SEDAR

Southeast Data, Assessment, and Review

SEDAR 65

Atlantic Blacktip Shark

Stock Assessment Report

December 2020

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

Please cite this document as:

SEDAR. 2020. SEDAR 65 Atlantic Blacktip Shark Stock Assessment Report. SEDAR, North Charleston SC. 438 pp. available online at: http://sedarweb.org/sedar-65

Table of Contents

Each Section is Numbered Separately

SEDAR

Southeast Data, Assessment, and Review

SEDAR 65

Atlantic Blacktip Shark

Section I: Introduction

December 2020

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

I. Introduction

SEDAR 65 addressed the stock assessment for Atlantic Blacktip Shark. The Data Process was held via a series of webinars held April 2019 – September, 2019 and a workshop held October 29-November 1, 2019 in Charleston, SC. The SEDAR 65 Assessment Process was conducted through a series of webinars held from February, 2020 through July, 2020. The Review Workshop (RW) was held via webinar from 12 – 5 pm on October 29, 30 and November 2, 4 and 5 of 2020.

The Stock Assessment Report is organized into six sections. Section I is the Introduction which 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. Section II is the Data Workshop Report. It documents the discussions and data recommendations from the Data Workshop Panel. Section III is the Assessment Report. 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 three stages of the process (data, assessment, and review) can be found in Section IV for easy reference. Finally, Section V documents the discussions and findings of the Review Workshop. Section VI is the Addenda and Post-Review Workshop Documentation which consists of any analyses conducted during or after the RW to address reviewer concerns or requests. It may also contain documentation of the final RW-recommended base model, should it differ from the model put forward in the Assessment Report for review.

The final Stock Assessment Report (SAR) for Atlantic Blacktip Shark was disseminated to the public in December 2020. The Highly Migratory Species (HMS) Management Division of NOAA Fisheries' Office of Sustainable Fisheries in coordination with the scientists of the Southeast Fisheries Science Center will review the SAR, and determine whether the assessment represents Best Available Science and whether the results presented in the SAR is useful for providing management advice and developing fishing level recommendations. Additional analyses may be conducted if needed to determine the Overfishing Limit and Acceptable Biological Catch. This process is not part of the SEDAR process.

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 three stages. First is the Data Stage, where a workshop is held during which fisheries, monitoring, and life history data are reviewed and compiled. Second 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 3 workshops and all supporting documentation, is then forwarded to the Council SSC for certification as 'appropriate for management' and development of specific management recommendations.

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.

SEDAR Review Workshop Panels consist of a chair, three reviewers appointed by the Center for Independent Experts (CIE), and one or more SSC representatives appointed by each council having jurisdiction over the stocks assessed. The Review Workshop Chair is appointed by the council having jurisdiction over the stocks assessed and is a member of that council's SSC. Participating councils may appoint representatives of their SSC, Advisory, and other panels as observers.

2. Management Overview

A SUMMARY OF THE MANAGEMENT OF ATLANTIC LARGE COASTAL SHARKS THROUGH 2018

Presented to the 2019 Data Workshop of the Atlantic Blacktip shark Stock Assessment

Purpose of this document

This document provides a summary of the management and stock status determinations of the Atlantic stock of blacktip sharks in U.S. federal waters from Maine through Florida through 2018. This information is provided to help the assessment scientists who are conducting the 2019 Atlantic blacktip shark stock assessment. The information here is a summary version; specifics can be found in the Federal Register notices and fishery management plans and amendments referenced throughout. Because management has not always been specific to this species, some of the history is not specific to Atlantic blacktip sharks. The following summary, to the extent possible, focuses only on those management actions that likely affect Atlantic blacktip 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, NMFS (National Marine Fisheries Service) 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. 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 the Fishery Conservation Zone (FCZ) of the United States;
- 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.

2.1 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 NMFS.

After this, NMFS 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), 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 Economic Exclusive Zone (EEZ);
- Requiring annual commercial permits for fishermen who harvest and sell shark products (meat products and fins);

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

- 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 NMFS under the Trip Interview Program; and,
- Requiring NMFS observers on selected shark fishing vessels to document mortality of marine mammals and endangered species.

At that time, NMFS 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 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 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, NMFS 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, NMFS 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 (see Section 2.0 below).

In June 1998, NMFS held another LCS stock assessment. The 1998 stock assessment found that LCS were overfished and would not rebuild under 1997 harvest levels. For blacktip sharks, specifically, the assessment found that blacktip sharks were overfished and experiencing overfishing. Results of the 1998 stock assessment developed a blacktip-based rebuilding program, which was 20 percent of the 1995 quota for 30 years. Based in part on the results of the 1998 stock assessment, in April 1999, NMFS published the final 1999 FMP, which included numerous measures to rebuild or prevent overfishing of Atlantic sharks in commercial and recreational fisheries. The 1999 FMP amended and replaced the 1993 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., blacktip; *Carcharhinus limbatus*) 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;
- Established essential fish habitat (EFH) for 39 species of sharks;
- Implementing limited access in commercial fisheries;
- Establishing a shark public display quota;
- Establishing new procedures for counting dead discards and 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, NMFS 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. 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);
- 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, 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 five sharks, including blacktip sharks; and,
- Changing the administration for issuing permits for display purposes.

2006 Consolidated HMS FMP

NMFS 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, and was the first FMP for tunas. Amendment 1 to the Billfish Management Plan updated and amended the 1988 Billfish 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, NMFS 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 HMS limited access permits (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, NMFS released the Final EIS for Amendment 2 to the Consolidated HMS FMP, which implemented management measures based on the results of those assessments. Based on the stock assessment, blacktip sharks were separated for the first time into two stocks, Gulf of Mexico and Atlantic. The stock assessment for Gulf of Mexico blacktip sharks indicated that the stock was not overfished and did not have overfishing occurring. The stock assessment for Atlantic blacktip sharks indicated that the population was unknown. The stock assessment recommended that fishing mortality should be maintained and not increased for blacktip sharks in both the Gulf of Mexico and Atlantic regions. NMFS implemented management measures consistent with the recent stock assessment for blacktip sharks, among other things. 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 blacktip sharks 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 can be offloaded with fins naturally attached; and,
- Collecting shark life history information via the implementation of a shark research fishery and establishing a non-sandbar LCS quota (including blacktip sharks) of 50 mt dw for the shark research fishery.
- 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), NMFS published the final rule for Amendment 3 to the Consolidated HMS FMP. This Amendment focused on management for small coastal sharks, porbeagle sharks, and smoothhound sharks. While the measures were not specific to blacktip sharks, 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 blacktip 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), NMFS published the final rule for Amendment 5a to the Consolidated HMS FMP. While the measures were not specific to blacktip sharks, some of them may have resulted in fishermen changing fishing practices. The major measures that might have affected blacktip 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).
- Established the Aggregated LCS commercial quota at 168.9 mt dw.
- In the Gulf of Mexico, removed hammerhead 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 blacktip shark quota at 256.6 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, and scalloped) of 78 inches (6.5 feet) fork length.
- The size and retention limits for other shark species remained the same.

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

On August 18, 2015 (80 FR 50074), NMFS published the final rule for Amendment 6 to the 2006 Consolidated HMS FMP. While the measures were not specific to blacktip sharks, some of them may have resulted in fishermen changing fishing practices, particularly for fishermen using gillnet. The major measures that might have affected blacktip shark fishing were:

- 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; and
- Removed the upgrading restrictions for shark limited access permit holders.
- 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.

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

On April 4, 2017 (82 FR 16478), NMFS published the final rule for Amendment 5b to the 2006 Consolidated HMS FMP. While the measures were not specific to blacktip sharks, 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 blacktip 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 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 (91.4cm) from the hook as safely as practicable; and
- Establishing a circle hook requirement in the directed shark bottom longline fishery.

Table 1 FMP Amendments and regulations affecting Atlantic blacktip sharks

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; • Establishing 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, • Requiring trip reports by permitted fishermen and persons conducting shark tournaments and requiring fishermen to provide information to NMFS 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 NMFS observers on selected shark fishing vessels to document mortality of marine mammals and endangered species.
July 1, 1999 -Limited access permits issued immediately; application	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);

Effective Date	FMP/Amendment	Description of Action
and appeals processed over the next year (measures in italics were delayed)		• 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 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	Consolidated HMS FMP	• 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; • 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 • 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 blacktip sharks 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

Effective Date	FMP/Amendment	Description of Action
		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; • 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 NMFS within 10 days of the reporting period). • Prohibiting 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). • Established the Aggregated LCS commercial quota at 168.9 mt dw. • Implemented regional quota linkages between management groups whose species are often caught together in the same fisheries to prevent exceeding the newly established quotas through discarded bycatch. • Established a new recreational minimum size limit for the large hammerhead shark species (great, smooth, and scalloped) of 78 inches (6.5 feet) fork length. • 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, • Removed the upgrading restrictions for shark limited access permit holders.
April 4, 2017	Amendment 5b to the 2006 Consolidated HMS FMP	• 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 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 (91.4cm) from the hook as safely as practicable. • Establishing a circle hook requirement in the directed shark bottom longline fishery.

2.2 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, NMFS 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, NMFS completed its consideration of the economic effects of the 1997 LCS quotas on fishermen and submitted the analysis to the court. NMFS 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 NMFS 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, NMFS 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, NMFS 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, NMFS 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 NMFS 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-NMFS) 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, NMFS 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), NMFS 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, NMFS 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), NMFS announced the availability of a modeling document that explored the suggestions of the CIE and NRC peer reviews on LCS. Then NMFS held a 2002 LCS stock assessment workshop in June 2002. On October 17, 2002, NMFS 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, NMFS 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, NMFS 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. NMFS 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, NMFS 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, NMFS 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. NMFS 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.

NMFS 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, NMFS 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, NMFS 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 (November 30, 2004, 69 FR 6954).

Shark Rules After 2006 Consolidated HMS FMP

On February 16, 2006, NMFS published a temporary rule (71 FR 8223) to prohibit, through March 31, 2006, any vessel from fishing with any gillnet gear in the Atlantic Ocean waters between 32°00' N. Lat. (near Savannah, GA) and 27°51' N. Lat. (near Sebastian Inlet, FL) and extending from the shore eastward out to 80°00' W. long under the authority of the Atlantic Large Whale Take Reduction Plan (ALWTRP) (50 CFR 229.32 (g)) and ESA. NMFS took this action based on its determination that a right whale mortality was the result of an entanglement by gillnet gear within the Southeast U.S. Restricted Area in January of 2006.

In 2007, NMFS 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 September 16, 2011 (76 FR 57709), NMFS published a NOI that announced NMFS' 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. NMFS 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 sandbar sharks landings be included when determining the landings history of fishermen. Fishermen also requested, if an IFQ allocation occurred, that the sandbar research quota would be equally distributed to all qualified shark fishermen and that they would be allowed to land all sandbar sharks caught in the research fishery.

Table 2 Chronological list of most of the Federal Register publications relating to Atlantic large coastal sharks, when appropriate, specific to Atlantic blacktip 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

Federal Register Cite	Date	Rule or Notice
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
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

Federal Register Cite	Date	Rule or Notice
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
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

Federal Register Cite	Date	Rule or Notice
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
2004		
69 FR 6621	02/11/04	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	07/26/04	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	08/12/04	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

Federal Register Cite	Date	Rule or Notice
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
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

Federal Register Cite	Date	Rule or Notice
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
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 79005	12/24/2008	NMFS 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

Federal Register Cite	Date	Rule or Notice
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 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 29991	5/28/2010	Notice of Schedules for Atlantic Shark Identification Workshops and Protected Species Safe Handling Release, and Identification Workshops
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 34209	6/13/2011	Notice of Schedules for Atlantic Shark Identification Workshops and Protected Species Safe Handling, Release, and Identification Workshops

Federal Register Cite	Date	Rule or Notice
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
76 FR 44501	7/26/2011	Inseason Action To Close the Commercial Non-Sandbar Large Coastal Shark Research Fishery
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 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	NMFS Announces a Public Meeting for Selected Participants of the 2012 Shark Research Fishery
77 FR 35357	6/13/2012	NMFS Announces the Opening Date of the Commercial Atlantic Region Non-Sandbar Large Coastal Fishery
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 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
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 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 NMFS Closes the Gulf of Mexico Aggregated LCS and Hammerhead Shark Management Groups

Federal Register Cite	Date	Rule or Notice
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 30064	5/27/2014	Notice of Intent to Prepare an EA for Amendment 6 to the 2006 Consolidated HMS FMP
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
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
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 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 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 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

Federal Register Cite	Date	Rule or Notice
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 April 15 – December 31
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 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 8037	2/23/2018	Proposed Rule to Revise Atlantic Shark Fishery Closure Regulations
83 FR 21744	5/10/2018	Atlantic Region Commercial Aggregated Large Coastal Shark and Hammerhead Shark Management Groups Retention Limit Adjustment May 12 – December 31
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 July 18 – December 31
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	11/01/2018	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 Nov 6 – December 31
83 FR 60777	11/27/2018	Final Rule to Establish Quotas, Opening Dates, and Retention Limits for the 2019 Atlantic Shark Commercial Fishing Season

Table 3 List of Large Coastal or Atlantic Blacktip Shark Seasons, 1993-2018
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. “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	Jan. 1 - May 17	1,285

Year	Open dates	Quota (mt dw)
(LCS combined)	July 1 - Aug. 31	1,168
1997	Jan. 1 - April 7	642
(LCS combined)	July 1 - July 21	326
1998	Jan. 1 - Mar. 31	642
(LCS combined)	July 1 - Aug. 4	600
1999	Jan. 1 - Mar. 31	642
(LCS combined)	July 1 - July 28 Sept. 1 - Oct. 15	585
2000	Jan. 1 - Mar. 31	642
(LCS combined)	July 1 - Aug. 15	542
2001	Jan. 1 - Mar. 24	642
(LCS combined)	July 1 - Sept. 4	697
2002	Jan. 1 - April 15	735.5
(LCS combined)	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. blacktip)	391.5 (Ridgeback LCS) 465.5 (Non-ridgeback LCS)
	July 1 - Sept. 15 (All LCS)	424 (Ridgeback LCS) 498 (Non-ridgeback LCS)
2004	S. Atl: Jan 1 - Feb. 15 N. Atl: Jan 1 - April 15	244.7 18.1
(LCS combined)	S. Atl: July 1 - Sept. 30 N. Atl: July 1 - July 15	369.5 39.6
2005 (LCS combined)	S. Atl: Jan. 1 - Feb 15 N. Atl: Jan. 1 - April 30	133.3 6.3
	S. Atl: July 6 - Aug 31 N. Atl: July 21 - Aug 31	182 65.2
	S. Atl: Sept 1 - Nov. 15 N. Atl: Sept 1 - Sept. 15	187.5 4.9
2006 (LCS combined)	S. Atl: Jan 1 - Mar. 15 N. Atl: Jan 1 - April 30	141.3 5.3
	S. Atl: July 6 – Aug. 16 N. Atl: July 6 – Aug. 6	151.7 66.3
	S. Atl: Sept.1 – Oct. 3 N. Atl: Closed	50.3 Closed
2007	S. Atl: Closed N. Atl: January 1 – April 30	Closed (-112.9) 7.9
(LCS combined)	S. Atl: July 15 – August 15 N. Atl: July 6 – July 31	163.1 69.0

Year	Open dates	Quota (mt dw)
	S. Atl: merged with 2nd season N. Atl: CLOSED	
2008 (LCS combined except no sandbar allowed)	S. Atl: CLOSED to July 23 N. Atl: CLOSED to July 23	Closed (16.3) Closed (10.7)
	NSB Atlantic: July 24 - Dec. 31 NSB Research: July 24 - Dec. 31	187.8 37.5
2009 (LCS combined except no sandbar allowed)	NSB Atl: Jan 23 - July 1 NSB Research: Jan 23 - July 1	187.8 37.5
2010 (LCS combined except no sandbar allowed)	NSB Atl: July 15 – Dec 5 NSB Research: Jan 5 – Oct 12	169.7 37.5
2011 (LCS combined except no sandbar allowed)	NSB Atl: July 15 – Nov 15 NSB Research: Jan 1 – July 26	190.4 37.5
2012 All SHKs except LCS opened Jan 24; Porbeagle closed May 31	NSB Atl: July 15 – Dec 31 NSB Research: Jan 24 – Dec 31	183.2 37.5
2013 All SHKS opened Jan 1 Porbeagle sharks closed for entire year; ATL SCS and BN closed Sept 30	Agg LCS Atl: Jan 1 – Sept 30 Agg LCS Research: Jan 1 – Dec 31	188.3 50.0
2014 Porbeagle closed Dec 17	Agg LCS Atl: June 1 - Nov 30 Agg LCS Research: Jan 1 – Dec 31	168.9 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	Agg LCS Atl: July 1- Dec 31 Agg LCS Research: Jan 1 – Dec 31	168.9 50.0
2016 All SHKs opened Jan 1; Only allow 20% of ATL Agg LCS quota at the beginning of the year	Agg LCS Atl: Jan 1 – Dec 31 Agg LCS Research: Jan 1 – Dec 31	168.9 50.0

Year	Open dates	Quota (mt dw)
2017 All SHKs except wGOM LCS opened Jan 1; Only allow 20% of ATL Agg LCS quota at the beginning of the year	Agg LCS Atl: Jan 1 – Dec 31 Agg LCS Research: Jan 1 - Dec	168.9 50.0
2018 All SHKs opened Jan 1; Only allow 20% of ATL Agg LCS quota at the beginning of the year	Agg LCS Atl: Jan 1 – Dec 31 Agg LCS Research: Jan 1 - Dec	168.9 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 2018 shark regulations affecting Atlantic blacktip 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:** Quota as of Jan 1, 2018: 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:** Directed Permit: • 25 non-sandbar LCS/vessel/trip in the Atlantic region • 3 non-sandbar LCS/vessel/trip in the Atlantic region • 36 non-sandbar LCS/vessel/trip in the Atlantic region • 45 non-sandbar LCS/vessel/trip in the Atlantic region Incidental Permit: 3 non-sandbar LCS/vessel/trip	**Non-sandbar LCS Atlantic Region:** Quota as of Jan 1, 2018: Aggregated LCS:168.9 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. 83” straight fork length for 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		

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

2.3 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 Atlantic blacktip shark

Species	Blacktip shark (*Carcharhinus limbatus*)
Management Unit	Atlantic Ocean
Management Unit Definition	Starting in 2008, any water north and west of 25 20.4' N. lat. (approximately at Monroe and Miami-Dade county line)
Management Entity	NMFS, 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 Atlantic blacktip shark

Criteria	Value
Current Relative Biomass Level	Unknown
Domestic Minimum Stock Size Threshold	$(1\text{-}M)B_{MSY}$
Years to Rebuild	Unknown
Current Relative Fishing Mortality	Unknown
Maximum Fishing Mortality Threshold	Unknown
B_{MSY}	Unknown

Stock Projection Information for the Atlantic Blacktip Shark

Atlantic Blacktip Sharks
NMFS does not currently have a rebuilding plan for Atlantic blacktip sharks because the stock is unknown.

2.4 Quota Calculations

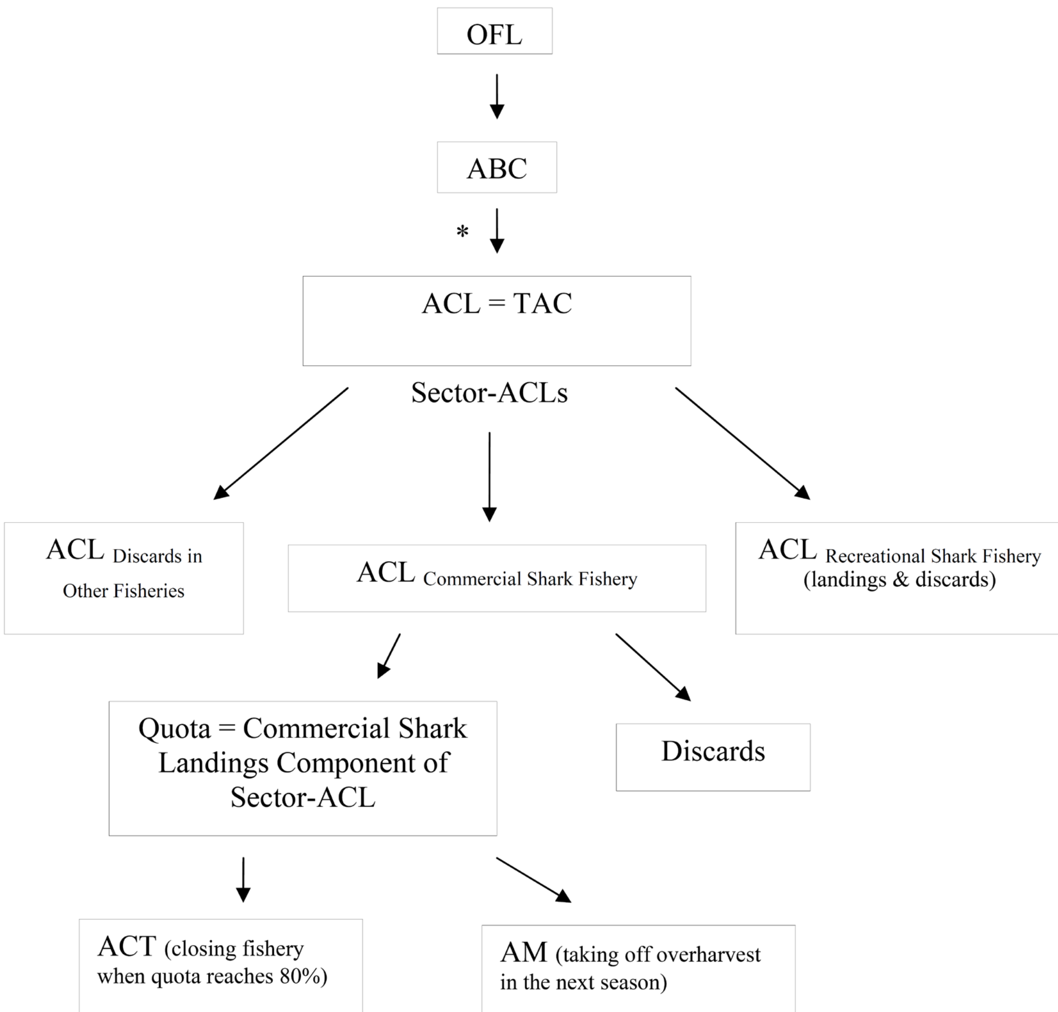
Atlantic Blacktip Sharks

Table 8 Quota calculation details for Atlantic blacktip sharks.

Current Commercial Landings Quota Value	Annual 168.9 mt for Aggregated LCS, not specific to Atl. blacktip
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?
NMFS currently does not have a quota for Atlantic blacktip sharks. Atlantic blacktip sharks are currently managed as part of the Aggregated LCS management group.

Our mechanism for calculating the commercial landings quotas (ACL sub-sector) is described in the figure below.



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 and discard estimates. However, bycatch and discard estimates are used to calculate what portion of the ABC should be provided to the commercial fishermen for the commercial landings quota (sub-sector ACL).

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

We need the analysts to provide the overfishing limit and the acceptable biological catch. We aim to be at least 50 percent certain of rebuilding an overfished stock or preventing overfishing, and for sharks generally, 70 percent certain.

2.5 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 10 Annual commercial blacktip 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
2009**	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
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

Table 10 Continued Annual commercial blacktip 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*
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**	583 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**	583 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*****	583 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*****	583 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*****	583 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*****	583 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*****	583 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 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, the base quota for Aggregated LCS was split into regional quotas, and blacktip sharks for the Gulf of Mexico received a separate quota. This base quota split between the two regions are as follows: Gulf of Mexico= 157.5 mt dw; Atlantic= 168.9 mt dw. The Gulf of Mexico blacktip base quota was established at 256.6 mt dw. Under Amendment 6, the Gulf of Mexico regional commercial quotas for LCS and blacktip was split into western and eastern sub-regional quotas as follows: Western Gulf of Mexico sub-regional quota= 231.5 mt dw for blacktip sharks, 72.0 mt dw for aggregated LCS; Eastern Gulf of Mexico sub-regional quota= 25.1 mt dw for blacktip sharks, 85.5 mt dw for aggregated LCS.
*****The default retention limit for LCS could be adjusted during the fishing year from zero to 55 non-sandbar LCS/vessel/trip.

Table 11 Annual recreational Atlantic blacktip shark 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

Year	**Fishing Year**	**Size Limit (straight line fork length)**	**Bag Limit**
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 =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2014	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2015	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2016	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2017	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip
2018	Calendar Year	Minimum size =4.5 ft	1 LCS/SCS/pelagic shark combined/vessel/trip

Table 12: 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 Limit[1] (# 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	54 [C,D]	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	54 [C,D]	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	54 [C,D]	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	54 [C,D]	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	54 [C,D]	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	54 [C,D]	1/1/2018	12/31/2018	NA	NA	NA	1 LCS/SCS/pelagic shark combined/vessel/trip [C, D, E]	1/1/2018	12/31/2018

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).

Table 13: Atlantic Blacktip Shark Commercial Regulatory History prepared by: Larry Redd 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]	2,436	1,218	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		
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		
		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	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		
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		
		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		
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		
		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		
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		
		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		
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		
		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		
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		
		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	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		
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		
		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		
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		
		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		
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		
		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
			NA	107	Closed	Met seasonal quota	9/16/2002	12/31/2002	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
			NA	76	Closed - Ridgeback LCS	Met seasonal quota	4/16/2003	6/30/2003	NA	NA	NA	NA	NA	NA	NA		
		424	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
			NA	107	Closed - Ridgeback LCS	Met seasonal quota	9/16/2003	12/31/2003	NA	NA	NA	NA	NA	NA	NA		
		465.5	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
			NA	46	Closed- Non-ridgeback LCS	Met seasonal quota	5/16/2003	6/30/2003	NA	NA	NA	NA	NA	NA	NA		
		498	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
			NA	107	Closed - Non-ridgeback LCS	Met seasonal quota	9/16/2003	12/31/2003	NA	NA	NA	NA	NA	NA	NA		
2004 [A,C,D,G,H]	1,107	244.7	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
			NA	136	Closed - SATL	Met seasonal quota	2/16/2004	6/30/2004	NA	NA	NA	NA	NA	NA	NA		
		369.5	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
			NA	92	Closed - SATL	Met seasonal quota	10/1/2004	12/31/2004	NA	NA	NA	NA	NA	NA	NA		
		18.1	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
			NA	76	Closed - NATL	Met seasonal quota	4/16/2004	6/30/2004	NA	NA	NA	NA	NA	NA	NA		
		39.6	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
			NA	169	Closed - NATL	Met seasonal quota	7/16/2004	12/31/2004	NA	NA	NA	NA	NA	NA	NA		
2005 [A,C,D,G,H]	1,107	133.3	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		
		182	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
		187.5	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
			NA	46	Closed - SATL	Met seasonal quota	11/16/2005	12/31/2005	NA	NA	NA	NA	NA	NA	NA		
		6.3	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		
		65.2	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
		4.9	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
			NA	107	Closed -NATL	Met seasonal quota	9/16/2005	12/31/2005	NA	NA	NA	NA	NA	NA	NA		

Table 13 continued: Atlantic Blacktip Shark Commercial Regulatory History prepared by: Larry Redd 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
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		
		151.7	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
		50.3	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
			NA	89	Closed _SATL	Met seasonal/regional quota	10/4/2006	12/31/2006	NA	NA	NA	NA	NA	NA	NA		
		5.3	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
			NA	66	Closed - NATL	Met seasonal/regional quota	5/1/2006	7/5/2006	NA	NA	NA	NA	NA	NA	NA		
		66.3	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
			NA	147	Closed -NATL	Met seasonal/regional quota	8/7/2006	12/31/2006	NA	NA	NA	NA	NA	NA	NA		
2007 [A,C,D,G,H]	1,107	0	NA	195	SATL - Closed	Met seasonal/regional quota	1/1/2007	7/14/2007	NA	NA	NA	NA	NA	NA	NA		
		163.1	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
			NA	138	Closed - SATL	Met seasonal/regional quota	8/16/2007	12/31/2007	NA	NA	NA	NA	NA	NA	NA		
		7.9	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
			NA	66	Closed - NATL	Met seasonal/regional quota	5/1/2007	7/5/2007	NA	NA	NA	NA	NA	NA	NA		
		69	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
			NA	153	Closed -NATL	Met seasonal/regional quota	8/1/2007	12/31/2007	NA	NA	NA	NA	NA	NA	NA		
2008 [I]	1,107	0	NA	205	Closed - SATL	working on rule; large overharvests in past	1/1/2008	7/23/2008	NA	NA	NA	NA	NA	NA	NA		
		0	NA	205	Closed - NATL	working on rule; large overharvests in past	1/1/2008	7/23/2008	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
	37.5	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
2009 [I]	187.8	0	NA	22	Non Sandbar ATL-Closed	implementation of season	1/1/2009	1/22/2009	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
			NA	183	Non Sandbar ATL-Closed		7/2/2009	12/31/2009	NA	NA	NA	NA	NA	NA	NA		
	37.5	0	NA	22	Non- Sandbar Research- Closed	implementation of season	1/1/2009	1/22/2009	NA	NA	NA	NA	NA	NA	NA		
		37.5	NA	160	Non Sandbar Research- Open		1/23/2009	7/1/2009	NA	NA	NA	NA	NA	NA	NA	1/23/2009	7/1/2009
			NA	183	Non Sandbar Research- Closed		7/2/2009	12/31/2009	NA	NA	NA	NA	NA	NA	NA		
2010 [I]	187.8	0	NA	195	Non Sandbar ATL - Closed	implementation of season	1/1/2010	7/14/2010	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	144	Non Sandbar ATL- Open		7/15/2010	12/5/2010	NA	NA	NA	NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	7/15/2010	12/5/2010
			NA	26	Non Sandbar ATL- Closed	Met seasonal/regional quota	12/6/2010	12/31/2010	NA	NA	NA	NA	NA	NA	NA		
	37.5	0	NA	4	Non Sandbar Research - Closed	implementation of season	1/1/2010	1/4/2010	NA	NA	NA	NA	NA	NA	NA		
		37.5	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
			NA	80	Non Sandbar Research- Closed	Met seasonal/regional quota	10/13/2010	12/31/2010	NA	NA	NA	NA	NA	NA	NA		
2011 [I]	187.8	0	NA	195	Non Sandbar ATL - Closed	implementation of season	1/1/2011	7/14/2011	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	3 non-sandbar LCS per vessel per trip for incidental permit holders.	7/15/2011	11/15/2011
			NA	46	Non Sandbar ATL - Closed	Met seasonal/regional quota	11/16/2011	12/31/2011	NA	NA	NA	NA	NA	NA	NA		
	37.5	37.5	NA	207	Non Sandbar Research - Open		1/1/2011	7/26/2011	NA	NA	NA	NA	NA	NA	NA	1/1/2011	7/26/2001
			NA	158	Non Sandbar Research - Closed	Met seasonal/regional quota	7/27/2011	12/31/2011	NA	NA	NA	NA	NA	NA	NA		
2012 [I]	187.8	0	NA	196	Non Sandbar ATL- Closed	implementation of season	1/1/2012	7/14/2012	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
			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
	37.5	0	NA	23	Non Sandbar Research- Closed	implementation of season	1/1/2012	1/23/2012	NA	NA	NA	NA	NA	NA	NA		
		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
2013 [I]	188.3	188.3	NA	273	ATL Aggregated LCS- 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	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2013	9/30/2013
			NA	92	ATL Aggregated LCS- Closed	Met seasonal/regional quota	10/1/2013	12/31/2013	NA	NA	NA	NA	NA	NA	NA		
	50	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

Table 13 continued: Atlantic Blacktip Shark Commercial Regulatory History prepared by: Larry Redd 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
2014 [I]	168.9	0	NA	151	ATL Aggregated LCS- Closed	implementation of season	1/1/2014	5/31/2014	NA	NA	NA	NA	NA	NA	NA		
		168.9	NA	183	ATL Aggregated LCS- 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.	6/1/2014	11/30/2014
		NA	NA	31	ATL Aggregated LCS- Closed	Met seasonal/regional quota	12/1/2014	12/31/2014	NA	NA	NA	NA	NA	NA	NA		
	50	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
2015 [I,K]	168.9	0	NA	151	ATL Aggregated LCS- Closed	implementation of season	1/1/2015	5/31/2015	NA	NA	NA	NA	NA	NA	NA		
		168.9	NA	184	ATL Aggregated LCS- 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
			NA									NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	7/1/2015	12/31/2015
	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
2016 [I,K]	168.9	168.9	NA	366	ATL Aggregated LCS- 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	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	7/15/2016
			NA									NA	NA	NA	45 non-sandbar LCS per vessel per trip for directed permit holder	7/15/2016	10/19/2016
			NA									NA	NA	NA	25 non-sandbar LCS per vessel per trip for directed permit holders	10/19/2016	12/31/2016
	50	50	NA	366	Researach Aggregated LCS- Open		1/1/2016	12/31/2016	NA	NA	NA	NA	NA	NA	NA	1/1/2016	12/31/2016
2017 [I,K]	168.9	168.9	NA	365	ATL Aggregated LCS- 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	4/15/2017
			NA									NA	NA	NA	3 non-sandbar LCS per vessel per trip for directed permit holders	4/15/2017	7/16/2017
			NA									NA	NA	NA	36 non-sandbar LCS per vessel per trip for directed permit holders	7/16/2017	12/31/2017
			NA									NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2017	12/31/2017
	50	50	NA	365	Research Aggregated LCS- Open		1/1/2017	12/31/2017	NA	NA	NA	NA	NA	NA	NA	1/1/2017	12/31/2017
2018 [I,K]	168.9	168.9	NA	365	ATL Aggregated LCS- 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	5/12/2018
			NA									NA	NA	NA	3 non-sandbar LCS per vessel per trip for directed permit holders	5/12/2018	7/18/2018
			NA									NA	NA	NA	36 non-sandbar LCS per vessel per trip for directed permit holders	7/18/2018	12/31/2018
			NA									NA	NA	NA	3 non-sandbar LCS per vessel per trip for incidental permit holders.	1/1/2018	12/31/2018
	50	50	NA	365	Research Aggregated LCS- Open		1/1/2018	12/31/2018	NA	NA	NA	NA	NA	NA	NA	1/1/2018	12/31/2018

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 (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

Table 14 Atlantic States Management history

State	Confirmed by State for the SEDAR 2017 Sandbar assessment	pre-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Atlantic Region																									
Connecticut [A]	Yes	no shark regulations	no shark regulations	no shark regulations	no shark regulations	no shark regulations	no shark regulations	no shark regulations	no shark regulations	no shark regulations	no shark regulations	no shark regulations	no shark regulations	no shark regulations	no shark regulations	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	Great hammerhead, smooth hammerhead, scalloped hammerhead 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 [A]	Yes	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	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	no new shark regulations	no new shark regulations	no new shark regulations	no new shark regulations	no new shark regulations	ASMFC Plan	ASMFC Plan	ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan	Sharks – ASMFC Coastal Shark Plan	Sharks – ASMFC Coastal Shark Plan; Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	Sharks – ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan	no new shark regulations	no new shark regulations
Florida [A]	Yes	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.	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	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	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: min size – 54” except no min. size on blacknose, blacktip, bonnethead, smooth dogfish, finetooth, Atlantic sharpnose; Commercial/recreational possession limit – 1 shark/person/day, max. 2 sharks/vessel on any vessel with 2 or more persons on board; Allowable gear – hook and line only; 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; Prohibited species same as federal regulations plus prohibition on harvest of lemon and sandbar sharks in state waters, direct and continuous transit through state waters to place of landing of lemon sharks and sandbar sharks legally caught in federal waters is allowed. Prohibition on harvest of tiger sharks and great, smooth, and scalloped hammerheads from state waters will be implemented on January 1, 2012.	no new shark regulations	no new shark regulations	Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	no new shark regulations	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 [A]	Yes	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 All other sharks 2/person/day or 2 /boat/day, whichever is less. 54"TL min. size, only one shark over 84" TL	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	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	No new shark regulations	Recreational: 1 shark from the Small Shark Composite (bonnethead, sharpnose, and spiny dogfish, min size 30” FL; 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; 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; 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; 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; Sharks may not be landed in Georgia if harvested using gillnets	Commercial/Recreational: 1/person/boat for sharks from the Small Shark Composite (bonnethead, sharpnose, and spiny dogfish, min size 30” FL; All other sharks - 1 shark/person or boat, whichever is less, min size 54” FL Prohibited Species: same as federal, plus silky sharks; All species must be landed head and fins intact; Sharks may not be landed in Georgia if harvested using gillnets; ASMFC Coastal Shark Plan	no new shark regulations	Commercial/Recreational: 1/person for sharks from the Small Shark Composite (bonnethead, Atlantic sharpnose, and spiny dogfish), min size 30” FL. All other sharks - 1 shark/person or boat, whichever is less, min size 54” FL. Hammerheads (great, scalloped and smooth)- 1/person, minimum size – 78” FL. Prohibited Species: same as federal, plus silky sharks; All species must be landed head and fins intact; Sharks may not be landed in Georgia if harvested using gillnets; ASMFC Coastal Shark Plan; Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	no new shark regulations	no new shark regulations	no new shark regulations	no new shark regulations
Maine [A]	No	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	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	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	Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	no new shark regulations	no new shark regulations	no new shark regulations	no new shark regulations
Maryland [A]	No		4000 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		Size limit of 58 inches FL or a carcass less than 31 inches; recreational bag limit of one shark per person per day; by 1998: maximum gillnet mesh size of 6 inches; no longlining in tidal waters.						By Feb 2004: minimum FL reduced to 54 inches, carcass length the same (31 inches); recreational catch limit of 1 shark per person per day; reference to federal regs 50 CFR 635.	ASMFC Coastal Shark Plan	By May 2006: no new shark regulations		By Oct 2008: no new shark regulations	ASMFC Plan	Sharks – ASMFC Coastal Shark Plan		ASMFC Coastal Shark Plan	Recreational catch required to be tagged; ASMFC Coastal Shark Plan	Recreational catch required to be tagged; ASMFC Coastal Shark Plan; 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); Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	no new shark regulations	no new shark regulations	no new shark regulations	no new shark regulations
Massachusetts [A]	No	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations		By May 2006: Prohibition on harvest, catch, take, possession, transportation, selling or offer to sell any basking, dusky, sand tiger, or white sharks.		By Oct 2008: no new shark regulations	No new shark regulations	ASMFC Coastal Shark Plan except that the tails and fins of smooth dogfish must remain attached through landing	ASMFC Coastal Shark Plan (no shark species may be landed with tails or fins removed 322 CMR 6.37(3)(d))	ASMFC Coastal Shark Plan (no shark species may be landed with tails or fins removed 322 CMR 6.37(3)(d))	ASMFC Coastal Shark Plan (no shark species may be landed with tails or fins removed 322 CMR 6.37(3)(d))	ASMFC Coastal Shark Plan (no shark species may be landed with tails or fins removed 322 CMR 6.37(3)(d)); Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	Sharks – ASMFC Coastal Shark Plan (no shark species may be landed with tails or fins removed 322 CMR 6.37(3)(d))	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:	no new shark regulations	no new shark regulations
New Hampshire [A]	No	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No commercial take of porbeagle	Prohibited sharks listed; 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; NH Wholesale Marine Species License and a Federal Dealer permit required for all dealers purchasing listed sharks; 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	Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	no new shark regulations	no new shark regulations	no new shark regulations	no new shark regulations
New Jersey [A]	No				No shark-specific regulations; by 1998: no longline fishing; restrictions on the use of gillnets						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		By May 2006: no sale during federal closures; Finning prohibited; Prohibited Species: basking, bigeye sand tiger, sand tiger, whale and white sharks		By Oct 2008: no new shark regulations	No new shark regulations	ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan	Sharks – ASMFC Coastal Shark Plan	Sharks – ASMFC Coastal Shark Plan; Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	Sharks – ASMFC Coastal Shark Plan	Sharks ASMFC Coastal Shark Plan	no new shark regulations	no new shark regulations
New York [A]	No				By 1998: prohibition on finning sharks; no other shark regulations						By Feb 2004: reference to federal regs 50 CFR part 635; prohibited sharks listed		By May 2006: no new shark regulations		By Oct 2008: no new shark regulations	No new shark regulations	ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan	Sharks – ASMFC Coastal Shark Plan	Sharks – ASMFC Coastal Shark Plan; Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	ASMFC Coastal Shark Plan. Separate requirement that 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	A SMFC Coastal Plan. Non-stainless, non-offset circle hooks must be used when taking sharks.	no new shark regulations	no new shark regulations
North Carolina [A]	Yes	1990: prohibition on finning 1990 – 7500 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	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 inch 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	No new shark regulations	No new shark regulations	Open seasons and species groups same as federal; 4000 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	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	Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	no new shark regulations	no new shark regulations	no new shark regulations	no new shark regulations
Rhode Island [A]	No	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	– ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan	Sharks - RIMFC Regulations part VII 7.24	Sharks – ASMFC Coastal Shark Plan. Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	Sharks – ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan. A person who does not hold a license or permit shall possess, sell, offer for sale, trade or distribute a shark fin.	no new shark regulations	no new shark regulations
South Carolina [A]	No				By 1998: federal regs adopted by reference; use of gillnets prohibited in the shark fishery						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		By May 2006: non-Atlantic sharpnose/bonnethead sharks – 1 shark/boat/trip, min size – 54” FL		By Oct 2008: no new shark regulations	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	Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	no new shark regulations	no new shark regulations	no new shark regulations	no new shark regulations
Virginia [A]	No	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		7500 lb commercial trip limit; minimum size of 58 inches FL or 31 inches carcass length (but can keep up to 200 lbs dw of sharks per day less than 31 inches carcass length); prohibition on finning; recreational: possession limit of 1 shark per person per day	By 1998: no longlining in state waters	no new shark regulations	no new shark regulations	no new shark regulations	no new shark regulations	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	ASMFC Plan	ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan - Great hammerhead, smooth hammerhead, scalloped hammerhead recreational minimum size of 78” FL	Sharks – ASMFC Coastal Shark Plan	ASMFC Coastal Shark Plan	no new shark regulations	no new shark regulations
		A- These state regulations could affect issues from when Atlantic blacktip sharks were managed with all other LCS regions.																							

Table 14: Gulf State Management history

State	Confirmed by State for the SEDAR 2017 Sandbar assessment	pre-1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Gulf of Mexico Region																									
Alabama [A]	No	no shark regulations	First shark regulations implemented: state shark fishery closes with the federal shark fishery		By 1998: only short lines in state waters; time/area and size restrictions on the recreational use of gillnets						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		By May 2006: Recreational & Commercial non-sharpnose min size – 54" FL or 30" dressed; Prohibition: Atlantic angel, bigeye thresher, dusky, longfin make, sand tiger, basking, whale, white, and nurse sharks		By Oct 2008: no new regs	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; state waters close when federal season closes; no shark fishing on weekends, Memorial Day, Independence Day, or Labor Day; 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	no new shark regulations	no new shark regulations	Great hammerhead, smooth hammerhead, scalloped hammerhead 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 [A]	No			Ban on entanglement nets	No new shark regulations						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		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		By Oct 2008: Commercial: 33 per vessel per trip limit, no min size	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	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 [A]	No			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 inches total length for small coastal sharks and 37 inches total length for large coastal sharks							By Feb 2004: no new shark regulations		By May 2006: 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		Recreational: min size - LCS/Pelagics 37" TL; SCS 25" TL; bag limit - LCS/Pelagics 1/person/day up to 3/vessel/day; SCS 4/person/day; Commercial and prohibited species – same as federal regulations; Prohibition on finning	no new shark regulations	no new shark regulations	no new shark regulations	no new shark regulations	no new shark regulations	It is unlawful for commercial fishermen to possess sandbar sharks. Prohibition on finning	no new shark regulations	no new shark regulations
Puerto Rico [A]	Yes	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	No shark regulations	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	no new shark regulations	Swordfish or billfish, tuna and shark are covered under the federal Atlantic HMS regulations (50 CFR, Part 635); Fishers who capture these species are required to comply with said regulation; billfish captured incidentally with long line must be released by cutting the line close to the fishhook, avoiding the removal of the fish from the water; in the case of tuna and swordfish, fishers shall obtain a permit according to the requirements of the federal government; Year-round closed season on nurse sharks	no new shark regulations	no new shark regulations	no new shark regulations	Swordfish or billfish, tuna, and shark are covered under the federal Atlantic HMS regulations (50 CFR, Part 635), which also apply in territorial waters; Fishers who capture these species are required to comply with said regulation; billfish captured incidentally with long line must be released by cutting the line close to the fishhook, avoiding the removal of the fish from the water; in the case of tuna and swordfish, fishers shall obtain a permit according to the requirements of the federal government; Year-round closed season on nurse sharks.	no new shark regulations	no new shark regulations	no new shark regulations	no new shark regulations
Texas [A]	Yes	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.		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						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		By May 2006: no new shark regulations		By Oct 2008: no new shark regulations	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	no new shark regulations	no new shark regulations	no new shark regulations	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.	no new shark regulations	no new shark regulations

A- These state regulations could affect issues from when Atlantic blacktip sharks were managed with all other LCS regions.

3. Assessment History & Review

The blacktip shark was first assessed individually in 1998 and later in 2002 and 2006. Prior to that, it was part of the Large Coastal Shark complex, which was first assessed in 1991 and subsequently updated in 1994, 1996, and 1998. In the 1998 Shark Evaluation Workshop (NMFS 1998), a Bayesian surplus production modeling approach was used to assess blacktip sharks, concluding that the 1997 stock size was 44-50% of the stock size at MSY. The 2002 Stock Evaluation Workshop saw the use of multiple assessment methodologies, including surplus production, delay difference, and age-structured production models. These different models produced a range of predictions on stock status, but in general indicated that the stock was near and likely above MSY and, with the exception of some of the ASPM (age-structured production model) runs, F was below F_{MSY}. The ASPM baseline run yielded particularly optimistic results, estimating that the stock was well above MSY and F below F_{MSY} (Cortés et al. 2002). Resource status was thus estimated to have improved since the 1998 assessment and the report noted that an increase of 20-50% in the 2000 TAC (total allowable catch) might be sustainable in the long term (Cortés et al. 2002).

The first assessment of blacktip sharks under the SEDAR framework took place in 2006 (SEDAR 11, NMFS 2006). This was the first assessment where two separate stocks, Gulf of Mexico and South Atlantic, were considered. While catches were available since 1981, only a few indices of abundance were available, starting only in 1992 and showing conflicting trends. The ASPM was used as the base model to take advantage of the increasing age-specific biological and selectivity information available, but another formulation of the ASPM and two Bayesian production models were also run for contrast. Stock status results conflicted among models (spanning the range from not overfished with no overfishing to overfished with overfishing). Given the uncertainty and lack of reliability of stock status results, the CIE reviewers determined that the assessment did not allow to reach a conclusion on the status of the stock.

References

Cortés, E., L. Brooks, 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.

NMFS (National Marine Fisheries Service). 1998. Report of the Shark Evaluation Workshop. NOAA/NMFFS Panama City Laboratory.

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.

4. Regional Maps

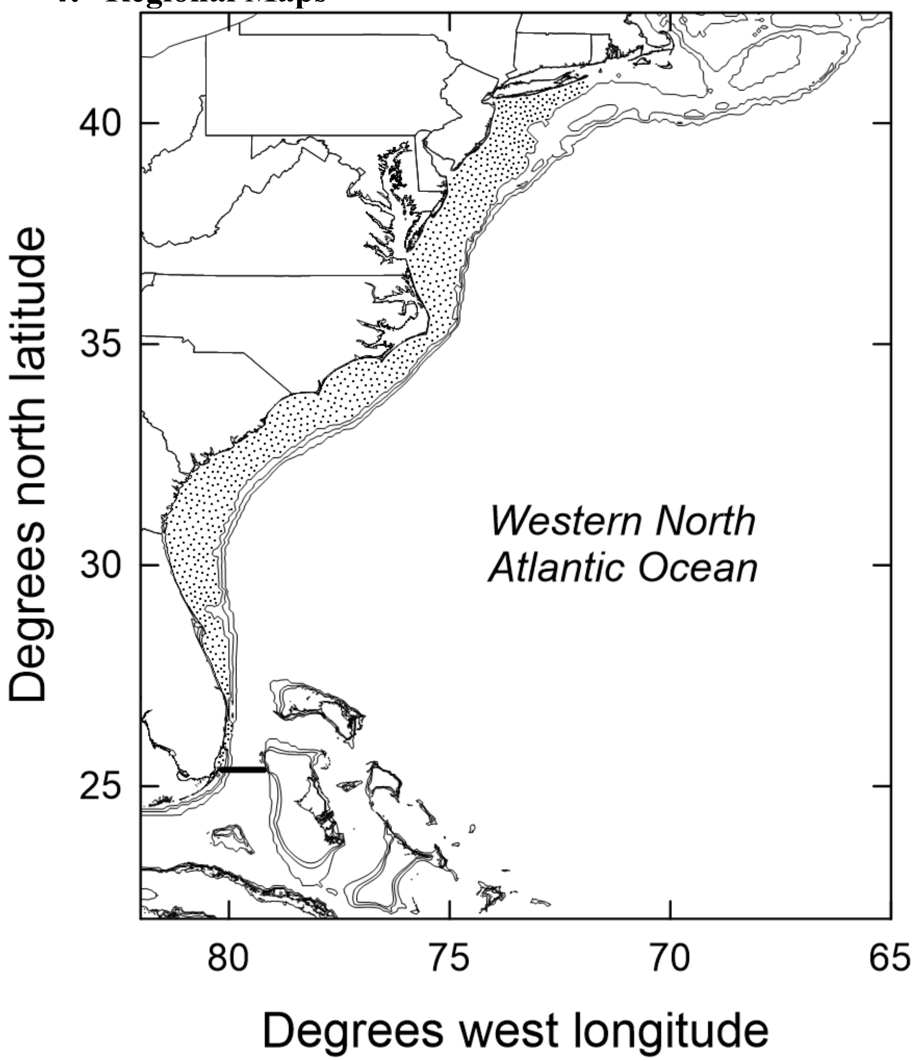


Figure 1. Distribution of blacktip sharks (*Carcharhinus limbatus*) off the east coast of the United States indicated by shaded area. The 50, 100 and 200 m isobaths are indicated. Note that area shaded includes continental shelf waters less than 50 m; however, blacktip sharks are captured, although infrequently, at depths out to 100 m. The horizontal black line at 25º20.4’ latitude indicates the boundary between the Atlantic region and the Gulf of Mexico region for management purposes.

5. 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 65

Atlantic Blacktip Shark

SECTION II: Data Workshop Report

January 2020

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

1. Introduction

1.1 Workshop Time and Place

The SEDAR 65 Data Workshop meeting was held October 29 – November 1, 2019 in Charleston South Carolina. Three data webinars were held prior to the workshop on May 28th, June 20th, and September 10th. An additional webinar was held post the Data workshop on December 5th, 2019.

1.2 Terms of Reference

1. Define the unit stock for the SEDAR 65 stock assessment as from the northern extent of the stock to the east coast of Florida at the mainland at 25°20.4' N. lat., proceeding due east (the northern Miami-Dade County line).
   a. The potential for population substructure within that stock unit may be examined, if feasible.
   b. If feasible, document if the range of the stock has changed in recent years (e.g., moved further north) compared to historical norms.
2. Review, discuss, and tabulate available life history information.
   a. Evaluate age, growth, natural mortality, and reproductive characteristics.
   b. Provide appropriate models to describe population growth, maturation, and fecundity by age, sex, and/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.
3. Recommend discard mortality rates.
   a. Review available research and published literature.
   b. Provide estimates of discard mortality rate by fishery, gear type, depth, and other strata as feasible or appropriate.
   c. Include thorough rationale for recommended discard mortality rates.
   d. Provide estimates of uncertainty around recommended discard mortality rates.
4. Provide measures of relative population abundance that are appropriate for stock assessment.
   a. Consider and discuss all available and relevant fishery-dependent and -independent data sources. Document all programs evaluated; address program objectives, methods, coverage, sampling intensity, and other relevant characteristics.
   b. Provide maps of fishery and survey coverage.
   c. Develop fishery and survey CPUE indices by appropriate strata (e.g., age or size, and fishery) and include measures of precision and accuracy.
   d. Develop fishery and survey CPUE length compositions by appropriate strata (e.g., age or size, and fishery) and include both the number of individuals measured as well as relevant alternative measures of effective sample size (i.e., alternative measures of sampling effort

such as the number of trips, hauls, sets, baskets of gear, etc. that were sampled for length measurements).

   e. Discuss the degree to which available indices and length compositions adequately represent fishery and population conditions.
   f. Recommend which data sources adequately and reliably represent population abundance for use in assessment modeling.
   g. Provide appropriate measures of uncertainty for the abundance indices to be used in stock assessment models.
   h. Rank the available indices with regard to their reliability and suitability for use in assessment modeling.

5. Provide commercial catch statistics across all fisheries, including both landings and discards in both pounds and number.
   a. Evaluate and discuss the adequacy of available data for accurately characterizing harvest and discard by fishery sector or gear.
   b. Provide length distributions for both landings and discards if available and include both the number of individuals measured as well as relevant alternative measures of effective sample size (i.e., alternative measures of sampling effort such as the number of trips, hauls, sets, baskets of gear, etc. that were sampled for length measurements).
   c. Discuss the degree to which available length distributions adequately represent commercial fishery conditions.
   d. Provide estimates of uncertainty around each set of landings and discard estimates if available.
6. Provide recreational catch statistics, including both landings and discards in both pounds and number.
   a. Evaluate and discuss the adequacy of available data (including species id) for accurately characterizing harvest and discard by species and types of recreational fishing.
   b. Provide length distributions for both landings and discards if available and include both the number of individuals measured as well as relevant alternative measures of effective sample size (i.e., alternative measures of sampling effort such as the number of trips, hauls, sets, baskets of gear, etc. that were sampled for length measurements).
   c. Discuss the degree to which available length distributions adequately represent recreational fishery conditions.
   d. Provide estimates of uncertainty around each set of landings and discard estimates.
7. Identify and describe ecosystem, climate, species interactions, habitat considerations, and/or episodic events that would be reasonably expected to affect population dynamics.
8. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. If possible, include specific guidance on sampling intensity (number of samples including age and length structures) and appropriate strata and coverage.
9. Prepare the Data Workshop report providing complete documentation of workshop actions and decisions in accordance with project schedule deadlines (Section II of the SEDAR assessment report).

1.3 List of Participants

Participants	Affiliation
Panelists	
Dean Courtney	NMFS
Enric Cortes	NMFS
William Driggers	NMFS
Heather Moncrief - cox	NMFS
Xinsheng Zhang	NMFS
Andrea Kroetz	NMFS
John Carlson	NMFS
Eric Hoffmayer	NMFS
Adam Pollack	NMFS
Alyssa Mathers	NMFS
Heather Baertlein	NMFS
Bryan Frazier	SCDNR
James Gelsleichter	UNF
Robert Hueter	MOTE
Steve Kajiura	FAU
Rob Latour	VIMS
John Mohan	TAMU
Staff	
Kathleen Howington	SEDAR
Cierra Graham	SAFMC
Clifford Hutt	NMFS/HMS
Julie Neer	SEDAR
Workshop Observers	
Rusty Hudson	DSF
Kaitlyn O'Brien	VIMS
Liz Vinyard	SCDNR
Ashley Galloway	SCDNR
Michelle Passeritti	U of SC
Steve Durkee	NMFS
Webinar Participants	
Vivian Matter	NMFS
Kevin McCarthy	NMFS
Lisa Natanson	NMFS
Carolyn Belcher	NMFS
Elizabeth Babcock	RSMAS
Cami McCandless	NMFS

Webinar Observers

Delisse Ortiz	NMFS
Guy Dubeck	NMFS
Ian Miller	NMFS
Jackie Wilson	NMFS
Steve Durkee	NMFS
Tobey Curtis	NMFS
Karyl Brewster-Geisz	NMFS

1.4 List of Data Workshop Working Papers

Documents prepared for the SEDAR 65 Data workshop			
Document #	**Title**	**Author**	**Date Received**
SEDAR65-DW01	Reproductive parameters for blacktip sharks (Carcharhinus limbatus) from the western North Atlantic Ocean	Natanson et. al.	10/9/19 Revised: 10/29/19, 11/5/19 , 11/22/19
SEDAR65-DW02	Age and growth parameters for blacktip sharks, Carcharhinus limbatus, in the western North Atlantic Ocean	Deacy and Moncrief-Cox	10/8/19
SEDAR65-DW03	Bycatch estimates of blacktip shark in the south Atlantic coastal gillnet fishery	Carlson et. al.	9/25/19
SEDAR65-DW04	Bycatch estimates of blacktip shark in the shark bottom longline fishery	Carlson et. al.	9/25/19
SEDAR65-DW05	Size composition and indices of relative abundance of the Atlantic blacktip shark (Carcharhinus limbatus) in coastal Virginia waters	Latour et. al.	10/4/19 Revised: 10/23/19
SEDAR65-DW06	Mark/recapture data for blacktip sharks, Carcharhinus limbatus, in U.S. Atlantic from the NOAA Fisheries Cooperative Shark Tagging Program	Cami McCandless	12/5/19
SEDAR65-DW07	Standardized catch rates of blacktip sharks, Carcharhinus limbatus, caught during the South Carolina Department of Natural Resources, Cooperative Atlantic States Shark Pupping and Nursery long-gillnet survey	Cami McCandless and Bryan Frazier	11/29/19 Revised: 12/31/19
SEDAR65-DW08	Standardized catch rates of blacktip sharks, Carcharhinus limbatus, from the NOAA Cooperative Atlantic States Shark Pupping and Nursery longline survey using generalized linear mixed models	Cami McCandless, Bryan Frazier, James Gelsleichter, and Carolyn Belcher	11/29/19

SEDAR65-DW09	Standardized catch rates of blacktip sharks, *Carcharhinus limbatus*, from the NOAA Cooperative Atlantic States Shark Pupping and Nursery longline survey	Cami McCandless and Lisa Natanson	11/29/19
SEDAR65-DW10	Standardized recruitment index for blacktip sharks caught during the South Carolina Department of Natural Resources, Cooperative Atlantic States Shark Pupping and Nursery short-gillnet survey	Bryan Frazier and Cami McCandless	11/29/19
SEDAR65-DW11	Standardized catch rates of blacktip sharks, *Carcharhinus limbatus*, from the South Carolina Department of Natural Resources red drum and Southeast Area Monitoring and Assessment Program longline surveys	Cami McCandless and Bryan Frazier	11/29/19
SEDAR65-DW12	Standardized catch rates of blacktip sharks, Carcharhinus limbatus, from the Georgia Department of Natural Resources, Southeast Area Monitoring and Assessment Program longline survey	Cami McCandless, Donna McDowell and Carolyn Belcher	11/29/19 Modified: 12/5/19
SEDAR65-DW13	Standardized catch rates of blacktip sharks (Carcharhinus limbatus) from the South Carolina Department of Natural Resources drumline survey	Bryan S. Frazier, Adam G. Pollack	11/26/19
SEDAR65-DW14	Estimation of blacktip shark, *Carcharhinus limbatus*, discards in the northeast gillnet fishery using data collected by the NOAA Northeast Fisheries Observer Program	Cami McCandless, Joe Mello, and Kathy Sosebee	12/5/19
SEDAR65-DW15	Distribution and Length Data for Blacktip Sharks Captured on the NOAA/NMFS/SEFSC/MSLABS Bottom Longline Survey in the Western North Atlantic Ocean	Adam G. Pollack, William B. Driggers III, David S. Hanisko[2] and G. Walter Ingram, Jr.	10/29/19
SEDAR65-DW16	An index of abundance from the Marine Recreational Information Program data	Babcock	10/8/19
SEDAR65-DW17	Catch rates of blacktip sharks (Carcharhinus limbatus) in US Atlantic Ocean from the Shark Bottom Longline Observer Program, 1994-2018	Carlson et.al.	10/4/19

Reference Documents			
SEDAR65-RD01	SEDAR64-RD-12 Model-estimated conversion factors for calibrating Coastal Household Telephone Survey (CHTS) charter boat catch and effort estimates with For Hire Survey (FHS) estimates in the Atlantic and Gulf of Mexico with application to red grouper and greater amberjack	Dettloff and Matter	10/1/19
SEDAR65-DW18	Stress response and post-release mortality of blacktip sharks (*Carcharhinus limbatus*) captured in shore-based and charter boat-based recreational fisheries Stress response and post-release mortality of blacktip sharks (*Carcharhinus limbatus*) captured in shore-based and charter boat-based recreational fisheries.	Frazier	10/25/19
SEDAR65-DW19	Preliminary catches of blacktip sharks in the U.S. Atlantic ocean	Cortes	10/24/19
SEDAR65-DW20	An Updated Literature Review of Post-release Live-discard Mortality Rate Estimates in Sharks for use in SEDAR 65	Dean Courtney and Alyssa Mathers	11/1/19 Revised: 12/4/19
SEDAR65-DW21	Estimating Post-Release Mortality And Capture Stress Of Blacktip Sharks In The Gulf Of Mexico Recreational Fishery	John Mohan	12/6/19

2. Life History

2.1 Life History Work Group Participants

William Driggers, Leader……………………………………………………...NMFS Pascagoula
Bethany Deacy, *not present*………………………………………………….…..LDWF
Bryan Frazier…………………………………………………………………...SCDNR
Jim Gelsleichter………...…….…………………………………………….…UNF
Eric Hoffmayer……………………………………….........................NMFS Pascagoula
Steve Kajiura……………………………………………………………….……FAU
John Mohan…………………………………………………………………TAMUG
Heather Moncrief-Cox…………………………………….……………….NMFS Panama City
Lisa Natanson, *not present*……………………………………………….. NMFS Narragansett

2.2 Summary of Life History Documents

SEDAR65-DW-01: Reproductive parameters for blacktip sharks (*Carcharhinus limbatus*) from the western North Atlantic Ocean.
Lisa J. Natanson, Bethany M. Deacy, Heather E. Moncrief-Cox and William B. Driggers III
Reproductive parameters for blacktip sharks off the east coast of the United States in the western North Atlantic Ocean were estimated using data from the SEFSC Shark Bottom Longline Observer Program and the NEFSC and SEFSC Bottom Longline surveys. Sharks examined ranged in size from 80-178 cm FL for females and 71-158 cm FL for males. Median FL_{50} at maturity was 115.15 cm for males, 123.05 cm for females, and 117.48 cm for sexes combined. Median Age_{50} at maturity was 5.34 years for males, 6.69 years for females, and 5.78 years for sexes combined. Brood size from 87 females ranged from 1 to 7 with a mean of 4.09 (±0.13 SD). There was a significant but weak relationship between maternal age/length and brood size.

SEDAR65-DW-02: Age and growth parameters for blacktip sharks, *Carcharhinus limbatus*, in the western North Atlantic Ocean.
Bethany M. Deacy and Heather E. Moncrief-Cox
Through fishery-dependent and -independent sources, a total of 547 blacktip sharks were collected off the east coast of the United States between 2006 and 2018, which were used to generate age and growth parameters for this species. Three-parameter von Bertalanffy growth curves were produced for females (n=269) males (n=278), and both sexes combined. Results of these growth curves showed a difference between sexes (females: $L_\infty = 166.23 \pm 2.47$ cm FL, $k = 0.16 \pm 0.01$, $t_0 = -2.59 \pm 0.16$; males: $L_\infty = 145.03 \pm 1.82$ cm FL, $k = 0.23 \pm 0.02$, $t_0 = -1.97 \pm 0.16$). Maximum ages observed were 17.5 years and 13.5 years, for females and males, respectively. A long-term recapture that validates annual band deposition in this species up to 13 years of age is discussed.

SEDAR65-DW-06: Mark recapture data for blacktip sharks, *Carcharhinus limbatus*, in the U.S. Atlantic from the NOAA Cooperative Shark Tagging Program.
Camilla T. McCandless
Mark/recapture information from the NOAA Cooperative Shark Tagging Program covering the period from 1965 through 2018 were summarized for blacktip sharks, *Carcharhinus limbatus*, tagged in the U.S. Atlantic. Seasonal distribution of combined tagging and recapture events for all life stages (young of the year, juvenile, adult) of blacktip sharks included waters off Florida and the U.S. Virgin Islands in all seasons. Shark tagging and recapture events for all life stages remained in these waters in the winter, extended north up to New Jersey in the spring and summer, and reduced back down to North Carolina in the fall. Out of 12,912 tagging events along the U.S. Atlantic (60%) and Gulf of Mexico (40%), there was no movement between the two regions and limited exchange (2 fish) between the Atlantic and the Caribbean.

SEDAR65-DW-15: Distribution and Length Data for Blacktip Sharks Captured on the NOAA/NMFS/SEFSC/MSLABS Bottom Longline Survey in the Western North Atlantic Ocean.
Adam G. Pollack, William B. Driggers III, David S. Hanisko and G. Walter Ingram, Jr.
Measurements from 825 females, ranging in size from 51.0-158.0 cm fork length, and 730 males, ranging in size from 47.6 to 158.0 cm FL, were used to generate length-length and length-weight conversions. Precaudal length, fork length, natural total length and stretched total length were measured from the tip of the snout to the anterior margin of the precaudal pit, the caudal notch, the tip of the upper lobe of the caudal fin while in a "natural" position and the tip of the upper lobe of the caudal fin while fully extended along the axis of the body, respectively. All length measures were taken on a straight line along the axis of the body to the nearest millimeter. All length measures were converted to centimeters before analyses. Any sharks with estimated lengths and/or weights were omitted from analyses.

2.3 Life history Information Summary and Consensus

2.3.1 Stock definition datasets and decisions

Efforts were made to contact curators of known tagging databases to determine if any blacktip sharks were documented to move between waters off the US east coast and the Gulf of Mexico. Similarly, persons actively using advanced tagging technologies were contacted. No records of movements between the two areas were found (e.g. SEDAR65-DW-06, Moncrief-Cox, pers. comm., Hueter, pers. comm.).

The Indices Group requested that the Life History Group determine the northern extent of the range of blacktip sharks off the east coast. The northern range of blacktip sharks in the western Atlantic was previously identified as Cape Hatteras, NC, with individuals found north of that area considered rare strays (Bigelow & Schroeder 1948). However, recent telemetry data have revealed that blacktip sharks regularly migrate as far north as the southern coast of Long Island, NY. These data come from sharks instrumented with acoustic transmitters off St Helena Sound, SC (Frazier, unpublished) and Palm Beach, FL (Bowers and Kajiura, unpublished). At least 7% of adult sharks instrumented in St Helena Sound, SC and 43% of adult male blacktip sharks tagged in Palm Beach, FL have been subsequently detected off Long Island, NY in the summer months. Individuals have been demonstrated to repeatedly migrate from Palm Beach, FL to Long Island, NY over multiple years. The repeated migration of a sizeable proportion of

the population indicates that the sharks are not merely straying that far north. Their regular seasonal detection suggests that the northern range for this species extends to at least Long Island, NY.
Decision: Tagging studies show no movement of blacktip sharks between water off the US east coast and the Gulf of Mexico.
Decision: Blacktip sharks range from southern Florida to at least New York off the US east coast.

2.3.2 Age and Growth Datasets and Decisions

Age and growth data were presented by Deacy and Moncrief-Cox (SEDAR65-DW-02) based on growth band counts from 269 females and 278 males. Vertebrae were collected from fishery-dependent and independent sources at locations ranging from 24 56.60ºN to 37 11.00ºN latitude. Aged sharks ranged in size from 46.8-178.0 cm FL for females and 41.0-165.0 cm FL for males. The maximum observed ages for females was 17.5 years, which was two years older than reported for females in the same area by Carlson et al. (2006). The maximum observed age for males was 13.5 years, in agreement with Carlson et al. (2006). Von Bertalanffy growth models (VBGF) were generated individually for each sex and for sexes combined. Resulting VBGF parameter estimates were similar to those of Carlson et al. (2006). As referenced in Deacy and Moncrief-Cox (SEDAR65-DW-02), a vertebral sample from a known age male shark was used for validation of growth band periodicity.
Decision: Use sex-specific growth model parameters and a maximum age of 17.5 years from SEDAR65-DW-02.

2.3.3 Reproduction Datasets and Decisions

Reproductive parameters for blacktip sharks in the western Atlantic were estimated using data from the SEFSC Shark Bottom Longline Observer Program and the NEFSC Bottom Longline Survey to calculate size and age at median maturity, mean brood size, and the relationships between maternal length/age and brood size. Data from 283 male (range 71-158 cm FL) and 247 female (range 80-178 cm FL) blacktip sharks were used to calculate reproductive parameters. Median FL_{50} at maturity was 115.15 cm FL for males, 123.05 cm FL for females, and 117.34 cm FL for sexes combined. Data from 242 male (87-153 cm FL) and 182 female (80-178 cm FL) with direct age estimates and reproductive conditions were used to obtain median age at maturity. Median Age_{50} at maturity was 5.34 years for males, 6.69 years for females, and 5.78 years for sexes combined. Brood size from 87 females ranged from 1 to 7 with a mean of 4.09 (±0.13 SD). There were weak but significant relationships between maternal length/age and brood size. The biennial reproductive cycle of females suggested by Castro (1996) was supported by recently conducted hormonal analyses (J. Gelsleichter, pers, comm). Additionally, recent observations of a late May/June time of parturition (B. Frazier, pers. comm.) were consistent with past reports by Castro (1996) and Ulrich et al. (2007).

Decision: Use reproductive parameters presented in SEDAR65-DW-01.
Decision: Use maturity ogives presented in SEDAR65-DW-01.

2.4 Tables

Table 1 Summary of Recommended Life History Parameters

Growth parameters	Female / Male / Sexes combined	Reference
L_∞ (cm)	166.23 (2.47)/ 145.03 (1.82) / 159.30 (1.87)	SEDAR65-DW-02
k	0.16 (0.01) / 0.23 (0.02) / 0.17 (0.01)	SEDAR65-DW-02
t_o (years)	-2.59 (0.16) / -1.97 0.16) / -2.51 (0.13)	SEDAR65-DW-02
Maximum observed age (years)	17.5 / 13.5	SEDAR65-DW-02
Sample size	269 / 278 / 547	SEDAR65-DW-02
Length-weight relationships		
PCL (cm)	PCL = 1.92990 + 0.885043*FL	SEDAR65-DW-15
NTL (cm)	NTL = 4.89349 + 1.15734*FL	SEDAR65-DW-15
STL (cm)	STL = 9.00754 + 1.16776*FL	SEDAR65-DW-15
Wt (kg)	Wt = $(4.63\text{x}10^{-6})\text{FL}^{3.21575}$	SEDAR65-DW-15
Age at 50% maturity		
Female	t_{mat}= 6.69 years a = -12.07 (2.52) b = 1.80 (0.35)	SEDAR65-DW-01
Male	t_{mat}= 5.34 years a = -9.09 (1.72) b = 1.70 (0.29)	SEDAR65-DW-01
Size at 50% maturity		
Female	FL_{mat}= 123.05 cm FL a = -30.09 (4.66) b = 0.24 (0.04)	SEDAR65-DW-01
Male	FL_{mat}= 115.15 cm FL a =-31.41 (5.34) b = 0.27 (0.04)	SEDAR65-DW-01
Reproductive cycle	Biennial	Castro 1996, Gelscleichter pers. comm.
Fecundity	4.09 (SD = 0.13) pups per brood	SEDAR65-DW-01
Maternal age/fecundity relationship	Brood size = -0.04078 + 0.38445*Age	SEDAR65-DW-01
Maternal size/fecundity relationship	Brood size = -5.82556+0.06857*FL	SEDAR65-DW-01
Gestation	11 months	Castro 1996, Ulrich et al. 2007
Pupping month	late May / June	Castro 1996, Ulrich et al. 2007, Frazier pers. comm.

Values in parentheses represent standard error unless otherwise noted.

Table 2. Proportion of mature blacktip sharks (*Carcharhinus limbatus*) 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	0.01	0.00	0.00
100	0.02	0.00	0.02
105	0.06	0.01	0.06
110	0.16	0.04	0.20
115	0.37	0.12	0.49
120	0.65	0.32	0.79
125	0.85	0.62	0.94
130	0.95	0.85	0.98
135	0.98	0.95	1.00
140	0.99	0.98	1.00
145	1.00	1.00	1.00
150	1.00	1.00	1.00
155	1.00	1.00	1.00
160	1.00	1.00	1.00
165	1.00	1.00	1.00
170	1.00	1.00	1.00
175	1.00	1.00	1.00
180	1.00	1.00	1.00

Table 3. Proportion of mature blacktip sharks (*Carcharhinus limbatus*) in 1 year age classes by sex.

Age (years)	Sexes Combined	Females	Males
1	0.00	0.00	0.00
2	0.00	0.00	0.00
3	0.02	0.00	0.02
4	0.07	0.01	0.09
5	0.24	0.05	0.36
6	0.58	0.22	0.75
7	0.86	0.64	0.94
8	0.96	0.91	0.99
9	0.99	0.98	1.00
10	1.00	1.00	1.00
11	1.00	1.00	1.00
12	1.00	1.00	1.00
13	1.00	1.00	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

2.5 Literature cited

Bigelow, H.B., and W.C. Schroeder. (1948) Sharks. *In*: Tee-Van, J., Breder, C.M., Hildebrand, S.F., Parr, A.E., & Schroeder, W.C. (Eds), Fishes of the Western North Atlantic. Part One. Lancelets, Cyclostomes, Sharks. Sears Foundation for Marine Research, Yale University, New Haven, 576 pp.

Carlson, J.K., J.A. Sulikowski, and I.E. Baremore. 2006. Do differences in life history exist for blacktip sharks, *Carcharhinus limbatus*, from the United States South Atlantic Bight and Eastern Gulf of Mexico? Environmental Biology of Fishes 77:279-292.

Castro, J. I. 1996. Biology of the Blacktip Shark, *Carcharhinus limbatus*, off the southeastern United States. Bulletin of Marine Science 59:508–522.

Ulrich, G.F, C.M. Jones. W.B. Driggers III, J.M. Drymon, D. Oakley and C. Riley. 2007. Habitat utilization, relative abundance, and seasonality of sharks in the estuarine and nearshore waters of South Carolina. American Fisheries Society Symposium 50:125-139

2.6 Research Recommendations:

1. Increase sampling intensity throughout range, particularly at depths less than 20 m.
2. Investigate sex- and life stage-specific movements of blacktip sharks to determine if migratory behaviors change based on maturity or reproductive condition.
3. Animals should be tagged throughout their range, including the northern extent of the population range off New York, to gain a more complete understanding of migratory and residency patterns.
4. Identify environmental conditions (e.g. dissolved oxygen, temperature, salinity, etc.) and ecological factors (e.g. prey abundance, community structure, etc.) that correlate with migration, movement patterns, and preferred habitats. This will allow prediction of future range changes based on habitat suitability models.
5. Identification of population structure based on genetic information or other intrinsic natural markers/tracers.

3. Catches

3.1 Catches Workgroup Participants

Enric Cortés, Leader…………………………………………………….....NMFS Panama City
Heather Baertlein, co-Leader. ……………………………………………NMFS HMS Division
Robert Hueter ……..…….………………………………………………Mote Marine Laboratory
Cliff Hutt…………………………………………………………………NMFS HMS Division
Alyssa Mathers…………………………………………………………. NMFS Panama City
Vivian Matter, *not present*……………………………………………………….. NMFS Miami
Xinsheng Zhang.……………………………………………………….… NMFS Panama City

3.2 List of Working and Reference Papers

Documents Prepared for the Assessment Process		
SEDAR 65-DW-03	Bycatch estimates of blacktip shark in the south Atlantic coastal gillnet fishery	John Carlson, Alyssa Mathers and Kevin McCarthy
SEDAR 65-DW-04	Bycatch estimates of blacktip shark in the shark bottom longline fishery	John Carlson, Alyssa Mathers Heather Moncrief-Cox and Kevin McCarthy
SEDAR 65-DW-14	Estimation of blacktip shark, *Carcharhinus limbatus*, discards in the northeast gillnet fishery using data collected by the NOAA Northeast Fisheries Observer Program	Camilla T. McCandless, Joseph J. Mello, and Katherine A. Sosebee
SEDAR 65-DW-18	Stress response and post-release mortality of blacktip sharks (*Carcharhinus limbatus*) captured in shore-based and charter boat-based recreational fisheries	D. Nick Weber, Bryan S. Frazier, Nicholas M. Whitney, James Gelsleichter, Gorka Sancho
SEDAR 65-DW-19	SEDAR 65-DW19: Preliminary catches of blacktip sharks in the U.S. Atlantic ocean	Enric Cortés and Heather Baertlein
SEDAR 65-DW-20	An updated literature review of post-release live-discard mortality rate estimates in sharks for use in SEDAR 65	Dean Courtney amd Alyssa Mathers

Reference Documents		
SEDAR 65-RD-01	Model-estimated conversion factors for calibrating Coastal Household (SEDAR 64 – RD-12)	K. Dettloff and V. Matter
SEDAR 65-RD-02	Sample size sensitivity analysis for calculating MRIP weight estimates (SEDAR 67-WP-06)	K. Dettloff and V. Matter
SEDAR 65-RD-04	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	Dean Courtney

3.3 Relevant Terms of Reference

<u>Term of Reference 3</u>

Recommend discard mortality rates. a) Review available research and published literature. b) Provide estimates of discard mortality rate by fishery, gear type, depth, and other strata as feasible or appropriate. c) Include thorough rationale for recommended discard mortality rates. d) Provide estimates of uncertainty around recommended discard mortality rates.

<u>Term of Reference 5</u>

Provide commercial catch statistics across all fisheries, including both landings and discards in both pounds and number. a) Evaluate and discuss the adequacy of available data for accurately characterizing harvest and discard by fishery sector or gear. b) Provide length distributions for both landings and discards if available and include both the number of individuals measured as well as relevant alternative measures of effective sample size (i.e., alternative measures of sampling effort such as the number of trips, hauls, sets, baskets of gear, etc. that were sampled for length measurements). c) Discuss the degree to which available length distributions adequately represent commercial fishery conditions. d) Provide estimates of uncertainty around each set of landings and discard estimates if available.

<u>Term of Reference 6</u>

Provide recreational catch statistics, including both landings and discards in both pounds and number. a) Evaluate and discuss the adequacy of available data (including species id) for accurately characterizing harvest and discard by species and types of recreational fishing. b). Provide length distributions for both landings and discards if available and include both the number of individuals measured as well as relevant alternative measures of effective sample size (i.e., alternative measures of sampling effort such as the number of trips, hauls, sets, baskets of gear, etc. that were sampled for length measurements). c) Discuss the degree to which available length distributions adequately represent recreational fishery conditions. d) Provide estimates of uncertainty around each set of landings and discard estimates.

Term of Reference 8
Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. If possible, include specific guidance on sampling intensity (number of samples including age and length structures) and appropriate strata and coverage.

3.4 Data Review

3.4.1 Review of working papers

SEDAR 65 – DW-03: Bycatch estimates of blacktip shark in the south Atlantic coastal gillnet fishery.
J Carlson, A Mathers, and K McCarthy

This document presents U.S. south Atlantic blacktip shark discards (in numbers of fish, dead or alive) from the commercial gillnet fishery from 1998–2018. Also included are discard rates, number of observed trips, discard rate standard errors, and number of logbook trips reporting effort.

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 were derived separately for sharks discarded dead and sharks discarded alive as reported by the on-board observer. Total bycatch by year for the fishery was estimated by multiplying the derived bootstrap CPUE estimates by the total number of reported sets for the US South Atlantic. Total effort data reflects all gillnet trip reports received by the Coastal Fisheries Logbook Program (hereafter Logbook Program) in the southeast United States. Calculated US south Atlantic blacktip shark discards (in numbers of fish, dead or alive) from the commercial gillnet fishery are provided. In all the estimates, data was pooled without considering strata due to the sparse nature of the bycatch events.

SEDAR 65 - DW-04: Bycatch estimates of blacktip shark in the shark bottom longline fishery**.**
J Carlson, A Mathers and K McCarthy

This document presents calculated blacktip shark dead discards (in numbers of sharks) from the commercial shark bottom longline fishery (1993–2018) and the shark research fishery (2008–2018). Also included are calculated blacktip shark live discards (in numbers of sharks) from the same sources.

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 were derived separately for sharks discarded dead and sharks discarded alive as reported by the on-board observer. 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. Total discards were calculated as the product of observer reported yearly mean dead and live discard rates by hook and the yearly total fishing effort (bottom longline hooks) reported to the coastal logbook program. Calculated blacktip shark dead discards (in numbers of sharks) from commercial shark bottom longline fishery and the shark research fishery are provided. Calculated blacktip shark live discards (in numbers of sharks) from the commercial shark bottom longline fishery and the shark research fishery are provided. In all the estimates, data was pooled without considering strata due to the sparse nature of the bycatch events.

SEDAR 65 - DW-14: Estimation of blacktip shark, *Carcharhinus limbatus*, discards in the northeast gillnet fishery using data collected by the NOAA Northeast Fisheries Observer Program.
C. McCandless, J. Mello and K. Sosebee

This document presents dead and live discards of blacktip sharks, *Carcharhinus limbatus*, from the Northeast Region's Mid-Atlantic sink-gillnet fishing fleet. Discards were estimated in numbers and weight. The authors followed the approach of ratio-estimators based on the methodology described in Rago et al. (2005), updated in Wigley et al, (2007). The derived ratio estimators from the Northeast Fisheries Observer Program data were applied to the dealer landings data for estimation of blacktip shark discards from the Northeast Region's Mid-Atlantic sink-gillnet fishing fleet from 1995 to 2018. In addition, back-calculated live and dead discard estimates based on average discard rates (1995-2018) and total annual landings were provided. The estimated live discards are very small, except for 1998-2002, and the estimated dead discards are very small, except for 1998 and 1999.

SEDAR 65-DW-18: Stress response and post-release mortality of blacktip sharks (*Carcharhinus limbatus*) captured in shore-based and charter boat-based recreational fisheries.
D. Nick Weber, Bryan S. Frazier, Nicholas M. Whitney, James Gelsleichter, Gorka Sancho

This document estimated post-release mortality rates for blacktip sharks captured on rod-and-reel by shore-based and charter boat-based fishermen using acoustic transmitters (n = 81). Additionally, 24 individuals were double-tagged with pop-off satellite archival tags (PSATs) to validate the survivorship results obtained from the acoustic transmitters. The stress response associated with both recreational capture methods was quantified using numerous blood chemistry parameters. Overall, 18.5% of blacktip sharks died post-release (17.1% shore-based; 20.0% charter boat-based). The survivorship results inferred from acoustic transmitters were consistent with results inferred from PSATs, validating our use of acoustic transmitters to assess PRM in blacktip sharks. Fight time (i.e. time on the line) had a significant effect on blood pH, lactate, hematocrit, potassium, and glucose for sharks caught from shore, but only on lactate for sharks caught from charter boats. Fifty percent of foul-hooked sharks (i.e. sharks hooked anywhere but the jaw) died post-release.

SEDAR 65-DW-19: Preliminary catches of blacktip sharks in the U.S. Atlantic Ocean
E Cortes and H Baertlein

Commercial landings, commercial discard estimates, and recreational catch estimates of blacktip sharks in the U.S. Atlantic coast for 1981-2018 are presented in this document. Information on the geographical distribution of both commercial landings and recreational catches is also included. Gear-specific information of commercial landings and fishing mode and fishing area of recreational catches are summarized. Length composition information from recreational sources is also presented.

SEDAR65-DW20: An updated literature review of post-release live-discard mortality rate estimates in sharks for use in SEDAR 65
D. Courtney and A. Mathers

This working paper summarizes literature reviewed for estimates of delayed discard mortality rates (M_D) in sharks, and identifies those available for blacktip sharks (*Carcharhinus limbatus*). Estimates of immediate (i.e. at-vessel) discard-mortality rates (M_A) are also identified. Previous SEDAR HMS shark Assessment Process (AP) and Data Workshop (DW) post-release live-discard mortality (PRLDM) rate decisions are provided.

3.4.2 Commercial Catch Datasets and Decisions

Commercial landings

An additional 14 years of commercial landings data were available since the last Atlantic blacktip shark assessment (SEDAR 11; NMFS 2006) (**Table 1** and **Table 2; Figure 1** and **Figure 2**). U.S. commercial landings in weight (pounds dressed weight; lb dw) were thus available for the period 1981-2018. These data were gathered from different sources over the time series. As in SEDAR 11, landings for 1981-1985 were assumed to be equal to the average for 1986-1988. The 1986-1990 landings were a legacy data set from the 1996 Large Coastal Shark Stock Evaluation Workshop (NMFS 1996), which included shark landings from longlines and gillnets for the Florida East coast, Georgia and South Carolina, and North Carolina (see Appendix 3 of the 1996 SEW). Specifically, the members of the catch subgroup at that workshop compiled a table that represented the available data, observations and/or perceptions on the proportion of large coastal shark landings represented by sandbar and blacktip sharks. Sources of this legacy data included observer data and observations of biologists and fin dealers. Available data were often applied across un-sampled years when the general perceptions of the fishery supported this. Gillnet landings estimates for Large Coastal sharks in North Carolina were prorated by the North Carolina Division of Marine Fisheries. These estimates of the North Carolina data set reflect the exclusion of all sharks other than the Large Coastal species from the North Carolina database, wherever possible.

Commercial landings for 1991-2012 come from the Atlantic portion of the FINS database (Atlantic Coastal Cooperative Statistics Program [ACCSP]). No data from the FINS database

(Gulf Fisheries Information Network [GulfFIN]) representing the Gulf of Mexico region were included. Landings for 2013-2018 come from the NOAA Fisheries Highly Migratory Species commercial landings (eDealer) database.

Commercial landings of U.S. Atlantic blacktip shark by gear from the ACCSP for 1991-2018 were dominated by longlines (56%) and gillnets (33%) (**Table 3, Figure 3**). The remaining 11% included a combined "other gears" consisting of a "not coded" category (6%), hook and line (4%), and an assortment of other gears that contributed minimally. Based on this characterization of landings by gear type, commercial landings were split into three categories: longlines, gillnets, and other gears.

Blacktip landings by state were dominated by Florida (63.3%), North Carolina (16.7%), New Jersey (6.5%), Virginia (6.3%), and South Carolina (4.3%), with Florida consistently dominating through time. Most landings thus corresponded to the southeast region (**Table 4, Figure 4**).

Commercial landings were also calculated in numbers to satisfy ToR 5. They were calculated by dividing annual landings in weight (lb dw) by average weights (lb dw) from the Southeast Gillnet Observer Program (GNOP) and the Reef Fish and Shark Bottom Longline Observer Programs (collectively referred to as BLLOP hereforth) 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 a weight-length regression. Average weights were available for 1999-2018 from the GNOP and for 1993-2018 from the BLLOP. For the GNOP, the average weight for 1986-1998 was taken as the average for the first 5 years of data (1999-2003); for the BLLOP, the average weight for 1986-1992 came from Parrack (1990).

Discussion and decisions

Based on input from the commercial shark fishing industry, it was clarified that the market in the early 1980s was inconsistent with the landings calculated for 1981–1985 because there was very little shark fishing effort in those years. To account for the low shark fishing effort, it was proposed that landings for 1981 and 1982 be set to zero and landings for 1983–1985 assumed to linearly increase to the average for 1986-1988.

It was also proposed that the "other gears" series be back-calculated to 1983 for consistency with the longline and gillnet series. Because some of the records contained in the other gears series under the "not coded" category were rather high in 1991 and 1992, it was proposed that the values for 1986-1990 be computed as the mean for the entire time series (1991-2018)

Decision: Set the 1981 and 1982 landings to 0.

Decision: Assume a linear increase of landings in 1983-1985 from 0 in 1982 to the mean of 1986-1988 to represent growing market for shark products. Apply this increase to the three fleets considered (longlines, gillnets, and other gears)

Decision: Reconstruct the other gears series to start also in 1983, setting 1986-1990 values equal to the mean of the entire time series (1991-2018)

Commercial dead discards

Working papers SEDAR65-DW-03 and SEDAR65-DW-04 provided estimates of dead discards of Atlantic blacktip sharks for the gillnet fishery and longline fishery for the southeast region, respectively, based on observer reports and commercial logbook data.

After the Data Workshop, Working Paper SEDAR65-DW-14 was submitted on December 5, 2019. This document 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. After reviewing the document, the Panel expressed concern about the magnitude of the discard estimates in weight when compared to those in numbers, which may have been caused by mis-identification issues. The Panel then asked the authors to include landings data in the paper and to address mis-identification problems. In response, the authors re-ran the analyses 1) excluding all discards from observed trips that had high numbers of small (<40 cm FL, the known size at birth) blacktip sharks reported as these fish were likely misidentified, and 2) using the dealer data instead of VTR data due to the discrepancy between the VTR and dealer data in the early years (after the initiation of mandatory reporting). The final updated paper, which also included a correction in the computation of the variance, was submitted on December 10, 2019.

Discussion and decisions

Estimates of dead discards were produced for 1993-2018 for longlines and 1999-2018 for gillnets for the southeast region, and 1995-2018 for gillnets in the northeast region. For consistency with the landings, which started in 1983, it was also proposed that the longline and gillnet dead discards be back-calculated to 1983 using the mean for the entire time series. For the northeast gillnet fishery, the average discard ratios across all years were applied to the annual total landings.

It was brought up that the ratio method used for these three papers that provided discard estimates was a reasonable approach. However, pooling all data without considering strata due to the sparse nature of the bycatch events is a limitation of the bycatch estimates, although the northeast gillnet estimates used quarters as strata and improved temporal resolution. However, the estimated northeast gillnet discards are very inconsistent, with multiple years without any discards. The Panel expressed concern for the large annual and interannual variability/uncertainty in the bycatch estimates. The Panel thus recommended during the Data Workshop that the authors work with the assessment team during the assessment process to explore ways to address these concerns. Furthermore, after reviewing the discard estimates for the northeast gillnet fishery during the SEDAR 65 post Data Workshop webinar on December 5, 2019, the Panel recommended that all these three estimates of (dead and live) discards not be included in the base run, but instead be considered in the uncertainty analysis (i.e., alternative states of nature).

Recommendations for continuing work:

- Use running average to smooth annual bycatch estimates

- Use multi-year-block average bycatch estimates to replace annual bycatch estimates. The defined multi-year-block should be consistent with major management changes.

- Use multi-year-block average estimated CPUEs, but using censored annual logbook data or dealer landing data to estimate bycatch. In this case, the interannual variability of bycatch estimates is driven by interannual variability in effort from the logbook data, or in landing data from dealers.

Decision: Back-calculate dead discards to 1983 for longlines and gillnets using the mean for the entire time series (1993 – 2018 for southeast longlines; 1999-2018 for southeast gillnets; 1995-2018 for northeast gillnets)

Decision: Do not include the three estimates of dead discards (southeast longline, southeast gillnet, and northeast gillnet) in the base run. Include all three estimates of dead discards in a sensitivity run.

Commercial post-release live discard mortality

Working papers SEDAR65-DW-03 and SEDAR65-DW-04 also provided estimates of Atlantic blacktip sharks released alive in the gillnet and longline fisheries for the southeast region, based on observer reports and commercial logbook data.

See the "Commercial dead discards" section above for a description and treatment of the discard estimates (both dead and live) provided in document SEDAR65-DW-14.

Discussion and decisions

Preliminary estimates of live post-release mortality (the proportion of sharks released alive that die) was accounted for in commercial gears by multiplying estimated blacktip sharks released alive in gillnets and longlines (SEDAR65-DW-03 and SEDAR65-DW04) by a post-release mortality rate of 0.31 derived for gillnets, as described in Hueter et al.(2006) and summarized below, and 0.097 derived for hook and line (taken as a proxy for bottom longline gear; Whitney et al. 2017). However, new estimates of post-release mortality rates became available at the workshop for bottom longline fisheries (SEDAR65-RD06). Specifically, a rate of 44.2% (±8.3% 95% CIs) was proposed (N. Whitney pers. com. to B. Frazier) as described in SEDAR65-RD06 and summarized below.

Previous SEDAR panels (SEDAR29) adopted 31% as the best estimate of the post-release live-discard mortality rate for Gulf of Mexico blacktip sharks captured in gillnet fisheries (SEDAR65-DW20, their Table 4) obtained from juvenile blacktip sharks captured with research gillnets (Hueter *et al*. 2006). The same approach was adopted by the Panel here. In addition, 95% CIs for gillnet fisheries were calculated by the Panel using methods and data available in Hueter *et al.* (2006). Release and recapture data for blacktip sharks captured in research gillnets and summarized by their condition at release was obtained from Hueter *et al.* (2006, their Table 3):

Condition	Tagged	Recaptured	Ratio
1	928	58	0.0625
2	939	39	0.0415
3	666	24	0.0360
4	365	4	0.0110

The relative survival (Beta^) of tagged blacktip sharks released in conditions 2–4 was estimated relative to that of blacktip sharks released in condition 1 as the ratio of recapture rates using equation (10) in Hueter et al (2006); lower and upper 95% CIs were obtained using equation (11) in Hueter *et al.* (2006) adapted from Hueter *et al.* (2006, their Table 4):

	Beta^	LCI	UCI
Ratio of ratios (condition 2: condition 1)	0.6645	0.4474	0.9870
Ratio of ratios (condition 3: condition 1)	0.5766	0.3621	0.9181
Ratio of ratios (condition 4: condition 1)	0.1753	0.0641	0.4795

Hueter *et al.* (2006) obtained estimates of absolute post-release mortality by assuming all sharks in condition 1 survived the catch–tag–release event. Using this approach 31% (898 of 2,898) of blacktip sharks released from gillnets are estimated to have died (adapted from Hueter *et al.* (2006, their Table 5):

Condition	Number tagged	Survival rate	Death rate	Number dying	Percent dying (PRLDM)
1	928	1	0	0	
2	939	0.66	0.34	319.26	
3	666	0.58	0.42	279.72	
4	365	0.18	0.82	299.30	
Total	2898			898.28	31%

Lower and upper 95% CIs (alpha = 0.05) for cryptic post-release mortality of blacktip sharks released from gill nets were calculated by the Panel using the same approach (Adapted from Hueter *et al.* 2006, their Tables 4, and 5):

Condition	Number tagged	Survival rate LCI	Death rate UCI	Number dying UCI	Percent dying UCI (PRLDM)
1	928	1	0	0	
2	939	0.45	0.55	516.45	
3	666	0.36	0.64	426.24	
4	365	0.06	0.94	343.1	
Total	2898			1285.79	44.4%

Condition	Number tagged	Survival rate UCI	Death rate LCI	Number dying LCI	Percent dying LCI (PRLDM)
1	928	1	0	0	
2	939	0.99	0.01	9.39	
3	666	0.92	0.08	53.28	
4	365	0.48	0.52	189.80	
Total	2898			252.47	8.7%

Because all sharks in condition 1 are assumed to survive (death rate =0), this approach may underestimate the total post-release mortality. Similarly, a previous literature review developed for Gulf of Mexico blacktip sharks during SEDAR 29 (Courtney 2012) suggested that the best estimate of the post-release live-discard mortality rate of blacktip sharks captured in gillnets, 31%, obtained from juvenile blacktip sharks captured with research gillnets Hueter *et al*. (2006), may need to be adjusted upward to reflect the relative difference in the at-vessel gillnet mortality rate observed for juvenile blacktips captured with research gillnets (38%) (Hueter and Manire, 1994) relative to that of sub-adult blacktips captured in scientifically monitored commercial gillnets (90%) (Thorpe and Frierson, 2009). However, the Panel discussed that the new approach developed here to calculate 95% CIs was the preferred approach for developing the range of uncertainty for blacktip shark post-release mortality in gillnet fisheries because it was based on data available from the original publication, which resulted in a relatively wide range of uncertainty.

A new estimate of acute post-release mortality rates for coastal sharks caught in the Florida commercial shark demersal longline fishery, 44.2% ±8.3% (±95% CI), was presented and discussed by the Panel for use in SEDAR 65 demersal longline fisheries (SEDAR65-RD06). The estimate was based on a large sample size (N = 95) of physically recovered acceleration data loggers (ADLs) released on blacktip sharks captured near Madeira Beach, FL, and Key West, FL. At both study sites, specific fishing locations and practices were directed by commercial longline captains to ensure methods were consistent with typical commercial fishing practices. Post-release mortality rates were calculated as the percentage of blacktip sharks that died post-release out of the number of tags recovered. Mortality was identified from recovered tag data as a lack of movement and a constant depth, assumed to be associated with a negatively buoyant shark on the bottom.

Accelerometer deployments, all shark species tagged in the study, lasted between 0.7 and 205 h (mean 20.9 ± 18.7 h). Ninety one % of mortalities, all tagged sharks in the study, occurred within 5 h of release, and all mortalities occurred within 12 h of release.

The 95% confidence interval obtained for post-release mortality estimates in demersal longlines (SEDAR65-RD06) was based on methods in Goodyear (2002) which was not available for the Panel to review. Consequently, the Panel re-calculated 95% CIs for demersal longlines during the meeting using a binomial distribution with 95 releases and 42 mortalities, and obtained a slightly wider range of uncertainty (34.0 % to 54.8%). The binomial 95% CI calculations were later verified in R version 3.3.2 (R Development Core Team, 2016) using the library "binom" (Dorai-Raj 2014): binom.confint(x = 42, n = 95, method = "exact").

Decision: Back-calculate live discards to 1983 for longlines and gillnets using the mean for the entire time series (1993 – 2018 for southeast longlines; 1999-2018 for southeast gillnets; 1995-2018 for northeast gillnets)

Decision: Do not include the three estimates of live discards (southeast longline, southeast gillnet, and northeast gillnet) in the base run. Include all three estimates of live discards in a sensitivity run.

Decision: Use a post-release live discard mortality rate of 31% for commercial gillnets (with a 95% CI of 8.7%-44.4%) and 44.2% for bottom longlines (with a binomial 95% CI of 34.0%-54.8%)

	Estimate	Lower 95% CL	Upper 95% CL
Gillnet	31%	8.7%	44.4%
Demersal Longline	44.2%	34.0%	54.8%

Commercial length compositions

The only data sources for lengths of commercially caught sharks are the observer programs (BLLOP and GNOP in this case). Length composition information from these programs will be provided separately.

3.4.3 Recreational Catch Datasets and Decisions

Recreational catches of Atlantic blacktip sharks, computed as the sum of estimates from the Marine Recreational Information Program (MRIP) and the Southeast Region Headboat Survey (SRHS), were available for 1981-2018. The MRIP estimates include Access Point Angler Intercept Survey (APAIS) and Fishing Effort Survey (FES) calibrations. Annual recreational catch estimates of blacktip sharks in the Atlantic 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 (by initially applying a post-release mortality rate of 0.097 from Whitney et al. (2017). Type B2 estimates for SRHS became available in 2004. Catches are reported in both numbers and weight for types A and B1, but only in numbers for type B2. Annual weight estimates for type B2 were computed by multiplying B2 catches in numbers by an average weight obtained by dividing AB1 catch in weight by catch in numbers.

The overwhelming majority of Atlantic blacktip shark catches were reported in MRIP. Catches showed a generally decreasing trend from 1981 to 2018, punctuated by several peaks, most notably in 1985, 1990, 1997, and 2004 (for A, B1, and B2), and in 1993, 2009, and 2015 (for B2 only) (**Table 1, Table 2**).

By fishing mode, most AB1 Atlantic blacktip shark catches were from shore (49%) and by private boats (45%), with charter boats and headboats contributing very little (**Figure 5**). By fishing area, most blacktip catches occurred less than 3 miles from shore (44%) and in inshore waters (42%), with the remaining 14% of catches in waters over three miles from shore (**Figure 6**). Most of the catches were in the southeast region, with Florida-East coast (50%), South Carolina (31%), and Georgia (13%) accounting for 94% of all blacktips (**Figure 7**).

Discussion and decisions

Concern was expressed over the inter-annual variability and high uncertainty of the recreational dataset for both AB1 and B2 catches. In particular, a peak in B2 catches was noted in 2009 based on two records from wave 3 (May-June) in inshore waters of South Carolina, which resulted in unusually high estimates of 404,126 and 1,925,555 sharks. Additional research revealed that this high estimate was generated from 5 interviews all intercepted on the same day at the same pier in Beaufort County, SC. The anglers interviewed reported releasing 3, 4, 4, 8, and 8 blacktip sharks, respectively. The interaction of the FES and APAIS calibration effects on the shore effort estimates appear to have resulted in these unusually high releases. Based on this information, the Group decided that smoothing this 2009 value by setting it equal to the geometric mean of the three preceding and three ensuing years was warranted.

In addition to the peak in B2 catches in 2009, there remained concern about the various peaks in the recreational estimates in general. It was proposed to run a three-year moving average (based either on the arithmetic or geometric mean) to smooth the series while preserving the average trend. These transformations resulted in means for the entire time series (1981-2018) of 29,026 and 23,474 sharks for the arithmetic mean and geometric mean moving average series, respectively (compared to 28,743 for the untransformed series), or a 1% increase and 18% decrease, respectively, with respect to the untransformed series. Furthermore all the annual values in the transformed series fell between the 95% CIs (**Table 5, Table 6; Figure 8, Figure 9, Figure 10**).

Decision: Smooth the 2009 B2 catch value by setting it equal to the geometric mean of the 3 preceding and ensuing years

Decision: Remove peaks in AB1s and B2s by running a 3-year moving average (based on the arithmetic mean)

Recreational post-release live discard mortality

Based on document SEDAR65-DW-18, a post-release mortality rate of 18.5% was proposed (average of 17.1% for shore-based fishing and 20.0% for charter boats). This more recent rate was considered to have improved previous research and was therefore adopted. The need to provide estimates of uncertainty for these estimates was also noted and a proposal to use a binomial distribution to generate them presented and approved.

Post release mortality (PRM) rates were estimated for blacktip sharks captured and released alive on rod-and-reel by shore-based (n = 41) and charter boat-based (n=40) fishermen using acoustic transmitters (total n = 81). Blacktip sharks were caught with rod-and-reel by participating recreational anglers from the shore (i.e. beach) and onboard charter fishing boats in the coastal waters of South Carolina and Florida. All fishing from charter boats was conducted by the clients who hired the charter, and thus a wide range of angler experience was sampled. Anglers used their personal fishing equipment, which varied in size and strength, and no input was provided by the authors on the fishing equipment (e.g. rod and reel type/size, hook type/size) or capture techniques. Survivorship was assessed by passively monitoring sharks following release and examining movements of sharks among fixed acoustic receivers deployed along the eastern coast of the U.S. as part of both the Atlantic Cooperative Telemetry (ACT) and the Florida Atlantic Coast Telemetry (FACT) Networks. Sharks that were detected multiple times by an acoustic receiver more than 10 days post-release were considered to have survived the capture event (and any associated tag ingestion during predation events, typically regurgitated within around 5 days of ingestion). Additionally, a subset of acoustically tagged individuals from shore-based (n = 12) and charter boat-based (n = 12) fishing were double-tagged with pop-off satellite archival tags (PSATs, total n = 24) to validate the survivorship results obtained from the acoustic transmitters. The survivorship results inferred from acoustic transmitters were consistent with results inferred from PSATs, Fifteen sharks (n = 7 shore-based; n = 8 charter boat-based) died within 10 days of being released by recreational anglers, resulting in post-release mortality rates of 17.1% (shore-based) and 20.0% (charter boat-based).

The Panel calculated 95% CIs for the recreational fishery during the meeting using a binomial distribution with 81 releases and 15 mortalities, and obtained a PRM rate for recreational fisheries of 18.5 and a range of uncertainty from 10.8 % to 28.7%. The binomial 95% CI calculations were later verified in R version 3.3.2 (R Development Core Team, 2016) using the library “binom” (Dorai-Raj 2014): binom.confint(x = 15, n = 81, method = "exact").

The new estimate of post-release mortality obtained for blacktip sharks captured in recreational fisheries in the coastal waters of South Carolina and Florida is consistent with an updated estimate from the Gulf of Mexico recreational fisheries where 22 tags with conclusive data resulted in 5 mortalities and a PRM estimate of 22.7% with a 95% binomial CI of 7.8-45.4% (pers. comm. John Mohan; also see SEDAR65-RD04, their Appendix B).

Decision: Use overall post-release mortality rate of 18.5% for hook and line recreational fisheries (with a binomial 95% CI of 10.8%-28.7%)

	Estimate	Lower 95% CI	Upper 95% CI
Recreational	18.5%	10.8%	28.7%

Using the new estimate of post-release mortality of 18.5% resulted in almost a doubling (90% increase) of animals released alive assumed to have died compared to the numbers obtained using the previous estimate of 9.7%. In absolute terms, this translated to an increase from 991,810 mortalities to 1,891,596 mortalities during the entire time series (1981-2018).

Recreational length compositions

Lengths were available from the MRIP and the SRHS. Length-frequency distributions showed that mostly immature individuals are caught as determined by comparing to the median sizes at maturity for males and females (115 cm FL and 123 cm FL, respectively; SEDAR 65-DW-01). The mean fork length from MRIP (75.4 cm) was not significantly smaller than that from SRHS (78.0 cm) (Welch two sample t-test data: $t = 0.8582$, $df = 141.58$, $P = 0.3922$; **Figure 11**). There were, however, highly significant differences in the size of blacktip sharks caught by fishing mode (ANOVA: $F = 7.05$, $df = 3$, $P = 0.00011$), with blacktips caught from shore being significantly smaller than those caught by private boats, charter boats, or headboats (Multiple comparison test of means for unbalanced data: contrasts fit: Shore – Cbt, $P < 0.001$; Shore – Hbt, $P < 0.00797$; Shore – Pri, $P < 0.00802$; **Figure 12**). Similarly, there were highly significant differences in the size of blacktip sharks caught by fishing area (ANOVA: $F = 11.99$, $df = 3$, $P = 1.07E-07$), with blacktips caught inshore being significantly smaller than those caught in the ocean (≤ 3 miles), ocean (> 3 miles), or in headboats (Multiple comparison test of means for unbalanced data: contrasts fit: Inshore – Hbt, $P < 0.0272$; Inshore – Ocean (≤ 3 mi), $P < 0.001$; Inshore – Ocean (>3 mi), $P < 0.0014$; **Figure 13**). No significant differences in the size of blacktip sharks by state were found (ANOVA: $F = 1.462$, $df = 7$, $P = 0.177$; **Figure 14**).

A study conducted by the South Carolina Department of Natural Resources (SCDNR) was presented at the Workshop that included ten shore-based shark angling groups (consisting of 2–10 members) who were requested to keep logbooks for one year to log effort, gear, species, bait, water temperature, length, sex, and fishing location. A total of six logbooks were recorded. As part of this study, 166 lengths of blacktip sharks measured in SC and FL were made available. Inclusion of these lengths gave a picture of the size composition of the catches of blacktip sharks caught from shore different from that provided by MRIP. Shore-based animals recorded in these logbooks were mostly mature (vs. immature in the MRIP database). The Group argued that these new lengths should be included as they provide evidence that larger blacktips can also be caught from shore, likely from beaches, by anglers targeting large blacktips, whereas the samples provided by MRIP are typically collected at piers or docks and are likely from anglers targeting other species but catching smaller blacktips (**Figure 15**).

Decision: Include Atlantic blacktip shark lengths from the SCDNR study (n=166)

3.5 Research recommendations

- Increase public education outreach activities for species identification in the recreational fishery. This is important because the fishery has become largely recreational, there are no species identification training workshops for recreational fishers, and it is difficult to distinguish blacktip from spinner sharks, especially as 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.

3.6 Literature Cited

Carlson, J., A. Mathers, and K. McCarthy. 2019a. Bycatch estimates of blacktip shark in the south Atlantic coastal gillnet fishery. SEDAR65-DW-03. SEDAR, North Charleston, SC.

Carlson, J., A. Mathers, H. Moncrief-Cox, and K. McCarthy. 2019b. Bycatch estimates of blacktip shark in the shark bottom longline fishery. SEDAR65-DW-04. SEDAR, North Charleston, SC.

Courtney, D. 2012. A preliminary review of post-release live-discard mortality estimates for sharks. SEDAR29-WP-17. SEDAR, North Charleston, SC.

Dorai-Raj, S. 2014. binom: Binomial confidence intervals for several parameterizations. R package version 1.1-1. https://CRAN.R-project.org/package=binom.

Hueter, R. E., and Manire, C. A. 1994. Bycatch and catch-release mortality of small sharks in the Gulf coast nursery grounds of Tampa Bay and Charlotte Harbor. Technical Report No. 368 (Final report to NOAA/NMFS, MARFIN Project NA17FF0378-01), 183 pp. Available from Mote Marine Laboratory.

Hueter, R. E., Manire, C. A., Tyminski, J. P., Hoenig, J. M., and Hepworth, D. A. 2006. Assessing mortality of released or discarded fish using a logistic model of relative survival derived from tagging data. Transactions of the American Fisheries Society, 135:500-508.

McCandless, C. T., Mello, J. J., and Sosebee, K. A. 2019. Estimation of blacktip shark, *Carcharhinus limbatus*, discards in the northeast gillnet fishery using data collected by the NOAA Northeast Fisheries Observer Program. SEDAR65-DW14. SEDAR, North Charleston, SC. 10 pp.

NMFS. 1996. 1996 Report of the Shark Evaluation Workshop. National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC), Miami, FL. 80 p.

NMFS. 2006. SEDAR 11. Stock assessment report: large coastal shark complex, blacktip and sandbar shark. NOAA, NMFS, Highly Migratory Species (HMS), Silver Spring, MD.

Parrack, M.L. 1990. A study of shark exploitation in U.S. Atlantic coastal waters during 1986-1989. NOAA/NMFS SEFC contrib. MIA-90/91-03, 14 p.

R Core Team. 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Thorpe, T., and Frierson, D. 2009. Bycatch mitigation assessment for sharks caught in coastal anchored gillnets. Fisheries Research, 98:102-112.

Whitney, N.M., White, C.F., Anderson, P.A., Hueter, R.E., and G.B. Skomal. 2017. The physiological stress response, postrelease behavior, and mortality of blacktip sharks (Carcharhinus limbatus) caught on circle and J-hooks in the Florida recreational fishery. Fish. Bull. 115:532-543.

3.7 Tables

Table 1. Catches of blacktip sharks in the U.S. Atlantic in weight (lb dressed). B2 dead were obtained as the annual B2 live release estimates multiplied by the overall post-release mortality rate, 18.5%, assumed for hook and line recreational fisheries.

Year	Unreported commercial catches	Bottom longlines	Gillnets	Other gears	Recreational catches (A+B1)	Recreational catches (B2 dead)	Total
1981					47092	595924	643016
1982					569953	96652	666606
1983		117654	156572	13927	82381	93535	464070
1984		235309	313144	27854	199303	206718	982328
1985		352963	469716	41781	762918	30328	1657706
1986		546144	352931	41781	297951	97588	1336395
1987		175361	632155	41781	57384	9835	916516
1988	95172	337384	424063	41781	72175	14942	985517
1989	80892	370196	359204	41781	103798	15608	971479
1990		283349	375659	41781	85675	13931	800395
1991		212125	354837	491096	442506	28386	1528949
1992		756923	87757	234581	178352	379223	1636836
1993		807599	335794	99764	129048	79936	1452141
1994		396013	20022	33314	254666	1184496	1888511
1995		573084	62577	41805	96245	97286	870996
1996		231129	404648	24586	347566	166697	1174626
1997		123687	112990	11594	134772	109794	492836
1998		117429	68892	9432	357963	299781	853496
1999		128348	83778	9297	386373	166531	774327
2000		188258	96767	7682	184545	439377	916629
2001		109355	156606	5082	137276	620594	1028913
2002		200569	270521	13940	70650	408989	964669
2003		225246	235939	12878	87192	221422	782676
2004		97734	176299	11657	42494	801983	1130166
2005		107426	109778	5810	978424	1296155	2497593
2006		117754	219294	4751	69958	296926	708683
2007		30858	48869	2155	146318	299452	527652
2008		118901	159135	4434	61241	1197343	1541053
2009		171886	30113	38086	24669	303174	567929
2010		164057	89956	17814	44388	324191	640406
2011		143771	38845	7655	24290	165085	379646
2012		106103	68209	40171	40389	136353	391226
2013		156418	81966	25843	18874	406311	689412
2014		206387	65028	10592	15749	528133	825889
2015		193274	36023	528	38481	758443	1026749
2016		175635	70933	1907	47534	125576	421585
2017		175775	42433	1753	13739	189677	423378
2018		93515	29955	1661	6648	395902	527681

Table 2. Catches of blacktip sharks in the U.S. Atlantic in numbers. B2 dead were obtained as the annual B2 live release estimates multiplied by the overall post-release mortality rate, 18.5%, assumed for hook and line recreational fisheries**.**

Year	Unreported commercial catches	Bottom longlines	Gillnets	Other gears	Recreational catches (A+B1)	Recreational catches (B2 dead)	Total
1981					6827	86395	93223
1982					57164	9694	66858
1983		4902	3568	580	33139	37626	79816
1984		9805	7137	1161	28894	29969	76966
1985		14707	10705	1741	137138	5452	169743
1986		22756	8044	1741	19913	6522	58975
1987		7307	14407	1741	40660	7202	71317
1988	3966	14058	9665	1741	21595	4479	55503
1989	3371	15425	8187	1741	27132	4623	60478
1990		11806	8562	1741	12135	2020	36263
1991		8839	8087	20462	96461	6364	140213
1992		31538	2000	9774	30414	65396	139123
1993		24636	7653	3043	25395	16092	76819
1994		18735	456	1576	30597	143805	195169
1995		24573	1426	1793	21950	22609	72351
1996		9060	9222	964	62069	29799	111115
1997		4050	2575	380	30336	25885	63226
1998		3600	1570	289	113397	96371	215227
1999		4090	2350	296	49380	21457	77574
2000		5743	3798	234	26758	63700	100233
2001		3255	2557	151	19283	89953	115199
2002		7043	5740	490	9466	59294	82033
2003		7525	4730	430	31811	81591	126088
2004		3297	4417	393	5986	116216	130310
2005		3877	2647	210	87462	115873	210068
2006		4569	5625	184	10280	43048	63706
2007		1419	11462	99	17576	43394	73951
2008		3726	6349	139	7168	173580	190962
2009		4528	1128	1003	2792	43953	53405
2010		4583	3145	498	2283	47000	57509
2011		5625	2031	299	2055	23934	33944
2012		4195	3899	1588	5846	19768	35296
2013		5446	5119	900	2727	58906	73098
2014		8356	3492	429	2278	76567	91122
2015		6181	3075	17	5306	109957	124536
2016		5942	1264	65	6520	18206	31996
2017		6797	6583	68	1527	27499	42474
2018		2863	1948	51	500	57397	62759

Table 3. Commercial landings (lb dw) by gear type, ACCSP (1991-2018).

