SEDAR

Southeast Data, Assessment, and Review

SEDAR 82

Stock Assessment Report

South Atlantic Gray Triggerfish

April 2024

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

Table of Contents

Each section is numbered separately

SEDAR

Southeast Data, Assessment, and Review

SEDAR 82

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SECTION I: Introduction

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Table of Contents

Introduction

SEDAR 82 addressed the stock assessment for South Atlantic Gray Triggerfish. The process consisted of an in-person Data Workshop (September 2022), a series of assessment webinars (March 2023-January 2024), and an in-person Review Workshop (March 2024).

The Stock Assessment Report (SAR) is organized into 6 sections. Section I – Introduction contains a brief description of the SEDAR Process, Assessment and Management Histories for the species of interest, and the management specifications requested by the Cooperator. The Data Workshop Report can be found in Section II. It documents the discussions and data recommendations from the Data Workshop Panel. Section III is the Assessment Process 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 stages of the process can be found in Section IV for easy reference. Section V documents the discussions and findings of the Review Workshop (RW). Finally, Section VI – Addenda and Post-Review Workshop Documentation 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 SAR for South Atlantic Gray Triggerfish was disseminated to the public in May 2024. The South Atlantic Fishery Management Council's Scientific and Statistical Committee (SSC) will review the final SAR. The SSC is tasked with recommending whether the assessment represents Best Available Science, whether the results presented in the SARs are useful for providing management advice and developing fishing level recommendations for the Council. An SSC may request additional analyses be conducted or may use the information provided in the SAR as the basis for their Fishing Level Recommendations (e.g., Overfishing Limit and Acceptable Biological Catch). A review of the assessment will be conducted by the South Atlantic Fishery Management Council's SSC in October 2024, followed by the Council receiving that information at its December 2024.

1 SEDAR PROCESS DESCRIPTION

SouthEast Data, Assessment, and Review (**SEDAR**) is a cooperative Fishery Management Council process initiated in 2002 to improve the quality and reliability of fishery stock assessments in the South Atlantic, Gulf of Mexico, and US Caribbean. SEDAR seeks improvements in the scientific quality of stock assessments and the relevance of information available 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 normally organized around two workshops and a series of webinars. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. The second stage is the Assessment Process, which is conducted via a workshop and/or a series of webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. The final step 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 stages 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 Cooperator. Workshop participants are drawn from state and federal agencies, non-government organizations, Council members, Council advisors, and the fishing industry with a goal of including a broad range of disciplines and perspectives. All participants are expected to contribute to the process by preparing working papers, contributing, providing assessment analyses, and completing the workshop report.

2 MANAGEMENT OVERVIEW

2.1 Fishery Management Plan and Amendments

The following summary describes only those management actions that likely affect gray triggerfish fisheries and harvest.

Original Snapper Grouper Fishery Management Plan

The Fishery Management Plan (FMP), Regulatory Impact Review, and Final Environmental Impact Statement for the Snapper Grouper Fishery of the South Atlantic Region, approved in 1983 and implemented in August of 1983, establishes a management regime for the fishery for snappers, groupers, and related demersal species of the continental shelf of the southeastern United States in the exclusive economic zone (EEZ) under the area of authority of the South Atlantic Fishery Management Council (Council) and the territorial seas of the states, extending from the North Carolina/Virginia border through the Atlantic side of the Florida Keys to 83° W longitude. In the case of the sea basses and scup, the management regime applies only to south of Cape Hatteras, North Carolina. Regulations apply only to federal waters.

SAFMC FMP Amendments affecting Gray Triggerfish

Description of Action	FMP/Amendment	Effective Date
-Gear limitations – poisons, explosives, fish traps, trawls. -Designated modified habitats or artificial reefs as Special Management Zones (SMZs).	FMP (1983)	08/31/83
-Prohibited trawl gear to harvest fish south of Cape Hatteras, NC and north of Cape Canaveral, FL. -Directed fishery defined as vessel with trawl gear and ≥200 lbs s-g on board. -Established rebuttable assumption that vessel with s-g on board had harvested such fish in the exclusive economic zone (EEZ).	Amendment # 1	01/12/89
-Prohibited gear: fish traps except black sea bass traps north of Cape Canaveral, FL; entanglement nets; longline gear inside 50 fathoms; bottom longlines to harvest wreckfish; powerheads and bangsticks in designated SMZs off S. Carolina. -Required permits (commercial & for-hire) and specified data collection regulations. -Established an assessment group and annual adjustment procedure (framework). -No retention of snapper grouper spp. caught in other fisheries with gear prohibited in snapper grouper fishery if captured snapper grouper had no bag limit or harvest was prohibited. If had a bag limit, could retain only the bag limit	Amendment # 4	01/01/92
-Required dealer, charter and headboat federal permits. -Allowed sale under specified conditions. -Specified allowable gear and made allowance for experimental gear. -Allowed multi-gear trips in NC. -Added localized overfishing to list of problems and objectives. -Adjusted bag limit and crew specs. for charter and head boats.	Amendment # 7	01/23/95

-Established program to limit initial eligibility for snapper grouper fishery: Must demonstrate landings of any species in the snapper grouper (SG) fishery management unit (FMU) in 1993, 1994, 1995 or 1996; and have held valid SG permit between 02/11/96 and 02/11/97. -Granted transferable permit with unlimited landings if vessel landed ≥ 1,000 pounds (lbs) of snapper grouper species in any of the years -Granted non-transferable permit with 225 lb trip limit to all other vessels. -Modified problems, objectives, optimum yield (OY), and overfishing definitions. -Allowed retention of snapper grouper species in excess of bag limit on permitted vessel with a single bait net or cast nets on board.	Amendment # 8	12/14/98
-All snapper grouper without a bag limit: aggregate recreational bag limit 20 fish/person/day, excluding tomtate and blue runner.	Amendment # 9	2/24/99
-Identified essential fish habitat (EFH) and established habitat areas of particular concern (HAPC) for species in the snapper grouper FMU.	Amendment # 10	07/14/00
-Maximum sustainable yield (MSY) proxy = 40% static SPR. -Overfishing level = F>F30% static SPR. -Approved definitions for overfished and overfishing. MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}. MFMT = F_{MSY}	Amendment # 11	12/02/99
-Extended for an indefinite period the regulation prohibiting fishing for and possessing snapper grouper spp. within the *Oculina* Experimental Closed Area.	Amendment #13A (2003b)	04/26/04
-Established eight deepwater Type II marine protected areas (MPAs) to protect a portion of the population and habitat of long-lived deepwater snapper grouper species. Also protected known spawning areas of many snapper grouper species including gray triggerfish.	Amendment #14 (2007)	2/12/09

-Prohibit the sale of bag-limit caught snapper grouper species.	Amendment # 15B	2/15/10
-Captain and crew on for-hire trips cannot retain the bag limit of vermilion snapper and species within the 3-fish grouper aggregate. -For vermilion snapper: directed com quota split Jan-June and July- Dec; reduce bag limit from 10 to 5 and a rec closed recreational season November through March.	Amendment # 16	7/29/09
-Provide presentation of spatial information for EFH and EFH-HAPC designations under the Snapper Grouper FMP.	Amendment #19 (Comprehensive Ecosystem-Based Amendment 1)	7/22/10
-Required use of non-stainless steelcircle hooks when fishing for snapper grouper species with hook-and-line gear north of 28 deg. N latitude in the South Atlantic EEZ.	Amendment #17A	3/3/11
-Establish acceptable biological catch (ABC) control rules, establishABCs, sector allocations, annual catch limits (ACLs), and accountability measures (AMs) for species not undergoing overfishing. - Gray triggerfish commercial ACL = 305,262 lb ww; recreational ACL = 367,303 lb ww. - Commercial AM for gray triggerfish is in season closure whenACL met; recreational AM is to reduce length of fishing season following ACL overage as needed. -Remove some species from SouthAtlantic FMU and designate others as ecosystem component species.	Amendment # 25 (Comprehensive ACL Amendment)	4/16/12
- Designate the Deepwater MPAs asEFH-HAPCs. - Limit harvest of snapper grouper species in SC SMZs to the bag limit.	Amendment #23 (Comprehensive Ecosystem-based Amendment 2)	1/30/12
-Modify the restriction on retention of bag limit quantities of vermilion snapper and species within the 3-fishgrouper aggregate by captain and crew of for-hire vessels -Minimize regulatory delay when adjustments to snapper grouper species' ABC, ACLs, and ACTs areneeded as a result of new stock assessments. -Increase the number of allowable crew members from three to four on dual-permitted vessels.	Amendment #27	1/27/14

-Establish a 12-inch (30.5-cm) fork length (FL) minimum size limit for gray triggerfish in Federal waters off North Carolina, South Carolina, and Georgia for both the commercial and recreational sectors. -Increase the minimum size limit for gray triggerfish off the east coast of Florida from 12 inches (30.5 cm), total length to 14 inches (35.6 cm), FL for both the commercial and recreational sectors. -Establish a total ABC/ACL of 717,000 lbs ww (for gray triggerfish the SAFMC set the ACL = ABC) and set the commercial ACL to 312,325 lbs ww and the recreational ACL to 404,675 lbs ww. - Establish a commercial split season for gray triggerfish with 50% of the commercial ACL allocated to January through June and 50% to July-December - Establish a commercial trip limit of 1,000 lbs ww for gray triggerfish	Amendment #29	7/1/2015
- Modified accountability measures	Amendment #34	2/22/2016

SAFMC Regulatory Amendments affecting Gray Triggerfish

Description of Action	Amendment	Effective Date
-Prohibited fishing in SMZs except with hand-held hook-and-line and spearfishing gear.	Regulatory Amendment # 1	03/27/87
-Established 2 artificial reefs off Ft. Pierce, FL as SMZs.	Regulatory Amendment # 2	03/30/89
-Established artificial reef at Key Biscayne, FL as SMZ.	Regulatory Amendment # 3	11/02/90
-Established 8 SMZs off S. Carolina, where only hand-held, hook-and-line gear and spearfishing (excluding powerheads) was allowed.	Regulatory Amendment # 5	07/31/93
-Established actions which applied only to EEZ off Atlantic coast of FL: Bag limits – 5 hogfish/person/day (recreational only), 2 cubera snapper/person/day > 30” TL; 12” TL – gray triggerfish.	Regulatory Amendment # 6	05/22/95
-Established 10 SMZs at artificial reefs off South Carolina.	Regulatory Amendment # 7	01/29/99

-Established 12 SMZs at artificial reefs off Georgia; revised boundaries of 7 existing SMZs off Georgia to meet CG permit specs; restricted fishing in new and revised SMZs.	Regulatory Amendment # 8	11/15/00
- Establish trip limits for vermilion snapper and gag, increase trip limit for greater amberjack, and reduce bag limit for black sea bass.	Regulatory Amendment # 9	Bag limit: 6/22/11 Trip limits: 7/15/11
-Revise the ABCs, ACLs (including sector ACLs), and ACTs implemented by the ComprehensiveACL Amendment (SAFMC 2011c).The revisions may prevent a disjunction between the established ACLs and the landings used to determine if AMs are triggered. - Gray triggerfish commercial ACL = 272,880 lb ww; recreational ACL = 353,638 lb ww.	Regulatory Amendment # 13	7/17/13
-Adjust ACLs for vermilion snapper and red porgy, and remove the 4-month recreational closure for vermilion snapper.	Regulatory Amendment # 18	9/5/13
-Increase yellowtail snapper ACL. -Remove measure that closes all shallow water groupers when the gag commercial ACL is met. -Reduce gag commercial ACL.	Regulatory Amendment #15	9/12/13
-Increase commercial and recreational ACL for black sea bass. -Establish November-April black sea bass pot prohibition.	Regulatory Amendment #19	9/23/13 (ACL) 10/23/13 (pots)
-Change start date of commercial and recreational fishing years for greater amberjack to March 1 -Change commercial fishing year for black sea bass to Jan 1-Dec 31 -Change recreational fishing year for black sea bass to April 30-March 31 -Establish 300 pound gw commercial trip limit for black sea bass using hook-and-line gear from Jan 1 to Apr 30. From May 1 to Dec31, the trip limit is 1,000 pounds gwfor hook-and-line gear and pot gear.NOTE: black sea bass pots prohibited annually from Nov 1 to April 30. -Revise AMs for vermilion snapper and black sea bass (recreational) -Reduce gag trip limit to 500 poundsgw when 75% of ACl is met	Regulatory Amendment # 14	12/8/14

- Best fishing practices & powerheads	Regulatory Amendment 29	7/15/2020
- Reduced commercial minimum size limit for gray triggerfish off east FL to 12 inches fork length	Regulatory Amendment 27	2/26/2020
- Reduced recreational minimum size limit for gray triggerfish off east FL to 12 inches fork length - Modified the recreational 20-fish aggregate, such that no more than 10 fish within the aggregate can be gray triggerfish	Regulatory Amendment 26	3/20/2020
- 30 Special Management Zones off NC & 4 off SC were established at artificial reef sites	Regulatory Amendment 34	5/3/2021

2.2 Emergency and Interim Rules

Emergency Rule effective 9/3/1999: reopen the Amendment 8 Snapper Grouper Permit application process.

Emergency Rule effective 12/3/2010: Delay the effective date of the area closure for snapper grouper species implemented through Amendment 17A.

2.3 Secretarial Amendments

None

2.4 Control Date Notices

Notice of Control Date effective July 30, 1991: Anyone entering federal snapper grouper fishery (other than for wreckfish) in the EEZ off S. Atlantic states after 07/30/91 was not assuredof future access if limited entry program developed.

Notice of Control Date effective October 14, 2005: The Council is considering management measures to further limit participation or effort in the commercial fishery for snapper grouper species (excluding Wreckfish).

Notice of Control Date effective March 8, 2007: The Council may consider measures to limit participation in the snapper grouper for-hire fishery.

Notice of Control Date effective January 31, 2011: Anyone entering federal snapper grouper fishery off S. Atlantic states after 09/17/10 was not assured of future access if limited entry program is developed.

Notice of Control Date effective June 15, 2016: Fishermen entering the federal for-hire recreational sector for the Snapper Grouper fishery after June 15, 2016, was not assured of future access should a management regime that limits participation in the sector be prepared and implemented.

2.5 Management Program Specifications

2.5.1 General Management Information

South Atlantic

Species	Gray triggerfish
Management Unit	Southeastern US
Management Unit Definition	NC/VA border southward to the SAFMC/GMFMC boundary
Management Entity	South Atlantic Fishery Management Council
Management Contacts SERO / Council	SAFMC: Michael Schmidtke SERO: Jack McGovern
Current stock exploitation status	Unknown
Current stock biomass status	Unknown

2.5.2 Management Parameters

Criteria	South Atlantic – Proposed (values from SEDAR 82)		
	Definition	Base Run Values	Median of Base Run MCBs
MSST[1]	(1-M) B_{MSY}		
	0.5 B_{MSY}		
MFMT	F_{MSY}, if available; $F_{30\%\ SPR}$ proxy [2]		
F_{MSY}	F_{MSY}		
MSY	Yield at F_{MSY}, landings and discards, pounds and numbers		
B_{MSY}[1]	Total or spawning stock, to be defined		
R_{MSY}	Recruits at MSY		
F Target	75% F_{MSY}		
Yield at F_{TARGET} (equilibrium)	Landings and discards, pounds and numbers		
M	Natural mortality, average across ages		
Terminal F	Exploitation		
Terminal Biomass[1]	Biomass		
Exploitation Status	F/MFMT		
Biomass Status[1]	B/MSST		
	B/B_{MSY}		
Generation Time			
$T_{REBUILD}$ (if appropriate)			

1. Biomass values reported for management parameters and status determinations should be based on the biomass metric recommended through the assessment process and the Scientific and Statistical Committee (SSC). This may be total, spawning stock or some measure thereof, and should be applied consistently in this table.

2. If an acceptable estimate of F_{MSY} is not provided by the assessment a proxy value may be considered. The current F_{MSY} proxy for this stock is F30% SPR; other values may be recommended by the assessment process for consideration by the SSC.

NOTE: "Proposed" columns are for indicating any definitions that may exist in FMPs or amendments that are currently under development and should therefore be evaluated in the current assessment. Please clarify whether landings parameters are 'landings' or 'catch' (Landings + Discard). If 'landings', please indicate how discards are addressed.

NOTE: Because this is the first assessment of this stock, there are no existing values for management parameters. The default proxy for F_{MSY} is F30%SPR.

2.5.3 Stock Rebuilding Information

N/A

2.5.4 General Projection Specifications

Snapper Grouper Amendment 29 includes an action to modify the ABC and ACLs for gray triggerfish and change the minimum size limit for gray triggerfish. Projections should accountfor changes in selectivity due to regulation changes in Snapper Grouper Amendment 29.

Amendment 29 was submitted for Secretarial Review on October 14, 2014. NMFS approved the amendment on February 20, 2015. As of March 5, 2015, the regulations have not been implemented. Implementation is expected in April 2015. The amendment will specify a 12 inch FL minimum size limit for gray triggerfish in federal waters off of the NC, SC, and GA for both the recreational and commercial sectors; will specify 14 inch FL minimum size limit for gray triggerfish in federal waters off of the east coast of Florida for the commercial and recreational sectors; and will change the total ABC/ACL to 717,000 lbs ww (for gray triggerfish the SAFMC set the ACL = ABC) and set the commercial ACL to 312,325 lbs. ww and the recreational ACL to 404,675 lbs. ww.

South Atlantic

Requested Information	Value
First Year of Management	Assume management begins in 2025. However, if stock neither overfished or overfishing, a projection with the revised ABC and OFL should be provided assuming that landings limits are changed in the 2025 fishing year.
Interim basis	ACL, if landings are within 10% of the ACL; average landings otherwise.
Projection Outputs	
Landings	Pounds and numbers
Discards	Pounds and numbers
Exploitation	F & Probability F>MFMT
Biomass (total or SSB, as appropriate)	B & Probability B>MSST (and Prob. B>B_{MSY} if under rebuilding plan)
Recruits	Number

2.5.5 Base Run Projections Specifications. Long Term and Equilibrium conditions.

Criteria	Definition	If overfished	If overfishing	Neither overfished nor overfishing
Projection Span	Years	$T_{REBUILD}$	10	10
Projection Values	$F_{CURRENT}$	X	X	X
	F_{MSY}	X	X	X
	75% F_{MSY}	X	X	X
	$F_{REBUILD}$	X		
	F=0	X		

NOTE: Exploitation rates for projections may be based upon point estimates from the base run (current process) or upon the median of such values from the MCBs evaluation of uncertainty. The critical point is that the projections be based on the same criteria as the management specifications.

2.5.6 P-star projections. Short term specifications for OFL and ABC recommendations. Additional P-star projections may be requested by the SSC once ABC control rule is applied.

Criteria		Overfished	Not overfished
Projection Span	Years	Interim + 5	Interim + 5
Probability Values	50%	Probability of stock rebuild	Probability of overfishing

2.5.7 Quota Calculation Details

If the stock is managed by quota, please provide the following information.

Current acceptable biological (ABC)	ABC = 717,000 pounds ww
Value	
Commercial annual catch limit (ACL)	312,325 lbs ww (split season: 156,162 lbs ww January-June; 156,162 lbs ww July-December)
Recreational ACL	404,675 lbs ww
Next Scheduled Quota Change	
Annual or averaged quota?	Annual (seasonal commercial quotas with carryover of unused ACL from season 1 to season 2)
If averaged, number of years to average	n/a
Does the quota include bycatch/discard?	n/a*

*The ABC values are "landings only" provided by SSC through their ABC control rule for data poor species. ABC and ACLs provided do not include discards.

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

The South Atlantic SSC recommended the ABC using the Only Reliable Catch Stock (ORCS) approach from the ABC Control Rule in April 2013. The Council then set ABC=ACL through Amendment 29 and specified sector ACLs according to existing allocation percentages (based on historic catch) from Regulatory Amendment 13.

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 SSC's recommended ABC was for landed catch only did not include estimates of discard and bycatch.

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

An assessment for gray triggerfish was most recently attempted in 2013 through SEDAR 32. An ageing issue was identified with Gray Triggerfish and it was subsequently removed from SEDAR 32.

Therefore landings based methods were used to determine ABC, with the current value being derived from the ORCS method.

2.6 Regulatory Timeline

The following tables provide a timeline of federal management actions by fishery.

2.6.1 Annual Commercial Gray Triggerfish Regulatory Summary

Year	Fishing Season	Size Limit	Trip Limit (lbs ww)	Seasonal Quota	ACL (lbs ww)	Open Date	Close Date	Other
1993	Calendar Year	none	none		none	1/1		
1994	Calendar Year	none	none		None	1/1		
1995	Calendar Year	12" TL (began in May) (E FL only)	none		None	1/1		
1996-2011	Calendar Year	12" TL (E FL only)	none		None	1/1		
2012	Calendar Year	12" TL (E FL only)	none		321,551	1/1	9/11	Re-opened 12/12 to 12/19
2013	Calendar Year	12" TL (E FL only)	none		342,531	1/1	7/7	Re-opened 10/28 to 11/14
2014	Calendar Year	12" TL (E FL only)	none		282,328	1/1	5/12	
2015	Jan-June	12" TL (E FL only)	none	172,439	344,878	1/1	5/8	
	July-Dec	E FL: 14" FL GA-NC: 12" FL	1,000	172,439		7/1	9/8	
2016	Jan-June	E FL: 14" FL GA-NC: 12" FL	1,000	155,542	311,084	1/1	4/2	Re-opened 6/13
	July-Dec		1,000	155,542		7/1	12/16	
2017	Jan-June	E FL: 14" FL GA-NC: 12" FL	1,000	160,257	320,514	1/1	none	
	July-Dec		1,000	160,257		7/1	11/8	
2018	Jan-June	E FL: 14" FL GA-NC: 12" FL	1,000	160,255	320,510	1/1	6/13	
	July-Dec		1,000	160,255		7/1	11/6	
2019	Jan-June	E FL: 14" FL GA-NC: 12" FL	1,000	163,399	326,799	1/1	4/17	
	July-Dec		1,000	163,399		7/1	10/27	
2020	Jan-June	E FL: 14" FL (ended in March)/ 12" FL (began in March) GA-NC: 12" FL	1,000	157,162	314,325	1/1	none	
	July-Dec	12" FL	1,000	157,162		7/1	11/29	

2.6.2 Annual Recreational Gray Triggerfish Regulatory Summary

Year	Fishing Season	Size Limit	Bag Limit	ACL (lbs ww)	Open Date	Close Date	Other
1993	Calendar Year	none	none	none	1/1		
1994	Calendar Year	none	none	none	1/1		
1995	Calendar Year	12” TL (E FL only) (began in May)	none	none	1/1		
1996-1998	Calendar Year	12” TL (E FL only)	none	none	1/1		
1999	Calendar Year	12” TL (E FL only)	Included in 20 fish aggregate snapper grouper limit (effective in February)	none	1/1		
2000-2011	Calendar Year	12” TL (E FL only)	Included in 20 fish aggregate snapper grouper limit	none	1/1		
2012	Calendar Year	12” TL (E FL only)	Included in 20 fish aggregate snapper grouper limit	367,303	1/1		
2013	Calendar Year	12” TL (E FL only)	Included in 20 fish aggregate snapper grouper limit	353,638	1/1		
2014	Calendar Year	12” TL (E FL only)	Included in 20 fish aggregate snapper grouper limit	353,638	1/1	11/26/14	In-season closure due to exceeding ACL in previous year
2015	Calendar Year	12” TL (E FL only) (ended in July) E FL: 14” FL GA-NC: 12” FL (began in July)	Included in 20 fish aggregate snapper grouper limit	404,675	1/1		
2016-2019	Calendar Year	E FL: 14” FL GA-NC: 12” FL	Included in 20 fish aggregate snapper grouper limit	404,675	1/1		
2020	Calendar Year	E FL: 14” FL (ended in March)/ 12” FL (began in March) GA-NC: 12” FL	10 fish (began in March); Included in 20 fish aggregate snapper grouper limit	404,675	1/1		

2.7 Closures due to Meeting Commercial Quota or Commercial/Recreational ACL

Commercial: 9/11/2012 (Re-opened 12/12-12/19); 7/7/2013 (Re-opened 10/28-11/14); 5/12/2014; 5/8/2015 (Season 1); 9/8/2015; 4/2/2016 (Season 1; re-opened 6/13); 12/16/2016; 11/8/2017; 6/13/2018 (Season 1); 11/6/2018; 4/17/2019 (Season 1); 10/27/2019

- *Season 1 indicates closure due to meeting the January through June commercial seasonal quota, which is 50% of the ACL*

Recreational: 11/26/14 (Closed when 74% of ACL was harvested because ACL exceeded by 6% in 2013)

2.8 State Regulatory History

2.8.1 North Carolina

There are currently no North Carolina state-specific regulations for gray triggerfish. North Carolina has complemented federal regulations for all snapper grouper species via proclamation authority since 1991. Between 1992 and 2005, species-specific regulations were added to the proclamation authority contained in rule 15A NCAC 03M .0506. In 2002, North Carolina adopted its Inter-Jurisdictional Fishery Management Plan (IJ FMP), which incorporates all ASMFC and council-managed species by reference, and adopts all federal regulations as minimum standards for management. In completing the 2008 update to the IJ FMP, all species-specific regulations were removed from rule 15A NCAC 03M .0506, and proclamation authority to implement changes in management was moved to rule 15A NCAC 03M .0512. Since this time, all snapper grouper regulations have been contained in a single proclamation, which is updated anytime an opening/closing of a particular species in the complex occurs, as well as anychanges in allowable gear, required permits, etc. Beginning in 2015, commercial and recreational regulations are contained in separate proclamations. The most current Snapper Grouper proclamations (and all previous versions) can be found using this link: http://portal.ncdenr.org/web/mf/proclamations.

15A NCAC 03M .0506 SNAPPER-GROUPER COMPLEX

(a) In the Atlantic Ocean, it is unlawful for an individual fishing under a Recreational Commercial Gear License with seines, shrimp trawls, pots, trotlines or gill nets to take anyspecies of the Snapper-Grouper complex.

(b) The species of the snapper-grouper complex listed in the South Atlantic Fishery Management Council Fishery Management Plan for the Snapper-Grouper Fishery of the SouthAtlantic Region are hereby incorporated by reference and copies are available via the Federal Register posted on the Internet at www.safmc.net and at the Division of Marine Fisheries, P.O.Box 769, Morehead City, North Carolina 28557 at no cost.

History Note: Authority G.S. 113-134; 113-182; 113-221; 143B-289.52;
Eff. January 1, 1991;

Amended Eff. April 1, 1997; March 1, 1996; September 1, 1991;
Temporary Amendment Eff. December 23, 1996;
Amended Eff. August 1, 1998; April 1, 1997;
Temporary Amendment Eff. January 1, 2002; August 29, 2000; January 1, 2000; May 24, 1999; Amended Eff. October 1, 2008; May 1, 2004; July 1, 2003; April 1, 2003; August 1, 2002; Readopted Eff. April 1, 2019.Temporary Amendment Eff. January 1, 2002; August 29, 2000; January 1, 2000; May 24, 1999;
Amended Eff. October 1, 2008; May 1, 2004; July 1, 2003; April 1, 2003; August 1, 2002.

15A NCAC 03M .0512 COMPLIANCE WITH FISHERY MANAGEMENT PLANS

(a) In order to comply with management requirements incorporated in Federal Fishery Management Council Management Plans or Atlantic States Marine Fisheries Commission Management Plans or to implement state management measures, the Fisheries Director may, byproclamation, take any or all of the following actions for species listed in the InterjurisdictionalFisheries Management Plan:
(1) Specify size;
(2) Specify seasons;
(3) Specify areas;
(4) Specify quantity;
(5) Specify means and methods; and
(6) Require submission of statistical and biological data.
(b) Proclamations issued under this Rule shall be subject to approval, cancellation, or modification by the Marine Fisheries Commission at its next regularly scheduled meeting or anemergency meeting held pursuant to G.S. 113-221.1.
History Note: Authority G.S. 113-134; 113-182; 113-221; 113-221.1; 143B-289.4;
Eff. March 1, 1996;
Amended Eff. October 1, 2008;
Pursuant to G.S. 150B-21.3A, rule is necessary without substantive public interest Eff. January 9, 2018.

2.8.2 South Carolina

Sec. 50-5-2730 of the SC Code states:
"Unless otherwise provided by law, any regulations promulgated by the federal government under the Fishery Conservation and Management Act (PL94-265) or the Atlantic Tuna Conservation Act (PL 94-70) which establishes seasons, fishing periods, gear restrictions, sales restrictions, or bag, catch, size, or possession limits on fish are declared to be the law ofthis State and apply statewide including in state waters."

As such, South Carolina gray triggerfish regulations are (and have been) derived directly from the federal regulations as promulgated under Magnuson-Stevens Fishery Conservation and

Management Act. There are no known separate gray triggerfish regulations that have been codified in the South Carolina Code.

2.8.3 Georgia

There are currently no Georgia state regulations for gray triggerfish. However, the authority rests with the Georgia Board of Natural Resources to regulate this species if deemed necessary in the future.

2.8.4 Florida

Year	Minimum Size Limit	Recreational Daily Harvest Limit	Commercial Daily Harvest Limit	Regulation Changes
1995	12" TL	None	None	
1996	12" TL	None	None	
1997	12" TL	None	None	
1998	12" TL	None	Same as federal waters	Required landing in whole condition Designated as restricted species Required federal commercial permit for fishing in state waters Required hook-and-line and spearing as only allowable gear.
1999	12" TL	None	Same as federal waters	
2000	12" TL	None	Same as federal waters	
2001	12" TL	None	Same as federal waters	
2002	12" TL	None	Same as federal waters	
2003	12" TL	None	Same as federal waters	
2004	12" TL	None	Same as federal waters	
2005	12" TL	None	Same as federal waters	
2006	12" FL	None	Same as federal waters	Change in the legal measurement from TL to FL
2007	12" FL	None	Same as federal waters	
2008	12" FL	None	Same as federal waters	

2009	12” FL	None	Same as federal waters	
2010	12” FL	None	Same as federal waters	
2011	12” FL	None	Same as federal waters	
2012	12” FL	None	Same as federal waters	
2013	12” FL	None	Same as federal waters	
2014	12” FL	None	Same as federal waters	
2015	14” FL	None	Same as federal waters	Increased the minimum size limit to 14” FL Raised the statewide importation and sale size limit to 14” FL
2016	12” FL	10 fish per person per day	Same as federal waters	Decreased the minimum size limit to 12” FL Decreased the statewide importation and sale size limit to 12” FL Created a recreational bag limit of 10 fish per person per day
2017	14” FL	10 fish per person per day	Same as federal waters	
2018	14” FL	10 fish per person per day	Same as federal waters	
2019	14” FL	10 fish per person per day	Same as federal waters	
2020	14” FL	10 fish per person per day	Same as federal waters	Required anyone who intends to fish for or harvest certain reef fish (including gray triggerfish) from a private recreational vessel in Florida to obtain the State Reef Fish Angler designation.
2021	14” FL	10 fish per person per day	Same as federal waters	Required new gear requirements when fishing for reef fish (including gray triggerfish) using hook-and-line and natural baits.

[1994]

REEF FISH, CH 46-14, F.A.C. (Effective March 1, 1994)

- Establishes a minimum size limit of 12 inches for gray triggerfish, effective January 1,1995

[1998]
REEF FISH, CH 46-14, F.A.C. (Effective December 31, 1998)

- Added gray triggerfish and other reef fish species to conform to new or existing federal regulations
- Requires gray triggerfish to be landed in whole condition.
- Designated gray triggerfish as a restricted species
- Requires federal commercial fishing permit when fishing in state waters
- Requires hook and line and spearing as the only allowable gear.

[2006]
REEF FISH, CH 68B-14, F.A.C. (Effective July 1, 2006)

- Provides that, for purposes of determining the legal size of reef fish species, "total length" means the straight line distance from the most forward point of the head withthe mouth closed, to the farthest tip of the tail with the tail compressed or squeezed, while the fish is lying on its side
- Changes the legal measurement for gray triggerfish from total length to fork length

[2015]
REEF FISH, CH 68B-14, F.A.C. (Effective July 7, 2015)

- Sets a 14-inch minimum fork length minimum size limit for gray triggerfish in Atlantic state waters
- Raises the minimum size limit for the importation and sale of gray triggerfish to 14 inches fork length

[2016]
REEF FISH, CH 68B-14, F.A.C. (Effective Nov. 17, 2016)

- Reduces the recreational and commercial minimum size limits to 12 inches fork length for harvest in Atlantic Ocean and statewide importation and sale.
- Creates a recreational bag limit of 10 fish in Atlantic state waters.

[2020]
REEF FISH, CH 68B-14, F.A.C. (Effective July 1, 2020)

- Requires anyone who intends to fish for or harvest certain reef fish (including gray triggerfish) from a private recreational vessel in Florida to obtain the State Reef Fish Angler designation.

[2021]
REEF FISH, CH 68B-14, F.A.C. (Effective January 1, 2021)

- Requires anyone fishing for reef fish (including gray triggerfish) using hook-and-line gear and natural baits to use the following hooks:
    - North of 28° North latitude: non-offset, non-stainless-steel circle hooks.
    - South of 28° North latitude: non-stainless-steel hooks.

3 ASSESSMENT HISTORY AND REVIEW

South Atlantic Gray Triggerfish has been assessed by catch curve analysis and resulting static spawning potential ratios (SPR) for the 1988, 1990, 1996, and 1999 fishing years (Beaufort Laboratory 1991; Broome et al. 2011; Huntsman et al. 1992; Potts et al. 1998; Potts and Brennan 2001). Annual age composition estimates were derived from length composition data and age-length keys based on limited ageing data. Since age at maturity was unknown, it was assumed to be the average age to attain one-half asymptotic length. Additionally, estimated fishing mortality rates for the assessed years were conditional on assumed natural mortality rates ranging from 0.2 to 0.3. Estimated SPR values were 30%, 27%, 29%, and 62% for the 1988, 1990, 1996, and 1999 fishing years, respectively.

A subsequent assessment was conducted by students and staff of the NMFS RTR unit at Virginia Polytechnic Institute and State University (Broome et al. 2011). This effort also relied on catch curve analyses but also attempted to fit an age aggregated surplus production model (ASPIC; Prager 2005) to index and landings data from the late 1980's to 2009. The study yielded no conclusive findings as to the status of the stock and the authors suggested many of the same research recommendations as those highlighted in earlier assessments.

A benchmark assessment for South Atlantic Gray Triggerfish was conducted through the SEDAR process and was completed in 2016 with an assessment period 1988-2014 (SEDAR 2016). The SEDAR 41 assessment had passed the assessment workshop and progressed to a CIE review, when on the final day of the review, a consequential error was discovered in the age composition data associated with the one index of abundance (SERFS trap/video) in the age-structured model. The age data that had been provided represented uncorrected counts of annuli in the aging structures, rather than corrected calendar ages, as had been intended. As a result, a large proportion of the ages in model years 1991 – 2007 were one-year younger than they should have been. This error could not be resolved in the remaining hours of the review workshop and the CIE Review Panel did not recommend the assessment for management (SEDAR 2016). Quoting the Executive Summary of the SEDAR 82 Review Workshop Report (SEDAR 2016, Section V; pdf page 413):

> "[a]n error with the Chevron Trap survey age composition data used in the base configuration of the BAM model was discovered during the RW (the age compositions used at the Assessment Workshop were based on the number of annuli and the corrected data were based on calendar-year age). Based on the magnitude of changes to the data, results and model diagnostics developed from the Assessment Workshop base model as well as concerns about overfitting the CVID survey, the Review Panel felt that the proposed base model parameterization was inappropriate to provide information on Gray Triggerfish stock status or benchmarks."

An age aggregated surplus production model (ASPIC; Prager 2005) had also been run, as a supporting analysis. But due to low contrast in the landings and index of abundance, it was considered non-informative, and was also not recommended for management.

The error in the age data and its effect on the model results dictate that the assessment results documented in the SEDAR 41 report (SEDAR 2016) should be interpreted with caution. However, many other data sources and life history inputs provided to the SEDAR 41 assessment and modeling decisions that occurred during the SEDAR process, were sound, and were reviewed favorably by the CIE panel. Thus, while all inputs to the SEDAR 82 assessment have been updated where appropriate, and special attention has been given to ensure the quality of the aging data, the current assessment drew upon and benefitted from much of the work done by the many contributors to the SEDAR 41 assessment.

Beaufort Laboratory. 1991. South Atlantic snapper grouper assessment 1991. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407 page 21.

Broome, M., D. Claar, E. Hamman, T. Matthews, M. Salazar, K. Shugart-Schmidt, A. Tillman, M. Vincent, and J. M. Berkson. 2011. Exploratory assessment of four stocks in the US South Atlantic: bank sea bass [Centropristis ocyurus], gray triggerfish [Balistes capriscus], sand perch [Diplectrum formosum], tomtate [Haemulon aurolineatum. NOAA Technical Memorandum NMFS-SEFSC-617 page 133.

Huntsman, G., J. Potts, R. Mays, R. Dixon, P. Willis, M. Burton, and B. Harvey. 1992. A stock assessment of the snapper-grouper complex in the US South Atlantic based on fish caught in 1990. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407 page 104.

Potts, J. C., and K. Brennan. 2001. Trends in catch data and estimated static SPR values for fifteen species of reef fish landed along the southeastern United States. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407 page 41.

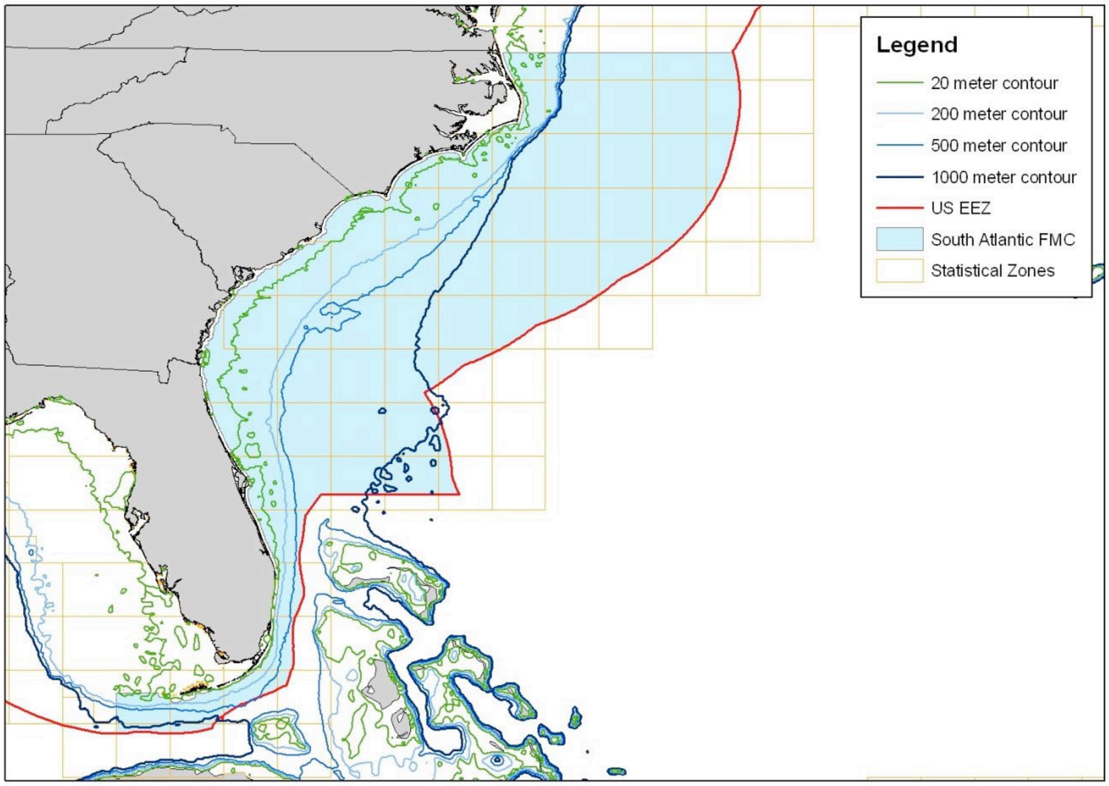
Potts, J. C., M. L. Burton, and C. S. Manooch III. 1998. Trends in catch data and estimated static SPR values for fifteen species of reef fish landed along the southeastern United States. Report to the South Atlantic Fishery Management Council, One Southpark Circle, Suite 306, Charleston, SC 29407 page 45.

Prager, M. H., 2005. User's Manual for ASPIC: A Stock-Production Model Incorporating Covariates (ver. 5) And Auxiliary Programs. National Marine Fishery Service, Beaufort Laboratory Document BL-2004-01, Beaufort, NC.

SEDAR. 2016. SEDAR 41 Stock Assessment Report: South Atlantic Gray Triggerfish. SEDAR, North Charleston SC page 428.

4 REGIONAL MAPS

Figure 4.1 South Atlantic Fishery Management Council and EEZ Boundaries.



5 SEDAR ABBREVIATIONS

ABC	Acceptable 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
APAIS	Access Point Angler Intercept Survey
ASMFC	Atlantic States Marine Fisheries Commission
B	Biomass (stock) level
BAM	Beaufort Assessment Model
B_{msy}	B capable of producing MSY on a continuing basis
BSIA	Best Scientific Information Available
CHTS	Coastal Household Telephone Survey
CFMC	Caribbean Fishery Management Council

CIE	Center for Independent Experts
CPUE	Catch Per Unit Effort
EEZ	Exclusive Economic Zone
F	Fishing mortality (instantaneous)
FES	Fishing Effort Survey
FIN	Fisheries Information Network
F_{MSY}	F to produce MSY under equilibrium conditions
F_{OY}	F rate to produce OY under equilibrium
$F_{XX\%\ SPR}$	F rate resulting in retaining XX% of the maximum spawning production under equilibrium conditions
F_{max}	F maximizing the average weight yield per fish recruited to the fishery
F_o	F close to, but slightly less than, Fmax
FL FWCC	Florida Fish and Wildlife Conservation Commission
FWRI	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)
MARFIN	Marine Fisheries Initiative
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MDMR	Mississippi Department of Marine Resources
MFMT	Maximum Fishing Mortality Threshold: 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
MSA	Magnuson Stevens Act
MSST	Minimum Stock Size Threshold: 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
OST	Office of Science and Technology, NOAA
OY	Optimum Yield

SAFMC	South Atlantic Fishery Management Council
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	Southeast Fisheries Science Center, NMFS
SERFS	Southeast Reef Fish Survey
SERO	Southeast Regional Office, NMFS
SRFS	State Reef Fish Survey (Florida)
SRHS	Southeast Region Headboat Survey
SPR	Spawning Potential Ratio: B relative to an unfished state of the stock
SSB	Spawning Stock Biomass
SS	Stock Synthesis
SSC	Scientific and Statistical Committee
TIP	Trip Interview Program: biological data collection program of the SEFSC and Southeast States
TPWD	Texas Parks and Wildlife Department
Z	total mortality (M+F)

SEDAR

Southeast Data, Assessment, and Review

SEDAR 82

South Atlantic Gray Triggerfish

Data Workshop Final Report

January 2023

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

1. Introduction

1.1 Workshop Time and Place

The SEDAR 82 Data Workshop was held September 19 – 23 , 2022 in Charleston SC. Three data webinars were held prior to the workshop on May 27th, July 27th, and September 7th. Two additional webinars were held post the Data workshop on October the 3rd and October 28th, 2022.

1.2 Terms of Reference

1) Review stock structure and unit stock definitions.
   a) Characterize changes in spatial distribution of Gray Triggerfish catches including catches in the Mid Atlantic.

2) Review, discuss, and summarize available life history information.
   a) Evaluate age, growth, natural mortality, meristic conversions (length-weight relationship, length-length relationship), and reproductive characteristics (maturity, fecundity, sex ratio, and spawning season).
   b) Evaluate the aging structure and its ability to provide reliable ages. Evaluate age data and methodology across ageing facilities and discuss validation techniques.

   c) Provide appropriate models to describe population and fleet specific (if warranted) growth, maturity, and fecundity by age, sex, or length as applicable.
   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 natural mortality and other model based parameter values.
   e) Discuss the adequacy of available life history information for conducting stock assessments and recommend life history information for use in population modeling.

3) Provide measures of population abundance that are appropriate for stock assessment
   a) Consider all available and relevant fishery-dependent and -independent data sources
   b) Document all programs evaluated; address program objectives, methods, coverage, sampling intensity, and other relevant characteristics.
   c) Provide maps of fishery dependent and independent survey coverage.
   d) Develop fishery and survey CPUE indices, standardize as appropriate, generate measures of precision, and document all methods.
   e) Document pros and cons of available indices regarding their ability to represent abundance.
      i) Characterize species identification issues and identify whether the index is representative of Gray Triggerfish Stock.
   f) For recommended indices, document any known or suspected temporal patterns in catchability not accounted for by standardization.
   g) Categorize the available indices into one of three tiers: suitable and recommended, suitable and not recommended, or not suitable; provide justifications for the categorization.
   h) For any recommended fishery independent surveys provide age and length composition as appropriate.

4) Provide commercial catch statistics, including both landings and discards in both pounds and numbers.
   a) Characterize any species identification issues and correct for these instances as appropriate.
   b) Review SEDAR 41 methods for pooling gear types into a single commercial gear and, if appropriate, maintain that fleet structure; otherwise recommend an alternative fleet structure.
   c) Evaluate and discuss the adequacy of available data for accurately characterizing landings and discards by fishery sector or gear. Discuss any temporal trends in the reliability of the commercial estimates and potential impacts of COVID-19. Compare discard rates from other sectors within the South Atlantic and with analogous fisheries in adjoining regions.
   d) Provide length and age distributions for both landings and discards as appropriate.
   e) Provide maps of fishery effort and harvest by fishery sector or gear.
   f) Develop catch streams (landings and discards), generate measures of precision, and document all methods.

5) Provide recreational catch statistics for each stock being assessed, including both landings and discards in both pounds and number.

   a) Characterize any species identification issues and correct for these instances as appropriate.
   b) Review SEDAR 41 methods for pooling gear types into two recreational gears and, if appropriate, maintain that fleet structure; otherwise recommend an alternative fleet structure.
   c) Evaluate and discuss the adequacy of available data for accurately characterizing landings and discards by fishery sector or gear. Discuss any temporal trends in the reliability of the recreational estimates.
   d) Evaluate the potential source of outliers in MRIP catch data and potential impacts of COVID-19.
   e) Provide length and age distributions for both landings and discards as appropriate.
   f) Provide maps of fishery effort and harvest by fishery sector or gear.
   g) Develop catch streams (landings and discards), generate measures of precision, and document all methods.

6) Recommend discard mortality rates.
   a) Review available research and published literature.
      i) Consider research directed at Gray Trigger as well as similar species from the southeastern United States and other areas.
   b) Provide estimates of discard mortality rate by fleet and temporal structure as appropriate.
   c) Provide estimates of uncertainty around recommended discard mortality rates
   d) Document the rationale for recommended rates and uncertainties.

7) Describe any known evidence regarding ecosystem, climate, species interactions, habitat considerations, and/or episodic events *(such as red tide and upwelling events)* that would reasonably be expected to affect Gray Trigger population dynamics.
   a) Identify available analysis that could improve the understanding of important ecosystem relationships or trends that can be accounted for in the assessment.

8) Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment.

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

1.3 List of Participants

Participants **Affiliation**

Appointee	**Function**	**Affiliation**
ADT		
Mike Rinaldi	ADT	ACCSP
Meredith Whitten	ADT	NCDMF

Jie Cao	ADT	SSC
Walter Bubley	ADT	SSC
Nikolai Klibansky	Lead Analyst	SFD-AFB
Erik Williams	Assessment Support	SFD-AFB
Kyle Shertzer	Assessment Support	SFD-AFB
Other Panel Members		
Harry Morales	Appointed Observer	SGAP
Wilson Laney	Technical Chair	Habitat AP
Jeff Buckel	Panelist	SSC
Amy Dukes	Panelist	SCDNR
Elizabeth Gooding	Panelist	SCDNR
Steve Brown	Panelist	FLFWC
Bev Sauls	Panelist	FLFWC
Kevin Thompson	Panelist	FLFWC
Kim Johnson,	Commercial Statistics Lead	FSD-SDDD
Michael Judge	Commercial Statistics Lead	FSD-SDDD
Alan Lowther	Commercial Statistics Lead	FSD-SDDD
Ken Brennen	Recreational Statistics Lead	SFD-DAAS
Vivian Matter	Recreational Statistics Lead	FSD-RFMB
Jennifer Potts	Life History Lead	FATES-BLH
Eric Fitzpatrick	Indices Lead/data compiler	SFD-DAAS
Kevin McCarthy	Panelist	SFD-CFMB
Matt Nuttall	Panelist	SFD-DAAS
Nate Bacheler	Panelist	PEMS-ACRF
Rob Cheshire	Panelist	SFD-AFB
Andy Ostrowski	Panelist	FATES-BLH
Robert Allman	Panelist	FATES-BLH
Walt Rogers	Panelist	FATES-BLH
Samantha Binion-Rock	Panelist	FSD-RFMB
Kelly Adler	Panelist	FSD-RFMB
Michaela Pawluk	Discard mortality lead	FSD-RFMB
STAFF		
Kathleen Howington	Coordinator	SEDAR
Alisha Gray	SERO Rep	SERO
Kerry Marhefka	Council rep	SAFMC
Judd Curtis	Staff contact	SAFMC
Chip Collier	Observer	SAFMC
Julie Neer	Observer	SAFMC
Michael Schmidke	Observer	SAFMC
NON-PANEL DATA PROVIDERS (DID NOT ATTEND WORKSHOP)		
Michelle Willis	Data Provider	SCDNR

Tracey Smart	Data Provider	SCDNR
Marcel Reichert	Data Provider	SCDNR
Eric Hiltz	Data Provider	SCDNR
Dawn Franco	Data Provider	GADNR
Julie Califf	Data Provider	GADNR
Larry Beerkircher	Data Provider	FSD-CVB
Sydney Alhale	Data Provider	FSD-SDDD
Jose Diaz	Data Provider	FSD-CFMB
Others		
Chris Bradshaw	Observer	FLFWC
Dominique Lazarre	Observer	FLFWC
Erin Pickett	Observer	NOAA
Jesus Rivera	Observer	USC
Jonathan Peake	Observer	FLFWC
Joseph Evens	Observer	SCDNR
Julie Simpson	Observer	ACCSP
Julie Vecchio	Observer	SCDNR
Kevin Spanik	Observer	SCDNR
Margaret Finch	Observer	SCDNR
Ron Hill	Observer	NOAA
Sarah Beggerly	Observer	NOAA
Virginia Shervette	Observer	USC
Willow Patten	Observer	NCDNR
Zach Gillum	Observer	NOAA
Catlyn Wells	Observer	SCDNR
David Wyanski	Observer	SCDNR
Tony Constant	Observer	SGAP
Maria Kappos	Observer	FLFWC
Amy Dukes	Observer	SCDNR
Beverly Barnett	Observer	NOAA
David Wyanski	Observer	SCDNR

1.4 List of Data Workshop Working Papers

Document #	Title	Authors	Date Submitted
Documents Prepared for the Data Workshop			
SEDAR82-DW01	Report to SEDAR 82 Gray Triggerfish Research Track Panel: Data used in Morphometric Conversions in SEDAR 41	Jennifer C. Potts	7/8/2022
SEDAR82-DW02	Summary of Management Actions for Gray Triggerfish (Balistes capriscus) from the South Atlantic as Documented within the	G. Malone, K. Godwin, S. Atkinson, A.	7/12/22

	Management History Database	Rios	
SEDAR82-DW03	Synopsis of Age Validation Study of Gray Triggerfish through Chemical Marking	Jennifer C. Potts, Walter D. Rogers, Troy C. Rezek, and Amanda R. Rezek	7/25/2022
SEDAR82-DW04	Standardized video counts of southeast US Atlantic gray triggerfish (*Balistes capriscus*) from the Southeast Reef Fish Survey	Nathan Bacheler, Rob Cheshire, and Kyle Shertzer	8/3/2022
SEDAR82-DW05	Gray Triggerfish Fishery-Independent Index of Abundance and Length/Age Compositions in US South Atlantic Waters Based on a Chevron Trap Survey (1990-2021)	Wally J. Bubley and Michelle Willis	9/2/2022
SEDAR82-DW06	Evaluation and Limitations of MRIP Intercept Data for Developing a Gray Triggerfish Abundance Index	Eric Fitzpatrick and Erik Williams	8/29/22
SEDAR82-DW07	Exploratory data analysis and qualitative evaluation of the Stephens and MacCall subsetting method following increased management regulations in the South Atlantic headboat fishery	Eric Fitzpatrick	8/25/22
SEDAR82-DW08	Nominal Length and Age distributions of Southeast U.S. Atlantic gray triggerfish (*Balistes capriscus*) from recreational and commercial fisheries	Sustainable Fisheries Branch, National Marine Fisheries Service, Southeast Fisheries Science Center contact: Eric Fitzpatrick	9/13/22 Revised: 9/21/2022, 11/22/2022
SEDAR82-DW09	General Recreational Survey Data for Gray Triggerfish in the South Atlantic	Mathew A Nuttall	9/16/22 Revised: 10/20/2022
SEDAR82-DW10	Standardized catch rates of gray triggerfish (*Balistes capriscus*) from headboat at-sea-observer data	Sustainable Fisheries Branch, National Marine Fisheries Service, Southeast Fisheries Science Center contact: Eric Fitzpatrick	9/16/22
SEDAR82-DW11	A Summary of Length Frequency and Hook Usage from the Size Distribution of Gray Triggerfish Discards recorded during Recreational Fishery Surveys in the South Atlantic	Ellie Corbett, Beverly Sauls	9/20/2022
SEDAR82-DW12	Correcting an error in Runde et al's (2019) estimates of discard survival by release	Jeffrey A. Buckel and Brendan J. Runde	9/21/2022

	condition, discard survival by depth, and overall discard survival of gray triggerfish in the southeastern US hook-and-line fishery.		
SEDAR82-DW13	Descriptions of Florida's Atlantic Coast Gray Triggerfish (*Balistes capriscus)* recreational fishery assessed using fishery-dependent survey data	Ellie Corbett, Maria Kappos, Beverly Sauls	9/21/2022
SEDAR82-DW14	Illuminating otoliths: new insights for life history of Balistes triggerfishes	Virginia Shervette and Jesús Rivera Hernández	9/25/22
Reference Documents			
SEDAR82-RD01	Sedar 41 Stock Assessment Report South Atlantic Gray Triggerfish	Sedar 43 Panel	6/14/2021
SEDAR82-RD02	Sedar 43 Stock Assessment Report Gulf Of Mexico Gray Triggerfish	Sedar 41 Panel	6/14/2021
SEDAR82-RD03	Territoriality, Reproductive Behavior, And Parental Care In Gray Triggerfish, Balistes Capriscus, From The Northern Gulf Of Mexico	Carrie M. Simmons And Stephen T. Szedlmayer	6/14/2021

SEDAR82-RD04	Validation Of Annual Growth-Zone Formation In Gray Triggerfish Balistes Capriscus Dorsal Spines, Fin Rays, And Vertebrae	Robert J. Allman, Carrie L. Fioramonti, William F. Patterson, And Ashley E. Pacicco	6/14/2021
SEDAR82-RD05	Factors Affecting Estimates Of Size At Age And Growth In Gray Triggerfish *Balistes Capriscus* From The Northern Gulf Of Mexico	R. J. Allman, W. F. Patterson, C. L. Fioramonti And A. E. Pacicco	6/14/2021
SEDAR82-RD06	Population Structure, Connectivity, And Hylogeography Of Two Balistidae With High Potential For Larval Dispersal: Balistes Capriscus And Balistes Vetula	Luca Antoni	6/14/2021
SEDAR82-RD07	Genetic Variation Of Gray Triggerfish In U.S. Waters Of The Gulf Of Mexico And Western Atlantic Ocean As Inferred From Mitochondrial DNA Sequences	Luca Antoni, Nicholas Emerick, And Eric Saillant	6/14/2021

SEDAR82-RD08	Spatial Connectivity In An Adult-Sedentary Reef Fish With Extended Pelagic Larval Phase	L. Antoni And E. Saillant	6/14/2021
SEDAR82-RD09	Behavior Of Gray Triggerfish *Balistes Capriscus* Around Baited Fish Traps Determined From Fine-Scale Acoustic Tracking	Nathan M. Bacheler, Kyle W. Shertzer, Jeffrey A. Buckel, Paul J. Rudershausen, Brendan J. Runde	6/15/2021
SEDAR82-RD10	Fine-Scale Movement Patterns And Behavioral States Of Gray Triggerfish *Balistes Capriscus* Determined From Acoustic Telemetry And Hidden Markov Models	Nathan M. Bacheler, Theo Michelot, Robin T. Cheshire, Kyle W. Shertzer	6/15/2021
SEDAR82-RD11	Age, Growth And Longevity Of The Gray Triggerfish, *Balistes Capriscus* (Tetraodontiformes: Balistidae), From The Southeastern Brazilian Coast	Roberto A. Bernardes	6/15/2021

SEDAR82-RD12	Age, Growth, And Mortality Of Gray Triggerfish (*Balistes Capriscus*) From The Southeastern United States	Michael L. Burton, Jennifer C. Potts, Daniel R. Carr, Michael Cooper, Jessica Lewis	6/15/2021
SEDAR82-RD13	Age Validation And Growth Of Gray Triggerfish, Balistes Capriscus, In The Northern Gulf Of Mexico	Carrie Lee Fioramonti	6/15/2021
SEDAR82-RD14	SEDAR43-WP-03: Reproductive Parameters Of Gray Triggerfish (Balistes Capriscus) From The Gulf Of Mexico: Sex Ratio, Maturity And Spawning Fraction	Gary R. Fitzhugh, Hope M. Lyon, And Beverley K. Barnett	6/15/2021
SEDAR82-RD15	Refuge Spacing Similarly Affects Reef-Associated Species From Three Phyla	Thomas K. Frazer And William J. Lindberg	6/15/2021
SEDAR82-RD16	Sixteen Lessons From A 40-Year Quest To Understand The Mysterious Life Of The Gray Triggerfish	Francois Gerlotto	6/15/2021

SEDAR82-RD17	Trends In Relative Abundance Of Reef Fishes In Fishery-Independent Surveys In Waters Off The Southeastern United States	Dawn M. Glasgow, Walter J. Bubley, Tracey I. Smart, And Marcel J. M. Reichert	6/15/2021
SEDAR82-RD18	Feeding Habits Of 2 Reef-Associated Fishes, Red Porgy (*Pagrus Pagrus*) And Gray Triggerfish (*Balistes Capriscus*), Off The Southeastern United States	Sarah F. Goldman, Dawn M. Glasgow, Michelle M. Falk	6/15/2021
SEDAR82-RD19	A Review Of The Biology And Fishery For Gray Triggerfish, Balistes Capriscus, In The Gulf Of Mexico	Douglas E. Harper And David B. Mcclellan	6/16/2021
SEDAR82-RD20	Movement Patterns Of Gray Triggerfish, Balistes Capriscus, Around Artificial Reefs In The Northern Gulf Of Mexico	J.L. Herbig And S.T. Szedlmayer	6/16/2021
SEDAR82-RD21	Stock Structure Of Gray Triggerfish, Balistes Capriscus, On Multiple Spatial Scales In The Gulf Of Mexico	G. W. Ingram	6/16/2021
SEDAR82-RD22	Age And Growth Of Gray Triggerfish (Balistes Capriscus) From A North-Central Gulf Of Mexico Artificial Reef Zone	Amanda E Jefferson, Robert J Allman, Ashley E Pacicco, James S Franks, Frank J Hernandez, Mark A Albins, Sean P Powers, Robert L Shipp, J Marcus Drymon	6/16/2021
SEDAR82-RD23	The Reproductive Biology Of The Gray Triggerfish Balistes Capriscus (Pisces: Balistidae) In The Gulf Of Gabe`S (South-Eastern Mediterranean Sea)	Hichem Kacem And Lassad Neifar	6/16/2021
SEDAR82-RD24	Simplicity And Diversity In The Reproductive Ecology Of Triggerfish (Balistidae) And Filefish (Monacanthidae)	Hiroshi Kawase	6/16/2021
SEDAR82-RD25	Age, Growth, And Reproduction Of Gray Triggerfish *Balistes Capriscus* Off The Southeastern U.S. Atlantic Coast	Amanda M. Kelly	6/16/2021

SEDAR82-RD26	Gray Triggerfish Reproductive Biology, Age, And Growth Off The Atlantic Coast Of The Southeastern USA	Amanda Kelly-Stormer, Virginia Shervette, Kevin Kolmos, David Wyanski, Tracey Smart, Chris Mcdonough & Marcel J. M. Reichert	6/16/2021
SEDAR82-RD27	Evolution Of Female Egg Care In Haremic Triggerfish, *Minecanthus Aculeatus*	Tetsuok Uwamur	6/16/2021
SEDAR82-RD28	Oogenesis And Fecundity Type Of Gray Triggerfish In The Gulf Of Mexico	Erik T. Langand Gary R. Fitzhugh	6/16/2021
SEDAR82-RD29	A Snapshot Of The Age, Growth, And Reproductive Status Of Gray Triggerfish (*Balistes Capriscus*, Gmelin 1789) On Three Artificial Reefs In The Northwest Gulf Of Mexico	Adam M. Lee	6/16/2021
SEDAR82-RD30	Age, Growth And Reproductive Biology Of 'the Gray Triggerfish (Balistes Capriscus) From The Southeastern United States, 1992-1997	Jennifer L. Moore	6/16/2021
SEDAR82-RD31	Growth Of Gray Triggerfish, Balistes Capriscus, Based On Growth Checks Of The Dorsal Spine	P.K. Ofori-Danson	6/16/2021
SEDAR82-RD32	Shelf-Edge Reefs As Priority Areas For Conservation Of Reef Fish Diversity In The Tropical Atlantic	George Olavo, Paulo A. S. Costa, Agnaldo S. Martins And Beatrice P. Ferreira	6/16/2021
SEDAR82-RD33	SEDAR62-WP17: Do Sagittal Otoliths Provide More Reliable Age Estimates Than Dorsal Spines For Gray Triggerfish?	William F. Patterson Iii, Virginia R. Shervette, And Beverly K. Barnett, And Robert J. Allman	6/16/2021

SEDAR82-RD34	Low Discard Survival Of Gray Triggerfish In The Southeastern Us Hook-And-Line Fishery	Brendan J. Runde, Paul J. Rudershausen, Beverly Sauls, Chloe S. Mikles, Jeffrey A. Buckel	6/16/2021
SEDAR82-RD35	Assessment Of Genetic Stock Structure Of Gray Triggerfish (Balistes Capriscus) In U.S. Waters Of The Gulf Of Mexico And South Atlantic Regions	Eric Saillant And Luca Antoni	6/16/2021
SEDAR82-RD36	Age And Growth Of Gray Triggerfish Balistes Capriscus From Trans-Atlantic Populations	Virginia R. Shervette, Jesús M. Rivera Hernández, Francis Kofi Ewusie Nunoo	6/16/2021
SEDAR82-RD37	Recruitment Of Age-0 Gray Triggerfish To Benthic Structured Habitat In The Northern Gulf Of Mexico	Carrie M. Simmons And Stephen T. Szedlmayer	6/16/2021
SEDAR82-RD38-	Description Of Reared Preflexion Gray Triggerfish, Balistes Capriscus, Larvae From The Northern Gulf Of Mexico	Carrie M. Simmons And Stephen T. Szedlmayer	6/16/2021
SEDAR82-RD39	Competitive Interactions Between Gray Triggerfish (Balistes Capriscus) And Red Snapper (Lutjanus Campechanus) In Laboratory And Field Studies In The Northern Gulf Of Mexico	Carrie M. Simmons And Stephen T. Szedlmayer	6/16/2021
SEDAR82-RD40	Snapper Grouper Advisory Panel Gray Triggerfish Fishery Performance Report October 2021	SAFMC Snapper Grouper Advisory Panel	3/3/2022
SEDAR82-RD41	SSC Final Meeting Report May 3-5, 2016	South Atlantic Science and Statistical Committee	5/26/2022
SEDAR82-RD42	Application of three-dimensional acoustic telemetry to assess the effects of rapid recompression on reef fish discard mortality	Erin Collings Bohaboy, Tristan L. Guttridge, Neil Hammerschlag, Maurits P. M. Van Zinnicq Bergmann, and William F. Patterson III	5/27/2022

SEDAR82-RD43	Spatial And Temporal Patterns Of Habitat Use By Fishes Associated With *Sargassum* Mats In The Northwestern Gulf Of Mexico	R. J. David Wells and Jay R. Rooker	5/27/2022
SEDAR82-RD44	SEDAR 80- WP03: Photographic Guide to Extracting, Handling, and Reading Otoliths from *Balistes* Triggerfish Species	Jesus Rivera Hernandez and Virginia Shervette	5/27/2022
SEDAR82-RD45	Queen triggerfish *Balistes vetula*: Validation of otolith-based age, growth, and longevity estimates via application of bomb radiocarbon	Virginia R. Shervette, Jesu´s M. Rivera Herna´ndez	5/27/2022
SEDAR82-RD46	Larval and juvenile fishes associated with pelagic Sargassum in the north-central Gulf of Mexico	Hoffmayer, E.R.; Franks, J.S.; Comyns, B.H.; Hendon, J.R.; Waller, R.S.	5/27/2022
SEDAR82-RD47	Fishes associated with pelagic Sargassum and open water lacking Sargassum in the Gulf Stream off North Carolina	Casazza, Tara L.; Ross, Steve W.	5/27/2022
SEDAR82-RD48	SEDAR 41 -DW20: Standardized catch rates of gray triggerfish (Balistes capriscus) in the southeast U.S. from commercial logbook data	Sustainable Fisheries Branch, National Marine Fisheries Service (contact: Rob Cheshire)	8/25/2022
SEDAR82-RD49	SEDAR 41 – DW13: Preliminary standardized catch rates of Southeast US Atlantic gray triggerfish (Balistes capriscus) from headboat logbook data	Sustainable Fisheries Branch, National Marine Fisheries Service (contact: Eric Fitzpatrick)	8/25/2022
SEDAR82-RD50	Representative Biological Sampling of Recreational Harvest on the East Coast of Florida to Improve Stock Assessments in the South Atlantic	Beverly Sauls	9/8/2022
SEDAR82-RD51	A Survey to Characterize Harvest and Regulatory Discards in the Offshore Recreational Charter Fishery off the Atlantic Coast of Florida	Beverly Sauls, Oscar Ayala	9/8/2022

SEDAR82-RD52	SEDAR62 - WP11: The Effects of Hook Type on Gray triggerfish Catch per unit Effort	Rachel Germeroth and Beverly Sauls	9/9/2022
SEDAR82-RD53	SEDAR 74 - DW12: SEFSC Computation of Uncertainty for General Recreational Landings-in-Weight Estimates, with Application to SEDAR 74 Gulf of Mexico Red Snapper	Matthew Nuttall and Kyle Dettloff	9/20/2022
SEDAR82-RD54	SEDAR68 - DW11: Estimates of Historic Recreational Landings of Scamp and Yellowmouth Grouper in the South Atlantic Using the FHWAR Census Method	Ken Brennan	9/20/2022
SEDAR82-RD55	SEDAR41-DW30: Discards of gray triggerfish (*Balistes capriscus*) for the headboat fishery in the US South Atlantic	Kelly Fitzpatrick	9/20/2022
SEDAR82-RD56	Southeast Florida Coral Reef Fishery-Independent Baseline Assessment: 2012-2016 Summary Report	A. Kirk Kilfoyle, Brian K. Walker, Kurtis Gregg, Dana P. Fisco, and Richard E. Spieler	9/21/2022
SEDAR82-RD57	Ecosystem Status Report for the U.S. South Atlantic Region	J.Kevin Craig, G. Todd Kellison, Samantha M. Binion-Rock, Seann D. Regan, MandyKarnauskas, Sang-Ki Lee, Ruoying He, Dennis M. Allen, Nathan M. Bacheler, HannahBlondin, Jeffrey A. Buckel, Michael L. Burton, Scott L. Cross, Amy Freitag, Sarah H.Groves, Christine A. Hayes, Matthew E. Kimball, James W. Morley, Roldan C. Muñoz,Grant D. Murray, Janet J. Reimer, Kyle W.	9/21/2022

		Shertzer, Taylor A. Shropshire, Katie I.Siegfried, J. Christopher Taylor, Denis L. Volkov	

2. Life History

2.1 Overview

The life history working group (LHG) was tasked with combining data from the NOAA\NMFS\ Southeast Fisheries Science Center's Beaufort Laboratory (BFT) and South Carolina Department of Natural Resources (SCDNR). BFT's dataset had samples from fishery-dependent surveys collected throughout the South Atlantic jurisdiction, North Carolina through the east coast of Florida and the Keys south of highway U.S. 1. The SCDNR dataset contained samples collected from the fishery-independent South East Reef Fish Survey (SERFS). The LHG reviewed the age data from the different labs, and discussed models that describe growth and reproduction, the biological unit stock based on literature, estimates of natural mortality, migration, and movements of gray triggerfish.

Group Membership

Panel members
Jennifer Potts – NMFS (LH Working Group Co-Leader)
Walter Rogers -NMFS (LH Working Group Co-Leader)
Walter Bubley – SCDNR
Robert Allman - NMFS

Participants
Joseph Evans – SCDNR
Kevin Spanik – SCDNR
David Wyanski - SCDNR
Kevin Kolmos* - SCDNR
(*Provided data analyses, but did not attend)

Observers
Jie Cao – SSC, NCSU
Wilson Laney – Technical Lead of SEDAR82
Kerry Marhefka
Catherine Wells

2.2 Stock Definition and Description

Atlantic gray triggerfish are managed in the U.S. South Atlantic as a single stock and genetic evidence supports this management strategy. Antoni et al. (2011) examined genetic variation in 150 gray triggerfish from 5 locations (South Texas, Louisiana, West Florida, Southeastern Florida and South Carolina). Their analysis found no significant spatial heterogeneity in haplotype distribution across location, indicating homogeneity in the distribution of genetic variants among populations in the northern Gulf of Mexico and the U.S. South Atlantic. A subsequent study examined 12 locations spanning the species range and found 4 genetically distinct populations: a North Atlantic group that consisted of the North American, European, and Northwest African populations, a Mediterranean group, a southeastern Atlantic group that included populations from the Gulf of Guinea and Southwest Africa, and a southwestern Atlantic group (Antoni 2017). Tagging studies in the Gulf of Mexico indicate that adults are highly sedentary, with adult migration unlikely to contribute to significant gene flow (Ingram 2001; Herbig and Szedlmayer 2016). Conversely, juveniles are often associated with floating *Sargassum* mats and can spend 4-7 months in the pelagic zone before recruiting to benthic habitat, allowing for wide dispersal via oceanic currents (Wells and Rooker 2004; Casazza and Ross 2008; Simmons and Szedlmayer 2011).

2.3 Natural Mortality

Natural mortality, *M*, is variable at different stages of a fish's life. Gray triggerfish use various strategies for protection from predators, but also have certain vulnerabilities. Adult males construct and protect nests that are occupied by spawning females (Simmons and Szedlmayer, 2012). Juveniles occupying *Sargassum* mats and other flotsam are vulnerable to pelagic predators feeding in and around these floating structures. As these juveniles settle to benthic habitats, they are vulnerable to predation by a different suite of demersal predators. Adult gray triggerfish have durable skin and have been observed wedging themselves into rock crevices for protection. Because of these variable vulnerabilities and defense mechanisms, the Life History group suggested using an age-varying estimate of natural mortality for gray triggerfish. Following the arguments put forth during SEDAR68 (SEDAR, 2021), the Life History group agreed that the equation from Lorenzen (1996) should be used (Table 1).

The age varying estimates of *M* are size based (Lorenzen, 1996; Charnov et al., 2012), but may not tell the full story. A small fish that can have a relatively long life may not be subject to as high natural mortality on the oldest ages as estimated from the size-based equations. The Life History group suggests scaling the age specific *M*'s to a point estimate of *M* based on longevity. During the Data Workshop the age-based equation described in Then et al. (2015) was used. Following the advice of Dr. Lorenzen and Dr. Then, a subset of the Then et al. (2015) data (Table 2) was used to remodel the age-based equation to reflect the species associated with the reef fish community. As decided during SEDAR68 (SEDAR, 2021), Balistidae and Polyprionidae were omitted from the analysis due to concerns with the data from the studies cited for them, in particular the age data. The resulting value of M from each equation were presented to the Panel. These *M* estimates were used to scale the age varying values for the fully recruited ages (Table 1).

Age estimates from the SEDAR82 dataset indicated a maximum dorsal spine-based age of 16 years. The maximum age in the $\Delta^{14}C$ study (Patterson et al., 2019) and in the NMFS age validation study (Potts et al., 2022) was 12 years. After the Data Workshop, the working paper submitted by Shervette and Hernández (2022) reported a maximum otolith-based age of 21 years. The authors did not report a spine-based age from the purported 21-year-old fish. Based on the results of the NMFS age validation study and the updated age reading methodology, a maximum age of 16 years was deemed reasonable by the Life History group.

Recommendations and ADT/Panel Decision

1. The most appropriate estimates of *M* to use in the assessment model are the age-varying *M* estimates related to fish size, such as Lorenzen (1996) equation, but scaled to a point estimate based on maximum age of gray triggerfish for the fully recruited ages (age-5 in the case of SEDAR82 data from years 2015 – 2021).
2. The Then et al. (2015) age-based equation to estimate *M* should be used for scaling the age-varying *M*.
3. Further discuss the range of maximum age for sensitivity analyses.

2.4 Age Data

Age data considered for this assessment were provided by NMFS-Beaufort Laboratory and SCDNR, and are from readings taken from thin sections of the first dorsal spine. Staff from both labs have noted that spine sections can be moderately difficult to read, and consistency in readings over time and among researchers has varied. Given the issues that arose in the age data during SEDAR32 and then in preparation for SEDAR41, a research recommendation was made to validate the age readings of gray triggerfish before a subsequent assessment.

Multiple age validation studies for gray triggerfish have been conducted following SEDAR 41. Allman et al. (2016) captured eight fish from offshore habitats, marked them with oxytetracycline (OTC), and held them in an aquaculture facility, replicating ambient light and mean seasonal bottom temperatures measured from the capture area. Four of the fish survived for a period of 262 days (October to July). Dorsal spines, fin rays, and vertebrae sections taken from each of those fish showed one annulus (translucent zone) forming in the late winter months. A recent pilot study compared age estimates from first dorsal spines, vertebrae, and whole sagittal otoliths to the $\Delta^{14}C$ chronometer derived from the eye lens material (n = 20; Patterson et al. 2021). The results suggested that readings from spines underestimated ages and that readings from otoliths were more consistent with the $\Delta^{14}C$ values. A recent study conducted by the NMFS Beaufort Laboratory captured YOY and adult fish off of North Carolina, chemically marked the fish, and held them for as many as two full years (Potts et al., 2022). The initial results showed that spines underestimated fish age starting around age-5 when compared to otoliths (Figure 1). Further inspection of the spines revealed compacted growth layers on some of the spines from fish aged ≥ 5 years. When those growth zones were enumerated, the estimated ages from spines were more closely aligned with the otolith ages (Figure 2). Following this study, the age reading methodology developed during an age workshop in 2013 (Potts, 2014) was updated and shared with staff at SCDNR. This updated methodology was used to read spine sections from fish collected from 2015 – present, and provided for this assessment.

During the SEDAR82 data scoping call held May 27, 2022, one participant engaged in age and growth research of triggerfish species raised serious concerns about the utility of spine-based age data. In order to address these concerns, the SEDAR82 Panel invited all researchers who had undertaken age validation studies of gray triggerfish to present their research during the scheduled SEDAR82 Pre-Data Workshop webinar on July 27, 2022. Three researchers submitted presentations for the webinar: Robert Allman (Allman et al., 2016), Jennifer Potts (Potts et al., 2022), and Virginia Shervette (Patterson et al., 2019; Shervette et al., 2021; Shervette and Hernández, 2022). Dr. Shervette was not available for the webinar, but the Panel reviewed and discussed her research. Panelists noted that paired spine and otolith age readings from Dr. Shervette's research showed a pattern of under-ageing similar to results from initial age readings from Potts et al. (2022), where spines in age-5+ fish under-aged compared to otoliths. Typically, age calibration sets of samples are exchanged between laboratories submitting age data for an assessment. Though Dr. Shervette stated that she would not be submitting age data for this assessment, she was requested to participate in an exchange of otolith and spine samples from her study and spine samples from SCDNR and NMFS (n = 100 each) to determine if her age readings were consistent with the SCDNR and NMFS laboratories. Dr. Shervette declined to participate in the exchange.

The Life History group discussed and presented aspects of the age data submitted by SCDNR and NMFS. Both labs used the updated age reading methodology on spine samples collected since SEDAR41 (2015 – 2021), and NMFS staff read a calibration set of samples used in SEDAR41 using the new reading methodology. When compared to readings using the new methodology, the original spine-based age readings exhibited a similar pattern of under-ageing as previously described for spines compared to otoliths (Figure 3). These results indicated that the updated spine reading methodology produced ages closer to the validated ages. During the Data Workshop, the group spent some time in the lab examining spine sections and determined that age readings were consistent among readers, and that each person could identify compacted growth layers in the older fish. Unfortunately, neither lab had time to re-examine the samples used for age data that was submitted to SEDAR41. Given the results of the age validation studies and other research, the group felt that data from fish aged 0 to 4 years in the SEDAR41 data were useable. These data were important in the development of the growth model because there were no age-0 and few age-1 fish in the data sets subsequent to SEDAR41 (years 2015 – 2021).

The Life History group considered converting the annuli counts to calendar, or cohort, ages for this assessment. All researchers found it difficult to assign margin codes, 0 – 4 (Table 3), to the spine sections due to the irregularity in growth zone formation. NMFS did attempt to assign margin codes (Figure 4), and SCDNR only noted presence or absence of the annulus on the margin of the spine as was done with SEDAR41 data. Margin types documented from the spine sections in the NMFS age validation study showed a similar pattern to the pattern from all of NMFS samples (Figure 5). Given the results of the age validation study (Potts et al, 2022) and the new age data set, all samples from fish age-1 or older collected January – July with a fast growth (opaque) zone, on the margin would be advanced by 1. If an annulus (translucent zone) appeared on the margin in samples collected in January-July, then the annuli count was equivalent to the calendar age. For all samples from fish age-1 or older collected August – December, the annuli count was equivalent to the calendar age. This is a slight change from what was done in SEDAR41, where the annuli count was advanced by 1 for samples from fish age-1+ with a fast growth zone on the margin in months January – June. For all fish with zero annuli, conversion to calendar age followed same protocol used in SEDAR41 (SEDAR, 2016):

- If the fish was caught January – June, then calendar age was assumed to be 1;
- If the fish was caught July – September and the FL > 160 mm, then calendar age = 1;
- If the fish was caught July – September and the FL < 160 mm, then calendar age = 0.

A working paper by Shervette and Hernández (2022) was submitted for SEDAR82 after the data workshop was concluded as a follow-up to the July scoping call presentation. The paper questioned the utility of age data derived from readings from spine sections. Dr. Shervette was invited to present and discuss the results from this study during the Post-Data Workshop webinar on October 3, 2022. The discussion centered around the estimate of maximum age in the population and growth models derived from ages read from otoliths. Without an exchange of samples and comparison of age readings by the different researchers, we could not determine the extent of the differences in analyses comparing otolith ages to spine ages and the updated age reading methodology for spines.

Recommendations and ADT/Panel Decisions:

1. Calendar age should be used for age composition and growth modeling.
2. Age data from samples collected between 2015 and 2021 and read with the new methodology can be used in the assessment model for age composition of the stock.
3. For growth models, age data submitted for SEDAR41 (pre-2015) for age-0 to age-4 fish and all new age data (2015 – 2021) can be used for growth models.

Research recommendations:

1. Build set of paired otolith and spine samples to test the updated age reading methodology for spines.
2. Re-read all spine samples used in SEDAR41 with updated age reading methodology.
3. Create new calibration set of spine samples with better sections (n = 300), compared to old set.
4. Conduct an ageing workshop for personnel from southeast US ageing laboratories to ensure consistency in age determination.

2.5 Growth

Age data approved by the ADT and Panel for use in modeling growth of gray triggerfish includes those from age-0 through age-4 fish submitted to SEDAR41 and all of the age data from years 2015-2021 submitted for the current SEDAR. The calendar ages were converted to fractional ages based on the peak spawning month of July. A correction factor was applied to length-at-age data to account for biases caused by minimum size limits in commercial and recreational fisheries (McGarvey and Fowler, 2002; Diaz et al., 2004). Inverse weighting by sample size at calendar age was included in the growth model because sample sizes at the tails of the distribution of size-at-age were small. Incorporating the size limit bias on the fishery-dependent samples, inverse weighting of samples, and assuming constant CV, resulted in the following population growth model parameters FL_∞ = 441.39 mm, K = 0.356, and t_0 = -0.943 (n = 17,392; Table 4).

Because gray triggerfish exhibit sexually dimorphic growth, the Life History group also estimated growth of males and females separately. The data available for these models were limited due to the fact that fish are generally not assigned a sex during dockside sampling. The majority of samples used in these models were from the SERFS fishery-independent survey. The resulting parameters are listed in Table 4.

Growth was modeled to estimate the size-at-age of the gray triggerfish retained in the fishery landings. No size-limit bias correction was used in this model, but inverse weighting by sample size at age and assuming a constant CV were used. The resulting parameters are included in Table 4.

The working paper submitted by Shervette and Hernández (2022) provided a population growth model using otolith-derived ages. The samples used in the study were collected from fishery-independent and fishery-dependent surveys off the coast of North Carolina and South Carolina over a span of 10 years (n = 1,044). Growth models were calculated for the entire population, as well as for males and females separately (See Table 3 of Shervette and Hernández, 2022). Authors of this paper used slightly different assumptions for converting annuli counts to calendar ages and computing fractional ages, and did not correct for the size limit bias on the fishery-dependent samples, nor inverse weight each sample by sample size at calendar age. Annuli counts from these data were recomputed using the criteria established to estimate growth models for the current SEDAR. Using the size limit bias correction, inverse weighting and assuming constant CV about size at age resulted in the following population growth parameters: FL_∞ = 463.72 (S. E. = 34.74), K = 0.23 (S. E. = 0.06), t_0 = -0.31 (S. E. = 0.04). These parameters were determined using data from a smaller sample set that was limited to the northern range of the South Atlantic population, therefore caution should be used when comparing to the parameters in Table 4, which are comprised of samples over many years and represent the entire management area.

Recommendations and ADT/Panel Decisions

1. When estimating population growth parameters from fractional age-at-length data incorporate a size bias correction for fishery-dependent samples subject to minimum size limits, inversely weight data by sample size at calendar age, and assume constant CV.
2. When estimating sex-specific growth parameters from fractional age-at-length data, incorporate a size bias correction for fishery-dependent samples subject to minimum size limits, inversely weight data by sample size at calendar age, and assume constant CV.
3. When estimating size-at-age of fish retained in the fishery landings, growth parameters from fractional age-at-length data were used. The input data were inversely weighted by sample size at calendar age, and assume constant CV.

4. Use the re-estimated population growth parameters from data from Shervette and Hernández (2022) as a sensitivity run.

2.6 Reproduction

Fishery-independent and fishery-dependent data were collected by the Marine Resources Monitoring Assessment and Prediction (MARMAP) program, the Southeast Area Monitoring and Assessment Program, South Atlantic (SEAMAP-SA) at the South Carolina Department of Natural Resources (SCDNR), and the Southeast Fisheries Independent Survey (SEFIS) at the Southeast Fisheries Science Center (SEFSC), Beaufort, NC. Fishery-independent samples were collected via MARMAP's reef fish survey during 1978 to 2009, and then by the collaborative Southeast Reef Fish Survey (consisting of MARMAP, SEAMAP-SA, and SEFIS) from 2010 to 2021, mostly with chevron traps. Fishery-dependent samples were collected via MARMAP's short-term port sampling efforts or special projects. A total of 19,643 samples was available for analysis, 7,906 of which had accompanying calendar age and histologically processed reproductive data. Specimens identified as females (n=4,299) were analyzed for sexual maturity. Additionally, 1,763 specimens were macroscopically sexed and, when combined with the histologically staged specimens, totaled 9,669 specimens available for sex-ratio analysis by age.

Maturity, batch fecundity, spawning season duration, spawning frequency, and sex ratio: Gonad tissue samples collected by MARMAP and SERFS were processed histologically and examined under a microscope by two independent readers using standard procedures (Brown-Peterson et al. 2011; Smart et al., 2015) to determine sex and reproductive phase. Female specimens with developing, spawning capable, regressing, or regenerating gonads were considered mature. Maturity data from all months of capture were used to estimate calendar age and fork length at maturity. Fork lengths (mm) were rounded to the nearest cm to create 10 mm bins.

Maturity: The Logit link of a logistic model (proportion mature = 1 - 1/(1 + exp(a+b*calendar age)) provided the best fit for estimating female age at maturity based on AIC values (Table 5). The youngest mature female was age 0, and all females were mature by age 5. Because all female specimens were mature by age 5, and deviations between dorsal spine and otolith derived ages began at age 5 and older, we felt justified utilizing all data, including associated historic age data that were not read using the updated spine ageing protocol developed by Potts et al. (2022). The estimate of female age at 50% maturity (A_{50}) was 0.2 years (Figure 6 and Table 5). This A_{50} estimate was deemed biologically unrealistic, therefore the Life History group recommended to use the predicted proportion mature for females while setting Age 0 fish to 0% mature (Table 6).

Batch Fecundity: There currently are no estimates of batch fecundity for gray triggerfish in the South Atlantic (SA) region of the U.S. Because gray triggerfish lay demersal eggs, it is not possible to use traditional indicators of spawning (i.e., hydration in oocytes) to delineate specific batches. Lang and Fitzhugh (2015) developed a methodology to identify and quantify batches when oocytes are in the advanced vitellogenic (yolked) stage. This study estimated that batch fecundity (BF) in 65 specimens from the GOM ranged from 0.34 to 2.0 million eggs and was significantly related to fork length (FL): BF=8704*FL – 1,776,483 (r2 =0.56; range of FL=266-386 mm). This equation was deemed appropriate to use in the SA since there is no genetic evidence of separate stocks between the GOM and SA. Ongoing work to develop a South Atlantic-specific equation is being conducted using the methodology described in Lang and Fitzhugh (2015), This new equation may be available prior to the end of the upcoming research track assessment.

<u>Spawning Season Duration</u>: The spawning season for gray triggerfish has been described as occurring in late spring and summer months for the U.S. South Atlantic (Moore 2001, Kelly-Stormer et al. 2017) and the Gulf of Mexico (Hood and Johnson 1997, Ingram 2001), which is consistent with the results of the current analysis. Age-specific spawning season duration was calculated by utilizing the first and last spawning events of the season by age (Table 7). Because this value can be affected by small sample size, we also calculated overall spawning season duration by pooling all ages. The beginning and end of the spawning season were defined as the earliest (April 10th) and latest (October 4th) date that specimens were collected in any year, respectively. Note that only two spawning females have been captured in April (n=150 adult females) and only fourteen in September and October (n=1,499 adult females) during the history of SERFS sampling. Therefore, we decided to use the more conservative 116 day estimate of spawning duration that was used in SEDAR 41 (SEDAR 2016).

<u>Spawning Frequency</u>: Spawning frequency refers to the number of spawning events within a spawning season and is calculated by dividing the number of days in the spawning season by the spawning interval. Spawning frequency was determined using histological examination of gonad tissue. Females were categorized as actively spawning if indicators of imminent (oocyte maturation, including germinal vesicle migration and hydration) or recent (postovulatory follicle complexes, POC) spawning were observed. Because gray triggerfish are nest builders, females tend to remain inside or near the nests (Simmons and Szedlmayer 2012) and are thus not as likely to enter traps. Therefore, the occurrence of specimens with indicators of imminent or recent spawning is low compared to other reproductive states noted in histological samples (Table 7). The total duration of an individual spawning event was estimated to be 30 hours, so these data were normalized to a 24-hour period to determine proportion of spawning females per day. For each calendar age, the spawning frequency was obtained by multiplying the proportion of spawning adult females by the age specific spawning season duration (Table 8). This analysis accounts for the occurrence of skipped spawning and variation in spawning season duration related to size/age. Because there were over 150 fish in each age group, we recommended using the age-specific approach when determining proportion of spawning fish per age class, with a weighted average for the plus group (5+) instead of the age-independent approach for the population. Results of these analyses showed that the overall proportion of spawners increased with age (Table 7).

Measure of reproductive potential: The Life History group recommended using the total egg production (TEP) method of estimating stock reproductive potential; the equation by age class is: TEP = (proportion female) x (proportion mature) x (# of batches) x (batch fecundity). Based on the concerns regarding spine-based age estimates from age 5+ fish in historic samples, data were pooled to estimate spawning fraction by age with this plus group and subsequently the # of egg batches per fish per spawning season (Table 7).

Sex Ratio: The proportion of females (0.54) is greater than would be expected if the population sex ratio was 1:1, but the significant result is likely the result of a large dataset and has no biological significance (Table 8). When examining age-specific sex-ratios, the proportion of females was relatively constant at ages 1-4 and 5+ (Table 7). With respect to size, the proportion of females was relatively constant at sizes < 35 cm FL, and appeared to trend downward at > 36 cm FL (Table 9). Specimens > 50 cm FL were almost exclusively males, reflecting the sexual dimorphism characteristic of the species. Because there were relatively large sample sizes by age, and no age-specific sex ratio trends were observed, we recommend using a 1:1 sex-ratio for the population, regardless of age.

ADT Recommendations:

1. Use maturity age vector as presented: Because age at 50% maturity of females was biologically unrealistic, it was recommended to set maturity of age 0 fish to 0%, while using the predicted maturity values for ages 1-5+.
2. Use length based (FL) batch fecundity equation developed by Lang and Fitzhugh (2015) in the Gulf of Mexico as presented. Traditional methods of estimating batch fecundity are not appropriate for the demersal egg-laying reproductive strategy of gray triggerfish. There is ongoing work to develop a South Atlantic specific equation using the same methodology that may be available prior to the end of the research track assessment.
3. Use age specific number of batches for ages 1-4 and then weighted average for 5+ group as presented.
4. Use the population spawning season duration from SEDAR 41 of 116 days as presented, if needed.
5. Use sex ratio of the gray triggerfish as presented (1:1) for the population, with no age specific component.

2.7 Movements and Migrations

A few studies on the movement of gray triggerfish have been reported since SEDAR41 (SEDAR2016). The SEDAR41 assessment report provides a detailed review of the studies available before 2016. Two new studies looked at movement and behavior of adult gray triggerfish. Another study focused on the dispersion of juveniles through genetic analyses.

The two studies focused on the movement and behavior of adult gray triggerfish include Herbig and Szedlmayer (2016) and Bacheler et al. (2019). Herbig and Szedlmayer (2016), working on artificial reefs located in the northern Gulf of Mexico, used acoustic tags and a Vemco positioning system to track the movements of 17 tagged adult gray triggerfish. These fish were monitored for up to one year. They exhibited high site fidelity and high residency, which supports the conclusions of Ingram and Patterson (2001) and Addis et al. (2013). These tagged fish also exhibited homing behavior by leaving the tagging site, visiting other nearby reefs (7 – 8 km away) and then returning to the original site. Bacheler et al. (2019) used acoustic telemetry to define fine-scale movement patterns of gray triggerfish off the coast of North Carolina. These 30 tagged fish were tracked for up to 43 days. Thirteen of the fish permanently emigrated from the study site (0.5 km^2). Of the fish remaining in the study site, they showed their diel movement to be 200% higher during the day than at night. Bacheler et al. (2019) encouraged the wider use of acoustic tags for longer periods of time to gain more insight to the behavior of demersal fish.

Antoni and Saillant (2016) utilized genetic techniques and moment and maximum likelihood estimates to determine dispersion patterns. Because gray triggerfish juveniles remain in the pelagic habitat from 4 – 7 months (Simmons and Szedlmayer. 2011), they can recruit to benthic habitat as far away as 1,809 km. The results of this study suggest high dependency on recruitment to the population from nonlocal spawning stocks.

2.8 Morphometric Conversions

The morphometric conversions were not updated from SEDAR41. Following a review of the SEDAR41 regression analyses, the panel determined an adequate number of samples spanning the full range of the South Atlantic stock were used. A report detailing the data was supplied (Potts, 2022) and the parameter values for the various morphometric conversions are displayed in Tables 10 and 11.

2.9 Research Recommendations

Age validation

- Patterson et al. (2021) examined core material from gray triggerfish eye lenses to develop a bomb radiocarbon chronometer that was be applied to validate age estimates from dorsal spines and otoliths. Results suggested spine readings underestimated ages compared to otoliths in Gulf of Mexico (GOM) fish. Similar studies should be conducted in the SA.
- Potts et al. (in review) indicated that SA gray triggerfish otoliths provide accurate ages from age 1-12, and first dorsal spines provide accurate ages from age 1-5. However, a new age reading method is being developed for dorsal spine sections that may alleviate under-ageing. More paired otolith and spine samples need to be collected and read to assess the efficacy of this new reading method.

- MARFIN funding has been awarded to Drs. William Patterson (University of Florida), David Portnoy, and Christopher Hollenbeck (Texas A&M University-Corpus Christi) to develop protocols for DNA methylation-based ageing in GOM fish. This work should be reproduced in the SA.
- Panelists suggest that periodic inter-agency ageing workshops be conducted to ensure continued precision and accuracy for gray triggerfish age products.

Movement, migration, and effects of storm events

- More research on gray triggerfish movements and migrations in Atlantic waters is needed. Bachelor et al. (2019) utilized acoustic telemetry to determine fine-scale, diel movement patterns of gray triggerfish off of the coast of North Carolina, but additional tagging studied are needed to document migration patterns to and from locations of spawning aggregation in the South Atlantic (SA).
- Adult fish are caught in bottom trawl surveys north of Cape Hatteras in fall months. Future studies are needed to document this seasonal northern movement.

Spawning location, seasonality, duration, and behavior

- The recommendation from S41 regarding spawning locations remains somewhat unresolved: "Tagging studies are needed to define spawning locations (only shelf edge or not) and, movement, the results of which could be used to help inform fishing mortality and natural mortality."
- Farmer et al. (2017) utilized multi-decadal data from SERFS to identify broad spawning locations and model spawning seasonality for various reef fish species in the southeastern U.S. However, limitations in spatio-temporal fisheries-independent sampling efforts resulted in gaps in the data needed to fully characterize timing and location of spawning. Authors of this study suggested that fisheries-independent surveys expand efforts to include more gear types, increase sampling into fall and winter months, and sample in a wider variety of topographical and hydrological conditions.
- Determine if spawning season varies latitudinally in the SA.
- Spawning/nesting behaviors, and their effect on reproductive output, needs to be examined in the SA. Simmons and Szedlmayer (2012) (SEDAR82-RD03) examined territoriality, nest building, harem spawning, and parental care of spawning gray triggerfish on artificial reefs in the GOM.
- Territoriality and competition for nests needs to be investigated in the SA, as these behaviors may affect reproductive output.

Fecundity type, annual and batch fecundity:

- The recommendation from S41 regarding fecundity remains unresolved: "Determine fecundity type and estimate annual fecundity in Atlantic waters"

Early life history

- Early life history parameters (size and age at settlement and duration of pelagic stage) are largely unknown in the South Atlantic. Simmons and Szedlmayer (2011) suggest a 4 – 7 month pelagic stage in GOM gray triggerfish, with peak recruitment to benthic habitats occurring in September-December. Age-0 fish as small as 38 mm FL were found on artificial reefs during this study. Similar studies need to be conducted in the South Atlantic that sample both benthic and pelagic habitats for pre and post-recruitment gray triggerfish.

Discard/bycatch mortality

- Further investigation of discard mortality in both recreational and commercial fisheries is necessary in the SA.
- Buckel and Runde (2022) estimated 0.411 discard survival in recreational hook-and-line fisheries off of North Carolina and Florida. This survival rate needs to be determined for commercially caught fish.

Climate Change

- The recommendation from S41 regarding climate change remains unresolved: "Impact of climate change on mortality and recruitment"
- Investigate potential for latitudinal shifts/expansion in the species distribution as water temperatures increase.
- Burton (2008) and Morley et al. (2018) suggest that climate change could cause alterations in spawning seasonality, migration patterns, and growth rates. These effects need to be further investigated.
- Bacheler et al. (2019) used fine-scale acoustic telemetry to quantify movements of gray triggerfish associated with tropical storm events. Further study needs to document these movements more comprehensively as storm events increase in intensity.
- Study potential effects of changing ocean currents on *Sargassum sp.* distribution, as it provides critical nursery habitat for juvenile gray triggerfish.

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2.11 Tables

Table 2.11.1. Estimates of natural mortality (*M*) of the South Atlantic gray triggerfish population based on Lorenzen (1996) size-based age specific estimated and scaled to the point estimate (Then et al., 2015; maximum age equation) of the fully recruited ages, age-5+.

Equation	*M* estimate
Then et al. (2015)	0.386
Then et al. (2015) Reef fish Group	0.385

Age	Lorenzen (1996)	Scaled to Then et al. (2015)	Scaled to Then et al. (2015) reef fish group
0	0.83	0.86	0.86
1	0.60	0.62	0.61
2	0.50	0.52	0.51
3	0.45	0.46	0.46
4	0.42	0.43	0.43
5	0.40	0.41	0.41
6	0.39	0.40	0.40
7	0.38	0.39	0.39
8	0.38	0.39	0.39
9	0.37	0.38	0.38
10	0.37	0.38	0.38
11	0.37	0.38	0.38
12	0.37	0.38	0.38
13	0.37	0.38	0.38
14	0.37	0.38	0.38
15	0.37	0.38	0.38
16	0.37	0.38	0.38

Table 2.11.2. List of the subset of data used from Then et al. (2015) to recompute the maximum age equation for estimating natural mortality. Families included are reef associated species.

Family name
Serranidae
Sparidae
Pomacanthidae
Pomacentridae
Scaridae
Malacanthidae
Labridae
Lutjanidae
Haemulidae
Carangidae
Acanthuridae

Table 2.11.3. Margin codes for age structures.

Code	Description
1	Annulus on the margin of the age structure. In the case of spines, the annulus is the translucent zone, or slow-growth zone
2	After the annulus, less than 1/3 of the fast growth zone formed relative to the previous fast growth zone (opaque zone).
3	After the annulus, 1/3 – 2/3 of the fast growth zone formed relative to the previous fast growth zone (opaque zone).
4	After the annulus, more than 2/3 of the fast growth zone formed relative to the previous fast growth zone (opaque zone).

Table 2.11.4. Gray triggerfish growth parameters (± 1 S. E.) for the population and males and females incorporating the correction for size limit bias on the fishery-dependent samples, inverse weighting and assuming constant CV; fishery-dependent growth model incorporating inverse weighting and assuming constant CV, only.

Model	N	FL_∞ (± 1 S. E.)	K (± 1 S. E.)	t_0 (± 1 S. E.)
Population	17,392	441.391 (33.159)	0.356 (0.125)	-0.943 (0.439)
Females	4,734	381.593 (33.285)	0.424 (0.207)	-0.885 (0.578)
Males	3,981	448.775 (35.750)	0.364 (0.130)	-0.790 (0.396)
Fishery-dependent	9,455	514.472 (12.502)	0.123 (0.143)	-6.398 (6.620)

Table 2.11.5. Model parameters when developing age at maturity for female gray triggerfish using a logistic model with a logit link. Proportion mature = 1 - 1/(1 + exp(a+b*calendar age).

Distribution	**N**	**Intercept**	**b**	**A_{50} (yr)**
Logit	4,299	-0.34	1.44	0.23

Table 2.11.6. Age-specific maturity of female gray triggerfish. The recommendation is to utilize the predicted values for all ages, except age 0 fish.

Age (Calendar Age)	**# Total**	**# Immature**	**# Mature**	**Observed Mature**	**Predicted Mature**	**Recommendation**
0	2	2	0	0.00	0.42	**0.00**
1	137	27	110	0.80	0.75	**0.75**
2	620	55	565	0.91	0.93	**0.93**
3	1,198	21	1,177	0.98	0.98	**0.98**
4	1,101	4	1,097	1.00	1.00	**1.00**
5+	1,241	0	1,241	1.00	1.00	**1.00**

Table 2.11.7. Age-specific reproductive parameters associated with fecundity calculations for female gray triggerfish, including proportion of fish with indicators of spawning by longevity of indicators (30 hrs), spawners normalized to daily proportions, spawning interval, spawning season duration, and estimated number of batches per individual per year.

Calendar Age (yr)	# Adult Females	# Spawners (~30 hr)	Proportion Spawners (~30 hr)	Proportion Spawners (~24 h)	Average Spawning Interval (d)	Estimated Spawning Season Duration (d)	# Batches/ind.fish by Age
1	181	2	0.011	0.009	113	8	0.1
2	625	19	0.030	0.024	41	87	2.1
3	904	36	0.040	0.032	31	104	3.3
4	672	46	0.068	0.055	18	79	4.3
5+	643	52	0.081	0.065	15	98	6.3

Table 2.11.8. Age-specific sex-ratio of gray triggerfish by calendar age.

Calendar Age	Female	Male	Total	Proportion Female
0	3	1	4	0.75
1	192	136	328	0.59
2	815	670	1,485	0.55
3	1,488	1,178	2,666	0.56
4	1,301	1,134	2,435	0.53
5+	1,504	1,247	2,751	0.55
Total	**5,303**	**4,366**	**9,669**	**0.55**

Table 2.11.9. Size-specific sex-ratio of gray triggerfish in 1 cm FL bins.

FL Bin (cm)	Female	Male	Total	Proportion Female
8	2	0	2	1.00
10	4	1	5	0.80
11	2	0	2	1.00
12	1	0	1	1.00
13	3	2	5	0.60
14	14	6	20	0.70
15	17	8	25	0.68
16	37	16	53	0.70
17	50	30	80	0.63
18	84	63	147	0.57
19	86	76	162	0.53
20	120	97	217	0.55
21	116	92	208	0.56
22	186	150	336	0.55
23	175	135	310	0.56
24	321	212	533	0.60
25	268	180	448	0.60
26	386	231	617	0.63
27	351	217	568	0.62
28	610	328	938	0.65
29	506	260	766	0.66
30	765	410	1,175	0.65
31	650	349	999	0.65
32	789	472	1,261	0.63
33	645	467	1,112	0.58
34	763	592	1,355	0.56
35	589	382	971	0.61
36	675	568	1,243	0.54
37	424	422	846	0.50
38	448	495	943	0.48
39	249	350	599	0.42
40	259	452	711	0.36
41	150	322	472	0.32
42	118	369	487	0.24
43	55	207	262	0.21
44	44	190	234	0.19
45	19	138	157	0.12
46	17	118	135	0.13
47	8	72	80	0.10
48	4	61	65	0.06
49	2	26	28	0.07
50	1	21	22	0.05
51	1	16	17	0.06
52	1	8	9	0.11
53	0	4	4	0.00
54	1	4	5	0.20
55	0	1	1	0.00
56	1	0	1	1.00
58	0	1	1	0.00
Total	**10,017**	**8,621**	**18,638**	**0.54**

Table 2.11.10. Gray triggerfish: Length – length conversion equations as provided for SEDAR41: Total length is max TL including filaments.

Equation	Units	n	R^2	SE	Range of X
FL = 25.58 + 0.80*TL	mm	10,127	0.97	0.57, 0.00	76 -691
FL = 16.61 + 1.14*SL	mm	10,175	0.98	0.42, 0.00	59 - 505
TL = -18.27 + 1.21*FL	mm	10,127	0.97	0.75, 0.00	75 - 578
TL = 1.73 + 1.38*TL	mm	10,137	0.95	0.86, 0.00	59 - 525
SL = -9.62 + 0.86*FL	mm	10,175	0.98	0.38, 0.00	75 - 578
SL = 12.12 + 0.69*TL	mm	10,137	0.95	0.60, 0.00	76 - 691

Table 2.11.11. Gray triggerfish: Ln – Ln transformed whole weight (g) – length (mm) and that regression equation converted to the power equation. Total length is max TL including filaments. These parameters were used in SEDAR41.

Variables	a (SE)	b (SE)	MSE	n	R^2	Range of X	Converted Power Equation
W - FL	-10.51 (0.02)	2.97 (0.00)	0.02	36,573	0.94	75 – 620	$W = 2.75 \times 10^{-5} L^{2.97}$
W - TL	-9.53 (0.03)	2.74 (0.01)	0.02	10,068	0.96	76 – 691	$W = 7.34 \times 10^{-5} L^{2.74}$
W - SL	-9.04 (0.02)	2.81 (0.00)	0.01	10,118	0.98	59 - 505	$W = 1.12 \times 10^{-4} L^{2.81}$
FL - W	3.68 (0.00)	0.32 (0.00)	0.00	36,573	0.94	11 - 6200	$L = 39.65 W^{0.32}$

2.12 Figures

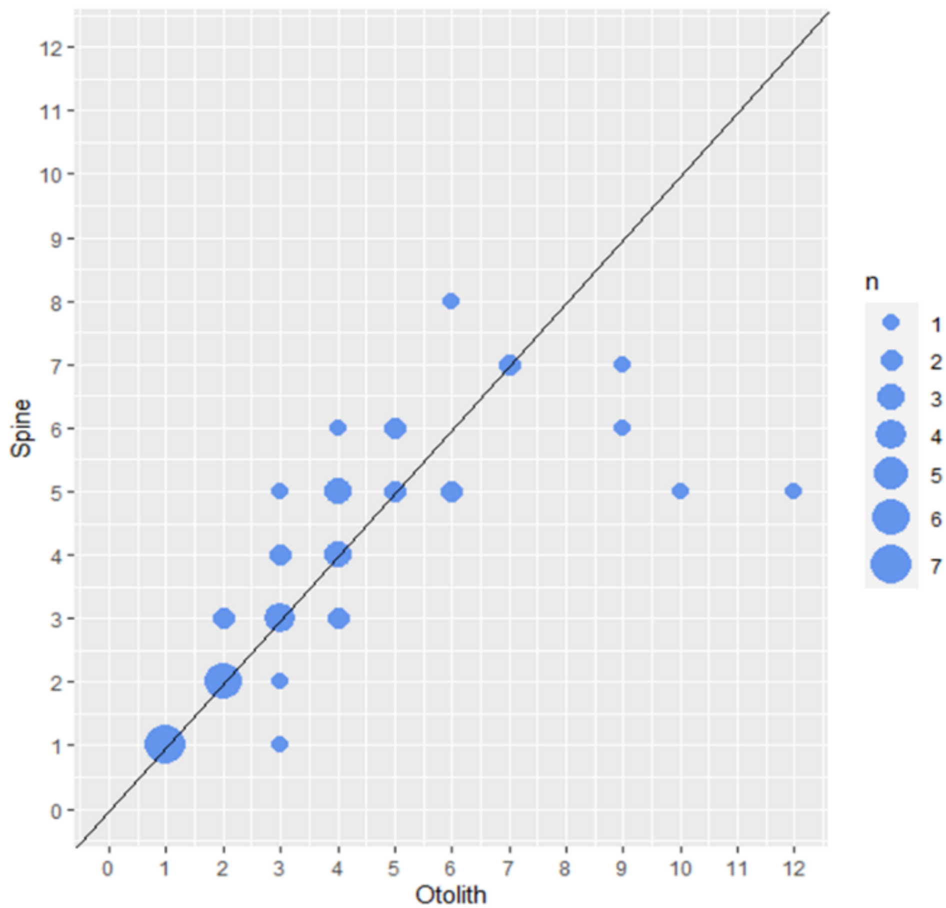

Figure 2.12.1. Age bias plot of gray triggerfish spine ages compared to otolith ages in the NMFS age validation study (Potts et al. 2022). These data are from the initial readings of the age structures.

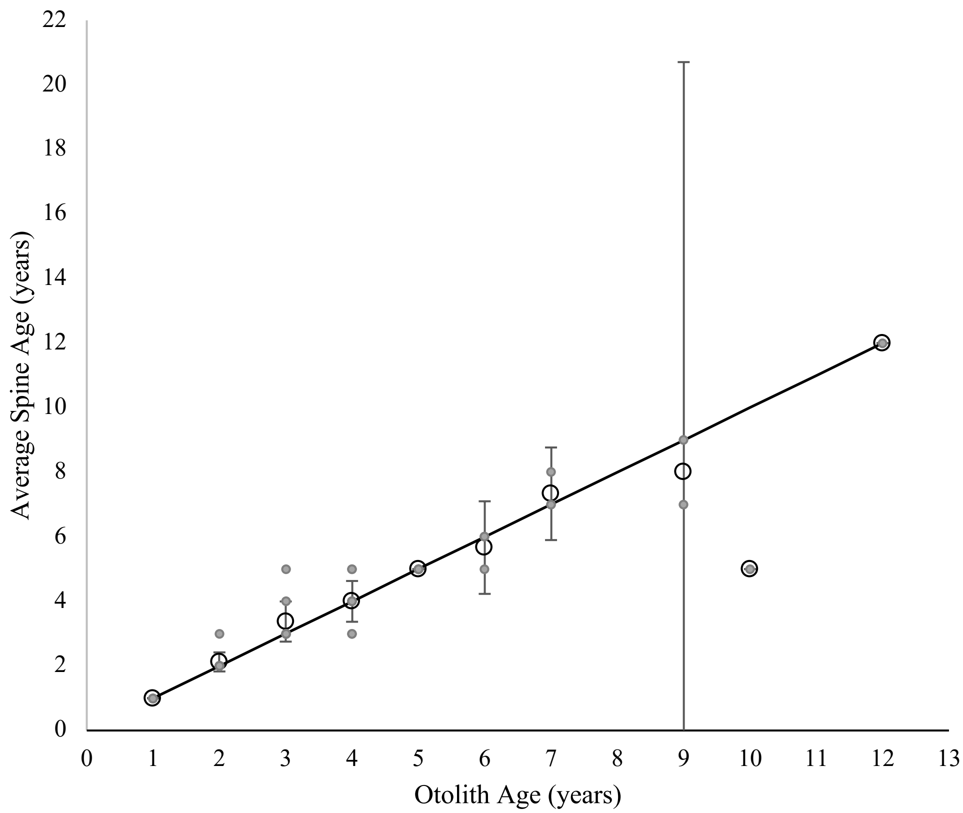

Figure 2.12.2. Gray triggerfish age bias plot after developing new age reading methodology following age validation study by NMFS Beaufort Laboratory. The 1:1 line represents the otolith readings. The open circles are the average age from the spine readings (including the 95% C.I.). The gray dots are the observed data points (may not represent a single data point).

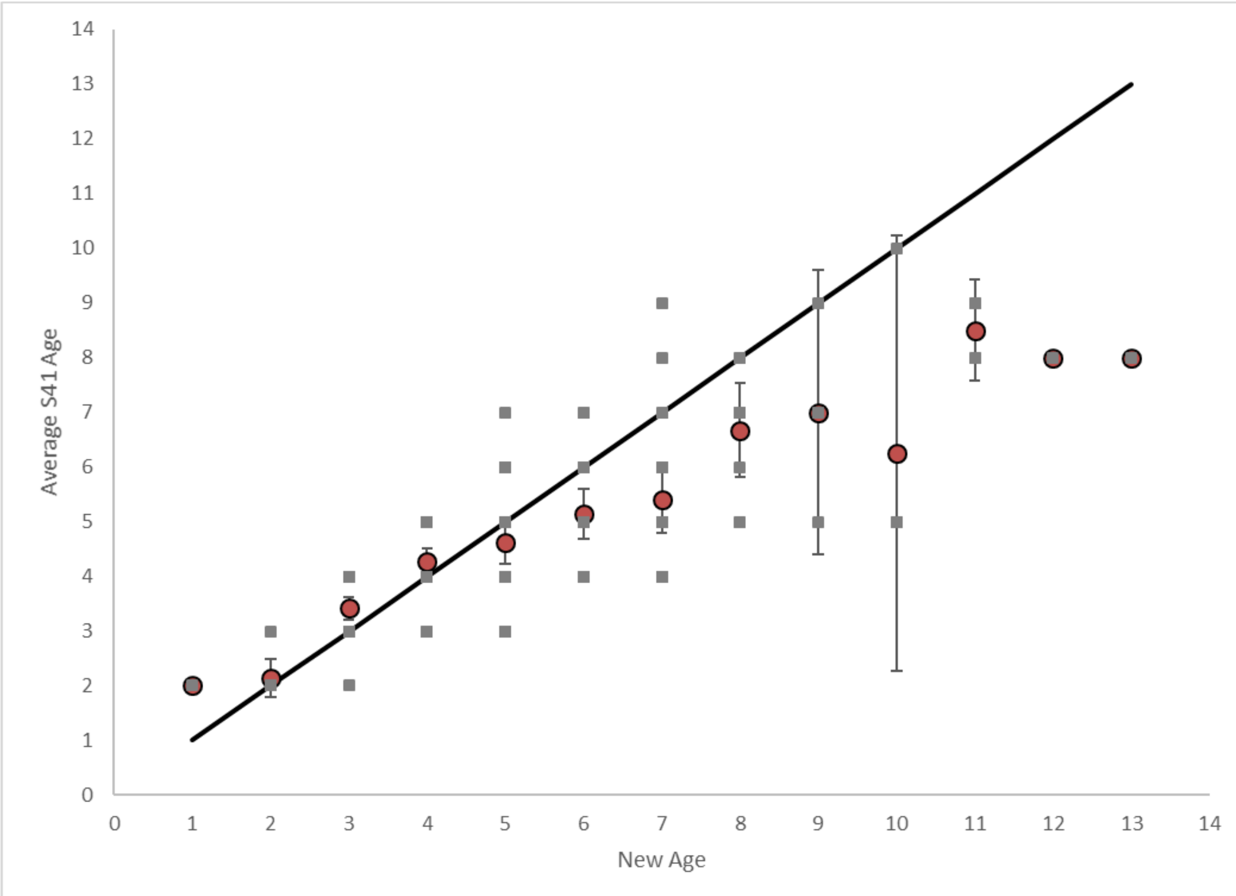

Figure 2.12.3. Gray triggerfish age bias plot of readings using the original age reading methodology compared to readings using the new methodology developed as a result of the NMFS age validation study. The 1:1 line represents the new readings. The red dots are the average age from the original readings (including the 95% C.I.). The gray dots are the observed data points.

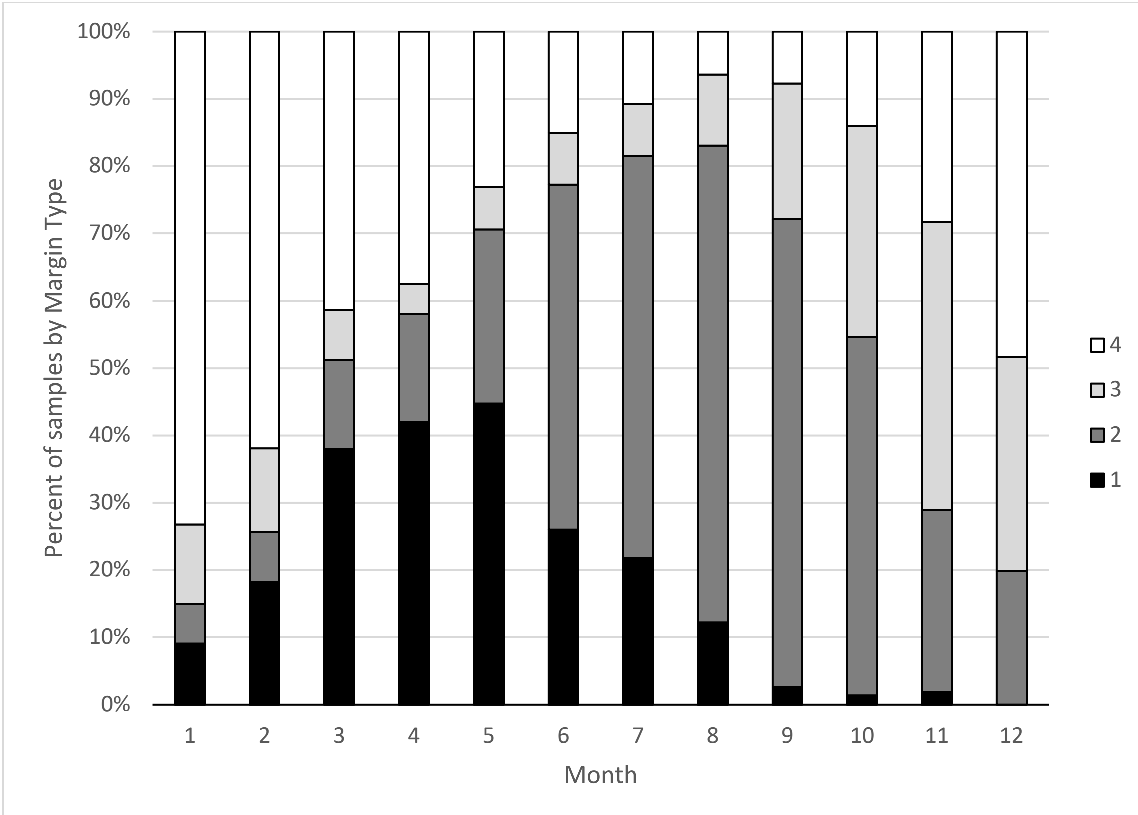

Figure 2.12.4. Margin type on spine sections of NMFS age data (2015 – 2021, n = 6032). Margin type = 1, annulus on margin; 2, <1/3 of fast growth zone formed after last annulus; 3, 1/3 – 2/3 of fast growth zone formed after last annulus; 4, >2/3 of fast growth zone formed after last annulus.

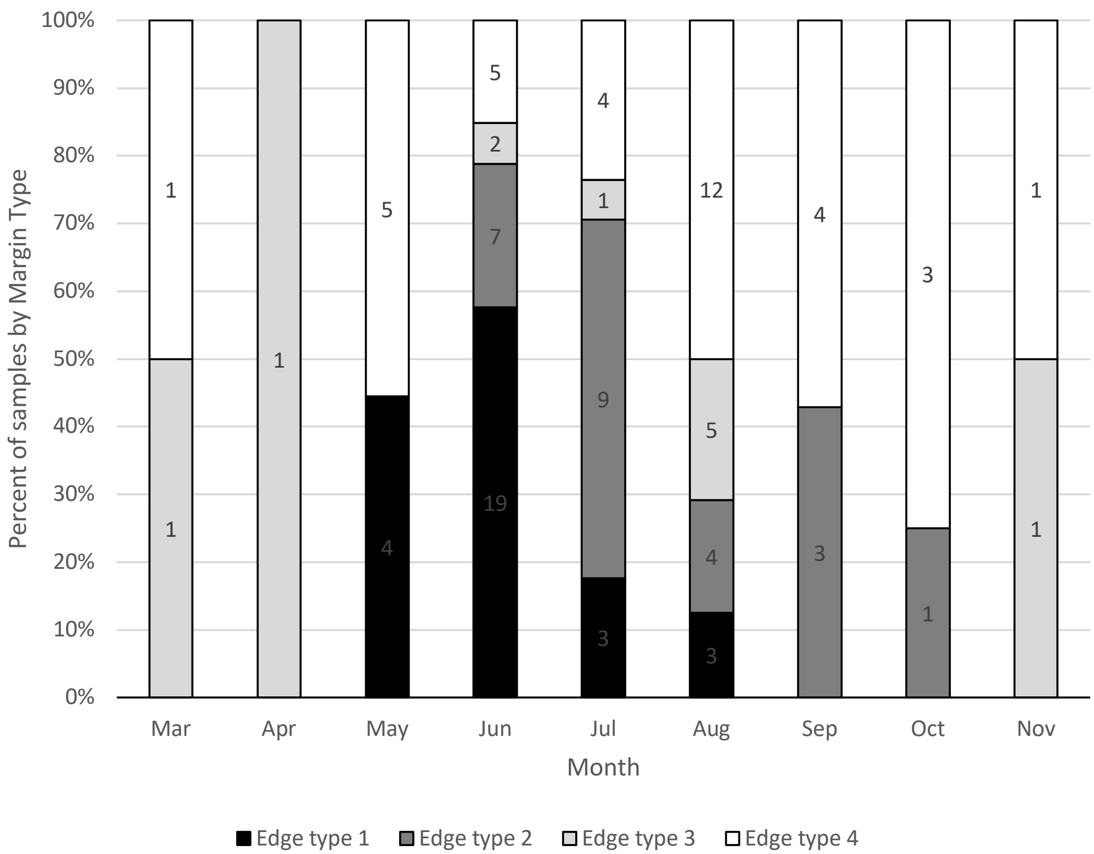

Figure 2.12.5. Margin types by month of spine sections used in NMFS age validation study. Margin type = 1, annulus on margin; 2, <1/3 of fast growth zone formed after last annulus; 3, 1/3 – 2/3 of fast growth zone formed after last annulus; 4, >2/3 of fast growth zone formed after last annulus.

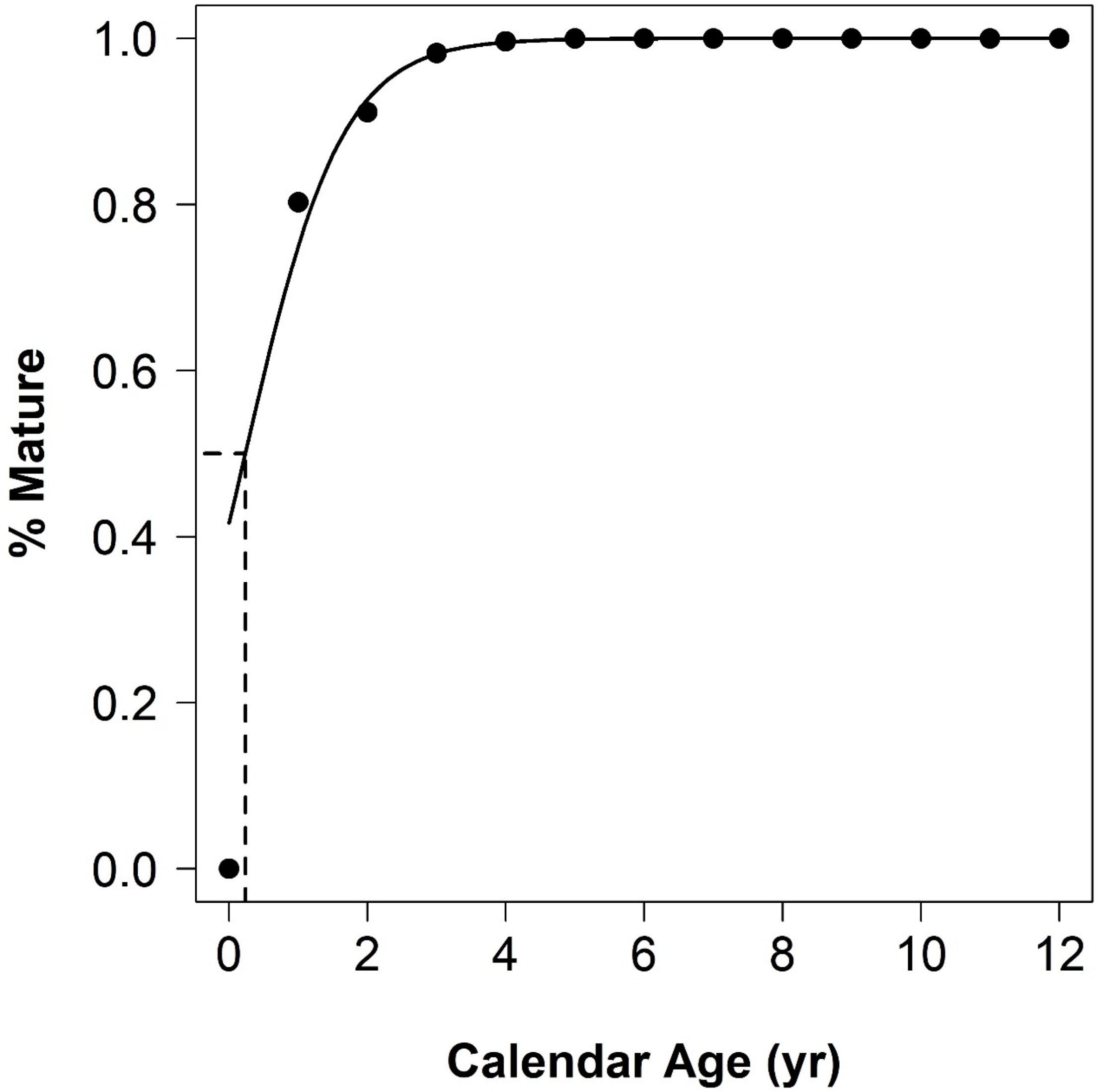

Figure 2.12.6. Maturity ogive for female gray triggerfish. Dots indicate observed proportion mature by calendar age, while the solid line indicates the modeled maturity ogive. The dotted line indicates age at 50% maturity (A_{50}).

3. Commercial Fishery Statistics

3.1 Overview

Commercial landings for the US South Atlantic (SA) Gray Triggerfish stock were developed by gear groupings (handlines and other) in whole weight pounds for the period 1950−2020 based on federal and state databases. Corresponding landings in numbers were based on mean weights estimated from the Trip Interview Program (TIP) by year, state, and gear. The percentage of Gray Triggerfish from the total unclassified triggerfish landings was determined using Coastal Fisheries Logbook Program (CFLP). Commercial discards were calculated from vessels fishing in the US SA using data from CFLP and observer collected data from 1993–2020.

Sampling intensity for lengths and age by gear and year were considered, and length and age compositions were developed by gear (handlines and other) and year for which sample size was deemed adequate. For years which did not have adequate sample sizes an average of the remaining years was used.

3.1.1 Commercial Workgroup Participants

Alan Lowther	Workgroup leader	SEFSC Miami
Mike Rinaldi	Rapporteur/Data provider	ACCSP
Steve Brown	Data provider	FL FWC
Chris Bradshaw	Data provider	FL FWC
Julie Califf*	Data provider	GA DNR
Amy Dukes	Data provider	SC DNR
Meredith Whitten	Data provider	NC DMF
Kevin McCarthy	Data Provider	SEFSC Miami
Kimberley Johnson	Data provider	SEFSC Galveston
Michaela Pawluk	Data provider	SEFSC Galveston
Mike Judge	Data Provider	SEFSC Miami
Larry Beerkircher*	Data provider	SEFSC Miami

*Did not attend workshop

3.1.2 Issues Discussed at the Data Workshop

Most methodologies remained consistent with those of SEDAR 41. Issues discussed included stock boundaries, gear groupings, and the apportioning of unclassified triggerfish. For estimating discards from the commercial fishery, the workgroup discussed how CFLP was used in the past and the potential of using observer collected information to estimate discards. The workgroup discussed under-reporting and misreporting of discards from the CFLP. While observer data have now established a fairly long timeline for the vertical line fishery, the group could not find observer data from the trap fishery. The group recommend using a slightly different approach for SEDAR 82 which includes CFLP for the trap/other fishery and using available observer data for the vertical line fishery.

3.2 Review of Working Papers

SEDAR 82 – DW02: Summary of Management Actions for Gray Triggerfish (*Balistes capriscus*) from the SA as Documented within the Management History Database: The report discussed the previous federal management actions for Gray Triggerfish, including size limits, annual catch limits (ACLs), trip limits, bag limits, and closures for the commercial and recreational fisheries. The workgroup factored federal fisheries closures into their analyses for CFLP logbook proportioning of commercial landings.

SEDAR 82 – DW08: Nominal Length and Age distributions of Southeast U.S. Atlantic Gray Triggerfish *Balistes capriscus* from recreational and commercial fisheries: The report discussed the data and methodologies used to develop nominal length and age compositions for commercial and recreational landings. The workgroup decided to recommend a two-fleet structure to the commercial landings based on the report and additional data from E. Fitzpatrick. The report showed a difference between size and age distribution across the different fleets, although the other gear distributions had low sample sizes. If necessary, the fleets may be combined at the analyst's discretion.

3.3 Commercial Landings

DW ToR #4*: Provide commercial catch statistics, including both landings and discards in both pounds and numbers. Characterize any species identification issues and correct for these instances as appropriate. Review SEDAR 41 methods for pooling gear types into a single commercial gear and, if appropriate, maintain that fleet structure; otherwise recommend an alternative fleet structure. Evaluate and discuss the adequacy of available data for accurately characterizing landings and discards by fishery sector or gear. Discuss any temporal trends in the reliability of the commercial estimates and potential impacts of COVID-19. Compare discard rates from other sectors within the SA and with analogous fisheries in adjoining regions. Provide length and age distributions for both landings and discards as appropriate. Provide maps of fishery effort and harvest by fishery sector or gear. Develop catch streams (landings and discards), generate measures of precision, and document all methods.*

Commercial landings of Gray Triggerfish were compiled from 1950 through 2020 for the US SA. Sources for landings included the Florida Fish and Wildlife Conservation Commission trip ticket program (FWC), South Carolina Department of Natural Resources (SCDNR), North Carolina Division of Marine Fisheries (NCDMF), and the Atlantic Coastal Cooperative Statistics Program (ACCSP). Further discussion of how landings were compiled from the above sources can be found in section 3.3.4. Detailed descriptions of historical federal and state data collections can be found in Appendix A.

3.3.1 Misidentification and Unclassified Triggerfish

Until 2013, all landings of triggerfish on the Atlantic coast were reported as unclassified. After SEDAR 41, NCDMF and FWC improved their reporting forms to capture species-specific information for triggerfishes. Since 2014, 62% of commercial triggerfish landings are reported as Gray Triggerfish. Data from TIP confirm the trend, as most triggerfish landed in the SA are Gray Triggerfish. In states that still allow reporting of unclassified triggerfish, unclassified landings should be proportioned out to determine Gray Triggerfish landings by year, state, and gear. Species proportions for NC were provided by TIP from 1984-2020 by year and gear. Low sample sizes made the proportions for NC unreliable, so an average proportion across years (1984-2020) will be used for years with low samples sizes, or before TIP sampling began. Species proportions for SC, GA, and FL will come from CFLP. The taxonomic level of the TIP data for SC wasn't detailed enough to calculate appropriate proportions for this species. Due to low sample sizes in the GA landings from CFLP, SC proportions were applied to GA unclassified landings. Low sample sizes for triggerfish from TIP caused FL proportions to be unrepresentative of the fishery. The percentage of Gray Triggerfish of all triggerfish reported to the CFLP by state and year is shown in Figure 3.1.

Decision 1: The workgroup recommended applying proportions to all unclassified landings to account for Gray Triggerfish, using the best available method for each state.

This decision was approved by the plenary.

3.3.2 Commercial Gears Considered and SEDAR 41 Review

The workgroup investigated reported gears landing Gray Triggerfish from various data sources (ACCSP, CFLP, FWC, SCDNR, & NCDMF) and determined the predominate gear was some type of handline. The group affirmed the approach taken in SEDAR 41. Gears utilized for landings north of the North Carolina were reviewed. Data contacts from mid-Atlantic states confirmed that Gray Triggerfish caught in pot/trap gears were incidental and did not constitute a distinct fishery. It was the workgroup's recommendation to then categorize landings into two gear groups: handline and other. A list of gears included in the handline category can be found in Table 3.1.

Decision 2: The workgroup suggested two gear groupings to characterize the Gray Triggerfish fishery (handlines and other). Handlines which include hook and line, electric/hydraulic bandit reels, and trolling make up 93.8% of the landings by weight.

This decision was approved by the plenary.

3.3.3 Stock Boundaries

DW ToR #1*: Review stock structure and unit stock definitions*

Landings of triggerfish can be found as far north as Massachusetts, and all landings north of North Carolina are reported as unclassified. While unclassified triggerfish landings can be apportioned to species using commercial landings proportions attained from other commercial data sources (i.e. TIP, CFLP), no such commercial data exist for the Mid and North Atlantic regions. The workgroup stayed consistent with SEDAR 41 decisions and decided that 100% of all northern triggerfish landings could be assumed to be Gray Triggerfish. Representatives from the northern states were contacted and indicated the majority or all of their landings of triggerfish were Gray Triggerfish. Additionally, as the proportion of triggerfish in NC ranges from 95%-100%, it was the workgroup's recommendation to assign 100% of the triggerfish landings as Gray Triggerfish north of North Carolina.

Decision 3: Because unclassified triggerfish landings north of NC cannot be apportioned by species, the workgroup recommended including those landings with the assumption that 100% are Gray Triggerfish.

This decision was approved by the plenary.

The Commercial Workgroup considered the southern boundary and determined that US 1 in Monroe County, FL would be used as the dividing line between the SA and Gulf of Mexico stocks. From 1986–2020, logbook proportions were used to divide landings in Monroe County. Prior to 1986, only the east coast of Monroe County will be included. These decisions are based on the granularity of the data available.

Decision 4: The workgroup recommended using the east coast of FL and the SA jurisdiction of the FL keys as the southern boundary of the Atlantic Gray Triggerfish stock.

This decision was approved by the plenary.

Maps of the Atlantic stock area and specific areas in FL can be found in Figures 3.3 and 3.4.

3.3.4 Commercial Landings by Gear and State

Statistics on commercial landings (1950 to present) for all species on the Atlantic coast are maintained in the Atlantic Coastal Cooperative Statistics Program (ACCSP) Data Warehouse. The Data Warehouse is an online database of fisheries dependent data provided by the ACCSP state and federal partners. Data sources and collection methods are illustrated by state in Figure

3.5. The Data Warehouse was queried in June 2022 for all triggerfish landings (annual summaries by gear category) for 1950−2020 from Florida (east coast including Monroe County) through Maine (ACCSP 2022). Data are presented using the gear categories as determined at the Data Workshop. The specific ACCSP gears in each category are listed in Table 3.1. Commercial landings in pounds (whole weight) were developed based on methodologies for gear as defined by the workgroup for each state as available by gear for 1950−2020.

Decision 5: The workgroup recommends providing all available data from 1950–2020.

This decision was approved by the plenary.

Florida

Comparisons were made between Florida's commercial trip ticket data (1986-2020) to the NMFS general canvas (1976-1996) and logbook data (1992-2020). All three datasets were very similar in landings trends and level of landings reported for matching years. It was decided to use the landings from the Florida trip ticket data over the general canvas and logbook since (1) general canvas data are Florida trip ticket data since 1997, and (2) trip ticket data were more complete and include a longer time series than the logbook data. Two issues arose with regard to Gray Triggerfish landings from Florida SA waters. First, until June of 2013, all trip ticket reports of triggerfish species were reported as unclassified triggerfish (this was also the case with the general canvas data). Secondly was how to separate SA from Gulf of Mexico landings in Monroe County (Florida Keys). While Gray Triggerfish landings in Monroe County were not large compared to the rest of Florida, it was estimated from the NMFS logbook data that the amount of SA Gray Triggerfish landed in Monroe County was as much as 9% of Florida landings in a given year. It was decided to use the NMFS logbook data to proportion out SA Gray Triggerfish from the unclassified triggerfish in the trip ticket data since the logbook data are reported to species back to 1992, and since it was believed that fisher reported area fished data were generally more accurate than area fished data reported by dealers. Additionally, it was decided to use NMFS logbook data to apportion landings by gear in the trip ticket data. While both programs collected gear by trip over the same time series (since 1992), the workgroup decided that gear reported by fisher would generally be more accurate than dealer reported gears.

The amount of SA Gray Triggerfish by year in the Florida trip ticket data was determined by calculating the proportion of Monroe County SA Gray Triggerfish separately from the rest of SA Florida in the logbook data for years 1993-2020. This was done by dividing the amount of SA Gray Triggerfish into total triggerfish landings for both Monroe and non-Monroe SA Florida, then applying those proportions to the corresponding years for Monroe county and the non-Monroe SA Florida triggerfish landings from the trip ticket data. An average proportion for both SA Monroe County and non-Monroe SA Florida was calculated from the combined 1993-2014 logbook data (the same time frame used for SEDAR 41 was used for this calculation to better represent regional distribution in previous years) and applied to corresponding total triggerfish landings in the trip ticket data from 1986-1992. SA Monroe County and non-Monroe SA landings were then combined into total SA Gray Triggerfish landings for Florida. NMFS logbook data were then used to calculate proportions of Florida SA Gray Triggerfish harvest by gear. This was done by dividing landings for each gear into total Florida SA landings, then applying those proportions to the Florida trip ticket SA landings by year from 1993-2020. The average proportion of logbook landings from 1993-2014 by gear was then applied to trip ticket landings from 1986-1992.

