Southeast Data, Assessment, and Review

SEDAR 58
Atlantic Cobia

Stock Assessment Report

January 6, 2020

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

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SECTION I: Introduction

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I. Introduction

SEDAR 58 addressed the stock assessment for Atlantic Cobia. A Stock ID Workshop was held June 5-7, 2018 in Charleston, SC. The Data Workshop was held April 1-5, 2019 in Charleston, SC. The SEDAR 58 Assessment Process was conducted through a series of webinars held from April to October 2019. The Review Workshop (RW) took place November 19-21, 2019 in Beaufort, NC.

The Stock Assessment Report is organized into six sections. Section I is the Introduction which contains a brief description of the SEDAR Process, Assessment, and Management Histories for the species of interest, and the management specifications requested by the Cooperator. Section II is the Data Workshop Report. It documents the discussions and data recommendations from the Data Workshop Panel. Section III is the Assessment Report. This section details the assessment model, as well as documents any changes to the data recommendations that may have occurred after the Data Workshop. Section IV is the Addenda and Post-Review Workshop Documentation which consists of any analyses conducted during or after the RW to address reviewer concerns or requests. It may also contain documentation of the final RW-recommended base model, should it differ from the model put forward in the Assessment Report for review. Consolidated Research Recommendations from all three stages of the process (data, assessment, and review) can be found in Section V for easy reference. Finally, Section VI documents the discussions and findings of the Review Workshop.

The final Stock Assessment Report (SAR) for Atlantic Cobia was disseminated to the public in January 2020. The Atlantic States Marine Fisheries Commission's (ASMFC) Cobia Technical Committee (TC) will review the SAR to develop options for harvest quotas within the management unit. The TC may request additional projection model runs to define options that they will provide to the ASMFC's South Atlantic State/Federal Fisheries Management Board (Board). Documentation on TC recommendations is not part of the SEDAR process and is handled through ASMFC. The Board will review the SAR, consider use of the recommended reference points, and consider harvest quota options at their February 2020 meeting.

1. SEDAR Process Description

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

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

SEDAR is typically organized around three stages. First is the Data Stage, where a workshop is held during which fisheries, monitoring, and life history data are reviewed and compiled. Second is the

Assessment Stage, which is conducted via a workshop and/or series of webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. The final stage is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products. The completed assessment, including the reports of all 3 workshops and all supporting documentation, is then forwarded to the Council SSC for certification as 'appropriate for management' and development of specific management recommendations.

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

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

2. Cobia Management Overview

2.1 South Atlantic Fishery Management Plan and Amendments

The following summary describes only those management actions that likely affect Atlantic and Florida East Coast Zone cobia fisheries and harvest.

SAFMC FMP Amendments affecting Atlantic and Florida East Coast Zone Cobia

Description of Action	FMP/Amendment	Effective Date
• Cobia added to fishery management unit. • *Management Objective*: Institute management measures necessary to increase yield per recruit and average size and to prevent overfishing. • Maximum Sustainable Yield (MSY) is estimated at 1,057,000 pounds, Estimated Domestic Annual Harvest (EDAH) is estimated at 1,000,000 pounds (in 1981), and Total Allowable Level of Foreign Fishing (TALFF) is zero. • Optimum Yield (OY) is defined as all cobia equal to or larger than 33 inches in length from the tip of the head to the center of the tail (fork length) which can be harvested by U.S. fishermen given prevailing economic conditions and fishing techniques. • Minimum size limit for recreational and commercial is 33 inches FL.	Original FMP LINK	02/04/1983
• Establish fishing year as January 1-December 31. • Clarify minimum size limit is 33 inches FL *or* 37 inches TL. • *Identified problem*: Cobia are presently harvested at a size below that necessary for maximum yield and may be overfished in some areas beyond the management area. Most southeastern states have not yet adopted the recommended minimum size limit. Also, no management action has been taken by states which have jurisdiction over cobia populations in Chesapeake Bay, which appear to have been overfished. Federal enforcement capability is limited and not believed to be very effective in this case.	Amendment 1 LINK	09/22/1985

• Annual permits are required for charter boats fishing for coastal migratory pelagics for hire. Charter boats normally fish under bag limits but may also be eligible to obtain commercial permits to fish under the commercial quota when not under charter. • Permits are issued for an April through March permit year, are available at any time, and are valid through the following March. Permits for the following permit year become available in February.	Amendment 2 LINK	*CH vessel permit requirement*: 08/24/1978 *All else*: 06/30/1987
• Prohibited drift gill nets for coastal pelagic species.	Amendment 3 LINK	08/14/1989
• *Identified problem*: The condition of the cobia stock is not known and increased landings over the last ten years have prompted concern about overfishing. • *Definition of overfishing*: ○ A mackerel or cobia stock shall be considered overfished if the spawning stock biomass per recruit (SSBR) is less than the target level percentage recommended by the assessment group, approved by the Scientific and Statistical Committee (SSC), and adopted by the Councils. The target level percentage shall not be less than 20 percent. ○ When a stock is overfished (as defined in (a)), the act of overfishing is defined as harvesting at a rate that is not consistent with a program to rebuild the stock to the target level percentage, and the assessment group will develop ABC ranges for recovery periods consistent with a program to rebuild an overfished stock. ○ When a stock is not overfished (as defined in (a)), the act of overfishing is defined as a harvest rate that if continued would lead to a state of the stock that would not at least allow a harvest of OY on a continuing basis, and the assessment group will develop ABC ranges based upon OY (currently MSY). • Added cobia to the Annual Stock Assessment procedures. • Bag limit 2-fish/person/day with 1-day possession limit.	Amendment 5 LINK	08/20/1990
• Specify the minimum size limit is 33”FL (removed 37” TL) • Changed MSY=2.2 million pounds based on results from 1992 Report of the Mackerel Stock Assessment Panel.	Amendment 6 LINK	12/03/1992

• *Identified problem*: Localized reduction of fish abundance due to high fishing pressure. • Extended management of cobia through NY (i.e. through the jurisdiction of the MAFMC); extended 2-fish bag limit and 33” FL minimum size limit through the MAFMC’s area. • Required additional information on each species, including cobia, from the Assessment Panel. • *Overfishing Definition*: For species like cobia, when there is insufficient information to determine whether the stock or migratory group is overfished (transitional SPR), overfishing is defined as a fishing mortality rate in excess of the fishing mortality rate corresponding to a default threshold static SPR of 30 percent. If overfishing is occurring, a program to reduce fishing mortality rates to at least the level corresponding to management target levels will be implemented. • Modified the Stock Assessment Panel process. • Optimum Yield (OY) for cobia is set at MSY, currently 2.2 million pounds, in accord with the recommendation of the SPRMSC that, because of limited data, SPR not be used for cobia.	Amendment 8 LINK	04/03/1998
• Addressed Sustainable Fishery Act definitions. o Optimum Yield (OY) for the coastal migratory pelagic fishery is the amount of harvest that can be taken by U.S. fishermen while maintaining the Spawning Potential Ration (SPR) at or above 40% Static SPR. o Overfishing for all species in the coastal migratory pelagics management unit is defined as a fishing mortality rate (F) in excess of the fishing mortality rate at 30% Static SPR (F30% Static SPR). The “threshold level” for all species in the coastal migratory pelagic management unit is defined as 10% Static SPR.	Amendment 11 LINK	12/02/1999
• Established Essential Fish Habitat (EFH) in the South Atlantic.	Amendment 10 LINK	07/14/2000
• Updated existing EFH information for the Coastal Migratory Pelagics FMP (not regulatory).	Amendment 19 LINK	07/22/2010

• Established separate Gulf and Atlantic migratory stocks at the SAFMC/GMFMC boundary. • Set the MSY, Minimum Stock Size Threshold (MSST), and Maximum Fishing Mortality Threshold (MFMT) for Atlantic migratory group cobia. ○ MSY is the value from the most recent stock assessment. Currently MSY is unknown. ▪ ABC for Atlantic migratory group Cobia will be used as a proxy for MSY pending results from the SEDAR assessment. ○ The value for MSST is the value from the most recent stock assessment based on MSST = [(1-M) or 0.5 whichever is greater]*BMSY. Currently MSST is unknown. ○ The value for MFMT is the value of FMSY or proxy of F30%SPR from the most recent stock assessment. Currently MFMT is unknown. • The total ACL for Atlantic migratory group cobia will be used to determine whether overfishing is occurring. Currently OFL is unknown. • Adopt the Gulf Council's ABC Control Rule as an interim control rule. ○ ABC equals the mean plus 1.5 times the standard deviation of the most recent 10 years of landings data (1,571,399 lb whole weight). • Define allocations for Atlantic migratory group cobia based upon landings from the ALS, MRFSS, and headboat databases. The allocation would be based on the following formula for each sector: ○ Sector apportionment = (50% * average of long catch range (lbs) 2000-2008 + (50% * average of recent catch trend (lbs) 2006-2008). ▪ 8% commercial ▪ 92% recreational. • Annual Catch Limit (ACL) for Atlantic migratory group cobia: ACL = OY = ABC (currently 1,571,399 lb based on the SSC Interim Control Rule) ○ Recreational Sector ACL = 92% = 1,445,687 lbs. ○ Commercial Sector ACL = 8% = 125,712 lbs. • The recreational sector ACT equals sector ACL[(1-PSE) or 0.5, whichever is greater] (currently 1,184,688 lb). No commercial sector ACTs for Atlantic migratory group cobia.	Amendment 18 LINK	01/30/2012

• *Commercial AM for Atlantic migratory group cobia*: prohibit harvest, possession, and retention when the commercial quota (total ACL x commercial allocation) is met or projected to be met. All purchase and sale is prohibited when the commercial quota is met or projected to be met. o Commercial payback of overage: payback only if overfished - If the commercial sector ACL is exceeded, the Assistant Administrator for Fisheries shall file a notification with the Office of the Federal Register to reduce the commercial sector ACL in the following year by the amount of the overage. ▪ Only deduct overages if the Total ACL is exceeded. • *Recreational AM for Atlantic migratory group cobia*: if the recreational sector quota (total ACL x recreational allocation) is exceeded, the RA shall publish a notice to reduce the length of the following fishing year by the amount necessary to ensure landings do not exceed the recreational sector quota for the following fishing year. o Compare the recreational ACL with recreational landings over a range of years. For 2011, use only 2011 landings. For 2012, use the average landings of 2011 and 2012. For 2013 and beyond, use the most recent three-year (fishing years) running average. If in any year the ACL is changed, the sequence of future ACLs will begin again starting with a single year of landings compared to the ACL for that year, followed by two-year average landings compared to the ACL in the next year, followed by a three-year average of landings ACL for the third year and thereafter. ▪ Only adjust the recreational season length if the Total ACL is exceeded. o Recreational payback of any overage from one year to the next: payback only if overfished - If the recreational ACL is exceeded, the Assistant Administrator for Fisheries shall file a notification with the Office of the Federal Register to reduce the recreational ACL in the following year by the amount of the overage. The ACT would also be adjusted according to the ACT formula. ▪ Only deduct overages if the Total ACL is exceeded.	Amendment 18 continued	01/30/2012
• Limit harvest and possession of coastal migratory pelagic species (with the use of all non-prohibited fishing gear) in the Special Management Zones (SMZs) off South Carolina.	Amendment 21 LINK	01/30/2012

• Requires weekly electronic reporting for headboats in South Atlantic	Amendment 22 LINK	01/27/2014
• Modified the boundary between Gulf migratory group cobia and Atlantic migratory group cobia to the GA/FL line. • The Atlantic migratory group ACL would be equal to the ABC for the Atlantic migratory group cobia (as determined by the SSCs). ○ Atlantic cobia ABC=ACL= 690,000lbs for 2015; 670,000lbs for 2016+ • The Gulf migratory group cobia ABC (as determined by the SSCs) would be divided into a Gulf Zone ACL and a Florida East Coast Zone ACL (Florida/Georgia border to the Gulf and South Atlantic Councils jurisdictional boundary) based on 1998-2012 (15 years) landings to establish the percentage split for the Gulf ABC. ○ Allocated 36% of the Gulf ACL to the Florida east coast zone cobia (FLEC ACL= 900,000lbs 2015; 930,000lbs 2016+)	Amendment 20B LINK	03/1/2015
• SAFMC considering removing Atlantic migratory cobia from the CMP Fishery Management Plan	Amendment 31	Under development; anticipate taking final action later in 2018

SAFMC Regulatory Amendments affecting Atlantic and Florida East Coast Zone Cobia

Description of Action	FMP/Amendment	Effective Date
For Atlantic cobia only • Recreational minimum size limit of 36" FL. • Recreational bag limit of 1 fish per person per day or 6 per vessel per day (whichever is more restrictive). • Commercial trip limit of 2 fish per person per day or 6 fish per vessel per day (whichever is more restrictive). • Recreational AM: next year's landings are monitored for persistent increase in landings. ○ If necessary, the length of the following fishing season will be reduced to ensure that recreational landings meet the recreational ACT but do not exceed the recreational ACL (based on recreational landings in the previous year). ▪ only if the STOCK ACL is exceeded. ○ If necessary, reduce the recreational vessel limit for the following fishing year to ensure that recreational landings meet the recreational ACT but do not exceed the recreational ACL (based on the recreational landings in the previous year). ▪ Only if the STOCK ACL is exceeded. • Cobia removed from limited harvest species list.	Framework Amendment 4 LINK	09/05/2017

2.2 Emergency and Interim Rules - None for cobia.

2.3 Secretarial Amendments - None for cobia.

2.4 Control Date Notices - None for cobia.

2.5 Management Program Specifications

2.5.1 Table General Management Information South Atlantic

Species	Cobia (*Rachycentron canadum*)
Management Unit	Atlantic cobia: Mid-Atlantic and Southeastern US to GA/FL border Florida East Coast zone cobia: From the GA/FL border to the jurisdictional boundary between the Gulf and South Atlantic Councils.
Management Unit Definition	Atlantic cobia: All waters from the intersection of New York, Connecticut, and Rhode Island to a line extending due east of the Florida/Georgia border. Florida East Coast zone cobia: the EEZ south and east of the line of demarcation between the Atlantic Ocean and Gulf of Mexico, and south of a line extending due east of the Florida/Georgia border.
Management Entity	South Atlantic Fishery Management Council (Note: Mid-Atlantic Council participates as voting member on South Atlantic Council's Mackerel Cobia Committee.)
Management Contacts **SERO / Council**	SAFMC: Christina Wiegand SERO: Karla Gore
Current stock exploitation status	Not undergoing overfishing
Current stock biomass status	Not overfished

2.5.2 Table Management Parameters Atlantic Cobia

Criteria	**South Atlantic – Current (SEDAR 28)**			
	Definition	**Base Run Values**	**Units**	**Median of Base Run MCBs**
M	Average of Lorenzen M (if used)	0.26	Instantaneous natural mortality; per year	-
$F_{CURRENT}$	Geometric mean of apical fishing mortality rates for 2009-2011 ($F_{2009-2011}$)	0.276	Per year	-
F_{TARGET}	-	-	-	-
Yield at F_{TARGET} (equilibrium)	-	-	-	-
F_{MSY}	F_{MSY}	0.461	Per year	-
B_{MSY}	Biomass at MSY	1991.6	Metric tons	-
R_{MSY}	-	-	-	-
SSB_{2011}	Spawning stock biomass in 2011	693	Metric tons	
SSB_{MSY}	Spawning stock biomass at MSY	536.8	Metric tons	
MSST	MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}	397.2	Metric tons	-
MFMT	F_{MSY}	0.461	Per year	-
MSY	Yield at F_{MSY}	808	1000 lb	-
OY	Yield at F_{OY}	-	-	-
F_{OY}	F_{OY} = 65%,75%, 85% F_{MSY}	65% FMSY = 0.299 75% FMSY=0.345 85% FMSY=0.391	-	-
Exploitation Status	$F_{2009-2011}/F_{MSY}$	0.599	-	-
	F_{2011}/F_{MSY}	0.423	-	
Biomass Status[1]	SSB_{2011}/MSST	1.75	-	-
	SSB_{2011}/SSB_{MSY}	1.29	-	
Terminal F (2011)	F_{2011}	0.195	-	-
Terminal Biomass (2011) [1]	SSB	693	mature female weight, metric tons	-
Generation Time	-	-	-	-
$T_{REBUILD}$ (if appropriate)	-	-	-	-

Criteria	**South Atlantic – Proposed (SEDAR 58)**			
	Definition	**Base Run Values**	**Units**	**Median of Base Run MCBs**
M	Average of Lorenzen M (if used)			
$F_{CURRENT}$	Geometric mean of apical fishing mortality rates (F)			
F_{TARGET}	-			
Yield at F_{TARGET} (equilibrium)	-			
F_{MSY}	F_{MSY}			
B_{MSY}	Biomass at MSY			
R_{MSY}	-			
SSB	Spawning stock biomass			
SSB_{MSY}	Spawning stock biomass at MSY			
MSST[1]	MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}			
MFMT	F_{MSY}			
MSY	Yield at F_{MSY}			
OY	Yield at F_{OY}			
F_{OY}	FOY = 65%,75%, 85% F_{MSY}			
Exploitation Status	F/F_{MSY}			
	F/F_{MSY}			
Biomass Status[1]	SSB/MSST			
	SSB/SSB_{MSY}			
$F_{CURRENT}$	-			
Terminal Biomass [1]	-			
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 SSC. This may be total, spawning stock or some measure thereof, and should be applied consistently in this table.
- 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.

2.5.3 Table 2.5.3. Stock Rebuilding Information

2.5.4 Stock not overfished, so no rebuilding plan in place. Table 2.5.4. General Projection Specifications *South Atlantic*

First Year of Management	Late-2021 or mid-2022
Interim basis	Ask SEDAR 58 Panel to provide guidance on appropriate assumptions to address harvest and mortality levels in interim years; recent SEDAR assessments have asked for ACL, if ACL is met Average exploitation, if ACL is not met.
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 . Table 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 Table P-star projections. Short term specifications for OFL and ABC recommendations. Additional P-star projections may be requested by the SSC once the ABC control rule is applied.

Basis	Value	Years to Project	P* applies to
P*	50%	Interim + 5	Probability of overfishing
P*	40%	Interim + 5	Probability of overfishing
Exploitation	F_{MSY}	Interim + 5	NA
Exploitation	75% of F_{MSY}	Interim + 5	NA

2.5.7 Table Quota Calculation Details

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

	Atlantic Cobia	**FLEC Cobia**
Current Acceptable Biological Catch (ABC) and Total Annual Catch Level (ACL) Value for Cobia	ACL = ABC = OY ACL = 670,000 lbs	ACL = 36% ABC ACL = 930,000 lbs
Commercial ACL for Cobia	8% ACL = 50,000 lbs	8% ACL = 70,000 lbs
Recreational ACL for Cobia	92% ACL = 620,000 lbs	92% ACL = 860,000
Next Scheduled Quota Change	None	None
Annual or averaged quota?	Annual	Annual
If averaged, number of years to average	-	-
Does the quota include bycatch/discard?	No	No

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

- Gulf Council's ABC Control Rule: ABC equals the mean plus 1.5 times the standard deviation of the most recent 10 years of landings data.
  - *NOTE*: The Gulf's ABC Control Rule was adopted for Atlantic cobia as an interim control rule until results from SEDAR 28 became available (ABC value derived by the Gulf Council's ABC Control was adopted by the South Atlantic Council's SSC as their ABC recommendation for Atlantic cobia).
- Atlantic and Florida East Coast Cobia Sector Allocation: (50% * average of long catch range (lbs) 2000-2008 + (50% * average of recent catch trend (lbs) 2006-2008). The allocation would be 8% commercial and 92% recreational. The commercial and recreational allocations specified would remain in effect until modified
- FL East Coast Zone Allocation of Gulf Cobia ACL: 1998-2012 (15 years) landings to establish the percentage split (36% to FLEC zone) for the Gulf ACL.

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

- No.

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

2.6 Management and Regulatory Timeline

- See tables 2.6.1 and 2.6.2

2.6.1 . Closures Due to Meeting Commercial Quota or Commercial/Recreational ACL

- See tables 2.6.1 and 2.6.2

2.7 . State Regulatory History

- Please see section 2.8

References

None provided.

Table 2.6.1 Atlantic Migratory Group Cobia Recreational Federal Regulatory History prepared by: Christina Wiegand, SAFMC staff

Year	Migratory Group	Quota (lbs ww)	ACL (lbs ww)	Days Open	Fishing Season	Reason for Closure	Season Start Date (first day implemented)	Season end Date (last day effective)	Size Limit	Size Limit Start Date	Size Limit End Date	Retention Limit (# fish)	Retention Limit Start Date	Retention Limit End Date
1983 [A]	NA	NA	NA	33	OPEN	NA	1-Jan	3-Feb	NONE	NA	NA	NONE	NA	NA
	NA	NA	NA	330	OPEN	NA	4-Feb	31-Dec	33in FL [A]	4-Feb	31-Dec	NONE	NA	NA
1984	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	NONE	NA	NA
1985	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL [B]	1-Jan	31-Dec	NONE	NA	NA
1986	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL	1-Jan	31-Dec	NONE	NA	NA
1987	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL	1-Jan	31-Dec	NONE	NA	NA
1988	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL	1-Jan	31-Dec	NONE	NA	NA
1989	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL	1-Jan	31-Dec	NONE	NA	NA
1990	NA	NA	NA	230	OPEN	NA	1-Jan	19-Aug	33in FL or 37in TL	1-Jan	31-Dec	NONE	NA	NA
	NA	NA	NA	133	OPEN	NA	20-Aug	31-Dec	33in FL or 37in TL	20-Aug	31-Dec	2 per person per day [C]	20-Aug	31-Dec
1991	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1992	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL [B]	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1993	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1994	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1995	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1996	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1997	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1998	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1999	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2000	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2001	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2002	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2003	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2004	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2005	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2006	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2007	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2008	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2009	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2010	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2011	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2012	NA	NA	NA	28	OPEN	NA	1-Jan	29-Jan	33in FL	1-Jan	29-Jan	2 per person per day	1-Jan	29-Jan
	Atlantic[D]	SEE ACL	1,445,687	336	OPEN	NA	30-Jan	31-Dec	33in FL	30-Jan	31-Dec	2 per person per day	30-Jan	31-Dec
2013	Atlantic[D]	SEE ACL	1,445,687	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2014	Atlantic[D]	SEE ACL	1,445,687	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2015	Atlantic[D]	SEE ACL	1,445,687	58	OPEN	NA	1-Jan	28-Feb	33in FL	1-Jan	28-Feb	2 per person per day	1-Jan	28-Feb
	Atlantic[E]	SEE ACL[F]	630,000	305	OPEN	NA	1-Mar	31-Dec	33in FL	1-Mar	31-Dec	2 per person per day	1-Mar	31-Dec
	Florida East Coast[E]	SEE ACL[F]	830,000	305	OPEN	NA	1-Mar	31-Dec	33in FL	1-Mar	31-Dec	2 per person per day	1-Mar	31-Dec
2016	Atlantic[E]	SEE ACL	620,000	170	CLOSED	2015 ACL EXCEEDED	1-Jan	19-Jun	33in FL	1-Jan	19-Jun	2 per person per day	1-Jan	19-Jun
	Florida East Coast[E]	SEE ACL	860,000	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2017	Atlantic[E]	SEE ACL	620,000	23	CLOSED	2016 ACL EXCEEDED	1-Jan	23-Jan	33in FL	1-Jan	23-Jan	2 per person per day	1-Jan	23-Jan
	Atlantic[E]	-	-	-	-	-	-	-	36in FL[G]	5-Sep	31-Dec	1 per person per day OR 6 per vessel per day whichever more restrictive [D]	5-Sep	31-Dec
	Florida East Coast[E]	SEE ACL	860,000	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec

Notes:

A = Original FMP (effective 2/4/1983) implemented 33 inch FL size limit

B = Amendment 1 (effective 9/22/1985) included clarification of minimum size limit is 33 in FL or 37 in TL; Amendment 6 (effective 12/3/1992) removed clarification of 37in TL as minimum size limit C = Amendment 5 (effective 8/20/1990) included implementation of 2 fish/person/day bag limit with one day possession limit

D = CMP Amendment 18 (effective 1/30/2012) included establishment of separate Gulf and Atlantic migratory stocks with a boundary at the SAFMC/GMFMC line; implemented ACLs

E = Amendment 20B (effective 3/1/2015) included setting boundary between Gulf and Atlantic migratory groups at the FL/GA line, a portion of the Gulf migratory group ACL allocated to the FLEC Zone F = Amendment 20 B also included adjustment to Atlantic cobia ACL based on SEDAR 28

G = CMP Framework Amendment 4 (effective 9/5/2017) included adjustments to recreational harvest limits, size limits, and accountability measures

Table 2.6.2 Atlantic Migratory Group Cobia Commercial Federal Regulatory History prepared by: Christina Wiegand, SAFMC staff

Year	Migratory Group	Quota (lbs ww)	ACL (lbs ww)	Days Open	Fishing Season	Reason for Closure	Season Start Date (first day implemented)	Season end Date (last day effective)	Size Limit	Size Limit Start Date	Size Limit End Date	Retention Limit (# fish)	Retention Limit Start Date	Retention Limit End Date
1983 [A]	NA	NA	NA	33	OPEN	NA	1-Jan	3-Feb	NONE	NA	NA	NONE	NA	NA
	NA	NA	NA	330	OPEN	NA	4-Feb	31-Dec	33in FL [A]	4-Feb	31-Dec	NONE	NA	NA
1984	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	NONE	NA	NA
1985	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL [B]	1-Jan	31-Dec	NONE	NA	NA
1986	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL	1-Jan	31-Dec	NONE	NA	NA
1987	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL	1-Jan	31-Dec	NONE	NA	NA
1988	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL	1-Jan	31-Dec	NONE	NA	NA
1989	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL	1-Jan	31-Dec	NONE	NA	NA
1990	NA	NA	NA	230	OPEN	NA	1-Jan	19-Aug	33in FL or 37in TL	1-Jan	19-Aug	NONE	NA	NA
	NA	NA	NA	133	OPEN	NA	20-Aug	31-Dec	33in FL or 37in TL	20-Aug	31-Dec	2 per person per day [C]	20-Aug	31-Dec
1991	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1992	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL or 37in TL [B]	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1993	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1994	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1995	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1996	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1997	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1998	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
1999	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2000	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2001	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2002	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2003	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2004	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2005	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2006	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2007	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2008	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2009	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2010	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2011	NA	NA	NA	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2012	NA	NA	NA	28	OPEN	NA	1-Jan	29-Jan	33in FL	1-Jan	29-Jan	2 per person per day	1-Jan	29-Jan
	Atlantic [D]	SEE ACL	125,712	336	OPEN	NA	30-Jan	31-Dec	33in FL	30-Jan	31-Dec	2 per person per day	30-Jan	31-Dec
2013	Atlantic [D]	SEE ACL	125,712	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2014	Atlantic [D]	SEE ACL	125,712	343	OPEN	NA	1-Jan	10-Dec	33in FL	1-Jan	10-Dec	2 per person per day	1-Jan	10-Dec
				20	CLOSED	ACL MET	11-Dec	31-Dec						
2015	Atlantic [D]	SEE ACL	125,712	58	OPEN	NA	1-Jan	28-Feb	33in FL	1-Jan	28-Feb	2 per person per day	1-Jan	28-Feb
	Atlantic [E]	SEE ACL [F]	60,000	305	OPEN	NA	1-Mar	31-Dec	33in FL	1-Mar	31-Dec	2 per person per day	1-Mar	31-Dec
	Florida East Coast [E]	SEE ACL [F]	70,000	305	OPEN	NA	1-Mar	31-Dec	33in FL	1-Mar	31-Dec	2 per person per day	1-Mar	31-Dec
2016	Atlantic [E]	SEE ACL	50,000	339	OPEN	NA	1-Jan	5-Dec	33in FL	1-Jan	5-Dec	2 per person per day	1-Jan	5-Dec
				25	CLOSED	ACL MET	6-Dec	31-Dec						
	Florida East Coast [E]	SEE ACL	70,000	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec
2017	Atlantic [E]	SEE ACL	50,000	246	OPEN	ACL MET	1-Jan	4-Sep	33in FL	1-Jan	4-Sep	2 per person per day	1-Jan	4-Sep
	Atlantic [E]	-	-	117	CLOSED	ACL MET	5-Sep	31-Dec	-	-	-	2 per person per day OR 6 per vessel per day whichever more restrictive [G]	5-Sep	31-Dec
	Florida East Coast [E]	SEE ACL	70,000	365	OPEN	NA	1-Jan	31-Dec	33in FL	1-Jan	31-Dec	2 per person per day	1-Jan	31-Dec

Notes:

A = Original FMP (effective 2/4/1983) implemented 33 inch FL size limit

B = Amendment 1 (effective 9/22/1985) included clarification of minimum size limit is 33 in FL or 37 in TL; Amendment 6 (effective 12/3/1992) removed clarification of 37in TL as minimum size limit C = Amendment 5 (effective 8/20/1990) included implementation of 2 fish/person/day retention limit with one day possession limit

D = CMP Amendment 18 (effective 1/30/2012) included establishment of separate Gulf and Atlantic migratory stocks with a boundary at the SAFMC/GMFMC line; implemented ACLs

E = Amendment 20B (effective 3/1/2015) included setting boundary between Gulf and Atlantic migratory groups at the FL/GA line, a portion of the Gulf migratory group ACL allocated to the FLEC Zone F = Amendment 20 B (effective 3/1/2015)also included adjustment to Atlantic cobia ACL based on SEDAR 28

G = Framework Amendment 4 (effective 9/5/2017) included removing Atlantic cobia removed from the limited harvest species list and changed retention limits

2.8 . State Regulatory History

State Regulatory Histories for Cobia
Updated: April 3, 2018

2.8.1 New York

Year	Recreational	Commercial
~1997 - 2017	*Minimum Size*: 37" TL *Bag Limit*: 2 pp/d	*Minimum Size*: 37" TL *Possession Limit*: 2 pv

Confirming start year for NY regulations

2.8.2 New Jersey **

Year	Recreational	Commercial
~1997 - 2017	*Minimum Size*: 37" TL *Bag Limit*: 2 pp/d	*Minimum Size*: 37" TL

Confirming start year for NJ regulations

2.8.3 Delaware **

Year	Recreational	Commercial
2017	None	None

2.8.4 Maryland **

Year	Recreational	Commercial
2017	None	None

2.8.5 Virginia **

History of commercial cobia regulations in Virginia state waters

Year	Minimum size limit	Possession limit	Vessel limit	Season	Other
1990	37 inches TL	2/person	-	Year-round	-
1991	37 inches TL	2/person	-	Year-round	-
1992	37 inches TL	2/person	-	Year-round	-
1993	37 inches TL	2/person	-	Year-round	-
1994	37 inches TL	2/person	-	Year-round	-
1995	37 inches TL	2/person	-	Year-round	-
1996	37 inches TL	2/person	-	Year-round	-
1997	37 inches TL	2/person	-	Year-round	-
1998	37 inches TL	2/person	-	Year-round	-
1999	37 inches TL	2/person	-	Year-round	-
2000	37 inches TL	2/person	-	Year-round	-
2001	37 inches TL	2/person	-	Year-round	-
2002	37 inches TL	2/person	-	Year-round	-
2003	37 inches TL	2/person	-	Year-round	-
2004	37 inches TL	2/person	-	Year-round	-
2005	37 inches TL	2/person	-	Year-round	-
2006	37 inches TL	2/person	-	Year-round	-
2007	37 inches TL	2/person	-	Year-round	-
2008	37 inches TL	2/person	-	Year-round	-
2009	37 inches TL	2/person	-	Year-round	-
2010	37 inches TL	2/person	-	Year-round	-
2011	37 inches TL	2/person	-	Year-round	-
2012	37 inches TL	2/person	-	Year-round	-
2013	37 inches TL	2/person	-	Year-round	-
2014	37 inches TL	2/person	-	Year-round	Commercial hook-and-line licensees may possess 6 per day
2015	37 inches TL	2/person	-	Year-round	Commercial hook-and-line licensees may possess 6 per day
2016	37 inches TL	2/person	-	Year-round	Commercial hook-and-line licensees may possess 6 per day
2017	37 inches TL	2/person	-	Jan. 1-Sep. 30	Commercial hook-and-line licensees may possess 6 per day

History of recreational cobia regulations in Virginia state waters

Year	Minimum size limit	Possession limit	Vessel limit	Season	Other
1990	37 inches TL	2/person	-	Year-round	-
1991	37 inches TL	2/person	-	Year-round	-
1992	37 inches TL	2/person	-	Year-round	-
1993	37 inches TL	2/person	-	Year-round	-
1994	37 inches TL	2/person	-	Year-round	-
1995	37 inches TL	2/person	-	Year-round	-
1996	37 inches TL	2/person	-	Year-round	-
1997	37 inches TL	2/person	-	Year-round	-
1998	37 inches TL	2/person	-	Year-round	-
1999	37 inches TL	2/person	-	Year-round	-
2000	37 inches TL	2/person	-	Year-round	-
2001	37 inches TL	1/person	-	Year-round	-
2002	37 inches TL	1/person	-	Year-round	-
2003	37 inches TL	1/person	-	Year-round	-
2004	37 inches TL	1/person	-	Year-round	-
2005	37 inches TL	1/person	-	Year-round	-
2006	37 inches TL	1/person	-	Year-round	-
2007	37 inches TL	1/person	-	Year-round	-
2008	37 inches TL	1/person	-	Year-round	-
2009	37 inches TL	1/person	-	Year-round	-
2010	37 inches TL	1/person	-	Year-round	-
2011	37 inches TL	1/person	-	Year-round	-
2012	37 inches TL	1/person	-	Year-round	-
2013	37 inches TL	1/person	-	Year-round	-
2014	37 inches TL	1/person	-	Year-round	-
2015	37 inches TL	1/person	-	Year-round	-
2016	40 inches TL	1/person	2/vessel	Jan. 1-Aug. 30	Only 1>50 inches TL allowed per vessel per day; gaffing prohibited
2017	40 inches TL	1/person	3/vessel	Jun. 1-Sep. 15	Only 1>50 inches TL allowed per vessel per day; gaffing prohibited; mandatory recreational reporting

2.8.6 **North Carolina ****

History of Rules

The first appearance of cobia in the N.C. Fisheries Rules for Coastal Waters rulebook is in 1991. Rule 15A NCAC 03M .0507 (Hook-and-Line Fishing Restricted) provided the Fisheries Director proclamation authority to impose size and harvest limit restrictions for cobia, as well as other federally-managed species:

> **15A NCAC 03M .0507 HOOK-AND-LINE FISHING RESTRICTED**
>
> The Fisheries Director may, by proclamation, establish size and harvest limit restrictions for the following species taken by hook-and-line:
>
> (1) Blue marlin;
> (2) White marlin;
> (3) Sailfish
> (4) Cobia;
> (5) Dolphin;
> (6) Bluefish;
> (7) Spotted seatrout; and
> (8) Weakfish.
>
> *History Note: Statutory Authority G.S. 113-134; 113-182; 113-221; 143B-289.4; Eff. January 1, 1991.*

Rule 15A NCAC 03M .0507 was amended in 1991 and 1992 to remove weakfish from the rule and to add tunas and flounder. It was further amended in 1994 to remove bluefish.

In 1996, rule 15A NCAC 03M .0507 was retitled and reconstructed to remove the director's proclamation authority and to incorporate federal regulations at that time into state rules as follows:

> **15A NCAC 03M .0507 RECREATIONAL FISHING RESTRICTIONS**
>
> (a) Blue marlin:
>   (1) It is unlawful to possess blue marlin less than 86 inches in length from the lower jaw to the fork in the tail.
>   (2) It is unlawful to possess more than one blue marlin per person per day.
> (b) ….
> (c) ….
> (d) ….
> (e) Cobia:
>   (1) It is unlawful to possess cobia less than 33 inches fork length taken by hook-and-line.
>   (2) It is unlawful to possess more than two cobia per person per day taken by hook-and-line.
> (f) …

> (g) …
> *History Note: Statutory Authority G.S. 113-134; 113-182; 113-221; 143B-289.4; Eff. January 1, 1991. Amended Eff. March 1, 1996; March 1, 1994; February 1, 1992; September 1, 1991.*

Also in 1996, the proclamation authority originally granted to the Fisheries Director in rule 15A 03M .0507 above was moved into a new rule, 15A NCAC 03M .0512 (Compliance with Fishery Management Plans). This new rule provided broader authority to the Fisheries Director to complement federal regulations and interstate fishery management plan requirements as per below:

> **15A NCAC 03M .0512 COMPLIANCE WITH FISHERY MANAGEMENT PLANS**
>
> In order to comply with management requirements incorporated in Federal Fishery Management Council Management Plans or Atlantic States Marine Fisheries Commission Management Plan, the Fisheries Director may, by proclamation, suspend the minimum size and harvest limits established by the Marine Fisheries Commission, and implement different minimum size and harvest limits. Proclamations issued under this Section shall be subject to approval, cancellation, or modification by the Marine Fisheries Commission at its next regularly scheduled meeting or an emergency meeting held pursuant to G.S. 113-221(e1).
>
> *History Note: Authority G.S. 113-134; 113-182; 113-221; 143B-289.4; Eff. March 1, 1996.*

In 1999, rule 15A NCAC 03M .0507 was again amended and retitled to apply only to billfish. Cobia was removed and placed into a new, stand-alone rule 15A NCAC 03M .0516 that was first adopted as a temporary rule in 1999, with permanent adoption in 2000. This rule has remained in place and unchanged through March 2018:

> **15A NCAC 03M .0516 COBIA**
>
> (a) It is unlawful to possess cobia less than 33 inches fork length.
> (b) It is unlawful to possess more than two cobia per person per day.
> *History Note: Authority G.S. 113-134; 113-182; 143B-289.52; Temporary Adoption Eff. July 1, 1999;*
>
> *Eff. August 1, 2000.*

One final rule change relevant to cobia is the modification of rule 15A NCAC 03M .0512 (Compliance with Fishery Management Plans) described above. In 2002, North Carolina adopted its Inter-Jurisdictional Fishery Management Plan (IJ FMP), which incorporates all ASMFC and council-managed finfish species by reference, and adopts all federal regulations as minimum standards for management. In completing the 2008 update to the IJ FMP, the proclamation authority contained in rule 15A NCAC 03M .0512 to implement changes in management was broadened to include additional items beyond size and harvest limits (see below). An information update to the IJ FMP was completed and approved in November 2015 and contained no additional regulatory changes.

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, by proclamation, take any or all of the following actions for species listed in the Interjurisdictional Fisheries 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 an emergency 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.

<u>History of Management Measures</u>

Cobia regulations remained mostly consistent from February 1992 until February 2016. The earliest cobia proclamation FF-5-92 was issued on February 11, 1992 accordance with 15A NCAC 03M .0507 with the following measures:

- No person may possess cobia less than 33 inches fork length or 37 inches total length.
- No person may possess more than two fish per person per day for recreational fisheries.

While FF-5-92 clearly established a minimum size limit for both commercial and recreational fisheries, it appeared to only establish a possession limit for recreational fisheries. Proclamation FF-4-94, effective February 15, 1994 revised the possession limit as follows:

- No person may possess cobia less than 33 inches fork length or 37 inches total length.
- No person may possess more than two fish per person per day taken by hook and line.

The above change applies a possession limit to cobia harvested by hook and line, regardless of the intent to sell. Proclamation FF-19-94, effective July 1, 1994, removed reference to the 37-inch total length minimum size limit alternative. In 1996, amendments to rule 15A NCAC 03M .0507 in 1999 (noted in the previous section) codified the minimum size limit and two-fish per person daily possession limit for hook and line that were previously in proclamation. In 1999, when cobia measures were moved into current rule 15A NCAC 03M .0516, the two-fish per person daily possession limit was modified to remove any reference to gear type, hence applying equally to all commercial and recreational fisheries.

In February 2016, the N.C. Marine Fisheries Commission received information regarding the significant overharvest of the recreational annual catch limit and the contribution of North Carolina's recreational harvest to that overage. The commission voted to modify the possession limits for both commercial and recreational harvest via proclamation FF-9-2016 (http://portal.ncdenr.org/web/mf/proclamation-ff-09-2016) as detailed below (note that not all members of a commercial fishing operation, i.e. crew, are required to have a Standard Commercial Fishing License to participate in the operation):

- Recreational: possession limit of one fish per person per day.
- Commercial: possession limit of two fish per license holder per day.

The above action was taken in an attempt to extend the recreational season for cobia, as NOAA Fisheries indicated that federal recreational accountability measures required a shortened season in 2016 to constrain harvest. A NOAA Fishery Bulletin was issued on March 10, 2016 closing federal waters to harvest on June 20, 2016.

In May 2016, the N.C. Marine Fisheries Commission voted to not complement the recreational federal waters closure, but to keep state waters open to recreational harvest of cobia by implementation of the following management measures via proclamation FF-25-2016, effective May 23, 2016. (http://portal.ncdenr.org/web/mf/proclamation-ff-25-2016):

- Recreational (all modes): Season open through September 30, 2016; minimum size limit of 37 inches fork length;
    - Private vessel: Harvest allowed Monday, Wednesday, Saturday; possession limit of one fish per person per day, or no more than two fish per vessel per day when more than one person is onboard the vessel.
    - Shore based: Harvest allowed seven days/week; possession limit of one fish per person per day.
    - For-hire: Harvest allowed seven days/week; possession limit of one fish per person per day, or four fish per vessel per day when four or more people are onboard the vessel.
- Commercial: minimum size limit of 33 inches fork length; possession limit of two fish per Standard Commercial Fishing License holder per day in a commercial operation; season to close when commercial annual catch limit is met.

On May 27, 2016 proclamation FF-28-2016 was issued (http://portal.ncdenr.org/web/mf/proclamation-ff-28-2016), revising the commercial possession limits, based on stakeholder input. The revised measures allowed for possession of two fish per person per day, not to exceed four fish per vessel per day in a commercial fishing operation, thus removing the per license holder requirement.

Closure of the commercial cobia fishery in federal waters on December 6, 2016 was complemented via proclamation FF-55-2016 (http://portal.ncdenr.org/web/mf/proclamation-ff-55-2016). This proclamation also maintained the recreational season closure through December 31, 2016, and reopened both commercial and recreational harvest in state waters in accordance with rule 15A NCAC 03M .0516 effective January 1, 2017.

At its February 2017 meeting, the N.C. Marine Fisheries Commission voted to implement the recreational and commercial management measures for 2017 detailed below via proclamation FF-13-2017 issued April 10, 2017 (http://portal.ncdenr.org/web/mf/proclamation-ff-13-2017). The commission also voted to require recreational anglers to tag and report length and weight of all fish at a N.C. Saltwater Fishing Tournament Citation Weigh Station. Due to lack of statutory authority to require citation weigh stations to engage in this activity, anglers were requested to provide this information on a voluntary basis (via catch cards distributed to weigh stations or an online reporting form).

- Recreational (all modes): Season of May 1 through August 31, 2017; minimum size limit of 36 inches fork length; possession limit of one fish per person per day, no more than four fish per vessel per day when four or more people were on the vessel (includes captain and mate on for-hire vessels).
- Commercial: Season closes when federal annual catch limit is met; minimum size limit of 33 inches fork length; possession limit of two fish per person per day.

On August 25, 2017 proclamation FF-31-2017 (http://portal.ncdenr.org/web/mf/proclamation-ff-31-2017) was issued effective September 5, 2017 to complement the commercial provisions of Framework Amendment 4 to the Coastal Migratory Pelagics FMP (minimum size limit of 33 inches fork length; possession limit of two fish per person per day or six fish per vessel per day, whichever is more restrictive), and to maintain the recreational season closure through April 30, 2018 as per direction from the N.C. Marine Fisheries Commission. Subsequently, on August 31, 2017 proclamation FF-32-2017 (http://portal.ncdenr.org/web/mf/proclamation-ff-32-2017) was issued effective September 5, 2017 to complement the commercial federal waters closure due to the annual catch limit being met (still maintaining the recreational closure through April 30, 2018). The result was that the commercial fishery was closed the same day that Framework Amendment 4 regulations became effective. Proclamation FF-32-2017 also established the reopening of the commercial fishery on January 1, 2018 under the Framework Amendment 4 management measures noted above.

In January 2018, the N.C. Division of Marine Fisheries (NCDMF) submitted its Cobia Implementation Plan to the Atlantic States Marine Fisheries Commission (ASMFC) for technical review, as required by the recently approved (October 2017) ASMFC Interstate FMP for Atlantic Cobia. NCDMF submitted two recreational management options, only one of which was recommended by the ASMFC Cobia Technical Committee for approval by the ASMFC South Atlantic State/Federal Management Board at its February 2018 meeting. A third option was submitted for technical review in late February, and was approved by the Board in early March. The following commercial and recreational management measures were issued via proclamation FF-10-2018 (http://portal.ncdenr.org/web/mf/proclamation-ff-10-2018) on March 20, 2018 and will be effective May 1, 2018. Recreational measures are designed to constrain harvest to North Carolina's recreational harvest target of 236,313 pounds, while commercial measures will remain consistent with the coastwide measures established in Framework Amendment 4 of the Coastal Migratory Pelagics FMP and subsequently incorporated into the ASMFC Interstate FMP.

- Recreational (all modes): Season of May 1 through December 31; minimum size limit of 36 inches fork length
    - Private vessel/shore: May 1 through May 31 -- possession limit of one fish per person per day, not to exceed two fish per vessel per day if more than one person is onboard; June 1 through December 31 – possession limit of one fish per vessel per day.

  - For-hire: Possession limit of one fish per person per day, not to exceed four fish per vessel per day if four or more people are onboard.
- Commercial: Minimum size limit of 33 inches fork length; possession limit of two fish per person per day up to six fish per vessel per day, whichever is more restrictive; season closes when commercial annual catch limit is met.

A summary of all commercial and recreational cobia regulations in North Carolina state waters is contained in Tables 1 (recreational) and 2 (commercial).

Table 1. North Carolina recreational regulations in state waters, 1992-2018. Minimum size limits are inches fork length (FL).

Year	Season	Min. Size (FL)	Daily Possession Limit	Regulation
1992	Year-round	33	2 fish/person	15A NCAC 03M .0507/FF-5-92
1993	Year-round	33	2 fish/person	15A NCAC 03M .0507/FF-5-92
1994	Year-round	33	2 fish/person	15A NCAC 03M .0507/FF-4-94, FF-19-94
1995	Year-round	33	2 fish/person	15A NCAC 03M .0507/FF-19-94
1996	Year-round	33	2 fish/person	15A NCAC 03M .0507/FF-19-94
1997	Year-round	33	2 fish/person	15A NCAC 03M .0507FF-19-94
1998	Year-round	33	2 fish/person	15A NCAC 03M .0507/FF-19-94
1999	Year-round	33	2 fish/person	15A NCAC 03M .0507/.0516
2000	Year-round	33	2 fish/person	15A NCAC 03M .0516
2001	Year-round	33	2 fish/person	15A NCAC 03M .0516
2002	Year-round	33	2 fish/person	15A NCAC 03M .0516
2003	Year-round	33	2 fish/person	15A NCAC 03M .0516
2004	Year-round	33	2 fish/person	15A NCAC 03M .0516
2005	Year-round	33	2 fish/person	15A NCAC 03M .0516
2006	Year-round	33	2 fish/person	15A NCAC 03M .0516
2007	Year-round	33	2 fish/person	15A NCAC 03M .0516
2008	Year-round	33	2 fish/person	15A NCAC 03M .0516
2009	Year-round	33	2 fish/person	15A NCAC 03M .0516
2010	Year-round	33	2 fish/person	15A NCAC 03M .0516
2011	Year-round	33	2 fish/person	15A NCAC 03M .0516
2012	Year-round	33	2 fish/person	15A NCAC 03M .0516
2013	Year-round	33	2 fish/person	15A NCAC 03M .0516
2014	Year-round	33	2 fish/person	15A NCAC 03M .0516
2015	Year-round	33	2 fish/person	15A NCAC 03M .0516
2016	1/1 - 2/26	33	2 fish/person	15A NCAC 03M .0516
	2/27 - 5/22	33	1 fish/person	15A NCAC 03M .0512/FF-9-2016
	5/23 - 9/30	37	**Private:** M/W/Sat, 1 fish/person up to 2 fish/vessel when more than 1 person onboard **Shore**: 1 fish/person **For-hire**: 1 fish/person up to 4 fish/vessel when 4 or more people onboard	15A NCAC 03M .0512/FF-25-2016, FF-55-2016
2017	1/1 - 4/30	33	2 fish/person	15A NCAC 03M .0512/FF-55-2016
	5/1 – 8/31	36	**All modes**: 1 fish/person up to 4 fish/vessel when 4 or more people onboard	15A NCAC 03M .0512/FF-13-2017, FF-31-2017, FF-32-2017
2018	5/1 – 12/31	36	**Private/shore:** 5/1-5/31, 1 fish/person up to 2 fish/vessel when more than 1 person onboard; 6/1 – 12/31, 1 fish/vessel. **For-hire:** 1 fish/person up to 4 fish/vessel when 4 or more people onboard	15A NCAC 03M .0512/FF-10-2018

Table 2. North Carolina commercial cobia regulations in state waters, 1992-2018.

Year	Season	Min. Size (FL)	Daily Possession Limit	Regulation
1992	Year-round	33	none	15A NCAC 03M .0507/FF-5-92
1993	Year-round	33	none	15A NCAC 03M .0507/FF-5-92
1994	Year-round	33	2 fish/person (by hook-and-line)	15A NCAC 03M .0507/FF-4-94/FF-19-94
1995	Year-round	33	2 fish/person (by hook-and-line)	15A NCAC 03M .0507/FF-19-94
1996	Year-round	33	2 fish/person (by hook-and-line)	15A NCAC 03M .0507/FF-19-94
1997	Year-round	33	2 fish/person (by hook-and-line)	15A NCAC 03M .0507/FF-19-94
1998	Year-round	33	2 fish/person (by hook-and-line)	15A NCAC 03M .0507/FF-19-94
1999	Year-round	33	2 fish/person	15A NCAC 03M .0507/.0516
2000	Year-round	33	2 fish/person	15A NCAC 03M .0516
2001	Year-round	33	2 fish/person	15A NCAC 03M .0516
2002	Year-round	33	2 fish/person	15A NCAC 03M .0516
2003	Year-round	33	2 fish/person	15A NCAC 03M .0516
2004	Year-round	33	2 fish/person	15A NCAC 03M .0516
2005	Year-round	33	2 fish/person	15A NCAC 03M .0516
2006	Year-round	33	2 fish/person	15A NCAC 03M .0516
2007	Year-round	33	2 fish/person	15A NCAC 03M .0516
2008	Year-round	33	2 fish/person	15A NCAC 03M .0516
2009	Year-round	33	2 fish/person	15A NCAC 03M .0516
2010	Year-round	33	2 fish/person	15A NCAC 03M .0516
2011	Year-round	33	2 fish/person	15A NCAC 03M .0516
2012	Year-round	33	2 fish/person	15A NCAC 03M .0516
2013	Year-round	33	2 fish/person	15A NCAC 03M .0516
2014	Year-round	33	2 fish/person	15A NCAC 03M .0516
2015	Year-round	33	2 fish/person	15A NCAC 03M .0516
2016	1/1 - 2/26	33	2 fish/person	15A NCAC 03M .0516
	2/27 - 5/22	33	2 fish/license holder	15A NCAC 03M .0512/FF-9-2016
	5/23 – 5/29	33	2 fish/license holder	15A NCAC 03M .0512/FF-25-2016
	5/30 – 12/6	33	2 fish/person, not to exceed 4 fish/vessel	15A NCAC 03M .0512/FF-28-2016, FF-55-2016
2017	1/1 - 4/30	33	2 fish/person	15A NCAC 03M .0512/FF-55-2016
	5/1-9/5	33	2 fish/person*	15A NCAC 03M .0512/FF-13-2017, FF-31-2017, FF-32-2017
2018	1/1 – 12/31	33	2 fish/person or 6 fish/vessel, whichever is more restrictive	15A NCAC 03M .0512/FF-32-2017, FF-10-2018

*The effective date of Framework Amendment 4 regulations (9/5/2017; complemented via FF-31-2017) coincided with the effective date of the federal waters closure of the commercial fishery (complemented via FF-32-2017).

2.8.7 South Carolina**

1989: SC Code of Laws Section 50-17-510(3) adopted minimum size limits for certain species where size limits were established under the Fishery Conservation and Management Act (PL94-265); a 33 inch fork length minimum was specifically listed for cobia.

1992: SC Code of Laws Section 50-17-510(C) adopted the federal minimum size limits automatically for all species managed under the Fishery Conservation and Management Act (PL94-265); and Section 50-17-510(F) adopted the federal catch and possession limits for a number of listed species managed under the Fishery Conservation and Management Act (PL94-265) as the Law of the State of SC, with cobia specifically listed.

2000: SC Marine-related Laws reorganized under SC Code of Laws Title 50 Chapter 5.

SC Code of Laws Section 50-5-2730 reads – "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 of this State and apply statewide including in state waters." As such, SC cobia–related regulation was pulled directly from the federal regulations as promulgated under Magnuson.

2012: SC designated cobia as a gamefish under SC Code Section 50-5-1700(D) and (E) and made it "unlawful to sell, purchase, trade, or barter or attempt to sell, purchase, trade, or barter cobia taken from state waters."

2016: Through SC Code Section 50-5-15(67) SC created a "Southern Cobia Management Zone" in "all waters of the State south of 032° 31.0' N latitude, the approximate latitude of Jeremy Inlet, Edisto Island." This was done to create special state management of fish participating in a well-documented spawning aggregation each year in the southern sounds of the state. Regulation within this area is described in SC Code Section 50-5-2730(B)(2), which states that "cobia (Rachycentron canadum) located in the Southern Cobia Management Zone. Subject to the size limit established by federal regulation, possession of cobia caught in the Southern Cobia Management Zone is limited to one per person per day, and no more than three per boat per day, from June 1 to April 30. It is unlawful to take and possess cobia in the Southern Cobia Management Zone from May 1 to May 31, and at any time federal regulations provide for the closure of the recreational cobia season in the waters of the South Atlantic Ocean."

2.8.8 **Georgia****

The Georgia Legislature, the Board of Natural Resources and the Department of Natural Resources, an executive agency, share regulatory responsibilities for wildlife in the state of Georgia with the Board and Department as subordinates. Title 27 (Game and Fish Code) Chapter 4 of the Georgia Statutes contain the laws directly related to the management of wildlife including marine fishes (O.C.G.A. 27-4-10). In 2012, the legislature amended the Game and Fish Code extensively and in doing so granted the Board and Department additional powers to promulgate regulations affecting marine fisheries. Previously the legislature maintained management authority over a select group of marine fishes while allowing the Board and Department authority over others. With the 2012 amendment, the legislature set parameters within which the Board and Department regulate marine fishes. Board of Natural Resources Rule 391-2-4-.04, Saltwater Finfishing, contains regulations for these fishes, including cobia.

Current Cobia Regulations in Georgia (March 2018)

The size and creel limit for both recreational and commercial cobia harvest are the same, 36 inch fork length minimum size, and one fish per person or six fish per vessel whenever six or more licensed fishermen are onboard. The recreational season is March 1 through October 31 (Board Rule 391-2-4-.04(3)(h). The GADNR Commissioner has the authority to reduce the season length, annually, if necessary (O.C.G.A. 27-4-130(a). For commercial harvest, the season is open in conjunction with the federal season and will close once the commercial Annual Catch Limit (ACL) is met (Board Rule 391-2-4-.04 (4)(c)).

License Requirements

In Georgia, a license is required to fish recreationally (O.C.G.A. 27-2-1) or commercially (O.C.G.A. 27-4-110). Recreational fishing licenses are required of residents and non-residents fishing in state territorial waters as well as the EEZ. All persons under the age of 16, regardless of residency, and residents born before July 1, 1952 are not required to purchase recreational licenses. Other exemptions exist for active military and individuals with disabilities, check with the GADNR for details. Commercial fishing licenses are required to sell seafood landed in Georgia from Georgia waters or from the EEZ.

Penalties for Violations

Penalties for violations of Georgia laws and regulations are established in Georgia Statutes. Most violations of game and fish laws are misdemeanors though some may be elevated to misdemeanors of high and aggravated nature, Title 27, Chapter 4.

Gear Restrictions

There are few restrictions on recreational gear for the harvest of cobia; only gig and gillnet are prohibited. Commercially, cobia may be harvested using trawl nets, cast nets, seines, and pole-and line, though only pole-and-line are practical. (Board Rule 391-2-4-.12)

Commercial Landings and Data Reporting Requirements

Georgia requires commercial harvesters (O.C.G.A. 27-4-118) and seafood dealers (O.C.G.A. 27-4-136) to submit landings data. Information to be supplied for each trip includes trip date; vessel identification; trip number; species; quantity; units of measure; disposition; value; county or port landed; state landed; dealer identification; unloading date; market; grade; gear; quantity of gear; days at sea; number of crew; fishing time; and number of sets.

Commercial finfish harvest limits are equivalent to recreational limits unless otherwise noted. This means that commercial harvesters may land and sell no more than one fish per person per day not to exceed 6 fish per boat and minimum size and landing restrictions are the same as recreational. (Board Rule 391-2-4-.04) The season is open in conjunction with the federal season and will close once the commercial Annual Catch Limit (ACL) is met (Board Rule 391-2-4-.04 (4)(c)).

Other Restrictions

Cobia, as with all marine species except sharks, must be landed with head and fins intact. Transfer between vessels at sea is prohibited. (Board Rule 391-2-4-.04 (5)(a) and (b))

Management Chronology

1957: Gill nets prohibited in state waters.

1989: The Georgia Legislature established O.C.G.A. 27-4-130.1, Open seasons, creel limits, and minimum size limits for certain finfish species. For cobia a closed season of December 1 through March 15 was established ((a)(3)). Furthermore, the legislature authorized the Board to manage cobia seasons beyond this closed season as well as to set size limits between 20 and 40 inches and to establish a maximum daily creel not to exceed 10 fish ((b)(3)).

1989: The Board of Natural Resources adopted Rule 391-2-4-.04, Saltwater Finfishing. Specifically for cobia, it established a March 16 to November 30th open season ((3)(c)), a two cobia per person daily creel and possession limit ((4)(c)), and a 33-inch fork length minimum size ((5)(c)).

2012: The Georgia Legislature repealed O.C.G.A. 27-4-130.1 and moved those species therein to O.C.G.A. 27-4-10. Cobia ((a)(28)) parameters were set at 0 to 40 inches and five fish. Further, the board was authorized to set size limits, open seasons, creel and possession limits and possession and landing specifications on a state-wide, regional and local basis. Finally, the Commissioner of the Department was empowered to close waters to recreational and commercial fishing by species for a period of up to six months within a calendar year.

2012: The Board of Natural Resources implemented the necessary requirements of the Legislative repeal while keeping cobia management intact, with the exception of resorting species; cobia became letter (h).

2014: The Board of Natural Resources amended 391-2-4-.04, Saltwater Finfishing, for Cobia ((3)(h)) to allow fishing all year, but kept the two cobia per person creel and possession limit and the 33-inch fork length minimum size limit as well as the landing restrictions of head and fins intact and prohibition on transfer at sea.

2018: The Board of Natural Resources amended 391-2-4-.04, Saltwater Finfishing, for Cobia ((3)(h)) to 36 inch fork length minimum size, and one fish per person or six fish per vessel whenever six or more licensed fishermen are onboard, with the size and creel limit for both recreational and commercial cobia harvest are the same. The recreational season is March 1 through October 31 (Board Rule 391-2-4-.04(3)(h). The GADNR Commissioner has the authority to reduce the season length, annually, if necessary (O.C.G.A. 27-4-130(a). For commercial harvest, the season is open in conjunction with the federal season and will close once the commercial Annual Catch Limit (ACL) is met (Board Rule 391-2-4-.04 (4)(c)).

2.8.9 **Florida**

Cobia Regulation History

Year	Minimum Size Limit	Recreational Daily Harvest Limits	Commercial Daily Harvest Limits	Regulation Changes	Rule Change Effective Date
1980	None	None	None		
1981	None	None	None		
1982	None	None	None		
1983	None	None	None		
1984	None	None	None		
1985	37 inches TL (equivalent to 33 inches FL)	None	None	Established a minimum size limit of 37 inches TL (equivalent to 33 inches FL).	June 13, 1985
1986	37 inches TL (equivalent to 33 inches FL)	None	None		
1987	37 inches TL (equivalent to 33 inches FL)	2 fish or 250 pounds per person, whichever is greater	None		
1988	37 inches TL (equivalent to 33 inches FL)	2 fish or 250 pounds per person, whichever is greater	None		
1989	37 inches TL (equivalent to 33 inches FL)	2 fish or 100 pounds per person, whichever is greater	None		
1990	33 inches FL	2 fish per person	2 fish per person	Set the minimum size limit at 33 inches FL. Established a 2-fish daily bag limit for all fishermen, commercial and recreational. Fish must be landed in whole condition.	Jan. 1, 1990

1991	33 inches FL	2 fish per person	2 fish per person		
1992	33 inches FL	2 fish per person	2 fish per person		
1993	33 inches FL	2 fish per person	2 fish per person		
1994	33 inches FL	2 fish per person	2 fish per person		
1995	33 inches FL	2 fish per person	2 fish per person		
1996	33 inches FL	2 fish per person	2 fish per person		
1997	33 inches FL	2 fish per person	2 fish per person		
1998	33 inches FL	2 fish per person	2 fish per person		Aug. 31, 1998
1999	33 inches FL	2 fish per person	2 fish per person		
2000	33 inches FL	2 fish per person	2 fish per person		
2001	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel	Designated cobia as a “restricted species.” Established a daily recreational limit of 1-fish per person and 6-fish per vessel, whichever is less. Established a daily commercial limit of 2-fish per person and 6-fish per vessel, whichever is less.	March 22, 2001
2002	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2003	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		

2004	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2005	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2006	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2007	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2008	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2009	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2010	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2011	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2012	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2013	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2014	33 inches FL	1 fish per person and 6	2 fish per person and 6		

		fish per vessel	fish per vessel		
2015	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2016	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2017	33 inches FL	1 fish per person and 6 fish per vessel	2 fish per person and 6 fish per vessel		
2018	33 inches FL	Atlantic Region: 1 fish per person and 6 fish per vessel Gulf Region: 1 fish per person and 2 fish per vessel	Atlantic Region: 2 fish per person and 6 fish per vessel Gulf Region: 1 fish per person and 2 fish per vessel	Defined the Gulf Region for cobia management in Florida to be all Florida waters lying north of the Monroe-Collier county line (25°48.216' N. lat.). Defined the Atlantic Region for cobia management in Florida to be all Florida waters lying outside of the Gulf Region. Established a commercial vessel limit of 1 fish per person for the Gulf Region. Established a recreational and commercial vessel limit of 2 fish for the Gulf Region. This shall not be construed to exceed the 1-fish per person bag limit.	Feb. 11, 2018

**These states have proposed regulatory changes for Atlantic cobia under ASMFC's IFMP, which will be implemented April 2018.

2.9 Gulf of Mexico

The following tables summarize the Gulf of Mexico Blueline Tilefish management history.

2.9.1 Gulf of Mexico Harvest Restrictions (Trip Limits)

Harvest Restrictions (Trip Limits*)								
*Trip limits do not apply during closures (if season is closed, then trip limit is 0)								
Species Affected	**First Yr In Effect**	**Effective Date**	**End Date**	**Fishery**	**Possession Limit (per person)**	**Region Affected**	**FR Reference**	**Amendment Number or Rule Type**
Cobia	1990	1/1/1990	-	All	2	Gulf of Mexico Federal Waters		CMP Amendment 5
	2018	2/11/2018	-	All	1	Florida State Waters ONLY	68B-19.004	https://www.flrules.org/gateway/RuleNo.asp?title=COBIA&ID=68B-19.004
"Gulf of Mexico" refers to the Gulf migratory group of cobia occuring within the Gulf Council's jurisdiction, which is from the Texas/Mexico border east to the Dade/Monroe County line in Florida								

2.9.2 Gulf Of Mexcio Harvest Restrictions (size Limits)

Harvest Restrictions (Size Limits*)									
*Size limits do not apply during closures									
Species Affected	**First Yr In Effect**	**Effective Date**	**End Date**	**Fishery**	**Size Limit**	**Length Type**	**Region Affected**	**FR Reference**	**Amendment Number or Rule Type**
Cobia	1985	1/1/1985	-	All	33"	FL	Gulf of Mexico Federal Waters		Original CMP FMP

2.9.3 Gulf Of Mexico Harvest Restrictions Fishery Closures

Harvest Restrictions (Fishery Closures*)									
*Area specific regulations are documented under spatial restictions									
Species Affected	**First Yr In Effect**	**Effective Date**	**End Date**	**Fishery**	**Closure Type**	**First Day Closed**	**Last Day Closed**	**Region Affected**	**FR Reference**
Cobia	None								

2.9.4 Gulf of Mexico Harvest Restrictions (Spatial Restrictions)

Harvest Restrictions (Spatial Restrictions)

Area	First Yr In Effect	Effective Date	End Date	Fishery	First Day Closed	Last Day Closed	Restriction in Area	FR Reference	Amendment Number or Rule Type
Gulf of Mexico Stressed Areas	1984	11/8/1984	Ongoing	Both	Year round		Prohibited powerheads for Reef FMP	49 FR 39548	Original Reef Fish FMP
	1984	11/8/1984	Ongoing	Both	Year round		Prohibited pots and traps for Reef FMP	49 FR 39548	Original Reef Fish FMP
Alabama Special Management Zones	1994	2/7/1994	Ongoing	Both	Year round		Allow only hook-and line gear with three or less hooks per line and spearfishing gear for fish in Reef FMP	59 FR 966	Reef Fish Amendment 5
EEZ, inside 50 fathoms west of Cape San Blas, FL	1990	2/21/1990	Ongoing	Both	Year round		Prohibited longline and buoy gear for Reef FMP	55 FR 2078	Reef Fish Amendment 1
EEZ, inside 20 fathoms east of Cape San Blas, FL	1990	2/21/1990	4/17/2009	Both	Year round		Prohibited longline and buoy gear for Reef FMP	55 FR 2078	Reef Fish Amendment 1
EEZ, inside 50 fathoms east of Cape San Blas, FL	2009	4/18/2009	10/15/2009	Both	18-Apr	28-Oct	Prohibited bottom longline for Reef FMP	74 FR 20229	Emergency Rule
EEZ, inside 35 fathoms east of Cape San Blas, FL	2009	10/16/2009	4/25/2010	Both	Year round		Prohibited bottom longline for Reef FMP	74 FR 53889	Sea Turtle ESA Rule
	2010	4/26/2010	Ongoing	Rec	Year round		Prohibited bottom longline for Reef FMP	75 FR 21512	Reef Fish Amendment 31
	2010	4/26/2010	Ongoing	Com	1-Jun	31-Aug	Prohibited bottom longline for Reef FMP	75 FR 21512	Reef Fish Amendment 31
Madison-Swanson	2000	4/19/2000	6/2/2004	Both	Year round		Fishing prohibited except HMS[1]	65 FR 31827	Reef Fish Regulatory Amendment
	2004	6/3/2004	Ongoing	Both	1-May	31-Oct	Fishing prohibited except surface trolling	70 FR 24532 74 FR 17603	Reef Fish Amendment 21 Reef Fish Amendment 30B
	2004	6/3/2004	Ongoing	Both	1-Nov	30-Apr	Fishing prohibited	70 FR 24532 74 FR 17603	Reef Fish Amendment 21 Reef Fish Amendment 30B
Steamboat Lumps	2000	4/19/2000	6/2/2004	Both	Year round		Fishing prohibited except HMS[1]	65 FR 31827	Reef Fish Regulatory Amendment
	2004	6/3/2004	Ongoing	Both	1-May	31-Oct	Fishing prohibited except surface trolling	70 FR 24532 74 FR 17603	Reef Fish Amendment 21 Reef Fish Amendment 30B
	2004	6/3/2004	Ongoing	Both	1-Nov	30-Apr	Fishing prohibited	70 FR 24532 74 FR 17603	Reef Fish Amendment 21 Reef Fish Amendment 30B
The Edges	2010	7/24/2009	Ongoing	Both	1-Jan	30-Apr	Fishing prohibited	74 FR 30001	Reef Fish Amendment 30B Supplement
20 Fathom Break	2014	7/5/2013	Ongoing	Rec	1-Feb	31-Mar	Fishing for SWG prohibited[2]	78 FR 33259	Reef Fish Framework Action
Flower Garden	1992	1/17/1992	Ongoing	Both	Year round		Fishing with bottom gears prohibited[3]	56 FR 63634	Sanctuary Designation
Riley's Hump	1994	2/7/1994	8/18/2002	Both	1-May	30-Jun	Fishing prohibited	59 FR 966	Reef Fish Amendment 5
Tortugas Reserves	2002	8/19/2002	Ongoing	Both	Year round		Fishing prohibited	67 FR 47467	Tortugas Amendment
Pulley Ridge	2006	1/23/2006	Ongoing	Both	Year round		Fishing with bottom gears prohibited[3]	70 FR 76216	Essential Fish Habitat (EFH) Amendment 3

[1] HMS: highly migratory species (tuna species, marlin, oceanic sharks, sailfishes, and swordfish)

[2] SWG: shallow-water grouper (black, gag, red, red hind, rock hind, scamp, yellowfin, and yellowmouth)

[3] Bottom gears: Bottom longline, bottom trawl, buoy gear, pot, or trap

2.9.5 Gulf of Mexico Harvest Restrictions (Gear Restrictions*)

Harvest Restrictions (Gear Restrictions*)						
*Area specific gear regulations are documented under spatial restictions						
Gear Type	**First Yr In Effect**	**Effective Date**	**End Date**	**Gear/Harvesting Restrictions**	**Region Affected**	**FR Reference**
Cobia	None					
[1]Except when, purchased from a fish processor, filleted carcasses may be used as bait crab and lobster traps.						

2.9.6 **Gulf of Mexico Quota ACL closure**

Year	Fixed Closed Months	Recreational Landings	Commercial Landings	Total Landings	ACT	ACL	ACT %	ACL %	Quota Closure
2000	None	1,508,489	129,890	1,638,379	None	None	N/A	N/A	None
2001		1,555,656	92,365	1,648,021					
2002		1,227,708	105,320	1,333,028					
2003		2,060,423	111,636	2,172,059					
2004		2,090,425	101,181	2,191,606					
2005		1,461,039	87,582	1,548,621					
2006		1,572,637	81,948	1,654,585					
2007		1,685,402	73,208	1,758,610					
2008		1,312,126	68,723	1,380,849					
2009		996,105	62,239	1,058,344					
2010		1,317,728	82,361	1,400,089					
2011		1,683,588	69,168	1,752,756					
2012		924,697	51,911	976,608	1,310,000	1,460,000	74.6%	66.9%	
2013		1,211,101	82,531	1,293,632	1,310,000	1,460,000	98.8%	88.6%	
2014		923,426	78,481	1,001,907	1,310,000	1,460,000	76.5%	68.6%	
2015		811,564	70,314	881,878	1,450,000	1,610,000	60.8%	54.8%	
2016		888,898	74,608	963,506	1,500,000	1,660,000	64.2%	58.0%	
2017*		427,561	56,321	483,882	1,500,000	1,660,000	32.3%	29.1%	

Data were pulled from the SERO ACL monitoring website on March 20, 2018. *2017 data are preliminary.

Landings are in pounds landed weight (whole and gutted combined)

All landings are for the Gulf migratory group as defined in each year. Beginning in 2017, landings are for the Gulf's jurisdictional area for cobia, from the Texas/Mexico border to the Dade/Monroe County line.

CMP Amendment 18 (effective date: 1/30/2012) separated Gulf and Atlantic Migratory stocks with a boundary at the SAFMC/GMFMC jurisdicitonal line. Amendment 20B (effective date: 3/1/2015) set the boundary for the Gulf and Atlantic migratory groups at the FL/GA line, a portion of the Gulf migratory group ACL is allocated to the FL East Coast zone. FL East Coast zone includes east coast of FL through the SAFMC/GMFMC jurisdicational line. ACL's and landings? in this table do not include FL East Coast Zone. Information on FL East Coast Zone is included in the SAFMC management history documents.

2.10 ASMFC MANAGEMENT HISTORY

Interstate Fishery Management Plan (ISFMP) for Atlantic Migratory Group (AMG) Cobia

The ISFMP established a management regime for state territorial seas (0-3 nautical miles from shore) and internal waters for the range of AMG cobia (New Jersey-Georgia), under the authority of the Atlantic States Marine Fisheries Commission's (ASMFC) South Atlantic State/Federal Fisheries Management Board (Board). The ISFMP was developed and approved as a complement to the SAFMC Coastal Migratory Pelagics (CMP) FMP. As such, the ASMFC works with the SAFMC to develop management measures. ASMFC implements management measures from the ISFMP in state waters and provides the SAFMC with a recommendation that similar measures be implemented in federal waters.

The ISFMP established the following coastwide measures for state waters to complement SAFMC CMP FMP Framework Amendment 4:

Commercial

1. Minimum size limit: 33 inches fork length or total length equivalent (37 inches).
2. Maximum possession/vessel limit: 2 fish per person, not to exceed 6 fish per vessel.
3. Adherence to the federal commercial Annual Catch Limit (ACL) (currently, 50,000 pounds); if federal waters are closed to commercial fishing due to the commercial ACL being met, state waters will be closed to commercial fishing as well.

Recreational

1. Minimum size limit: 36 inches fork length or total length equivalent (40 inches).
2. Maximum bag limit: 1 fish per person.
3. Maximum vessel limit: 6 fish per vessel per day.

A recreational harvest limit (RHL) was also established and set equivalent to 99% of the federal recreational ACL (current ACL: 620,000 pounds; current RHL: 613,800 pounds). This RHL is allocated to states within the management range that do not have *de minimis* status. Allocated amounts for each state are soft harvest targets, and are evaluated in 3-year time periods. Individual states may set season and vessel limits in addition to the coastwide size and bag limits listed above to achieve their harvest target. Current state allocation percentages and harvest targets are shown in Table 1.

Table 1. Allocated state recreational harvest targets for Atlantic Migratory Group cobia by weight and percentage of the Recreational Harvest Limit (613,800 pounds).

State	Pounds Percentage of RHL
Georgia	58,311 9.5%
South Carolina	74,885 12.2%
North Carolina	236,313 38.5%
Virginia	244,292 39.8%

After 3 years, if a state's average annual landings over the 3-year time period are greater than their annual soft harvest target, that state must adjust their season length or vessel limits for the following 3 years, as necessary, to prevent exceeding their target in the future. States reporting an under-harvest over a 3-year period may present a plan to extend seasons or increase vessel limits to allow increased harvests that will not exceed the harvest target. State harvests will next be evaluated against targets in 2021 for 2018-2020 harvests. Current state season and vessel limits are shown in Table 2.

Table 2. State recreational season and vessel limits.

State	**Recreational Season and Daily Vessel Limits**
Georgia	Season: March 1-October 31; Vessel Limit: 6 fish
South Carolina	Season: None, but will close when federal waters close; Vessel Limit: 3 fish in Southern Cobia Management Zone and 6 fish in all other state waters
North Carolina	Private Vessels – Season: May 1-May 31, Vessel Limit: 2 fish; Season: June 1-December 31, Vessel Limit: 1 fish For-Hire Vessels – Season: May 1-December 31, Vessel Limit: 4 fish
Virginia	Season: June 1-September 30; Vessel Limit: 3 fish, only 1 of which may be over 50 inches total length

States with less than 1% of coastwide recreational landings over the previous 3 years may apply for *de minimis* status under the ISFMP. *De minimis* status is intended to allow some harvest for states with historically minimal levels of harvest. *De minimis* states do not receive recreational harvest target allocations. These states may match the season and daily vessel limits of an adjacent or the nearest non-*de minimis* state or implement a 1 fish daily vessel limit with no season. *De minimis* states are subject to coastwide recreational size and bag limits as well as all commercial coastwide measures. All jurisdictions from Maryland through New Jersey have been granted *de minimis* status.

Effective Date: April 1, 2018

2.11 Assessment History & Review

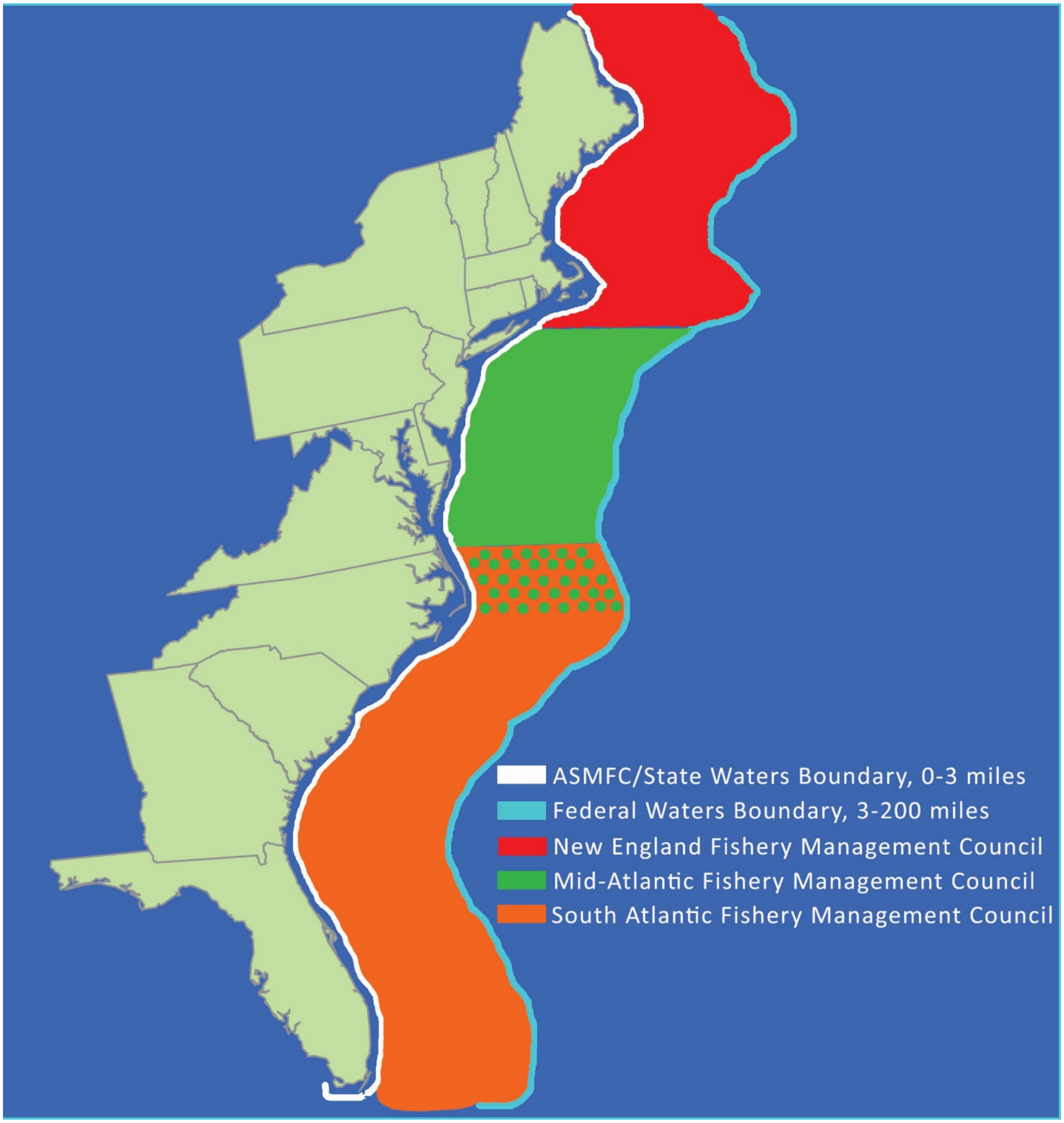
Historically, cobia has been overseen by the Mackerel Stock Assessment Panel (MSAP) under the purview of the Coastal Migratory Pelagics Fishery Management Plan. The most recent assessments of South Atlantic cobia were done in 1995 (Thompson 1995), and 2013 (SEDAR 2013). The 1995 assessment assumed the South Atlantic stock extended north from the Florida Keys. A VPA with a recreational fishery-dependent index (MRFSS) for tuning was used. The results of the VPA suggested that total mortality (Z) was equal to natural mortality (assumed M=0.4), suggesting a very low fishing mortality rate (F). A similar assessment in 1994 also indicated stable catches and low F in the South Atlantic with no indication of overfishing (Thompson 1994). The 2013 benchmark assessment was the first time the South Atlantic stock of cobia were assessed using the SEDAR process. For that assessment, the southern stock boundary was the Florida/Georgia border. The 2013 assessment was carried out using a catch-age statistical model and included life history parameters estimated externally, landings, discards, multiple indices, and length and age compositions.

References Cited:

- SEDAR. 2013. SEDAR 28 – South Atlantic Cobia Stock Assessment Report. SEDAR, North Charleston SC. 420 pp. available online at: http://www.sefsc.noaa.gov/sedar/Sedar_Workshops.jsp?WorkshopNum=28
- Thompson, N.B. 1994. An assessment of cobia in southeast U.S. waters. Miami Laboratory Contribution No. MIA-94/95-31.
- Thompson, N.B. 1994. An assessment of cobia in southeast U.S. waters. Miami Laboratory Contribution No. MIA-93/94-38.

3. Regional Maps

Figure 4.1: ASMFC jurisdictional boundaries. SEDAR 58 developed models for one region: North of the GA/FL state border line to New York.



4. SEDAR Abbreviations (South East Data Assessment and Review)

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

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

SSB	Spawning Stock Biomass
SSC	Science and Statistics Committee
TIP	Trip Incident Program; biological data collection program of the SEFSC and Southeast States.
TPWD	Texas Parks and Wildlife Department
Z	total mortality, the sum of M and F

SEDAR

Southeast Data, Assessment, and Review

SEDAR 58

Atlantic Cobia

SECTION II: Data Workshop Report

May 2019

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

1 Introduction

1.1 Workshop Time and Place

The SEDAR 58 Data Workshop meeting was held April 1-5, 2019 in Charleston South Carolina. Two data webinars were held prior to the workshop on August 29, and October 25, 2018.

1.2 Terms of Reference

1) Define the unit stock for the SEDAR 58 Atlantic Cobia stock assessment to include the US Atlantic Seaboard north of the Georgia-Florida border.

2) Review, discuss, and tabulate available life history information.
    a. Evaluate age, growth, natural mortality, and reproductive characteristics.
    b. Provide appropriate models to describe population and fleet specific (if warranted) growth, maturation, and fecundity by age, sex, or length as applicable.
    c. Evaluate the adequacy of available life-history information for conducting stock assessments and recommend life history information for use in population modeling.
    d. Provide estimates or ranges of uncertainty for all life history information.

3) Recommend discard mortality rates.
    a. Review available research and published literature.
    b. Consider research directed at these species as well as similar species from the SE and other areas.
    c. Provide estimates of discard mortality rate by fishery, gear type, depth, and other feasible or appropriate strata.
    d. Include thorough rationale for recommended discard mortality rates.
    e. Provide justification for any recommendations that deviate from the range of discard mortality provided in the last benchmark or other prior assessment.
    f. Provide estimates of uncertainty around recommended discard mortality rates.

4) Provide measures of population abundance that are appropriate for stock assessment.
    a. Consider and discuss 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 and survey coverage.
    d. Develop fishery and survey CPUE indices by appropriate strata (e.g. age, size, area, and fishery) and include measures of precision and accuracy.
    e. Discuss the degree to which available indices adequately represent fishery and population conditions.

   f. Recommend which data sources are considered adequate and reliable for use in assessment modeling and indicate why.
   g. Rank the available indices with regard to their reliability and suitability for use in assessment modeling.
   h. Provide appropriate measures of uncertainty for the abundance indices to be used in stock assessment models.

5) Provide commercial catch statistics, including both landings and discards in both pounds and number.
   a. Evaluate and discuss the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector or gear.
   b. Provide length and age distributions for both landings and discards if feasible.
   c. Provide maps of fishery effort and harvest.
   d. Provide estimates of uncertainty around each set of landings and discard estimates.

6) Provide recreational catch statistics, including both landings and discards in both pounds and number.
   a. Evaluate and discuss the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector or gear.
   b. Provide length and age distributions for both landings and discards if feasible.
   c. Provide maps of fishery effort and harvest.
   d. Provide estimates of uncertainty around each set of landings and discard estimates.

7) Identify and describe ecosystem, climate, species interactions, habitat considerations, and/or episodic events that would be reasonably expected to affect population dynamics.

8) Incorporate socioeconomic information into considerations of environmental events that affect stock status and related fishing effort and catch levels as practicable.

9) Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment. Include specific guidance on sampling intensity (number of samples including age and length structures) and appropriate strata and coverage. Also provide recommendations for methods to improve precision/estimates of uncertainty in recreational landings.

10) Review, evaluate, and report on the status and progress of all research recommendations listed in the last assessment, peer review reports, and SSC report concerning this stock.

11) Prepare the Data Workshop Report providing complete documentation of workshop actions and decisions in accordance with project schedule deadlines (Section II. of the SEDAR stock assessment report).

1.3 List of Participants

Data Workshop Panelists

Katie Siegfried	SEFSC Beaufort
Rob Cheshire	SEFSC Beaufort
Jennifer Potts	SEFSC Beaufort
Chris Kalinowsky*	GADNR
Hank Liao	ODU
Anne Markwith	NCDMF
Andy Ostrowski	SEFSC Beaufort
Matt Perkinson	SCDNR
George Sedberry	SAFMC SSC
Justin Yost	SCDNR
Dan Crear	VIMS
Riley Gallagher/Jacob Krause	NCSU
Beth Wrege	SEFSC Miami
Alan Bianchi/Amanda Tong	NC DMF
Julie DeFilippi-Simpson	ACCSP
Amy Dukes	SC DNR
Kevin McCarthy	SEFSC Miami
Ken Brennan	SEFSC Beaufort
Wes Blow*	SAFMC Mack/Cobia AP
Collins Doughtie	SAFMC Mack/Cobia AP
Kelly Fitzpatrick*	SEFSC Beaufort
Dawn Franco	GA DNR
Bill Gorham	SAFMC Mack/Cobia AP
Alex Aspinwall	VMRC
Vivian Matter	SEFSC Miami
Bill Parker*	Fisherman – SC
Kayla Rudnay	SC DNR
Lee Southard*	Fisherman – GA
Tom Sminkey	NMFS S&T
Chris Wilson*/Drew Cathey	NC DMF
Andrew Scheld*	VIMS
Rob Cheshire	SEFSC Beaufort
Katie Siegfried	SEFSC Beaufort
Mike Denson	SC DNR
Eric Fitzpatrick	SEFSC Beaufort
Anne Lange,	SA SSC
Kevin Weng*	VIMS

* Appointees marked with an * were appointed to the workshop panel but did not attend the workshop. Most provided data and reviewed the use of the data, and were available via email or phone for questions as needed.

Council Representatives

Anna Beckwith *	SAFMC
Mel Bell	SAFMC
Steve Poland	SAFMC

*Did not attend workshop.

Council and Agency Staff

Kathleen Howington	SEDAR
Cierra Graham	SAFMC
Christina Wiegand *	SAFMC
Mike Errigo	SAFMC
Mike Larkin*	SERO
Mike Schmidtke	ASMFC

*Participated in webinars but did not attend the Data Workshop.

Data Workshop Attendees

Karl Brecker	Fisherman
Tonya Darden	SCDNR
William Garla	Fisherman
Jackie Allen	SCDNR
Matt Walker	SCDNR
Mike Rinaldi	ACCSP
Gregg Waugh	SAFMC

Webinar Participating Data Providers

Julie Califf	GADNR
Larry Beerkircher	SEFSC

1.4 List of Data Workshop Working Papers

Atlantic Cobia Data Workshop document list. List includes documents submitted for the Stock ID Work Group meeting through the Data Workshop.