Gear type	Weight (lb dw)	Percent
BY HAND, DIVING GEAR	44	4.0E-06
DIP NETS	43	3.9E-06
DREDGE	817	7.5E-05
FYKE NETS	1	1.3E-07
GILL NETS	3599256	0.33
HAND LINE	14476	1.3E-03
HAUL SEINES	4653	4.3E-04
HOOK AND LINE	383591	0.04
LONG LINES	6111466	0.56
NOT CODED	641689	0.06
OTHER FIXED NETS	160	1.5E-05
OTHER GEARS	5660	5.2E-04
OTHER SEINES	1768	1.6E-04
OTHER TRAWLS	61475	5.6E-03
OTTER TRAWLS	26231	2.4E-03
POTS AND TRAPS	384	3.5E-05
POUND NETS	387	3.6E-05
PURSE SEINE	223	2.1E-05
SPEARS	270	2.5E-05
TRAMMEL NETS	6093	5.6E-04
TROLL LINES	22634	2.1E-03
	10881321	1
GILL NETS + LONGLINES		0.89

Table 4. Commercial landings (lb dw) by state, ACCSP (1991-2018).

State	Weight (lb dw)	Percent
CT	12	1.07E-06
FL	6892785	0.6335
GA	207094	0.0190
MA	580	5.33E-05
MD	100988	0.0093
NC	1812974	0.1666
NJ	704663	0.0648
NY	2936	0.0003
RI	113	1.04E-05
SC	469940	0.0432
VA	689107	0.0633
	10881191	1
	Northeast	0.07
	Southeast	0.93

Table 5. Catches of blacktip sharks in the U.S. Atlantic in weight (lb dressed) after smoothing the recreational series with a three-year moving average (arithmetic mean). B2 dead were obtained as the annual B2 live release estimates multiplied by the overall post-release mortality rate, 18.5%, assumed for hook and line recreational fisheries.

Year	Unreported commercial catches	Bottom longlines	Gillnets	Other gears	Recreational catches (A+B1)	Recreational catches (B2 dead)	Total
1981					233142	262037	495179
1982					233142	262037	495179
1983		117654	156572	13927	283879	132302	704335
1984		235309	313144	27854	348201	110194	1034701
1985		352963	469716	41781	420057	111545	1396062
1986		546144	352931	41781	372751	45917	1359524
1987		175361	632155	41781	142503	40788	1032589
1988	95172	337384	424063	41781	77785	13462	989647
1989	80892	370196	359204	41781	87216	14827	954116
1990		283349	375659	41781	210659	19308	930757
1991		212125	354837	491096	235511	140513	1434082
1992		756923	87757	234581	249969	162515	1491745
1993		807599	335794	99764	187355	547885	1978397
1994		396013	20022	33314	159986	453906	1063241
1995		573084	62577	41805	232826	482826	1393117
1996		231129	404648	24586	192861	124592	977816
1997		123687	112990	11594	280100	192091	720461
1998		117429	68892	9432	293036	192035	680824
1999		128348	83778	9297	309627	301896	832946
2000		188258	96767	7682	236065	408834	937606
2001		109355	156606	5082	130824	489653	891519
2002		200569	270521	13940	98373	417002	1000404
2003		225246	235939	12878	66779	477464	1018306
2004		97734	176299	11657	369370	773187	1428246
2005		107426	109778	5810	363625	798355	1384994
2006		117754	219294	4751	398233	630844	1370876
2007		30858	48869	2155	92505	597907	772295
2008		118901	159135	4434	77409	633329	993208
2009		171886	30113	38086	43433	641576	925094
2010		164057	89956	17814	31116	297490	600433
2011		143771	38845	7655	36356	208543	435170
2012		106103	68209	40171	27851	235916	478251
2013		156418	81966	25843	25004	356932	646163
2014		206387	65028	10592	24368	564296	870671
2015		193274	36023	528	33921	470717	734464
2016		175635	70933	1907	33252	357899	639625
2017		175775	42433	1753	22640	237052	479653
2018		93515	29955	1661	22640	237052	384823

Table 6. Catches of blacktip sharks in the U.S. Atlantic in numbers after smoothing the recreational series with a three-year moving average (arithmetic mean). B2 dead were obtained as the annual B2 live release estimates multiplied by the overall post-release mortality rate, 18.5%, assumed for hook and line recreational fisheries.

Year	Unreported commercial catches	Bottom longlines	Gillnets	Other gears	Recreational catches (A+B1)	Recreational catches (B2 dead)	Total
1981					32377	44572	76948
1982					32377	44572	76948
1983		4902	3568	0	39732	25763	73966
1984		9805	7137	1161	66390	24349	108841
1985		14707	10705	1741	61982	13981	103116
1986		22756	8044	1741	65904	6392	104836
1987		7307	14407	1741	27389	6068	56912
1988	3966	14058	9665	1741	29796	5435	64659
1989	3371	15425	8187	1741	20287	3707	52717
1990		11806	8562	1741	45243	4335	71687
1991		8839	8087	20462	46337	24593	108318
1992		31538	2000	9774	50757	29284	123353
1993		24636	7653	3043	28802	75098	139232
1994		18735	456	1576	25981	60835	107583
1995		24573	1426	1793	38205	65404	131401
1996		9060	9222	964	38119	26098	83463
1997		4050	2575	380	68601	50685	126291
1998		3600	1570	289	64371	47905	117734
1999		4090	2350	296	63178	60509	130424
2000		5743	3798	234	31807	58370	99953
2001		3255	2557	151	18503	70982	95448
2002		7043	5740	490	20187	76946	110406
2003		7525	4730	430	15755	85700	114140
2004		3297	4417	393	41753	104560	154421
2005		3877	2647	210	34576	91712	133022
2006		4569	5625	184	38439	67438	116256
2007		1419	11462	99	11675	86674	111329
2008		3726	6349	139	9179	91809	111202
2009		4528	1128	1003	4081	93011	103752
2010		4583	3145	498	2377	43129	53731
2011		5625	2031	299	3395	30234	41584
2012		4195	3899	1588	3542	34202	47427
2013		5446	5119	900	3617	51747	66830
2014		8356	3492	429	3437	81810	97524
2015		6181	3075	17	4701	68243	82218
2016		5942	1264	65	4451	51887	63609
2017		6797	6583	68	2849	34367	50664
2018		2863	1948	51	2849	34367	42078

3.8 Figures

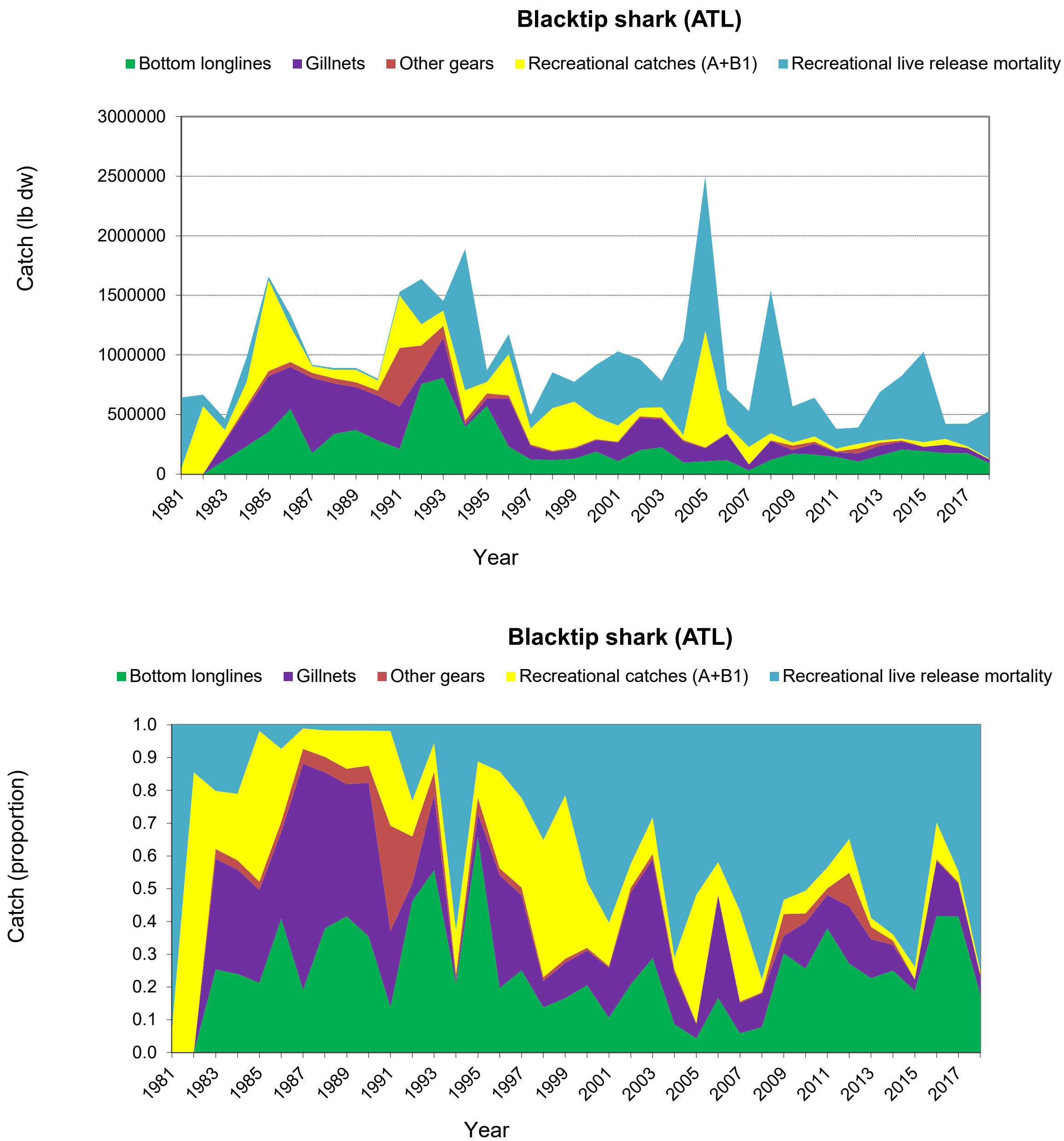
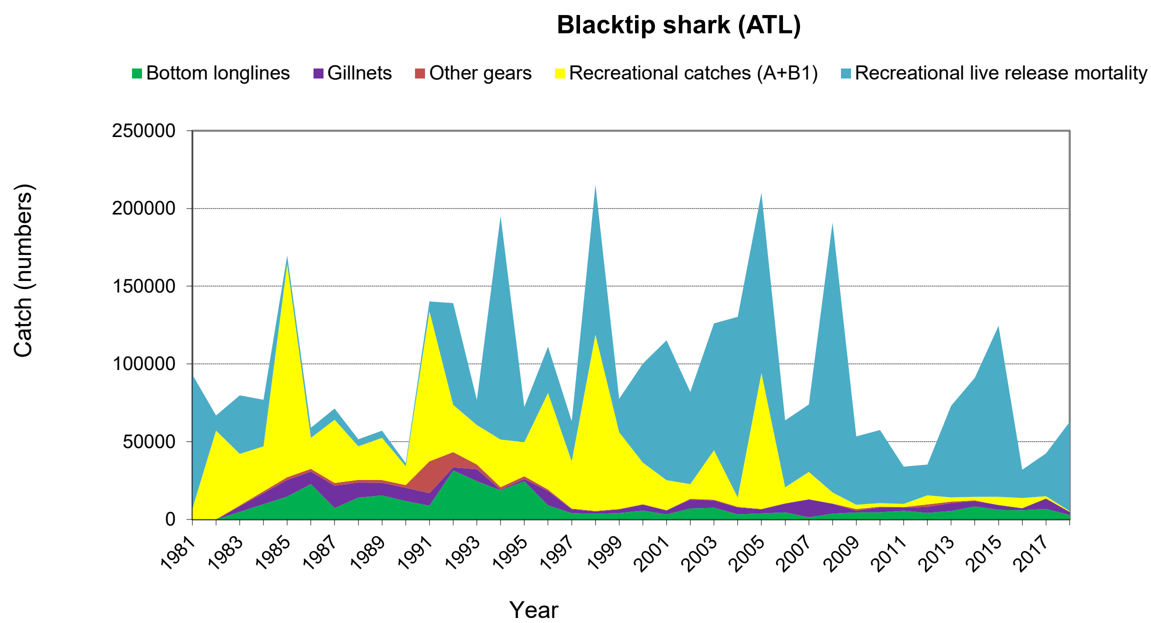


Figure 1. Commercial and recreational catches of Atlantic blacktip sharks in weight (lb dw), 1981-2018. Top panel: stacked catches by year; bottom panel: proportions by year.



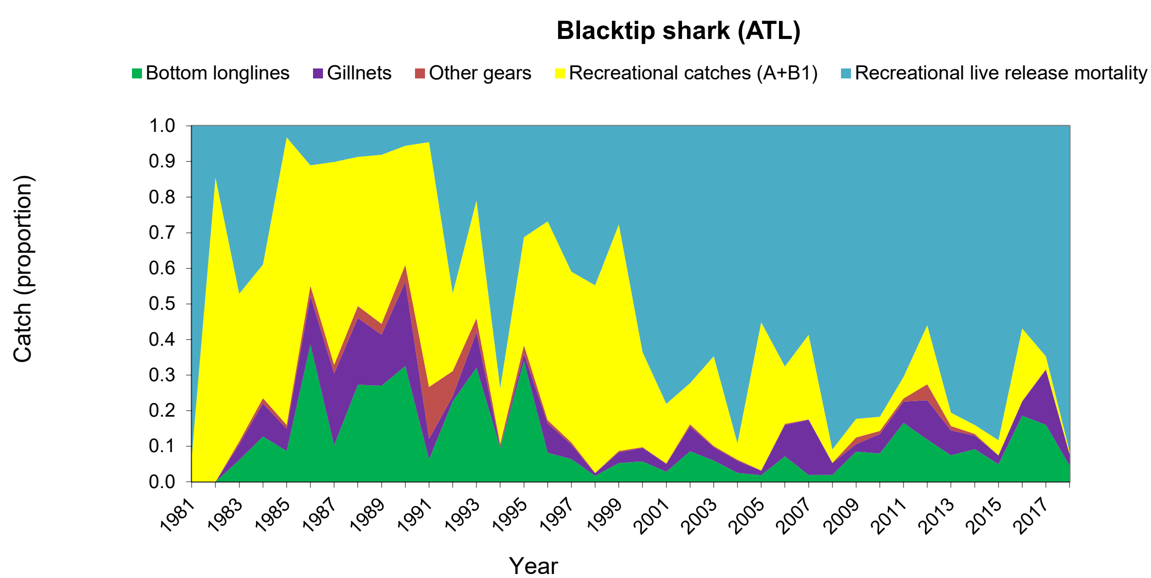
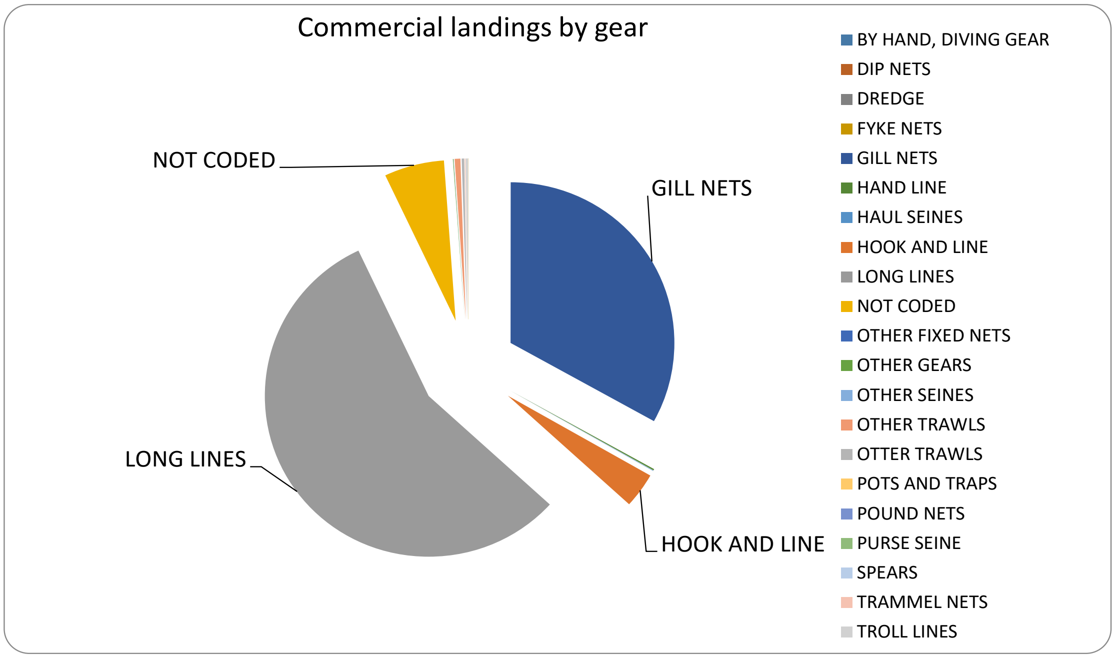


Figure 2. Commercial and recreational catches of Atlantic blacktip sharks in numbers, 1981-2018. Top panel: stacked catches by year; bottom panel: proportions by year.



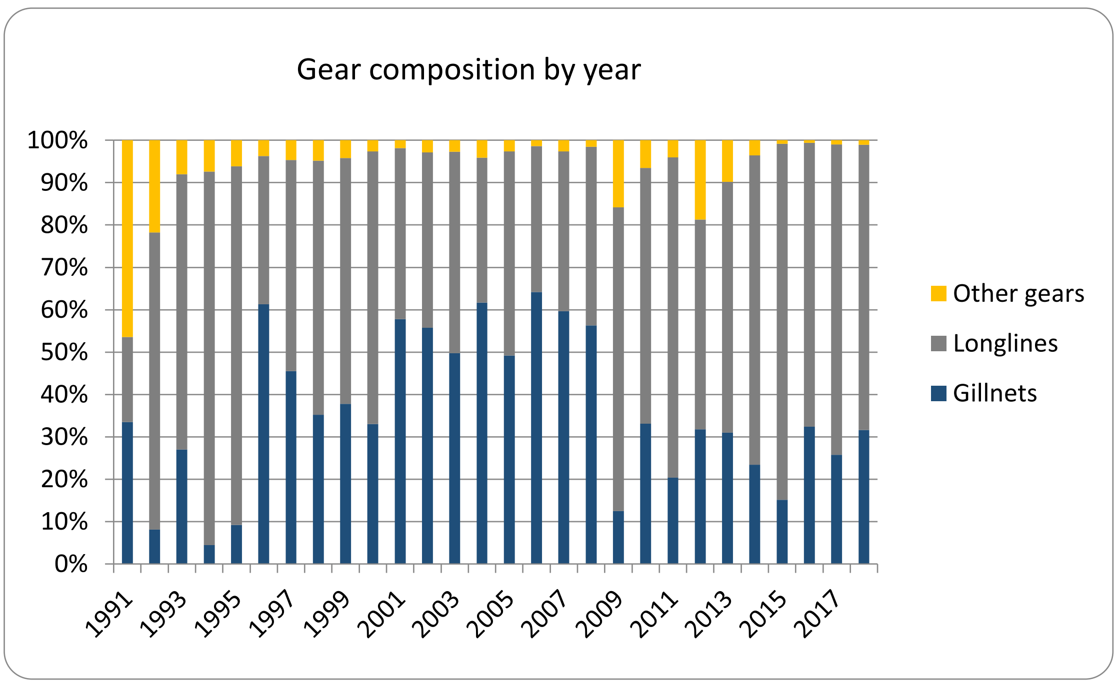


Figure 3. Commercial landings (lb dw) by gear type from the ACCSP for 1991-2018. Top panel: relative contribution for the entire time period; bottom panel: annual composition of the main gears by year.

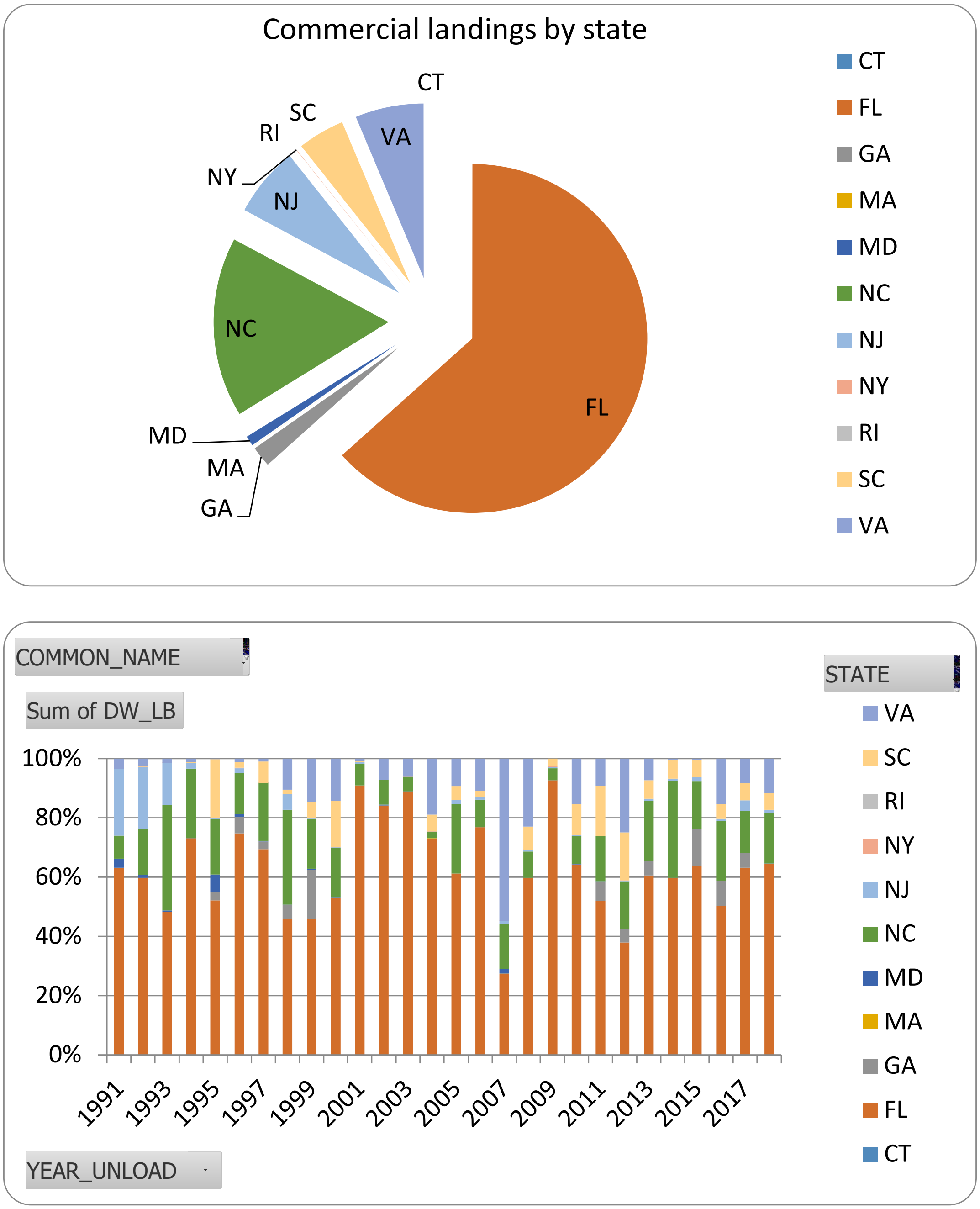


Figure 4. Commercial landings (lb dw) by state from the ACCSP for 1991-2018. Top panel: relative contribution for the entire time period; bottom panel: annual composition of the main gears by year

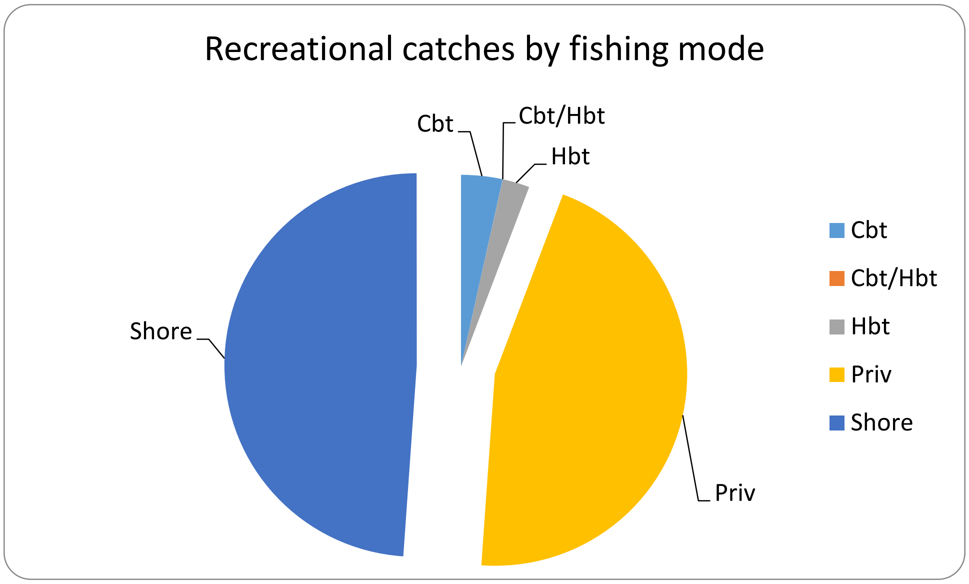


Figure 5. Recreational catches (AB1, numbers) of Atlantic blacktip sharks by fishing mode, 1981–-2018. Shore=fishing from shore; Private= private boats; Hbt=headboats; Cbt=charterboats.

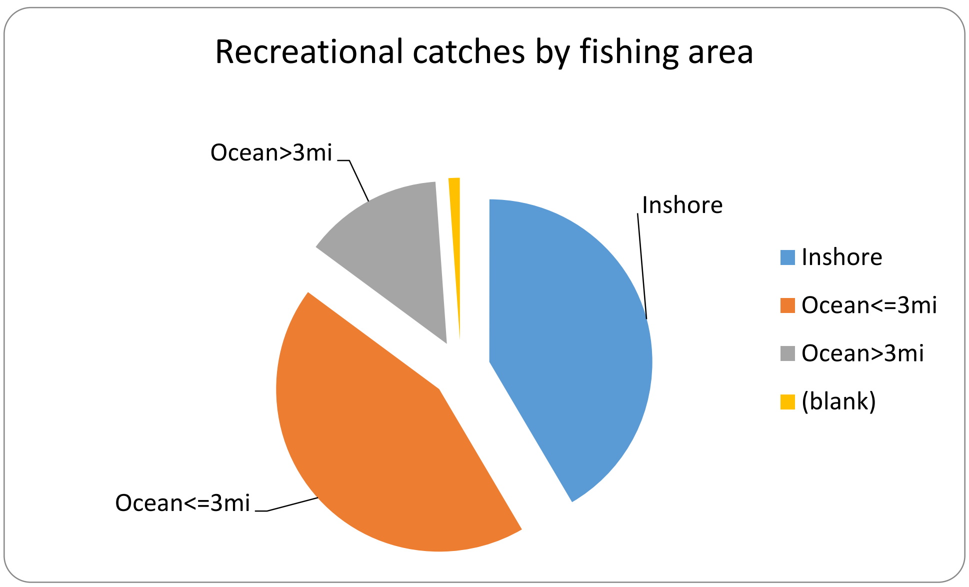


Figure 6. Recreational catches (AB1, numbers) of Atlantic blacktip sharks by fishing area, 1981-2018. Note: "Blank" indicates catches reported in the SRHS.

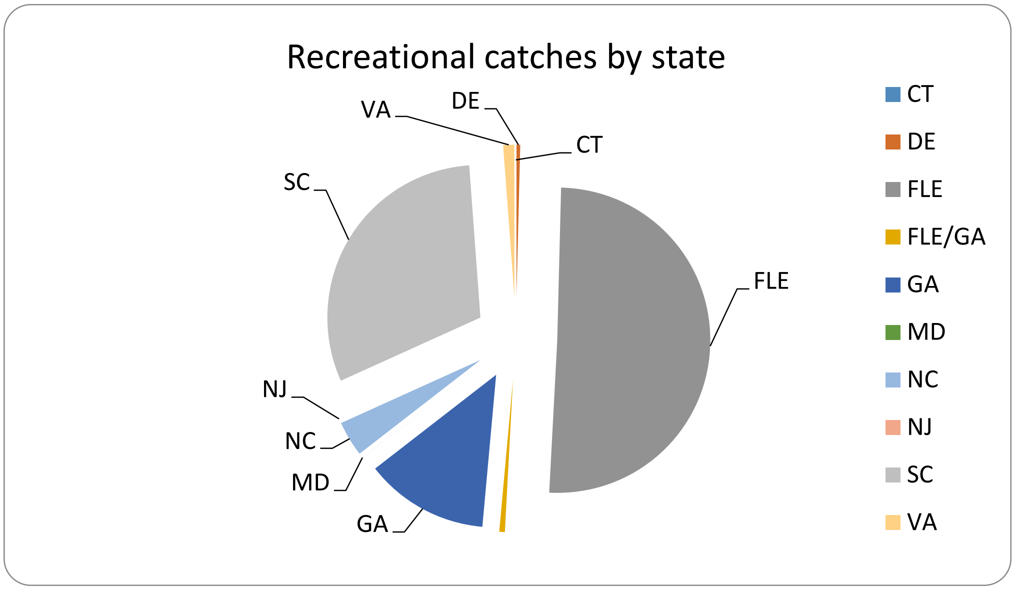


Figure 7. Recreational catches (AB1, numbers) of Atlantic blacktip sharks by state, 1981-2018.

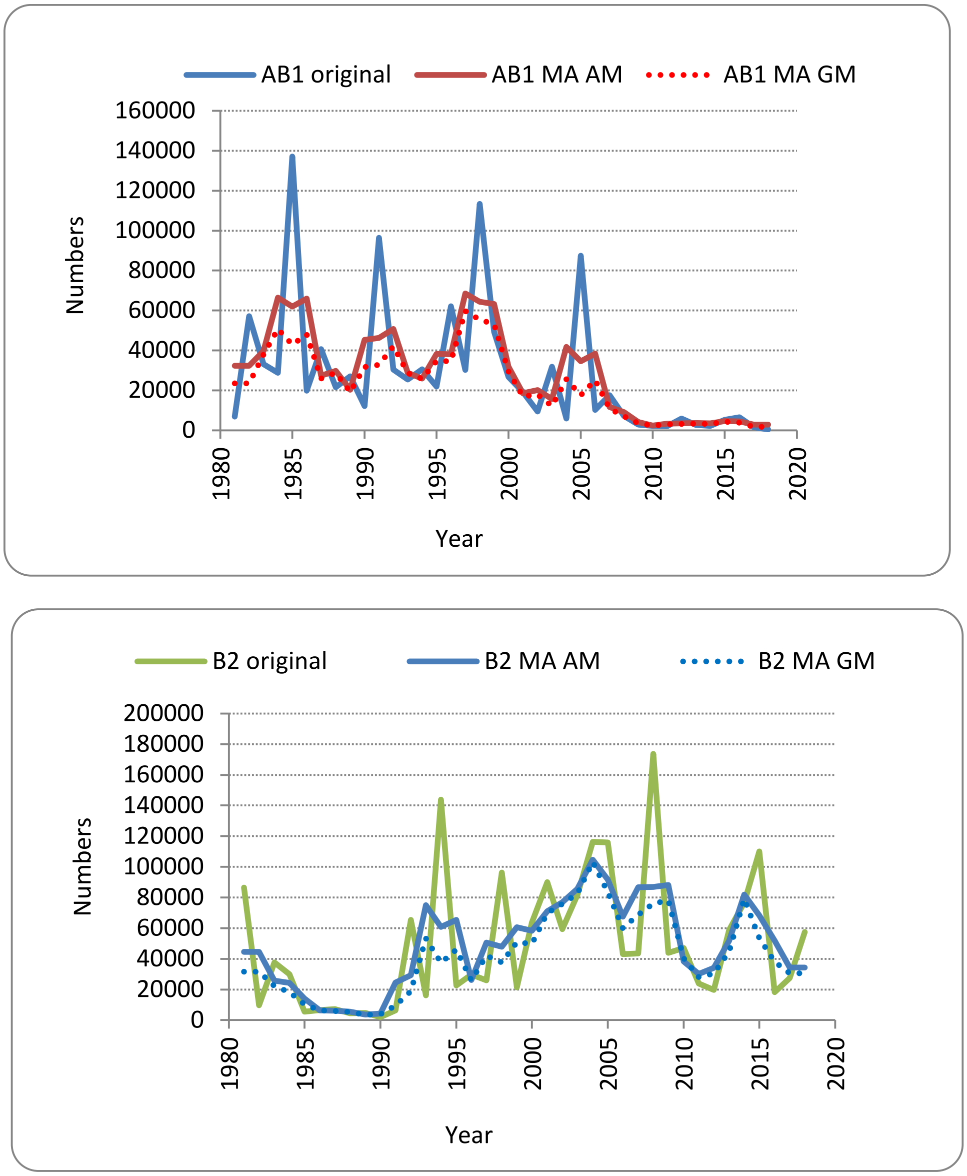


Figure 8. Recreational AB1 (top) and B2 (bottom) catches of Atlantic blacktip sharks in numbers, 1981-2018, comparing the original data, a 3-year moving average based on the arithmetic mean (MA AM), and a 3-year moving average based on the geometric mean (MA GM).

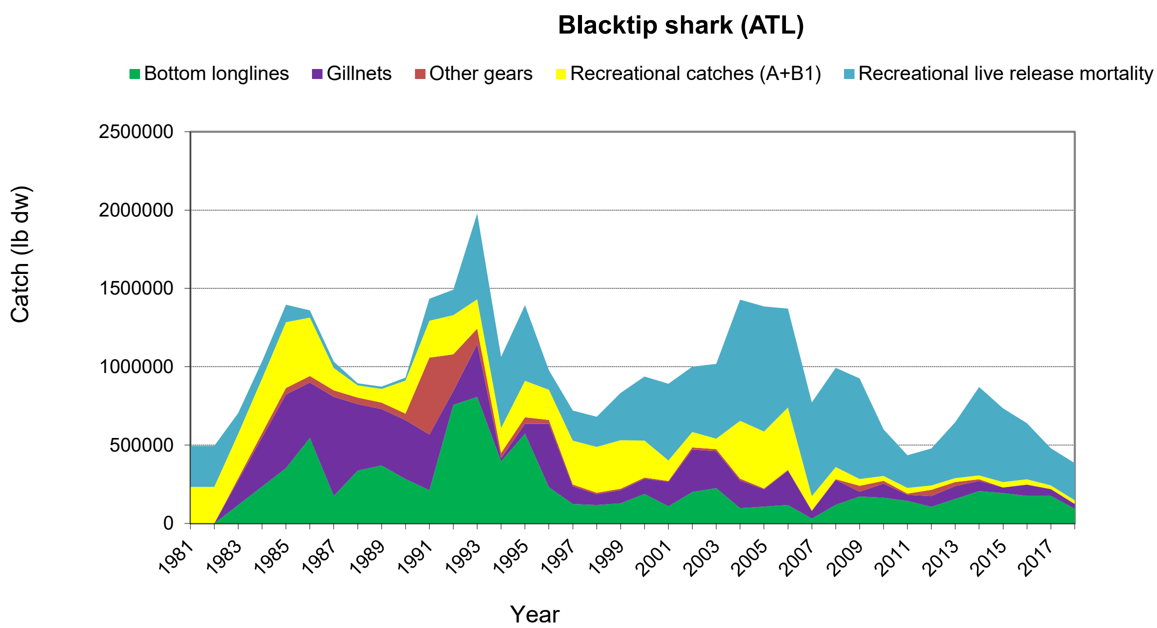


Figure 9. Commercial and recreational catches of Atlantic blacktip sharks in weight (lb dw), 1981-2018, with the recreational catches smoothed with a 3-year moving average (arithmetic mean).

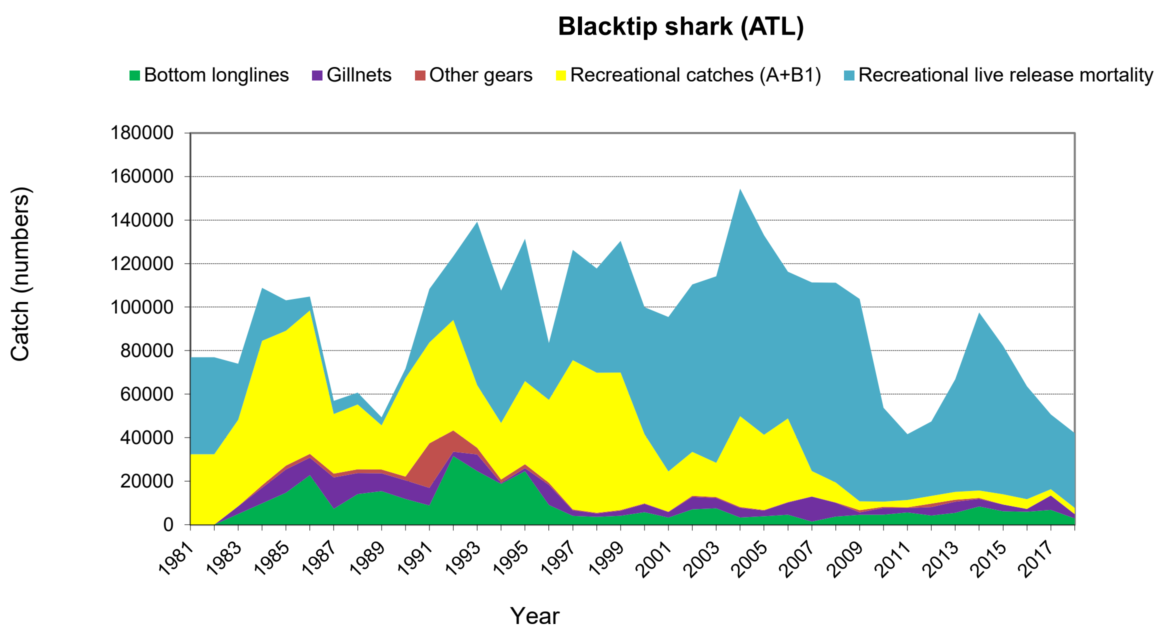


Figure 10. Commercial and recreational catches of Atlantic blacktip sharks in numbers, 1981-2018, with the recreational catches smoothed with a 3-year moving average (arithmetic mean).

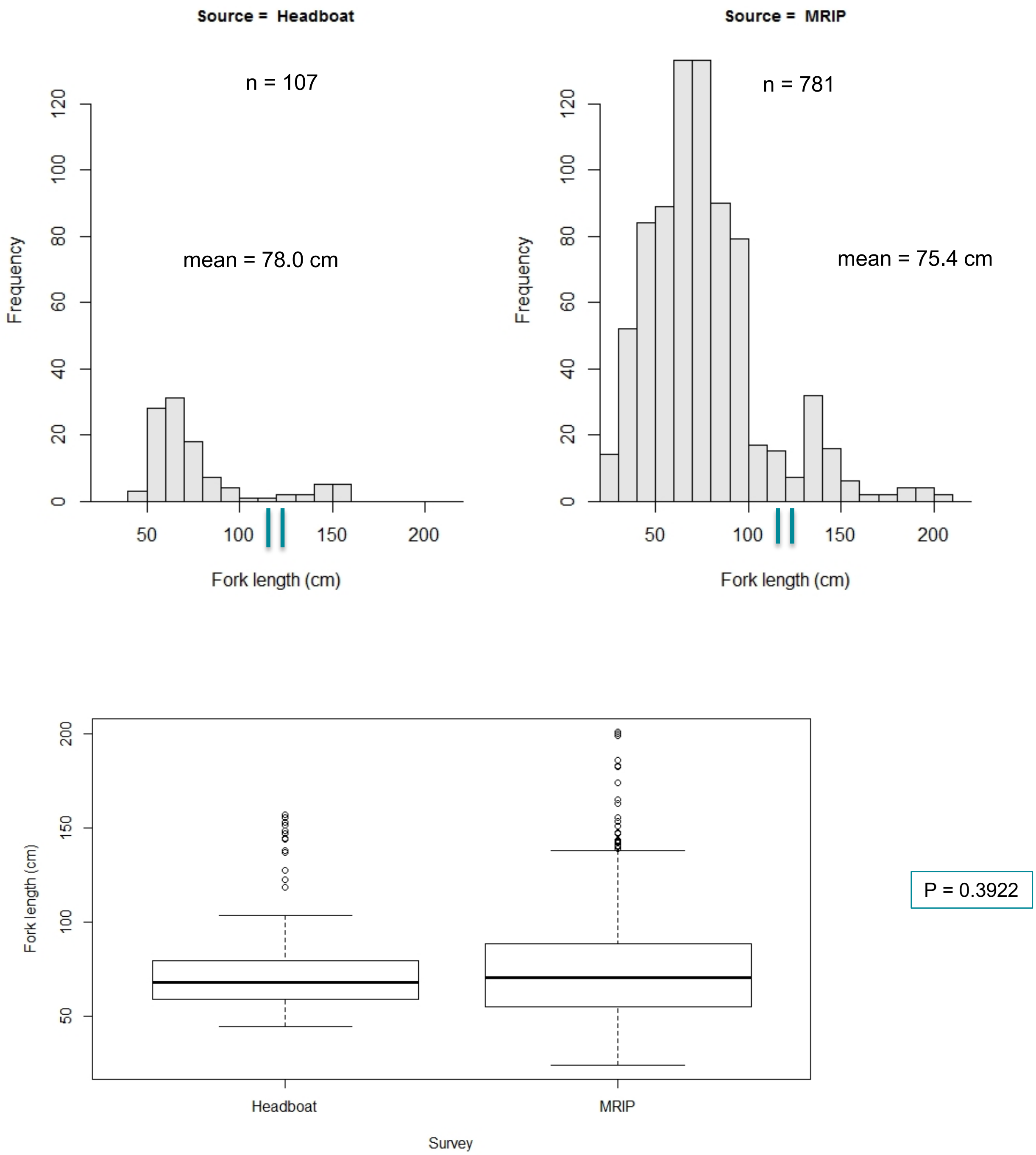


Figure 11. Length-frequency histograms of Atlantic blacktip sharks from the MRIP and SRHS surveys (top panel) and boxplot of fork length by survey (bottom panel). Vertical bars in the top panel denote median length at maturity for males (115 cm FL) and females (123 cm FL), respectively.

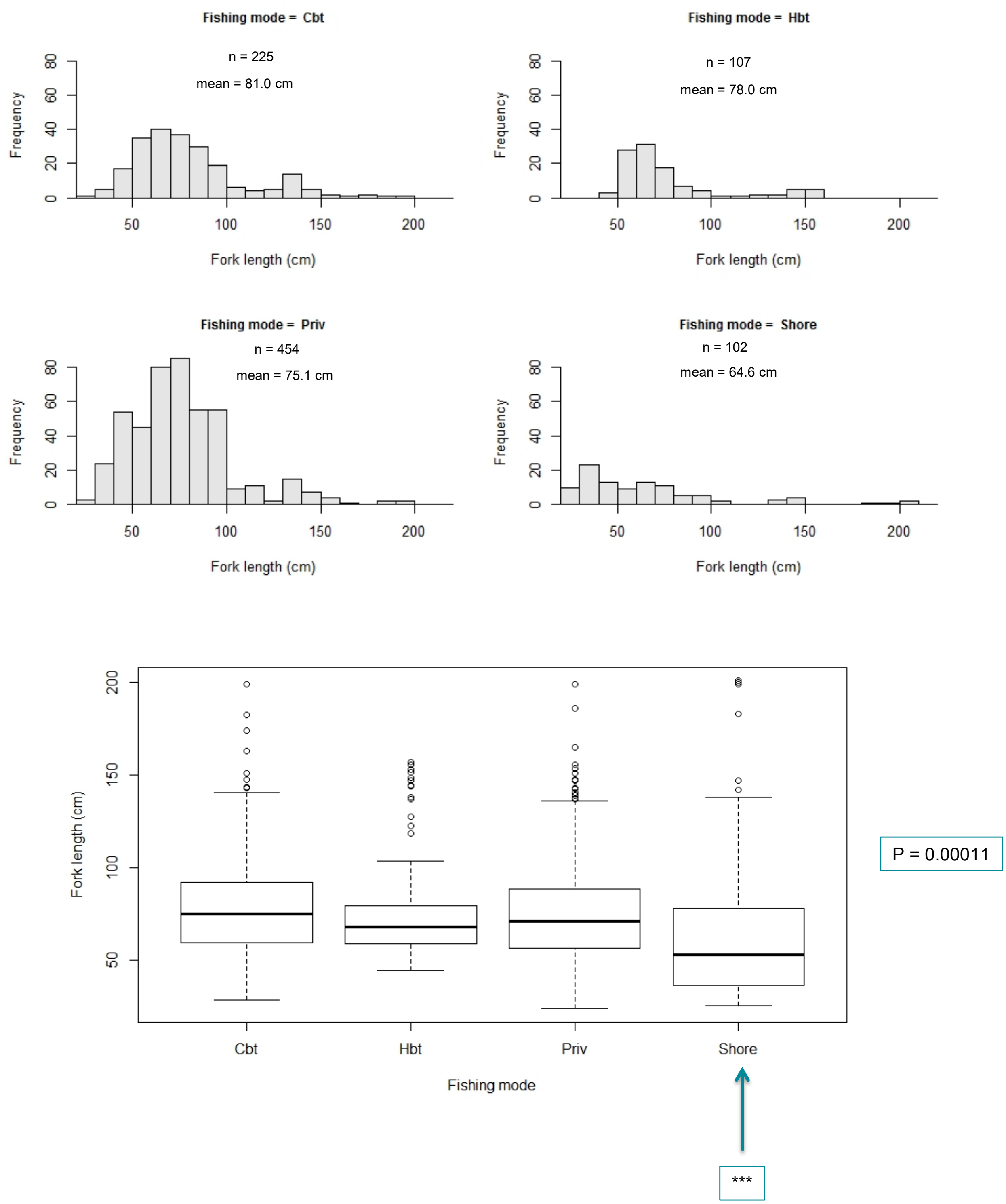


Figure 12. Length-frequency histograms of Atlantic blacktip sharks from the MRIP and SRHS surveys by fishing mode (top panel) and boxplot of fork length by fishing mode (bottom panel).

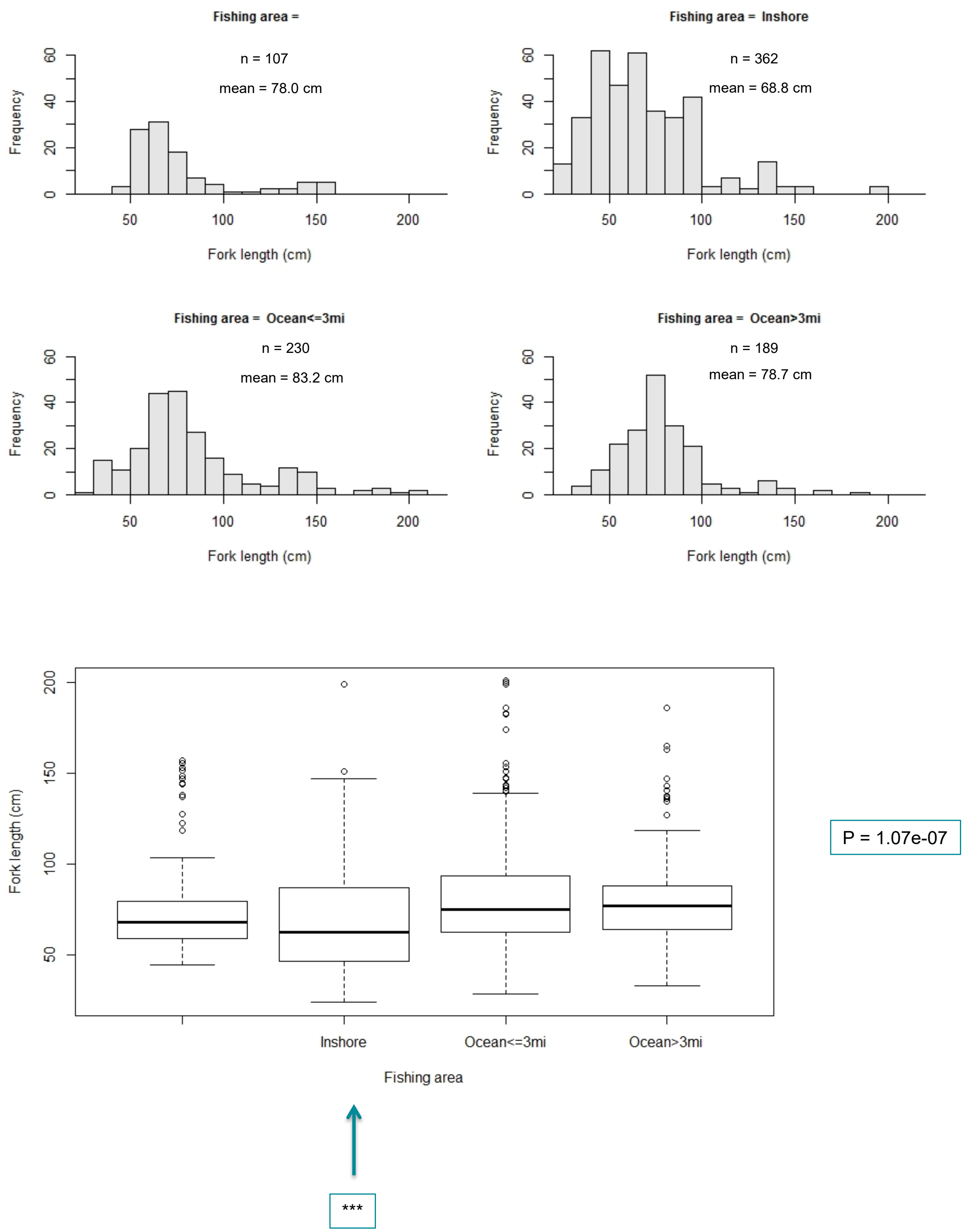


Figure 13. Length-frequency histograms of Atlantic blacktip sharks from the MRIP and SRHS surveys by fishing area (top panel) and boxplot of fork length by fishing area (bottom panel). Blank fishing area denotes lengths form the SRHS.

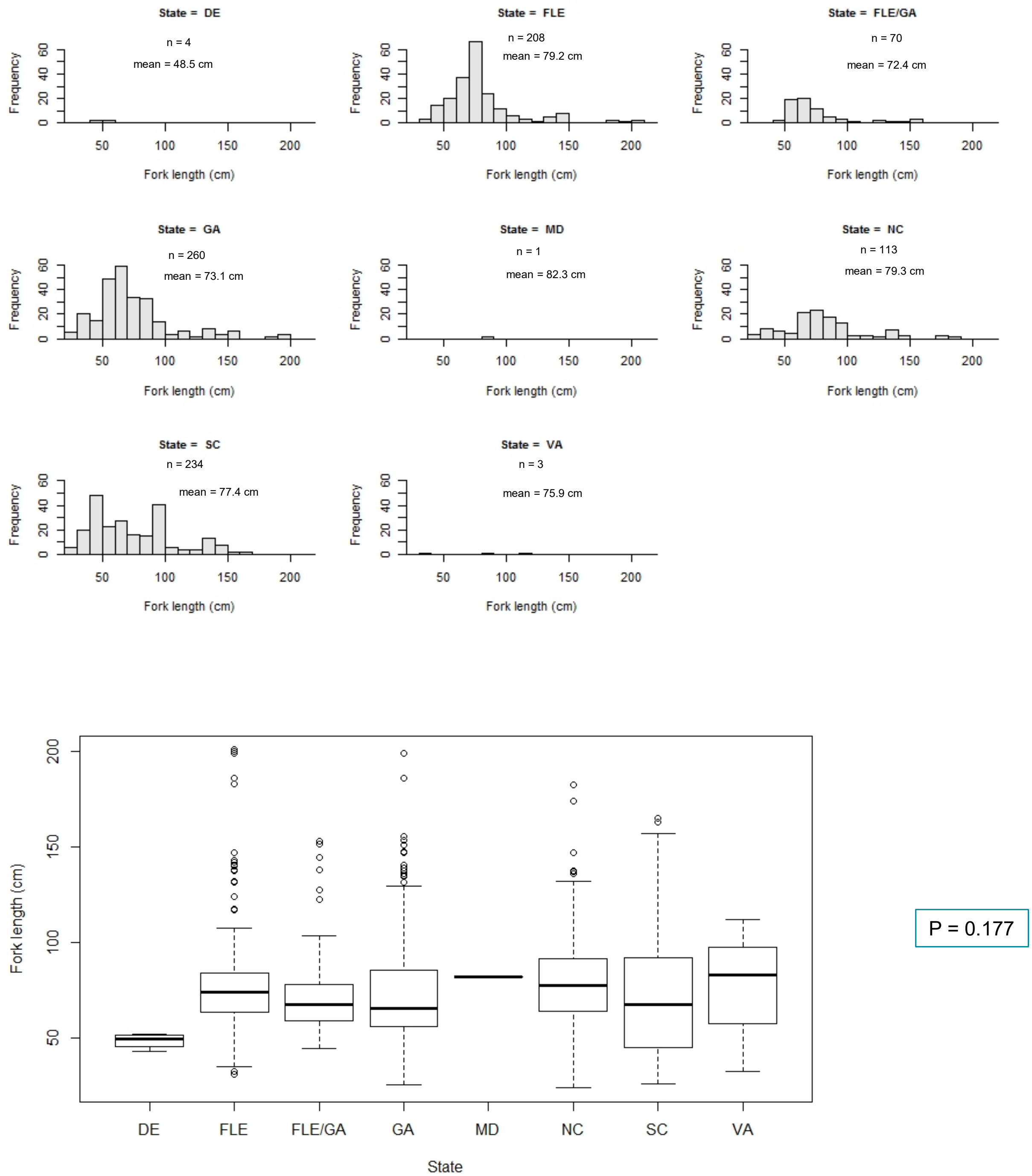


Figure 14. Length-frequency histograms of Atlantic blacktip sharks from the MRIP and SRHS surveys by state (top panel) and boxplot of fork length by state (bottom panel).

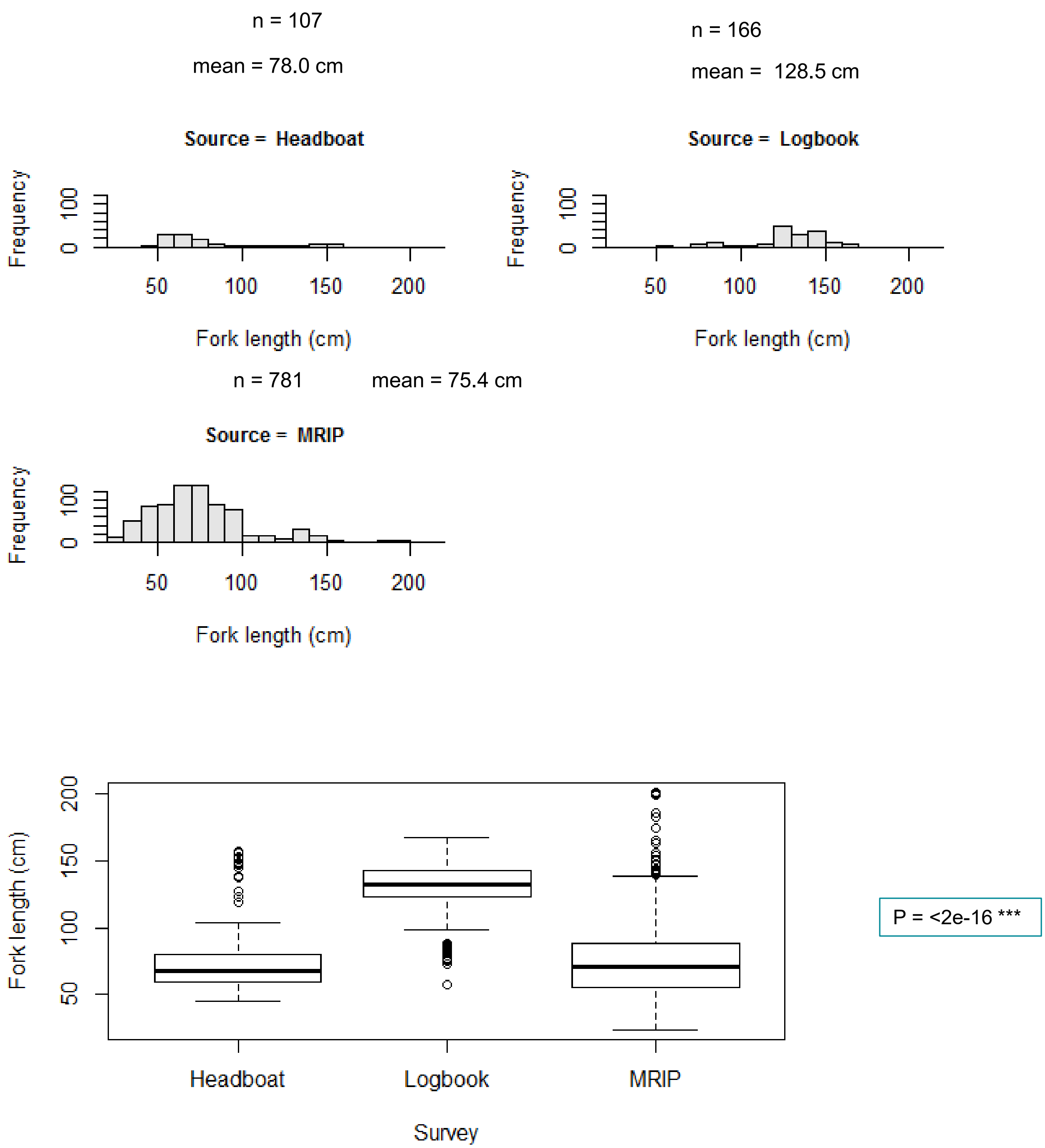


Figure 15. Length-frequency histograms of Atlantic blacktip sharks from the MRIP and SRHS surveys, with the added logbook survey from SCDNR (top panel) and boxplot of fork length by survey (bottom panel). Vertical bars in the top panel denote median length at maturity for males (115 cm FL) and females (123 cm FL), respectively.

4. Indices of Population Abundance

4.1 Overview

Twelve (12) indices of abundance were considered for use in the assessment models. Indices were constructed using both fishery independent and 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 was fishery dependent or independent, the data were standardized using a form of the generalized linear model (Aitchison, 1955). Elements considered for each data series ranged from the statistical diagnostics of the analysis to the temporal and spatial coverage of the index (Table 1). The Group also used a flowchart developed by ICCAT in its decision making process. In previous SEDARs for sharks, the indices working group ranked indices on a scale of 1-5 as a means of relative weight for the stock assessment. The Group discussed that there is likely little difference among several of the categorical designations and decided to drop that method and to either 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.

4.2 Workgroup Participants

John Carlson, Leader…………………………………NOAA Fisheries Service- Panama City, FL
Cami McCandless, *not present at workshop*…………NOAA Fisheries Service, Narragansett, RI
Bryan Frazier……………………………..........South Carolina Department of Natural Resources
Robert J Latour……………………………........................Virginia Institute of Marine Science
Adam Pollack…………………………………………NOAA Fisheries Service- Pascagoula, MS
Kaitlyn O'Brien..……………………………….……………Virginia Institute of Marine Science
Andrea Kroetz……………………………...……...NOAA Fisheries Service- Panama City, FL
James Gelsleichter………………………………………........University of North Florida
Dean Courtney………………………………………NOAA Fisheries Service- Panama City, FL

4.3 Review of Indices

4.3.1 Fishery Dependent indices

Marine Recreational Information Program Data (SEDAR65-DW16)

The Marine Recreational Information Program (MRIP) catch data set was used to derive a standardized index of abundance for Atlantic blacktip sharks using delta-lognormal generalized linear mixed models. The Group noted that this is a stock wide survey that was fully analyzed with the diagnostics and characterization of uncertainty fully acceptable. However, as the author noted, the fraction of the catch of carcharhinid sharks identified to species in the MRIP data has declined over the last 30 years, as more sharks have been released alive rather than landed. While this is a success from a management perspective, the trip interceptor cannot identify the species. Thus, this index is likely to be biased. Moreover, the Group also noted that identification of blacktip sharks especially as it relates to spinner shark would be biased.

Decision: The Group thus recommended that this index not be utilized.

*SEFSC Shark Bottom Longline Observer Program (SEDAR65-DW-17)***.**

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 previous stock assessment for Atlantic blacktip shark utilized data from this fishery as an index of abundance and as an input to the stock assessment model (SEDAR21). A combined data set was developed based on observer programs from Morgan et al. (2009) and Mathers et al. (2018). Following the definition of the South Atlantic from the Office of Sustainable Fisheries, Highly Migratory Species Management Division, data were excluded from the Gulf of Mexico. 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 2008-2018 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 Florida) over a long temporal period (1993-2018). Data was standardized using the Delta-Generalized Linear Mixed Model approach, which is common in fisheries.

Decision: The Group determined that despite the series being noisy due to observational error, the series should be retained for use in the stock assessment.

4.3.2 Fishery Independent Indices

Virginia Shark Monitoring and Assessment Program (SEDAR65-DW05)

The Virginia Shark Monitoring and Assessment Program (VASMAP), which is based out of the Virginia Institute of Marine Science (VIMS), has been sampling shark populations in the coastal waters of Virginia since 1974 using standardized fisheries-independent longline gear. Data have been incorporated into stock assessments conducted by NOAA Fisheries for shark populations in the Atlantic, and are used by the Atlantic States Marine Fisheries Commission (ASMFC) and the Virginia Marine Resources Commission (VMRC) in their respective shark management policies. The Group noted that although the series is limited spatially, it is based on 6 fixed stations in offshore waters of Chesapeake Bay and captures blacktip sharks as they migrate north in spring and in fall when returning south. The series is the longest temporally. However, in early years due to funding and logistics, many years are missing or suffer from small sample size.

Decision: The Group thus recommended three alternate time series for this data be developed and potentially utilized in the stock assessment: 1) including the entire time series regardless of sample size (1974-2018), 2) truncated to match the year when the catch series begins (1981-2018), and 3) the time series which would be considered to be the most robust in regards to sampling (1990-2018).

NOAA Fisheries-Southeast Fisheries Science Center-Mississippi Laboratory Bottom Longline Survey (SEDAR65-DW15)

The National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center (SEFSC) Mississippi Laboratories (MSLABS) has conducted standardized bottom longline surveys in the Gulf of Mexico (GOM), Caribbean, and western North Atlantic Ocean since 1995. Data from the NOAA/NMFS/SEFSC/MSLABS Bottom Longline Survey were examined to determine the feasibility of constructing an index of relative abundance for blacktip sharks captured in the western North Atlantic Ocean. Despite good spatial and temporal coverage, both the authors of the study and the Group noted that there were not sufficient numbers of blacktip sharks caught in the survey to produce a reliable index of relative abundance (n=45). This was largely due to the timing of the survey, which occurs when most blacktip sharks are either in areas further north or in shallow waters inaccessible by the NOAA vessel.

Decision: The Group did not recommend this series for use in the assessment.

NOAA Fisheries-Northeast Fisheries Science Center- Bottom Longline Survey (SEDAR65-DW09)

The Northeast Fisheries Science Center (NEFSC) coastal shark bottom longline survey is conducted by the Apex Predators Program. The primary objective of this survey is to conduct a standardized, systematic survey of the shark populations off the US Atlantic coast to provide unbiased indices of the relative abundance for species occurring in the waters from Florida to the Mid-Atlantic. Data from this survey were used to examine the trends in relative abundance of blacktip sharks in the waters off the east coast of the United States. The majority (72%) of the catch consisted of mature males and the proportion of sets with positive catch (at least one blacktip shark caught) was 26%. Catch per unit effort (CPUE) in number of sharks per 100 hook hours was 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 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 blacktip shark relative abundance across survey years from 1996 to 2018. This survey has been used in previous assessments for sandbar and dusky sharks (SEDAR21-DW-28) and the updates to these assessments. Review of the initial analysis indicated that the CVs in later years may be biased low. Additional analyses were requested and incorporation of an additional variable corrected the problem.

Decision: The Group recommended this series be retained for use in the assessment.

South Carolina Department of Natural Resources SEAMAP Longline Survey (SEDAR65-DW11)

The South Carolina Department of Natural Resources (SCDNR) Southeast Area Monitoring and Assessment Program (SEAMAP) multispecies survey started in 2007 as a replacement for the prior SCDNR red drum longline survey. This survey was developed to increase the geographical and seasonal coverage of the prior survey and move it from a fixed-station to a random-stratified multispecies survey. Thirty sites are randomly selected from a predetermined list of sites (40-100 sites/strata) during each sampling period (2- month periods: March/April, May/June, July/August, September/October, and November/December). Each of four strata (Winyah Bay, Charleston Harbor, St. Helena Sound and Port Royal Sound) is sampled once during each time period. The catch per unit effort (CPUE) from the SCDNR SEAMAP longline survey was used to examine blacktip shark relative abundance in South Carolina's estuarine and nearshore 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. The standardized CPUE results from the SCDNR SEAMAP longline survey indicate a variable but slight increasing trend overall in blacktip shark relative abundance across survey years from 2007 to 2018 with a notable peak in 2013. This peak was also seen in the SCDNR long-gillnet survey (SEDAR65-WP-07) and, not as pronounced, in the COASTSPAN longline survey (SEDAR65-WP-08). The Group noted that the survey suffers from limited spatial coverage but has good temporal coverage. The survey is also based on a stratified random design located within the core of the species range. This survey was previously used in stock assessments for Atlantic sharpnose sharks (SEDAR34-WP36) and the sandbar shark update (SEDAR 54).

Decision: The Group recommended that this series be retained for use in the assessment.

South Carolina Department of Natural Resources Drumline Survey (SEDAR 65 – DW21)

The SCDNR drumline survey has been conducted since 2013 and is currently an ongoing program. It uses an index station protocol to sample for large coastal sharks in estuarine waters as well as sounds in SC. Sampling typically occurs from April through November. Data from this survey were used to look at trends in relative abundance for mature blacktip sharks. A binomial model was developed using the drumline data because of the use of a single hook fished on each line. Year and month were retained in the final model. Nominal and standardized presence/absence results from this survey indicate a stable or slightly increasing population across the survey timeframe. The Group discussed the fact that this time series is not very long temporally. However, the survey samples mostly large juveniles and adults with a high proportion positive of catches.

Decision: As there are few series that sample this portion of the population exclusively, the Group recommended the series be retained.

South Carolina Department of Natural Resources Red Drum Survey (SEDAR65-DW11)

The South Carolina Department of Natural Resources (SCDNR) conducts a long-term monitoring program for adult red drum, *Sciaenops ocellatus,* in the coastal waters of South Carolina and regularly has shark bycatch. A fixed-station longline survey was conducted from 1994 to 2006 before being modified to the aforementioned multispecies random stratified survey. Catch per unit effort (CPUE) in number of sharks per 100 hook hours was used to examine blacktip shark relative abundance. The proportion of SCDNR red drum survey sets with positive catch (at least one blacktip shark caught) was 13%. 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. The standardized CPUE results from the SCDNR red drum longline survey indicate a variable but slight decreasing trend overall in blacktip shark relative abundance across survey years from 1996 to 2006. This survey was previously used in stock assessments for sandbar and blacknose sharks (SEDAR21-WP-30) and Atlantic sharpnose sharks (SEDAR34-WP-36). While the series is not designed for sharks, blacktip sharks comprise a good proportion of the catch and the series is long term.

Decision: The Group recommended that this series be retained for use in the assessment.

Georgia Department of Natural Resources SEAMAP Longline Survey (SEDAR65-DW12)

In 2006 a pilot study to work out the logistics of a Georgia Department of Natural Resources (GADNR) Southeast Area Monitoring and Assessment Program (SEAMAP) longline survey was conducted. The objectives of this survey are to develop a state specific sampling protocol that provides a fisheries independent index of abundance for adult red drum, to sample adult red drum and develop information on catch per unit effort (CPUE) and size, to collect migratory and stock identification data on adult red drum, to evaluate age composition and reproductive status of red drum <90 cm total length, and to disseminate accomplishments and results to the Atlantic States Marine Fisheries Commission (ASMFC) and the National Marine Fisheries Service (NMFS) for inclusion in stock assessment efforts. The GADNR SEAMAP survey gear also targets multiple coastal shark species. The survey design was finalized and sampling began in 2007. This survey has been previously used in stock assessments for Atlantic sharpnose shark when combined with the SCDNR SEAMAP survey and details on the combined index are available in the addendum to SEDAR34-WP-34 and SEDAR34-WP-36.

Differences in bait and hook type were found to have a significant effect on blacktip shark catches, but could not be accounted for in the model since the differences did not overlap within years. 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. The resulting relative abundance has an overall decreasing trend due to the high first year and is likely influenced by the change in bait and hook type. The highest estimate is in 2007, the only year when both mixed bait sets and mixed hook sets were used. Following this year there is a variable but overall increasing trend from 2008 to 2015 when the bait and hook type are held constant (squid bait, mixed hooks). There is another dip in 2016 when small hooks are removed but mixed baits are returned. The trend increases again for the remainder of the time series while the mixed baits and large hooks are held constant from 2016 to 2018. Running the analyses again without 2007 produces an overall increasing trend but retains the variability.

Decision: Because of the variability in methods and their influence on the abundance trend, the Group recommended this series not be retained for use in the stock assessment.

COASTSPAN Longline (SEDAR65-DW08)

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 the South Carolina Department of Natural Resources (SCDNR), Georgia Department of Natural Resources (GADNR), and the University of North Florida (UNF) in collaboration with the National Marine Fisheries Service's (NMFS) Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) survey began sampling for sharks using longline and/or gillnet methods in several of their state's estuaries and nearshore waters. Sampling in South Carolina and, on a very limited basis, in Georgia began in 1998 by SCDNR and Savannah State University, respectively. GADNR took over Georgia sampling in 2000 and UNF began sampling in northern Florida in 2008. Exploratory sampling in the early years and a shift in spatial coverage in later years limit the start of the time series to 2005. The CPUE (sharks per 100 hook hours) 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 indices of abundance from the COASTSPAN longline survey show a slight decreasing trend overall in both total and YOY (young-of-the-year) blacktip shark relative abundance across survey years with notable peaks in 2008 and 2013. A peak in 2013 was also seen in the SCDNR Southeast Area Monitoring Program (SEAMAP) longline survey (SEDAR65-WP-11) and the COASTSPAN long-gillnet survey (SEDAR65-WP-07). This survey has been previously used in stock assessments for Atlantic sharpnose shark, bonnethead and sandbar shark (SEDAR34-WP-37, SEDAR21-WP-30).

Decision: The Group evaluated the time series and, due to the temporal and spatial coverage, decided that it should be recommended for use. After consulting with the lead stock assessment analyst, the Group also recommended the series be split into Age 0 sharks only and all life stages combined. The Age 0 sharks time series will be used as a recruitment index for the stock assessment. The Group noted that both the Age 0 and juvenile time series should not be included in a model at the same time because they are based on the same data set.

COASTSPAN Long and Short Gillnet (SEDAR65-DW07 and SEDAR65-DW10)

In an effort to examine the use of South Carolina's estuarine waters as nursery areas for coastal shark species, the South Carolina Department of Natural Resources (SCDNR) Marine Resources Division, in collaboration with the National Marine Fisheries Service's (NMFS) Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Survey began sampling for sharks using gillnet methods (230 m x 3 m net with 10.3 cm stretched mesh) in several estuaries within South Carolina since 1998. A small gillnet survey (45 m x 3 m with 10.3 cm stretched mesh) was added in 2006 to supplement large gillnet sampling and facilitate sampling in areas too small for the large gillnet. For both gillnet surveys the catch per unit effort (CPUE) in number of sharks per net hour was used to examine blacktip shark trends in abundance. The gillnets are set on station and inspected (hauled) multiple times and re-set to reduce bycatch before the final haulback. For the small gillnet each of these hauls is modeled separately. During long gillnet sets, once the end set gillnet anchor is deployed sometimes the net is immediately retrieved at the start set anchor to begin inspecting the net, resulting in records with short soak times (<5 minutes). To avoid unreasonably high catch rates due to these short soak times with the long gillnets, all sets conducted consecutively at the same station were grouped and the combined catch and soak times were considered a single set. The CPUEs were standardized using delta-lognormal generalized linear models. Standardized CPUE results from the COASTSPAN short-gillnet survey from 2006-2018 indicate a slight increasing trend overall in YOY blacktip shark relative abundance during the survey years with notable peaks in 2007 and 2012. The standardized CPUE results from the COASTSPAN long-gillnet survey from 2001-2018 also indicate a slight increasing trend overall for all life stages and YOY blacktip shark relative abundance across survey years with a notable peak in 2013. This peak was also seen in the SCDNR Southeast Area Monitoring Program (SEAMAP) longline survey (SEDAR65-WP-11) and, not as pronounced, in the COASTSPAN longline survey (SEDAR65-WP-08). These surveys have been used previously in the assessments for Atlantic sharpnose and bonnethead sharks (SEDAR34-WP-36). Although the series is limited spatially and based on a fixed station sampling design, the time series is located within the core of the species range.

Decision: The Group recommended this series be retained for use in the assessment.

4.4 Research Recommendations

1. Explore the utility of combining multiple indices into one index using the Bayesian hierarchical model (Conn, 2009) or other similar methodology. The data series that could potentially be combined are:
    - For Age 0
        - Coastspan Longline, Coastspan Gillnet Short Net, Coastspan Gillnet Long Net
    - For All Ages
        - NEFSC Bottom Longline, Shark Bottom Longline Observer, Virginia Institute of Marine Science, SEAMAP Longline, SCDNR Red Drum Longline
2. Investigate alternate methods in future assessments for standardizing indices of abundances outside the Delta-Lognormal method (Lo et al. 1992).
3. Explore the utility of standardized age-0 indices as recruitment indices in the stock assessment model.

4.5 Literature Cited

Aitchison, J. (1955). On the distribution of a positive random variable having a discrete probability mass at the origin. Journal of the American Statistical Association 50: 901-908.

Conn, P.B. (2009). Hierarchical analysis of multiple noisy abundance indices. Canadian Journal of Fisheries and Aquatic Sciences, 67:108-120.

Lo, N.C.H., Jacobson, L.D. and Squire, J.L. (1992). Indices of relative abundance from fish spotter data based on delta-lognormal models. Canadian Journal of Fisheries and Aquatic Sciences 49:2515-2526.

4.6 Tables

Table 1. 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 2. Indices recommended by the Indices Working Group, including the corresponding SEDAR document number and index type (fishery independent or dependent).

Index Name	SEDAR Document Number	Index Type
SEFSC Shark Bottom Longline Observer Program	SEDAR65-DW-17	Dependent
Virginia Shark Monitoring and Assessment Program	SEDAR65-DW05	Independent
NOAA Fisheries-Northeast Fisheries Science Center-Bottom Longline Survey	SEDAR65-DW09	Independent
South Carolina Department of Natural Resources SEAMAP Longline Survey	SEDAR65-DW11	Independent
South Carolina Department of Natural Resources Drumline Survey	SEDAR 65 – DW21	Independent
South Carolina Department of Natural Resources Red Drum Survey	SEDAR65-DW11	Independent
COASTSPAN Longline	SEDAR65-DW08	Independent
COASTSPAN Long and Short Gillnet	SEDAR65-DW07 and SEDAR65-DW10	Independent

Table 3. Recommended indices of abundance including index name and SEDAR document number. CV is the coefficient of variation for the annual index value.

Year	Shark Bottom Longline Fishery	CV	Shark Research Fishery	CV	VIMS (Original)	CV	VIMS (Catch Series)	CV	VIMS (Robust Series)	CV
1974					0.7469	0.7437				
1975					1.1763	0.5683				
1976										
1977										
1978										
1979										
1980					0.0943	0.7123				
1981					0.0504	0.8973	0.0500	0.5708		
1982										
1983					0.1169	1.2217	0.1145	0.9001		
1984										
1985										
1986										
1987					0.1604	1.0616	0.1555	0.9388		
1988					0.1707	1.0215	0.1567	1.1678		
1989										
1990					0.0266	1.3347	0.0273	0.7614	0.0260	0.7673
1991					0.0124	1.8805	0.0125	0.7852	0.0120	0.7901
1992					0.0216	1.3499	0.0219	0.7791	0.0211	0.7844
1993										
1994	19.4100	0.7100								
1995	46.0500	0.4400			0.0611	1.0088	0.0599	1.0097	0.0580	1.0125
1996	28.0300	0.4900			0.0371	1.0039	0.0370	1.0058	0.0354	1.0083
1997	2.5800	0.9300			0.0711	0.7561	0.0701	0.6663	0.0691	0.6719
1998	34.6300	0.5800			0.0045	0.4682	0.0045	1.0100	0.0043	1.0122
1999	93.8700	0.3500			0.2107	0.5608	0.2188	0.4473	0.2177	0.4551
2000	132.3400	0.4300			0.0109	0.9634	0.0105	1.0123	0.0104	1.0139
2001	46.5700	0.5100			0.0320	1.2198	0.0321	0.5688	0.0310	0.5757
2002	190.2100	0.2600			0.1087	0.6660	0.1062	0.5768	0.1016	0.5839
2003	18.2900	0.6400								
2004	52.6000	0.4000			0.0401	0.8875	0.0396	0.6480	0.0383	0.6539
2005	106.5800	0.4600								
2006	91.3500	0.5400			0.0660	0.7513	0.0635	0.5736	0.0632	0.5805
2007	27.4800	0.6800			0.0440	0.8838	0.0436	0.6490	0.0422	0.6553
2008			94.6000	0.5800	0.2774	0.4119	0.2787	0.3208	0.2771	0.3282
2009			108.4100	0.3500	0.0926	1.0833	0.0897	0.6293	0.0861	0.6401
2010			69.9500	0.2600	0.0842	0.7442	0.0835	0.5156	0.0820	0.5228
2011			74.7700	0.2600	0.0497	1.0076	0.0511	0.7615	0.0512	0.7667
2012			176.6500	0.4200	0.0328	1.0677	0.0322	0.6537	0.0309	0.6608
2013			100.0900	0.5100	0.2257	0.5884	0.2209	0.5254	0.2235	0.5330
2014			213.3700	0.2400	0.0760	0.8985	0.0763	0.3929	0.0744	0.4006
2015			144.8000	0.3000	0.0279	0.9791	0.0285	0.4818	0.0279	0.4876
2016			124.3600	0.3700	0.0844	0.6713	0.0843	0.2961	0.0825	0.3038
2017			266.4400	0.3200	0.0944	0.6746	0.0945	0.4609	0.0921	0.4681
2018			42.1300	0.5000	0.1238	0.6438	0.1230	0.3593	0.1212	0.3670

Table 3. Cont.: Recommended indices of abundance including index name and SEDAR document number. CV is the coefficient of variation for the annual index value.

Year	NMFS-NEFSC Bottom Longline	CV	SCDNR SEAMAP LL	CV	SCDNR Red Drum Survey	CV	SCDNR Drumline Survey	CV	Coastspan Longline (All ages)	CV
1974										
1975										
1976										
1977										
1978										
1979										
1980										
1981										
1982										
1983										
1984										
1985										
1986										
1987										
1988										
1989										
1990										
1991										
1992										
1993										
1994										
1995										
1996	0.0032	1.0173			1.2274	0.6400				
1997					1.2726	0.6040				
1998	0.0315	0.4825			0.4577	0.6102				
1999					0.3944	0.8652				
2000					1.3585	0.4409				
2001	0.0131	0.5612			0.3487	1.2696				
2002					0.5890	0.7197				
2003					1.0194	0.5536				
2004	0.0310	0.4841			0.4589	0.7920				
2005					0.3098	0.9044			3.0231	0.2860
2006					1.3158	0.4324			1.5217	0.3796
2007	0.0008	1.9006	1.7214	0.3529					1.2054	0.5417
2008			0.8375	0.5103					3.4409	0.3795
2009	0.0263	0.6062	1.2200	0.3571					1.9428	0.2760
2010			0.8986	0.2888					2.0045	0.2486
2011			1.5343	0.2856					1.6024	0.2641
2012	0.1218	0.3836	1.5427	0.2560					2.6903	0.2341
2013			2.7065	0.2112			0.1655	0.2253	3.6962	0.2047
2014			1.7660	0.2006			0.2058	0.1612	1.9738	0.2960
2015	0.1485	0.3513	1.9826	0.2068			0.1741	0.1799	1.4657	0.2989
2016			0.9741	0.2685			0.1359	0.1803	1.7694	0.2462
2017			1.1241	0.2341			0.1854	0.1654	1.5851	0.2819
2018	0.3183	0.2468	1.4639	0.2194			0.2067	0.1860	1.0245	0.3064

Table 3. Cont.: Recommended indices of abundance including index name and SEDAR document number. CV is the coefficient of variation for the annual index value.

Year	Coastspan Longline (Age 0)	CV	Coastspan Gillnet Long Net (All age)	CV	Coastspan Gillnet Long Net (Age 0)	CV	Coastspan Gillnet Short Net (Age 0)	CV
1974								
1975								
1976								
1977								
1978								
1979								
1980								
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990								
1991								
1992								
1993								
1994								
1995								
1996								
1997								
1998								
1999								
2000								
2001			0.7976	0.2830	0.7001	0.3356		
2002			0.3089	0.4301	0.2226	0.6537		
2003			0.9009	0.3185	0.8146	0.3725		
2004			0.1496	1.1760	0.1451	1.3325		
2005	2.8189	0.3037	0.8355	0.4021	0.9064	0.4633		
2006	1.4128	0.4026	1.1390	0.3691	1.0225	0.3704	0.4978	0.4516
2007	1.2135	0.5519	0.4859	0.4220	0.4904	0.5854	1.4930	0.5187
2008	2.8834	0.3891	0.5520	0.4518	0.5644	0.5376	0.3010	1.1630
2009	1.8817	0.3067	1.0722	0.3632	0.7493	0.4790	0.3086	1.1235
2010	1.7531	0.2862	1.0557	0.4180	0.6152	0.5843	0.5651	0.4762
2011	1.5969	0.2827	0.7263	0.4749	0.2755	0.7552	0.6010	0.4853
2012	2.6555	0.2460	0.9271	0.7757	0.8465	0.9029	1.0683	0.2875
2013	3.4398	0.2168	3.6840	0.3590	3.8455	0.4166	0.8272	0.4261
2014	1.8919	0.3177	1.2765	0.4608	0.8915	0.5349	0.2497	0.6939
2015	0.8971	0.3923	0.7070	0.3013	0.4001	0.5242	0.5397	0.4586
2016	1.6699	0.2699	0.6067	0.5169	0.1181	0.8992	0.2959	0.5259
2017	1.6069	0.2941	1.3203	0.4210	1.3561	0.4949	0.6881	0.4061
2018	1.0313	0.3190	1.4201	0.3151	0.9674	0.4563	1.2167	0.3111

4.7 Figures

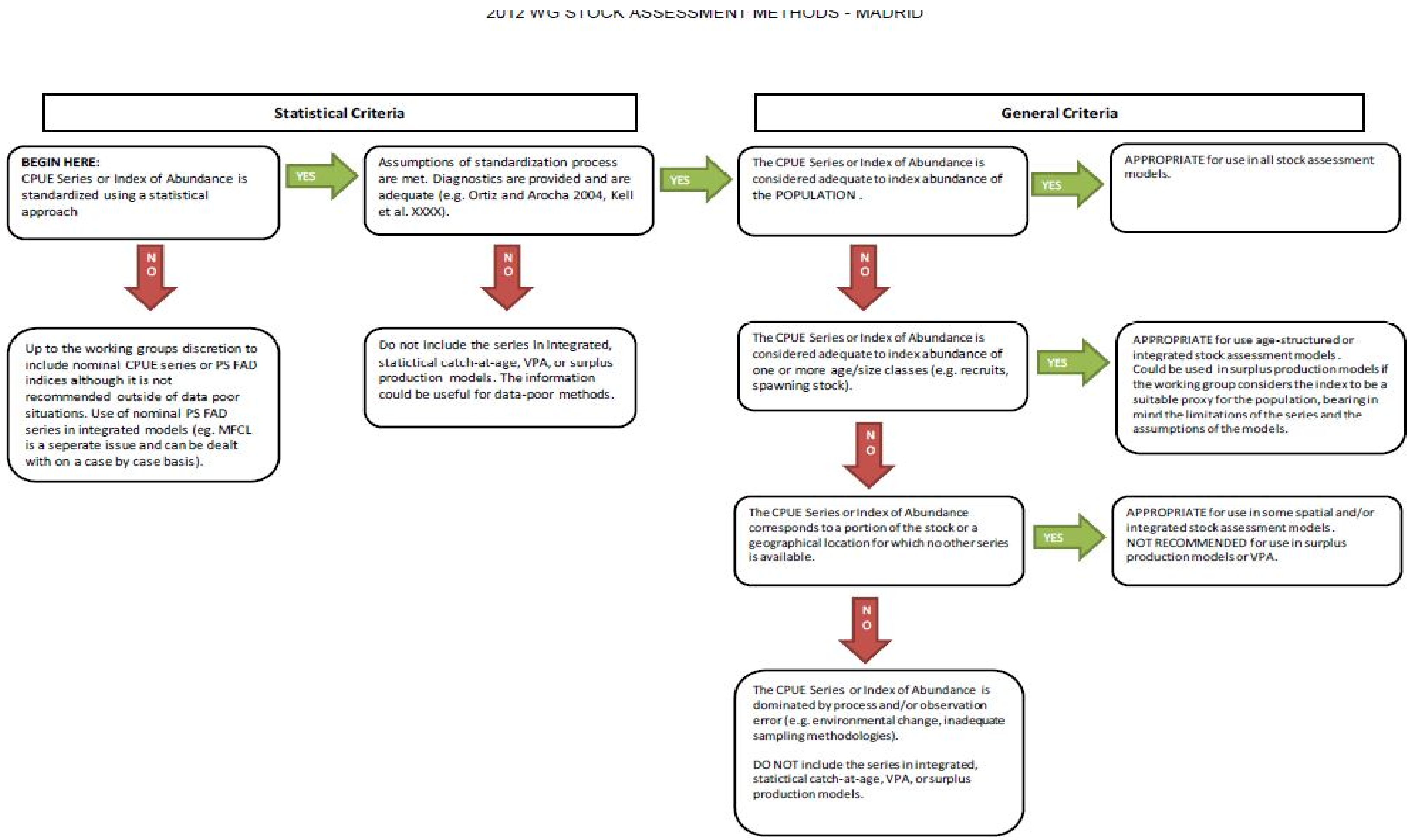


Figure 1. A flowchart to facilitate the appropriate application of CPUE series to stock assessment models used by ICCAT.

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 specific abundance indices for Atlantic blacktip shark.

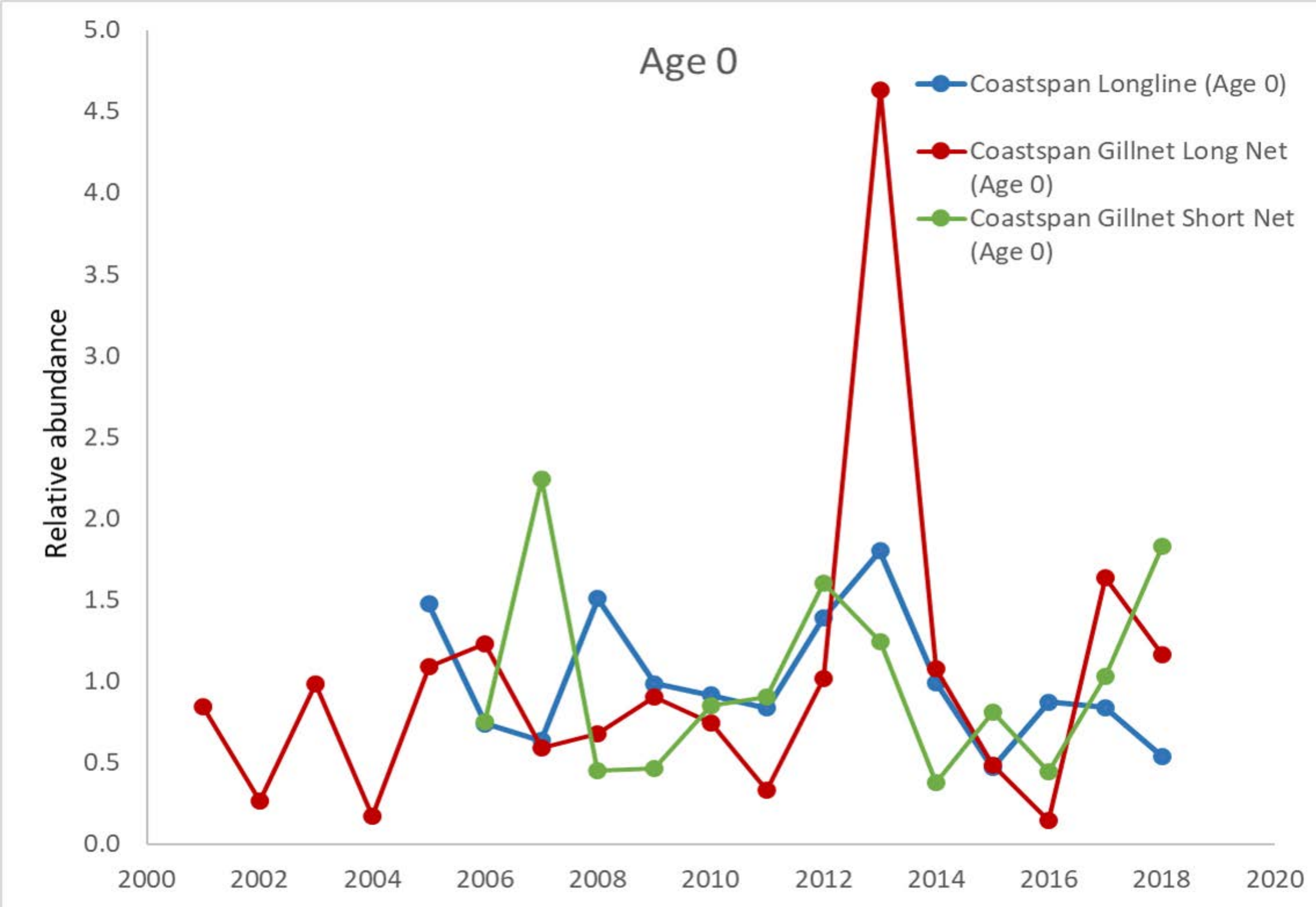


Figure 3. Plot of mean annual values of relative abundance for each time series recommended for the Atlantic Ocean stock of Age 0 blacktip shark by the Indices Working Group. For each index, values were converted to a common scale for plotting purposes by dividing mean annual values for a time series by the average of all mean annual values for that specific time series.

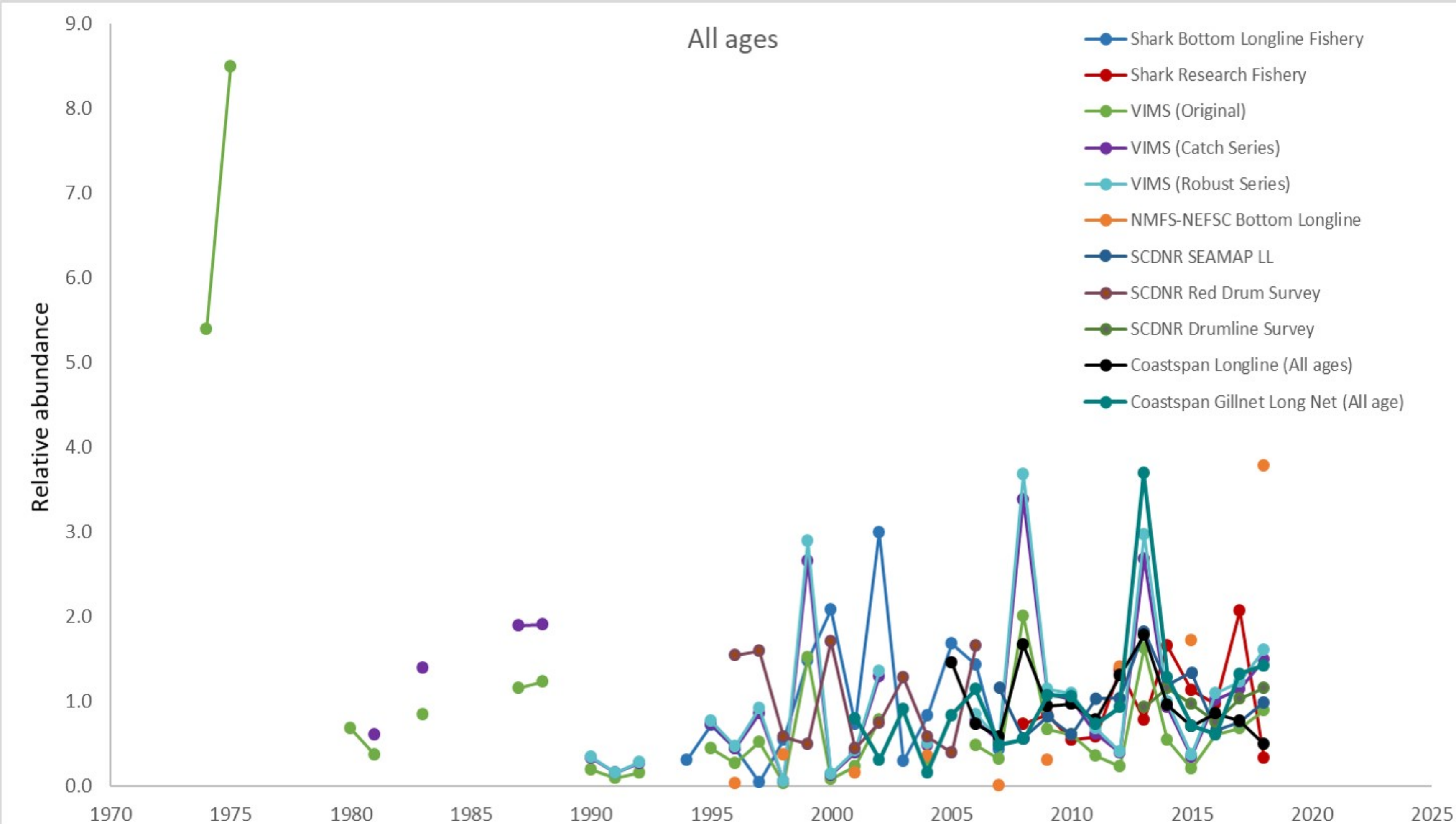


Figure 4. Plot of mean annual values of relative abundance for each time series recommended for the Atlantic Ocean stock for all ages of blacktip shark by the Indices Working Group. For each index, values were converted to a common scale for plotting purposes by dividing mean annual values for a time series by the average of all mean annual values for that specific time series

5. TOR # 7 Ecological Factors Affecting Blacktip Sharks

Assessment Term of Reference 7 requires the SEDAR group to "Identify and describe ecosystem, climate, species interactions, habitat considerations, and/or episodic events that would be reasonably expected to affect population dynamics." As highly migratory, long-lived marine fishes with protracted life histories, sharks can be impacted by a wide range of ecological factors and changes in their environments. The panel discussed specific ecological factors with the potential to affect population dynamics of Atlantic blacktip sharks and constructed the following list, not in order of priority or impact:

- Changes in blacktip shark prey and predator abundance and trophic interactions
- Temperature changes in blacktip habitat and how those affect prey/predator distribution and the sharks themselves, including the sharks' range, migration, and reproductive biology
- Habitat alterations such as beach renourishment and dredging that affect quality and availability of habitat critical to blacktip shark life stages
- Environmental contaminants from anthropogenic pollutants, currently a low risk factor for blacktip sharks but with the potential to have a greater effect on shark health and population status
- Harmful algal blooms, hypoxia, and other human-influenced ecological disruptions that impact blacktip shark habitat
- Hurricanes and other large weather events that cause disturbances in blacktip shark habitat
- Changes in patterns of discarded bycatch from trawlers in areas where previously blacktip sharks would aggregate near the boats

Ideally, an ecosystem-based management approach would take all these various factors into consideration to assure sustainability of the Atlantic blacktip shark stock. To achieve that goal, and to improve the stock assessment process for this shark, the group recommends the following research recommendations, not in rank order:

- Quantify seasonal and spatial distribution of prey for Atlantic blacktip sharks, and use stomach contents analysis to determine the relative importance of different forage fish species in the diet. This is important in the New York Bight area where blacktip sharks were not previously abundant and are now exploiting resources that have not been previously subjected to this level of exploitation. It might also be important in the southern end of their range because, although anglers state that blacktip sharks are following baitfish down the coast, the peak in baitfish abundance occurs a few months before the blacktip sharks arrive off south Florida.
- Model the effects of changing stock distribution, due to ecological factors, on the results of fixed-station, fisheries-independent surveys for stock assessment. In general such surveys assume that changes in relative abundance are a result of changing stock size, rather than shifts in range and distribution as a result of ecological change. Modeling how ecological factors affect stock distribution allows for better quantification of stock abundance as measured by fixed-station surveys.
- Conduct research on ecological changes in blacktip shark inshore nursery areas on the U.S. Atlantic coast and how those changes have affected recruitment.
- Assess the levels of environmental contaminants in blacktip sharks and how those affect the sharks' physiology and reproductive success.
- Study the response of blacktip sharks to harmful algal blooms and how those phenomena affect the status of the Atlantic stock of these sharks.

6. Appendix 1 Length Frequency

Materials and Methods

Length composition data for Atlantic blacktip sharks were available from both fishery-dependent and fishery-independent surveys from 1974-2019 (n=17, Table 1). Data were recorded by fisheries research biologists, scientific observers, and recreational fishermen (e.g., logbook data). Length data used in analyses from fishery-dependent surveys were sourced from the Marine Recreational Information Program (MRIP), Southeast Region Head Boat Survey (SRHS), South Carolina Department of Natural Resources (SCDNR) shore-based fishing logbook data, Southeast Fisheries Science Center (SEFSC) Panama City Laboratory Shark Bottom Longline Observer Program (SBLOP), SEFSC Panama City Gillnet Observer Program (GNOP), and the University of Florida longline program (i.e., bottom longline program before it was taken over by SEFSC-SBLOP). Length data from fishery-independent surveys were sourced from the Virginia Shark Monitoring and Assessment Program (VASMAP), SEFSC Mississippi Lab bottom longline, Northeast Fishery Science Center (NEFSC) longline, Southeast Area Monitoring and Assessment Program (SEAMAP) Longline from Georgia-University of North Florida, SCDNR-SEAMAP longline, SCDNR drumline, SCDNR red drum longline, Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) longline, COASTSPAN gillnet, Florida Atlantic University (FAU) drumline/longline, and SCDNR small gillnet survey.

Data on Atlantic blacktip shark size, sex, capture location, and date were recorded for each specimen. For analyses purposes, data were restricted to the western Atlantic. Fork length (FL) measurements in centimeters (cm) were used to create length compositions and data were filtered to include only true measurements (i.e., no estimated measurements). Length data were omitted from analyses if it exceeded biologically plausible measurements for this species; age-0 length is reported to be around 40 cm FL and maximum size was around 180 cm FL (S65-DW02). Data were binned into size classes of 5 cm FL increments and subset by sex. Data matrices were then created for each sex to include the proportion of animals in each size bin per year for input into Stock Synthesis. Length-frequency compositions histograms were created for males, females, and combined sexes of Atlantic blacktip shark. Age at 50% maturity was indicated by vertical bars and was designated as 123.05 cm FL for females and 115.15 cm FL for males. Each survey used in this report was analyzed separately.

Results

A total of 10,945 records of Atlantic blacktip shark specimens were considered within the scope of this study in the years of 1974-2019. Fishery-dependent surveys contributed 6,585 specimens and fishery-independent surveys contributed 4,360 specimens (Table 1). Atlantic blacktip sharks ranged in size from 40 cm FL to 180 cm FL, covering a wide range of the species' size range from young-of-the-year to adult sharks. Variability in the size distribution and numbers of recorded specimens was present among the different surveys (Table 1). Length-frequency histograms indicate a wide range of sizess for blacktip sharks captured in each survey (Figure 1).

6.1 Tables

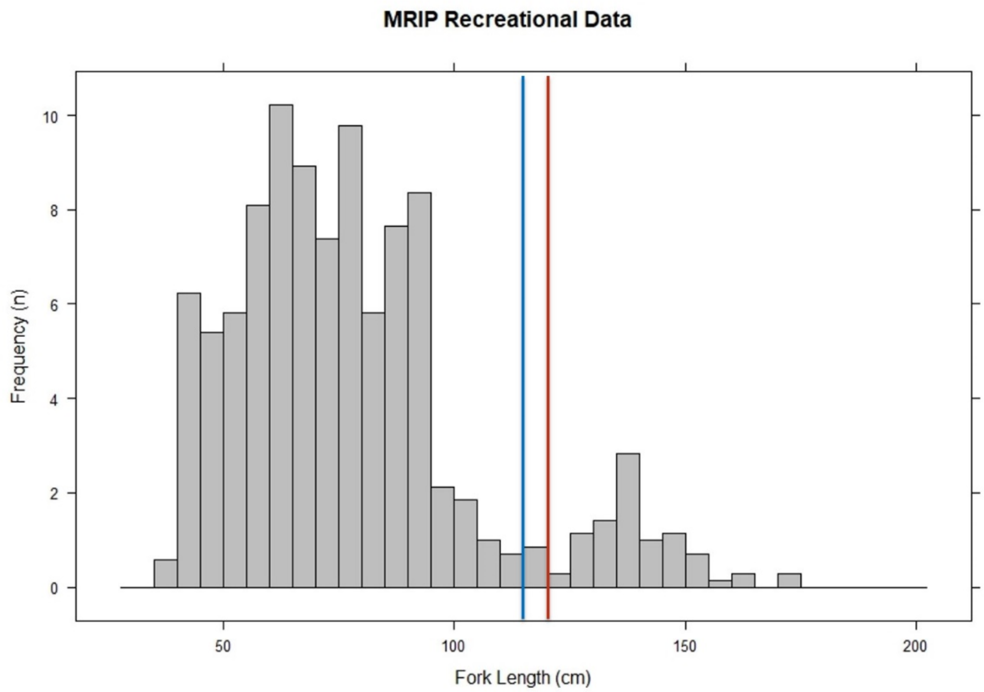
Table 1. Fishery-dependent and fishery-independent surveys that were used to create length compositions for Atlantic blacktip sharks.

Data Source	Year	Sample Size
Fishery Dependent		
Marine Recreational Information Program (MRIP)	1981-2018	781
Southeast Region Head Boat Survey (SRHS)	1989-2018	107
South Carolina Department of Natural Resources (SCDNR) Shore Fishing	2013-2018	166
Southeast Fisheries Science Center (SEFSC) Panama City Lab Shark Bottom Longline Observer Program (SBLOP)	2005-2018	3,708
Southeast Fisheries Science Center (SEFSC) Panama City Lab Gillnet Observer Program (GNOP)	1999-2018	124
University of Florida Shark Bottom Longline Observer Program[1]	1994-2005	1,699
	Total	**6, 585**
Fishery Independent		
Virginia Shark Monitoring and Assessment Program (VASMAP)	1974-2018	324
Southeast Fisheries Science Center (SEFSC) Mississippi Laboratory Bottom Longline	1996-2018	19
Northeast Fisheries Science Center (NEFSC) Bottom Longline	1996-2018	638
Southeast Area Monitoring and Assessment Program (SEAMAP) Longline (Georgia-University of North Florida)	2007-2018	218
South Carolina Department of Natural Resources (SCDNR) SEAMAP Longline	2007-2018	1,032
South Carolina Department of Natural Resources (SCDNR) Drumline	2013-2019	302
South Carolina Department of Natural Resources (SCDNR) Red Drum longline	1994-2008	301
Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Longline	1999-2019	641
Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Gillnet	1999-2019	487
Florida Atlantic University Drumline/Longline	2014-2019	123
South Carolina Department of Natural Resources (SCDNR) Small Gillnet Survey	2006-2019	275
	Total	**4, 360**

[1] From 1994-2005, the shark bottom longline observer program was administered by the Florida Museum of Natural History at the University of Florida

6.2 Figures

Figure 1. Length-frequency distributions of Atlantic blacktip sharks from fishery-dependent and fishery-independent surveys. Red vertical lines indicate 50% maturity for females (123 cm FL) and blue vertical lines indicate 50% maturity for males (115 cm FL).



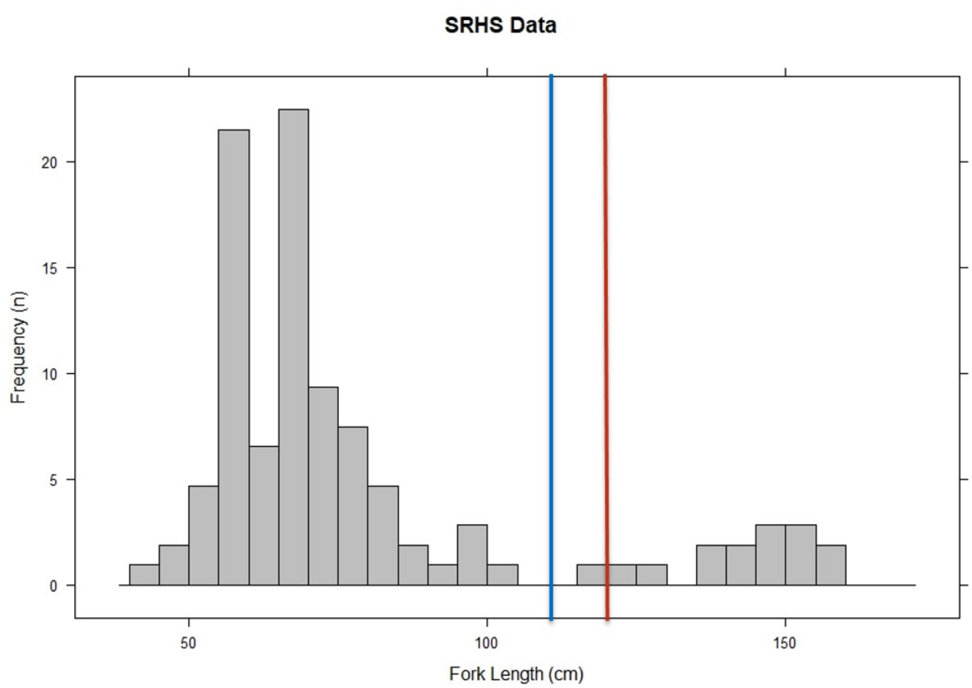
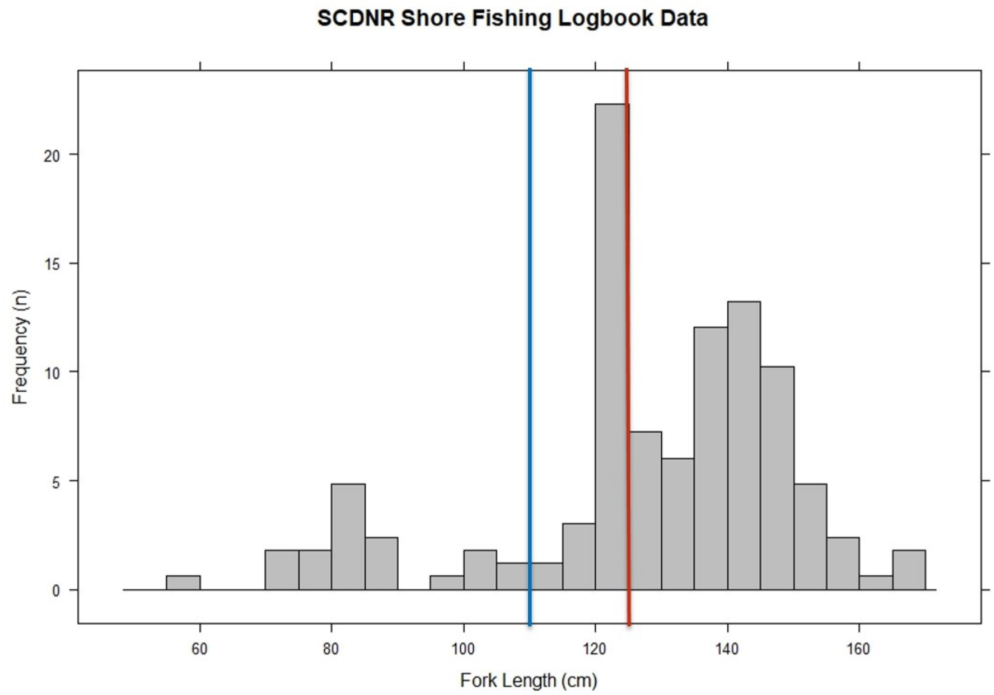
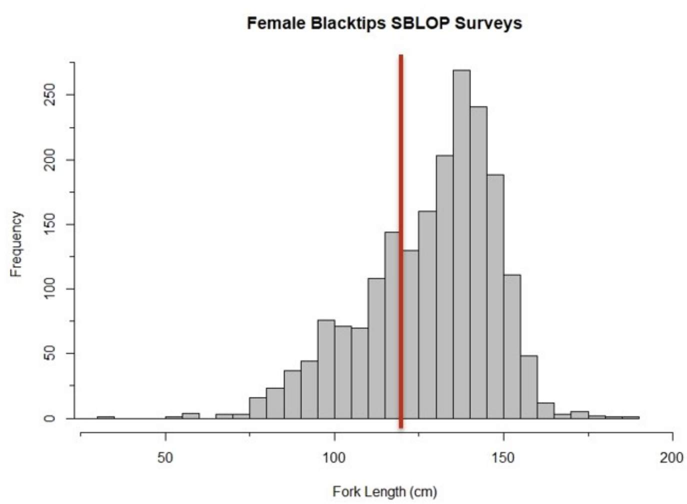


Figure 1 Continued:. Length-frequency distributions of Atlantic blacktip sharks from fishery-dependent and fishery-independent surveys. Red vertical lines indicate 50% maturity for females (123 cm FL) and blue vertical lines indicate 50% maturity for males (115 cm FL).





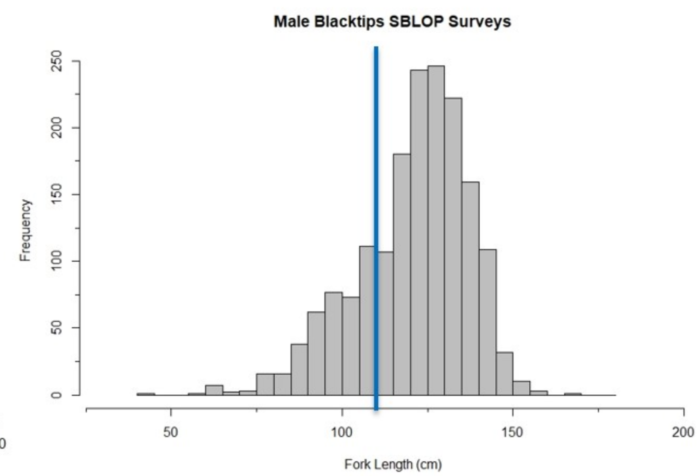


Figure 1 Continued:. Length-frequency distributions of Atlantic blacktip sharks from fishery-dependent and fishery-independent surveys. Red vertical lines indicate 50% maturity for females (123 cm FL) and blue vertical lines indicate 50% maturity for males (115 cm FL).

