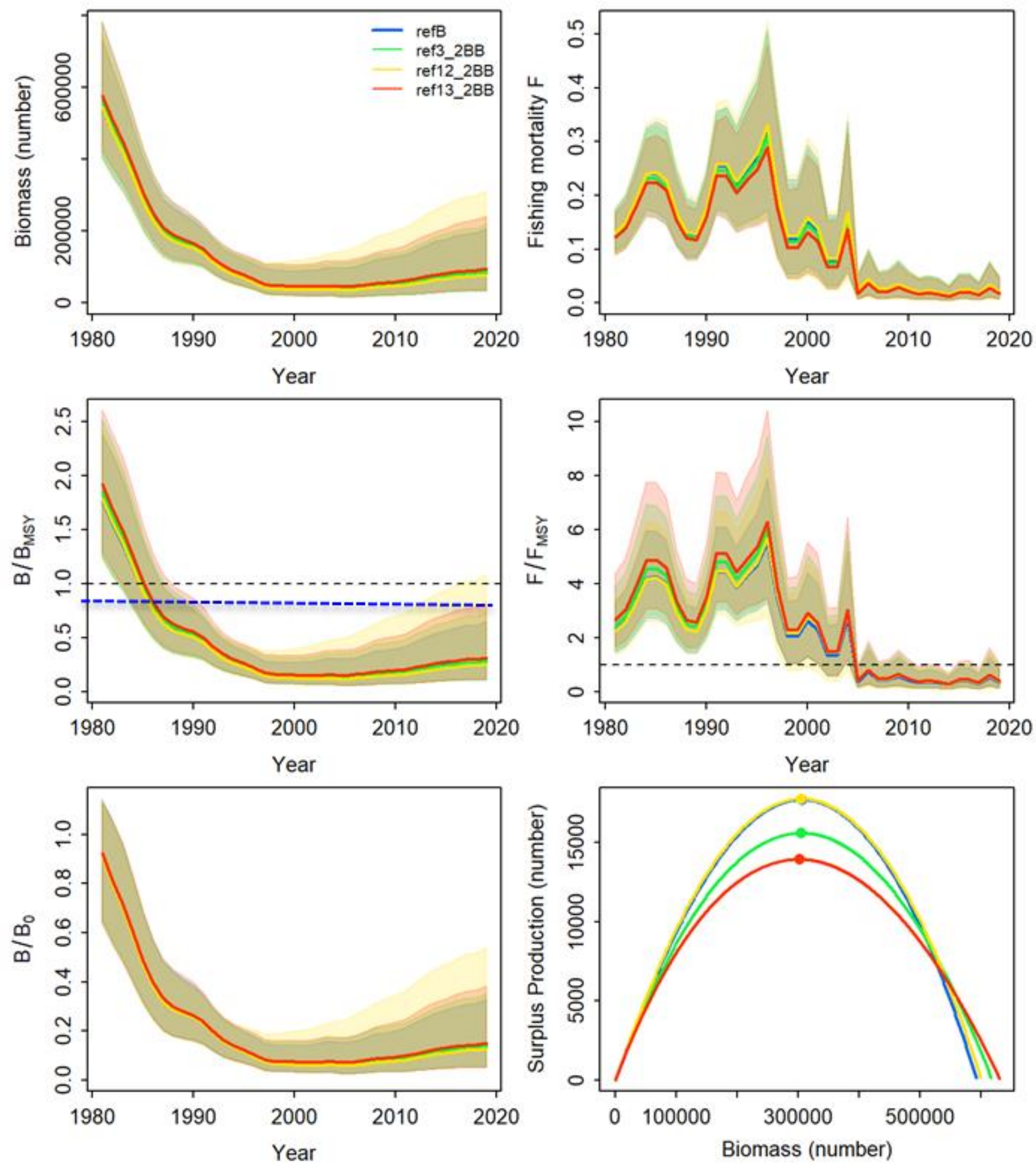


Figure 3.13b. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}, blue dash line is the Minimum Stock Size Threshold ((1-*M*)B_{MSY}) reference line for the base run) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to B_0 (B/B_0) and surplus production curve (bottom panels) for the base run and the Panel-approved sensitivity runs with the base, high and low mean values of *r* priors associated with 2 times the base run *CV* value (see **Section 3.1.8** Uncertainty analysis for a description of each sensitivity run).

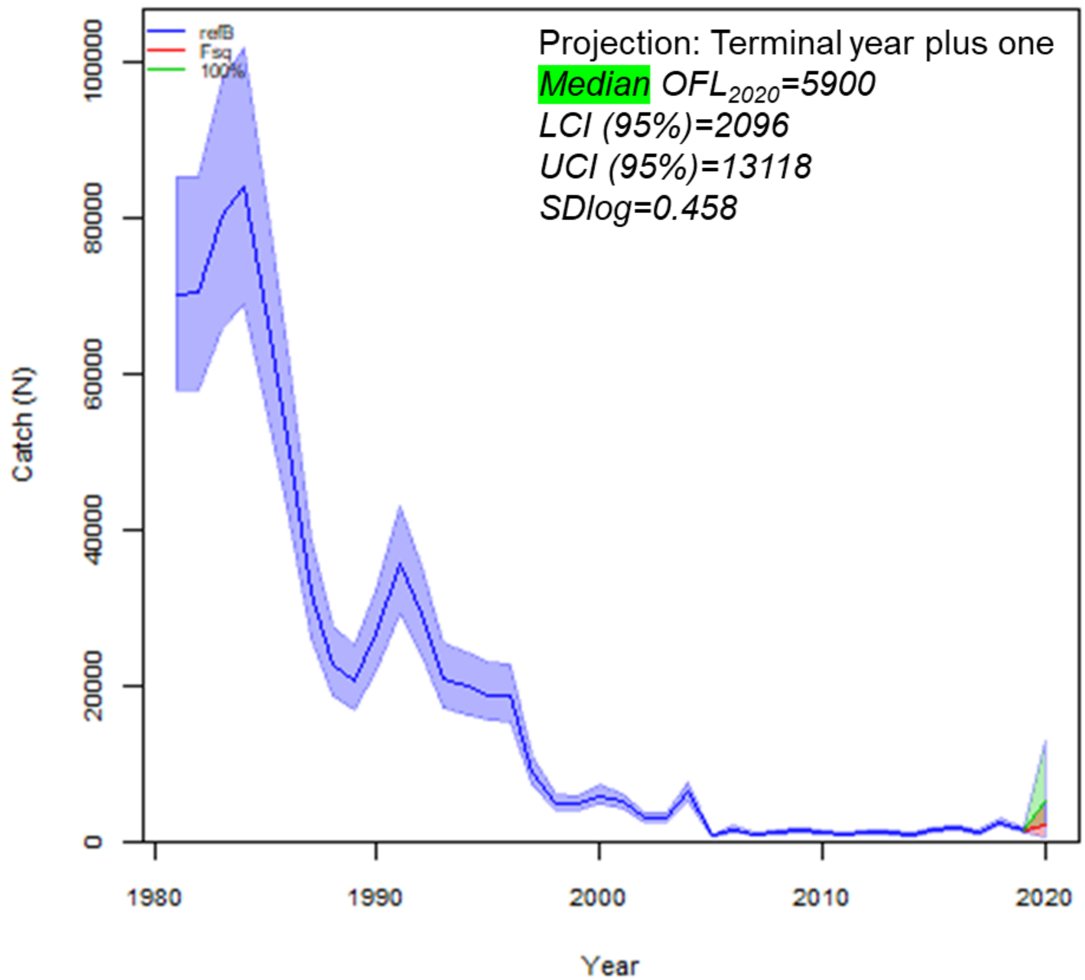


Figure 3.14. Stock trajectories and OFL_{2020} (i.e. catch in 2020 that corresponds to the estimate of 100% F_{MSY} applied to the stock biomass in 2020) and catch in 2020 that corresponds to the mean of the last 3-year fishing mortality (F_{sq}) applied to the stock biomass in 2020 estimated with the terminal year plus one projection in JABBA for the base run.

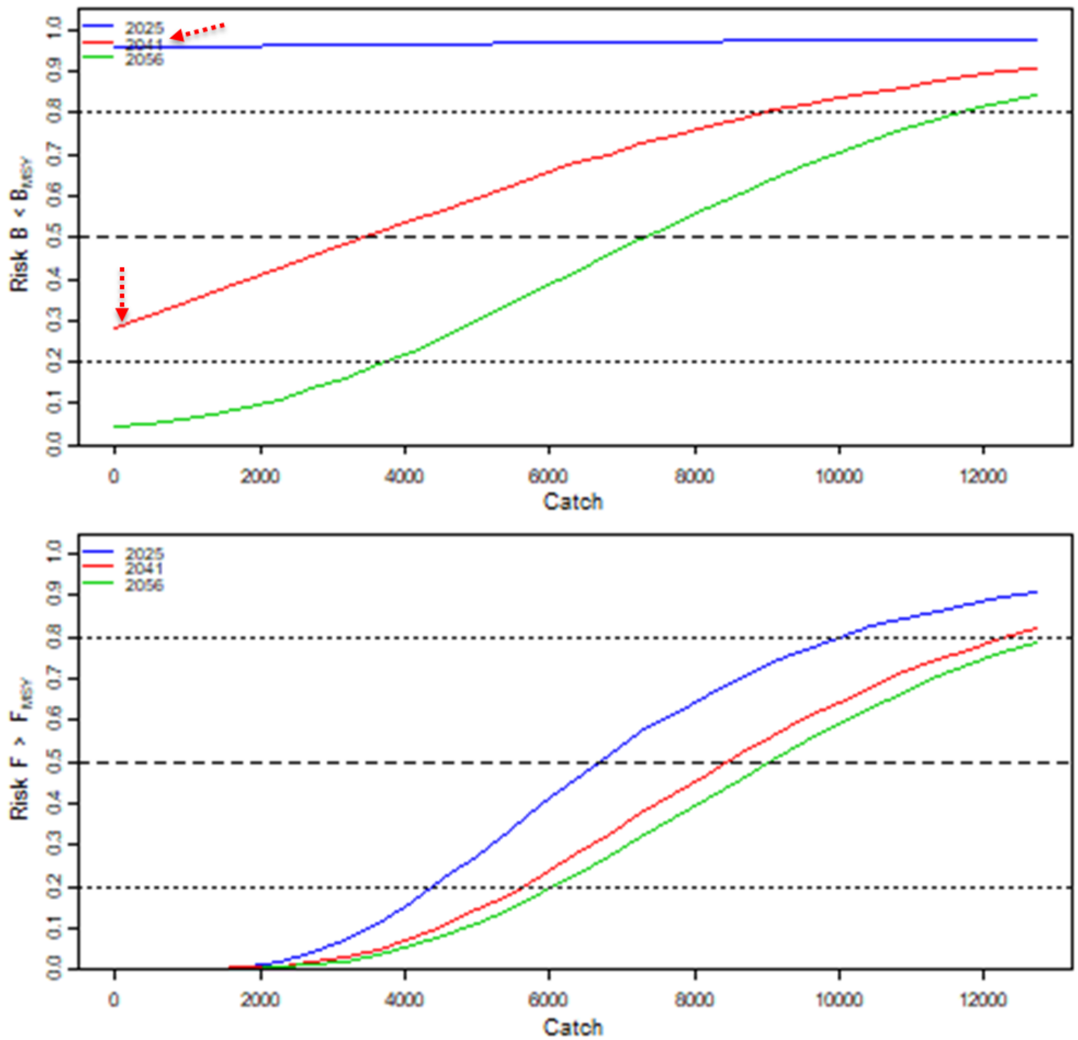


Figure 3.15. Risk of great hammerheads falling below B_{MSY} and rising above F_{MSY} for projections years 2025, 2041 and 2056 for the base run. Year in which F=0 results in a 70% probability of rebuilding (red arrows in the upper panel) (Year $F=0_{p70}$) is 2041. For Year $F=0_{p70}$ > 10 years, target rebuilding year ($Year_{rebuild}$) is 2056 (2041 plus one generation time). The lower panel shows the risk of rising above F_{MSY} with various fixed levels of catch (7264 sharks yr^{-1}) for projections years 2025, 2041 and 2056 for the base run.

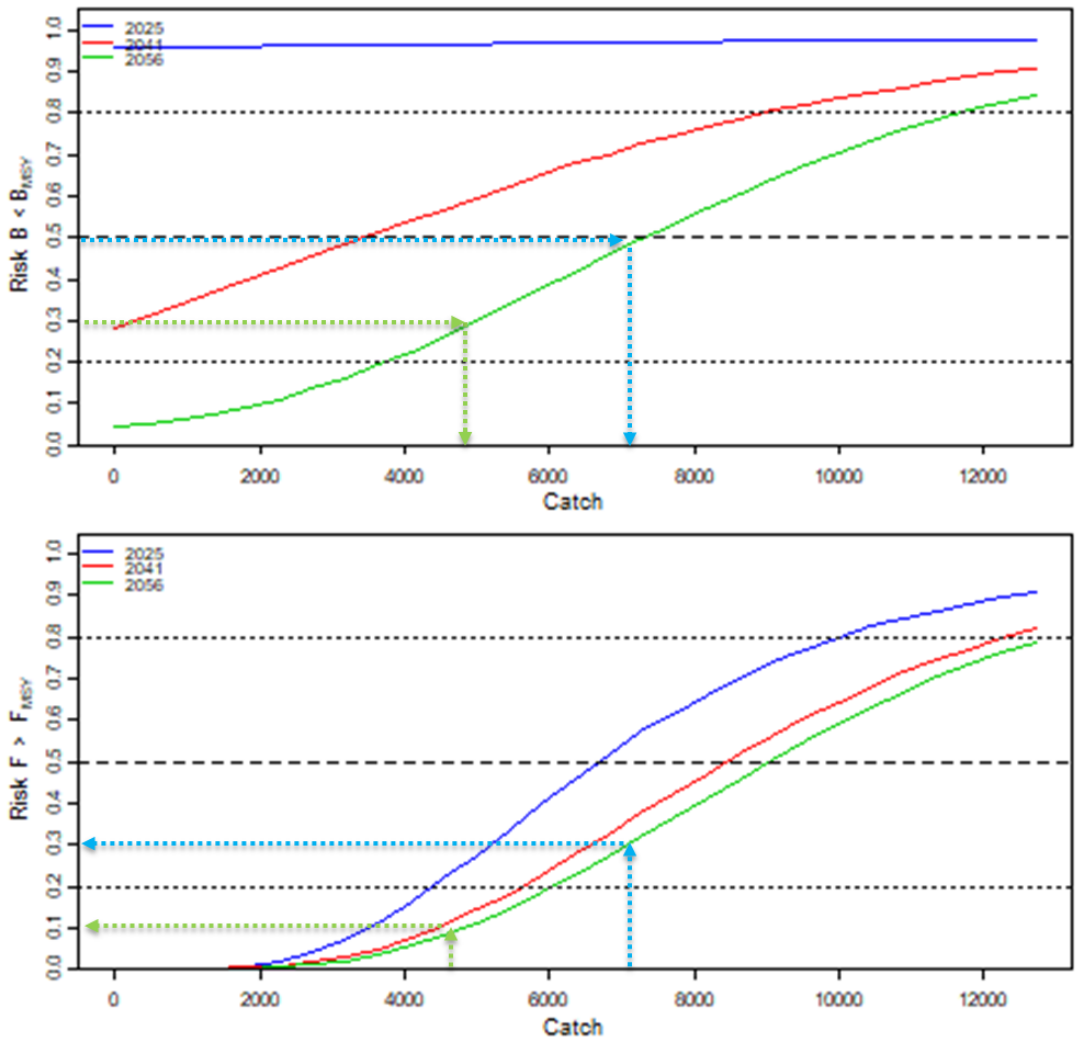


Figure 3.16. Catch-based projections for years 2025, 2041 and 2056 ($Year_{rebuild}$) for the base run. A fixed level of catch (7264 sharks yr^{-1}) allows rebuilding of the stock with 50% probability by $Year_{rebuild}$ ($B < B_{MSY} < 50\%$, blue arrows on upper panel). A fixed level of catch (4994 sharks yr^{-1}) allows rebuilding of stock with 70% probability by $Year_{rebuild}$ ($B < B_{MSY} < 30\%$, green arrows on the upper panel). The lower panel shows the risk of rising above F_{MSY} with the fixed level of catch (7264 sharks yr^{-1}) and fixed level of catch (4994 sharks yr^{-1}) for the base run.

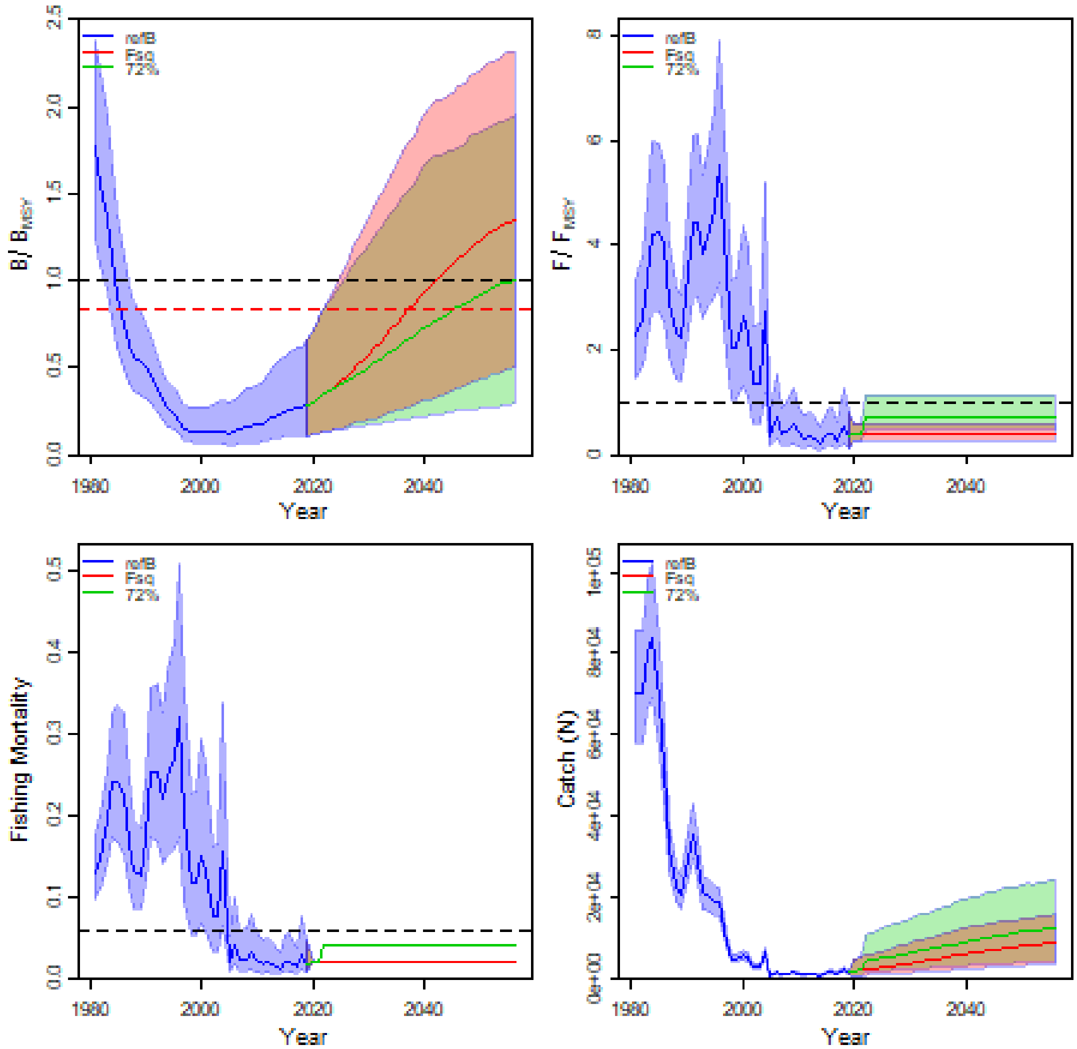


Figure 3.17. *F*-based projections for Year$_{rebuild}$ (2056) under the mean of the last 3-year fishing mortality (F_{sq}) and 72% F_{MSY} for the base run. Trends in biomass relative to B_{MSY} (B/B_{MSY}, red dash line is the Minimum Stock Size Threshold ((1-M)B_{MSY}) reference line) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (upper panels) and fishing mortality and catch (lower panels). A fixed level of F (72% F_{MSY}=0.042 yr^{-1}) allows rebuilding of the stock with 50% probability by Year$_{rebuild}$ (upper left panel). Trajectories of F/F_{MSY}, fishing mortality, and catch were provided here for completeness.

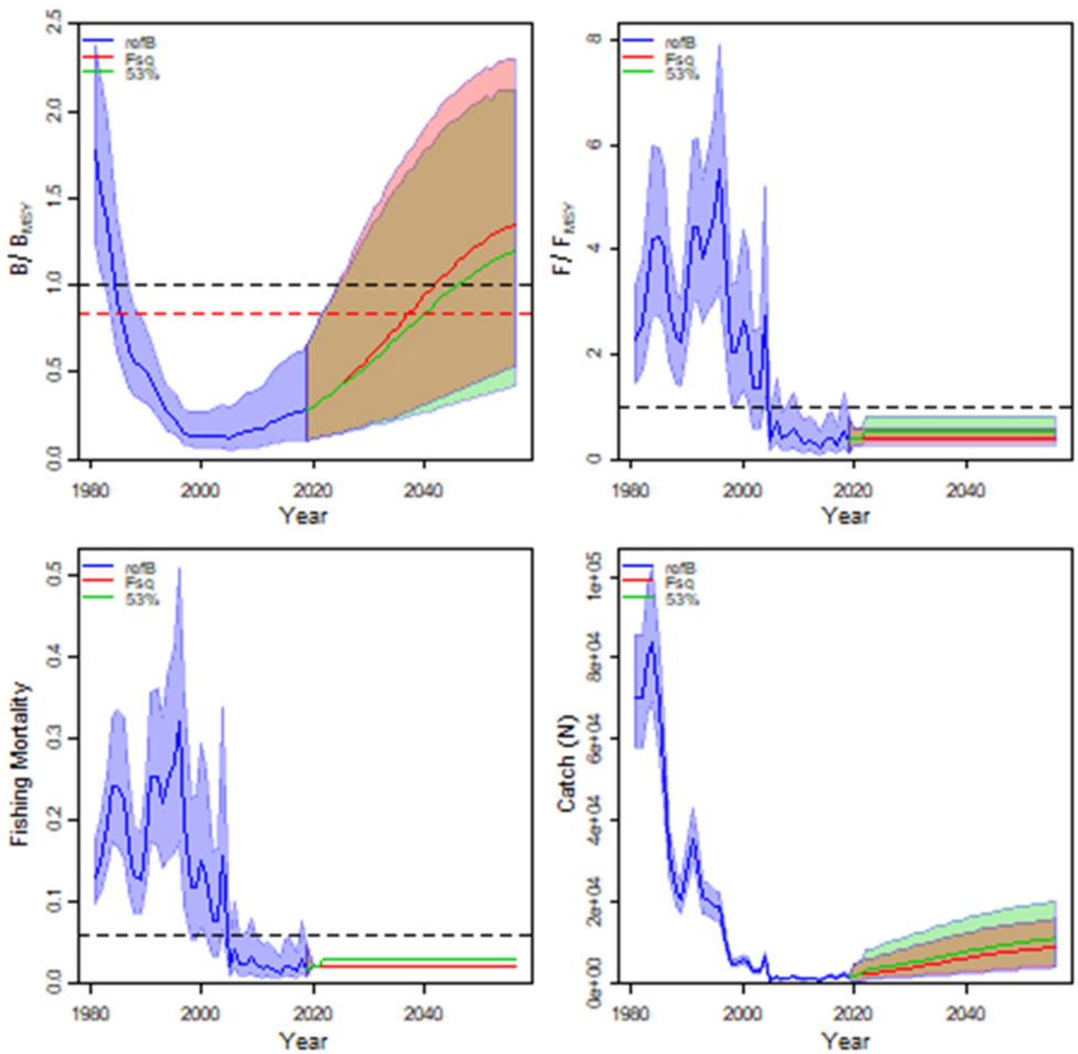


Figure 3.18. *F*-based projections for $\text{Year}_{\text{rebuild}}$ (2056) under the mean of the last 3-year fishing mortality (F_{sq}) and 53% F_{MSY} for the base run. Trends in biomass relative to B_{MSY} (B/B_{MSY}, red dash line is the Minimum Stock Size Threshold ($(1\text{-}M)B_{MSY}$) reference line) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (upper panels) and fishing mortality and catch (lower panels). A fixed level of *F* (53% F_{MSY}=0.031 yr^{-1}) allows rebuilding of the stock with 70% probability by $\text{Year}_{\text{rebuild}}$. Trajectories of F/F_{MSY}, fishing mortality, and catch were provided here for completeness.

3.8 APPENDICES

Appendices 3.9.1 to **3.9.9** include additional plots for each of the Panel-approved nine sensitivity runs in the following order:

1) ref2B (400xC_{MAX}, CV=2)

2) ref3B (40xC_{MAX}, CV=2)

3) ref1_1B (6xC_{MAX}, CV=2)

4) ref1_2B (6xC_{MAX}, CV=200)

5) ref12BB (High r)

6) ref13BB (Low r)

7) ref3_2BB (High CV)

8) ref12_2BB (High r & High CV)

9) ref13_2BB (Low r & High CV)

Appendix 3.9.1: Plots for the Panel-approved 1) ref2B (400xCMAX, *CV*=2) sensitivity run.

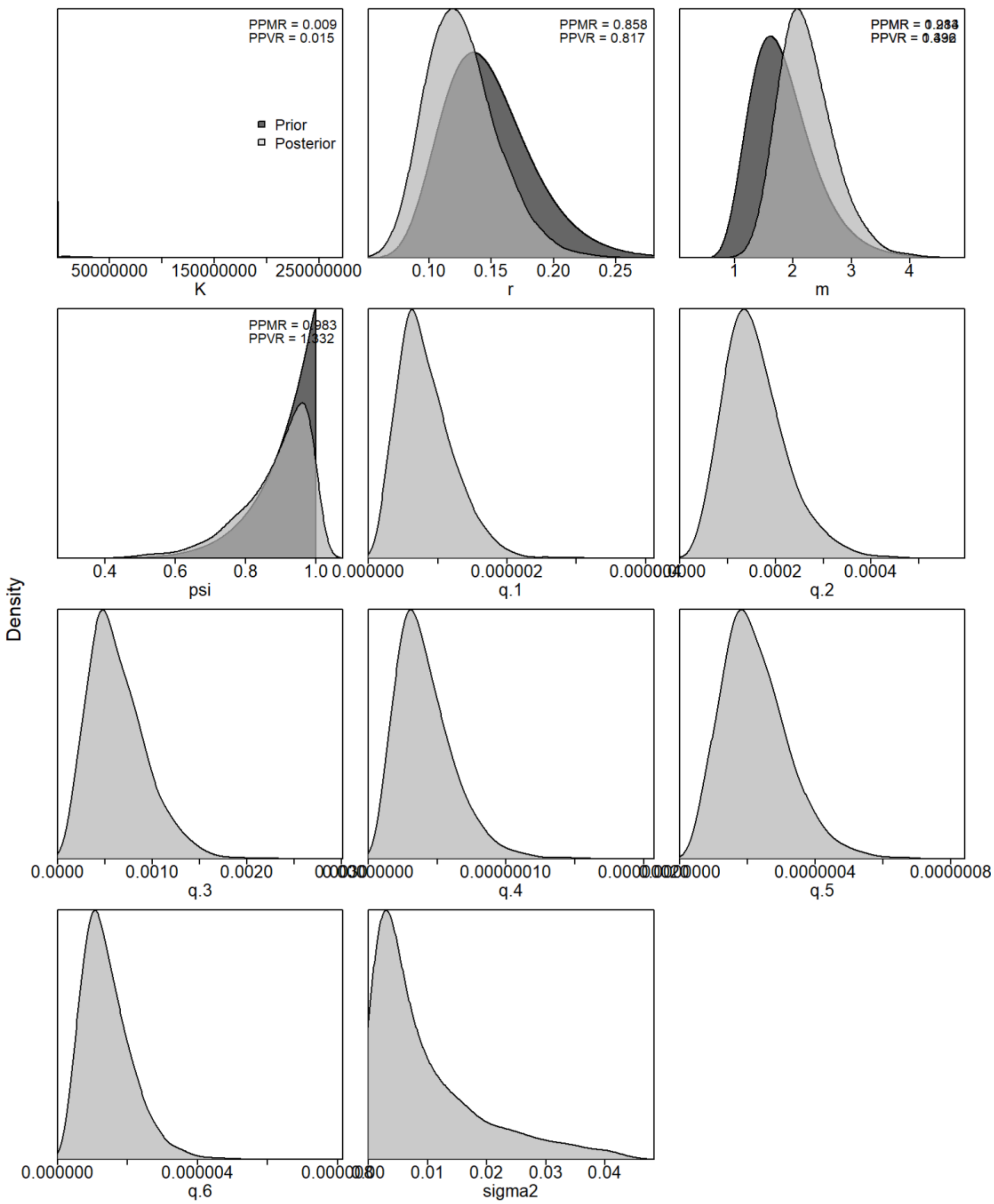


Figure 3.9.1.1. Prior and posterior distribution of various model parameters. *PPRM*: Posterior to Prior Ratio of Medians; *PPRV*: Posterior to Prior Ratio of Variances.

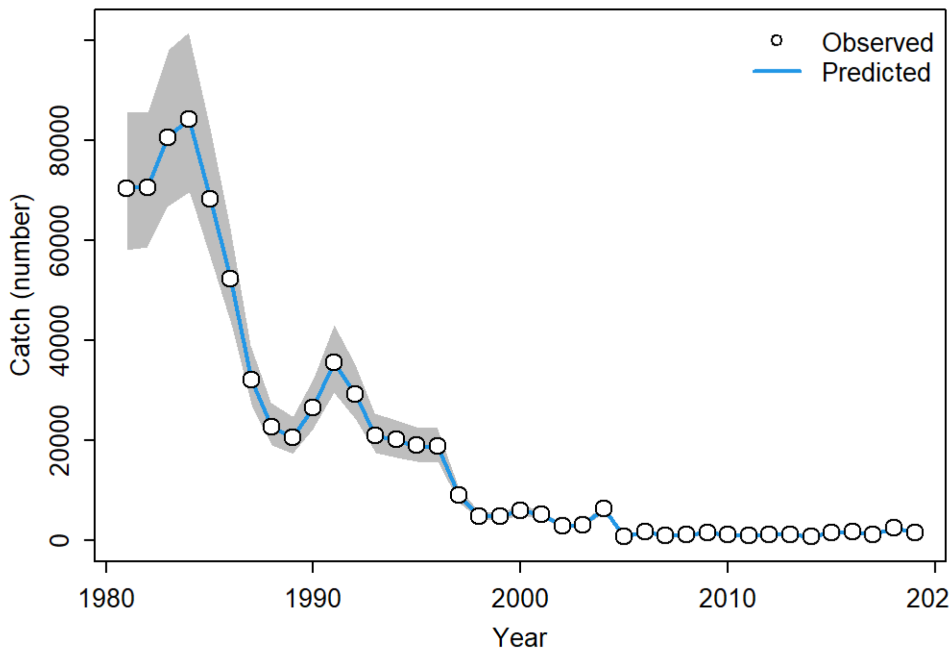


Figure 3.9.1.2. Catches of great hammerheads in numbers (1981-2019).

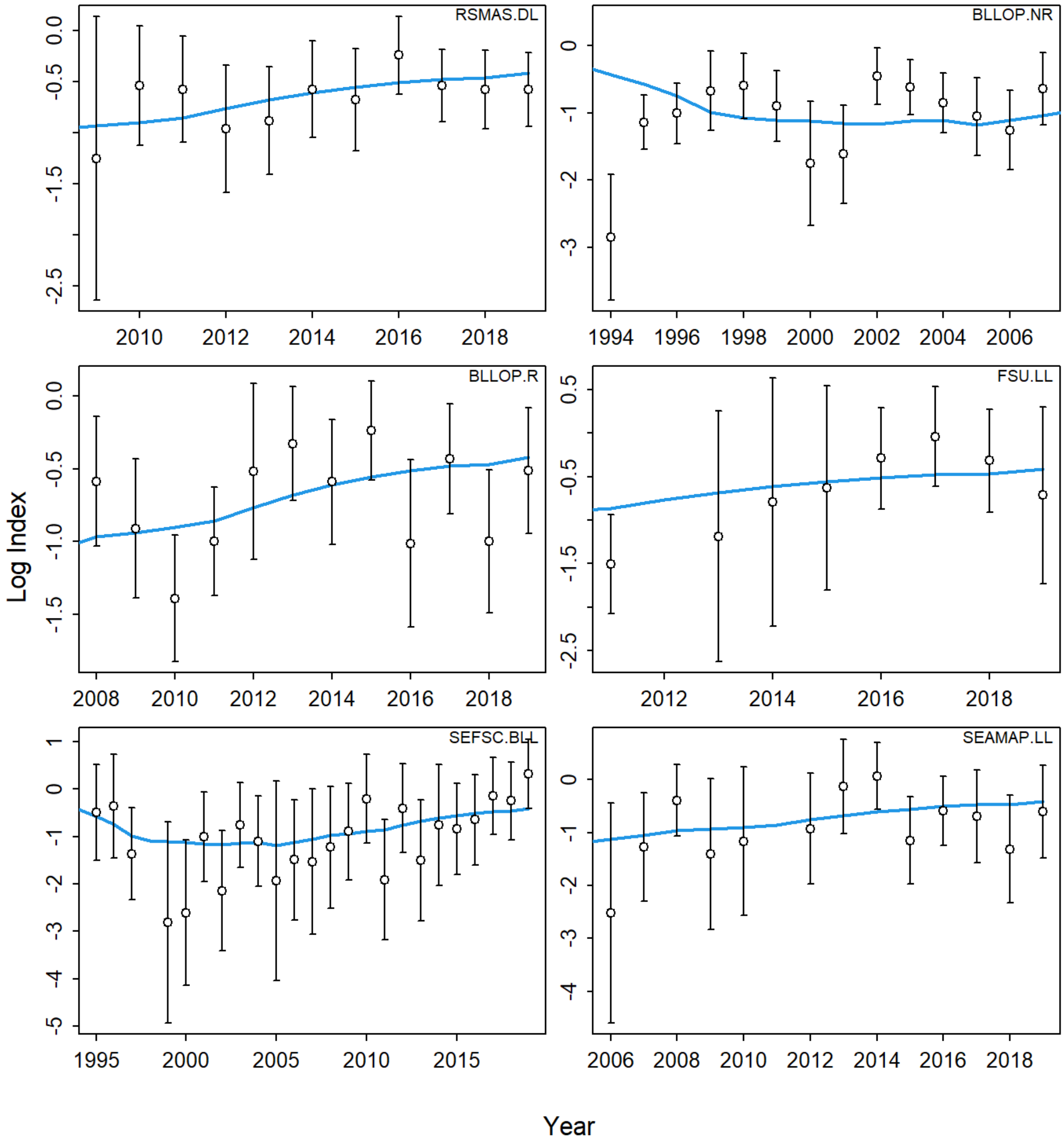


Figure 3.9.1.3. JABBA fits to the standardized catch-per-unit-effort (CPUE) (in log scale) data sets from the six indices of abundance. The solid line is the model predicted value and the circles are observed data values. Vertical lines represent the estimated 95% confidence intervals around the CPUE values.

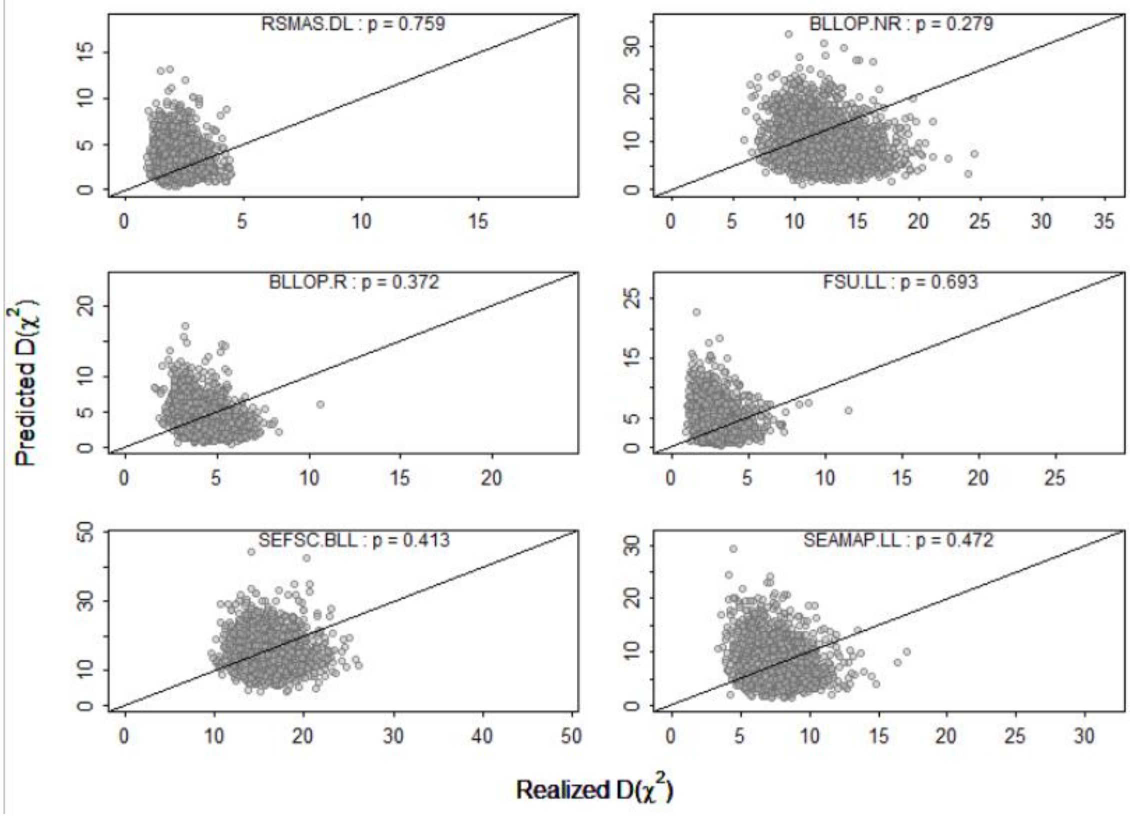


Figure 3.9.1.4. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of each of the six indices of abundance in the base run. A general rule of thumb is that $\rho = 0.5$ is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive checks test if the model error assumptions are consistent with the underlying data generation process.

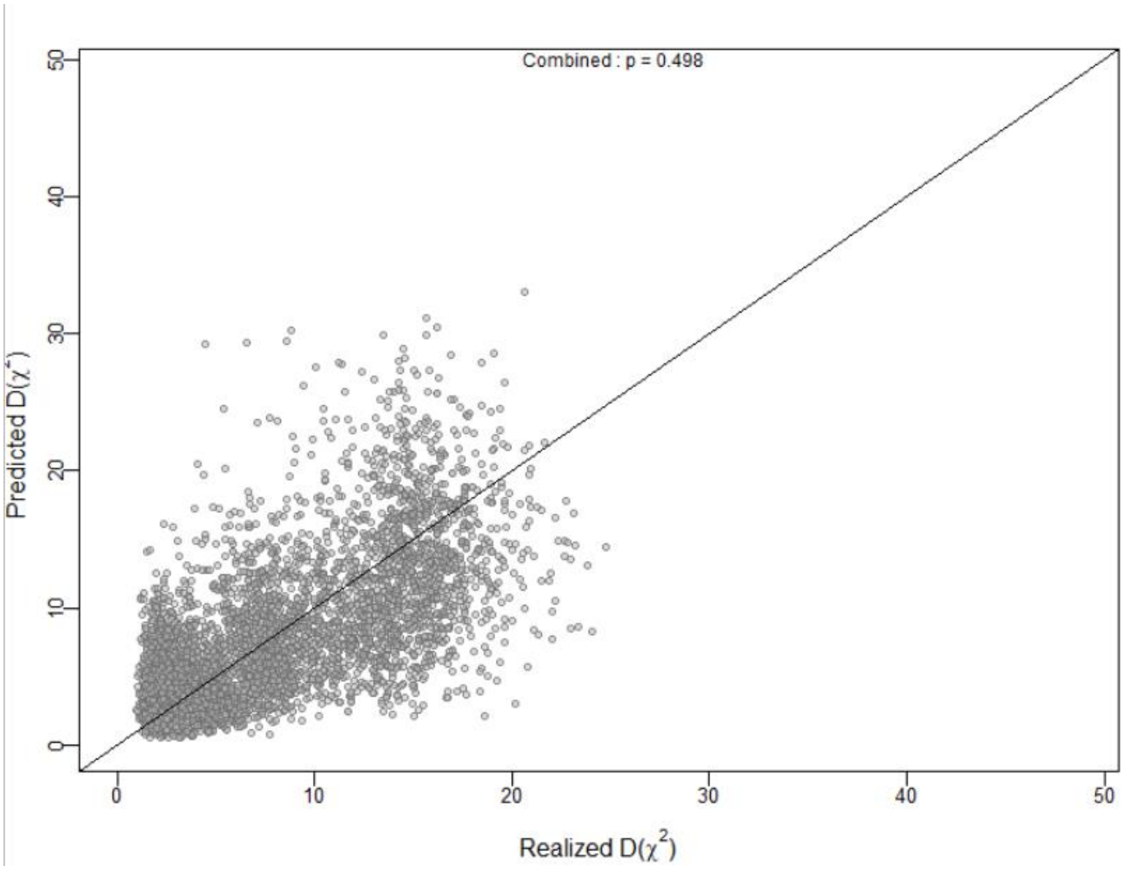


Figure 3.9.1.5. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of the combined CPUE for the base run. A general rule of thumb is that ρ = 0.5 is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

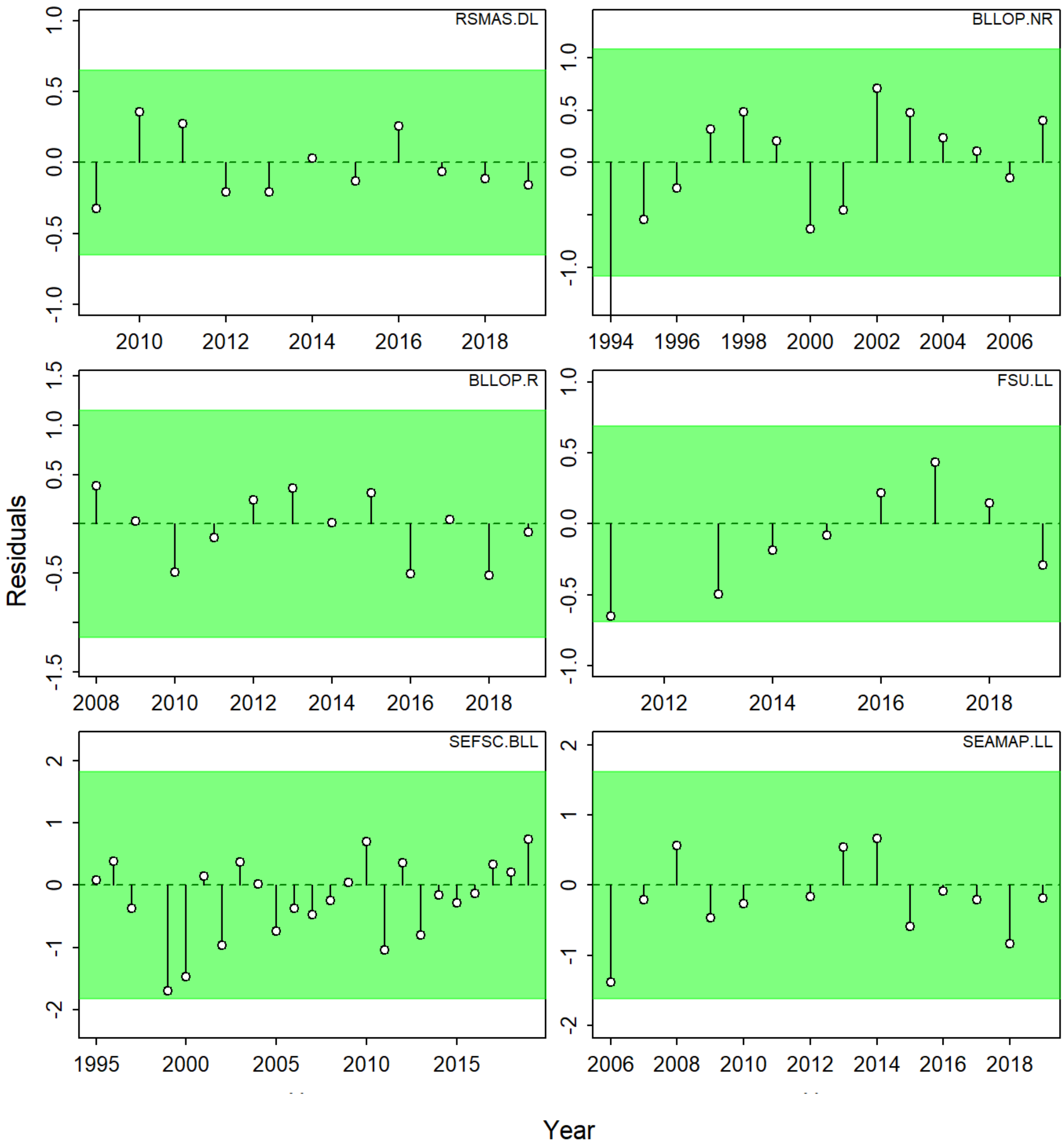


Figure 3.9.1.6. Runs test to quantitatively evaluate the randomness of the time series of CPUE residuals for each of the six indices of abundance. Green panels indicate no evidence of lack of randomness of time-series residuals (p>0.05) while red panels indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

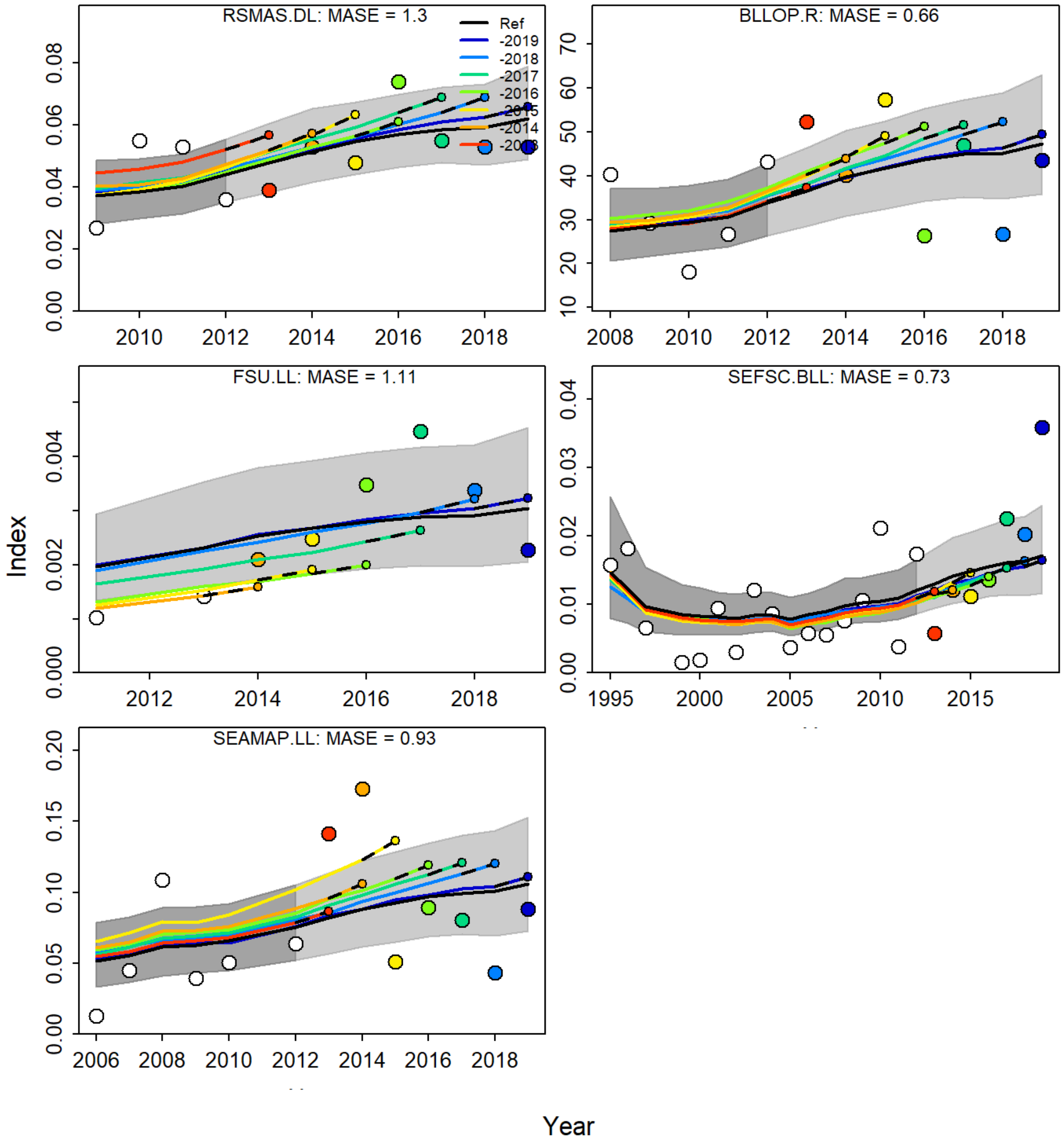


Figure 3.9.1.7. Hindcasting cross-validation results (HCxval), showing one-year-ahead forecasts of CPUE values, performed with seven hindcast model runs relative to the expected CPUE. The CPUE observations, used for cross-validation, are highlighted as color-coded solid circles with associated light-grey shaded 95% confidence interval. The model reference year refers to the end points of each one-year-ahead forecast and the corresponding observation (i.e. year of peel + 1). The joint *MASE* value is 0.88.