	Title	Authors
Documents Prepared for the Stock ID Workshop (StID)		
SEDAR58-SID-01	Predicting the distribution of cobia, *Rachycentron canadum*, seasonally, for mid-century, and for the end-of-century	Crear et al. 2018
SEDAR58-SID-02	Use of Pop-Up Satellite Archival Tags (PSATs) to Investigate the Movements, Habitat Utilization, and Post-Release Survival of Cobia (*Rachycentron canadum*) that Summer in Virginia Waters	Jensen & Graves 2018
SEDAR58-SID-03	Summary results of a genetic-based investigation of cobia (*Rachycentron canadum*)	McDowell et al. 2018
SEDAR58-SID-04	Population Genetic Analysis of Cobia within U.S. Coastal Waters	Darden et al. 2018
SEDAR58-SID-05	Evaluation of cobia movements using tag-recapture data from the Gulf of Mexico and South Atlantic coast of the United States	Perkinson et al. 2018
SEDAR58-SID-06	Summary Report of the North Carolina Division of Marine Fisheries Cobia (*Rachycentron canadum*) Acoustic Tagging	Poland 2018
SEDAR58-SID-07	A brief summary of scientifically collected distribution data for cobia (*Rachycentron canadum*) in US waters of the Atlantic and Gulf of Mexico	Klibansky 2018
SEDAR58-SID-08	Cobia Telemetry Working Paper (revised 4/10/2018)	Young et al. 2018
SEDAR58-SID-09	Distribution and abundance of cobia (*Rachycentron canadum*) larvae captured in ichthyoplankton samples during National Marine Fisheries Service and Southeast Area Monitoring and Assessment Program fishery-independent resource surveys	Hanisko et al. 2018
SEDAR58-SID-10	Spatial and Temporal Distribution of Cobia, Southeast US and Gulf of Mexico	Wrege 2018
SEDAR58-SID-11	VIMS Cobia Tagging Program	Weng et al. 2018

Documents Prepared for the Data Workshop (DW)		
Document #	Title	Authors
SEDAR58-DW01	Analyses and applications of Cobia length-age data collected by Virginia Marine Resources Commission between 1999 and 2018 (Revised 3/29/19)	Liao et al. 2018
SEDAR58-DW02	Fishery Dependent Index for Atlantic Cobia from MRIP Data, 1981-2017	Sminkey 2018
SEDAR58-DW03	Comparisons in growth between Cobia males and females and among years using Virginia length-age data collected by Virginia Marine Resources Commission between 1999 and 2017 (revised 3/22/19)	Liao et al. 2018
SEDAR58-DW04	Discard mortality ad-hoc group (revised 4/26/19)	Discard MortalityAd-hoc Group
SEDAR58-DW05	Investigation of Cobia Length Frequency Distributions and Potential for Differences Amongst Data Sets	Yost et al. 2019
SEDAR58-DW06	Release Condition and Observed Discard Mortality of Cobia in the For-Hire Recreational Fisheries in Florida	Duffin 2019
SEDAR58-DW07	SCDNR Charterboat Logbook Program Data, 1993-2017	Errigo et al. 2019
SEDAR58-DW08	Bycatch of cobia, *Rachycentron canadum*, in the Atlantic coastal gillnet fishery (revised 4/16/19)	Carlson and McCarthy 2019
SEDAR58-DW09	Preliminary standardized index of Southeast US Atlantic cobia (Rachycentron canadum) from headboat data. (revised 4/5/19)	SERFS 2019
SEDAR58_DW10	Estimates of Historic Recreational Landings of Cobia in the Atlantic Using the FHWAR Census Method	Brennan 2019
SEDAR58-DW11	Cobia Stock ID ProcessReport Compilation	SEDAR, 2018

	Reference Documents	
SEDAR58-RD01	SEDAR 28 South Atlantic Cobia Stock Assessment Report	SEDAR 28
SEDAR58-RD02	SEDAR 28 Gulf of Mexico Cobia Stock Assessment Report	SEDAR 28
SEDAR58-RD03	List of documents and working papers for SEDAR 28 (South Atlantic Cobia and Spanish Mackeral) – all documents available on the SEDAR website.	SEDAR 28
SEDAR58-RD04	Managing A Marine Stock Portfolio: Stock Identification, Structure, and Management of 25 Fishery Species along the Atlantic Coast of the United States	McBride 2014
SEDAR58-RD05	Chapter 22: Interdisciplinary Evaluation of Spatial Population Structure for Definition of Fishery Management Units (excerpt from Stock Identification Methods – Second Edition)	Cadrin et al. 2014
SEDAR58-RD06	Mitochondrial DNA Analysis of Cobia *Rachycentron canadum* Population Structure Uisng Restriction Fragment Length Polymorphisms and Cytochrome B Sequence Variation	Hrincevich 1993
SEDAR58-RD07	Population Genetic Comparisons among Cobia from the Northern Gulf of Mexico, U.S. Western Atlantic, and Southeast Asia	Gold et al. 2013
SEDAR58-RD08	Population genetics of Cobia (*Rachycentron canadum*): implications for fishery management along the coast of the southeastern United States	Darden et al. 2014
SEDAR58-RD09	Growth, mortality, and movement of cobia (*Rachycentron canadum*)	Dippold et al. 2017
SEDAR58-RD10	Assessment of cobia, *Rachycentron canadum*, in the waters of the U.S. Gulf of Mexico	Williams, 2001
SEDAR58-RD11	Life history of Cobia, *Rachycentron canadum* (Osteichthyes: Rachycentridae), in North Carolina waters	Smith 1995
SEDAR58-RD12	A review of age, growth, and reproduction of cobia *Rachycentron canadum*, from US water of the Gulf of Mexico and Atlantic ocean	Franks and Brown-Peterson, 2002
SEDAR58-RD13	An assessment of cobia in Southeast US waters	Thompson 1995
SEDAR58-RD14	Reproductive biology of cobia, *Rachycentron canadum*, from coastal waters of the southern United States	Brown-Peterson et al. 2001

SEDAR58-RD15	Age and growth of cobia, *Rachycentron canadum*, from the northeastern Gulf of Mexico	Franks et al. 1999
SEDAR58-RD16	Synopsis of biological data on the cobia *Rachycentron canadum* (Pisces: Rachycentridae)	Shaffer and Nakamura 1989
SEDAR58-RD17	Age, growth, and reproductive biology of greater amberjack and cobia from Louisiana waters	Thompson et al. 1991
SEDAR58-RD18	Cobia (*Rachycentron canadum*) stock assessment study in the Gulf of Mexico and in the South Atlantic	Burns et al. 1998
SEDAR58-RD19	Gonadal maturation in the cobia, *Rachycentron canadum*, from the northcentral Gulf of Mexico	Lotz et al. 1996
SEDAR58-RD20	Length-weight relationships, location and depth distributions for select Gulf of Mexico reef fish species	Pulver & Whatley 2016
SEDAR58-RD21	Inshore spawning of cobia (*Rachycentron canadum)* in South Carolina	Lefebvre & Denson 2012
SEDAR58-RD22	Determining the stock boundary between South Atlantic and Gulf of Mexico managed stocks of Cobia, *Rachycentron canadum*, through the use of telemetry and population genetics	Perkinson et al. 2018
SEDAR58-RD23	SAFMC Mackerel Cobia Advisory Panel and Cobia Sub-Panel Cobia Fishery Performance Report April 2017	SAFMC Mackerel Cobia AP & Cobia Sub-Panel 2017
SEDAR58-RD24	Spawning of the Cobia, *Rachycentron canadum*, in the Chesapeake Bay Area, with Observations of Juvenile Specimens	Joseph et al. 1964
SEDAR58-RD25	SEDAR28-DW02: South Carolina experimental stocking of Cobia *Rachycentrom canadum*	Denson 2012
SEDAR58-RD26	Applying network methods to acoustic telemetry data: Modeling the movements of tropical marine fishes	Finn et al. 2014
SEDAR58-RD27	Developing a deeper understanding of animal movements and spatial dynamics through novel application of network analyses	Jacoby et al. 2012
SEDAR58-RD28	Status of the South Carolina Fisheries for Cobia	Hammond 2001
SEDAR58-RD29	Dynamic ocean management increases the efficiency and efficacy of fisheries management	Dunn et.al. 2016
SEDAR58-RD30	Using Pop-off Satellite Archival Tags To Monitor and Track Dolphinfish and Cobia	Hammond 2008
SEDAR58-RD31	Cusk (Brosme brosme) and climate change: assessing the threat to a candidate marine fish species under the US Endangered Species Act	Hare et al 2012

2 Life History

2.1 Overview

Participant List

Jennifer Potts, *Workgroup leader*, SEFSC Beaufort
Chris Kalinowsky*, Data provider, GADNR
Hank Liao, Data provider, ODU
Anne Markwith, Data provider, NCDMF
Andy Ostrowski, Data provider, *Rapporteur*, SEFSC Beaufort
Matt Perkinson, Data provider, SCDNR
George Sedberry, Participant, SAFMC SSC
Justin Yost, Data provider, SCDNR
Riley Gallagher, Data provider, *Rapporteur*, NCSU
Jacob Krause, Data provider, NCSU
Dan Crear, Data provider, VIMS
*Not able to attend workshop

The Life History Group (LHG) was tasked with reviewing, discussing and tabulating available life history information, which included age data, growth, natural mortality and reproductive characteristics. Life history data were limited for cobia because recreational and commercial samples are limited and there have been no directed fishery-independent surveys of the stock. The majority of the fishery landings come from the charter boat and private recreational fishery sectors, where there is a lack of directed effort to sample the catches for biological samples (e.g., age structures and reproductive tissue). The majority of the data to be considered for this assessment were from carcass collection programs instituted in Virginia and South Carolina.

In addition to evaluating the life history parameters, the LHG made research recommendations to improve our understanding of the Atlantic Cobia stock and provided an update of research recommendations from SEDAR 28. We attempted to be more concise in our new research recommendations. We acknowledge that many projects directed at better understanding of the Cobia stock identification throughout the Southeastern Region have begun, but it is too early to report findings.

2.2 Review of Working Papers

The LHG reviewed three of the working papers submitted to SEDAR 58 Data Workshop. The three papers that were germane to the life history group were S58DW01, S58DW03, and S58DW05. The other papers pertained to other work groups or *ad hoc* groups.

(SEDAR58-DW01) Analyses and Applications of Cobia Length-age Data Collected by Virginia Marine Resources Commission between 1999 and 2018. Hank Liao, Alexander Aspinwall, Rob O'Reilly, and Cynthia Jones

Summary

The Virginia Marine Resources Commission (VMRC) began collecting length-age data in 1999 from the recreational Cobia fishery, and in 2007 began accepting Cobia carcass donations (including the carcasses from Cobia tournaments) from recreational anglers. In order to determine whether the change in sampling represents the recreational catch, they compared length frequency distributions collected by VMRC from the recreational and commercial fisheries to those collected by MRIP; compared mean lengths between the cobia collected randomly by VMRC and those donated by Virginia recreational fishermen; compared year effect on the mean lengths of cobia collected by VMRC from 1999 to 2018; and evaluated cohort progressions in the landing age distributions developed using Virginia ALKs and Virginia harvest estimated by MRIP; as well as comparing length distributions between Virginia and other Atlantic states. Results indicate that the length distributions and mean lengths shifted between 1999-2006 and 2007-2018. During the earlier period, VMRC staff collected more large fish and during the later period, carcasses donated revealed a wider distribution of fish and many more smaller fish. There was no evidence suggesting that Virginia recreational fishermen intentionally or unintentionally donated their smaller carcasses.

Critique

Working paper DW01 provides a good overview and comparison of the methods used by the VMRC to collect biological data from the recreational fishery and appropriately analyzes differences between two sample periods as modifications were made to the sampling program. The sampling changes, analytical methods, results and interpretation were discussed widely at SEDAR 58. The consensus of the LHG was that changes between the two periods presented were likely due to gradual changes. One, the cobia population may be changing due to fishing pressure. Two, some fishing strategies used by recreational anglers in Virginia have changed (sight casting) that may influence the likelihood of capturing more, smaller fish. These two factors may be reflective of the recreational fishery and not related to a sampling bias associated with the fishery.

The information in this paper were useful to the LHG.

(SEDAR58-DW03) Comparisons in growth between Cobia males and females and among years using Virginia length-age data collected by Virginia Marine Resources Commission between 1999 and 2018. SEDAR58-DW03 Revised 22 March 2019. Hank Liao, Alexander Aspinwall, Rob O'Reilly, and Cynthia Jones. 2019.

Summary

This paper addresses concerns raised by working paper SEDAR58-DW01 (Liao et al. 2018) regarding length and growth data (1999-2018) from VA. That analysis found that the VA Sportfish Collection Program (a carcass donation program) did not result in the observed decreases of the mean lengths during the period of 2007 to 2018 that were found when VMRC collected fish (a specimen purchase program) for length-age data from 1999-2018. A new analysis was conducted to verify the results of SEDAR58-DW01 and to identify possible causes (e.g., change in fishing or sex ratios) for any verified changes found by further analysis of length and growth. There was a negative correlation between the sex ratio and the mean length through the time series, and variation in the mean length is explained by the sex ratio. Increasingly, anglers donated more males during the more recent years. Males are smaller than females of the same age on average. The higher sex ratio resulted in a lower growth estimate. There also seemed to be a period of low growth for females from 2013 through 2018, indicating that female Cobia perhaps grew more slowly during recent years. Significantly different sex-specific growth rates occurred between the early donation period (2007-2012) and the later donation period (2013-2018); and between the combined VMRC collections and the early donation period (no significant difference between those two data sets so they were combined), and the second donation period. These results may indicate that the donation program data did not change the calculated growth rate immediately after implementation in 2007. The data also indicate that there was a decrease in VA cobia growth rate during the recent years (2013-2018). The Liao et al. (2018) working paper (SEDAR58-DW01) concluded that the VA donation program might not be the factor causing the observed annual reductions of mean fork length in the VA samples. By examining the growth of Cobia among different time-periods, this follow-up study has drawn similar conclusions to the original working paper (SEDAR58-DW01). Possible explanations for the decrease in VA Cobia growth during the past several years include donation of more males, increased abundance of males, or increasing sample sizes, which are more representative of the true sex ratios in the catch.

Critique

A good follow-up study. The “random” VMRC specimen collection (1999 – 2006) was done by buying fish from recreational fishermen, and there may be an effect of the purchase of specimens that was not mentioned. Recreational fishermen may sell the biggest fish among those they caught to maximize payment if sold by weight.

The VA data could be used in the benchmark stock assessment, as they satisfy the SEDAR data criteria: they are the most recent, best available, and scientifically sound data.

(SEDAR58-DW05) Investigation of Cobia Length Frequency Distributions and Potential for Differences Amongst Data Sets. Justin Yost, Joseph Ballenger, and Michael R. Denson, SCDNR

Summary

This working paper described the fishery-dependent data of five different data sets: three from SCDNR (tournament fish, charter boat donations, and private recreational donations) and two from NMFS [Marine Recreational Information Program (MRIP) and Southeast Region Headboat Survey (SRHS)]. SCDNR conducted a fishery-independent tagging study; however, due to the samples coming from mostly undersized fish, and thus not comparable to fishery-dependent data, they were removed from further consideration. The authors explored fork length comparisons among the datasets and across years.

Statistical analyses were performed on the data sets reported in the working paper. Fishery-dependent data set sample sizes, total from 2007-2016, ranged from 157 fish (MRIP) to 1292 (SCDNR Charter boat donations), and mean fork lengths ranged from 994 mm (private boat recreational) to 1055 mm (Tournament; see Table 1). Based on non-parametric analyses, there was a significant difference in fork length distributions from tournaments compared to all other sectors, where fish landed in tournaments were larger. MRIP, SHRS, and private boat modes showed no significant differences in fork length distributions, suggesting they are sampling the same population of cobia. Cobia landed in the charter boat fishery were significantly larger than those landed by private recreational boat anglers, but they were not significantly different from MRIP and SRHS. Year differences were explored for SCDNR fishery-dependent data, and showed no differences among annual fork length distribution except for 2007, which was lower than all other years, which is suggestive of a strong year class in 2004 that was just large enough to enter the fishery in 2007. Fork lengths were compared across sexes and showed that females were larger than males, an expected outcome since this species experiences dimorphic growth. Fork lengths were then compared by location (offshore vs. inshore) and found that the offshore fish tended to be larger than inshore fish, which may explain some of the difference in the size of fish landed in the charter boat and private boat modes. The private boat anglers tended to fish inshore more often, while charter boats tended to fish offshore. Another possible explanation of this observation was that inshore portion of the stock appears to be overfished due to the fish being more accessible to recreational anglers.

Based on the findings of this analysis, tournament fish were larger than fish landed in other modes, as were offshore fish compared to inshore. While there were no significant differences between pooled SCDNR samples across years, except for 2007 samples (a potential strong 2004 year-class collected in 2007), there was a slight difference between charter boat landings and private boat landings, but not among other fishery-dependent data.

Critique

This working paper offers a suite of analyses across data sources, years, sex, and location. Strong year classes have been suggested to have an influence on the recreational landings. Offshore fish and tournament fish were found to be larger than inshore and other recreational data sources. Tournament samples were biased and should be excluded for describing the size and age composition of general recreational catch, but included for estimating growth curves. All other recreational fishery-dependent sources should be included in further analyses for this assessment.

2.3 Age Data

Cobia age data were compiled from several sources with five laboratories involved in the processing and reading of the samples. Data sets were from GADNR, SEFSC Beaufort, which included NCDMF samples, Gulf Coast Research Lab (GCRL), SCDNR and ODU (collections from VMRC). Following the protocol established during SEDAR28 (2013), all age data were presented as calendar-age (year-class) as converted from increment counts and edge type. Table 2.11.1 provides a breakdown of number of samples by year and by fishery. Very few age samples were collected from the commercial fishery. For the recreational fishery, the samples were further broken down by state of landing. The majority of the recreational age samples came from South Carolina and Virginia. Not all recreational fishery samples could be classified to mode of fishing because most of the samples were from carcass collection programs (donated fish carcasses) with no notation along with the sample. This issue pertained primarily to the carcass samples donated in Virginia. The fishery-independent samples were collected through SEAMAP trawl survey and hook-and-line fishing. These samples included fish that were under the minimum size limit and filled in the missing portion of the population retained in the fishery. The LHG discussed the varying aspects of the data sets and their utility in the stock assessment.

Issues with the age data sets included the inclusion of Cobia sampled from tournaments, the low sample size from the commercial fishery, and data from carcass collection programs to obtain samples from the recreational fishery. Samples from tournaments showed varying trends in sizes compared to general recreational data. Tournaments in SC showed that the fish sampled in tournaments were significantly larger than fish landed in the general recreational fishery landings (SEDAR58-DW05). In contrast, tournament samples in VA did not show a consistent pattern of larger fish on average landed during tournaments compared to general recreational fishing, but sample sizes were very low, so no real conclusion could be made (SEDAR58-DW01). Due to the differing results between states and motivations of anglers in tournaments, the LHG felt that age data from tournament samples should not be used to characterize the recreational fishery, but would be included in the population growth model. Regarding the age data from commercially harvested Cobia, the sample sizes in any one year are too low to be used for annual age composition (Table 2.11.1). If an age-structured model is used in this assessment, then the commercial age samples could be pooled for one age composition to be applied to all commercial landings.

The age data from the general recreational fishery were collected from various sources and in various ways. Sources included two primary carcass collection programs operated by

SCDNR and VMRC, a few carcass samples from NCDMF, directed studies during short periods of time and a few samples from the Southeast Region Headboat Survey (SRHS). The main concern with the data available centers around the carcass collection programs in SC and VA. NCDMF has a carcass collection program that yielded very few Cobia. Figure 2.12.1 illustrates the comparison length frequencies of MRIP intercepts in NC to the carcass donations, with no differences noted. Two working papers, SEDAR58-DW01 and SEDAR58-DW05, gave details on the other programs and attempted to compare the carcass data to MRIP and SRHS data. SCDNR and VMRC felt that it was crucial to collect biological samples of Cobia to inform management of the species better, so they instituted their carcass collection programs in 2005 and 2007, respectively. VMRC staff intercepted Cobia landed in the commercial fishery, recreational fishery and tournaments between 1999 and 2006 with limited success. Because Cobia is considered a "rare event species", MRIP and SRHS do not intercept many animals, thus a comparison to the carcass data was not informative. The data from the carcass collection programs were evaluated individually.

Concerns about the SCDNR carcass collection program were the limited location of collection points and the motivation of the anglers to donate their fish. The SCNDR program had the advantage of being able to distinguish whether the donated carcass came from a charter boat landing or private boat landing. The donation centers were limited to the southern end of South Carolina, specifically Hilton Head area, where the bulk of the fishery is located. Initially the samples were coming from a mixture of offshore and inshore/estuarine fishing, but as the inshore portion of the population was fished down and subsequently restricted by the state, effort moved near-shore/off-shore areas. Overall, a comparison of the carcass collected samples to MRIP and SRHS showed a similar mean and length range of the fish across survey types. A look at the annual trend in the length frequencies revealed the 2007 samples to be significantly smaller from all the other years. That year, the majority of the effort was directed at the inshore portion of the stock that showed a very strong year-class of age-3 fish. Heavy fishing pressure on that portion of the stock resulted in a shift of effort to offshore waters around 2010, until SCDNR closed the inshore fishery completely in 2016 during the spawning season when cobia are present. The SCDNR staff involved in Cobia research felt that the interaction with the fishers in the Hilton Head Island area and public outreach and education have contributed to the carcass collection program in a positive way. They feel that they receive virtually every Cobia landed on charter boat trips. Also, these data were used in SEDAR28. In the absence of an expanded sampling program and a directed study consisting of a more sufficient random sampling program alongside the carcass donation program to compare data, these SCDNR's carcass collection samples are the best available information about the recreational fishery in South Carolina.

Concerns about the VMRC carcass collection program were the lack of information on the fishing mode and the shift in the length frequencies through the years to more small fish in the donations. Fishermen and staff of VMRC reported that the charter boats and private boats fish for Cobia in the same areas, so selectivity of the fish in each mode was assumed the same.

Thus, general recreational age compositions should be acceptable. Most concern about the VMRC data was the shift in annual length frequencies to more small fish in the last 5 years of carcass collections. Figure 5 of SEDAR58-DW01 illustrated the largest shift to more small fish between the period of random collection by VMRC staff and the donated fish. Figures 1 and 2 of SEDAR58-DW01 provide the annual length frequencies of the samples illustrating in more detail the shift in the lengths of the fish donated to more small fish. One possible reason for the shift to more, smaller fish could have been the ease of handling the carcass to get it into a bag and into a freezer. Fishermen present during the workshop stated that it was easy to fold a large carcass and bag it, easing the concern of the LHG. One VMRC staff member stated that the fishing technique for Cobia in Virginia waters had been changing in the past 7-8 years from solely "chum fishing" to more "sight casting". The fishermen described the sight casting technique and explained why the smaller fish, presumably males, swimming with one large fish, presumably female, would be caught in higher proportions. The sight casting technique has been used for much longer in the South Carolina Cobia fishery. Another concern was raised regarding the donation of the largest fish, or "citation fish". In order for a person to receive a citation, the angler must present the fish at a tackle shop, away from donation area. A person most likely would not return to the donation site to drop off the carcass. It was noted that the largest fish (>120 cm FL) continued to be donated at a similar level across the years. The explanation of the fishery helped to understand the shifts in the lengths of the samples donated. As with SCDNR data, in the absence of an expanded sampling program and a directed study consisting of a sufficient random sampling program alongside the carcass donation program to compare data, the VMRC data are the best available information about the recreational fishery in Virginia.

Recommendations:

1. Age data from fish landed during tournaments should not be used to characterize the recreational fishery. They can be used in the population growth model.
2. If an age-structured model is used in this assessment, then the commercial age samples should be pooled for one age composition to be applied to all commercial landings.
3. The age data from SRHS and carcass collection programs can be used for to characterize the general recreational fishery.

2.4 Growth

Growth of Atlantic Cobia was modelled on the population as a whole, and on sexes separately, because this species exhibits dimorphic growth. An examination of the mean FL-at-age by state, regardless of sex, did not result in significant differences, especially between Virginia and South Carolina where the majority of the samples were from (Figure 2.12.2). Because Cobia have dimorphic growth, with females larger than males, the sex specific mean FL-at-age by state was examined, also. Male Cobia from South Carolina appeared to slightly larger at ages 3-5 than those from North Carolina and Virginia, but not by an appreciable amount or at any other ages (Figure 2.12.3a). The female Cobia did not show a difference in FL-at-age, except for age-7 (Figure 2.12.3b). These analyses suggested that it was reasonable that the growth could be modeled as one population. The LHG also modelled sex-specific growth for use in the assessment model to estimate spawning stock biomass.

Due to the preponderance of age data being obtained from fishery landings subject to minimum size limit regulations, all growth models incorporated a left-truncated size distribution correction factor applied to samples from the fishery (McGarvey and Fowler, 2002). Minimum size limits were applied as appropriate by time-period and fishery to each sample. The fish that were subject to a size limit, but their FL fell below that minimum level were removed from the data input, because the model assumes zero probability of landing below the size limit. We estimated these parameters by fitting observed length-at-biological age (fractional age) data to the von Bertalanffy model by minimizing the negative log-likelihood function and assuming constant standard deviation (sigma) of FL across all ages using AD Model Builder estimation software (http://www.admb-project.org). The biological age was based on June as month of peak spawn. The von Bertalanffy parameters and standard errors for the population model and the sex-specific models are presented in Table 2.11.2 and shown in Figures 2.12.4 and 2.12.5.

Recommendations:

1. The population growth model, incorporating the correction for the bias in size-at-age due to the minimum size limit, is appropriate to use in the stock assessment.
2. The growth model for females, incorporating the correction for the bias in size-at-age due to the minimum size limit, is appropriate to use to estimate spawning stock biomass.

2.5 Natural Mortality

The LHG explored various methods of estimating natural mortality (*M*) based on life history parameters. The LHG felt that it was not appropriate to apply one point estimate to the entire age range of the fish, such as Hewitt and Hoenig (2005) or Then et al. (2014). Charnov et al. (2013) offers an age-varying natural mortality as a function of size of the fish. The age-specific *M* was calculated using the von Bertalanffy population growth parameters, L_∞ and K, the predicted fork length at the mid-point of each age. The mid-point of each year class was used to represent the mean size of the fish in a calendar year. The age-specific estimates of *M* are presented in Table 2.11.3.

Recommendation:

Use the age specific values of *M* as calculated using the Charnov et al (2013) method.

2.6 Reproductive Biology

Very limited reproduction data were provided since the last stock assessment of cobia (SEDAR 28) with the exception of sex ratio and additional histological samples for sexual maturity estimates. Because of this lack in additional data, many of the same recommendations that were provided in SEDAR 28 were recommended for this assessment. The majority of the reproductive information on spawning seasonality, frequency, and fecundity are presented in published works by Brown-Peterson et al. (2001) and Franks and Brown-Peterson (2002), and are referenced as such. All age-related results presented in this section were based on calendar age. Information below on spawning seasonality, sexual maturity, sex ratio, and spawning frequency is based on the most accurate technique (histology) utilized to assess reproductive condition in fishes.

2.6.1 Spawning Seasonality

No new data were provided since the last assessment; thus, this section covers the conclusions from SEDAR 28.

Spawning season was determined based on the occurrence of hydrated oocytes and/or post-ovulatory follicles from spawning cobia collected along the Atlantic coast of the southeastern U.S., and has been reported to occur from April through July and peak during May and June (Brown-Peterson et al. 2001). It has been reported in the literature that cobia along the South Atlantic coast of the United States spawn from May through September (Joseph et al, 1964; Hassler and Rainville, 1975; Shaffer and Nakamura, 1989; Brown-Peterson et al, 2001), however each of these studies reported relatively low sample sizes and a fairly restricted geographic collection area. Data available from recent collection efforts (1990-2012) show that mean values of a female gonadosomatic index based on specimens collected in South Carolina waters were highest in May, and those collected in North Carolina waters peaked in June. It has also been reported in the literature that cobia spawning peaks in Virginia in July (Joseph et al., 1964; Richards, 1967; Mills, 2000).

It has been well documented that cobia begin a "migration" or move into nearshore waters in the South Atlantic when temperatures reach 20-25℃ (Shaffer and Nakamura, 1989; Biesiot et al., 1994; Smith, 1995). Figures 2.12.6, 2.12.7 and 2.12.8 describe the mean temperature profiles for coastal waters off SC, NC and VA, which suggest that these temperatures are typically found in SC in May, NC in June and VA in July. Previous samples were collected during tournaments over a broad geographic area and time-period leading researchers to conclude that the entire population was spawning over a period of several months. However, the GSI and temperature data suggest that cobia in the Southeast region may actually spawn for a much shorter period (30-45 days) that is brought on locally by critical temperatures (beginning at 20-25 and then subsiding over a 30-45 day period). This hypothesis is supported by the genetically distinct spawning aggregations identified in VA and in SC as reported in SEDAR28- DW01. If spawning were to occur over the extended season suggested in the literature, distinct population segments would not be identifiable. This is an important consideration in estimating the number of spawning days in a spawning season.

Recommendations:

The spawning season appears to be concentrated into a four-six week period for a given location based on GSI and temperature data. This coupled with differences in genetic population structure within the two known inshore aggregations provide enough uncertainty around the spawning season of the total population that the LHG recommends using spawning stock biomass in the model for spawning potential.

2.6.2 Sexual Maturity

Histological evaluation of fish gonads are considered the best method in assessing sexual maturity. After exploring the data, it was discovered that the Virginia samples were evaluated macroscopically limiting the ability to determine if a fish was immature or in an early developmental stage. For this reason, the LHG eliminated these samples from the maturity evaluation. SCDNR SEAMAP survey provided additional undersized cobia for age at maturity estimates; however, age-2 fish appear to be large enough to avoid the trawl survey and are still limited in this assessment.

Sexual maturity for male cobia in the Atlantic remain similar to findings in SEDAR 28 and appear to occur at a very small size. Because of the paucity of samples of cobia smaller than 200 mm FL, it is not possible to determine the smallest size at which male cobia reach sexual maturity, but this appears to occur well before they reach age-1. The smallest mature male evaluated by SCDNR using histological techniques was 207 mm FL and 2-4 months of age, corroborating findings reported by Brown-Peterson et al. (2001) and Brown-Peterson et al. (2002). Sample sizes of small female cobia in the dataset were also limited. Thirty-one age 0-1 fish were examined compared to only eight from SEDAR 28, and all of these fish were immature. Of the age-2 fish (n=21), 62% were sexually mature (Table 2.11.4). The only caveat regarding these animals was that they were likely the fastest growing and largest two-year olds collected from the fishery due to the 33” FL minimum size regulations. All of the age-3 fish (n=264) were determined to be sexually mature with the caveat that the slower growing age-3 fish have not recruited potentially due to the minimum size limit. Additional data support findings from SEDAR 28 suggesting female cobia above 800 mm FL are likely to be mature, regardless of age (Table 2.11.5). Smith (1995) similarly found that most 2 year-old females were sexually mature, with 25% maturity at 700-800 mm FL and 100% maturity above 800 mm FL.

Recommendations:

The size of cobia appears to be more strongly correlate with maturity than age thus a size at maturity vector is recommended (Table 2.11.6). If an age structured assessment model is used, an age at maturity vector is recommended. Due to the limited number of samples at the youngest ages and the influence of the minimum size limit on size at age of those young fish, the LHG recommends using age-2 for age at 50% maturity, with 0% mature at ages 0 and 1 and 100% of all fish age-3+ mature. Again, due to the influence of the minimum size limit on the young fish, there is a chance that not all age-3 fish are mature. When back-calculating the length of the fish to age using the von Bertalanffy growth curve, not all age-3 fish would be mature based on growth parameters. Thus, a sensitivity run, similar to SEDAR 28, could be made using 0% mature at ages 0 and 1, 50% mature at age-2, 75% mature at age-3, and 100% mature age-4+.

2.6.3 Sex ratio

VMRC and SCDNR significantly increased the amount of data for sex ratio determination since SEDAR 28. VMRC noted a change in the fork length of the donated carcasses from the Virginia recreational fishery (SEDAR58-DW01), potentially due to the changes in fishing techniques for cobia in that area and/or change in the overall population. This trend was reflected in the sex ratio going from predominately a female-based fishery to a 1:1.35 male:female ratio during the period following the last assessment. Information on cobia sex ratio by length class (mm FL), year, and age class are available in Tables 2.11.7, 2.11.8 and 2.11.9, respectively. The male:female sex ratio for all adult cobia in fishery-independent and fishery-dependent collections from 1984-2017 was **1:1.4**, which was significantly different from a 1:1 ratio based on size (Chi-square= 987.629, 28 df, P =<0.001, n = 4919), on age (Chi-square= 35.905, 16 df, P = <0.001, n=4950), and on year captured (Chi-square= 136.366, 33 df, P =

<0.001, n=5038). As expected, due to cobia having sexual dimorphic growth, evaluating the sex ratio by length show the largest fish were skewed towards females.

Recommendation for AW:

A male:female sex ratio of 1:1.4 is recommended to be used in this assessment, which is the same ratio used in SEDAR 28.

2.6.4 Spawning Frequency

No new data were provided since the last assessment thus this section covers the conclusions from SEDAR 28.

Spawning frequency estimates range from 4 to 6 days (table 2.11.10). Estimates of spawning frequency were determined according to the procedures of Hunter and Macewicz (1985) using FOMs and POFs. Cobia from southeastern United States (SEUS; n=23) and north central Gulf of Mexico (NCGOM; n=135) were estimated to spawn every 4 to 5 days (Brown-Peterson et al. 2001). Spawning frequency estimates for the SEUS were based on data from April, May, and June (spawning season).

SCDNR examined cobia collected via hook and line from estuarine and offshore waters of southern South Carolina in April-June 2007 and 2008. Fish were collected from tournaments, cooperating anglers, recreational fishing guides, and SCDNR employees. Ovaries were examined using histological techniques similar to Brown-Peterson et al. (2001), and spawning frequency was estimated using POFs following procedures of Hunter and Macewicz (1985).

The majority of the catch were late developing stage, gravid or had POF's (99%), which was not unexpected as most of the catch occurred while fish were in spawning aggregations, both inshore and offshore, as described by Lefebvre and Denson (2012) (Table 2.11.11). Spawning frequency was estimated to be 6.1 days, similar to what was reported by Brown-Peterson et al. (2001) (Table 2.11.12).

Recommendation for AW:

Use 6 days as the spawning frequency based on the larger sample size provided by SCDNR.

2.6.5 Batch Fecundity (BF)

No new data were provided since the last assessment thus this section covers the conclusions from SEDAR 28.

Only limited information to estimate fecundity is available for cobia along the Atlantic coast and Gulf of Mexico.

Batch fecundity (BF) estimates were taken from datasets published by Brown-Peterson et al. (2001) but the BF method was found to be difficult to apply to cobia as hydrated females were rarely sampled. Estimates were based on an indirect method (denoted as neutral buffered formalin or NBF method) as recently recommended by the lead investigator (Pers. Comm. Nancy Brown-Peterson). Sample size is low (n=39) and therefore observations were combined from SEUS, EGOM, and NCGOM. Relative batch fecundity ranged from 0.99 to 255 eggs/g ovary free body weight (mean 53.1, SD 59.1) by the NBF method. The data suggested a power, rather than a linear function for the relation of batch fecundity and body weight, but the coefficient of determination was low (r^2=0.146, Figure 2.12.9).

Batch fecundity alone does not fully represent reproductive investment. No size or age-based estimates are available regarding the number of spawns per year; thus, annual egg production can only be poorly estimated. A simplification is to assume that egg production is proportional to biomass of spawning females such that the number of eggs or larvae produced per gram of female body mass is constant among mature females with no effect of age structure on a per-unit basis. This is the Spawning Stock Biomass (SSB) assumption which is equivalent to the exponent b equal to 1 in the generalized fecundity (F) equation $F = aW^b$ where W = female weight.

However the batch fecundity relationship, while poorly fit, suggests b is greater than one (Figure 2.12.9). In addition, it is becoming better understood generally among fishes with indeterminate fecundity type that older and larger females are more likely to spawn more batches per year thus further increasing the likelihood that $b > 1$. While difficult to estimate, it is likely older cobia contribute disproportionately more to egg production.

Recommendation for AW:

Due to the limitations of the reproductive parameters, use female SSB as an estimate of reproductive potential.

2.7 Meristic Conversions

SEDAR 58 panel assigned the length type and fish weight for the biological data inputs to be in fork length and whole (round) weight. Thus, some data sets which have other length types included or lengths with no weights, or vice versa, needed conversion equations to predict the missing data. Data from Virginia to Georgia with paired length types and weight-length data were compiled for the regression analyses. Data sets included were from VMRC, SCDNR, SRHS, MRIP, and Smith (1995) study. Linear regressions for length-length and LN-LN transformed weight-length were modelled. The weight-length equations were converted to the power equation, $W = aL^b$, adding ½ MSE for transformation bias. Table 2.11.13 provides the parameters, standard errors, sample sizes and ranges of each independent variable.

Recommendation:

Use the meristic conversion equations as presented in Table 2.11.13.

2.8 Research Recommendations

Because the Cobia fishery is primarily a recreational fishery and considered a rare event species, sampling programs conducted by state and federal agencies do not encounter Cobia very often. For this reason, SCDNR, NCDMF and VMRC have started carcass collection programs along their coastal counties in an attempt to get more biological samples. In any carcass collection program, the donated samples may not be truly random or representative of the landings. Questions arise such as what motivates a person to donate their fish carcass, or are the donation sites evenly distributed throughout the study area. Some of the programs have offered incentives (e.g., t-shirt, hat or towel) to encourage donations. The concern of anglers leaving the landing site to file for a citation for large fish or simply to go to another location to clean fish may bias the donation of carcasses. Following the LHG discussions regarding the data available for SEDAR58, we suggest the following recommendations:

1. Validate the carcass collection programs as representing the recreational fishery. E.g., Side-by-side comparison to a random port sampling program.
2. State agencies should work together to achieve more consistency in their programs.
3. Increase public education for the importance of the programs.
4. Expand the geographic range of the donation sites.

The largest gap in biological knowledge of Atlantic Cobia is in the reproductive biology. SCDNR has been able to collect gonad tissue and histologically process the samples. Other states were able to provide macroscopic sex and maturity data, but that was not adequate to distinguish immature from maturing fish. The LHG also acknowledges that obtaining fecundity estimates is difficult for Cobia, but would greatly enhance a stock assessment. Because spawning appears to be tightly correlated with water temperature, further refinement of spawning seasons by area is needed. Some recommendations to get more reproductive biology data include:

1. Histological processing of all gonad tissue to better estimate the maturity schedule of Atlantic Cobia. In particular, focus on the fish aged 0 – 3 years and cover full geographic range of the species.
2. Determine the contribution to the population from the inshore spawning stock and the offshore spawning stock.
3. Obtain estimates of fecundity and periodicity of the Atlantic Cobia stock.

During the stock ID process of SEDAR58, there was discussion regarding the potential separation of the inshore and offshore portions of the Atlantic Cobia stock. Understanding more about that separation may be crucial to management of the population. Some research recommendations include:

1. Use otolith chemistry techniques to elucidate the contribution of inshore and offshore spawned Cobia to the Atlantic population.
2. Expand genetics studies to refine the possible stock separation of the inshore and offshore segments of the population.

The tagging studies in the area have been increasing our knowledge of the migratory pattern of the Atlantic Cobie, but they could be expanded to provide more data.

1. Direct tagging studies to obtain estimates of mortality
2. Determine tag retention and reporting rates
3. Hold a workshop to ensure consistent tagging methods across states at the program level.

2.9 Progress Report of SEDAR28 Research Recommendations

1. The LHWG recommends implementation of a tagging study along the entire east coast of Florida and the evaluation of genetic samples from the same to determine more precise stock boundaries.
Ongoing acoustic telemetry studies in Florida through South Carolina (2016 – present) and North Carolina through Virginia (2017 – present). Genetic samples are being collection along with the telemetry study.

2. Recommend developing a tagging program for inshore and offshore South Atlantic Cobia populations. The goal would be to deploy tags inshore during the spring migration and offshore during the fall and winter to get a clearer picture of fall and spring migrations and to better identify spawning areas and aggregations.
This recommendation is being accomplished with the telemetry studies referenced in point #1. There is still a need to identify spawning areas/aggregations.

3. Explore the feasibility of satellite tags for Cobia movement studies.
The state of Virginia is starting a study in 2019 and there are 27 satellite tagged fish from North Carolina to Florida.

4. Provide genetic sampling kits to interested groups to better understand the stock division line between the Gulf and Atlantic Cobia stocks. Possible collectors of genetic samples could include Charter operators, fishing clubs and state fisheries personnel.
Ongoing studies throughout the South Atlantic and Gulf of Mexico.

5. Further research is needed on Cobia release mortality.
This research is ongoing. See Release Mortality section of the SEDAR58 Data Workshop report.

6. To increase the overall amount of data available on Cobia, it is recommended that port samplers do complete workups when sampling, including otolith removal for aging, length, weight, sex, genetic sampling and record a catch location.
VMRC and SCDNR have continued their carcass collection programs, which have been successful in obtaining biological information. NCDMF has a carcass collection program, but needs to increase awareness and public participation in it. Carcass collection programs have not been able to collect all aspects of the biological information needed. See section 2.8 of the LHG report for recommendations concerning the carcass collection programs and the need for more reproductive biology data.

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2.11 Tables

Table 2.11.1. Number is annual Atlantic Cobia age samples by fishery, and for the recreational fishery, by state.

Year	Commercial	Fishery Independent	General Recreational				Tournaments		
State			VA	NC	SC	GA	VA	NC	SC
1984				3					
1985				2					
1986	1			22					
1987				18					
1988		4		9	1			7	
1989	4	10		62				16	
1990	3	17		80	3			20	
1991	1			13				3	
1992				12				8	
1993				1				15	
1994				3				13	
1995				10					
1996				13	18				
1997				7	13				
1998	5								
1999	10		124						
2000	7		111						
2001	7		52				20		
2002	36		26						
2003	2		7						
2004	2		7						
2005	6		10	2	47				66
2006	3		25		38				17
2007	12	1	25		341		31		
2008	5	7	40		276		6		
2009	3	4	106		205				
2010	3	5	106	11	215				
2011	11	23	89		217				
2012	3	5	76		223	1		1	
2013	13	8	190		300				
2014		13	287		244	3			
2015		15	342		189				
2016		15	255	11	142				
2017	5	27	239	34					
Grand Total	142	155	2117	313	2472	4	57	83	83

Table 2.11.2. Growth model parameters and standard errors (SE) for Atlantic Cobia for the population and sex-specific. Lengths are FL in mm.

Model	N	L_∞	SE	K	SE	t_0	SE
Population	5,088	1261.5	7.2	0.3086	0.0073	-0.5269	0.0487
Females	2,780	1333.9	7.2	0.3180	0.0077	-0.4918	0.0554
Males	1,903	1098.7	6.6	0.3651	0.0115	-0.6549	0.0633

Table 2.11.3. Age-specific natural mortality of Atlantic Cobia based on Charnov et al. (2013) and using the predicted fork length at the mid-point of each calendar age.

Age	FL (mm)	*M*
1	589	0.97
2	768	0.65
3	900	0.51
4	996	0.44
5	1067	0.40
6	1119	0.37
7	1157	0.35
8	1185	0.34
9	1205	0.33
10	1220	0.33
11	1231	0.32
12	1239	0.32
13	1245	0.32
14	1250	0.31
15	1253	0.31
16	1255	0.31

Table 2.11.4**.** Count of female cobia by age and reproductive phase. Reproductive phase terminology from Brown-Peterson et al., 2011.

Age	Immature	Developing	Spawning-capable	Recent	Regressing	Total
0	15					15
1	16					16
2	8	8	2		3	21
3		44	114	46	8	212
4		20	42	81	9	152
5		17	20	81	7	125
6		22	12	49	1	84
7		13	11	26	5	55
8		8	4	19		31
9		6	4	10		20
10		3	3	5		11
11		1	2	3		6
12		3				3
13		2		1		3
Total	**39**	**147**	**214**	**321**	**33**	**754**

Table 2.11.5**.** Female cobia mean fork length (mm) by age and reproductive phase.

Age	Immature	Developing	Spawning-capable	Recent	Regressing	Total
0	326					326
1	451					451
2	701	799	797		891	769
3		887	969	945	947	946
4		1005	1045	1032	1017	1031
5		1069	1114	1091	1081	1091
6		1107	1151	1153	1094	1140
7		1174	1173	1167	1149	1168
8		1233	1231	1210		1219
9		1256	1227	1261		1253
10		1267	1333	1308		1304
11		1210	1370	1227		1272
12		1273				1273
13		1380		1399		1386
Total	**454**	**1035**	**1036**	**1088**	**1031**	**1028**

Table 2.11.6 Size at maturity for female cobia fork length (mm).

Female FL (mm)	% Mature	n
251-300	0%	4
301-350	0%	8
351-400	0%	6
401-450	0%	4
451-500	0%	6
501-550	0%	1
551-600	0%	2
601-650	33%	3
701-750	33%	6
751-800	60%	5
801-850	100%	13
851-900	100%	36
901-950	100%	80
951-1000	100%	108
1001-1050	100%	114
1051-1100	100%	102
1101-1150	100%	88
1151-1200	100%	76
1201-1250	100%	42
1251-1300	100%	32
1301-1350	100%	14
1351-1400	100%	6
1401-1450	100%	2
Total	**95%**	**768**

Table 2.11.7**.** Sex ratio of Atlantic cobia by fork length (mm).

FL (mm)	M	F	n	M:F ratio
201-250	5		5	
251-300	7	5	12	1:0.7
301-350	5	8	13	1:1.6
351-400	10	13	23	1:1.3
401-450	13	16	29	1:1.2
451-500	10	12	22	1:1.2
501-550	7	9	16	1:1.3
551-600	6	2	8	1:0.3
601-650	6	3	9	1:0.5
651-700	7	2	9	1:0.3
701-750	14	9	23	1:0.6
751-800	23	14	37	1:0.6
801-850	193	73	266	1:0.4
851-900	440	211	651	1:0.5
901-950	433	291	724	1:0.7
951-1000	374	349	723	1:0.9
1001-1050	254	374	628	1:1.5
1051-1100	151	345	496	1:2.3
1101-1150	76	322	398	1:4.2
1151-1200	30	273	303	1:9.1
1201-1250	10	199	209	1:19.9
1251-1300	4	140	144	1:35.0
1301-1350	2	87	89	1:43.5
1351-1400	2	44	46	1:22.0
1401-1450		21	21	
1451-1500		9	9	
1501-1550		3	3	
1551-1600		2	2	
1601-1650		1	1	
Total	**2082**	**2837**	**4919**	**1:1.4**

Table 2.11.8. Sex ratio of Atlantic cobia by year.

Year captured	Male	Female	n	M:F ratio
1984	1	3	4	1:3.0
1985		2	2	
1986	17	8	25	1:0.5
1987	12	9	21	1:0.8
1988	8	16	24	1:2.0
1989	55	39	94	1:0.7
1990	55	55	110	1:1.0
1991	5	10	15	1:2.0
1992	7	16	23	1:2.3
1993	4	13	17	1:3.3
1994	8	9	17	1:1.1
1995		10	10	
1996	18	21	39	1:1.2
1997	10	14	24	1:1.4
1998	2	2	4	1:1.0
1999	10	65	75	1:6.5
2000	21	76	97	1:3.6
2001	15	49	64	1:3.3
2002	14	45	59	1:3.2
2003	1	8	9	1:8.0
2004		8	8	
2005	40	89	129	1:2.2
2006	35	48	83	1:1.4
2007	186	198	384	1:1.1
2008	143	174	317	1:1.2
2009	128	151	279	1:1.2
2010	126	196	322	1:1.6
2011	136	165	301	1:1.2
2012	147	143	290	1:1.0
2013	188	289	477	1:1.5
2014	223	288	511	1:1.3
2015	230	285	515	1:1.2
2016	159	240	399	1:1.5
2017	120	170	290	1:1.4
Total	**2124**	**2914**	**5038**	**1:1.4**

Table 2.11.9. Sex ratio of Atlantic cobia by age in years.

Age	M	F	n	M:F ratio
0	25	20	45	1:0.8
1	38	44	82	1:1.2
2	42	74	116	1:1.8
3	454	690	1144	1:1.5
4	558	660	1218	1:1.2
5	392	478	870	1:1.2
6	203	329	532	1:1.6
7	146	262	408	1:1.8
8	93	120	213	1:1.3
9	64	99	163	1:1.5
10	39	48	87	1:1.2
11	26	33	59	1:1.3
12	10	21	31	1:2.1
13	7	7	14	1:1
14	6	2	8	1:0.3
15	1	2	3	1:2
16		1	1	
Total	**2104**	**2890**	**4994**	**1:1.4**

Table 2.11.10. Spawning frequency of cobia in the Southeastern United States and North Central Gulf of Mexico using POF and FOM analysis.

	Southeastern United States Region (SEUS)	North Central Gulf of Mexico Region (NCGOM)
Spawning frequency	(n=23)	(n=135)
POFs %	19.4	24.8
Frequency (POFs)	5.2 days	4.0 days
FOM %	19.4	19.8
Frequency (FOM)	5.2 days	5.0 days

Table 2.11.11. State of ovary development of female cobia caught in South Carolina in 2007 and 2008. (*n* = number of fish; PC = percent composition.)

Stage	**Inshore**		**Offshore**		**Unknown**	
	n	PC	*n*	PC	*n*	PC
Immature	0	0	0	0	0	0
Early developing	1	2	1	3	1	1
Late Developing	51	80	20	59	97	84
Gravid	2	3	0	0	3	3
Postovulatory 1-Recent spawn	3	5	1	3	4	4
Postovulatory 2-Prior spawn	7	11	11	32	9	8
Spent	0	0	1	3	1	1
Recovering	0	0	0	0	0	0

Table 2.11.12. Mean estimated spawning frequencies of cobia from three regions in the southern United States. Spawning frequencies were estimated from the percentage of ovaries in the late developing ovarian class containing either postovulatory follicles (POF).

Spawning frequency	Inshore Captures	Offshore Captures	Unknown Capture Location	**All areas combined**
Samples (n)	64	34	115	**213**
% POFs	15.625	35.294	11.304	**16.432**
Frequency (POFs)	6.4 days	2.8 days	8.8 days	**6.1 days**

Table 2.11.13. Meristic conversion equations for Atlantic Cobia. All length types are mm and whole (round) weights (WW) are kg.

Equation	**Parameters (SE)**				**n**	**r2**	**Independent variable range**	
	a	**SE**	**b**	**SE**			**Min**	**Max**
WW = aFL^b	1.65*10-9	0.07	3.28	0.01	3238	0.97	200	1610
FL = aWW^b	489.85	0.002	0.29	0.001	3238	0.97	0.06	54.7
WW = aTL^b	1.91*10-9	0.06	3.21	0.01	2455	0.98	90	1758
TL = aWW^b	528.48	0.002	0.31	0.001	2455	0.98	0.002	54.7
FL = a + b*TL	8.19	1.55	0.88	0.00	5672	0.99	214	1753
TL = a + b*FL	5.91	1.75	1.12	0.00	5672	0.99	200	1610

2.12 Figures

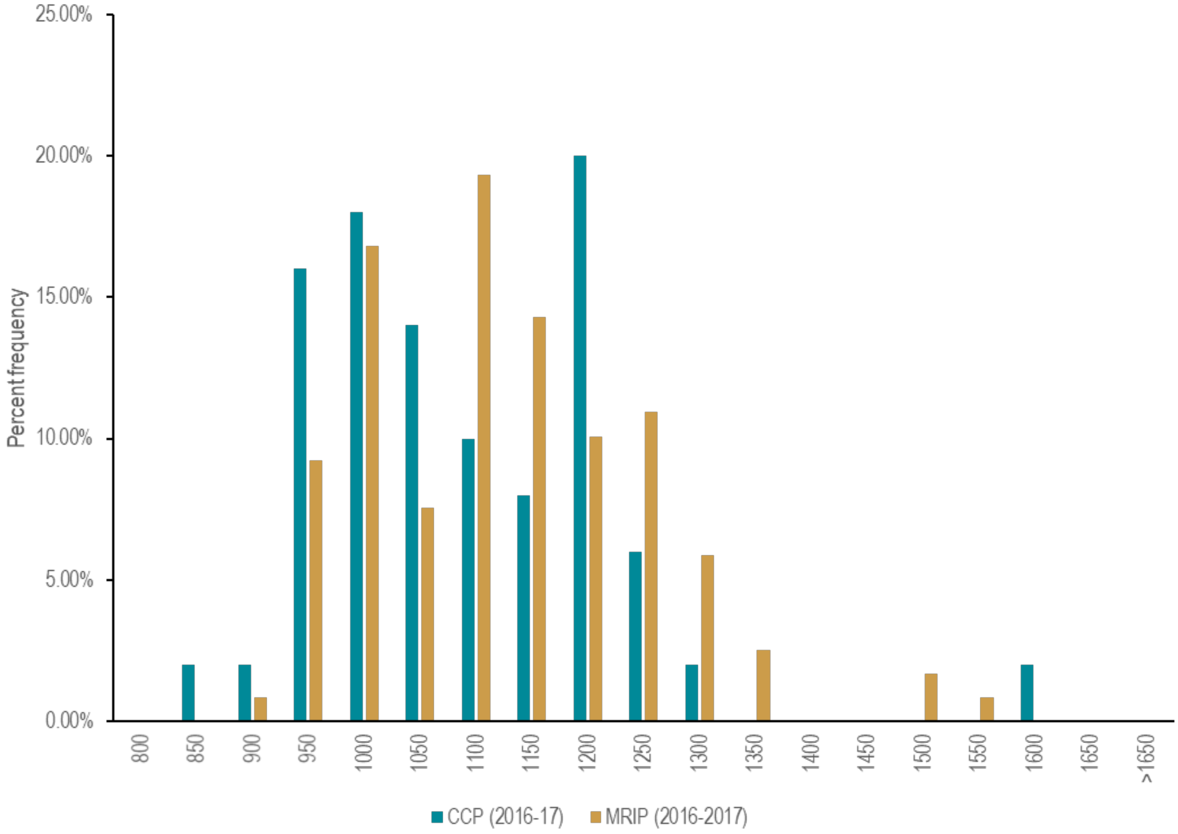


Figure 2.12.1. Comparison of 2016-2017 length frequencies of Cobia samples by MRIP and NCDMF Carcass Collection Program (CCP).

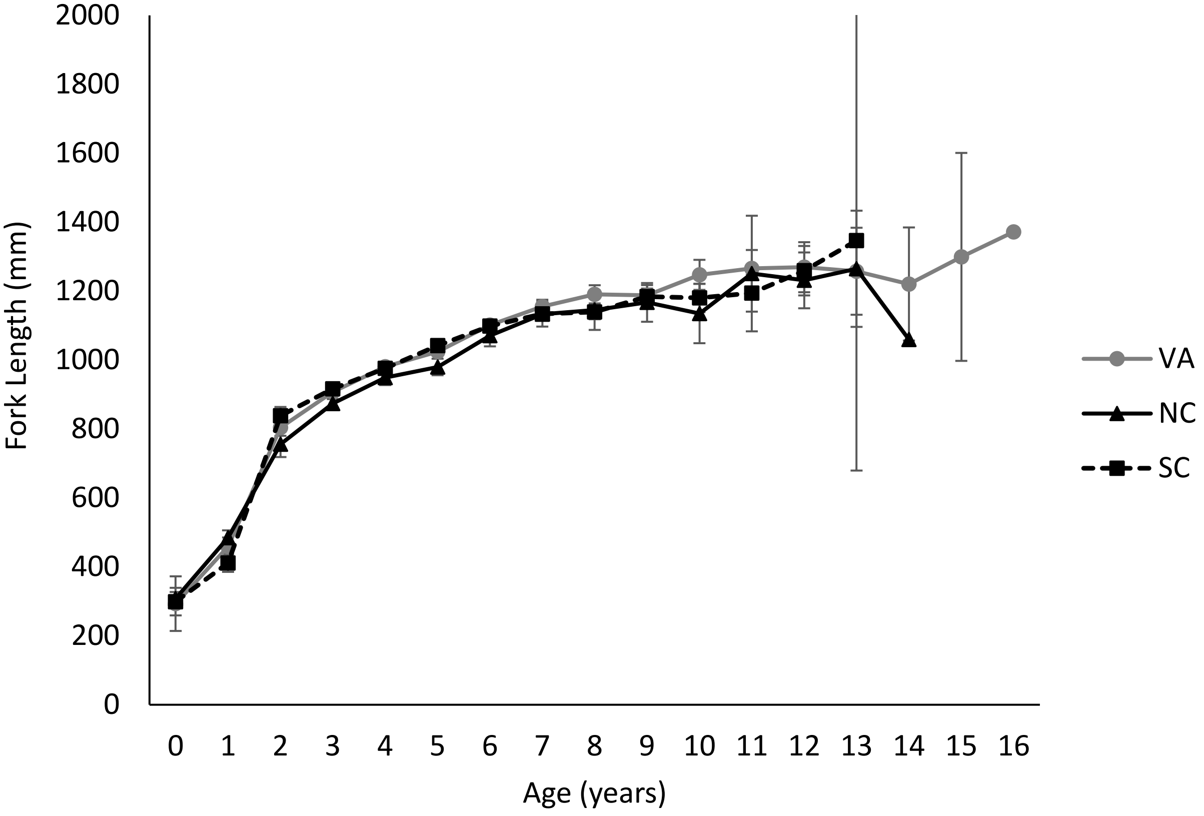
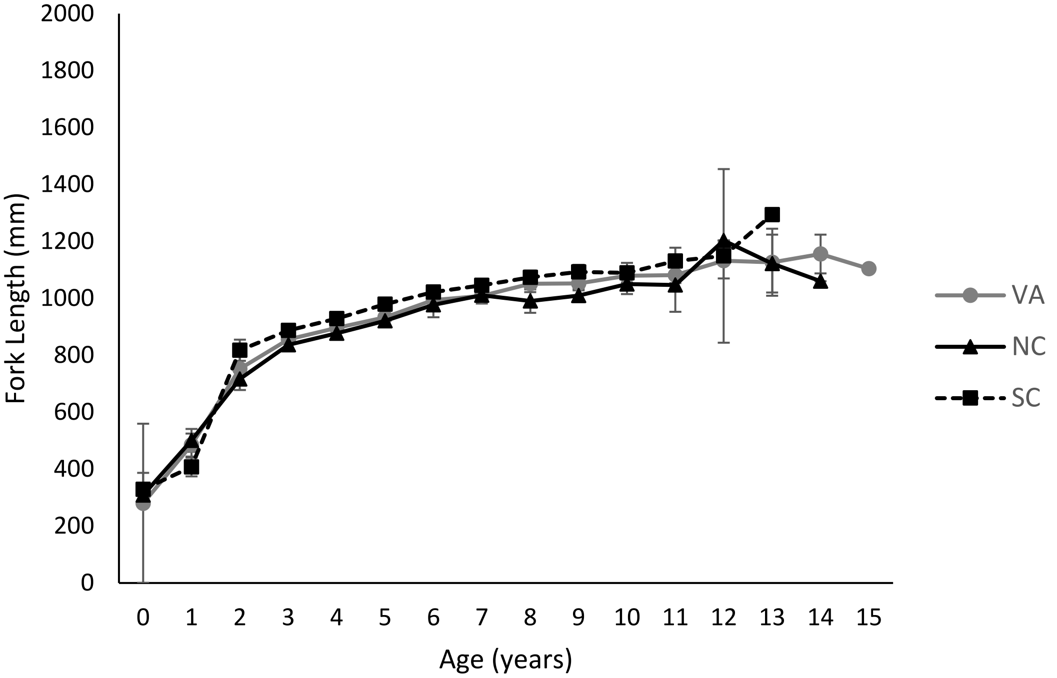


Figure 2.12.2. Mean FL-at-age by state of landing for Atlantic Cobia, regardless of sex. Error bars represent 95% confidence intervals.

A. Male Cobia



B. Female Cobia

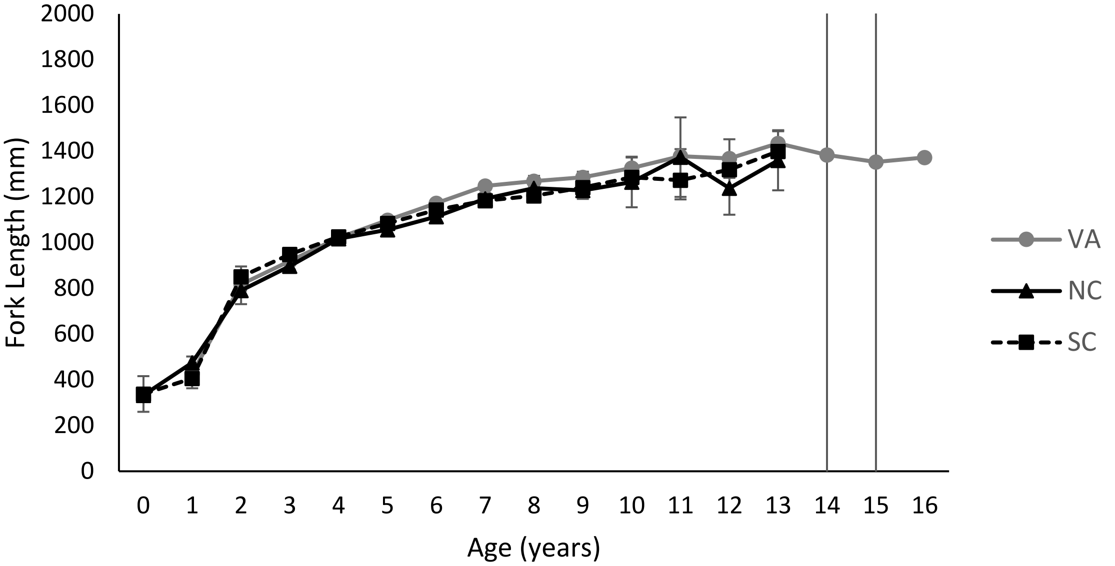


Figure 2.12.3. Sex specific mean FL-at-age by state of landing for Atlantic Cobia. Error bars represent 95% confidence intervals.

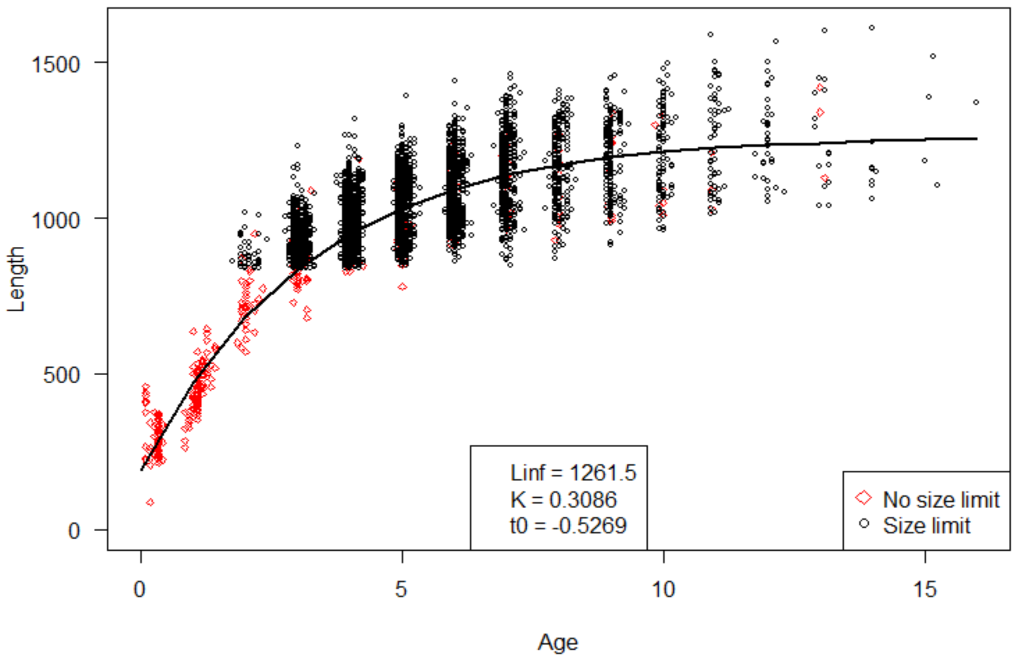


Figure 2.12.4. Atlantic Cobia fork length-at-biological age and von Bertalanffy population growth model with parameters.

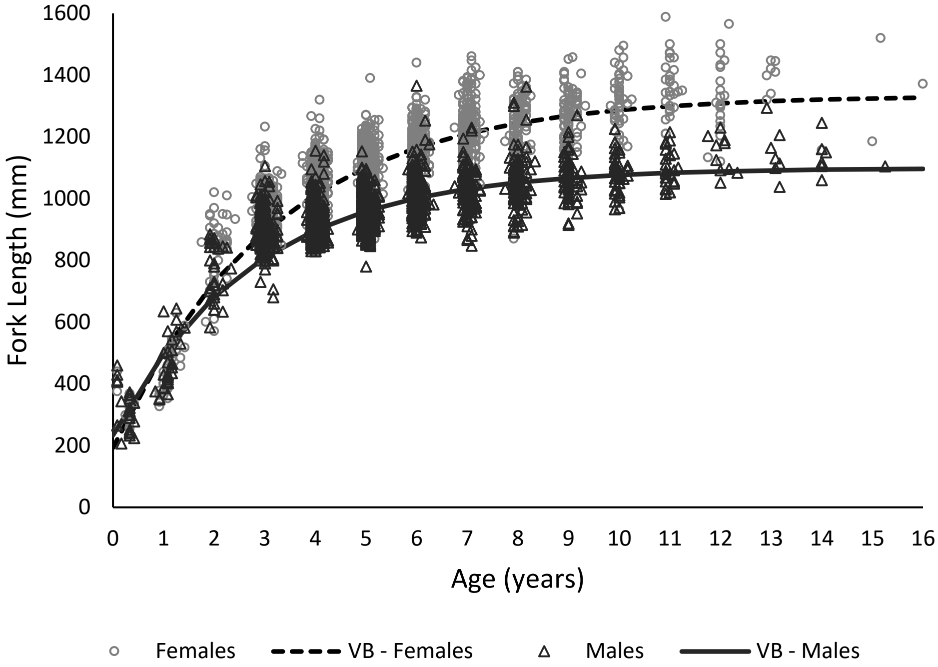


Figure 2.12.5. Atlantic Cobia fork length-at-biological age and von Bertalanffy growth models by sex of the fish.

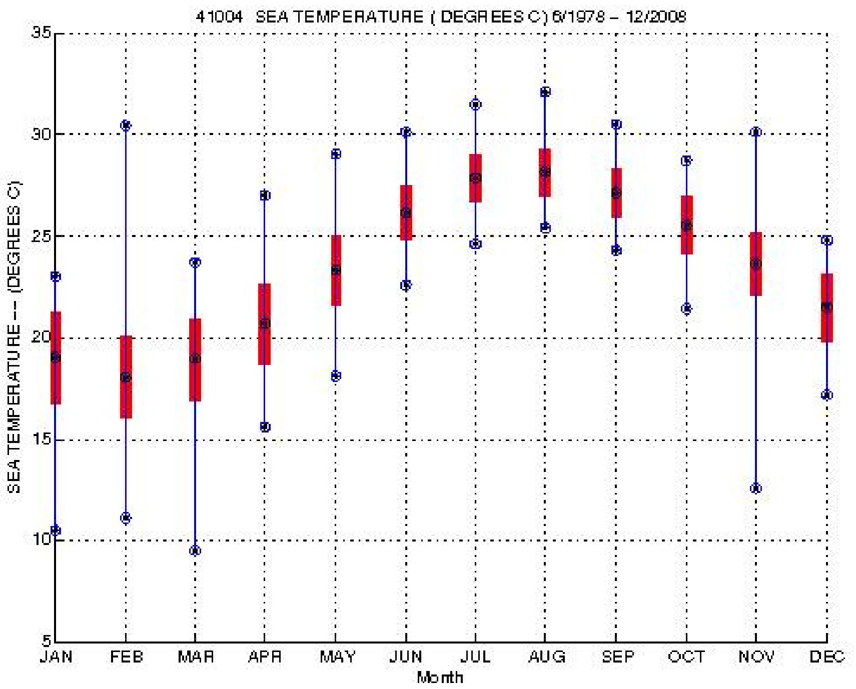


Figure 2.12.6. Mean monthly temperature profile for waters offshore of South Carolina.

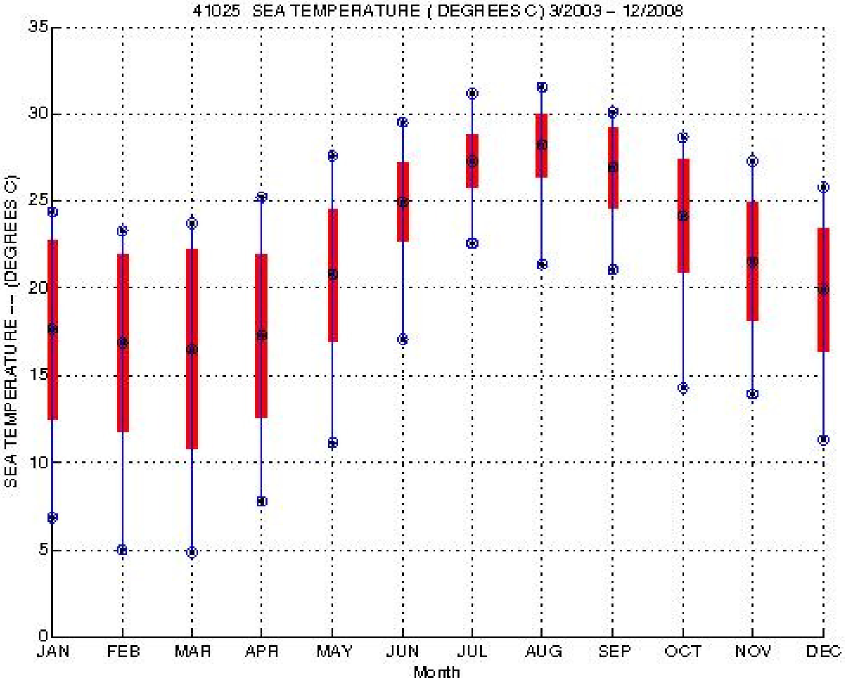


Figure 2.12.7. Mean monthly temperature profile for waters offshore of North Carolina.

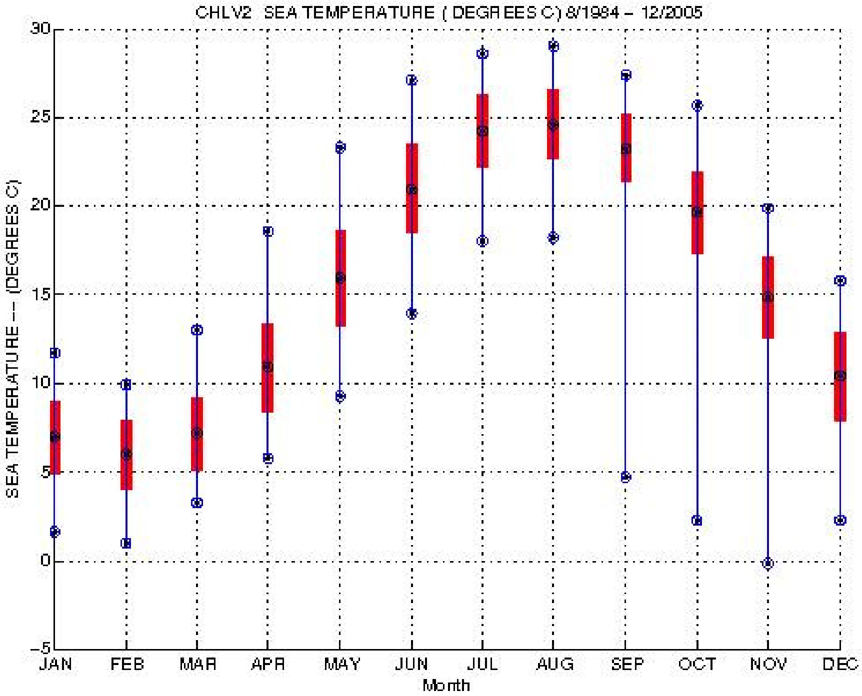


Figure 2.12.8. Mean monthly temperature profile for waters offshore of Virginia.

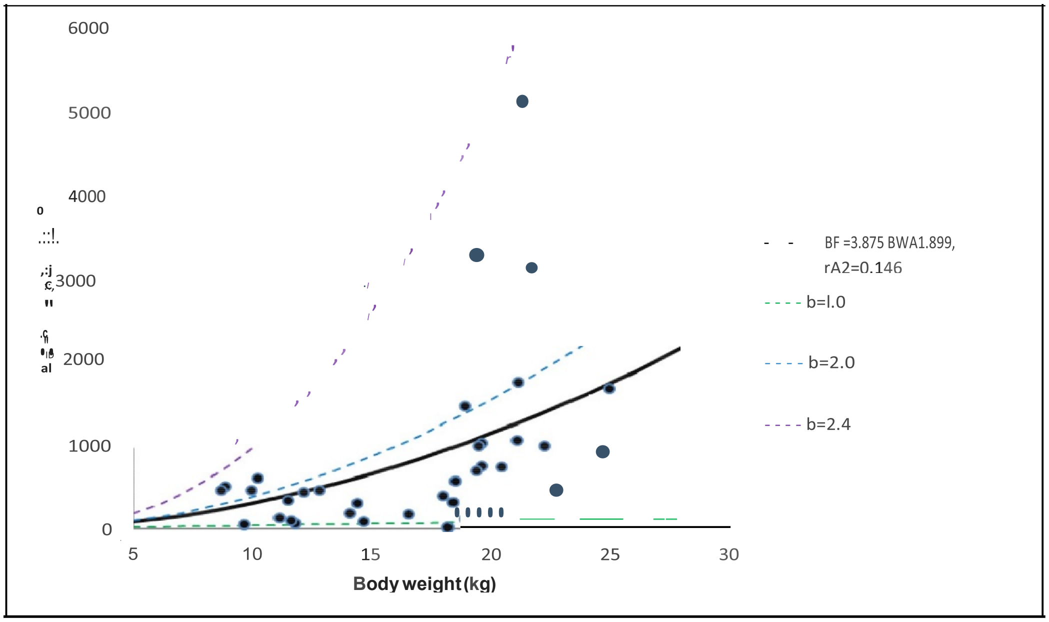


Figure 2.12.9. Power function of Cobia batch fecundity (y-axis) and female body weight. Best fish shown by solid line. Range in values of exponent *b* represented by dashed lines. (Y-axis = “Batch fecundity (1000s)”; See SEDAR (2013) Cobia stock assessment full report for original figure.)

3 Commercial Fishery Statistics

3.1 Overview

Commercial landings for the US Atlantic cobia stock were developed in whole weight pounds for the period 1928-2017 based on federal and state trip databases. Corresponding landings in numbers of fish were based on mean weights estimated from best available size composition data. The SEDAR 58 Stock ID Workshop established the Florida/Georgia state line as the delimiting stock boundary.

Commercial discards were calculated from recreational fisher reported discard rates, gear-specific (handline and gillnet) effort from the commercial fishery, and observer reported discard and kept rates.

Sampling intensity for lengths by year were considered and length compositions were developed by year.

3.1.1 Commercial Workgroup Participants

Beth Wrege	Workgroup leader	SEFSC Miami
Julie DeFilippi-Simpson	Data provider	ACCSP
Amy Dukes	Data provider	SC DNR
Eric Hiltz*	Data provider	SC DNR
Amanda Tong	Data provider	NC DMF
Alan Bianchi*	Data provider	NC DMF
Julie Califf*	Data provider	GA DNR
Larry Beerkircher*	Data provider	SEFSC Miami
Alex Aspinwall	Data provider	VA VMRC
Kevin McCarthy	Data provider	SEFSC Miami
Refik Orhun*	Data provider	SEFSC Miami
Mike Rinaldi	Data provider/rapporteur	ACCSP

*Did not attend workshop

3.1.2 Issues Discussed at the Data Workshop

Issues discussed by the commercial workgroup concerning cobia landings included the sparsity of commercial landings and discard data. Gear groupings of handline, longline, and other were originally provided, but were not used. For discards, the workgroup discussed limited available data from the CFLP (Coastal Fisheries Logbook Program).

3.2 Review of Working Papers

SEDAR58-DW04: The group reviewed this working paper, and decided to provide no comment.

SEDAR58-DW05: This working paper compares the length frequency distribution of five fishery-dependent datasets, three data sets provided by South Carolina Department of Natural Resources (SCDNR) fishery-dependent sampling program beginning in 2007 (tournament, charter boat captain donations, and private recreational donations), two traditional NMFS fishery-dependent sampling efforts operating in the region (the Marine Recreational Information Program (MRIP) and the Southeast Region Headboat Survey (SRHS)) and one fishery-independent dataset collected by SCDNR staff from a Cooperative Research Program (CRP) funded grant to determine if SCDNR's carcass collection program is an accurate representation of the recreational fishery.

SEDAR58-DW08: This paper was used to estimate discards from the gillnet fishery.
SEDAR58-DW09: The group reviewed this working paper, and decided to provide no comment.

3.3 Commercial Landings

Commercial landings of cobia were compiled from 1928 through 2017 for the Atlantic Coast north of the Florida-Georgia state line. Sources for landings in the U.S. South Atlantic (Georgia through North Carolina) included the North Carolina Division of Marine Fisheries (NCDMF) and the Atlantic Coastal Cooperative Statistics Program (ACCSP). Landings from the Mid- and North Atlantic (north of the NC-VA border were from the Virginia Marine Resources Commission (VMRC) and ACCSP. Further discussion of how landings were compiled from the above sources can be found in section 3.3.4.

3.3.1 Commercial Gears

The workgroup compiled reported gears landing cobia from various data sources. Based on the SEDAR 28 gear groupings, the predominant commercial fleets were categorized into three gear groups: handline, longline, and other. After discussions with the modeler and data compiler during the SEDAR 58 workshop, it was decided not to separate by gear but to aggregate gears to a single fleet. Cobia landings were provided as a single commercial fleet per year. The list of gears that were aggregated, **but not included in the assessment**, are found in Table 3.10.1.

3.3.2 Stock Boundaries

DW ToR #1: *Define the unit stock for the SEDAR 58 Atlantic Cobia stock assessment to include the US Atlantic Seaboard north of the Georgia-Florida border.*

Per Data Workshop Term of Reference #1, landings along the U.S. Atlantic coast north of the Georgia-Florida border were examined. The unit stock for South Atlantic cobia was defined by the SEDAR 58 Stock ID Workshop group.

A map of the area in which landings of cobia were considered can be found in Figure 3.11.1.

3.3.3 Misidentification and Unclassified Cobia

Cobia are a relatively distinct species, and there were no species identification issues known at present. No higher taxonomic groupings (i.e. Cobias) were reported in the commercial fishery. Therefore, no misidentification or classification issues accompanied reported cobia landings.

3.3.4 Commercial Landings by State

Statistics on commercial landings (1950 to present) for all species on the Atlantic coast are maintained in the 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 Section 3.3. The Data Warehouse was queried in December 2018 for all cobia landings (annual summaries by gear category) from 1950−2017 from Georgia through Maine (ACCSP 2019). Data are presented using the gear categories as determined at the Data Workshop. The specific ACCSP gears in each category are listed in Table 3.10.1. Commercial landings in pounds (whole weights using state specific conversion factors) were provided.

Multiple gear revisions occurred during the workshop. Data presented showed that the gear By Hand, Diving Gear should be reassigned into the Other category. Alignment analyses were performed for the SEDAR 28 and 58 data sets. The data from each workshop were in almost complete alignment for overlapping years, and therefore data from 1928-1949 (included in the SEDAR 28) were incorporated. The group was then informed by the lead analyst that gear groupings would not be necessary for the assessment. **All landings were then aggregated into year and state summaries.**

Georgia

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.

South Carolina

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.

South Carolina began collecting TIP length frequencies in 1983 as part of the Cooperative Statistics Program (CSP). 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.

SCDNR provided landings data for cobia from 1978 – 2017. Data from 1978 – 2003 were collected in monthly totals through collaborative efforts by SCDNR and the NMFS Cooperative Statistics Program and data collected from 2004 – 2017 were more comprehensive, as SCDNR instituted a mandatory Trip Ticket Program in late 2003.

These landings data were correlated, compared, and confirmed with ACCSP data. In the years 2001 to 2003, there were differences between those data sets. For those three years, the data provided by the agency, which was greater in reported pounds, was used for this assessment.

Cobia landed weights were collected as both gutted and whole. Annual Catch Limits are categorized as “landed weight” since both categories are present in the fishery. All gutted were converted to whole weight using the state conversion factor of 1.1. Additionally, all landings through this time period were associated to single values, rather than associating them to a gear grouping. This was a suggestion made to the Commercial Working Group from the lead analyst.

North Carolina

NCDMF provided North Carolina’s landings data from 1928 to 2017. This data set was a collective grouping of historical data collection by the NMFS/NCDMF Cooperative Statistics Program, its predecessors, and the NC Trip Ticket Program. Data collection continuity was sporadic in the earlier years of the dataset prior to 1950. Data continuity and accuracy dramatically increased over time. From 1994 to 2017 landings data collection was provided by the NC Trip Ticket Program and considered the most consistent and inclusive portion of the dataset. In 1999 NCDMF started sharing the landings data in the ACCSP data warehouse. Final assessment data was provided by the NC Trip Ticket Program due to the need for primary gear reassignments on multi-gear trips.

Gear categorizations were determined to be unnecessary at the time of this data workshop for a number of reason among them lack of correlations with other commercial data sets such as length frequency data. The NC commercial landings were therefore compiled annually without associated gear categorization for the reported years.

Atlantic cobia landings were reported in both whole and gutted conditions. The majority of landings were reported in gutted weight, which were converted to whole with a state conversion factor of 1.25 per pound. Whole weight records were directly supplied without conversion.

Virginia

VMRC provided Virginia's landings data from 1950 to 2017. This data set combined historical data from the NMFS prior to 1993, and mandatory reporting data from 1993 to 2017.

These data were provided at the trip level, in the original gear categories requested by the ACCSP. In addition to gear, fishing area was provided. However, both of these fields were deemed unnecessary during the SEDAR 58 process. These data were then aggregated by total pounds per year.

Combined State Results

Landings are presented in pounds whole weight, numbers of fish, and mean weight in Table 3.10.2 and shown graphically in Figures 3.11.2 and 3.11.3.

The Workgroup reported commercial landings according to the following:

- Landings should be reported as whole weight in pounds and number of fish
- Final landings data came from the following sources:
    - MD-North 1950-2017 (ACCSP)
    - VA 1950-1992 (ACCSP)
      1993-2017 (VMRC)
    - NC: 1950-2017 (NCDMF)
    - SC: 1950-2017 (SCDNR)
    - GA: 1950-2017 (ACCSP)

Whole vs. Gutted Weight

States use state-specific conversion factors for cobia to convert from the grade condition of gutted to whole weights. While this was presented as a possible issue between data sets, the group decided to remain consistent with existing practice from SEDAR 28. Whole weights in pounds were used, and a recommendation for addressing best practice for applying conversion factors can be found in later sections.

Confidentiality Issues

The elimination of the previous gear grouping created new confidentiality considerations. Landings of cobia were pooled across states by gear to meet the rule-of-three in the original data sets (SEDAR 28), and confidential data were flagged. Eliminating the previous gear grouping then required the combining across states to meet the rule-of-three confidentially requirements for Sedar 62. These combined state totals per-year resulted in completely non-confidential summaries. Therefore, no confidential data are flagged for the final data set of annual Cobia landings in whole weight pounds and numbers of individual fish, the Atlantic Coast states combined (ME-GA).

Uncertainty

The commercial workgroup estimated uncertainty in commercial fishery landings. The uncertainty estimates were determined using the same methodology used in SEDAR 28. These estimates of uncertainty are not coefficients of variation, but are estimates of possible reporting error; i.e., represent the range in actual commercial landings relative to the reported landings.

In making these uncertainty estimates, the following assumption was made:

- Landings may be underreported during all years; however, underreporting was likely highest during early years of the time series and were more accurate in recent years. This assumption was based upon the following information and data workshop expert testimony: during the period 1950 (beginning of landings time series) to 1961 landings were summarized annually by state and likely did not include landings from small scale dealers. In the years 1962 to 1977 landings data were collected annually, but under a more all-inclusive program (General Canvass). Monthly landings summaries were collected during the period 1978 to the beginning of trip ticket data collection (VA-1993, NC-1994, SC-2004, GA-2004). The most recent landings data, collected through state trip ticket programs, were assumed to be most reliable and inclusive of all commercial landings.

The group agreed, based upon expert opinion, an upper bound be set to account for underreported landings. See Table 3.10.5 for state specific bounds.

3.3.5 Converting Landings in Weight to Landings in Numbers

The weight in pounds for each sample was calculated, as was the mean weight by year. The landings in pounds whole weight were divided by the mean weight for the year to derive landings in numbers

3.4 Commercial Discards

Vertical line fishery

The data set for calculating commercial vertical line (handline, electric and hydraulic reel) vessel discard rates of cobia included all trips from vessels that reported to the coastal discard logbook program between January 1, 2002 and December 31, 2017 in the US South Atlantic. Total effort reported to the coastal logbook program were used to calculate total discards from the vertical line fishery The available data for other gears were too few for discards to be calculated or, for gillnet vessels, observer data were available for discard calculation (as described in the following section). Two methods were used to calculate discards: a continuity method following the methods of SEDAR 28 and the standard practice method developed for SEDAR 32 and used for subsequent South Atlantic assessments.

SEDAR 58 continuity methods:
- Fisher reported discard logbook data used to calculate discard rate
- Fisher reported coastal logbook data used to calculate total effort

*Total discards/year = mean discard rate (2002-2017) * yearly total effort*

- Discards calculated for vertical line (handline and bandit reels; effort=hook hours) and trolling (effort=hook hours) vessels separately, then summed and reported as vertical line continuity method in Table 3.10.4
- Dropped trips by vessels that reported "no discards" on more than 30% of trips, however, retained trips by vessels with no discards on six or fewer trips. That 30% rule was based upon the frequency of trips with no discards observed in the limited observer data examined during SEDAR 28.

SEDAR standard practice methods:
- Used discard and coastal logbook data sets

*Calculated discards/year for the years 2002-2017 = yearly discard rate * yearly total effort*

*Calculated discards/year for the years 1993-2001 = mean discard rate (2002-2006) * yearly total effort*

- Discards calculated for vertical line (handline and bandit reels; effort=hook hours) and trolling (effort=hook hours) vessels separately, then summed and reported as vertical line standard practice in Table 3.10.4

- Followed methods used beginning with SEDAR 32, includes filters to address reports of no discards and mackerel targeted trips
- Effort from trips with only mackerel landings were excluded – assumed those trips were not fishing in cobia habitat, therefore, were unlikely to catch/discard cobia
- Discard logbook data from vessels that never reported a discard of any species were excluded
- Discard logbook data from a vessel were excluded if the number of trips until a reported discard from that vessel exceeded the mean number of trips before discards were reported by vessels in the fishery + 2 standard deviations above that mean. Data were excluded from vertical line vessels with more than 20 trips before reporting discards and for trolling vessels, more than 26 trips

Discards were reported in numbers of fish. Converting numbers of fish to pounds of discarded fish used the formula recommended by the life history working group:

$$\text{Whole weight in kg} = 1.91 * 10^{-9} * TL^{3.21}$$

Where TL is in mm. No size composition of discards from the vertical line fishery was available from the discard logbook program. The commercial working group, therefore, recommended using the mean length of discards observed from the Virginia recreational private and charter fleets during 2016-17. Those were the only discard length data available during the data workshop. The mean length of discarded cobia in that data set was 35.78 inches TL. Mean weight of a discarded cobia was estimated as 13.21 pounds. Cobia discards in pounds from the commercial vertical line fishery are provided in Table 3.10.5

Gillnet Discards Calculated Using Observer Data

Discards from the commercial gillnet fishery were calculated following the methods described in working paper SEDAR58-DW08. Total calculated discards from the gillnet fishery are provided in Table 3.10.4. Observer data were available for the years 1999-2016. No trips were observed in 2017. Discards were calculated by disposition, live or dead.

Mean lengths (live discards 33.07 inches TL; dead discards 31.14 inches TL) of discarded cobia was calculated from available data in the gillnet observer data set. Mean weight of a dead discarded cobia was estimated to be 8.46 pounds whole weight using the TL to whole weight conversion described above. Live discard mean weight was estimated to be 10.26 pounds whole weight. Yearly total weights of discarded cobia from the commercial gillnet fishery are provided in Table 3.10.5.

Work Group Recommendations
The SEDAR 58 Commercial Work Group recommended using discards calculated following the standard practice method for the commercial vertical line fishery and discards calculated using gillnet observer data for the commercial gillnet fishery.

3.5 Commercial Effort

Map products were created that reflected commercial effort along the Atlantic Coast. The data used for those map products ranged from 2012 – 2017 and included coastal fisheries logbook program data (CFLP – federal only) from Texas to Maine. In order to preserve confidentiality, data were aggregated by month for the entire time series. Grids with confidential data or no landings were left hollow.

10 year blocks were decided in order to stay consistent with SEDAR 28, and the data were truncated at the GA/FL boundary and cut off at 30 degrees North. Effort will be defined as trips, with the trip ticket starting dates for each state as NC-1994, VA-1993, SC – 2004.

3.6 Biological Sampling

Biological sample data were obtained from the TIP sample data at NMFS/SEFSC, and ranged from 1983 to 2017. Data were filtered to eliminate those records that included a size or effort bias, non-random collection of length data, or were not from commercial trips.

The data were also filtered to reduce the number of columns from gear groups. The group reviewed the data and sample sizes, and decided they were adequate at the annual level but not the gear level.

3.6.1 Sampling Intensity

The number of fish ranged from a high of 259 (all gears combined) in 1990 for Virginia through Georgia to a low of zero for many strata. For multiple years, number of fish sampled were less than 10 for all gears for Virginia through the Georgia.

3.6.2 Length/Age Distribution

The group decided that age/length frequency data were not within the purview of the commercial group. The group provided length data from the TIP program to the data compiler, who created the mean weights. The mean weights were passed back to the commercial group, who then used those weights to convert the landings and discards from pounds to number of individuals.

3.6.3 Adequacy for Characterizing Catch

The commercial group was informed that length sampling was inadequate for separate gears, and all gears combined provided an adequate sample size. However, many years have low sample sizes and should be aggregated across years if used in the model.

3.7 Comments on Adequacy of Data for Assessment Analyses

Landings data for assessment analyses appear to be mostly adequate. There is a clear landings history for the available time series. There was no issue concerning species identification, and Cobia have been reported consistently at the species level. Definition of stock boundaries was not an issue. However, landed condition (gutted vs. whole) was discussed by the group, and it was decided to stay consistent with the approach from SEDR 28. Each state will investigate the proportion of landings in different conditions, and the group provided a research recommendation on best practice for conversion factors moving forward.

Discard calculations posed some difficulties due to scarcity of data, and only the discards from the vertical line fishery were utilized. The available data for other gears were too few for discards to be calculated or, for gillnet vessels, observer data were available for discard calculation. Biological sampling data, while suffering from small sample size, was deemed adequate.

3.8 Research Recommendations

The following recommendations stem from both review of SEDAR 28 recommendations and group discussion.

1. Programmatic funding should be allocated to expand existing observer coverage to ensure complete spatial coverage for the South Atlantic.

2. Funding should be allocated towards the development of standardized map products.
    a. This includes various federal and state logbook grids from Maine to Texas.
    b. All grids need to include SDO registration.
    c. Includes translation tables between each grid.
    d. Creation of map products that compare commercial fishing effort between the CFLP and state trip ticket data.