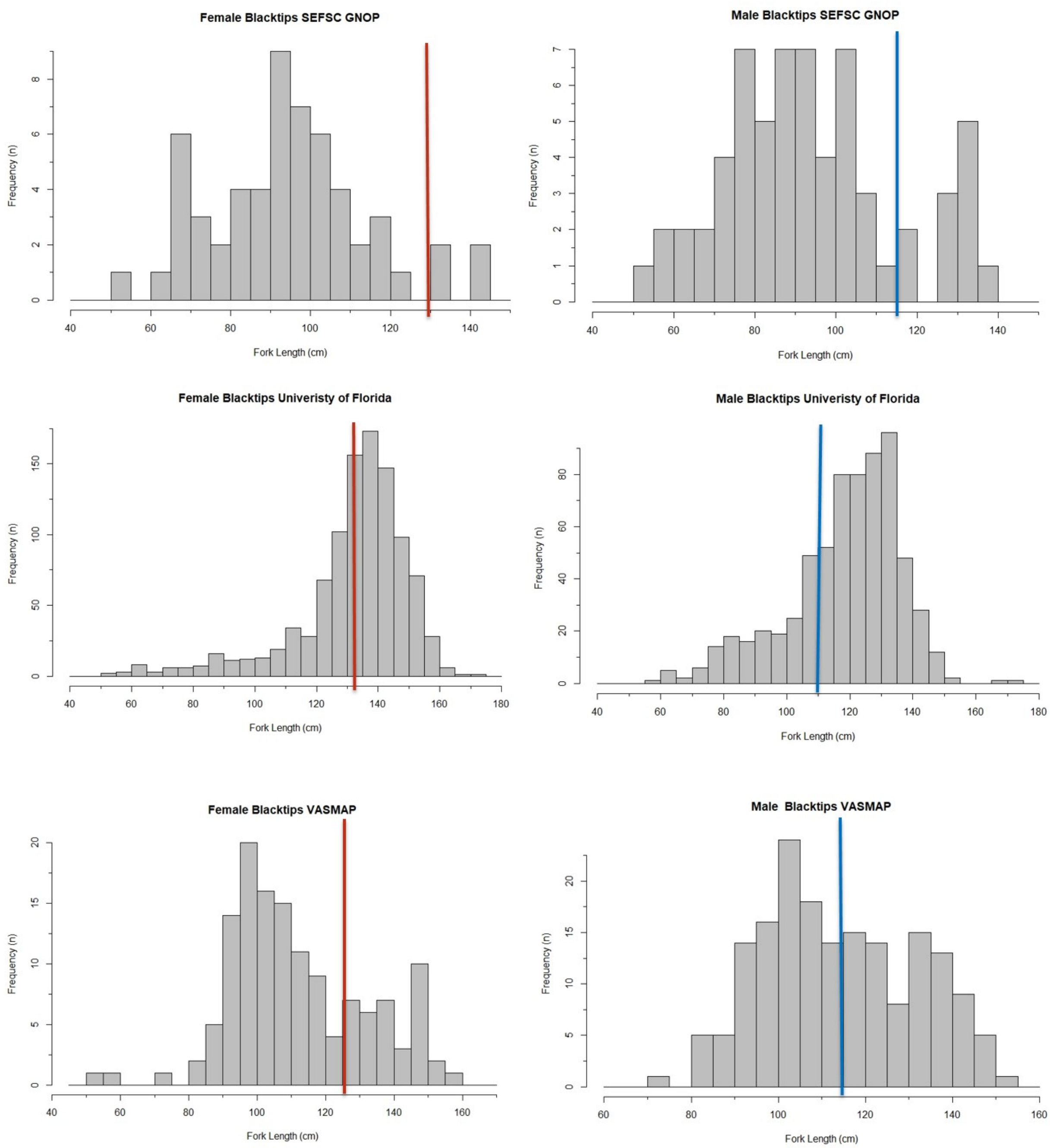


Figure 1 Continued:. Length-frequency distributions of Atlantic blacktip sharks from fishery-dependent and fishery-independent surveys. Red vertical lines indicate 50% maturity for females (123 cm FL) and blue vertical lines indicate 50% maturity for males (115 cm FL).

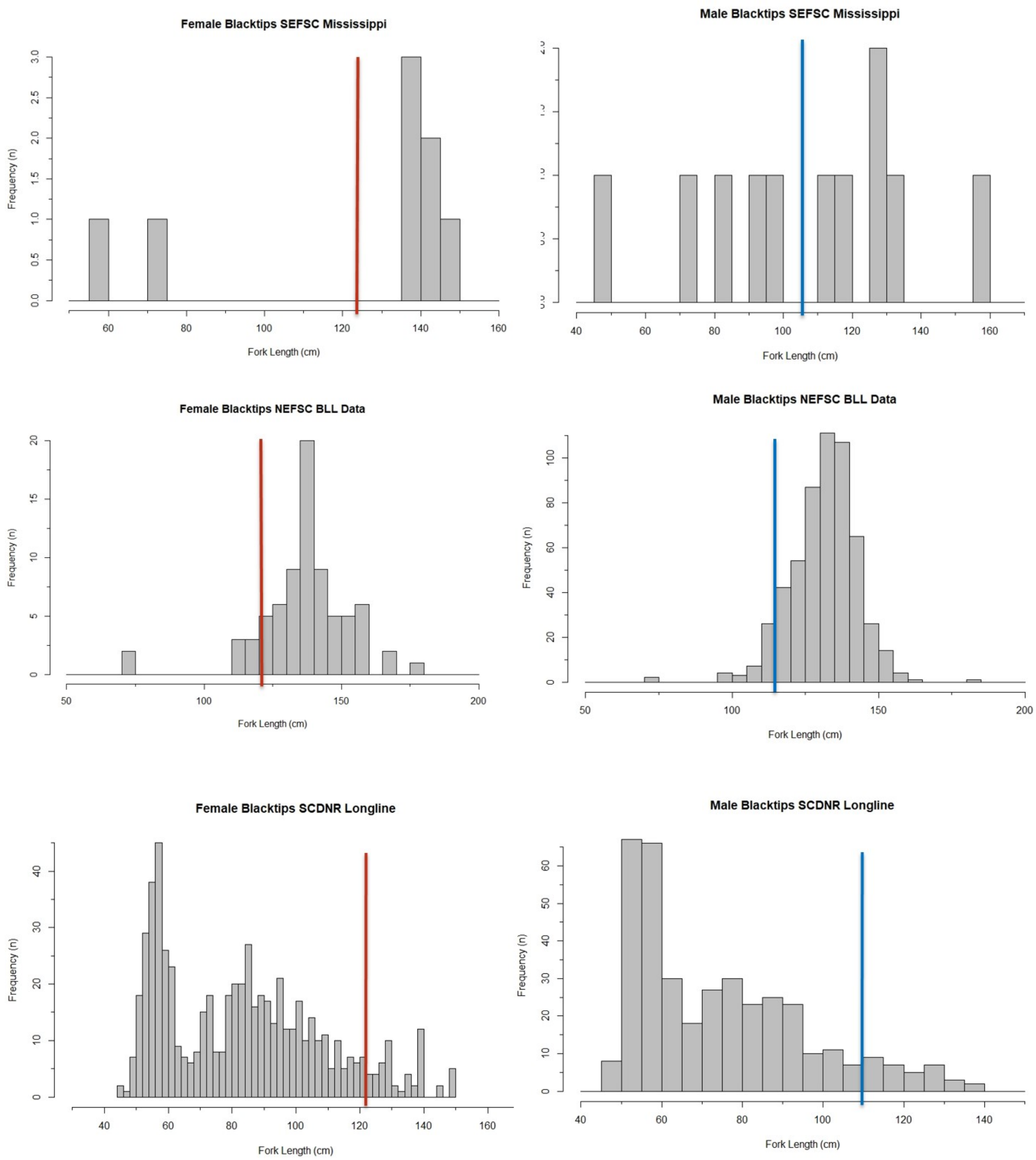


Figure 1 Continued:. Length-frequency distributions of Atlantic blacktip sharks from fishery-dependent and fishery-independent surveys. Red vertical lines indicate 50% maturity for females (123 cm FL) and blue vertical lines indicate 50% maturity for males (115 cm FL).

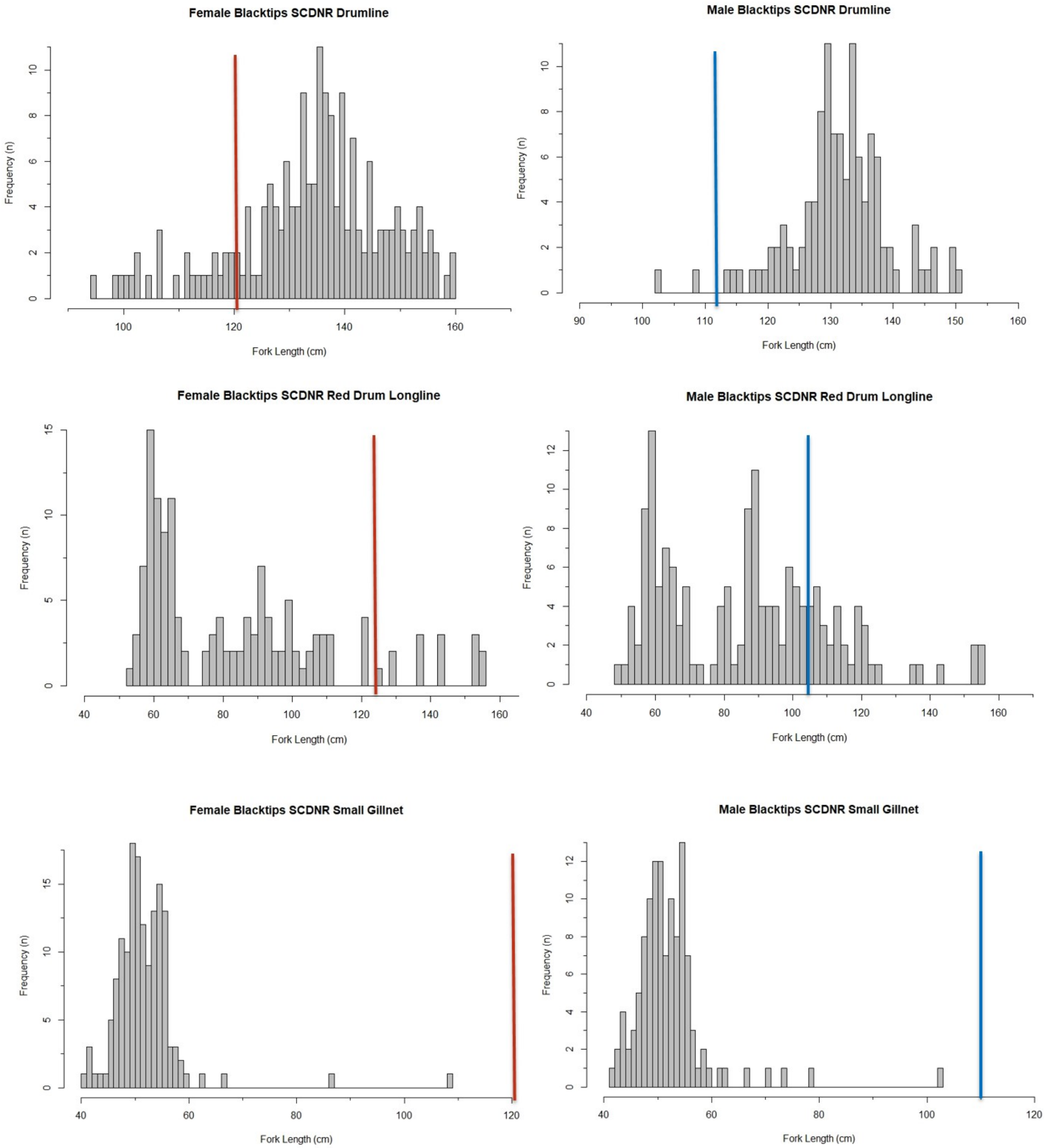
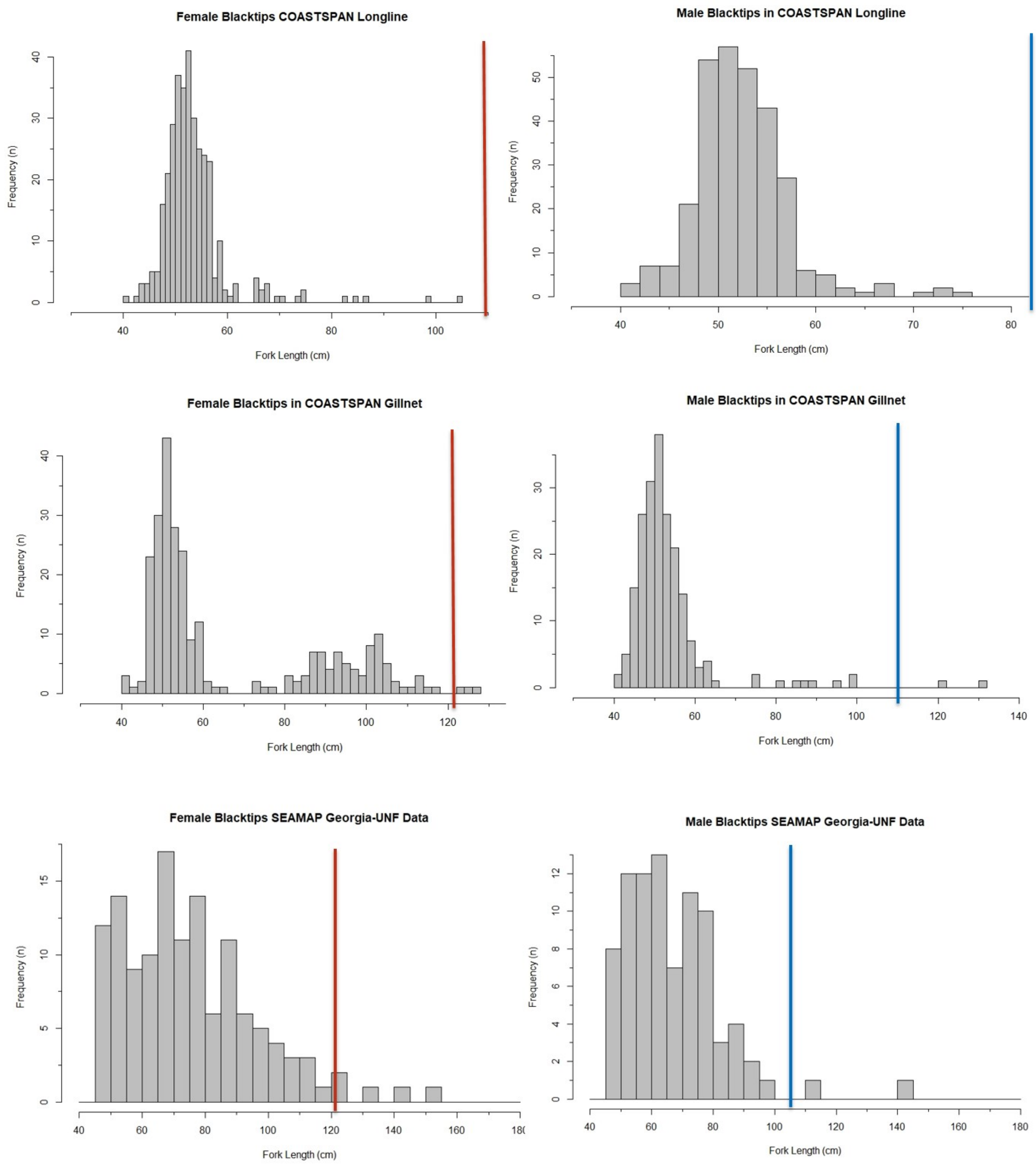


Figure 1 Continued:. Length-frequency distributions of Atlantic blacktip sharks from fishery-dependent and fishery-independent surveys. Red vertical lines indicate 50% maturity for females (123 cm FL) and blue vertical lines indicate 50% maturity for males (115 cm FL).



SEDAR

Southeast Data, Assessment, and Review

SEDAR 65

HMS Blacktip Shark

Section III: Assessment Report

October 2020

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

Table of Contents

1. **Introduction**

1.1. Workshop Time and Place

The SEDAR 65 HMS Blacktip Shark assessment process was held over a series of webinars from February 2020 – August 2020.

1.1.1. Terms of Reference

1. Review any changes in data following the Data Workshop (DW) and any analyses suggested by the DW. Summarize data as used in each assessment model. Provide justification for any deviations from DW 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. Provide 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.
4. Characterize uncertainty in the assessment and estimated values.
    a. Consider uncertainty in input data, modeling approach, and model configuration.
    b. Consider and include other sources as appropriate for this assessment.
    c. Provide appropriate measures of model performance, reliability, and 'goodness of fit'.
    d. Provide measures of uncertainty for estimated parameters
5. Provide estimates of yield and productivity.
    a. Include yield-per-recruit, spawner-per-recruit, and stock-recruitment models.
6. Provide estimates of population benchmarks or management criteria to include associated uncertainty, with available data, applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and 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. Provide declarations of 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 biological 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 stock is overfished, then utilize projections to determine:

i. Year in which F=0 results in a 70% probability of rebuilding (Year F=0p70).

ii. Target rebuilding year (Year-rebuild).

1. Year F=0p70 if Year F=0p70 ≤ 10 years, or

2. Year F=0p70 + 1 generation time if Year F=0p70 > 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 stock is undergoing overfishing, then utilize projections to determine:

i. F=Freduce (different reductions in F that should end overfishing with a 50% and 70% probability).

c. 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).

d. If data-limitations preclude classic projections (i.e. a, b, and c above), explore alternate projection models to provide management advice.

10. Provide recommendations for future research and data collection.

a. Be as specific as practicable in describing sampling design and sampling intensity.

b. Emphasize items that will improve future assessment capabilities and reliability.

c. Consider data, monitoring, and assessment needs.

11. Complete the Assessment Process (AP) Report in accordance with project schedule deadlines (Section III of the SEDAR Stock Assessment Report).

1.1.2. List of Participants

SEDAR 65 Assessment Panel Appointee	Function	Affiliation
Dean Courtney	Lead Assessment Scientist	NMFS Panama City
Enric Cortes	Assessment Support Scientist	NMFS Panama City
Xinsheng Zhang	Assessment Support Scientist	NMFS Panama City
Elizabeth Babcock	Panelist	RSMAS
Rob Latour	Panelist	VIMS
Carolyn Belcher	Panelist	GADNR
Robert Hueter	Panelist	Mote Marine Lab.
STAFF		
Kathleen Howington	Coordinator	SEDAR
Heather Balchowsky-Baertlein	Observer	NMFS/HMS
Karyl Brewster-Geisz	HMS: Management	NMFS/HMS
Clifford Hutt	Observer	NMFS/HMS
Other		
Rusty Hudson	Observer	DSF
Bryan Frazier	Observer	SCDNR
Bryan Keller	Observer	NMFS/IA
Cami McCandless	Observer	NMFS/NEFSC
Chip Collier	Observer	SAFMC
Cassidy Peterson	Observer	NMFS/SEFSC
Delisse Ortiz	Observer	NMFS/HMS
Guy Eroh	Observer	NMFS
Guy Dubeck	Observer	NMFS/HMS
Jim Gelsleichter	Observer	UNF
John Carlson	Observer	NMFS Panama City
Kaitlyn O'Brien	Observer	VIMS

1.1.4. List of Assessment Process Working and Reference Papers

Working Documents prepared for SEDAR 65 Assessment Workshop			
Document #	**Title**	**Author**	**Date Received**
SEDAR65-AW01	Hierarchical analysis of U.S Atlantic blacktip shark recruitment indices.	Cami McCandless	1/9/2020
SEDAR65-AW02	Estimates of vital rates and population dynamics parameters of interest of blacktip sharks (*Carcharhinus limbatus*) in the Atlantic Ocean	Enric Cortés	3/6/2020
SEDAR65-AW03	Reconciling indices of relative abundance of the Atlantic blacktip shark (Carcharhinus limbatus)	Robert Latour	3/6/2020
SEDAR65-AW04	Hierarchical cluster analysis and cross-correlations of selected CPUE indices for the SEDAR 65 assessment	Dean Courtney	3/6/2020
SEDAR65-AW05	Review of available length composition data submitted for use in the SEDAR 65 Atlantic *Carcharhinus limbatus* stock assessment	Andrea Kroetz and Dean Courtney	3/12/2020
SEDAR65-AW06	Improving discard time series for use in assessment sensitivity analyses	Camilla McCandless, John Carlson, Xinsheng Zhang Enric Cortés	3/25/2020

Reference Documents			
Document #	**Title**	**Author**	**Date Received**
SEDAR65-RD05	Community interactions and density dependence in the southeast United States coastal shark complex	Peterson et.al.	10/30/19
SEDAR65-RD06	Discard mortality of Carcharhinid sharks in the Florida commercial shark fishery	Whitney	11/4/19
SEDAR65-RD07	Survey of the Florida recreational shark fishery utilizing shark tournament and selected longline data	Hueter	11/1/19
SEDAR65 – RD08	Utility of citizen science data: A case study in land-based shark fishing	Kesley J. Gibson, Matthew K. Streich, Tara S. Topping, Gregory W. Stunz	12/20/19
SEDAR 65-RD09	Stock Synthesis model runs conducted for North Atlantic shortfin mako shark	Dean Courtney, Enric Cortés, and Xinsheng Zhang	5/7/2020

Reference Documents			
Document #	**Title**	**Author**	**Date Received**
SEDAR 65 – RD10	Stock Synthesis model sensitivity to data weighting: an example from preliminary model runs previously conducted for North Atlantic blue shark	Dean Courtney, Enric Cortés, Xinsheng Zhang, and Felipe Carvalho	5/7/2020
SEDAR 65-RD11	Capture stress and post-release mortality of blacktip sharks in recreational charter fisheries of the Gulf of Mexico	John A. Mohan, Elizabeth R. Jones, Jill M. Hendon, Brett Falterman, Kevin M. Boswell, Eric R. Hoffmayer and R.J. David Wells	5/20/2020
SEDAR65-RD12	Proposal of implementation of low-fecundity spawner-recruitment relationship for shortfin mako in the North Atlantic.	Mikihiko Kai and Felipe Carvalho	6/24/2020
SEDAR65-RD13	Examples of Stock Synthesis diagnostic methods and results implemented for previously completed North Atlantic shortfin mako Stock Synthesis model runs.	Courtney, D., Carvalho, F., Winker, H., and L. Kell.	6/24/2020
SEDAR65-RD14	Example of a Stock Synthesis projection approach at alternative fixed total allowable catch (TAC) limits implemented for three previously completed North Atlantic shortfin mako Stock Synthesis model runs	Courtney, D. and J. Rice	6/24/2020

1.2. Statements Addressing each Term of Reference

Note: Original ToRs are in normal font. Statements addressing ToRs are in italics.

1.2.1. Statements Addressing Term of Reference 1.

Review any changes in data following the Data Workshop (DW) and any analyses suggested by the DW. Summarize data as used in each assessment model. Provide justification for any deviations from DW recommendations.

The SEDAR 65 Assessment Process Schedule of Events (AP timeline) was modified based on consensus comments and recommendations of the AP Panel in order to accommodate the DW decision for the AP Analytical Team to continue analysis of commercial dead discard and commercial post-release live discard mortality during the AP. The AP Panel adopted the following decisions during the Pre-assessment Webinar.

1) *Modify the Assessment Webinar I AP Schedule of Events to include the evaluation of uncertainty in the catch time series as follows. During Assessment Webinar I (week of March 23, 2020), the AP Analytical Team will analyze commercial dead discard and commercial post-release live discard mortality in an AP working paper [Due March 6, 2020] and present results to the AP Panel for their review. In preparation for Assessment Webinar III, the AP Lead Analyst will develop a base model without commercial bycatch discard estimate(s) (dead discards + live discards that subsequently die from post-release mortality), and present preliminary results to the AP Panel for their review. In contrast, the previous Assessment Webinar I Schedule of Events (week of March 23) included the following: Introduce and discuss uncertainty analyses (alternative states of nature) and develop reference case model run(s) which are robust to the major uncertainties identified.*
2) *Modify the Assessment Webinar II AP Schedule of Events to include the evaluation of uncertainty in the catch time series as follows. During Assessment Webinar II (week of April 13, 2020), the AP Analytical Team will develop alternative reference case catch streams (as alternate states of nature) which are robust to the major uncertainties identified in commercial bycatch discard estimation, recreational catch and live discard*

estimation, and post-release live-discard mortality estimation, and present preliminary results to the AP Group for their review. In contrast, the previous Assessment Webinar II Schedule of Events (week of April 13) included the following: Finalize uncertainty analyses and reference case model run(s).

3) *Move the following tasks to the Assessment Webinar III AP Schedule of Events. The AP Lead Analyst will adapt the base case model to develop reference case model run(s) (as alternate states of nature) which are robust to the major uncertainties identified in commercial bycatch discard estimation (and post-release mortality), and present preliminary results to the AP Panel for their review. In contrast, the previous Assessment Webinar III Schedule of Events (week of May 4) included the following: Introduce and discuss sensitivity analyses (model diagnostics) and projections.*
4) *Move the following tasks to the Assessment Webinar IV AP Schedule of Events. The AP Lead Analyst will finalize reference case model run(s) which are robust to the major uncertainties identified in commercial bycatch discard estimation (and post-release mortality), and present results to the AP Panel for their review. The AP Lead Analyst will introduce sensitivity analyses and model diagnostic methodology and preliminary results for the reference case model run(s). In contrast, the previous Assessment Webinar IV Schedule of Events (week of June 1) included the following: Finalize sensitivity analyses and projections.*
5) *Move the following tasks to the Assessment Webinar V AP Schedule of Events. The AP Lead Analyst will finalize any changes to the model indicated by the sensitivity analyses and diagnostics and will present results of the finalized reference case model run(s) to the AP Group for their review. The AP Lead Analyst will introduce projection methodology to the AP Group for their review. In contrast, the previous Assessment Webinar V Schedule of Events (week of June 22) included the following: Review and finalize any changes to model and projections.*
6) *Add an additional Assessment Webinar to the AP Schedule of Events to include the following tasks. The AP Lead Analyst will present projection results for finalized reference case model run(s) to the AP Group for their review and finalize any changes to the projections.*

The SEDAR 65 Assessment Process Schedule of Events (AP timeline) was also modified based on consensus comments and recommendations of the AP Panel in order to accommodate the development of sensitivity analyses robust to uncertainty in indices of relative abundance. The AP Panel adopted the following decisions during the Pre-assessment Webinar.

1) *Move the following tasks to the Assessment Webinar II. The AP Lead Analyst will adapt the base case model to develop reference case model run(s) (as alternate states of nature) which are robust to the major uncertainties identified in the indices of relative abundance, and present preliminary results to the AP Group for their review. In contrast, the previous Assessment Webinar I Schedule of Events (week of April 13) included the following. Finalize uncertainty analyses and reference case model run(s).*
2) *Move the following tasks to the Assessment Webinar III (week of May 4, 2020). The AP Lead Analyst will finalize reference case model run(s) which are robust to the indices of abundance and present results to the AP Group for their review. The AP Lead Analyst will introduce sensitivity analyses and model diagnostic methodology and preliminary results for the reference case model run(s). In contrast, the previous Assessment Webinar III Schedule of Events (week of May 4) included the following: Introduce and discuss sensitivity analyses (model diagnostics) and projections.*

1.2.2. Statements Addressing Term of Reference 2.

Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations for each model considered.

1) *The AP Panel agreed that Stock Synthesis was the most complete modelling platform for the available data, and that it was not necessary to evaluate other stock assessment modelling platforms.*

1.2.3. Statements Addressing Term of Reference 3.

Provide 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; and b) Include appropriate measures of precision for parameter estimates.

Stock population parameter estimates are provided in Section 3.4. Parameter estimates and their associated measures of asymptotic uncertainty are provided in Section 3.4.1.4. Selectivity methods are provided in Section 3.3.1.6 and selectivity results are reported in Section 3.4.1.5. Predicted log recruitment deviations and predicted age-0 recruits obtained from the stock-recruitment relationship are provided in Section 3.4.1.6. Estimates of annual fishing mortality rates are provided in Section 3.4.2. Estimates of stock biomass, total and spawning stock fecundity (a proxy for female spawning biomass), are provided in Section 3.4.3.

1.2.4. Statements Addressing Term of Reference 4.

Characterize uncertainty in the assessment and estimated values: a) Consider uncertainty in input data, modeling approach, and model configuration; b) Consider and include other sources as appropriate for this assessment; c) Provide appropriate measures of model performance, reliability, and 'goodness of fit'; and d) Provide measures of uncertainty for estimated parameters.

Input data uncertainty tuning methods and results (data weighting) are provided in Section 3.3.1.7. Recruitment deviation variability and the associated recruitment deviation bias adjustment ramp are provided in Section 3.3.1.8. Measures of overall model fit are reported in Section 3.4.1. Model convergence and diagnostics are provided in Section 3.4.1.1. Model fits to abundance indices and the associated catchability estimates are provided in Section 3.4.1.2. Model fits to length composition data are provided in Section 3.4.1.3. Robustness of model results to uncertainty in the input data, the modeling approach, and the model configuration are evaluated with sensitivity analysis in Section 3.4.4. Due to time constraints, only one sensitivity analysis was completed in time for review by the AP panel (logistic selectivity). Results of the *logistic sensitivity analysis are compared to results of the base model configuration in Section 3.4.4.1.*

1.2.5. Statements Addressing Terms of Reference 5.

Provide estimates of yield and productivity: 5.a) Include yield-per-recruit, spawner-per-recruit, and stock-recruitment models.

Stock recruit productivity (Section 3.3.1.3) and natural mortality (Section 3.3.1.5) are input as fixed parameters to take advantage of the biological information available (as described in Section 2.3 above).

1.2.6. Statements Addressing Terms of Reference 6.

Provide estimates of population benchmarks or management criteria to include associated uncertainty, with available data, applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards: a) Evaluate existing or proposed management criteria as specified in the management summary; and b) Recommend and define proxy values when necessary, and provide appropriate justification.

Estimates of benchmark and biological reference points (MSY, MSST, F_{MSY}, SSF_{MSY}, SSF/SSF_{MSY}, F/F_{MSY}) are provided in Section 3.4.5.

1.2.7. Statements Addressing Terms of Reference 7.

Provide declarations of stock status relative to management benchmarks or alternative data poor approaches if necessary.

Stock status based on the status determination criteria is provided in Section 3.4.5.

1.2.8. Statements Addressing Terms 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 biological reference point estimates and population metrics (e.g., biomass and exploitation) used to evaluate stock status.

Time series trajectories of the two stock status metrics (SSF/SSFMSY, F/FMSY) are provided with approximate 95% asymptotic confidence intervals in Section 3.4.5 and associated figures.

Markov Chain Monte Carlo (MCMC) was proposed during the AP for use to obtain MCMC credibility intervals for some estimated and derived parameters. However, MCMC credibility intervals are not available for this report because of time constraints resulting from the 2019 Covid-19 crisis including a lack of IT resources necessary to perform MCMC analyses while on mandatory telework.

1.2.9. Statements Addressing Terms of Reference 9.

Project future stock conditions and develop rebuilding schedules, if warranted. Provide the estimated generation time for the stock.

Projections for the Stock Synthesis base model configuration are provided separately as a Review Workshop document. The projection methods follow those from a previous Atlantic HMS sandbar shark update assessment conducted in Stock Synthesis.

Markov Chain Monte Carlo, MCMC, projections were proposed during the AP. However, MCMC projections are not available for this report because of time constraints resulting from the 2019 Covid-19 crisis including a lack of IT resources necessary to perform MCMC analyses while on mandatory telework.

1.2.10. Statements Addressing Terms of Reference 10.

Provide recommendations for future research and data collection.

Recommendations for future research and data collection are provided in Section 3.4.8.

1.2.11. Statements Addressing Terms of Reference 11.

Complete the Assessment Process (AP) Report in accordance with project schedule deadlines.
The completed AP Report is provided as Section III of this SEDAR 65 Stock Assessment Report.

1.3. Additional Panel Comments

The AP Panel adopted the following decisions regarding commercial landings (Section 2.1.1) during the Pre-assessment Webinar and assessment Webinar I.

1) *Input commercial landings in the assessment model in their native format (weight).*
2) *Convert commercial landings from pounds dressed weight (lb. dw) to kilograms whole weight using the conversion ratio for dressed weight (dw) to whole weight (ww) of ww = 1.39*dw for use in the assessment model.*
3) *Aggregate **c**ommercial catch data into fleets for use in Stock Synthesis based on a review of the available length composition data.*

The AP Panel adopted the following decisions regarding recreational catch (section 2.1.2) during the Pre-assessment Webinar and Assessment Webinar I.

1) *Input recreational catch and discards in the assessment model in their native format (numbers).*
2) *Aggregate recreational catch and discard time series into "fleets" for input in the stock assessment model based on a review of the available length composition data.*

The AP Panel adopted the following decisions regarding commercial discards (Section 2.1.3) during the Pre-assessment Webinar and Assessment Webinar I.

1) *The AP Analytical Team will implement the DW recommendations for continued analyses of commercial dead discard and commercial live discard mortality, present results in an AP working paper, and present results to the AP Group for their review during Assessment Webinar I.*
2) *Input commercial discards in the stock assessment model in their native format (numbers).*
3) *Aggregate commercial discard time series into "fleets" for input in the stock assessment model sensitivity analyses based on a review of the available length composition data.*

   F5 (Com-LL Discard) = Bottom longlines,
   F6 (Com-GN Discard) = Gillnets.

4) *Use multi-year block averaging of the discard ratios to create discard estimates for commercial gillnet and bottom longline fisheries (McCandless 2020, their Table 1) for use in Stock Synthesis model sensitivity analyses.*

The AP Panel adopted the following decisions regarding commercial Low Catch and High Catch scenarios (Sections 2.1.4 and 3.2.4) during Assessment Webinars II and V.

1) *Evaluate the low and high catch scenarios presented during Assessment Webinars II and V as sensitivity analyses.*

The AP Panel adopted the following decisions regarding indices of abundance (Section 2.2.1) during the Pre-assessment Webinar.

1) *Include only the VIMS robust series (1990 – 2018) in the base model. Evaluate the remaining series within sensitivity analyses, if time permits.*
2) *Include the COASTSPAN Longline series All-ages (age-0 and juveniles combined) in the base model as an index of relative abundance. Evaluate the age-0 series as a hierarchical recruitment index in sensitivity analyses. Do not include both the age-0 series and the all-ages series (age-0 and juveniles combined) in a model at the same time, because they are not independent.*

3) *Include the COASTSPAN long gillnet and short gillnet series All-ages (age-0 and juveniles combined) in the base model as indices of relative abundance. Evaluate the age-0 series as a hierarchical recruitment index in sensitivity analyses, as discussed below. Do not include both the age-0 series and the all-ages series (age-0 and juveniles combined) in a model at the same time, because they are not independent.*

The AP Panel adopted the following decisions regarding sensitivity analyses to alternative index of abundance groupings (Section 2.2.2) during the Pre-assessment Webinar and Assessment Webinar I.

1) *Develop combined indices of abundance with Bayesian hierarchical models and with DFA (separately for age-0 and for all ages) in AP working papers. Review combined indices of abundance during Assessment Webinar I.*
2) *Evaluate the combined age-0 series as recruitment indices in sensitivity analyses. Do not include the combined age-0 series in a model with the individual age-0 series at the same time.*
3) *Bayesian hierarchical models and DFA models produced similar combined index results. Include only DFA combined indices in Stock Synthesis model sensitivity analyses due to time constraints*
4) *Include the DFA age-0 combined index in Stock Synthesis model sensitivity analyses.*
5) *Include the DFA all-ages combined index in Stock Synthesis model sensitivity analyses.*
6) *Include hierarchical cluster analysis and cross-correlations proposed groupings in Stock Synthesis model sensitivity analyses.*

The AP Panel adopted the following decisions regarding sensitivity analyses to alternative index of abundance groupings (Section 3.2.6) during Assessment Webinar V.

1) *Preliminary model fits to the DFA age-0 index (presented during Assessment Webinar V) resulted in a good fit to the index, but the model failed to converge within reasonable parameter bounds. Preliminary model fits to the DFA all-age index (presented during Assessment Webinar V) resulted in a poor fit to the index and also included the same*

length data within multiple fleets. Consequently, a recommendation was made in coordination with the AP Panel during Assessment Webinar V to exclude DFA from further sensitivity analyses within this assessment.

2) *A pragmatic decision was made in coordination with the AP Panel during Assessment Webinar V to conduct a single abundance index sensitivity analysis that removed the two relative abundance indices S4 (NEFSC-BLL) and S7 (SCDNR-DL), which had a relatively poor fit in preliminary runs of the Stock Synthesis reference case model (as described in the stock assessment results Section 3.4.1.2 below).*

The AP Panel adopted the following decisions regarding life history inputs (Sections 2.3 and 3.2.7) during the Pre-assessment Webinar and Assessment Webinar I.

1) *The AP Panel agreed that stock recruit steepness and natural mortality for use in the stock assessment model will be based on demographic analyses developed from the life history data presented during the DW as summarized in the DW report. The demographic analyses will be provided in an AP working paper, and presented to the combined DW Panel and AP Panel for their review during Assessment Webinar I.*
2) *The combined DW and AP Panels discussed the need to look at Stock Synthesis model sensitivity to different scenarios for steepness but noted that the mean steepness value of 0.4 obtained from the deterministic methods is justified for the reference case.*
3) *The combined DW and AP Panels discussed that the lower and upper values of the range of steepness obtained with the deterministic methods (0.32 and 0.52) are empirically justifiable but that there is still a need to double check the credibility of the different scenarios after implementation within a Stock Synthesis population dynamics model sensitivity analysis.*

The AP Panel adopted the following decisions regarding length composition (Section 2.4) during the Pre-assessment Webinar and assessment Webinar I.

1) *Evaluate stock assessment model sensitivity to alternative length based selectivity for catch and discards, based on the available length compositions.*

2) *Evaluate stock assessment model sensitivity to alternative measures of length frequency sample size for input in the stock assessment model such as number of unique sets/trips/hauls/tows etc. with a length measurement in addition to the total number of lengths measured.*
3) *Develop sensitivity analyses of commercial bottom longline length composition to the relatively smaller length composition observed in the size composition of discarded versus kept sharks.*
4) *Evaluate the large length composition data set of unknown measurement type (n = 1,353) available for commercial gillnet catch.*
5) *Develop sensitivity analyses of recreational length composition to the significantly smaller mean length observed in the MRIP and SRHS survey inshore area and shore-based fishing mode, e.g., as described above.*

The AP Panel adopted the following decisions regarding the stock assessment modelling platform (Section 3) during the Pre-assessment Webinar and Assessment Webinar I.

1) *An integrated modeling approach, Stock Synthesis, will be implemented to utilize the available data, which include catch, CPUE, length composition, and life history.*

The AP Panel adopted the following decisions regarding selectivity (Section 3.3.1.6) during the Pre-assessment Webinar and Assessment Webinar II.

1) *Fit an asymptotic selectivity curve to commercial catch length composition obtained from the BLLOP (both UF and SEFSC). E.g., using the double normal selectivity function in Stock Synthesis, fix initial selectivity (the smallest length bin) equal to zero, fix final selectivity (the largest length bin) equal to one, and estimate the peak and ascending width.*

2) *Allow for the possibility of dome-shaped selectivity for commercial catch length composition obtained from the GNOP. E.g., using the double normal selectivity function in Stock Synthesis, fix (or estimate) initial selectivity slightly larger than zero, estimate the peak, ascending width, descending width, and final selectivity.*

3) *Allow for the possibility of dome-shaped selectivity for recreational catch length composition obtained from MRIP and SRHS. E.g., using the double normal selectivity function in Stock Synthesis, fix (or estimate) initial and final selectivity slightly above zero, and estimate the peak, ascending width, and descending width and final selectivity.*

4) *Fit an asymptotic selectivity curve to recreational catch length composition obtained for SCDNR Shore sensitivity analysis (if included in a sensitivity analysis). E.g., using the double normal selectivity function in Stock Synthesis, fix (or estimate) initial selectivity slightly above zero, fix final selectivity equal one, and estimate the peak and ascending width.*

5) *Fit an asymptotic selectivity curve for survey length composition obtained from NEFSC BLL and SCDNR DL. E.g., as described above.*

6) *Allow for the possibility of dome-shaped selectivity for survey length composition obtained from VIMS BLL, SEAMAP BLL, SCDNR-RD BLL, COAST BLL (All-age and Age-0), COAST GNL (All-age and Age-0), and COAST GNS (Age-0). E.g., as described above.*

7) *Calculate preliminary selectivity curve for the DFA combined indices (both All-ages and Age-0) as a weighted average of selectivity obtained for each survey, with weights equal to the factor loadings obtained from the DFA analysis.*

8) *Calculate preliminary selectivity curve for the hierarchical Age-0 combined index as average of selectivity obtained each survey*

2. **Data Review and Update**

2.1. Catches

2.1.1. Commercial Landings

Commercial landings of blacktip sharks in the U.S. Atlantic were obtained from the DW for the period 1983 – 2018 in weight (pounds dressed weight; lb. dw; **Table 2.1**). Commercial landings of blacktip sharks in the U.S. Atlantic were converted to kilograms whole weight (kg ww) using a conversion ratio for dressed weight (dw) to whole weight (ww) of ww = 1.39*dw (**Table 2.2**). The commercial landings time series (**Table 2.2**) were kept in their native format (weight), converted to units of metric tons (1 mt = 1,000 kg), and aggregated into three fleets (F1 – F3) for use in the stock assessment model:

F1 (Com-LL Kept) = Bottom longlines;
F2 (Com-GN Kept) = Gillnets; and
F3 (Com-Other Kept) = Other gears + Unreported commercial catches.

The total proportions of landings in weight for bottom longline, gillnets, and other gears were 24%, 19%, and 4%, respectively (**Tables 2.1** and **2.2)**.

2.1.2. Recreational Catch

Recreational catches of blacktip sharks in the U.S. Atlantic were obtained from the DW for the period 1981 – 2018 in numbers (**Table 2.3**). The smoothed annual recreational catch estimates of blacktip sharks in the Atlantic 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; B2-Live). The data were smoothed as described in DW recommendations and decisions regarding blacktip shark recreational catch estimation as summarized in the DW report.

Annual recreational type B2 catch estimates of blacktip sharks in the Atlantic were multiplied by an overall post-release mortality rate of 18.5% for hook and line recreational fisheries to obtain the number of fish released alive, reported by the fisher, that were estimated to have died (B2-Dead; **Table 2.3**). The post-release mortality rate was obtained from the DW recommendations and decisions regarding blacktip shark recreational catch post release mortality estimation as summarized in the DW report.

	Estimate	Lower 95% CI	Upper 95% CI
Recreational	18.5%	10.8%	28.7%

The recreational catch time series (**Table 2.3**) were kept in their native format (numbers), converted to units of thousands, and aggregated into one fleet (F4) for use in the stock assessment model:

F4 (Recreational) = Recreational (A+B1) + Recreational (B2-dead).

The total proportions of landings in numbers for types A + B1 recreational catch and type B2-dead recreational catch were 31% and 53%, respectively (**Table 2.3**).

2.1.3. Commercial Discards

Commercial discards were not included in the reference case model because of uncertainty in bycatch estimation, as described below. Commercial discards were included within proposed sensitivity analyses, as described below.

Bycatch estimation of commercial dead and live discards of blacktip sharks in the U.S. Atlantic was considered to be unreliable during the DW, and the DW recommended against using the bycatch estimates in the base model. The DW recommendations and decisions regarding blacktip shark commercial bycatch estimation (dead and live discards) are summarized below.

1) *Do not include the three estimates of dead discards (southeast longline, southeast gillnet, and northeast gillnet) in the base run. Include all three estimates of dead discards in a sensitivity run.*
2) *Do not include the three estimates of live discards (southeast longline, southeast gillnet, and northeast gillnet) in the base run. Include all three estimates of live discards in a sensitivity run.*
3) *Use a post-release live discard mortality rate of 31% for commercial gillnets (with a 95% CI of 8.7%-44.4%) and 44.2% for bottom longlines (with a binomial 95% CI of 34.0%-54.8%)*

	Estimate	*Lower 95% CL*	*Upper 95% CL*
Gillnet	*31%*	*8.7%*	*44.4%*
Demersal Longline	*44.2%*	*34.0%*	*54.8%*

The following alternative scenarios were identified during the DW as possible examples for the use of the uncertain bycatch estimation in sensitivity model runs.

1) *Use running average to smooth annual bycatch estimates.*
2) *Use multi-year-block average bycatch estimates to replace annual bycatch estimates. The defined multi-year-block should be consistent with major management changes.*
3) *Use multi-year-block average estimated CPUEs, but using censored annual logbook data or dealer landing data to estimate bycatch. In this case, the interannual variability of bycatch estimates is driven by interannual variability in effort from the logbook data, or in landing data from dealers.*

The AP Analytical Team implemented the DW recommendations for continued analyses of commercial discard estimates (both live and dead) from commercial gillnet and longline fisheries. Results were presented to the Assessment Webinar I Panel in SEDAR65-AW06 (McCandless et al. 2020). The working document authors recommended the use of multi-year block averaging of the discard ratios to create discard estimates (McCandless et al. 2020, their Tables 1 – 3; **Table 2.4**). The estimated annual number of live shark discards in commercial gillnet and bottom longline fisheries was multiplied by the DW recommended post release live-discard mortality rate estimates of 31% and 44.2%, respectively, in order to obtain post release mortality (PRM) estimates for live discards in the commercial gillnet and bottom longline fisheries (**Table 2.4**) for use in Stock Synthesis sensitivity model runs.

2.1.4. Low and High Catch Scenarios

The following changes were made to the base input data (**Tables 2.2** and **2.3**) in order to achieve the Low Catch scenario and the High Catch scenario. The changes were presented to the AP Panel during Assessment Webinar II and are summarized in **Table 2.5**. The low catch scenario (**Table 2.5**) used the annual percent standard error estimates (-1PSEs) available for both the A+B1 and B2 recreational time series for the years 1981 – 2018. The recreational post-release mortality rate lower 95% CL of 10.8% (vs. 18.5% in reference case) was applied to the -1PSE of B2. The resulting values used in the Low Catch scenario are provided in **Table 2.6**.

In contrast, the high catch scenario (**Table 2.5**) used the annual +1PSEs available for both the A+B1 and B2 recreational time series for the years 1981 – 2018. The recreational post-release mortality rate upper 95% CL of 28.7% (vs. 18.5% in reference case) was applied to the +1PSE of B2. The high catch scenario also included estimates of both commercial dead discards and commercial live discard post-release mortality (**Table 2.4)** (converted to annual discard weight vs. no discards in reference case). The high catch scenario included a post-release mortality rate of 54.8% for bottom longline (vs. 44.2% in **Table 2.4**) and 44.4% for gillnets (vs. 31% in **Table 2.4**). The high catch scenario also used a dressed weight to whole weight conversion ratio of 2.0 (vs. 1.39 in reference case). The resulting values used in the High Catch scenario are provided in **Table 2.7**.

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 **Table 2.8**. 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 SEDAR65-DW papers identified below are referenced in section 1.4 of the DW (List of Data Workshop Working Papers).

Two fishery-dependent series were recommended by the DW from the Southeast Fisheries Science Center (SEFSC) Shark Bottom Longline Observer Program (SEDAR65-DW17). The first was obtained from the shark bottom longline fishery (1994 – 2007). The second was obtained from the shark research fishery (2008 – 2018).

Three fishery-independent series were recommended by the DW from the Virginia Shark Monitoring and Assessment Program (SEDAR65-DW05). The DW recommended that three alternative time series be developed from this data for potential use in the stock assessment: 1) the entire time series regardless of sample size (1974 – 2018); 2) a truncated time series to match the year when the catch series begins (1981 – 2018); and 3) the time series which would be considered to be the most robust by the working paper author in regards to sampling (1990 – 2018).

One fishery-independent series was recommended by the DW from the NOAA Fisheries Northeast Fisheries Science Center Bottom Longline Survey (SEDAR65-DW09). The series occurred intermittently between the years 1996 – 2018.

Two series were recommended by the DW from fishery-independent longline surveys conducted by the South Carolina Department of Natural Resources (SCDNR) (SEDAR65-DW11). The first series was obtained from the SCDNR Southeast Area Monitoring and Assessment Program (SEAMAP) Longline Survey (2007 – 2018). The second series was obtained from the SCDNR

Red Drum Longline Survey (1996 – 2006). The SEAMAP survey replaced the prior red drum survey and was developed to increase the geographical and seasonal coverage and move from a fixed-station single species survey to a random-stratified multispecies survey.

One series was recommended by the DW from the fishery-independent drumline survey conducted by SCDNR (SEDAR65-DW21). The survey occurred during the years 2013 – 2018 and sampled mostly large juveniles and adults. The series was standardized using only a binomial model of standardized presence/absence because of the use of a single hook fished on each drum line.

Two series were recommended by the DW from the fishery-independent Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) longline survey (SEDAR65-DW08). The survey occurred during the years 2005 – 2018 and sampled mostly age-0 and some juveniles in state estuaries and nearshore waters. The first series included only age-0 sharks, based on an assumed cutoff length at age-0. The second series included all-ages sampled (age-0 and juveniles combined). The DW noted that the age-0 series could be used as a recruitment index for the stock assessment. The DW noted that both the age-0 and all-ages (age-0 and juveniles combined) time series should not be included in a model at the same time because they are based on the same data set and would therefore not be independent.

Three series were recommended by the DW from the fishery-independent COASTSPAN Long and Short Gillnet Surveys (SEDAR65-DW07 and SEDAR65-DW10). Two series were obtained from the long gillnet survey (230 m x 3 m net with 10.3 cm stretched mesh) during the years 2001 – 2018, which sampled mostly age-0 and some juveniles in several estuaries within South Carolina. The first series included only age-0 sharks, based on an assumed cutoff length at age-0. The second included all-ages sampled (age-0 and juveniles combined). The DW noted a peak in 2013 in the standardized indices obtained from the long gillnet survey that was also seen in the SCDNR SEAMAP longline survey (SEDAR65-WP11), and, although not as pronounced, in the COASTSPAN longline survey (SEDAR65-WP08). A small gillnet survey (45 m x 3 m with 10.3 cm stretched mesh) was added in 2006 to supplement large gillnet sampling and facilitate sampling in geographically restricted areas that were too small for the large gillnet. One series (age-0) was obtained from the short gillnet survey during the years 2006 – 2018.

2.2.2. Sensitivity Analyses to Alternative Index of Abundance Groupings

Combined indices of abundance were developed for use in stock assessment model sensitivity analyses during the AP using both Bayesian hierarchical models and Dynamic Factor Analysis (DFA) separately for age-0 and for All-ages. Indices of abundance for sensitivity analyses were developed based on DW recommendations and decisions regarding alternative groupings of blacktip shark indices of abundance for use in stock assessment model (Stock Synthesis) sensitivity analyses, as summarized below. The DW recommended breaking the indices of abundance into two groups and then exploring the utility of combining multiple indices within each group separately using both a Bayesian hierarchical model (Conn 2010) and DFA (Peterson et al. 2017). The first group included indices predominantly composed of age-0 (recruits) (**Table 2.8,** R1-R3): R1 is the COASTSPAN Longline Age-0 index (SEDAR65-DW08); R2 is the COASTSPAN Gillnet Long Net Age-0 index (SEDAR65-DW07); and R3 is the SCDNR Gillnet Short Net Age-0 index (SEDAR65-DW10). The second group included indices composed primarily of age-0 but also included some older individuals (All-ages; **Table 2.8**, S1-S6): S1 is the Shark Bottom Longline Fishery index (SEDAR65-DW17); S2 is the Shark Research Fishery index (SEDAR65-DW17); S3 is the VIMS Robust Series index (SEDAR65-DW05); S4 is the NEFSC Bottom Longline index (SEDAR65-DW09); S5 is the SCDNR SEAMAP Longline Survey index (SEDAR65-DW11); and S6 is the SCDNR Red Drum Survey index (SEDAR65-DW11). The All-ages group excluded drumline (SEDAR65-DW21; **Table 2.8)**, which was standardized using a different approach from the other indices.

In response to DW recommendations, several AP working documents were produced that analyzed alternative abundance index groupings for use in sensitivity analyses. A combined hierarchical age-0 index and associated coefficient of variation (CV) were provided in SEDAR65-AW01 (McCandless 2020). A combined DFA age-0 index and a combined DFA all-age index along with associated measures of uncertainty were provided in SEDAR65-AW03

(Latour and Peterson 2020). Additionally, hierarchical cluster analysis and cross-correlations were evaluated in SEDAR65-AW04 (Courtney 2020) in order to identify potential abundance index groupings for use in sensitivity analyses. The alternative abundance index groupings identified using these methods are summarized below.

Both the hierarchical and DFA analyses of age-0 indices produced similar results, as discussed below. Consequently, a decision was made in coordination with the AP Panel that sensitivity analysis to the hierarchical analysis of age-0 indices would not be implemented in the Stock Assessment. In addition, index groupings identified in the hierarchical cluster analysis and cross-correlations of accepted indices were not implemented in sensitivity analyses due to time constraints of the AP. Instead, a pragmatic decision was made in coordination with the AP Panel to conduct a single abundance index sensitivity analysis which removed two indices (S4-NEFSC BLL and S7-SCDNR Drumline) which had a relatively poor fit in preliminary runs of the Stock Synthesis reference case model (as described in the Stock Assessment section below).

Hierarchical Analysis of Age-0 Indices (SEDAR65-AW01)

McCandless (2020) analyzed the U.S. Atlantic blacktip shark age-0 indices of abundance recommended for use during the SEDAR 65 DW (**Table 2.8**) for a hierarchical trend. Results were presented during Assessment Webinar I with both the DW panel and AP in attendance. The age-0 indices (standardized to their means) and coefficients of variation were used in hierarchical analysis to estimate individual index process error, assuming a lognormal error structure, and a hierarchical index of abundance. Hierarchical analysis of the Atlantic blacktip shark recruitment indices resulted in a slight increasing trend in abundance across years with a notable peak in 2013 and little variation in process error across the individual surveys. The combined hierarchical age-0 index and associated CV are provided in McCandless (2020, their Table 2 and Figures 1 and 2) and reproduced here in **Table 2.9**. More details of the methods and results are provided in McCandless (2020).

DFA of Age-0 Indices (SEDAR65-AW03)

Latour and Peterson (2020) analyzed the combined trend for U.S. Atlantic blacktip shark age-0 indices of abundance recommended for use during the SEDAR 65 DW (**Table 2.8**) with DFA.

Results were presented during Assessment Webinar I with both the DW panel and AP in attendance. A single common trend was estimated and each time-series, assumed to be independent. The COASTPAN longline survey index was relatively more influential than either the SCDNR COASTPAN long or short gillnet indices in the resulting combined DFA index. The DFA age-0 combined model converged successfully and resulted in a common trend that generally increased from 2001 – 2010, but decreased thereafter (Latour and Peterson 2020, their Figure 2a) in a pattern similar to that resulting from the hierarchical analysis described above. The back-transformed common trend resulting from the DFA model fitted to the age-0 Atlantic blacktip shark time-series of relative abundance along with associated uncertainty is provided in Latour and Peterson (2020, their Figure 3) and reproduced here in **Table 2.10.** More details of the DFA methods and results are provided in Latour and Peterson (2020).

DFA of All-ages Indices (SEDAR65-AW03)

Latour and Peterson (2020) analyzed the combined trend for U.S. Atlantic blacktip shark all-ages indices of abundance recommended for use during the SEDAR 65 DW (**Table 2.8**) with DFA, excluding drumline. Results were presented during Assessment Webinar I with both the DW panel and AP in attendance. A single common trend was estimated and each time-series was assumed to be independent. The DFA all-ages combined model converged successfully and resulted in a common trend that generally increased but fluctuated (Latour and Peterson 2020, their Figure 4). In general, the SEAMAP Longline and Shark Bottom Longline Observer indices, as described above, were relatively more influential than the other indices in the resulting DFA all-ages combined index, however factor loadings (a measure of relative influence) were low for all indices and fits of the common trend to the most influential indices were marginal. The back-transformed common trend resulting from the DFA model fitted to the all-ages Atlantic blacktip shark time-series of relative abundance along with associated uncertainty are provided in Latour and Peterson (2020, their Figure 5) and reproduced here in **Table 2.11.** More details of the methods and results are provided in Latour and Peterson (2020).

Hierarchical Cluster Analysis and Cross-correlations of Accepted Indices (SEDAR65-AW04)

Courtney (2020) analyzed the U.S. Atlantic blacktip shark indices of abundance recommended for use during the SEDAR 65 DW with hierarchical cluster analysis and cross-correlations.

Results were presented during Assessment Webinar I with both the DW panel and AP in attendance. Indices with conflicting information were identified. Consequently, it may be reasonable to assume that the conflicting indices reflect alternative hypotheses about states of nature and to run separate stock assessment model sensitivity analyses for single or sets of indices identified that represent a common hypothesis. However, some index groupings identified with hierarchical cluster analysis and cross-correlations were suspect because they may have been influenced by highly positively and negatively correlated series with low sample size (n=2), even after adjusting the data set to remove some series with low sample size and to remove outliers. Similarly, the groupings identified for age-0 indices were sensitive to removal of the outlier year 2013. Consequently, the following index groupings were recommended based on robust Spearman's correlation and associated hierarchical cluster analyses: 1) The series S4 on its own; 2) series S1-S10 without S4**;** 3) Series S1, S3; and 4) Series (S6, S7, S2, S5). More details of the methods and results are provided in Courtney (2020).

2.3. Life History Inputs

Life history data used in the stock assessment model were obtained directly from the DW report (reproduced here in **Table 2.12**) and were unchanged for use in the stock assessment unless noted otherwise below.

Estimates of Vital Rates (SEDAR65-AW02)

Cortés (2020) estimated vital rates and population dynamics parameters including Beverton-Holt stock-recruitment steepness (*h*) for the North Atlantic population of blacktip sharks based on biological information provided in the SEDAR 65 Data Workshop Report for use as inputs into Stock Synthesis. Results were presented during Assessment Webinar I with both the DW Panel and the AP Panel in attendance. Four age-aggregated and two age-structured methods (Euler-Lotka equation and Leslie matrix) were used to obtain deterministic parameter values and their plausible range. Additionally, Monte Carlo simulation of the Leslie matrix approach was used to characterize parameter value uncertainty. The author noted that parameter values obtained from the uncertainty analysis were likely to have been underestimated because the life history data used in the simulation were obtained under stock conditions not likely to be reflective of ideal conditions needed for estimation of maximum stock productivity (i.e., very low population size after exploitation has ceased). In contrast, the author noted that the mean steepness value of 0.4 inferred from the deterministic methods using the theoretical longevity was similar to that obtained from published values of the maximum lifetime reproductive rate for 33 shark stock assessments, which corresponded to steepness values ranging from 0.20 to 0.83 with a mean of 0.46 (SD = 0.20). The author noted that the lower and upper values of the range obtained with the deterministic methods (0.32 and 0.52) could be useful to inform plausible low and high productivity states of nature, respectively. The author suggested that the minimum estimates of instantaneous natural mortality rates corresponding to the deterministic age-structured Euler-Lotka/Leslie Matrix approaches be used as inputs for the Stock Synthesis reference case, reproduced here in **Table 2.13** separately for females and males using the same methods. Additionally, the author noted that the estimates of generation time obtained (median, LCL, and UCL of 12.5, 11.2, and 20.1, respectively) could be useful to inform the time horizon for projections. More details of the methods and results are provided in Cortés (2020).

The author also provided the AP Analytical Team with mean estimates of instantaneous natural mortality rates corresponding to the deterministic age-structured Euler-Lotka/Leslie Matrix approaches for use in Stock Synthesis model sensitivity analyses (**Table 2.14)** separately for females and males using the same methods.

2.4. Length Composition Data

Atlantic blacktip shark length composition data submitted for use in the SEDAR 65 stock assessment were reviewed in SEDAR65-AW05 (Kroetz and Courtney 2020) and SEDAR65-AW07 (Courtney et al. 2020) and presented during Assessment Webinars I and IV. Detailed methods and results are provided in Kroetz and Courtney (2020) and Courtney et al. (2020). Length composition data available for commercial and recreational gear types were aggregated into 'fleets' with similar length composition based on a review of the available length compositions, as described below. Fits to length composition data by fleet are provided separately in the Stock Assessment section of the report.

2.4.1. Commercial Bottom Longline Length Composition

Length composition data available for the commercial bottom longline gear type were aggregated into a single fleet, which was assumed to capture predominantly mature blacktip sharks. Commercial bottom longline length composition was obtained from the Shark Bottom Longline Observer Program (SBLOP) conducted by the University of Florida (UF 1994-2005, n = 1,699) and the Southeast Fisheries Science Center (SEFSC) Panama City Lab (2005-2018, n = 3,708) (Kroetz and Courtney 2020, their Table 1). Predominantly mature sharks were observed in the fishery-dependent bottom longline length composition data obtained from both UF (1994-2005) and SEFSC (2005-2018) (Kroetz and Courtney 2020, their Appendix A).

During Assessment Webinar I, a potential sensitivity analysis was identified, but not implemented, to evaluate the relatively smaller size of discarded versus kept Atlantic blacktip sharks observed in the SBLOP length composition data. As noted above, predominantly mature sharks were observed in the SBLOP length composition data. However, an examination of the SBLOP length composition data by fate (kept versus discarded) resulted in a different distribution in length for sharks discarded dead (relatively smaller) compared to the sharks that were kept (predominantly mature) (Kroetz and Courtney 2020, their Appendix C). A plausible hypothesis based on this result is that kept vs discarded blacktip sharks may have a different length composition. However, the potential sensitivity analysis was not implemented due to time constraints of the AP.

2.4.2. Commercial Gillnet Length Composition

Length composition data available for the commercial gillnet gear type were aggregated into a single fleet, which was assumed to capture predominantly mature blacktip sharks prior to 2006 and predominantly immature blacktip sharks after 2006. Commercial gillnet length composition data were obtained from the SEFSC Panama City Lab Gillnet Observer Program (GNOP) 1999-2018. However, the SEFSC-GNOP length composition sample size was very low (n = 124; Kroetz and Courtney 2020, their Table 1 and Appendix A). Consequently, a second data set (n = 1,353) was examined of unknown measurement type observed in fishery-dependent sampling of the gillnet fishery available from the GNOP (Kroetz and Courtney 2020, their Appendix B). These data were not included in the original analyses because the measurement type (direct or estimated) was not specified. The size composition of unknown measurement type (Kroetz and Courtney 2020, their Appendix B) spanned a relatively wider range than those directly measured for fork length (GNOP 1999-2018, n = 124; Kroetz and Courtney 2020, their Appendix A). The size composition of unknown measurement type also differed for males and females.

Atlantic blacktip shark fork length (FL cm straight) data obtained from the SEFSC-GNOP 1999-2018 (n = 1477) were updated in SEDAR65-AW07 (Courtney et al. 2020) to include measured lengths, FL cm straight, previously excluded as ‘unknown’ measurements (Kroetz and Courtney 2020) due to exclusion of a field in the database. This field describes the length measurement taken as directed or estimated, which was added to the database beginning 2010. Before this year, directed lengths were taken and present in the database, however the field describing the length type did not exist.

Inter-annual variation was identified in both gillnet gear type and mean length within the updated length composition data available from SEFSC-GNOP 1999-2018 in SEDAR65-AW07 (Courtney et al. 2020). The largest inter-annual variation occurred after the year 2006 when the proportion of measured lengths obtained from the GNOP gear type(s) recorded in the database as “GILL NETS, DRIFT, RUNAROUND” decreased and the proportion of measured lengths obtained from GNOP gear type(s) recorded in the database as “GILL NETS, SINK/ANCHOR, OTHER” increased. An examination of binned length-frequency data provided for use in the SEDAR 65 stock assessment identified that the gillnet gear type “GILL NETS, DRIFT, RUNAROUND” captured predominantly mature blacktip sharks while the gillnet gear type “GILL NETS, SINK/ANCHOR, OTHER” captured predominantly immature blacktip sharks.

2.4.3. Recreational Length Composition

Length composition data available for the recreational gear type were aggregated into a single fleet, which was assumed to capture predominantly immature blacktip sharks. Recreational data were obtained from the recreational (A+B1) length composition data described in SEDAR65-DW19 (Cortés and Balchowsky-Baertlein 2019) and SEDAR65-AW05 (Kroetz and Courtney 2020). Predominantly immature sharks were observed in the recreational (A+B1) sampling conducted by both the Marine Recreational Information Program (MRIP 1981-2018, n = 781) and the Southeast Region Head Boat Survey (SRHS 1989-2018, n = 107) (Cortés and Balchowsky-Baertlein 2019, their Figure 8; Kroetz and Courtney 2020, their Appendix A).

During Assessment Webinars I and III, differences in the mean size at capture by recreational fishing mode were identified and discussed. However, potential sensitivity analyses identified to evaluate the effect of the observed differences in size at capture by fishing mode were not implemented due to both limitations in the recreational length composition data, as described below, and time constraints of the AP.

During Assessment Webinar I, differences in the recreational Atlantic blacktip shark mean size at capture by fishing mode were identified and discussed. The differences in size were identified in a review of the available recreational (A + B1) catch length composition data described in SEDAR65-DW19 (Cortés and Balchowsky-Baertlein 2019) and SEDAR65-AW05 (Kroetz and Courtney 2020). Fork length of Atlantic blacktip shark recreational (A + B1) catch from the MRIP and SRHS surveys differed significantly both by fishing mode ($P = 0.0001$; Cortés and Balchowsky-Baertlein 2019, their Figure 9) and by fishing area ($P < 0.0001$; Cortés and Balchowsky-Baertlein 2019, their Figure 10). Mean fork length was smaller for the shore-based fishing mode and the inshore fishing area than for other fishing modes and fishing areas. During the DW, it was noted that age-0 Atlantic blacktip sharks occur in estuaries. Consequently, a plausible hypothesis to explain the observed differences in mean size at capture by fishing mode may be that age-0 Atlantic blacktip sharks are captured more frequently in estuaries compared to other locations.

In contrast, during Assessment Webinar I, the capture of relatively large Atlantic blacktip sharks by some shore-based anglers was also identified and discussed. The relatively large sharks were identified in a review of the shore-based recreational catch sampling (A + B1 + B2-Released Alive) conducted by South Carolina Department of Natural Resources (SCDNR 2013-2018, n = 166) (Kroetz and Courtney 2020, their Appendix A). During the DW, it was noted that mature Atlantic blacktip sharks occur along coastal beaches and that shore-based anglers participating in the SCDNR logbook sampling program were fishing along coastal beaches. Consequently, a plausible hypothesis to explain the relatively large Atlantic blacktip sharks observed in SCDNR shore-based fishing mode may be that some shore-based fishing is targeting mature Atlantic blacktip sharks along coastal beaches.

During Assessment Webinar III, Atlantic HMS staff presented a review of the available length composition data for Atlantic blacktip sharks sampled from recreational catch and identified a small (10 cm) but significant ($t = -3.62$, $p < 0.001$) difference in blacktip shark average size between targeted recreational shark trips and recreational trips that did not indicate they were targeting sharks (incidental). However, it was noted during the webinar that the length distributions of recreationally caught blacktip sharks on targeted and incidental trips largely overlapped, except that targeted trips captured proportionally fewer blacktip sharks at smaller sizes. The number of recreational trips landing large coastal sharks (LCS) increased over time, but the number of recreational trips targeting LCS remained relatively stable. It was also noted during the webinar that there has been an increase in the number of serious shore-based anglers targeting large sharks. However, these data may not be represented in the recreational sampling data because fishing occurs primarily at night and it is primarily catch and release.

A potential sensitivity analysis was identified, but not implemented, to evaluate the effect of the capture of smaller Atlantic blacktip sharks in the inshore area and shore-based fishing mode by apportioning total recreational catch (A + B1 and B2-Dead) into two fleets. The first fleet would include the capture of smaller Atlantic blacktip sharks in the inshore area and shore-based fishing mode based on the five-year moving average of the observed proportion of Atlantic blacktip shark recreational (A + B1) catch from the inshore area (42%; calculated from Cortés and Balchowsky-Baertlein 2019, their Table 6) and shore-based fishing mode (49%; calculated from

Cortés and Balchowsky-Baertlein 2019, their Table 5). The second fleet would exclude the observed proportion of Atlantic blacktip shark recreational (A + B1) catch in the inshore area and the shore-based fishing mode, based on the proportions described above.

The potential sensitivity analysis was not implemented due to the limitations in the recreational catch length composition data, as described above, which may not accurately reflect that some shore-based anglers target relatively large sharks. In addition, time constraints of the AP precluded further analysis of the potential effect of Federal actions such as the implementation of a minimum size limit or the implementation of Federal bag limits on the resulting recreational length composition data.

2.5. References

Conn, P. B. 2010. Hierarchical analysis of multiple noisy abundance indices. Canadian Journal of Fisheries and Aquatic Sciences 67:108–120.

Cortés, E. 2020. Estimates of vital rates and population dynamics parameters of interest of blacktip sharks (*Carcharhinus limbatus*) in the Atlantic Ocean. SEDAR65-AW02. SEDAR, North Charleston, SC. 17 pp

Cortés, E., and H. Balchowsky-Baertlein. 2019. Preliminary catches of blacktip sharks in the U.S. Atlantic Ocean. SEDAR65-DW19. SEDAR, North Charleston, SC. 23 pp.

Courtney, D. 2020. Hierarchical cluster analysis and cross-correlations of selected CPUE indices for the SEDAR 65 assessment. SEDAR65-AW04. SEDAR, North Charleston, SC. 29 pp.

Courtney, D., A. Mathers, and A. Kroetz. 2020. Updated commercial gillnet length composition data for use in SEDAR 65. SEDAR65-AW07. SEDAR, North Charleston, SC. 20 pp

Kroetz, A., and D. Courtney. 2020. Review of available length composition data submitted for use in the SEDAR 65 Atlantic *Carcharhinus limbatus* stock assessment. SEDAR65-AW05. SEDAR, North Charleston, SC. 13 pp.

Latour, R. J., and C. D. Peterson. 2020. Reconciling indices of relative abundance of the Atlantic blacktip shark (*Carcharhinus limbatus*). SEDAR65-AW03. SEDAR, North Charleston, SC. 10pp.

McCandless, C. T. 2020. Hierarchical analysis of U.S Atlantic blacktip shark recruitment indices. SEDAR65-AW01. SEDAR, North Charleston, SC. 5 pp.

McCandless, C., J. Carlson, X. Zhang, and E. Cortés. 2020. Improving discard time series for use in assessment sensitivity analyses. SEDAR65-AW06. SEDAR, North Charleston, SC. 10 pp.

Peterson, C. D., C. N. Belcher, D. M. Bethea, W. B. Driggers III, B. S. Frazier, and R. J. Latour. 2017. Preliminary recovery of coastal sharks in the south-east United States. Fish and Fisheries 18:845–859.

2.6. Tables

Table 2.1. Commercial landings of blacktip sharks in the U.S. Atlantic for the period 1983 – 2018 in weight (pounds dressed weight; lb. dw)[1] (as described in Section 2.1.1 above).

Year	Unreported commercial catches	Bottom longlines	Gillnets	Other gears
1983		117654	156572	13927
1984		235309	313144	27854
1985		352963	469716	41781
1986		546144	352931	41781
1987		175361	632155	41781
1988	95172	337384	424063	41781
1989	80892	370196	359204	41781
1990		283349	375659	41781
1991		212125	354837	491096
1992		756923	87757	234581
1993		807599	335794	99764
1994		396013	20022	33314
1995		573084	62577	41805
1996		231129	404648	24586
1997		123687	112990	11594
1998		117429	68892	9432
1999		128348	83778	9297
2000		188258	96767	7682
2001		109355	156606	5082
2002		200569	270521	13940
2003		225246	235939	12878
2004		97734	176299	11657
2005		107426	109778	5810
2006		117754	219294	4751
2007		30858	48869	2155
2008		118901	159135	4434
2009		171886	30113	38086
2010		164057	89956	17814
2011		143771	38845	7655
2012		106103	68209	40171
2013		156418	81966	25843
2014		206387	65028	10592
2015		193274	36023	528
2016		175635	70933	1907
2017		175775	42433	1753
2018		93515	29955	1661

[1] SEDAR 65 DW Report (their Table 1)

Table 2.2. Commercial landings of blacktip sharks in the U.S. Atlantic in kilograms whole weight (kg ww) obtained using a conversion ratio for dressed weight (dw) to whole weight (ww) of ww = 1.39*dw[1] (as described in Section 2.1.1 above).

Year	Unreported commercial catches	Bottom longlines	Gillnets	Other gears
1983		74180	98718	8781
1984		148361	197436	17562
1985		222541	296153	26343
1986		344341	222521	26343
1987		110564	398570	26343
1988	60005	212719	267369	26343
1989	51002	233406	226476	26343
1990		178650	236851	26343
1991		133744	223723	309633
1992		477236	55330	147902
1993		509186	211716	62901
1994		249684	12624	21004
1995		361326	39454	26358
1996		145725	255128	15502
1997		77984	71239	7310
1998		74038	43436	5947
1999		80922	52822	5862
2000		118695	61011	4843
2001		68948	98739	3204
2002		126458	170562	8789
2003		142016	148758	8119
2004		61621	111155	7349
2005		67731	69214	3663
2006		74243	138264	2995
2007		19456	30812	1359
2008		74967	100333	2795
2009		108373	18986	24013
2010		103437	56717	11232
2011		90647	24491	4826
2012		66897	43006	25328
2013		98621	51679	16294
2014		130126	41000	6678
2015		121858	22712	333
2016		110737	44723	1202
2017		110825	26754	1105
2018		58961	18886	1047

[1] Pers. Comm. Enric Cortés

Table 2.3. Smoothed annual recreational catch estimates of blacktip sharks in the Atlantic obtained from the DW for the period 1981 – 2018 in numbers (as described in Section 2.1.2 above): 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), type B2 (number of fish released alive reported by the fisher; B2-Live), and type B2 multiplied by a post-release mortality rate of 18.5% for hook and line recreational fisheries to obtain the number of fish released alive that were estimated to have died (B2-Dead).

	Recreational catch		
Year	**A + B1**	**B2-Live**	**B2-Dead**
1981	32377	240928	44572
1982	32377	240928	44572
1983	39732	139260	25763
1984	66390	131616	24349
1985	61982	75572	13981
1986	65904	34550	6392
1987	27389	32797	6068
1988	29796	29377	5435
1989	20287	20039	3707
1990	45243	23435	4335
1991	46337	132935	24593
1992	50757	158291	29284
1993	28802	405933	75098
1994	25981	328840	60835
1995	38205	353537	65404
1996	38119	141069	26098
1997	68601	273974	50685
1998	64371	258944	47905
1999	63178	327078	60509
2000	31807	315514	58370
2001	18503	383689	70982
2002	20187	415925	76946
2003	15755	463246	85700
2004	41753	565189	104560
2005	34576	495741	91712
2006	38439	364531	67438
2007	11675	468508	86674
2008	9179	496267	91809
2009	4081	502764	93011
2010	2377	233131	43129
2011	3395	163427	30234
2012	3542	184878	34202
2013	3617	279714	51747
2014	3437	442217	81810
2015	4701	368883	68243
2016	4451	280471	51887
2017	2849	185768	34367
2018	2849	185768	34367

Table 2.4. Commercial discard estimates (both live and dead numbers of sharks) obtained from commercial gillnet and longline fisheries using multi-year block averaging of the discard ratios obtained from SEDAR65-AW06 (McCandless et al. 2020, their Tables 1 – 3). The estimated annual number of live discards in commercial gillnet and bottom longline fisheries was multiplied by the DW recommended post release live-discard mortality rate estimates of 31% and 44.2% (as described in Section 2.1.3 above) to obtain post release mortality (PRM) estimates for live discards in the commercial gillnet and bottom longline fisheries, respectively.

	Northeast Gillnet			Southeast Gillnet			Bottom Longline		
Yr	Live discard	Live discard PRM	Dead discard	Live discard	Live discard PRM	Dead discard	Live discard	Live discard PRM	Dead discard
1981									
1982									
1983	2	0.5	1						
1984	2	0.5	1						
1985	2	0.7	2						
1986	3	0.8	2						
1987	4	1.4	3						
1988	2	0.6	1						
1989	12	3.7	8						
1990	9	2.8	6						
1991	18	5.6	13						
1992	26	8.0	18						
1993	38	11.7	27				116	51.3	2499
1994	41	12.8	29				239	105.5	5139
1995	45	14.0	32				91	40.4	1966
1996	57	17.7	41				266	117.4	5716
1997	63	19.5	45				122	54.1	2634
1998	444	137.8	543	1277	395.7	4052	143	63.1	3071
1999	376	116.7	460	989	306.5	3139	131	57.8	2814
2000	340	105.5	415	1037	321.4	3291	124	54.8	2666
2001	5	1.7	6	3018	935.5	5345	96	42.5	2076
2002	5	1.6	6	3021	936.5	5350	130	57.5	2803
2003	5	1.6	6	1792	555.4	7684	131	57.8	2817
2004	4	1.4	5	1779	551.5	7630	102	44.9	2187
2005	3	0.8	3	2084	646.0	8937	86	38.1	1854
2006	3	0.8	3	542	168.1	629	86	38.1	1854
2007	5	1.6	6	834	258.5	968	46	20.5	996
2008	5	1.4	5	249	77.0	158	44	19.2	893
2009	6	1.7	6	283	87.9	181	97	43.0	1994
2010	3	1.0	4	187	58.1	119	81	35.7	1656
2011	6	1.9	7	239	74.2	153	58	25.6	1188
2012	5	1.5	6	244	75.7	156	34	15.1	702
2013	5	1.5	6	129	40.1	83	49	21.6	1003
2014	7	2.1	8	231	71.7	148	67	29.5	1369
2015	3	1.1	4	215	66.8	137	60	26.6	1232
2016	4	1.1	4	197	60.9	125	36	15.8	734
2017	3	1.0	4	148	45.8	94	38	16.6	770
2018	3	1.0	4	195	60.6	125	28	12.2	565

Table 2.5. Changes made to the commercial catch (**Panel A**) and recreational catch (**Panel B**) in order to achieve the Low Catch and High Catch scenarios (as described in section 2.1.4 above). "Base" indicates the catch data used in the Reference Case (**Tables 2.2** and **2.3**).

Panel A.
Commercial Catch (weight)

Scenario	Gear	Landings	Dead discards	Released alive that die	PRM of commercial released alive	DW to WW ratio
Reference Case	Longlines	Base	No	No	n/a	1.39
	Gillnets	Base	No	No	n/a	1.39
	Other gear	Base	No	No	n/a	1.39
Low Catch	Longlines	Base	No	No	n/a	1.39
	Gillnets	Base	No	No	n/a	1.39
	Other gear	Base	No	No	n/a	1.39
High Catch	Longlines	Base	Yes	Yes	54.8%	2.00
	Gillnets	Base	Yes	Yes	44.4%	2.00
	Other gear	Base	No	No	n/a	2.00

Panel B.
Recreational (numbers)

Scenario	AB1	B2 that die	PRM of recreational released alive
Reference Case	Base	Base	18.50%
Low Catch	-1PSE	-1PSE	10.80%
High Catch	+1PSE	+1PSE	28.70%

Table 2.6. Low Catch scenario (sensitivity analysis) of Atlantic blacktip sharks in weight (kg ww) and numbers as described in section 2.1.4 above. Commercial landings are in weight; recreational catches are in numbers and smoothed. The conversion ratio for dw to ww is ww=1.39dw.

Year	Unreported commercial catches	Bottom longlines	Gillnets	Other gears	Recreational catches (A+B1)	Recreational catches (B2)	Recreational catches (B2) that die
1981					17642	33318	3598
1982					17642	33318	3598
1983		74181	98719	8781	20022	35404	3824
1984		148362	197437	17562	33998	31187	3368
1985		222543	296156	26343	33617	20503	2214
1986		344344	222523	26343	40279	18628	2012
1987		110565	398574	26343	16788	18765	2027
1988	60006	212721	267372	26343	18256	17084	1845
1989	51002	233409	226478	26343	10980	11040	1192
1990		178652	236853	26343	19420	14701	1588
1991		133745	223725	309636	19856	67751	7317
1992		477240	55331	147904	23082	85598	9245
1993		509191	211718	62901	19350	228517	24680
1994		249686	12624	21004	16920	201586	21771
1995		361329	39455	26358	25121	224411	24236
1996		145727	255130	15502	23632	103900	11221
1997		77984	71240	7310	36298	186246	20115
1998		74039	43436	5947	33389	172354	18614
1999		80923	52822	5862	30664	214572	23174
2000		118696	61012	4843	17663	229873	24826
2001		68948	98740	3204	9285	288422	31150
2002		126459	170563	8789	9416	314005	33913
2003		142017	148760	8119	6590	307841	33247
2004		61621	111156	7349	16518	372158	40193
2005		67732	69215	3663	14665	333113	35976
2006		74244	138265	2995	17042	264714	28589
2007		19456	30812	1359	6401	294514	31808
2008		74967	100334	2795	5418	301112	32520
2009		108374	18987	24013	2226	307921	33255
2010		103438	56717	11232	918	147109	15888
2011		90648	24492	4826	1084	100898	10897
2012		66898	43006	25328	1043	110975	11985
2013		98622	51679	16294	1526	162551	17556
2014		130127	41000	6678	1817	295201	31882
2015		121859	22712	333	1987	248974	26889
2016		110738	44723	1202	1501	216032	23331
2017		110826	26754	1105	804	134107	14484
2018		58961	18887	1047	804	134107	14484

Table 2.7. High Catch scenario (sensitivity analysis) of Atlantic blacktip sharks in weight (kg ww) and numbers as described in section 2.1.4 above. Commercial landings are in weight; recreational catches are in numbers and smoothed. The conversion ratio for dw to ww is ww=2.0dw.

Year	Unreported commercial catches	Bottom longlines	Gillnets	Other gears	Recreational catches (A+B1)	Recreational catches (B2)	Recreational catches (B2) that die
1981					47111	448538	128730
1982					47111	448538	128730
1983		106735	142116	12634	59443	243116	69774
1984		213471	284158	25269	98783	232045	66597
1985		320206	426239	37903	90348	130641	37494
1986		495459	320310	37903	91653	50472	14486
1987		159086	573677	37903	38136	46830	13440
1988	86339	306073	384783	37903	41805	41670	11959
1989	73385	335840	326398	37903	30163	29039	8334
1990		257053	341194	37903	72339	32169	9232
1991		192439	322742	445519	74614	198120	56860
1992		686676	80788	212811	80449	230984	66292
1993		808861	306377	90505	39917	583349	167421
1994		460316	20043	30222	36020	456094	130899
1995		562547	58838	37925	51968	482663	138524
1996		345330	369733	22305	53257	178238	51154
1997		187034	105408	10518	101800	361701	103808
1998		199731	275825	8556	96397	345534	99168
1999		198570	211974	8435	96643	439585	126161
2000		252080	187564	6969	46771	401155	115132
2001		164085	513961	4610	28620	478956	137460
2002		256197	531883	12647	31626	517845	148622
2003		282773	598122	11682	25629	619125	177689
2004		148971	465069	10575	67861	759363	217937
2005		145259	470766	5271	55556	659916	189396
2006		151260	229869	4310	60861	466088	133767
2007		48139	49541	1955	17570	644190	184883
2008		134400	150643	4022	13522	693437	199016
2009		226437	34957	34552	6616	699727	200822
2010		204046	87003	16161	4504	321436	92252
2011		158702	39896	6944	6355	228638	65619
2012		112787	66203	36443	6711	261769	75128
2013		168721	76512	23445	6317	399850	114757
2014		218724	63410	9609	5551	591445	169745
2015		211231	35213	479	7585	490756	140847
2016		179550	75466	1730	7560	346820	99537
2017		178016	39461	1590	5072	240395	68993
2018		102037	30197	1507	5072	240395	68993

Table 2.8. Indices of relative abundance recommended by the Index Working Group of the SEDAR 65 Data Workshop for the Atlantic stock of blacktip shark (see SEDAR 65 Data Workshop report). The CV is the coefficient of variation for the annual index value. The SEDAR 65 DW report number is identified for each series.

	S1		S2						S3	
Year	**Shark Bottom Longline Fishery (DW-17)**	**CV**	**Shark Research Fishery (DW-17)**	**CV**	**VIMS Original (DW-05)**	**CV**	**VIMS Catch Series (DW-05)**	**CV**	**VIMS Robust Series (DW-05)**	**CV**
1974					0.747	0.639				
1975					1.176	0.646				
1976										
1977										
1978										
1979										
1980					0.094	0.647				
1981					0.050	0.573	0.050	0.571		
1982										
1983					0.117	0.897	0.115	0.900		
1984										
1985										
1986										
1987					0.160	0.934	0.156	0.939		
1988					0.171	1.161	0.157	1.168		
1989										
1990					0.027	0.763	0.027	0.761	0.026	0.767
1991					0.012	0.785	0.012	0.785	0.012	0.790
1992					0.022	0.780	0.022	0.779	0.021	0.784
1993										
1994	19.410	0.710								
1995	46.050	0.440			0.061	1.008	0.060	1.010	0.058	1.012
1996	28.030	0.490			0.037	1.005	0.037	1.006	0.035	1.008
1997	2.580	0.930			0.071	0.667	0.070	0.666	0.069	0.672
1998	34.630	0.580			0.004	1.010	0.005	1.010	0.004	1.012
1999	93.870	0.350			0.211	0.451	0.219	0.447	0.218	0.455
2000	132.340	0.430			0.011	1.012	0.010	1.012	0.010	1.014
2001	46.570	0.510			0.032	0.569	0.032	0.569	0.031	0.576
2002	190.210	0.260			0.109	0.575	0.106	0.577	0.102	0.584
2003	18.290	0.640								
2004	52.600	0.400			0.040	0.648	0.040	0.648	0.038	0.654
2005	106.580	0.460								
2006	91.350	0.540			0.066	0.573	0.063	0.574	0.063	0.580
2007	27.480	0.680			0.044	0.649	0.044	0.649	0.042	0.655
2008			94.600	0.580	0.277	0.322	0.279	0.321	0.277	0.328
2009			108.410	0.350	0.093	0.625	0.090	0.629	0.086	0.640
2010			69.950	0.260	0.084	0.516	0.083	0.516	0.082	0.523
2011			74.770	0.260	0.050	0.763	0.051	0.761	0.051	0.767
2012			176.650	0.420	0.033	0.652	0.032	0.654	0.031	0.661
2013			100.090	0.510	0.226	0.527	0.221	0.525	0.224	0.533
2014			213.370	0.240	0.076	0.393	0.076	0.393	0.074	0.401
2015			144.800	0.300	0.028	0.484	0.028	0.482	0.028	0.488
2016			124.360	0.370	0.084	0.296	0.084	0.296	0.082	0.304
2017			266.440	0.320	0.094	0.461	0.095	0.461	0.092	0.468
2018			42.130	0.500	0.124	0.359	0.123	0.359	0.121	0.367

Table 2.8. Continued.

	S4		S5		S6		S7		S8	
Year	**NMFS-NEFSC Bottom Longline (DW-09)**	**CV**	**SCDNR SEAMAP Longline Survey (DW-11)**	**CV**	**SCDNR Red Drum Survey (DW-11)**	**CV**	**SCDNR Drumline Survey (DW-21)**	**CV**	**COASTSPAN Longline All-age (DW-08)**	**CV**
1974										
1975										
1976										
1977										
1978										
1979										
1980										
1981										
1982										
1983										
1984										
1985										
1986										
1987										
1988										
1989										
1990										
1991										
1992										
1993										
1994										
1995										
1996	0.003	1.017			1.227	0.640				
1997					1.273	0.604				
1998	0.031	0.483			0.458	0.610				
1999					0.394	0.865				
2000					1.359	0.441				
2001	0.013	0.561			0.349	1.270				
2002					0.589	0.720				
2003					1.019	0.554				
2004	0.031	0.484			0.459	0.792				
2005					0.310	0.904			3.023	0.286
2006					1.316	0.432			1.522	0.380
2007	0.001	1.901	1.721	0.353					1.205	0.542
2008			0.838	0.510					3.441	0.380
2009	0.026	0.606	1.220	0.357					1.943	0.276
2010			0.899	0.289					2.005	0.249
2011			1.534	0.286					1.602	0.264
2012	0.122	0.384	1.543	0.256					2.690	0.234
2013			2.707	0.211			0.166	0.225	3.696	0.205
2014			1.766	0.201			0.206	0.161	1.974	0.296
2015	0.148	0.351	1.983	0.207			0.174	0.180	1.466	0.299
2016			0.974	0.269			0.136	0.180	1.769	0.246
2017			1.124	0.234			0.185	0.165	1.585	0.282
2018	0.318	0.247	1.464	0.219			0.207	0.186	1.025	0.306

Table 2.8. Continued.

	R1		S9		R2		S10 (and R3)	
Year	COASTSPAN Longline Age-0 (DW-08)	CV	COASTSPAN Gillnet Long Net All-age (DW-07)	CV	COASTSPAN Gillnet Long Net Age-0 (DW-07)	CV	SCDNR Gillnet Short Net Age-0 (DW-10)	CV
1974								
1975								
1976								
1977								
1978								
1979								
1980								
1981								
1982								
1983								
1984								
1985								
1986								
1987								
1988								
1989								
1990								
1991								
1992								
1993								
1994								
1995								
1996								
1997								
1998								
1999								
2000								
2001			0.798	0.283	0.700	0.336		
2002			0.309	0.430	0.223	0.654		
2003			0.901	0.318	0.815	0.372		
2004			0.150	1.176	0.145	1.333		
2005	2.819	0.304	0.836	0.402	0.906	0.463		
2006	1.413	0.403	1.139	0.369	1.023	0.370	0.498	0.452
2007	1.214	0.552	0.486	0.422	0.490	0.585	1.493	0.519
2008	2.883	0.389	0.552	0.452	0.564	0.538	0.301	1.163
2009	1.882	0.307	1.072	0.363	0.749	0.479	0.309	1.124
2010	1.753	0.286	1.056	0.418	0.615	0.584	0.565	0.476
2011	1.597	0.283	0.726	0.475	0.275	0.755	0.601	0.485
2012	2.656	0.246	0.927	0.776	0.847	0.903	1.068	0.288
2013	3.440	0.217	3.684	0.359	3.845	0.417	0.827	0.426
2014	1.892	0.318	1.277	0.461	0.892	0.535	0.250	0.694
2015	0.897	0.392	0.707	0.301	0.400	0.524	0.540	0.459
2016	1.670	0.270	0.607	0.517	0.118	0.899	0.296	0.526
2017	1.607	0.294	1.320	0.421	1.356	0.495	0.688	0.406
2018	1.031	0.319	1.420	0.315	0.967	0.456	1.217	0.311

Table 2.9. Hierarchical analysis of the Atlantic blacktip shark recruitment indices (age-0) and associated coefficient of variation (CV) obtained from SEDAR65-AW01 (McCandless 2020, their Table 2 and Figures 1), as described above in Section 2.2.2.

Year	Hierarchical (Age-0)	CV
2001	0.993	0.545
2002	0.494	0.705
2003	1.121	0.536
2004	0.566	0.859
2005	1.376	0.379
2006	0.938	0.356
2007	1.013	0.410
2008	1.079	0.400
2009	0.952	0.365
2010	0.909	0.347
2011	0.792	0.354
2012	1.430	0.335
2013	2.064	0.344
2014	0.910	0.368
2015	0.612	0.370
2016	0.649	0.373
2017	1.076	0.351
2018	1.026	0.371

Table 2.10. The back-transformed common trend resulting from the DFA model fitted to the age-0 Atlantic blacktip shark time-series of relative abundance along with associated uncertainty (**Panel A**; Latour and Peterson 2020, their Figure 3) along with DFA factor loadings by fleet (**Panel B**), provided from the authors of SEDAR65-AW03 (Latour and Peterson 2020), as described above in Section 2.2.2. Fleets as defined in **Table 2.8**.

Panel A

Year	Index	SE	CV
2001	0.895	0.3074	0.3436
2002	0.820	0.2815	0.3433
2003	0.902	0.2648	0.2937
2004	0.895	0.2365	0.2643
2005	1.212	0.1384	0.1142
2006	0.930	0.1324	0.1423
2007	0.839	0.1321	0.1575
2008	1.237	0.1321	0.1068
2009	1.096	0.1321	0.1205
2010	1.006	0.1321	0.1313
2011	0.967	0.1321	0.1367
2012	1.299	0.1321	0.1017
2013	1.556	0.1321	0.0849
2014	1.088	0.1321	0.1215
2015	0.709	0.1321	0.1863
2016	0.838	0.1321	0.1578
2017	0.897	0.1327	0.1479
2018	0.723	0.1448	0.2002

Panel B

Fleet	Factor loadings
COASTSPAN Longline Age-0 (DW-08)	0.964
COASTSPAN Gillnet Long Net Age-0 (DW-07)	0.414
SCDNR Gillnet Short Net Age-0 (DW-10)	-0.13

Table 2.11. The back-transformed common trend resulting from the DFA model fitted to the all-ages Atlantic blacktip shark time-series of relative abundance along with associated uncertainty (**Panel A**; Latour and Peterson 2020, their Figure 5) along with DFA factor loadings by fleet (**Panel B**), provided from the authors of SEDAR65-AW03 (Latour and Peterson 2020), as described above in Section 2.2.2. Fleets as defined in **Table 2.8**.

Panel A

Year	Index	SE	CV
1990	0.306	0.9465	3.0895
1991	0.267	0.9139	3.4206
1992	0.276	0.8644	3.1266
1993	0.312	0.7876	2.5209
1994	0.353	0.6343	1.7963
1995	0.407	0.5596	1.3748
1996	0.321	0.4982	1.5538
1997	0.281	0.5001	1.7788
1998	0.607	0.4848	0.7992
1999	1.246	0.5007	0.4018
2000	1.257	0.5008	0.3986
2001	1.428	0.4852	0.3399
2002	1.727	0.5021	0.2907
2003	1.154	0.5061	0.4385
2004	1.440	0.4856	0.3372
2005	1.744	0.4986	0.2859
2006	1.264	0.4700	0.3720
2007	0.925	0.3373	0.3648
2008	0.503	0.3345	0.6651
2009	0.614	0.3282	0.5343
2010	0.478	0.3342	0.6985
2011	0.930	0.3342	0.3592
2012	1.660	0.3281	0.1977
2013	2.976	0.3342	0.1123
2014	2.404	0.3342	0.1390
2015	1.888	0.3282	0.1738
2016	0.812	0.3345	0.4118
2017	0.928	0.3374	0.3634
2018	0.869	0.3684	0.4240

Panel B

Fleet	Factor loadings
Shark Bottom Longline Fishery (DW-17)	0.416
Shark Research Fishery (DW-17)	0.325
VIMS Robust Series (DW-05)	0.145
NMFS-NEFSC Bottom Longline (DW-09)	0.304
SCDNR SEAMAP Longline Survey (DW-11)	0.674
SCDNR Red Drum Survey (DW-11)	-0.292

Table 2.12. Life history data obtained from the SEDAR65 DW report (their Table 1). Values in parentheses represent standard error unless otherwise noted. References are as listed within the SEDAR65 DW.

Parameter(s)	Value(s)	Reference(s)
Growth relationships	Female / Male / Sexes combined	
L_∞ (cm)	166.23 (2.47)/ 145.03 (1.82) / 159.30 (1.87)	SEDAR65-DW-02
K	0.16 (0.01) / 0.23 (0.02) / 0.17 (0.01)	SEDAR65-DW-02
t_o (years)	-2.59 (0.16) / -1.97 (0.16) / -2.51 (0.13)	SEDAR65-DW-02
Maximum observed age (years)	17.5 / 13.5	SEDAR65-DW-02
Sample size	269 / 278 / 547	SEDAR65-DW-02
Length-weight relationships		
PCL (cm)	PCL = 1.92990 + 0.885043*FL	SEDAR65-DW-15
NTL (cm)	NTL = 4.89349 + 1.15734*FL	SEDAR65-DW-15
STL (cm)	STL = 9.00754 + 1.16776*FL	SEDAR65-DW-15
Wt (kg)	$Wt = (4.63x10^{-6})FL^{3.21575}$	SEDAR65-DW-15
Age at 50% maturity		
Female	t_{mat}= 6.69 years	SEDAR65-DW-01
	a = -12.07 (2.52) b = 1.80 (0.35)	
Male	t_{mat}= 5.34 years	SEDAR65-DW-01
	a = -9.09 (1.72) b = 1.70 (0.29)	
Size at 50% maturity		
Female	FL_{mat}= 123.05 cm FL	SEDAR65-DW-01
	a = -30.09 (4.66) b = 0.24 (0.04)	
Male	FL_{mat}= 115.15 cm FL	SEDAR65-DW-01
	a =-31.41 (5.34) b = 0.27 (0.04)	
Reproductive cycle	Biennial	Castro 1996, Gelsleichter pers. comm.
Fecundity	4.09 (SD = 0.13) pups per brood	SEDAR65-DW-01
Maternal age/fecundity relationship	Brood size = -0.04078 + 0.38445*Age	SEDAR65-DW-01
Maternal size/fecundity relationship	Brood size = -5.82556+0.06857*FL	SEDAR65-DW-01
Gestation	11 months	Castro 1996, Ulrich et al. 2007
Pupping month	late May / June	Castro 1996, Ulrich et al. 2007, Frazier pers. comm.

Table 2.13. Minimum 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 in SEDAR65-DW19 (Cortés 2020, his Table 2) separately for females and males using the same methods, as described above in Section 2.3.

Females		Males	
Age	M	Age	M
0	0.198	0	0.273
1	0.198	1	0.237
2	0.198	2	0.203
3	0.185	3	0.183
4	0.171	4	0.170
5	0.161	5	0.161
6	0.153	6	0.155
7	0.147	7	0.150
8	0.143	8	0.147
9	0.139	9	0.144
10	0.136	10	0.142
11	0.133	11	0.140
12	0.131	12	0.139
13	0.130	13	0.138
14	0.128	14	0.137
15	0.127	15	0.137
16	0.126	16	0.136
17	0.125	17	0.136
18	0.125	18	0.136
19	0.124	19	0.136
20	0.123	20	0.135
21	0.123	21	0.135
22	0.123		
23	0.122		
24	0.122		
25	0.122		
26	0.122		
27	0.122		
28	0.121		
29	0.121		
30	0.121		
31	0.121		
Average	0.139	Average	0.158

Table 2.14. Mean estimates of instantaneous natural mortality rates (yr^{-1}) for use in Stock Synthesis model sensitivity analyses obtained with six life-history invariant estimators used in the Euler-Lotka and Leslie matrix approaches in SEDAR65-DW19 (Cortés 2020) separately for females and males, as described above in Section 2.3.

Females		Males	
Age	M	Age	M
0	0.261	0	0.340
1	0.252	1	0.328
2	0.247	2	0.322
3	0.244	3	0.318
4	0.241	4	0.315
5	0.239	5	0.314
6	0.238	6	0.312
7	0.237	7	0.311
8	0.236	8	0.311
9	0.235	9	0.310
10	0.235	10	0.310
11	0.234	11	0.309
12	0.234	12	0.309
13	0.234	13	0.309
14	0.233	14	0.309
15	0.233		
16	0.233		
17	0.233		
18	0.233		
Average	0.239	Average	0.315

Table 2.15 Commercial and recreational gear types were aggregated into four 'fleets' (F1, F2, F3, and F4) with similar length composition based on a review of the available length composition data cited in the footnotes (**Panel A**); Length composition data provided for fisheries-independent scientific surveys is identified in **Panel B**.

Panel A

Data source	Years of coverage	Sample size (number of sharks)	Fleet	Survey
Fishery dependent				
University of Florida Longline[1]	1994 – 2005	1,699	F1 (Com-BLL-Kept)	S1 (Shark-BLL-Obs)
Southeast Fisheries Science Center (SEFSC) Panama City Lab Shark Bottom Longline Observer Program (SBLOP)[1]	2005 – 2018	3,708	F1 (Com-BLL-Kept)	S2 (Shark-BLL-Res)
Southeast Fisheries Science Center (SEFSC) Panama City Lab Gillnet Observer Program (GNOP)[2]	1999 – 2018	1,477	F2 (Com-GN-Kept)	
Marine Recreational Information Program (MRIP)[1]	1981 – 2018	781	F4 (Recreational)	
Southeast Region Head Boat Survey (SRHS)[1]	1989 – 2018	107	F4 (Recreational)	
South Carolina Department of Natural Resources (SCDNR) Shore Fishing[1]	2013 – 2018	166	Recommended for use in stock assessment model sensitivity analyses during the AP	
	Total	**7,938**		

[1] SEDAR65-AW05 (Kroetz and Courtney 2020).
[2] SEDAR65-AW07 (Courtney et al. 2020).

Table 2.15. Continued

Panel B

Data source	Years of coverage	Sample size (number of sharks)		Survey
Fishery independent				
Virginia Shark Monitoring and Assessment Program (VASMAP)[1]	1990 – 2018	324		S3 (VIMS-BLL-Robust)
Southeast Fisheries Science Center (SEFSC) Bottom Longline[1]	1996 – 2018	19	Survey not recommended for use in the stock assessment model during the DW	
Northeast Fisheries Science Center (NEFSC) Bottom Longline[1]	1996 – 2018	638		S4 (NEFSC-BLL)
Southeast Area Monitoring and Assessment Program (SEAMAP) Longline (Georgia-University of North Florida)[1]	2007 – 2018	218	Survey not recommended for use in the stock assessment model during the DW	
South Carolina Department of Natural Resources (SCDNR) SEAMAP Longline[1]	2007 – 2018	1,032		S5 (SCDNR-SEAMAP-BLL)
South Carolina Department of Natural Resources (SCDNR) Red Drum longline[1]	1994 – 2008	301		S6 (SCDNR_Red_Drum_BLL)
South Carolina Department of Natural Resources (SCDNR) Drumline[1]	2013 – 2019	302		S7 (SCDNR-DL)
Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Longline[1]	1999 – 2019	641		S8 (COASTSPAN-BLL-All-ages)
Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Gillnet[1]	1999 – 2019	487		S9 (COASTSPAN-GNL-All-ages)
Florida Atlantic University Drumline/Longline[1]	2014 – 2019	123	Survey not recommended for use in the stock assessment model during the DW	
South Carolina Department of Natural Resources (SCDNR) Small Gillnet Survey[1]	2006 – 2019	275		S10 (COASTSPAN-GNS-Age-0)
	Total	**4,360**		

[1] SEDAR65-AW05 (Kroetz and Courtney 2020).

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, released 03/26/2020; 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) 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

Commercial landings, recreational catch, indices of abundance, life history, and length composition used in this assessment were obtained as described in the Data Workshop (DW) and

Assessment Process (AP) working documents summarized in Section 2 above and summarized here in **Table 3.1**.

3.2.1. Commercial Landings

Commercial landings were entered in Stock Synthesis in metric tons (one mt = 1,000 kg) aggregated into three “fleets” (F1 – F3) (**Table 3.1**):

F1 (Com-BLL-Kept) = Bottom longline (1983 – 2018);

F2 (Com-GN-Kept) = Gillnets (1983 – 2018); and

F3 (Com-Other-Kept) = Other gears + Unreported commercial catches (1983 – 2018).

Annual commercial landings of blacktip sharks in the U.S. Atlantic during the years 1983 – 2018 were obtained from the DW (lb. dressed weight; **Table 2.1**), converted to kilograms whole weight (kg ww; **Table 2.2**).

3.2.2. Recreational Catch

Recreational catch was entered in Stock Synthesis in numbers (thousands) aggregated into one fleet (F4):

F4 (Recreational) = Recreational A+B1+B2-Dead (1981 – 2018), as defined below.

Annual recreational catch of blacktip sharks in the U.S. Atlantic during the years 1981 – 2018 was obtained from the DW (numbers of sharks; **Tables 2.3**). The data were smoothed as described in DW recommendations and decisions summarized in the DW report. The smoothed annual recreational catch estimates of blacktip sharks in the Atlantic 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; B2-Live). Annual recreational type B2 catch estimates of blacktip sharks in the Atlantic were multiplied by an overall post-release mortality rate of 18.5% for hook and line recreational fisheries to obtain the number of fish released alive, that were estimated to have died (B2-Dead; **Table 2.3**) as described in DW recommendations and decisions summarized in the DW report.

3.2.3. Commercial Discards

Commercial discard estimates were not included in the base case model because of uncertainty in bycatch estimation as described in DW recommendations and decisions summarized in the DW report. Instead, commercial discard estimates were developed during the AP for use within sensitivity analyses, as described in Section 2.1.3 above, and summarized here. The AP Analytical Team implemented the DW recommendations for continued analyses of commercial discard estimates (both live and dead) from commercial gillnet and longline fisheries using multi-year block averaging of the discard ratios to create discard estimates (**Table 2.4**). The estimated annual number of live shark discards in commercial gillnet and bottom longline fisheries was multiplied by the DW recommended post release live-discard mortality rate estimates of 31% and 44.2%, respectively. The resulting post release mortality (PRM) estimates for live discards in the commercial gillnet and bottom longline fisheries were provided in **Table 2.4** for use in Stock Synthesis sensitivity model runs.

3.2.4. Low and High Catch Scenarios

Based on the DW recommendations, low and high catch scenarios were developed during the AP for use in sensitivity analyses, as described in Section 2.1.4 above, and summarized here. The AP Analytical Team made several changes to the base case input data (**Tables 2.5**) in order to develop the low and high catch scenarios. The Low Catch scenario (**Table 2.6**) used the annual percent standard error estimates (-1PSEs) available for both the A+B1 and B2 recreational time series for the years 1981-2018. The recreational post-release mortality rate lower 95% CL of 10.8% (vs. 18.5% in reference case) was applied to the -1PSE of B2. In contrast, the high catch scenario (**Table 2.7**) used the annual +1PSEs available for both the A+B1 and B2 recreational time series for the years 1981-2018. The recreational post-release mortality rate upper 95% CL of 28.7% (vs. 18.5% in reference case) was applied to the +1PSE of B2. The high catch scenario also included estimates of both commercial dead discards and commercial live discard post release mortality (**Table 2.4)** (converted to annual discard weight vs. no discards in reference case). The high catch scenario included a post-release mortality rate of 54.8% for bottom longline (vs. 44.2% in **Table 2.4**) and 44.4% for gillnets (vs. 31% in **Table 2.4**). The high catch scenario also used a dressed weight to whole weight conversion ratio of 2.0 (vs. 1.39 in reference case).

3.2.5. Indices of Abundance and Catchability

Ten indices of relative abundance (**Table 3.1**) were input in Stock Synthesis as "surveys" S1 – S10:
S1 (Shark-BLL-Obs) = Shark Bottom Longline Fishery (1994 – 2007);
S2 (Shark-BLL-Res) = Shark Bottom Longline Research Fishery (2008 – 2018);
S3 (VIMS-BLL-Robust) = VIMS Bottom Longline Robust Series (1990 – 2018);
S4 (NEFSC-BLL) = NMFS-NEFSC Bottom Longline (1996 – 2018);
S5 (SCDNR-SEAMAP-BLL) = SCDNR SEAMAP Bottom Longline Survey (2007 – 2018);
S6 (SCDNR-Red-Drum-BLL) = SCDNR Red Drum Bottom Longline Survey (1996 – 2006);
S7 (SCDNR-DL) = SCDNR Drumline Survey (2013 – 2018);
S8 (COASTSPAN-BLL-All-ages) = COASTSPAN Bottom Longline All-age (2005 – 2018);
S9 (COASTSPAN-GNL-All-ages) = COASTSPAN Gillnet Long Net All-age (2001 – 2018);
and S10 (COASTSPAN-GNS-Age-0) = SCDNR Gillnet Short Net Age-0 (2006 – 2018) as described below.

The ten indices of relative abundance were recommended by the Index Working Group of the Data Workshop for use in the base model configuration. The indices of relative abundance and the associated annual coefficients of variation (CVs) were obtained from both fisheries-dependent observer programs (S1 and S2) and fisheries-independent scientific surveys (S3 – S10), as described in Section 2.2.1 and **Table 2.8**.

Indices were input in the base model configurations with inverse CV weighting. Indices were treated as relative abundance and assumed to have log-normally distributed error. Inverse CV weighting was calculated as sqrt(ln(1+CV^2)), which is approximated by the CV. Annual CVs for each index were obtained from the DW (**Table 2.8**) and modified by data weighting as 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 S1 with time blocks (1981 – 1996, 1997 – 2004, 2005 – 2007) and for index S2 with time blocks (2008 – 2017, 2018). Time blocks were obtained based on the model fit to available length composition data for each survey, as described below. In contrast, time-blocks were not required to fit the available length composition data for the remaining surveys S3 – S10. Consequently, the median unbiased analytical solution for *q* was obtained from Stock Synthesis for these surveys by setting *q* equal to a constant scaling factor (Methot et al. 2020).

3.2.6. Alternative Index of Abundance Groupings

In response to DW recommendations, several AP working documents were produced that analyzed alternative abundance index groupings for use in sensitivity analyses, as described in Section 2.2.2 above, and summarized here. Combined indices included a Bayesian hierarchical age-0 index (**Table 2.9**), a combined Dynamic Factor Analysis (DFA) age-0 index (**Table 2.10**), and a combined DFA all-age index (**Table 2.11**) along with associated measures of uncertainty. Potential abundance index groupings for use in sensitivity analyses were also identified with hierarchical cluster analysis and cross-correlations.

However, both the Bayesian hierarchical and DFA analyses of age-0 indices produced similar results. Consequently, a decision was made in coordination with the AP Panel that sensitivity analysis to the Bayesian hierarchical analysis of age-0 indices would not implemented in the Stock Assessment. Preliminary model fits to the DFA age-0 index (Assessment Webinar V) resulted in a good fit to the index, but the model failed to converge within reasonable parameter bounds. Preliminary model fits to the DFA all-age index (Assessment Webinar V) resulted in a poor fit to the index and also included the same length data within multiple fleets. Consequently, a recommendation was made (Assessment Webinar V) to exclude DFA from further sensitivity analyses within this assessment, and to limit DFA analysis to fishery independent data in future assessments. In addition, alternative index groupings identified in the hierarchical cluster analysis and cross-correlations of accepted indices were not implemented in sensitivity analyses due to time constraints of the AP.

Consequently, a pragmatic decision was made in coordination with the AP Panel to conduct a single abundance index sensitivity analysis that removed the two relative abundance indices S4 (NEFSC-BLL) and S7 (SCDNR-DL), which had a relatively poor fit in preliminary runs of the Stock Synthesis reference case model (as described in the stock assessment results Section 3.4.1.2 below).

3.2.7. Life History Data

Life history data used in the stock assessment model were obtained directly from the DW report, and reproduced in **Table 2.12**, as described in Section 2.3 above. In addition, an AP working document developed vital rates and population dynamics parameters including Beverton-Holt stock-recruitment steepness (*h*) and natural mortality based on biological information provided in the DW report, as described in Section 2.3 above, and summarized here. The mean steepness value of 0.4 inferred from the deterministic methods using the theoretical longevity was recommended during the AP for use in the base case Stock Synthesis model. The minimum estimates of instantaneous natural mortality rates (**Table 2.13**) corresponding to the deterministic age-structured Euler-Lotka/Leslie Matrix approaches were recommended during the AP for use in the base case Stock Synthesis model. In addition, the lower and upper values of the range of steepness values obtained with the deterministic methods (0.32 and 0.52) were recommended during the AP for use in Stock Synthesis model low and high productivity states of nature sensitivity analyses. The mean estimates of instantaneous natural mortality rates (**Table 2.14**) corresponding to the deterministic age-structured Euler-Lotka/Leslie Matrix approaches were also provided during the AP for use in Stock Synthesis model sensitivity analyses.