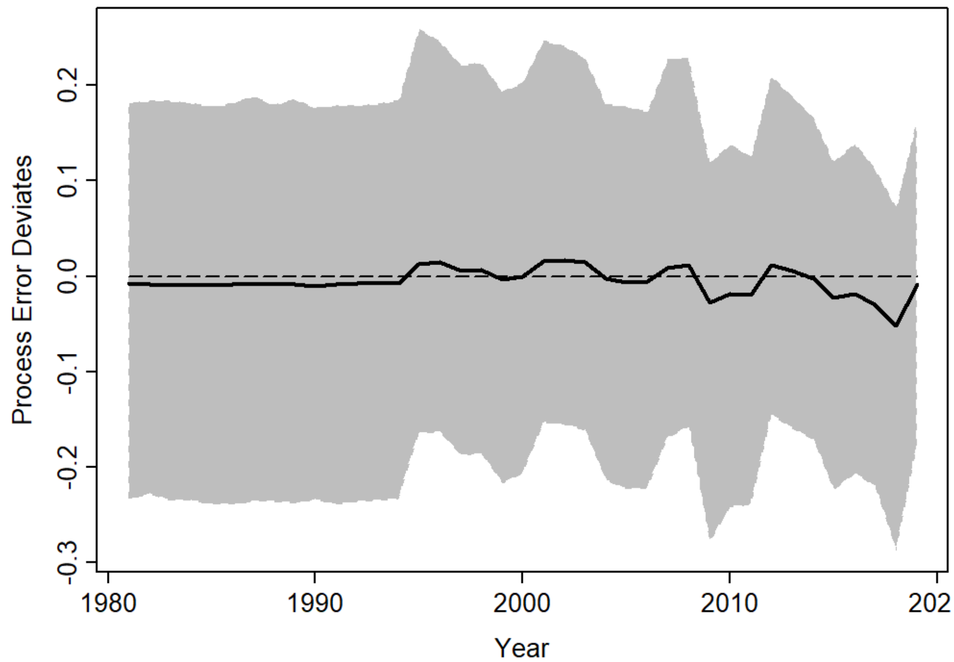


Figure 3.9.1.8. Process error deviates (median: solid line) with shaded grey area indicating 95% credibility intervals.

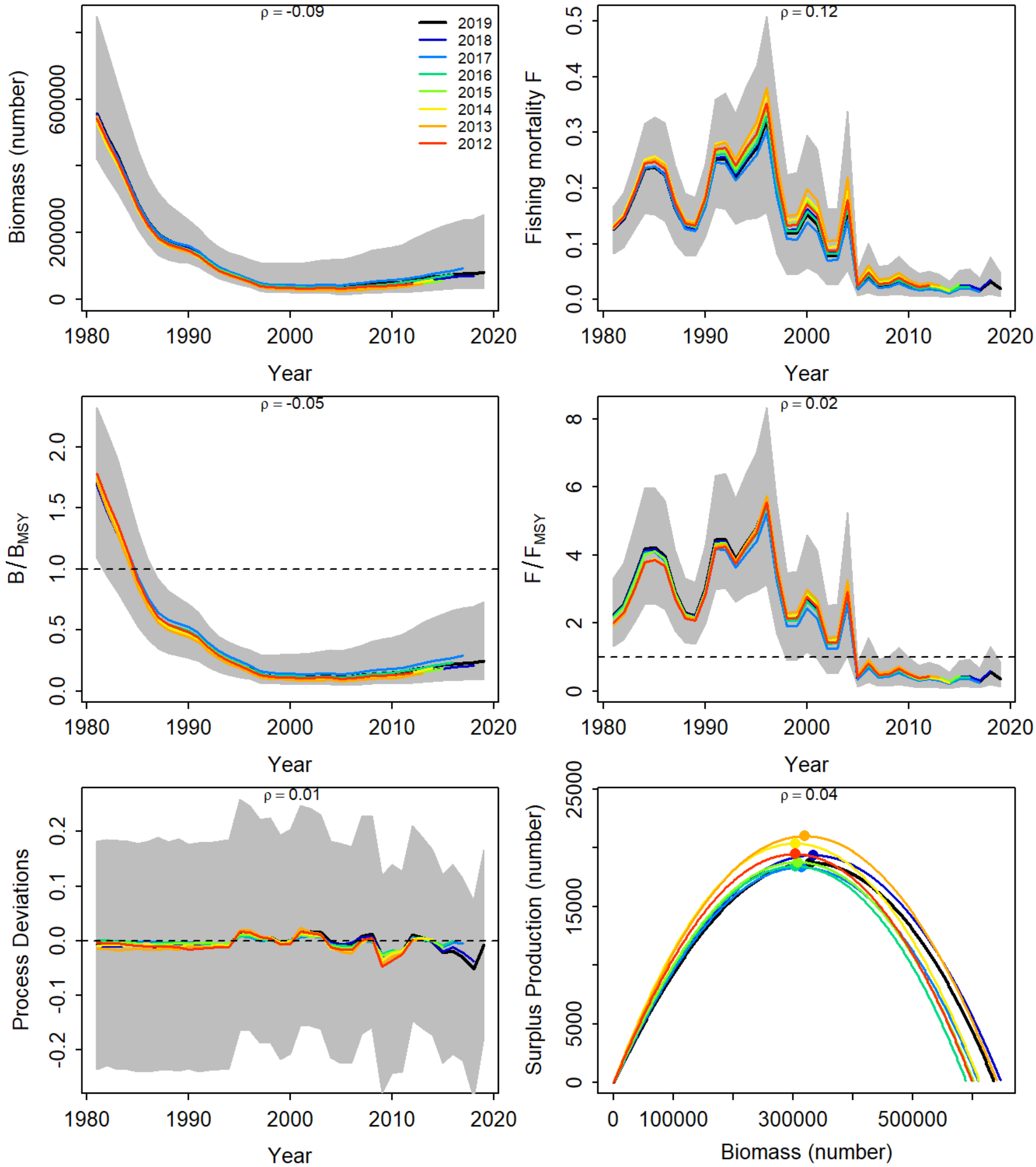


Figure 3.9.1.9. Retrospective analysis conducted by removing one year at a time sequentially (n=7) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and process deviations and surplus production curve (bottom panels).

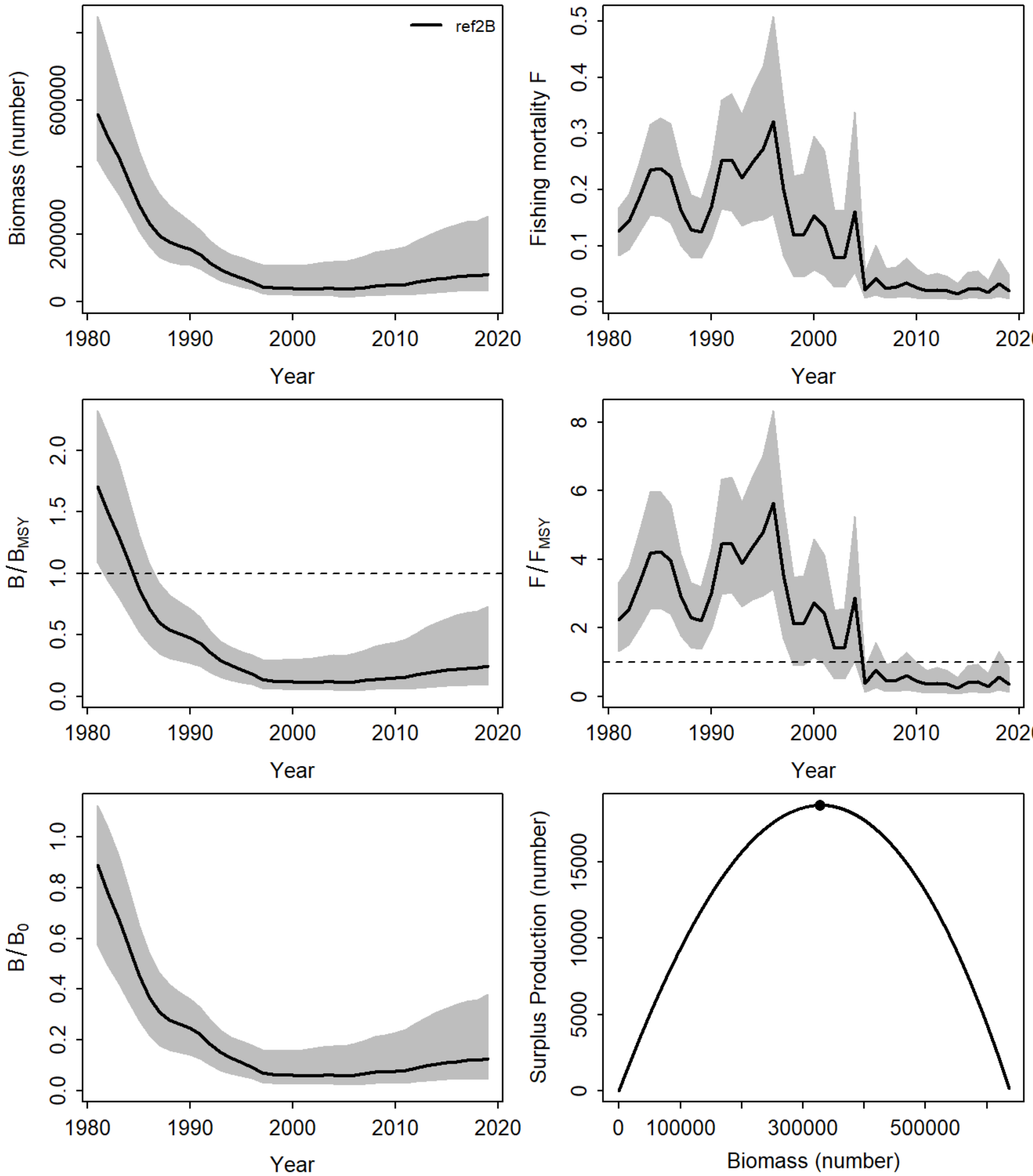


Figure 3.9.1.10. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to B_0 (B/B_0) and surplus production curve (bottom panels).

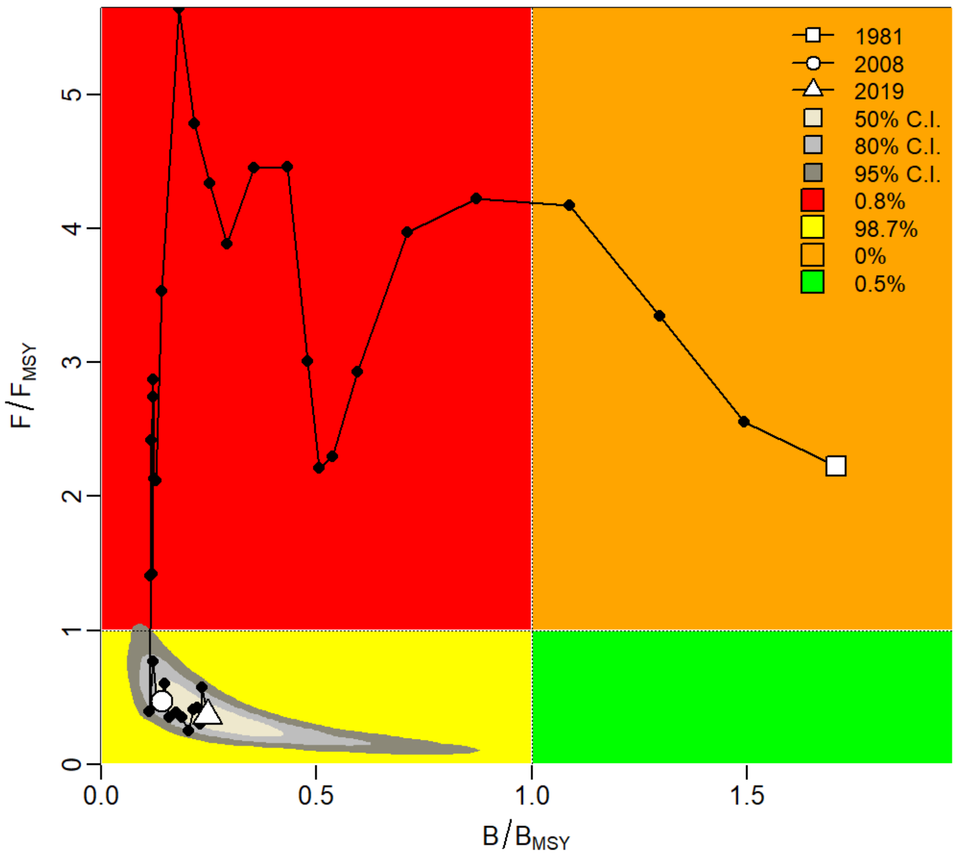


Figure 3.9.1.11. Kobe phase plot showing estimated trajectories (1981-2019) of B/B_{MSY} and F/F_{MSY}. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend.

Appendix 3.9.2: Plots for the Panel-approved 2) ref3B (40xC_{MAX}, *CV*=2) sensitivity run.

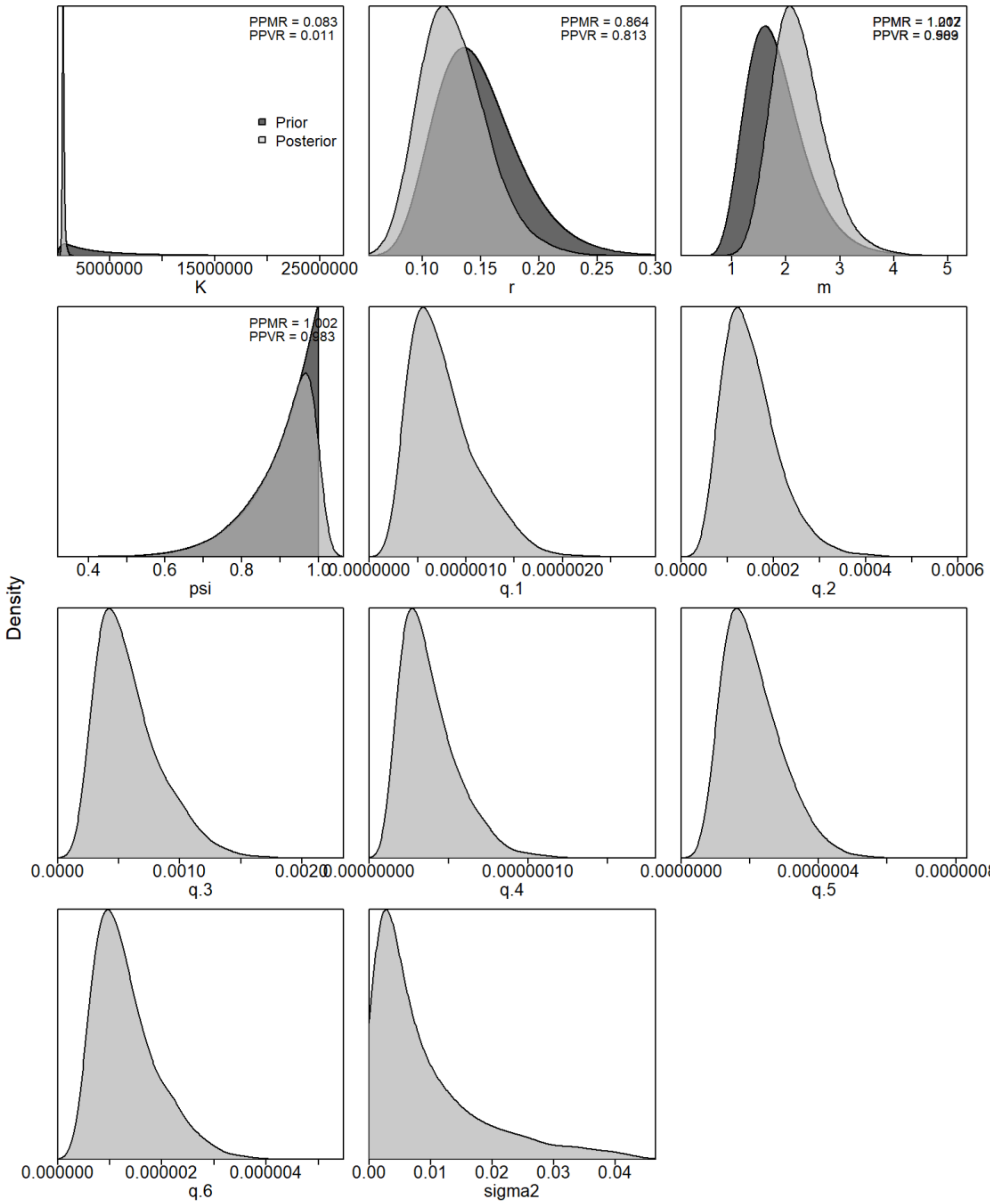


Figure 3.9.2.1. Prior and posterior distribution of various model and management parameters. *PPRM*: Posterior to Prior Ratio of Medians; *PPRV*: Posterior to Prior Ratio of Variances.

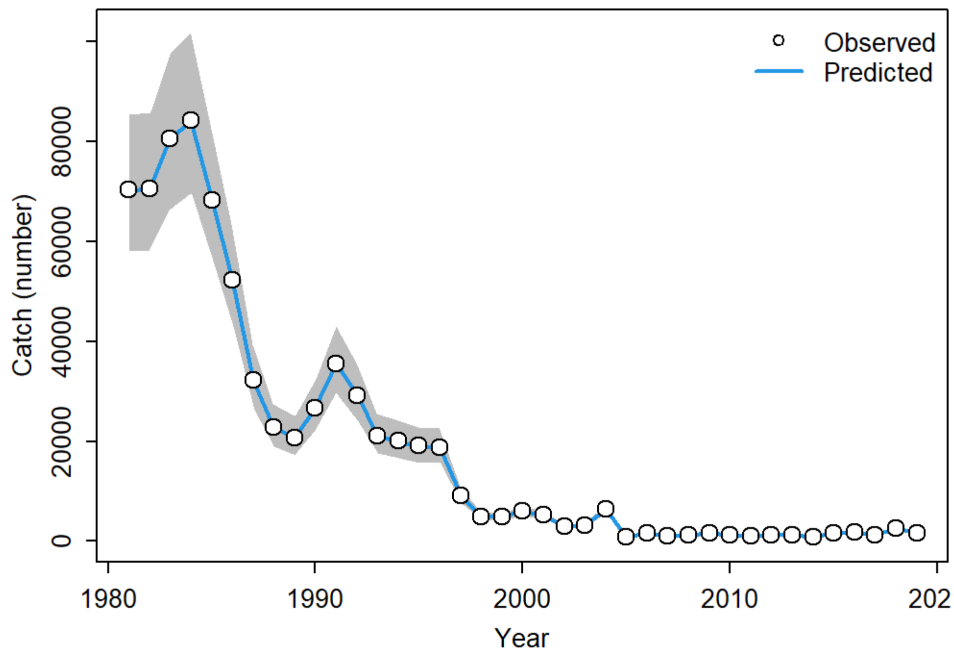


Figure 3.9.2.2. Catches of great hammerheads in numbers (1981-2019).

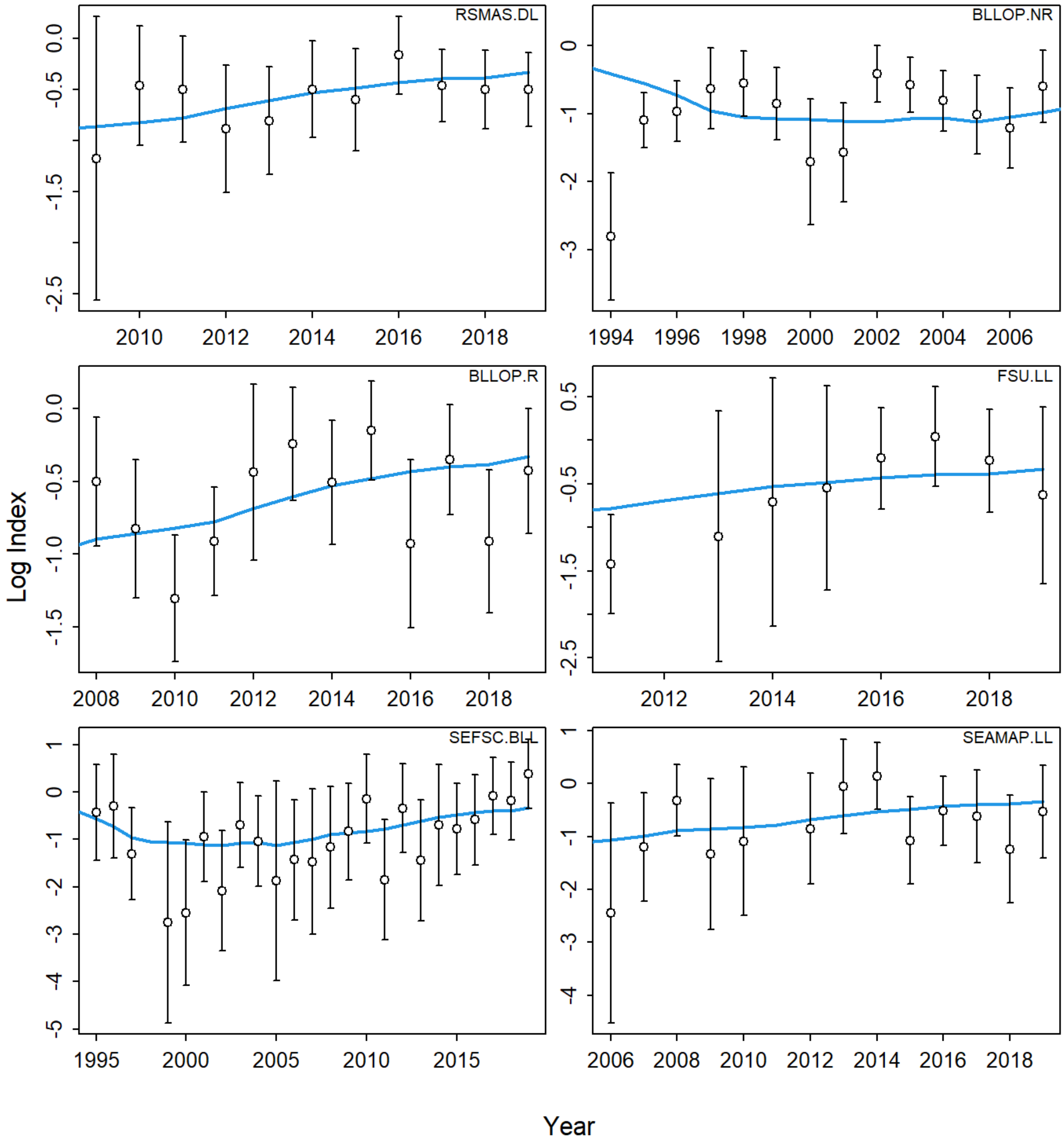


Figure 3.9.2.3. JABBA fits to the standardized catch-per-unit-effort (CPUE) (in log scale) data sets from the six indices of abundance. The solid line is the model predicted value and the circles are observed data values. Vertical lines represent the estimated 95% confidence intervals around the CPUE values.

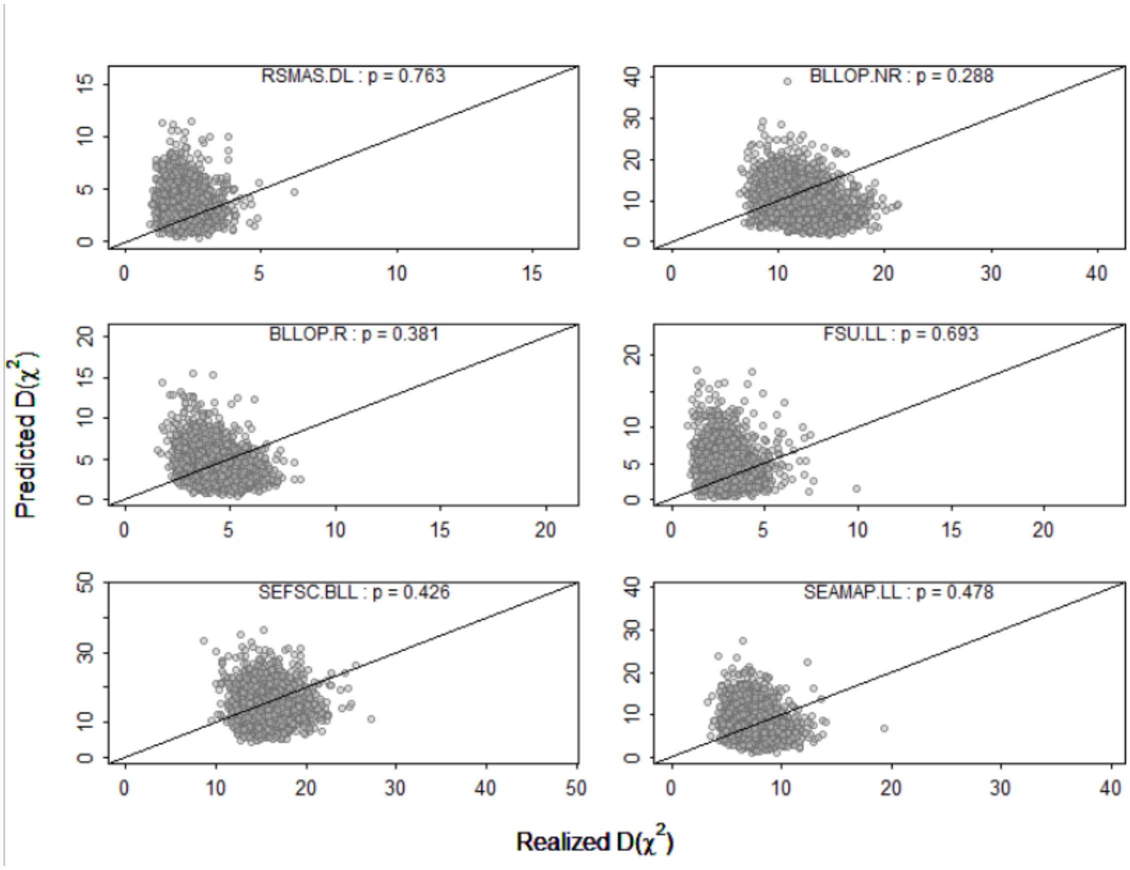


Figure 3.9.2.4. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of each of the six indices of abundance in the base run. A general rule of thumb is that $\rho = 0.5$ is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

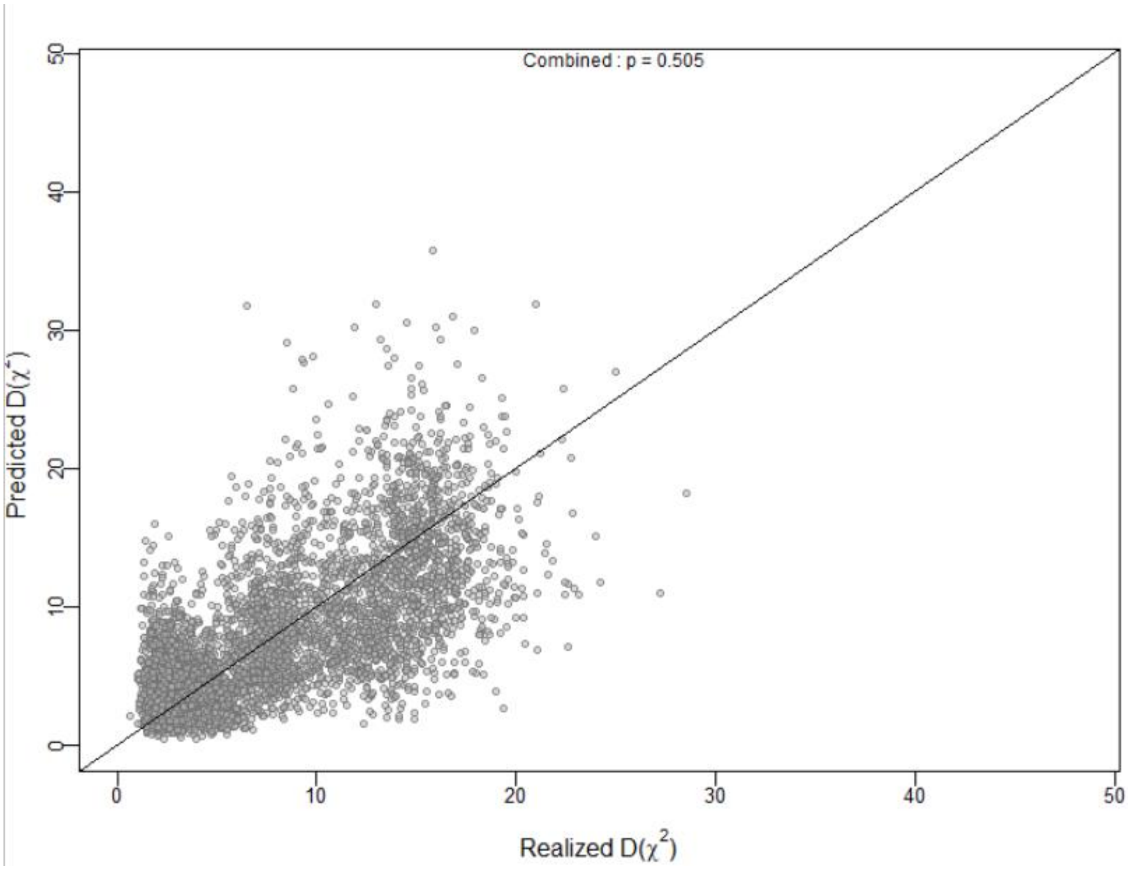


Figure 3.9.2.5. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of the combined CPUE for the base run. A general rule of thumb is that ρ = 0.5 is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

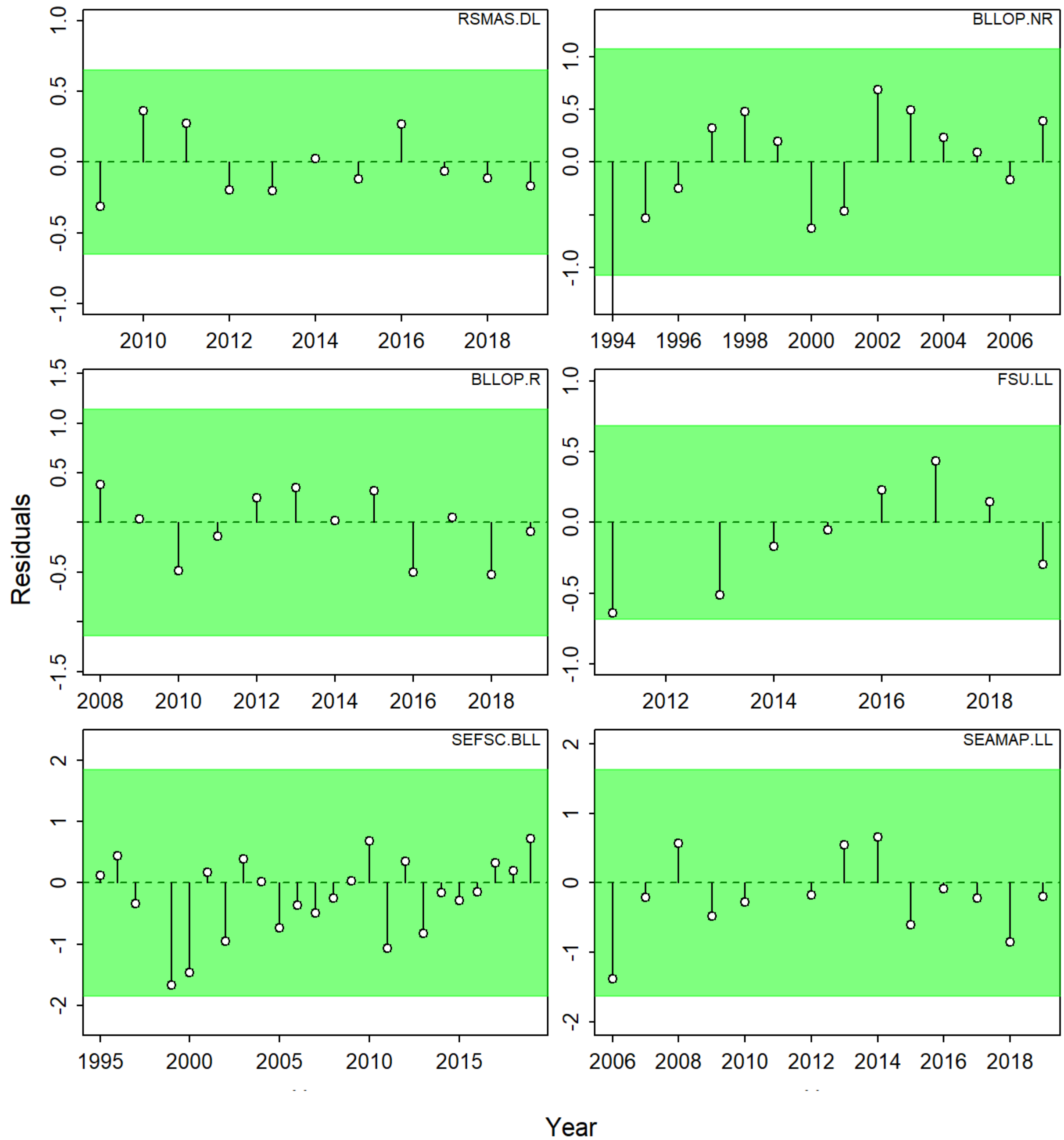


Figure 3.9.2.6. Runs test to quantitatively evaluate the randomness of the time series of CPUE residuals for each of the six indices of abundance. Green panels indicate no evidence of lack of randomness of time-series residuals ($p>0.05$) while red panels indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

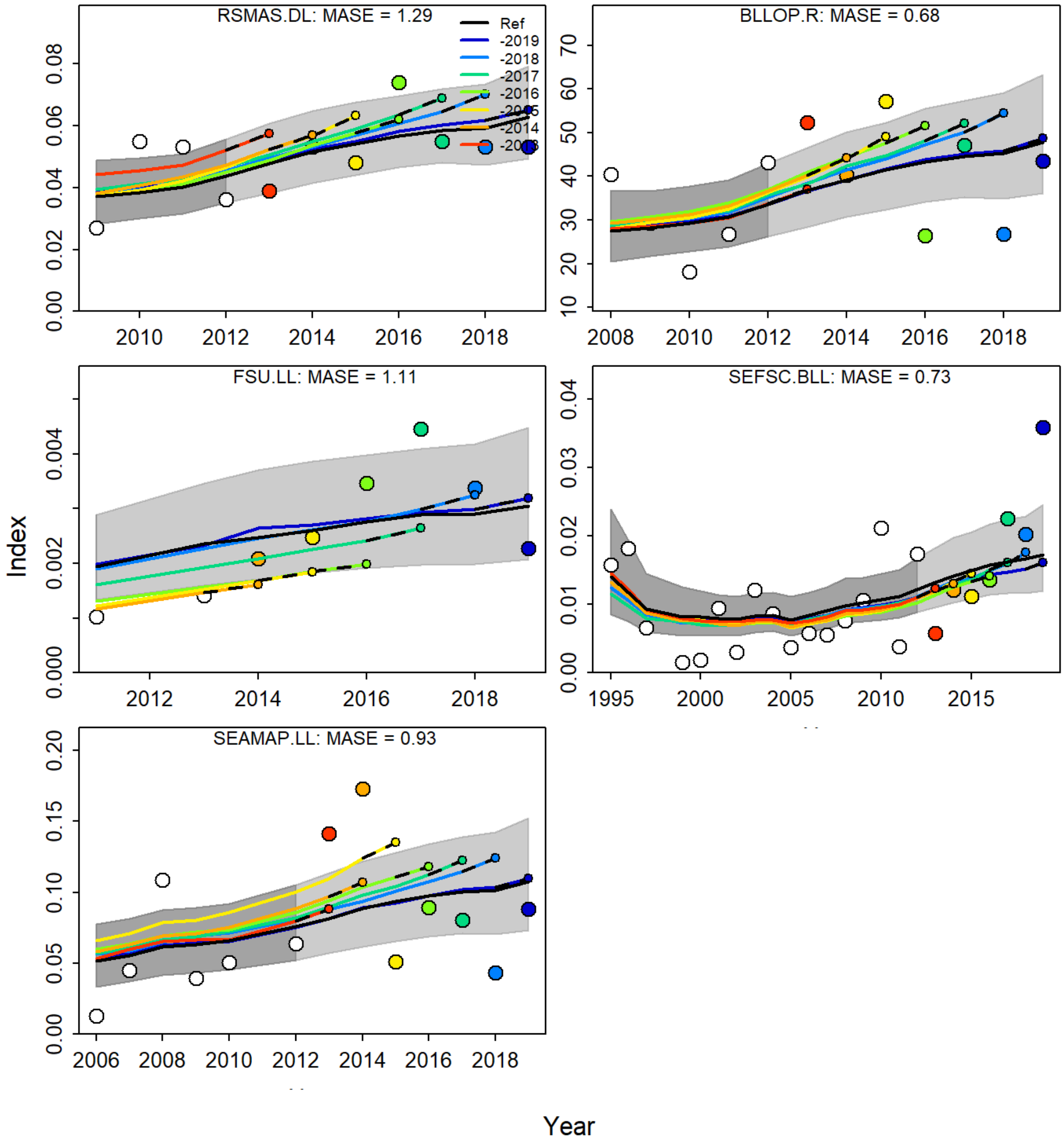


Figure 3.9.2.7. Hindcasting cross-validation results (HCxval), showing one-year-ahead forecasts of CPUE values, performed with seven hindcast model runs relative to the expected CPUE. The CPUE observations, used for cross-validation, are highlighted as color-coded solid circles with associated light-grey shaded 95% confidence interval. The model reference year refers to the end points of each one-year-ahead forecast and the corresponding observation (i.e. year of peel + 1). The joint *MASE* value is 0.88.

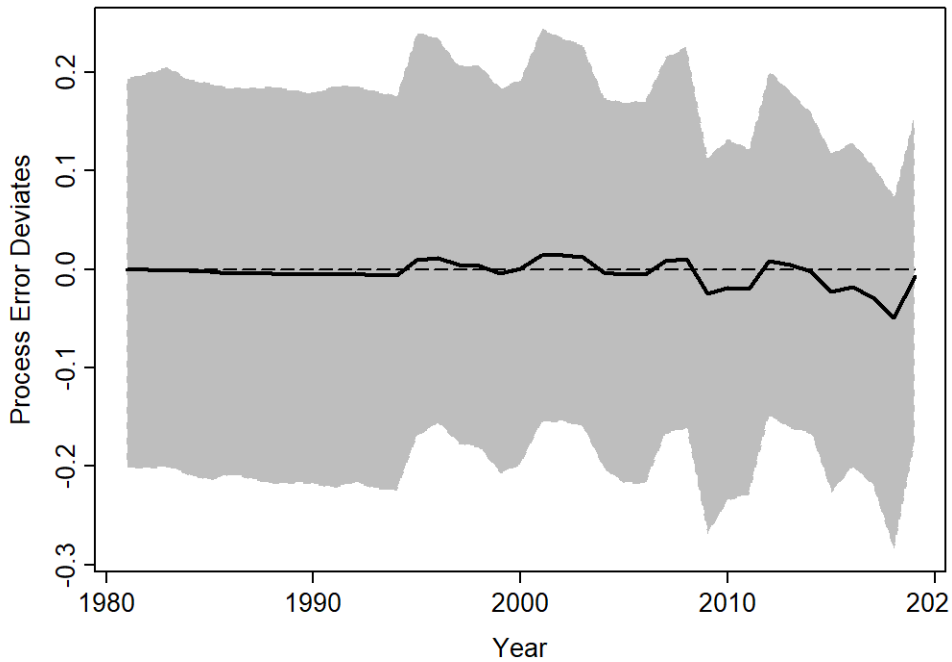


Figure 3.9.2.8. Process error deviates (median: solid line) with shaded grey area indicating 95% credibility intervals.

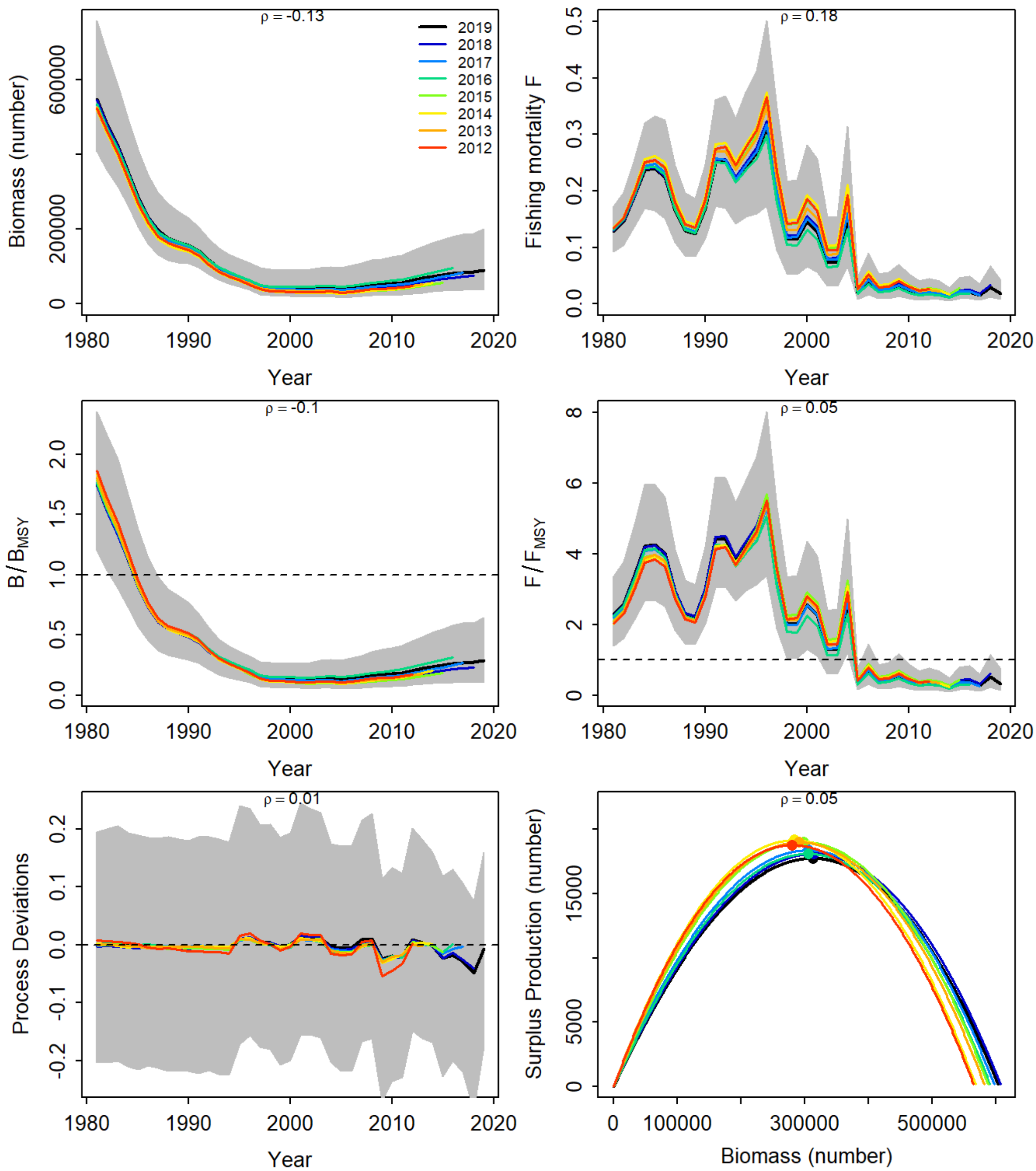


Figure 3.9.2.9. Retrospective analysis conducted by removing one year at a time sequentially (n=7) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and process deviations and surplus production curve (bottom panels).