3. Develop statistically robust discard estimation techniques.

4. Standardize how effort data are collected, processed, and utilized in relation to catch.
    a. There may be inconsistencies among commercial data sets for effort, since there is not a vessel permit required for cobia rather an individual catch limit.
        i. A single trip ticket may group multiple individual catches together with total effort, while multiple trip tickets may separate individual catch yet replicate the vessel effort.

5. Create outreach strategies to further enhance the implementation plan for the commercial electronic logbook and include state partners. This will increase the data validity.
    a. This data collection effort will greatly improve reporting periodicity, reduce recall basis, provide increased spatial trends, provide more robust discard data, this list is endless, but should address where this data will fill in data gaps within a SEDAR

6. The group recommends a workshop to establish a best practice for converting landings (e.g., gutted to whole weight).
    a. This workshop should address multiple species and jurisdictions.

7. The group suggests that the partners include cobia in an RFP for updating federal and state specific conversion factors.

8. The group recommends a workshop to establish a best practice for assigning uncertainty to landing series, as recommended in the best practices workshop.

3.9 Literature Cited

Atlantic Coastal Cooperative Statistics Program. 2019. Annual Landings by Custom Gear Category; generated by Mike Rinaldi using ACCSP Data Warehouse, Arlington, VA: accessed January 2019.

3.10 Tables

Table 3.10.1 Specific ACCSP gears in each requested gear category for commercial cobia landings. **NOT USED**

HANDLINE			
GEAR CODE	**GEAR NAME**	**TYPE CODE**	**GEAR TYPE**
300	HOOK AND LINE	HOOK AND LINE	HOOK AND LINE
301	HOOK AND LINE, MANUAL	HOOK AND LINE	HOOK AND LINE
302	HOOK AND LINE, ELECTRIC	HOOK AND LINE	HOOK AND LINE
303	ELECTRIC/HYDRAULIC, BANDIT REELS	HOOK AND LINE	HOOK AND LINE
320	TROLL LINES	TROLL LINES	HOOK AND LINE
700	HAND LINE	HAND LINE	HAND LINE
701	TROLL AND HAND LINES CMB	HAND LINE	HAND LINE
760	BY HAND, NO DIVING GEAR	BY HAND, NO DIVING GEAR	BY HAND
LONGLINE			
GEAR CODE	**GEAR NAME**	**TYPE CODE**	**GEAR TYPE**
400	LONG LINES	LONG LINES	LONG LINES
401	LONG LINES, VERTICAL	LONG LINES	LONG LINES
402	LONG LINES, SURFACE	LONG LINES	LONG LINES
403	LONG LINES, BOTTOM	LONG LINES	LONG LINES
404	LONG LINES, SURFACE, MIDWATER	LONG LINES	LONG LINES
405	LONG LINES, TROT	LONG LINES	LONG LINES
OTHER			
GEAR CODE	**GEAR NAME**	**TYPE CODE**	**GEAR TYPE**
750	BY HAND, DIVING GEAR	BY HAND, DIVING GEAR	BY HAND
000	NOT CODED	NOT CODED	NOT CODED
010	HAUL SEINES	HAUL SEINES	HAUL SEINES
020	OTHER SEINES	OTHER SEINES	HAUL SEINES
022	COMMON SEINE	OTHER SEINES	HAUL SEINES

Table 3.10.1 cont. Specific ACCSP gears in each requested gear category for commercial cobia landings. **NOT USED**

OTHER			
GEAR CODE	**GEAR NAME**	**TYPE CODE**	**GEAR TYPE**
050	POUND NETS	POUND NETS	FIXED NETS
030	PURSE SEINE	PURSE SEINE	PURSE SEINES
072	TRAP NETS	OTHER FIXED NETS	FIXED NETS
090	OTTER TRAWLS	OTTER TRAWLS	TRAWLS
091	OTTER TRAWL BOTTOM, CRAB	OTTER TRAWLS	TRAWLS
092	OTTER TRAWL BOTTOM, FISH	OTTER TRAWLS	TRAWLS
095	OTTER TRAWL BOTTOM, SHRIMP	OTTER TRAWLS	TRAWLS
096	OTTER TRAWL BOTTOM, OTHER	OTTER TRAWLS	TRAWLS
097	OTTER TRAWL MIDWATER	OTTER TRAWLS	TRAWLS
110	OTHER TRAWLS	OTHER TRAWLS	TRAWLS
120	FLY NET	OTHER TRAWLS	TRAWLS
130	POTS AND TRAPS	POTS AND TRAPS	POTS AND TRAPS
131	POTS AND TRAPS, CONCH	POTS AND TRAPS	POTS AND TRAPS
132	POTS AND TRAPS, BLUE CRAB	POTS AND TRAPS	POTS AND TRAPS
139	POTS AND TRAPS, FISH	POTS AND TRAPS	POTS AND TRAPS
140	POTS AND TRAPS, SPINY LOBSTER	POTS AND TRAPS	POTS AND TRAPS
200	GILL NETS	GILL NETS	GILL NETS
201	GILL NETS, FLOATING DRIFT	GILL NETS	GILL NETS
203	GILL NETS, FLOATING ANCHOR	GILL NETS	GILL NETS
204	GILL NETS, SINK ANCHOR	GILL NETS	GILL NETS

Table 3.10.1 cont. Specific ACCSP gears in each requested gear category for commercial cobia landings. **NOT USED**

OTHER			
GEAR CODE	**GEAR NAME**	**TYPE CODE**	**GEAR TYPE**
205	GILL NETS, RUNAROUND	GILL NETS	GILL NETS
207	GILL NETS, OTHER	GILL NETS	GILL NETS
500	DREDGE	DREDGE	DREDGE
511	DREDGE, NEW BEDFORD	DREDGE	DREDGE
602	PATENT TONGS	TONGS	RAKES, HOES, AND TONGS
660	SPEARS	SPEARS	SPEARS AND GIGS
661	SPEARS, DIVING	SPEARS	SPEARS AND GIGS
662	GIGS	SPEARS	SPEARS AND GIGS
800	OTHER GEARS	OTHER GEARS	OTHER GEARS
801	UNSPECIFIED GEAR	OTHER GEARS	OTHER GEARS
802	COMBINED GEARS	OTHER GEARS	OTHER GEARS

Table 3.10.2 Table with the Cobia landings by year in whole weight pounds, numbers of individual fish, and mean weights for all Atlantic Coast states combined (ME-GA). Mean weights for 1928-1982 are the calculated average from best available size composition data. .

	Atlantic Coast		
Year	Pounds, WW	Number of individuals	Mean Weights
1928	250	11	23.15752
1929	350	15	23.15752
1930	200	9	23.15752
1931	300	13	23.15752
1932	4,515	195	23.15752
1934	25,300	1,093	23.15752
1936	9,300	402	23.15752
1937	22,400	967	23.15752
1938	23,500	1,015	23.15752
1939	11,700	505	23.15752
1940	2,500	108	23.15752
1941	1,000	43	23.15752
1947	1,800	78	23.15752
1950	11,400	492	23.15752
1951	11,800	510	23.15752
1952	3,800	164	23.15752
1953	13,700	592	23.15752
1954	28,200	1,218	23.15752
1955	9,200	397	23.15752
1956	27,100	1,170	23.15752
1957	48,600	2,099	23.15752
1958	25,500	1,101	23.15752
1959	48,900	2,112	23.15752
1960	30,700	1,326	23.15752
1961	38,700	1,671	23.15752
1962	41,100	1,775	23.15752
1963	49,900	2,155	23.15752
1964	24,500	1,058	23.15752
1965	19,900	859	23.15752
1966	12,100	523	23.15752
1967	12,800	553	23.15752
1968	10,900	471	23.15752
1969	9,000	389	23.15752
1970	9,200	397	23.15752
1971	14,400	622	23.15752
1973	4,769	206	23.15752
1974	5,511	238	23.15752

	Atlantic Coast		
Year	Pounds, WW	Number of individuals	Mean Weights
1976	5,931	256	23.15752
1977	3,492	151	23.15752
1978	2,707	117	23.15752
1979	4,616	199	23.15752
1980	8,459	365	23.15752
1981	17,838	770	23.15752
1982	31,291	1,351	23.15752
1983	18,008	740	24.35
1984	13,795	607	22.72
1985	11,307	538	21.00
1986	25,734	1,394	18.46
1987	40,740	1,876	21.71
1988	28,588	1,152	24.82
1989	33,453	2,377	14.07
1990	44,357	3,139	14.13
1991	43,816	2,105	20.81
1992	35,933	1,512	23.77
1993	39,526	2,129	18.57
1994	47,020	1,626	28.92
1995	67,557	2,576	26.23
1996	62,591	3,645	17.17
1997	63,522	1,846	34.40
1998	43,622	1,678	26.00
1999	27,474	1,345	20.42
2000	43,580	2,302	18.93
2001	42,513	2,048	20.76
2002	44,375	1,474	30.11
2003	39,310	1,489	26.39
2004	32,916	1,240	26.54
2005	28,884	1,358	21.27
2006	34,708	1,396	24.86
2008	33,876	1,135	29.84
2009	42,423	2,034	20.86
2010	56,661	1,816	31.21
2011	34,222	1,293	26.48
2012	42,811	1,832	23.37
2013	53,605	8,382	6.40
2014	70,064	2,343	29.90
2015	84,901	2,518	33.72
2016	92,535	4,063	22.77
2017	68,365	5,714	11.96

Table 3.10.3 Uncertainty in commercial landings by year range.

Year Range	Uncertainty
1928 - 1949	0.50
1950 - 1961	0.25
1962 - 1977	0.20
1978 - 1992	0.10
1993 - 2017	0.05

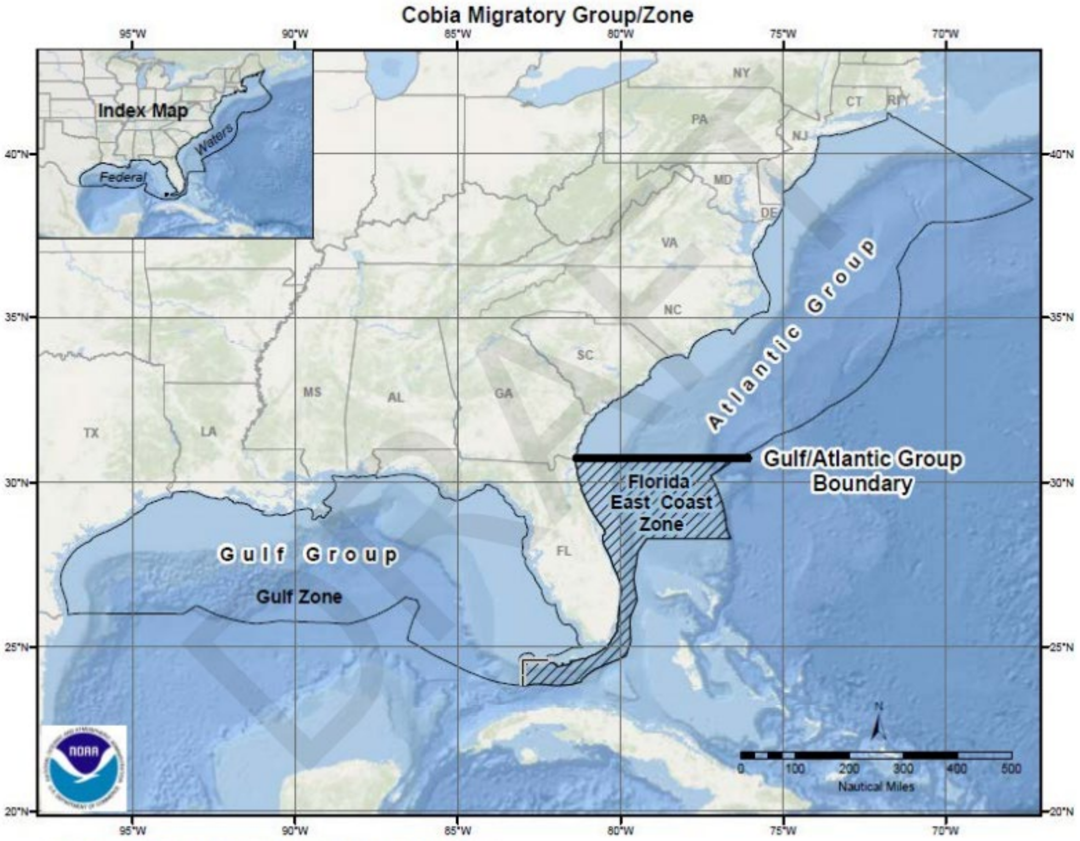
Table 3.10.4. Calculated yearly cobia discards from the commercial vertical line and gillnet fisheries by year. Discards are reported in number of individual fish.

Year	Cobia Vertical Line Calculated Discards Continuity Method	Cobia Vertical Line Calculated Discards Standard Practice Method	Cobia Gillnet Observer Calculated Dead Discards	Cobia Gillnet Observer Calculated Live Discards
1993	121	628	N/A	N/A
1994	148	733	N/A	N/A
1995	137	715	N/A	N/A
1996	140	753	N/A	N/A
1997	145	728	N/A	N/A
1998	118	606	N/A	N/A
1999	102	575	0	0
2000	110	899	0	0
2001	120	979	0	0
2002	107	1,346	0	190
2003	85	1,167	0	0
2004	79	399	569	0
2005	80	741	23	22
2006	89	67	22	0
2007	90	1,194	0	179
2008	90	583	69	89
2009	92	1,971	344	462
2010	79	743	118	173
2011	67	1,544	88	184
2012	60	1,303	118	417
2013	66	975	0	73
2014	64	685	100	0
2015	58	414	0	532
2016	59	875	0	32
2017	56	85	N/A	N/A

Table 3.10.5. Calculated yearly cobia discards from the commercial vertical line and gillnet fisheries by year. Discards are reported in pounds whole weight.

Year	Cobia Vertical Line Calculated Discards Continuity Method	Cobia Vertical Line Calculated Discards Standard Practice Method	Cobia Gillnet Observer Calculated Dead Discards	Cobia Gillnet Observer Calculated Live Discards
1993	1,605	8,293	N/A	N/A
1994	1,959	9,690	N/A	N/A
1995	1,814	9,449	N/A	N/A
1996	1,856	9,947	N/A	N/A
1997	1,911	9,617	N/A	N/A
1998	1,563	8,005	N/A	N/A
1999	1,346	7,602	0	0
2000	1,449	11,881	0	0
2001	1,592	12,937	0	0
2002	1,417	17,781	0	1,950
2003	1,130	15,421	0	0
2004	1,040	5,268	4,815	0
2005	1,051	9,798	195	226
2006	1,175	892	186	0
2007	1,194	15,782	0	1,837
2008	1,186	7,703	584	913
2009	1,216	26,043	2,911	4,742
2010	1,040	9,813	999	1,776
2011	882	20,399	745	1,889
2012	797	17,223	999	4,280
2013	869	12,891	0	749
2014	839	9,057	846	0
2015	763	5,472	0	5,460
2016	776	11,564	0	328
2017	738	1,119	N/A	N/A

3.11 Figures



Esri Ocean Basemap Sources: Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

Figure 3.11.1 Region of cobia landings, included the combined states (ME-GA) along the U.S. Atlantic Coast, depicted here as the Atlantic Group.

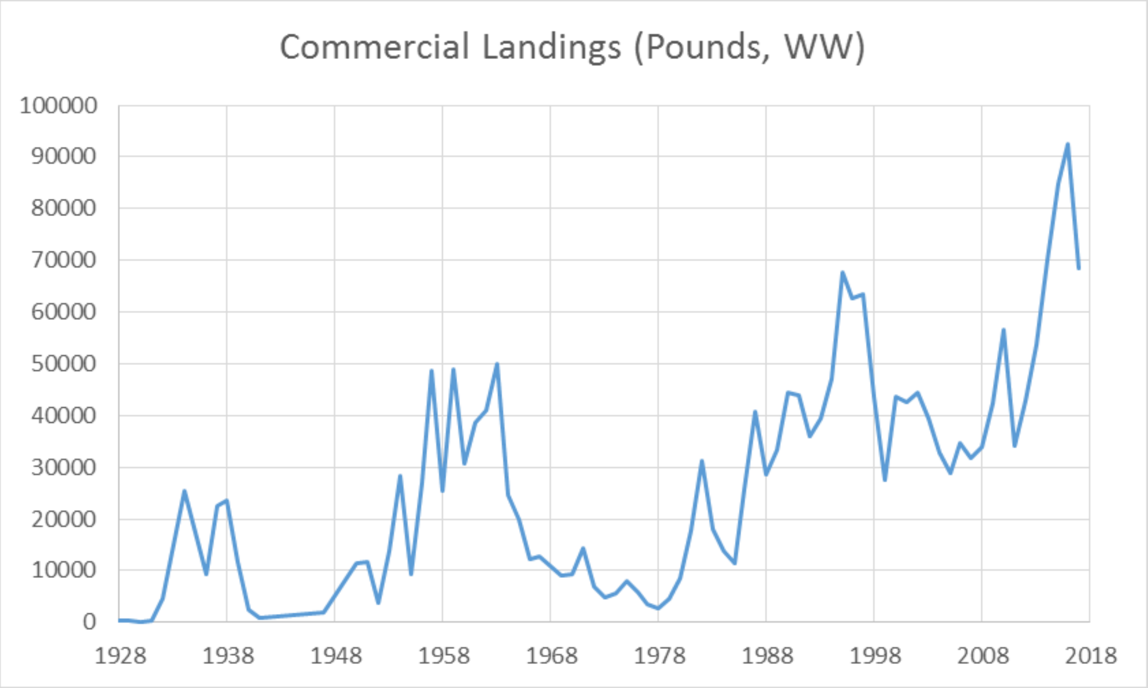


Figure 3.11.2 Cobia landings, in whole weight pounds, for all states (GA-ME) by year.

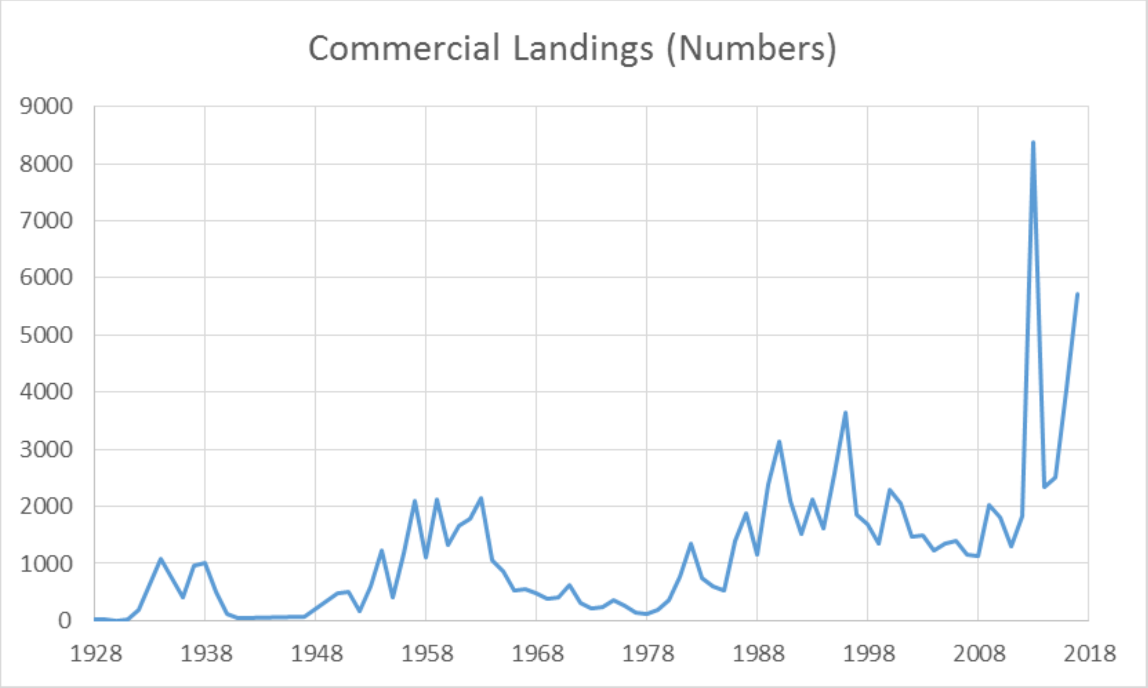
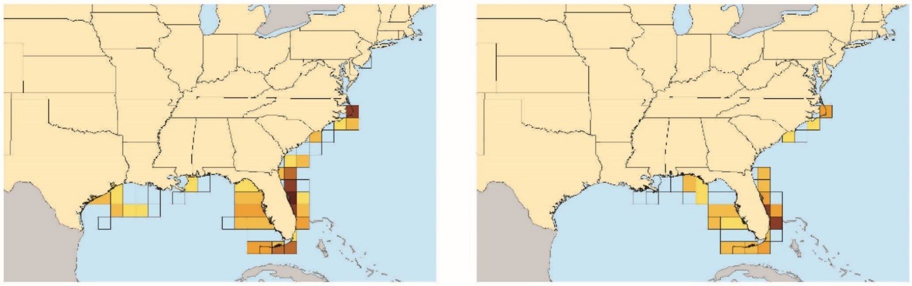
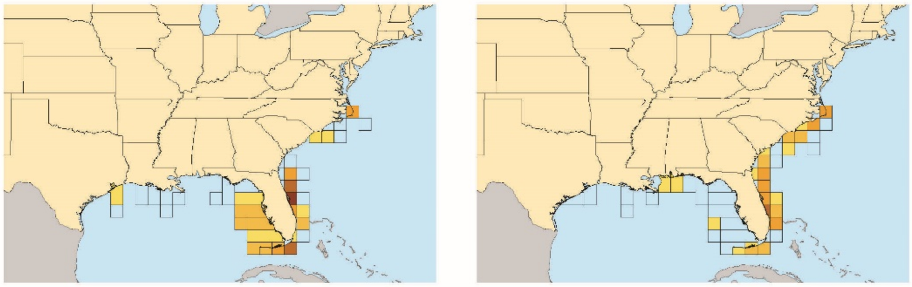


Figure 3.11.3 Cobia landings, in numbers of fish, for all states (GA-ME) by year.



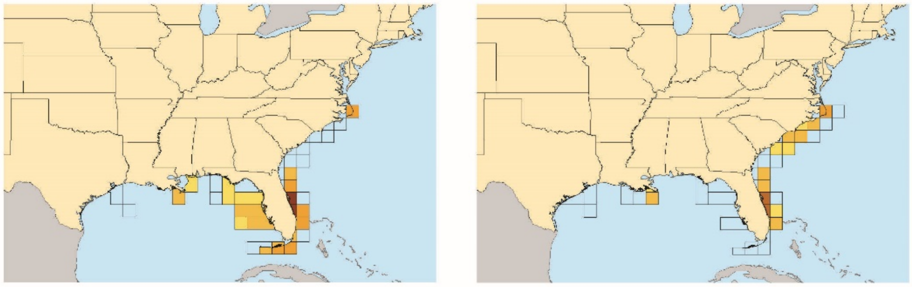
Reported Pounds of Cobia in January 2012-2017

Reported Pounds of Cobia in April 2012-2017



Reported Pounds of Cobia in February 2012-2017

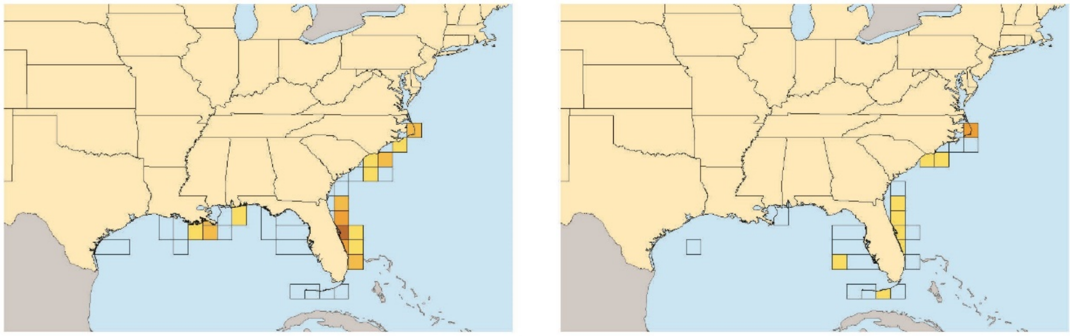
Reported Pounds of Cobia in May 2012-2017



Reported Pounds of Cobia in March 2012-2017

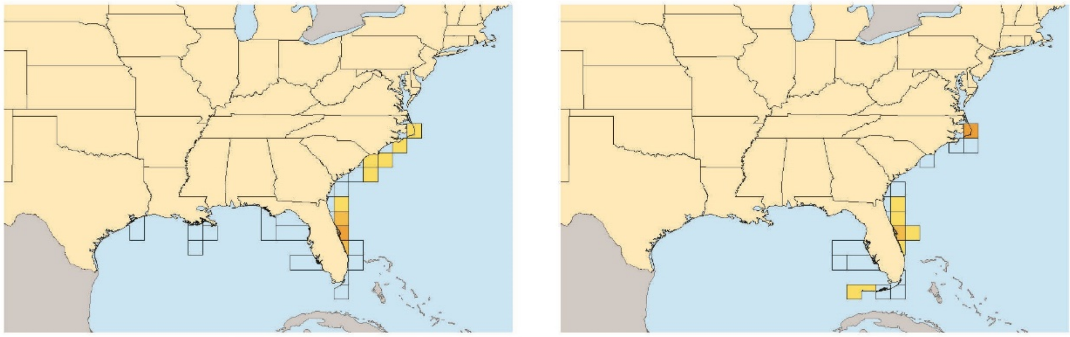
Reported Pounds of Cobia in June 2012-2017

Figure 3.11.4 Maps of cobia harvest 2012-2017 in the South Atlantic as reported to the CFLP.



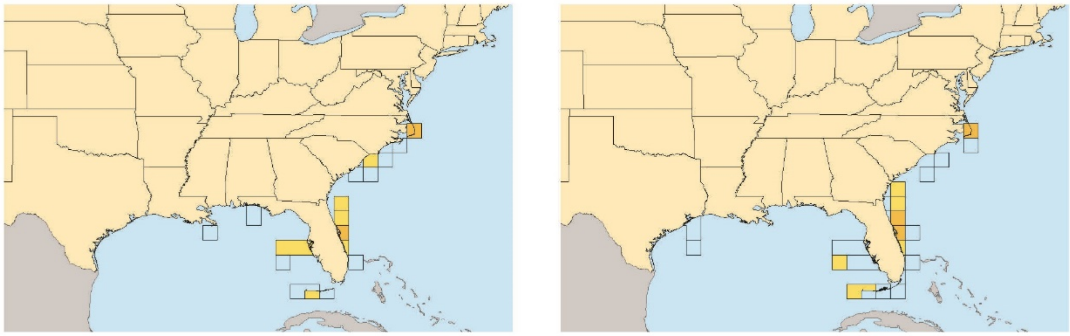
Reported Pounds of Cobia in July 2012-2017

Reported Pounds of Cobia in October 2012-2017



Reported Pounds of Cobia in August 2012-2017

Reported Pounds of Cobia in November 2012-2017



Reported Pounds of Cobia in September 2012-2017

Reported Pounds of Cobia in December 2012-2017

Figure 3.11.4 Cont. Maps of cobia harvest 2012-2017 in the South Atlantic as reported to the CFLP.

4 Recreational Fishery Statistics

Atlantic Cobia report

4.1 Overview

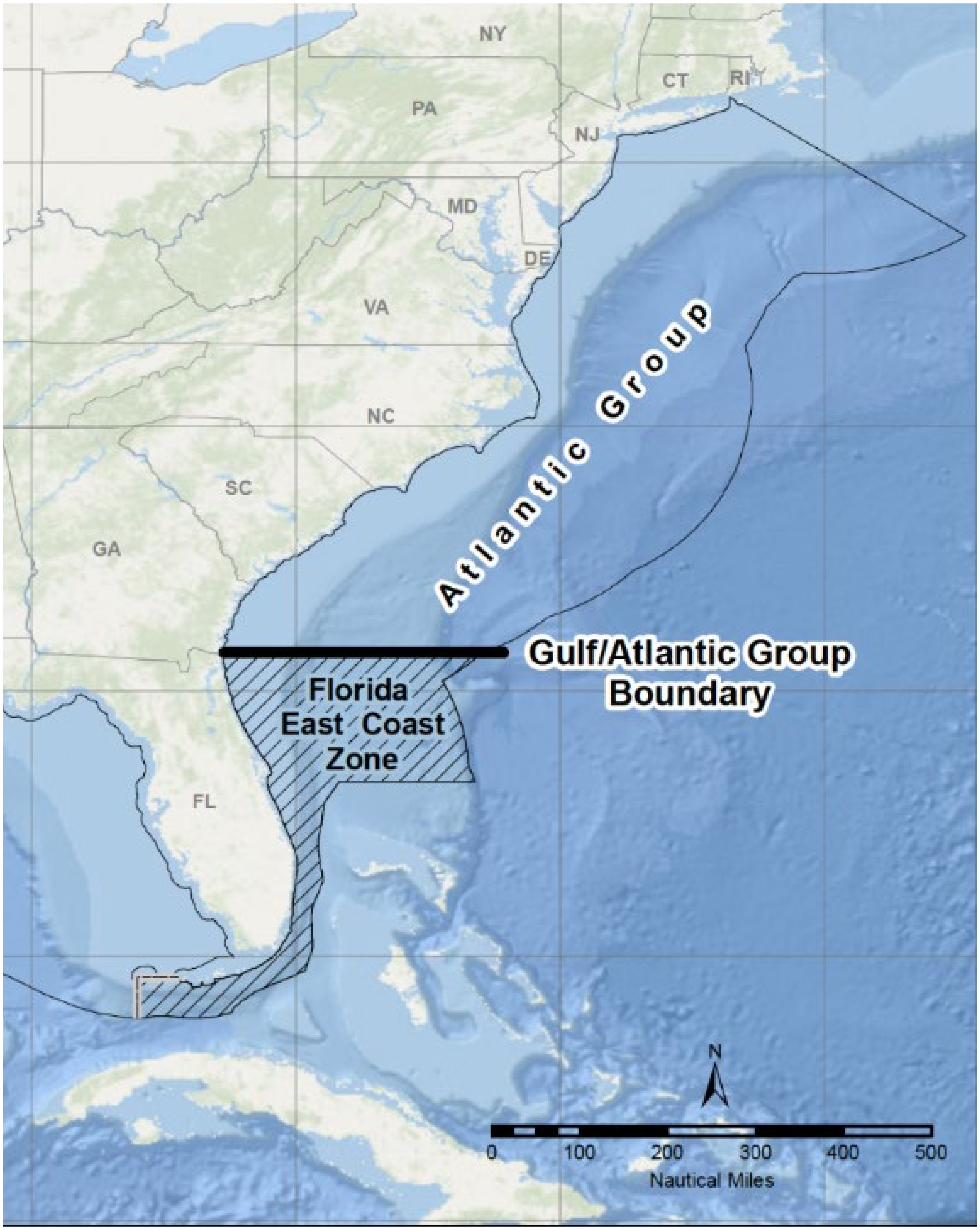
4.1.1 Group membership

Members- Ken Brennan (Leader \NMFS Beaufort), Alex Aspinwall (VMRC), Andrew Cathey (NCDNR), Collins Doughtie (Fisherman-SC), Kelly Fitzpatrick (NMFS Beaufort), Dawn Franco (GADNR), Bill Gorham (Fisherman – NC), Vivian Matter (NMFS SEFSC), Kayla Rudnay (SCDNR)

4.1.2 Issues

1) Headboat logbook forms did not include cobia on a universal form until 1984 in the South Atlantic.
2) Headboat discards. Data are available from the SRHS since 2004. Review whether they 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.
3) Use of new MRIP FES/APAIS/FHS calibrations
4) Usefulness of historical data sources such as the Fishing, Hunting, and Wildlife-Associated Recreation Survey (FHWAR) to generate estimates of landings prior to 1981. Review whether other data sources are also available.
5) Evaluate adequacy of available data and discuss the use of new recreational Cobia data sets
6) Provide estimates of uncertainty around each set of landings and discard estimates
7) Provide length and age distributions for both landings and discards if feasible.
8) Review, evaluate, and report on the status and progress of all research recommendations listed in the last assessment,

4.1.3 South Atlantic Fishery Management Council Cobia Group Management Boundaries



4.2 Review of Working Papers

SEDAR58-DW01, *Analyses and applications of Cobia length-age data collected by Virginia Marine Resources Commission between 1999 and 2018.*

Atlantic Cobia (Rachycentron canadum) are an economically important species that have become increasingly popular amongst recreational anglers in Virginia. Since 1999, Virginia Marine Resources Commission (VMRC) has collected biological data from the recreational Cobia fishery in order to provide length-age information for future stock assessments. The precision of length-age estimates depend on the sample size (Quinn and Deriso 1999), however, the conventional collection method provides few Cobia. In order to increase the sample size of Cobia length-age data, VMRC has been collecting Cobia carcass donations (including the carcasses from Cobia tournaments) from recreational anglers through the marine sportfish collection program since 2007. Because the carcass donation program is not designed to sample randomly and fishermen donate the carcasses more or less opportunistically, the Cobia Data workshop has raised concerns on whether or not Virginia length data from carcass donations may represent the catch and be used in the future stock assessment. Therefore, it is important that the concern should be addressed properly before the data can be used. The primary goal of this study is to find out if the carcass donations have introduced biases into the length distributions toward either smaller or larger fish compared to those fish collected randomly. The specific objectives are: 1) Compare Virginia length frequency distributions collected by VMRC from the recreational and commercial fisheries to those collected by MRIP; 2) compare the mean lengths between the cobia collected randomly by VMRC and donated by Virginia recreational fishermen; 3) compare year effect on the mean lengths of cobia collected VMRC from 1999 to 2018; 4) examine cohort progressions in the landing age distributions developed using Virginia ALKs and Virginia harvest estimated by MRIP; and 5) compare length distributions between Virginia and other Atlantic states.

SEDAR58-DW07, *SCDNR Charterboat Logbook Program Data, 1993-2017*

The South Carolina Department of Natural Resources (SCDNR) charterboat logbook program was used to develop indices of abundance for Cobia from 1998-2017. The indices of abundance are standardized catch per unit effort (CPUE; catch per angler hour). A delta-lognormal GLM was used to produce annual abundance estimates for Cobia. The index is meant to describe the population trends of fish caught by charter vessels (6-pack) operating in or off of South Carolina.

SEDAR58-DW10, *Estimates of Historic Recreational Landings of Cobia in the Atlantic Using the FHWAR Census Method.*

The Fishing, Hunting, and Wildlife-Associated Recreation Survey (FHWAR) method utilizes a combination of information including U.S. angler population estimates and angling effort estimates from 1955 – 1985 FHWAR, along with estimates of recreational effort and landings from the MRIP 1981 – 1985. The FWHAR method also used both sources of information to adjust for recall bias, an issue that must be addressed when considering using the FHWAR Survey for historical recreational landings. By using data from FHWAR and the MRIP to calibrate this adjustment, the effect of the 12-month angler recall period is reduced. The historical landings of cobia that were calculated using this method show a gradual increase from 1955 to 1980. The FHWAR method could be used for other species by adjusting the geographic range of the FHWAR surveys to match management boundaries and the associated MRIP catch and effort data for a particular species.

SEDAR58-RD28, *Status of the South Carolina fisheries for cobia*

The cobia has been a recognized and desired gamefish among recreational fishermen in South Carolina since the 1960's. Throughout the majority of the state's coast very few recreational anglers actually target cobia. However, in the last decade, the recreational fishery for cobia has undergone an exponential growth in Beaufort County. It is usually taken as a fish of opportunity, where one is seen at the surface and then targeted. When targeted, anglers pursue cobia by fishing at buoys located at the mouths of bays, coastal shipwrecks and coastal artificial reefs. Only in Port Royal Sound and to a lesser extent Calibogue and St. Helena Sounds, all in Beaufort County, are adult cobia regularly found in inshore waters. This inshore spring run begins in April and can last into July. This inshore movement of cobia has come to support a major spring recreational fishery in Beaufort County.

SEDAR58-RD42, *Model-estimated conversion factors for calibrating Coastal Household Telephone Survey (CHTS) charterboat catch and effort estimates with For-Hire Survey (FHS) estimates in the Atlantic and Gulf of Mexico with application to red grouper and greater amberjack.*

In July 2018, NOAA Fisheries released new recreational catch estimates for all species and all modes, including charter mode estimates. As a result, the Southeast Fisheries Science Center (SEFSC) conducted an analysis using the newly released data to correct for the charter effort change from the Coastal Household Telephone Survey (CHTS) to the For-Hire Survey (FHS). The present analysis uses a statistically sound, consistent methodology to provide improved calibrations for estimating FHS charterboat effort and landings with associated uncertainties from CHTS estimates. Estimates based on these calibrations are calculated for all sub-regions and years in which only CHTS estimates are available, producing a consistent time series of FHS estimates across all years of recreational data collection.

The working group reviewed the working papers SEDAR58-DW01, SEDAR58-DW07 and SEDAR58-RD28 describing additional available data sources. Authors gave presentations to describe survey methods and data available from the SCDNR charterboat logbook, SC Finfish Survey, VMRC carcass program and VMRC Cobia recreational data application. These working papers were used to determine which data sets should be included in the recreational data and all decisions were presented in plenary sessions. Final outcomes are shown in section 4.3.4 Potential Sources for Additional Landings Data. SEDAR58-DW10 served as a reference for a method used in previous SEDARs for estimating historical landings. SEDAR58-RD-42 documents an update to the method used to calibrate the MRIP charter estimates for the change to the For-Hire Survey.

4.3 Recreational Landings

4.3.1 Marine Recreational Information Program (MRIP)

Introduction

The Marine Recreational Information Program (MRIP), formerly the Marine Recreational Fisheries Statistics Survey, conducted by the NOAA Fisheries (NMFS) provides estimated 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 (SH), private and rental boat fishing (PR), and for-hire charter and guide fishing (CH). MRIP also provides estimates for headboat mode (HB) in the mid and north Atlantic regions. MRIP covers coastal Atlantic states from Maine to Florida. Sampling is not conducted in Wave 1 (Jan/Feb) north of Florida because fishing effort is very low or non-existent, with the exception of NC, where wave 1 has been sampled since 2006. When the survey first began in Wave 2 (Mar/Apr), 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, NC lab.

Until 2013, recreational catch, effort, and participation were estimated through a suite of independent but complementary surveys. Effort data were collected using two telephone surveys: (1) the Coastal Household Telephone Survey (CHTS) which used random digit dialing of coastal households to obtain detailed information about the previous two months of recreational fishing trips from the anglers and (2) the weekly For-Hire Survey which interviews charterboat operators (captains or owners) to obtain the trip information with only one-week recall period.

In the Atlantic coast charter effort estimation changed in 2004 from the CHTS to the FHS. In order to maintain a consistent time series of charter estimates, charter estimates were calibrated on the Atlantic coast prior to 2004 (SEDAR58-RD42). Figure 4.12.1 shows the CHTS and calibrated FHS charter catch estimates for Atlantic cobia from 1981 to 2003.

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. Catch rates from dockside intercept surveys are combined with estimates of effort from telephone interviews to estimate total landings and discards by wave, mode, and area fished (inland, state, and federal waters). Catch estimates from early years of the survey are highly variable with high proportional standard errors (PSE's), and sample size in the dockside intercept portion have been increased over time to improve precision of catch estimates.

In 2013, MRIP implemented a new Access Point Angler Intercept Survey to remove sources of potential bias from the sampling process. Then, in 2015, MRIP launched a new household Fishing Effort Survey to improve efficiency and minimize the risk of error in private boat and shore effort estimates (NOAA Fisheries 2018). Figure 4.12.2 shows the calibrated APAIS and FES catch estimates for Atlantic cobia from 1981 to 2017. Full documentation on improved survey methods and calibrations are available on the MRIP website at: https://www.fisheries.noaa.gov/topic/recreational-fishing-data.

Coverage overlap with the Southeast Region Headboat Survey

In the South Atlantic, 1981-1985 MRIP charter and headboat modes were combined into one single mode for estimation purposes. Since the NMFS Southeast Region Headboat Survey (SRHS) began in this region in 1981, the MRIP combined charter/headboat mode must be split in order to not double the estimated landings from the headboat mode for these years. MRIP charter/headboat mode was split in these years by using a ratio of SRHS headboat angler trip estimates to MRIP charterboat angler trip estimates for 1986-1990. 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 strip out the headboat component when needed.

For cobia, which is considered a high profile species in headboat catch, the SRHS estimates will start in 1981 since captains were more likely to include this species as a write-in. Cobia MRIP charter/headboat mode was split for all years 1981-1985 and the headboat component was deleted from the MRIP dataset to avoid duplication with the SRHS.

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 30 fish, except for the final species level, where the minimum is 1 fish. 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.

Catch Estimates

Final MRIP landings estimates are shown in tables 4.11.1 and 4.11.2 by year and mode and in Figure 4.12.3. Estimates are shown for the Atlantic coast, Georgia and north. There is an increase in landings over the last 10-15 years. Recreational Workgroup anglers point to an increase in angler effort, technology and social media.

4.3.2 Southeast Region Headboat Survey (SRHS)

Introduction

The Southeast Region Headboat Survey estimates landings and effort for headboats in the South Atlantic and Gulf of Mexico. The Headboat Survey was started in 1972 but only included vessels from North Carolina and South Carolina until 1975. In 1976 the survey was expanded to northeast Florida (Nassau-Indian River counties) and Georgia, followed by southeast Florida (St. Lucie-Monroe counties) in 1978. For SEDAR58, only data from Georgia north through North Carolina were included. Due to headboat area definitions and confidentiality issues, Georgia and South Carolina landings must be combined. The portion of the SRHS covering Georgia through North Carolina generally include 30-35 vessels participating in the area annually.

The Headboat Survey incorporates two components for estimating catch and effort. 1) Information about the size of fish landed are 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 headboat logbook was changed several times during the early years of the Headboat Survey. In the case of cobia, the logbook used in North Carolina and South Carolina did not list cobia until 1984. Georgia and Florida had a mix of the different versions in use from 1980 to 1983. The Headboat Survey did not have a universal logbook form that included cobia for all areas until 1984. However, cobia were routinely written in by captains, which was evident by examining numerous logbooks from 1980 to 1983. The write-ins may be attributed to the fact that cobia are considered a high profile species in headboat catches. Another consideration regarding this issue, cobia estimated headboat landings are consistent coast wide from 1981-1983.
Issue 1: From 1981-1983 cobia was only listed on 1 of 3 versions of the Headboat Survey logbook form being used in the South Atlantic.
Option 1: Start headboat time series in 1984 when a universal form was in use in all areas from NC- FL. MRIP headboat landings will be used 1981-1983.
Option 2: Use estimated headboat landings based on available logbook data 1981- 2017.

Decision: Option 2
Note: Because of the inconsistencies in the form in the early years, the Indices Group determined that for the index of abundance analysis, 1991 would be the most appropriate year to start the time series in order to avoid any potential bias.

Catch Estimates
Final SRHS landings estimates are shown in Table 4.11.3. and Figure 4.12.4.

4.3.3 Historic Recreational Landings

Introduction
The historic recreational landings time period is defined as pre-1981 for the charterboat, headboat, private boat, and shore fishing modes, which represents the start of the Marine Recreational Fisheries Statistics Survey (MRFSS) and availability of landings estimates for cobia. The Recreational Working Group was tasked with evaluating historical sources and methods to compile landings of cobia prior to the available time series of MRFSS and headboat estimated landings. It was decided to use a method approved in previous SEDARs, which is the FHWAR method.

FHWAR census method
The 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey presented summary tables of U.S. population estimates, along with estimates of hunting and fishing participation and effort from surveys conducted by the USFWS every 5 years from 1955 to 1985 (Table 4.11.4). This information was used to develop an alternative method for estimating recreational landings prior to 1981.

The two key components from these FHWAR surveys that were used in the census method were the estimates of U.S. saltwater anglers and the estimates of U.S. saltwater days. The first objective was to determine the total saltwater anglers and saltwater days from New England to the South Atlantic (NE-SA) by using the summary information of U.S. anglers and U.S. saltwater anglers from the FHWAR surveys. The ratio of U.S saltwater anglers to the total U.S anglers was applied to the total number of anglers for the NE-SA to yield the total saltwater anglers for NE-SA. The same method was used to calculate the total saltwater days for the NE-SA from the FHWAR surveys 1955-1985.

In the FHWAR surveys the South Atlantic included the entire state of Florida, east and west coasts. In order to address the management boundaries for cobia the saltwater angler days for Florida's east and west coasts (FLE & FLW) had to be separated from the NE-SA saltwater angler days using the ratio of the MRFSS total angler trips for FL to the MRFSS total angler trips for the Atlantic (Delaware to FLW). The average ratio from 1984-1986 was applied to the total saltwater days for the NE-SA 1955-1985 to remove FL effort.

Similar to the Saltwater Angling Survey (SWAS), there was a 12 month recall period for respondents, which resulted in greater reporting bias. Research concluded this bias resulted in overestimates of both the catch and effort estimates in the FHWAR surveys from 1955 to 1985. Consequently, an adjustment for recall bias was necessary. The total saltwater days for the NE-GA 1955-1985 were adjusted for recall bias in the FHWAR surveys. The MRFSS total angler trips for the SA 1984 to1986 was averaged and divided by the total saltwater days for 1985 from the FHWAR survey. This multiplier was then applied to the total NE-GA saltwater days 1955-1985 to adjust for recall bias.

The mean CPUE for cobia in the Atlantic from the MRIP estimates from 1981 to 1985 was then applied to the adjusted saltwater angler days for the NE-GA 1955-1985 to estimate the historical cobia landings for those years (Table 4.11.4). During group discussions there was agreement that Cobia was not frequently targeted prior to 1970 and CPUE was expected to be very low.

Issue: Available historical cobia landings limited 1950-1980.
Option 1: Use available recreational time series for the MRFSS\MRIP and headboat estimates 1981-2010.
Option 2: Estimate cobia landings using the FHWAR method. Total cobia landings using the FHWAR census method (South Atlantic 1955-1980) are presented with the total estimated cobia landings (MRIP and SRHS landings) (South Atlantic 1981-2017) in Table 4.11.5 and Figure 4.12.5.
Decision: *Option 2*

4.3.4 Potential Sources for Additional Landings Data

SCDNR Charterboat Logbook Program Data, 1993 – 2017
The Recreational Fisheries Working Group discussed the possibility of replacing the MRIP charter mode estimates for South Carolina from 1993 to 2017 with the SCDNR Charterboat Logbook Program estimates. The SCDNR Charterboat Logbook Program is a mandatory trip-level reporting system, with compliance tracked monthly. Failure to comply with reporting requirements can result in a misdemeanor. These data ideally represent total catch and effort of 6-pack charter trips off South Carolina, however, the data is self-reported, with limited field validation. SCDNR charterboat logbook data were compared with MRIP charter mode estimates (Figure 4.12.6). The Recreational Fisheries Working Group recommended using the MRIP charterboat estimates instead of the SCDNR Charterboat Logbook Program estimates for 1993 – 2017. The MRIP estimates represent a longer time series and concern was expressed that replacing

the MRIP dataset with the SCDNR Charterboat logbook dataset would disrupt the continuity of the time series and would only replace landings for one state (SC) and one mode (charter). Additionally, since MRIP estimates are currently used to monitor annual catch limits (ACLs), it is recommended to use these estimates for the recreational landings data.
Recommendation: Use MRIP for charter mode landings coast-wide.

Virginia Marine Resources Commission Recreational Cobia Permit Landings
In 2016, the Virginia Marine Resources Commission (VMRC) developed a recreational cobia permit to monitor effort and landings of cobia in Virginia. The permit is required for the captain or operator of the vessel if they intend to possess or land cobia in Virginia. All permittees must report trip and catch level data on a weekly basis online through the VA Saltwater Journal, the VA Saltwater Journal App or on paper forms provided by the Commission. Permittees are required to report the number of fish kept, the number of fish released, the number of individuals on board, trip date, type of trip (Charter/Private), and mode of fishing (e.g. shore, pier, vessel, kayak). Permittees may also report the length and weight of individual fish caught on each trip. All reports of no activity or no catch are required no later than 21 days after the end of the recreational cobia season. Recreational reporting was voluntary in 2016 and became mandatory in 2017. Total recreational reported landings in 2017 from the private and charter fleet was 3,104 fish. Using the recreational reporting rate in 2017 (70.2%), the total expanded landings for the recreational fleet was 4,421 fish. Recreational reported landings through Virginia's cobia permit program should not be included in the SEDAR 58 stock assessment but may be used in later assessments as the program is further developed.

4.4 Recreational Discards

4.4.1 MRIP discards

Discarded live fish are reported by the anglers interviewed by MRIP so both the identity and quantities reported are unverified. Discarded fish size is unknown for all modes of fishing covered by MRIP. At-sea sampling of headboat discards was initiated as part of the improved for-hire surveys to characterize the size distribution of live discarded fishes in the headboat fishery, however, the SRHS produces estimates of total discards in the headboat fishery since that class of caught fish was added to the logbook (2004). All estimates of live released fish (B2 fish) in charter or charterboat/headboat combined mode were adjusted in the same manner as the landings (calibration factors, substitutions, etc. described above in section 4.3.1). Size or weight of discarded fishes is not estimated by the MRIP. Final MRIP discard estimates are shown in Table 4.11.6 by year and mode and in Figure 4.12.7. Discards increased in the last two years due to the federal closure.

4.4.2 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”. These self-reported data are currently not validated within the Headboat Survey. Due to low cobia sample sizes in the At-Sea Observer Headboat program, it was determined that the logbook discard data would be used from 2004-2017 (Table 4.11.7). The MRIP charter mode, MRIP private mode, and mean MRIP CH:SRHS discard ratio method used in SEDAR 28 (SEDAR 28-Assessment Workshop Report, 2013) were considered as sources for proxy discard estimates for headboat discards 1981-2003.

Issue 1: Proxy for estimated headboat discards from 1981-2003.

Option 1: Apply the MRFSS private boat discard:landings ratio to estimated headboat landings in order to estimate headboat discards from 1981-2003.

Option 2: Apply the MRFSS charterboat discard:landings ratio to estimated headboat landings in order to estimate headboat discards from 1981-2003.

Option 3: Mean MRIP CH:SRHS discard ratio method: Calculate the ratio of the mean ratio of SRHS discard:landings (2004-2017) and MRIP CH discard:landings (2004-2017). Apply this ratio to the yearly MRIP charterboat discard:landings ratio (1981-2003) in order to determine the yearly SRHS discard:landings ratio (1981-2003). This ratio is then applied to the SRHS landings (1981-2003) in order to estimate headboat discards (1981-2003).

Option 4: Assume negligible discards of cobia prior to 2004.

Decision: *Option 4.* The MRIP private mode discard ratio did not agree with the SRHS discard ratio and was not recommended for use (Figure 4.12.8). The MRIP charterboat discard ratio followed a similar pattern to the SRHS discards in the later years, but at a higher scale and with increased variability, therefore it was not recommended for use. The SEDAR Best Practice method (mean MRIP CH:SRHS discard ratio method) scaled the MRIP CH discard ratio to the SRHS landings, however it was impacted by the variability of the MRIP CH discard estimates and therefore was not recommended for use. Due to the extremely low catch and discards of cobia in the headboat fishery, it is recommended to assume negligible discards of cobia prior to 2004 (Figure 4.12.9). The final estimated headboat discards 2004-2017 are presented in Figure 4.12.10 along with the proxy discard estimates.

4.4.3 Headboat At-Sea Observer Survey Discards

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. Headboat vessels are 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 number and species of fish landed and discarded, size of landed and discarded fish. Data are also collected on the length of the trip, area fished (inland, state, and federal waters) Forty-five cobia catch records were collected between 2004-2017 from NC, SC, and GA. Of these records only 28 included observed cobia discards. Due to low cobia sample sizes the At-Sea Observer data was not used in this assessment.

4.4.4 Virginia Marine Resources Commission Cobia Permit Reporting

Recreational Cobia Permit Discards

The VMRC recreational cobia permit requires the captain or operator of the vessel to report all activity, including the number of fish discarded. In 2016 recreational reporting was voluntary and sample size was low. A total of 92 fish were reported discarded in the charter and private boat modes combined. In 2017, a total of 9,005 cobia were reported as discarded from the charter and private fleet combined. Using the recreational reporting rate in 2017 (70.2%), the total expanded discards for the recreational fleet was 12,827 fish. This estimate potentially does not account for unpermitted, incidental catch. The total number of recreational reported discards through Virginia's cobia permit program was not recommended for inclusion due to the limited time series. However, the available discards lengths could potentially be used to characterize the discard length composition in Virginia.

4.5 Biological Sampling

4.5.1 Sampling Intensity Length/Age/Weight

MRIP Charter, Private, and Shore

The MRIP angler intercept survey includes the collection of fish lengths from the harvested (landed, whole condition) catch. Up to 15 of each species landed 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, e.g., cobia, and 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 fishes 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.

The number of cobia measured in the Atlantic coast (Georgia and north) in the MRIP charter fleet, private-rental mode, and shore mode are summarized by year and state in tables 4.11.8, 4.11.9, and 4.11.10, respectively. The number of angler trips with measured or weighed cobia along the Atlantic coast (Georgia and north) in the MRIP charter fleet, private-rental mode, and shore mode are summarized by year and state in tables 4.11.11, 4.11.12, and 4.11.13, respectively. Dockside mean weights of cobia weighed from MRIP in the Atlantic coast (Georgia and north) are tabulated for 1981-2017 in Table 4.11.14. There was an increase in average weight over the last 5 years (up to 38lb in 2015) which coincided with an estimated weight of 40 lbs from fisherman at the data workshop.

Headboat Survey Biological Sampling

Lengths were collected from 1972 to 2017 by headboat dockside samplers. From 1972 to 1975, only North Carolina and South Carolina were sampled whereas Georgia and northeast Florida were sampled beginning in 1976. The Southeast Region Headboat Survey conducted dockside sampling southeast portion of the US from the NC-VA border through the Florida Keys beginning in 1978. Weights are typically collected for the same fish measured during dockside sampling. Also, biological samples (scales, otoliths, spines, stomachs, and gonads) are collected routinely and processed for aging, diet studies, and maturity studies.

Annual numbers of cobia measured for length in the headboat fleet and the number of trips from which cobia were measured are summarized in Table 4.11.15. Dockside mean weights for the headboat fishery are tabulated for 1978-2017 in Table 4.11.16.

Any existing total length measurements without an associated fork length measurement were converted using the following equation derived by the Life History Working Group for the Atlantic stock at the SEDAR 58 data workshop:

$FL = 8.19 + 0.88TL$ ($N = 5672$, $R^2 = 0.99$)

SCDNR State Finfish Survey (SFS)

Cobia lengths were collected through the SCDNR State Finfish Survey (SFS) from 1988 to 2017. 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 private boat mode, and is conducted year-round (January- December) from inception through 2013, at which time SFS was only conducted in wave 1 (January and February). The survey uses a questionnaire and interview procedure similar to the intercept portion of the MRIP survey. From 1988 through March 2009, mid-line lengths were measured, and from April 2009 to 2017, total lengths were measured. A total of 427 cobia lengths were collected by SFS personnel. The Recreational Fisheries Working Group recommended the SCDNR SFS length data for all modes be used to supplement the MRIP length data for length compositions. It was decided to omit length frequencies obtained in 1988 from SFS due to a potential for data overlap between SFS and MRIP surveys, resulting in 1992 being the first representative year for this data series. A total of two data points were omitted from the SFS survey. Total length measurements from 2009-2017 were converted to fork length measurements using the following equation derived by the Life History Working Group for the Atlantic stock at the SEDAR 58 data workshop:

$FL = 8.19 + 0.88TL$ ($N = 5672$, $R^2 = 0.99$)

Summarized length data from 1992 – 2017 can be found in Table 4.11.17.

VMRC Recreational Cobia Permit Discards

In 2016, a total of 89 cobia lengths were recreationally reported as discarded from the charter and private modes combined. The smallest discarded cobia is 482 mm total length and the largest discarded cobia is 1,422 mm total length. The average size of discarded cobia in 2016 is 964 mm total length. In 2017, a total of 1,635 cobia lengths were recreationally reported as discarded from the charter and private modes combined. The smallest discarded cobia is 406mm and the largest discarded cobia is 1,778 mm. The average size of discarded cobia in 2017 is 898 mm total length. The available discards lengths could potentially be used to characterize the discard length composition of the shore, charter, and private modes in Virginia.

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. The number of cobia aged from the recreational fishery (mode unknown) by year and state is summarized in Table 4.11.18. In some cases mode of catch was either not recorded or the samples were taken from freezers or coolers left outside of fishing centers or marinas and trip information was not collected. Therefore the number of trips with aged samples was not reported in any mode.

4.6 Recreational Effort

4.6.1 MRIP Recreational & Charter Effort

Effort estimation for the recreational fishery surveys are produced via the Fishing Effort Survey (FES) for private/rental boats and shore mode and the For-Hire Survey (FHS) for charterboat mode. The methods have changed during the full time series (see section 4.3 for descriptions of survey method changes and adjustments to survey estimates for uniform time-series of catch estimates). Angler trip estimates are tabulated in Tables 4.11.19 by year and mode. An angler-trip is a single day of fishing in the specified mode, not to exceed 24 hours. Figure 4.12.11 shows MRIP angler trips for Atlantic coast states, Georgia and north.

4.6.2 Headboat Effort

Catch and effort data are reported on logbooks provided to all headboats in the Survey. These forms are completed by the captain or designated crew member after each trip and represent the total number and weight of all the species kept, along with the total number of fish discarded for each species. Data on effort are provided as number of anglers on a given trip. Numbers of anglers are standardized, depending on the type of trip (length in hours), by converting number of anglers to "angler days" (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.

Estimated headboat angler days have decreased in the South Atlantic in recent years (Table 4.11.20 and Figure 4.11.12). The most obvious factor which impacted the headboat fishery in both the Atlantic and Gulf of Mexico was the high price of fuel. This coupled with the economic down turn starting in 2008 has resulted 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 the factors that most affected the amount of trips, number of passengers, and overall fishing effort.

4.7 Comments on adequacy of data for assessment analyses

Regarding the adequacy of the available recreational data for assessment analyses, the RWG discussed the following:

- Landings, as adjusted, appear to be adequate for the time period covered.
- Size data appear to adequately represent the landed catch for all modes.

4.8 Itemized list of tasks for completion following workshop

Length and age compositions will be completed before the Assessment Workshop.

4.9 Research Recommendations

4.9.1 Evaluation and progress of research recommendations from last assessment

Research recommendations from SEDAR 28 were evaluated and progress on each item is outlined below:

1) Increase proportion of fish with biological data within MRFSS sampling.
    a) Efforts are ongoing to collect more biological data such as length and weight for fish sampled within MRIP.
2) Continue to develop methods to collect a higher degree of information on released fish (length, condition, etc.) in the recreational fishery.
    a) In 2016, Virginia developed a Cobia permit data application that specifically collects information on released fish. Full description of this program can be found in section 4.3.4.
    b) North Carolina is also working on a coast-wide discard application that could provide information in the future.
3) Require mandatory reporting for all charterboats state and federal.
    a) Establishment of federal logbooks for charter captains that have valid federal finfish permits is pending approval and implementation is expected in summer of 2019.
    b) State logbook are still a work in progress with no current actions pending.
4) Continue development of electronic mandatory reporting for for-hire sector.
    a) Southeast For-Hire Integrated Electronic Reporting (SEFHIER) is currently working to provide more robust for-hire data that is timely and can be integrated with existing programs.
5) Continued research efforts to incorporate/require logbook reporting from recreational anglers.
    a) Two applications that have been created and are currently used by the recreational fishery along the Atlantic coast are My Fish Count and VA cobia permit. There is one pending application from North Carolina that will be a coast-wide application for released fish.
6) Establish a review panel to evaluate methods for reconstructing historical landings (SWAS, FWS, etc.).
    a) FHWAR method was reviewed by assessment panels and established as “Best Practice” in SEDAR Data Best Practices procedural workshop.
7) Quantify historical fishing photos for use in reconstructing recreational historical landings.
    a) SAFMC FIS funded 2018-2019
8) Narrow down the sampling universe. Identify angler preference and effort. Require a reef fish stamp for anglers targeting reef fish, pelagic stamp for migratory species, and deep water complex stamp for deep-water species. The program would be similar to the federal duck stamp required of hunters. This would allow the managers to identify what anglers were fishing for.
    a) National Saltwater Angler Registry
    b) VA cobia permit
9) Continue and expand fishery dependent at-sea-observer surveys to collect discard information, which would provide for a more accurate index of abundance.
    a) Continued in Atlantic but expansion is funding limited

4.9.2 Research recommendations

1) Improve recreational reporting applications –
    a) Standardized across states (i.e., Harbor Light Scamp app, My Fish Count app).
    b) Capable of capturing length with photo.
2) Standardize carcass collection protocols across states.
3) Increase recreational biological sampling (i.e., NC, GA).
4) Increase citizen Science involvement in tagging and tissue collection efforts.

4.10 Literature Cited

Brennan, K., 2019. SEDAR58-DW-10, Estimates of Historic Recreational Landings of Cobia in the Atlantic Using the FHWAR Census Method. SEDAR, North Charleston, SC. 8pp.

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4.11 Tables

Table 4.11.1. Atlantic coast (Georgia and north) cobia landings (numbers of fish and whole weight in pounds) for charterboat mode and charterboat/headboat mode (MRIP). CH and CH/HB mode adjusted for FHS conversion prior to 2004. CH/HB mode landings are from the Mid-Atlantic (sub-region 5) through 2003. After 2004 CH and HB modes are estimated separately in these sub-regions.

	Estimated CH Landings			Estimated CH/HB Landings		
YEAR	Number	CV	Pounds	Number	CV	Pounds
1981						
1982						
1983				6	0.00	175
1984	306	0.00	8,095			
1985	1,371	0.00	36,315	1,470	0.00	30,021
1986	1,850	0.00	49,020	284	0.00	8,535
1987	1,270	0.14	25,738			
1988	2,289	0.50	60,634			
1989	1,243	0.00	28,779	147	0.00	4,413
1990	1,594	0.00	30,089			
1991	2,327	0.00	49,835	170	0.01	5,122
1992	2,091	0.22	46,772			
1993	7,065	0.62	160,986			
1994	542	0.40	14,098	0	0.00	-
1995	3,064	0.20	97,065			
1996	3,597	0.61	60,728			
1997	574	0.00	16,986			
1998	1,240	0.31	49,435			
1999	817	0.00	24,238			
2000	498	0.46	13,984			
2001	1,297	0.23	31,659			
2002	1,853	0.12	50,689	3	0.00	104
2003	3,520	0.29	98,712	1	0.00	24
2004	3,306	0.37	103,088			
2005	1,957	0.45	56,996			
2006	823	0.31	21,106			
2007	2,833	0.00	75,931			
2008	885	0.51	24,475			
2009	820	0.35	18,682			
2010	3,167	0.25	101,689			
2011	557	0.28	21,814			
2012	564	0.02	17,410			
2013	3,010	0.03	75,319			
2014	2,109	0.12	55,709			
2015	2,473	0.23	76,530			
2016	3,694	0.32	118,920			
2017	1,209	0.26	40,872			

Table 4.11.2. Atlantic coast (Georgia and north) cobia landings (numbers of fish and whole weight in pounds) for private/rental boat mode and shore mode (MRIP).

	Estimated PR Landings			Estimated SH Landings		
YEAR	Number	CV	Pounds	Number	CV	Pounds
1981	2,631	0.00	73,051			
1982	11,196	0.02	296,597			
1983	1,611	0.00	42,670	0	0.00	0
1984	17,136	0.00	453,950	0	0.00	0
1985	12,706	0.12	314,658	0	0.00	0
1986	21,323	0.18	600,810	9,587	0.00	253,967
1987	5,898	0.06	125,737	17,585	0.00	356,453
1988	8,562	0.11	226,828	908	0.00	24,042
1989	16,959	0.25	427,494	3,234	0.39	74,905
1990	16,261	0.07	354,219	0	0.00	0
1991	11,352	0.21	288,972	7,291	0.39	156,122
1992	16,488	0.17	423,467	4,283	0.71	95,818
1993	6,668	0.06	188,731	1,804	0.00	41,100
1994	8,143	0.19	228,256	3,273	0.38	85,204
1995	20,406	0.46	619,786	3,912	0.07	123,933
1996	89,852	0.03	2,182,432	552	0.00	10,386
1997	13,382	0.07	399,009	4,674	0.00	140,494
1998	9,494	0.39	305,489	255	0.00	9,977
1999	21,346	0.51	635,678	1,469	0.00	43,591
2000	12,961	0.29	385,250	0	0.00	0
2001	9,699	0.39	276,039	424	0.00	10,353
2002	5,295	0.47	153,737	9,440	0.10	270,471
2003	47,537	0.53	1,347,668	793	0.00	22,252
2004	28,123	0.12	874,305	0	0.00	0
2005	31,221	0.40	922,669	24,007	0.08	717,807
2006	49,949	0.24	1,433,790			
2007	32,921	0.08	925,020	0	0.00	0
2008	24,544	0.03	695,791	3,195	0.00	91,728
2009	45,222	0.17	1,249,667	6,462	0.62	134,632
2010	44,851	0.14	1,468,536	2,453	1.00	81,505
2011	24,641	0.25	771,424	6,166	0.64	255,595
2012	27,400	0.04	846,529	18,287	0.00	549,691
2013	62,971	0.24	1,533,440	0	0.00	0
2014	45,441	0.25	1,255,332	4,688	0.00	121,997
2015	100,668	0.13	3,847,916	7,150	0.09	262,630
2016	57,191	0.04	1,805,571	14,810	0.00	502,403
2017	38,448	0.17	1,267,397	0	0.00	0

Table 4.11.3. Estimated headboat landings of cobia in the South Atlantic 1981-2017. Due to headboat area definitions and confidentiality issues, Georgia and South Carolina landings must be combined.

	Number			Pounds		
Year	NC	SCGA	South Atlantic	NC	SCGA	South Atlantic
1981	85		85	1,565		1,565
1982	37	13	50	644	227	871
1983	44	13	57	1,308	228	1,536
1984	43	25	68	1,077	626	1,702
1985	16	32	48	357	713	1,070
1986	53	55	108	910	821	1,731
1987	43	97	140	710	1,601	2,311
1988	82	82	164	1,984	1,796	3,780
1989	79	70	149	1,535	1,477	3,012
1990	154	49	203	4,403	1,319	5,721
1991	203	160	363	3,856	3,126	6,981
1992	201	101	302	4,505	2,231	6,737
1993	116	114	230	2,243	2,486	4,729
1994	180	118	298	3,512	2,300	5,812
1995	184	147	331	3,896	3,110	7,006
1996	46	76	122	1,347	2,192	3,540
1997	91	216	307	2,179	5,117	7,296
1998	51	200	251	1,286	4,907	6,193
1999	48	113	161	971	2,342	3,313
2000	66	141	207	1,397	2,985	4,382
2001	95	156	251	2,190	3,764	5,953
2002	75	197	272	1,739	4,428	6,167
2003	48	69	117	1,040	1,496	2,536
2004	82	125	207	2,552	3,843	6,395
2005	83	101	184	1,857	2,271	4,127
2006	40	96	136	808	1,925	2,734
2007	32	574	606	544	9,666	10,211
2008	32	203	235	775	6,136	6,911
2009	5	148	153	90	2,836	2,925
2010	20	116	136	492	3,036	3,527
2011	19	104	123	332	1,869	2,200
2012	25	112	137	343	1,513	1,855
2013	51	172	223	1,444	4,891	6,334
2014	78	157	235	2,068	4,535	6,604
2015	39	89	128	693	1,645	2,338
2016	31	53	84	520	906	1,426
2017	4		4	85		85

Table 4.11.4. FHWAR estimation method for historical cobia landings (1955-1985).

Year	US saltwater angler days	Proportion anglers NY-GA	Saltwater angler days (NY-GA)	Mean CPUE (MRFSS 1981-1985)	Recall bias adjustment	Adjusted saltwater angler days (NY-GA)	Adjusted cobia landings (n)
1955	58,621,000	0.32	6,046,942	0.0002	3.32	15,951,624	2,609
1960	80,602,000	0.29	7,712,294	0.0002	3.32	23,293,761	3,810
1965	95,837,000	0.33	10,201,818	0.0002	3.32	33,840,793	5,535
1970	113,694,000	0.33	12,305,878	0.0002	3.32	34,831,840	5,697
1975	167,499,000	0.33	17,679,316	0.0002	3.32	52,044,539	8,513
1980	164,040,000	0.32	16,783,303	0.0002	3.32	54,980,835	8,993
1985	171,055,000	0.33	18,099,435	0.0002	3.32	60,189,443	9,845

Table 4.11.5. Estimated cobia landings (number) using FHWAR census method (1955-1980), MRIP and SRHS (1981-2017) estimation methods.

Year	Est. landings (n)	Year	Est. landings (n)
1955	2,609	1987	24,893
1956	2,849	1988	11,923
1957	3,090	1989	21,732
1958	3,330	1990	18,057
1959	3,570	1991	21,504
1960	3,810	1992	23,164
1961	4,155	1993	15,766
1962	4,500	1994	12,256
1963	4,845	1995	27,713
1964	5,190	1996	94,123
1965	5,535	1997	18,938
1966	5,568	1998	11,241
1967	5,600	1999	23,794
1968	5,633	2000	13,665
1969	5,665	2001	11,672
1970	5,697	2002	16,864
1971	6,261	2003	51,969
1972	6,824	2004	31,635
1973	7,387	2005	57,370
1974	7,950	2006	50,908
1975	8,513	2007	36,360
1976	8,609	2008	28,859
1977	8,705	2009	52,657
1978	8,801	2010	50,607
1979	8,897	2011	31,487
1980	8,993	2012	46,387
1981	2,716	2013	66,204
1982	11,246	2014	52,472
1983	1,673	2015	110,419
1984	17,509	2016	75,779
1985	15,595	2017	39,661
1986	33,152		

Table 4.11.6. Atlantic coast (Georgia and north) cobia discards in numbers of fish for the recreational fishing modes by year (MRIP). CH and CH/HB mode adjusted for FHS conversion prior to 2004. CH/HB mode landings are from the Mid-Atlantic (sub-region 5) through 2003. After 2004 CH and HB modes are estimated separately in this sub-region.

	Estimated CH Discards		Estimated CH/HB Discards		Estimated HB Discards		Estimated PR Discards		Estimated SH Discards	
YEAR	Number	CV	Number	CV	Number	CV	Number	CV	Number	CV
1981	0	0.00					7,507	0.00		
1982	0	0.00					0	0.00		
1983	0	0.00	0	0.00			0	0.00	9,464	0.00
1984	0	0.00			0	0.00	0	0.00	6,108	0.00
1985	0	0.00	95	0.00	0	0.00	8,096	0.19	50,412	0.00
1986	0	0.00	0	0.00			9,112	0.00	0	0.00
1987	0	0.00					736	0.46	0	0.00
1988	229	1.00					6,044	0.23	0	0.00
1989	68	0.00	0	0.00			2,821	0.40	10,877	0.12
1990	0	0.00					9,102	0.20	1,855	0.00
1991	315	0.83	426	0.87			22,750	0.41	19,839	0.14
1992	55	0.00					7,419	0.17	7,260	0.33
1993	48	1.00					2,771	0.73	1,674	0.00
1994	21	1.00	778	0.00			12,145	0.14	19,234	0.04
1995	336	0.04					6,612	0.38	1,758	0.00
1996	153	0.57					5,336	0.39	536	0.00
1997	0	0					9,549	0.12	26,513	0.03
1998	933	0.20					16,683	0.30	10,570	0.00
1999	0	0.00					44,619	0.30	25,179	0.00
2000	1,638	0.61					11,844	0.44	12,471	0.00
2001	0	0.00					27,242	0.21	8,222	0.00
2002	66	1.00	20	0.00			26,193	0.13	9,344	0.22
2003	1,242	0.12	0	0.00			46,996	0.16	16,409	0.05
2004	5,766	0.99			38	0.00	26,219	0.09	4,057	0.00
2005	1,394	0.00					36,954	0.12	12,221	0.09
2006	458	0.58					53,641	0.10		
2007	121	0.00					41,542	0.10	8,652	0.00
2008	670	0.31					22,149	0.09	15,672	0.00
2009	961	0.80					51,407	0.12	35,669	0.32
2010	1,683	0.44					46,583	0.13	31,595	0.11
2011	595	0.38					77,698	0.11	30,021	0.15
2012	270	0.27			179	0.00	30,003	0.10	58,264	0.28
2013	1,169	0.30					66,796	0.33	12,180	0.00
2014	2,052	0.25					74,435	0.18	56,600	0.03
2015	539	0.45					73,195	0.15	24,092	0.00
2016	3,223	0.48					91,125	0.15	50,617	0.05
2017	3,742	0.07					160,939	0.31	53,899	0.00

Table 4.11.7. Estimated South Atlantic cobia discards for SRHS by year and state, 2004-2017. Discards are assumed to be negligible prior to 2004. Due to headboat area definitions and confidentiality issues, Georgia and South Carolina landings must be combined.

	NC		SCGA		South Atlantic	
Year	Released live (n)	Released dead (n)	Released live (n)	Released dead (n)	Released live (n)	Released dead (n)
2004	2	-	14	-	16	-
2005	-	-	10	-	10	-
2006	-	-	12	-	12	-
2007	-	-	36	-	36	-
2008	-	-	22	-	22	-
2009	5	-	157	1	162	1
2010	-	-	151	-	151	-
2011	3	-	28	-	31	-
2012	2	-	48	-	50	-
2013	4	-	63	-	67	-
2014	14	-	85	-	99	-
2015	1	-	71	-	72	-
2016	13	-	90	-	103	-
2017	27	-	124	-	151	-

Table 4.11.8. Number of cobia measured in the Atlantic (Georgia and north) in the MRIP charter fleet by year and state.

YEAR	GA	SC	NC	VA	MD	DE	NJ	TOTAL
1984		2						2
1985		3						3
1986	4		1	1	1			7
1987	15		5					20
1988	3	4	1					8
1989			3	1	1			5
1990			8					8
1991		1	3	2				6
1992	3	1	9					13
1993			14					14
1994			5					5
1995		2	13					15
1996		2	30					32
1997	1	2	8					11
1998		1	34					35
1999	4		6					10
2000		1	7					8
2001			10					10
2002	2	4	8	1				15
2003	1		19	1				21
2004	3	2	14					19
2005	1	1	12	1		1		16
2006	1	1	6				1	9
2007	5		5	1				11
2008	1	8	2					11
2009	2	1	3	4				10
2010	3	3	54	3	1			64
2011	1		23	1				25
2012	1	3	11	2				17
2013	1	1	12	8				22
2014	1	2	42	2				47
2015		6	43	5				54
2016		7	50	4	1			62
2017	1		24	4				29
TOTAL	54	58	485	41	4	1	1	644

Table 4.11.9. Number of cobia measured in the Atlantic (Georgia and north) in the MRIP private fleet by year and state.

YEAR	GA	SC	NC	VA	MD	NJ	TOTAL
1981			1	1			2
1982	3	2	1				6
1983	2						2
1984	3	3	2				8
1985	6	3	1	15			25
1986	3	5	5	9		1	23
1987	2		13	1			16
1988		4	15				19
1989	6	10	22	5			43
1990	1	5	35	6			47
1991		3	12	7	1		23
1992	4	4	12	10			30
1993			5	4			9
1994		1	15	10			26
1995			12	6			18
1996	1	5	10	12			28
1997		1	15	3			19
1998		3	6	5			14
1999		8	2	6	1		17
2000			5	7			12
2001	1		6	11			18
2002			9	3			12
2003		10	6	3	1		20
2004	2	4	14	3			23
2005			21	5			26
2006		2	10	5			17
2007	1	5	5	17			28
2008	9	1	4	6			20
2009		4	10	13			27
2010	4	4	36	14			58
2011	4		12	4			20
2012	6	8	10	1			25
2013	3	7	56	26			92
2014	3	6	24	13			46
2015	4	6	57	34			101
2016		7	17	31			55
2017			24	13			37
Total	68	121	510	309	3	1	1,012

Table 4.11.10. Number of cobia measured in the Atlantic (Georgia and north) in the MRIP shore mode by year and state.

YEAR	SC	NC	VA	NJ	TOTAL
1986		1			1
1987	1	2			3
1988		1			1
1989		3			3
1991		9			9
1992		3			3
1993		1			1
1994		2			2
1995		4			4
1996		1			1
1997			1		1
1998		1			1
1999		1			1
2001		1			1
2002		4	1		5
2003		1			1
2005		3	1		4
2008		1	1		2
2009		2			2
2010		1			1
2011		4			4
2012				1	1
2014		2			2
2015		7			7
2016		4			4
TOTAL	1	59	4	1	65

Table 4.11.11 Number of angler trips with measured or weighed cobia in the Atlantic (Georgia and north) in the MRIP charter fleet by year and state.

YEAR	GA	SC	NC	VA	MD	DE	NJ	TOTAL
1984		2						2
1985		3						3
1986	4		1	1	1			7
1987	11		5					16
1988	3	3	1					7
1989			3	1	1			5
1990			5					5
1991		1	3	1				5
1992	3	1	8					12
1993			7					7
1994			4					4
1995		1	10					11
1996		2	12					14
1997	1	2	5					8
1998		1	11					12
1999	4		3					7
2000		1	4					5
2001			9					9
2002	2	1	6	1				10
2003	1		12	1				14
2004	2	2	8					12
2005	1	1	4	1		1		8
2006	1	1	4				1	7
2007	4		4	1				9
2008	1	5	2					8
2009	1	1	3	4				9
2010	3	3	19	1	1			27
2011	1		12	1				14
2012	1	3	7	1				12
2013	1	1	6	1				9
2014	1	1	15	1				18
2015		5	20	2				27
2016		3	32	2	1			38
2017	1		10	2				13
TOTAL	47	44	255	22	4	1	1	374

Table 4.11.12. Number of angler trips with measured or weighed cobia in the Atlantic (Georgia and north) in the MRIP private fleet by year and state.

YEAR	GA	SC	NC	VA	MD	NJ	TOTAL
1981			1	1			2
1982	3	2	1				6
1983	1						1
1984	3	3	1				7
1985	3	3	1	12			19
1986	1	5	5	8		1	20
1987	2		13	1			16
1988		4	13				17
1989	5	8	19	5			37
1990	1	5	26	5			37
1991		3	12	4	1		20
1992	2	4	11	5			22
1993			5	4			9
1994		1	13	7			21
1995			11	6			17
1996	1	3	8	9			21
1997		1	11	3			15
1998		3	5	5			13
1999		6	2	5	1		14
2000			5	5			10
2001	1		6	8			15
2002			6	3			9
2003		9	6	3	1		19
2004	1	3	8	2			14
2005			9	5			14
2006		2	8	5			15
2007	1	3	5	14			23
2008	3	1	4	3			11
2009		3	10	13			26
2010	3	4	29	12			48
2011	4		7	4			15
2012	3	4	9	1			17
2013	2	5	32	20			59
2014	3	5	19	13			40
2015	4	4	33	27			68
2016		4	13	27			44
2017			18	12			30
TOTAL	47	98	385	257	3	1	791

Table 4.11.13. Number of angler trips with measured or weighed cobia in the Atlantic (Georgia and north) in the MRIP shore fleet by year and state.

YEAR	SC	NC	VA	NJ	TOTAL
1986		1			1
1987	1	2			3
1988		1			1
1989		3			3
1991		8			8
1992		3			3
1993		1			1
1994		2			2
1995		4			4
1996		1			1
1997			1		1
1998		1			1
1999		1			1
2001		1			1
2002		4	1		5
2003		1			1
2005		3	1		4
2008		1	1		2
2009		2			2
2010		1			1
2011		4			4
2012				1	1
2014		2			2
2015		7			7
2016		4			4
TOTAL	1	58	4	1	64

Table 4.11.14. Mean weight (lb) of cobia weighed from the MRIP in the Atlantic (Georgia and north) by year and mode, 1981-2017.

	Charterboat				Private				Shore			
YEAR	N	Mean	Min	Max	N	Mean	Min	Max	N	Mean	Min	Max
1981					2	4.18	2.2	6.15				
1982					6	12.35	1.33	35.21				
1983					2	45.64	36.38	54.89				
1984	2	13.23	9.93	16.53	8	32.81	17.62	62.46				
1985	3	20.29	17.42	23.15	25	23.21	1.54	56				
1986	7	30.8	22.05	50.83	23	20.12	1.6	50.93	1	41.01	41.01	41.01
1987	20	25.24	12.13	48.64	16	16.48	0.44	34.08	3	1.29	0.29	3.15
1988	6	23.48	9.92	42.99	9	26.07	1.15	50.46	1	49.04	49.04	49.04
1989	5	12.57	1.02	28.87	43	22.49	0.45	71.62	3	24.77	0.9	53.81
1990	8	22.76	3.15	56.53	47	19.37	0.23	65.48				
1991	6	28.03	17.2	44.11	23	19.53	0.22	80.25	9	29.9	0.9	71.87
1992	13	21.41	10.55	38.11	30	29.45	5.11	56.65	3	40.19	28.19	52.59
1993	14	23.05	7.73	40.84	9	27.46	15.94	61.34	1	33.58	33.58	33.58
1994	5	34.75	22.24	52.57	26	35.25	1.66	66.99	2	24.54	18.35	30.73
1995	15	32.04	13.89	60.22	18	30.8	7.93	69.74	4	38.84	27.67	51.35
1996	32	17.19	2	66.76	28	28.01	0.13	62.62	1	32.02	32.02	32.02
1997	11	31.47	20.64	56.28	19	34.35	20.01	57.17	1	36.74	36.74	36.74
1998	35	39.8	13.07	69.15	14	35.6	10.79	80.13	1	52.03	52.03	52.03
1999	10	36.36	10.47	68.4	17	16.69	1.82	60.8	1	48.06	48.06	48.06
2000	8	32.64	13.92	62.44	12	36.6	6.87	71.58				
2001	10	25.55	10.58	58.63	18	33.63	13.23	69.09	1	67.28	67.28	67.28
2002	15	30.87	11.46	74.9	12	37.31	18.08	56.08	5	42.81	19.62	73.2
2003	21	24.07	10.8	71.22	20	29.07	18.19	65.36	1	39.55	39.55	39.55
2004	19	35.96	14.55	61.73	23	32.62	13.67	69.08				
2005	16	41.61	13.76	77.16	26	26.94	2.87	57.01	4	19.98	0.66	39.13
2006	9	27.21	14.77	38.91	17	34.64	14.77	77.65				
2007	11	28.67	14.77	58.69	28	34.24	15.43	64.99				
2008	11	25.54	10.71	60.08	20	29.01	13.45	55.12	2	40.9	20.06	61.73
2009	10	27.87	15.21	44.18	27	25.3	4.63	55.12	2	21.61	11.24	31.97
2010	64	31.2	10.14	60.12	58	34.08	4.63	81.57	1	19.84	19.84	19.84
2011	25	29.67	9.26	80.03	20	51.88	11.9	131.61	4	22.43	1.32	44.09
2012	17	45.54	3.31	84.99	25	27.41	11.9	44.78	1	3.31	3.31	3.31
2013	22	26.29	14.33	46.3	92	23.53	0.66	52.03				
2014	47	26.09	13.67	60.63	46	23.66	14.11	38.58	2	32.79	30.31	35.27
2015	54	28.99	11.02	70.99	101	39.23	7.28	135.03	7	36.41	19.4	60.41
2016	62	33.36	5.51	59.52	55	31.67	18.08	53.25	4	32.41	22.6	41.89
2017	29	35.13	14.77	82.06	37	34.66	18.74	54.72				
Total	642	29.9	1.02	84.99	1,002	29.34	0.13	135.03	65	31.59	0.29	73.2

Table 4.11.15. Number of cobia measured and positive trips in the SRHS by year and state.

Year	Fish (n)			Trips (n)		
	NC	SCGA	South	NC	SCGA	South
1974	0	3	3	0	3	3
1975	0	0	0	0	0	0
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	1	0	1	1	0	1
1979	2	0	2	2	0	2
1980	1	0	1	1	0	1
1981	1	0	1	1	0	1
1982	3	0	3	3	0	3
1983	4	0	4	4	0	4
1984	3	2	5	3	2	5
1985	6	1	7	6	1	7
1986	4	3	7	4	3	7
1987	6	4	10	5	3	8
1988	2	5	7	2	5	7
1989	5	2	7	5	2	7
1990	3	6	9	1	6	7
1991	5	8	13	5	7	12
1992	9	2	11	7	2	9
1993	4	9	13	4	7	11
1994	0	9	9	0	7	7
1995	7	9	16	7	8	15
1996	3	4	7	3	3	6
1997	5	4	9	5	4	9
1998	3	6	9	3	5	8
1999	4	1	5	4	1	5
2000	0	1	1	0	1	1
2001	6	0	6	6	0	6
2002	5	1	6	4	1	5
2003	2	1	3	2	1	3
2004	4	0	4	3	0	3
2005	4	0	4	4	0	4
2006	2	2	4	2	2	4
2007	0	7	7	0	7	7
2008	2	1	3	2	1	3
2009	0	2	2	0	2	2
2010	1	7	8	1	5	6
2011	1	1	2	1	1	2
2012	0	4	4	0	2	2
2013	6	5	11	3	5	8
2014	8	14	22	5	8	13
2015	0	2	2	0	2	2
2016	1	3	4	1	3	4
2017	1	0	1	1	0	1

Table 4.11.16. Mean weight (kg) of cobia measured in the SRHS by year and state, 1972-2017.

	NC				SCGA				South Atlantic			
Year	N	Mean (kg)	Min (kg)	Max (kg)	N	Mean (kg)	Min (kg)	Max (kg)	N	Mean (kg)	Min (kg)	Max (kg)
1978	1	9.52	9.52	9.52					1	9.52	9.52	9.52
1979	2	12.35	11.7	12.99					2	12.35	11.7	12.99
1980	1	5.96	5.96	5.96					1	5.96	5.96	5.96
1981	1	4.25	4.25	4.25					1	4.25	4.25	4.25
1982	3	9.1	3.7	16.8					3	9.1	3.7	16.8
1983	4	8.81	6.5	12.93					4	8.81	6.5	12.93
1984	3	10.47	7.38	12.7	2	14.95	6.8	23.1	5	25.42	14.18	35.8
1985	6	9.7	3	17.44	1	12.6	12.6	12.6	7	22.3	15.6	30.04
1986	3	5.92	5.45	6.2	3	8.27	5.6	11.8	6	14.18	11.05	18
1987	3	11.77	9.29	13.45	4	9.8	5.5	14.3	7	21.57	14.79	27.75
1988	2	10.51	10.11	10.9	5	9.19	1.1	17.1	7	19.7	11.21	28
1989	5	8.96	6.19	12.52	2	13.33	12.38	14.28	7	22.29	18.57	26.8
1990	3	10.82	7.31	13.61	6	8.5	5.37	11.73	9	19.33	12.68	25.34
1991	5	6.69	4.15	10.36	8	9.19	3.81	14.38	13	15.88	7.96	24.74
1992	8	10.81	5.15	18.18	2	7.76	7.15	8.37	10	18.57	12.3	26.55
1993	4	9.51	7.14	12.82	9	9.98	5.51	15.3	13	19.48	12.65	28.12
1994					9	8.7	4.66	15.25	9	8.7	4.66	15.25
1995	7	9.14	6.2	12.65	9	9.7	5.03	15.43	16	18.84	11.23	28.08
1996	3	13.74	12.71	15.43	4	11.43	10.41	12.14	7	25.17	23.12	27.57
1997	5	8.93	5.94	12.29	4	10.46	7.67	13.05	9	19.39	13.61	25.34
1998	3	11.25	6.05	15.27	6	10.67	5.34	17.72	9	21.92	11.39	32.99
1999	4	10.86	9.16	12.55	1	10.39	10.39	10.39	5	21.25	19.55	22.94
2000					1	10.06	10.06	10.06	1	10.06	10.06	10.06
2001	6	10.74	4.79	14.88					6	10.74	4.79	14.88
2002	5	12.33	7.29	19.02	1	7.74	7.74	7.74	6	20.07	15.03	26.76
2003	2	14.07	10.53	17.6	1	5.66	5.66	5.66	3	19.73	16.19	23.26
2004	4	16.26	11.95	20.24					4	16.26	11.95	20.24
2005	4	10.37	6.83	15.2					4	10.37	6.83	15.2
2006	2	7.52	6.04	9	2	9.89	8.02	11.76	4	17.41	14.06	20.76
2007					7	9.35	6.93	14.83	7	9.35	6.93	14.83
2008	2	9.86	9.55	10.17	1	16.78	16.78	16.78	3	26.64	26.33	26.95
2009					2	16.06	5.91	26.21	2	16.06	5.91	26.21
2010	1	11.16	11.16	11.16	7	9.56	6.85	13.8	8	20.72	18.01	24.96
2011	1	10.32	10.32	10.32	1	5.52	5.52	5.52	2	15.84	15.84	15.84
2012					2	15.66	14.31	17	2	15.66	14.31	17
2013	6	12.28	8.06	20.07	5	11.35	6.02	23.13	11	23.63	14.08	43.2
2014	8	10.79	4.91	19.09	14	20.13	6.36	47.34	22	30.93	11.27	66.43
2015					2	8.06	7.84	8.28	2	8.06	7.84	8.28
2016	1	21.36	21.36	21.36	3	8.48	7.5	10.21	4	29.84	28.86	31.57
2017	1	7.87	7.87	7.87					1	7.87	7.87	7.87

Table 4.11.17. SCDNR State Finfish Survey number of cobia measured (total and by mode), mean length, standard deviation of length, and minimum and maximum size range (all modes combined). No length measurements were recorded during 1997 or 2013-2016 (this primarily due to the survey only being conducted in wave 1 for the latter years). Total length measurements from 2009-2017 were converted to fork length using the following equation developed for the South Atlantic stock at the SEDAR 58 data workshop: FL = 8.19 + 0.88TL (N = 5672, $R^2 = 0.99$).