3.2.8. Length Composition Data

The commercial and recreational gear types were aggregated into 'fleets' (F1, F2, F3, and F4) with similar length composition based on a review of the available length composition data, as described above in Section 2.4 (**Table 2.15)**, and summarized in **Tables 3.1** and **3.2**. This approach is consistent with the previous Atlantic HMS SEDAR benchmark stock assessment conducted in Stock Synthesis for Atlantic smooth dogfish (Anon. 2015). Fishery-independent length composition data were also provided for many of the fishery independent scientific survey indices of relative abundance as described above in Section 2.4 (**Table 2.15)**, and summarized in **Tables 3.1** and **3.2**.

A minimum annual sample size of 30 was established for the base model configuration (**Table 3.2**) 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 consistent with the previous Atlantic HMS SEDAR benchmark stock assessment conducted in Stock Synthesis for Atlantic smooth dogfish (Anon. 2015). However, the minimum annual sample size was reduced from 30 to 20 for fleet F4 in an effort to increase the number of years with recreational length composition data within selectivity time-blocks, as described below. Total sample size differs in some cases between **Table 2.15** and **Table 3.2** because sex specific data are included in **Table 3.2**. Length data in **Table 3.2** were also limited to the years with catch and survey data included in the base model configuration **(Table 3.1)**. Fits to length composition data by fleet and survey are provided below in the assessment model results section.

3.3. Model Configuration and Equations

The Stock Synthesis model for the Atlantic population of blacktip sharks is a single stock that encompasses the U.S. East Coast Atlantic waters defined in the DW report. Based on the DW recommendations, the end year of the assessment data included in the model was 2018, and the start year of the base model configurations was 1981, based on the availability of catch data.

3.3.1. Base Model Configuration

A two sex model was implemented in the base model configuration to account for sexually dimorphic growth (Natanson et al. 2019). 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 (Courtney et al. 2020; Kroetz and Courtney 2020). 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 in the base model configuration was set equal to 30 years for both sexes, which is consistent with the theoretical maximum age of females (31 years) and above that of males (21 years) obtained from the estimation of vital rates for the North Atlantic population of blacktip sharks (Cortés 2020). The theoretical maximum ages are well above the observed maximum age for females (17.5 yr) and males (13.5 yr) provided in the SEDAR 65 Data Workshop Report and reproduced here in **Table 2.12**.

3.3.1.1. Length at Age and Weight at Length

Growth in length at age for the base model configuration was assumed to follow the separate von Bertalanffy growth (VBG) relationships recommended in the DW report for females and males (**Table 2.12**). The VBG length at age-0 (LAmin = L_0 cm FL), VBG length at age-infinity (LAmax = L_{inf} cm FL), and VBG growth coefficient (k) were input in the assessment base model configurations as fixed parameters separately for males and females (**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.

In the base model configuration, the lower edge of the first population size bin was defined as 40 cm FL. The parameter for LAmin was defined as the length at age-0 and was fixed at 56.4 and 52.8 cm FL for females and males, respectively, following the VBG relationships described above. The parameter for LAmax was defined as the length at age-infinity (L_{inf}) and set equal to 166.2 and 145.0 cm FL for females and males, respectively, following the VBG relationships described above.

The VBG relationship implemented in the base model configuration resulted in a relatively larger length at age-0 (LAmin) for females and males (56.4 and 52.8 cm FL, respectively) than the approximate size at birth (c. 45 cm FL) obtained from the scientific literature. The approximate size at birth, c. 45 cm FL, was based on the midpoint of the range given in Castro (1996), which was 55-60 cm TL. Using the TL to FL relationship given in **Table 2.12** (NTL = 4.89349 + 1.15734 FL) resulted in 45 cm FL. Consequently, an attempt was made to account for growth from the approximate observed size at birth, c. 45 cm FL, by fixing the lower edge of the first population size bin equal to 40 cm FL in the base model configuration. The same approach was used in the SEDAR 39 Stock Synthesis model developed for Atlantic smooth dogfish (Anon. 2015) to address a similar discrepancy between the VBG relationship and the observed size at birth in that assessment.

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. In the base model configuration, 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 recent 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, for the base model configuration, 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 for Atlantic blacktip shark available in this assessment. However, stock assessment model sensitivity to the assumed uncertainty in length at age was evaluated by estimating the CVs for L_{Amin} and L_{Amax} within the logistic model sensitivity analysis, as described below.

Sex-specific weight (kg) at length (cm FL) was assumed to follow the sex-combined weight-at-length relationship recommended in the DW report $Wt = (4.63x10^{-6})FL^{3.21575}$ (**Table 2.12**). The two weight-at-length relationship parameters were input in the base model configuration as fixed parameters separately for males and females.

3.3.1.2. Annual Pup Production at Age

Annual pup production at age in the Stock Synthesis base model configuration (**Table 3.4**) was calculated as follows. Litter size (LS) was obtained as -0.04078 + 0.38445*Age (**Table 2.12)**, while imposing a minimum litter size of one and a maximum litter size of seven obtained from SEDAR65-DW-01 (Natanson et al. 2019, their Figure 1). Female fraction mature at age was obtained from the DW report (DW Section II, their Table 3; e.g., see equations in **Table 2.12**). Female fraction maternal at age was obtained from the fraction mature at age by assuming an 11 month gestation period (**Table 2.12**), approximated by 1-year from maturity to maternity. Pup production at age was obtained as (LS at age)* (Fraction Maternal at age). Annual pup production at age was obtained by assuming a two year reproductive cycle (**Table 2.12**) and calculated as [(LS at age)* (Fraction Maternal at age)]/two.

3.3.1.3. Stock Recruit Model and Steepness (*h*)

A Beverton-Holt (BH) stock-recruitment relationship was assumed and implemented in the base 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. For the base model configuration, the stock-recruit steepness parameter was fixed at a value obtained analytically based on life history, h = 0.40, obtained from the assessment document SEDAR65-AW02 (Cortés 2020), as described in Section 2.3 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 in the base model configuration 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.

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 (in 1,000s) multiplied by annual pup production at age at the beginning of each calendar year assuming a 1:1 ratio of male to female pups.

An examination of preliminary base model configuration output with the program r4ss (Taylor et al. 2020) indicated that there was little recruitment information in the data prior to the mid-1990s. There was also a ramp up in recruitment information from about 1994 until the mid-2000s consistent with the increasing availability of length composition data during that time period (**Table 3.2**). Consequently, main recruitment deviations were estimated in the base model configuration during the years 1994 – 2012, with early recruitment deviations beginning 10 years prior to the main recruitment (1984 – 1993). Main recruitment deviations are zero centered. The estimation of early recruitment deviations allows for recruitment in early periods without biasing recruitment estimates in the main period.

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 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.

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. In the base model configuration, ‘spawning’ timing was defined as January 1 and recruitment timing was defined as July 1 (month 7) approximately one month after pupping, which occurs for Atlantic blacktip sharks in late May and June (**Table 2.12**). The timing of reproductive output in the base model configuration is consistent with the previous 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 base model configuration at age-specific values, separately for females and males, obtained independently with life history invariant methods in the assessment document SEDAR65-AW02 (Cortés 2020), as described above in Section 2.3 and provided in **Table 2.13.** Natural mortality was assumed to occur beginning at age-0 consistent with the previous 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 SEFSC PCL to conduct Atlantic HMS domestic shark stock assessments (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**) and fit to the available length composition data (40 – 165+ cm FL straight with a 5 cm bin width; Kroetz and Courtney 2020; Courtney et al. 2020). 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 (Kroetz and Courtney 2020; Courtney et al. 2020) separately for each fleet with the SELEX24 helper spreadsheet.[1] Selectivity at the first bin (p5) was fixed at the values obtained with the SELEX24 helper spreadsheet, and the remaining parameters were estimated within the base model configuration setting initial values equal to those obtained with the SELEX24 helper spreadsheet. This approach allowed for either asymptotic selectivity or dome-shaped selectivity depending on base model configuration fits to the available length composition 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 with the SELEX24 helper

[1] (SELEX24 helper spreadsheet available: https://vlab.ncep.noaa.gov/web/stock-synthesis; accessed August 2020)

spreadsheet, the prior means for the double normal selectivity function were set equal to estimated values obtained from preliminary model runs of the base model configuration.

Sex-specific selectivity was implemented for fleets with sufficient sex-specific length composition data (F1, S3 – S10; **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, 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.

Asymptotic selectivity was proposed during Assessment Webinars II and IV for fleets that capture the largest sharks F1 (Com-BLL-Kept), F2 (Com-GN-Kept), S4 (NEFSC-BLL), and S7 (SCDNR-DL) (**Table 3.5**). An assumption was that large sharks would be targeted and retained (kept) by both the commercial bottom longline and gillnet fisheries. An examination of the available fishery-dependent length composition data obtained from observer programs identified predominantly large sharks (> size at maturity) in both F1 (Com-BLL-Kept; Kroetz and Courtney 2020) and F2 (Com-GN-Kept; Courtney et al. 2020). Similarly, an examination of the available fishery-independent length composition data obtained for surveys S4 (NEFSC-BLL) and S7 (SCDNR-DL) identified that they also captured predominantly large sharks (> size at maturity) (Kroetz and Courtney 2020). The remaining fleets and surveys all captured relatively smaller sharks (Kroetz and Courtney 2020).

Asymptotic selectivity was implemented with a logistic selectivity curve for F1, F2, S4, and S7 in preliminary model runs. 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 base model configuration for F1, F2, S4, and S7 with final selectivity at the largest size bins estimated in the model based on fit to the length composition data, as described above.

Time blocks were added to the estimation of selectivity for F1 (1981 – 1996; 1997 – 2004; 2005 – 2007; 2008 – 2017,2018), F2 (1981 – 2006; 2007 – 2018), and F4 (1981 – 1989; 1990 – 1999; 2000 – 2018) in order to account for observed inter-annual variation observed in Pearson residuals of preliminary model fits to length composition data for these fleets (**Table 3.5**). Corresponding time blocks were also added to the estimation of catchability, *q*, for surveys S1 and S2, as described above, because the surveys S1 and S2 are fit using the length based selectivity obtained for F1 (mirrored F1; **Table 3.5**).

In preliminary model runs, the addition of time blocks resulted in a very large number of poorly estimated selectivity parameters (i.e., CVs > 50%, highly correlated > 0.95, 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) the large number of poorly estimated selectivity parameters. Poorly estimated selectivity time block parameters were fixed to their estimated values obtained during the time block with the most data. 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 parameters were fixed at their initial values obtained as described above. In addition, the minimum sample size was reduced from 30 to 20 for fleet F4, as described above, in order to increase the number of years of length composition data available in each time block. The final year of length composition data for F2 (2018) was removed from the model because of low sample size of females in 2018.

3.3.1.7. Data Weighting

A Francis (2011) two-stage data weighting approach was implemented in the base 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)
$$\mathrm{RMSE}_{smoother} = \sqrt{\left(\tfrac{1}{N}\right)\sum_{t=1}^{N}\left(Y_t - \hat{Y}_t\right)^2} \quad .$$

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 base model configuration 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 data **at best** as well as the smoother (Francis 2011; Lee et al. 2014a, 2014b; e.g., Courtney et al. 2017b).

On the 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 S1 – S10 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 length composition variance adjustment factors for the base model configuration 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, which was consistent with the RMSE of recruitment variability obtained from the main recruitment deviation period (0.28, 1994 – 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):

```
   1979  #_last_yr_nobias_adj_in_MPD; begin of ramp
   2012  #_first_yr_fullbias_adj_in_MPD; begin of plateau
 2018.8  #_last_yr_fullbias_adj_in_MPD
 2018.9  #_end_yr_for_ramp_in_MPD
 0.6913  #_max_bias_adj_in_MPD
```

3.3.1.9. Initial Population State

The Atlantic blacktip shark 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 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 (>1.00E-05) 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

Uncertainty 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).

Markov Chain Monte Carlo, MCMC, was proposed during the AP to obtain MCMC credibility intervals for some estimated and derived parameters. However, MCMC credibility intervals are not available for this report because of time constraints resulting from the 2019 Covid-19 crisis including a lack of IT resources necessary to perform MCMC analyses while on mandatory telework.

3.3.1.12. Sensitivity Analyses

The base model configuration sensitivity to selectivity and natural mortality was evaluated with a logistic sensitivity analysis. The logistic sensitivity analysis was implemented by modifying the base model configuration to include asymptotic selection (full selection) at large lengths for fleets and surveys that captured blacktip sharks at relatively large lengths. The logistic sensitivity analysis also implemented mean natural mortality obtained from life history invariant methods

(Section 3.1.7; **Table 2.14**) and estimated the CVs for L_{Amin} and L_{Amax} (Section 3.3.1.1) within the model. In addition, the CVs of length at age-0 and length at age-Linf were estimated within the length-at-age transition matrix, and the minimum annual length composition sample size was reduced from 30 to 20 for fleet F2, as described in Section 3.4.4.1 below.

Additional sensitivity analyses to the base model configuration were proposed during the AP:

Low Catch scenario (Sections 2.1.4 and 3.2.4; **Tables 2.5** and **2.6**);
High Catch scenario (Sections 2.1.4 and 3.2.4; **Tables 2.5** and **2.6**);
Remove CPUE indices S4 (NEFSC-BLL) and S7 (SCDNR-DL) (Section 3.2.6);
Low Productivity (stock recruit steepness h = 0.32, Sections 2.3 and 3.2.7); and
High Productivity (stock recruit steepness h = 0.52, Sections 2.3 and 3.2.7).

However, the additional sensitivity analyses are not available for this report because of time constraints resulting from the 2019 Covid-19 crisis including a lack of IT resources necessary to perform additional sensitivity analyses while on mandatory telework.

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, 2018 (SSF_{2018}, and F_{2018}). 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 the current 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 current 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 ≥ 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 Atlantic blacktip shark stock 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 base model configuration, $\bar{M}_a$ was calculated as the arithmetic mean of the female age-specific values of *M* used for the baseline run (0.139; **Table 2.13**). Consequently, for the base 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

Projections for the Stock Synthesis base model configuration are provided separately as a Review Workshop document. The projection methods follow those from a previous Atlantic HMS sandbar shark update assessment conducted in Stock Synthesis version 3.24 (Anon 2017a) and updated to Stock Synthesis version 3.30 (Anon 2017b; Courtney and Rice 2020).

Markov Chain Monte Carlo, MCMC, projections were proposed during the AP. However, MCMC projections are not available for this report because of time constraints resulting from the 2019 Covid-19 crisis including a lack of IT resources necessary to perform MCMC analyses while on mandatory telework.

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. The final gradient was reasonably small ($5.49*10^{-5}$) and no parameters were estimated above the maximum correlation threshold *(cormax = 0.95)* or below the minimum correlation threshold (*cormin* = 0.01). No parameters were estimated on a boundary condition, and CVs were less than 0.5 for all estimated parameters excluding recruitment deviations (**Table 3.7**).

3.4.1.2. Indices of Abundance and Catchability

Model fits to indices of abundance included in the base 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. Estimates of catchability, *q*, are provided for indices S1 (with time blocks during the years 1981 – 1996, 1997 – 2004, and 2005 – 2007) and S2 (with time blocks during the years

2008 – 2017 and 2018) (**Table 3.8; Figure 3.2**). The median unbiased analytical solution for q, calculated in Stock Synthesis, is provided for the remaining indices S3 – S10 (**Table 3.8; Figure 3.2**). Fits to the indices of abundance S4 (NEFSC-BLL) and S7 (SCDNR-DL) were poor. Fits to the remaining indices appeared to balance high inter-annual variability within each of the individual indices.

3.4.1.3. Length Composition

Fits to length composition included in the base 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 the annual length compositions within each length composition data set were generally poor (**Figure 3.3**). Time-blocks and sex specific selectivity were added in preliminary model runs to improve the fits to fleets F1, F2, and F4. However, 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. The maximum diameter of Pearson residuals was relatively large for F4 (Recreational catch, Max = 10), S7 (SCNDR Drum Line, Max = 8), and S9 (COASTSPAN Gillnet Long, Max = 4) indicating a relatively poorer fit to these length composition data sets than to the others.

In contrast, fits to aggregate length compositions (**Figure 3.4**) appeared to be reasonably accurate – indicating that the estimated selectivity curves in the base model configuration removed sharks from the modeled population in aggregate at comparable length to that observed in the data for each fleet and survey.

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**. 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).

3.4.1.5. Length Based Selectivity

Estimated selectivity at length (cm FL straight) obtained in the base 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 base model configuration are provided in **Table 3.9** and **Figure 3.6**. Estimated log recruitment deviations were estimated for early (1984 – 1993), main (1994 – 2017), late (2018), and forecast (2019) 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 the early recruitment period (1918 – 1984) and during the forecast period 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 base model configuration. First, the instantaneous annual fishing mortality rate (Continuous *F*) was obtained from Stock Synthesis output separately for each fleet F1 – F4 (**Figure 3.8**). A plot of total annual landings (mt) by fleet is also provided (**Figure 3.8)** for comparison. Total annual landings include both commercial landings (mt) and recreational catch (A + B1 + B2-Dead), as described above. Recreational catch data were entered in numbers (1,000s) and converted internally within Stock Synthesis to weight (mt) based on the weight at length of recreational fishery (F4) removals obtained from Stock Synthesis.

Second, the total fishing mortality rate across all fleets was obtained from Stock Synthesis output as the total annual fishing mortality rate experienced by the population (F=Z-M) (**Table 3.9**). Total annual F is provided relative to F_{MSY}, F/F_{MSY}, along with the asymptotic standard error of the derived quantity obtained from Stock Synthesis output (**Table 3.10** and **Figures 3.8** and **3.9)**.

3.4.3. Stock Biomass (Total and Spawning Stock)

Annual total biomass, *B*, and annual spawning stock fecundity, SSF, obtained from the base model configuration are provided in **Table 3.9**. Annual SSF is provided relative to $\mathrm{SSF_{MSY}}$, $\mathrm{SSF/SSF_{MSY}}$, 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, and as a result, the asymptotic standard error of the derived quantity is not available from Stock Synthesis output. Consequently, annual SSF is plotted along with its asymptotic standard error obtained from Stock Synthesis and then compared to MSST (**Figure 3.9)**.

3.4.4. Sensitivity Analyses

3.4.4.1. Logistic Selectivity

The logistic sensitivity analysis was implemented by modifying the base model configuration to include asymptotic selection with full selection (selectivity equal to 1.0) at large lengths for fleets and surveys that captured blacktip sharks at relatively large lengths. Results of the logistic sensitivity analysis are provided in **Appendix 3.B** and are described below.

The base model configuration was modified to include logistic selectivity with full selection (selectivity equal to 1.0) at large lengths for fleets F1 and F2 and surveys S4 and S7 (**Table 3.B.1)**. Preliminary model runs with this selectivity configuration resulted in poor fits to length composition data sets at the largest sizes for fleets F1 and F2 and surveys S4 and S7 (not shown). Consequently, the following additional modifications from the base model configuration were implemented in the logistic sensitivity analysis in an effort to improve fits to these length composition data sets at the largest sizes. The mean natural mortality at age for females and males obtained from life history invariant methods (**Table 2.14**) was implemented in order to evaluate the effect of natural mortality on the numbers at length at the largest sizes in the modeled population. The CVs of length at age-0 and length at age-Linf within the length-at-age transition matrix were estimated (separately for females and males; **Figure 3.B.1**) in an effort to include additional estimated process in the model fit to length composition data at both the youngest and oldest ages. The minimum annual length composition sample size was reduced from 30 to 20 for fleet F2 (**Table 3.2**) in an effort to include more years of annual length composition data within selectivity time-blocks for F2.

After making the modifications indicated above, the logistic sensitivity analysis was implemented analogously to the base model configuration. Two stage data weighting for the logistic sensitivity analysis is provided in **Table 3.B.2**. Estimated catchability, *q*, for surveys S1, and S2 along with the median unbiased analytical solution for *q* obtained for the remaining fleets are provided in **Table 3.B.3**. The steepness of the Beverton-Holt stock recruit relationship, h = 0.4, and the parameter representing the standard deviation in recruitment, σ_R = 0.28 for the main recruitment deviation period (1994 – 2017), were unchanged from the base model configuration. The years chosen for bias adjustment, and the maximum bias adjustment parameter value for the logistic sensitivity analysis were obtained analogously to the base model configuration:

```
1977.2  #_last_yr_nobias_adj_in_MPD; begin of ramp
2012.2  #_first_yr_fullbias_adj_in_MPD; begin of plateau
2018.8  #_last_yr_fullbias_adj_in_MPD
  2019  #_end_yr_for_ramp_in_MPD (Stock Synthesis sets bias_adj to 0.0 for fcast yrs)
0.6839  #_max_bias_adj_in_MPD (-1 to override ramp and set biasadj=1.0 for all estimated recdevs)
```

The Hessian matrix for the logistic sensitivity analysis inverted and, consequently, was assumed to be positive definite. No parameters were estimated above the maximum correlation threshold *(cormax = 0.95)* or below the minimum correlation threshold (*cormin* = 0.01). No parameters were estimated on a boundary condition. In contrast to the base model configuration, three estimated parameters in the logistic sensitivity analysis had CVs > 0.5 (excluding recruitment deviations). The final gradient for the logistic sensitivity analysis ($1.03*10^{-4}$) was also relatively larger than that obtained for base model configuration $5.49*10^{-5}$.

Parameter estimates for the logistic sensitivity analysis along with their priors, asymptotic standard errors, and resulting CVs are provided in **Table 3.B.4**.

The estimated CVs in length at age-0 and length at age-Linf obtained in the logistic sensitivity analysis resulted in a narrower distribution of length at age for the oldest ages (**Figure 3.B.1**) compared to the base model configuration (**Figure 3.1**). Fits to the standardized indices of relative abundance in the logistic sensitivity analysis (not shown) were indistinguishable from those obtained for the base model configuration (**Figure 3.2)**. Fits to the annual length compositions for fleets F1 and F2 and surveys S4 and S7 were relatively poor at the largest sizes (**Figures 3.B.2** and **3.B.3**) compared to those obtained for the same fleets in the base model configuration (**Figures 3.3** and **3.4**). As expected, selectivity at length estimated within the logistic sensitivity analysis increased asymptotically (to a maximum of 1.0) at the largest sizes (≥

150 cm FL straight) for fleets F1 and F2 and surveys S4, and S7, but also for survey S3 (**Figure 3.B.4**). In contrast, selectivity at length estimated within the base case model configuration decreased asymptotically at the large sizes (≥ 150 cm FL straight) with the shape of the descending selectivity curve and its asymptotic value at the large sizes estimated based on model fit to the length composition data (**Figure 3.5**). Males were fully selected for survey S7 in the logistic sensitivity analysis (**Figure 3.B.4**). In contrast, females were fully selected for S7 in the base model configuration (**Figure 3.5**).

The estimated main log recruitment deviations (1994 – 2007) were similar in the logistic sensitivity analysis (**Figure 3.B.5**) and the base model configuration (**Figure 3.6**). However, the base model configuration resulted in increasing recruitment (positive recruitment deviations) for the most recent two years (2017, 2018), while the logistic sensitivity analysis resulted in recruitment deviations closer to zero in 2017 and 2018. The logistic sensitivity analysis also resulted in relatively more recruitment deviations below zero in early years (< 1994). Expected recruitment from the stock-recruitment relationship and the bias adjustment applied to the stock-recruitment relationship were similar for the logistic sensitivity analysis (**Figure 3.B.6**) and the base model configuration (**Figure 3.7**). However, the logistic sensitivity analysis resulted in fewer years with log deviations > 0.5 (2013) compared to the base model configuration (2000, 2001, and 2013).

Annual total biomass, *B*, spawning stock fecundity, SSF, and total fishing mortality (*F=Z-M*) were relatively lower in the logistic sensitivity analysis (**Table 3.B.5**) compared to the base model configuration (**Table 3.9**). In contrast, the annual numbers of age-0 recruits were relatively larger in the logistic sensitivity analysis (**Table 3.B.5 and Figure 3.B.5**) compared to the based model configuration (**Table 3.9** and **Figure 3.6**). Fishing mortality by fleet (Continuous *F*) was dominated by the recreational catch for both the logistic sensitivity analysis (**Figure 3.B.7**) and the base model configuration (**Figure 3.8**).

As described above, recreational catch data were entered in numbers (1,000s) and converted internally within Stock Synthesis to weight (mt) based on the weight at length of recreational fishery (F4) removals obtained from Stock Synthesis. The logistic sensitivity analysis conversion in stock Synthesis from numbers to mt resulted in relatively larger recreational catch in weight (A + B1 + B2-Dead) during the years 2000 – 2018 (**Figure 3.B.7**, Upper panel) compared to the base model configuration (**Figure 3.8**, Upper panel). One explanation for this difference is that the double normal selectivity function implemented for fleet F4 resulted in relatively higher selectivity at large size (and, as a result, larger recreational catch in weight) in the logistic sensitivity analysis compared to the base case. The logistic sensitivity analysis resulted in a **fixed** parameter value at a relatively larger final selectivity during the years 2000 – 2018 (Size_DblN_end_logit_F4_Rec_A_B1_B2PRM(4) fixed at a value of -1.20; **Table 3.B.4** and **Figure 3.B.4).** In contrast, the **estimated** parameter value obtained in the base model configuration (Size_DblN_end_logit_F4_Rec_A_B1_B2PRM(4) estimated at a value of -3.21; **Table 3.7** and **Figure 3.5**).

In general, the observed differences in selectivity obtained from each model (when fit to the same observed length composition data) are consistent with the different underlying predicted population numbers at age obtained from each model (**Figure 3.B.9**). In addition, the predicted population numbers at age obtained from each model are also multiplied by different age-length transition matrices in each model (**Figures 3.B.1** and **3.1**) to produce the underlying predicted population numbers at length in each model (**Figure 3.B.10**). The predicted population numbers at length in each model are then multiplied by the different selectivity at length (and different continuous fishing mortality for each fishing fleet) obtained for each model (**Figures 3.B.4** and **3.5**) to produce the predicted proportions at length for each model (**Figures 3.B.2** and **3.3**).

Annual total fishing mortality ($F=Z-M$) relative to MSY (F/F_{MSY}) was lower for the logistic sensitivity analysis (**Table 3.B.6; Figures 3.B.7** and **3.B.8**) compared to the base model configuration (**Table 3.10**; **Figures 3.8** and **3.9**). Annual total F exceeded F_{MSY} during the years 1997 – 2006 for the logistic sensitivity analysis (**Table 3.B.6; Figure 3.B.8)**. In contrast, annual total F exceeded F_{MSY} during the years 1993, 1995, 1997 – 2009, and 2014 for the base model configuration (**Table 3.10; Figure 3.9)**.

Annual spawning stock fecundity, SSF, did not fall below the MSST for either the logistic sensitivity analysis (**Table 3.B.6; Figure 3.B.8**) or the base model configuration (**Table 3.10;**

Figure 3.9). SSF relative to MSY (SSF/SSF_{MSY}) was similar for the logistic sensitivity analysis (**Table 3.B.6**) compared to the base model configuration (**Table 3.10**). SSF approached SSF_{MSY} and then recovered for both the logistic sensitivity analysis (**Figure 3.B.8**) and the base model configuration (**Figure 3.9**).

SSF approached SSF_{MSY} earlier for the logistic sensitivity analysis (2009 – 2012; **Table 3.B.6** and **Figure 3.B.8**) compared to the base model configuration (2012 – 2015; **Figure 3.9**). SSF also recovered to a relatively higher level in the terminal year of the assessment, 2018, for the logistic sensitivity analysis (SSF_{2018}/SSF_{MSY} = 1.39, SE = 0.286; **Table 3.B.6**; **Figure 3.B.8**) compared to the base model configuration (SSF_{2018}/SSF_{MSY} = 1.16, SE = 0.255; **Table 3.10**; **Figure 3.9**)

3.4.5. Benchmarks and Reference Points

The base model configuration predicted that the stock was not overfished (SSF_{2018} > MSST) and that the stock was not experiencing overfishing ($F_{2018} > F_{MSY}$) in the terminal year of the assessment (**Tables 3.10** and **3.11; Figures 3.9** and **3.10).** In contrast, the base model configuration predicted that the stock had experienced overfishing, annual total $F > F_{MSY}$, during some years of the assessment: 1993, 1995, 1997 – 2009, and 2014 (**Table 3.10**; **Figures 3.9** and **3.10**).

Similarly, the logistic sensitivity analysis also predicted that the stock was not overfished (SSF_{2018} > MSST) and that the stock was not experiencing overfishing ($F_{2018} > F_{MSY}$) in the terminal year of the assessment (**Tables 3.B.6** and **3.11; Figures 3.B.8** and **3.B.11)**. The logistic sensitivity analysis also predicted that the stock had experienced overfishing, annual total $F > F_{MSY}$, during some years of the assessment: 1997 – 2006 (**Table 3.B.6**; **Figures 3.B.8** and **3.B.11**).

Markov Chain Monte Carlo, MCMC, was proposed during the AP for use to obtain MCMC credibility intervals for benchmarks. However, MCMC credibility intervals are not available for this report because of time constraints resulting from the 2019 Covid-19 crisis including a lack of IT resources necessary to perform MCMC analyses while on mandatory telework.

3.4.6. Projections

Projections results for the Stock Synthesis base model configuration are provided separately in a Review Workshop document.

Markov Chain Monte Carlo, MCMC, was proposed during the AP for use to obtain MCMC credibility intervals for projections. However, MCMC credibility intervals are not available for this report because of time constraints resulting from the 2019 Covid-19 crisis including a lack of IT resources necessary to perform MCMC analyses while on mandatory telework.

3.5. Discussion

Stock status determinations obtained from the base model configuration and the logistic sensitivity analysis were consistent. Both models predicted that the stock was not overfished (SSF_{2018} > MSST) and that overfishing was not occurring ($F_{2018} > F_{MSY}$) in the terminal year of the assessment (**Table 3.11**, **Figures 3.10** and **3.B.11**).

Both the base model configuration and the logistic sensitivity analysis predicted that the stock had experienced overfishing, annual total $F > F_{MSY}$, prior to the terminal year. The base model configuration predicted that the stock had experienced overfishing during the years 1993, 1995, 1997 – 2009, and 2014 (**Table 3.10**; **Figures 3.9** and **3.10**). The logistic sensitivity analysis predicted that the stock had experienced overfishing during the years 1997 – 2006 (**Table 3.B.6**; **Figures 3.B.8** and **3.B.11**).

SSF declined in response to increased fishing mortality relatively earlier for the logistic sensitivity analysis (2009 – 2012; **Table 3.B.6** and **Figure 3.B.8**) compared to the base model configuration (2012 – 2015; **Figure 3.9**). SSF also recovered in response to reduced fishing mortality relatively more quickly (SSF_{2018}/SSF_{MSY} = 1.39, SE = 0.286; **Table 3.B.6**; **Figure 3.B.8**) compared to the base model configuration (SSF_{2018}/SSF_{MSY} = 1.16, SE = 0.255; **Table 3.10**; **Figure 3.9**)

One explanation for the different trajectories in recovery of SSF relative to SSF_{MSY} may be the higher natural mortality rate imposed in the logistic sensitivity analysis, which resulted in a compressed age structure. The base case model implemented the minimum estimates of instantaneous natural mortality rates obtained from life history invariant methods, as recommended during the AP (**Table 2.13**). In contrast, the logistic sensitivity analysis implemented relatively higher mean estimates of instantaneous natural mortality rates obtained from the same life history invariant methods (**Table 2.14**). The relatively higher natural mortality rates were implemented in an attempt to improve the logistic sensitivity model fit to the largest sharks (> 150 cm FL) by reducing the number of older (and larger) sharks in the underlying modeled population. Implementing the relatively higher natural mortality in the logistic sensitivity analysis had the anticipated effect of reducing the proportion of older (and larger) sharks compared to the base model configuration (**Figures 3.B.9** and **3.B.10**). The compressed age structure resulting from higher natural mortality in the logistic sensitivity analysis may have resulted in a more rapid response in the modeled population to changes in fishing mortality over time.

In addition, the effect of imposing logistic selectivity for fleets F1 and F2 (which capture relatively large sharks > 150 cm FL) also removed large sharks (> 150 cm FL) from the underlying modeled population at proportionally higher rates than smaller sharks. The anticipated effect of the compressed age structure resulting from imposing logistic selectivity is also a more rapid response in the modeled population to changes in fishing mortality over time, as described above.

In contrast, as described above in Section 3.3.1.6, the implementation of a double normal selectivity function in the base model configuration allowed for either asymptotic selectivity or dome-shaped selectivity to be estimated within the model based on the model fit to the available length composition data. Fits of the base model configuration to the available length composition data resulted in dome-shaped selectivity for fleets F1 and F2 with proportionally fewer large sharks (> 150 cm FL) selected by these fleets.

The anticipated effect of proportionally fewer smaller (immature) sharks in the underlying modeled population under dome-shaped selectivity is a lagged recovery of SSF following a reduction of fishing mortality by approximately one generation (Anon. 2017b). Following a reduction of fishing mortality, mature females alive at the time in the modeled population must first produce pups, the pups must then survive until maturity at higher rates under reduced fishing mortality, and then they must produce pups of their own before contributing to an observed increase in SSF.

This is the first time that Atlantic blacktip sharks have been assessed using Stock Synthesis within SEDAR. An advantage of the integrated modeling approach is that the development of statistical models that combine several sources of information into a single analysis allows for consistency in assumptions and permits the uncertainty associated with all data sources to be propagated to final model outputs (Maunder and Punt 2013).

However, a disadvantage of utilizing a pre-packaged integrated modeling approach is that increased model complexity of the package itself can lead to the possibility of implementation errors when developing a new model. Arguably, the amount of time required by an analyst to detect and correct implementation errors in a new complex integrated stock assessment model can be similar to the amount of time required to program and debug a new tailored stock assessment model (Courtney et al. 2007). In order to accommodate the extended timeline required to implement a new Stock Synthesis model for Atlantic blacktip sharks well as the modified AP time line required to accommodate additional analyses of commercial catch data, additional stock assessment modelling platforms were not evaluated.

In an attempt to gain efficiencies from previous Stock Synthesis experience within the SEFSC PCL stock assessment enterprise, this implementation of the Atlantic blacktip shark Stock Synthesis model and the format of this assessment report followed a previous Atlantic HMS SEDAR benchmark stock assessment conducted in Stock Synthesis (version 3.24) by the SEFSC PCL for Atlantic smooth dogfish (Anon. 2015). However, two major advancements were made in this integrated Stock Synthesis model.

First, as described above, length based selectivity was estimated internally within Stock Synthesis based on model fits to the available length composition data. The implementation of length based selectivity was adapted from a North Pacific swordfish assessment implemented in Stock Synthesis (Courtney and Piner 2009, 2010). In contrast, the length based selectivity implemented in previous Atlantic HMS domestic shark stock assessments conducted by the SEFSC PCL with both Stock Synthesis (Anon. 2015) and SSASPM (Anon. 2012, 2013a, 2013b) depended upon obtaining selectivity externally to the stock assessment model.

Second, as described above, recreational catch (A + B1 + B2-Dead) was entered in Stock Synthesis in its native format (numbers in 1000s) and then converted within Stock Synthesis to weight (mt) based on the underlying modeled population numbers at age, the modeled length at age relationship along with its uncertainty, and the estimated length based selectivity of the recreational fishery (F4). In contrast, the recreational catch entered in previous Atlantic HMS domestic shark stock assessments conducted by the SEFSC PCL with both Stock Synthesis (Anon. 2015) and SSASPM (Anon. 2012, 2013a, 2013b) depended upon obtaining recreational catch in weight externally to the model using conversion factors.

3.6. Recommendations for Future Research and Data Collection

Additional research may be needed on the variable effects of Federal and state recreational management actions on the annual length composition of Atlantic blacktip shark recreational catch (A + B1 + B2-Dead). During Assessment Webinars I and III, it was discussed that data limitations resulting from recreational length sampling might not accurately reflect the effect of

Federal management actions on length composition of retained and discarded Atlantic blacktip sharks over time. Federal management actions include implementation of a minimum size limit (54 inches straight fork length) in Federal waters during calendar years 2000 – 2018 and the implementation of Federal bag limits of 4 LCS (Large Coastal Sharks; 1993), 2 LCS (1997) and 1 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.

The selectivity parameterization approach implemented here estimated selectivity parameters where possible and fixed (or reformulated) poorly estimated selectivity parameters where necessary. 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). This pragmatic approach was implemented here in order to remove sharks from the modeled population at the correct aggregate size sampled by each data set (**Figures 3.4 and 3.B.3**), while allowing relatively poorer fits to some poor quality annual length composition data sets (e.g., because of low sample size; **Figures 3.3 and 3.B.2**). An assumption was that poor quality annual length composition data sets were not necessarily representative of annual changes in the length composition sampled in that year (e.g., because of low sample size and observation error). In contrast, the aggregate length composition data obtained from the poor quality data were assumed to be representative of the length composition sampled in that data set (e.g., because of higher sample size and reduced observation error in aggregate). 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.

The observation of proportionally few large sharks in the sampled length composition data compared to that expected based on life history may result for reasons other than dome-shaped selectivity. 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 also 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. An attempt was made here to evaluate the effect of uncertainty in selectivity for fleets F1 and F2 and surveys S4 and S7 on the underlying population numbers at age predicted over time within the stock assessment model by implementing logistic selectivity for F1, F2, S4, and S7 within the logistic sensitivity analysis.

A growing number of model diagnostic methods are becoming available for use in integrated stock assessment models such as Stock Synthesis (e.g., Maunder and Piner 2015, 2017; Carvalho et al. 2017). Examples of implementing some of these diagnostic methods were provided as reference document (SEDAR65-RD13; Courtney et al. 2020). However, this set of diagnostics was not implemented within the current assessment due to time constraints. Additional research is also ongoing to improve the interpretation of model diagnostics in both model development and in model selection for use in providing management advice. For example, Maunder et al (2020) describe a risk-based approach based on individual model diagnostic results that assigned different weights to models used for management advice within an ensemble of candidate models.

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 a SSASPM (Anon. 2012, 2013a, 2013b).

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. Consequently, an attempt was made here to evaluate model sensitivity to the combined effect of these interactions by estimating the CV in L_{Amin} within the logistic model sensitivity analysis described above.

3.7.References

Anonymous. 2012. HMS Gulf of Mexico blacktip shark. SEDAR 29 stock assessment report. May 2012. SEDAR, 4055 Faber Place Drive, Suite 201, North Charleston, SC 29405. Available: http://sedarweb.org/docs/sar/S29_GOM%20blacktip%20report_SAR_final.pdf (Accessed August 2020).

Anonymous. 2013a. HMS bonnethead shark. SEDAR 34 stock assessment report. September 2013. SEDAR, 4055 Faber Place Drive, Suite 201, North Charleston, SC 29405. Available: http://sedarweb.org/docs/sar/S34_Bonnethead_SAR.pdf (Accessed August 2020).

Anonymous. 2013b. HMS Atlantic sharpnose shark. SEDAR 34 stock assessment report. September 2013. SEDAR, 4055 Faber Place Drive, Suite 201, North Charleston, SC 29405. Available: http://sedarweb.org/docs/sar/S34_ATSH_SAR.pdf (Accessed August 2020).

Anonymous. 2015. HMS Atlantic smooth dogfish shark. SEDAR 39 stock assessment report. March 2015. SEDAR, 4055 Faber Place Drive, Suite 201, North Charleston, SC 29405.

Available: https://sedarweb.org/docs/sar/S39_Atl_smooth_dog_SAR.pdf (Accessed August 2020).

Anonymous. 2016. Report of the 2015 blue shark stock assessment session (Oceanário de Lisboa, Lisbon, Portugal – 27-31 July 2015). SCRS/2015/018; Collect. Vol. Sci. Pap. ICCAT, 72(4): 866-1019. Available: https://www.iccat.int/Documents/Meetings/Docs/2015_BSH%20ASSESS_REPORT_ENG.pdf (Accessed August 2020).

Anonymous. 2017a. HMS sandbar shark. SEDAR 54 stock assessment report. October 2017. SEDAR, 4055 Faber Place Drive, Suite 201 North Charleston, SC 29405. Available: https://sedarweb.org/docs/sar/S54_Final_SAR_with_exec_summary.pdf (Accessed August 2020).

Anonymous. 2017b. Report of the 2017 shortfin mako assessment meeting (Madrid, Spain 12–16 June 2017). SCRS/2017/007; Collect. Vol. Sci. Pap. ICCAT, 74(4): 1465-1561. Available: https://www.iccat.int/Documents/CVSP/CV074_2017/n_4/CV074041465.pdf (Accessed August 2020).

Anonymous. 2018. SEDAR 54 HMS sandbar shark post-review updates. February 2018. SEDAR, 4055 Faber Place Drive, Suite 201 North Charleston, SC 29405. Available: http://sedarweb.org/sedar-54 (Accessed February 2019).

Carvalho, F., A. E. Punt, Y. J. Chang, M. N. Maunder, and K. R. Piner. 2017. Can diagnostic tests help identify model misspecification in integrated stock assessments? Fisheries Research 192:28–40.

Castro, J. I. 1996. Biology of the blacktip shark, *Carcharhinus limbatus*, off the southeastern United States. Bulletin of Marine Science 59:508–522.

Cortés, E. 2020. Estimates of vital rates and population dynamics parameters of interest of blacktip sharks (*Carcharhinus limbatus*) in the Atlantic Ocean. SEDAR65-AW02. SEDAR, North Charleston, SC. 17 pp

Courtney, D. 2016. Preliminary Stock Synthesis model runs conducted for North Atlantic blue shark. SCRS/2015/151; Collect. Vol. Sci. Pap. ICCAT 72(5):1186-1232. Available: https://www.iccat.int/Documents/CVSP/CV072_2016/n_5/CV072051186.pdf (Accessed August 2020).

Courtney, D., F. Carvalho, H. Winker, and L. Kell. 2020. Examples of Stock Synthesis diagnostic methods and results implemented for previously completed North Atlantic shortfin mako Stock Synthesis model runs. SCRS/2019/088. Collect. Vol. Sci. Pap. ICCAT 76(10):173-234. Available: https://www.iccat.int/Documents/CVSP/CV076_2019/n_10/CV07610173.pdf (Accessed Aug 2020)

Courtney, D., E. Cortés, and X. Zhang. 2017a. Stock Synthesis model runs conducted for North Atlantic shortfin mako shark. SCRS/2017/125; Collect. Vol. Sci. Pap. ICCAT, 74(4):1759-1821. Available: https://www.iccat.int/Documents/CVSP/CV074_2017/n_4/CV074041759.pdf (Accessed August 2020).

Courtney, D., E. Cortés, X. Zhang, and F. Carvalho. 2017b. Stock Synthesis model sensitivity to data weighting: An example from preliminary model runs previously conducted for North Atlantic blue shark. SCRS/2016/066; Collect. Vol. Sci. Pap. ICCAT, 73(8):2860-2890. Available: https://www.iccat.int/Documents/CVSP/CV073_2017/n_8/CV073082860.pdf (Accessed August 2020).

Courtney, D. L., J. N. Ianelli, D. Hanselman, and J. Heifetz. 2007. Extending statistical age-structured assessment approaches to Gulf of Alaska rockfish (*Sebastes spp.*). *In* J. Heifetz, J. Dicosimo, A. J. Gharrett, M. S. Love, V. M. O'Connell, and R. D. Stanley (eds). Biology, assessment, and management of North Pacific rockfishes. Alaska Sea Grant College Program. AK-SG-07-01. Available: https://seagrant.uaf.edu/bookstore/pubs/AK-SG-07-01.html (Accessed August 2020).

Courtney, D., A. Mathers, and A. Kroetz. 2020. Updated commercial gillnet length composition data for use in SEDAR 65. SEDAR65-AW07. SEDAR, North Charleston, SC.

Courtney, D. and K. Piner. 2009. Age structured stock assessment of north Pacific swordfish (*Xiphias gladius*) with Stock Synthesis under a single stock scenario. ISC/09/BILLWG-3/08. Available: http://isc.fra.go.jp/pdf/BILL/ISC09_BILL_3/BILL_Nov09_FINAL_WP08.pdf (Accessed August 2020).

Courtney, D. and K. Piner. 2010. Age structured stock assessment of north Pacific swordfish (*Xiphias gladius*) with Stock Synthesis under a two stock scenario. ISC/10/BILLWG-1/01. Available: http://isc.fra.go.jp/pdf/BILL/ISC10_BILL_1/BILL_Apr10_FINAL_WP01.pdf (Accessed August 2020).

Courtney, D. and J. Rice. 2020. Example of a Stock Synthesis projection approach at alternative fixed total allowable catch (TAC) limits implemented for three previously completed North Atlantic shortfin mako Stock Synthesis model runs. SCRS/2019/082. Collect. Vol. Sci. Pap. ICCAT, 76(10):78-114. Available: https://www.iccat.int/Documents/CVSP/CV076_2019/n_10/CV07610078.pdf (Accessed 6/23/2020).

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2011. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software 27:233–252.

Francis, R. I. C. C. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68:1124–1138.

Francis, R. I. C. C. 2017. Revisiting data weighting in fisheries stock assessment models. Fisheries Research 192:5–15.

Hurtado-Ferro, F., A. E. Punt, and K. T. Hill. 2014. Use of multiple selectivity patterns as a proxy for spatial structure. Fisheries Research 158:102–115.

Kroetz, A., and D. Courtney. 2020. Review of available length composition data submitted for use in the SEDAR 65 Atlantic *Carcharhinus limbatus* stock assessment. SEDAR65-AW05. SEDAR, North Charleston, SC. 13 pp.

Lee, H.-H., K. R. Piner, M. G. Hinton, Y.-J. Chang, A. Kimoto, M. Kanaiwa, N.-J. Su, W. Walsh, C.-L. Sun, and G. DiNardo. 2014a. Sex-structured population dynamics of blue marlin *Makaira nigricans* in the Pacific Ocean. Fisheries Science 80:869–878.

Lee, H.-H., K. R. Piner, R. D. Methot Jr., and M. N. Maunder. 2014b. Use of likelihood profiling over a global scaling parameter to structure the population dynamics model: An example using blue marlin in the Pacific Ocean. Fisheries Research 158:138–146.

Maunder, M. N., and K. R. Piner. 2015. Contemporary fisheries stock assessment: many issues still remain. ICES Journal of Marine Science 72:7–18.

Maunder, M. N., and K. R. Piner, 2017. Dealing with data conflicts in statistical inference of population assessment models that integrate information from multiple diverse data sets. Fisheries Research 192:16–27.

Maunder, M. N. and A. E. Punt. 2013. A review of integrated analysis in fisheries stock assessment. Fisheries Research 142:61–74.

Maunder, M. N., H. Xu, C. E. Lennert-Cody, J. L. Valero, A. Aires-da-Silva, C. Minte-Vera. 2020. Implementing reference point-based fishery harvest control rules within a probabilistic framework that considers multiple hypotheses (No. SAC-11-INF-F), Scientific Advisory Commitee, Inter-American Tropical Tuna Commission. San Diego. Available: https://www.iattc.org/Meetings/Meetings2020/SAC-11/Docs/_English/SAC-11-INF-F_Implementing%20risk%20analysis.pdf (Accessed August 2020).

McAllister, M. K., and J. N. Ianelli. 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. Canadian Journal of Fisheries and Aquatic Sciences 54:284–300.

Methot Jr., R. D. and I. G. Taylor. 2011. Adjusting for bias due to variability of estimated recruitments in fishery assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68:1744–1760.

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.

Methot Jr., R. D., C. R. Wetzel, I. G. Taylor, and K. Doering. 2020. Stock Synthesis user manual version 3.30.15. U.S. Department of Commerce, NOAA Processed Report NMFS-NWFSC-PR-2020-05. Available: https://doi.org/10.25923/5wpn-qt71; and https://vlab.ncep.noaa.gov/web/stock-synthesis (Accessed August 2020).

Monnahan, C. C., T. A. Branch, J. T. Thorson, I. J. Stewart, and C. S. Szuwalski. 2019. Overcoming long Bayesian run times in integrated fisheries stock assessments. ICES Journal of Marine Science 76:1477–1488, https://doi.org/10.1093/icesjms/fsz059.

Natanson L. J., B. M. Deacy, H. E. Moncrief-Cox, W. B. Driggers III. 2019. Reproductive parameters for blacktip sharks (*Carcharhinus limbatus*) from the western North Atlantic Ocean. SEDAR65-DW01. SEDAR, North Charleston, SC. 10 pp.

NMFS. 2019. 2018 Stock assessment and fishery evaluation (SAFE) report for Atlantic highly migratory species, April 2019. Atlantic Highly Migratory Species Management Division, 1315 East West Highway, Silver Spring, MD 20910. Available: https://www.fisheries.noaa.gov/content/atlantic-hms-stockassessment-and-fisheries-evaluation-reports (Accessed August 2020).

Punt, A. E. 2017. Some insights into data weighting in integrated stock assessments. Fisheries Research 192:52–65.

Punt, A. E., F. Hurtado-Ferro, and A. R. Whitten. 2014. Model selection for selectivity in fisheries stock assessments. Fisheries Research 158:124–134.

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available: https://www.R-project.org (Accessed August 2020).

Restrepo, V. R., and J. E. Powers. 1999. Precautionary control rules in US fisheries management: specification and performance. – ICES Journal of Marine Science 56:846–852.

Restrepo, V. R., G. G. Thompson, P. M. Mace, W. L. Gabriel, L. L. Low, A. D. MacCall, R. D. Methot, J. E. Powers, B. L. Taylor, P. R. Wade, and J. F. Witzig. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson–Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-31. 54 pp.

Sampson, D. B. 2014. Fishery selection and its relevance to stock assessment and fishery management. Fisheries Research 158:5–14.

Taylor, I., and other contributors. 2020. r4ss: R Code for Stock Synthesis. R package version 1.38.0. Available: https://github.com/r4ss/r4ss (Accessed August 2020).

Taylor, I. G., and R. D. Methot Jr. 2013. Hiding or dead? A computationally efficient model of selective fisheries mortality. Fisheries Research 142:75–85

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.

3.8. Tables

Table 3.1. Time series of commercial landings, recreational catch, relative abundance, and length composition data used in the Stock Synthesis base model configuration.

Time series	Symbol	Commercial landings, recreational catch (A+B1+B2-Dead) and relative abundance	Name	Definition	Length composition (**see Table 2.15)**
1	F1	Commercial landings (t)	Com-BLL-Kept	Bottom longlines (1983 – 2018)	UF [1] + SBLOP[2] (1994 – 2018)
2	F2	Commercial landings (t)	Com-GN-Kept	Gillnets (1983 – 2018)	GNOP[3] (2000 – 2018)
3	F3	Commercial landings (t)	Com-Other-Kept	Other gears + Unreported commercial landings (1983 – 2018)	Mirror F1
4	F4	Recreational catch (1000s)	Recreational	Recreational (A+B1) + Recreational (B2-dead) (1981 – 2018)	MRIP [4]+ SRHS[5] (1981 – 2018)
5	S1	Relative abundance (numbers)	Shark-BLL-Obs	Bottom Longline Fishery (1994 – 2007)	Mirror F1
6	S2	Relative abundance (numbers)	Shark-BLL-Res	Shark Bottom Longline Research Fishery (2008 – 2018)	Mirror F1
7	S3	Relative abundance (numbers)	VIMS-BLL-Robust	VIMS Bottom Longline Survey Robust Series (1990 – 2018)	1990 – 2018
8	S4	Relative abundance (numbers)	NEFSC-BLL	NMFS-NEFSC Bottom Longline Survey (1996 – 2018)	1996 – 2018
9	S5	Relative abundance (numbers)	SCDNR-SEAMAP-BLL	SCDNR SEAMAP Bottom Longline Survey (2007 – 2018)	2007 – 2018
10	S6	Relative abundance (numbers)	SCDNR-Red-Drum-BLL	SCDNR Red Drum Bottom Longline Survey (1996 – 2006)	1996 – 2006
11	S7	Relative abundance (numbers)	SCDNR-DL	SCDNR Drumline Survey (2013 – 2018)	2013 – 2018
12	S8	Relative abundance (numbers)	COASTSPAN-BLL-All-ages	COASTSPAN Bottom Longline Survey All-age (2005 – 2018)	2005 – 2018
13	S9	Relative abundance (numbers)	COASTSPAN-GNL-All-ages	COASTSPAN Gillnet Long Net Survey All-age (2001 – 2018)	2001 – 2018
14	S10	Relative abundance (numbers)	COASTSPAN-GNS-Age-0	SCDNR Gillnet Short Net Survey Age-0 (2006 – 2018)	2006 – 2018

[1] University of Florida (UF) Longline 1994 – 2005.
[2] Southeast Fisheries Science Center (SEFSC) Panama City Lab Shark Bottom Longline Observer Program (SBLOP) 2005 – 2018.
[3] Southeast Fisheries Science Center (SEFSC) Panama City Lab Gillnet Observer Program (GNOP) 1999 – 2018.
[4] Marine Recreational Information Program (MRIP) 1981 – 2018.
[5] Southeast Region Head Boat Survey (SRHS) 1989 – 2018.

Table 3.2. Length composition sample size (number of sharks measured) for fleets (F) and surveys (S) included in the Stock Synthesis base model configuration.

	F1 (Com-BLL-Kept) 1994-2018 Min.[1] 30		F2 (Com-GN-Kept) 2000-2018 Min.[2] 30	F4 (Recreational) 1981-2018 Min. 20	S3 (VIMS-BLL-Robust) 1990-2018 Min. 30		S4 (NEFSC-BLL) 1996-2018 Min. 30		S5 (SCDNR-SEAMAP-BLL) 2007-2018 Min. 30	
Year	(♀)	(♂)	(♀,♂,Unknown)[2]	(♀,♂,Unknown)	(♀)	(♂)	(♀)	(♂)	(♀)	(♂)
1981				2						
1982				15						
1983				16						
1984				10						
1985				60						
1986				45						
1987				62						
1988				29						
1989				38						
1990				15	1	1				
1991				31	0	1				
1992				41	2	0				
1993				27	0	0				
1994	46	30		43	0	0				
1995	235	164		38	3	2				
1996	79	108		53	0	3	1	5		
1997	1	2		27	5	7	0	0		
1998	56	14		36	0	1	5	26		
1999	195	55		17	2	14	0	0		
2000	119	113	42	13	0	1	0	0		
2001	54	13	0	14	2	2	0	18		
2002	163	104	265	14	5	11	0	0		
2003	19	18	332	14	0	0	0	0		
2004	43	36	169	11	2	2	2	25		
2005	27	48	181	21	0	0	0	0		
2006	348	86	336	12	3	4	0	0		
2007	59	41	1	14	0	5	0	1	84	56
2008	68	31	6	7	28	26	0	0	106	82
2009	64	27	20	5	0	3	5	22	50	28
2010	84	57	10	10	8	4	0	0	37	19
2011	153	116	18	7	1	3	0	0	33	25
2012	276	271	42	23	5	2	21	77	33	20
2013	61	120	25	1	8	6	0	0	62	35
2014	306	408	10	22	4	5	0	0	44	15
2015	157	80	10	12	18	7	26	114	55	31
2016	185	140	4	9	18	14	0	0	37	14
2017	192	261	2	4	10	6	0	0	32	22
2018	3	39	3	4	6	8	16	266	43	31
Total	2993	2382	1476	822	131	138	76	554	616	378
Proportion (♀,♂)	100%		58%	NA	96%		100%		96%	

Table 3.2. Continued.

Year	S6 (SCDNR-Red-Drum-BLL) 1996-2006 Min. 30 (♀)	(♂)	S7 (SCDNR-DL) 2013-2018 Min. 30 (♀)	(♂)	S8 (COASTSPAN-BLL-All-ages) 2005-2018 Min. 30 (♀)	(♂)	S9 (COASTSPAN-GNL-All-ages) 2001-2018 Min. 30 (♀)	(♂)	S10 (COASTSPAN-GNS-Age-0) 2006-2018 Min. 30 (♀)	(♂)
1996	8	7								
1997	19	20								
1998	4	7								
1999	1	6								
2000	10	14								
2001	3	1					15	15		
2002	22	16					3	5		
2003	21	37					18	18		
2004	4	4					1	0		
2005	3	2			36	29	10	10		
2006	22	26			7	6	5	6	1	3
2007					3	1	5	6	7	1
2008					4	0	6	1	1	0
2009					1	9	3	5	2	0
2010					34	31	5	3	11	6
2011					19	17	3	3	7	10
2012					49	41	13	2	27	18
2013			16	7	19	13	43	56	15	8
2014			43	15	13	11	21	7	4	4
2015			27	19	13	10	11	12	14	11
2016			23	22	28	23	19	2	7	9
2017			41	21	28	29	31	28	13	9
2018			24	20	23	16	23	11	18	22
Total	117	140	174	104	277	236	235	190	127	101
Proportion (♀,♂)	98%		99%		99%		96%		98%	

[1] Years with less than minimum sample size were excluded from the fit in the model likelihood.
[2] Min = 20 for F2 in the logistic sensitivity analysis.
[3] Sex-combined length composition data (♀, ♂, Unknown) were input for fleets F2 and F4 because the available sex-specific data (♀, ♂) were only a fraction (58%) of the sex-combined data for fleet F2 and were not available for fleet F4. Sex-specific length composition data were input for fleet F1 and for all surveys because sex-specific data made up higher proportions (96-100%) of the sex-combined data.

Table 3.3. The von Bertalanffy growth (VBG) relationship implemented separately for females and males in the Stock Synthesis base model configuration.

Age (yr.)	Female cm FL predicted from the VBG parameters below	Male cm FL predicted from VBG parameters below
0	56.4	52.8
1	72.6	71.8
2	86.5	86.8
3	98.3	98.8
4	108.3	108.3
5	116.9	115.8
6	124.2	121.8
7	130.4	126.6
8	135.7	130.4
9	140.2	133.4
10	144.1	135.8
11	147.3	137.7
12	150.1	139.2
13	152.5	140.4
14	154.5	141.3
15	156.3	142.1
16	157.7	142.7
17	159.0	143.2
18	160.1	143.6
19	161.0	143.9
20	161.8	144.1
21	162.4	144.3
22	163.0	144.4
23	163.5	144.6
24	163.9	144.7
25	164.2	144.7
26	164.5	144.8
27	164.8	144.8
28	165.0	144.9
29	165.2	144.9
30	165.3	144.9

VBG parameters	Female	Male
L_{inf}	166.2	145.0
k	0.160	0.230
t_0	-2.59	-1.97
CV implemented for L_{Amin}	0.093	0.097
CV implemented for L_{inf}	0.090	0.082

Table 3.4. Annual pup production at age used in the base model configuration.

Age (yr.)	Litter size (LS) [1]	Fraction mature [2]	Fraction maternal [3]	Pup production [4]	Annual pup production [5]
0	0.00	0.00	0.00	0.0	0.00
1	0.00	0.00	0.00	0.0	0.00
2	0.00	0.00	0.00	0.0	0.00
3	1.11	0.00	0.00	0.0	0.00
4	1.50	0.01	0.00	0.0	0.00
5	1.88	0.05	0.01	0.0	0.01
6	2.27	0.22	0.05	0.1	0.06
7	2.65	0.64	0.22	0.6	0.29
8	3.03	0.91	0.64	1.9	0.97
9	3.42	0.98	0.91	3.1	1.56
10	3.80	1.00	0.98	3.7	1.86
11	4.19	1.00	1.00	4.2	2.09
12	4.57	1.00	1.00	4.6	2.29
13	4.96	1.00	1.00	5.0	2.48
14	5.34	1.00	1.00	5.3	2.67
15	5.73	1.00	1.00	5.7	2.86
16	6.11	1.00	1.00	6.1	3.06
17	6.49	1.00	1.00	6.5	3.25
18	6.88	1.00	1.00	6.9	3.44
19	7.00	1.00	1.00	7.0	3.50
20	7.00	1.00	1.00	7.0	3.50
21	7.00	1.00	1.00	7.0	3.50
22	7.00	1.00	1.00	7.0	3.50
23	7.00	1.00	1.00	7.0	3.50
24	7.00	1.00	1.00	7.0	3.50
25	7.00	1.00	1.00	7.0	3.50
26	7.00	1.00	1.00	7.0	3.50
27	7.00	1.00	1.00	7.0	3.50
28	7.00	1.00	1.00	7.0	3.50
29	7.00	1.00	1.00	7.0	3.50
30	7.00	1.00	1.00	7.0	3.50

[1] Litter size (LS) = -0.04078 + 0.38445*Age (**Table 2.12**); Min LS = 1; Max LS = 7 (SEDAR65-DW-01, their Figure 1).
[2] Fraction mature obtained from the DW report (DW Section II, their Table 3; e.g. see equations in **Table 2.12)**.
[3] Fraction maternal assumed an 11 month gestation period (**Table 2.12)**, approximated here by one year from maturity to maternity.
[4] Pup production was obtained as (LS at age)* (Fraction maternal at age).
[5] Annual pup production was obtained by assuming a two year reproductive cycle (**Table 2.12**) and calculated as [(LS at age)* (Fraction maternal at age)]/2.

Table 3.5. Selectivity functions and number of estimated parameters in the base model configuration.

Fleet	Fleet name	Proposed selectivity pattern	Implemented selectivity pattern	Sex	Number of parameters	Sub-total
1	F1 (Com-BLL-Kept)	Logistic	Double Normal	Sex specific	17 Selectivity[1]	17
2	F2 (Com-GN-Kept)	Logistic	Double Normal	Combined sex	4 Selectivity[2]	4
3	F3 (Com-Other-Kept)	Mirror Fleet 1	Mirror F1	Combined sex	NA	
4	F4 (Recreational)	Double Normal	Double Normal	Combined sex	7 Selectivity[3]	7
5	S1 (Shark-BLL-Obs)	Mirror Fleet 1	Mirror F1	Combined sex	3 Catchability[4]	3
6	S2 (Shark-BLL-Res)	Mirror Fleet 1	Mirror F1	Combined sex	2 Catchability[5]	2
7	S3 (VIMS-BLL-Robust)	Double Normal	Double Normal	Sex specific	4 Selectivity	4
8	S4 (NEFSC-BLL)	Logistic	Double Normal	Sex specific	5 Selectivity	5
9	S5 (SCDNR-SEAMAP-BLL)	Double Normal	Double Normal	Sex specific	5 Selectivity	5
10	S6 (SCDNR-Red-Drum-BLL)	Double Normal	Double Normal	Sex specific	5 Selectivity	5
11	S7 (SCDNR-DL)	Logistic	Double Normal	Sex specific	6 Selectivity	6
12	S8 (COASTSPAN-BLL-All-ages)	Double Normal	Double Normal	Sex specific	3 Selectivity	3
13	S9 (COASTSPAN-GNL-All-ages)	Double Normal	Double Normal	Sex specific	3 Selectivity	3
14	S10 (COASTSPAN-GNS-Age-0)	Double Normal	Double Normal	Sex specific	4 Selectivity	2
					Total (Selectivity; Catchability)	66
	Other Estimated Parameters					
	ln(R_0)					1
	Recruitment deviations				1984 – 2018	35
					Grand Total	102

[1] Time blocks in selectivity for F1 (1981 – 1996, 1997 – 2004, 2005 – 2007, 2008 – 2017, 2018).
[2] Time blocks in selectivity for F2 (1981 – 2006, 2007 – 2018).
[3] Time blocks in selectivity for F4 (1981 – 1989, 1990 – 1999, 2000 – 2018).
[4] Time blocks in catchability for S1 (1981 – 1996, 1997 – 2004, 2005 – 2007).
[5] Time blocks in catchability for S2 (2008 – 2017, 2018).

Table 3.6. Two stage data weighting used in the base model configuration, as described above in Section 3.3.1.7; 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 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 (Shark-BLL-Obs)	0.5300	0.3010	0.8310
S2 (Shark-BLL-Res)	0.3736	0.0004	0.3740
S3 (VIMS-BLL-Robust)	0.6417	0.1923	0.8340
S4 (NEFSC-BLL)	0.6704	0.1766	0.8470
S5 (SCDNR-SEAMAP-BLL)	0.2826	0.0000	0.2826
S6 (SCDNR-Red-Drum-BLL)	0.7120	0.0000	0.7120
S7 (SCDNR-DL)	0.1830	0.0000	0.1830
S8 (COASTSPAN-BLL-All-ages)	0.3031	0.0000	0.3031
S9 (COASTSPAN-GNL-All-ages)	0.4588	0.0902	0.5490
S10 (COASTSPAN-GNS-Age-0)	0.5637	0.0000	0.5637

Panel B

Length composition data source	Mean of input n	Adjustment method	Sample size adjustment	Mean of adjusted input n
F1 (Com-BLL-Kept)	231.7	Francis	0.080	18.5
F2 (Com-GN-Kept)	195.3	Harmonic mean	0.198	38.6
F4 (Recreational)	37.3	Francis	0.205	7.6
S3 (VIMS-BLL-Robust)	43.0	Harmonic mean	0.637	27.4
S4 (NEFSC-BLL)	137.8	Harmonic mean	0.269	37.1
S5 (SCDNR-SEAMAP-BLL)	82.8	Francis	0.162	13.5
S6 (SCDNR-Red-Drum-BLL)	45.8	Harmonic mean	0.311	14.2
S7 (SCDNR-DL)	51.0	Harmonic mean	0.784	40.0
S8 (COASTSPAN-BLL-All-ages)	47.0	Harmonic mean	0.269	12.7
S9 (COASTSPAN-GNL-All-ages)	51.6	Harmonic mean	0.416	21.5
S10 (COASTSPAN-GNS-Age-0)	42.5	Harmonic mean	0.368	15.6

Table 3.7. Base model configuration parameters. 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_Cnt	Phase	Min	Max	Init	Parm_StDev	Pr_type	Prior	Pr_SD	CV
L_at_Amin_Fem_GP_1	56.40	_	-3	5.00	100.00	56.40	_	Normal	56.40	1000	NA
L_at_Amax_Fem_GP_1	166.23	_	-4	50.00	600.00	166.23	_	Normal	166.23	1000	NA
VonBert_K_Fem_GP_1	0.16	_	-5	0.01	0.65	0.16	_	Normal	0.06	0.2	NA
CV_young_Fem_GP_1	0.09	_	-2	0.01	0.30	0.09	_	Normal	0.09	0.01	NA
CV_old_Fem_GP_1	0.09	_	-3	0.01	0.30	0.09	_	Normal	0.09	0.01	NA
Wtlen_1_Fem_GP_1	0.00	_	-3	-3.00	3.00	0.00	_	Normal	0.00	0.8	NA
Wtlen_2_Fem_GP_1	3.22	_	-3	-3.00	5.00	3.22	_	Normal	3.22	0.8	NA
L_at_Amin_Mal_GP_1	52.84	_	-3	5.00	100.00	52.84	_	Normal	52.84	1000	NA
L_at_Amax_Mal_GP_1	145.03	_	-4	50.00	600.00	145.03	_	Normal	145.03	1000	NA
VonBert_K_Mal_GP_1	0.23	_	-5	0.01	0.65	0.23	_	Normal	0.23	0.2	NA
CV_young_Mal_GP_1	0.10	_	-2	0.01	0.30	0.10	_	Normal	0.10	0.01	NA
CV_old_Mal_GP_1	0.08	_	-3	0.01	0.30	0.08	_	Normal	0.08	0.01	NA
Wtlen_1_Mal_GP_1	0.00	_	-3	-3.00	3.00	0.00	_	Normal	0.00	0.8	NA
Wtlen_2_Mal_GP_1	3.22	_	-3	-3.00	5.00	3.22	_	Normal	3.22	0.8	NA
FracFemale_GP_1	0.50	_	-99	0.00	1.00	0.50	_	No_prior			NA
SR_LN(R0)	6.06	1	1	2.30	13.82	5.40	0.179	Normal	7.04	1000	3%
SR_BH_steep	0.40	_	-2	0.20	0.99	0.40	_	Normal	0.40	1000	NA
SR_sigmaR	0.28	_	-4	0.20	1.90	0.28	_	Normal	0.28	1000	NA
Early_RecrDev_1984	-0.18	2	4	-10.00	10.00	0.00	0.256	dev			
Early_RecrDev_1985	-0.27	3	4	-10.00	10.00	0.00	0.242	dev			
Early_RecrDev_1986	-0.09	4	4	-10.00	10.00	0.00	0.243	dev			
Early_RecrDev_1987	0.07	5	4	-10.00	10.00	0.00	0.241	dev			
Early_RecrDev_1988	-0.11	6	4	-10.00	10.00	0.00	0.250	dev			
Early_RecrDev_1989	-0.01	7	4	-10.00	10.00	0.00	0.252	dev			
Early_RecrDev_1990	-0.02	8	4	-10.00	10.00	0.00	0.261	dev			
Early_RecrDev_1991	0.08	9	4	-10.00	10.00	0.00	0.251	dev			
Early_RecrDev_1992	0.09	10	4	-10.00	10.00	0.00	0.256	dev			
Early_RecrDev_1993	0.28	11	4	-10.00	10.00	0.00	0.262	dev			
Main_RecrDev_1994	0.26	12	3	-10.00	10.00	0.00	0.255	dev			
Main_RecrDev_1995	0.20	13	3	-10.00	10.00	0.00	0.243	dev			
Main_RecrDev_1996	-0.19	14	3	-10.00	10.00	0.00	0.239	dev			
Main_RecrDev_1997	-0.22	15	3	-10.00	10.00	0.00	0.234	dev			
Main_RecrDev_1998	-0.27	16	3	-10.00	10.00	0.00	0.228	dev			
Main_RecrDev_1999	-0.37	17	3	-10.00	10.00	0.00	0.218	dev			

Table 3.7. Continued.

Label	Value	Active_Cnt	Phase	Min	Max	Init	Parm_StDev	Pr_type	Prior	Pr_SD	CV
Main_RecrDev_2000	-0.55	18	3	-10.00	10.00	0.00	0.210	dev			
Main_RecrDev_2001	-0.53	19	3	-10.00	10.00	0.00	0.184	dev			
Main_RecrDev_2002	-0.29	20	3	-10.00	10.00	0.00	0.179	dev			
Main_RecrDev_2003	-0.10	21	3	-10.00	10.00	0.00	0.175	dev			
Main_RecrDev_2004	0.17	22	3	-10.00	10.00	0.00	0.198	dev			
Main_RecrDev_2005	0.17	23	3	-10.00	10.00	0.00	0.165	dev			
Main_RecrDev_2006	0.01	24	3	-10.00	10.00	0.00	0.170	dev			
Main_RecrDev_2007	0.13	25	3	-10.00	10.00	0.00	0.168	dev			
Main_RecrDev_2008	0.27	26	3	-10.00	10.00	0.00	0.170	dev			
Main_RecrDev_2009	0.25	27	3	-10.00	10.00	0.00	0.170	dev			
Main_RecrDev_2010	0.15	28	3	-10.00	10.00	0.00	0.162	dev			
Main_RecrDev_2011	0.19	29	3	-10.00	10.00	0.00	0.164	dev			
Main_RecrDev_2012	0.42	30	3	-10.00	10.00	0.00	0.143	dev			
Main_RecrDev_2013	0.54	31	3	-10.00	10.00	0.00	0.133	dev			
Main_RecrDev_2014	-0.07	32	3	-10.00	10.00	0.00	0.172	dev			
Main_RecrDev_2015	-0.14	33	3	-10.00	10.00	0.00	0.164	dev			
Main_RecrDev_2016	-0.16	34	3	-10.00	10.00	0.00	0.163	dev			
Main_RecrDev_2017	0.13	35	3	-10.00	10.00	0.00	0.157	dev			
Late_RecrDev_2018	0.09	36	6	-10.00	10.00	0.00	0.162	dev			
ForeRecr_2019[1]	0	37	6	-10	10	0	0.283103	dev			
LnQ_base_S1_Shark_BLL_Obs(5)	-1.69	38	1	-25.00	25.00	3.36	0.421	Sym_Beta	0.00	0.05	25%
LnQ_base_S2_Shark_BLL_Res(6)	-1.08	39	1	-25.00	25.00	-0.76	0.415	Sym_Beta	0.00	0.05	38%
LnQ_base_S3_VIMS_Robust(7)	-8.90	_	-1	-25.00	25.00	-8.72	_	No_prior			NA
LnQ_base_S4_NEFSC_BLL(8)	-8.06	_	-1	-25.00	25.00	-8.60	_	No_prior			NA
LnQ_base_S5_SCDNR_SEAMAP_BLL(9)	-6.33	_	-1	-25.00	25.00	-6.33	_	No_prior			NA
LnQ_base_S6_SCDNR_Red_Drum_BLL(10)	-6.57	_	-1	-25.00	25.00	-6.50	_	No_prior			NA
LnQ_base_S7_SCDNR_Drumline(11)	-7.49	_	-1	-25.00	25.00	-7.62	_	No_prior			NA
LnQ_base_S8_COASTSPAN_BLL_All_ages(12)	-4.44	_	-1	-25.00	25.00	-4.41	_	No_prior			NA
LnQ_base_S9_COASTSPAN_GN_Long_All_ages(13)	-5.37	_	-1	-25.00	25.00	-5.73	_	No_prior			NA
LnQ_base_S10_COASTSPAN_GN_Short_Age_0(14)	-5.20	_	-1	-25.00	25.00	-5.16	_	No_prior			NA
LnQ_base_S1_Shark_BLL_Obs(5)_BLK3repl_1981	-3.11	40	1	-25.00	25.00	-2.94	0.561	Sym_Beta	0.00	0.05	18%
LnQ_base_S1_Shark_BLL_Obs(5)_BLK3repl_2005	-1.60	41	1	-25.00	25.00	-1.37	0.646	Sym_Beta	0.00	0.05	40%
LnQ_base_S2_Shark_BLL_Res(6)_BLK4repl_2018	-2.33	42	1	-25.00	25.00	-1.70	0.640	Sym_Beta	0.00	0.05	27%
Size_DblN_peak_F1_Com_BLL_Kept(1)	144.26	43	2	47.50	162.50	144.30	2.377	Sym_Beta	138.00	0.05	2%
Size_DblN_top_logit_F1_Com_BLL_Kept(1)	-5.36	44	3	-6.00	4.00	-5.40	2.219	Sym_Beta	-6.00	0.05	41%
Size_DblN_ascend_se_F1_Com_BLL_Kept(1)	6.92	45	3	-1.00	9.00	7.00	0.154	Sym_Beta	7.10	0.05	2%
Size_DblN_descend_se_F1_Com_BLL_Kept(1)	3.99	46	3	-1.00	9.00	3.90	0.625	Sym_Beta	4.70	0.05	16%
Size_DblN_start_logit_F1_Com_BLL_Kept(1)	-5.98	47	2	-15.00	9.00	-5.80	1.462	Sym_Beta	-15.00	0.05	24%
Size_DblN_end_logit_F1_Com_BLL_Kept(1)	-3.70	48	2	-15.00	9.00	-3.90	0.888	Sym_Beta	9.00	0.05	24%
SzSel_Male_Peak_F1_Com_BLL_Kept(1)	-11.52	49	4	-50.00	50.00	-11.46	1.574	Normal	0.00	1000	14%
SzSel_Male_Ascend_F1_Com_BLL_Kept(1)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Descend_F1_Com_BLL_Kept(1)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Final_F1_Com_BLL_Kept(1)	0.00		-4	-15.00	15.00	0.00		Normal	0.00	1000	NA

[1] Forecast recruitment deviation (year 2019) not included in the number of estimated parameters.

Table 3.7. Continued.

Label	Value	Active_Cnt	Phase	Min	Max	Init	Parm_StDev	Pr_type	Prior	Pr_SD	CV
SzSel_Male_Scale_F1_Com_BLL_Kept(1)	0.66	50	5	-15.00	15.00	0.69	0.069	Normal	1.00	1000	10%
Size_DblN_peak_F2_Com_GN_Kept(2)	83.78	51	2	47.50	162.50	77.40	11.073	Sym_Beta	121.60	0.05	13%
Size_DblN_top_logit_F2_Com_GN_Kept(2)	-0.20	_	-3	-6.00	4.00	-0.20	_	Sym_Beta	-0.20	0.05	NA
Size_DblN_ascend_se_F2_Com_GN_Kept(2)	6.17	52	3	-1.00	9.00	6.20	0.352	Sym_Beta	6.90	0.05	6%
Size_DblN_descend_se_F2_Com_GN_Kept(2)	4.78	53	3	-1.00	9.00	4.80	0.470	Sym_Beta	5.00	0.05	10%
Size_DblN_start_logit_F2_Com_GN_Kept(2)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_F2_Com_GN_Kept(2)	-999.00	_	-2	-999.00	9.00	-999.00	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_peak_F4_Rec_A_B1_B2PRM(4)	76.95	54	2	47.50	162.50	58.00	10.890	Sym_Beta	64.90	0.05	14%
Size_DblN_top_logit_F4_Rec_A_B1_B2PRM(4)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_F4_Rec_A_B1_B2PRM(4)	6.60	_	-3	-1.00	9.00	6.60	_	Sym_Beta	6.60	0.05	NA
Size_DblN_descend_se_F4_Rec_A_B1_B2PRM(4)	4.70	55	3	-1.00	9.00	6.20	0.760	Sym_Beta	7.20	0.05	16%
Size_DblN_start_logit_F4_Rec_A_B1_B2PRM(4)	0.00	_	-2	-15.00	9.00	0.00	_	Sym_Beta	0.00	0.05	NA
Size_DblN_end_logit_F4_Rec_A_B1_B2PRM(4)	-3.21	56	2	-15.00	9.00	-2.30	0.753	Sym_Beta	-15.00	0.05	23%
Size_DblN_peak_S3_VIMS_Robust(7)	93.16	57	2	47.50	162.50	93.00	1.934	Sym_Beta	96.40	0.05	2%
Size_DblN_top_logit_S3_VIMS_Robust(7)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_S3_VIMS_Robust(7)	3.82	58	3	-1.00	9.00	3.90	0.585	Sym_Beta	4.40	0.05	15%
Size_DblN_descend_se_S3_VIMS_Robust(7)	7.31	59	3	-1.00	9.00	7.30	0.292	Sym_Beta	6.50	0.05	4%
Size_DblN_start_logit_S3_VIMS_Robust(7)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_S3_VIMS_Robust(7)	-999.00	_	-2	-15.00	9.00	-999.00	_	Sym_Beta	-15.00	0.05	NA
SzSel_Male_Peak_S3_VIMS_Robust(7)	0.00	_	-4	-50.00	50.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Ascend_S3_VIMS_Robust(7)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Descend_S3_VIMS_Robust(7)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Final_S3_VIMS_Robust(7)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Scale_S3_VIMS_Robust(7)	0.85	60	5	-15.00	15.00	0.86	0.232	Normal	1.00	1000	27%
Size_DblN_peak_S4_NEFSC_BLL(8)	136.09	61	2	47.50	162.50	135.90	2.769	Sym_Beta	135.10	0.05	2%
Size_DblN_top_logit_S4_NEFSC_BLL(8)	-5.10	_	-3	-6.00	4.00	-5.10	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_S4_NEFSC_BLL(8)	5.79	62	3	-1.00	9.00	5.80	0.264	Sym_Beta	5.50	0.05	5%
Size_DblN_descend_se_S4_NEFSC_BLL(8)	5.24	63	3	-1.00	9.00	5.30	0.637	Sym_Beta	4.50	0.05	12%
Size_DblN_start_logit_S4_NEFSC_BLL(8)	-6.10	_	-2	-15.00	9.00	-6.10	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_S4_NEFSC_BLL(8)	-3.38	64	2	-15.00	9.00	-3.40	1.087	Sym_Beta	-15.00	0.05	32%
SzSel_Fem_Peak_S4_NEFSC_BLL(8)	0.00	_	-4	-50.00	50.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Ascend_S4_NEFSC_BLL(8)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Descend_S4_NEFSC_BLL(8)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Final_S4_NEFSC_BLL(8)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Scale_S4_NEFSC_BLL(8)	0.13	65	5	-15.00	15.00	0.13	0.036	Normal	1.00	1000	28%
Size_DblN_peak_S5_SCDNR_SEAMAP_BLL(9)	52.64	66	2	47.50	162.50	50.50	1.982	Sym_Beta	55.30	0.05	4%
Size_DblN_top_logit_S5_SCDNR_SEAMAP_BLL(9)	-1.72	67	3	-6.00	4.00	-4.60	0.600	Sym_Beta	-6.00	0.05	35%
Size_DblN_ascend_se_S5_SCDNR_SEAMAP_BLL(9)	3.12	68	3	-1.00	9.00	1.90	0.999	Sym_Beta	3.20	0.05	32%
Size_DblN_descend_se_S5_SCDNR_SEAMAP_BLL(9)	7.39	69	3	-1.00	9.00	8.10	0.464	Sym_Beta	7.20	0.05	6%
Size_DblN_start_logit_S5_SCDNR_SEAMAP_BLL(9)	-999.00	_	-2	-15.00	9.00	-999.00	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_S5_SCDNR_SEAMAP_BLL(9)	-3.00	_	-2	-15.00	9.00	-3.00	_	Sym_Beta	-3.00	0.05	NA

Table 3.7. Continued.

Label	Value	Active_Cnt	Phase	Min	Max	Init	Parm_StDev	Pr_type	Prior	Pr_SD	CV
SzSel_Male_Peak_S5_SCDNR_SEAMAP_BLL(9)	0.00	_	-4	-50.00	50.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Ascend_S5_SCDNR_SEAMAP_BLL(9)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Descend_S5_SCDNR_SEAMAP_BLL(9)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Final_S5_SCDNR_SEAMAP_BLL(9)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Scale_S5_SCDNR_SEAMAP_BLL(9)	0.68	70	5	-15.00	15.00	0.67	0.113	Normal	1.00	1000	17%
Size_DblN_peak_S6_SCDNR_Red_Drum_BLL(10)	57.89	71	2	47.50	162.50	57.50	1.673	Sym_Beta	57.70	0.05	3%
Size_DblN_top_logit_S6_SCDNR_Red_Drum_BLL(10)	-1.53	72	3	-6.00	4.00	-1.80	0.455	Sym_Beta	-6.00	0.05	30%
Size_DblN_ascend_se_S6_SCDNR_Red_Drum_BLL(10)	3.35	73	3	-1.00	9.00	2.90	0.757	Sym_Beta	3.30	0.05	23%
Size_DblN_descend_se_S6_SCDNR_Red_Drum_BLL(10)	6.56	74	3	-1.00	9.00	6.90	0.561	Sym_Beta	7.20	0.05	9%
Size_DblN_start_logit_S6_SCDNR_Red_Drum_BLL(10)	-999.00	_	-2	-15.00	9.00	-999.00	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_S6_SCDNR_Red_Drum_BLL(10)	-3.10	_	-2	-15.00	9.00	-3.10	_	Sym_Beta	-3.10	0.05	NA
SzSel_Fem_Peak_S6_SCDNR_Red_Drum_BLL(10)	0.00	_	-4	-50.00	50.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Ascend_S6_SCDNR_Red_Drum_BLL(10)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Descend_S6_SCDNR_Red_Drum_BLL(10)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Final_S6_SCDNR_Red_Drum_BLL(10)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Scale_S6_SCDNR_Red_Drum_BLL(10)	0.77	75	5	-15.00	15.00	0.76	0.212	Normal	1.00	1000	28%
Size_DblN_peak_S7_SCDNR_Drumline(11)	145.16	76	2	47.50	162.50	143.40	2.539	Sym_Beta	131.70	0.05	2%
Size_DblN_top_logit_S7_SCDNR_Drumline(11)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_S7_SCDNR_Drumline(11)	6.55	77	3	-1.00	9.00	6.50	0.200	Sym_Beta	5.30	0.05	3%
Size_DblN_descend_se_S7_SCDNR_Drumline(11)	4.21	78	3	-1.00	9.00	4.60	0.424	Sym_Beta	5.50	0.05	10%
Size_DblN_start_logit_S7_SCDNR_Drumline(11)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_S7_SCDNR_Drumline(11)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15.00	0.05	NA
SzSel_Male_Peak_S7_SCDNR_Drumline(11)	-12.19	79	4	-50.00	50.00	-9.92	2.338	Normal	0.00	1000	19%
SzSel_Male_Ascend_S7_SCDNR_Drumline(11)	-1.44	80	4	-15.00	15.00	-1.30	0.333	Normal	0.00	1000	23%
SzSel_Male_Descend_S7_SCDNR_Drumline(11)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Final_S7_SCDNR_Drumline(11)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Scale_S7_SCDNR_Drumline(11)	0.76	81	5	-15.00	15.00	0.79	0.130	Normal	1.00	1000	17%
Size_DblN_peak_S8_COASTSPAN_BLL_All_ages(12)	47.50	_	-2	47.50	60.00	47.50	_	Sym_Beta	51.30	0.05	NA
Size_DblN_top_logit_S8_COASTSPAN_BLL_All_ages(12)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_S8_COASTSPAN_BLL_All_ages(12)	6.60	_	-3	-1.00	9.00	6.60	_	Sym_Beta	6.60	0.05	NA
Size_DblN_descend_se_S8_COASTSPAN_BLL_All_ages(12)	3.14	82	3	-1.00	9.00	3.10	0.221	Sym_Beta	-0.30	0.05	7%
Size_DblN_start_logit_S8_COASTSPAN_BLL_All_ages(12)	0.00	_	-2	-15.00	9.00	0.00	_	Sym_Beta	0.00	0.05	NA
Size_DblN_end_logit_S8_COASTSPAN_BLL_All_ages(12)	-5.33	83	2	-15.00	9.00	-5.70	0.544	Sym_Beta	-15.00	0.05	10%
SzSel_Male_Peak_S8_COASTSPAN_BLL_All_ages(12)	0.00	_	-4	-20.00	20.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Ascend_S8_COASTSPAN_BLL_All_ages(12)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Descend_S8_COASTSPAN_BLL_All_ages(12)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Final_S8_COASTSPAN_BLL_All_ages(12)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Scale_S8_COASTSPAN_BLL_All_ages(12)	0.63	84	5	-15.00	15.00	0.62	0.117	Normal	1.00	1000	19%
Size_DblN_peak_S9_COASTSPAN_GN_Long_All_ages(13)	47.50	_	-2	47.50	60.00	47.50	_	Sym_Beta	49.70	0.05	NA
Size_DblN_top_logit_S9_COASTSPAN_GN_Long_All_ages(13)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_S9_COASTSPAN_GN_Long_All_ages(13)	6.60	_	-3	-1.00	9.00	6.60	_	Sym_Beta	6.60	0.05	NA
Size_DblN_descend_se_S9_COASTSPAN_GN_Long_All_ages(13)	3.03	85	3	-1.00	9.00	3.30	0.323	Sym_Beta	2.90	0.05	11%
Size_DblN_start_logit_S9_COASTSPAN_GN_Long_All_ages(13)	0.00	_	-2	-15.00	9.00	0.00	_	Sym_Beta	0.00	0.05	NA
Size_DblN_end_logit_S9_COASTSPAN_GN_Long_All_ages(13)	-3.80	86	2	-15.00	9.00	-3.30	0.345	Sym_Beta	-2.00	0.05	9%

Table 3.7. Continued.

Label	Value	Active_Cnt	Phase	Min	Max	Init	Parm_StDev	Pr_type	Prior	Pr_SD	CV
SzSel_Male_Peak_S9_COASTSPAN_GN_Long_All_ages(13)	0.00	_	-4	-20.00	20.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Ascend_S9_COASTSPAN_GN_Long_All_ages(13)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Descend_S9_COASTSPAN_GN_Long_All_ages(13)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Final_S9_COASTSPAN_GN_Long_All_ages(13)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Scale_S9_COASTSPAN_GN_Long_All_ages(13)	0.84	87	5	-15.00	15.00	0.92	0.179	Normal	1.00	1000	21%
Size_DblN_peak_S10_COASTSPAN_GN_Short_Age_0(14)	47.50	_	-2	47.50	60.00	47.50	_	Sym_Beta	47.70	0.05	NA
Size_DblN_top_logit_S10_COASTSPAN_GN_Short_Age_0(14)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_S10_COASTSPAN_GN_Short_Age_0(14)	6.60	_	-3	-1.00	9.00	6.60	_	Sym_Beta	6.60	0.05	NA
Size_DblN_descend_se_S10_COASTSPAN_GN_Short_Age_0(14)	2.55	88	3	-1.00	9.00	2.60	0.326	Sym_Beta	3.30	0.05	13%
Size_DblN_start_logit_S10_COASTSPAN_GN_Short_Age_0(14)	0.00	_	-2	-15.00	9.00	0.00	_	Sym_Beta	0.00	0.05	NA
Size_DblN_end_logit_S10_COASTSPAN_GN_Short_Age_0(14)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15.00	0.05	NA
SzSel_Male_Peak_S10_COASTSPAN_GN_Short_Age_0(14)	0.00	_	-4	-20.00	20.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Ascend_S10_COASTSPAN_GN_Short_Age_0(14)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Descend_S10_COASTSPAN_GN_Short_Age_0(14)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Final_S10_COASTSPAN_GN_Short_Age_0(14)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Scale_S10_COASTSPAN_GN_Short_Age_0(14)	0.50	89	5	-15.00	15.00	0.53	0.184	Normal	1.00	1000	37%
Size_DblN_peak_F1_Com_BLL_Kept(1)_BLK2repl_1981	139.45	90	2	47.50	162.50	142.00	5.861	Sym_Beta	144.30	0.05	4%
Size_DblN_peak_F1_Com_BLL_Kept(1)_BLK2repl_1997	136.09	91	2	47.50	162.50	136.09	3.744	Sym_Beta	144.30	0.05	3%
Size_DblN_peak_F1_Com_BLL_Kept(1)_BLK2repl_2005	119.50	92	2	47.50	162.50	123.23	8.492	Sym_Beta	144.30	0.05	7%
Size_DblN_ascend_se_F1_Com_BLL_Kept(1)_BLK2repl_1981	7.57	93	3	-1.00	9.00	7.69	0.354	Sym_Beta	7.00	0.05	5%
Size_DblN_ascend_se_F1_Com_BLL_Kept(1)_BLK2repl_1997	5.51	94	3	-1.00	9.00	5.46	0.475	Sym_Beta	7.00	0.05	9%
Size_DblN_ascend_se_F1_Com_BLL_Kept(1)_BLK2repl_2005	6.19	95	3	-1.00	9.00	6.50	0.625	Sym_Beta	7.00	0.05	10%
Size_DblN_descend_se_F1_Com_BLL_Kept(1)_BLK2repl_1981	4.69	96	3	-1.00	9.00	4.50	1.052	Sym_Beta	3.90	0.05	22%
Size_DblN_descend_se_F1_Com_BLL_Kept(1)_BLK2repl_1997	5.22	97	3	-1.00	9.00	5.30	0.551	Sym_Beta	3.90	0.05	11%
Size_DblN_descend_se_F1_Com_BLL_Kept(1)_BLK2repl_2005	6.65	98	3	-1.00	9.00	6.60	0.653	Sym_Beta	3.90	0.05	10%
Size_DblN_peak_F2_Com_GN_Kept(2)_BLK5repl_1981	99.47	99	2	47.50	162.50	99.90	5.127	Sym_Beta	121.60	0.05	5%
Size_DblN_peak_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1981	68.86	100	2	47.50	162.50	50.90	6.045	Sym_Beta	64.90	0.05	9%
Size_DblN_peak_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1990	84.28	101	2	47.50	162.50	66.10	3.682	Sym_Beta	64.90	0.05	4%
Size_DblN_start_logit_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1981	0.00	_	-2	-15.00	9.00	0.00	_	Sym_Beta	0.00	0.05	NA
Size_DblN_start_logit_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1990	0.00	_	-2	-15.00	9.00	0.00	_	Sym_Beta	0.00	0.05	NA
Size_DblN_end_logit_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1981	-2.99	102	2	-15.00	9.00	-3.10	0.568	Sym_Beta	-15.00	0.05	19%
Size_DblN_end_logit_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1990	-2.53	103	2	-15.00	9.00	-2.80	0.532	Sym_Beta	-15.00	0.05	21%

Table 3.8. Catchability, *q*, estimated for index S1 with time blocks (1981 – 1996, 1997 – 2004, 2005 – 2007) and for index S2 with time blocks (2008 – 2017, 2018), along with the median unbiased analytical solution for *q* calculated in Stock Synthesis for the remaining indices S3 – S10.

Label	ln(*q*)	*q*
Base years		
S1 (Shark-BLL-Obs; 1997 – 2004)	-1.68974	0.1846
S2 (Shark-BLL-Res; 2008 – 2017)	-1.07833	0.3402
S3 (VIMS-BLL-Robust; 1990 – 2018)	-8.90468	0.0001
S4 (NEFSC-BLL; 1996 – 2018)	-8.05628	0.0003
S5 (SCDNR-SEAMAP-BLL; 2007 – 2018)	-6.32516	0.0018
S6 (SCDNR-Red-Drum-BLL; 1996 – 2006)	-6.57149	0.0014
S7 (SCDNR-DL; 2013 – 2018)	-7.48655	0.0006
S8 (COASTSPAN-BLL-All-ages; 2005 – 2018)	-4.44297	0.0118
S9 (COASTSPAN-GNL-All-ages; 2001 – 2018)	-5.37234	0.0046
S10 (COASTSPAN-GNS-Age-0; 2006 – 2018)	-5.20349	0.0055
Time blocks		
S1 (Shark-BLL-Obs; 1981 – 1996)	-3.10568	0.0448
S1 (Shark-BLL-Obs; 2005 – 2007)	-1.59525	0.2029
S2 (Shark-BLL-Res; 2018)	-2.32934	0.0974

Table 3.9. Total biomass (*B*), spawning stock fecundity (SSF), recruits (*R*), and total fishing mortality (*F=Z-M*) obtained from the base 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		1140	427	
Init		1140	427	
1981	56320	1140	427	0.030
1982	55739	1135	426	0.030
1983	55045	1129	426	0.029
1984	54019	1121	353	0.045
1985	52447	1106	321	0.044
1986	50739	1086	382	0.044
1987	49088	1062	441	0.025
1988	47757	1040	365	0.027
1989	46637	1012	399	0.021
1990	45731	984	391	0.032
1991	44864	954	428	0.046
1992	43671	913	423	0.051
1993	42677	871	499	0.063
1994	41514	834	483	0.045
1995	41161	815	447	0.057
1996	40310	793	299	0.041
1997	39706	774	288	0.067
1998	38556	757	269	0.068
1999	37172	742	242	0.082
2000	35338	729	200	0.068
2001	33812	725	203	0.073
2002	32270	720	257	0.084
2003	30657	706	309	0.087
2004	29379	682	398	0.113
2005	28205	654	388	0.095
2006	27315	625	323	0.084
2007	26700	594	353	0.073
2008	26531	564	394	0.076
2009	26361	534	374	0.069
2010	26321	509	330	0.036
2011	26696	494	336	0.025
2012	27469	487	419	0.026
2013	28444	486	472	0.035
2014	29029	485	257	0.055
2015	29354	486	241	0.051
2016	29450	495	239	0.042
2017	29570	506	321	0.028
2018	29725	520	314	0.026

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 from the base model configuration.

Year	F/F_{MSY}	SE	SSF/SSF_{MSY}	SE	SSF/MSST
1981	0.57	0.106	2.54	NA	2.95
1982	0.59	0.111	2.53	0.018	2.93
1983	0.57	0.109	2.51	0.020	2.92
1984	0.87	0.173	2.50	0.024	2.90
1985	0.86	0.176	2.46	0.030	2.86
1986	0.86	0.182	2.42	0.038	2.81
1987	0.48	0.103	2.36	0.047	2.75
1988	0.52	0.112	2.32	0.053	2.69
1989	0.41	0.089	2.25	0.061	2.62
1990	0.62	0.136	2.19	0.069	2.54
1991	0.89	0.201	2.12	0.077	2.47
1992	0.99	0.229	2.03	0.090	2.36
1993	1.23	0.292	1.94	0.105	2.25
1994	0.88	0.218	1.86	0.121	2.16
1995	1.10	0.276	1.81	0.133	2.11
1996	0.80	0.206	1.76	0.145	2.05
1997	1.31	0.347	1.72	0.154	2.00
1998	1.32	0.361	1.68	0.164	1.96
1999	1.59	0.448	1.65	0.174	1.92
2000	1.32	0.385	1.62	0.186	1.88
2001	1.41	0.425	1.61	0.192	1.87
2002	1.64	0.502	1.60	0.200	1.86
2003	1.69	0.528	1.57	0.208	1.83
2004	2.20	0.689	1.52	0.213	1.76
2005	1.85	0.598	1.46	0.214	1.69
2006	1.64	0.542	1.39	0.214	1.62
2007	1.42	0.477	1.32	0.214	1.53
2008	1.47	0.503	1.26	0.211	1.46
2009	1.35	0.471	1.19	0.209	1.38
2010	0.69	0.245	1.13	0.209	1.32
2011	0.49	0.172	1.10	0.212	1.28
2012	0.51	0.178	1.08	0.217	1.26
2013	0.68	0.233	1.08	0.223	1.26
2014	1.08	0.378	1.08	0.229	1.25
2015	0.98	0.353	1.08	0.235	1.26
2016	0.83	0.302	1.10	0.242	1.28
2017	0.55	0.199	1.13	0.249	1.31
2018	0.51	0.183	1.16	0.255	1.34

Table 3.11. Summary of benchmark and reference point results for the base configuration and logistic sensitivity analysis. 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_{2018}, and F_{2018}). Benchmarks are reported relative to equilibrium MSY reference points (SSF_{MSY}, and F_{MSY}) and to the Minimum Stock Size Threshold, 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 assessment model configuration (**Tables 2.13** and **2.14**). 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 3.4.5.

	Base model configuration		Logistic sensitivity	
Parameters	102		90	
Objective function	553.3		593.0	
Gradient	$5.49*10^{-5}$		$1.03*10^{-4}$	
$\bar{M}_a$	0.139		0.239	
$\left(1-\bar{M}_a\right)$	0.861		0.761	
Steepness	0.4		0.4	
	Est	CV	Est	CV
SSF_{2018}	520	39%	341	39%
F_{2018}	0.026	---	0.019	---
R_{2018}	314	33%	587	34%
SSF_0	1,140	18%	637	19%
R_0	427	18%	785	19%
MSY	471	22%	738	19%
SSF_{MSY}	449	18%	246	19%
F_{MSY}	0.051	9%	0.052	3%
SSF_{2018}/SSF_{MSY}	1.158	22%	1.390	21%
F_{2018}/F_{MSY}	0.509	36%	0.366	34%
MSST	387		187	
SSF_{2018}/MSST	1.344		1.825	
Stock status	SSF_{2018} > MSST		SSF_{2018} > MSST	
Fishery status	$F_{2018} < F_{MSY}$		$F_{2018} < F_{MSY}$	

3.9. Figures

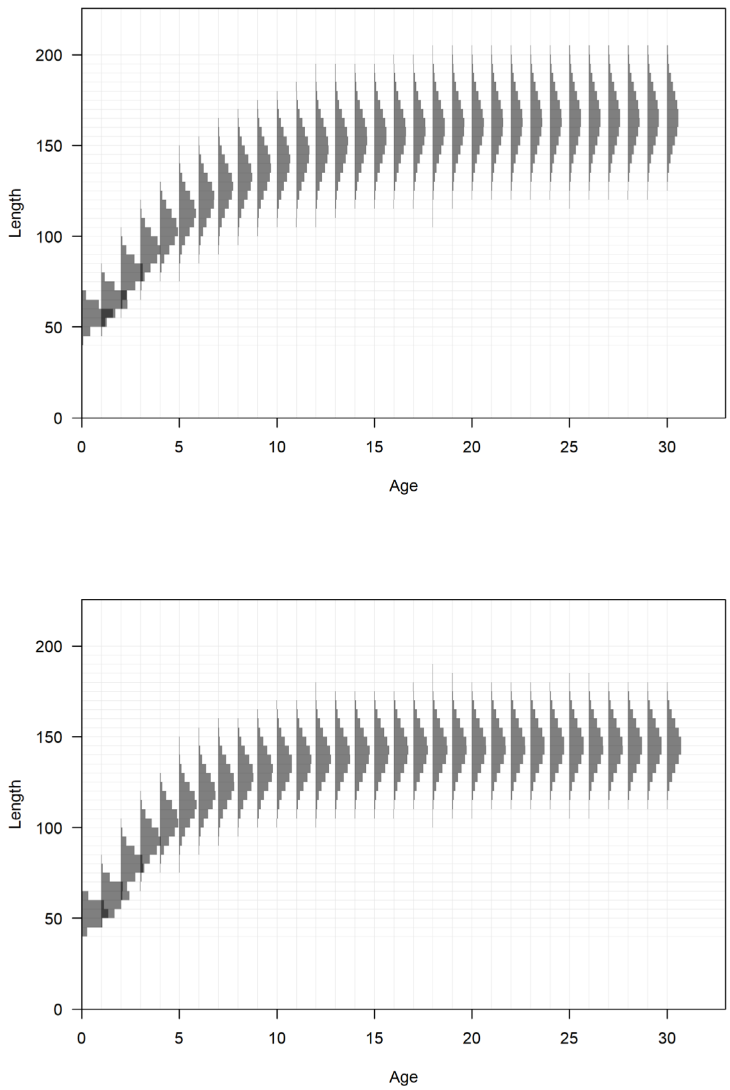


Figure 3.1. Distribution of mean length (cm FL straight) at each age implemented separately for females (upper panel) and males (lower panel) in the base model configuration.

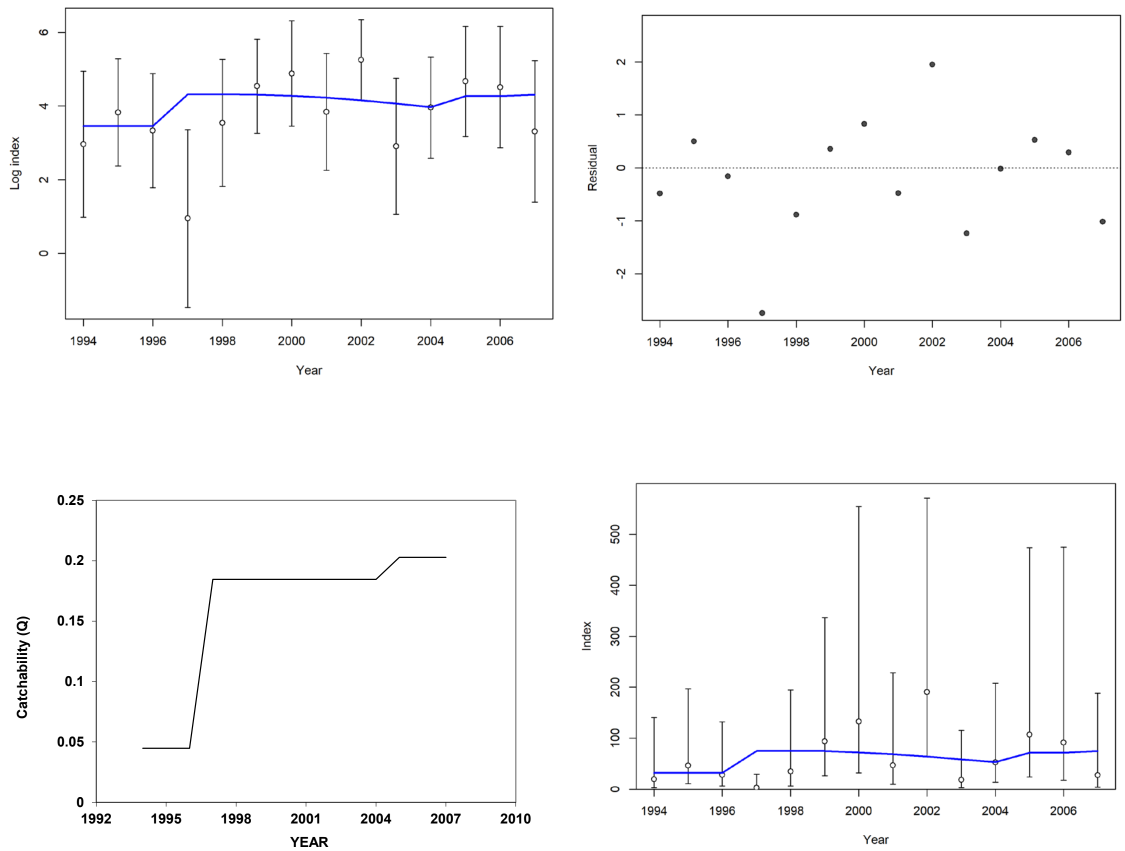


Figure 3.2. Fits to abundance index S1 (Shark-BLL-Obs; 1994 – 2007; **Table 3.1**) in the base model configuration: Upper left panel is predicted (blue line) and observed (open circles with approximate 95% confidence intervals based on the input standard error, SE) on the natural log scale; Upper right 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.

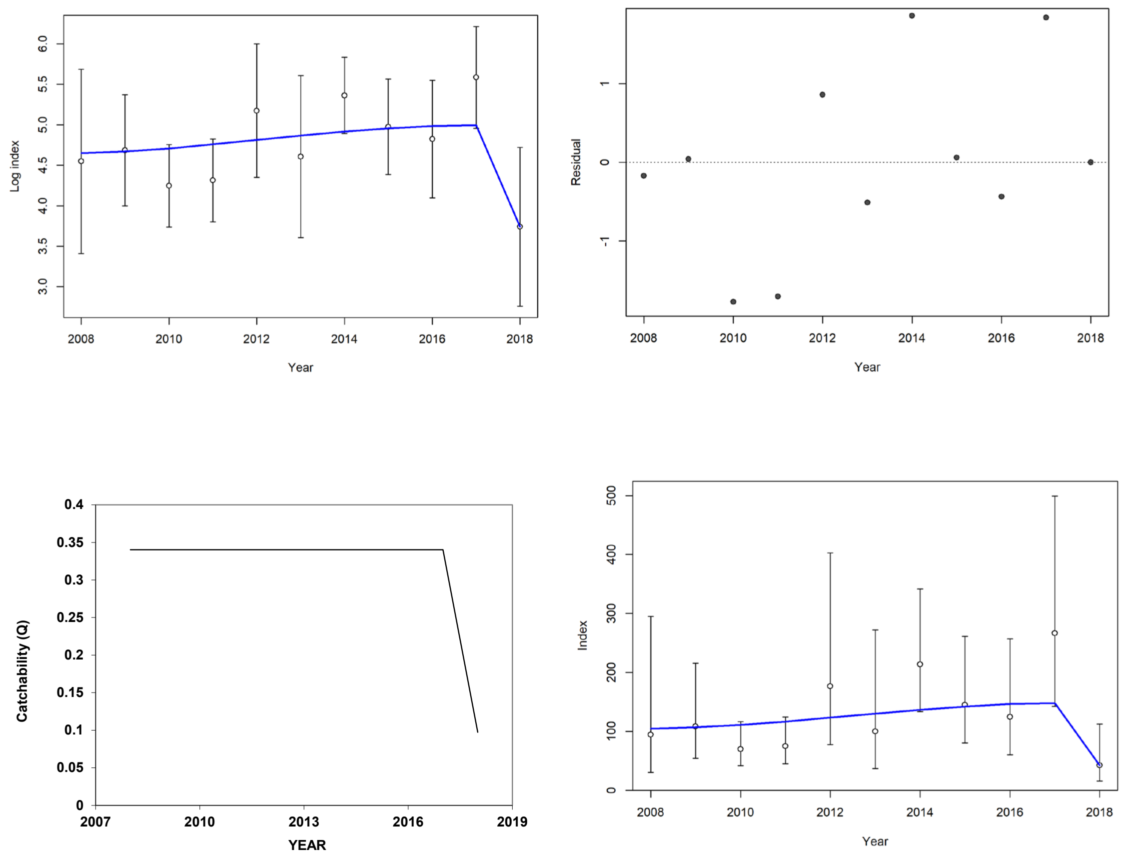


Figure 3.2. Continued: Fits to abundance index S2 (Shark-BLL-Res; 2008 – 2018).

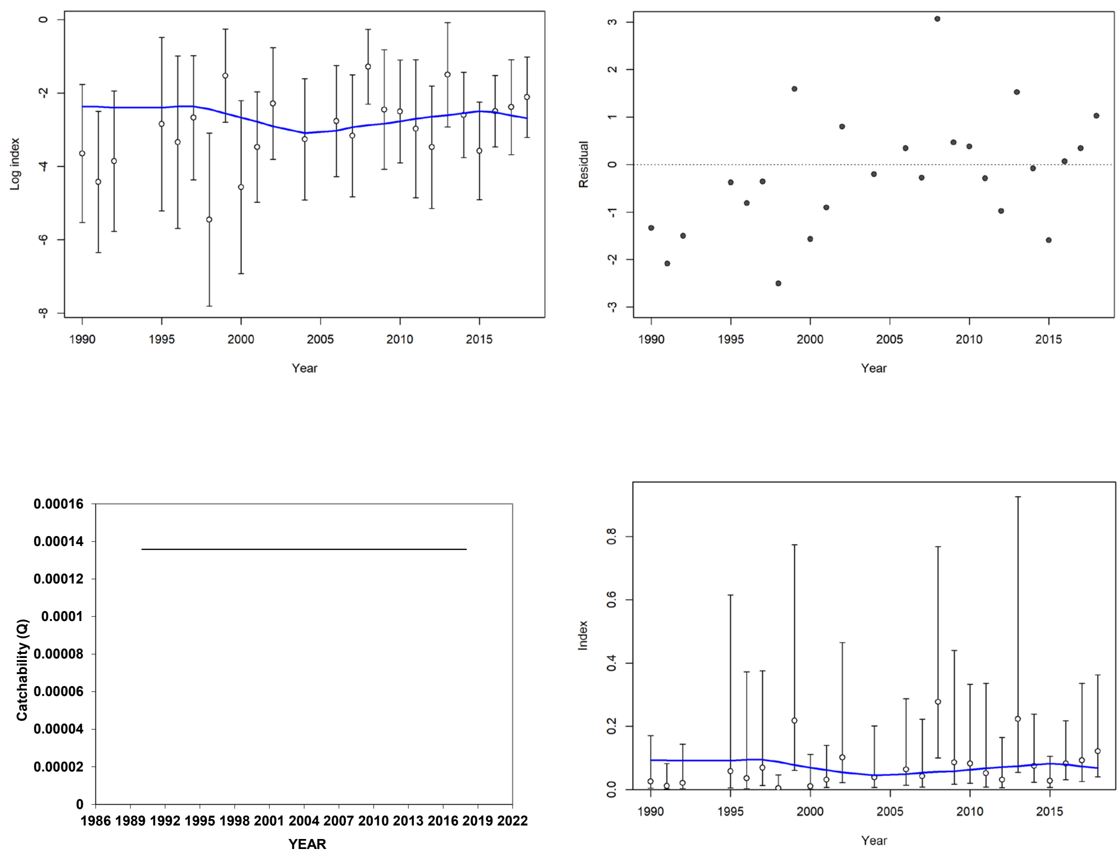


Figure 3.2. Continued: Fits to abundance index S3 (VIMS-BLL-Robust; 1990 – 2018).

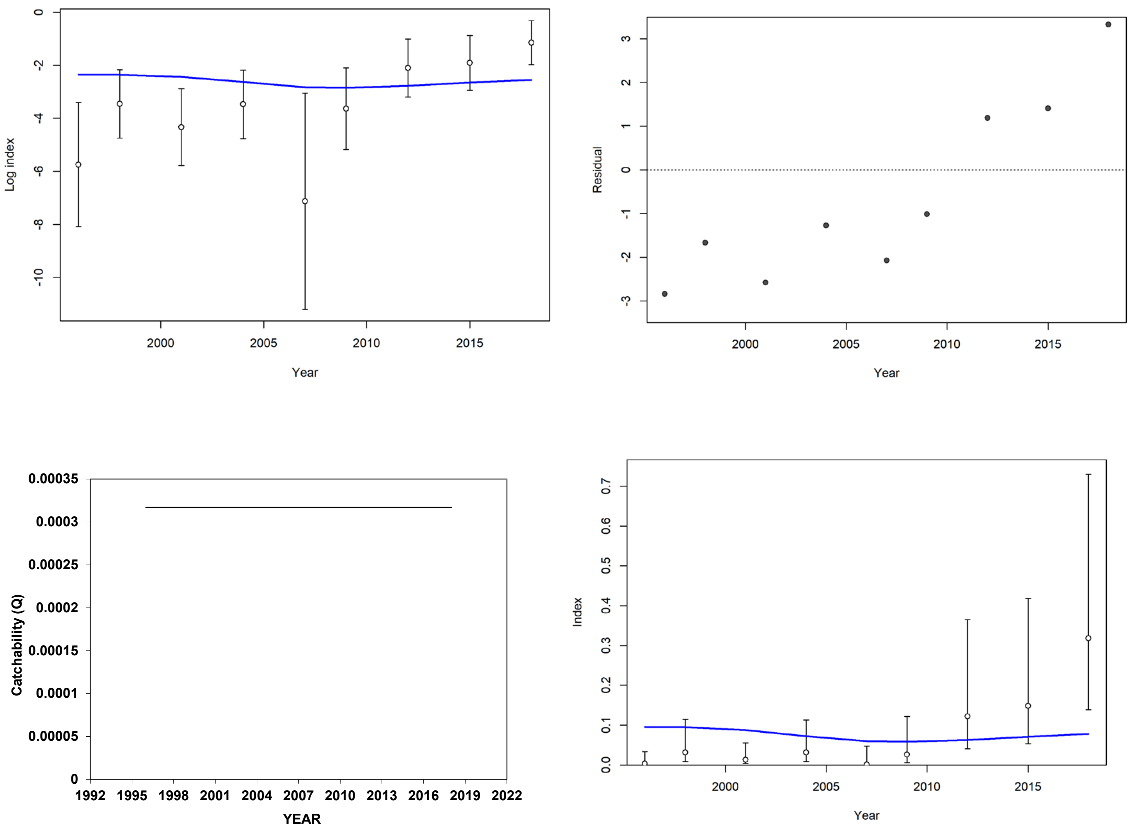


Figure 3.2. Continued: Fits to abundance index S4 (NEFSC-BLL; 1996 – 2018).