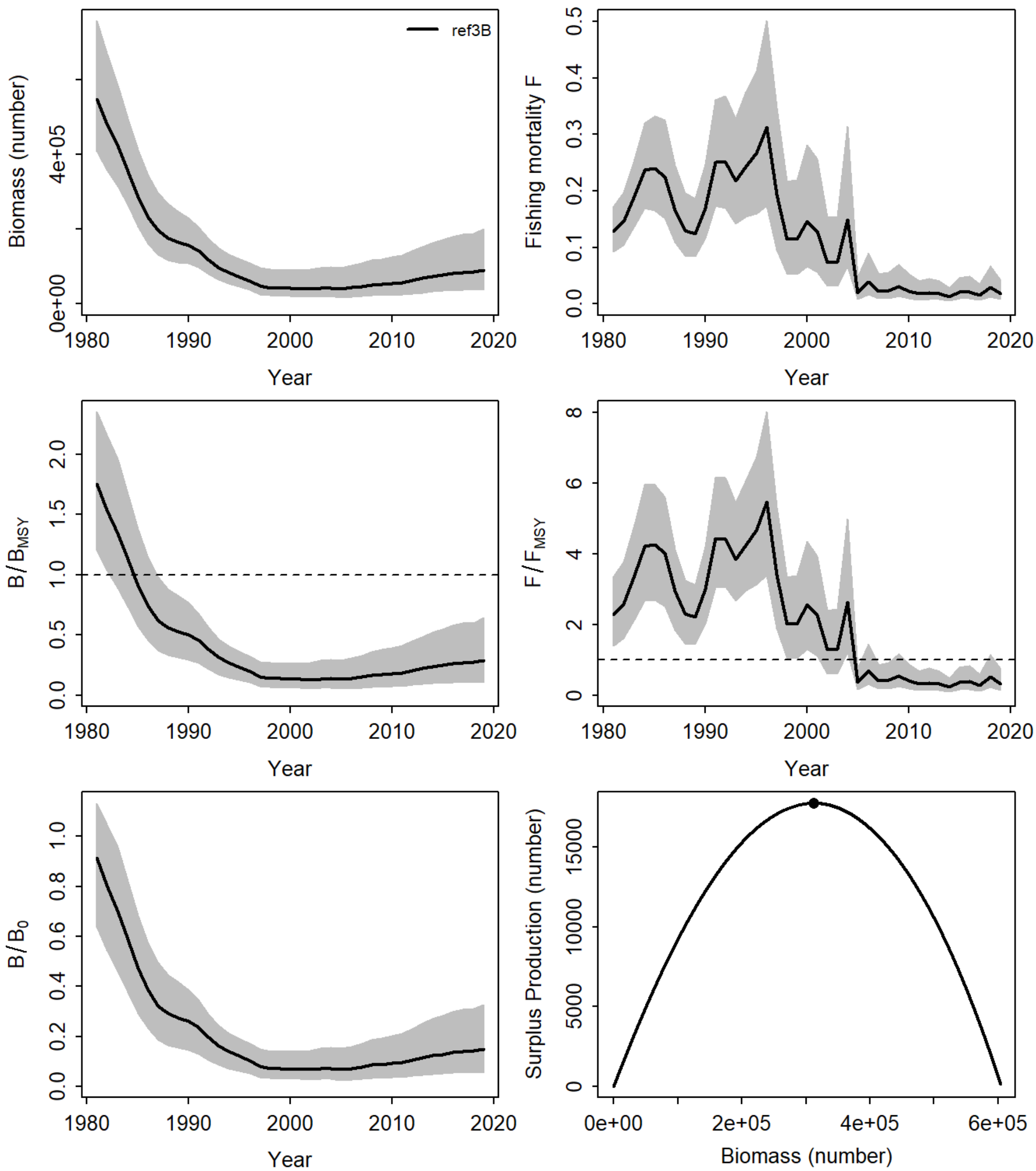


Figure 3.9.2.10. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to B_0 (B/B_0) and surplus production curve (bottom panels).

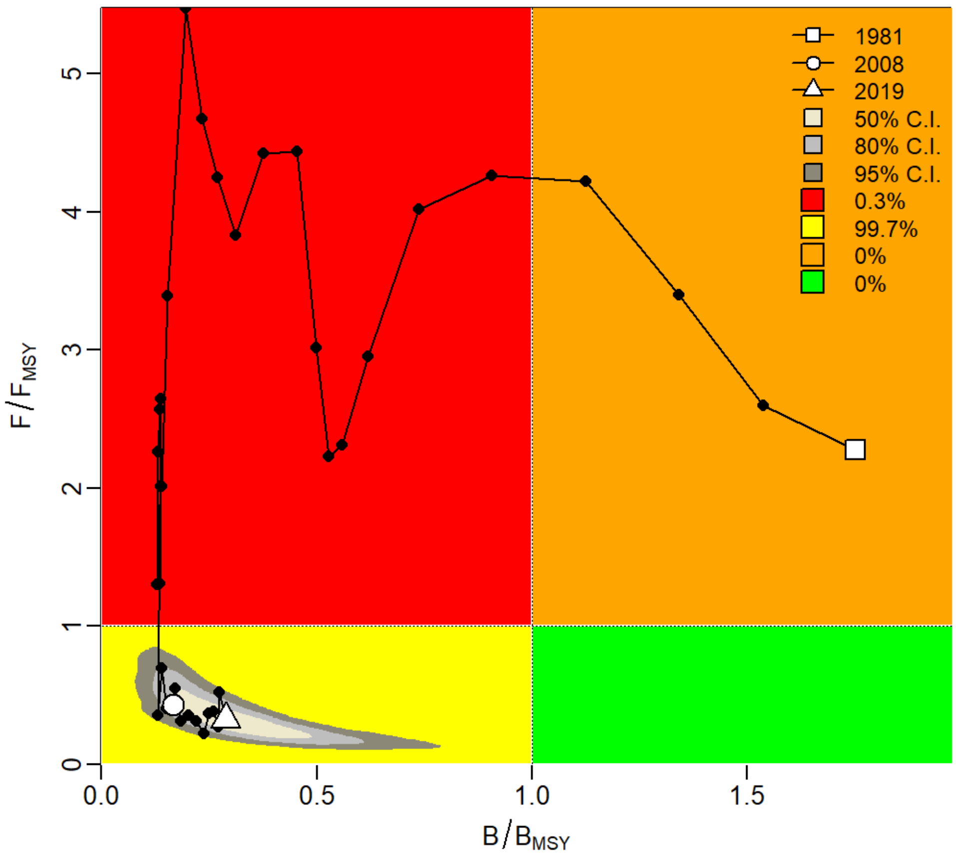


Figure 3.9.2.11. Kobe phase plot showing estimated trajectories (1981-2019) of B/B_{MSY} and F/F_{MSY}. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend.

Appendix 3.9.3: Plots for the Panel-approved 3) ref1_1B (6xCMAX, *CV*=2) sensitivity run.

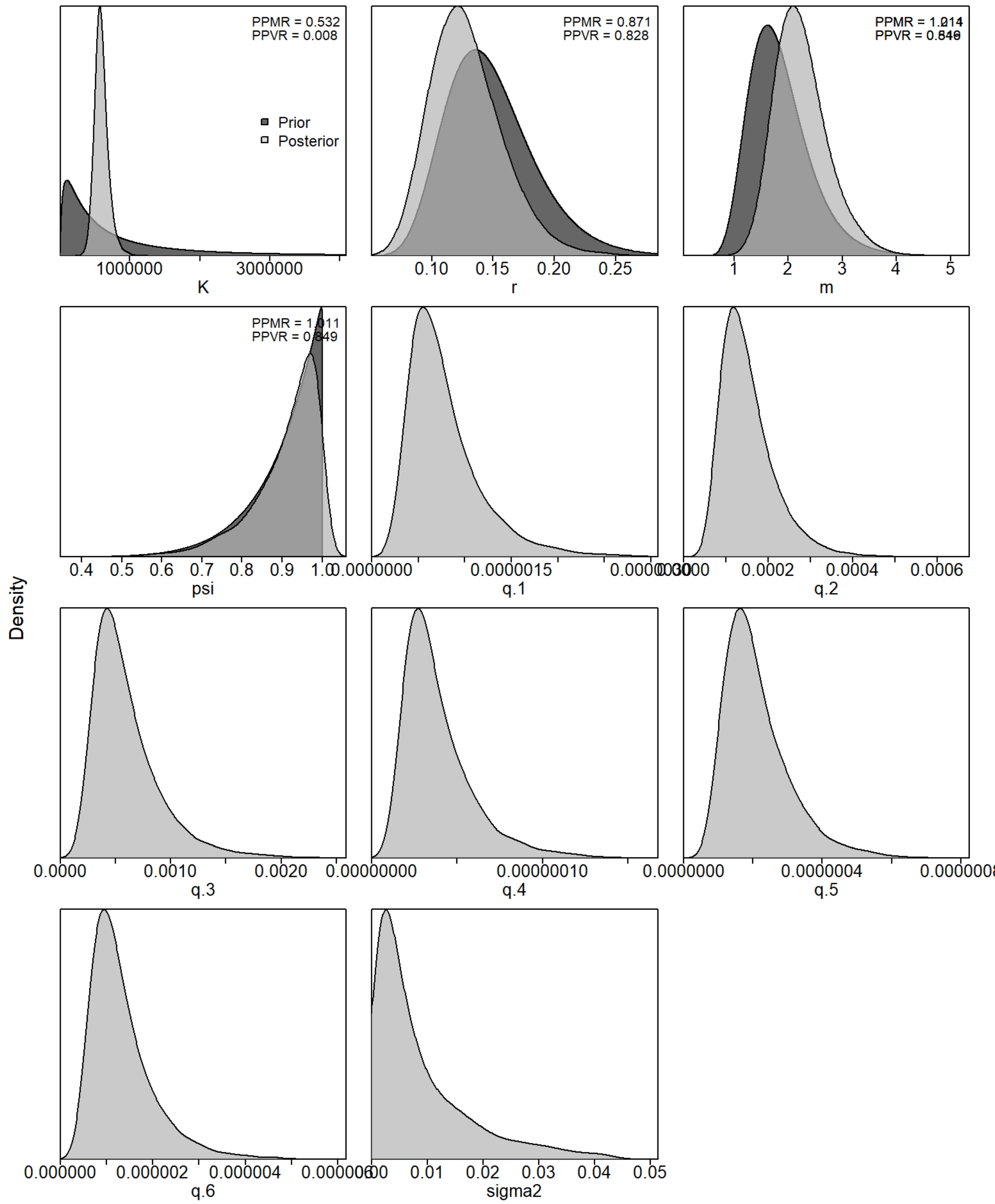


Figure 3.9.3.1. Prior and posterior distribution of various model and management parameters. *PPRM*: Posterior to Prior Ratio of Medians; *PPRV*: Posterior to Prior Ratio of Variances.

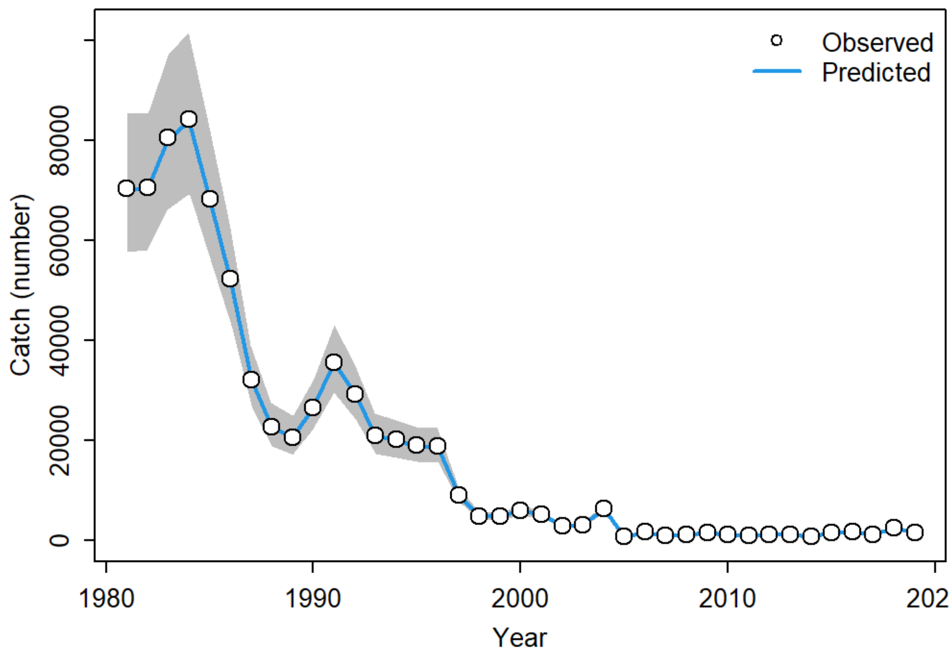


Figure 3.9.3.2. Catches of great hammerheads in numbers (1981-2019).

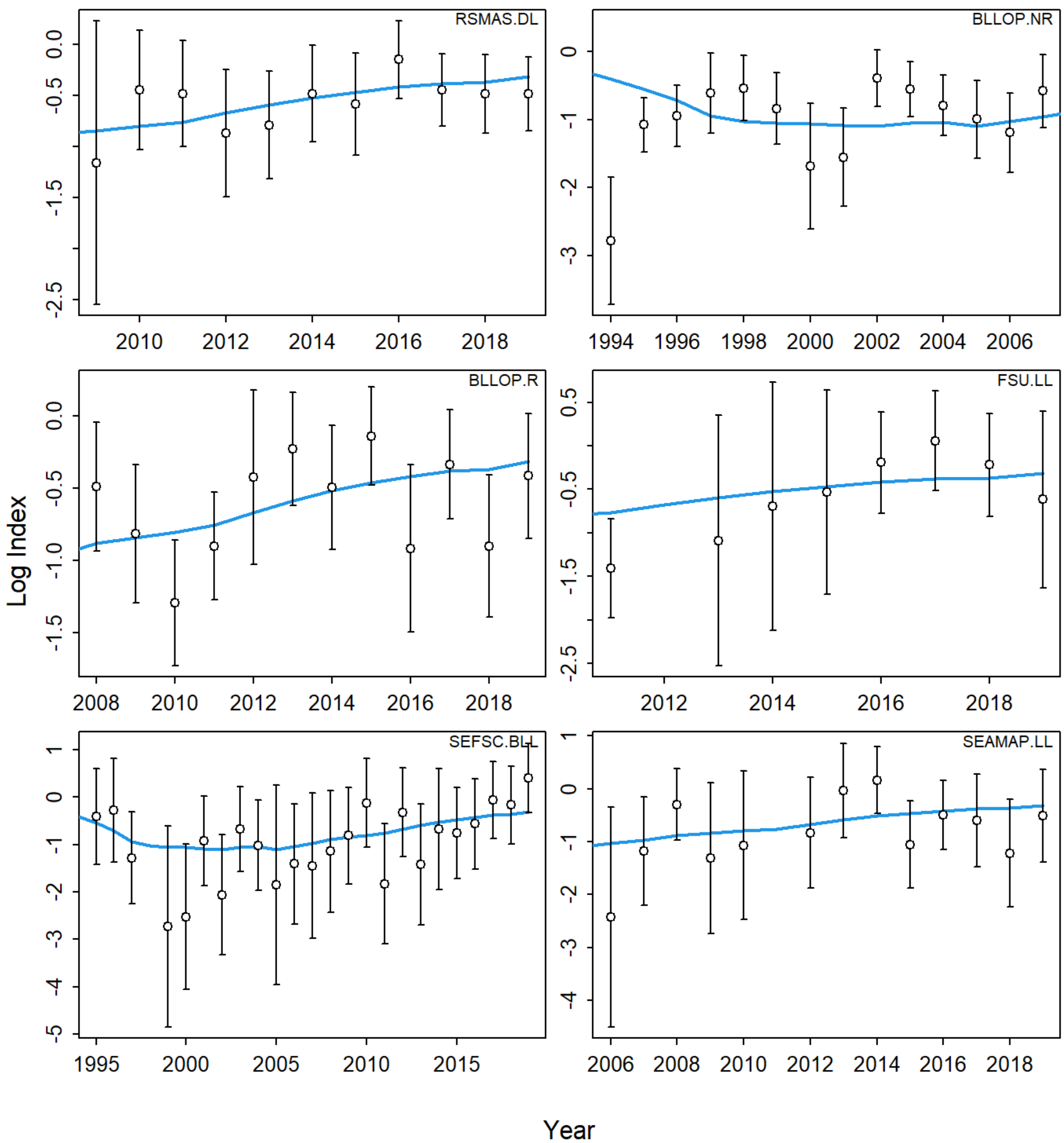


Figure 3.9.3.3. JABBA fits to the standardized catch-per-unit-effort (CPUE) (in log scale) data sets from the six indices of abundance. The solid line is the model predicted value and the circles are observed data values. Vertical lines represent the estimated 95% confidence intervals around the CPUE values.

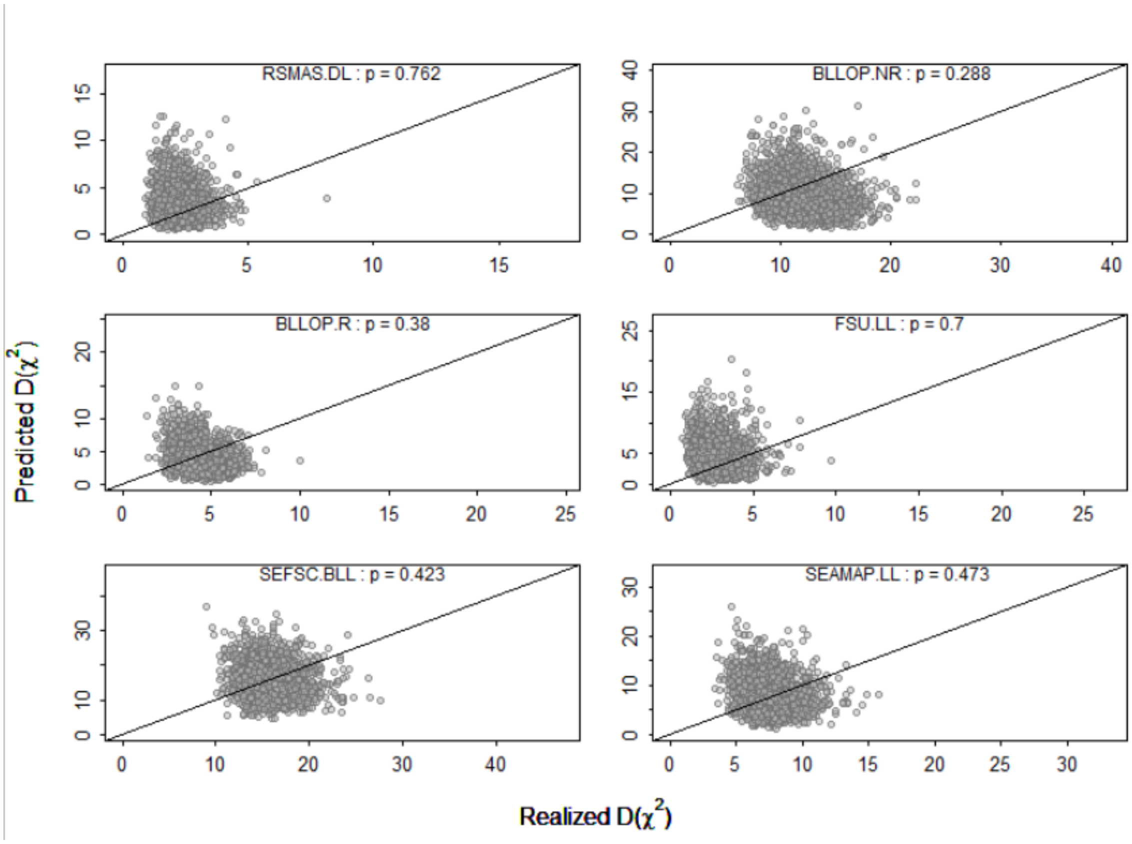


Figure 3.9.3.4. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of each of the six indices of abundance in the base run. A general rule of thumb is that ρ = 0.5 is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

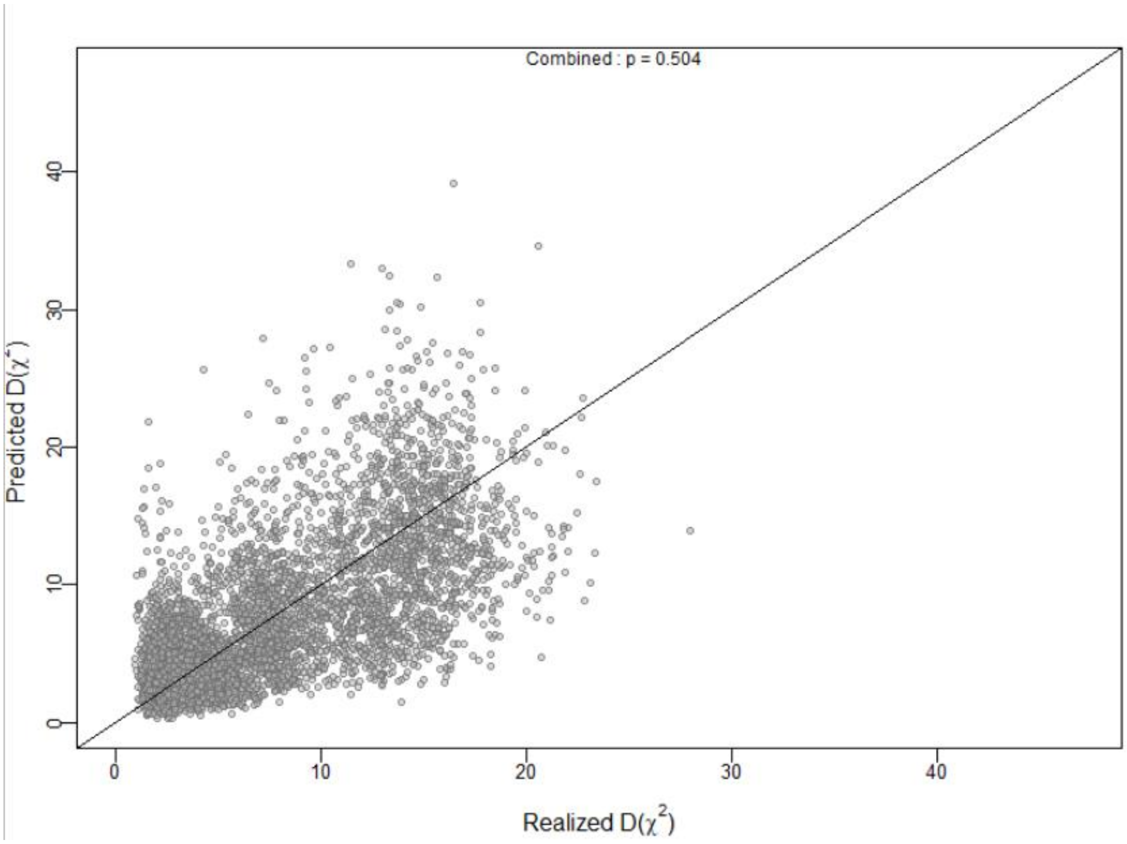


Figure 3.9.3.5. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of the combined CPUE for the base run. A general rule of thumb is that ρ = 0.5 is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

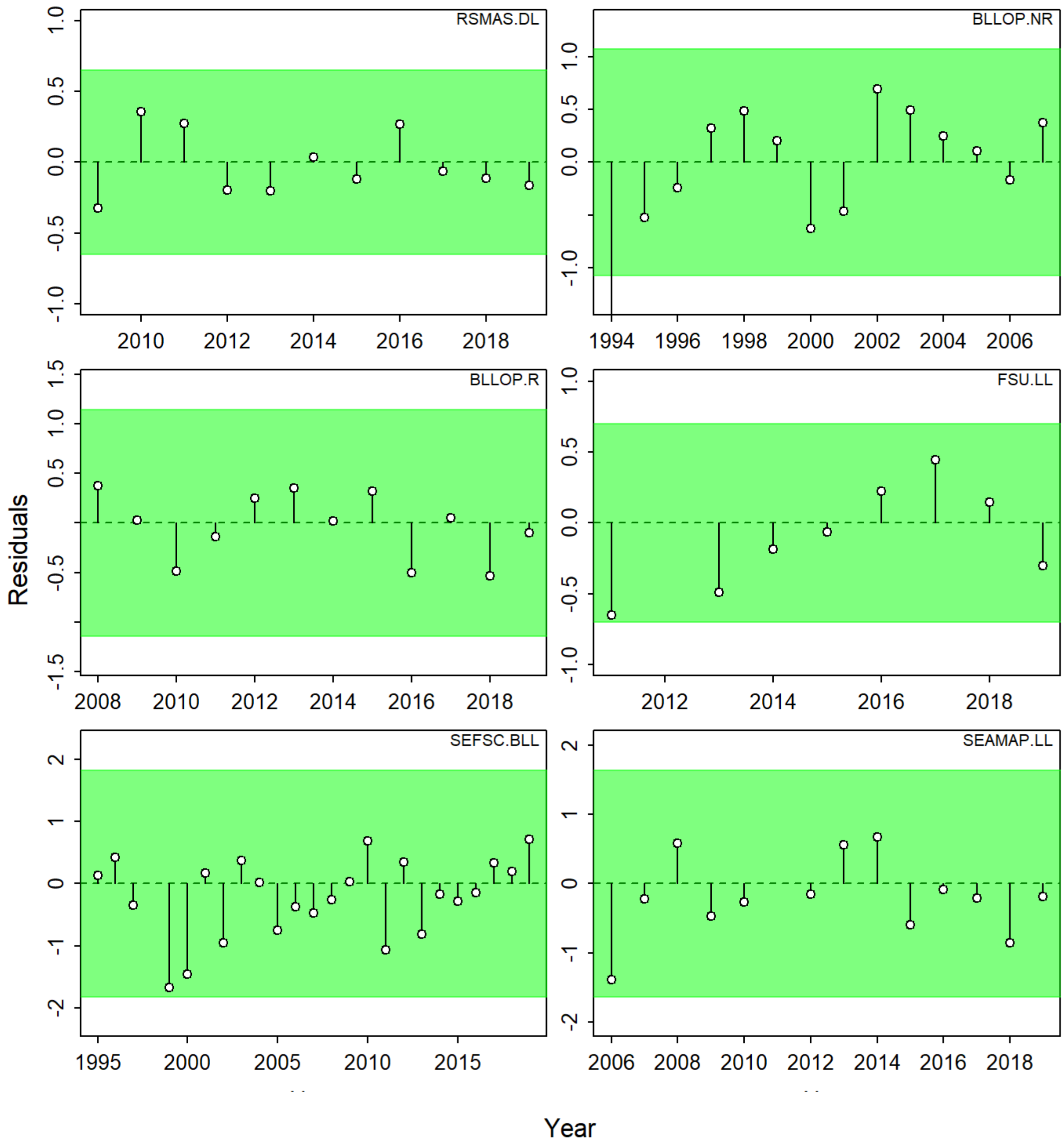


Figure 3.9.3.6. Runs test to quantitatively evaluate the randomness of the time series of CPUE residuals for each of the six indices of abundance. Green panels indicate no evidence of lack of randomness of time-series residuals (*p*>0.05) while red panels indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

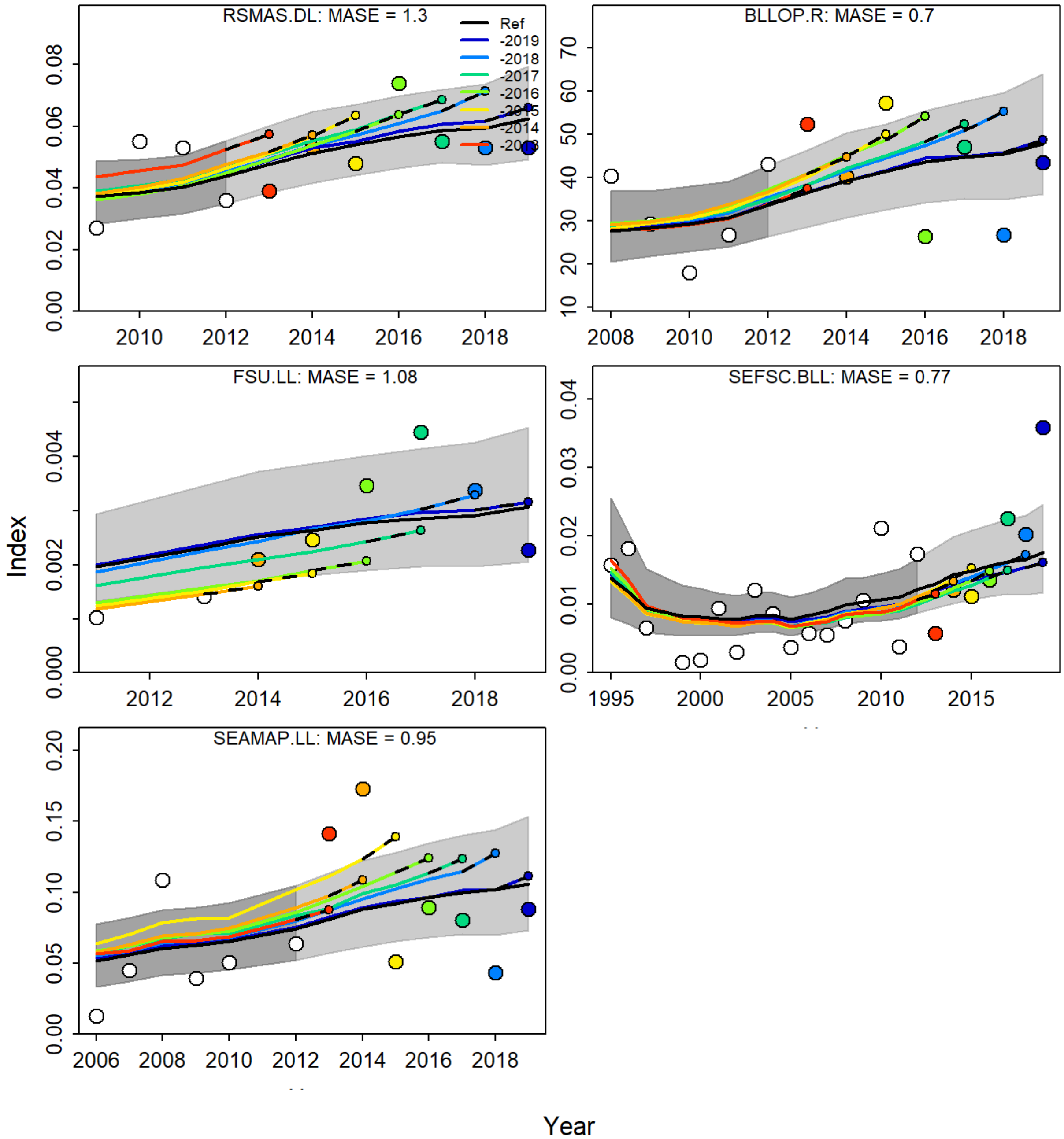


Figure 3.9.3.7. Hindcasting cross-validation results (HCxval), showing one-year-ahead forecasts of CPUE values, performed with seven hindcast model runs relative to the expected CPUE. The CPUE observations, used for cross-validation, are highlighted as color-coded solid circles with associated light-grey shaded 95% confidence interval. The model reference year refers to the end points of each one-year-ahead forecast and the corresponding observation (i.e. year of peel + 1). The joint *MASE* value is 0.90.

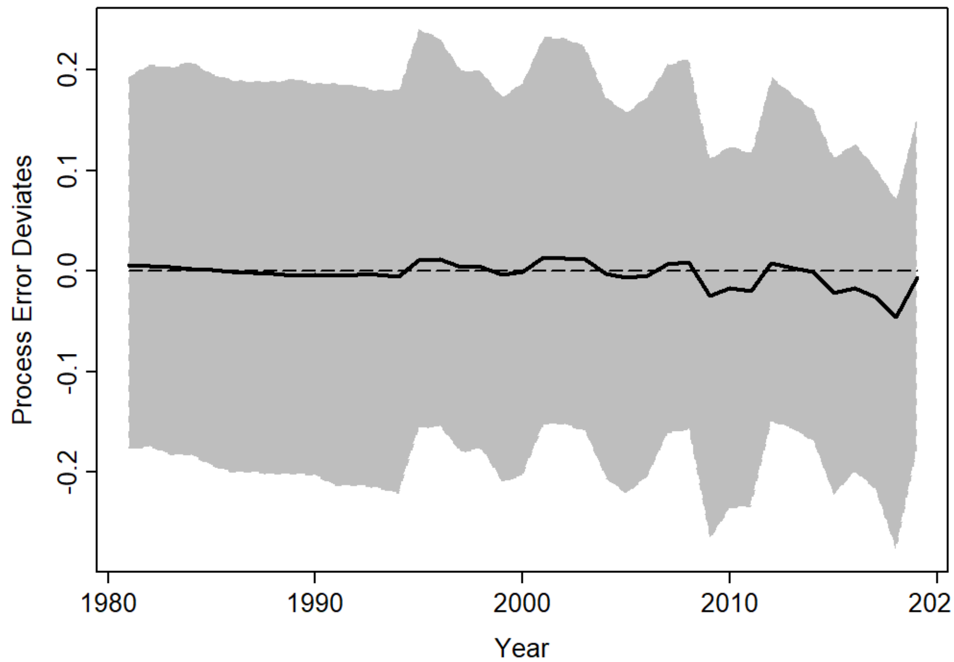


Figure 3.9.3.8. Process error deviates (median: solid line) with shaded grey area indicating 95% credibility intervals.

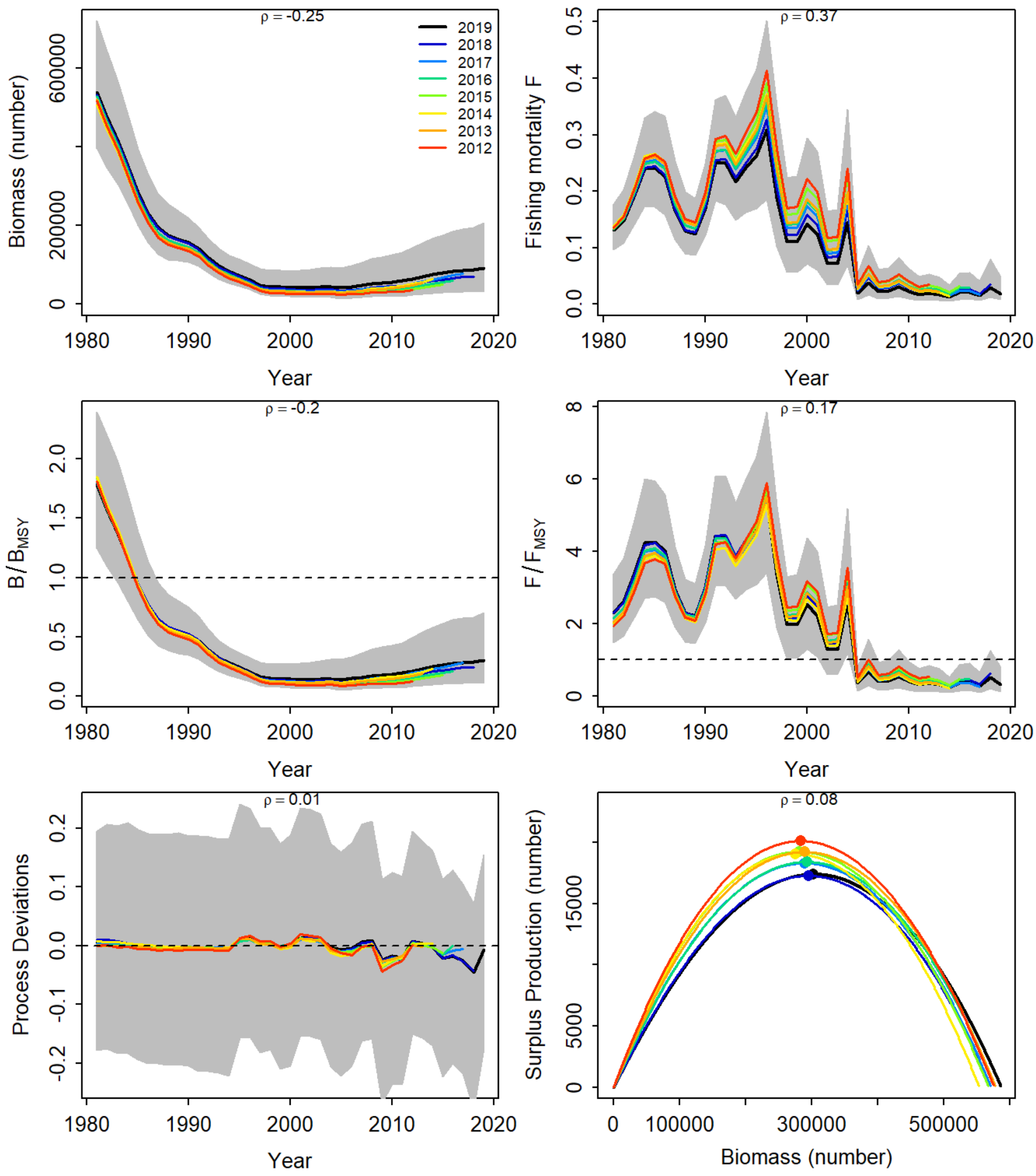


Figure 3.9.3.9. Retrospective analysis conducted by removing one year at a time sequentially (n=7) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and process deviations and surplus production curve (bottom panels).

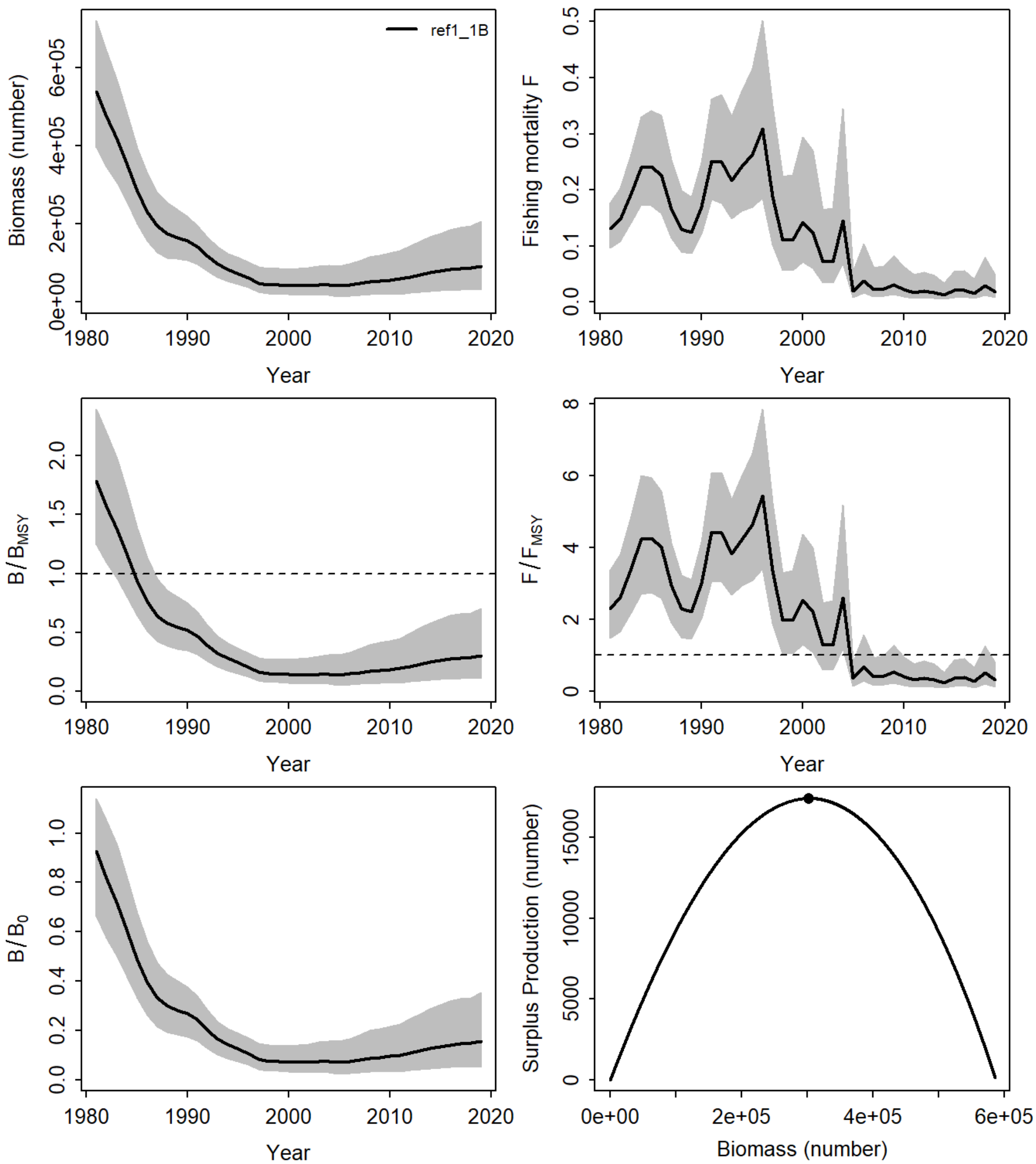


Figure 3.9.3.10. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to B_0 (B/B_0) and surplus production curve (bottom panels).

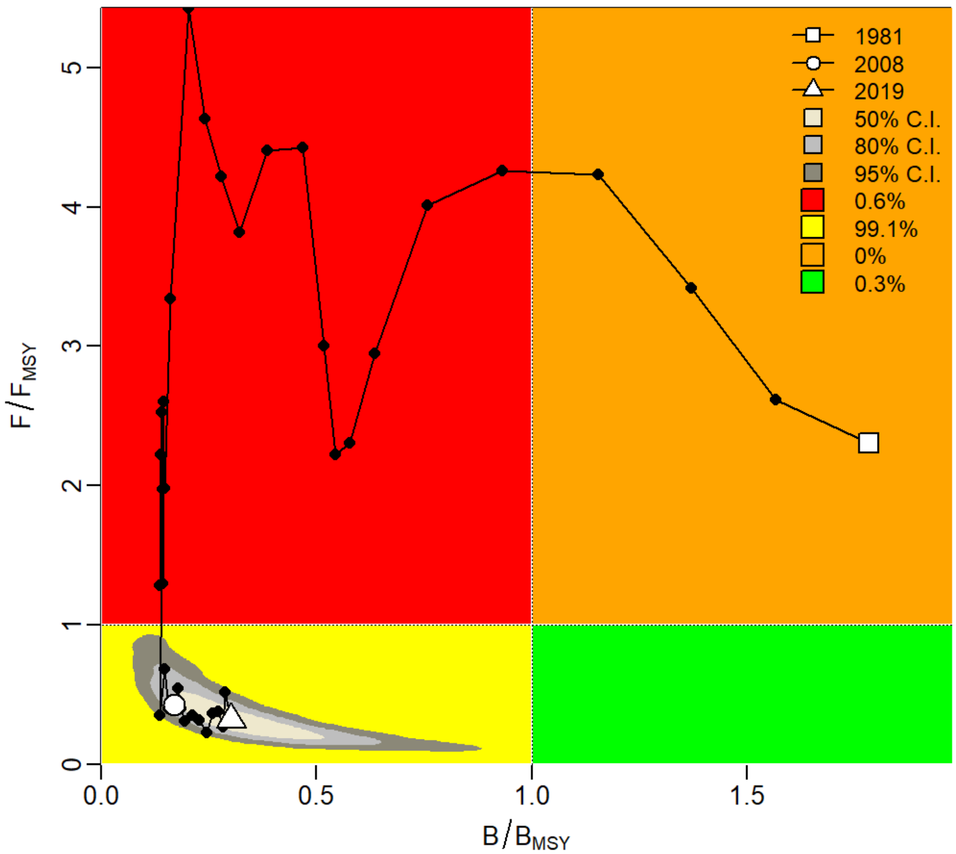


Figure 3.9.3.11. Kobe phase plot showing estimated trajectories (1981-2019) of B/B_{MSY} and F/F_{MSY}. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend.

Appendix 3.9.4: Plots for the Panel-approved 4) ref1_2B (6xC_{MAX}, *CV*=200) sensitivity run.