Year	Cobia (n)	Fish (n)			Mean FL (mm)	Std Dev FL (mm)	Min FL (mm)	Max FL (mm)
		Charter	Private	Shore				
1989	-	-	-	-	-	-	-	-
1990	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-
1992	4	-	4	-	1,122.50	146.5	986	1,305
1993	2	-	2	-	600.5	340.1	360	841
1994	-	-	-	-	-	-	-	-
1995	-	-	-	-	-	-	-	-
1996	2	-	2	-	1,496.00	33.9	1,472	1,520
1997	-	-	-	-	-	-	-	-
1998	11	-	10	1	994.2	220.9	463	1,260
1999	31	-	31	-	1,002.60	85.9	912	1,418
2000	4	-	4	-	917.3	52.7	878	995
2001	8	-	8	-	1,010.30	59.8	935	1,135
2002	22	-	22	-	1,048.10	126.3	865	1,255
2003	14	1	13	-	926.4	167.6	580	1,349
2004	16	1	15	-	968.3	188.8	835	1,452
2005	21	-	21	-	908.7	42.1	830	1,000
2006	18	-	18	-	982	163.6	845	1,502
2007	80	-	80	-	909.2	50.3	810	1,060
2008	64	-	64	-	957.7	129.5	410	1,350
2009	33	-	33	-	909.2	139	720	1,336
2010	10	-	10	-	838.3	72.7	760	976
2011	17	1	16	-	814.5	33.9	770	886
2012	19	-	19	-	961.79	130.38	752.67	1279.79
2017	1	-	1	-	880	-	880	880

Table 4.11.18. Number of cobia aged in the recreational fishery by year and state. States not shown did not age any cobia for this time period.

Year	GA	NC	SC	VA
1984		3		
1985		2		
1986		22		
1987		18		
1988		9	1	
1989		62		
1990		80	3	
1991		13		
1992		12		
1993		1		
1994		3		
1995		10		
1996		13	18	
1997		7	13	
1999				124
2000				111
2001				52
2002				26
2003				7
2004				7
2005		2	47	10
2006			38	25
2007			341	25
2008			276	40
2009			205	106
2010		11	215	106
2011			217	89
2012	1		223	76
2013			300	190
2014	3		244	287
2015			189	342
2016		11	142	255
2017		34		239

Table 4.11.19. Atlantic coast (Georgia and north) estimated number of angler trips for charterboat mode, headboat mode, and charterboat/headboat mode, private boat mode, and shore mode (MRIP). CH and CH/HB mode adjusted for FHS conversion prior to 2004. CH/HB mode estimates are from the South Atlantic (sub-region 6) from 1981-1985 and from the Mid-Atlantic (sub-region 5) from 1981-2003. After 2004 CH and HB modes are estimated separately in sub-regions 4 and 5. Headboat mode from 1981 to 1985 were excluded to avoid overlap with the SRHS.

YEAR	Estimated CH	Estimated CH/HB	Estimated HB	Estimated PR	Estimated SH
1981	188,980	3,577,559	-	17,765,901	34,007,002
1982	190,708	4,956,027		18,293,526	35,488,354
1983	214,268	3,944,756		18,960,548	37,465,725
1984	310,914	2,872,587		20,039,286	35,880,449
1985	319,869	2,984,604		22,500,116	34,287,470
1986	262,628	3,446,445		22,487,902	34,364,897
1987	273,377	2,424,739		21,588,527	34,419,954
1988	249,830	2,260,431		21,497,141	36,138,703
1989	302,899	1,762,892		21,664,812	36,751,891
1990	241,455	1,918,381		22,693,637	40,113,617
1991	274,726	2,221,546		22,754,553	40,799,495
1992	294,771	1,446,438		23,096,869	41,037,935
1993	323,906	2,473,730		23,568,468	41,906,506
1994	383,406	2,262,497		24,079,060	42,505,393
1995	454,901	2,319,843		24,291,643	42,437,852
1996	367,716	1,527,297		25,613,101	43,167,914
1997	330,886	1,964,558		27,780,753	45,284,094
1998	296,665	1,273,064		28,217,416	45,083,354
1999	251,121	1,167,321		29,971,784	49,827,082
2000	248,041	1,426,682		32,467,729	54,271,568
2001	259,310	1,696,622		33,503,927	56,328,542
2002	244,728	1,218,576		34,002,275	55,374,503
2003	250,760	1,478,871		35,092,246	57,716,219
2004	1,015,109		674,260	36,623,026	59,354,499
2005	1,222,234		767,540	37,161,398	60,477,945
2006	959,881		649,374	37,423,372	62,721,146
2007	1,465,095		971,084	38,139,032	60,228,146
2008	1,053,439		871,784	38,625,010	63,611,011
2009	1,022,662		790,333	39,264,641	63,911,446
2010	829,794		580,114	41,666,922	67,239,285
2011	981,394		580,930	37,741,397	60,658,094
2012	930,555		628,596	39,335,516	64,427,619
2013	1,086,379		968,396	37,872,952	62,103,965
2014	1,087,452		831,745	36,807,698	63,121,977
2015	1,196,276		696,087	34,715,854	61,414,441
2016	698,979		470,309	34,597,161	64,448,600
2017	773,158		596,982	35,192,629	62,657,638

Table 4.11.20 South Atlantic headboat estimated angler days by year and state, 1981-2017.

Year	NC	SCGA	South Atlantic
1981	19,374	59,030	78,404
1982	26,939	67,539	94,478
1983	23,830	65,733	89,563
1984	28,865	67,314	96,179
1985	31,384	66,001	97,385
1986	31,187	67,227	98,414
1987	35,261	78,806	114,067
1988	42,421	76,468	118,889
1989	38,678	62,708	101,386
1990	43,240	57,151	100,391
1991	40,936	67,982	108,918
1992	41,176	61,790	102,966
1993	42,786	64,457	107,243
1994	36,691	63,716	100,407
1995	40,295	64,953	105,248
1996	35,142	57,613	92,755
1997	37,189	63,056	100,245
1998	37,399	63,344	100,743
1999	31,596	57,356	88,952
2000	31,351	42,443	73,794
2001	31,779	51,602	83,381
2002	27,601	44,739	72,340
2003	22,998	37,982	60,980
2004	27,255	50,462	77,717
2005	31,573	35,797	67,370
2006	25,736	57,992	83,728
2007	29,002	62,695	91,697
2008	17,158	48,861	66,019
2009	19,468	43,010	62,478
2010	21,071	46,908	67,979
2011	18,457	46,210	64,667
2012	20,766	42,064	62,830
2013	20,547	42,853	63,400
2014	22,691	44,092	66,783
2015	22,716	41,479	64,195
2016	21,565	43,954	65,519
2017	20,170	38,655	58,825

4.12 Figures

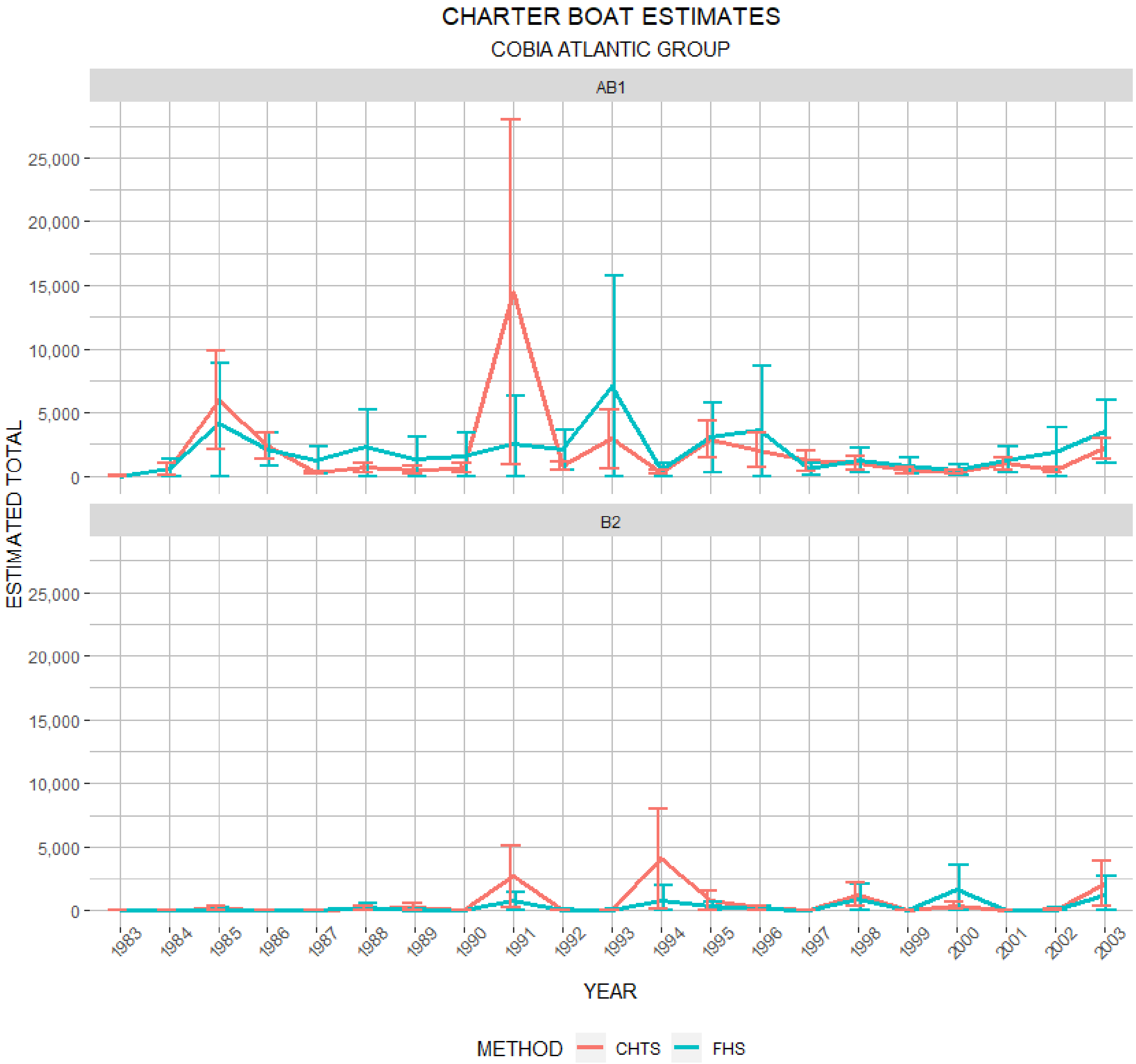
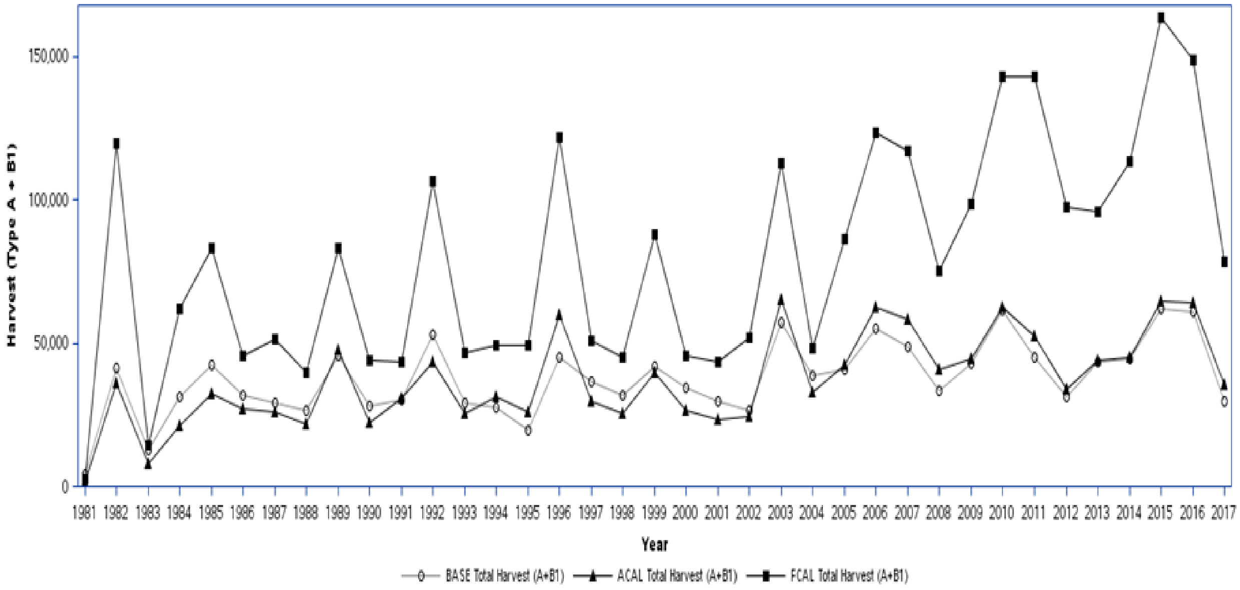


Figure 4.12.1. Coastal Household Telephone Survey (CHTS) and For-Hire Survey (FHS) charter landing (AB1) and discard (B2) estimates in numbers of fish for Atlantic cobia from 1981 to 2003.

a)



b)

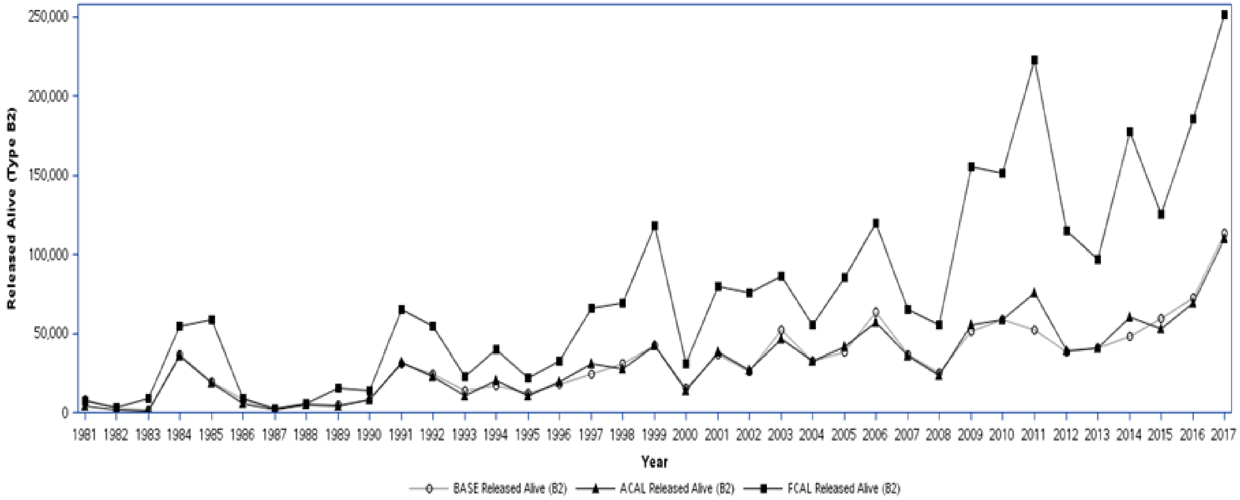
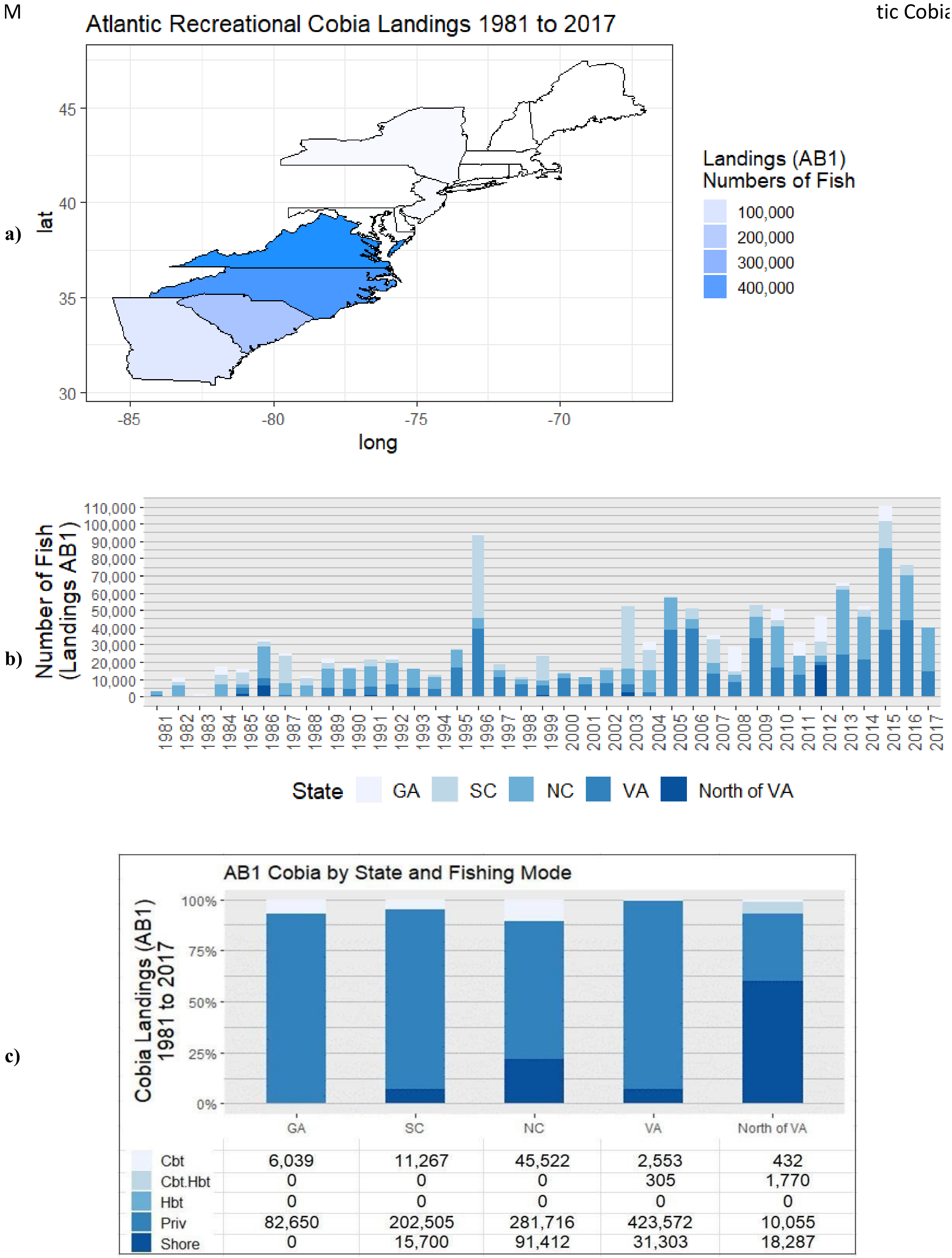


Figure 4.12.2. MRIP base (circle), APAIS calibrated (triangle), and fully calibrated APAIS and FES (square) catch estimates for Atlantic cobia from 1981 to 2017. Catch estimates are shown in numbers of fish: (a) landings and (b) discards. These calibration graphs include sub-regions 4-6. Florida could not be separated for sub-region 6 on the MRIP online comparison tool.



	GA	SC	NC	VA	North of VA
Cbt	6,039	11,267	45,522	2,553	432
Cbt.Hbt	0	0	0	305	1,770
Hbt	0	0	0	0	0
Priv	82,650	202,505	281,716	423,572	10,055
Shore	0	15,700	91,412	31,303	18,287

Figure 4.12.3. Atlantic estimated number of cobia landings from MRFSS/MRIP, and SRHS (1981 - 2017) by state (a), by state and year (b), and by state and mode (c). *Due to confidentiality concerns, SRHS landings from Georgia have been grouped together with South Carolina.

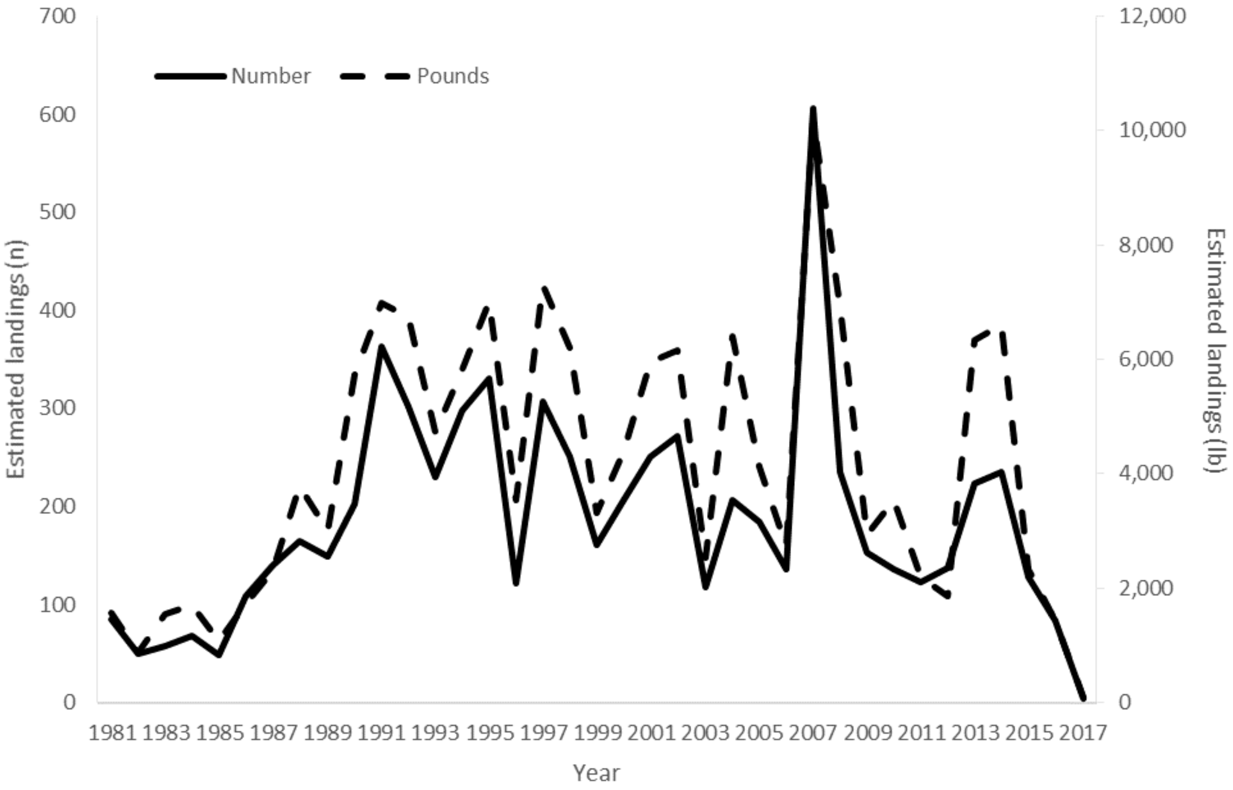


Figure 4.12.4. South Atlantic estimated cobia landings (number and pounds) for the headboat fishery, 1981-2017.

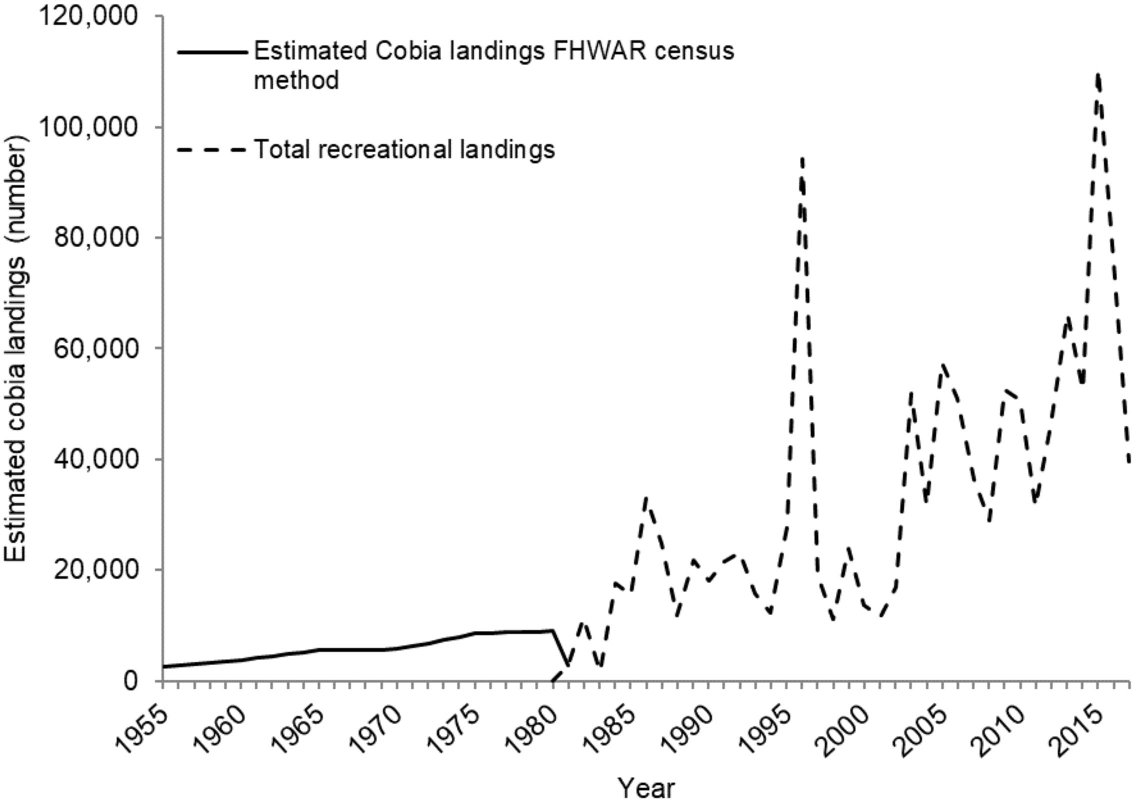


Figure 4.12.5. Estimated cobia landings (number) using FHWAR census method (1955-1984), MRFSS (1985-2003), and MRIP (2004-2017) estimation methods.

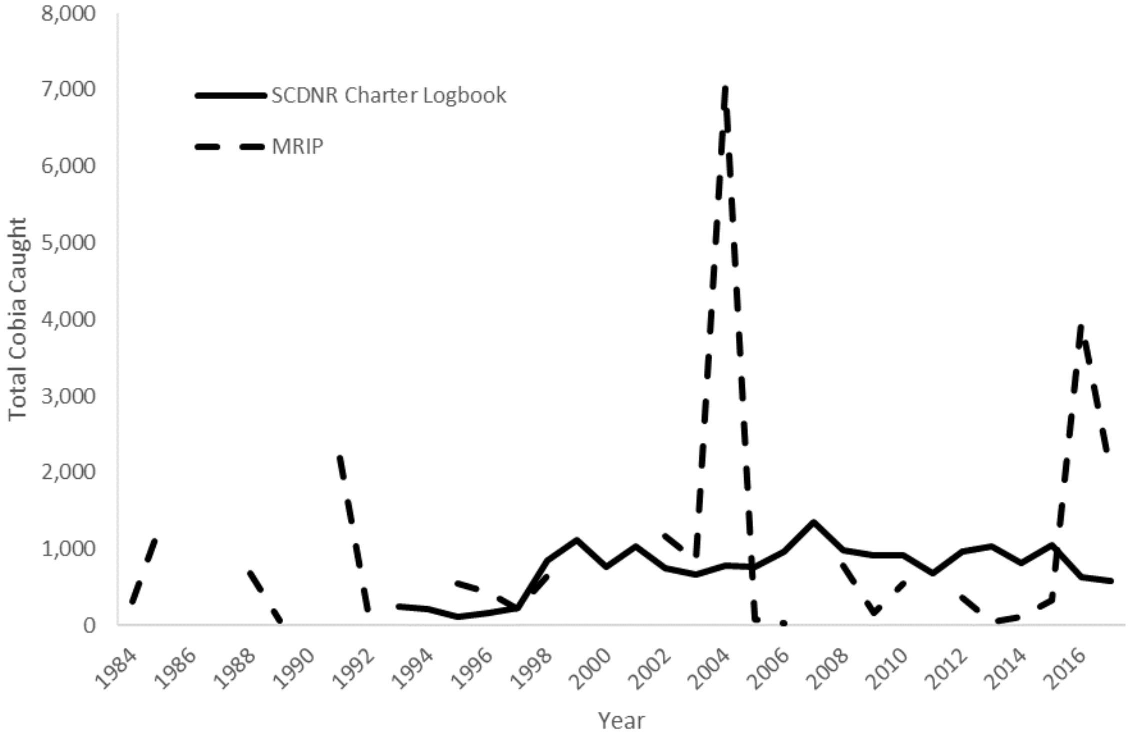
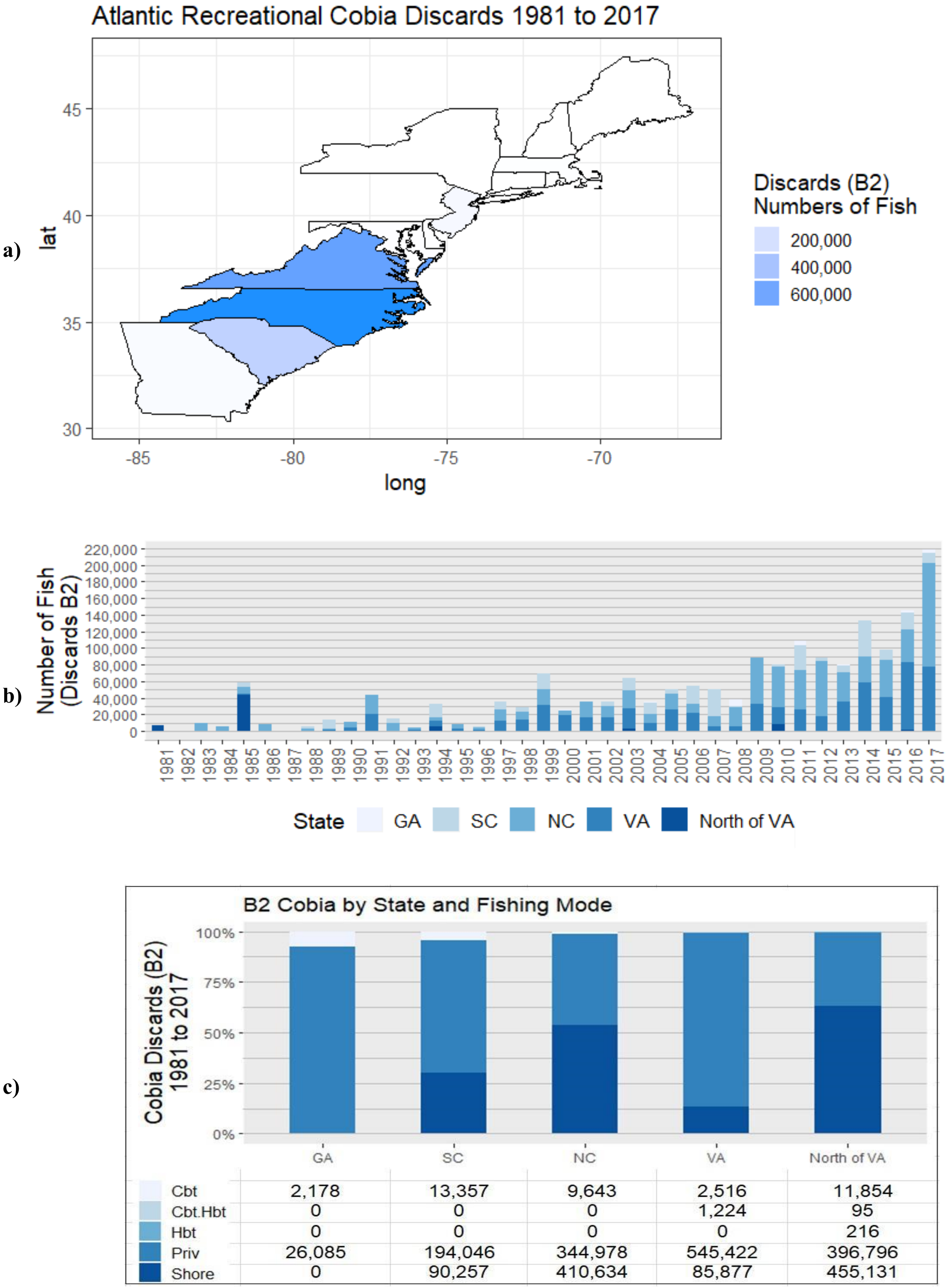


Figure 4.12.6. Comparison of South Carolina total catch (a+b1+b2) from MRFSS charter mode and SCDNR charterboat logbook program, 1993-2017.



	GA	SC	NC	VA	North of VA
Cbt	2,178	13,357	9,643	2,516	11,854
Cbt.Hbt	0	0	0	1,224	95
Hbt	0	0	0	0	216
Priv	26,085	194,046	344,978	545,422	396,796
Shore	0	90,257	410,634	85,877	455,131

Figure 4.12.7. Atlantic estimated number of cobia discards from MRFSS/MRIP, and SRHS (1981 - 2017) by state (a), by state and year (b), and by state and mode (c). *Due to confidentiality concerns, SRHS landings from Georgia have been grouped together with South Carolina.

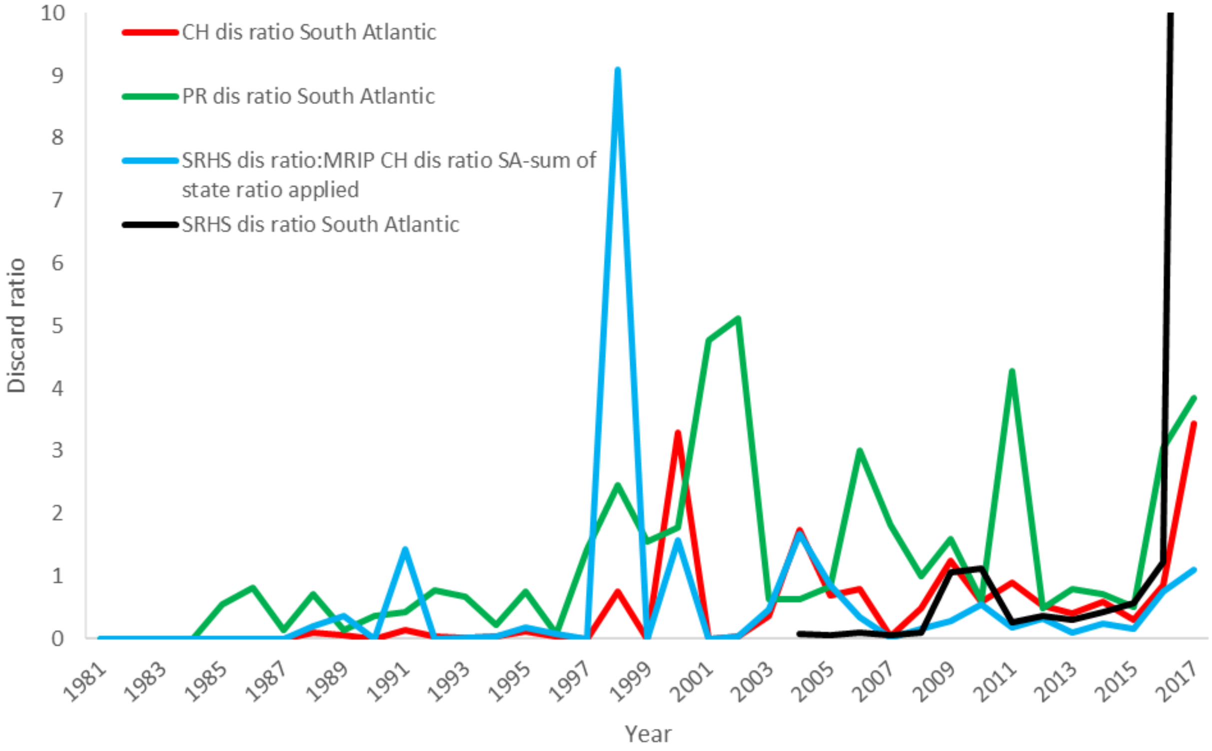


Figure 4.12.8. MRIP CH (1981-2017), MRIP PR (1981-2017), MRIP CH:SRHS discard ratio methods (1981-2017), and SRHS discard ratios (2004-2017).

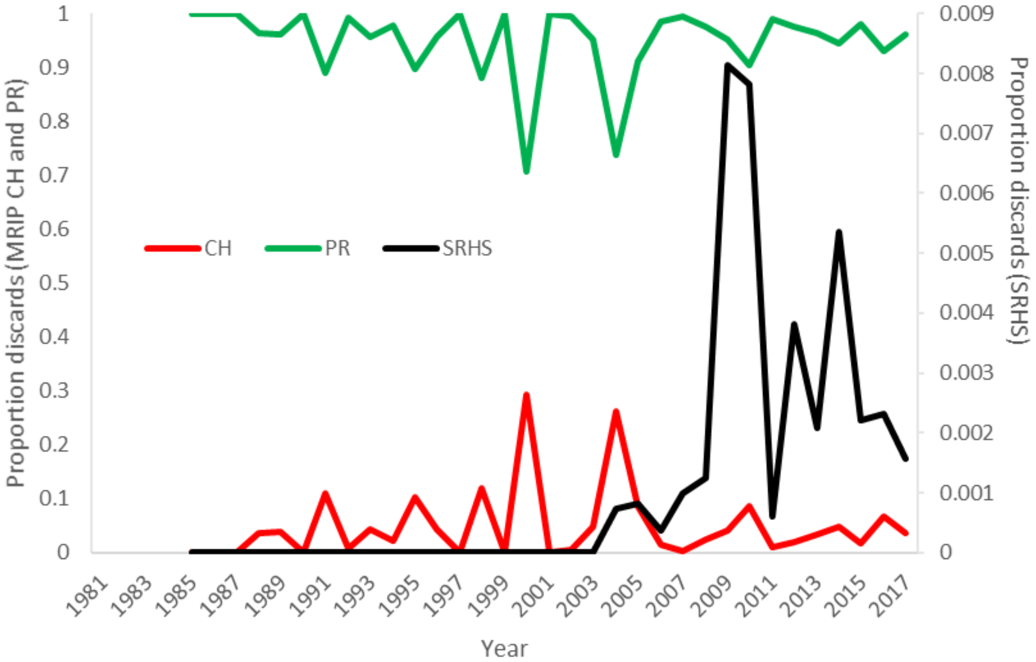


Figure 4.12.9. Proportion of cobia discards in the recreational fishery by mode, 1981-2017.

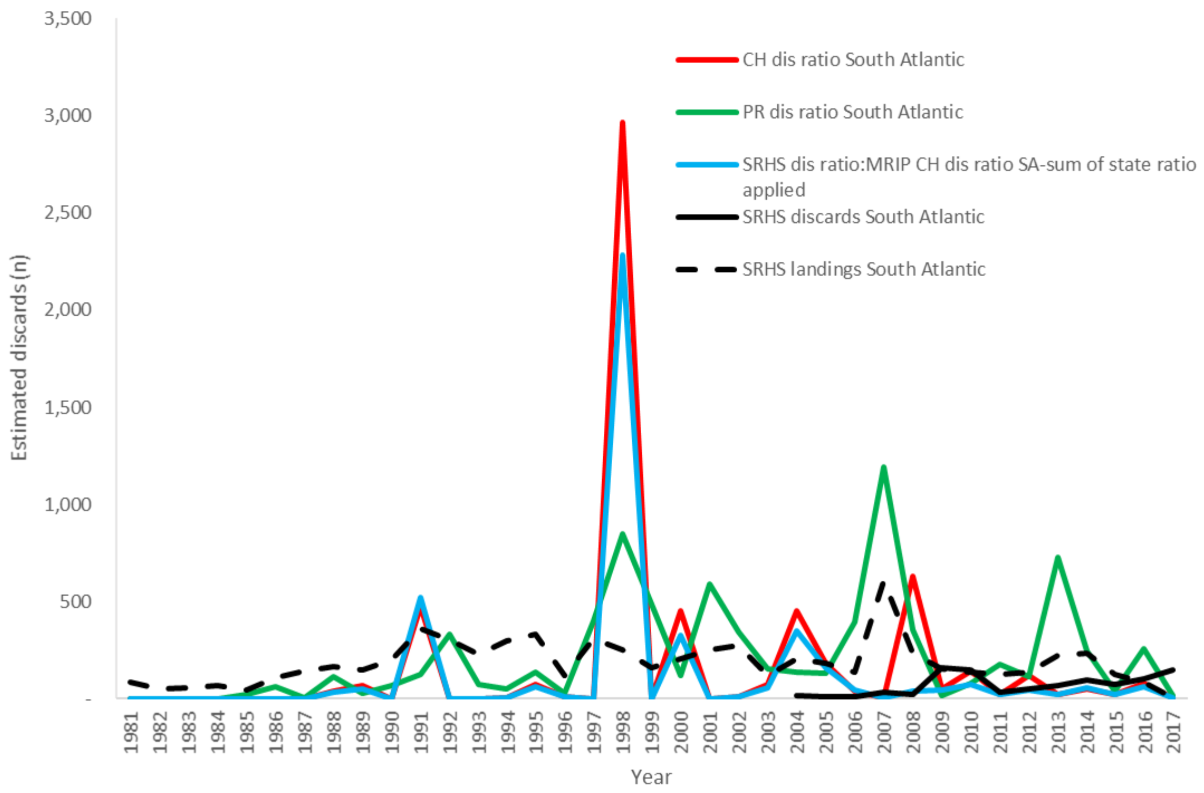
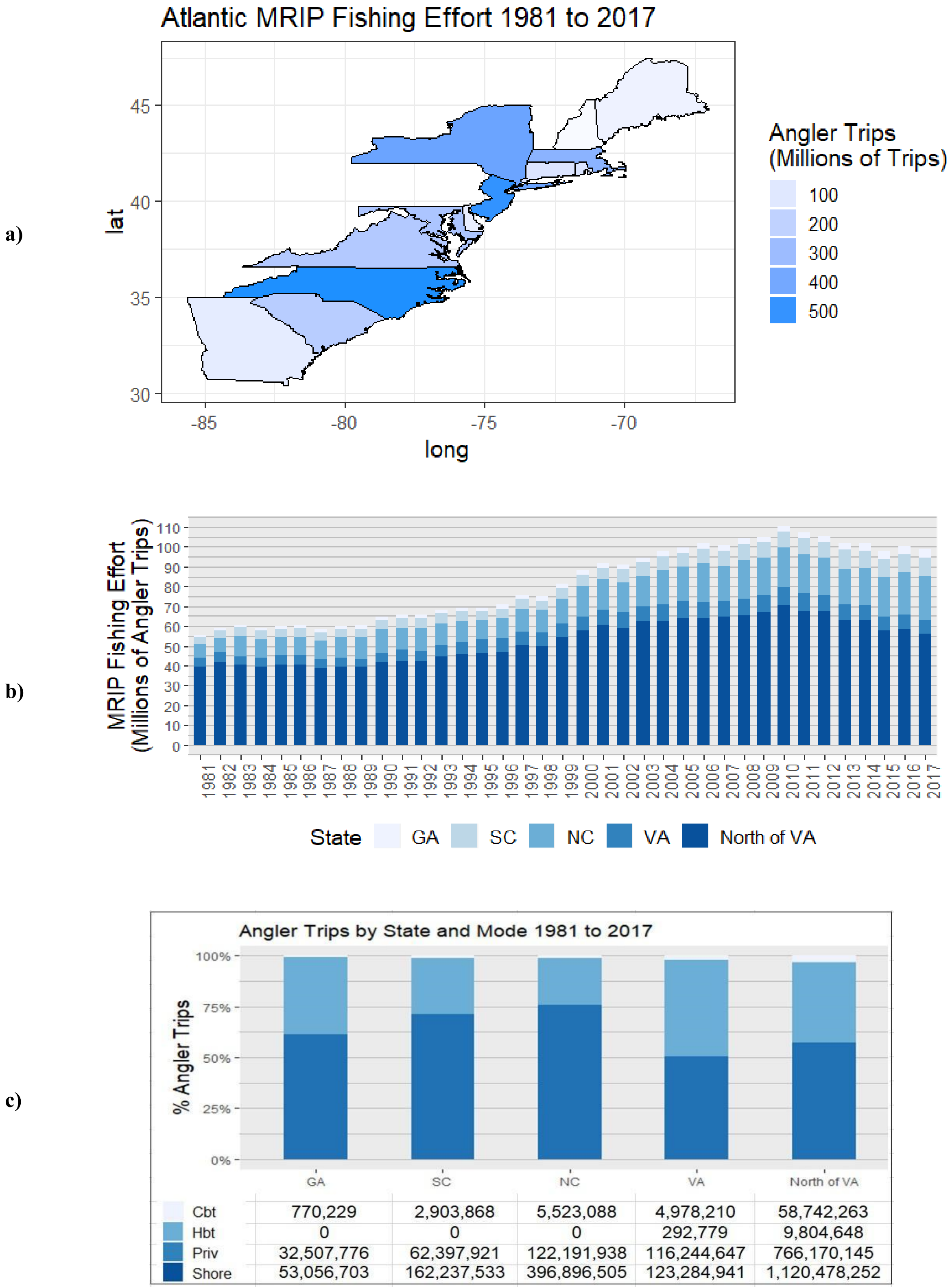


Figure 4.12.10. SRHS discards (2004-2017) and landings with calculated discards using the MRIP CH proxy (1981-2017), MRIP PR (1981-2017), and MRIP CH:SRHS discard ratio proxy methods (1981-2017).



	GA	SC	NC	VA	North of VA
Cbt	770,229	2,903,868	5,523,088	4,978,210	58,742,263
Hbt	0	0	0	292,779	9,804,648
Priv	32,507,776	62,397,921	122,191,938	116,244,647	766,170,145
Shore	53,056,703	162,237,533	396,896,505	123,284,941	1,120,478,252

Figure 4.12.11. Atlantic estimated number of angler trips from MRFSS/MRIP (1981 - 2017) by state (a), by state and year (b), and by state and mode (c).

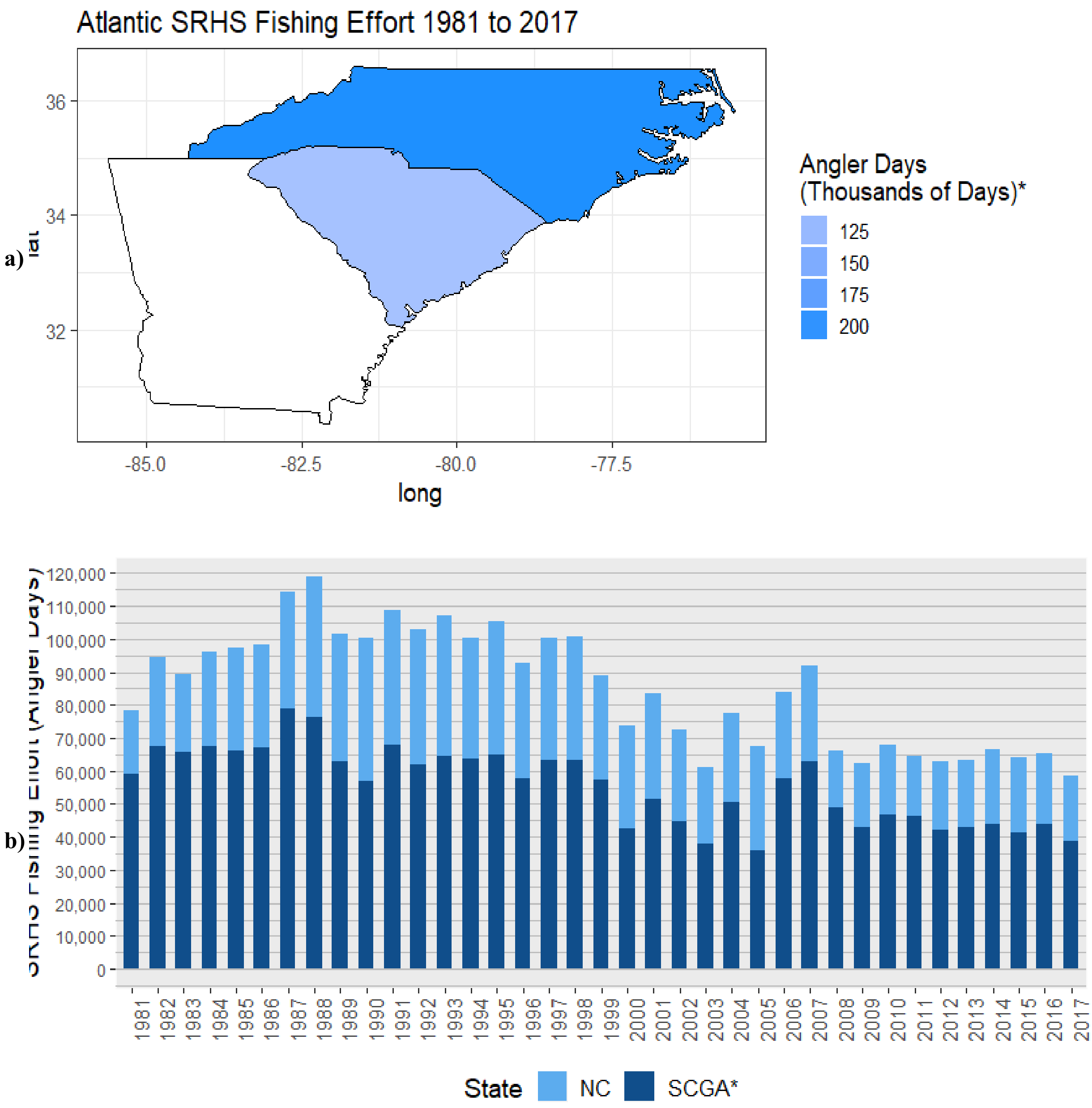


Figure 4.12.12. South Atlantic estimated number of angler days from SRHS (1981 - 2017) by State (a), and by state and year (b). *Due to confidentiality concerns, effort from Georgia has been grouped together with and South Carolina.

5 Measure of Population Abundance (Indices)

5.1 Overview

Several fishery-independent data sets were considered for use as an index of abundance during the data scoping webinar. During the data webinar, all fishery-independent datasets were deemed as needing no further consideration because of small sample sizes, limited geographic extent, or difficulty in determining effort. The NMFS bottom longline and NEFSC bottom trawl surveys were not further considered due to extremely low catches of cobia in all years and a patchy distribution of catches across areas. MARMAP chevron trap was also not further considered due to extremely low sample sizes of cobia. SEAMAP was not considered due to low sample sizes, with a percent of occurrence of 0% to 3% reported, for cobia. There is limited spatio-temporal overlap between the cobia migration and the SERFS video survey. The proportion of positive video samples was extremely low.

Several fishery-dependent data sets were considered for use as an index of abundance both during the data webinar and data workshop. During the data webinar, several datasets were deemed as needing no further consideration because of small sample sizes, limited geographic extent, or difficulty in determining effort. VA harvest reports were not further considered due to extremely low sample sizes of cobia, difficulty in determining effort, and only a small area of the species range being sampled. Data from the headboat at-sea observer program was also considered, but sample sizes were extremely low for cobia. The Southeast commercial logbook data were excluded due to low sample sizes and difficulty determining cobia effort. In addition, commercial landings are reported in pounds and the trip limit is in numbers which eliminates the ability to determine the impact of strict bag limits.

Several indices of abundance were considered by the SEDAR 58 data workshop panelists for use in the South Atlantic cobia assessment model. These indices are listed in Table 5.7.1, with pros and cons of each in Table 5.7.2. Due to the lack of data, a fishery-independent index for cobia was not developed. The DW recommended only the SRHS index for potential use in the cobia stock assessment.

5.1.1 Group membership

Membership of this DW Index Working Group (IWG) included Rob Cheshire (work group leader), Eric Fitzpatrick, Katie Siegfried, Tom Sminkey, Anne Lange, and Mike Errigo. Several other participants of the data workshop contributed in the IWG discussions throughout the week. Recreational fishers provided descriptions of changes in the fishing effort and methods over the scale of the recreational indices. This information informed several decisions on the adequacy of the data.

5.2 Review of Working Papers

The working group reviewed three working papers describing index construction; SEDAR58-DW02, SEDAR58-DW07, and SEDAR58-DW09. Presentations from these working papers served as a starting point to describe the computation of a fishery-dependent index from the MRIP recreational data, SCDNR charter boat data, and the recreational headboat data. These working papers were helpful for determining which indices should be recommended for use and were revised to reflect to the decisions during the workshop.

5.3 Fishery-independent Indices

Fishery-independent data for cobia were not available for creation of a reliable index.

5.4 Fishery-dependent Indices

5.4.1 Recreational Headboat Index (SEDAR58-DW09)

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 5.8.1). The southern extent for cobia was the Georgia-Florida state boundary based on the SEDAR 58 stock identification workshop. 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 id. Biological data and discard data were recorded for some trips in some years.

The IWG discussed inclusion of headboat data from the mid-Atlantic Vessel Trip Reports (VTRs) for areas north of North Carolina with that from the SRHS for index development. The mid-Atlantic VTR data is a limited time series and the survey covered a limited number of headboats in the region, and there are concerns about both inconsistent reporting across much of the fleet as well as under-reporting, particularly in the early years of the survey. Therefore, these data were excluded from index development.

The development of the CPUE index is described in more detail in SEDAR58-DW09. The SEDAR 58 DW index working group decisions summarized in SEDAR58-DW09 include:

- Begin data series in 1991 due to inconsistent reporting in the 1980s. Cobia were not listed on the logbook form until 1984 but these new forms were not distributed or requested consistently. Data suggest the percentage of vessels reporting cobia was ramping up in the 1980s and began to stabilize in 1991 (Figure 5.8.2).
- Full and half-day trips were included in the standardization. The working group decided that including half-day trips added additional information about the nearshore cobia population even though the proportion of trips not catching cobia increased.

5.4.2 Methods of Estimation

Data Filtering Techniques

Extreme values occur more frequently in self-reported data because there are limited methods for validating data. Recent SEDAR stock assessments have removed values at the extreme upper tail of distribution for CPUE and associated fields of self-reported fishery-dependent data. The number of anglers on a trip can also influence CPUE when calculated as fish/angler-hour. Trips with the largest 0.5% values for CPUE were removed. Removing a small percentage of the trips with extreme values is an unbiased method to correct for potential errors in self-reported data.

Logbooks submitted by vessels that participated infrequently in the fishery are likely to be less accurate and may add noise to the data. Even if a vessel fished infrequently for one year, the number of trips should be greater than 30. We removed vessels that had fewer than 30 trips in the logbook database. It is rare for a headboat to fish with few anglers. There is anecdotal information that headboats would sometimes fish with just the crew and that logbooks for these trips were submitted. Experienced crew are likely to be more efficient at catching fish than paying customers. Captains may also limit distance to reduce fuel costs for trips with few paying customers. Trips with 6 or fewer anglers were excluded.

To identify headboat trips that best characterize the cobia fishery, vessels that consistently caught cobia were selected (25 headboats representing 90% (prior to any filtering) of cobia effort and landings). Positive cobia trips from these 'core' vessels increased from 4% (all data) to 6% (model input). Selecting data using a core group of vessels while removing vessels that inconsistently or never reported cobia more appropriately reflects cobia effort in the headboat fishery.

Seasonal closures occurred in 2016 (closed June 19) and 2017 (closed January 23). 2015 was chosen as the terminal year due to these regulations. Filtering steps and justification are presented in Table 5.7.3.

Model Input

YEAR (y) - Year was necessarily included, as standardized catch rates by year are the desired outcome. Years modeled were 1991-2015.

SEASON (s) - For SEDAR 58, seven of the months (September-March) were dropped due to inconsistent cobia trips leaving two levels for season in the model (April-June, July-August). The seasonal pattern in CPUE across months seems consistent across regions.

INLET REGION (i) - The inlet regions were defined by evenly distributing the total trips into 3 latitudinal regions. The three regions include inlets from NC to GA (St. Mary's GA- Murrell's Inlet SC (1), Little River, SC – Carolina Beach NC(2), Masonboro Inlet NC – Oregon Inlet NC (3)).

TRIP TYPE (t) – Full and half day trips were included in the standardization.

VESSEL SIZE (v) - A factor was explored for the vessel size using the quartiles of the maximum number of anglers across all trips as breaks for the factors. The proxy for vessel size is the maximum anglers reported over all trips for a vessel. Due to limited data and convergence issues, vessel size was modified to two levels: 1-79 maximum anglers ('small') or greater than 79 anglers ('large').

PERCENT FULL (p)
The number of anglers reported for a trip was divided by the maximum number of anglers for a vessel to obtain an estimate of crowding. This was then divided into 4 equally spaced factors but subsequently led to convergence issues due to low sample sizes and therefore was modified to two levels: 1-47% (‘partial’) or greater than 47% (‘full’).

ANGLER PARTY SIZE (a)
The number of anglers reported for a trip was divided into 4 equally spaced factors but led to convergence issues due to low sample sizes and therefore was modified to two levels: 6-30 anglers (‘small’) or greater than 30 anglers (‘large’).

Standardization

Zero-inflated models are valuable tools for modeling distributions that do not fit standard error distributions due to excessive number of zeroes. These data distributions are often referred to as “zero-inflated” and are a common condition of count based ecological data. Zero inflation is considered a special case of over-dispersion that is not readily addressed using traditional transformation procedures (Hall 2000). Due to the high proportion of zero counts found in our data set, we used a zero-inflated mixed model approach that accounts for the high occurrence of zero values, as well as the positive counts. The model does so by combining binomial and count processes (Zuur et al. 2009).

The modeling approach used here was similar to that used in SEDAR41 for gray triggerfish and red snapper for the video index. We initially considered a full null model (1) using both a zero-inflated Poisson (ZIP) and a zero-inflated negative binomial (ZINB) formulation,

$$Count = y + s + i + t + v + p + a \mid y + s + i + t + v + p + a \qquad (1)$$

In this formulation, variables to the left of the “|” apply to the count sub-model, and variables to the right apply to the binomial sub-model. In this analysis, we favored a simpler null model because of the relatively small proportion of positive counts for cobia,

$$Count = y \mid y \qquad (2)$$

which allowed us to add covariates using a step-wise forward selection process (rather than the backward selection). However, prior to adding covariates we compared ZIP and ZINB formulations. We compared the variance structure of each model formulation using AIC and likelihood ratio tests (Zuur et al 2009) to determine the most appropriate model error structure for the development of a cobia headboat index. The results of these tests support the ZINB formulation (similar results were obtained when using the full null model). These results concur with our expectations based on the over-dispersion within the headboat data. A comparison between the fitted and original data for the ZIP and ZINB model formulations is shown in Figure 5.8.3. The rootogram (Kleiber and Zeileis 2016) in the lower panels of Figure 5.8.3 extends the Tukey (1977) rootogram to regression models. These plots are useful as diagnostics specific to overdispersion and/or excess zeros in count data models. The models attempted prior to the data workshop as well as the models presented at the data workshop (bold) are presented in Table 5.7.4.

We used a step-wise forward model selection procedure to systematically include important covariates in our model formulation. In this procedure, we added each explanatory variable one at a time, alternating between the count (negative binomial) and binomial components. The variable with the largest ΔAIC was added, and the process repeated until no variable resulted in ΔAIC>2. The final cobia ZINB model formulation included year (y), season (*s*), trip type (*t*), vessel size (*v*) and party size (*a*) in the negative binomial component, and year (y), season (s), trip type (t), vessel size (v) and inlet region (*i*) in the binomial component,

$$Count = y + s + t + v + a \mid y + s + t + v + i \tag{3}$$

Diagnostics of the final model showed no clear patterns of association between Pearson's residuals and fitted values, or between the fitted values and original data (see SEDAR58-DW09 for diagnostics) indicating acceptable model choice (Zuur et al 2009). Finally, a comparison of predicted values against the original data distribution (Figure 5.8.4) demonstrates how the model fits the original data.

5.4.2.1 Sampling Intensity

The resulting data set contained 27,700 trips with 6% positive cobia trips.

5.4.2.2 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 this report). However, the sample sizes for the headboat fleet are likely very small. Other recreational size and age compositions should have a similar distribution.

5.4.2.3 Catch Rates

Standardized catch rates and associated error bars are shown in Figure 5.7.5 and are tabulated in Table 5.8.5. During the DW, trip type (full day and half day trip) was included as a covariate in the final model run and was very similar to the initial index that only included full day trips. By including half day trips, the bootstrap convergence rate increased from 74% to 98% and appears to reduce the unrealistic changes in population size in a few years while the proportion positive decreased from 11% for full-day trips to 6% for full and half-day trips combined.

5.4.2.4 Uncertainty and Measures of Precision

Measures of precision were computed using a bootstrap procedure with 1000 iterations of the model using randomly sampled trips with replacement. The samples were drawn from the entire data set with the sample size matching the size of the initial data set. Annual CVs of catch rates are tabulated in Table 5.7.5 and applied to the estimated index to develop error estimates (Figure 5.8.5).

5.4.2.5 Comments on Adequacy for Assessment

The index of abundance created from the headboat data was considered by the indices working group to be adequate for potential use in the cobia assessment. The data cover the majority of the range of the stock as described for the South Atlantic and is a complete vessel census of the headboat 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 sampling was consistent over time, and some of the data were verified by port samplers and observers. Headboat effort generally targets snapper-grouper species and not necessarily a focal species, which should minimize changes in catchability relative to fishery-dependent indices that target specific species. The primary caveat concerning this index was that it was derived from fishery-dependent self-reported data.

5.4.3 SCDNR Charter Boat Logbook Program (SEDAR58-DW07)

In 1993, SCDNR's Marine Resources Division (MRD) initiated a mandatory logbook reporting system for all charter vessels to collect basic catch and effort data. Under state law, vessel owners/operators carrying fishermen on a for-hire basis are required to submit monthly trip level reports of their fishing activity in waters off of SC. The charter boat logbook program is a complete census and should theoretically represent the total catch and effort of the charter boat trips in waters off of SC. The charter logbook reports include: date, number of fishermen, fishing locale (inshore, 0-3 miles, >3miles), fishing location (based on a 10x10 mile grid map), fishing method, hours fished, target species, and catch (number of landed and released fish by species) per vessel per trip. The logbook forms have remained similar throughout the program's existence with a few exceptions: in 1999 the logbooks forms were altered to begin collecting the number of fish released alive and the number of fish released dead (prior to 1999 only the total number of fish released were recorded) and in 2008 additional fishing methods were added to the logbook forms, including cast, cast and bottom, and gig. Data represent 6-pack charter vessels only and are self-reported with no field validation.

5.4.3.1 Methods of Estimation

Data

The original calculation included all SCDNR charterboat logbook entries which reported using bottom fishing as the method of fishing for that trip. Data were available from 1993 to 2010; however, it was determined by the Indices Working Group that the dataset would be truncated to only include data from 1998 onwards. This decision is due to a change in effort within the fishery. The percentage of trips reporting targeting cobia increased from an average of 2% from 1993-1997 to an average of 6% from 1998-2017.

Data Subsetting

During the Data Workshop, a method of subsetting trips to better get at effective cobia effort was developed. One method identified cobia trips using the top co-occurring species with cobia. If a trip either caught or reported targeting one of these species, it was included in the index calculation along with trips that either caught or reported targeting cobia. All other trips were excluded. Several versions of the co-occurring species were developed based co-occurrance values in the data and fishermen input.

Methods
The CPUE index was standardized using a Delta-GLM approach in a Bayesian framework using the rstan package in R (version 2.18.1, Stan Development Team 2018). The factors included in the model that were significant are Year (1998-2017), Locale (Inshore (inside the col regs line), Nearshore (0-3 miles), Offshore (outside of 3 miles)), and Month (4-8). Only April through August was used for months since these were the peak months of the fishery. Cobia catch drops off significantly outside of this time-period. The posterior distribution from the fitted model was used to estimate the uncertainty in the index (Dick pers. comm.).

5.4.3.2 Sampling Intensity

Data represent SC licensed 6-pack charter vessel trips operating in or off of SC from 1998 – 2017. SCDNR charterboat logbook vessel trips included in this analysis represent all logbook entries which reported using bottom fishing as the method of fishing. The SCDNR charterboat logbook data represent 148,739 fishing trips in which anglers caught 16,051 cobia and harvested 7,141 cobia.

5.4.3.3 Size/Age data

Limited size and age data specific to SC charter boats are available from this dataset. However, the sizes/ages represented in this index should be similar to those of landings from similar recreational fleets (See section 4 of this report).

5.4.3.4 Catch Rates

Catch per unit effort was calculated as the number of fish caught per angler-hour.

5.4.3.5 Uncertainty and Measures of Precision

The posterior distribution from the fitted model was used to estimate the uncertainty in the index (Dick pers. comm.).

5.4.3.6 Comments on Adequacy for Assessment

The index of abundance created from the SC charterboat logbook data was considered by the indices working group for use in the cobia assessment. However, although it was used in SEDAR 28, the working group decided not to recommend it for use during this assessment due to several important changes from SEDAR 28 to the present. During SEDAR 28, the dataset covered a large portion of the South Atlantic stock's geographic range and landings. Since 2015, VA landings have increased significantly, becoming one of the more important areas for cobia harvest. Also, since 2010, the SC fishery has been in decline, reducing its portion of the overall cobia landings. The catch rates for inshore/nearshore waters had decreased in recent years while offshore catch rates increased (Figure 5.8.6). The agency experts and fishermen agreed that the decline was likely driven by (1) conservation outreach to reduce harvest of cobia, (2) the gamefish status instituted in 2012, (3) changes in fishing methods (shift from bottom fishing to sight-casting in recent years), and (4) suspected localized depletion of the southern inshore cobia stock.

An attempt was made to standardize the inshore/nearshore waters to North and South. However, many of the records in recent years lacked sufficient detail to split the areas and none of the records before 2007 could be identified at this scale. The species associated with cobia vary widely across bottom and pelagic species, demonstrating the difficulty in defining trips with cobia effort. Some of the pros of this index are that it includes discards, does not have issues with the bag limit, and is a complete census, which may provide better data than a survey for rare event species like cobia. However, the panel felt the problems identifying cobia effort and the inability to standardize across areas suspected to have localized depletion decreased the confidence in this index to track population changes. One run, which included only trips where cobia were not identified as a target but were caught, was attempted based on the idea that non-directed trips were less biased. The sample size was reduced significantly, and the geographic range was limited relative to the stock, though the trend was similar to the headboat index.

5.4.4 MRIP (SEDAR58-DW02)

The Marine Recreational Information Program (MRIP) conducts complementary surveys in NY to GA (range of cobia stock being assessed) from March to December each year, providing a time series of catch and effort estimates from March 1981 through 2017 (the terminal year of this stock assessment). For this index both harvested fish per angler trip (A+B1 catch per trip) and total fish per angler trip (A+B1+B2 catch per trip) were used for cobia catch rate computation. In this analysis, no higher level taxa were included because cobia is considered unique enough that the angler can either identify the fish to species (=cobia) or has no idea what he just caught (=unidentified fish). It would not be reasonable to estimate the fraction of those unidentified fish likely to be cobia, so no adjustment for unidentified cobia is included.

For more information on the methodology and variables collected by the MRIP APAIS, see https://www.fisheries.noaa.gov/recreational-fishing-data/types-recreational-fishing-surveys#access-point-angler-intercept-survey. The APAIS Procedures Manual is available in download form (.pdf file) on this webpage.

5.4.4.1 Methods of Estimation

Data from 1981 – 2017 from Waves 3 - 5 (May-October) were used to produce an annual catch per trip index using the MRIP weighted survey data files (download at https://www.fisheries.noaa.gov/recreational-fishing-data/recreational-fishing-data-downloads#general-survey-data-downloads).

The unit of effort used was the angler-trip, defined as a single day of fishing within a specific mode by the angler. MRIP catch data from the APAIS are categorized into three types: A, available, counted, measured, weighed fish by species; B1, unavailable fish (discarded, not whole, dead) reported to species, if possible, by the angler; B2, released alive fish, reported to species, if possible, by the angler. In the newest MRIP APAIS data files, all catch records are ‘standardized’ to the interviewed angler, accounting for grouped type A catch by multiple anglers within a boat party. The unique interview record of catch provides for grouped catch but not all contributing anglers were interviewed. However, the record counts were adjusted such that the calculated CPUE would correctly represent the total grouped catch, per species, of the group of contributing anglers.

A directed trip methodology was used to identify and include angler-trips in the computation of the CPUE for this index. A trip directed for cobia was defined as any angler trip that caught cobia (A, B1, or B2) and any trip likely to catch cobia defined by target species reported in the interview by the angler (Table 5.7.6). Many species of fish, including grouped taxa such as unidentified sharks, were caught with at least one cobia. Several subsets of co-occurring species assemblages were employed to define trips directed at cobia (Table 5.7.6). However, the species associated with cobia cover a wide range of habitat preferences indicating mixed effort trips or opportunistic cobia fishing within a trip. The entire range from NY to GA was examined but catch of cobia north of VA was rare so additional trials were confined to VA to GA to produce an index. Only trips from May to October were included in this index (APAIS 'waves' 3 - 5) to cover the most active cobia fishing season; catches of cobia from Nov. - Apr. were rare, and appropriate inclusion of directed trips with 0 catch was even less certain so those months were not included in the annual index.

Since the CPUE measures both retained and discarded or released fish, the index should not be strongly affected by changes in bag limit regulations.

Standardization

This index was also standardized using a Delta-GLM approach following the methods of Dick (2004). The units of effort used for the nominal and standardized index were angler-hours. The factors included in the model were Year (1981-2017), Month (May-Oct), State (GA, SC, NC, and VA), and Mode (Charter, Private, and Shore). A jackknife approach was used to estimate the amount of variation in the model run as per Dick (2004).

5.4.4.2 Sampling Intensity

In the Atlantic, a total of 28,554 interviews were conducted from 1981 – 2017 in waves 3-5 that caught or targeted cobia, or targeted king mackerel (highest frequency of co-occurrance NC-GA) in VA to GA. All trips used hook-and-line gear.

5.4.4.3 Size/Age data

Length data for landed cobia is extremely rare in the MRIP APAIS time series. Length frequency distributions can be obtained from the length-frequency catch query tool on the MRIP website: https://www.st.nmfs.noaa.gov/recreational-fisheries/access-data/run-a-data-query/queries/index. The sizes/ages represented in this index should be the same as those of landings from the corresponding fleet (See section 4 of this report) and the recommendations of the Life History Workgroup.

5.4.4.4 Catch Rates

Both the nominal and standardized indices were relatively flat and low throughout the 1980s and 1990s (Figure 5.8.7). The indices then jump up to another period of stability until 2010 at which point the nominal index trends upward until 2017. In contrast, the standardized index makes the large jump in 2010, then remains stable until it jumps again in 2016-2017, when VA really enters the fishery (Figure 5.8.7).

5.4.4.5 Uncertainty and Measures of Precision

For cobia, year, month, and state provided the greatest reductions in deviance for the positive trips model, and year, month, state, and mode for the proportion positive model.

5.4.4.6 Comments on Adequacy for Assessment

The index of abundance created from the MRIP data was not considered by the indices working group to be adequate for potential use in the cobia assessment. The dataset has good spatial coverage, which covered the entire geographic range of Atlantic cobia as described above. The index included discards and is a long time series. The index also does not have problems with the bag limit or species identification. However, the problem of correctly identifying the trips to be included in the index, based on species assemblages likely to be caught with cobia, or appropriate targeted species that could produce cobia catch, was insurmountable. The most commonly occurring co-catch in the NC-GA range was king mackerel, but they do not co-occur temporally and spatially with cobia in VA. In the mid-Atlantic range, NY-VA, the most common co-catch was Atlantic croaker, but if all trips that targeted or caught croaker were included that would add > 2 million 0-cobia trips in VA alone (VA produced only ~133,000 trips targeting or catching cobia). Due to this problem of identifying the appropriate parameters needed to include the correct effort in this CPUE index, it is recommended that the MRIP Index not be used in this cobia assessment.

An index was developed for VA-only in an attempt to evaluate trends in a very important region in the overall landings in recent years. This index has the same problems as the overall MRIP index. However, it is the only data source that covers this region. The information is included here to inform assessment analysts of potential differences in trends in a portion of the stock not included in the recommended index. After discussions with fishermen familiar with the VA fishery, two different species groups were used to identify effective cobia effort. The two groups were Bluefish (all trips that either caught or reported targeting bluefish) and sharks (all trips that either caught or reported targeting a complex of elasmobranchs including sandbar shark, blacktip shark, and cownose ray). The factors included in the model were Year (1981-2017), Month (May-Oct), and Mode (Charter, Headboat, Private, and Pier). The standardization proceeded the same as it did for the full MRIP index.

5.4.5 Other Data Sources Considered

No other datasets were introduced at the SEDAR 58 data workshop.

5.5 Consensus Recommendations and Survey Evaluations

Only the recreational headboat index was recommended for potential use in the cobia stock assessment.

5.6 Literature Cited

Dick, E.J. 2004. Beyond ‘lognormal versus gamma’: discrimination among error distributions for generalized linear models. Fisheries Research. 70:351-366.

Hall, D. B. 2000. Zero-Inflated Poisson binomial regression with random effects: a case study. Biometrics, 56: 1030-1039. Phillipines.

Kleiber C. and A. Zeileis. 2016. “Visualizing Count Data Regressions Using Rootograms.” The American Statistician, 70(3), 296–303. doi: 10.1080/00031305.2016.1173590.

Tukey, J. 1977. Exploratory Data. Reading, Mass: Addison-Wesley Pub. Co.

Zuur, A.F., E.N. Ieno, N.J. Walkder, A.A. Saveliev, and G.M. Smith. 2009. Mixed Effects Models and Extensions in Ecology with R. Spring Science and Business Media, LLC, New York, NY.

5.7 Tables

Table 5.7.1. Table of the data considered for the construction of a CPUE index.

Fishery Type	Data Source	Area	Years	Units	Standardization Method	Use?
Recreational fishery-dependent	Headboat	NC-GA	1991-2015	Count/trip, caught	ZINB	Yes
Recreational charter, fishery-dependent	SCDNR Charter Logbooks	All of SC	1998-2017	Number / angler-hour, caught and discarded	Delta-GLM in Bayesian format	No
Recreational, Private/Charter/Pier	MRIP	VA-GA	1981-2017	Number/angler-hour, caught and discarded	Delta-GLM	No

Table 5.7. 2. Table of the pros and cons for each data set considered at the data workshop.

Fishery-dependent indices

Recreational Headboat (*Recommended for use*)

Pros:

- Vessel census
- Covers most of the management area
- Longest time series available
- Some data are verified by port samplers and observers
- Large sample size
- Non-targeted for focal species, which should minimize changes in catchability relative to fishery-dependent indices that target specific species

Cons:

- Fishery-dependent
- Does not include areas North of NC
- Mostly presence/absence
- Two most recent years unavailable due to closures

SCDNR Charterboat *(Not recommended for use)*

Pros:

- Relatively long time series
- Census of charter boats (rare species)
- Includes discards

Cons:

- Fishery-dependent
- Difficulty in defining effort (many trips catching cobia not listed as target species)
- Fishing behavior impacted by management and conservation outreach (gamefish status)
- Limited spatial coverage relative to SEDAR 58 stock definition
- Limited dockside validation
- Localized depletion for specific areas (inadequate data to standardize)

MRIP *(Not recommended for use)*

Pros:

- Includes discards
- Good spatial coverage
- Relatively long time series

Cons:

- Fishery-dependent
- Difficult to define cobia effort

- Inadequate coverage of rare event species

Table 5.7.3. Subsetting steps and justification for the cobia headboat logbook index.

Step	Filtering step	# cobia trips	# total trips	% cobia trips	Justification
1	Raw data	3,405	102,427	3%	-
2	Filter outliers (anglers and catch)	3,360	101,539	3%	Standard outlier removal procedure
3	Filter vessels with < 30 trips & less than 3 years in fleet	3,313	99,993	3%	Select vessels consistently in fleet that represent the fishery
4	Filter September - March	2,710	77,463	3%	Select months that reflect the highest probability of encountering a cobia
5	Retain 1991-2015	2,298	44,232	5%	Due to inconsisent reporting of cobia in the 1980s and seasonal closures in 2016 and 2017, the time series was truncated
6	Retain full and half daytrips only	1,988	40,502	5%	To examine the possible effects of trip type on cobia catch while eliminating the variability associated with multiday and 3/4 day trips
7	Retain "core" vessels (25)	1,728	27,700	6%	Identify vessels that consistently report cobia

Table 5.7.4. Progression of model runs leading up to the SEDAR 58 cobia data workshop for the cobia headboat logbook index. Model runs 1-11 were exploratory and examined prior to the data workshop while runs 11 and 12 were provided for the data workshop (12) or generated at the data workshop (13).

Run	Year	Region	Trip Type	Season	Percent Full	Vessel Size	Party Size
1	1981-2015	state	all, 2 levels	all years	5 levels	5 levels	5 levels
2	1981-2015	state	all, 2 levels	April - Sept.	5 levels	5 levels	5 levels
3	1981-2015	3 inlet regions	all, 2 levels	April - Sept.	5 levels	5 levels	5 levels
4	1981-2015	3 inlet regions	all, 2 levels	April - Sept.	2 levels	2 levels	2 levels
5	1992-2015	3 inlet regions	all, 2 levels	all years	5 levels	5 levels	5 levels
6	1992-2015	3 inlet regions	all, 2 levels	April - Sept.	5 levels	5 levels	5 levels
7	1992-2015	3 inlet regions	all, 2 levels	April - Sept.	2 levels	2 levels	2 levels
8	1991-2015	3 inlet regions	all, 2 levels	April - Aug.	5 levels	5 levels	5 levels
9	1991-2015	3 inlet regions	all, 2 levels	April - Aug., 2 levels	5 levels	5 levels	5 levels
10	1991-2015	3 inlet regions	all, 2 levels	April - Aug., 2 levels	2 levels	2 levels	2 levels
11	1991-2015	3 inlet regions	full day & multiday, 1 level	April - Aug., 2 levels	2 levels	2 levels	2 levels
12	**1991-2015**	**3 inlet regions**	**full day only**	**April - Aug., 2 levels**	**2 levels**	**2 levels**	**2 levels**
13	**1991-2015**	**3 inlet regions**	**full and half day**	**April - Aug., 2 levels**	**2 levels**	**2 levels**	**2 levels**

Table 5.7.5. The relative nominal *Count*, number of trips, proportion positive, standardized index, and CV for the SEDAR 58 SRHS cobia index.

Year	Relative Nominal (Count)	N	Proportion Positive	Standardized index	CV
1991	1.23	1058	0.06	1.02	0.17
1992	1.26	1204	0.07	0.95	0.16
1993	1.03	1355	0.07	0.83	0.13
1994	0.90	1230	0.06	0.72	0.11
1995	1.55	1298	0.09	1.14	0.13
1996	0.53	1211	0.04	0.46	0.11
1997	0.67	1265	0.05	0.64	0.17
1998	0.87	1197	0.06	0.78	0.14
1999	0.85	1194	0.05	0.82	0.12
2000	0.82	1292	0.05	0.77	0.14
2001	0.70	1107	0.05	0.70	0.17
2002	1.20	1048	0.07	1.17	0.16
2003	0.82	1129	0.06	0.88	0.14
2004	0.86	1302	0.06	0.89	0.13
2005	1.14	973	0.06	1.09	0.13
2006	0.71	1110	0.05	0.85	0.15
2007	1.50	1162	0.09	1.59	0.19
2008	1.30	974	0.09	1.37	0.10
2009	0.78	859	0.05	1.08	0.12
2010	0.74	1120	0.05	1.00	0.20
2011	0.81	1026	0.06	0.83	0.16
2012	0.90	920	0.07	1.09	0.14
2013	1.77	829	0.11	2.04	0.15
2014	1.13	960	0.08	1.23	0.12
2015	0.96	877	0.05	1.04	0.13

Table 5.7.6. MRIP top ten species associations with cobia for the mid-atlantic (VA-North) and South Atlantic (NC-GA).

Mid-Atlantic		South Atlantic	
Species	Fish	Species	Fish
COBIA	525	COBIA	2413
ATLANTIC CROAKER	98	KING MACKEREL	352
BLUEFISH	56	BLACK SEA BASS	238
SUMMER FLOUNDER	50	BLUEFISH	221
SPOT	40	LITTLE TUNNY	196
COWNOSE RAY	37	SPANISH MACKEREL	180
UNIDENTIFIED (SHARKS)	32	DOLPHIN	172
BLACK SEA BASS	29	GREATER AMBERJACK	134
SANDBAR SHARK	17	PINFISH	134
OYSTER TOADFISH	15	GREAT BARRACUDA	124

5.8 Figures

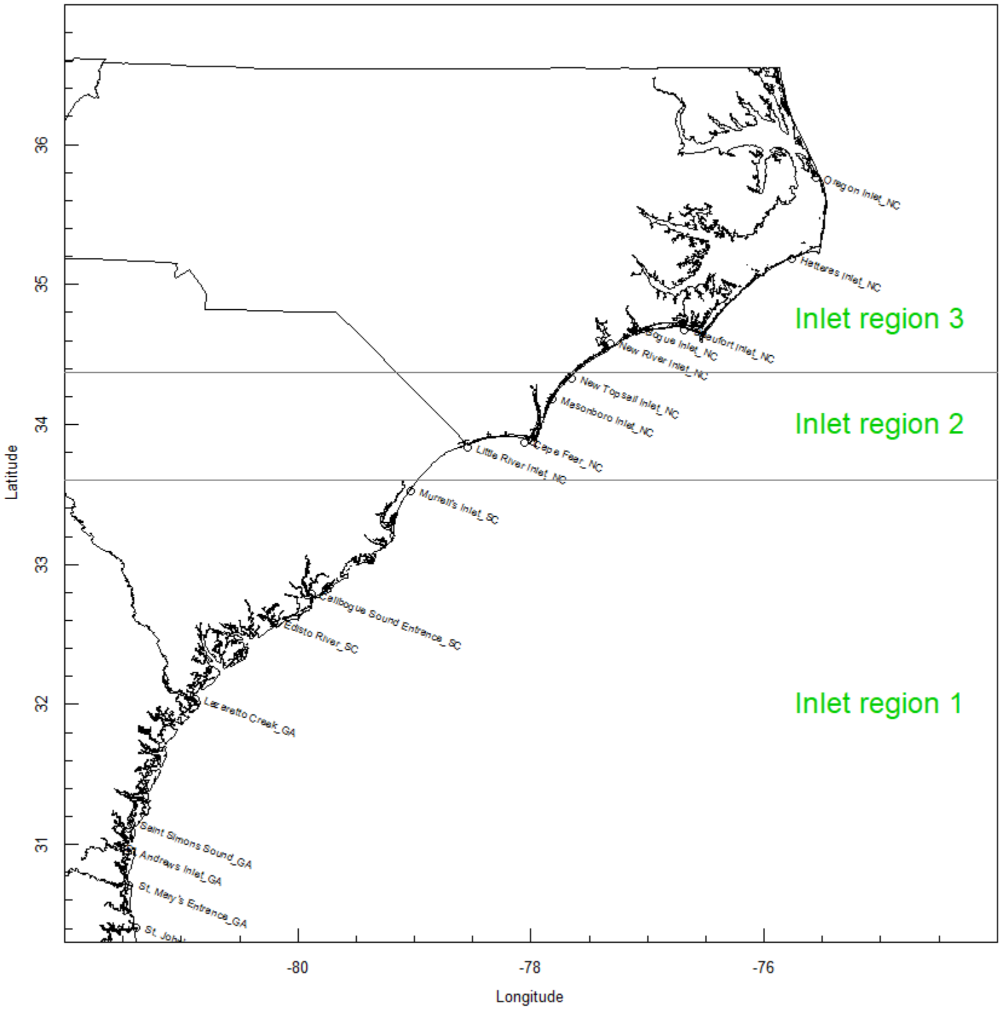


Figure 5.8.1. Map of headboat sampling area definition, inlet region (i). The delineation was determined using tertiles of inlet from positive cobia trips. None of the Florida information was included.

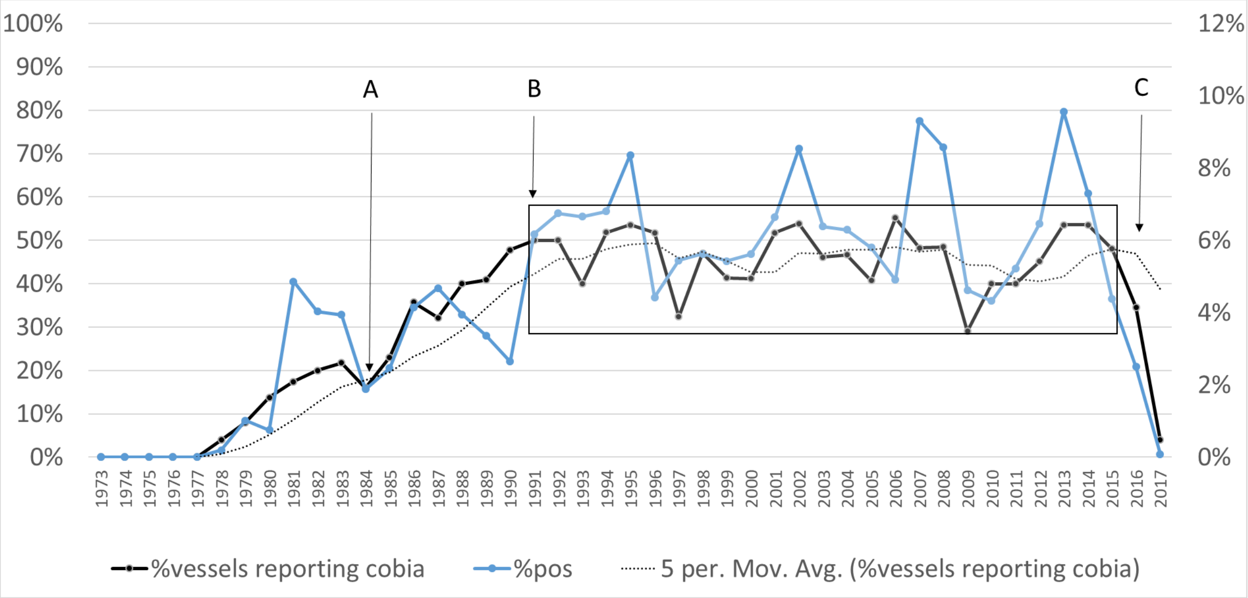


Figure 5.8. 2. Percentage of headboats reporting cobia (black line) and percentage of total headboat trips that reported cobia (blue line). The year cobia were added to the headboat logbook form (A), year where full reporting is assumed (B), and period with closures (C) are shown. The box shows the years included in the headboat index.

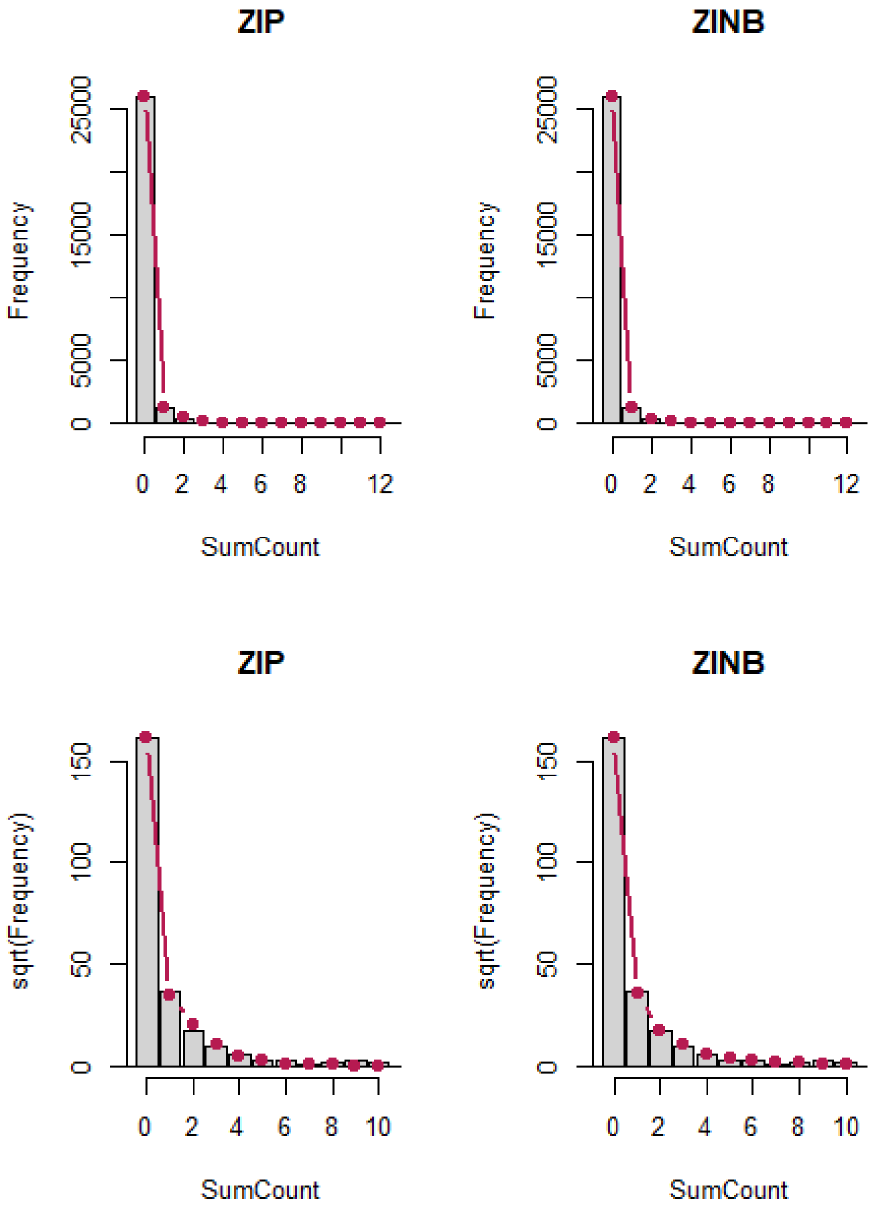
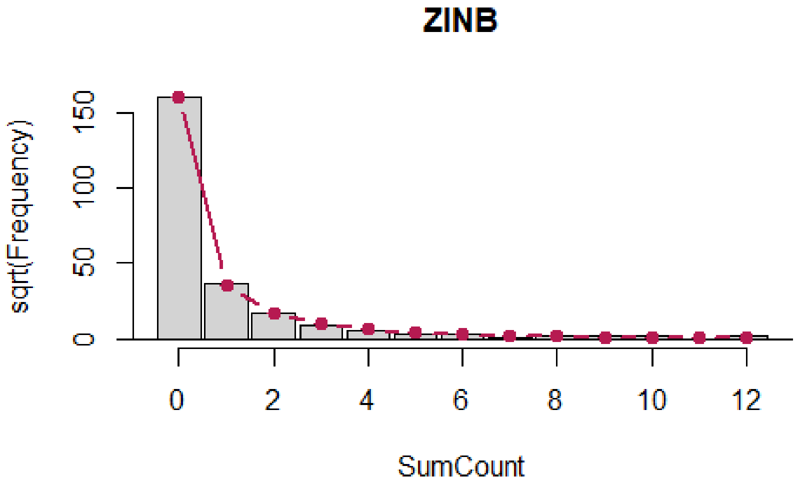


Figure 5.8.3. Model formulation comparison, with ZIP (left) and ZINB (right) fitted values plotted against the original data distribution with all covariates included. The lower panels are square root transformed and truncated at 20 fish for inspection of goodness of fit over the range of values for the bulk of the data.