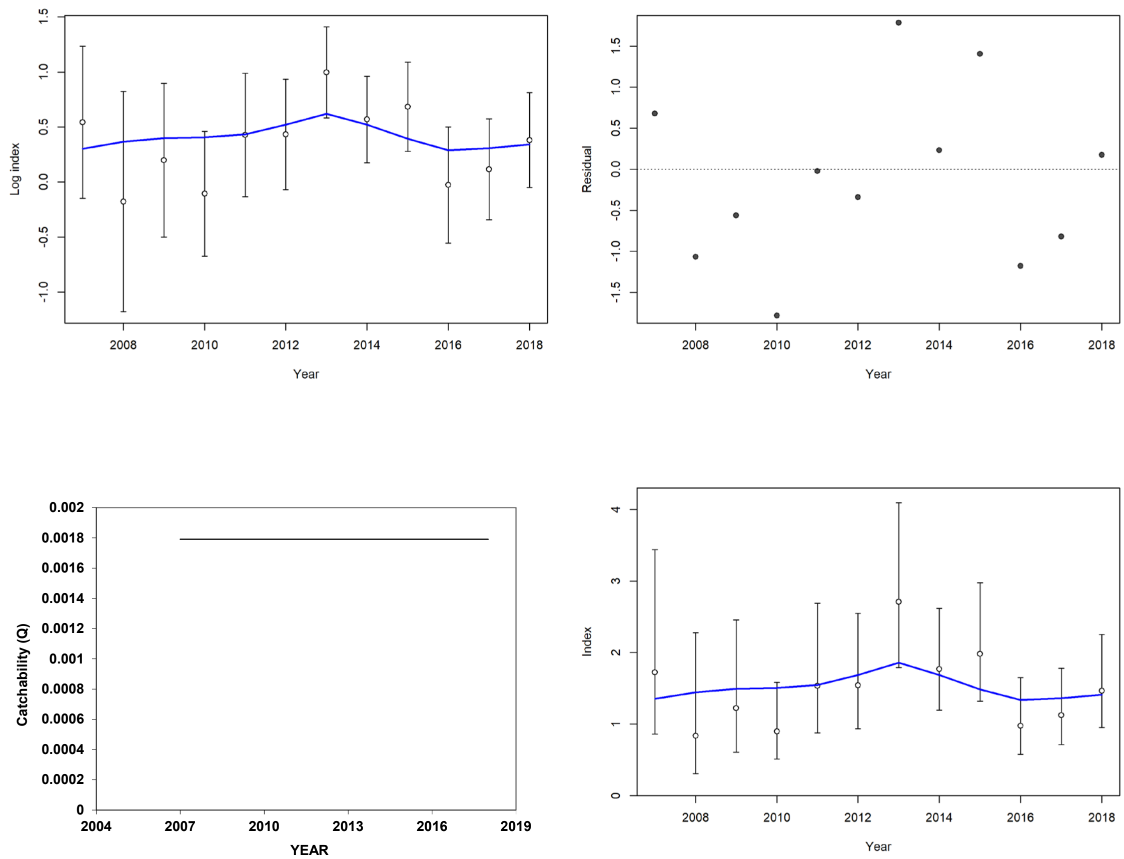


Figure 3.2. Continued: Fits to abundance index S5 (SCDNR-SEAMAP-BLL; 2007 – 2018).

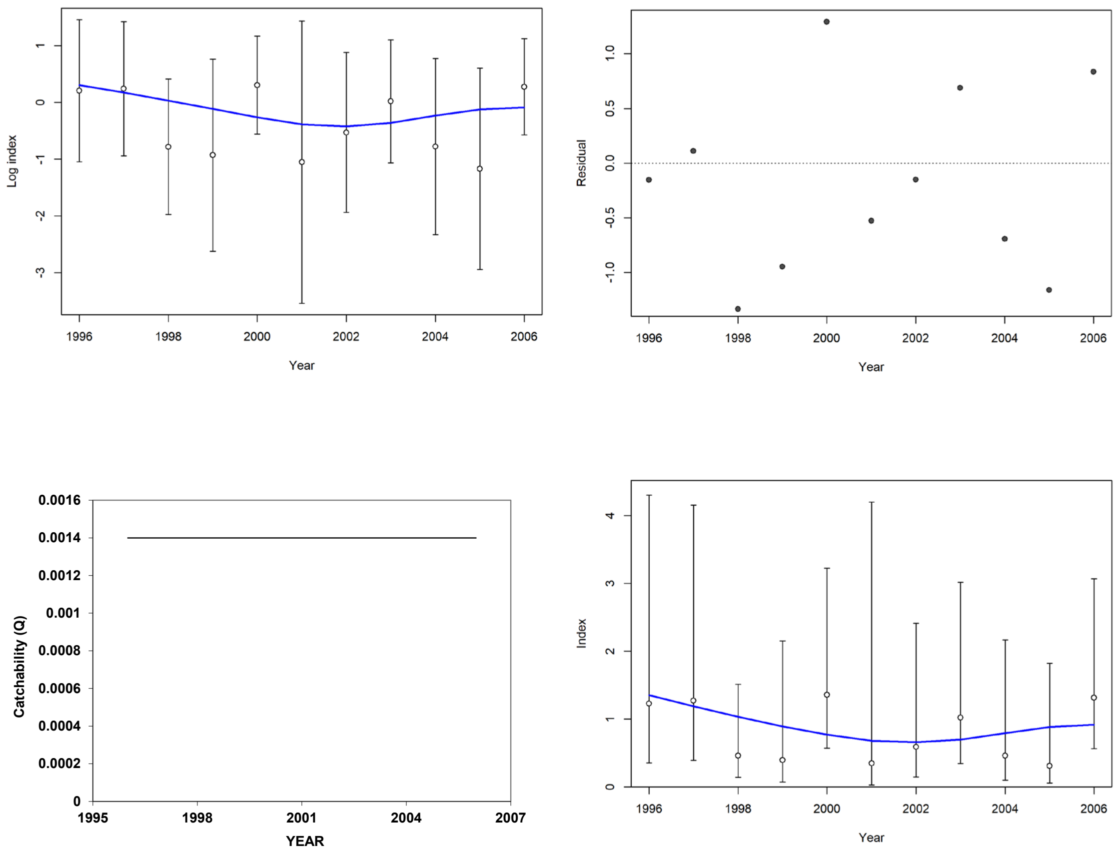


Figure 3.2. Continued: Fits to abundance index S6 (SCDNR-Red-Drum-BLL; 1996 – 2006).

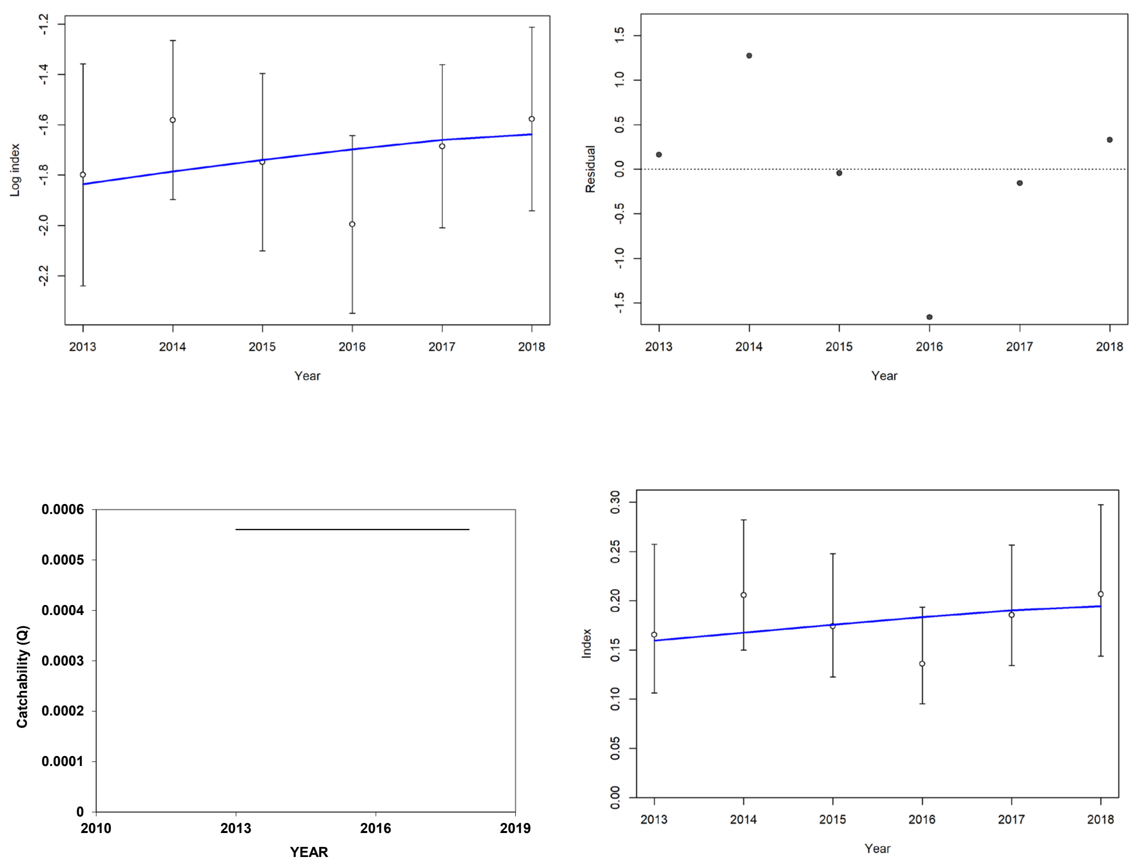


Figure 3.2. Continued: Fits to abundance index S7 (SCDNR-DL; 2013 – 2018).

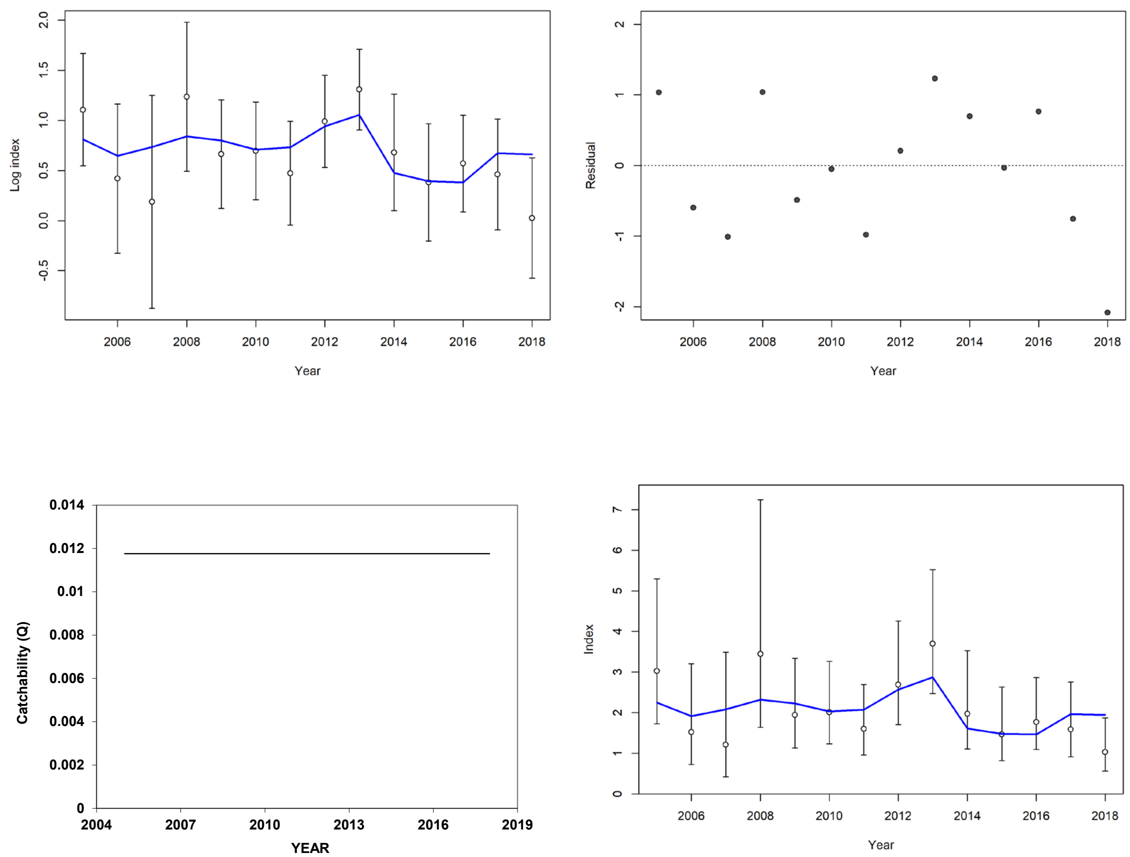


Figure 3.2. Continued: Fits to abundance index S8 (COASTSPAN-BLL-All-ages; 2005 – 2018).

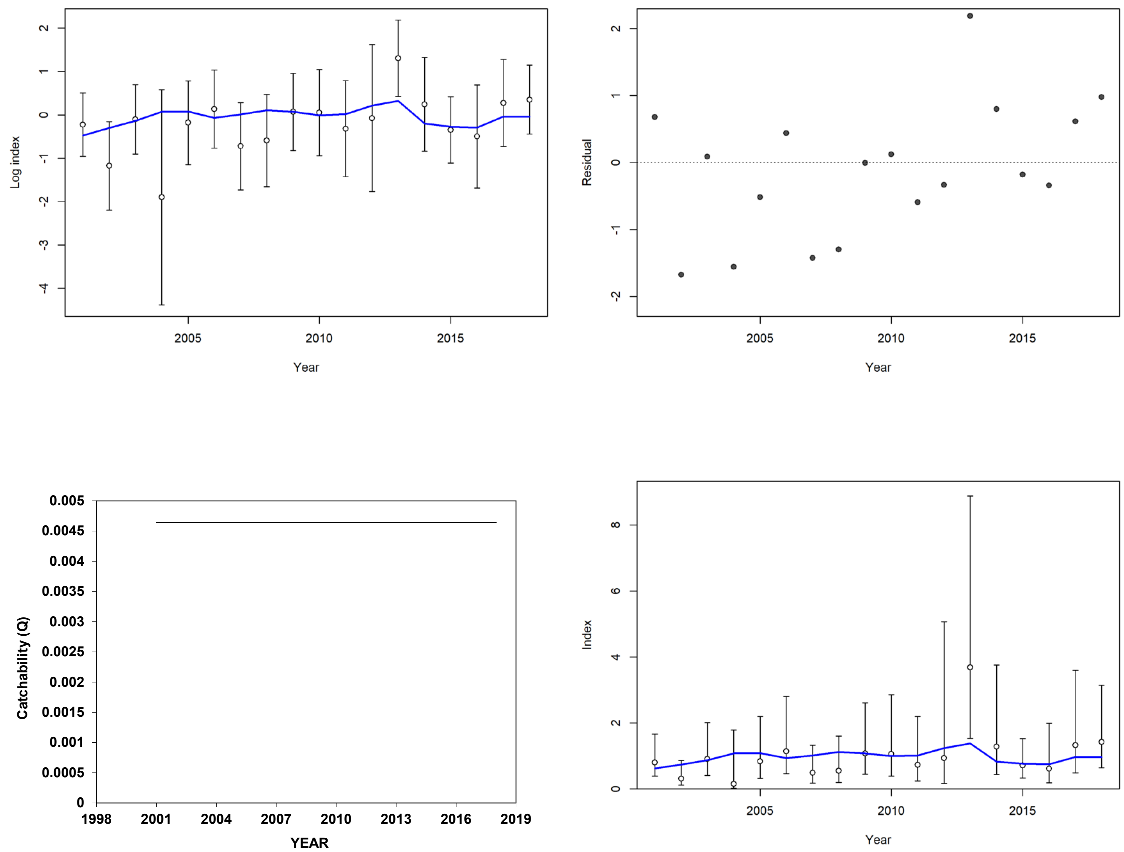


Figure 3.2. Continued: Fits to abundance index S9 (COASTSPAN-GNL-All-ages; 2001 – 2018).

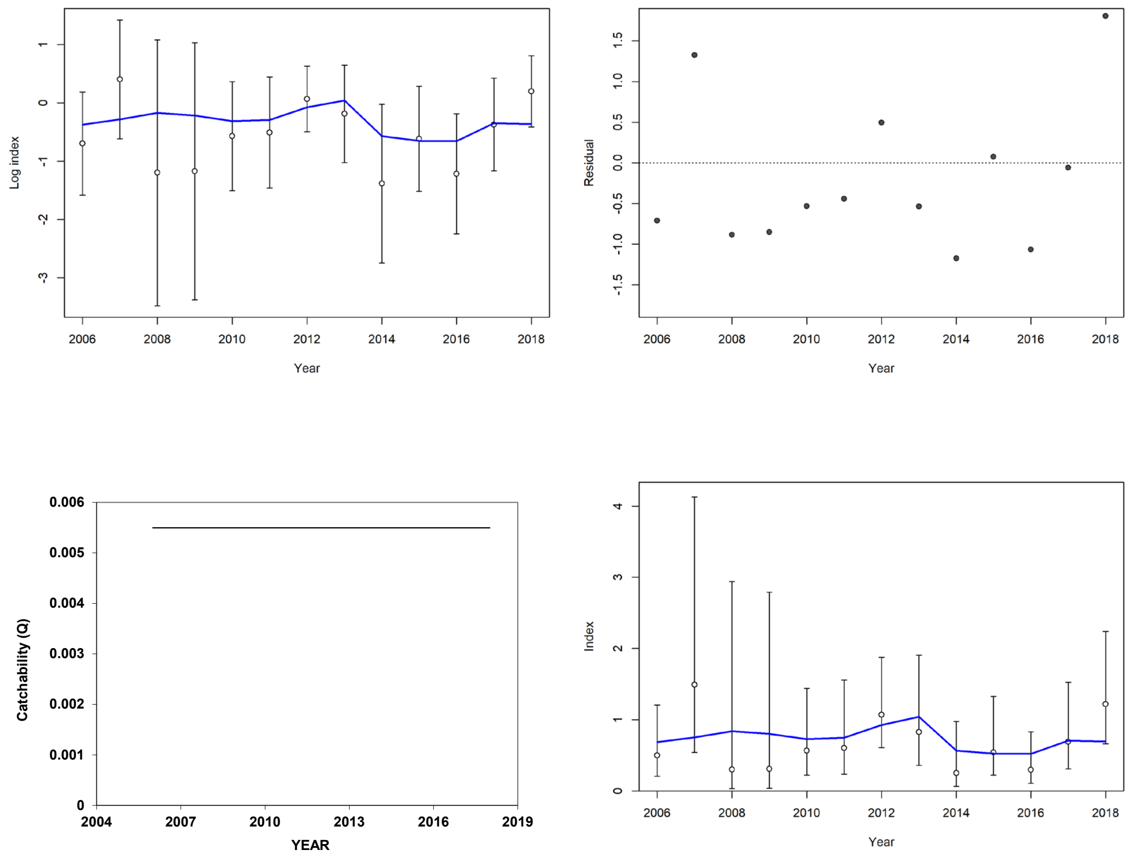
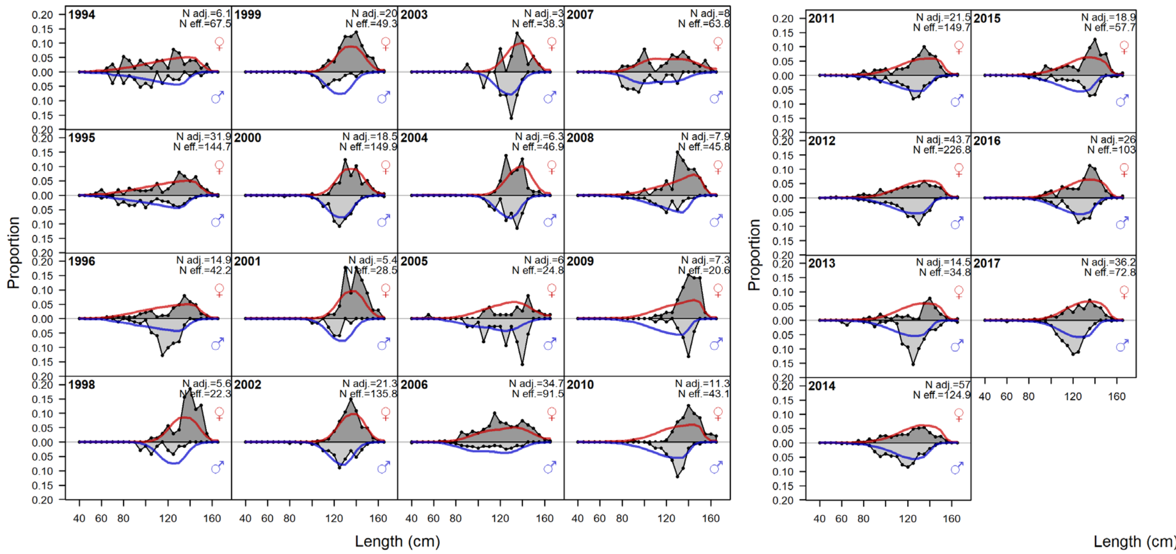


Figure 3.2. Continued: Fits to abundance index S10 (COASTSPAN-GNS-Age-0; 2006 – 2018).

Figure 3.3. Observed and predicted annual length compositions (Upper panels) and Pearson residuals (Lower panel) in the base 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. 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.



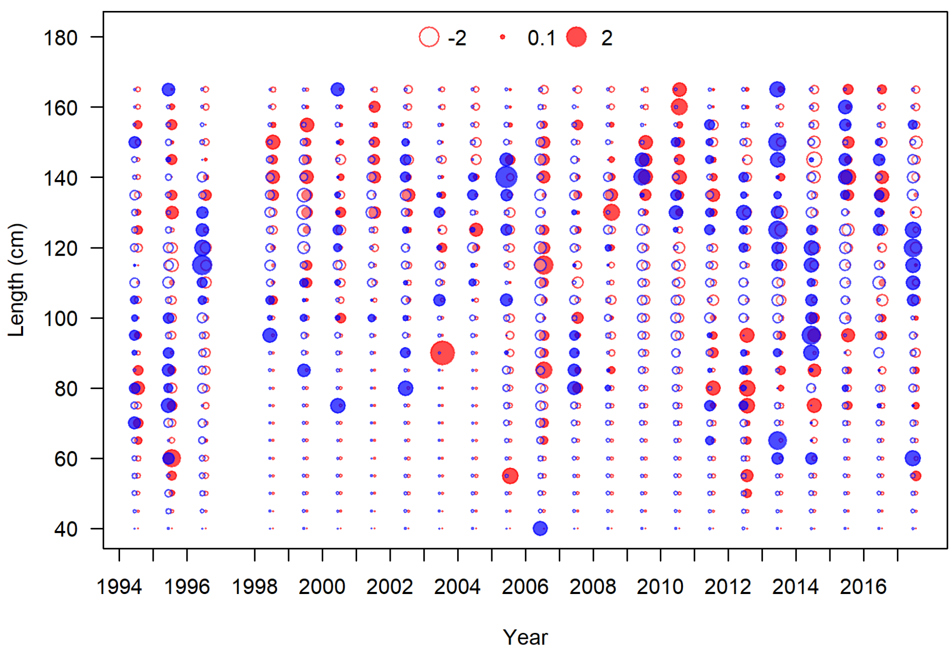
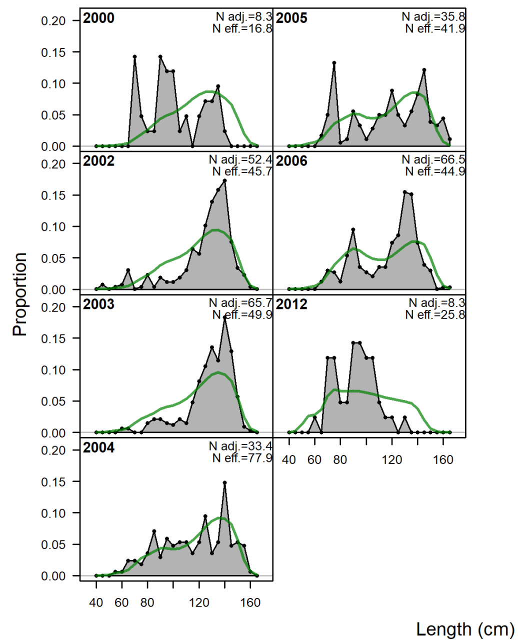


Figure 3.3. Continued. Fits to length composition obtained for F1 (Com-BLL-Kept; 1994 – 2018).



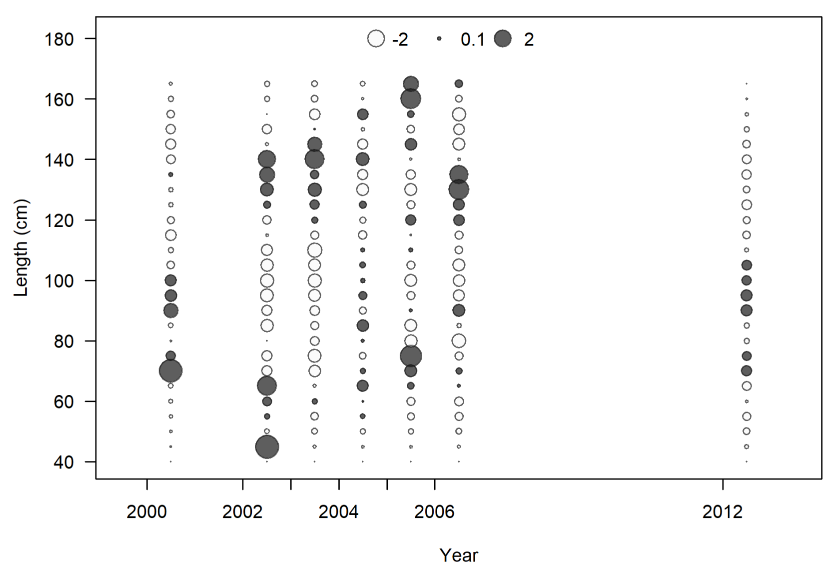
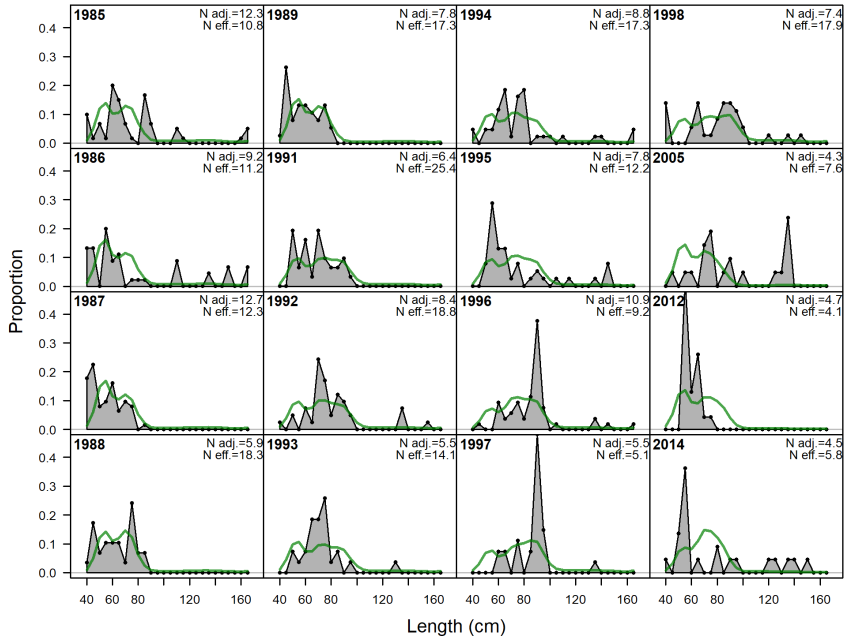


Figure 3.3. Continued. Fits to length composition obtained for F2 (Com-GN-Kept; 2000 – 2018).



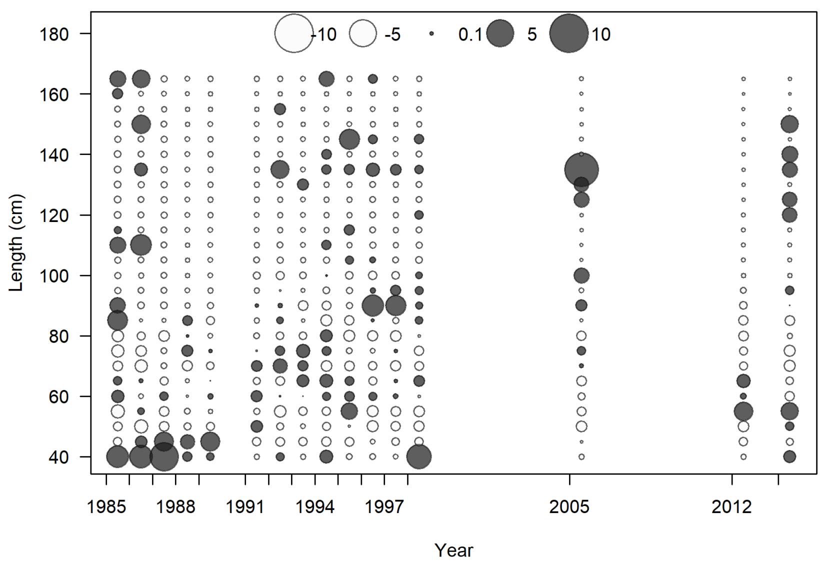
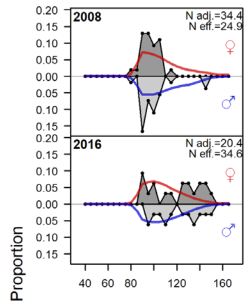


Figure 3.3. Continued. Fits to length composition obtained for F4 (Recreational; 1981 – 2018).



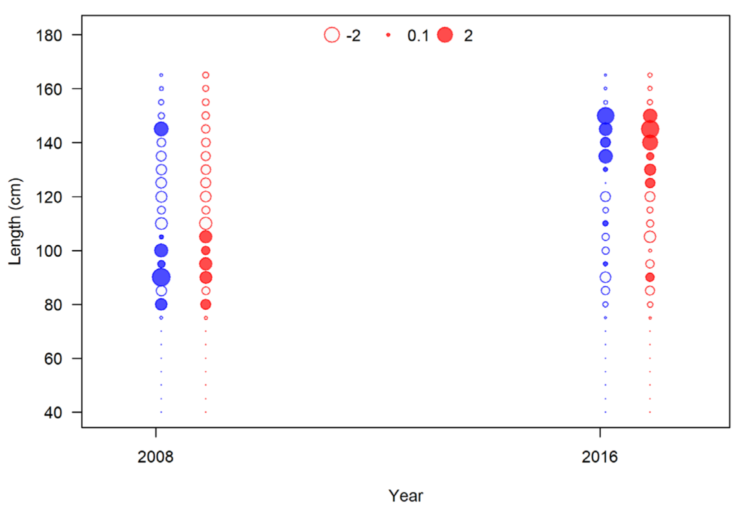
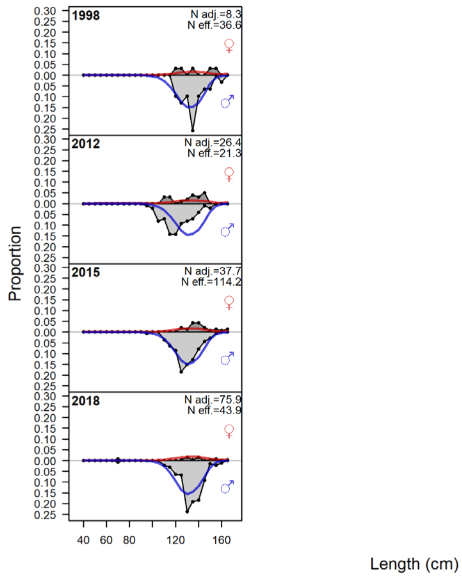


Figure 3.3. Continued. Fits to length composition obtained for S3 (VIMS-BLL-Robust; 1990 – 2018).



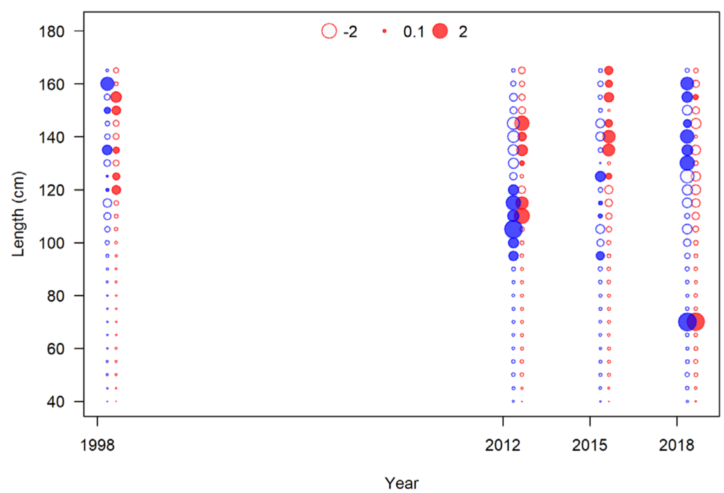
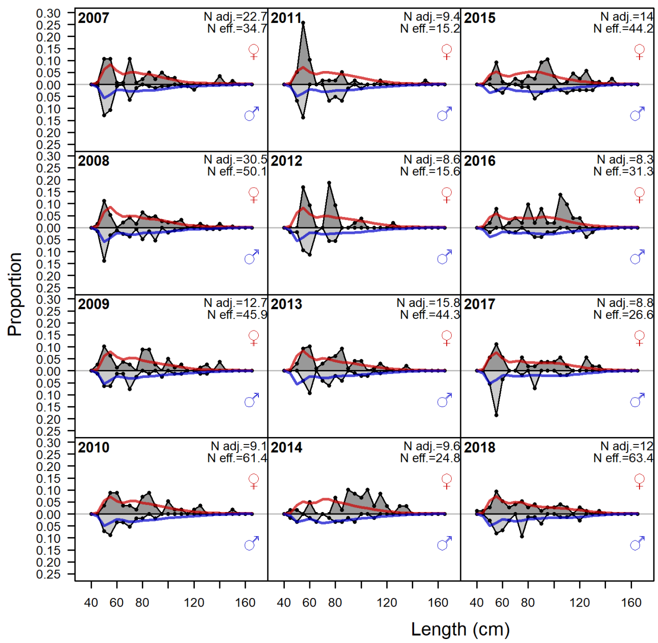


Figure 3.3. Continued. Fits to length composition obtained for S4 (NEFSC-BLL; 1996 – 2018).



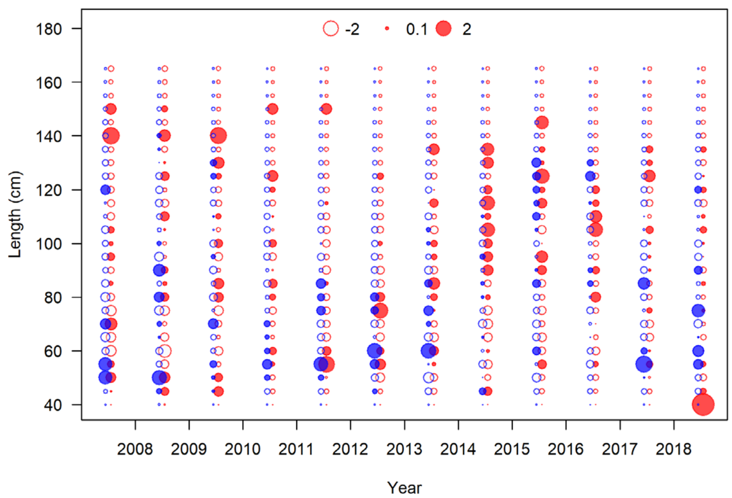
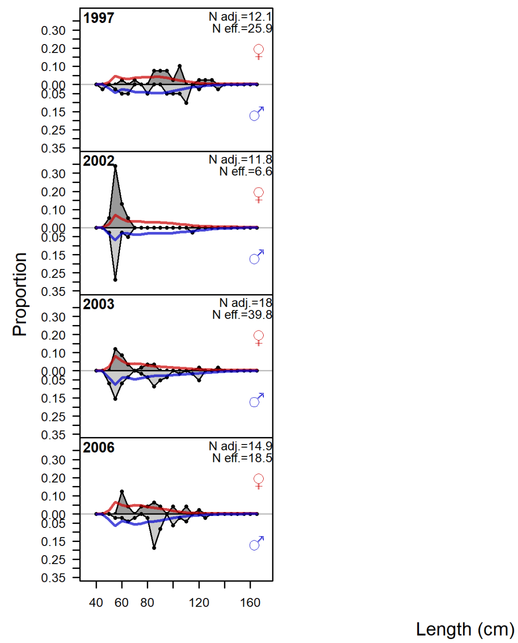


Figure 3.3. Continued. Fits to length composition obtained for S5 (SCDNR-SEAMAP-BLL; 2007 – 2018).



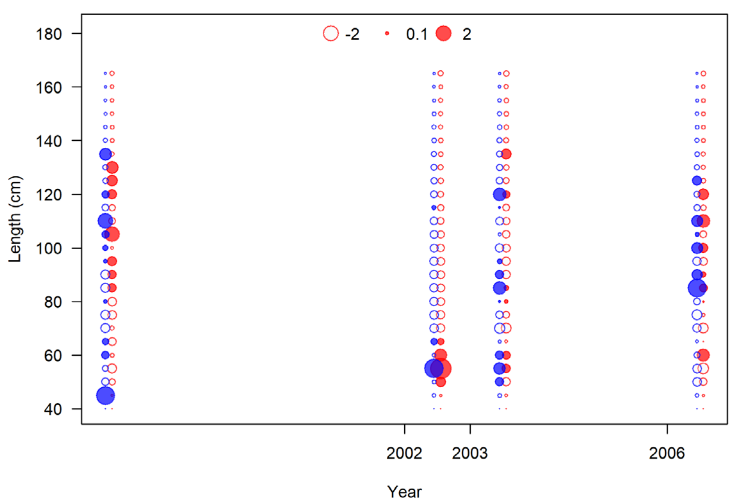
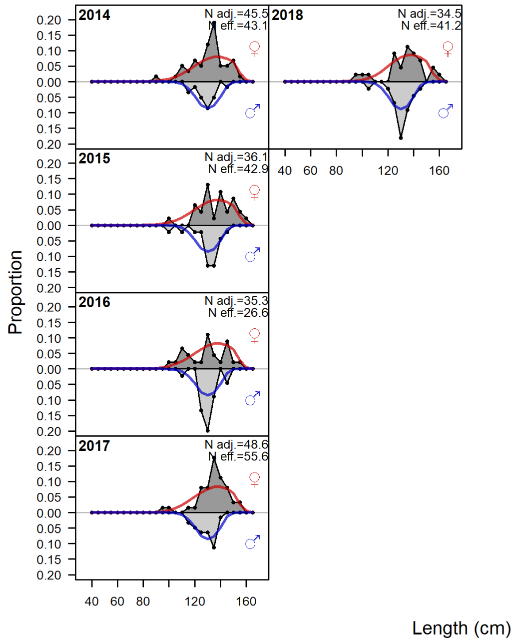


Figure 3.3. Continued. Fits to length composition obtained for S6 (SCDNR-Red-Drum-BLL; 1996 – 2006).



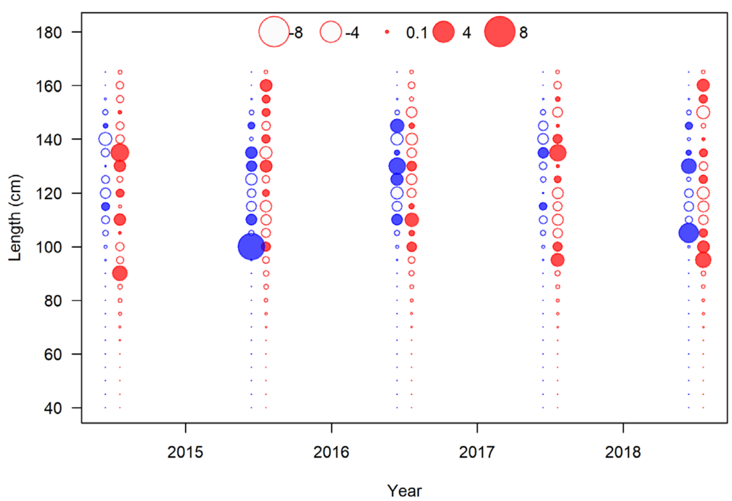
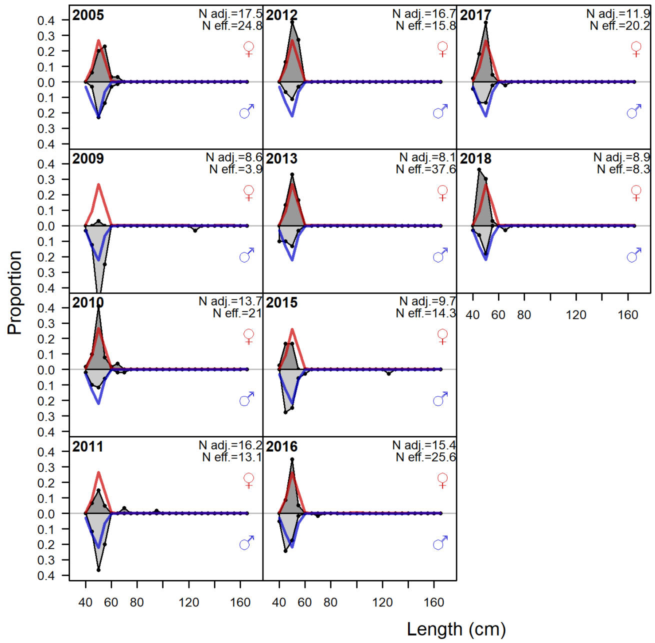


Figure 3.3. Continued. Fits to length composition obtained for S7 (SCDNR-DL; 2013 – 2018).



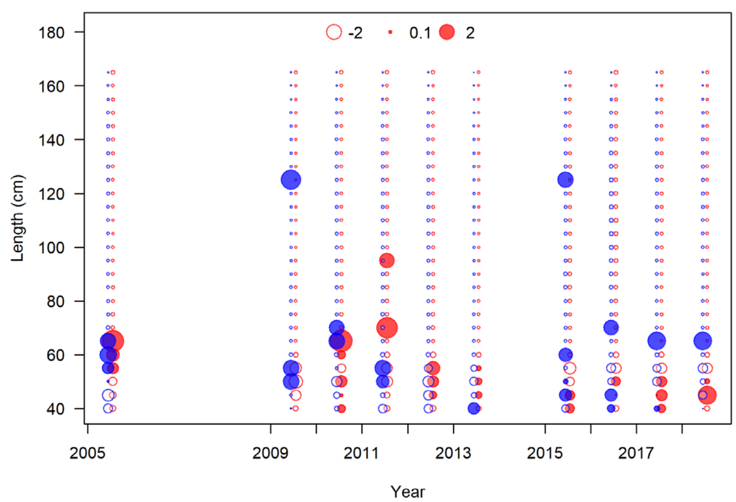
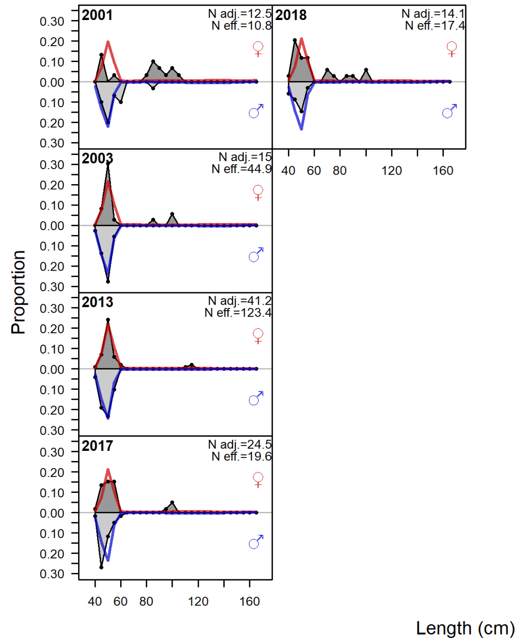


Figure 3.3. Continued. Fits to length composition obtained for S8 (COASTSPAN-BLL-All-ages; 2005 – 2018).



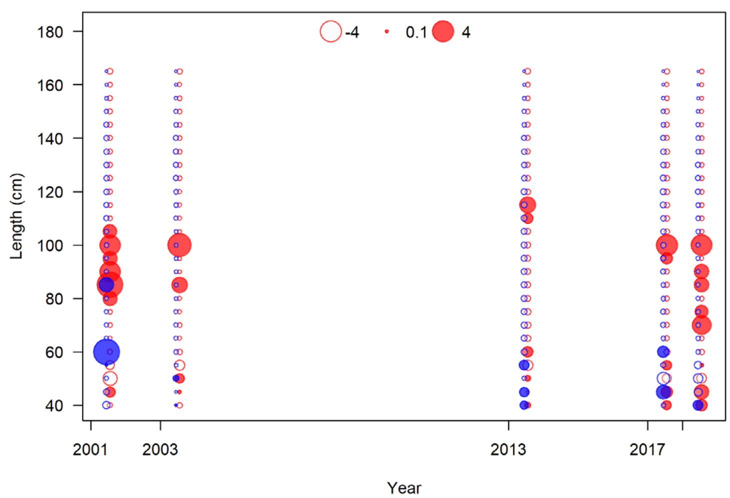
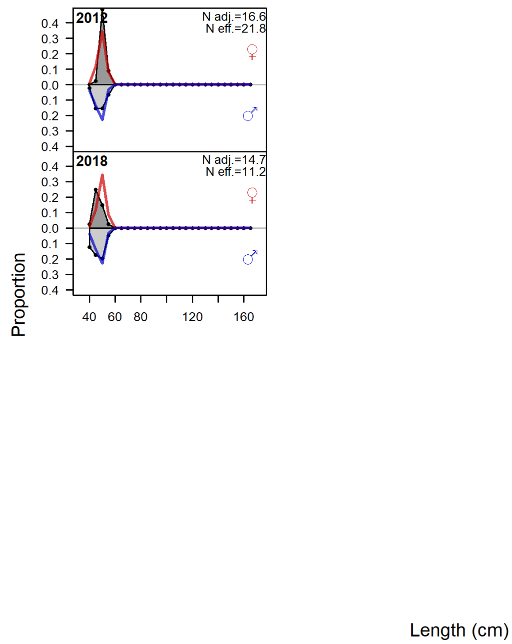


Figure 3.3. Continued. Fits to length composition obtained for S9 (COASTSPAN-GNL-All-ages; 2001 – 2018).



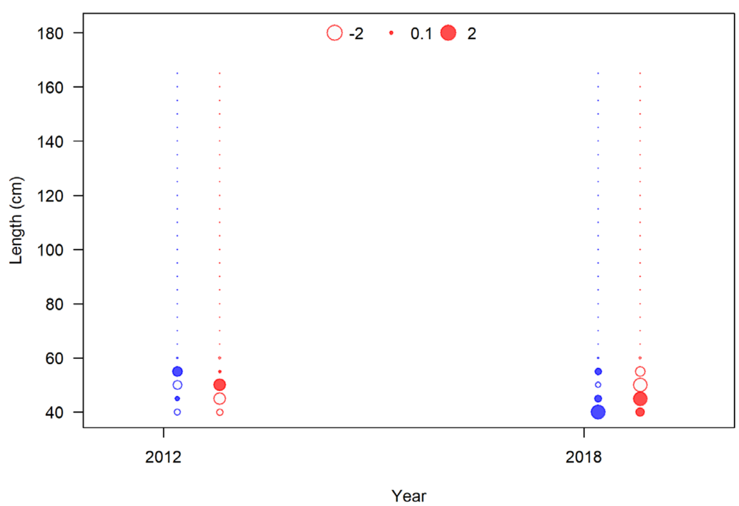


Figure 3.3. Continued. Fits to length composition obtained for S10 (COASTSPAN-GNS-Age-0; 2006 – 2018).

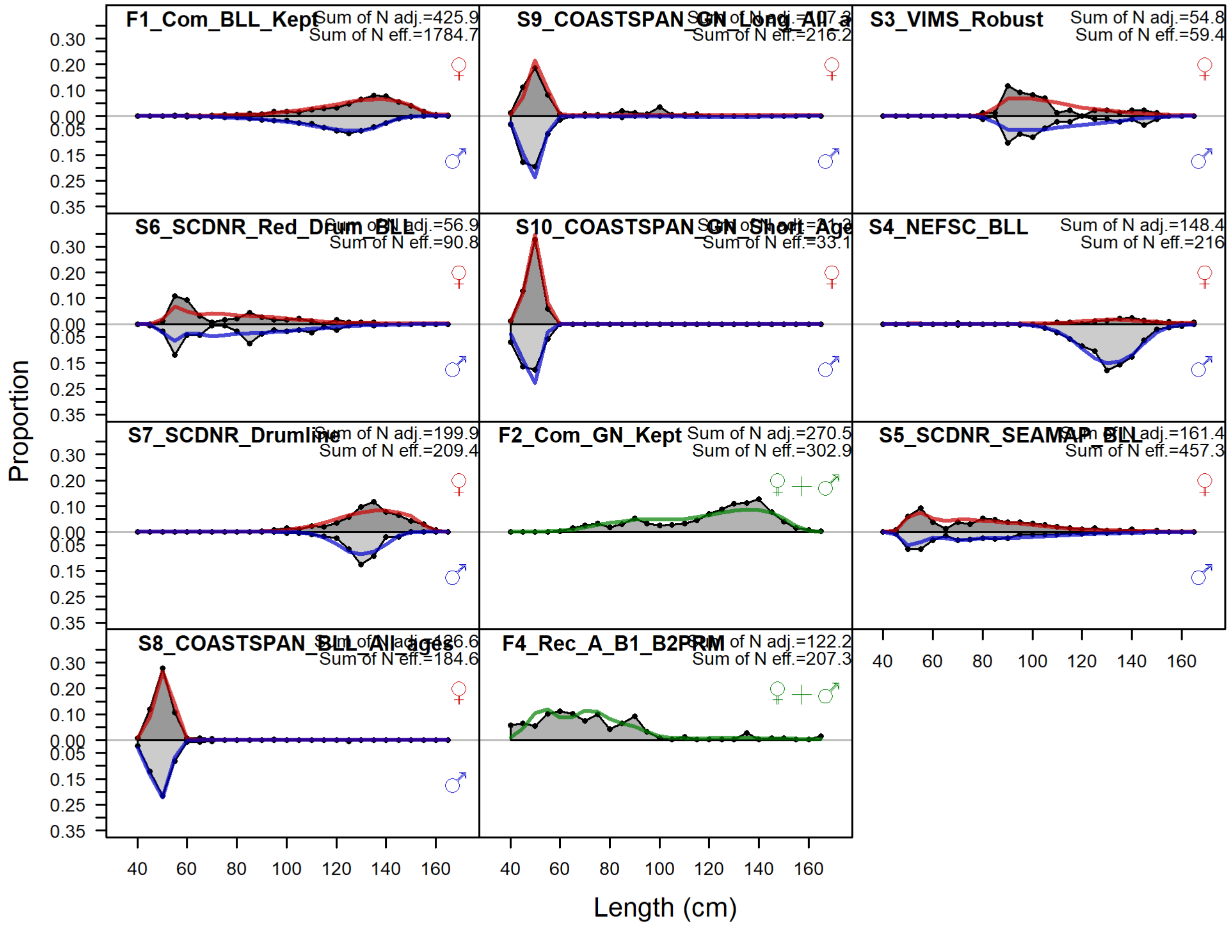
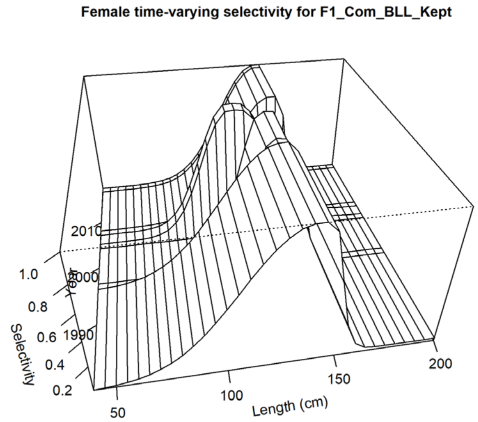


Figure 3.4. Predicted (line) and observed (shaded) aggregated length compositions in the base model configuration model. Years with annual length composition sample size less than the minimum input sample size (Min; **Table 3.2)** were excluded from the model fit, and are not plotted. The value "N adj" 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.



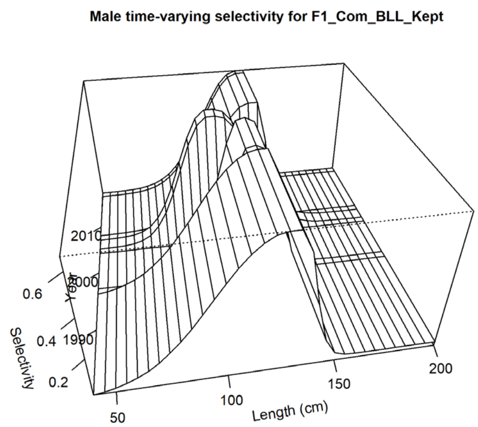


Figure 3.5. Estimated selectivity at length (cm FL straight) obtained in the base model configuration (**Table 3.5)** for F1 (Com-BLL-Kept; 1994 – 2018).

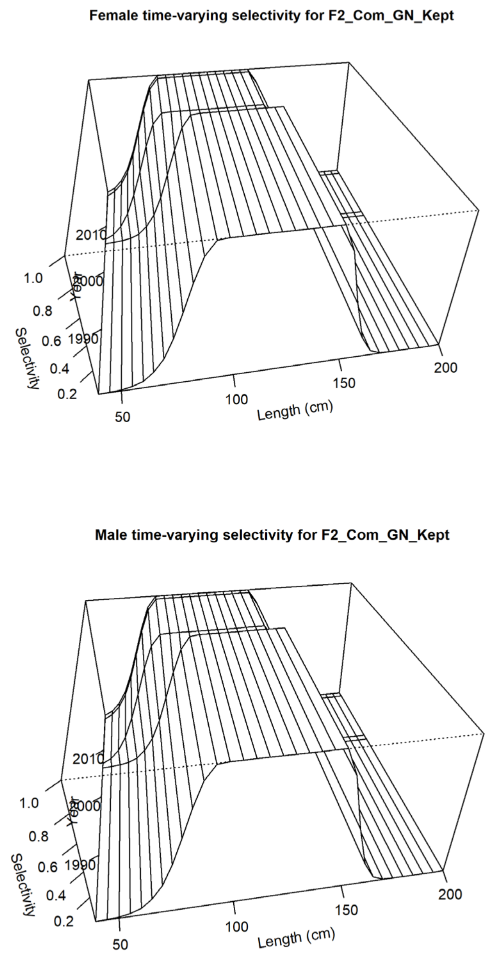
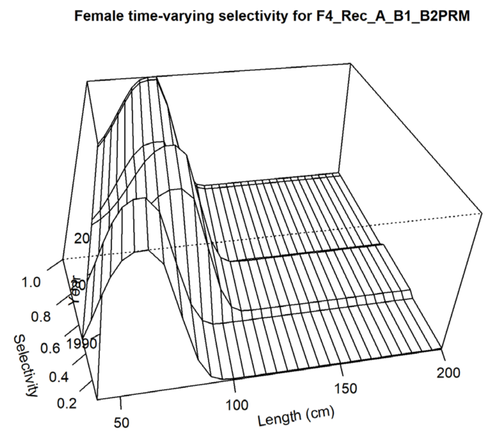


Figure 3.5. Continued. F2 (Com-GN-Kept; 2000 – 2018).



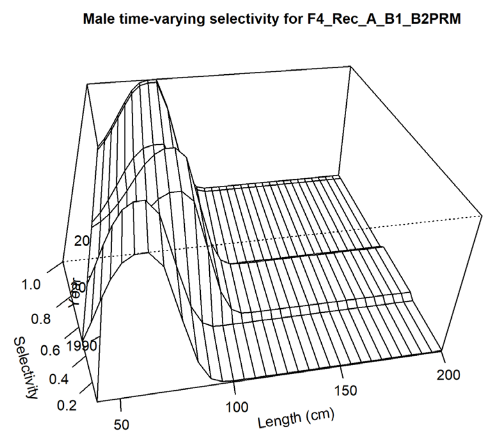


Figure 3.5. Continued. F4 (Recreational; 1981 – 2018).

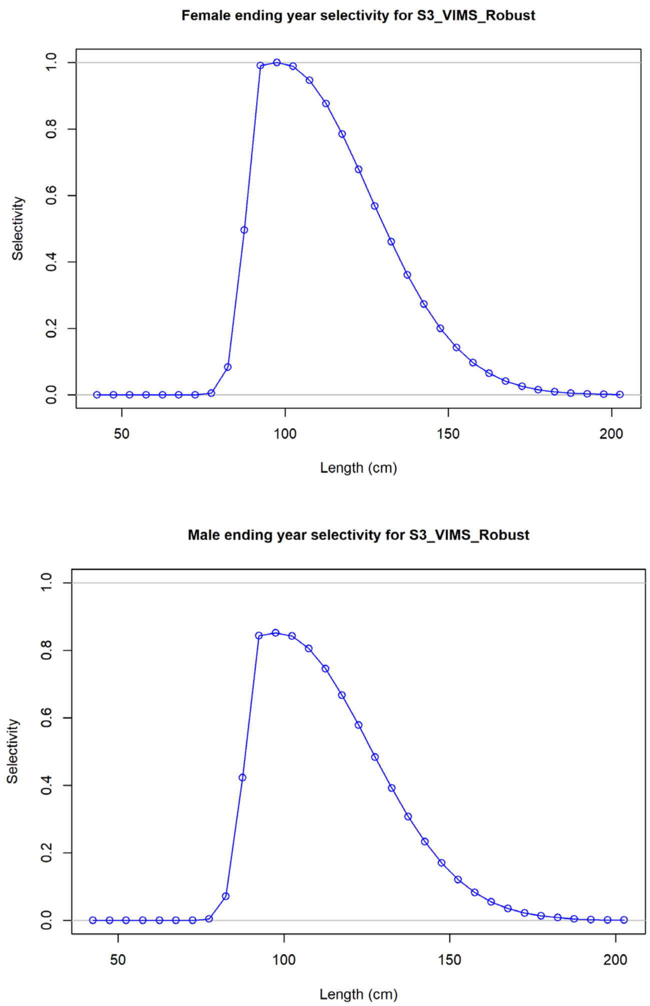


Figure 3.5. Continued. S3 (VIMS-BLL-Robust; 1990 – 2018).

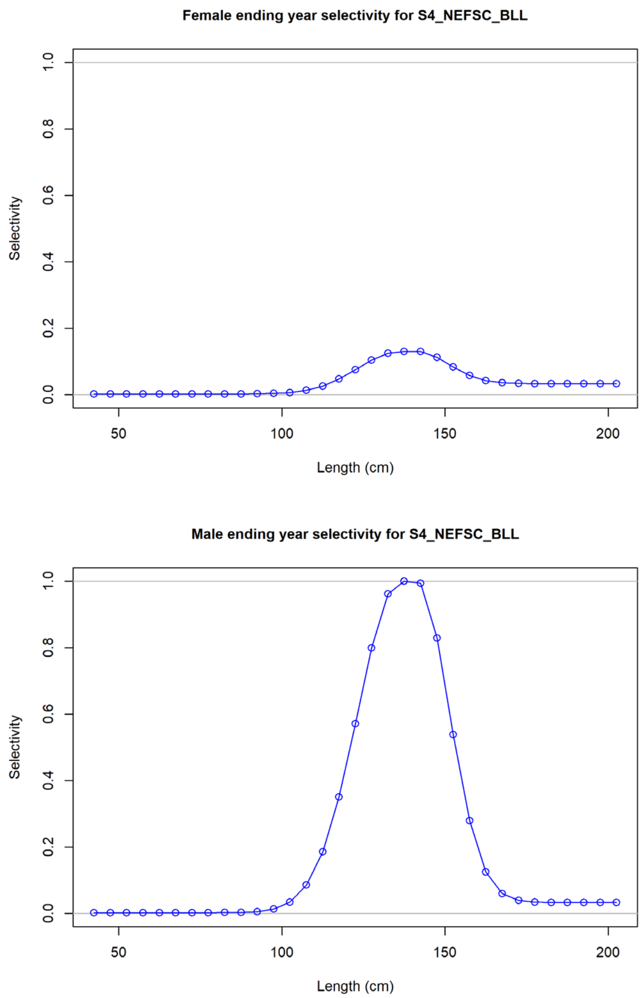
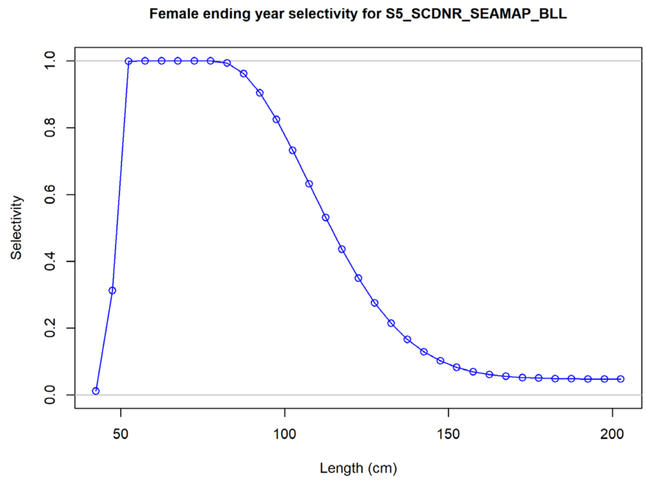


Figure 3.5. Continued. S4 (NEFSC-BLL; 1996 – 2018).



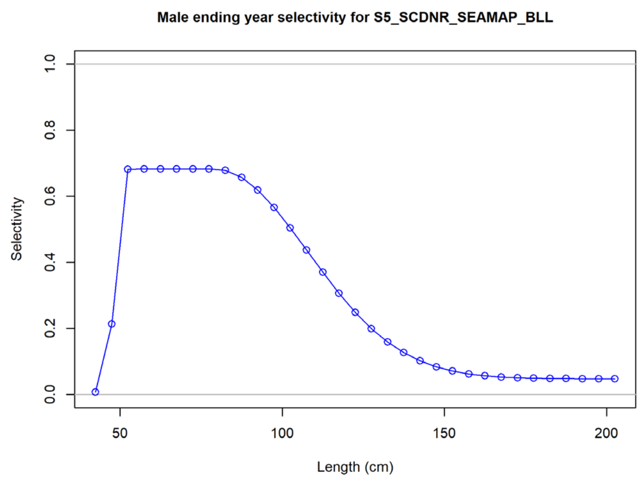


Figure 3.5. Continued. S5 (SCDNR-SEAMAP-BLL; 2007 – 2018).

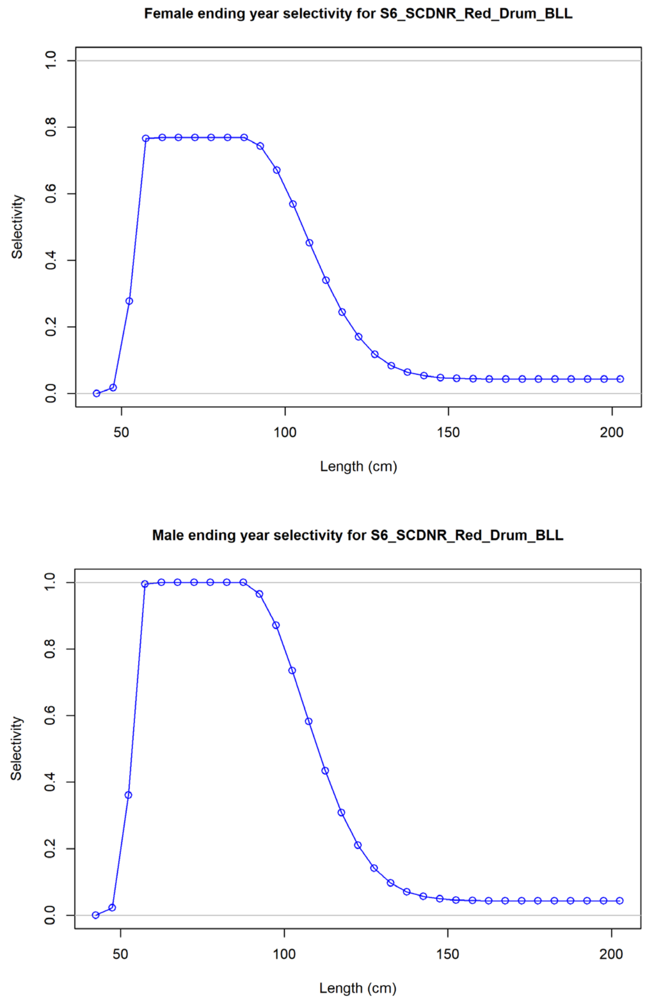


Figure 3.5. Continued. S6 (SCDNR-Red-Drum-BLL; 1996 – 2006).

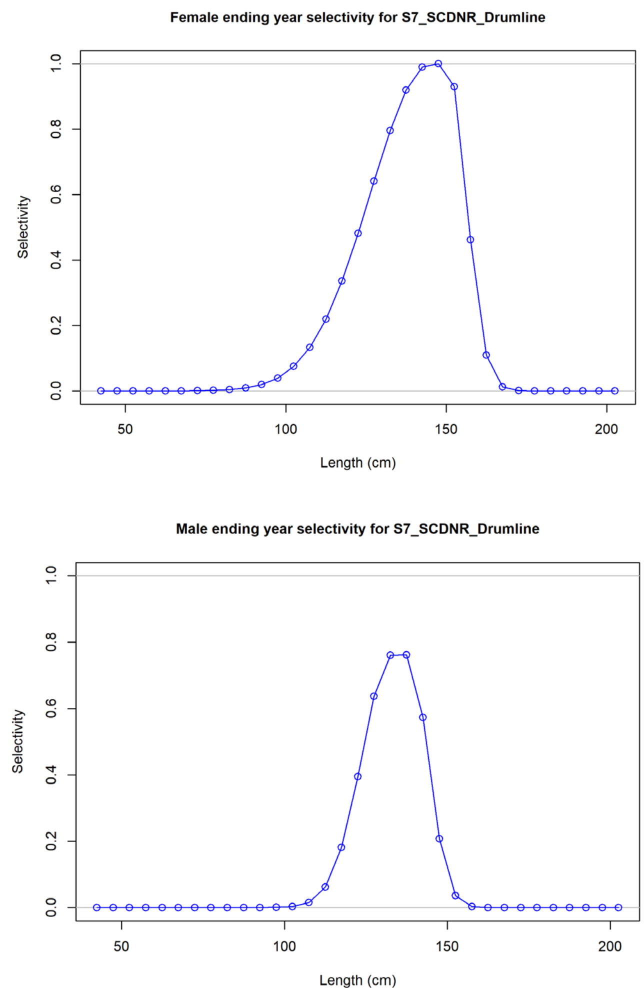
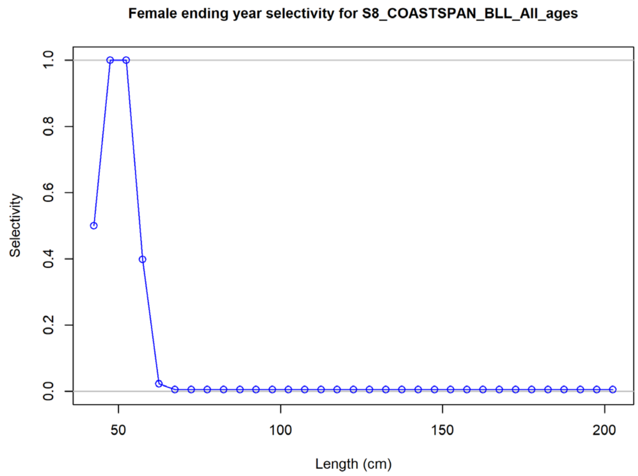


Figure 3.5. Continued. S7 (SCDNR-DL; 2013 – 2018).



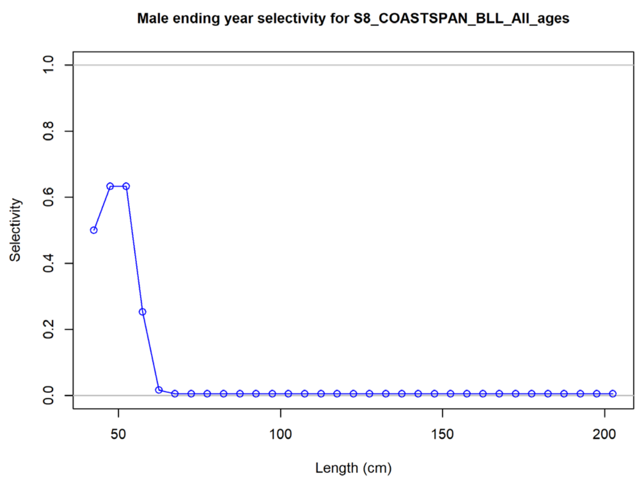
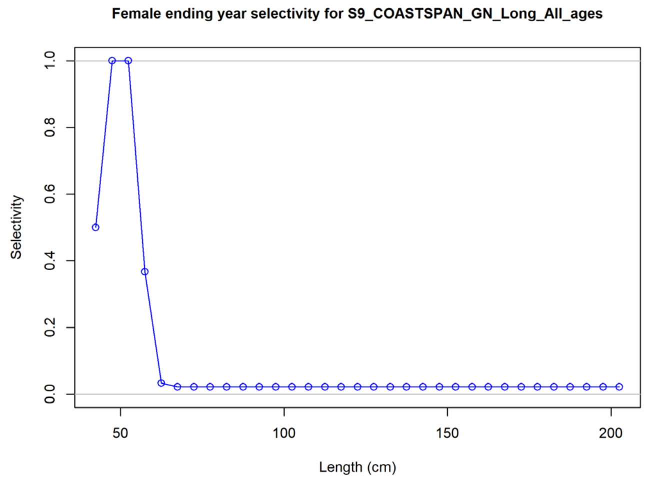


Figure 3.5. Continued. S8 (COASTSPAN-BLL-All-ages; 2005 – 2018).



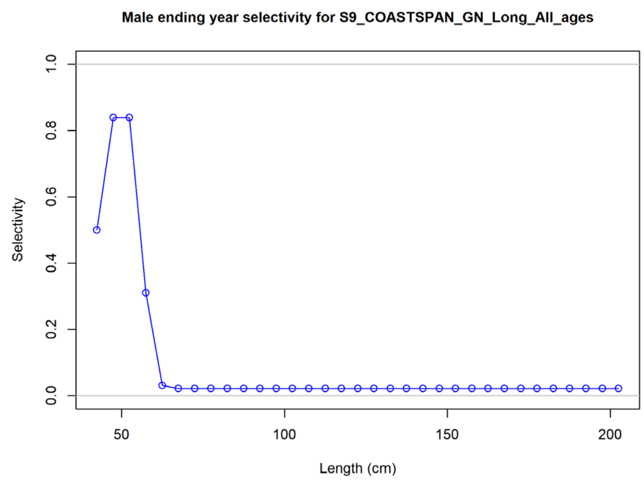


Figure 3.5. Continued. S9 (COASTSPAN-GNL-All-ages; 2001 – 2018).

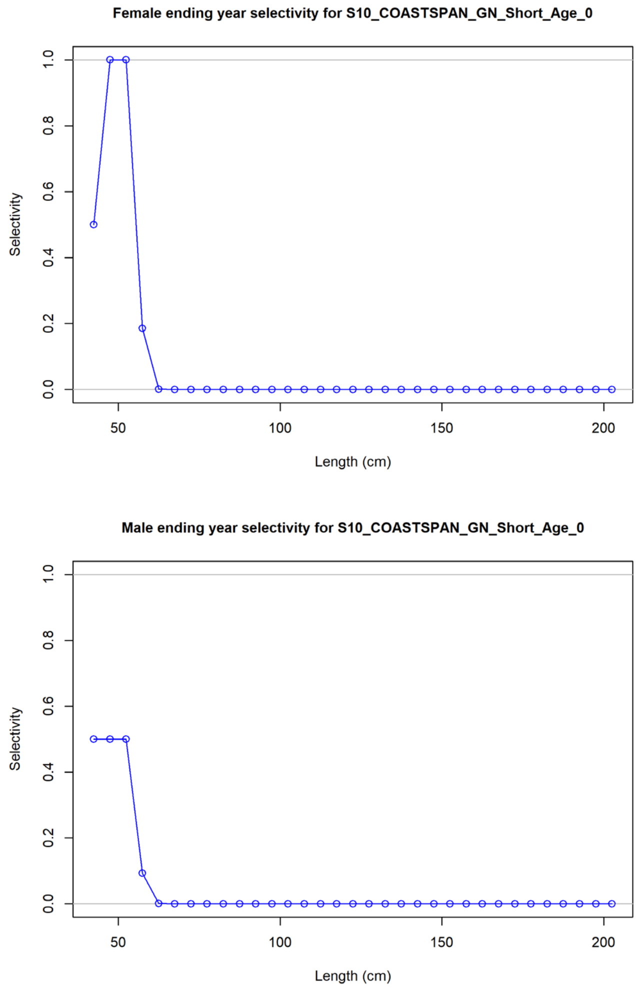


Figure 3.5. Continued. S10 (COASTSPAN-GNS-Age-0; 2006 – 2018).

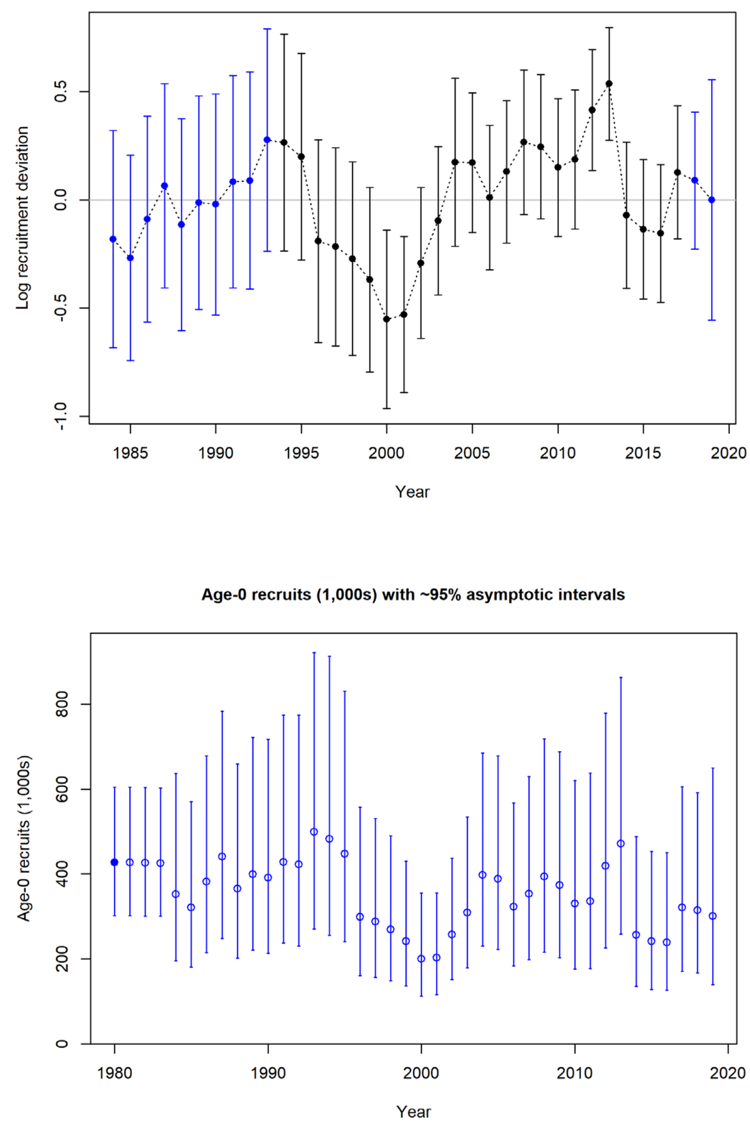


Figure 3.6. Upper panel is the estimated log recruitment deviations for the early (1984 – 1993, blue), main (1994 – 2017, black), late (2018, blue), and forecast (2019, blue) recruitment periods with associated 95% asymptotic confidence intervals in the base model configuration. Lower panel is the estimated annual age-0 recruits (circles) with 95% asymptotic confidence intervals. Age-0 recruits follow the assumed stock recruitment relationship exactly in years prior to 1984 and after 2018.

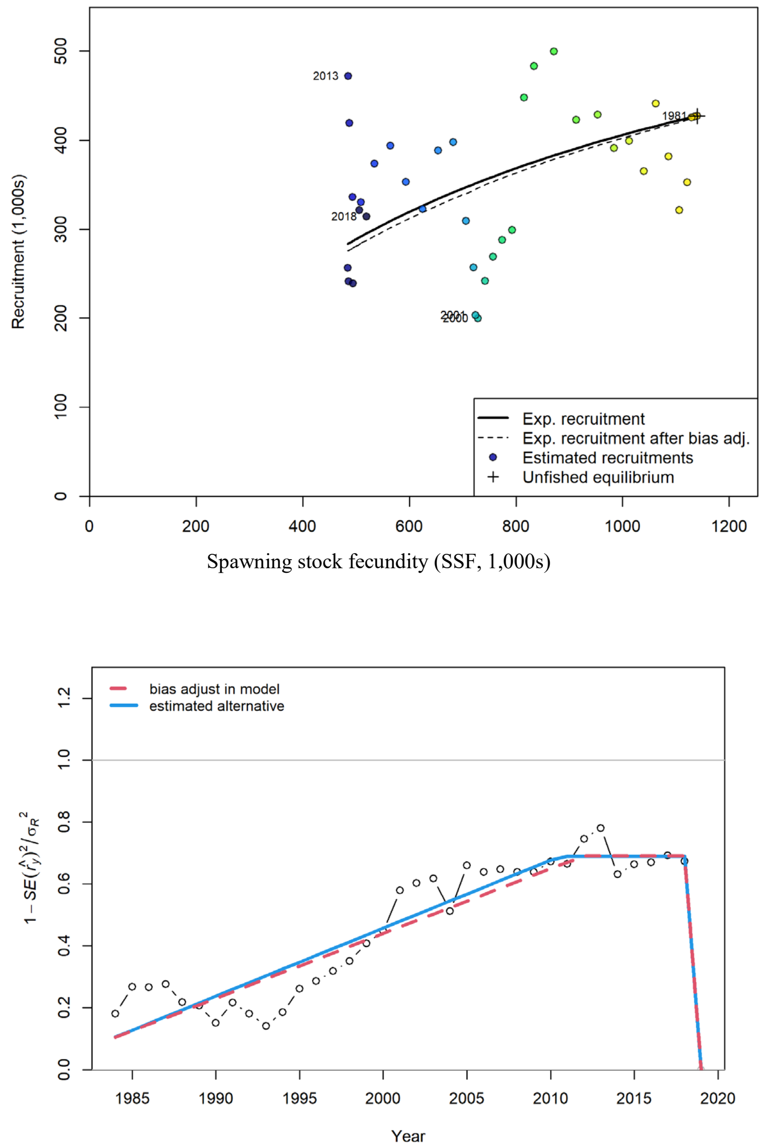


Figure 3.7. Expected recruitment (Upper panel) from the stock-recruitment relationship (solid line), expected recruitment after implementing the bias adjustment correction (dashed line), estimated annual recruitments (circles), unfished equilibrium (plus), and first (1981) and last (2018) years along with years with log deviations > 0.5 (2000, 2001 and 2013) in the base 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 base model configuration.

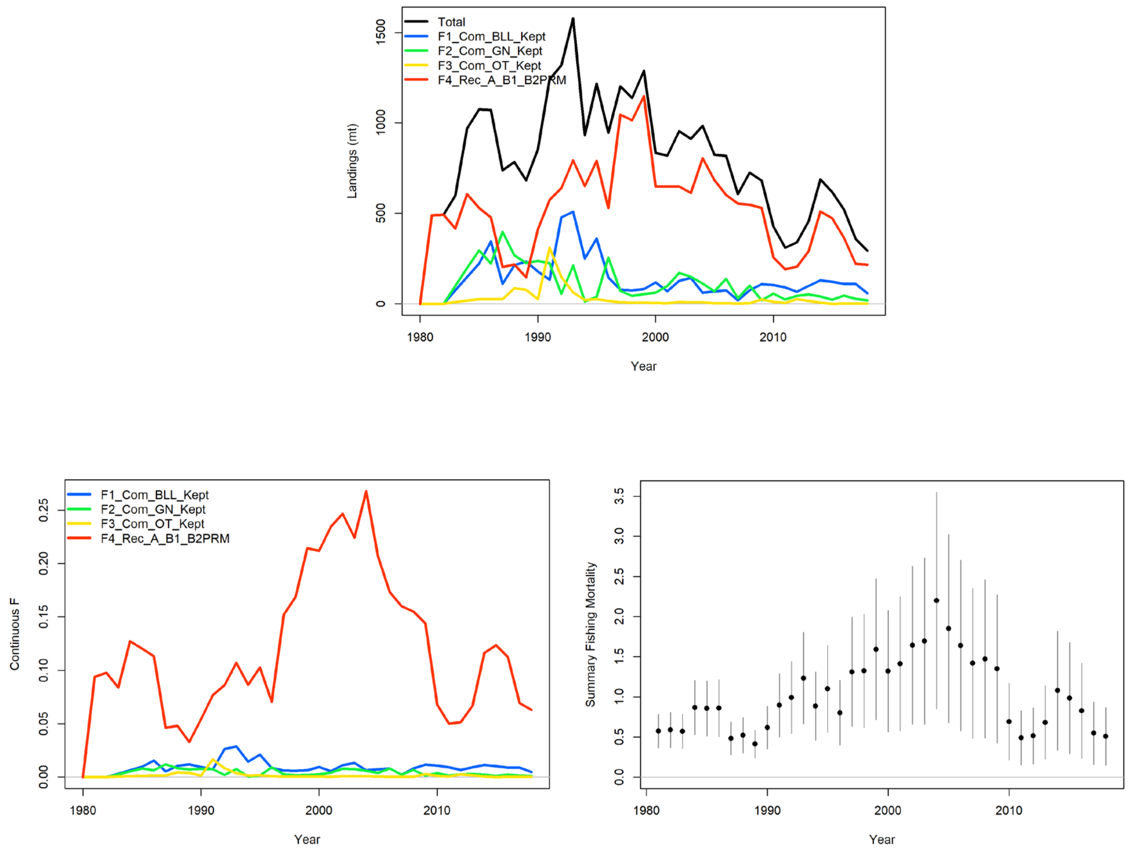
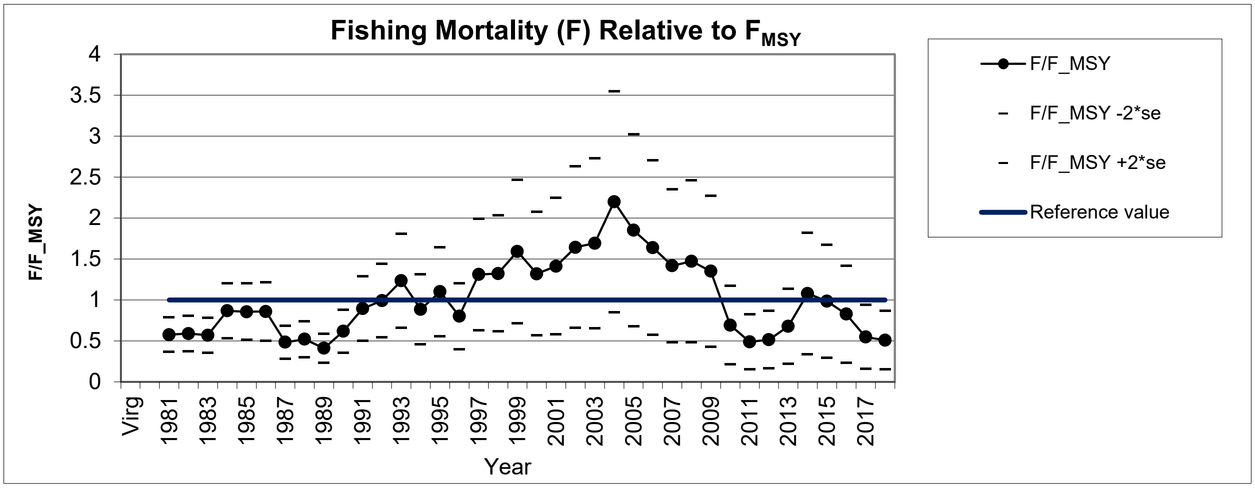


Figure 3.8. Total landings (Upper panel), continuous fishing mortality by fleet (Continuous *F*; Lower left panel), and the summary fishing mortality of all fleets combined (Lower right panel) in the base model configuration. The summary fishing mortality is plotted as a ratio calculated as the total fishing mortality rate experienced by the population ($F=Z-M$) relative to F_{MSY}. Error bars are the 95% asymptotic standard errors, ± 1.96*SE, obtained from Stock Synthesis output. Total landings include commercial landings (mt) along with recreational catch plus recreational discards assumed to die from post release mortality (A + B1 + B2 dead). Recreational data was entered in numbers (1,000s) and converted internally within Stock Synthesis to weight (mt) based on the weight at length of recreational fishery removals obtained in the Stock Synthesis base model configuration.



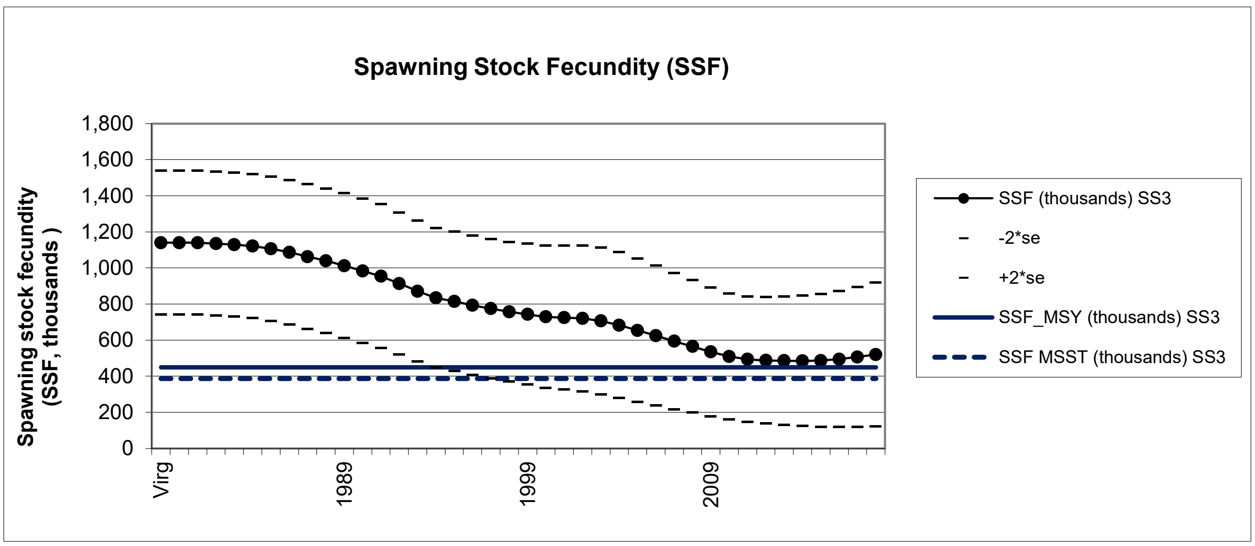


Figure 3.9. Summary fishing mortality (*F*) relative to F_{MSY} (Upper panel) and spawning stock fecundity (SSF) (Lower Panel) in the base model configuration. Summary fishing mortality, *F*, is calculated as the total fishing mortality rate experienced by the population (*F=Z-M*) obtained from Stock Synthesis output. 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 $\left(1-\bar{M}_a\right)$ *$\mathrm{SSF}_{\mathrm{MSY}}$, with $\bar{M}_a$ calculated as the arithmetic mean of the female age-specific values of *M* used in the base model configuration (0.139, **Table 2.13**).

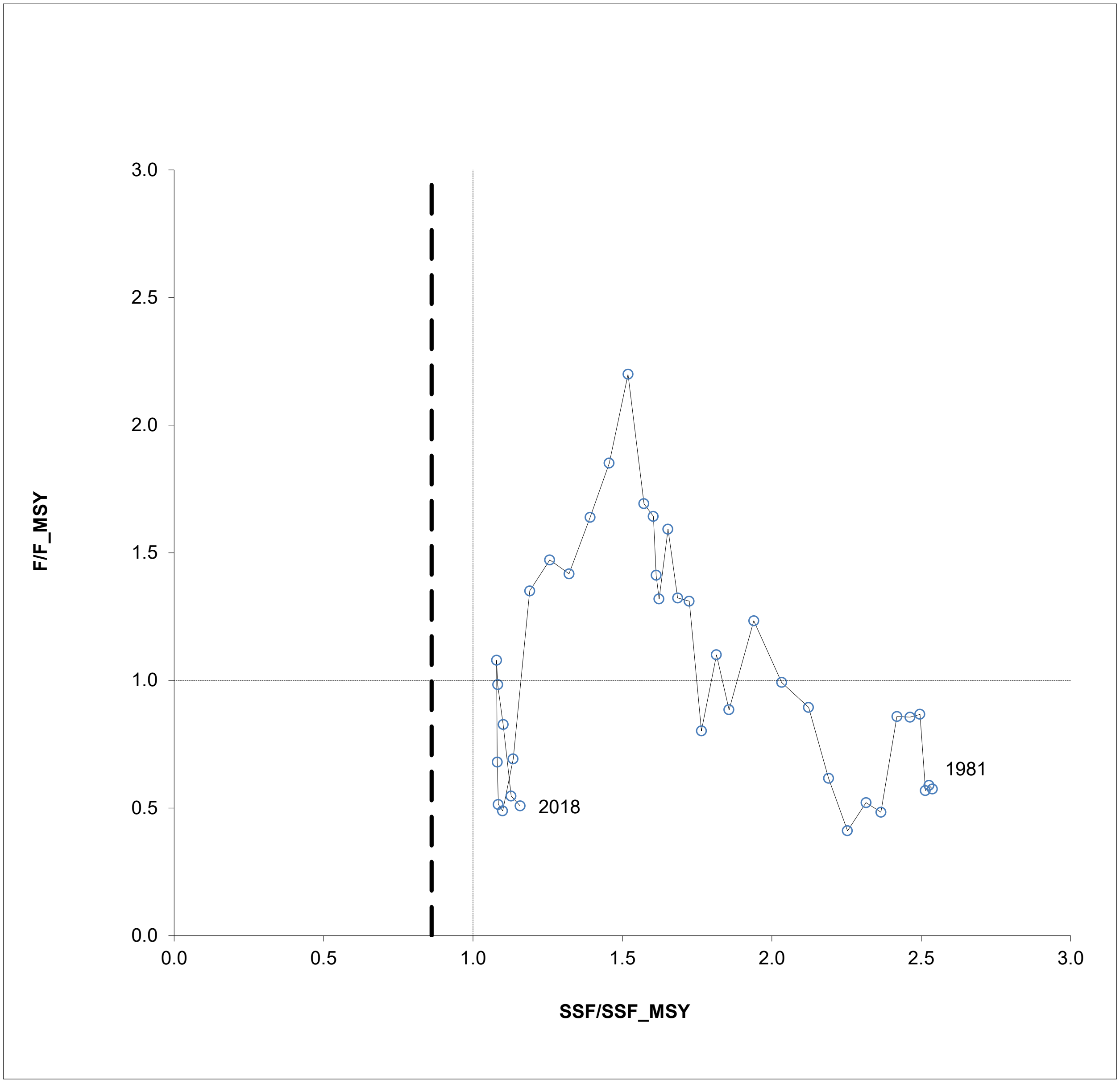


Figure 3.10. Phase plot of the relative spawning stock fecundity (SSF) and relative fishing mortality (*F*) trajectories by year from 1981 to 2018 for the base model configuration. The dotted horizontal and vertical lines indicate F_{MSY} and $\mathrm{SSF}_{\mathrm{MSY}}$. The dashed vertical line indicates MSST $=\left(1-\bar{M}_a\right)*\mathrm{SSF}_{\mathrm{MSY}}$, with $\bar{M}_a$ calculated as the arithmetic mean of the female age-specific values of *M* used in the base model configuration (0.139, **Table 2.13**).

Appendix 3.A. Francis (2011) Method (Stage 1) CPUE Variance Adjustments.

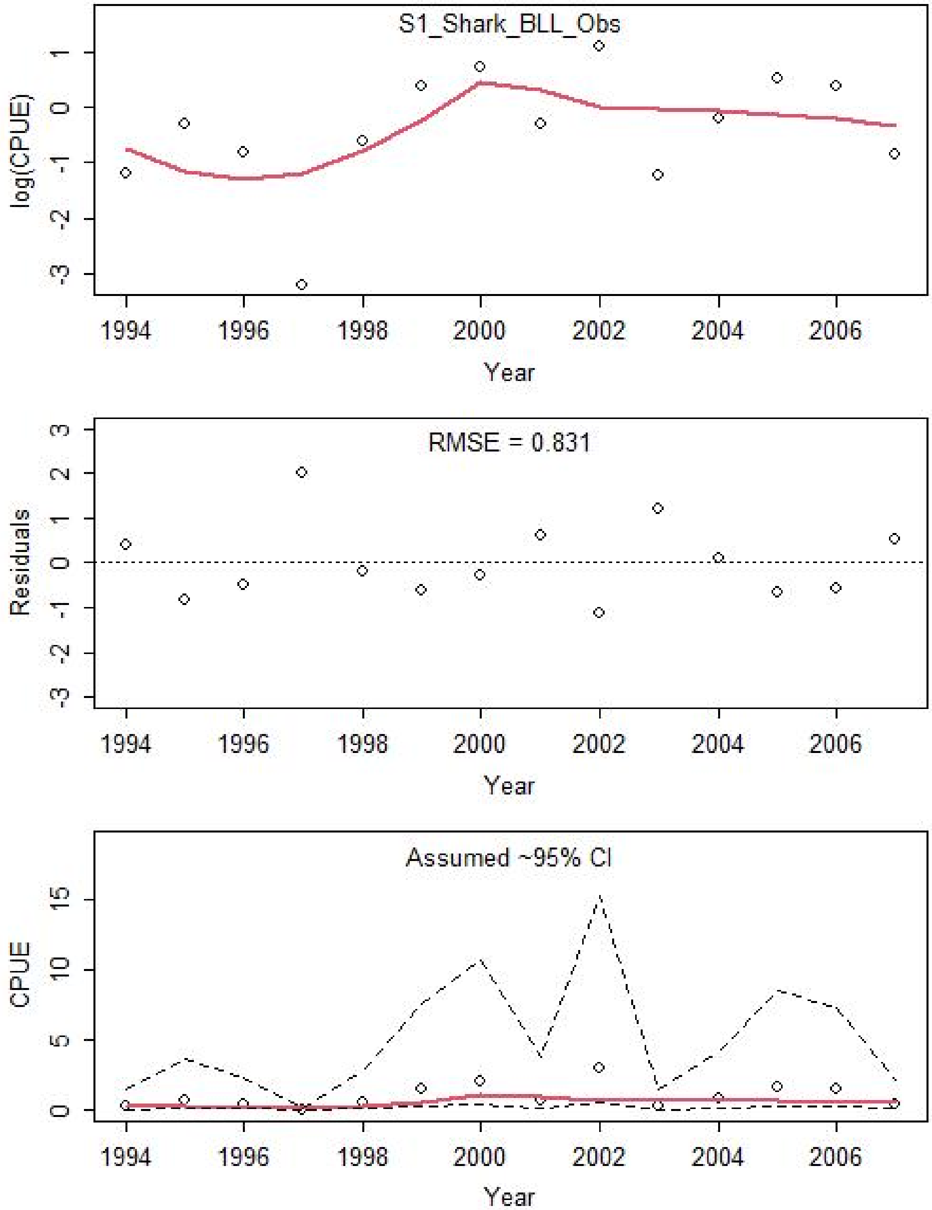


Figure 3.A.1. LOESS smoother fits used to estimate the RMSEsmoother for each CPUE series; Upper panel: Smoother fits to log (CPUE) data; Middle panel: Residual plots and estimated RMSE for each CPUE series; Lower panel: LOESS smoother fits illustrated for CPUE indices along with approximate 95% confidence intervals after applying the variance adjustment.

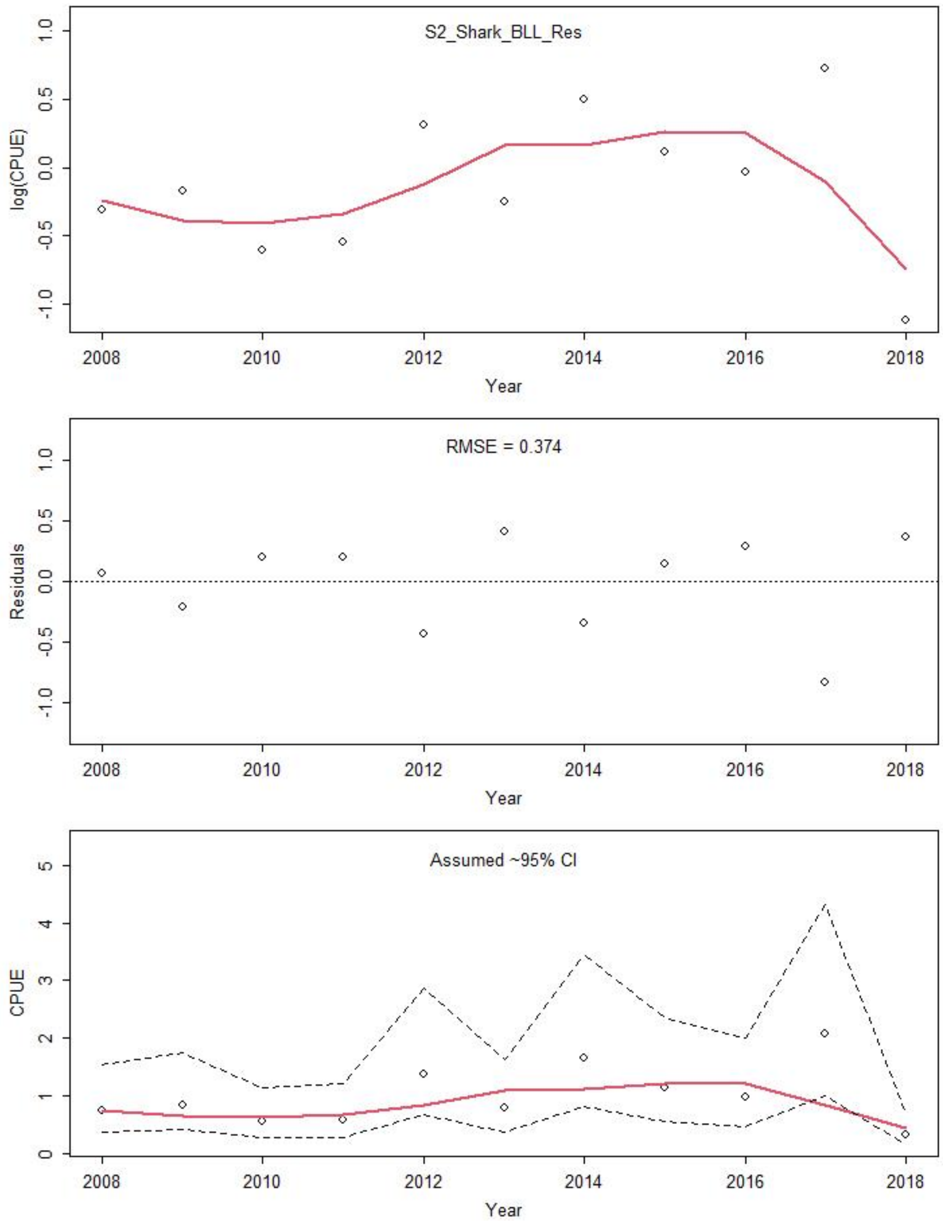


Figure 3.A.1. Continued.

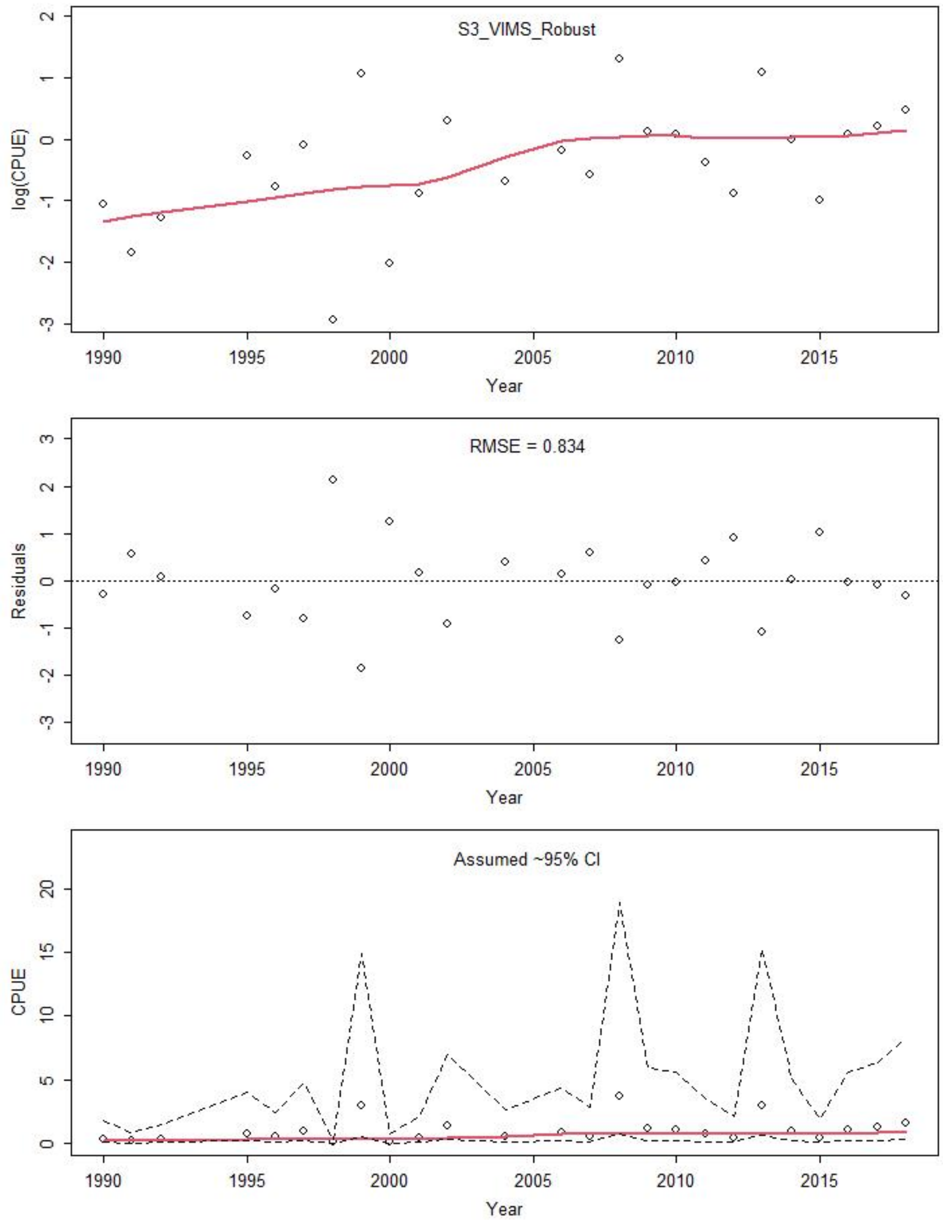


Figure 3.A.1. Continued.

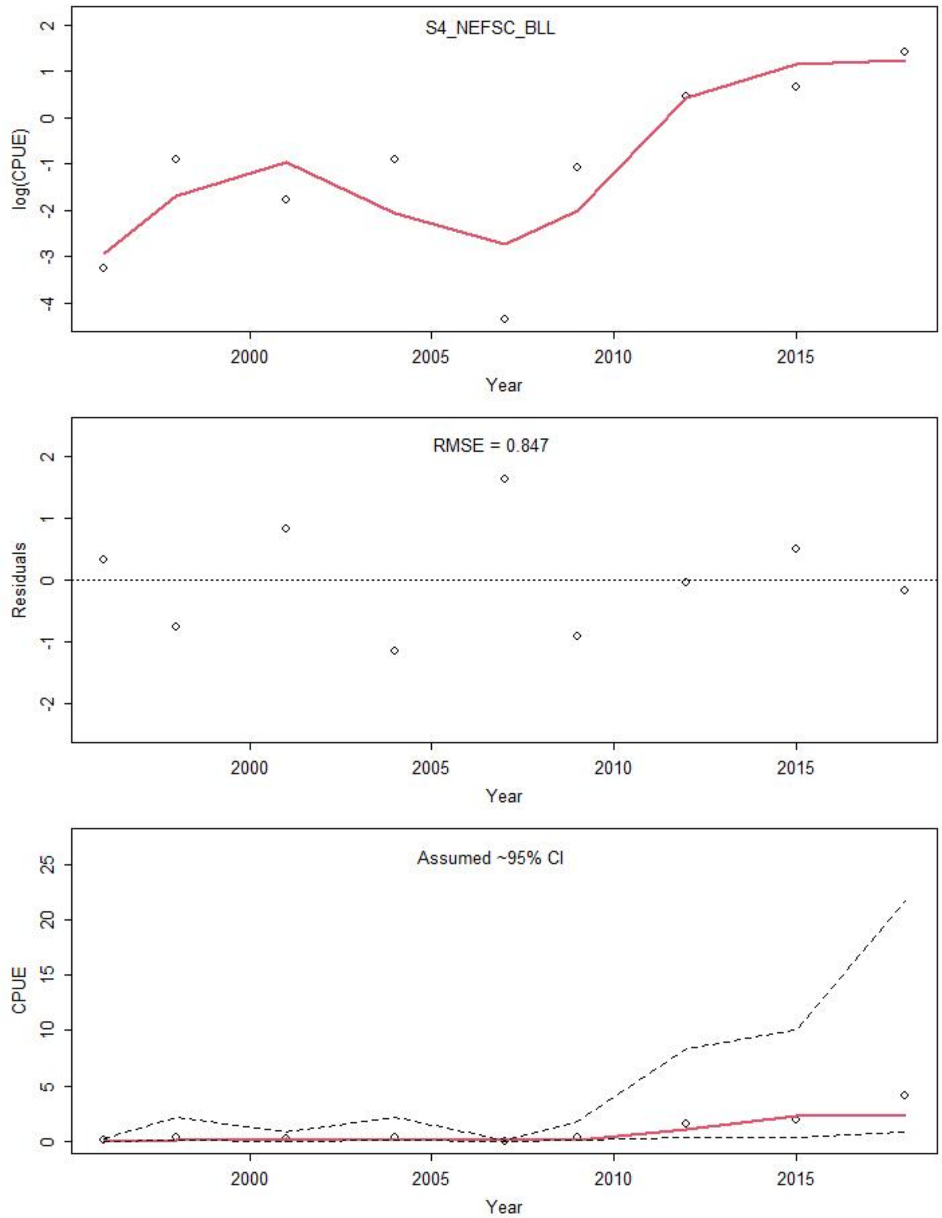


Figure 3.A.1. Continued.

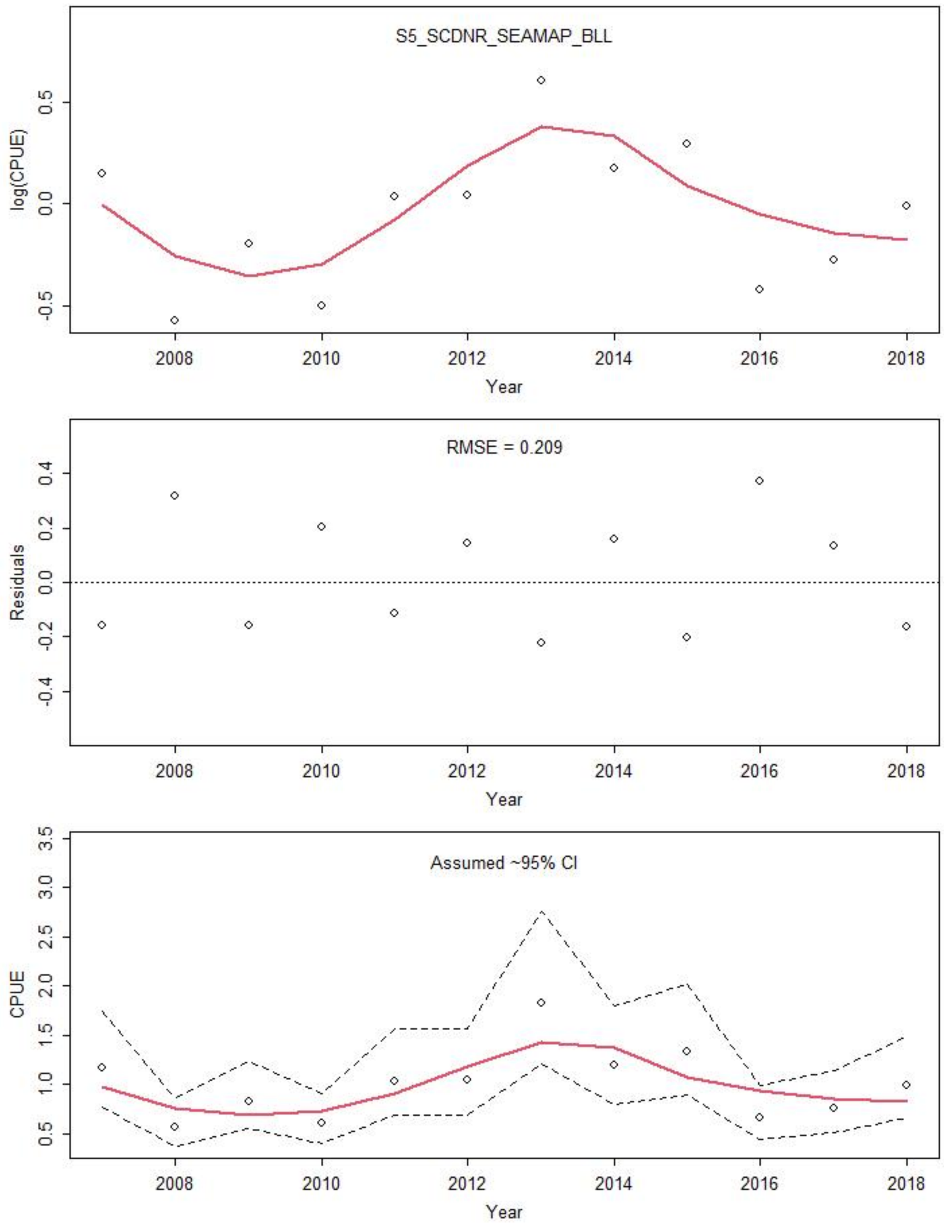


Figure 3.A.1. Continued.