One additional issue with triggerfish landings in SA Florida was how the fish were graded. Historically, Florida has used the original NMFS conversion factor of 1.04 and accepted all reports of triggerfish as gutted. However, industry representatives and commercial fish house samples all indicated that most fish were landed in whole condition except for a portion of the Florida east coast that encompassed the region from New Smyrna Beach to Cape Canaveral (Volusia, Indian River and Brevard counties). The workgroup agreed landings from this region would be treated as gutted while the rest of SA Florida would be treated as whole fish landings. Final landings are in whole (live) pounds.

Decision 6: The Workgroup recommends using 1993-2020 logbook data to apportion Florida landings prior to 1993.

This decision was approved by the plenary.

<u>Georgia</u>
GA DNR staff examined ACCSP landings and compared them to state held versions. It was determined that ACCSP landings were a match and would be used in place of state provided data for the entire time series.

<u>South Carolina</u>
Prior to 1972, commercial landings data were collected by various federal fisheries agents based in South Carolina, either U.S. Fish or Wildlife or National Marine Fisheries Service personnel. In 1972, South Carolina began collecting landings data from coastal dealers in cooperation with federal agents. Mandatory monthly landings reports, on forms supplied by the Department, are required from all licensed wholesale dealers in South Carolina. Until fall of 2003, those monthly reports were summaries collecting species, pounds landed, disposition (gutted or whole) and market category, gear type and area fished; since September 2003, landings have been reported by a mandatory trip ticket system collecting landings by species, disposition and market category, pounds landed, ex-vessel prices with associated effort data to include gear type and amount, time fished, area fished, vessel and fisherman information.

SCDNR provided landings data for unclassified triggerfish from 1978 – 2013. Data from 1978 – 2003 were collected in monthly totals through collaborative efforts by SCDNR and the NMFS Cooperative Statistics Program, and all data were correlated and confirmed with the ACCSP data warehouse. Data provided from 2004 – 2013 were more comprehensive because SCDNR instituted a mandatory Trip Ticket Program in late 2003. All landings data are provided by year and approved gear type.

Triggerfish were landed whole; therefore, no conversions were necessary, and all landings through this time period were associated with gears used. Landings data for triggerfish were partitioned by gear/gear combinations into Handline and Other as recommended by the Commercial Workgroup.

Between the years 1978 to 2013, the vast majority of landings were assigned to unclassified triggerfish. In order to apportion these landings to Gray Triggerfish, two data sources were examined: TIP and Commercial logbook. TIP sampling data were determined to be biased as sampling efforts in SC were target-based, only having targets set forth for Gray Triggerfish. Commercial logbook data, collected from 1993 – 2013 was determined to be a viable dataset to calculate a proportion percentage. The average proportion for years 1993 to 2011 by gear was calculated and applied to the unclassified triggerfish landings provided by SCDNR data by year and gear for 1978 to 1992. Data from 2012 and 2013 were not used in this average proportion because during each of those years, the Allowable Catch Limit (ACL) was reached and commercial fishing for Gray Triggerfish was closed. Data from1993 to 2013 was proportioned by the corresponding yearly calculated proportion from the commercial logbook data. Mean weights by year and gear provided by TIP were used to convert pounds to numbers of fish.

<u>North Carolina</u>

NCDMF provided landings data from 1978–2020. Data from 1978–1993 were provided by the NMFS Cooperative Statistics Program and are also stored in the NCDMF database; data from 1994–2020 were provided by the NC Trip Ticket Program. Up to three gears can be listed on a trip ticket; therefore, landings were analyzed to look at gear combinations, and no gear reassignments were deemed necessary for this species. Data from NCDMF is also stored in the ACCSP Data Warehouse. Data were provided by NCDMF to capture all three gears and the most recent edits to the data.

North Carolina began using species specific triggerfish codes in 2013, although some landings after that time are still reported as unclassified triggerfish. All triggerfish landings prior to 2013 are unclassified. Therefore, proportions from the TIP were used to determine the proportion of Gray Triggerfish from the unclassified landings. TIP proportions are provided by year, state, and gear grouping for 1983–2013. Gear groupings provided by SEFSC (L. Beerkircher, personal communication) for triggerfish were Handline and Other and match the gear groupings recommended by the Commercial Workgroup. Average proportions by gear were used for years before 1984 and for any year in the other gear group where a proportion was not available.

The majority of triggerfish landed in NC are whole so a conversion from gutted to whole weight was not necessary for this species. Final landings in pounds were calculated by multiplying the unclassified triggerfish landings by the Gray Triggerfish proportion by year, state, and gear. These proportioned landings were then combined with the classified Gray Triggerfish landings. Mean weights from 1983–2020 by state and gear provided by TIP were used to convert pounds to numbers of fish. Average mean weights were used for years before 1984.

Virginia through Massachusetts

All northern landings have been provided by ACCSP. 100% of triggerfish landings were assumed to be Gray Triggerfish. There are relatively few landings of triggerfish north of North Carolina which can be seen in north/south comparison in Figure 3.2. Annual mean weights from North Carolina were used to estimate numbers of fish.

Combined State Results

Landings for Florida through North Carolina by gear category are presented in pounds whole weight (Table 3.2; Figure 3.6) and numbers of fish (Table 3.3; Figure 3.7). Handlines are the dominant gear and account for 93.8% of the total landings for the period of 1950–2020. Landings for Virginia through Massachusetts by gear category are presented in pounds whole weight and numbers of fish (Tables 3.4 and 3.5).

A consistent Gray Triggerfish fishery began in the mid-1970s and steadily grew through the 1980s to just under 100,000 pounds annually. A dramatic increase in landings began in 1990 and peaked in 1994 at almost 450,000 pounds. In SEDAR 41, several commercial fishermen on the panel noted this is about when Gray Triggerfish became more heavily targeted and fishermen switched from longline to bandit gear. Beginning in 1998, landings fell to below 200,000 pounds in 2004 and rose again to over 450,000 pounds again by 2011. Possible reasons for this large dip in landings included the reduction of snapper grouper permits in 1998. Other possible explanations include shifts in effort. Several fishers from North Carolina and Florida recalled switching to Vermilion Snapper and shark fishing.

Decision 7: The workgroup made the following decisions for reporting commercial landings:

- Landings should be reported as whole weight in pounds and number of fish
- Final landings data would come from the following sources:
    - VA-North: 1950-2020 (ACCSP)
    - NC: 1950-1993 (ACCSP)
      1994-2020 (NCDMF)

- SC: 1950-1979 (ACCSP)
  1980-2020 (SCDNR)
- GA: 1950-2020 (ACCSP)
- FL: 1950-1985 (ACCSP)
  1986-2020 (FWC)

This decision was approved by the plenary.

Whole vs. Gutted Weight
Gray Triggerfish in the SA are typically landed in whole weight; however, it was discovered that some fishermen in FL land triggerfish in gutted condition. For this analysis, landings in NC, SC, and GA were reported as is in whole weight. Based on input from fishermen, FL landings from Volusia, Indian River, and Brevard counties were considered gutted and converted to whole weight using the FL conversion factor of 1.04.

Decision 8: The work group provided Gray Triggerfish landings in whole weight pounds.

This decision was approved by the plenary.

Confidentiality Issues

Landings of Gray Triggerfish were pooled across states by gear to meet the rule of 3 and ensure confidential landings were not presented in this report. Landings by state and gear will be provided to the data compiler for use in the assessment.

Uncertainty
As per the terms of reference for SEDAR 82, the commercial workgroup has been asked to address uncertainty in the data. Since no measure of variance can be calculated for landings, the workgroup recommended using the methodology used in SEDAR 41. Relative CVs were developed by year and state based upon method of data collection. For the earliest years annual landings summaries were collected at the state level and an estimated CV of 0.5 was assumed. As data collections improved in each of these states, estimated CVs become smaller, with the eventual CV of 0.05 for each state (Table 3.7). The changes in data collection can also be seen in Figure 3.5.

Decision 9: The workgroup recommends estimating landings uncertainty by using the SEDAR 41 values with adjustments for 2014-2020 based on improved species-level reporting.

This decision was approved by the plenary.

3.3.5 Converting Landings in Weight to Landings in Numbers

The weight in pounds for each handline or other gear length sample was calculated, as was the mean weight by state, gear, and year. Where the sample size was low or no samples existed, the mean across all years, 1983-2020, by state and gear, was used (Table 3.6). Due to low sample sizes, GA landings used SC mean weights by year and gear. To convert northern landings, NC mean weights were used. The landings in whole weight (Table 3.2 and Figure 3.6) were then divided by the mean weight for each year to derive landings in numbers (Table 3.3 and Figure 3.7).

3.4 Commercial Discards

3.4.1 Directed Fishery Discards

In the South Atlantic, the standard method for estimating commercial discards from the vertical line and trap fishery, including the previous Gray Triggerfish assessments (SEDAR 41), used data from the SEFSC Coastal Fisheries Discard Logbook program (McCarthy 2015). Previous assessments have noted the drawbacks to this method based on the self-reported nature of the data which may result in under-reporting of discards. For this SEDAR the use of available observer data was considered as an alternative approach for estimating commercial discards. This method is similar to the method derived for red grouper in the Gulf of Mexico (Smith et al. 2018) and has been accepted as the standard method for estimating commercial discards in the Gulf of Mexico.

This data workshop deferred the discussion of discard estimation until the SEFSC workgroup investigating and comparing these methods could report on their results. This occurred as a Post-Workshop webinar on October 28, 2022. The methods and conclusions have been documented in a Working Paper (McCarthy et al. 2023) that will be provided for the Assessment Workshop. Included in the Working Paper is the bottom-line conclusion that the observer program methodology should be used for calculating discards from the vertical line fishery. Because there is no historical observer coverage in the trap fishery, the decision was made to use the discard estimates from the discard logbook program.

Decision 10: The Workgroup (at the post-workshop webinar) accepts the conclusion of the Working Group to use observer data where available (vertical line gear) and use data from the Coastal Fisheries Logbook Program where observer data are not available (other gears, primarily traps).

This decision was approved by the plenary.

3.4.2 Shrimp Bycatch

The possibility of constructing Gray Triggerfish bycatch estimates from the SA shrimp fishery was investigated. Beginning in 2008, a mandatory observer program was put in place to sample trips in the penaeid and rock shrimp fisheries. The observer sampling protocol however does not require Gray Triggerfish to be recorded at the species level, but instead they are lumped into a general finfish category. Prior to 2008, Gray Triggerfish had been recorded to the species level on species characterization trips. Between 1997 and 2013, only 46 Gray Triggerfish were reported. Of the 46 fish, 44 were reported on 6 of 18 species characterization trips between 2001 and 2003. The other 2 fish were reported on 2 of 243 species characterization trips between 2005 and 2007.

This disparity in triggerfish observed between the 2001-2003 and 2005-2007 time periods is likely attributed to the differences in shrimp fisheries sampled. The 2001-2003 trips were largely off the eastern coast of Florida and likely rock shrimp trips. The latter time period predominately sampled trips to the north in the penaeid fishery. These limited data may suggest there is minimal Gray Triggerfish bycatch in the rock shrimp fishery and little to none in the penaeid fishery. Anecdotal evidence supplied by several fishermen at the SEDAR 41 data workshop support this. One fisher recalled rarely seeing Gray Triggerfish while shrimping between Florida's Cape Canaveral and Brunswick, Georgia dating back to the 1950's. It is also important to note these species characterization trips were voluntary and may not be representative of the penaeid and/or rock shrimp fleets (Scott-Denton 2014). It is due to these limited data and potential sampling biases, as well as personal communication with the shrimp observer program (Scott-Denton 2023) that the situation had not changed, that we recommend not modelling shrimp bycatch.

Decision 11: Bycatch from the shrimp fishery will not be constructed due to insufficient data and potential sampling bias.

This decision was approved by the plenary.

3.5 Commercial Effort

Previous SEDAR Data Workgroup reports have included a map of the distribution of directed commercial effort in trips by year from the Coastal Fisheries Logbook Program (CFLP) for informational purposes. In addition, the distribution of harvest by statistical grid, as reported to the CFLP, and the distribution of harvest by depth and latitude have been presented. Due to the loss of staff and competing priorities we had difficulty reproducing these informational maps for this report. The SEFSC will resolve these issues, and provide comparable maps for the assessment report.

3.6 Biological Sampling

Commercial length data were available from the SEFSC TIP for all years, 1983 to 2020. TIP data were pulled from the SEFSC TIPONLINE.TIP_MV table, which is a master view table that collapses the one-to many relational tables in the main TIP database tables. The TIP_MV table is audited weekly to ensure the contents agree with the master data tables.

Data were assigned as SA samples via a hierarchal procedure. If area fished was in the interview's effort information (e.g., usually derived from captain) this was used. If this information was not available, but area fished was provided in the interview's landings information (e.g., derived from the dealer's records), then the landings information was used. If area fished was in neither the effort nor the landings information, then the state and county of landing were used to make a region assignment. Where a single trip used multiple gears, the primary gear was assigned to each record with an assumption that the first gear recorded entered by a sampler was the primary gear type used during the trip.

Data were filtered to exclude disabled trips, non-commercial trips, trips for which a bias was indicated, and observations for which the sample was indicated as non-random. The latter filtering should be interpreted as applying to fish selection within a sample, rather than trip selection itself. Trips that fished gears from both gear categories (handline and other) were dropped.

The workgroup recommended weighting handline samples, using commercial landings, by year and gear to adjust for sampling intensities across states. Georgia and South Carolina samples may need to be combined. No weighting for other gear is recommended as sampling is sparse in most states.

Sampling Intensity

For handline, North Carolina provides the most length samples, South Carolina provides ample samples after 2004, and Georgia provides adequate samples for the years 1995-2005. Florida provided consistent length samples for 1992-2021. For other gears, the numbers of length samples available were inconsistent across years and states sampled. Nominal length and age compositions for the handline fleet can be found in SEDAR82-WP08.

3.6.1 Length/Age Distribution

<u>Landings</u>

All Gray Triggerfish lengths were converted to FL in mm using the morphometric conversion provided and binned into one-centimeter groups with a floor of 0.6 cm and a ceiling of 0.5 cm. The length data and landings data were divided into handlines and other gears. Annual weighted length compositions of Gray Triggerfish will be provided for the SEDAR 82 Assessment Workshop. Length was converted to weight (whole weight in pounds) using conversions provided by the SEDAR 82 Life History Group.

Discards
Observer reported length frequency data of discarded Gray Triggerfish were available for use in the SEDAR 82 stock assessment. Sampling protocols and collection procedures of those data are reported in Gulf and South Atlantic Fisheries Foundation (2008). Those data were collected from vessels fishing vertical line gear (handline and electric/hydraulic reels) between latitudes 30N and 33N during 2007-2011. No length frequency data were available from the commercial trap fishery due to lack of observer coverage. The available length composition data were provided to the data compiler.

3.6.2 Adequacy for Characterizing Catch

Length sampling has been inadequate for other gear, and in 1983 sample sizes were low for handline gear. Particular attention needs to be paid to sample size when using the length compositions.

3.7 Comments on Adequacy of Data for Assessment Analyses

The workgroup feels the landings data for assessment analyses are adequate. There is a clear landings history for the available time series. Commercial landings of triggerfish were relatively unsubstantial prior to the 1970s, so it is likely any Gray Triggerfish landings made prior to 1950 were negligible. There was an issue concerning species identification. All landings were reported to their respective states as unclassified triggerfish. Additional commercial data sources such as the TIP and the CFLP were needed to apportion the landings to species. There were no commercial data available north of North Carolina to develop proportions to apply to the relatively small amount of unclassified triggerfish landings in the north. These landings were subsequently dropped. There was a slight issue in regards to landing condition. It was initially thought all Gray Triggerfish landings were in whole weight. However, in consulting with industry representatives and port agents in Florida, South Carolina, and North Carolina, it was found that a segment of the commercial fleet landed triggerfish gutted, while the rest of the fleet landed them whole. To address the gutted landings, landings from several counties in Florida were considered gutted and were converted to whole pounds.

Discard calculations are less adequate as there may be issues concerning the quality of self-reported data, especially where ‘no discard’ reports are concerned. While it is generally accepted that a trip without discards, of any kind, can and will happen, there is high level of uncertainty in the accuracy of ‘no discard’ reports. There has been an increase in the number of ‘no discard’ reports over the past ten years, from roughly 30% to 60% of all discard reports. It is likely some fishers may simply report 'no discards' to satisfy their reporting requirements. However, due to the relatively low discard rate for this particular species, the inclusion, or exclusion, of all 'no discard' reports have little impact on the overall take of Gray Triggerfish.

Some biological sampling data may be inadequate. As discussed in the previous section, length samples are low, or nonexistent, over the entire time series for 'other' gear and are low in some years for handline.

3.8 Literature Cited

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3.9 Research Recommendations

Landings

- Require species level reporting in state trip ticket programs. Some states have made this change which helps to reduce the uncertainty in commercial landings data.
- Characterize landings by fishing area to better understand species spatial distribution.
- Encourage the use of electronic logbook reporting and auditing to enhance spatial information.
- Improve dealer reporting of catch areas and reduce the use of unknown values in landings data.
- Consider the management history of other species that may have direct or indirect impacts on the assessment species (e.g., increased fishing effort for target species due to more restrictive management of another species).
- Review the approach for developing commercial uncertainty estimates.

Discard

- Expand observer coverage for the South Atlantic to improve discard estimates.
- Expand use of electronic reporting to reduce duplicative reporting requirements.

Biosampling

- Increase TIP sampling across all states and standardize TIP sampling protocol to get representative samples at the species level.

3.10 Tables

Table 3.1 Specific ACCSP gears in each gear category for Gray Triggerfish commercial landings.

HAND LINE GEAR				
GEAR_CODE	*GEAR_NAME*	*TYPE_CODE*	*TYPE_NAME*	*SEDAR 41 CATEGORY*
300	HOOK AND LINE	007	HOOK AND LINE	HAND LINE
301	HOOK AND LINE, MANUAL	007	HOOK AND LINE	HAND LINE
302	HOOK AND LINE, ELECTRIC	007	HOOK AND LINE	HAND LINE
303	ELECTRIC/HYDRAULIC, BANDIT REELS	007	HOOK AND LINE	HAND LINE
304	HOOK AND LINE, CHUM	007	HOOK AND LINE	HAND LINE
305	HOOK AND LINE, JIG	007	HOOK AND LINE	HAND LINE
306	HOOK AND LINE, TROLL	007	HOOK AND LINE	HAND LINE
307	HOOK AND LINE, CAST	007	HOOK AND LINE	HAND LINE
308	HOOK AND LINE, DRIFTING EEL	007	HOOK AND LINE	HAND LINE
309	HOOK AND LINE, FLY	007	HOOK AND LINE	HAND LINE
310	HOOK AND LINE, BOTTOM	007	HOOK AND LINE	HAND LINE
320	TROLL LINES	007	HOOK AND LINE	HAND LINE
321	TROLL LINE, MANUAL	007	HOOK AND LINE	HAND LINE
322	TROLL LINE, ELECTRIC	007	HOOK AND LINE	HAND LINE
323	TROLL LINE, HYDRAULIC	007	HOOK AND LINE	HAND LINE
324	TROLL LINE, GREEN-STICK	007	HOOK AND LINE	HAND LINE
330	HAND LINE	013	HAND LINE	HAND LINE
331	TROLL & HAND LINE CMB	013	HAND LINE	HAND LINE
340	AUTO JIG	013	HAND LINE	HAND LINE
700	HAND LINE	013	HAND LINE	HAND LINE
701	TROLL AND HAND LINES CMB	013	HAND LINE	HAND LINE
702	HAND LINES, AUTO JIG	013	HAND LINE	HAND LINE
***ALL OTHER GEARS ARE GROUPED AS OTHER**				

Table 3.2 Gray Triggerfish landings, in whole weight pounds, FL to NC by gear.

Year	Handline	Other
1950	911	62
1951	1,077	73
1952	497	34
1953	83	6
1954	2,567	174
1955	2,567	174
1956	911	62
1957	2,981	202
1958	1,822	124
1959	2,319	157
1960	2,236	152
1961	2,485	169
1962	9,110	618
1963	5,715	388
1964	3,975	270
1965	1,859	126
1966	1,398	95
1967	2,899	197
1968	2,733	185
1969	1,325	90
1970	2,014	137
1971	4,389	298
1972	7,702	523
1973	8,199	556
1974	14,905	1,012
1975	28,987	1,967
1976	17,972	1,220
1977	17,144	1,163
1978	38,004	2,646
1979	39,551	2,784
1980	48,725	5,059
1981	57,713	21,401
1982	86,231	10,414
1983	61,350	6,947
1984	69,164	4,516
1985	66,436	1,988
1986	66,953	1,753
1987	72,468	1,500

Year	Handline	Other
1988	77,300	3,651
1989	94,132	3,186
1990	175,242	16,430
1991	243,628	27,286
1992	254,384	7,844
1993	320,204	4,377
1994	361,848	10,461
1995	460,786	10,896
1996	404,150	28,953
1997	528,841	19,316
1998	399,080	9,042
1999	263,393	8,340
2000	193,107	2,685
2001	210,123	4,804
2002	184,663	7,110
2003	178,492	4,018
2004	233,051	9,835
2005	262,716	4,340
2006	231,500	6,292
2007	307,342	8,445
2008	311,835	8,198
2009	338,688	16,388
2010	421,289	20,084
2011	456,915	24,516
2012	259,275	20,982
2013	300,572	16,664
2014	271,080	4,527
2015	337,998	4,104
2016	300,291	7,464
2017	310,870	12,269
2018	306,024	7,534
2019	312,591	8,605
2020	303,991	6,345

Table 3.3 Gray Triggerfish landings, in numbers of fish, FL to NC by gear.

Year	Handline	Other
1950	324	26
1951	382	31
1952	176	14
1953	29	2
1954	912	73
1955	912	73
1956	324	26
1957	1,059	85
1958	647	52
1959	824	66
1960	794	64
1961	882	71
1962	3,236	260
1963	2,030	163
1964	1,412	114
1965	660	53
1966	497	40
1967	1,029	83
1968	971	78
1969	471	38
1970	715	58
1971	1,559	125
1972	2,736	220
1973	2,912	234
1974	5,294	426
1975	10,295	828
1976	6,383	513
1977	6,089	490
1978	13,412	1,166
1979	13,894	1,219
1980	16,907	2,424
1981	19,953	10,066
1982	29,749	4,762
1983	15,122	3,246
1984	20,486	1,717
1985	18,552	782
1986	17,913	765
1987	19,294	653

Year	Handline	Other
1988	22,848	1,044
1989	30,311	1,363
1990	57,296	7,016
1991	84,149	9,943
1992	89,114	3,455
1993	106,297	1,672
1994	122,428	2,801
1995	158,252	5,088
1996	152,228	14,427
1997	204,060	9,739
1998	154,754	4,244
1999	93,396	4,225
2000	70,112	2,367
2001	95,117	2,419
2002	70,233	4,967
2003	66,356	2,613
2004	92,775	5,174
2005	103,802	2,242
2006	82,830	2,984
2007	103,685	5,074
2008	106,376	4,233
2009	119,612	9,704
2010	140,772	9,876
2011	152,748	9,937
2012	84,521	10,448
2013	101,055	7,303
2014	99,373	1,996
2015	107,786	1,673
2016	106,733	3,008
2017	125,394	5,058
2018	111,259	3,016
2019	104,346	3,651
2020	101,498	2,911

Table 3.4 Gray Triggerfish landings, in whole weight pounds, VA to ME by gear. Confidential landings have been hidden and are indicated with a '*'.

Year	Handline	Other
1981	100	
1982	100	
1983	600	300
1984		
1985		
1986		
1987		
1988		
1989		
1990	3	358
1991	125	1,115
1992	176	718
1993	602	3,877
1994	14,022	3,922
1995	7,977	11,798
1996	4,890	11,789
1997	4,315	10,813
1998	2,990	5,578
1999	3,508	6,540
2000	835	4,326
2001	2,552	2,597
2002	4,000	11,257
2003	3,975	7,433
2004	*	8,175
2005	1,104	4,775
2006	1,026	4,012
2007	4,620	5,969
2008	2,293	3,446
2009	4,938	10,965
2010	3,640	7,797
2011	3,975	13,569
2012	5,395	28,937
2013	4,797	20,973
2014	1,265	9,348
2015	386	4,751
2016	729	6,872

2017	2,217	24,051
2018	2,550	17,058
2019	1,658	11,262
2020	1,398	6,832

Table 3.5 Gray Triggerfish landings, in numbers of fish, VA to ME by gear. Since no biological sampling data exists in the north, annual mean weights from North Carolina were used. Confidential landings have been hidden and are indicated with a '*'.

Year	Handline	Other
1981	34	
1982	34	
1983	83	161
1984		
1985		
1986		
1987		
1988		
1989		
1990	*	77
1991	42	287
1992	59	385
1993	204	1,651
1994	4,890	662
1995	2,791	6,330
1996	1,912	6,325
1997	1,732	5,801
1998	1,191	2,993
1999	1,259	3,509
2000	296	4,533
2001	962	1,393
2002	1,525	10,576
2003	1,491	5,564
2004	*	5,642
2005	415	2,562
2006	377	2,152
2007	1,568	3,651
2008	795	2,377
2009	1,825	7,143
2010	1,199	5,705
2011	1,288	7,976
2012	1,651	19,091
2013	1,529	11,770
2014	398	5,545
2015	127	2,295
2016	235	3,113

2017	816	10,382
2018	928	8,626
2019	551	5,224
2020	443	2,834

Table 3.6 Mean weights in pounds whole weight for Gray Triggerfish used for developing landings in numbers by year, state and gear.

	Florida		Georgia		South Carolina		North Carolina		Virginia-North	
Year	HANDLINE	OTHER	HANDLINE	OTHER	HANDLINE	OTHER	HANDLINE	OTHER	HANDLINE	OTHER
1950-1982	2.82	2.38	2.84	2.18	2.84	2.18	2.93	1.86	2.93	1.86
1983	2.82	2.38	2.84	2.18	2.84	2.18	7.27	1.86	7.27	1.86
1984	2.82	2.38	2.84	6.21	2.84	6.21	4.58	1.86	4.58	1.86
1985	3.41	2.38	2.84	2.18	2.84	2.18	4.59	3.35	4.59	3.35
1986	3.06	2.38	2.84	2.18	2.84	2.18	4.76	1.86	4.76	1.86
1987	2.82	2.38	2.84	2.18	2.84	2.18	4.59	1.86	4.59	1.86
1988	2.82	2.38	2.84	3.11	2.84	3.11	3.90	7.50	3.90	7.50
1989	2.82	2.38	2.84	2.18	2.84	2.18	3.65	1.86	3.65	1.86
1990	2.82	2.38	2.84	2.18	2.84	2.18	3.44	4.63	3.44	4.63
1991	2.82	3.55	2.84	2.18	2.84	2.18	2.98	3.89	2.98	3.89
1992	2.65	2.38	2.84	2.18	2.84	2.18	2.99	1.86	2.99	1.86
1993	3.44	3.56	2.84	2.18	2.84	2.18	2.95	2.35	2.95	2.35
1994	3.50	2.38	2.84	2.18	2.84	2.18	2.87	5.92	2.87	5.92
1995	3.22	4.02	2.84	2.18	2.84	2.18	2.86	1.86	2.86	1.86
1996	2.82	1.01	2.84	2.18	2.84	2.18	2.56	1.86	2.56	1.86
1997	2.47	2.57	2.84	2.18	2.84	2.18	2.49	1.86	2.49	1.86
1998	2.29	2.40	2.84	2.18	2.84	2.18	2.51	1.86	2.51	1.86
1999	2.91	2.05	2.84	2.18	2.84	2.18	2.79	1.86	2.79	1.86
2000	2.14	2.38	2.84	2.18	2.84	2.18	2.82	0.95	2.82	0.95
2001	1.96	2.27	2.00	2.18	2.00	2.18	2.65	1.86	2.65	1.86
2002	2.20	2.38	2.84	2.18	2.84	2.18	2.62	1.06	2.62	1.06
2003	2.36	3.01	2.84	2.18	2.84	2.18	2.67	1.34	2.67	1.34
2004	1.87	3.71	2.84	2.18	2.84	2.18	2.53	1.45	2.53	1.45
2005	1.99	1.78	2.65	2.18	2.65	2.18	2.66	1.86	2.66	1.86
2006	2.81	2.14	2.90	2.41	2.90	2.41	2.72	1.86	2.72	1.86
2007	3.29	2.62	2.85	1.20	2.85	1.20	2.95	1.63	2.95	1.63
2008	3.58	5.19	2.83	1.68	2.83	1.68	2.88	1.45	2.88	1.45
2009	3.35	1.89	2.91	2.07	2.91	2.07	2.71	1.54	2.71	1.54
2010	3.17	2.86	2.84	2.18	2.84	2.18	3.04	1.37	3.04	1.37
2011	3.06	2.59	2.81	2.96	2.81	2.96	3.09	1.70	3.09	1.70
2012	3.13	1.97	2.73	2.18	2.73	2.18	3.27	1.52	3.27	1.52
2013	3.01	2.70	2.67	2.18	2.67	2.18	3.14	1.78	3.14	1.78
2014	3.07	2.44	1.99	2.18	1.99	2.18	3.18	1.69	3.18	1.69
2015	3.18	2.69	3.22	2.18	3.22	2.18	3.04	2.07	3.04	2.07
2016	2.48	2.28	2.90	2.84	2.90	2.84	3.10	2.21	3.10	2.21
2017	2.04	2.13	2.72	3.38	2.72	3.38	2.72	2.32	2.72	2.32
2018	2.64	3.08	2.89	2.18	2.89	2.18	2.75	1.98	2.75	1.98
2019	3.10	2.78	2.85	2.18	2.85	2.18	3.01	2.16	3.01	2.16
2020	2.92	2.02	2.88	2.18	2.88	2.18	3.15	2.41	3.15	2.41

Table 3.7 Estimated CVs for landings by year and state.

Upper						
Year Range	**VA-North**	**NC**	**GA**	**SC**	**FL**	**Coastal**
1950-1961	0.25	0.25	0.25	0.25	0.25	0.25
1962-1977	0.2	0.2	0.2	0.2	0.2	0.2
1978-1985	0.2	0.1	0.1	0.1	0.1	0.1
1986-1993	0.2	0.1	0.1	0.1	0.05	0.085
1994-2001	0.1	0.05	0.1	0.1	0.05	0.066
2002-2003	0.1	0.05	0.05	0.1	0.05	0.065
2004-2013	0.1	0.05	0.05	0.05	0.05	0.052
2014-2020	0.05	0.05	0.05	0.05	0.05	0.05

Lower						
Year Range	**VA-North**	**NC**	**GA**	**SC**	**FL**	**Coastal**
1950-2013	NA	0.05	0.13	0.12	0.12	0.105
2014-2020	NA	0.05	0.13	0.05	0.05	0.052

3.11 Figures

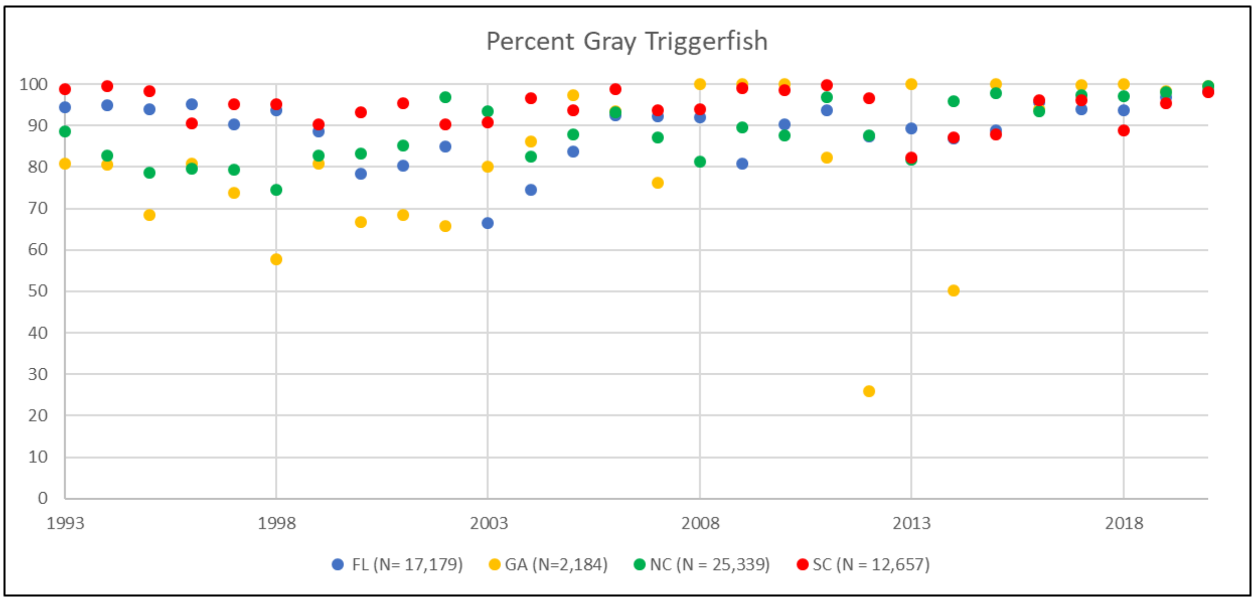

Figure 3.1 Percentage of Gray Triggerfish relative to total triggerfish landings (Gray, Queen, and Ocean) as reported to the CFLP. Anomalous Georgia logbook reporting for 2012 and 2014 may result from low sample size and fishers selecting the incorrect species from the logbook species list.

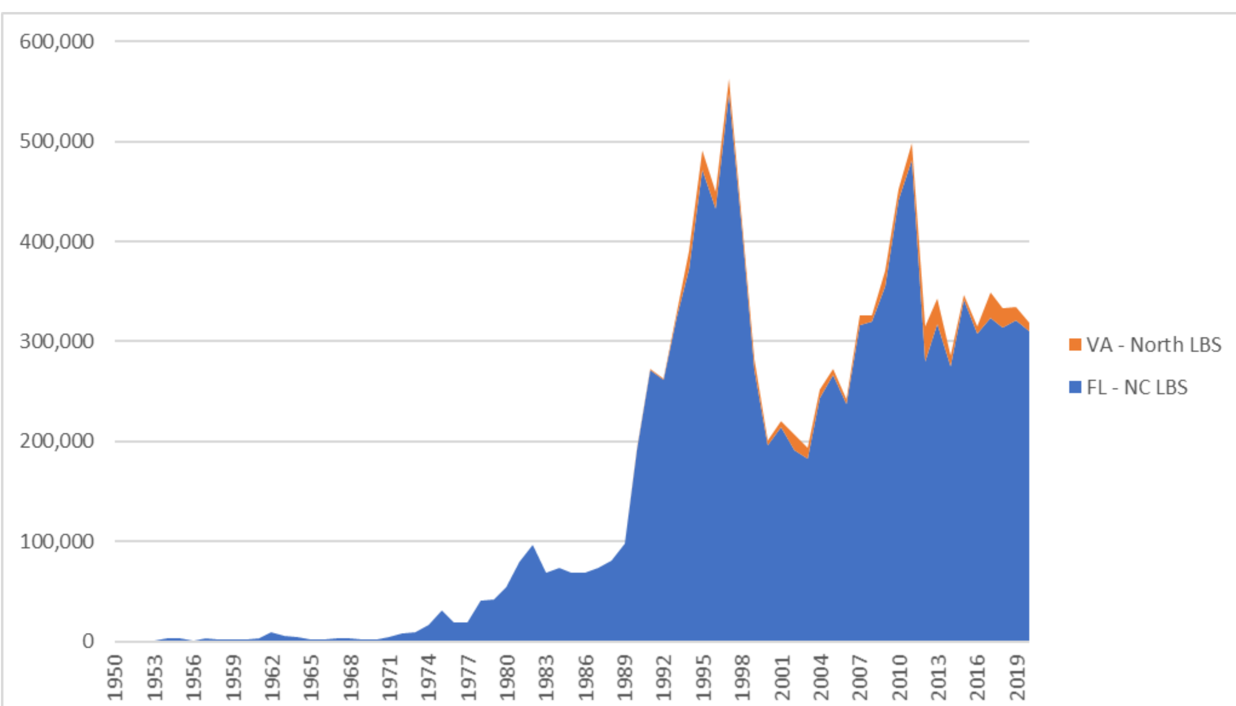

Figure 3.2 Comparison of total triggerfish landings between the South (FL to NC) and the North (VA to ME). Weights shown here are pre-apportioned weights and possess landings of all triggerfish species.

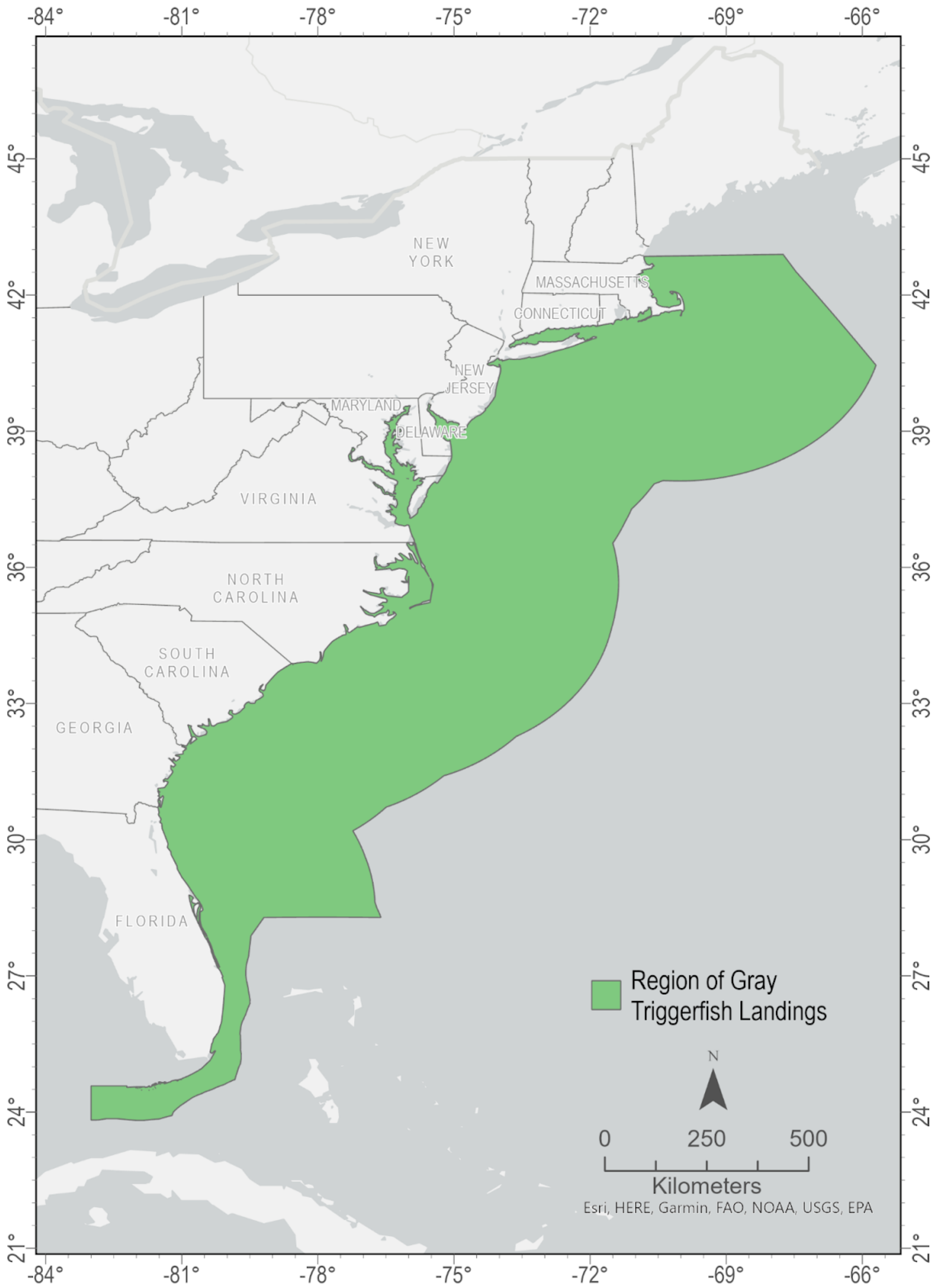

Figure 3.3 Region of Gray Triggerfish landings.

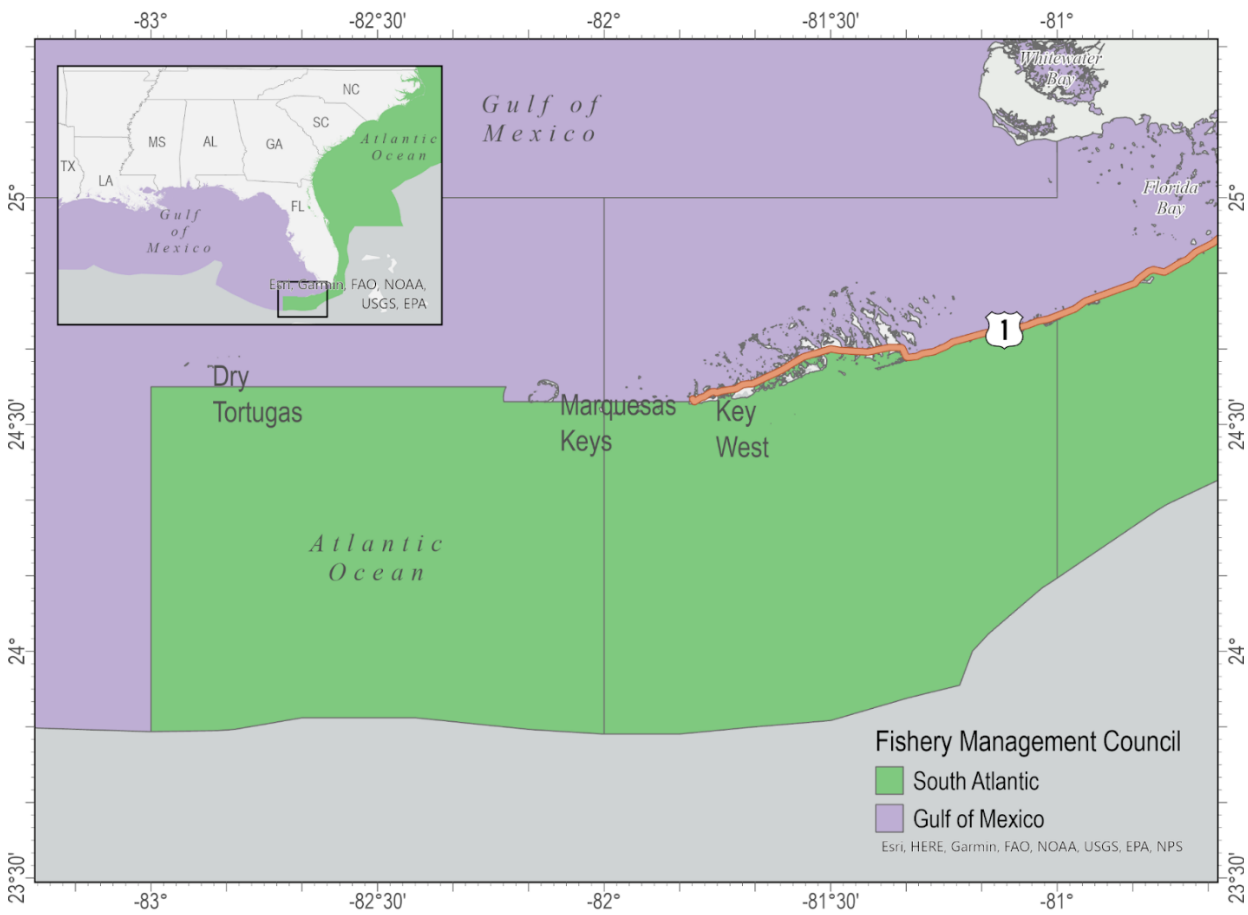

Figure 3.4 Close-up of the southern boundary as defined by the Gulf of Mexico/South Atlantic Council boundary.

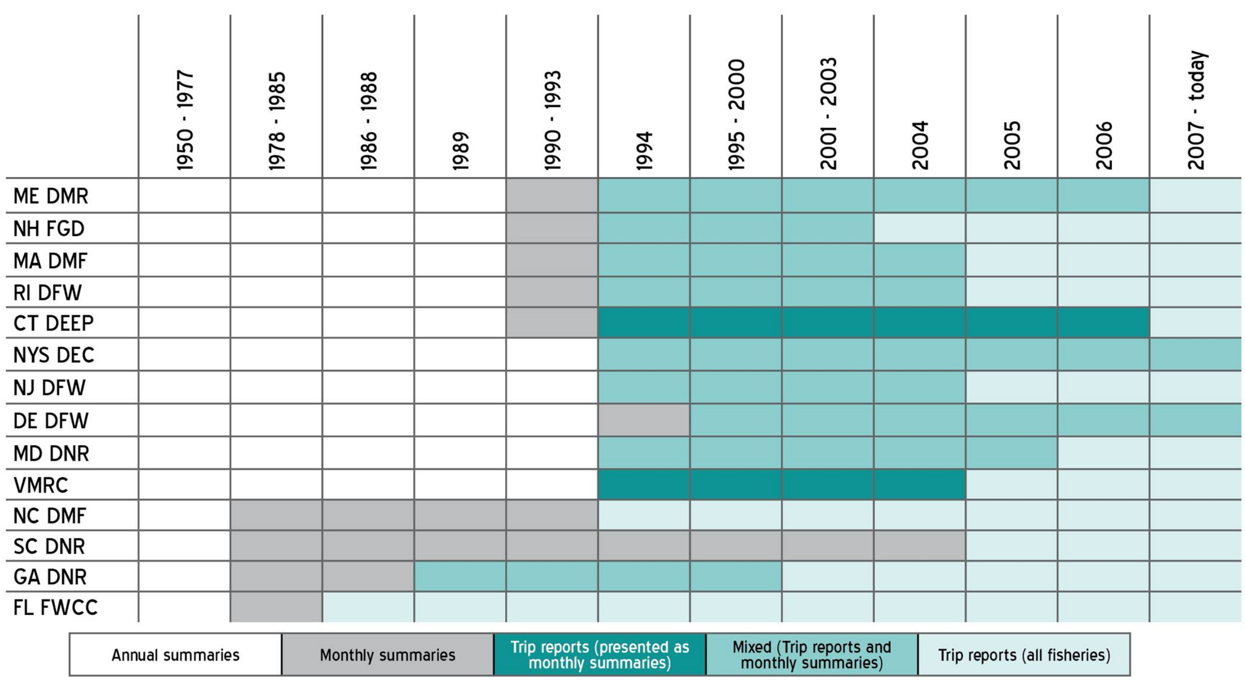

Figure 3.5 Atlantic Coastal Cooperative Statistics Program (ACCSP) Data Warehouse – data sources and collection methods by state. Early summaries provided by NMFS.

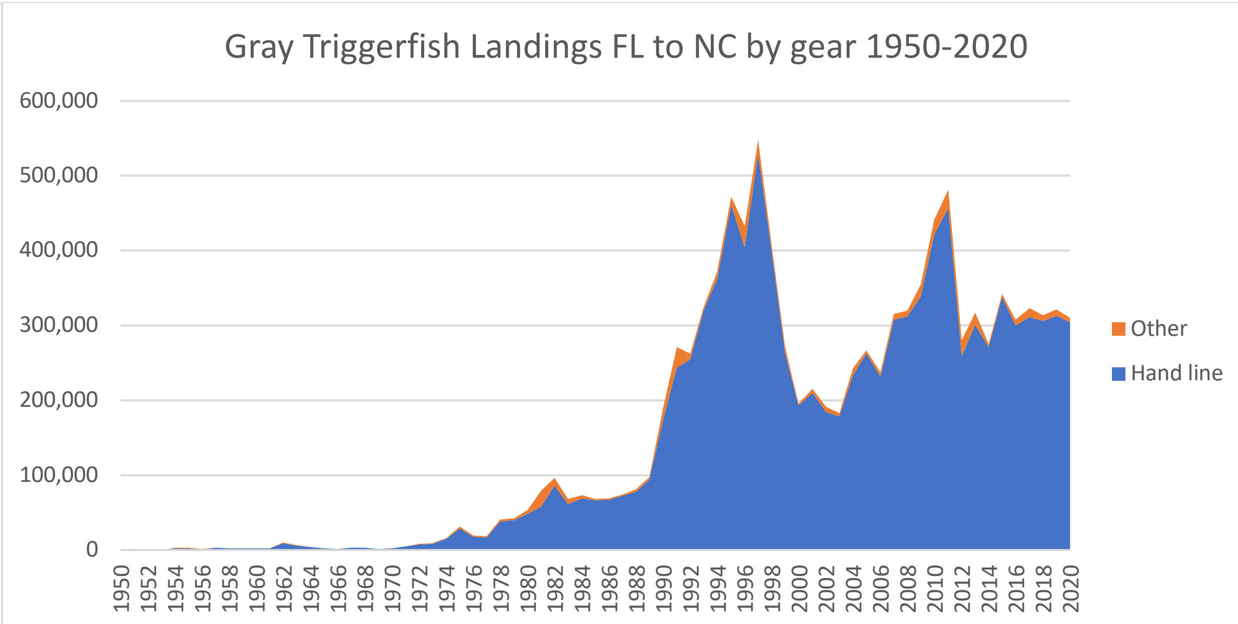

Figure 3.6 Gray Triggerfish landings, in whole weight pounds, for FL through NC by gear.

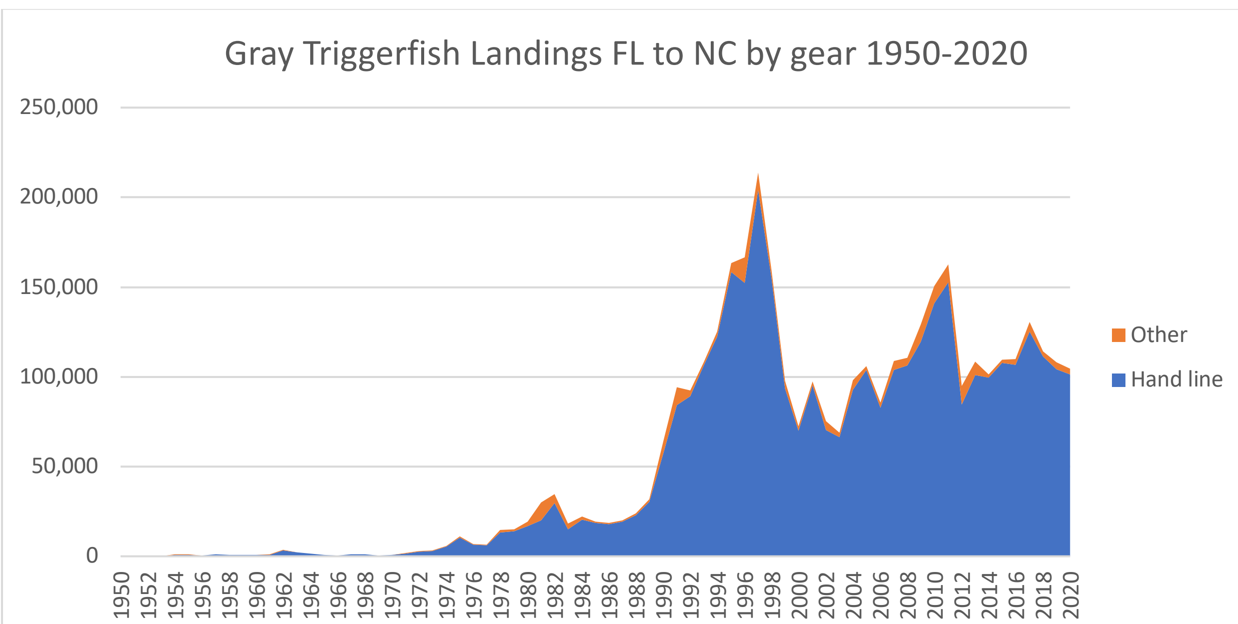

Figure 3.7 Gray Triggerfish landings, in numbers of fish, for FL through NC by gear.

APPENDIX A:

NMFS SECPR Accumulated Landings System (ALS)

Information on the quantity and value of seafood products caught by fishermen in the U.S. has been collected starting in the late 1800s (inaugural year is species dependent). Fairly serious collection activity began in the 1920s. The data set maintained by the Southeast Fisheries Science Center (SEFSC) in the SECPR database management system is a continuous dataset that begins in 1962.

In addition to the quantity and value, information on the gear used to catch the fish, the area where the fishing occurred and the distance from shore are also recorded. Because the quantity and value data are collected from seafood dealers, the information on gear and fishing location are estimated and added to the data by data collection specialists. In some states, this ancillary data are not available.

Commercial landings statistics have been collected and processed by various organizations during the 1962-to-present period that the SECPR data set covers. During the 16 years from 1962 through 1978, these data were collected by port agents employed by the Federal government and stationed at major fishing ports in the southeast. The program was run from the Headquarters Office of the Bureau of Commercial Fisheries in Washington DC until 1970. After 1970 it was run by the newly created National Marine Fisheries Service, which had replaced the Bureau of Commercial Fisheries. Data collection procedures were established by Headquarters and the data were submitted to Washington for processing and computer storage. In 1978, the responsibility for collection and processing were transferred to the SEFSC.

In the early 1980s, the NMFS and the state fishery agencies within the Southeast began to develop a cooperative program for the collection and processing of commercial fisheries statistics. With the exception of two counties, one in Mississippi and one in Alabama, all of the general canvass statistics are collected by the fishery agency in the respective state and provided to the SEFSC under a comprehensive Cooperative Statistics Program (CSP).

The purpose of this documentation is to describe the current collection and processing procedures that are employed for the commercial fisheries statistics maintained in the SECPR database.

1960 - Late 1980s
================

Although the data processing and database management responsibility were transferred from the Headquarters in Washington DC to the SEFSC during this period, the data collection procedures remained essentially the same. Trained data collection personnel, referred to as fishery reporting specialists or port agents, were stationed at major fishing ports throughout the Southeast Region. The data collection procedures for commercial landings included two parts.

The primary task for the port agents was to visit all seafood dealers or fish houses within their assigned areas at least once a month to record the pounds and value for each species or product type that were purchased or handled by the dealer or fish house. The agents summed the landings and value data and submitted these data in monthly reports to their area supervisors. All of the monthly data were submitted in essentially the same form.

The secondary task was to estimate the quantity of fish caught by specific types of gear and the location of the fishing activity. Port agents provided this gear/area information for all of the landings data they collected. The objective was to have gear and area information assigned to all monthly commercial landings data.

There are two problems with the commercial fishery statistics that were collected from seafood dealers. First, dealers do not always record the specific species that are caught and second, fish or shellfish are not always purchased at the same location where they are unloaded, i.e., landed. Dealers have always recorded fishery products in ways that meet their needs, which sometimes make it ambiguous for scientific uses. Although the port agents can readily identify individual species, they usually were not at the fish house when fish were being unloaded and thus, could not observe and identify the fish.

The second problem is to identify where the fish were landed from the information recorded by the dealers on their sales receipts. The NMFS standard for fisheries statistics is to associate commercial statistics with the location where the product was first unloaded, i.e., landed, at a shore-based facility. Because some products are unloaded at a dock or fish house and purchased and transported to another dealer, the actual 'landing' location may not be apparent from the dealers' sales receipts. Historically, communications between individual port agents and the area supervisors were the primary source of information that was available to identify the actual unloading location.

Cooperative Statistics Program
==============================

In the early 1980s, it became apparent that the collection of commercial fisheries statistics was an activity that was conducted by both the federal government and individual state fishery agencies. Plans and negotiations were initiated to develop a program that would provide the fisheries statistics needed for management by both federal and state agencies. By the mid-1980s, formal cooperative agreements had been signed between the NMFS/SEFSC and each of the eight coastal states in the southeast, Puerto Rico and the US Virgin Islands.

Initially, the data collection procedures used by the states under the cooperative agreements were essentially the same as the historical NMFS procedures. As the states developed their data collection programs, many of them promulgated legislation that authorized their fishery agencies to collect fishery statistics. Many of the state statutes include mandatory data submission by seafood dealers.

Because the data collection procedures (regulations) are different for each state, the type and detail of data varies throughout the Region. The commercial landings database maintained in SECPR contains a standard set of data that is consistent for all states in the Region.

A description of the data collection procedures and associated data submission requirements for each state follows.

Florida
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Prior to 1986, commercial landings statistics were collected by a combination of monthly mail submissions and port agent visits. These procedures provided quantity and value, but did not provide information on gear, area or distance from shore. Because of the large number of dealers, port agents were not able to provide the gear, area and distance information for monthly data. This information, however, is provided for annual summaries of the quantity and value and known as the Florida Annual Canvas data (see below).

Beginning in 1986, mandatory reporting by all seafood dealers was implemented by the State of Florida. The State requires a report (ticket) be completed and submitted to the State for every trip. Dealers have to report the type of gear as well as the quantity (pounds) purchased for each species. Information on the area of catch can also be provided on the tickets for individual trips.

As of 1986 the ALS system relies solely on the Florida trip ticket data to create the ALS landings data for all species other than shrimp.

Georgia
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Prior to 1977, the National Marine Fisheries Service collected commercial landings data Georgia. From 1977 to 2001 state port agents visited dealers and docks to collect the information on a regular basis. Compliance was mandatory for the fishing industry. To collect more timely and accurate data, Georgia initiated a trip ticket program in 1999, but the program was not fully implemented to allow complete coverage until 2001. All sales of seafood products landed in Georgia must be recorded on a trip ticket at the time of the sale. Both the seafood dealer and the seafood harvester are responsible for insuring the ticket is completed in full.

South Carolina
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Prior to 1972, commercial landings data were collected by various federal fisheries agents based in South Carolina, either U.S. Fish or Wildlife or National Marine Fisheries Service personnel. In 1972, South Carolina began collecting landings data from coastal dealers in cooperation with federal agents. Mandatory monthly landings reports on forms supplied by the Department are required from all licensed wholesale dealers in South Carolina. Until fall of 2003, those monthly reports were summaries collecting species, pounds landed, disposition (gutted or whole) and market category, gear type, and area fished; since September 2003, landings have been reported by a mandatory trip ticket system collecting landings by species, disposition and market category, pounds landed, ex-vessel prices with associated effort data to include gear type and amount, time fished, area fished, along with vessel and fisherman information.

South Carolina began collecting TIP length frequencies in 1983 as part of the Cooperative Statistics Program. Target species and length quotas were supplied by NMFS and sampling targets were established for monthly commercial trips by gear sampling was set to collect those species with associated length frequencies. In 2005, SCDNR began collecting age structures (otoliths and spines) in addition to length frequencies, using ACCSP funding to supplement CSP funding. Typically for every four fish measured a single age structure was collected. This sampling periodicity was changed in 2010 to collect both a length and age structure from every fish intercepted as a recommendation from the SEFSC.

North Carolina
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The National Marine Fisheries Service prior to 1978 collected commercial landings data for North Carolina. Port agents would conduct monthly surveys of the state's major commercial seafood dealers to determine the commercial landings for the state. Starting in 1978, the North Carolina Division of Marine Fisheries entered into a cooperative program with the National Marine Fisheries Service to maintain the monthly surveys of North Carolina's major commercial seafood dealers and to obtain data from more dealers.

The North Carolina Division of Marine Fisheries Trip Ticket Program (NCTTP) began on 1 January 1994. The NCTTP was initiated due to a decrease in cooperation in reporting under the voluntary NMFS/North Carolina Cooperative Statistics Program in place prior to 1994, as well as an increase in demand for complete and accurate trip-level commercial harvest statistics by fisheries managers. The detailed data obtained through the NCTTP allows for the calculation of effort (i.e., trips, licenses, participants, vessels) in a given fishery that was not available prior to 1994 and provides a much more detailed record of North Carolina's seafood harvest.

NMFS SECPR Annual Canvas Data for Florida

The Florida Annual Data files from 1976–1996 represent annual landings by county (from dealer reports) which are broken out on a percentage estimate by species, gear, area of capture, and distance from shore. These estimates are submitted by Port agents, which were assigned responsibility for the particular county, from interviews and discussions from dealers and fishermen collected throughout the year. The estimates are processed against the annual landings totals by county on a percentage basis to create the estimated proportions of catch by the gear, area and distance from shore. The sum of percentages for a given Year, State, County, Species combination will equal 100.

Area of capture considerations: ALS is considered to be a commercial landings database which reports where the marine resource was landed. With the advent of some state trip ticket programs as the data source the definition is more loosely applied. As such one cannot assume reports from the ALS by State or county will accurately inform you of Gulf vs. South Atlantic vs. Foreign catch. To make that determination you must consider the area of capture.

4. Recreational Fishery Statistics

4.1 Overview

4.1.1 Group Membership

Leads

Ken Brennan- National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center (SEFSC) Fisheries Statistics Division (FSD)

Vivian Matter- NMFS SEFSC Sustainable Fisheries Division (SFD)

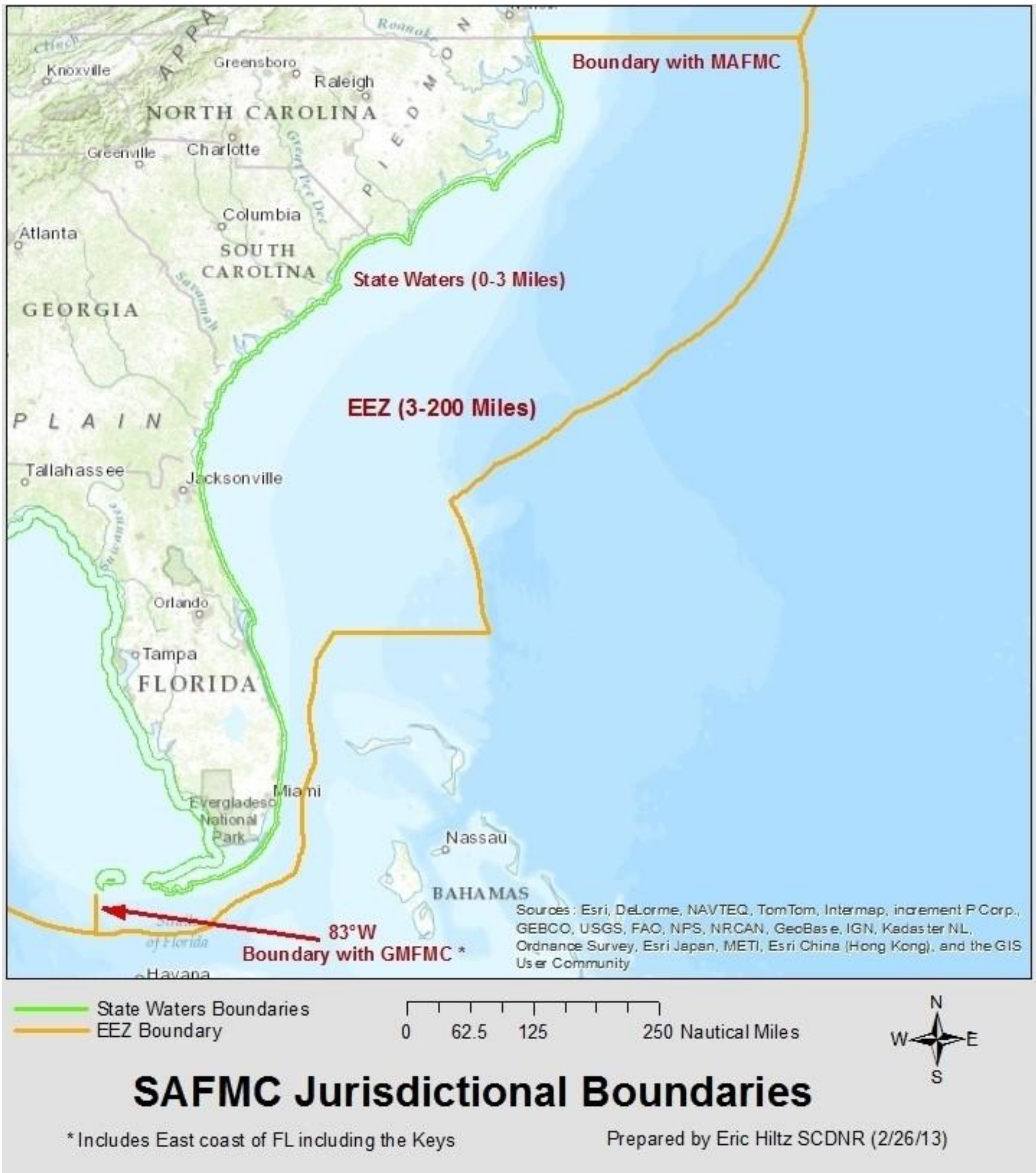
Members

Samantha Binion-Rock- NMFS SEFSC SFD
Rob Cheshire- NMFS SEFSC FSD
Eric Fitzpatrick- NMFS SEFSC SFD
Elizabeth Gooding- South Carolina Department of Natural Resources (SCDNR)
Maria Kappos- Florida Fish and Wildlife Conservation Commission (FWCC)
Matthew Nuttall- NMFS SEFSC SFD
Beverly Sauls- FWCC

4.1.2 Tasks

1. Summarize stock identification parameters
2. Review fully calibrated MRIP FES/APAIS/FHS landings and discard estimates
3. Allocate MRIP catch estimates from Monroe County to the Gulf of Mexico or South Atlantic
4. Evaluate MRIP catch estimates by mode of fishing to determine appropriate modes for inclusion in the Gray Triggerfish assessment
5. Determine when Gray Triggerfish was included in the SRHS universal logbook form
6. Evaluate usefulness of historical data sources such as the Fishing, Hunting, and Wildlife-Associated Recreation Survey (FHWAR) to generate estimates of landings prior to 1981
7. Provide estimates of uncertainty around each set of landings and discard estimates
8. Review whether SRHS discard estimates (2004+) are reliable for use and determine if there are other sources of data prior to 2004 that could be used as a proxy to estimate headboat discards
9. Provide nominal length distributions for both landings and discards if feasible
10. Evaluate adequacy of available data
11. Provide research recommendations to improve recreational data
12. ***Any other issues…***

4.1.3 South Atlantic Fishery Management Council Gray Triggerfish Group Management Boundaries



4.1.4 Stock ID Recommendations
Task 1:

Geographic Boundaries

SEDAR 82 assessment boundaries include areas from East Florida, including the Keys, to as far north as there are data available. The SRHS data extends north through North Carolina and the MRIP survey coverage extends north through Maine.

Species Identification

There were no species misidentification issues for SEDAR 82, but catch estimates of unidentified triggerfish (Balistidae family) are present in the general recreational dataset, some of which is assumed to be Gray Triggerfish. Proportions of identified Gray Triggerfish to other triggerfish species were analyzed by the Recreational Working Group (RWG). Refer to section 4.3.1 for details on the partitioning of unidentified triggerfish catch amongst species.

4.2 Review of Working Papers

Nominal Length and Age distributions of Southeast U.S. Atlantic gray triggerfish (Balistes capriscus) from recreational and commercial fisheries (SEDAR 82-DW-08)

This document outlines the data and methodologies used to develop nominal length and age compositions of commercial and recreational landings for the SEDAR 82 South Atlantic gray triggerfish assessment. These compositions were developed using data sources approved in the last assessment (SEDAR 41). This working paper outlines data availability and provides nominal compositions. At the Data Workshop, methodologies for tracking cohorts in the assessment model are considered. A more detailed working paper will be developed following the data workshop that describes the weighted length and age compositions.

General Recreational Survey Data for Gray Triggerfish in the South Atlantic (SEDAR 82-DW-09)

General recreational survey data for Gray Triggerfish from the Marine Recreational Information Program (MRIP) are summarized from 1981 to 2021 for Atlantic states from Maine to eastern Florida, including the Florida Keys. Charter, private, shore, headboat (Virginia to Maine) fishing modes are presented. These fully calibrated MRIP estimates take into account the change in the Fishing Effort Survey, the redesigned Access Point Angler Intercept Survey, and the For-Hire Survey. Tables and figures presented include calibration comparisons, landing and discard estimates, associated CVs, sample sizes, fish sizes, and effort estimates.

A Summary of Length Frequency and Hook Usage from the Size Distribution of Gray Triggerfish Discards recorded during Recreational Fishery Surveys in the South Atlantic (SEDAR 82-DW-11)

This report summarizes available size distribution and release condition data for Gray Triggerfish captured by the at-sea observer programs for the headboat fleet operating along the South Atlantic coast from East Florida to North Carolina. In addition, three years of at- sea observer data on size distribution of discards observed in the charter fleet off the east coast of Florida are also summarized.

Descriptions of Florida's Atlantic Coast Gray Triggerfish (Balistes capriscus) recreational fishery assessed using fishery-dependent survey data (SEDAR 82-DW-13)

This report summarizes the for-hire and private recreational fishing fleets for Gray Triggerfish on the east coast of Florida. Three statewide surveys (Marine Fisheries Initiative Survey, State Reef Fish Survey, and At-sea) sampled charter, headboat, and private fishing vessels. All data are aggregated by fleet (charter, headboat, private) and region. Regions of Florida are designated as northeast Florida (NEFL – Nassau to Brevard counties), southeast Florida (SEFL – Indian River to Miami-Dade counties), and Florida Keys (KEYS – Monroe County). Tables and figures include summaries of harvested and discarded estimates, fishing depth, release condition, and fish size.

4.3 Recreational Data Sources

4.3.1 Marine Recreational Information Program (MRIP)

Introduction

The Marine Recreational Information Program (MRIP), formerly the Marine Recreational Fisheries Statistics Survey, conducted by NOAA Fisheries (NMFS) provides estimates of catch per unit effort, total effort, landings, and discards for six two-month periods (waves) each year. MRIP provides estimates for three main recreational fishing modes: shore-based fishing (Shore), private and rental boat fishing (Priv), and for-hire charter and guide fishing (Cbt). MRIP also provides estimates for headboat mode (Hbt) in the mid and north Atlantic regions. MRIP covers all coastal Atlantic states from Maine to Florida. When the survey first began in Wave 2 (Mar/Apr) of 1981, headboats were included in the for-hire mode, but were excluded after 1985 to avoid overlap with the Southeast Region Headboat Survey (SRHS), conducted by the NMFS Beaufort laboratory.

Recreational catch, effort, and participation were estimated through a suite of independent but complementary surveys that are described in SEDAR 68-DW-13. Over the years, effort data have been collected from three different surveys: (1) the Coastal Household Telephone Survey (CHTS) which used random digit dialing of coastal households to obtain information about recreational fishing trips, (2) the weekly For-Hire Survey which interviews charterboat operators (captains or owners) to obtain trip information and replaced the CHTS for the charter mode (in 2000 for the Gulf of Mexico and East Florida and 2004 for the Atlantic coast north of Georgia), and (3) the Fishing Effort Survey which is a mail based survey whose sample frame consists of anglers from the National Saltwater Angler Registry and replaced the CHTS for the private and shore modes in 2018. Catch data are collected through dockside angler interviews in the Access Point Angler Intercept Survey (APAIS), which samples recreational fishing trips after they have been completed. In 2013, MRIP implemented a new APAIS to remove sources of potential bias from the sampling process. Catch rates from dockside intercept surveys are combined with estimates of effort to estimate total landings and discards by wave, mode, and area fished (inland, state, and federal waters).

Catch estimates from the early years of the survey are highly variable with high proportional standard errors (PSE's), and sample sizes in the dockside intercept portion have been increased over time to improve precision of catch estimates. Several quality assurance and quality control improvements were implemented for the intercept surveys in 1990. Prior to 1990, the contractor did not have regional representatives hired to supervise the samplers in any given area. All samplers were hired as independent sub-contractors and communicated directly with the contractor's home office staff. It is much more likely that the samplers who worked in the 80's would have varied more in their interpretation of sampling protocols and their ability to identify at least some of the more difficult-to-recognize species. There were a number of other changes made to enhance consistency in sampling protocols and improve error-checking in the Statement of Work for the 1990-1992 contracts. Improvements have continued over the years, but the biggest changes happened at that time (personal communication, NMFS). Catch rate data have improved through increased sample quotas and additional sampling (requested and funded by the states) to the intercept portion of the survey. Most recently, APAIS sample sizes from Florida through North Carolina were increased with additional funds that became available in 2020 from the Modernizing Recreational Fisheries Management Act.

Unidentified Triggerfish Estimates

Catch estimates of unidentified triggerfish (i.e., leatherjacket family) are present in the MRIP dataset. The Recreational Working Group (RWG) analyzed the proportion of identified Gray Triggerfish catch to that of Ocean Triggerfish and Queen Triggerfish to determine the proportion of unidentified catch composed of Gray Triggerfish (Table 17 in S82-DW-09). The RWG recommends using the same ratio as that applied in SEDAR 41 (0.94), which was calculated from MRIP catch estimates for years 2000+ and largely unchanged when updated with catch estimates from recent years (2000-2021): AB1 = 93.4% and B2 = 93.1%. The choice of years in this analysis follows from a relative confidence in species identification in the later time period of the MRIP survey.

Task 2: In order to maintain a consistent time series, charter estimates were calibrated on the Atlantic prior to 2004 (SEDAR64-RD-12). CHTS and calibrated FHS charter catch estimates for South Atlantic Gray Triggerfish from 1981 to 2003 are shown in Figure 1 of SEDAR 82-DW-09. Calibrated APAIS and FES estimates for South Atlantic Gray Triggerfish from 1981 to 2021 are shown in Figure 2 of SEDAR 82-DW-09.

Monroe County

Monroe County landings are included in the official MRIP West Florida estimates. However, landings from this county can be estimated separately using domain estimation. The Monroe County domain includes only intercepted trips returning to that county as identified in the intercept survey data. Estimates are then calculated within this domain using standard design-based estimation which incorporates the MRIP design stratification, clustering, and sample weights (SEDAR68-DW-13). Although Monroe county estimates can be separated using this process, they cannot be partitioned into those from the Atlantic Ocean and those from the Gulf of Mexico (SEDAR-PW-07).

Task 3: For SEDAR 82, MRIP Gray Triggerfish landings from Monroe County were allocated to the South Atlantic because Gray Triggerfish is a reef associated species and so Monroe county catches are most likely from the Atlantic side of the Florida Keys. This recommendation is in agreement with previous South Atlantic Gray Triggerfish assessments (SEDAR 32 and 41).

Adjustment to Fishing Modes

Task 4a: Between 1981 and 1985 in the South Atlantic and between 1981 and 2003 in the Mid- and North Atlantic, MRIP charter and headboat modes were combined into a single mode for estimation purposes.

- South Atlantic – Since complete coverage of the NMFS Southeast Region Headboat Survey (SRHS) began in the South Atlantic in 1981, the MRIP combined charter/headboat mode must be split in order to not double the estimated headboat landings in these early years. The MRIP charter/headboat mode (1981-1985) was split by using a ratio of SRHS headboat angler trip estimates to MRIP charterboat angler trip estimates for 1986-1990. In accordance with SEDAR Best Practices, the mean ratio was calculated by state (or state equivalent to match SRHS areas to MRIP states) and then applied to the 1981-1985 estimates to split out the headboat component when needed (SEDAR-PW-07). To avoid duplication of South Atlantic headboat estimates, the MRIP headboat component from this split was deleted for all South Atlantic states (North Carolina to eastern Florida) and SRHS estimates are used to represent headboat fishing for all years (1981+).
- Mid- and North Atlantic – To maintain separate fleet structure for the recreational modes, the combined cbt/hbt mode estimates in the Mid and North Atlantic regions must be split. As recommended by the S82 RWG, estimates for the MRIP combined charter/headboat mode were split using ratios of MRIP charterboat:headboat effort from raw MRIP intercept data. These effort-based ratios were calculated by year (1981-2003), state, and mode and applied to the combined for-hire estimates for both catch and effort. Catch-based ratios were considered, but the relative infrequency of non-zero Gray Triggerfish catch resulted in most ratios allocating 100% of the catch to a single mode in each year-state-mode strata. The effort data, conversely, provided a wider range of non-zero estimates for both charterboat and headboat and a larger number of ratios estimated between 0% and 100%.

Task 4b: The Recreational Working Group also discussed the validity of the MRIP shore mode estimates for South Atlantic Gray Triggerfish. The Group recommended that all shore mode estimates be included as was done in previous assessments. Discussion with FWRI regional supervisors suggests shore mode is plausible from the piers in FLE and bridges in the FL Keys; however, the catch will most likely be of smaller, under-sized fish. Gray Triggerfish have been observed on underwater pier cameras from Deerfield Beach, FL. In recent years, Gray Triggerfish have been caught and reported from shore mode in New Jersey and Long Island in the summer months near jetties, docks, and bridge pilings (George 2020).

Uncertainty

Coefficient of variation (CV) estimates for Marine Recreational Information Program (MRIP) survey catch totals are provided for stock assessments by the Southeast Fisheries Science Center (SEFSC). Variances of total catch-in-number estimates are computed directly from the raw survey data to obtain CVs appropriate for custom aggregations by year, wave, sub-region, state, and mode using standard survey methods (SEDAR 68-DW-10).

4.3.2 Southeast Region Headboat Survey (SRHS)

The Southeast Region Headboat Survey estimates landings and effort for headboats in the South Atlantic and Gulf of Mexico. The Headboat Survey incorporates two components for estimating catch and effort. 1) Information about the size of fish landed is collected by port samplers during dockside sampling, where fish are measured to the nearest mm and weighed to the nearest 0.01 kg. These data are used to generate mean weights for all species by area and month. Port samplers also collect otoliths for ageing studies during dockside sampling events. 2) Information about total catch and effort are collected via the logbook, a form filled out by vessel personnel and containing total catch and effort data for individual trips. These logbooks are summarized by vessel to generate estimated landings by species, area, and time strata. The South Atlantic and Gulf of Mexico Headboat Surveys generally include 70-80 vessels participating in each region annually.

In the early years of the SRHS, there was only partial geographic coverage in the South Atlantic. Landings are available in NC and SC beginning in 1974. Landings are not available for GA/NEFL from 1974-1975 or SEFL from 1974-1980. Estimates for these areas/time periods can be calculated from several methods using the ratio of NC and SC landings from 1974-1980 for periods of partial coverage. For GA/NEFL a five year ratio is calculated by dividing the total landings for NEFL (1976-1978) by NC and SC combined total landings (1976-1978). This ratio is then multiplied to the 1974 and1975 combined total landings for NC and SC, resulting in the total landings for NEFL for 1974 and 1975. The same approach was used to calculate landings for SEFL 1974-1980 by using the total landings from 1981-1985. This same method and landings were accepted for use in SEDAR 32 and was also supported in SEDAR 41.

Uncertainty

The SRHS is designed to be a census and so reporting compliance and accuracy are the primary components of the uncertainty in landings and discard estimates over time. Headboat activity is monitored by port agents to validate trips and the information collected informs compliance evaluations. As in SEDAR 74, a proxy for uncertainty in landings was calculated using the compliance ratio (reported trips/estimated trips) with an additional buffer coefficient of variation (CV) of 0.05. An additional step was added to calculate annual compliance ratios by state/region which are then proportionally weighted the state/regional landings to give annual proxy CV estimates:

$$\text{proxyCV}_i = 1 - \sum_{j=1}^{n} \left[\left(\frac{\mathrm{n}_{ij}}{\mathrm{N}_{ij}} \right) * \left(\frac{\mathrm{L}_{ij}}{\mathrm{L}_i} \right) \right] + 0.05$$

where n is the number of reported trips, N is the number of estimated trips, and L is the landings in number for year *i* and state/region *j*. This method balances conflicting biases in uncertainty. Methodologies to account for catch from unreported trips leverage information from similar vessels, months, areas, and trip types and are likely to decrease our estimate of uncertainty. However, the quality of reporting from compliant vessels is likely to have improved over time which would suggest these uncertainty estimates are low.

4.3.3 Headboat At-Sea Observer Survey

An observer survey of the recreational headboat fishery was launched in NC and SC in 2004 and in GA and FL in 2005 to collect more detailed information on recreational headboat catch, particularly for discarded fish. This coverage continued through 2017. Headboat vessels were randomly selected throughout the year in each state. Biologists board selected vessels with permission from the captain and observe anglers as they fish on the recreational trip. Data collected include the species, number, final disposition, and size of landed and discarded fish. Data are also collected on the length of the trip and area fished (inland, state, and federal waters) (SEDAR 82-DW-11).

4.3.4 South Carolina Department of Natural Resources (SCDNR)

SCDNR State Finfish Survey (SFS)

The SFS collects finfish intercept data in South Carolina through a non-random intercept survey at public boat landings along the SC coast. The survey focuses on known productive sample sites, targets primarily the private boat mode, and was conducted year-round (January-December) from its inception through 2013, after which time the SFS was only conducted in wave 1 (January-February). The survey uses a questionnaire and interview procedure similar to the intercept portion of the MRIP survey. Mid-line (or fork) lengths were measured from 1988 through March 2009 and maximum total lengths (to the end of the longest tendril) have been measured since April 2009.

SCDNR Charter Boat Logbook Program Data

The SCDNR Charterboat Logbook Program is a mandatory logbook program and is a complete census. However, the data is self-reported, and there is no field validation on catch or effort. The SEDAR 41 Recreational Fisheries Working Group determined these data should not replace the MRIP dataset, since the data only represent one state (SC) and one mode (charter). After discussing this data source, the previous SEDAR 41 recommendation was upheld.

4.4 Recreational Landings

4.4.1 MRIP Landings

Weight Estimation

The Southeast Fisheries Science Center used the MRIP sample data to obtain an average weight by strata using the following hierarchy: species, region, year, state, mode, wave, and area (SEDAR32-DW-02). The minimum number of weights used at each level of substitution is 15 fish, except for the final species level where the minimum is 1 fish (SEDAR67-WP-06). Average weights are then multiplied by the landings estimates in numbers to obtain estimates of landings in weight. These estimates are provided in pounds whole weight.

Coefficient of variation (CV) estimates for these average (fish) weights and associated landings-in-weights are calculated using approach #2 in SEDAR 74-DW-12. Briefly, all observations of fish weight are averaged at the trip level, from which the mean and standard error of these trip-level summaries are calculated at the same strata used in SEFSC weight estimation, combined to the year/mode level (e.g., year and mode), and converted to coefficients of variation (CV). These uncertainty estimates for SEFSC average weights are then combined with those for landings-in-number (Goodman 1960) as an uncertainty estimate for landings-in-weight. The Recreational Working Group recommended using this approach for calculating uncertainty around average (fish) weight and landings-in-weight estimates, as was done in SEDAR 74.

Catch Estimates

Final MRIP landings estimates and associated coefficients of variation, in numbers of fish, are shown by year and mode in Table 3 of SEDAR 82-DW-09 and by year in Table 5 of SEDAR 82-DW-09. Estimates are provided for all Atlantic states from Maine to eastern Florida, including the Florida Keys. Final MRIP landings estimates in pounds whole weight are shown by year and state in Table 6 of SEDAR 82-DW-09 and by year and mode in Table 7 of SEDAR 82-DW-09.

The Recreational Working Group investigated the 1991 landings estimate, which is relatively high compared to that from neighboring years. The estimate of 335,799 fish for that year came primarily from shore mode in state waters of Florida.

Strata: FL Keys, shore, wave 1, and ocean <= 10 miles

Two angler trips contributed to the estimate for this strata. Of these two trips, one harvested one fish (seen by interviewer) and one harvested two fish (seen by interviewer) and released one fish, resulting in a landings estimate of 127,083 fish.

Strata: FLE, shore, wave 6, and ocean <= 3 miles

Six angler trips contributed to the estimate for this strata. Of these six trips, one harvested three fish (not seen by interviewer), one harvested four fish (not seen by interviewer), one harvested one fish (seen by interviewer), one released one fish, one released 6 fish, one released 15 fish, resulting in a landings estimate of 193,158 fish.

The Recreational Working Group contacted FWRI regional supervisors concerning these shore landings from Florida. As noted above (task 4b) these shore estimates are plausible from piers in East Florida and bridges in the Keys.

The Recreational Working Group also investigated the 1997 landings estimate, which is relatively high compared to neighboring years. The estimate of 558,923 fish for that year came primarily from New Jersey, wave 4, the combined cbt/hbt mode, and ocean > 3 miles. Five angler trips contributed to the estimate for this strata, all from the same fishing party. Of these five trips, one harvested nine fish (seen by interviewer), three harvested ten fish (not seen by interviewer), and one harvested eleven fish (not seen by interviewer), resulting in a landings estimate of 403,170 fish. One of these trips also released two live fish. The Recreational Working Group contacted the Office of Science and Technology, who investigated this particular landings estimate. No error in the data was identified, however, it was noted that this estimate has a high PSE.

4.4.2 SRHS Headboat Logbook Landings

The headboat logbook form was changed several times during the early years of the SRHS. In the case of gray triggerfish, the logbook form used in North Carolina and South Carolina included triggerfish starting in 1974, but did not specifically list gray triggerfish until 1984. The logbook form for Georgia and Florida included gray triggerfish in 1980. The Headboat Survey did not have a universal logbook form that included gray triggerfish for all areas until 1984. Dockside sampling records were reviewed for the years when only triggerfish were listed on the form and it was demonstrated that nearly all reported triggerfish were gray triggerfish for North Carolina and South Carolina.

Task 5: Based on this information the headboat logbook data was used for the time period it was available (1974-2013) in SEDAR32. This was also supported in SEDAR 41(1974-2014).

Catch Estimates

Final SRHS landings estimates are shown in Table 4.12.1.

4.4.3 Historic Recreational Landings

Introduction

The historic recreational landings time period is defined as pre-1981 for the charter, private, shore, headboat (Virginia to Maine) fishing modes, which represents the start of the Marine Recreational Information Program (MRIP) and availability of landings estimates for Gray

Triggerfish. For Gray Triggerfish, SRHS estimated landings (NC to FL) start in 1974. The Recreational Working Group was tasked with evaluating historical sources and methods to compile landings estimates for Gray Triggerfish prior to the start of the surveys.

FHWAR Census Method

The 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (FHWAR) presents summary tables of U.S. population estimates, along with estimates of hunting and fishing participation and effort from surveys conducted by the US Fish and Wildlife Service every 5 years from 1955 to 1985 (SEDAR 68-DW-11). This information was used to develop an alternative method for estimating historical recreational landings.

The two key components from these FHWAR surveys that were used in this census method were the estimates of U.S. saltwater anglers and U.S. saltwater days. These estimates are used to calculate the historical effort of South Atlantic saltwater anglers. The mean CPUE from the total recreational estimates from 1981 to 1985 for Gray Triggerfish is then applied to the historical effort estimates for South Atlantic anglers to provide historical estimates of recreational Gray Triggerfish landings.

Task 6: Historical Gray Triggerfish landings:

- 1955-1973: Historical Gray Triggerfish landings from the FHWAR method, with scaling based on estimates from years 1981-1985 are shown in Table 4.12.2.
- 1974-1980: Headboat SRHS estimates start in 1974. General recreational catch estimates for 1974-1980 were estimated as the product of the expected fraction of total landings comprised of GenRec (over this time period) and the annual FHWAR total landings estimate, the former calculated as:
  - $\%GenRec = 1 - avg\left(\frac{SRHS_y}{FHWAR_y}\right)$

  over years (y) 1974-1980. These estimates are shown in Table 4.12.3

The SEDAR 82 Recreational Working Group recommended to include the historical landings estimates from the FHWAR method because this method has been accepted as a best practice for SEDARs and is the most representative method available for characterizing recreational landings prior to standardized data collection programs. The Recreational Working Group provided one historical recreational time series covering all regions and fleets. If it is determined at the assessment stage that this time series is needed by fleet and/or by regions, this analysis can be subsequently provided at that time.

Uncertainty

As a proxy for uncertainty in historical (FHWAR) total recreational landings, CVs of the mean catch rate (CPUE) from the combined (MRIP and SRHS) recreational catch from 1981 to 1985 are provided. CVs calculated using the FHWAR method for total recreational landings is 0.34.

4.4.5 Total Recreational Landings

Combined landings estimates (MRIP and SRHS) are shown in Table 4.12.3, Table 4.12.4, Figure 4.13.1, and mapped in Figure 4.13.2. The majority of recreational landings for Atlantic Gray Triggerfish come from the private mode (about 52%). The headboat mode contributes about 30% and charterboat contributes 8%. The shore mode makes up the remaining 10% of recreational landings. Geographically, most landings come from eastern Florida (about 48%), followed by North Carolina (about 19%) and New Jersey in the Mid-Atlantic (about 11%). Gray triggerfish landings have generally increased from 1981 – 2021.

Uncertainty

Task 7: To provide an associated measure of uncertainty for total recreational landings estimates, coefficients of variation (CVs) are calculated from the sum total of variance in reported SRHS logbook landings and MRIP landings data. Details of this approach are outlined in SEDAR 68-DW-31.

4.5 Recreational Discards

4.5.1 MRIP Discards

Fish reported to have been discarded alive are not seen by MRIP interviewers and so neither the identity nor the quantities of discarded fish can be verified. The size and weight of discarded fish are also unknown for all modes of fishing. MRIP discard estimates and associated coefficients of variation, in numbers of fish, are shown by year and mode in Table 4 of SEDAR 82-DW-09 and by year in Table 5 of SEDAR 82-DW-09. Estimates are provided for all Atlantic states from Maine to eastern Florida, including the Florida Keys.

The working group investigated the 2016 discards estimate, which is relatively high compared to the rest of the time series. The estimate of 2,551,708 fish for that year came primarily from eastern Florida and the private mode, but from different waves and areas fished:

- Wave 4 and Ocean > 3 miles – Twenty seven trips which, on average, released four live fish and resulted in a discards estimate of 436,553 fish. These trips also, on average, harvested two fish (combination of those seen and not seen by an interviewer).

- Wave 6 and Ocean <= 3 miles - Ten trips which, on average, released five live fish and resulted in a discards estimate of 837,965 fish. These trips also, on average, harvested two fish (combination of those seen and not seen by an interviewer).
- Wave 6 and Ocean > 3 miles - Ten trips which, on average, released seven live fish and resulted in a discards estimate of 260,000 fish. These trips also, on average, harvested one fish (combination of those seen and not seen by an interviewer).

Higher than normal discard estimates were present in the general recreational, headboat logbook, and headboat at-sea observer data.

4.5.2 SRHS Headboat Logbook Discards

The Southeast Region Headboat Survey logbook form was modified in 2004 to include a category to collect self-reported discards for each reported trip. This category is described on the form as the number of fish by species released alive and number released dead. Port agents instructed each captain on criteria for determining the condition of discarded fish. A fish is considered “released alive” if it is able to swim away on its own. If the fish floats off or is obviously dead or unable to swim, it is considered “released dead”. As of Jan 1, 2013 the SRHS began collecting logbook data electronically. Changes to the trip report were also made at this time, one of which removed the condition category for discards (i.e., released alive vs. released dead). The form now collects only the total number of fish released, regardless of condition.

Self-reported headboat discards are not currently validated within the SRHS. However, discard information from the At-Sea Observer Survey is used to validate the SRHS discard rates. The early years (2004-2007) of discard data collection efforts suffered from some inconsistencies and misinterpretation of the instructions. A comparison of the catch rates from the At-Sea Observer data and the SRHS logbook for gray triggerfish revealed a pattern of under reporting discards in the SRHS logbooks for 2004 to 2007 in Florida (Figure 4.13.3). The lack of observer coverage in other states for these years prevents a similar comparison. The SEDAR 82 Recreational Working Group recommended to use SRHS logbook discard estimates from 2008-2021 and use a proxy method for earlier years.

Task 8: Proxy for estimated headboat discards from 1974-2007

Prior to 1974 there is limited information to inform discarding of gray triggerfish. The SEDAR 82 RWG assumed there was no discarding of gray triggerfish prior to 1974 since there was no size limit and anecdotal information that most of the headboat anglers were fishing for meat rather than sport during this time. Uncertainty about the desirability of gray triggerfish during this time period adds to the uncertainty of this assumption. The best practice discard proxy method used in many recent SEDAR assessments relies on the MRIP charter discard rates scaled by the average ratio of SRHS discard rates: MRIP charter rates in recent years. The equation below was used to estimate SHRS discards for 1981-2007. The 1988 MRIP charter landings were exceptionally low and discards relatively high causing an unlikely discard rate (3.2*landings). The 1988 MRIP charter discard rate was replaced with the 3-year average MRIP charter discard rate for 1987,1988, and 1989 (1.1*landings). This is still a large value in the time series but reduced significantly to a value more compatible with the other large value in 2016 with better sampling.

$$HBD_i = HBL_i * \frac{CHD_i}{CHL_i} * \left[\frac{\sum_{i=2008}^{i=2021} \frac{HBD_i}{HBL_i}}{\sum_{i=2008}^{i=2021} \frac{CHD_i}{CHL_i}}\right]$$

where HBD is the estimate of SRHS headboat discards, HBL is the estimate of SRHS headboat landings, CHD is the estimate of MRIP charter discards, and CHL is the estimate of MRIP charter landings. There are no MRIP charter estimates for 1974-1980 so the average discard rate from 1981-1985 was applied to the SRHS landings to get discard estimates. Final estimated discards (1974-2021) are presented in Table 4.12.5 along with the proxy discard estimates.

Uncertainty

Uncertainty in SRHS discards for 2008-2019 use the same method described for the landings. MRIP charter boat discard CVs are used as a proxy for SRHS headboat discard CVs from 1981 to 2007. SRHS headboat landings CVs are used as a proxy for SRHS headboat discard CVs from 1974 to 1980.

4.5.3 Total Recreational Discards

Combined discard estimates (MRIP and SRHS) are shown in Table 4.12.6, Figure 4.13.4, and mapped in Figure 4.13.5. The majority of recreational discards for Atlantic gray triggerfish come from the private mode (about 65%). The headboat mode contributes about 10% and charterboat contributes 2%. The shore mode makes up the remaining 23% of recreational discards. Geographically, most discards come from eastern Florida (about 79%), followed by the Florida Keys (about 8%) and North Carolina (about 5%). Gray triggerfish discards have generally increased from 1981 – 2021, with a higher than normal estimate in 2016 that was described above.

4.6 Biological Sampling

4.6.1 Landings

4.6.1.1 MRIP Biological Sampling

The MRIP angler intercept survey includes the collection of fish lengths from the harvested catch (landed, whole condition). Up to 15 of each landed species per angler interviewed are measured to the nearest mm along a centerline (defined as tip of snout to center of tail along a straight line, not curved over body). In those fish with a forked tail, this measure would typically be referred to as a fork length. In those fish that do not have a forked tail, it would typically be referred to as a total length, with the exception of some fish that have a single, or few, caudal fin rays that extend further. Weights are typically collected for the same fish measured, although weights are preferred when time is constrained. Ageing structures and other biological samples are not collected during MRIP assignments because of concerns over the introduction of bias to survey data collection. Discarded fish size is not collected by MRIP for any fishing mode.

Summaries of fish size for MRIP-sampled Gray Triggerfish in the South Atlantic by state (1981-2021) are provided in Table 8 of SEDAR 82-DW-09 (millimeters fork length) and Table 9 of SEDAR 82-DW-09 (pounds whole weight). Comparable summaries of fish size by mode are provided in Table 10 of SEDAR 82-DW-09 (millimeters fork length) and Table 11 of SEDAR 82-DW-09 (pounds whole weight). These summaries include the number of measured Gray Triggerfish, number of angler trips from which Gray Triggerfish were measured, and the minimum, average, standard deviation, and maximum size of all measured Gray Triggerfish.

4.6.1.2 SRHS Biological Sampling

Lengths were collected by headboat dockside samplers beginning in 1972. From 1972 to 1975, only North Carolina and South Carolina were sampled whereas Georgia and northeast Florida sampling began in 1976. The SRHS conducted dockside sampling throughout the southeast portion of the US (from the NC-VA border to the Florida Keys) beginning in 1978. SRHS dockside sampling has been conducted in all Gulf states since 1986, except for Mississippi where sampling started in 2010. Weights are typically collected for the same fish measured during dockside sampling. Biological samples (scales, otoliths, spines, stomachs, and gonads) are also collected routinely and processed for aging, diet studies, and maturity studies.

Summaries of fish size, in kilograms whole weight, for SRHS-sampled Gray Triggerfish in the South Atlantic (1972-2021) are provided in Table 4.12.7. These summaries include the annual number of measured Gray Triggerfish, the number of trips from which Gray Triggerfish were measured, and the minimum, average, and maximum size of Gray Triggerfish measured by SRHS dockside samplers.

The length unit for gray triggerfish was inconsistent in the early years (1972-1982) of the survey and should be excluded from life history analyses and size compositions. Any existing total length or whole weight measurements without an associated fork length measurement were converted using the length-length and length-weight morphometric equations derived by the Life History Working Group for the South Atlantic stock (SEDAR 82-DW-01).

4.6.1.3 SCDNR Biological Sampling

Gray Triggerfish lengths are available from SCDNR's State Finfish Survey (SFS) and supplement MRIP's length data from this state for a portion of time series. Lengths were collected year-round through a non-random intercept survey at public boat landings along the SC coast from 1988 to 2012. The survey focused on known productive sample sites and primarily targeted the private boat mode. The SFS used a questionnaire and interview procedure similar to the intercept portion of the MRIP survey. In 2013, SCDNR took over MRIP sampling responsibilities in SC, so the SFS survey was terminated except for January and February sampling. During the year-round SFS sampling from 1988 to 2012, personnel collected 220 Gray Triggerfish lengths. To date, zero Gray Triggerfish have been sampled during the January-February SFS since 2011.

4.6.1.4 Nominal Length Frequency Distributions of Landings

Task 9a: Nominal length frequencies were generated for the recreational fleet using length data from federal and state data sources described above (MRIP, SRHS, and SCDNR). Sample sizes are shown in Table 1 from SEDAR 82-DW-08. Headboat, charter, and private mode length frequencies were compared in Figure 2 from SEDAR 82-DW-08. These length frequency distributions indicate the headboat, charter, and private boat fisheries retain similarly sized fish. However, charter and private modes were combined in the last assessment (SEDAR 41) and this aggregation will be explored in the assessment stage. Annual length frequency distributions by fleet are shown in Figure 4.13.6. Although some annual variations shown can be attributed to management regulations, overall the distributions do not seem to be impacted by regulations.

4.6.1.5 Aging Data

Age samples are collected as part of the SRHS sampling protocol. Age samples collected from the private/rental boat, charterboat, and shore modes are not typically collected as part of the MRIP sampling protocol. These samples come from a number of sources including state agencies, special projects, and sometimes as add-ons to the MRIP survey. Triggerfish spines collected from East Florida were collected from two short-term MARFIN studies (SEDAR 82-DW-RD50 and SEDAR 82-DW-RD51) and two state-funded long-term monitoring programs (the For-Hire At-Sea Observer Program and State Reef Fish Survey, described in SEDAR 82-DW-13). Spines collected from Florida are processed at the SEFSC age and growth lab in Beaufort. The number of Gray Triggerfish aged from the recreational fishery by year and mode is summarized in Table 4.12.8 and annual nominal age compositions are shown in Figure 4.13.7. If sufficient data are available, the recreational ages will be weighted by the length frequency distribution by year and fleet in the assessment stage.

4.6.2 Discards

4.6.2.1 Headboat and Charterboat At-Sea Observer Survey Biological Sampling

At-sea sampling of headboat trips are conducted to characterize the size distribution of live discarded fish in the headboat fishery. Headboat observer data was collected year-round from Florida, Georgia, South Carolina, and North Carolina. A summary of live discard length data from these states was provided to analysts and described in SEDAR 82-DW-11. Data collected from 2005 to 2020 observed 5,138 trips and recorded 3,238 discarded Gray Triggerfish. The discard rate per trip was: SEFL (35%), NEFL/GA (9%), FL Keys (7%), NC (3%), and South Carolina (1%). Florida has also conducted limited at-sea sampling of the charter fleet. From 2013 to 2015 in the charter fleet, at-sea biologists observed 674 trips on Florida's south Atlantic coast. Positive trips accounted for 24% of total charter trips. Furthermore, 15.72% of positive trips included Gray Triggerfish discards.

Florida conducted a 3 year MARFIN (Marine Fisheries Initiative Survey) study (2017-2020) which implemented a biological sampling program to improve stock assessments in the data-poor region of the South Atlantic. Recreational anglers were surveyed at fishing access points at major inlets. Data collected from private and charter boats included length, weight, age structures and sex ratios of reef fishes and other managed species. This pilot survey has since been expanded to the State Reef Fish Survey (SRFS) which now incorporates charter mode in long-term monitoring on the Atlantic coast (SEDAR 82-DW-13).

4.6.2.2 Nominal and Weighted Length Frequency Distributions of Discards

Task 9b: Length measurements from 3,614 discarded fish were used to generate headboat and charterboat discard length frequency distributions for the South Atlantic region.

- Headboat lengths in the South Atlantic region (n=3238) are available from 2005 to 2020 and the mean FL measured was 278mm. These data are summarized in Table 6 of SEDAR 82-DW-11. Headboat vessels report fishing effort in logbook trip reports through the Southeast Region Headboat Survey. Logbook effort was provided by the NMFS Southeast Fisheries Science Center in Beaufort, NC. Size data collected from discards observed at-sea were weighted proportional to fishing effort to account for the difference in sampling by trip types throughout the South Atlantic region. A full accounting of the weighting procedure applied to the raw length data is provided in SEDAR 82-DW-11. Annual headboat discard length compositions are presented in Figure 4.13.8.

- Charter lengths from east Florida (n=376) are available from 2013 to 2015 and the mean FL was 272mm. These data are summarized in Table 7 of SEDAR 82-DW-11. No sample weights were applied to charter data. Annual charterboat discard length compositions presented in Figure 4.13.9.

It is important to note the changes in length regulations that likely impacted the discard length trends. From 1995 to 2014 Florida was the only state in the South Atlantic region with a minimum size limit, which was 12 inches. In 2015, the size limit in Florida increased to 14 inches and a 12" limit was implemented in the remaining states. However, in 2020 Florida reduced the minimum size back to 12 inches, which made it consistent with the rest of the region (SEDAR 82-DW-02).

These discard length compositions were reviewed and recommended by the Recreational Working Group.

4.7 Recreational Effort

4.7.1 MRIP Effort

MRIP effort estimates are produced via the Fishing Effort Survey (FES) for private/rental boats and shore mode and the For-Hire Survey (FHS) for charterboat mode. MRIP effort is calculated in units of angler trips, which represents a single day of fishing in the specified mode that does not exceed 24 hours, and is provided by year and state in Table 15 of SEDAR 82-DW-09 and by year and mode in Table 16 of SEDAR 82-DW-09. These summaries include all Atlantic states from Maine to eastern Florida, including the Florida Keys.

4.7.2 SRHS Effort

Effort data from the SRHS is provided as the number of anglers on a given trip, which is standardized to "angler days" based on the length of the trip (e.g., 40 anglers on a half-day trip would yield 40 * 0.5 = 20 angler days). Angler days are summed by month for individual vessels. Each month, port agents collect these logbook trip reports and check for accuracy and completeness. Although reporting via the logbooks is mandatory, compliance is not 100% and is variable by location. To account for non-reporting, a correction factor is developed based on sampler observations, angler numbers from office books, and any available information. This information is used to provide estimates of total catch by month and area, along with estimates of effort.

In order to summarize recreational fishing effort across the South Atlantic, SRHS effort estimates are also provided in units of angler trips to match that provided by the MRIP survey. Monthly estimates of angler trips are calculated as the product of the reported number of anglers and ratios for the estimated number of total trips to the reported number of total trips (SEDAR 28-DW-12).

SRHS effort estimates (in angler days) are provided in Table 4.12.9. Estimated headboat angler days have decreased in the South Atlantic in recent years (Table 4.12.9). The most obvious factor which impacted the headboat fishery were the restrictions caused by COVID, resulting in a marked decline in angler days in the South Atlantic headboat fishery. Reports from industry staff, captains/owners, and port agents indicated fuel prices, the economy and fishing regulations are additional factors that most affected the amount of trips, number of passengers, and overall fishing effort.

4.7.3 Total Recreational Fishing Effort

Combined effort estimates in angler trips (MRIP and SRHS) are shown by year and mode in Table 4.12.10, Figure 4.13.10, and mapped in Figure 4.13.11. These effort estimates depict all recreational fishing activity along the Atlantic coast and are not specific to Gray Triggerfish. The majority of recreational fishing effort throughout the Atlantic comes from the shore mode (about 65%). The headboat mode contributes about 0.3% and charterboat contributes 1.2%. The private mode makes up the remaining 34% of recreational fishing effort. Geographically, most effort comes from eastern Florida (about 33%), followed by the North Carolina and New Jersey in the Mid-Atlantic (both about 11%). Recreational fishing effort has generally increased from 1981 – 2010, with some decline in years 2010-2021.

4.8 Comments on Adequacy of Data for Assessment Analyses

Task 10: Regarding the adequacy of the available recreational data for assessment analyses, the Recreational Working Group discussed the following:

- Landings and discards, as adjusted, appear to be adequate for the time period covered
- Size data appear to adequately represent the landed catch for all modes
- Discard size data from the headboat observer program appear to be adequate for describing the size composition of discarded Gray Triggerfish for the headboat fishery as that data is available since 2005 and covers all South Atlantic states.
- Discard size data from the charter observer program is not adequate due to limited temporal and geographic coverage. Florida has recently implemented discard size data collection from charter observer program. Data from other states are needed, currently Florida is the only state to collect discard lengths from the charter mode (2013-2015). Future analysis would benefit from the inclusion of the remaining South Atlantic states (SEDAR 82-DW-11).
- Age data are not adequate… Florida pilot tested a dockside biological sampling methodology (SEDAR-DW-RD51) and recently incorporated biological sampling in two state funded long-term monitoring projects (For-Hire Observer Program and State Reef Fish Survey), but a comprehensive coast-wide biological sampling program is needed to represent the range of this stock.
- Fleet structure recommendations: Suggest keeping headboat mode separate from combined general recreational mode (cbt, priv, and shore) which gives the model more flexibility and follows fleet structure used in SEDAR 41. There are different patterns in landings between these fleets as well as good composition data for each fleet.

4.9 Itemized List of Tasks for Completion following Workshop

- Weighted length and age compositions will be completed for the Assessment Workshop (completion of Task 9)

4.10 Research Recommendations

4.10.1 Evaluation and Progress of Research Recommendations from Last Assessment

Research recommendations from SEDAR 41 were evaluated and progress on each item is outlined below:

1. ***Complete analysis of available historic photos for trends in CPUE and mean size of landed Red Snapper and Gray Triggerfish for pre-1981 time period. (Ultimately all species)***
   - Evaluation of Progress
     - Developed methods through FISHstory pilot project, which is now complete

2. ***Formally archive data and photos for all other SEDAR target species***
   - Evaluation of Progress
     - ~1,375 photos – king mackerel measured in all
     - Requesting additional funding through ACCSP to continue and expand project to get photos throughout SA and other species of interest (e.g., red snapper)
     - Broader geographic spread and timeframe

3. ***For Hire Survey (FHS) should collect additional variables (e.g. depth fished)***
   - Evaluation of Progress
     - Not currently collected in FHS
     - Included on southeast electronic for-hire integrated electronic reporting (SEFHIER)

4. ***Increasing sample sizes for at-sea headboat observers (i.e. number of trips sampled)***
   - Evaluation of Progress
     - No change in recent years with regard to sample sizes, but the program is ongoing
     - FL FWC has secured long-term funds to continue at-sea headboat observer coverage on the Atlantic coast and to extend it to the charter fishery

5. ***Compute variance estimate for headboat landings***
   - Evaluation of Progress
     - Completed

6. ***Mandatory logbooks for all federally permitted for-hire vessels***
   - Evaluation of Progress
     - Completed - SEFHIER

4.10.2 Research Recommendations for SEDAR 82

Task 11:

1. Consider additional collections and analyses of historical photos for gray triggerfish to track desirability over time
2. Formally archive data and photos for all other SEDAR target species
3. For Hire Survey (FHS) should collect additional spatial and depth information
4. Develop statistically valid methods to identify outlier estimates and adjust sample weights for records that have a disproportionately high influence on total catch estimates and establish new SEDAR best practice methods
5. Implement procedures to measure noncompliance and validate catch and effort for for-hire vessel logbooks in SEFHIER (e.g., dockside validation)
6. Address the lack of survey coverage for non-federally permitted headboats operating in state waters
7. Establish comprehensive coastwide biological sampling program for collection of ageing structures similar to the biological sampling program coordinated by GulfFIN in the Gulf of Mexico.
8. Expand charter fishery observer coverage to North Carolina, South Carolina, and Georgia similar to the headboat at-sea observer programs.

4.11 Literature Cited

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4.12 Tables

Table 4.12.1. Estimated SRHS headboat landings of South Atlantic Gray Triggerfish. Landings are provided in number of fish and pounds whole weight; CVs are not available in weight units.

	Number						Pounds				
Year	NC	SC	GA/NEFL	SEFL	Total	CV	NC	SC	GA/NEFL	SEFL	Total
1974	10,575	16,516	14,932	20,952	62,974	0.7	58,242	73,736	47,818	44,446	224,241
1975	12,035	10,452	12,394	17,391	52,272	0.7	59,476	48,189	39,691	36,892	184,249
1976	8,153	8,543	6,881	9,139	32,716	0.7	41,835	36,625	22,756	19,388	120,604
1977	5,838	11,877	6,972	9,570	34,257	0.7	33,647	49,101	24,079	20,301	127,128
1978	8,163	5,886	12,612	10,335	36,996	0.7	40,523	24,546	35,845	21,924	122,838
1979	9,192	4,400	9,741	9,045	32,378	0.7	46,081	25,609	31,760	19,187	122,637
1980	3,939	7,450	4,272	6,071	21,732	0.7	20,721	37,814	13,453	12,878	84,866
1981	3,222	3,218	8,988	10,235	25,663	0.44	17,566	17,383	21,588	25,381	81,919
1982	4,678	6,531	8,665	9,630	29,504	0.35	24,341	27,163	26,594	19,251	97,348
1983	4,955	4,967	11,847	6,838	28,607	0.39	21,905	20,729	27,022	13,321	82,977
1984	7,676	3,622	9,836	5,762	26,896	0.34	34,149	13,973	25,058	14,290	87,470
1985	9,815	4,150	13,239	8,396	35,600	0.53	41,334	17,340	31,635	14,271	104,580
1986	6,628	4,526	9,607	7,610	28,371	0.52	24,701	18,530	22,890	13,816	79,937
1987	2,387	4,324	8,307	14,558	29,576	0.45	11,233	18,129	18,154	22,755	70,271
1988	1,743	3,629	11,842	17,712	34,926	0.45	6,438	13,288	23,132	26,962	69,820
1989	944	3,284	7,593	25,546	37,367	0.53	3,124	13,440	14,614	54,195	85,373
1990	11,213	3,838	14,511	42,142	71,704	0.62	30,785	11,087	24,022	49,780	115,674
1991	23,463	10,019	14,708	37,339	85,529	0.62	75,491	22,415	23,112	38,608	159,626
1992	41,965	19,775	11,372	18,621	91,733	0.58	88,438	42,702	18,209	20,972	170,321
1993	64,058	25,523	7,902	9,587	107,070	0.29	139,493	72,890	15,563	13,412	241,359
1994	48,995	24,697	5,280	11,415	90,387	0.34	106,604	54,638	10,507	18,214	189,964
1995	60,426	20,389	4,908	7,644	93,367	0.33	119,249	42,472	9,793	10,396	181,910
1996	55,476	24,989	3,478	6,011	89,954	0.32	100,070	44,651	6,428	12,532	163,682
1997	61,432	32,583	7,717	4,438	106,170	0.27	115,851	58,112	12,959	5,491	192,414
1998	36,535	20,258	4,720	4,344	65,857	0.31	81,121	38,768	8,363	6,476	134,727
1999	18,320	11,398	5,564	1,936	37,218	0.28	38,231	22,787	10,505	2,960	74,483
2000	15,683	10,671	3,016	4,722	34,092	0.35	28,519	21,196	5,263	7,497	62,475
2001	13,001	9,231	1,849	8,897	32,978	0.42	26,378	20,289	3,307	14,029	64,003
2002	30,061	11,710	2,585	13,274	57,630	0.45	52,742	22,011	4,951	18,636	98,340
2003	20,029	11,930	3,285	10,507	45,751	0.47	39,555	22,553	5,905	13,667	81,681
2004	31,908	12,733	8,284	25,148	78,073	0.48	71,596	25,396	15,239	37,243	149,475
2005	35,609	5,667	5,259	17,047	63,582	0.41	71,165	12,283	8,842	21,931	114,222
2006	19,931	8,781	5,319	9,120	43,151	0.46	41,841	18,832	9,231	12,619	82,524
2007	38,704	15,328	7,608	4,763	66,403	0.42	81,568	28,372	14,247	9,100	133,287
2008	22,879	7,292	5,391	9,196	44,758	0.49	45,451	15,329	12,298	17,547	90,625
2009	31,910	8,676	10,073	9,286	59,945	0.15	63,691	19,690	26,456	18,820	128,657
2010	30,153	13,345	12,918	12,391	68,807	0.16	61,614	31,569	31,079	28,300	152,561
2011	19,954	10,861	9,899	12,642	53,356	0.10	44,680	26,525	26,744	27,652	125,602
2012	19,325	7,388	7,590	14,793	49,096	0.09	42,891	17,729	20,879	34,910	116,409
2013	30,367	10,068	7,248	8,804	56,487	0.10	64,922	23,392	17,405	15,507	121,226
2014	26,468	9,072	6,391	11,177	53,108	0.08	56,196	21,733	15,625	19,718	113,273
2015	24,896	6,445	3,782	10,849	45,972	0.07	59,554	18,138	10,847	21,063	109,601
2016	17,223	6,765	3,646	10,206	37,840	0.06	33,352	20,105	9,736	17,221	80,414
2017	24,425	9,501	3,353	6,079	43,358	0.08	44,258	22,727	7,448	12,217	86,649
2018	20,966	7,330	2,793	4,002	35,091	0.05	41,136	15,664	7,819	7,824	72,444
2019	21,994	9,201	2,643	1,931	35,769	0.06	34,723	11,968	7,135	4,353	58,178
2020	17,275	7,409	2,341	1,116	28,141	0.06	35,212	14,999	6,654	2,952	59,817
2021	16,193	7,127	2,050	819	26,189	0.05	33,745	14,861	4,229	1,824	54,658

Table 4.12.2. Estimated historical recreational landings estimated for Gray Triggerfish for all recreational fleets combined in the Atlantic 1955-1973.

Year	Total Rec			
	Landings (num)	CV(num)	Landings (LBS)	CV(LBS)
1955	61,499	0.34	223,856	0.34
1956	64,886	0.34	236,185	0.34
1957	68,273	0.34	248,514	0.34
1958	71,661	0.34	260,846	0.34
1959	75,048	0.34	273,175	0.34
1960	78,436	0.34	285,507	0.34
1961	83,499	0.34	303,936	0.34
1962	88,563	0.34	322,369	0.34
1963	93,627	0.34	340,802	0.34
1964	98,691	0.34	359,235	0.34
1965	103,755	0.34	377,668	0.34
1966	108,034	0.34	393,244	0.34
1967	112,314	0.34	408,823	0.34
1968	116,594	0.34	424,402	0.34
1969	120,874	0.34	439,981	0.34
1970	125,153	0.34	455,557	0.34
1971	136,083	0.34	495,342	0.34
1972	147,013	0.34	535,127	0.34
1973	157,943	0.34	574,913	0.34

Table 4.12.3. Total recreational landings-in-number estimates (AB1) and associated coefficients of variation (CV) for South Atlantic Gray Triggerfish combined across all surveys (MRIP and SRHS) by year and mode. Estimates are summarized according to the chosen fleet structure for the SEDAR 82 stock assessment (GenRec = Shore+Cbt+Priv). CVs are not available for the GenRec fleet until 1981 and so, for 1974-1980, uncertainty in headboat catch was assumed representative of that for GenRec.

Year	Shore	Hbt	Cbt	Priv	GenRec Landings	GenRec CV	Hbt Landings	Hbt CV
1974	0	62,974	0	0	131,018	0.70	62,974	0.70
1975	0	52,272	0	0	139,497	0.70	52,272	0.70
1976	0	32,716	0	0	138,084	0.70	32,716	0.70
1977	0	34,257	0	0	136,669	0.70	34,257	0.70
1978	0	36,996	0	0	135,256	0.70	36,996	0.70
1979	0	32,378	0	0	133,841	0.70	32,378	0.70
1980	0	21,732	0	0	132,428	0.70	21,732	0.70
1981	10,588	25,663	6,178	179,928	196,693	0.65	25,663	0.44
1982	29,364	29,710	12,118	49,992	91,474	0.34	29,710	0.35
1983	49,928	28,713	6,047	71,284	127,259	0.39	28,713	0.39
1984	91,879	26,896	11,280	121,711	224,870	0.39	26,896	0.34
1985	5,674	39,317	8,688	85,585	99,947	0.59	39,317	0.49
1986	0	29,065	1,610	71,927	73,537	0.35	29,065	0.51
1987	40,715	30,210	2,009	102,303	145,027	0.40	30,210	0.44
1988	64,228	34,926	1,759	96,496	162,483	0.41	34,926	0.45
1989	39,565	43,760	17,990	224,810	282,366	0.31	43,760	0.47
1990	16,652	73,768	7,412	208,339	232,403	0.22	73,768	0.61
1991	335,799	87,814	10,869	287,192	633,860	0.37	87,814	0.61
1992	121,610	92,004	19,408	143,987	285,005	0.24	92,004	0.58
1993	94,096	124,666	22,685	145,819	262,599	0.30	124,666	0.28
1994	53,243	91,588	26,608	94,135	173,987	0.19	91,588	0.33
1995	21,178	93,828	15,919	102,631	139,728	0.20	93,828	0.33
1996	46,869	90,352	18,531	170,745	236,146	0.26	90,352	0.32
1997	25,140	266,001	279,296	94,656	399,092	0.62	266,001	0.60
1998	17,688	66,371	11,341	76,105	105,134	0.32	66,371	0.30
1999	3,686	37,556	15,566	101,756	121,008	0.18	37,556	0.28
2000	35,863	34,443	6,397	86,116	128,376	0.27	34,443	0.35
2001	7,960	33,274	14,659	105,250	127,870	0.21	33,274	0.42
2002	41,888	61,212	45,343	172,225	259,456	0.20	61,212	0.43
2003	12,943	47,212	32,164	202,242	247,349	0.26	47,212	0.46
2004	18,137	89,925	37,854	266,934	322,925	0.25	89,925	0.43
2005	43,599	63,859	22,196	188,989	254,784	0.22	63,859	0.41
2006	2,109	43,353	22,455	235,475	260,040	0.27	43,353	0.45
2007	13,501	79,274	89,125	338,664	441,290	0.17	79,274	0.37
2008	7,083	46,505	27,255	300,048	334,386	0.21	46,505	0.47
2009	104,623	66,878	35,164	459,429	599,216	0.17	66,878	0.14
2010	24,962	70,328	45,646	321,238	391,846	0.18	70,328	0.15
2011	5,587	54,860	27,008	207,838	240,433	0.24	54,860	0.09
2012	62,803	51,596	51,179	209,598	323,581	0.22	51,596	0.09
2013	29,918	57,241	38,717	245,333	313,969	0.18	57,241	0.10
2014	92,386	55,882	48,244	428,267	568,898	0.21	55,882	0.08
2015	14,242	52,334	59,002	147,424	220,667	0.19	52,334	0.12
2016	49,752	48,391	16,414	723,301	789,468	0.38	48,391	0.13
2017	16,543	53,041	68,515	442,242	527,299	0.16	53,041	0.11
2018	70,754	40,930	67,281	255,552	393,588	0.17	40,930	0.07
2019	32,750	40,028	72,077	343,459	448,287	0.22	40,028	0.07
2020	15,071	35,627	92,857	495,593	603,522	0.30	35,627	0.07
2021	10,425	32,616	43,200	528,713	582,338	0.26	32,616	0.10

Table 4.12.4. Total recreational landings-in-weight estimates (LBS) and associated coefficients of variation (CV) for South Atlantic Gray Triggerfish combined across all surveys (MRIP and SRHS) by year and mode. Estimates are summarized according to the chosen fleet structure for the SEDAR 82 stock assessment (GenRec = Shore+Cbt+Priv). CVs are not available in weight units for SRHS headboat landings and so are assumed equal to those estimated for landings-in-number. CVs are not available for the GenRec fleet until 1981 and so, for 1974-1980, uncertainty in headboat catch was assumed representative of that for GenRec.

Year	Shore	Hbt	Cbt	Priv	GenRec LBS	GenRec CV	Hbt LBS	Hbt CV
1974	0	224,241	0	0	478,041	0.70	224,241	0.70
1975	0	184,249	0	0	508,979	0.70	184,249	0.70
1976	0	120,604	0	0	503,821	0.70	120,604	0.70
1977	0	127,128	0	0	498,660	0.70	127,128	0.70
1978	0	122,838	0	0	493,503	0.70	122,838	0.70
1979	0	122,637	0	0	488,342	0.70	122,637	0.70
1980	0	84,866	0	0	483,185	0.70	84,866	0.70
1981	22,294	81,919	22,121	496,164	540,579	0.67	81,919	0.44
1982	56,969	97,808	25,626	134,437	217,032	0.38	97,808	0.35
1983	104,298	83,214	9,747	101,084	215,128	0.45	83,214	0.39
1984	135,381	87,470	30,956	156,482	322,819	0.39	87,470	0.34
1985	5,009	112,871	18,239	68,438	91,686	0.53	112,871	0.49
1986		82,817	5,933	188,372	194,305	0.37	82,817	0.51
1987	110,535	71,999	4,865	199,352	314,752	0.43	71,999	0.44
1988	146,285	69,820	4,007	174,406	324,698	0.42	69,820	0.45
1989	76,957	104,864	59,954	408,154	545,066	0.30	104,864	0.45
1990	50,964	120,633	26,134	287,104	364,202	0.23	120,633	0.60
1991	832,762	165,157	27,481	675,722	1,535,965	0.39	165,157	0.60
1992	351,035	170,945	57,751	367,795	776,581	0.25	170,945	0.58
1993	155,604	272,092	58,906	231,028	445,537	0.29	272,092	0.28
1994	109,397	192,530	63,181	172,720	345,298	0.20	192,530	0.33
1995	42,384	182,934	31,559	201,504	275,447	0.21	182,934	0.33
1996	112,573	164,738	45,608	387,403	545,584	0.26	164,738	0.32
1997	57,645	528,024	610,464	167,607	835,716	0.64	528,024	0.64
1998	42,326	136,023	28,535	189,495	260,356	0.32	136,023	0.30
1999	9,054	75,237	43,012	230,907	282,974	0.20	75,237	0.28
2000	96,351	63,596	13,524	171,054	280,929	0.29	63,596	0.35
2001	18,658	64,651	36,358	261,369	316,385	0.22	64,651	0.42
2002	91,727	105,758	132,550	314,402	538,680	0.20	105,758	0.42
2003	31,167	84,919	77,535	429,432	538,134	0.26	84,919	0.46
2004	41,515	176,659	74,136	590,478	706,129	0.25	176,659	0.42
2005	101,489	114,818	54,501	406,518	562,508	0.23	114,818	0.41
2006	4,385	82,997	53,476	463,893	521,753	0.27	82,997	0.45
2007	29,341	159,256	177,342	690,359	897,042	0.17	159,256	0.37
2008	16,860	94,435	64,756	681,896	763,512	0.21	94,435	0.47
2009	203,107	143,360	67,283	1,016,543	1,286,933	0.18	143,360	0.14
2010	52,698	155,728	108,805	737,670	899,172	0.18	155,728	0.16
2011	13,455	129,835	58,631	545,943	618,028	0.24	129,835	0.09
2012	133,241	122,597	137,988	465,592	736,821	0.21	122,597	0.09
2013	67,405	122,769	85,440	531,414	684,259	0.18	122,769	0.10
2014	201,925	119,052	113,813	1,037,354	1,353,091	0.21	119,052	0.08
2015	36,221	122,741	157,943	384,223	578,387	0.19	122,741	0.11
2016	106,992	101,031	37,559	1,386,906	1,531,458	0.37	101,031	0.13
2017	31,531	103,912	153,086	867,442	1,052,059	0.16	103,912	0.11
2018	159,324	84,630	147,464	587,112	893,899	0.17	84,630	0.07
2019	82,125	68,829	159,934	817,111	1,059,169	0.22	68,829	0.08
2020	34,817	76,540	211,625	1,283,522	1,529,964	0.30	76,540	0.07
2021	26,043	71,022	101,977	1,373,769	1,501,789	0.26	71,022	0.11

Table 4.12.5. Estimated SRHS headboat discards of South Atlantic Gray Triggerfish. Discards are provided in number of fish. CVs are not available for SRHS discards from 1974-2007 and so uncertainty in (MRIP) charterboat discards from 1981-2007 and (SRHS) headboat landings from 1974-1980 are assumed representative of that for SRHS discards over these time periods.

Year	NC	SC	GA/NEFL	Total	CV
1974	5,722	8,937	19,416	34,074	0.7
1975	6,510	5,654	16,111	28,275	0.7
1976	4,683	4,907	9,202	18,792	0.7
1977	2,980	6,064	8,445	17,489	0.7
1978	4,529	3,266	12,733	20,528	0.7
1979	4,823	2,309	9,857	16,989	0.7
1980	2,127	4,024	5,586	11,737	0.7
1981	2,390	2,387	14,258	19,035	0.61
1982	895	1,249	3,499	5,643	0.58
1983	3,848	3,857	14,511	22,216	0.54
1984	2,869	1,354	5,831	10,054	0.34
1985	6,056	2,561	13,350	21,967	0.46
1986	2,839	1,939	7,374	12,152	0.78
1987	0	0	0	0	0.56
1988	2,963	6,169	50,235	59,367	0.60
1989	47	165	1,667	1,880	0.54
1990	0	0	0	0	0.47
1991	950	406	2,107	3,463	0.35
1992	1,020	481	729	2,230	0.27
1993	0	0	0	0	0.33
1994	1,481	747	505	2,732	0.26
1995	6,729	2,271	1,398	10,398	0.24
1996	2,011	906	344	3,260	0.28
1997	2,602	1,380	515	4,497	0.36
1998	0	0	0	0	0.31
1999	8,479	5,275	3,471	17,226	0.37
2000	2,863	1,948	1,413	6,224	0.34
2001	2,400	1,704	1,983	6,087	0.25
2002	15,276	5,951	8,059	29,286	0.20
2003	4,337	2,583	2,986	9,906	0.26
2004	14,330	5,718	15,014	35,062	0.17
2005	25,413	4,044	15,919	45,377	0.30
2006	12,569	5,537	9,105	27,211	0.31
2007	10,450	4,139	3,340	17,929	0.31
2008	56	169	10,811	11,036	0.49
2009	45	104	10,290	10,439	0.15
2010	5	34	19,352	19,391	0.16
2011	103	210	11,239	11,552	0.10
2012	4	8	12,673	12,685	0.09
2013	207	367	8,187	8,761	0.10
2014	284	300	11,567	12,151	0.08
2015	740	194	29,331	30,265	0.07
2016	2,102	847	64,258	67,207	0.06
2017	1,888	1,282	25,396	28,566	0.08
2018	1,760	777	21,359	23,896	0.05
2019	4,742	2,839	18,905	26,486	0.06
2020	2,728	709	11,081	14,518	0.06
2021	4,845	1,045	8,727	14,617	0.05

Table 4.12.6. Total recreational discard-in-number estimates (B2) and associated coefficients of variation (CV) for South Atlantic Gray Triggerfish combined across all surveys (MRIP and SRHS) by year and mode. Estimates are summarized according to the chosen fleet structure for the SEDAR 82 stock assessment (GenRec = Shore+Cbt+Priv). Discard estimates are not available for the GenRec fleet until 1981.

Year	Shore	Hbt	Cbt	Priv	GenRec B2	GenRec CV	Hbt B2	Hbt CV
1974	0	34,074	0	0			34,074	0.7
1975	0	28,275	0	0			28,275	0.7
1976	0	18,792	0	0			18,792	0.7
1977	0	17,489	0	0			17,489	0.7
1978	0	20,528	0	0			20,528	0.7
1979	0	16,989	0	0			16,989	0.7
1980	0	11,737	0	0			11,737	0.7
1981	10,673	19,035	3,107	91,477	105,256	0.54	19,035	0.61
1982	29,823	5,643	1,418	15,494	46,734	0.45	5,643	0.58
1983	406,080	22,216	3,061	51,923	461,064	0.08	22,216	0.54
1984	0	10,054	4,387	73,390	77,778	0.94	10,054	0.34
1985	20,299	22,016	2,567	77,187	100,054	0.63	22,016	0.46
1986	189,065	12,152	113	100,761	289,939	0.52	12,152	0.78
1987	122,666	0	0	120,955	243,621	0.46	0	0
1988	30,827	59,367	5,572	105,671	142,071	0.34	59,367	0.60
1989	318,810	1,880	216	278,860	597,886	0.31	1,880	0.54
1990	19,776	124	113	146,658	166,548	0.35	124	0.00
1991	577,243	3,933	981	245,255	823,479	0.47	3,933	0.33
1992	262,576	2,481	1,434	114,652	378,662	0.23	2,481	0.26
1993	26,699	218	247	107,721	134,666	0.24	218	1.00
1994	22,000	2,904	726	122,612	145,338	0.33	2,904	0.25
1995	17,248	10,405	1,048	156,975	175,271	0.29	10,405	0.24
1996	151,516	3,276	877	130,493	282,887	0.31	3,276	0.28
1997	18,151	10,792	13,315	127,406	158,872	0.30	10,792	0.60
1998	13,185	0	0	68,127	81,312	0.25	0	0
1999	24,927	17,265	4,614	125,850	155,391	0.21	17,265	0.37
2000	38,790	6,779	1,645	149,181	189,616	0.23	6,779	0.32
2001	24,092	6,112	1,915	101,587	127,594	0.20	6,112	0.25
2002	35,869	29,411	14,429	206,212	256,510	0.23	29,411	0.20
2003	17,300	9,906	4,511	321,359	343,170	0.25	9,906	0.26
2004	44,813	35,069	11,834	280,979	337,626	0.23	35,069	0.17
2005	25,621	45,377	10,350	244,563	280,534	0.19	45,377	0.30
2006	17,772	27,211	9,584	260,334	287,690	0.24	27,211	0.31
2007	41,632	17,929	13,591	449,594	504,816	0.19	17,929	0.31
2008	42,251	11,036	13,412	242,119	297,782	0.19	11,036	0.49
2009	72,678	11,141	11,736	421,220	505,634	0.35	11,141	0.14
2010	54,367	19,391	7,852	255,617	317,836	0.23	19,391	0.16
2011	15,580	11,598	6,495	126,342	148,417	0.23	11,598	0.09
2012	95,535	13,228	4,714	107,914	208,163	0.27	13,228	0.09
2013	36,157	8,882	15,550	304,324	356,031	0.29	8,882	0.10
2014	33,771	12,173	17,848	388,695	440,314	0.20	12,173	0.08
2015	67,281	31,261	20,990	480,820	569,090	0.22	31,261	0.07
2016	566,897	67,247	16,598	1,968,173	2,551,668	0.35	67,247	0.06
2017	58,956	29,991	31,095	632,403	722,454	0.23	29,991	0.09
2018	44,902	24,484	16,695	598,478	660,075	0.26	24,484	0.05
2019	173,369	26,523	28,952	323,982	526,302	0.25	26,523	0.06
2020	11,713	15,126	13,505	339,870	365,088	0.34	15,126	0.06
2021	53,901	15,103	9,250	587,202	650,353	0.25	15,103	0.05

Table 4.12.7. Summary of weight measurements (kilograms whole weight) from SRHS-intercepted Gray Triggerfish by state and year. Summaries include the number of fish weighed by SRHS (Fish), the number of angler trips from which those fish were weighed (Trips), and the minimum (Min), geometric mean (Mean), and maximum (Max) size of fish weights.

	NCSC					GAFL				
Year	Fish	Min	Mean	SD	Max	Fish	Min	Mean	SD	Max
1972	112	0.86	2.19	0.680	3.86					
1973	96	0.82	2.17	0.707	4.54					
1974	298	0.77	2.15	0.693	4.77					
1975	377	0.02	2.15	0.688	4.36					
1976	340	0.23	2.15	0.743	4.22	82	0.09	1.06	0.583	4.45
1977	381	0.27	2.00	0.723	4.50	76	0.45	1.58	0.774	4.43
1978	348	0.05	2.08	0.662	4.33	249	0.17	1.25	0.908	4.06
1979	203	0.85	2.31	0.687	5.00	147	0.24	1.13	0.773	3.75
1980	230	0.26	2.35	0.769	5.00	197	0.14	1.29	0.867	7.11
1981	74	0.16	2.38	0.885	4.43	402	0.12	1.10	0.670	4.01
1982	221	0.47	2.11	0.754	4.80	329	0.25	1.17	0.692	4.70
1983	330	0.40	2.00	0.816	5.15	645	0.19	0.97	0.620	4.80
1984	327	0.15	1.78	0.951	5.12	526	0.20	1.18	0.722	5.30
1985	396	0.25	1.89	0.806	4.90	567	0.20	0.93	0.801	10.70
1986	373	0.12	1.82	0.731	4.70	346	0.20	0.91	0.759	4.70
1987	249	0.43	2.11	0.865	5.03	303	0.12	0.83	0.608	4.00
1988	178	0.02	1.58	0.835	8.36	253	0.16	0.82	0.689	7.00
1989	156	0.38	1.64	0.827	6.20	552	0.07	0.77	0.601	6.10
1990	239	0.21	1.25	0.487	3.46	554	0.09	0.72	0.379	3.11
1991	222	0.02	1.34	0.844	8.83	456	0.06	0.63	0.367	2.77
1992	460	0.14	0.99	0.452	3.30	278	0.10	0.67	0.398	3.32
1993	590	0.11	0.99	0.468	4.36	217	0.18	0.78	0.520	3.30
1994	772	0.18	0.95	0.384	3.41	257	0.10	0.88	0.718	7.26
1995	661	0.21	0.91	0.394	2.54	207	0.18	0.76	0.526	4.22
1996	943	0.07	0.82	0.372	4.69	104	0.37	0.94	0.498	2.96
1997	1,240	0.02	0.83	0.334	3.68	314	0.19	0.75	0.476	4.50
1998	551	0.20	0.95	0.418	3.69	403	0.18	0.72	0.379	3.89
1999	386	0.30	0.96	0.394	3.05	321	0.23	0.79	0.425	3.64
2000	202	0.27	0.86	0.347	2.00	214	0.24	0.75	0.408	2.61
2001	144	0.28	0.94	0.301	2.00	345	0.21	0.69	0.358	4.03
2002	278	0.23	0.88	0.407	2.68	301	0.12	0.73	0.365	2.67
2003	363	0.24	0.88	0.376	3.05	598	0.16	0.64	0.272	2.96
2004	323	0.18	1.00	0.463	3.96	970	0.26	0.66	0.286	2.06
2005	212	0.12	0.92	0.373	2.25	739	0.22	0.61	0.295	3.93
2006	168	0.11	0.99	0.464	3.72	592	0.33	0.68	0.309	3.08
2007	214	0.31	0.93	0.475	5.67	687	0.33	0.85	0.368	3.64
2008	146	0.40	0.96	0.294	1.83	385	0.23	0.91	0.345	2.60
2009	114	0.34	0.98	0.365	2.38	566	0.40	1.02	0.418	3.41
2010	296	0.25	0.93	0.325	2.46	863	0.42	1.05	0.435	3.17
2011	166	0.41	1.05	0.353	2.27	813	0.15	1.10	0.469	3.46
2012	385	0.23	1.05	0.552	8.60	640	0.32	1.14	0.550	5.70
2013	1,105	0.31	0.97	0.317	3.28	855	0.24	0.99	0.399	3.11
2014	642	0.34	0.99	0.338	2.68	787	0.39	1.01	0.437	3.26
2015	212	0.25	1.09	0.366	2.03	443	0.37	1.00	0.491	4.40
2016	317	0.31	0.95	0.379	2.50	554	0.20	0.99	0.425	4.31
2017	164	0.38	0.93	0.404	2.79	407	0.32	0.94	0.424	5.88
2018	243	0.33	0.91	0.363	3.10	237	0.16	1.00	0.487	3.46
2019	146	0.15	0.84	0.316	1.98	220	0.26	1.18	0.495	3.63
2020	4	0.63	0.80	0.278	1.21	57	0.53	1.24	0.503	3.20
2021						2	0.72	1.54	1.167	2.37

Table 4.12.8. Number of fish and trips sampled for ages for Gray Triggerfish by year and mode of fishing.