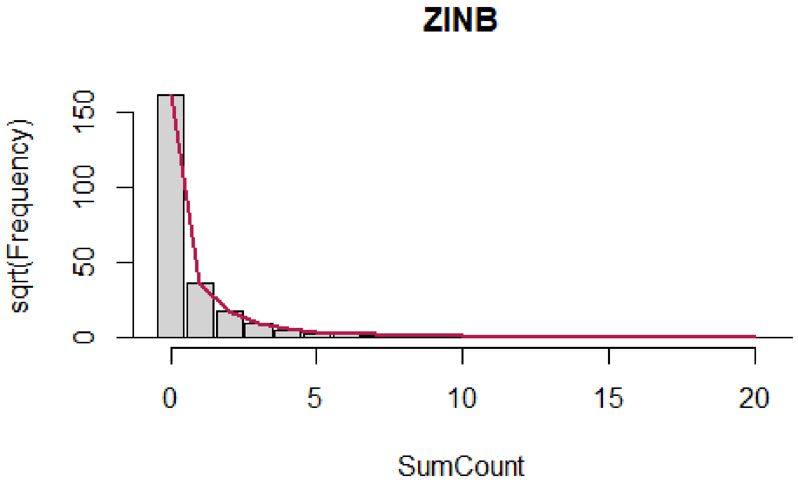


Figure 5.8.4. Model diagnostic plots of fitted model values (red line) against the original data distribution for the preferred model.

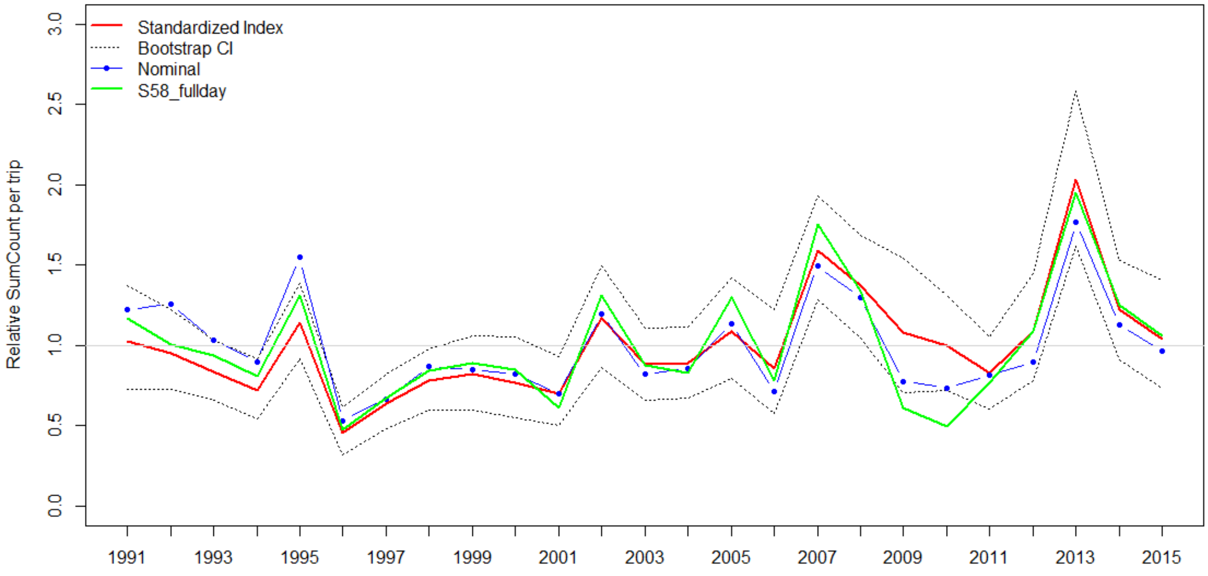


Figure 5.8.5. Relative standardized index (solid red line) with 2.5% and 97.5% confidence intervals (dashed lines) and the relative nominal index (blue) for cobia in the SRHS headboat logbook data and the standardized index with full day trips only (green).

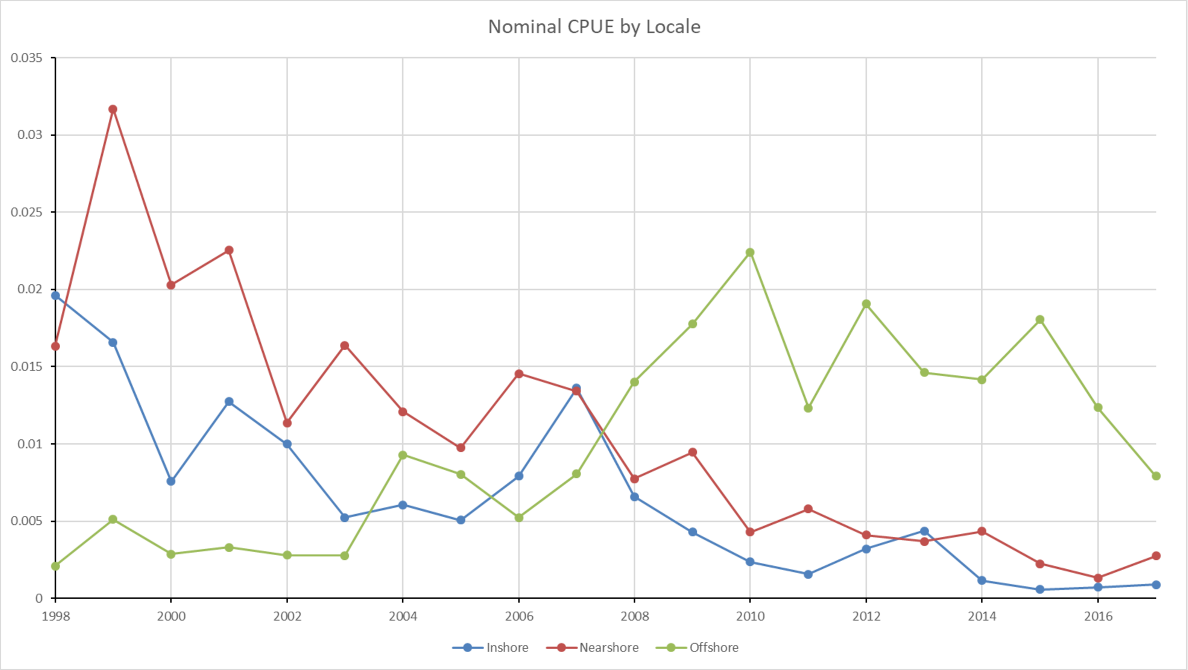


Figure 5.8.6. Nominal SC charter logbook CPUE by locale.

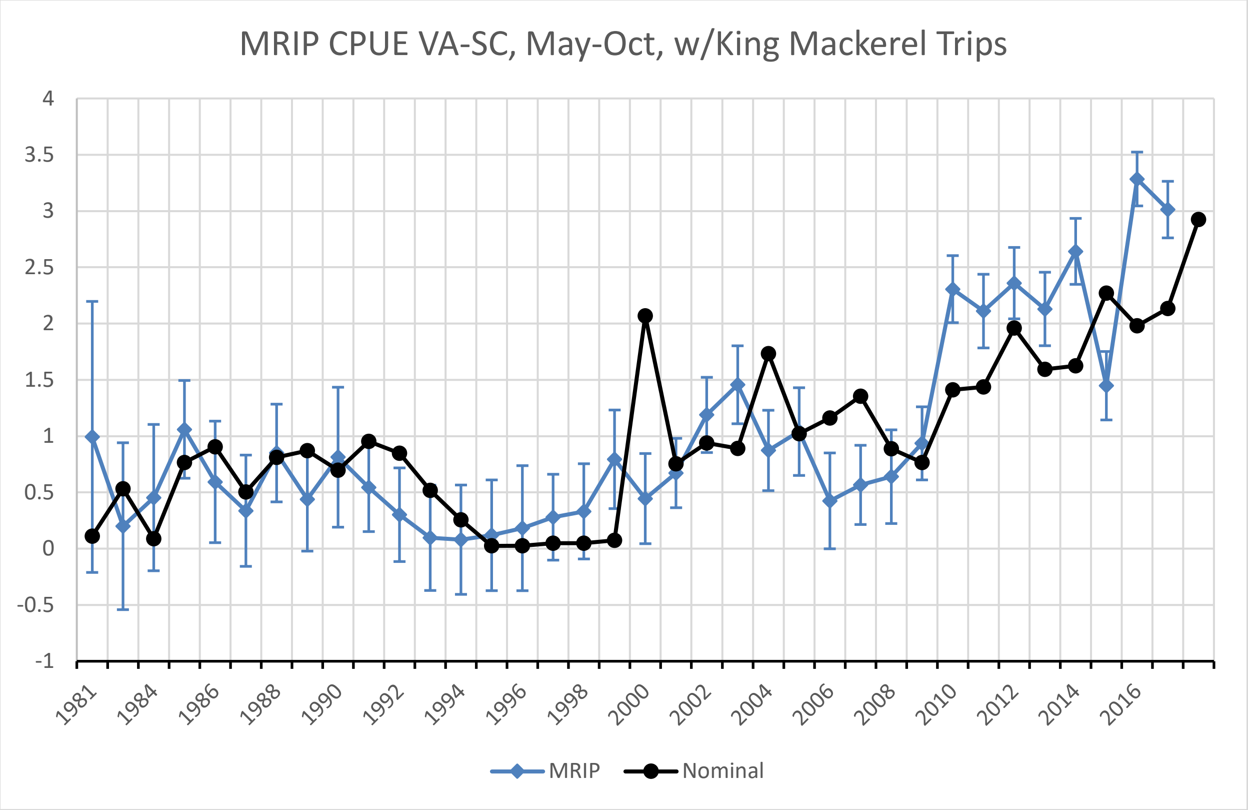


Figure 5.8.7. MRIP nominal and standardized indices using king mackerel trips to define cobia trips in addition to trips catching cobia or listed as targeting cobia.

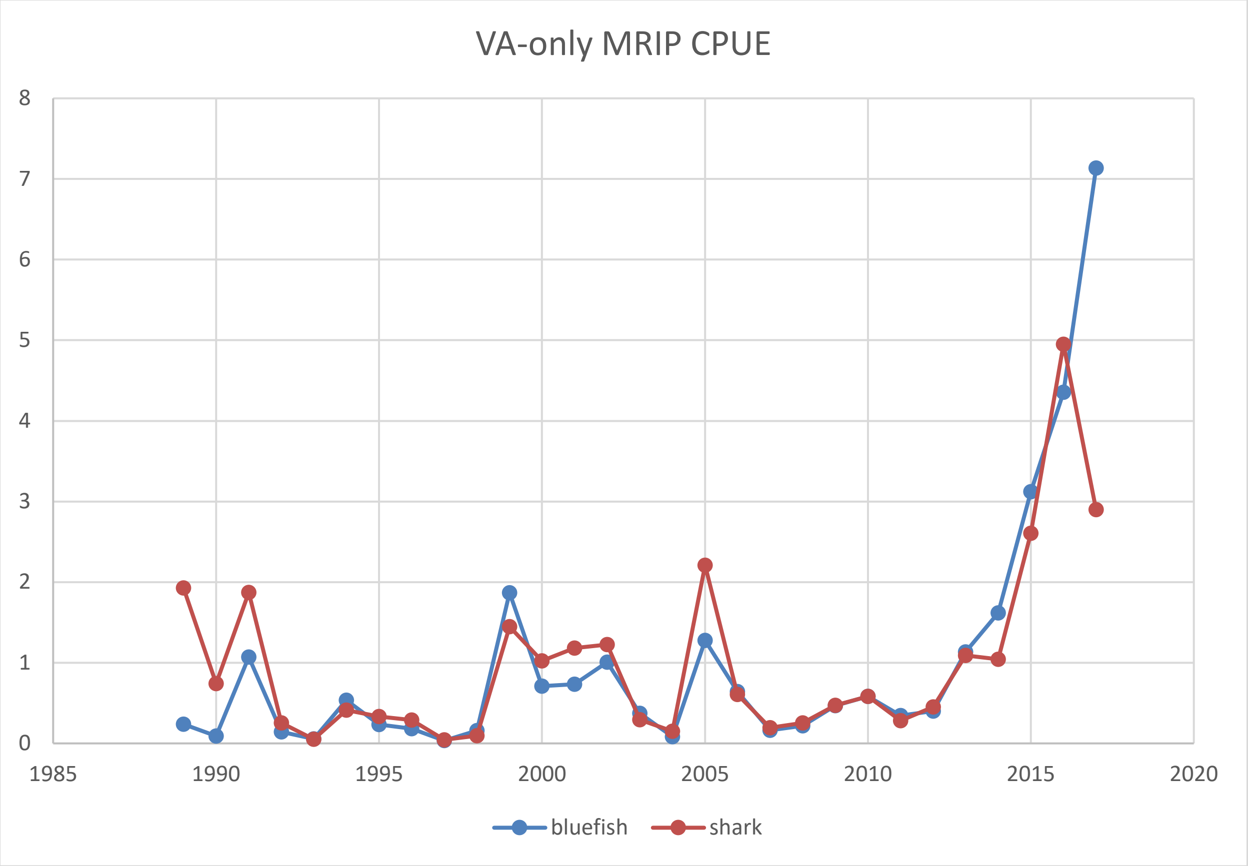


Figure 5.8.8. Virginia-only MRIP CPUE for private, charter, and pier anglers.

5.9 Research Recommendations

5.9.1 Review of SEDAR 28 Research Recommendations

- SEDAR 28 DW - Explore SEFIS video data as a potential fishery independent index of abundance for cobia.

  The SEFIS video data are collected in association with the chevron trap survey and were evaluated for use in SEDAR 58. This survey focuses on bottom species and takes place outside of the primary cobia season. Cobia have been observed on very few occasions (1-3%) in the videos. It is unlikely that this survey would provide a useful index of cobia abundance.

- SEDAR 28 DW - Using simulation analysis, evaluate the utility of including interaction terms in the development of a standardized index and identify the potential effects these interaction terms have on stock assessments.

  Simulation analyses evaluating the utility of including interaction terms in developing a standardized index, to our group's knowledge, have not been attempted for cobia.

- SEDAR 28 AW - Develop a fishery-independent sampling program for abundance of cobia and other coastal migratory species. Fishery -dependent abundance indices used in this assessment were uncertain in part due to the lack of an effective sampling methodology.

  No new fishery-independent surveys have been implemented for cobia and other coastal migratory species.

5.9.2 Research Recommendations

- Develop a fishery-independent sampling program for abundance of cobia and other coastal migratory species.
- Improve MRIP coverage for rare event species
- Improve validation methods for SC Charter Logbook
- Improve effort definition of gear and target species within trips (mixed effort)

6 Discard Mortality

6.1 Overview

An ad-hoc panel discussed discard mortality during the SEDAR 58 Data Workshop. Participants included data providers, analysts, and professionals from the fishing industry representing both commercial and recreational fisheries. The panel reviewed available data and relevant research results to provide recommended estimates of discard mortality for each fishery.
ToR #6 Provide recreational catch statistics, including both landings and discards in both pounds and number.

a) Evaluate and discuss the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector or gear.
b) Provide length and age distributions for both landings and discards if feasible.
c) Provide maps of fishery effort and harvest.
d) Provide estimates of uncertainty around each set of landings and discard estimates.

6.1.1 Recreational fishery

A total of five (5) data sources were recommended by the ad-hoc group including: 1.) The South Carolina Department of Natural Resources (SCDNR) Cobia Broodstock Collection Program, 2.) An Acoustic Telemetry Study (Young et al. 2018), 3.) SCDNR Charterboat Logbook Program, 4.) A Virginia Institute for Marine Sciences (VIMS) Satellite Archival Tag Study (Jensen and Graves 2018) and 5.) The Commercial Logbook Program (NOAA SEFSC). Additional fish in an unpublished paper from North Carolina State University (NCSU) and North Carolina Division of Marine Fisheries were included in the acoustic telemetry analysis. The discard mortality ad-hoc group reviewed each data source independently and outlined all major uncertainties when estimating mortality. After further review, the ad-hoc group decided to use data from the acoustic telemetry study (Young et al. 2016) and the commercial logbook program to estimate discard mortality for each sector. All other studies/programs were used to confirm or inform upper and lower bounds around the mortality estimates as sensitivity runs on the model.

Jacob Krause, a PhD candidate from NCSU, used a Cormack-Jolly-Seber model on data provided from the acoustic telemetry study to estimate release mortality (i.e. any mortality associated with catch-and-release and the surgical procedure to insert a transmitter). Jacob found that the median mortality estimate was 4.6% (95% credible interval; 0.3%, 12.4%). There was discussion amongst the group if cobia caught by researchers are reflective of the recreational fishery. It was determined that researchers are using the same methods and techniques to catch cobia as seen in the recreational fishery. The group recognized there could be additional mortality due to the increased handling time and surgical process which was not typical of the recreational fishery, as such the release mortality estimate may provide an upper bound for discard mortality. Recognizing the aforementioned uncertainties in release mortality, the group found that the model was appropriate for use in estimating discard mortality.

The second data source used to estimate discard mortality was the commercial logbook data provided by NOAA SEFSC. The commercial logbook data estimated discard mortality from handline gear. Other estimated discards from the commercial logbook data included the bandit fishery and the long line fishery. The ad-hoc group updated discard mortality estimates from the commercial logbook data as was done previously in SEDAR 28. The discard mortality estimate for the handline fishery was 5.5%, which is consistent with the handline discard mortality estimate from SEDAR 28. The ad-hoc group noted that the overall mortality of cobia was relatively low. Estimates of discard mortality ranged from 0% (VIMS Satellite Archival Tag Study) to 12.4% (Upper bound from acoustic telemetry study). The group determined that a 0% lower bound estimate was not realistic and therefore adopted the lower bound (2%) from the SEDAR 28 assessment. The group decided that 5 % was a reasonable discard mortality estimate for the recreational hook and line fishery based on results from additional data sources and the discard mortality estimate from SEDAR 28 (5%).

6.1.2 Commercial fishery

Commercial dead discards were estimated using three data sources: 1.) Shark Gillnet observer program (NMFS), 2.) North Carolina Division of Marine Fisheries (NCDMF) Gill Net Observer Program, and 3.) NMFS Supplemental Discard Logbook Program. The shark gill net observer program was designed to monitor bycatch from the shark gill net fishery. The NCDMF observer program was designed to monitor fisheries for protected species interactions in the inshore gill net fishery by onboard observations. The ad-hoc group noted that the sample size of interactions for gill net gears is small (n< 10 fish/year) and for several years the sample size is less than five observed fish. The group noted that there were no releases in 2010 however, that observation was still considered in the time-series average. Discard mortality was estimated by dividing the total number of dead releases (27 fish released dead) by the total number of all releases (64 releases) from the time-series (2004-2017). The discard mortality estimate was 45%, which is well within the bounds of the gill net discard mortality estimate from SEDAR 28. The Supplemental Discard Logbook Program provided disposition (discarded dead, most animals discarded dead, discarded alive, most animals discarded alive, kept for bait, unknown, or unreported) of animals caught in commercial fisheries. In the South Atlantic, 20% of federally permitted vessels were required to report discarded fish and protected species since 2001 (2002 was the first full year of reporting). Discard logbook disposition data were used to estimate discard mortality for the commercial vertical line (handline, electric and hydraulic reel, and trolling gear) fishery. A single value for discard mortality was estimated as the number of cobia released dead (assumed to be the total of those reported as “released dead” plus the number reported as “most animals released dead”) divided by the total number of reported discards. The estimated discard mortality for the commercial vertical line fishery was 5.6%. That estimate falls within the range of discard mortalities for recreational hook and line gear.

Observed immediate discard mortality for gill net gears was 55%. The working group recommended an upper bound of 77% discard mortality as was recommended during SEDAR 28. A discard mortality of 36% was recommended as a lower bound as was recommended during SEDAR 28.

Summary of Recommendations

Recreational discard mortality:
- 5 % model base run with 2% and 12% recommended for sensitivity model runs

Commercial discard mortality for gillnet:
- 55% model base run with 36% and 77% recommended for sensitivity model runs

Commercial discard mortality for vertical line:
- Use recreational discard mortality estimates: 5% for base run, 2% and 12% for sensitivity runs

6.1.3 Research recommendations

Recommendations based on the previous SEDAR 28 recommendations:

1. SEDAR 28-During discussion at the data workshop it was noted that the logbook categories for discards (all dead, majority dead, majority alive, all alive) are not useful for informing discard mortality. Consider simplified logbook language in regard to discards (e.g., list them as dead or alive).
    - New recommendation based on same concern: The group recommends that the SEDAR send a recommendation to the Southeast Fisheries Science Center (SEFSC) Fisheries Statistics Division Director clarifying the discard disposition. The group also noted that obtaining adequate discard data is best achieved by collaboration with stakeholder and state/federal partners.
2. SEDAR 28- Further research is needed on cobia release mortality.
    - The discard mortality ad-hoc group addressed this recommendation from SEDAR 28 and agree that additional research is still needed on cobia release mortality.

New SEDAR 58 recommendations:

1. The group recommends continuing electronic tagging to estimate release mortality and total mortality. Increases in spatial coverage (i.e. receiver arrays) and the number of tags both spatially and temporally to increase the precision of mortality estimates. Furthermore, elucidating the effect of temperature on discard mortality through the use of temperature tags.
2. The group recommends the use of conventional tagging. The tagging of telemetered fish informs the fates (i.e. harvest or catch and release of the telemetered fish). For all conventionally tagged fish, high value tags are need to estimate tag reporting rate and estimates of tag loss.

3. The group recommends a SEDAR/council/state or regional management (ASMFC) sponsored tagging workshop to codify methodologies.

Literature cited

Jensen, D. and J. Graves. 2018. Use of Pop-Up Satellite Archival Tags (PSATs) to Investigate the Movements, Habitat Utilization, and Post-Release Survival of Cobia (Rachycentron canadum) that Summer in Virginia Waters. SEDAR58-SID-02. SEDAR, North Charleston, SC. 13 pp.

Young, J., M. Perkinson, K. Brenkert, E. Reyier, and J. Whittington. 2018. Cobia Telemetry Working Paper. SEDAR58-SID-08. SEDAR, North Charleston, SC. 15 pp.

7 Ecosystem

7.1 Ecosystem Workgroup Participant list

Dan Crear, Bill Parker, Hank Liao, George Sedberry, Beth Wrege, Collins Doughtie, Kevin Weng, Karl Brenkert, Mike Denson

7.2 Overview

ToR #7: Identify and describe ecosystem, climate, species interactions, habitat considerations, and/or episodic events that would be reasonably expected to affect population dynamics.

The ad hoc work group determined that along the Atlantic coast of the US there is insufficient data to determine the habitats utilized by almost all life stages of cobia (larvae, juveniles 0-2, wintering adults) making it extremely difficult to evaluate the corresponding risk to the population from climate change, weather events or human pertubation.

Along the Atlantic coast (GA and north) adults migrate into nearshore waters based on temperature cues (>20 C) in the spring and form spawning aggregations and leave nearshore waters when sea surface temperatures exceed 32 C (SEDAR 58 Stock ID Workshop working paper). In some cases, cobia enter high salinity estuaries to spawn (Port Royal Sound, St. Helena Sound, and Chesapeake Bay, SEDAR 28, GSI data Table 2.3). Other than these two, the number and extent of spawning locations have not been enumerated nor documented. Some of these discrete segments of the stock spawn in smaller groups and do not spawn with the rest of the population and have been documented as genetically distinct population segments. Only two areas have been analyzed with sufficient sample sizes to identify these smaller reproductive pools (inshore southern South Carolina and Chesapeake Bay) (SEDAR 58 Stock ID Workshop S58-SID04).

Presumably eggs, larvae, and small juveniles occupy inshore and nearshore waters for a portion of their first year. Cobia eggs/larvae have been identified in ichthyoplankton surveys outside Chesapeake Bay and Southern SC estuaries, but other locations have not been reported.

In the fall, the population leaves nearshore waters, however it is currently unknown where cobia over winter. Because cobia seem sensitive to thermal cues, it is assumed they move into deeper offshore waters or closer to the Gulf stream suggesting a West-East migration. These movements have been confirmed by several pop-up satellite archival tags deployed in VA waters on adult cobia (SEDAR 58 Stock ID Workshop S58-SID02). However, this hypothesis needs to be tested further throughout the range. Very few records of small juveniles through age 2 fish have been collected and it is generally unknown what habitats they utilize.

Because of the paucity of information on cobia life history and the habitats they occupy throughout the year the work group believes that research should focus on documenting these basic questions prior to moving on to potential threats.

7.3 Research Recomendations

-Determine locations of all genetically distinct population segments

-Identify spawning aggregations and duration and timing of spawning

-Further charachterize spawning habitat: salinity, water temperature, day length, habitat type (i.e. structured, vegetated, sandy)

-Identify the habitat of 0-2 year olds juveniles and sub-adults

-Determine habitat use during the winter

-Document the distribution and mechanism for transport of eggs, larvae and post-larvae

-Evaluate the impacts of increased temperature, increased eutrophication of estuarine and nearshore waters, and decreased salinity on egg, larvae and juvenile survival

-Evaluate the impacts of increased temperature, increased eutrophication of estuarine and nearshore waters, and decreased salinity on the food web supporting larvae and juveniles

-Determine factors affecting changes in growth, maturity at age, egg production, and sex ratio as temperature increases forcing a change in habitat use

-Identify threats to different life stages by invasive species

-Better understand the relationship between prey species and co-occurring species (blue crab, calico crab, hardhead catfish, eels, cownose rays etc.)

-Identify levels of pollutants (mercury, microplastics, ethinyl-estradiol) affecting cobia and determine the impacts on growth, maturity at age, egg production, sex ratio and behavior

7.4 Ecosystem Group Reference List

Climate Change

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Food resources
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Pollution/Water quality/Sound
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Distribution

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Non-Peer Reviewed Literature

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Jensen, D. and J. Graves. 2018. Use of Pop-Up Satellite Archival Tags (PSATs) to Investigate the Movements, Habitat Utilization, and Post-Release Survival of Cobia (Rachycentron canadum) that Summer in Virginia Waters. SEDAR58-SID-02. SEDAR, North Charleston, SC. 13 pp.

8 Socio – economic

8.1 Overview

There is relatively limited socioeconomic information available for cobia fisheries and the human communities they support. What follows includes a brief summary of the social and economic dimensions of cobia fisheries as described primarily in relevant management documents. Additional context and content were added following a discussion by SEDAR 58 participants in the socio economic ad-hoc group.

ToR #8: Incorporate socioeconomic information into considerations of environmental events that affect stock status and related fishing effort and catch levels as practicable.

Atlantic Cobia support important recreational fisheries throughout the region. Recreational effort is highest in North Carolina and Virginia, which typically represent 70-90% of all directed trips targeting cobia. In South Carolina, high levels of inshore effort are thought to have produced reductions in local abundances, leading fishery managers to enact restrictive management measures beginning in 2015. Private vessels are the dominant fishing mode, though cobia is also an important target for charter vessels and fishing guides in South Carolina, North Carolina, and Virginia. Additionally, shore and pier fishing effort has been increasing in North Carolina recently and typically follows targeting by private vessels earlier in the season. Chumming and sight casting are the most common methods used by anglers to target cobia. Cobia may also occasionally be caught on recreational trips targeting other species outside directed effort during the spring and summer seasons. The South Atlantic Fisheries Management Council evaluated recreational engagement of South Atlantic fishing communities by assessing recreational fishing infrastructure, the number of charter permits, and other relevant data (SAFMC 2018). They found that several communities in North Carolina (Atlantic Beach, Hatteras, Manteo, and Morehead City) and South Carolina (Charleston, Hilton Head, Little River, and Murrells Inlet) exceeded their ranking threshold and were likely to have some dependence on recreational fishing, though this analysis was not specific to Atlantic cobia. It is noted that fishing communities in Virginia were not included in this analysis though cobia may be an important recreational resource to certain areas (e.g., Hampton and Virginia Beach). Economic activity dependent on recreational cobia fisheries is a function of recreational effort and related expenditures and may be substantial in some areas of North Carolina and Virginia. Additionally, a stated preference survey of cobia anglers in Virginia conducted in 2017 revealed a high willingness-to-pay for cobia trips, suggesting the species yields considerable economic value to the recreational sector (i.e., benefits in excess of fishing costs) (Scheld et al., manuscript under review).

Commercial landings of Atlantic cobia are small and typically represent less than $200,000 in ex-vessel revenues annually. Landing prices are generally between $2/lb and $3/lb. A substantial portion of commercial landings are as bycatch or incidental catch when targeting other species, and cobia was found to make up less than 1% of annual all-species revenues for commercial vessels landing cobia from Georgia, South Carolina, and North Carolina from 2012 through 2016 (SAFMC 2018). In Virginia, there is a small directed hook-and-line fishery (ASMFC 2017). Cobia is a state designated gamefish in South Carolina and may not be harvested in state waters for commercial sale; however, fish caught in federal waters can be landed commercially. Due to the small level of commercial landings, economic impacts and associated business activity are thought to be modest (SAFMC 2018).

Fishing mortality by the commercial sector is managed through state and federal limited entry programs as well as individual and vessel trip harvest limits. The recreational fishery is the dominant source of fishing mortality however (>95% of annual landings typically). Managing fishing mortality by the recreational sector is challenging due to difficulties in observing and quantifying catch, harvest, and effort. Furthermore, the recreational sector is composed of thousands of anglers with varying motivations and behaviors, making it difficult to accurately predict effort. Directed effort has generally been found to follow the species' north-south and inshore-offshore seasonal migratory behavior. Shifts in local inshore/offshore abundances or seasonal availability could lead to shifts in recreational effort and harvest. Anecdotal information and stated preference survey data suggest that recreational anglers are responsive to regulations, reducing trip-taking and fishing effort in response to restrictive regulations (Scheld et al., manuscript under review). Directed recreational effort may also depend on the availability and quality of opportunities to target alternative species, suggesting changes in abundances and fishery conditions of substitute species may influence fishing effort and harvests of Atlantic cobia (Scheld et al., manuscript under review).

Environmental factors that may affect fishing effort for Cobia are increasing water temperatures and eddies. The warmer temperatures can cause Cobia to move into fishing areas earlier in the year than expected or even truncate their availability, limiting catch to a period of time as short as two weeks. Cobia could also be moving further northward as mean water temperatures rise in mid and north Atlantic. Otherwise, socio-economic changes for the fishery are more likely related to anglers shifting fishing effort inshore due to high fuel prices or shifting offshore in recent years to protect inshore spawning aggregations.

8.2 Research Needs

- Obtain better data (e.g., more comprehensive and timely) to estimate the annual economic impacts, net benefits, and economic contributions of recreational and commercial Atlantic cobia fishing on coastal communities and regions.
- Obtain cost and expenditure data for recreational fishing trips targeting cobia by fishing mode, for different states, and for anglers returning to private sites, who would not be sampled by the MRIP.
- Estimate willingness-to-pay associated with recreational cobia angling.

8.3 Citations

Atlantic States Marine Fisheries Commission (ASMFC). 2017. Interstate Fishery Management Plan for Atlantic Migratory Group Cobia. NOAA award # NA15NMF4740069. Arlington, VA. 85 pp.

Scheld, A.M., W.M. Goldsmith, S. White, H. Small, and S. Musick. Quantifying the behavioral and economic effects of alternative regulatory measures in Virginia's recreational cobia fishery. Under review at the North American Journal of Fisheries Management.

South Atlantic Fishery Management Council (SAFMC). 2018. Amendment 31 to the Fishery Management Plan for Coastal Migratory Pelagics Resources in the Gulf of Mexico and Atlantic Region. NOAA award # FNA10NMF441001. Charleston, SC. 209 pp.

9 Analytical Approach

Based on the reports produced by the working groups of the Data Workshop, there are sufficient data to attempt to fit an age-structured statistical catch at age model. We also plan to attempt an age-structured production model, a production model, and the models contained in the DLM toolbox. The data provided includes catches, discards, a CPUE index, length and age compositions and life history information.

Southeast Data, Assessment, and Review

SEDAR 58

Atlantic Cobia

This information is distributed solely for the purpose of peer review. It does not represent and should not be construed to represent any agency determination or policy.

NOTE: Modifications to the model results reported in this report were made during the Review Workshop held November 19-21, 2019. For complete results reflecting those changes, please see the Addendum of the Stock Assessment Report (Section IV)

SECTION III: Assessment Workshop Report
November 2019

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

Document History

November 2019	Original release.

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1. Workshop Proceedings

1.1 Introduction

1.1.1 Workshop Time and Place

The SEDAR 58 Assessment Process was conducted through a series of webinars on the following dates: June 20th, July 17th, August 14th, September 13th, September 23rd, and October 10th, 2019.

1.1.2 Terms of Reference

1. Review any changes in data following the Data Workshop and any analyses suggested by the Data Workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.
2. Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations for each model considered.
    - Fully document and describe the impacts (on population parameters and management benchmarks) of any changes to the model structure, methods, application or fitting procedures made between this assessment and the prior assessment (SEDAR 28).
3. Provide estimates of stock population parameters, if feasible.
    - Include fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship (if applicable), and other parameters as necessary to describe the population.
    - Include appropriate and representative measures of precision for parameter estimates.
    - Compare and contrast population parameters and time series estimated in this assessment with values from the previous assessment (SEDAR 28), and comment on the impacts of changes in data, assumptions, or assessment methods on estimated population conditions.
4. Provide estimates of yield and productivity.
    - Include yield-per-recruit, spawner-per-recruit, and stock-recruitment models.
5. Provide estimates of population benchmarks or management criteria consistent with the available data, applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards. Include values for fishing mortality (including assumed discard mortality if appropriate), spawning stock biomass, fishery yield, SPR, and recruitment for potential population benchmarks.
    - Evaluate existing or proposed management criteria as specified in the management summary.
    - Recommend proxy values when necessary.
    - Compare and contrast reference values estimated in this assessment with values from the previous assessment (SEDAR 28), and comments on the impacts of changes in data, assumptions or assessment methods on reference point differences.
6. Characterize uncertainty in the assessment and estimated values.
    - Consider uncertainty in input data, modeling approach, and model configuration.

  - Provide a continuity model consistent with the prior assessment configuration, if one exists, updated to include the most recent observations. Alternative approaches to a strict continuity run that distinguish between model, population, and input data influences on findings, may be considered.
  - Consider other sources as appropriate for this assessment.
  - Provide appropriate measures of model performance, reliability, and 'goodness of fit'.
  - Provide measures of uncertainty for estimated parameters and model output.
7. Provide declarations of stock status relative to benchmarks, or alternative data poor approaches if necessary.
8. Perform probabilistic analysis of proposed reference points, stock status, and yield.
    - Provide the probability of overfishing at various harvest or exploitation levels.
    - Provide a probability density function for biological reference point estimates.
    - If the stock is overfished, provide the probability of rebuilding within mandated time periods as described in the management summary or applicable federal regulations.
9. Project future stock conditions (biomass, abundance, and exploitation) and develop rebuilding schedules if warranted; including estimated generation time. Stock projections shall be developed in accordance with the following:
    - If stock is overfished
      F=0, F=Fcurrent, F=Fmsy, F=Ftarget
      F=Frebuild (max that rebuild in allowed time)
    - If stock is not overfished
      F=Fcurrent, F=Fmsy, F=Ftarget
    - If data limitations preclude standard projections (i.e. bullets above), explore alternate models to provide management advice.
10. Provide recommendations for future research and data collection.
    - Be as specific as practicable in describing sampling design and sampling intensity.
    - Emphasize items which will improve future assessment capabilities and reliability.
    - Consider data, monitoring, and assessment needs.
11. Review, evaluate, and report on the status and progress of all research recommendations listed in the last assessment, peer review reports, and SSC report concerning this stock.
12. Complete the Assessment Workshop Report in accordance with project schedule deadlines (Section III of the SEDAR stock assessment report).

1.1.3 List of Participants

Assessment PANELISTS	
Katie Siegfried	SEFSC Beaufort – Lead Analyst
Rob Cheshire	SEFSC Beaufort
Jeff Buckel	SAFMC SSC
Mike Denson	SC DNR
Alex Aspinwall	VMRC
Cynthia Jones	ODU
Anne Lange	SAFMC SSC
Kyle Shertzer	SEFSC Beaufort
Erik Williams	SEFSC Beaufort
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Wes Blow	SAFMC Mack/Cobia AP
Collins Doughtie	SAFMC Mack/Cobia AP
Stephen Donalson	SAFMC Mack/Cobia AP
Bill Gorham	SAFMC Mack/Cobia AP
Bill Parker	Fisherman – SC
Lee Southard	Fisherman - GA
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Mel Bell	SAFMC
Steve Poland	SAFMC
Council and Agency STAFF	
Kathleen Howington	SEDAR
Cierra Graham	SAFMC
Christina Wiegand	SAFMC
Mike Errigo	SAFMC
Mike Larkin	SERO
Mike Schmidtke	ASMFC

1.1.4 List of Assessment Workshop Working Papers

Documents Prepared for the Assessment Workshop		
Final Assessment Reports		
SEDAR58-SAR1	Assessment of Atlantic Cobia	To be prepared by SEDAR 58
Reference Documents		
SEDAR58-RD01	SEDAR 28 South Atlantic Cobia Stock Assessment Report	SEDAR 28
SEDAR58-RD02	SEDAR 28 Gulf of Mexico Cobia Stock Assessment Report	SEDAR 28
SEDAR58-RD03	List of documents and working papers for SEDAR28 (South Atlantic Cobia and Spanish Mackerel) – all documents available on the SEDAR website.	SEDAR 28
SEDAR58-RD04	Managing A Marine Stock Portfolio: Stock Identification, Structure, and Management of 25 Fishery Species along the Atlantic Coast of the United States	McBride 2014
SEDAR58-RD05	Chapter 22: Interdisciplinary Evaluation of Spatial Population Structure for Definition of Fishery Management Units (excerpt from Stock Identification Methods – Second Edition)	Cadrin et al. 2014
SEDAR58-RD06	Mitochondrial DNA Analysis of Cobia *Rachycentron canadum* Population Structure Uisng Restriction Fragment Length Polymorphisms and Cytochrome B Sequence Variation	Hrincevich 1993
SEDAR58-RD07	Population Genetic Comparisons among Cobia from the Northern Gulf of Mexico, U.S. Western Atlantic, and Southeast Asia	Gold et al. 2013
SEDAR58-RD08	Population genetics of Cobia (*Rachycentron canadum*): implications for fishery management along the coast of the southeastern United States	Darden et al. 2014
SEDAR58-RD09	Growth, mortality, and movement of cobia (*Rachycentron canadum*)	Dippold et al. 2017

SEDAR58-RD10	Assessment of cobia, *Rachycentron canadum*, in the waters of the U.S. Gulf of Mexico	Williams, 2001
SEDAR58-RD11	Life history of Cobia, *Rachycentron canadum* (Osteichthyes: Rachycentridae), in North Carolina waters	Smith 1995
SEDAR58-RD12	A review of age, growth, and reproduction of cobia *Rachycentron canadum*, from US water of the Gulf of Mexico and Atlantic ocean	Franks and Brown-Peterson, 2002
SEDAR58-RD13	An assessment of cobia in Southeast US waters	Thompson 1995
SEDAR58-RD14	Reproductive biology of cobia, *Rachycentron canadum*, from coastal waters of the southern United States	Brown-Peterson et al. 2001
SEDAR58-RD15	Age and growth of cobia, *Rachycentron canadum*, from the northeastern Gulf of Mexico	Franks et al. 1999
SEDAR58-RD16	Synopsis of biological data on the cobia *Rachycentron canadum* (Pisces: Rachycentridae)	Shaffer and Nakamura 1989
SEDAR58-RD17	Age, growth, and reproductive biology of greater amberjack and cobia from Louisiana waters	Thompson et al.1991
SEDAR58-RD18	Cobia (*Rachycentron canadum*) stock assessment study in the Gulf of Mexico and in the South Atlantic	Burns et al. 1998
SEDAR58-RD19	Gonadal maturation in the cobia, *Rachycentron canadum*, from the northcentral Gulf of Mexico	Lotz et al. 1996
SEDAR58-RD20	Length-weight relationships, location and depth distributions for select Gulf of Mexico reef fish species	Pulver & Whatley 2016
SEDAR58-RD21	Inshore spawning of cobia (*Rachycentron canadum)* in South Carolina	Lefebvre & Denson 2012
SEDAR58-RD22	Determining the stock boundary between South Atlantic and Gulf of Mexico managed stocks of Cobia, *Rachycentron canadum*, through the use of telemetry and population genetics	Perkinson et al. 2018
SEDAR58-RD23	SAFMC Mackerel Cobia Advisory Panel and Cobia Sub-Panel Cobia Fishery Performance Report April 2017	SAFMC Mackerel Cobia AP & Cobia Sub-Panel 2017

SEDAR58-RD24	Spawning of the Cobia, *Rachycentron canadum*, in the Chesapeake Bay Area, with Observations of Juvenile Specimens	Joseph et al. 1964
SEDAR58-RD25	SEDAR28-DW02: South Carolina experimental stocking of Cobia *Rachycentrom canadum*	Denson 2012
SEDAR58-RD26	Applying network methods to acoustic telemetry data: Modeling the movements of tropical marine fishes	Finn et al. 2014
SEDAR58-RD27	Developing a deeper understanding of animal movements and spatial dynamics through novel application of network analyses	Jacoby et al. 2012
SEDAR58-RD28	Status of the South Carolina Fisheries for Cobia	Hammond 2001
SEDAR58-RD29	Dynamic ocean management increases the efficiency and efficacy of fisheries management	Dunn et.al. 2016
SEDAR58-RD30	Using Pop-off Satellite Archival Tags To Monitor and Track Dolphinfish and Cobia	Hammond 2008
SEDAR58-RD31	Cusk (Brosme brosme) and climate change: assessing the threat to a candidate marine fish species under the US Endangered Species Act	Hare et al 2012
SEDAR58-RD32	Dynamic habitat suitability modelling reveals rapid poleward distribution shift in a mobile apex predator	Hill et. al. 2016
SEDAR58-RD33	Seasonal forecasting of tuna habitat for dynamic spatial management	Hobday et. al. 2011
SEDAR58-RD34	Near real-time spatial management based on habitat predictions for a longline bycatch species	Hobday et. al. 2006
SEDAR58-RD35	Seasonal forecasting for decision support in marine fisheries and aquaculture	Hobday et. al. 2016
SEDAR58-RD36	Changing spatial distribution of fish stocks in relation to climate and population size on the Northeast United States continental shelf	Nye et.al. 2009

SEDAR58-RD37	Projecting changes in the distribution and productivity of living marine resources: A critical review of the suite of modelling approaches used in the large European project VECTORS	Peck et. al. 2016
SEDAR58-RD38	Climate Change Affects Marine Fishes Through the Oxygen Limitation of Thermal Tolerance	Portner and Knust 2007
SEDAR58-RD39	Effects of water temperature and fish size on growth and bioenergetics of cobia (Rachycentron canadum)	Sun and Chen 2014
SEDAR58-RD40	Effect of temperature on growth and energy budget of juvenile cobia (Rachycentron canadum)	Sun et. al. 2006
SEDAR58-RD41	Managing living marine resources in a dynamic environment: The role of seasonal to decadal climate forecasts	Tomoassi et. al. 2017
SEDAR58-RD42	Model-estimated conversion factors for calibrating Coastal Household Telephone Survey (CHTS) charterboat catch and effort estimates with For-Hire Survey (FHS) estimates in the Atlantic and Gulf of Mexico with application to red grouper and greater amberjack	Dettloff & Matter 2019
SEDAR58-RD43	Understanding the Virginia Cobia Stock Through Analysis of Trophy Fish	Weng et. al. 2019
SEDAR58-RD44	Technical Documentation of he Beaufort Assessment Model	Williams and Shertzer, 2015
SEDAR58-RD45	Evolutionary assembly rules for fish life histories	Charnov et.al. 2013

1.2 Statements Addressing Each Term of Reference

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

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

Section 2 reviews the data and explains the deviations from Data Workshop recommendations.

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

- Fully document and describe the impacts (on population parameters and management benchmarks) of any changes to the model structure, methods, application or fitting procedures made between this assessment and the prior assessment (SEDAR 28)."

The data available supported the use of the Beaufort Assessment Model. The impacts of changing model structure or input data are shown through sensitivity analysis. The Panel agreed to conduct a continuity run in pieces, as a true continuity is often not possible to achieve. In particular, sensitivities S1-S3e, and S6 incorporate the previous assessment's data and/or assumptions.

3. "Provide estimates of stock population parameters, if feasible.

- Include fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship (if applicable), and other parameters as necessary to describe the population.
- Include appropriate and representative measures of precision for parameter estimates.
- Compare and contrast population parameters and time series estimated in this assessment with values from the previous assessment (SEDAR 28), and comment on the impacts of changes in data, assumptions, or assessment methods on estimated population conditions."

Requested values are in Tables 6-16 and measures of precision are shown in Figures 17, and 20-24. Comparison plots are provided in Figures 39 and 40 and a discussion is in section 4.9.2.

4. "Provide estimates of yield and productivity.

- Include yield-per-recruit, spawner-per-recruit, and stock-recruitment models."

Figures 16 and 18-19 display requested relationships. The stock-recruit model is not meant to be a Beverton-Holt, rather, it is used with steepness fixed at 0.99 for computational convenience.

5. “Provide estimates of population benchmarks or management criteria consistent with the available data, applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards. Include values for fishing mortality (including assumed discard mortality if appropriate), spawning stock biomass, fishery yield, SPR, and recruitment for potential population benchmarks.

- Evaluate existing or proposed management criteria as specified in the management summary.
- Recommend proxy values when necessary.
- Compare and contrast reference values estimated in this assessment with values from the previous assessment (SEDAR 28), and comments on the impacts of changes in data, assumptions or assessment methods on reference point differences.”

All requested values are provided in Tables 6-16. A proxy value was chosen by the Panel ($F_{40\%}$). Though $F_{40\%}$ and F_{msy} are not directly comparable, the comparison plots are provided (Figure 39)

6. “Characterize uncertainty in the assessment and estimated values.

- Consider uncertainty in input data, modeling approach, and model configuration.
- Provide a continuity model consistent with the prior assessment configuration, if one exists, updated to include the most recent observations. Alternative approaches to a strict continuity run that distinguish between model, population, and input data influences on findings, may be considered.
- Consider other sources as appropriate for this assessment.
- Provide appropriate measures of model performance, reliability, and ‘goodness of fit’.
- Provide measures of uncertainty for estimated parameters and model output.”

Uncertainty was characterized using an ensemble modeling approach. This approach entails creating a new data set by varying input data using either/both bootstrapping or/and monte carlo methods and running the assessment model for each new data set. The set of models is the ensemble from which we calculate statistics to provide uncertainty estimates. Section 3.7 describes the method, and Table 16 provides the medians and standard deviations of the ensemble model outputs.

7. “Provide declarations of stock status relative to benchmarks, or alternative data poor approaches if necessary.”

Table 16 provides the needed quantities.

8. “Perform probabilistic analysis of proposed reference points, stock status, and yield.

- Provide the probability of overfishing at various harvest or exploitation levels.
- Provide a probability density function for biological reference point estimates.”

Densities of reference points are provided in Figures 20-22. The stochastic projections are completed to provide probability of overfishing at various harvest levels (Figures 36-38).

9. “Project future stock conditions (biomass, abundance, and exploitation) and develop rebuilding schedules if warranted; including estimated generation time. Stock projections shall be developed in accordance with the following:

- If stock is not overfished

$F=F_{current}$, $F=F_{msy}$, $F=F_{target}$”

Section 3.8.3 describes the projection scenarios. The F_{target} *chosen by the Panel was 75% of the* $F_{40\%}$ *value. Results are described in section 4.11 and shown in Tables 18-20 and Figures 36-38.*

10. “Provide recommendations for future research and data collection.

- Be as specific as practicable in describing sampling design and sampling intensity.
- Emphasize items which will improve future assessment capabilities and reliability.
- Consider data, monitoring, and assessment needs.”

The research recommendations were compiled from members of the Panel and reported in section 5.3 of the report.

11. “Review, evaluate, and report on the status and progress of all research recommendations listed in the last assessment, peer review reports, and SSC report concerning this stock.”

The research recommendations in Section 5.3 are largely carried over from the previous assessment. There has not been a fishery independent sampling program developed. The age sampling program has expanded to Virginia, but is still a carcass collection program rather than a port sampling design. There is work underway to better characterize reproductive parameters, though the work is not complete (see the SEDAR 58 Stock ID workshop report). The telemetry work for this species is ongoing, and with continuing funding will help to provide better mortality estimates and may help to characterize the migratory dynamics.

12. “Complete the Assessment Workshop Report in accordance with project schedule deadlines (Section III of the SEDAR stock assessment report).”

Report submitted in a timely manner.

2 Data Review and Update

In this benchmark assessment, the start year is 1986 and the terminal year is 2017. The composition data and non-hindcasted landings data start in 1986, and the Assessment Panel decided to start the model in the year when the best data become available. The Panel's decision was also based on model runs that demonstrated the fact that including earlier years of hindcasted landings data did not affect model results. Data sources from SEDAR28 were also considered here; however, all data were re–examined and evaluated using current methodologies, including data prior to 2011 (the terminal year of SEDAR28). The input data for this assessment are described below, with focus on modifications from recommendations of the Data Workshop and those used in the last assessment:

2.1 Data Review

In this benchmark assessment, the Beaufort Assessment Model (BAM) was fitted to data sources similar to those used in the SEDAR28 benchmark with some modifications and additions.

- Landings: Commercial (all gears), and General recreational (headboat, charterboat, and private boat modes).
- Discards: Commercial (handline and nets), General recreational (all modes).
- Index of abundance: Headboat CPUE
- Length compositions of landings: Commercial handline
- Age compositions of landings: General recreational

In addition to data fitted by the model, this assessment utilized life-history information that was treated as input. Such inputs, some of which remained the same for this assessment as were used in the last assessment, were provided by the life history working group: natural mortality, female maturity at age, sex ratio, and somatic growth. The discard mortality rates were compiled by the discard mortality working group.

2.2 Data Update

The following is a summarization of the data differences between this benchmark assessment and the last (SEDAR28). Data available for this assessment are summarized in Tables 1–5.

- Discards and discard mortality: The discard mortality working group provide a gillnet discard mortality rate of 0.55, compared to 0.51 in SEDAR28. Commercial and recreational discards were updated through 2017. The estimates for commercial and recreational discards are either model- or ratio-based, therefore the entire time series of estimates were provided.
- Indices of abundance: As per the data workshop recommendations, neither the SCDNR index of abundance, nor the MRFSS index of abundance were used in this assessment, though they were in the SEDAR28 assessment. The headboat index is the sole index used in this benchmark assessment.
- Size/age compositions landings: Commercial and general recreational composition data were corrected and updated through 2017, the terminal year of the assessment, though general recreational length compositions and commercial age compositions were not used. All of the updated composition data are subject to the same minimum sample size used in SEDAR28 (n=30 trips for lengths and n=10 trips for ages) though sample sizes (i.e., trip numbers) were not available for several years and states. The number of fish sampled represented the sample size for general recreational compositions, as often a single fish is caught per trip.

- Growth curves: Additional growth curves were requested by the Assessment Panel, and the analyst and Life History Working Group chairperson conducted the analyses. The Panel requested a female–only and a landings–only growth curve. The landings–only growth curve is meant to represent the average size of the fish captured by the fleet, therefore the fitting procedure did not adjust for the size limit. The females–only growth curve is meant to be used to calculate the female biomass, and therefore needs to reflect the population. Size correction methodology was used for the female–only curve to account for fishery dependent observations (lengths) being truncated by the size limit.
- The iterative reweighting method used in SEDAR28 was not used for composition data, as the Dirichlet multinomial distribution was used. The Dirichlet multinomial is a self-weighting distribution, thus removing the need for weights on the composition data. The index was weighted using the iterative reweighting procedure.
- The Charnov et al. (2013) method was used to calculate natural mortality. The Charnov et al. method is a meta–analysis that includes data from multiple studies that generate methods to estimate natural mortality. The Lorenzen method (Lorenzen 1996) used in SEDAR28 is one method used in the Charnov et al. meta–analysis.

2.2.1 Discard Mortality

The discard mortalities for all the gears were revisited by the discard mortality working group. The group reviewed five data sources from state and federal government agencies. After discussion the observed immediate discard mortality for gillnet gears was 55%. The working group recommended an upper bound of 77% and a lower bound of 36% discard mortality as was recommended during SEDAR28. For lines, the group noted that the overall discard mortality of cobia was relatively low. Estimates of discard mortality ranged from 0% to 12.4%. The group determined that a 0% lower bound estimate was not realistic and therefore adopted the lower bound of 2% from SEDAR28. The group decided that 5% was a reasonable discard mortality estimate based on results from additional data sources and the discard mortality estimate from SEDAR28.

2.2.2 Recreational Landings and Discards

Estimates were available from the recalibrated MRIP data, and were used as input for the landings and discards for all recreational modes except headboat through 2017. Headboat landings were provided through 2017, and headboat discards were calculated using a model-based approach. Headboat and general recreational landings and discards were combined into one general recreational fleet, by applying the discard mortality rate to live discards and combining the result with the landings to create one time series of removals for the general recreational fleet.

2.2.3 Commercial Landings and Discards

The commercial discards were revised for the entire time series, as it is a model-based approach, and provided through 2017. Commercial landings were updated through 2017. Commercial landings and discards were combined into one time series, consistent with SEDAR28, by applying the discard mortality rate to live discards and combining the result with the landings for one time series of removals for the commercial fleet.

2.2.4 Indices of Abundance

The fishery-dependent index was considered in light of new management measures effected since the last assessment. Closures for the recreational season have been intermittent since 2015. The change in closures since SEDAR28 clearly affects catch per effort, and it likely invalidates catch per effort as a meaningful index of abundance. Thus, the headboat index was only updated through 2015 for this assessment. This index was the only index of abundance used in the assessment.

2.2.5 Length Compositions

Length compositions for both fleets were corrected and updated through 2017. The Assessment Panel considered several possible applications of length composition data. The Panel considered including general recreational length compositions in years with no age composition data, or when the age data were sparse. However, no growth curve is estimated internally, and the quality of the age compositions is such that the length compositions were not needed to supplement, and thus they were not used in the assessment. For the commercial fleet, length compositions were inadequate to produce annual length compositions. Therefore, the Assessment Panel agreed to pool the commercial length compositions across years into a single composition.

2.2.6 Age Compositions

The commercial age compositions were discussed by the Assessment Panel, in light of the fact that the samples for ageing were not randomly sampled. The Assessment Panel decided to not use the commercial age compositions, as they did not represent the fleet. The general recreational age compositions were discussed at both the data workshop and during the assessment process. The majority of the samples are from carcass collection programs in Virginia and South Carolina. The general recreational age samples from SEDAR28 were largely carcass samples as well, therefore the discussion focused on whether the samples were different from each state. In order to account for differences, the Assessment Panel decided to weight the age samples by landings in order to provide an age composition representative of the entire fleet across states.

3 Stock Assessment Methods

This assessment updates the primary model applied during the SEDAR28 benchmark for cobia. The methods are reviewed below, and any changes since the SEDAR28 benchmark are noted.

3.1 Overview

This assessment used the Beaufort Assessment Model (BAM, Williams and Shertzer 2015), which applies an integrated catch-age formulation, implemented with the AD Model Builder software (Fournier et al. 2012). In essence, the model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2014). 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). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic such as red porgy, tilefish, blueline tilefish, gag, greater amberjack, snowy grouper, vermilion snapper, and red snapper.

3.2 Data Sources

The catch-age model included data from two fleets that caught cobia in southeastern U.S. waters north of the Georgia Florida border: commercial and general recreational. The model was fitted to data on annual removals (in units of 1000 lb whole weight for commercial and 1000 fish for general recreational), which comprised landings and dead discards. Dead discards were computed using the discard mortalities provided at the Data Workshop. The model was also fitted to pooled length compositions of commercial landings, annual age compositions of general recreational landings, and a fishery-dependent index (headboat). Data used in the model are tabulated in §2 of this report.

3.3 Model Configuration

Model structure and equations of the BAM are detailed in Williams and Shertzer (2015). The assessment time period was 1986–2017. 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 exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The model included age classes $1 - 12^{+}$, where the oldest age class 12^{+} allowed for the accumulation of fish (i.e., plus group).

3.3.2 Initialization

Initial (1986) abundance at age was estimated in the model as follows. First, the equilibrium age structure was computed for ages 2–12 based on natural and initial fishing mortality (F_{init}), where F_{init} is an estimated parameter. Second, lognormal deviations around that equilibrium age structure were estimated. The deviations were lightly penalized, such that the initial abundance of each age could vary from equilibrium if suggested by early composition data, but remain estimable if data were uninformative. Given the initial abundance of ages 2–12, initial (1986) abundance of age-1 fish was computed using the same methods as for recruits in other years (described below).

3.3.3 Growth

Mean size at age of the population (total length, TL) was modeled with the von Bertalanffy equation (Figure 1), and weight at age (whole weight, WW) was modeled as a function of total length. Parameters of growth and conversions (TL-WW) were estimated by the Life History Working Group and were treated as input to the assessment model. The von Bertalanffy parameter estimates for the population from the DW were $L_{\infty} = 1262$, $K = 0.31$, and $t_0 = -0.53$. However, the Panel decided to use two modified growth curves instead; one to fit to landings (landings only with no size limit correction), and one to calculate spawning stock biomass (females only with a size limit correction) For the landings–only growth curve, $L_{\infty} = 1287$, $K = 0.26$, and $t_0 = -1.74$, and for the females–only growth curve, $L_{\infty} = 1334$, $K = 0.32$, and $t_0 = -0.49$. For fitting length composition data, the distribution of size at age was assumed normal with coefficient of variation (CV) estimated by the assessment model. A constant CV, rather than constant standard deviation, was suggested by the size at age data. Only the CV for the landings–only curve is estimated within the model.

3.3.4 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 Charnov et al. (2013). The Charnov et al. (2013) approach relates the natural mortality at age to the von Bertalanffy growth equation parameters (of the whole population) and length at age: $\mathrm{M}_a = K \times [L_a/L_\infty]^{-1.5}$, where L_∞ and K are von Bertalanffy parameters and L_a is length at age.

3.3.5 Female maturity and Spawning stock

Female maturity was modeled with a logistic function; the age at 50% female maturity was estimated to be ~ 1 year. No new data on maturity were available for this assessment, therefore the values from SEDAR28 were applied. Spawning stock was modeled as biomass of mature females measured at the time of peak spawning. For cobia, peak spawning was considered to occur mid–June.

3.3.6 Recruitment

In this assessment, steepness was not estimable, even when applying a prior distribution to inform the estimation (Shertzer and Conn 2012). Likelihood profiles showed no minimum in the likelihood surface either, therefore the Panel concluded that the stock–recruit relationship is not well–defined. In the assessment, annual recruitment was estimated as deviations around an overall average. For coding convenience, this was achieved by using a Beverton–Holt recruitment model with steepness fixed at 0.99 to represent average recruitment. Expected recruitment of age-1 fish was predicted from the fixed average with annual variation in recruitment assumed to occur with lognormal deviations beginning in 1986.

3.3.7 Landings

The model included time series of landings from two fleets: commercial (all gear) and general recreational (headboat, charterboat, and private boats combined). Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in units of weight (1000 lb whole weight for commercial and 1000 fish for recreational). Observed landings were provided back to the first assessment year (1986) for each fleet.

3.3.8 Discards

Live and dead commercial discards were provided from 1993 to 2017. Live commercial discards were reduced to dead discards using the gear-specific mortality rates, as suggested by the Panel described in §2.2.1, then the dead discards were combined with landings to produce one removal time series. Live discards from the general recreational fleet were available from 1986-2017, and the single removals time series was computed similarly to what was done for the commercial fleet.

3.3.9 Fishing

For each time series of landings, 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.

3.3.10 Selectivities

Selectivity curves were estimated using a parametric approach. This approach applies plausible structure on the shape of the selectivity curves, and achieves greater parsimony than occurs with unique parameters for each age. Selectivities of landings from all fleets were modeled as flat-topped, using a two-parameter logistic function. The selectivity of the fishery-dependent index was the same as that of the general recreational fleet.

Age and length composition data are critical for estimating selectivity parameters, and ideally, a model would have sufficient composition data from each fleet over time to estimate distinct selectivities in each time block assumed in the model. The commercial length compositions informed the commercial fleet selectivity, and only one time block was modeled due to lack of regulatory change in the fleet. The general recreational age compositions informed the general recreational fleet selectivities. Two time blocks were modeled due to reports from stakeholders and state scientists that fishing behaviors changed in 2007. The Panel requested multiple runs with different pivotal years for selectivity time blocks (2005–2009), and 2007 was the pivotal year that resulted in the best overall likelihood and best general age composition likelihood. The use of a second time block for the selectivity of the general recreational fleet is a departure from the assumption of time–invariant selectivity in SEDAR28.

3.3.11 Indices of abundance

The model was fit to a fishery–dependent index standardized from headboat logbooks (1991–2015). The predicted index is conditional on selectivity of the general recreational fleet and was computed from abundance at the midpoint of the year.

3.3.12 Catchability

In the BAM, catchability scales indices of relative abundance to estimated population abundance at large. Several options for time-varying catchability were implemented in the BAM following recommendations of the 2009 SEDAR procedural workshop on catchability (SEDAR Procedural Guidance 2009). In particular, the BAM allows for density dependence, linear trends, and random walk, as well as time-invariant catchability. For cobia, catchability of the index was assumed to be constant, as the Panel decided there was little reason to think catchability for cobia on headboats has changed since 1986.

3.3.13 Biological reference points

Biological reference points (benchmarks) were calculated based on the fishing rate that would allow a stock to attain 40% of the maximum spawning potential which would have been obtained in the absence of fishing mortality. Computed benchmarks included $L_{\mathrm{F40\%}}$, fishing mortality rate at $L_{\mathrm{F40\%}}$ ($F_{40\%}$), and spawning stock at $L_{\mathrm{F40\%}}$ ($\mathrm{SSB}_{\mathrm{F40\%}}$)(Gabriel and Mace 1999). In this assessment, spawning stock measures biomass of mature females. 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 fishery estimated as the full F averaged over the last three years of the assessment.

3.3.14 Fitting criterion

The fitting criterion was a penalized likelihood approach in which observed landings were fit closely, and observed composition data and the abundance index were fit to the degree that they were compatible. Landings and index data were fitted using lognormal likelihoods. Length and age composition data were fitted using the Dirichlet-multinomial distribution, with sample size represented by the annual number of fish, adjusted by an estimated variance inflation factor.

The SEDAR28 benchmark fit composition data using the multinomial distribution, and many SEDAR assessments since then have applied a robust version of the multinomial likelihood, as recommended by Francis (2011). More recent work has questioned use of the multinomial distribution in stock assessment models (Francis 2014), and of the alternative distributions, two appear most promising, the Dirichlet-multinomial and logistic-normal (Francis 2017; Thorson et al. 2017). Both are self-weighting and therefore iterative re-weighting (e.g., Francis (2011)) is unnecessary, and both better account for intra-haul correlations (i.e., fish caught in the same set are more alike in length or age than fish caught in a different set). The Dirichlet-multinomial allows for observed zeros (the logistic-normal does not), and has recently been implemented in Stock Synthesis (Methot and Wetzel 2013). This assessment used the Dirichlet-multinomial distribution in the base run.

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 modified the effect of the input CVs. In this application to cobia, CVs of landings (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 to the landings, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). Weights on the index were adjusted iteratively, starting from initial weights in an attempt to achieve standard deviations of normalized residuals (SDNRs) near 1.0.

The compound objective function also included several penalties or prior distributions, applied to CV of growth (based on the empirical estimate), $F_{\text{initratio}}$ (prior of 1.0), and selectivity parameters. Penalties or 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.

3.3.15 Configuration of base run

The base run was configured as described above. However, the base run configuration was not considered to represent all uncertainty. Sensitivities, retrospective analyses, and ensemble modeling was conducted to better characterize the uncertainty in base run point estimates.

3.3.16 Sensitivity analyses

Sensitivity runs were chosen to investigate issues that arose specifically with this benchmark assessment. They were intended to demonstrate directionality of results with changes in inputs or simply to explore model behavior, and not all were considered equally plausible. Sensitivity runs vary from the base run as follows.

- S1: Start model in 1950 to match SEDAR28 start year.
- S2: Include length compositions for the general recreational fleet.
- S3: Use the life history values from SEDAR28. Runs 3a–3e incrementally and additively incorporate each value: length–weight relationship, time of spawn, sex ratio, growth curve, and natural mortality.

- S4: Remove the headboat index.
- S5: Smooth the peak in general recreational removals in 1996 (used the geometric mean of 2 years before and after peak).
- S6: Shift general recreational landings down 3 fold.
- S7: Used the bounds of ensemble parameters that would reach upper bound of status. Runs 7a–c are each parameter, or set of parameters, separately: Landings and discards +1SD, and the upper bound of discard mortality; the lower bound of M using the von Bertalanffy parameters bounds; and the index +1SD.
- S8: Used the bounds of ensemble parameters that would reach lower bound of status. Runs 8a–c are each parameter, or set of parameters, separately: Landings and discards -1SD, and the lower bound of discard mortality; the upper bound of M using the von Bertalanffy parameters bounds; and the index -1SD.
- S9: Runs a–e are the 5 retrospective peels. Retrospective analyses, or peels, were run by incrementally dropping one year at a time for five iterations making the terminal years 2016, 2015, 2014, 2013, and 2012.
- S10: Shift general recreational landings up 3 fold.

3.4 Parameters Estimated

The model estimated annual fishing mortality rates of each fleet (66 parameters), selectivity parameters (6 parameters), Dirichlet-multinomial variance inflation factors (2 parameters), a catchability coefficient associated with the index (1 parameter), initial mean recruitment (1 parameter), initial fishing mortality (1 parameter), variance of the recruitment deviations (1 parameter), annual recruitment deviations (31 parameters), deviations in the initial age structure (15 parameters), and CV of size at age for the landings growth curve (1 parameter).

3.5 Per Recruit and Equilibrium Analyses

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 MSY proxy-related benchmarks (described in §3.6), 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 of the assessment (2015–2017).

3.6 Benchmark/Reference Point Methods

In this assessment of cobia, the quantities $F_{40\%}$, $\mathrm{SSB}_{\mathrm{F}40\%}$, $B_{\mathrm{F}40\%}$, and $L_{\mathrm{F}40\%}$ were estimated as proxies for MSY–based reference points. Steepness was not reliably estimable, so the stock-recruit relationship was not used to identify a maximum yield. Instead, steepness was fixed at 0.99 in order to assume an average level of recruitment while estimating deviations around the mean. $F_{40\%}$ was used by consensus of the Panel to generate fishing benchmarks. However, because the stock-recruitment relationship was not estimated, assumptions about recruitment are required to generate biomass benchmarks. Here, equilibrium recruitment was assumed equal to expected recruitment (arithmetic average). On average, expected recruitment is higher than that estimated directly from the spawner-recruit curve, because of lognormal deviation in recruitment. Thus, in this assessment, 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,

$$R_{eq} = \frac{R_0\left[\varsigma 0.8h\Phi_F - 0.2(1-h)\right]}{(h-0.2)\Phi_F} \tag{1}$$

where R_0 is virgin recruitment, h is steepness which is fixed in this assessment, and $\Phi_F = \phi_F/\phi_0$ is spawning potential ratio given growth, maturity, and total mortality at age (including natural and fishing mortality rates). Because steepness is fixed at 0.99, R_{eq} as a function of F is approximately a straight horizontal line. 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 the highest ASY, and the estimate of $L_{\mathrm{F}40\%}$ is that ASY. The value of $F_{40\%}$ is the F giving 40% spawning potential ratio. The estimates of $L_{\mathrm{F}40\%}$ and $\mathrm{SSB}_{\mathrm{F}40\%}$ follow from the corresponding equilibrium age structure and recruitment.

Estimates of $L_{\mathrm{F}40\%}$ 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 (2015–2017). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of $L_{\mathrm{F}40\%}$ and related benchmarks.

The maximum fishing mortality threshold (MFMT) is proposed to be set to $F_{40\%}$, and the minimum stock size threshold (MSST) as $\mathrm{MSST} = 75\%\mathrm{SSB}_{\mathrm{F}40\%}$. Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. Current status of the stock is represented by SSB in the latest assessment year (2017), and current status of the fishery is represented by the geometric mean of F from the latest three years (2015–2017).

3.7 Uncertainty and Measures of Precision

For the base run of the catch-age model (BAM), uncertainty in results and precision of estimates was computed thoroughly through an ensemble modeling approach (Scott et al. 2016) 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 stock assessment (Restrepo et al. 1992; Legault et al. 2001; SEDAR 2004; 2009; 2010). 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 assessment model many times with different values of “observed” data and key input parameters. A chief advantage of the ensemble modeling approach is that the resulting ensemble model describes a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity runs. A minor disadvantage of the approach is that computational demands are relatively high, though parallel computing can somewhat mitigate those demands.

In this assessment, the BAM was successively re-fit in $n = 4000$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. The value of $n = 4000$ was chosen because at least 3000 runs were desired, and it was anticipated that not all runs would be valid. Of the 4000 trials, approximately 0.975% were discarded, based on a 0.5% trim on $R0$ or because the model did not properly converge. This left $n = 3961$ trials used to characterize uncertainty, which was sufficient for convergence of standard errors in management quantities.

The ensemble model should be interpreted as providing an approximation to the uncertainty associated with each output. The results are approximate as all runs are given equal weight in the results, yet some might provide better fits to data than others.

3.7.1 Bootstrap of observed data

To include uncertainty in time series of observed landings, discards, and the index of abundance, multiplicative lognormal errors were applied through a parametric bootstrap. To implement this approach in the ensemble modeling, 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 ($\hat{O}_{s,y}$),

$$O_{s,y} = \hat{O}_{s,y}[\exp(x_{s,y} - \sigma^2_{s,y}/2)] \tag{2}$$

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, $\sigma_{s,y} = \sqrt{\log(1.0 + CV^2_{s,y})}$. As used for fitting the base run, CVs of commercial landings in most years were assumed to be 0.05. The CVs for recreational landings and both commercial and recreational discards were those provided by the data providers(see Table 3). The CVs of indices of abundance were those provided by the data providers (see 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 were drawn at random with replacement using the cell probabilities of the original data. For each year of each data source, the number of individuals sampled was the same as in the original data (number of fish), and the effective sample sizes used for fitting (number of trips) was unmodified.

3.7.2 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 A point estimate of natural mortality at age was provided by the Life History Working Group, though no uncertainty was provided. Because natural mortality is inherently uncertain, the Panel attempted to vary M in the ensemble modeling approach in a way consistent with Charnov et al. (2013). The model in Charnov et al. (2013) is based on a linear regression in log space of the relationship between M and von Bertalanffy growth parameters. Charnov et al. (2013) provides estimates of the standard error of the slope and intercept of that regression. In this step of the ensemble modeling, we used those estimates of uncertainty to regenerate a new slope and intercept, assuming normal distributions, from which we calculated a new natural mortality vector at age for each of the 4000 models.

Discard mortalities Similarly, discard mortalities (δ) were subjected to Monte Carlo variation as follows. The discard mortality working group provided point estimates and an upper and lower bound for each gear type. A new value for commercial and recreational lines discard mortality was drawn for each model from a uniform distribution (range [0.02, 0.12]) with center equal to the point estimate ($\delta = 0.05$). Similarly, a new value for commercial gillnet discard mortality was drawn for each model from a uniform distribution (range [0.36, 0.77]) with center equal to the point estimate ($\delta = 0.55$).

Recreational Landings and Discards CVs The recreational landings and all discards were allowed to vary based on the CVs provided. Once the landings and discards time series were drawn for each fleet and gear, the discards were decremented by the selected value for discard mortality relevant to the gear, and the result was added to the landings for each fleet.

3.8 Projections—Probabilistic Analysis

Projections were run to predict stock status in years after the assessment, 2018–2024, as requested in the TORs.

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 MSY benchmarks (§3.6).

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.

3.8.1 Initialization of projections

Although the terminal year of the assessment is 2017, the assessment model computes abundance at age (N_a) at the start of 2018. For projections, those estimates were used to initialize N_a. However, the assessment has no information to inform the strength of 2018 recruitment, and thus it computes 2018 recruits (N_1) as the expected value, that is, without deviation from the estimate of mean recruitment, 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 (2018) of projections included this variability in N_1. The deterministic projections were not adjusted in this manner, because deterministic recruitment follows mean recruitment.

Fishing rates that define the projections were assumed to start in 2020. Because the assessment period ended in 2017, the projections required an initialization period (2018 and 2019). F_{current} was assumed during the interim period.

3.8.2 Uncertainty of projections

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 2018) 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 mean annual recruitment values ($\bar{R}_y$). Variability is added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{3}$$

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 component.

The procedure generated 20,000 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.

3.8.3 Projection scenarios

The TORs for this assessment described three projections scenarios: $F = F_{40\%}$, $F = 75\%F_{40\%}$, and $F = F_{\text{current}}$. In each, the landings in the interim period (2018–2019) were calculated based on F_{current}.

- Scenario 1: $F = F_{\text{current}}$, with F_{current} also assumed for the interim period.
- Scenario 2: $F = F_{40\%}$, with F_{current} assumed for the interim period.
- Scenario 3: $F = 75\%F_{40\%}$, with L_{current} assumed for the interim period.

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

The Beaufort Assessment Model (BAM) fit well to the available data. Predicted length compositions from the commercial fishery were reasonably close to observed data, as were predicted age compositions (Figure 2). The model was configured to fit observed commercial and recreational landings closely (Figures 3–4). The fit to the index of abundance generally captured the observed trend but not all annual fluctuations (Figure 5).

4.2 Parameter Estimates

Estimates of all parameters from the catch-age model are shown in Appendix B. Estimates of management quantities and some key parameters, such as those of the spawner-recruit model, are reported in sections below.

4.3 Stock Abundance and Recruitment

Estimated abundance at age shows little trend, though the last few years are some of the lowest in the time series (Figure 6; Table 6). Total estimated abundance at the end of the assessment period showed a sharp decline since 2013. Annual number of recruits is shown in Table 6 (age-1 column) and in Figure 7. In the most recent decade, a notably strong year class (age-1 fish) was predicted to have occurred in 2010, but the most recent four years had lower than average recruitment.

4.4 Total and Spawning Biomass

Estimated biomass at age, as well as total biomass and spawning biomass followed a similar pattern as abundance at age (Figures 8 and 9 ; Tables 7 and 8).

4.5 Selectivity

Selectivities of landings from commercial and recreational fleets are shown in Figures 10–11. In the general recreational fleet, the selectivity shifted toward younger ages with the reported change in fisher behavior. In the most recent years, full selection occurred near age-4 for both fleets.

Average selectivities of landings were computed from F-weighted selectivities in the most recent period of regulations (Figure 12). These average selectivities were used to compute benchmarks. All selectivities from the most recent period, including average selectivities, are tabulated in Table 9.

4.6 Fishing Mortality and Landings

The estimated fishing mortality rates (F) generally increased through the assessment time period, with a previous peak in 1996 (Figure 13). The general recreational fleet has been the largest contributor to total F (Table 10). Estimates of total F at age are shown in Table 11. Table 12 shows total landings at age in numbers, and Table 13 in weight. In general, the majority of estimated landings were from the general recreational fleet (Figures 14, 15; Tables 14, 15).

4.7 Spawner-Recruitment Parameters

The spawner-recruit relationship with fixed steepness, from which we estimate deviations from the average recruitment, is shown in Figure 16 depicted graphically by recruits per spawner as a function of spawners. Values of recruitment-related parameters were as follows: unfished age-1 recruitment $\widehat{R_0} = 1,336,484$, and standard deviation of recruitment residuals in log space $\widehat{\sigma_R} = 0.53$. Uncertainty in these quantities was estimated through the ensemble modeling (Figure 17).

4.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 18). Per recruit analyses applied the most recent selectivity patterns averaged across fleets, weighted by F from the last three years (2015–2017).

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 19). By definition, the F that provides 40% SPR is $F_{40\%}$, and the corresponding landings and spawning biomass are $L_{\mathrm{F40\%}}$ and $\mathrm{SSB}_{\mathrm{F40\%}}$.

4.9 Benchmarks / Reference Points

As described in §3.6, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the expected recruitment (Figure16). Reference points estimated were $F_{40\%}$, $L_{\mathrm{F40\%}}$, $B_{\mathrm{F40\%}}$ and $\mathrm{SSB}_{\mathrm{F40\%}}$. Standard deviations of benchmarks were approximated as those from ensemble model (§3.7).

Estimates of benchmarks are summarized in Table 16. Point estimates of $L_{\mathrm{F40\%}}$-related quantities were $F_{40\%} = 0.69$ (y^{-1}), $L_{\mathrm{F40\%}} = 3923.780$ (klb), $B_{\mathrm{F40\%}} = 0.29$ (mt), and $\mathrm{SSB}_{\mathrm{F40\%}} = 2980.975$ (mt). Distributions of these benchmarks from the ensemble model are shown in Figure 20.

4.9.1 Status of the Stock and Fishery

The estimated time series of spawning stock biomass showed little overall trend, though the terminal year is the lowest in the time series (Figure 9). Current stock status was estimated in the base run to be $\mathrm{SSB}_{2017}/\mathrm{MSST} = 1.88$ and $\mathrm{SSB}_{2017}/\mathrm{SSB}_{\mathrm{F}40\%} = 1.41$ (Table 16 and Figure 21), indicating that the stock is not overfished. Uncertainty from the ensemble modeling suggested that the estimate of SSB relative to both $\mathrm{SSB}_{\mathrm{F}40\%}$ and SSB/MSST is robust (Figures 22, 23). More specifically, about 99.8% of ensemble modeling runs indicate the stock is above MSST, while only 0.2% of the models in the ensemble indicated an overfished status. Age structure estimated by the base run showed slightly fewer younger fish in the last decade than the (equilibrium) age structure expected at $L_{\mathrm{F}40\%}$ (Figure 24), however the rest of the age structure is above expected values in the terminal year (2017).

The estimated time series of fishing mortality rate has a slightly increasing trend, though the peak year was 1996 (Figure 13). Current fishery status in the terminal year, with current F represented by the geometric mean from 2015–2017, was estimated by the base run to be $F_{2015-2017}/F_{40\%} = 0.29$ (Table 16 and Figures 22 and 23). The results of the ensemble model are consistent with those results, as only 0.5% of models within the ensemble estimate the stock is undergoing overfishing.

4.9.2 Comparison to previous assessment

When estimates from this assessment are compared to estimates from the SEDAR28 assessment for cobia, a notable difference is the magnitude of the biomass and spawning stock biomass estimates (Figure 40). In this assessment, updated and recalibrated MRIP estimates of general recreational landings and discards were used. Those estimates are several times higher per year than the estimates used in SEDAR28, and are the result of an improvement in the estimation of recreational effort (for details of how the MRIP is an improvement of MRFSS, see https://www.fisheries.noaa.gov/recreational-fishing-data/how-marine-recreational-information-program-has-improved). Regardless of the magnitude of biomass and SSB, the status benchmarks remain on similar scales (Figure 39). The time trends in abundance, recruitment, and relative status are very similar between this assessment and the last as well (e.g. Figures 39 and 40). Natural mortality estimates provided by the Data Workshop were higher than used for SEDAR28. The higher natural mortality (0.97–0.31 in this assessment compared to 0.56–0.24 in SEDAR28) leads the model to estimate a more productive stock. Length and age composition data are fit better using the Dirichlet-multinomial distribution in this assessment (Figures 2 in both reports), as is the headboat index of abundance using the iterative reweighting process.

4.10 Sensitivity and Retrospective Analyses

Sensitivity runs, described in §3.3, were used for exploring data or model issues that arose during the assessment process, for evaluating implications of assumptions in the base assessment model, and for interpreting ensemble model results in terms of expected effects of input parameters (Figures 25–33). Sensitivity runs are a tool for better understanding model behavior, and therefore should not be used as the basis for management. All runs are not considered equally plausible in the sense of alternative states of nature. Time series of $F/F_{40\%}$ and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F}40\%}$ demonstrate sensitivity to natural mortality (Figure 31) and the SEDAR28 life history inputs (Figure 27). The majority of the runs agreed with the status indicated by the base run (Figure 33, Table 17). Results appeared to be most sensitive to natural mortality.

Retrospective analyses did not suggest any patterns of substantial over- or underestimation in terminal-year estimates starting in 2017 (Figures 34 and 35).

4.11 Projections

Projections based on $F = F_{40\%}$, which is higher than F_{current} drove the stock towards $L_{\text{F40\%}}$ values (Figures 36 and 37, Tables 18 and 19). The 75%$F_{40\%}$ projection was similar to the $F = F_{40\%}$ scenario (Figure 38, Table 20).

5 Discussion

5.1 Comments on the Assessment

Estimated benchmarks played a central role in this assessment; Values of $\text{SSB}_{\text{F40\%}}$ and $F_{40\%}$ were used to gauge the status of the stock and fishery. Computation of benchmarks was conditional on selectivity, and if selectivity patterns change again 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 ($\text{SSB}_{2017}/\text{MSST} = 1.88$), and that overfishing is not occurring ($F_{2015-2017}/F_{40\%} = 0.29$). The ensemble model indicated that the stock status is most likely above MSST with 99.8% of the runs indicating the stock is not overfished. Only about 0.4% of the ensemble model runs indicate that the stock is experiencing overfishing. The decreasing trend for biomass is dependent on what appears to be below average recruitment in the last four years of the assessment. The stock has been declining over the last few years of the assessment, and this decline will likely continue if recruitment remains low.

The recent low recruitment in 2014 did not continue into the terminal year of the assessment. No mechanism for the recent low recruitment has been identified, and periodic low recruitment events are estimated throughout the time series. Input from the stakeholders suggests the recent low recruitment was short lived, which is consistent with modeling results. Multiple years of low recruitment would likely negatively affect the stock status, however monitoring the age compositions into the future will provide the data needed to make that determination.

In addition to more years of data, this benchmark assessment included several modifications to previous data. First, MRIP recalibrated data were used. Next, the SCDNR and MRFSS indices were excluded after the value of all three indices was re-evaluated. All composition data were updated and any needed corrections were made, including the exclusion of commercial age compositions due to non-random sampling.

In general, fishery dependent indices of abundance may not track actual abundance well, because of factors such as hyperstability. Furthermore, this issue can be exacerbated by management measures. In this assessment, fishery dependent indices were not extended beyond 2015, because of the seasonal closures. Such regulations change fisher behavior, thus altering the portion of the population or habitat represented by the logbook data that would be used to create an index of abundance. As such management measures become more common in the southeast U.S., the continued utility of fishery dependent indices in SEDAR stock assessments will be questionable. This situation amplifies the importance of fishery independent sampling.

5.2 Comments on the 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 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. New management regulations that alter those proportions or selectivities would likely affect projection results.

- The projections assumed that the estimated level of recruitment 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, possibly due to environmental or ecological conditions, stock trajectories may be affected. In this assessment, the lowest recruitment occurred in the terminal four years, and if this is not reversed, the stock projections are overly optimistic.

- 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.

5.3 Research Recommendations

- Develop a fishery independent sampling program for abundance of cobia and other coastal migratory species. Fishery dependent abundance indices used in this assessment were uncertain in part due to the lack of an effective sampling methodology.

- Implement a systematic age sampling program for the general recreational sector. Age samples were important in this assessment for identifying strong year classes but sample sizes were relatively small and disparate in time and space.

- Better characterize reproductive parameters including age at maturity, batch fecundity, spawning seasonality, and spawning frequency.

- Age-dependent natural mortality was estimated by indirect methods for this assessment of cobia. Telemetry- and conventional-tag programs for cobia should be maintained as they may prove useful for estimating mortality.

- Better characterize the migratory dynamics of the stock and the degree of fidelity to spawning areas.

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7 Tables

Table 1. Life-history characteristics at age, including average body length and weight (mid-year), proportion females mature, and natural mortality at age. The CV of length was estimated by the assessment model; other values were treated as input.

Age	Total length (mm)	Total length (in)	CV length	Whole wgt (kg)	Whole wgt (lb)	Fem. mat.	prop. fem.	M
1	589.4	23.2	0.12	2.02	4.44	0.0	0.58	0.97
2	768.7	30.3	0.12	4.82	10.62	0.5	0.58	0.65
3	900.2	35.4	0.12	8.09	17.82	1.0	0.58	0.51
4	996.6	39.2	0.12	11.29	24.89	1.0	0.58	0.44
5	1067.4	42.0	0.12	14.14	31.17	1.0	0.58	0.40
6	1119.2	44.1	0.12	16.52	36.42	1.0	0.58	0.37
7	1157.3	45.6	0.12	18.43	40.64	1.0	0.58	0.35
8	1185.2	46.7	0.12	19.93	43.94	1.0	0.58	0.34
9	1205.7	47.5	0.12	21.08	46.48	1.0	0.58	0.33
10	1220.7	48.1	0.12	21.96	48.40	1.0	0.58	0.33
11	1231.7	48.5	0.12	22.61	49.85	1.0	0.58	0.32
12	1239.8	48.8	0.12	23.10	50.93	1.0	0.58	0.32
13	1245.7	49.0	0.12	23.47	51.73	1.0	0.58	0.32
14	1250.0	49.2	0.12	23.74	52.33	1.0	0.58	0.31
15	1253.2	49.3	0.12	23.93	52.77	1.0	0.58	0.31
16	1255.6	49.4	0.12	24.08	53.09	1.0	0.58	0.31

Table 2. Observed time series of landings (L) and dead discards (D) combined for the commercial (comm) and general recreational (GR) fleets. Landings are in units of 1000 lb whole weight for commercial landings and discards, and in units of 1000 fish for general recreational landings and discards.

Year	LD.comm	LD.GR
1986	25.734	33.608
1987	40.740	24.930
1988	28.588	12.236
1989	33.453	22.420
1990	44.357	18.605
1991	43.816	23.670
1992	35.933	23.900
1993	39.606	15.991
1994	47.118	13.865
1995	67.648	28.148
1996	62.684	94.424
1997	63.618	20.741
1998	43.700	12.650
1999	27.541	27.283
2000	43.652	14.963
2001	42.593	13.445
2002	45.518	18.645
2003	39.367	55.201
2004	37.783	33.440
2005	29.256	59.899
2006	34.953	53.614
2007	32.733	38.877
2008	35.021	30.785
2009	48.003	57.067
2010	58.689	54.608
2011	36.050	36.904
2012	46.204	50.826
2013	54.060	70.214
2014	70.952	59.131
2015	87.942	115.314
2016	92.754	83.032
2017	68.402	50.597

Table 3. Landings (L), Discards (D, l-D represents live discards and d-D represents dead discards), and CVs used in the ensemble model for the commercial (Comm) and general recreational (GR) fleets. Landings and discards from commercial handline (HL) and commercial gillnet (GN) gear are combined into one commercial removals time series.