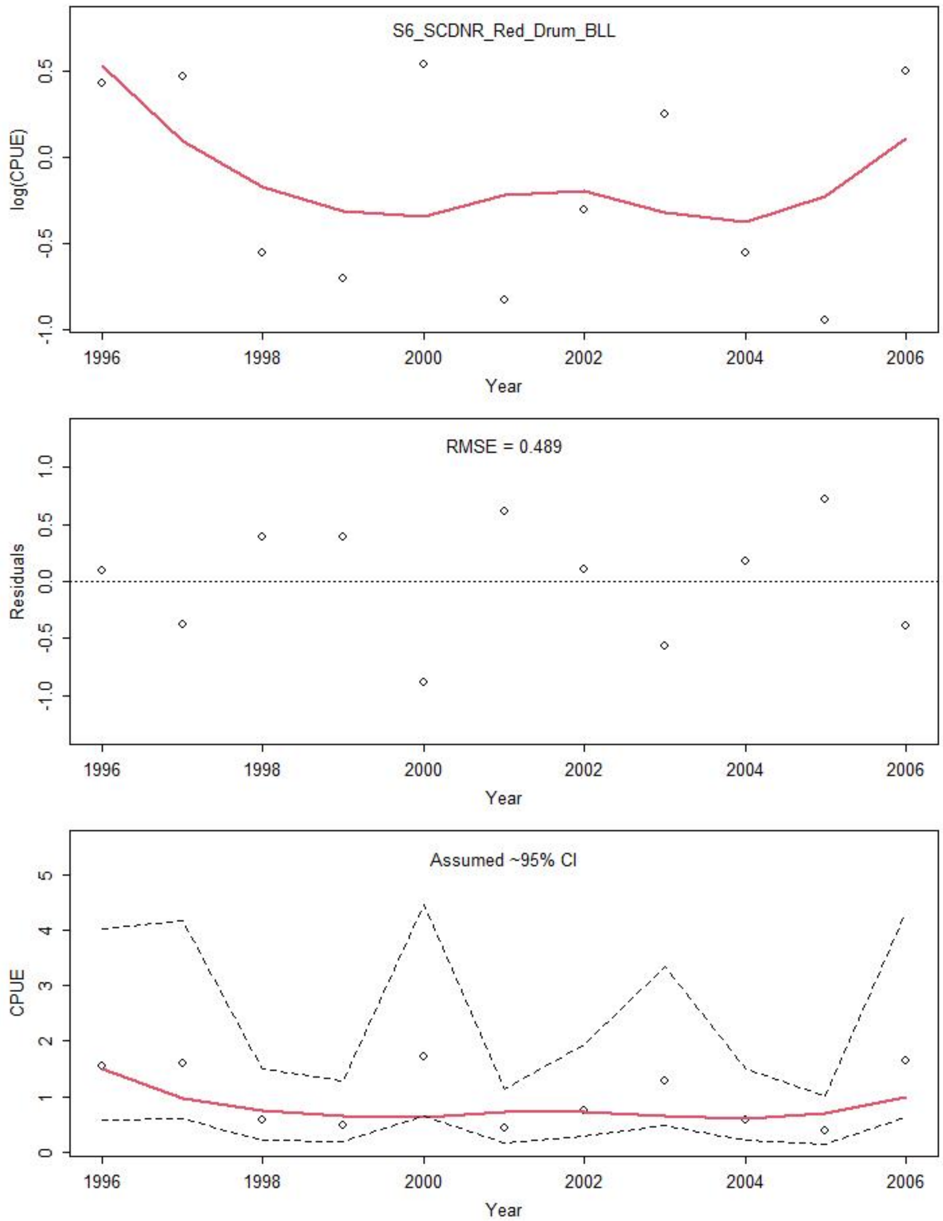


Figure 3.A.1. Continued.

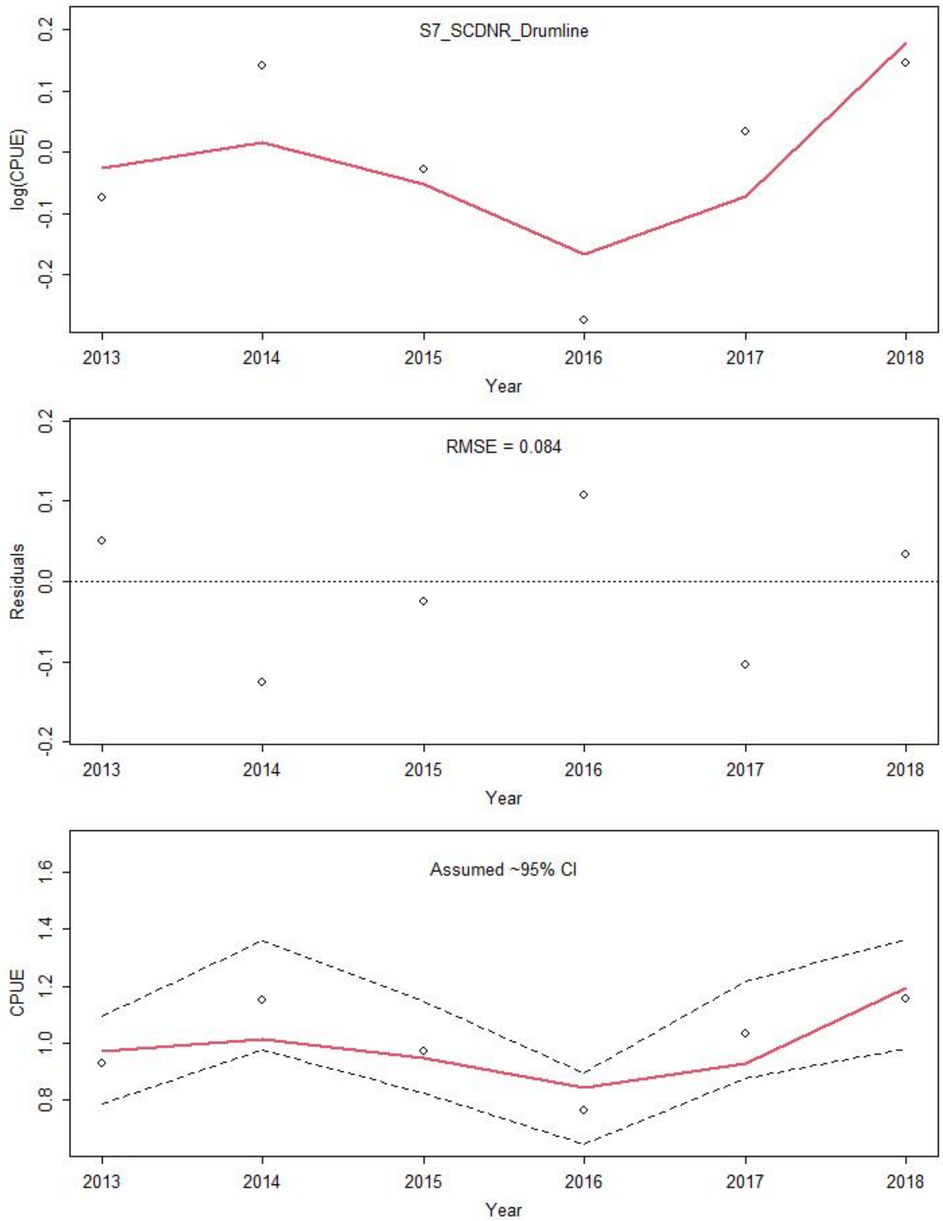


Figure 3.A.1. Continued.

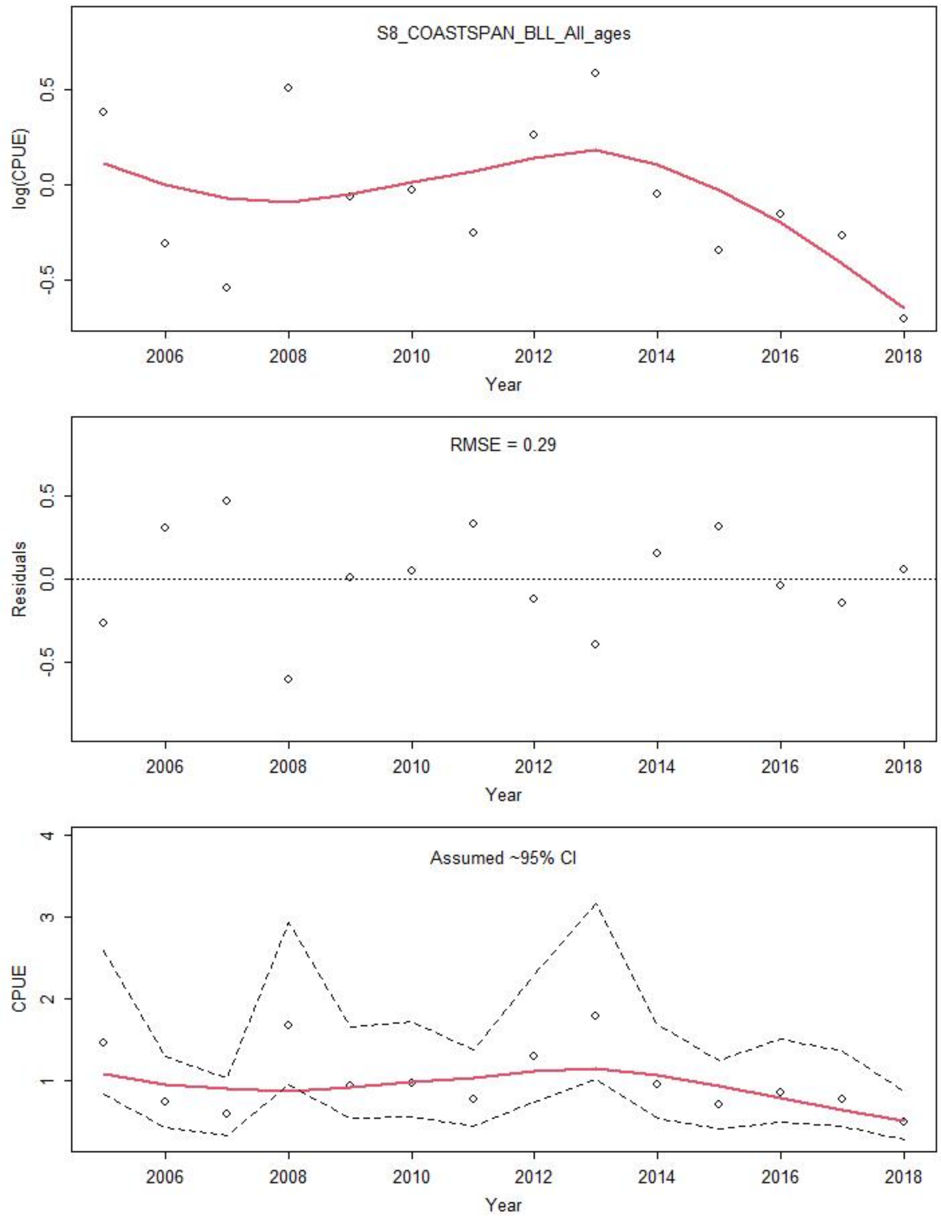


Figure 3.A.1. Continued.

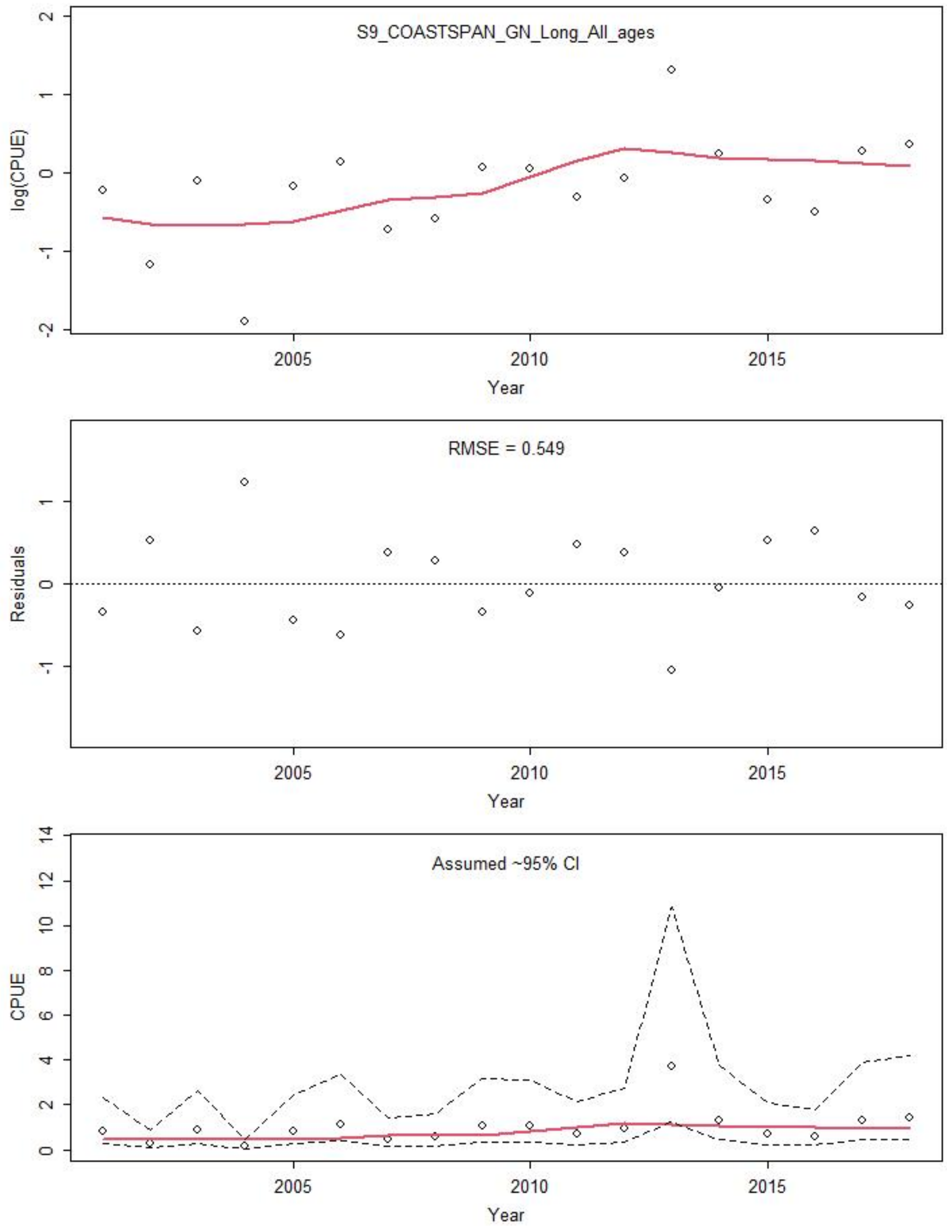


Figure 3.A.1. Continued.

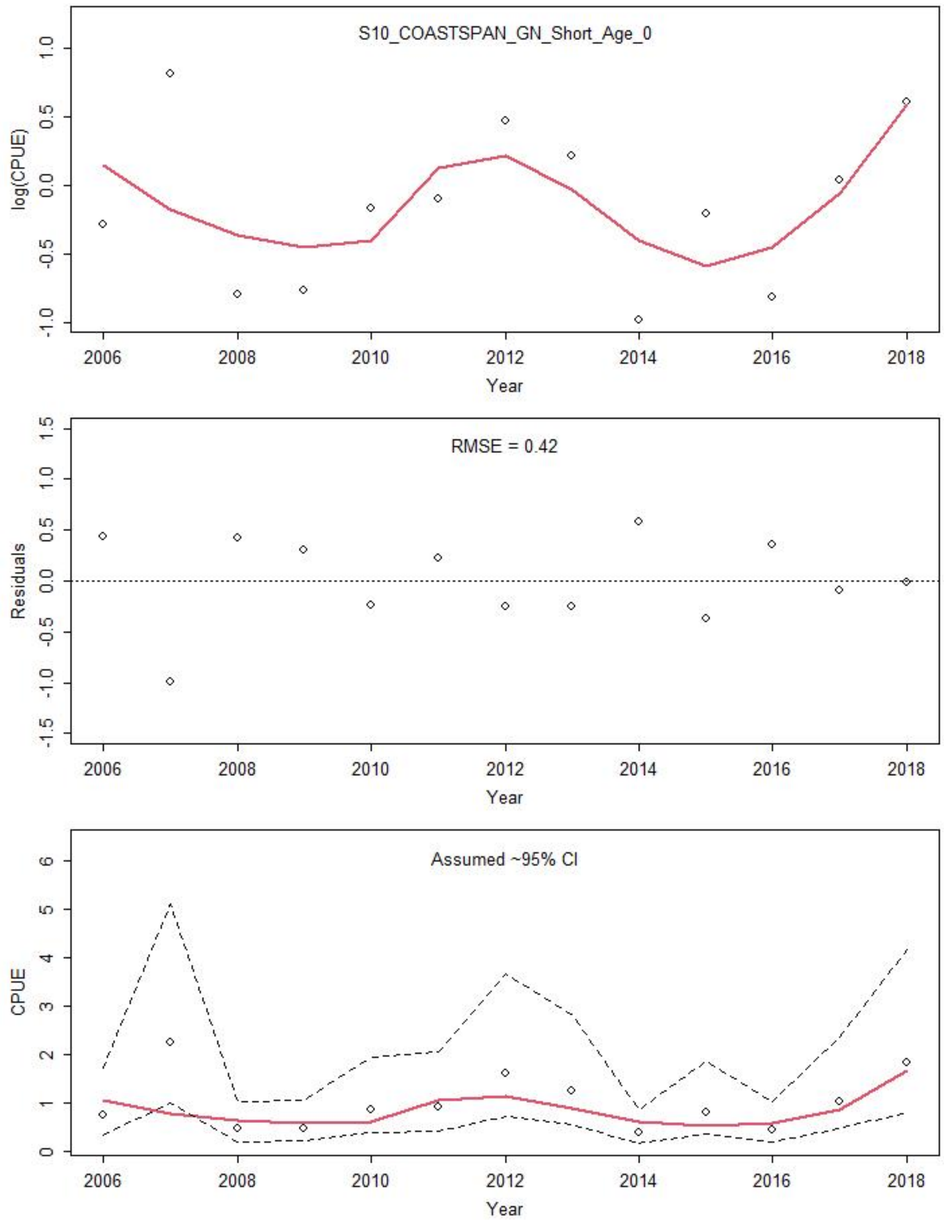


Figure 3.A.1. Continued.

Appendix 3.B. Logistic Sensitivity Analysis.

Table 3.B.1. Selectivity functions and number of estimated parameters in the logistic model sensitivity analysis.

Fleet	Fleet name	Proposed selectivity pattern	Implemented selectivity pattern	Sex	Number of parameters	Sub-total
1	F1 (Com-BLL-Kept)	Logistic	Logistic	Sex specific	10 Selectivity[1]	10
2	F2 (Com-GN-Kept)	Logistic	Logistic	Combined sex	4 Selectivity[2]	4
3	F3 (Com-Other-Kept)	Mirror Fleet 1	Mirror Fleet 1	Combined sex	NA	
4	F4 (Recreational)	Double Normal	Double Normal	Combined sex	5 Selectivity[3]	5
5	S1 (Shark-BLL-Obs)	Mirror Fleet 1	Mirror Fleet 1	Combined sex	3 Catchability[4]	3
6	S2 (Shark-BLL-Res)	Mirror Fleet 1	Mirror Fleet 1	Combined sex	2 Catchability[5]	2
7	S3 (VIMS-BLL-Robust)	Double Normal	Double Normal	Sex specific	3 Selectivity	3
8	S4 (NEFSC-BLL)	Logistic	Logistic	Sex specific	3 Selectivity	3
9	S5 (SCDNR-SEAMAP-BLL)	Double Normal	Double Normal	Sex specific	4 Selectivity	4
10	S6 (SCDNR-Red-Drum-BLL)	Double Normal	Double Normal	Sex specific	4 Selectivity	4
11	S7 (SCDNR-DL)	Logistic	Logistic	Sex specific	4 Selectivity	4
12	S8 (COASTSPAN-BLL-All-ages)	Double Normal	Double Normal	Sex specific	3 Selectivity	3
13	S9 (COASTSPAN-GNL-All-ages)	Double Normal	Double Normal	Sex specific	3 Selectivity	3
14	S10 (COASTSPAN-GNS-Age-0)	Double Normal	Double Normal	Sex specific	2 Selectivity	2
					Total (Selectivity; Catchability)	50
	Other Estimated Parameters					
	ln(R_0)					1
	CV (Length at Age-0)				2 (male and female)	2
	CV (Length at Age-Linf)				2 (male and female)	2
	Recruitment deviations				1984-2018	35
					Grand Total	90

[1] Time blocks in selectivity for F1 (1981 – 1996, 1997 – 2004, 2005 – 2007, 2008 – 2017, 2018).
[2] Time blocks in selectivity for F2 (1981 – 2006, 2007 – 2018).
[3] Time blocks in selectivity for F4 (1981 – 1989, 1990 – 1999, 2000 – 2018).
[4] Time blocks in catchability for S1 (1981 – 1996, 1997 – 2004, 2005 – 2007).
[5] Time blocks in catchability for S2 (2008 – 2017, 2018).

Table 3.B.2. Two stage data weighting used in the logistic model sensitivity analysis. The stage-1 CPUE (survey) variance adjustments (**Appendix 3.A**) 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 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 (Shark-BLL-Obs)	0.5300	0.3010	0.8310
S2 (Shark-BLL-Res)	0.3736	0.0004	0.3740
S3 (VIMS-BLL-Robust)	0.6417	0.1923	0.8340
S4 (NEFSC-BLL)	0.6704	0.1766	0.8470
S5 (SCDNR-SEAMAP-BLL)	0.2826	0.0000	0.2826
S6 (SCDNR-Red-Drum-BLL)	0.7120	0.0000	0.7120
S7 (SCDNR-DL)	0.1830	0.0000	0.1830
S8 (COASTSPAN-BLL-All-ages)	0.3031	0.0000	0.3031
S9 (COASTSPAN-GNL-All-ages)	0.4588	0.0902	0.5490
S10 (COASTSPAN-GNS-Age-0)	0.5637	0.0000	0.5637

Panel B

Length composition data source	Mean of input n	Adjustment method	Sample size adjustment	Mean of adjusted input n
F1 (Com-BLL-Kept)	223.8	Francis	0.081	18.0
F2 (Com-GN-Kept)	156.9	Harmonic mean	0.175	27.5
F4 (Recreational)	37.3	Francis	0.170	6.3
S3 (VIMS-BLL-Robust)	43.0	Harmonic mean	0.669	28.8
S4 (NEFSC-BLL)	137.8	Harmonic mean	0.281	38.7
S5 (SCDNR-SEAMAP-BLL)	82.8	Francis	0.166	13.7
S6 (SCDNR-Red-Drum-BLL)	45.8	Harmonic mean	0.313	14.3
S7 (SCDNR-DL)	51.0	Harmonic mean	0.789	40.3
S8 (COASTSPAN-BLL-All-ages)	47.0	Harmonic mean	0.275	12.9
S9 (COASTSPAN-GNL-All-ages)	51.6	Harmonic mean	0.444	22.9
S10 (COASTSPAN-GNS-Age-0)	42.5	Harmonic mean	0.385	16.4

Table 3.B.3. Catchability, q, estimated for index S1 with time blocks (1981 – 1996, 1997 – 2004, 2005 – 2007) and for index S2 with time blocks (2008 – 2017, 2018), along with the median unbiased analytical solution for q calculated in Stock Synthesis for the remaining indices S3 – S10.

Label	ln(q)	q
Base years		
S1 (Shark-BLL-Obs; 1997 – 2004)	-1.7357	0.1763
S2 (Shark-BLL-Res; 2008 – 2017)	-1.02259	0.3597
S3 (VIMS-BLL-Robust; 1990 – 2018)	-9.4129	0.0001
S4 (NEFSC-BLL; 1996 – 2018)	-6.91941	0.0010
S5 (SCDNR-SEAMAP-BLL; 2007 – 2018)	-6.94236	0.0010
S6 (SCDNR-Red-Drum-BLL; 1996 – 2006)	-7.31933	0.0007
S7 (SCDNR-DL; 2013 – 2018)	-7.03282	0.0009
S8 (COASTSPAN-BLL-All-ages; 2005 – 2018)	-4.99825	0.0067
S9 (COASTSPAN-GNL-All-ages; 2001 – 2018)	-5.92893	0.0027
S10 (COASTSPAN-GNS-Age-0; 2006 – 2018)	-5.77026	0.0031
Time blocks		
S1 (Shark-BLL-Obs; 1981 – 1996)	-2.98926	0.0503
S1 (Shark-BLL-Obs; 2005 – 2007)	-1.96116	0.1407
S2 (Shark-BLL-Res; 2018)	-1.33987	0.2619

Table 3.B.4. Logistic sensitivity analysis parameters. 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_Cnt	Phase	Min	Max	Init	Parm_StDev	Pr_type	Prior	Pr_SD	CV
L_at_Amin_Fem_GP_1	56.40	_	-3	5.00	100.00	56.40	_	Normal	56.40	1000	NA
L_at_Amax_Fem_GP_1	166.23	_	-4	50.00	600.00	166.23	_	Normal	166.23	1000	NA
VonBert_K_Fem_GP_1	0.16	_	-5	0.01	0.65	0.16	_	Normal	0.06	0.2	NA
CV_young_Fem_GP_1	0.10	1	2	0.01	0.30	0.10	0.006	Normal	0.09	0.01	6%
CV_old_Fem_GP_1	0.05	2	3	0.01	0.30	0.05	0.008	Normal	0.09	0.01	16%
Wtlen_1_Fem_GP_1	0.00	_	-3	-3.00	3.00	0.00	_	Normal	0.00	0.8	NA
Wtlen_2_Fem_GP_1	3.22	_	-3	-3.00	5.00	3.22	_	Normal	3.22	0.8	NA
L_at_Amin_Mal_GP_1	52.84	_	-3	5.00	100.00	52.84	_	Normal	52.84	1000	NA
L_at_Amax_Mal_GP_1	145.03	_	-4	50.00	600.00	145.03	_	Normal	145.03	1000	NA
VonBert_K_Mal_GP_1	0.23	_	-5	0.01	0.65	0.23	_	Normal	0.23	0.2	NA
CV_young_Mal_GP_1	0.11	3	2	0.01	0.30	0.11	0.007	Normal	0.10	0.01	6%
CV_old_Mal_GP_1	0.06	4	3	0.01	0.30	0.06	0.006	Normal	0.08	0.01	11%
Wtlen_1_Mal_GP_1	0.00	_	-3	-3.00	3.00	0.00	_	Normal	0.00	0.8	NA
Wtlen_2_Mal_GP_1	3.22	_	-3	-3.00	5.00	3.22	_	Normal	3.22	0.8	NA
FracFemale_GP_1	0.50	_	-99	0.00	1.00	0.50	_	No_prior			NA
SR_LN(R0)	6.67	5	1	2.30	13.82	6.73	0.188	Normal	7.04	1000	3%
SR_BH_steep	0.40	_	-2	0.20	0.99	0.40	_	Normal	0.40	1000	NA
SR_sigmaR	0.28	_	-4	0.20	1.90	0.28	_	Normal	0.28	1000	NA
Early_RecrDev_1984	-0.21	6	4	-10.00	10.00	0.00	0.250	dev			
Early_RecrDev_1985	-0.31	7	4	-10.00	10.00	0.00	0.240	dev			
Early_RecrDev_1986	-0.16	8	4	-10.00	10.00	0.00	0.239	dev			
Early_RecrDev_1987	-0.06	9	4	-10.00	10.00	0.00	0.235	dev			
Early_RecrDev_1988	-0.21	10	4	-10.00	10.00	0.00	0.242	dev			
Early_RecrDev_1989	-0.15	11	4	-10.00	10.00	0.00	0.242	dev			
Early_RecrDev_1990	-0.15	12	4	-10.00	10.00	0.00	0.248	dev			
Early_RecrDev_1991	-0.07	13	4	-10.00	10.00	0.00	0.240	dev			
Early_RecrDev_1992	-0.02	14	4	-10.00	10.00	0.00	0.249	dev			
Early_RecrDev_1993	0.24	15	4	-10.00	10.00	0.00	0.257	dev			
Main_RecrDev_1994	0.19	16	3	-10.00	10.00	0.00	0.263	dev			
Main_RecrDev_1995	0.18	17	3	-10.00	10.00	0.00	0.251	dev			
Main_RecrDev_1996	-0.20	18	3	-10.00	10.00	0.00	0.248	dev			
Main_RecrDev_1997	-0.26	19	3	-10.00	10.00	0.00	0.240	dev			
Main_RecrDev_1998	-0.27	20	3	-10.00	10.00	0.00	0.238	dev			
Main_RecrDev_1999	-0.30	21	3	-10.00	10.00	0.00	0.229	dev			

Table 3.B.4. Continued.

Label	Value	Active_Cnt	Phase	Min	Max	Init	Parm_StDev	Pr_type	Prior	Pr_SD	CV
Main_RecrDev_2000	-0.41	22	3	-10.00	10.00	0.00	0.225	dev			
Main_RecrDev_2001	-0.44	23	3	-10.00	10.00	0.00	0.195	dev			
Main_RecrDev_2002	-0.28	24	3	-10.00	10.00	0.00	0.188	dev			
Main_RecrDev_2003	-0.13	25	3	-10.00	10.00	0.00	0.185	dev			
Main_RecrDev_2004	0.26	26	3	-10.00	10.00	0.00	0.206	dev			
Main_RecrDev_2005	0.20	27	3	-10.00	10.00	0.00	0.172	dev			
Main_RecrDev_2006	-0.02	28	3	-10.00	10.00	0.00	0.174	dev			
Main_RecrDev_2007	0.16	29	3	-10.00	10.00	0.00	0.172	dev			
Main_RecrDev_2008	0.33	30	3	-10.00	10.00	0.00	0.174	dev			
Main_RecrDev_2009	0.30	31	3	-10.00	10.00	0.00	0.175	dev			
Main_RecrDev_2010	0.21	32	3	-10.00	10.00	0.00	0.166	dev			
Main_RecrDev_2011	0.21	33	3	-10.00	10.00	0.00	0.167	dev			
Main_RecrDev_2012	0.43	34	3	-10.00	10.00	0.00	0.144	dev			
Main_RecrDev_2013	0.52	35	3	-10.00	10.00	0.00	0.133	dev			
Main_RecrDev_2014	-0.16	36	3	-10.00	10.00	0.00	0.175	dev			
Main_RecrDev_2015	-0.23	37	3	-10.00	10.00	0.00	0.165	dev			
Main_RecrDev_2016	-0.28	38	3	-10.00	10.00	0.00	0.163	dev			
Main_RecrDev_2017	0.00	39	3	-10.00	10.00	0.00	0.157	dev			
Late_RecrDev_2018	0.02	40	6	-10.00	10.00	0.00	0.161	dev			
ForeRecr_2019[1]	0	41	6	-10	10	0	0.283103	dev			
LnQ_base_S1_Shark_BLL_Obs(5)	-1.74	42	1	-25.00	25.00	0.00	0.415	Sym_Beta	0.00	0.05	24%
LnQ_base_S2_Shark_BLL_Res(6)	-1.02	43	1	-25.00	25.00	-1.12	0.414	Sym_Beta	0.00	0.05	41%
LnQ_base_S3_VIMS_Robust(7)	-9.41	_	-1	-25.00	25.00	-9.52	_	No_prior			NA
LnQ_base_S4_NEFSC_BLL(8)	-6.92	_	-1	-25.00	25.00	-6.99	_	No_prior			NA
LnQ_base_S5_SCDNR_SEAMAP_BLL(9)	-6.94	_	-1	-25.00	25.00	-6.94	_	No_prior			NA
LnQ_base_S6_SCDNR_Red_Drum_BLL(10)	-7.32	_	-1	-25.00	25.00	-7.04	_	No_prior			NA
LnQ_base_S7_SCDNR_Drumline(11)	-7.03	_	-1	-25.00	25.00	-7.25	_	No_prior			NA
LnQ_base_S8_COASTSPAN_BLL_All_ages(12)	-5.00	_	-1	-25.00	25.00	-5.09	_	No_prior			NA
LnQ_base_S9_COASTSPAN_GN_Long_All_ages(13)	-5.93	_	-1	-25.00	25.00	-6.13	_	No_prior			NA
LnQ_base_S10_COASTSPAN_GN_Short_Age_0(14)	-5.77	_	-1	-25.00	25.00	-5.95	_	No_prior			NA
LnQ_base_S1_Shark_BLL_Obs(5)_BLK3repl_1981	-2.99	44	1	-25.00	25.00	-3.09	0.611	Sym_Beta	0.00	0.05	20%
LnQ_base_S1_Shark_BLL_Obs(5)_BLK3repl_2005	-1.96	45	1	-25.00	25.00	-2.09	0.622	Sym_Beta	0.00	0.05	32%
LnQ_base_S2_Shark_BLL_Res(6)_BLK4repl_2018[2]	-1.34	46	1	-25.00	25.00	-1.55	0.845	Sym_Beta	0.00	0.05	63%
Size_inflection_F1_Com_BLL_Kept(1)	127.23	47	2	5.00	150.00	127.46	3.732	Sym_Beta	105.00	0.05	3%
Size_95%width_F1_Com_BLL_Kept(1)	31.19	48	3	0.01	60.00	31.28	2.995	Sym_Beta	10.00	0.05	10%
SzSel_Male_Infl_F1_Com_BLL_Kept(1)	-8.66	49	4	-50.00	50.00	-8.72	2.001	Normal	0.00	1000	23%
SzSel_Male_Slope_F1_Com_BLL_Kept(1)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Scale_F1_Com_BLL_Kept(1)	1.00	_	-5	-15.00	15.00	1.00	_	Normal	1.00	1000	NA
Size_inflection_F2_Com_GN_Kept(2)	62.63	50	2	5.00	150.00	68.94	5.193	Sym_Beta	102.36	0.05	8%
Size_95%width_F2_Com_GN_Kept(2)[2]	8.50	51	3	0.01	60.00	8.08	7.418	Sym_Beta	23.05	0.05	87%

[1]Forecast recruitment deviation (year 2019) not included in the number of estimated parameters.
[2] CV > 0.5.

Table 3.B.4. Continued.

Label	Value	Active_Cnt	Phase	Min	Max	Init	Parm_StDev	Pr_type	Prior	Pr_SD	CV
Size_DblN_peak_F4_Rec_A_B1_B2PRM(4)	50.20	52	2	47.50	162.50	64.90	10.112	Sym_Beta	64.90	0.05	20%
Size_DblN_top_logit_F4_Rec_A_B1_B2PRM(4)[2]	-3.53	53	3	-6.00	4.00	-6.00	2.571	Sym_Beta	-6.00	0.05	73%
Size_DblN_ascend_se_F4_Rec_A_B1_B2PRM(4)	7.00	_	-3	-1.00	9.00	7.00	_	Sym_Beta	7.00	0.05	NA
Size_DblN_descend_se_F4_Rec_A_B1_B2PRM(4)	7.20	_	-3	-1.00	9.00	7.20	_	Sym_Beta	7.20	0.05	NA
Size_DblN_start_logit_F4_Rec_A_B1_B2PRM(4)	-1.10	_	-2	-15.00	9.00	-1.10	_	Sym_Beta	0.00	0.05	NA
Size_DblN_end_logit_F4_Rec_A_B1_B2PRM(4)	-1.20	_	-2	-15.00	9.00	-1.20	_	Sym_Beta	-15.00	0.05	NA
Size_inflection_S3_VIMS_Robust(7)	87.43	54	2	5.00	150.00	89.75	1.988	Sym_Beta	89.75	0.05	2%
Size_95%width_S3_VIMS_Robust(7)	6.23	55	3	0.01	60.00	4.23	2.211	Sym_Beta	4.23	0.05	35%
SzSel_Fem_Infl_S3_VIMS_Robust(7)	0.00	_	-4	-50.00	50.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Slope_S3_VIMS_Robust(7)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Scale_S3_VIMS_Robust(7)	0.79	56	5	-15.00	15.00	0.10	0.209	Normal	1.00	1000	27%
Size_inflection_S4_NEFSC_BLL(8)	131.95	57	2	5.00	150.00	132.41	3.355	Sym_Beta	117.49	0.05	3%
Size_95%width_S4_NEFSC_BLL(8)	19.86	58	3	0.01	60.00	20.11	2.781	Sym_Beta	4.99	0.05	14%
SzSel_Fem_Infl_S4_NEFSC_BLL(8)	0.00	_	-4	-50.00	50.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Slope_S4_NEFSC_BLL(8)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Scale_S4_NEFSC_BLL(8)	0.06	59	5	-15.00	15.00	0.10	0.014	Normal	1.00	1000	26%
Size_DblN_peak_S5_SCDNR_SEAMAP_BLL(9)	56.62	60	2	47.50	162.50	51.90	5.105	Sym_Beta	55.30	0.05	9%
Size_DblN_top_logit_S5_SCDNR_SEAMAP_BLL(9)[2]	-1.88	61	3	-6.00	4.00	-4.40	0.960	Sym_Beta	-6.00	0.05	51%
Size_DblN_ascend_se_S5_SCDNR_SEAMAP_BLL(9)	6.30	_	-3	-1.00	9.00	6.30	_	Sym_Beta	3.20	0.05	NA
Size_DblN_descend_se_S5_SCDNR_SEAMAP_BLL(9)	7.38	62	3	-1.00	9.00	8.70	0.866	Sym_Beta	7.20	0.05	12%
Size_DblN_start_logit_S5_SCDNR_SEAMAP_BLL(9)	-1.20	_	-2	-15.00	9.00	-1.20	_	Sym_Beta	0.00	0.05	NA
Size_DblN_end_logit_S5_SCDNR_SEAMAP_BLL(9)	-1.10	_	-2	-15.00	9.00	-1.10	_	Sym_Beta	-15.00	0.05	NA
SzSel_Male_Peak_S5_SCDNR_SEAMAP_BLL(9)	0.00	_	-4	-50.00	50.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Ascend_S5_SCDNR_SEAMAP_BLL(9)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Descend_S5_SCDNR_SEAMAP_BLL(9)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Final_S5_SCDNR_SEAMAP_BLL(9)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Scale_S5_SCDNR_SEAMAP_BLL(9)	0.76	63	5	-15.00	15.00	0.74	0.130	Normal	1.00	1000	17%
Size_DblN_peak_S6_SCDNR_Red_Drum_BLL(10)	61.75	64	2	47.50	162.50	54.40	5.931	Sym_Beta	57.70	0.05	10%
Size_DblN_top_logit_S6_SCDNR_Red_Drum_BLL(10)	-0.92	65	3	-6.00	4.00	-4.70	0.803	Sym_Beta	-6.00	0.05	88%
Size_DblN_ascend_se_S6_SCDNR_Red_Drum_BLL(10)	6.30	_	-3	-1.00	9.00	6.30	_	Sym_Beta	3.30	0.05	NA
Size_DblN_descend_se_S6_SCDNR_Red_Drum_BLL(10)	5.56	66	3	-1.00	9.00	8.10	2.238	Sym_Beta	7.20	0.05	40%
Size_DblN_start_logit_S6_SCDNR_Red_Drum_BLL(10)	-1.20	_	-2	-15.00	9.00	-1.20	_	Sym_Beta	0.00	0.05	NA
Size_DblN_end_logit_S6_SCDNR_Red_Drum_BLL(10)	-1.10	_	-2	-15.00	9.00	-1.10	_	Sym_Beta	-15.00	0.05	NA
SzSel_Fem_Peak_S6_SCDNR_Red_Drum_BLL(10)	0.00	_	-4	-50.00	50.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Ascend_S6_SCDNR_Red_Drum_BLL(10)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Descend_S6_SCDNR_Red_Drum_BLL(10)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Final_S6_SCDNR_Red_Drum_BLL(10)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Scale_S6_SCDNR_Red_Drum_BLL(10)	0.77	67	5	-15.00	15.00	0.68	0.213	Normal	1.00	1000	27%
Size_inflection_S7_SCDNR_Drumline(11)	129.81	68	2	5.00	150.00	126.96	2.515	Sym_Beta	115.00	0.05	2%
Size_95%width_S7_SCDNR_Drumline(11)	17.92	69	3	0.01	60.00	12.53	2.078	Sym_Beta	8.00	0.05	12%
SzSel_Fem_Infl_S7_SCDNR_Drumline(11)	-6.18	70	4	-50.00	50.00	-0.60	3.046	Normal	0.00	1000	49%
SzSel_Fem_Slope_S7_SCDNR_Drumline(11)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Fem_Scale_S7_SCDNR_Drumline(11)	0.54	71	5	-15.00	15.00	0.70	0.121	Normal	1.00	1000	22%

[2] CV > 0.5.

Table 3.B.4. Continued.

Label	Value	Active_Cnt	Phase	Min	Max	Init	Parm_StDev	Pr_type	Prior	Pr_SD	CV
Size_DblN_peak_S8_COASTSPAN_BLL_All_ages(12)	47.50	_	-2	47.50	60.00	47.50	_	Sym_Beta	51.30	0.05	NA
Size_DblN_top_logit_S8_COASTSPAN_BLL_All_ages(12)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_S8_COASTSPAN_BLL_All_ages(12)	6.30	_	-3	-1.00	9.00	6.30	_	Sym_Beta	2.90	0.05	NA
Size_DblN_descend_se_S8_COASTSPAN_BLL_All_ages(12)	3.10	72	3	-1.00	9.00	3.10	0.217	Sym_Beta	-0.30	0.05	7%
Size_DblN_start_logit_S8_COASTSPAN_BLL_All_ages(12)	-1.20	_	-2	-15.00	9.00	-1.20	_	Sym_Beta	0.00	0.05	NA
Size_DblN_end_logit_S8_COASTSPAN_BLL_All_ages(12)	-5.00	73	2	-15.00	9.00	-5.30	0.523	Sym_Beta	-15.00	0.05	10%
SzSel_Male_Peak_S8_COASTSPAN_BLL_All_ages(12)	0.00	_	-4	-20.00	20.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Ascend_S8_COASTSPAN_BLL_All_ages(12)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Descend_S8_COASTSPAN_BLL_All_ages(12)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Final_S8_COASTSPAN_BLL_All_ages(12)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Scale_S8_COASTSPAN_BLL_All_ages(12)	0.66	74	5	-15.00	15.00	0.65	0.123	Normal	1.00	1000	19%
Size_DblN_peak_S9_COASTSPAN_GN_Long_All_ages(13)	47.50	_	-2	47.50	60.00	47.50	_	Sym_Beta	49.70	0.05	NA
Size_DblN_top_logit_S9_COASTSPAN_GN_Long_All_ages(13)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_S9_COASTSPAN_GN_Long_All_ages(13)	6.30	_	-3	-1.00	9.00	6.30	_	Sym_Beta	9.00	0.05	NA
Size_DblN_descend_se_S9_COASTSPAN_GN_Long_All_ages(13)	2.92	75	3	-1.00	9.00	3.20	0.278	Sym_Beta	2.90	0.05	10%
Size_DblN_start_logit_S9_COASTSPAN_GN_Long_All_ages(13)	-1.20	_	-2	-15.00	9.00	-1.20	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_S9_COASTSPAN_GN_Long_All_ages(13)	-3.42	76	2	-15.00	9.00	-2.90	0.326	Sym_Beta	-2.00	0.05	10%
SzSel_Male_Peak_S9_COASTSPAN_GN_Long_All_ages(13)	0.00	_	-4	-20.00	20.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Ascend_S9_COASTSPAN_GN_Long_All_ages(13)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Descend_S9_COASTSPAN_GN_Long_All_ages(13)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Final_S9_COASTSPAN_GN_Long_All_ages(13)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Scale_S9_COASTSPAN_GN_Long_All_ages(13)	0.87	77	5	-15.00	15.00	0.96	0.183	Normal	1.00	1000	21%
Size_DblN_peak_S10_COASTSPAN_GN_Short_Age_0(14)	47.50	_	-2	47.50	60.00	47.50	_	Sym_Beta	47.70	0.05	NA
Size_DblN_top_logit_S10_COASTSPAN_GN_Short_Age_0(14)	-6.00	_	-3	-6.00	4.00	-6.00	_	Sym_Beta	-6.00	0.05	NA
Size_DblN_ascend_se_S10_COASTSPAN_GN_Short_Age_0(14)	6.30	_	-3	-1.00	9.00	6.30	_	Sym_Beta	9.00	0.05	NA
Size_DblN_descend_se_S10_COASTSPAN_GN_Short_Age_0(14)	2.55	78	3	-1.00	9.00	2.60	0.320	Sym_Beta	3.30	0.05	13%
Size_DblN_start_logit_S10_COASTSPAN_GN_Short_Age_0(14)	-1.20	_	-2	-15.00	9.00	-1.20	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_S10_COASTSPAN_GN_Short_Age_0(14)	-15.00	_	-2	-15.00	9.00	-15.00	_	Sym_Beta	-15.00	0.05	NA
SzSel_Male_Peak_S10_COASTSPAN_GN_Short_Age_0(14)	0.00	_	-4	-20.00	20.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Ascend_S10_COASTSPAN_GN_Short_Age_0(14)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Descend_S10_COASTSPAN_GN_Short_Age_0(14)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Final_S10_COASTSPAN_GN_Short_Age_0(14)	0.00	_	-4	-15.00	15.00	0.00	_	Normal	0.00	1000	NA
SzSel_Male_Scale_S10_COASTSPAN_GN_Short_Age_0(14)	0.53	79	5	-15.00	15.00	0.57	0.191	Normal	1.00	1000	36%
Size_inflection_F1_Com_BLL_Kept(1)_BLK2repl_1981	117.73	80	4	5.00	150.00	117.15	11.356	Sym_Beta	105.00	0.05	10%
Size_inflection_F1_Com_BLL_Kept(1)_BLK2repl_1997	124.68	81	4	5.00	150.00	124.84	2.825	Sym_Beta	105.00	0.05	2%
Size_inflection_F1_Com_BLL_Kept(1)_BLK2repl_2005	107.09	82	4	5.00	150.00	106.88	6.652	Sym_Beta	105.00	0.05	6%
Size_inflection_F1_Com_BLL_Kept(1)_BLK2repl_2018	147.29	83	4	5.00	150.00	141.24	10.223	Sym_Beta	105.00	0.05	7%
Size_95%width_F1_Com_BLL_Kept(1)_BLK2repl_1981	43.17	84	4	0.01	60.00	42.42	10.240	Sym_Beta	10.00	0.05	24%
Size_95%width_F1_Com_BLL_Kept(1)_BLK2repl_1997	14.69	85	4	0.01	60.00	14.68	3.675	Sym_Beta	10.00	0.05	25%
Size_95%width_F1_Com_BLL_Kept(1)_BLK2repl_2005	23.86	86	4	0.01	60.00	24.12	7.383	Sym_Beta	10.00	0.05	31%
Size_95%width_F1_Com_BLL_Kept(1)_BLK2repl_2018	31.28	_	-4	0.01	60.00	31.28	_	Sym_Beta	10.00	0.05	NA
Size_inflection_F2_Com_GN_Kept(2)_BLK5repl_1981	120.42	87	4	5.00	150.00	121.28	5.915	Sym_Beta	102.36	0.05	5%
Size_95%width_F2_Com_GN_Kept(2)_BLK5repl_1981	45.08	88	4	0.01	60.00	46.28	4.880	Sym_Beta	23.05	0.05	11%

Table 3.B.4. Continued.

Label	Value	Active_Cnt	Phase	Min	Max	Init	Parm_StDev	Pr_type	Prior	Pr_SD	CV
Size_DblN_peak_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1981	64.90	_	-2	47.50	162.50	64.90	_	Sym_Beta	64.90	0.05	NA
Size_DblN_peak_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1990	64.90	_	-2	47.50	162.50	64.90	_	Sym_Beta	64.90	0.05	NA
Size_DblN_descend_se_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1981	4.96	89	3	-1.00	9.00	2.90	1.121	Sym_Beta	7.20	0.05	23%
Size_DblN_descend_se_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1990	6.52	90	3	-1.00	9.00	2.90	0.868	Sym_Beta	7.20	0.05	13%
Size_DblN_start_logit_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1981	9.00	_	-2	-15.00	9.00	9.00	_	Sym_Beta	0.00	0.05	NA
Size_DblN_start_logit_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1990	-1.10	_	-2	-15.00	9.00	-1.10	_	Sym_Beta	0.00	0.05	NA
Size_DblN_end_logit_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1981	-2.10	91	2	-15.00	9.00	-1.20	0.661	Sym_Beta	-15.00	0.05	32%
Size_DblN_end_logit_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1990	-1.20	_	-2	-15.00	9.00	-1.20	_	Sym_Beta	-15.00	0.05	NA
Size_DblN_end_logit_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1990	-1.20	_	-2	-15.00	9.00	-1.20	_	Sym_Beta	-15.00	0.05	NA

Table 3.B.5. Total biomass (B), spawning stock fecundity (SSF), recruits (R), and total fishing mortality (F=Z-M) obtained from the logistic sensitivity analysis.

	Total biomass B (mt)	Female spawning stock fecundity SSF (1,000s pups)	Recruits R (1,000s pups)	Total fishing mortality F=Z-M
Virg		637	785	
Init		637	785	
1981	44181	637	785	0.024
1982	43688	634	783	0.024
1983	43128	631	782	0.023
1984	42113	624	627	0.036
1985	40578	611	565	0.036
1986	38971	595	648	0.036
1987	37440	577	705	0.020
1988	36162	561	602	0.022
1989	35134	544	630	0.017
1990	34307	527	623	0.026
1991	33506	508	663	0.038
1992	32477	478	674	0.043
1993	31944	448	851	0.051
1994	31280	420	784	0.037
1995	31527	411	768	0.045
1996	31071	398	516	0.033
1997	30744	386	480	0.056
1998	29748	378	470	0.056
1999	28456	373	450	0.067
2000	26757	370	403	0.055
2001	25250	374	393	0.058
2002	23907	376	462	0.066
2003	22663	367	529	0.067
2004	22203	347	756	0.080
2005	21880	324	686	0.066
2006	21844	305	531	0.059
2007	22186	285	618	0.051
2008	22911	271	708	0.052
2009	23499	257	667	0.047
2010	24085	250	599	0.025
2011	24989	254	602	0.017
2012	26302	268	772	0.018
2013	27775	282	873	0.024
2014	28332	292	450	0.039
2015	28487	301	426	0.037
2016	28146	315	418	0.032
2017	27818	329	566	0.021
2018	27564	341	587	0.019

Table 3.B.6. 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 from the base model configuration.

Year	F/F_{MSY}	SE	SSF/SSF_{MSY}	SE	SSF/MSST
1981	0.46	0.090	2.59	NA	3.41
1982	0.47	0.093	2.58	0.011	3.39
1983	0.44	0.089	2.57	0.017	3.37
1984	0.68	0.143	2.54	0.025	3.34
1985	0.68	0.146	2.49	0.037	3.27
1986	0.69	0.151	2.42	0.050	3.18
1987	0.38	0.084	2.35	0.064	3.09
1988	0.41	0.093	2.29	0.073	3.00
1989	0.33	0.073	2.21	0.084	2.91
1990	0.50	0.115	2.15	0.093	2.82
1991	0.74	0.171	2.07	0.102	2.72
1992	0.82	0.196	1.95	0.120	2.56
1993	0.98	0.237	1.82	0.138	2.39
1994	0.70	0.177	1.71	0.155	2.25
1995	0.86	0.216	1.67	0.164	2.20
1996	0.62	0.159	1.62	0.172	2.13
1997	1.06	0.277	1.57	0.178	2.06
1998	1.08	0.288	1.54	0.182	2.02
1999	1.29	0.352	1.52	0.187	1.99
2000	1.05	0.294	1.51	0.195	1.98
2001	1.11	0.320	1.52	0.206	2.00
2002	1.26	0.372	1.53	0.217	2.01
2003	1.28	0.387	1.49	0.227	1.96
2004	1.53	0.466	1.41	0.229	1.86
2005	1.26	0.393	1.32	0.227	1.74
2006	1.13	0.363	1.24	0.221	1.63
2007	0.98	0.320	1.16	0.217	1.52
2008	1.00	0.333	1.10	0.210	1.45
2009	0.91	0.305	1.05	0.206	1.38
2010	0.47	0.160	1.02	0.206	1.34
2011	0.33	0.113	1.03	0.212	1.36
2012	0.35	0.117	1.09	0.223	1.43
2013	0.46	0.151	1.15	0.235	1.51
2014	0.75	0.252	1.19	0.244	1.56
2015	0.70	0.239	1.23	0.254	1.61
2016	0.60	0.209	1.28	0.267	1.68
2017	0.40	0.138	1.34	0.278	1.76
2018	0.37	0.125	1.39	0.286	1.83

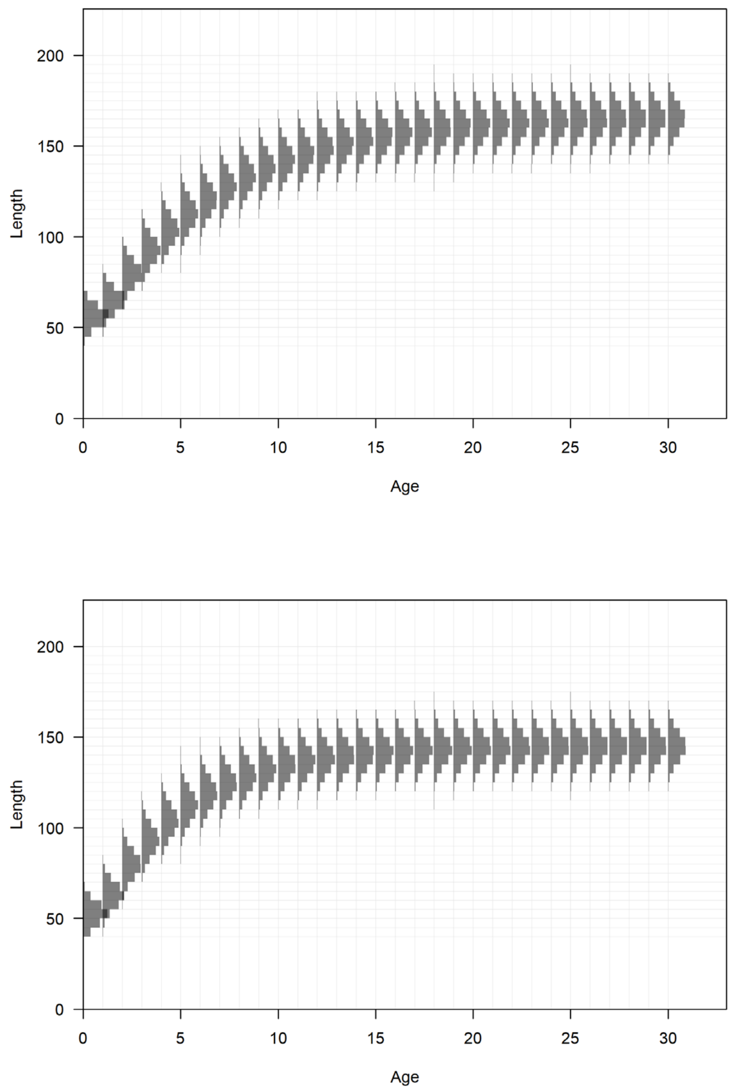
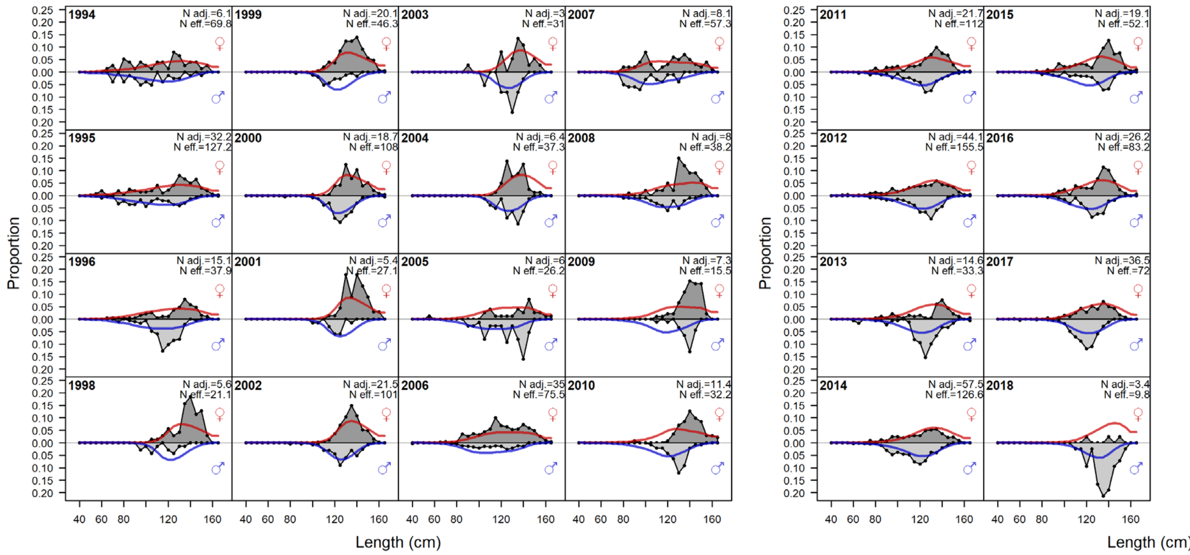


Figure 3.B.1. Distribution of mean length (cm FL straight) at each age implemented separately for females (upper panel) and males (lower panel) in the logistic sensitivity analysis.

Figure 3.B.2. Observed and predicted annual length compositions (Upper panels) and Pearson residuals (Lower panel) in the logistic sensitivity analysis. 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. 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.



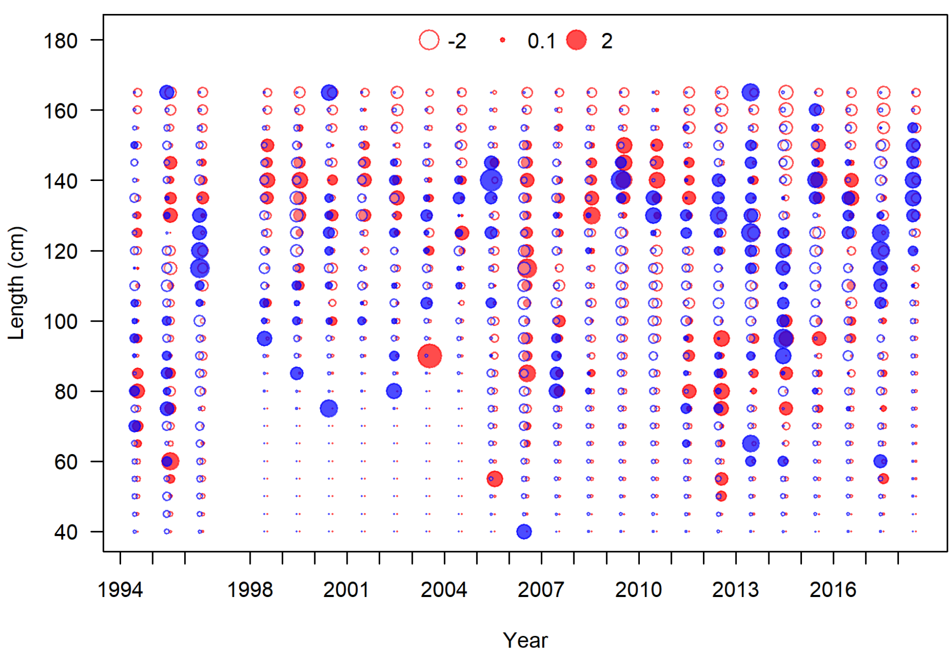
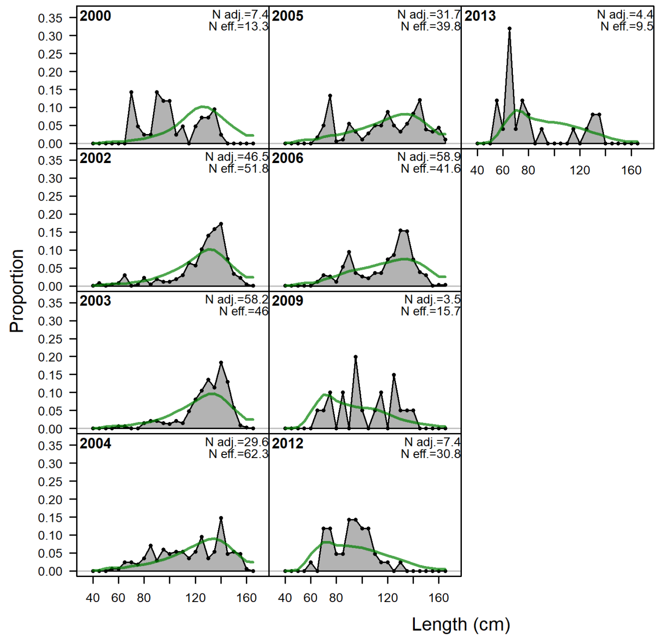


Figure 3.B.2. Continued. F1 (Com-BLL-Kept; 1994 – 2018).



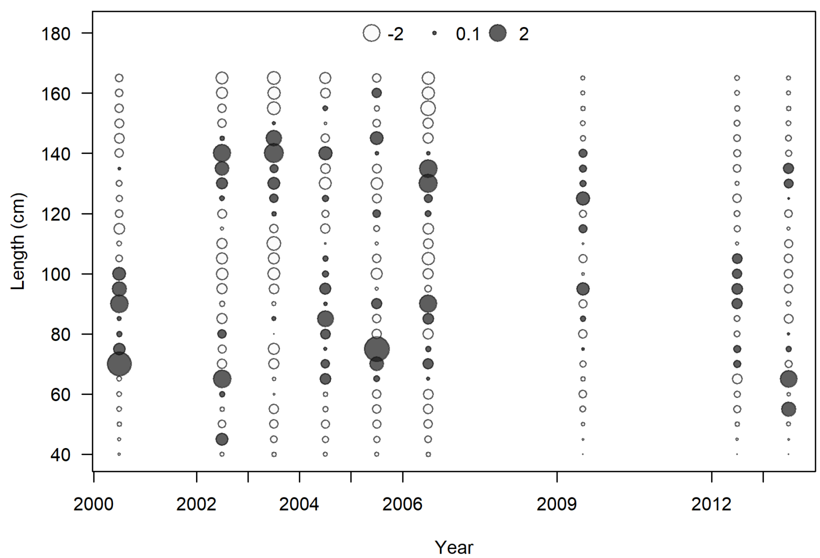
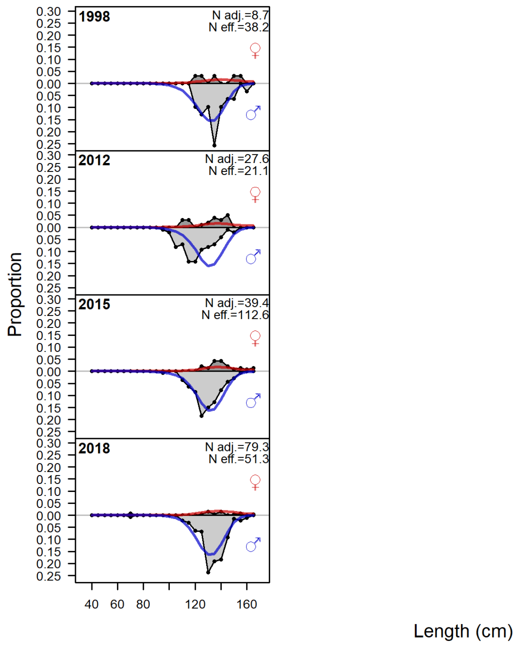


Figure 3.B.2. Continued. F2 (Com-GN-Kept; 2000 – 2018).



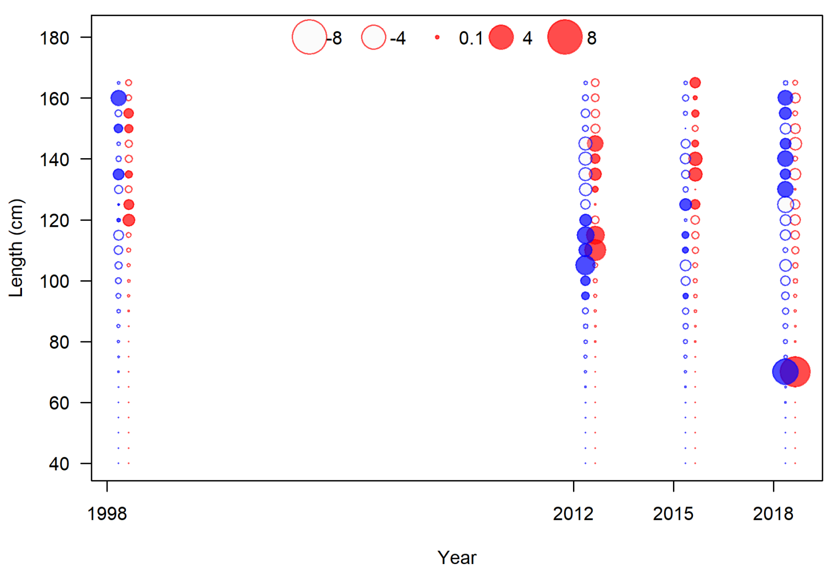
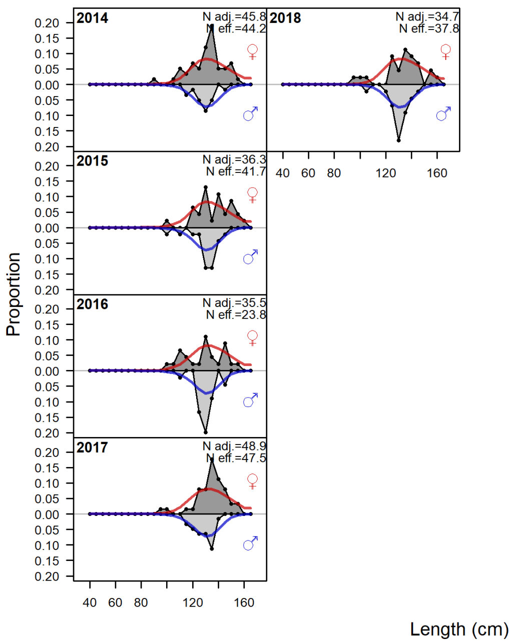


Figure 3.B.2. Continued. S4 (NEFSC-BLL; 1996 – 2018).



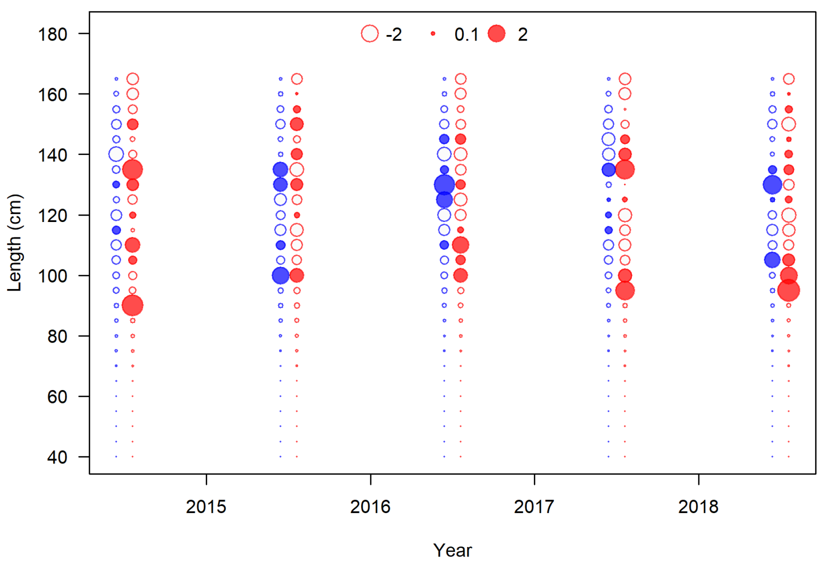


Figure 3.B.2. Continued. S7 (SCDNR-DL; 2013 – 2018).

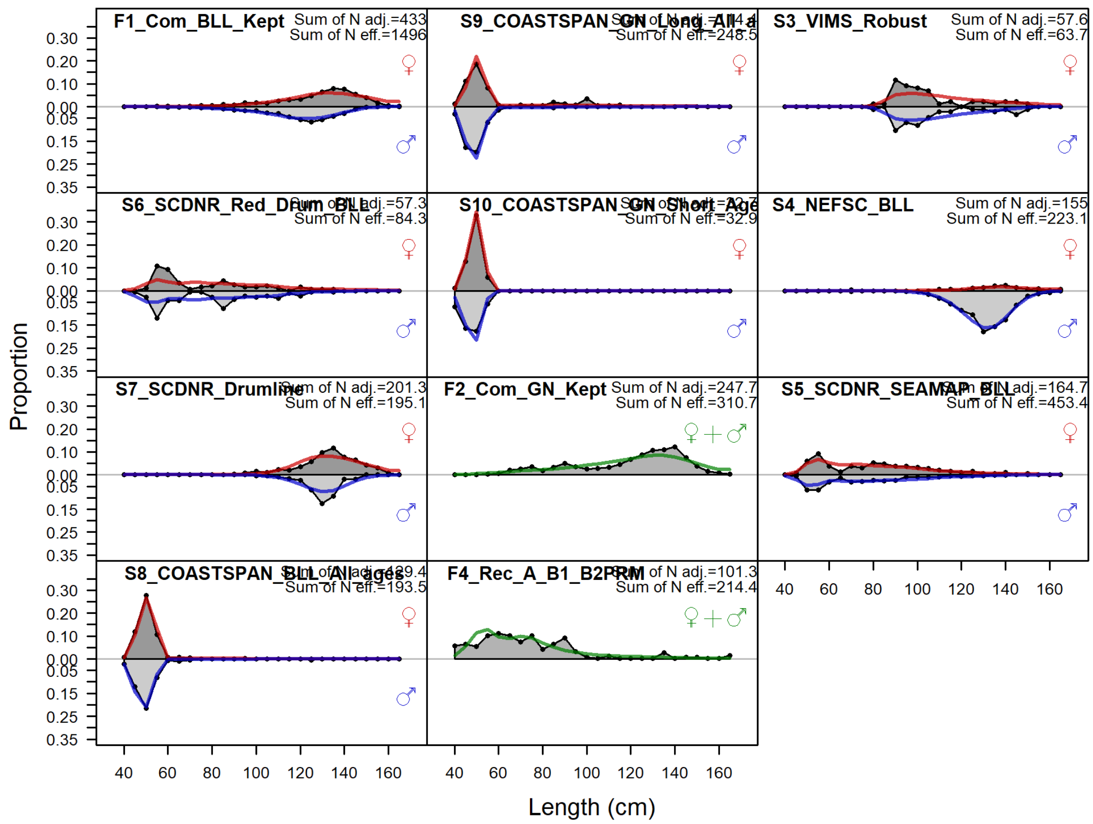


Figure 3.B.3. Predicted (line) and observed (shaded) aggregated length compositions in the logistic sensitivity analysis. Years with annual length composition sample size less than the minimum input sample size (Min; **Table 3.2)** were excluded from the model fit, and are not plotted. The value "N adj" 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.

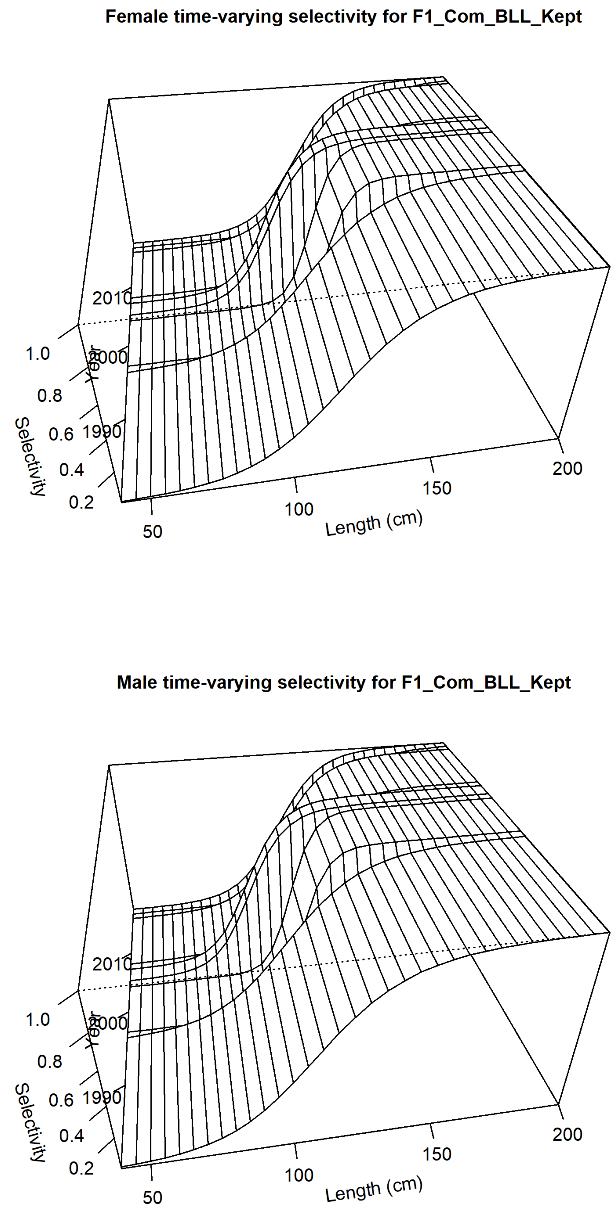
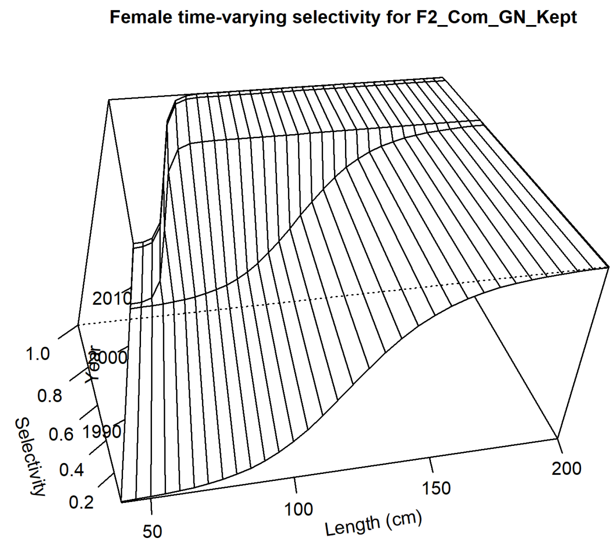


Figure 3.B.4. Selectivity at length (cm FL straight) obtained in the logistic sensitivity analysis (**Table 3.B.1**.) for F1 (Com-BLL-Kept; 1994 – 2018).



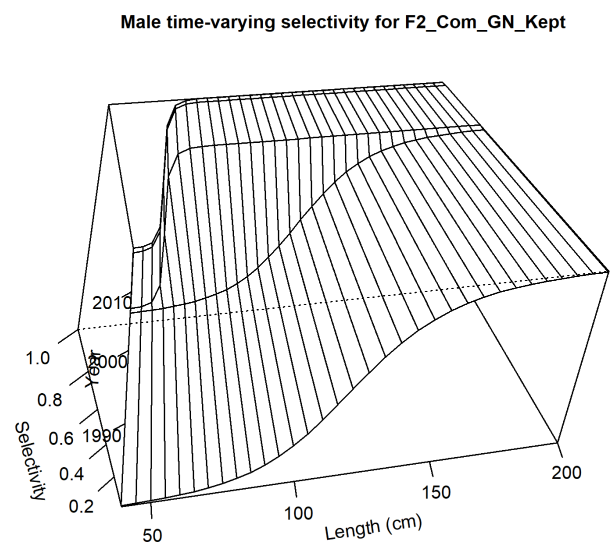
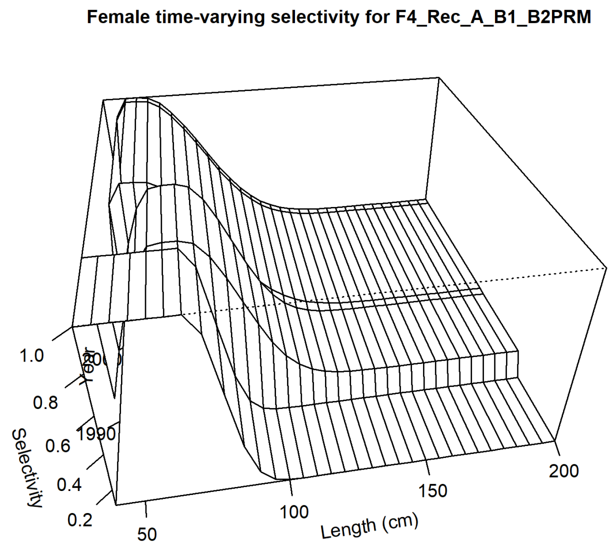


Figure 3.B.4. Continued. F2 (Com-GN-Kept; 2000 – 2018).



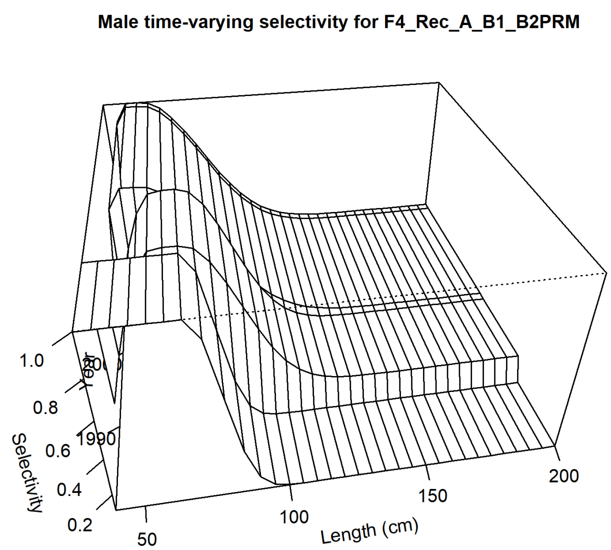


Figure 3.B.4. Continued. F4 (Recreational; 1981 – 2018).

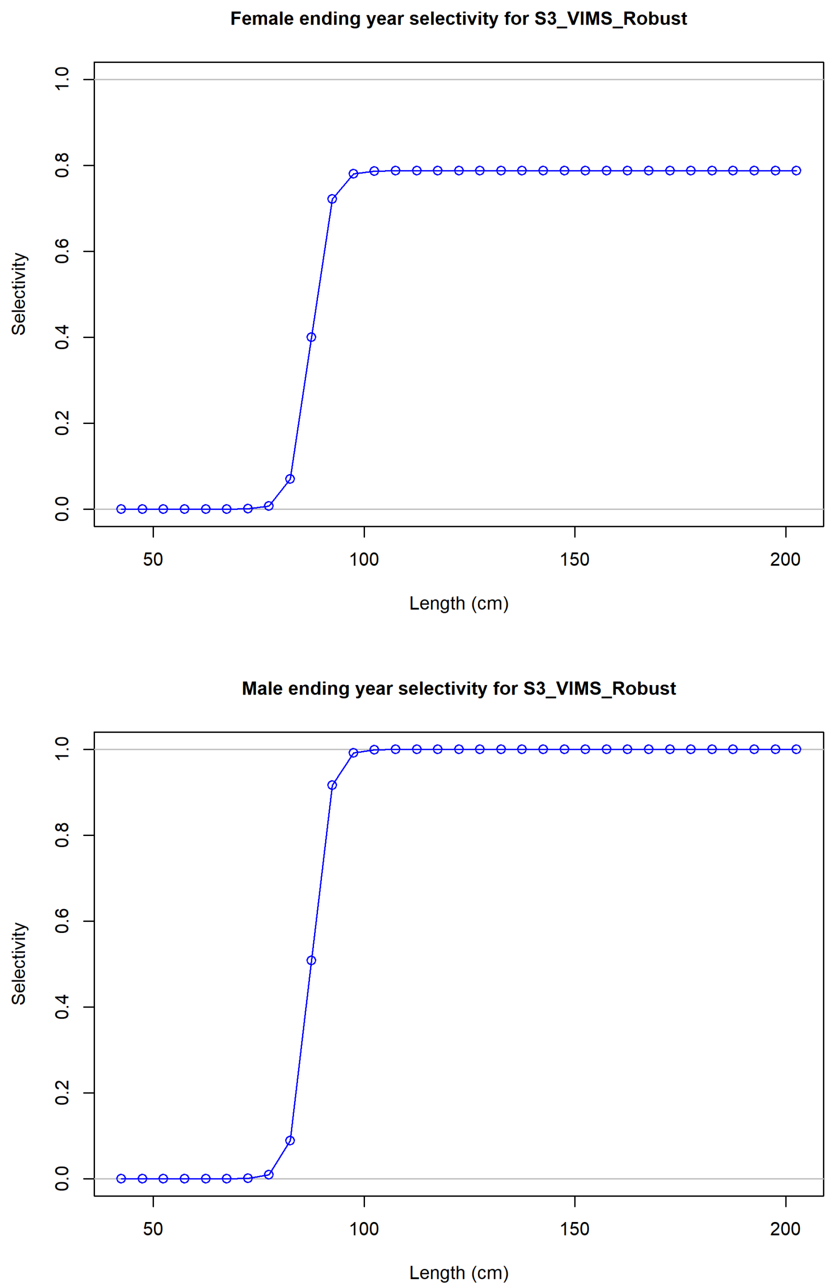


Figure 3.B.4. Continued. S3 (VIMS-BLL-Robust; 1990 – 2018).

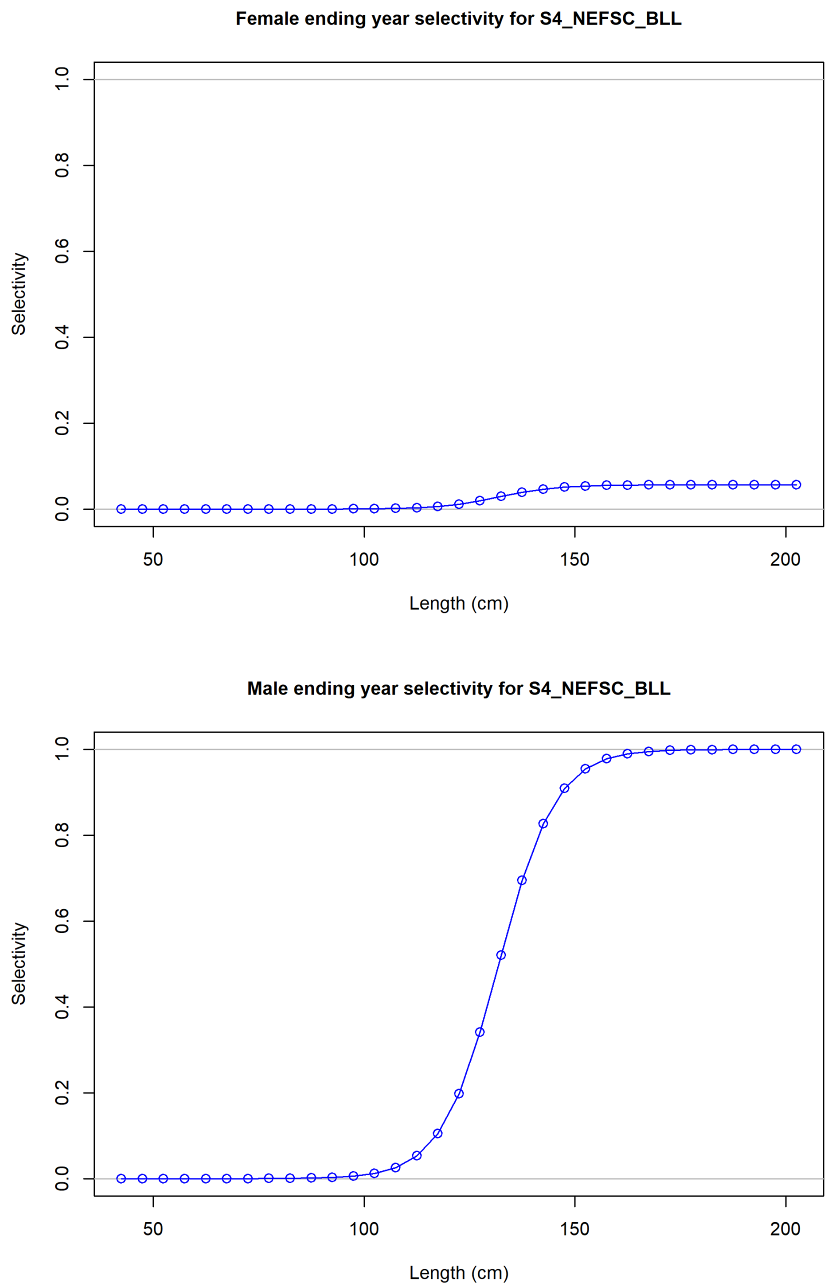


Figure 3.B.4. Continued. S4 (NEFSC-BLL; 1996 – 2018).

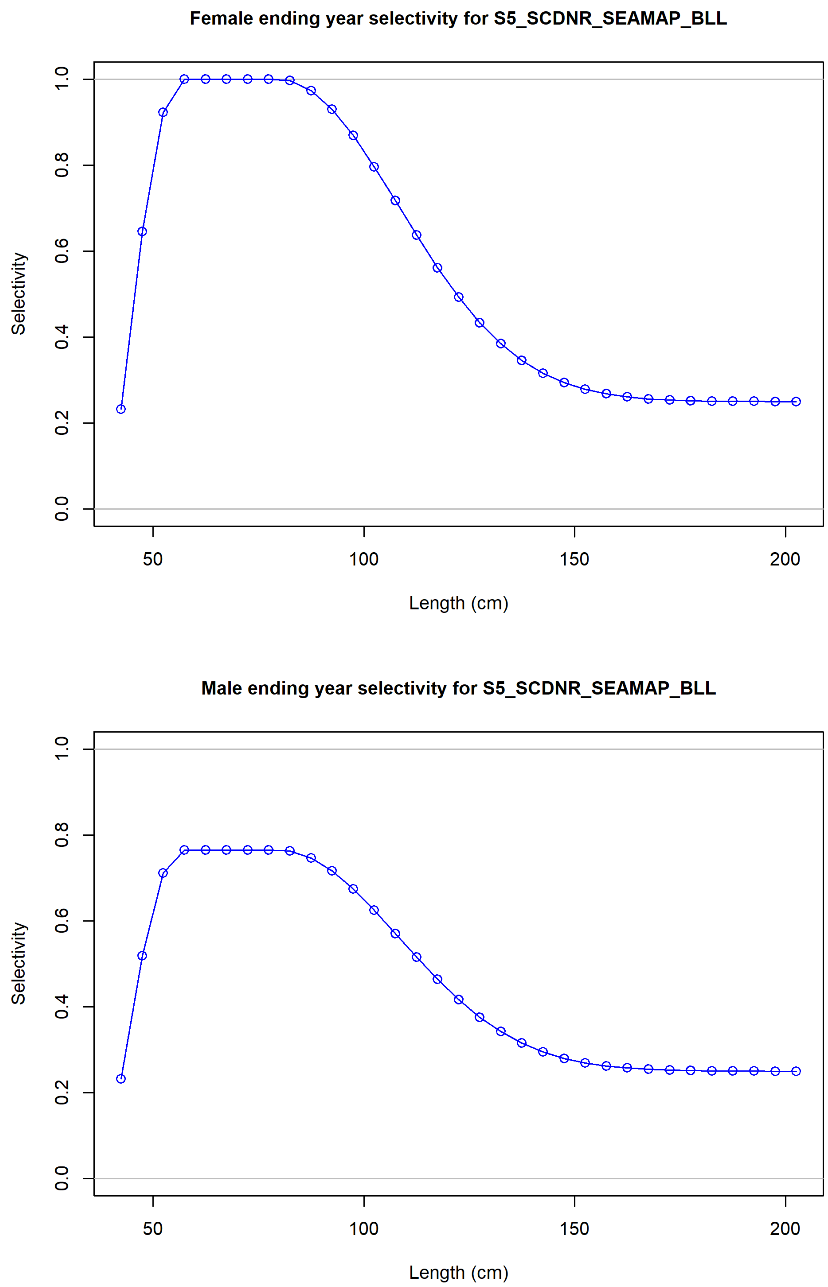


Figure 3.B.4. Continued. S5 (SCDNR-SEAMAP-BLL; 2007 – 2018).

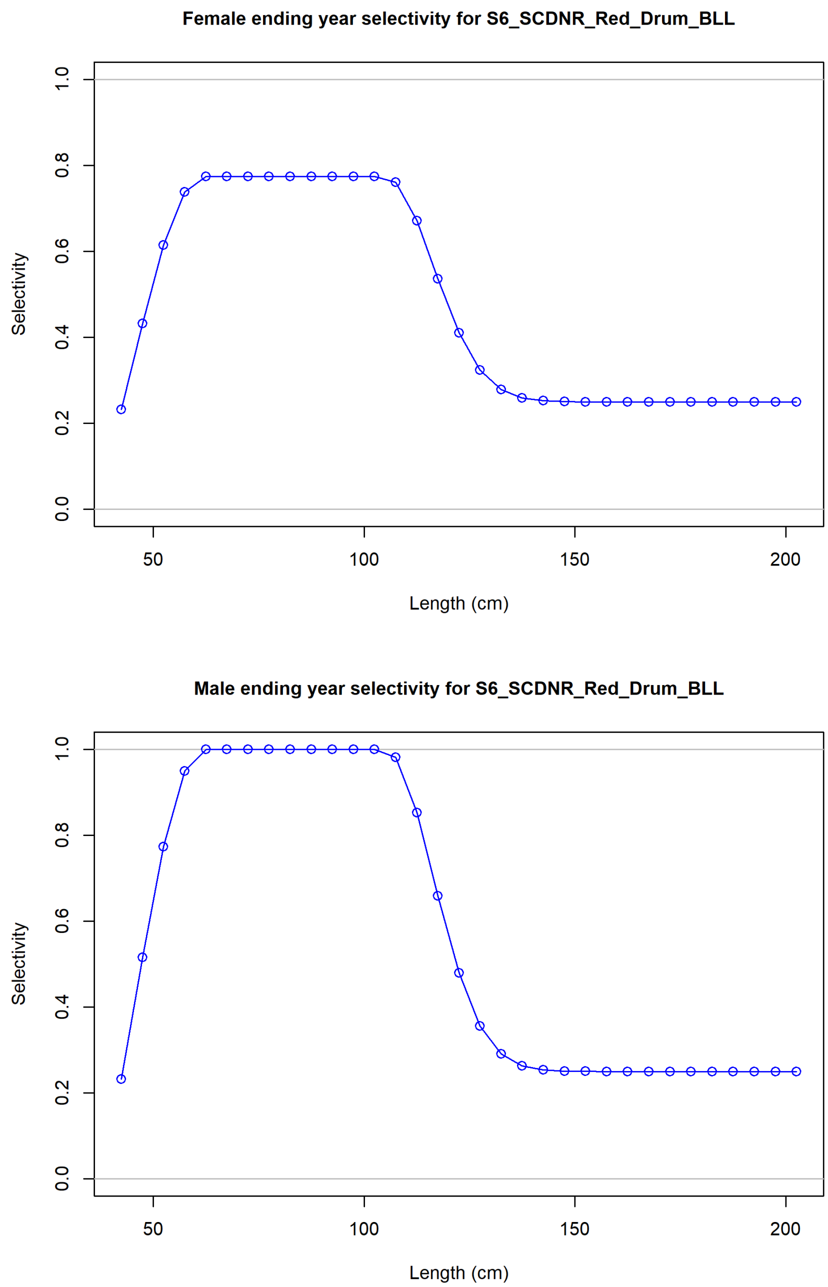
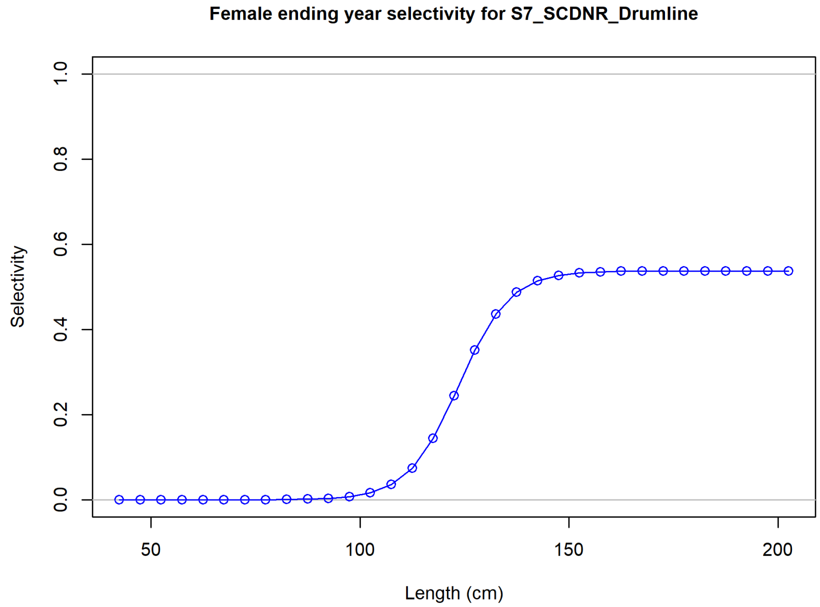


Figure 3.B.4. Continued. S6 (SCDNR-Red-Drum-BLL; 1996 – 2006).



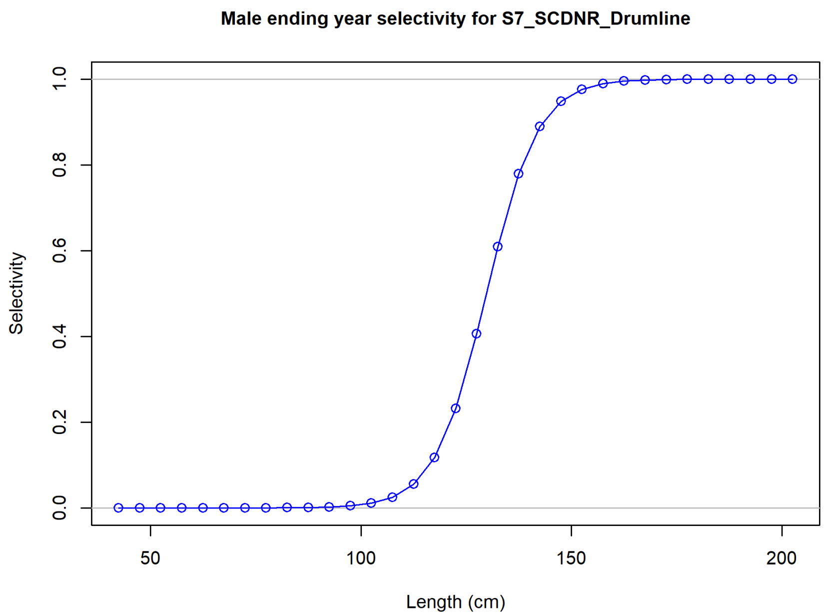
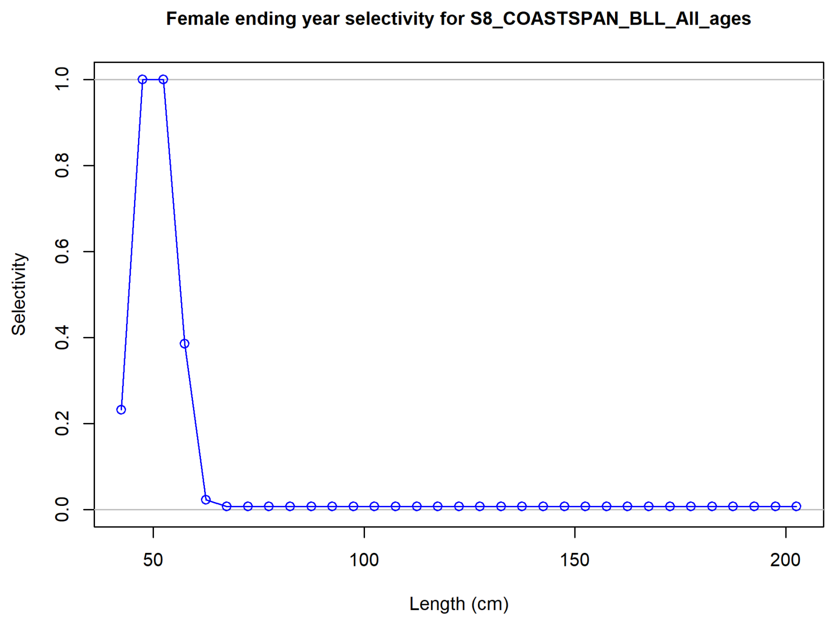


Figure 3.B.4. Continued. S7 (SCDNR-DL; 2013 – 2018).



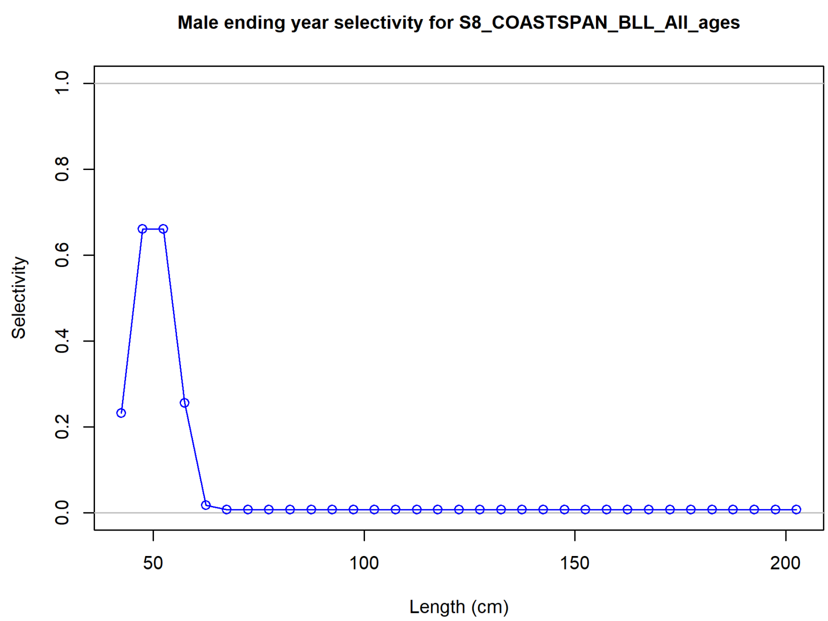
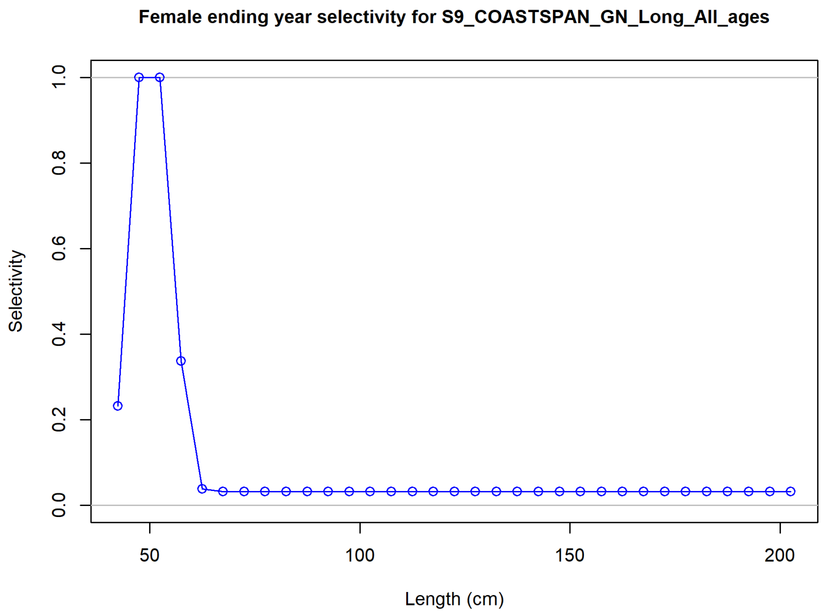


Figure 3.B.4. Continued. S8 (COASTSPAN-BLL-All-ages; 2005 – 2018).



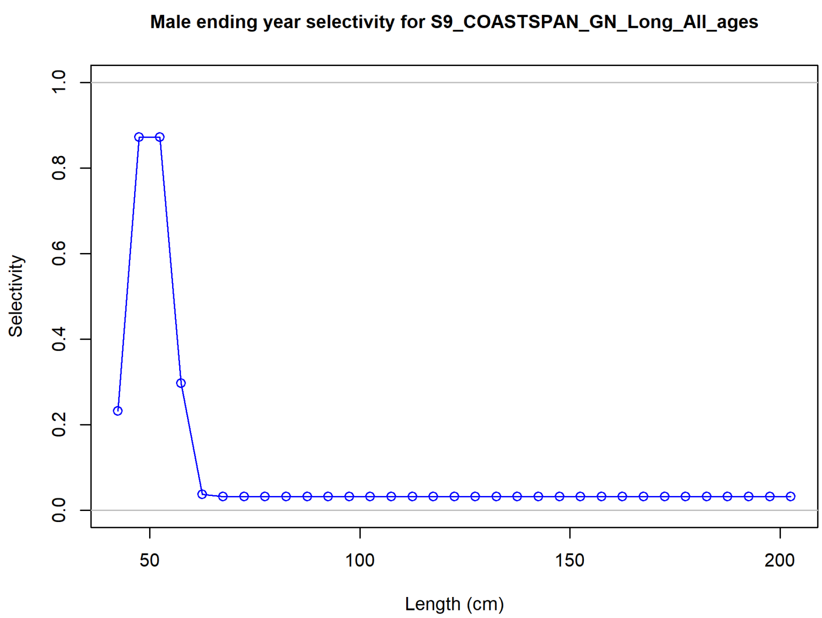


Figure 3.B.4. Continued. S9 (COASTSPAN-GNL-All-ages; 2001 – 2018).

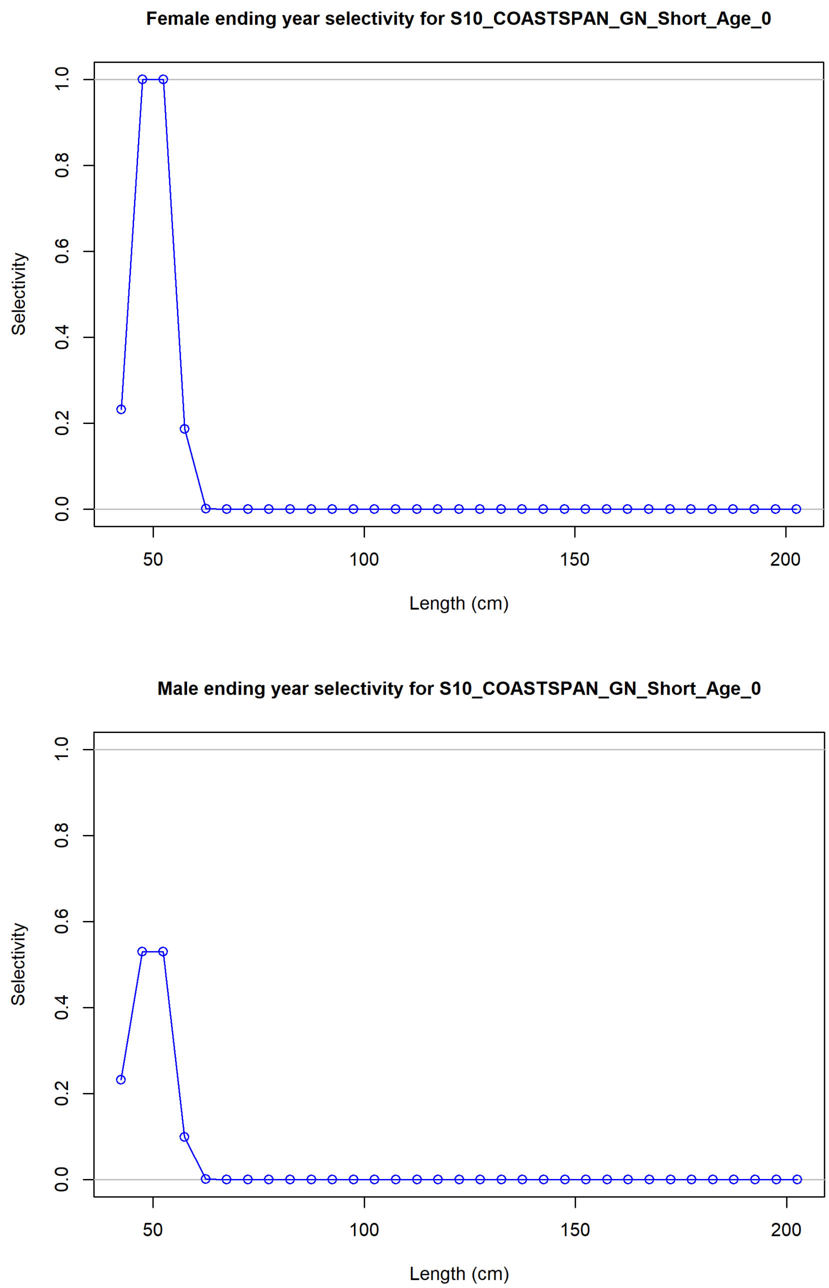


Figure 3.B.4. Continued. S10 (COASTSPAN-GNS-Age-0; 2006 – 2018).

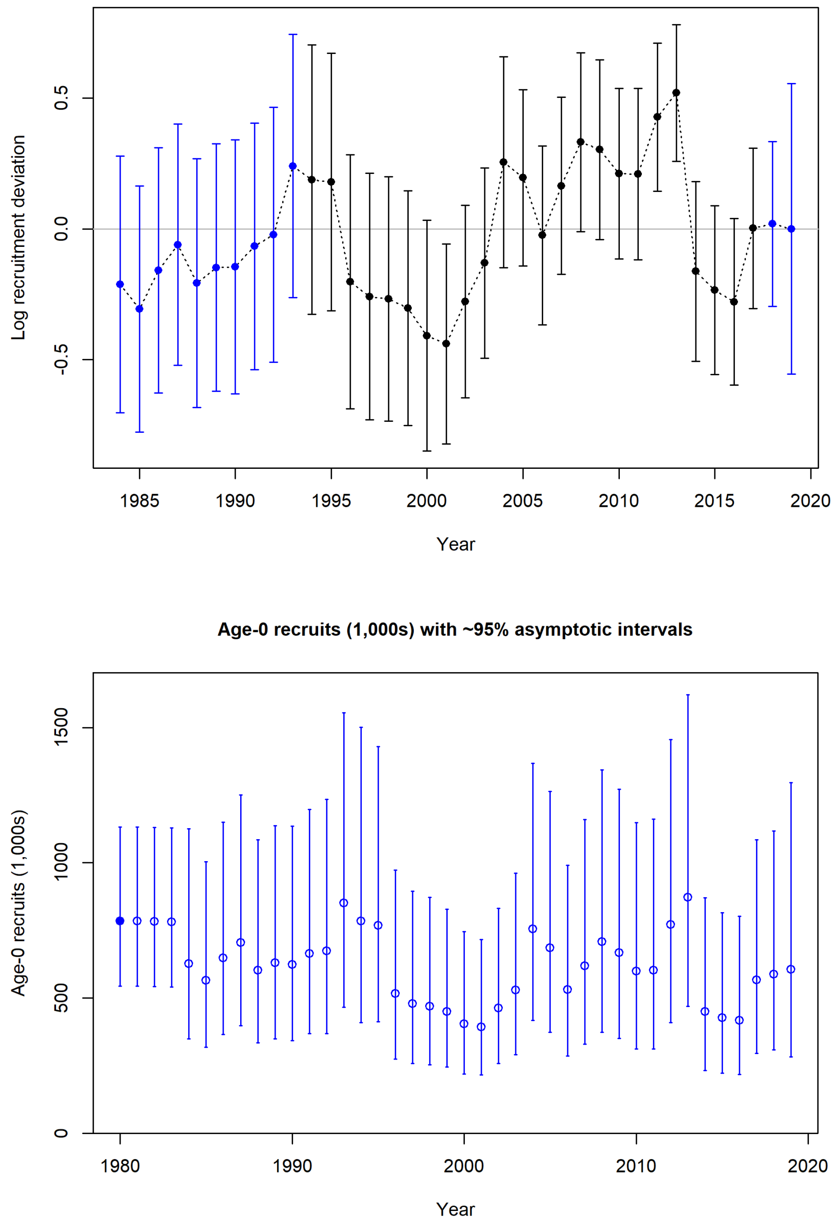


Figure 3.B.5. Upper panel is the estimated log recruitment deviations for the early (1984 – 1993, blue), main (1994 – 2017, black), late (2018, blue), and forecast (2019, blue) recruitment periods with associated 95% asymptotic confidence intervals in the logistic sensitivity analysis. Lower panel is 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 1984 and after 2018.

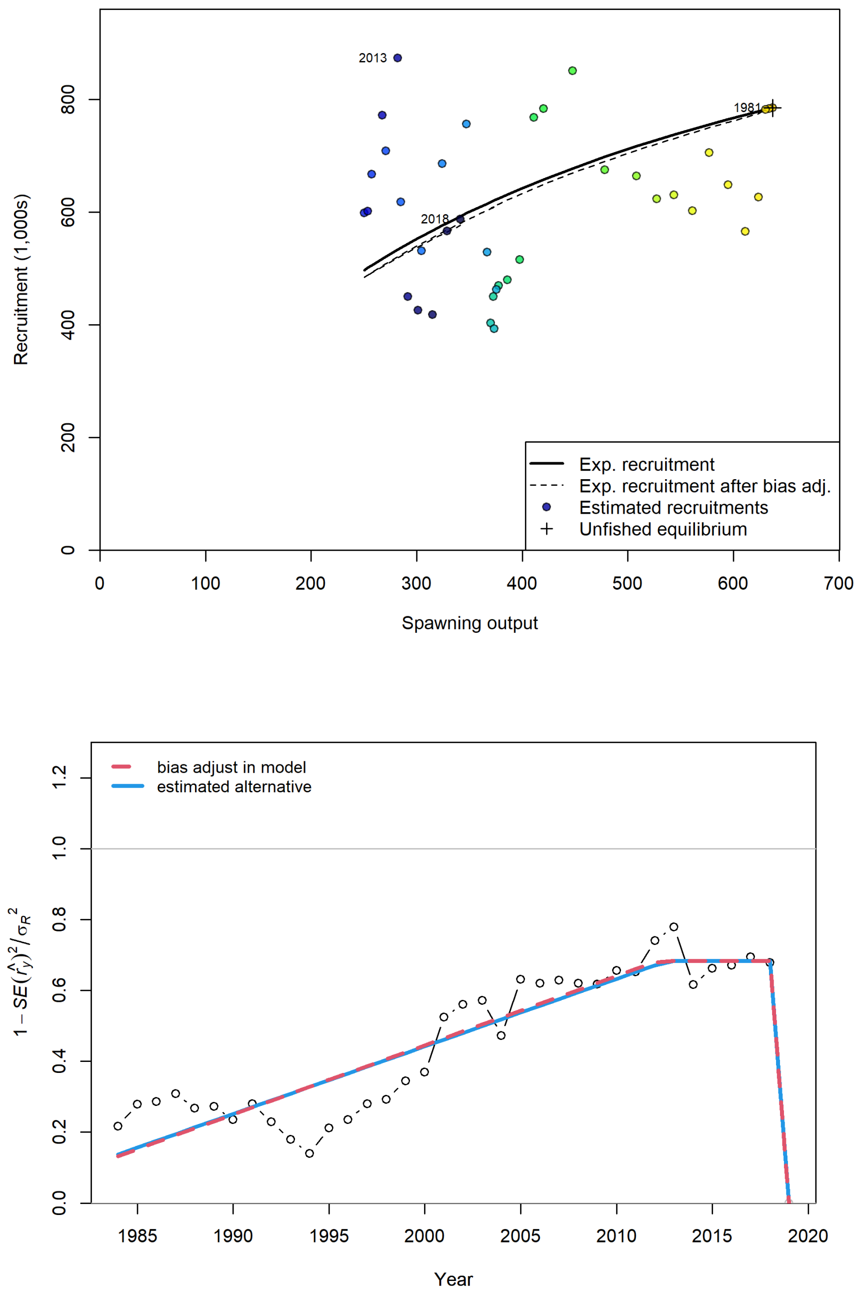


Figure 3.B.6. Expected recruitment (Upper panel) from the stock-recruitment relationship (solid line), expected recruitment after implementing the bias adjustment correction (dashed line), estimated annual recruitments (circles), unfished equilibrium (plus), and first (1981) and last (2018) years along with years with log deviations > 0.5 (2013) in the logistic sensitivity analysis. Bias adjustment ramp (Lower panel) applied to the stock-recruitment relationship (red stippled line) and the estimated alternative (blue line) in the logistic sensitivity analysis. The y-axis of the lower panel is the bias adjustment fraction (Methot and Taylor 2011).