	Recreational					
	Headboat		Private		Charterboat	
Year	n.fish	n.trips	n.fish	n.trips	n.fish	n.trips
1990	18	10				
1991	42	24				
1992	1	2				
1994	1	1				
1997	2	2				
2001			4	1		
2002					5	4
2003	35	18	1	1	5	3
2004	9	4	4	2	48	18
2005	68	19			91	35
2006	129	30			29	9
2007	97	51			30	2
2008	21	13			3	2
2009	31	30			1	1
2010	100	56			1	1
2011	68	38			3	2
2012	137	46	2	1		
2013	508	135			7	6
2014	557	171			29	11
2015	286	133	2	2		
2016	594	238				
2017	404	180	8	6	47	23
2018	291	146	31	16	44	13
2019	92	56	17	17	53	23
2020			15	4	13	4

Table 4.12.9. Estimated SRHS headboat effort (in angler days) for South Atlantic anglers.

Year	NC	SC	GA/FLE	Total
1981	19,374	59,030	298,883	377,287
1982	26,939	67,539	293,133	387,611
1983	23,830	65,733	277,863	367,426
1984	28,865	67,314	288,994	385,173
1985	31,384	66,001	280,845	378,230
1986	31,187	67,227	317,058	415,472
1987	35,261	78,806	333,041	447,108
1988	42,421	76,468	301,775	420,664
1989	38,678	62,708	316,864	418,250
1990	43,240	57,151	322,895	423,286
1991	40,936	67,982	280,022	388,940
1992	41,176	61,790	264,523	367,489
1993	42,786	64,457	236,973	344,216
1994	36,691	63,231	242,781	342,703
1995	40,295	61,739	210,714	312,748
1996	35,142	54,929	199,857	289,928
1997	37,189	60,150	173,273	270,612
1998	37,399	61,342	155,341	254,082
1999	31,596	55,499	164,052	251,147
2000	31,351	40,291	182,249	253,891
2001	31,779	49,265	163,389	244,433
2002	27,601	42,467	151,546	221,614
2003	22,998	36,556	145,011	204,565
2004	27,255	48,763	175,400	251,418
2005	31,573	34,036	172,839	238,448
2006	25,736	56,074	175,522	257,332
2007	29,002	60,729	157,150	246,881
2008	17,158	47,287	123,943	188,388
2009	19,468	40,919	136,420	196,807
2010	21,071	44,951	123,662	189,684
2011	18,457	44,645	132,492	195,594
2012	20,766	41,003	147,699	209,468
2013	20,547	40,963	165,679	227,189
2014	22,691	42,025	195,890	260,606
2015	22,716	39,702	194,979	257,397
2016	21,565	42,207	196,660	260,432
2017	20,170	36,914	126,126	183,210
2018	16,813	37,611	120,560	174,984
2019	15,552	41,470	119,712	176,734
2020	14,154	34,080	84,005	132,239
2021	19,719	47,908	120,367	187,994

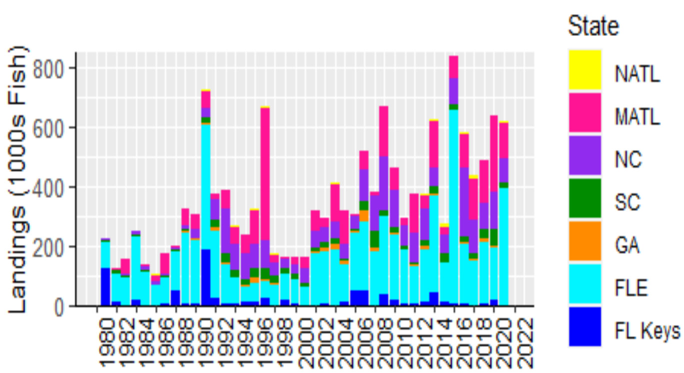
Table 4.12.10. Total recreational fishing effort (in angler trips) for South Atlantic anglers by mode and year (MRIP and SRHS). MRIP headboat estimates are used for all years in the Mid and North Atlantic. SRHS headboat estimates are used for all years in the South Atlantic.

Year	Cbt	Hbt	Priv	Shore	Total
1981	2,109,871	1,400,088	26,243,346	61,051,974	90,805,279
1982	2,319,110	2,665,919	28,814,670	71,079,552	104,879,251
1983	1,877,734	2,201,593	28,359,367	72,925,742	105,364,435
1984	1,432,564	1,967,972	32,550,446	70,268,700	106,219,682
1985	1,682,357	1,754,555	32,813,013	66,635,354	102,885,280
1986	2,053,787	1,860,432	33,714,334	67,003,400	104,631,952
1987	1,811,598	1,263,897	33,995,973	70,569,249	107,640,717
1988	1,467,809	1,484,203	31,172,800	68,682,483	102,807,295
1989	1,564,242	1,330,381	33,035,097	68,901,320	104,831,040
1990	1,316,810	1,563,695	33,031,502	72,854,735	108,766,742
1991	1,662,697	1,383,266	35,195,540	79,437,858	117,679,360
1992	1,475,681	1,213,732	35,351,776	76,711,530	114,752,719
1993	1,545,545	1,756,034	37,064,297	76,264,706	116,630,582
1994	1,655,694	1,342,155	37,251,603	75,985,191	116,234,643
1995	1,720,246	1,368,804	36,404,884	74,594,344	114,088,278
1996	1,659,919	1,101,619	38,414,584	77,708,431	118,884,552
1997	1,571,882	1,146,524	40,634,525	79,337,393	122,690,325
1998	1,495,813	980,533	40,307,829	77,995,218	120,779,394
1999	1,435,654	996,394	42,159,862	80,863,789	125,455,698
2000	1,358,705	1,143,470	47,327,712	85,915,626	135,745,513
2001	1,606,843	1,012,445	47,066,544	89,441,326	139,127,157
2002	1,472,188	1,045,776	48,316,477	87,503,283	138,337,724
2003	1,570,488	1,061,426	50,746,742	89,543,460	142,922,116
2004	1,393,761	1,131,376	51,084,719	92,137,812	145,747,667
2005	1,574,278	1,217,925	52,105,095	95,371,726	150,269,023
2006	1,340,345	1,124,329	54,519,616	96,451,728	153,436,017
2007	1,818,780	1,347,876	56,050,865	93,674,785	152,892,305
2008	1,362,263	1,157,756	54,684,210	97,729,745	154,933,974
2009	1,365,822	1,078,238	56,034,342	98,061,652	156,540,054
2010	1,097,737	865,866	60,092,042	99,423,215	161,478,860
2011	1,319,030	898,542	55,943,541	97,635,193	155,796,306
2012	1,266,240	959,673	53,645,542	92,910,405	148,781,860
2013	1,426,349	1,326,242	52,164,168	88,578,752	143,495,511
2014	1,484,941	1,251,596	52,707,034	94,337,336	149,780,906
2015	1,644,964	1,116,559	49,242,699	92,115,428	144,119,650
2016	1,171,084	898,601	48,278,000	91,695,999	142,043,684
2017	1,185,535	879,475	47,882,656	92,459,668	142,407,334
2018	1,234,904	802,820	44,545,369	85,648,186	132,231,279
2019	1,561,034	868,561	44,517,675	85,225,976	132,173,247
2020	1,158,206	692,180	48,126,125	89,222,176	139,198,687
2021	1,697,997	780,128	45,904,351	91,961,520	140,059,653

4.13 Figures

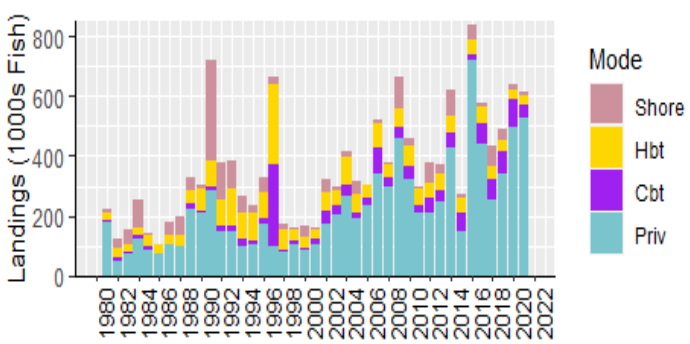
A

Total Recreational Landings



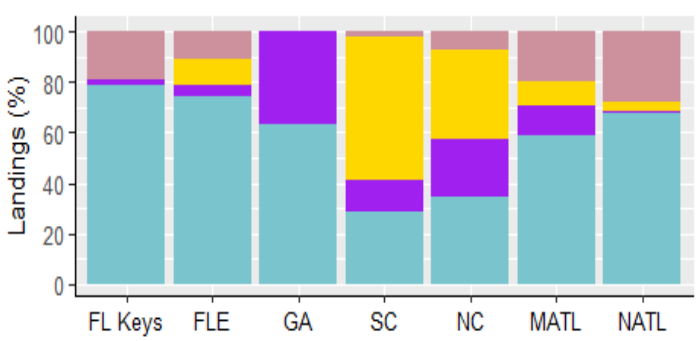
State	Catch (%)
NATL	0.7
MATL	20.4
NC	18.7
SC	5.2
GA	1.6
FLE	48.0
FL Keys	5.3

B



Mode	Catch (%)
Shore	12.0
Hbt	16.6
Cbt	9.8
Priv	61.5

C



Mode	NATL	MATL	NC	SC	GA	FL Keys	FLE
Shore	29	604	193	14	0	147	794
Hbt	4	292	993	438	0	0	744
Cbt	1	344	635	94	90	22	271
Priv	70	1795	954	221	153	621	5319

Figure 4.13.1. Total recreational landings (AB1) for South Atlantic Gray Triggerfish across all surveys (MRIP and SRHS). Landings are provided (A) by state and year (1981-2021) in thousands of fish, (B) by mode and year in thousands of fish, and (C) by mode and state in percentage of total landings (graph) and 1000s fish (table). MRIP headboat estimates are used 1981-1985 in the Gulf and for all years in the Mid and North Atlantic. SRHS headboat estimates are used 1986+ in the Gulf and for all years in the South Atlantic.

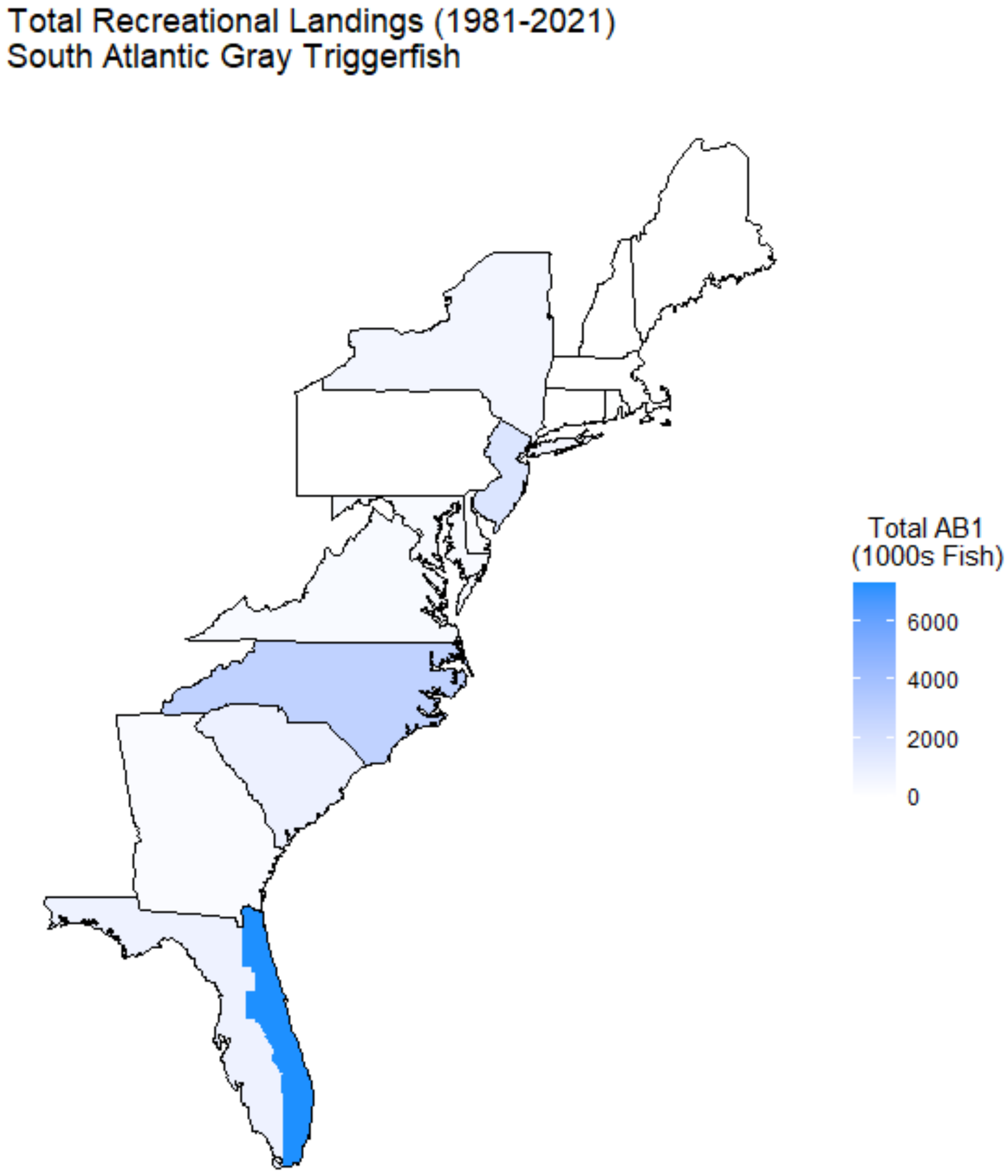
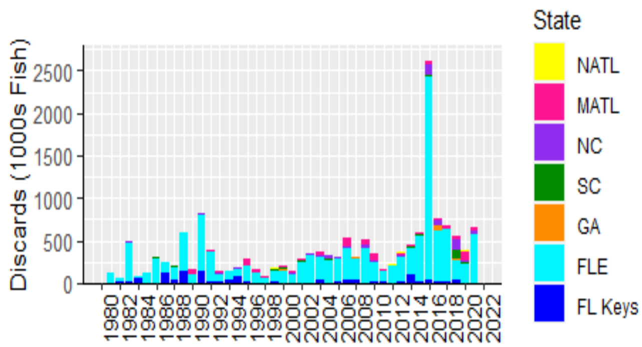


Figure 4.13.2. Distribution of total recreational landings (AB1), in thousands of fish, for Gray Triggerfish across the South Atlantic. Estimates are combined across all surveys (MRIP and SRHS) and years (1981-2021). MRIP landings estimates for western Florida only include the Florida Keys.

Figure 4.13.3. Discard rates (discards/(anglers*hours fished)) on log scale for the SRHS logbook and headboat at-sea observer data for Florida (FL) and North Carolina, South Carolina, and Georgia combined (NCSCGA).

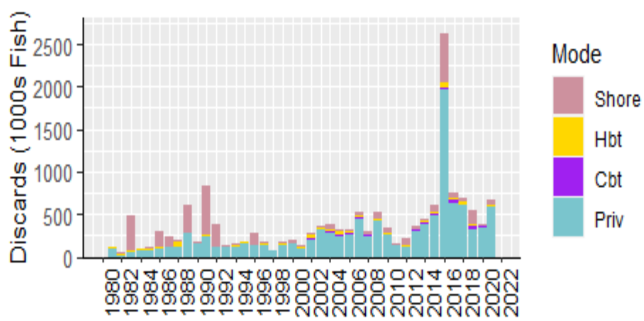
Total Recreational Discards

A



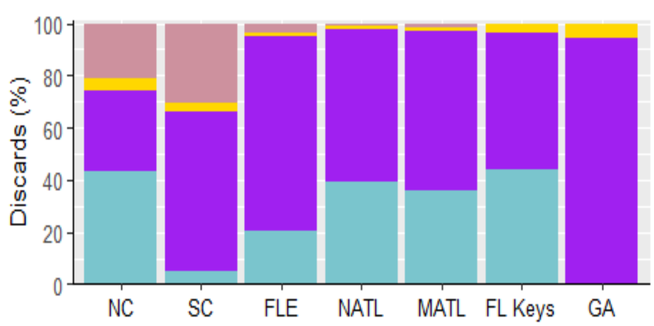
State	Discards (%)
NATL	0.5
MATL	6.2
NC	4.6
SC	1.5
GA	0.9
FLE	78.7
FL Keys	7.6

B



Mode	Discards (%)
Shore	24.1
Hbt	4.3
Cbt	2.1
Priv	69.5

C



Mode	NATL	MATL	NC	SC	GA	FLE	FL Keys
Shore	33	356	312	12	0	2589	532
Hbt	1	13	152	72	0	441	0
Cbt	2	18	33	8	8	215	43
Priv	49	605	226	141	132	9261	637

Figure 4.13.4. Total recreational discards (B2) for South Atlantic Gray Triggerfish across all surveys (MRIP and SRHS). Discards are provided (A) by state and year (1981-2021) in thousands of fish, (B) by mode and year in thousands of fish, and (C) by mode and state in percentage of fish (graph) and 1000s of fish (table). MRIP headboat estimates are used 1981-1985 in the Gulf and for all years in the Mid and North Atlantic. SRHS headboat estimates are used 1986+ in the Gulf and for all years in the South Atlantic.

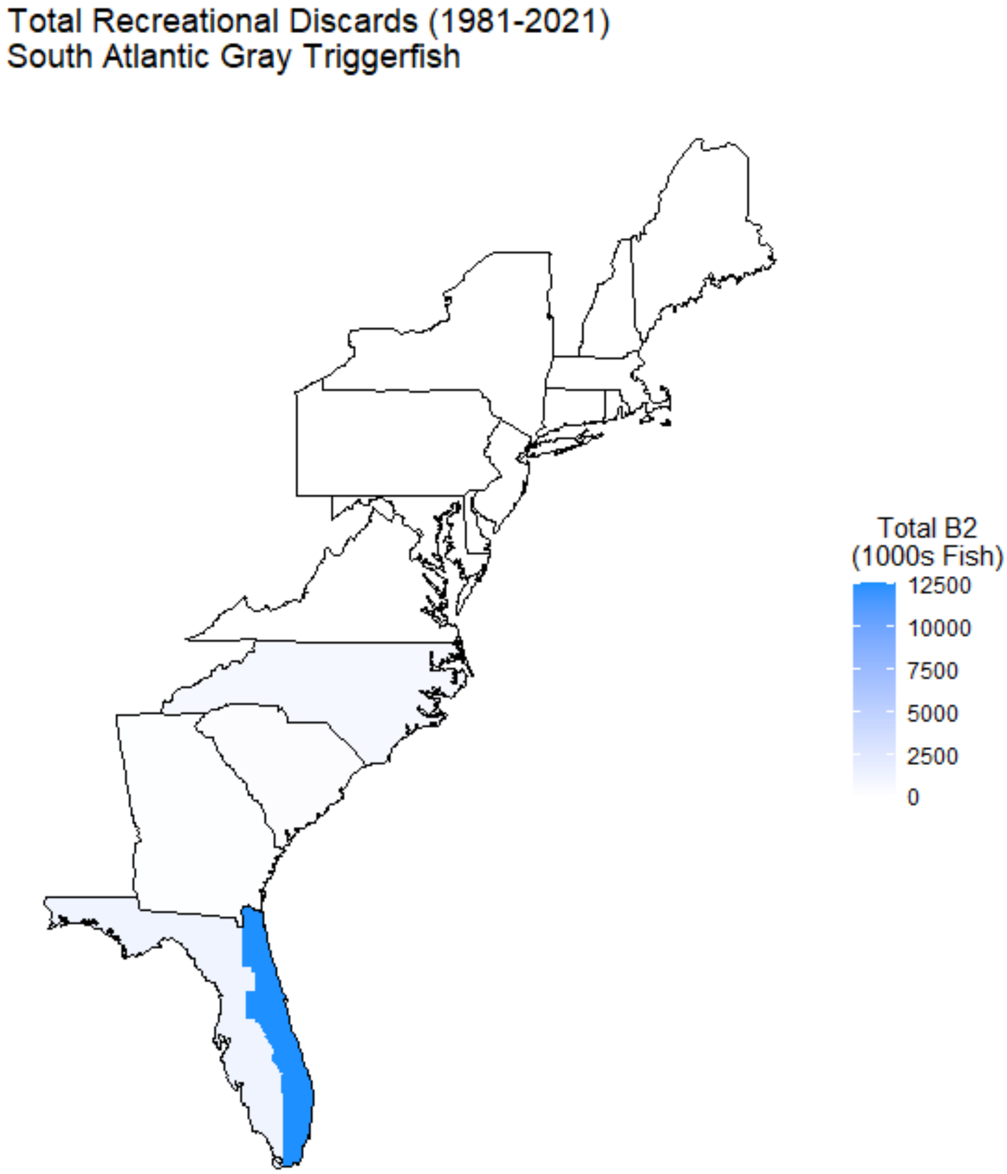


Figure 4.13.5. Distribution of total recreational discards (B2), in thousands of fish, for Gray Triggerfish across the South Atlantic. Estimates are combined across all surveys (MRIP and SRHS) and years (1981-2021). MRIP discards estimates for western Florida only include the Florida Keys.

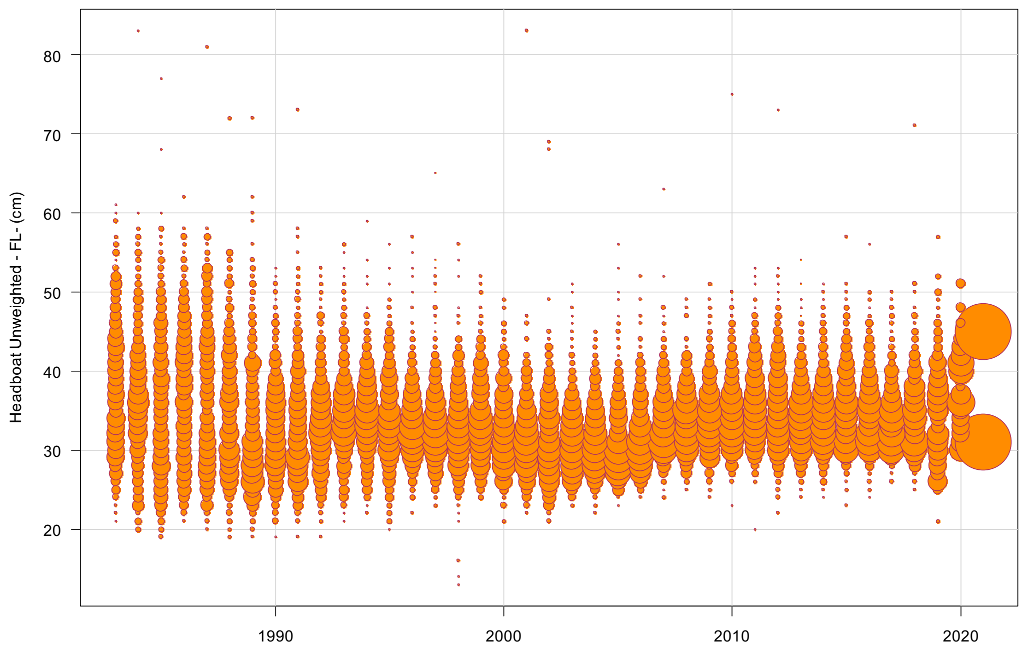


Figure 4.13.6. (A) Annual nominal length distribution of the recreational **headboat** fishery.

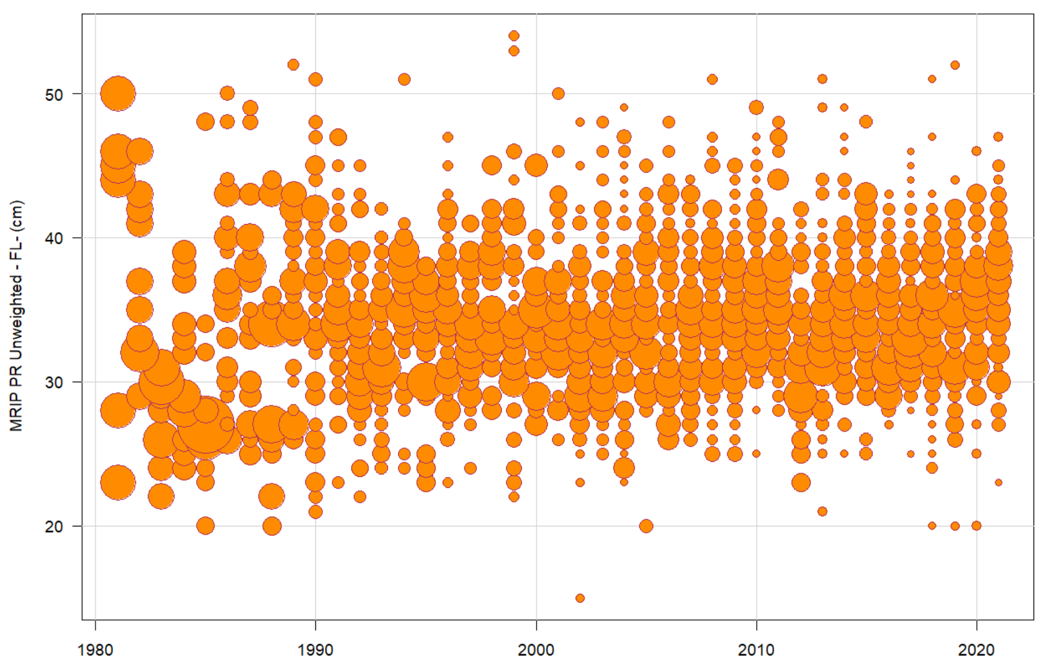


Figure 4.13.6. (B) Annual nominal length distribution of the recreational **private** fishery.

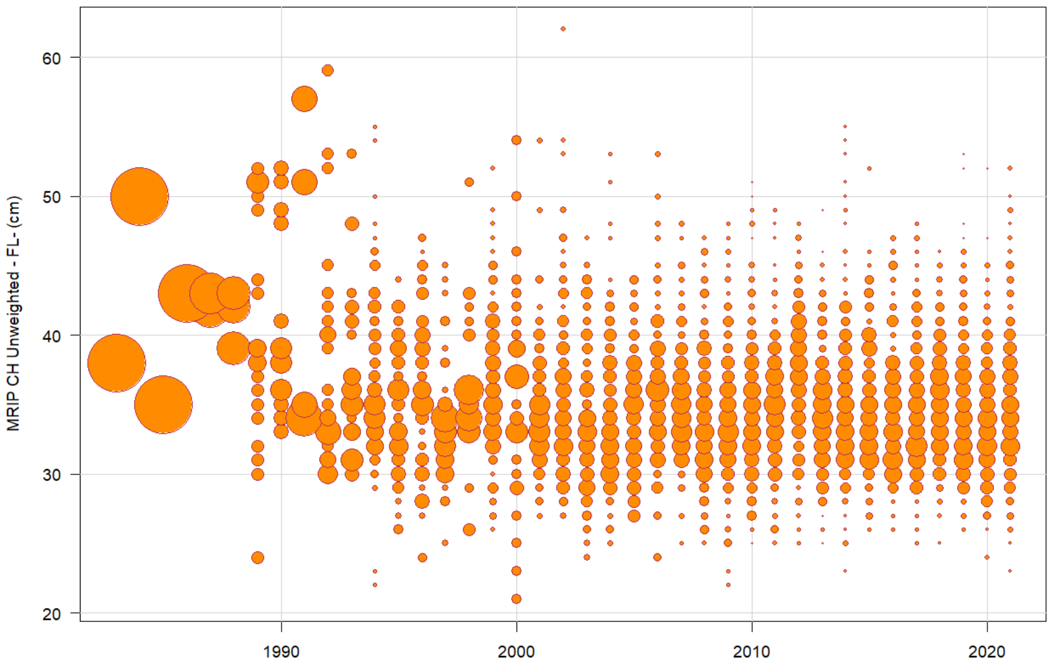


Figure 4.13.6. (C) Annual nominal length distribution of the recreational **charterboat** fishery.

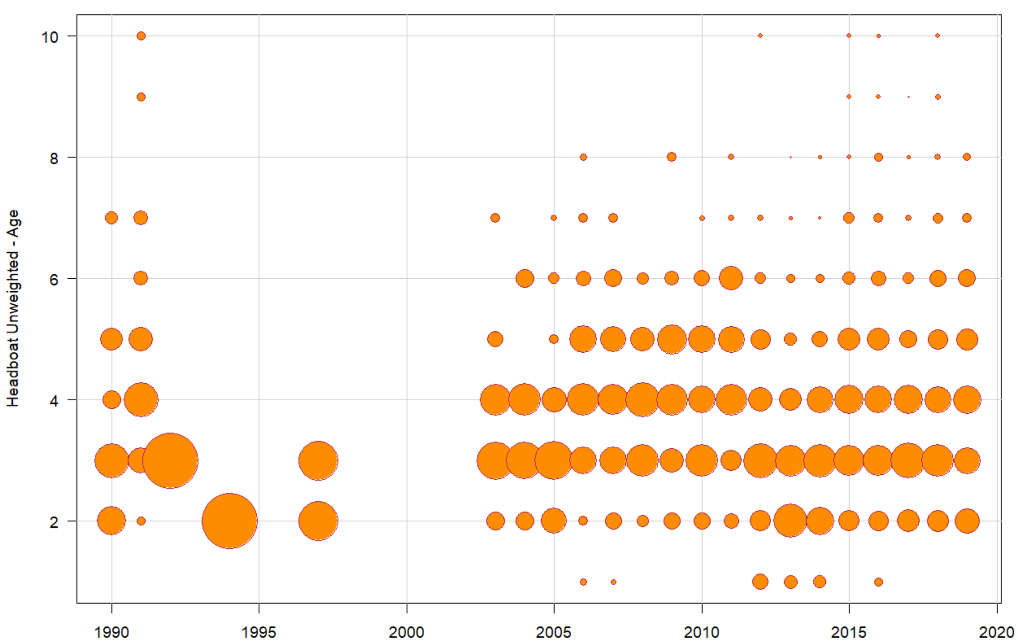


Figure 4.13.7. (A) Annual nominal age distribution of the recreational **headboat** fishery.

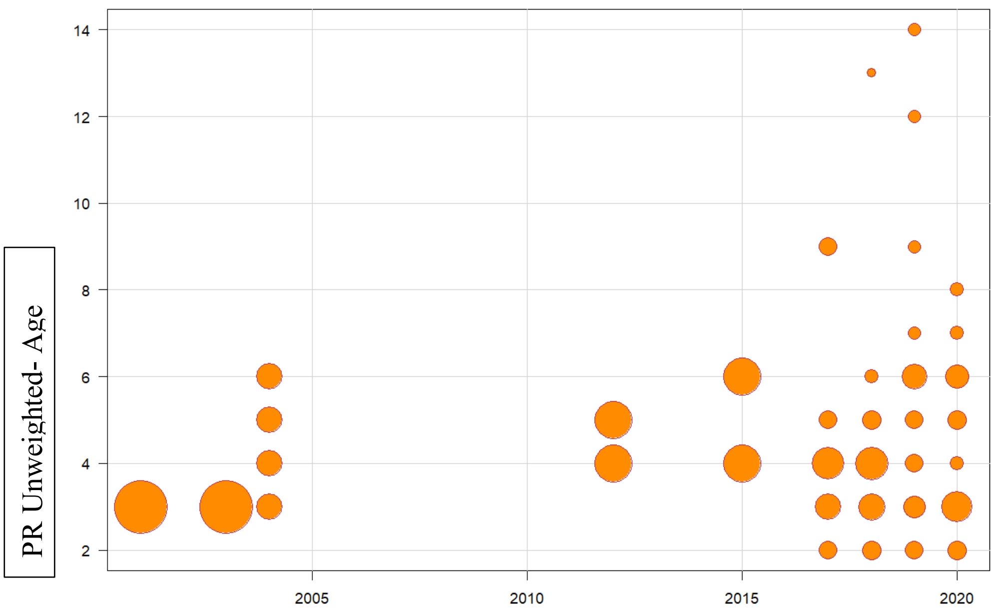


Figure 4.13.7. (B) Annual nominal age distribution of the recreational **private** fishery.

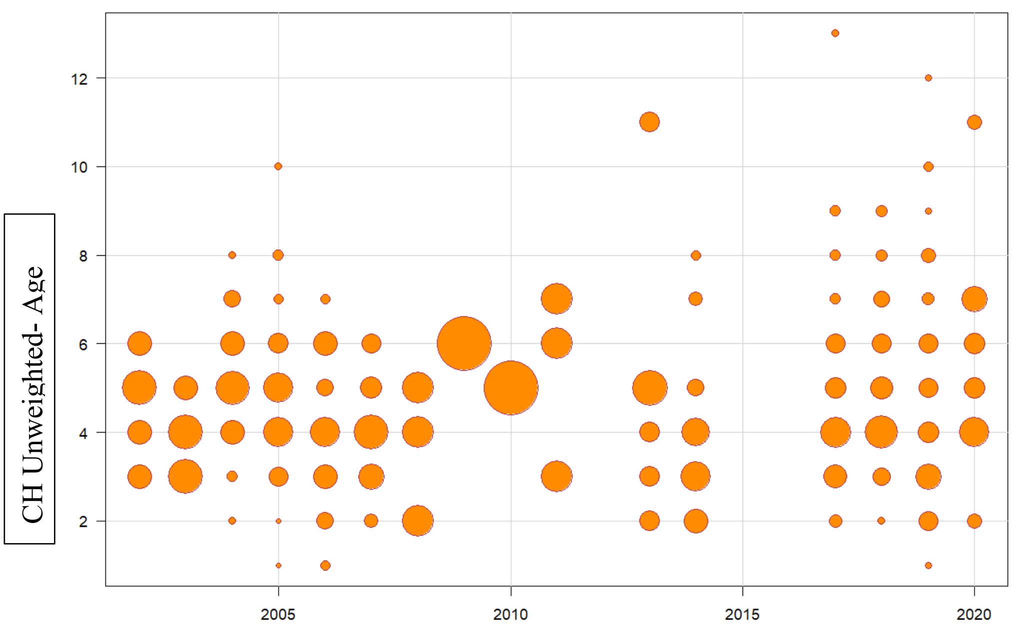


Figure 4.13.7. (C) Annual nominal age distribution of the recreational **charterboat** fishery.

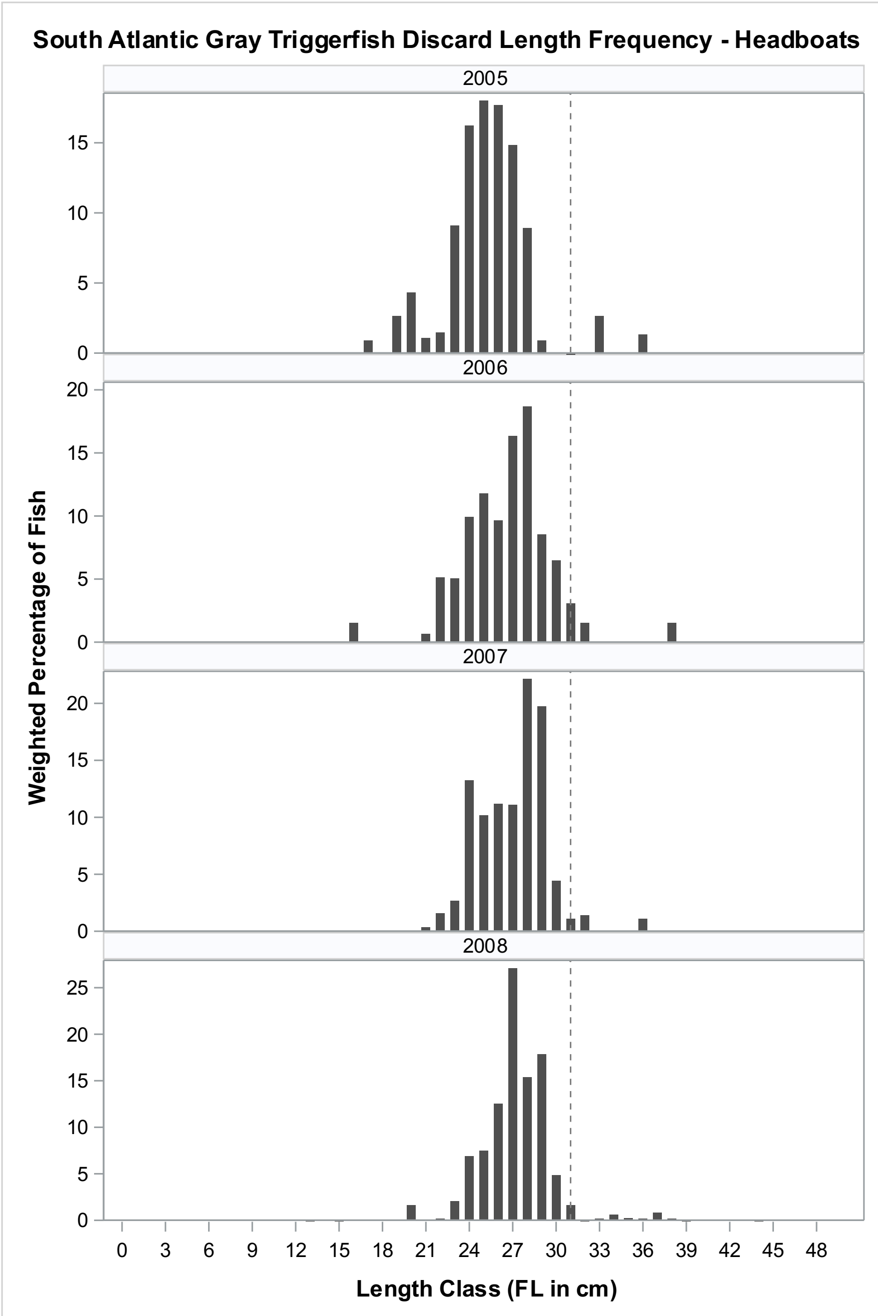


Figure 4.13.8. Weighted length frequencies of discarded Gray Triggerfish measured by at-sea observers on headboats along the South Atlantic from 2005-2020.

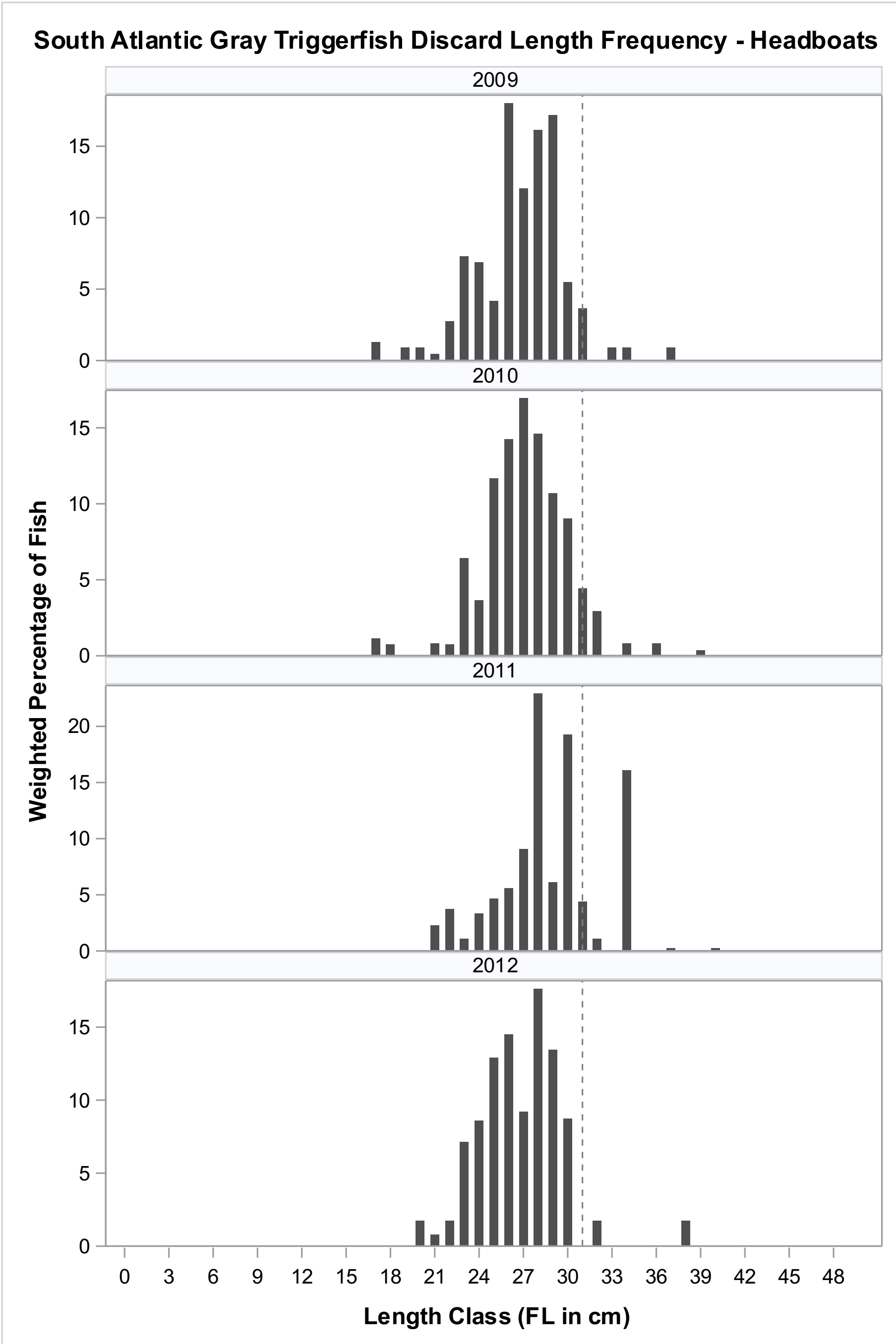


Figure 4.13.8. (continued) Weighted length frequencies of discarded Gray Triggerfish measured by at-sea observers on headboats along the South Atlantic from 2005-2020.

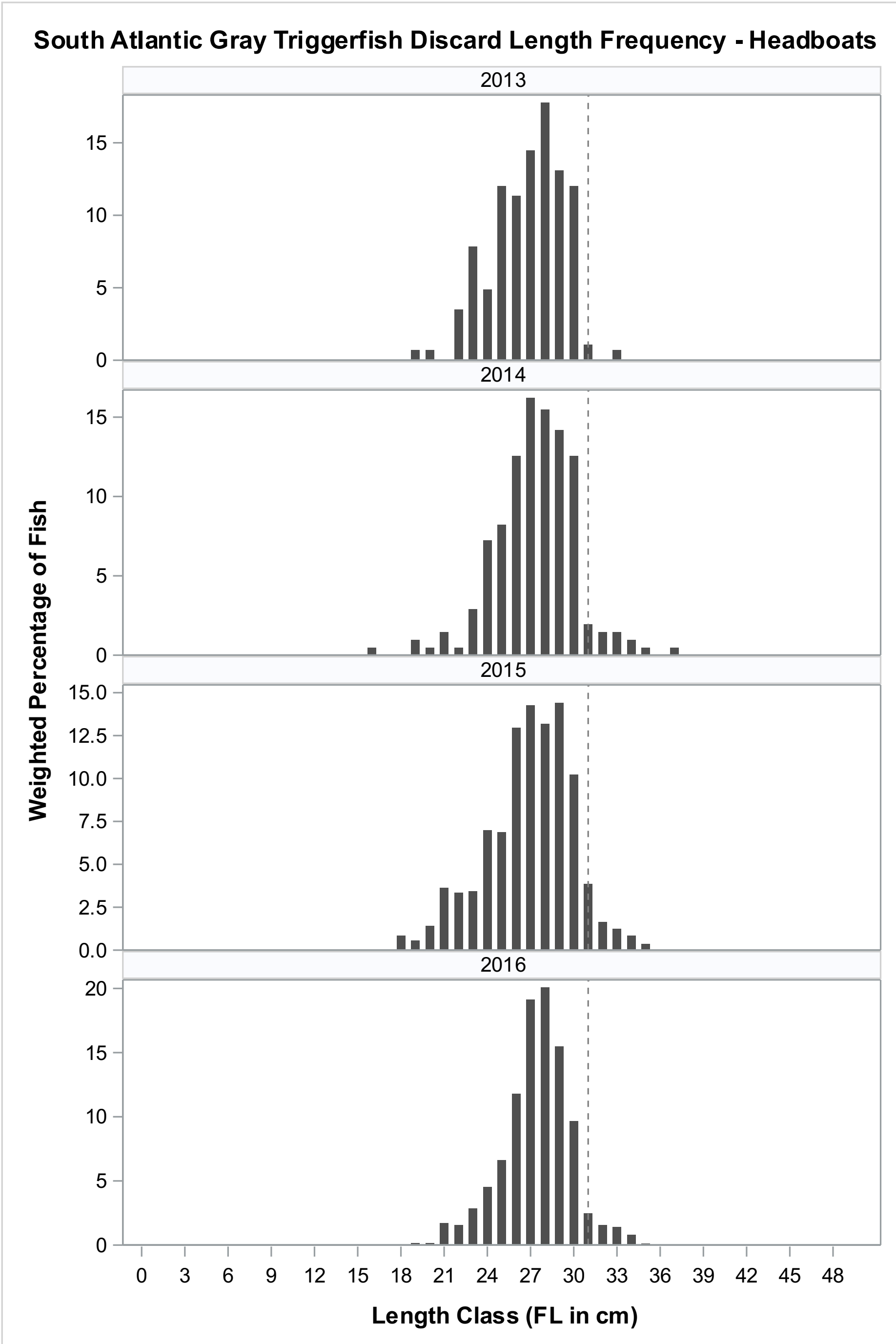


Figure 4.13.8. (continued) Weighted length frequencies of discarded Gray Triggerfish measured by at-sea observers on headboats along the South Atlantic from 2005-2020.

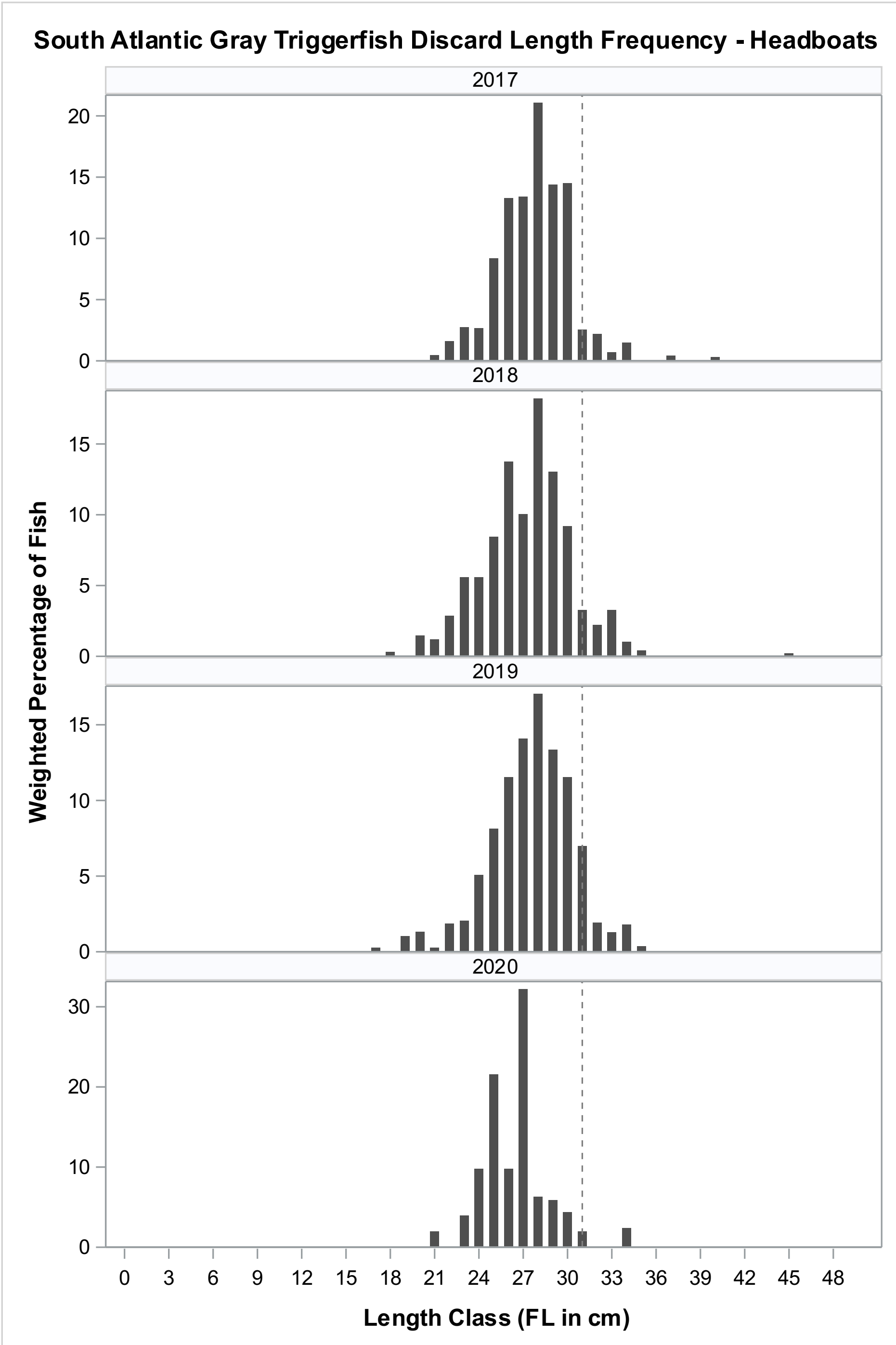


Figure 4.13.8. (continued) Weighted length frequencies of discarded Gray Triggerfish measured by at-sea observers on headboats along the South Atlantic from 2005-2020.

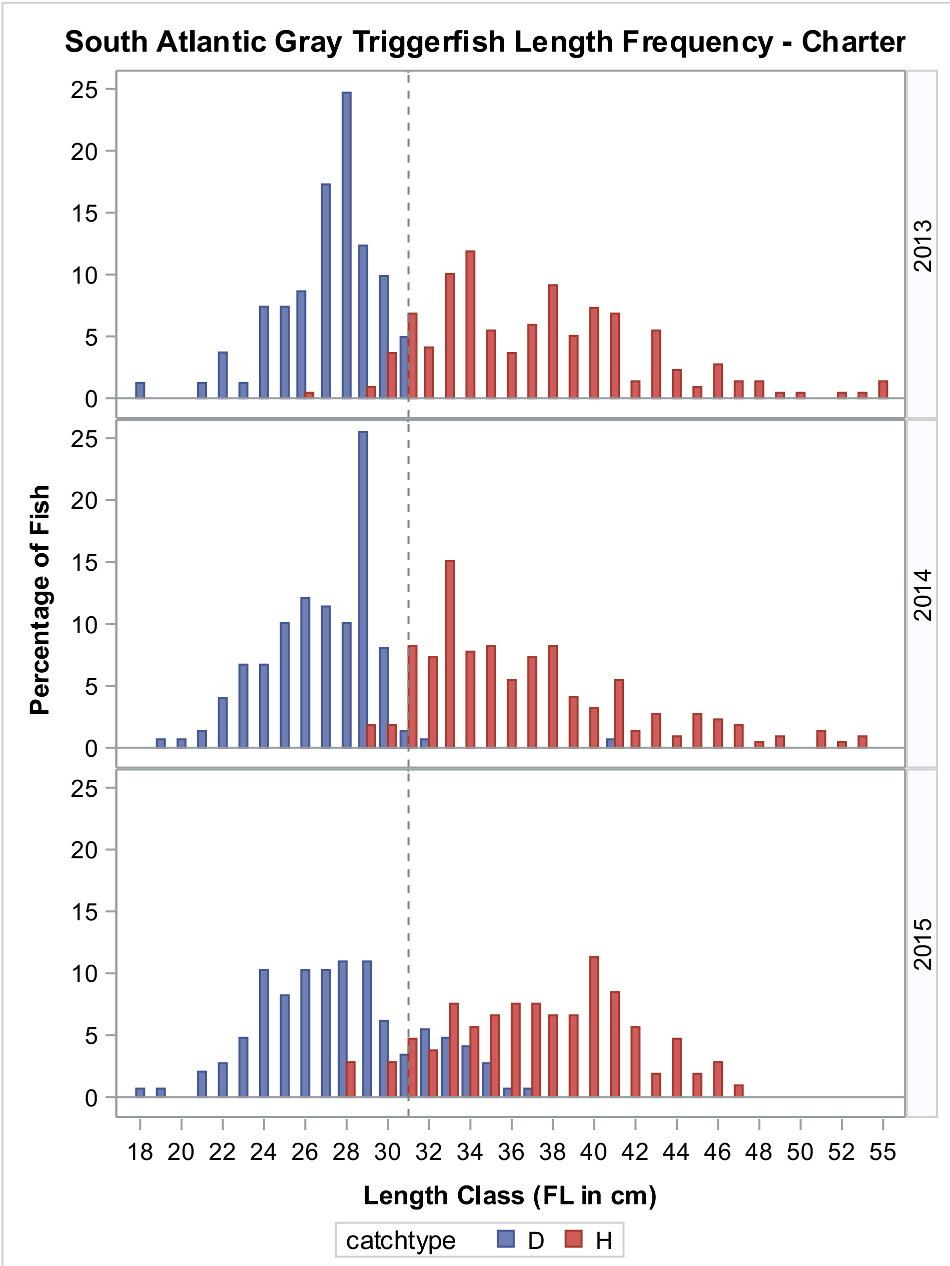
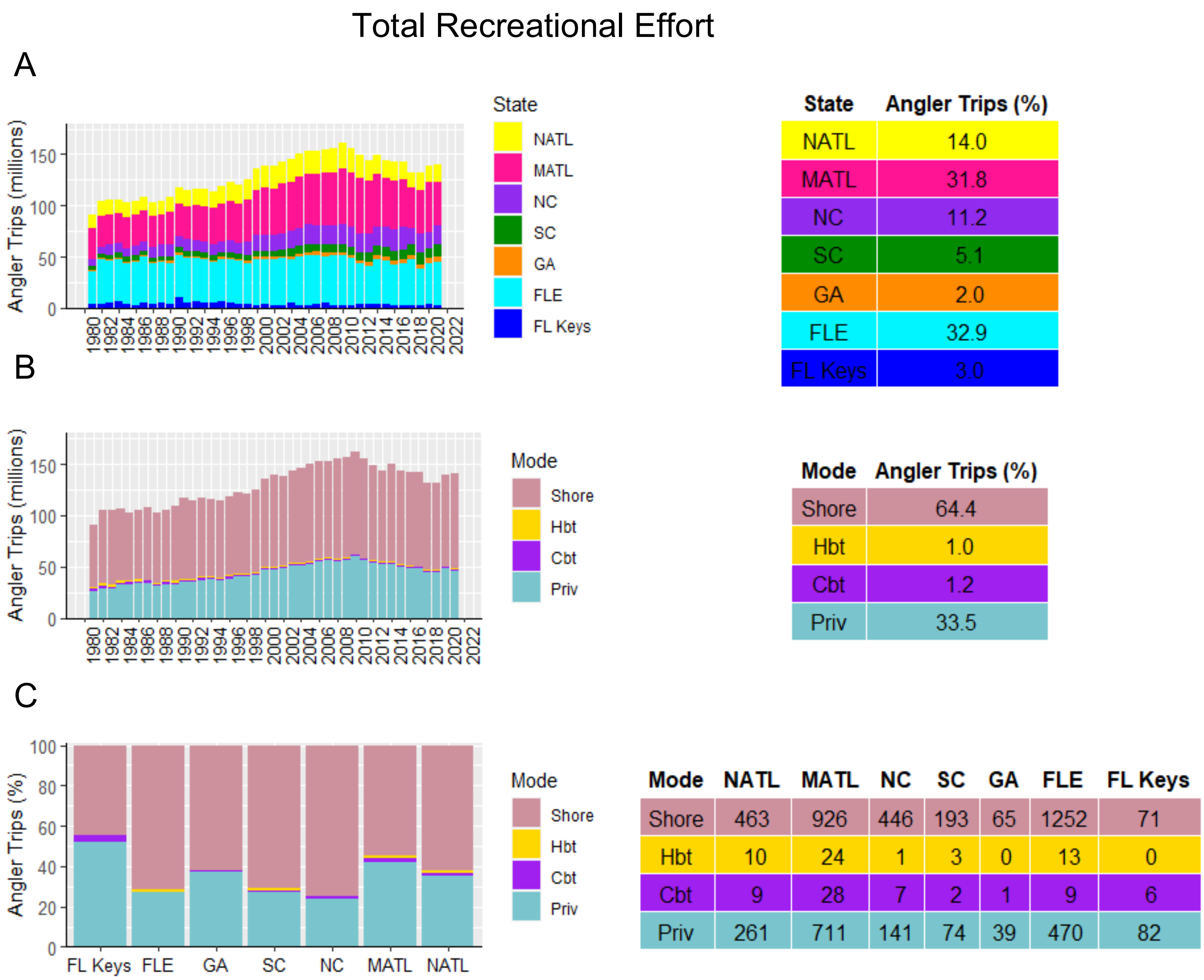


Figure 4.13.9. Un-weighted (raw) length frequencies of harvested and discarded Gray Triggerfish measured by at-sea observers on charter boats in South Atlantic Florida only waters from 2013-2015.



State	Angler Trips (%)
NATL	14.0
MATL	31.8
NC	11.2
SC	5.1
GA	2.0
FLE	32.9
FL Keys	3.0

Mode	Angler Trips (%)
Shore	64.4
Hbt	1.0
Cbt	1.2
Priv	33.5

Mode	NATL	MATL	NC	SC	GA	FLE	FL Keys
Shore	463	926	446	193	65	1252	71
Hbt	10	24	1	3	0	13	0
Cbt	9	28	7	2	1	9	6
Priv	261	711	141	74	39	470	82

Figure 4.13.10. Total recreational fishing effort for South Atlantic anglers in millions of angler trips (MRIP and SRHS). Effort is provided (A) by state and year (1981-2021), (B) by mode and year, and (C) by mode and state as a percentage (graph) and numbers (table). MRIP headboat estimates are used for all years in the Mid and North Atlantic. SRHS headboat estimates are used for all years in the South Atlantic.

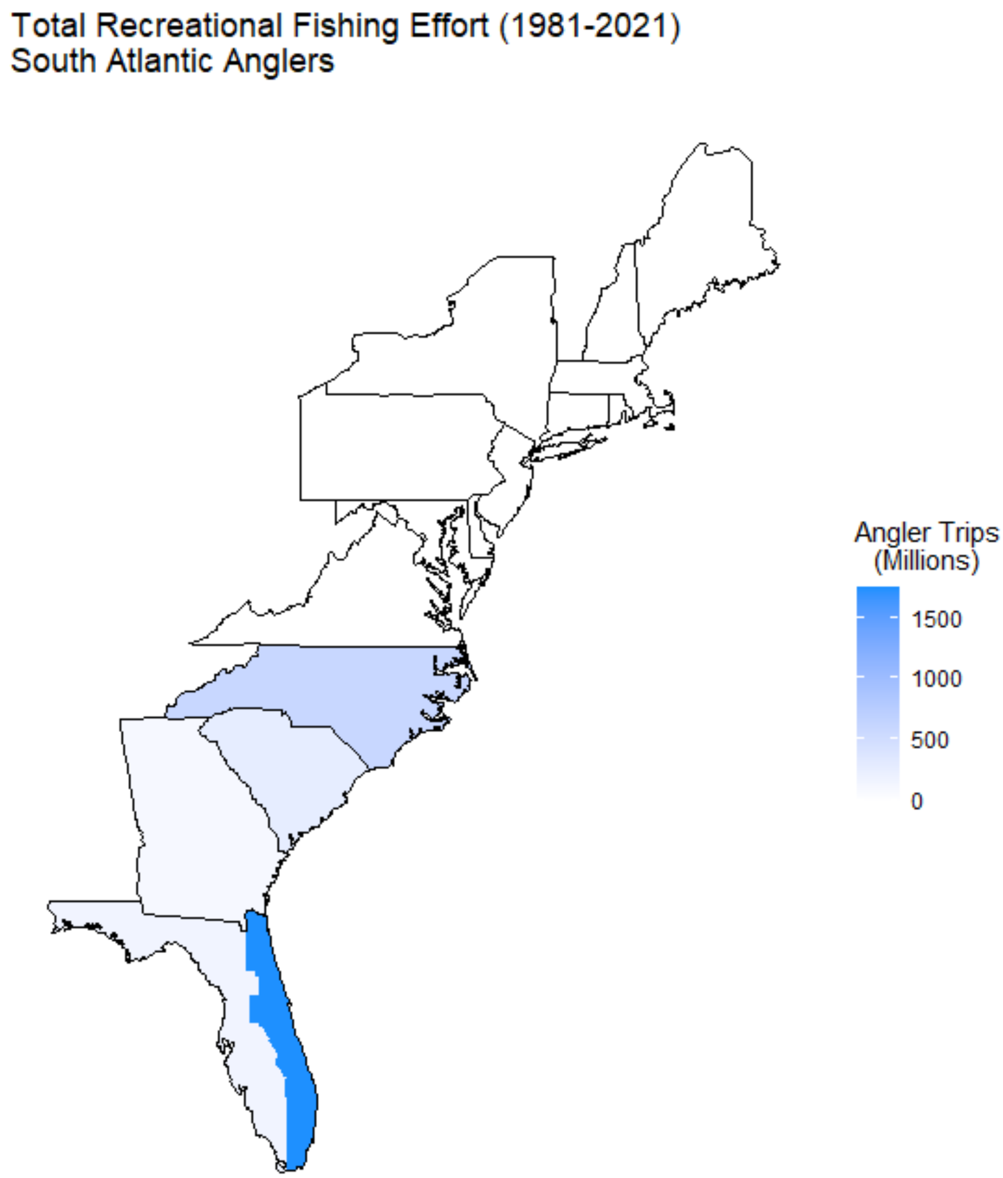


Figure 4.13.11. Distribution of total recreational fishing effort (angler trips in millions) by South Atlantic anglers. Estimates are combined across all surveys (MRIP and SRHS) and years (1981-2021). MRIP effort estimates for western Florida only include the Florida Keys.

5. Indices of Population Abundance

5.1 Overview

Five fishery-independent data sets were considered for use as an index of abundance (Table 5.1). During the data webinar prior to the DW, three of these datasets were discarded because of small sample sizes or limited geographic extent (SEAMAP trawl survey, MARMAP blackfish trap and MARMAP Florida trap). A cursory examination of the Northeast Bottom Trawl Survey was also undertaken and indicated very low sample sizes of Gray Triggerfish. Two fishery-independent data sets were retained for further consideration at the DW: SERFS chevron traps and SERFS video survey.

Four fishery-dependent data sets were considered for use as an index of abundance (Table 5.1). Ultimately, the DW recommended three of these fishery-dependent indices for potential use in the assessment model: recreational headboat logbook, headboat at-sea observer, and commercial handline.

In total, the DW recommended two fishery-independent indices (SERFS chevron traps and video survey) and three fishery-dependent indices (recreational headboat, headboat at-sea observer, and commercial handline) for potential use in the gray triggerfish stock assessment. These indices are listed in Table 5.1, with pros and cons of each in Table 5.2.

Group membership

Membership of this DW Index Working Group (IWG) included Nate Bacheler, Eric Fitzpatrick (lead), Wally Bubley, Kevin Thompson and Erik Williams. Several other DW panelists and observers contributed to the IWG discussions throughout the DW workshop. During the DW, only two participants were present due to COVID-19 travel guidelines while the remaining participants contributed through email as well as the post-DW webinars.

5.2 Review of Working Papers

The relevant working papers describing index construction were presented to the IWG. Final working papers reflect decisions made during the DW, using addenda if necessary. In addition to working papers on index construction, the IWG also discussed any reference documents available at the DW that were relevant to indices of abundance: SEDAR82 WP04, SEDAR82 WP05, SEDAR82 WP06, SEDAR82 WP07, SEDAR82 WP10, SEDAR82 RD48 and SEDAR82 RD49. The index working papers provide information on sample sizes, diagnostics of model fits, and in some cases, maps of catch and effort. A summary of each index is provided below.

5.3 Fishery-independent Indices

The Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program has conducted most of the historical fishery-independent sampling in the U.S. South Atlantic (North Carolina to Florida). MARMAP has used a variety of gears over time, but chevron traps are one of the primary gears used to monitor reef fish species and have been deployed since the late 1980s. In 2009, MARMAP began receiving additional funding to monitor reef fish through the SEAMAP-SA program. In 2010, the Southeast Fishery-Independent Survey (SEFIS) was initiated by NMFS to work collaboratively with MARMAP/SEAMAP-SA using identical methods to collect additional fishery-independent samples in the region. Together, these three programs are now called the Southeast Reef Fish Survey (SERFS). In 2010, video cameras were attached to a subset of traps deployed by SERFS, and beginning in 2011 and continuing to present, all traps included video cameras. With the advent of the partner programs, sampling coverage in the region has expanded, primarily in Florida. SERFS now samples between Cape Hatteras, North Carolina and St. Lucie Inlet, Florida, and it targets a sampling universe of approximately 4,300 sites of hard-bottom habitats between approximately 15 and 115 meters deep.

Hard-bottom sampling stations were selected for sampling in one of three ways. First, most sites (75.0%) were randomly selected from the SERFS sampling frame that consisted of approximately 4,300 sampling stations on or very near hard bottom habitat. Second, some stations (13.3%) in the sampling frame were sampled opportunistically even though they were not randomly selected for sampling in a given year. Third, new hard-bottom stations were added during the study period through the use of information from various sources including fishermen, charts, and historical surveys (11.7%). These new locations were investigated using a vessel echosounder or drop cameras and sampled if hard bottom was detected. Only those new stations landing on or near hardbottom habitat were included in the analyses. All sampling for this study occurred during daylight hours between April and October on the R/V *Savannah*, R/V *Palmetto*, R/V *Sand Tiger*, or the NOAA Ship *Pisces* using identical methodologies as described below. Samples were intentionally spread out spatially on each cruise (see Figure 2 in Bacheler and Carmichael 2014).

Chevron traps were constructed from plastic-coated, galvanized 2-mm diameter wire (mesh size = 3.4 cm^2) and measured 1.7 m × 1.5 m × 0.6 m, with a total volume of 0.91 m^3 (Collins et al. 1990). Trap mouth openings were shaped like a teardrop and measured approximately 18 cm wide and 45 cm high. Each trap was baited with 24 menhaden (*Brevoortia* spp.). Traps were typically deployed in groups of six, and each trap in a set was deployed at least 200 m from all other traps to provide some measure of independence between traps. A soak time of 90 minutes was targeted for each trap deployed. Hydrographic data were collected via CTD during each set, which included bottom temperature (^oC).

5.3.1 Chevron trap

5.3.1.1 Methods, Gears, and Coverage

An index of abundance was developed from the catch of the chevron traps by standardizing catch (number of gray triggerfish caught) using a zero-inflated negative binomial model (SEDAR82-DW05; Zuur et al. 2009). Data were filtered to include only monitoring efforts beginning in 1990 that contained appropriate catch IDs, station types, appropriate soak times, and no missing covariate data as described in the working paper. Effort (trap soak minutes) was included as an offset in the regression. Analyses were computed using the *pscl* library in R (Jackman 2008; Zeileis et al 2008; R Development Core Team

2014). Model covariates were treated as continuous variables and included sampling characteristics (day of year and latitude) and environmental data (temperature and depth). Detailed information regarding index development can be found in the associated working paper (SEDAR82-DW05)

5.3.1.2 Sampling Intensity and Time Series

Chevron traps were deployed from 1990 through 2021 (note no sampling occurred in 2020 due to COVID-19), ranging from 213 to 1832 traps per year meeting the depth criteria for this analysis. The spatial coverage of the survey has adequately covered the center of distribution of gray triggerfish in the region and percent positives were high enough to develop an index of abundance for the full time series. The annual number of traps (collections) used to compute the index is shown in Table 5.3.

5.3.1.3. Size/Age data

Length measurements were taken for every fish captured. Dorsal fin spines were removed from all or a predetermined random sub-sample of individuals per year. The calendar ages of gray triggerfish collected by chevron traps (1990-2021) ranged from 0 to 12 years (median = 3, mean = 3.23, n= 10,432). Age composition data are available for estimating the selectivity of this gear.

5.3.1.4. Catch Rates

Standardized catch rates are shown in Table 5.3 and in Figure 5.1. The units on catch rates are in numbers of fish and normalized to the long-term mean of the time series. Effort was modeled as an offset, rather than as the denominator in the response variable.

5.3.1.5. Uncertainty and Measures of Precision

Measures of precision were computed using a bootstrap procedure (Efron and Tibshirani 1994), in which sampling events were drawn at random (by year) with replacement. The calculated CVs are shown in Table 5.3.

5.3.1.6 Comments on Adequacy for Assessment

This index was recommended for the assessment. The dataset has good spatial coverage relative to the range of gray triggerfish and percent positives were high enough to create a meaningful index. Because the chevron trap index is fishery-independent and has accompanying selectivity information (lengths and ages), it was considered by the IWG to be the highest-ranking sources of information on trends in population abundance.

One topic discussed by the group, but not explicitly addressed, was the non-independence between chevron traps and the video survey; this topic was identified for future research.

5.3.2 Video Survey

5.3.2.1 Methods, Gears, and Coverage

SERFS began affixing high-definition video cameras to chevron traps on a limited basis in 2010 (Georgia and Florida only), but, since 2011, has attached cameras to all chevron traps as part of their normal monitoring efforts. In 2015, the video cameras were changed from Canon to GoPro to implement a wider field of view and thus observe more fish. A calibration study (detailed below) with both camera types used simultaneously was undertaken to account for differences in fish counts.

Canon Vixia HFS-200 high-definition video cameras in Gates underwater housings were attached to chevron traps in 2011–2014, facing outward over the mouth. In 2015, Canon cameras were replaced with GoPro Hero 4 cameras over the trap mouth. Fish were counted exclusively using cameras over the trap mouth. A second high-definition GoPro Hero, Hero 3+, or Hero 4 video or Nikon Coolpix S210/S220 still camera was attached over the nose of most traps in an underwater housing, and was used to quantify microhabitat features in the opposite direction. Cameras were turned on and set to record before traps were deployed, and were turned off after trap retrieval. Trap-video samples were excluded from our analysis if videos were unreadable for any reason (e.g., too dark, camera out of focus, files corrupt) or the traps did not fish properly (e.g., bouncing or dragging due to waves or current, trap mouth was obstructed).

In advance of the switch to GoPro cameras exclusively in 2015, a calibration study was conducted in the summer of 2014 where Canon and GoPro cameras were attached to traps side-by-side and fish were counted at the same time. A total of 54 side-by-side comparisons were recorded. Gray triggerfish were observed in 41 videos and were used to develop a calibration factor that expanded Canon counts to make them comparable to GoPro counts.

Relative abundance of reef fish on video has been estimated using the *MeanCount* approach (Conn 2011; Schobernd et al. 2014). *MeanCount* was calculated as the mean number of individuals of each species over a number of video frames in the video sample. Video reading time was limited to an interval of 20 total minutes, commencing 10 minutes after the trap landed on the bottom to allow time for the trap to settle. One-second snapshots were read every 30 seconds for the 20-minute time interval, totaling 41 snapshots read for each video. The mean number of individuals for each target species in the 41 snapshots is the *MeanCount* for that species in each video sample. Zero-inflated modeling approaches described below require count data instead of continuous data like *MeanCount*. Therefore, these analyses used a response variable called *SumCount*, which was simply the sum of all individuals seen across all video frames. *SumCount* and *MeanCount* track exactly linearly with one another when the same numbers of video frames are used in their calculation (Bacheler and Carmichael 2014). Therefore, *SumCount* values were only used from videos where 41 frames were read (94.7% of all samples).

SERFS employed video readers to count fish on videos. There was an extensive training period for each video reader, and all videos from new readers were re-read by fish video reading experts until they were very high quality. After that point, 10% or 15 videos (whichever was larger) were re-read annually by fish video reading experts as part of quality control. Video readers also quantified microhabitat features (biotic density and substrate composition), in order to standardize for habitat types sampled over time. Water clarity was also scored for each sample as poor, fair, or good. If bottom substrate could not be seen, then water clarity was considered poor, and if bottom habitat could be seen but the horizon was not visible, water clarity was considered fair. If the horizon could be seen in the distance, water clarity was considered to be good. Including water clarity in index models allowed for a standardization of fish counts based on variable water clarities over time and across the study area. A CTD cast was also taken for each simultaneously deployed group of traps, within 2 m of the bottom, and water temperature from these CTD casts was available for standardization models.

5.3.2.2 Sampling Intensity and Time Series

Overall, there were 15,144 survey videos with data available covering a period of 12 years (2011–2021; note no sampling occurred in 2020 due to COVID-19). Although data were available from 2010, they were not considered here due to limitations in spatial coverage and a different camera used in that year. For the years considered, several data filters were applied. We removed any data points in which the survey video was considered unreadable by an analyst (e.g., too dark, corrupt video file), or if the trapping event was flagged for any irregularity that could have affected catch rates (e.g., trap dragged or bounced). Additionally, any survey video for which fewer than 41 video frames were read was removed from the full data set. Standardizing the number or readable frames for any data point was essential due to our use of *SumCount* as a response variable (see above). We also identified any video sample in which corresponding predictor variables were missing and removed them from the final data set.

Of the 15,144 video samples considered for inclusion, 2,072 were removed based on the data filtering process described above, leaving 13,072 videos included in the analysis, of which 4,538 were positive for gray triggerfish (34.7%). The spatial distribution of the videos included in the analysis cover the area from Cape Hatteras, North Carolina, to St. Lucie Inlet, Florida. These data span a wide latitudinal and depth range, covering a substantial region of the south Atlantic coastal shelf. Detailed information on the depth, latitudinal, and seasonal distribution of sampling can be found in the index working paper (SEDAR82WP04).

5.3.2.3. Size/Age data

As currently implemented, the size and age composition of populations sampled with the SERFS video survey gear are unknown, and therefore selectivity of the gear cannot be estimated from data. However, in a different system, Langlois et al. (2015) compared length compositions of snappers and groupers caught in traps to those observed on video cameras, and found those length compositions to be quite similar. Based on that, the IWG recommended applying selectivity of chevron traps to the video gear, in one of two ways: 1) if chevron trap selectivity is flat-topped, the video gear selectivity should mirror that of the chevron traps, or 2) if chevron trap selectivity is dome-shaped, the video gear selectivity should mirror only the ascending portion and then assume flat-topped selectivity. This recommendation was based on the expectation that the video survey gear should be flat-topped, because there is no known reason why larger (older) individuals would be less observable on video than smaller (younger) individuals. The IWG recognized the need for age/size compositions of the video survey, and recommended future research to remedy this limitation.

5.3.2.4. Catch Rates

Annual standardized index values for gray triggerfish, including CVs, are presented in Table 5.4 and in Figure 5.2.

5.3.2.5. Uncertainty and Measures of Precision

Using a bootstrap procedure with 1000 replicates, confidence intervals of 2.5% and 97.5% were calculated for each year of the survey (Figure 5.2), as were CVs (Table 5.4).

5.3.2.6 Comments on Adequacy for Assessment

The gray triggerfish video index (2011-2021) was recommended for use in the assessment. Non-independence between the video survey and chevron traps was discussed and identified as a topic for future research.

5.4 Fishery-Dependent Indices

In general, indices from fishery-independent data are believed to represent abundance more accurately than those from fishery-dependent data. This is because fishery-dependent indices can be strongly affected by factors other than abundance, such as management regulations on the focal or other species, shifts in targeting, changes in fishing efficiency (technology creep), and density dependent catchability (hyperdepletion or hyperstability). The standardization procedures attempt to account for some of these issues to the extent possible.

5.4.1 Recreational Headboat Index

The headboat fishery in the South Atlantic includes for-hire vessels that typically accommodate 11-70 passengers and charge a fee per angler. The fishery uses hook and line gear, generally targets hard bottom reefs as the fishing grounds, and generally targets species in the snapper-grouper complex. This fishery is sampled separately from other fisheries, and the available data were used to generate a fishery-dependent index.

Headboats in the South Atlantic are sampled from North Carolina to the Florida Keys (Figure 5.3). Data have been collected since 1972, but logbook reporting did not start until 1973. In addition, only North Carolina and South Carolina were included in the earlier years of the data set. In 1976, data were collected from North Carolina, South Carolina, Georgia, and northern Florida, and starting in 1978, data were collected from southern Florida.

Variables reported in the data set include year, month, day, area, location, trip type, number of anglers, species, catch, and vessel identification. Biological data and discard data were recorded for some trips in some years.

The IWG discussed the starting and ending years for this index:

- Although data were reported throughout the 1980s, the CPUE during that time period was considered unreliable as a measure of abundance. This was due to increases in desirability to keep gray triggerfish throughout the 1980s, and the fact that the headboat logbooks contained no information on discards during that period.
- Many regulatory changes of snapper-grouper species were implemented in 1992, and they may have affected targeting of gray triggerfish. In addition, a 12-inch size limit was implemented in 1995 in state and federal waters off the east coast of Florida. For this reason, the index was computed starting in 1995.
- Similarly, regulatory changes in 2010 on other species (implementation of ACLs, red snapper closure) increased the desirability of gray triggerfish. This likely resulted in increased targeting and catchability, and therefore the terminal year of the index was set to 2009. It was noted that fishery-independent indices extend through 2021.

5.4.1.1 Methods of Estimation

Data Filtering

Trips to be included in the computation of the index need to be determined based on effective effort for gray triggerfish. This may not be straightforward, because some trips caught gray triggerfish only incidentally, and some trips likely directed effort at gray triggerfish unsuccessfully. Given that direct information on species targeted is not available, effective effort must be inferred.

To determine which trips should be used to compute the index, the method of Stephens and MacCall (2004) was applied. The Stephens and MacCall method uses multiple logistic regression to estimate a probability for each trip that the focal species was caught, given other species caught on that trip. Species compositions differ across the South Atlantic; thus, the method was applied separately for two different regions: north (NC – Ft. Pierce, FL) and south (Ft. Pierce, FL- the FL Keys) (Shertzer *et al.* 2009). To avoid rare species, the number of species in each analysis was limited to those species that occurred in 1% or more of trips. The most general model therefore included all species in the snapper-grouper complex which occurred in 1% or more of trips as main effects, excluding red porgy. Red porgy was removed because of regulations (closure followed by strict bag limits), which could erroneously remove trips likely to have caught gray triggerfish in recent years. A backward stepwise AIC procedure (Venables and Ripley 1997) was then used to perform further selection among possible species as predictor variables. In this procedure, a generalized linear model with Bernoulli response was used to relate presence/absence of gray triggerfish in headboat trips to presence/absence of other species.

Additional analysis examined potential shifts in fishing behavior by investigating results of the Stephens and MacCall subsetting method on multiple species to determine the utility of this method in periods of extensive management at identifying effective effort. SEDAR82-WP07 recommends taking a precautionary approach when using this index following the 2010 red snapper closure while indicated several indices may no longer be tracking abundance due to effects of increased management.

Model Description

Response and explanatory variables

The response variable, landings per unit effort (LPUE), has units of self-reported fish kept (numbers)/angler and was calculated as the number of gray triggerfish kept divided by the number of anglers. All explanatory (predictor) variables were modeled as categorical, rather than as continuous.

Years – 1995-2009

Area – Areas were pooled into regions of North Carolina (NC=2,3,9,10), South Carolina (SC=4,5), Georgia and North Florida (GNFL=6,7,8), and south Florida (SFL=11,12,17).

Season – The seasons were defined as winter (January, February, March), spring (April, May, June), summer (July, August, September) and fall (October, November, December).

Party – Five categories for the number of anglers on a boat were considered in the standardization process. The categories included: ≤20 anglers, 21-40 anglers, 41-60 anglers, 61-80 anglers, and >80 anglers. The minimum number of anglers per vessel was set at 6, which excluded the lower 0.5% of trips.

These trips were excluded because they were possibly misreported and likely don't reflect the behavior of headboats in general.

Trip Type – Trip types of half and full day trips were included in the analysis. Three-quarter day trips were pooled with half-day trips (<10%). Multi-day trips were removed because most were in Florida and likely targeting deepwater species for some portion of the trip.

Standardization

LPUE was modeled using the delta-glm approach (Lo *et al*. 1992; Dick 2004; Maunder and Punt 2004). In particular, fits of lognormal and gamma models were compared for positive LPUE. Also, the combination of predictor variables was examined to best explain LPUE patterns (both for positive LPUE and the Bernoulli submodels). All analyses were performed in the R programming language (R Development Core Team 2014), with much of the code adapted from Dick (2004).

Bernoulli submodel. One component of the delta-GLM is a logistic regression model that attempts to explain the probability of either catching or not catching gray triggerfish on a particular trip. First, a model was fit with all main effects to determine which effects should remain in the binomial component of the delta-GLM. Stepwise AIC (Venables and Ripley1997) with a backward selection algorithm was then used to eliminate those that did not improve model fit. In this case, the stepwise AIC procedure did not remove any predictor variables. No concerning patterns were apparent in the quantile residuals (Dunn and Smyth 1996).

Positive LPUE submodel. To determine predictor variables important for describing positive LPUE, the positive portion of the model was fitted with all main effects using both the lognormal and gamma distributions. Stepwise AIC (Venables and Ripley1997) with a backward selection algorithm was then used to eliminate those that did not improve model fit. In this case, no predictor variables were removed for either error distribution.

Both submodels (Bernoulli and either lognormal or gamma) were then combined, and the models were compared using AIC. In this case, the delta-lognormal distribution performed best and was therefore used in the final model. No concerning patterns were apparent in standard diagnostic plots of residuals.

5.4.1.2 Sampling Intensity

The resulting data set contained more than 38,000 trips across all years with approximately 54–75% of those trips having positive catches of gray triggerfish. Annual numbers of trips used to compute the index are shown in Table 5.5.

5.4.1.3 Size/Age data

The sizes/ages represented in this index should be the same as those of landings from the corresponding fleet (See section 4 of the DW report).

5.4.1.4 Catch Rates

Standardized catch rates and associated error bars are shown in Figure 5.4, and tabulated in Table 5.5. The units on catch rates were number of fish landed per angler.

5.4.1.5 Uncertainty and Measures of Precision

Measures of precision were computed using the bootstrap procedure. Annual CVs of catch rates are tabulated in Table 5.5.

5.4.1.6 Comments on Adequacy for Assessment

The index of abundance created from the headboat data was considered by the IWG to be adequate for use in the assessment. The data cover a wide geographic range relative to most of the stock, and logbooks are intended to represent a census of the headboat landings. The data set has an adequately large sample size and has a long enough time series to provide potentially meaningful information for the assessment. For the duration of the index, sampling was consistent over time, and some of the data were verified by port samplers and observers.

The primary caveat concerning this index was that it was derived from fishery-dependent data. Headboat effort generally targets snapper-grouper species and not necessarily the focal species, which should minimize changes in catchability relative to other fishery-dependent indices that target more effectively (i.e., commercial indices). Nonetheless, as regulations have tightened on other co-occurring species, triggerfish have become increasingly targeted, particularly in recent years. The ultimate patterns and trends in this index also tracked patterns observed in the earlier years of the SERFS trap and video indices, a potential indication that this data was tracking population appropriately and not effort and would not lead to potential issues in the assessment phase with competing trends

5.4.2 Headboat at-sea observer program

Standardized catch rates were examined from the headboat at-sea observer data (not to be confused with the Southeast Regional Headboat Survey (SRHS)). Two indices, a discard index and a catch (harvested and discarded) index were developed from the same data source as alternative indices to discuss at the data workshop. The analysis included areas from central North Carolina through south Florida. The index is meant to describe population trends of fish in the size/age range of fish landed and discarded by headboat vessels. Data filtering and subsetting steps were applied to the data to model trips that were likely to have directed gray triggerfish effort.

All sampled trips were included in the indices, since gray triggerfish may be caught during bottom fishing for reef fishes. The at-sea-observer program began in 2004 in North and South Carolina and 2005 in Florida and Georgia. The Atlantic coast of the Florida Keys are included in the time-series; however, headboats were not sampled in this area from 2008-2010 due to funding.

Trip-level information included state, county, Florida region (Brevard County north, or south of Brevard County), year, month, day, dock to dock hours (total trip hours), the number of hours fished (to the nearest half hour), the total number of anglers on the boat, the number of anglers observed on a trip, the number of gray triggerfish harvested and discarded, individual fish length (midline, in mm), and the minimum and maximum depth of the fishing trip. Depth information was not collected for South Carolina, North Carolina, and Georgia; therefore, it was not used in this analysis.

5.4.2.1 Methods of Estimation

Data from 2004 were dropped from the analysis because Georgia and Florida were not sampled. Prior to 2015 there was a 12" TL minimum size in Florida only. During this period gray triggerfish discards were infrequent in North Carolina, South Carolina and Georgia where no size limit was in place. In 2015, Florida implemented a 14" FL minimum size while Georgia, South Carolina and North Carolina implemented a 12" FL minimum size. In April 2020, all states implemented a 12" FL minimum size. Coastwide sample coverage during 2020 and 2021 was severely reduced due to the pandemic, and these years were dropped from the analysis. Two indices were explored: a discard index from 2005-2019 and a coastwide harvest + discard (catch) index from 2010-2019 (Table 1). The Southeast headboat survey provides a historic harvest-only index with a terminal year of 2009, thus starting this catch index prior to 2010 would duplicative.

CPUE were modeled using the delta-glm approach (Lo et al. 1992; Dick 2004; Maunder and Punt 2004). In particular, fits of lognormal and gamma models were compared for positive CPUE. Also, the combination of predictor variables was examined to best explain CPUE patterns (both for positive CPUE and or positive CPUE). All analysis were performed in the R programming language, with much of the code adapted from Dick (2004).

One component of the delta-GLM is a logistic regression model that attempts to explain the probability of either catching or not catching gray triggerfish on a particular trip. First, a model was fit with all main effects in order to determine which effects should remain in the binomial component of the delta-GLM. Stepwise AIC (Venables and Ripley1997) with a backwards selection algorithm was then used to eliminate those that did not improve model fit.

Then, to determine predictor variables important for predicting positive CPUE, the positive portion of the model was fitted with all main effects using both the lognormal and gamma distributions. Stepwise AIC (Venables and Ripley1997) with a backwards selection algorithm was then used to eliminate those that did not improve model fit. All predictor variables were modeled as fixed effects (and as factors rather than continuous variables).

Both components of the model were then fit together (with the code adapted from Dick 2004) using the lognormal and gamma distributions and models were compared using AIC. With CPUE/DPUE as the dependent variable.

5.4.2.2 Sampling Intensity

From 2010 to 2019,2,576 trips were included in the analysis. The proportion of positive trips among factors and factor levels varied between 14% and 59%. Annual sample sizes used to compute the index are shown in Table 5.6.

5.4.2.3 Size/Age data

The sizes/ages represented in this index should be the similar to those of landings from the corresponding fleet (See section 4 of the DW report). However, this index also includes discards, which presumably occurred primarily off Florida as result of the 12-inch size limit in that location until 2015.

5.4.2.4 Catch Rates

Standardized catch rates and associated error bars are shown in Figure 5.5 and are tabulated in Table 5.6. The units on catch rates were number of fish caught per angler-hour. Caught fish included harvested and discarded gray triggerfish).

5.4.2.5 Uncertainty and Measures of Precision

Measures of precision were computed using the delta method described by Lo *et al*. (1992). Annual CVs of catch rates are tabulated in Table 5.6.

5.4.2.6 Comments on Adequacy for Assessment

The dataset has good spatial coverage relative to the range of gray triggerfish. The index included discards and is a sufficiently long time series to be recommended for the assessment. While the index created from headboat at-sea observer data is based on fishery-dependent data, the recommendation was to consider this index for use in the assessment. With the inclusion of discards compared to the SRHS logbook index, the IWG panel recognized the importance of characterizing the headboat fleet following years of increased management.

5.4.3 Commercial Handline Index

Landings and fishing effort of commercial vessels operating in the southeast U.S. Atlantic have been monitored by the NMFS Southeast Fisheries Science Center through the Coastal Fisheries Logbook Program (CFLP). The program collects information about each fishing trip from all vessels holding federal permits to fish in waters managed by the Gulf of Mexico and South Atlantic Fishery Management Councils. Initiated in the Gulf in 1990, the CFLP began collecting logbooks from Atlantic commercial fishers in 1992, when 20% of Florida vessels were targeted. Beginning in 1993, sampling in Florida was increased to require reports from all vessels permitted in coastal fisheries, and since then has maintained the objective of a complete census of federally permitted vessels in the southeast U.S.

Catch per unit effort (CPUE) from the logbooks was used to develop an index of abundance for gray triggerfish landed with vertical lines (manual handline and electric reel), the dominant gear for this gray triggerfish stock. The time series used for construction of the index spanned 1993−2009, when all vessels with federal snapper-grouper permits were required to submit logbooks on each fishing trip. Discussions among the IWG and commercial fishermen at the SEDAR 41 DW revealed targeting changes for gray triggerfish related to the 2010 closure of red snapper and other species (e.g., shallow-water grouper closures). Fishermen indicated that they avoided red snapper since the closure and were targeting other species including gray triggerfish. For this reason the catch rate for gray triggerfish extends only through 2009.

5.4.3.1 Methods of Estimation

Data Treatment

For each fishing trip, the CFLP database included a unique trip identifier, the landing date, fishing gear deployed, areas fished, number of days at sea, number of crew, gear-specific fishing effort, species caught, and weight of the landings. Fishing effort data available for vertical line gear included number of lines fished, hours fished, and number of hooks per line. For this southeast U.S. Atlantic stock, areas used in analysis were those between 24 and 37 degrees latitude, inclusive of the boundaries (Figure 5.6).

Data were restricted to include only those trips with landings and effort data reported within 45 days of the completion of the trip. Reporting delays beyond 45 days likely resulted in less reliable effort data (landings data may be reliable even with lengthy reporting delays if trip ticket reports were referenced by the reporting fisher). Also excluded were records reporting multiple gears fished, which prevents designating catch and effort to specific gears. Therefore, only those trips that reported one gear fished were included in the analyses. Where trips reported multiple areas, the first area reported was used in the analysis. Only the latitude from the area designated was used in the analysis assuming most trips with multiple areas fished were moving across the shelf rather than north and south.

Clear outliers (>99.5 percentile) in the data were also excluded from the analyses. These outliers were identified for all snapper/grouper trip manual handlines as records reporting more than 6 lines fished, 8 hooks per line fished, 10 days at sea, 5 crew members or 100 hours fished; outliers were identified for electric reels as records reporting more than 6 lines fished, 10 hooks per line fished, 12 days at sea, 5 crew members or 137 hours fished. Trips reporting fewer than 4 hours fished for both gears were removed. Positive gray triggerfish trips reporting greater than 12 pounds/hook-hr were excluded for both gears.

To determine which trips should be used to compute the index, the method of Stephens and MacCall (2004) was applied. The Stephens and MacCall method uses multiple logistic regression to estimate a probability for each trip that the focal species was caught, given other species caught on that trip. Species compositions differ across the south Atlantic; thus, the method was applied separately for areas north and south of Cape Canaveral , which has been identified as a zoogeographical boundary (Shertzer et al. 2009). Cape Canaveral falls in the middle of the one degree commercial sampling grid and was assigned to the south with the split at 29 degrees. To avoid rare species, the number of species in each analysis was limited to those species that occurred in 1% or more of trips. The most general model therefore included all species in the snapper-grouper complex which occurred in 1% or more of trips as main effects, excluding red porgy. Red porgy was removed because of regulations (closure followed by strict bag limits), which could erroneously remove trips likely to have caught gray triggerfish in recent years. A backward stepwise AIC procedure (Venables and Ripley 1997) was then used to perform further selection among possible species as predictor variables. In this procedure, a generalized linear model with Bernoulli response was used to relate presence/absence of gray triggerfish in commercial trips to presence/absence of other species. An alternative generalized linear model with Bernoulli response related the catch in pounds of other species to the presence/absence of gray triggerfish. Although the alternative method theoretically may be more efficient at identifying species associations, the IWG rejected the method due to concerns that the increase in trip limits in recent years may bias the results.

Model Description

Response and explanatory variables

The response variable, CPUE, was calculated for each trip as,

CPUE = pounds of gray triggerfish/hook-hour where hook-hours is the product of number of lines fished, number of hooks per line, and total hours fished. Explanatory variables, all categorical, are described below. The explanatory variables were year, month, area, crew size, and days at sea, each described below:

Years – Year was necessarily included, as standardized catch rates by year are the desired outcome. Years modeled were 1993–2009.

Season – The seasons were defined as winter (January, February, March), spring (April, May, June), summer (July, August, September) and fall (October, November, December).

Lat – Location is reported as latitude and longitude in one degree increments centered at the middle (e.g., CFLP lat=28 is centered at 28.5 degrees). The few trips with latitude reported north of 34 degrees and south of 24 degrees were pooled into the 34 and 24 degree bins, respectively (Figure 5.6).

Crew size – Crew size (crew) was pooled into three levels: one, two, and three or more.

Days at sea – Days at sea (sea days) was pooled into three levels: one or two days, three or four days, and five or more days.

Standardization

CPUE was modeled using the delta-glm approach (Lo et al. 1992; Dick 2004; Maunder and Punt 2004). In particular, fits of lognormal and gamma models were compared for positive CPUE. Also, the combination of predictor variables was examined to best explain CPUE patterns (both for positive CPUE and the Bernoulli submodels). All analyses were performed in the R programming language (R Development Core Team 2014), with much of the code adapted from Dick (2004).

Bernoulli submodel. One component of the delta-GLM is a logistic regression model that attempts to explain the probability of either catching or not catching gray triggerfish on a particular trip. First, a model was fitted with all main effects to determine which effects should remain in the binomial component of the delta-GLM. Stepwise AIC (Venables and Ripley1997) with a backward selection algorithm was then used to eliminate those that did not improve model fit. In this case, the stepwise AIC procedure did not remove any predictor variables. No concerning patterns were apparent in the quantile residuals (Dunn and Smyth 1996).

Positive CPUE submodel. To determine predictor variables important for describing positive CPUE, the positive portion of the model was fitted with all main effects using both the lognormal and gamma distributions. Stepwise AIC (Venables and Ripley1997) with a backward selection algorithm was then used to eliminate those that did not improve model fit. In this application, the lognormal distribution outperformed the gamma distribution.

Both submodels (Bernoulli and lognormal) were then combined into a single delta-lognormal model (1993-2009), with all predictors used for both submodels. No concerning patterns were apparent in standard diagnostic plots of residuals.

5.4.3.2 Sampling Intensity

Annual numbers of trips used to compute the index is typically greater than 1000, as shown in Table 5.7.

5.4.3.3 Size/Age data

The sizes/ages represented in this index should be the same as those of landings from the corresponding fleet (See section 3 of the DW report).

5.4.3.4 Catch Rates

Standardized catch rates and associated error bars are shown in Figure 5.7 and are tabulated in Table 5.7. The units on catch rates were pounds of fish landed per hook-hour.

5.4.3.5 Uncertainty and Measures of Precision

Estimates of variance were based on 1000 bootstrap runs where trips were chosen randomly with replacement (Efron and Tibshirani 1994). Annual CVs of catch rates are tabulated in Table 5.7.

5.4.3.6 Comments on Adequacy for Assessment

The index of abundance created from the commercial logbook data was considered by the IWG to be recommended for use in the assessment. The data cover a wide geographic range relative to that of the stock, and logbooks represent a census of the fleet. The data set has an adequately large sample size and has a long enough time series to provide potentially meaningful information for the assessment. The primary caveat concerning this index was that it was derived from fishery-dependent data. Although the index was computed starting in 1993, the assessment might justifiably start the index in 1995, when size-limit regulations were implemented off the coast of Florida.

5.4.4 Other Fishery-Dependent Data Sources Considered During the DW

Several data sources were discussed during the pre-DW webinar for the potential to support indices of abundance, and some of these were discarded based on initial summaries of data. One data source was recommended during the webinar for further consideration, but was subsequently not recommended by the DW for use in the assessment: Marine Recreational Information Program (MRIP) data.

Due to the evidence identified in the working paper (SEDAR82-WP06) (difficulty identifying effective effort, split effort on a trip, shifts in sampling intensity, desirability) the IWG recommendation for the SEDAR 82 DW is to not pursue the development of a gray triggerfish index of abundance from the MRIP intercept data.

5.5 Consensus Recommendations and Survey Evaluations

The DW recommended two fishery-independent (chevron traps and videos) and three fishery-dependent indices (headboat, MRFSS, commercial handline) for potential use in the gray triggerfish stock assessment. Pearson correlations and significance values (p-values) between indices are presented in Table 5.8. All recommended indices and their CVs are in Table 5.9, and the indices are compared graphically in Figure 5.8.

5.6 Literature Cited

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5.7 Tables

Table 5.7.1. Table of the data sources considered for indices of abundance.

Fishery Type	Data Source	Area	Yrs	Units	Standardization Method	Issues	Consideration
Recreational	Headboat	NC-FL	1995-2009	N kept/ angler	Delta-GLM	Fishery-dependent, self reported	Yes
Recreational	Headboat-at-sea-observer	NC-FL	2005-2009	N caught/ angler	Delta-GLM	Fishery-dependent. Samples same fleet as headboat.	Yes
Commercial	Commercial logbook handline	NC-FL	1993-2009	lb kept/ hook-hour	Delta-GLM	Fishery-dependent, self reported	Yes
Independent	SERFS: chevron trap	NC-FL	1990-2021	N caught	Zero inflated negative binomial	Expanded spatial coverage through time	Yes
Independent	SERFS: video survey	NC-FL	2011-2021	N observed	Zero inflated negative binomial	Ages/sizes unknown	Yes

Table 5.7.2. Table of the pros and cons for each data set considered at the data workshop. Note that several data sources were considered (Table 5.1), but discarded, prior to the DW.

<u>Fishery-independent index</u>

SERFS Chevron Trap Index (*Recommended for use*)

Pros:

- Fishery-independent random hard bottom survey
- Adequate regional coverage
- Standardized sampling techniques
- All fish caught are aged and measured

Cons:

- Expanded spatial coverage over time
- Gray triggerfish caught in traps affected by feeding motivation/hunger

SERFS Video Index (*Recommended for use*)

Pros:

- Fishery-independent random hard bottom survey
- Adequate regional coverage
- Standardized sampling techniques
- Relatively high detection probabilities
- Likely to be less selective than capture gears

Cons:

- time series
- Ages/sizes observed are unknown

<u>Fishery-dependent indices</u>

Recreational Headboat (*Recommended for use*)

Pros:

- Complete census
- Covers the entire management area

- Some data are verified by port samplers and observers
- Large sample size
- Strongly correlated with headboat at-sea-observer index
- Generally non-targeted for focal species, which should minimize changes in catchability relative to fishery-dependent indices that target specific species
- Concurrence of trends and patterns with fishery-independent indices

Cons:

- Fishery-dependent (i.e., potentially affected by regulations, targeting, hyperdepletion, hyperstability)
- Little information on discard rates, particularly before mid-2000s
- Catchability may vary over time or with abundance
- Effective effort is difficult to identify
- Does not include discarded fish

Commercial Logbook – Handline (*Recommended for use*)

Pros:

- Complete census
- Covers the entire management area
- Large sample size
- Concurrence of trends and patterns with fishery-independent indices

Cons:

- Fishery-dependent (i.e., potentially affected by regulations, targeting, hyperdepletion, hyperstability)
- Data are self-reported and largely unverified
- Catchability may vary over time or with abundance
- Landings could be cross-referenced with other data sources, but effective effort difficult to identify
- No information on discard rates
- Potential shifts in species targeted; commercial fishermen more skillful than general recreational fishermen at targeting focal species

Headboat at-sea observer index (*Not recommended for use*)

Pros:

- Observer program
- Good discard data (provides number of discards and length frequency)
- Random sampling design
- Broad spatial coverage

Cons:

- Fishery-dependent (i.e., potentially affected by regulations, targeting, hyperdepletion, hyperstability)
- Relatively short time series
- Information overlaps with headboat index

Table 5.7.3 The annual summary of data informative to index development and the results of the standardization. The data includes number of collections included in index development, the number of positive collections for Gray Triggerfish, the proportion of those positive collections in relation to the included collections, the total number of Gray Triggerfish caught, and these totals for the survey. The results show the normalized nominal and standardized chevron trap catch of Gray Triggerfish from the MARMAP/SERFS fishery-independent chevron trap survey which meet criteria to be included in the standardization process. The zero-inflated negative binomial (ZINB) standardized catch also includes a coefficient of variation (CV) calculated from a bootstrapping procedure.

					Nominal Abundance	ZINB Standardized Abundance	
Year	Included Collections	Positive	Proportion Positive	Total Fish	Normalized	Normalized	CV
1990	310	35	0.11	70	0.23	0.24	0.21
1991	259	123	0.47	369	1.47	1.28	0.13
1992	286	84	0.29	192	0.69	0.82	0.14
1993	380	111	0.29	276	0.75	0.76	0.11
1994	340	134	0.39	396	1.2	1.12	0.11
1995	336	148	0.44	647	1.98	1.4	0.1
1996	323	128	0.4	572	1.82	1.52	0.11
1997	345	157	0.46	693	2.07	2.27	0.12
1998	373	110	0.29	494	1.36	1.91	0.13
1999	213	59	0.28	187	0.9	0.9	0.16
2000	272	81	0.3	245	0.93	0.71	0.19
2001	231	80	0.35	214	0.95	0.9	0.12
2002	225	86	0.38	285	1.31	1.38	0.15
2003	206	26	0.13	49	0.25	0.62	0.25
2004	259	63	0.24	164	0.65	1.08	0.15
2005	278	90	0.32	326	1.21	0.8	0.13
2006	281	64	0.23	147	0.54	0.65	0.17
2007	317	98	0.31	302	0.98	0.79	0.13
2008	277	64	0.23	322	1.2	0.9	0.16
2009	404	80	0.2	257	0.66	0.61	0.15
2010	732	175	0.24	469	0.66	0.59	0.12
2011	731	149	0.2	537	0.76	0.76	0.11
2012	1174	326	0.28	1082	0.95	0.99	0.08
2013	1358	361	0.27	1250	0.95	1.19	0.08
2014	1473	457	0.31	1647	1.15	1.27	0.08
2015	1464	409	0.28	1100	0.77	0.9	0.08
2016	1485	510	0.34	2101	1.46	1.28	0.09
2017	1541	451	0.29	1558	1.04	1.17	0.07
2018	1736	396	0.23	1263	0.75	0.87	0.09
2019	1665	365	0.22	1408	0.87	0.83	0.11
2020	-	-	-	-	-	-	-
2021	1832	288	0.16	862	0.48	0.48	0.13

Table 5.7.4 The nominal index (*SumCount*), number of trapping events (N), proportion positive, standardized index, and CV for the gray triggerfish index computed from the SERFS video survey.

Year	Relative nominal *SumCount*	*N*	Proportion positive	Standardized index	CV
2011	1.045	580	0.317	0.965	0.13
2012	1.014	1083	0.297	1.135	0.10
2013	1.172	1221	0.307	1.30	0.09
2014	1.094	1382	0.344	1.111	0.08
2015	0.943	1405	0.374	0.895	0.08
2016	1.197	1404	0.422	1.121	0.08
2017	1.281	1424	0.429	1.165	0.08
2018	0.767	1654	0.349	0.814	0.08
2019	0.973	1545	0.341	0.973	0.10
2020	-	0	-	-	-
2021	0.514	1374	0.254	0.522	0.12

Table 5.7.5 The number of trips (N), nominal LPUE, relative nominal LPUE, standardized index, and CV for gray triggerfish from headboat logbook data.

Year	N	Nominal LPUE	Relative nominal	Standardized LPUE	CV
1995	3275	0.39	1.08	0.88	0.04
1996	2431	0.57	1.61	0.94	0.04
1997	1925	0.54	1.51	1.22	0.04
1998	3033	0.44	1.23	1.00	0.03
1999	2648	0.32	0.89	0.87	0.03
2000	2602	0.28	0.79	0.59	0.04
2001	2591	0.20	0.56	0.60	0.04
2002	2183	0.34	0.96	0.73	0.04
2003	1806	0.42	1.17	0.93	0.04
2004	2306	0.47	1.31	1.52	0.03
2005	2100	0.30	0.84	1.19	0.04
2006	2137	0.25	0.71	0.97	0.04
2007	2243	0.32	0.89	1.11	0.03
2008	3215	0.24	0.68	1.06	0.03
2009	4049	0.27	0.75	1.40	0.03

Table 5.7.6. The number of observer trips (N), nominal CPUE, relative nominal, standardized index, and CV for gray triggerfish from headboat at-sea observer data (harvest+discards).

Year	N	Nominal CPUE	Relative nominal	Standardized CPUE	CV
2010	230	0.29	0.49	0.6	0.19
2011	239	0.34	0.58	0.74	0.17
2012	265	0.72	1.2	0.73	0.17
2013	255	1.63	2.72	1.31	0.17
2014	261	0.82	1.38	0.93	0.21
2015	227	0.37	0.62	1.02	0.18
2016	265	0.37	0.62	1.36	0.15
2017	269	0.87	1.46	1.38	0.17
2018	283	0.24	0.41	0.97	0.16
2019	282	0.32	0.53	0.97	0.17

Table 5.7.7. The number of trips (N), nominal CPUE, relative nominal CPUE, standardized index, and CV for gray triggerfish from commercial logbook data (handlines).

Year	N	Nominal CPUE	Relative nominal	Standardized CPUE	CV
1993	770	0.41	0.62	0.76	0.07
1994	1281	0.64	0.97	0.89	0.05
1995	1479	0.62	0.93	1.01	0.05
1996	1167	0.76	1.14	1.04	0.05
1997	1593	0.93	1.40	1.53	0.04
1998	1427	1.06	1.59	1.38	0.05
1999	1415	0.79	1.19	1.06	0.05
2000	1348	0.47	0.71	0.76	0.05
2001	1582	0.42	0.64	0.69	0.05
2002	1714	0.46	0.69	0.66	0.05
2003	1352	0.62	0.93	0.75	0.06
2004	1233	0.77	1.15	1.14	0.05
2005	1296	0.74	1.12	1.24	0.05
2006	1219	0.72	1.08	0.99	0.05
2007	1453	0.63	0.95	1.00	0.05
2008	1369	0.62	0.94	0.98	0.05
2009	1052	0.64	0.97	1.13	0.05

Table 5.7.8. Pearson correlation values for indices recommended for use.

	HB at-sea (catch)	MARMAP trap	SERFS video	HB at-sea (discard)	SRHS Headboat	Comm HL
HB at-sea (catch)	1					
MARMAP trap	0.75	1				
SERFS video	0.48	0.74	1			
HB at-sea (discard)	0.75	0.53	-0.1	1		
SRHS Headboat	-	0.04	-	-	1	
Comm HL	-	0.51	-	-	0.67	1

Table 5.7.9. Gray triggerfish standardized indices of abundance and annual CVs recommended for potential use in the stock assessment. HB=headboat logbook index, CVT=chevron trap index, Video=SERFS video index, Comm=commercial handline index, and HB at-sea= Headboat at-sea observer index. Each index is scaled to its mean.

	Standardized Indices					CVs				
Year	HB	CVT	Video	Comm	HB at-sea	HB	CVT	Video	Comm	HB at-sea
1990		0.24					0.2			
1991		1.26					0.12			
1992		0.86					0.14			
1993		0.76		0.76			0.11		0.07	
1994		1.08		0.89			0.11		0.05	
1995	0.88	1.35		1.01		0.04	0.1		0.05	
1996	0.94	1.68		1.04		0.04	0.1		0.05	
1997	1.22	1.99		1.53		0.04	0.12		0.04	
1998	1	1.7		1.38		0.03	0.13		0.05	
1999	0.87	0.87		1.06		0.03	0.16		0.05	
2000	0.59	0.66		0.76		0.04	0.19		0.05	
2001	0.6	0.93		0.69		0.04	0.11		0.05	
2002	0.73	1.39		0.66		0.04	0.14		0.05	
2003	0.93	0.6		0.75		0.04	0.23		0.06	
2004	1.52	1.1		1.14		0.03	0.14		0.05	
2005	1.19	0.75		1.24		0.04	0.12		0.05	
2006	0.97	0.63		0.99		0.04	0.16		0.05	
2007	1.11	0.79		1		0.03	0.13		0.05	
2008	1.06	0.85		0.98		0.03	0.15		0.05	
2009	1.4	0.62		1.13		0.03	0.15		0.05	
2010		0.55			0.6		0.12			0.19
2011		0.73	0.965		0.74		0.11	0.13		0.17
2012		1.04	1.135		0.73		0.08	0.1		0.17
2013		1.18	1.3		1.31		0.08	0.09		0.17
2014		1.29	1.111		0.93		0.07	0.08		0.21
2015		0.89	0.895		1.02		0.07	0.08		0.18
2016		1.28	1.121		1.36		0.09	0.08		0.15
2017		1.21	1.165		1.38		0.07	0.08		0.17
2018		0.88	0.814		0.97		0.08	0.08		0.16
2019		0.84	0.973		0.97		0.09	0.1		0.17
2020								-		
2021		0.48	0.522				0.13	0.12		

5.8 Figures

Figure 5.8.1. The nominal (red dots) and standardized index (solid black line) for gray triggerfish computed from SERFS chevron traps. Gray shaded area represents 95% confidence interval as estimated from 5,000 bootstraps.

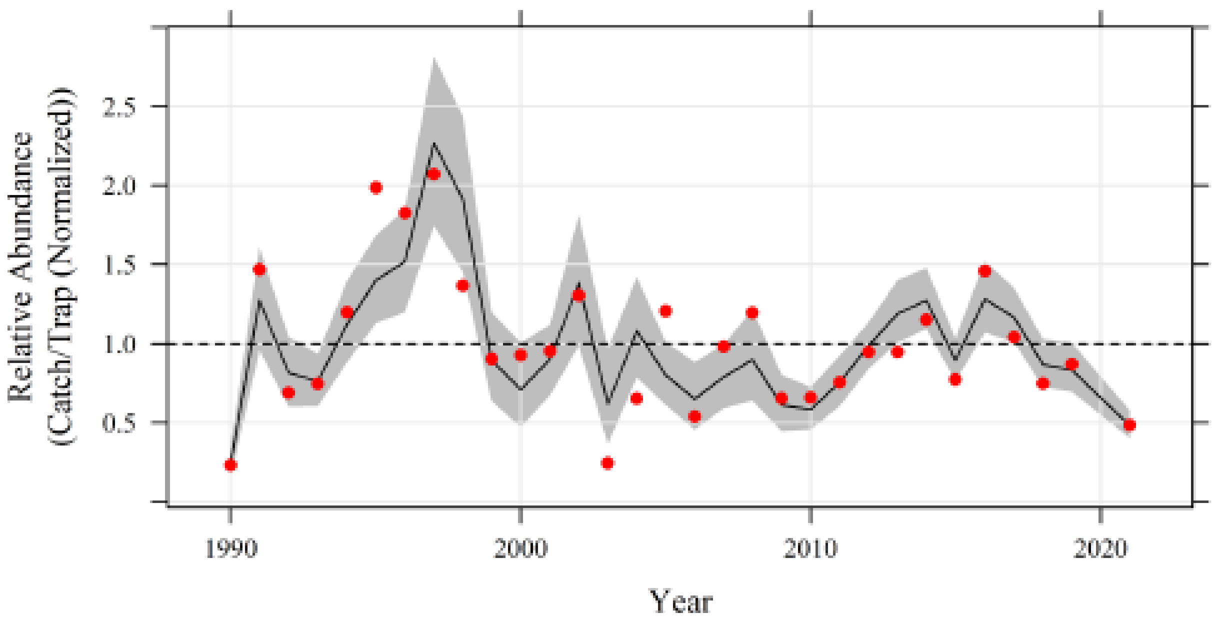


Figure 5.8.2. The nominal and standardized index for gray triggerfish computed from the SERFS video survey.

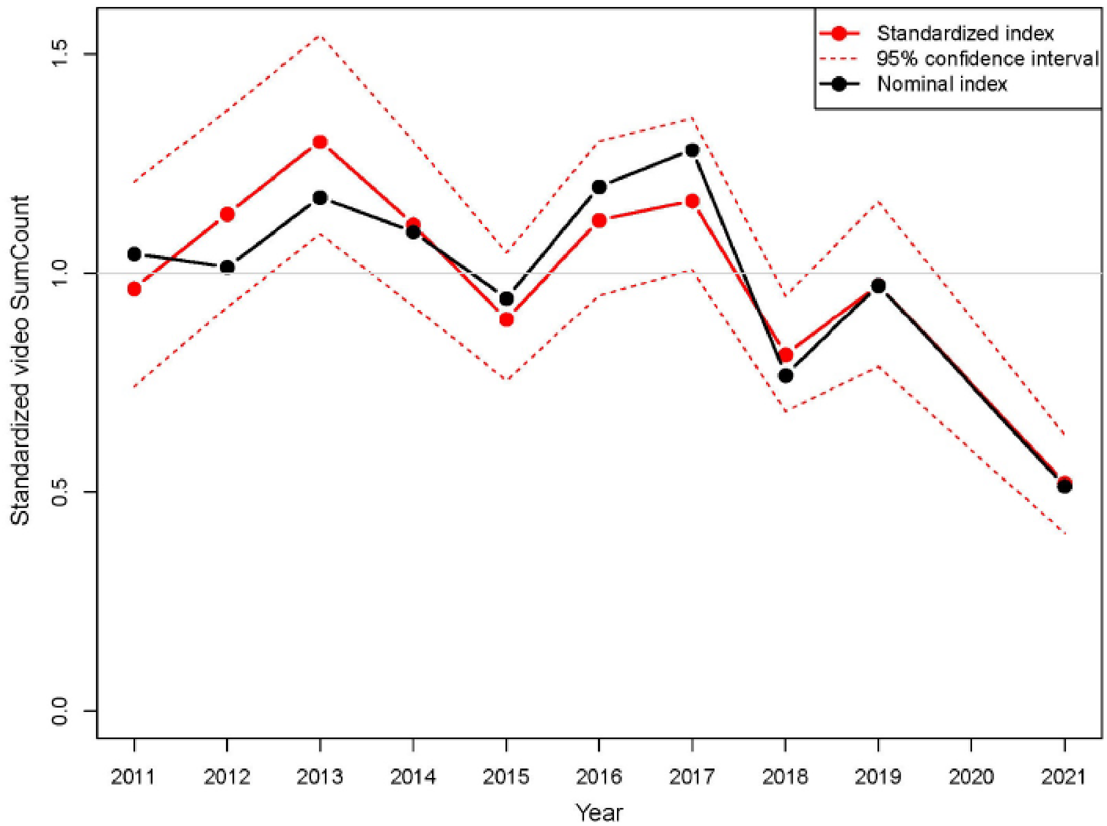


Figure 5.8.3. Map of headboat sampling area definitions. For analysis, areas were pooled as described in the text.

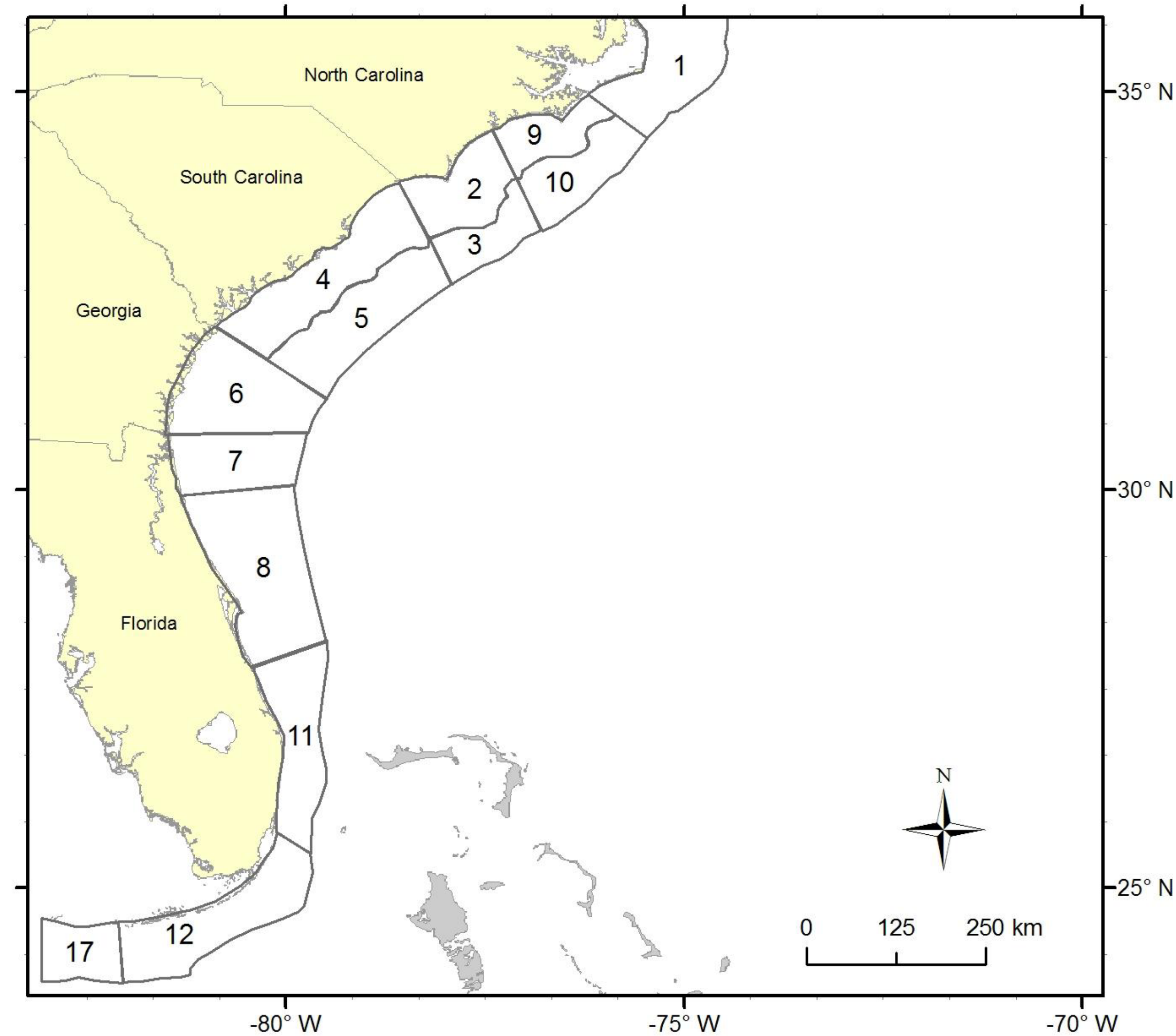


Figure 5.8.4. The nominal and standardized index for gray triggerfish computed from headboat data. Error bars represent approximate 95% confidence intervals.

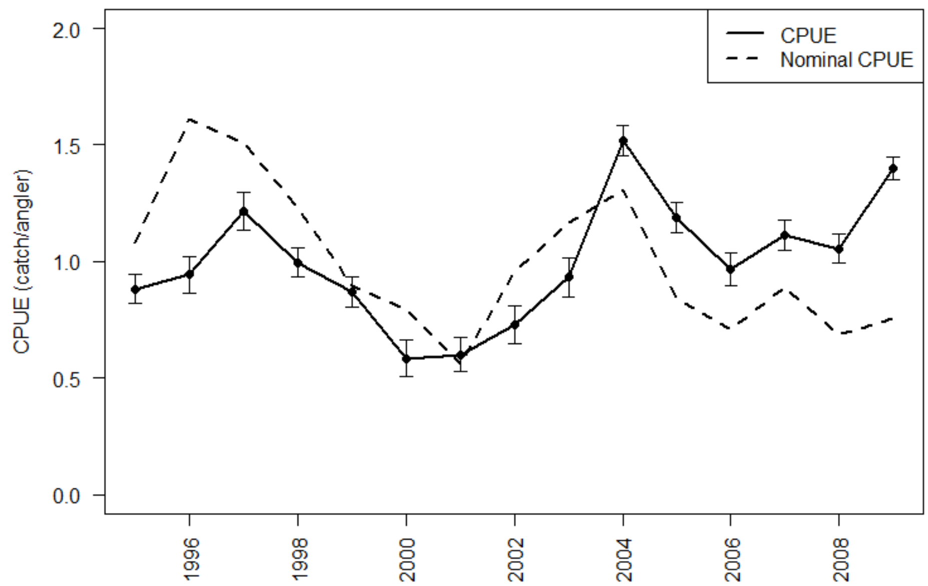


Figure 5.8.5. The nominal and standardized index for gray triggerfish computed from headboat at-sea observer data (harvest + discards). Error bars (dashed) represent approximate 95% confidence intervals. The east coast of Florida (EFL) had different regulations than the states north of Florida (GANC).

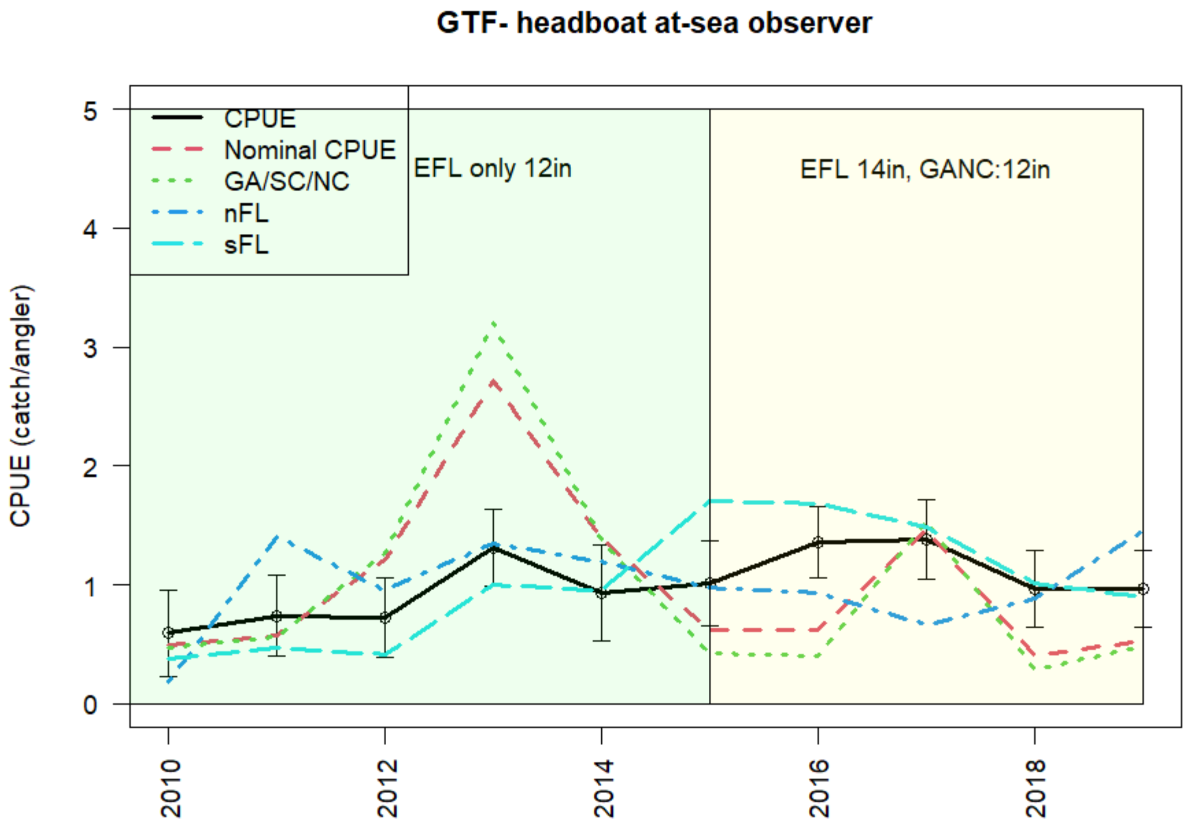


Figure 5.8.6. Latitude reported in the Coastal Fisheries Logbook Program (CFLP, commercial logbooks). Area is recorded in degrees where the first two digits signify degrees latitude, second two degrees longitude. Only latitude was used in this analysis.

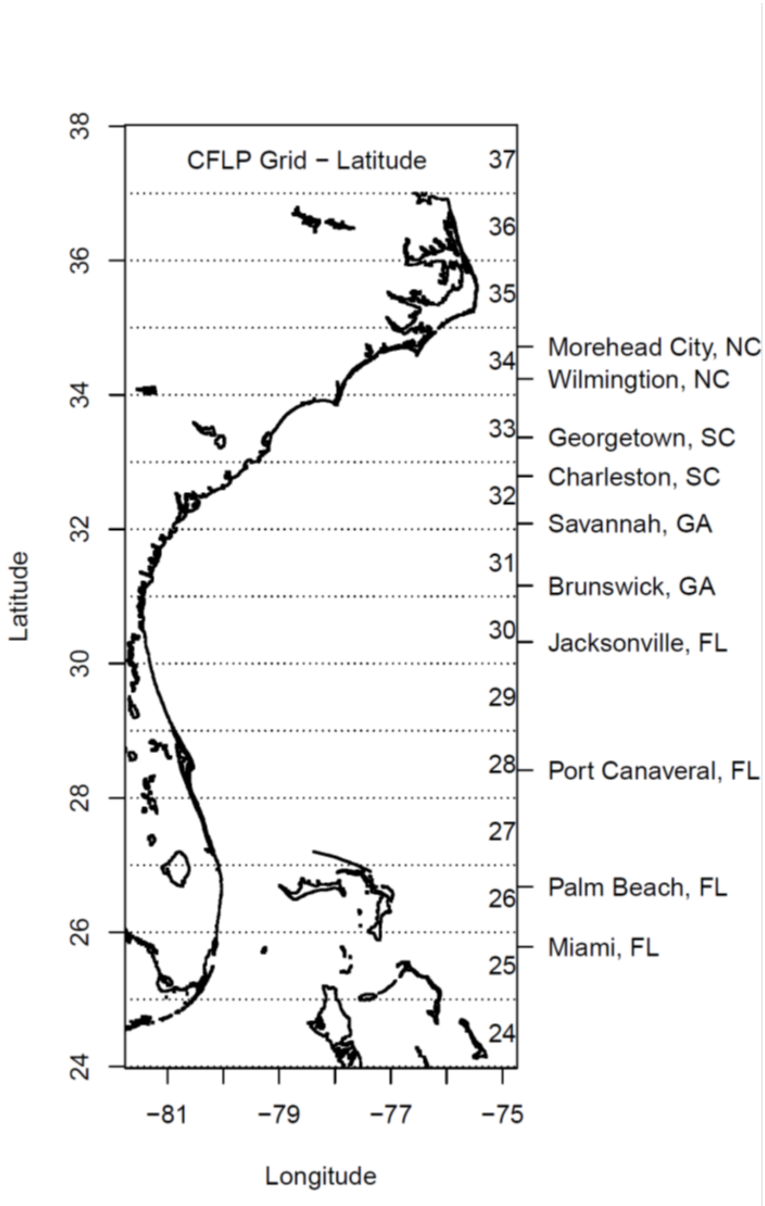


Figure 5.8.7. The nominal and standardized index for gray triggerfish computed from commercial logbook handline data, 1993–2009. Error bars represent approximate 95% confidence intervals. The nominal (Nominal CPUE), Standardized Stephens and MacCall approach approved for use in SEDAR 41 (SandM.CPUE), SEDAR 32 positive-only (SEDAR 32 Pos CPUE), and SEDAR 41 positive-only (SEDAR 41 Pos CPUE) runs are shown.

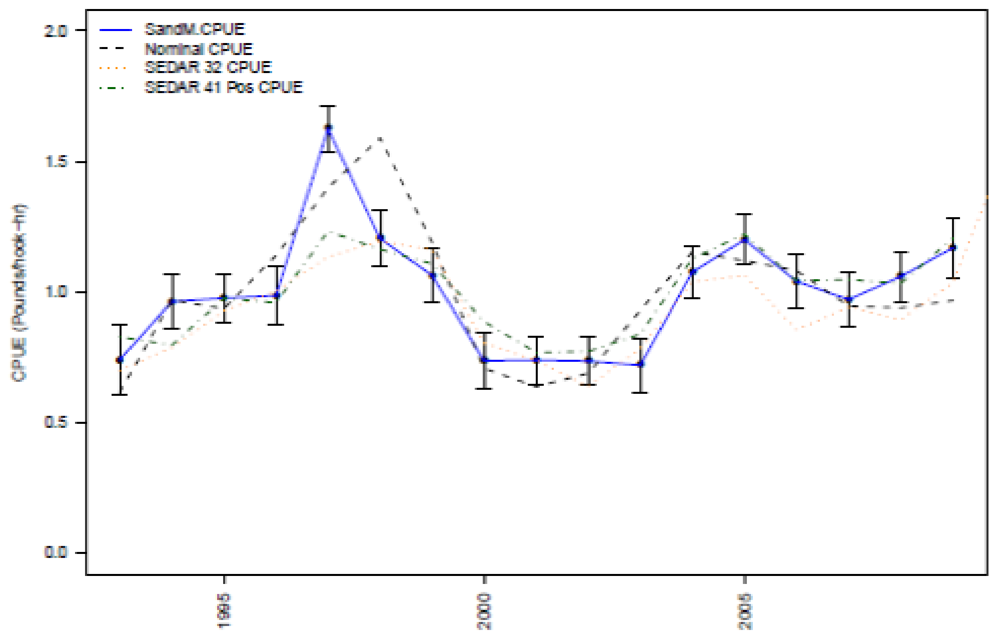
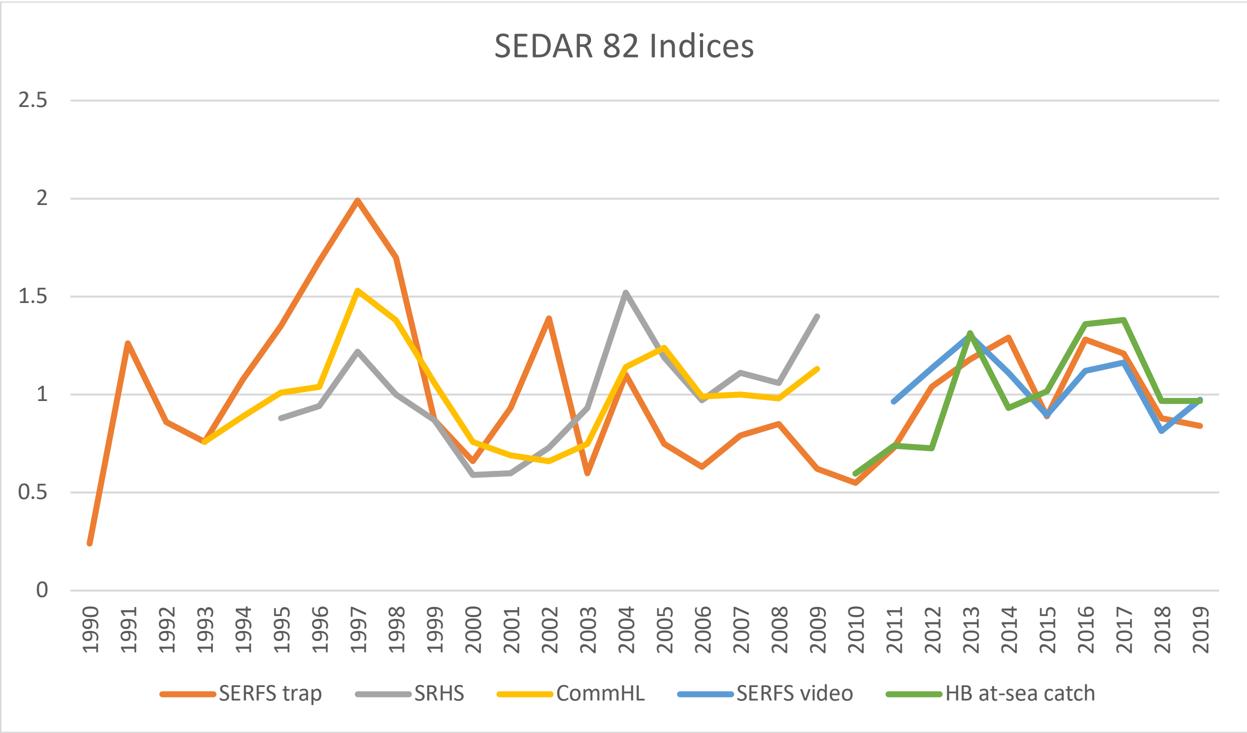


Figure 5.8.8. All indices (scaled to their respective means) recommended for potential use in the gray triggerfish stock assessment.



6. Ecosystem Report

Work Group report text for Terms of Reference 7, and 7a

Terms of Reference addressed in this document:

7) Describe any known evidence [emphasis added] regarding ecosystem, climate, species interactions, habitat considerations, and/or episodic events *(such as red tide and upwelling events)* that would reasonably be expected to affect Gray Trigger population dynamics.

7a) Identify available analysis that could improve the understanding of important ecosystem relationships or trends that can be accounted for in the assessment [emphasis added].

Work Group Membership:

Dr. Chip Collier, South Atlantic Fishery Management Council
Dr. Judd Curtis, South Atlantic Fishery Management Council
Dr. Wilson Laney, Department of Applied Ecology, NC State University (Lead)
Ms. Kerry Marhefka, South Atlantic Fishery Management Council
Ms. Beverly Sauls, Florida Fish and Wildlife Conservation Commission
Dr. Kevin Thompson, Florida Fish and Wildlife Conservation Commission
Dr. Julie Vecchio, South Carolina Department of Natural Resources

6.1 Introductory Considerations

The first topic we considered was to define Gray Triggerfish habitat. A good concise description is provided by Kelly-Stormer et al. (2017):

"The Gray Triggerfish *Balistes capriscus* is a moderately long-lived species that is associated with hard-bottom habitat along the eastern and western coasts of the Atlantic Ocean and supports fisheries from as far north as the Mediterranean (Kacem and Neifar 2014), as far south as Brazil (Bernardes and Dias 2000), and along both Atlantic coasts (SEDAR 2006; Aggrey-Fynn 2013). Individuals of this species spend some time in the water column as juveniles, when they are associated with *Sargassum* spp. (Ingram 2001; Wells and Rooker 2004; Casazza and Ross 2008); eventually, they settle into a more benthic existence and are most commonly associated with natural and artificial reefs, rocky outcroppings/hard bottom, and wrecks. Adult Gray Triggerfish feed diurnally on invertebrate prey, such as mollusks, crustaceans, and echinoderms (Frazer et al. 1991; Vose and Nelson 1994; Blitch 2000)."

An unique aspect of Gray Triggerfish life history is that their reproduction entails nest-building and guarding. Such behavior is uncommon among marine species and has both beneficial and detrimental aspects.

Essential Fish Habitat descriptions for Gray Triggerfish may be found on the South Atlantic Fishery Management Council web site. The EFH and EFH-HAPC designations are for most Snapper-Grouper species in the complex (wording from User Guide is below). See the link to the EFH User Guide Definition and clarifications for the Snapper Grouper FMP: https://safmc.net/documents/2022/05/efh-user-guide.pdf/

The spatial representations of EFH and EFH-HAPCS can be viewed online on the EFH Webservice run by FWRI: https://myfwc.maps.arcgis.com/apps/webappviewer/index.html?id=961f8908250a404ba99fac3aa37ac723

The Work Group, after further discussion, generated a list of potential tools for identifying parameters that have known ecosystem effects on Gray Triggerfish (although, per C. Collier, we really have NO IDEA what may be ecosystem drivers for Gray Triggerfish). These included the South Atlantic Ecopath/Ecosim model, or MICE subvariant (which does include Gray Triggerfish) and the Malin Pinsky et al. process-based, dynamic range model, using Baysian framework (also per C. Collier).

We considered additional environmental parameters that have been shown to influence populations of other species, some of which might affect Gray Triggerfish:

- Contaminants, including endocrine disrupters and microplastics (what are Gray Triggerfish body burdens and have impacts been documented?)
- Are there chlorophyll a linkages and any links to recruitment?
- Relevant Research Papers: RD39, RD43, RD47
- "…pelagic *Sargassum* serves as nursery habitat and may influence the recruitment success of several species [Wells and Rooker 2004]."