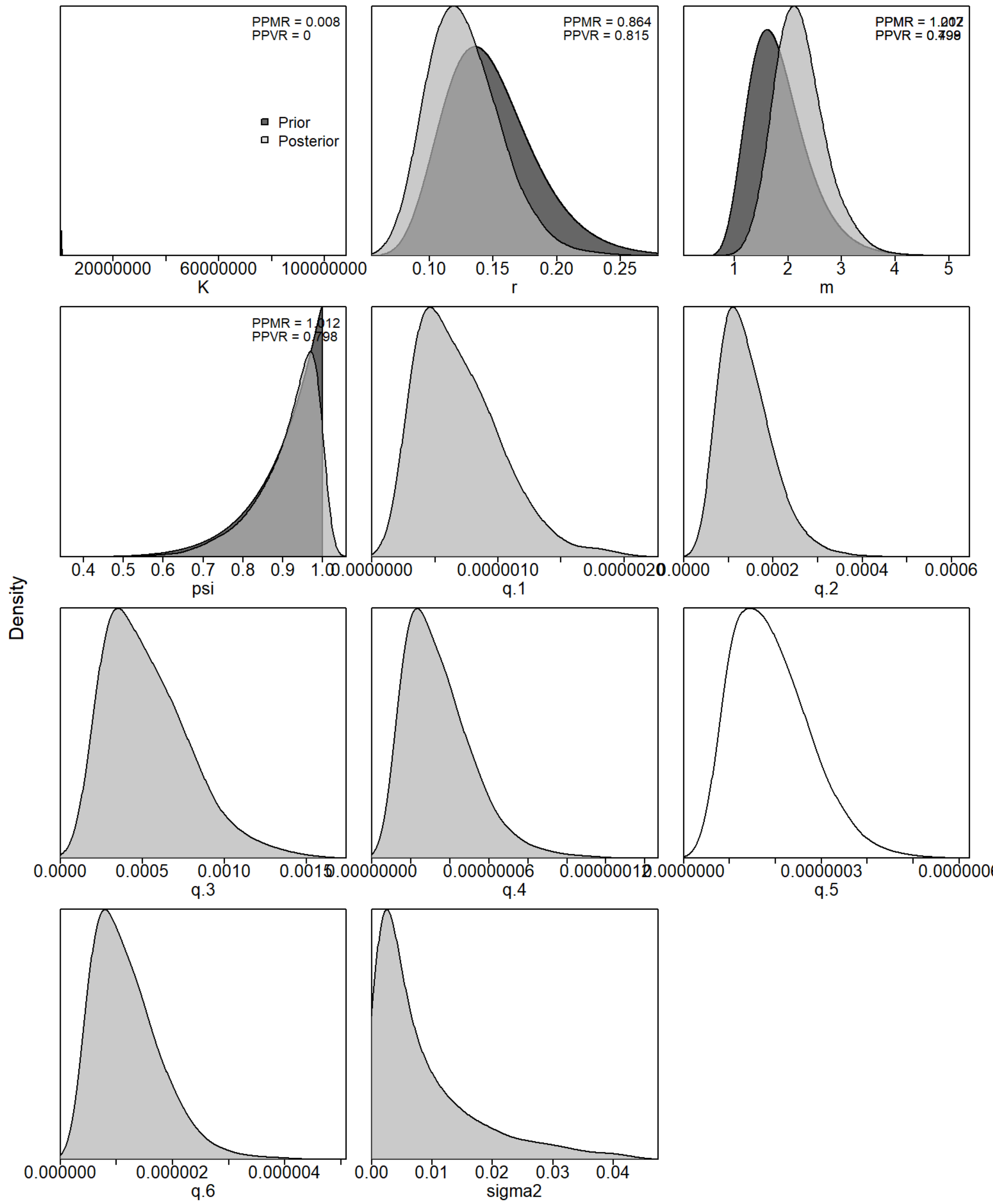


Figure 3.9.4.1. Prior and posterior distribution of various model and management parameters. *PPRM*: Posterior to Prior Ratio of Medians; *PPRV*: Posterior to Prior Ratio of Variances.

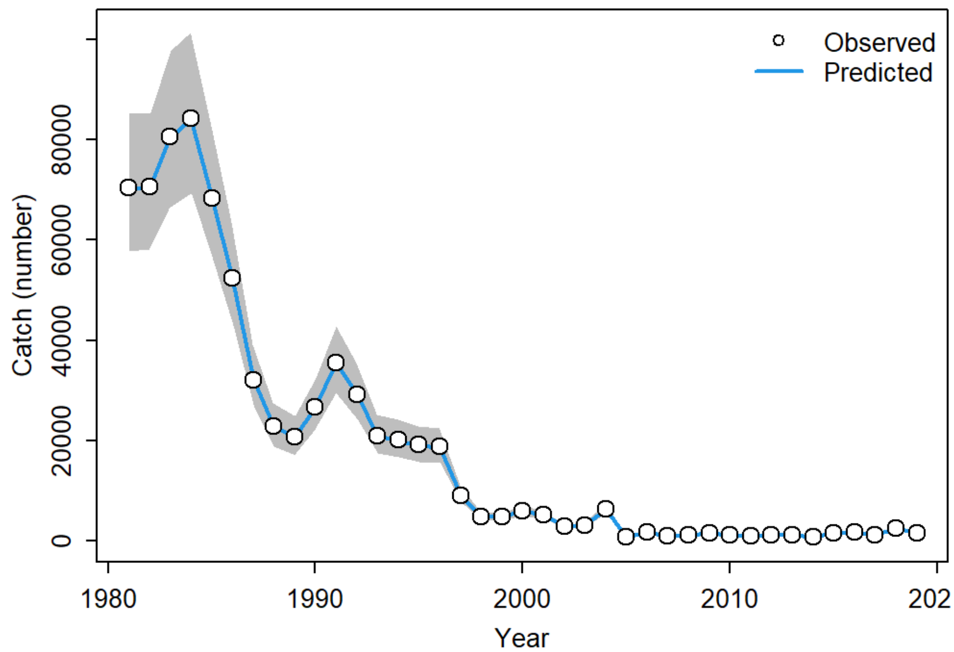


Figure 3.9.4.2. Catches of great hammerheads in numbers (1981-2019).

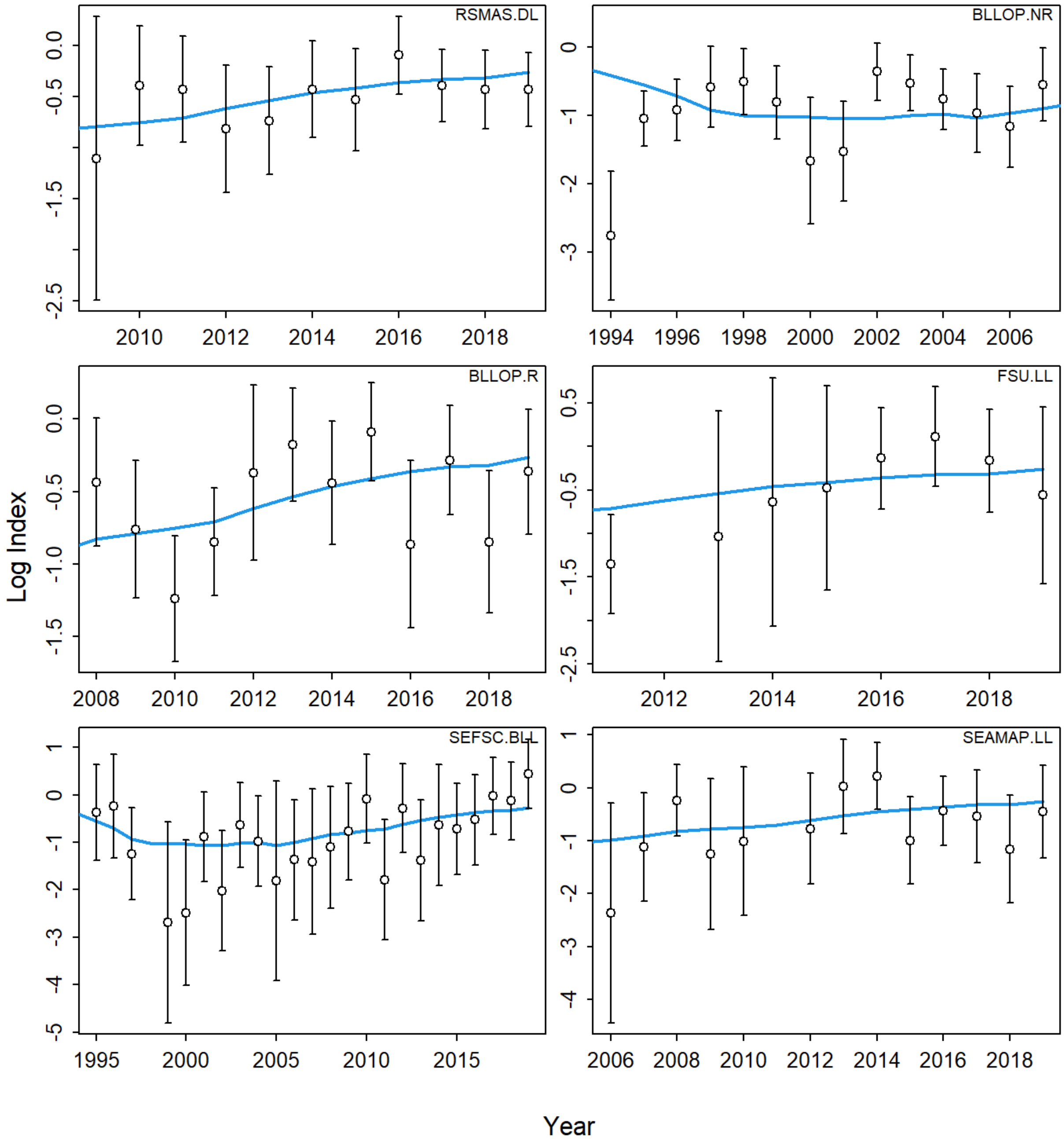


Figure 3.9.4.3. JABBA fits to the standardized catch-per-unit-effort (CPUE) (in log scale) data sets from the six indices of abundance. The solid line is the model predicted value and the circles are observed data values. Vertical lines represent the estimated 95% confidence intervals around the CPUE values.

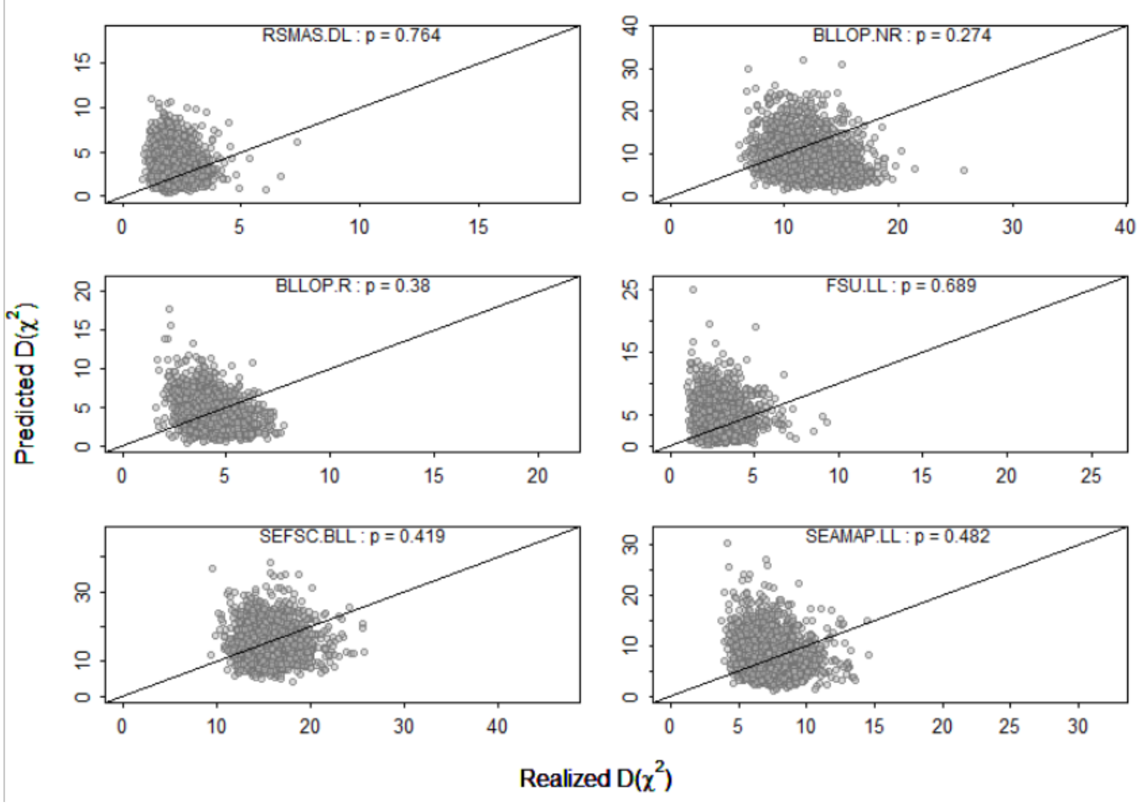


Figure 3.9.4.4. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of each of the six indices of abundance in the base run. A general rule of thumb is that ρ = 0.5 is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

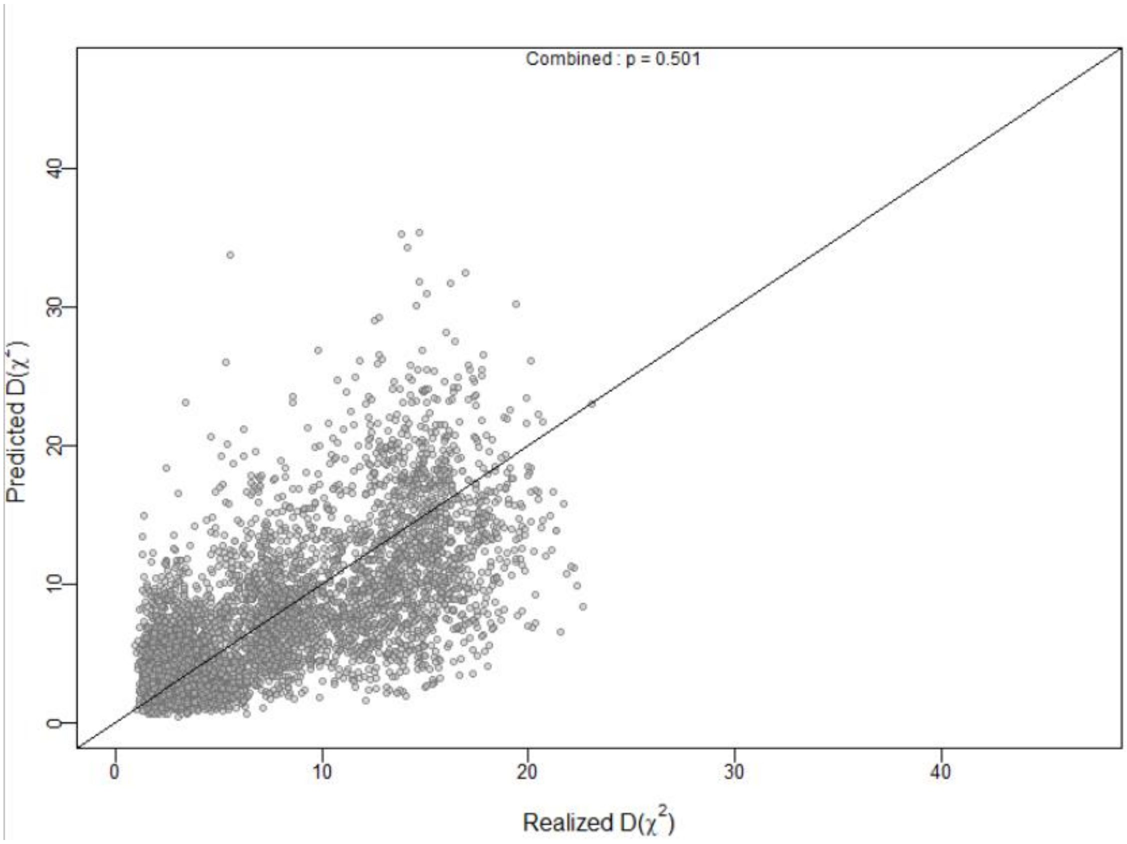


Figure 3.9.4.5. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of the combined CPUE for the base run. A general rule of thumb is that ρ = 0.5 is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

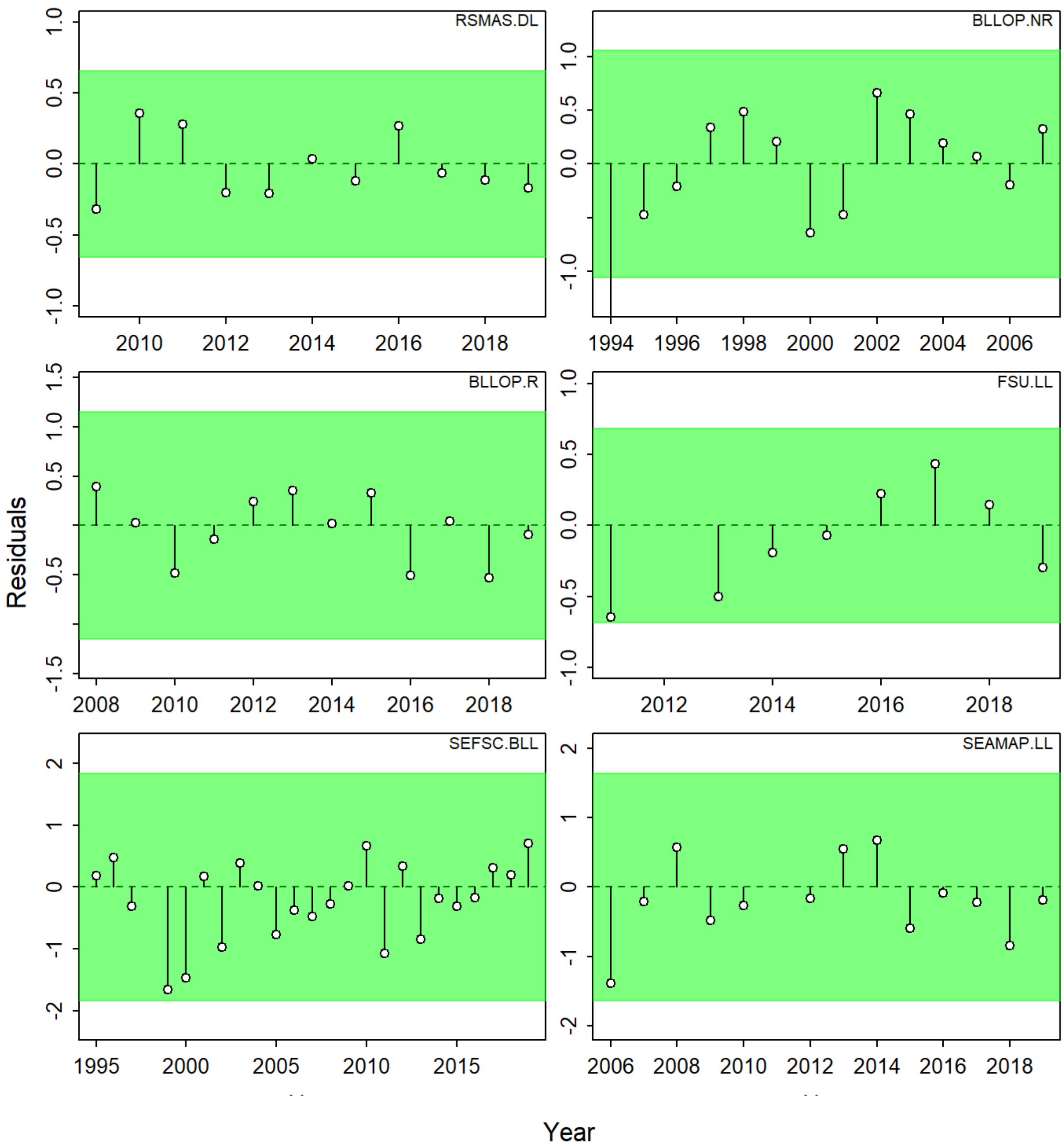


Figure 3.9.4.6. Runs test to quantitatively evaluate the randomness of the time series of CPUE residuals for each of the six indices of abundance. Green panels indicate no evidence of lack of randomness of time-series residuals (p>0.05) while red panels indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

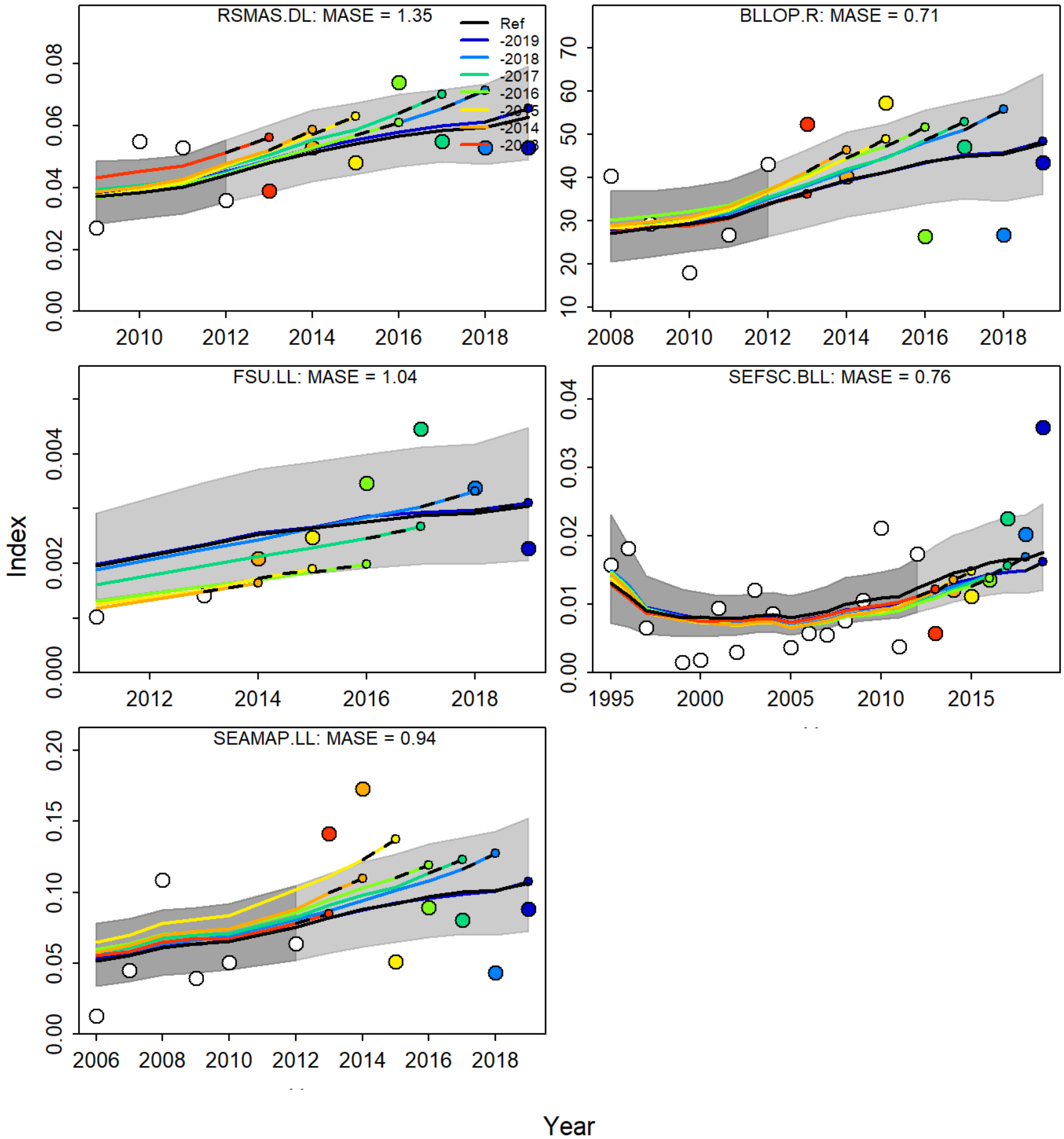


Figure 3.9.4.7. Hindcasting cross-validation results (HCxval), showing one-year-ahead forecasts of CPUE values, performed with seven hindcast model runs relative to the expected CPUE. The CPUE observations, used for cross-validation, are highlighted as color-coded solid circles with associated light-grey shaded 95% confidence interval. The model reference year refers to the end points of each one-year-ahead forecast and the corresponding observation (i.e. year of peel + 1). The joint *MASE* value is 0.89.

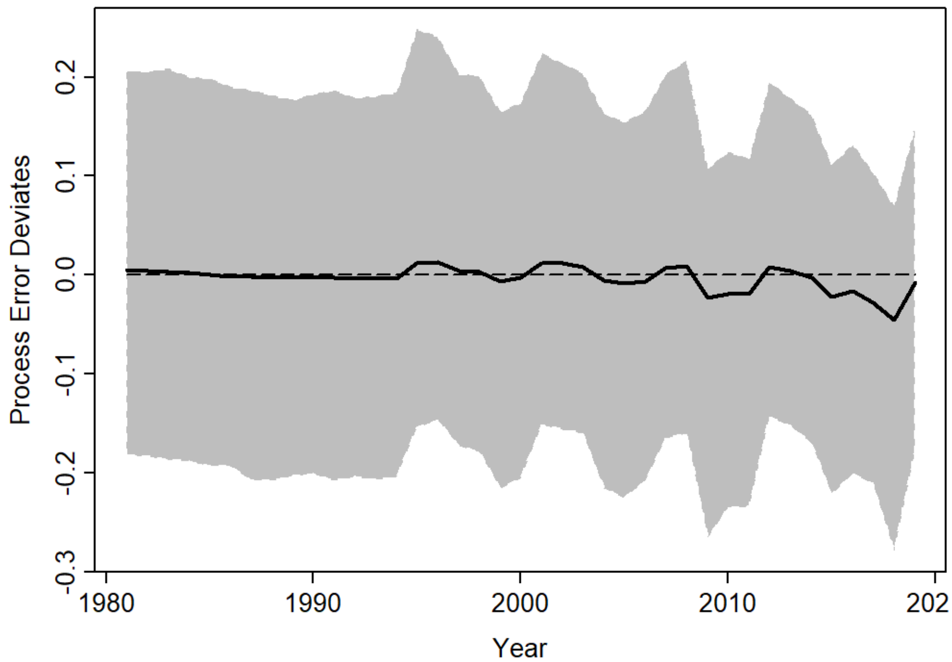


Figure 3.9.4.8. Process error deviates (median: solid line) with shaded grey area indicating 95% credibility intervals.

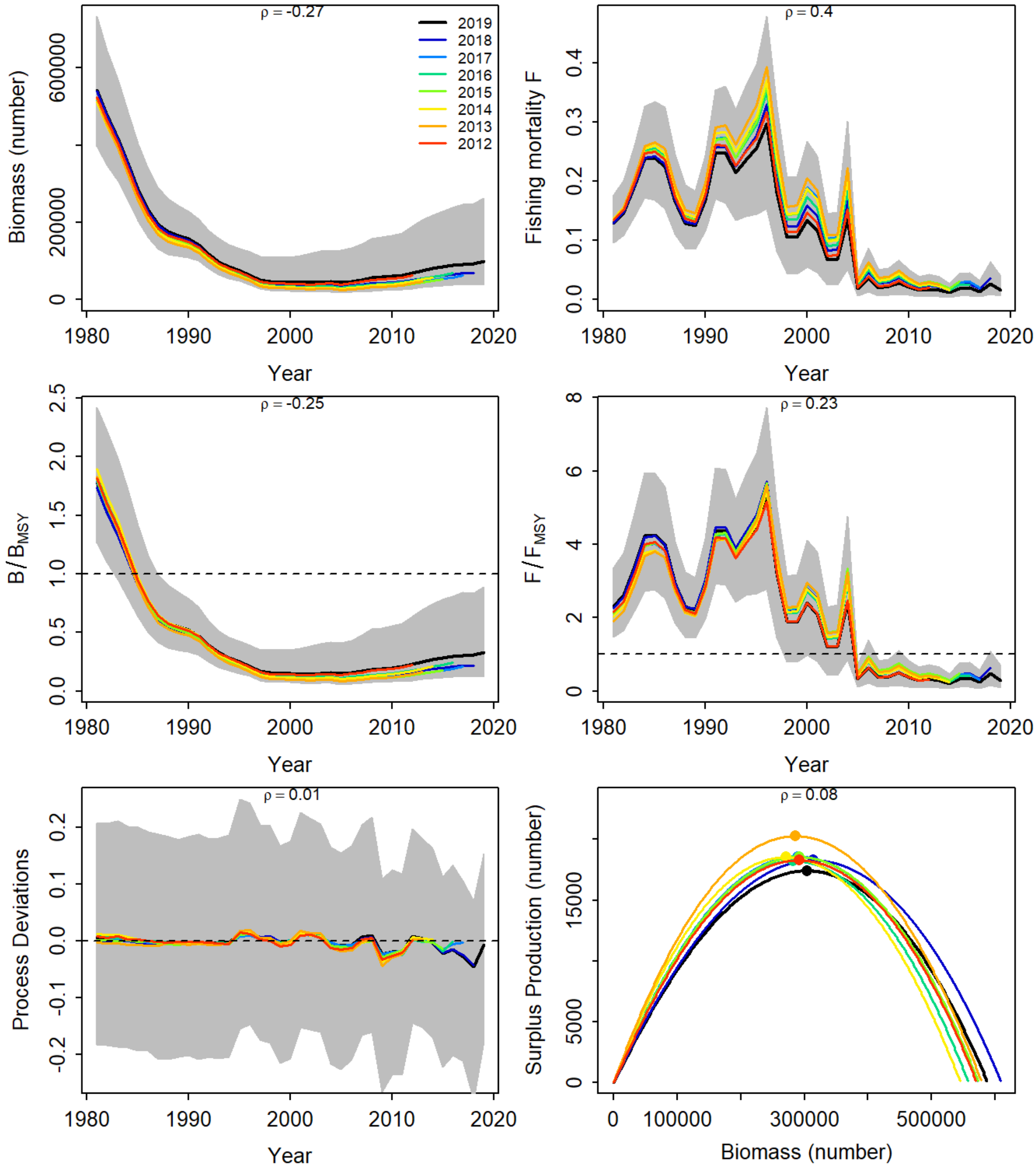


Figure 3.9.4.9. Retrospective analysis conducted by removing one year at a time sequentially (n=7) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and process deviations and surplus production curve (bottom panels).

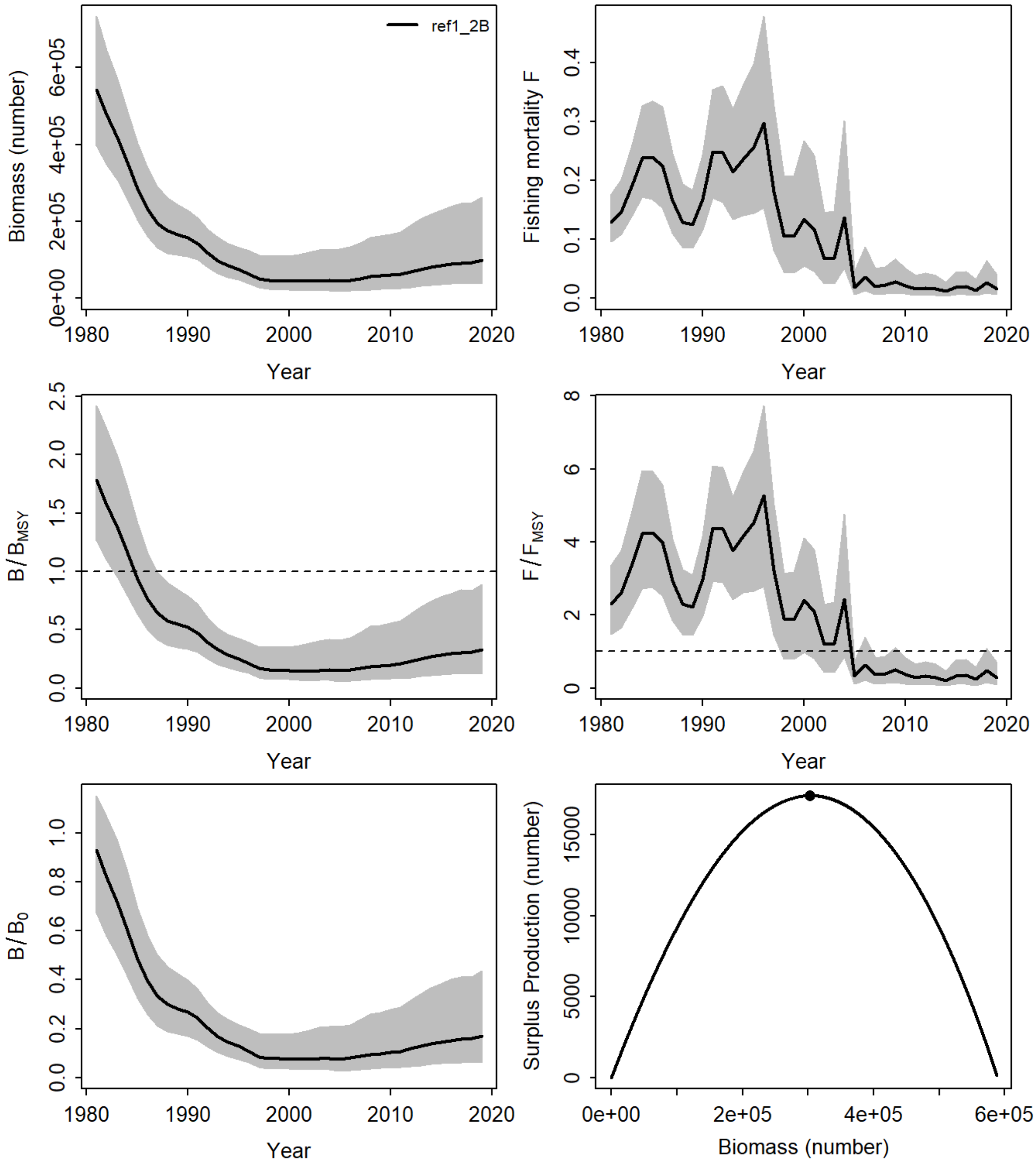


Figure 3.9.4.10. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to B_0 (B/B_0) and surplus production curve (bottom panels).

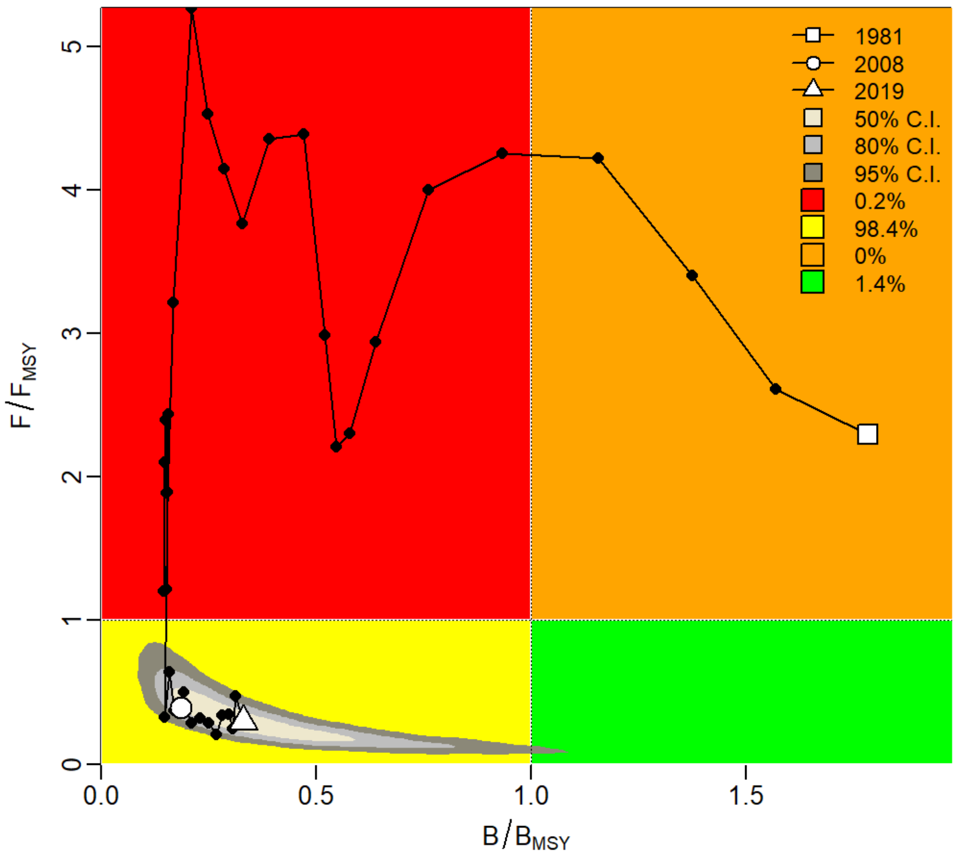


Figure 3.9.4.11. Kobe phase plot showing estimated trajectories (1981-2019) of B/B_{MSY} and F/F_{MSY}. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend.

Appendix 3.9.5: Plots for the Panel-approved 5) ref12BB (High *r*) sensitivity run.

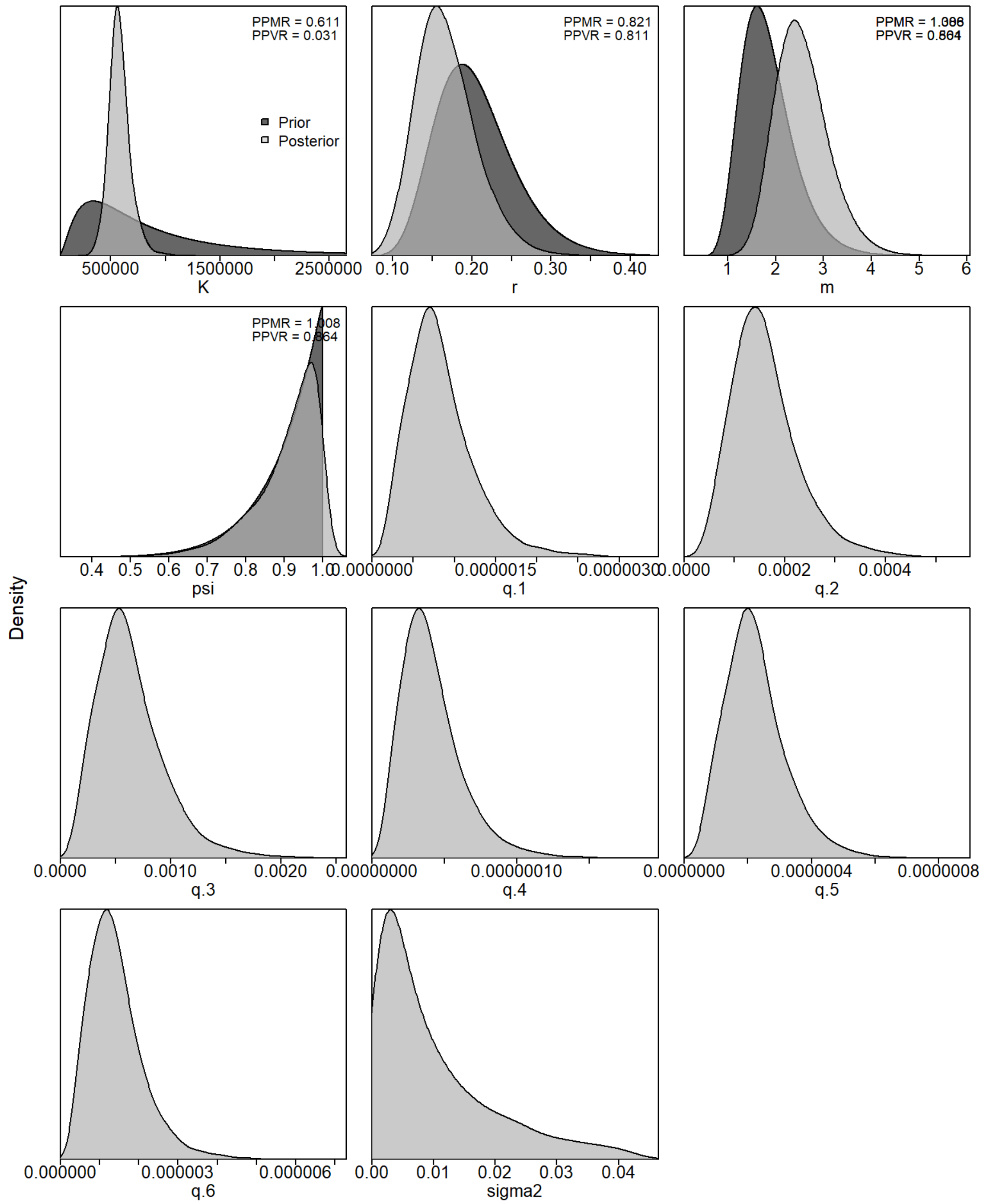


Figure 3.9.5.1. Prior and posterior distribution of various model and management parameters. *PPRM*: Posterior to Prior Ratio of Medians; *PPRV*: Posterior to Prior Ratio of Variances.

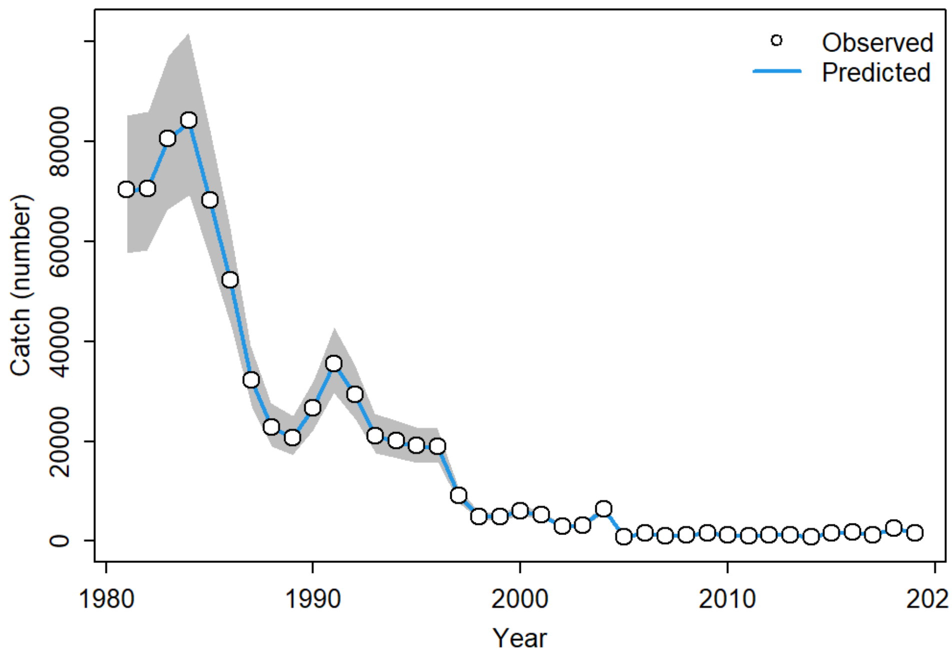


Figure 3.5.5.2. Catches of great hammerheads in numbers (1981-2019).

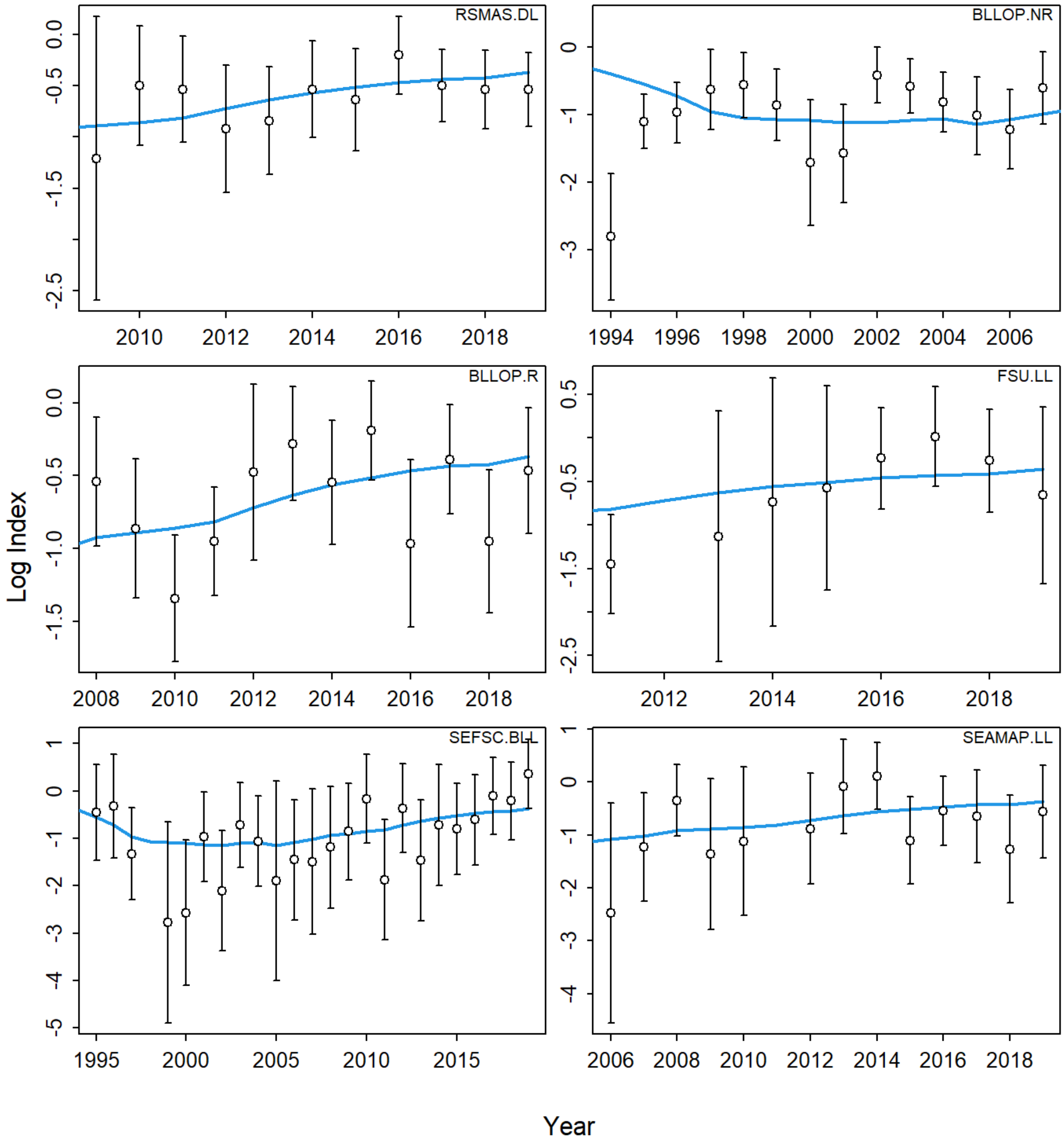


Figure 3.9.5.3. JABBA fits to the standardized catch-per-unit-effort (CPUE) (in log scale) data sets from the six indices of abundance. The solid line is the model predicted value and the circles are observed data values. Vertical lines represent the estimated 95% confidence intervals around the CPUE values.