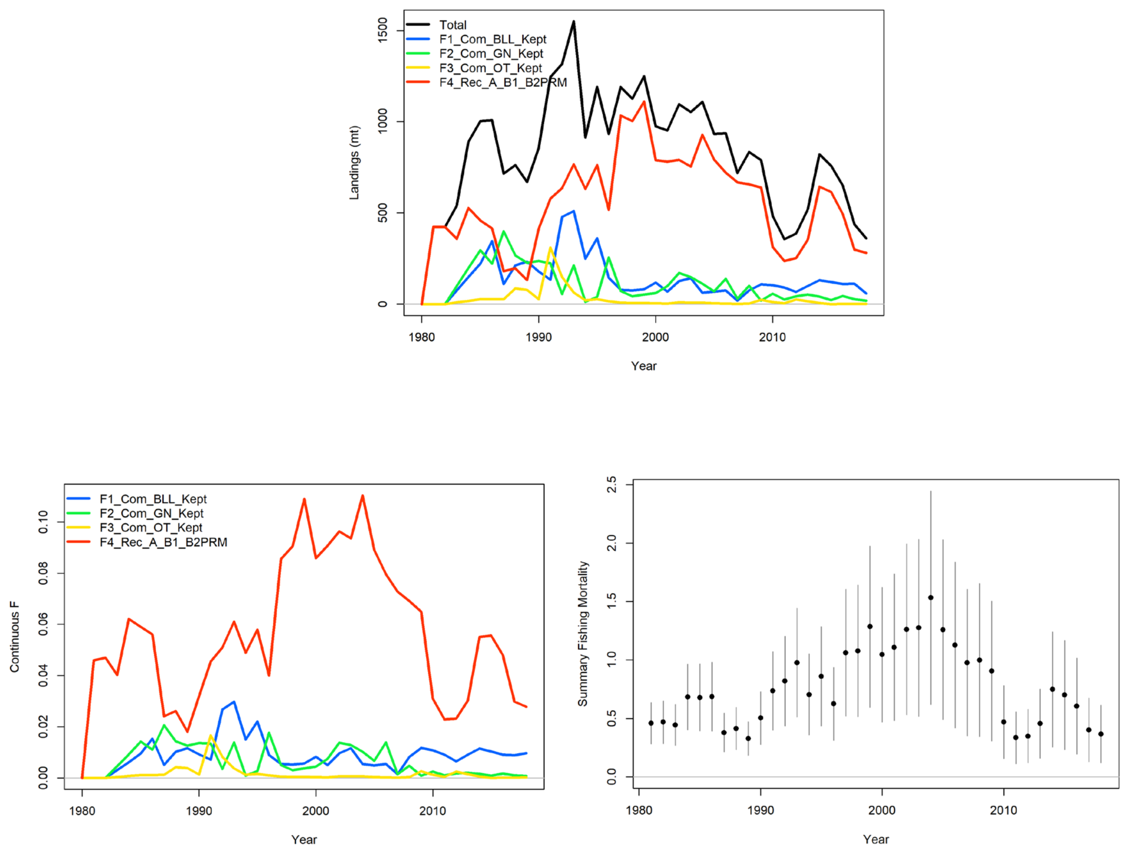
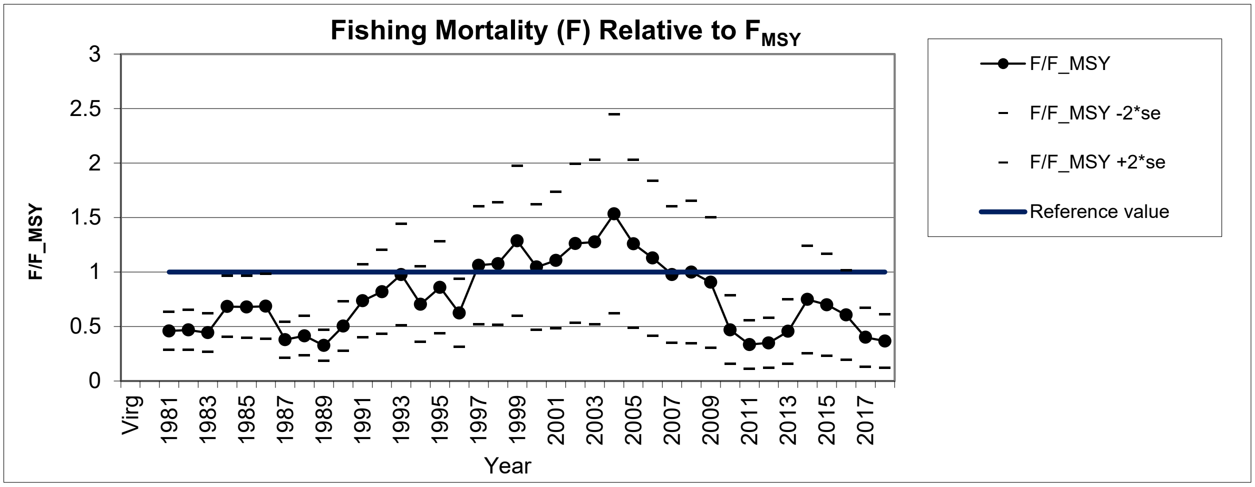


Figure 3.B.7. Total landings (Upper panel), continuous fishing mortality by fleet (Continuous *F*; Lower left panel), and the summary fishing mortality of all fleets combined (Lower right panel) in the logistic sensitivity analysis. The summary fishing mortality is plotted as a ratio calculated as the total fishing mortality rate experienced by the population (F=Z-M) relative to F_{MSY}. Error bars are the 95% asymptotic standard errors, ± 1.96*SE, obtained from Stock Synthesis output. Total landings include commercial landings (mt) along with recreational catch plus recreational discards assumed to die from post release mortality (A + B1 + B2 dead). Recreational data was entered in numbers (1,000s) and converted internally within Stock Synthesis to weight (mt) based on the weight at length of recreational fishery removals obtained in the Stock Synthesis logistic sensitivity analysis.



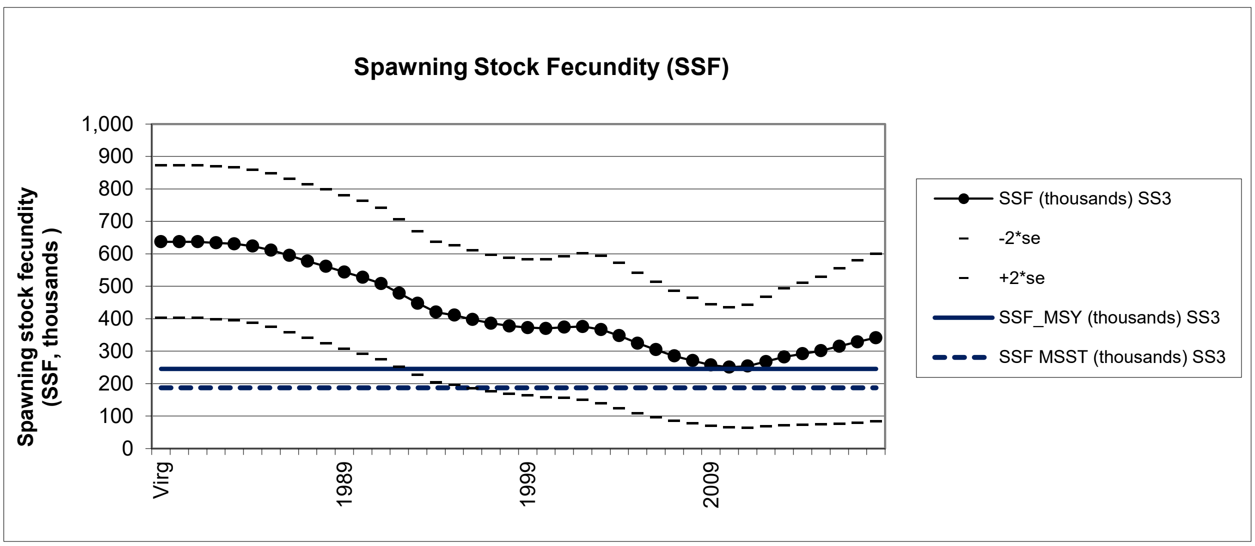


Figure 3.B.8. Summary fishing mortality (F) relative to F_{MSY} (Upper panel) and spawning stock fecundity (SSF) (Lower Panel) in the logistic sensitivity analysis. Summary fishing mortality, F, is calculated as the total fishing mortality rate experienced by the population ($F=Z-M$) obtained from Stock Synthesis output. 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 $\left(1-\bar{M}_a\right)$ *SSF_{MSY}, with $\bar{M}_a$ calculated as the arithmetic mean of the female age-specific values of M used in the logistic sensitivity analysis (0.239, **Table 2.14**).

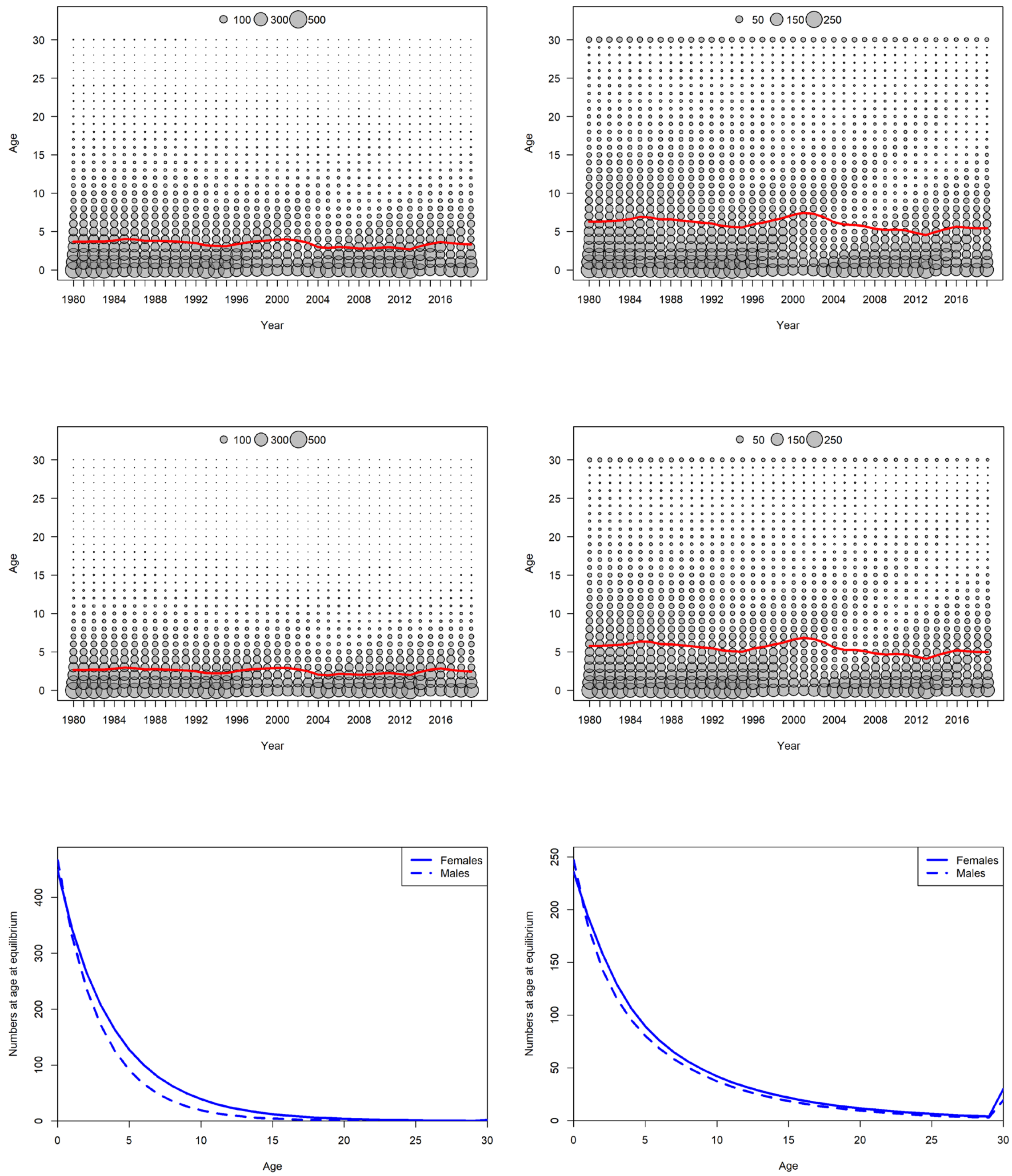


Figure 3.B.9. Beginning of year expected numbers (1000s) at age for females (Upper panels) and males (Middle panels) along with the equilibrium age distribution in the population (Lower panels) for the logistic sensitivity analysis (Left panels) and the base model configuration (Right panels).

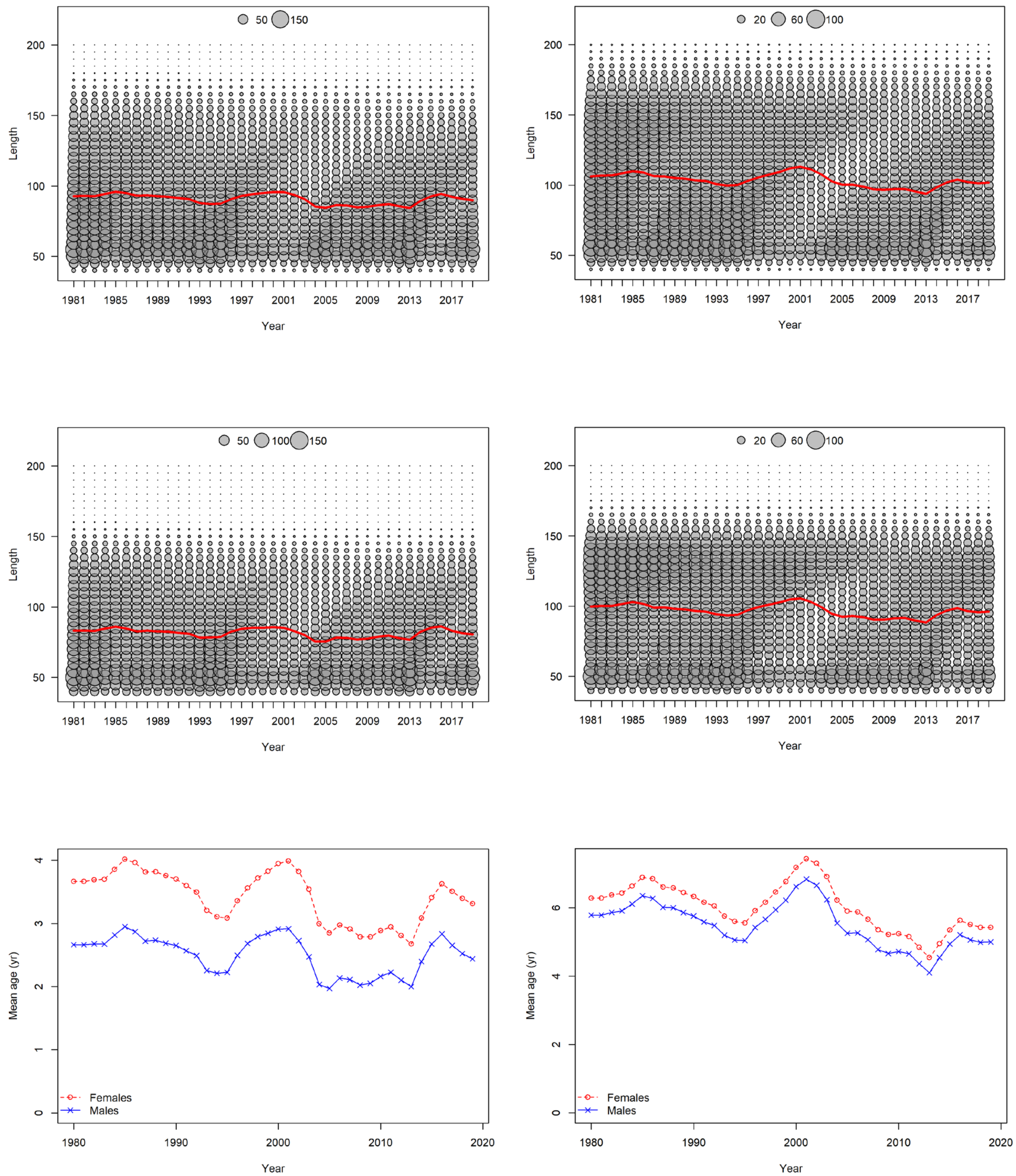


Figure 3.B.10. Beginning of year expected numbers (1000s) at length (cm FL straight) for females (Upper panels) and males (Middle panels) along with beginning of year mean age in the population (Lower panels) for the logistic sensitivity analysis (Left panels) and the base model configuration (Right panels).

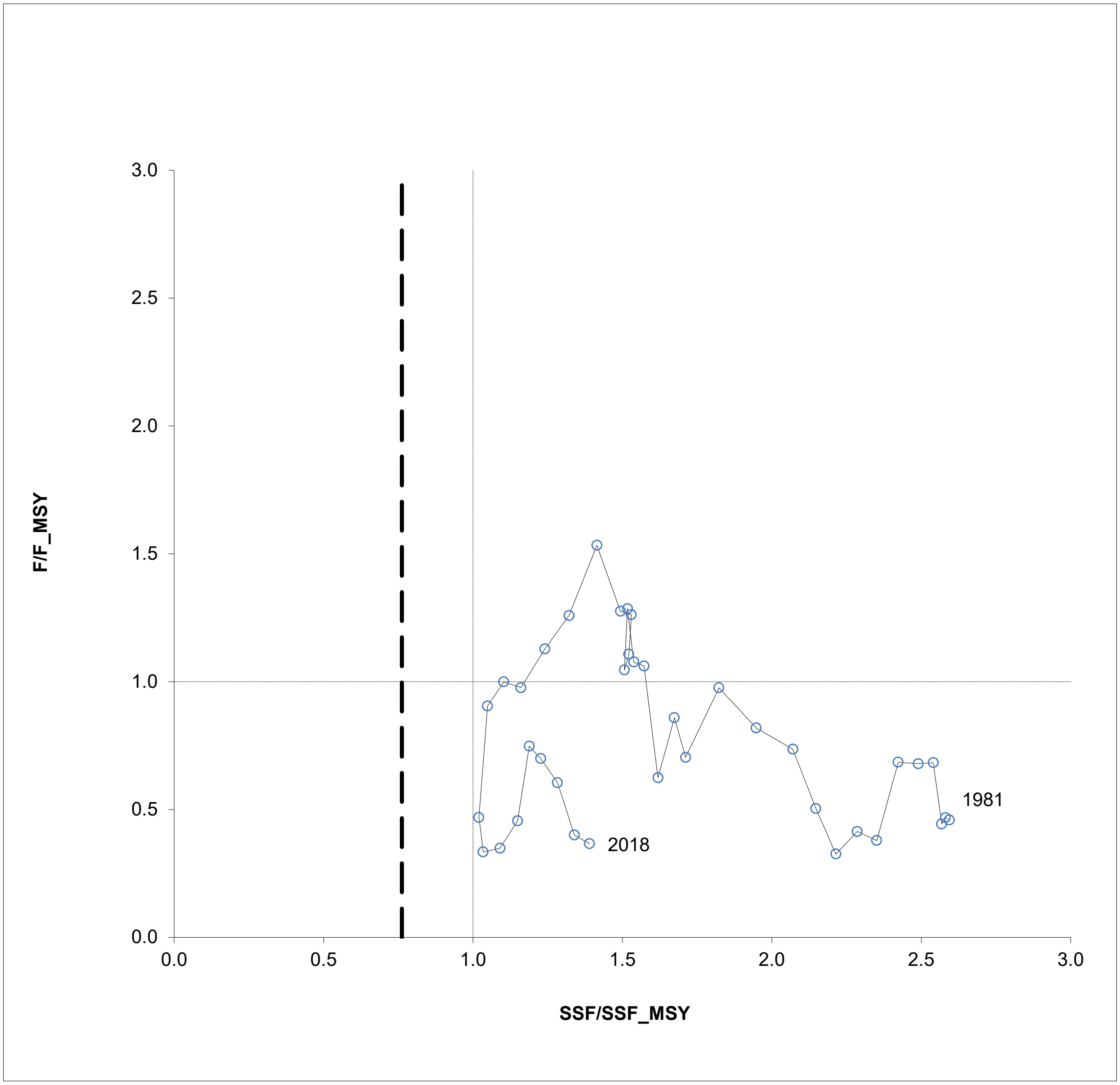


Figure 3.B.11. Phase plot of the relative spawning stock fecundity (SSF) and relative fishing mortality (*F*) trajectories by year from 1981 to 2018 in the logistic sensitivity analysis. The dotted horizontal and vertical lines indicate F_{MSY} and SSF_{MSY}. The dashed vertical line indicates MSST $=\left(1-\bar{M}_a\right)*SSF_{MSY}$, with $\bar{M}_a$ calculated as the arithmetic mean of the female age-specific values of *M* used in the logistic sensitivity analysis (0.239, **Table 2.14**).

SEDAR

Southeast Data, Assessment, and Review

SEDAR 65

Atlantic Blacktip Shark

SECTION IV: Research Recommendations

December 2020

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

Table of Contents

1. Data Workshop

1.1 Life History

- Increase sampling intensity throughout range, particularly at depths less than 20 m.
- Investigate sex- and life stage-specific movements of blacktip sharks to determine if migratory behaviors change based on maturity or reproductive condition.
- Animals should be tagged throughout their range, including the northern extent of the population range off New York, to gain a more complete understanding of migratory and residency patterns.
- Identify environmental conditions (e.g. dissolved oxygen, temperature, salinity, etc.) and ecological factors (e.g. prey abundance, community structure, etc.) that correlate with migration, movement patterns, and preferred habitats. This will allow prediction of future range changes based on habitat suitability models.
- Identification of population structure based on genetic information or other intrinsic natural markers/tracers.

1.2 Catches

- Increase public education outreach activities for species identification in the recreational fishery. This is important because the fishery has become largely recreational, there are no species identification training workshops for recreational fishers, and it is difficult to distinguish blacktip from spinner sharks, especially as 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.

1.3 Indices

- Explore the utility of combining multiple indices into one index using the Bayesian hierarchical model (Conn, 2009) or other similar methodology. The data series that could potentially be combined are:
- For Age 0: Coastspan Longline, Coastspan Gillnet Short Net, Coastspan Gillnet Long Net
- For All Ages: NEFSC Bottom Longline, Shark Bottom Longline Observer, Virginia Institute of Marine Science, SEAMAP Longline, SCDNR Red Drum Longline
- .Investigate alternate methods in future assessments for standardizing indices of abundances outside the Delta-Lognormal method (Lo et al. 1992).
- Explore the utility of standardized age-0 indices as recruitment indices in the stock assessment model.

1.4 Ecological Research Recommendations

- Quantify seasonal and spatial distribution of prey for Atlantic blacktip sharks, and use stomach contents analysis to determine the relative importance of different forage fish species in the diet. This is important in the New York Bight area where blacktip sharks were not previously abundant and are now exploiting resources that have not been previously subjected to this level of exploitation. It might also be important in the southern end of their range because, although anglers state that blacktip sharks are following baitfish down the coast, the peak in baitfish abundance occurs a few months before the blacktip sharks arrive off south Florida.
- Model the effects of changing stock distribution, due to ecological factors, on the results of fixed-station, fisheries-independent surveys for stock assessment. In general such surveys assume that changes in relative abundance are a result of changing stock size, rather than shifts in range and distribution as a result of ecological change. Modeling how ecological factors affect stock distribution allows for better quantification of stock abundance as measured by fixed-station surveys.
- Conduct research on ecological changes in blacktip shark inshore nursery areas on the U.S. Atlantic coast and how those changes have affected recruitment.
- Assess the levels of environmental contaminants in blacktip sharks and how those affect the sharks' physiology and reproductive success.
- Study the response of blacktip sharks to harmful algal blooms and how those phenomena affect the status of the Atlantic stock of these sharks.

2. Assessment Process

Additional research may be needed on the variable effects of Federal and state recreational management actions on the annual length composition of Atlantic blacktip shark recreational catch (A + B1 + B2-Dead). During Assessment Webinars I and III, it was discussed that data limitations resulting from recreational length sampling might not accurately reflect the effect of Federal management actions on length composition of retained and discarded Atlantic blacktip sharks over time. Federal management actions include implementation of a minimum size limit (54 inches straight fork length) in Federal waters during calendar years 2000 – 2018 and the implementation of Federal bag limits of 4 LCS (Large Coastal Sharks; 1993), 2 LCS (1997) and 1 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.

The selectivity parameterization approach implemented here estimated selectivity parameters where possible and fixed (or reformulated) poorly estimated selectivity parameters where necessary. 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). This pragmatic approach was implemented here in order to remove sharks from the modeled population at the correct aggregate size sampled by each data set (**Figures 3.4 and 3.B.3**), while allowing relatively poorer fits to some poor quality annual length composition data sets (e.g., because of low sample size; **Figures 3.3 and 3.B.2**). An assumption was that poor quality annual length composition data sets were not necessarily representative of annual changes in the length composition sampled in that year (e.g., because of low sample size and observation error). In contrast, the aggregate length composition data obtained from the poor quality data were assumed to be representative of the length composition sampled in that data set (e.g., because of higher sample size and reduced observation error in aggregate). 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.

The observation of proportionally few large sharks in the sampled length composition data compared to that expected based on life history may result for reasons other than dome-shaped selectivity. 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 also 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. An attempt was made here to evaluate the effect of uncertainty in selectivity for fleets F1 and F2 and surveys S4 and S7 on the underlying population numbers at age predicted over time within the stock assessment model by implementing logistic selectivity for F1, F2, S4, and S7 within the logistic sensitivity analysis.

A growing number of model diagnostic methods are becoming available for use in integrated stock assessment models such as Stock Synthesis (e.g., Maunder and Piner 2015, 2017; Carvalho et al. 2017). Examples of implementing some of these diagnostic methods were provided as reference document (SEDAR65-RD13; Courtney et al. 2020). However, this set of diagnostics was not implemented within the current assessment due to time constraints. Additional research is also ongoing to improve the interpretation of model diagnostics in both model development and in model selection for use in providing management advice. For example, Maunder et al (2020) describe a risk-based approach based on individual model diagnostic results that assigned different weights to models used for management advice within an ensemble of candidate models.

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 a SSASPM (Anon. 2012, 2013a, 2013b).

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. Consequently, an attempt was made here to evaluate model sensitivity to the combined effect of these interactions by estimating the CV in L_{Amin} within the logistic model sensitivity analysis described above.

3. Review Workshop

1. TOR 6 Consider the research recommendations provided by the Data Workshop and Assessment Process and make any additional recommendations or prioritizations warranted.

a. Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.

The assessment team did explore the different ways of combining indices, as recommended from the data workshop. For age-0 the hierarchical Bayesian and dynamic factor analysis produced similar indices, so the latter was used. The inclusion in the assessment resulted in poor fit, non-convergence, or convergence to unreasonable parameter values. A subset of indices was used in a sensitivity analysis. The review panel shares the assessment panel’s conclusion that this could further be explored if more time was available.

The review panel supports the assessment panel's own research recommendations, which include: a) Investigating ways to set up reproductive timing in Stock Synthesis (different versions) and to investigate sensitivities to different choices. This appears to be an important, but largely a technical issue. b) Studying the effect of recreational management actions on the length compositions. c) Investigating different ways to parametrize selectivity. In addition to the suggestions by the assessment panel, which are simpler functions and more informed priors, a suggestion could be to look into formulations based on random effects (state-space models). This allows flexible models for selectivity with few model parameters by setting up processes (e.g. for F at a given length), then the only model parameters to be estimated are only the level and standard deviation of the processes. A model based on this principle (Nielsen and Berg 2014) is routinely used in many ICES assessments and another such model has recently been developed at the Northeast Fisheries Science Center (https://github.com/timjmiller/wham). d) Investigating the proportionally few large sharks observed compared to the number of large sharks estimated to be in the population. This apparent dome-shaped selectivity can be caused by a number of different things including spatial distribution. It would be useful to report this "cryptic biomass" to monitor if it is e.g. increasing over time. Further this also relates to flexible modelling of the selectivity (see c above). e) Improved model diagnostics. This and future assessments would benefit, and be simpler to evaluate, if a standard set of model diagnostics were developed and provided. These could include: residuals (already provided, but should be decorrelated), retrospective analysis, leave-out analysis, jitter-analysis, and simulation validation.

In addition the review panel have suggested a number of research recommendations under TOR 8.

b. Provide recommendations on possible ways to improve the SEDAR process.

The SEDAR process for this meeting was well organized. The meeting was efficient. The assessment panel was able to quickly answer questions and produce new runs and requested diagnostics. So within the constraints imposed by covid this meeting was close to optimal. The support staff was excellent and very helpful.

The presentation team can help the review team by preparing focused presentations, as they are easier to follow (larger fonts, more figures, and less text) than on screen browsing of assessment reports.

Having an assessment review online is not a good substitute for an actual review meeting. The discussion is slower, and hence fewer issues are raised. Also you cannot easily stand up and make an illustrative drawing where needed. Furthermore, the sharing of knowledge, which for other review meetings has been substantial (e.g. sharing tips and tricks of modelling, or introduction to new tools or software) does not happen if all breaks are in isolation. Having informal discussions in person is much better for networking between assessment panel and reviewers, and overall makes the meetings more pleasant and productive.

It might be useful for the chairs of the data workshop working groups to attend parts of the review panel to answer specific questions.

2. TOR 8 Provide suggestions on key improvements in data or modeling approaches that should be considered when scheduling the next assessment.

In addition to the recommendations from the data and assessment panels discussed above, and the recommendations in section 6, the following improvements are recommended for the next assessment.

Recommendations for research activities:

- Species and fleet specific conversions between dressed weight and whole weight should be considered.
- A multi-species analysis of catch rates in the recreational fishery might be useful to extract an abundance index that is not biased by the issues with identification of sharks that are released alive.
- Longevity is poorly estimated and is one basis for estimates of M. Better estimates of longevity, and an independent estimate of natural mortality, for example from a tagging study, would be useful.
- The data workshop discussed whether blacktip sharks may be migrating northward. This migration could be modeled in a spatially explicit assessment. Spatially explicit models might also be useful for explaining differences in trends in indices from different locations.
- The apparent dome shaped selectivity in several gears implies that there are sharks in the population that are older than the oldest individual observed. Whether this is realistic could be validated with fishery independent research.

Recommendations for improvements to data for the assessment:

- The lack of data on catches and size distribution of catches during the peak of the fishery in the 1980s remains a key uncertainty in this assessment. Future work to improve catch reconstruction or evaluate model sensitivity to the catch reconstruction is recommended.
- There is a need to better characterize the length composition, particularly in recreational fisheries, which may be influenced by both state and federal regulations.

Recommendations to the assessment methods:

- Model runs that do not fix parameters should be explored to more accurately characterize the uncertainty in parameter estimates. For example, if there is not enough data to estimate a selectivity parameter for two time blocks, rather than estimating it in one time block and applying the estimated value as a fixed parameter in the other, the data from both time blocks can be pooled to estimate the parameter.
- Bootstrapping the data could be used to quantify the uncertainty contained in the data. Current estimates of uncertainty are conditional on the full dataset and the modeling assumptions.
- Projections should be done using MCMC or profile likelihood methods to evaluate whether the normal approximation was adequate. [assessment]
- Further research is needed on inconsistency of indices including the hierarchical models considered in this analysis.
- Improved model diagnostics are needed, as recommended in the assessment panel report and as described under TOR 6a.
- Explore whether some other functional form of the stock recruit relationship would be more appropriate for this species, such as the low fecundity model that was used in the low productivity sensitivity. Explore using reference points that don't depend on MSY such as SPR-based reference points.
- Investigate the timing and duration of the recruitment period, the duration of age 0 natural mortality, and the possibility of age 0 catches occurring during the recruitment period.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 65

Atlantic Blacktip Shark

SECTION V: Review Workshop Report

December 2020

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

1. Introduction

1.1. Workshop Time and Place

The Review Workshop for SEDAR-65 Atlantic Blacktip Shark stock assessment was held via webinar October 29-30, 2020 from 12 pm – 5 pm EDT and November 2, 4, and 5 2020 from 12 pm – 5 pm EST.

1.2. Terms of Reference

1. 1. Evaluate the data used in the assessment, including discussion of the strengths and weaknesses of data sources and decisions, and consider the following:
   a. Are data decisions made by the DW and AP sound and robust?
   b. Are data uncertainties acknowledged, reported, and within normal or expected levels?
   c. Are data applied properly within the assessment model?
   d. Are input data series reliable and sufficient to support the assessment approach and findings?
2. Evaluate and discuss the strengths and weaknesses of the method(s) used to assess the stock, taking into account the available data, and considering the following:
   a. Are methods scientifically sound and robust?
   b. Are assessment models configured properly and consistent with standard practices?
   c. Are the methods appropriate for the available data?
3. Evaluate the 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. Is the stock overfished? What information helps you reach this conclusion?
   c. Is the stock undergoing overfishing? What information helps you reach this conclusion?
   d. Is there an informative stock recruitment relationship? Is the stock recruitment curve reliable and useful for evaluation of productivity and future stock conditions?
   e. Are the quantitative estimates of the status determination criteria for this stock reliable? If not, are there other indicators that may be used to inform managers about stock trends and conditions?
4. Evaluate the stock projections, 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 results informative and robust, and useful to support inferences of probable future conditions?
   d. Are key uncertainties acknowledged, discussed, and reflected in the projection results?
5. 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.

6. Consider the research recommendations provided by the Data Workshop and Assessment Process and make any additional recommendations or prioritizations warranted.
   a. Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.
   b. Provide recommendations on possible ways to improve the SEDAR process.
7. Consider whether the stock assessment constitutes the best scientific information available using the following criteria as appropriate: relevance, inclusiveness, objectivity, transparency, timeliness, verification, validation, and peer review of fishery management information.
8. Provide suggestions on key improvements in data or modeling approaches that should be considered when scheduling the next assessment.
9. Prepare a Peer Review Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference.

1.3. List of Participants

Review Panelist		
Beth Babcock	Chair	University of Miami: RSMAS
Anders Nielsen	CIE	DTU-Aqua Technical University of Denmark
John Neilson	CIE	Independent fisheries Scientist
Joe Powers	CIE	Joseph Powers Consulting
Analytical Representatives		
Dean Courtney	Lead Assessment Representative	NMFS: HMS
Xinsheng Zhang	Assessment Representative	NMFS: HMS
Enric Cortes	Assessment representative	NMFS:HMS
Council and Agency Staff		
Kathleen Howington	Coordinator	SEDAR
Karyl Brewster-Geiz	HMS Management	NMFS: HMS
Clifford Hutt	HMS Staff	NMFS: HMS
Heather Baertlein	HMS Staff	NMFS: HMS
Review Workshop Attendees		
Catherine Puma	Observer	University of Miami
Chip Collier	Observer	SAFMC
John Carlson	Observer	NMFS
Julie Neer	Observer	SEDAR
Manoj Shivani	Observer	NTVI Federal
Rusty Hudson	Observer	DSF

1.4. List of Review Workshop Working Papers & Documents

Documents Prepared for SEDAR 65 Review Workshop			
SEDAR65-RW01	Updated Commercial Gillnet Length Composition Data for use in SEDAR 65	Dean Courtney, Alyssa Mathers, and Andrea Kroetz	9/18/2020
SEDAR65 RW02	Projections Conducted for the Atlantic Blacktip Shark Stock Synthesis Base Model Configuration at Alternative Fixed Total Allowable Catch (TAC) Limits	Dean Courtney	10/5/2020
Reference Documents			
SEDAR65-RD15	Marine Recreational Information Program Transition to Improved Survey Designs	John Foster and Kelly Denit	10/22/2020
SEDAR65-RD16	APAIS At-a-Glance	NOAA Fisheries, Marine Recreational Information Program	10/22/2020
SEDAR65-RD17	Field Procedures Manual: Access-Point Angler Intercept Survey	Atlantic Coastal Cooperative Statistics Program	10/22/2020
SEDAR65-RD18	National Marine Fisheries Service's Marine Recreational Information Program Survey Design and Statistical Methods for Estimation of Recreational Fisheries Catch and Effort	Katherine J. Papacostas and John Foster	10/22/2020
SEDAR65-RD19	Review of the Marine Recreational Information Program. .	The National Academies of Sciences, Engineering, and Medicine	10/22/2020
SEDAR65-RD20	Age-specific natural mortality rates in stock assessments: size-based vs. density-dependent	Joseph E. Powers	10/30/2020
SEDAR65-RD21	Modelling the effects of density-dependent mortality in juvenile red snapper caught as bycatch in Gulf of Mexico shrimp fisheries: Implications for management	Robyn E. Forrest, Murdoch K McAllister, Steven J.D. Martell, Carl J. Walters	10/30/2020

2. Review Panel Report

2.1. Executive Summary

The SEDAR 65 Review Panel for Atlantic blacktip shark met online between October 29 and November 5, 2020. The panel reviewed the data used in the assessment, the assessment methodology, and the results for the base model and sensitivity analyses, including diagnostics. In addition, the panel requested additional diagnostics and sensitivities.

The data available for this assessment are relatively complete for a shark population, including multiple fishery-independent indices of abundance, and at least some length frequency data from several components of the fishery. Available information on the reproductive biology of the species can inform steepness. On the other hand, the catch data are highly uncertain because there was little data collection in the 1980s when commercial catches were higher, and because recent total mortality is dominated by the recreational fishery which is largely catch and release. Thus, the total mortality is strongly dependent on the estimated number of live releases and their assumed release mortality.

The assessment and projections were done using Stock Synthesis, following usual practices for developing statistical catch at age models. This was the first Stock Synthesis application to Atlantic blacktip shark, which was last assessed in 2006 using age structured production and surplus production models. The analysts presented sensitivity analyses that addressed uncertainty about total catch (including discards), selectivity, stock productivity, and indices to include. The panel acknowledges that considerable work was needed to produce the input data and specify the model for a species that had not been assessed before with Stock Synthesis. Both the data workshop report and the assessment panel report were very clear and detailed and provided good justification for all decisions.

The jitter analysis conducted at the request of the panel showed that the base model mostly converged to the same solution for multiple starting values, which provided confidence that the model had converged adequately.

The panel discussed how to interpret the stock recruitment relationship when both the spawning stock fecundity and recruitment are in the units of age 0 pups. Also, there are no data about recruitment at low stock sizes, so that steepness had to be inferred from biological data. The panel requested a sensitivity that estimated steepness, which found, as expected, that the estimated trends were similar to the base model but the perception of MSY-based reference points was different. Since the steepness value assumed in the assessment is well supported by the biological data, the base model is considered appropriate.

The panel also discussed how the model estimated uncertainty. Since some parameters were fixed in the model set up, estimates of uncertainty used in the projections may underestimate true uncertainty. Also, the use of a normal approximation to estimate probabilities in the projections may be biased if the distributions of stock status metrics are not symmetrical. However, the treatment of uncertainty is consistent with established practice for Stock Synthesis and the sensitivity analyses show that the evaluation of status is robust to a range of uncertainties. The panel recommends further consideration of uncertainty for the next assessment.

The panel requested a sensitivity analysis starting in 1990 to evaluate the influence of the poorly estimated catches in the 1980s, which found generally similar trends in SSF/SSF_{MSY} in the assessed time period for most configurations, but much higher uncertainty, confirming that catches are a key uncertainty in this assessment.

In general, the panel concluded that the assessment was well done. Decisions about how to use data and how to set up the model were in accordance with best practices and well documented in the data and assessment reports. The conclusion is that the stock is not overfished (SSF_{2018} > MSST) and overfishing is not occurring ($F_{2018} < F_{MSY}$) and this result appears to be robust across the sensitivity analyses.

2.2. Statements addressing each TOR

1. Evaluate the data used in the assessment, including discussion of the strengths and weaknesses of data sources and decisions, and consider the following:

*a) **Are data decisions made by the DW and AW sound and robust?***

SEDAR 65 marks the first time that a Stock Synthesis model has been developed for Atlantic blacktip shark. As noted by the assessment team, Stock Synthesis offers a number of advantages compared with the assessment approach used in the last assessment (SEDAR 11, Age Structured Production Model and Bayesian surplus production models), including the ability to combine several sources of information into a single analysis allowing for consistency in assumptions and permitting the uncertainty associated with all data sources to be propagated to the final model output. However, this flexible assessment approach can have very significant input data requirements. In particular, the model developed by the assessment team required a comprehensive set of input data, given that the model is sex-disaggregated, has three commercial fleets, a recreational fleet and ten indices of abundance. The available length-frequency data to support the model appears to be quite limited. The problem is exacerbated during the early years of the time series.

Data decisions made by the Data and Assessment workshops are well documented in the working papers that were made available by the assessment team. It was clear that influential data decisions were carefully considered by team members. An example of this diligence was illustrated on P. 28 of the Data Workshop, where the assessment team tracked down the root of an anomalously high recreational fishery CPUE in 2009. This gives confidence to the credibility and robustness of the conclusions of the assessment team.

There appears to be a better foundation of data to build the assessment compared with SEDAR 11. A long time has passed since the last assessment and along with 14 years of catch data, there is new information available concerning life history, stock definition, and productivity. There also has been important work on post-release mortality. The indices of abundance considered in the SEDAR 11 assessment showed contradictory trends which limited confidence in the assessment, but in the current model the contradictory trends are much less apparent.

Overall, the data decisions appear to be sound and robust and based on the best available information. However, the panel expressed some concern over the assumptions made to reconstruct the commercial fishery catches between 1981 and 1990, and noted that the reconstructions relied, to a large extent, on expert opinion rather than official data. Another significant data decision involved the use of the 1.39 conversion factor for conversion to whole weight from dressed weight. It was noted that other agencies use a conversion factor of 2.0 for large coastal sharks. However, the sensitivity analysis that explores the high catch scenario uses the latter conversion factor.

The assessment team evaluated the potential impact of assumptions made to reconstruct the commercial fishery. While noting that the analysis was somewhat problematic as the start of the truncated catch series was after exploitation had already occurred for many years, the assessment showed generally similar trends in SSF as did the base model.

*b) **Are data uncertainties acknowledged, reported, and within normal or expected levels?***

Yes, data uncertainties are within normal or expected levels, generally speaking. However, the growing number of released blacktip sharks in the recreational fishery in recent years comprise an increasing concern, as there is uncertainty regarding both the species identification and size of the released individuals. Given the dominance of the recreational fishery in the recent overall catch, this is an important and growing issue.

The Panel also noted in some cases, fixing parameter values and external smoothing can mask uncertainty that is inherent in the data, and this can result in some loss of credibility and confidence in the uncertainty estimates in the model results.

c) Are data applied properly within the assessment model?

Generally speaking, the data are appropriately implemented in the SS model. For the indices of abundance, they were usually standardized using generalized linear models in a two step delta lognormal approach. As mentioned in b) above, the Panel expressed concern that fixing some initial parameter values rather than allowing their estimation results in some loss of confidence in uncertainty estimates from the model.

d) Are input data series reliable and sufficient to support the assessment approach and findings?

The assessment team characterized this stock as being relatively data rich compared with other shark assessments, pointing to the available fishery independent indices, relatively complete life history information and gear-specific information concerning post release mortality. The review panel agrees with this characterization, and concludes that the available data are reliable and sufficient to support the assessment approach.

A caveat to the above is that commercial catch during the 1980s was a legacy dataset that had previously been reconstructed using expert opinion and other data sources in the absence of official statistics.

2. Evaluate and discuss the strengths and weaknesses of the method(s) used to assess the stock, taking into account the available data, and considering the following:

a) Are methods scientifically sound and robust?

Yes, the model is scientifically sound and robust. The model presented by the assessment panel for HMS Atlantic Blacktip Shark is the Stock Synthesis assessment model (SS3). Stock Synthesis is among the most applied stock assessment models in the US and in the world. It is part of the NOAA Fish and Fisheries Toolbox (Fish-Tools https://nmfs-fish-tools.github.io/). Stock Synthesis has been validated in numerous peer reviewed assessments (e.g SEDAR 54: HMS Sandbar Shark, SEDAR 39: Atlantic Smooth Dogfish, and SEDAR 44: Atlantic Red Drum), in peer reviewed scientific journal papers (e.g. Methot & Wetzel 2013, Punt & Maunder 2013, and Zhu et al. 2016), and in meetings dedicated to evaluate assessment models (e.g. World Conference on Stock Assessment Methods for Sustainable Fisheries, 2013, Boston; Workshop on Recent Advances in Stock Assessment Models Worldwide, 2010, Nantes; and many Center for the Advancement of Population Assessment Methodology (CAPAM http://www.capamresearch.org/) workshops).

Stock Synthesis is one of the most general and complex assessment models, which is an advantage because it is applicable in many different scenarios and is able to accommodate many different types of observations. The many possible ways to setup and configure Stock Synthesis also increases the difficulty and knowledge required to operate the model correctly. It is therefore important to thoroughly validate the model implementation (configuration and data entry). The model for blacktip shark was validated via standard (Pearson) residuals, which are not optimal for the multinomial distribution assumed for the length compositions and did show substantial patterns. It would have strengthened the confidence in the model implementation substantially if the main results and conclusions had been confirmed by comparing to an independent (simpler) model or if the main results had been compared to the previous model used for blacktip shark (ASPM). Such an analysis had been completed by the assessment team in a previous assessment of sandbar shark as a proof of concept and found that Stock Synthesis could be configured to be very similar to the ASPM.

b) Are assessment models configured properly and consistent with standard practices?

The model has been configured properly and consistently with standard practices. In fact, the configuration options are in some cases inspired by already peer reviewed assessments (SEDAR 39: Smooth Dogfish and ICCAT Shortfin Mako assessment: Courtney and Rice. 2020).

In broad strokes the configuration can be summarized by: a) Yearly catches in weight/numbers from 4 fleets are assumed known without error. b) Indices of abundance from 10 fleets are assumed log-normally distributed with externally estimated CV’s (Francis adjusted). c) Length compositions are assumed multinomially distributed with Francis or Harmonic mean adjusted effective sample sizes. d) Parametric selection curves are estimated if sufficiency length composition data are available, otherwise the selectivity is mirrored from an assumed similar fleet. e) The underlying population model is sex- and age-structured, with Beverton-Holt stock-recruitment (with penalized deviances), sex-specific Von Bertalanffy growth, and a common length-weight relationship.

The details of the configuration include parameters that are fixed, prior distributions on other parameters, assumed variances or effective sample sizes, and indices which are smoothed across years. Such things – while not uncommon in assessment models – does obstruct the models ability to correctly quantify the uncertainties.

c) Are the methods appropriate for the available data?

Yes, Stock Synthesis is capable of including data in its original format. The catches given in weight are included as weights, the recreational catches given in numbers are included as numbers, and the length compositions are included where available. One detail is that the length compositions are included as multinomial, which implicitly assume that compositions from a fleet within a year are negatively correlated, but the data most often show that such observations are positively correlated across neighboring length groups. This could affect the estimated uncertainties.

3. Evaluate the 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?

The stock assessment utilized the Stock Synthesis modeling platform which integrated survey data, CPUEs, size frequencies, growth and reproductive life history with the catch history of the stock. The final model was selected after extensive examination of the data, alternative model structures and sensitivity diagnostic tests. The final model selected integrated these data in a biologically and statistically appropriate manner such that the ensuing estimates were useful for status inferences. This was the information that allowed the conclusions made under 3.b and 3.c. below.

b. Is the stock overfished? What information helps you reach this conclusion?

The stock is not overfished. The definition of an overfished condition is when the Spawning Stock Fecundity (SSF) is less than the Minimum Sock Size Threshold (MSST) where MSST is (1-M)SSF_{MSY}. M is the mean natural mortality rate of 0.139 in the base run. Thus, MSST=0.861 SSF_{MSY} in the base run. The assessment estimates that the current SSF_{2018} is 1.344 SSF_{MSST}. Thus, the stock is not overfished. Sensitivity analyses also found that SSF was greater than MSST.

c. Is the stock undergoing overfishing? What information helps you reach this conclusion?

The stock is not undergoing overfishing. The definition of overfishing condition is when the fishing mortality rate (F) is greater than F_{MSY}. The assessment estimates that the current F_{2018}/F_{MSY} is 0.509 in the base case. Sensitivity analyses also found that F was less than F_{MSY}.

d. Is there an informative stock recruitment relationship? Is the stock recruitment curve reliable and useful for evaluation of productivity and future stock conditions?

The stock recruitment relationship that was chosen was a Beverton-Holt with the steepness parameter fixed at 0.4 and the scale parameter estimated internal to Stock Synthesis. The key parameter in any stock recruitment relationship is the steepness or equivalently the slope of the SR curve at the origin. Even though that parameter was fixed, it was based upon life history data (pupping rates, maturity, etc.). Thus, there was a basis for the specification that related to the biology of the species. The specification of steepness is equivalent to a specification of a Spawner Potential Ratio (SPR) at MSY. SPR_{MSY} specifications are used as a proxy for defining MSY conditions in many fish stocks.

The functional form chosen was the Beverton-Holt. Alternative forms might have been specified, But the key parameter for determining productivity is the steepness. Regardless of the functional form, steepness of 0.4 would be used and there is a biological basis for that value. Alternative functional forms, such as the low fecundity stock recruit relationship used in the low productivity sensitivity, would likely have changed the scale of the SSF, but the dynamics would be similar. Also, a sensitivity analysis that estimated steepness of 0.99 fit less well than the base case with fixed steepness of 0.4.Therefore, the SR relationship so determined is informative and of adequate reliability for evaluation of productivity and future stock conditions.

e. Are the quantitative estimates of the status determination criteria for this stock reliable? If not, are there other indicators that may be used to inform managers about stock trends and conditions?

Yes, they are reliable as discussed above. The status determination as required in the fisheries management plan (FMP) are estimated in this assessment, as well as estimates of variance. These will be the scientific basis for managers' decisions.

4. Evaluate the stock projections, including discussing strengths and weaknesses, and consider the following:

a. Are the methods consistent with accepted practices and available data?

The methods used in the projections were consistent with accepted practices and available data. The projections were done using the standard methods available within the Stock Synthesis modeling software. Due to a lack of time, instead of using MCMC to find the probabilities of exceeding reference points, the probabilities were calculated from the assumption that SSF/SSF_{MSY} and F/F_{MSY} were normally distributed around their MLE value with a standard deviation equal to the estimated standard error based on the likelihood. This approach has been used before for sandbar sharks (SEDAR 54: Anonymous 2017, 2018) and shortfin mako sharks (Courtney and Rice. 2020). For mako and sandbar sharks, the method was found to be consistent with MCMC but slightly more pessimistic about the TAC that would allow rebuilding.

b. Are the methods appropriate for the assessment model and outputs?

Yes. The projection methods are appropriate for the assessment model outputs. Projections were made for a range of constant catch scenarios for the following models: (1) Base Model, (2) Logistic Sensitivity, (3) Drop CPUE Sensitivity, (4) High Catch Sensitivity, (5) Low Catch Sensitivity, (6) Low Productivity Sensitivity, and (7) High Productivity Sensitivity. Future selectivity was assumed to be the same as the average in recent years, recruitment was generated from the stock recruit relationship. Projections were done through 2043, which is twice the mean generation time. Modeling choices seemed appropriate and were well documented for the projections.

c. Are the results informative and robust, and useful to support inferences of probable future conditions?

Yes. The results are informative in that they provide estimates of the probability $SSF>SSF_{MSY}$, SSF>MSST, and $F>F_{MSY}$ based on the normal approximation to the distribution of the ratios. This allows evaluation of whether the standard of 70% has been met. The sensitivity analyses imply that the findings are generally robust to uncertainty.

d. Are key uncertainties acknowledged, discussed, and reflected in the projection results?

Yes. Uncertainties are acknowledged through the sensitivity analysis. The sensitivities range from the most optimistic High Catch and Low Productivity cases, which imply that catches could more than double while still achieving management targets to the more pessimistic Drop CPUE sensitivity, which would require reduction in catches. Also, the MLE standard errors are perpetuated through the projections to approximate parameter uncertainty. The possibility that the normal approximation may underestimate the uncertainties that could be estimated by MCMC was adequately discussed. The possibility that fixing parameters in the model (e.g. steepness, some selectivity parameters) may underestimate uncertainty was also discussed.

5. 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.

As described in the assessment report, a two-stage data weighting was used in the base case configuration (see Section 3.3.1.7 of the assessment report). In the first stage, survey CPUE variability is computed. In the second stage, the length composition data are adjusted for effective sample size. The assessment team also investigated the sensitivity of the results to alternative groupings of the indices. Finally, the impacts of uncertainty in the input data on stock assessment results and projections were investigated using sensitivity analyses.

When assessment parameters were not fixed by the analysts, uncertainty in estimated and derived parameters was obtained from Stock Synthesis output as the asymptotic parameter standard deviations at the converged solution. Time series trajectories of the two stock status metrics

(SSF/SSF_{MSY}, F/F_{MSY}) are provided with approximate 95% asymptotic confidence intervals for the reconstructed population and the projections.

b. Ensure that the implications of uncertainty in technical conclusions are clearly stated.

The assessment report included seven sensitivity runs, investigating the impacts of uncertainty in selection patterns, catch and productivity. Of the seven runs, the two that varied selection patterns were considered by the assessment team to be the most complete.

The assessment team planned to provide estimates of credible intervals for reference points using MCMC techniques, but constraints associated with telework interfered with that plan, and only MLE results were available. However, the assessment team presented results for other shark species assessments (sandbar and shortfin mako) that indicated that MCMC and MLE results were comparable, but the MLE estimates were slightly more conservative for the two examples provided.

6. Consider the research recommendations provided by the Data Workshop and Assessment Process and make any additional recommendations or prioritizations warranted.

a. Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.

The assessment team did explore the different ways of combining indices, as recommended from the data workshop. For age-0 the hierarchical Bayesian and dynamic factor analysis produced similar indices, so the latter was used. The inclusion in the assessment resulted in poor fit, non-convergence, or convergence to unreasonable parameter values. A subset of indices was used in a sensitivity analysis. The review panel shares the assessment panel's conclusion that this could further be explored if more time was available.

The review panel supports the assessment panel's own research recommendations, which include: a) Investigating ways to set up reproductive timing in Stock Synthesis (different versions) and to investigate sensitivities to different choices. This appears to be an important, but largely a technical issue. b) Studying the effect of recreational management actions on the length compositions. c) Investigating different ways to parametrize selectivity. In addition to the suggestions by the assessment panel, which are simpler functions and more informed priors, a suggestion could be to look into formulations based on random effects (state-space models). This allows flexible models for selectivity with few model parameters by setting up processes (e.g. for F at a given length), then the only model parameters to be estimated are only the level and standard deviation of the processes. A model based on this principle (Nielsen and Berg 2014) is routinely used in many ICES assessments and another such model has recently been developed at the Northeast Fisheries Science Center (https://github.com/timjmiller/wham). d) Investigating the proportionally few large sharks observed compared to the number of large sharks estimated to be in the population. This apparent dome-shaped selectivity can be caused by a number of different things including spatial distribution. It would be useful to report this "cryptic biomass" to monitor if it is e.g. increasing over time. Further this also relates to flexible modelling of the selectivity (see c above). e) Improved model diagnostics. This and future assessments would benefit, and be simpler to evaluate, if a standard set of model diagnostics were developed and provided. These could include: residuals (already provided, but should be decorrelated), retrospective analysis, leave-out analysis, jitter-analysis, and simulation validation.

In addition the review panel have suggested a number of research recommendations under TOR 8.

b. Provide recommendations on possible ways to improve the SEDAR process.

The SEDAR process for this meeting was well organized. The meeting was efficient. The assessment panel was able to quickly answer questions and produce new runs and requested diagnostics. So within the constraints imposed by covid this meeting was close to optimal. The support staff was excellent and very helpful.

The presentation team can help the review team by preparing focused presentations, as they are easier to follow (larger fonts, more figures, and less text) than on screen browsing of assessment reports.

Having an assessment review online is not a good substitute for an actual review meeting. The discussion is slower, and hence fewer issues are raised. Also you cannot easily stand up and make an illustrative drawing where needed. Furthermore, the sharing of knowledge, which for other review meetings has been substantial (e.g. sharing tips and tricks of modelling, or introduction to new tools or software) does not happen if all breaks are in isolation. Having informal discussions in person is much better for networking between assessment panel and reviewers, and overall makes the meetings more pleasant and productive.

It might be useful for the chairs of the data workshop working groups to attend parts of the review panel to answer specific questions.

7. Consider whether the stock assessment constitutes the best scientific information available using the following criteria as appropriate: relevance, inclusiveness, objectivity, transparency, timeliness, verification, validation, and peer review of fishery management information.

The stock assessment constitutes the best scientific information available. The assessment has gone through several stages of peer review through the SEDAR 65 process, including reviews of data inputs, assessment model structure and application, and the interpretation of results in terms of status determinations. These reviews provided public participation for transparency and comment and were inclusive of a wide array of contributing scientists. These processes promoted objectivity and verification/validation. The assessment is relevant to the management needs of the FMP.

The timeliness is limited in that the last year of data is 2018 and the assessment/review process is lengthy. That is the tradeoff of having detailed reviews. The life history of Atlantic blacktip is such that large annual changes in biomass are not expected, nor are the catches Nevertheless, managers should keep that in mind when scheduling future assessments.

8. Provide suggestions on key improvements in data or modeling approaches that should be considered when scheduling the next assessment.

In addition to the recommendations from the data and assessment panels discussed above, and the recommendations in section 6, the following improvements are recommended for the next assessment.

Recommendations for research activities:

- Species and fleet specific conversions between dressed weight and whole weight should be considered.
- A multi-species analysis of catch rates in the recreational fishery might be useful to extract an abundance index that is not biased by the issues with identification of sharks that are released alive.
- Longevity is poorly estimated and is one basis for estimates of M. Better estimates of longevity, and an independent estimate of natural mortality, for example from a tagging study, would be useful.
- The data workshop discussed whether blacktip sharks may be migrating northward. This migration could be modeled in a spatially explicit assessment. Spatially explicit models might also be useful for explaining differences in trends in indices from different locations.
- The apparent dome shaped selectivity in several gears implies that there are sharks in the population that are older than the oldest individual observed. Whether this is realistic could be validated with fishery independent research.

Recommendations for improvements to data for the assessment:

- The lack of data on catches and size distribution of catches during the peak of the fishery in the 1980s remains a key uncertainty in this assessment. Future work to improve catch reconstruction or evaluate model sensitivity to the catch reconstruction is recommended.
- There is a need to better characterize the length composition, particularly in recreational fisheries, which may be influenced by both state and federal regulations.

Recommendations to the assessment methods:

- Model runs that do not fix parameters should be explored to more accurately characterize the uncertainty in parameter estimates. For example, if there is not enough data to estimate a selectivity parameter for two time blocks, rather than estimating it in one time block and applying the estimated value as a fixed parameter in the other, the data from both time blocks can be pooled to estimate the parameter.
- Bootstrapping the data could be used to quantify the uncertainty contained in the data. Current estimates of uncertainty are conditional on the full dataset and the modeling assumptions.
- Projections should be done using MCMC or profile likelihood methods to evaluate whether the normal approximation was adequate. [assessment]
- Further research is needed on inconsistency of indices including the hierarchical models considered in this analysis.
- Improved model diagnostics are needed, as recommended in the assessment panel report and as described under TOR 6a.
- Explore whether some other functional form of the stock recruit relationship would be more appropriate for this species, such as the low fecundity model that was used in the low productivity sensitivity. Explore using reference points that don't depend on MSY such as SPR-based reference points.
- Investigate the timing and duration of the recruitment period, the duration of age 0 natural mortality, and the possibility of age 0 catches occurring during the recruitment period.

9. Prepare a Peer Review Summary summarizing the Panel's evaluation of the stock assessment and addressing each Term of Reference.

This report addresses this TOR.

References for terms of reference section

Anonymous. 2017. HMS sandbar shark. SEDAR 54 stock assessment report. October 2017. SEDAR, 4055 Faber Place Drive, Suite 201 North Charleston, SC 29405. Available: https://sedarweb.org/docs/sar/S54_Final_SAR_with_exec_summary.pdf (Accessed September 2020).

Anonymous. 2018. HMS sandbar shark post-review updates. SEDAR 54. February 2018. SEDAR, 4055 Faber Place Drive, Suite 201 North Charleston, SC 29405. Available: http://sedarweb.org/docs/postsedar/Post_Review_Updates_SEDAR_2054_Final_22 Feb2018.pdf (Accessed September 2020).

Courtney, D. and J. Rice. 2020. Example of a Stock Synthesis projection approach at alternative fixed total allowable catch (TAC) limits implemented for three previously completed North Atlantic shortfin mako Stock Synthesis model runs. SCRS/2019/082. Collect. Vol. Sci. Pap. ICCAT, 76(10):78-114. Available: https://www.iccat.int/en/pubs_CVSP.html (Accessed September 2020).

Methot, Richard D. Jr., and Wetzel Chantell R. 2013, Stock synthesis: A biological and statistical framework for fish stock assessment and fishery management. Fisheries Research.

Nielsen, A. and Berg, C.W. 2014. Estimation of time-varying selectivity in stock assessments using state-space models. Fisheries Research 158, 96-101

Punt, André E., Maunder, Mark N. 2013. A review of integrated analysis in fisheries stock assessment. 2012. Fisheries Research.

Zhu, J., Maunder, M. N., Aires-da-Silva, A. M., Chen, Y. 2016. Estimation of growth within Stock Synthesis models: Management implications when using length-composition data. Fisheries Research

2.3. Summary results of analytical

The following analyses were requested and are discussed above with the specific terms of reference. They are also described in the addendum (Section 6 starting PDF page 361), in the sections indicated.

1. Conduct a jitter analysis for the Base Model (Section 1.3).

2. Check meaning of "CV weighting" for indices. Is the weight just the variance as calculated from the CV (Section 1.4)?

3. Check timing of age zero processes, including natural mortality, density dependence and growth (Section 1.5).

4. Run a sensitivity analysis with freely estimated steepness (Section 1.6).

5. Review the Low Fecundity Stock Recruit Relationship (Section 1.7).

6. Evaluate model sensitivity to initial catch reconstruction and varying start year (Section 1.8).

7. Evaluate model sensitivity to the 2018 survey catchability time block (Section 1.9).

8. Clarify which selectivity time block is used for each fleet in projections the years (Section 1.10).

9. Review the statistical distributions assumed for SSF/SSF_{MSY} and F/F_{MSY} in projections, including results from sandbar and shortfin mako shark assessments (Section 1.11).

2.4. Additional Comments

There are no additional comments from the review panel.

3. Submitted Comment – No Written Public Comment was Submitted

SEDAR

Southeast Data, Assessment, and Review

SEDAR 65

HMS Blacktip Shark

Section VI

Post-Review Workshop Addendum Report

November 2020

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

Table of Contents

1. **Summary**

Stock Synthesis projections and risk matrices were provided for the SEDAR 65 CIE Review at alternative fixed total allowable catch (TAC) limits under seven projection scenarios: 1) Base Model, 2) Logistic Sensitivity, 3) Drop CPUE Sensitivity, 4) High Catch Sensitivity, 5) Low Catch Sensitivity, 6) Low Productivity Sensitivity, and 7) High Productivity Sensitivity. Stock status determinations obtained from the projection scenarios were consistent. All projection scenarios predicted that the stock was not overfished in the final year of the assessment (SSF_{2018} > MSST) and that overfishing was not occurring in the final year of the assessment ($F_{2018} < F_{MSY}$). In contrast, risk matrix results diverged among the projection scenarios. Risk matrix results provided examples of the percentage of fixed annual removals (0 – 200% of average annual removals from 2014 – 2018 in increments of 10%) which resulted in a cumulative normal projection probability (Pr) ≥ 70% by 2043 (25 year projections) for $SSF_y > SSF_{MSY}$, $F_y < F_{MSY}$, and SSF_y > MSST, respectively:
1) Base Model (90% of average annual removals from 2014 – 2018),
2) Logistic Sensitivity (130% of average annual removals from 2014 – 2018),
3) Drop CPUE Sensitivity (60% of average annual removals from 2014 – 2018),
4) High Catch Sensitivity (≥ 200% of average annual removals from 2014 – 2018),
5) Low Catch Sensitivity (110% of average annual removals from 2014 – 2018),
6) Low Productivity Sensitivity (≥ 200%, of average annual removals from 2014 – 2018), and
7) High Productivity Sensitivity (140% of average annual removals from 2014 – 2018).

The Base Model configuration described in the SAR (their Section 3.3.1) was adapted for use in a jitter analysis for the SEDAR 65 CIE Review. Annual and summary benchmarks and reference points obtained from the Adapted Base Model (**Tables 6.6 – 6.8**) were consistent with those obtained previously from the Base Model configuration, as described in the SAR (their Tables 3.9 – 3.11). A total of 97 iterations of the jitter test for global convergence resulted in 67 model runs with the minimum total likelihood value equal to that of the Adapted Base Model (538.9 likelihood units), and 30 model runs with higher total likelihood values (539.4 to 1297.5 likelihood units). Given that all model runs implemented within the jitter test resulted in total likelihood values equal to or greater than the Adapted Base Model, the jitter test did not provide evidence to reject the hypothesis that the Adapted Base Model parameter optimization converged to the global solution.

The analytical team considers the Base Model described in the SAR (their Section 3.3.1) to be a preferable candidate for the base model for the reasons described below. During the SEDAR 65 RW, the SEDAR 65 Review Panel requested additional clarifications and analyses, which are also summarized below.

1.1. Introduction

The SEDAR 65 Review Workshop (RW) took place via webinar October 29 – November 5, 2020. During the RW, seven projection scenarios were presented and reviewed by the SEDAR 65 Review Panel: 1) Base Model, 2) Logistic Sensitivity, 3) Drop CPUE Sensitivity, 4) High Catch Sensitivity, 5) Low Catch Sensitivity, 6) Low Productivity Sensitivity, and 7) High Productivity Sensitivity. The projection scenarios were developed from sensitivity analyses to the Base Model configuration previously presented during the Assessment Process, but not included within the SAR, due to time constraints. The seven projection scenarios presented during the SEDAR 65 RW are summarized below.

During the SEDAR 65 RW, the SEDAR 65 Review Panel requested additional clarifications and analyses of the analytical team. Specific topics and requests are summarized below and the results are documented within the indicated report sections in parentheses:

1. Conduct a jitter analysis for the Base Model (Section 6.3).
2. Check meaning of “CV weighting” for indices. Is the weight just the variance as calculated from the CV (Section 6.4)?
3. Check timing of age zero processes, including natural mortality, density dependence and growth (Section 6.5).
4. Run a sensitivity analysis with freely estimated steepness (Section 6.6).
5. Review the Low Fecundity Stock Recruit Relationship (Section 6.7).
6. Evaluate model sensitivity to initial catch reconstruction (Section 6.8).
7. Evaluate model sensitivity to the 2018 survey catchability time block (Section 6.9).
8. Clarify which selectivity time block is used for each fleet in projections the years (Section 6.10).
9. Review the statistical distributions assumed for SSF/SSF_{MSY} and F/F_{MSY} in projections (Section 6.11).

1.2. Projections

Stock Synthesis projections and risk matrices were provided during the SEDAR 65 RW at alternative fixed total allowable catch (TAC) limits under seven projection scenarios: 1) Base Model, 2) Logistic Sensitivity, 3) Drop CPUE Sensitivity, 4) High Catch Sensitivity, 5) Low Catch Sensitivity, 6) Low Productivity Sensitivity, and 7) High Productivity Sensitivity. Projections were carried out using the forecast module internal to Stock Synthesis.

1.2.1. Projections Scenarios

The projection approach implemented was the same as that described in Courtney (2020). The projection approach used maximum likelihood estimation (MLE) to provide approximate annual projection probabilities based on a normal distribution assumption. The MLE projection approach generates approximate risk matrix probabilities more quickly than can be obtained with Markov Chain Monte Carlo (MCMC). Comparisons of MLE and MCMC projection results using the alternative fixed TAC limit approach are available from the SEDAR 54 domestic sandbar shark stock assessment update (Anon. 2017a, their Figure EX 3; Anon. 2018, their Figure A9) and from the recent ICCAT North Atlantic shortfin mako projections update provided in SEDAR 65 RD14 (Courtney and Rice 2020). MCMC projections are not available for this report because of time constraints resulting from the Covid-19 crisis including a lack of IT resources necessary to perform MCMC projections while on mandatory telework during the assessment.

Projections were implemented from 2019 to 2043. Generation time was assumed to be 12.5 years (Cortés 2020). Consequently, a time horizon of 25 years (2019 to 2043) was assumed to include two generations.

Projections were implemented with average commercial landings and with average recreational catches for the first three projection years (2019 – 2021). Average commercial landings by fleet (**Table 6.1**) were obtained from commercial landings of blacktip sharks in the U.S. Atlantic in metric tons whole weight (mt ww; SEDAR 65 Stock Assessment Report, SAR, their Table 2.2) during the most recent five years of data available in the assessment (2014 – 2018). Similarly, average recreational catches (**Table 6.2**) were obtained from annual smoothed recreational catch estimates in numbers (1000s, reported as a 3-year moving average in SEDAR 65 SAR, their Table 2.3) for blacktip sharks in the Atlantic during the most recent five years of data available in the assessment (2014 – 2018).

Projections were implemented at alternative fixed annual total allowable catch, TAC, limits for the remaining projection years (2022 – 2043). Twenty one alternative fixed TAC levels were evaluated ranging from 0 – 200% of the average annual commercial landings and recreational catches in increments of 10%. The selectivity of each fleet and the proportion of catch among fleets during the projection period was assumed to be constant and equal to the values obtained during the base years for catchability and selectivity as described in the SAR.

1.2.1.1. Base Model

The Base Model configuration is described in the SAR (their Section 3.3.1). Projection results for the Base Model configuration are provided in Courtney (2020) and are also summarized here.

1.2.1.2. Logistic Sensitivity

The Logistic Sensitivity is described in the SAR (their Appendix 3.B).

1.2.1.3. Drop CPUE Sensitivity

The Drop CPUE Sensitivity is described in the SAR (their Section 3.2.6).

1.2.1.4. High Catch Sensitivity

The High Catch Sensitivity is described in the SAR (their Sections 2.1.4 and 3.2.4, and their Tables 2.5 and 2.7).

1.2.1.5. Low Catch Sensitivity

The Low Catch Sensitivity is described in the SAR (their Sections 2.1.4 and 3.2.4, and their Tables 2.5 and 2.6).

1.2.1.6. Low Productivity Sensitivity

The Low Productivity Sensitivity was implemented using a stock recruit steepness value of $h = 0.32$ as described in the SAR (their Section 3.2.7 and Table 2.14). The Low Productivity Sensitivity also implemented the Low Fecundity Stock Recruit (LFSR; Taylor et al. 2013) relationship available in Stock Synthesis (Methot et al. 2020). The LFSR was implemented following the methods outlined in Kai and Carvalho (2017) with the Beta parameter fixed at 3 and the Sfrac parameter obtained analytically from a stock recruit steepness value of $h = 0.32$ (Kai and Carvalho 2017; their equations 3 and 4). This implementation of the LFSR is consistent with the LFSR implementation in the ICCAT 2017 North Atlantic shortfin mako (SMA) base model configuration (Anon. 2017b).

1.2.1.7. High Productivity Sensitivity

The High Productivity Sensitivity was implemented using a Beverton Holt stock recruit relationship with steepness $h = 0.52$ as described in the SAR (their Section 3.2.7 and Table 2.14). In addition, the upper 95% confidence interval of fecundity at age was used in the calculation of spawning stock fecundity (SSF).

1.2.2. Projections Results

Stock status determinations obtained from the projection scenarios were consistent (**Table 6.3)**. All projection scenarios predicted that the stock was not overfished in the final year of the assessment ($SSF_{2018} > MSST$) and that overfishing was not occurring in the final year of the assessment ($F_{2018} < F_{MSY}$).

In contrast, the risk matrix results diverged among the projection scenarios (**Table 6.4**). Risk matrix results provide examples of the percentage of fixed annual removals (0 – 200% of average annual removals from 2014 – 2018 in increments of 10%; **Tables 6.1 and 6.2**) which result in a cumulative normal projection probability (Pr) ≥ 0.70 by 2043 for $SSF_y > SSF_{MSY}$, $F_y < F_{MSY}$, and $SSF_y > MSST$, respectively.

1.2.2.1. Base Model

The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ indicates that a TAC of 100% of the average removals (2014 – 2018) results in a $\geq$ 70% probability of $SSF_y > SSF_{MSY}$ by 2043 (**Tables 6.4 and 6.A.1**). In comparison, the risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ indicates that a TAC of 90% of the average removals (2014 – 2018) results in ≥ 70% probability of $F_y < F_{MSY}$ by 2043 (**Tables 6.4 and 6.A.2**). The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ indicates that TACs of 130% of average removals (2014 – 2018) result in ≥ 70% probability of SSF_y > MSST by 2043 (**Tables 6.4 and 6.A.3**). In comparison, the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC are provided in **Figure 6.A.1**.

1.2.2.2. Logistic Sensitivity

The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ indicates that a TAC of 150% of the average removals (2014 – 2018) results in a $\geq$ 70% probability of $SSF_y > SSF_{MSY}$ by 2043 (**Tables 6.4 and 6.B.1**). In comparison, the risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ indicates that a TAC of 130% of the average removals (2014 – 2018) results in ≥ 70% probability of $F_y < F_{MSY}$ by 2043 (**Tables 6.4 and 6.B.2**). The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ indicates that TACs of 180% of average removals (2014 – 2018) results in ≥ 70% probability of SSF_y > MSST by 2043 (**Tables 6.4 and 6.B.3**). In comparison, the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC are provided in **Figure 6.B.1**.

1.2.2.3. Drop CPUE Sensitivity

The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ indicates that a TAC of 60% of the average removals (2014 – 2018) results in a $\geq$ 70% probability of $SSF_y > SSF_{MSY}$ by 2043 (**Tables 6.4 and 6.C.1**). In comparison, the risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ indicates that a TAC of 70% of the average removals (2014 – 2018) results in ≥ 70% probability of $F_y < F_{MSY}$ by 2043 (**Tables 6.4 and 6.C.2**). The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ indicates that TACs of 80% of average removals (2014 – 2018) results in ≥ 70% probability of SSF_y > MSST by 2043 (**Tables 6.4 and 6.C.3**). In comparison, the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC are provided in **Figure 6.C.1**.

1.2.2.4. High Catch Sensitivity

The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ indicates that a TAC of ≥ 200% of the average removals (2014 – 2018) results in a ≥ 70% probability of $SSF_y > SSF_{MSY}$ by 2043 (**Tables 6.4 and 6.D.1**). In comparison, the risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ indicates that a TAC of ≥ 200% of the average removals (2014 – 2018) results in ≥ 70% probability of $F_y < F_{MSY}$ by 2043 (**Tables 6.4 and 6.D.2**). The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ indicates that TACs of ≥ 200% of average removals (2014 – 2018) results in ≥ 70% probability of SSF_y > MSST by 2043 (**Tables 6.4 and 6.D.3**). In comparison, the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC are provided in **Figure 6.D.1**.

1.2.2.5. Low Catch Sensitivity

The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ indicates that a TAC of 170% of the average removals (2014 – 2018) results in a ≥ 70% probability of $SSF_y > SSF_{MSY}$ by 2043 (**Tables 6.4 and 6.E.1**). In comparison, the risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ indicates that a TAC of 110% of the average removals (2014 – 2018) results in ≥ 70% probability of $F_y < F_{MSY}$ by 2043 (**Tables 6.4 and 6.E.2**). The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ indicates that TACs of 190% of average removals (2014 – 2018) results in ≥ 70% probability of SSF_y > MSST by 2043 (**Tables 6.4 and 6.E.3**). In comparison, the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC are provided in **Figure 6.E.1**.

1.2.2.6. Low Productivity Sensitivity

The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ indicates that a TAC of ≥ 200% of the average removals (2014 – 2018) results in a ≥ 70% probability of $SSF_y > SSF_{MSY}$ by 2043 (**Tables 6.4 and 6.F.1**). In comparison, the risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ indicates that a TAC of ≥ 200% of the average removals (2014 – 2018) results in ≥ 70% probability of $F_y < F_{MSY}$ by 2043 (**Tables 6.4 and 6.F.2**). The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ indicates that TACs of ≥ 200% of average removals (2014 – 2018) results in ≥ 70% probability of SSF_y > MSST by 2043 (**Tables 6.4 and 6.F.3**). In comparison, the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC are provided in **Figure 6.F.1**.

1.2.2.7. High Productivity Sensitivity

The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ indicates that a TAC of 150% of the average removals (2014 – 2018) results in a ≥ 70% probability of $SSF_y > SSF_{MSY}$ by 2043 (**Tables 6.4 and 6.G.1**). In comparison, the risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ indicates that a TAC of 140% of the average removals (2014 – 2018) results in ≥ 70% probability of $F_y < F_{MSY}$ by 2043 (**Tables 6.4 and 6.G.2**). The risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ indicates that TACs of 170% of average removals (2014 – 2018) results in ≥ 70% probability of SSF_y > MSST by 2043 (**Tables 6.4 and 6.G.3**). In comparison, the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC are provided in **Figure 6.G.1**.

1.2.3. Projections Discussion

Projection scenario summary data differed slightly from that reported in the SAR (their Table 3.11) for both the Base Model and Logistic Sensitivity (**Table 6.3**), as a result of the additional parameters (25) estimated for the projection scenarios. The projection approach implemented here utilized estimated recruitment deviations in the projection period (stochastic recruitment) by treating the future projection period as part of the estimation period. Stochastic recruitment uncertainty in the projection period was implemented as an approximation of the recruitment uncertainty that would have been achieved by randomly sampling annual recruitment from a stock recruitment relationship with a statistical distribution (Maunder et al. 2006). Because there are no observation data in the projection period, the estimated recruitment deviations shrank to zero in the projection period, while the estimated variances of the recruitment deviations in the projection period were included within the projection uncertainty obtained from Stock Synthesis output for the annual ratios of SSF_y/SSF_{MSY} and F_y/F_{MSY} during the projection period.

Maximum likelihood estimation (MLE) of uncertainty during the projection period was obtained as the asymptotic normal standard errors reported in Stock Synthesis output for the annual ratios of SSF_y/SSF_{MSY} and F_y/F_{MSY} during the projection period. Cumulative probabilities (70%) of $SSF_y/ SSF_{MSY} > 1$ and $F_y/F_{MSY} < 1$ were calculated in R using the cumulative normal distribution.

Projections were implemented using the Stock Synthesis version 3.30.15.00 forecast module (Methot et al. 2020). Stock Synthesis projection results were summarized using the R language for statistical computing version 4.0.0 (R Core Team 2020), and the R library package ‘r4ss’ version 1.38.0 (Taylor et al. 2020).

1.3. Jitter Analysis

Jitter analysis of the Stock Synthesis Base Model configuration was provided during the SEDAR 65 RW. A 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) with a jitter fraction of 10%. The jitter feature was implemented in R (version 4.0.2; R Core Team 2020) using the function SS_RunJitter available in the r4ss package (version 1.40.1; Taylor et al. 2020).

1.3.1. Jitter Scenarios

1.3.1.1. Adapted Base Model

The Base Model configuration described in the SAR (their Section 3.3.1) was adapted for use in the jitter analysis for the SEDAR 65 CIE Review. First, a minor transcription error was identified in the length composition data input in the Base Model for S8 (COASTSPAN-BLL-All-ages; 2005 – 2018; SAR, their Table 3.2 and Figure 3.3). The data reported in the Base Model for S8 (SAR, their Table 3.2) are identical to those used here (**Table 6.5)**, but the model fit to the length composition data changed slightly after correction of the transcription error in the model (**Figure 6.1**). Second, the Stock Synthesis forecast module was turned off. As a result, the number of estimated parameters was reduced by removal of the forecast recruitment in the 2019. An unanticipated result was that the recruitment in 2018 was assumed to be equal to the stock recruitment relationship (**Figures 6.2 and 6.3**). Third, parameter bounds were adjusted for the jitter analysis as recommended in the Stock Synthesis manual (version 3.30.15; Methot et al. 2020). Parameter bounds were adjusted from [-25, 25] to [-10, 10] for catchability, ln(*q*), of S1 (Shark-BLL-Obs, 1997 – 2004, 1981 – 1996, 2005 – 2007) and S2 (Shark-BLL-Res, 2008 – 2017, 2018) as described in the SAR, their Tables 3.7 and 3.8. Parameter bounds were also adjusted from [-15, 15] to [0, 1] for Double Normal selectivity sex specific offset scale of F1 (Com-BLL-Kept), S3 (VIMS-BLL-Robust), S4 (NEFSC-BLL), S5 (SCDNR-SEAMAP-BLL), S6 (SCDNR-Red-Drum-BLL), S7 (SCDNR-DL), S8 (COASTSPAN-BLL-All-ages), S9 (COASTSPAN-GNL-All-ages), and S10 (COASTSPAN-GNS-Age-0) as described in the SAR, their Tables 3.5 and 3.7.

Annual and summary benchmarks and reference points obtained from the Adapted Base Model (**Tables 6.6 – 6.8**) were consistent with those obtained previously from the Base Model configuration, as described in the SAR (their Tables 3.9 – 3.11). Total biomass (*B*), spawning stock fecundity (SSF), recruits (*R*), and total fishing mortality ($F=Z-M$) obtained from the Adapted Base Model are provided in **Table 6.6**. Total annual fishing mortality ($F=Z-M$) relative to MSY (F/F_{MSY}), annual spawning stock fecundity relative to MSY ($\text{SSF}/\text{SSF}_{\text{MSY}}$), and annual SSF relative to MSST (SSF/MSST) obtained from the Adapted Base Model are provided in **Table 6.7**. A summary of benchmark and reference point results for the Adapted Base Model is provided in **Table 6.8**. 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_{2018}, and F_{2018}). Benchmarks are reported relative to equilibrium MSY reference points (SSF_{MSY}, and F_{MSY}) and to the Minimum Stock Size Threshold, 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 assessment model configuration. 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 in the SAR, their sections 3.3.1.13 and 3.4.5.

1.3.2. Jitter Analysis Results

A total of 97 iterations of the jitter test for global convergence resulted in 67 model runs with the minimum total likelihood value equal to that of the Adapted Base Model (538.9, likelihood units), and 30 model runs with higher total likelihood values (539.4 to 1297.5, likelihood units) (**Table 6.9 and Figures 6.4 and 6.5**). Given that all model runs implemented within the jitter test for global convergence resulted in total likelihood values equal to or greater than the Adapted Base Model (538.9, likelihood units), the jitter test did not provide evidence to reject the hypothesis that the Adapted Base Model parameter optimization converged to the global solution.

1.4. Variance Weighting for Indices

The "CV weighting" for indices was defined incorrectly within the SAR (their Section 3.2.5) as "inverse CV weighting." The standard error (SE) was used as the index weighting in this assessment (Methot et al. 2020). Indices were assumed to be log normally distributed with units of ln(index). The SE of ln(index) can be obtained from the CV (on the untransformed scale) as sqrt(ln(1+CV^2)) (Methot et al. 2020). However, for the purposes of this assessment, the SE of ln(index) was approximated by the CV (on the untransformed scale).

1.5. Timing of Age Zero Processes

The timing of age zero processes including natural mortality, density dependence, and fishing mortality were clarified during the SEDAR 65 RW, as follows.

- Recruitment timing set to month 7
    - Stock Synthesis starts the recruits at the beginning of the season (Jan 1).
    - Stock Synthesis gives them the same mortality rate throughout the season (year).
    - Stock Synthesis reports the number of recruits referenced to month 7.

- Stock Synthesis uses M and time elapsed from Jan 1 to July 1 to calculate the number of recruits on Jan 1 needed to get the specified recruitment on July 1.
- Since there is fishing mortality (*F*) on age-0 animals, this *F* is also applied beginning on Jan 1.

1.6. Model Sensitivity to Steepness

Base Model sensitivity to Beverton-Holt stock-recruitment steepness (*h*) was evaluated during the SEDAR 65 RW. The stock-recruit model "fit" to recruitment was evaluated for the Base Model configuration with steepness estimated at its upper bound (h = 0.99). The Base Model configuration described in the SAR (their Section 3.3.1) was adapted for use in the steepness sensitivity analyses by turning off the Stock Synthesis forecast module. Steepness was then estimated at its upper bound (h = 0.99; **Table 6.10**). The resulting "fit" of the expected stock-recruitment relationship (the horizontal solid line in **Figure 6.6** Lower panel) was compared to the estimated recruitment (the colored points in **Figure 6.6** Lower panel). In comparison, the stock-recruit model "fit" to recruitment is provided for Base Model configuration (**Figure 6.6** Upper panel).

Spawning stock size trajectories were also evaluated for the Base Model steepness sensitivity runs with steepness estimated at its upper bound (h = 0.99, as described above) and with steepness fixed at a range of values (h = 0.52, 0.6, 0.7, 0.8, 0.9, 0.99) (**Figure 6.7**). Steepness sensitivity runs with steepness fixed at h = 0.32 and h = 0.5 failed to converge. Spawning Stock Fecundity (SSF in millions; **Figure 6.7** Upper panel) was relatively larger at lower steepness values. In contrast, SSF/SSF_{MSY} (**Figure 6.7** Lower panel) was relatively smaller at lower steepness values. Sensitivity model runs with higher steepness values also resulted in steeper rates of decline and recovery than sensitivity model runs with lower steepness values. These results are consistent with the expectation that stocks with lower steepness values are less resilient to high fishing mortality and recover relatively more slowly than the stocks with higher steepness values. It was noted during the SEDAR 65 RW that the stock-recruit steepness parameter for the Base Model configuration was fixed at a value obtained analytically based on life history, h = 0.40, as described in the SAR (their Section 3.3.1.3).

1.7. Low Fecundity Stock Recruit Relationship

Base Model sensitivity to the Low Fecundity Stock Recruit Relationship, LFSR, was discussed during the SEDAR 65 RW. It was noted that the LFSR was implemented in projections for the Low Productivity sensitivity model run, as described above in Section 6.2.1.6. Comparative model results obtained with the LFSR are provided in **Table 6.3** and comparative plots are provided in **Figures 6.8 – 6.10**. Technical aspects of the LFSR implementation for this stock at the fixed steepness value of $h = 0.32$ may require further evaluation. In particular, the time series of SSF estimated with the LFSR at the fixed steepness value of $h = 0.32$ was highly uncertain (included zero). Consequently projection results from the LFSR implementation for this stock at the fixed steepness value of $h = 0.32$ should be interpreted cautiously.

1.8. Model Sensitivity to Initial Catch Reconstruction

Base Model sensitivity to initial catch reconstruction was evaluated during the SEDAR 65 RW by changing the start year of the model from 1981 to 1989. As described in SEDAR 65 Data Workshop Report (their Section 3.4.2, Commercial Catch Datasets and Decisions), a decision was made by the Data Workshop Panel to set commercial landings for 1981 and 1982 equal to zero, and then to assume a linear increase in landings during 1983-1985 from 0 in 1982 to the mean of commercial landings in 1986-1988, in order to represent the growing market for shark products during this time period. The 1986-1990 landings were a legacy data set from the 1996 Large Coastal Shark Stock Evaluation Workshop (SEDAR 11, NMFS 1996).

The Base Model configuration described in the SAR (their Section 3.3.1) was adapted for use in the Initial Catch Sensitivity model runs by changing the start year in the model from 1981 to 1989 (**Figure 6.11**). Commercial landings, recreational catch, and recreational length composition data prior to 1989 were removed. Time blocks in selectivity prior to 1989 were removed. The year 1989 was chosen for the start year because it preceded all abundance indices used in the Base Model. The forecast module was also turned off, as described above. An R1 Offset parameter was estimated, which adjusts the initial equilibrium recruitment by allowing estimation of an initial equilibrium fishing mortality rate for each fleet with an initial equilibrium catch. If it is assumed that equilibrium catch has had an effect on the equilibrium population size and age structure at the beginning of the assessment period, then implementing the R1 Offset can improve fit to early size composition data and reduce compensation for this effect in early recruitment deviations.

Three sensitivities to initial equilibrium catch were evaluated. Fleet names are defined within the SAR (e.g., their Table 3.1).

- Initial Catch Sensitivity 1 (Model Run 08 from SEDAR 65 RW).
    - Set initial equilibrium commercial landings F1, F2, F3 = zero.
    - Set initial equilibrium recreational catch F4 = average (1989-1993).
    - Estimate initial equilibrium *F* needed to remove initial catch for F4 (one parameter).
    - Do not include a prior on initial *F* estimation.
    - Set initial equilibrium catch standard error = $1.0*10^{-6}$.

- Initial Catch Sensitivity 2 (Model Run 09 from SEDAR 65 RW).
    - Set initial equilibrium commercial landings F1 and F2 = 10% of average (1989-1993).
    - Set initial equilibrium commercial landings F3 = zero .
    - Set initial equilibrium recreational catch F4 = average (1989-1993).
    - Estimate initial equilibrium *F* needed to remove initial landings for F1, F2, and initial catch for F4 (three parameters).
    - Include a normal prior on initial *F* estimation.
    - Set equilibrium catch standard error = 0.01.

- Initial Catch Sensitivity 3 (Model Run 10 from SEDAR 65 RW).
    - Set initial equilibrium commercial landings F1, F2, F3 = zero.
    - Set initial equilibrium recreational catch F4 = average (1989-1993).
    - Estimate initial equilibrium *F* needed to remove initial catch for F4.
    - Include a normal prior on initial *F* estimation.
    - Set equilibrium catch standard error = 0.01.

The model runs were sensitive to the assumed initial conditions in 1989. Initial Catch Sensitivity 1 resulted in poor parameter estimation (**Table 6.11**). Individual parameter estimates for ln(R0), the R1 Offset, and initial *F* had a very large gradient. Parameter estimates for ln(R0) and initial *F* were highly correlated > 0.95. Initial Catch Sensitivity 2 also resulted in poor parameter estimation (**Table 6.12**). Initial *F* for fleets F1 and F2 was estimated at a lower bound, and multiple parameter estimates were highly correlated > 0.95. Initial Catch Sensitivity 3 resulted in improved parameter estimation (**Table 6.13**). However, some selectivity parameters for the fit to recreational length composition were poorly estimated in the early time block, and the final model gradient (0.0037) was relatively large in comparison to the Base Model configuration with the forecast module turned off (< $1.0*10^{-5}$). Spawning Stock Fecundity, SSF, SSF/SSF_{MSY} obtained from Initial Catch Sensitivity 3 were similar to those obtained for the Base Model configuration, as described above (**Figure 6.12**).

The analytical team considers that the Base Model described in the SAR is a preferable candidate for the base model in comparison to the Initial Catch Sensitivity model runs summarized here. The Initial Catch Sensitivity model runs were sensitive to assumptions made about catch prior to 1989. Consequently, the analytical team prefers the approach adopted in the Base Model, which reconstructs historical catch based on the best available information, as described in the SAR and the SEDAR 65 Data Workshop Report.

1.9. Model Sensitivity to the 2018 Survey Catchability Time Block

Base Model sensitivity to the 2018 time block in survey catchability was evaluated during the SEDAR 65 RW. The Base Model configuration described in the SAR (their Section 3.3.1) was adapted for use in the sensitivity model by removing the time block from the fit to the Shark Bottom Longline Research Fishery (2008 – 2018) index of relative abundance (S2; Shark-BLL-Res; SAR their Table 3.1). The forecast module was also turned off, as described above. Model results after removal of the 2018 time block were similar to those with the time block included, indicating that the Base Model configuration was not highly sensitive to removing the 2018 time block in survey catchability for S2 (**Table 6.14**; **Figures 6.13 – 6.15**).

1.10. Projection Selectivity

The selectivity used for each fleet in projections was defined incorrectly in the SEDAR 65 Review Workshop document (Courtney 2020, RD02) as being equal to the values obtained during the final year of the assessment (2018). Selectivity time blocks were defined in the SAR, their Table 3.5. Selectivity used in the projections was the selectivity estimated during the "base years" for each fleet. The base selectivity years for F1 (Com-BLL-Kept) were 2008-2017. The base selectivity years for F2 (Com-GN-Kept) were 2007-2018. The base selectivity years for F4 (Recreational) were 2000-2018.

1.11. Projection Statistical Distributions for SSF/SSF_{MSY} and F/F_{MSY}

Comparisons of MLE and MCMC status and projection results using the alternative fixed TAC limit approach were presented during the Review Workshop for results previously obtained from the SEDAR 54 domestic sandbar shark stock assessment update (Anon. 2017a; Anon. 2018) and from the recent ICCAT North Atlantic shortfin mako projections update provided in SEDAR 65 RD14 (Courtney and Rice 2020).

In the SEDAR 54 domestic sandbar shark stock assessment update (Anon. 2017a; Anon. 2018), the MCMC projections indicated that the TAC (based on the MLE projections) that would allow stock rebuilding by 2070 with a 50% or 70% probability slightly exceeded SSF/SSF_{MSY} = 1 in the rebuilding year, which is due to the slight non-normality of the MCMC estimates of SSF/SSF_{MSY} and should be interpreted with caution. In this case, MLE projections would produce slightly more conservative results. In the recent ICCAT North Atlantic shortfin mako projections update provided in SEDAR 65 RD14 (Courtney and Rice 2020), the MLE probabilities of $F < F_{MSY}$ and SSF > SSF_{MSY} were slightly lower than those from MCMC for all fixed TAC levels, similar to the SEDAR 54 Sandbar.

1.12. Conclusions

The analytical team considers that the Base Model described in the SAR is a preferable candidate for the base model in comparison to the RW Adapted Base Model (Section 6.3.1.1). Annual and summary benchmarks and reference points obtained from the RW

Adapted Base Model (Section 6.3.1.1; **Tables 6.6 – 6.8**) were consistent with those obtained previously from the Base Model configuration, as described in the SAR (their Tables 3.9 – 3.11). Changes in Base Model results resulting from the RW Adapted Base Model correcting an error in the Base Model fit to length composition data for S8 (COASTSPAN-BLL-All-ages; 2005 – 2018; SAR, their Table 3.2 and Figure 3.3; **Table 6.5 and Figure 6.1**) were minor. However, the RW Adapted Base Model also reduced the number of estimated recruitment parameters by turning off the forecast module (**Table 6.8**; **Figures 6.2 and 6.3**). This change had the unintended consequence of turning off estimation of the recruitment deviation in 2018, which needs further investigation before it can be recommended for use in the base case model.

The sensitivity scenarios explored gave a consistent picture of stock status (i.e., not overfished and overfishing not occurring) providing evidence that model results were robust to assumptions on the magnitude of the catches, gear selectivity, stock productivity, and to a lesser extent, indices of abundance. However, the sensitivity runs were not explored as in depth as the base run and results from these runs should be considered with caution.

1.13. References

Anonymous. 2017a. HMS sandbar shark. SEDAR 54 stock assessment report. October 2017. SEDAR, 4055 Faber Place Drive, Suite 201 North Charleston, SC 29405. Available: https://sedarweb.org/docs/sar/S54_Final_SAR_with_exec_summary.pdf (Accessed September 2020).

Anonymous. 2017b. Report of the 2017 shortfin mako assessment meeting (Madrid, Spain 12–16 June 2017). SCRS/2017/007; Collect. Vol. Sci. Pap. ICCAT, 74(4): 1465-1561. Available: https://www.iccat.int/Documents/CVSP/CV074_2017/n_4/CV074041465.pdf (Accessed August 2020).

Anonymous. 2018. HMS sandbar shark post-review updates. SEDAR 54. February 2018. SEDAR, 4055 Faber Place Drive, Suite 201 North Charleston, SC 29405. Available:

http://sedarweb.org/docs/postsedar/Post_Review_Updates_SEDAR_2054_Final_22Feb2018.pdf (Accessed September 2020).

Courtney, D. 2020. Projections conducted for the Atlantic blacktip shark Stock Synthesis base model configuration at alternative fixed total allowable catch (TAC) limits. SEDAR65-RD02, October 2020. SEDAR, North Charleston, SC. 19 p. Available: http://sedarweb.org/sedar-65-rw02-projections-conducted-atlantic-blacktip-shark-stock-synthesis-base-model-configuration (Accessed November 2020).

Courtney, D., and J. Rice. 2020. Example of a Stock Synthesis projection approach at alternative fixed total allowable catch (TAC) limits implemented for three previously completed North Atlantic shortfin mako Stock Synthesis model runs. SCRS/2019/082. Collect. Vol. Sci. Pap. ICCAT, 76(10):78-114. Available: https://www.iccat.int/en/pubs_CVSP.html (Accessed September 2020).

Kai M., and F. Carvalho. 2017. Proposal of implementation of low-fecundity spawner-recruitment relationship for shortfin mako in the North Atlantic. SCRS/2017/132. Collect. Vol. Sci. Pap. ICCAT, 74(4): 1830-1835. Available: https://www.iccat.int/Documents/CVSP/CV074_2017/n_4/CV074041830.pdf (Accessed November 2020).

Methot Jr., R. D., and I. G. Taylor. 2011. Adjusting for bias due to variability of estimated recruitments in fishery assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68:1744–1760.

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.

Methot Jr., R. D., C. R. Wetzel, I. G. Taylor, and K. Doering. 2020. Stock Synthesis user manual version 3.30.15. U.S. Department of Commerce, NOAA Processed Report NMFS-NWFSC-PR-2020-05. Available: https://doi.org/10.25923/5wpn-qt71; and https://vlab.ncep.noaa.gov/web/stock-synthesis (Accessed August 2020).

NMFS. 1996. 1996 Report of the Shark Evaluation Workshop. National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC), Miami, FL. 80 p.

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. R version 4.0.2. Available: https://www.R-project.org (Accessed October 2020).

Taylor, I., and other contributors. 2020. r4ss: R Code for Stock Synthesis. R package version 1.40.1. Available: https://github.com/r4ss/r4ss (Accessed October 2020).

Taylor, I. G., V. Gertseva, R. D., Methot Jr., and M. N. Maunder. 2013. A stock–recruitment relationship based on pre-recruit survival, illustrated with application to spiny dogfish shark. Fisheries Research 142:15–21.

1.14. Tables

Table 6.1. Annual commercial landings of blacktip sharks in the U.S. Atlantic in metric tons whole weight (mt ww; 2014 – 2018; adapted from the SEDAR 65 SAR, their Table 2.2).

Year	F1 Bottom Longlines (mt ww)	F2 Gillnets (mt ww)	F3 Other Gears (mt ww)
2014	130.126	41.000	6.678
2015	121.858	22.712	0.333
2016	110.737	44.723	1.202
2017	110.825	26.754	1.105
2018	58.961	18.886	1.047
Average (2014 – 2018)	106.501	30.815	2.073

Table 6.2. Annual smoothed recreational catch estimates (1000s, reported as a 3-year moving average in SEDAR 65 SAR, their Table 2.3) of blacktip sharks in the Atlantic (2014 – 2018). Type A is the number of sharks killed or kept seen by the interviewer, type B1 is the number of sharks killed or kept reported to the interviewer by the angler, and type B2PRM is the number of sharks released alive reported by the fisher multiplied by a post-release mortality rate of 18.5%. Total is A + B1 + B2PRM.

	F4 Recreational catch (1000s)		
Year	**A + B1**	**B2PRM**	**Total**
2014	3.437	81.810	85.247
2015	4.701	68.243	72.944
2016	4.451	51.887	56.338
2017	2.849	34.367	37.216
2018	2.849	34.367	37.216
Average (2014 – 2018)			57.792

Table 6.3. Summary results from projections. Table definitions as in the SAR, their Table 3.11. 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_{2018}, and F_{2018}). Benchmarks are reported relative to equilibrium MSY reference points (SSF_{MSY}, and F_{MSY}) and to the Minimum Stock Size Threshold, 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 assessment model configuration as described in the SAR, their Tables 2.13 and 2.14. 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 in the SAR, their Sections 3.3.1.13 and 3.4.5.

	Base Model Configuration		Logistic Sensitivity		Drop CPUE Sensitivity		High Catch Sensitivity		Low Catch Sensitivity		Low Productivity Sensitivity		High Productivity Sensitivity	
	Projections		Projections		Projections		Projections		Projections		Projections		Projections	
Parameters	127[1]		115[1]		127		127		127		127		127	
Objective function	553.3		593.0		450.6		554.2		555.0		554.4		552.7	
Gradient	$5.49*10^{-5}$		$1.03*10^{-4}$		$4.06*10^{-6}$		$5.21*10^{-8}$		$1.01*10^{-4}$		$3.79*10^{-5}$		$5.15*10^{-6}$	
$\bar{M}_a$	0.139		0.239		0.139		0.139		0.139		0.139		0.139	
$\left(1-\bar{M}_a\right)$	0.861		0.761		0.861		0.861		0.861		0.861		0.861	
Steepness	0.4		0.4		0.4		0.4		0.4		0.4		0.4	
	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
SSF_{2018}	520	39%	341	39%	342	25%	1,211	45%	1,806	222%	2,249	89%	929	45%
F_{2018}	0.026	---	0.019	---	0.037	---	0.023	---	0.004	---	0.007	---	0.025	---
R_{2018}	314	33%	587	34%	238	23%	697	38%	797	204%	1,074	81%	337	36%
SSF_0	1,140	18%	637	19%	976	9%	2,379	23%	2,174	188%	2,730	73%	1,734	22%
R_0	427	18%	785	19%	366	9%	892	23%	815	188%	1,023	73%	407	22%
MSY	492[1]	21%[1]	749[1]	19%	434	10%	1,012	27%	1,156	195%	1,406	80%	773	27%
SSF_{MSY}	449	18%	245[1]	19%	384	9%	939	24%	857	188%	1,399	73%	617	22%
F_{MSY}	0.049[1]	8%[1]	0.050[1]	3%	0.048	7%	0.050	9%	0.038	14%	0.033	17%	0.075	9%
SSF_{2018}/SSF_{MSY}	1.158	22%	1.392[1]	21%	0.892	18%	1.289	23%	2.108	35%	1.607	17%	1.505	24%
F_{2018}/F_{MSY}	0.533[1]	36%	0.384[1]	34%	0.774	26%	0.452	41%	0.103	204%	0.202	78%	0.331	40%
MSST	387	---	187	---	331	---	809	---	738	---	1,205	---	532	---
SSF_{2018}/MSST	1.344	---	1.828[1]	---	1.036	---	1.497	---	2.448	---	1.866	---	1.748	---
Stock status	SSF_{2018} > MSST		SSF_{2018} > MSST		SSF_{2018} > MSST		SSF_{2018} > MSST		SSF_{2018} > MSST		SSF_{2018} > MSST		SSF_{2018} > MSST	
Fishery status	$F_{2018} < F_{MSY}$		$F_{2018} < F_{MSY}$		$F_{2018} < F_{MSY}$		$F_{2018} < F_{MSY}$		$F_{2018} < F_{MSY}$		$F_{2018} < F_{MSY}$		$F_{2018} < F_{MSY}$	

[1] Projection scenario parameter estimates differ slightly from those reported in the SAR (their Table 3.11) as a result of the 25 additional recruitment deviation parameters estimated in the projection period.

Table 6.4. Summary of risk matrix results as described in **Appendices 6.A – 6.G**. Risk matrix results provide examples of the percentage of fixed annual removals (0 – 200% of average annual removals from 2014 – 2018 in increments of 10%; **Tables 6.1 and 6.2**) which result in a cumulative normal projection probability (Pr) ≥ 0.70 by 2043 for $SSF_y > SSF_{MSY}$, $F_y < F_{MSY}$, and $SSF_y > MSST$, respectively.

		Pr ($SSF_y > SSF_{MSY}$) ≥ 0.70	Pr ($F_y < F_{MSY}$) ≥ 0.70	Pr ($SSF_y > MSST$) ≥ 0.70	
Projection scenario	Model configuration	Percentage of fixed annual removals	Percentage of fixed annual removals	Percentage of fixed annual removals	Source
1	Base Model	100%	90%	130%	(**Appendix 6.A**)
2	Logistic Sensitivity	150%	130%	180%	(**Appendix 6.B**)
3	Drop CPUE Sensitivity	60%	70%	80%	(**Appendix 6.C**)
4	High Catch Sensitivity	≥ 200%	≥ 200%	≥ 200%	(**Appendix 6.D**)
5	Low Catch Sensitivity	170%	110%	190%	(**Appendix 6.E**)
6	Low Productivity Sensitivity	≥ 200%	≥ 200%	≥ 200%	(**Appendix 6.F**)
7	High Productivity Sensitivity	150%	140%	170%	(**Appendix 6.G**)

Table 6.5. Length composition data described in the SAR for S8 (COASTSPAN-BLL-All-ages; 2005 – 2018; their Table 3.2) and used in both the Base Model and the Adapted Base Model.

	S8 (COASTSPAN-BLL-All-ages) 2005-2018 Min. 30	
Year	(♀)	(♂)
1996		
1997		
1998		
1999		
2000		
2001		
2002		
2003		
2004		
2005	36	29
2006	7	6
2007	3	1
2008	4	0
2009	1	9
2010	34	31
2011	19	17
2012	49	41
2013	19	13
2014	13	11
2015	13	10
2016	28	23
2017	28	29
2018	23	16
Total	277	236

Table 6.6. Adapted Base Model total biomass (*B*), spawning stock fecundity (SSF), recruits (*R*), and total fishing mortality (*F=Z-M*), obtained as described above.

	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		1145	429	
Init		1145	429	
1981	56579	1145	429	0.029
1982	55998	1140	428	0.030
1983	55305	1135	428	0.029
1984	54278	1126	354	0.044
1985	52704	1111	323	0.044
1986	50994	1092	383	0.044
1987	49341	1068	443	0.025
1988	48007	1045	367	0.027
1989	46884	1017	401	0.021
1990	45975	989	393	0.032
1991	45105	959	430	0.046
1992	43910	918	425	0.051
1993	42916	876	502	0.063
1994	41757	839	487	0.045
1995	41410	820	451	0.056
1996	40567	797	301	0.041
1997	39973	779	290	0.067
1998	38831	762	271	0.067
1999	37452	747	244	0.081
2000	35620	734	201	0.067
2001	34096	730	205	0.072
2002	32556	726	259	0.084
2003	30943	712	311	0.086
2004	29669	688	401	0.112
2005	28499	660	392	0.094
2006	27613	631	325	0.083
2007	27005	600	356	0.072
2008	26843	570	397	0.075
2009	26672	540	373	0.069
2010	26649	515	339	0.035
2011	27018	500	334	0.025
2012	27801	493	423	0.026
2013	28779	492	475	0.035
2014	29366	491	258	0.055
2015	29690	493	242	0.050
2016	29780	501	239	0.042
2017	29896	513	325	0.028
2018	30005	527	298	0.026

Table 6.7. Adapted Base Model 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 as described above.

Year	F/F_{MSY}	SE	SSF/SSF_{MSY}	SE	SSF/MSST
1981	0.60	0.112	2.54	NA	2.95
1982	0.61	0.117	2.53	0.017	2.93
1983	0.59	0.115	2.51	0.020	2.92
1984	0.90	0.182	2.50	0.023	2.90
1985	0.89	0.186	2.46	0.030	2.86
1986	0.89	0.192	2.42	0.038	2.81
1987	0.50	0.109	2.37	0.047	2.75
1988	0.54	0.119	2.32	0.053	2.69
1989	0.43	0.094	2.25	0.062	2.62
1990	0.64	0.144	2.19	0.070	2.54
1991	0.93	0.212	2.12	0.079	2.47
1992	1.03	0.242	2.03	0.092	2.36
1993	1.28	0.309	1.94	0.107	2.25
1994	0.92	0.230	1.86	0.123	2.16
1995	1.14	0.293	1.82	0.135	2.11
1996	0.83	0.218	1.77	0.147	2.05
1997	1.36	0.367	1.73	0.156	2.00
1998	1.37	0.382	1.69	0.166	1.96
1999	1.65	0.475	1.66	0.176	1.92
2000	1.37	0.408	1.63	0.188	1.89
2001	1.46	0.451	1.62	0.195	1.88
2002	1.70	0.532	1.61	0.203	1.87
2003	1.75	0.560	1.58	0.211	1.83
2004	2.27	0.728	1.52	0.216	1.77
2005	1.91	0.631	1.46	0.217	1.70
2006	1.69	0.572	1.40	0.217	1.62
2007	1.47	0.502	1.33	0.217	1.54
2008	1.52	0.528	1.26	0.214	1.47
2009	1.40	0.495	1.20	0.212	1.39
2010	0.71	0.256	1.14	0.212	1.33
2011	0.51	0.181	1.11	0.215	1.29
2012	0.53	0.187	1.09	0.220	1.27
2013	0.70	0.245	1.09	0.227	1.27
2014	1.12	0.397	1.09	0.232	1.26
2015	1.02	0.372	1.09	0.238	1.27
2016	0.86	0.318	1.11	0.245	1.29
2017	0.57	0.209	1.14	0.252	1.32
2018	0.53	0.195	1.17	0.259	1.36

Table 6.8. Summary results for the Adapted Base Model used in jitter analyses, obtained as described above. Table definitions as in the SAR, their Table 3.11 (e.g., see **Table 6.3**).

	Base Model Configuration [1]		Base Model + No Forecast		Base Model + No Forecast + Corrected Fit to Length Comp (S8)		Base Model + No Forecast + Corrected Fit to Length Comp (S8) + Parameter Bounds Adjusted	
							Adapted Base Model (Jitter)	
Parameters	102		101		101		101	
Objective function	553.3		554.2		538.9		538.9	
Gradient	$5.49*10^{-5}$		$4.74*10^{-6}$		$2.72*10^{-5}$		$2.44*10^{-4}$	
$\bar{M}_a$	0.139		0.139		0.139		0.139	
$(1-\bar{M}_a)$	0.861		0.861		0.861		0.861	
Steepness	0.4		0.4		0.4		0.4	
	Est	CV	Est	CV	Est	CV	Est	CV
SSF_{2018}	520	39%	525	39%	527	40%	527	40%
F_{2018}	0.026	---	0.026	---	0.026	---	0.026	---
R_{2018}	314	33%	297	30%	298	30%	298	30%
SSF_0	1,140	18%	1,143	18%	1,146	18%	1,145	18%
R_0	427	18%	428	18%	429	18%	429	18%
MSY	471	22%	493	21%	494	22%	494	21%
SSF_{MSY}	449	18%	451	18%	452	18%	451	18%
F_{MSY}	0.051	9%	0.049	8%	0.049	8%	0.049	8%
SSF_{2018}/SSF_{MSY}	1.158	22%	1.164	22%	1.168	22%	1.167	22%
F_{2018}/F_{MSY}	0.509	36%	0.536	36%	0.533	37%	0.534	37%
MSST	387	---	388	---	389	---	389	---
SSF_{2018}/MSST	1.344	---	1.351	---	1.356	---	1.355	---
Stock status	SSF_{2018} > MSST		SSF_{2018} > MSST		SSF_{2018} > MSST		SSF_{2018} > MSST	
Fishery status	$F_{2018} < F_{MSY}$		$F_{2018} < F_{MSY}$		$F_{2018} < F_{MSY}$		$F_{2018} < F_{MSY}$	

[1] Base Model reported in the SAR, their Table 3.11.

Table 6.9. Adapted Base Model jitter results for global convergence (97 iterations), obtained as described above.