With respect to climate effects, we considered the following possibilities:

- Ocean acidification, potential impacts to Gray Triggerfish or their prey base
- Temperature changes, what is the Gray Triggerfish optimal temperature range, most sensitive life stage (egg?, larvae?, juveniles?), range contraction or expansion?
- Climate cycles, any evidence for ENSO, AMO, linkages to Gray Triggerfish recruitment?
- South Atlantic Climate Vulnerability Assessment (CVA) for Gray Triggerfish
- Any ocean current changes (Gulf Stream) and Gray Triggerfish impact (could there be impacts to *Sargassum* juvenile habitat, or recruitment)?

We considered the possibility there may be species interactions which could have an impact on Gray Triggerfish:

- Consider diet data: what do they prey upon, what preys upon them?

- Are they affected by South Atlantic fish community changes: Red Snapper resurgence, Red Lionfish invasion, grouper declines, etc.?
- One relevant quote: "These competitive interactions indicate that management efforts to rebuild and increase gray triggerfish populations may have unintentional negative effects on red snapper populations, particularly for smaller fish [Gulf of Mexico; Simmons and Szedlmayer 2018]."
- Predator/prey cycles affecting Gray Triggerfish (also see below under episodic events)?

We considered whether there may be any known evidence for habitat parameters influencing Gray Triggerfish population dynamics. These include:

- Habitat Suitability Index Model development which identified key parameters?
- What are the criteria for nest site selection?
- How tightly tied to Sargassum distribution is Gray Triggerfish distribution and/or recruitment?
- Are there Gray Triggerfish benefits from protected areas (per K. Marhefka)? Monitoring data from Florida Keys, Grays Reef, Monitor NMSs? Future monitoring of Council-designated protected areas, for both compliance and biological changes (Per C. Collier)?
- Relationship with stony coral disease, fish community effects?
- Artificial Reefs construction, concentration or enhancement for Gray Triggerfish [see RD10, Simmons and Szedlmayer 2011]?
- South Atlantic Regional Marine Fish Habitat Assessment (NOAA Fisheries).

Finally, the Work Group considered **episodic events** which could affect Gray Triggerfish, and for which data may be available for our examination that might be useful to the understanding of Gray Triggerfish population dynamics:

- What is the incidence of **red tide** within the South Atlantic; how much impact has there been on Gray Triggerfish? Are State fish kill databases useful as a source of data?
- What is the impact of **upwelling events** on Gray Triggerfish? We know these happen on FL east coast (per B. Hartig) and in SC (per M. Bell).
- Is there any impact on Gray Triggerfish from **hurricanes**?
- Do Gray Triggerfish populations fluctuate in synchrony with **prey base population fluctuations** (i.e., a'la Snowy Owls and lemmings; Lynx and Snowshoe Hare)?
- Do Gray Triggerfish populations fluctuate in synchrony with ***Sargassum*** maxima and minima?

6.2 Summary of Findings Relative to TOR 7 and 7a

We failed to document any specific anthropogenic or environmental factors (including biotic components of the ecosystem) which have been definitively shown to affect Gray Triggerfish population dynamics, and which could be modeled in SEDAR 82. Our review which follows summarizes what is presently known about how the factors we identified for further exploration may affect Gray Triggerfish populations. Given further study (see our Research Recommendations), additional information may be generated which enables future assessments to consider inclusion of environmental or biotic metrics which have been shown to influence Gray Triggerfish population dynamics.

Investigation of Identified Questions/Topics

Our approach to investigating the individual topics we listed which could possibly have an impact on Gray Triggerfish population dynamics, or be used to investigate such impacts, was to seek literature which addressed them. Literature was sought by systematically using the Google Advanced Scholar search engine, within either the Microsoft Edge, or Firefox, browsers, to locate relevant literature on a given topic. We also employed previously-developed reviews of pertinent literature, such as Michel (2013). Relevant literature we discovered under each topic heading (see below) was then summarized in the text and sources included in the Literature Cited.

Ecosystem Effects: Ecopath/Ecosim Modeling

The South Atlantic Fishery Management Council (SAFMC) developed both an Ecopath/Ecosim model, and a MICE submodel, both of which include Gray Triggerfish. Those models have been reviewed and approved by the SAFMC Science and Statistical Committee (SSC) and are available for use in exploring factors which may affect Gray Triggerfish population dynamics. The South Atlantic Region (SAR) EwE Model was adapted and refined from South Atlantic Bight models first developed in 2001 (Okey and Pugliese 2001). It has since been through 20 years of improvements and updates, with the current iteration reviewed and endorsed by the SSC in 2020 (Gentry et al. 2021).

To our knowledge no queries have been run to address any specific Gray Triggerfish questions. However, the model run used to address the potential impact of Red Snapper high recruitment does indicate younger age classes of that species (Ages 1-3) do prey on both Gray, and Ocean triggerfishes (Gentry et al. 2021); see the discussion included below in Species Interactions.

Ecosystem Effects: Pinsky model

Malin Pinsky and colleagues are doing work which may ultimately have some utility for exploration of Gray Triggerfish population dynamics but have not yet modeled Gray Triggerfish.

Ecosystem Effects: Contaminants, Endocrine Disruptors, Microplastics

Each of these three pollutants of anthropogenic origin have been documented to have adverse impacts upon fish populations. Literature sources were sought which would document any impacts to Gray Triggerfish populations on the U.S. Atlantic Coast.

CONTAMINANTS

Gray Triggerfish are documented to bioaccumulate various contaminants (Continental Shelf Associates 1999, Neff et al. 2001, Xue et al. 2017). These include metals, polycyclic aromatic hydrocarbons (PAHs), radionuclides and parabens and their metabolites.

Continental Shelf Associates (1999) sampled and analyzed Gray Triggerfish residing in and near oil production platforms in the Gulf of Mexico as well as those from nearby control sites. They indicated that "The objective of this study was to determine the concentrations of selected radionuclides, metals, and hydrocarbons in produced water and produced sand discharges from Gulf of Mexico offshore platforms and to compare the concentrations with those in samples of ambient seawater, sediment, interstitial water, and marine animals collected in the vicinity of the discharges and from areas distant from the discharges." The authors report concentrations of As, Ba, Cu, Fe, Hg, Ni, Pb, V, and Zn in Gray Triggerfish (see Figure 1, which reproduces Figure 7.7 of Continental Shelf Associates 1999), as well as concentrations of PAH and radionuclides.

Neff et al. (2001) included Gray Triggerfish as a species sampled and analyzed during their study, which was also conducted at offshore oil platforms in the Gulf of Mexico. Their objective was "…to determine if marine animals bioaccumulate polycyclic aromatic hydrocarbons (PAHs) from produced water
discharges to offshore waters of the Gulf of Mexico." Gray Triggerfish were sampled during spring and fall 0f 1995. Although they did detect PAH in Gray Triggerfish tissues (see their Table 8, Page 13) they determined that "Concentrations of individual PAHs in fish muscle were low. Higher concentrations of individual PAHs were detected with similar frequency in fish from the reference and discharging platforms. Thus, the fish were not bioaccumulating PAHs from the produced water discharges [emanating from the oil platforms].

The Xue et al. (2017) study measured six parabens and four of their common metabolites in abiotic (water, sediment) and biotic (fish including sharks, invertebrates, plants) samples collected from a subtropical marine food web in coastal east Florida (Xue et al. 2017). They sampled Gray Triggerfish liver and kidney tissue from fish collected in the Atlantic Ocean off Ponce Inlet, with TL of 293-294 mm and weight of 405-509 gm. Their Table S2 reports the concentrations of detected parabens and metabolites (in ng/g wet weight) found in Gray Triggerfish liver. They also reported stable-nitrogen and stable-carbon isotope values and corresponding derived relative trophic level (TL) in the Florida Atlantic marine food web (see their Table S3). Gray Triggerfish sampled had a $\delta13C$ value of -17.26 and $\delta15N$ value of 10.79, with a corresponding derived relative trophic level of 2.45. Their findings were: "methyl paraben (MeP) was found in all abiotic (100%) and a majority of biotic (87%) samples. 4-Hydroxy benzoic acid (4-HB) was the most abundant metabolite, found in 97% of biotic and all abiotic samples analyzed. The food chain accumulation of MeP and 4-HB was investigated for this food web. The trophic magnification factor (TMF) of MeP was estimated to be 1.83, which suggests considerable bioaccumulation and biomagnification of this compound in the marine food web. In contrast, a low TMF value was found for 4-HB (0.30), indicating that this compound is metabolized and excreted along the food web. This is the first study to document the widespread occurrence of parabens and their metabolites in fish, invertebrates, seagrasses, marine macroalgae, mangroves, seawater, and ocean sediments and to elucidate biomagnification potential of MeP in a marine food web." Again, while we were unable to access the full paper, there is no information in the paper's abstract or supplemental information which indicates whether the sampled levels are problematic.

Lozano-Bilbao et al. (2021) sampled Gray Triggerfish and Ocean Triggerfish in the Canary Islands (east-central Atlantic Ocean) to determine heavy metals (Al, Cd, Pb), macroelements (Ca, K, Mg, Na) and microelements and trace elements (B, Ba, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Sr, V, Zn) in muscle samples. While both triggerfish species contained various concentrations of the metals, macroelements, microelements and trace elements sampled, none were deemed to exceed action levels which precluded human consumption. Interestingly, in contrast to the perception of some authors in the south Atlantic that Gray Triggerfish tend to be relatively more sedentary, they were considered "highly migratory" by the authors, based on studies conducted by others in the Gulf of Mexico, and south Atlantic.

A recent review by Barbo et al. (2023) indicates that contamination by Per- and polyfluoroalkyl substances (PFAS/PFOS) is significant in freshwater fish within the United States and poses a significant human health risk. They indicate their results are specific to freshwater fish species and such a risk may not be present in marine species, but that further research is needed.

We have thus far not located any studies which provide concentration levels of contaminants which might have an adverse impact on Gray Triggerfish survival or functionality. We solicit any further information which may address that topic.

ENDOCRINE DISRUPTING COMPOUNDS/CHEMICALS (EDCs)

The Ad-Hoc Ecosystem Work Group wondered if Gray Triggerfish are being impacted by EDCs. The reason for that concern is that anthropogenically-produced endocrine disrupting compounds released in the environment may cause significant impacts to fish (and other aquatic fauna as well) if they are present at concentrations which produce an impact. We failed to locate any literature that documented impacts of EDCs specifically on Gray Triggerfish. However, we do provide herein a brief review of literature regarding the impacts of such compounds on riverine and marine fishes, and why further exploration with respect to whether impacts are occurring to east coast Gray Triggerfish populations is warranted.

Relatively early reviews noted the documented impacts of EDCs to freshwater species, and encouraged research to determine whether impacts were occurring to estuarine and marine species. Oberdorster and Cheek (2001) noted that all definitions of endocrine disruption "…include the important, though frequently implicit, stipulation that the animal is not distressed or in obvious discomfort. Instead, a superficially healthy animal is experiencing alterations in hormone synthesis, transport, receptor interaction, metabolism, excretion, or feedback regulation." They noted further that "… hormone disruption may occur during sex differentiation, and its effects may not be manifested until after sexual maturation." They provide a "…review [that] will cover basic endocrinology of marine and estuarine invertebrates and vertebrates, methods for detecting endocrine disruption, and examples of endocrine disruption in various species. Hutchinson et al. (2000) indicated that "Exposure assessment for endocrine disruptors should direct specific tests for wildlife species, placing hazard data into a risk assessment context." They noted for fish species, "Higher tier endocrine-disruptor testing should include fish development and fish reproduction tests, whereas a full life-cycle test could be subsequently used to refine aquatic risk assessments when necessary."

Such testing was done by Zillioux et al. (2001) employing the Sheepshead Minnow (*Cyprinodon variegatus*), an estuarine species. They found reproductive success of exposed individuals was reduced, hatching success was reduced, and that "Histological examination indicated generalized edema, damage to gill epithelia, hepatic toxicity, fibrosis of the testis, and evidence of sex reversal, including testes–ova and spermatagonia-like cells in ovaries." Larkin et al.'s (2003) "…review discusses various methodologies that can be used to understand, at the gene level, the consequences to fish upon exposure to endocrine disrupting compounds (EDCs)." Goksøyr (2006) published a further review which noted "… the number of nuclear hormone receptors being potential targets for EDCs has increased dramatically the last decade, opening up new avenues for possible endocrine disruptor effects." He stated "In studies with Atlantic salmon [*Salmo salar*], data showed that 4-nonylphenol, a model xenoestrogen previously used in large volumes, for example, in paints and detergents, acts as an estrogen mimic, as a steroid metabolism disruptor, and by modulating estrogen receptor (ER) levels, indicating that one single compound exerts all of these three mechanisms, depending on the dose given to the organism." Hotchkiss et al. (2008) in their review "…(1) address what have we learned about the effects of EDCs on fish, wildlife, and human health, (2) discuss representative animal studies on (anti)androgens, estrogens and 2,3,7,8-tetrachlorodibenzo-p-dioxin–like chemicals, and (3) evaluate regulatory proposals being considered for screening and testing these chemicals."

Additional reviews noted the challenges of dealing with EDCs (Auriel et al. 2006), discussed the effect of EDCs on sex and gonadal development in fish (Scholz and Kluver 2009), addressed endocrine disrupters and water quality (Burkhardt-Holm 2010), discussed the effects of EDCs on fish immune systems (Milla et al. 2011), conducted a review of pharmaceuticals and EDCs (Tijani et al. 2013), and examined whether EDC impacts were being distinguished from natural phenomena (Bahamonde et al. 2013).

Studies in the laboratory and field began to document additional behavioral impacts and generate data on impacts to fish communities. Pojana et al. (2007) looked at EDC levels in sediments, water and biota in Venice Lagoon, Italy. Baker et al. (2009) examined EDCs in southern California coastal fish. Brar et al. (2010) looked at EDC in wild fish in San Francisco Bay and "…provided an initial characterization of thyroid endocrine-related effects and their relationship to accumulated contaminants in two indigenous fish species." Niemuth et al. (2015) documented the impact on adult male fish of a widely-used drug, Metformin. Heintz et al. (2015) determined that EDC exposure altered risk-taking behavior in guppies (*Poecilia reticulata*). Ojemaye and Petrick (2019) examined occurrence, levels and associated risks of EDCs in coastal fish in South Africa.

Given the widespread occurrence of EDCs, and their already well-documented impact on fish and other aquatic organisms in some south Atlantic rivers (Penland 2017) which discharge into the Atlantic Ocean, it would appear prudent to encourage studies to determine if Gray Triggerfish (as well as other reef-dwelling species in the south Atlantic) are being impacted, especially given their complex reproductive behavior (i.e., nest construction and harem-guarding males) and life history which involves residency in multiple habitats.

MICROPLASTICS

Microplastics have been defined (Stevens 2015) as "A small piece of plastic, 5 millimeters (0.2 inch) or smaller in size. Microplastics may have been produced at that small size, or their size may be the result of the breakdown of water bottles, plastic bags or other things that started out larger." As noted by Kappos (2022) "Microplastics threaten the health of numerous marine organisms at all trophic levels." Threats from the microplastics derive from their direct consumption by fish and their invertebrate prey, including prey as small as copepods (Cole et al. 2015, Kappos 2022). Indirect microplastic consumption may occur incidental to prey consumption, and their impact is further compounded by transference throughout the food web through predator-prey interactions (Kappos 2022) as well as the potential for ingestion of pathogens which colonize the plastic particles (Bowley et al. 2020). Their presence in our rivers, estuaries and ocean is generally regarded as pervasive and is anticipated to only worsen (Kane et al. 2020, Borelle et al. 2020). They are present in all habitats used by Gray Triggerfish, including the ocean floor where nests are constructed and eggs and adults reside (Kane et al. 2020, Pabortsava and Lampitt 2020) as well as within the oceanic water column and in pelagic *Sargassum* where larvae, postlarvae and juvenile early life stages are present (Laffolley et al. 2011, Lestrade 2020).

Presence of microplastics within multiple fish species, including Gray Triggerfish, has been well-documented. Kappos (2022) sampled five species of forage fishes from four locations (two urban, two non-urban) in southeast Florida and the Florida Keys. The species were Striped Mullet *Mugil cephalus*, Scaled Sardine *Harengula jaguana*, Redfin Needlefish *Strongylura notata*, Pinfish *Lagodon rhomboides*, and Irish Mojarra *Diapterus auratus*. Every sampled fish except one (n= 248) had microplastics within their systems, with a total of 2,126 pieces found (Kappos 2022). Frequency of microplastics within the fishes was highest in one of the urban areas, and within two of the fish species, Redfin Needlefish and Pinfish, increases in microplastic frequency were observed as the fish matured.

Lestrade (2020) sampling in the Gulf of Mexico, "…examined 1) microplastic concentrations and ingestion by juvenile fishes associated with *Sargassum*; 2) the microbial communities associated with the *Sargassum* and microplastics; and 3) the influence of microplastic ingestion on the microbiomes of juvenile Gray Triggerfish." She found "Microplastic abundance was significantly higher in *Sargassum* habitats relative to open water habitats. Microplastics were identified in the stomach contents of many species of juvenile fishes with total microplastic frequency of occurrence ranging between 14.7-24.7%. Microplastics had a unique microbiome when compared to the surrounding environment. The microplastic microbiome was found to influence Gray Triggerfish gut microbiomes. The results from this project demonstrate that microplastics are being ingested by juvenile fishes in *Sargassum* and the unique microbiome of microplastics are influencing fish gut microbiomes."

Gove et al. (2020) sampled larval fishes in waters of Hawaii and also documented microplastics in triggerfish (family Balistidae; species not specified). They "…demonstrate that surface slicks, meandering lines of convergence on the ocean surface, are important larval fish nurseries that disproportionately accumulate nonnutritious, toxin-laden preysize plastics. Plastic pieces were found in numerous larval fish taxa at a time when nutrition is critical for survival. Surface slicks are a ubiquitous coastal ocean feature, suggesting that plastic accumulation in these larval fish nurseries could have far reaching ecological and socioeconomic impacts."

Finally, one adult Gray Triggerfish reported by Stevens (2015) contained 47 pieces of plastic in the stomach. It had been caught near the surface in the North Atlantic subtropical gyre.

Given the results from sampling Gray Triggerfish and other species in various locations, we believe that similar studies carried out in the south Atlantic would yield similar results from sampling both juvenile and adults.

Ecosystem Effects: Linkages to Chlorophyll a Concentrations

We did not locate any literature which suggested linkages between Gray Triggerfish and chlorophyll a concentration. Clearly, its pelagic *Sargassum* juvenile habitat possesses a strong chlorophyll a signature which enables remote sensing (Gower and King 2019, Wang et al. 2019, Johns et al. 2020), therefore if there was a known relationship between *Sargassum* areal extent and Gray Triggerfish juvenile density, quantification might be possible. Gray Triggerfish larval and postlarval stages presumably feed on small organisms that could be linked to chlorophyll a concentration, suggesting there is a relationship between chlorophyll a and larval and postlarval life stages. Further research on this topic is clearly warranted.

Climate Effects: Ocean Acidification

Goldman et al. (2016) directly addressed the potential for impacts on Gray Triggerfish resulting from ocean acidification. They state: "Ocean acidification is of particular concern for gray triggerfish because a large part of its diet is composed of pelagic pteropods. Ocean acidification causes shell dissolution in pteropods and some benthic invertebrates that are CaCO3-secreting organisms (Doney et al., 2009). Calcified structures provide protection from predators; therefore, pteropods would be adversely affected by the rising atmospheric CO2 levels caused by human fossil fuel combustion and deforestation (Doney et al., 2009), and adverse effects on pteropods would, in turn, have serious effects on populations of Gray Triggerfish. This study is far more comprehensive than previous studies have been and covers a large geographic area, providing a baseline study that can be used to monitor potential dietary shifts that result from climate change."

Considerable additional information is available regarding ocean acidification and the effects it may produce within the planet's oceans and upon its fauna. We provide herein a brief summary of some relevant literature on general aspects of ocean acidification, as well as some specific to individual species, which may be useful.

Taylor et al. (2015) examined the impact of CO2-induced acidification on a shrimp species (*Lysmata*
californica) and determined short-term exposure to CO2-induced pH reduction can significantly affect exoskeleton mineralization and shrimp biophotonics, with potential impacts on crypsis, physical defense, and predator avoidance. Their methodology may prove useful for conducting similar experiments on Gray Triggerfish prey species.

Logan (2016) considered whether ocean acidification increases the susceptibility of Blue Mussels (*Mytilus edulis*) to pollution. This was of interest given Gray Triggerfish likely prey on that species at least seasonally. He documented "…behavioural and physiological responses to OA [ocean acidification that] are likely to increase susceptibility to a whole range of pollutants, not just TBT,
by increasing potential uptake."

The IPCC Summary for Policymakers, The Ocean and Cryosphere in a Changing Climate (IPCC 2019) comprehensively addresses the impact of ocean acidification on ecosystem services provided by the oceans, many of which may impact Gray Triggerfish.

Saba et al. (2019) "…present recommendations for research priorities that target better understanding of the ecological impacts of acidification in the U. S. Mid-Atlantic region. Suggested priorities are: 1) Determining the impact of multiple stressors on our resource species as well as the magnitude of acidification; 2) Filling information gaps on major taxa and regionally important species in different life stages to improve understanding of their response to variable temporal scales and sources of acidification; 3) Improving experimental approaches to incorporate realistic environmental variability and gradients, include interactions with other environmental stressors, increase transferability to other systems or organisms, and evaluate community and ecosystem response; 4) Determining the capacity of important species to acclimate or adapt to changing ocean conditions; 5) Considering multi-disciplinary, ecosystem-level research that examines acidification impacts on biodiversity and biotic interactions; and 6) Connecting potential acidification-induced ecological impacts to ecosystem services and the economy." They provide a list of species for which no acidification studies have been conducted. Their recommendations we believe are equally applicable to the south Atlantic.

Tomasetti and Gobler (2020) expressed concern regarding the potential for ocean acidification to put fisheries at risk, because water quality criteria and associated regulations have not kept pace with science.

Finally, Leung et al. (2022) posed the question as to whether ocean acidification is really a threat to marine calcifiers. They conducted a meta-analysis of 985 studies, and reported that "…many calcifiers (e.g., echinoderms, crustaceans, and cephalopods) are found to be tolerant to near-future ocean acidification (pH ≈ 7.8 by the year 2100), but coccolithophores, calcifying algae, and corals appear to be sensitive." Their findings may provide some insight into the future dynamics of Gray Triggerfish prey species.

Based on the Craig et al (2021) analysis, ocean acidification in the south Atlantic has increased over a decadal time frame (see Craig et al. 2021, Figure 4.13),

<u>Climate Effects: Temperature Changes</u>

Whitfield et al. (2007) nicely summarize the changes in the south Atlantic through 2006, as a result of bottom temperature increase:

"Off the North Carolina coast there has already been a documented shift in faunal composition, from temperate to tropical species associated with a 1˚C rise in winter bottom water temperatures (Parker and Dixon 1998). In addition to lionfish, 14 other Pacific marine fish species are currently surviving off the coast of Florida (Semmens et al. 2004). One being a predatory grouper, *Cromileptes altivelis* with high potential to become established. The effect of climate change, overfishing and invasive species have been implicated in ecosystem decline and collapse in several marine ecosystems (Harris and Tyrrell 2001; Stachowicz et al. 2002; Frank et al. 2005). Along the southeast U.S. shelf, the high number of stressors acting in synergism may eventually have unexpected and irreversible consequences for the native communities and economically valuable fisheries in this region. This scenario implies a direct economic cost within an open marine environment that is related to invasive species—a cost which is just beginning to be recognized."

With respect to Gray Triggerfish encounters north of North Carolina, they are commonly occurring there as noted in the Spatiotemporal section of this report. However, we have now looked at the best data sets available to evaluate this and there is just no evidence of any directional change (increase or decrease) in gray triggerfish in the northwestern Atlantic (Klibansky, personal communication to RWL), . Briggs and Waldman (2002) indicated that the species is common in New York waters during summer, in "recent years" (Briggs and Waldman 2002, Page 73). With respect to temperatures and their influence on the fish faunal assemblages in NY waters, they note: "The inshore waters between the New York Bight and Cape Hatteras undergo extreme seasonal temperature changes, which favors a migratory rather than an endemic fauna (Parr 1933, Grosslein and Azarovitz 1982). In the New York Bight apex, there is a range of about 25 °C between summer and winter surface temperatures in nearshore areas (from 1 °C to 26 °C), and inshore bottom temperatures range from a maximum of about 21 °C in summer to less than 1 °C in winter. As such, there is considerable latitudinal movement of fishes across the Virginian province, with New York waters becoming habitable by representatives of the Acadian province in winter, and the Carolinian province during summer. In particular, the south shore bays of Long Island often host early life stages of subtropical fishes carried northward by the Gulf Stream. Fish diversity reaches a maximum in late summer and early autumn, and a minimum in late winter and early spring." Given that temperatures continue to rise as a consequence of climate change, additional changes in faunal composition are anticipated.

Climate Effects: Climate Cycles

Most of the climate cycles which are affecting biological communities in the south Atlantic are addressed in the Ecosystem Status Report for the U.S. South Atlantic Region (Craig et al.2021). The cycles (aka climate drivers) addressed include the Atlantic Multidecadal Oscillation (AMO), North Atlantic Oscillation (NAO), El Nino Southern Oscillation (ENSO), North Atlantic Sea Surface Temperature Tripole and the Atlantic Warm Pool (AWP). Each of these is defined in the text and graphically depicted. In order to develop an ecosystem-wide perspective, the suite of indicators developed for the U.S. South Atlantic region were synthesized by the authors using multivariate analyses (Craig et al. 2022, Page 97). Traffic light plots are employed for visualizing qualitative changes in different components of the ecosystem over time (see Figures 11.1a-f, Pages 101-110). The south Atlantic region is influenced by multiple long-term modes of climate variability that interact to determine the physical conditions in the ecosystem. Many of these drivers have contrasting effects on wind and moisture transport in the atmosphere, rainfall, sea surface temperatures, and storm activity, therefore it is difficult to predict the consequences of annual to decadal shifts in these modes of climate variability on the ecosystem (Craig et al. 2021).

While the report does not analyze Gray Triggerfish as an individual species, it does address the reef fish community in general. The South Atlantic ecosystem has experienced a number of changes in the fish community, in that the offshore hard-bottom reef fishes, both targeted and not targeted by fisheries, have shown declines in abundance since the 1980s and 1990s (Craig et al. 2021, Figures 7.1 and 8.1). The underlying causes of many of these changes is unknown, though potential explanations include continued overfishing or changes in bycatch mortality, lags in recovery due to life history characteristics (e.g., long-lived, old age at maturity), or environmental factors that affect productivity (Craig et al. 2021).

The report ends with Research Recommendations (Craig et al. 2021, Pages 112-114), many of which will benefit our understanding of Gray Triggerfish dynamics, if they are implemented.

Climate Effects: South Atlantic Climate Vulnerability Assessments

Vulnerability of south Atlantic fish species is currently being evaluated by the SEFSC. The methodology employed for the assessment is addressed in detail in Morrison et al. (2015). Gray Triggerfish in the south Atlantic were reported as "low" in terms of total sensitivity and "moderate" in terms of climate vulnerability, whereas in the Florida Keys and Gulf of Mexico they were deemed "low" and "low" respectively (see Seara et al. 2022, Appendix I).

Those who fish for a living are also subject to climate effects, not just to changes in fish community structure, but also weather patterns (i.e, more and stronger tropical cyclones) which affect their ability to fish. The vulnerability of south Atlantic fishing communities to climate changes is the topic of a recent review by Seara et al. (2022). Communities in the south Atlantic which they profiled range from east Florida to North Carolina (Miami and Fernandina Beach, FL; Savannah, GA; Little River, SC; and Wanchese, NC; Seara et al. 2022). Gray Triggerfish is a component of landings in each of the profiled communities.

Climate Effects: Ocean Current Changes

Based on the analysis in Craig et al. (2021) the Gulf Stream has been in a more onshore position in recent years which has implications for coastal circulation, upwelling and nutrient delivery to the shelf, and coastal upwelling has declined since 2014 (Fig. 4.6), suggesting potential effects on delivery of nutrients to the photic zone.

Species Interactions: Gray Triggerfish Dietary Preferences and Predators

As with most species, fluctuations in prey or predator abundances may influence cohort strength and population abundance of egg, larval, pelagic juvenile, and demersal subadult and adult Gray Triggerfish. Impacts could occur at any life stage; however, given the fact that Gray Triggerfish occupy different habitats during the pelagic larval and juvenile stages, and the benthic egg, subadult and adult stages, the prey and predator species involved in such interactions will belong to different communities.

Multiple papers describe the diet and feeding of Gray Triggerfish and document prey species (Durie and Turingen 2001; Kauppert 2002; Goldman et al. 2016). Goldman et al. (2016) found that in the South Atlantic Bight (SAB) "Gray triggerfish also had a diverse diet, composed of 131 different prey taxa. Barnacles, gastropods, and decapods were their main prey. Of the 4 explanatory variables, latitude was highly significant, and season, depth, and length were statistically significant." See Goldman et al. (2016), Figures 6 and 8 for details of Gray Triggerfish diet by composition (percent frequency) and weight.

Dolphinfish (*Coryphaena hippurus*) are a frequent predator on Gray Triggerfish when the latter species is occupying its preferred *Sargassum* pelagic habitat during the early juvenile stages (Oxenford 1999, Rudershausen et al. 2010, Moore 2014, Poland 2014, Brewton et al. 2016) at least in the south Atlantic. In Moore's study (Moore 2014) in addition to Dolphinfish, Blackfin Tuna and Wahoo were also documented as predators on the family Balistidae. Interestingly, a study of dolphinfish diets in the southern New England portion of their range does not document Gray Triggerfish or other members of the family Balistidae as prey items (Teffer et al. 2015) which may reflect the relative absence of those species further north. Poland (2014) found that Dolphinfish and Wahoo both preyed upon Gray Triggerfish off North Carolina. In contrast to Moore's (2014) findings of predation on Balistidae by Dolphinfish, Blackfin Tuna and Wahoo, an additional study of the Sargasso Sea food web and predators of interest to the International Commission for Conservation of Atlantic Tunas (ICCAT) also did not document

Gray Triggerfish, or fishes within the family Balistidae, as prey for multiple species investigated (species included: Yellowfin Tuna, Albacore Tuna, Bigeye Tuna, Bluefin Tuna and Skipjack Tuna, Swordfish, Blue Marlin, White Marlin, Sailfish, Wahoo, Blackfin Tuna, Little Tunny (Atlantic black skipjack tuna), Dolphinfish, Shortfin Mako and Blue Shark; see Luckhurst 2015).

Another documented predator on subadult Gray Triggerfish is Red Snapper (Gentry et al. 2021), a species which has exhibited significant increases in the south Atlantic. A study done using the SAFMC EwE model documented Red Snapper predation on both Gray and Ocean triggerfishes, based on the sources used for the diet data incorporated into the EwE model (Gentry et al. 2021). In their study, Gentry et al. (2021) used "Diets for each of these [Red Snapper] age stanzas [which] were compiled from published literature and stomach-content analyses that reported the range of fish lengths or ages in their results." Gray Triggerfish was determined a species affected by its interactions with Red Snapper (i.e., see Figures 8-11 in Gentry et al. 2021).

Species Interactions: Impacts of Fish Community Changes

In addition to the above-noted significant increase in Red Snapper abundance in the south Atlantic and the modeled benefits/impacts to Gray Triggerfish, the proliferation of non-native, invasive Red Lionfish has also occurred within habitats used by Gray Triggerfish (Whitfield et al. 2007). As Whitfield et al. (2007) note "The potential impacts of lionfish to native communities are likely to be through direct predation, competition and overcrowding." Their conclusions are that "…lionfish are continuously distributed from south Florida to North Carolina and also found in the Bahamas, Bermuda and along the northeast U.S. shelf as juveniles…." and that "…the distribution and abundance [of lionfish] are likely to increase further and that the impact of lionfish on the ecosystem will also continue to increase." Further, they note "Lionfish may also affect the use of habitat by other species through physical overcrowding and aggressive tendencies." Their final conclusion is: "Along the southeast U.S. shelf the high number of stressors acting in synergism may eventually have unexpected and irreversible consequences for the native communities and economically valuable fisheries in this region. This scenario implies a direct economic cost within an open marine environment that is related to invasive species—a cost which is just beginning to be recognized."

Diet studies on Red Lionfish which we located did not include either Gray Triggerfish, or members of the family Balistidae, among prey species (Munoz et al. 2011, Dahl and Patterson 2014, Sancho et al. 2018), therefore direct predation on triggerfish does not appear to occur. This does not preclude other potential impacts to Gray Triggerfish resulting from the Red Lionfish invasion.

Species Interactions: Gray Triggerfish as Harassers of Other Species

In the Gulf of Mexico, Gray Triggerfish are documented as harassing Ages 1-3 Red Snapper, taking bites of their scales (Simmons and Szedlmayer 2018).

<u>Species Interactions: Predator-prey Cycles</u>

Our search did not document any known predator-prey cycles which include Gray Triggerfish either as an impacted species (prey), or a controlling species (as a predator). The South Atlantic EwE model should be a useful tool in providing insight into predator-prey relationships of Gray Triggerfish which may be examined to determine whether such linkages in fact exist; the likelihood is that the sort of detailed, long-term monitoring that has occurred to document such cycles in terrestrial ecosystems is not done in the marine habitats in which Gray Triggerfish reside.

<u>Habitat Parameters: Habitat Suitability Index Modeling</u>

Literature searching has thus far failed to locate a Habitat Suitability Index (HIS) model for Gray Triggerfish. It should be possible to construct such a model, using the time series of data from existing surveys (i.e., SERFS) and/or the habitat model developed by Farmer et al. (2017). Input from other members of the Work Group and/or the entire Research Track Stock Assessment Panel are welcomed for this topic.

<u>Habitat Parameters: Gray Triggerfish Nest Site Selection Criteria</u>

The Ecosystem Work Group speculated whether Gray Triggerfish nest site selection criteria could be a limiting factor with respect to their distribution within the south Atlantic, or within areas to the north where fisheries for them may be expanding (see the Spatiotemporal TORs section of this report). The one reference which we located (Lobel and Johannes 1980) does not provide nest site selection criteria for Gray Triggerfish. The two Pacific triggerfishes which are the subject of the paper may or may not use similar site selection criteria to those of Gray Triggerfish.

<u>Habitat Parameters: Linkages Between *Sargassum* Distribution and Gray Triggerfish Cohort Strength and Recruitment</u>

"The management of many GOM stocks would benefit from the consideration of environmental influences on their recruitment. A good example is the floating *Sargassum* (*Sargassum* spp.) habitat that affects early life stage survival of Gray Triggerfish *Balistes capriscus* (Wells and Rooker 2004). The Gray Triggerfish is currently overfished (NOAA Fisheries 2016), while sargassum biomass is believed
to have decreased in recent years (Powers et al. 2013)." This quote from Gruss et al. (2018) is somewhat dated but still very relevant, since there has been a good deal of work done in the Gulf of Mexico to integrate environmental parameters into assessment models, for Gag Grouper and Red Grouper.

Habitat Parameters: Protected Area Benefits

With respect to protected area benefits for Gray Triggerfish, a study by Arendt et al. (2009) provides a good deal of insight. Arendt and co-authors from the South Carolina Department of Natural Resources, Marine Resources Division, video-monitored an unfished, unpublicized, newly-created mid-continental shelf reef off Georgia from 1999 through 2008, as part of the South Atlantic Bight Synoptic Observational Network (SABSOON). The study collected a large amount of data on Gray Triggerfish, which are summarized herein.

The investigators found that observations of Gray Triggerfish "… increased dramatically during the first half of the study, after which time they decreased to near year one levels." They also noted Gray Triggerfish may have spawned at the site during the study (Arendt et al. 2009). A majority of the Gray Triggerfish observations in the recorded videos were retained for analysis (see Arendt et al. 2009, Table 4). Gray Triggerfish were part of a group of benthic species (others were Atlantic Spadefish, Black Sea Bass, groupers, Sheepshead and snappers) which "… were observed with significantly greater (Appendix 1) frequency and abundance between January and June than during July to December (Figure 3). Inter-annual differences were also noted for this group of fishes in all seasons, with increasing abundance indices between 1999 and 2004 followed by significant decreases between 2004 and 2008. The decrease in abundance indices for these fishes during the second half of the study may have reflected less time spent at this small reef as its resources became insufficient to support a large resident group of fishes." Unfortunately, as the authors also noted, the "secret" reef was reportedly discovered by a spearfisherman who removed reef fishes from the site, and continued to do so even after being asked to discontinue. Implementation of fishing on the site likely explained at least a portion of the decrease in abundance. The authors also noted "Indeed, over-grazing of invertebrates at the relatively small research site by black sea bass and triggerfish may have eventually led to a decline in their respective abundance indices in later years of this study."

The study documented the association of Gray Triggerfish with other species at the site. Quoting from the study: "Seasonal groupings of species and species groups (Figure 8) were also revealed by a Principal Components Analysis (PCA) which compared similarity and correspondence between daily abundance indices among species and species groups; however, the largest (first) component only accounted for 15% of the variance in this data set (Appendix 2). In other words, although there was substantial similarity in the seasons when these species or species groups were observed, differences in daily and inter-annual observations for a given species or species group were only weakly attributable to co-occurrence with the species or species groups examined." The species most closely associated with Gray Triggerfish were Atlantic Spadefish and Black Sea Bass (see Figure 8 in Arendt et al. 2009). A second PCA was conducted using days on which values for seven environmental metrics were available (those being barometric pressure, lunar phase, photoperiod, salinity, temperature, tide stage, time of day and wave height). Additional conclusions from the study were: "Circumstantial evidence (a function of short-duration visual sampling) suggests that several reef fish species [including Gray Triggerfish] were reproductively active; thus, prior to the decline (regardless of the origin) in their abundance indices the reef contributed to their "production" rather than simply attraction." They noted further: "Collection of fisheries video data from a series of index stations at a variety of habitats across the continental shelf would greatly enhance our ability to model habitat/energy linkages, as well as to predict the responses of reef and pelagic fish assemblages to short- and long-term changes in oceanographic conditions. Expanded use of remote visual and other technologies could potentially permit future fisheries management to be based on near real-time data, to include estimates [of] year class strengths as well as seasonal distribution data for a variety of marine species." We note such monitoring is already taking place via SERFS and hopefully, given further analysis, will enable detection of changes in Gray Triggerfish populations at least throughout their south Atlantic range.

One protected area in the south Atlantic which hosts Gray Triggerfish is Gray's Reef National Marine Sanctuary (NMS). Rowley (2020) produced a bibliography which includes multiple published papers which specifically reference Gray Triggerfish (Bacheler et al. 2016a, 2017; Farmer et al. 2017; and Kelly-Stormer et al. 2017). Although our review of these references did not reveal any discussion of Gray Triggerfish status within Gray's Reef NMS, they do provide useful information regarding the relationship of the species to the ecosystem in which it resides.

Farmer et al. (2017) generated predictive maps for Gray Triggerfish which may prove useful in assessing the potential for spatiotemporal distribution and/or determining whether protected areas provide benefits. They noted that "Many multi-year and multispecies spawning locations were located close to existing MPAs, where expansion or reorientation of those MPAs might provide conservation benefits."

Additional literature was reviewed which sought to assess whether the establishment of marine protected areas (MPAs) was of benefit to fish communities (Bacheler et al. 2016b, Pickens et al. 2021, Runde et al. 2021). Although Bacheler et al. (2016b) included Gray Triggerfish as one of the species they monitored, there was no indication of any increase across time when comparing mean annual densities observed (see their Table 3, Page 459, for Gray Triggerfish time series). They noted six possible reasons why they may not have observed any MPA benefit: 1) a lack of power in their experimental design and analytical approach; 2) data were not collected long enough after the closure to detect an effect; 3) size, shape, and placement of the MPAs they surveyed may not be optimal given the biology and ecology of the focal species in the region and the longitudinal orientation of the shelf-edge reef system relative to that of the MPAs; 4) not enough area was protected from fishing; 5) the reef features in the SEUS MPAs with which reef fish associate lie very close to the MPA boundaries, so fishing on the boundaries could draw fish out of the MPA; and finally 6) low compliance rates with fishing restrictions due to inadequate enforcement or insufficient knowledge of regulations in the fishing community.

Pickens et al. (2021) also included Gray Triggerfish in their analysis. They found no difference in Gray Triggerfish sizes when the time series of data for 2000-2018 was analyzed. They found "…no change or a decrease in managed reef fish abundance in each MPA relative to adjacent fished areas" although they did see some positive change for Red Porgy. They further noted that "Based on these metrics, it does not appear that the SEUS MPAs have yet been effective at protecting managed reef fish species. Given these MPAs have low enforcement, future assessments should examine compliance within the SEUS MPAs to determine if lack of success is due to illegal fishing, species examined, or MPA design before making a final determination if deep-water MPAs are an effective strategy for fisheries managers in the SEUS." As was the case for Bacheler et al. (2016b) they noted multiple reasons why their analysis may not have revealed any significant differences: 1) some of their indicator species, including Gray Triggerfish, had size limit changes during the period of analysis, which might have caused some bias, although they did not deem the change for Gray Triggerfish to be significant; 2) a second reason was the short span of time since the MPAs were implemented; 3) size of the MPAs may not have been sufficient; 4) MPA placement and design could also have been a factor affecting MPA effectiveness; and 5) sampling design could have influenced their results and explain why metrics did not support that SEUS MPAs provide effective protection for reef fish.

Runde et al. (2021) also included Gray Triggerfish as a monitored species. The authors included Gray Triggerfish in both catch-per-unit-effort (CPUE) analysis, as well as in multivariate analysis of community composition. The CPUE of Gray Triggerfish did increase within the MPA area when comparing "before" and "after" values (see their Table 3, Page 6, Runde et al. 2021). They concluded that " most of our analyses did not show an effect, although single- and assessed-species evaluations indicated positive effects [we're presuming this includes Gray Triggerfish]." The authors acknowledged that "Overall, the amount and quality of available data on the SEUSA MPAs is poor."

Ongoing studies which include monitoring should be reviewed periodically to see if changes (either detrimental, or beneficial) in population abundance and/or size of Gray Triggerfish are occurring within designated MPAs. This would be consistent with Runde et al. (2021) recommendations: "The addition of sites within MPA boundaries to existing surveys such as SERFS could result in a greater ability to detect positive MPA effects, if present."

Habitat Parameters: Stony Coral Tissue Loss Disease (SCTLD) and Fish Community Impacts

We wondered whether Stony Coral Tissue Loss Disease (SCTLD) and the attendant changes that result in reef structure and coral diversity have any impact on Gray Triggerfish populations. SCTLD is a relatively recent, highly-virulent, multi-hosted disease arrival to the Florida Keys reef system and has had devastating impacts upon reef-building corals throughout the Florida Keys and the Caribbean (i.e., see Walton et al. 2018, Sharp et al. 2020, Brandt et al. 2021, Estrada-Saldivar et al. 2021, Kolodziej et al. 2021 and Croquer et al. 2022). Most of the literature reviewed focused on changes within the coral community itself and do not mention changes in the associated fish community. A notable exception is for the butterflyfishes, which play a role in SCTLD transmission (Noonan and Childress 2020). The authors concluded that "…foureye butterflyfish recruit to and feed on SCTLD-infected corals which may influence the progression and/or transmission of this insidious coral disease."

Additional literature was reviewed which summarized reef fish community monitoring within the interval during and subsequent to SCTLD emergence (Grove et al. 2022). The authors selected Gray Triggerfish as an "allocation species" for southeast Florida, which indicates it will be monitored. Selection criteria (see Grove et al. 2022, Pages 5-6) were that species be "fishery-targeted" and that the CV be sufficient to enable change detection. That appears to raise the possibility that changes in Gray Triggerfish abundance may be detectable as monitoring continues. Sampling was impacted by Covid-19 and was not completed as originally planned

(Grove et al. 2022). The data collected are available; however delving into the database and analyzing Gray Triggerfish data was deemed beyond the scope of this Work Group's task.

We solicit any additional information that we may have overlooked that may provide insight into whether the spread of SCTLD is having a negative impact on Gray Triggerfish populations.

<u>Habitat Parameters: Artificial Reefs, Oil Rigs, Offshore Wind Turbines</u>

Clearly the establishment of artificial reefs (ARs) and emplacement of offshore oil rigs, offshore wind turbines, and hard structures such as coastal bridges, has benefits for species such as Gray Triggerfish which feed upon invertebrates that encrust these structures. Documentation from the Virginia Marine Fisheries Commission's Game Fish Tagging Program shows Gray Triggerfish are most often captured around such structures (i.e., Chesapeake Bay Bridge Tunnel; see the Spatiotemporal section of this report).

<u>Habitat Parameters: South Atlantic Marine Regional Fish Habitat Assessment and South Atlantic Bight Marine Assessment</u>

Once the South Atlantic Marine Regional Fish Habitat Assessment document, which we understand will be prepared by the NMFS SEFSC is available, it should provide insight into Gray Triggerfish habitat use and habitat condition within the south Atlantic. The South Atlantic Bight Marine Assessment (Conley et al. 2017) mentions Gray Triggerfish as a component species of the south Atlantic ecosystem but does not provide any detailed insights which are useful for stock assessment purposes. "The Nature Conservancy's South Atlantic Bight Marine Assessment (SABMA) is a data collection and analysis initiative designed to improve understanding of the regional distribution of key habitats and species. The assessment includes, but is not limited to, coastal wetlands, seagrass beds, oyster reefs, live hard bottom habitats, sea turtles, and marine mammals. Available data resources and other scientific information were assembled to produce regional baselines on the status of each resource. These baselines were then evaluated comprehensively to define conservation priority areas, places where individual habitats and species overlap. The SABMA conservation portfolio highlights areas where significant species, natural communities, and ecological processes hold the greatest promise for conservation success [Conley et al. 2017]."

<u>Episodic Events: Red Tide Impacts</u>

"Red Tide" is the commonly-used term for discolored waters (either reddish or brown) in marine or estuarine settings, being produced by a harmful algal bloom (HAB). *Karenia brevis* is a single-celled, naturally occurring dinoflagellate (Florida Fish and Wildlife Conservation Commission, undated *Karenia Brevis* Fact Sheet) and is the most common cause of "Red Tide." Two additional species, a dinoflagellate named *Pyrodinium bahamense* and a genus of diatom named *Pseudo-nitzschia* may also produce HABs (Florida Fish and Wildlife Commission, undated Fact Sheets). Each of these organisms when at high concentrations and/or after their death emit/produce toxins which may be lethal to fish and other taxa, and the toxins may concentrate in filter-feeding shellfish. *Karenia brevis* produces neurotoxins called brevetoxins that can sicken or kill fish, seabirds, turtles, and marine mammals. *Pyrodinium bahamense* produces a suite of neurotoxins called saxitoxins. Some species of *Pseudo-nitzschia* produce a neurotoxin called domoic acid, which can sicken or kill marine mammals and seabirds. The toxins all may affect human health adversely when concentrated by shellfish or pufferfish. They also may cause oxygen depletion at high concentrations when they die and sink to the bottom (Florida Fish and Wildlife Conservation Commission, undated Fact Sheets).

Definitive mechanisms for *K. brevis* bloom initiation are unknown and there are approximately 24 thoughts and hypothesis described to explain them (Vargo 2009). These include: "…seven [that] are related to rainfall and/or riverine flux, six [which] invoke the benthos or bottom flux in one form or another, seven [that] involve water column hydrodynamics or are unrelated to the benthos or land sources, and four [that] are primarily chemical/allelopathy based. Nutrient sources for growth and maintenance of the algae range from atmospheric deposition, N-fixation, riverine and benthic flux, and zooplankton excretion to decaying fish killed by the toxic dinoflagellate with no one source being conclusively identified as a primary contributor to prolonged bloom maintenance" (Vargo 2009).

Red tide events occur most often on the Florida west coast (Alcock 2007, Gannon et al. 2009, Vargo 2009), but they are also known from the U.S. East Coast and in other countries around the world as well (Rounsefell and Nelson 1966, Tester et al. 1988, Anderson 1995, Anderson et al. 2001, Anderson 2007, Anderson 2009) and may be caused by multiple algae species other than the three primary ones addressed in the preceding paragraph (Anderson 1995; see his Table 1, Page 1190; Anderson 2007). Red tide events have been historically uncommon on the Florida east coast, with only three documented events prior to 1988 (Tester et al. 1988). All three events were precipitated by Florida west coast blooms which were conveyed around Florida by the Florida Current-Gulf Stream system (Tester et al. 1988) and all were of short duration. The first red tide event recorded in North Carolina occurred in 1987 (Pietrafesa et al. 1988, Tester et al. 1988, Tester et al. 1991). Tester et al. (1988, Page 810) indicated they believed future red tide events in North Carolina would likely result from the same ocean current transport mechanisms (i.e., Florida Current-Gulf Stream transport) that caused the 1987 event. Pietrafesa et al. (1988) provide a detailed explanation of how ocean currents and winds combined to bring the red tide organism inshore, and how such an event could possibly occur again. Tyler (1988) assessed whether there was potential for any additional outbreaks in the future. She determined that such outbreaks were unlikely (Tyler 1988, Page 13).

As noted by Anderson (2009) "The nature of the HAB problem has changed considerably over the last three decades throughout the world." Anderson's (2009) Figure 3 shows the cumulative global increase in the recorded distribution of the causative organisms and the confirmed appearance of paralytic shellfish poisoning (PSP) toxins in shellfish. He states: "Clearly, a dramatic expansion in the areas affected by PSP toxins has occurred in recent years. A similar pattern applies to many of the other HAB types. Few would argue that the number of toxic blooms, the economic losses from them, the types of resources affected, and the number of toxins and toxic species have all increased dramatically in recent years throughout the world. Disagreement only arises with respect to the reasons for this expansion."

Quantification of the fish killed by red tide events is difficult (Landsberg et al. 2009). Fish kills caused by red tide cannot be reliably quantified because of their magnitude and the spatial and temporal scale over which they occur (Landsberg et al. 2009, Page 604). The authors further note "…there is no accountability for the number of eggs or larval stages killed (Kimm-Brinson and Ramsdell, 2001; Colman and Ramsdell, 2003), the effect on juvenile recruitment (Riley et al., 1989; Warlen et al., 1998), or the extent of post-bloom mortalities." Despite the noted difficulty in quantify the impacts of red tide-caused fish kills, estimates of the number of fish killed by red tides have been attempted in Texas (Rubec, 1999) and Florida (FWC, unpublished). Per Landsberg et al. (2009), "Counts of the numbers of dead fish stranding along a specific beach area are likely to be underestimates. One possible method to evaluate short-term effects is to review the commercial fisheries landings data (FWC, unpublished; Brown, personal communication to Landsberg et al. 2009) or to conduct independent assessments. ***Such assessments when compared to non-red tide years or regions may help to determine if short-term declines during or following red tides appear to influence fishery numbers in areas where red tides are endemic [emphasis added]."***

Alcock (2007) notes that: "Little research has been conducted on the effects that red tide has on specific fish communities. Smith (1975; 1979) documented the decimation and subsequent re-colonization of an offshore reef fish community in the Gulf of Mexico following a single red tide event in 1971. This event appeared to have caused a hypoxic "dead zone" offshore of Tampa Bay and Sarasota and Manatee counties, similar to the dead zone that occurred during the summer of 2005. Smith estimated that 80-90% of the reef fishes were killed by the red tide and that all the species that disappeared from the reefs re-colonized the area within a year. However, Smith believed that several years may be required to re-establish the community to its former structure in terms of relative abundance of each species. Because Smith's work was narrowly focused and targeted only one reef fish community and a single red tide event, much remains to be learned about the ecological effects of red tide on economically and ecologically important fisheries."

Gray Triggerfish may be among the fish species adversely impacted by red tides (Landsberg et al. 2009, Gulf of Mexico Fishery Management Council 2021). While Landsberg et al. (2009) includes triggerfish in a list of impacted species, we have had little success in documenting Gray Triggerfish named in lists of species killed during red tide events within reports or literature documenting such events. One of the early studies we located (Ingle and Sykes 1964) does not include Gray Triggerfish in the list of impacted fish species resulting from a kill in Tampa Bay (see their Table 2, Pages 103-104, and Table 1, Pages 125-127). The GMFMC (2021) indicated "Gray triggerfish are found within fish communities of species negatively affected by high mortality due to red tide. However, although their abundance varied, studies have shown that gray triggerfish that remained in red tide areas were able to survive, suggesting that the stock is more tolerant and resilient to environmental stresses (Dupont and Coy 2008; DuPont et al. 2010)." Dupont et al. (2010) reports Gray Triggerfish were among a group of five fish species that "… were observed at all sites during all sampling times, although their abundances varied greatly…." They further noted "These species [including Gray Triggerfish] survived the red tide as remnant populations or returned soon after its dissipation as they were observed during the pre-event sampling time (summer 2005) as well as all subsequent sampling times."

There are several examples in the literature of development of ecosystem-based fishery management models, as well as stock assessments, for species other than Gray Triggerfish, which consider the impacts of red tide and other environmental variables on the individual species. These are for Gag Grouper (Lenfest Ocean Program 2016) and Red Grouper (Dell'Apa et al. 2020), both developed for populations of those species located in the Gulf of Mexico. Background information on these species and fisheries for them is in Karnauskus et al. (2013). Model details regarding indicator selection and model development are provided in Kelble et al. (2013), Sagarese et al. (2014a-b, 2015), Walter et al. (2013, 2015) and Harford et al. (2018). Modelers used remotely-sensed satellite data to generate a red tide index which was then incorporated into the assessment models (Walter et al. 2015). As noted in Walter et al. (2015), "Enhanced reporting of red tides, in addition to observations from offshore waters by recreational and commercial fishers, could increase understanding of how red tide events impact offshore species [which could include Gray Triggerfish]."

Fundamental to the development of a Gray Triggerfish assessment model which incorporated red tide events, and oceanic factors which affected recruitment, is a greater understanding of how these variables and events may affect south Atlantic Gray Triggerfish. We believe a great deal of additional information and understanding is needed before this would be possible.

In the meantime, there is an organization which is tracking red tide events in the south Atlantic (see http://cprweb.marine.usf.edu/about-us/)/). The Collaboration for Prediction of Red tides (CPR) is a jointly funded project between the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWC- FWRI) and the University of South Florida's College of Marine Science (USF-CMS). Their mission focuses on development of an automated, coupled physical-biological model capable of predicting and tracking the dominant Florida red tide species, *Karenia brevis*, within coastal waters of the southeastern United States. The work of CPR should be useful for potentially developing assessment models which could incorporate a red tide index, should it be deemed a significant factor in Gray Triggerfish population dynamics.

Finally, Tyler's (1988) study, as well as a relatively recent interview with a NOAA scientist suggests red tide outbreaks within at least eastern North Carolina should not be a major concern (Martin 2018). NOAA Ecologist Wayne Litaker indicated in an interview that red tides are a "rare event" in NC and that he doesn't anticipate such events but once every 50-60 years.

Based on our current review, including the interview with Wayne Litaker, red tide does not appear to be a major factor in the south Atlantic at present

Episodic Events: South Atlantic Upwellings

Information regarding South Atlantic upwellings is provided in Craig et al. (2021), Section 4.6. Coastal upwelling has declined since the early 2010s while primary productivity was low from 2010 – 2015 compared to earlier and later years. These observations, along with increases in winter-spring temperatures since 2014, suggest recent changes in ocean dynamics in the U.S. South Atlantic ecosystem. For additional information on upwellings in the south Atlantic see particularly the following citations: Blanton et al. (1981), Atkinson et al. (1984), Schwing et al. (1996), and Hyun and He (2010).

Episodic Events: Hurricanes

One study was located which examined the movements of Gray Triggerfish in response to tropical storm events (Bacheler et al. 2019). The authors employed fine-scale acoustic telemetry on 30 Gray Triggerfish, before, during and after two tropical storm events which occurred in North Carolina in 2017. Their results were (quoting from the abstract): "During storms, gray triggerfish movement and emigration rates were 100% and 2550% higher, respectively, than on days with no storms. We found that increased movement rates were much more strongly correlated with wave orbital velocity (i.e., wave-generated oscillatory flow at the seabed) than either barometric pressure or bottom water temperature, two covariates that have been demonstrated to be important for organisms in shallower water. Higher movement rates during storms were due to increased mobility at night, and emigrations typically occurred at night in the direction of deeper water. Overall, we found significant storm effects on the movement behavior of a demersal fish species in the open ocean, despite our study occurring in deeper water than previous studies that have examined storm effects on animal movement. We conclude that tropical storms are a driving force behind the structure of marine ecosystems, in part by influencing movements of mobile animals."

Episodic Events: Prey Base (or Predator) Population Fluctuations

No information was located as yet which indicates Gray Triggerfish are included in any dynamic predator-prey population fluctuations (a 'la, Snowy Owls and Lemmings, or Canada Lynx and Snowshoe Hares, etc.). It is not inconceivable however, given the fact Gray Triggerfish juveniles are obligate *Sargassum* dwellers, and Dolphinfish, which are also closely associated with *Sargassum,* are frequent predators on them, that such an association may exist. Long-term monitoring of the *Sargassum* habitat may be productive in determining whether such fluctuations occur.

Episodic Events: *Sargassum* Abundance Maxima, Minima

Searches turned up multiple relatively recent papers regarding *Sargassum* habitat dynamics, as well as the behavioral cues that enable one species related to Gray Triggerfish to find it. Significant information regarding the *Sargassum* habitat, its ecology, and measures for its conservation and management may be found in Laffolley et al. (2011).

Cox (2016) used an experimental approach in the laboratory to examine the role of natural chemical cues from *Sargassum* patches and the synthetic chemical Dimethylsulfonionpropionate (DMSP) for an associated fish, the Planehead Filefish (*Stephanolepis hispidus*) and a control fish species not associated with *Sargassum*, the Masked Goby (*Coryphopterus personatus*). Choice trials with a Y-maze apparatus determined that *S. hispidus* responded significantly to chemical cues from *Sargassum* while *C. personatus* did not. DMSP cues did not result in any significant behavioral responses for either fish. Demonstrating *S. hispidus* can respond to chemical cues from *Sargassum* helps further our understanding of this unique floating algal reef and how fishes may locate it (Cox 2016). It is possible Gray Triggerfish juveniles employ similar cues to recruit to their pelagic *Sargassum* habitat.

Gower and King (2019), Wang (2019) and Johns et al. (2020) all address the recent expansion of *Sargassum* within the Atlantic Ocean. Since *Sargassum* has a distinctive signature, it can be tracked by satellite (Gower and King 2019). Imagery revealed a dramatic expansion which took place beginning in 2011. The expansion was in contrast to its prior annual pattern in which it grew in spring in the western Gulf of Mexico, moved east into the eastern Gulf and Loop Current, then into the Atlantic Gulf Stream and Sargasso Sea in the fall (Gower and King 2019). Wang et al. (2019)
suggest, increased nutrients from coastal upwelling and from the Amazon River may be a cause of this change. Johns et al. (2020) consider the highlights of the expansion to be: *Sargassum* was exported to the tropical Atlantic during the 2009–2010 NAO anomaly; Windage is required to reproduce the observed *Sargassum* distributions; Exceeding a biosphere tipping point may have led to a tropical Atlantic Sargasso Sea; *Sargassum* is aggregated seasonally by Inter-Tropical Convergence Zone (ITCZ) winds; and finally, Growth in the central tropical Atlantic is enhanced by vertical mixing dynamics.

We did not find any information suggesting Gray Triggerfish may have benefitted in any way from the significant expansion of *Sargassum* habitat. As noted in the Spatiotemporal section of the Data Workshop report, recruitment dynamics of Gray Triggerfish are likely very complex and more study is certainly needed to develop a complete understanding of how eggs in nests, wind up as juveniles in *Sargassum*.

6.3 Research Recommendations

Employ the South Atlantic EwE model to test hypotheses regarding environmental drivers for Gray Triggerfish (predator-prey relationships, etc.).

Encourage studies of contaminant, EDCs and microplastics body burdens in Gray Triggerfish to determine lethal and sub-lethal (chronic) impacts that may affect the population dynamics of the species at any of its life stages.

Encourage further study of the relationships between Gray Triggerfish egg hatching success and swim-up, larval and postlarval recruitment to *Sargassum* pelagic habitat, settlement of juveniles from the pelagic *Sargassum* to benthic reef and/or hard structure habitats, and sources and sinks for juveniles and adults.

Continue to explore possible relationships between environmental variables and climate cycles, and Gray Triggerfish population dynamics.

Investigate to what extent Gray Triggerfish prey could be impacted by increasing ocean acidification.

Encourage the collection of additional diet data to refine Gray Triggerfish predator-prey relationships.

Determine nest site selection criteria used by Gray Triggerfish and whether there may be an optimal nest configuration which maximizes hatching success.

Complete needed climate vulnerability assessments for habitats and species in the south Atlantic.

Continue to explore whether artificial reef creation and addition of other hard structures (e.g., offshore wind infrastructure) results in increased or expanding Gray Triggerfish population size.

Determine the vulnerability of Gray Triggerfish life stages to harmful algal blooms and associated toxins, including Red Tide events.

Continue to investigate through additional acoustic telemetry the impact of episodic events on Gray Triggerfish.

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6.4 Figures

Figure 1. Reproduction of Figure 7.5 from Continental Shelf Associates, Inc. 1999 showing concentrations of metals from Gray Triggerfish captured at various locations in the Gulf of Mexico.

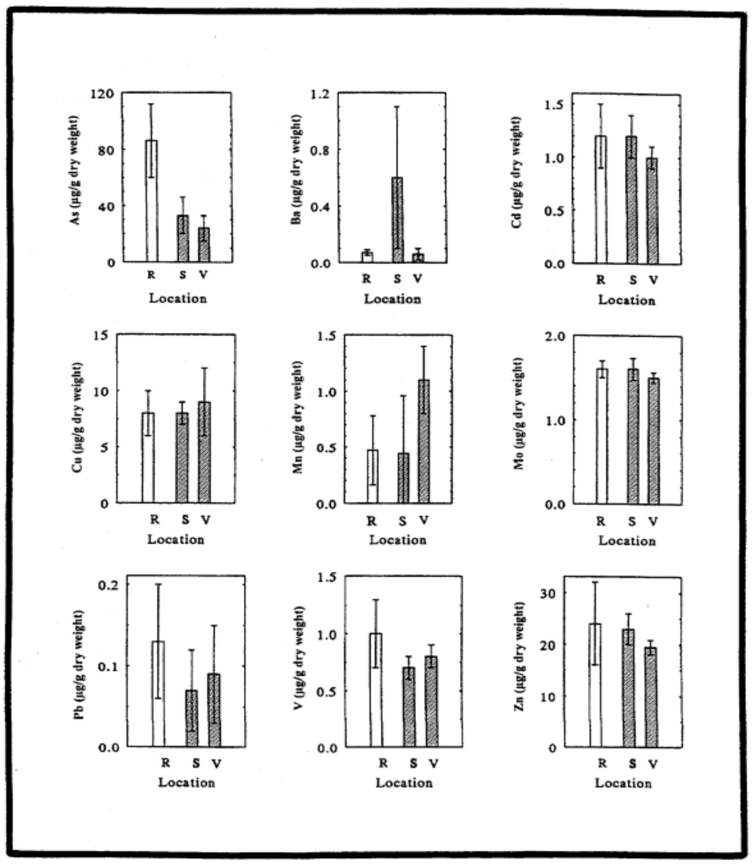

Figure 7.5. Concentrations of As, Ba, Cu, Fe, Hg, Ni, Pb, V, and Zn in gray triggerfish. Locations include a reference site (R) (High Island A-389) and two discharge sites (S = South Marsh Island 130B, and V = Vermilion 214A).

7-22

Figure 2. Figure 7.7 from Continental Shelf Associates, Inc., showing concentrations of metals in Gray Triggerfish and Red Snapper.

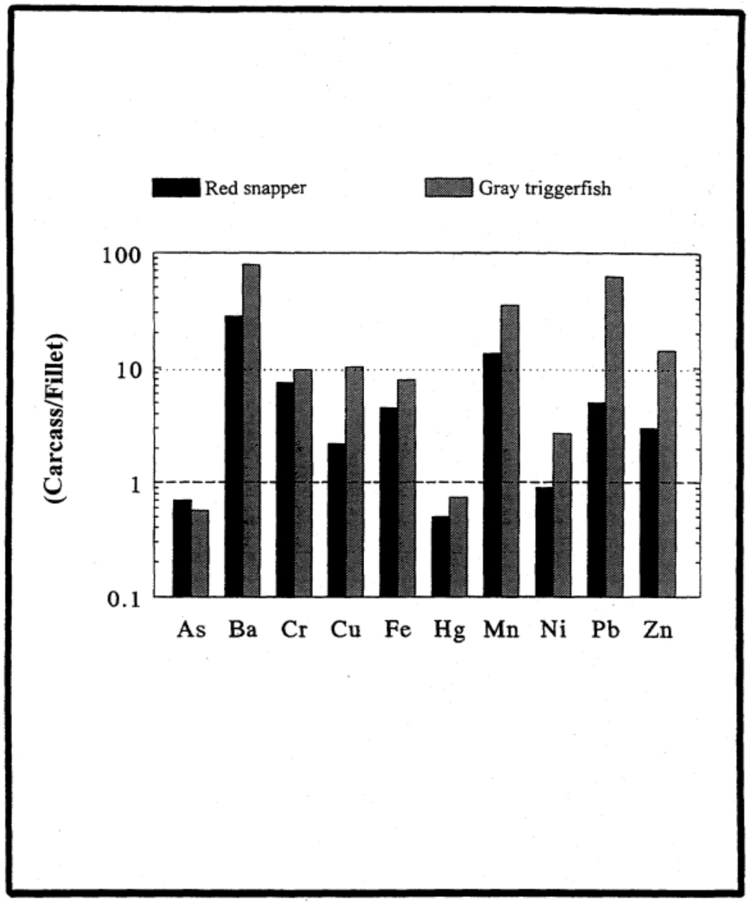

Figure 7.7. Concentrations of metals in carcass/fillet for red snapper and gray triggerfish from discharge sites at Vermilion 214A and South Marsh Island 130B.

7-25

7. Spatiotemporal Report

Prepared by: Spatiotemporal Ad-Hoc Work Group

Ad-Hoc Work Group Members Present In-Person:

- Dr. Wally Bubley, Marine Resources Division, South Carolina Department of Natural Resources
- Dr. Jie Cao, Department of Applied Ecology, North Carolina State University
- Maria Kappos, Florida Fish and Wildlife Conservation Commission
- Dr. Wilson Laney, Department of Applied Ecology, North Carolina State University (WG Lead)
- Beverly Sauls, Florida Fish and Wildlife Conservation Commission
- Dr. Kevin Thompson, Florida Fish and Wildlife Conservation Commission

Ad-Hoc Work Group Collaborators Present:

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- Angel Willey, Fishing and Boating Services, Maryland Department of Natural Resources
- Dr. Erik Williams, SEFSC, National Marine Fisheries Service
- Erik Zlokovitz, Fishing and Boating Services, Maryland Department of Natural Resources

7.1 Terms of Reference addressed in this document:

1)Review stock structure and unit stock definitions.

Stock structure and unit stock were thoroughly reviewed and defined in 2015 in response to SEDAR 41 TOR 1 (see SEDAR 2016, Page 6). Edited text, and a figure, from that report are incorporated here (text from SEDAR 2016, Pages 24-25, and Figure 2.1, from Page 58) and edited as appropriate for SEDAR 82.

Gray Triggerfish settled juveniles and adults inhabit both natural and artificial reefs ranging from Nova Scotia to Argentina, including the Gulf of Mexico and off Bermuda in the western Atlantic (Harper and McClellan, 1997; Fioramonti, 2012) and from Norway to the northwestern coast of Africa in the eastern Atlantic (Ofori-Danson 1989; Fioramonti 2012) (see Figure 2.1).

This widespread Gray Triggerfish geographic distribution pattern has existed at least since the early 1900's, based on historical ichthyological literature and specimens in museum collections (i.e., see Smith 1907, pp. 339-340; Hildebrand and Schroeder 1928, pp. 340-342; Bigelow and Schroeder 1953, pp. 520-521; Leim and Scott 1966, pp. 412-413). Gray Triggerfish have been documented in multiple locations in Nova Scotia since 1910 (Leim and Scott 1966). Gray Triggerfish juveniles inhabit pelagic *Sargassum* spp. prior to settlement. In the Mid-Atlantic, juvenile Gray Triggerfish have been documented in New Jersey, Delaware Bay, the Atlantic Coast of Maryland, and lower Chesapeake Bay to the mouth of the Potomac River (Hildebrand and Schroeder 1928, pp. 340-342; Martin and Drewry 1978, pp. 260-262). Based on earlier studies and their own study, Simmons and Szedlmayer (2011) concluded Gray Triggerfish spend 4-7 months in the pelagic zone before settlement to benthic substrate. Some tagging studies indicate large juveniles and adults are highly sedentary (i.e., Ingram 2001) but they have also been shown to undertake longer seasonal movements (Herbig and Szedlmayer 2016) and longer offshore movements in response to storms (Bacheler et al. 2019).

Genetic stock structure of Gray Triggerfish from the Gulf of Mexico and the western Atlantic was initially investigated by Antoni et al. (2011) using mitochondrial DNA sequences from samples along Texas, Louisiana, west coast Florida, east coast Florida, and South Carolina. Their results indicated homogeneity of genetic variants between the Gulf of Mexico and U.S. South Atlantic, but their sample sizes were relatively low (n = 150) and the use of only one locus may not provide adequate resolution to reveal more subtle differences. The authors also noted that larvae and small juveniles utilize *Sargassum* spp. habitat for a few weeks to a few months, thus accounting for genetic mixing between the two bodies of water. A follow-up study by Sallient and Antoni (2014 MARFIN Final Report) included additional markers (mtND4 and 17 microsatellites) and specimens (n=665) from six locations in the Gulf of Mexico and two U.S. South Atlantic locations ranging from south Texas to South Carolina. Similar to their prior study, analyses of both genetic data sets suggest genetic homogeneity throughout the U.S. sampling region which was consistent with large neighborhood sizes. Therefore, there appears to be no stock structure within the U.S. Atlantic, within the Gulf of Mexico, or between the U.S. Atlantic and Gulf of Mexico, indicating Gray Triggerfish are demographically connected within U.S. waters.

Sallient and Antoni (2014) also evaluated genetic connectivity between the eastern and western Atlantic Gray Triggerfish populations using both mtND4 and 17 microsatellites. Interestingly, they detected high connectivity between U.S. and European (i.e., France) populations with West Africa populations representing a genetically distinct stock. The authors suggest the genetic uniqueness of the African Gray Triggerfish populations is likely the result of current pattern influence on larval dispersal. Additionally, they note the potential of a large portion of Gray Triggerfish along the western European coast to have originated from U.S. stocks – based on a lower abundance of Gray Triggerfish along the European coast in combination with a high European effective population size estimate which is similar in magnitude to U.S. stock estimates. The similar levels of genetic diversity, effective population size estimates, and allele frequency distributions support their proposal.

During the 2015 and 2022 Data Workshops, little new genetic information was available (the only new information we located published after SEDAR 41 was Antoni 2017). Based on his analysis of population structure, phylogeography, and migration patterns examined for Gray Triggerfish and contrasted with predictions of larval transport based on surface circulation data, Antoni (2017) concluded that "…recruitment depends largely on the output of spawning populations located hundreds or thousands of kilometers away from a given stock, highlighting the need to conserve populations across each species' range [conclusion for both Gray and Queen triggerfish] in particular in areas where circulation patterns predict a low likelihood of incoming migrants." Therefore, single stock management of Gray Triggerfish along the U.S. Atlantic appears to be biologically appropriate for the time being, with the caveat there needs to be much greater understanding of larval transport and recruitment dynamics for the species. However, for purposes of this assessment, Gray Triggerfish stock definition is from the Florida Keys (Atlantic side) to as far north as landings are recorded.

Recommendation

The "South Atlantic" Gray Triggerfish stock be defined as the population occurring in the SAFMC jurisdiction in the Florida Keys in the south to as far north as landings are recorded.

Research Recommendation

In order to determine the source of Gray Triggerfish recruiting to those populations which are currently being targeted either commercially or recreationally, additional studies should be conducted to determine the recruitment dynamics of the species, including larval sources and larval transport.

1a) Characterize **changes in spatial distribution** of Gray Triggerfish catches including **catches in the Mid Atlantic**.

As noted above under TOR 1, Gray Triggerfish exhibit a wide Atlantic Ocean geographic range on the United States East Coast and Canadian Maritimes based on encounters during fishery-independent sampling, since its original description as a species, as well as in Central and South America, the west coast of Africa, and Europe and the Mediterranean Sea (Figure 1).

Gray Triggerfish in other portions of the range have exhibited relatively recent changes in spatiotemporal distribution which have been attributed to climate change (ICES 2008, 2009). The areas included the Bay of Biscay and Iberian Coast (ICES 2008) where Gray Triggerfish were stated to have increased due to climate change (ocean warming, changes in current patterns in the North Atlantic, bringing more southerly water into the northeast); and the Celtic Sea, where sightings of Gray Triggerfish, normally a rare, migrant species, have increased (ICES 2009). Given these changes on the opposite side of the Atlantic Ocean, it is appropriate to look for signs of similar changes on the U.S. Atlantic Coast.

Data Sources

To address TOR 1a, we examined both fishery-independent, and fishery-dependent data sets to explore whether catches of the species in the Mid-Atlantic and further northward are occurring, when they occur, and whether they have increased over time and/or whether a noticeable northward shift in distribution has occurred.

We also discovered and examined several non-traditional fishery-dependent data sets (Tables 1-5). These included state record and "trophy" Gray Triggerfish for which citations were issued by state marine recreational angler award programs in Virginia and Connecticut (Tables 1-4) as well as a database of Gray Triggerfish tagged, released and recaptured by the Virginia Marine Resources Commission's Game Fish Tagging Program (see Musick and Gillingham 2022, Musick et al. 2022 and multiple additional annual reports which are included in the Literature Cited; Table 5). These data sets document the size of larger Gray Triggerfish being captured, as well as the season of capture.

Finally, we also reviewed online fishing publications (i.e., see Michelson 2020 as an example) for information on Gray Triggerfish distribution and seasonality of angling activity; searched social media platforms for information on recreational anglers targeting Gray Triggerfish north of North Carolina; and interviewed and/or communicated with staff of marine fishery agencies in Virginia, Maryland and New Jersey to inquire regarding anglers targeting Gray Triggerfish in their jurisdictions (personal interviews conducted opportunistically by Spatiotemporal Ad-Hoc Work Group Lead Wilson Laney during the Atlantic States Marine Fisheries Commission Annual Meeting in Long Branch, New Jersey, November 7-10, 2022).

Fishery-Independent Survey Data

Regional offshore fishery-independent data sets examined included: Northeast Area Monitoring and Assessment Program (NEAMAP) trawl survey; Northeast Fishery Science Center Trawl Survey (NEFSC; N. Klibansky, personal communication); Southeast Area Monitoring and Assessment Program (SEAMAP); and Southeast Reef Fish Survey (SERFS; video and Chevron Trap). Through inquiries to colleagues regarding the documentation of Gray Triggerfish in additional fishery-independent surveys conducted by states, we discovered that the Maryland Coastal Bays Survey also historically captured Gray Triggerfish (personal communications from Jim Uphoff, Angel Willey and Craig Weedon, Maryland Department of Natural Resources, to RWL and NK).

The NEAMAP trawl survey was initiated in 2006 in order to sample shallower depth strata which could no longer be sampled by the NEFSC Bottom Trawl Survey after a larger vessel became the platform (https://www.vims.edu/research/departments/fisheries/programs/multispecies_fisheries_research/neamap/index.php). Three large-scale trawl surveys are included in NEAMAP: Maine/New Hampshire conducted by the Maine Department of Marine Resources; Massachusetts survey led by the Massachusetts Division of Marine Fisheries; and NEAMAP-Mid-Atlantic which is overseen by the Virginia Institute of Marine Science (VIMS). We requested and received all data for Gray Triggerfish encountered during NEAMAP sampling (Jim Gartland, VIMS, personal communication and unpublished data). The NEAMAP trawl survey has encountered Gray Triggerfish since 2007 (see Figure 2) in samples from Virginia through Connecticut. Figure 2 reflects distribution of all the Gray Triggerfish individuals encountered during NEAMP surveys (n = 95), for the entire time series (Jim Gartland, VIMS, personal communication to RWL).

The CPUE for the NEAMAP time series is plotted in Figure 3. There is no increasing trend evident across the time series. Rather, catches of Gray Triggerfish are relatively flat with the majority of values less than 0.05. The highest value occurred in the second year of the time series (2007).

The Northeast Fishery Science Center Trawl Survey protocols are described in detail in Stauffer (2004) and Politis et al. (2014). The Northeast Fisheries Science Center (NEFSC) has conducted an autumn (fall) bottom trawl survey annually since 1963, a spring bottom trawl survey annually since 1968, a winter bottom trawl survey conducted annually since 1991, and a Northern Shrimp survey (outlined under a separate set of protocols). The spring and autumn/fall bottom trawl surveys provide synoptic coverage of continental shelf waters from Cape Hatteras, North Carolina, to the Scotian shelf in Canadian waters. Surveys were generally conducted aboard the FRV ALBATROSS IV and DELAWARE II, until the spring of 2009, when the HENRY V. BIGELOW replaced the ALBATROSS IV (Stauffer 2004; Politis et al. 2014). The survey has encountered Gray Triggerfish.

The full NEFSC Trawl Survey time series was examined for Gray Triggerfish captures by the SEDAR82 Lead Analyst (N. Klibansky, personal communication to RWL). Figure 4 shows the length-frequency of Gray Triggerfish captured in the NEFSC Trawl Survey, by season, binned by latitude. The numbers of fish are not scaled by the number of tows. The distribution of fish north of 36 ˚N latitude is hard to see because there are not that many individuals caught in trawls north of that latitude (the NC/VA border lies between 36 and 37 ˚N). The numbers captured north of the NC/VA border are insufficient to determine whether there is an increasing trend in the presence of the species (Nikolai Klibansky, personal communication to RWL). However, the graphical depiction of the fall data in Figure 4 does document a bimodal distribution, which suggests that "…the same two size modes (10cm and ~32cm) represented in the south (34-36 N lat) in the fall, are represented up to 42 N lat in the fall as well" (N. Klibansky, personal communication to RWL). The 32cm mode seems to represent adult fish which is what is observed in the recreational lengths. The 10cm mode is "…not represented in any of our other SEDAR data sets…." and these may be age-0 fish that have just settled from their pelagic *Sargassum* habitat (N. Klibansky, personal communication to RWL). See more discussion below regarding these observations.

We also examined the SEAMAP Coastal Trawl Survey database (W. Bubley, personal communication to RWL). The SEAMAP Coastal Trawl Survey has been conducted since 1986. A detailed description of the methodology and protocols for that survey may be found in Zimney (2021).

The SEAMAP trawl survey does encounter Gray Triggerfish, however the numbers are very low and multiple years encountered none. Figure 5 shows the numbers encountered by year, unadjusted for the number of tows made, or the time of the tows. There is no evident trend.

The final regional fishery-independent data set which was examined and analyzed for Gray Triggerfish abundance and distribution is the SERFS. Both the video and Chevron Trap data were examined and analyzed and detailed methodology and protocols are provided for each survey in Data Workshop reports (Bacheler et al. 2022 analyze the video data, and Bubley and Willis 2022 analyze the Chevron Trap data). The SERFS currently samples between Cape Hatteras, North Carolina, and St. Lucie Inlet, Florida. This survey ***targets hardbottom habitats*** [emphasis added] between approximately 15 and 115 meters deep. SERFS began affixing high-definition video cameras to Chevron Traps on a limited basis in 2010 (Georgia and Florida only), and has attached cameras to all Chevron Traps since 2011. In 2015, the video cameras were changed from Canon to GoPro to implement a wider field of view and thus observe more fish (Bacheler et al. 2022).

Analysis of the SERFS video data (see Table 3 in Bacheler et al. 2022) indicated a generally increasing trend in the proportion of positive videos (i.e., those in which Gray Triggerfish were observed) through 2017, with a decline thereafter. Data are missing for 2020 since sampling was not conducted that year due to Covid (Bacheler et al. 2022). The same trend is evident in the bubble plots of Gray Triggerfish observed (see Figure 2 of Bacheler et al. 2022). The authors do not indicate whether the data were analyzed with a view toward detecting any shifts in distribution of the species (e.g., changes in center of distribution).

Analysis of the SERFS Chevron Trap data are presented in Bubley and Willis (2022). This survey as previously noted targets the preferred hardbottom (reef) habitat of post-settlement juveniles and mature adults (i.e., see Sedberry et al. 2006). Data are sufficient to provide for the development of an index and standardization (see Table 3, Figure 7 in Bubley and Willis 2022). Figure 7 of their report shows an increasing trend early in the time series, with a peak in 1997 (per their Table 3), followed by a steep decline and relative stability at lower relative abundance levels, until the terminal year (2021) of the time series when abundance declines to the lowest recent value, comparable to those observed at the beginning of the time series. The authors do not indicate whether the data could be analyzed for detecting any shifts in distribution of the time series within their study area (again, looking for changes in the center of distribution for the species).

A general statement which should be made at this point is that given the preferred reef and/or hard structure habitat preference of Gray Triggerfish (i.e., see Sedberry et al. 2006), trawls are likely not the optimal gear with which to sample them for determination of any trends in abundance or distribution, at least not within their Atlantic Coast range where trawl sampling generally seeks to avoid hard bottom habitats in order to avoid habitat and/or gear damage (although, in the Gulf of Mexico, Gray Triggerfish are readily captured with trawls in sufficient numbers to develop indices of abundance; see Pollock et al. 2019). Captures of Gray Triggerfish in bottom trawl surveys throughout the Atlantic Ocean do occur, but not in numbers sufficient to provide for the development of a useful index. The SERFS sampling methodologies would appear to be far more useful in this regard; however, that program does not extend north of Cape Hatteras, so is of limited geographic utility in assessing trends in abundance or distribution north of Cape Hatteras.

The Maryland Coastal Bays Survey historically captured Gray Triggerfish, but not in recent years (Angel Willey and Craig Weedon, Maryland DNR, personal communication to RWL and NK). That survey employs sampling using a 16-foot trawl at 20 fixed sites throughout Maryland's coastal bays on a monthly basis from April through October (1972 to present). Beach seine sampling (100-foot bag seine) is conducted at 19 fixed sites in June and September (1993 to present). The two beach seine sampling months were not consistent prior to 1993. The survey captured 50 individuals by beach seine and trawl, mostly in 1991 but with some in 1989, 1995, 2000 and 2002 (Maryland DNR, unpublished data). The range in TL was 49-84 mm, with mean of 66 mm, and the most productive sites were near an inlet (Craig Weedon, Maryland DNR, personal communication to RWL). These sizes are consistent with those of juveniles settling from their *Sargassum* pelagic habitat. The absence of Gray Triggerfish in more recent years was deemed due to dropping July sampling, and also dropping sampling at a site which had previously yielded Gray Triggerfish (Craig Weedon, Maryland DNR, personal communication to RWL and NK).

Klibansky (personal communication to RWL) provided general comments about the task of trying to evaluate the potential for range shifts for Gray Triggerfish (or any other species assessed in the southeast, for that matter). As he notes, "…we generally only have the data to detect pretty large changes in distribution. To identity subtle changes in a species range over time, we need precise information on relative abundance over time and space. That means we need an index of abundance with a spatial distribution that is broad enough to cover the area we are interested in with sufficient samples collected over that area for many years." He notes further that "… our indices (e.g., SERFS survey) are [not] rich enough to detect spatial changes over time, even within the Southeast US Atlantic." For other types of data where we could only very roughly characterize CPUE over time, we would only be able to detect a big change in distribution (N. Klibansky, personal communication to RWL).

<u>Fishery-Dependent Survey Data</u>

Fishery-dependent data sets examined included commercial (ACCSP data warehouse) and recreational (MRIP) fishery landings data from the states north of the North Carolina/Virginia border. These data time series were examined and analyzed by Fitzpatrick and Williams (2022), as well in sections of the Data Workshop Report (see Lowther et al. 2022, and Brennan et al. 2022).

Fitzpatrick and Williams (2022; E. Williams, personal communication to RWL) examined the limitation of MRIP data from throughout the US east coast range, for developing a Gray Triggerfish abundance index. Although they concluded that "…the development of a gray triggerfish index of abundance from the MRIP intercept data…." should NOT be pursued, their Figure 11 (reproduced herein as Figure 6, heat map of Gray Triggerfish landings by latitude and year, does seem to hint at an increase in the number of Gray Triggerfish intercepts northward and toward the end of the time series, an interpretation with which one of the authors doesn't completely disagree (E. Williams, personal communication to RWL). However, Williams further notes that it is of questionable importance to document such a shift in context with the current assessment, given the time scale over which such a species shift may be occurring. He does concur (E. Williams, personal communication to RWL) that the information is important but "…a little ahead of its direct utility."

Further analysis of the MRIP, and Southeast Region Headboat Survey (SRHS) data is found in Brennan et al. (2022). They observed that "Geographically, most [recreational] landings come from eastern Florida (about 48%), followed by North Carolina (about 19%) and New Jersey in the Mid-Atlantic (about 11%). Gray triggerfish landings have generally increased from 1981 – 2021." Private boat landings are also relatively high in New Jersey: "Geographically, most [private boat] effort comes from eastern Florida (about 33%), followed by the North Carolina and New Jersey in the Mid-Atlantic (both about 11%). Recreational fishing effort has generally increased from 1981 – 2010, with some decline in years 2010-2021." See their Figure 4.13.2 for a visual depiction of the distribution of total recreational landings (AB1), in thousands of fish, for Gray Triggerfish across the South and Mid-Atlantic. See also Figure 7, this report, which illustrates that the proportional contribution of Gray Triggerfish landings from north of North Carolina may be relatively large in some years (Samantha Binion-Rock, personal communication to RWL).

Analysis of the commercial landings data is provided by Lowther et al. (2022), which also provides the details of their methodology. They determined commercial landings of Gray Triggerfish occur as far north as Massachusetts (Lowther et al. 2022, Page 4). Although the northern landings data are reported as "unclassified" triggerfish, their decision is to report all landings of triggerfish north of North Carolina as Gray Triggerfish. They determined that "There are relatively few landings of triggerfish north of North Carolina" (Lowther et al. 2022, Page 8). That conclusion is borne out in the table provided by C. Collier and M. Rinaldi (C. Collier, personal communication to RWL) and included herein as Table 1. Although the commercial landings are small, in one of the five-year time periods examined the amount approached five percent of the US east coast total landings for the species (2010-2014). The commercial landings data and analysis do not suggest any noticeable substantial increase in landings north of North Carolina.

Nontraditional Data Time Series

We examined nontraditional data sets from state angler recognition programs (Table 2) to assess the seasonality and numbers of certifications being issued during the time series provided, as well as documenting state record Gray Triggerfish (Table 3). Multiple authors (Quinn 1987, Lucy and Davy 2000 and Musick et al. 2022) note the benefits which nontraditional data sources may provide for management use. Quinn (1987) defined "angler recognition program" as "…a program that gives awards to anglers who submit official affidavits for the catch of large fish." His survey indicated (Quinn 1987, Table 2) that all but three of the U.S. East Coast states had established such programs. He noted that returns to such trophy fish programs can contribute to the assessment of the effects of management strategies on fish population structures. Successful programs, he noted, "…can increase angling participation and inject enthusiasm into the sport…." It may be that in this case, the time series is still relatively young and sample size relatively small, but we still felt it was worth examination and would provide insight to Gray Triggerfish distribution and seasonality of catches north of North Carolina.

Our current survey of state agency web sites documented current angler recognition and state record programs in all East Coast states except Maine (see Tables 2, 3 and Appendix 1). All states except Maryland, Pennsylvania, Massachusetts and Maine include Gray Triggerfish as an eligible species in either their angler recognition program, or in their state record listing, or both. We documented the state “record” Gray Triggerfish from those states which listed that species (Table 3) to determine the largest sizes of fish being caught and documented in northern waters. We also created a table of Gray Triggerfish citations issued by month of capture, for those states which provided that information online (Virginia and Connecticut, see Tables 4 and 5). We also examined the seasonality and numbers of Gray Triggerfish captured, tagged, released and recaptured in Virginia’s Game Fish Tagging Program (Musick and Gillingham 2022, Musick et al. 2022).

The nontraditional data document the capture of relatively large Gray Triggerfish in states as far north as New Hampshire, with lengths ranging from 15.5 to 22 inches (38.75-55.0 cm), and weights ranging from 2 pounds 1.12 ounces (New Hampshire) to 7.63 pounds (New York) (Table 3). The year in which state record fish north of North Carolina were first documented ranges from as early as 2008 (New Jersey) to as recently as 2021 (Rhode Island). The timing of state record catches suggests that Gray Triggerfish are relatively recent arrivals to those states, at least in sufficient numbers for anglers to begin encountering them and/or targeting them. Although Virginia citations for large Gray Triggerfish have been issued in every month except February, across all years, most citations of the 638 total recorded during the time series (2001-2022) were issued during summer and fall (Table 4) with the greatest numbers in the period July through November. For the smaller Connecticut time series (2006-2021; Table 5) far fewer citations were issued (total of 10) and for those seven fish for which the month of capture was available, all were captured in the fall (September through October).

Musick and Gillingham (2022) provide summary tagging data for the entire tagging program time series (1995-2021; 2001-2021 for Gray Triggerfish) for the Virginia Game Fish Tagging Program. There were 1,837 Gray Triggerfish tags and 407 recaptures from 2001-2021 (see their Table 2, Page 39). Gray Triggerfish had a high historical recapture rate of 22.2%. The top tagging location in 2021 was Off VA Beach midshore waters (39.4% of effort, see Table 20 in Musick and Gillingham 2022, Page 36). In previous years (2001-2020), False Cape was the top tagging site (15.3% of effort). The highest number of recaptures in 2021 took place at the Anglo-African Wreck (n=9, see Table 21 in Musick and Gillingham 2022). Tagged triggerfish ranged in size from 9-19 inches TL (22.5-47.5 cm), with the peak effort at 14 inches (35 cm; n=18, Musick and Gillingham 2022, Figure 10, Page 35); all fish were mature (>7.2” TL). Historically, peak effort from 2001-2021 took place at the 13-inch TL size class (n=177 tags). Days at large ranged from 0 to 75 days. Recaptures of Gray Triggerfish took place during the months of July through October (see Table 6, this report). A majority of the recaptures occurred in Virginia waters relatively near to where the fish were originally tagged. Through 2020 (Musick and Gillingham 2021) the top recapture location was off the Virginia Beach oceanfront (n=47 tags, Table 45 in Musick and Gillingham 2020). Triggerfish were recaptured at 72 locations ranging as far north as Chincoteague, VA (Can Wreck, Winter Quarter Shoal), and as far south as Oregon Inlet, N.C. (n = 2). Recaptured triggerfish were at large from zero to 649 days, with an average of 32 days at large. Examples of data available for the tagged Gray Triggerfish are provided in Figures 8-10.

Social Media Posts and Other Online Information

Social media posts accessible via the Internet indicate targeted recreational fishing for Gray Triggerfish is now commonplace in states north of North Carolina primarily on a seasonal basis (mostly summer and fall). A list of links to some of these postings is provided in Appendix 2 (we did NOT conduct an exhaustive search, so there are likely many more). One such post (Newhall 2019; see https://www.thefisherman.com/article/triggerfish-fiesta-from-the-jetties-to-the-reefs/#close-modal) stated: "Triggerfish, in respectable abundance, have been showing up in New Jersey waters for ***many years now*** [emphasis added]. There has even been an increased amount of triggers caught in the northern part of the Garden State as opposed to just being exclusive to the southern portion of the state. ***This is another example of migration change and expansion of range*** [emphasis added]***.***" Additional sources document angling for the species in Delaware Bay (Burnley 2020).

7.2 Conclusions

No index from fishery-independent or fishery-dependent data is available from existing time series which provides a reliable trend indicator for Gray Triggerfish abundance and distribution for the area north of North Carolina; therefore, whether or not a statistically-significant change has occurred in their spatiotemporal distribution is not possible to say at this time. However, documented commercial landings occur as far north as Massachusetts, and documented recreational landings are routinely occurring in the Mid-Atlantic states, especially in New Jersey. Gray Triggerfish, including large adults (probably at least Age 7, based on the documented sizes; N. Klibansky, personal communication to RWL) are routinely caught and landed in that area each year as reflected in "trophy fish" citations issued for Gray Triggerfish by participating states. Although most captures occur in summer and fall, Gray Triggerfish trophy citations have been awarded in every month of the year except for February, in Virginia, although a majority of them occur in summer and fall. The percentage of coastal commercial landings in New Jersey rival those from North Carolina (Lowther et al. 2022) and the proportion of MRIP landings from New Jersey is occasionally also substantial (see Figure 7). Available nontraditional data and social media posts suggest the numbers of Gray Triggerfish may be gradually increasing with time, given that large adults are routinely caught and certified annually, and that recreational fisheries for them are occurring on an annual basis. Anglers in at least one jurisdictions (New Jersey; Joe Cimino, personal communication to RWL) are already advocating for management measures for the species. The perception on the part of some anglers is there is an ongoing northward migration and range expansion of Gray Triggerfish occurring due to climate change.

7.3 Research Recommendations

Consider whether the SERFS video or Chevron Trap time series may be analyzed to detect any shift in center of distribution for Gray Triggerfish.

Examine the time series of Gray Triggerfish trophy citations issued by jurisdictions north of North Carolina, either individually or cumulatively, for any utility in establishing an index.

Examine the time series of Gray Triggerfish captured, tagged, released and recaptured by the Virginia Game Fish Tagging Program, to determine if a useful index might be generated.

Contact additional colleagues who coordinate long-term inshore/estuarine fishery-independent surveys to determine if there are additional Gray Triggerfish records north of North Carolina, and whether an index might be constructed.

Examine social media posts to see if a useful index of anglers targeting Gray Trigger fish could be generated for recent time periods (decades?, five-year periods?, annual?).

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7.4 Tables

Table 7.4.1. Commercial landings data for Gray Triggerfish from the ACCSP Consolidated State and Federal Dealer Reporting by percentage for South Atlantic, and Virginia-north, by five-year time period (spatial of landing; data and analysis courtesy of M. Rinaldi, personal communication to C. Collier and RWL)

YEAR RANGE	SOUTH ATLANTIC	VIRGINIA-NORTH
1980-1984	99.73 %	0.27 %
1985-1989	100.00 %	0.00 %
1990-1994	98.43 %	1.57 %
1995-1999	96.99 %	3.01 %
2000-2004	95.84 %	4.16 %
2005-2009	97.34 %	2.66 %
2010-2014	95.09 %	4/91 %
2015-2020	96.03 %	3.97 %
Grand Total	96.83 %	3.17 %

Table 7.4.2. Status of angler "trophy" fish citation programs AND State Records for Gray Triggerfish in ASMFC South Atlantic states (SAFMC jurisdiction) and states north of North Carolina (MAFMC, NEFMC jurisdictions). States listed from south to north. NA = not applicable since Gray Triggerfish are not included in the citation program or they do not have criteria for Gray Triggerfish angler awards.

STATE	ANGLER CITATION AWARD and/or STATE RECORD PROGRAM?	GRAY TRIGGERFISH INCLUDED	GRAY TRIGGERFISH CITATION CRITERIA
Florida	YES, Trophy Catch, and Big Catch, both designed for freshwater fish; and Catch a Florida Memory, for saltwater species	YES	Minimum weight of 1 lb; new record for fish under 25 lbs must weigh at least 2 ozs more than existing record
Georgia	YES, Angler Award Program, but only includes freshwater and/or anadromous species; Georgia does maintain state record catches for marine species	YES	NA
South Carolina	YES, Angler Recognition Program, but only includes freshwater and/or anadromous species; South Carolina does maintain state record catches for marine species	YES	NA
North Carolina	YES, North Carolina Saltwater Fishing Tournament, aka Citation Program, in place since ?	YES	Minimum weight 5 pounds; no length requirement
Virginia	YES, Virginia Saltwater Fishing Tournament, in place since 1957	YES, since 1999	Minimum weight 4 pounds, minimum length 20 inches for release citation

STATE	ANGLER CITATION AWARD and/or STATE RECORD PROGRAM?	GRAY TRIGGERFISH INCLUDED	GRAY TRIGGERFISH CITATION CRITERIA
Maryland	YES, FishMaryland recreational fishing award program since 2019; other similar programs prior to that beginning 1957	NO, but under consideration (personal communication, E. Zlokovitz)	NA
Delaware	YES, Delaware Sportfishing Tournament, operating since the 1930's	YES	Adult division: minimum weight 5 pounds; length 20 inches for release citation; youth division, weight 3.5 pounds, length 18 inches
Pennsylvania	YES, Angler Award Program, in operation since at least 1986, for freshwater and anadromous species only; also has state record fish listings	NO	NA
New Jersey	YES, Skillful Angler Program, operating since 1983	YES	NA
New York	YES, Angler Achievement Awards Program, for freshwater and anadromous species; also Annual Marine Angler Reward Program	YES	Minimum length criterion 14 inches; no weight requirement
Connecticut	YES, Trophy Fish Award Program and Angler Recognition; marine Certificate of Merit awarded	YES	No criteria specified for Gray Triggerfish

STATE	ANGLER CITATION AWARD and/or STATE RECORD PROGRAM?	GRAY TRIGGERFISH INCLUDED	GRAY TRIGGERFISH CITATION CRITERIA
Massachusetts	YES, Freshwater Sportfishing Awards Program, includes anadromous species	NO	NA
Rhode Island	YES, Rhode Island Game Fish Award Program, includes both fresh- and saltwater species	YES	Minimum length criterion 17 inches; minimum weight 3 lbs
New Hampshire	YES, Trophy and Record Fish Programs	YES	NA
Maine	NO, there appears to be no angler recognition program in Maine; there is a state record list but it does not include Gray Triggerfish	NO	NA

Table 7.4.3. **State Record** Gray Triggerfish Catches **including those north of North Carolina**, both current and historical state record fish. All information was derived from materials accessible from the Internet via state agency web sites, or other posted information. ND=no data available from the internet site(s) examined. Access the information through the links provided in Table 1 and/or Appendix 1:

STATE	DATE	ANGLER (home state), LOCATION	LENGTH	WEIGHT
Florida	04/28/2012	Kenneth Baker (FL), Pensacola	ND	13.25 lb
Georgia	09/15/1989	Dean Williams (GA), Savannah Snapper Banks, Atlantic Ocean	25.25 inches	11 lb 3 oz
Georgia	11/14/1987	Elizabeth C. Zeagler (GA), Savannah Snapper Banks, Atlantic Ocean	29 inches	11 lb 4.8 oz
South Carolina	1989	J. Hilton (SC), Murrells Inlet	ND	13 lb 9 oz
North Carolina	1992	Annette F. Carrico (NC?), Morehead City	ND	11 lb 6 oz
North Carolina	1990	Billy R. Ayers (NC?), off Wrightsville Beach, Atlantic Ocean	ND	11 lb 4 oz
Virginia	11/01/2017	Dave Walden (VA), Chenango Wreck site 50 miles off Virginia Beach, Atlantic Ocean **(this was the first VA state record for the species)**	18.5 inches TL	6 lb 12 oz
Maryland	09/25/2020	Logan Liddick (PA), shipwreck 14 miles off Ocean City, Atlantic Ocean	20 inches	6.0 lbs
Maryland	10/30/2019	Mike Glyphis (MD), 16 miles off Ocean City, Atlantic Ocean		5.6 lbs
Maryland	10/31/2014	**Wayne Gower (MD), off Ocean City (this was the first MD state record for the species)**		5 lb 2 oz
Delaware				5 lb 15 oz
Delaware	09/30/2012	Buddy J. Masten (DE), fishing at the Ice Breakers	20 inches	6 lb 5 oz, or 6.32 lbs
New Jersey	08/14/2020	Jeff Meyer (PA), spearfishing,	20 inches	5 lb 7 oz

STATE	DATE	ANGLER (home state), LOCATION	LENGTH	WEIGHT
New Jersey	07/16/2019	Kevin Cavanagh (NJ), spearfishing, off Monmouth Beach	22 inches	5 lb 5 oz
New Jersey	10/16/2018	Brian Cassidy (NJ), spearfishing, off Monmouth Beach	16 3/8 inches	3 lb 13 oz
New Jersey	09/08/2016	James Massamino (NJ), Sea Girt Reef off Manasquan Inlet	19.25 inches	6 lb 11 oz
New Jersey	2008	Ronald Pires (NJ?), High Bar Harbor		5 lb 12 oz
New York	10/03/1999	Steven Newman (NY),		7.63 lbs
Connecticut	2016	Keith Mehmet (CT?), Pine Island, Groton (harvested)	19 inches	6 lb 1.5 oz
Connecticut	2013	Christopher Otis (CT?), Niantic Bay,	19.25 inches	4 lb 8 oz
Rhode Island	10/??/2021	G. Castonguay (MA),	22 inches	4 lbs 8 oz
New Hampshire	08/31/2012	Timothy D. Moore, Jr. (NH), Piscataqua River at Portsmouth	15.5 inches	2 lbs 1.12 oz

Table 7.4.4. Gray Triggerfish "trophy" citations time series for Virginia's annual Saltwater Fishing Tournament, 2000-2022. The tournament online database was created in 2000, but the species was first included in the tournament in 2001. Citation Gray Triggerfish must weigh **four pounds** or larger. Data for 2022 are through December 7. Years affected by Covid are highlighted in yellow. No adjustment has been made for angler effort. The database contains additional data which are not included in this table. All data are available online at: https://mrc.virginia.gov/vswft/index.shtm

YEAR (TOTAL)	NUMBER ISSUED BY MONTH OF CAPTURE									
	Jan	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2000											
2001 (13)	0	0	0	0	1	0	2	4	4	2	0
2002 (43)	0	0	0	0	0	1	4	11	21	6	0
2003 (6)	0	0	0	0	0	0	1	3	1	1	0
2004 (19)	0	0	0	0	0	3	1	2	11	0	2
2005 (16)	0	0	0	0	0	3	4	1	3	5	0
2006 (22)	0	0	0	1	1	5	2	1	7	0	5
2007 (40)	2	1	0	0	1	2	3	8	23	0	0
2008 (19)	0	0	0	0	1	3	3	4	4	3	1
2009 (16)	2	0	0	0	1	0	7	1	4	1	0
2010 (9)	0	0	0	0	0	1	3	2	3	0	0
2011 (11)	0	0	0	0	1	4	1	2	3	0	0
2012 (51)	0	0	0	0	4	14	9	10	14	0	0
2013 (28)	0	0	0	2	2	2	6	6	7	1	2
2014 (23)	0	0	0	0	3	2	0	4	8	6	0
2015 (53)	0	0	0	0	0	3	8	11	10	9	12
2016 (9)	0	0	0	0	0	2	1	1	1	3	1
2017 (8)	0	0	0	0	0	1	0	1	3	3	0
2018 (13)	0	0	0	0	0	2	1	2	3	5	0
2019 (56)	0	0	0	0	4	11	3	15	15	5	3
2020 (76)	0	0	1	0	0	3	3	8	20	37	4
2021 (93)	0	0	0	0	2	9	12	24	22	7	17
2022 (14)	0	0	0	0	1	1	2	3	4	3	
TOTALS (638)	4	1	1	3	22	72	76	124	191	97	47

Table 7.4.5. Gray Triggerfish "trophy" citations time series for Connecticut's annual Saltwater Trophy Fish Awards, 2006-2021. Years affected by Covid are highlighted in yellow. No adjustment has been made for angler effort. The database contains additional data which are not included in this table. Data are available in annual or multiyear reports online at: https://portal.ct.gov/DEEP/Fishing/General-Information/Trophy-Fish-Award-Program Reports for 2006 through 2008 were combined and did not include dates of capture for the individual fish. Reports for 2015 and 2016 were not included at the site.

YEAR (TOTAL)	**NUMBER ISSUED BY MONTH OF CAPTURE**										
	Jan	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2006 (1)											
2007 (2)											
2008 (0)											
2009 (1)	0	0	0	0	0	0	1	0	0	0	0
2010 (1)	0	0	0	0	0	0	0	1	0	0	0
2011 (0)	0	0	0	0	0	0	0	0	0	0	0
2012 (0)	0	0	0	0	0	0	0	0	0	0	0
2013 (1)	0	0	0	0	0	0	0	0	1	0	0
2014 (0)	0	0	0	0	0	0	0	0	0	0	0
2015 (-)											
2016 (-)											
2017 (2)	0	0	0	0	0	0	1	1	0	0	0
2018 (0)	0	0	0	0	0	0	0	0	0	0	0
2019 (0)	0	0	0	0	0	0	0	0	0	0	0
2020 (1)	0	0		0	0	0	0	0	1	0	0
2021 (1)	0	0	0	0	0	0	0	0	1	0	0
TOTALS (10)	0	0	0	0	0	0	2	2	3	0	0

Table 7.4.6. Virginia Game Fish Tagging Program data for Gray Triggerfish tagged/released, and recaptured, 2001-2021. Annual reports for the program are available for download online at: https://www.vims.edu/research/units/centerspartners/map/recfish/vgftp_reports/index.php The program began tagging Gray Triggerfish in 2001; no release or recapture data for Gray Triggerfish were provided in that report. The data for all the individual fish captures/releases are not provided in the remaining annual reports; complete data are provided only for recaptures hence those were selected for inclusion in this table. Total numbers of Gray Triggerfish tagged and released each year are provided in parenthesis in the far left-hand column. Years affected by Covid are highlighted in yellow.

YEAR (TOTAL TAGGED/RELEASED)	**NUMBER RECAPTURED BY MONTH**										
	Jan	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2001 (14)											
2002 (56)	0	0	0	0	1	3	8	7	4	0	0
2003 (31)	0	0	0	0	0	1	5	4	1	1	0
2004 (193	0	0	0	0	0	25	6	1	3	7	0
2005 (23	0	0	0	0	0	0	2	0	0	2	0
2006 (79)	0	0	0	0	0	9	12	8	3	0	0
2007 (262)	0	0	0	0	8	15	6	5	11	1	0
2008 (212)	0	0	0	0	9	32	19	11	2	0	0
2009 (176)	0	0	0	0	1	7	16	7	8	0	0
2010 (95)	0	0	0	0	2	2	4	7	1	0	0
2011 (13)	0	0	0	0	0	0	0	1	2	0	0
2012 (89	0	0	0	0	1	3	6	2	4	0	0
2013 (24)	0	0	0	0	0	2	0	0	0	0	0
2014 (53)	0	0	0	0	0	1	1	0	2	0	0
2015 (50)	0	0	0	0	0	2	2	2	1	0	0
2016 (22)	0	0	0	0	0	4	2	0	0	0	0
2017 (185)	0	0	0	0	1	4	5	3	1	2	1
2018 (53)	0	0	0	0	1	0	1	0	2	0	0
2019 (33)	0	0	0	0	0	1	5	2	0	0	0
2020 (47)	0	0	0	0	0	0	0	0	0	0	0
2021 (127)	0	0	0	0	1	16	9	2	0	6	0
TOTAL TAGGED 1,837											
RECAPS BY MONTH ACROSS YEARS					25	127	109	62	45	19	1

7.5 Figures

Figure 7.5.1 of SEDAR 41, computer Generated Native Distribution Map for *Balistes capriscus* (Gray Triggerfish) (modeled future range map based on IPCC A2 emissions scenario). www.aquamaps.org, version of Aug. 2013. Web. Accessed 5 Aug. 2014.

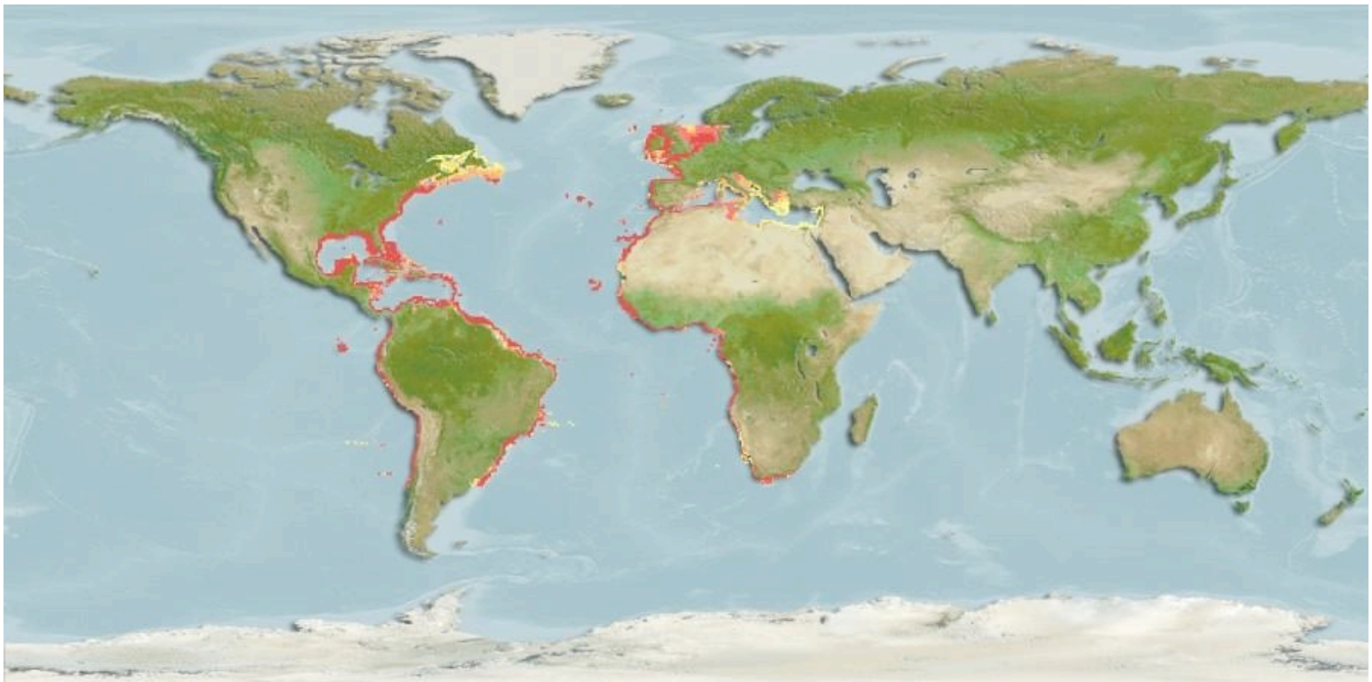


Figure 7.5 2.

NEAMAP time series catch data map for Gray Triggerfish. Data courtesy Jim Gartland, Virginia Institute of Marine Sciences. Available for download at: https://infogram.com/gray-triggerfish-1h7z2lo0ne8l2ow?live

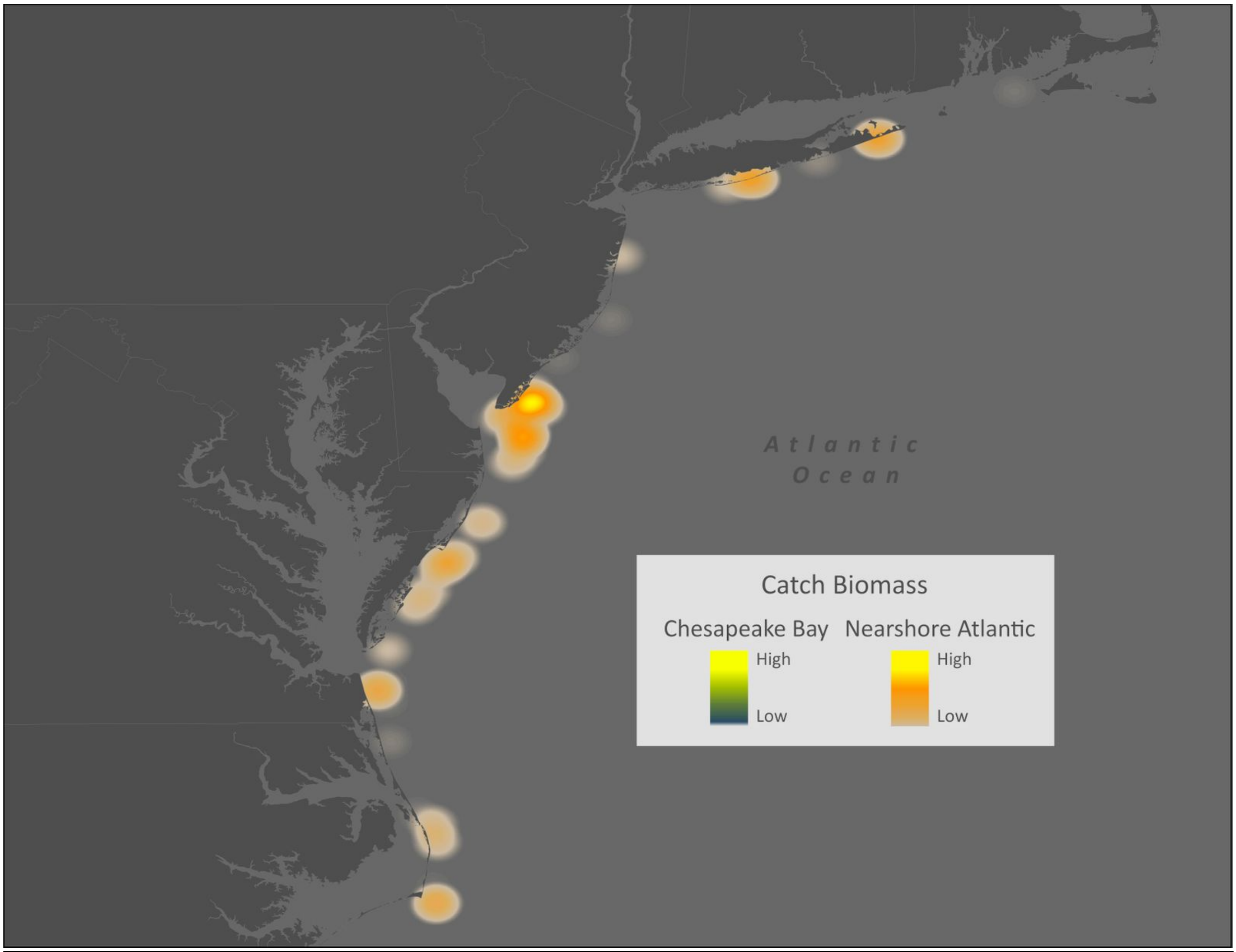


Figure 7.5.3. Catch per unit effort (CPUE) of Gray Triggerfish for the NEAMAP time series (figure courtesy of Dr. Judd Curtis, South Atlantic Fishery Management Council, using NEAMAP unpublished data provided by Dr. Jim Gartland, Virginia Institute of Marine Science; CPUE = mean catch (# individuals / # tows) by year; Error bar = standard error of the mean)

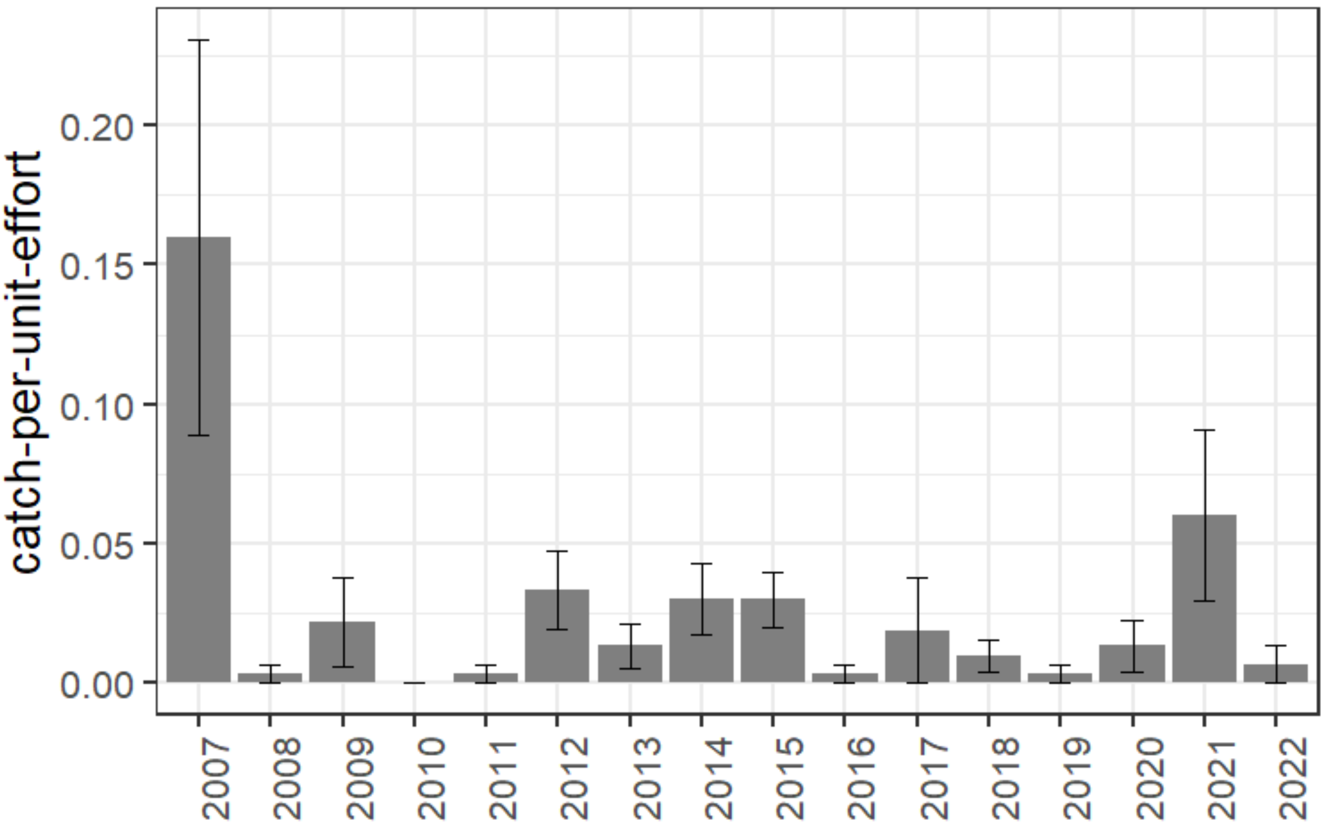


Figure 7.5. 4. Histograms of Gray Trigger lengths captured in the Northeast Fishery Science Center Trawl Survey, by season and latitude bin (figure courtesy of Dr. Nikolai Klibansky using NEFSC unpublished data).

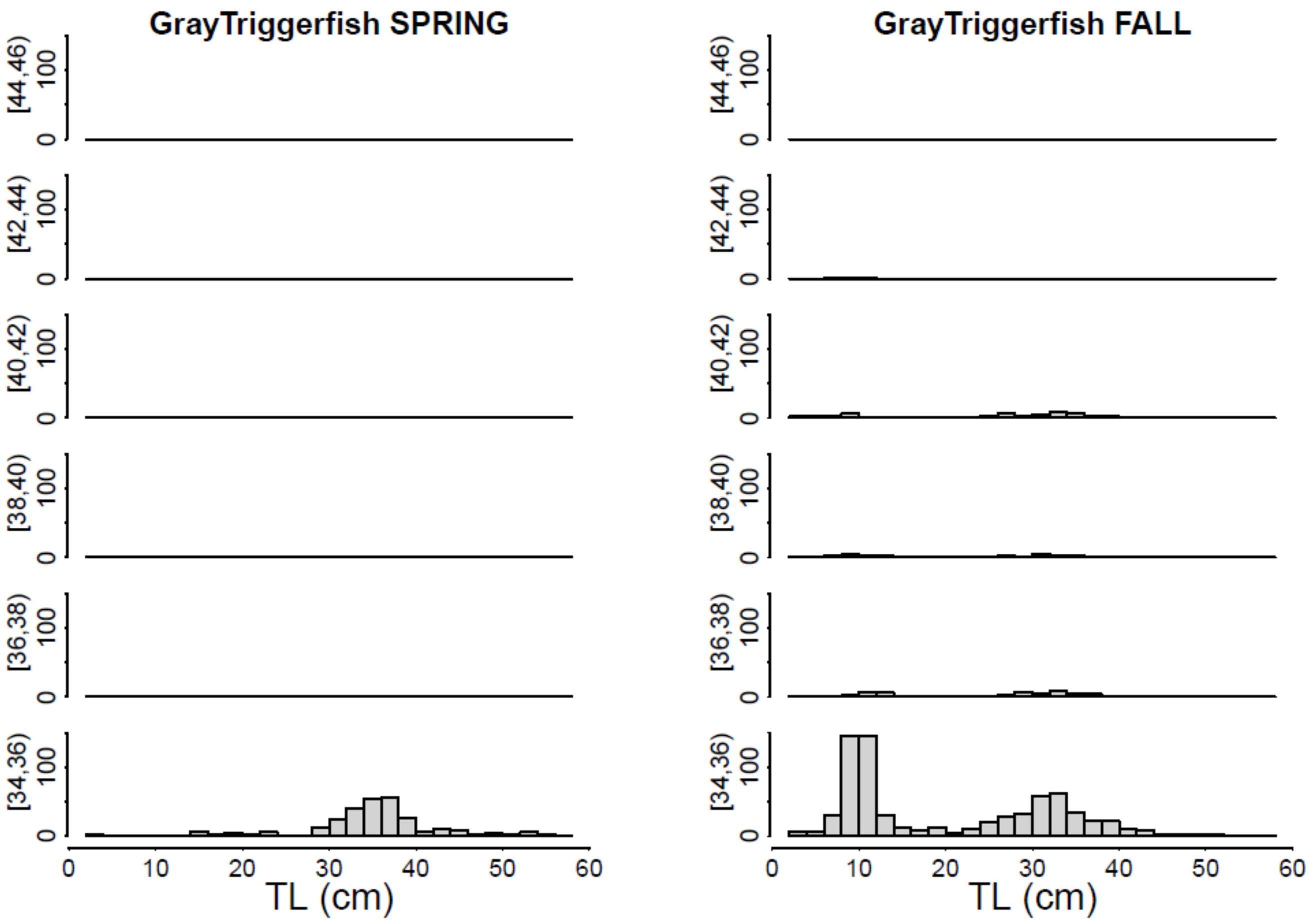


Figure 7.5.5. Number of Gray Triggerfish captured per year by the SEAMAP Coastal Trawl Survey, unadjusted for number of tows or other parameters (graphic courtesy of W. Bubley, South Carolina Department of Natural Resources, Marine Resources Division; unpublished data; personal communication to RWL).

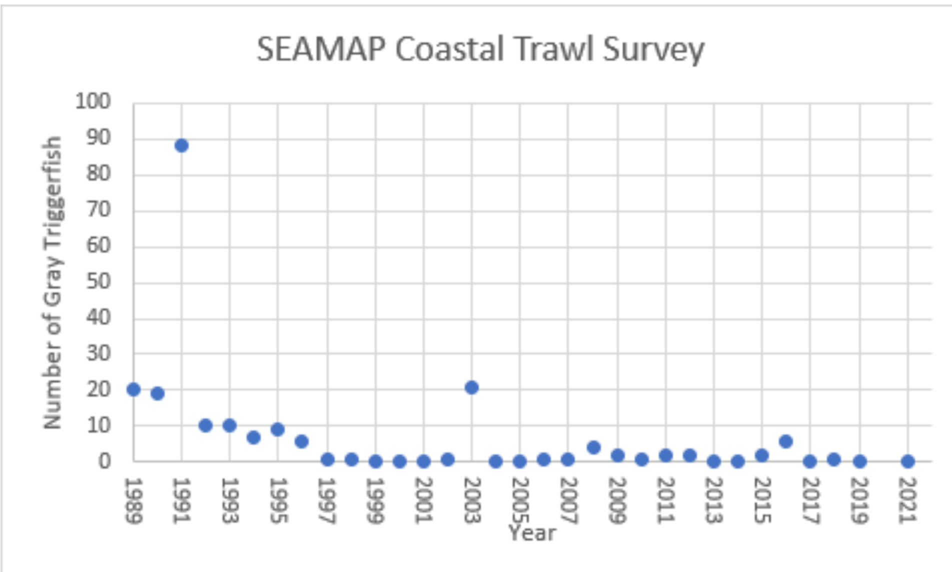


Figure 7.5.6. Figure 11 from Fitzpatrick and Williams (2022) showing heat map of positive gray triggerfish MRIP intercepts by latitude and year.

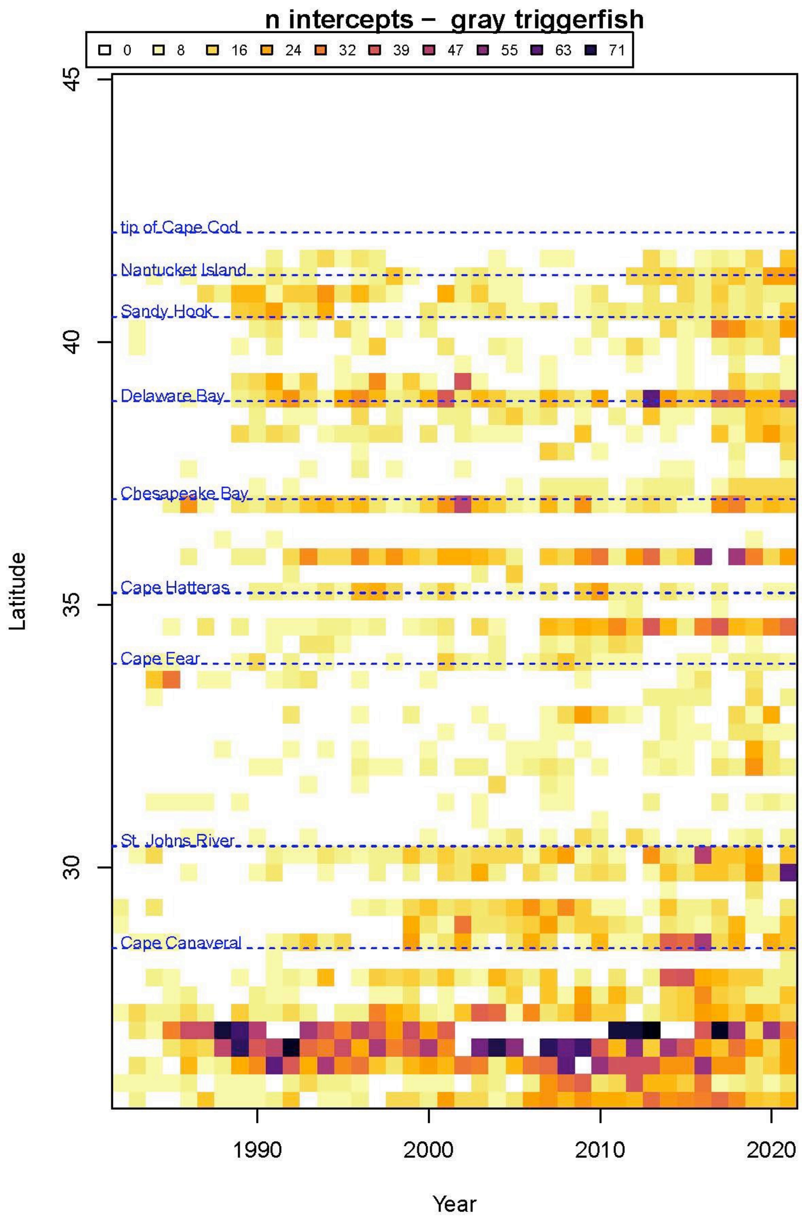


Figure 7.5.7.

Proportional contribution to total recreational landings of Gray Triggerfish, by state, 1980-2020 (figure courtesy of Samantha Binion-Rock, personal communication to RWL).

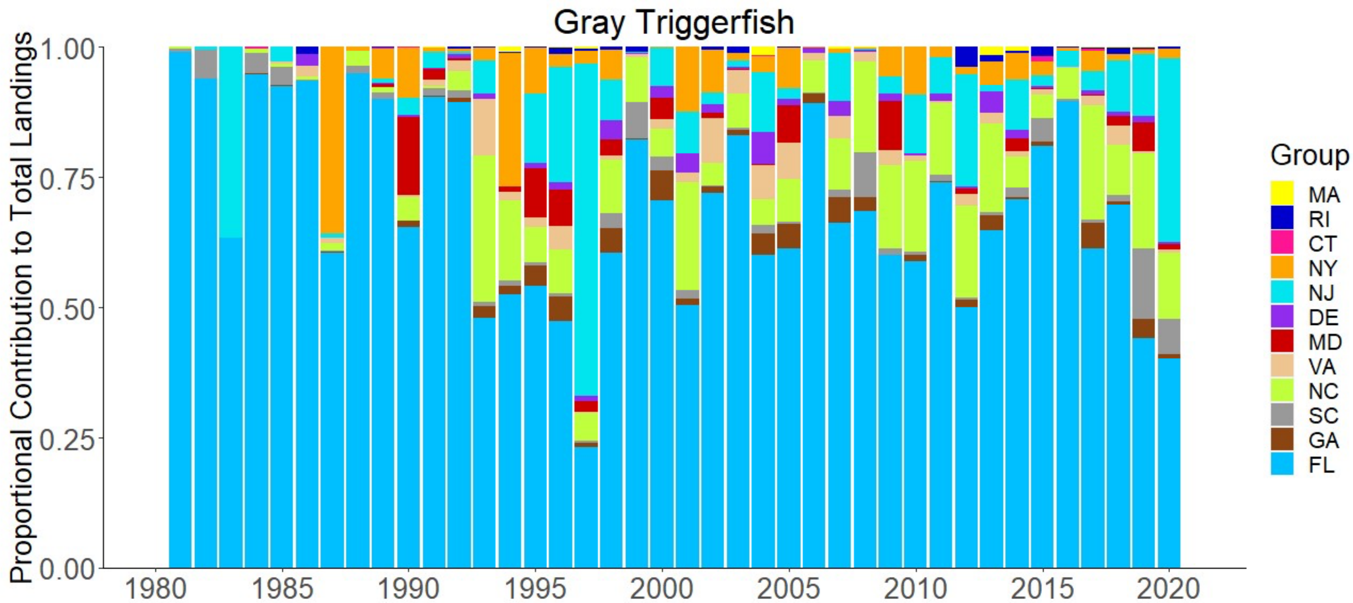


Figure 7.5.8.

Figure 19 a from Musick and Gillingham (2012), showing percentages of Gray Triggerfish tagged at locations in Virginia during 2012 (N = 89 tagged).

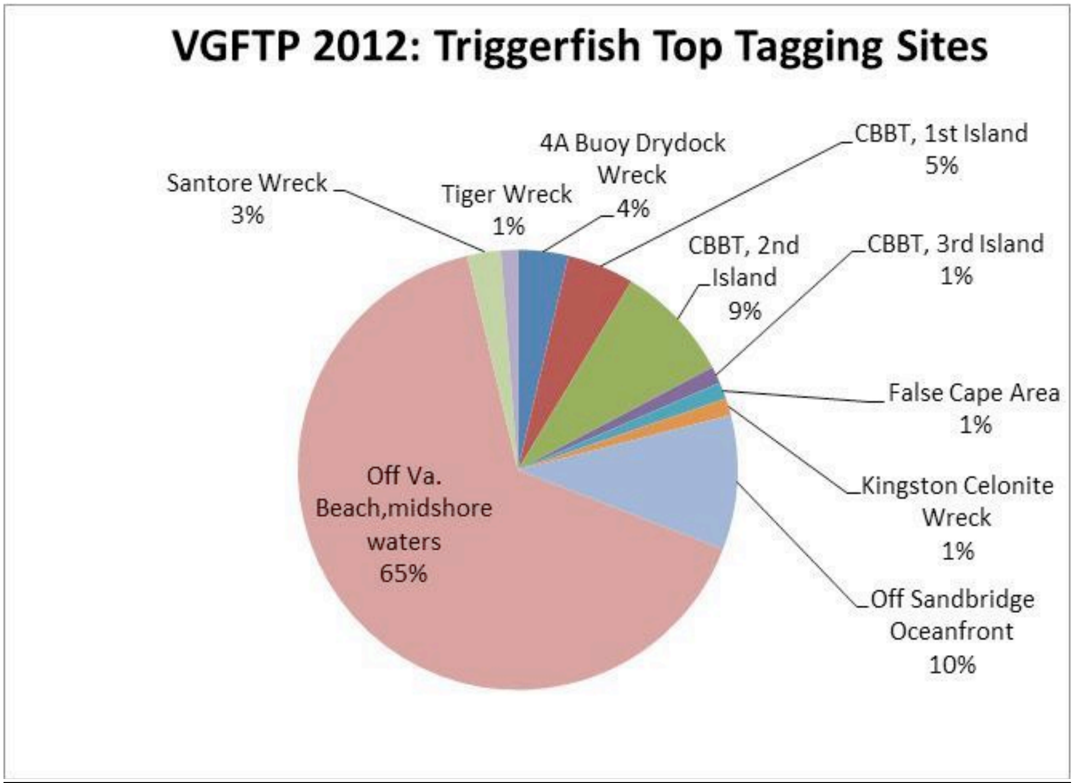


Figure 7.5.9.

Figure 19b from Musick and Gillingham (2012) showing percentages of Gray Triggerfish recaptured in Virginia waters during 2012 (N = 17 recaptures).

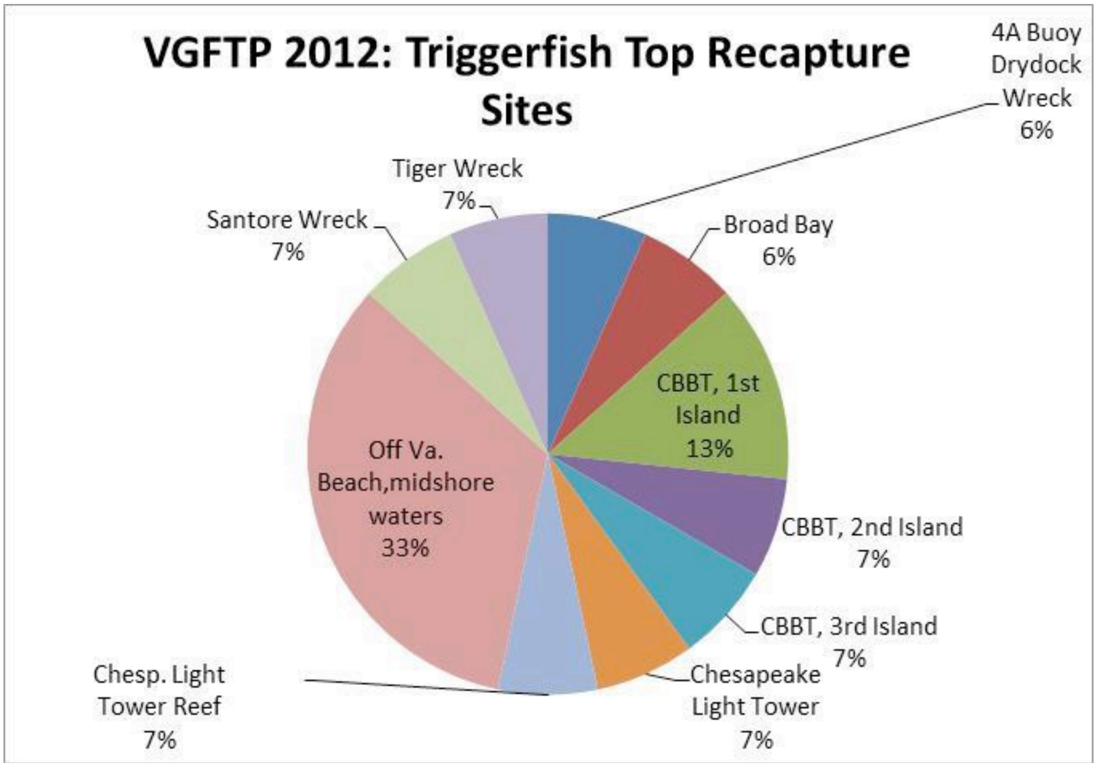
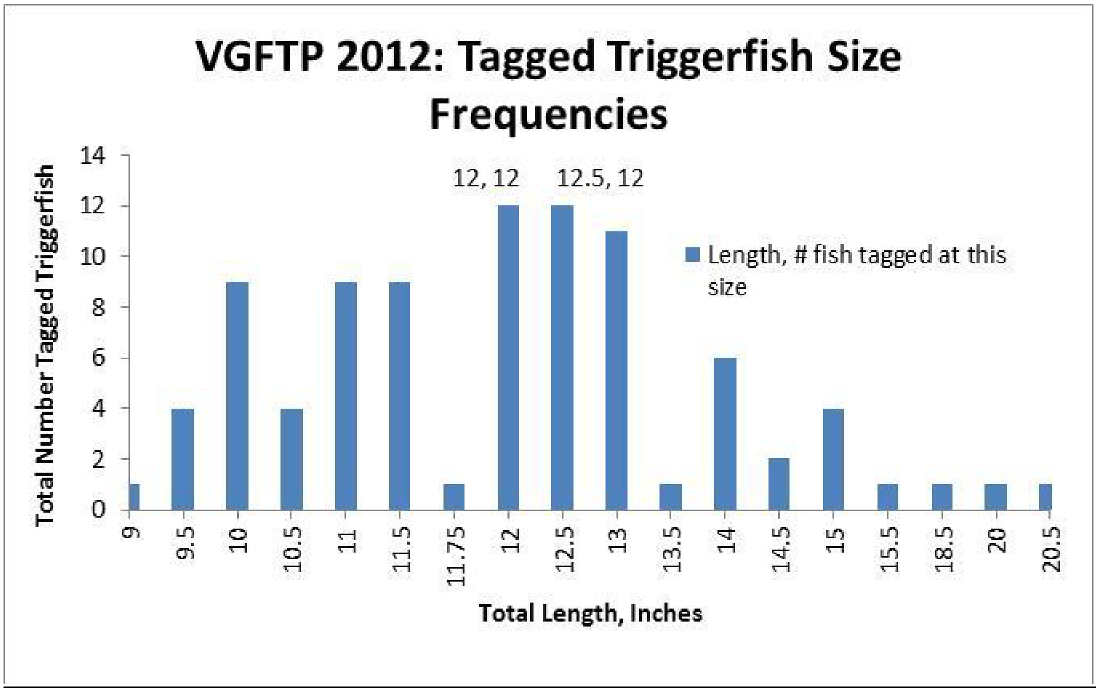


Figure 7.5.10.