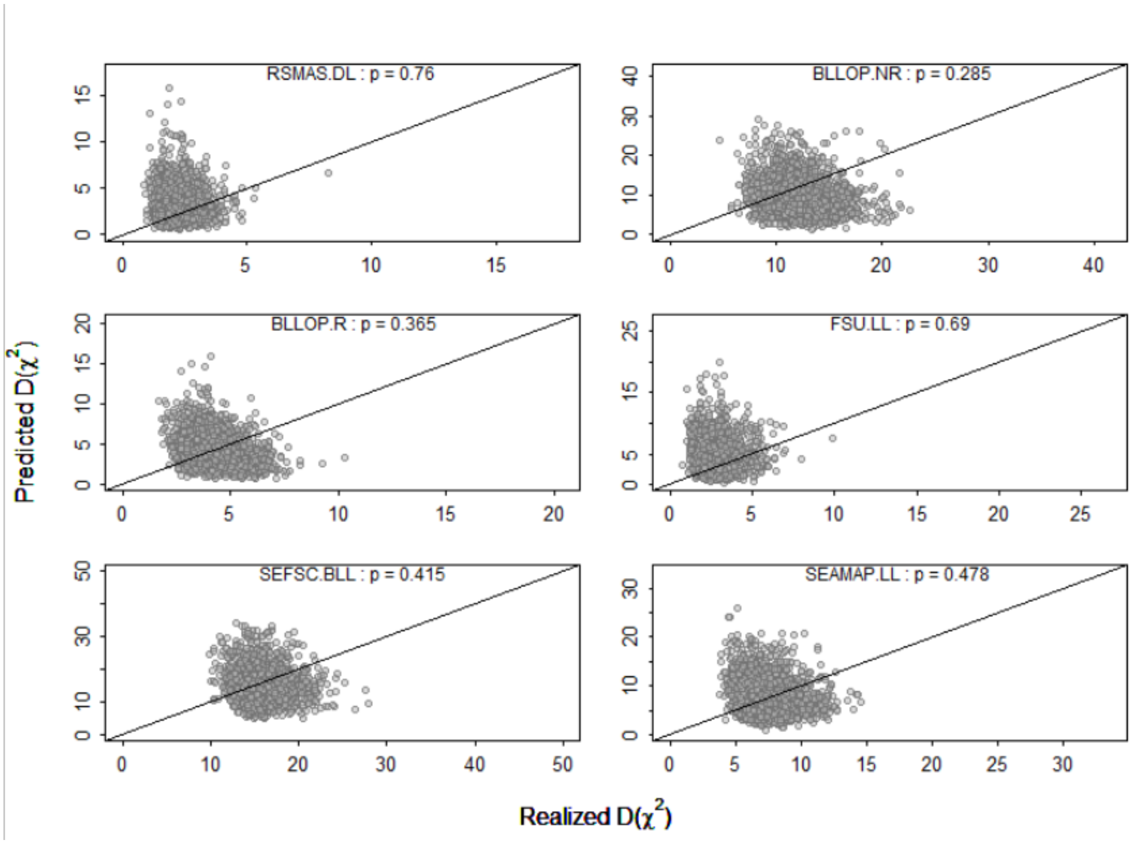


Figure 3.9.5.4. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of each of the six indices of abundance in the base run. A general rule of thumb is that ρ = 0.5 is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

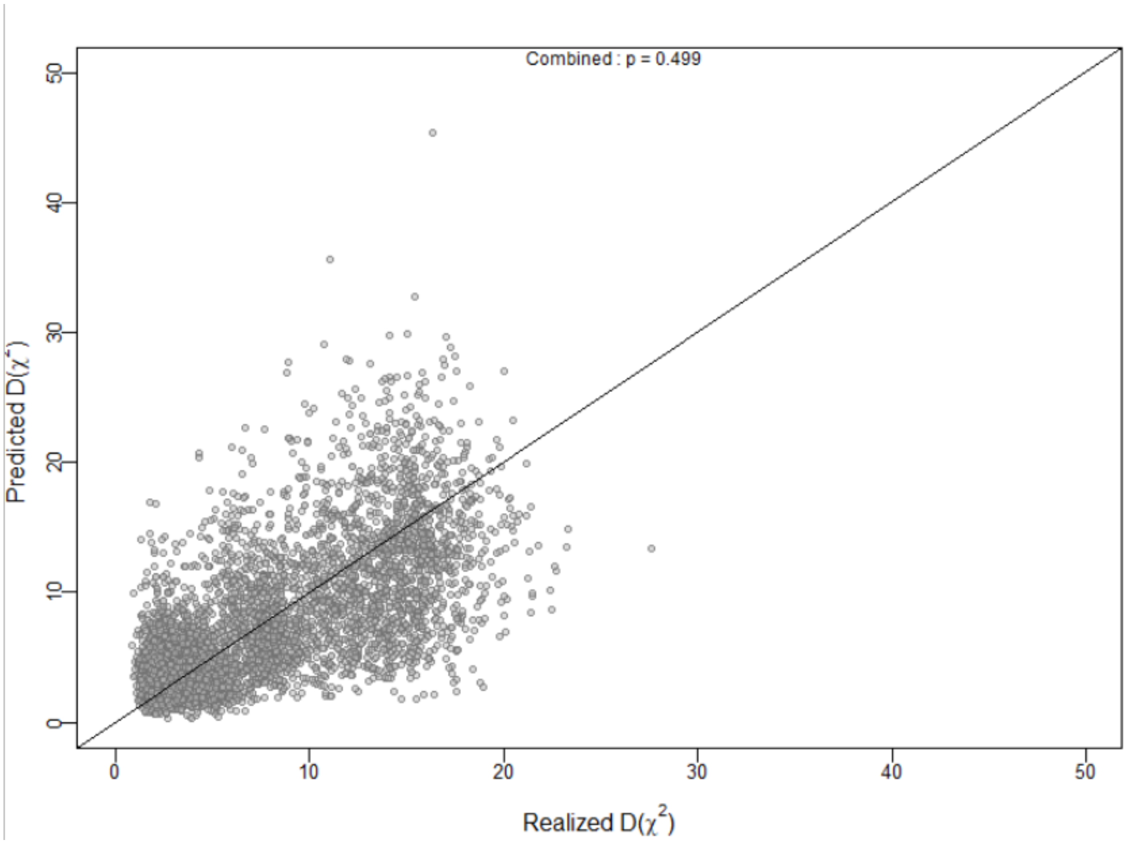


Figure 3.9.5.5. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of the combined CPUE for the base run. A general rule of thumb is that $\rho = 0.5$ is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

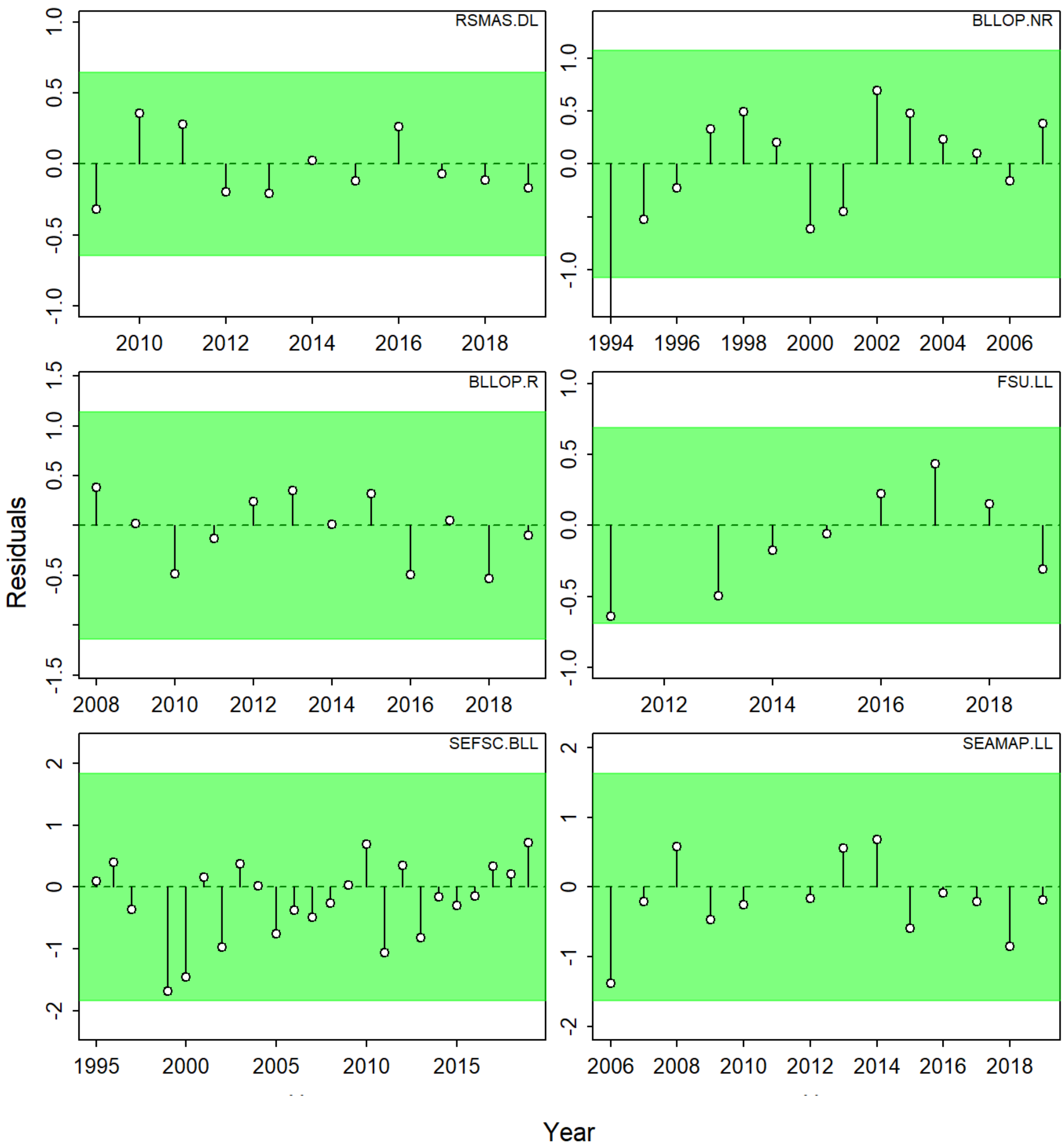


Figure 3.9.5.6. Runs test to quantitatively evaluate the randomness of the time series of CPUE residuals for each of the six indices of abundance. Green panels indicate no evidence of lack of randomness of time-series residuals (p>0.05) while red panels indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

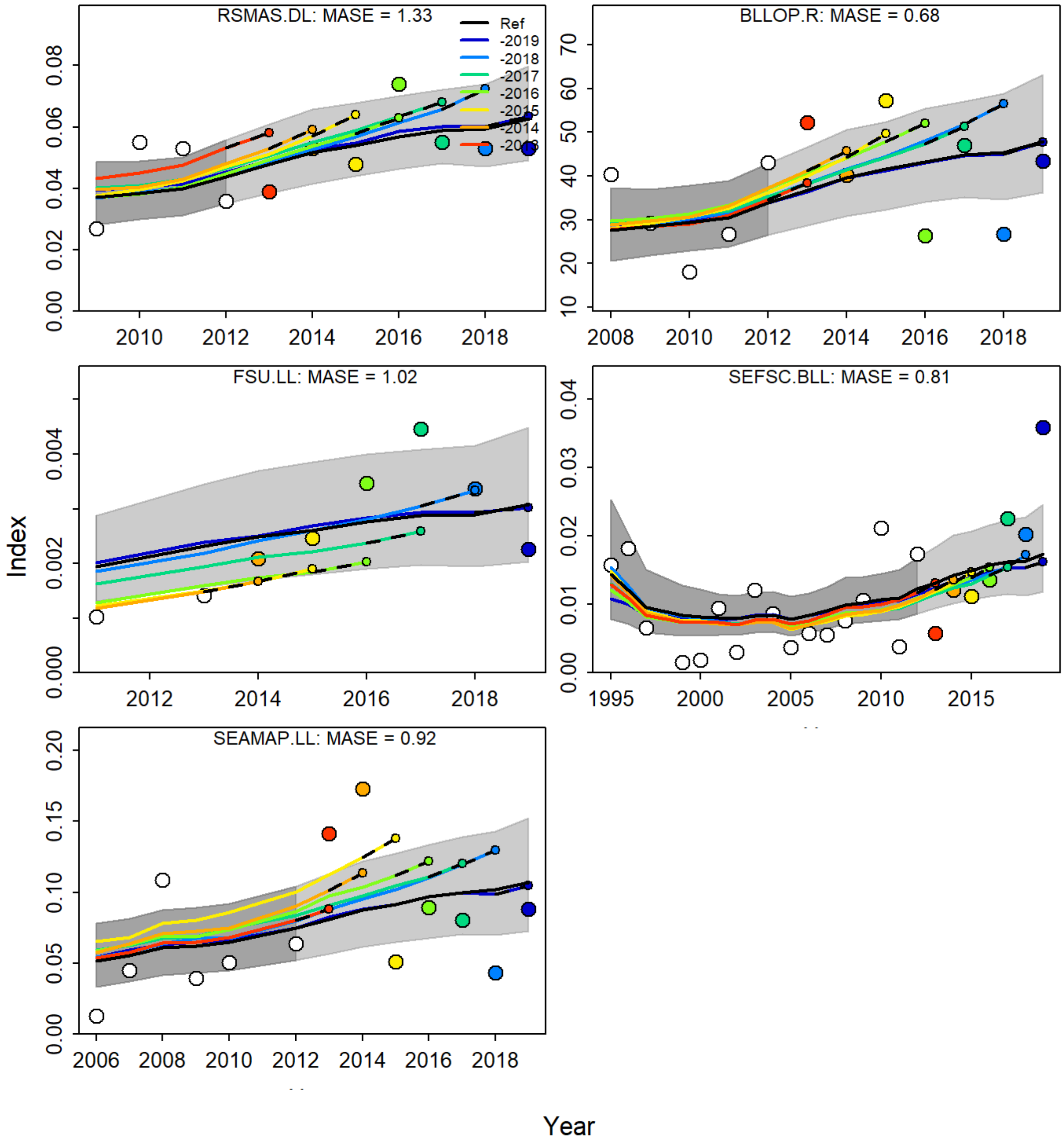


Figure 3.9.5.7. Hindcasting cross-validation results (HCxval), showing one-year-ahead forecasts of CPUE values, performed with seven hindcast model runs relative to the expected CPUE. The CPUE observations, used for cross-validation, are highlighted as color-coded solid circles with associated light-grey shaded 95% confidence interval. The model reference year refers to the end points of each one-year-ahead forecast and the corresponding observation (i.e. year of peel + 1). The joint *MASE* value is 0.89.

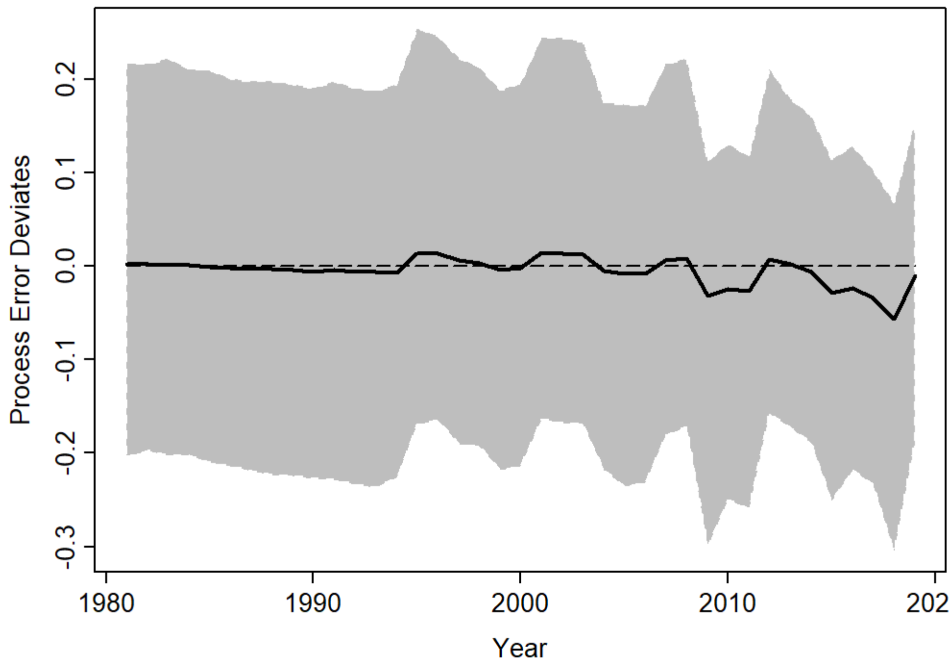


Figure 3.9.5.8. Process error deviates (median: solid line) with shaded grey area indicating 95% credibility intervals.

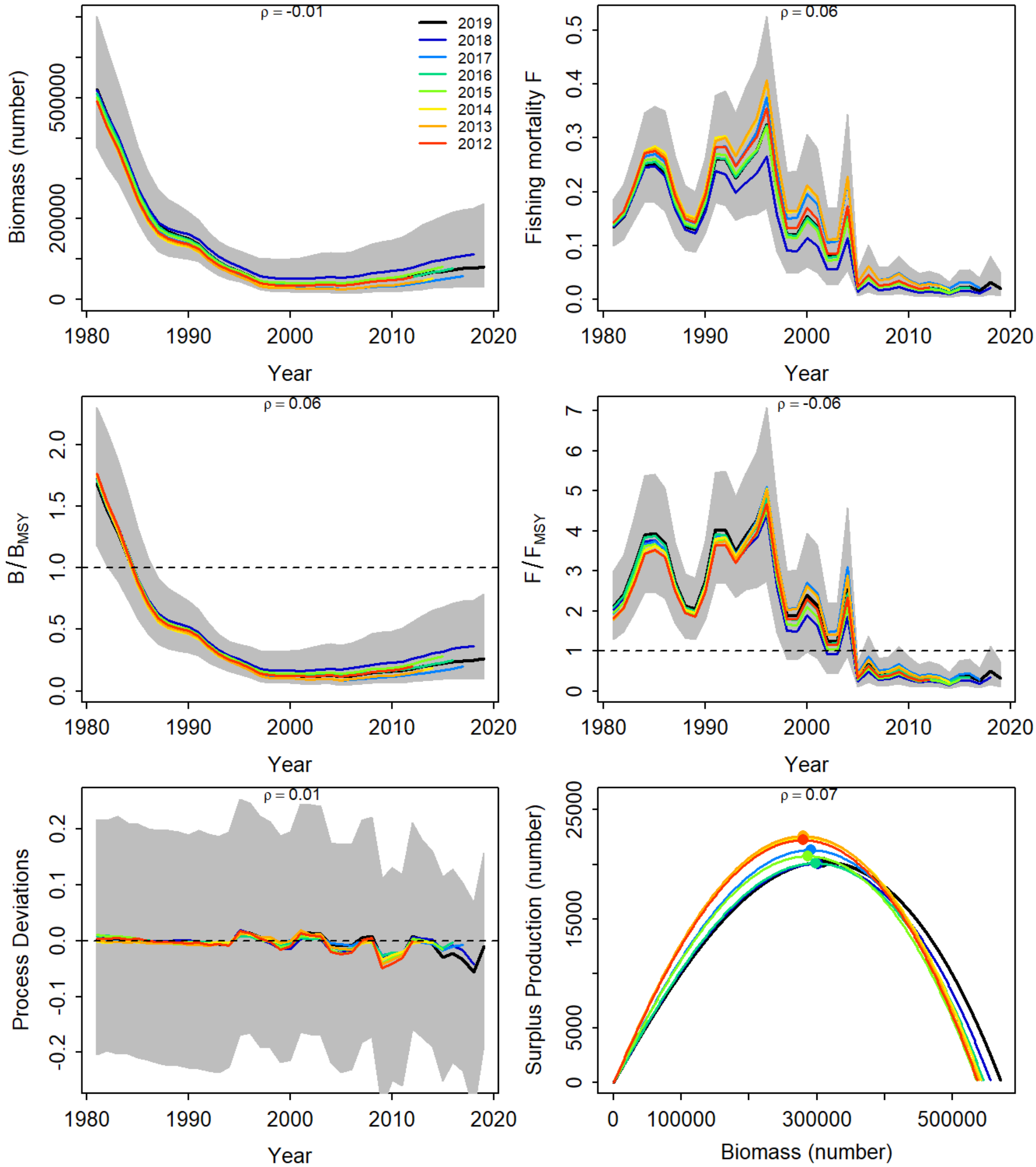


Figure 3.9.5.9. Retrospective analysis conducted by removing one year at a time sequentially (n=7) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and process deviations and surplus production curve (bottom panels).

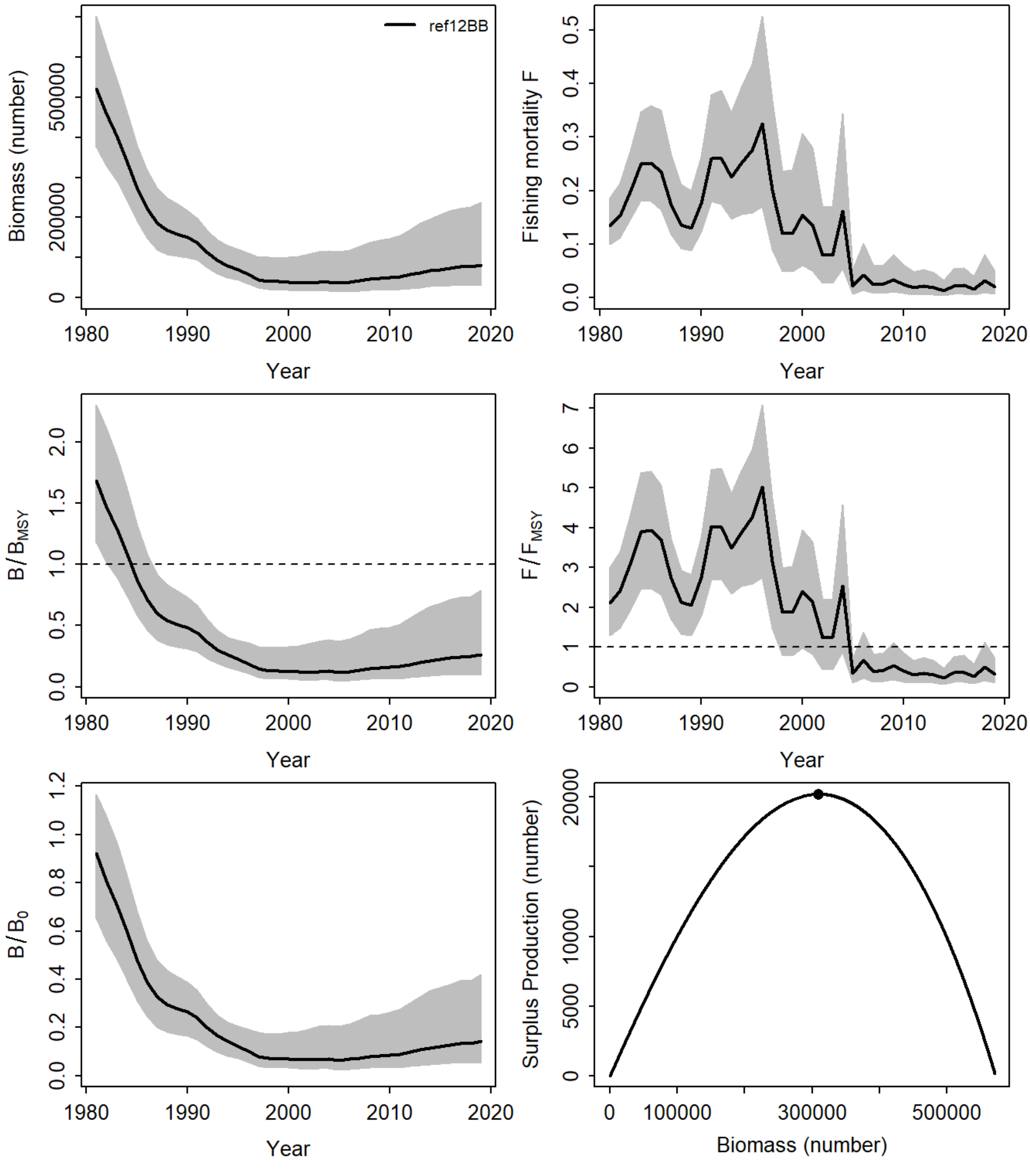


Figure 3.9.5.10. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to B_0 (B/B_0) and surplus production curve (bottom panels).

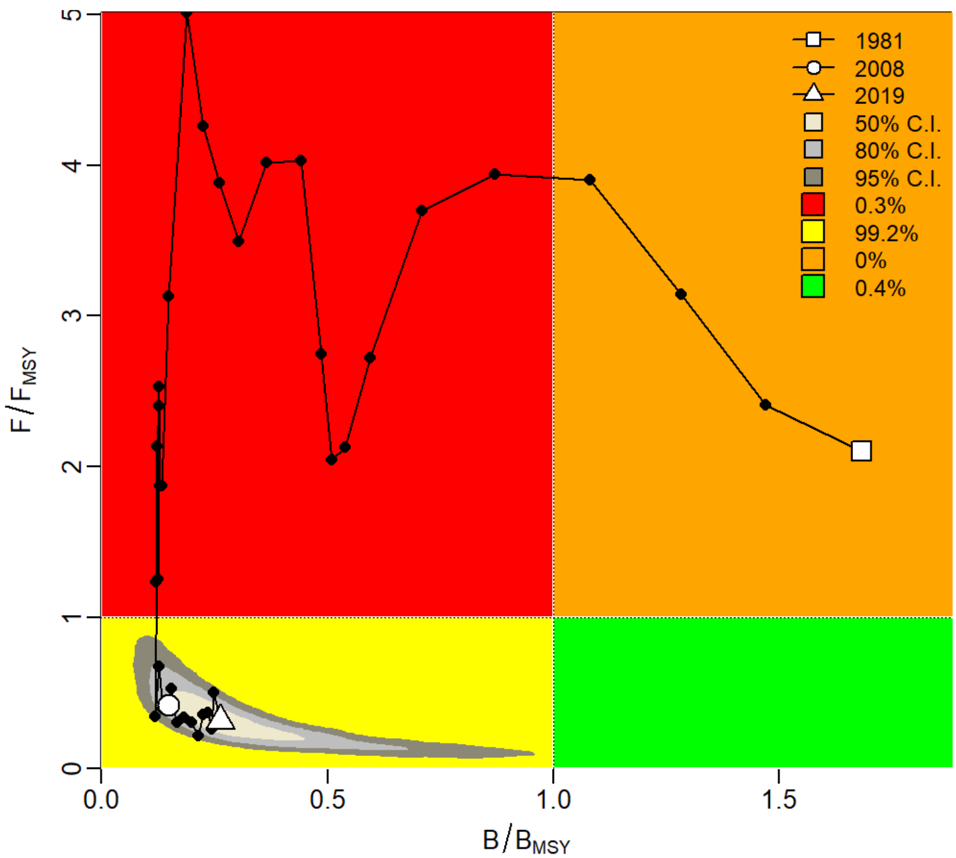


Figure 3.9.5.11. Kobe phase plot showing estimated trajectories (1981-2019) of B/B_{MSY} and F/F_{MSY}. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend.

Appendix 3.9.6: Plots for the Panel-approved 6) ref13BB (Low *r*) sensitivity run.

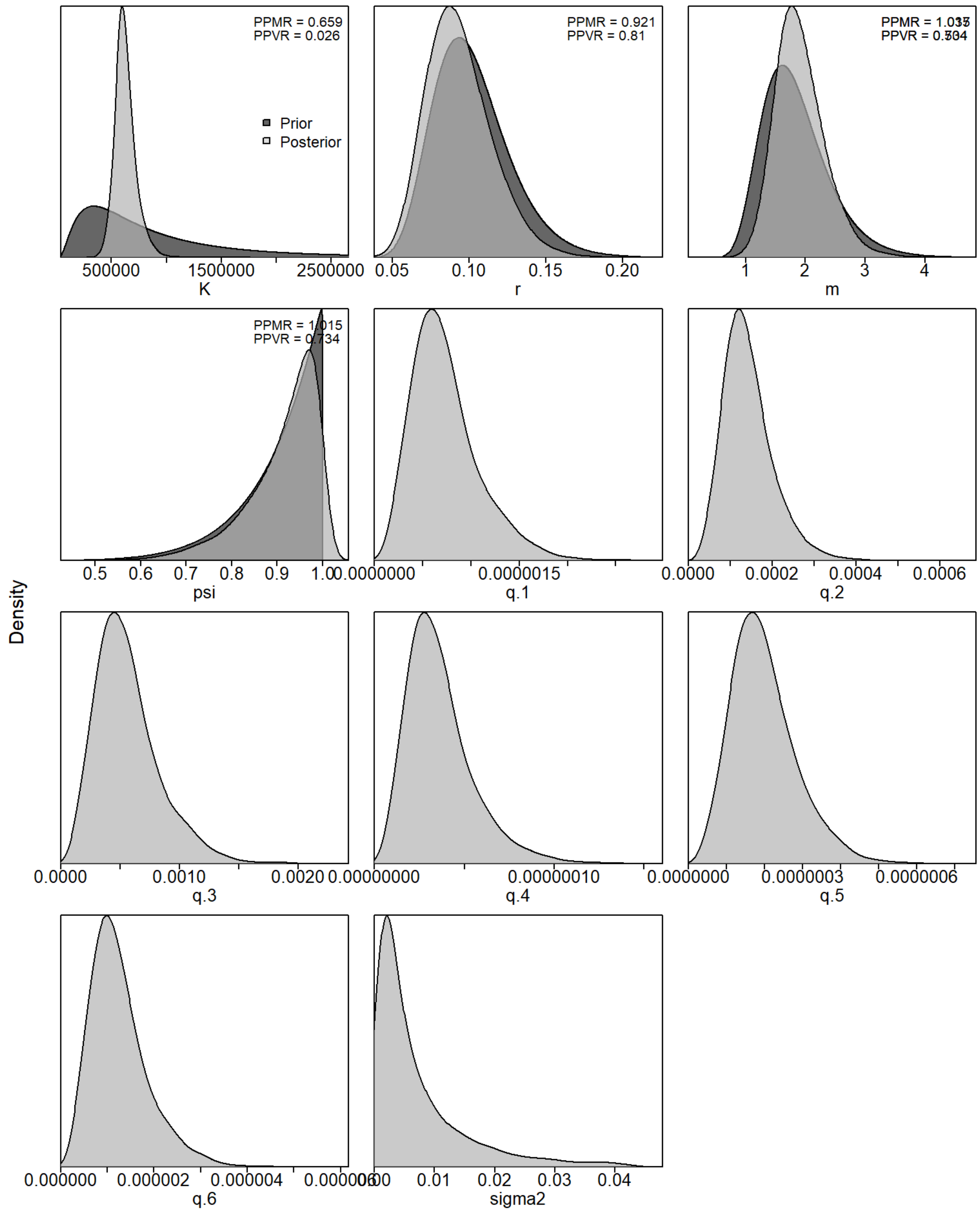


Figure 3.9.6.1. Prior and posterior distribution of various model and management parameters. *PPRM*: Posterior to Prior Ratio of Medians; *PPRV*: Posterior to Prior Ratio of Variances.

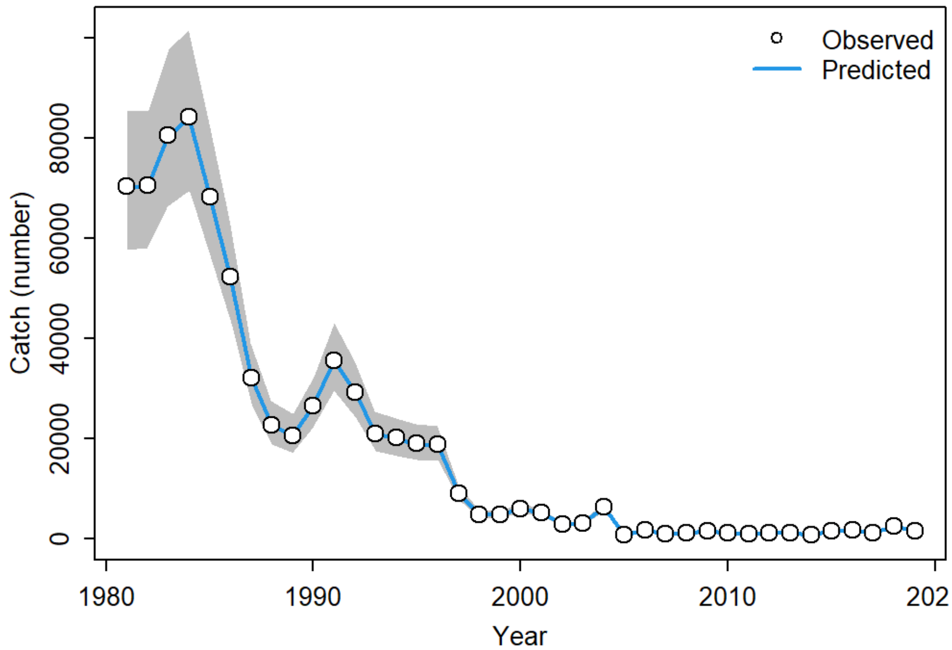


Figure 3.9.6.2. Catches of great hammerheads in numbers (1981-2019).

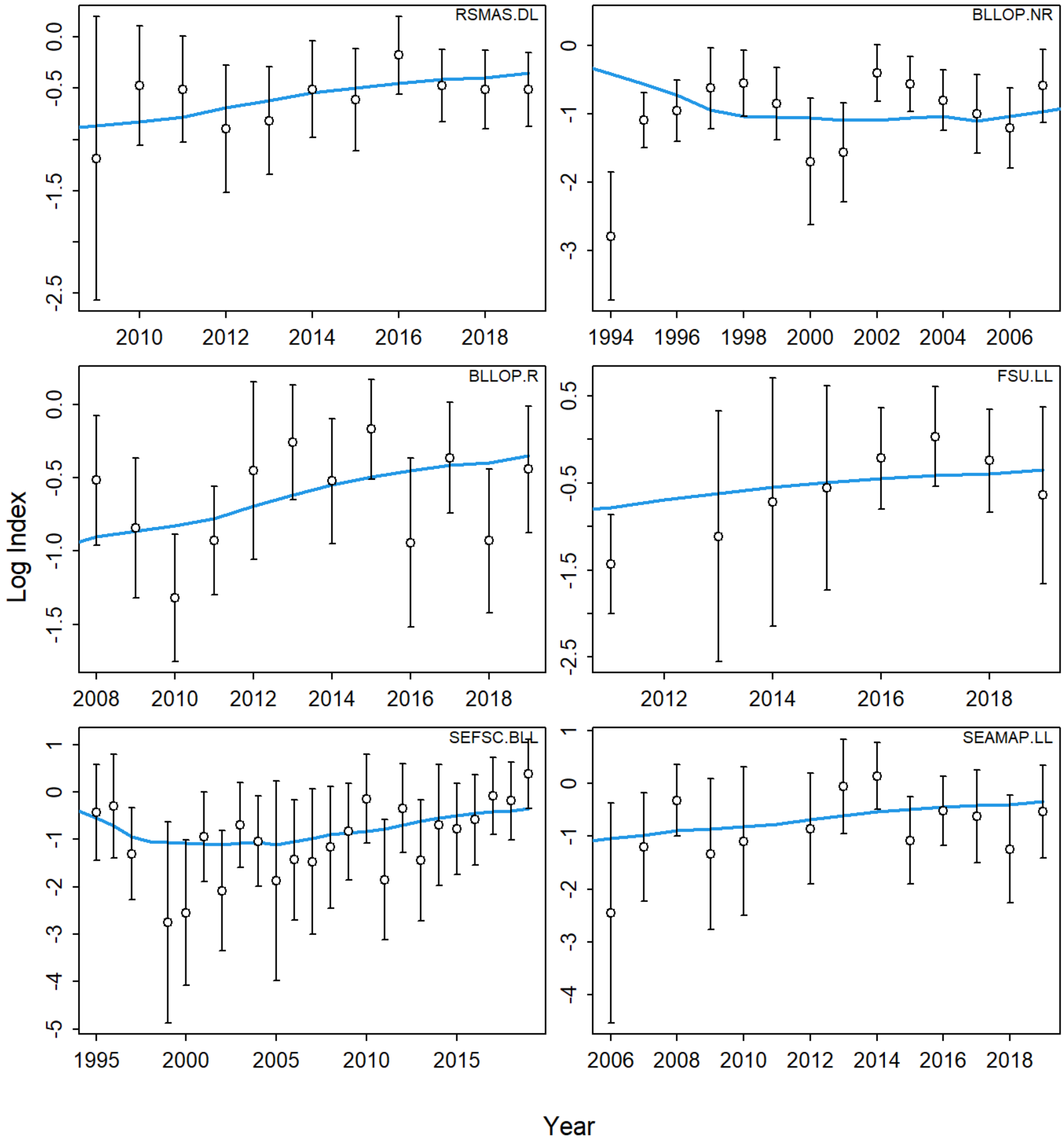


Figure 3.9.6.3. JABBA fits to the standardized catch-per-unit-effort (CPUE) (in log scale) data sets from the six indices of abundance. The solid line is the model predicted value and the circles are observed data values. Vertical lines represent the estimated 95% confidence intervals around the CPUE values.

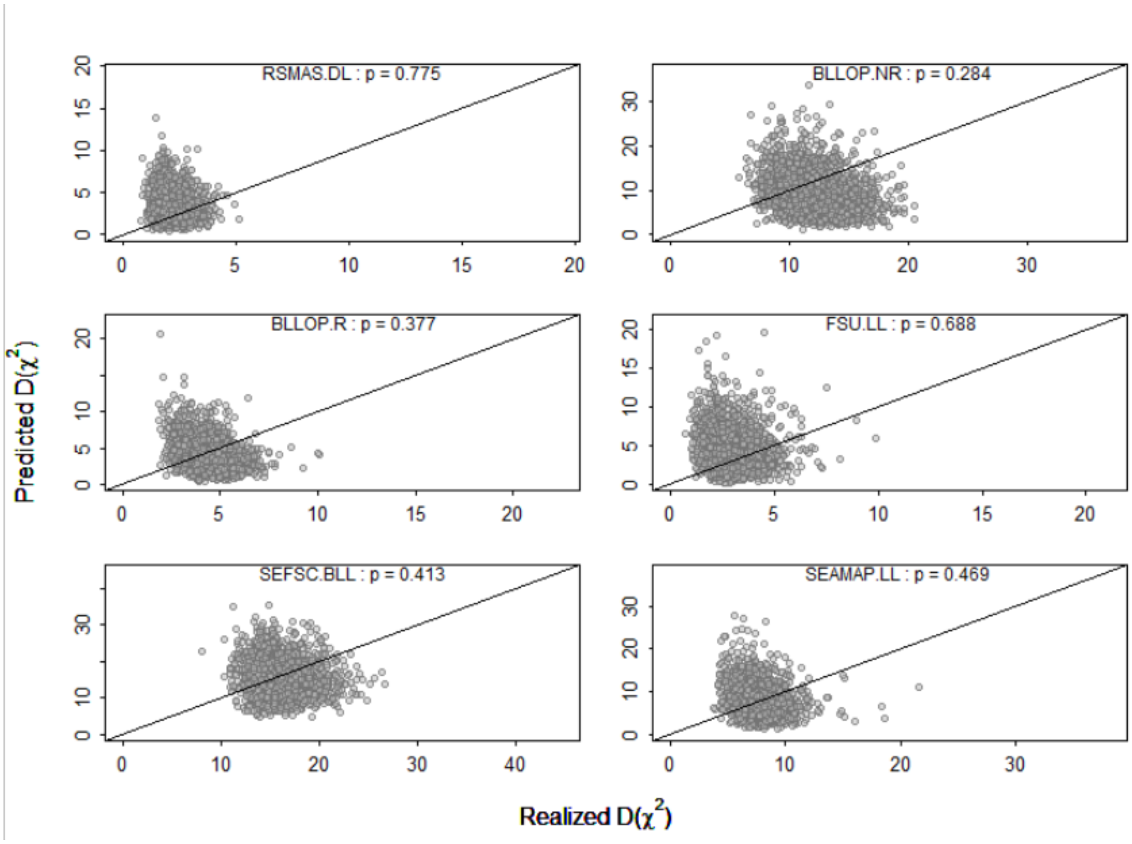


Figure 3.9.6.4. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of each of the six indices of abundance in the base run. A general rule of thumb is that ρ = 0.5 is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

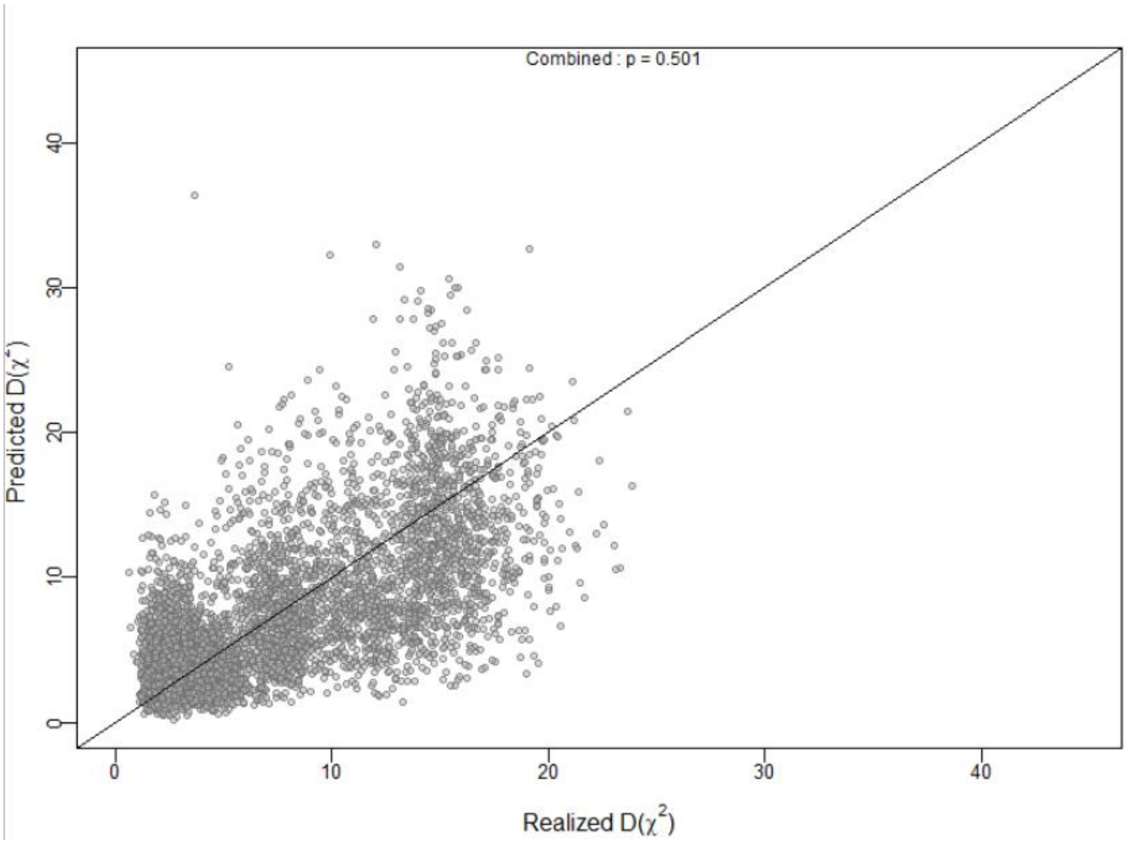


Figure 3.9.6.5. Posterior predictive check of CPUE fits compared to the posterior predictive distribution (new JABBA feature recommended by A.E. Punt) of the combined CPUE for the base run. A general rule of thumb is that ρ = 0.5 is ideal and a range 0.2-0.8 is acceptable. In essence the posterior predictive check tests if the model error assumptions are consistent with the underlying data generation process.