Year	GR L	Comm L	Comm HL D	Comm GN d-D	Comm GN l-D	GR D	GR L CVs	Comm L CVs	GR D CVs	Comm D CVs
1986	33.152	25.734	0.000	0.000	0.000	9.1120	0.120	0.10	0.00	0.000
1987	24.893	40.740	0.000	0.000	0.000	0.7360	0.010	0.10	0.46	0.000
1988	11.923	28.588	0.000	0.000	0.000	6.2730	0.100	0.10	0.23	0.000
1989	21.732	33.453	0.000	0.000	0.000	13.767	0.210	0.10	0.12	0.000
1990	18.057	44.357	0.000	0.000	0.000	10.958	0.070	0.10	0.16	0.000
1991	21.504	43.816	0.000	0.000	0.000	43.331	0.110	0.10	0.22	0.000
1992	23.164	35.933	0.000	0.000	0.000	14.733	0.190	0.10	0.19	0.000
1993	15.766	39.526	1.605	0.000	0.000	4.4930	0.160	0.05	0.45	15.13
1994	12.256	47.020	1.959	0.000	0.000	32.179	0.170	0.05	0.05	15.13
1995	27.713	67.557	1.814	0.000	0.000	8.7060	0.340	0.05	0.28	15.13
1996	94.123	62.591	1.856	0.000	0.000	6.0250	0.030	0.05	0.34	15.13
1997	18.938	63.522	1.911	0.000	0.000	36.062	0.050	0.05	0.04	15.13
1998	11.241	43.622	1.563	0.000	0.000	28.186	0.340	0.05	0.18	15.13
1999	23.794	27.474	1.346	0.000	0.000	69.798	0.460	0.05	0.19	15.13
2000	13.665	43.580	1.449	0.000	0.000	25.953	0.280	0.05	0.21	15.13
2001	11.672	42.513	1.592	0.000	0.000	35.464	0.340	0.05	0.16	15.13
2002	16.864	44.375	1.417	0.000	1.950	35.623	0.170	0.05	0.11	12.47
2003	51.969	39.310	1.130	0.000	0.000	64.647	0.500	0.05	0.11	11.18
2004	31.635	32.916	1.040	4.815	0.000	36.095	0.110	0.05	0.17	18.75
2005	57.370	28.884	1.051	0.195	0.226	50.579	0.220	0.05	0.09	18.07
2006	50.908	34.708	1.175	0.186	0.000	54.111	0.230	0.05	0.10	19.61
2007	36.360	31.663	1.194	0.000	1.837	50.351	0.070	0.05	0.08	20.54
2008	28.859	33.876	1.186	0.584	0.913	38.513	0.030	0.05	0.05	14.19
2009	52.657	42.423	1.216	2.911	4.742	88.200	0.170	0.05	0.15	30.43
2010	50.607	56.661	1.040	0.999	1.776	80.012	0.140	0.05	0.09	18.27
2011	31.487	34.222	0.882	0.745	1.889	108.35	0.230	0.05	0.09	25.80
2012	46.387	42.811	0.797	0.999	4.280	88.767	0.020	0.05	0.19	23.77
2013	66.204	53.605	0.869	0.000	0.749	80.211	0.230	0.05	0.28	14.73
2014	52.472	70.064	0.839	0.846	0.000	133.19	0.220	0.05	0.10	13.88
2015	110.42	84.901	0.763	0.000	5.460	97.899	0.120	0.05	0.11	14.19
2016	75.779	92.535	0.776	0.000	0.328	145.07	0.040	0.05	0.10	21.59
2017	39.661	68.365	0.738	0.000	0.000	218.73	0.160	0.05	0.23	22.14

Table 4. Observed index of abundance and CVs from headboats (HB).

Year	HB	HB CV
1991	1.02	0.26
1992	0.95	0.25
1993	0.83	0.20
1994	0.72	0.18
1995	1.14	0.20
1996	0.46	0.17
1997	0.64	0.27
1998	0.78	0.21
1999	0.82	0.18
2000	0.77	0.22
2001	0.70	0.26
2002	1.17	0.24
2003	0.88	0.21
2004	0.89	0.21
2005	1.09	0.20
2006	0.86	0.23
2007	1.59	0.30
2008	1.37	0.16
2009	1.08	0.19
2010	1.00	0.30
2011	0.83	0.24
2012	1.09	0.22
2013	2.04	0.23
2014	1.23	0.19
2015	1.04	0.20
2016	.	.
2017	.	.

Table 5. Sample sizes (number of fish) of length compositions (len) or age compositions (age) by fleet. Data sources are commercial lines (comm) and general recreational (GR). The commercial fleet is a pooled composition over 1986–2017, rather than a single year of data..

Year	len.comm	age.GR
1986	.	22
1987	.	18
1988	.	.
1989	.	62
1990	.	80
1991	.	13
1992	.	12
1993	.	.
1994	.	.
1995	.	10
1996	.	31
1997	.	13
1998	.	.
1999	1449	124
2000	.	111
2001	.	52
2002	.	26
2003	.	.
2004	.	.
2005	.	57
2006	.	63
2007	.	203
2008	.	225
2009	.	265
2010	.	293
2011	.	246
2012	.	269
2013	.	445
2014	.	487
2015	.	484
2016	.	386
2017	.	273

Table 6. Estimated total abundance at age (1000 fish) at start of year.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1986	1246.74	286.12	184.80	91.72	132.31	103.47	25.58	28.16	22.48	10.27	8.08	6.32	4.88	3.73	2.84	6.42	2163.92
1987	1531.51	472.42	148.98	109.39	56.09	81.08	64.58	16.25	18.07	14.57	6.66	5.29	4.14	3.20	2.46	6.12	2540.79
1988	2605.51	580.34	246.01	88.29	67.31	34.78	51.29	41.60	10.57	11.87	9.57	4.42	3.51	2.75	2.14	5.76	3765.72
1989	1172.31	987.48	302.54	146.68	55.50	43.30	22.93	34.48	28.24	7.25	8.14	6.63	3.06	2.43	1.92	5.52	2828.42
1990	1558.48	444.24	514.37	179.54	90.61	34.64	27.59	14.88	22.59	18.69	4.80	5.44	4.43	2.04	1.64	5.03	2929.02
1991	2076.37	590.62	231.50	306.02	112.03	57.56	22.52	18.28	9.96	15.27	12.63	3.27	3.71	3.02	1.41	4.60	3468.77
1992	841.48	786.87	307.74	137.63	190.38	70.79	37.20	14.83	12.15	6.69	10.25	8.57	2.22	2.52	2.07	4.11	2435.49
1993	639.45	318.90	410.04	183.03	85.72	120.49	45.83	24.53	9.87	8.17	4.50	6.97	5.82	1.51	1.73	4.25	1870.82
1994	1972.55	242.35	166.26	244.54	115.18	55.25	79.64	30.87	16.69	6.79	5.62	3.12	4.83	4.04	1.06	4.19	2952.97
1995	824.14	747.60	126.36	99.21	154.30	74.61	36.72	53.96	21.13	11.54	4.69	3.92	2.18	3.38	2.85	3.70	2170.29
1996	2112.54	312.29	389.29	74.90	61.17	96.09	47.44	23.78	35.28	13.95	7.62	3.13	2.62	1.45	2.27	4.41	3188.23
1997	648.64	799.77	161.69	223.33	40.86	30.74	47.93	23.98	12.13	18.17	7.19	3.96	1.63	1.36	0.76	3.51	2025.64
1998	1184.47	245.79	416.47	95.87	137.93	25.52	19.61	31.15	15.73	8.04	12.04	4.81	2.65	1.09	0.92	2.89	2204.99
1999	2747.22	448.90	128.12	248.22	60.26	88.75	16.84	13.19	21.15	10.79	5.51	8.34	3.33	1.84	0.76	2.67	3805.90
2000	1958.28	1041.03	233.79	75.95	152.69	37.32	56.06	10.83	8.57	13.88	7.08	3.65	5.53	2.21	1.23	2.30	3610.39
2001	1136.47	742.16	542.59	139.26	47.62	97.83	24.50	37.51	7.32	5.85	9.47	4.88	2.52	3.81	1.54	2.45	2805.78
2002	1277.68	430.72	386.91	323.59	87.66	30.72	64.71	16.52	25.54	5.03	4.02	6.58	3.39	1.75	2.67	2.80	2670.30
2003	2362.70	484.23	224.51	230.51	202.90	56.16	20.16	43.28	11.16	17.43	3.43	2.77	4.53	2.34	1.22	3.81	3671.13
2004	419.81	895.15	251.88	132.19	138.25	120.23	33.74	12.32	26.71	6.95	10.86	2.16	1.74	2.85	1.49	3.20	2059.54
2005	2569.76	159.08	466.16	149.27	81.22	85.46	75.79	21.66	7.99	17.49	4.55	7.18	1.43	1.15	1.91	3.13	3653.23
2006	1627.50	973.48	82.69	273.30	88.06	46.75	49.69	44.79	12.92	4.81	10.54	2.77	4.37	0.87	0.71	3.09	3226.35
2007	1127.96	616.56	506.15	48.56	162.28	51.27	27.54	29.76	27.08	7.89	2.94	6.50	1.71	2.70	0.54	2.37	2621.80
2008	1846.98	427.55	321.28	292.78	28.85	100.10	32.59	17.86	19.49	17.92	5.22	1.96	4.34	1.14	1.82	1.96	3121.84
2009	1105.90	700.10	222.88	187.79	177.93	18.21	65.13	21.63	11.97	13.20	12.13	3.57	1.34	2.97	0.79	2.61	2548.16
2010	1125.86	419.17	364.51	126.81	107.65	105.79	11.16	40.70	13.65	7.63	8.41	7.81	2.30	0.86	1.93	2.21	2346.48
2011	3482.49	426.73	218.22	207.40	72.72	64.03	64.83	6.98	25.70	8.71	4.87	5.42	5.03	1.48	0.56	2.70	4597.87
2012	1613.09	1320.02	222.34	126.18	123.12	44.82	40.66	42.00	4.56	16.99	5.76	3.25	3.62	3.36	1.00	2.20	3572.95
2013	1909.07	611.41	687.21	126.27	72.04	72.89	27.34	25.30	26.40	2.90	10.79	3.69	2.08	2.32	2.18	2.07	3583.97
2014	309.95	723.59	318.24	388.46	71.37	42.21	44.01	16.84	15.74	16.59	1.82	6.85	2.34	1.32	1.49	2.72	1963.55
2015	1108.21	117.48	376.80	182.33	226.16	43.11	26.27	27.95	10.80	10.20	10.75	1.19	4.48	1.53	0.87	2.78	2150.92
2016	962.04	420.00	61.03	204.89	94.78	121.57	23.88	14.84	15.95	6.23	5.88	6.26	0.69	2.61	0.90	2.15	1943.69
2017	1335.20	364.59	218.16	33.26	107.08	51.22	67.69	13.56	8.52	9.24	3.61	3.44	3.66	0.41	1.54	1.80	2222.98
2018	1334.59	506.03	189.57	121.50	18.22	60.74	29.94	40.36	8.17	5.18	5.62	2.22	2.11	2.25	0.25	2.08	2328.83

Table 7. Estimated biomass at age (1000 lb) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1986	5540.4	3038.2	3293.9	2282.9	4123.5	3767.9	1039.3	1237.2	1044.8	497.1	402.6	322.1	252.6	194.9	149.9	340.8	27528.7
1987	6805.9	5016.4	2655.5	2722.5	1748.0	2952.7	2624.4	714.1	839.7	705.0	331.8	269.2	214.1	167.3	130.1	325.0	28221.4
1988	11578.5	6162.4	4385.0	2197.6	2097.7	1266.3	2084.3	1828.1	491.4	574.5	477.1	224.9	181.4	143.7	113.1	305.6	34111.7
1989	5209.5	10485.6	5392.7	3650.6	1729.7	1577.0	931.9	1514.8	1312.6	350.8	405.7	337.5	158.3	127.2	101.4	293.2	33578.8
1990	6925.6	4717.2	9168.4	4468.3	2823.9	1261.3	1121.1	653.9	1050.1	904.8	239.2	277.1	229.3	106.9	86.6	267.0	34300.6
1991	9227.0	6271.7	4126.4	7616.5	3491.7	2096.2	915.1	803.1	462.8	739.0	629.6	166.7	192.0	158.3	74.3	244.1	37214.3
1992	3739.5	8355.5	5485.3	3425.3	5933.5	2577.6	1511.5	651.5	564.8	323.6	511.0	436.3	114.9	131.8	109.3	218.5	34089.6
1993	2841.5	3386.3	7308.8	4555.4	2671.3	4387.9	1862.2	1078.1	459.0	395.7	224.2	354.7	301.2	78.9	91.3	225.3	30222.1
1994	8765.8	2573.5	2963.5	6086.3	3589.8	2011.9	3236.2	1356.5	775.8	328.5	280.0	159.0	250.0	211.4	55.8	222.4	32866.1
1995	3662.3	7938.6	2252.2	2469.2	4808.9	2717.2	1492.3	2371.1	981.9	558.4	233.9	199.7	112.7	176.6	150.4	196.4	30321.7
1996	9387.7	3316.2	6938.8	1864.0	1906.6	3499.2	1927.7	1044.8	1640.0	675.3	379.9	159.4	135.4	76.1	119.9	234.1	33305.0
1997	2882.5	8492.4	2881.9	5558.3	1273.4	1119.5	1947.6	1053.6	563.7	879.6	358.3	201.9	84.2	71.2	40.3	186.5	27594.6
1998	5263.5	2609.8	7423.2	2386.1	4298.8	929.2	797.0	1368.6	731.3	389.1	600.3	244.9	137.3	57.1	48.5	153.4	27438.7
1999	12208.3	4766.6	2283.5	6177.8	1877.9	3232.0	684.1	579.6	983.0	522.3	274.9	425.1	172.4	96.1	40.1	141.5	34465.8
2000	8702.3	11054.2	4167.2	1890.2	4758.9	1358.9	2278.0	475.8	398.2	671.5	353.0	186.1	285.9	115.5	64.8	121.9	36882.9
2001	5050.4	7880.6	9671.5	3465.9	1484.2	3562.7	995.6	1648.2	340.2	283.1	472.0	248.5	130.3	199.5	81.1	130.3	35643.9
2002	5677.8	4573.7	6896.5	8053.7	2732.2	1118.6	2629.7	725.8	1187.2	243.6	200.4	335.1	175.5	91.5	141.1	148.6	34930.5
2003	10499.5	5141.8	4001.8	5737.1	6323.7	2045.0	819.2	1901.9	518.5	843.5	171.1	141.1	234.6	122.1	64.2	202.4	38767.4
2004	1865.6	9505.2	4489.7	3290.0	4308.7	4378.4	1371.3	541.5	1241.4	336.6	541.5	110.0	90.2	149.3	78.5	169.8	32467.5
2005	11419.7	1689.2	8309.0	3715.0	2531.3	3112.3	3079.9	951.7	371.3	846.4	226.9	365.7	73.9	60.4	100.5	166.0	37019.4
2006	7232.5	10337.0	1474.0	6802.1	2744.5	1702.4	2019.0	1968.1	600.5	233.0	525.1	141.1	226.2	45.4	37.5	164.2	36252.6
2007	5012.4	6547.1	9021.8	1208.6	5057.6	1867.1	1119.1	1307.6	1258.8	382.1	146.6	330.9	88.4	141.1	28.7	125.9	33643.2
2008	8207.6	4540.0	5726.5	7286.9	899.0	3645.3	1324.1	784.6	905.9	867.3	260.1	100.1	224.7	59.7	95.9	104.3	35032.3
2009	4914.5	7434.0	3972.7	4673.8	5545.5	663.4	2646.4	950.4	556.4	638.9	604.7	181.9	69.4	155.4	41.7	138.7	33187.7
2010	5003.2	4451.1	6497.2	3156.1	3355.0	3852.6	453.5	1788.4	634.5	369.5	419.5	397.9	119.0	45.2	101.9	117.5	30762.0
2011	15475.8	4531.2	3889.6	5161.9	2266.6	2331.6	2634.3	306.4	1194.5	421.5	242.7	276.0	260.4	77.6	29.8	143.3	39243.0
2012	7168.3	14016.8	3963.3	3140.3	3836.9	1632.1	1652.1	1845.5	212.1	822.3	286.8	165.6	187.2	175.9	52.7	116.6	39274.7
2013	8483.6	6492.4	12249.1	3142.7	2245.2	2654.6	1111.1	1111.8	1227.1	140.2	537.7	188.1	107.8	121.5	114.9	110.0	40037.5
2014	1377.4	7683.6	5672.5	9668.2	2224.2	1537.3	1788.4	740.1	731.7	803.1	90.8	348.6	121.3	69.2	78.5	144.6	33079.0
2015	4924.7	1247.4	6716.2	4538.0	7048.6	1569.9	1067.7	1228.0	502.0	493.6	535.7	60.6	231.7	80.2	46.1	147.7	30438.3
2016	4275.2	4460.0	1087.8	5099.3	2953.8	4427.1	970.3	652.1	741.2	301.4	293.0	318.6	35.9	136.5	47.6	114.2	25913.8
2017	5933.5	3871.5	3888.5	827.8	3337.1	1865.3	2750.7	595.9	396.0	447.3	179.9	175.3	189.4	21.2	81.4	95.7	24656.3
2018	5930.7	5373.3	3379.0	3023.9	567.7	2212.1	1216.5	1773.6	379.6	250.7	280.2	112.9	109.3	117.7	13.2	110.2	24851.2

Table 8. Estimated time series and status indicators. Fishing mortality rate is apical F. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB mature female biomass, and SSBknum in 1000s of mature females) at the time of peak spawning (end of March). The $MSST_{\mathrm{F40}}$ is defined by $\mathrm{MSST} = 0.75 SSB_{\mathrm{F40}}$. *Prop.fem is proportion of age-2^+ population that is female.*

Year	F	F/F_{40}	B	B/B_{unfished}	SSB	SSBknum	$SSB/SSBB_{\mathrm{F40}}$	$SSB/MSST_{\mathrm{F40}}$	Prop.fem
1986	0.1039	0.1500	12487	0.826	5474	363	1.84	2.45	0.58
1987	0.0901	0.1301	12801	0.847	4902	352	1.64	2.19	0.58
1988	0.0474	0.0685	15473	1.024	5086	397	1.71	2.27	0.58
1989	0.0827	0.1195	15231	1.008	5957	522	2.00	2.66	0.58
1990	0.0620	0.0896	15559	1.029	6517	525	2.19	2.92	0.58
1991	0.0683	0.0986	16880	1.117	6472	501	2.17	2.89	0.58
1992	0.0664	0.0959	15463	1.023	6800	545	2.28	3.04	0.58
1993	0.0452	0.0653	13708	0.907	6753	495	2.27	3.02	0.58
1994	0.0393	0.0568	14908	0.986	6037	401	2.03	2.70	0.58
1995	0.0849	0.1227	13754	0.910	5874	440	1.97	2.63	0.58
1996	0.3336	0.4819	15107	0.999	5407	401	1.81	2.42	0.58
1997	0.0813	0.1174	12517	0.828	5286	441	1.77	2.36	0.58
1998	0.0471	0.0680	12446	0.823	5474	414	1.84	2.45	0.58
1999	0.0916	0.1324	15633	1.034	5152	380	1.73	2.30	0.58
2000	0.0520	0.0751	16730	1.107	5874	510	1.97	2.63	0.58
2001	0.0444	0.0641	16168	1.070	6945	591	2.33	3.11	0.58
2002	0.0523	0.0756	15844	1.048	7061	541	2.37	3.16	0.58
2003	0.1428	0.2063	17585	1.163	6567	481	2.20	2.94	0.58
2004	0.0937	0.1353	14727	0.974	6662	538	2.23	2.98	0.58
2005	0.1766	0.2552	16792	1.111	6293	454	2.11	2.81	0.58
2006	0.1632	0.2357	16444	1.088	6032	494	2.02	2.70	0.58
2007	0.0832	0.1202	15260	1.010	6521	535	2.19	2.92	0.58
2008	0.0599	0.0865	15890	1.051	6382	484	2.14	2.85	0.58
2009	0.1201	0.1734	15054	0.996	6239	488	2.09	2.79	0.58
2010	0.1197	0.1730	13953	0.923	5995	454	2.01	2.68	0.58
2011	0.0841	0.1215	17800	1.178	5548	409	1.86	2.48	0.58
2012	0.1242	0.1795	17815	1.179	6335	574	2.13	2.83	0.58
2013	0.1346	0.1945	18161	1.201	7157	610	2.40	3.20	0.58
2014	0.1042	0.1505	15004	0.993	7100	578	2.38	3.18	0.58
2015	0.2210	0.3193	13807	0.913	6113	430	2.05	2.73	0.58
2016	0.2156	0.3114	11754	0.778	4764	336	1.60	2.13	0.58
2017	0.1671	0.2414	11184	0.740	4212	313	1.41	1.88	0.58
2018	.	.	11272	0.746	.	.	.	.	0.58

Table 9. Selectivity at age for the commercial fleet (comm), general recreational fleet (GR), and landings averaged across fisheries (L.avg). TL is total length. For time-varying selectivities, values shown are from the terminal assessment year.

Age	TL(mm)	TL(in)	comm	GR	L.avg
1	589.4	23.2	0.029	0.000	0.001
2	768.7	30.3	0.168	0.019	0.023
3	900.2	35.4	0.580	0.446	0.450
4	996.6	39.2	0.904	0.971	0.969
5	1067.4	42.0	0.985	0.999	0.999
6	1119.2	44.1	0.998	1.000	1.000
7	1157.3	45.6	1.000	1.000	1.000
8	1185.2	46.7	1.000	1.000	1.000
9	1205.7	47.5	1.000	1.000	1.000
10	1220.7	48.1	1.000	1.000	1.000
11	1231.7	48.5	1.000	1.000	1.000
12	1239.8	48.8	1.000	1.000	1.000
13	1245.7	49.0	1.000	1.000	1.000
14	1250.0	49.2	1.000	1.000	1.000
15	1253.2	49.3	1.000	1.000	1.000
16	1255.6	49.4	1.000	1.000	1.000

Table 10. Estimated time series of fully selected fishing mortality rates for the commercial fleet (F.comm) and the general recreational fleet (F.GR). Also shown is apical F, the maximum F at age summed across fleets.

Year	F.comm	F.GR	Apical F
1986	0.002	0.102	0.104
1987	0.003	0.087	0.090
1988	0.002	0.045	0.047
1989	0.002	0.081	0.083
1990	0.003	0.059	0.062
1991	0.002	0.066	0.068
1992	0.002	0.064	0.066
1993	0.002	0.043	0.045
1994	0.003	0.037	0.039
1995	0.004	0.081	0.085
1996	0.004	0.329	0.334
1997	0.004	0.077	0.081
1998	0.003	0.044	0.047
1999	0.002	0.090	0.092
2000	0.003	0.049	0.052
2001	0.002	0.042	0.044
2002	0.002	0.050	0.052
2003	0.002	0.141	0.143
2004	0.002	0.092	0.094
2005	0.002	0.175	0.177
2006	0.002	0.161	0.163
2007	0.002	0.081	0.083
2008	0.002	0.058	0.060
2009	0.003	0.117	0.120
2010	0.004	0.116	0.120
2011	0.002	0.082	0.084
2012	0.003	0.121	0.124
2013	0.003	0.132	0.135
2014	0.004	0.101	0.104
2015	0.005	0.216	0.221
2016	0.007	0.209	0.216
2017	0.006	0.161	0.167
2018	.	.	.

Table 11. Estimated instantaneous fishing mortality rate (per yr) at age

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1986	0.000	0.003	0.014	0.052	0.090	0.101	0.103	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104
1987	0.000	0.002	0.013	0.046	0.078	0.088	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090
1988	0.000	0.001	0.007	0.024	0.041	0.046	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
1989	0.000	0.002	0.012	0.042	0.072	0.081	0.082	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
1990	0.000	0.002	0.009	0.032	0.054	0.061	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
1991	0.000	0.002	0.010	0.035	0.059	0.067	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
1992	0.000	0.002	0.010	0.033	0.057	0.065	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066
1993	0.000	0.001	0.007	0.023	0.039	0.044	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
1994	0.000	0.001	0.006	0.020	0.034	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
1995	0.000	0.003	0.013	0.044	0.074	0.083	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
1996	0.001	0.008	0.046	0.166	0.288	0.326	0.332	0.333	0.334	0.334	0.334	0.334	0.334	0.334	0.334	0.334
1997	0.000	0.003	0.013	0.042	0.071	0.079	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081	0.081
1998	0.000	0.002	0.007	0.024	0.041	0.046	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
1999	0.000	0.002	0.013	0.046	0.079	0.089	0.091	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092
2000	0.000	0.002	0.008	0.027	0.045	0.051	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
2001	0.000	0.001	0.007	0.023	0.039	0.043	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044
2002	0.000	0.002	0.008	0.027	0.045	0.051	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
2003	0.001	0.004	0.020	0.071	0.123	0.139	0.142	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.143
2004	0.000	0.002	0.013	0.047	0.081	0.091	0.093	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094
2005	0.001	0.004	0.024	0.088	0.152	0.172	0.176	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177
2006	0.001	0.004	0.022	0.081	0.141	0.159	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.163
2007	0.000	0.002	0.037	0.081	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
2008	0.000	0.001	0.027	0.058	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060
2009	0.000	0.003	0.054	0.116	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120
2010	0.000	0.003	0.054	0.116	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120	0.120
2011	0.000	0.002	0.038	0.082	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084	0.084
2012	0.000	0.003	0.056	0.120	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124	0.124
2013	0.000	0.003	0.060	0.131	0.134	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135
2014	0.000	0.003	0.047	0.101	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104	0.104
2015	0.000	0.005	0.099	0.214	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221	0.221
2016	0.000	0.005	0.097	0.209	0.215	0.216	0.216	0.216	0.216	0.216	0.216	0.216	0.216	0.216	0.216	0.216
2017	0.000	0.004	0.075	0.162	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167

Table 12. Estimated total landings at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1986	0.34	0.55	2.07	3.76	9.39	8.36	2.13	2.36	1.89	0.87	0.68	0.54	0.41	0.32	0.24	0.55
1987	0.39	0.86	1.52	3.95	3.48	5.72	4.69	1.19	1.33	1.07	0.49	0.39	0.31	0.24	0.18	0.45
1988	0.37	0.59	1.37	1.71	2.24	1.32	2.00	1.64	0.42	0.47	0.38	0.18	0.14	0.11	0.09	0.23
1989	0.27	1.61	2.79	4.85	3.17	2.82	1.53	2.32	1.91	0.49	0.55	0.45	0.21	0.17	0.13	0.38
1990	0.29	0.59	3.72	4.52	3.91	1.70	1.40	0.76	1.16	0.96	0.25	0.28	0.23	0.11	0.08	0.26
1991	0.41	0.83	1.81	8.44	5.31	3.11	1.25	1.02	0.56	0.86	0.71	0.19	0.21	0.17	0.08	0.26
1992	0.16	1.05	2.30	3.67	8.78	3.72	2.01	0.81	0.67	0.37	0.56	0.47	0.12	0.14	0.11	0.23
1993	0.09	0.32	2.20	3.39	2.72	4.36	1.71	0.92	0.37	0.31	0.17	0.26	0.22	0.06	0.07	0.16
1994	0.26	0.23	0.82	4.01	3.20	1.74	2.59	1.01	0.55	0.22	0.19	0.10	0.16	0.13	0.04	0.14
1995	0.22	1.40	1.28	3.42	9.06	4.98	2.52	3.73	1.47	0.80	0.33	0.27	0.15	0.24	0.20	0.26
1996	1.79	1.89	13.65	9.33	12.74	22.54	11.43	5.77	8.60	3.40	1.87	0.77	0.64	0.36	0.56	1.09
1997	0.17	1.48	1.60	7.42	2.30	1.97	3.15	1.59	0.81	1.21	0.48	0.27	0.11	0.09	0.05	0.24
1998	0.19	0.27	2.43	1.87	4.56	0.96	0.76	1.21	0.62	0.32	0.47	0.19	0.10	0.04	0.04	0.11
1999	0.67	0.78	1.28	9.02	3.79	6.36	1.24	0.98	1.58	0.81	0.41	0.63	0.25	0.14	0.06	0.20
2000	0.33	1.23	1.48	1.63	5.57	1.55	2.39	0.47	0.37	0.60	0.31	0.16	0.24	0.10	0.05	0.10
2001	0.16	0.74	2.92	2.54	1.49	3.47	0.89	1.38	0.27	0.22	0.35	0.18	0.09	0.14	0.06	0.09
2002	0.20	0.49	2.39	6.91	3.21	1.28	2.78	0.71	1.11	0.22	0.18	0.29	0.15	0.08	0.12	0.12
2003	0.87	1.27	3.43	12.85	19.48	6.13	2.26	4.90	1.27	1.98	0.39	0.32	0.52	0.27	0.14	0.44
2004	0.11	1.62	2.60	4.92	8.89	8.81	2.54	0.94	2.04	0.53	0.83	0.17	0.13	0.22	0.11	0.25
2005	1.13	0.50	8.65	10.17	9.51	11.37	10.37	2.99	1.11	2.42	0.63	1.00	0.20	0.16	0.27	0.44
2006	0.68	2.90	1.43	17.31	9.58	5.78	6.32	5.74	1.66	0.62	1.36	0.36	0.57	0.11	0.09	0.40
2007	0.07	0.84	14.57	3.06	10.70	3.43	1.86	2.02	1.85	0.54	0.20	0.45	0.12	0.19	0.04	0.16
2008	0.10	0.45	6.71	13.38	1.38	4.87	1.60	0.88	0.97	0.89	0.26	0.10	0.22	0.06	0.09	0.10
2009	0.09	1.37	9.19	16.77	16.64	1.73	6.24	2.08	1.16	1.28	1.18	0.35	0.13	0.29	0.08	0.26
2010	0.11	0.86	15.02	11.29	10.04	10.01	1.07	3.91	1.32	0.74	0.82	0.76	0.22	0.08	0.19	0.22
2011	0.23	0.60	6.35	13.18	4.84	4.33	4.42	0.48	1.77	0.60	0.34	0.37	0.35	0.10	0.04	0.19
2012	0.14	2.67	9.48	11.64	11.89	4.39	4.02	4.17	0.46	1.70	0.58	0.33	0.36	0.34	0.10	0.22
2013	0.18	1.33	31.66	12.56	7.50	7.70	2.92	2.71	2.84	0.31	1.17	0.40	0.23	0.25	0.24	0.23
2014	0.03	1.33	11.46	30.29	5.83	3.50	3.69	1.42	1.33	1.40	0.15	0.58	0.20	0.11	0.13	0.23
2015	0.17	0.42	28.01	28.68	37.20	7.19	4.42	4.73	1.84	1.73	1.83	0.20	0.76	0.26	0.15	0.48
2016	0.18	1.55	4.44	31.49	15.24	19.83	3.93	2.45	2.65	1.03	0.98	1.04	0.12	0.44	0.15	0.36
2017	0.20	1.07	12.44	4.05	13.64	6.62	8.83	1.78	1.12	1.22	0.48	0.46	0.48	0.05	0.20	0.24

Table 13. Estimated total landings at age in whole weight (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1986	3.05	8.47	45.14	105.14	314.38	319.71	89.74	107.20	90.96	43.37	35.39	28.39	22.35	17.38	13.40	30.55
1987	3.57	13.25	33.23	110.49	116.44	218.66	197.73	53.99	63.79	53.67	25.45	20.72	16.53	13.02	10.14	25.42
1988	3.39	9.05	29.92	47.84	74.98	50.37	84.37	74.26	20.06	23.50	19.66	9.30	7.53	6.01	4.74	12.84
1989	2.43	24.65	60.90	135.70	106.09	107.62	64.73	105.58	91.93	24.62	28.68	23.94	11.26	9.12	7.29	21.15
1990	2.63	8.97	81.26	126.55	131.12	65.13	58.91	34.48	55.64	48.03	12.79	14.87	12.34	5.81	4.71	14.56
1991	3.73	12.74	39.54	236.07	177.95	118.86	52.80	46.50	26.93	43.07	36.98	9.83	11.36	9.43	4.44	14.62
1992	1.42	16.01	50.21	102.77	293.94	142.19	84.85	36.70	31.97	18.35	29.20	25.01	6.61	7.64	6.36	12.73
1993	0.81	4.83	48.07	94.86	91.13	166.52	71.92	41.78	17.87	15.44	8.82	13.99	11.92	3.15	3.65	9.04
1994	2.39	3.50	17.95	112.16	107.10	66.64	109.05	45.87	26.36	11.18	9.61	5.47	8.64	7.36	1.95	7.78
1995	1.97	21.41	27.87	95.79	303.32	190.22	106.27	169.42	70.50	40.17	16.95	14.52	8.23	12.99	11.08	14.52
1996	16.23	29.02	297.78	261.06	426.65	861.66	481.92	261.98	413.07	170.43	96.56	40.64	34.63	19.62	31.03	60.71
1997	1.54	22.65	34.83	207.71	77.06	75.16	132.99	72.18	38.80	60.67	24.89	14.08	5.89	5.02	2.85	13.22
1998	1.68	4.16	53.08	52.32	152.86	36.70	32.02	55.17	29.62	15.79	24.55	10.05	5.65	2.37	2.02	6.40
1999	6.07	11.98	27.98	252.50	126.97	243.26	52.40	44.54	75.92	40.42	21.43	33.24	13.53	7.61	3.19	11.26
2000	2.96	18.78	32.20	45.48	186.46	59.16	100.91	21.15	17.78	30.05	15.91	8.42	12.98	5.29	2.98	5.60
2001	1.46	11.40	63.68	71.22	49.74	132.73	37.74	62.70	13.00	10.84	18.22	9.62	5.06	7.81	3.18	5.13
2002	1.85	7.46	52.13	193.48	107.56	48.98	117.19	32.46	53.34	10.97	9.09	15.25	8.01	4.21	6.51	6.88
2003	7.87	19.53	74.87	359.65	652.58	234.42	95.53	222.52	60.96	99.34	20.31	16.80	28.01	14.72	7.76	24.48
2004	0.96	24.77	56.68	137.70	297.73	336.65	107.29	42.51	97.94	26.61	43.12	8.80	7.23	12.06	6.35	13.79
2005	10.24	7.70	188.70	284.71	318.66	434.68	437.44	135.62	53.15	121.42	32.80	53.03	10.76	8.85	14.78	24.47
2006	6.13	44.41	31.30	484.40	321.00	220.99	266.56	260.70	79.93	31.06	70.56	19.02	30.58	6.20	5.11	22.50
2007	0.60	12.85	318.04	85.50	358.43	131.16	78.46	91.72	88.68	26.96	10.42	23.61	6.33	10.18	2.07	9.12
2008	0.88	6.83	146.33	374.47	46.32	186.21	67.51	40.02	46.41	44.51	13.46	5.19	11.69	3.13	5.05	5.50
2009	0.85	21.05	200.51	469.27	557.40	66.08	263.12	94.52	55.57	63.93	60.98	18.39	7.05	15.89	4.27	14.27
2010	1.01	13.12	327.69	315.97	336.37	382.85	44.97	177.43	63.23	36.88	42.19	40.15	12.04	4.62	10.43	12.05
2011	2.05	9.20	138.66	368.74	162.21	165.42	186.53	21.71	84.98	30.04	17.43	19.89	18.82	5.65	2.17	10.49
2012	1.28	40.98	206.79	325.69	398.35	167.95	169.67	189.57	21.89	84.98	29.88	17.29	19.63	18.57	5.58	12.39
2013	1.60	20.44	690.83	351.54	251.35	294.53	123.03	123.16	136.51	15.63	60.37	21.18	12.19	13.83	13.12	12.59
2014	0.27	20.43	250.13	847.60	195.39	133.87	155.43	64.34	63.89	70.25	8.00	30.83	10.75	6.19	7.04	12.99
2015	1.56	6.48	611.23	802.57	1245.92	274.98	186.59	214.65	88.13	86.82	94.93	10.79	41.33	14.42	8.31	26.69
2016	1.59	23.81	96.89	881.30	510.47	758.18	165.80	111.49	127.23	51.82	50.77	55.39	6.26	23.98	8.38	20.17
2017	1.86	16.43	271.41	113.21	456.84	253.10	372.46	80.72	53.84	60.96	24.69	24.14	26.19	2.96	11.36	13.41

Table 14. Estimated time series of landings in numbers (1000 fish) for the commercial fleet (L.comm) and general recreational (L.GR))

Year	L.comm	L.GR	Total
1986	0.81	33.64	34.45
1987	1.32	24.95	26.26
1988	1.00	12.24	13.24
1989	1.22	22.44	23.65
1990	1.61	18.61	20.22
1991	1.55	23.69	25.23
1992	1.24	23.92	25.16
1993	1.32	16.00	17.32
1994	1.52	13.86	15.39
1995	2.18	28.14	30.32
1996	2.15	94.25	96.40
1997	2.22	20.70	22.93
1998	1.51	12.64	14.15
1999	0.96	27.25	28.21
2000	1.59	14.96	16.55
2001	1.56	13.45	15.01
2002	1.59	18.64	20.24
2003	1.35	55.18	56.53
2004	1.28	33.42	34.70
2005	1.01	59.91	60.92
2006	1.22	53.69	54.92
2007	1.17	38.91	40.08
2008	1.22	30.82	32.04
2009	1.64	57.18	58.82
2010	2.00	54.64	56.64
2011	1.27	36.91	38.18
2012	1.70	50.79	52.49
2013	2.04	70.19	72.22
2014	2.51	59.18	61.69
2015	2.95	115.13	118.08
2016	3.00	82.89	85.89
2017	2.29	50.59	52.88
.	.	.	.

Table 15. Estimated time series of landings in whole weight (1000 lb) for the commercial fleet (L.comm) and general recreational (L.rec).

Year	L.comm	L.GR	Total
1986	25.74	1248.89	1274.63
1987	40.75	935.35	976.09
1988	28.59	449.23	477.82
1989	33.46	792.23	825.68
1990	44.36	633.45	677.81
1991	43.82	801.03	844.85
1992	35.94	830.03	865.97
1993	39.61	564.19	603.80
1994	47.12	495.88	543.00
1995	67.65	1037.58	1105.23
1996	62.68	3440.30	3502.98
1997	63.61	725.94	789.55
1998	43.70	440.75	484.44
1999	27.54	944.76	972.30
2000	43.65	522.47	566.12
2001	42.59	460.94	503.53
2002	45.52	629.85	675.37
2003	39.37	1899.97	1939.34
2004	37.78	1182.40	1220.18
2005	29.26	2107.76	2137.01
2006	34.95	1865.50	1900.45
2007	32.73	1221.39	1254.13
2008	35.02	968.48	1003.51
2009	48.01	1865.16	1913.16
2010	58.69	1762.32	1821.01
2011	36.05	1207.93	1243.98
2012	46.20	1664.30	1710.50
2013	54.06	2087.83	2141.89
2014	70.95	1806.47	1877.42
2015	87.94	3627.45	3715.39
2016	92.75	2800.79	2893.54
2017	68.40	1715.18	1783.58
.	.	.	.

Table 16. Estimated status indicators, benchmarks, and related quantities from the base run of the Beaufort Assessment Model, conditional on estimated current selectivities averaged across fleets. Median values and standard deviations (SD) approximated from the ensemble model are also provided. Rate estimates (F) are in units of y^{-1}*; status indicators are dimensionless; and biomass estimates are whole weight in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured as mature female biomass.*

Quantity	Units	Estimate	Median	SD
$F_{40\%}$	y^{-1}	0.69	0.69	0.14
$B_{\mathrm{F40\%}}$	mt	10643	10776	5597
$\mathrm{SSB}_{\mathrm{F40\%}}$	mt	2980.975	3012	1097
MSST	mt	2236	2266	1007
$L_{\mathrm{F40\%}}$	1000 lb	3923.780	3945	2098
$Lknum_{\mathrm{F40\%}}$	1000 fish	149.958	151	87
$R_{\mathrm{F40\%}}$	1000 age-1 fish	1513761	1537431	1054
$F_{2015-2017}/F_{40\%}$	—	0.29	0.30	0.17
$\mathrm{SSB}_{2017}/\mathrm{MSST}$	—	1.88	1.90	0.33
$\mathrm{SSB}_{2017}/\mathrm{SSB}_{\mathrm{F40\%}}$	—	1.41	1.42	0.25

Table 17. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last three assessment years.

Run	Description	$F_{40\%}$	$\mathrm{SSB}_{\mathrm{F}40\%}$ (mt)	$L_{\mathrm{F}40\%}$ (1000 lb)	$L_{\mathrm{F}40\%}$ (1000s)	$\mathrm{F}_{\mathrm{current}}/F_{40\%}$	$\mathrm{SSB}_{2017}/\mathrm{SSB}_{\mathrm{F}40\%}$	R0(1000)
Base	—	0.692	2980.97	3924	150	0.29	1.41	1336
S1	early start year	0.696	2996.49	3945	151	0.28	1.47	1310
S2	Include length comps	0.714	2562.88	3375	129	0.36	1.28	1079
S3	S28 LH values all	0.319	1749.02	1863	58	1.27	0.86	310
S3a	S28 l-w	0.693	3595.82	4733	149	0.29	1.41	1330
S3b	S28 + time of spawn	0.722	3658.11	4790	152	0.28	1.42	1330
S3c	S28 and sex ratio	0.722	3153.54	4790	152	0.28	1.42	1330
S3d	S28 and growth	0.627	2554.97	3813	143	0.32	1.43	1357
S3e	S28 and M	0.341	1799.72	1897	60	1.19	0.88	310
S4	Remove index	0.707	3339.82	4397	168	0.23	1.63	1491
S5	no MRIP peak	0.693	2795.09	3680	141	0.31	1.37	1245
S6	lower GR landings	0.681	1047.92	1381	53	0.3	1.41	470
S7	Upper values of ensemble parms	0.906	4851.73	7392	294	0.13	1.66	3070
S7a	Upper Ensemble L/D/DiscM	0.691	3317.5	4367	167	0.26	1.45	1487
S7b	Upper Ensemble Index	0.501	2303.66	2498	90	0.6	1.13	667
S7c	Lower Ensemble M	0.693	2979.09	3921	150	0.29	1.41	1335
S8	Lower values of ensemble parms	0.501	1809.41	1962	71	0.62	1.11	524
S8a	Lower Ensemble L/D/DiscM	0.692	2982.45	3926	150	0.29	1.41	1337
S8b	Lower Ensemble Index	0.691	2343.18	3085	118	0.29	1.4	1051
S8c	Upper Ensemble M	0.909	4353.64	6633	264	0.14	1.64	2755
S10	upper GR landings	0.696	8781.05	11553	440	0.29	1.42	3937

Table 18. Projection results with fishing mortality rate fixed at $F = F_{\text{current}}$ *starting in 2020.* R *= number of age-1 recruits (in 1000s),* F *= fishing mortality rate (per year),* S *= spawning stock (mt),* L *= landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*). The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)
2018	1335	1360	0.27	0.31	4058	3954	83	89	2798	2885
2019	1334	1359	0.33	0.34	3649	3758	87	94	2798	2885
2020	1334	1359	0.17	0.21	3750	3828	46	59	1394	1738
2021	1334	1359	0.17	0.21	4004	4002	52	63	1535	1855
2022	1334	1359	0.17	0.21	4184	4115	55	65	1634	1935
2023	1335	1360	0.17	0.21	4307	4189	57	67	1700	1983
2024	1335	1360	0.17	0.21	4389	4236	58	67	1743	2013

Table 19. Projection results with fishing mortality rate fixed at $F = F_{40\%}$ starting in 2020. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*). The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)
2018	1335	1360	0.27	0.31	4058	3954	83	89	2798	2885
2019	1334	1359	0.33	0.34	3649	3758	87	94	2798	2885
2020	1334	1359	0.69	0.69	3217	3321	160	170	4770	4970
2021	1333	1358	0.69	0.69	2850	2920	142	146	3958	4079
2022	1332	1357	0.69	0.69	2710	2763	136	138	3646	3709
2023	1332	1357	0.69	0.69	2656	2701	133	135	3527	3572
2024	1332	1356	0.69	0.69	2635	2677	133	134	3481	3515

Table 20. Projection results with fishing mortality rate fixed at $F = 75\% F_{40\%}$ *starting in 2020.* R *= number of age-1 recruits (in 1000s),* F *= fishing mortality rate (per year),* S *= spawning stock (mt),* L *= landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*). The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)
2018	1335	1360	0.27	0.31	4058	3954	83	89	2798	2885
2019	1334	1359	0.33	0.34	3649	3758	87	94	2798	2885
2020	1334	1359	0.52	0.52	3381	3490	127	135	3802	3969
2021	1333	1358	0.52	0.52	3157	3233	121	124	3439	3546
2022	1333	1358	0.52	0.52	3060	3124	118	120	3278	3342
2023	1333	1358	0.52	0.52	3017	3071	117	118	3207	3254
2024	1333	1357	0.52	0.52	2998	3044	116	118	3175	3215

8 Figures

Figure 1. Mean length at age (mm) and estimated upper and lower 95% confidence intervals of the population.

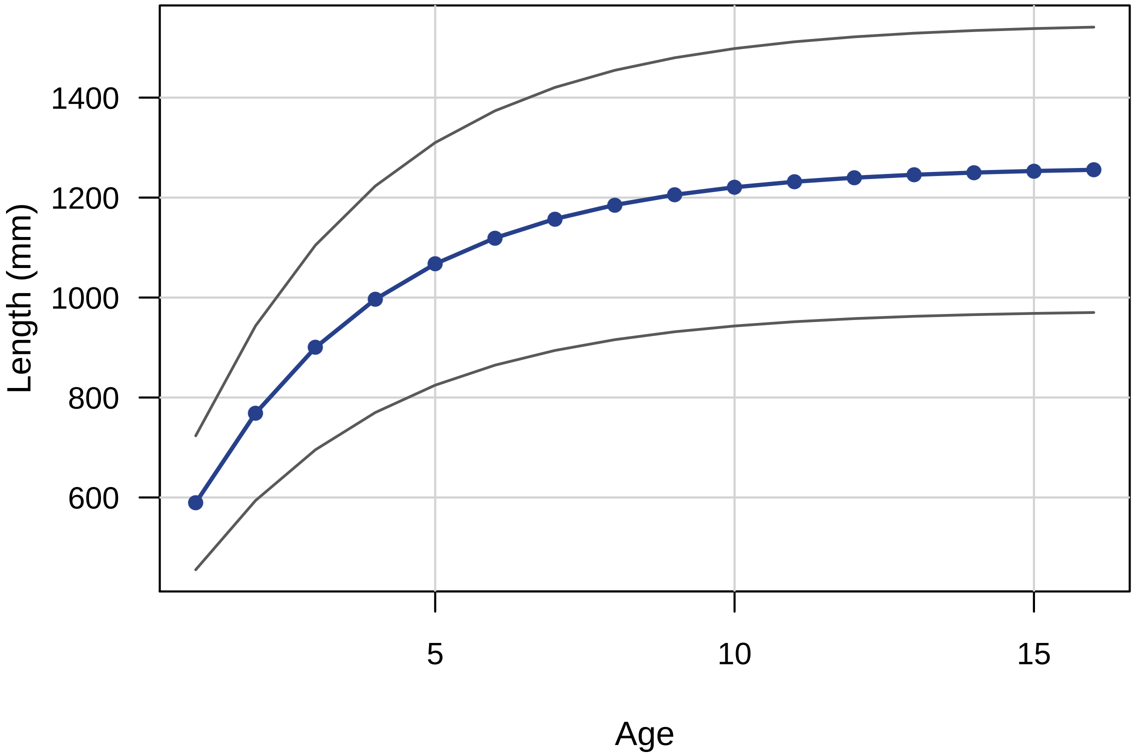


Figure 2. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet from the base run. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, comm to the commercial fleet, and GR to the general recreational fleet. N indicates the number of fish samples taken. For the commercial fleet, length compositions from 1986–2017 were pooled.

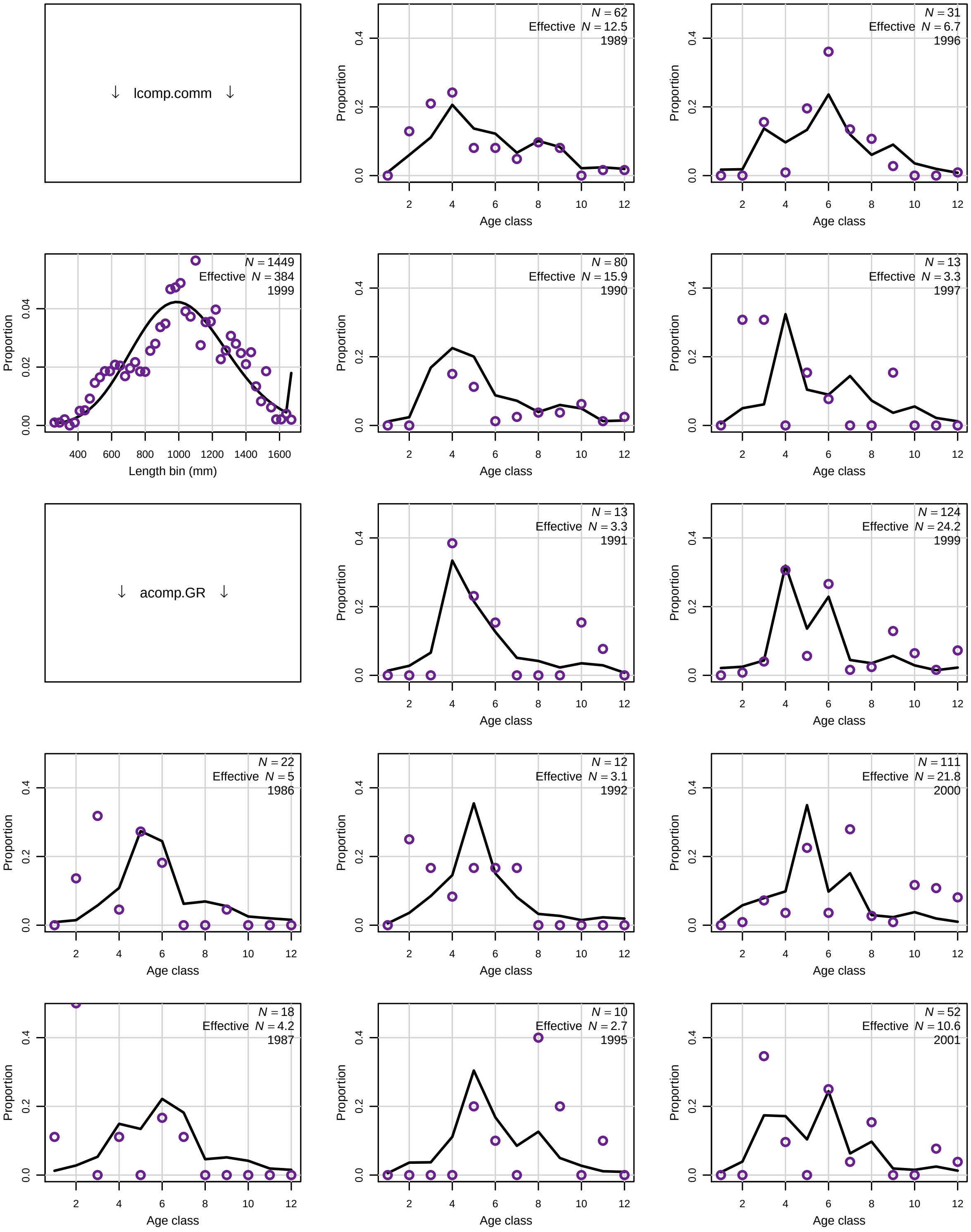


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey from the base run.

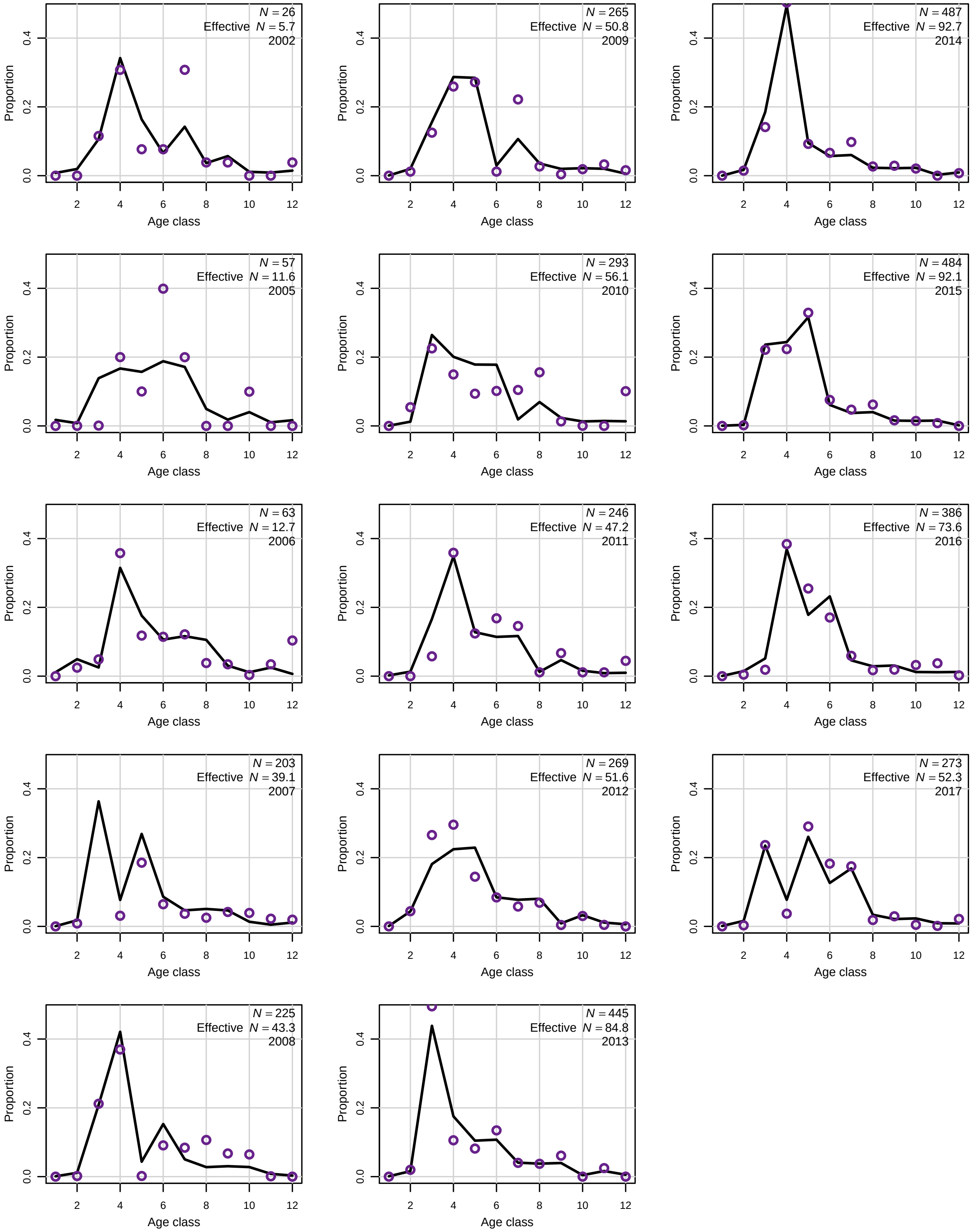


Figure 3. Observed (open circles) and estimated (line, solid circles) commercial landings (1000 lb whole weight).

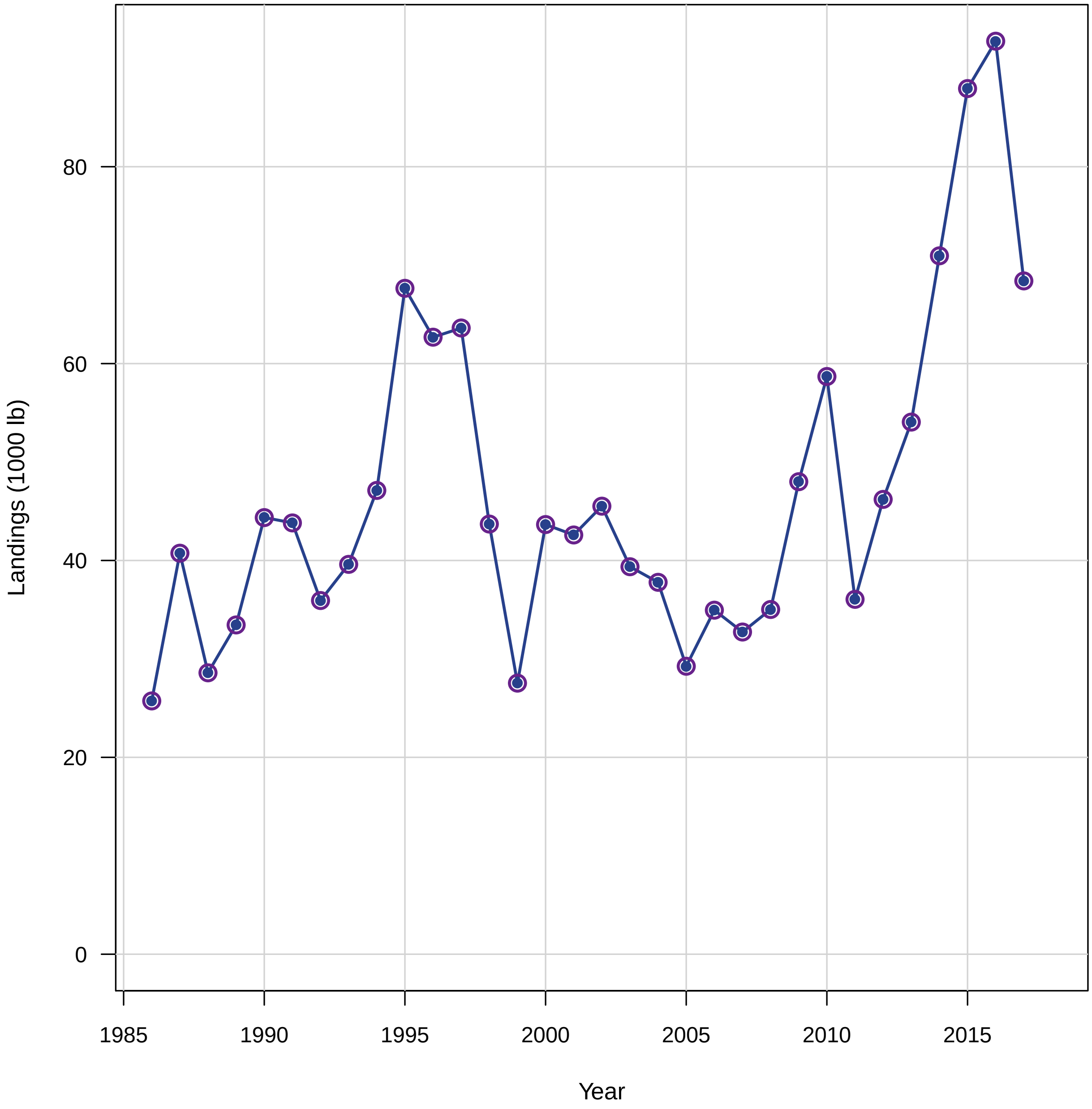


Figure 4. Observed (open circles) and estimated (line, solid circles) general recreational landings (1000 fish).

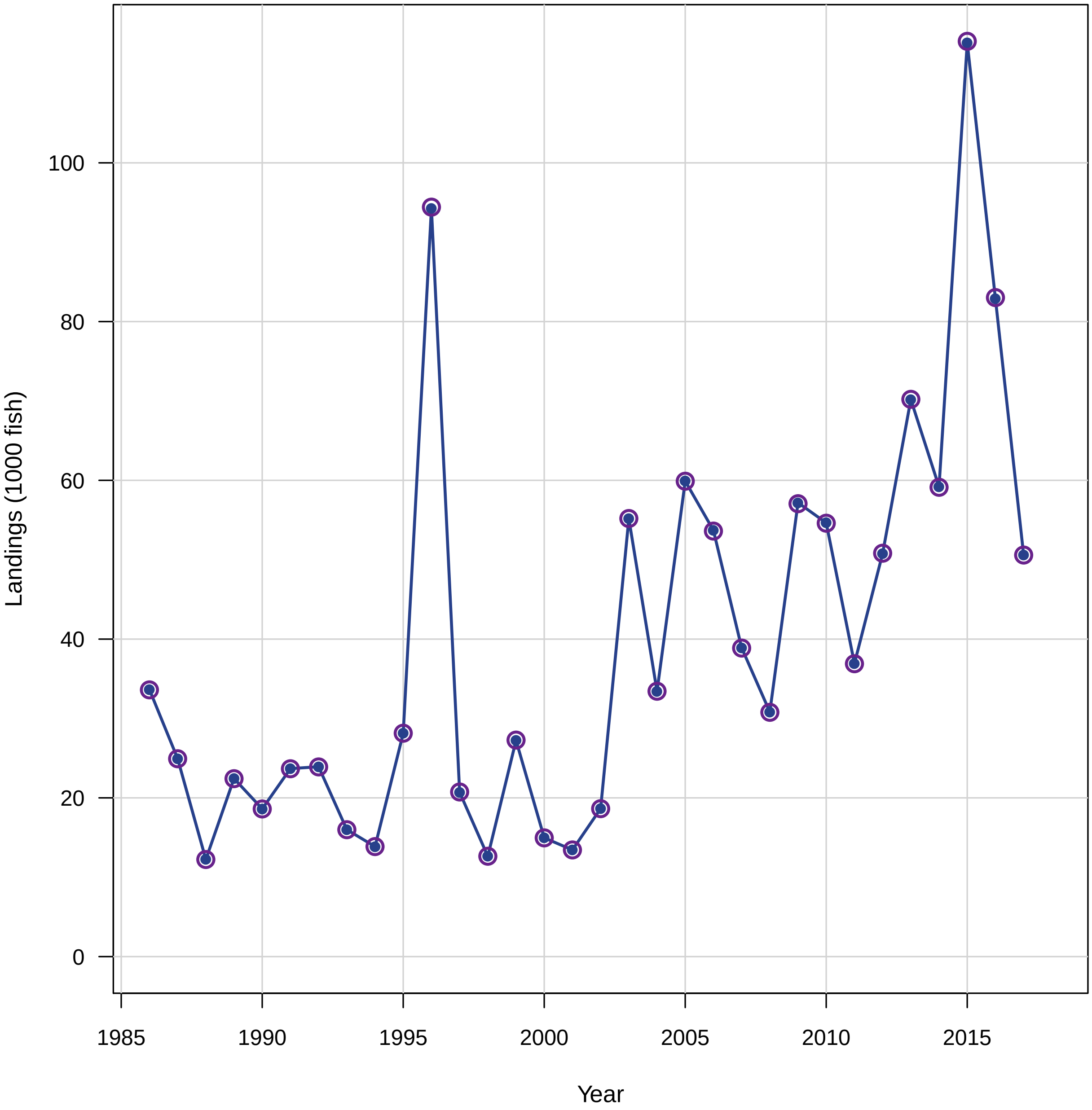


Figure 5. Observed (open circles) and estimated (line, solid circles) index of abundance from the headboat fleet.

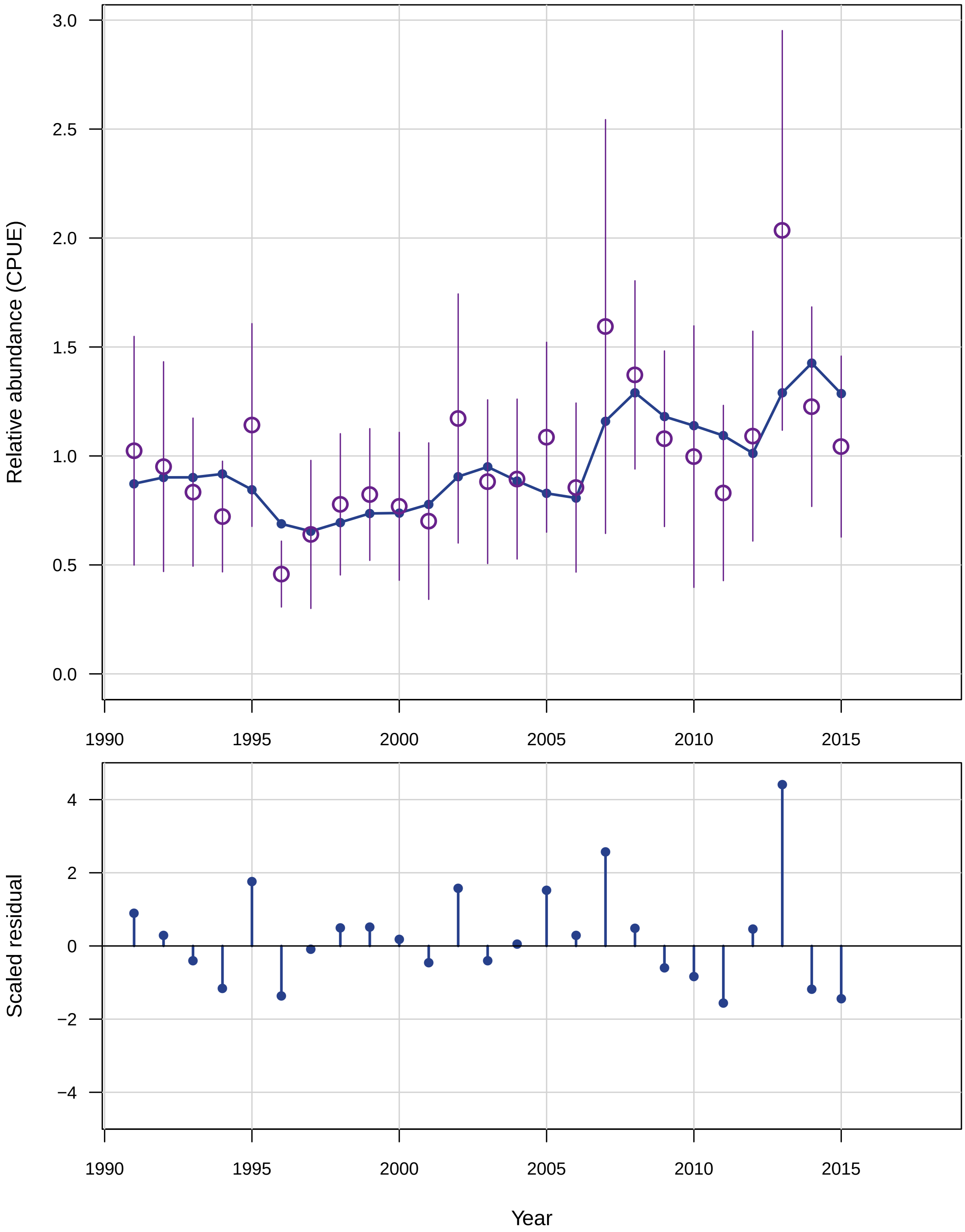


Figure 6. Estimated abundance at age at start of year.

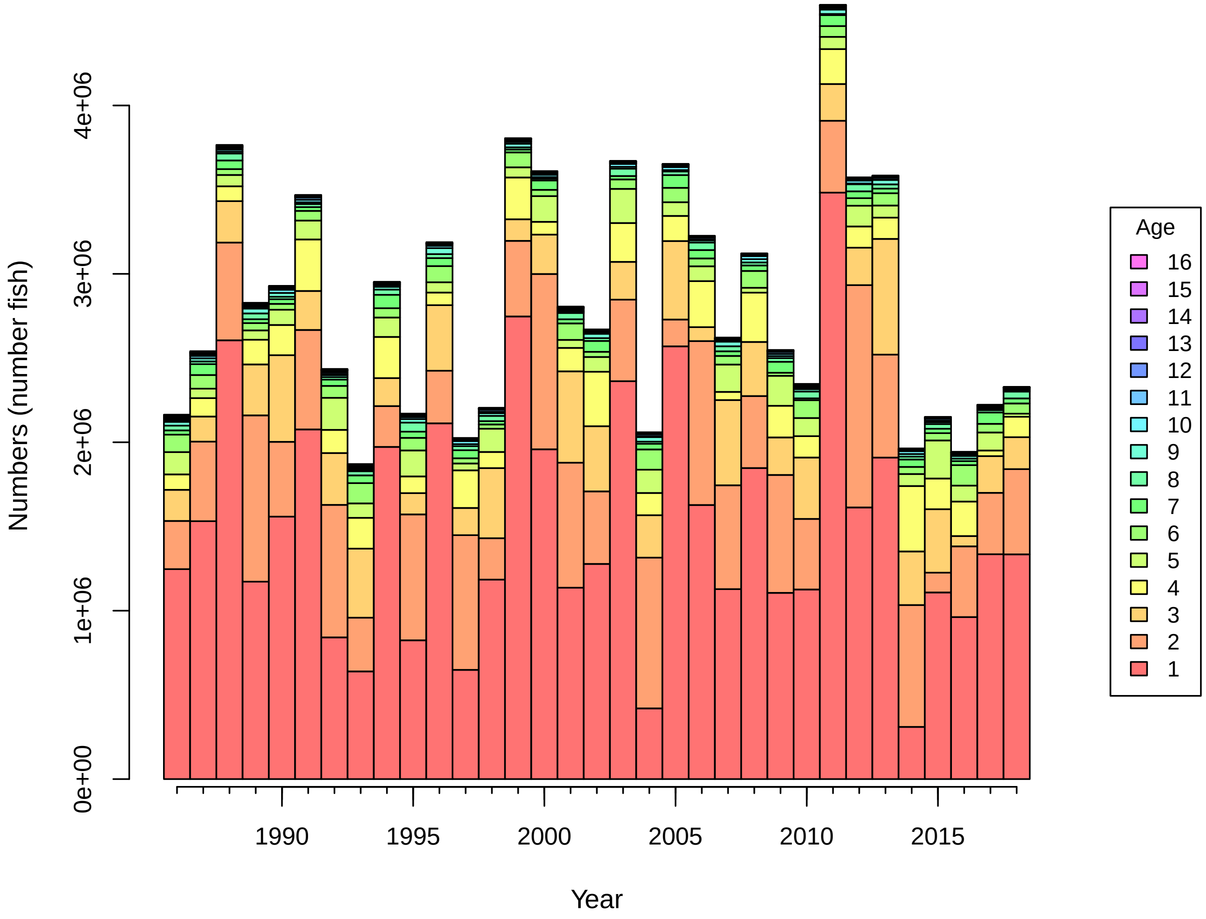


Figure 7. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates $R_{\mathrm{F40\%}}$. *Bottom panel: log recruitment residuals.*

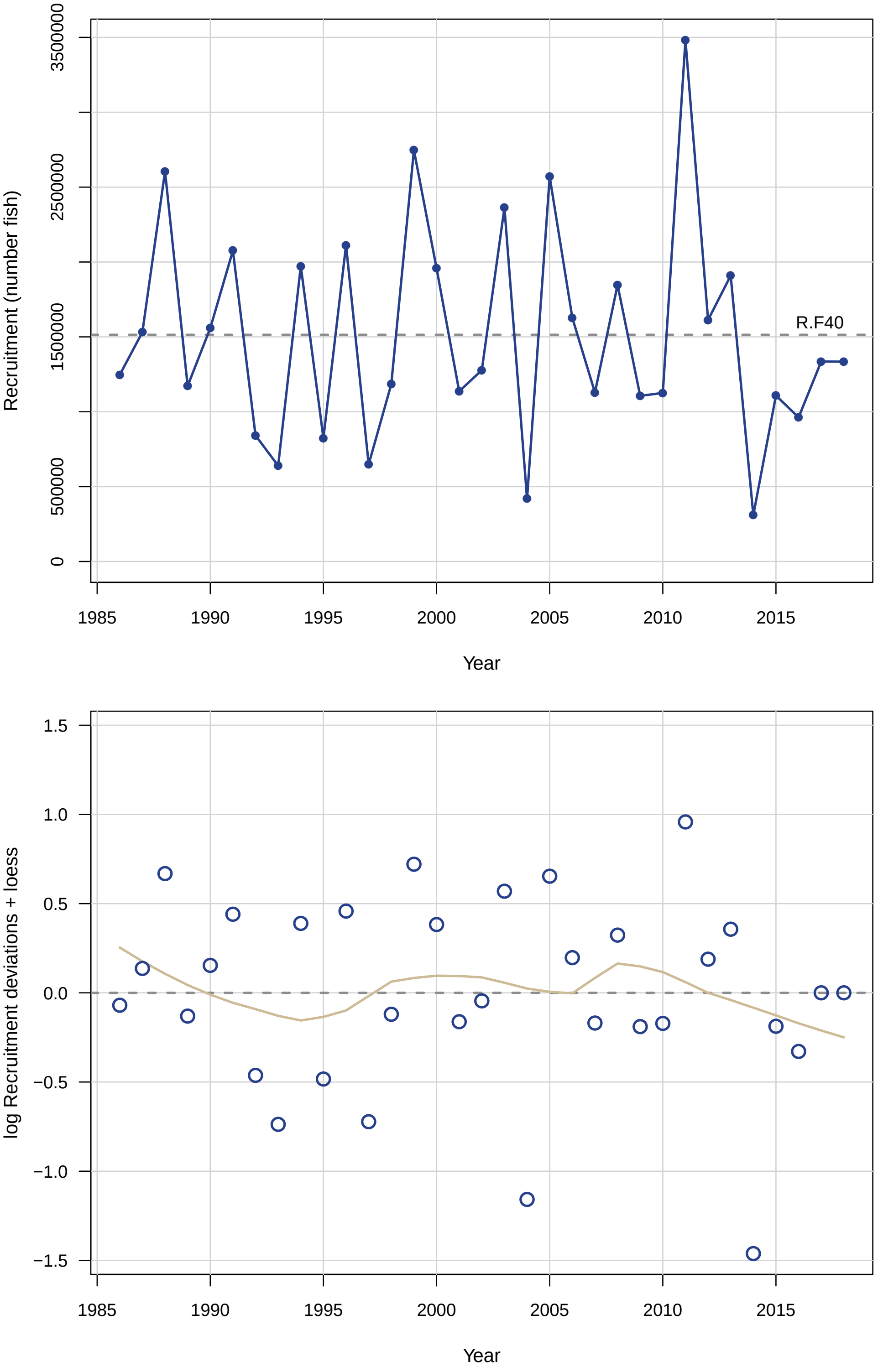


Figure 8. Estimated biomass at age at start of year.

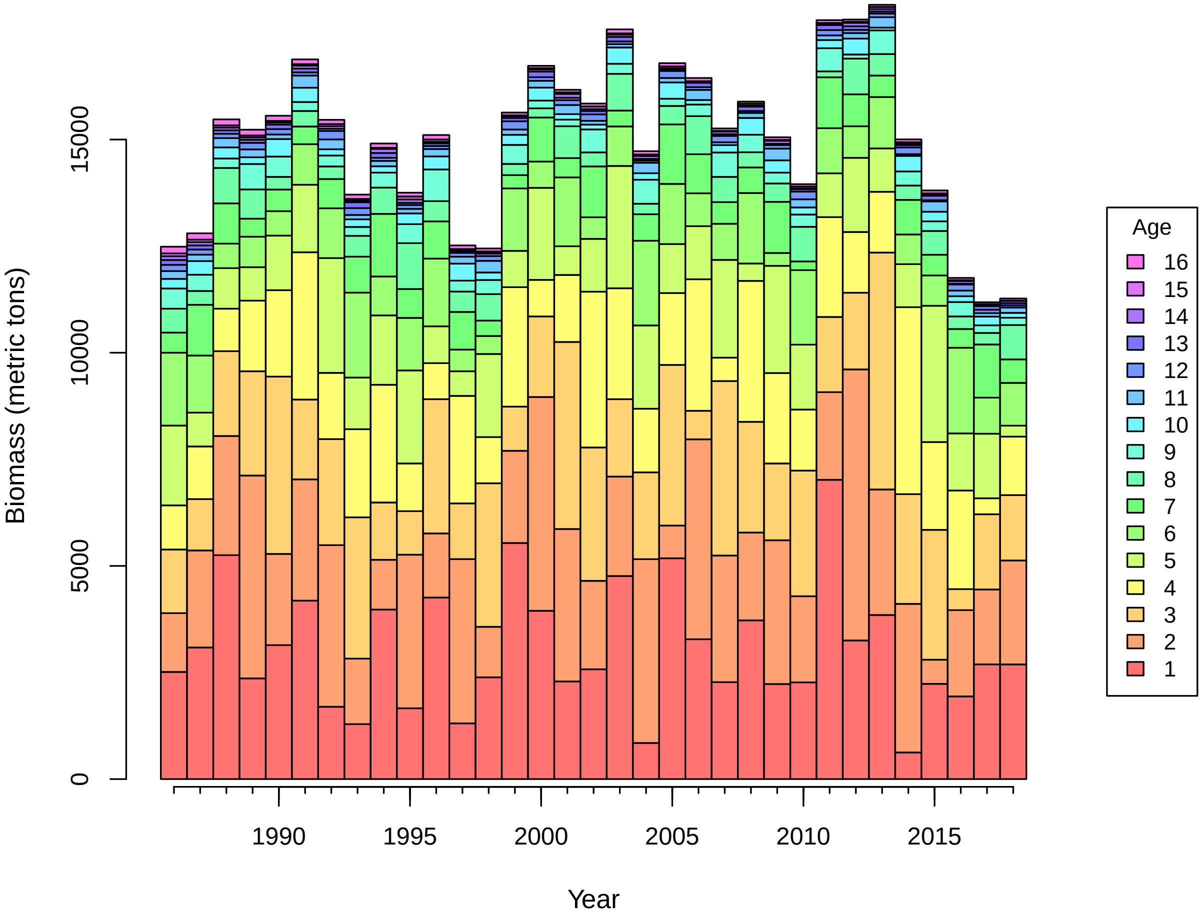


Figure 9. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates $B_{\mathrm{F40\%}}$. *Bottom panel: Estimated spawning stock (mature female biomass) at time of peak spawning.*

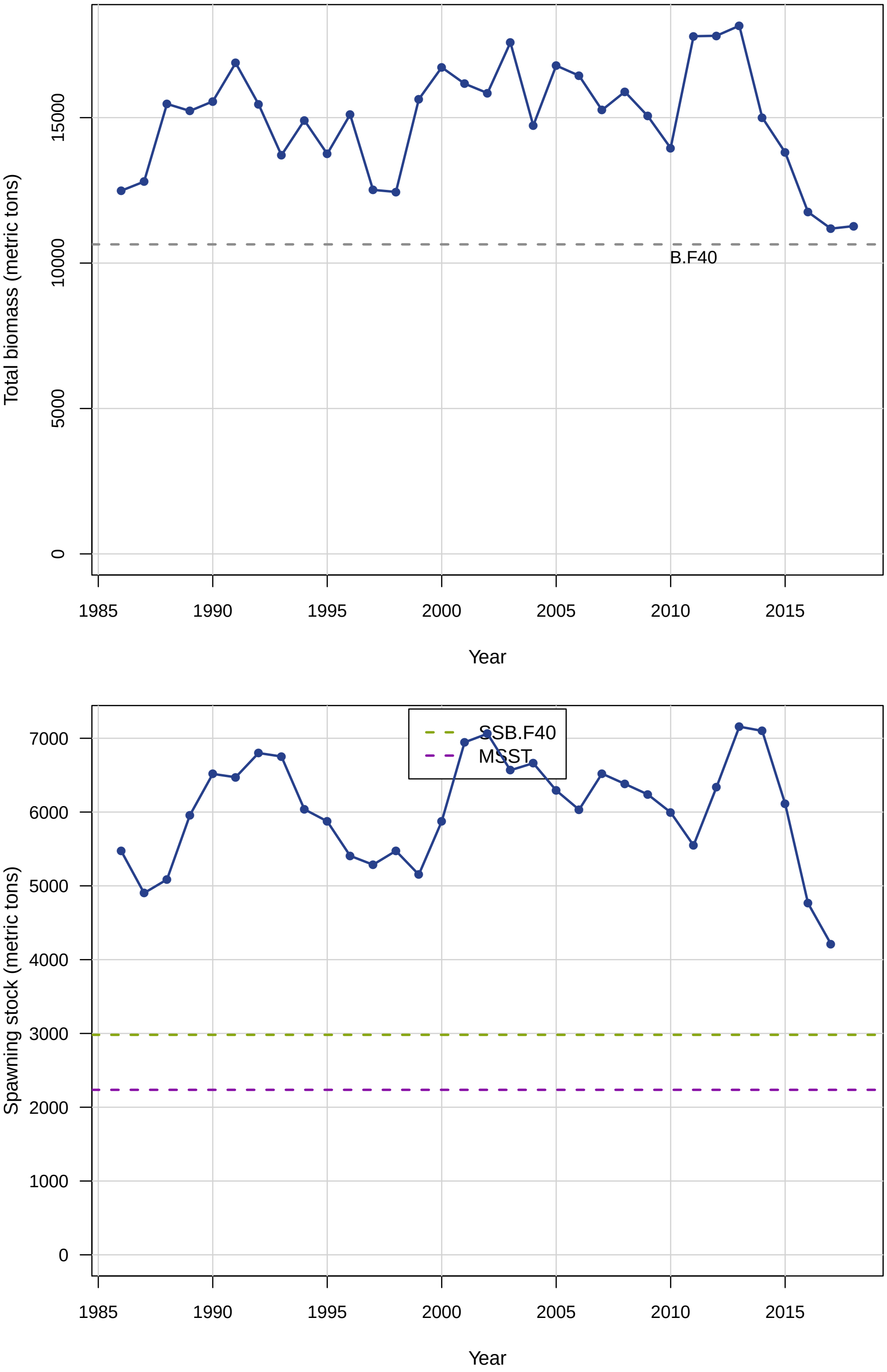


Figure 10. Estimated selectivity of the commercial fleet. Years indicated on plot signify the first year of a time block.

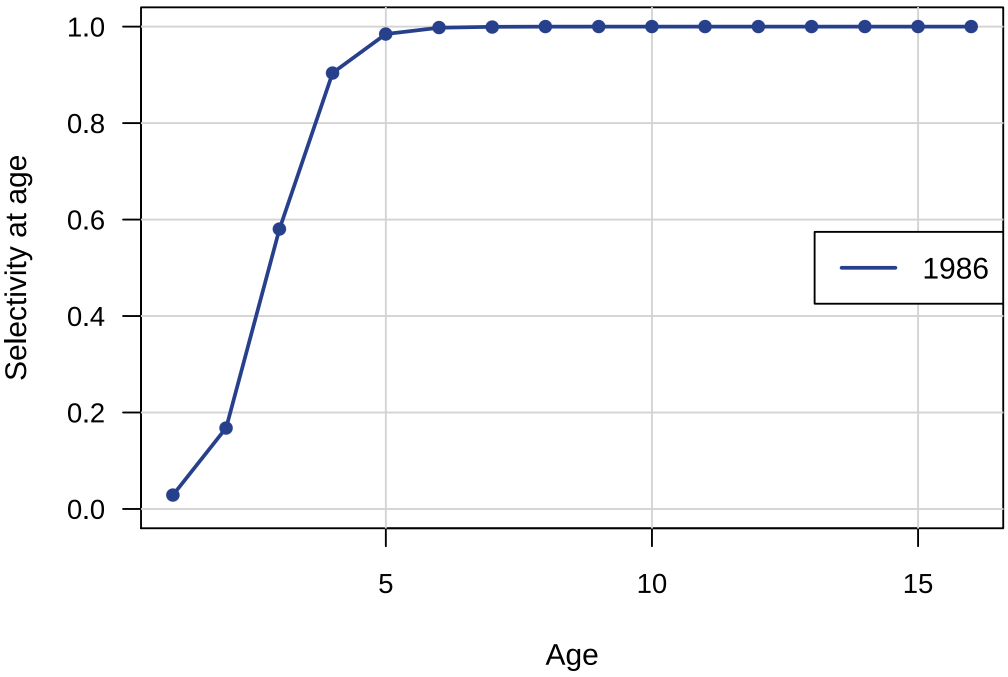


Figure 11. Estimated selectivities of the general recreational fleet. Years indicated on plot signify the first year of a time block.

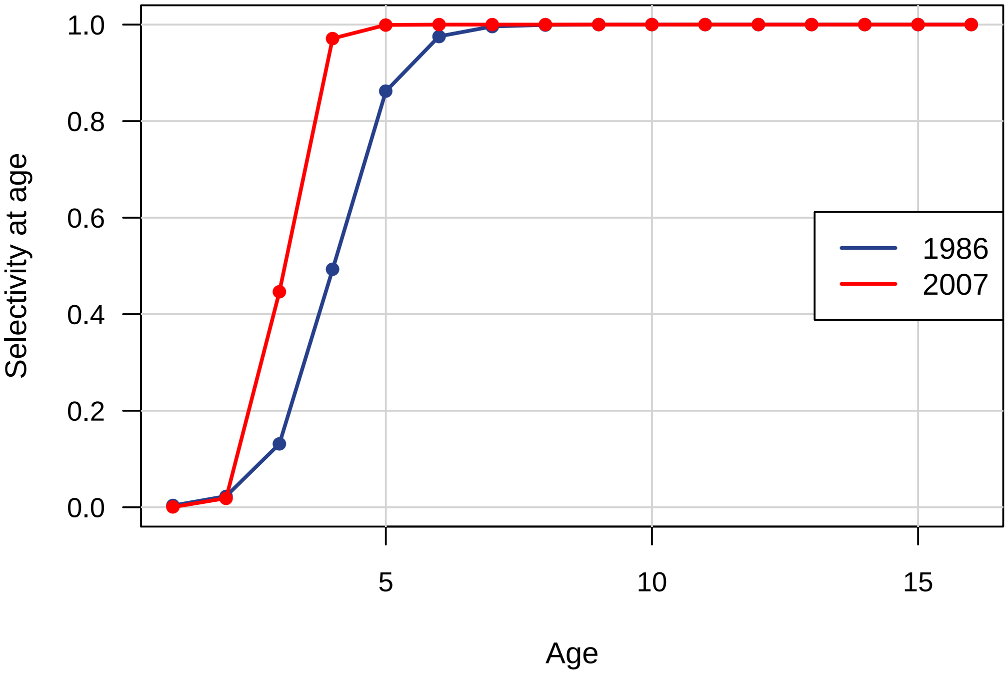


Figure 12. Average selectivity from the terminal assessment years, weighted by geometric mean F s from the last three assessment years, and used in computation of benchmarks and projections.

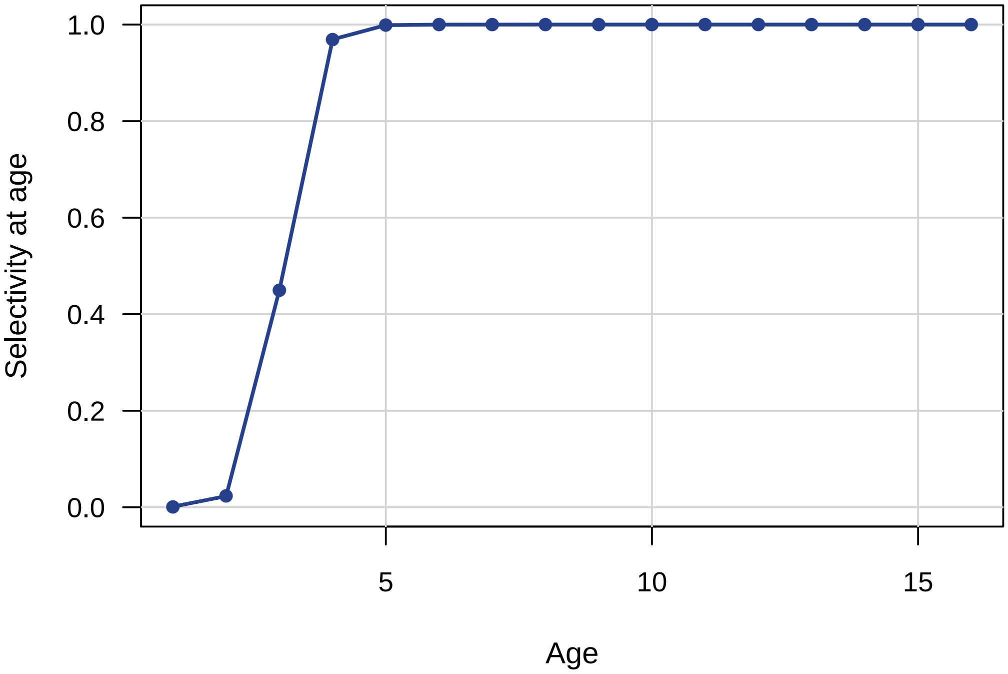


Figure 13. Estimated fully selected fishing mortality rate (per year) by fishery. comm refers to the commercial fleet, and GR to the general recreational fleet.

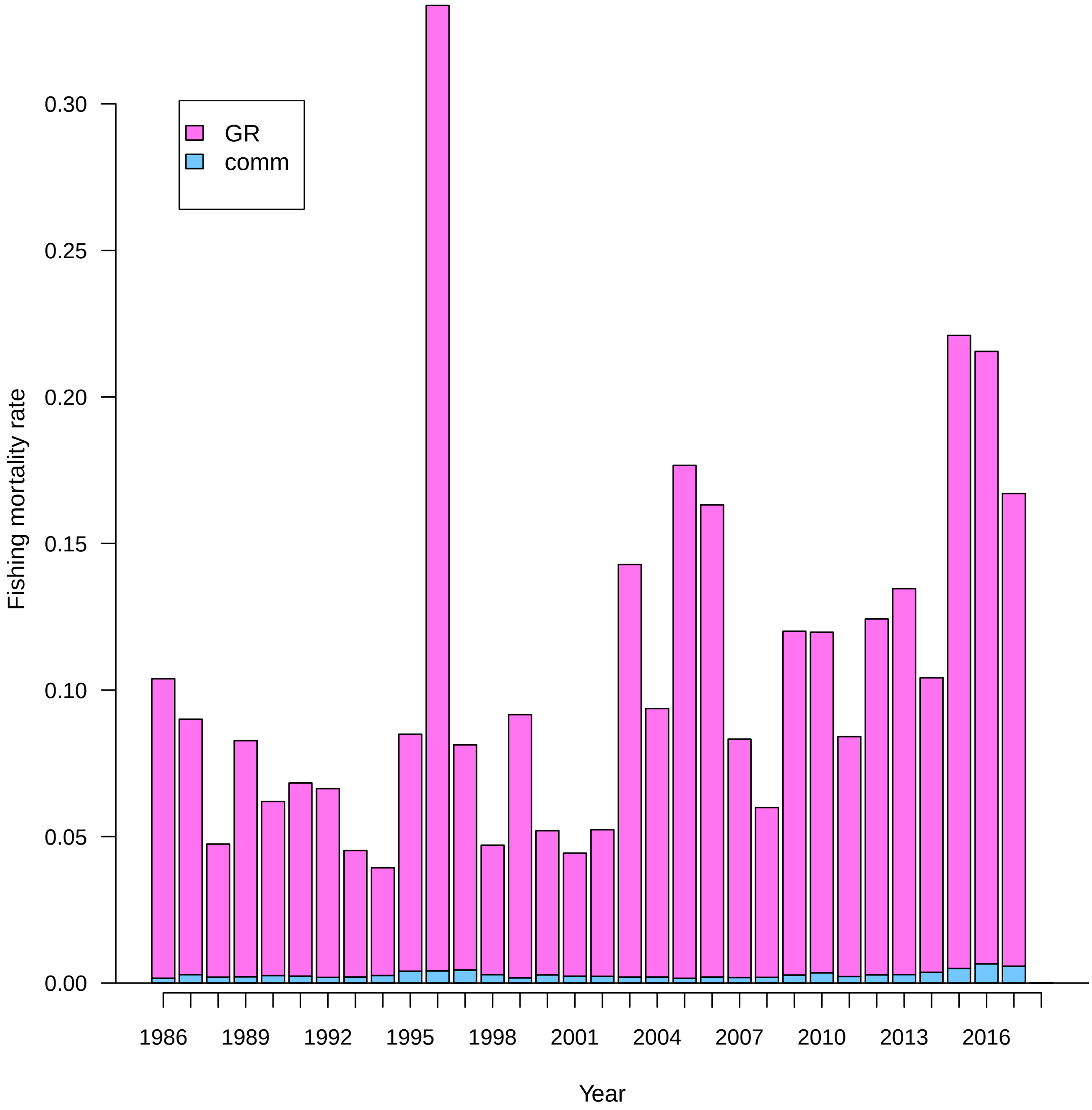


Figure 14. Estimated landings in numbers by fishery from the catch-age model. comm refers to the commercial fleet, and GR to the general recreational fleet.