Figure 20 from Musick and Gillingham (2012) showing length-frequency of Gray Triggerfish tagged in Virginia waters during 2012 (N = 89).



7.6 Appendix 1

Links to State Angler Recognition and Record Fish Programs and Lists

Florida (does not break out separately for East Coast): See: https://catchafloridamemory.com/programs/records/

https://catchafloridamemory.com/about/rules/

https://myfwc.com/fishing/freshwater/fishing-tips/angler-recognition/

Georgia: For state record list See: https://coastalgadnr.org/SaltwaterRecords; Georgia maintains separate state records for female, and male, anglers.

https://georgiawildlife.com/fishing/anglerawards;

South Carolina: See: https://www.dnr.sc.gov/fishaward/index.html and

https://www.dnr.sc.gov/fish/saltrecs/records.html

North Carolina: See: https://deq.nc.gov/about/divisions/marine-fisheries/public-information-and-education/coastal-fishing-information/nc-saltwater-fishing-tournament and

https://deq.nc.gov/about/divisions/marine-fisheries/public-information-and-education/coastal-fishing-information/nc-saltwater-fishing-tournament/north-carolina-state-saltwater-records

Virginia: Gray Triggerfish was added to the list of eligible species for state record consideration in 1996 with an initial qualifying weight of 6 pounds. In 1999, gray triggerfish was added to the VA Citation list of eligible species for both weight (4 pounds) and release (20 inches); see Tables 1 and 2. See: https://mrc.virginia.gov/vswft/index.shtm

Maryland catches are documented on their web site (https://dnr.maryland.gov/Fisheries/Pages/state-records.aspx) and links are provided to photographs of the anglers with their record fish.

Pennsylvania: Pennsylvania's angler recognition program, and state record fish, do not include Gray Triggerfish. Here are the links for their program: https://www.fishandboat.com/Fish/PennsylvaniaFishes/BiggestFish/Pages/default.aspx

https://www.fishandboat.com/Fish/PennsylvaniaFishes/StateRecordFish/Pages/default.aspx

Delaware: https://dnrec.alpha.delaware.gov/fish-wildlife/fishing/tournament/

New Jersey: See the information on NJ's program at: https://dep.nj.gov/njfw/fishing/freshwater/skillful-angler-program/; and https://dep.nj.gov/njfw/fishing/freshwater/new-jersey-state-record-fish-program/ New Jersey has separate categories for hook-and-line, and spearfishing.

New York: See: https://www.dec.ny.gov/outdoor/7727.html and

https://www.dec.ny.gov/outdoor/7906.html#Records and

https://www.dec.ny.gov/outdoor/7906.html#Annual

Connecticut: Connecticut includes Gray Triggerfish in its Exotic Marine Species Category, with separate records for harvested, and catch/released fish. Certificates of Merit are awarded, see: https://portal.ct.gov/DEEP/Fishing/General-Information/Trophy-Fish-Award-Program for annual reports.

Massachusetts: Massachusetts has a program for freshwater and anadromous species and state records for those species. See: https://www.mass.gov/guides/freshwater-sportfishing-awards-program and https://www.mass.gov/service-details/sportfishing-awards-current-leaders. They also maintain state records for marine species, https://www.mass.gov/service-details/massachusetts-saltwater-game-fish-records, but currently do NOT include a record for Gray Triggerfish.

Rhode Island: Rhode Island has an angler recognition award program for both fresh- and saltwater fish, and also maintains a state record fish list. See: https://dem.ri.gov/natural-resources-bureau/natural-resources-divisions/fish-wildlife/freshwater-fishing/game-fish and https://dem.ri.gov/natural-resources-bureau/fish-wildlife/reports-publications/sportfish-records. Although they include criteria for Gray Triggerfish in the award program and it is listed as a "qualifying saltwater species," the only Gray Triggerfish catch included on their web site is one documented in the "Rhode Island Notable Catches Saltwater Species" listing.

New Hampshire: See the information on New Hampshire's program at: https://www.wildlife.state.nh.us/fishing/trophy.html

Maine: We could find no indication that Maine has an angler recognition program for either fresh- or saltwater species. There is a list of state record species for Maine, https://fishingnortheast.net/choose-your-state/maine/maine-fresh-and-saltwater-record-fish/, but it does not include Gray Triggerfish

7.7 Appendix 2

<u>Social Media Links for Locations North of NC Including Gray Triggerfish as a Target Species</u>

Chesapeake Bay: https://www.fishingchartersvirginiabeach.com/post/triggerfish-fishing-guide

Chesapeake Bay Bridge Tunnel: https://fishtalkmag.com/blog/spadefish-and-triggerfish-cbbt

Chesapeake Bay Bridge Tunnel: https://www.soundingsonline.com/voices/variety-is-the-spice-of-life-summer-fishing-at-the-chesapeake-bay-bridge-tunnel

Virginia Fishing Reports 2009: https://www.tidalfish.com/threads/virginia-fishing-reports-chesapeake-bay-inshore-and-offshore-reports-july-19-2009.550507/

Virginia (what's biting when; shows triggerfish seasonality): https://www.rudeetours.com/fishing-trips/whats-biting-when/

Virginia Gray Triggerfish Regulations: https://app.fishrulesapp.com/regulations/2081

Virginia Gray Triggerfish State Record: https://mrc.virginia.gov/vswft/state_records/VA-state-record_gray-triggerfish_11-01-17.pdf

Virginia Beach Angler's Club Records (includes GT):
http://www.virginiabeachanglersclub.org/State%20Records.html

Virginia: Shaaf Pond (one triggerfish caught): https://fishbrain.com/fishing-waters/rIM4IR9Q/shaaf-pond

Virginia Beach (charter fishing for triggerfish): https://explorecova.com/fishing-virginia-beach/

Virginia Beach (charter fishing for triggerfish): http://www.knottellincharters.com/rates.html

Virginia Offshore Wreck Fishing: https://chesapeakebaymagazine.com/wreck-fishing/

Virginia Game Fish Tagging Program Annual Reports:
https://www.vims.edu/research/units/centerspartners/map/recfish/vgftp_reports/index.php

Maryland Fishing Guide 2021 (with record GT): https://outdoorsman.guide/wp-content/uploads/2021/06/Maryland-Fishing-Guidebook-DNR-Regulations-Report-2021.pdf

Maryland Fishing Report, August 3, 2022: https://news.maryland.gov/dnr/2022/08/03/maryland-fishing-report-august-3/

New Jersey Marine Digest 2021 (with Gray Triggerfish article):
https://www.nj.gov/dep/fgw/pdf/2021/digmar21.pdf

New Jersey Angler Data Request 2009: https://www.state.nj.us/dep/fgw/news/2009/mardataneeded.htm

New Jersey and New York summer surf fishing for Gray Triggerfish:
https://www.onthewater.com/summer-triggerfish

Delaware Gray Triggerfish:
https://fishspecies.dnrec.delaware.gov/FishSpecies.aspx?habitat=2&species=121

Delaware Cape Region: https://www.capegazette.com/article/news-not-all-bad-recreational-fishermen/226066

Delaware Surf Fishing: https://www.delaware-surf-fishing.com/delaware-fish-id/gray-triggerfish-balistes-capriscus/

Delaware State Record Triggerfish: https://www.delaware-surf-fishing.com/trigger-fish-breaks-delaware-state-record/

https://www.thehulltruth.com/mid-atlantic-chesapeake-bay/1097073-fishing-triggers.html

8. Discard Mortality Report

Discard Mortality Participants

Kelly Adler
Judd Curtis
Maria Kappos
Nikolai Klibansky
Wilson Laney
Kevin McCarthy
Micki Pawluk
Beverly Sauls

In order to identify discard mortality rates for South Atlantic Gray Triggerfish for SEDAR 82, the discard mortality working group reviewed the relevant literature. The working group considered literature from the previous assessment (SEDAR 41) and newer sources identified by the data workshop panel. The working group discussed strengths and weaknesses of each source. These sources are discussed below, a brief summary of each is provided in Table 1 and potential concerns are summarized in Table 2.

Ansley & Harris (1981), collected a variety of reef fish species, including Gray Triggerfish, off the Georgia coast in order to quantify potential migratory movements and estimate standing stock biomass. There were 195 Gray Triggerfish tagged in this study, of which 45 were recaptured, which is on par with several other studies in the literature reviewed. This study did not directly calculate mortality and was therefore deemed uninformative by SEDAR 41. The study has been included in Table 1 for a comparison of tagging recapture rates across studies; however, it was not used to inform the estimate of discard mortality for this assessment.

Collins (1996) caught 875 fish from 19 different species using hook-and-line gear, evaluated each fish at the surface in a holding tank for their ability to swim down, and then transferred them to a cage at depth to be reassessed the following day. The overall mortality rate from this study was relatively low, approximately 17%; however, several issues in the design and sample size of gray triggerfish precluded its inclusion in our discard mortality estimate. First, by keeping individuals in cages they are not susceptible to predation, which may be an increased risk when fish are recovering from barotrauma (Campbell et al., 2010). Second, the fish were only evaluated immediately after capture, and once more 24 hours later, meaning delayed mortality effects beyond 24 hours are not considered. Thus the study may substantially underestimate discard mortality. Lastly, of the 875 fish caught, only 6 were Gray Triggerfish. The sample size is therefore too low to be informative of Gray Triggerfish discard mortality.

Patterson et al. (2002) indirectly estimated tagging mortality from release condition for 2,932 Red Snapper and 842 Gray Triggerfish. Fish were caught on hook-and-line gear, retrieved slowly to minimize barotrauma, tagged, and then released, with their swimming behavior post tagging being used to assess release condition. This study was deemed uninformative by SEDAR 41 as it estimates tagging mortality rather than discard mortality, since the retrieval method specifically attempts to mitigate barotrauma.

Another study evaluating discard mortality using release condition was conducted by Stephen & Harris (2010) in which they sought to characterize discard mortality for the commercial fishing fleet. For this study, the captain of a commercial fishing vessel was trained by an observer to evaluate release condition of discarded fish. A total of 732 Gray Triggerfish were caught; however, only 25 were discarded. Of the 25 discarded fish, 93% were presumed dead based on their release condition. This mortality rate is significantly higher than previous studies, and as such was removed as an outlier by SEDAR 41. An important consideration when comparing this study with previous studies is that this study was conducted on a commercial vessel using electric bandit reels, while in previous studies fish were retrieved manually. The faster rate of retrieval likely has an impact on release condition, especially if fishing in deeper waters; however, a sample size of 25 is too small to reasonably inform commercial discard mortality rates. Further studies from commercial vessels with larger sample sizes are needed to better characterize commercial discard mortality.

Rudershausen et al. (2010) mainly focused on Black Sea Bass; however, a reasonably large sample of Gray Triggerfish were tagged in the study (n=332). The study compared tag return rates of fish from various release condition categories. The main assumption of their analysis was that fish in the best release condition category experience no delayed mortality effects; therefore, the ratio of tag returns from the worst condition categories to the ratio of returns for the best release category would give the estimated mortality rate due to discard. An overall discard mortality estimate across release conditions within the fishery was not presented in the manuscript, but personal communication with one of the authors led to an estimate of ~15% discard mortality. This rate was considered by the author to be likely an underestimate according to the SEDAR 41 report.

Further datasets considered by SEDAR 41 included the commercial discard logbook dataset and the Florida headboat observer dataset, both of which were used to estimate discard mortality based on release condition. For the commercial logbook discard dataset, mortality estimates ranged from ~5-9% with logbook data indicating the majority of Gray Triggerfish were released alive. The Florida headboat dataset (2005-2011) indicated that 12% of discards were observed to be in fair to poor condition. Both of these estimates were predicated on the assumption that a fish that is released in good condition will survive. This assumption is also central to several of the other studies reviewed. More recent research has cast doubt on the validity of this assumption, in part due to potential mortality caused by post-release predation and other sources of delayed mortality.

A study by Runde et al. (2019) off the coast of North Carolina tagged Gray Triggerfish caught with either hook-and-line gear or traps, and used a Cox proportional hazard model to compare tag return rates of discarded fish to a control group of fish tagged at depth using SCUBA in order to calculate survival rate after discard. All fish tagged at the surface were evaluated for release condition so comparisons of survival rates could be made across release conditions. SCUBA tagged fish were assumed to have a survival rate of 1 (i.e. 100% survival). A total of 649 Gray Triggerfish were tagged (SCUBA: n=215, hook-and-line: n=242, trap: n=192). Surface tagged fish were assigned one of three condition categories: 1 – no visible trauma, swam down, 2 – visible trauma, still swam down, 3 floated. For conditions 1 and 2, survival rate was calculated by comparing tag return rates to those of the control group tagged at depth, while condition 3 fish were presumed dead. In addition to tagging, necropsies were performed on 68 fish to assess internal injuries from barotrauma.

Overall discard survival rate for the recreational fisheries in North Carolina and Florida in Runde et al. (2019) were calculated by simulating populations of fish with condition categories and depths fished reflective of the recreational fishery. Discard survival was estimated as 0.411 (CI: 0.279, 0.623) in North Carolina and 0.411 (CI: 0.275,0.636) in Florida – meaning discard mortality rate would be estimated as 0.589. Looking only at the fish in condition 1, individuals with hook and line showed a survival rate relative to the control group individuals of 0.485 (i.e. discard mortality rate of 0.515); whereas previous studies have assumed this value to be 1. The necropsies performed on selected fish corroborate these results. It was found that for fish in condition category 1, 24 of 32 fish (75%) caught with hook and line, and 12 of 24 fish

(50%) caught with traps, sustained severe internal injury. This result is highly significant with regards to previous studies/data used in previous SEDARs, as it implies the assumption of 100% survival of best condition fish is likely violated. This study suggests previous studies have grossly underestimated the effect of delayed mortality due to discard on this species.

In the previous assessment (SEDAR 41), the discard mortality estimate was informed by Collins (1996), Rudershausen et al. (2010), SEDAR32-DW11, and SEDAR32-DW14. The final recommendation was for a discard mortality rate of 12.5%, with a confidence interval from 5% - 20%. Both commercial and recreational fleets were assumed to have the same discard mortality rate, and the rate was assumed to be constant through time.

After reviewing the available literature, the SEDAR 82 Discard Mortality Working Group agreed the study by Runde et al. (2019) represents the best available science regarding discard mortality rate for Gray Triggerfish. To come up with a recommended rate to be used in the assessment, the working group looked at the rates reported for the North Carolina and Florida fisheries. Both fisheries were centered on the same discard survival rate, with slightly differing confidence intervals. Since both fisheries were centered on the same rate, the working group felt justified in recommending a single discard mortality rate across the whole region, rather than adjusting the rate by state. To calculate a mortality rate recommendation, we subtracted the survival rate from 1, yielding a recommended discard mortality rate of 0.589 or 58.9%. To calculate a recommended confidence interval for sensitivity analyses, we took the lower of the two lows from the North Carolina and Florida confidence intervals, and the higher of the two highs. This yields a recommendation of 0.589 (CI: 0.364,0.725). The reasoning for this choice in upper and lower bounds was to use confidence intervals of both regions to characterize uncertainty of discard mortality in a stock assessment of the entire US Southeast Atlantic. Note that these estimates incorporate a correction to the original computation described in SEDAR82-DW12 based on work by Sutradhar & Austin (2018).

The working group discussed the possibility of estimating discard mortality rate separately for the commercial and recreational fleets. However, since both fleets are comprised almost exclusively of hook-and-line gears, the working group felt justified in recommending a single discard mortality rate across fleets. Still the working group included the caveat that if evidence suggests a significant difference in depth fished for the commercial fleet, the value should be adjusted to reflect that difference. Additionally, it is unclear whether hydraulic/electric reels significantly impact discard mortality. If further research shows an impact of those gear types, the recommendation would be to estimate discard mortality separately for the commercial and recreational fleets.

8.1 Recommendation

The plenary accepted the working group's recommendation of discard mortality of 58.9% with a sensitivity interval ranging from 36.4 to 72.5% for all sectors.

8.2 Future Research Recommendations

The new study by Runde et al. (2019) represents an important step forward in determining the discard mortality rate of Gray Triggerfish caught in the hook-and-line fisheries. Further studies should seek to confirm the results of this study, increasing sample size and spatial coverage to increase confidence in the estimate. Additionally, a similar study is needed for the commercial fishery, especially for bandit reels, which may have a higher probability of causing barotrauma due to the retrieval speed. A similar study covering the mean depths fished in the commercial fishery, and using gear typical of the commercial fishery, would allow for better characterization of mortality across fleets and help to determine whether separate discard mortality estimates are necessary.

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Sutradhar, R., & Austin, P. C. (2018). Relative rates not relative risks: Addressing a widespread misinterpretation of hazard ratios. *Annals of Epidemiology*, *28*, 54–57.

8.3 Tables

Table 8.3.1. Discard mortality literature review summary. Details on the various data sources considered in determining a discard mortality estimate. For each data source (Source), table lists the type of source (Type; i.e. a published study vs. fishery dependent data summary), the number of Gray Triggerfish in the study (n), the estimation method (Method) used if mortality was estimated, the tag recapture rate (R_{rate}) for tagging studies, and the mortality estimate (D_{mort}) provided in the manuscript or by the author in the case of Rudershausen, Buckel, and Burgess 2010. NA = not applicable, CL = Commercial discard logbook dataset, FLHB = Florida Headboat observer dataset

Source	Type	n	Method	R_{rate}	D_{mort}
Ansley and Harris 1981	Study	195	NA	23.10%	NA
Collins 1996	Study	6	Evaluated at surface, caged at depth, re-evaluated after 24hrs	NA	17%
Patterson et al 2002	Study	842	Indirect - Release condition	19.00%	<1%
Steven and Harris 2010	Study	25	Indirect - Release condition	NA	93%
Rudershausen, Buckel and Burgess 2010	Study	332	Direct - cox proportional hazard; control: condition 1 fish	8.43%	15%
Runde et al 2019 (corrected)	Study	649	Direct - cox proportional hazard; control: SCUBA tagged fish	28.80%	58.90%
SEDAR32-DW11	CL	5632	Indirect - Release condition	NA	5-9%
SEDAR32-DW14	FLHB	741	Indirect - Release condition	NA	12%

Table 8.3.2. Potential issues. A brief summary of the caveats or potential issues for each study examined which may impact the estimate provided by the study.

Data source	Potential Issues
Ansley and Harris 1981	1) Does not provide a mortality estimate - non-informative
Collins 1996	2) Small sample size 3) Does not account for delayed mortality
Patterson et al 2002	3) Does not account for delayed mortality 4) Fish retrieval potentially not representative of fishery
Steven and Harris 2010	2) Small sample size 3) Does not account for delayed mortality 5) Captain reported conditions, may not be as reliable
Rudershausen, Buckel and Burgess 2010	6) Assumes no mortality for best condition fish
Runde et al 2019 (corrected)	7) Did not include electric/hydraulic reels, may be too low for commercial discards
SEDAR32-DW11	3) Does not account for delayed mortality 6) Assumes no mortality for best condition fish
SEDAR32-DW14	3) Does not account for delayed mortality 6) Assumes no mortality for best condition fish

9. Gray Triggerfish Desirability Trends

9.1 Group Membership

Beverly Sauls - FWC (Co-lead)
Chip Collier – SAFMC Staff
Elizabeth Gooding - SCDNR
Judd Curtis – SAFMC Staff
Ken Brennan - NMFS
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Walter Bubbly – SCDNR
Wilson Laney – SAFMC SSC, SEDAR 82 Chair

9.2 Group Discussion

Gray triggerfish are caught in conjunction with other snapper-grouper species. They are one of the few species caught bottom fishing offshore where reducing hook size results in catch of fish still above the minimum size limit. The market value, landings, and ad hoc information from anglers and commercial fishing operators suggest that there are have been changes in the desire to keep them for consumption or sale over the last 40 years. These changes can impact our understanding of several stock assessment input time series. Trends in landings of recreational and commercial gray triggerfish operating in the US South Atlantic increased in the mid to late 1980s and early 1990s (Figures 4.13.1 and 3.6). These increases coincide with increases in the recreational and commercial landings in the northeastern Gulf of Mexico between 1986 and 1990 (Harper and McClellan, 1997; Valle et al., 2001). Johnson and Saloman (1984) reported a dramatic increase in landings between 1967 and 1977 in the northwestern Gulf of Mexico. However, this was prior to the much larger increase in the 1990s. Atlantic gray triggerfish landings increased first in eastern Florida followed by the Carolinas (Figure 10.3.1). Landings alone are a poor indicator of desirability and could reflect population abundance trends. However, increased landings in conjunction with changes in market value and ad hoc information from resource participants support desirability changes in gray triggerfish.

All fishery sectors and regions show an increase in landings between the mid-1980s and mid-1990s. After this initial increase, cumulative landings are mostly linear indicating no big increases in landings for headboats across all regions and the North Carolina commercial sector (Figure 10.3.1). However, other recreational and commercial cumulative landings in South Carolina and Florida show another increase starting around 2005, coinciding with an increase in the price per pound. The commercial and recreational cumulative landings north of North Carolina (VA north) are linear after about 1995. One explanation for headboat cumulative landings not showing an increase in 2005 is the gear is typically provided by the vessel, and they are unlikely to change to smaller hooks to target gray triggerfish.

Ex-vessel price per pound can indicate an increase in desirability. However, this can be driven by supply and demand for a suite of species. Inflation adjusted gray triggerfish price per pound increased over the entire time series with a sharp increase in about 2005 (Figure 10.3.2). If this increase were based on market conditions alone, other species should have similar trends. However, a sample of other species' normalized* nominal price per pound showed that only gray triggerfish and greater amberjack increased in 2005 (Figure 10.3.3).

Several reasons for this change in desirability have been proposed. For both recreational and commercial sectors, the increase in landings of gray triggerfish in the late 1980s coincided with population declines in other species historically preferred for consumption (Burton et al., 2015, Figure 10.3.1). Gray triggerfish have leathery skin which makes them a challenge to filet without some minor instruction, which is now readily available online. Another suggested deterrent for keeping gray triggerfish, relative to other species, is the thick slime that decreases quality of ice in the fish box. Once the barriers to keeping gray triggerfish were overcome, an increased awareness of meat quality has raised demand, and recreational and commercial fishers may have started targeting gray triggerfish by using smaller hooks as suggested by several online fishing forums. There was a change in the rate of increase of the ex-vessel price per pound starting around 2006 which may have increased targeting in the commercial sector in more recent years. There was some discussion indicating that commercial vessel captains gave low market value fish to their crews in early years. Recreational targeting is recorded in MRIP with two options to indicate primary species targeted on a trip. This information has limited use since interviews are conducted after a trip, and fishers tend to report targeting what they caught when using gear with limited selection such as hook and line bottom fishing. However, the approximate tripling of trips reporting targeting of gray triggerfish between 2005 and 2018 may provide some corroboration of suspected changes in targeting in the recreational sector with even higher targeting for the most recent years.

It is unlikely the fishery-dependent indices of abundance can be standardized temporally and spatially to account for the changes in desirability given the limited understanding of the rate or timing of the change. Discards and associated uncertainty may be underestimated for methods that assume constant discard proportions relative to landings in later years to predict earlier years. Bias in reporting of less desirable species might be another source of increased uncertainty in discard estimates although this has not been evaluated.

Panelists suggested topics for further research to gain an understating of changes in desirability. These include collecting more extensive information from commercial operators and dealers involved in the fishery since the 1980s, evaluating trends on hook sizes for offshore fishing, searching restaurant menu offerings or recipes for gray triggerfish over time, and evaluating trends in a suite of historically under-utilized species in relation to the decline in more popular species.

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[*] normalized – series of values divided by mean of the series to evaluate trends on a similar scale

9.3 Figures

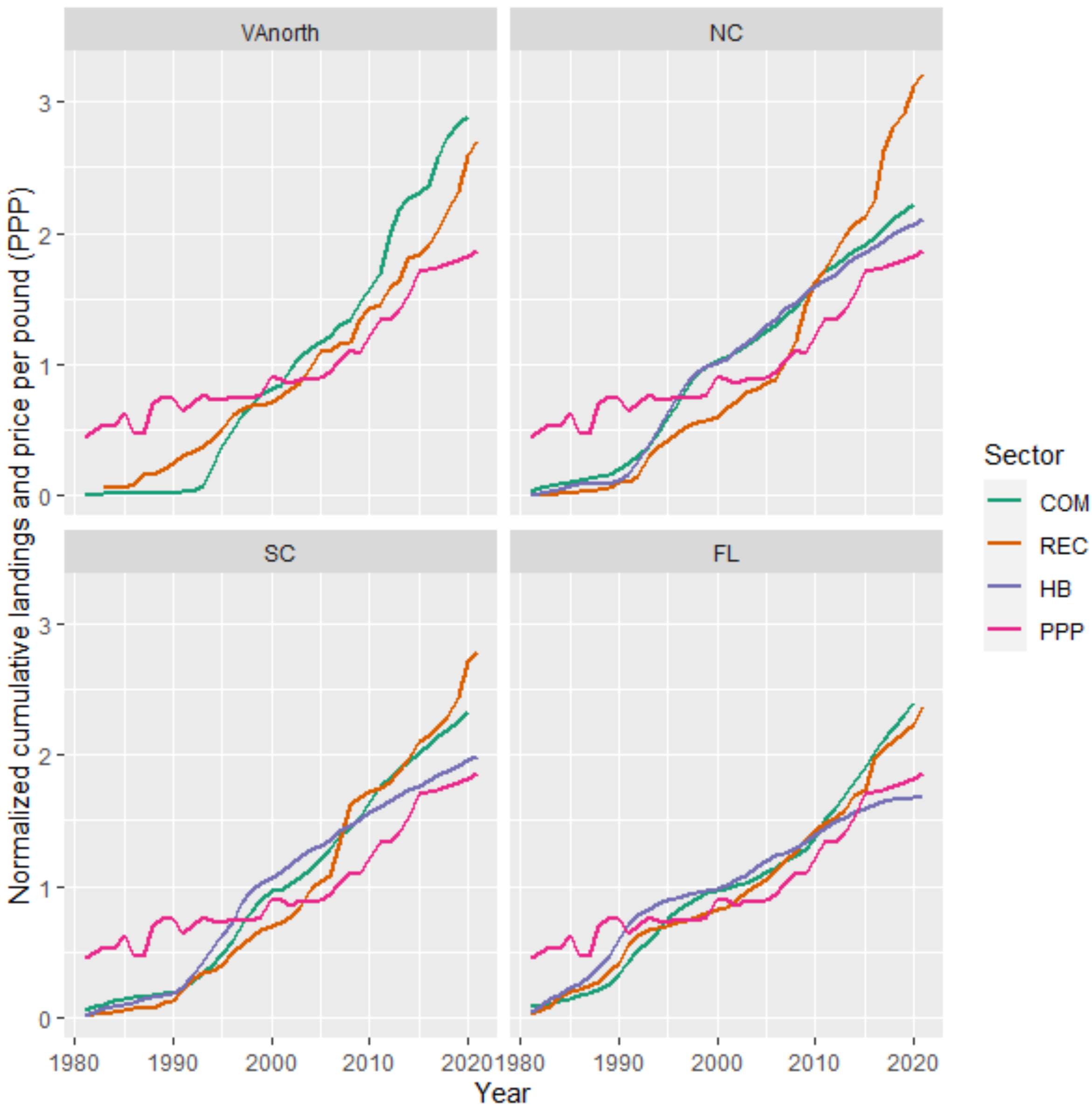

Figure 9.3.1. Recreational headboat (HB), MRIP (REC - charter, private, and shore) and commercial (COM) normalized* cumulative landings of gray triggerfish in U.S. Atlantic and normalized* inflation adjusted price per pound (PPP). Constant landings would be linear, low or decreasing landings would appear flat, and increasing landings would be appear steeper when plotted as cumulative values.

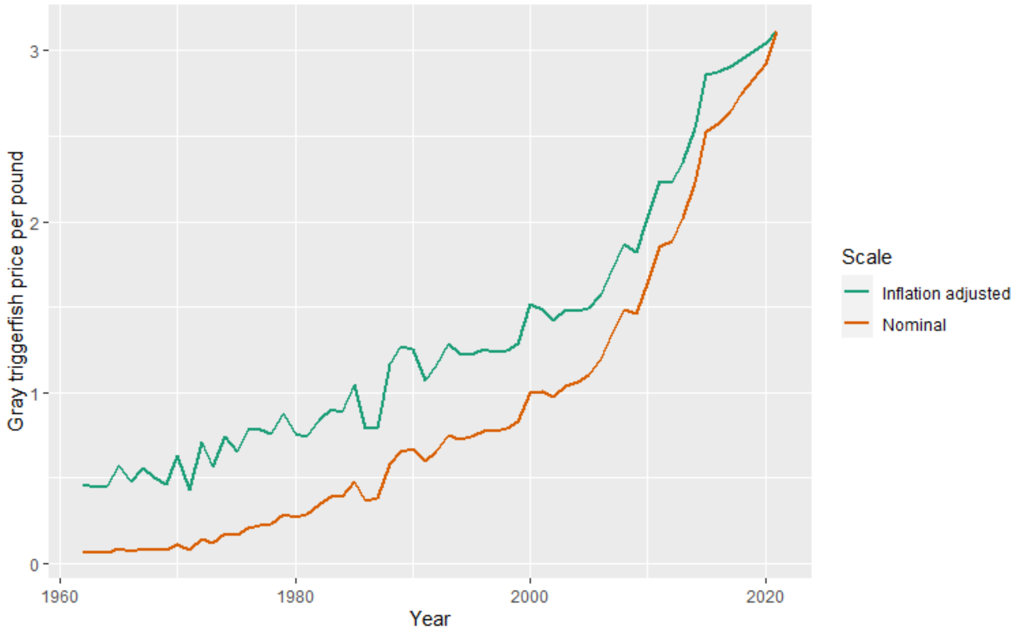

Figure 9.3.2. Nominal and inflation adjusted gray triggerfish price per pound.

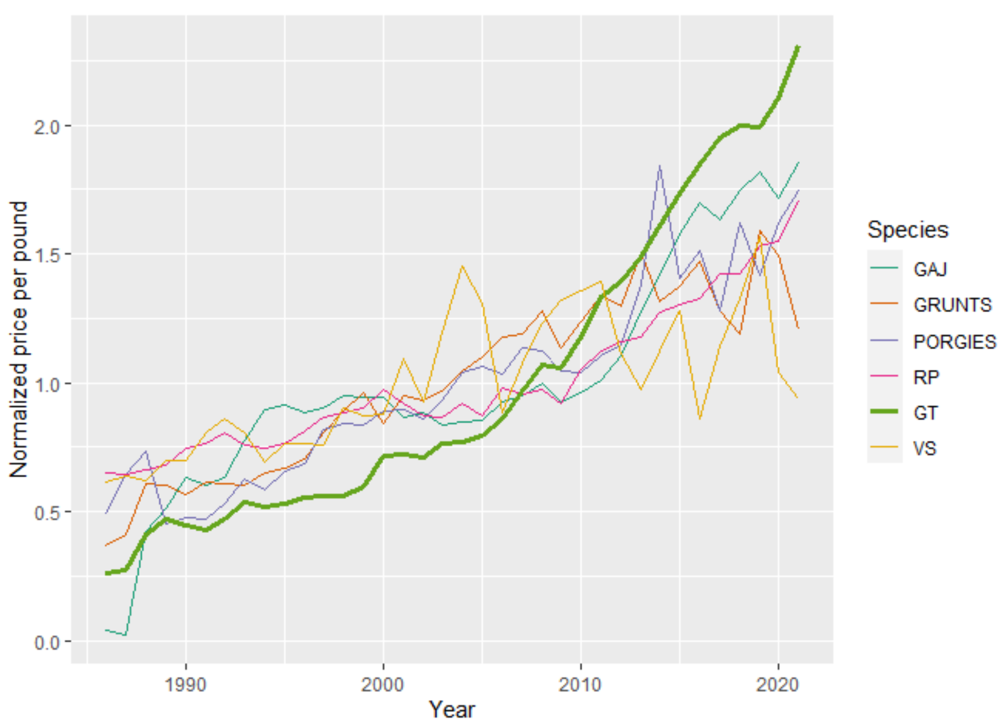

Figure 9.3.3. Normalized* nominal price per pound for gray triggerfish (GT), greater amberjack (GAJ), grunt complex (GRUNTS), porgy complex (PORGIES), red porgy (RP), and vermilion snapper (VS).

SEDAR

Southeast Data, Assessment, and Review

SEDAR 82

South Atlantic Gray Triggerfish

SECTION III: Assessment Report

February 2024

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

List of Tables

List of Figures

1 Introduction

1.1 Executive Summary

The primary objectives of this assessment were to build on the previous assessment (SEDAR 41, 2016 Benchmark SEDAR41 2016), considering new and existing data sources and analytical methods, and to develop methods to be used for future operational assessments. This assessment was conducted by the Southeast Fisheries Science Center in cooperation with regional data providers, for the assessment period 1982-2021.

Available data on this stock included indices of abundance, landings, discards, and samples of annual length compositions and age compositions from fishery-dependent and fishery-independent sources. A single index of abundance was developed during the SEDAR process and fitted by the model: a fishery independent index combining chevron trap and video data, collected by the Southeast Reef Fish Survey (SERFS). Landings and discard data were available from all significant recreational and commercial sources.

The model used in the previous assessment of this stock—and updated here—was the Beaufort Assessment Model (BAM), an integrated statistical catch-age formulation (Williams and Shertzer 2015). A base run of BAM was configured to provide estimates of key management quantities, such as stock and fishery status. Uncertainty in estimates from the base run was evaluated through a mixed Monte Carlo/Bootstrap Ensemble (MCBE) analysis.

Estimated time series of stock status (SSB/MSST) showed a gradual decline during the assessment period, to a minimum value in the terminal year. Current stock status was estimated in the base run to be $\mathrm{SSB}_{2021}/\mathrm{MSST} = 1.33$, indicating that the stock is not overfished. Through its history, SSB has never dropped below MSST. Results from the MCBE suggested that the estimate of SSB/MSST is rather uncertain, but the stock status is not (Figures 42, 43). The assessment showed that 70.3% of MCBE runs agreed with the stock status result from the base model, that the stock is not overfished in the terminal year.

The estimated time series of $F/F_{40\%}$ from the base model suggests that F has only exceeded $F_{40\%}$ in 2009 and 2010, and in the two most recent years of the assessment (2020 and 2021). However, there is considerable uncertainty in $F/F_{40\%}$ as demonstrated by the MCBE, especially toward the end of the assessment period. Current fishery status in the terminal year, with current F represented by the geometric mean from $2019-2021$ ($F_{\text{current}} = F_{2019-2021} = 0.65$), was estimated by the base run to be $F_{2019-2021}/F_{40\%} = 1.16$. Thus, at the end of the assessment Gray Triggerfish was undergoing overfishing. However, results from the MCBE show that there is a lot of uncertainty in the status of the fishery. The assessment showed that 53.6% of MCBE runs agreed with the fishing status result from the model, and the median value of $F_{2019-2021}/F_{40\%}$ from the MCBE runs (1.06) suggests overfishing. The majority of recent fishing mortality for this stock is from the general recreational landings (Table 12; Figure 33).

1.2 Workshop Time and Place

The SEDAR 82 Assessment Process for South Atlantic Gray Triggerfish was conducted via a series of webinars held between March 2023 and January 2024.

1.3 Terms of Reference

1. Review any changes in data or analyses following the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.
2. Develop population assessment model(s) that are appropriate for the available data.
   a. Provide standard model outputs such as parameter estimates and derived quantities.
   b. Evaluate model diagnostics.
   c. If multiple models are applied, then compare and contrast model performances and appropriateness.
   d. Identify modeling issues encountered.
   e. Comment on the data component weighting used in this stock assessment, if necessary.
3. Recommend biological reference points for use in management.
4. Characterize uncertainty in the assessment and estimated values.
   a. Incorporate uncertainty of appropriate input data.
   b. Provide measures of uncertainty for estimated parameters and derived quantities, including biological reference points and stock status that incorporates appropriate input parameter and data uncertainty.
5. Provide recommendations for future research to improve the assessment. Distinguish between long term research needs and short-term research recommendations that could potentially be implemented for Gray Triggerfish Operational Assessments.
6. Complete an Assessment Workshop Report in accordance with project schedule deadlines.

1.4 List of Participants

Assessment Development Team

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1.5 Document List

Document number	Title	Authors	Date Received
	Documents Prepared for the Assessment Process		
SEDAR82-AW01	South Atlantic U.S. gray triggerfish (*Balistes capriscus*) age and length composition from the recreational fisheries	Fitzpatrick 2022*b*	12/12/2022
SEDAR82-AW02	South Atlantic U.S. gray triggerfish (*Balistes capriscus*) age and length composition from the commercial fisheries	Fitzpatrick 2022*a*	12/12/2022
SEDAR82-AW03	Commercial Discard Estimation of South Atlantic Gray Triggerfish	McCarthy et al. 2022	2/21/2023
	Reference Documents		
SEDAR82-RD58	Timing and locations of reef fish spawning off the southeastern United States	Farmer et al. 2017	11/30/2022
SEDAR82-RD59	Virginia Game Fish Tagging Program Annual Report 2021	Musick and Gillingham 2022	12/14/2022
SEDAR82-RD60	Report of the Working Group on Fish Ecology (WGFE)	ICES 2008	12/14/2022
SEDAR82-RD60	Report of the Working Group on Fish Ecology (WGFE)	ICES 2009	12/14/2022
SEDAR82-RD61	Seaweed, seaweed everywhere	Gower and King 2019	1/4/2023
SEDAR82-RD62	The great Atlantic *Sargassum belt*	Wang et al. 2019	1/4/2023
SEDAR82-RD63	The establishment of a pelagic Sargassum population in the tropical Atlantic: Biological consequences of a basin-scale long distance dispersal event	Johns et al. 2020	1/4/2023
SEDAR82-RD64	Southeast Florida and South Carolina Anglers' Release Practices and Their Attitudes Toward Descending Devices	Responsive Management 2022	3/3/2023

1.6 Comments on Terms of Reference

Note: Original ToRs are in normal font. Statements addressing ToRs are in italics and preceded by a dash (−).

1. Review any changes in data or analyses following the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.
   - *See section 2.*
2. Develop population assessment model(s) that are appropriate for the available data.
   a. Provide standard model outputs such as parameter estimates and derived quantities.
      - *See section 4.2.*
   b. Evaluate model diagnostics.
      - *See sections describing results of sensitivity analysis (4.10), an age-structured production model (4.11), and retrospective analysis (4.12).*
   c. If multiple models are applied, then compare and contrast model performances and appropriateness.
      - *See section 4.11 describing results of the age-structured production model.*
   d. Identify modeling issues encountered.
      - *See discussion section 5.1*
   e. Comment on the data component weighting used in this stock assessment, if necessary.
      - *All data components were given equal weight, but see section 3.3.15 for considerations given to data weighting.*
3. Recommend biological reference points for use in management.
   - *See methods sections 3.3.14 and 3.5 and results section 4.8.*
4. Characterize uncertainty in the assessment and estimated values.
   a. Incorporate uncertainty of appropriate input data.
      - *See methods section 3.9*
   b. Provide measures of uncertainty for estimated parameters and derived quantities, including biological reference points and stock status that incorporates appropriate input parameter and data uncertainty.
      - *See results section 4.8*
5. Provide recommendations for future research to improve the assessment. Distinguish between long term research needs and short-term research recommendations that could potentially be implemented for Gray Triggerfish Operational Assessments.

− *See research recommendations section 6*

6. Complete an Assessment Workshop Report in accordance with project schedule deadlines.
   - *This SEDAR 82 Research Track Assessment Report satisfies this ToR.*

2 Data Review and Update

In the current SEDAR 82 assessment, data through 2021 were considered. For some data sources, the data were simply updated with the additional years of data (2015-2021) using the same methods as in the prior assessments. However, for some sources, it was necessary to update data prior to 2015 as well. The input data for this assessment are described below, with emphasis on the data that required modification beyond just the addition of years. A summary timeline of data sources fit to in this assessment is plotted in Figure 1.

2.1 Data Review

In this research track assessment, the Beaufort assessment model (BAM) was fitted to many of the same data sources as in the SEDAR 41, 2016 Benchmark.

- Landings: commercial handline (south and north), recreational headboat (south), general recreational (south and north)
- Discards: recreational headboat (south), general recreational (south and north)
- Indices of abundance: SERFS trap/video
- Length compositions of discards: recreational headboat
- Age compositions of landings: commercial handline, recreational headboat, and SERFS trap/video survey.

Contrasts to data used in the SEDAR 41, 2016 Benchmark assessment include:

- The SEDAR 82 model time period was 1982 − 2021 in contrast to 1988 − 2014 for the SEDAR 41, 2016 Benchmark.
- Although the basic fleet structure for removals (landings and discards) was the same as in SEDAR 41, 2016 Benchmark, in SEDAR 82 removals were spatially divided along the North Carolina-Virginia line [i.e. the northern boundary of the Southeast Fishery Management Council's (SAFMC) jurisdiction] and modeled separately. Landings or discards from north of this line are referred to as "nort" and those from south of this line are referred to as "south". All indices and composition data are from the southern region that encompasses the SAFMC jurisdiction.
- The age composition data was divided into two time periods (period a, early: 1982 − 2014 and (period b, late: 2015 − 2021) due to improvements in aging methods in the latter period. In the early period ages 1-5+ were used in age compositions while in the late period ages 1-8+ were used.

2.2 Data Update

2.2.1 Life History

Some life-history inputs from SEDAR 41, 2016 Benchmark remained the same in SEDAR 82, but several others were updated based on newer data. The length to weight conversion equation, time of peak spawning, and length to batch fecundity equation were the same. Population and fishery growth model parameters, proportions female-at-age, maturity-at-age, number of batches spawned-at-age, maximum observed age, natural mortality constant, and natural mortality-at-age were all updated for SEDAR 82. Primary life-history information is summarized in Table 1. Discard mortality rates also differed from SEDAR 41, 2016 Benchmark.

2.2.2 Landings and Discards

Landings estimates were combined into three fleets: commercial handline, recreational headboat, and general recreational (Table 2). Data providers also provided coefficients of variation (CVs) associated with landings (Table 3), which were not used in fitting the stock assessment model but were used to generate bootstrap data sets during the uncertainty analysis. Commercial landings of Gray Triggerfish were compiled from 1950 through 2021 for the entire U.S. Atlantic Coast, in whole weight (WW). Only landings from 1982 to 2021 were included in this assessment as landings prior to 1982 were minimal. Sources for landings in the U.S. South Atlantic (Florida through North Carolina) included the Florida Trip Ticket program (FTT), South Carolina Department of Natural Resources (SCDNR), North Carolina Division of Marine Fisheries (NCDMF), and the Atlantic Coastal Cooperative Statistics Program (ACCSP).

Commercial handline landings included gear types such as hook and line, bandit reels, and similar hook gear. Landings from other commercial gear types and commercial dead discards were limited and these were included in the commercial handline landings in the assessment. Commercial dead discards were provided to the assessment team in numbers and were converted to weight (1000 lb) during the assessment process. Weight of discards was computed by converting the available recreational discard length compositions to weight with equation 2. Annual mean weights were computed, and then an overall mean weight of a discarded fish as 1.06 lb. Commercial dead discards in numbers were multiplied by that value to compute dead discards in weight. The total weight of commercial dead discards over the assessment period was 12.5 1000 lb.

Commercial handline landings were divided into separate spatial fleets, north and south of the North Carolina-Virginia border (NC-VA border; northern Council boundary). The north landings include any landings north of the northern Council boundary. The south landings extend to the Florida Keys in Monroe County, Florida along US Highway 1 (southern Council boundary). Landings in Monroe County were apportioned by data providers to exclude landings north of the Florida Keys, which are considered part of the Gulf of Mexico (Table 2).

For this assessment, estimates of recreational landings and discards from the private, charter, and shore modes were based on current Marine Recreational Information Program (MRIP) methodology. This included landings from 1981 to 2021, from the Florida Keys to Massachusetts. These removals were combined into general recrational landings and discards, but were divided into separate spatial fleets, north and south of the NC-VA border. For the northern area, headboat mode landings and discards were included with the general recreational landings and discards. In the southern, recreational landings and discards from the headboat mode were provided by the Southeast Region Headboat Survey (SRHS) (Table 2), and were retained as a separate fleet.

In years where landings or discards were estimated to be zero, but were non-zero earlier and later in the time series, these zeros were considered to be missing information and were filled with linear interpolation by the assessment team. A simple method was applied, using the R function `stats::approx` which fills a missing value $t, y_t)$ in a time series by interpolating a straight line from adjacent non-missing values $(t-1, y_{t-1})$ and $(t+1, y_{t+1})$. This method was applied to commercial landings (north) for $1984 - 1989$, general recreational landings (north) for 1981, general recreational discards (north) for 1988, and headboat discards (south) in 1987, 1990, 1993, and 1998.

2.2.3 Indices of abundance

Two indices of abundance were recommended for use in SEDAR 82: SERFS chevron trap (Bubley and Willis 2022) and SERFS video index (Bacheler et al. 2022). These indices were developed from the SERFS which deploys chevron traps with video cameras mounted on them. Trap and video data are paired. The separate indices showed very similar trends and were combined into a single SERFS trap/video index using an averaging approach (Conn Method; Conn 2010). The resulting index and CVs are presented in Table 4.

2.2.4 Length Composition

Length compositions were developed from the recreational headboat discard sampling data from the U.S. South Atlantic. Sample sizes by year and fleet are reported in Tables 5 (number of trips) and 6 (number of fish). Following the methodology of SEDAR 41, 2016 Benchmark and other Beaufort Lab stock assessments, the contribution of each length was weighted by the discards by state.

2.2.5 Age Composition

Age data were available from the commercial handline, recreational headboat, and SERFS sampling programs in the U.S. South Atlantic. The age composition data was divided into two time periods (period a, early: 1982 − 2014 and period b, late: 2015 − 2021) due to improvements in aging methods in the latter period. In the early period ages 1-5+ were used in age compositions while in the late period ages 1-8+ were used. Sample sizes by year and fleet are reported in Tables 5 (trips) and 6 (fish).

3 Stock Assessment Methods

This assessment updates the primary model applied during the SEDAR 41, 2016 Benchmark assessment for Gray Triggerfish (*Balistes capriscus*) off the Southeastern United States (hereafter South Atlantic Gray Triggerfish). The methods are reviewed below, and any changes since the SEDAR 41, 2016 Benchmark are emphasized.

3.1 Overview

This operational assessment updated the primary model applied in SEDAR 41, 2016 Benchmark (SEDAR41 2016), which was developed using the Beaufort Assessment Model (BAM) software (Williams and Shertzer 2015). BAM applies a statistical catch-age formulation, coded in AD Model Builder (Fournier et al. 2012). BAM is referred to as an integrated model because it uses multiple data sources relevant to population and fishery dynamics (e.g. removals, length and age compositions, and indices of abundance) in a single framework (Schaub et al. 2024). In essence, the catch-age model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008). Quantities to be estimated are systematically varied until characteristics of the simulated population match available data on the real population. The model is similar in structure to Stock Synthesis (Methot and Wetzel 2013) and other stock assessment models used in the United States (Dichmont et al. 2016; Li et al. 2021). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as Black Sea Bass, Blueline Tilefish, Gag, Greater Amberjack, Red Grouper, Red Porgy, Red Snapper, Snowy Grouper, Tilefish, and Vermilion Snapper, as well as in the previous SEDAR assessment of Gray Triggerfish (SEDAR41 2016).

3.2 Data Sources

The catch-age model included data from the fishery independent SERFS trap/video survey, and fleets that landed or discarded South Atlantic Gray Triggerfish: commercial handline, recreational headboat, and the general recreational fleet. The model was fitted to closely to annual landings and dead discards (Table 2) with a CV of 0.05. As noted in section 2 CVs associated with landings (Table 3) were used in the uncertainty analysis, but not the base model. The model was also fitted to the fishery independent SERFS trap/video survey index of abundance (Table 4). The model was also fitted to annual length compositions of headboat recreational discards and annual age compositions from commercial handline and recreational headboat landings, and from the SERFS trap/video survey. Samples sizes associated with composition data are provided in numbers of trips (Table 5) and numbers of fish (Table 6). Data used in the model are described in section 2 of this report, the SEDAR 82 Data Workshop Report (SEDAR82-DW 2023), and Data Workshop working papers (see https://sedarweb.org/assessments/sedar-82).

3.3 Model Configuration

Model structure and equations of the BAM are detailed in Williams and Shertzer (2015). The time period for this assessment was 1982 – 2021. A general description of the assessment model follows.

3.3.1 Stock dynamics

In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced mortality from fishing and natural sources. The population was assumed closed to immigration and emigration. The modeled population included age classes $1 - 8^{+}$, where the oldest age class 8^{+} allowed for the accumulation of fish (i.e., plus group).

3.3.2 Initialization

Initial (1982) abundance at age was estimated in the model as follows. The equilibrium age structure was computed for ages 1–8 based on natural mortality and initial fishing mortality (F_{init}). The value of F_{init} was estimated in the model, with a light normal prior centered at a low value, since landings prior to 1982were very low. The prior was necessary since likelihood profiling conducted during the assessment suggested that the data provided little information to freely estimate F_{init}. Lognormal deviations around the equilibrium age structure were found not to deviate from zero during model development and thus were fixed at zero.

3.3.3 Natural mortality rate

The natural mortality rate (M) was assumed constant over time, but decreasing with age. The form of M as a function of age was based on Lorenzen (1996). As in previous SEDAR assessments, the age-dependent estimates of M_a were rescaled to provide the same fraction of fish surviving from age-5 through the oldest observed age (16 yr) as would occur with constant $M = 0.38$ (SEDAR82-DW 2023). This approach using cumulative mortality is consistent with the findings of Hoenig (1983) and Hewitt and Hoenig (2005). For the MCBE analysis, M was randomly drawn from a uniform distribution from $0.2387 - 0.5313$, and M_a rescaled accordingly.

3.3.4 Growth

Mean length in the population [l_a; fork length (FL) in millimeters, (mm)] was modeled with the von Bertalanffy function of age (a)

$$l_a = L_\infty(1 - exp[-K(a - t_0 + \tau)]) \qquad (1)$$

where $L_\infty = 441$, $K = 0.36$, and $t_0 = -0.94$, are parameters estimated external to the assessment model during the SEDAR 82 process and $\tau = 0.5$, representing a fraction of the year (Figure 2A). Here, l_a is being computed at midyear. All parameters in Eq. 1 were treated as fixed input to the assessment model. For fitting length composition data, the distribution of size at age was assumed normal with coefficient of variation estimated by external fitting ($CV_l = 0.16$). A constant CV, rather than constant standard deviation, was suggested by the size at age data. The population growth model is used in the assessment model to generate a length-age conversion matrix applied to the population and discards (Figure 3A).

A separate growth model, also using Eq. 1,was developed external to the assessment based on fishery-dependent ages and length data, and was applied to the landings. The estimated parameters for this where $L_{\infty,L} = 517$, $K_L = 0.12$, $t_{0,L} = -6.62$, and $CV_{l,L} = 0.11$ (Figure 2B). The fishery growth model is used in the assessment model to generate a length-age conversion matrix applied to the landings (Fig 3B).

3.3.5 Age Error

An ageing error matrix was developed for SEDAR 82 using methods developed by Punt et al. (2008) using Agemat software developed by the Northwest Fisheries Science Center (Johnson et al. 2023). Data used to develop the age error matrix were for a set of fish aged using both otoliths and dorsal spines, in an age validation study conducted prior to this assessment. Otoliths ages are considered to be more accurate for this species, but spines are much easier to collect, thus most of the available age data are based on spine ages. All of the age data used in the current assessment were based on spines. Thus, the age-error matrix estimates error for each age between otolith and spine ages. A comparison of models developed using Agemat software showed modeling age error with a consant CV across ages was the most parsimonious approach. The resulting matrix is shown in Figure 4.

3.3.6 Weight-Length conversion

Weight at age [w_a; WW in kilograms (kg)] was modeled as a power function of l_a

$$w_a = \theta_1 l_a^{\theta_2} \tag{2}$$

where $\theta_1 = 2.8e - 08$ and $\theta_2 = 2.97$ are parameters estimated external to the assessment model during the SEDAR 41, 2016 Benchmark process and treated as fixed input to the assessment model (Table 1).

3.3.7 Spawning stock

Spawning stock was modeled using fecundity measured at the time of peak spawning. For Gray Triggerfish, peak spawning was considered to occur at the end of June (June 29^{th}; $spawn\_time\_frac = 181/365 = 0.5$. Batch fecundity ($f_{\text{batch}}$; eggs) was computed from fork length (FL; mm) with the equation

$$f_{\text{batch}} = c + dL \tag{3}$$

where $c = -1776483$, $d = 8704$. Note that although this equation allows f_{batch} to be negative at smaller sizes (F¡204mm), these smaller fish would generally be younger than age-1 and are not included in the assessment model (Table 1).

Number of batches spawned (n_{batch}) also vary with age (Table 1). Annual fecundity for each mature female is the product of f_{batch} and n_{batch}. Spawning stock fecundity per fish, is the product of annual fecundity, proportion female, and proportion of females mature (Figure 5A). Spawning stock fecundity per fish is represented in Figure 5B and Table 1 in the reprod column (in units of 10^{12} eggs per fish). In the model, this reprod vector is multiplied by numbers of fish-at-age alive at the time of spawning to compute the spawning stock (i.e. total egg production; the SSB analog) defining stock size. In this report, the terms "spawning stock biomass" and abbreviation SSB are still used because they are customary, but in all cases refer to total egg production.

3.3.8 Recruitment

Expected recruitment of age-1 fish was predicted from spawning stock fecundity using the mean recruitment model. This is a slight modification from the approach of SEDAR 41, 2016 Benchmark. That assessment used the Beverton–Holt spawner–recruit model, but because the steepness parameter (h) could not be estimated (went to its upper bound), the mean recruitment model was approximated by fixing steepness at $h = 0.99$. Instead, the SEDAR 82 assessment applies the mean recruitment model directly, by estimating the average annual recruitment (here, R_0).

This modification was made after initial model explorations, including likelihood profiling on h, found that steepness still could not be estimated. This result is not uncommon, as steepness is often difficult to estimate reliably (Conn et al. 2010). The underlying assumption of the mean recruitment model is that recruitment is independent of spawning biomass, which is known to be incorrect for extremely low values of spawning biomass (e.g., zero spawners, zero recruits), unless recruits derive from outside the system. This approach has been applied in other recent Beaufort Lab stock assessments (SEDAR73 2021; SEDAR76 2023) and is recommended as a "null model" by Brooks (2024).

To include annual variability in recruitment, the model estimates lognormal deviations around that average, and estimates the standard deviation (σ_R) of this lognormal distribution. In early runs of the model, σ_R had a tendency to be estimated at the lower bound and thus was initialized at a value of 0.6 from a meta-analysis, and estimated with a normal prior. Annual variation in recruitment was assumed to occur with lognormal deviations for years $1990 - 2018$ only. The first year recruitment residuals were estimated (1990) was the year when age composition data was first available (for the headboat fleet), providing information on year class strength. The last year that recruitment residuals were estimated (2018) was two years prior to the last year of age composition data (for the commercial handline fleet). Gray Triggerfish start to be selected by this fleet around age-3, so year class strength for the 2018 age-1 recruits may be detected in the 2020 age composition data.

3.3.9 Landings and Discards

Time series of removals from three fleets were modeled over the $1982 - 2021$ assessment period: commercial handline, general recreational, and recreational headboat. Landings for each fleet over the assessment period were provided by the Data Workshop panel. Commercial discard estimates were only available for the southern area, and were a small proportion of commercial landings. So for the southern area, a discard mortality rate of 0.59was applied to commercial discards, and the estimated dead discards were pooled with commercial handline landings. Headboat discards were also a small proportion of headboat landings, but length compositions of headboat discards were available to inform selectivity, and so headboat landings and discards were modeled separately. General recreational discards were assumed to have the same selectivity as for headboat discards, in part due to insufficient composition data to model a separate selectivity. The same discard mortality rate was assumed for all fleets and for the entire assessment period ($\delta = 0.59$). As noted in section 2.2.2, landings and discards were modeled as spatial sub-fleets (south and north), divided at the NC-VA border, when the data allowed. Removals were modeled with the Baranov catch equation (Baranov 1918) and were fitted in either units of weight (1000 lb whole weight, commercial) or numbers (1000 fish, recreational).

3.3.10 Fishing Mortality

For each time series of landings and discard mortalities, the assessment model estimated a separate full fishing mortality rate (F). Age-specific rates were then computed as the product of full F and selectivity at age. Apical F was computed as the maximum of F at age summed across fleets.

3.3.11 Selectivities

Selectivity at age was estimated using a two-parameter, flat-topped, logistic model in most cases. Headboat discard selectivity was the exception, which was modeled with a logistic-exponential function, which declines exponentially from 100% selection at age-1. The function has 4-parameters, but three were fixed during the assessment process, such that only the parameter describing the rate of decent of the curve was estimated.

Separate selectivity functions were estimated for commercial handline, recreational headboat landings, recreational headboat discards, as well as for the SERFS trap/video index. Selectivities for general recreational landings and discards were set equal to those estimated for recreational headboat landings and discards, respectively.

In the development of the base model, alternativee functional forms and time blocking of selectivity were investigated extensively in attempts to improve fits to composition data. But these alternative configurations generally increased complexity without improving fits substantially, and the assessment team chose the current configuration in the interest of parsimony. Examples of early configurations which were attempted but rejected include modeling recreational selectivity with a dome-shaped function, modeling separate selectivities for the headboat and general recreational fleets (see sensitivity run S15), and including multiple time blocks for the SERFS trap/video survey.

Consideration was also given to including separate selectivity time blocks for fishery-dependent selectivities associated with size limits, but it was judged that the limits that had been imposed likely had a negligible effect on selectivity. A 12 inch (304 mm) size limit was applied throughout the South Atlantic in 2015 (and Florida before that), but corresponds to age-1 fish not frequently caught by the fishery. A 14 inch (356 mm) size limit, corresponding to age-3 fish, was implemented in Florida from 2015-2020 but did not appear to have an overall effect on the composition data for the entire region.

3.3.12 Indices of abundance

The model was fit to a single index of relative abundance: SERFS trap/video. As noted in section 2.2.3 this index was a combination of separate chevron trap and video indices. The resulting index and CVs are presented in Table 4.

3.3.13 Catchability

In the BAM, catchability scales indices of relative abundance to the estimated vulnerable population at large. The catchability coefficient for the SERFS trap/video index was assumed constant through time.

3.3.14 Biological Reference Points

Because the assessment did not estimate a spawner-recruit relationship, but instead applied the null model, MSY could not be estimated directly, and instead a proxy was used for biological reference points (benchmarks). The proxy used here was based on a proxy for MSY ($L_{\mathrm{F40\%}}$), based on $F_{40\%}$; that is, the fishing rate that would allow a stock to attain 40% of the maximum spawning potential (SPR_{40}), which would have been obtained in the absence of fishing mortality. The value of $F_{40\%}$ was chosen here because of its commonality in fishery management and because it has been shown to be an effective proxy (e.g., Legault and Brooks (2013); Hartford et al. (2019)). The proxy of $F_{30\%}$ has been shown to be appropriate only for very resilient stocks (Brooks et al. 2010), and even $F_{40\%}$ might be an aggressive benchmark for some stocks (Clark 2002; Hartford et al. 2019; Zhou et al. 2020). Reference points based on $F_{40\%}$ have also been used in recent assessments for reef fishes in the South Atlantic (SEDAR68 2021). Computed benchmarks in SEDAR 82 associated with SPR_{40} included the fishing mortality rate ($F_{40\%}$), $L_{\mathrm{F40\%}}$, $D_{\mathrm{F40\%}}$ (discards at $F_{40\%}$), total biomass ($B_{\mathrm{F40\%}}$), and spawning stock ($\mathrm{SSB}_{\mathrm{F40\%}}$; Gabriel and Mace 1999). In this assessment, spawning stock measures population fecundity. The minimum stock size threshold MSST was also computed, by scaling $\mathrm{SSB}_{\mathrm{F40\%}}$ by a proportion p which is defined a $(1 - M)$ or 0.5, whichever is greater. Here $p = (1 - M) = 0.62$ and MSST is defined as $0.62 * \mathrm{SSB}_{\mathrm{F40\%}}$. These benchmarks are conditional on the estimated selectivity functions and the relative contributions of each fleet's fishing mortality. The selectivity pattern used here was the effort-weighted selectivities at age, with effort from each fleet estimated as the full F averaged over the last three years of the assessment.

3.3.15 Fitting criterion

The fitting criterion was a penalized likelihood approach in which observed landings and discards were fit closely, and observed composition data and the abundance index were fit to the degree that they were compatible. Landings, discards, and index data were fitted using lognormal likelihoods. Length and age composition data were fit using the Dirichlet-multinomial distribution, with sample size represented by the annual number of trips (Table 4), adjusted by an estimated variance inflation factor (i.e. one additional parameter for each fleet's composition data).

The SEDAR 41, 2016 Benchmark fit composition data using the robust multinomial with iterative re-weighting (Francis 2011). Since Francis (2011), additional work on this topic has questioned the use of the multinomial distribution in stock assessment models (Francis 2014), and has recommended the Dirichlet-multinomial as an alternative (Francis 2017; Thorson et al. 2017). A chief advantage of the Dirichlet-multinomial is that it is self-weighting through estimation of an additional variance inflation parameter for each composition component, making iterative re-weighting unnecessary. Another advantage is that it can better account for overdispersion, or, larger variance in the data than would be expected by the multinomial. Overdispersion can result from intra-haul correlation, which results when fish caught in the same set are more alike in length or age than fish caught in a different set (Pennington and Volstad 1994). The Dirichlet-multinomial has been implemented in Stock Synthesis (Methot and Wetzel 2013; Thorson et al. 2017) and in the BAM, and since the SEDAR 41, 2016 Benchmark has become the standard likelihood for fitting composition data in assessments of South Atlantic reef fishes.

The model includes the capability for each component of the likelihood to be weighted by user-supplied values. When applied to landings and indices, these weights modify the effect of the input CVs. In this application to Gray Triggerfish, CVs of landings and discards (in arithmetic space) were assumed equal to 0.05 to achieve a close fit to these data while allowing some imprecision. In practice, the small CVs are a matter of computational convenience, as they help achieve a close fit, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). In contrast to the SEDAR 41, 2016 Benchmark, iterative re-weighting was not conducted here, in part because the composition likelihoods were self-weighting. Thus, user-supplied data weights were all set equal in the base model, with effective relative weights among data components determined by CVs (landings, discards, index) and the estimated Dirichlet-multinomial variance parameters.

In addition, the compound objective function included several prior distributions, applied to the Dirichlet-multinomial variance inflation factor parameters associated with each set of composition data and the slope parameter for the selectivity function of the general recreational fleet. Priors were applied to maintain parameter estimates near reasonable values, and to prevent the optimization routine from drifting into parameter space with negligible gradient in the likelihood which can result in a non-positive definite Hessian matrix (an indication of incomplete or incorrect parameter solutions).

3.3.16 Parameters Estimated

The model estimated a total of 375 parameters including average fishing mortality rates (8 par.) and annual fishing mortality rates (320 par.) for each fleet; annual recruitment deviations (29 par.), selectivity parameters (7 par.), Dirichlet-multinomial variance inflation factors (7 par.), a catchability coefficient associated with each index (1 parameter), the standard deviation of the lognormal recruitment residuals (σ_R; 1 par.), initial F (F_{init}; 1 par.), and virgin recruitment (R_0; 1 par.).

3.4 Per Recruit and Equilibrium Analysis

Yield per recruit and spawning potential ratio were computed as functions of F, as were equilibrium landings and spawning biomass. Equilibrium landings were also computed as functions of biomass B, which itself is a function of F. As in computation of $F_{40\%}$-related benchmarks (described in section 3.5), per recruit and equilibrium analyses applied the most recent selectivity patterns averaged across fleets, weighted by each fleet's F from the last three years (2019–2021) of the assessment.

3.5 Benchmark/Reference Point Methods

A stock-recruit relationship wasn't estimable in this assessment, necessitating a proxy for MSY-based reference points. The quantities $F_{40\%}$, $\mathrm{SSB}_{\mathrm{F40\%}}$, $B_{\mathrm{F40\%}}$, and $L_{\mathrm{F40\%}}$ were estimated here and are recommended as proxies for MSY-based reference points. The value of $F_{40\%}$ is the F that provides 40% SPR. To compute biomass benchmarks, equilibrium recruitment was assumed equal to expected recruitment in arithmetic space (mean unbiased). However, in BAM, spawner-recruit parameters correspond to median-unbiased recruitment. Thus, on average, expected recruitment is higher than that estimated directly from the spawner-recruit model (i.e., R_0, when using the mean recruitment model), because of lognormal deviation in recruitment. Therefore, the method of benchmark estimation accounted for lognormal deviation by including a bias correction in equilibrium recruitment. The bias correction (ς) was computed from the variance (σ_R^2) of recruitment deviation in log space: $\varsigma = \exp(\sigma_R^2/2)$. Then, equilibrium recruitment (R_{eq}) associated with any F is

$$R_{eq} = \varsigma R_0 \tag{4}$$

where R_0 is median-unbiased virgin recruitment. The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of $F_{40\%}$ is the F giving 40% of the SPR, and the estimate of $L_{\mathrm{F40\%}}$ is that ASY. The estimates of $\mathrm{SSB}_{\mathrm{F40\%}}$, $B_{\mathrm{F40\%}}$, and $D_{\mathrm{F40\%}}$ follow from the corresponding equilibrium age structure.

Estimates of $L_{\mathrm{F40\%}}$ and related benchmarks are conditional on selectivity pattern. The selectivity pattern used here was an average of terminal-year selectivities from each fleet, where each fleet-specific selectivity was weighted in proportion to its corresponding estimate of F averaged over the last three years (2019–2021). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of $L_{\mathrm{F40\%}}$ and related benchmarks.

The maximum fishing mortality threshold (MFMT) is defined here as $F_{40\%}$, and the minimum stock size threshold (MSST) as $(1 - M) * \mathrm{SSB}_{\mathrm{F40\%}}$. Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. However, if the stock is overfished, the rebuilding target would be $\mathrm{SSB}_{\mathrm{F40\%}}$. Current status of the stock is represented by SSB in the latest assessment year (2021), and current status of the fishery is represented by the geometric mean of F from the latest three years (2019–2021). Generally, South Atlantic assessments have considered the mean over the terminal three years to be a more robust metric than that of a single, terminal year.

3.6 Sensitivity Analysis

Sensitivity of results to some key model inputs and assumptions was examined through sensitivity analyses. Sensitivity runs were chosen to address specific questions that arose during the SEDAR 82 assessment process. They were intended to demonstrate directionality of results with changes in inputs or simply to explore model behavior. For several of these sensitivity analyses where a parameter was fixed over a range (e.g. sensitivity to M, discard mortality, weight of data sources), results were generated for the runs associated with the lower and upper limits of the range, as well as several runs based on a sequence of values between those limits. In these instances the presentation of results focuses on the runs associated with the limits, and these runs are given identifying numbers (e.g. S1 and S2 associated with low and high values of M). These sensitivity model runs vary from the base run as follows.

- S1-S2: Vary initial F (F_{init}) as a fixed value.
  - F_{init} was fixed over a range from 0.01 (S1) to 0.5 (S2), generating a sequence of 21 runs.
- S3-S4: Vary natural mortality
  - M was fixed over a range from 0.2387 (S3) to 0.5313 (S4), generating a sequence of 5 runs.
- S5-S6: Vary discard mortality rate
  - Discard mortality rate was fixed over a range from 0.364 (S5) to 0.814 (S6) for all discard fleets modeled separately in the base model (i.e. recreational fleets), generating a sequence of 5 runs.
- S07: Assume no age error
- S08: Age comps for all years use age $1-8+$
- S09: Assume that batch fecundity is not age-dependent
- S10: Assume that batch number is not age-dependent
- S11: Assume that batch fecundity and batch number are not age-dependent
- S12: Estimate steepness
  - Use a Beverton-Holt stock-recruit relationship and estimate steepness, with an initial value of 0.8
- S13: Smooth general recreational discard value for 2016
- S14: Start SERFS trap/video index in 1990
- S15: Include general recreational (rGN) length compositions and estimate separate selectivity for rGN
- S16-S17: Vary weight of SERFS trap/video index
  - The weighting parameter for the SERFS trap/video index was fixed over a range from 0.2 (S16) to 5 (S17), generating a sequence of 13 runs.
- S18-S19: Vary weight of SERFS trap/video age comps
  - The weighting parameter for the SERFS trap/video age comps was fixed over a range from 0.2 (S18) to 5 (S19), generating a sequence of 13 runs.
- S20-S21: Vary weight of all age comps
  - The weighting parameter for all age comps was fixed over a range from 0.2 (S20) to 5 (S21), generating a sequence of 13 runs.
- S22-S23: Vary weight of all length comps
  - The weighting parameter for all length comps was fixed over a range from 0.2 (S22) to 5 (S23), generating a sequence of 13 runs.

3.7 Age Structured Production Model (ASPM)

Age Structured Production Models (ASPM) have been used in past South Atlantic assessments as supplementary analyses to compare with the primary statistical catch-at-age model. Recent research has shown that ASPMs can be informative diagnostics for detecting misspecification in key processes (Carvalho et al. 2017; 2021; Maunder and Piner 2017) Much of the documentation for the ASPM section of this report was originally printed in earlier reports (SFB-NMFS 2016*b*;*a*).

Age structured production models have existed since the advent of catch-at-age models in the mid-1980s (Fournier and Archibald 1982; Hilborn 1990; Kimura and Tagart 1982; Ludwig and Walters 1985; Megrey 1989). ASPMs have been used extensively for highly migratory pelagics, where age collection can be difficult, and other stock assessment analyses as well (Cubillos et al. 2002; Geromont and Butterworth 1999; Nishida et al. 2001; Nishida and Rademeyer 2011; Porch 2003; Restrepo 1997; Restrepo and Legault 1998; Ricard and Basson 2002). ASPMs can be viewed as either a simplified version of statistical catch-at-age models. The simplification from more advanced statistical catch-at-age models is due to the absence of any age or length composition data. Because no age or length data are used in an ASPM, then year class strength is expected to follow a simple production function (i.e. a stock-recruit function; Butterworth and Rademeyer 2008; Field et al. 2008). With this simplification, ASPMs have a greatly reduced number of parameters compared to a full statistical catch-at-age model. Of course with reduced parameters comes simplifying assumptions (e.g. fixed fleet selectivities). In this ASPM, using a mean recruitment model, recruitment is modeled as in the full BAM (statistical catch-at-age model) as an average value, independent of stock size (see section 3.3.8).

The ASPM is a direct modification of the full BAM, where age-structure is still represented but age-dependent processes and dynamics are fixed. In the BAM, much of the age-dependent life history information was already fixed (e.g. growth, maturity, fecundity, natural mortality). In the ASPM, selectivities are fixed at values estimated in the full BAM. The ASPM fits to landings and discards and the SERFS trap/video index, but age and length composition data is not fitted. So without age composition data, Dirichlet-Multinomial parameters were removed from the model. Recruitment deviations were fixed at zero. The parameters that the ASPM estimated were the average F and annual F-deviations for each fleet, the catchability parameter for the SERFS trap/video index, and R_0. These methods follow the basic workflow described by Carvalho et al. (2021, their section 3.2.2).

3.8 Retrospective Analysis

Retrospective analyses were run by reducing the terminal year of the model (2021) one year at a time (new terminal years 2016-2020), thereby trimming all time series accordingly, and rerunning the assessment model. This analysis facilitates investigation of patterns in model results, particularly terminal status estimates, that may occur when recent data are excluded.

Retrospective analyses should be interpreted with caution when data sources are not continuous between 2016 and 2021 (Figure 1). In this case the SERFS trap/video index was not available in 2020 and SERFS trap/video age compositions were not available in 2020 or 2021. The final year of recruitment deviations in each retrospective run was set to the terminal year minus three years to mirror the base run model configuration.

3.9 Monte Carlo/Bootstrap Ensemble (MCBE) Analysis

For the base run of the catch-age model (BAM), uncertainty in results and precision of estimates were computed through an ensemble modeling approach (Scott et al. 2016; Jardim et al. 2021) using a mixed Monte Carlo and bootstrap framework (Efron and Tibshirani 1993; Manly 1997). Monte Carlo and bootstrap methods are often used to characterize uncertainty in ecological studies, and the mixed approach has been applied successfully in previous SEDAR stock assessments (Restrepo et al. 1992; Legault et al. 2001; SEDAR68 2021; SEDAR73 2021; SEDAR76 2023). The approach is among those recommended for use in SEDAR assessments (SEDAR Procedural Guidance 2010).

The approach translates uncertainty in model input into uncertainty in model output, by fitting the model many times with different values of "observed" data and key input parameters. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or small set of sensitivity runs. A minor disadvantage of the approach is that computation times can be long, though current parallel computing techniques largely mitigate those demands (i.e. multiple models can be run simultaneously rather than sequentially).

In this assessment, the BAM was re-fit in $n = 2001$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. Of the 2001 trials, 1878 were ultimately retained in the uncertainty analysis. The remaining runs were discarded because of poor model convergence (maximum gradient ≥ 0.1) or unrealistic values of $F_{40\%}[2019-2021]$ (≥ 5) . A check was also conducted to see if any estimated parameters were near bounds (within 1% of the range between bounds from either bound) in each run, to see if they should be removed from the ensemble.

The MCBE should be interpreted as providing an approximation to the uncertainty associated with each output. The results are approximate for two related reasons. First, not all combinations of Monte Carlo parameter inputs are equally likely, as biological parameters might be correlated. Second, all runs are given equal weight in the results, yet some might provide better fits to data than others.

3.9.1 Bootstrapping of Observed Data

To include uncertainty in time series of observed landings, discards, and indices of abundance, multiplicative lognormal errors were applied through a parametric bootstrap. To implement this approach in the MCBE trials, random variables ($x_{s,y}$) were drawn for each year y of time series s from a normal distribution with mean 0 and variance $\sigma^2_{s,y}$ [that is, $x_{s,y} \sim N(0, \sigma^2_{s,y})$]. Annual observations were then perturbed from their original values ($\hat{O}_{s,y}$),

$$O_{s,y} = \hat{O}_{s,y}[\exp(x_{s,y} - \sigma^2_{s,y}/2)] \tag{5}$$

The term $\sigma^2_{s,y}/2$ is a bias correction that centers the multiplicative error on the value of 1.0. Standard deviations in log space were computed from CVs in arithmetic space, $\sigma_{s,y} = \sqrt{\log(1.0 + CV^2_{s,y})}$. The CVs used to generate bootstrap data sets of landings and discards were supplied by the data providers (Table 3). The CVs used to generate bootstrap data sets of indices of abundance were the same as those used when fitting the assessment model (Table 4).

Uncertainty in age and length compositions were included by drawing new distributions for each year of each data source, following a multinomial sampling process. Ages (or lengths) of individual fish (Table 6) were drawn at random with replacement using the cell probabilities of the original data. For each year of each data source, the number of fish sampled was the same as in the original data (Table 4).

3.9.2 Monte Carlo Sampling

In each successive fit of the model, several parameters were fixed (i.e., not estimated) at values drawn at random from distributions described below.

Natural mortality The point estimate of natural mortality ($M = 0.38$) was provided by the SEDAR 82 Workshop Panel with some uncertainty. To carry forward this source of uncertainty, Monte Carlo sampling was used to generate deviations from the point estimate. A new M value was drawn for each MCBE trial from a uniform distribution between 0.2387 and 0.5313. In each run of the ensemble, a drawn value of constant M was then used to rescale natural mortality at age, as described for the base model above.

Standard deviation of recruitment deviations (σ_R) In the base model, the standard deviation of recruitment deviations (σ_R) was initialized at a value of 0.6 from a meta-analysis, and estimated with a normal prior with $\mu = 0.6$. For each MCBE trial, a new initial value was drawn from a truncated normal distribution defined by $\mu = 0.6$ and $\sigma = 0.15$ truncated to 0.3 to 1.0, and the prior updated to be centered at the randomly drawn value.

Discard mortalities Similarly, discard mortalities δ applied to discard fleets included in the base model (i.e. recreational discards) were subjected to Monte Carlo variation as follows. New values for all sources of discards were drawn for each MCBE trial from a uniform distribution (range [0.364, 0.814]). Recall that in the base model commercial discards were minimal and were combined with commercial landings outside the model. Therefore the discard mortality rate for commercial discards was not randomized in the MCBE process.

3.10 Projection Analysis

Projections were run to quantify future stock conditions given different values of fishing mortality rate.The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment. Any time-varying quantities, such as selectivity, were fixed to the most recent values of the assessment period. A single selectivity curve was applied to calculate landings computed by averaging selectivities across fleets using geometric mean Fs from the last three years of the assessment period, similar to computation of $L_{\mathrm{F40\%}}$ benchmarks (section 3.5).

Expected values of SSB (time of peak spawning), F, recruits, and landings were represented by deterministic projections using parameter estimates from the base run. These projections were built on the estimated spawner-recruit relationship with bias correction, and were thus consistent with estimated benchmarks in the sense that long-term fishing at $F_{40\%}$ would yield $L_{\mathrm{F40\%}}$ from a stock size at $\mathrm{SSB}_{\mathrm{F40\%}}$. Uncertainty in future time series was quantified through stochastic projections that extended the ensemble model fits of the stock assessment model.

3.10.1 Initialization

Although the terminal year of the assessment is 2021, the assessment model computes abundance at age (N_a) at the start of 2022. For projections, those estimates were used to initialize N_a. However, the assessment has no information to inform the strength of 2022 recruitment, and thus it computes 2022 recruits (N_1) as the expected value, that is, without deviation from the spawner-recruit curve, and corrected to be unbiased in arithmetic space. In the stochastic projections, lognormal stochasticity was applied to these abundances after adjusting them to be unbiased in log space, with variability based on the estimate of σ_R. Thus, the initial abundance in year one of projections (2022) included this variability in N_1. The deterministic projections were not adjusted in this manner, because deterministic recruitment was set to mean recruitment.

Fishing rates that define the projections were assumed to start in 2024. Because the assessment period ended in 2021, the projections required an interim period (2022–2024). Fishing mortality during this interim period was set at the estimate of F_{current} from the assessment model.

3.10.2 Uncertainty

To characterize uncertainty in future stock dynamics stochasticity was included in replicate projections, each an extension of a single assessment fit from the ensemble. Thus, projections carried forward uncertainties in natural mortality and discard mortality, as well as in estimated quantities such as spawner-recruit parameters (R_0 and σ_R), selectivity curves, and in initial (start of 2022) abundance at age.

Initial and subsequent recruitment values were generated with stochasticity using a Monte Carlo procedure in which the estimated recruitment of each model within the ensemble is used to compute expected annual recruitment values ($\bar{R}_y$). Variability is added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{6}$$

Here ϵ_y is drawn from a normal distribution with mean 0 and standard deviation σ_R, where σ_R is the standard deviation from the relevant ensemble model run.

The procedure generated 20,001 replicate projections of models within the ensemble drawn at random (with replacement). In cases where the same model run was drawn, projections would still differ as a result of stochasticity in projected recruitment streams. Central tendencies were represented by the deterministic projections of the base run, as well as by medians of the stochastic projections. Precision of projections was represented graphically by the 5^{th} and 95^{th} percentiles of the replicate projections.

3.10.3 Scenarios

In the projections, management started in 2024, the earliest year possible. Projections were carried forward to 2031. In all scenarios $F = F_{\text{current}}$ from 2022 to 2024:

- Scenario 1: $F = F_{40\%}$ from 2024 to 2031
- Scenario 2: $F = 75\% F_{40\%}$ from 2024 to 2031

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

The Beaufort assessment model (BAM) generally fit well to the available data. Predicted age compositions from each fishery were reasonably close to observed data in most years. Fits to length compositions for the headboat recreational discards (rHD) were not quite as good (Figure 6,10, 14). The predicted distribution of lengths tended to be more platykurtic than the observed distribution. This is probably due to the fact that about 90% of the headboat discards fall into only three length bins ($240 - 300$ mm), the age-1 selectivity is fixed at 1.0, and the population growth model predicts a broader distribution of lengths at age-1 (Figure 3A). The model was configured to fit observed landings and discards closely (Figures 15, 16, 17, 18, 19, 20, 21, and 22). The fit to the SERFS trap/video index captured the general trend well but not all annual fluctuations (Figure 23).

4.2 Parameter Estimates

Estimates of all parameters from the catch-age model are shown in Appendix A. No parameters were hitting bounds. Estimates of management quantities and some key parameters, such as those of the mean-recruitment model, are reported in sections below.

4.3 Total Abundance, Spawning Biomass and Recruitment

Total abundance shows an early period of higher abundance prior to 1990. A drop and a pulse of increasing abundance occurs from $1990 - 1995$, followed by a decline to 1998. Abundance is relatively steady for the remainder of the assessment period, punctuated by a second pulse of higher abundance from $2010 - 2016$ (Figure 24 Table 7). The trend in total biomass is similar but shows a more gradual decline and leveling off, punctuated by the same two pulses (25; 8, and 9). These high periods appear to be driven by recruitment (red bars in Figure 24 and 25; Figure 26A), which is following trends in the SERFS trap/video index (Figure 23). The time series of landings, and to a lesser degree discards, tend to be positively correlated with abundance in the stock, showing relative highs similar to predicted biomass and a similar decrease from $1997 - 2000$ (Figures 34 and 35; Tables 18, 19, 20 and 21). Total biomass and spawning stock biomass (SSB) show similar trends, but with major highs and lows shifted one year later for SSB (Figure 27; Table 10). Recruitment has fluctuated during the period when deviations were estimated (1990-2018) ranging from 2,378,084 to 7,138,726 fish with relative lows in 1990, 1997, and 2017 and peaks in 1994, 2012, and 2014. However, there is little evidence of a long term trend (Figure 26A; Table 10). Similarly, recruitment deviations showed fluctuations over this same period with no evidence of a longterm trend (Figure 26B).

4.4 Selectivity

Selectivity of the SERFS trap/video index is shown in Figure 28. Selectivities of landings from commercial and recreational fleets are shown in Figures 29 and 30. selectivities of recreational discard fleets are shown in Figure 31. Recall that selectivities for a given fleet were the same for north and south areas. In the most recent years, full selection occurred near age-4 in the recreational fleets, age-5 in the commercial handline fleet, age-5 in the SERFS trap/video. Logistic selectivity functions were used for all landings fleets. Selectivities of discard mortalities had a negative exponential shape, with age at full selection fixed at age-1, an estimated 32% selection at age-2, and $\approx 0\%$ selection at age 3+ (Figure 31).

Average selectivities of landings were computed from F-weighted selectivities in the most recent period of regulations (Figure 32). These average selectivities were used to compute point estimates of benchmarks. All selectivities from the most recent period, including average selectivities, are tabulated in Table 11. In the average selectivity, full selection occurred near age-4, like the recreational fleets which are responsible for $> 80\%$ of the total removals in most years (Figures 34 and 35).

4.5 Fishing Mortality and Removals

Estimates of total F at age are shown in Table 13 and estimates of landings and discards at age (in numbers and pounds whole weight) are shown in Tables 14, 15, 16, 17. In any given year, the maximum F at age (i.e., apical F) may be less than that year's sum of fully selected Fs across fleets (e.g. 2016). This inequality exists because full selection occurs at different ages among gears.

The estimated fishing mortality rates (F) have generally increased over the assessment period (Figure 33; Tables 10 and 12), with local peaks in 1991, 1997, 2009, 2016, and 2020. The predominant source of fishing mortality is the general recreational fleet, particularly in recent decades. Most of the F is from the area south of the NC-VA border. Although fishing mortality in the north has been variable over time, on average, it has been a fairly steady proportion of total F (F_{sum}).

Estimated time series of landings and discards (in number and pounds whole weight) by fleet are shown in Tables 18, 19, 20, 21. The majority of estimated removals were from the general recreational fleet, followed by commercial handline, and recreational headboat (Figures 34, 35; Tables 18, 19). The proportion of total removals attributed to the general recreational fleet has increased over time.

4.6 Spawner-Recruitment Parameters

The mean recruit relationship and variability around that mean are shown in Figure 36. Values of recruitment-related parameters were as follows: unfished age-1 recruitment $\widehat{R_0} = 4306649$, and standard deviation of recruitment residuals in log space $\widehat{\sigma}_R = 0.41$ (which resulted in bias correction of $\varsigma = 1.09$). Uncertainty in recruitment quantities were estimated through the MCBE analysis (Figure 37).

4.7 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were each computed as functions of F. These computations applied the most recent selectivity patterns averaged across fleets, weighted by F from the last three years (2019–2021; Figures 38).

As in per recruit analyses, equilibrium removals and equilibrium spawning biomass were each computed as a functions of F (Figure 39). The equilibrium removals curve (or else equilibrium landings if discards are separated) is the curve from which F_{MSY} is typically estimated, as the value of F for which removals (landings) are maximized.

4.8 Benchmarks/Reference Points

As described in section 3.5, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the mean-unbiased recruitment (Figure 36). Reference points estimated were $F_{40\%}$, $L_{\mathrm{F40\%}}$, $D_{\mathrm{F40\%}}$, $B_{\mathrm{F40\%}}$, and $\mathrm{SSB}_{\mathrm{F40\%}}$. Based on $F_{40\%}$, three possible values of F at optimum yield (OY) were considered—$F_{\mathrm{OY}} = 65\% F_{40\%}$, $F_{\mathrm{OY}} = 75\% F_{40\%}$, and $F_{\mathrm{OY}} = 85\% F_{40\%}$—and for each, the corresponding yield was computed. Standard errors of benchmarks were approximated as those from MCBE analysis (section 3.9).

Maximum likelihood estimates (base run) of benchmarks, as well as median values from MCBE analysis, are summarized in Table 22. Point estimates of reference points were $F_{40\%} = 0.56$ (y^{-1}), $L_{\mathrm{F40\%}} = 1865$ (1000 lb), $B_{\mathrm{F40\%}} = 6266$ (mt), and $\mathrm{SSB}_{\mathrm{F40\%}} = 6951918$ (10^{12} eggs). Median estimates were $F_{40\%} = 0.57$ (y^{-1}), $L_{\mathrm{F40\%}} = 1904$ (1000 lb), $B_{\mathrm{F40\%}} = 6389$ (mt), and $\mathrm{SSB}_{\mathrm{F40\%}} = 7.33$ (10^{12} eggs). Note that the $L_{\mathrm{F40\%}}$ values (proxies for MSY) correspond to landings plus the small amount of commercial dead discards pooled with commercial landings. Distributions of these benchmarks from the MCBE analysis are shown in Figure 40.

4.9 Status of the Stock and Fishery

Estimated time series of stock status $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F40\%}}$ showed a steady decline throughout the beginning of the assessment period (Figure 41, Table 10). Base-run estimates of spawning biomass have never been below MSST. Current stock status relative to MSST was estimated in the base run to be SSB/MSST = 1.33 (Table 22), indicating that the stock is not overfished relative to $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{F40\%}}$, where $M = 0.38$. Median values from the MCBE analysis indicated similar results of SSB/MSST = 1.41 in the terminal year. The uncertainty analysis suggested that the terminal estimate of stock status is fairly robust (Figures 42, 43). Of the MCBE runs, 70.3% indicated that the stock was above MSST in 2021. Age structure estimated by the base run showed a steady decline in the proportion of fish in the population at older ages, especially age 6 and older, over the assessment period ($1982 - 2021$), approaching the equilibrium age structure expected at $F_{40\%}$ in recent years (Figure 44). In the terminal year (2021), there were relatively fewer fish in ages $4 - 6$ compared with the equilibrium expectation, driven by average to low recruitment from $2016 - 2018$ (Fig. 26).

The estimated time series of $F/F_{40\%}$ suggests that the fishing rate has been gradually increasing since the beginning of the assessment (1982) with overfishing in only a few years, including the most recent years (Table 10, Figure 41). Current fishery status in the terminal year, with current F represented by the geometric mean from years $2019-2021$, was estimated by the base run to be $F/F_{40\%} = 1.16$ (Table 22). The fishery status was less certain than the stock status (Figures 42, 43). Of the MCBE runs, approximately 53.6% agreed with the base run that the stock is not currently experiencing overfishing.

4.10 Sensitivity Analyses

Sensitivity runs, described in section 3.3, may be useful for evaluating implications of assumptions in the base model, and for interpreting MCBE results in terms of expected effects from input parameters. Time series of $F/F_{40\%}$, SSB/MSST, recruitment ($\bar{R}_y$), and SSB are plotted for all runs in each sensitivity analysis. Summarized results presented in Table 23. For analyses where parameters were fixed at a sequence of values, only the runs associated with the lower and upper limits of the sequence are presented in Table 23.

Figures show sensitivity to initial F (F_{init}; Figure 45), natural mortality rate (Figure 46), discard mortality rate (Figure 47), age error (Figure 48), using age comps from 1 to 8+ for all years (Figure 49), age-dependent batch fecundity (Figure 50), age-dependent batch number (Figure 51), age-dependent batch fecundity and batch number (Figure 52), estimating steepness (Figure 53), high 2016 value of general recreational discards in the south (Figure 54), start year of SERFS trap/video index (Figure 55), estimating a separate selectivity for general recreational (rGN) landings (Figure 56), weight on SERFS trap/video index (Figure 57), weight on SERFS trap/video age compositions (Figure 58), weight on all age compositions (Figure 59), and weight on all length compositions (Figure 60).

4.11 Age Structured Production Model (ASPM)

The fit to the SERFS trap/video index in the ASPM, suggested a gradual decline in abundance over the course of the assessment period, and failed to capture most interannual trend in the index (Figure 61). Comparing this with the base model index fit (Figure 61) suggests that estimation of recruitment deviations is necessary to adequately estimate the trend in the index. Results of the ASPM are presented in Figure 62 and Table 23. Without the influence of age or length composition information, the ASPM estimated a much higher R_0 value than the base model, suggesting that the size of the population is much larger. As a diagnostic, this suggests that for Gray Triggerfish, accounting for variability in recruitment is also important for estimating the scale of the spawning stock and the populaiton.

4.12 Retrospective Analyses

Retrospective analyses did not suggest any patterns of substantial over- or underestimation in terminal-year estimates of $F/F_{40\%}$, SSB/MSST, recruitment ($\bar{R}_y$), and SSB (Figure 63).

4.13 Projections

Projection results with $F = F_{40\%}$ from 2024 to 2031 are shown in Figures 64, 65, and 66 and Table 24. Projection results with $F = 75\%F_{40\%}$ from 2024 to 2031 are shown in Figures 67, 68, and 69, and Table 25. Among all scenarios considered, the probability that SSB exceeds MSST [$P(\text{SSB} > \text{MSST})$] is at least 0.7 in all years of all projections. Thus, under no management prescription considered in the projections thus far is the South Atlantic Gray Triggerfish stock predicted to be overfished.

5 Discussion

5.1 Comments on Assessment Results

Estimated benchmarks played a central role in this assessment. Values of MSST and $F_{40\%}$ were used to gauge the status of the stock and fishery. Computation of benchmarks was conditional on selectivity. If selectivity patterns change in the future, for example as a result of new size limits or different relative catch allocations among sectors estimates of benchmarks would likely change as well.

The base run of the BAM indicated that the stock is not overfished ($\text{SSB}_{2021}/\text{MSST} = 1.33$), but that overfishing is occurring ($F_{2019-2021}/F_{40\%} = 1.16$). Sensitivity runs and MCBE analyses show that that there is substantial uncertainty in these qualitative results, with considerably more uncertainty in the overfishing status than in the stock status. Almost half of the MCBE runs suggest that overfishing is not occurring. This is partly because the estimated F-status indicator $F/F_{40\%}$ is very close to the cutoff value of 1, so much of the distribution around $F/F_{40\%}$ is is below 1. Comparing the MCBE results (Figure 41) with sensitivity to natural mortality (Figure 46), it is clear that much of the uncertainty in this stock assessment was driven by variation in M over the range that was considered ($0.2387-0.5313$). This range was computed based on ranges chosen for other stock assessments in the South Atlantic region, which on average are 38% above and below the base value.

The ASPM diagnostic helped demonstrate that trends in abundance, indexed the SERFS trap/video survey, were not well explained by trends in removals. It was necessary to account for variability in recruitment to adequately fit the index. Similar patterns were presented an exampled provided by Carvalho et al. (2021). Furthermore, in the base model, the trend in recruitment was not well supported by information in the age compositions.

Results of several individual sensitivity runs suggest that stock status might be higher and fishery status might be lower than what is observed in the base run, for example, if there was no ageing error or if age-dependence of fecundity was not taken into account. Such analyses demonstrate the importance of including these relationships in the model, but they are not considered equally valid to the base model.

In this assessment, removals were separated into north and south subfleets, along a management boundary, in the interest of providing separate catch advice for the South Atlantic council area, south of that boundary. The northern removals were not simply excluded because it is hypothesized that they are part of the same biological stock, though further research in population structure is warranted. Gray Triggerfish tends to be a warmer water species and observations of the species north of the North Carolina/Virginia border are more limited than in areas to the south. Seasonal patterns of spring absence and fall presence of juvenile and adult Gray Triggerfish north of 36° N latitude in the Northeast Fisheries Science Center Bottom Trawl Survey and other data sources may suggest immigration from the south during the warmer months. Tagging data exist for Gray Triggerfish caught in Virginia waters, but most recaptured fish were caught after a short period at large, nearly all between June and November. Evidence from mitochondrial (Antoni et al. 2011) and microsatellite (Antoni 2017; Antoni and Saillant 2017) DNA suggest that Gray Triggerfish are genetically homogeneous from the waters off of east Texas in the Gulf of Mexico to South Carolina (i.e. the northern extent of sampling in the western Atlantic) and even shows connectivity with fish collected in France. Long distance movement is suggested by genetic analysis of Gray Triggerfish in other regions, inviting investigation into north and south movement in the US Atlantic as well.

5.2 Comments on Projections

As usual, projections should be interpreted in light of the model assumptions and key aspects of the data. Some major considerations are the following:

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5–10 years).
- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. Benchmarks (e.g. $L_{\mathrm{F40\%}}$) are conditional on the estimated selectivity functions and the relative contributions of each fleet's fishing mortality. New management regulations that reallocate harvest in a way that alters proportions of F by fleet or selectivity patterns would likely affect projection results.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes or an overall trend in average recruitment, possibly due to environmental or ecological conditions, stock trajectories will be affected.
- Projections apply the Baranov catch equation to relate F and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures are in effect, introducing additional and unquantified uncertainty into the projection results.

6 Research Recommendations

Although it is difficult to estimate the duration of potential research projects, research recommendations have been divided into short and long term groups. Recommendations in the short term group largely suggest further analysis of existing data, and progress may be made relatively quickly. But any of the recommendations could potentially be developed into short or long term projects.

Short term

- Continue to investigate aging methods and aging error: Are spines the best way to age triggerfish? What are the limits of spine based age readings? Increase the number of age samples used to estimate an age-error matrix and consider multiple sources of error. In this assessment, age-error due to differences in aging otoliths versus spines was characterized. But other sources of error, such as error between readers, could also be important.
- Refine estimates of age-dependent reproductive output and associated relationships (i.e. maturity, batch fecundity, and batch number) considering the newest methodologies.
- Investigate methods for standardizing age or length composition data available US South Atlantic Gray Triggerfish, accounting for covariates (e.g. depth, latitude, longitude, time of year).

Long term

- Improve understanding of recruitment, stock structure and potential range shifts in the Atlantic Ocean, including areas outside of SAFMC jurisdiction and outside of the US EEZ.
- Expand fishery independent information to northern areas, maintaining consistent sampling for the SERFS trap/video index of abundance and age compositions.
- Develop direct estimates of natural mortality and associated uncertainty.
- Investigate temporal variation in recruitment and survivorship, considering potential environmental relationships.

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8 Tables

Table 1. Life-history characteristics at age. Variables include size information of fish at midyear: fork length for the population (FL) and landings (FL_{L}) in millimeters (mm), whole weight (WW) in kilograms (kg) and pounds (lb) for the population. Other variables include proportion female (P_{fem}), proportion of females mature ($P_{\mathrm{fem.mat}}$), batch fecundity (f_{batch}) and number of batches (n_{batch}) of individual females. Reproductive value (reprod) is an SSB analog in units of million eggs produced per fish in the population. M = natural mortality.

Age	$\mathrm{FL}_{\mathrm{pop}}$ (mm)	FL_{L} (mm)	WW (kg)	WW (lb)	P_{fem}	$P_{\mathrm{fem.mat}}$	f_{batch}	n_{batch}	reprod	M
1	256	321	0.39	0.86	0.59	0.75	0.45	0.10	0.02	0.61
2	312	343	0.70	1.55	0.55	0.93	0.94	2.10	1.01	0.51
3	351	362	0.99	2.19	0.56	0.98	1.27	3.30	2.31	0.46
4	378	380	1.24	2.73	0.53	1.00	1.51	4.30	3.44	0.43
5	397	395	1.44	3.17	0.55	1.00	1.68	6.30	5.81	0.41
6	410	409	1.58	3.49	0.55	1.00	1.79	6.30	6.21	0.40
7	419	421	1.69	3.73	0.55	1.00	1.87	6.30	6.50	0.39
8	426	432	1.77	3.91	0.55	1.00	1.93	6.30	6.69	0.39

Table 2. Observed time series of landings (L) and discards (D) for commercial handline landings, south (L.cHLs); commercial handline landings, north (L.cHLn); recreational headboat landings, south (L.rHBs); general recreational landings, south (L.rGNs); general recreational landings, north (L.rGNn); recreational headboat discards, south (D.rHDs); general recreational discards, south (D.rGDs); and general recreational discards, north (D.rGDn). Commercial landings are in units of 1000 lb whole weight. Recreational landings and all discards are in units of 1000 fish.

Year	L.cHLs	L.cHLn	L.rHBs	L.rGNs	L.rGNn	D.rHDs	D.rGDs	D.rGDn
1982	96.64	0.10	29.50	91.17	0.51	3.32	27.53	0.10
1983	68.30	0.90	28.61	75.95	51.41	13.09	271.57	0.10
1984	73.68	0.82	26.90	221.80	3.07	5.92	45.81	0.10
1985	68.42	0.75	35.60	97.94	5.72	12.94	58.86	0.10
1986	68.70	0.67	28.37	51.64	22.59	7.16	169.93	0.84
1987	73.97	0.59	29.58	75.30	70.36	21.06	138.60	4.90
1988	80.95	0.52	34.93	160.64	1.85	34.97	83.68	4.44
1989	97.32	0.44	37.37	228.61	60.15	1.11	348.18	3.97
1990	191.67	0.36	71.70	184.32	50.15	1.57	60.79	37.38
1991	270.91	1.24	85.53	577.08	59.06	2.04	475.37	9.94
1992	262.23	0.89	91.73	262.11	23.17	1.31	218.49	4.69
1993	324.98	4.48	107.07	215.51	64.69	1.46	69.73	9.71
1994	372.84	17.97	90.39	118.10	57.09	1.61	78.17	7.53
1995	472.22	19.80	93.37	78.69	61.50	6.12	98.04	5.20
1996	433.61	16.70	89.95	118.10	118.44	1.92	118.15	48.48
1997	548.83	15.15	106.17	113.83	445.10	2.65	72.85	24.44
1998	408.76	8.58	65.86	79.30	26.35	6.40	39.80	8.10
1999	272.26	10.07	37.22	119.76	1.58	10.15	89.68	1.87
2000	196.18	5.17	34.09	99.51	29.21	3.67	105.49	6.52
2001	215.37	5.16	32.98	93.93	34.24	3.59	61.73	13.44
2002	192.13	15.29	57.63	191.36	71.67	17.25	142.78	8.38
2003	182.85	11.43	45.75	217.29	31.52	5.83	193.19	8.94
2004	243.26	8.90	78.07	202.43	132.34	20.65	177.03	21.84
2005	267.42	5.89	63.58	143.93	111.13	26.73	163.09	2.14
2006	238.18	5.05	43.15	253.24	7.00	16.03	166.61	2.84
2007	316.18	10.60	66.40	389.02	65.15	10.56	246.52	50.82
2008	320.40	5.75	44.76	322.04	14.10	6.50	173.74	1.66
2009	355.47	15.92	59.94	438.06	168.09	6.15	254.21	44.02
2010	441.72	11.45	68.81	317.65	75.72	11.42	146.04	41.17
2011	481.73	17.56	53.36	214.51	27.42	6.80	79.18	8.26
2012	280.64	34.38	49.10	194.69	131.39	7.47	112.11	10.82
2013	317.58	25.80	56.49	265.83	48.90	5.16	188.01	21.77
2014	275.90	10.62	53.11	410.45	161.22	7.16	247.26	12.09
2015	342.50	5.14	45.97	188.92	38.11	17.83	316.73	19.05
2016	308.18	7.61	37.84	724.98	75.04	39.58	1470.94	32.01
2017	323.64	26.31	43.36	421.06	115.93	16.83	413.00	13.36
2018	313.96	19.63	35.09	251.86	147.57	14.07	362.68	26.46
2019	321.79	12.94	35.77	304.86	147.69	15.60	283.32	26.69
2020	310.72	8.24	28.14	352.51	258.50	8.55	145.70	69.69
2021	210.23	9.04	26.19	464.52	124.24	8.61	358.12	25.22

Table 3. Observed time series of CVs used in the Monte Carlo/Bootstrap Ensemble (MCBE) associated with landings (L) and discards (D) for commercial handline landings, south (L.cHLs); commercial handline landings, north (L.cHLn); recreational headboat landings, south (L.rHBs); general recreational landings, south (L.rGNs); general recreational landings, north (L.rGNn); recreational headboat discards, south (D.rHDs); general recreational discards, south (D.rGDs); and general recreational discards, north (D.rGDn). These CVs were used to generate bootstrap data sets in the ensemble model analysis only. When fitting to landings and discards the assessment model, CVs of 0.05 were used.

Year	L.cHLs	L.cHLn	L.rHBs	L.rGNs	L.rGNn	D.rHDs	D.rGDs	D.rGDn
1982	0.10	0.10	0.35	0.34	0.34	0.58	0.68	0.68
1983	0.10	0.10	0.39	0.39	0.39	0.54	0.71	0.71
1984	0.10	0.10	0.34	0.37	0.37	0.34	0.69	0.69
1985	0.10	0.10	0.53	0.57	0.57	0.46	0.63	0.63
1986	0.10	0.10	0.52	0.35	0.35	0.78	0.52	0.52
1987	0.10	0.10	0.45	0.40	0.40	0.56	0.38	0.38
1988	0.10	0.10	0.45	0.41	0.41	0.60	0.32	0.32
1989	0.10	0.10	0.53	0.35	0.35	0.54	0.27	0.27
1990	0.10	0.10	0.62	0.22	0.22	0.47	0.35	0.35
1991	0.10	0.10	0.62	0.38	0.38	0.35	0.47	0.47
1992	0.10	0.10	0.58	0.24	0.24	0.27	0.22	0.22
1993	0.10	0.10	0.29	0.28	0.28	0.33	0.26	0.26
1994	0.06	0.06	0.34	0.18	0.18	0.26	0.32	0.32
1995	0.06	0.06	0.33	0.19	0.19	0.24	0.27	0.27
1996	0.06	0.06	0.32	0.26	0.26	0.28	0.34	0.34
1997	0.07	0.07	0.27	0.73	0.73	0.36	0.30	0.30
1998	0.06	0.06	0.31	0.31	0.31	0.31	0.25	0.25
1999	0.07	0.07	0.28	0.19	0.19	0.37	0.21	0.21
2000	0.07	0.07	0.35	0.27	0.27	0.34	0.22	0.22
2001	0.08	0.08	0.42	0.21	0.21	0.25	0.20	0.20
2002	0.06	0.06	0.45	0.18	0.18	0.20	0.21	0.21
2003	0.06	0.06	0.47	0.25	0.25	0.26	0.25	0.25
2004	0.05	0.05	0.48	0.23	0.23	0.17	0.22	0.22
2005	0.05	0.05	0.41	0.23	0.23	0.30	0.18	0.18
2006	0.05	0.05	0.46	0.27	0.27	0.31	0.25	0.25
2007	0.05	0.05	0.42	0.16	0.16	0.31	0.18	0.18
2008	0.05	0.05	0.49	0.20	0.20	0.49	0.18	0.18
2009	0.05	0.05	0.15	0.17	0.17	0.15	0.35	0.35
2010	0.05	0.05	0.16	0.18	0.18	0.16	0.23	0.23
2011	0.05	0.05	0.10	0.23	0.23	0.10	0.23	0.23
2012	0.06	0.06	0.09	0.21	0.21	0.09	0.27	0.27
2013	0.05	0.05	0.10	0.18	0.18	0.10	0.29	0.29
2014	0.05	0.05	0.08	0.21	0.21	0.08	0.20	0.20
2015	0.05	0.05	0.07	0.18	0.18	0.07	0.22	0.22
2016	0.05	0.05	0.06	0.37	0.37	0.06	0.35	0.35
2017	0.05	0.05	0.08	0.16	0.16	0.08	0.23	0.23
2018	0.05	0.05	0.05	0.16	0.16	0.05	0.26	0.26
2019	0.05	0.05	0.06	0.21	0.21	0.06	0.25	0.25
2020	0.05	0.05	0.06	0.29	0.29	0.06	0.33	0.33
2021	0.05	0.05	0.05	0.24	0.24	0.05	0.26	0.26

Table 4. Observed index of abundance and CVs from the SERFS trap/video survey (sTVs).

Year	sTVs	cv.sTVs
1982	.	.
1983	.	.
1984	.	.
1985	.	.
1986	.	.
1987	.	.
1988	.	.
1989	.	.
1990	.	.
1991	1.274	0.146
1992	0.880	0.164
1993	0.777	0.142
1994	1.095	0.140
1995	1.363	0.132
1996	1.690	0.130
1997	1.993	0.143
1998	1.706	0.151
1999	0.893	0.180
2000	0.689	0.206
2001	0.946	0.141
2002	1.403	0.160
2003	0.636	0.240
2004	1.117	0.162
2005	0.768	0.151
2006	0.653	0.181
2007	0.809	0.157
2008	0.871	0.172
2009	0.641	0.174
2010	0.566	0.151
2011	0.834	0.110
2012	1.087	0.088
2013	1.240	0.086
2014	1.213	0.086
2015	0.899	0.081
2016	1.201	0.090
2017	1.196	0.081
2018	0.854	0.086
2019	0.907	0.094
2020	.	.
2021	0.536	0.165

Table 5. Sample sizes (number of trips) for age compositions (ac) or length compositions (lc) for commercial handline, south, early years (cHLsa); commercial handline, south, late years (cHLsb); recreational headboat, south, early years (rHBsa); recreational headboat, south, late years (rHBsb); SERFS trap video survey, south, early years (sTVsa); SERFS trap video survey, south, late years (sTVsb); and recreational headboat discards, south, all years (rHDs). In early years (1982-2014), the assessment fit to ages 1-5+ and in the late years (2015-2021), it fit to ages 1-8+.

Year	ac.cHLsa	ac.cHLsb	ac.rHBsa	ac.rHBsb	ac.sTVsa	ac.sTVsb	lc.rHDs
1982	.	.	.	.	.	.	.
1983	.	.	.	.	.	.	.
1984	.	.	.	.	.	.	.
1985	.	.	.	.	.	.	.
1986	.	.	.	.	.	.	.
1987	.	.	.	.	.	.	.
1988	.	.	.	.	.	.	.
1989	.	.	.	.	.	.	.
1990	.	.	10	.	.	.	.
1991	.	.	21	.	56	.	.
1992	.	.	.	.	85	.	.
1993	.	.	.	.	119	.	.
1994	.	.	.	.	151	.	.
1995	.	.	.	.	145	.	.
1996	.	.	.	.	175	.	.
1997	.	.	.	.	185	.	.
1998	.	.	.	.	122	.	.
1999	.	.	.	.	62	.	.
2000	.	.	.	.	90	.	.
2001	.	.	.	.	91	.	.
2002	.	.	.	.	107	.	.
2003	.	.	18	.	34	.	.
2004	25	.	.	.	79	.	.
2005	.	.	18	.	100	.	44
2006	87	.	30	.	68	.	42
2007	196	.	51	.	100	.	41
2008	205	.	10	.	64	.	28
2009	178	.	26	.	79	.	49
2010	214	.	53	.	97	.	48
2011	213	.	35	.	116	.	31
2012	111	.	46	.	190	.	36
2013	97	.	134	.	281	.	40
2014	68	.	171	.	304	.	48
2015	.	121	.	133	.	191	70
2016	.	68	.	238	.	177	96
2017	.	55	.	165	.	195	82
2018	.	43	.	137	.	153	79
2019	.	40	.	51	.	158	87
2020	.	33	.	.	.	.	10
2021	.	.	.	.	.	.	.

Table 6. Sample sizes (number of fish) for age compositions (ac) or length compositions (lc) for commercial handline, south, early years (cHLsa); commercial handline, south, late years (cHLsb); recreational headboat, south, early years (rHBsa); recreational headboat, south, late years (rHBsb); SERFS trap video survey, south, early years (sTVsa); SERFS trap video survey, south, late years (sTVsb); and recreational headboat discards, south, all years (rHDs). In early years (1982-2014), the assessment fit to ages 1-5+ and in the late years (2015-2021), it fit to ages 1-8+.

Year	ac.cHLsa	ac.cHLsb	ac.rHBsa	ac.rHBsb	ac.sTVsa	ac.sTVsb	lc.rHDs
1982	.	.	.	.	.	.	.
1983	.	.	.	.	.	.	.
1984	.	.	.	.	.	.	.
1985	.	.	.	.	.	.	.
1986	.	.	.	.	.	.	.
1987	.	.	.	.	.	.	.
1988	.	.	.	.	.	.	.
1989	.	.	.	.	.	.	.
1990	.	.	18	.	.	.	.
1991	.	.	37	.	302	.	.
1992	.	.	.	.	165	.	.
1993	.	.	.	.	976	.	.
1994	.	.	.	.	393	.	.
1995	.	.	.	.	568	.	.
1996	.	.	.	.	1142	.	.
1997	.	.	.	.	726	.	.
1998	.	.	.	.	457	.	.
1999	.	.	.	.	181	.	.
2000	.	.	.	.	220	.	.
2001	.	.	.	.	224	.	.
2002	.	.	.	.	313	.	.
2003	.	.	35	.	72	.	.
2004	187	.	.	.	193	.	.
2005	.	.	66	.	337	.	110
2006	461	.	129	.	175	.	102
2007	673	.	97	.	330	.	111
2008	734	.	18	.	272	.	89
2009	686	.	27	.	238	.	124
2010	976	.	97	.	197	.	118
2011	1262	.	65	.	338	.	59
2012	760	.	137	.	451	.	61
2013	563	.	502	.	909	.	143
2014	423	.	557	.	976	.	212
2015	.	677	.	286	.	296	378
2016	.	292	.	594	.	295	440
2017	.	191	.	404	.	299	420
2018	.	112	.	291	.	298	358
2019	.	129	.	92	.	294	412
2020	.	104	.	.	.	.	50
2021	.	.	.	.	.	.	.

Table 7. Estimated total abundance at age (1000 fish) at start of year.

Year	1	2	3	4	5	6	7	8	Total
1982	4687.90	2504.81	1490.38	913.82	563.16	352.53	222.81	393.32	11128.73
1983	4687.90	2527.49	1494.97	915.04	563.48	352.53	222.80	393.30	11157.52
1984	4687.90	2372.84	1477.12	911.63	559.18	349.63	220.85	389.83	10968.99
1985	4687.90	2513.74	1408.55	882.65	537.18	333.88	210.74	371.77	10946.41
1986	4687.90	2502.30	1494.62	861.09	541.10	334.40	209.85	369.79	11001.05
1987	4687.90	2437.69	1477.05	920.84	535.26	341.80	213.28	373.39	10987.21
1988	4687.90	2445.05	1437.36	896.36	557.50	328.82	211.99	367.50	10932.47
1989	4687.90	2470.37	1445.36	867.47	537.17	338.76	201.71	359.04	10907.79
1990	2981.84	2329.30	1427.27	845.44	492.46	308.20	196.17	327.97	8908.65
1991	6044.29	1561.95	1368.21	832.38	473.73	277.96	175.51	301.45	11035.48
1992	5004.72	2955.20	881.92	699.47	368.86	208.22	123.11	213.34	10454.84
1993	5988.46	2580.42	1713.74	484.49	349.00	183.35	104.32	170.24	11574.01
1994	7138.73	3198.26	1513.30	940.30	238.78	170.63	90.31	136.57	13426.87
1995	6086.70	3820.31	1888.14	867.67	498.57	125.93	90.68	121.77	13499.77
1996	3361.89	3239.36	2256.17	1098.84	470.07	268.53	68.34	116.42	10879.64
1997	2378.08	1733.64	1891.75	1303.49	593.64	253.32	145.86	101.35	8401.12
1998	2864.19	1232.29	1003.05	1007.55	607.69	273.25	117.43	115.72	7221.16
1999	3280.60	1521.03	728.74	593.61	567.68	342.41	155.22	133.75	7323.06
2000	4458.24	1717.85	895.35	431.35	337.34	323.76	196.95	167.86	8528.71
2001	4020.58	2346.76	1012.29	528.04	244.71	192.39	186.25	211.95	8742.97
2002	4198.25	2135.51	1386.77	596.42	298.02	138.63	109.92	229.77	9093.29
2003	3030.20	2174.79	1243.86	778.94	310.50	155.16	72.77	180.09	7946.31
2004	3961.96	1524.40	1256.81	706.40	414.29	165.45	83.38	137.23	8249.91
2005	3813.49	2009.55	877.78	680.98	344.04	200.71	80.78	108.78	8116.10
2006	3021.48	1951.71	1163.03	483.06	338.90	170.17	100.04	95.42	7323.80
2007	4964.63	1529.96	1126.17	642.03	242.01	168.88	85.46	99.13	8858.29
2008	3678.46	2490.36	868.10	559.98	264.80	97.76	68.66	75.78	8103.89
2009	4942.80	1887.83	1430.23	446.92	243.47	112.78	41.90	62.51	9168.43
2010	3820.84	2482.44	1056.82	639.64	150.19	78.63	36.59	34.20	8299.34
2011	6194.81	1952.99	1411.68	507.78	238.48	53.70	28.23	25.67	10413.34
2012	6785.48	3298.55	1139.42	744.39	221.48	100.46	22.73	23.03	12335.54
2013	3978.22	3599.56	1922.35	605.23	342.84	100.38	45.84	21.08	10615.50
2014	7069.02	2039.98	2084.15	1054.53	296.04	165.79	48.89	32.91	12791.31
2015	6474.52	3658.69	1177.18	1093.54	484.60	134.80	76.06	37.90	13137.28
2016	4651.25	3300.79	2127.65	677.39	587.74	259.89	72.87	62.21	11739.80
2017	3264.66	1660.94	1681.31	1061.79	287.35	246.01	109.57	57.51	8369.13
2018	3336.98	1501.23	923.58	885.12	489.66	131.11	113.08	77.55	7458.32
2019	4687.90	1559.93	840.74	492.96	417.30	228.55	61.65	90.52	8379.56
2020	4687.90	2330.23	882.76	418.80	204.03	169.19	93.27	62.70	8848.88
2021	4687.90	2399.08	1306.09	381.55	133.52	62.49	52.07	48.47	9071.17

Table 8. Estimated total biomass at age (mt) at start of year.

Year	1	2	3	4	5	6	7	8	Total
1982	1837.67	1756.02	1480.67	1133.50	808.50	558.38	377.37	697.55	8649.67
1983	1837.67	1771.92	1485.24	1135.01	808.97	558.39	377.35	697.51	8672.07
1984	1837.67	1663.50	1467.50	1130.79	802.79	553.80	374.05	691.37	8521.46
1985	1837.67	1762.28	1399.38	1094.84	771.20	528.84	356.93	659.34	8410.47
1986	1837.67	1754.27	1484.88	1068.09	776.84	529.67	355.41	655.82	8462.64
1987	1837.67	1708.97	1467.43	1142.20	768.45	541.39	361.22	662.21	8489.54
1988	1837.67	1714.13	1427.99	1111.84	800.37	520.83	359.04	651.76	8423.63
1989	1837.67	1731.88	1435.95	1076.00	771.19	536.58	341.64	636.76	8367.67
1990	1168.89	1632.98	1417.98	1048.68	707.01	488.18	332.25	581.65	7377.61
1991	2369.38	1095.02	1359.30	1032.48	680.11	440.27	297.26	534.62	7808.45
1992	1961.86	2071.78	876.17	867.62	529.56	329.81	208.51	378.36	7223.67
1993	2347.49	1809.03	1702.58	600.96	501.04	290.42	176.69	301.91	7730.11
1994	2798.40	2242.17	1503.44	1166.34	342.81	270.27	152.96	242.21	8718.60
1995	2386.00	2678.27	1875.85	1076.25	715.77	199.47	153.58	215.95	9301.14
1996	1317.87	2270.99	2241.48	1363.00	674.86	425.34	115.75	206.48	8615.77
1997	932.21	1215.38	1879.43	1616.84	852.26	401.25	247.04	179.75	7324.15
1998	1122.77	863.91	996.52	1249.76	872.43	432.81	198.89	205.23	5942.30
1999	1286.00	1066.34	724.00	736.32	814.99	542.37	262.89	237.21	5670.11
2000	1747.64	1204.31	889.52	535.04	484.30	512.82	333.57	297.70	6004.92
2001	1576.08	1645.22	1005.70	654.98	351.31	304.73	315.45	375.90	6229.37
2002	1645.72	1497.12	1377.74	739.79	427.85	219.58	186.17	407.50	6501.48
2003	1187.84	1524.66	1235.75	966.19	445.77	245.77	123.26	319.39	6048.64
2004	1553.10	1068.69	1248.63	876.22	594.77	262.07	141.21	243.37	5988.06
2005	1494.90	1408.82	872.07	844.68	493.92	317.91	136.82	192.91	5762.02
2006	1184.43	1368.26	1155.45	599.19	486.54	269.54	169.44	169.22	5402.07
2007	1946.15	1072.60	1118.84	796.38	347.44	267.50	144.74	175.80	5869.45
2008	1441.97	1745.89	862.45	694.59	380.17	154.84	116.29	134.39	5530.58
2009	1937.59	1323.48	1420.92	554.35	349.54	178.63	70.96	110.86	5946.33
2010	1497.78	1740.34	1049.94	793.40	215.61	124.54	61.98	60.66	5544.25
2011	2428.38	1369.16	1402.48	629.85	342.38	85.06	47.82	45.52	6350.65
2012	2659.92	2312.48	1132.00	923.34	317.97	159.12	38.49	40.85	7584.18
2013	1559.47	2523.51	1909.83	750.72	492.21	159.00	77.63	37.39	7509.76
2014	2771.07	1430.15	2070.58	1308.04	425.01	262.60	82.80	58.37	8408.62
2015	2538.03	2564.96	1169.51	1356.42	695.71	213.52	128.82	67.21	8734.19
2016	1823.30	2314.05	2113.80	840.24	843.79	411.65	123.42	110.33	8580.58
2017	1279.75	1164.42	1670.36	1317.04	412.53	389.67	185.57	101.99	6521.34
2018	1308.10	1052.45	917.57	1097.91	702.98	207.68	191.52	137.54	5615.74
2019	1837.67	1093.61	835.26	611.47	599.10	362.02	104.42	160.53	5604.07
2020	1837.67	1633.63	877.01	519.48	292.91	267.99	157.96	111.20	5697.86
2021	1837.67	1681.90	1297.58	473.28	191.68	98.98	88.20	85.95	5755.24

Table 9. Estimated total biomass at age (1000 lb) at start of year.

Year	1	2	3	4	5	6	7	8	Total
1982	4051.30	3871.30	3264.30	2498.90	1782.40	1231.00	831.90	1537.80	19069.10
1983	4051.30	3906.40	3274.40	2502.20	1783.50	1231.00	831.90	1537.70	19118.40
1984	4051.30	3667.40	3235.30	2492.90	1769.80	1220.90	824.60	1524.20	18786.40
1985	4051.30	3885.10	3085.10	2413.70	1700.20	1165.90	786.90	1453.60	18541.70
1986	4051.30	3867.50	3273.60	2354.70	1712.60	1167.70	783.50	1445.80	18656.70
1987	4051.30	3767.60	3235.10	2518.10	1694.10	1193.50	796.30	1459.90	18716.00
1988	4051.30	3779.00	3148.10	2451.20	1764.50	1148.20	791.50	1436.90	18570.70
1989	4051.30	3818.10	3165.70	2372.10	1700.20	1182.90	753.20	1403.80	18447.40
1990	2576.90	3600.10	3126.10	2311.90	1558.70	1076.20	732.50	1282.30	16264.70
1991	5223.50	2414.10	2996.70	2276.20	1499.40	970.60	655.30	1178.60	17214.50
1992	4325.10	4567.40	1931.60	1912.80	1167.50	727.10	459.70	834.10	15925.30
1993	5175.30	3988.20	3753.50	1324.90	1104.60	640.30	389.50	665.60	17041.80
1994	6169.40	4943.10	3314.50	2571.30	755.80	595.80	337.20	534.00	19221.00
1995	5260.20	5904.50	4135.50	2372.70	1578.00	439.80	338.60	476.10	20505.30
1996	2905.40	5006.60	4941.60	3004.90	1487.80	937.70	255.20	455.20	18994.30
1997	2055.20	2679.40	4143.40	3564.50	1878.90	884.60	544.60	396.30	16146.80
1998	2475.30	1904.60	2196.90	2755.20	1923.40	954.20	438.50	452.50	13100.40
1999	2835.10	2350.90	1596.10	1623.30	1796.70	1195.70	579.60	523.00	12500.30
2000	3852.80	2655.00	1961.00	1179.50	1067.70	1130.60	735.40	656.30	13238.40
2001	3474.60	3627.10	2217.20	1444.00	774.50	671.80	695.40	828.70	13733.30
2002	3628.20	3300.60	3037.40	1630.90	943.20	484.10	410.40	898.40	14333.20
2003	2618.70	3361.30	2724.30	2130.10	982.70	541.80	271.70	704.10	13334.80
2004	3424.00	2356.00	2752.70	1931.70	1311.20	577.80	311.30	536.50	13201.30
2005	3295.70	3105.90	1922.60	1862.20	1088.90	700.90	301.60	425.30	12702.90
2006	2611.20	3016.50	2547.30	1321.00	1072.60	594.20	373.50	373.10	11909.40
2007	4290.50	2364.70	2466.60	1755.70	766.00	589.70	319.10	387.60	12939.80
2008	3179.00	3849.00	1901.40	1531.30	838.10	341.40	256.40	296.30	12192.70
2009	4271.60	2917.70	3132.60	1222.10	770.60	393.80	156.40	244.40	13109.30
2010	3302.00	3836.80	2314.70	1749.10	475.30	274.60	136.60	133.70	12222.90
2011	5353.60	3018.50	3091.90	1388.60	754.80	187.50	105.40	100.40	14000.60
2012	5864.10	5098.10	2495.60	2035.60	701.00	350.80	84.90	90.10	16720.10
2013	3438.00	5563.30	4210.40	1655.00	1085.10	350.50	171.10	82.40	16556.00
2014	6109.10	3152.90	4564.80	2883.70	937.00	578.90	182.50	128.70	18537.60
2015	5595.30	5654.70	2578.30	2990.40	1533.80	470.70	284.00	148.20	19255.40
2016	4019.60	5101.60	4660.10	1852.40	1860.20	907.50	272.10	243.20	18916.70
2017	2821.30	2567.10	3682.50	2903.50	909.50	859.10	409.10	224.80	14376.90
2018	2883.80	2320.20	2022.90	2420.50	1549.80	457.90	422.20	303.20	12380.50
2019	4051.30	2411.00	1841.40	1348.00	1320.80	798.10	230.20	353.90	12354.70
2020	4051.30	3601.50	1933.50	1145.20	645.70	590.80	348.20	245.20	12561.50
2021	4051.30	3707.90	2860.60	1043.40	422.60	218.20	194.40	189.50	12688.00

Table 10. Estimated time series of status indicators. Fishing mortality rate is apical F (F; a.k.a. F_{full}). Total biomass (B; mt) and spawning stock biomass (SSB; 1e+12 eggs) are at the start of the year. The MSST *is defined by* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{F40\%}}$*, with constant* $M = 0.38$*. SPR is static spawning potential ratio and* R_y *is expected annual recruitment.*

Year	F	$F/F_{40\%}$	B	B/B_{unfished}	SSB	$\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F40\%}}$	SSB/MSST	SPR	R_y
1982	0.059	0.105	8650	0.919	14.79	2.127	3.459	0.862	4687903
1983	0.071	0.126	8672	0.921	14.75	2.121	3.450	0.777	4687903
1984	0.106	0.189	8521	0.905	14.33	2.061	3.351	0.773	4687903
1985	0.064	0.115	8410	0.893	14.14	2.034	3.308	0.839	4687903
1986	0.050	0.089	8463	0.899	14.31	2.058	3.346	0.839	4687903
1987	0.078	0.138	8490	0.902	14.28	2.054	3.340	0.791	4687903
1988	0.089	0.158	8424	0.895	14.09	2.027	3.296	0.784	4687903
1989	0.146	0.261	8368	0.889	13.59	1.954	3.178	0.649	4687903
1990	0.163	0.291	7378	0.784	12.78	1.839	2.990	0.678	2981837
1991	0.415	0.738	7808	0.829	10.54	1.516	2.466	0.436	6044289
1992	0.291	0.519	7224	0.767	9.58	1.378	2.240	0.548	5004718
1993	0.308	0.549	7730	0.821	9.69	1.395	2.268	0.565	5988458
1994	0.232	0.414	8719	0.926	10.48	1.507	2.451	0.635	7138726
1995	0.211	0.377	9301	0.988	12.33	1.774	2.884	0.655	6086695
1996	0.211	0.375	8616	0.915	13.44	1.934	3.144	0.624	3361885
1997	0.369	0.657	7324	0.778	12.16	1.750	2.845	0.504	2378084
1998	0.166	0.295	5942	0.631	10.49	1.509	2.454	0.700	2864188
1999	0.153	0.273	5670	0.602	9.63	1.385	2.252	0.698	3280604
2000	0.153	0.272	6005	0.638	8.95	1.287	2.093	0.700	4458240
2001	0.160	0.285	6229	0.662	9.02	1.297	2.109	0.701	4020581
2002	0.245	0.436	6501	0.691	9.11	1.311	2.131	0.589	4198247
2003	0.221	0.394	6049	0.642	9.10	1.309	2.129	0.587	3030196
2004	0.317	0.565	5988	0.636	8.49	1.221	1.986	0.519	3961961
2005	0.296	0.528	5762	0.612	7.94	1.142	1.857	0.542	3813488
2006	0.289	0.514	5402	0.574	7.78	1.119	1.819	0.540	3021483
2007	0.500	0.891	5869	0.623	6.84	0.984	1.600	0.419	4964632
2008	0.448	0.797	5531	0.587	6.70	0.964	1.568	0.458	3678463
2009	0.726	1.293	5946	0.632	6.21	0.893	1.451	0.349	4942799
2010	0.625	1.112	5544	0.589	6.08	0.875	1.423	0.393	3820838
2011	0.460	0.819	6351	0.675	6.47	0.931	1.514	0.488	6194808
2012	0.385	0.685	7584	0.806	7.80	1.122	1.824	0.512	6785481
2013	0.320	0.569	7510	0.798	9.70	1.396	2.270	0.531	3978220
2014	0.379	0.676	8409	0.893	9.85	1.417	2.304	0.492	7069015
2015	0.215	0.383	8734	0.928	10.97	1.578	2.566	0.610	6474520
2016	0.464	0.826	8581	0.911	11.28	1.622	2.638	0.278	4651246
2017	0.378	0.672	6521	0.693	9.52	1.370	2.227	0.425	3264655
2018	0.355	0.632	5616	0.596	8.21	1.181	1.920	0.447	3336981
2019	0.497	0.884	5604	0.595	6.82	0.981	1.596	0.415	4687903
2020	0.779	1.387	5698	0.605	5.80	0.835	1.357	0.342	4687903
2021	0.717	1.276	5755	0.611	5.69	0.819	1.331	0.337	4687903

Table 11. Selectivity at age for commercial handline landings (L.cHLs), recreational headboat landings (L.rHBs), general recreational landings (L.rGNs), recreational headboat discards (D.rHDs), general recreational discards (D.rGDs), SERFS trap/video survey index (U.sTVs), selectivity of landings averaged across fisheries (L.avg), selectivity of discards averaged across fisheries (D.avg), and selectivity of total removals (Total = L.avg). All selectivities were estimated from age or length comps from the southern portion of the stock area, so fleet abbrevations have the suffix 's'. These selectivities were also applied to northern portions of the stock area, for which comp data was not available.

Age	L.cHLs	L.rHBs	L.rGNs	D.rHDs	D.rGDs	U.sTVs	L.avg	D.avg	Total
1	0.00	0.01	0.01	1.00	1.00	0.02	0.00	0.12	0.12
2	0.02	0.08	0.08	0.32	0.32	0.14	0.07	0.04	0.10
3	0.23	0.55	0.55	0.01	0.01	0.52	0.48	0.00	0.49
4	0.79	0.95	0.95	0.00	0.00	0.88	0.91	0.00	0.91
5	0.98	1.00	1.00	0.00	0.00	0.98	0.99	0.00	0.99
6	1.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
7	1.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00
8	1.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00

Table 12. Estimated time series of fully selected fishing mortality rates for commercial handline landings, south (L.cHLs); commercial handline landings, north (L.cHLn); recreational headboat landings, south (L.rHBs); general recreational landings, south (L.rGNs); general recreational landings, north (L.rGNn); recreational headboat discards, south (D.rHDs); general recreational discards, south (D.rGDs); and general recreational discards, north (D.rGDn). Also shown is F_{full} (i.e. apical F), the maximum F at age summed across fleets, and F_{sum}, the sum of all fleet-specific values of fully selected F.