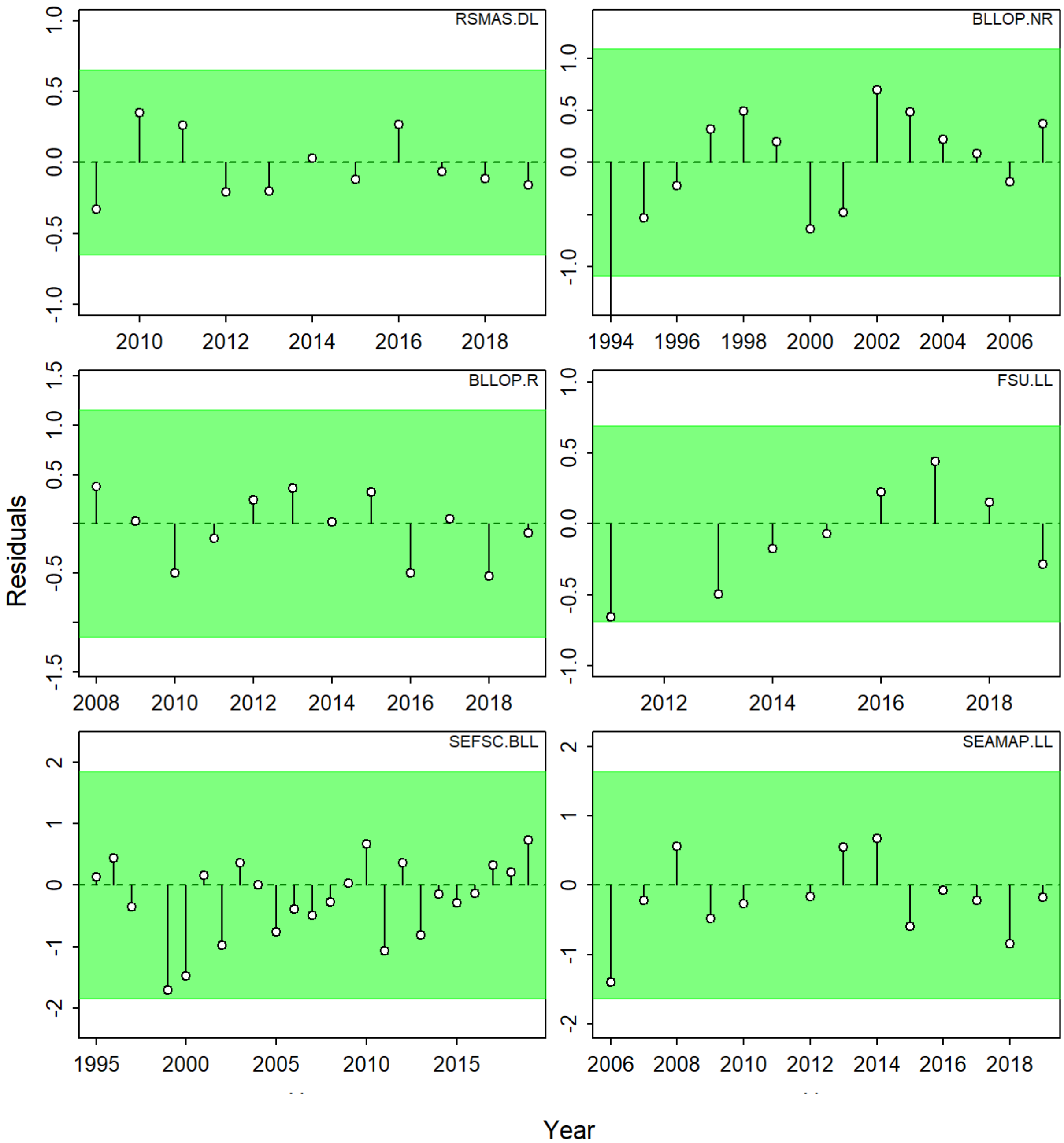


Figure 3.9.6.6. Runs test to quantitatively evaluate the randomness of the time series of CPUE residuals for each of the six indices of abundance. Green panels indicate no evidence of lack of randomness of time-series residuals (*p*>0.05) while red panels indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

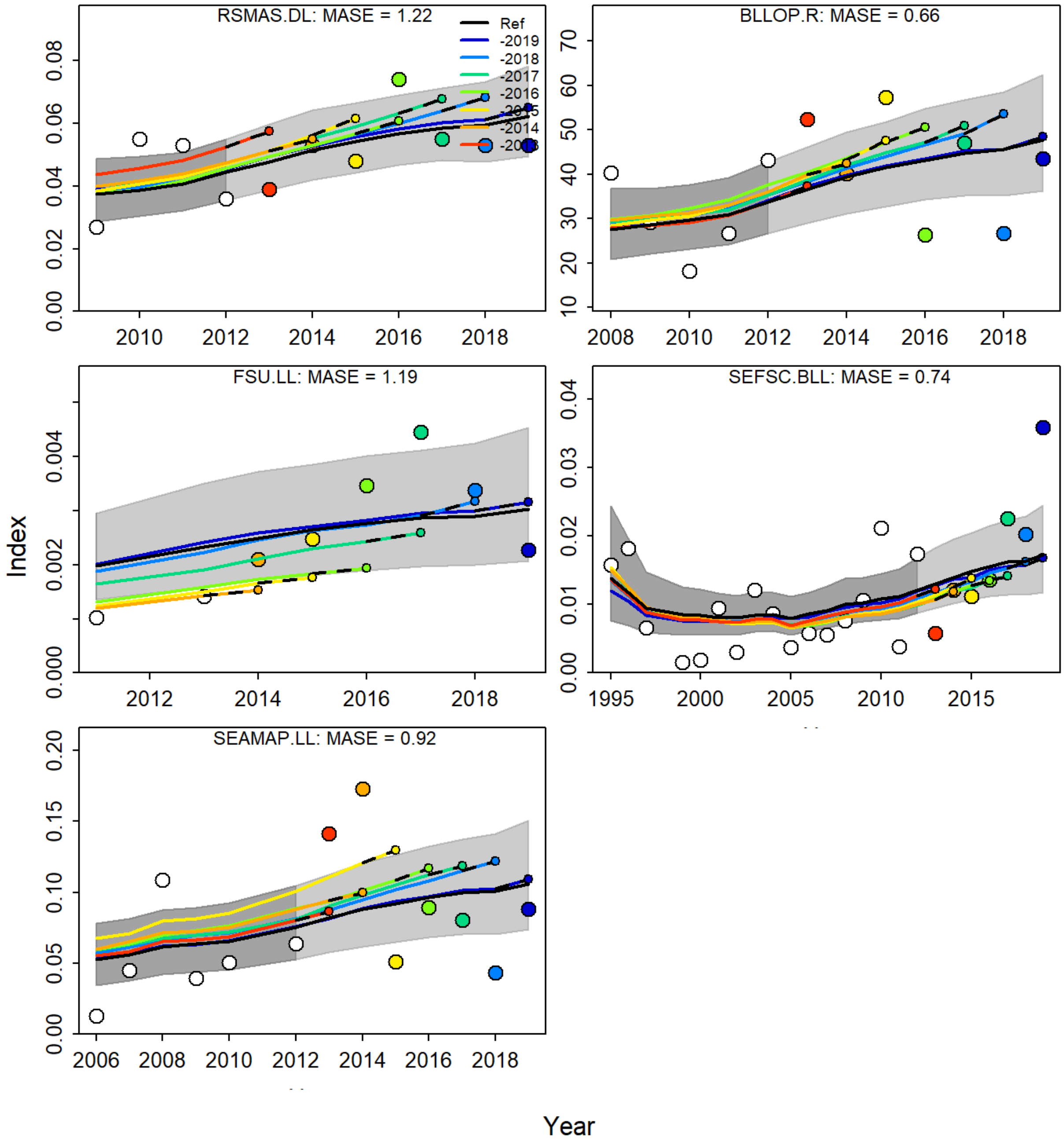


Figure 3.9.6.7. Hindcasting cross-validation results (HCxval), showing one-year-ahead forecasts of CPUE values, performed with seven hindcast model runs relative to the expected CPUE. The CPUE observations, used for cross-validation, are highlighted as color-coded solid circles with associated light-grey shaded 95% confidence interval. The model reference year refers to the end points of each one-year-ahead forecast and the corresponding observation (i.e. year of peel + 1). The joint *MASE* value is 0.88.

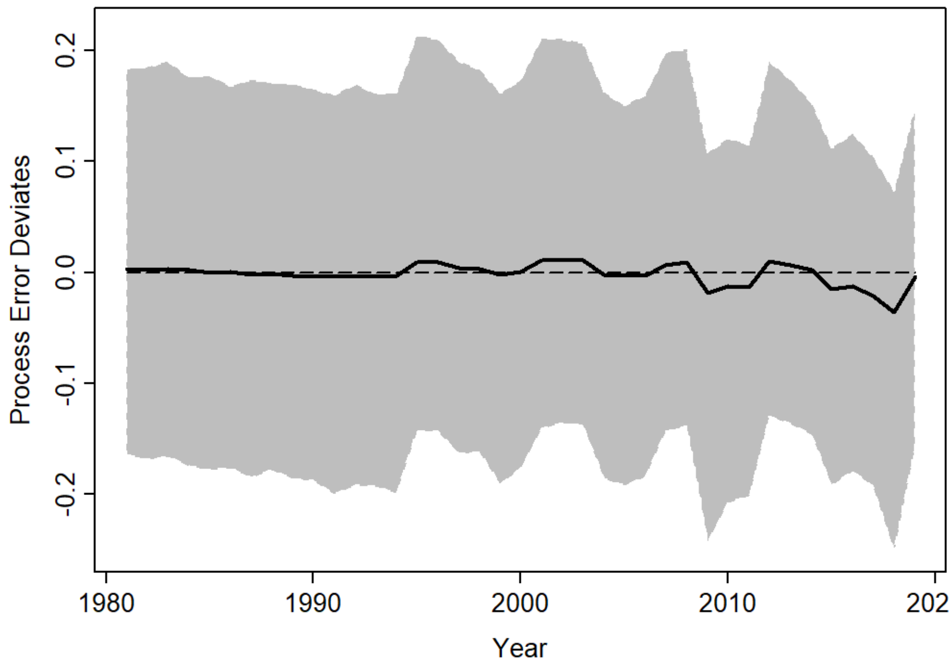


Figure 3.9.6.8. Process error deviates (median: solid line) with shaded grey area indicating 95% credibility intervals.

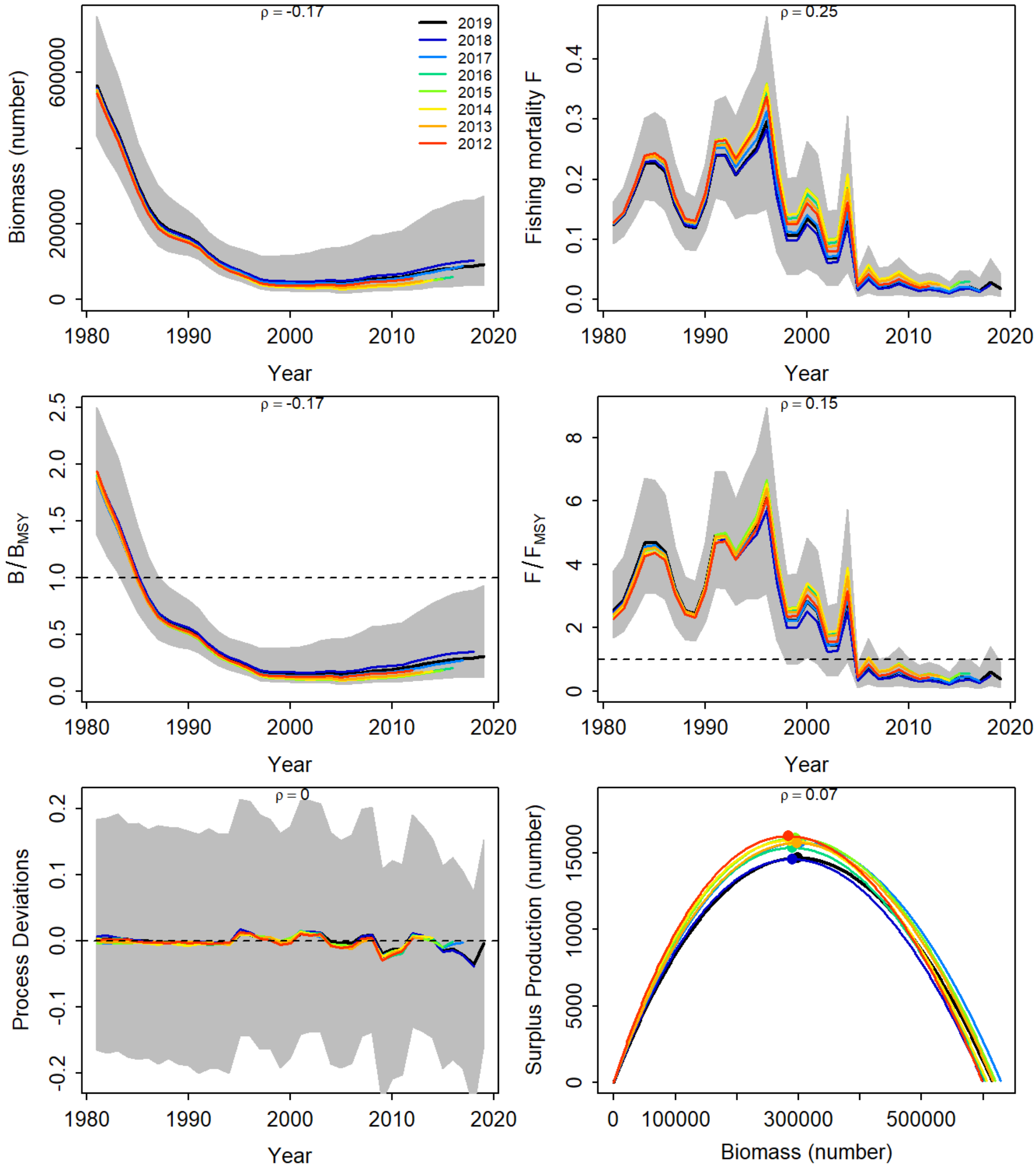


Figure 3.9.6.9. Retrospective analysis conducted by removing one year at a time sequentially (n=7) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and process deviations and surplus production curve (bottom panels).

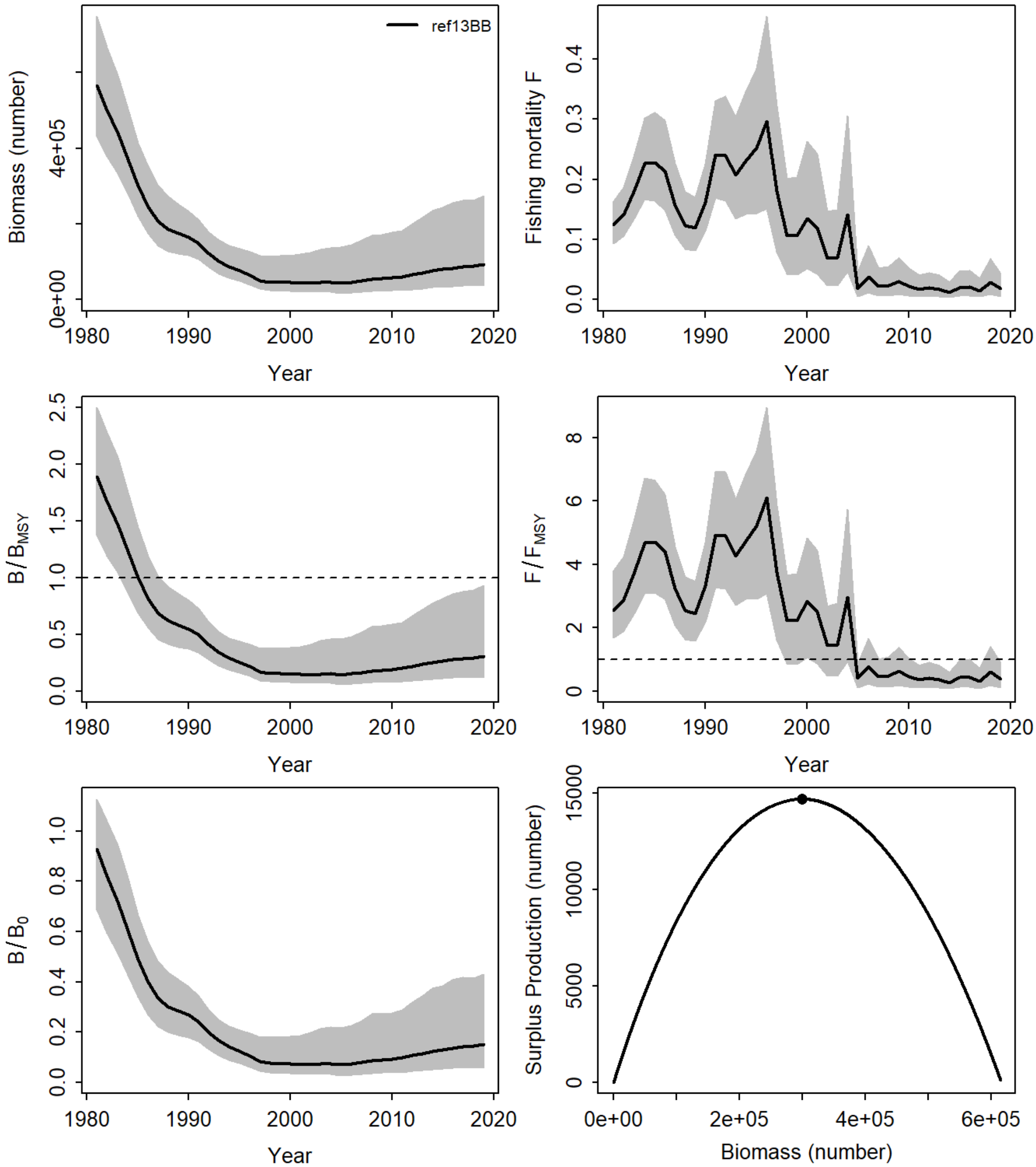


Figure 3.9.6.10. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to B_0 (B/B_0) and surplus production curve (bottom panels).

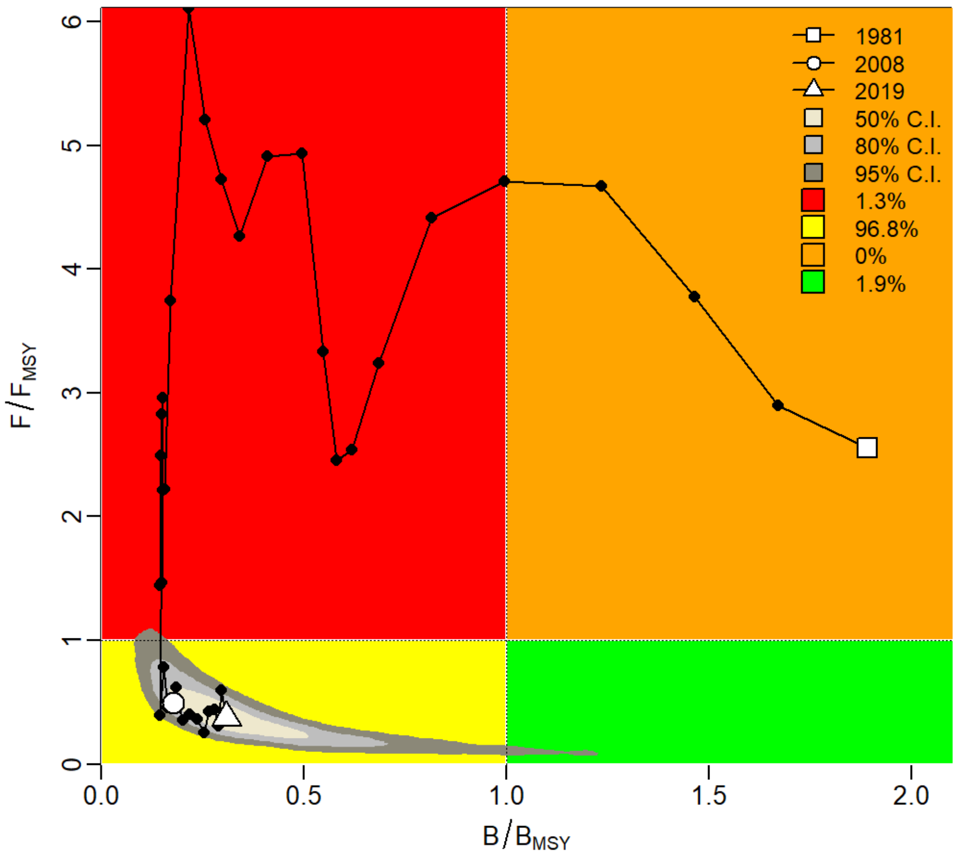


Figure 3.9.6.11. Kobe phase plot showing estimated trajectories (1981-2019) of B/B_{MSY} and F/F_{MSY}. Different grey shaded areas denote the 50%, 80%, and 95% credibility interval for the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend.

Appendix 3.9.7: Plots for the Panel-approved 7) ref3_2BB (High *CV*) sensitivity run.

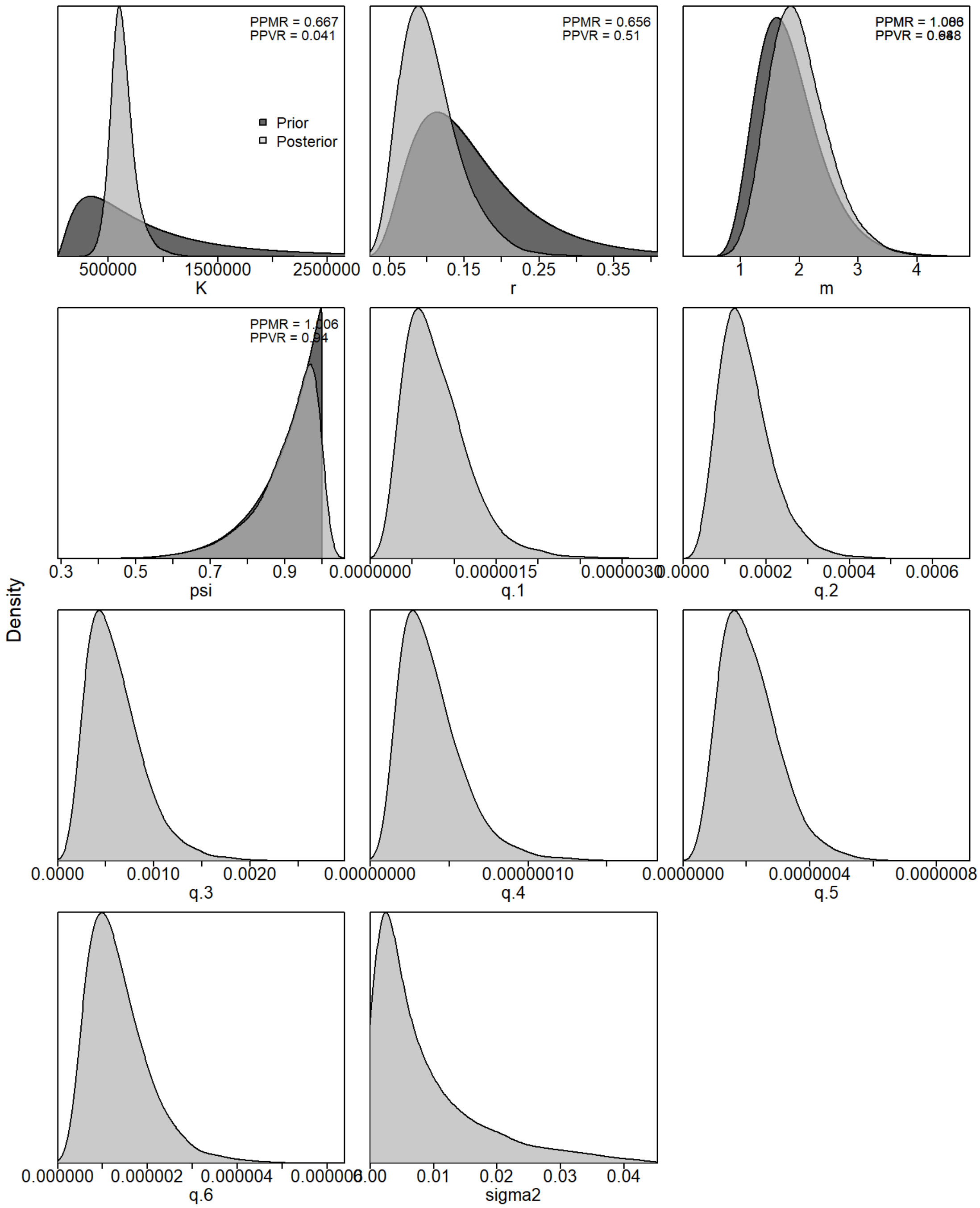


Figure 3.9.7.1. Prior and posterior distribution of various model and management parameters. *PPRM*: Posterior to Prior Ratio of Medians; *PPRV*: Posterior to Prior Ratio of Variances.

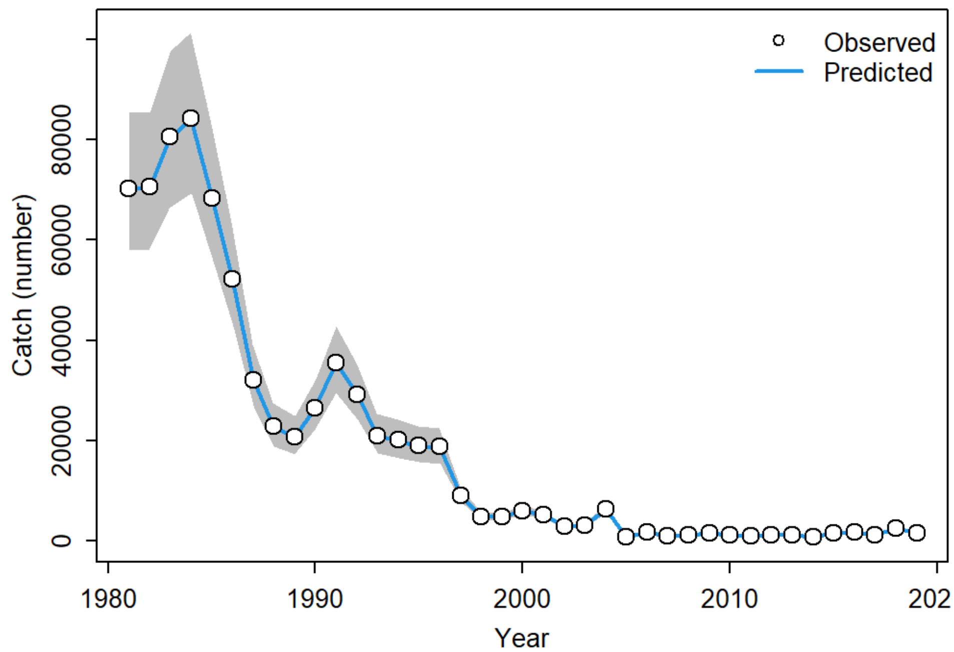
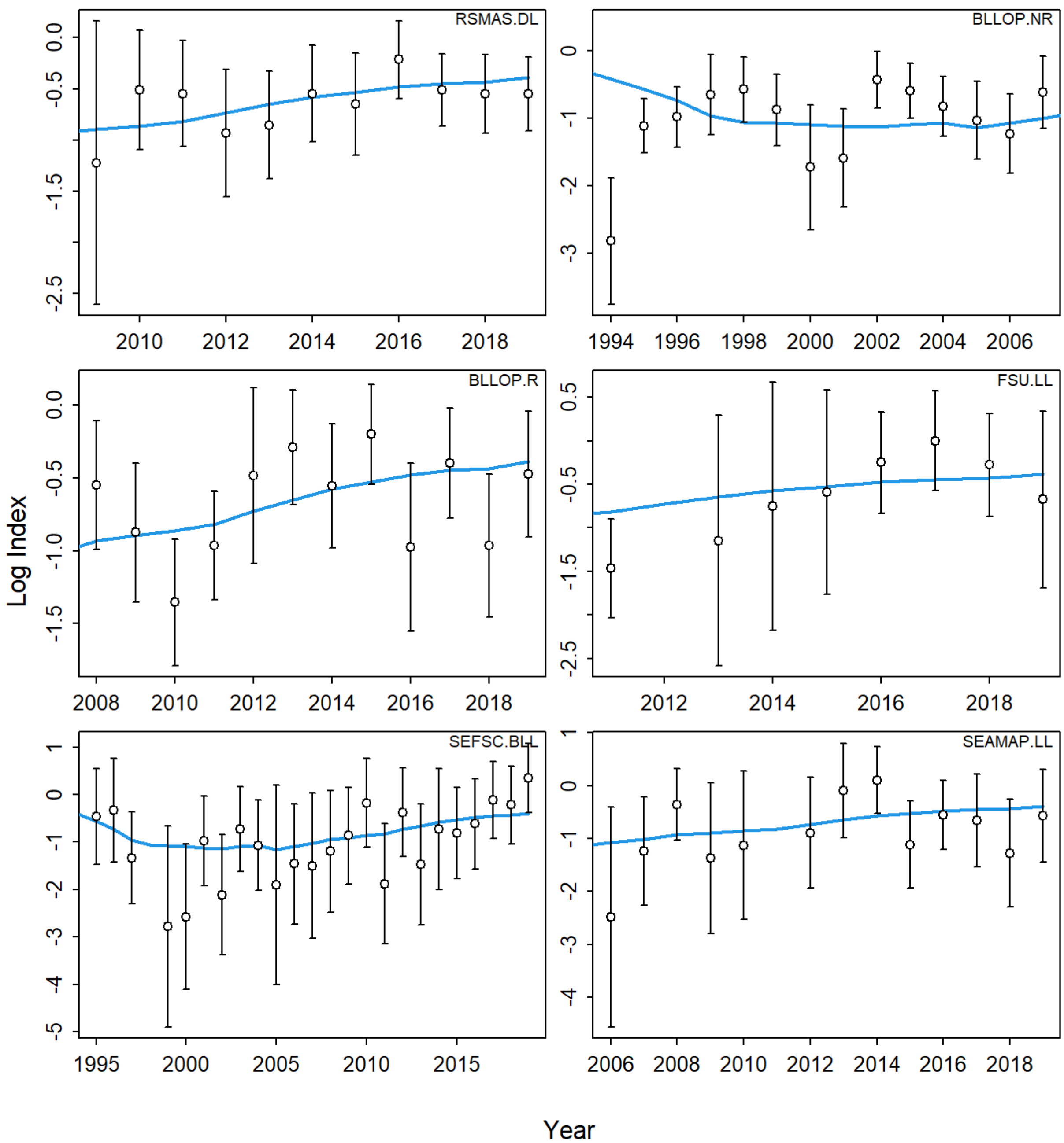


Figure 3.9.7.2. Catches of great hammerheads in numbers (1981-2019).



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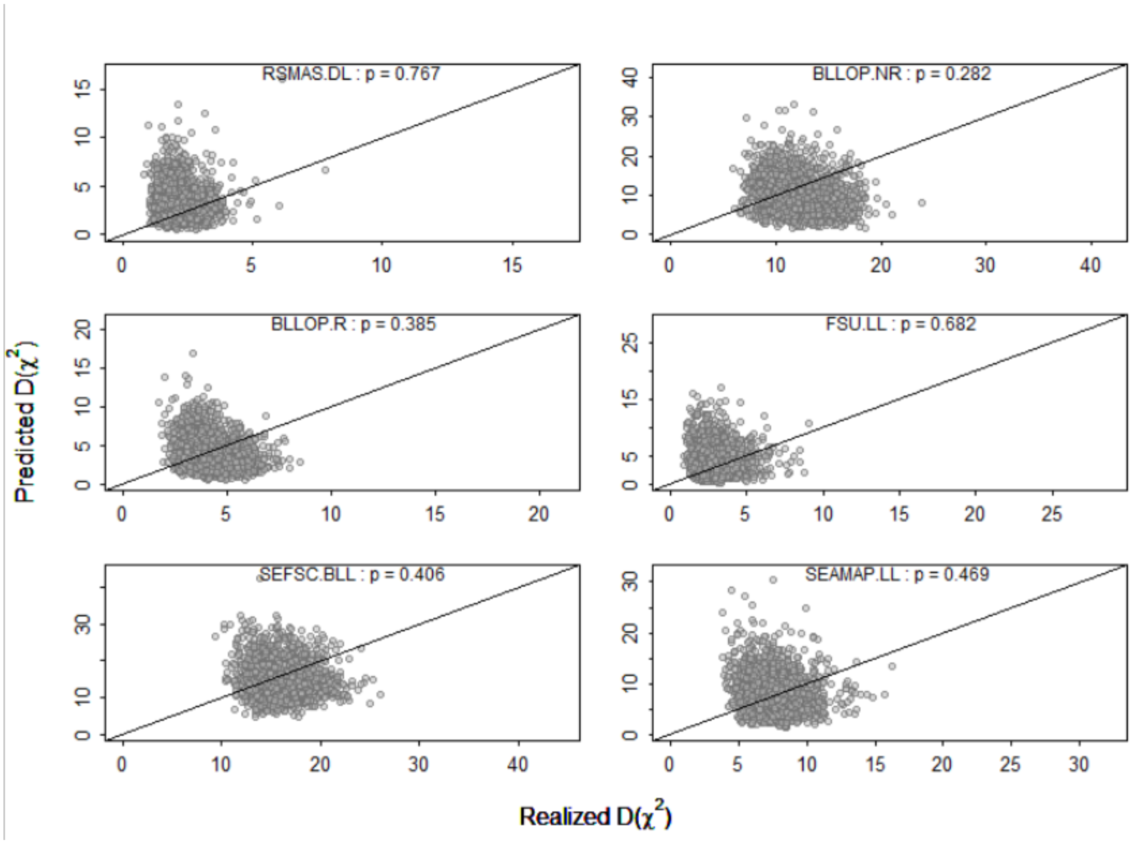

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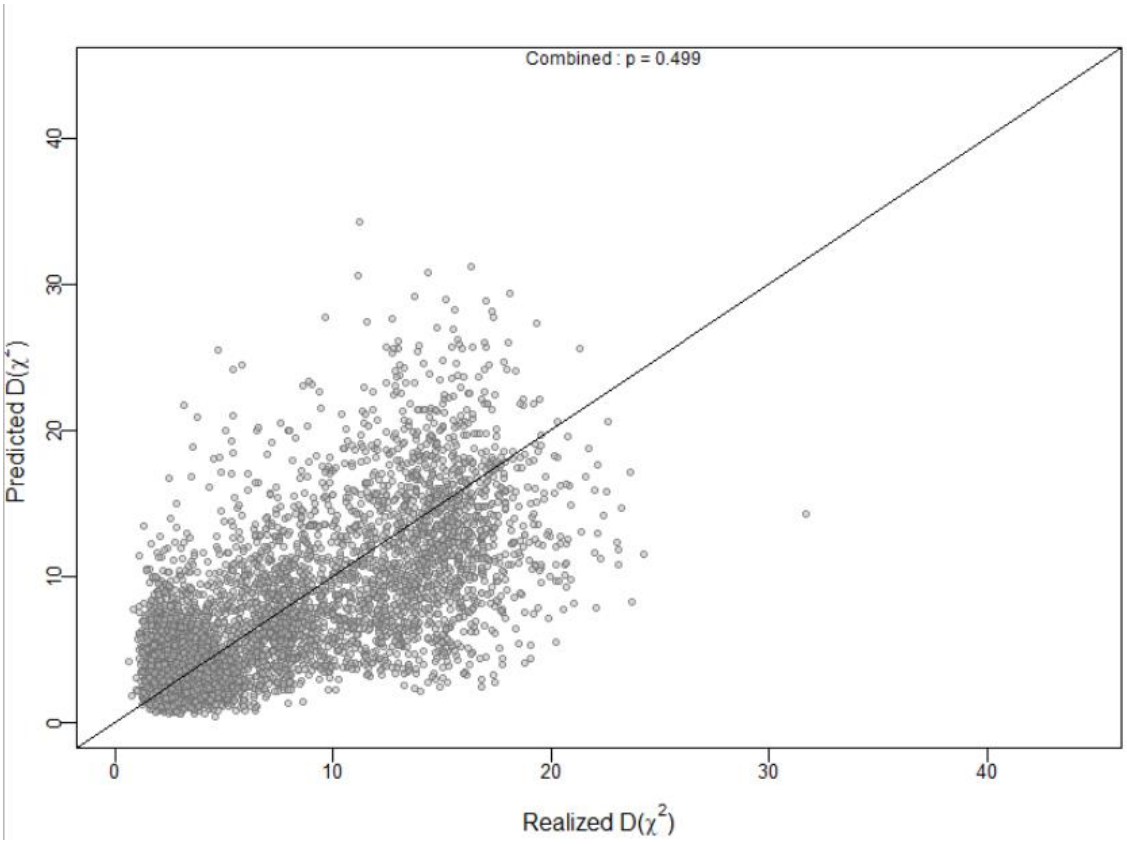

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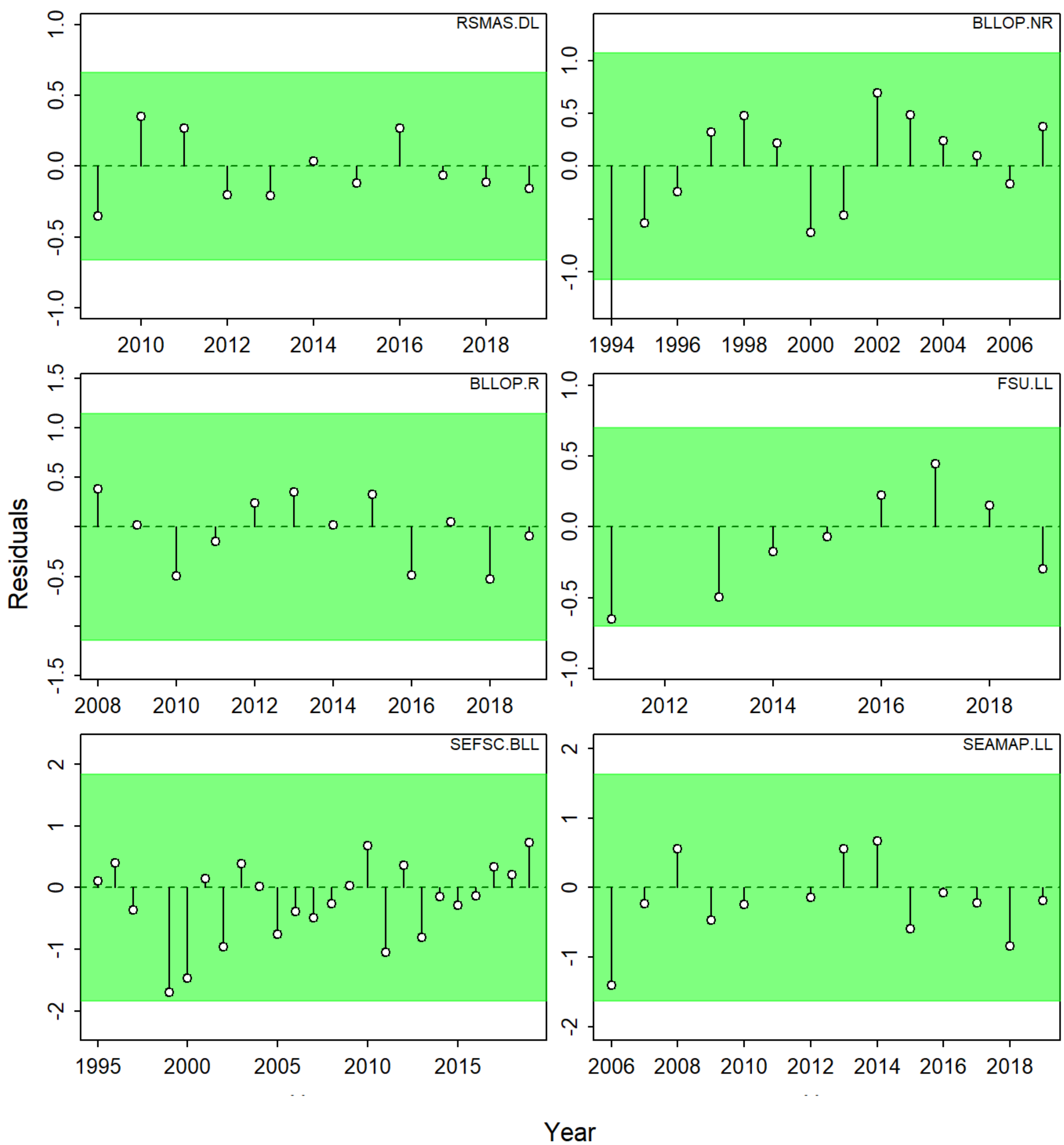

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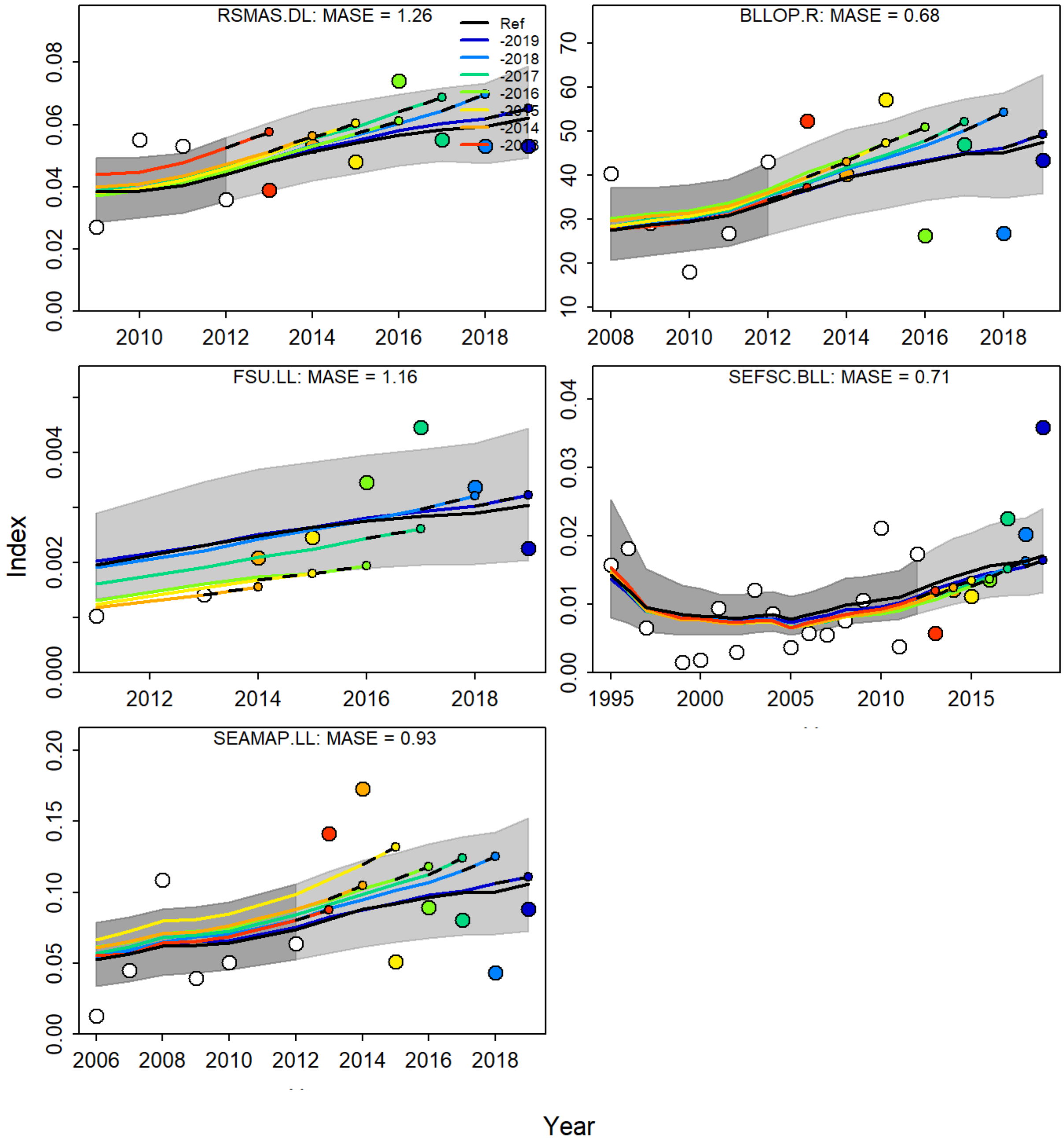

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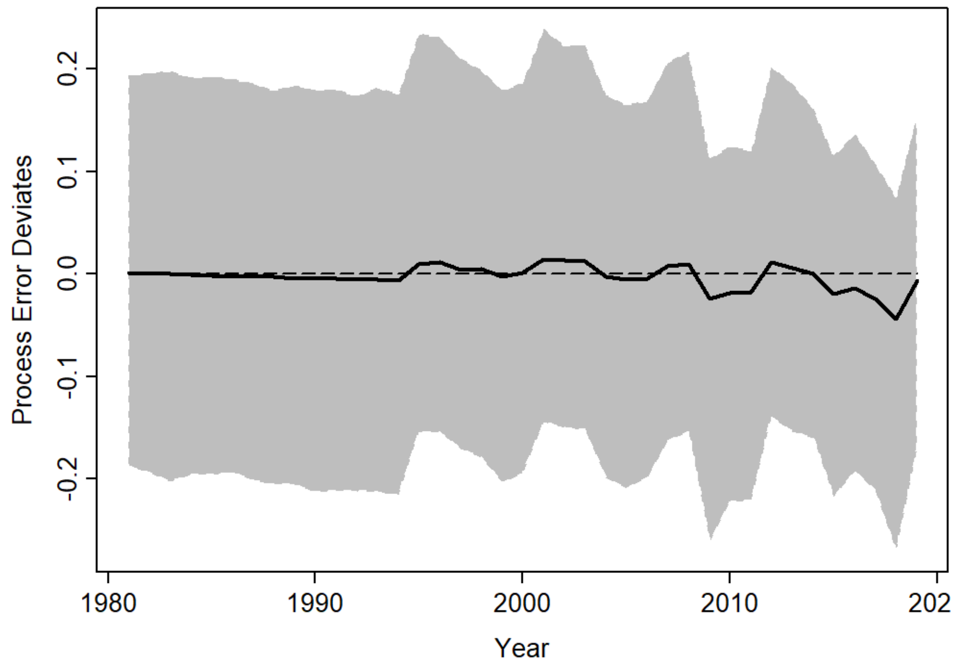

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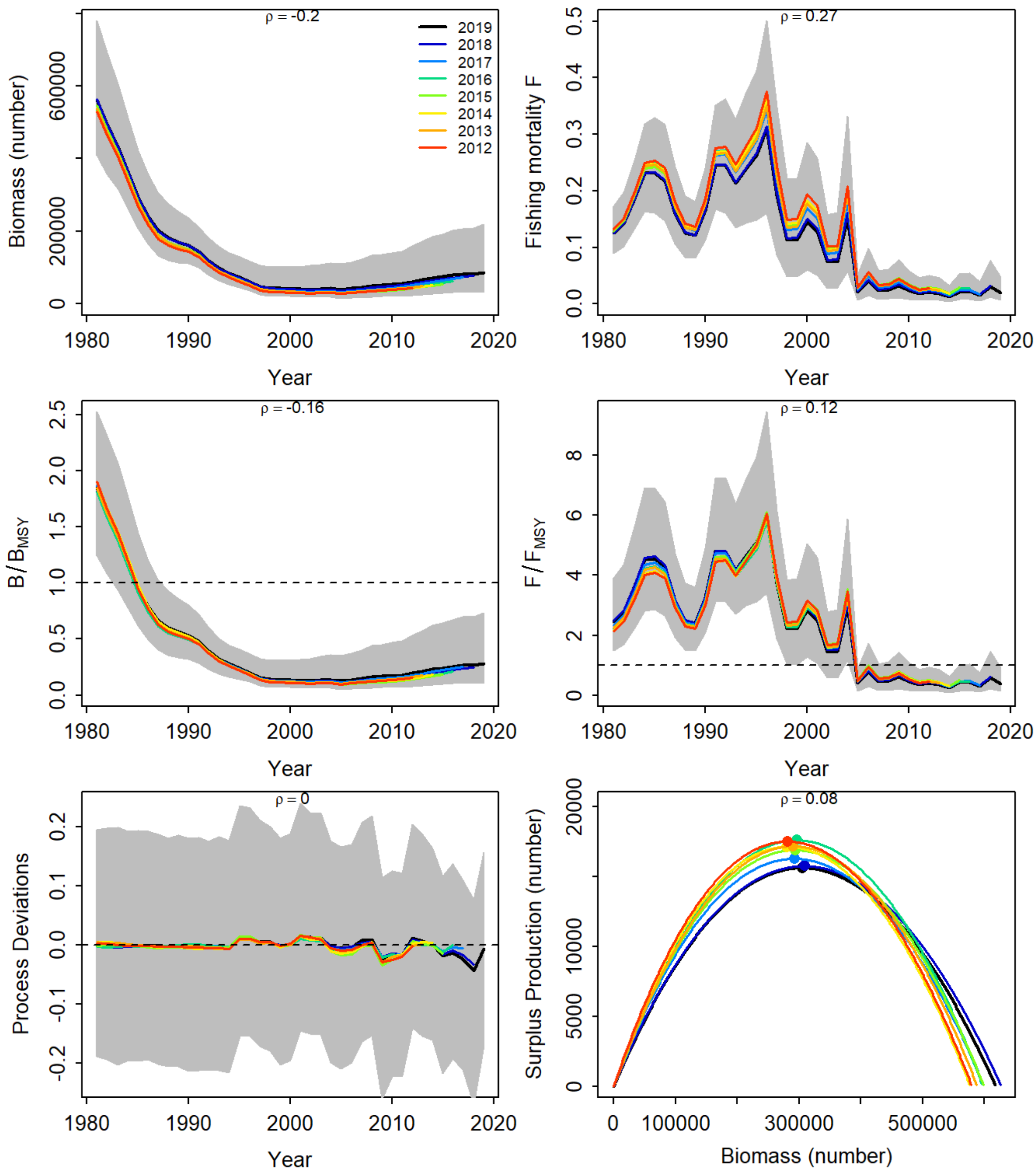