	Likelihood	Frequency
1	538.9[1]	67
2	539.4	1
3	540.3	3
4	540.4	1
5	540.5	1
6	540.6	1
7	540.8	1
8	540.8	1
9	541.3	1
10	541.5	2
11	541.7	2
12	541.8	1
13	541.9	1
14	542.0	1
15	542.4	1
16	543.0	1
17	545.5	2
18	545.6	2
19	546.7	1
20	548.0	1
21	576.3	1
22	707.2	1
23	846.2	1
24	1263.6	1
25	1297.5	1
	Total	97

[1] *Min* *538.9*

Table 6.10. Sensitivity analysis to estimated steepness, obtained as described above. Stock-recruitment parameter definitions (Upper panel) and their estimates (Lower Panel) indicated that the steepness parameter (Value = 0.99) was estimated at its upper boundary condition (Max = 0.99).

```
3 #_Spawner-Recruitment; Options: 1=NA; 2=Ricker; 3=std_B-H; 4=SCAA; 5=Hockey; 6=B-H_flattop; 7=survival_3Parm; 8=Shepherd_3Parm; 9=RickerPower_3parm
0  # 0/1 to use steepness in initial equ recruitment calculation
0  #  future feature:  0/1 to make realized sigmaR a function of SR curvature
#_          LO          HI        INIT       PRIOR       PR_SD     PR_type       PHASE     env-var     use_dev    dev_mnyr    dev_mxyr      dev_PH       Block     Blk_Fxn #  parm_name
           2.3       13.82      5.4994        7.04        1000           6           1           0           0           0           0           5           0           0 # SR_LN(R0)
           0.2        0.99        0.99         0.4        1000           6           2           0           0           0           0           5           0           0 # SR_BH_steep
           0.2         1.9    0.283103        0.28        1000           6          -4           0           0           0           0           5           0           0 # SR_sigmaR
            -5           5           0           0           1           6          -4           0           0           0           0           5           0           0 # SR_regime
            -5           5           0           0           1           6          -4           0           0           0           0           5           0           0 # SR_autocorr
```

DiagnosticTables

	Value	Phase	Min	Max	Init	Status	Parm_StDev	Gradient	Pr_type	Prior	Pr_SD	Pr_Like	Afterbo
SR_LN(R0)	5.499400	1	2.3	13.82	5.395150	OK	0.0866949	1.13163e-05	Normal	7.04	1e+03	0.0000012	OK
SR_BH_steep	0.990000	2	0.2	0.99	0.400000	HI	0.0001138	-1.2298e-06	Normal	0.40	1e+03	0.0000002	CHECK

Table 6.11. Model sensitivity to initial catch reconstruction (Initial Catch Sensitivity 1), obtained as described above. Unfished equilibrium recruitment (ln(R0)), initial fishing mortality (InitF) for fleet F4 (Recreational), R1 Offset (SR_regime) and some selectivity parameters (Size_DblN) for fleet F4 were poorly estimated, e.g., resulting in very large parameter estimate gradients (>> $1.0*10^{-4}$) and highly correlated parameter estimates (abs(corr) > 0.95) for initial fishing mortality, Catchability (LnQ) for S2 (Shark-BLL-Res), and ln(R0).

```
$parameters_with_highest_gradients
                                                      Value Gradient
SR_LN(R0)                                        6.22130000 68.76740
InitF_seas_1_flt_4F4_Rec_A_B1_B2PRM              0.05791500 65.94630
SR_regime_BLK1repl_1988                         -0.00796181 64.51400
Size_DblN_end_logit_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1989 -2.49665000 11.96700
Size_DblN_descend_se_F4_Rec_A_B1_B2PRM(4)        4.09601000  6.29821


$cormessage2
[1] 3 correlations above threshold (cormax=0.95)

$cormessage3
                             label.i                             label.j      corr
    1 InitF_seas_1_flt_4F4_Rec_A_B1_B2PRM                       SR_LN(R0) -0.992734
    2        LnQ_base_S2_Shark_BLL_Res(6)                       SR_LN(R0) -0.989909
    3        LnQ_base_S2_Shark_BLL_Res(6) InitF_seas_1_flt_4F4_Rec_A_B1_B2PRM  0.984823
```

Table 6.12. Model sensitivity to initial catch reconstruction (Initial Catch Sensitivity 2), obtained as described above. Initial fishing mortality (InitF) for F1 (Com-BLL-Kept) and F2 (Com-GN-Kept) were poorly estimated, e.g., resulting in parameter estimates at their lower boundary conditions (Min = 0.00) and highly correlated parameter estimates (abs(corr) > 0.95) for F1, F2, and F4 (Recreational) initial fishing mortality, Catchability (LnQ) for S2 (Shark-BLL-Res), and ln(R0).

Home | Bio | Sel | Timeseries | RecDev | S-R | Catch | SPR | Index | Numbers | CompDat | LenComp | Yield | Data | Pars | DiagnosticTables

DiagnosticTables

	Value	Phase	Min	Max	Init	Status	Parm_StDev	Gradient	Pr_type
SR_LN(R0)	7.2308000	1	2.3	13.82	5.395150	OK	1.0821600	0.000472244	Normal
SR_regime_BLK1repl_1988	-0.0186226	4	-5.0	5.00	0.000000	OK	0.0383031	0.000384794	Normal
InitF_seas_1_flt_1F1_Com_BLL_Kept	0.0004050	1	0.0	1.90	0.100000	LO	0.0004767	0.00213474	Normal
InitF_seas_1_flt_2F2_Com_GN_Kept	0.0001529	1	0.0	1.90	0.100000	LO	0.0001793	0.00319784	Normal

```
$cormessage2
[1] 16 correlations above threshold (cormax=0.95)

$cormessage4
[1] Highest 10 parameter correlations above threshold (to print more, increase 'printhighcor' input):

$cormessage5
                               label.i                              label.j      corr
    1     InitF_seas_1_flt_2F2_Com_GN_Kept                            SR_LN(R0) -0.999242
    2  InitF_seas_1_flt_4F4_Rec_A_B1_B2PRM     InitF_seas_1_flt_2F2_Com_GN_Kept  0.998110
    3  InitF_seas_1_flt_4F4_Rec_A_B1_B2PRM                            SR_LN(R0) -0.997698
    4     InitF_seas_1_flt_2F2_Com_GN_Kept    InitF_seas_1_flt_1F1_Com_BLL_Kept  0.996098
    5    InitF_seas_1_flt_1F1_Com_BLL_Kept                            SR_LN(R0) -0.995614
    6          LnQ_base_S2_Shark_BLL_Res(6)                            SR_LN(R0) -0.994977
    7          LnQ_base_S2_Shark_BLL_Res(6)     InitF_seas_1_flt_2F2_Com_GN_Kept  0.994656
    8  InitF_seas_1_flt_4F4_Rec_A_B1_B2PRM    InitF_seas_1_flt_1F1_Com_BLL_Kept  0.994456
    9          LnQ_base_S2_Shark_BLL_Res(6)  InitF_seas_1_flt_4F4_Rec_A_B1_B2PRM  0.993076
    10         LnQ_base_S2_Shark_BLL_Res(6)    InitF_seas_1_flt_1F1_Com_BLL_Kept  0.992480
```

Table 6.13. Model sensitivity to initial catch reconstruction (Initial Catch Sensitivity 3), obtained as described above. Unfished equilibrium recruitment (ln(R0)), initial fishing mortality (InitF) for fleet F4 (Recreational), and R1 Offset (SR_regime) were poorly estimated, e.g., resulting in relatively large parameter estimate gradients (> $1.0*10^{-4}$). Some selectivity parameters (Size_DblN) for fleet F4 were poorly estimated, e.g., resulting in highly correlated parameter estimates (abs(corr) > 0.95).

DiagnosticTables

	Value	Phase	Min	Max	Init	Status	Parm_StDev	Gradient	Pr_type
SR_LN(R0)	6.1124500	1	2.3	13.82	5.395150	OK	0.1976840	-0.00355494	Normal
SR_regime_BLK1repl_1988	-0.0098875	4	-5.0	5.00	0.000000	OK	0.0383940	-0.00325995	Normal
InitF_seas_1_flt_4F4_Rec_A_B1_B2PRM	0.0667340	1	0.0	1.90	0.100000	OK	0.0154832	-0.00309419	Normal

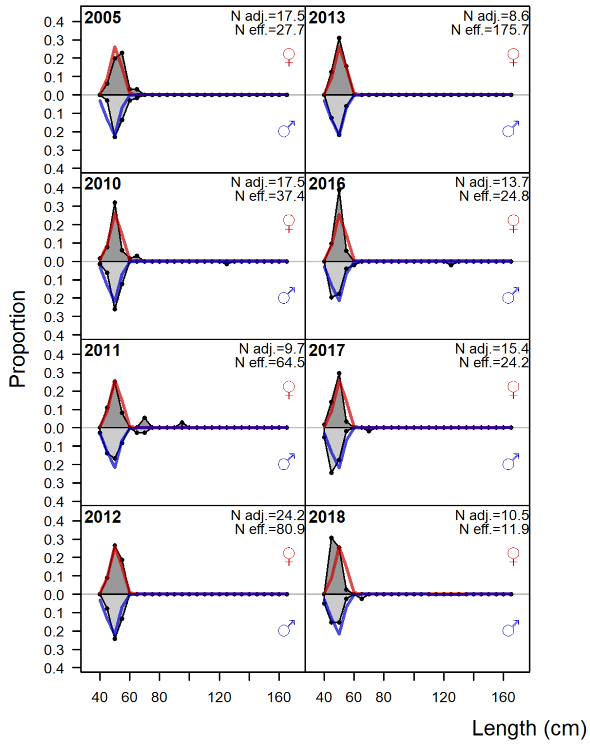
```
$cormessage2
[1] 1 correlation above threshold (cormax=0.95)

$cormessage3
                                               label.i                                          label.j      corr
    1 Size_DblN_peak_F4_Rec_A_B1_B2PRM(4)_BLK6repl_1989 Size_DblN_descend_se_F4_Rec_A_B1_B2PRM(4) -0.963509
```

Table 6.14. Summary results for the Base Model sensitivity to the 2018 time block in survey catchability for S2 (Shark-BLL-Res). Definitions as in the SAR, their Table 3.11.

	Base Model Configuration [1]		Base Model + No Forecast		Base Model + No Forecast + Remove 2018 Time Block (S2)	
Parameters	102		101		100	
Objective function	553.3		554.2		557.2	
Gradient	$5.49*10^{-5}$		$4.74*10^{-6}$		$7.48*10^{-6}$	
$\bar{M}_a$	0.139		0.139		0.139	
$(1-\bar{M}_a)$	0.861		0.861		0.861	
Steepness	0.4		0.4			
	Est	CV	Est	CV		
SSF_{2018}	520	39%	525	39%	527	41%
F_{2018}	0.026	---	0.026	---	0.026	---
R_{2018}	314	33%	297	30%	298	31%
SSF_0	1,140	18%	1,143	18%	1,142	19%
R_0	427	18%	428	18%	428	19%
MSY	471	22%	493	21%	492	22%
SSF_{MSY}	449	18%	451	18%	450	19%
F_{MSY}	0.051	9%	0.049	8%	0.049	8%
SSF_{2018}/SSF_{MSY}	1.158	22%	1.164	22%	1.170	23%
F_{2018}/F_{MSY}	0.509	36%	0.536	36%	0.537	38%
MSST	387	---	388	---	388	---
SSF_{2018}/MSST	1.344	---	1.351	---	1.358	---
Stock status	SSF_{2018} > MSST		SSF_{2018} > MSST		SSF_{2018} > MSST	
Fishery status	$F_{2018} < F_{MSY}$		$F_{2018} < F_{MSY}$		$F_{2018} < F_{MSY}$	

[1] Base Model as reported in the SAR, their Table 3.11.

1.15. Figures



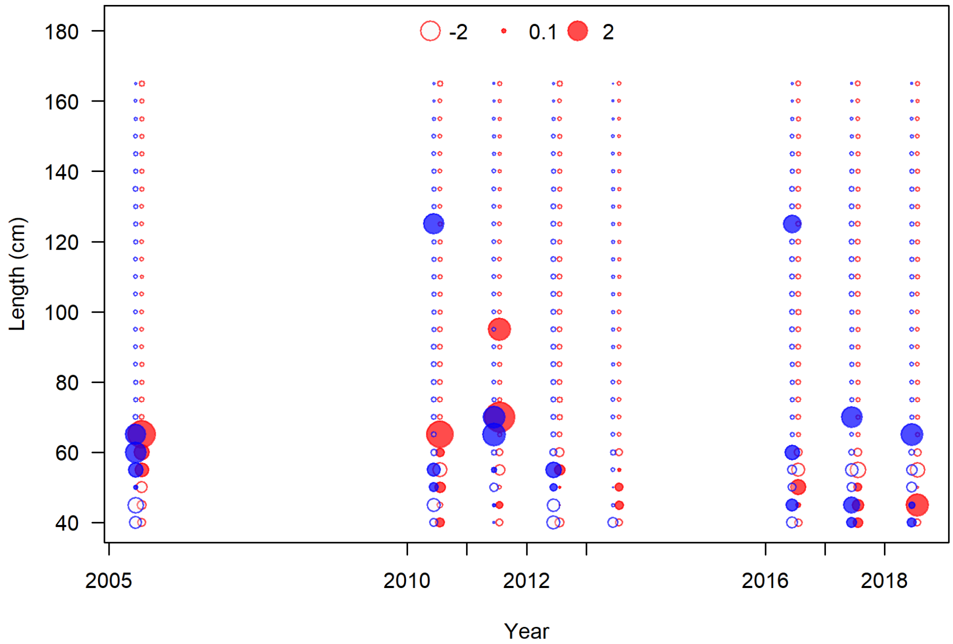


Figure 6.1. Model results for the Adapted Base Model used in jitter analyses, obtained as described above. Fits to length composition for S8 (COASTSPAN-BLL-All-ages, 2005 – 2018, as described in the SAR, their Table 3.2 and Figure 3.3).

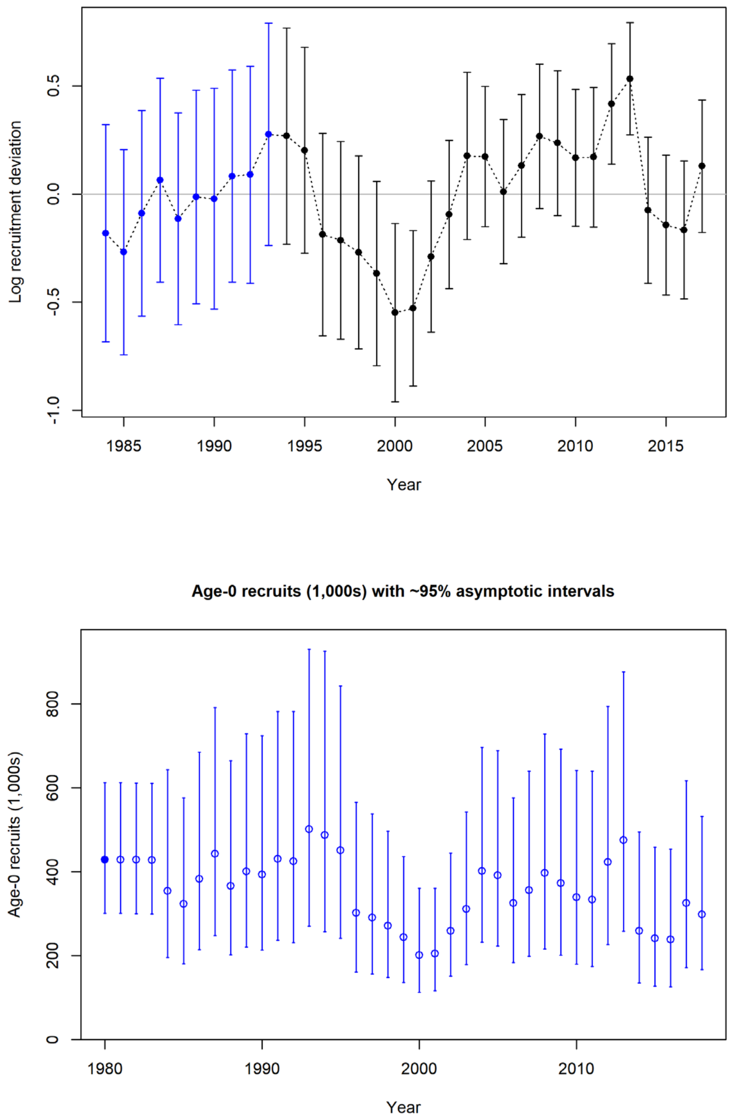


Figure 6.2. Model results for the Adapted Base Model used in jitter analyses, obtained as described above. Upper panel is the estimated log recruitment deviations for the early (1984 – 1993, blue) and main (1994 – 2017, black) recruitment periods with associated 95% asymptotic confidence intervals. Lower 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 1984 and in 2018.

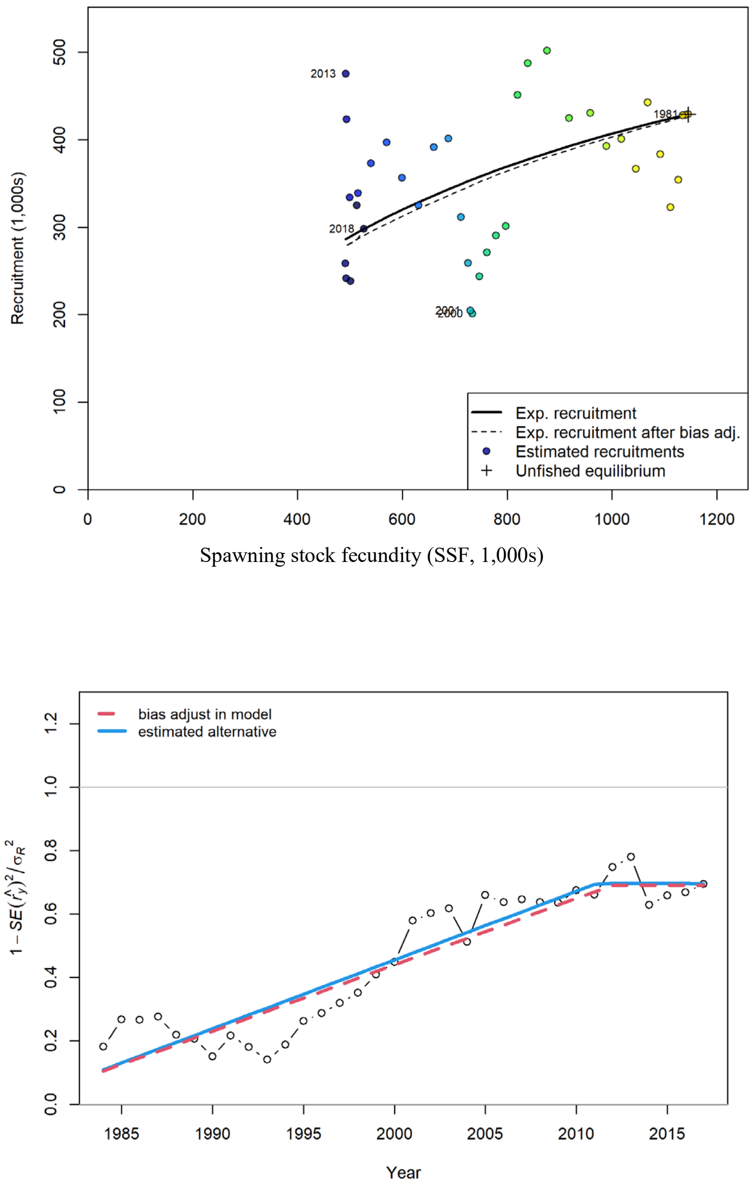


Figure 6.3. Model results for the Adapted Base Model used in jitter analyses, obtained as described above. Upper panel is expected recruitment from the stock-recruitment relationship (solid line), expected recruitment after implementing the bias adjustment correction (dashed line), estimated annual recruitments (circles), unfished equilibrium (plus), and first (1981) and last (2018) years along with years with log deviations > 0.5 (2000, 2001 and 2013). Lower panel is the bias adjustment ramp 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).

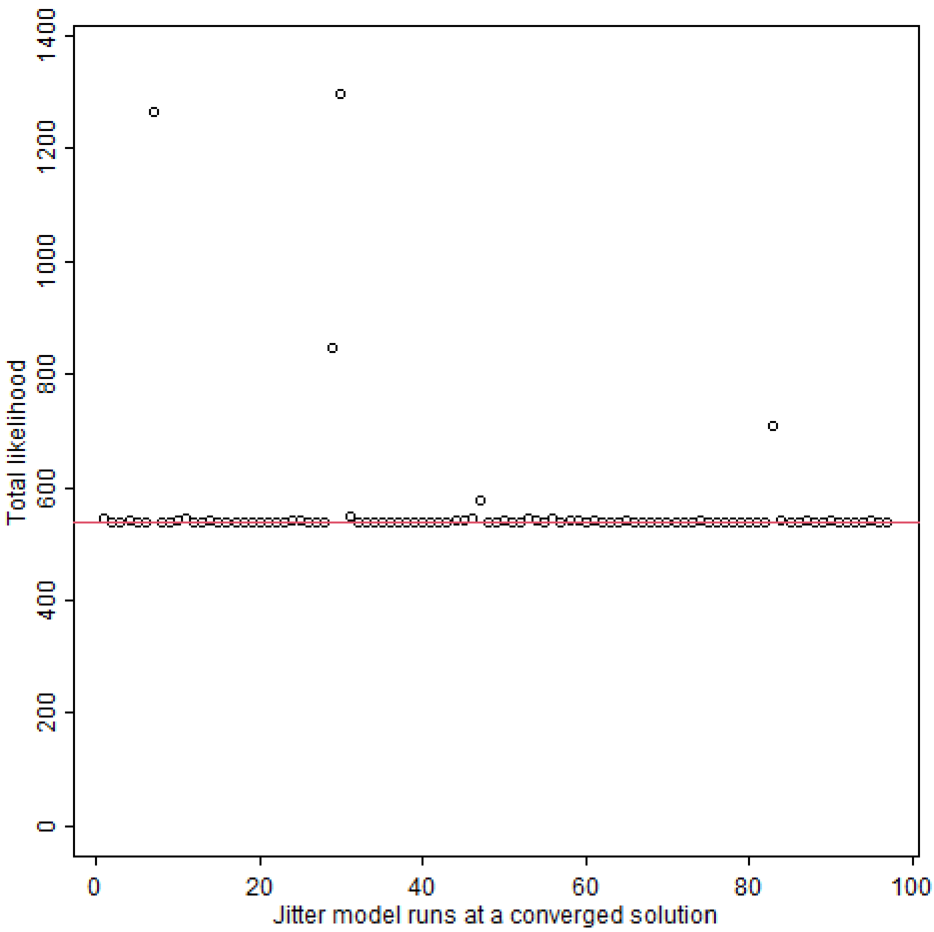


Figure 6.4. Model results for the Adapted Base Model used in jitter analyses, obtained as described above. Total likelihood results of a jitter test for global convergence (97 iterations); the horizontal line represents the total likelihood (538.9 likelihood units). The open circles represent the 67 jittered model runs with the same total likelihood value as the Adapted Base Model (538.9 likelihood units) and 30 jittered model runs with higher total likelihood values (539.4 to 1297.5 likelihood units).

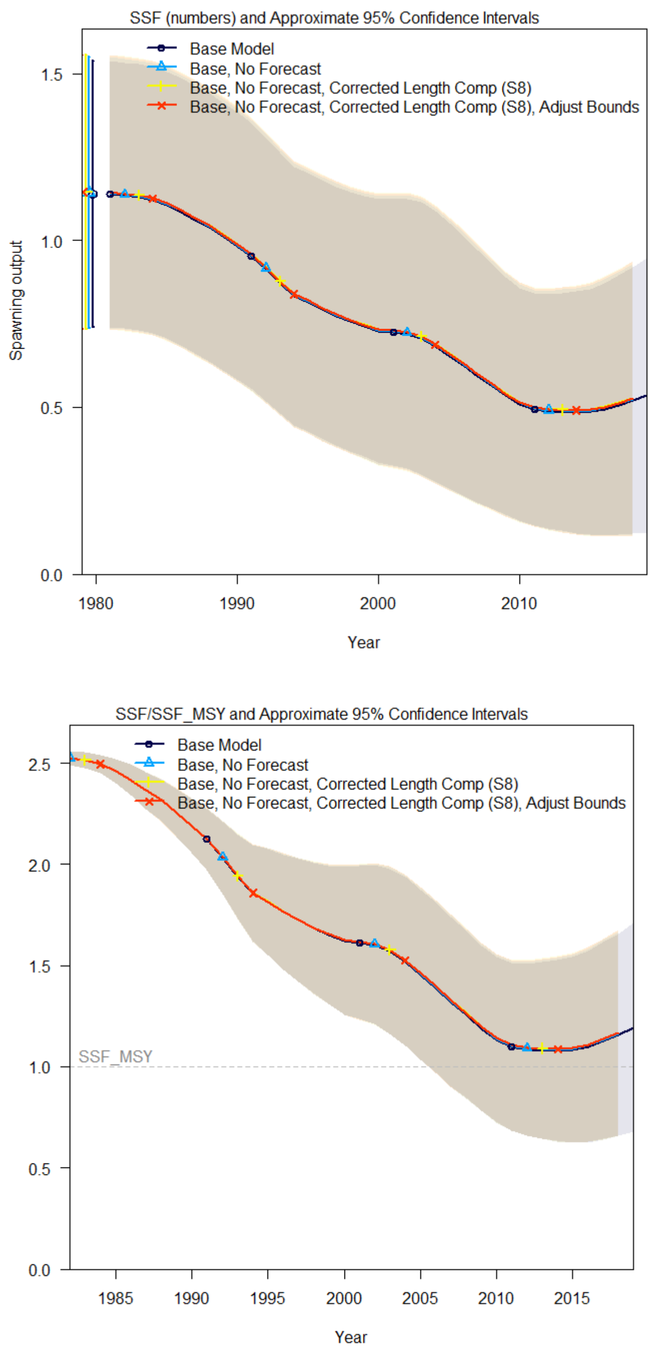


Figure 6.5. Model results for the Adapted Base Model used in jitter analyses, obtained as described above. Base Model reported in the SAR, their Table 3.11. Base Model reported in the SAR with no forecast. Base Model reported in the SAR with no forecast and corrected fit to length composition S8. Base Model reported in the SAR with no forecast, corrected fit to length composition S8, and adjusted parameter bounds (Adapted Base Model used in jitter analyses). Upper panel is Spawning Stock Fecundity (SSF in millions). Lower panel is SSF/SSF_{MSY}. Shaded areas are the asymptotic 95% confidence intervals.

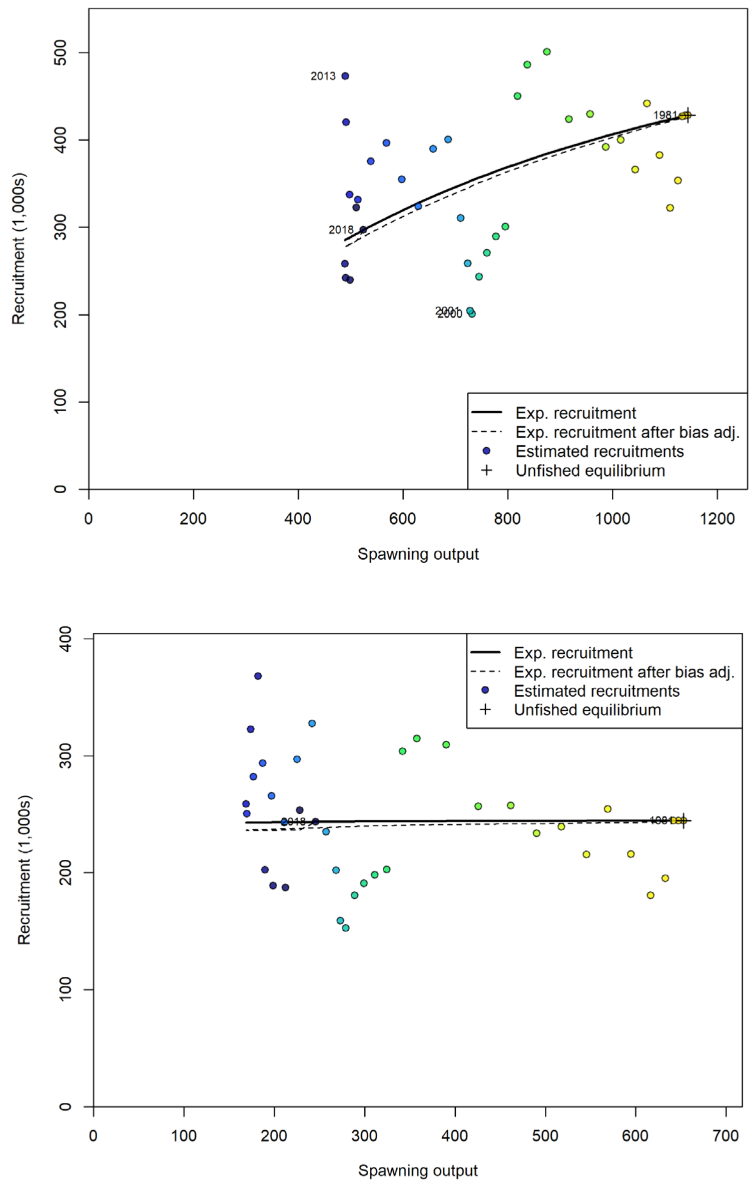
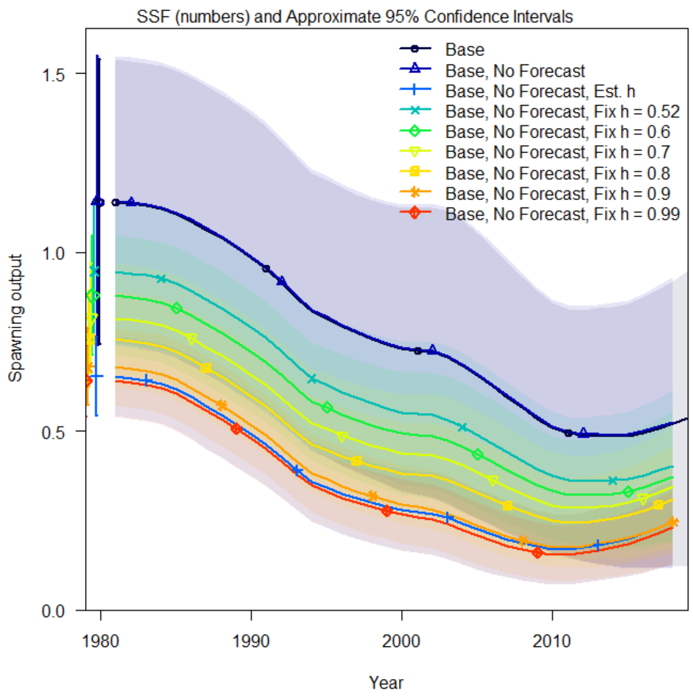


Figure 6.6. Sensitivity analysis to estimated steepness, obtained as described above. Upper panel is the Base Model reported in the SAR, their Table 3.11 and Figure 3.7, with no forecast and fixed steepness (h = 0.4). Lower panel is the sensitivity analysis to estimated steepness, with steepness of h = 0.99 estimated at its upper boundary condition (**Table 6.10**). Plots include expected recruitment 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 (2018) years along with years with log deviations > 0.5 (e.g., 2000, 2001 and 2013 in Upper panel). Point colors indicate year, with warmer colors indicating earlier years and cooler colors showing later years.



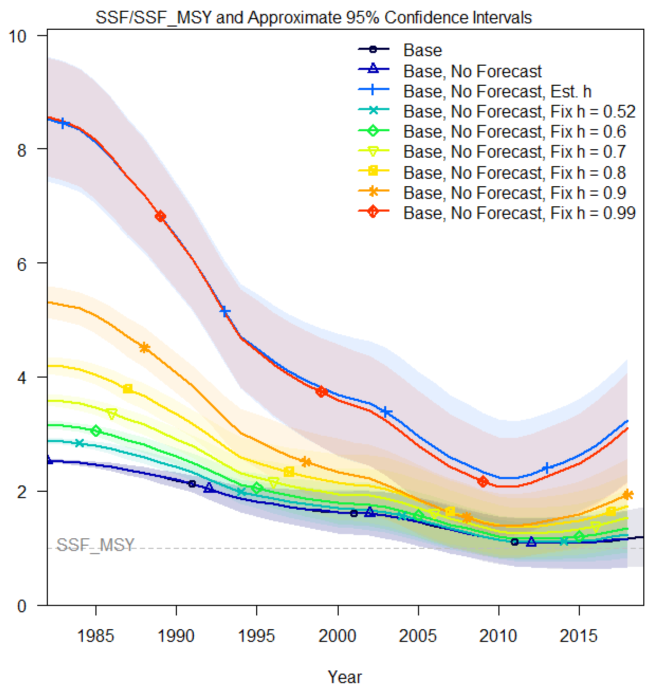
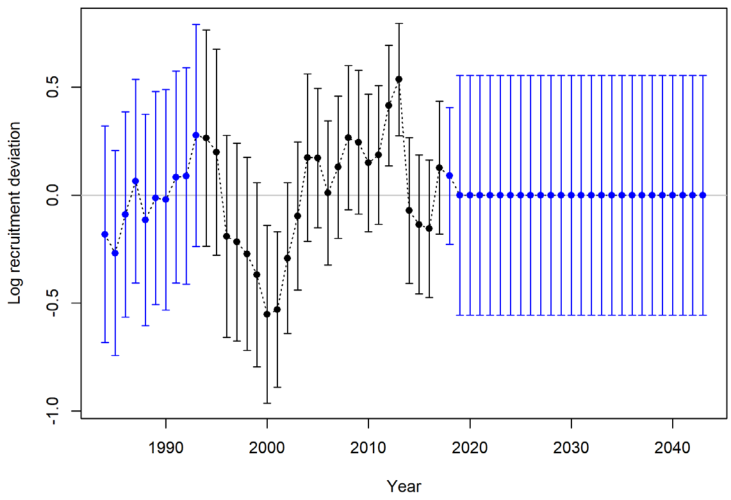


Figure 6.7. Sensitivity analysis to estimated steepness, obtained as described above. Base Model reported in the SAR, their Table 3.11 (Base). Base Model reported in the SAR with no forecast (Base, No Forecast). Sensitivity analysis to estimated steepness, with steepness of *h* = 0.99 estimated at its upper boundary condition (Base, No Forecast, Est h; **Table 6.10**). Sensitivity analysis to Base Model reported in the SAR with no forecast and fixed steepness of *h* = 0.52, 0.6, 0.7, 0.8, 0.9, and 0.99. Upper panel is Spawning Stock Fecundity (SSF in millions). Lower panel is SSF/SSF_{MSY}. Shaded areas are the asymptotic 95% confidence intervals.



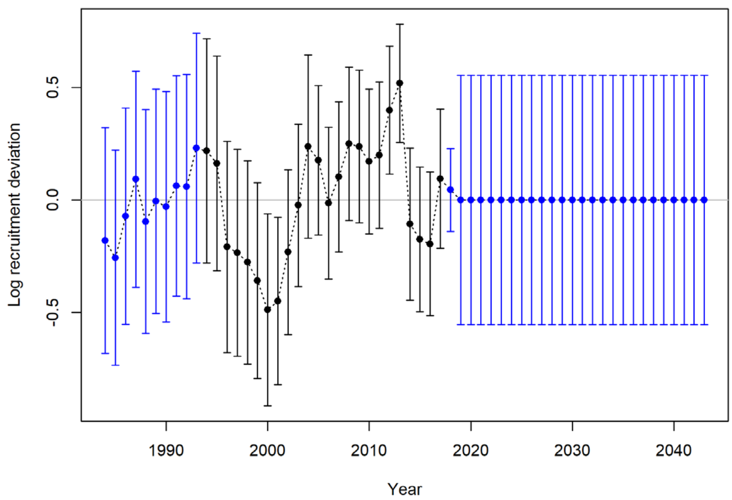
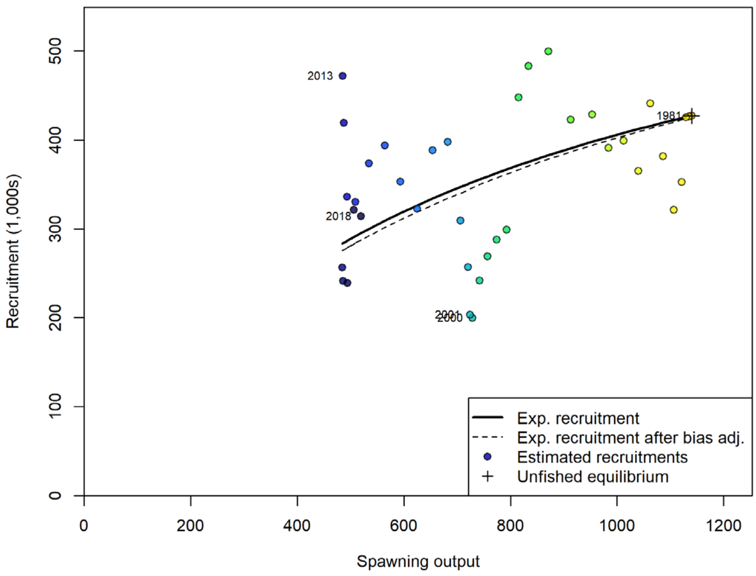


Figure 6.8. Model results for the Low Fecundity Stock Recruit Relationship (LFSR) implemented in the Low Productivity Sensitivity projections (Sections 6.2.1.6 and 6.2.2.6; **Appendix 6.F**). Upper panel is from the Base Model configuration as described in the SAR, their Figure 3.6, but with 25 projections years, 2019 – 2043 (Courtney 2020, RD02). Lower panel is the Low Productivity sensitivity as described above with 25 projections years, 2019 – 2043. Plots show estimated log recruitment deviations for the early (1984 – 1993, blue), main (1994 – 2017, black), late (2018, blue), and forecast (2019+, blue) recruitment periods with associated 95% asymptotic confidence intervals.



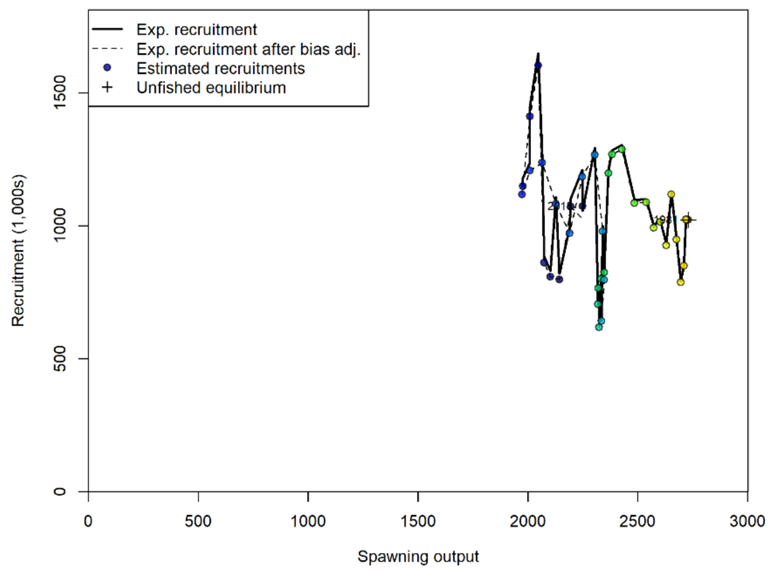


Figure 6.9. Model results for the Low Fecundity Stock Recruit Relationship (LFSR) implemented in the Low Productivity Sensitivity projections (Sections 6.2.1.6 and 6.2.2.6; **Appendix 6.F**). Upper panel is from the Base Model configuration as described in the SAR, their Figure 3.6, but with 25 projections years, 2019 – 2043 (Courtney 2020, RD02). Lower panel is the Low Productivity sensitivity as described above with 25 projections years, 2019 – 2043. Plots show expected recruitment during the assessment period (1981 – 2018) 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 (2018) years along with years with log deviations > 0.5 (2000, 2001 and 2013 in Upper panel). Point colors indicate year, with warmer colors indicating earlier years and cooler colors showing later years.

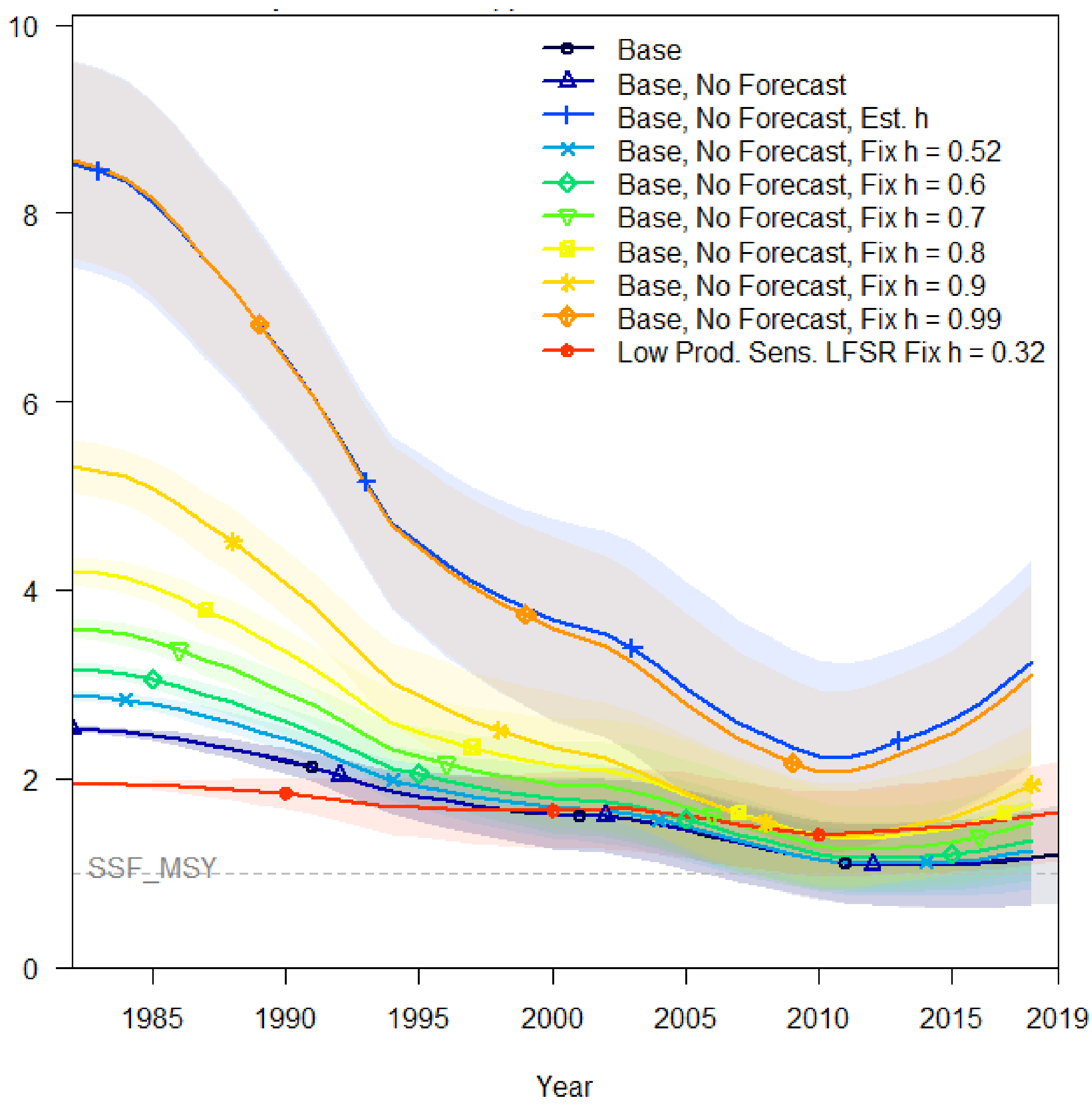


Figure 6.10. Model results for the Low Fecundity Stock Recruit Relationship (LFSR). The LFSR was implemented in the Low Productivity Sensitivity projections (Sections 6.2.1.6 and 6.2.2.6; **Appendix 6.F)**, and utilized the LFSR with a fixed steepness of *h* = 0.32 (Low Prod. Sens. LFSR Fix h = 0.32). Other model results are from the sensitivity analysis to estimated steepness as described in **Figure 6.7**. Upper panel is Spawning Stock Fecundity (SSF in millions). Lower panel is SSF/SSF_{MSY}. Shaded areas are the asymptotic 95% confidence intervals.

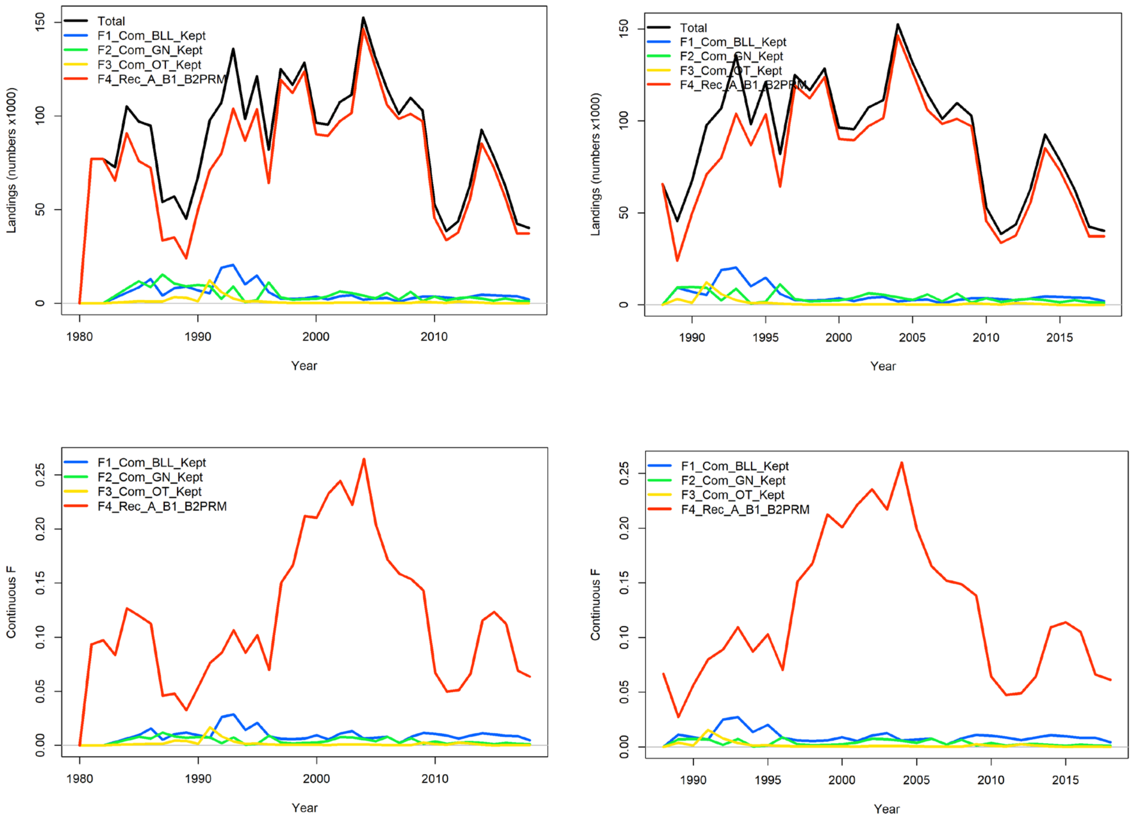


Figure 6.11. Model sensitivity to initial catch reconstruction, obtained as described above. Base Model from the SAR (Left panels) and Initial Catch Sensitivity model runs (Right panels). Fleet names are defined within the SAR (e.g., their Table 3.1). Total landings (Upper panels) and continuous fishing mortality by fleet (Lower panels). Commercial landings were entered in mt and converted within Stock Synthesis to numbers (1,000s) based on the length at age relationship and the weight at length of commercial fishery removals obtained by Stock Synthesis after accounting for fishery selectivity. Recreational catch plus recreational discards assumed to die from post release mortality (A + B1 + B2PRM) were entered in numbers (1,000s).

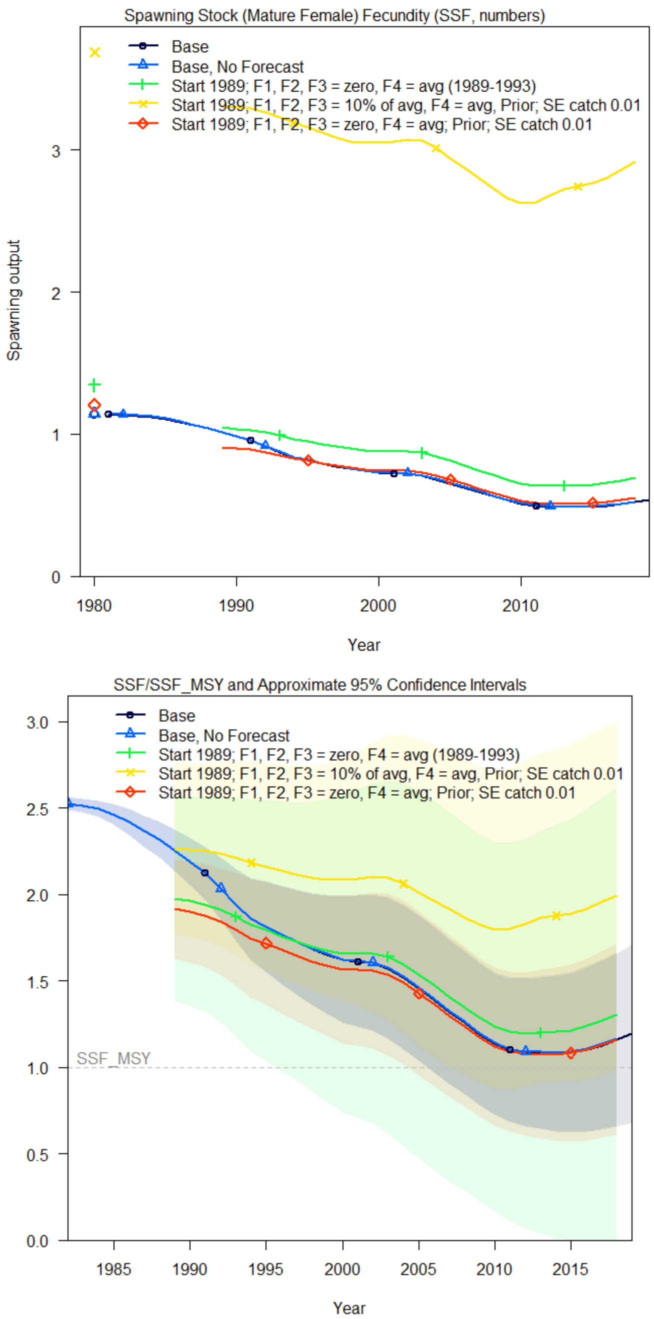


Figure 6.12. Model sensitivity to initial catch reconstruction, obtained as described above. Base Model reported in the SAR, their Table 3.11 (Base). Base Model reported in the SAR with no forecast (Base, No Forecast). Three sensitivities to initial equilibrium catch were evaluated as described above. Upper panel is Spawning Stock Fecundity (SSF in millions). Lower panel is SSF/SSF_{MSY}. Shaded areas are the asymptotic 95% confidence intervals.

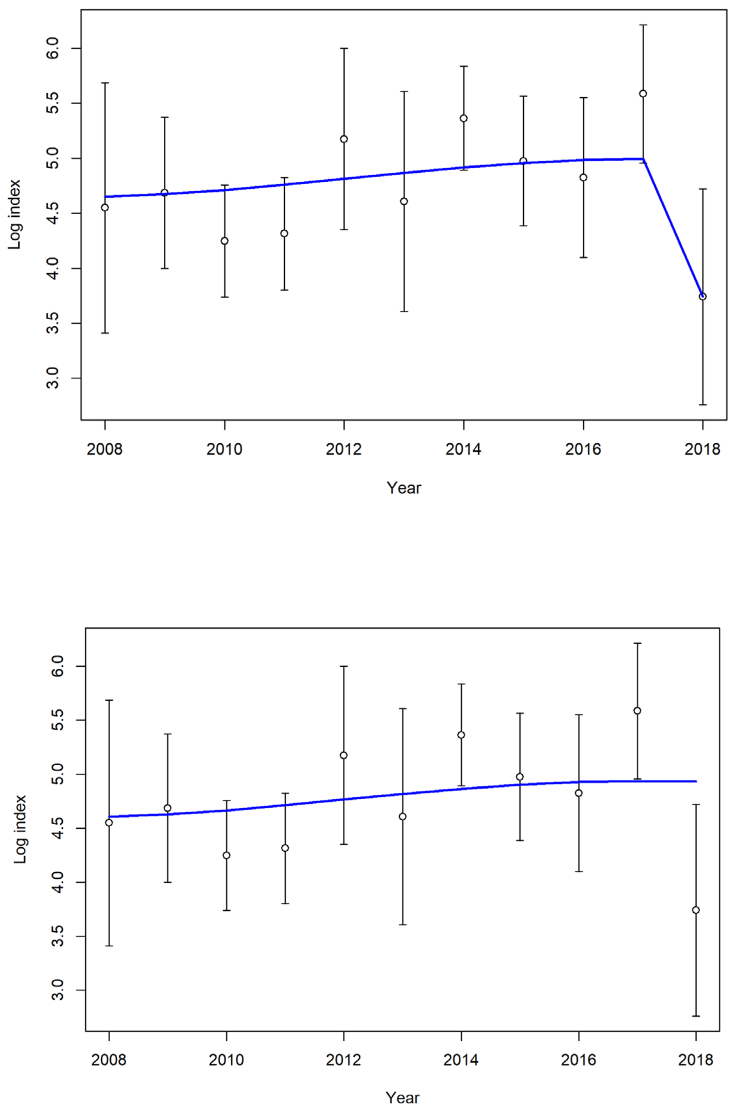


Figure 6.13. Model sensitivity to the 2018 survey catchability time block, obtained as described above. Upper panel is the Base Model (SAR, their Table 3.11) fit to the Shark Bottom Longline Research Fishery (2008 – 2018) index of relative abundance (S2; Shark-BLL-Res; SAR, their Table 3.1. and Figure 3.2). Lower panel is the sensitivity analysis fit to S2 obtained after removing the 2018 time block for S2 catchability. Plots show predicted (blue line) and observed (open circles with approximate 95% confidence intervals based on the input standard error, SE) on the natural log scale.

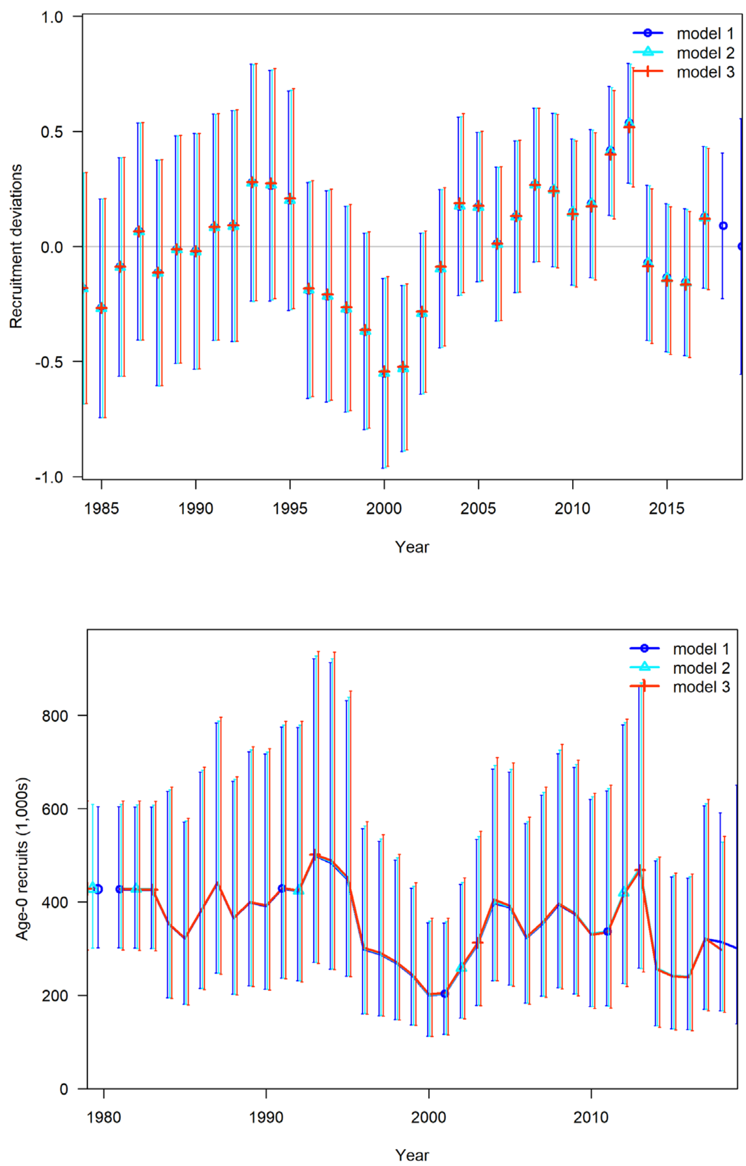


Figure 6.14. Model sensitivity to the 2018 survey catchability time block, obtained as described above. Base Model reported in the SAR, their Table 3.11 (Model 1). Base Model reported in the SAR with no forecast (Model 2). Sensitivity to the 2018 survey catchability time block obtained by removing the 2018 time block for S2 catchability (Model 3). Upper panel is the estimated log recruitment deviations with 95% asymptotic confidence intervals. Lower panel is the estimated annual age-0 recruits with 95% asymptotic confidence intervals.

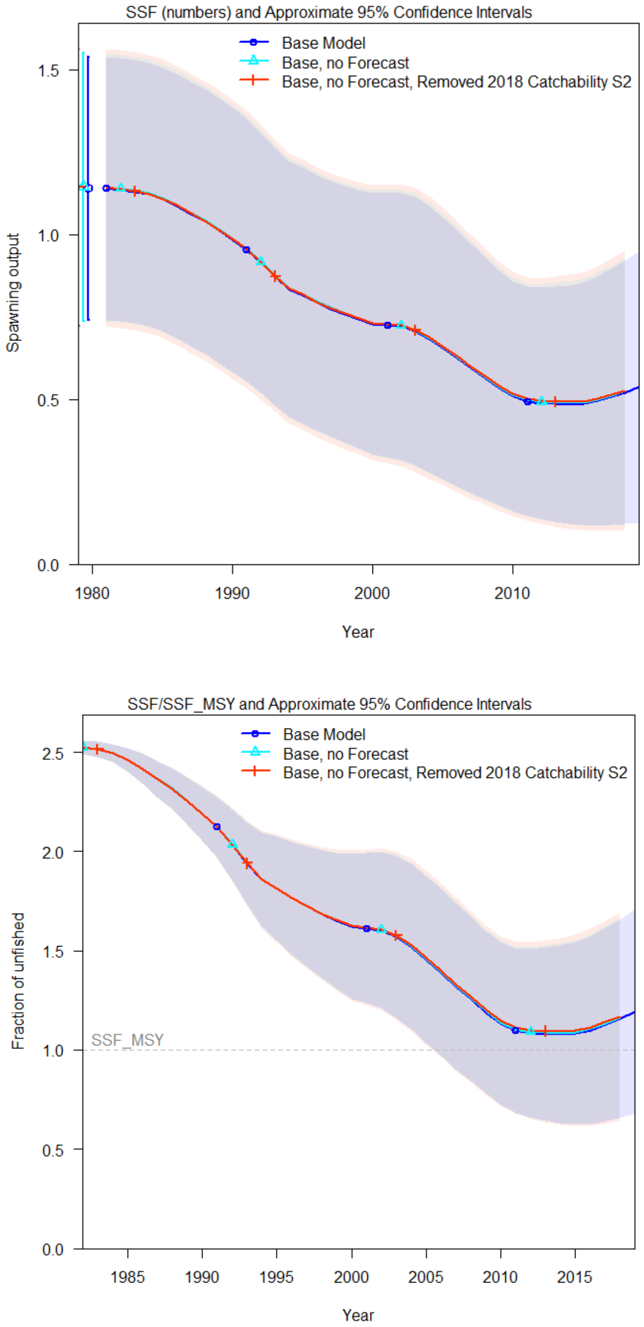


Figure 6.15. Model sensitivity to the 2018 survey catchability time block, obtained as described above. Base Model reported in the SAR, their Table 3.11 (Base). Base Model reported in the SAR with no forecast (Base, No Forecast). Sensitivity to the 2018 survey catchability time block, obtained by removing the 2018 time block for S2 catchability (Base, No Forecast, Removed 2018 Catchability S2). Upper panel is Spawning Stock Fecundity (SSF in millions). Lower panel is SSF/SSF_{MSY}. Shaded areas are the asymptotic 95% confidence intervals.

1.16. Appendices

1.16.1. **Appendix 6.A.** Base Model Risk Matrices and Projection Results

Table 6.A.1. SEDAR 65 Base Model risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The $Pr(SSF_y > SSF_{MSY})$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	77	80	83	83	83	85	92	98	100	100
10%	77	80	83	83	83	84	91	97	99	100
20%	77	80	83	83	83	84	90	96	99	100
30%	77	80	83	83	83	84	89	95	98	99
40%	77	80	83	83	83	83	88	93	97	98
50%	77	80	83	83	83	83	87	91	95	96
60%	77	80	83	83	83	82	86	89	92	94
70%	77	80	83	83	82	82	84	87	89	90
80%	77	80	83	83	82	82	83	84	85	86
90%	77	80	83	83	82	81	81	81	81	81
100%	77	80	83	83	82	81	80	77	76	75
110%	77	80	83	83	82	81	78	74	71	69
120%	77	80	83	83	82	80	76	70	65	62
130%	77	80	83	83	82	80	75	66	60	56
140%	77	80	83	83	82	79	73	63	54	50
150%	77	80	83	83	82	79	71	59	49	44
160%	77	80	83	83	81	79	69	55	44	39
170%	77	80	83	83	81	78	67	51	39	34
180%[1]										
190%	77	80	83	83	81	77	63	44	31	26
200%	77	80	83	83	81	77	61	41	27	22

[1] Model run crashed.

Table 6.A.2. SEDAR 65 Base Model risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The Pr($F_y < F_{MSY}$) is color coded to represent Pr ≥ 0.70 (green), 0.50 ≤ Pr < 0.70 (yellow), and Pr < 0.50 (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	71	70	70	100	100	100	100	100	100	100
10%	71	70	70	100	100	100	100	100	100	100
20%	71	70	70	100	100	100	100	100	100	100
30%	71	70	70	100	100	100	100	100	100	100
40%	71	70	70	100	100	100	100	100	100	100
50%	71	70	70	100	100	100	100	100	100	100
60%	71	70	70	100	100	100	100	100	100	100
70%	71	70	70	97	98	98	99	99	99	99
80%	71	70	70	91	91	92	93	94	94	95
90%	71	70	70	81	81	81	82	82	82	82
100%	71	70	70	70	70	69	69	68	67	66
110%	71	70	70	59	58	57	56	54	52	51
120%	71	70	70	49	48	47	45	43	41	40
130%	71	70	70	41	40	38	36	35	33	32
140%	71	70	70	34	33	32	30	29	28	27
150%	71	70	70	28	28	27	25	24	24	24
160%	71	70	70	24	23	22	22	21	22	22
170%	71	70	70	21	20	19	19	19	20	22
180%[1]										
190%	71	70	70	15	15	15	15	17	20	22
200%	71	70	70	14	13	13	14	16	20	24

[1] Model run crashed.

Table 6.A.3. SEDAR 65 Base Model risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided as the probability of spawning stock fecundity in projection year *y* (SSF_y) being above the Minimum Stock Size Threshold (MSST), where MSST is defined as $\left(1-\bar{M}_a\right)*SSF_{MSY}$, as described above. The $Pr(SSF_y > MSST)$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	90	91	92	92	93	93	97	100	100	100
10%	90	91	92	92	93	93	97	99	100	100
20%	90	91	92	92	92	93	96	99	100	100
30%	90	91	92	92	92	93	96	98	99	100
40%	90	91	92	92	92	93	95	98	99	99
50%	90	91	92	92	92	92	94	97	98	99
60%	90	91	92	92	92	92	94	95	97	98
70%	90	91	92	92	92	92	93	94	95	96
80%	90	91	92	92	92	92	92	92	93	93
90%	90	91	92	92	92	91	91	90	90	90
100%	90	91	92	92	92	91	90	88	87	86
110%	90	91	92	92	92	91	89	86	83	81
120%	90	91	92	92	92	91	88	83	78	76
130%	90	91	92	92	92	91	86	80	74	70
140%	90	91	92	92	92	90	85	77	69	64
150%	90	91	92	92	92	90	84	73	64	58
160%	90	91	92	92	91	90	82	70	58	52
170%	90	91	92	92	91	89	81	66	53	47
180%[1]										
190%	90	91	92	92	91	89	78	59	44	37
200%	90	91	92	92	91	89	76	56	39	32

[1] Model run crashed.

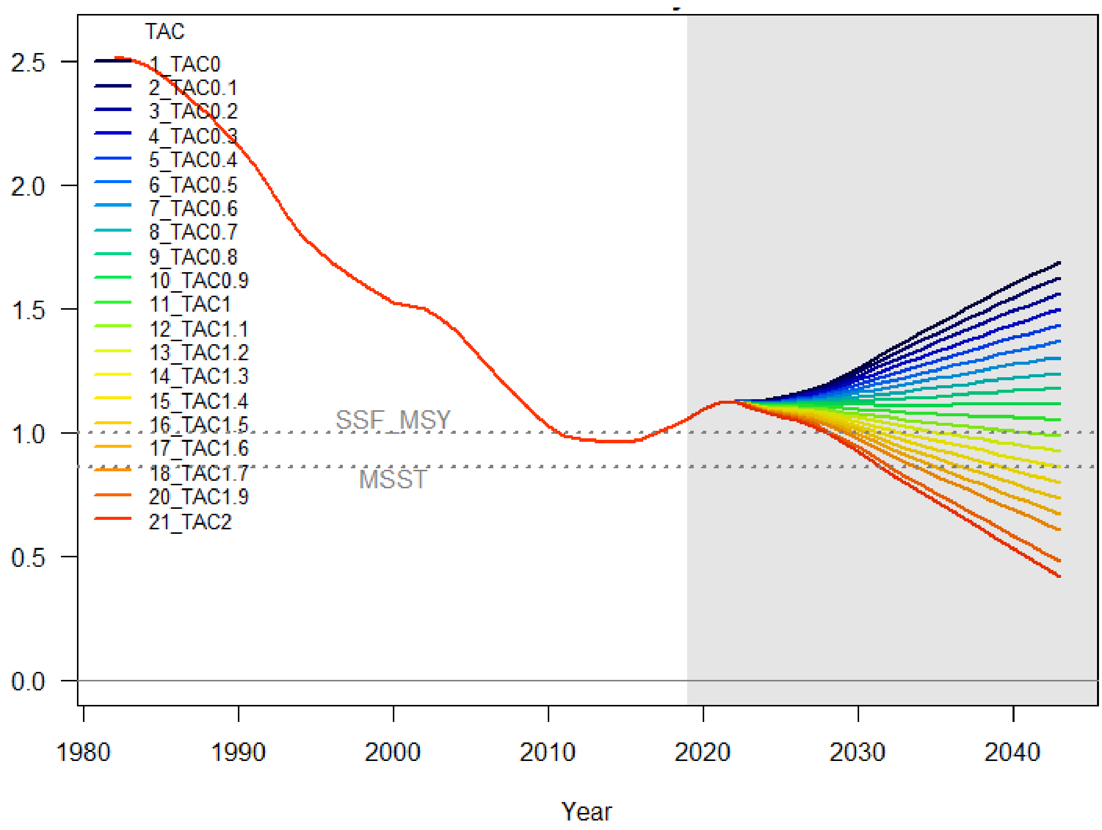


Figure 6.A.1. SEDAR 65 Base Model projection results (shaded area) at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of the average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided for the ratio of spawning stock fecundity in projection year *y* relative to spawning stock fecundity at equilibrium maximum sustainable yield (SSF_y/SSF_{MSY}; y-axis). Lines represent the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC, as described above. The minimum stock size threshold (MSST) is $\left(1-\bar{M}_a\right)*SSF_{MSY}$, as described above.

1.16.2. **Appendix 6.B.** Logistic Sensitivity Risk Matrices and Projection Results.

Table 6.B.1. SEDAR 65 Logistic Sensitivity risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The $Pr(SSF_y > SSF_{MSY})$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	94	95	96	96	96	96	100	100	100	100
10%	94	95	96	96	95	96	99	100	100	100
20%	94	95	96	96	95	95	99	100	100	100
30%	94	95	96	96	95	95	99	100	100	100
40%	94	95	96	96	95	95	98	100	100	100
50%	94	95	96	96	95	94	98	99	100	100
60%	94	95	96	96	95	94	97	99	99	100
70%	94	95	96	96	95	94	97	98	99	99
80%	94	95	96	96	95	93	96	97	98	98
90%	94	95	96	96	95	93	95	96	97	97
100%	94	95	96	96	94	93	94	94	95	95
110%	94	95	96	96	94	92	93	92	92	92
120%	94	95	96	96	94	92	92	90	89	88
130%	94	95	96	96	94	91	90	87	85	84
140%	94	95	96	96	94	91	88	84	81	79
150%	94	95	96	96	94	90	87	81	76	73
160%	94	95	96	96	94	90	85	77	70	67
170%	94	95	96	96	94	89	83	73	65	61
180%	94	95	96	96	93	88	81	69	60	55
190%	94	95	96	96	93	87	78	65	54	49
200%	94	95	96	96	93	87	76	61	49	43

Table 6.B.2. SEDAR 65 Logistic Sensitivity risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The Pr($F_y < F_{MSY}$) is color coded to represent Pr ≥ 0.70 (green), 0.50 ≤ Pr < 0.70 (yellow), and Pr < 0.50 (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	98	99	99	100	100	100	100	100	100	100
10%	98	99	99	100	100	100	100	100	100	100
20%	98	99	99	100	100	100	100	100	100	100
30%	98	99	99	100	100	100	100	100	100	100
40%	98	99	99	100	100	100	100	100	100	100
50%	98	99	99	100	100	100	100	100	100	100
60%	98	99	99	100	100	100	100	100	100	100
70%	98	99	99	100	100	100	100	100	100	100
80%	98	99	99	100	100	100	100	100	100	100
90%	98	99	99	100	100	100	100	100	100	100
100%	98	99	99	99	99	99	99	99	99	99
110%	98	99	99	97	97	96	96	96	96	96
120%	98	99	99	92	92	91	90	90	89	89
130%	98	99	99	86	85	83	81	80	78	77
140%	98	99	99	78	77	75	71	69	66	65
150%	98	99	99	70	69	65	61	58	55	53
160%	98	99	99	62	60	57	52	48	45	44
170%	98	99	99	54	53	49	44	41	38	37
180%	98	99	99	47	46	42	38	35	32	32
190%	98	99	99	43	40	36	32	30	29	28
200%	98	99	99	36	34	31	28	26	26	26

Table 6.B.3. SEDAR 65 Logistic Sensitivity risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided as the probability of spawning stock fecundity in projection year *y* (SSF_y) being above the Minimum Stock Size Threshold (MSST), where MSST is defined as $\left(1-\bar{M}_a\right)*SSF_{MSY}$, as described above. The $Pr(SSF_y > MSST)$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	99	99	99	99	99	100	100	100	100	100
10%	99	99	99	99	99	99	100	100	100	100
20%	99	99	99	99	99	99	100	100	100	100
30%	99	99	99	99	99	99	100	100	100	100
40%	99	99	99	99	99	99	100	100	100	100
50%	99	99	99	99	99	99	100	100	100	100
60%	99	99	99	99	99	99	100	100	100	100
70%	99	99	99	99	99	99	100	100	100	100
80%	99	99	99	99	99	99	99	100	100	100
90%	99	99	99	99	99	99	99	99	100	100
100%	99	99	99	99	99	99	99	99	99	99
110%	99	99	99	99	99	99	99	98	98	98
120%	99	99	99	99	99	99	98	98	97	97
130%	99	99	99	99	99	98	98	97	96	95
140%	99	99	99	99	99	98	97	95	93	92
150%	99	99	99	99	99	98	97	94	91	89
160%	99	99	99	99	99	98	96	92	88	85
170%	99	99	99	99	99	98	95	90	84	80
180%	99	99	99	99	99	98	94	87	80	75
190%	99	99	99	99	99	97	93	84	75	69
200%	99	99	99	99	99	97	92	81	70	64

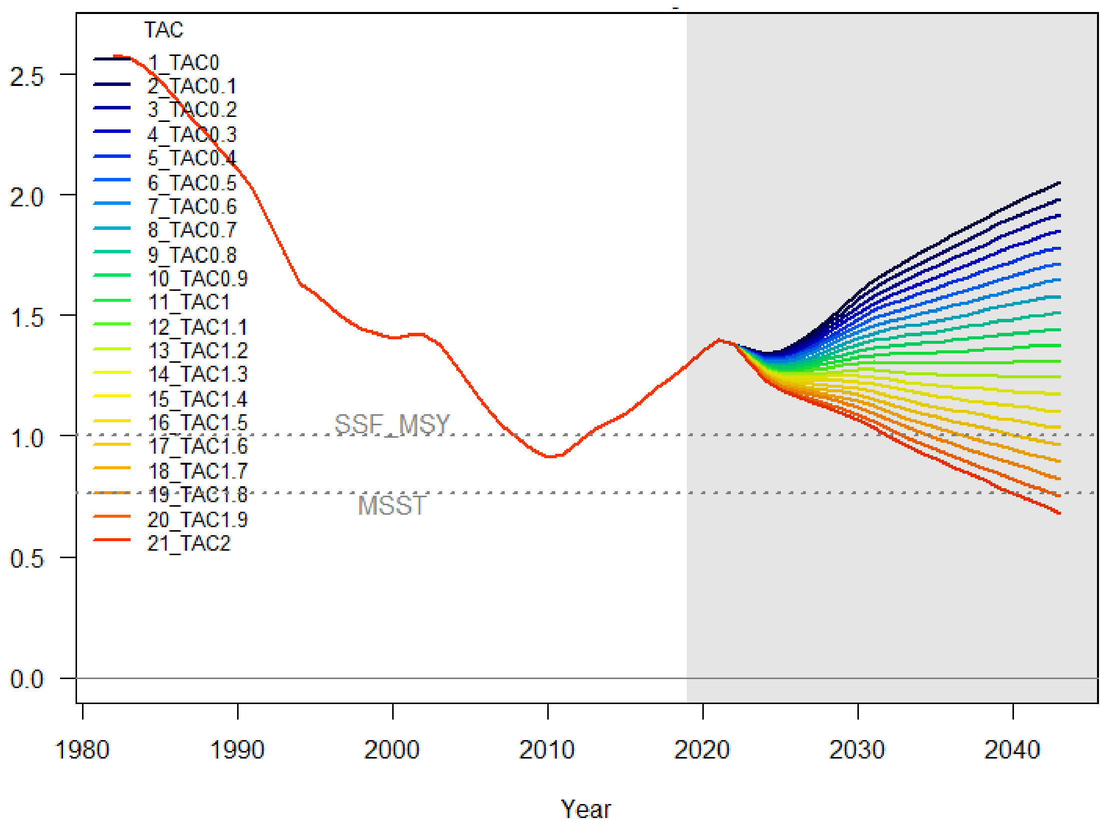


Figure 6.B.1. SEDAR 65 Logistic Sensitivity projection results (shaded area) at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of the average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided for the ratio of spawning stock fecundity in projection year *y* relative to spawning stock fecundity at equilibrium maximum sustainable yield (SSF_y/SSF_{MSY}; y-axis). Lines represent the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC, as described above. The minimum stock size threshold (MSST) is $(1-\bar{M}_a)$ *SSF_{MSY}, as described above.

1.16.3. **Appendix 6.C.** Drop CPUE Sensitivity Risk Matrices and Projection Results

Table 6.C.1. SEDAR 65 Drop CPUE Sensitivity risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The $Pr(SSF_y > SSF_{MSY})$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	32	40	47	48	49	52	74	94	99	100
10%	32	40	47	48	49	52	71	90	98	99
20%	32	40	47	48	49	51	68	86	95	98
30%	32	40	47	48	48	50	64	81	91	95
40%	32	40	47	48	48	49	61	75	85	90
50%	32	40	47	48	48	48	57	69	78	82
60%	32	40	47	48	48	47	54	62	70	73
70%	32	40	47	48	47	46	51	56	60	63
80%	32	40	47	48	47	46	47	49	51	52
90%	32	40	47	48	47	45	44	42	42	41
100%	32	40	47	48	46	44	41	36	33	32
110%	32	40	47	48	46	43	37	31	26	24
120%	32	40	47	48	46	42	34	26	20	18
130%	32	40	47	48	46	41	32	21	15	13
140%	32	40	47	48	45	40	29	17	11	9
150%	32	40	47	48	45	40	26	14	8	7
160%	32	40	47	48	45	39	24	11	6	5
170%	32	40	47	48	44	38	22	9	5	3
180%	32	40	47	48	44	37	20	7	3	3
190%	32	40	47	48	44	36	18	6	3	4
200%	32	40	47	48	44	35	16	5	2	4

Table 6.C.2. SEDAR 65 Drop CPUE Sensitivity risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The Pr($F_y < F_{MSY}$) is color coded to represent Pr ≥ 0.70 (green), 0.50 ≤ Pr < 0.70 (yellow), and Pr < 0.50 (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	24	23	24	100	100	100	100	100	100	100
10%	24	23	24	100	100	100	100	100	100	100
20%	24	23	24	100	100	100	100	100	100	100
30%	24	23	24	100	100	100	100	100	100	100
40%	24	23	24	100	100	100	100	100	100	100
50%	24	23	24	99	99	99	100	100	100	100
60%	24	23	24	90	91	92	95	97	98	98
70%	24	23	24	71	72	74	77	80	82	83
80%	24	23	24	51	52	53	54	56	56	57
90%	24	23	24	35	35	35	36	36	36	36
100%	24	23	24	24	24	24	24	24	24	24
110%	24	23	24	16	16	16	17	17	18	18
120%	24	23	24	11	11	12	12	13	15	16
130%	24	23	24	8	8	9	10	11	14	15
140%	24	23	24	6	6	7	8	10	14	17
150%	24	23	24	5	5	5	7	10	15	19
160%	24	23	24	4	4	4	6	10	17	23
170%	24	23	24	3	3	4	6	11	20	28
180%	24	23	24	2	3	3	6	12	24	35
190%	24	23	24	2	2	3	6	14	29	0
200%	24	23	24	2	2	3	6	16	36	30

Table 6.C.3. SEDAR 65 Drop CPUE Sensitivity risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided as the probability of spawning stock fecundity in projection year *y* (SSF_y) being above the Minimum Stock Size Threshold (MSST), where MSST is defined as $\left(1-\bar{M}_a\right)*SSF_{MSY}$, as described above. The Pr(SSF_y > MSST) is color coded to represent Pr ≥ 0.70 (green), 0.50 ≤ Pr < 0.70 (yellow), and Pr < 0.50 (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	64	70	75	75	76	78	91	99	100	100
10%	64	70	75	75	76	77	89	97	100	100
20%	64	70	75	75	75	77	87	96	99	100
30%	64	70	75	75	75	76	85	94	97	99
40%	64	70	75	75	75	75	83	91	95	97
50%	64	70	75	75	75	75	80	87	91	93
60%	64	70	75	75	74	74	77	82	86	88
70%	64	70	75	75	74	73	74	77	79	80
80%	64	70	75	75	74	72	71	71	71	71
90%	64	70	75	75	74	72	68	65	63	61
100%	64	70	75	75	73	71	65	59	54	51
110%	64	70	75	75	73	70	62	52	45	41
120%	64	70	75	75	73	69	58	46	37	33
130%	64	70	75	75	73	68	55	40	30	25
140%	64	70	75	75	72	67	52	34	23	19
150%	64	70	75	75	72	66	48	29	18	14
160%	64	70	75	75	72	66	45	25	14	10
170%	64	70	75	75	72	65	42	21	11	8
180%	64	70	75	75	71	64	39	17	8	6
190%	64	70	75	75	71	63	36	14	6	7
200%	64	70	75	75	71	62	33	12	6	7

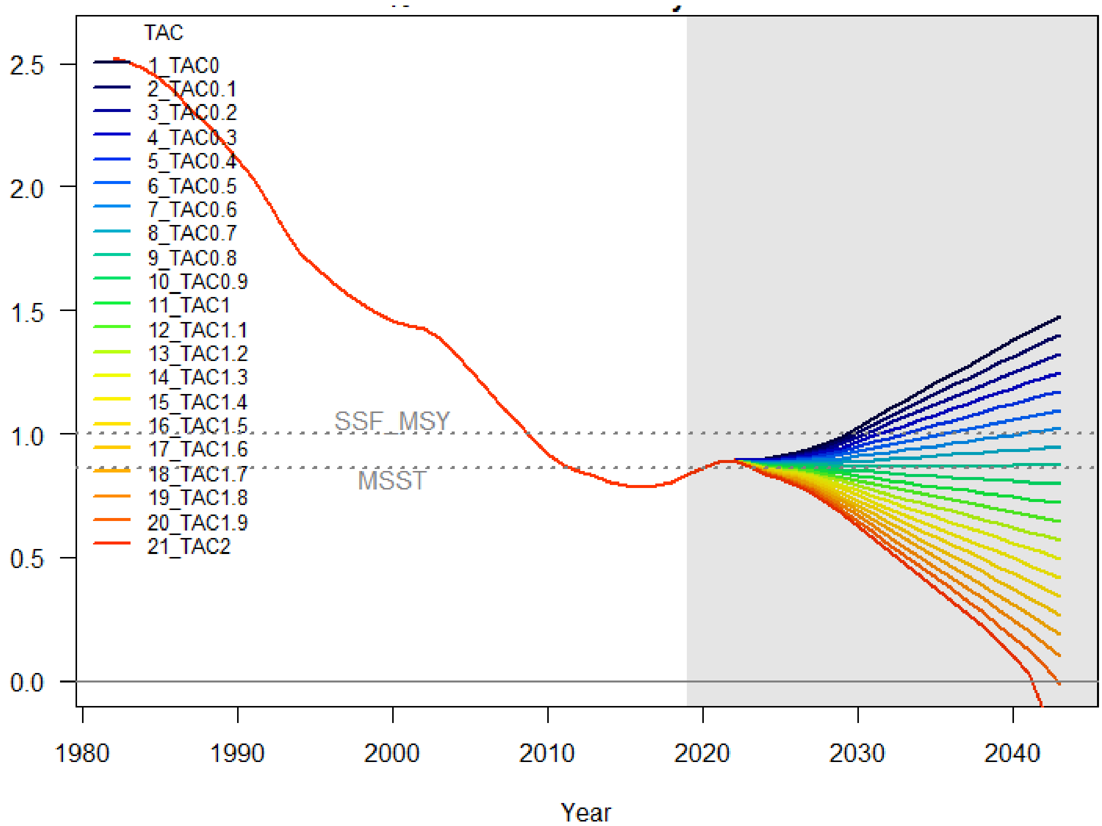


Figure 6.C.1. SEDAR 65 Drop CPUE Sensitivity projection results (shaded area) at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of the average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided for the ratio of spawning stock fecundity in projection year *y* relative to spawning stock fecundity at equilibrium maximum sustainable yield (SSF_y/SSF_{MSY}; y-axis). Lines represent the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC, as described above. The minimum stock size threshold (MSST) is $\left(1-\bar{M}_a\right)$ *SSF_{MSY}, as described above.

1.16.4. **Appendix 6.D.** High Catch Sensitivity Risk Matrices and Projection Results

Table 6.D.1. SEDAR 65 High Catch Sensitivity risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The $Pr(SSF_y > SSF_{MSY})$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	86	89	91	91	91	92	97	100	100	100
10%	86	89	91	91	91	92	97	99	100	100
20%	86	89	91	91	91	92	97	99	100	100
30%	86	89	91	91	91	92	97	99	100	100
40%	86	89	91	91	91	92	97	99	100	100
50%	86	89	91	91	91	92	96	99	100	100
60%	86	89	91	91	91	92	96	98	99	100
70%	86	89	91	91	91	92	96	98	99	100
80%	86	89	91	91	91	92	95	98	99	99
90%	86	89	91	91	91	91	95	97	98	99
100%	86	89	91	91	91	91	95	97	98	99
110%	86	89	91	91	91	91	94	96	97	98
120%	86	89	91	91	91	91	94	96	97	97
130%	86	89	91	91	91	91	94	95	96	97
140%	86	89	91	91	91	91	93	94	95	96
150%	86	89	91	91	91	91	93	93	94	94
160%	86	89	91	91	91	91	92	92	93	93
170%	86	89	91	91	91	91	92	92	92	91
180%	86	89	91	91	91	90	92	91	90	90
190%	86	89	91	91	90	90	91	90	89	88
200%	86	89	91	91	90	90	91	88	87	86

Table 6.D.2. SEDAR 65 High Catch Sensitivity risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The $Pr(F_y < F_{MSY})$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	100	100	100	100	100	100	100	100	100	100
10%	100	100	100	100	100	100	100	100	100	100
20%	100	100	100	100	100	100	100	100	100	100
30%	100	100	100	100	100	100	100	100	100	100
40%	100	100	100	100	100	100	100	100	100	100
50%	100	100	100	100	100	100	100	100	100	100
60%	100	100	100	100	100	100	100	100	100	100
70%	100	100	100	100	100	100	100	100	100	100
80%	100	100	100	100	100	100	100	100	100	100
90%	100	100	100	100	100	100	100	100	100	100
100%	100	100	100	100	100	100	100	100	100	100
110%	100	100	100	100	100	100	100	100	100	100
120%	100	100	100	100	100	100	100	100	100	100
130%	100	100	100	100	100	100	100	100	100	100
140%	100	100	100	100	100	100	100	100	100	100
150%	100	100	100	99	99	99	99	99	99	99
160%	100	100	100	98	98	97	98	98	98	98
170%	100	100	100	96	95	95	96	96	96	96
180%	100	100	100	93	93	92	92	92	92	92
190%	100	100	100	90	89	88	88	87	87	86
200%	100	100	100	86	85	84	83	82	81	80

Table 6.D.3. SEDAR 65 High Catch Sensitivity risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided as the probability of spawning stock fecundity in projection year *y* (SSF_y) being above the Minimum Stock Size Threshold (MSST), where MSST is defined as $\left(1-\bar{M}_a\right) * SSF_{MSY}$, as described above. The $Pr(SSF_y > MSST)$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	94	95	96	96	96	97	99	100	100	100
10%	94	95	96	96	96	97	99	100	100	100
20%	94	95	96	96	96	97	99	100	100	100
30%	94	95	96	96	96	97	99	100	100	100
40%	94	95	96	96	96	97	99	100	100	100
50%	94	95	96	96	96	97	99	100	100	100
60%	94	95	96	96	96	97	99	100	100	100
70%	94	95	96	96	96	97	98	99	100	100
80%	94	95	96	96	96	96	98	99	100	100
90%	94	95	96	96	96	96	98	99	100	100
100%	94	95	96	96	96	96	98	99	99	100
110%	94	95	96	96	96	96	98	99	99	99
120%	94	95	96	96	96	96	98	98	99	99
130%	94	95	96	96	96	96	97	98	99	99
140%	94	95	96	96	96	96	97	98	98	98
150%	94	95	96	96	96	96	97	97	98	98
160%	94	95	96	96	96	96	97	97	97	97
170%	94	95	96	96	96	96	97	96	96	96
180%	94	95	96	96	96	96	96	96	95	95
190%	94	95	96	96	96	96	96	95	94	94
200%	94	95	96	96	96	96	96	95	93	93

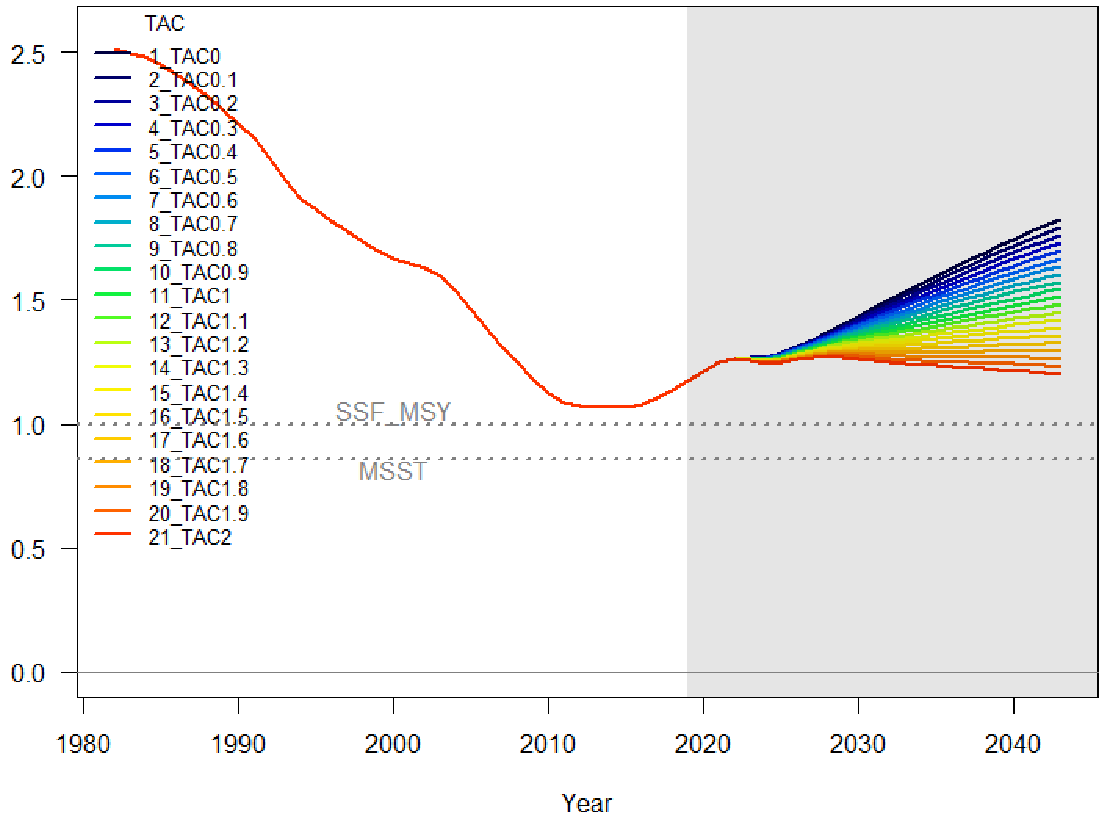


Figure 6.D.1. SEDAR 65 High Catch Sensitivity projection results (shaded area) at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of the average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided for the ratio of spawning stock fecundity in projection year y relative to spawning stock fecundity at equilibrium maximum sustainable yield (SSF_y/SSF_{MSY}; y-axis). Lines represent the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC, as described above. The minimum stock size threshold (MSST) is $(1-\bar{M}_a)$ *SSF_{MSY}, as described above.

1.16.5. **Appendix 6.E.** Low Catch Sensitivity Risk Matrices and Projection Results

Table 6.E.1. SEDAR 65 Low Catch Sensitivity risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The $Pr(SSF_y > SSF_{MSY})$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	94	95	95	95	95	96	98	99	100	100
10%	94	95	95	95	95	96	97	99	100	100
20%	94	95	95	95	95	95	96	98	99	99
30%	94	95	95	95	95	95	96	97	98	99
40%	94	95	95	95	95	95	95	96	97	97
50%	94	95	95	95	95	95	95	95	96	96
60%	94	95	95	95	95	95	94	94	94	94
70%	94	95	95	95	95	94	93	93	92	92
80%	94	95	95	95	95	94	93	91	90	89
90%	94	95	95	95	95	94	92	90	88	87
100%	94	95	95	95	95	94	91	88	86	85
110%	94	95	95	95	94	93	90	87	84	82
120%	94	95	95	95	94	93	89	85	82	80
130%	94	95	95	95	94	93	89	84	80	78
140%	94	95	95	95	94	93	88	82	78	76
150%	94	95	95	95	94	92	87	81	76	74
160%	94	95	95	95	94	92	86	80	75	72
170%	94	95	95	95	94	92	85	78	73	71
180%	94	95	95	95	94	92	85	77	72	69
190%	94	95	95	95	94	91	84	76	70	68
200%	94	95	95	95	94	91	83	75	69	66

Table 6.E.2. SEDAR 65 Low Catch Sensitivity risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The $Pr(F_y < F_{MSY})$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	81	81	80	100	100	100	100	100	100	100
10%	81	81	80	100	100	100	100	100	100	100
20%	81	81	80	100	100	100	100	100	100	100
30%	81	81	80	100	100	100	100	100	100	100
40%	81	81	80	100	100	100	100	100	100	100
50%	81	81	80	99	99	99	99	99	99	99
60%	81	81	80	96	96	96	96	96	96	96
70%	81	81	80	92	92	92	92	92	91	91
80%	81	81	80	88	88	88	87	87	86	86
90%	81	81	80	84	84	83	83	82	81	81
100%	81	81	80	80	80	79	78	78	77	76
110%	81	81	80	77	76	76	75	73	73	72
120%	81	81	80	73	73	72	71	70	69	68
130%	81	81	80	70	70	69	68	67	66	65
140%	81	81	80	68	67	67	65	64	63	62
150%	81	81	80	65	65	64	63	61	60	60
160%	81	81	80	63	63	62	61	59	58	57
170%	81	81	80	62	61	60	59	57	56	56
180%	81	81	80	60	59	58	57	56	55	54
190%	81	81	80	58	58	57	55	54	53	53
200%	81	81	80	57	56	56	54	53	52	51

Table 6.E.3. SEDAR 65 Low Catch Sensitivity risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > (1-\bar{M}_a)$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided as the probability of spawning stock fecundity in projection year *y* (SSF_y) being above the Minimum Stock Size Threshold (MSST), where MSST is defined as $(1-\bar{M}_a)$ *SSF_{MSY}, as described above. The Pr(SSF_y > MSST) is color coded to represent Pr ≥ 0.70 (green), 0.50 ≤ Pr < 0.70 (yellow), and Pr < 0.50 (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	96	97	97	96	97	97	98	100	100	100
10%	96	97	97	96	97	97	98	99	100	100
20%	96	97	97	96	97	97	98	99	100	100
30%	96	97	97	96	97	97	97	98	99	99
40%	96	97	97	96	97	97	97	98	98	99
50%	96	97	97	96	96	96	96	97	97	97
60%	96	97	97	96	96	96	96	96	96	96
70%	96	97	97	96	96	96	95	95	94	94
80%	96	97	97	96	96	96	95	93	93	92
90%	96	97	97	96	96	96	94	92	91	90
100%	96	97	97	96	96	96	93	91	89	88
110%	96	97	97	96	96	95	93	90	87	86
120%	96	97	97	96	96	95	92	88	85	83
130%	96	97	97	96	96	95	91	87	83	81
140%	96	97	97	96	96	95	90	86	81	79
150%	96	97	97	96	96	95	90	84	80	77
160%	96	97	97	96	96	94	89	83	78	76
170%	96	97	97	96	96	94	88	82	76	74
180%	96	97	97	96	96	94	87	80	75	72
190%	96	97	97	96	96	94	87	79	73	71
200%	96	97	97	96	96	93	86	78	72	69

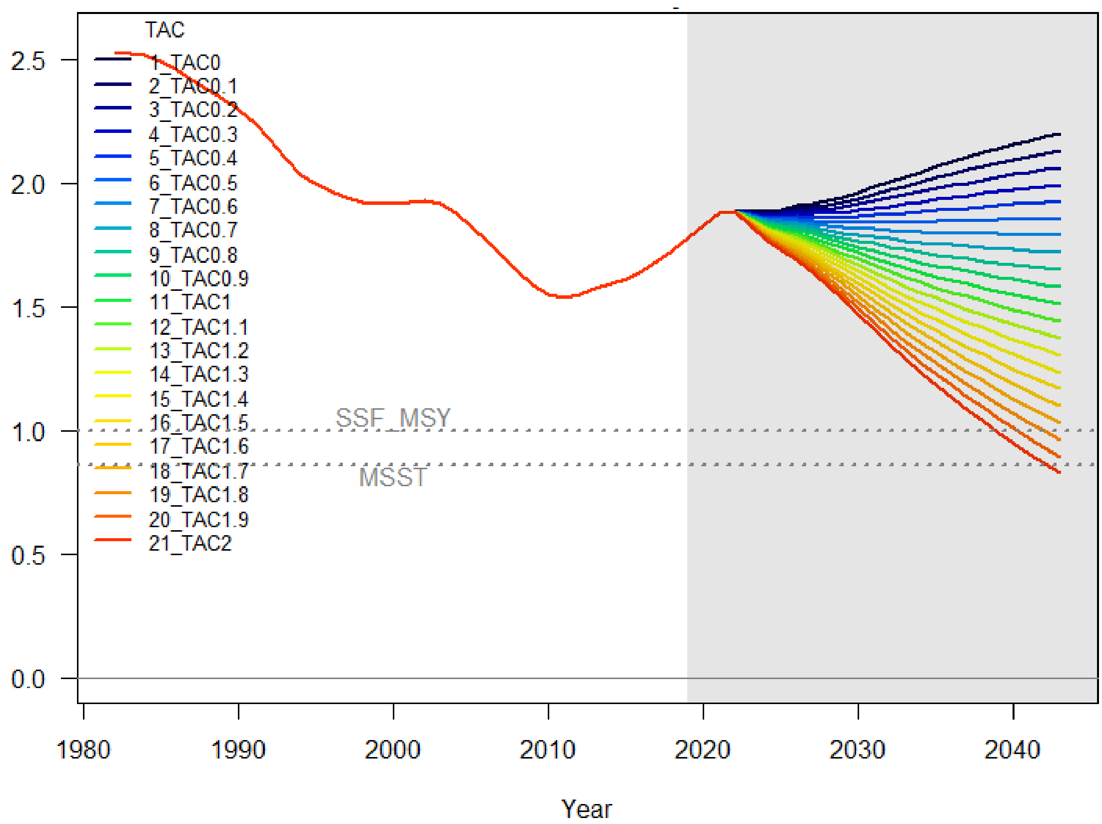


Figure 6.E.1. SEDAR 65 Low Catch Sensitivity projection results (shaded area) at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of the average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided for the ratio of spawning stock fecundity in projection year *y* relative to spawning stock fecundity at equilibrium maximum sustainable yield (SSF_y/SSF_{MSY}; y-axis). Lines represent the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC, as described above. The minimum stock size threshold (MSST) is $\left(1-\bar{M}_a\right)$ *SSF_{MSY}, as described above.

1.16.6. **Appendix 6.F.** Low Productivity Sensitivity Risk Matrices and Projection Results

Table 6.F.1. SEDAR 65 Low Productivity Sensitivity risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The $Pr(SSF_y > SSF_{MSY})$ is color coded to represent Pr ≥ 0.70 (green), 0.50 ≤ Pr < 0.70 (yellow), and Pr < 0.50 (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	99	99	100	100	100	100	100	100	100	100
10%	99	99	100	100	100	100	100	100	100	100
20%	99	99	100	100	100	100	100	100	100	100
30%	99	99	100	100	100	100	100	100	100	100
40%	99	99	100	100	100	100	100	100	100	100
50%	99	99	100	100	100	100	100	100	100	100
60%	99	99	100	100	100	100	100	100	100	100
70%	99	99	100	100	100	100	100	100	100	100
80%	99	99	100	100	100	100	100	100	100	100
90%	99	99	100	100	100	100	100	100	100	100
100%	99	99	100	100	100	100	100	100	100	100
110%	99	99	100	100	100	100	100	99	99	99
120%	99	99	100	100	100	100	99	99	99	99
130%	99	99	100	100	100	99	99	99	99	99
140%	99	99	100	100	100	99	99	99	98	98
150%	99	99	100	100	100	99	99	98	98	98
160%	99	99	100	100	100	99	99	98	97	97
170%	99	99	100	100	100	99	99	98	97	96
180%	99	99	100	100	100	99	99	97	96	95
190%	99	99	100	100	100	99	98	96	95	94
200%	99	99	100	100	99	99	98	96	94	92

Table 6.F.2. SEDAR 65 Low Productivity Sensitivity risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The Pr($F_y < F_{MSY}$) is color coded to represent Pr ≥ 0.70 (green), 0.50 ≤ Pr < 0.70 (yellow), and Pr < 0.50 (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	100	100	100	100	100	100	100	100	100	100
10%	100	100	100	100	100	100	100	100	100	100
20%	100	100	100	100	100	100	100	100	100	100
30%	100	100	100	100	100	100	100	100	100	100
40%	100	100	100	100	100	100	100	100	100	100
50%	100	100	100	100	100	100	100	100	100	100
60%	100	100	100	100	100	100	100	100	100	100
70%	100	100	100	100	100	100	100	100	100	100
80%	100	100	100	100	100	100	100	100	100	100
90%	100	100	100	100	100	100	100	100	100	100
100%	100	100	100	100	100	100	100	100	100	100
110%	100	100	100	99	99	99	99	99	99	99
120%	100	100	100	99	99	99	99	99	99	99
130%	100	100	100	97	97	97	97	97	97	97
140%	100	100	100	95	95	95	95	95	95	94
150%	100	100	100	93	93	92	92	92	91	91
160%	100	100	100	90	90	89	89	88	88	88
170%	100	100	100	87	87	86	85	85	84	84
180%	100	100	100	84	84	83	82	81	80	80
190%	100	100	100	81	80	79	78	77	76	75
200%	100	100	100	78	77	76	74	73	72	71

Table 6.F.3. SEDAR 65 Low Productivity Sensitivity risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided as the probability of spawning stock fecundity in projection year *y* (SSF_y) being above the Minimum Stock Size Threshold (MSST), where MSST is defined as $\left(1-\bar{M}_a\right)*SSF_{MSY}$, as described above. The $Pr(SSF_y > MSST)$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	100	100	100	100	100	100	100	100	100	100
10%	100	100	100	100	100	100	100	100	100	100
20%	100	100	100	100	100	100	100	100	100	100
30%	100	100	100	100	100	100	100	100	100	100
40%	100	100	100	100	100	100	100	100	100	100
50%	100	100	100	100	100	100	100	100	100	100
60%	100	100	100	100	100	100	100	100	100	100
70%	100	100	100	100	100	100	100	100	100	100
80%	100	100	100	100	100	100	100	100	100	100
90%	100	100	100	100	100	100	100	100	100	100
100%	100	100	100	100	100	100	100	100	100	100
110%	100	100	100	100	100	100	100	100	100	100
120%	100	100	100	100	100	100	100	100	100	100
130%	100	100	100	100	100	100	100	100	100	100
140%	100	100	100	100	100	100	100	100	100	99
150%	100	100	100	100	100	100	100	100	99	99
160%	100	100	100	100	100	100	100	99	99	99
170%	100	100	100	100	100	100	100	99	99	98
180%	100	100	100	100	100	100	100	99	98	98
190%	100	100	100	100	100	100	99	99	98	97
200%	100	100	100	100	100	100	99	98	97	96

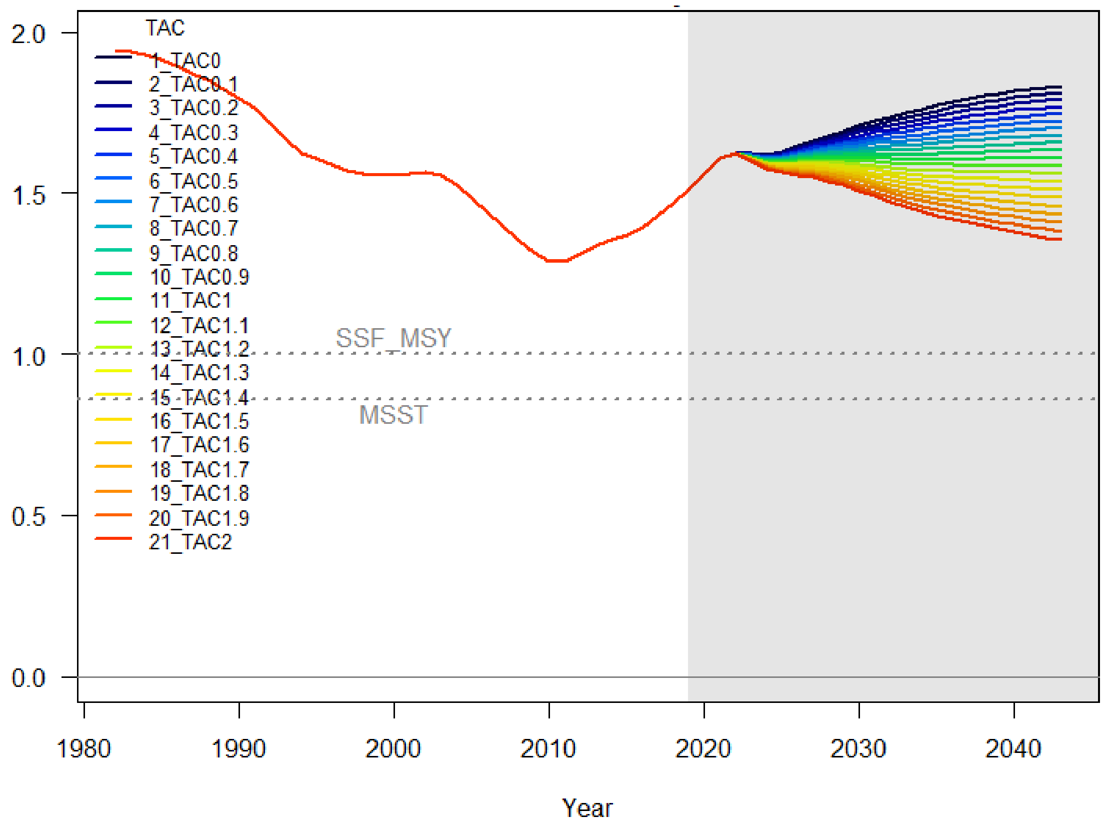


Figure 6.F.1. SEDAR 65 Low Productivity Sensitivity projection results (shaded area) at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of the average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided for the ratio of spawning stock fecundity in projection year *y* relative to spawning stock fecundity at equilibrium maximum sustainable yield (SSF_y/SSF_{MSY}; y-axis). Lines represent the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC, as described above. The minimum stock size threshold (MSST) is $\left(1-\bar{M}_a\right)$ *SSF_{MSY}, as described above.

1.16.7. **Appendix 6.G.** High Productivity Sensitivity Risk Matrices and Projection Results

Table 6.G.1. SEDAR 65 High Productivity Sensitivity risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The $Pr(SSF_y > SSF_{MSY})$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	94	95	94	94	94	96	100	100	100	100
10%	94	95	94	94	94	96	100	100	100	100
20%	94	95	94	94	94	96	100	100	100	100
30%	94	95	94	94	94	96	99	100	100	100
40%	94	95	94	94	94	95	99	100	100	100
50%	94	95	94	94	94	95	99	100	100	100
60%	94	95	94	94	94	95	98	100	100	100
70%	94	95	94	94	93	95	98	99	100	100
80%	94	95	94	94	93	94	97	98	99	99
90%	94	95	94	94	93	94	96	98	98	99
100%	94	95	94	94	93	94	95	96	97	97
110%	94	95	94	94	93	94	94	95	95	95
120%	94	95	94	94	93	93	93	92	92	92
130%	94	95	94	94	93	93	92	90	88	87
140%	94	95	94	94	93	93	90	87	84	82
150%	94	95	94	94	93	92	89	83	78	76
160%	94	95	94	94	93	92	87	80	73	69
170%	94	95	94	94	93	92	85	76	67	63
180%	94	95	94	94	93	91	83	71	61	56
190%	94	95	94	94	92	91	81	67	56	50
200%	94	95	94	94	92	91	78	63	50	44

Table 6.G.2. SEDAR 65 High Productivity Sensitivity risk matrix of cumulative normal projection probabilities for $F_y/F_{MSY} < 1$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. The Pr($F_y < F_{MSY}$) is color coded to represent Pr ≥ 0.70 (green), 0.50 ≤ Pr < 0.70 (yellow), and Pr < 0.50 (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	99	99	100	100	100	100	100	100	100	100
10%	99	99	100	100	100	100	100	100	100	100
20%	99	99	100	100	100	100	100	100	100	100
30%	99	99	100	100	100	100	100	100	100	100
40%	99	99	100	100	100	100	100	100	100	100
50%	99	99	100	100	100	100	100	100	100	100
60%	99	99	100	100	100	100	100	100	100	100
70%	99	99	100	100	100	100	100	100	100	100
80%	99	99	100	100	100	100	100	100	100	100
90%	99	99	100	100	100	100	100	100	100	100
100%	99	99	100	100	100	100	100	100	100	100
110%	99	99	100	98	98	98	99	99	99	99
120%	99	99	100	96	96	95	95	95	95	94
130%	99	99	100	92	91	90	89	88	86	86
140%	99	99	100	86	85	84	81	78	75	74
150%	99	99	100	80	78	76	72	67	64	62
160%	99	99	100	73	71	68	62	57	53	51
170%	99	99	100	66	64	60	54	49	45	43
180%	99	99	100	60	57	53	47	42	39	37
190%	99	99	100	54	51	47	41	36	34	33
200%	99	99	100	48	45	41	36	32	31	30

Table 6.G.3. SEDAR 65 High Productivity Sensitivity risk matrix of cumulative normal projection probabilities for $SSF_y/SSF_{MSY} > \left(1-\bar{M}_a\right)$ at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided as the probability of spawning stock fecundity in projection year *y* (SSF_y) being above the Minimum Stock Size Threshold (MSST), where MSST is defined as $\left(1-\bar{M}_a\right)*SSF_{MSY}$, as described above. The $Pr(SSF_y > MSST)$ is color coded to represent $Pr \geq 0.70$ (green), $0.50 \leq Pr < 0.70$ (yellow), and $Pr < 0.50$ (red).

TAC (0-200%)	2019	2020	2021	2022	2023	2025	2030	2035	2040	2043
0	97	98	97	97	97	98	100	100	100	100
10%	97	98	97	97	97	98	100	100	100	100
20%	97	98	97	97	97	98	100	100	100	100
30%	97	98	97	97	97	98	100	100	100	100
40%	97	98	97	97	97	98	100	100	100	100
50%	97	98	97	97	97	98	100	100	100	100
60%	97	98	97	97	97	98	99	100	100	100
70%	97	98	97	97	97	98	99	100	100	100
80%	97	98	97	97	97	98	99	99	100	100
90%	97	98	97	97	97	97	99	99	99	100
100%	97	98	97	97	97	97	98	98	99	99
110%	97	98	97	97	97	97	97	98	98	98
120%	97	98	97	97	97	97	97	96	96	96
130%	97	98	97	97	97	97	96	95	94	93
140%	97	98	97	97	97	97	95	93	91	89
150%	97	98	97	97	97	97	94	90	87	84
160%	97	98	97	97	97	96	93	88	82	79
170%	97	98	97	97	97	96	92	85	77	73
180%	97	98	97	97	97	96	90	81	72	67
190%	97	98	97	97	97	96	89	78	67	61
200%	97	98	97	97	96	96	87	74	61	55

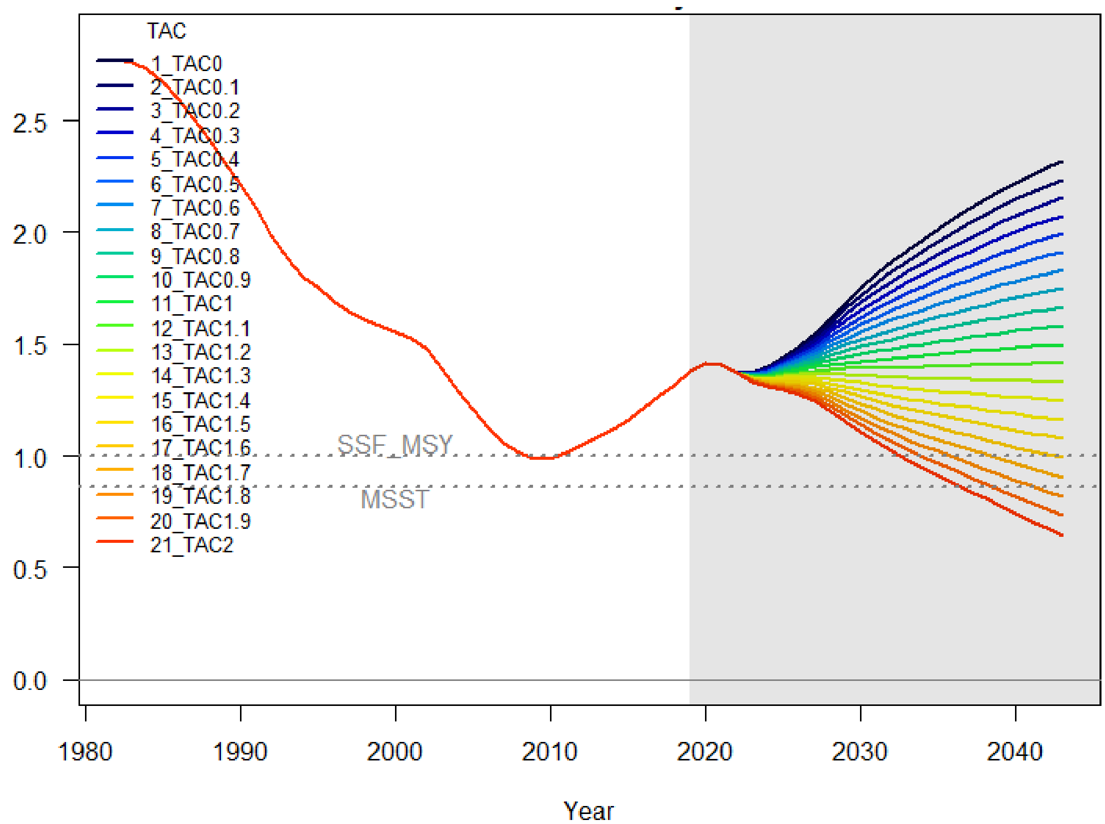


Figure 6.G.1. SEDAR 65 High Productivity Sensitivity projection results (shaded area) at alternative fixed levels of total annual removals due to fishing (TAC; 0-200% of the average annual removals from 2014 – 2018 in increments of 10%), as described above. Projection results are provided for the ratio of spawning stock fecundity in projection year *y* relative to spawning stock fecundity at equilibrium maximum sustainable yield (SSF_y/SSF_{MSY}; y-axis). Lines represent the 70% projection probabilities (30% of the cumulative normal distribution) obtained with MLE at each TAC, as described above. The minimum stock size threshold (MSST) is $\left(1-\bar{M}_a\right)$ $*SSF_{MSY}$, as described above.