Year	$F_{\mathrm{L.cHLs}}$	$F_{\mathrm{L.cHLn}}$	$F_{\mathrm{L.rHBs}}$	$F_{\mathrm{L.rGNs}}$	$F_{\mathrm{L.rGNn}}$	$F_{\mathrm{D.rHDs}}$	$F_{\mathrm{D.rGDs}}$	$F_{\mathrm{D.rGDn}}$	F_{full}	F_{sum}
1982	0.014	0.000	0.011	0.033	0.000	0.001	0.007	0.000	0.059	0.066
1983	0.010	0.000	0.011	0.028	0.019	0.003	0.067	0.000	0.071	0.138
1984	0.011	0.000	0.010	0.084	0.001	0.001	0.011	0.000	0.106	0.119
1985	0.011	0.000	0.014	0.038	0.002	0.003	0.014	0.000	0.064	0.082
1986	0.011	0.000	0.011	0.020	0.009	0.002	0.042	0.000	0.050	0.093
1987	0.012	0.000	0.011	0.028	0.027	0.005	0.034	0.001	0.078	0.118
1988	0.013	0.000	0.013	0.062	0.001	0.009	0.021	0.001	0.089	0.119
1989	0.016	0.000	0.015	0.091	0.024	0.000	0.087	0.001	0.146	0.235
1990	0.034	0.000	0.030	0.078	0.021	0.001	0.022	0.013	0.163	0.199
1991	0.056	0.000	0.042	0.287	0.029	0.000	0.101	0.002	0.415	0.518
1992	0.068	0.000	0.054	0.156	0.014	0.000	0.050	0.001	0.291	0.342
1993	0.091	0.001	0.060	0.120	0.036	0.000	0.014	0.002	0.308	0.324
1994	0.094	0.005	0.045	0.059	0.029	0.000	0.013	0.001	0.232	0.247
1995	0.105	0.004	0.041	0.034	0.027	0.001	0.018	0.001	0.211	0.231
1996	0.083	0.003	0.034	0.045	0.045	0.001	0.036	0.015	0.211	0.262
1997	0.102	0.003	0.042	0.045	0.177	0.001	0.033	0.011	0.369	0.415
1998	0.082	0.002	0.032	0.038	0.013	0.003	0.016	0.003	0.166	0.188
1999	0.061	0.002	0.021	0.068	0.001	0.004	0.032	0.001	0.153	0.190
2000	0.050	0.001	0.021	0.062	0.018	0.001	0.028	0.002	0.153	0.184
2001	0.058	0.001	0.021	0.058	0.021	0.001	0.017	0.004	0.160	0.182
2002	0.053	0.004	0.034	0.112	0.042	0.005	0.040	0.002	0.245	0.291
2003	0.049	0.003	0.026	0.125	0.018	0.002	0.071	0.003	0.221	0.297
2004	0.067	0.002	0.047	0.121	0.079	0.006	0.054	0.007	0.317	0.384
2005	0.081	0.002	0.043	0.097	0.075	0.008	0.050	0.001	0.296	0.355
2006	0.078	0.002	0.030	0.175	0.005	0.006	0.062	0.001	0.289	0.358
2007	0.113	0.004	0.049	0.287	0.048	0.003	0.062	0.013	0.500	0.578
2008	0.131	0.002	0.037	0.265	0.012	0.002	0.053	0.001	0.448	0.503
2009	0.165	0.007	0.050	0.364	0.140	0.002	0.063	0.011	0.726	0.801
2010	0.216	0.006	0.060	0.276	0.066	0.003	0.043	0.012	0.625	0.683
2011	0.221	0.008	0.042	0.168	0.022	0.001	0.016	0.002	0.460	0.479
2012	0.109	0.013	0.034	0.136	0.092	0.001	0.019	0.002	0.385	0.407
2013	0.104	0.008	0.032	0.149	0.027	0.001	0.049	0.006	0.320	0.376
2014	0.073	0.003	0.026	0.200	0.078	0.001	0.043	0.002	0.379	0.426
2015	0.081	0.001	0.022	0.092	0.019	0.003	0.056	0.003	0.215	0.278
2016	0.074	0.002	0.018	0.335	0.035	0.011	0.398	0.009	0.464	0.881
2017	0.080	0.007	0.022	0.211	0.058	0.006	0.154	0.005	0.378	0.543
2018	0.085	0.005	0.021	0.153	0.090	0.005	0.134	0.010	0.355	0.504
2019	0.111	0.004	0.028	0.237	0.115	0.004	0.075	0.007	0.497	0.583
2020	0.152	0.004	0.027	0.343	0.252	0.002	0.037	0.017	0.779	0.835
2021	0.123	0.005	0.025	0.445	0.119	0.002	0.091	0.006	0.717	0.816

Table 13. Estimated instantaneous fishing mortality rate F (per yr) at age

Year	1	2	3	4	5	6	7	8
1982	0.008	0.006	0.028	0.053	0.058	0.059	0.059	0.059
1983	0.071	0.027	0.035	0.062	0.067	0.068	0.068	0.068
1984	0.013	0.012	0.055	0.099	0.106	0.106	0.106	0.106
1985	0.018	0.010	0.032	0.059	0.064	0.064	0.064	0.064
1986	0.044	0.017	0.024	0.045	0.049	0.050	0.050	0.050
1987	0.041	0.018	0.039	0.072	0.077	0.078	0.078	0.078
1988	0.031	0.016	0.045	0.082	0.088	0.089	0.089	0.089
1989	0.089	0.039	0.076	0.136	0.146	0.146	0.146	0.146
1990	0.037	0.022	0.079	0.149	0.162	0.163	0.163	0.163
1991	0.106	0.062	0.211	0.384	0.412	0.414	0.415	0.415
1992	0.052	0.035	0.139	0.265	0.289	0.291	0.291	0.291
1993	0.017	0.024	0.140	0.278	0.306	0.308	0.308	0.308
1994	0.015	0.017	0.096	0.204	0.230	0.232	0.232	0.232
1995	0.021	0.017	0.081	0.183	0.209	0.211	0.211	0.211
1996	0.052	0.028	0.089	0.186	0.208	0.210	0.210	0.211
1997	0.047	0.037	0.170	0.333	0.366	0.369	0.369	0.369
1998	0.023	0.015	0.065	0.144	0.164	0.166	0.166	0.166
1999	0.037	0.020	0.064	0.135	0.152	0.153	0.153	0.153
2000	0.032	0.019	0.068	0.137	0.152	0.153	0.153	0.153
2001	0.023	0.016	0.069	0.142	0.158	0.160	0.160	0.160
2002	0.048	0.030	0.117	0.223	0.243	0.244	0.245	0.245
2003	0.077	0.038	0.106	0.201	0.220	0.221	0.221	0.221
2004	0.069	0.042	0.153	0.289	0.315	0.317	0.317	0.317
2005	0.060	0.037	0.137	0.268	0.294	0.296	0.296	0.296
2006	0.071	0.040	0.134	0.261	0.286	0.289	0.289	0.289
2007	0.080	0.057	0.239	0.456	0.496	0.500	0.500	0.500
2008	0.057	0.045	0.204	0.403	0.444	0.447	0.448	0.448
2009	0.079	0.070	0.345	0.661	0.720	0.726	0.726	0.726
2010	0.061	0.054	0.273	0.557	0.618	0.624	0.625	0.625
2011	0.020	0.029	0.180	0.400	0.455	0.460	0.460	0.460
2012	0.024	0.030	0.173	0.345	0.381	0.385	0.385	0.385
2013	0.058	0.036	0.140	0.285	0.317	0.319	0.320	0.320
2014	0.049	0.040	0.185	0.348	0.377	0.379	0.379	0.379
2015	0.064	0.032	0.093	0.191	0.213	0.215	0.215	0.215
2016	0.420	0.165	0.235	0.428	0.461	0.464	0.464	0.464
2017	0.167	0.077	0.182	0.344	0.375	0.377	0.378	0.378
2018	0.150	0.070	0.168	0.322	0.352	0.355	0.355	0.355
2019	0.089	0.059	0.237	0.452	0.493	0.496	0.497	0.497
2020	0.060	0.069	0.379	0.713	0.773	0.778	0.779	0.779
2021	0.103	0.080	0.354	0.659	0.712	0.716	0.717	0.717

Table 14. Total landings at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8
1982	0.95	7.27	32.71	38.77	26.27	16.64	10.57	18.66
1983	1.14	9.00	39.97	45.15	30.14	19.05	12.10	21.36
1984	1.90	13.83	63.25	70.03	46.18	29.15	18.50	32.66
1985	1.10	8.48	35.53	41.41	27.38	17.20	10.91	19.25
1986	0.81	6.25	28.30	31.14	21.43	13.40	8.45	14.89
1987	1.33	10.04	45.39	52.01	32.73	21.11	13.24	23.18
1988	1.53	11.54	50.41	57.54	38.71	23.06	14.94	25.91
1989	2.53	19.56	84.28	90.18	59.99	38.19	22.85	40.67
1990	1.71	19.18	87.00	95.76	60.74	38.43	24.58	41.10
1991	8.99	33.97	209.17	218.62	133.09	78.79	49.98	85.85
1992	4.98	42.33	91.88	133.71	76.70	43.76	26.00	45.06
1993	6.08	37.18	180.49	96.38	76.17	40.48	23.15	37.77
1994	4.90	30.95	111.53	142.35	40.53	29.36	15.62	23.62
1995	3.47	30.56	118.29	118.66	77.61	19.90	14.41	19.35
1996	2.09	28.69	152.97	152.40	73.01	42.28	10.82	18.43
1997	2.89	30.12	237.91	303.74	151.09	65.19	37.72	26.21
1998	1.30	7.85	50.22	110.19	75.67	34.55	14.93	14.71
1999	1.49	9.82	36.31	61.28	65.82	40.26	18.35	15.81
2000	2.17	11.92	47.11	45.06	39.12	38.03	23.25	19.82
2001	1.98	16.44	54.09	57.11	29.54	23.54	22.90	26.07
2002	3.52	25.75	122.58	97.57	53.12	24.98	19.90	41.61
2003	2.26	23.58	99.74	116.30	50.58	25.55	12.04	29.81
2004	4.31	23.96	142.93	145.78	92.75	37.43	18.95	31.20
2005	3.72	28.18	90.31	131.30	72.60	42.83	17.33	23.33
2006	2.86	26.69	116.99	91.08	69.93	35.51	20.98	20.01
2007	8.39	37.28	192.77	194.08	79.01	55.68	28.31	32.84
2008	5.33	51.61	129.01	153.10	79.00	29.49	20.81	22.97
2009	12.07	66.04	337.88	179.72	105.05	49.11	18.33	27.34
2010	7.35	67.89	204.02	226.32	58.02	30.71	14.36	13.42
2011	7.86	34.61	187.45	137.93	72.57	16.56	8.75	7.96
2012	8.44	58.15	145.60	178.84	58.36	26.78	6.09	6.17
2013	3.94	51.01	202.14	123.27	77.14	22.86	10.49	4.83
2014	9.42	39.03	283.32	254.75	77.21	43.67	12.94	8.71
2015	4.19	33.95	83.18	155.51	76.84	21.66	12.28	6.12
2016	6.63	75.07	353.80	194.46	180.85	80.71	22.74	19.41
2017	4.02	30.34	223.22	254.28	74.60	64.53	28.88	15.16
2018	3.81	25.33	114.05	200.29	120.60	32.64	28.29	19.40
2019	7.83	37.66	142.88	148.10	135.43	74.91	20.30	29.81
2020	12.75	90.21	225.99	177.98	92.49	77.36	42.83	28.80
2021	11.70	86.59	315.57	153.16	57.13	26.97	22.57	21.01

Table 15. Estimated total landings at age in weight (1000 lb)

Year	1	2	3	4	5	6	7	8
1982	1.60	14.89	79.09	107.74	82.19	57.62	39.94	76.02
1983	1.92	18.44	96.64	125.50	94.30	65.96	45.72	87.02
1984	3.20	28.35	152.91	194.63	144.50	100.94	69.91	133.06
1985	1.85	17.38	85.90	115.08	85.66	59.55	41.22	78.41
1986	1.36	12.80	68.41	86.54	67.05	46.38	31.92	60.65
1987	2.24	20.58	109.73	144.54	102.41	73.11	50.03	94.44
1988	2.58	23.65	121.87	159.92	121.12	79.86	56.46	105.53
1989	4.25	40.08	203.76	250.65	187.70	132.24	86.33	165.69
1990	2.87	39.32	210.33	266.14	190.05	133.06	92.87	167.41
1991	15.11	69.61	505.71	607.62	416.42	272.82	188.84	349.72
1992	8.38	86.75	222.13	371.63	240.00	151.54	98.24	183.56
1993	10.23	76.20	436.37	267.87	238.34	140.17	87.45	153.88
1994	8.24	63.43	269.65	395.63	126.82	101.67	59.02	96.24
1995	5.84	62.63	285.99	329.78	242.84	68.92	54.43	78.82
1996	3.51	58.80	369.82	423.57	228.44	146.39	40.86	75.06
1997	4.86	61.73	575.19	844.19	472.75	225.73	142.51	106.77
1998	2.18	16.09	121.41	306.25	236.77	119.62	56.39	59.92
1999	2.50	20.13	87.78	170.32	205.96	139.41	69.31	64.40
2000	3.64	24.42	113.90	125.24	122.42	131.69	87.86	80.74
2001	3.34	33.70	130.76	158.72	92.43	81.50	86.53	106.18
2002	5.92	52.77	296.36	271.17	166.21	86.49	75.20	169.49
2003	3.80	48.32	241.14	323.24	158.25	88.48	45.51	121.42
2004	7.24	49.10	345.55	405.17	290.21	129.60	71.61	127.08
2005	6.25	57.74	218.34	364.91	227.16	148.32	65.46	95.04
2006	4.81	54.70	282.85	253.15	218.81	122.97	79.27	81.52
2007	14.10	76.40	466.06	539.41	247.21	192.81	106.96	133.77
2008	8.96	105.76	311.90	425.52	247.20	102.11	78.62	93.56
2009	20.30	135.34	816.90	499.51	328.69	170.05	69.24	111.38
2010	12.36	139.13	493.24	629.00	181.55	106.34	54.25	54.68
2011	13.22	70.93	453.19	383.34	227.07	57.35	33.07	32.41
2012	14.20	119.17	352.02	497.05	182.61	92.72	23.00	25.13
2013	6.62	104.54	488.71	342.60	241.37	79.17	39.64	19.66
2014	15.84	80.00	684.97	708.02	241.57	151.21	48.88	35.48
2015	7.04	69.58	201.09	432.20	240.43	74.99	46.41	24.93
2016	11.15	153.84	855.38	540.47	565.87	279.46	85.90	79.07
2017	6.75	62.18	539.67	706.72	233.41	223.44	109.10	61.75
2018	6.41	51.92	275.74	556.66	377.36	113.03	106.88	79.03
2019	13.16	77.17	345.43	411.62	423.74	259.40	76.70	121.43
2020	21.43	184.86	546.38	494.66	289.40	267.89	161.83	117.30
2021	19.68	177.46	762.96	425.68	178.74	93.38	85.28	85.58

Table 16. Estimated total discards at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8
1982	26.18	4.68	0.09	0.00	0.00	0.00	0.00	0.00
1983	239.92	44.07	0.87	0.00	0.00	0.00	0.00	0.00
1984	44.20	7.48	0.15	0.00	0.00	0.00	0.00	0.00
1985	60.78	10.93	0.20	0.00	0.00	0.00	0.00	0.00
1986	150.37	27.14	0.54	0.00	0.00	0.00	0.00	0.00
1987	139.66	24.51	0.49	0.00	0.00	0.00	0.00	0.00
1988	104.45	18.32	0.35	0.00	0.00	0.00	0.00	0.00
1989	299.02	53.84	1.03	0.00	0.00	0.00	0.00	0.00
1990	78.67	20.67	0.41	0.00	0.00	0.00	0.00	0.00
1991	446.67	39.31	1.07	0.00	0.00	0.00	0.00	0.00
1992	186.90	37.16	0.35	0.00	0.00	0.00	0.00	0.00
1993	70.55	10.13	0.21	0.00	0.00	0.00	0.00	0.00
1994	75.79	11.34	0.17	0.00	0.00	0.00	0.00	0.00
1995	90.10	18.93	0.30	0.00	0.00	0.00	0.00	0.00
1996	126.45	41.15	0.93	0.00	0.00	0.00	0.00	0.00
1997	79.76	19.51	0.67	0.00	0.00	0.00	0.00	0.00
1998	47.29	6.82	0.18	0.00	0.00	0.00	0.00	0.00
1999	87.78	13.70	0.21	0.00	0.00	0.00	0.00	0.00
2000	102.20	13.23	0.22	0.00	0.00	0.00	0.00	0.00
2001	65.71	12.85	0.18	0.00	0.00	0.00	0.00	0.00
2002	143.33	24.55	0.51	0.00	0.00	0.00	0.00	0.00
2003	166.57	40.63	0.75	0.00	0.00	0.00	0.00	0.00
2004	193.65	25.19	0.66	0.00	0.00	0.00	0.00	0.00
2005	162.61	28.92	0.40	0.00	0.00	0.00	0.00	0.00
2006	151.66	33.18	0.63	0.00	0.00	0.00	0.00	0.00
2007	278.21	28.93	0.65	0.00	0.00	0.00	0.00	0.00
2008	147.86	33.63	0.36	0.00	0.00	0.00	0.00	0.00
2009	269.05	34.45	0.77	0.00	0.00	0.00	0.00	0.00
2010	162.73	35.42	0.46	0.00	0.00	0.00	0.00	0.00
2011	85.11	8.93	0.20	0.00	0.00	0.00	0.00	0.00
2012	112.03	18.15	0.20	0.00	0.00	0.00	0.00	0.00
2013	164.07	50.07	0.85	0.00	0.00	0.00	0.00	0.00
2014	242.32	23.45	0.75	0.00	0.00	0.00	0.00	0.00
2015	295.95	56.67	0.59	0.00	0.00	0.00	0.00	0.00
2016	1212.29	320.07	6.66	0.01	0.00	0.00	0.00	0.00
2017	374.77	66.25	2.13	0.00	0.00	0.00	0.00	0.00
2018	347.72	54.14	1.06	0.00	0.00	0.00	0.00	0.00
2019	292.42	32.93	0.55	0.00	0.00	0.00	0.00	0.00
2020	191.91	31.73	0.35	0.00	0.00	0.00	0.00	0.00
2021	333.49	57.59	0.92	0.00	0.00	0.00	0.00	0.00

Table 17. Estimated total discards at age in weight (1000 lb)

Year	1	2	3	4	5	6	7	8
1982	22.62	7.23	0.20	0.00	0.00	0.00	0.00	0.00
1983	207.34	68.11	1.90	0.00	0.00	0.00	0.00	0.00
1984	38.20	11.56	0.33	0.00	0.00	0.00	0.00	0.00
1985	52.53	16.89	0.44	0.00	0.00	0.00	0.00	0.00
1986	129.95	41.95	1.18	0.00	0.00	0.00	0.00	0.00
1987	120.70	37.89	1.07	0.00	0.00	0.00	0.00	0.00
1988	90.27	28.32	0.78	0.00	0.00	0.00	0.00	0.00
1989	258.41	83.22	2.26	0.01	0.00	0.00	0.00	0.00
1990	67.99	31.94	0.90	0.00	0.00	0.00	0.00	0.00
1991	386.02	60.76	2.35	0.01	0.00	0.00	0.00	0.00
1992	161.52	57.43	0.77	0.00	0.00	0.00	0.00	0.00
1993	60.97	15.65	0.47	0.00	0.00	0.00	0.00	0.00
1994	65.50	17.52	0.38	0.00	0.00	0.00	0.00	0.00
1995	77.87	29.26	0.66	0.00	0.00	0.00	0.00	0.00
1996	109.28	63.60	2.03	0.00	0.00	0.00	0.00	0.00
1997	68.93	30.16	1.46	0.00	0.00	0.00	0.00	0.00
1998	40.87	10.54	0.40	0.00	0.00	0.00	0.00	0.00
1999	75.86	21.18	0.47	0.00	0.00	0.00	0.00	0.00
2000	88.32	20.45	0.49	0.00	0.00	0.00	0.00	0.00
2001	56.79	19.87	0.40	0.00	0.00	0.00	0.00	0.00
2002	123.87	37.94	1.12	0.00	0.00	0.00	0.00	0.00
2003	143.95	62.80	1.64	0.00	0.00	0.00	0.00	0.00
2004	167.36	38.93	1.44	0.00	0.00	0.00	0.00	0.00
2005	140.53	44.70	0.88	0.00	0.00	0.00	0.00	0.00
2006	131.07	51.28	1.38	0.00	0.00	0.00	0.00	0.00
2007	240.43	44.72	1.43	0.00	0.00	0.00	0.00	0.00
2008	127.79	51.97	0.80	0.00	0.00	0.00	0.00	0.00
2009	232.52	53.25	1.69	0.00	0.00	0.00	0.00	0.00
2010	140.63	54.74	1.00	0.00	0.00	0.00	0.00	0.00
2011	73.55	13.80	0.44	0.00	0.00	0.00	0.00	0.00
2012	96.82	28.05	0.43	0.00	0.00	0.00	0.00	0.00
2013	141.79	77.39	1.86	0.00	0.00	0.00	0.00	0.00
2014	209.41	36.25	1.64	0.00	0.00	0.00	0.00	0.00
2015	255.76	87.58	1.29	0.00	0.00	0.00	0.00	0.00
2016	1047.68	494.69	14.59	0.02	0.00	0.00	0.00	0.00
2017	323.88	102.39	4.67	0.01	0.00	0.00	0.00	0.00
2018	300.50	83.67	2.33	0.01	0.00	0.00	0.00	0.00
2019	252.72	50.90	1.20	0.00	0.00	0.00	0.00	0.00
2020	165.85	49.05	0.76	0.00	0.00	0.00	0.00	0.00
2021	288.20	89.01	2.03	0.00	0.00	0.00	0.00	0.00

Table 18. Estimated time series of landings (L) in numbers (1000 fish) for commercial handline landings, south (L.cHLs); commercial handline landings, north (L.cHLn); recreational headboat landings, south (L.rHBs); general recreational landings, south (L.rGNs); general recreational landings, north (L.rGNn); and total landings.

Year	L.cHLs	L.cHLn	L.rHBs	L.rGNs	L.rGNn	Total
1982	30.61	0.03	29.51	91.18	0.51	151.84
1983	21.64	0.29	28.61	75.96	51.42	177.91
1984	23.35	0.26	26.90	221.93	3.07	275.51
1985	21.70	0.24	35.61	97.98	5.73	161.25
1986	21.81	0.21	28.38	51.66	22.59	124.65
1987	23.51	0.19	29.58	75.35	70.40	199.04
1988	25.73	0.16	34.94	160.96	1.85	223.64
1989	30.97	0.14	37.39	229.53	60.21	358.25
1990	61.28	0.12	71.82	185.07	50.20	368.49
1991	87.24	0.40	85.72	585.95	59.15	818.46
1992	85.31	0.29	91.93	263.72	23.18	464.43
1993	108.61	1.50	107.13	215.76	64.71	497.71
1994	127.36	6.14	90.32	117.98	57.06	398.88
1995	162.10	6.81	93.27	78.62	61.45	402.25
1996	148.84	5.74	89.86	117.94	118.28	480.67
1997	185.80	5.13	106.11	113.76	444.06	854.87
1998	134.95	2.83	65.91	79.37	26.36	309.41
1999	87.02	3.21	37.25	120.08	1.59	249.14
2000	61.86	1.63	34.11	99.67	29.23	226.49
2001	68.81	1.65	32.98	93.98	34.25	231.67
2002	63.03	5.01	57.65	191.62	71.71	389.03
2003	61.00	3.81	45.77	217.75	31.53	359.86
2004	81.18	2.97	78.10	202.62	132.42	497.30
2005	88.82	1.95	63.60	144.02	111.19	409.59
2006	79.32	1.68	43.14	252.93	7.00	384.07
2007	106.37	3.57	66.34	386.98	65.09	628.35
2008	109.12	1.96	44.75	321.40	14.10	491.32
2009	124.46	5.58	59.94	437.56	168.02	795.55
2010	157.28	4.08	68.75	316.34	75.64	622.09
2011	172.80	6.32	53.31	213.84	27.41	473.68
2012	100.54	12.31	49.11	194.95	131.51	488.43
2013	114.09	9.25	56.53	266.88	48.93	495.68
2014	98.13	3.77	53.14	412.47	161.53	729.04
2015	118.81	1.78	45.98	189.04	38.11	393.72
2016	105.74	2.62	37.81	712.60	74.90	933.66
2017	110.73	9.03	43.31	416.38	115.57	695.01
2018	105.08	6.59	35.07	250.56	147.12	544.42
2019	106.01	4.27	35.75	303.50	147.37	596.91
2020	105.04	2.78	28.15	353.44	259.00	748.41
2021	75.20	3.23	26.19	465.75	124.33	694.70

Table 19. Estimated time series of landings (L) in weight (1000 lb) for commercial handline landings, south (L.cHLs); commercial handline landings, north (L.cHLn); recreational headboat landings, south (L.rHBs); general recreational landings, south (L.rGNs); general recreational landings, north (L.rGNn); and total landings.

Year	L.cHLs	L.cHLn	L.rHBs	L.rGNs	L.rGNn	Total
1982	96.65	0.10	88.21	272.62	1.52	459.09
1983	68.30	0.90	85.52	227.06	153.70	535.48
1984	73.68	0.82	80.40	663.41	9.18	827.50
1985	68.43	0.75	106.29	292.49	17.09	485.04
1986	68.71	0.67	84.54	153.90	67.30	375.12
1987	73.98	0.59	88.16	224.55	209.79	597.08
1988	80.98	0.52	104.16	479.82	5.51	670.98
1989	97.37	0.44	111.20	682.61	179.07	1070.69
1990	191.96	0.36	212.75	548.26	148.73	1102.06
1991	271.61	1.24	252.53	1726.21	174.26	2425.85
1992	262.88	0.89	266.56	764.68	67.21	1362.22
1993	325.33	4.48	298.70	601.57	180.42	1410.50
1994	372.47	17.97	248.55	324.68	157.03	1120.70
1995	471.31	19.79	255.07	215.01	168.06	1129.25
1996	432.83	16.70	247.17	324.41	325.33	1346.45
1997	548.25	15.15	298.92	320.47	1250.95	2433.73
1998	409.44	8.58	192.24	231.51	76.88	918.65
1999	272.85	10.07	111.79	360.36	4.76	759.82
2000	196.41	5.17	102.19	298.59	87.55	689.91
2001	215.50	5.16	96.68	275.46	100.38	693.16
2002	192.24	15.29	164.54	546.89	204.66	1123.61
2003	182.99	11.43	129.65	616.79	89.31	1030.17
2004	243.39	8.90	221.79	575.41	376.06	1425.55
2005	267.55	5.89	181.49	410.99	317.29	1183.21
2006	238.12	5.05	121.70	713.48	19.75	1098.09
2007	315.62	10.60	185.62	1082.75	182.11	1776.71
2008	320.09	5.75	123.30	885.65	38.85	1373.63
2009	355.34	15.92	160.32	1170.40	449.42	2151.41
2010	440.70	11.44	181.80	836.59	200.04	1670.57
2011	480.06	17.55	139.90	561.12	71.93	1270.56
2012	280.84	34.38	129.55	514.23	346.89	1305.89
2013	318.31	25.80	148.52	701.13	128.55	1322.31
2014	276.20	10.63	142.28	1104.37	432.49	1965.97
2015	342.67	5.14	126.06	518.31	104.49	1096.68
2016	307.45	7.61	103.34	1947.97	204.75	2571.13
2017	322.51	26.30	120.02	1153.91	320.27	1943.02
2018	313.19	19.63	100.01	714.60	419.60	1567.03
2019	321.19	12.94	102.45	869.74	422.32	1728.64
2020	310.98	8.24	77.53	973.57	713.43	2083.75
2021	210.33	9.04	68.40	1216.29	324.68	1828.74

Table 20. Estimated time series of discards (D) in numbers (1000 fish) for recreational headboat discards, south (D.rHDs); general recreational discards, south (D.rGDs); general recreational discards, north (D.rGDn); and total discards.

Year	D.rHDs	D.rGDs	D.rGDn	Total
1982	3.32	27.53	0.10	30.95
1983	13.09	271.67	0.10	284.85
1984	5.92	45.82	0.10	51.83
1985	12.94	58.87	0.10	71.91
1986	7.16	170.05	0.84	178.05
1987	21.07	138.70	4.90	164.66
1988	34.97	83.72	4.44	123.13
1989	1.11	348.81	3.97	353.89
1990	1.57	60.80	37.38	99.75
1991	2.04	475.08	9.94	487.05
1992	1.31	218.40	4.69	224.41
1993	1.46	69.72	9.71	80.90
1994	1.61	78.15	7.53	87.30
1995	6.12	98.01	5.20	109.33
1996	1.92	118.13	48.48	168.53
1997	2.65	72.86	24.44	99.94
1998	6.40	39.80	8.10	54.29
1999	10.15	89.68	1.87	101.70
2000	3.67	105.48	6.52	115.66
2001	3.59	61.72	13.44	78.75
2002	17.25	142.76	8.38	168.39
2003	5.83	193.17	8.94	207.95
2004	20.65	177.01	21.84	219.50
2005	26.73	163.06	2.14	191.93
2006	16.03	166.60	2.84	185.47
2007	10.56	246.42	50.82	307.80
2008	6.50	173.70	1.66	181.85
2009	6.15	254.10	44.02	304.27
2010	11.42	146.02	41.17	198.60
2011	6.80	79.17	8.26	94.24
2012	7.47	112.09	10.82	130.37
2013	5.16	188.07	21.77	214.99
2014	7.16	247.27	12.09	266.52
2015	17.82	316.33	19.05	353.20
2016	39.58	1467.43	32.01	1539.03
2017	16.83	412.96	13.36	443.15
2018	14.07	362.39	26.45	402.92
2019	15.60	283.60	26.70	325.90
2020	8.55	145.74	69.70	224.00
2021	8.61	358.17	25.22	392.00

Table 21. Estimated time series of discards (D) in weight (1000 lb) for recreational headboat discards, south (D.rHDs); general recreational discards, south (D.rGDs); general recreational discards, north (D.rGDn); and total discards.

Year	D.rHDs	D.rGDs	D.rGDn	Total
1982	3.23	26.73	0.09	30.05
1983	12.74	264.52	0.09	277.35
1984	5.72	44.28	0.09	50.10
1985	12.57	57.20	0.09	69.86
1986	6.96	165.31	0.82	173.09
1987	20.42	134.48	4.75	159.66
1988	33.91	81.16	4.30	119.37
1989	1.08	338.96	3.86	343.90
1990	1.59	61.46	37.78	100.84
1991	1.88	438.08	9.16	449.13
1992	1.29	213.84	4.60	219.73
1993	1.39	66.45	9.26	77.09
1994	1.54	74.66	7.20	83.40
1995	6.04	96.62	5.13	107.79
1996	1.99	122.61	50.32	174.92
1997	2.67	73.31	24.59	100.56
1998	6.10	37.98	7.73	51.81
1999	9.73	85.99	1.79	97.51
2000	3.46	99.65	6.16	109.27
2001	3.51	60.39	13.15	77.05
2002	16.69	138.13	8.11	162.93
2003	5.85	193.59	8.96	208.39
2004	19.54	167.52	20.67	207.74
2005	25.92	158.12	2.08	186.11
2006	15.88	165.04	2.82	183.73
2007	9.83	229.44	47.31	286.59
2008	6.45	172.46	1.65	180.56
2009	5.81	240.06	41.59	287.45
2010	11.29	144.38	40.70	196.38
2011	6.34	73.76	7.70	87.79
2012	7.18	107.72	10.39	125.30
2013	5.31	193.36	22.38	221.05
2014	6.64	229.44	11.22	247.30
2015	17.39	308.66	18.59	344.64
2016	40.04	1484.55	32.38	1556.97
2017	16.36	401.59	13.00	430.95
2018	13.50	347.63	25.38	386.51
2019	14.59	265.25	24.97	304.81
2020	8.23	140.32	67.11	215.67
2021	8.33	346.51	24.40	379.24

Table 22. Estimated status indicators, benchmarks, and related quantities from the base run of the Beaufort catch-age model, conditional on estimated current selectivities averaged across fleets. Also presented are median values and measures of precision (standard errors, SE), 25th and 75th percentiles from the Monte Carlo Bootstrap Ensemble (MCBE). Rate estimates (F) are in units of y^{-1}*; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured in 1e+12 eggs . The* MSST *is defined by* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{F40\%}}$*, with constant* $M = 0.38$

			MCBE			
Quantity	Units	Estimate	Median	SE	25%	75%
$F_{40\%}$	y^{-1}	0.56	0.57	0.22	0.42	0.77
$85\%F_{40\%}$	y^{-1}	0.48	0.49	0.18	0.36	0.65
$75\%F_{40\%}$	y^{-1}	0.42	0.43	0.16	0.32	0.58
$65\%F_{40\%}$	y^{-1}	0.37	0.37	0.14	0.27	0.5
$F_{30\%}$	y^{-1}	0.89	0.91	0.39	0.65	1.26
$F_{40\%}$	y^{-1}	0.56	0.57	0.22	0.42	0.77
$F_{50\%}$	y^{-1}	0.37	0.38	0.13	0.28	0.5
$B_{\mathrm{F40\%}}$	metric tons	6266	6389	2043	5305	8322
$\mathrm{SSB}_{\mathrm{F40\%}}$	1e+12 eggs	6.95	7.33	0.68	6.9	7.85
MSST	1e+12 eggs	4.28	4.33	0.79	3.94	4.98
$L_{\mathrm{F40\%}}$	1000 lb whole	1865	1904	556	1586	2412
$D_{\mathrm{F40\%}}$	1000 lb dead fish	254	256	256	256	256
$D_{\mathrm{F40\%}}$	1000 dead fish	262	269	269	269	269
$R_{\mathrm{F40\%}}$	1000 fish	4688	4889	2877	3221	7530
$L_{85\%\mathrm{F40\%}}$	1000 lb whole	1770	1806	530	1500	2294
$L_{75\%\mathrm{F40\%}}$	1000 lb whole	1683	1724	510	1426	2185
$L_{65\%\mathrm{F40\%}}$	1000 lb whole	1578	1625	484	1344	2058
$F_{2019-2021}/F_{40\%}$	—	1.16	1.06	0.76	0.64	1.75
$\mathrm{SSB}_{2021}/\mathrm{MSST}$	—	1.33	1.41	0.69	0.91	2.03
$\mathrm{SSB}_{2021}/\mathrm{SSB}_{\mathrm{F40\%}}$	—	0.82	0.86	0.29	0.62	1.1

Table 23. Results from sensitivity runs of the Beaufort Assessment Model compared with the base model. Results of the age structured production model (ASPM; aspm) and retrospective (retro) runs are also presented. Current F represented by geometric mean of last three assessment years ($F/F_{40\%} = F_{2019-2021}/F_{40\%}$). $L_{\mathrm{F40\%}}$ is in 1000 lb weight. Spawning stock biomass (SSB) is measured in 1e+12 eggs. Stock and rebuild status based on terminal year ($\mathrm{SSB/MSST} = \mathrm{SSB}_{2021}/\mathrm{MSST}$; $\mathrm{SSB/SSB}_{\mathrm{F40\%}} = \mathrm{SSB}_{2021}/\mathrm{SSB}_{\mathrm{F40\%}}$). Years associated with reference points in retrospective runs differ from other runs. See text for full description of sensitivity, ASPM, and retrospective runs.

ID	Description	$F_{40\%}$	$\mathrm{SSB}_{\mathrm{F40\%}}$	$L_{\mathrm{F40\%}}$	$F/F_{40\%}$	SSB/MSST	R_0 (1000$fish$)
base	base	0.562	6.95	1864.75	1.16	1.33	4307
S01	F init lo	0.562	6.95	1865.19	1.16	1.33	4308
S02	F init up	0.562	6.95	1863.97	1.16	1.33	4302
S03	M lo	0.295	8.52	1384.31	3.07	0.50	1923
S04	M up	1.037	8.33	3292.91	0.38	2.88	11447
S05	Dmort lo	0.596	6.71	1894.14	1.10	1.37	4153
S06	Dmort up	0.532	7.19	1842.94	1.22	1.29	4457
S07	age error none	0.429	9.23	2415.76	0.66	1.88	5790
S08	age1to8	0.625	6.36	1722.24	1.39	1.20	3983
S09	fecbatchconstant	0.802	8.78	2044.73	0.81	1.65	4307
S10	nbatchconstant	1.597	9.92	2199.59	0.41	2.15	4307
S11	fecbatchnbatchconstant	3.000	20.50	2053.32	0.22	2.42	4307
S12	steep estimate init0.8	0.561	6.97	1868.96	1.16	1.33	4317
S13	smooth D rGDs 2016	0.562	6.85	1834.02	1.17	1.33	4241
S14	styr cpue sTVs 1990	0.544	7.19	1914.11	1.06	1.41	4493
S15	sel rGN rHB separate	0.420	5.14	1473.55	1.23	1.30	3186
S16	w cpue sTVs lo	0.570	6.63	1792.94	1.28	1.25	4092
S17	w cpue sTVs up	0.563	6.04	1654.35	1.59	1.05	3225
S18	w agec sTVs lo	0.530	7.39	1962.77	1.01	1.46	4479
S19	w agec sTVs up	0.644	6.21	1680.09	1.44	1.15	3936
S20	w agec all lo	0.563	6.87	1836.43	1.18	1.32	4160
S21	w agec all up	0.573	6.38	1723.99	1.32	1.23	4041
S22	w lenc all lo	0.563	6.94	1865.59	1.16	1.34	4300
S23	w lenc all up	0.561	6.96	1867.14	1.17	1.31	4266
aspm	aspm	0.478	18.91	4560.03	0.22	3.05	12732
retro20	retro endyr2020	0.534	7.12	1819.52	0.87	1.59	4399
retro19	retro endyr2019	0.488	7.06	1637.40	0.79	1.90	4384
retro18	retro endyr2018	0.431	6.98	1413.98	1.01	1.94	4318
retro17	retro endyr2017	0.401	7.30	1433.82	0.84	2.00	4436
retro16	retro endyr2016	0.424	7.02	1470.20	0.85	2.06	4259

Table 24. Projection results with fishing mortality rate fixed at $F = F_{40}$ starting in 2025 and projecting forward to 2031. From 2022 to 2024 the fishing mortality rate was fixed at $F_{\text{current}} = 0.65$. R = number of age-1 recruits (1000 fish), F = fishing mortality rate (per year), S = spawning stock (1e+12 eggs), L = landings expressed in numbers (n, 1000 fish) or whole weight (w, 1000 lb*), $P(SSB > MSST)$ = proportion of stochastic projection replicates with* SSB $> MSST$*. The subscript* b *indicates expected values (deterministic) from the base run; the subscript* m *indicates median values from the stochastic projections.*

Year	R_{b}	R_{m}	F_{b}	F_{m}	S_{b}	S_{m}	L_{b} (n)	L_{m} (n)	L_{b} (w)	L_{m} (w)	D_{b} (n)	D_{m} (n)	D_{b} (w)	D_{m} (w)	$P(SSB > MSST)$
2022	4688	4477	0.65	0.61	5.80	6.26	636	669	1679	1755	303	265	294	253	0.72
2023	4688	4473	0.65	0.61	6.07	6.44	703	697	1839	1839	303	267	292	257	0.73
2024	4688	4504	0.65	0.61	6.26	6.50	728	693	1911	1835	303	267	292	256	0.74
2025	4688	4488	0.56	0.56	6.49	6.63	649	657	1711	1745	262	247	253	237	0.76
2026	4688	4454	0.56	0.56	6.72	6.74	673	674	1786	1795	262	249	254	239	0.80
2027	4688	4476	0.56	0.56	6.85	6.84	687	684	1828	1826	262	249	254	239	0.83
2028	4688	4477	0.56	0.56	6.91	6.90	693	689	1849	1841	262	248	254	238	0.84
2029	4688	4455	0.56	0.56	6.93	6.92	696	691	1858	1848	262	246	254	236	0.85
2030	4688	4499	0.56	0.56	6.94	6.92	697	692	1862	1852	262	248	254	238	0.85
2031	4688	4490	0.56	0.56	6.95	6.93	697	691	1864	1852	262	248	254	238	0.85

Table 25. Projection results with fishing mortality rate fixed at $F = 75\%F_{40}$ starting in 2025 and projecting forward to 2031. From 2022 to 2024 the fishing mortality rate was fixed at $F_{\mathrm{current}} = 0.65$. R = number of age-1 recruits (1000 fish), F = fishing mortality rate (per year), S = spawning stock (1e+12 eggs), L = landings expressed in numbers (n, 1000 fish) or whole weight (w, 1000 lb), $P(SSB > MSST)$ = proportion of stochastic projection replicates with SSB $> MSST$. The subscript b indicates expected values (deterministic) from the base run; the subscript m indicates median values from the stochastic projections.

Year	R_{b}	R_{m}	F_{b}	F_{m}	S_{b}	S_{m}	L_{b} (n)	L_{m} (n)	L_{b} (w)	L_{m} (w)	D_{b} (n)	D_{m} (n)	D_{b} (w)	D_{m} (w)	$P(SSB > MSST)$
2022	4688	4510	0.65	0.61	5.80	6.23	636	668	1679	1751	303	267	294	256	0.72
2023	4688	4506	0.65	0.61	6.07	6.41	703	697	1839	1837	303	268	292	257	0.73
2024	4688	4489	0.65	0.61	6.26	6.48	728	693	1911	1836	303	266	292	256	0.73
2025	4688	4512	0.42	0.42	6.75	6.90	507	515	1339	1369	198	188	191	180	0.78
2026	4688	4456	0.42	0.42	7.36	7.46	556	559	1488	1499	199	188	192	181	0.85
2027	4688	4484	0.42	0.42	7.75	7.79	586	586	1582	1586	199	189	192	181	0.90
2028	4688	4456	0.42	0.42	7.95	7.97	602	600	1636	1635	199	188	192	180	0.93
2029	4688	4510	0.42	0.42	8.06	8.10	610	609	1662	1661	199	188	192	181	0.94
2030	4688	4472	0.42	0.42	8.11	8.13	613	612	1675	1674	199	187	192	180	0.95
2031	4688	4478	0.42	0.42	8.13	8.17	614	614	1680	1682	199	190	192	182	0.95

9 Figures

Figure 1. Timeline of data fit to in this assessment. Date types include landings (L), indices of abundance (index; CPUE), age compositions (comp), and length compositions. Data sources include the commercial (com) handline, recreational headboat and general recreational fleets, and the SERFS trap video survey. Sources of landings and discards are from north and south areas along the US Atlantic coast, divided at the border of Virginia and North Carolina. Age composition data were divided into early (a;$\leq$ 2014) and a late (b; $\geq$ 2015) years.

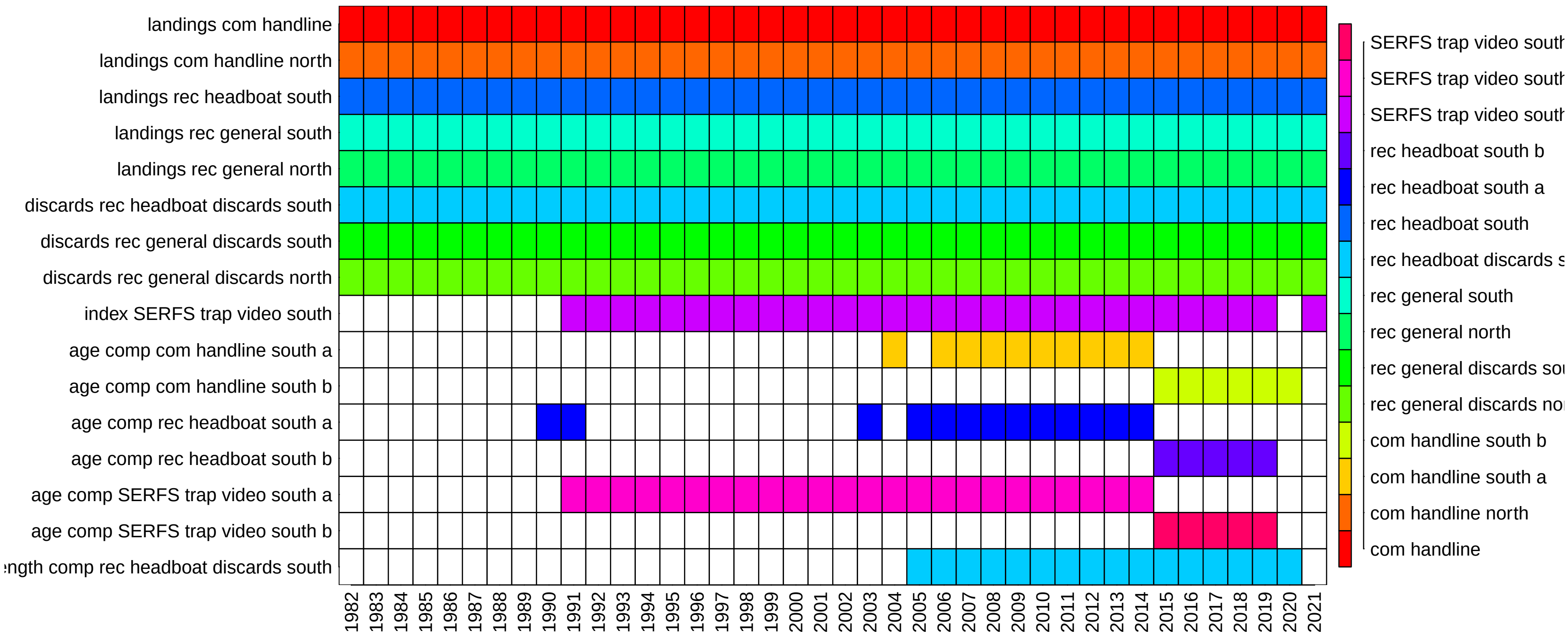
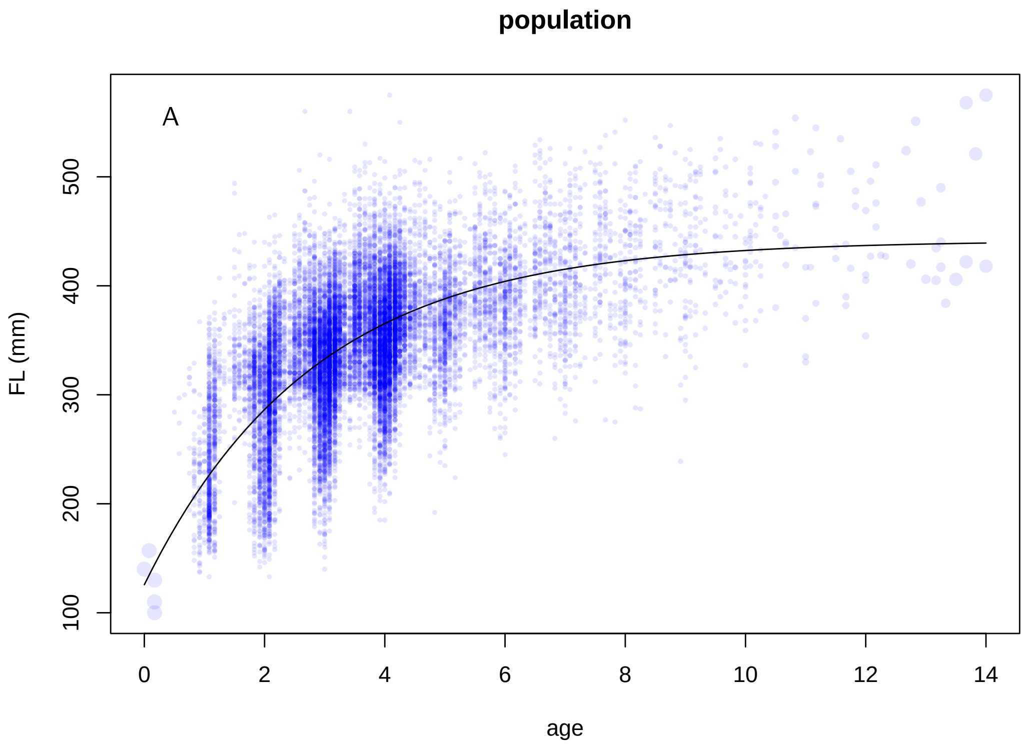


Figure 2. Fitting of growth models for the (A) population and (B) fishery.



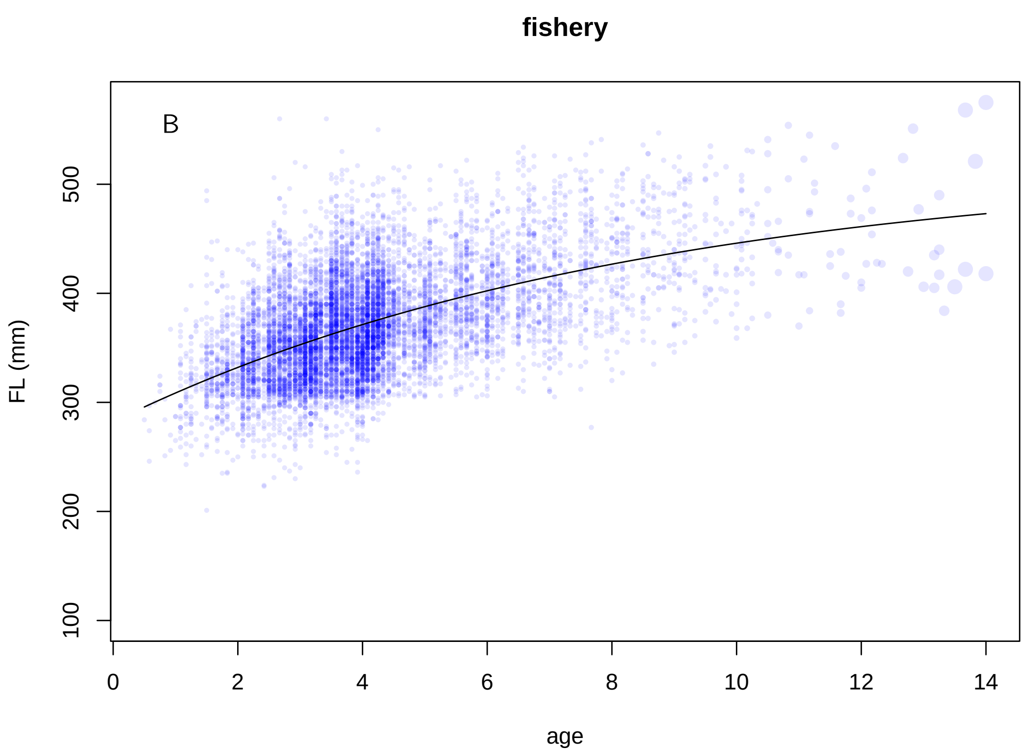
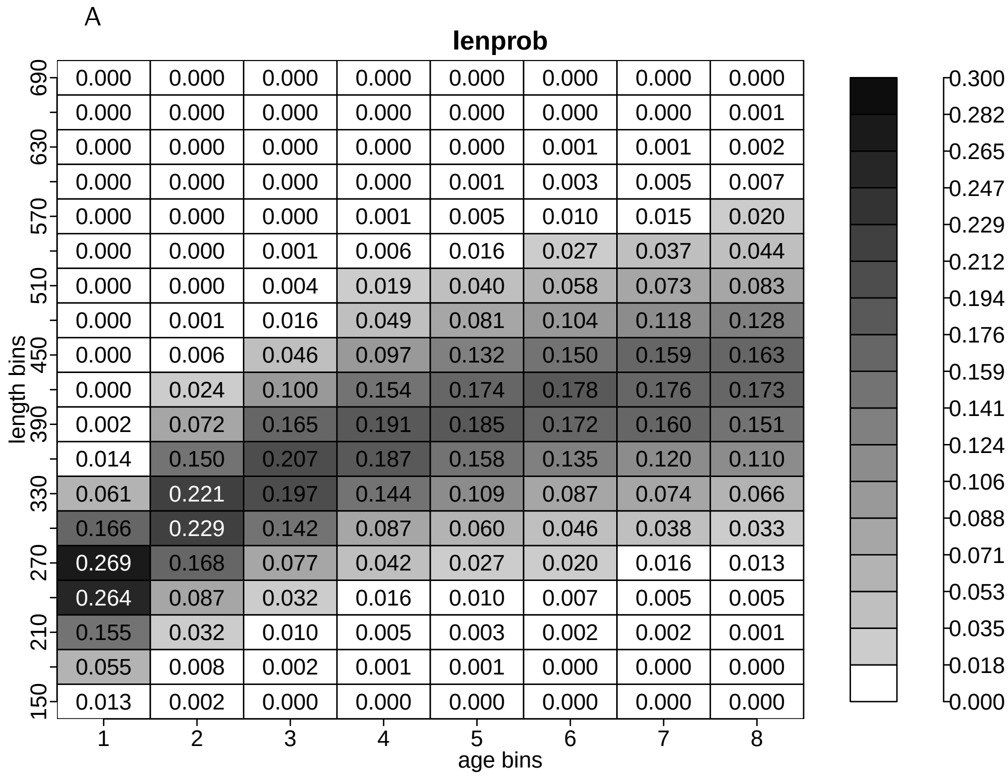


Figure 3. Length to age conversion matrices for the (A) population and (B) fishery, used in the model.



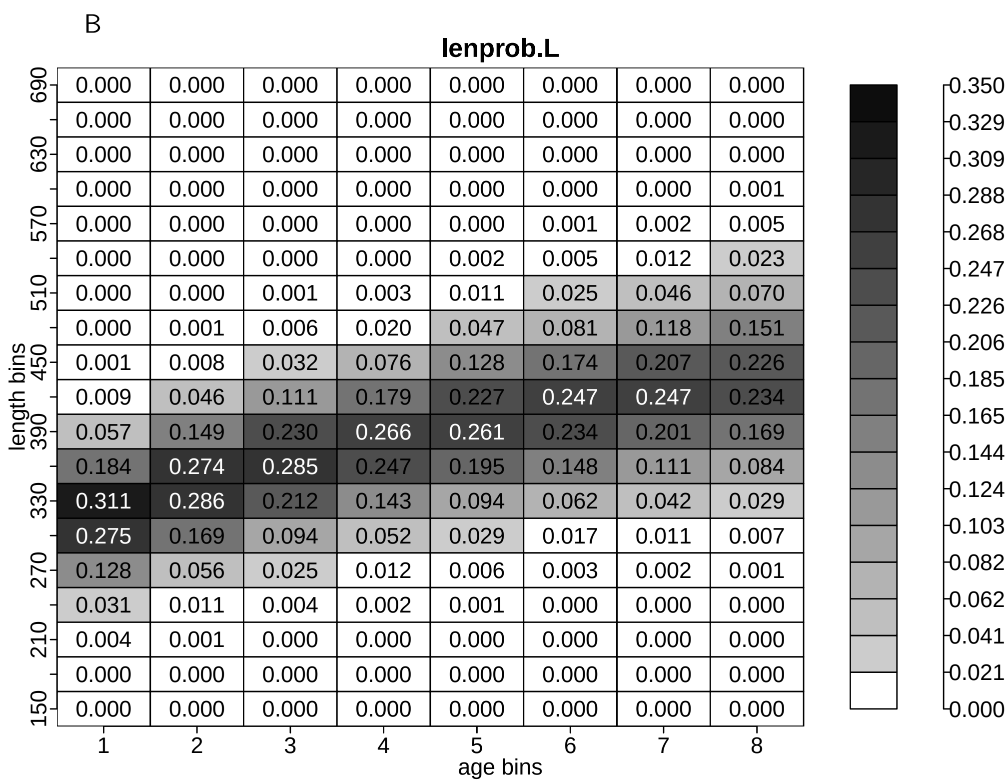


Figure 4. Aging error matrix used in the assessment, relating true ages to observed (comps) ages.

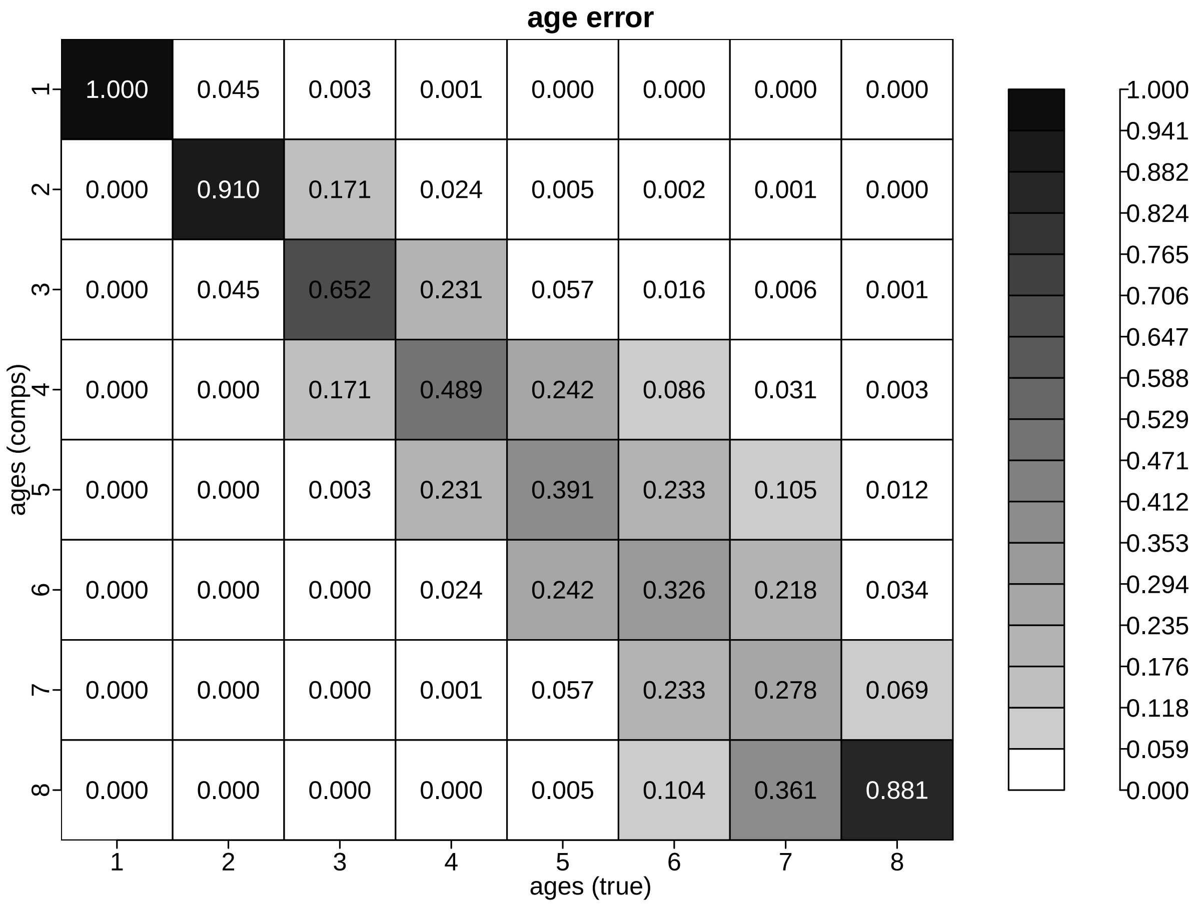
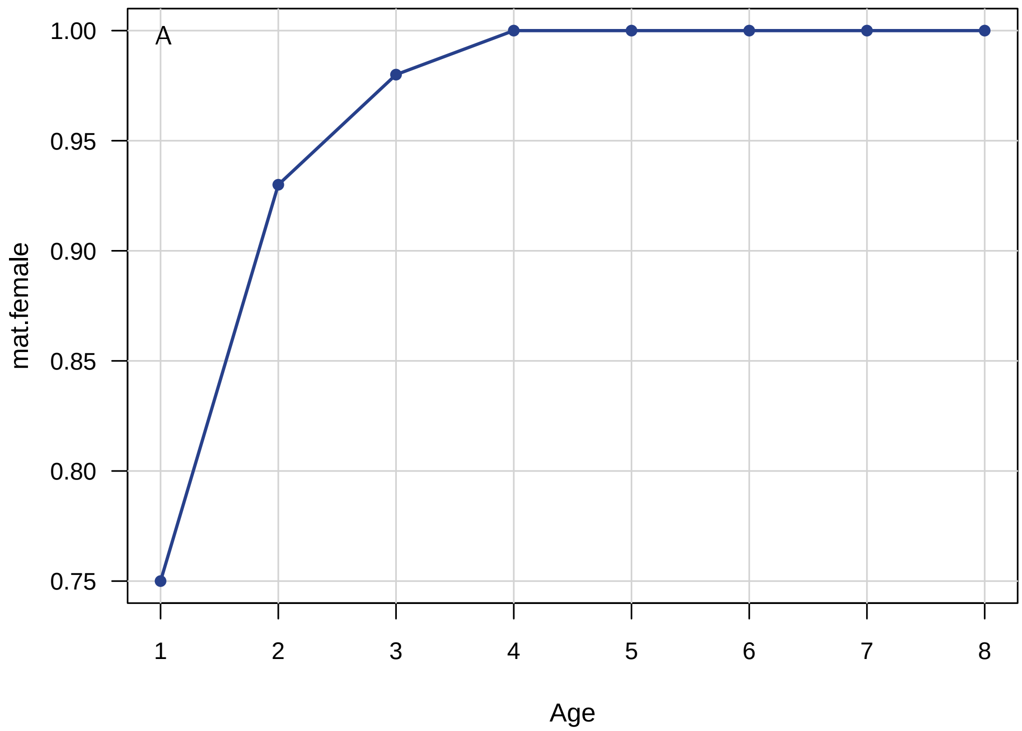


Figure 5. (A) Female maturity and (B) reproductive output (million eggs) at age.



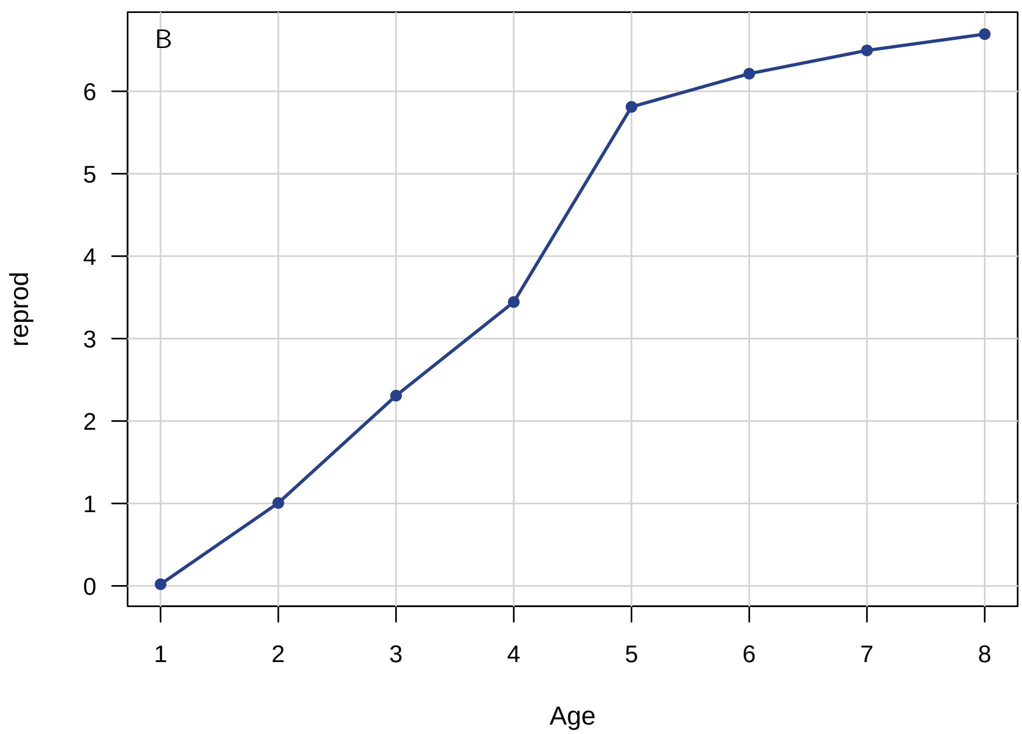


Figure 6. Observed (open circles) and estimated (solid line) annual age and length compositions by fleet. In panels indicating the data set: acomp = age compositions; lcomp = length compositions; cHLsa = commercial handline, south, early years; cHLsb = commercial handline, south, late years; rHBsa = recreational headboat, south, early years; rHBsb = recreational headboat, south, late years; sTVsa = SERFS trap video survey, south, early years; sTVsb = SERFS trap video survey, south, late years; and rHDs = recreational headboat discards, south, all years.
sM = MARMAP longline survey, rA = general recreational. N indicates the number of trips from which individual fish samples were taken. The four digit number in upper right corner of each panel indicates year of sampling (e.g. 1997, 1998).

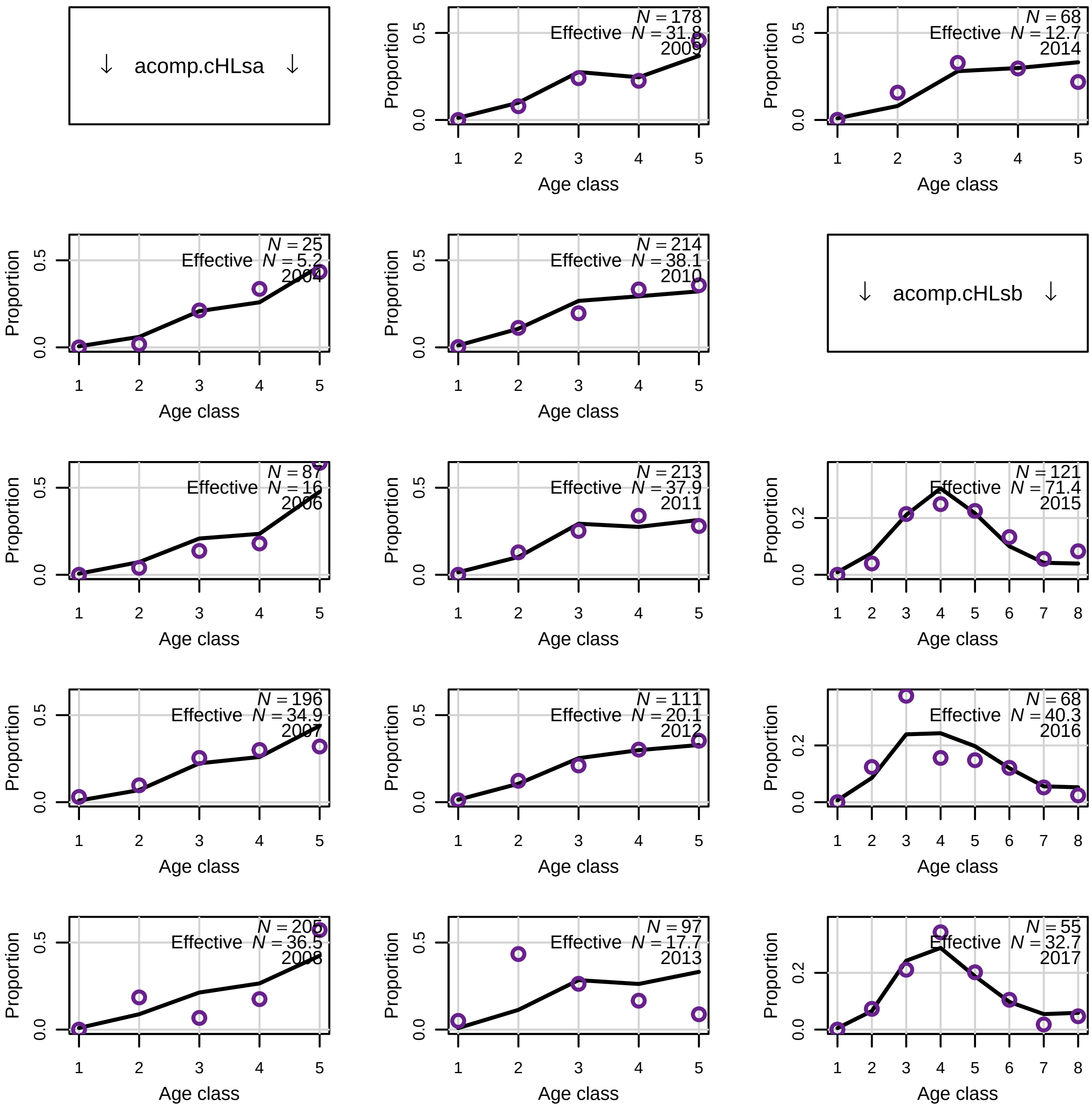


Figure 6. (cont.) Observed (open circles) and estimated (solid line) annual age and length compositions by fleet.

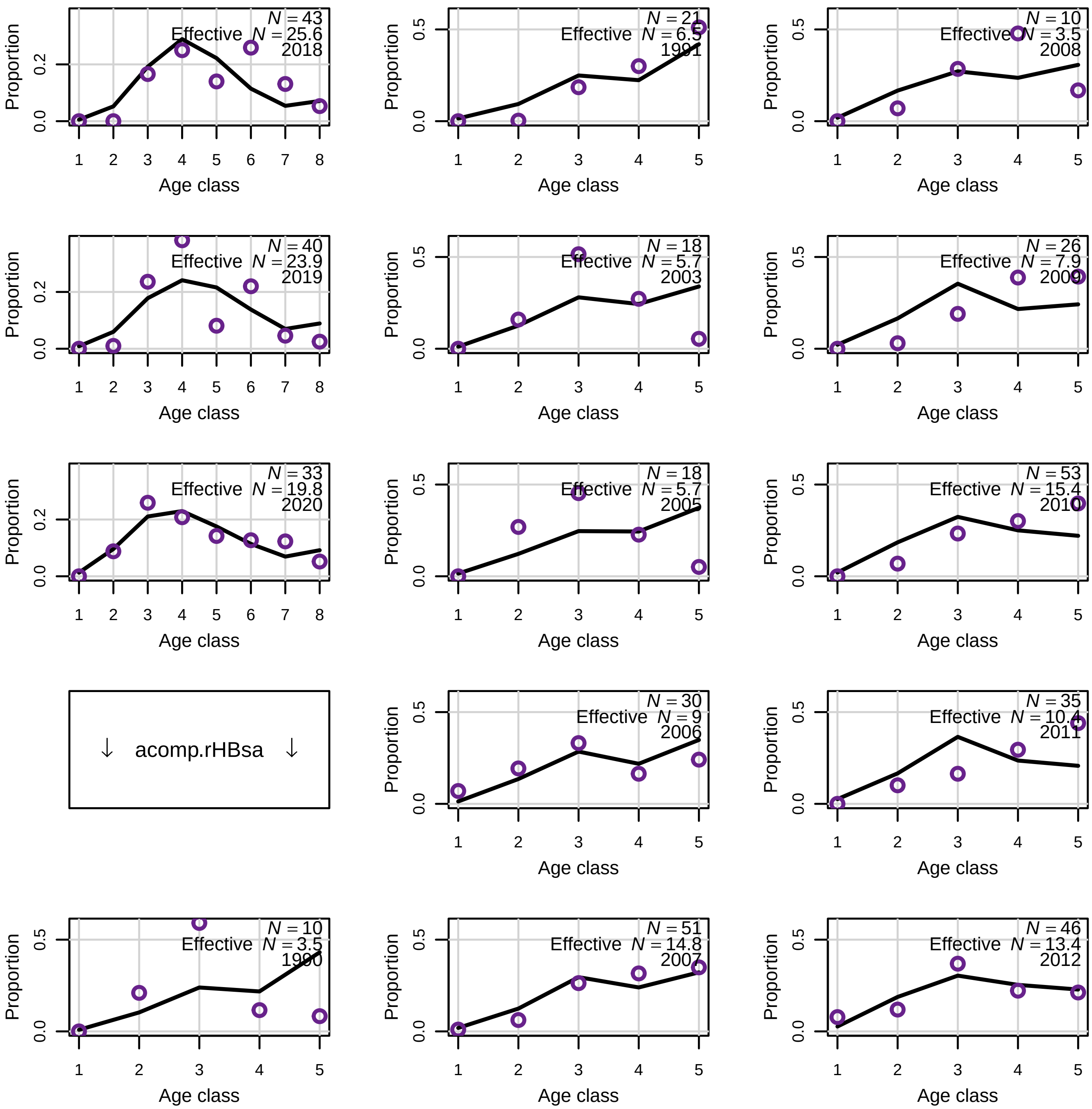


Figure 6. (cont.) Observed (open circles) and estimated (solid line) annual age and length compositions by fleet.

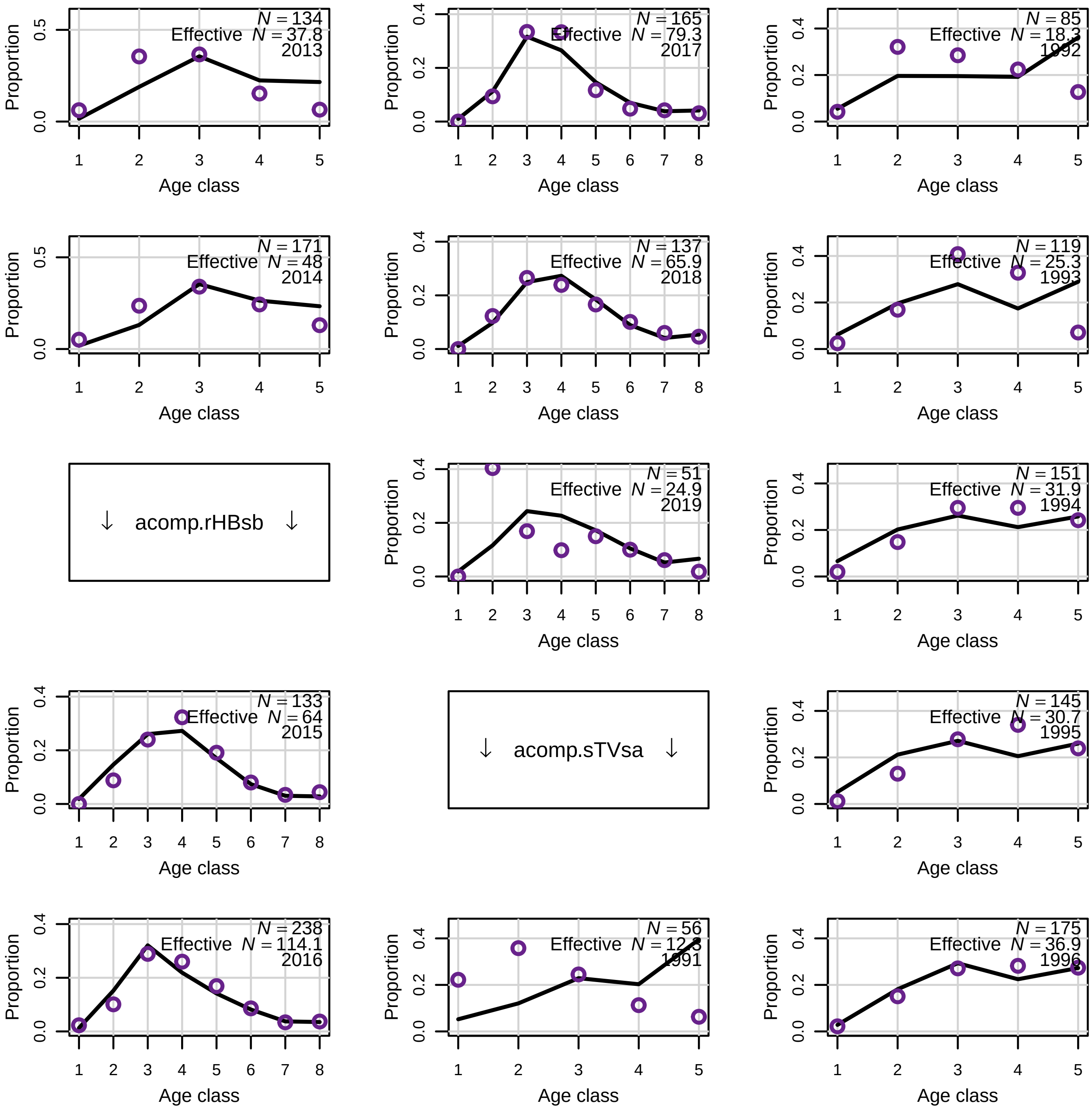


Figure 6. (cont.) Observed (open circles) and estimated (solid line) annual age and length compositions by fleet.

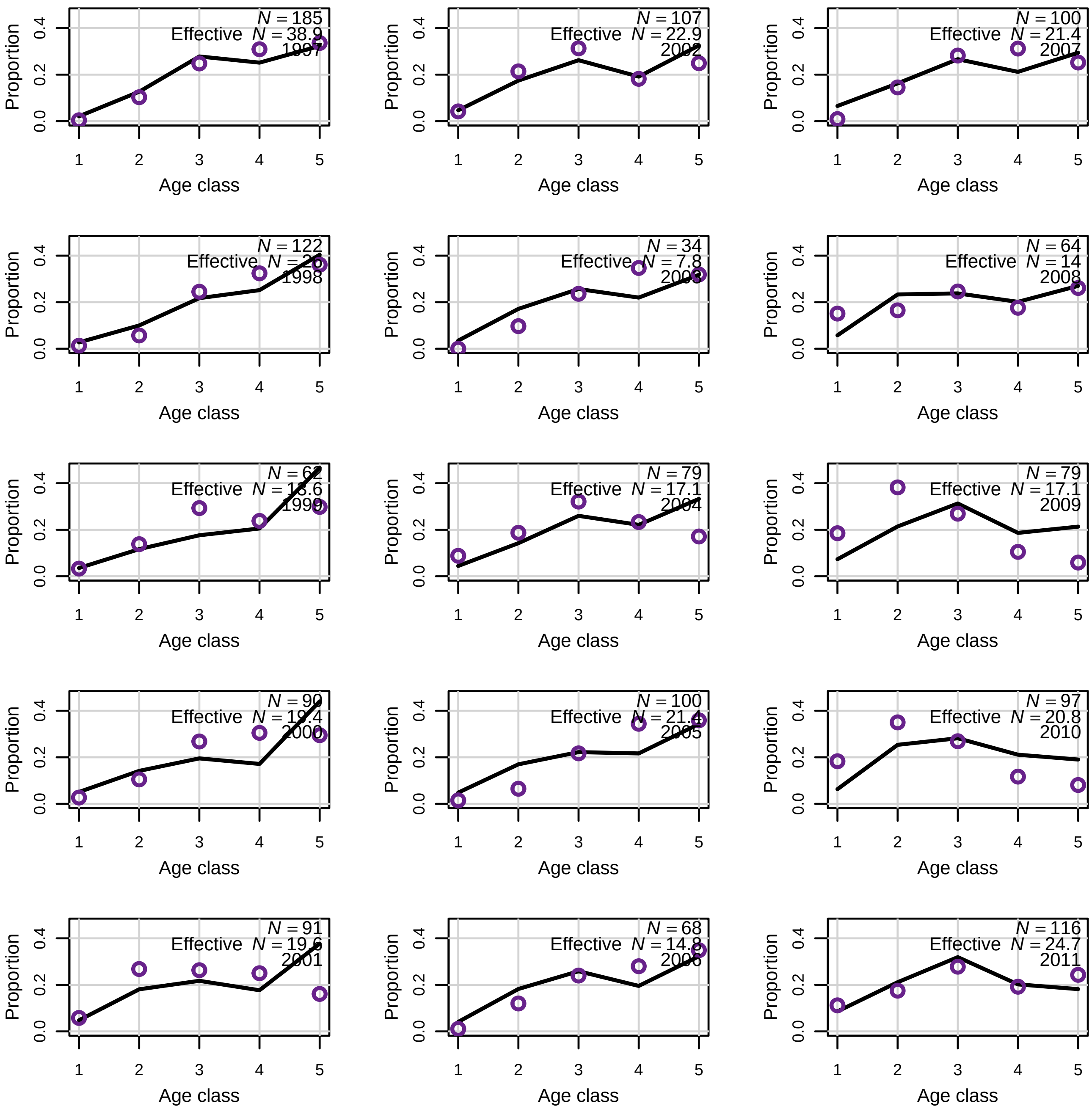


Figure 6. (cont.) Observed (open circles) and estimated (solid line) annual age and length compositions by fleet.

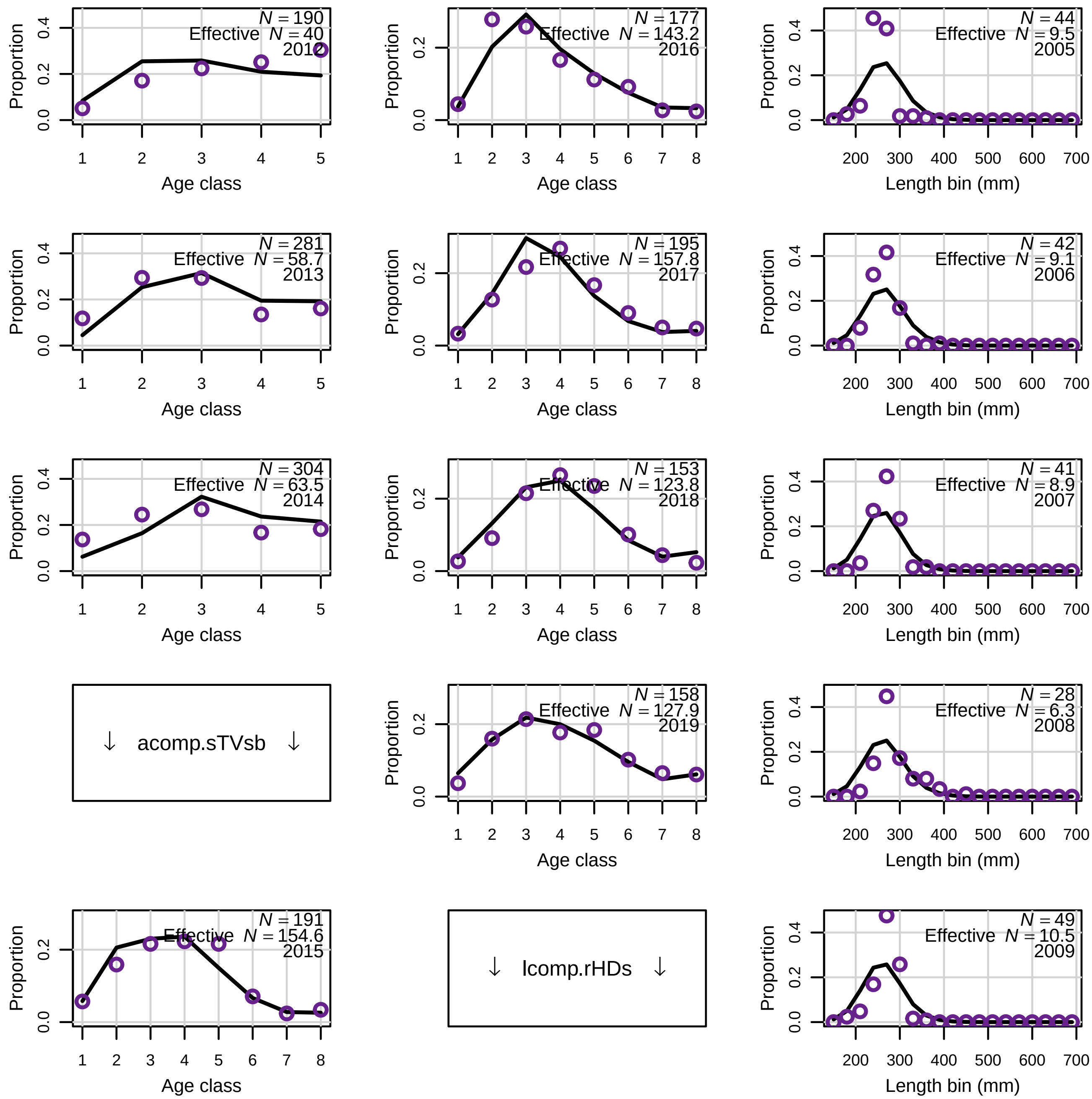


Figure 6. (cont.) Observed (open circles) and estimated (solid line) annual age and length compositions by fleet.

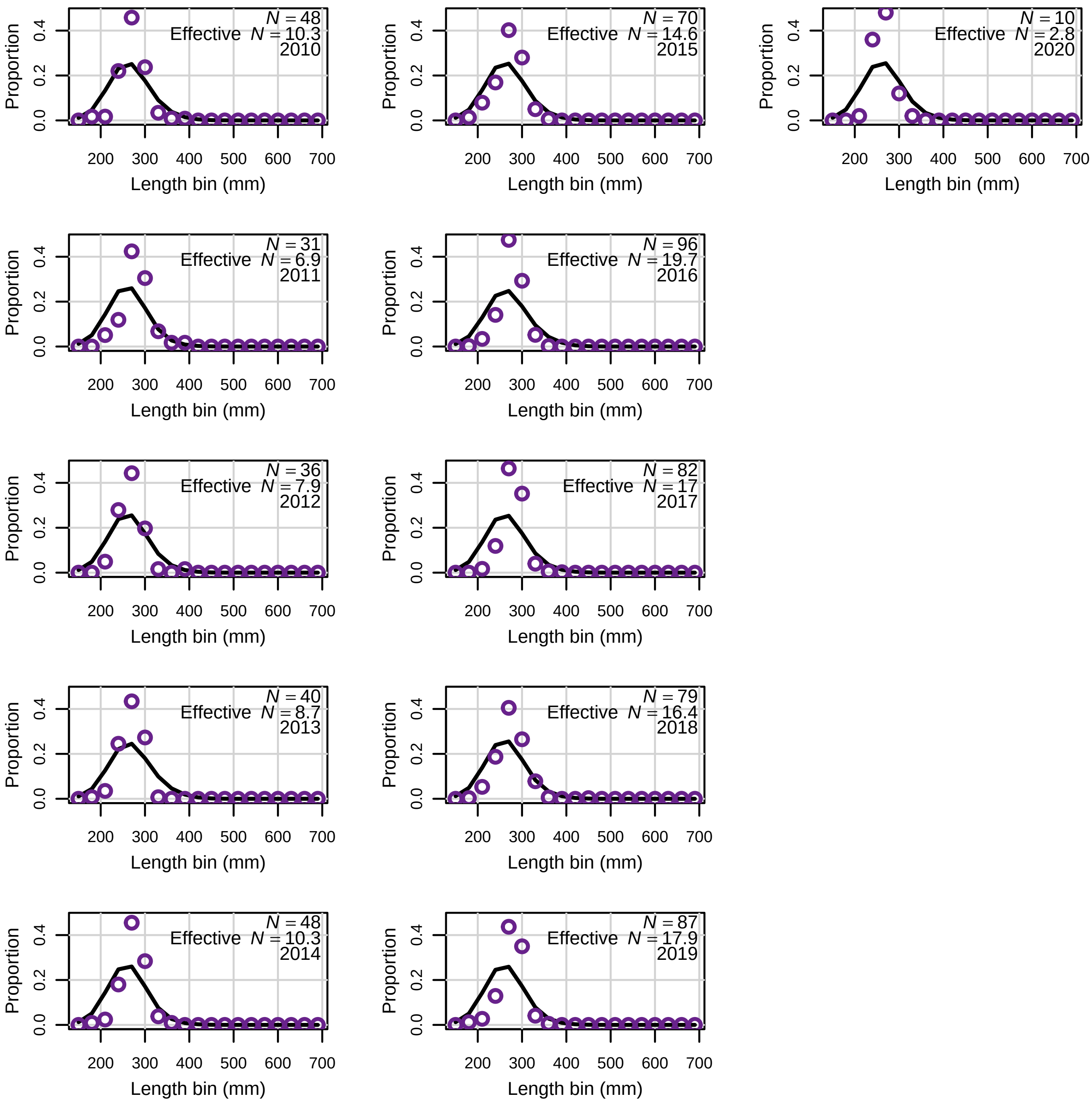


Figure 7. Observed (open circles) and estimated (solid line) pooled age compositions for commercial handline (south) for early (A; 1990 − 2014) and late (B; 2015 − 2019) periods.

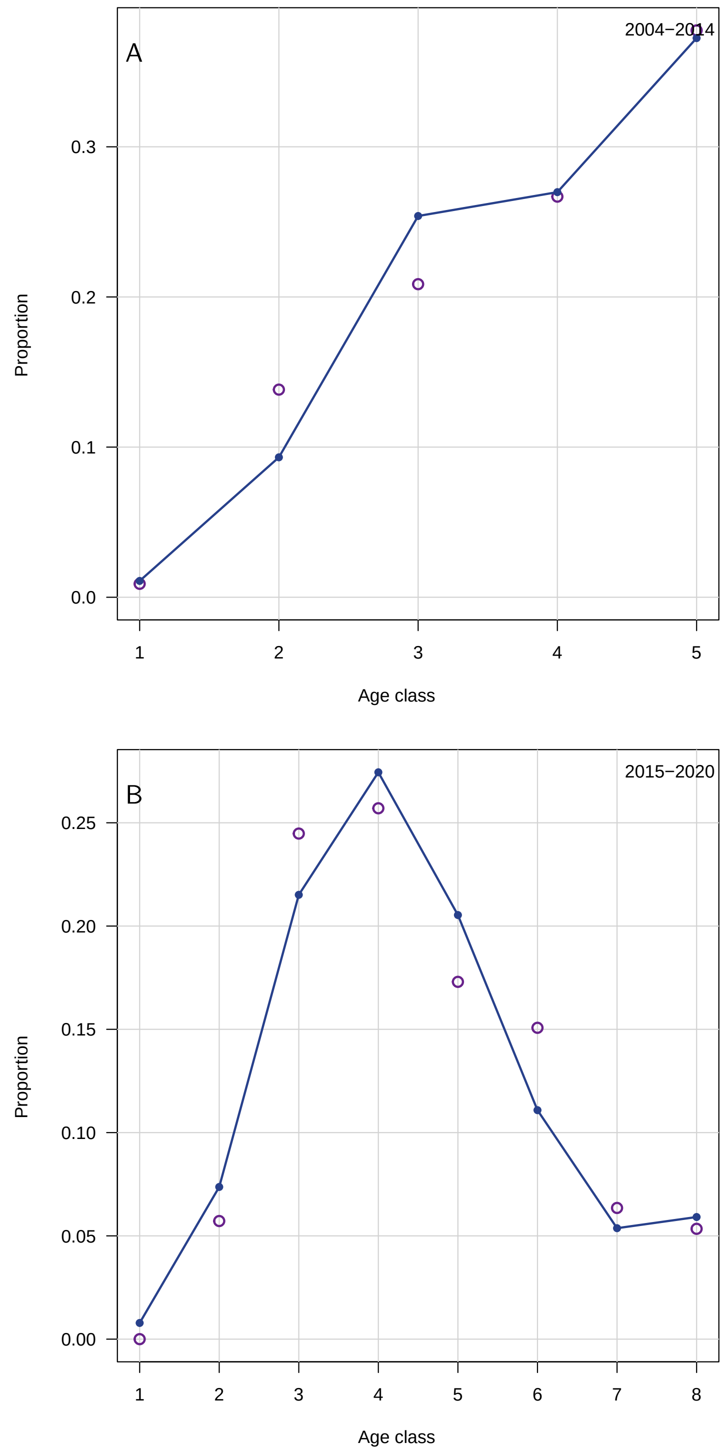


Figure 8. Observed (open circles) and estimated (solid line) pooled age compositions for recreational headboat (south) for early (A; $1990-2014$*) and late (B;* $2015-2019$*) periods.*

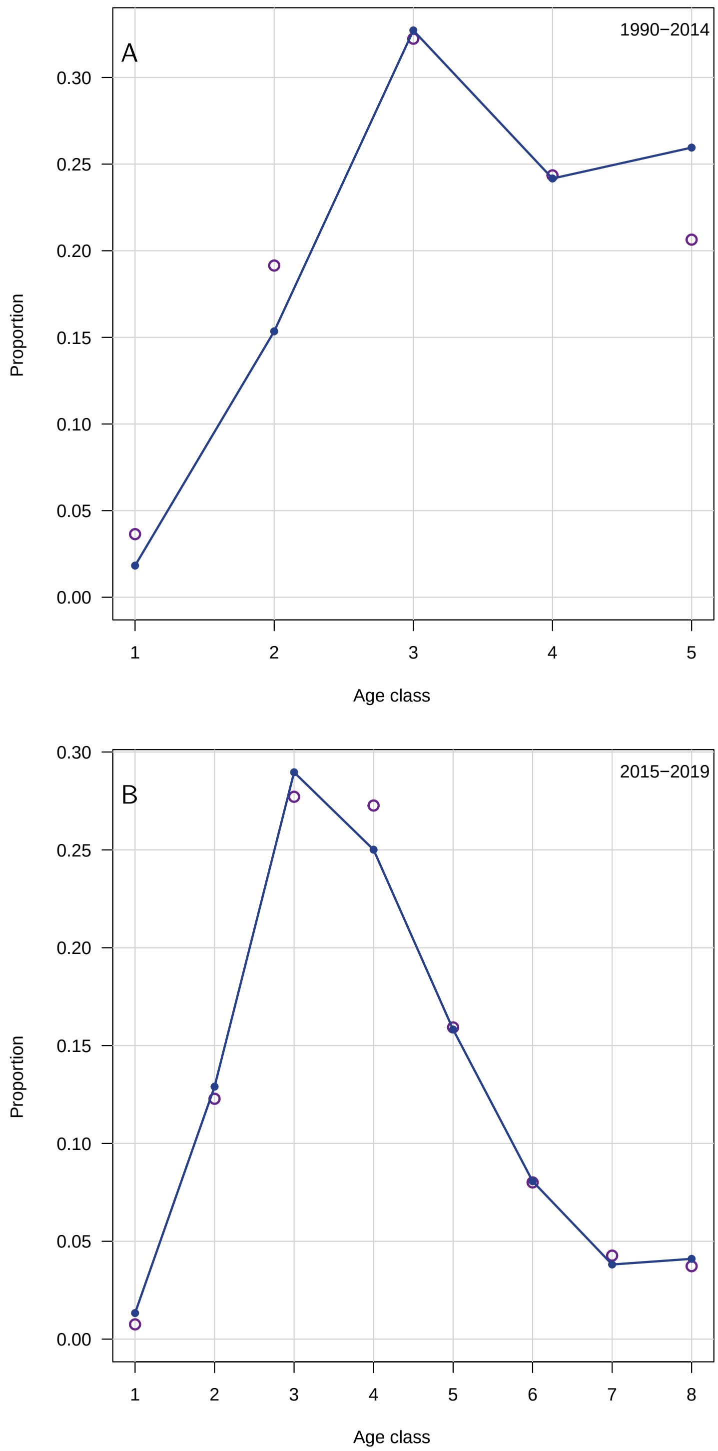


Figure 9. Observed (open circles) and estimated (solid line) pooled age compositions for the SERFS trap/video survey (south) for early (A; 1990 − 2014) and late (B; 2015 − 2019) periods.

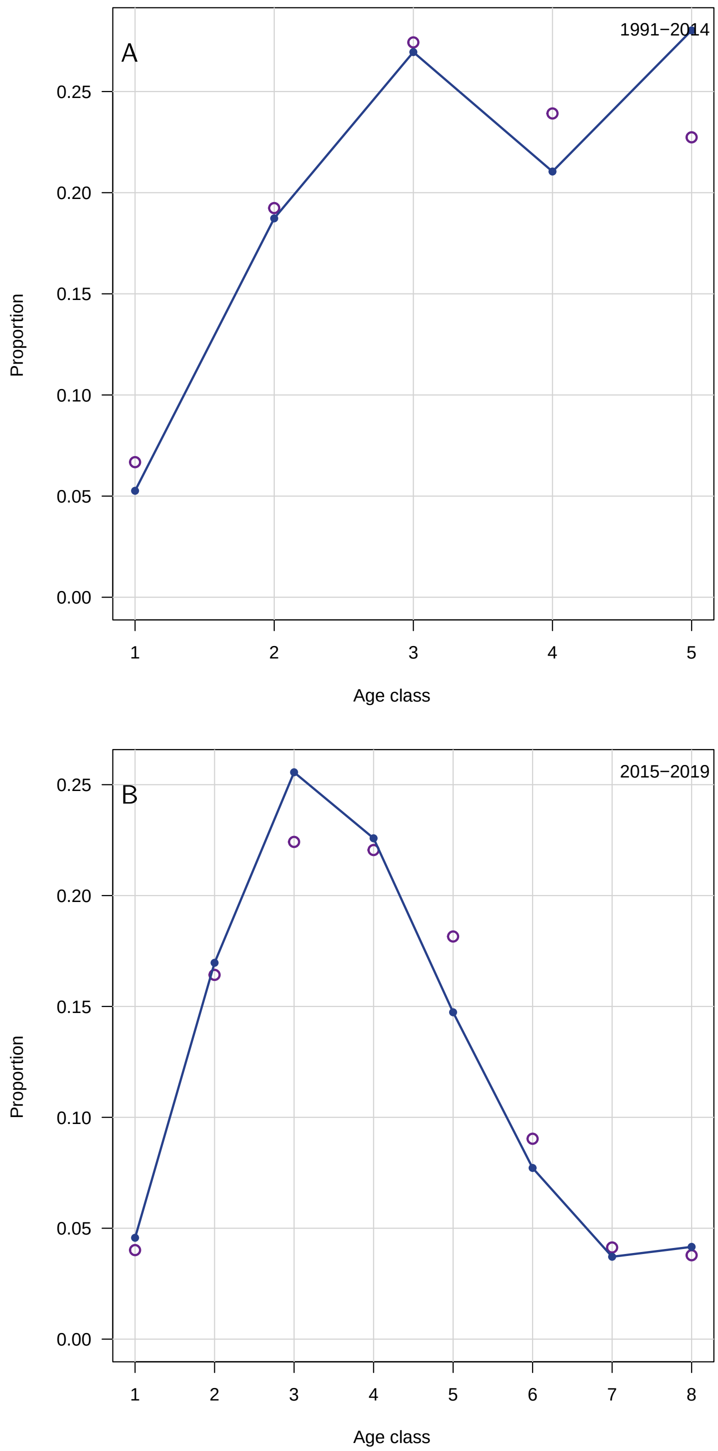


Figure 10. Observed (open circles) and estimated (solid line) pooled length compositions for recreational headboat discards (south) for all years (2005-2020).

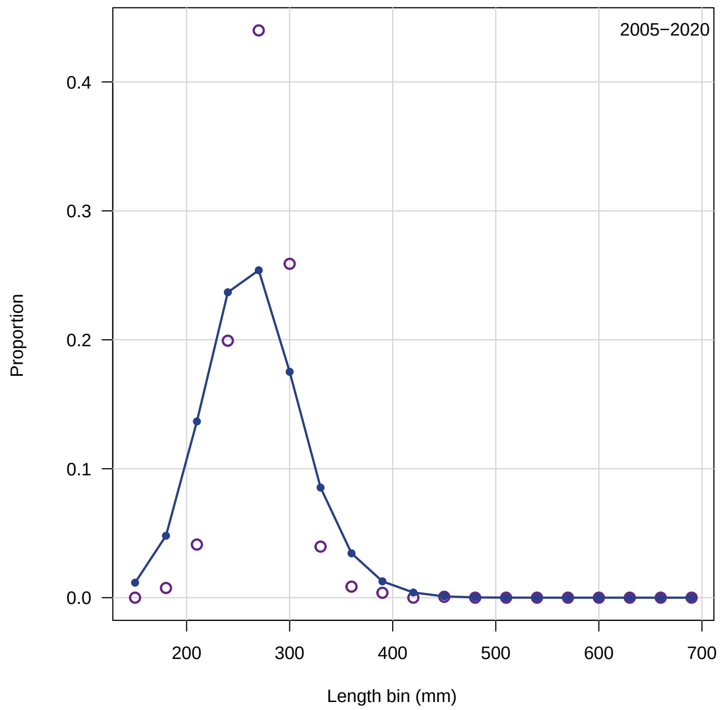


Figure 11. Pearson residual plots for age compositions for commercial handline (south) for early (A; 1990 – 2014) and late (B; 2015 – 2019) periods. Yellow circles indicate positive residuals. Blue circles indicate negative residuals. The size of circles is scaled uniquely in each panel and is relative to the legend above each panel. Pearson residuals are computed as $(ob - pr)/sqrt(pr * (1 - pr)/n_{\text{eff}})$*, where ob and pr are observed and predicted proportion at age and* n_{eff} *is effective sample size.*

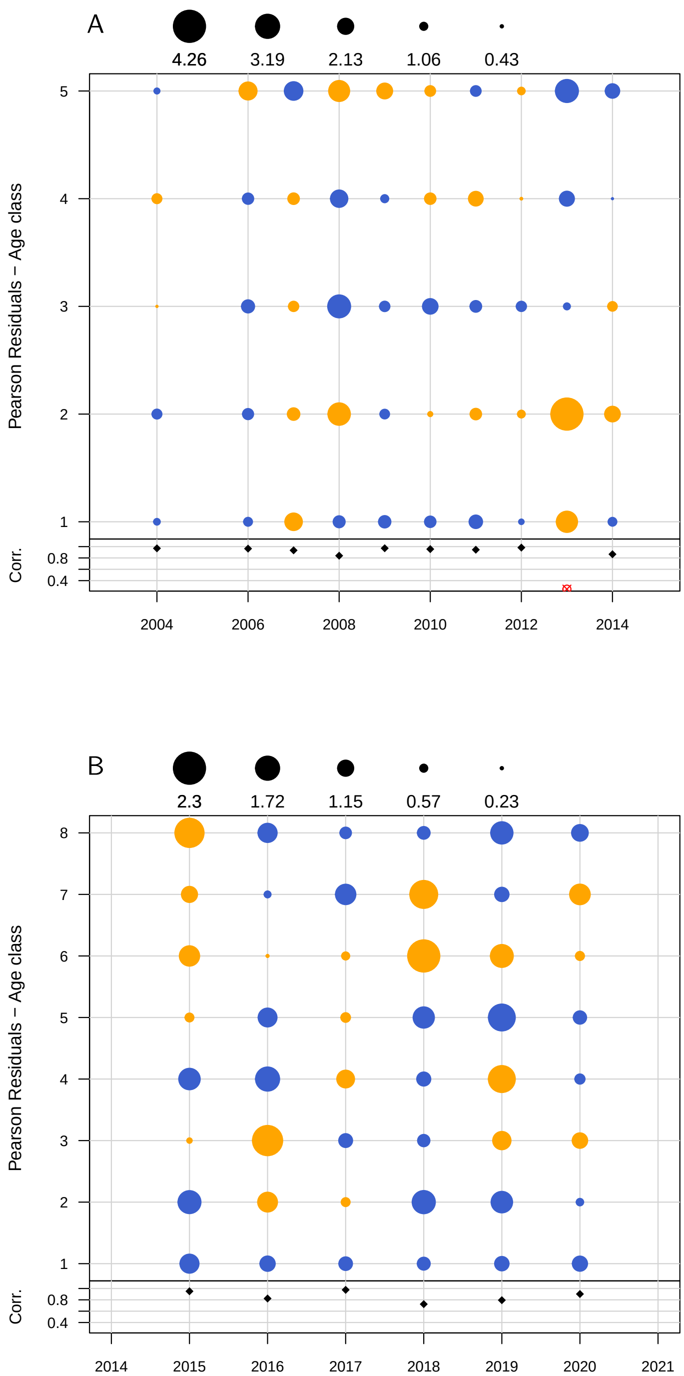
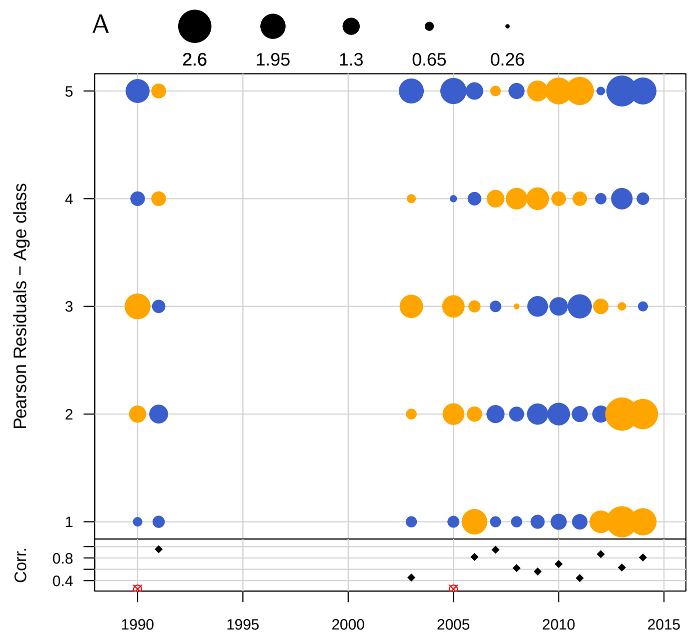


Figure 12. Pearson residual plots for age compositions for commercial handline (south) for early (A; 1990 − 2014) and late (B; 2015 − 2019) periods. Yellow circles indicate positive residuals. Blue circles indicate negative residuals. The size of circles is scaled uniquely in each panel and is relative to the legend above each panel. Pearson residuals are computed as $(ob - pr)/sqrt(pr * (1 - pr)/n_{\text{eff}})$*, where ob and pr are observed and predicted proportion at age and* n_{eff} *is effective sample size.*



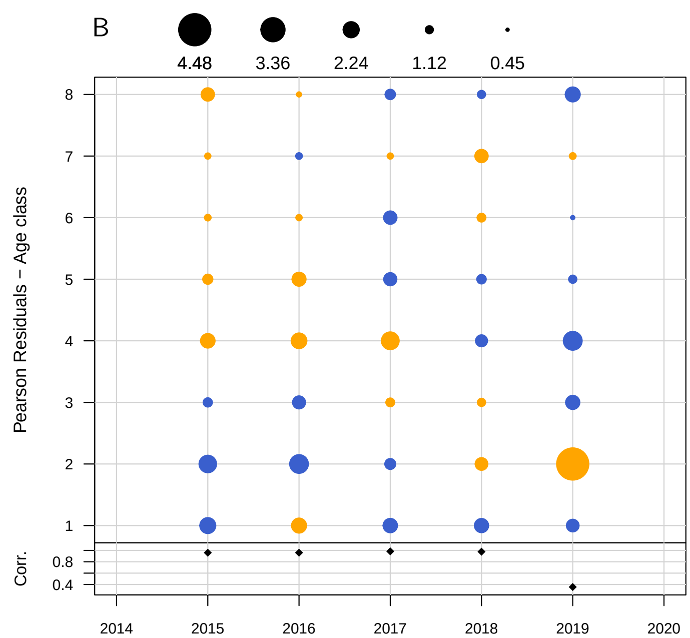


Figure 13. Pearson residual plots for age compositions for commercial handline (south) for early (A; 1990 − 2014) and late (B; 2015 − 2019) periods. Yellow circles indicate positive residuals. Blue circles indicate negative residuals. The size of circles is scaled uniquely in each panel and is relative to the legend above each panel. Pearson residuals are computed as $(ob - pr)/sqrt(pr * (1 - pr)/n_{\mathrm{eff}})$*, where ob and pr are observed and predicted proportion at age and* n_{eff} *is effective sample size.*

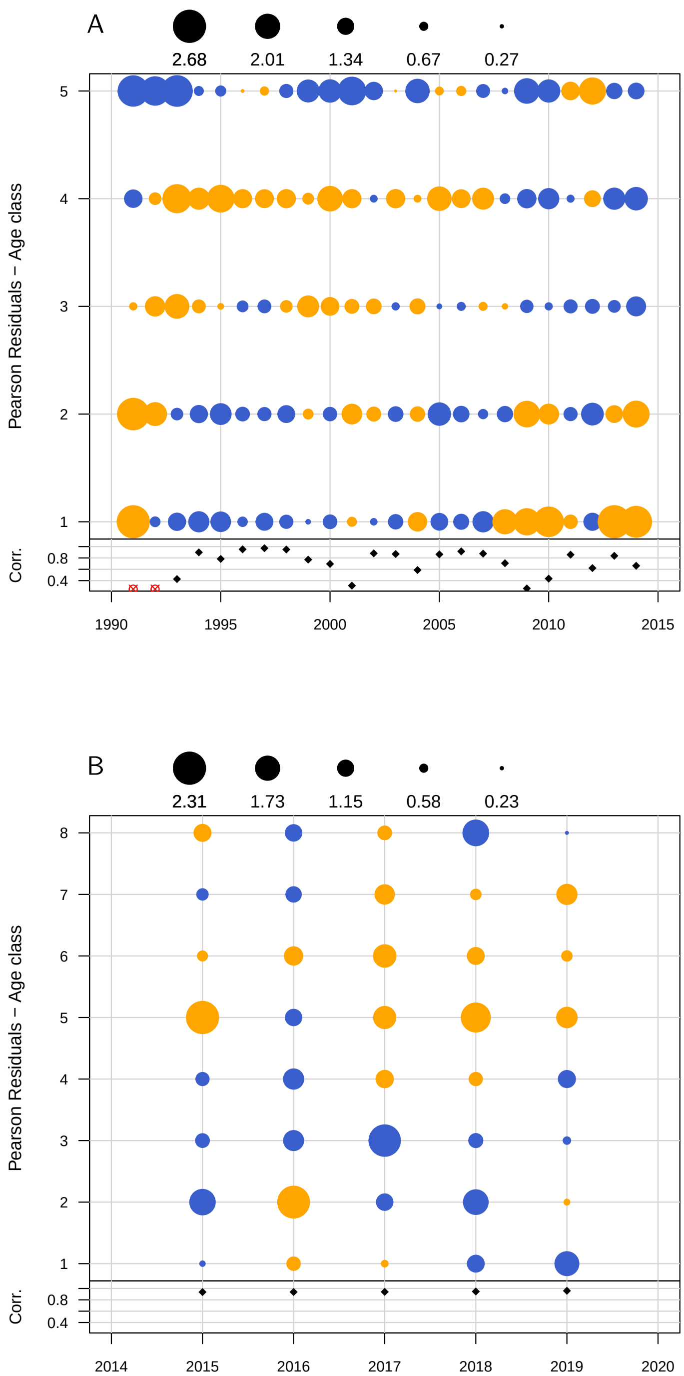


Figure 14. Pearson residual plots for age compositions for length compositions for recreational headboat discards (south) for all years (2005-2020). Yellow circles indicate positive residuals. Blue circles indicate negative residuals. The size of circles is scaled uniquely in each panel and is relative to the legend above each panel. Pearson residuals are computed as $(ob - pr)/sqrt(pr * (1 - pr)/n_{\text{eff}})$*, where ob and pr are observed and predicted proportion at age and* n_{eff} *is effective sample size.*

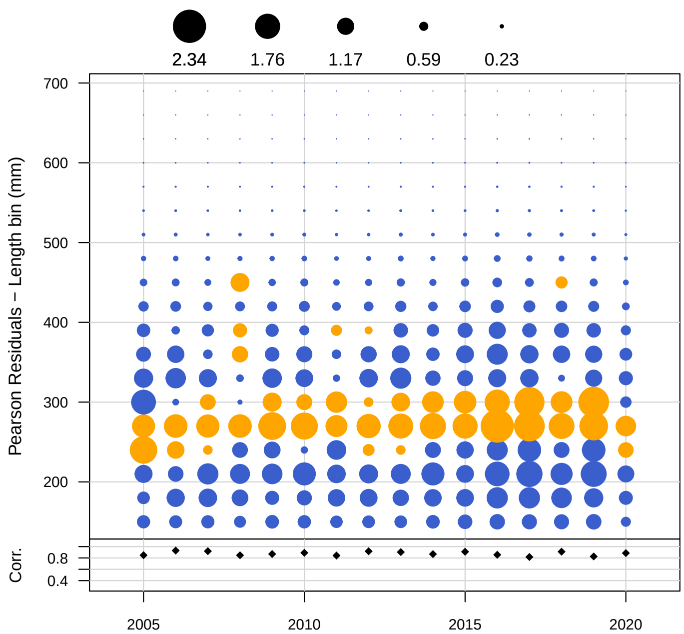


Figure 15. Observed (open circles) and estimated (line, solid circles) commercial handline (north) landings (1000 lb whole weight).

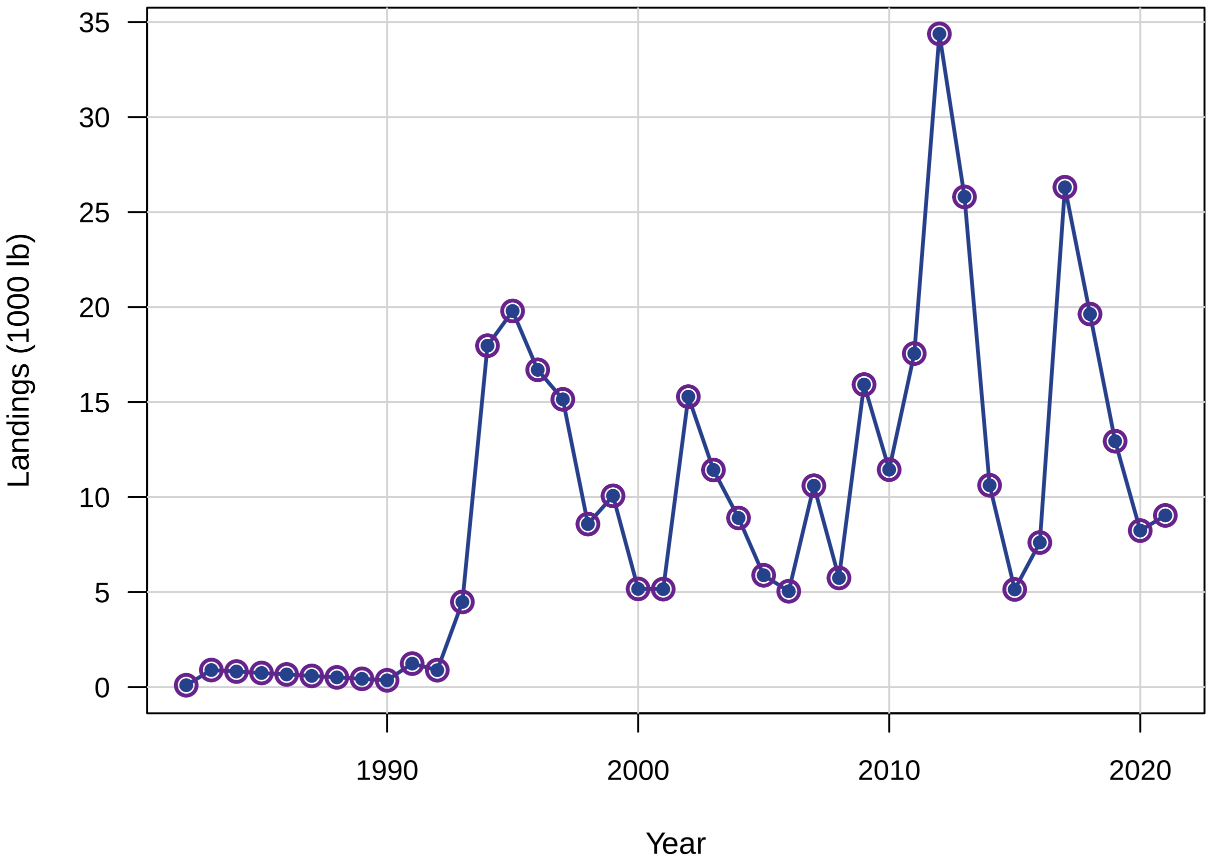


Figure 16. Observed (open circles) and estimated (line, solid circles) commercial handline (south) landings and dead discards (1000 lb whole weight).

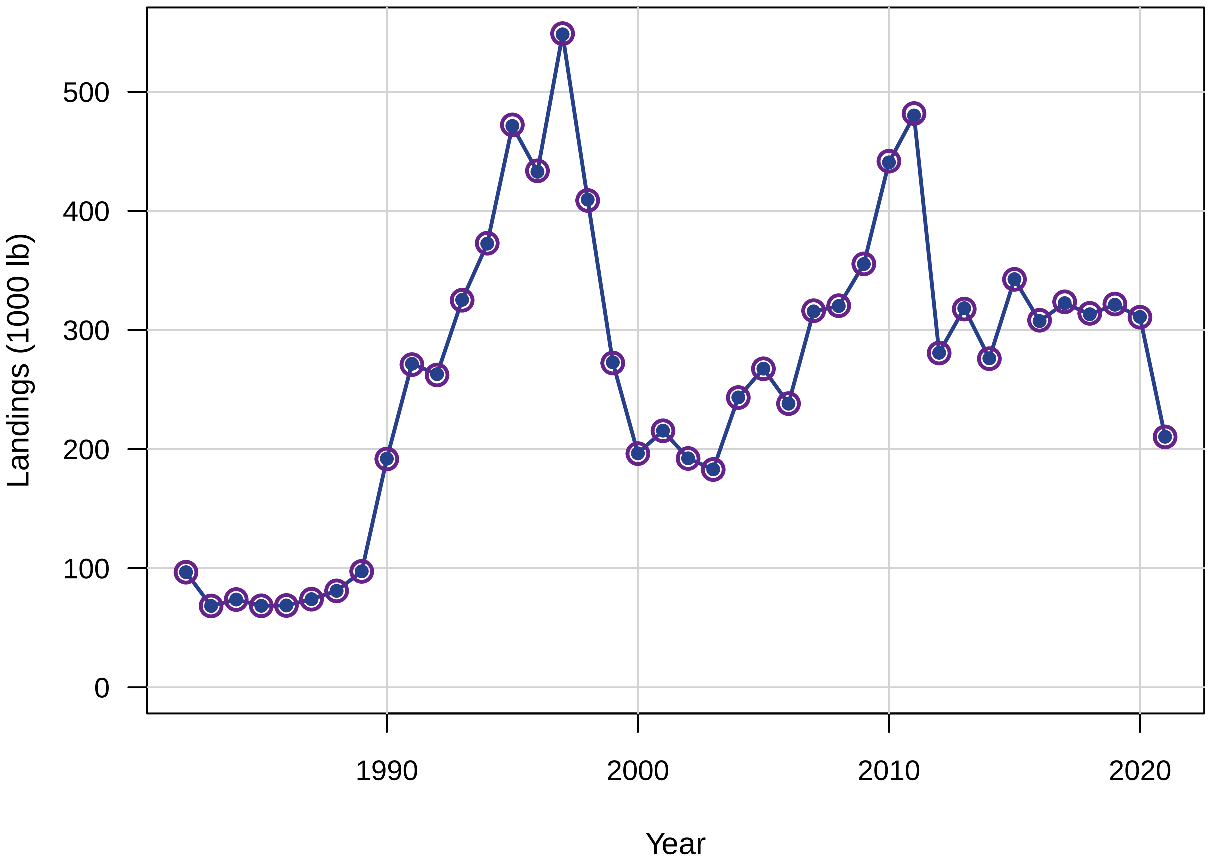


Figure 17. Observed (open circles) and estimated (line, solid circles) general recreational (north) landings (1000 fish).

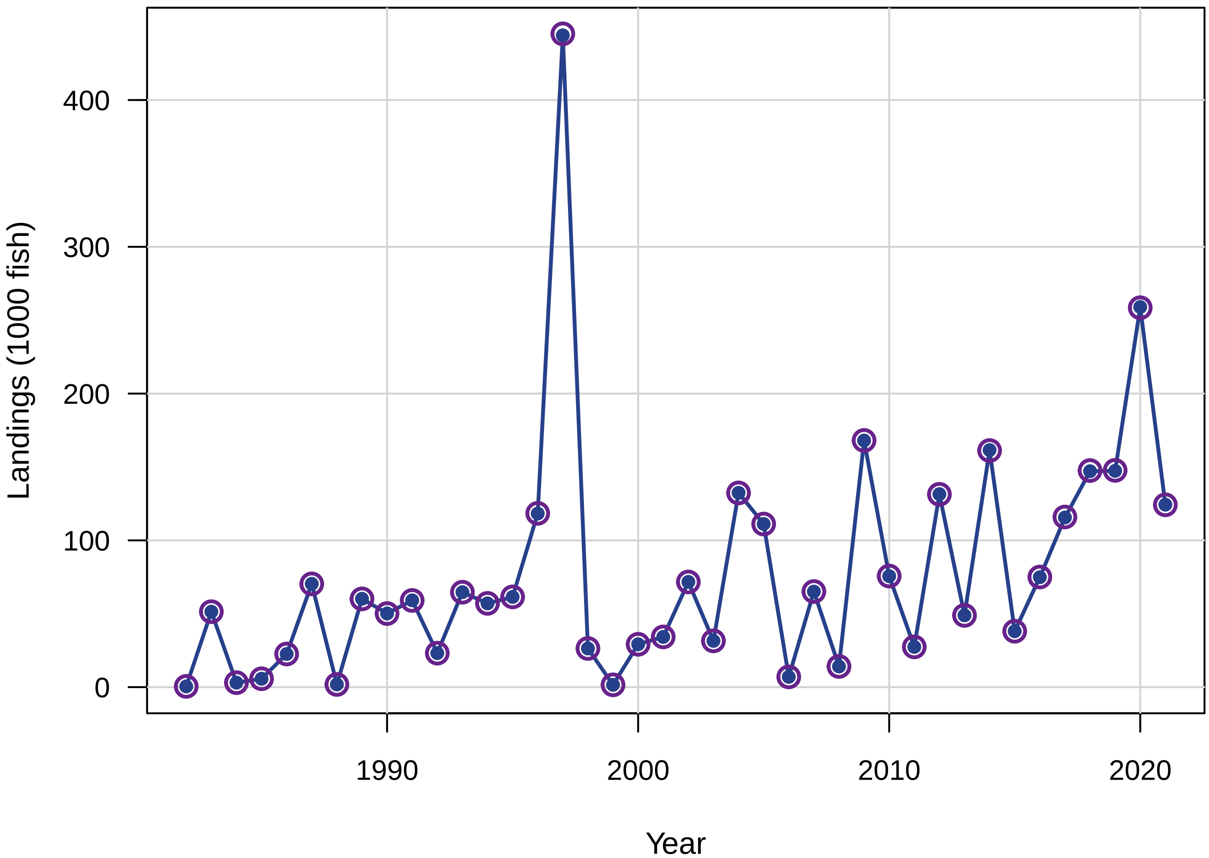


Figure 18. Observed (open circles) and estimated (line, solid circles) general recreational (south) landings (1000 fish).

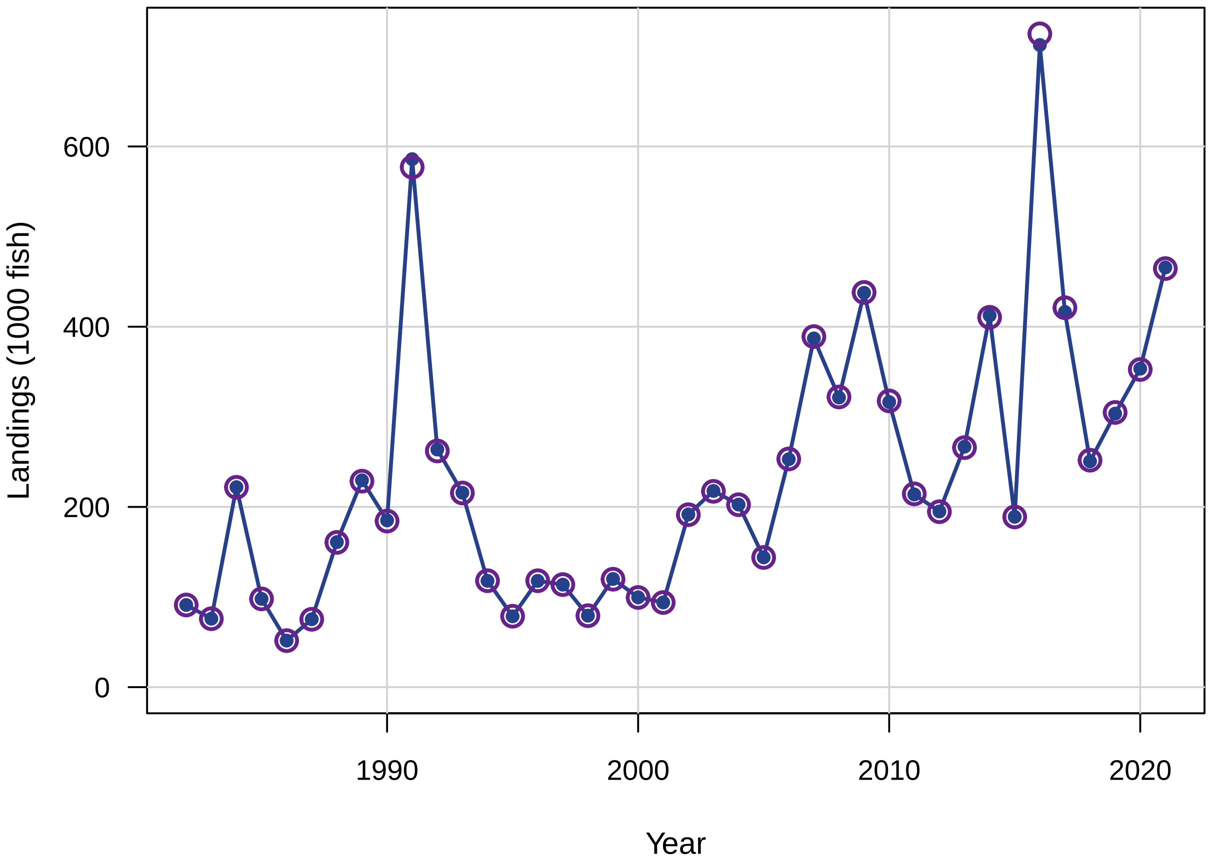


Figure 19. Observed (open circles) and estimated (line, solid circles) headboat recreational (south) landings (1000 fish).

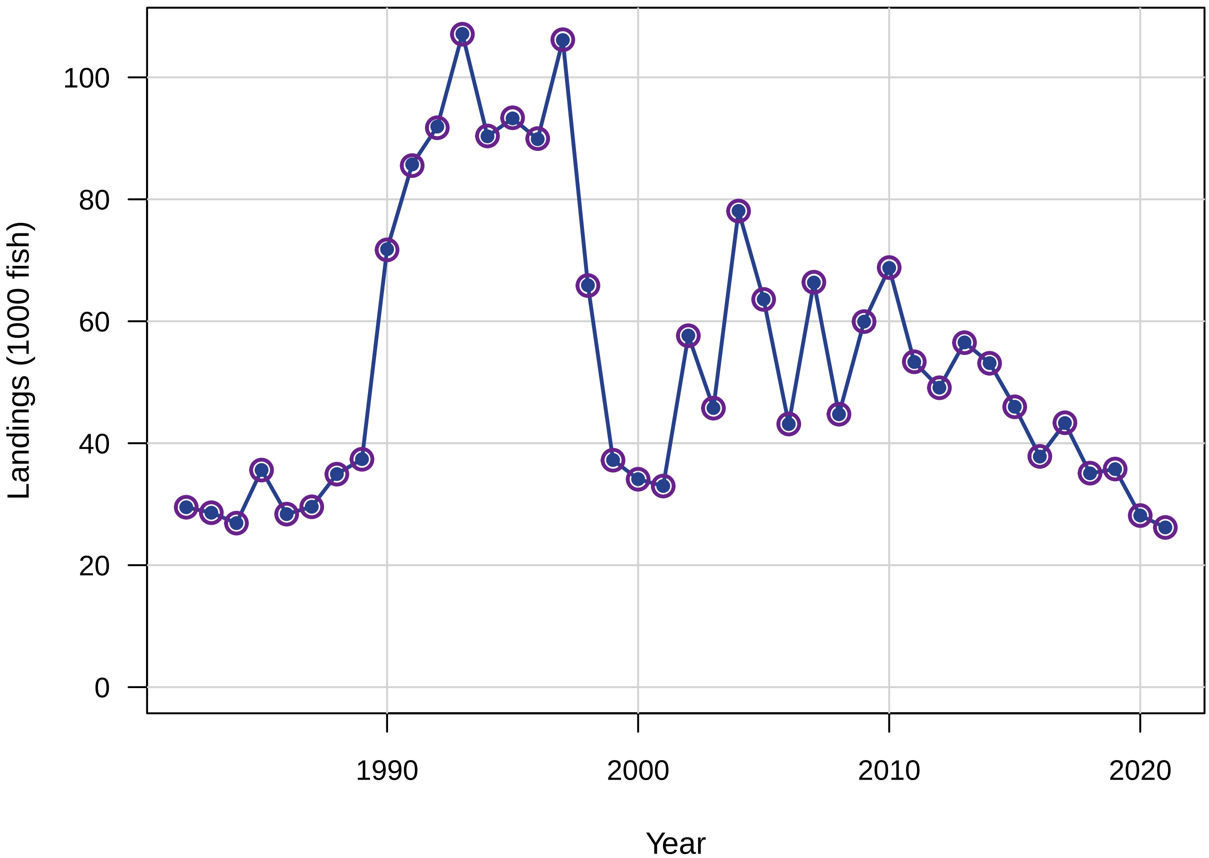


Figure 20. Observed (open circles) and estimated (line, solid circles) general recreational (north) discards (1000 dead fish).

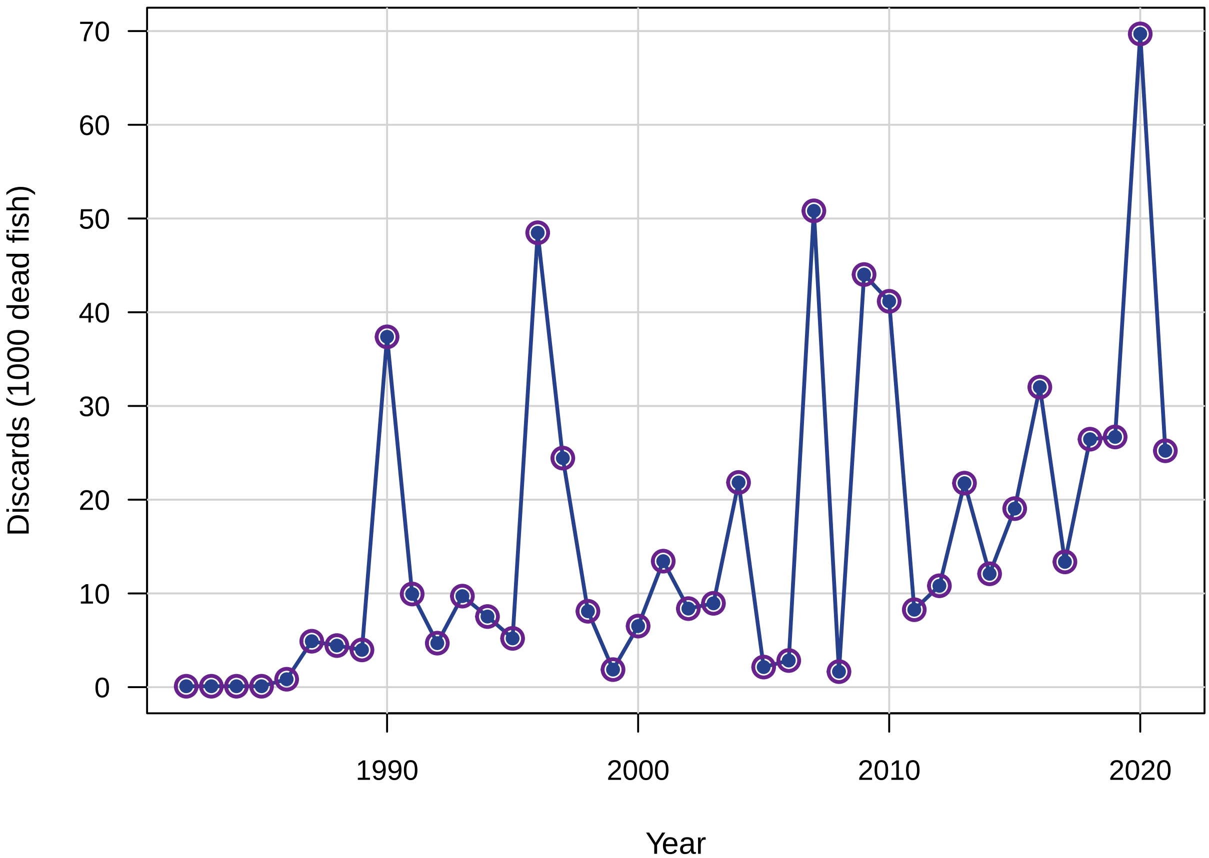


Figure 21. Observed (open circles) and estimated (line, solid circles) general recreational (south) discards (1000 dead fish).

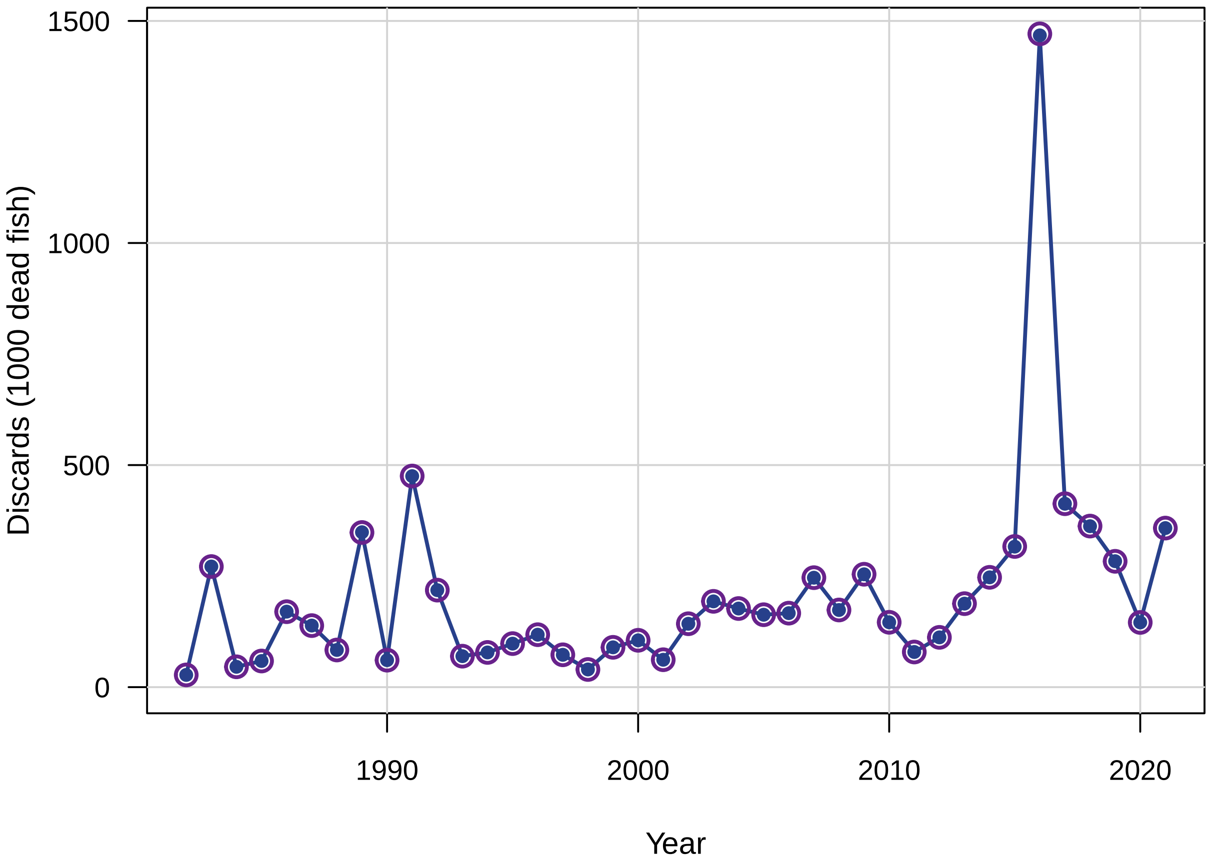


Figure 22. Observed (open circles) and estimated (line, solid circles) headboat recreational (south) discards (1000 dead fish).

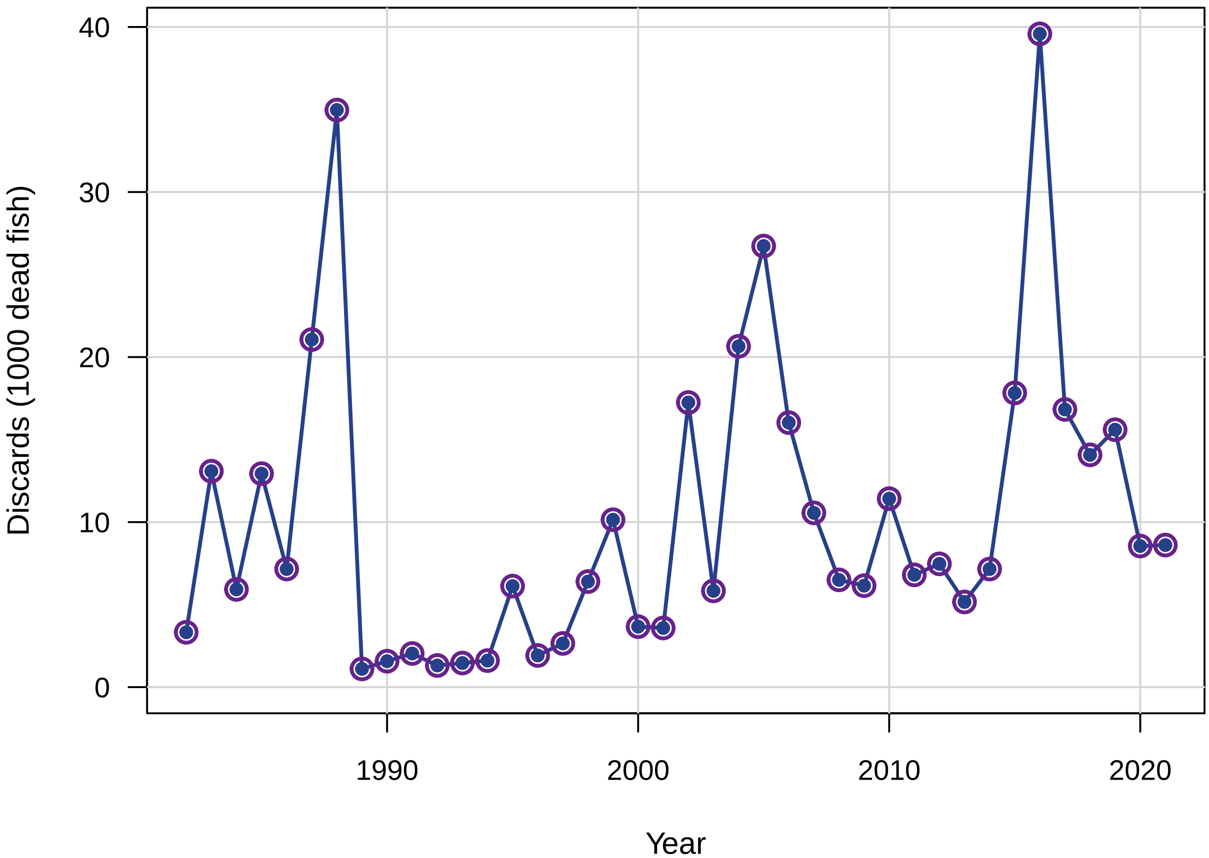


Figure 23. Observed (open circles) and estimated (line, solid circles) SERFS trap/video index In the upper panel, error bars indicate ±2 standard errors of the observed index (U_{ob}). In the lower panel are the log residuals of the fit to the index and the color of the box indicates the p-value of the runs test (green > 0.05, orange ≤ 0.05 and > 0.01, red < 0.01) and the width of the box is 3 times the standard error. Points that fall outside 3 standard errors are plotted in red..