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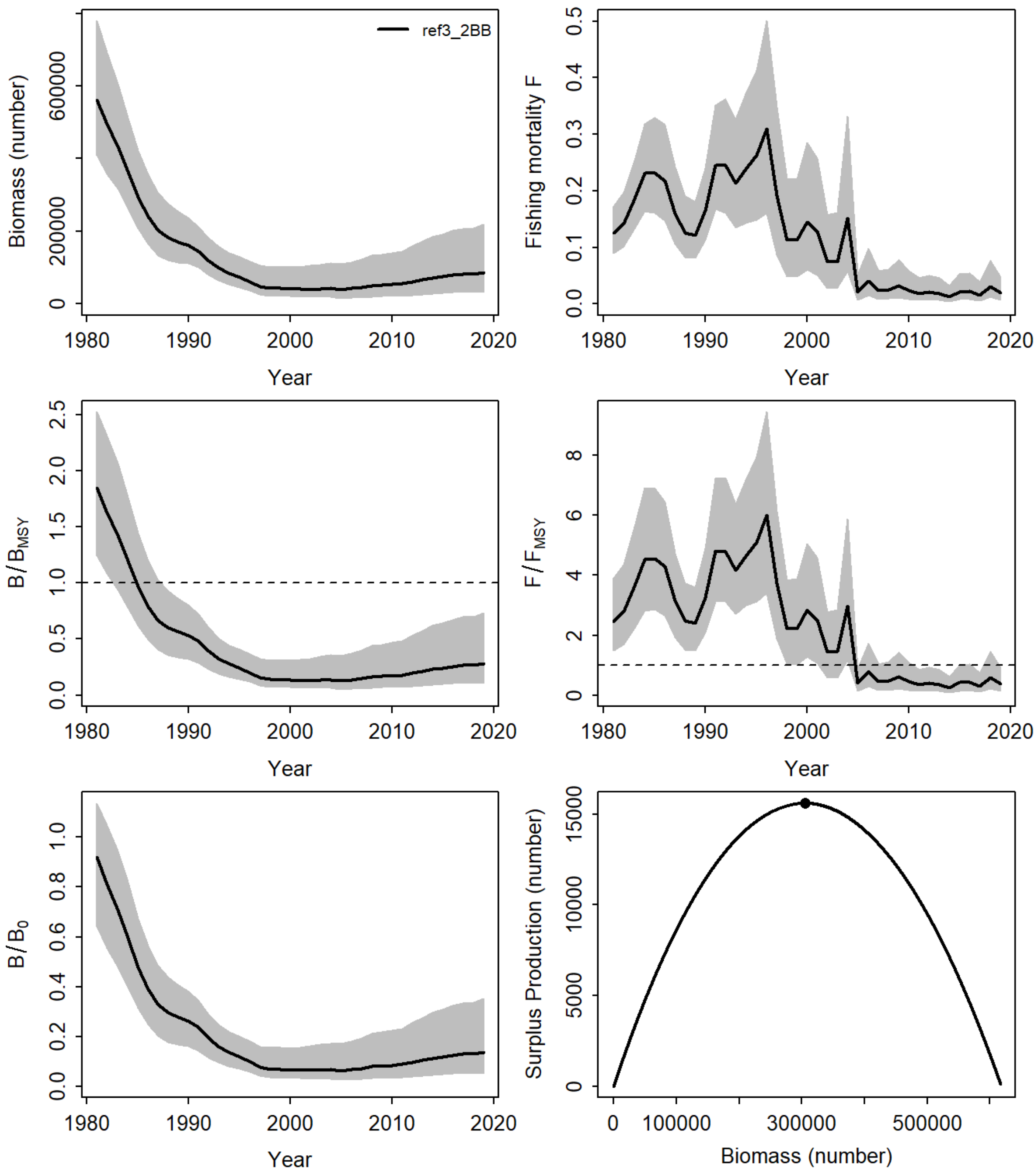

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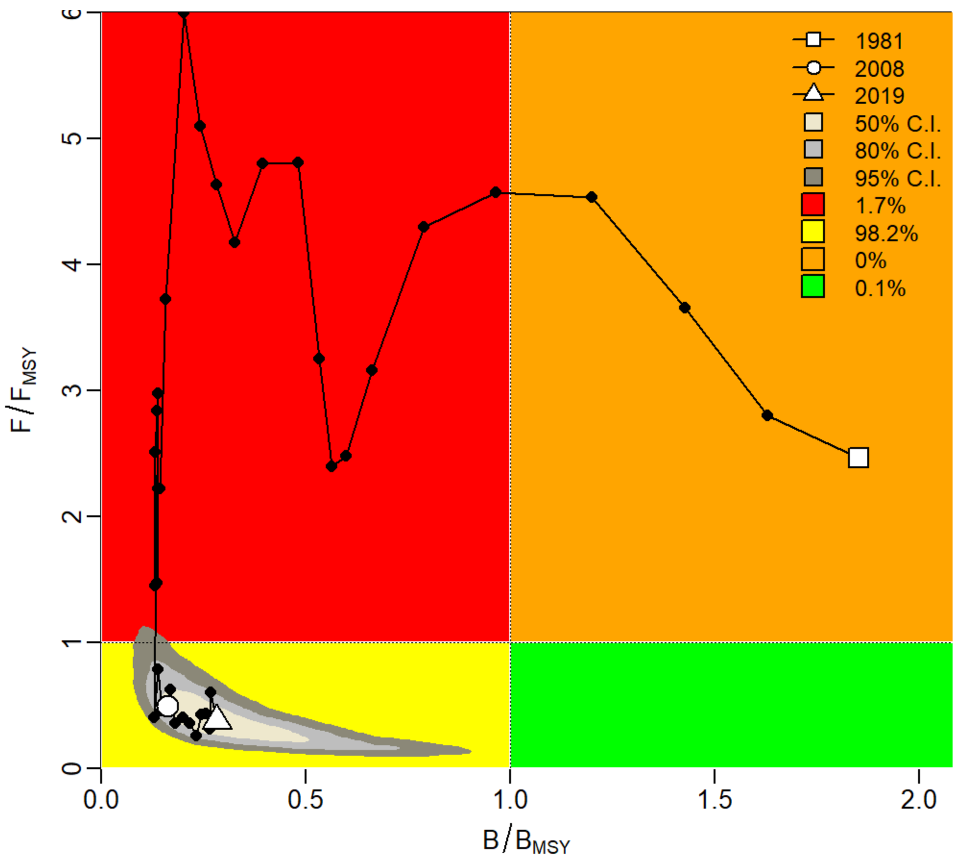

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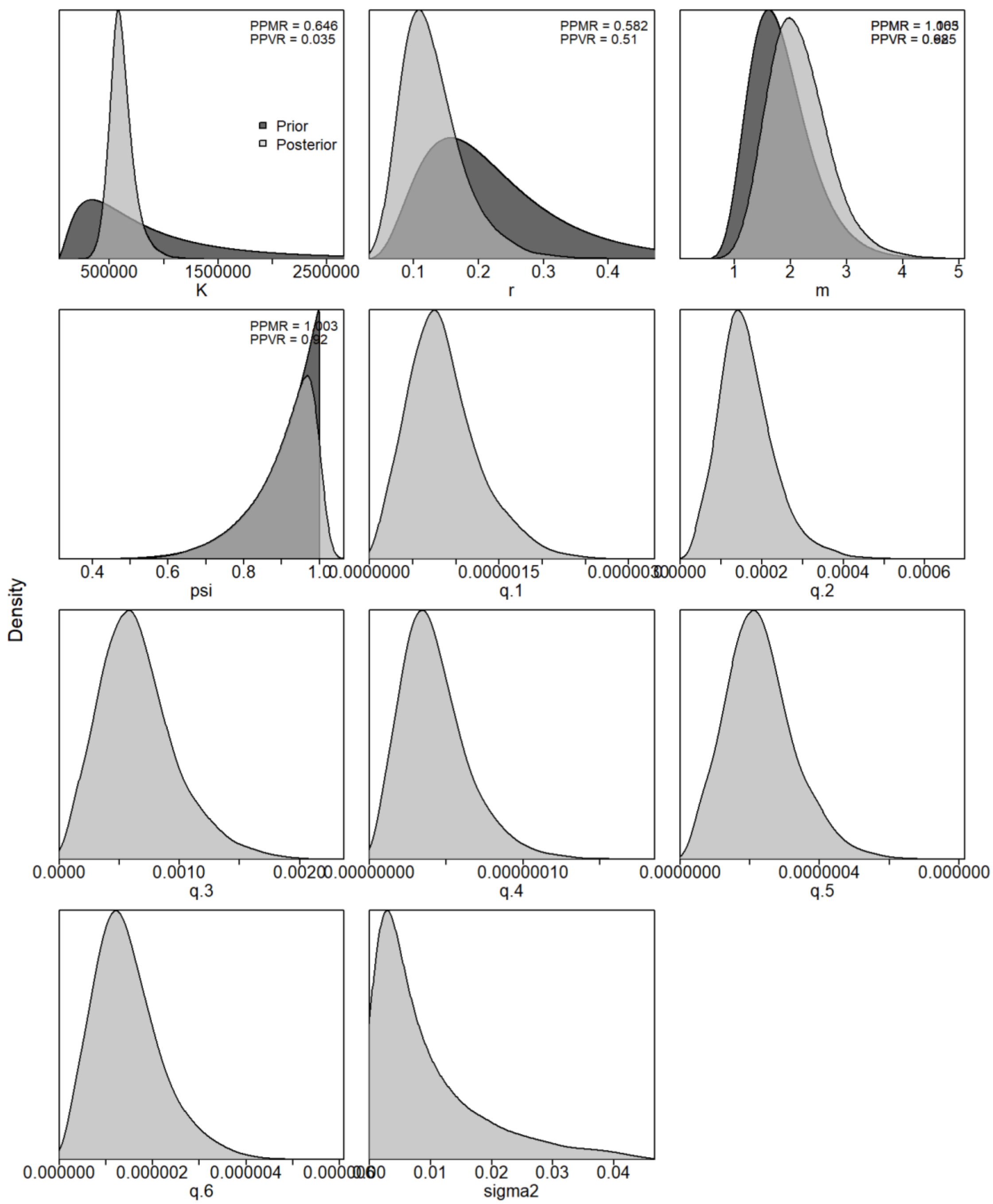
Appendix 3.9.8: Plots for the Panel-approved 8) ref12_2BB (High *r* & High *CV*) sensitivity run.



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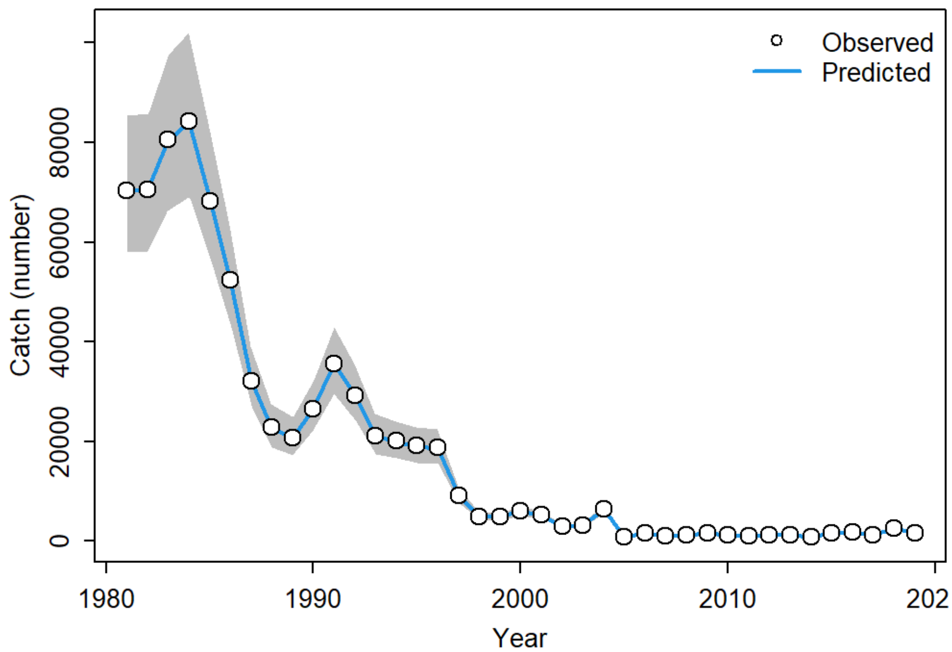

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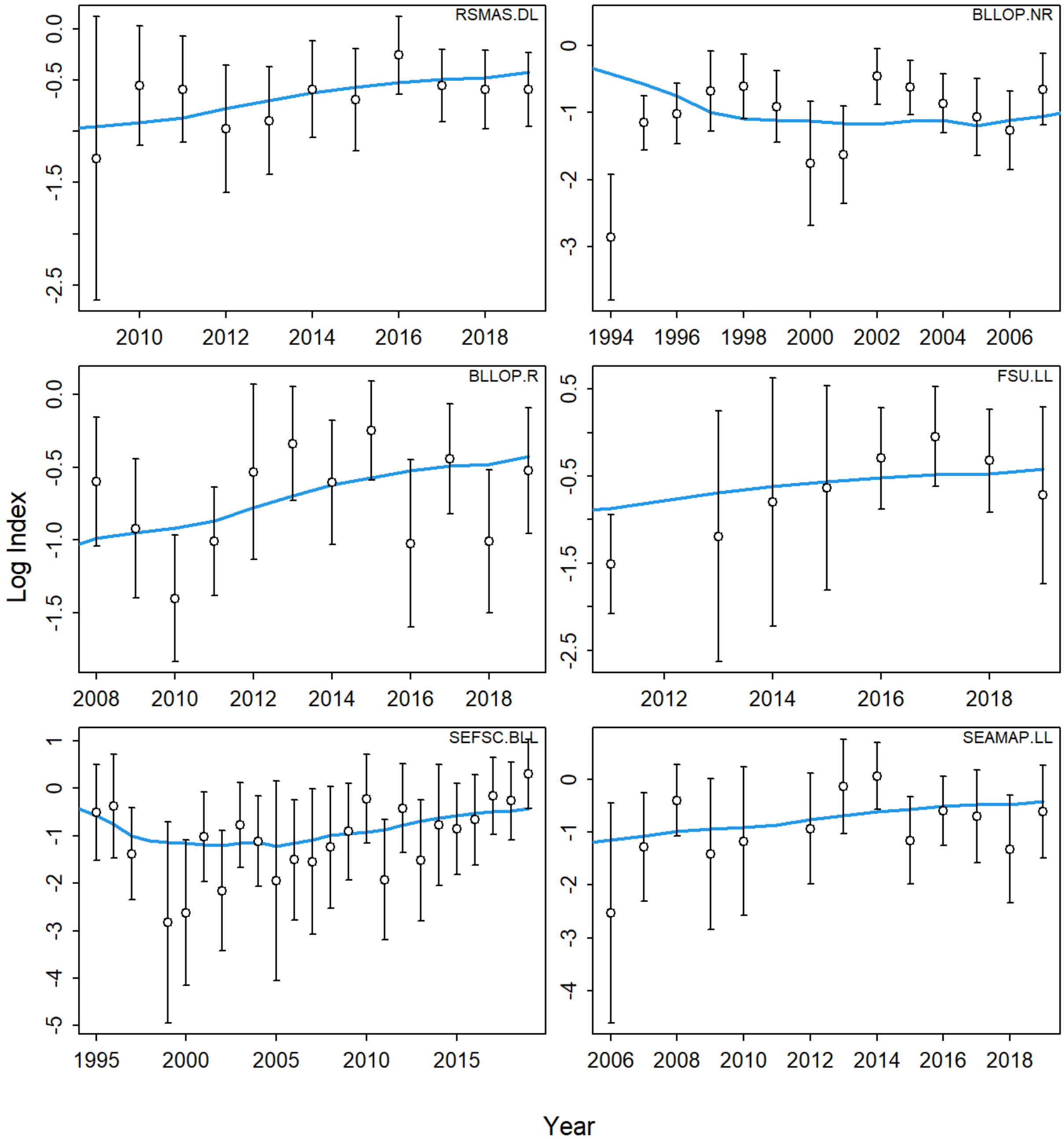

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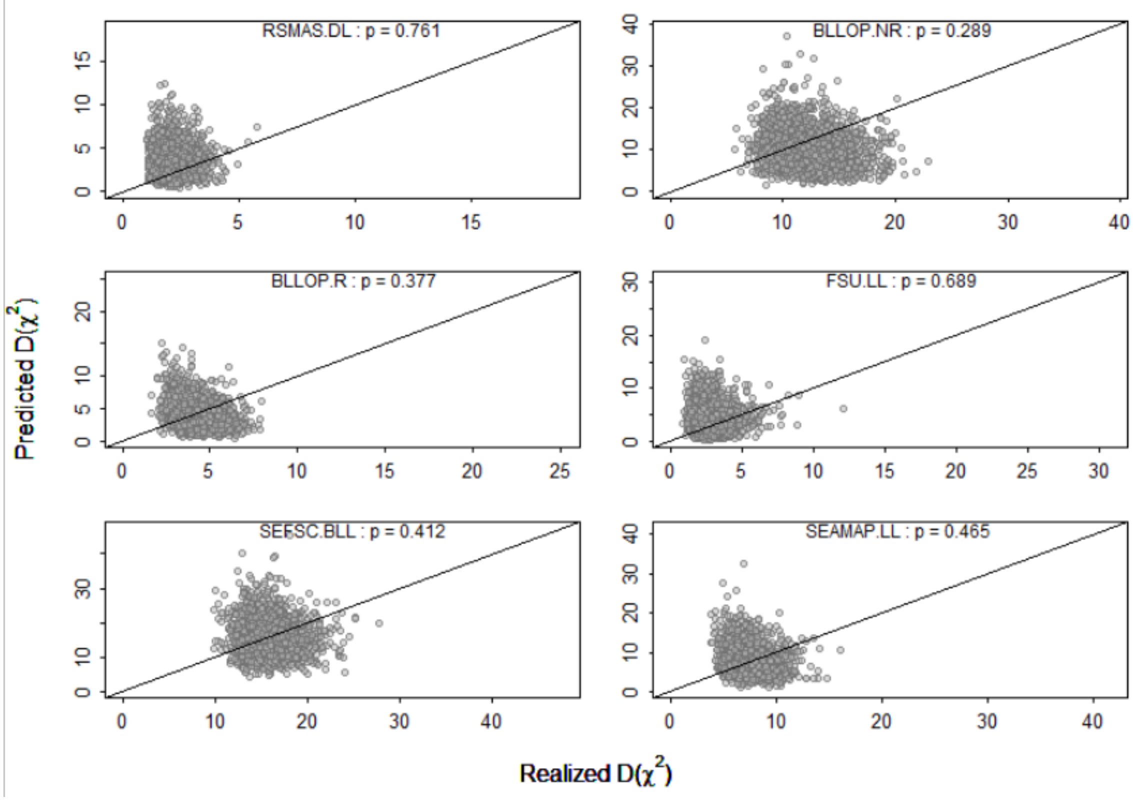

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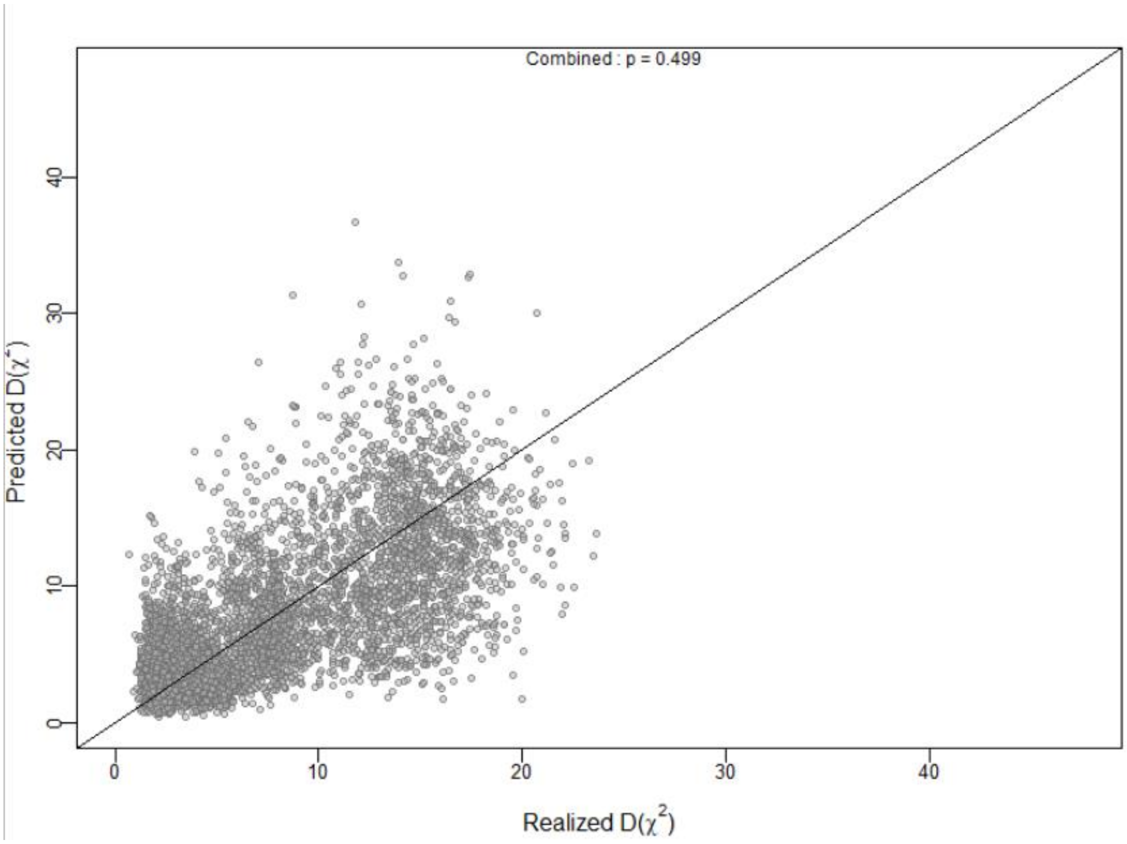

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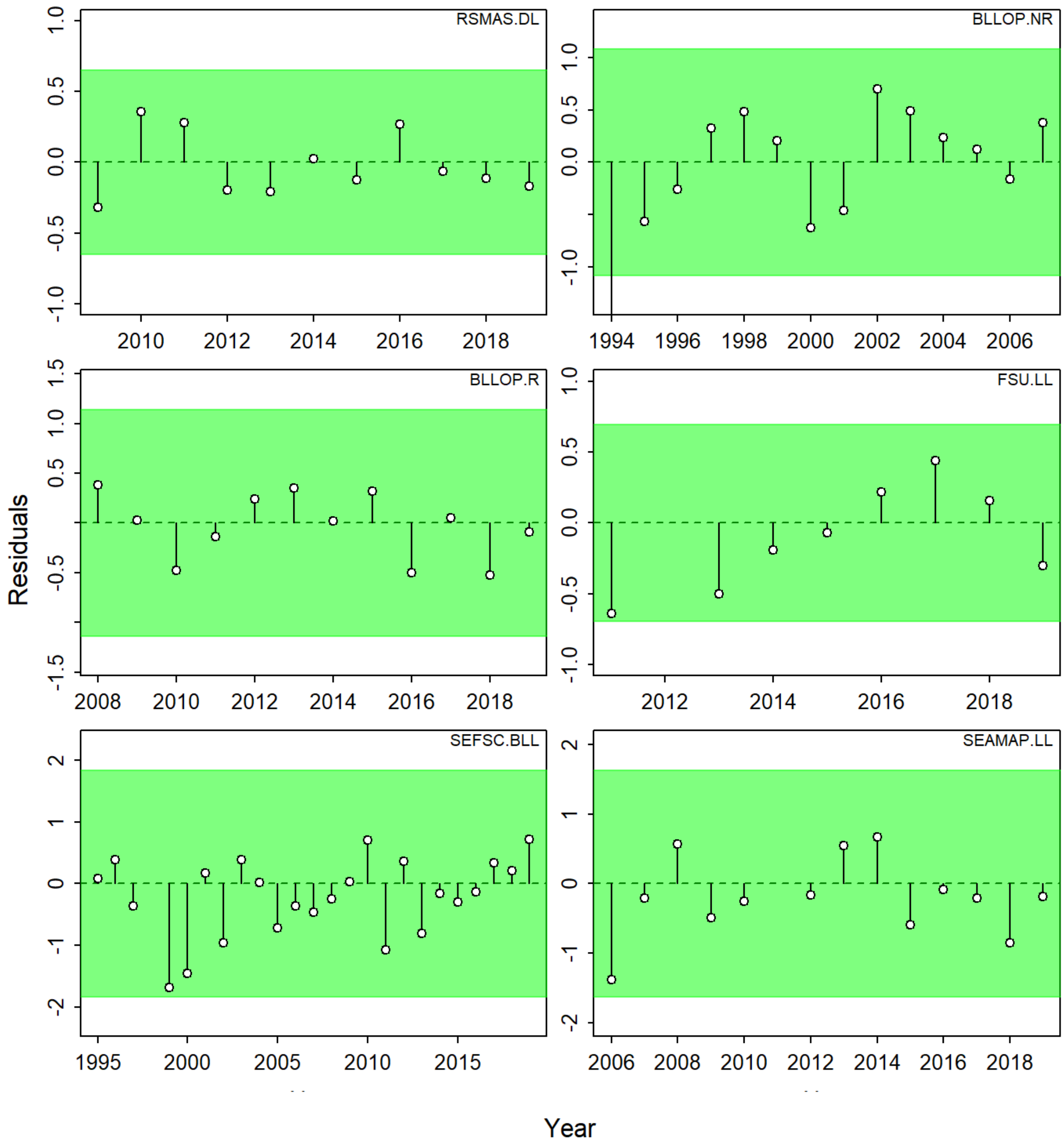

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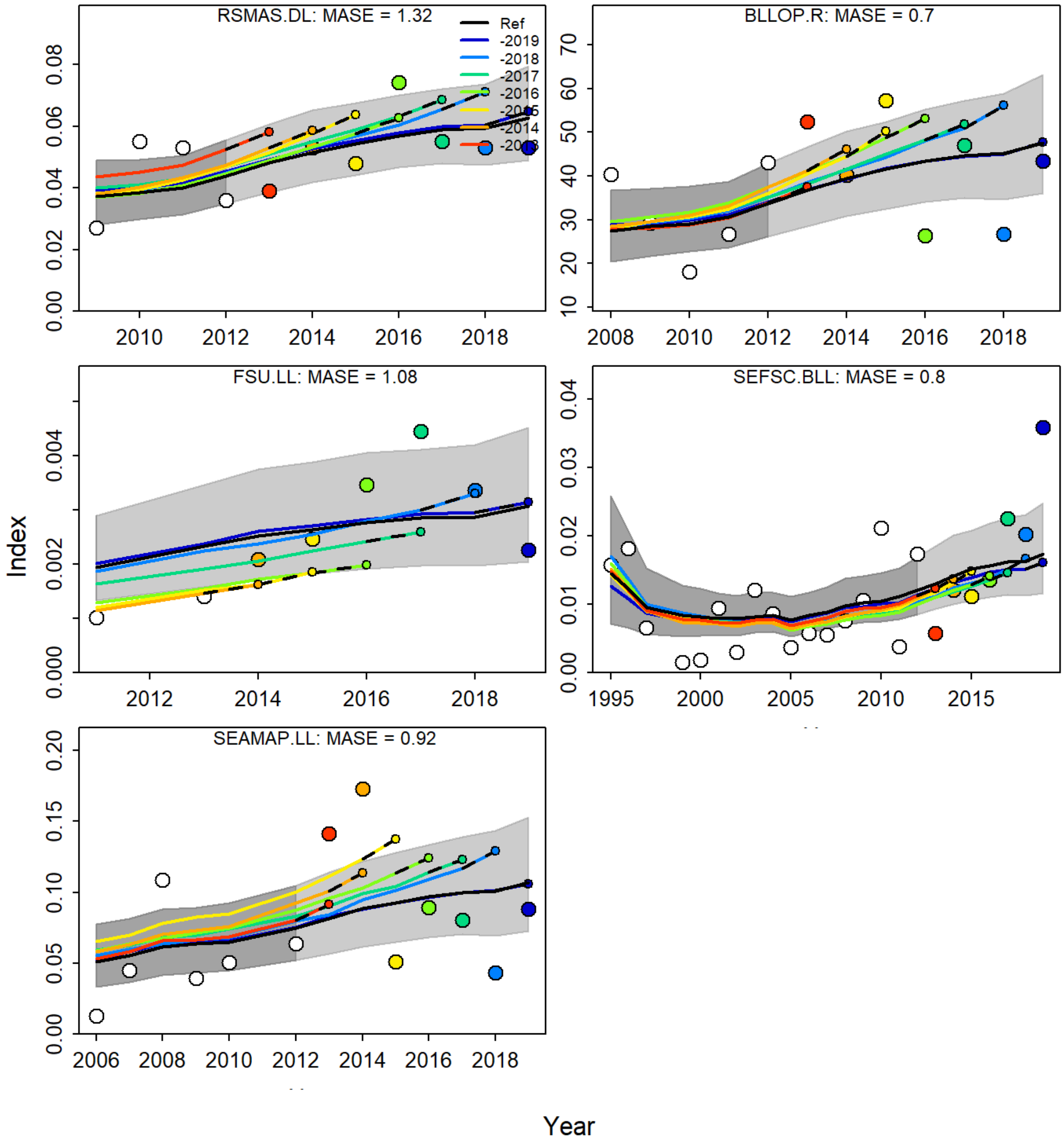

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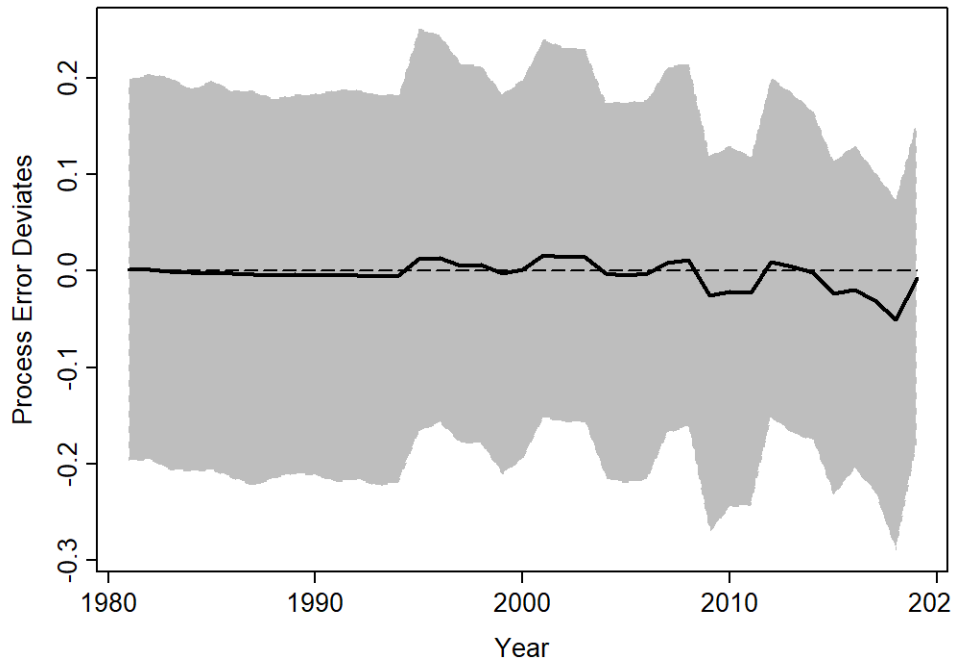

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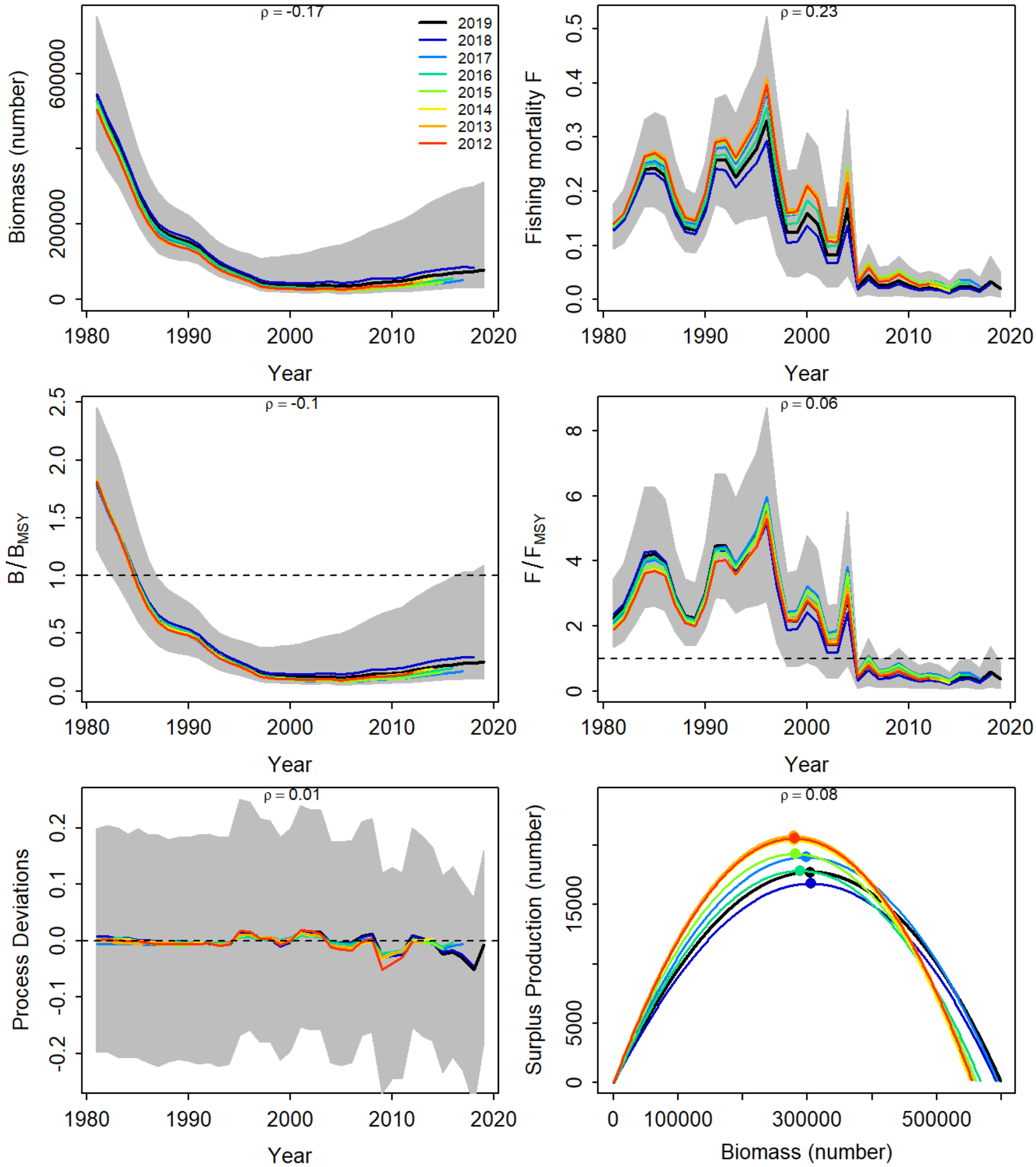

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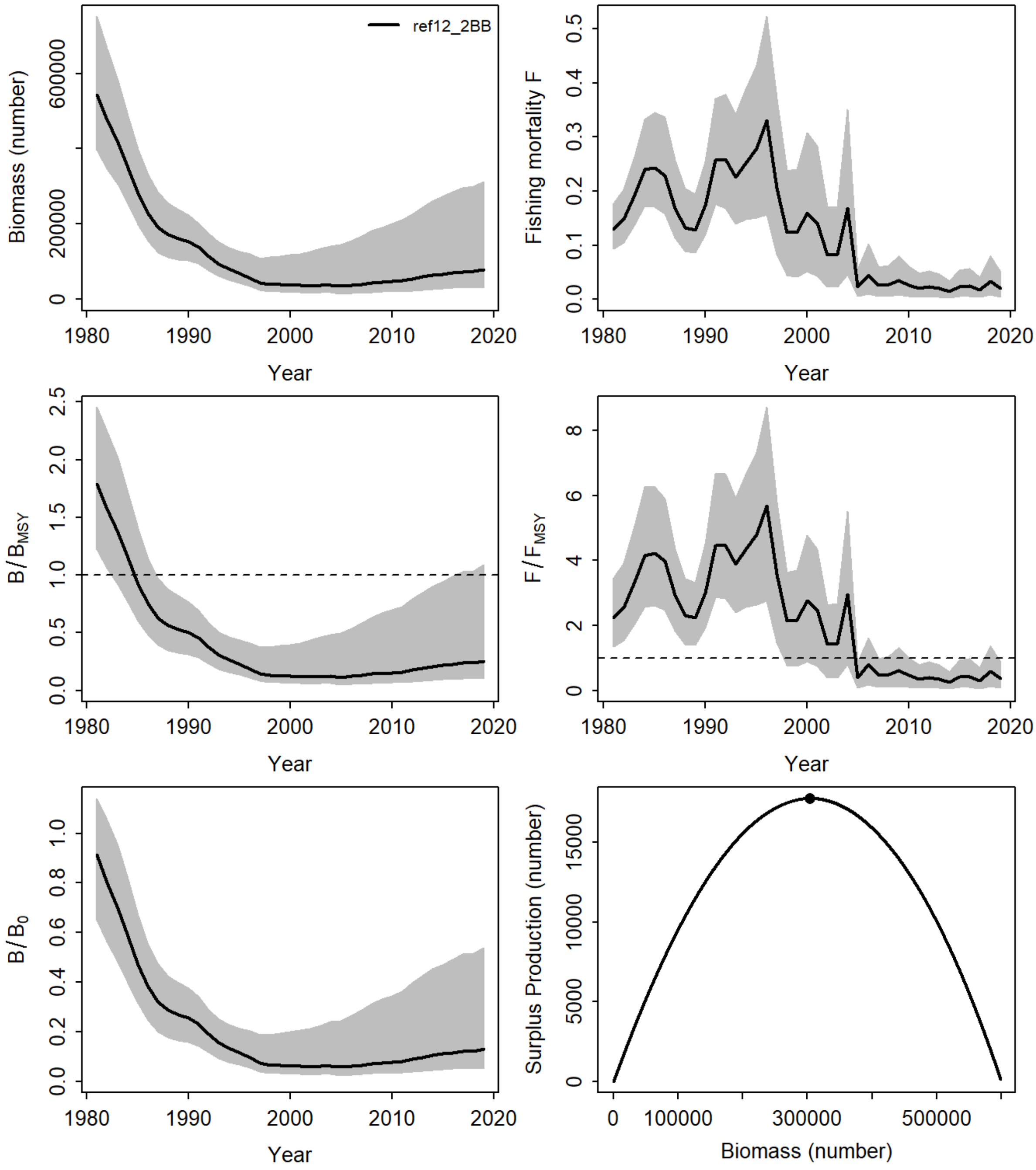

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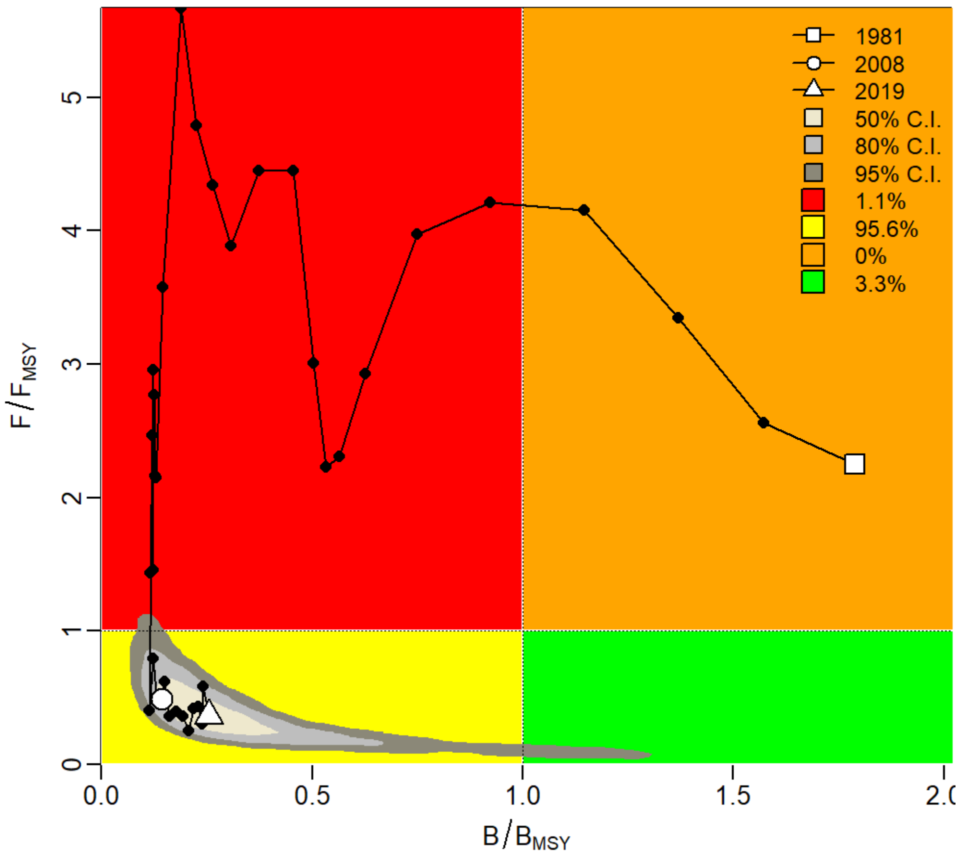

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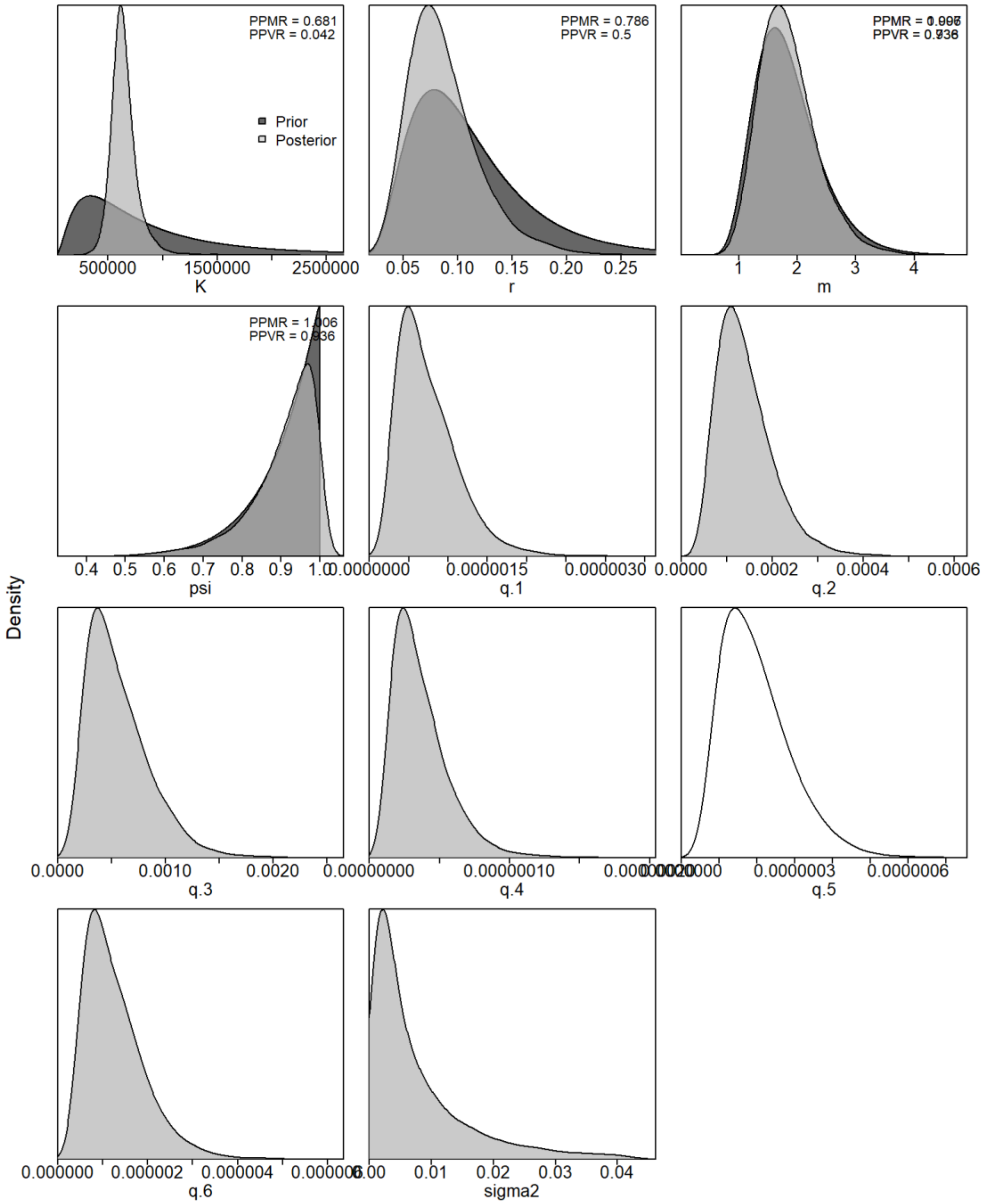