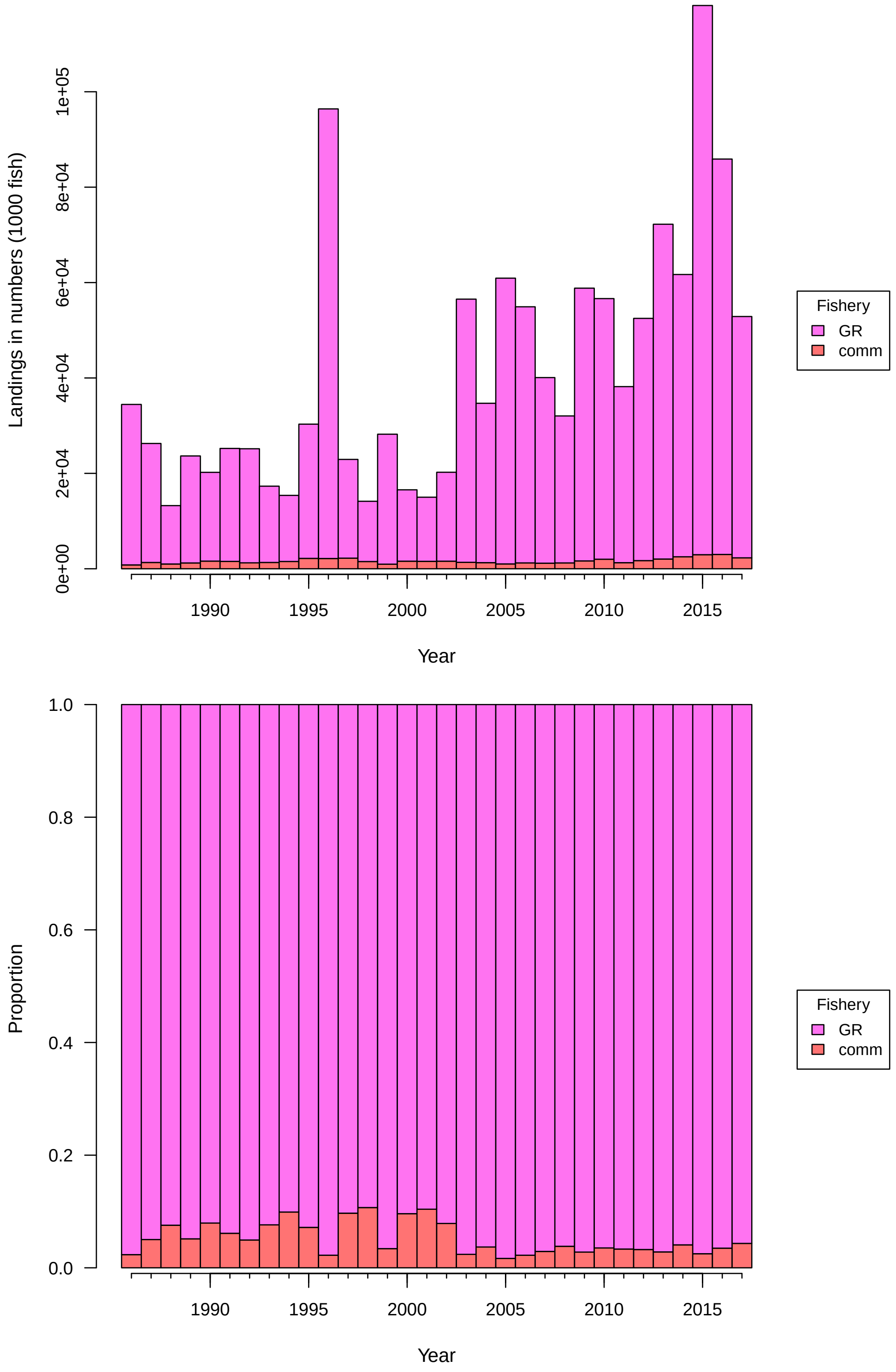


Figure 15. Estimated landings in whole weight by fishery from the catch-age model. comm refers to the commercial fleet, and GR to the general recreational fleet.

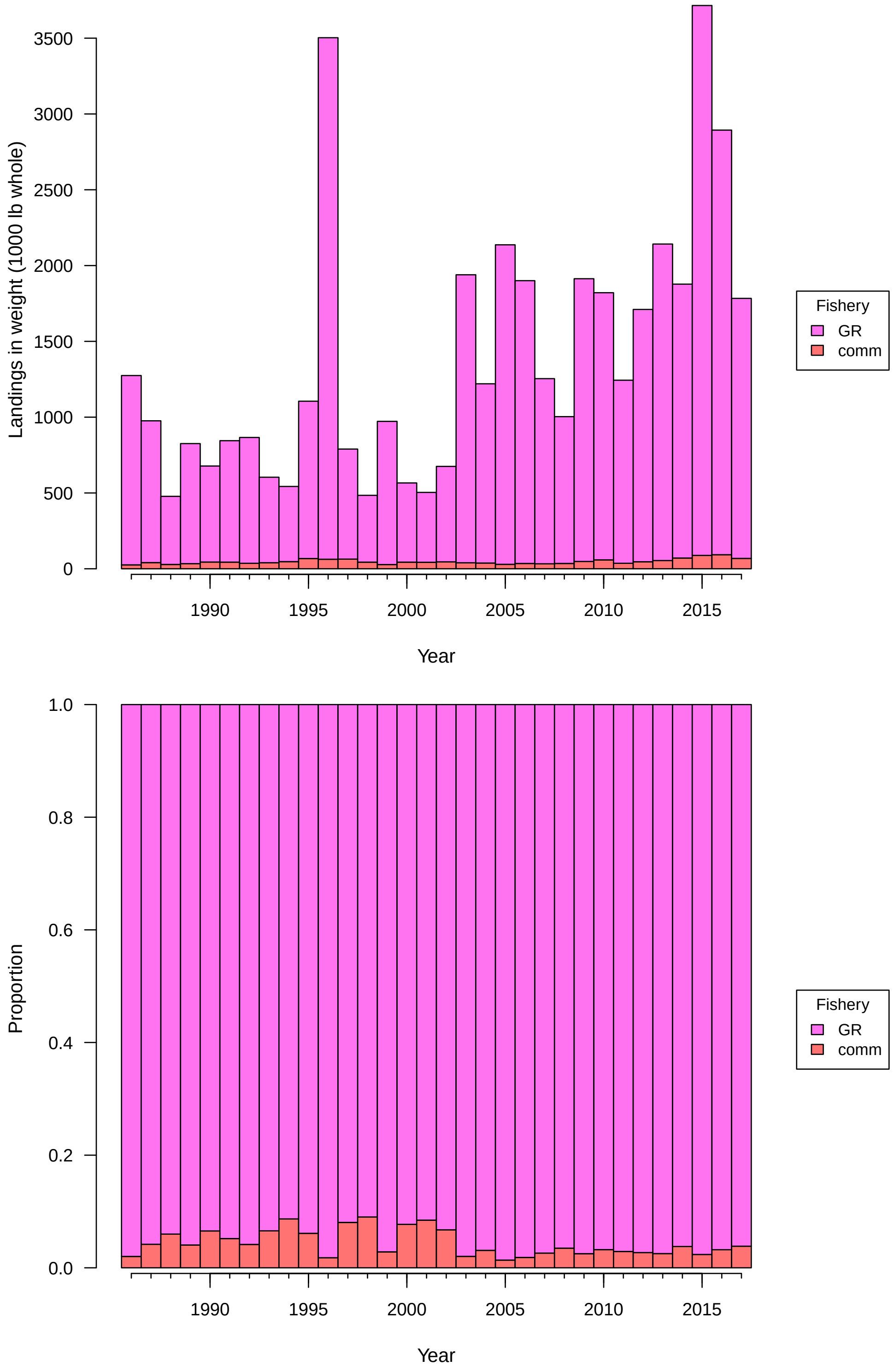


Figure 16. Top panel: Spawner-recruit relationship. The expected curve was used for computing management benchmarks. Years within panel indicate year of recruitment generated from spawning biomass. Bottom panel: log of recruits (number age-1 fish) per spawner as a function of spawners.

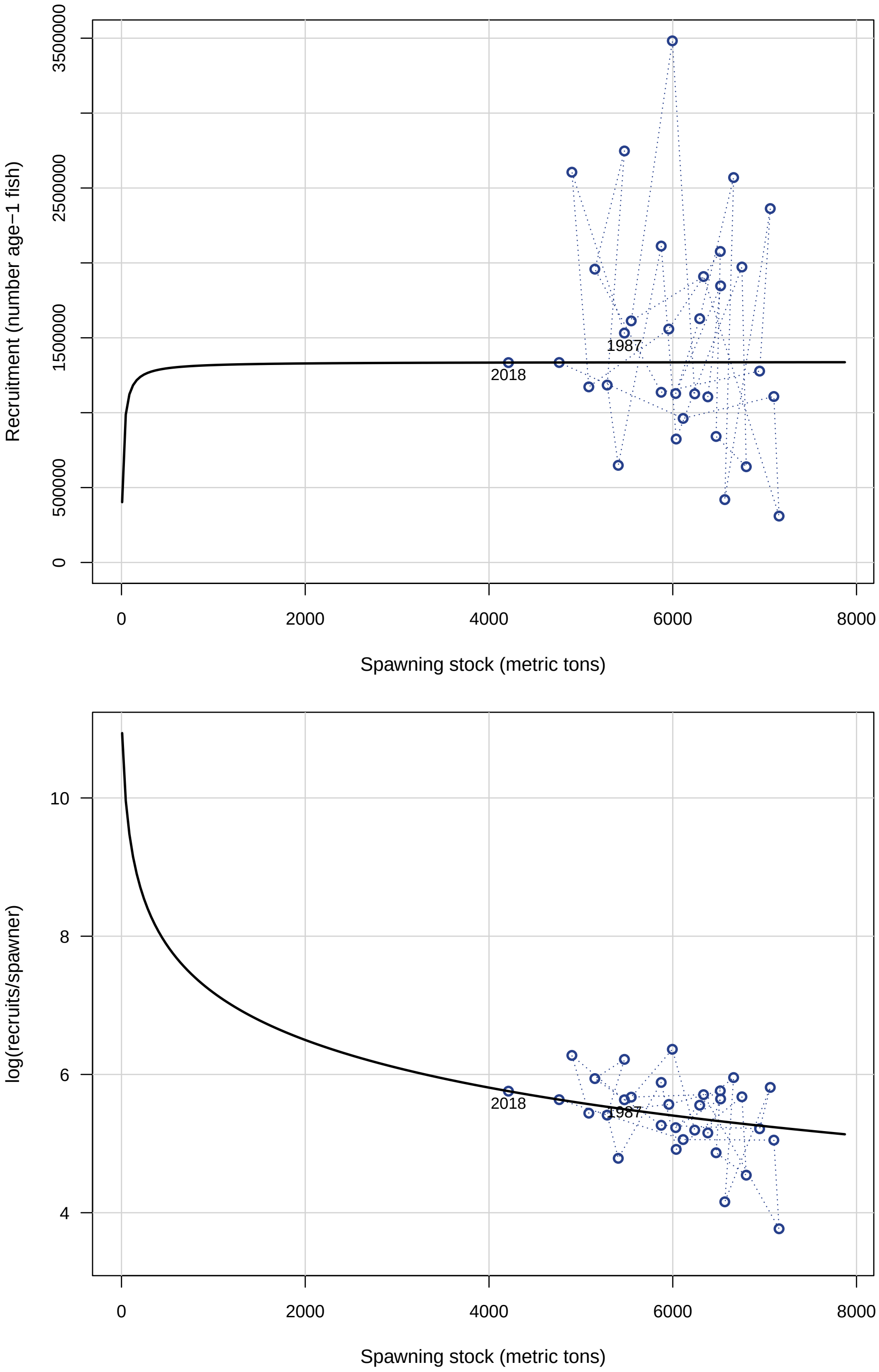


Figure 17. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), the SD of recruitment residuals, and unfished spawners per recruit. Vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model.

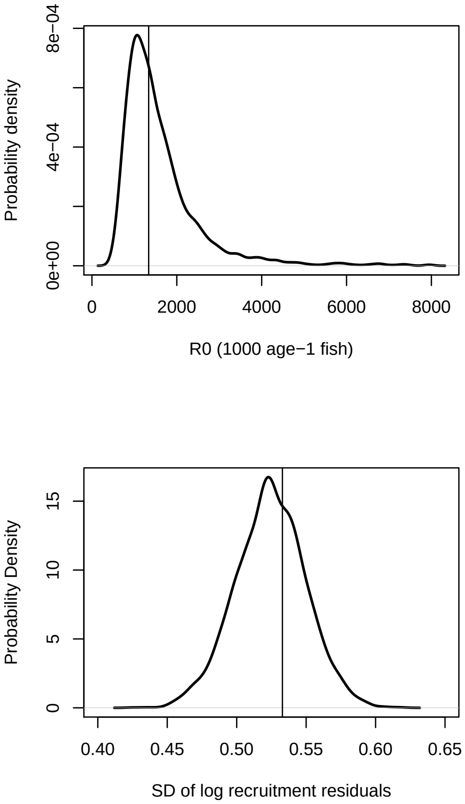


Figure 18. Top panel: yield per recruit (kg). Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$*. Both curves are based on average selectivity from the end of the assessment period.*

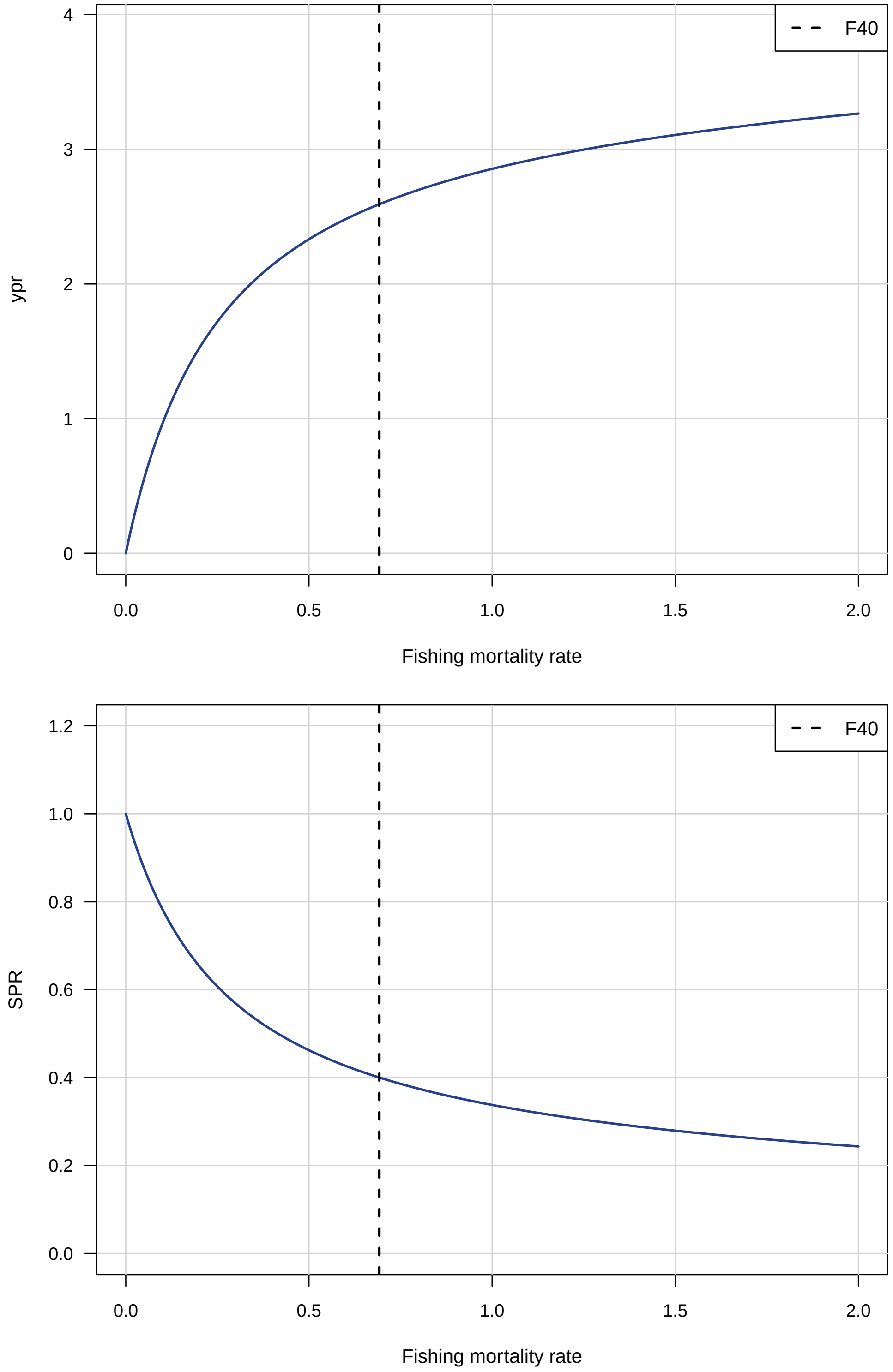


Figure 19. Top panel: equilibrium landings. The vertical dashed line occurs where fishing rate is $F_{40\%} = 0.69$ *and equilibrium landings are* $L_{\mathrm{F}40\%}$ *(1000 lb). Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.*

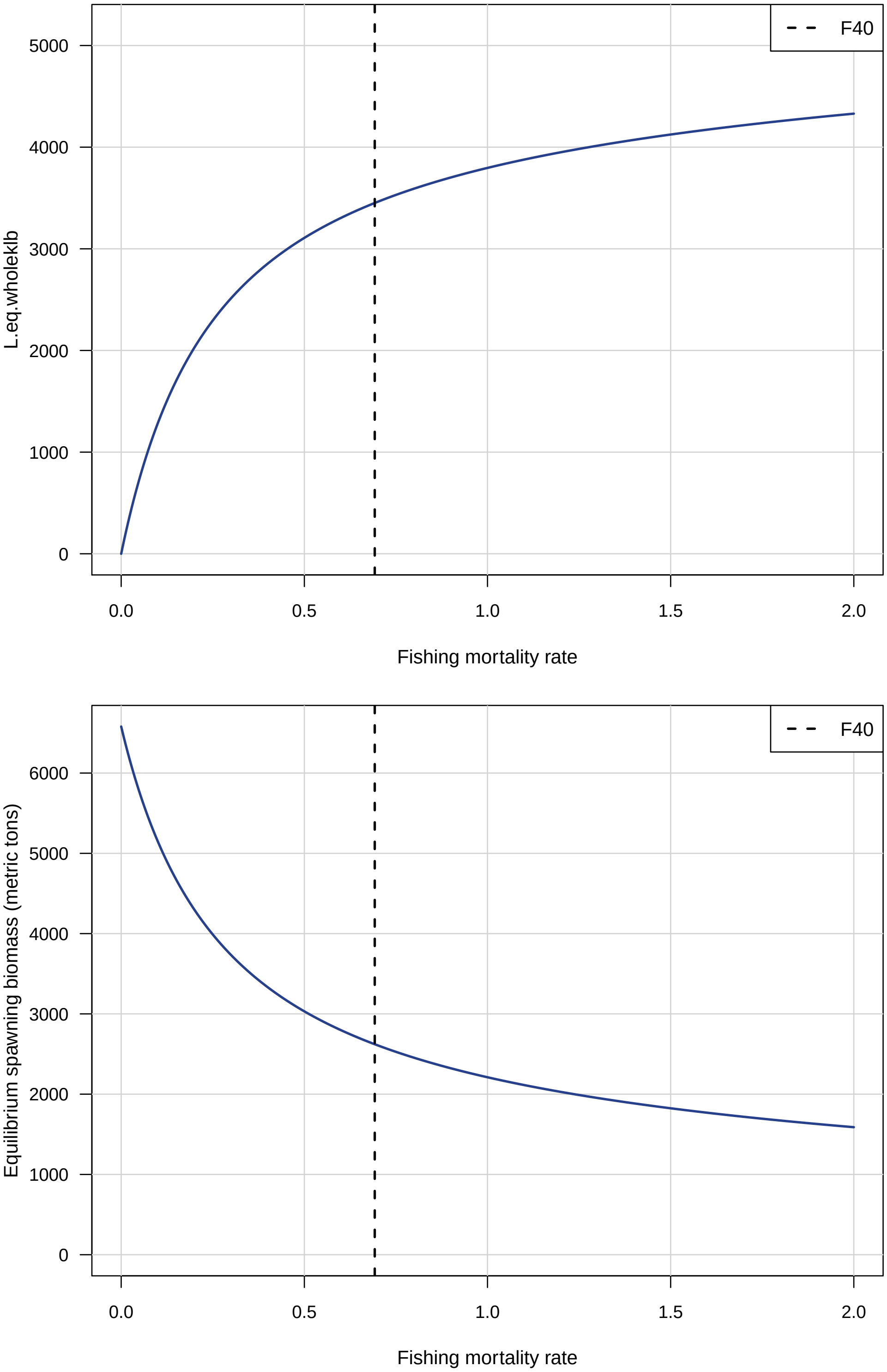


Figure 20. Probability densities of $F_{40\%}$-related benchmarks from the ensemble model of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.

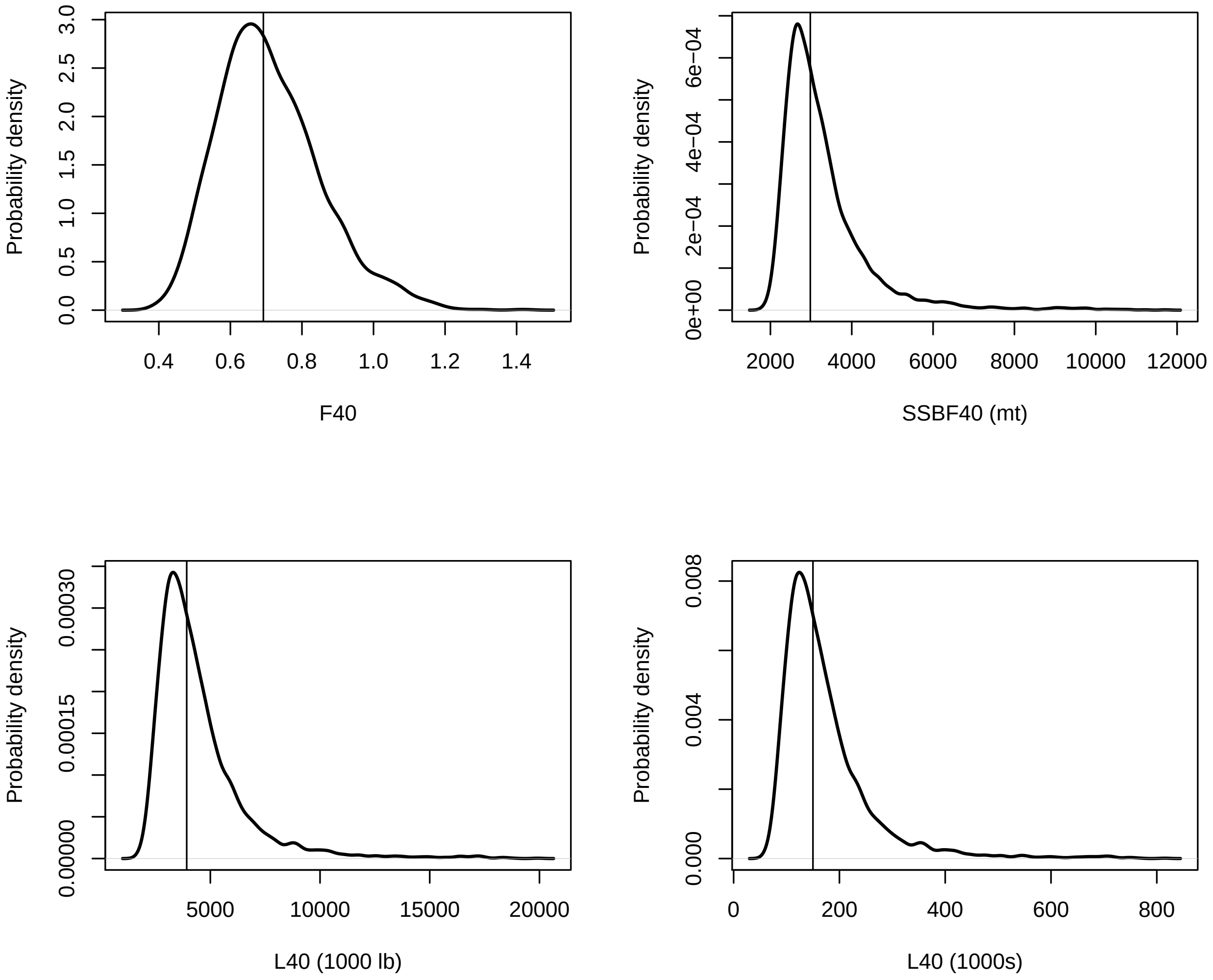


Figure 21. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5^{th} *and* 95^{th} *percentiles of the ensemble modeling. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Middle panel: spawning biomass relative to* $\mathrm{SSB}_{F40\%}$. *Bottom panel: F relative to* $F_{40\%}$.

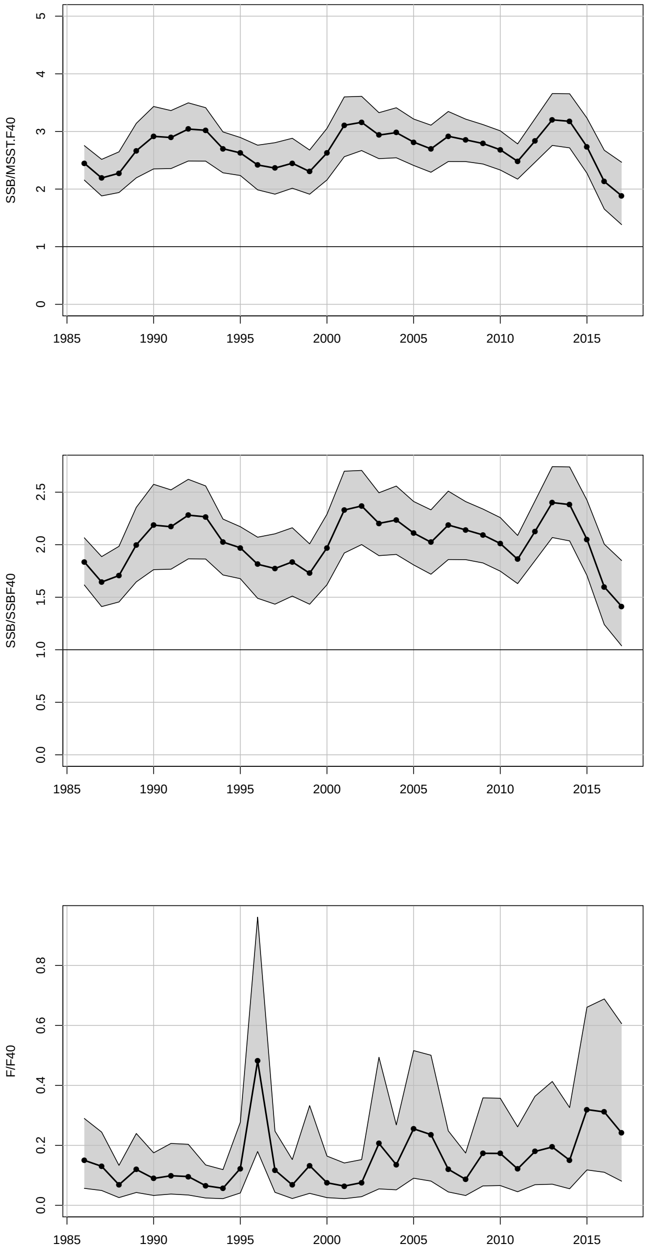


Figure 22. Probability densities of terminal status estimates from ensemble model of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.

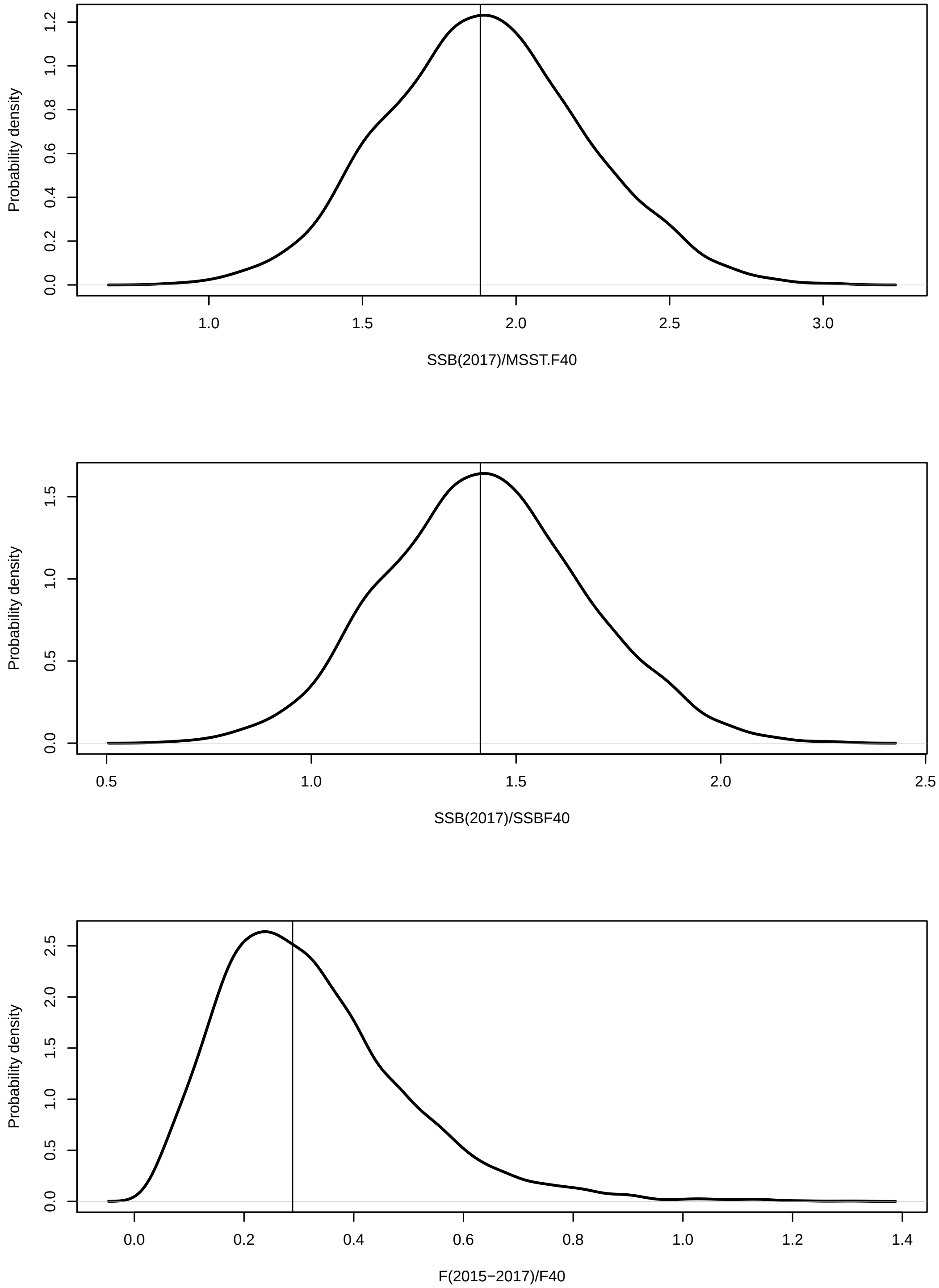


Figure 23. Phase plots of terminal status estimates from the ensemble model of the Beaufort Assessment Model. Top panel is status relative to MSST*, and the bottom panel is status relative to* $\mathrm{SSB}_{\mathrm{F40\%}}$*. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by* 5^{th} *and* 95^{th} *percentiles.*

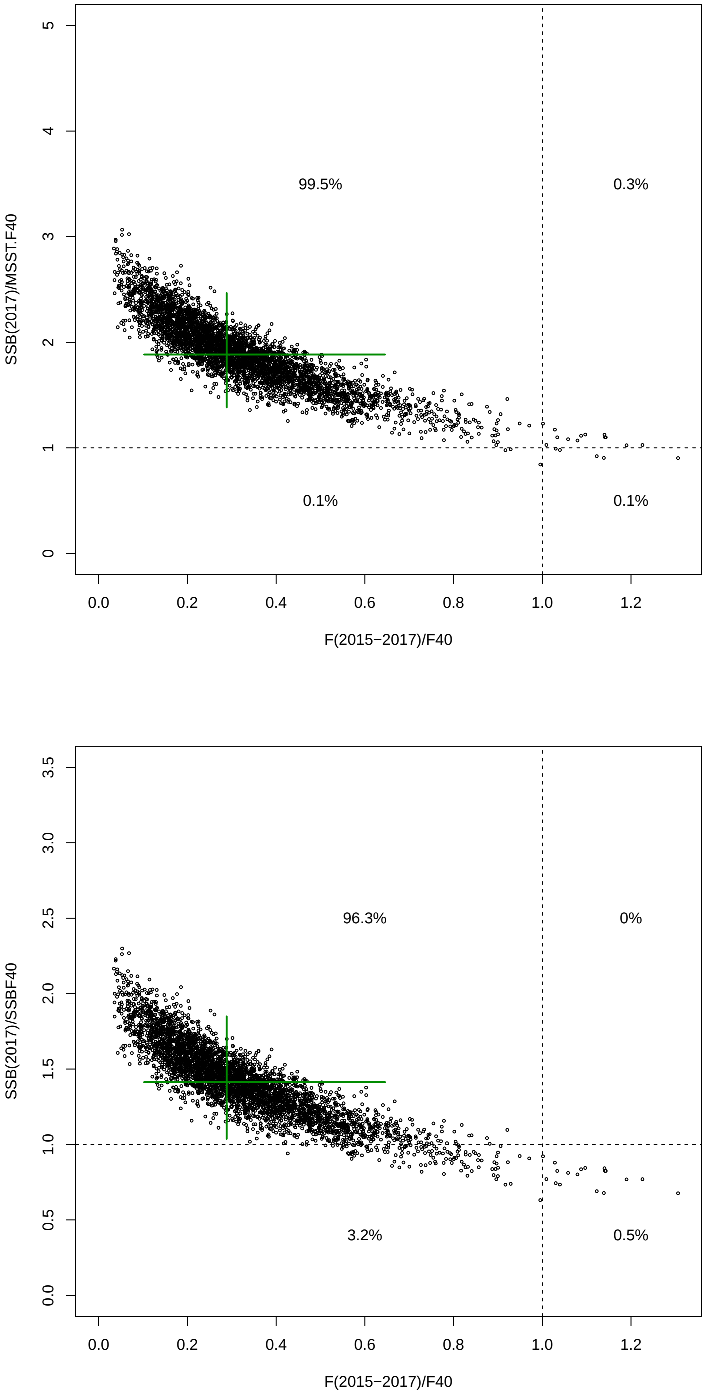


Figure 24. Age structure relative to the equilibrium expected at $L_{\mathrm{F40\%}}$.

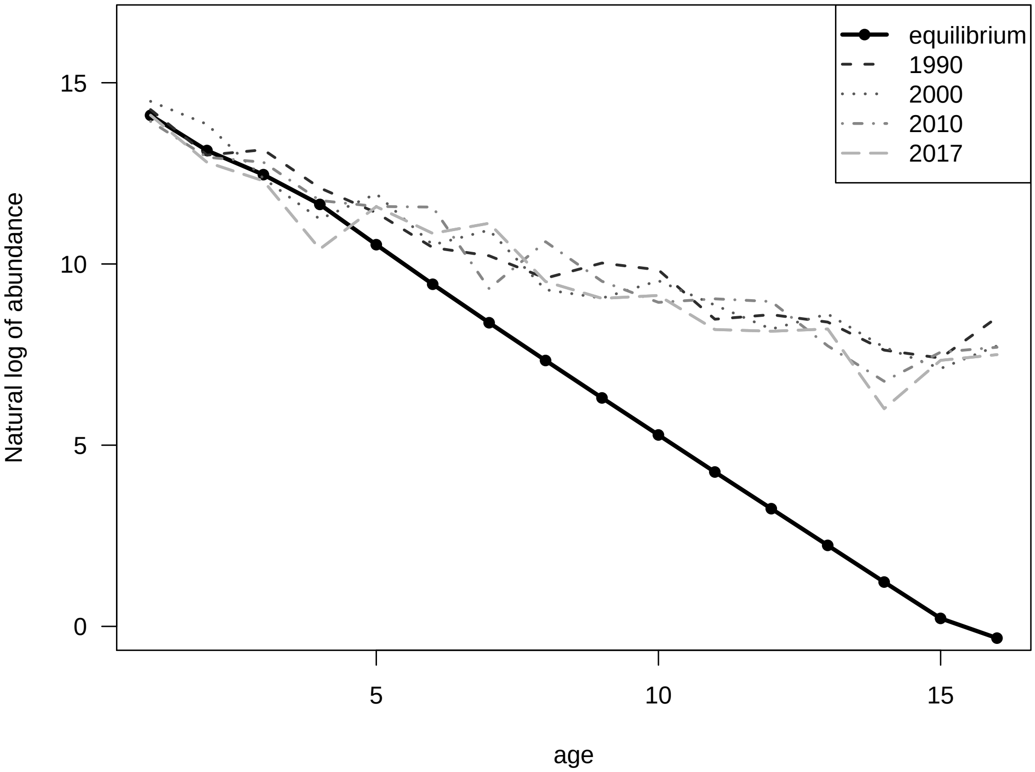


Figure 25. Sensitivity to an earlier start year (sensitivity run S1). Top panel: Ratio of F to $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.

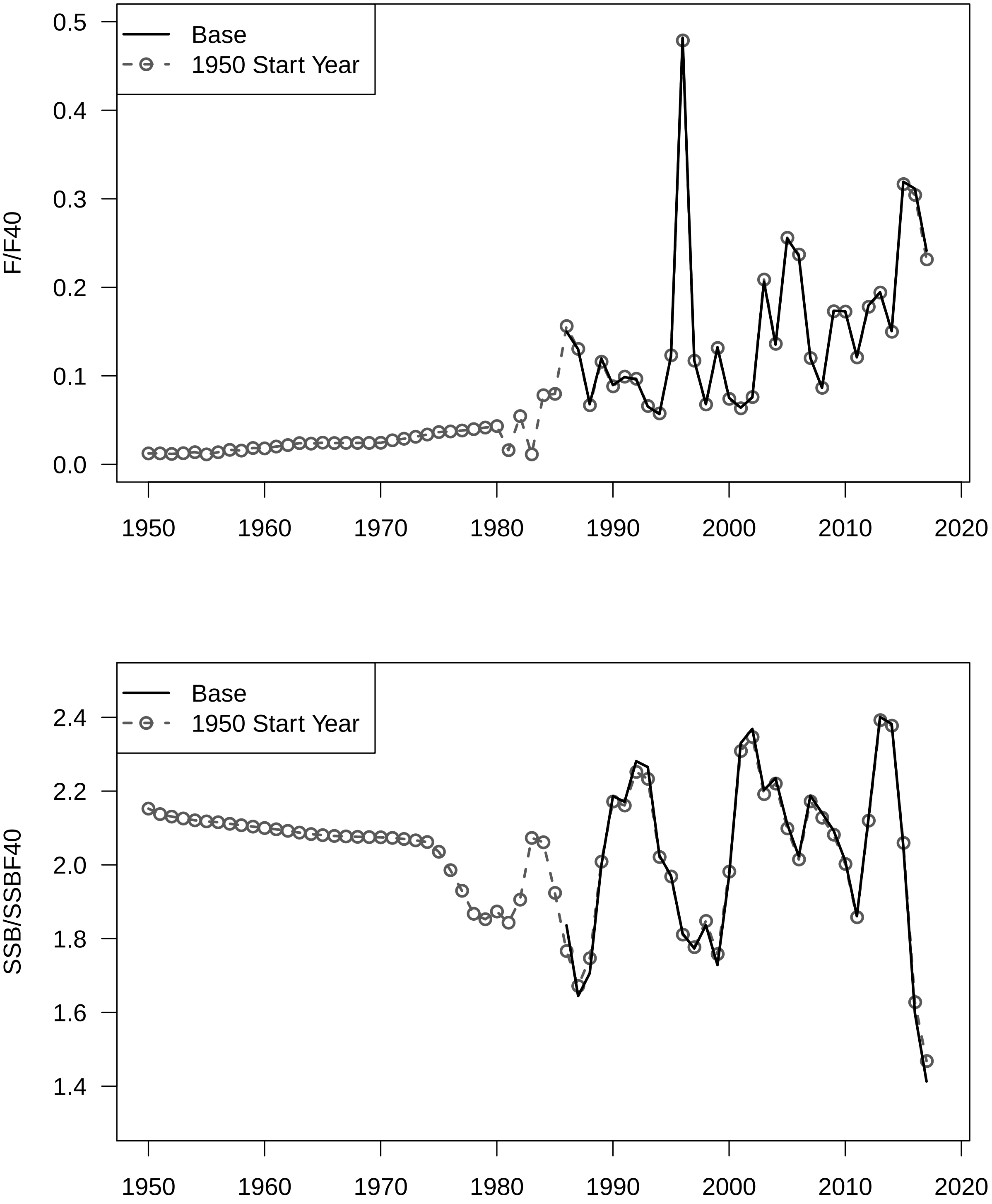
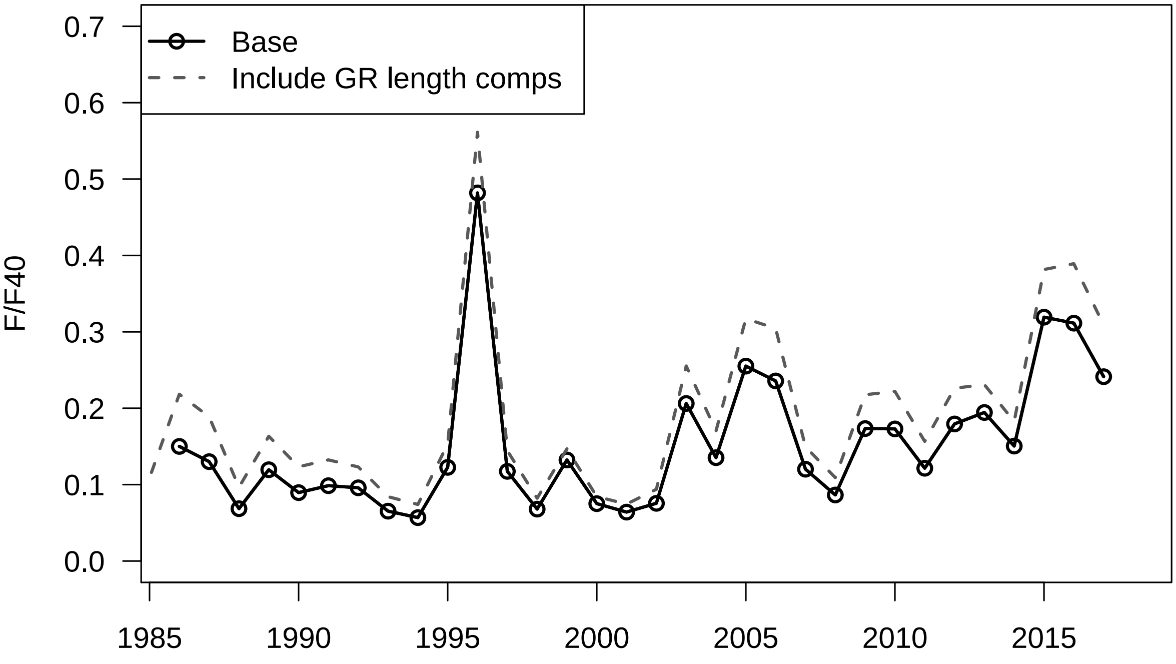


Figure 26. Sensitivity to including recreational length compositions (sensitivity run S2). Top panel: Ratio of F to $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.



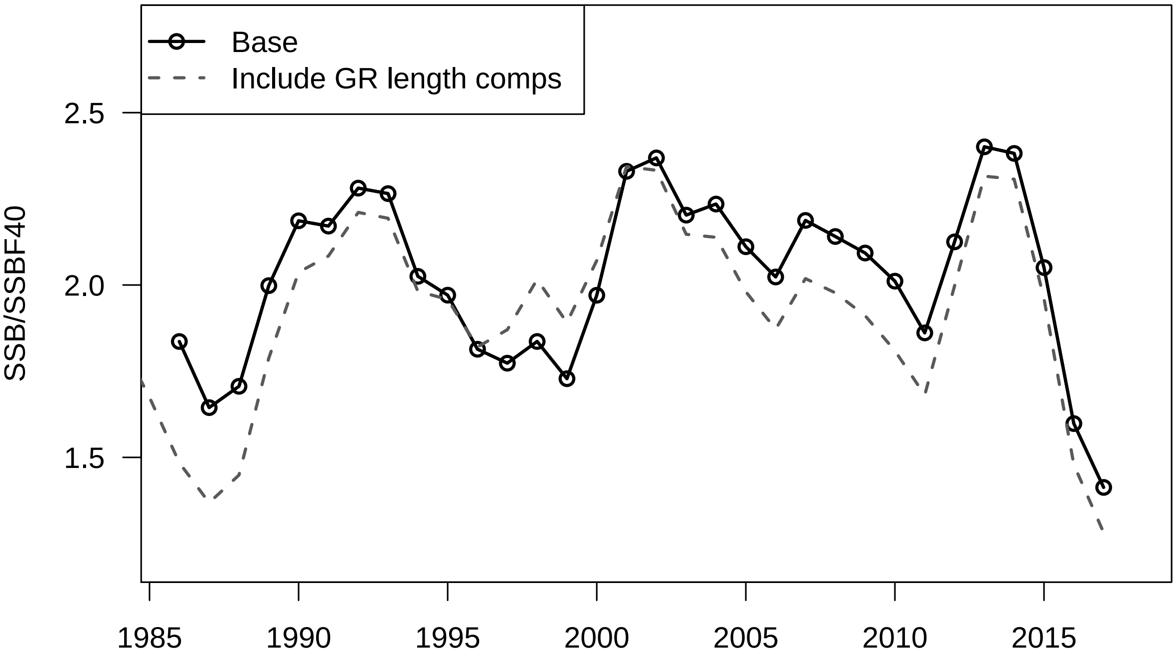


Figure 27. Sensitivity to SEDAR 28 life history values (sensitivity runs S3a-3). Top panel: Ratio of F to $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.

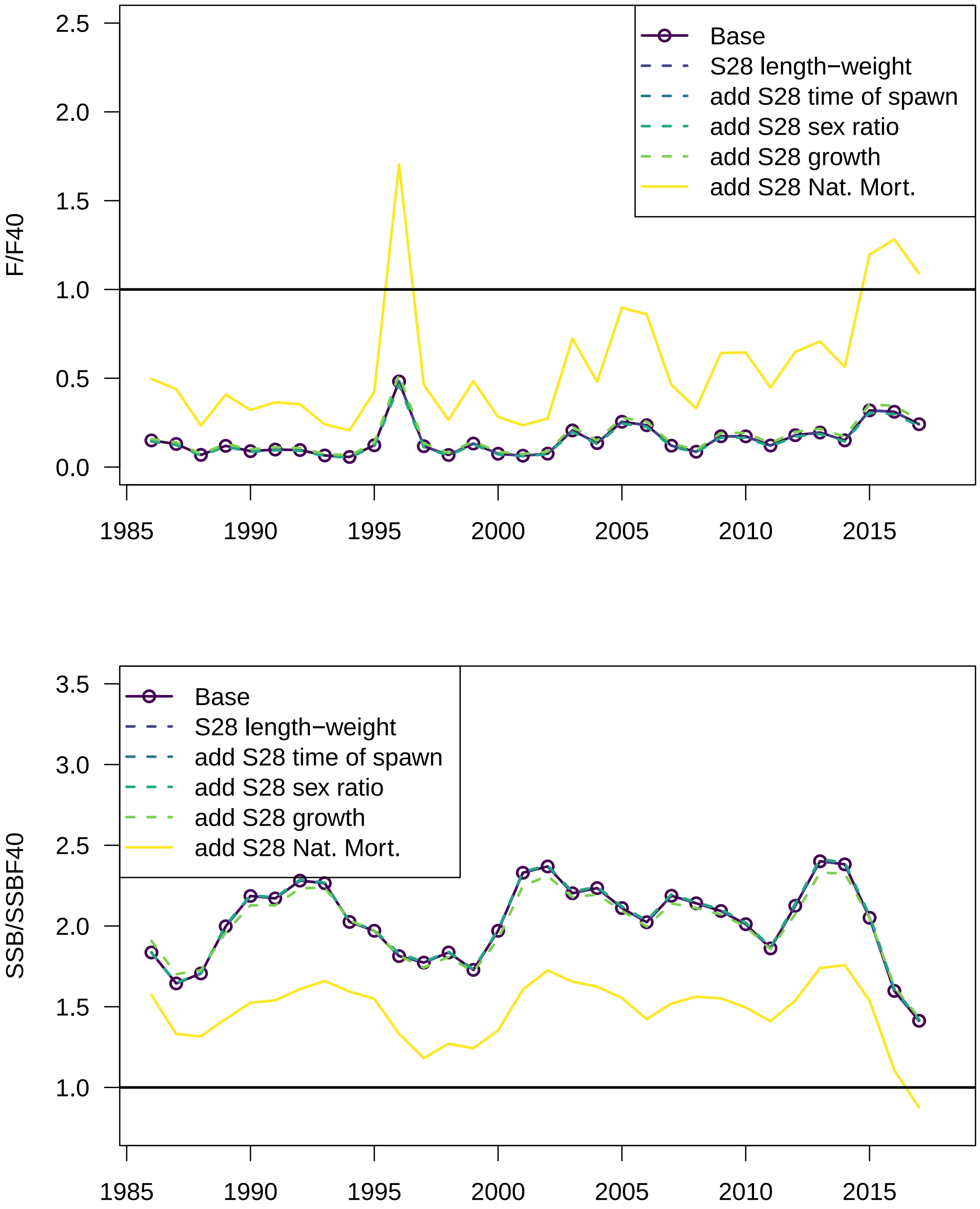


Figure 28. Sensitivity to including the headboat index (sensitivity run S4). Top panel: Ratio of F *to* $F_{40\%}$. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.

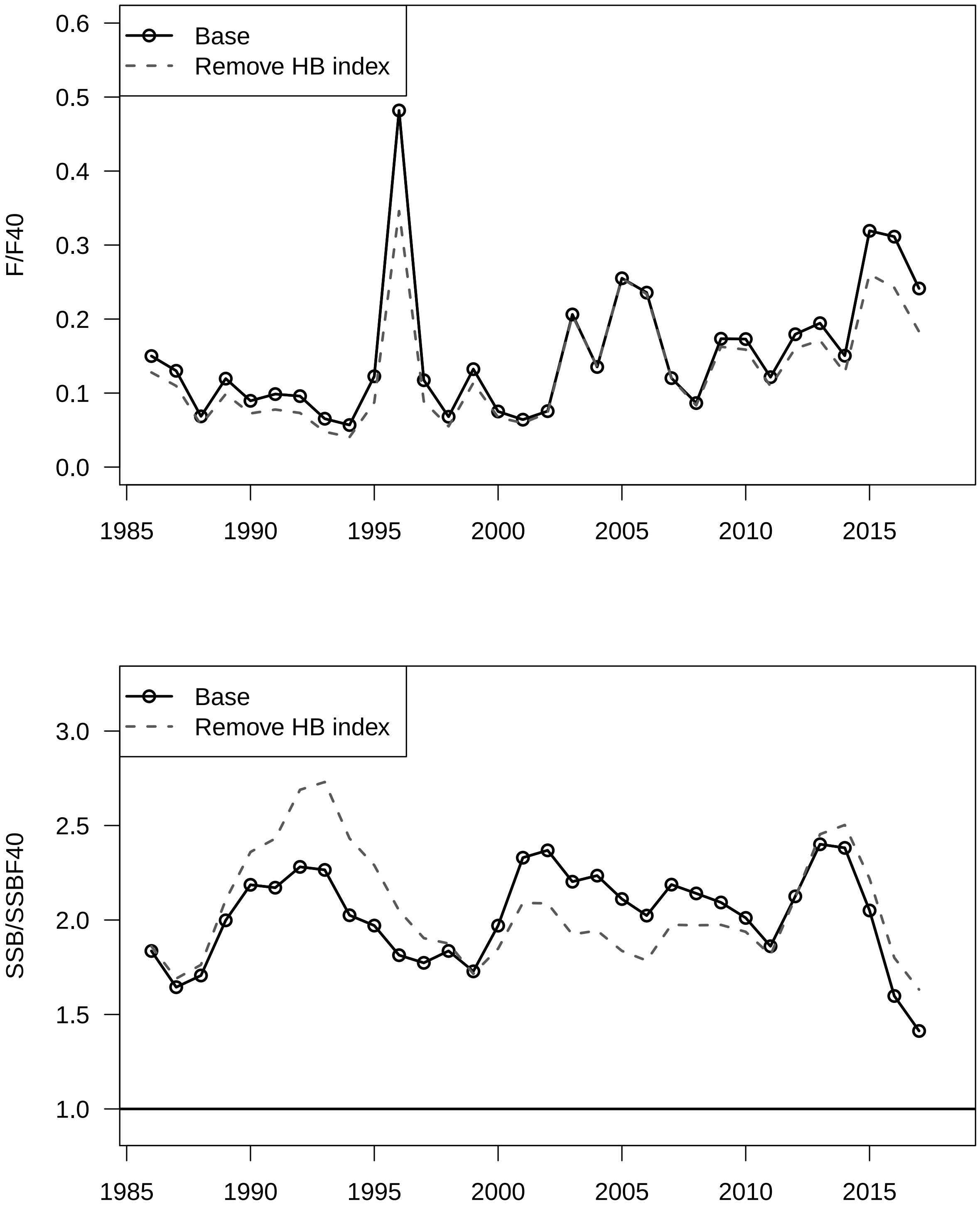
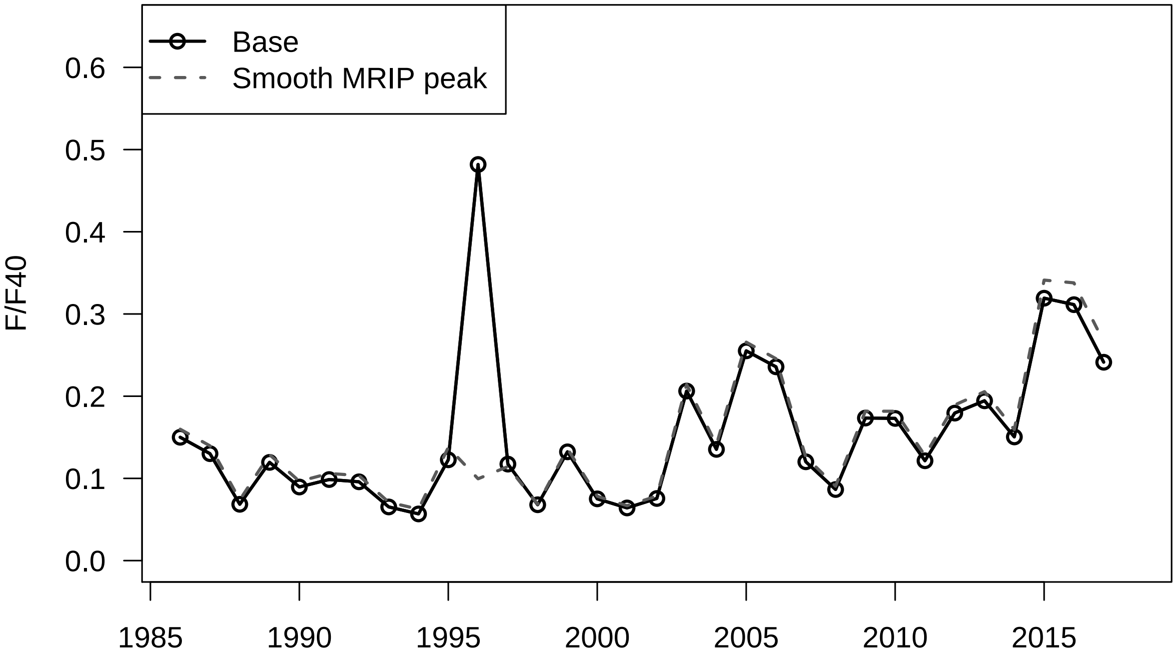


Figure 29. Sensitivity to smoothing the general recreational peak (sensitivity run S5). Top panel: Ratio of F *to* $F_{40\%}$. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.



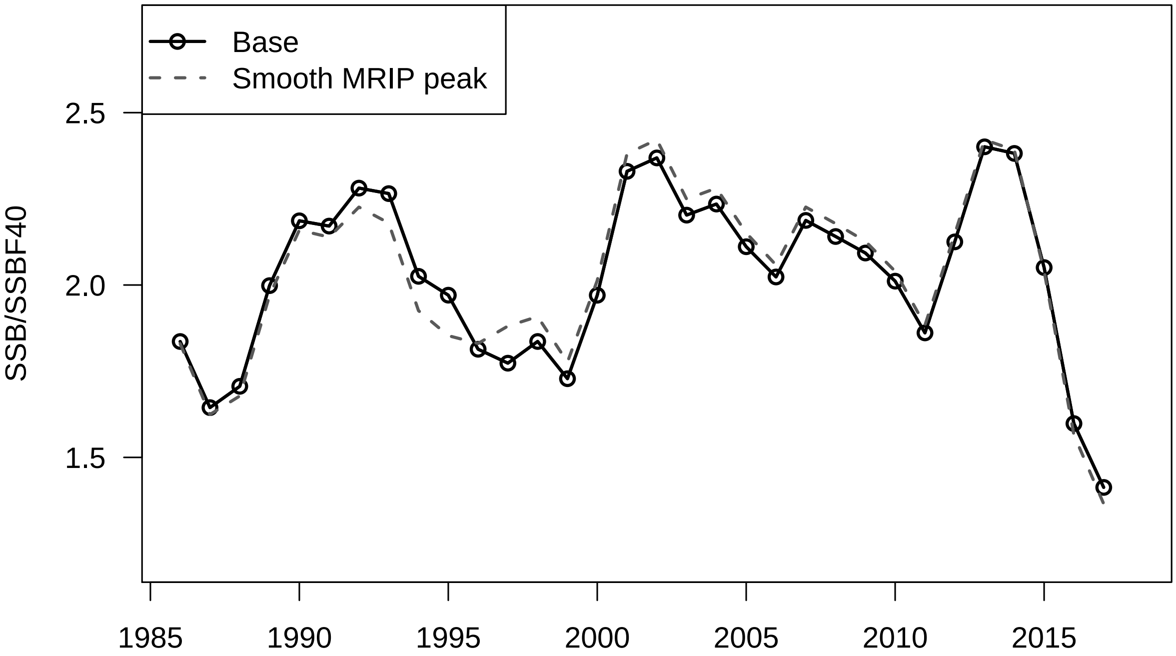


Figure 30. Sensitivity to higher and lower recreational landings (sensitivity runs S6 and S10). Top panel: Ratio of F *to* $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$*. Any lines not visible overlap results of the base run.*

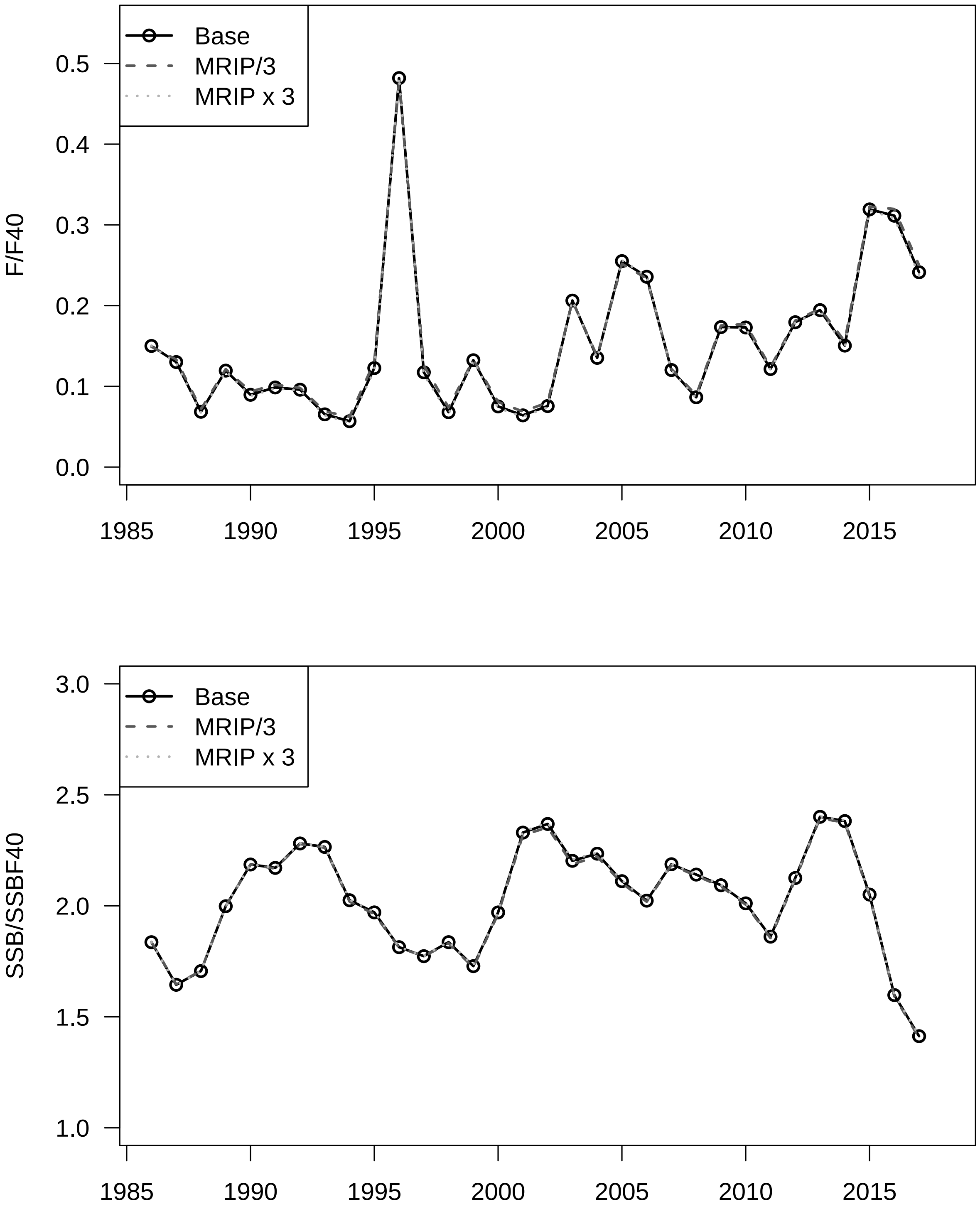


Figure 31. Sensitivity to changes in natural mortality (sensitivity runs S7b–S8b). Top panel: Ratio of F to $F_{40\%}$. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.

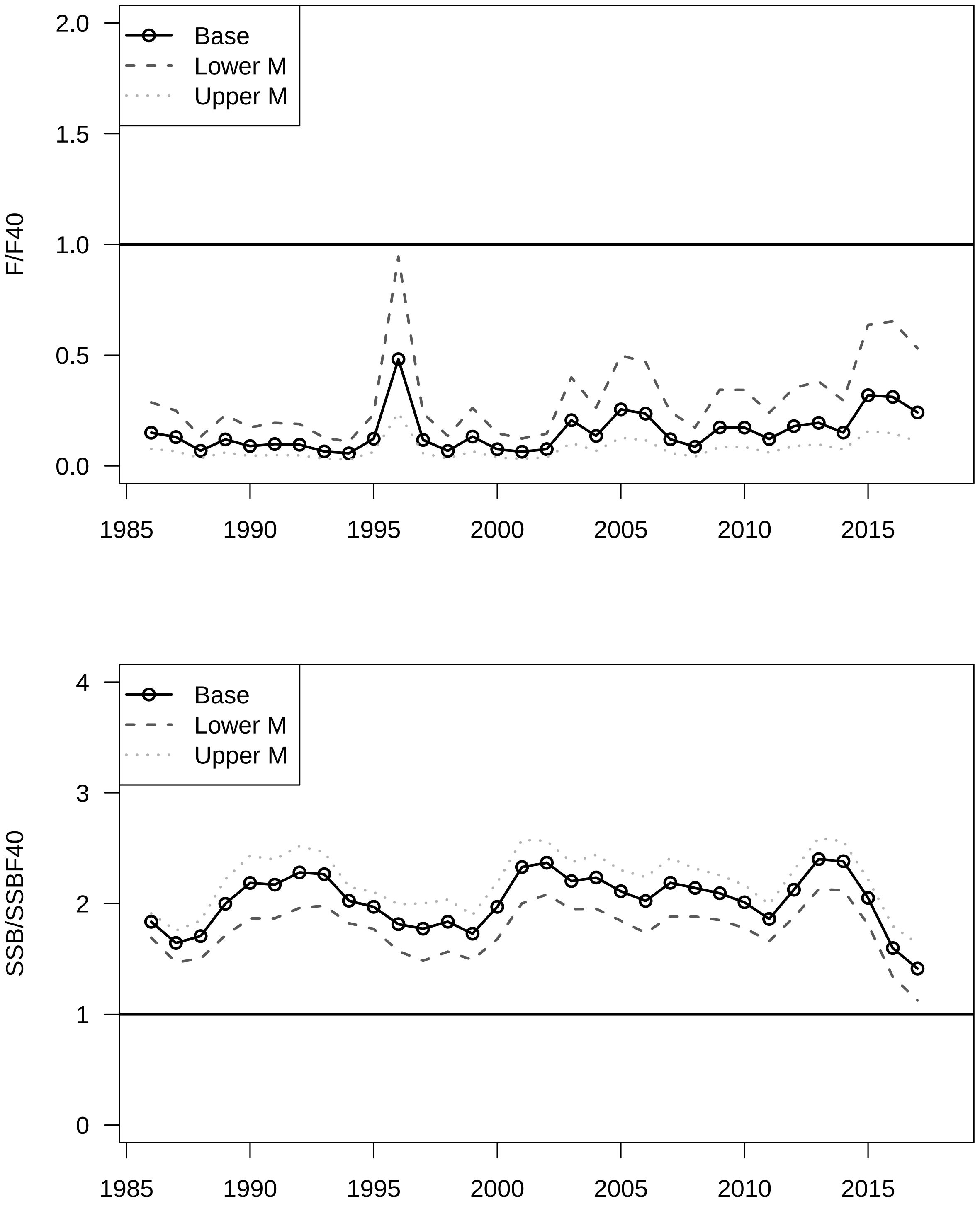


Figure 32. Individual sensitivity comparison of the parameters values provided to the ensemble model. This variation contains the upper and lower bounds for landings, discards, and discard mortality. (sensitivity run S7a–c and S8a–c). Top panel: Ratio of F *to* $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.

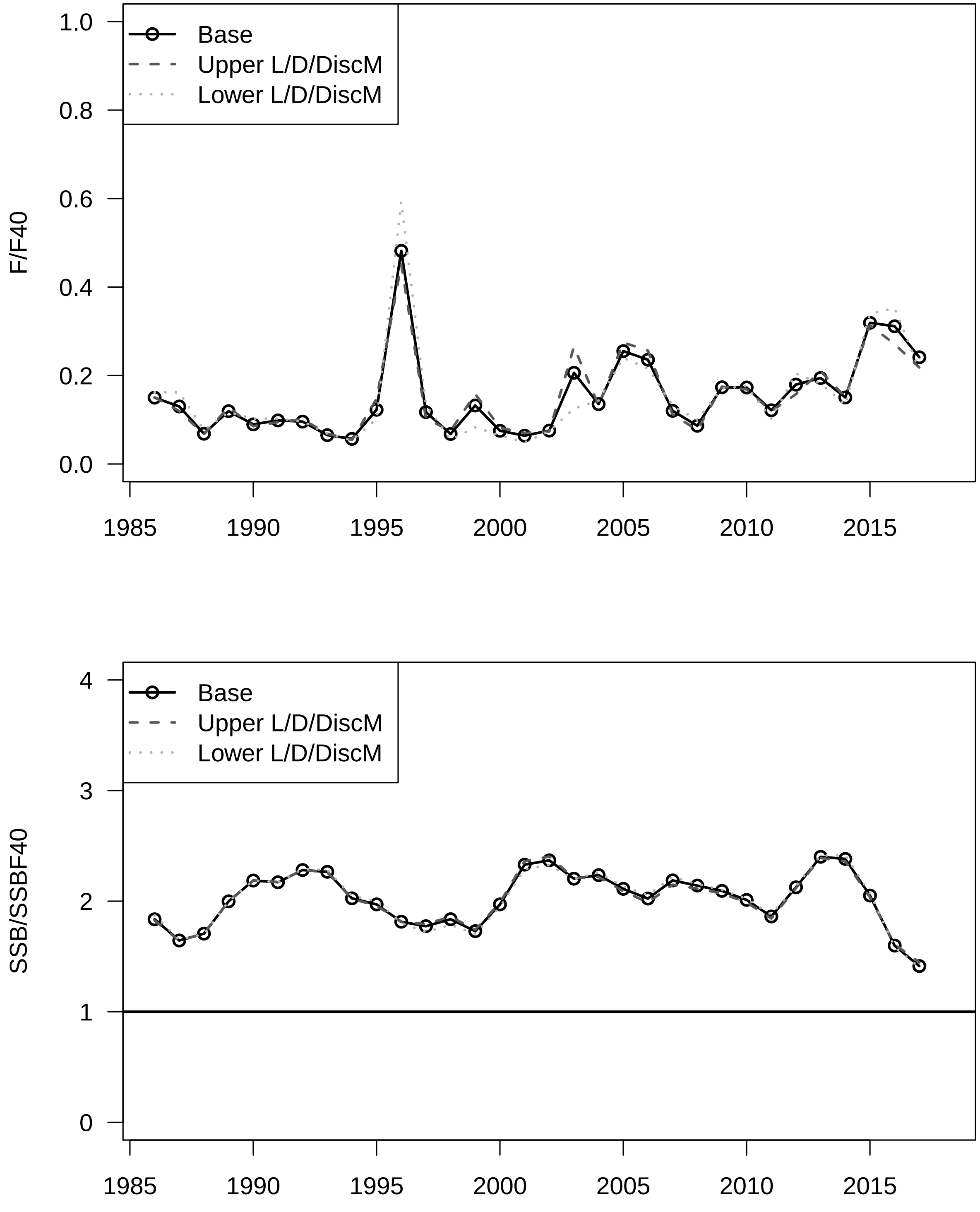


Figure 33. Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model.

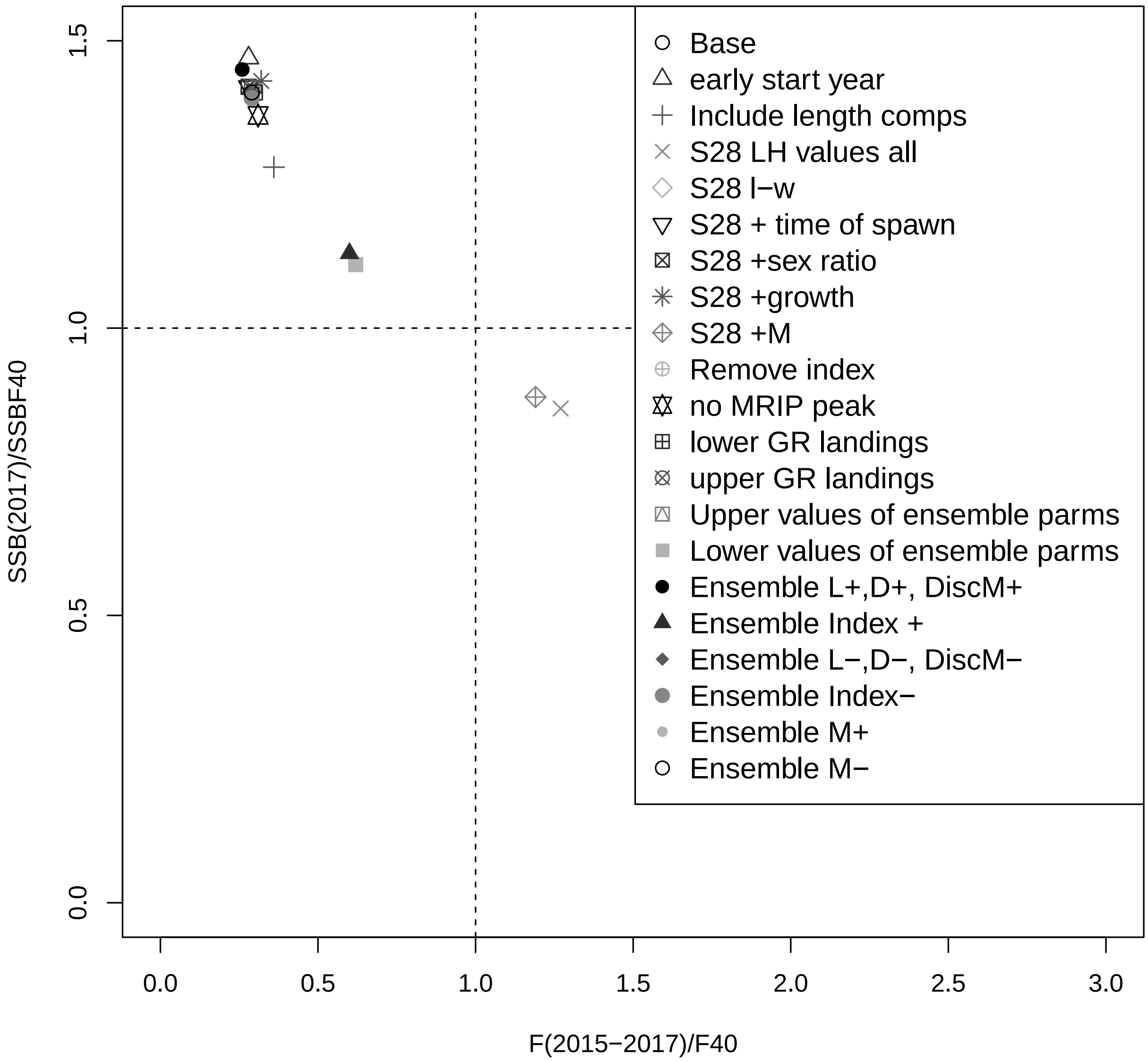


Figure 34. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S9a–e). Top panel: Recruits. Bottom panel: Spawning biomass. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

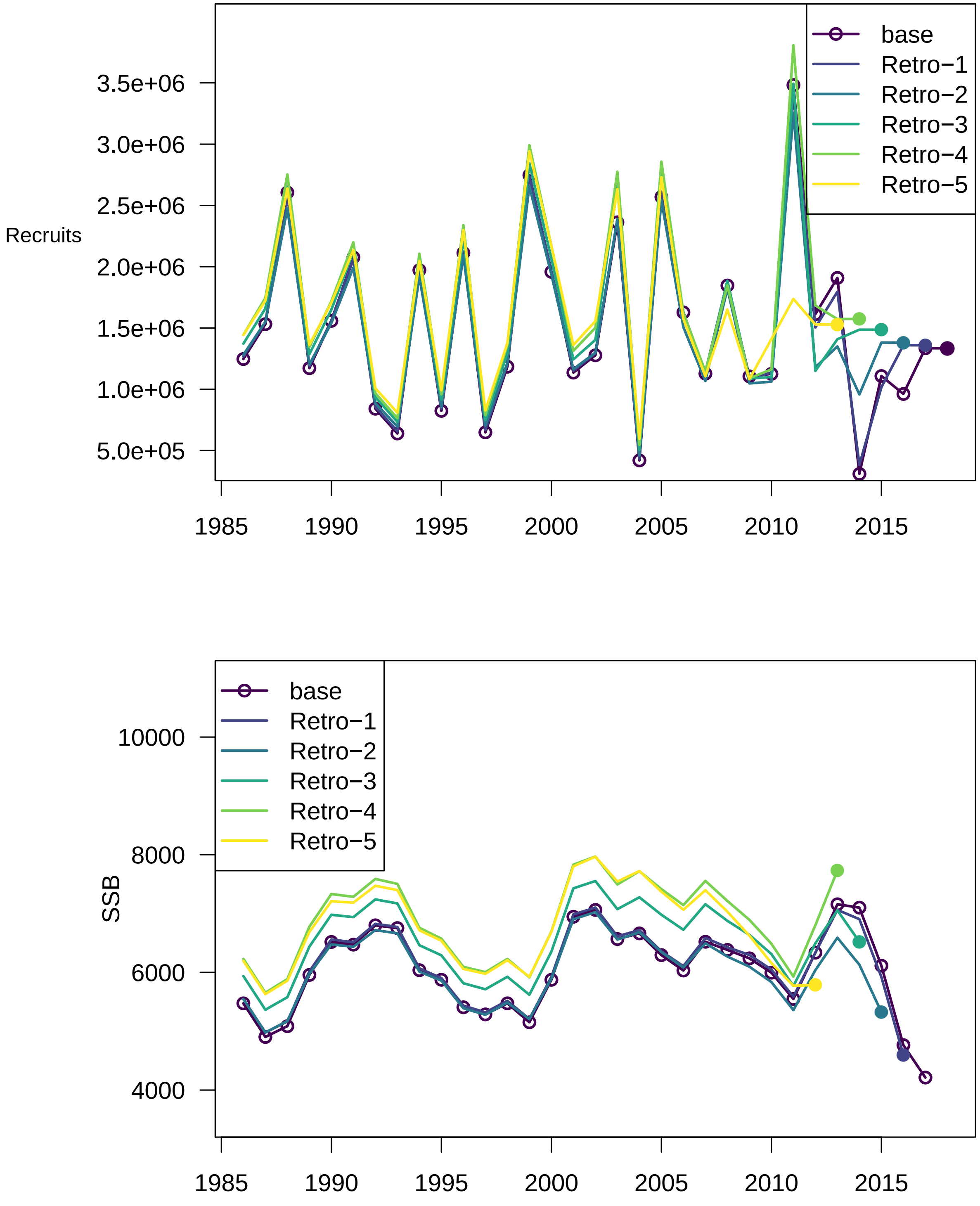


Figure 35. Retrospective status analyses. Sensitivity to terminal year of data (sensitivity runs S9a–e). Top panel: Fishing status. Bottom panel: Biomass status. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

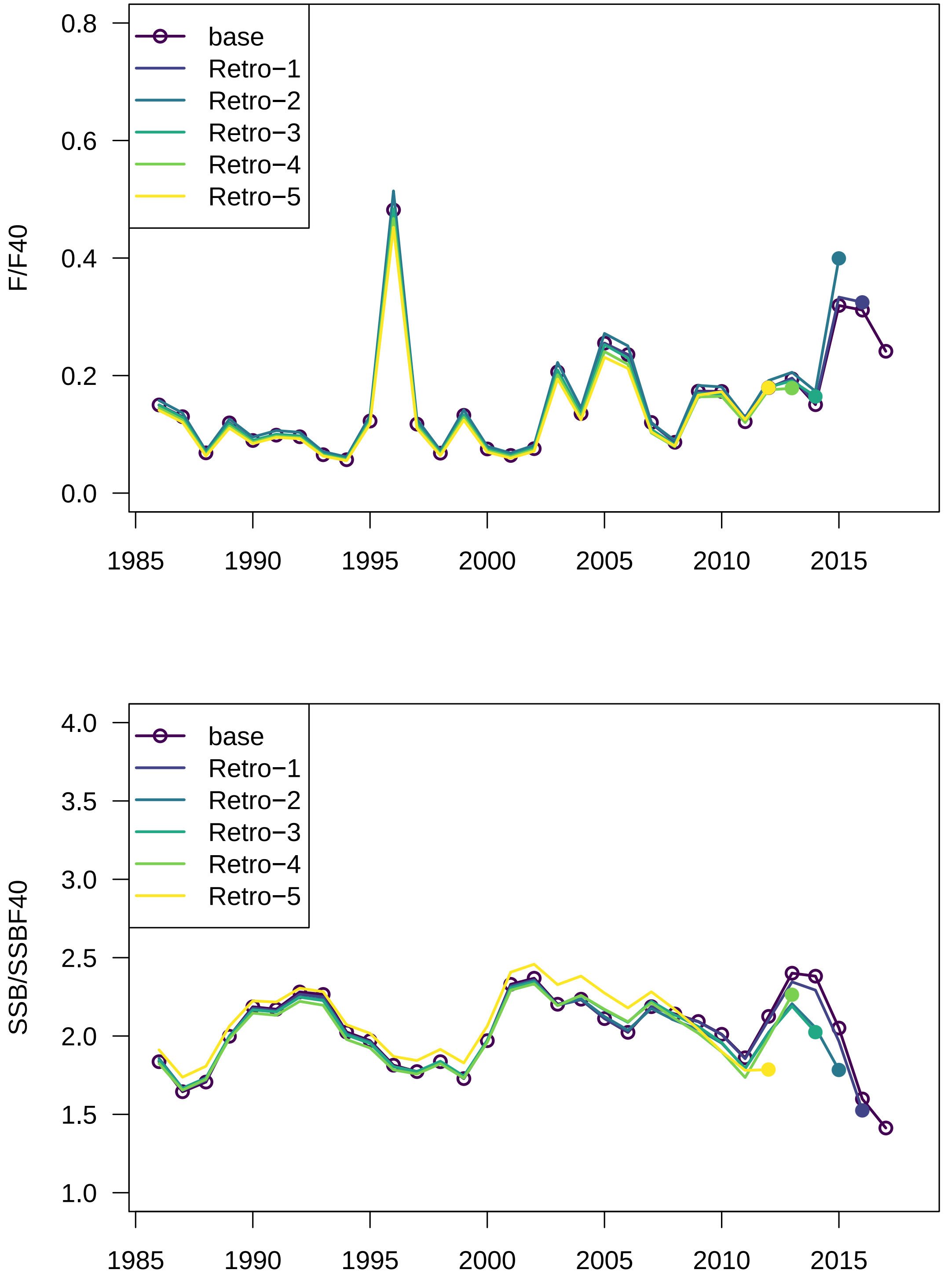


Figure 36. Projection results under scenario 1—fishing mortality rate fixed at F_{current}*, with 2020 as the first year of new regulations. The interim years (2018–2019) use a mean of the 2014–2017 landings. In all panels, expected values represented by solid lines, median values represented by dashed lines, and uncertainty represented by thin lines corresponding to* 5^{th} *and* 95^{th} *percentiles of replicate projections. Horizontal lines mark* $L_{\text{F40\%}}$*-related quantities from the base run (solid blue lines) and medians from the MCB runs(dashed green lines). Spawning stock (SSB) is at time of peak spawning.*

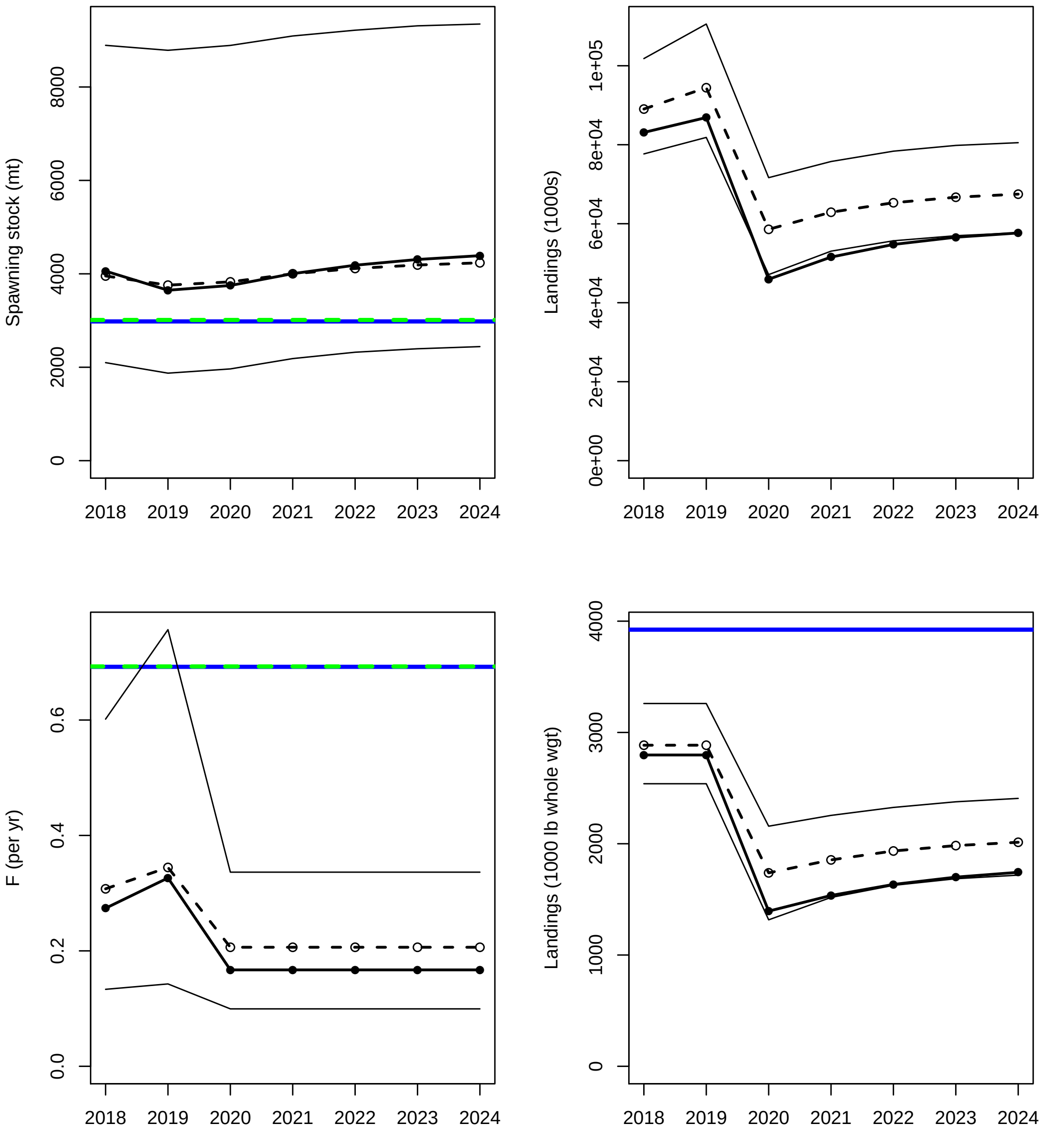


Figure 37. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{40\%}$*, with 2020 as the first year of new regulations. The interim years (2018–2019) use a mean of the 2014–2017 landings. In all panels, expected values represented by solid lines, median values represented by dashed lines, and uncertainty represented by thin lines corresponding to* 5^{th} *and* 95^{th} *percentiles of replicate projections. Horizontal lines mark* $L_{\mathrm{F40\%}}$*-related quantities from the base run (solid blue lines) and medians from the MCB runs(dashed green lines). Spawning stock (SSB) is at time of peak spawning.*

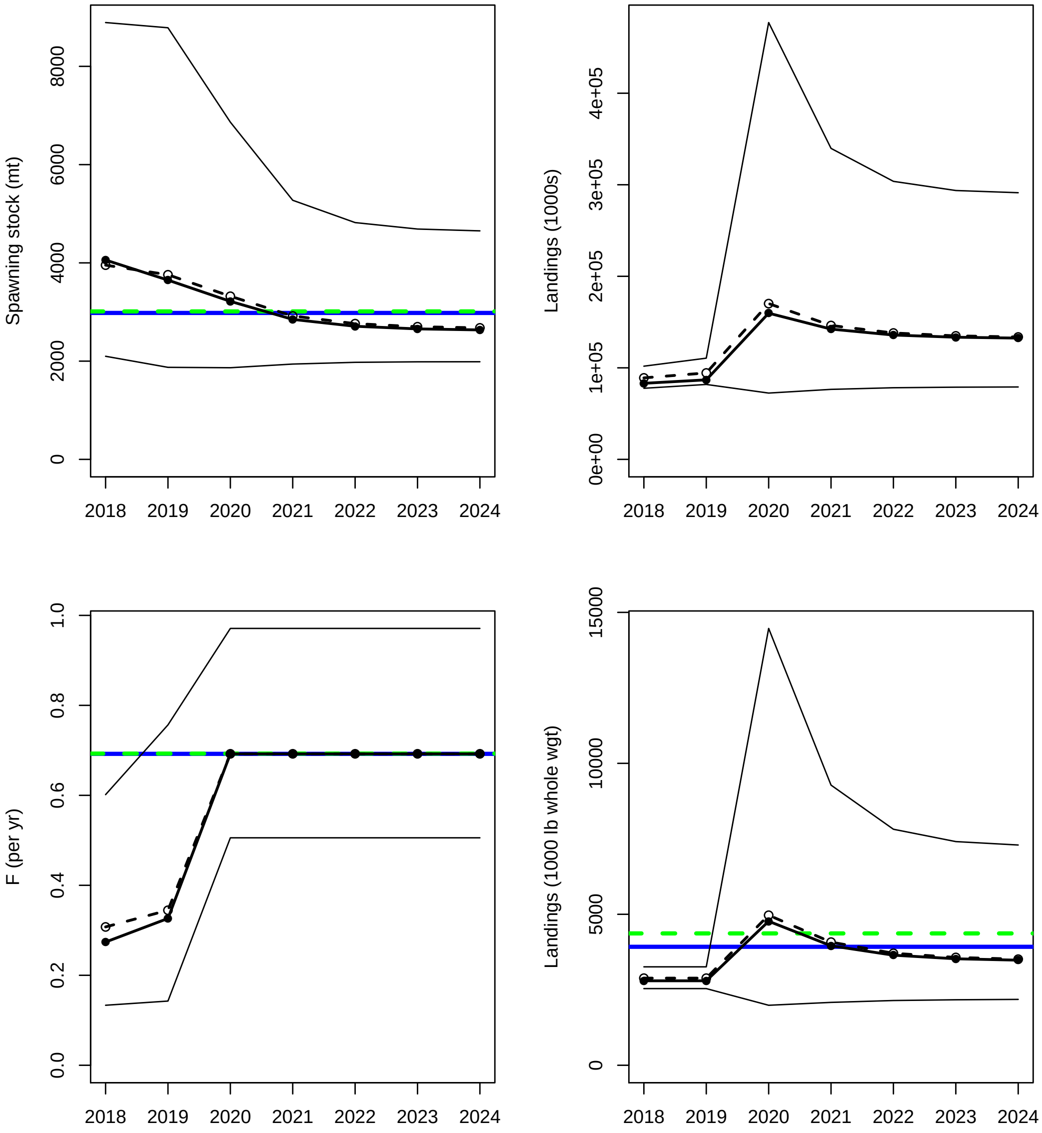


Figure 38. Projection results under scenario 3—fishing mortality rate fixed at $F = 75\% F_{40\%}$*, with 2020 as the first year of new regulations. The interim years (2018–2019) use a mean of the 2014–2017 landings. In all panels, expected values represented by solid lines, median values represented by dashed lines, and uncertainty represented by thin lines corresponding to* 5^{th} *and* 95^{th} *percentiles of replicate projections. Horizontal lines mark* $L_{\mathrm{F}40\%}$*-related quantities from the base run (solid blue lines) and medians from the MCB runs(dashed green lines). Spawning stock (SSB) is at time of peak spawning.*

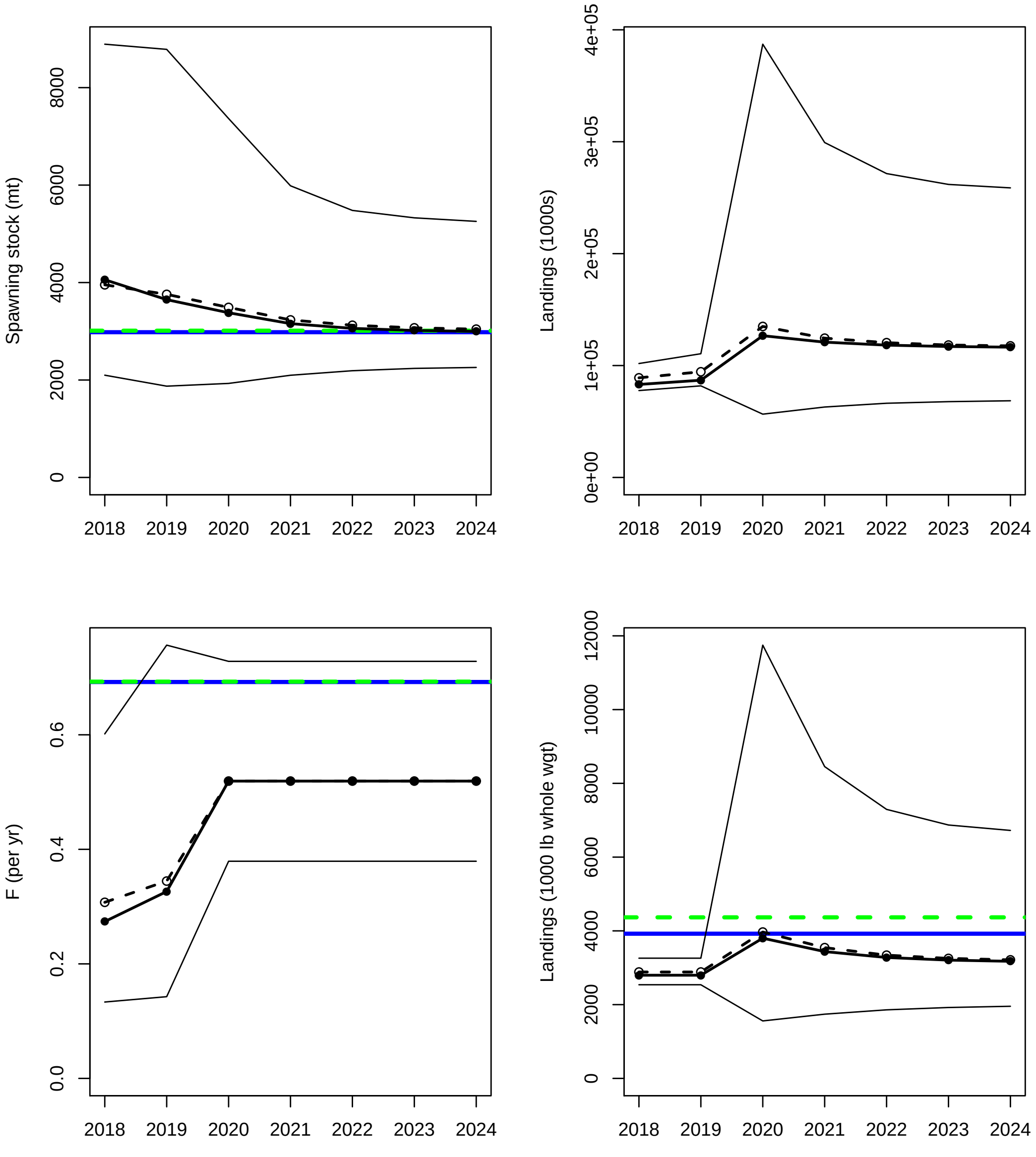


Figure 39. Comparing benchmark time series from current and last assessment. Solid line represents the base run of the current benchmark assessment and the dashed line represents the base run from the last assessment. Top panel: The biomass status time series. Bottom panel: The fishing status time series. The current benchmark assessment used $F_{40\%}$ as an MSY proxy, while the last assessment benchmarks are relative to MSY.