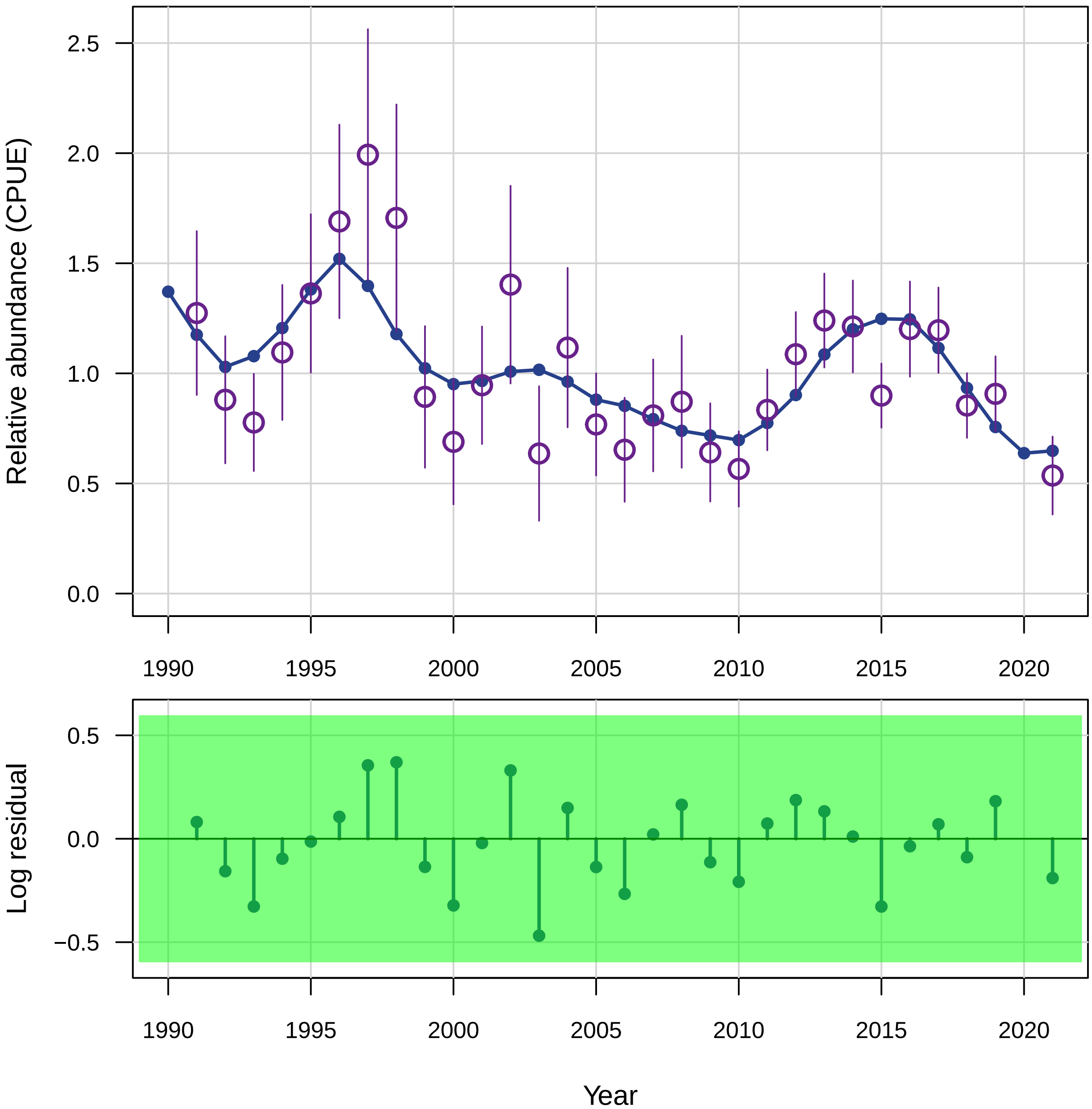


Figure 24. Estimated abundance (numbers) at age at start of year.

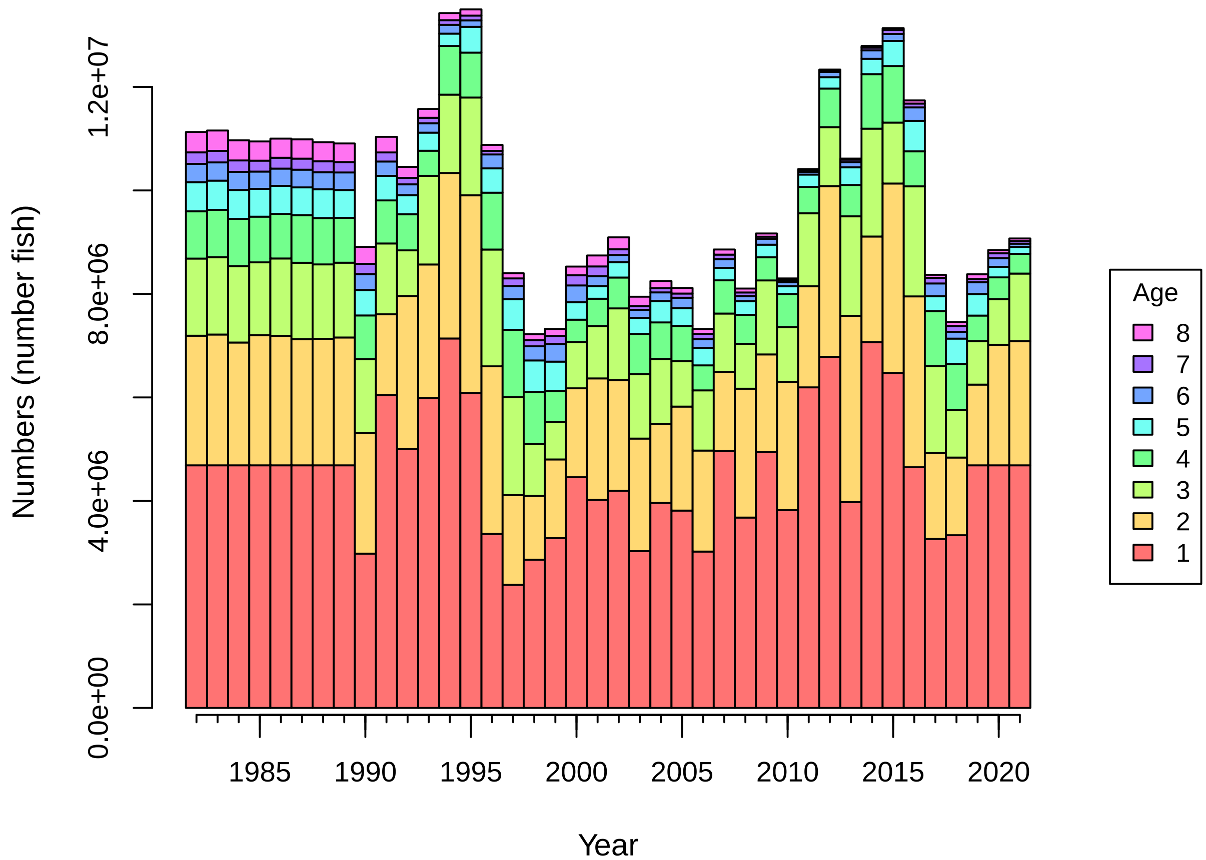


Figure 25. Estimated biomass at age at start of year.

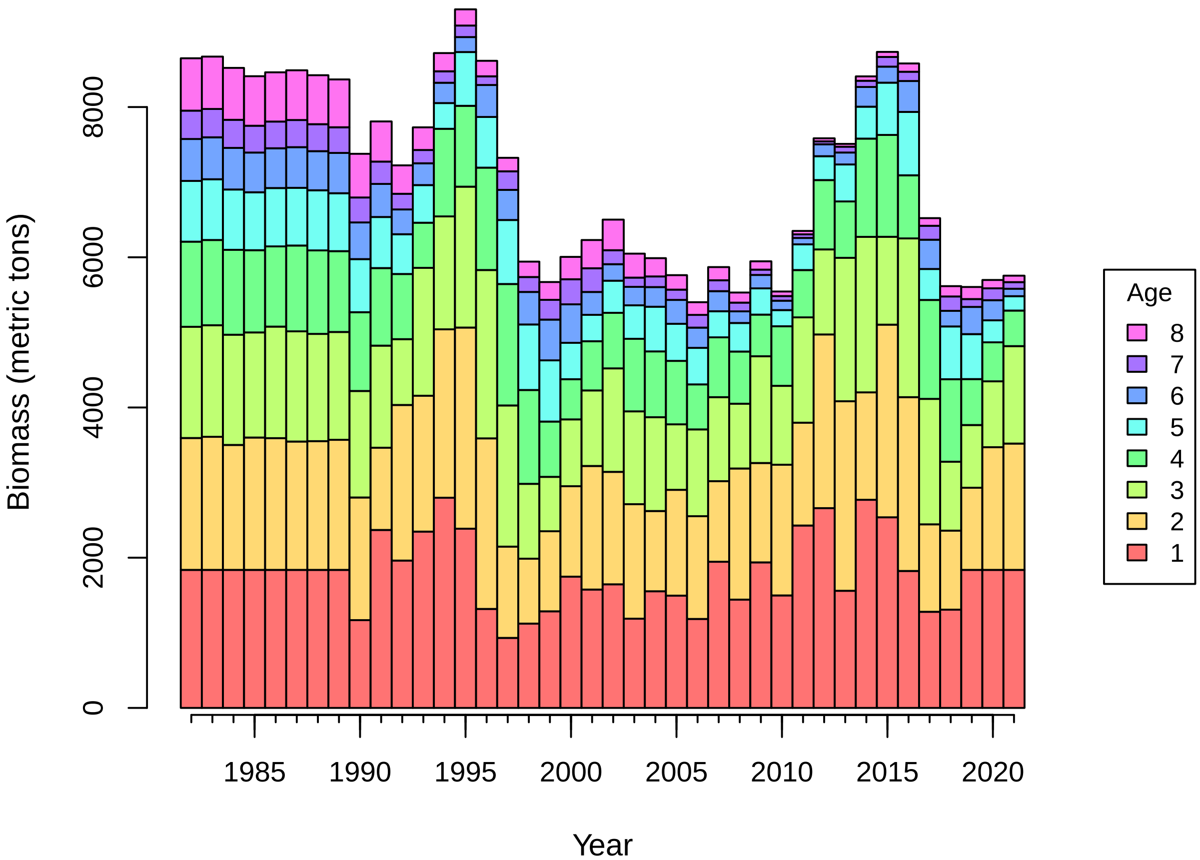


Figure 26. Estimated recruitment time series. (A) Estimated recruitment of age-1 fish. Horizontal dashed line indicates $R_{F40\%}$. (B) Log recruitment residuals (open circles). These are annual recruitment deviations (r_y) estimated within the model. The solid tan line is a lowess smoother fit to the residuals.

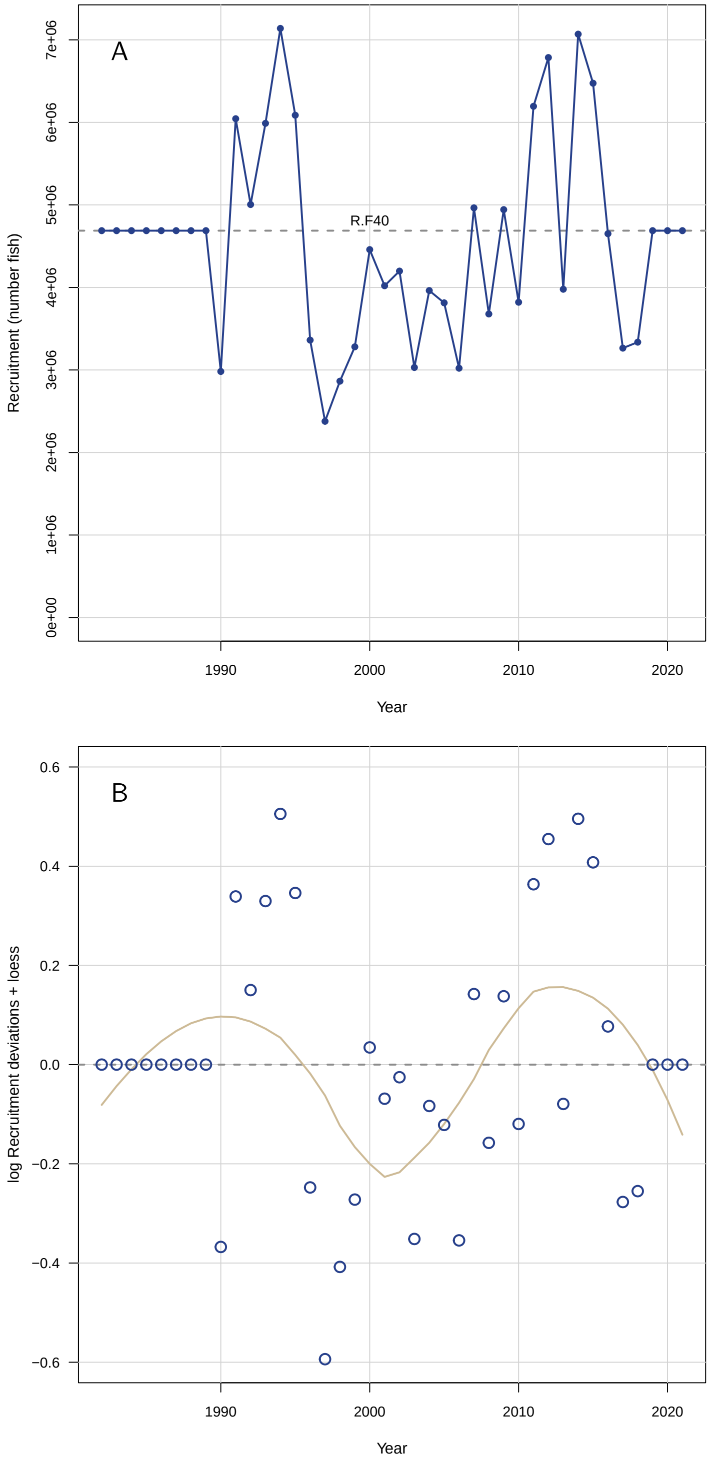


Figure 27. Estimated total biomass and spawning stock time series. (A) Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates $B_{\mathrm{F40\%}}$. (B) Estimated spawning stock (million eggs) at time of peak spawning (June 29^{th}; 0.5 yr).

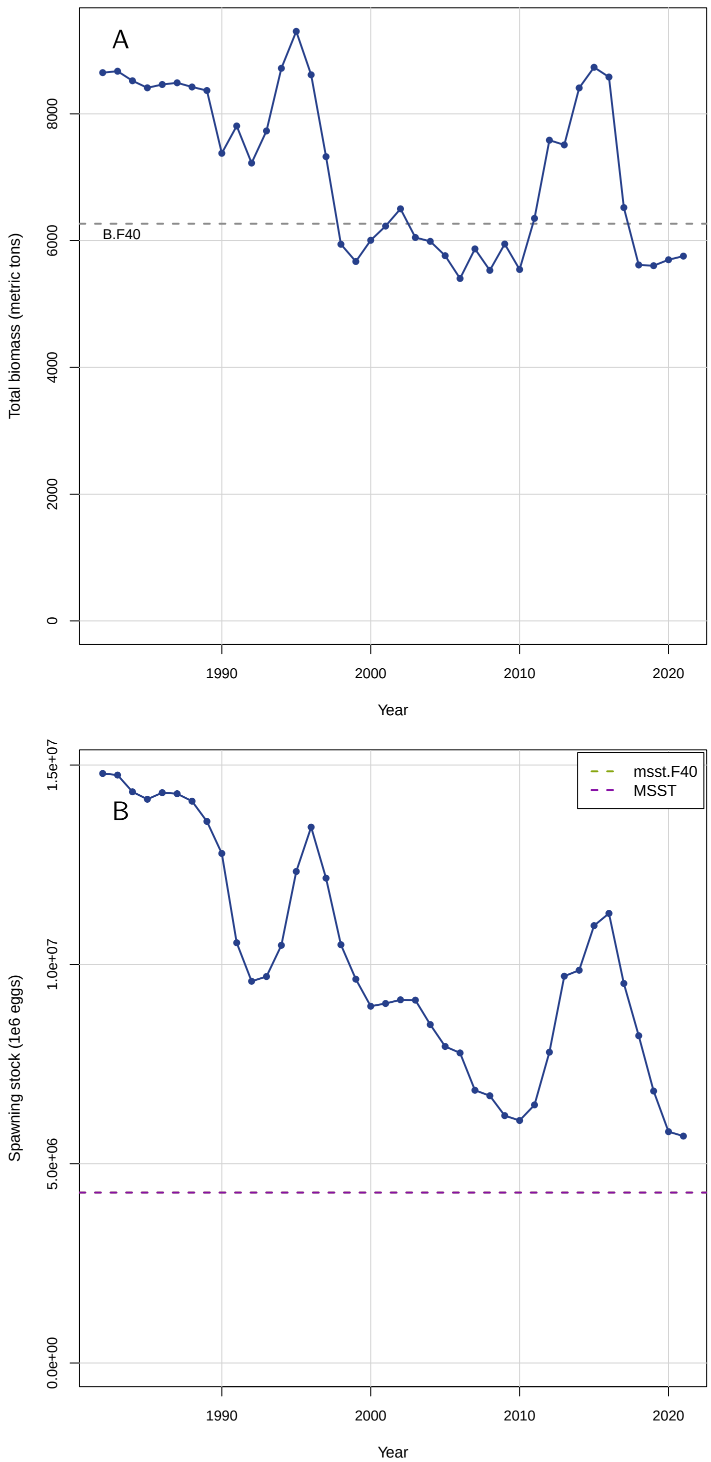


Figure 28. Selectivity for the SERFS trap/video index. The first year of each selectivity block is indicated in the legend. In this case, there was only one selectivity block.

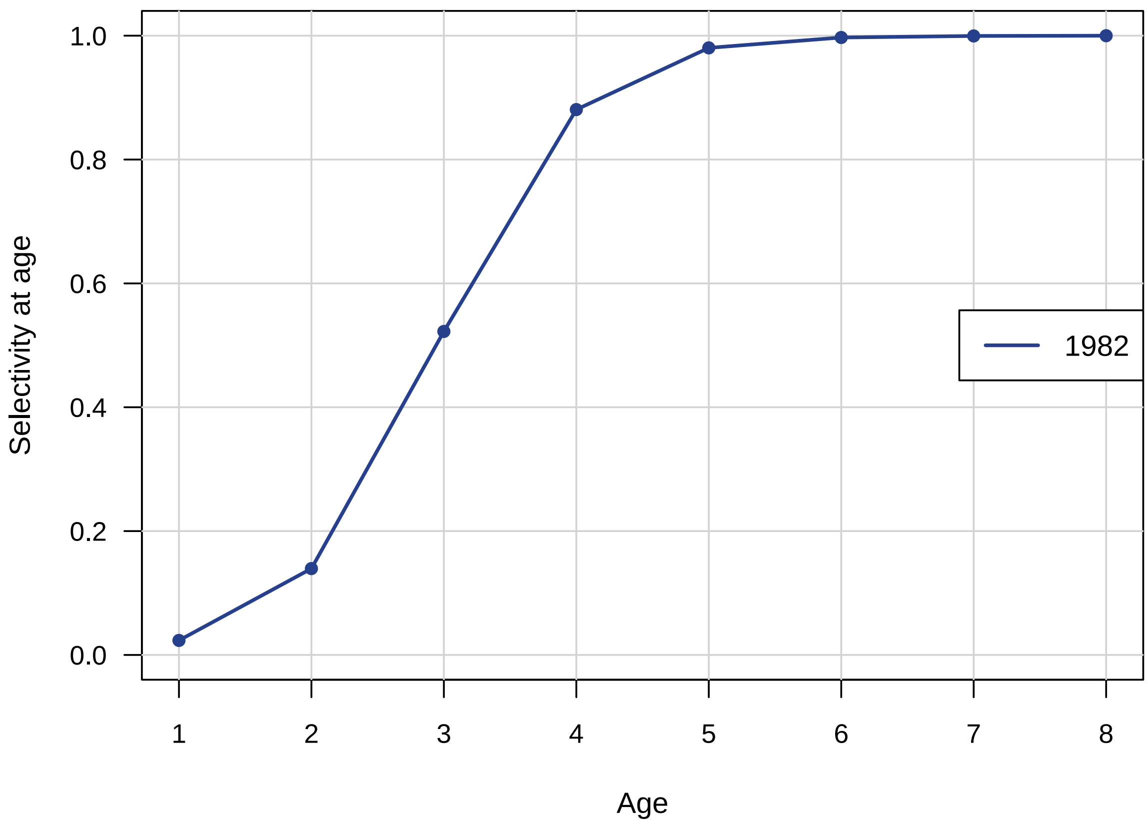


Figure 29. Selectivity for commercial handline landings. The first year of each selectivity block is indicated in the legend. In this case, there was only one selectivity block. The same selectivity was applied to both north and south areas.

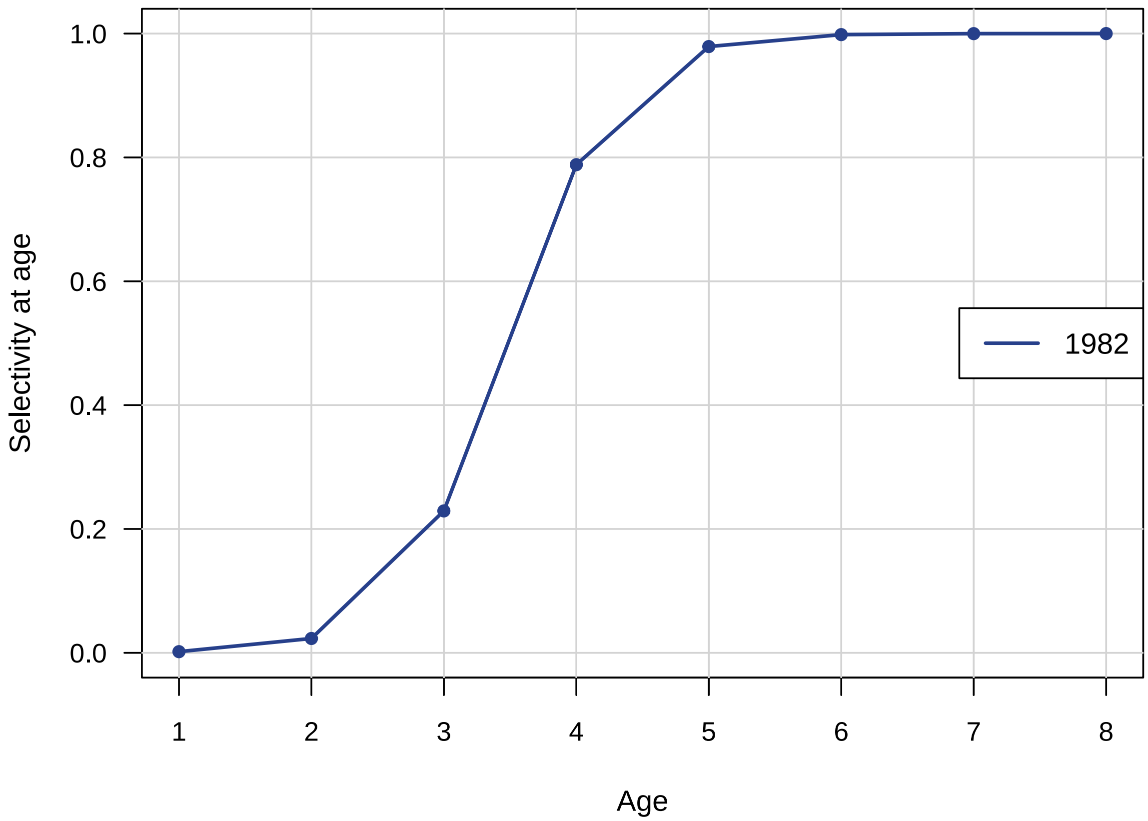
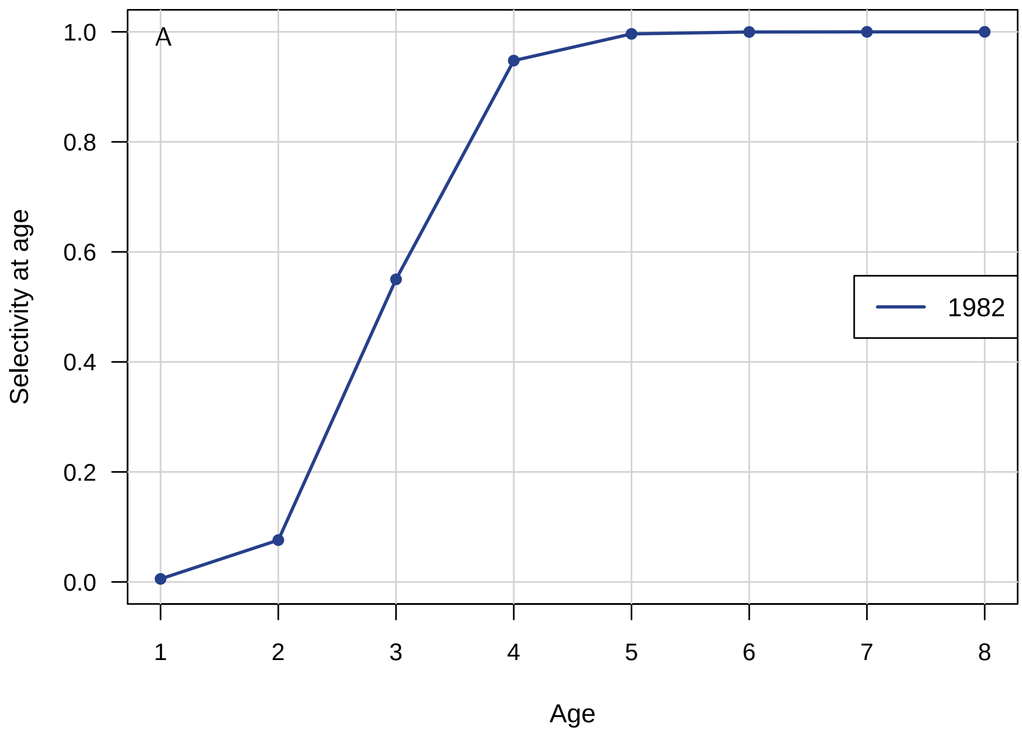


Figure 30. Selectivity for (A) headboat and (B) general recreational landings. The first year of each selectivity block is indicated in the legend. In this case, there was only one selectivity block. Note that the general recreational selectivity was assumed equal to the headboat selectivity. The same selectivity was applied to both north and south areas.



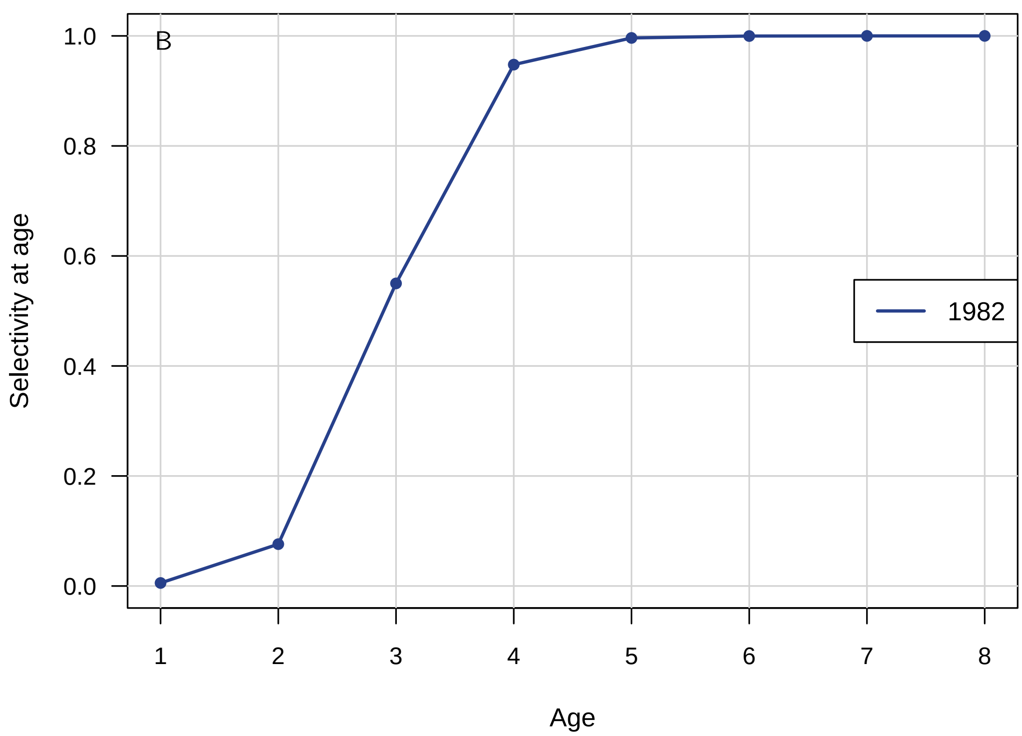


Figure 31. Selectivity for (A) headboat and (B) general recreational discards. The first year of each selectivity block is indicated in the legend. In this case, there was only one selectivity block. Note that the general recreational selectivity was assumed equal to the headboat selectivity. The same selectivity was applied to both north and south areas.

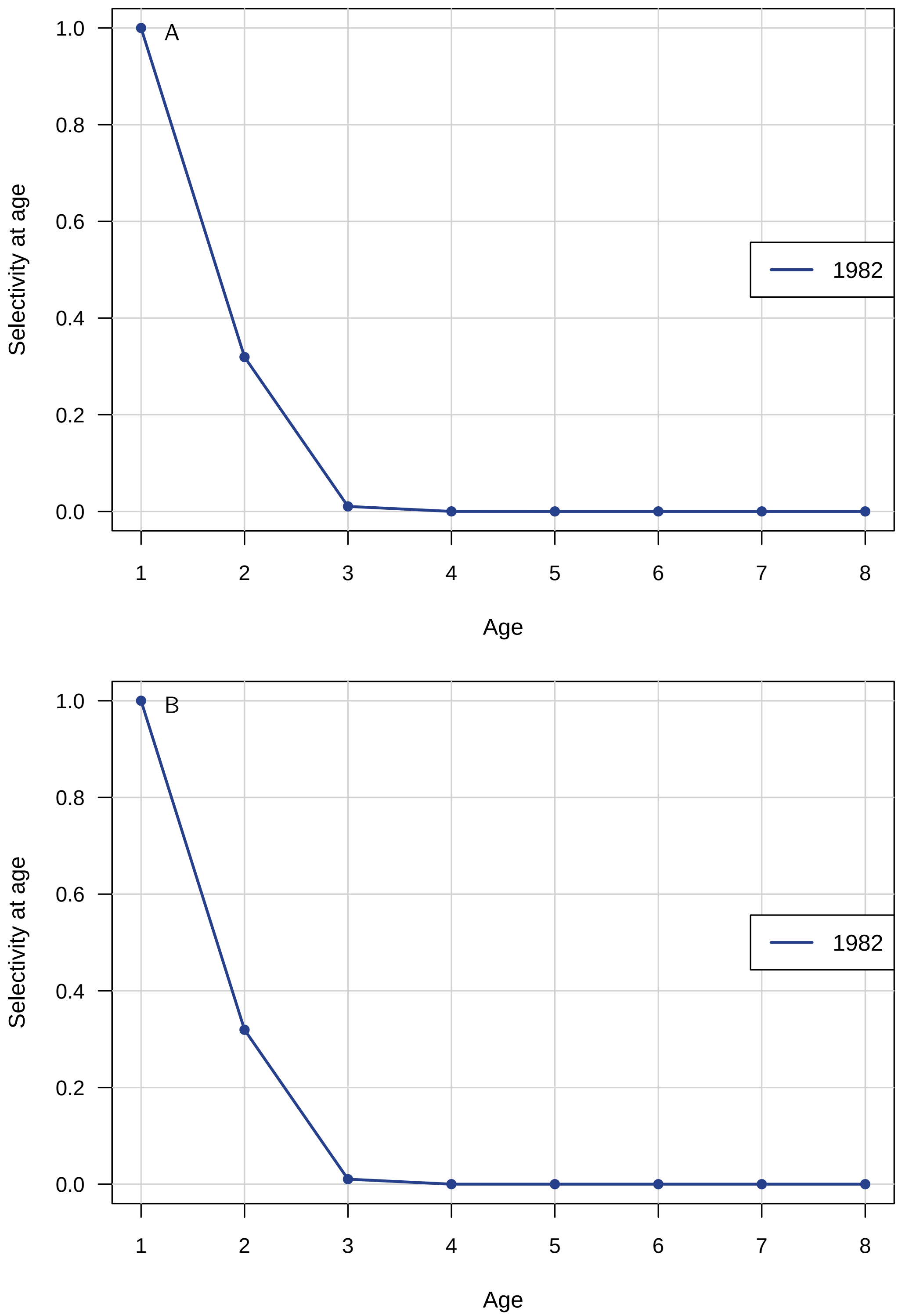


Figure 32. Average selectivity from the terminal assessment year weighted by geometric mean Fs from the last three assessment years, for (A) landings, (B) discards, and (C) total removals. These selectivities are used in computation of benchmarks and central-tendency projections.

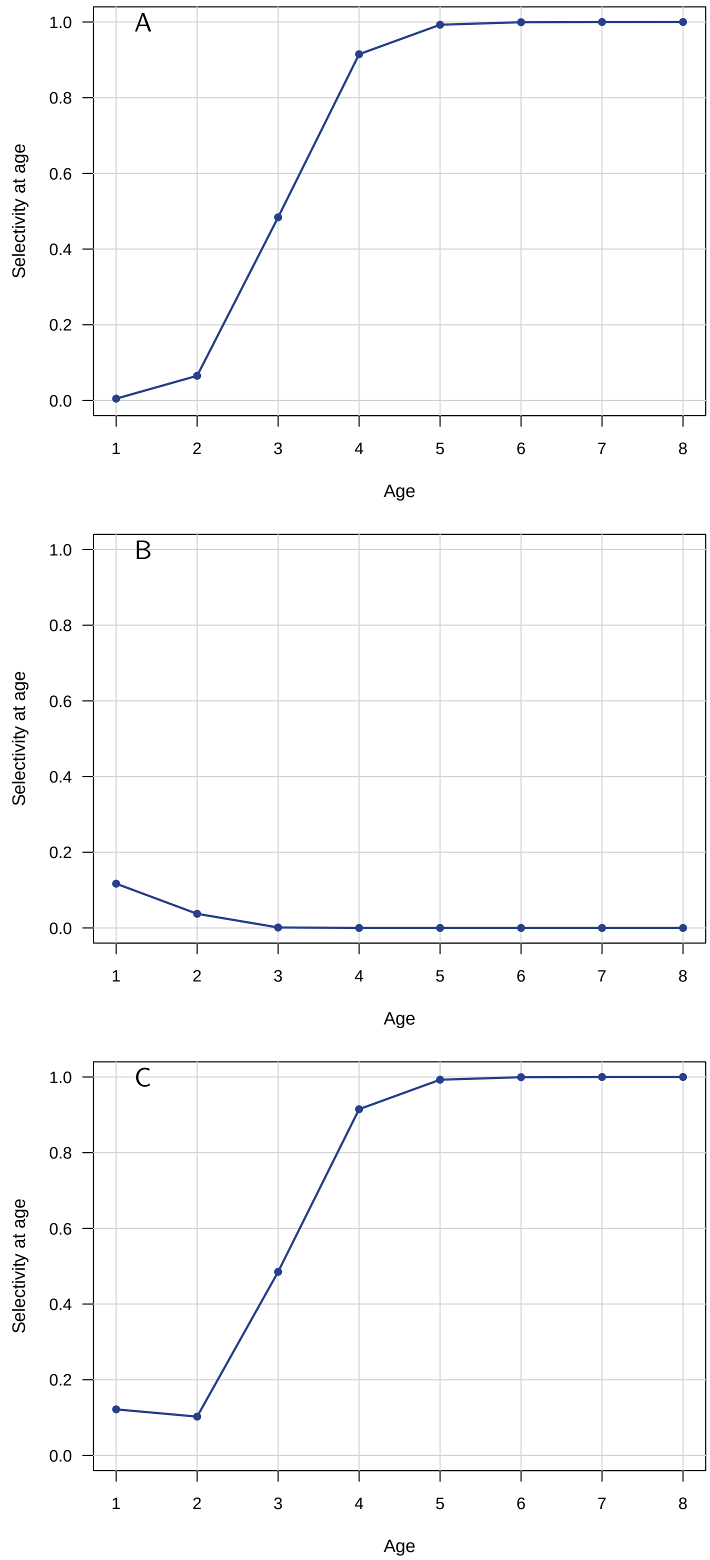


Figure 33. Estimated fully selected fishing mortality rate (per year) by fleet for discards (D) and landings (L) for general recreational discards, north (D.rGDn); general recreational discards, south (D.rGDs); headboat recreational discards, south (D.rHDs); general recreational landings, north (L.rGNn); general recreational landings, south (L.rGNs); headboat recreational landings, south (L.rHBs); commercial handline landings, north (L.cHLn); and commercial handline landings, south (L.cHLs).

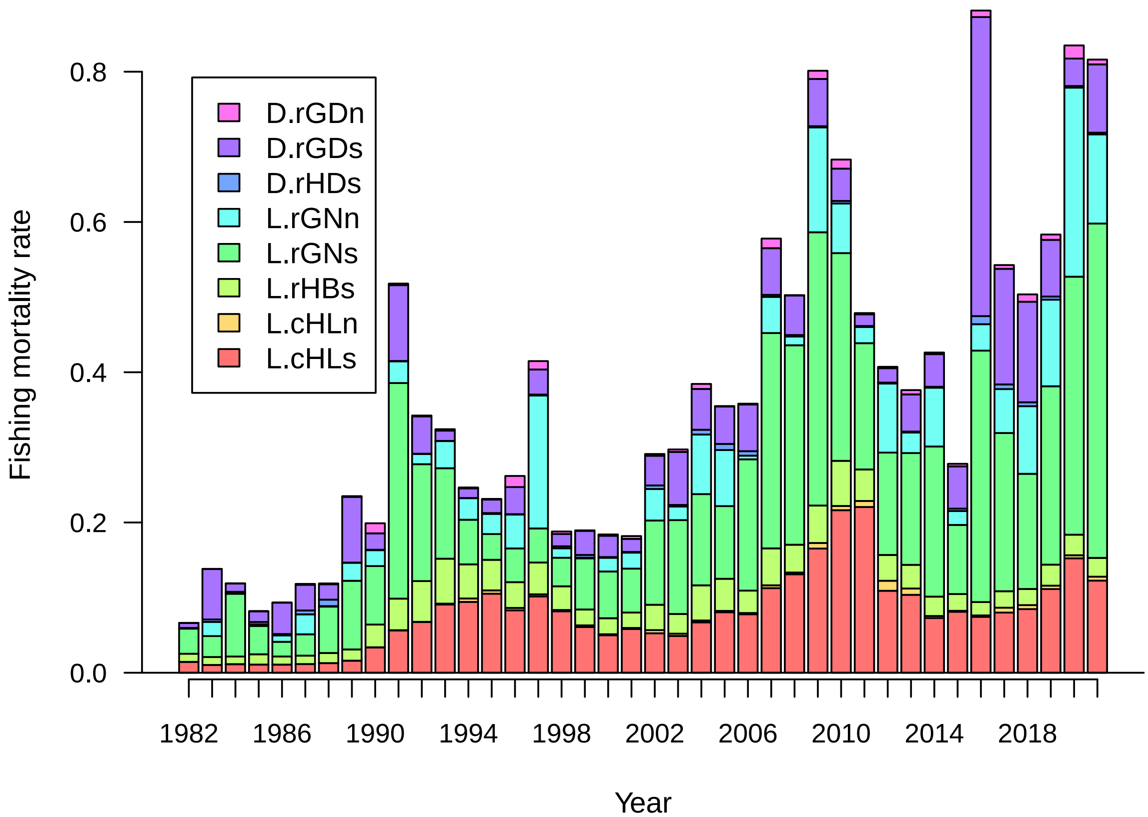
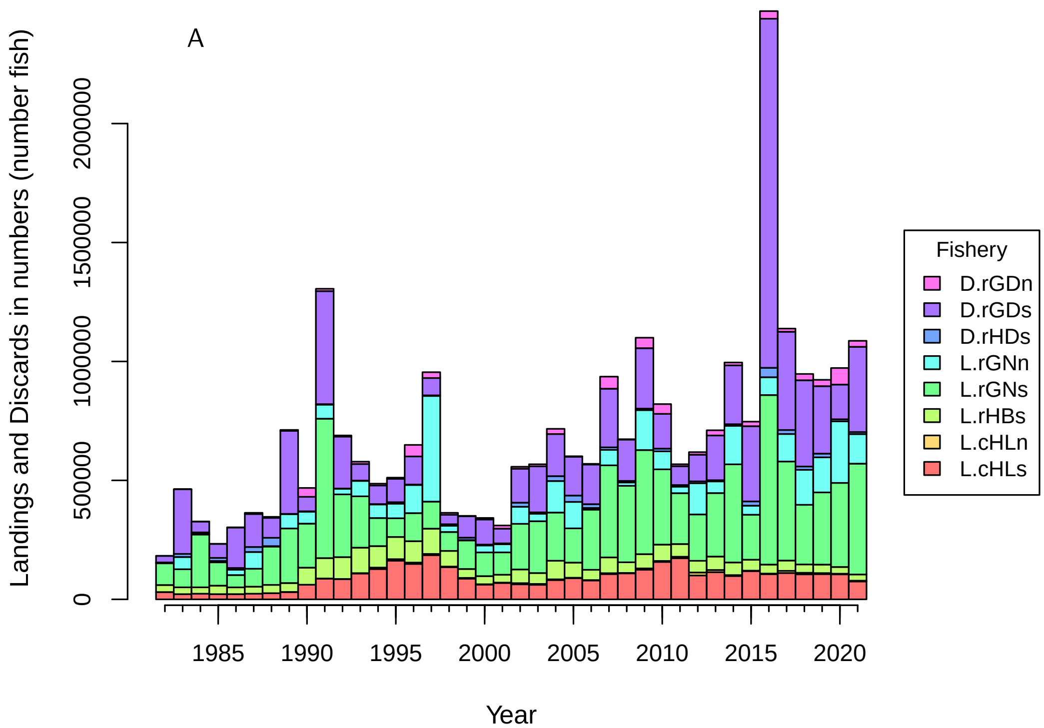


Figure 34. Estimated landings and discards in (A) absolute numbers and (B) proportion of total numbers by fleet from the catch-at-age model, for general recreational discards, north (D.rGDn); general recreational discards, south (D.rGDs); headboat recreational discards, south (D.rHDs); general recreational landings, north (L.rGNn); general recreational landings, south (L.rGNs); headboat recreational landings, south (L.rHBs); commercial handline landings, north (L.cHLn); and commercial handline landings, south (L.cHLs).



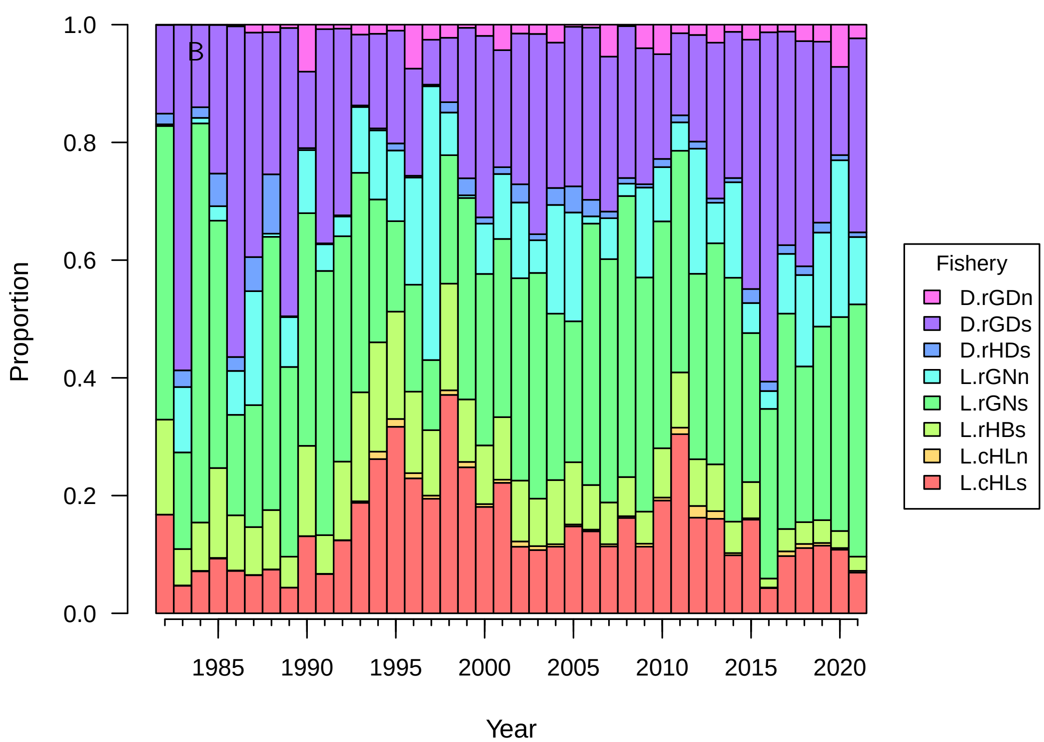


Figure 35. Estimated landings and discards in (A) absolute weight and (B) proportion of total weight by fleet from the catch-at-age model, for general recreational discards, north (D.rGDn); general recreational discards, south (D.rGDs); headboat recreational discards, south (D.rHDs); general recreational landings, north (L.rGNn); general recreational landings, south (L.rGNs); headboat recreational landings, south (L.rHBs); commercial handline landings, north (L.cHLn); and commercial handline landings, south (L.cHLs).

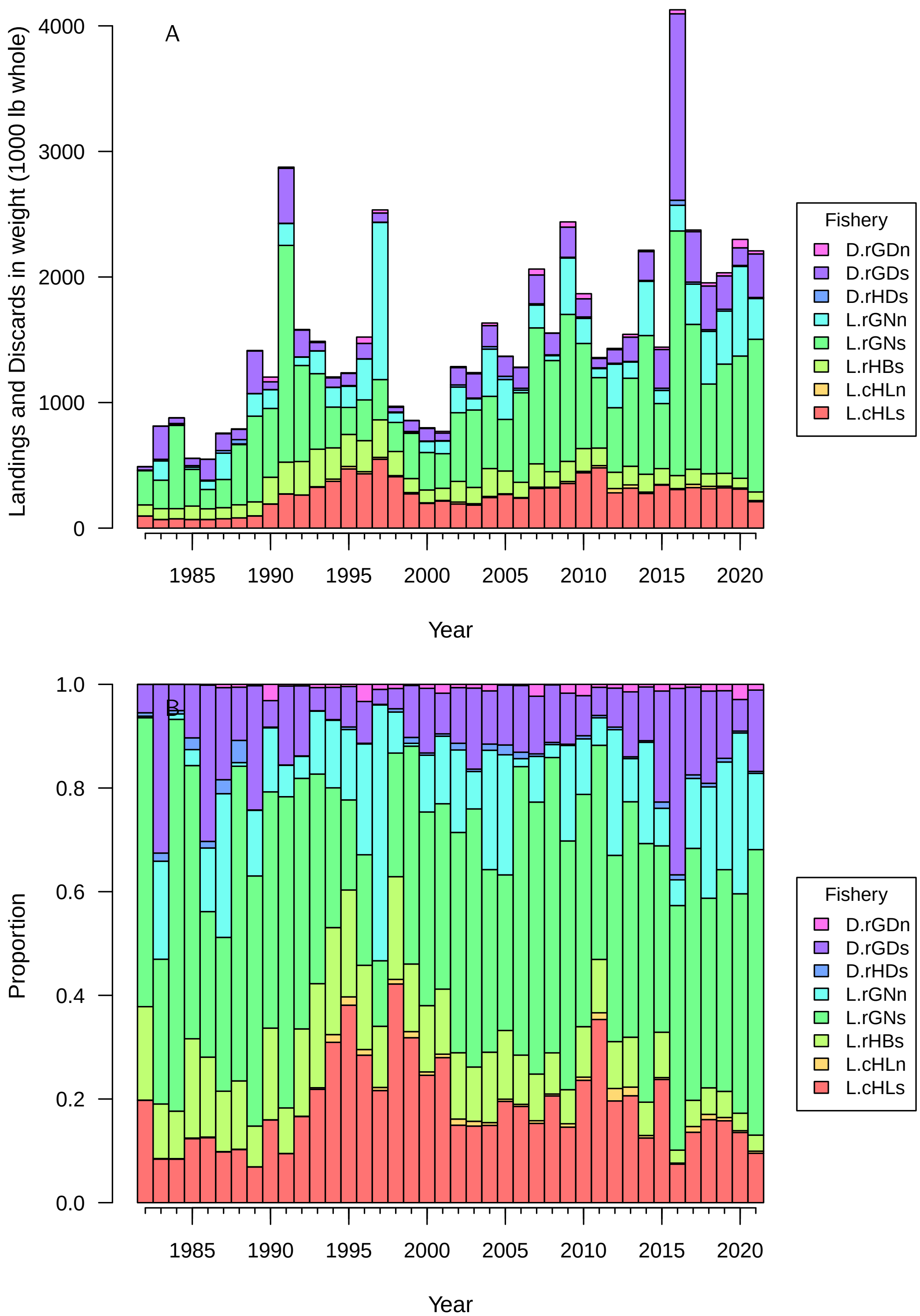


Figure 36. Spawner-recruit relationship, with and without lognormal bias correction. The expected (mean-unbiased) curve was used for computing management benchmarks.

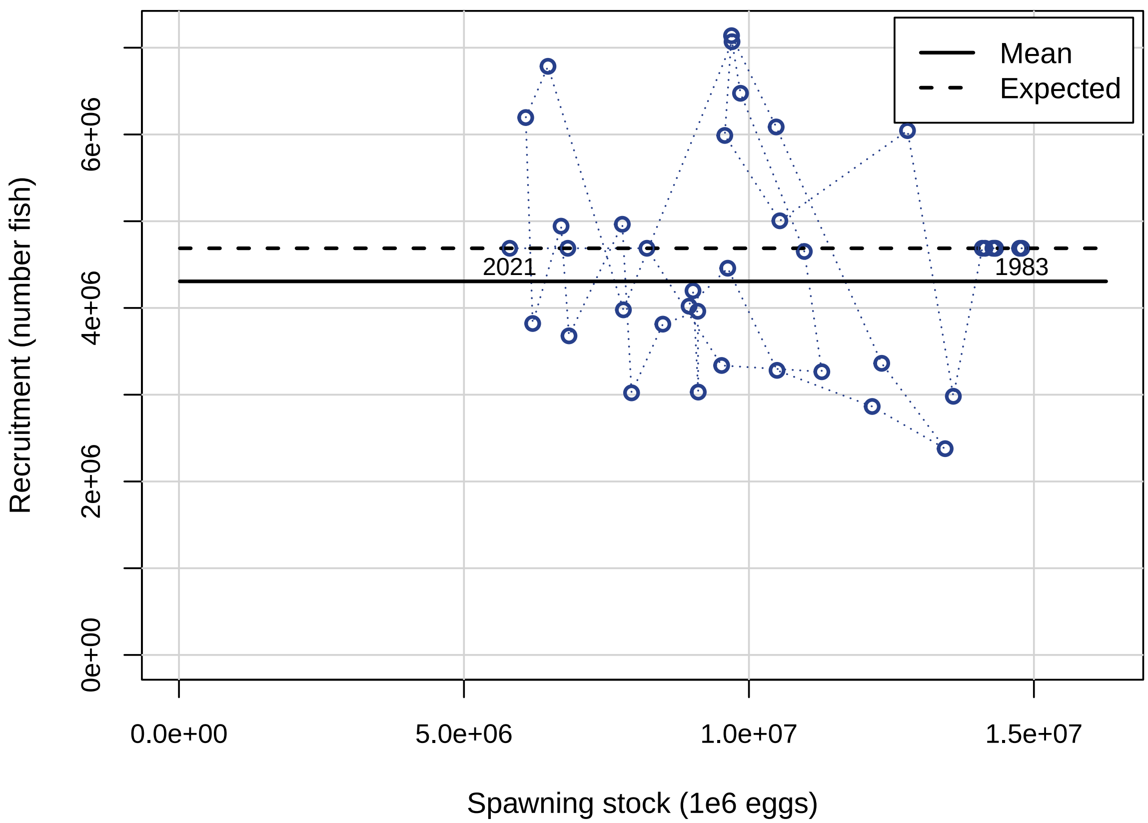


Figure 37. Probability densities of (A) spawner-recruit quantities R0 (unfished recruitment of age-1 fish), (B) steepness, (C) unfished spawners per recruit, and (D) the standard deviation of the recruitment residuals in log space. Solid vertical lines represent point estimates or values from the BAM base run; dashed and dotted vertical lines represent medians and 95% confidence limits from the MCBE runs, respectively (n = 1878). The solid colored lines represent 10 randomly selected simulation runs.

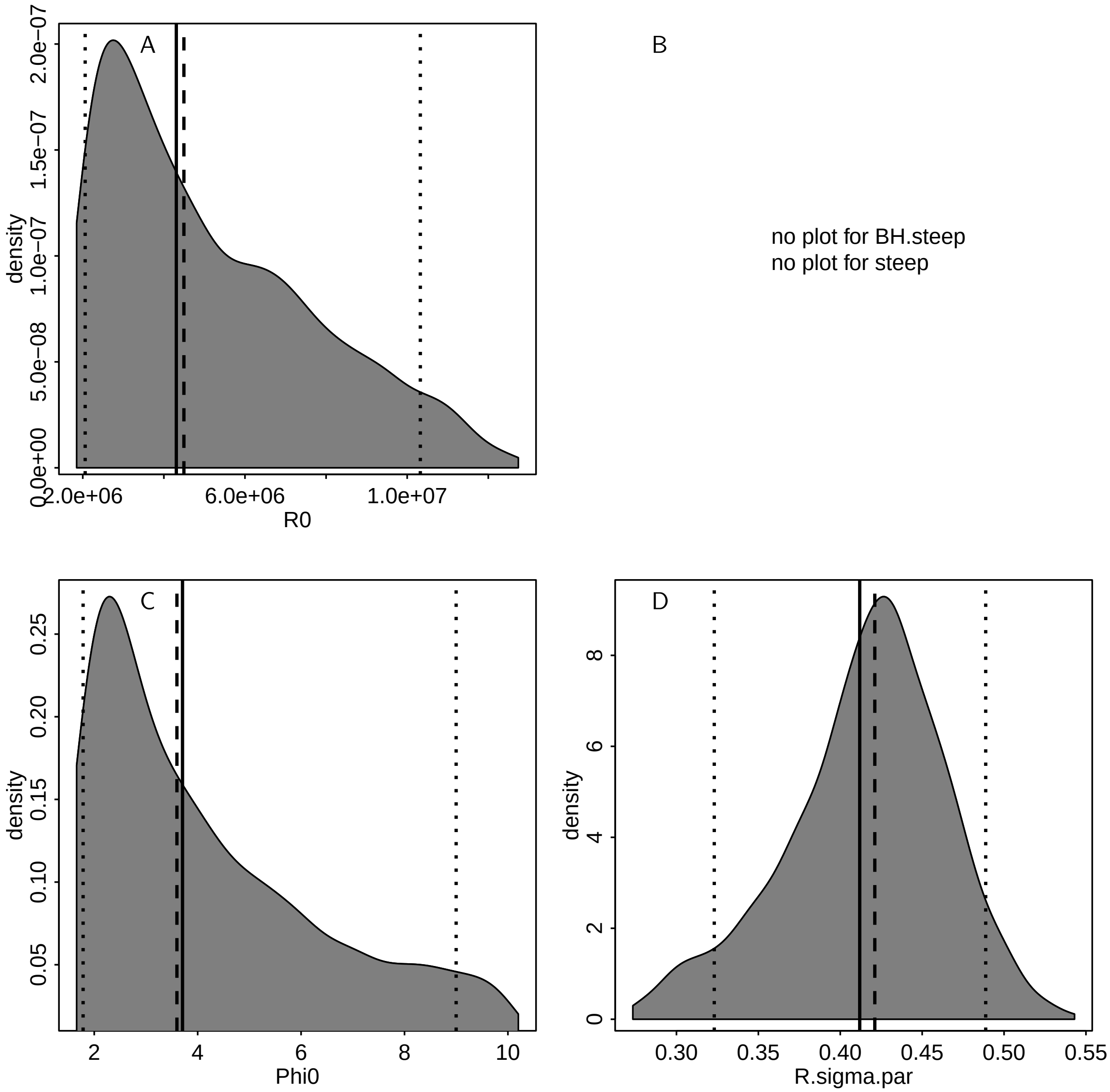


Figure 38. (A) Yield per recruit (lb) and (B) spawning potential ratio (spawning biomass per recruit relative to that at the unfished level) over a range of F. Both curves are based on average selectivity from the end of the assessment period (see Figure 32).

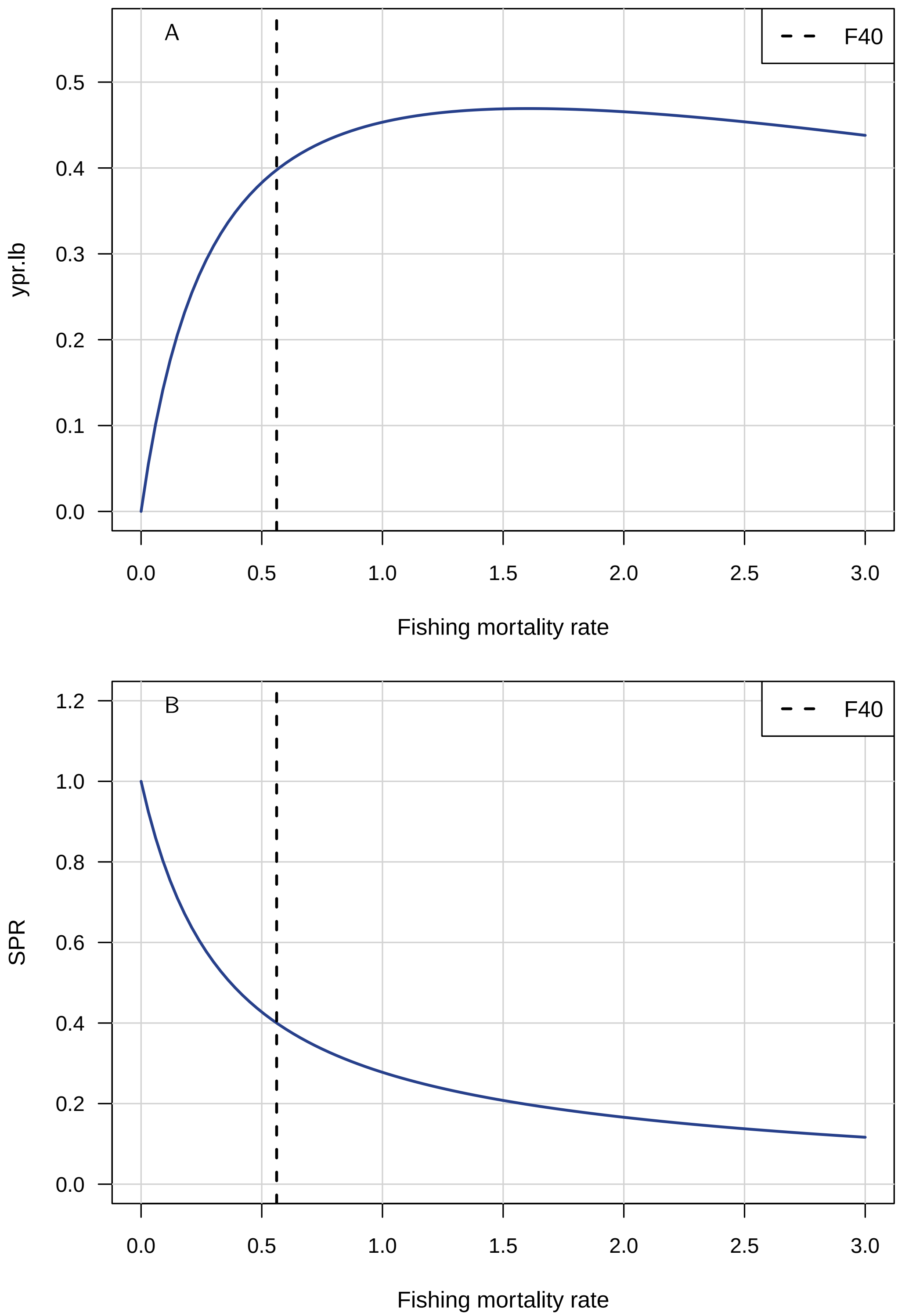


Figure 39. The top panels shows equilibrium landings at F. The peak occurs where fishing rate is $F_{40\%} = 0.56$ and equilibrium landings are $L_{\mathrm{F40\%}} = 1865$ (1000 lb). The bottom panel shows equilibrium spawning biomass at F. Both curves are based on average selectivity from the end of the assessment period.

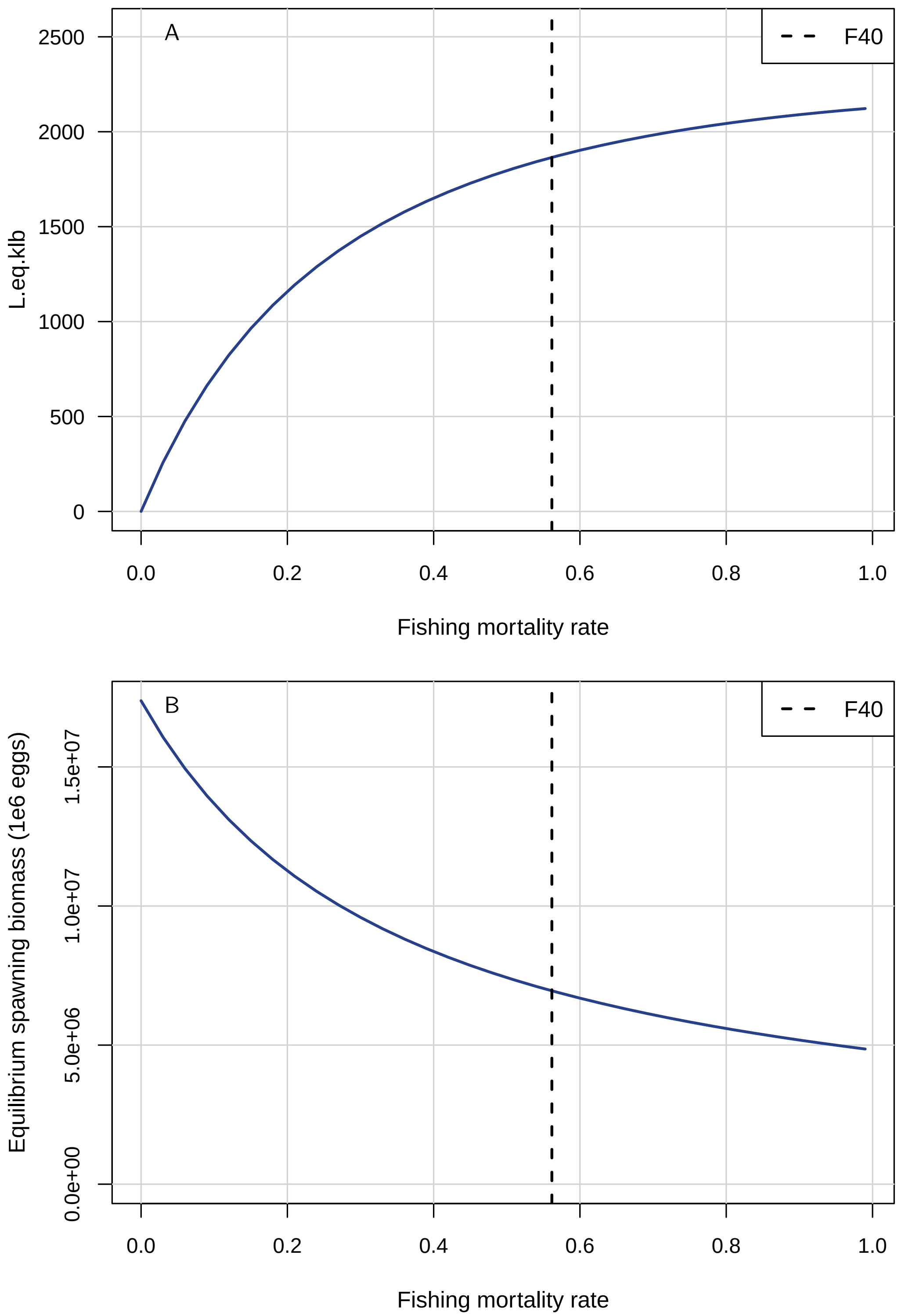


Figure 40. Probability densities of $F_{40\%}$-related benchmarks (A) $F_{40\%}$, (B) $MSST$, (C) $L_{F40\%}$, and (D) $B_{F40\%}$ from MCBE analysis ($n = 1878$). Vertical lines represent point estimates from the BAM base run; dashed vertical lines represent medians from the MCBE runs.

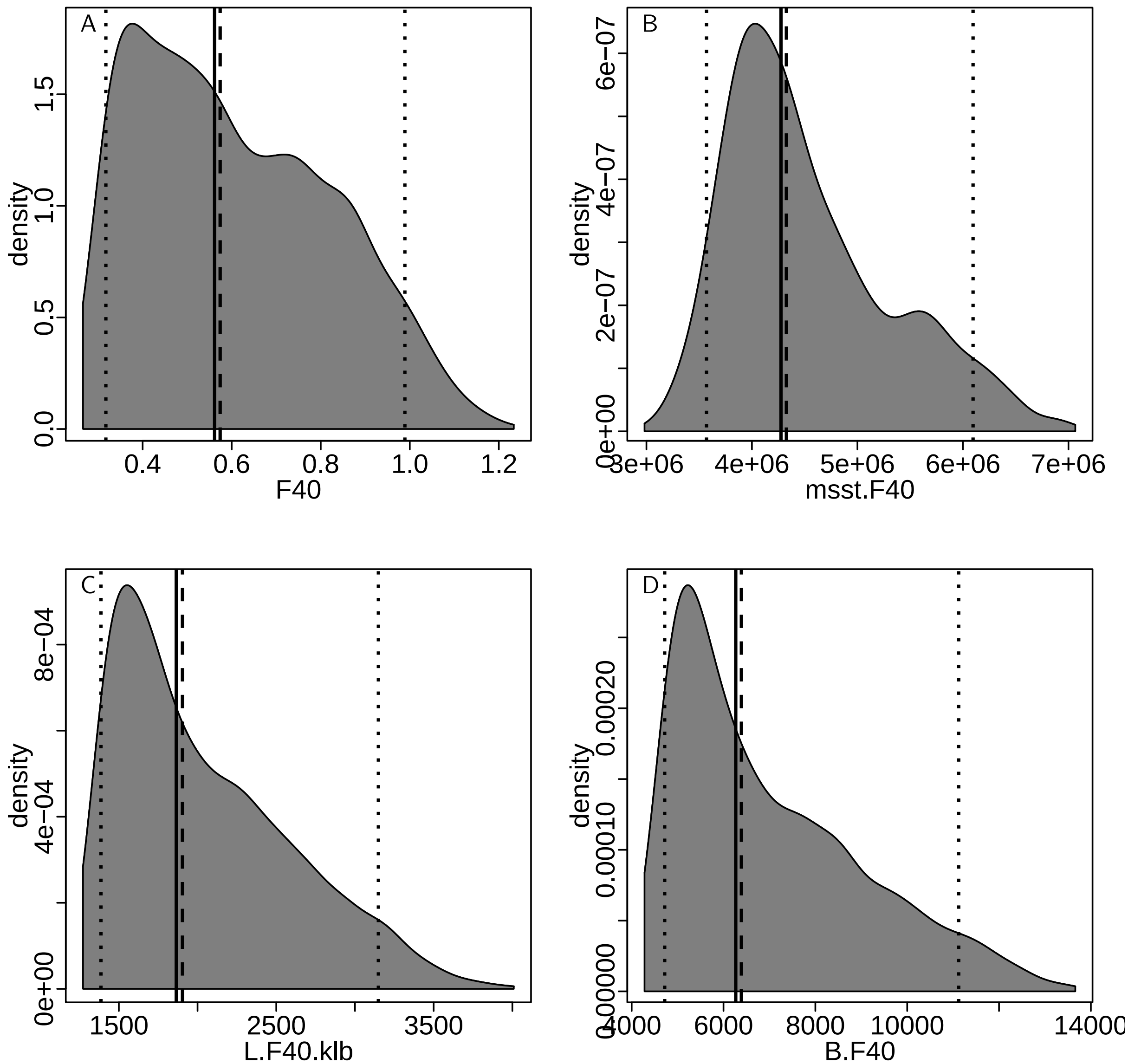


Figure 41. Estimated time series of SSB *and F relative to benchmarks: (top) spawning biomass relative to the minimum stock size threshold (*MSST*), (bottom) F relative to $F_{40\%}$. Shaded region represents 95% confidence bands from the MCBE runs (n = 1878).*

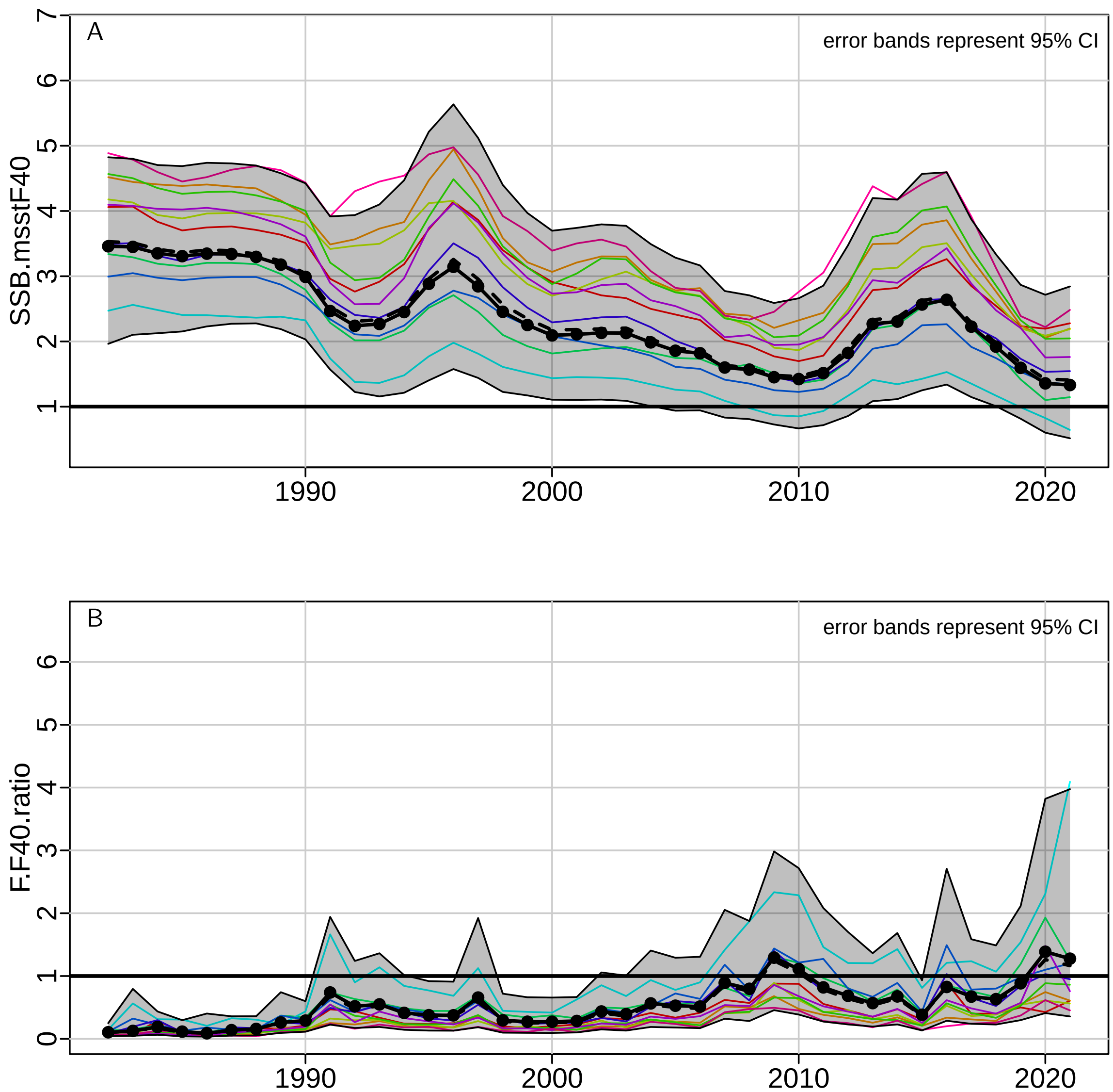
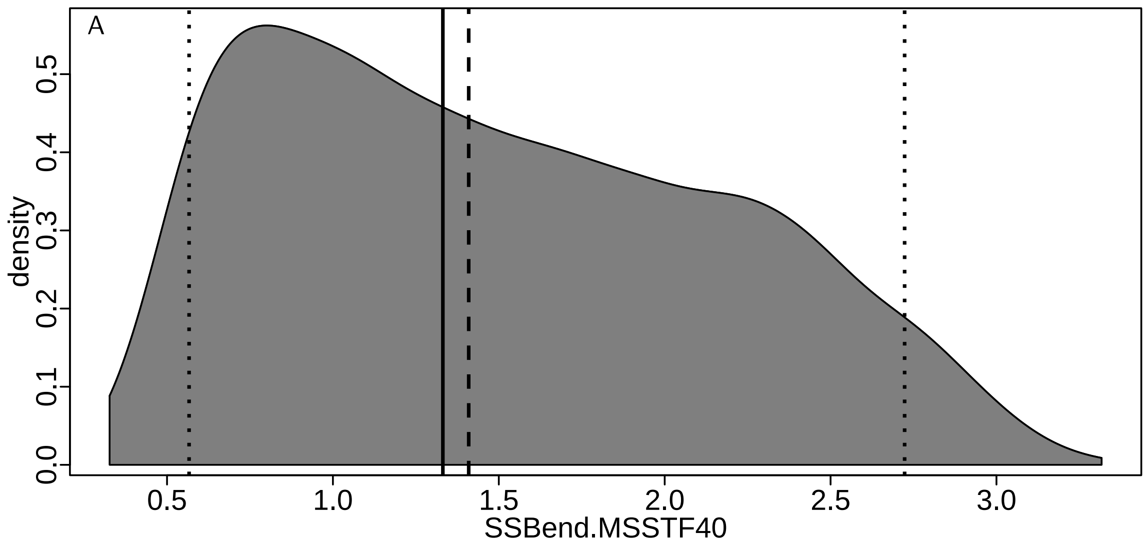


Figure 42. Probability densities of terminal status estimates from MCBE analysis of the Beaufort Assessment Model ($n = 1878$). Vertical lines represent point estimates from the BAM base run; dashed vertical lines represent medians from the MCBE runs.



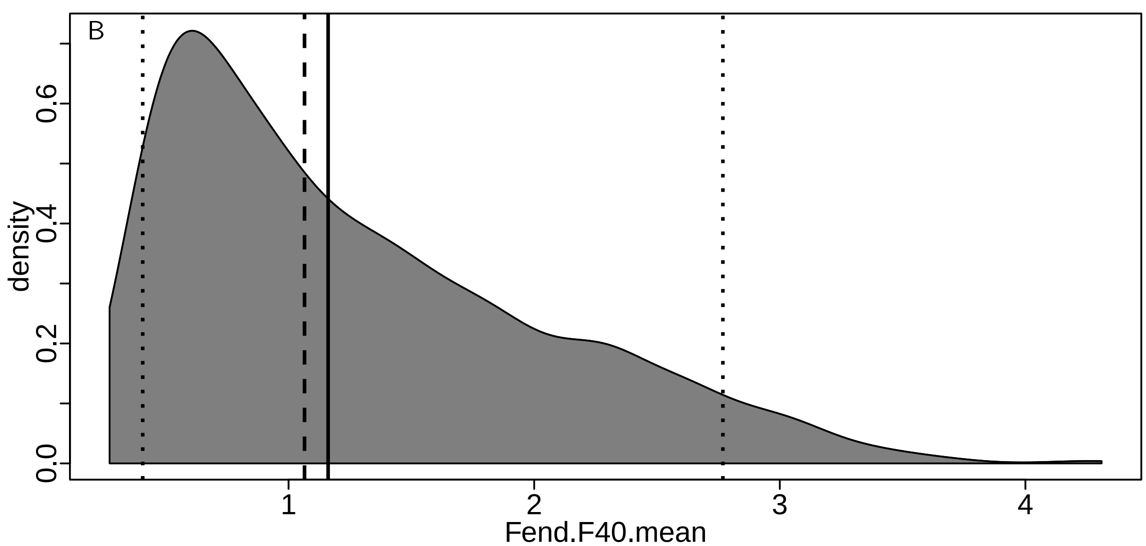


Figure 43. Phase plot of terminal status estimates from MCBE analysis of the Beaufort Assessment Model ($n = 1878$). Stock status is plotted along the vertical axis relative to MSST. *The intersection of crosshairs indicates estimates from the BAM base run; lengths of crosshairs defined by* 5^{th} *and* 95^{th} *percentiles of MCBE runs.*

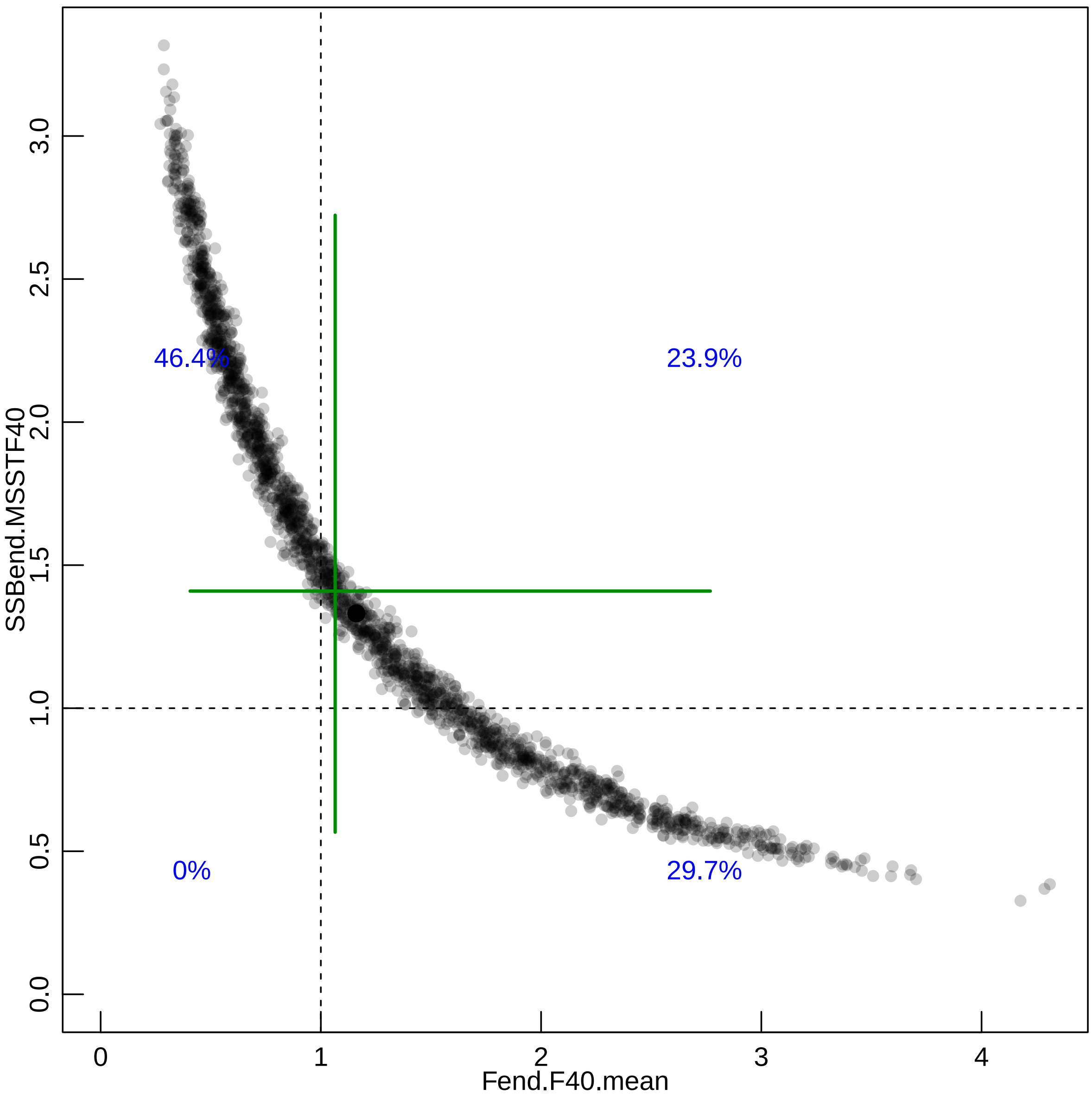


Figure 44. Estimated age structure from a series of individual years during the assessment, relative to the equilibrium expected at $F_{40\%}$.

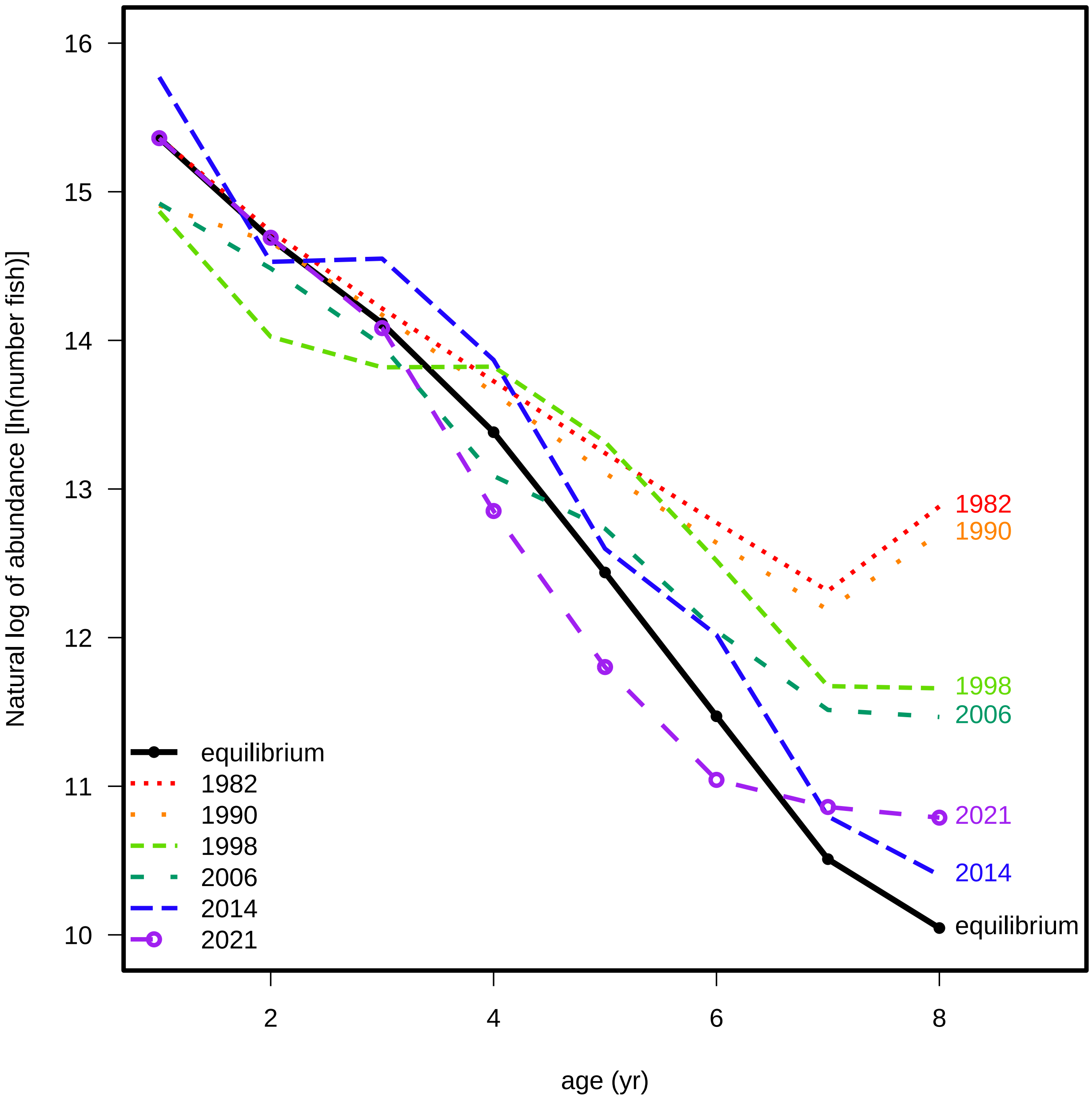


*Figure 45. Sensitivity to initial F (F_{init}) (S01-S02). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and MSST), as well as number of age-1 recruits and stock size (*SSB*; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B)* SSB/MSST*, (C) number of recruits, and (D)* SSB*.*

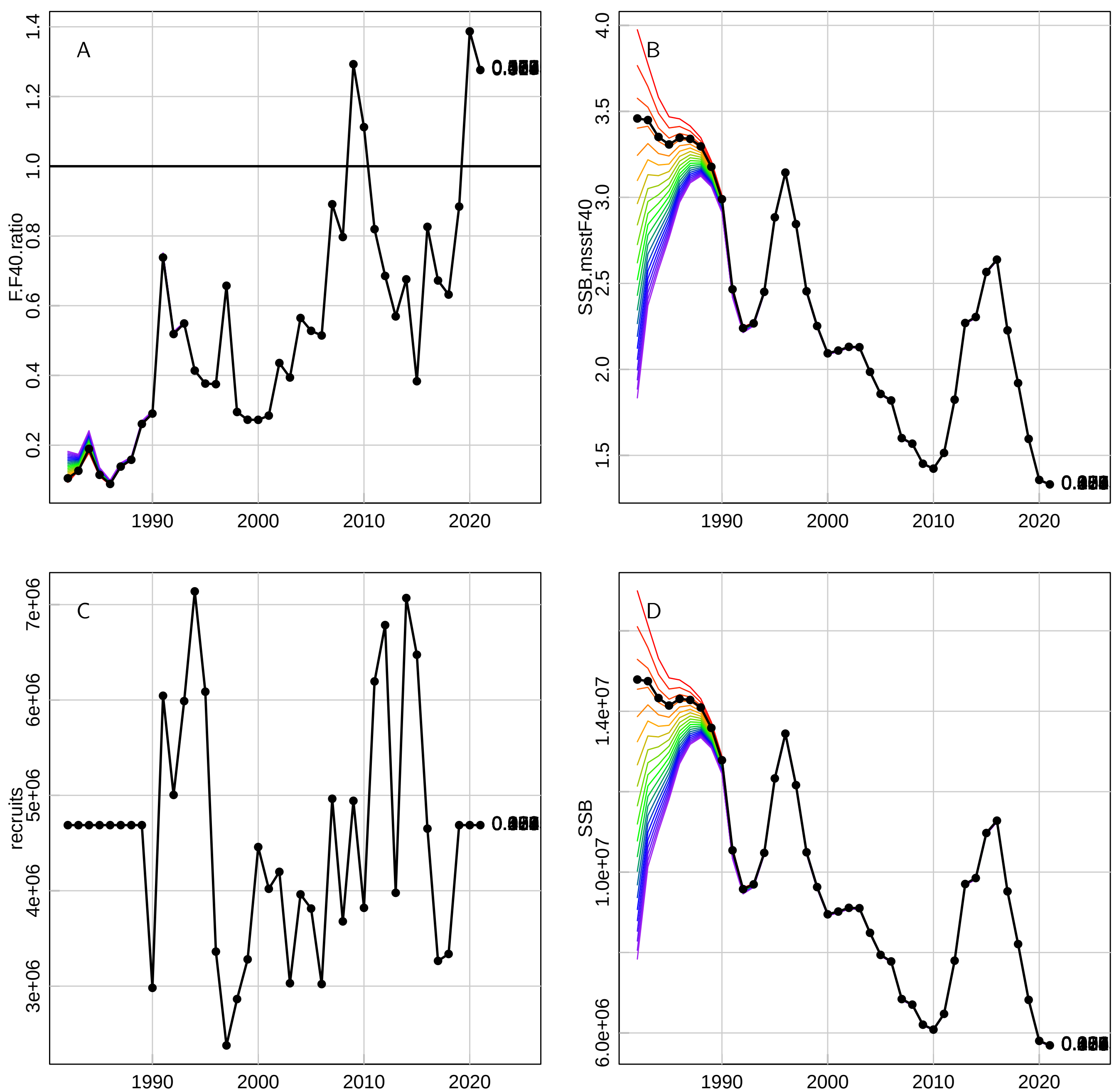


*Figure 46. Sensitivity to fixed values of natural mortality (S03-S04). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and MSST), as well as number of age-1 recruits and stock size (*SSB*; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B)* SSB/MSST, *(C) number of recruits, and (D)* SSB.

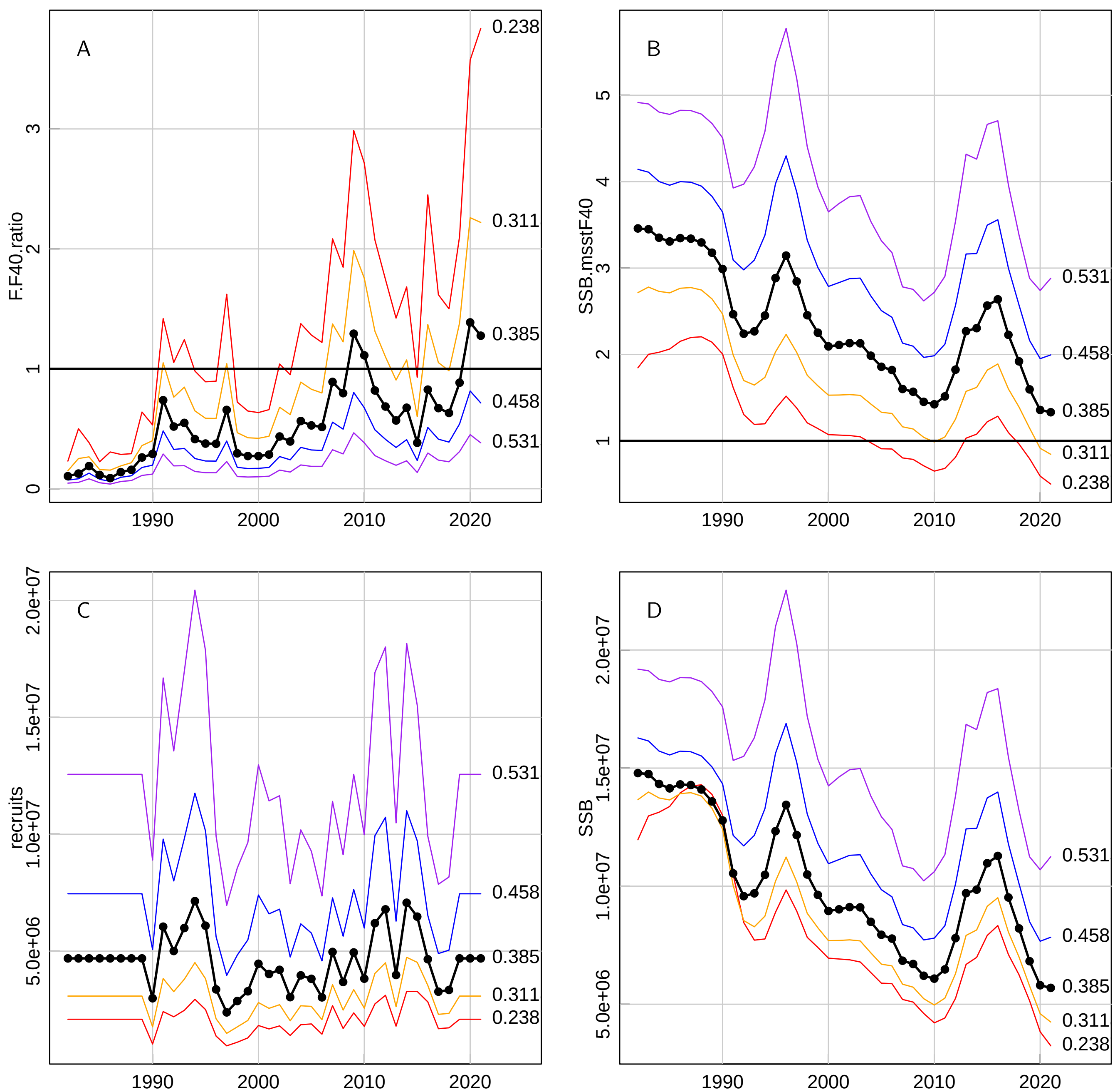


*Figure 47. Sensitivity to fixed values of discard mortality (S05-S06). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and MSST), as well as number of age-1 recruits and stock size (*SSB*; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B)* SSB/MSST, *(C) number of recruits, and (D)* SSB.

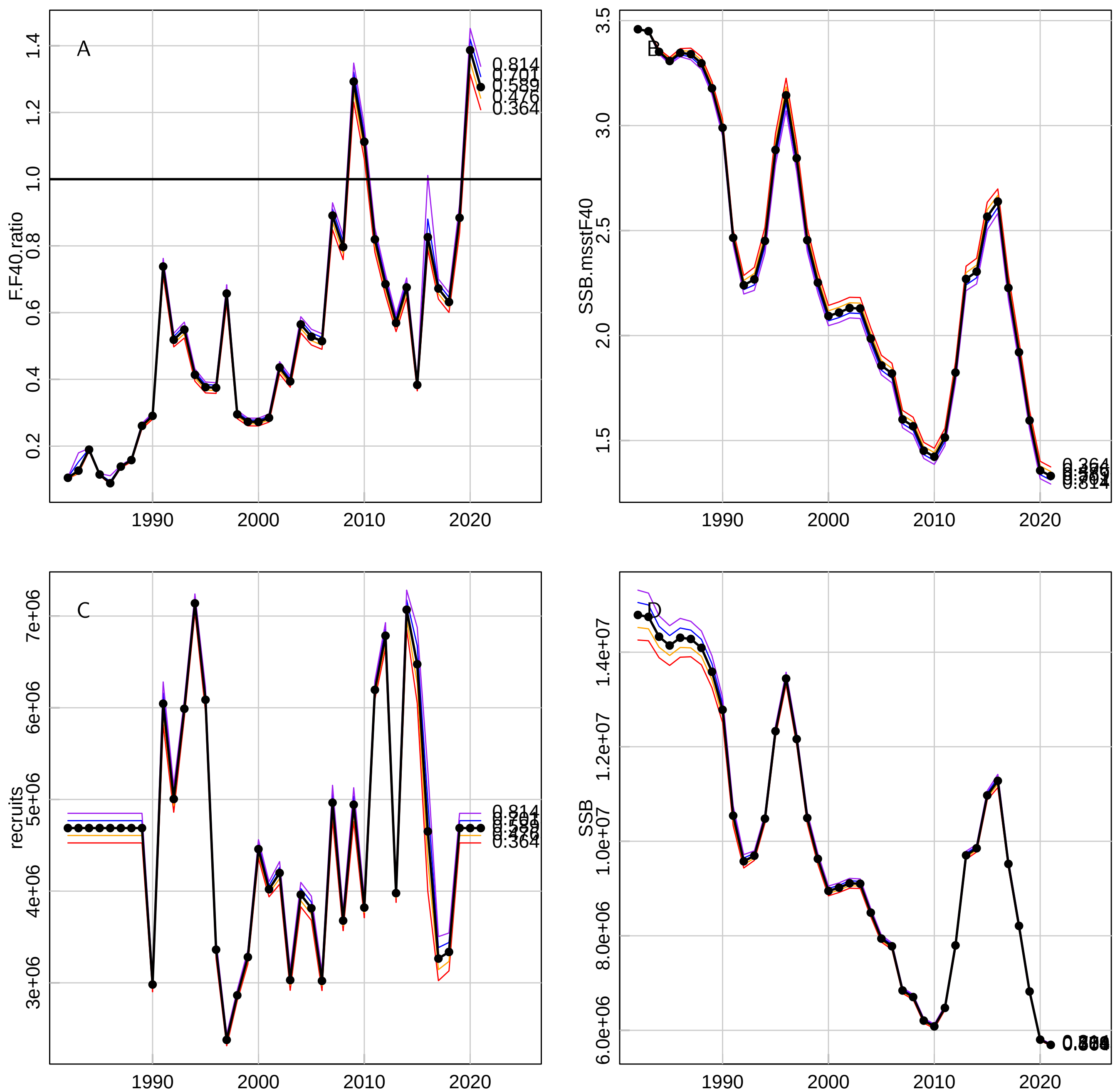


*Figure 48. Sensitivity to excluding age error (S07). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and MSST), as well as number of age-1 recruits and stock size (*SSB*; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B)* SSB/MSST*, (C) number of recruits, and (D)* SSB*.*

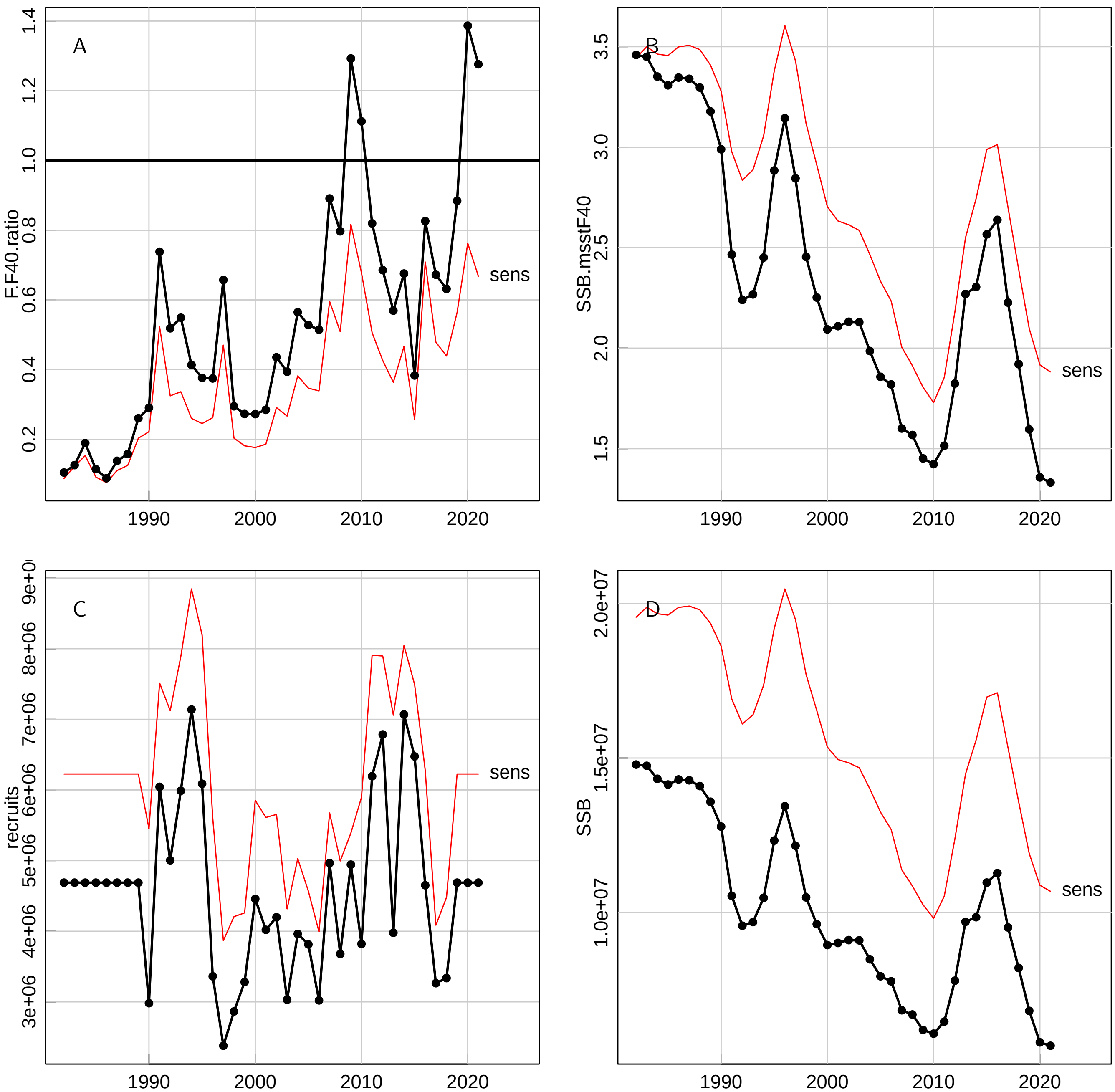


Figure 49. Sensitivity to using age comps from 1 to 8 for all years (S08). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and MSST), as well as number of age-1 recruits and stock size (SSB; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B) SSB/MSST, *(C) number of recruits, and (D)* SSB.

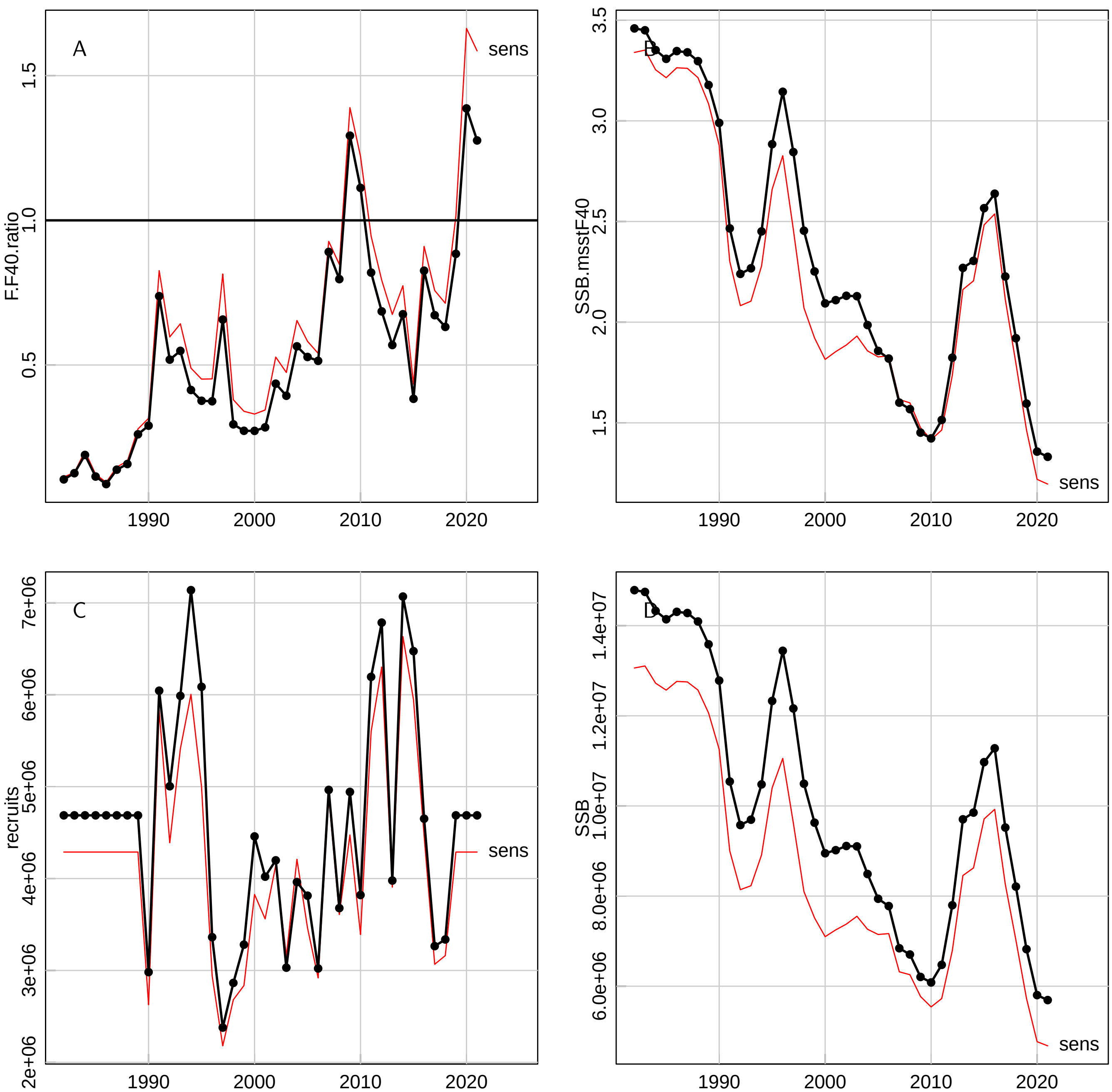


Figure 50. Sensitivity to age-dependent batch fecundity (S09). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and $MSST$), as well as number of age-1 recruits and stock size (SSB; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B) SSB/MSST*, (C) number of recruits, and (D)* SSB.

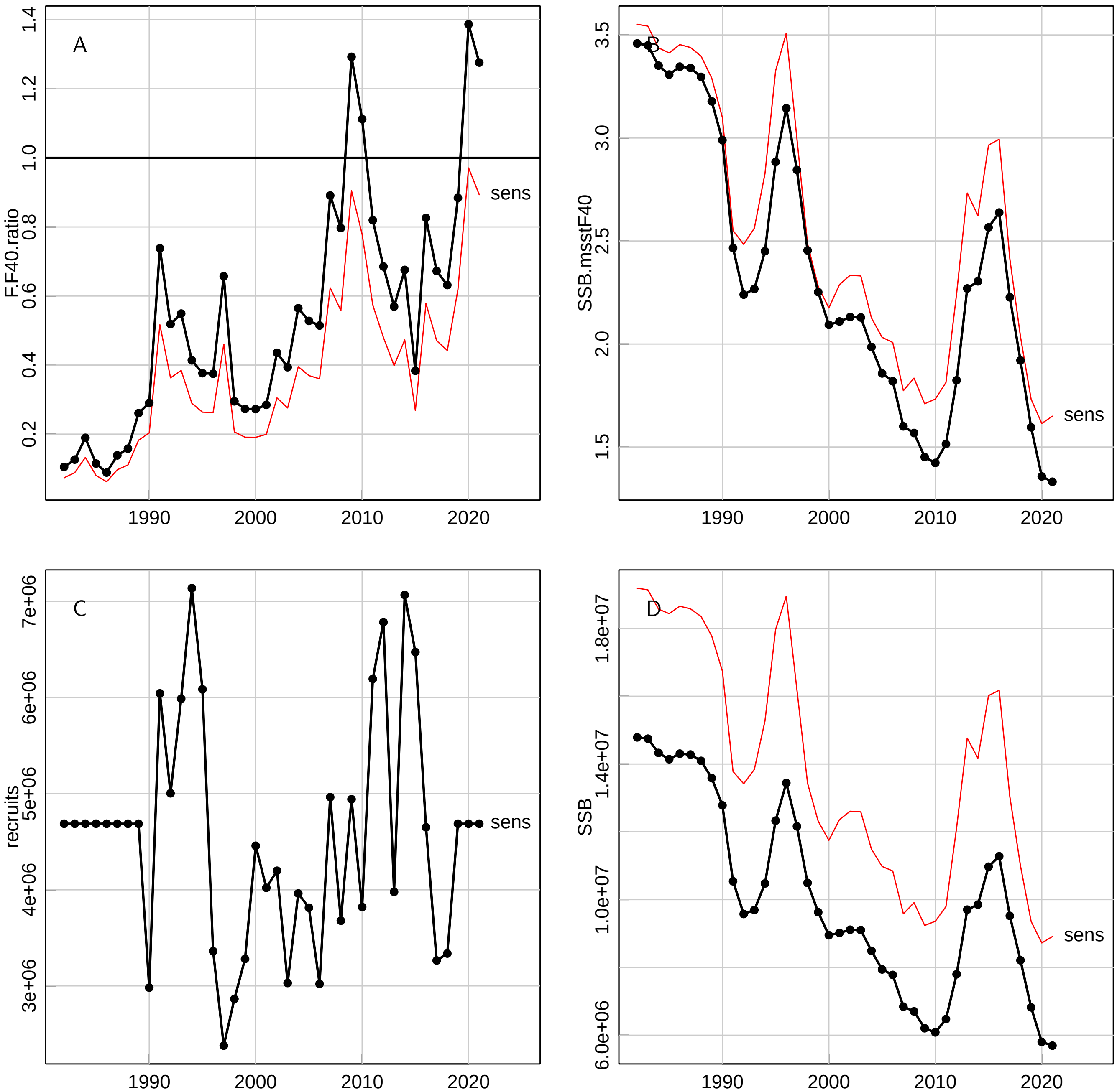


Figure 51. Sensitivity to age-dependent batch number (S10). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and $MSST$), as well as number of age-1 recruits and stock size (SSB; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B) SSB/MSST, *(C) number of recruits, and (D)* SSB.

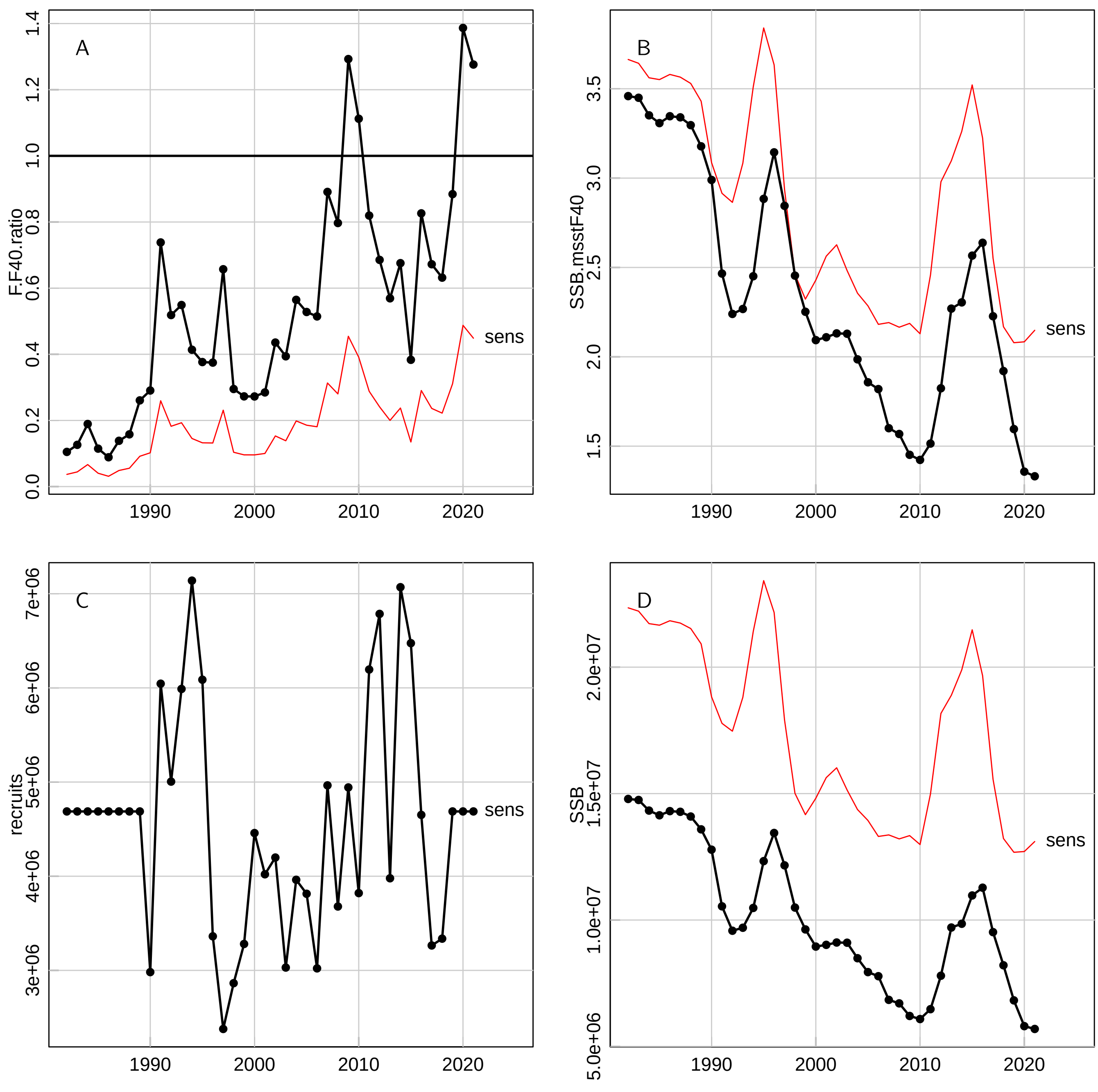


Figure 52. Sensitivity to age-dependent batch number and batch fecundity (S11). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and MSST), as well as number of age-1 recruits and stock size (SSB; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B) SSB/MSST, (C) number of recruits, and (D) SSB.

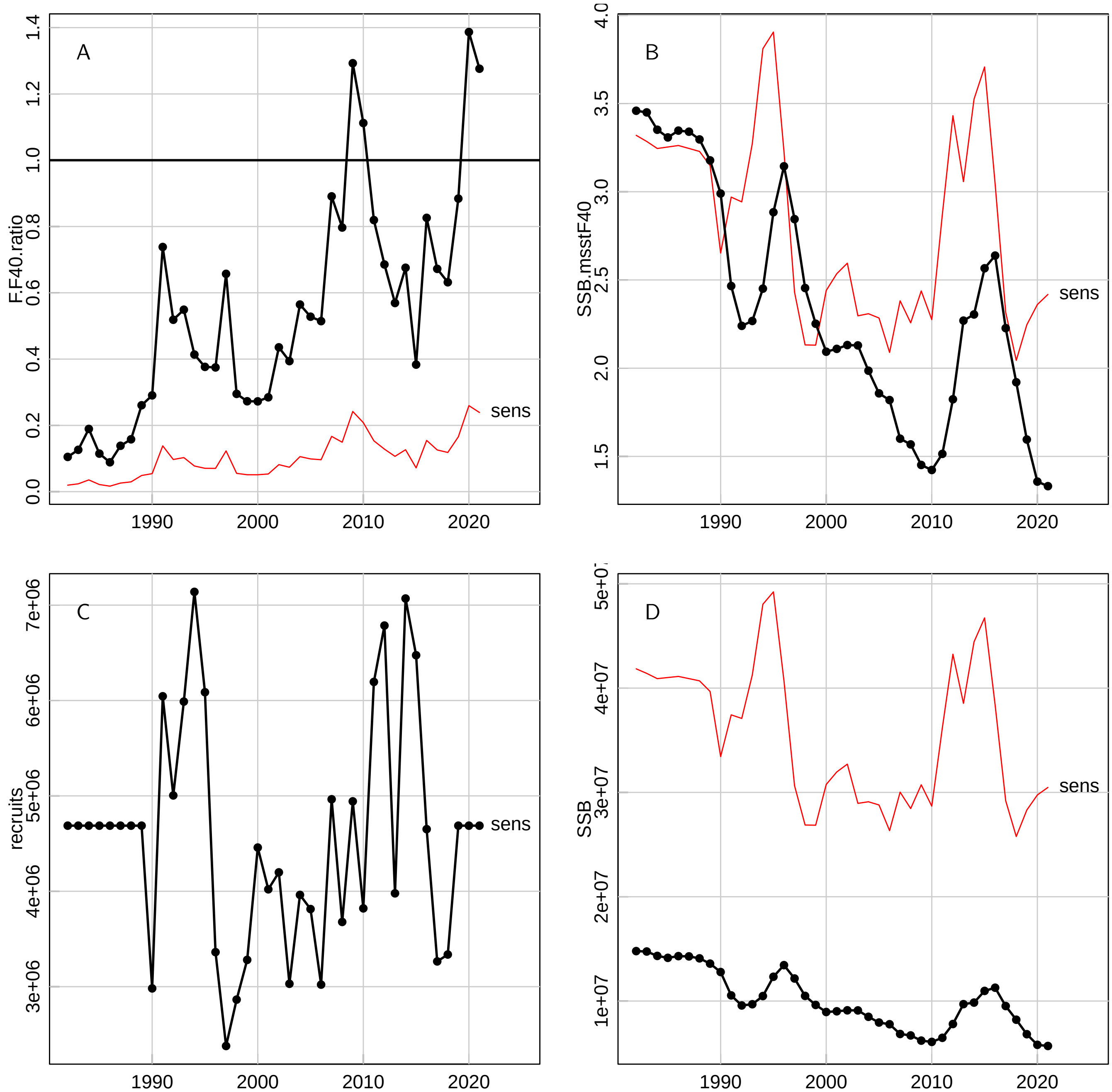


Figure 53. Sensitivity to estimating steepness (S12). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and MSST), as well as number of age-1 recruits and stock size (SSB; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B) SSB/MSST, (C) number of recruits, and (D) SSB.

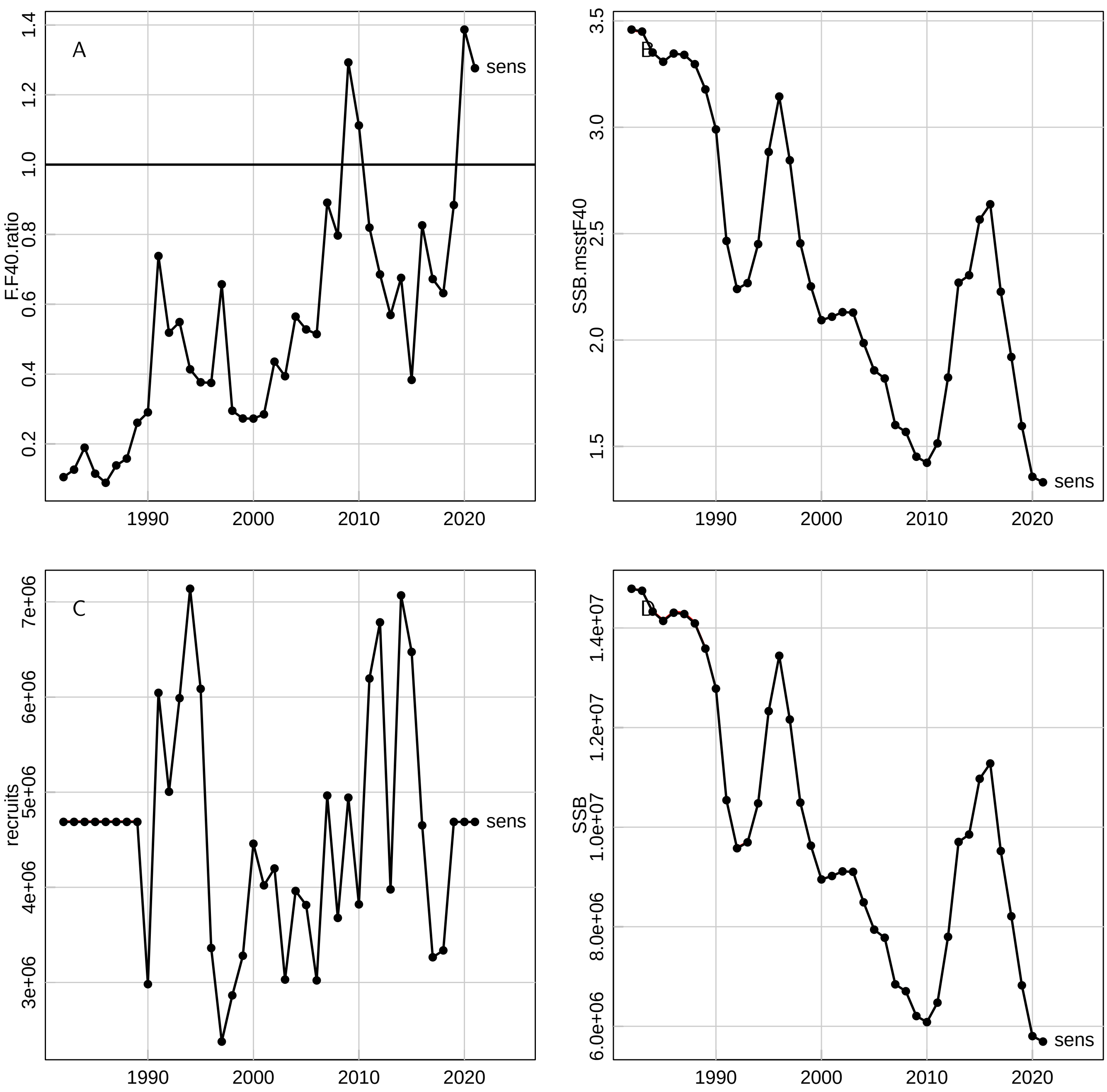


*Figure 54. Sensitivity to high value of general recreational discards (S13). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and $MSST$), as well as number of age-1 recruits and stock size (*SSB*; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B)* SSB/MSST*, (C) number of recruits, and (D)* SSB.

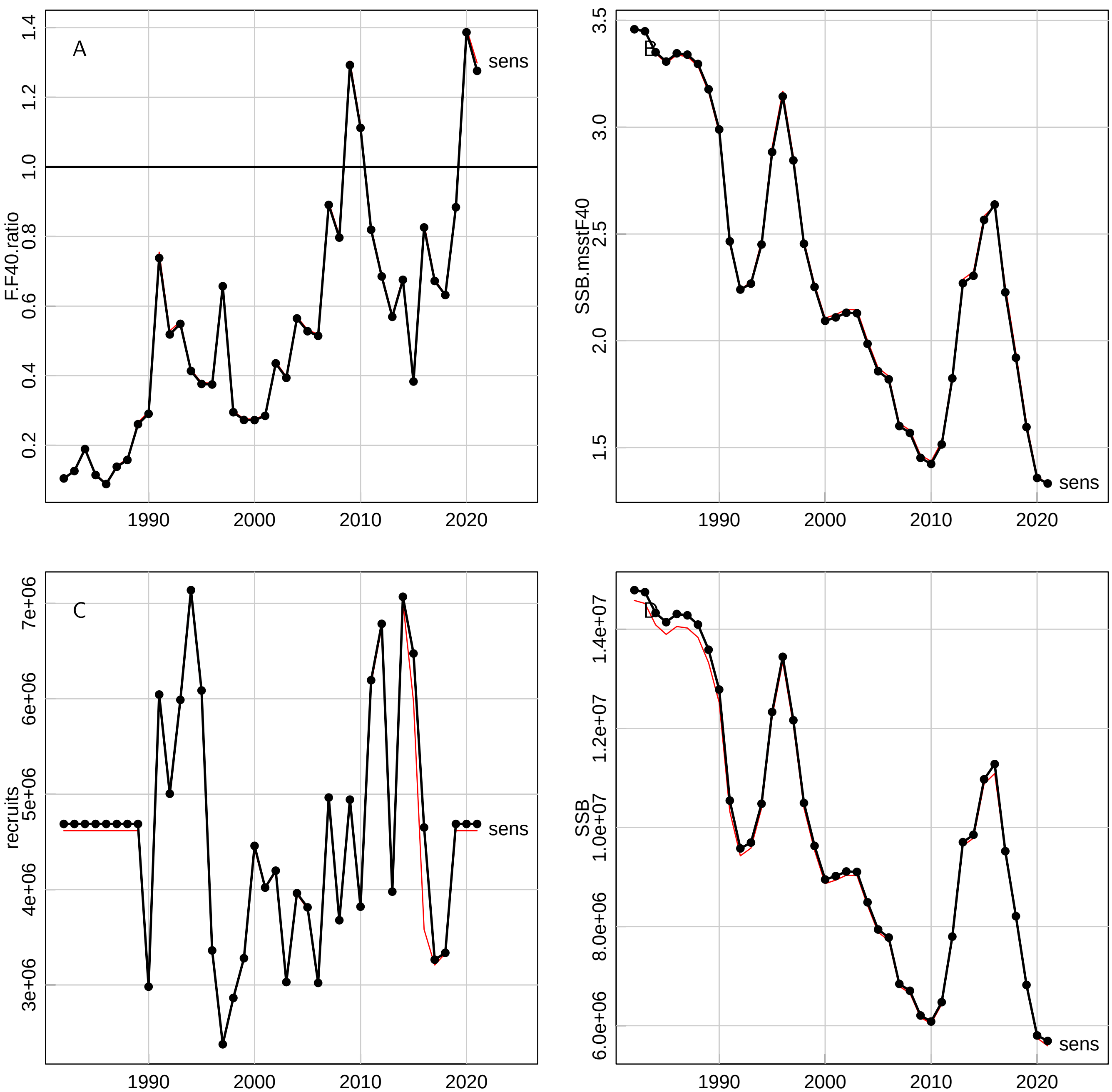


*Figure 55. Sensitivity to start year of SERFS trap/video index (S14). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and MSST), as well as number of age-1 recruits and stock size (*SSB*; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B)* SSB/MSST*, (C) number of recruits, and (D)* SSB.

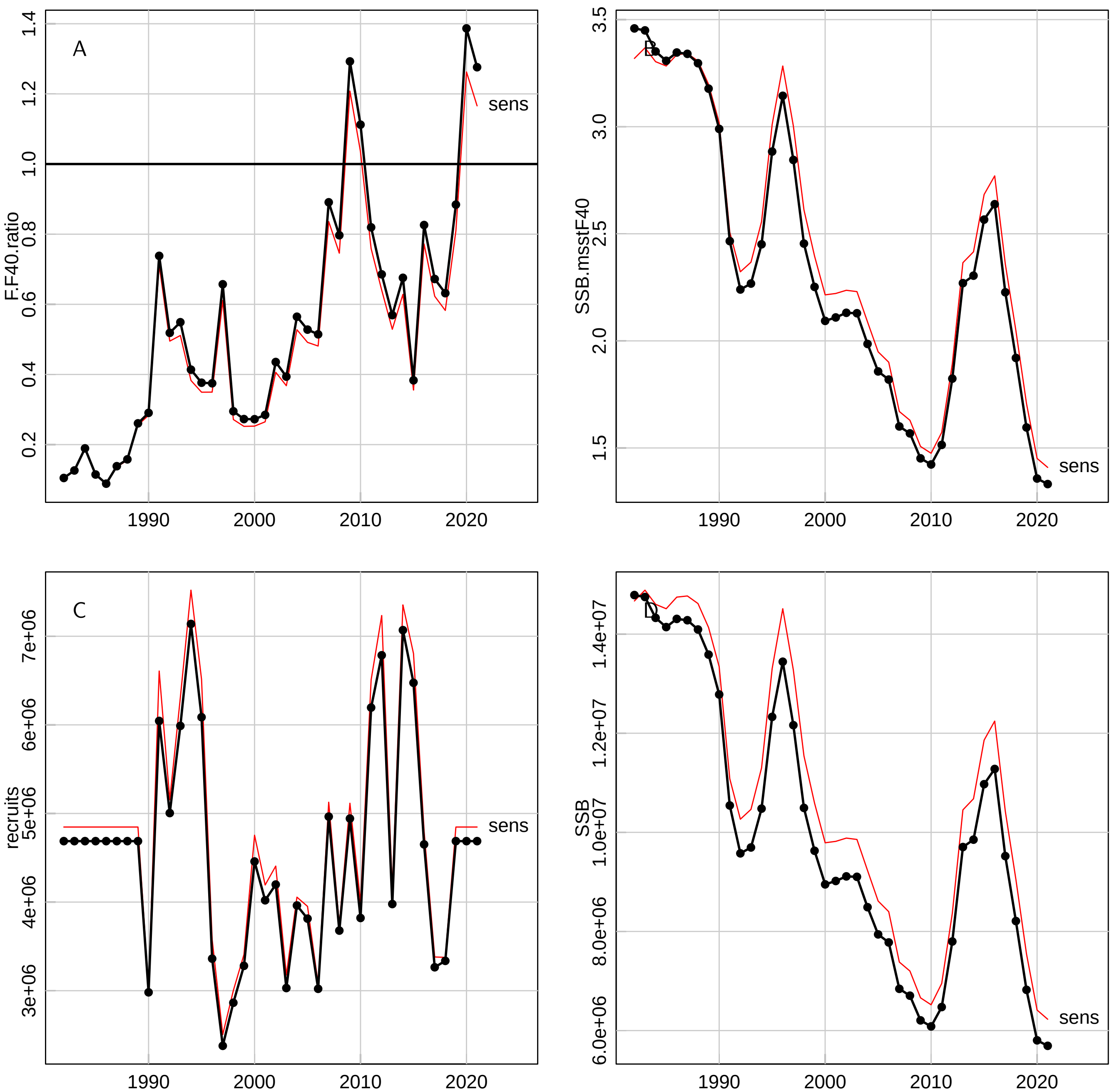


*Figure 56. Sensitivity to estimating selectivity for general recreational (rGN) landings (S15). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and $MSST$), as well as number of age-1 recruits and stock size (*SSB*; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B)* SSB/MSST, *(C) number of recruits, and (D)* SSB.

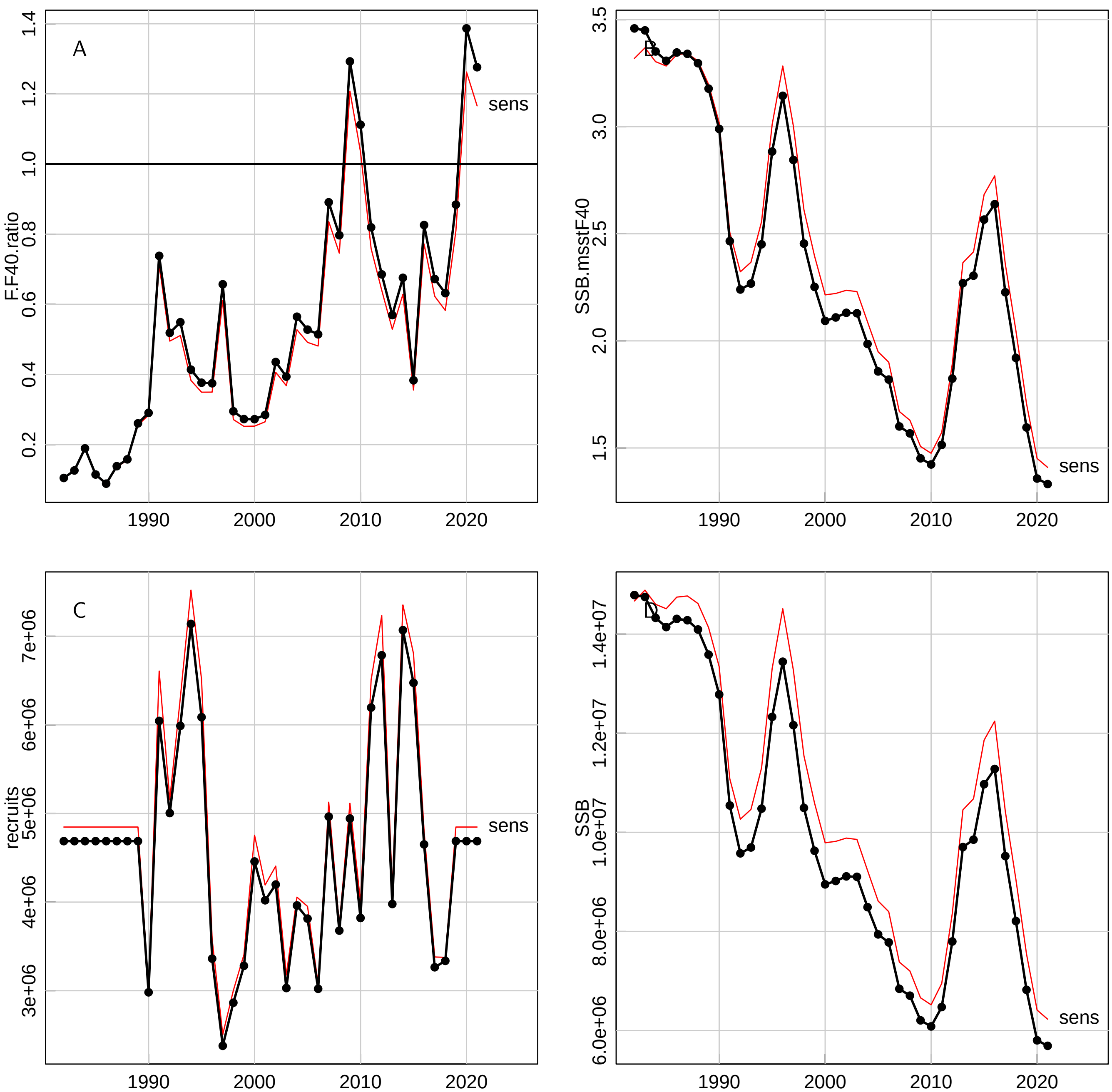


*Figure 57. Sensitivity to weight on SERFS trap/video index (S16-S17). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and $MSST$), as well as number of age-1 recruits and stock size (*SSB*; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B)* SSB/MSST*, (C) number of recruits, and (D)* SSB.

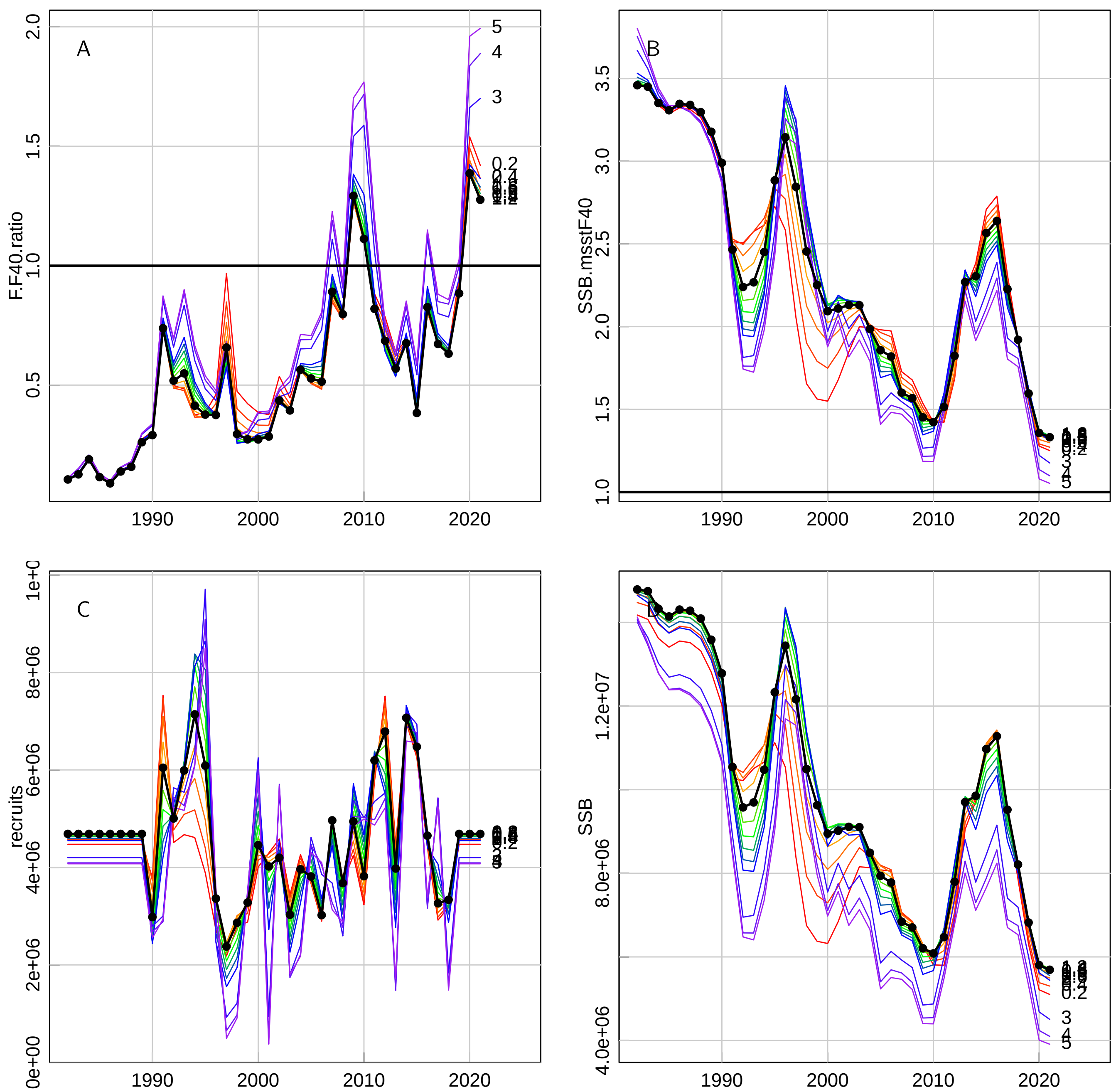


*Figure 58. Sensitivity to weight on SERFS trap/video age comps (S18-S19). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and MSST), as well as number of age-1 recruits and stock size (*SSB*; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B)* SSB/MSST*, (C) number of recruits, and (D)* SSB.