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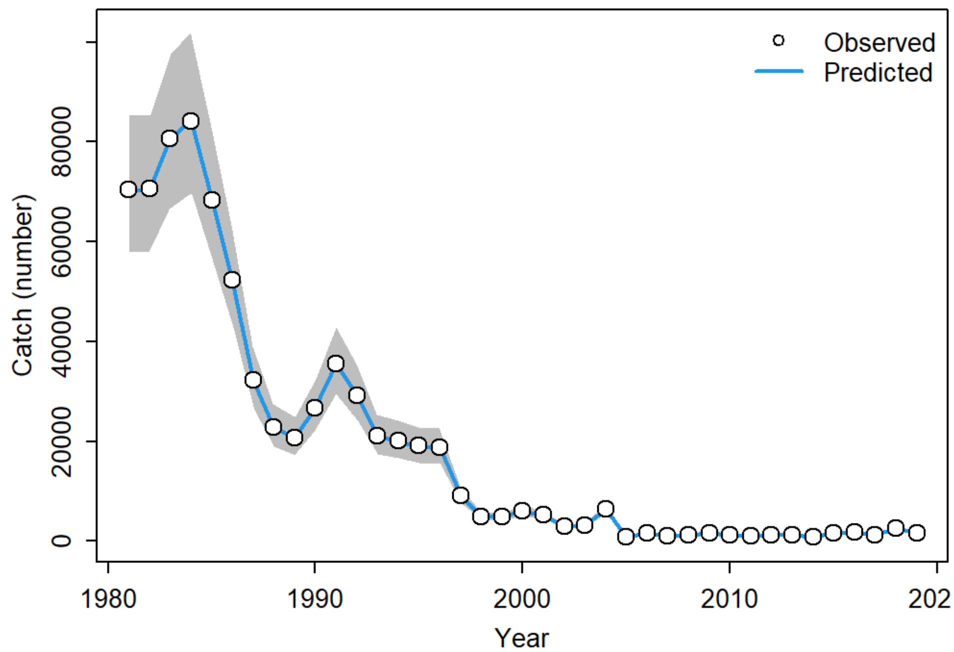

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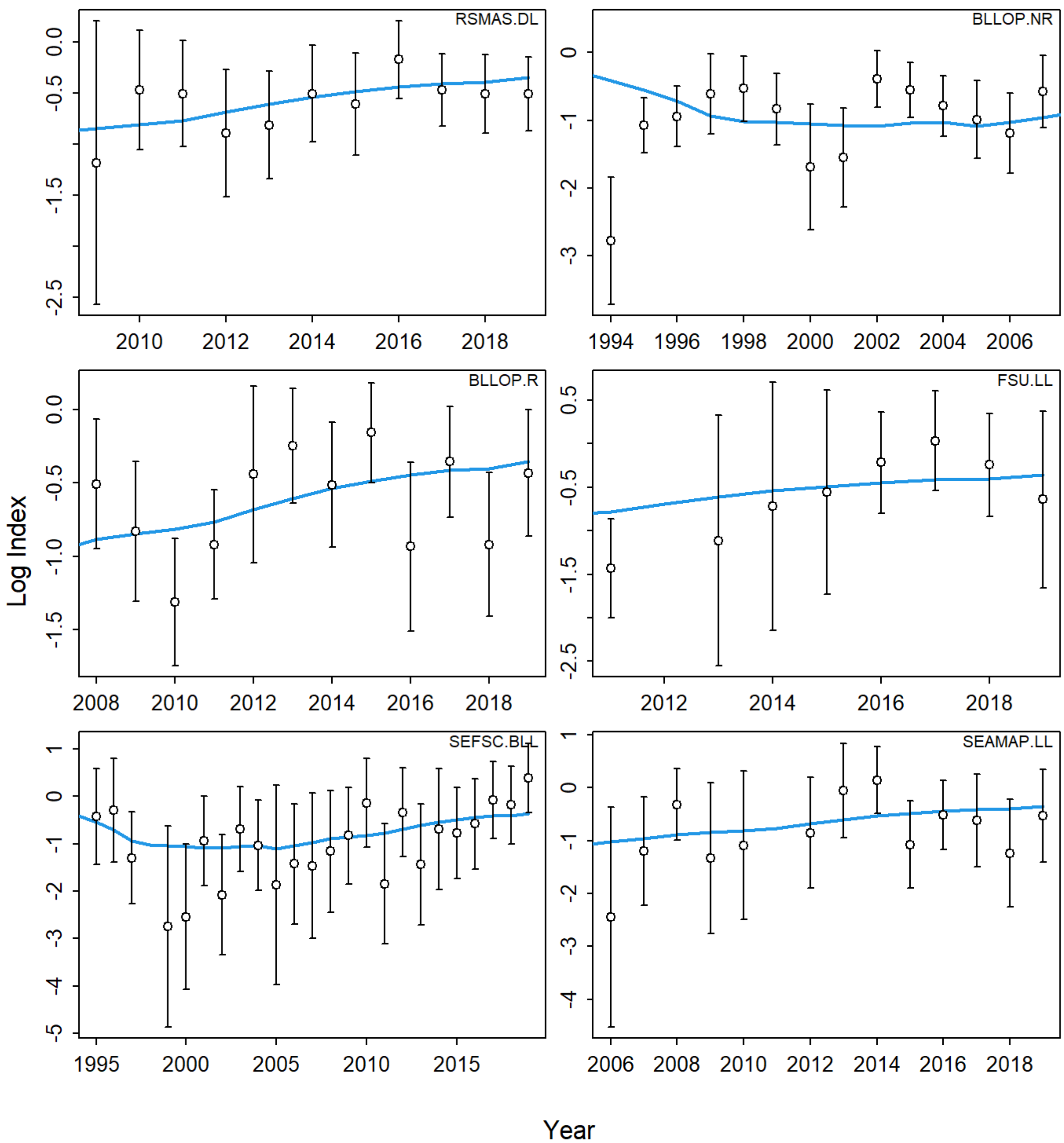

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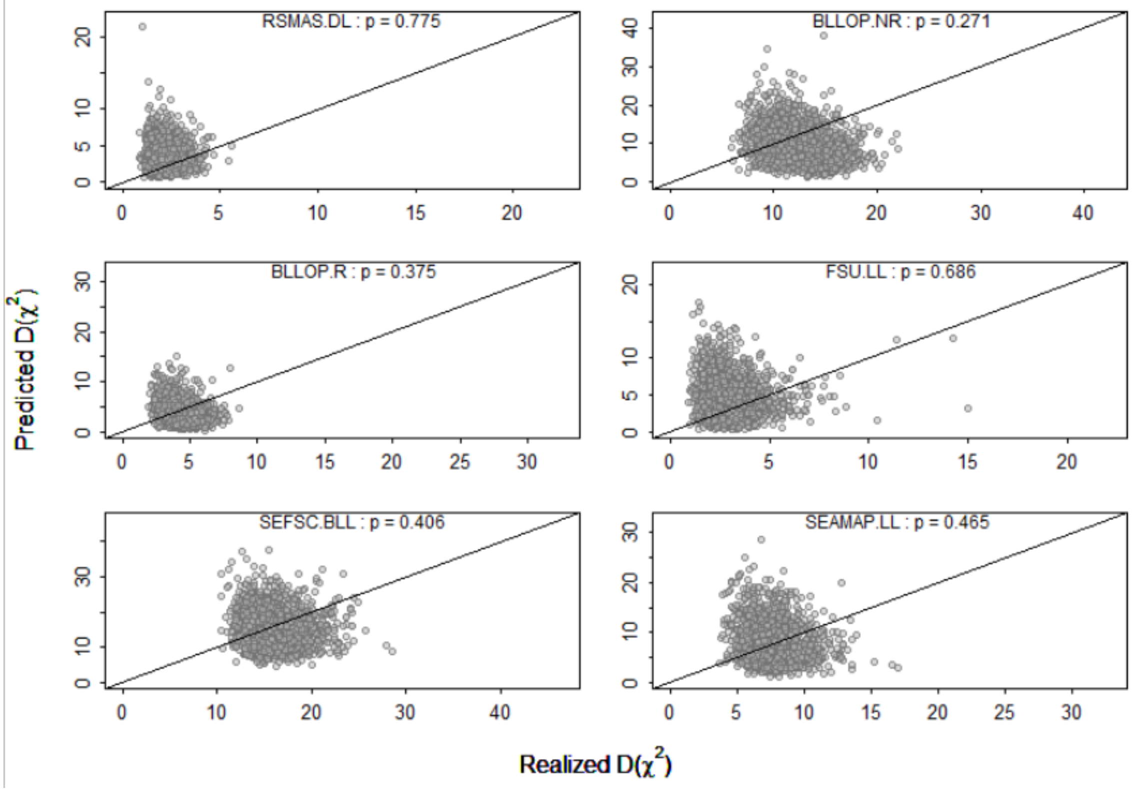

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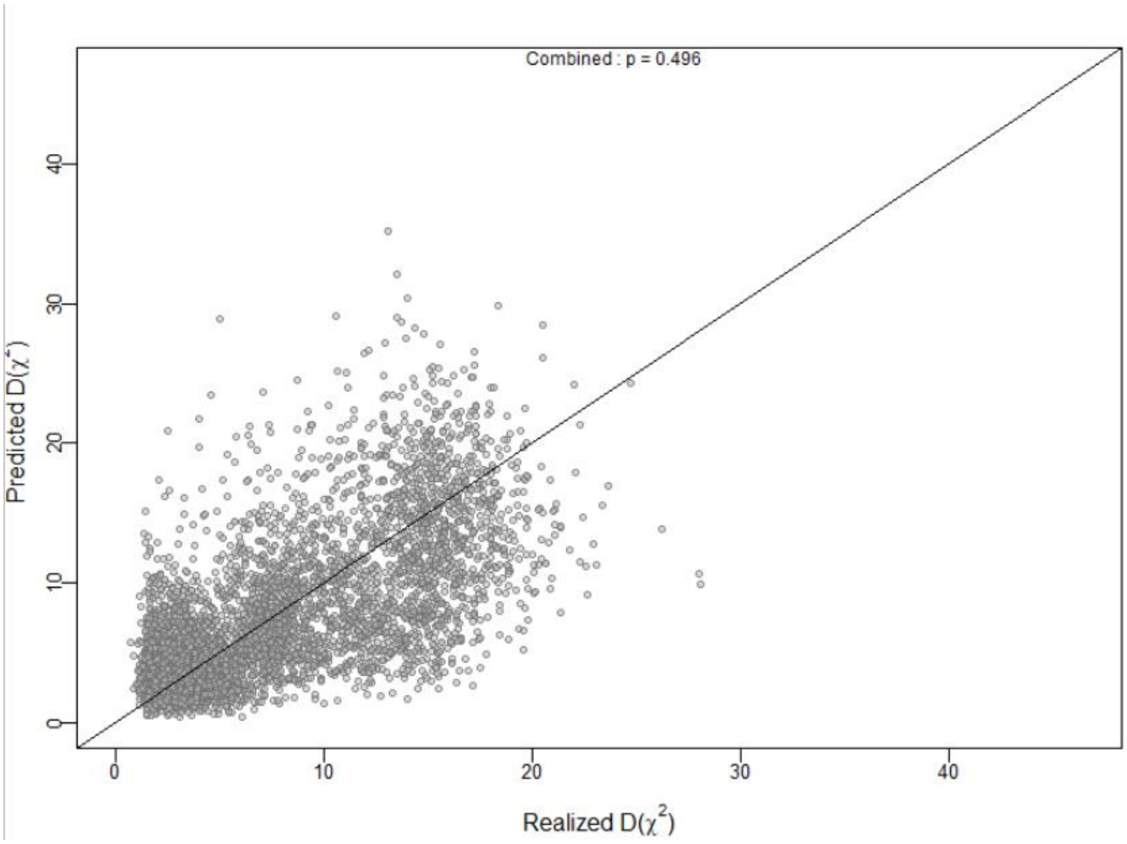

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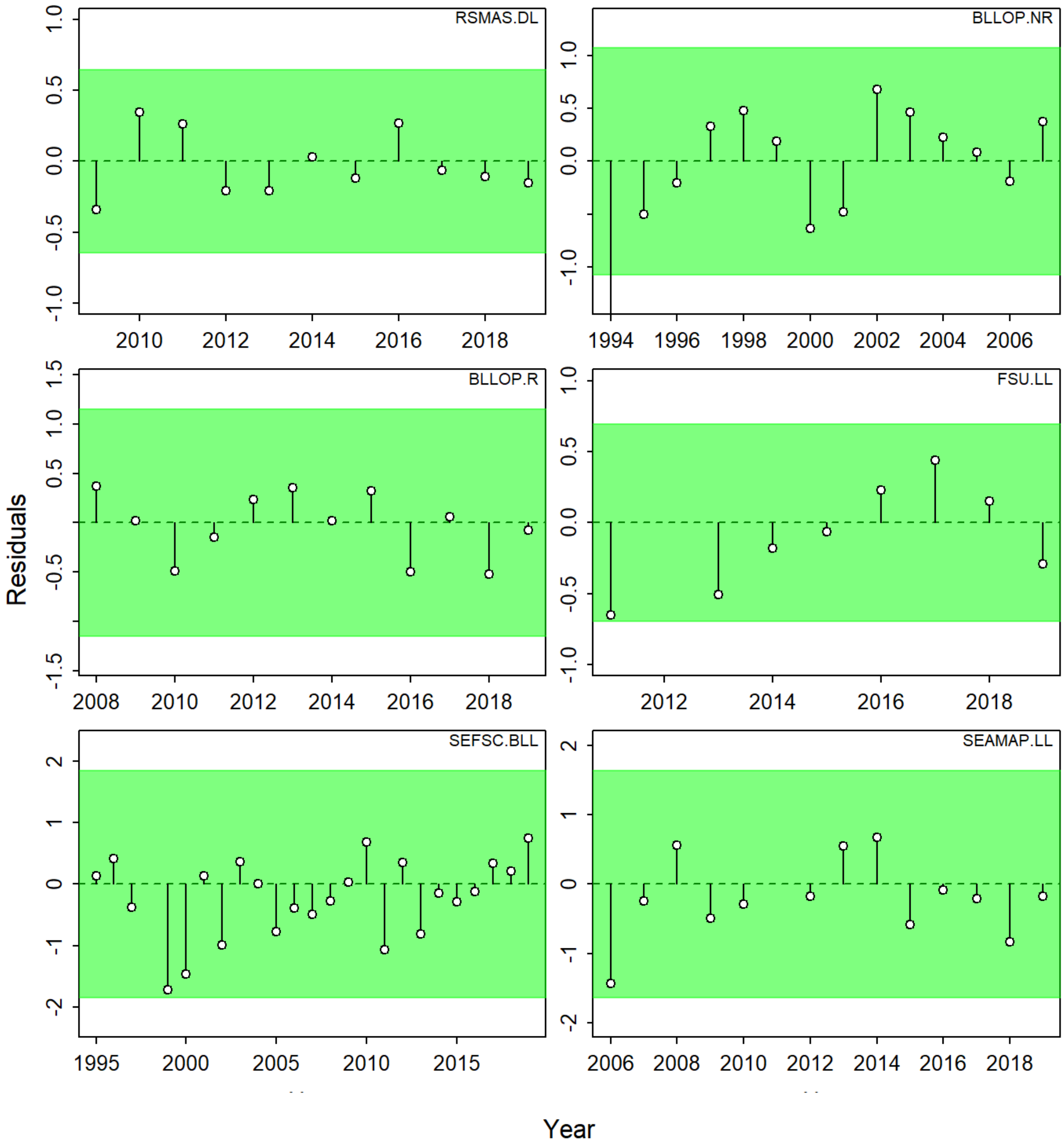

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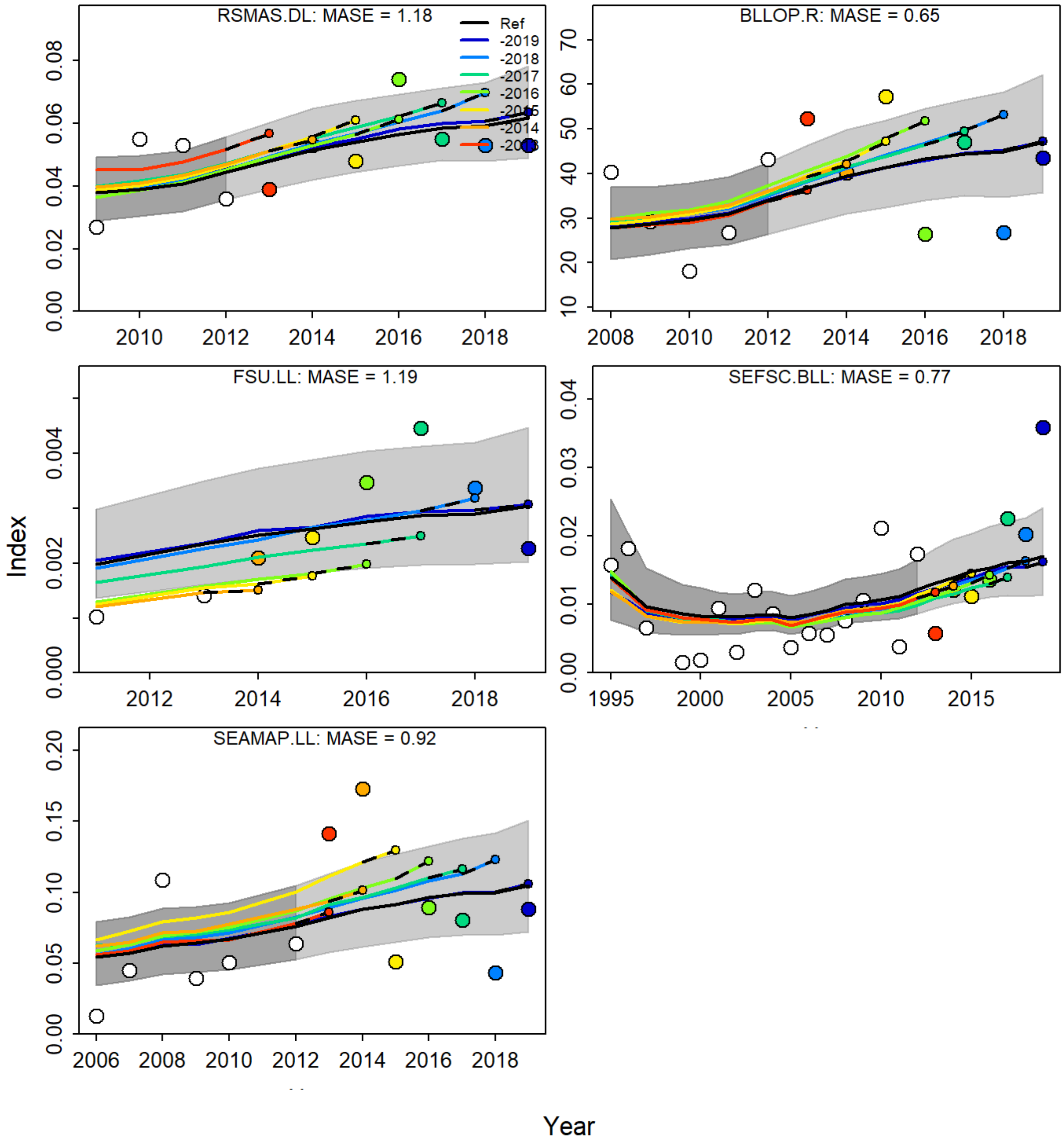

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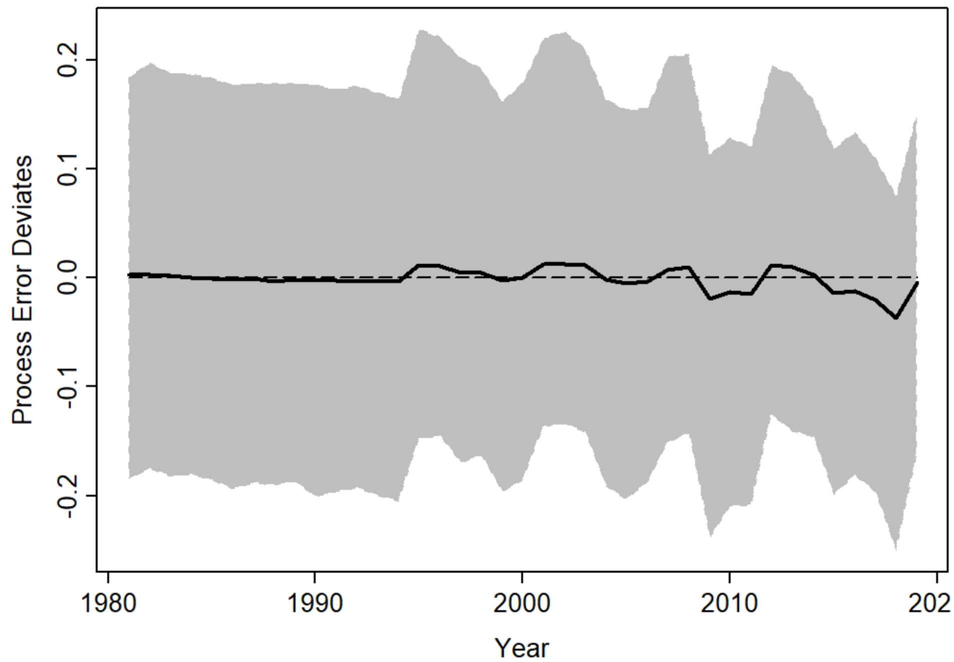

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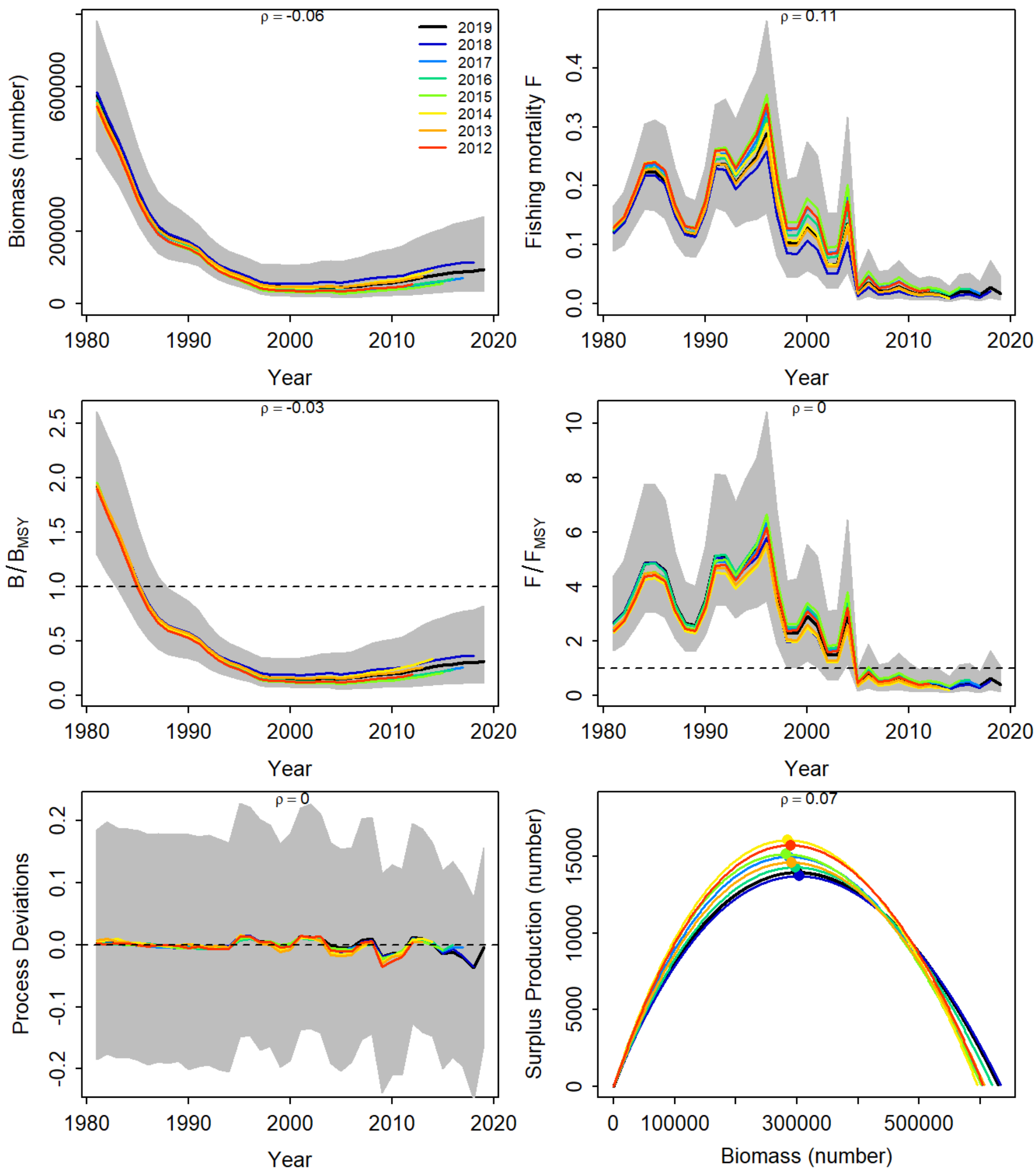

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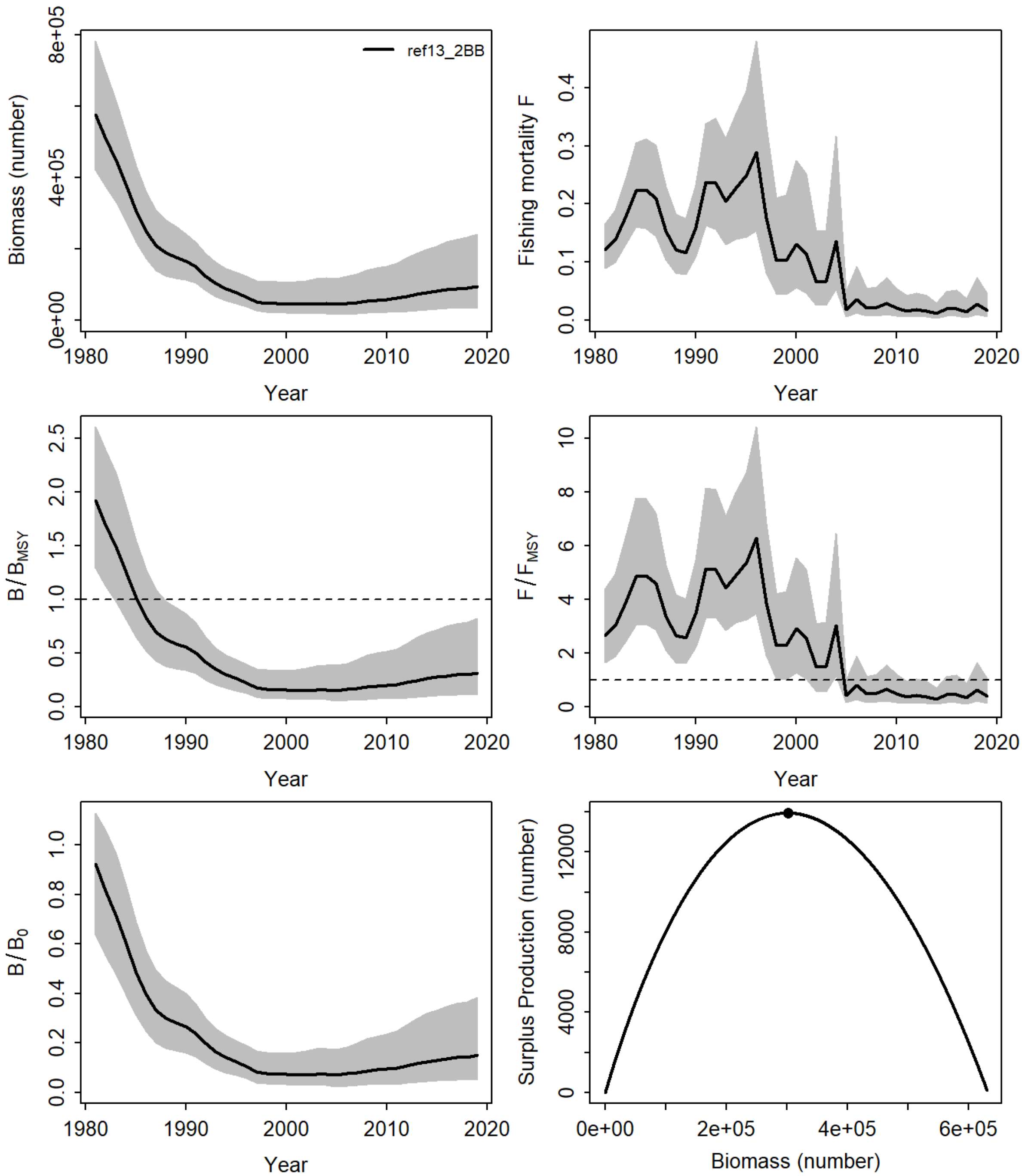

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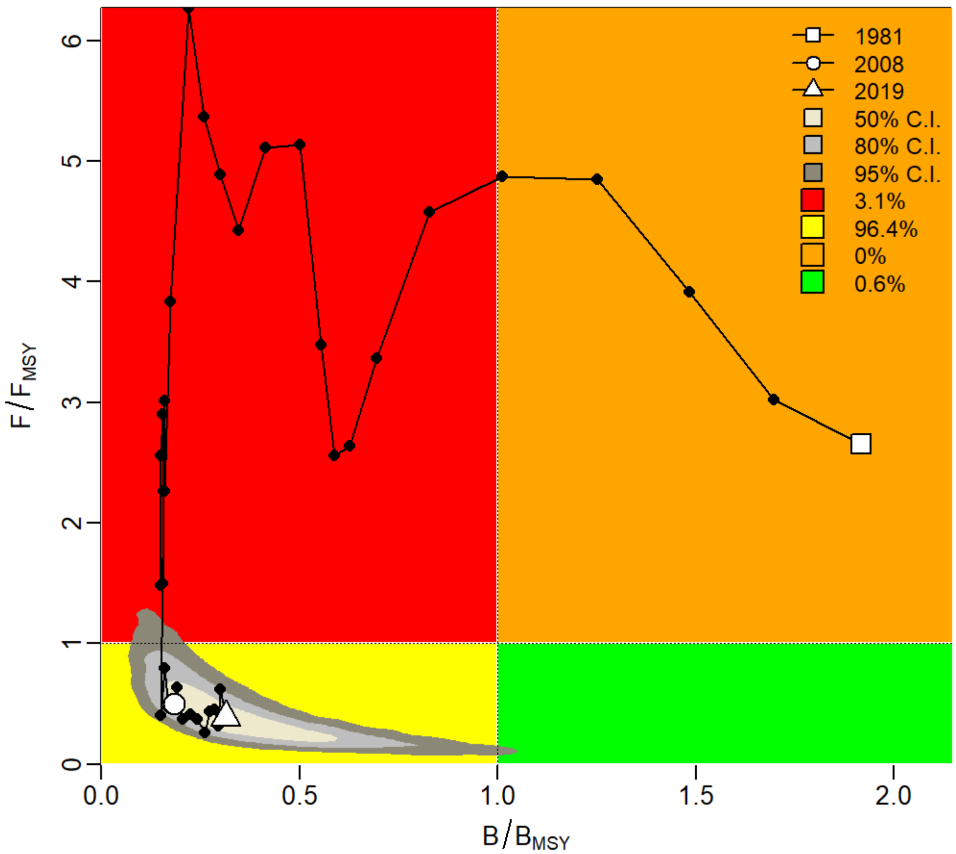

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SEDAR

Southeast Data, Assessment, and Review

SEDAR 77

HMS Hammerhead Sharks

SECTION V: Research Recommendations

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

Contents

1. **Stock ID**

1.1.Genetics Working Group

Smooth Hammerhead Sharks - We caution that no sampling or analyses included U.S. Caribbean jurisdictions (Puerto Rico and U.S. Virgin Islands) and recommend sampling efforts to determine if Smooth Hammerheads occur in the U.S. Caribbean jurisdictions and, if so, determine whether or not they are genetically differentiated from the core U.S. Atlantic population

Great Hammerhead Sharks - We recommend sampling and genetic analyses from the U.S. Caribbean jurisdictions. We also recommend sampling and genetic analysis of young-of-the year and small juvenile (< 110 cm total length) individuals because the current sample is dominated by individuals in the mobile phase of their life-cycle, which could mask structure based on reproductive philopatry.

Carolina Hammerhead Sharks - We caution that no sampling or analyses included U.S. Caribbean jurisdictions. We recommend sampling efforts to determine if Carolina Hammerheads occur in the U.S. Caribbean jurisdictions and, if so, determine whether or not they are genetically differentiated from the core U.S. Atlantic population.

Scalloped Hammerhead Sharks - We recommend genetic analyses of U.S. Caribbean Scalloped Hammerheads as a matter of urgency given that the Central & Southwest Atlantic Distinct Population Segment (DPS) of this species is listed under the Endangered Species Act (https://www.federalregister.gov/documents/2014/07/03/2014-15710/endangered-and-threatened-wildlife-and-plants-threatened-and-endangered-status-for-distinct).

1.2.Spatial Movements and Catches Working Group

Overall, the movement/migration data available for great hammerheads from the Gulf of Mexico and Atlantic Ocean is limited and the Spatial-Movement Workgroup recommends additional tagging (conventional, acoustic, and satellite) studies to better elucidate their movement patterns within the region.

Overall, spatial data, especially with respect to movements and migrations, available for smooth hammerhead from the Gulf of Mexico and Atlantic Ocean is scant at best and the Spatial-Movement workgroup recommends additional tagging (conventional, acoustic, and satellite) studies to better elucidate their movement patterns within the region.

Overall, the movement/migration data available for scalloped hammerhead from the Gulf of Mexico and Atlantic Ocean is limited and the Spatial-Movement workgroup recommends additional tagging (conventional, acoustic, and satellite) studies to better elucidate their movement patterns within the region.

Overall, the movement/migration data available for Carolina hammerhead from the Atlantic Ocean is non-existent and the Spatial-Movement workgroup recommends tagging (conventional, acoustic, and satellite) studies to better elucidate their movement patterns within the region.

A more in depth analysis than was possible for this stock ID workshop could be undertaken in the future as a research topic to help differentiate between stocks using catch and effort data and considering the effect of mis-identification, especially for recreational fisheries.

1.3. Catches Working Group

A more in depth analysis than was possible for this stock ID workshop could be undertaken in the future as a research topic to help differentiate between stocks using catch and effort data and considering the effect of mis-identification, especially for recreational fisheries.

2. Data workshop Research Recommendations

2.1. Life History

- Increase data and sample collection in all forms necessary for informing age related parameters for all hammerhead species, with particular attention to Carolina and smooth hammerheads of both sexes and female scalloped hammerheads.
- Investigate alternative methods for non-lethal estimation of age and/or maturity status (e.g., epigenetic ageing). Conduct age validation studies on scalloped hammerheads to reduce uncertainty in band counting methodology.
- Increased reproductive sampling for all species throughout their range, especially with regard to brood size, gestation period, and reproductive cycle.
- Improve standardization of reproductive measurements and sampling techniques across research groups to facilitate better estimates of reproductive parameters.
- Increase genetic surveillance of scalloped and Carolina hammerheads in the Atlantic in order to further delineate species-specific life history traits and important habitats
- Continued genetic monitoring of Carolina and scalloped hammerheads within nurseries to track the relative abundance of the two species.
- Determine life-stage specific movement patterns and habitat utilization for all hammerhead species using electronic tagging, with particular attention to identifying pupping areas for great and smooth hammerheads.
- Assess stock structure and movement between Caribbean and U.S. waters for scalloped and great hammerheads.
- Identify species-specific abiotic characteristics driving distributions and how environmental changes could impact the life history and distribution of hammerheads in the western North Atlantic Ocean.

2.2. Catches

- Increase public education outreach activities for species identification in the recreational fishery. This is important because there are no species identification training workshops for recreational fishers, and it is difficult to distinguish among different species, especially juveniles, by non-trained individuals.

- Improve the MRIP process to filter biased sampling that leads to unreal, extreme fluctuations in catch data for sharks, through a QA step that is applied with an objective, non-arbitrary procedure.

- Promote that the next stock assessment of hammerhead shark species/stocks be conducted under the auspices of an RFMO (e.g., WECAFC) so that all sources of removals and abundance indices and length compositions (if available) from Caribbean nations where the species/stock is distributed can be accounted for.

- Pooling observed sets for all areas by either each observed year or all observed years without considering variance of areas and seasons, along with an assumption of effort (*number of logbook hooks*) being a known constant, may cause the actual variance of discard estimates to be underestimated. This in turn will produce a narrower confidence interval, which may have a confidence level lower than desired. The pooling methods may need to be further evaluated in the future.
- Given the very small number of sets in which a non-zero bycatch was observed (positive sets), the panel recommended to use the grand mean of discard rates based on the pooled observed sets for all years and the annual logbook effort to produce annual discard estimates. Assuming the grand mean of discard rate based on all the pooled observed sets is a constant for the entire time series, and the trend of the discard estimates is solely driven by the logbook effort, which may need to be further evaluated in the future.
- The discard estimates and associated uncertainty estimates using the delta-lognormal method (SEDAR77-DW37 and SEDAR77-DW38) are regarded as an improvement over the discard estimates and associated uncertainty estimates using the ratio method reported in SEDAR77-DW20 and SEDAR77-DW21. More discard methods should be further explored in the future.

2.3.Indices

1. During the assessment process, explore the utility of combining multiple indices into one scalloped hammerhead index using the Bayesian hierarchical model (Conn, 2009) or Dynamic Factor Analysis (Peterson et al., 2017). The data series that could potentially be combined as a recruitment index are Texas Parks and Wildlife gillnet series, Gulfspan gillnet series, South Carolina Coastspan Gillnet Long and Short Series and the Coastspan Longline Series.

2. Examine the utility of spatiotemporal modelling as a way to improve the indices of abundance for the NEFSC longline survey.

2.4. Ecological Factors

- Improve understanding of all aspects of biology of hammerheads, particularly with regard to smooth and Carolina hammerhead occurrence, life history, and diet
- Investigate Bulls Bay, SC as a Habitat Area of Particular Concern for Carolina hammerhead

- Increase genetic surveillance to not only identify Carolina hammerhead individuals in the Atlantic, but also as a means to study use of nursery habitats and potential philopatry among all four species, potentially using close-kin mark-recapture techniques.
- Improve understanding of sex- and life stage-critical habitat for all species, particularly with regard to identification of essential habitat for data-poor species and life stages (Carolina and smooth hammerhead as well as young-of-year great hammerhead).
- Investigate impacts of environmental changes on life history characteristics, such as growth and reproduction
- Increase efforts in tagging and tracking to evaluate potential climate-induced range shifts
- Develop habitat suitability models for projecting climate-induced shifts in species distributions over time
- Increase effort for collecting environmental/oceanographic data with occurrence and movement data to identify linkages
- Assess the levels of environmental contaminants in hammerhead species and how those impact physiology and reproductive success
- Study the response of hammerhead species to harmful algal blooms and how those phenomena affect behavior and physiology

3. Assessment workshop research recommendations

3.1. Scalloped Hammerheads

3.1.1. Support research to objectively rank (and prioritize) model sensitivities typically conducted during an Atlantic HMS domestic shark SEDAR stock assessment based on likely improvement for understanding model performance and providing robust management advice.

3.1.2. Support research to evaluate the effect of federal and state management actions, such as size restrictions and bag limits, on CPUE standardization and length composition of recreational catch available for use in stock assessment.

3.1.3. Support research to investigate trade-offs in model fit and uncertainty resulting from the use of selectivity functions with fewer parameters and informed priors.

3.1.4. Investigate the use of super years for length composition data with low sample size that result in poor quality annual length composition distributions.

3.1.5. Investigate the use of logistic selectivity vs dome-shaped selectivity for length composition data sets with the largest sizes. For example, asymptotic selectivity is typically implemented for fleets with the largest length size within an areas as fleets approach including multiple fleets within a spatially-aggregated assessment model (e.g., Hurtado-Ferro et al. 2014; Punt et al. 2014). However, this approach contrasts with evidence that asymptotic selectivity curves for length size are unlikely under equilibrium conditions (Waterhouse et al 2014).

3.1.6. Investigate the effect of reproductive output timing implemented within the Stock Synthesis for Atlantic HMS domestic shark stock assessment models on the resulting model fit and population dynamics.

3.2.Great Hammerheads

3.2.1. • Since catches are dominated by recreational catches, decreasing the uncertainty associated with the recreational catches will be critical for improvement of future stock assessments of this stock.

3.2.2. • Since there are insufficient length composition data, programs to collect lengths to allow for a length-based, age-structured assessment in the future assessments should be developed.

3.3.Smooth Hammerheads

3.3.1. Since catches are dominated by recreational catches, decreasing the uncertainty associated with the recreational catches will be critical for improvement of future stock assessments of this stock.

3.3.2. • Since representative length composition data can be added to SSS as they become available to free the input requirement of the stock status on the value of depletion in a given year (i.e. a proxy of overfished stock status), programs to collect length data to allow their incorporation into SSS in future assessments should be developed.

3.3.3. • Since there are insufficient time series data to develop indices of abundance, programs to collect relative abundance data to allow their incorporation into SSS in future assessments should also be developed.

3.3.4. • Since some of the life history data were borrowed from other stocks, programs to obtain representative biological information for this stock should also be developed.

4. Review workshop research recommendations

The Review Workshop was forced to end after one day due to a approaching hurricane, so the review process shifted to a desk review. As such, no Summary Report was produced, and therefore no research recommendations.

SEDAR
Southeast Data, Assessment, and Review

SEDAR 77

HMS Hammerhead Sharks

SECTION VI: Review Workshop Report

January 2024

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

Table of Contents

1. INTRODUCTION

1.1 WORKSHOP TIME AND PLACE

The SEDAR 77 Review Workshop was to be conducted as an in-person meeting in Panama City Florida from August 28 – September 1, 2023. The Workshop was forced to end after the first day due to an approaching hurricane, so the review process shifted to a desk review.

1.2 TERMS OF REFERENCE

The following Terms of Reference apply to each individual stock as determined by the Stock ID process.

1. Evaluate the data used in the assessment, including discussion of the strengths and weaknesses of data sources and decisions. Consider the following:
    a. Are data decisions made by the DW and AW justified?
    b. Are data uncertainties acknowledged, reported, and within normal or expected levels?
    c. Is the appropriate model applied properly to the available data?
    d. Are input data series sufficient to support the assessment approach?
2. Evaluate and discuss the strengths and weaknesses of the methods used to assess the stock, taking into account the available data. Consider the following:
    a. Are methods scientifically sound and robust?
    b. Are the methods appropriate for the available data?
    c. Are assessment models configured properly and used in a manner consistent with standard practices?
3. Consider how uncertainties in the assessment, and their potential consequences, are addressed.
    a. Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the population, data sources, and assessment methods.

   b. Ensure that the implications of uncertainty in technical conclusions are clearly stated.
4. Evaluate the provisional assessment findings and consider the following:
   a. Are abundance, exploitation, and biomass estimates reliable, consistent with input data and population biological characteristics, and useful to support status inferences?
   b. Are the provisional stock status determination methods for each stock or stock complex appropriate? If not, are there other indicators that may be used to inform managers about stock trends and conditions?
5. Evaluate the stock projection methods, including discussing strengths and weaknesses, and consider the following:
   a. Are the methods consistent with accepted practices and available data?
   b. Are the methods appropriate for the assessment model and outputs?
   c. Are the provisional results informative and robust, and useful to support inferences of probable future conditions?
   d. Are key uncertainties acknowledged, discussed, and reflected in the provisional projection results?
6. Provide, or comment on, recommendations to improve the assessment
   a. Consider the research recommendations provided by the Data and Assessment workshops in the context of overall improvement to the assessments, and make any additional long-term research recommendations warranted.
   b. Provide suggestions on key improvements in data analysis or modeling approaches that should be considered when scheduling the subsequent operational assessment. These recommendations should be described in sufficient detail for application in the subsequent operational assessment, and consequently should be practical for short- term implementation (i.e., achievable within ~6 months).
   c. Comment on the degree of environmental and climate linkage(s) incorporated in the stock assessments and make recommendations for improvements in the future.

7. Provide recommendations on possible ways to improve the Research Track Assessment process.
8. Prepare a Review Workshop Summary Report describing the Panel’s evaluation of the Research Track stock assessment and addressing each Term of Reference.

1.3 LIST OF PARTICIPANTS

Review Workshop Participants

Review Panel

John Carlson (Chair) .... NMFS SEFSC
Alistair Dunn .... CIE Reviewer
Yan Jiao .... CIE Reviewer

Peter Stephenson ....CIE Reviewer

Analytic Team
Dean Courtney ....NMFS SEFSC
Xinsheng Zhang ....NMFS SEFSC

Appointed Observers
Fly Navarro ....

Staff
Kathleen Howington .... SEDAR
Michele Ritter ....SAFMC Staff

Workshop Observers
Andrea Kroetz...NMFS Panama City
Alyssa Mathers..NMFS Panama City
Heather Moncrief-Cox ....NMFS Panama City

Workshop Observers via Webinar
Heather Baertlein ....NOAA NMFS
Chip Collier..SAFMC Staff
Tessa Hunt-Woodland ....FWC
Max Lee ....Mote Marine Lab
Julie A Neer .... SEDAR
Cami McChandless ....NMFS NEFSC
Kaitlyn O'Brien ....VIMS
Michelle Passerotti...NMFS NEFSC
Adam Pollack...NMFS SEFSC
Christina Vaeth ....

Post-Review Workshop Webinar Observers
Jason Cope ....NMFS NWFSC
Meisha Key .... SEDAR
Max Lee ....Mote Marine Lab

1.4 LIST OF REVIEW WORKSHOP WORKING PAPERS AND DOCUMENTS

Documents Submitted for the Review Workshop			
SEDAR 77-RD55	Final Amendment 14 to the 2006 Consolidated Atlantic Highly Migratory Species Fishery Management Plan	NOAA fisheries: Highly Migratory Species	4/18/2023
SEDAR77-RD56	Meta-Analysis of Historical Stock Assessment Uncertainty for U.S. Atlantic HMS Domestic Sharks: An Example Application within a Tiered Acceptable Biological Catch (ABC) Control Rule	Dean Courtney and Joel Rice	7/25/23
SEDAR77-RD57	1996 REPORT OF THE SHARK EVALUATION WORKSHOP	NOAA, National Marine Fisheries Service	8/25/2023
SEDAR77-RD58	1998 REPORT OF THE SHARK EVALUATION WORKSHOP	NOAA, National Marine Fisheries Service	8/25/2023
SEDAR77-RD59	A study of Shark exploitation in the U.S. Atlantic Coastal waters During 1986 - 1989	Michael L. Parrack	8/25/2023
SEDAR77-RD60	REPORT OF THE SHARK EVALUATION WORKSHOP March 14-18, 1994	NOAA, National Marine Fisheries Service	8/25/2023
SEDAR77-RD61	Stock Assessment of Large Coastal Sharks in the U.S. Atlantic and Gulf of Mexico	Enric Cortés, Liz Brooks, Gerald Scott	8/25/2023
SEDAR77-RD62	Memo: SEFSC Scientific Review of Scalloped Hammerhead Stock	Bonnie Ponwith	8/25/2023

	Assessment by Hayes, et. al. (2009)		

2. REVIEW PANEL REPORT

The in-person Review Workshop was forced to end after the first day due to an approaching hurricane, the review process shifted to a desk review. Given this change in approach, no Review Workshop Panel Report was produced.