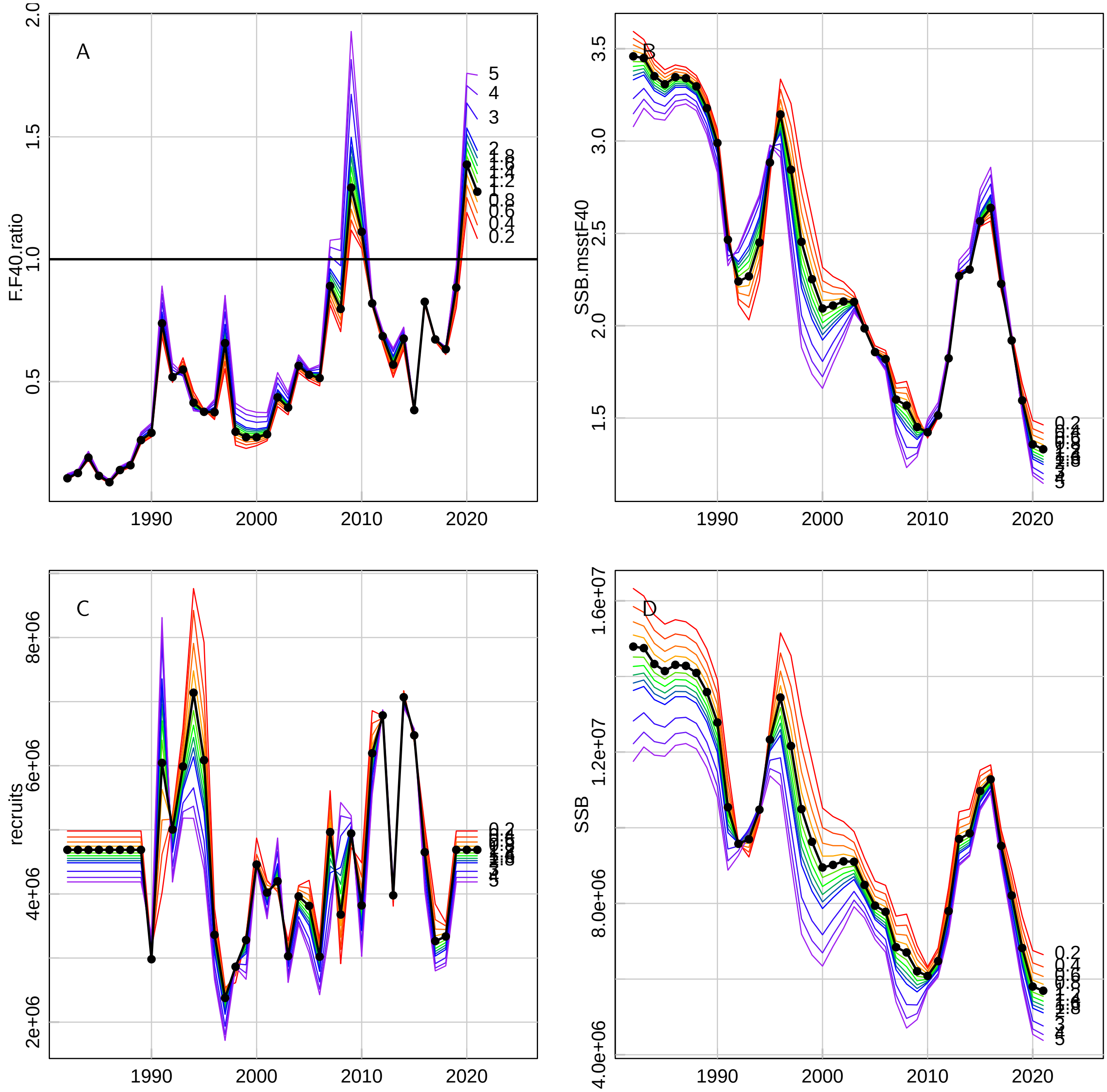


Figure 59. Sensitivity to weight on all age comps (S20-S21). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and MSST), as well as number of age-1 recruits and stock size (SSB; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B) SSB/MSST, (C) number of recruits, and (D) SSB.

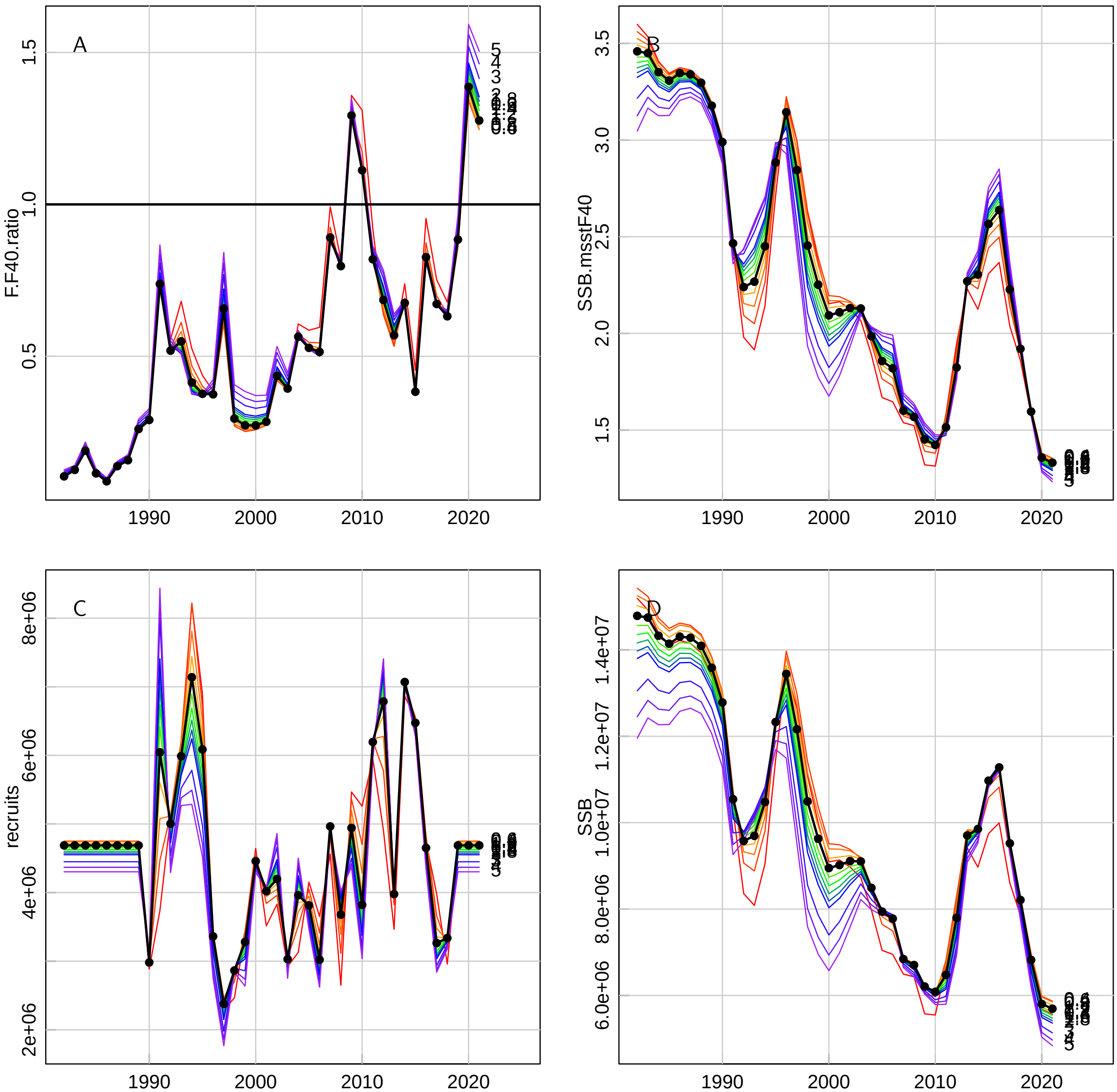


*Figure 60. Sensitivity to weight on all length comps (S22-S23). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and MSST), as well as number of age-1 recruits and stock size (*SSB*; million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B)* SSB/MSST*, (C) number of recruits, and (D)* SSB.

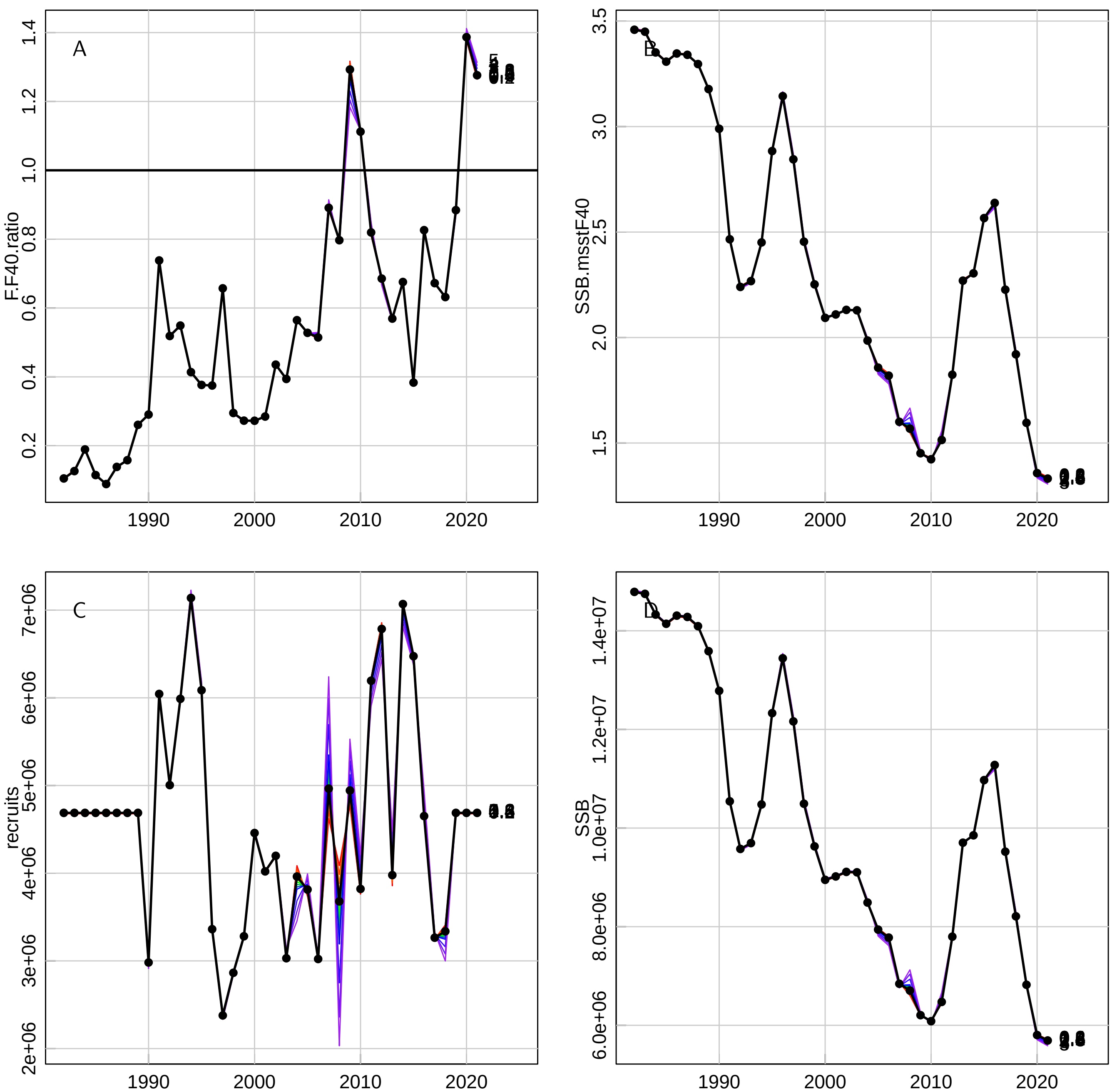


Figure 61. Observed (open circles) and estimated (line, solid circles) SERFS trap/video index for the Age-Structured Production Model (ASPM). In the upper panel, error bars indicate ±2 standard errors of the observed index (U_{ob}). In the lower panel are the log residuals of the fit to the index and the color of the box indicates the p-value of the runs test (green > 0.05, orange ≤ 0.05 and > 0.01, red < 0.01) and the width of the box is 3 times the standard error. Points that fall outside 3 standard errors are plotted in red..

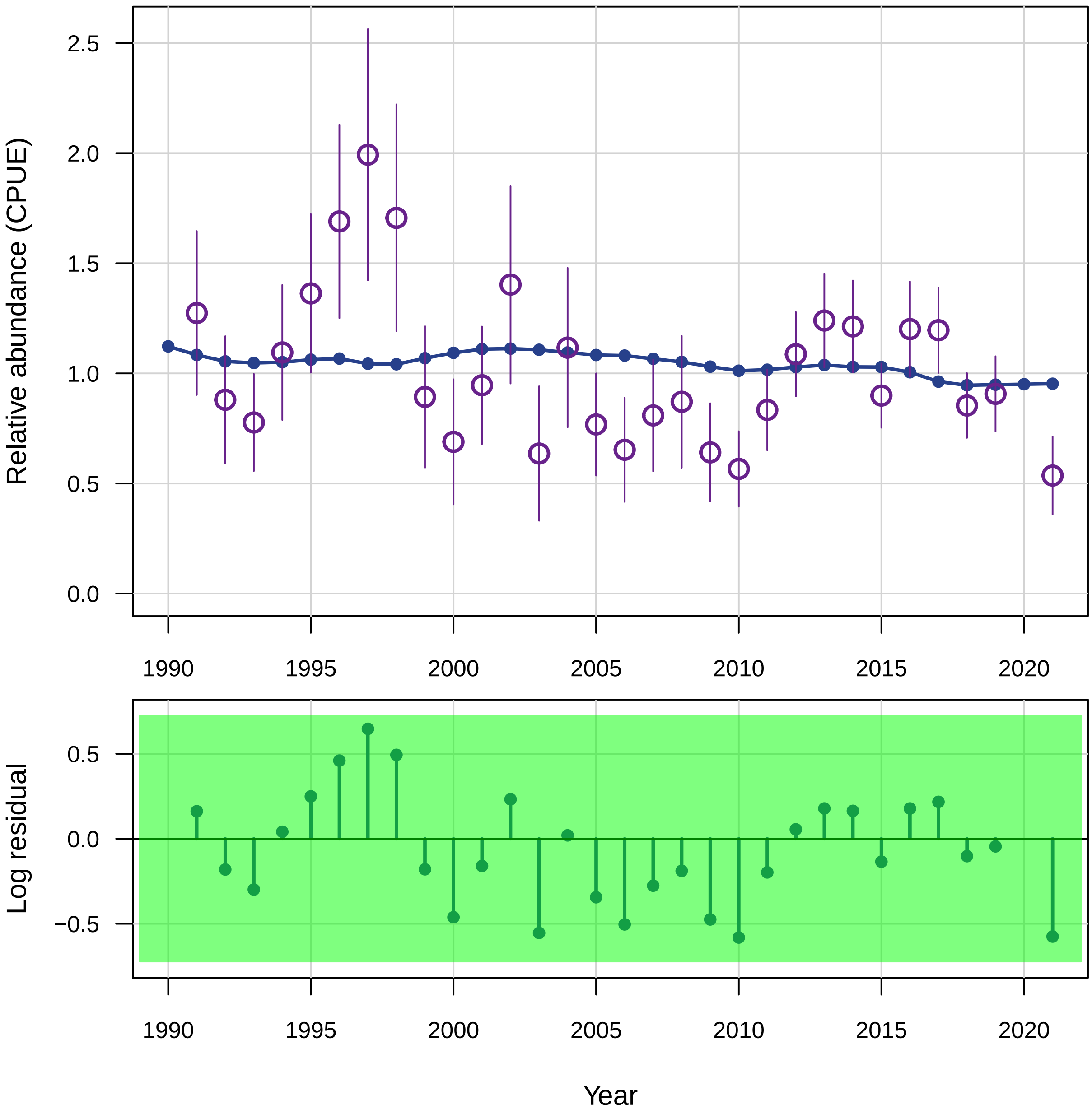


Figure 62. Sensitivity to age structure (age structured production model) (aspm). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and $MSST$), as well as number of age-1 recruits and stock size (SSB; *million eggs). Solid black line and solid circles indicate estimates from the BAM base run. Sensitivity runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B)* SSB/MSST, *(C) number of recruits, and (D)* SSB.

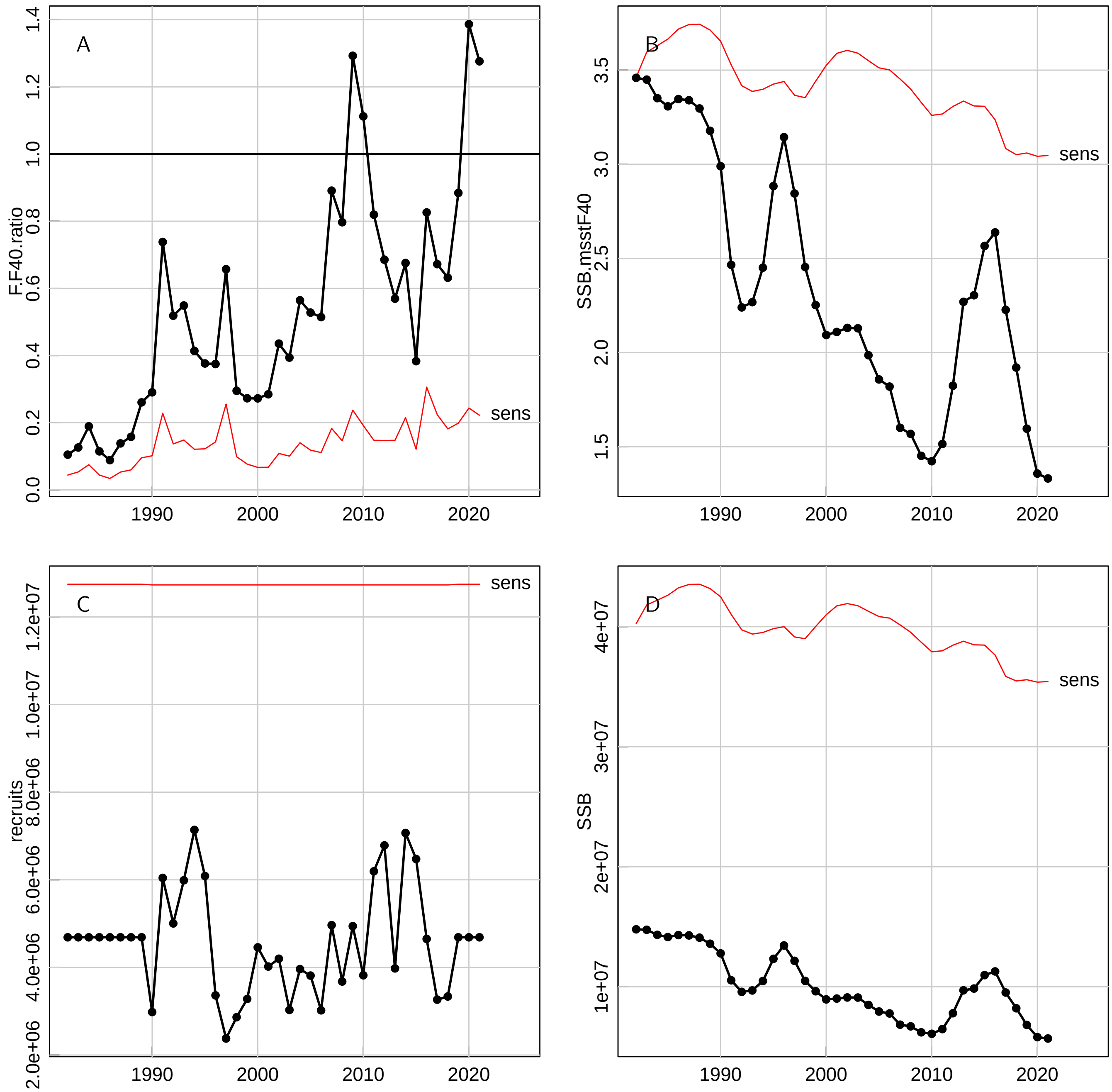


Figure 63. Retrospective analysis (retro). Estimated time series of F and SSB relative to benchmarks ($F_{40\%}$ and MSST), as well as number of age-1 recruits and stock size (SSB; *million eggs*)*. Solid black line and solid circles indicate estimates from the BAM base run. Retrospective runs are indicated by colored lines, represented in the legend. Values to the right of each time series indicate which is the sensitivity (sens) run, or indicate a fixed numeric value that was varied in that run. (A) $F/F_{40\%}$, (B)* SSB/MSST, *(C) number of recruits, and (D)* SSB.

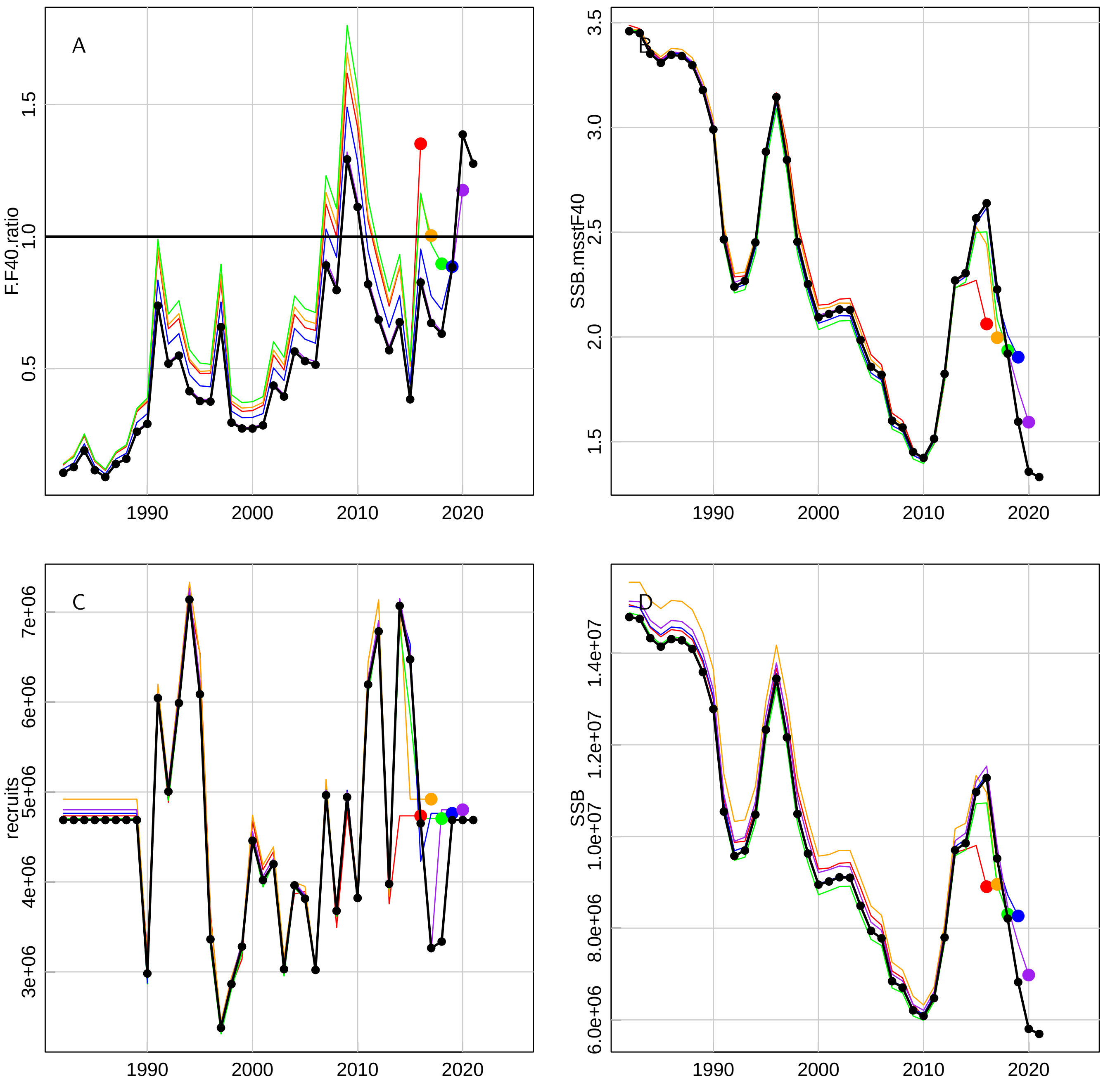


Figure 64. Plots of (A) F, (B) SSB*, and (C) recruitment for base years (black lines with gray shading) and projection years (blue lines with light blue shading) with fishing mortality rate at $F_{40\%}$. Expected values associated with the base run (solid time series lines) and medians of stochastic runs (dashed time series lines) are plotted. Shaded bands to 5^{th} and 95^{th} percentiles of stochastic runs. Solid horizontal green lines mark $F_{40\%}$-related benchmarks; dashed horizontal pink lines represent medians of stochastic runs. The terminal year of the assessment (2021) is indicated by a vertical black line.*

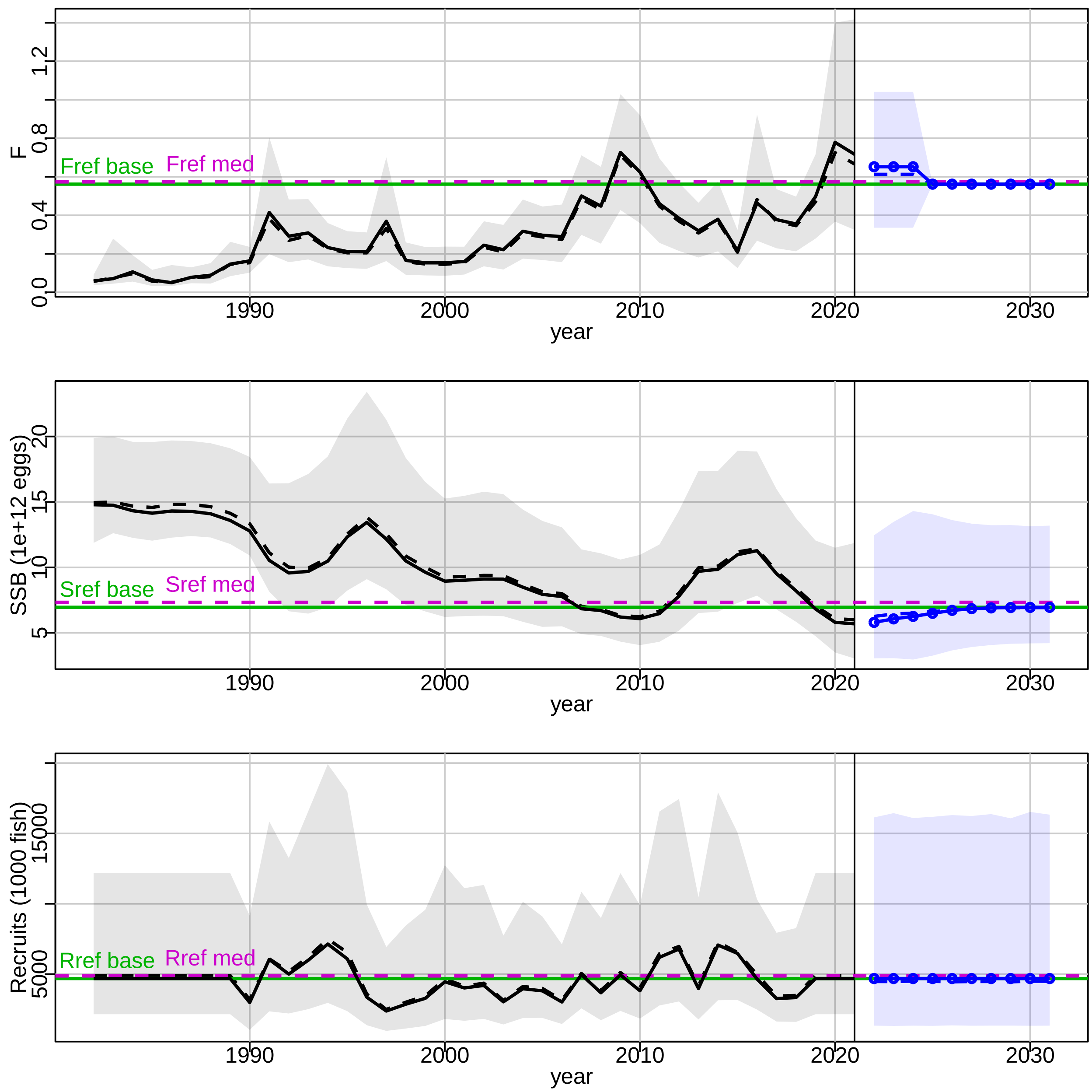


Figure 65. Plots of (A) landings, (B) discards, and (C) indices for base years (black lines with gray shading) and projection years (blue lines with light blue shading) with fishing mortality rate at $F_{40\%}$. Expected values associated with the base run (solid time series lines) and medians of stochastic runs (dashed time series lines) are plotted. Shaded bands to 5^{th} and 95^{th} percentiles of stochastic runs. Solid horizontal green lines mark $F_{40\%}$-related benchmarks; dashed horizontal pink lines represent medians of stochastic runs. The terminal year of the assessment (2021) is indicated by a vertical black line.

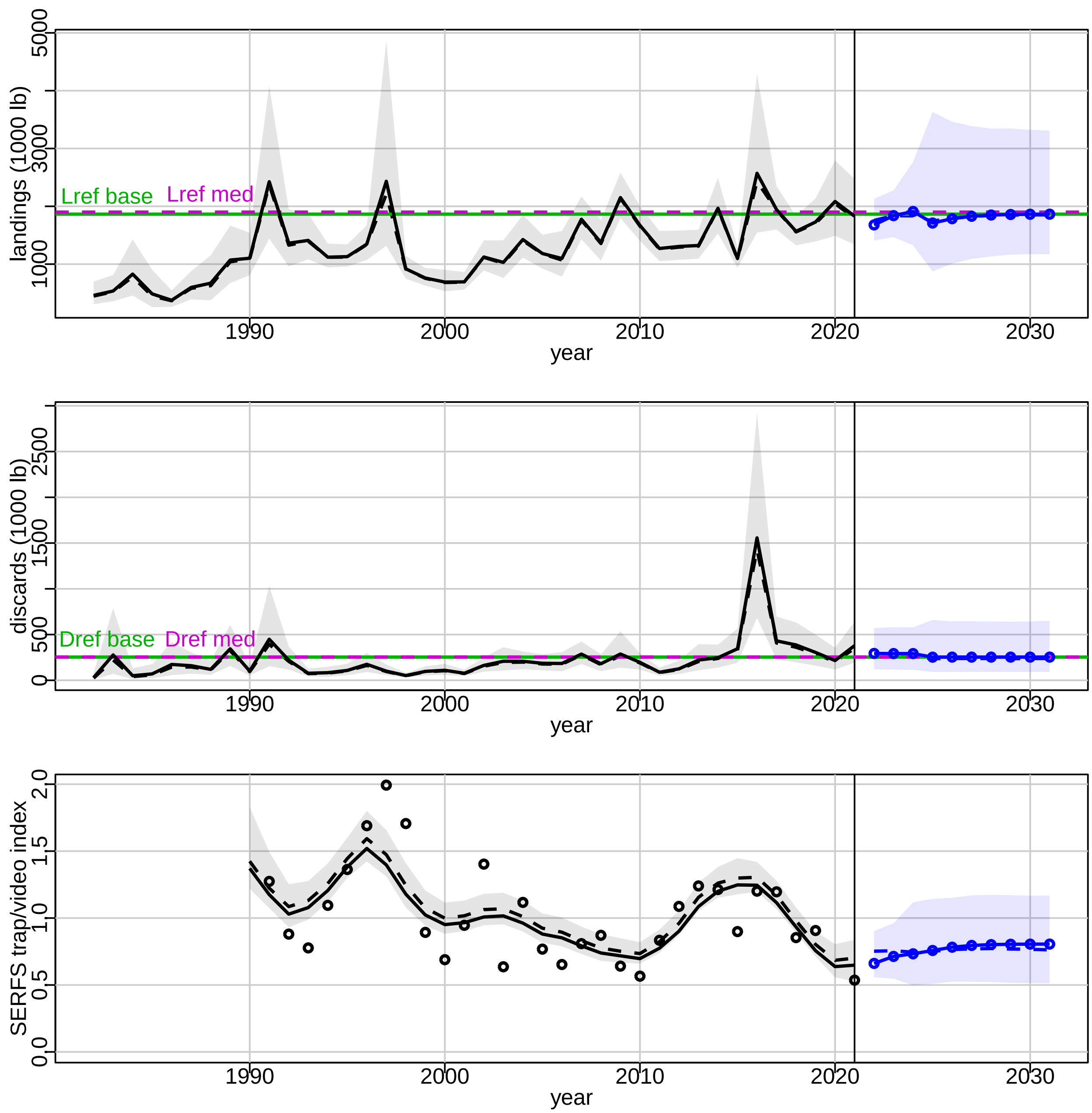


Figure 66. Plots of probability that SSB > $MSST$ *for base and projection years (solid line and open circles with fishing mortality rate at* $F_{40\%}$*. The terminal year of the assessment (*2021*) is indicated by a vertical black line. Expected values associated with the base run (solid time series lines) and medians of stochastic runs (dashed time series lines) are plotted. Probabilities 0.5 and 0.7 are indicated by horizontal black lines.*

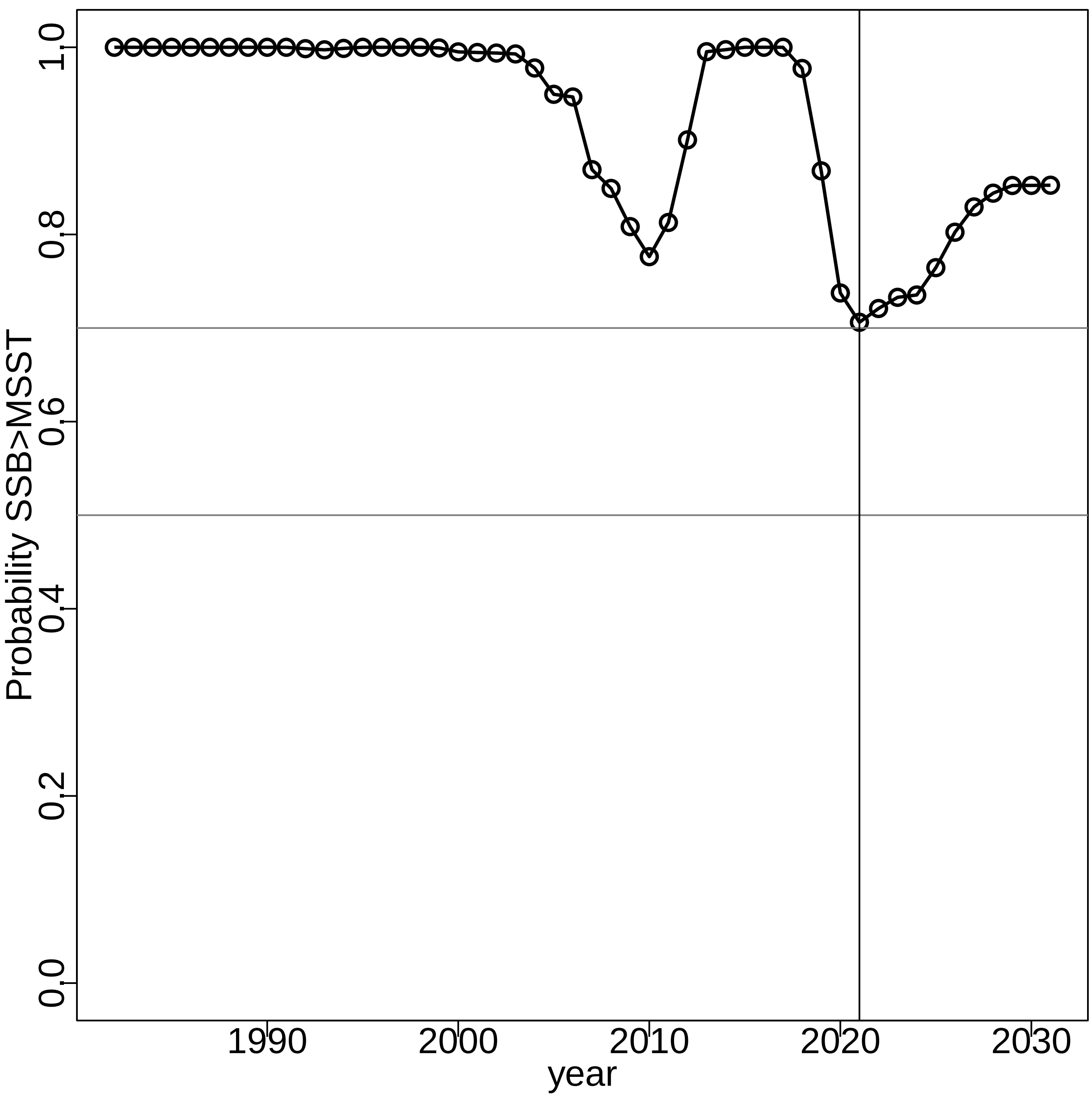


Figure 67. Plots of (A) F, (B) SSB, and (C) recruitment for base years (black lines with gray shading) and projection years (blue lines with light blue shading) with fishing mortality rate at 75%$F_{40\%}$. Expected values associated with the base run (solid time series lines) and medians of stochastic runs (dashed time series lines) are plotted. Shaded bands to 5th and 95th percentiles of stochastic runs. Solid horizontal green lines mark $F_{40\%}$-related benchmarks; dashed horizontal pink lines represent medians of stochastic runs. The terminal year of the assessment (2021) is indicated by a vertical black line.

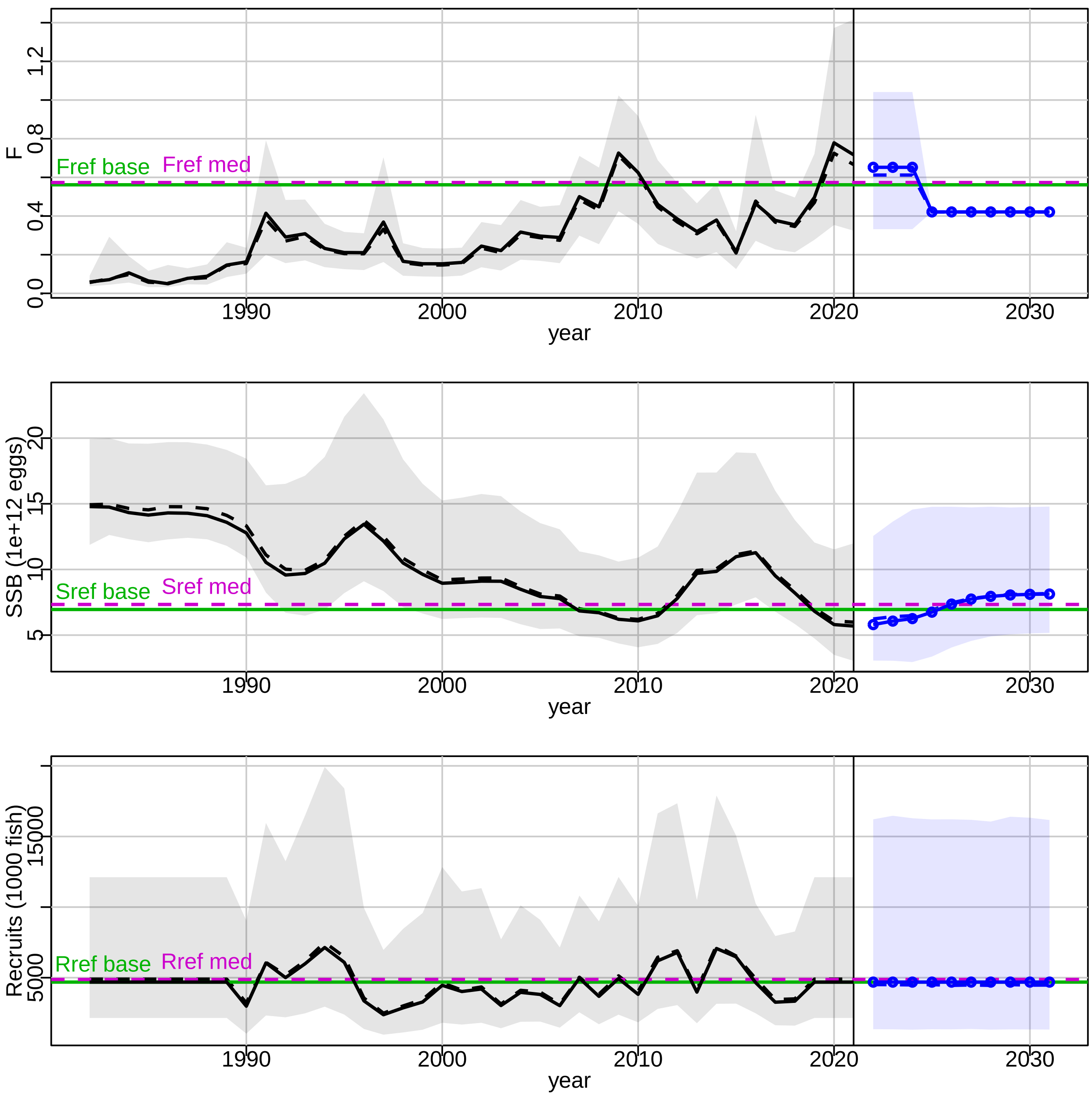


Figure 68. Plots of (A) landings, (B) discards, and (C) indices for base years (black lines with gray shading) and projection years (blue lines with light blue shading) with fishing mortality rate at 75%$F_{40\%}$. Expected values associated with the base run (solid time series lines) and medians of stochastic runs (dashed time series lines) are plotted. Shaded bands to 5^{th} and 95^{th} percentiles of stochastic runs. Solid horizontal green lines mark $F_{40\%}$-related benchmarks; dashed horizontal pink lines represent medians of stochastic runs. The terminal year of the assessment (2021) is indicated by a vertical black line.

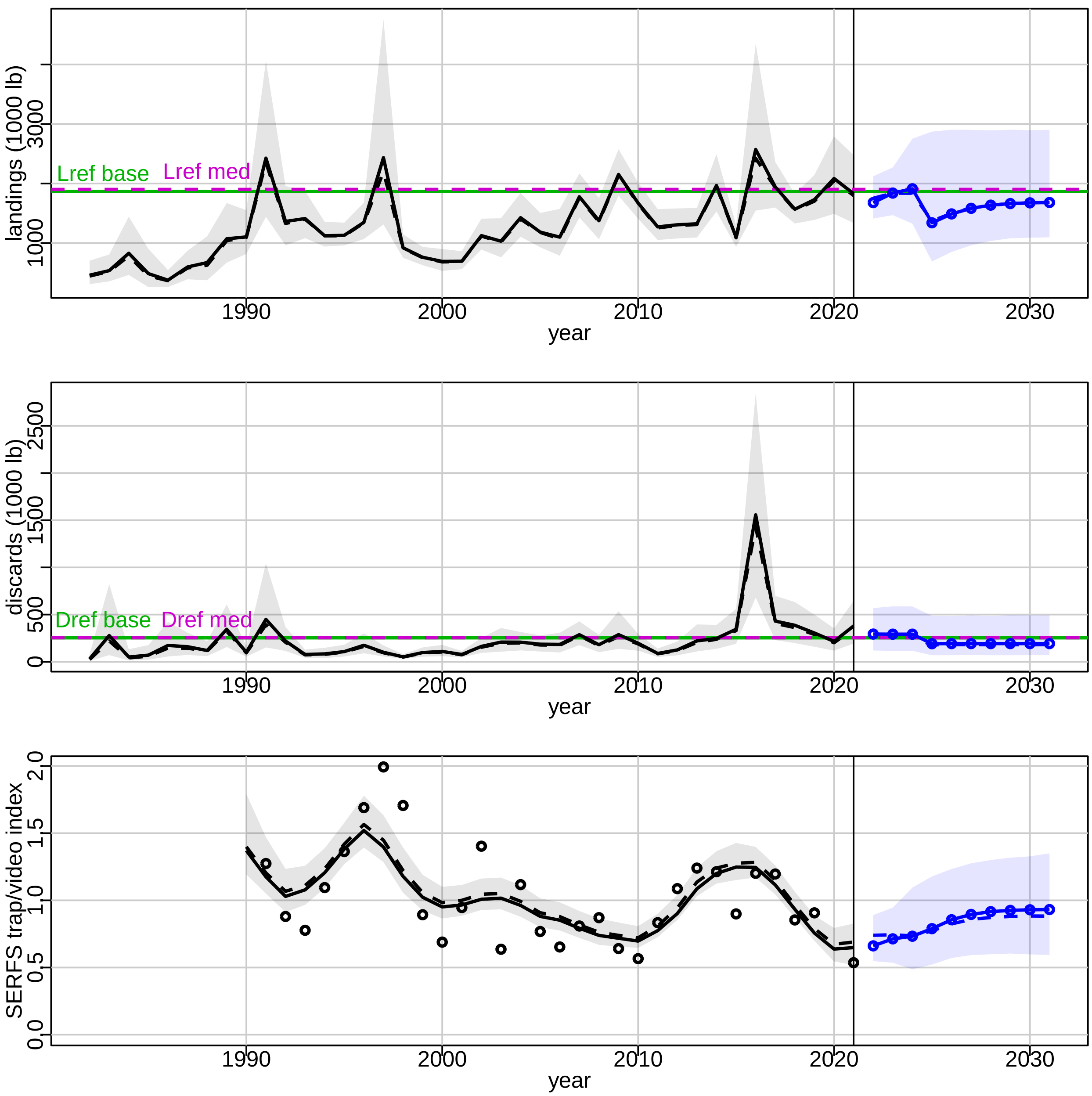
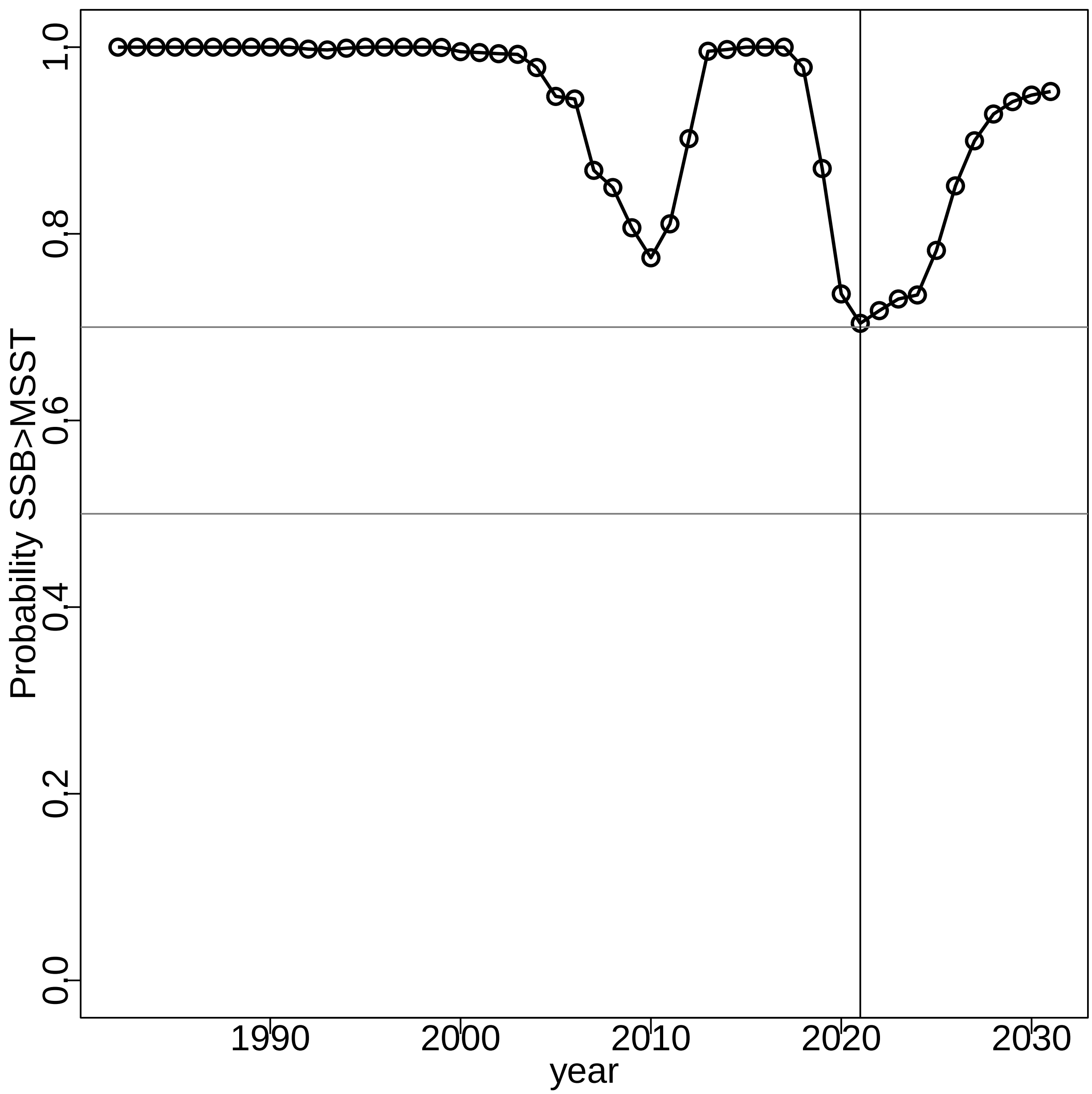


Figure 69. Plots of probability that SSB > $MSST$ *for base and projection years (solid line and open circles with fishing mortality rate at* $75\%F_{40\%}$*. The terminal year of the assessment (*2021*) is indicated by a vertical black line. Expected values associated with the base run (solid time series lines) and medians of stochastic runs (dashed time series lines) are plotted. Probabilities 0.5 and 0.7 are indicated by horizontal black lines.*



Appendix A Parameter estimates from the Beaufort Assessment Model

Table 26. Names and estimated values of parameters estimated in the base run of the Beaufort Assessment Model.

ID	Parameter	Value
1	log.R0	15.2760000
2	rec.sigma	0.4118900
3	log.dev.rec.1990	−0.3676200
4	log.dev.rec.1991	0.3389500
5	log.dev.rec.1992	0.1502200
6	log.dev.rec.1993	0.3296700
7	log.dev.rec.1994	0.5053700
8	log.dev.rec.1995	0.3459500
9	log.dev.rec.1996	−0.2476600
10	log.dev.rec.1997	−0.5938600
11	log.dev.rec.1998	−0.4078800
12	log.dev.rec.1999	−0.2721300
13	log.dev.rec.2000	0.0345940
14	log.dev.rec.2001	−0.0687340
15	log.dev.rec.2002	−0.0254930
16	log.dev.rec.2003	−0.3515300
17	log.dev.rec.2004	−0.0834210
18	log.dev.rec.2005	−0.1216200
19	log.dev.rec.2006	−0.3544100
20	log.dev.rec.2007	0.1421800
21	log.dev.rec.2008	−0.1576600
22	log.dev.rec.2009	0.1377700
23	log.dev.rec.2010	−0.1196900
24	log.dev.rec.2011	0.3635500
25	log.dev.rec.2012	0.4546300
26	log.dev.rec.2013	−0.0793260
27	log.dev.rec.2014	0.4955600
28	log.dev.rec.2015	0.4077100
29	log.dev.rec.2016	0.0769750
30	log.dev.rec.2017	−0.2770100
31	log.dev.rec.2018	−0.2550900
32	log.dm.lenc.rHDs	−1.4050000
33	log.dm.agec.cHLsa	−1.5572000
34	log.dm.agec.cHLsb	0.3513500
35	log.dm.agec.rHBsa	−0.9629300
36	log.dm.agec.rHBsb	−0.0911840
37	log.dm.agec.sTVsa	−1.3479000
38	log.dm.agec.sTVsb	1.4386000
39	selpar.01b01.cHLs	3.4799000
40	selpar.02b01.cHLs	2.5275000

Table 26. (continued)

ID	Parameter	Value
41	selpar.01b01.sTVs	2.9530000
42	selpar.02b01.sTVs	1.9090000
43	selpar.01b01.rHBs	2.9255000
44	selpar.02b01.rHBs	2.6975000
45	selpar.04b01.rHDs	0.9360000
46	log.q.cpue.sTVs	−14.3830000
47	log.avg.F.L.cHLs	−2.8340000
48	log.dev.F.L.cHLs.1982	−1.4001000
49	log.dev.F.L.cHLs.1983	−1.7441000
50	log.dev.F.L.cHLs.1984	−1.6436000
51	log.dev.F.L.cHLs.1985	−1.6949000
52	log.dev.F.L.cHLs.1986	−1.6972000
53	log.dev.F.L.cHLs.1987	−1.6304000
54	log.dev.F.L.cHLs.1988	−1.5255000
55	log.dev.F.L.cHLs.1989	−1.2967000
56	log.dev.F.L.cHLs.1990	−0.5515000
57	log.dev.F.L.cHLs.1991	−0.0413440
58	log.dev.F.L.cHLs.1992	0.1389800
59	log.dev.F.L.cHLs.1993	0.4344700
60	log.dev.F.L.cHLs.1994	0.4728800
61	log.dev.F.L.cHLs.1995	0.5822700
62	log.dev.F.L.cHLs.1996	0.3467400
63	log.dev.F.L.cHLs.1997	0.5473900
64	log.dev.F.L.cHLs.1998	0.3306900
65	log.dev.F.L.cHLs.1999	0.0345980
66	log.dev.F.L.cHLs.2000	−0.1629100
67	log.dev.F.L.cHLs.2001	−0.0089538
68	log.dev.F.L.cHLs.2002	−0.1113800
69	log.dev.F.L.cHLs.2003	−0.1829400
70	log.dev.F.L.cHLs.2004	0.1326000
71	log.dev.F.L.cHLs.2005	0.3154700
72	log.dev.F.L.cHLs.2006	0.2813600
73	log.dev.F.L.cHLs.2007	0.6502300
74	log.dev.F.L.cHLs.2008	0.8021500
75	log.dev.F.L.cHLs.2009	1.0341000
76	log.dev.F.L.cHLs.2010	1.3033000
77	log.dev.F.L.cHLs.2011	1.3227000
78	log.dev.F.L.cHLs.2012	0.6185100
79	log.dev.F.L.cHLs.2013	0.5680600
80	log.dev.F.L.cHLs.2014	0.2133400

Table 26. (continued)

ID	Parameter	Value
81	log.dev.F.L.cHLs.2015	0.3233400
82	log.dev.F.L.cHLs.2016	0.2366000
83	log.dev.F.L.cHLs.2017	0.3091800
84	log.dev.F.L.cHLs.2018	0.3656300
85	log.dev.F.L.cHLs.2019	0.6394600
86	log.dev.F.L.cHLs.2020	0.9524200
87	log.dev.F.L.cHLs.2021	0.7351800
88	log.avg.F.L.cHLn	−6.6874000
89	log.dev.F.L.cHLn.1982	−4.4104000
90	log.dev.F.L.cHLn.1983	−2.2199000
91	log.dev.F.L.cHLn.1984	−2.2847000
92	log.dev.F.L.cHLn.1985	−2.3603000
93	log.dev.F.L.cHLn.1986	−2.4757000
94	log.dev.F.L.cHLn.1987	−2.6051000
95	log.dev.F.L.cHLn.1988	−2.7298000
96	log.dev.F.L.cHLn.1989	−2.8473000
97	log.dev.F.L.cHLn.1990	−2.9742000
98	log.dev.F.L.cHLn.1991	−1.5771000
99	log.dev.F.L.cHLn.1992	−1.6913000
100	log.dev.F.L.cHLn.1993	0.0033891
101	log.dev.F.L.cHLn.1994	1.2948000
102	log.dev.F.L.cHLn.1995	1.2656000
103	log.dev.F.L.cHLn.1996	0.9451400
104	log.dev.F.L.cHLn.1997	0.8118200
105	log.dev.F.L.cHLn.1998	0.3190500
106	log.dev.F.L.cHLn.1999	0.5885900
107	log.dev.F.L.cHLn.2000	0.0534340
108	log.dev.F.L.cHLn.2001	0.1123100
109	log.dev.F.L.cHLn.2002	1.2104000
110	log.dev.F.L.cHLn.2003	0.8973000
111	log.dev.F.L.cHLn.2004	0.6778000
112	log.dev.F.L.cHLn.2005	0.3525500
113	log.dev.F.L.cHLn.2006	0.2808200
114	log.dev.F.L.cHLn.2007	1.1100000
115	log.dev.F.L.cHLn.2008	0.6355000
116	log.dev.F.L.cHLn.2009	1.7821000
117	log.dev.F.L.cHLn.2010	1.5058000
118	log.dev.F.L.cHLn.2011	1.8675000
119	log.dev.F.L.cHLn.2012	2.3717000
120	log.dev.F.L.cHLn.2013	1.9090000

Table 26. (continued)

ID	Parameter	Value
121	log.dev.F.L.cHLn.2014	0.8089100
122	log.dev.F.L.cHLn.2015	−0.0225270
123	log.dev.F.L.cHLn.2016	0.3914100
124	log.dev.F.L.cHLn.2017	1.6561000
125	log.dev.F.L.cHLn.2018	1.4493000
126	log.dev.F.L.cHLn.2019	1.2814000
127	log.dev.F.L.cHLn.2020	1.1752000
128	log.dev.F.L.cHLn.2021	1.4413000
129	log.avg.F.L.rHBs	−3.6175000
130	log.dev.F.L.rHBs.1982	−0.9103200
131	log.dev.F.L.rHBs.1983	−0.9385000
132	log.dev.F.L.rHBs.1984	−0.9754400
133	log.dev.F.L.rHBs.1985	−0.6745700
134	log.dev.F.L.rHBs.1986	−0.9150300
135	log.dev.F.L.rHBs.1987	−0.8781100
136	log.dev.F.L.rHBs.1988	−0.6950100
137	log.dev.F.L.rHBs.1989	−0.5899500
138	log.dev.F.L.rHBs.1990	0.1182000
139	log.dev.F.L.rHBs.1991	0.4468700
140	log.dev.F.L.rHBs.1992	0.7030400
141	log.dev.F.L.rHBs.1993	0.8004600
142	log.dev.F.L.rHBs.1994	0.5259900
143	log.dev.F.L.rHBs.1995	0.4157400
144	log.dev.F.L.rHBs.1996	0.2424200
145	log.dev.F.L.rHBs.1997	0.4543900
146	log.dev.F.L.rHBs.1998	0.1613100
147	log.dev.F.L.rHBs.1999	−0.2400500
148	log.dev.F.L.rHBs.2000	−0.2317700
149	log.dev.F.L.rHBs.2001	−0.2695300
150	log.dev.F.L.rHBs.2002	0.2282000
151	log.dev.F.L.rHBs.2003	−0.0226600
152	log.dev.F.L.rHBs.2004	0.5554000
153	log.dev.F.L.rHBs.2005	0.4641800
154	log.dev.F.L.rHBs.2006	0.1045000
155	log.dev.F.L.rHBs.2007	0.6042800
156	log.dev.F.L.rHBs.2008	0.3196000
157	log.dev.F.L.rHBs.2009	0.6182000
158	log.dev.F.L.rHBs.2010	0.8053400
159	log.dev.F.L.rHBs.2011	0.4451200
160	log.dev.F.L.rHBs.2012	0.2454800

Table 26. (continued)

ID	Parameter	Value
161	log.dev.F.L.rHBs.2013	0.1600300
162	log.dev.F.L.rHBs.2014	−0.0419950
163	log.dev.F.L.rHBs.2015	−0.1828700
164	log.dev.F.L.rHBs.2016	−0.4135500
165	log.dev.F.L.rHBs.2017	−0.2037200
166	log.dev.F.L.rHBs.2018	−0.2243700
167	log.dev.F.L.rHBs.2019	0.0407850
168	log.dev.F.L.rHBs.2020	0.0183480
169	log.dev.F.L.rHBs.2021	−0.0704270
170	log.avg.F.L.rGNs	−2.2503000
171	log.dev.F.L.rGNs.1982	−1.1492000
172	log.dev.F.L.rGNs.1983	−1.3291000
173	log.dev.F.L.rGNs.1984	−0.2322500
174	log.dev.F.L.rGNs.1985	−1.0295000
175	log.dev.F.L.rGNs.1986	−1.6830000
176	log.dev.F.L.rGNs.1987	−1.3103000
177	log.dev.F.L.rGNs.1988	−0.5346500
178	log.dev.F.L.rGNs.1989	−0.1425000
179	log.dev.F.L.rGNs.1990	−0.3023200
180	log.dev.F.L.rGNs.1991	1.0019000
181	log.dev.F.L.rGNs.1992	0.3897800
182	log.dev.F.L.rGNs.1993	0.1334100
183	log.dev.F.L.rGNs.1994	−0.5739800
184	log.dev.F.L.rGNs.1995	−1.1222000
185	log.dev.F.L.rGNs.1996	−0.8527800
186	log.dev.F.L.rGNs.1997	−0.8431500
187	log.dev.F.L.rGNs.1998	−1.0199000
188	log.dev.F.L.rGNs.1999	−0.4366700
189	log.dev.F.L.rGNs.2000	−0.5266700
190	log.dev.F.L.rGNs.2001	−0.5896300
191	log.dev.F.L.rGNs.2002	0.0621310
192	log.dev.F.L.rGNs.2003	0.1699000
193	log.dev.F.L.rGNs.2004	0.1416000
194	log.dev.F.L.rGNs.2005	−0.0856190
195	log.dev.F.L.rGNs.2006	0.5059700
196	log.dev.F.L.rGNs.2007	1.0007000
197	log.dev.F.L.rGNs.2008	0.9241400
198	log.dev.F.L.rGNs.2009	1.2390000
199	log.dev.F.L.rGNs.2010	0.9646100
200	log.dev.F.L.rGNs.2011	0.4670000

Table 26. (continued)

ID	Parameter	Value
201	log.dev.F.L.rGNs.2012	0.2569800
202	log.dev.F.L.rGNs.2013	0.3448300
203	log.dev.F.L.rGNs.2014	0.6400700
204	log.dev.F.L.rGNs.2015	−0.1362400
205	log.dev.F.L.rGNs.2016	1.1558000
206	log.dev.F.L.rGNs.2017	0.6924000
207	log.dev.F.L.rGNs.2018	0.3749700
208	log.dev.F.L.rGNs.2019	0.8124700
209	log.dev.F.L.rGNs.2020	1.1815000
210	log.dev.F.L.rGNs.2021	1.4406000
211	log.avg.F.L.rGNn	−3.7878000
212	log.dev.F.L.rGNn.1982	−4.8038000
213	log.dev.F.L.rGNn.1983	−0.1818600
214	log.dev.F.L.rGNn.1984	−2.9755000
215	log.dev.F.L.rGNn.1985	−2.3319000
216	log.dev.F.L.rGNn.1986	−0.9727200
217	log.dev.F.L.rGNn.1987	0.1591900
218	log.dev.F.L.rGNn.1988	−3.4642000
219	log.dev.F.L.rGNn.1989	0.0568550
220	log.dev.F.L.rGNn.1990	−0.0694920
221	log.dev.F.L.rGNn.1991	0.2462100
222	log.dev.F.L.rGNn.1992	−0.5043800
223	log.dev.F.L.rGNn.1993	0.4666600
224	log.dev.F.L.rGNn.1994	0.2371300
225	log.dev.F.L.rGNn.1995	0.1688800
226	log.dev.F.L.rGNn.1996	0.6875300
227	log.dev.F.L.rGNn.1997	2.0562000
228	log.dev.F.L.rGNn.1998	−0.5849100
229	log.dev.F.L.rGNn.1999	−3.2267000
230	log.dev.F.L.rGNn.2000	−0.2160000
231	log.dev.F.L.rGNn.2001	−0.0616620
232	log.dev.F.L.rGNn.2002	0.6167100
233	log.dev.F.L.rGNn.2003	−0.2250300
234	log.dev.F.L.rGNn.2004	1.2537000
235	log.dev.F.L.rGNn.2005	1.1931000
236	log.dev.F.L.rGNn.2006	−1.5435000
237	log.dev.F.L.rGNn.2007	0.7555100
238	log.dev.F.L.rGNn.2008	−0.6651200
239	log.dev.F.L.rGNn.2009	1.8193000
240	log.dev.F.L.rGNn.2010	1.0713000

Table 26. (continued)

ID	Parameter	Value
241	log.dev.F.L.rGNn.2011	−0.0497300
242	log.dev.F.L.rGNn.2012	1.4008000
243	log.dev.F.L.rGNn.2013	0.1859100
244	log.dev.F.L.rGNn.2014	1.2401000
245	log.dev.F.L.rGNn.2015	−0.2002200
246	log.dev.F.L.rGNn.2016	0.4405000
247	log.dev.F.L.rGNn.2017	0.9481400
248	log.dev.F.L.rGNn.2018	1.3800000
249	log.dev.F.L.rGNn.2019	1.6275000
250	log.dev.F.L.rGNn.2020	2.4081000
251	log.dev.F.L.rGNn.2021	1.6573000
252	log.avg.F.D.rHDs	−6.2890000
253	log.dev.F.D.rHDs.1982	−0.8369800
254	log.dev.F.D.rHDs.1983	0.5573100
255	log.dev.F.D.rHDs.1984	−0.2489100
256	log.dev.F.D.rHDs.1985	0.5258800
257	log.dev.F.D.rHDs.1986	−0.0552860
258	log.dev.F.D.rHDs.1987	1.0271000
259	log.dev.F.D.rHDs.1988	1.5296000
260	log.dev.F.D.rHDs.1989	−1.9014000
261	log.dev.F.D.rHDs.1990	−1.1896000
262	log.dev.F.D.rHDs.1991	−1.4551000
263	log.dev.F.D.rHDs.1992	−1.8264000
264	log.dev.F.D.rHDs.1993	−1.8683000
265	log.dev.F.D.rHDs.1994	−1.9532000
266	log.dev.F.D.rHDs.1995	−0.5072100
267	log.dev.F.D.rHDs.1996	−1.1529000
268	log.dev.F.D.rHDs.1997	−0.4257600
269	log.dev.F.D.rHDs.1998	0.3465500
270	log.dev.F.D.rHDs.1999	0.6692000
271	log.dev.F.D.rHDs.2000	−0.6343700
272	log.dev.F.D.rHDs.2001	−0.6145600
273	log.dev.F.D.rHDs.2002	0.9441500
274	log.dev.F.D.rHDs.2003	0.1384700
275	log.dev.F.D.rHDs.2004	1.2273000
276	log.dev.F.D.rHDs.2005	1.4788000
277	log.dev.F.D.rHDs.2006	1.1696000
278	log.dev.F.D.rHDs.2007	0.3601300
279	log.dev.F.D.rHDs.2008	0.0587390
280	log.dev.F.D.rHDs.2009	−0.1988200

Table 26. (continued)

ID	Parameter	Value
281	log.dev.F.D.rHDs.2010	0.5938900
282	log.dev.F.D.rHDs.2011	−0.3282300
283	log.dev.F.D.rHDs.2012	−0.3737800
284	log.dev.F.D.rHDs.2013	−0.3134600
285	log.dev.F.D.rHDs.2014	−0.3902700
286	log.dev.F.D.rHDs.2015	0.5351300
287	log.dev.F.D.rHDs.2016	1.7550000
288	log.dev.F.D.rHDs.2017	1.2168000
289	log.dev.F.D.rHDs.2018	1.0294000
290	log.dev.F.D.rHDs.2019	0.8044600
291	log.dev.F.D.rHDs.2020	0.1440900
292	log.dev.F.D.rHDs.2021	0.1628700
293	log.avg.F.D.rGDs	−3.2367000
294	log.dev.F.D.rGDs.1982	−1.7752000
295	log.dev.F.D.rGDs.1983	0.5381200
296	log.dev.F.D.rGDs.1984	−1.2552000
297	log.dev.F.D.rGDs.1985	−1.0112000
298	log.dev.F.D.rGDs.1986	0.0603450
299	log.dev.F.D.rGDs.1987	−0.1405100
300	log.dev.F.D.rGDs.1988	−0.6497900
301	log.dev.F.D.rGDs.1989	0.7994500
302	log.dev.F.D.rGDs.1990	−0.5873800
303	log.dev.F.D.rGDs.1991	0.9433200
304	log.dev.F.D.rGDs.1992	0.2350300
305	log.dev.F.D.rGDs.1993	−1.0558000
306	log.dev.F.D.rGDs.1994	−1.1229000
307	log.dev.F.D.rGDs.1995	−0.7867100
308	log.dev.F.D.rGDs.1996	−0.0861030
309	log.dev.F.D.rGDs.1997	−0.1636100
310	log.dev.F.D.rGDs.1998	−0.8777500
311	log.dev.F.D.rGDs.1999	−0.2038600
312	log.dev.F.D.rGDs.2000	−0.3272200
313	log.dev.F.D.rGDs.2001	−0.8210200
314	log.dev.F.D.rGDs.2002	0.0052948
315	log.dev.F.D.rGDs.2003	0.5859600
316	log.dev.F.D.rGDs.2004	0.3234500
317	log.dev.F.D.rGDs.2005	0.2350600
318	log.dev.F.D.rGDs.2006	0.4586500
319	log.dev.F.D.rGDs.2007	0.4578300
320	log.dev.F.D.rGDs.2008	0.2919500

Table 26. (continued)

ID	Parameter	Value
321	log.dev.F.D.rGDs.2009	0.4704400
322	log.dev.F.D.rGDs.2010	0.0898560
323	log.dev.F.D.rGDs.2011	−0.9264100
324	log.dev.F.D.rGDs.2012	−0.7178600
325	log.dev.F.D.rGDs.2013	0.2300700
326	log.dev.F.D.rGDs.2014	0.0998370
327	log.dev.F.D.rGDs.2015	0.3590500
328	log.dev.F.D.rGDs.2016	2.3156000
329	log.dev.F.D.rGDs.2017	1.3650000
330	log.dev.F.D.rGDs.2018	1.2255000
331	log.dev.F.D.rGDs.2019	0.6524200
332	log.dev.F.D.rGDs.2020	−0.0724240
333	log.dev.F.D.rGDs.2021	0.8387400
334	log.avg.F.D.rGDn	−6.3196000
335	log.dev.F.D.rGDn.1982	−4.3509000
336	log.dev.F.D.rGDn.1983	−4.3270000
337	log.dev.F.D.rGDn.1984	−4.3404000
338	log.dev.F.D.rGDn.1985	−4.3472000
339	log.dev.F.D.rGDn.1986	−2.1618000
340	log.dev.F.D.rGDn.1987	−0.4012600
341	log.dev.F.D.rGDn.1988	−0.5048600
342	log.dev.F.D.rGDn.1989	−0.5927800
343	log.dev.F.D.rGDn.1990	2.0089000
344	log.dev.F.D.rGDn.1991	0.1589100
345	log.dev.F.D.rGDn.1992	−0.5222800
346	log.dev.F.D.rGDn.1993	0.0558610
347	log.dev.F.D.rGDn.1994	−0.3792800
348	log.dev.F.D.rGDn.1995	−0.6398000
349	log.dev.F.D.rGDn.1996	2.1061000
350	log.dev.F.D.rGDn.1997	1.8268000
351	log.dev.F.D.rGDn.1998	0.6126600
352	log.dev.F.D.rGDn.1999	−0.9910000
353	log.dev.F.D.rGDn.2000	−0.0286440
354	log.dev.F.D.rGDn.2001	0.7375300
355	log.dev.F.D.rGDn.2002	0.2527900
356	log.dev.F.D.rGDn.2003	0.5959100
357	log.dev.F.D.rGDn.2004	1.3138000
358	log.dev.F.D.rGDn.2005	−1.0141000
359	log.dev.F.D.rGDn.2006	−0.5296800
360	log.dev.F.D.rGDn.2007	1.9618000

Table 26. (continued)

ID	Parameter	Value
361	log.dev.F.D.rGDn.2008	−1.2776000
362	log.dev.F.D.rGDn.2009	1.8001000
363	log.dev.F.D.rGDn.2010	1.9066000
364	log.dev.F.D.rGDn.2011	−0.1035700
365	log.dev.F.D.rGDn.2012	0.0266660
366	log.dev.F.D.rGDn.2013	1.1565000
367	log.dev.F.D.rGDn.2014	0.1648800
368	log.dev.F.D.rGDn.2015	0.6320000
369	log.dev.F.D.rGDn.2016	1.5731000
370	log.dev.F.D.rGDn.2017	1.0170000
371	log.dev.F.D.rGDn.2018	1.6910000
372	log.dev.F.D.rGDn.2019	1.3722000
373	log.dev.F.D.rGDn.2020	2.2728000
374	log.dev.F.D.rGDn.2021	1.2682000
375	F.init	0.0753210

Appendix B Abbreviations and Symbols

Table 27. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for gray triggerfish)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1
BAM	Beaufort Assessment Model (a statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
DW	Data Workshop (here, for gray triggerfish)
F	Instantaneous rate of fishing mortality
F_{MSY}	Fishing mortality rate at which MSY can be attained
FL	State of Florida
GA	State of Georgia
GLM	Generalized linear model
K	Average size of stock when not exploited by man; carrying capacity
kg	Kilogram(s); 1 kg is about 2.2 lb.
klb	Thousand pounds; thousands of pounds
lb	Pound(s); 1 lb is about 0.454 kg
m	Meter(s); 1 m is about 3.28 feet.
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
MCBE	Monte Carlo/Bootstrap Ensemble, an approach to quantifying uncertainty in model results
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on F_{MSY}
mm	Millimeter(s); 1 inch = 25.4 mm
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS, predecessor of MRIP
MRIP	Marine Recreational Information Program, a data-collection program of NMFS, descended from MRFSS
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for gray triggerfish as $(1-M)\mathrm{SSB}_{\mathrm{MSY}} = 0.7\mathrm{SSB}_{\mathrm{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as "NOAA Fisheries Service"
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY $\leq$ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SDNR	Standard deviation of normalized residuals
SEDAR	SouthEast Data Assessment and Review process
SEFIS	SouthEast Fishery-Independent Survey
SERFS	SouthEast Reef Fish Survey
SFA	Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended
SL	Standard length (of a fish)
SPR	Spawning potential ratio
SSB	Spawning stock biomass; mature biomass of males and females
$\mathrm{SSB}_{\mathrm{MSY}}$	Level of SSB at which MSY can be attained
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length) or SL (standard length)
VPA	Virtual population analysis, an age-structured assessment
WW	Whole weight, as opposed to GW (gutted weight)
yr	Year(s)

SEDAR

Southeast Data, Assessment, and Review

SEDAR 82

South Atlantic Gray Triggerfish

SECTION IV: Research Recommendations

SEDAR
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Table of Contents

1. DATA WORKSHOP RESEARCH RECOMMENDATIONS

1.1 LIFE HISTORY RESEARCH RECOMMENDATIONS

Age validation

- Patterson et al. (2021) examined core material from gray triggerfish eye lenses to develop a bomb radiocarbon chronometer that was be applied to validate age estimates from dorsal spines and otoliths. Results suggested spine readings underestimated ages compared to otoliths in Gulf of Mexico (GOM) fish. Similar studies should be conducted in the SA.
- Potts et al. (in review) indicated that SA gray triggerfish otoliths provide accurate ages from age 1-12, and first dorsal spines provide accurate ages from age 1-5. However, a new age reading method is being developed for dorsal spine sections that may alleviate under-ageing. More paired otolith and spine samples need to be collected and read to assess the efficacy of this new reading method.
- MARFIN funding has been awarded to Drs. William Patterson (University of Florida), David Portnoy, and Christopher Hollenbeck (Texas A&M University-Corpus Christi) to develop protocols for DNA methylation-based ageing in GOM fish. This work should be reproduced in the SA.
- Panelists suggest that periodic inter-agency ageing workshops be conducted to ensure continued precision and accuracy for gray triggerfish age products.

Movement, migration, and effects of storm events

- More research on gray triggerfish movements and migrations in Atlantic waters is needed. Bachelor et al. (2019) utilized acoustic telemetry to determine fine-scale, diel movement patterns of gray triggerfish off the coast of North Carolina, but additional tagging studied are needed to document migration patterns to and from locations of spawning aggregation in the South Atlantic (SA).

- Adult fish are caught in bottom trawl surveys north of Cape Hatteras in fall months. Future studies are needed to document this seasonal northern movement.

Spawning location, seasonality, duration, and behavior

- The recommendation from S41 regarding spawning locations remains somewhat unresolved: "Tagging studies are needed to define spawning locations (only shelf edge or not) and, movement, the results of which could be used to help inform fishing mortality and natural mortality."
- Farmer et al. (2017) utilized multi-decadal data from SERFS to identify broad spawning locations and model spawning seasonality for various reef fish species in the southeastern U.S. However, limitations in spatio-temporal fisheries-independent sampling efforts resulted in gaps in the data needed to fully characterize timing and location of spawning. Authors of this study suggested that fisheries-independent surveys expand efforts to include more gear types, increase sampling into fall and winter months, and sample in a wider variety of topographical and hydrological conditions.
- Determine if spawning season varies latitudinally in the SA.
- Spawning/nesting behaviors, and their effect on reproductive output, needs to be examined in the SA. Simmons and Szedlmayer (2012) (SEDAR82-RD03) examined territoriality, nest building, harem spawning, and parental care of spawning gray triggerfish on artificial reefs in the GOM.
- Territoriality and competition for nests needs to be investigated in the SA, as these behaviors may affect reproductive output.

Fecundity type, annual and batch fecundity:

- The recommendation from S41 regarding fecundity remains unresolved: "Determine fecundity type and estimate annual fecundity in Atlantic waters"

Early life history

- Early life history parameters (size and age at settlement and duration of pelagic stage) are largely unknown in the South Atlantic. Simmons and Szedlmayer (2011) suggest a 4 – 7 month pelagic stage in GOM gray triggerfish, with peak recruitment to benthic habitats occurring in September-December. Age-0 fish as small as 38 mm FL were found on artificial reefs during this study. Similar studies need to be conducted in the South Atlantic that sample both benthic and pelagic habitats for pre and post-recruitment gray triggerfish.

Discard/bycatch mortality

- Further investigation of discard mortality in both recreational and commercial fisheries is necessary in the SA.

- Buckel and Runde (2022) estimated 0.411 discard survival in recreational hook-and-line fisheries off of North Carolina and Florida. This survival rate needs to be determined for commercially caught fish.

Climate Change

- The recommendation from S41 regarding climate change remains unresolved: "Impact of climate change on mortality and recruitment"
- Investigate potential for latitudinal shifts/expansion in the species distribution as water temperatures increase.
- Burton (2008) and Morley et al. (2018) suggest that climate change could cause alterations in spawning seasonality, migration patterns, and growth rates. These effects need to be further investigated.
- Bacheler et al. (2019) used fine-scale acoustic telemetry to quantify movements of gray triggerfish associated with tropical storm events. Further study needs to document these movements more comprehensively as storm events increase in intensity.
- Study potential effects of changing ocean currents on *Sargassum sp.* distribution, as it provides critical nursery habitat for juvenile gray triggerfish.

1.2 COMMERCIAL FISHERY STATISTICS RESEARCH RECOMMENDATIONS

Landings

- Require species level reporting in state trip ticket programs. Some states have made this change which helps to reduce the uncertainty in commercial landings data.
- Characterize landings by fishing area to better understand species spatial distribution.
- Encourage the use of electronic logbook reporting and auditing to enhance spatial information.
- Improve dealer reporting of catch areas and reduce the use of unknown values in landings data.
- Consider the management history of other species that may have direct or indirect impacts on the assessment species (e.g., increased fishing effort for target species due to more restrictive management of another species).
- Review the approach for developing commercial uncertainty estimates.

Discard

- Expand observer coverage for the South Atlantic to improve discard estimates.
- Expand use of electronic reporting to reduce duplicative reporting requirements.

Biosampling

- Increase TIP sampling across all states and standardize TIP sampling protocol to get representative samples at the species level.

1.3 RECREATIONAL FISHERY STATISTICS RESEARCH RECOMMENDATIONS

Evaluation and Progress of Research Recommendations from Previous Assessment

Research recommendations from SEDAR 41 were evaluated and progress on each item is outlined below:

1. ***Complete analysis of available historic photos for trends in CPUE and mean size of landed Red Snapper and Gray Triggerfish for pre-1981 time period. (Ultimately all species)***
   - Evaluation of Progress
     - Developed methods through FISHstory pilot project, which is now complete
2. ***Formally archive data and photos for all other SEDAR target species***
   - Evaluation of Progress
     - ~1,375 photos – king mackerel measured in all
     - Requesting additional funding through ACCSP to continue and expand project to get photos throughout SA and other species of interest (e.g., red snapper)
     - Broader geographic spread and timeframe
3. ***For Hire Survey (FHS) should collect additional variables (e.g. depth fished)***
   - Evaluation of Progress
     - Not currently collected in FHS
     - Included on southeast electronic for-hire integrated electronic reporting (SEFHIER)
4. ***Increasing sample sizes for at-sea headboat observers (i.e. number of trips sampled)***
   - Evaluation of Progress
     - No change in recent years with regard to sample sizes, but the program is ongoing
     - FL FWC has secured long-term funds to continue at-sea headboat observer coverage on the Atlantic coast and to extend it to the charter fishery
5. ***Compute variance estimate for headboat landings***
   - Evaluation of Progress
     - Completed
6. ***Mandatory logbooks for all federally permitted for-hire vessels***
   - Evaluation of Progress
     - Completed - SEFHIER

Research Recommendations for SEDAR 82

1. Consider additional collections and analyses of historical photos for gray triggerfish to track desirability over time
2. Formally archive data and photos for all other SEDAR target species
3. For Hire Survey (FHS) should collect additional spatial and depth information
4. Develop statistically valid methods to identify outlier estimates and adjust sample weights for records that have a disproportionately high influence on total catch estimates and establish new SEDAR best practice methods

5. Implement procedures to measure noncompliance and validate catch and effort for for-hire vessel logbooks in SEFHIER (e.g., dockside validation).
6. Address the lack of survey coverage for non-federally permitted headboats operating in state waters.
7. Establish comprehensive coastwide biological sampling program for collection of ageing structures similar to the biological sampling program coordinated by GulfFIN in the Gulf of Mexico.
8. Expand charter fishery observer coverage to North Carolina, South Carolina, and Georgia similar to the headboat at-sea observer programs.

1.4 INDICES OF POPULATION ABUNDANCE RESEARCH RECOMMENDATIONS

- The DW recommended two fishery-independent (chevron traps and videos) and three fishery-dependent indices (headboat, MRFSS, commercial handline) for potential use in the gray triggerfish stock assessment.

1.5 ECOSYSTEM REPORT RESEARCH RECOMMENDATIONS

- Employ the South Atlantic EwE model to test hypotheses regarding environmental drivers for Gray Triggerfish (predator-prey relationships, etc.).
- Encourage studies of contaminant, EDCs and microplastics body burdens in Gray Triggerfish to determine lethal and sub-lethal (chronic) impacts that may affect the population dynamics of the species at any of its life stages.
- Encourage further study of the relationships between Gray Triggerfish egg hatching success and swim-up, larval and postlarval recruitment to *Sargassum* pelagic habitat, settlement of juveniles from the pelagic *Sargassum* to benthic reef and/or hard structure habitats, and sources and sinks for juveniles and adults.
- Continue to explore possible relationships between environmental variables and climate cycles, and Gray Triggerfish population dynamics.
- Investigate to what extent Gray Triggerfish prey could be impacted by increasing ocean acidification.
- Encourage the collection of additional diet data to refine Gray Triggerfish predator-prey relationships.
- Determine nest site selection criteria used by Gray Triggerfish and whether there may be an optimal nest configuration which maximizes hatching success.
- Complete needed climate vulnerability assessments for habitats and species in the south Atlantic.
- Continue to explore whether artificial reef creation and addition of other hard structures (e.g., offshore wind infrastructure) results in increased or expanding Gray Triggerfish population size.
- Determine the vulnerability of Gray Triggerfish life stages to harmful algal blooms and associated toxins, including Red Tide events.
- Continue to investigate through additional acoustic telemetry the impact of episodic events on Gray Triggerfish.

1.6 SPATIOTEMPORAL REPORT RESEARCH RECOMMENDATIONS

- Consider whether the SERFS video or Chevron Trap time series may be analyzed to detect any shift in center of distribution for Gray Triggerfish.
- Examine the time series of Gray Triggerfish trophy citations issued by jurisdictions north of North Carolina, either individually or cumulatively, for any utility in establishing an index.
- Examine the time series of Gray Triggerfish captured, tagged, released and recaptured by the Virginia Game Fish Tagging Program, to determine if a useful index might be generated.
- Contact additional colleagues who coordinate long-term inshore/estuarine fishery-independent surveys to determine if there are additional Gray Triggerfish records north of North Carolina, and whether an index might be constructed.
- Examine social media posts to see if a useful index of anglers targeting Gray Trigger fish could be generated for recent time periods (decades?, five-year periods?, annual?).

2. ASSESSMENT PROCESS RESEARCH RECOMMENDATIONS

Although it is difficult to estimate the duration of potential research projects, research recommendations have been divided into short- and long-term groups. Recommendations in the short-term group largely suggest further analysis of existing data, and progress may be made relatively quickly. But any of the recommendations could potentially be developed into short- or long-term projects.

Short-term

- Continue to investigate aging methods and aging error: Are spines the best way to age triggerfish? What are the limits of spine-based age readings? Increase the number of age samples used to estimate an age-error matrix and consider multiple sources of error. In this assessment, age-error due to differences in aging otoliths versus spines was characterized. But other sources of error, such as error between readers, could also be important.
- Refine estimates of age-dependent reproductive output and associated relationships (i.e., maturity, batch fecundity, and batch number) considering the newest methodologies.
- Investigate methods for standardizing age or length composition data available US South Atlantic Gray Triggerfish, accounting for covariates (e.g. depth, latitude, longitude, time of year).

Long-term

- Improve understanding of recruitment, stock structure and potential range shifts in the Atlantic Ocean, including areas outside of SAFMC jurisdiction and outside of the US EEZ.
- Expand fishery independent information to northern areas, maintaining consistent sampling for the SERFS trap/video index of abundance and age compositions.
- Develop direct estimates of natural mortality and associated uncertainty.
- Investigate temporal variation in recruitment and survivorship, considering potential environmental relationships.

3. REVIEW PANEL RESEARCH RECOMMENDATIONS

The Review Panel felt that there were too many research recommendations spread out over various report sections of the workshops, and that this list should be consolidated and prioritized prior to the Review Workshop to allow for a useful review. The Review Panel made an attempt to prioritize the provided recommendations for this assessment (see Figure 1).

The review panel discussed the research recommendations in the workshop reports, with the idea of using them as a resource to inform its deliberations. They were clustered and linked together and then, based on review panel discussions, they were categorized into short-term (before the next assessment) and longer-term researcher recommendations. They were also categorized across a gradient of high priority, to low priority in terms of bringing about improvements in the modelling and management advice for Gray Triggerfish (see Figure 1).

Additional Research Recommendations:

- The unit stock should be investigated further. Gray Triggerfish in the western Atlantic and the Gulf of Mexico is considered one population, and this is supported by genetic studies. The Review Panel noted that the Gulf of Mexico was not included but the area north of the North Carolina – Virginia border was. The appropriateness of unit stock for the area should be investigated further, particularly the inclusion of the area north of the Virginia-North Carolina border.
- Reproduction: Investigate the age varying batch fecundity, spawning frequency, and timing (length) of the spawning season as this affects estimates of population egg production.
- Examine current fishery independent surveys north of North Carolina – Virginia border for information.
- Studies of fish behavior in and around the traps, like the one reported in Bacheler et al. 2013 for Black Seabass, are recommended for Gray Triggerfish to further investigate processes affecting trap catch rates, such as trap saturation, and the (possibly non-linear) relationship with Gray Triggerfish abundance.

Recent stock estimates, short-term projections and quota calculations are affected by lack of information about recent recruitment. The most reliable recruitment estimates were based on multiple years of data for the cohort. Per standard SEFSC procedures, long-term recruitment (in this case constant recruitment at the virgin R_0 level) was assumed in modeling the last three years and for short-term catch projections. This common approach reduces variance but also biases projections and catch calculations high when recent recruitment is low (as it is currently) and biases them low when recent recruitment is high. The Review Panel recommended investigating recent trends or shifts in recruitment in future assessments to test whether other recent levels of recruitment are more appropriate for the projection recruitment estimates.

It may be useful to include short-term projections in retrospective analyses i.e., to see if projections are capable of reproducing model estimates based on data in later years (see also under TOR 2c).

SEDAR

Southeast Data, Assessment, and Review

SEDAR 82

South Atlantic Gray Triggerfish

SECTION V: Review Workshop Report

April 2024

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Table of Contents

1. INTRODUCTION

1.1 WORKSHOP TIME AND PLACE

The SEDAR 82 Review Workshop was held in Atlantic Beach, North Carolina March 12-14, 2024.

1.2 TERMS OF REFERENCE

1) Evaluate the data used in the assessment. Consider the following:
   a) Are data decisions made by the DW and AW justified?
   b) Are data uncertainties acknowledged, reported, and properly characterized?
   c) For model derived data and parameter inputs (e.g. indices of abundance, life history quantities) are the methods appropriate?

2) Evaluate and discuss the strengths and weaknesses of the methods used to assess the stock, taking into account the available data. Consider the following:
   a) Are the methods appropriate for the available data?
   b) Are assessment models configured properly and used in a manner consistent with standard practices?
   c) Were modeling issues clearly identified and addressed? If not, recommend potential methods for addressing these issues.

3) Consider how uncertainties in the assessment are addressed.
   a) Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the input data.
   b) Comment on sources of uncertainty not accounted for and possible approaches for incorporating these sources into future assessments (e.g. ecosystem, management policies).

4) Provide, or comment on, recommendations to improve the assessment.
   a) Consider the research recommendations provided by the Data and Assessment

workshops in the context of overall improvement to the assessment and make any additional research recommendations warranted.

b) If applicable, provide recommendations for improvement or for addressing any inadequacies identified in the data or assessment modeling. These recommendations should be described in sufficient detail for application and should be practical for short-term implementation (e.g., achievable within ~6 months). Longer-term recommendations should instead be listed as research recommendations above.

5) Provide recommendations on possible ways to improve the Research Track Assessment process.

6) Prepare a Review Workshop Summary Report describing the Panel's evaluation of the Research Track stock assessment and addressing each Term of Reference.

1.3 LIST OF PARTICIPANTS

Review Panel

Marcel Reichert (Chair) .... SAFMC SSC
Mark Dickey-Collas .... CIE Reviewer
Steven Holmes .... CIE Reviewer
Larry Jacobson .... CIE Reviewer
Anna Markwith .... SAFMC SSC
Alexei Sharov .... SAFMC SSC

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Council Representation

Kerry Marhefka .... South Carolina

Staff

Julie A Neer .... SEDAR
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Workshop Observers

Jie Cao .... NC State
Walt Rogers .... NMFS SEFSC
Amy Schueller .... NMFS SEFSC
Matt Vincent .... NMFS SEFSC

Workshop Observers via Webinar

Manuel Coffill-Rivera..
Michele Ritter .... SAFMC Staff
Michael Schmidtke .... SAFMC Staff
Mclean Seward.. NC DNR
Meredith Whitten .... NC DNR

2. REVIEW PANEL REPORT

An independent peer review of the SEDAR 82 Gray Triggerfish Research Track Stock Assessment was conducted during an in-person Review Workshop on March 12-14, 2024, in Atlantic Beach, NC. The data, analyses and stock modeling presented were part of a Research Track Stock Assessment (called "assessment" in this report). The results were not meant to be a quantitative basis for management recommendations as they did not include the most recent data. This is not a deficiency because research track assessments are meant to build a robust assessment tool to be utilized in future assessments and includes evaluating all available data and exploration of potential changes to methodology. Stock status was presented as a demonstration in the report so that the Review Panel could evaluate the approach used. The Research Track will be followed by an Operational Assessment at some time in the future that will include updated data, including for the most recent years, and results are expected to be used for management.

The Review Panel appreciated the collegial nature of the review deliberations. The Assessment Team was responsive to the Review Panel's comments, questions, and requests for additional analyses. The Review Panel thanks the entire Assessment Team for the significant amount of work involved and for the reports detailing the data, analyses, exploration, and modeling. In particular, the panel acknowledges Dr. Erik Williams and Dr. Nikolai Klibansky (Assessment Lead) who presented an overview of the assessment, provided additional clarification and analyses, and answered Review Panel questions. The Review Panel also thanks SEDAR and South Atlantic Fisheries Management Staff for their invaluable assistance during the review process.

During the review workshop, the Review Panel was able to conduct a thorough review of the Gray Triggerfish assessment. This report summarizes its findings and recommendations.

Executive Summary

An independent peer review of the SEDAR 82 Gray Triggerfish research track assessment was conducted during an in-person Review Workshop on March 12-14, 2024, in Atlantic Beach, NC. The Review Panel consisted of Marcel Reichert (Chair), Anne Markwith (SAFC SSC), Alexei Sharov (SAFMC SSC), Steven Holmes (CIE), Mark Dickey-Collas (CIE), and Larry Jacobson (CIE).

The Review Panel unanimously concluded that the modeling approaches are appropriate, technically sound, suitable for use in the next operational assessment, and are expected to generate stock status information useful for management advice. The diagnostics were thorough and retrospective analysis and sensitivity runs did not show disconcerting patterns. Given the nature of this research track assessment, the Review Panel acknowledged that data input will change for the upcoming operational assessment and as a result, adjustments to the assessment model may have to be made but noted that none are expected to be fatal to the assessment. During the review a variety of data and model inputs, assumption, and uncertainties were discussed and detailed in this report. Some significant ones were the assumption of stock structure, use of one abundance index, ageing issues, reproductive parameters, and constant recruitment.

The Review Panel concluded that the assumption of one stock was reasonable but noted that the unit stock for the area should be investigated further, particularly in the north. There was considerable discussion of the use of only one abundance index. The Review Panel concluded that the one fishery independent index (the combined SERFS trap and video index) was appropriate for Gray Triggerfish in this assessment, but justification not to use other indices was not well documented. Possible trap saturation and geographic and habitat coverage of the survey were noted as sources of uncertainty. Gray Triggerfish age data was based on spines. A large number of spines of fish that have a current age above five years are being re-examined, but data was not available for the Assessment Team yet. The Review Panel acknowledged that for the operational assessment, these new age estimates may result in adjusted maximum age and consequent estimates of natural mortality, selectivity, growth parameter estimates, and may allow for an older +group. Gray Triggerfish desirability has increased over time, affecting recreational and commercial landings data uncertainty in the model, especially in earlier years of the time series. Longer-term, greater integration of environmental factors and ecosystem considerations in assessment models will be needed to help address species interactions and climate change effects. The Review Panel agreed with the choice of one growth model for sexes combined in the assessment model but recommended that the necessity and potential advantages for sex specific growth be considered in a next benchmark assessment. The assumption of constant average recruitment in the model was considered appropriate by the review panel. Modifications should be considered in the next assessment if conditions change (e.g., stock biomass declines markedly)

ADDRESSING THE REVIEW WORKSHOP TERMS OF REFERENCE

1) *Evaluate the data used in the assessment. Consider the following:*

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

The Review Panel focused on the assessment process and model and evaluated the data for their appropriateness and suitability in this context. The review Panel determined that the data were used appropriately and that the decisions were well documented and justified but discussed several data issues.

The Review Panel concluded that the assumption of one stock was reasonable but noted that the Gulf of Mexico outside the management area was not included, but the area outside the management area north of the North Carolina-Virginia border was. Gray Triggerfish in the western Atlantic is considered one population, and this is supported by genetic studies. In a future benchmark assessment, the appropriateness of unit stock for the area should be investigated further, particularly in the north.

Ageing, characteristics of Gray Triggerfish age data, and approaches to modeling age data were discussed extensively by the Review Panel. Gray Triggerfish can be aged using otoliths, but routine otolith collection is considered impractical due to the relative difficulty of removal and can affect fish value (e.g., for commercial catch), and otolith processing is laborious. The first dorsal spine is routinely used instead of otoliths to obtain sufficient age data for modeling. The traditional spine ageing techniques were deemed to produce reliable ages up to 5 years by experts at the Data Workshop. The Data Workshop also determined that spine-based ages determined using an updated technique were reliable up to age 8. The updated technique was used for the assessment data from 2015 onwards. A large number of spines of fish above age 5 will be re-examined by the data providers using the adjusted methodology. This is expected to align the new ages with the validated otolith and spine information. The Review Panel supports this re-examination.

The assessment modeling used age 5+ year as the plus-group up to 2015 and age 8+ years afterwards. Age error matrices were used in modeling the age data. These are standard and appropriate approaches to dealing with changes in ageing procedures and variance in ageing. These approaches can be used in the future if the historical age data are not revised for some reason although updated age data would be ideal in estimating mortality and age structure.

This assessment employed a single estimate of natural mortality (M) using the Then et al. (2015) method that was based on a maximum age of 16 years and scaled to age specific values according to Lorenzen, 1996. The Review Panel noted that a maximum age of 16 years was chosen rather than the 21 years reported in Shervette & Hernandez (2022). The explanation is that the otolith-based 21 years of the oldest fish could not be matched with a corresponding spine age. As a result, 16 years was chosen as this was the next oldest fish. The Review Panel noted that the M estimate based on a maximum age of 21 years was within the range of sensitivity runs. Assumptions about maximum age and natural mortality can be modified for the next assessment if more information becomes available, particularly after historical samples are re-aged. The vector of M at age was scaled based on the one 16-year-old fish. Review Panel members recommended that alternative methods be considered to estimate M in the next assessment (e.g., determine “maximum” age based on more than one fish).

The Review Panel acknowledged that the new age estimates for the older fish may have several consequences that should be considered in the next assessment, though none are expected to amount to a major obstacle:

- The maximum age may have to be adjusted, and consequently the estimation of M.
- Updated age compositions may affect the selectivity parameter estimates.

- As the current Von Bertlanffy parameter estimates are based on current spine-based data, the growth curve may have to be re-analyzed.
- It may allow for an older +group.

The Review Panel noted that Gray Triggerfish have sexually dimorphic growth. "*Because Gray Triggerfish exhibit sexually dimorphic growth, the Life History group also estimated growth of males and females separately. The data available for these models were limited due to the fact that fish are generally not assigned a sex during dockside sampling. The majority of samples used in these models were from the SERFS fishery-independent survey.*" (data workshop report PDF page 23). However, the Life History Working Group did not make a recommendation as to the use of sexual dimorphic growth in the assessment. In the current model, a single growth curve (both sexes combined) was used. The Assessment Lead explained that there is no sex (ratio) data available for landings or discards, so it would be difficult, if not impossible, to model dimorphic growth patterns and their effects on mortality and abundance. However, catch, age, size data and modeling were based on combined sex data so that data structure and model calculations were consistent. The assessment model measured female spawning biomass (SSB) as effective fecundity (number of eggs produced per year) considering age-specific sex ratios and female reproductive parameters, such as batch fecundity and number of batches, so some effects of dimorphic growth on fecundity were included in the modeling. The Review Panel agreed with the choice of one growth model for sexes combined in the assessment model and that it would be impractical to fully include sex specificity in the model at this time. There seemed to be no strong demonstrated shortcomings related to not including dimorphic growth and a major focus on the topic is probably not worth the effort at this time in terms of improving the current assessment model. However, the Review Panel considered it useful to examine sex data from commercial and recreational catch samples, and the recommends that the necessity and potential advantages for sex specific growth be considered in a next benchmark assessment.

There was considerable discussion on the use of stock size indices available for use in the assessment. The Assessment Team included only one index in the model, the combined fishery independent SERFS trap-video index. However, PDF page 133 in the Data Workshop Report lists three additional, fishery dependent CPUE indices for consideration without making a clear recommendation. The justification for using only one index was not clearly laid out in the assessment report. The Assessment Lead explained that there were questions about catchability in the fishery dependent CPUE for Gray Triggerfish over time, including effects of technological changes (e.g., the transition from LORAN to GPS location systems) and changes in desirability (from discarded to targeted species). The Data Workshop report described some of this (e.g., PDF page 138). Despite these concerns, the fishery dependent indices generally had good agreement with the SERFS trap-video index. Given this information, the Review Panel agreed that using one, fishery-independent index with desirable properties in terms of major habitat coverage and sample size, was appropriate for Gray Triggerfish in this assessment but the rationale for excluding the others should be clearly explained in an assessment report addendum and the next assessment. Additional indices can be added easily in future (benchmark) assessments if they are still available and deemed suitable.

The Review Panel recommended that current fishery independent surveys north of the North Carolina – Virginia border be examined in the next benchmark assessment as potential abundance indices and for climate related distribution effects (see also under TOR 3b).

The nature and properties of the multispecies SERFS trap/video survey was also discussed extensively. The combined survey (SERFS trap and video) was used because of the data dependency (video cameras are mounted on the traps) and lack of length (age) data available for the video index. The Review Panel supports this decision. The Review Panel agreed that the combined SERFS index was important and used appropriately in the assessment. The Review Panel's endorsement and recommendations for future research are based on good coverage of Gray Triggerfish habitat in the surveyed area, consistent methodology, and length of the survey. The Review Panel recommended for future assessments to investigate possible trap saturation, the geographical coverage of the survey relative to the stock (e.g. is the entire stock area surveyed?), and if the available Gray Triggerfish habitat is sampled with appropriate probability? These may stem from the fact that trap saturation can affect the assumed linear relationship with stock size, uncertainty about the correspondence between the sampling frame for the survey and Gray Triggerfish habitat, and lack of sampling north of Cape Hatteras and south of the St. Lucie area. All surveys have strengths and some weaknesses that require consideration and special attention in modeling. The SERFS index is a valuable resource for monitoring and managing Gray Triggerfish and other species.

Disparity in the survey abundance trend of Gray Triggerfish relative to the steeper decline in model estimated spawning stock biomass (SSB) was discussed extensively by the Review Panel (see Figures 23 and 27 in the assessment report). SSB was expressed as total egg production in this assessment (see bottom of page 18 of the assessment report). A close correspondence in trends between the survey and egg production may not be expected because the commercial and recreational fisheries for Gray Triggerfish have selected larger fish (that produce more eggs) in recent years with a disproportionate effect on overall egg production. Therefore, different trends for the survey and egg production are not necessarily evidence of poor model performance. The Review Panel noted that in the next assessment it would be good to clearly state in figures and tables how SSB is defined.

Catches, including commercial and recreational landing and discards, were recorded as low before and during the early 1980s when the model starts. The group discussed the accuracy of early catch data and the possibility of missing catch for early years. The market and commercial fishery for Gray Triggerfish were not well developed at this time and Gray Triggerfish was not strongly targeted in the recreational fishery (see also above). However, Gray Triggerfish are common as bycatch and discard mortality rates are relatively high (about 60%). If there was substantial fishing effort for any species, Gray Triggerfish were likely killed. The sensitivity runs exploring F_{init} suggested that the model results were not sensitive to F_{init}. Despite the uncertainty, the Review Panel accepted the use of these data streams based on the results of the sensitivity analysis and because no other information was available. However, these catch data are an important source of uncertainty in the current assessment and every effort should be made to understand potential effects of uncertain catch and to improve the data to improve the assessment.

The Review Panel discussed the relationship between batch fecundity and fish length. The current model uses a linear relationship with length, rather than a more traditional non-linear relationship. The Assessment Lead explained that the linear relationship was based on a paper by Lang and Fitzhugh (2015) where there was no significant difference in fit for linear and nonlinear models, possibly due to variability in the data. The Review Panel agreed with using the linear relationship but noted that size- and age-related reproductive parameters related to fecundity and spawning season should be further investigated (see also under TOR 4a).

b) Are data uncertainties acknowledged, reported, and properly characterized?

Some data uncertainties the Review Panel discussed are described above. Overall, the Review Panel felt that the data uncertainties were thoroughly characterized, and complimented the Assessment Team on how the uncertainty was investigated, reported, and handled in the assessment model.

c) For model derived data and parameter inputs (e.g. indices of abundance, life history quantities) are the methods appropriate?

The Review Panel concluded that the data and parameters inputs were appropriate for this assessment.

There was discussion about the decision to assume variability in recruitment around a constant average level, rather than using Beverton-Holt or other stock-recruit relationship function. Recruitment in the model was based on age-1 fish after Gray Triggerfish have started their demersal life and after density dependent effects may be readily estimated. Attempts to estimate stock recruitment parameters resulted in steepness close to 1. Low abundance of Gray Triggerfish has not been observed, complicating estimating a steepness parameter. A sensitivity run attempting to estimate steepness (S12) supported this. Steepness parameters from similar species can be used in modeling, but such information was not available for Gray Triggerfish. The model was capable of estimating substantial interannual variation in recruitment despite the assumption of a constant underlying mean. Problems estimating spawner-recruit curves and recruitment at low stock size are common in stock assessment work. The Review Panel ultimately agreed with the recruitment assumptions in the model. Modifications should be considered in the next assessment if conditions change (e.g., stock biomass declines markedly) or additional information becomes available.

2) Evaluate and discuss the strengths and weaknesses of the methods used to assess the stock, taking into account the available data. Consider the following:

a) Are the methods appropriate for the available data?

The assessment was based on the Beaufort Assessment Model (BAM) which is an integrated statistical catch at age model that has been extensively tested and used by the SEFSC for stock assessment of a variety of stocks in the South Atlantic where age structure information is available. The use of the model is appropriate because it allows the inclusion of information on size and age structure of the catches and surveys, fishery dependent and independent indices of abundance, and life history parameters (growth, natural mortality, maturity, fecundity). The Review Panel concluded that the modeling struck a good balance between parsimony and realism and did not estimate parameters for which there is too little information in the data. The time series of catch and age information was sufficient to estimate trends in abundance, biomass, fishing mortality, and spawning potential.

In addition to the BAM model, an Age Structured Production Model (ASPM) was used for supplementary analyses to compare with the primary statistical catch-at-age model. ASPMs can be viewed as a simplified version of statistical catch-at-age models due to the absence of any age or length composition data. The ASPM used was a direct modification of the full BAM, where age-structure is still represented but age-dependent processes and dynamics are fixed. The Review Panel agreed running the ASPM was a useful exercise because results highlighted the importance of age and length composition in BAM based estimates.

b) Are assessment models configured properly and used in a manner consistent with standard practices?

The Review Panel concluded that the assessment model was configured and used in an appropriate manner consistent with modern practices. As described below, several related assumptions and assessment decisions were discussed.

The constant recruitment assumption in modeling might make Gray Triggerfish appear too resilient to overfishing at low SSB levels, and this should be considered in choosing reference points. It may be possible to predict steepness for fish like Gray Triggerfish based on their biological characteristics or find estimates for similar species. This is a topic for the next benchmark assessment, particularly if abundance continues to decline.

The use of SSB defined as number of eggs was discussed by the Review Panel. In general, the Review Panel felt that the methods were justifiable, and results could be used to develop minimum stock size thresholds (MSST) and fishing mortality reference points.

Egg production was defined in modeling as the fraction mature females multiplied by batch size multiplied by the number of spawning events per year summed over all females in the population. Each of these factors changes with age. The complexity and data requirements are greater but all necessary information was available, and it is a good approach for Gray Triggerfish (see also comments under TOR 1a).

One effect of using egg production is that larger and older Gray Triggerfish are calculated to make a larger reproductive contribution to spawning potential than if calculations are based on spawning biomass. This changes the relationship between stock size or egg production and common reference points based on per-recruit modeling (see below). Changes in the relationship between egg production and reference points like F_{40} and $MSST_{40}$ for Gray Triggerfish needs to be better documented and should be considered in providing management advice (as detailed below).

The assessment used $F_{40\%}$ (the fishing mortality that reduces reproduction per recruit to 40% of the unfished level) as a proxy for F_{msy}. $F_{40\%}$ is a well-known proxy for F_{msy}. However, the simulation work that supports $F_{40\%}$ used spawning biomass instead of egg production in calculations. For Gray Triggerfish, reproductive output per unit weight increases with age, i.e. the relationship between spawning biomass and reproductive potential is not constant with age. This potentially implies a lower stock biomass at the target fishing mortality using egg production in place of spawning biomass for spawning potential. It may also be important to remember that spawner-recruit steepness and potential declines in recruitment at low spawning biomass are not considered in reference point calculations based on $F_{40\%}$. Where a stock-recruitment relationship is estimable, B_{msy} as a proportion of B_0 increases as steepness decreases. These points can be considered in developing harvest control approaches for Gray Triggerfish.

The Review Panel requested several additional analyses and figures to explore the potential disagreement between the SERFS trap/video index and the age compositions (see addendum to the assessment report). The additional analyses illustrated that recruitment events estimated in the model and index trends were in good agreement and that age composition data showed some year class signals.

Other sensitivity results suggested that there was a reasonable and appropriate balancing of size composition, age composition and survey data in the model. Model results were surprisingly robust to weights applied to different sources of information.

c) Were modeling issues clearly identified and addressed? If not, recommend potential methods for addressing these issues.

Modeling issues were clearly identified and addressed. The Review Panel noted that short-term projections were provided to allow a review of the methodology. Recent stock estimates, short-term projections and quota calculations are affected by lack of information about recent recruitment. The most reliable recruitment estimates are based on multiple years of data for the cohort. Constant recruitment at the virgin R_0 level was assumed in modeling the most recent three years for Gray Triggerfish and in projections for short-term catch calculations. This common approach reduces variance, but also biases projections and catch calculations high when recent recruitment is low (as it is currently), and biases them low when recent recruitment is high.

The Panel considered it would be useful to include short-term projections in a retrospective analysis to see if projections are capable of producing model estimates based on data in later years (hindcasting).

The sensitivity runs covered an appropriate suite of explorations and assumptions, and assisted the Review Panel with evaluating the model.

The examination of the retrospective analyses did not show concerning patterns.

3) Consider how uncertainties in the assessment are addressed.

a) Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty in the input data.

The Review Panel considered uncertainty well addressed through the Monte Carlo Bootstrap Ensemble (MCBE) method and by the sensitivity runs, and much appreciated the profiling and additional work. MCBE results further strengthened the view that the model was performing well in capturing the dynamics of the input data.

Uncertainty in natural mortality (M) was addressed in the assessment report through the sensitivity analysis. The Review Panel felt that it would be good to explore approaches outside the assessment modeling to reduce uncertainty in M (e.g., estimate M directly, see also Research Recommendation under TOR 4b below).

b) Comment on sources of uncertainty not accounted for and possible approaches for incorporating these sources into future assessments (e.g. ecosystem, management policies).

Climate change, ecosystem, and multispecies components were not incorporated in the model. The Review Panel noted that there are many general approaches to potentially incorporate these aspects in future assessments when they are identified (also see Research Recommendations). Other unaccounted uncertainties were fish movement and total available Gray Triggerfish habitat relative to the sampling frame for SERFS (see also under TOR 1a).

4) Provide, or comment on, recommendations to improve the assessment

a) Consider the research recommendations provided by the Data and Assessment workshops in the context of overall improvement to the assessment, and make any additional research recommendations warranted.

The Review Panel felt that there were too many research recommendations spread out over various report sections of the workshops, and that this list should be consolidated and prioritized prior to the Review Workshop to allow for a useful review. The Review Panel made an attempt to prioritize the provided recommendations for this assessment (see Figure 1).

The review panel discussed the research recommendations in the workshop reports, with the idea of using them as a resource to inform its deliberations. They were clustered and linked together and then, based on review panel discussions, they were categorized into short-term (before the next assessment) and longer-term researcher recommendations. They were also categorized across a gradient of high priority, to low priority in terms of bringing about improvements in the modelling and management advice for Gray Triggerfish (see Figure 1).

Additional Research Recommendations:

- The unit stock should be investigated further. Gray Triggerfish in the western Atlantic and the Gulf of Mexico is considered one population, and this is supported by genetic studies. The Review Panel noted that the Gulf of Mexico was not included but the area north of the North Carolina – Virginia border was. The appropriateness of unit stock for the area should be investigated further, particularly the inclusion of the area north of the Virginia-North Carolina border.
- Reproduction: Investigate the age varying batch fecundity, spawning frequency, and timing (length) of the spawning season as this affects estimates of population egg production.
- Examine current fishery independent surveys north of North Carolina – Virginia border for information.
- Studies of fish behavior in and around the traps, like the one reported in Bacheler et al. 2013 for Black Seabass, are recommended for Gray Triggerfish to further investigate processes affecting trap catch rates, such as trap saturation, and the (possibly non-linear) relationship with Gray Triggerfish abundance.

b) If applicable, provide recommendations for improvement or for addressing any inadequacies identified in the data or assessment modeling. These recommendations should be described in sufficient detail for application, and should be practical for short-term implementation (e.g., achievable within ~6 months). Longer-term recommendations should instead be listed as research recommendations above.

Recent stock estimates, short-term projections and quota calculations are affected by lack of information about recent recruitment. The most reliable recruitment estimates were based on multiple years of data for the cohort. Per standard SEFSC procedures, long-term recruitment (in this case constant recruitment at the virgin R_0 level) was assumed in modeling the last three years and for short-term catch projections. This common approach reduces variance but also biases projections and catch calculations high when recent recruitment is low (as it is currently) and biases them low when recent recruitment is high. The Review Panel recommended investigating recent trends or shifts in recruitment in future assessments to test whether other recent levels of recruitment are more appropriate for the projection recruitment estimates.

It may be useful to include short-term projections in retrospective analyses i.e., to see if projections are capable of reproducing model estimates based on data in later years (see also under TOR 2c).

5) Provide recommendations on possible ways to improve the Research Track Assessment process.

The Review Panel felt that it would be good to structure the Review Workshop such that there is a clearer separation between the presentation of the data and the assessment model. This will allow more opportunity to discuss the data before the start of the assessment model presentation and discussion. Related, the Review Panel noted that the availability of Data Workshop Lead(s) to present the data, clarify data issues, and answer questions would have been very helpful in the review.

Some Review Panel members commented that the total volume of documents was rather large, which may have complicated their review, and felt that providing just or at least identifying the most critical documents may assist reviewers with preparing for the review more efficiently. At minimum, they felt that it would be useful to have a clearer understanding of which documents were to be reviewed and which are optional background provided as extra information.

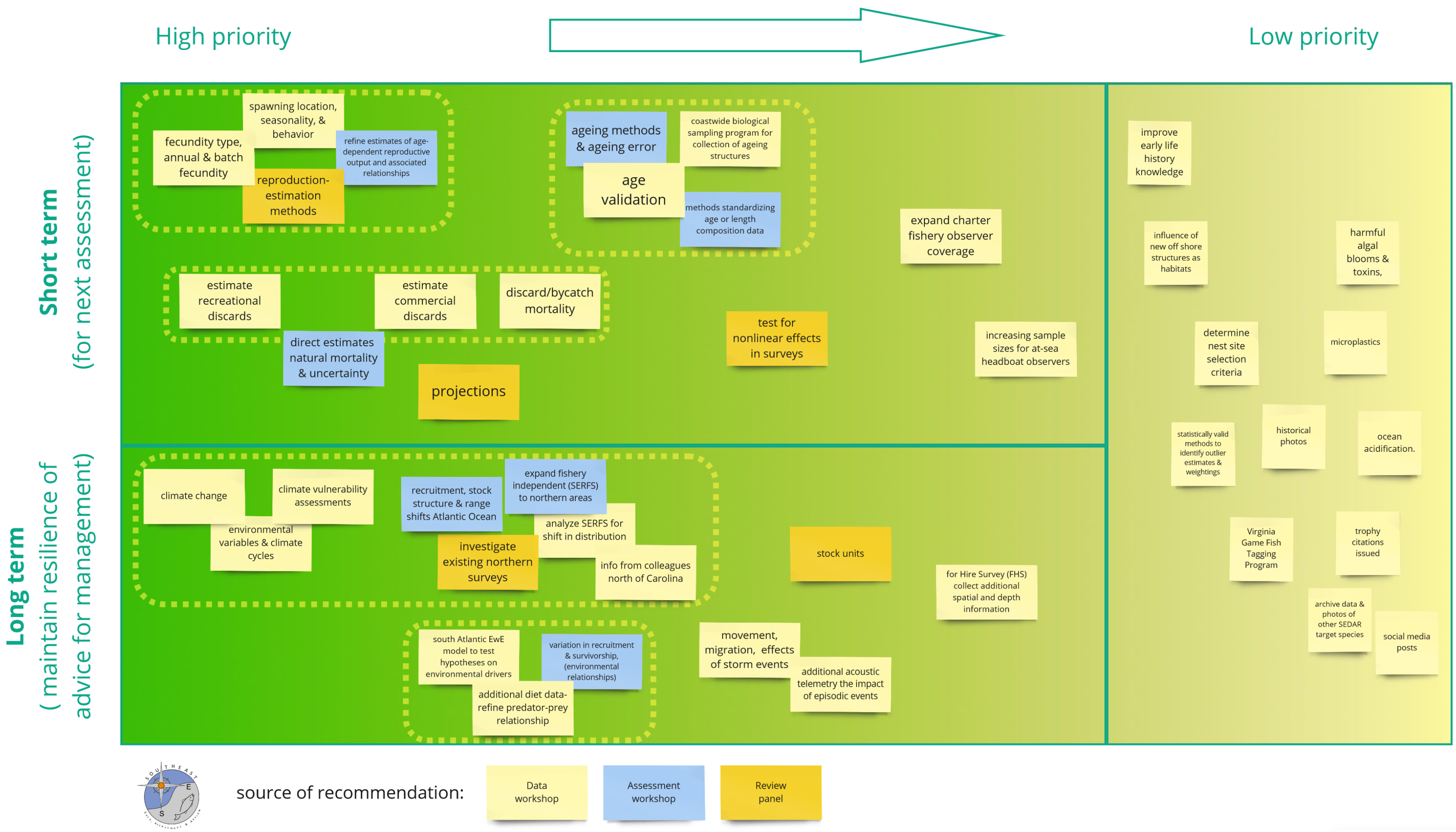
The Review Panel recommends considering modeling and management approaches likely to be successful as climate and marine ecosystems change. Abundance, distribution, and productivity of Gray Triggerfish are likely to change but current stock assessment, stock definitions and management approaches assume that the past is representative of the future. Based on TOR, assessments should explicitly consider the possibility of bias and other errors due to climate change when making modeling decisions and providing management advice.

The Review Panel was primarily male (incl. all white male CIE reviewers of similar age). It is recommended that diversity, equity, and inclusion be considered in assembling future Review Panels. Such a policy would help develop (train) future reviewers and help expand the pool of highly skilled personnel available to review assessments.

6) Prepare a Review Workshop Summary Report describing the Panel's evaluation of the Research Track stock assessment and addressing each Term of Reference.

The review report was completed and submitted to SEDAR staff on 04/22/2024.

Figure 1. The review panel considered the research recommendations listed by the data and assessment workshops, and the research areas that the review panel felt needed addressing (TORs 3a and 3b). The recommendations are considered in terms of short-term and long-term research across a gradient of priorities to improve the stock assessments and management advice.



SEDAR

Southeast Data, Assessment, and Review

SEDAR 82

South Atlantic Gray Triggerfish

SECTION VI: Post Review Workshop Addenda

April 2024

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SEDAR 82 Review Workshop: Sensitivity to ratio of weighting on survey index and age compositions

Nikolai Klibansky

28 March, 2024

Description

At the SEDAR 82 Review Workshop, reviewers requested further analysis of tradeoffs between fitting the survey index and age compositions. The group developed an analysis where the survey index was upweighted as the age compositions were downweighted, such that the ratio of the index to age composition weighting (i.e. weight ratio) varied from 0.04 to 25. A set of 9 sensitivity runs was generated, each employing a different combination of weights. The weighting terms were multiplied by the likelihood components associated with the index and age compositions in the objective function. Dirichlet multinomial overdispersion parameters associated with the age compositions were fixed at zero for these sensitivity runs. Other aspects of each run were the same as in the base model. When generating likelihood profiles associated with the index or age compositions, the resulting likelihood components were divided by the weighting terms which had been applied during fitting. The separate age composition likelihood components were then summed to generate on overall profile for age compositions. These likelihoods were then converted to delta log likelihoods, by taking the set of 9 log likelihoods for each component (i.e. index or age compositions) minus the minimum log likelihood among all runs for that component. This allows the likelihood profiles from separate components to be displayed more easily in a plot.

Interpretation

Likelihood profiling showed the SERFS trap/video likelihood component decreased as the weight ratio increased and the age composition likelihood component increased (Fig. 1). When the weight ratio was 1 as in the base model, the age composition likelihood component was closer to it's minimum than the index component. This suggests that if we decrease the weight ratio to try to fit the age compositions better, the fit does not improve very much compared with how much the fit to the index worsens. Going in the other direction, when the weight ratio increases, upweighting the index, the fit to the age composition worsens (i.e. delta likelihood increases) about as fast as the fit to the index improves. Note that the run with the weight ratio of 1 is not equal to the base model result because the Dirichlet multinomial parameters were fixed in this analysis.

As the weight ratio increases, the fit to the index improves, as expected (Fig. 2). The base run fit is similar to the run with a weight ratio of 1, but not identical. Time series trends in predicted recruitment are generally similar, but are shifted up or down based on varying estimates of unfished recruitment (R_0; Fig. 3).Sensitivity runs with weight ratios of 1-2.5 and the base run were near the top of the set of recruitment time series because they had the highest R_0 estimates. Decreasing or increasing the weight ratio led to lower estimates of R_0, but the overall range was modest and much smaller than the range of R_0 values in the Monte Carlo Bootstrap Ensemble analysis performed for the SEDAR 82 assessment (see SEDAR 82 report). Time series trends in fishing mortality and stock size, relative to benchmarks (F/F_{40}, $SSB/MSST_{F40}$) show more variation than recruitment, but were still moderate compared to analogous plots from the MCBE analysis (SEDAR 82 Report).

Overall this set of sensitivity analyses suggested that the model results were fairly consistent when the ratio of the weights applied to the SERFS trap/video index and the age compositions were varied over a wide range.

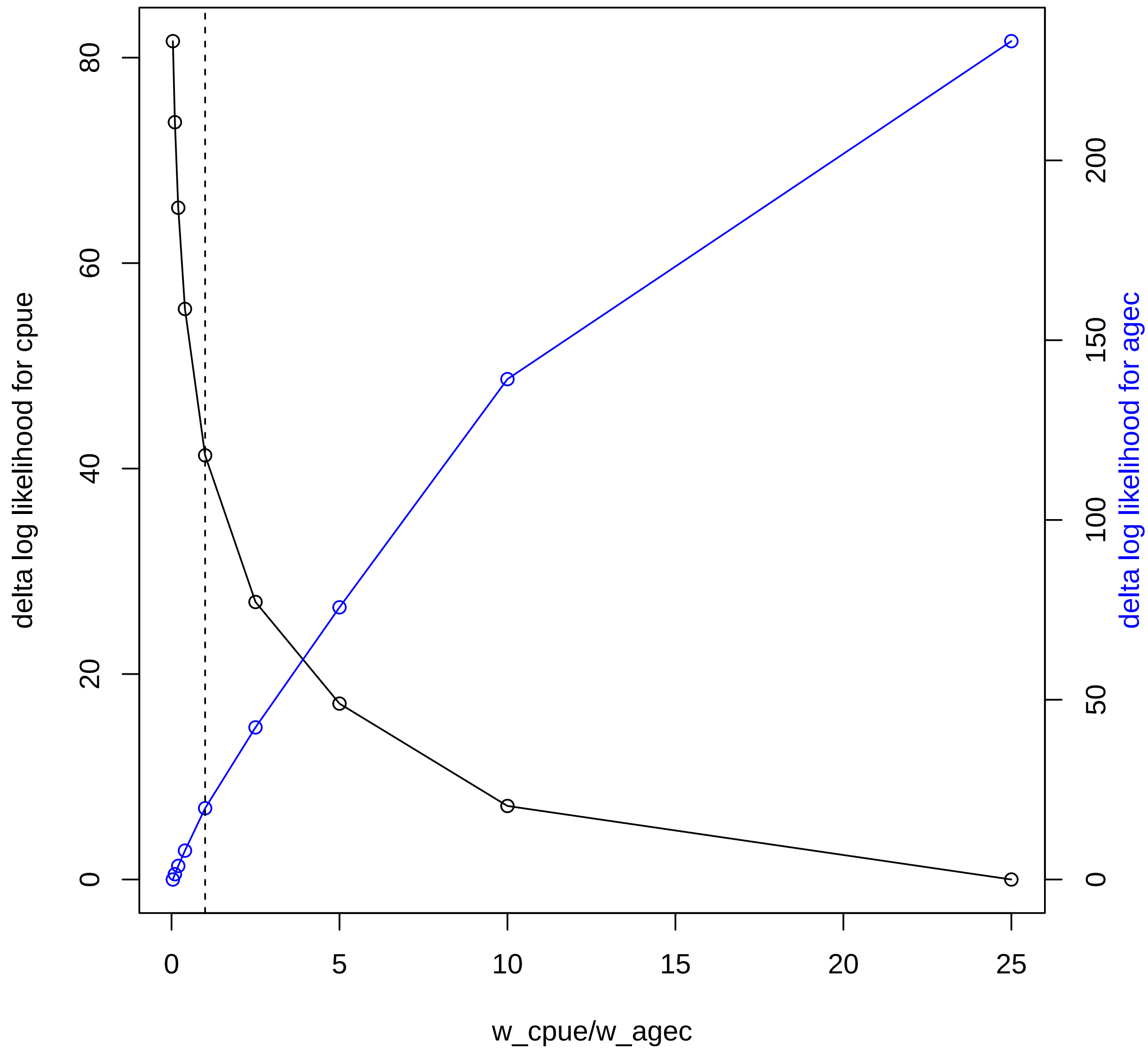

Figure 1: Weight ratio (w_cpue/w_agec) plotted against the delta log likelihoods for the SERFS trap/video index (black line; left y-axis) and age compositions (blue line; right y-axis). The delta log likelihood is the log likelihood for each run minus the minimum log likelihood among all runs. The vertical dashed line is plotted at a weight ratio of 1 to emphasize the likelihood components where the weights were equal. Note that this run is not equal to the base model result because the Dirichlet multinomial parameters were fixed in this analysis.

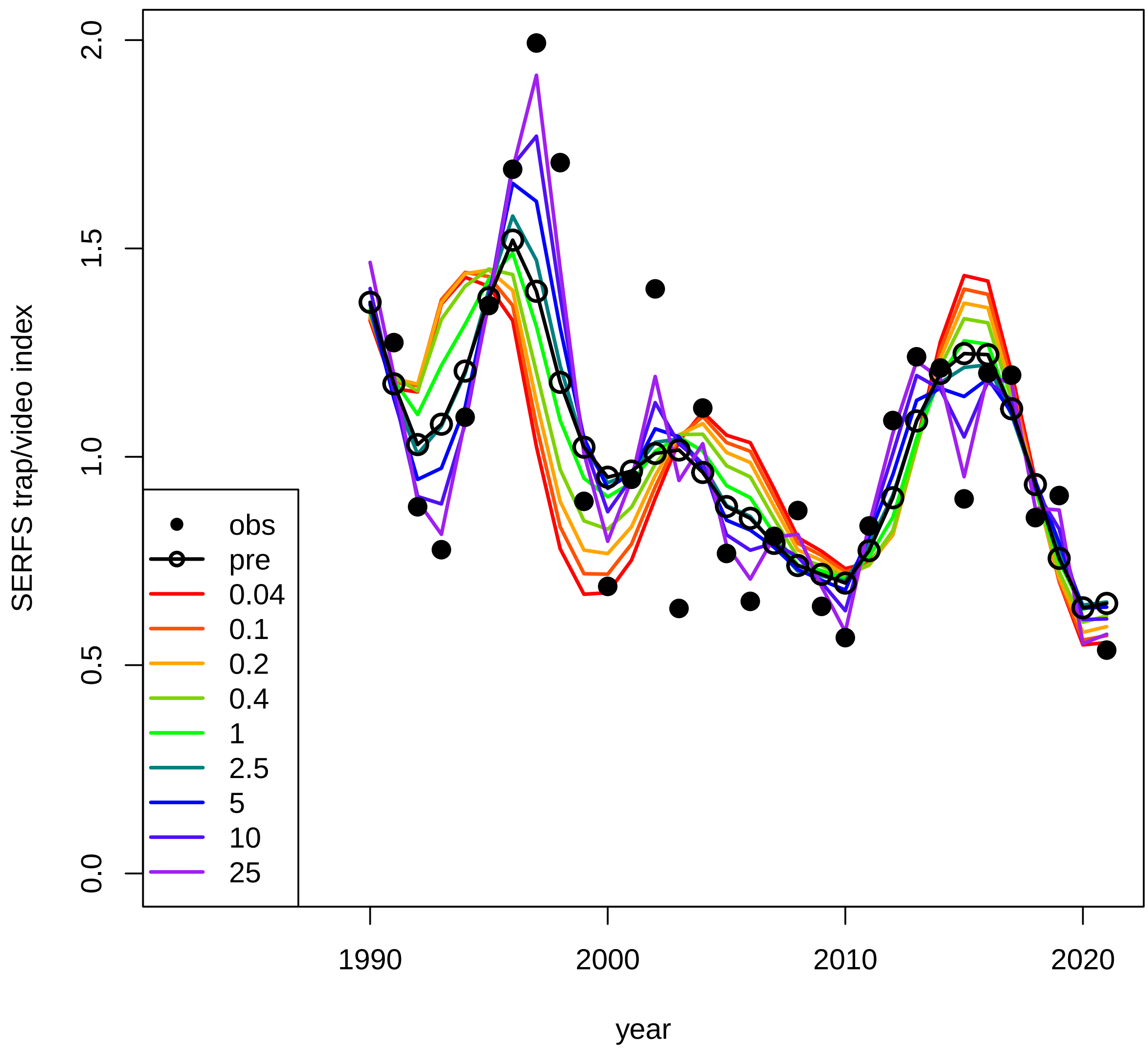

Figure 2: Observed (solid black points), base model predicted (black circles with solid black line), and sensitivity run predicted (colored lines) SERFS trap/video index for each of the sensitivity runs. The legend shows the weight ratios associated with each run, the colors of the corresponding lines, and the symbols used to plot the observed and base run predicted time series.

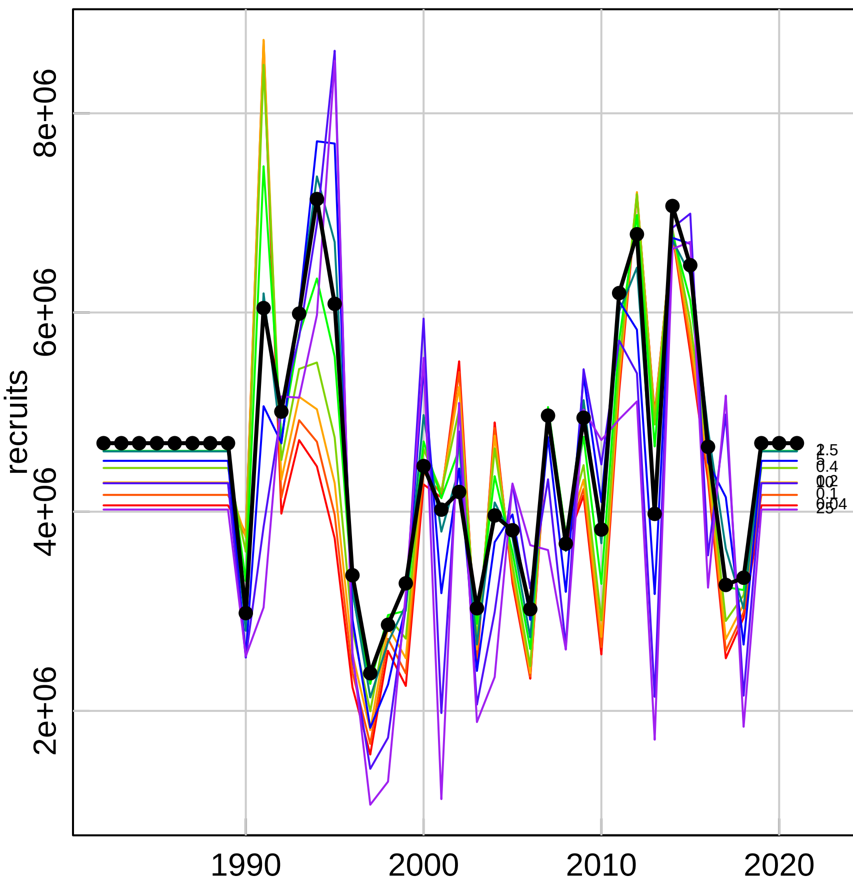

Figure 3: Predicted recruitment time series for each of the sensitivity runs (colored lines) and the base run (black line and points). Labels to the right of each time series indicate weight ratios associated with each run.

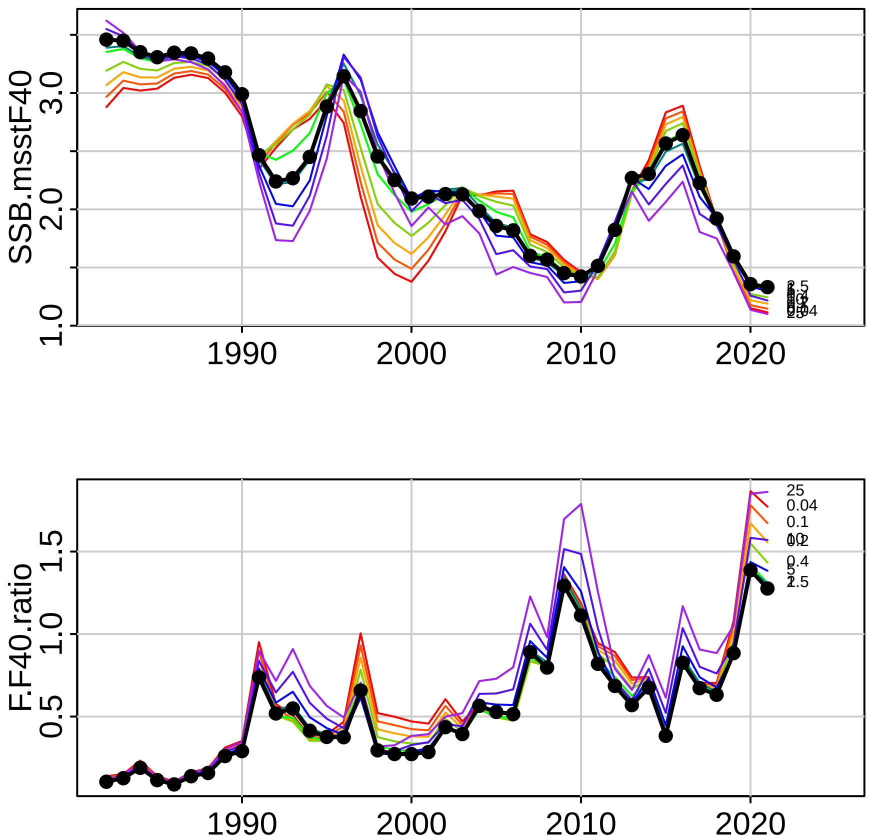

Figure 4: Stock and fishery status time series for each of the sensitivity runs (colored lines) and the base run (black line and points). Labels to the right of each time series indicate weight ratios associated with each run.

Selection of indices of abundance for the SEDAR 82 gray triggerfish stock assessment

Nikolai Klibansky

March 28, 2024

The SEDAR 82 CIE review panel requested additional documentation regarding the selection of indices of abundance used in the assessment. The original documentation on this topic was provided under subsubsection 2.2.3 Indices of Abundance in the SEDAR 82 assessment report (SEDAR 2024). The additional documentation requested by the reviewers is provided in this addendum by modifying the original text from subsubsection 2.2.3. Note that the SEDAR 82 report (released February 27, 2024) has not been modified to reflect these modifications.

2.2.3 Indices of abundance

Two fishery independent indices of abundance were recommended for potential use in SEDAR 82 by the data workshop (SEDAR82-DW 2023): SERFS chevron trap (1990-2021; Bubley and Willis 2022) and SERFS video index (2011-2021; Bacheler et al. 2022). These indices were developed from the SERFS which deploys chevron traps with video cameras mounted on them. Trap and video data are paired. The separate indices showed very similar trends and were combined into a single SERFS trap/video index using an averaging approach (Conn Method; Conn 2010) for use in the current assessment. The resulting index and CVs are presented in Table 4.

Three fishery dependent indices of abundance based on standardized catch per unit effort (CPUE) were also recommended for potential use in this assessment by the data workshop (SEDAR82-DW 2023), and were considered by the assessment panel, but were not selected for use. These indices were the commercial logbook landings index (1993-2009; SFB-NMFS 2014), recreational Southeast Regional Headboat Survey (SRHS) index (1995-2009; SFB-NMFS 2015), and the recreational headboat-at-sea landings index (2010-2019; Fitzpatrick 2022). The commercial index and headboat landings index had both been developed for SEDAR 41, 2016 Benchmark but had not been used in that model due changes in targeting by the fishing fleets that couldn't be accounted for by the standardization process and conflicts with the fishery independent indices. These concerns remained in the current assessment. In addition, these indices represented a similar size range of fish and a similar spatial range as the SERFS trap/video index, but over a substantially shorter time series. Therefore they were again excluded from the assesment of South Atlantic Gray Triggerfish. The headboat-at-sea landings index, which is different than the SRHS index and a headboat-at-sea discard index (see SEDAR82-DW 2023) showed a very similar trend as the SERFS trap/video index in years where they overlapped, and represented a similar size range of fish and spatial range. The length of the time series was considerably shorter than the SERFS trap/video index, and the data workshop panel noted general concerns with the fishery-dependent nature of the index, thus it was judged that including it in the model would not be an improvement.

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