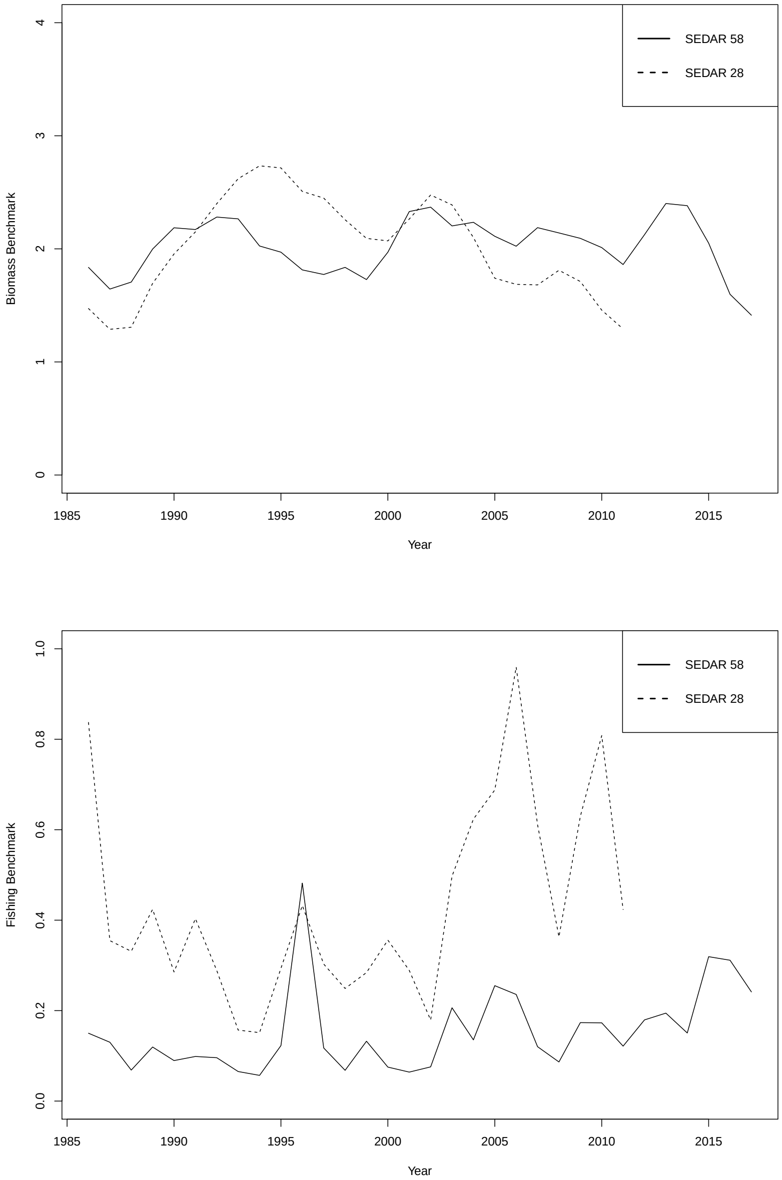
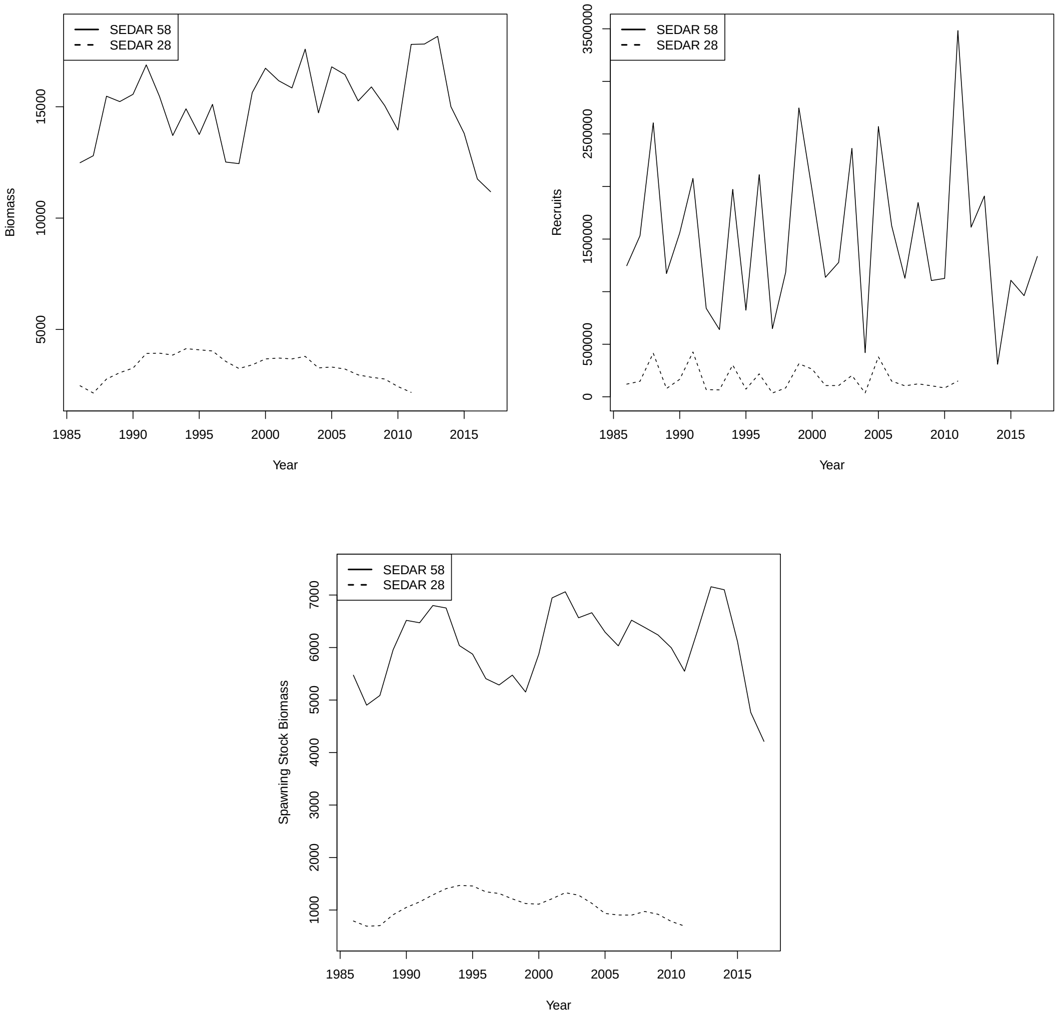


Figure 40. Comparing biological time series from current and last assessment. Solid line represents the base run of the current benchmark assessment and the dashed line represents the base run from the last assessment. Top left panel: The biomass time series. Top right panel: The recruits time series. Bottom panel: The spawning stock biomass time series.



Appendix A Abbreviations and symbols

Table 21. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for cobia)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1r
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 cobia)
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
MCB	Monte Carlo/Bootstrap, 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 cobia 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
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)

Appendix B Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 125  Objective function value = 13080.1  Maximum gradient component = 7.24114e-005
# len_cv_val_L:
0.246292621485
# log_Nage_dev:
 -0.571328040022 -0.358342787465 -0.548122374181 0.260829557102 0.419324643272 -0.603359869552
 -0.152158192589 -0.0322672153625 -0.480429211345 -0.385742488652 -0.305583223533 -0.238638083007
 -0.184200540903 -0.140679899472 -0.318324840424
# log_R0:
14.1055527809
# rec_sigma:
0.532932145998
# log_rec_dev:
 -0.0694796444876 0.136721164855 0.668450534870 -0.130327997171 0.153934145879 0.440601799111
 -0.462591085839 -0.737264515102 0.389220079552 -0.483226508904 0.458152828414 -0.722379662494
 -0.120131014324 0.721056839717 0.382722529967 -0.161814326411 -0.0451280651772 0.569589501647
 -1.15799561285 0.653739759898 0.197120251717 -0.169403447254 0.323530009507 -0.189306956630
 -0.171359623719 0.957952063844 0.188575919280 0.356668713740 -1.46160033067 -0.187480914497 -0.328546436467
# log_dm_comm_lc:
-1.02103135285
# log_dm_GR_ac:
-1.45865439127
# selpar_A50_comm1:
2.83209618760
# selpar_slope_comm1:
1.92078313134
# selpar_A50_GR1:
4.01560662751
# selpar_slope_GR1:
1.85980822364
# selpar_A50_GR2:
3.05783704693
# selpar_slope_GR2:
3.73727321921
# log_q_HB:
-12.9192930395
# log_avg_F_comm:
-5.92021529102
# log_F_dev_comm:
 -0.487779367253 0.0732171657719 -0.285515029334 -0.216855653613 -0.0579331424753 -0.120272589380
 -0.328147344087 -0.247568173700 -0.0331454907806 0.416825963356 0.437357880978 0.506009214636
 0.0751102092042 -0.390213621618 0.0396750163590 -0.127202260730 -0.151770861108 -0.264850197327
 -0.251406869977 -0.494656744256 -0.255108348645 -0.346319200731 -0.322767162581 0.0263585120872
 0.273144008934 -0.187567046743 0.0449441866246 0.0841282947079 0.311444995691 0.617852841923
 0.898041870000 0.764968944068
# log_avg_F_GR:
-2.41856201273
# log_F_dev_GR:
 0.137868901365 -0.0213906685533 -0.673321602171 -0.100035457446 -0.403893089266 -0.301160539319
 -0.323582992323 -0.725418467052 -0.885387983217 -0.0968190452480 1.30811572509 -0.147693859879
 -0.701238227792 0.00835454649220 -0.592892263235 -0.751750553330 -0.576578726199 0.457674941746
 0.0280803909524 0.675598087090 0.592851358402 -0.0906238656171 -0.430000197215 0.275532200198
 0.266226483886 -0.0841310096070 0.310141199692 0.391202184762 0.121118932610 0.886116606085
 0.852969222745 0.594067766348
# F_init:
0.00505862261875
```

Appendix C Beaufort Assessment Model code for Cobia

```
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##
//##  SEDAR 58  SA Cobia, 2019
//##  (Modified from: SEDAR 50  SA BLT assessment model, 2017)
//##  NMFS, Beaufort Lab, Sustainable Fisheries Branch
//##
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
DATA_SECTION

!!cout << "Starting Beaufort Assessment Model" << endl;
!!cout << endl;
!!cout << "                BAM!" << endl;
!!cout << endl;

//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//-- BAM DATA_SECTION: set-up section
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>

// Starting and ending years of the model (year data starts)
init_int styr;
init_int endyr;

// Starting and ending years to estimate recruitment deviations from S-R curve
init_int styr_rec_dev;
init_int endyr_rec_dev;
// Ending years of 3 phases of constraints on recruitment deviations
// (allows possible heavier constraint (weights defined later) in early and late period, with lighter constraint in the middle)
init_int endyr_rec_phase1;
init_int endyr_rec_phase2;
// ending years of selectivity block 1
//init_int endyr_selex_phase1_comm; // comm
init_int endyr_selex_phase1_GR; // GR
// ending years of selectivity block 2

//number assessment years
number nyrs;
number nyrs_rec;

//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   nyrs=endyr-styr+1.;
   nyrs_rec=endyr_rec_dev-styr_rec_dev+1.;
 END_CALCS

// Number of ages in population model(classes are 1,...,N+; assumes last age is plus group
init_int nages;
// Vector of ages for age bins in population model, last is a plus group
init_vector agebins(1,nages);

//Total number of ages used to match age comps: plus group may differ from popn, first age must not
init_int nages_agec;

//Vector of ages for age bins in age comps
init_vector agebins_agec(1,nages_agec);

// Number length bins used to match length comps and width of bins (mm)
init_int nlenbins;          //used to match data
init_number lenbins_width;  //width of length bins (mm)

// Vector of length bins (mm; midpoint of bin) used to match length comps and bins used to compute plus group
init_vector lenbins(1,nlenbins);

// Max value of F used in spr and msy calculations
init_number max_F_spr_msy;
// Number of iterations in spr calculations
init_int n_iter_spr;
//Total number of iterations for msy calcs
int n_iter_msy;
 LOCAL_CALCS
n_iter_msy=n_iter_spr;
 END_CALCS

// Starting and ending years to compute arithmetic average recruitment for SPR-related values
init_int styr_rec_spr;
init_int endyr_rec_spr;
//Arithmetic average recruitment for SPR-related values
number nyrs_rec_spr;
 LOCAL_CALCS
   nyrs_rec_spr=endyr_rec_spr-styr_rec_spr+1.;
 END_CALCS


// Number of years at end of time series over which to average sector Fs, for weighted selectivities
init_int selpar_n_yrs_wgted;
// Multiplicative bias correction of recruitment (may set to 1.0 for none or negative to compute from recruitment variance)
init_number set_BiasCor;

//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//-- BAM DATA_SECTION: observed data section
```

```
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>

//## comm ######## LANDINGS ########
//## comm ## Starting and ending years of landings (bt50 landings+discards; includes comm and cO (commercial other))
init_int styr_comm_L;
init_int endyr_comm_L;
//## comm ## Observed landings (1000 lbs) and assumed CVs
init_vector obs_comm_L(styr_comm_L,endyr_comm_L);
init_vector comm_L_cv(styr_comm_L,endyr_comm_L);

//## comm ######## LENGTH COMPS ########
//## comm ## Number and vector of years of length compositions to be pooled
init_int nyr_comm_lenc_pool;
init_ivector yrs_comm_lenc_pool(1,nyr_comm_lenc_pool);
//# Annual sample size (nfish) of length comp data; used to weight years for pooling
init_vector nfish_comm_lenc_pool(1,nyr_comm_lenc_pool);
//## comm ## Number and vector of years of length compositions, after pooling
init_int nyr_comm_lenc;
init_ivector yrs_comm_lenc(1,nyr_comm_lenc);
//## comm ## Sample size of length comp data (first row observed n.trips, second row n.fish)
init_vector nsamp_comm_lenc(1,nyr_comm_lenc);
init_vector nfish_comm_lenc(1,nyr_comm_lenc);
//## comm ## Observed length comps (3cm bins; proportions by year)
init_matrix obs_comm_lenc(1,nyr_comm_lenc,1,nlenbins);

//#######################################################################################################
//## Recreational Headboat
//#######################################################################################################
//## HB ######## INDEX ########
//## HB ## Starting and ending years of CPUE index
init_int styr_HB_cpue;
init_int endyr_HB_cpue;
//## HB ## Observed index CPUE and CVs
init_vector obs_HB_cpue(styr_HB_cpue,endyr_HB_cpue);//Observed CPUE
init_vector HB_cpue_cv(styr_HB_cpue,endyr_HB_cpue); //CV of cpue

//#######################################################################################################
//## General Recreational
//#######################################################################################################
//## GR ######## LANDINGS ########
//## GR ## Starting and ending years of landings (bt50 landings+discards)
init_int styr_GR_L;
init_int endyr_GR_L;
//## GR ## Observed landings (1000 lbs) and assumed CVs
init_vector obs_GR_L(styr_GR_L,endyr_GR_L);   //vector of observed landings by year
init_vector GR_L_cv(styr_GR_L,endyr_GR_L);    //vector of CV of landings by year

//  Age compositions
init_int nyr_GR_agec;
init_ivector yrs_GR_agec(1,nyr_GR_agec);
init_vector nsamp_GR_agec(1,nyr_GR_agec);
init_vector nfish_GR_agec(1,nyr_GR_agec);
init_matrix obs_GR_agec(1,nyr_GR_agec,1,nages_agec);

//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//-- BAM DATA_SECTION: parameter section
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//#######################################################################################################
//## Parameter values and initial guesses
//#######################################################################################################
//######## Population ########
init_vector set_Linf(1,7); // VonBert Linf (mmFL)
init_vector set_K(1,7); // VonBert K
init_vector set_t0(1,7); // VonBert t0
init_vector set_len_cv(1,7); // CV of length at age
//########Landings growth curve
init_vector set_Linf_L(1,7);            // VonBert Linf (mmFL)
init_vector set_K_L(1,7);               // VonBert K
init_vector set_t0_L(1,7);              // VonBert t0
init_vector set_len_cv_L(1,7);          // CV of length at age
//########Female only growth curve (popl and landings)
init_vector set_Linf_F(1,7);            // VonBert Linf (mmFL)
init_vector set_K_F(1,7);               // VonBert K
init_vector set_t0_F(1,7);              // VonBert t0
init_vector set_len_cv_F(1,7);          // CV of length at age
//######## Constant M ########
init_vector set_M_constant(1,7); // constant M (used only to compute MSST=(1-M)SSBmsy)
//######## StockRecruitment ########
init_vector set_steep(1,7);          // SR steepness parameter
init_vector set_log_R0(1,7);         // SR log_R0 parameter
init_vector set_R_autocorr(1,7);     // SR recruitment autocorrelation (lag 1)
init_vector set_rec_sigma(1,7);      // standard deviation of recruitment in log space
//######## DirichletMultinomial ########
init_vector set_log_dm_comm_lc(1,7);   // Dirichlet-multinomial overdispersion parameter (log-space): comm length comps
init_vector set_log_dm_GR_ac(1,7);    //Dirichlet-multinomial overdispersion parameter
//######## Selectivity ########
init_vector set_selpar_A50_comm1(1,7); // comm age at 0.5 selectivity
init_vector set_selpar_slope_comm1(1,7); // comm slope of ascending limb
init_vector set_selpar_A50_GR1(1,7);  // GR age at 0.5 selectivity
init_vector set_selpar_slope_GR1(1,7); // GR slope of ascending limb
init_vector set_selpar_A50_GR2(1,7); // GR age at 0.5 selectivity (block 2)
init_vector set_selpar_slope_GR2(1,7); // GR slope of ascending limb (block 2)
//######## IndexCatchability ########
init_vector set_log_q_HB(1,7);       // HB CPUE (log q)
//######## FishingMortality ########
```

```
init_vector set_F_init(1,7);   // initial F (not log space)
init_vector set_log_avg_F_comm(1,7); // comm log mean F
//init_vector set_log_avg_F_cL(1,7); // cL log mean F
init_vector set_log_avg_F_GR(1,7); // GR log mean F

//######################################################################################################
//## Dev vectors
//######################################################################################################
init_vector set_log_F_dev_comm(1,3);  // comm F devs
//init_vector set_log_F_dev_cL(1,3); // cL F devs
init_vector set_log_F_dev_GR(1,3); // GR F devs
init_vector set_log_RWq_dev(1,3); // Random walk on q
init_vector set_log_rec_dev(1,3); // recruitment devs
init_vector set_log_Nage_dev(1,3); // Nage devs

//######## F dev initial guesses ########
//## comm (1962 - 2015)
init_vector set_log_F_dev_comm_vals(styr_comm_L,endyr_comm_L);
// ## GR (1973 - 2015)
init_vector set_log_F_dev_GR_vals(styr_GR_L,endyr_GR_L);

//######## Rec dev initial guesses (1958 - 2015) ########
init_vector set_log_rec_dev_vals(styr_rec_dev,endyr_rec_dev);

//######## initial N age devs, all ages but the first one (2 to 15) ########
init_vector set_log_Nage_dev_vals(2,nages);

//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//-- BAM DATA_SECTION: likelihood weights section
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
init_number set_w_L; // landings

init_number set_w_I_HB;         // HB index
init_number set_w_lc_comm;        // comm length comps
init_number set_w_ac_GR; //weight for the Recreational age comps
init_number set_w_Nage_init;    // log N.age.dev residuals (initial abundance)for fitting initial abundance at age (excluding first age)
init_number set_w_rec;          // SR residuals (for fitting SR curve)
init_number set_w_rec_early;    // constraint on early recruitment deviations
init_number set_w_rec_end;      // constraint on ending recruitment deviations
init_number set_w_fullF;        // penalty if F exceeds 3.0 (reduced by factor of 10 each phase, not applied in final phase of optimization) full F summed over fisheries
init_number set_w_Ftune;        // weight on tuning F (penalty not applied in final phase of optimization)

//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//-- BAM DATA_SECTION: miscellaneous stuff section
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>

// Length-weight parameter a (W=aL^b); mm to kg
init_number wgtpar_a;
// Length-weight parameter b (W=aL^b); mm to kg
init_number wgtpar_b;

// vector of maturity-at-age for females (ages 1 - 15 )
init_vector maturity_f_obs(1,nages);
// Proportion female by age (assumed 50:50 sex ratio)
init_vector prop_f_obs(1,nages);
// time of year (as fraction) for spawning
init_number spawn_time_frac;
// age-dependent natural mortality at age (ages 1 - 15 )
init_vector set_M(1,nages);

// Spawner-recruit parameters:  SR function switch (integer 1=Beverton-Holt, 2=Ricker)
init_int SR_switch;

// switch for rate increase in q: Integer value (choose estimation phase, negative value turns it off)
init_int set_q_rate_phase;
// annual positive rate of increase on all fishery dependent q's due to technology creep
init_number set_q_rate;

// density dependence on fishery catchability coefficients (DDq) switch: Integer value (choose estimation phase of random walk, negative value turns it off)
init_int set_q_DD_phase;
// q_DD exponent, value of zero is density independent, est range is (0.1,0.9)
init_number set_q_DD_beta;
// SE of q_DD exponent (0.128 provides 95% CI in range 0.5)
init_number set_q_DD_beta_se;
// Age to begin counting q_DD (should be age near full exploitation)
init_int set_q_DD_stage;      //age to begin counting biomass, should be near full exploitation

// Variance (sd^2) of fishery dependent random walk catchabilities (0.03 is near the sd=0.17 of Wilberg and Bence)
init_number set_RWq_var;     //assumed variance of RW q

// Tuning F (not applied in last phase of optimization, or not applied at all if penalty weight=0)
init_number set_Ftune;
// Year for tuning F
init_int set_Ftune_yr;

// threshold sample sizes ntrips (>=)for length comps (set to 99999.0 if sel is fixed):
init_number minSS_comm_lenc; // comm len comps
//threshold sample sizes for age comps
init_number minSS_GR_agec;

// Input for deterministic F-based projections
// Last year of projections, must be later than assessment endyr by default
init_int endyr_proj; // Projection end year (must be later than assessment endyr)
init_int styr_regs;   // Apply current F until styr_regs, then the projection F
init_int Fproj_switch;  // Switching indicating value to use for defining projection F: 1=Fcurrent, 2=Fmsy, 3=F30, 4=F40
```

```
init_number Fproj_mult; // Multiplier 'c' applied to compute projection F, for example Fproj=cFmsy
// Calculate projection start year
int styr_proj;
 LOCAL_CALCS
   styr_proj=endyr+1;
 END_CALCS

// Aging error matrix (columns are true age 1- 15 , rows are ages as read for age comps: columns should sum to one)
init_matrix age_error(1,nages,1,nages);

//------------------------------------<< 999 >>-------------------------------------
// END OF READING IN VALUES FROM .dat file
//------------------------------------<< 999 >>-------------------------------------
// #######Indexing integers for year(iyear), age(iage),length(ilen) ###############
int iyear;
int iage;
int ilen;
int ff;

number sqrt2pi;
number g2mt;                    //conversion of grams to metric tons
number g2kg;                    //conversion of grams to kg
number g2klb;                   //conversion of grams to 1000 lb
number mt2klb;                  //conversion of metric tons to 1000 lb
number mt2lb;                   //conversion of metric tons to lb
number dzero;                   //small additive constant to prevent division by zero
number huge_number;             //huge number, to avoid irregular parameter space

init_number end_of_data_file;
//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   if(end_of_data_file!=999)
   {
       cout << "*** WARNING: Data File NOT READ CORRECTLY ****" << endl;
       exit(0);
   }
   else
   {cout << "Data File read correctly" << endl;}
 END_CALCS

//##################################################################################################
PARAMETER_SECTION //##################################################################################################
//##################################################################################################

 LOCAL_CALCS
  const double Linf_LO=set_Linf(2); const double Linf_HI=set_Linf(3); const double Linf_PH=set_Linf(4);
  const double K_LO=set_K(2); const double K_HI=set_K(3); const double K_PH=set_K(4);
  const double t0_LO=set_t0(2); const double t0_HI=set_t0(3); const double t0_PH=set_t0(4);
  const double len_cv_LO=set_len_cv(2); const double len_cv_HI=set_len_cv(3); const double len_cv_PH=set_len_cv(4);

  const double Linf_L_LO=set_Linf_L(2); const double Linf_L_HI=set_Linf_L(3); const double Linf_L_PH=set_Linf_L(4);
  const double K_L_LO=set_K_L(2); const double K_L_HI=set_K_L(3); const double K_L_PH=set_K_L(4);
  const double t0_L_LO=set_t0_L(2); const double t0_L_HI=set_t0_L(3); const double t0_L_PH=set_t0_L(4);
  const double len_cv_L_LO=set_len_cv_L(2); const double len_cv_L_HI=set_len_cv_L(3); const double len_cv_L_PH=set_len_cv_L(4);

  const double Linf_F_LO=set_Linf_F(2); const double Linf_F_HI=set_Linf_F(3); const double Linf_F_PH=set_Linf_F(4);
  const double K_F_LO=set_K_F(2); const double K_F_HI=set_K_F(3); const double K_F_PH=set_K_F(4);
  const double t0_F_LO=set_t0_F(2); const double t0_F_HI=set_t0_F(3); const double t0_F_PH=set_t0_F(4);
  const double len_cv_F_LO=set_len_cv_F(2); const double len_cv_F_HI=set_len_cv_F(3); const double len_cv_F_PH=set_len_cv_F(4);

  const double M_constant_LO=set_M_constant(2); const double M_constant_HI=set_M_constant(3); const double M_constant_PH=set_M_constant(4);
  const double steep_LO=set_steep(2); const double steep_HI=set_steep(3); const double steep_PH=set_steep(4);
  const double log_R0_LO=set_log_R0(2); const double log_R0_HI=set_log_R0(3); const double log_R0_PH=set_log_R0(4);
  const double R_autocorr_LO=set_R_autocorr(2); const double R_autocorr_HI=set_R_autocorr(3); const double R_autocorr_PH=set_R_autocorr(4);
  const double rec_sigma_LO=set_rec_sigma(2); const double rec_sigma_HI=set_rec_sigma(3); const double rec_sigma_PH=set_rec_sigma(4);

  const double log_dm_comm_lc_LO=set_log_dm_comm_lc(2); const double log_dm_comm_lc_HI=set_log_dm_comm_lc(3); const double log_dm_comm_lc_PH=set_log_dm_comm_lc(4);
  const double log_dm_GR_ac_LO=set_log_dm_GR_ac(2); const double log_dm_GR_ac_HI=set_log_dm_GR_ac(3); const double log_dm_GR_ac_PH=set_log_dm_GR_ac(4);

  const double selpar_A50_comm1_LO=set_selpar_A50_comm1(2); const double selpar_A50_comm1_HI=set_selpar_A50_comm1(3); const double selpar_A50_comm1_PH=set_selpar_A50_comm1(4);
  const double selpar_slope_comm1_LO=set_selpar_slope_comm1(2); const double selpar_slope_comm1_HI=set_selpar_slope_comm1(3); const double selpar_slope_comm1_PH=set_selpar_slope_comm1(4);

  const double selpar_A50_GR1_LO=set_selpar_A50_GR1(2); const double selpar_A50_GR1_HI=set_selpar_A50_GR1(3); const double selpar_A50_GR1_PH=set_selpar_A50_GR1(4);
  const double selpar_slope_GR1_LO=set_selpar_slope_GR1(2); const double selpar_slope_GR1_HI=set_selpar_slope_GR1(3); const double selpar_slope_GR1_PH=set_selpar_slope_GR1(4);
  const double selpar_A50_GR2_LO=set_selpar_A50_GR2(2); const double selpar_A50_GR2_HI=set_selpar_A50_GR2(3); const double selpar_A50_GR2_PH=set_selpar_A50_GR2(4);
  const double selpar_slope_GR2_LO=set_selpar_slope_GR2(2); const double selpar_slope_GR2_HI=set_selpar_slope_GR2(3); const double selpar_slope_GR2_PH=set_selpar_slope_GR2(4);

  const double log_q_HB_LO=set_log_q_HB(2); const double log_q_HB_HI=set_log_q_HB(3); const double log_q_HB_PH=set_log_q_HB(4);

  const double F_init_LO=set_F_init(2); const double F_init_HI=set_F_init(3); const double F_init_PH=set_F_init(4);
  const double log_avg_F_comm_LO=set_log_avg_F_comm(2); const double log_avg_F_comm_HI=set_log_avg_F_comm(3); const double log_avg_F_comm_PH=set_log_avg_F_comm(4);
  const double log_avg_F_GR_LO=set_log_avg_F_GR(2); const double log_avg_F_GR_HI=set_log_avg_F_GR(3); const double log_avg_F_GR_PH=set_log_avg_F_GR(4);

  //-dev vectors-----------------------------------------------------------------------------------------------------------
  const double log_F_dev_comm_LO=set_log_F_dev_comm(1); const double log_F_dev_comm_HI=set_log_F_dev_comm(2); const double log_F_dev_comm_PH=set_log_F_dev_comm(3);
  const double log_F_dev_GR_LO=set_log_F_dev_GR(1); const double log_F_dev_GR_HI=set_log_F_dev_GR(2); const double log_F_dev_GR_PH=set_log_F_dev_GR(3);

  const double log_RWq_LO=set_log_RWq_dev(1); const double log_RWq_HI=set_log_RWq_dev(2); const double log_RWq_PH=set_log_RWq_dev(3);

  const double log_rec_dev_LO=set_log_rec_dev(1); const double log_rec_dev_HI=set_log_rec_dev(2); const double log_rec_dev_PH=set_log_rec_dev(3);
  const double log_Nage_dev_LO=set_log_Nage_dev(1); const double log_Nage_dev_HI=set_log_Nage_dev(2); const double log_Nage_dev_PH=set_log_Nage_dev(3);

 END_CALCS

////--------------Growth---------------------------------------------------------------------------
```

```
  //Population growth parms and conversions
  init_bounded_number Linf(Linf_LO,Linf_HI,Linf_PH);
  init_bounded_number K(K_LO,K_HI,K_PH);
  init_bounded_number t0(t0_LO,t0_HI,t0_PH);
  init_bounded_number len_cv_val(len_cv_LO,len_cv_HI,len_cv_PH);
  vector Linf_out(1,8);
  vector K_out(1,8);
  vector t0_out(1,8);
  vector len_cv_val_out(1,8);

  vector meanlen_TL(1,nages);   //mean total length (mm) at age all fish

  vector wgt_g(1,nages);        //whole wgt in g
  vector wgt_kg(1,nages);       //whole wgt in kg
  vector wgt_mt(1,nages);       //whole wgt in mt
  vector wgt_klb(1,nages);      //whole wgt in 1000 lb
  vector wgt_lb(1,nages);       //whole wgt in lb

  init_bounded_number Linf_L(Linf_L_LO,Linf_L_HI,Linf_L_PH);
  init_bounded_number K_L(K_L_LO,K_L_HI,K_L_PH);
  init_bounded_number t0_L(t0_L_LO,t0_L_HI,t0_L_PH);
  init_bounded_number len_cv_val_L(len_cv_L_LO,len_cv_L_HI,len_cv_L_PH);
  vector Linf_L_out(1,8);
  vector K_L_out(1,8);
  vector t0_L_out(1,8);
  vector len_cv_val_L_out(1,8);
  vector meanlen_TL_L(1,nages);   //mean total length (mm) at age all fish

  vector wgt_g_L(1,nages);        //whole wgt in g
  vector wgt_kg_L(1,nages);       //whole wgt in kg
  vector wgt_mt_L(1,nages);       //whole wgt in mt
  vector wgt_klb_L(1,nages);      //whole wgt in 1000 lb
  vector wgt_lb_L(1,nages);       //whole wgt in lb
  vector wgt_klb_gut_L(1,nages);  //gutted wgt in 1000 lb
  vector wgt_lb_gut_L(1,nages);   //gutted wgt in lb

  init_bounded_number Linf_F(Linf_F_LO,Linf_F_HI,Linf_F_PH);
  init_bounded_number K_F(K_F_LO,K_F_HI,K_F_PH);
  init_bounded_number t0_F(t0_F_LO,t0_F_HI,t0_F_PH);
  init_bounded_number len_cv_val_F(len_cv_F_LO,len_cv_F_HI,len_cv_F_PH);
  vector Linf_F_out(1,8);
  vector K_F_out(1,8);
  vector t0_F_out(1,8);
  vector len_cv_val_F_out(1,8);
  vector meanlen_TL_F(1,nages);   //mean total length (mm) at age all fish

  vector wgt_g_F(1,nages);        //whole wgt in g
  vector wgt_kg_F(1,nages);       //whole wgt in kg
  vector wgt_mt_F(1,nages);       //whole wgt in mt
  vector wgt_klb_F(1,nages);      //whole wgt in 1000 lb
  vector wgt_lb_F(1,nages);       //whole wgt in lb

  matrix len_comm_mm(styr,endyr,1,nages);          //mean length at age of commercial handline landings in mm
  matrix wholewgt_comm_klb(styr,endyr,1,nages);    //whole wgt of commercial handline landings in 1000 lb
  matrix len_HB_mm(styr,endyr,1,nages);          //mean length at age of HB landings in mm
  matrix wholewgt_HB_klb(styr,endyr,1,nages);    //whole wgt of HB landings in 1000 lb
  matrix len_GR_mm(styr,endyr,1,nages);          //mean length at age of GR landings in mm
  matrix wholewgt_GR_klb(styr,endyr,1,nages);    //whole wgt of GR landings in 1000 lb

  matrix lenprob(1,nages,1,nlenbins);           //distn of size at age (age-length key, 3 cm bins) in population
  number zscore_len;                            //standardized normal values used for computing lenprob
  vector cprob_lenvec(1,nlenbins);              //cumulative probabilities used for computing lenprob
  number zscore_lzero;                          //standardized normal values for length = 0
  number cprob_lzero;                           //length probability mass below zero, used for computing lenprob

  matrix lenprob_L(1,nages,1,nlenbins);
  number zscore_len_L;                            //standardized normal values used for computing lenprob
  vector cprob_lenvec_L(1,nlenbins);              //cumulative probabilities used for computing lenprob
  number zscore_lzero_L;                          //standardized normal values for length = 0
  number cprob_lzero_L;                           //length probability mass below zero, used for computing lenprob

  matrix lenprob_F(1,nages,1,nlenbins);
  number zscore_len_F;                            //standardized normal values used for computing lenprob
  vector cprob_lenvec_F(1,nlenbins);              //cumulative probabilities used for computing lenprob
  number zscore_lzero_F;                          //standardized normal values for length = 0
  number cprob_lzero_F;                           //length probability mass below zero, used for computing lenprob


  //matrices below are used to match length comps
  matrix lenprob_comm(1,nages,1,nlenbins);     //distn of size at age in comm
  matrix lenprob_HB(1,nages,1,nlenbins);     //distn of size at age in HB
  matrix lenprob_GR(1,nages,1,nlenbins);     //distn of size at age in GR

  vector len_sd(1,nages);
  vector len_cv(1,nages); //for fishgraph
  //All Fishery-dependent
  vector len_sd_L(1,nages);
  vector len_cv_L(1,nages); //for fishgraph
  //Females
  vector len_sd_F(1,nages);
  vector len_cv_F(1,nages);

//----Predicted length and age compositions
  matrix pred_comm_lenc(1,nyr_comm_lenc,1,nlenbins); //predicted length comps pooled across years
  matrix pred_comm_lenc_yr(1,nyr_comm_lenc_pool,1,nlenbins); //annual predicted length comps
```

```
  matrix pred_GR_agec(1,nyr_GR_agec,1,nages_agec);
  matrix pred_GR_agec_allages(1,nyr_GR_agec,1,nages);
  matrix ErrorFree_GR_agec(1,nyr_GR_agec,1,nages);

//Sample size (perhaps adjusted herein) used in fitting comp data
  vector nsamp_comm_lenc_allyr(styr,endyr);
  vector nsamp_GR_agec_allyr(styr,endyr);

//Nfish used in MCB analysis (not used in fitting)
  vector nfish_comm_lenc_allyr(styr,endyr);
  vector nfish_GR_agec_allyr(styr,endyr);

//Computed effective sample size for output (not used in fitting)
  vector neff_comm_lenc_allyr(styr,endyr);
  vector neff_GR_agec_allyr(styr,endyr);

//-----Population-----------------------------------------------------------------------------------
  matrix N(styr,endyr+1,1,nages);           //Population numbers by year and age at start of yr
  matrix N_mdyr(styr,endyr,1,nages);        //Population numbers by year and age at mdpt of yr: used for comps and cpue
  matrix N_spawn(styr,endyr,1,nages);       //Population numbers by year and age at peaking spawning: used for SSB
  init_bounded_vector log_Nage_dev(2,nages,log_Nage_dev_LO,log_Nage_dev_HI,log_Nage_dev_PH);
  vector log_Nage_dev_output(1,nages);      //used in output. equals zero for first age
  matrix B(styr,endyr+1,1,nages);           //Population biomass by year and age at start of yr
  vector totB(styr,endyr+1);                //Total biomass by year
  vector totN(styr,endyr+1);                //Total abundance by year
  vector SSB(styr,endyr);                   //Total spawning biomass by year (female mature biomass)
  vector SSB_knum(styr,endyr);              //Total spawning numbers by year (number of mature females)
  vector rec(styr,endyr+1);                 //Recruits by year
  vector prop_f(1,nages);
  vector maturity_f(1,nages);
  vector reprod(1,nages);
  vector reprodknum(1,nages);

//---Stock-Recruit Function (Beverton-Holt, steepness parameterization)----------
  init_bounded_number log_R0(log_R0_LO,log_R0_HI,log_R0_PH);                  //log(virgin Recruitment)
  vector log_R0_out(1,8);
  number R0;                                  //virgin recruitment
  init_bounded_number steep(steep_LO,steep_HI,steep_PH); //steepness
  vector steep_out(1,8);
  init_bounded_number rec_sigma(rec_sigma_LO,rec_sigma_HI,rec_sigma_PH);  //sd recruitment residuals
  vector rec_sigma_out(1,8);
  init_bounded_number R_autocorr(R_autocorr_LO,R_autocorr_HI,R_autocorr_PH);  //autocorrelation in SR
  vector R_autocorr_out(1,8);

  number rec_sigma_sq;                        //square of rec_sigma
  number rec_logL_add;                        //additive term in -logL term

  init_bounded_dev_vector log_rec_dev(styr_rec_dev,endyr_rec_dev,log_rec_dev_LO,log_rec_dev_HI,log_rec_dev_PH);
  vector log_rec_dev_output(styr,endyr+1);             //used in t.series output. equals zero except for yrs in log_rec_dev
  vector log_rec_dev_out(styr_rec_dev,endyr_rec_dev);  //used in output for bound checking

  number var_rec_dev;                           //variance of log recruitment deviations, from yrs with unconstrainted S-R(XXXX-XXXX)
  number sigma_rec_dev;                         //sample SD of log residuals (may not equal rec_sigma
  number BiasCor;                               //Bias correction in equilibrium recruits
  number S0;                                    //equal to spr_F0*R0 = virgin SSB
  number B0;                                    //equal to bpr_F0*R0 = virgin B
  number R1;                                    //Recruits in styr
  number R_virgin;                              //unfished recruitment with bias correction
  vector SdS0(styr,endyr);                      //Spawners relative to the unfished level


  init_bounded_number log_dm_comm_lc(log_dm_comm_lc_LO,log_dm_comm_lc_HI,log_dm_comm_lc_PH);
  init_bounded_number log_dm_GR_ac(log_dm_GR_ac_LO,log_dm_GR_ac_HI,log_dm_GR_ac_PH);

  vector log_dm_comm_lc_out(1,8);
  vector log_dm_GR_ac_out(1,8);
//------------------------------------------------------------------------------------------------------------------------------------------------
////---Selectivity-------------------------------------------------------------------------

//Commercial handline-------------------------------------------------
  matrix sel_comm(styr,endyr,1,nages);
  vector sel_comm_vec(1,nages);

  init_bounded_number selpar_A50_comm1(selpar_A50_comm1_LO,selpar_A50_comm1_HI,selpar_A50_comm1_PH);
  init_bounded_number selpar_slope_comm1(selpar_slope_comm1_LO,selpar_slope_comm1_HI,selpar_slope_comm1_PH);

  vector selpar_A50_comm1_out(1,8);
  vector selpar_slope_comm1_out(1,8);

  //Headboat -------------------------------------------------
  matrix sel_HB(styr,endyr,1,nages);
  vector sel_HB_block1(1,nages);
  vector sel_HB_block2(1,nages);

  //General Rec
  matrix sel_GR(styr,endyr,1,nages);
  vector sel_GR_block1(1,nages);
  vector sel_GR_block2(1,nages);

  init_bounded_number selpar_A50_GR1(selpar_A50_GR1_LO,selpar_A50_GR1_HI,selpar_A50_GR1_PH);
  init_bounded_number selpar_slope_GR1(selpar_slope_GR1_LO,selpar_slope_GR1_HI,selpar_slope_GR1_PH);
  init_bounded_number selpar_A50_GR2(selpar_A50_GR2_LO,selpar_A50_GR2_HI,selpar_A50_GR2_PH);
  init_bounded_number selpar_slope_GR2(selpar_slope_GR2_LO,selpar_slope_GR2_HI,selpar_slope_GR2_PH);

  vector selpar_A50_GR1_out(1,8);
```

```
  vector selpar_slope_GR1_out(1,8);
  vector selpar_A50_GR2_out(1,8);
  vector selpar_slope_GR2_out(1,8);

//Weighted total selectivity--------------------------------------------
  //effort-weighted, recent selectivities
  vector sel_wgted_L(1,nages);  //toward landings
  vector sel_wgted_tot(1,nages);//toward Z, landings plus deads discards

//----------------------------------------------------------------------------------------------------------------------------------------------
//-------CPUE Predictions--------------------------------
  vector pred_HB_cpue(styr_HB_cpue,endyr_HB_cpue);                   //predicted HB index (number fish per effort)
  matrix N_HB(styr_HB_cpue,endyr_HB_cpue,1,nages);                   //used to compute HB index

//---Catchability (CPUE q's)----------------------------------------------------------
  init_bounded_number log_q_HB(log_q_HB_LO,log_q_HB_HI,log_q_HB_PH);

  vector log_q_HB_out(1,8);

  number q_rate;
  vector q_rate_fcn_HB(styr_HB_cpue,endyr_HB_cpue);         //increase due to technology creep (saturates in 2003)

  number q_DD_beta;
  vector q_DD_fcn(styr,endyr);    //density dependent function as a multiple of q (scaled a la Katsukawa and Matsuda. 2003)
  number B0_q_DD;                 //B0 of ages q_DD_age plus
  vector B_q_DD(styr,endyr);      //annual biomass of ages q_DD_age plus

//Fishery dependent random walk catchability
  init_bounded_vector q_RW_log_dev_HB(styr_HB_cpue,endyr_HB_cpue-1,log_RWq_LO,log_RWq_HI,log_RWq_PH);

//Fishery dependent catchability over time, may be constant

 vector q_HB(styr_HB_cpue,endyr_HB_cpue);

//----------------------------------------------------------------------------------------------------------------------------------------------
//---Landings in numbers (total or 1000 fish) and in wgt (whole klb)--------------------------------------------------
  matrix L_comm_num(styr,endyr,1,nages);   //landings (numbers) at age
  matrix L_comm_klb(styr,endyr,1,nages);   //landings (1000 lb whole weight) at age
  vector pred_comm_L_knum(styr,endyr);     //yearly landings in 1000 fish summed over ages
  vector pred_comm_L_klb(styr,endyr);      //yearly landings in 1000 lb whole summed over ages

  matrix L_GR_num(styr,endyr,1,nages);   //landings (numbers) at age
  matrix L_GR_klb(styr,endyr,1,nages);   //landings (1000 lb whole weight) at age
  vector pred_GR_L_knum(styr,endyr);     //yearly landings in 1000 fish summed over ages
  vector pred_GR_L_klb(styr,endyr);      //yearly landings in 1000 lb whole summed over ages

  matrix L_total_num(styr,endyr,1,nages);//total landings in number at age
  matrix L_total_klb(styr,endyr,1,nages);//landings in klb whole wgt at age
  vector L_total_knum_yr(styr,endyr);    //total landings in 1000 fish by yr summed over ages
  vector L_total_klb_yr(styr,endyr);     //total landings (klb whole wgt) by yr summed over ages

////---MSY calcs----------------------------------------------------------------------------
  number F_comm_prop;       //proportion of F_sum attributable to comm, last X=selpar_n_yrs_wgted yrs
  number F_GR_prop;       //proportion of F_sum attributable to GR, last X=selpar_n_yrs_wgted yrs

  number F_init_comm_prop;  //proportion of F_init attributable to comm, first X yrs
  number F_init_GR_prop;  //proportion of F_init attributable to GR, first X yrs

  number F_temp_sum;      //sum of geom mean Fsum's in last X yrs, used to compute F_fishery_prop

  vector F_end(1,nages);
  vector F_end_L(1,nages);
  number F_end_apex;

  number SSB_msy_out;           //SSB (total mature biomass) at msy
  number F_msy_out;             //F at msy
  number msy_klb_out;           //max sustainable yield (1000 lb whole wgt)
  number msy_knum_out;          //max sustainable yield (1000 fish)
  number B_msy_out;             //total biomass at MSY
  number R_msy_out;             //equilibrium recruitment at F=Fmsy
  number spr_msy_out;           //spr at F=Fmsy

  number F20_dum; //intermediate calculation for F20
  number F30_dum; //intermediate calculation for F30
  number F40_dum; //intermediate calculation for F40
  number F20_out;               //F20
  number F30_out;               //F30
  number F40_out;               //F40
  number SSB_F30_out;
  number SSB_F30_knum_out;
  number B_F30_out;
  number R_F30_out;
  number L_F30_knum_out;
  number L_F30_klb_out;

  number SSB_F40_out;
  number SSB_F40_knum_out;
  number B_F40_out;
  number R_F40_out;
  number L_F40_knum_out;
  number L_F40_klb_out;
  number rec_mean;   //arithmetic average recruitment used in SPR-related quantities

  vector N_age_msy(1,nages);         //numbers at age for MSY calculations: beginning of yr
  vector N_age_msy_spawn(1,nages);   //numbers at age for MSY calculations: time of peak spawning
```

```
  vector L_age_msy(1,nages);         //landings at age for MSY calculations
  vector Z_age_msy(1,nages);         //total mortality at age for MSY calculations
  vector F_L_age_msy(1,nages);       //fishing mortality landings (not discards) at age for MSY calculations
  vector F_msy(1,n_iter_msy);        //values of full F to be used in equilibrium calculations
  vector spr_msy(1,n_iter_msy);      //reproductive capacity-per-recruit values corresponding to F values in F_msy
  vector R_eq(1,n_iter_msy);         //equilibrium recruitment values corresponding to F values in F_msy
  vector L_eq_klb(1,n_iter_msy);     //equilibrium landings(klb whole wgt) values corresponding to F values in F_msy
  vector L_eq_knum(1,n_iter_msy);    //equilibrium landings(1000 fish) values corresponding to F values in F_msy
  vector SSB_eq(1,n_iter_msy);       //equilibrium reproductive capacity values corresponding to F values in F_msy
  vector SSB_eq_knum(1,n_iter_msy);
  vector B_eq(1,n_iter_msy);         //equilibrium biomass values corresponding to F values in F_msy

  vector FdF_msy(styr,endyr);
  vector FdF30(styr,endyr);
  vector FdF40(styr,endyr);
  vector SdSSB_msy(styr,endyr);
  number SdSSB_msy_end;
  number FdF_msy_end;
  number FdF_msy_end_mean;           //geometric mean of last X yrs

  vector SdSSB_F30(styr,endyr);
  vector Sdmsst_F30(styr,endyr);
  number SdSSB_F30_end;
  number Sdmsst_F30_end;
  number FdF30_end_mean;             //geometric mean of last selpar_n_yrs_wgted yrs
  vector L_age_F30(1,nages);         //landings at age for F30 calculations

  vector SdSSB_F40(styr,endyr);
  vector Sdmsst_F40(styr,endyr);
  number SdSSB_F40_end;
  number Sdmsst_F40_end;
  number FdF40_end_mean;             //geometric mean of last selpar_n_yrs_wgted yrs
  number Fend_mean_temp;  //intermediate calc for geometric mean of last selpar_n_yrs_wgted yrs
  number Fend_mean;  //geometric mean of last selpar_n_yrs_wgted yrs
  vector L_age_F40(1,nages);         //landings at age for F40 calculations

  vector wgt_wgted_L_klb(1,nages);   //fishery-weighted average weight at age of landings in whole weight
  number wgt_wgted_L_denom;          //used in intermediate calculations

  number iter_inc_msy;               //increments used to compute msy, equals 1/(n_iter_msy-1)

////--------Mortality------------------------------------------------------------------

  vector M(1,nages);                         //age-dependent natural mortality
  init_bounded_number M_constant(M_constant_LO,M_constant_HI,M_constant_PH);   //age-indpendent: used only for MSST
  vector M_constant_out(1,8);
  number smsy2msstM;                         //scales Smsy to get msst using (1-M). Used only in output.
  number smsy2msst75;                        //scales Smsy to get msst using 75%. Used only in output.

  matrix F(styr,endyr,1,nages);
  vector Fsum(styr,endyr);                   //Full fishing mortality rate by year
  vector Fapex(styr,endyr);                  //Max across ages, fishing mortality rate by year (may differ from Fsum bc of dome-shaped sel
  matrix Z(styr,endyr,1,nages);

  init_bounded_number log_avg_F_comm(log_avg_F_comm_LO,log_avg_F_comm_HI,log_avg_F_comm_PH);
  vector log_avg_F_comm_out(1,8);
  init_bounded_dev_vector log_F_dev_comm(styr_comm_L,endyr_comm_L,log_F_dev_comm_LO,log_F_dev_comm_HI,log_F_dev_comm_PH);
  vector log_F_dev_comm_out(styr_comm_L,endyr_comm_L);
  matrix F_comm(styr,endyr,1,nages);
  vector F_comm_out(styr,endyr);        //used for intermediate calculations in fcn get_mortality
  number log_F_dev_init_comm;
  number log_F_dev_end_comm;

  init_bounded_number log_avg_F_GR(log_avg_F_GR_LO,log_avg_F_GR_HI,log_avg_F_GR_PH);
  vector log_avg_F_GR_out(1,8);
  init_bounded_dev_vector log_F_dev_GR(styr_GR_L,endyr_GR_L,log_F_dev_GR_LO,log_F_dev_GR_HI,log_F_dev_GR_PH);
  vector log_F_dev_GR_out(styr_GR_L,endyr_GR_L);
  matrix F_GR(styr,endyr,1,nages);
  vector F_GR_out(styr,endyr); //used for intermediate calculations in fcn get_mortality
  number log_F_dev_init_GR;
  number log_F_dev_end_GR;

  init_bounded_number F_init(F_init_LO,F_init_HI,F_init_PH); //scales early F for initialization
  vector F_init_out(1,8);
  number F_init_denom;  //interim calculation. From Erik's red snapper ASPM

//---Per-recruit stuff----------------------------------------------------------------------------------
  vector N_age_spr(1,nages);         //numbers at age for SPR calculations: beginning of year
  vector N_age_spr_spawn(1,nages);   //numbers at age for SPR calculations: time of peak spawning
  vector L_age_spr(1,nages);         //catch at age for SPR calculations
  vector Z_age_spr(1,nages);         //total mortality at age for SPR calculations
  vector spr_static(styr,endyr);     //vector of static SPR values by year
  vector F_L_age_spr(1,nages);       //fishing mortality of landings (not discards) at age for SPR calculations
  vector F_spr(1,n_iter_spr);        //values of full F to be used in per-recruit calculations
  vector spr_spr(1,n_iter_spr);      //reproductive capacity-per-recruit values corresponding to F values in F_spr
  vector spr_ratio(1,n_iter_spr);    //reproductive capacity-per-recruit relative to spr_F0 values corresponding to F values in F_spr
  vector L_spr(1,n_iter_spr);        //landings(lb)-per-recruit (ypr) values corresponding to F values in F_spr

  vector N_spr_F0(1,nages);          //Used to compute spr at F=0: at time of peak spawning
  vector N_bpr_F0(1,nages);          //Used to compute bpr at F=0: at start of year
  vector N_spr_initial(1,nages);     //Initial spawners per recruit at age given initial F
  vector N_initial_eq(1,nages);      //Initial equilibrium abundance at age
  vector F_initial(1,nages);         //initial F at age
  vector Z_initial(1,nages);         //initial Z at age
  number spr_initial;                //initial spawners per recruit
```

```
  number spr_F0;                     //Spawning biomass per recruit at F=0
  number bpr_F0;                     //Biomass per recruit at F=0

  number iter_inc_spr;               //increments used to compute msy, equals max_F_spr_msy/(n_iter_spr-1)

////-------SDNR output-----------------------------------------------------------------------------------

  number sdnr_lc_comm;
  number sdnr_ac_GR;
  number sdnr_I_HB;

////-------Objective function components--------------------------------------------------------------------------------------
  number w_L;

  number w_I_HB;

  number w_lc_comm;
  number w_ac_GR;

  number w_Nage_init;
  number w_rec;
  number w_rec_early;
  number w_rec_end;
  number w_fullF;
  number w_Ftune;

  number f_comm_L;
  number f_GR_L;

  number f_HB_cpue;

  number f_HB_RWq_cpue;

  number f_comm_lenc;
  number f_GR_lenc;

  number f_GR_agec;

//  Penalties and constraints. Not all are used.
  number f_Nage_init;              //weight on log devs to estimate initial abundance (excluding first age)
  number f_rec_dev;                //weight on recruitment deviations to fit S-R curve
  number f_rec_dev_early;          //extra weight on deviations in first recruitment stanza
  number f_rec_dev_end;            //extra weight on deviations in ending recruitment stanza
  number f_fullF_constraint;       //penalty for Fapex>X
  number f_Ftune;                  //penalty for tuning F in Ftune yr.  Not applied in final optimization phase.
  number f_priors;                 //prior information on parameters

   //init_number xdum;
   objective_function_value fval;
   number fval_data;
   number grad_max;

 //--Dummy variables ----
   number denom;                   //denominator used in some calculations
   number numer;                   //numerator used in some calculations

  //---------- Projection quantities--------------------------------------------------------------------
  number F_reg_proj;    //value used to define the projections
  vector F_proj(styr_proj,endyr_proj);         //F by yr for projections (=F_reg_proj after regulations start, current F till then)
  vector L_knum_proj(styr_proj,endyr_proj);    //total landings in 1000 fish for projections
  vector L_klb_proj(styr_proj,endyr_proj);     //total landings in weight (1000 lb) for projections

  vector B_proj(styr_proj,endyr_proj);         //Biomass for projections
  vector SSB_proj(styr_proj,endyr_proj);       //SSB for projections
  vector R_proj(styr_proj,endyr_proj);         //recruits for projections
  vector FL_age_proj(1,nages);          //F (landings) by age for projections

  matrix N_proj(styr_proj,endyr_proj,1,nages);           //Population numbers by year and age at start of yr
  matrix N_spawn_proj(styr_proj,endyr_proj,1,nages);     //Population numbers by year and age at peaking spawning: used for SSB in projections
  matrix Z_proj(styr_proj,endyr_proj,1,nages);           //Z by year and age for projections
  matrix L_age_proj(styr_proj,endyr_proj,1,nages);       //Projected landings at age in numbers

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
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//INITIALIZATION_SECTION
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
GLOBALS_SECTION
  #include "admodel.h"          // Include AD class definitions
  #include "admb2r.cpp"         // Include S-compatible output functions (needs preceding)
  #include <time.h>
time_t start,finish;
long hour,minute,second;
double elapsed_time;

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
RUNTIME_SECTION
 maximum_function_evaluations 1000, 2000,3000, 5000, 10000;//, 10000, 10000;
 convergence_criteria 1e-2, 1e-2,1e-3, 1e-3, 1e-4;//, 1e-4, 1e-4;

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
PRELIMINARY_CALCS_SECTION

// Set values of fixed parameters or set initial guess of estimated parameters
```

```
//Population
 Linf=set_Linf(1);
 K=set_K(1);
 t0=set_t0(1);
 len_cv_val=set_len_cv(1);

 //All fisheries
 Linf_L=set_Linf_L(1);
 K_L=set_K_L(1);
 t0_L=set_t0_L(1);
 len_cv_val_L=set_len_cv_L(1);
 //Females
 Linf_F=set_Linf_F(1);
 K_F=set_K_F(1);
 t0_F=set_t0_F(1);
 len_cv_val_F=set_len_cv_F(1);

 M=set_M;
 M_constant=set_M_constant(1);
 smsy2msstM=1.0-M_constant;
 smsy2msst75=0.75;

 log_R0=set_log_R0(1);
 steep=set_steep(1);
 R_autocorr=set_R_autocorr(1);
 rec_sigma=set_rec_sigma(1);

 log_dm_comm_lc=set_log_dm_comm_lc(1);
 log_dm_GR_ac=set_log_dm_GR_ac(1);

 log_q_HB=set_log_q_HB(1);

 q_rate=set_q_rate;
 q_rate_fcn_HB=1.0;
 q_DD_beta=set_q_DD_beta;
 q_DD_fcn=1.0;

 q_RW_log_dev_HB.initialize();

  if (set_q_rate_phase<0 & q_rate!=0.0)
 {

   for (iyear=styr_HB_cpue; iyear<=endyr_HB_cpue; iyear++)
     {   if (iyear>styr_HB_cpue & iyear <=2003)
         {//q_rate_fcn_HB(iyear)=(1.0+q_rate)*q_rate_fcn_HB(iyear-1); //compound
            q_rate_fcn_HB(iyear)=(1.0+(iyear-styr_HB_cpue)*q_rate)*q_rate_fcn_HB(styr_HB_cpue);  //linear
         }
         if (iyear>2003) {q_rate_fcn_HB(iyear)=q_rate_fcn_HB(iyear-1);}
     }
 } //end q_rate conditional

 w_L=set_w_L;

 w_I_HB=set_w_I_HB;

 w_lc_comm=set_w_lc_comm;
 w_ac_GR=set_w_ac_GR;

 w_Nage_init=set_w_Nage_init;
 w_rec=set_w_rec;
 w_rec_early=set_w_rec_early;
 w_rec_end=set_w_rec_end;
 w_fullF=set_w_fullF;
 w_Ftune=set_w_Ftune;

 F_init=set_F_init(1);

 log_avg_F_comm=set_log_avg_F_comm(1);
 log_avg_F_GR=set_log_avg_F_GR(1);

 log_F_dev_comm=set_log_F_dev_comm_vals;
 log_F_dev_GR=set_log_F_dev_GR_vals;

 selpar_A50_comm1=set_selpar_A50_comm1(1);
 selpar_slope_comm1=set_selpar_slope_comm1(1);

 selpar_A50_GR1=set_selpar_A50_GR1(1);
 selpar_slope_GR1=set_selpar_slope_GR1(1);
 selpar_A50_GR2=set_selpar_A50_GR2(1);
 selpar_slope_GR2=set_selpar_slope_GR2(1);

sqrt2pi=sqrt(2.*3.14159265);
g2mt=0.000001;         //conversion of grams to metric tons
g2kg=0.001;            //conversion of grams to kg
mt2klb=2.20462;        //conversion of metric tons to 1000 lb
mt2lb=mt2klb*1000.0;   //conversion of metric tons to lb
g2klb=g2mt*mt2klb;     //conversion of grams to 1000 lb
dzero=0.00001;
huge_number=1.0e+10;

SSB_msy_out=0.0;

iter_inc_msy=max_F_spr_msy/(n_iter_msy-1);
iter_inc_spr=max_F_spr_msy/(n_iter_spr-1);
```

```
 maturity_f=maturity_f_obs;

 prop_f=prop_f_obs;

//Fill in sample sizes of comps, possibly sampled in nonconsec yrs
//Used primarily for output in R object

      nsamp_comm_lenc_allyr=missing;
  nsamp_GR_agec_allyr=missing;

      nfish_comm_lenc_allyr=missing;
  nfish_GR_agec_allyr=missing;

      for (iyear=1; iyear<=nyr_comm_lenc; iyear++)
         {if (nsamp_comm_lenc(iyear)>=minSS_comm_lenc)
           {nsamp_comm_lenc_allyr(yrs_comm_lenc(iyear))=nsamp_comm_lenc(iyear);
            nfish_comm_lenc_allyr(yrs_comm_lenc(iyear))=nfish_comm_lenc(iyear);}}
      for (iyear=1; iyear<=nyr_GR_agec; iyear++)
         {if (nsamp_GR_agec(iyear)>=minSS_GR_agec)
           {nsamp_GR_agec_allyr(yrs_GR_agec(iyear))=nsamp_GR_agec(iyear);
             nfish_GR_agec_allyr(yrs_GR_agec(iyear))=nfish_GR_agec(iyear);}}

//fill in Fs for msy and per-recruit analyses
  F_msy(1)=0.0;
  for (ff=2;ff<=n_iter_msy;ff++) {F_msy(ff)=F_msy(ff-1)+iter_inc_msy;}
  F_spr(1)=0.0;
  for (ff=2;ff<=n_iter_spr;ff++) {F_spr(ff)=F_spr(ff-1)+iter_inc_spr;}


//fill in F's, Catch matrices, and log rec dev with zero's
  F_comm.initialize(); L_comm_num.initialize();
  F_GR.initialize(); L_GR_num.initialize();

  F_comm_out.initialize();
  F_GR_out.initialize();

  sel_comm.initialize();
  sel_comm_vec.initialize();
  sel_HB.initialize();
  sel_GR.initialize();

  sel_HB_block1.initialize();
  sel_HB_block2.initialize();
  sel_GR_block1.initialize();
  sel_GR_block2.initialize();


  log_rec_dev_output.initialize();
  log_rec_dev=set_log_rec_dev_vals;
  log_Nage_dev_output.initialize();
  log_Nage_dev=set_log_Nage_dev_vals;


//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
TOP_OF_MAIN_SECTION
  time(&start);
  arrmblsize=20000000;
  gradient_structure::set_MAX_NVAR_OFFSET(1600);
  gradient_structure::set_GRADSTACK_BUFFER_SIZE(2000000);
  gradient_structure::set_CMPDIF_BUFFER_SIZE(2000000);
  gradient_structure::set_NUM_DEPENDENT_VARIABLES(10000);

//>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
PROCEDURE_SECTION

 //cout<<"start"<<endl;

 //get_M_at_age(); //Needed only if M is estimated

  get_length_weight_at_age();
  //cout << "got length, weight, fecundity transitions" <<endl;
  get_reprod();
  //cout << "got reprod" << endl;
  get_length_at_age_dist();
  //cout<< "got predicted length at age distribution"<<endl;
  get_weight_at_age_landings();
  //cout<< "got weight at age of landings"<<endl;
  get_spr_F0();
  //cout << "got F0 spr" << endl;
  get_selectivity();
  //cout << "got selectivity" << endl;
  get_mortality();
  // cout << "got mortalities" << endl;
  get_bias_corr();
  //cout<< "got recruitment bias correction" << endl;
  get_numbers_at_age();
  //cout << "got numbers at age" << endl;
  get_landings_numbers();
  //cout << "got landings in numbers" << endl;
  get_landings_wgt();
  //cout << "got landings in wgt" << endl;
  // get_dead_discards();
```

```
  //cout << "got dead discards in num and wgt" << endl;
  get_catchability_fcns();
  //cout << "got catchability_fcns" << endl;
  get_indices();
  //cout << "got indices" << endl;
  get_length_comps();
  // cout<< "got length comps"<< endl;
   get_age_comps();
  //cout<< "got age comps"<< endl;
   evaluate_objective_function();
   //cout << "objective function calculations complete" << endl;


FUNCTION get_length_weight_at_age
//population total length in mm
    //compute mean length (mm TL) and weight (whole) at age
    meanlen_TL=Linf*(1.0-mfexp(-K*(agebins-t0+0.5))); //Actually fork length
    wgt_kg=wgtpar_a*pow(meanlen_TL,wgtpar_b);             //whole wgt in kg
    wgt_g=wgt_kg/g2kg;                                    //convert wgt in kg to weight in g
    wgt_mt=wgt_g*g2mt;                                    //convert weight in g to weight in mt
    wgt_klb=mt2klb*wgt_mt;                                //1000 lb of whole wgt
    wgt_lb=mt2lb*wgt_mt;                                  //lb of whole wgt

//All fisheries
meanlen_TL_L=Linf_L*(1.0-mfexp(-K_L*(agebins-t0_L+0.5)));    //Landings total length in mm
    wgt_kg_L=wgtpar_a*pow(meanlen_TL_L,wgtpar_b);             //whole wgt in kg
    wgt_g_L=wgt_kg_L/g2kg;                                    //convert wgt in kg to weight in g
    wgt_mt_L=wgt_g_L*g2mt;                                    //convert weight in g to weight in mt
    wgt_klb_L=mt2klb*wgt_mt_L;                               //1000 lb of whole wgt
    wgt_lb_L=mt2lb*wgt_mt_L;                                 //1000 lb of whole wgt

//Females
meanlen_TL_F=Linf_F*(1.0-mfexp(-K_F*(agebins-t0_F+0.5)));    //Landings total length in mm
    wgt_kg_F=wgtpar_a*pow(meanlen_TL_F,wgtpar_b);             //whole wgt in kg
    wgt_g_F=wgt_kg_F/g2kg;                                    //convert wgt in kg to weight in g
    wgt_mt_F=wgt_g_F*g2mt;                                    //convert weight in g to weight in mt
    wgt_klb_F=mt2klb*wgt_mt_F;                               //1000 lb of whole wgt
    wgt_lb_F=mt2lb*wgt_mt_F;                                 //1000 lb of whole wgt

//batchfec = mfexp(batchfecpar_a + batchfecpar_b*meanlen_TL);  // batch fecundity at length [should be batchfec = exp(a+bL) based on Harris 2004]
//fec = batchfec*nbatch/fecpar_scale;                             // annual fecundity at length scaled to fecpar_scale units

FUNCTION get_reprod

    //reprod=elem_prod(prop_f,elem_prod(maturity_f,fec));
reprod=elem_prod(elem_prod(prop_f,maturity_f),wgt_mt_F);
reprodknum=elem_prod(prop_f,maturity_f)/1000.0;

FUNCTION get_length_at_age_dist
  //compute matrix of length at age, based on the normal distribution
    //population
for (iage=1;iage<=nages;iage++)
   {len_cv(iage)=len_cv_val;
    len_sd(iage)=meanlen_TL(iage)*len_cv(iage);
zscore_lzero=(0.0-meanlen_TL(iage))/len_sd(iage);
cprob_lzero=cumd_norm(zscore_lzero);

    //All fishery dependent
//len_cv_L(iage)=mfexp(log_len_cv_L+log_len_cv_dev_L(iage));
    len_cv_L(iage)=len_cv_val_L;
    len_sd_L(iage)=meanlen_TL_L(iage)*len_cv_L(iage);
zscore_lzero_L=(0.0-meanlen_TL_L(iage))/len_sd_L(iage);
cprob_lzero_L=cumd_norm(zscore_lzero_L);

//Females
//len_cv_L(iage)=mfexp(log_len_cv_L+log_len_cv_dev_L(iage));
    len_cv_F(iage)=len_cv_val_F;
    len_sd_F(iage)=meanlen_TL_F(iage)*len_cv_F(iage);
zscore_lzero_F=(0.0-meanlen_TL_F(iage))/len_sd_F(iage);
cprob_lzero_F=cumd_norm(zscore_lzero_F);

    //first length bin
//population
    zscore_len=((lenbins(1)+0.5*lenbins_width)-meanlen_TL(iage)) / len_sd(iage);
    cprob_lenvec(1)=cumd_norm(zscore_len);          //includes any probability mass below zero
    lenprob(iage,1)=cprob_lenvec(1)-cprob_lzero;    //removes any probability mass below zero

//All fishery dependent
    zscore_len_L=((lenbins(1)+0.5*lenbins_width)-meanlen_TL_L(iage)) / len_sd_L(iage);
    cprob_lenvec_L(1)=cumd_norm(zscore_len_L);          //includes any probability mass below zero
    lenprob_L(iage,1)=cprob_lenvec_L(1)-cprob_lzero_L;    //removes any probability mass below zero

//Females
    zscore_len_F=((lenbins(1)+0.5*lenbins_width)-meanlen_TL_F(iage)) / len_sd_F(iage);
    cprob_lenvec_F(1)=cumd_norm(zscore_len_F);          //includes any probability mass below zero
    lenprob_F(iage,1)=cprob_lenvec_F(1)-cprob_lzero_F;    //removes any probability mass below zero

    //most other length bins
    //population
    for (ilen=2;ilen<nlenbins;ilen++)
      {
        zscore_len=((lenbins(ilen)+0.5*lenbins_width)-meanlen_TL(iage)) / len_sd(iage);
cprob_lenvec(ilen)=cumd_norm(zscore_len);
        lenprob(iage,ilen)=cprob_lenvec(ilen)-cprob_lenvec(ilen-1);
      }
```

```
//All fishery dependent
    for (ilen=2;ilen<nlenbins;ilen++)
      {
        zscore_len_L=((lenbins(ilen)+0.5*lenbins_width)-meanlen_TL_L(iage)) / len_sd_L(iage);
cprob_lenvec_L(ilen)=cumd_norm(zscore_len_L);
        lenprob_L(iage,ilen)=cprob_lenvec_L(ilen)-cprob_lenvec_L(ilen-1);
      }

//Females
    for (ilen=2;ilen<nlenbins;ilen++)
      {
        zscore_len_F=((lenbins(ilen)+0.5*lenbins_width)-meanlen_TL_F(iage)) / len_sd_F(iage);
cprob_lenvec_F(ilen)=cumd_norm(zscore_len_F);
        lenprob_F(iage,ilen)=cprob_lenvec_F(ilen)-cprob_lenvec_F(ilen-1);
      }

    //last length bin is a plus group
//population
    zscore_len=((lenbins(nlenbins)-0.5*lenbins_width)-meanlen_TL(iage)) / len_sd(iage);
lenprob(iage,nlenbins)=1.0-cumd_norm(zscore_len);
      lenprob(iage)=lenprob(iage)/(1.0-cprob_lzero);  //renormalize to account for any prob mass below size=0

//All fishery dependent
    zscore_len_L=((lenbins(nlenbins)-0.5*lenbins_width)-meanlen_TL_L(iage)) / len_sd_L(iage);
lenprob_L(iage,nlenbins)=1.0-cumd_norm(zscore_len_L);
      lenprob_L(iage)=lenprob_L(iage)/(1.0-cprob_lzero_L);  //renormalize to account for any prob mass below size=0

//Females
    zscore_len_F=((lenbins(nlenbins)-0.5*lenbins_width)-meanlen_TL_F(iage)) / len_sd_F(iage);
lenprob_F(iage,nlenbins)=1.0-cumd_norm(zscore_len_F);
      lenprob_F(iage)=lenprob_F(iage)/(1.0-cprob_lzero_F);  //renormalize to account for any prob mass below size=0
   }

  //fleet and survey specific length probs, all assumed here to equal the popn
  lenprob_comm=lenprob_L;

  lenprob_HB=lenprob;

FUNCTION get_weight_at_age_landings  ///***in whole weight

  for (iyear=styr; iyear<=endyr; iyear++)
  {
    len_comm_mm(iyear)=meanlen_TL_L;
    wholewgt_comm_klb(iyear)=wgt_klb_L;
    //len_cL_mm(iyear)=meanlen_TL;
    //wholewgt_cL_klb(iyear)=wgt_klb;
    len_HB_mm(iyear)=meanlen_TL_L;
    wholewgt_HB_klb(iyear)=wgt_klb_L;
    len_GR_mm(iyear)=meanlen_TL_L;
    wholewgt_GR_klb(iyear)=wgt_klb_L;
  }


FUNCTION get_spr_F0
  //at mdyr, apply half this yr’s mortality, half next yr’s
  N_spr_F0(1)=1.0*mfexp(-1.0*M(1)*spawn_time_frac); //at peak spawning time
  N_bpr_F0(1)=1.0;      //at start of year
  for (iage=2; iage<=nages; iage++)
  { N_spr_F0(iage)=N_spr_F0(iage-1)*mfexp(-1.0*(M(iage-1)*(1.0-spawn_time_frac) + M(iage)*spawn_time_frac));
    N_bpr_F0(iage)=N_bpr_F0(iage-1)*mfexp(-1.0*(M(iage-1)));
  }
  N_spr_F0(nages)=N_spr_F0(nages)/(1.0-mfexp(-1.0*M(nages))); //plus group (sum of geometric series)
  N_bpr_F0(nages)=N_bpr_F0(nages)/(1.0-mfexp(-1.0*M(nages)));

  spr_F0=sum(elem_prod(N_spr_F0,reprod));
  bpr_F0=sum(elem_prod(N_bpr_F0,wgt_mt));



FUNCTION get_selectivity
  sel_comm_vec=logistic(agebins, selpar_A50_comm1, selpar_slope_comm1);
  sel_GR_block1=logistic(agebins, selpar_A50_GR1, selpar_slope_GR1);
  sel_GR_block2=logistic(agebins, selpar_A50_GR2, selpar_slope_GR2);
  sel_HB_block1=sel_GR_block1; // Use GR selectivity for HB
  sel_HB_block2=sel_GR_block2; // Use GR selectivity for HB

  //-------- comm --------//
  for (iyear=styr; iyear<=endyr; iyear++)
{sel_comm(iyear) = sel_comm_vec;}

  //---- GR and HB ----//
  //BLOCK 1 for selex
  for (iyear=styr; iyear<=endyr_selex_phase1_GR; iyear++)
   {
    sel_HB(iyear)=sel_HB_block1;
    sel_GR(iyear)=sel_GR_block1;
   }
  //BLOCK 2 for selex
  for (iyear=(endyr_selex_phase1_GR+1); iyear<=endyr; iyear++)//iyear<=endyr_selex_phase2_GR; iyear++)
   {
    sel_HB(iyear)=sel_HB_block2;
    sel_GR(iyear)=sel_GR_block2;
   }
```

```
FUNCTION get_mortality
  Fsum.initialize();
  Fapex.initialize();
  F.initialize();
  //initialization F is avg from first 3 yrs of observed landings
  log_F_dev_init_comm=sum(log_F_dev_comm(styr_comm_L,(styr_comm_L+2)))/3.0;
  //log_F_dev_init_cL=sum(log_F_dev_cL(styr_cL_L,(styr_cL_L+2)))/3.0;
  log_F_dev_init_GR=sum(log_F_dev_GR(styr_GR_L,(styr_GR_L+2)))/3.0;

  for (iyear=styr; iyear<=endyr; iyear++)
  {
    if(iyear>=styr_comm_L & iyear<=endyr_comm_L) //spans full time series
{F_comm_out(iyear)=mfexp(log_avg_F_comm+log_F_dev_comm(iyear));}
    F_comm(iyear)=sel_comm(iyear)*F_comm_out(iyear);
    Fsum(iyear)+=F_comm_out(iyear);


if(iyear>=styr_GR_L & iyear<=endyr_GR_L) //starts in 1981
{F_GR_out(iyear)=mfexp(log_avg_F_GR+log_F_dev_GR(iyear));}
    if (iyear<styr_GR_L)
{F_GR_out(iyear)=mfexp(log_avg_F_GR+log_F_dev_init_GR);}
F_GR(iyear)=sel_GR(iyear)*F_GR_out(iyear);
    Fsum(iyear)+=F_GR_out(iyear);

    //Total F at age
    F(iyear)=F_comm(iyear);  //first in additive series (NO +=)
    //F(iyear)+=F_cL(iyear);
    // F(iyear)+=F_HB(iyear);
    F(iyear)+=F_GR(iyear);

    Fapex(iyear)=max(F(iyear));
    Z(iyear)=M+F(iyear);

   }  //end iyear

FUNCTION get_bias_corr
  var_rec_dev=norm2(log_rec_dev(styr_rec_dev,endyr_rec_dev)-
              sum(log_rec_dev(styr_rec_dev,endyr_rec_dev))/nyrs_rec)
              /(nyrs_rec-1.0);
  //if (set_BiasCor <= 0.0) {BiasCor=mfexp(var_rec_dev/2.0);}   //bias correction based on empirical residuals
  rec_sigma_sq=square(rec_sigma);
  if (set_BiasCor <= 0.0) {BiasCor=mfexp(rec_sigma_sq/2.0);}   //bias correction based on Rsigma
  else {BiasCor=set_BiasCor;}

FUNCTION get_numbers_at_age
//Initialization
  R0=mfexp(log_R0);
  S0=spr_F0*R0;
  R_virgin=SR_eq_func(R0, steep, spr_F0, spr_F0, BiasCor, SR_switch);

  B0=bpr_F0*R_virgin;
  B0_q_DD=R_virgin*sum(elem_prod(N_bpr_F0(set_q_DD_stage,nages),wgt_mt(set_q_DD_stage,nages)));

  // Commented out code block from Erik’s ASPM for red snapper
  F_init_denom=mfexp(log_avg_F_comm+log_F_dev_init_comm)+mfexp(log_avg_F_GR+log_F_dev_init_GR); //+mfexp(log_avg_F_cL+log_F_dev_init_cL)
  F_init_comm_prop= mfexp(log_avg_F_comm+log_F_dev_init_comm)/F_init_denom;
  //F_init_cL_prop= mfexp(log_avg_F_cL+log_F_dev_init_cL)/F_init_denom;
  F_init_GR_prop= mfexp(log_avg_F_GR+log_F_dev_init_GR)/F_init_denom;

  F_initial=sel_comm(styr)*F_init*F_init_comm_prop+
            //sel_cL(styr)*F_init*F_init_cL_prop+
            sel_GR(styr)*F_init*F_init_GR_prop;

//F_initial=sel_initial*F_init;
  Z_initial=M+F_initial;

//Initial equilibrium age structure
  N_spr_initial(1)=1.0*mfexp(-1.0*Z_initial(1)*spawn_time_frac); //at peak spawning time;
  for (iage=2; iage<=nages; iage++)
    {
      N_spr_initial(iage)=N_spr_initial(iage-1)*
                   mfexp(-1.0*(Z_initial(iage-1)*(1.0-spawn_time_frac) + Z_initial(iage)*spawn_time_frac));
    }
  N_spr_initial(nages)=N_spr_initial(nages)/(1.0-mfexp(-1.0*Z_initial(nages))); //plus group
  spr_initial=sum(elem_prod(N_spr_initial,reprod));
  if (styr==styr_rec_dev) {R1=SR_eq_func(R0, steep, spr_F0, spr_initial, 1.0, SR_switch);} //without bias correction (deviation added later)
  else {R1=SR_eq_func(R0, steep, spr_F0, spr_initial, BiasCor, SR_switch);} //with bias correction
  if(R1<10.0) {R1=10.0;} //Avoid unrealistically low popn sizes during search algorithm

//Compute equilibrium age structure for first year
  N_initial_eq(1)=R1;
  for (iage=2; iage<=nages; iage++)
  {
    N_initial_eq(iage)=N_initial_eq(iage-1)*
        mfexp(-1.0*(Z_initial(iage-1)));
  }
  //plus group calculation
  N_initial_eq(nages)=N_initial_eq(nages)/(1.0-mfexp(-1.0*Z_initial(nages))); //plus group

//Add deviations to initial equilibrium N
  N(styr)(2,nages)=elem_prod(N_initial_eq(2,nages),mfexp(log_Nage_dev));

  if (styr==styr_rec_dev) {N(styr,1)=N_initial_eq(1)*mfexp(log_rec_dev(styr_rec_dev));}
  else {N(styr,1)=N_initial_eq(1);}
```

```
  N_mdyr(styr)(1,nages)=elem_prod(N(styr)(1,nages),(mfexp(-1.*(Z_initial(1,nages))*0.5))); //mid year
  N_spawn(styr)(1,nages)=elem_prod(N(styr)(1,nages),(mfexp(-1.*(Z_initial(1,nages))*spawn_time_frac))); //peak spawning time

  SSB(styr)=sum(elem_prod(N_spawn(styr),reprod));
  SSB_knum(styr)=sum(elem_prod(N_spawn(styr),reprodknum));
  B_q_DD(styr)=sum(elem_prod(N(styr)(set_q_DD_stage,nages),wgt_mt(set_q_DD_stage,nages)));

//Rest of years
  for (iyear=styr; iyear<endyr; iyear++)
  {
    if(iyear<(styr_rec_dev-1)||iyear>(endyr_rec_dev-1)) //recruitment follows S-R curve (with bias correction) exactly
    {
        N(iyear+1,1)=BiasCor*SR_func(R0, steep, spr_F0, SSB(iyear),SR_switch);
        N(iyear+1)(2,nages)=++elem_prod(N(iyear)(1,nages-1),(mfexp(-1.*Z(iyear)(1,nages-1))));
        N(iyear+1,nages)+=N(iyear,nages)*mfexp(-1.*Z(iyear,nages)); //plus group
        N_mdyr(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-1.*(Z(iyear+1)(1,nages))*0.5))); //mid year
        N_spawn(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-1.*(Z(iyear+1)(1,nages))*spawn_time_frac))); //peak spawning time
        SSB(iyear+1)=sum(elem_prod(N_spawn(iyear+1),reprod));
SSB_knum(iyear+1)=sum(elem_prod(N_spawn(iyear+1),reprodknum));
B_q_DD(iyear+1)=sum(elem_prod(N(iyear+1)(set_q_DD_stage,nages),wgt_mt(set_q_DD_stage,nages)));
    }
    else   //recruitment follows S-R curve with lognormal deviation
    {
        N(iyear+1,1)=SR_func(R0, steep, spr_F0, SSB(iyear),SR_switch)*mfexp(log_rec_dev(iyear+1));
        N(iyear+1)(2,nages)=++elem_prod(N(iyear)(1,nages-1),(mfexp(-1.*Z(iyear)(1,nages-1))));
        N(iyear+1,nages)+=N(iyear,nages)*mfexp(-1.*Z(iyear,nages)); //plus group
        N_mdyr(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-1.*(Z(iyear+1)(1,nages))*0.5))); //mid year
        N_spawn(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-1.*(Z(iyear+1)(1,nages))*spawn_time_frac))); //peak spawning time
        SSB(iyear+1)=sum(elem_prod(N_spawn(iyear+1),reprod));
SSB_knum(iyear+1)=sum(elem_prod(N_spawn(iyear+1),reprodknum));
        B_q_DD(iyear+1)=sum(elem_prod(N(iyear+1)(set_q_DD_stage,nages),wgt_mt(set_q_DD_stage,nages)));
    }
  }

  //last year (projection) has no recruitment variability
  N(endyr+1,1)=BiasCor*SR_func(R0, steep, spr_F0, SSB(endyr),SR_switch);
  N(endyr+1)(2,nages)=++elem_prod(N(endyr)(1,nages-1),(mfexp(-1.*Z(endyr)(1,nages-1))));
  N(endyr+1,nages)+=N(endyr,nages)*mfexp(-1.*Z(endyr,nages)); //plus group


FUNCTION get_landings_numbers //Baranov catch eqn
  for (iyear=styr; iyear<=endyr; iyear++)
  {
    for (iage=1; iage<=nages; iage++)
    {
      L_comm_num(iyear,iage)=N(iyear,iage)*F_comm(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
      //L_cL_num(iyear,iage)=N(iyear,iage)*F_cL(iyear,iage)*
        //(1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
      L_GR_num(iyear,iage)=N(iyear,iage)*F_GR(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
    }
    pred_comm_L_knum(iyear)=sum(L_comm_num(iyear))/1000.0;
//pred_cL_L_knum(iyear)=sum(L_cL_num(iyear))/1000.0;
    pred_GR_L_knum(iyear)=sum(L_GR_num(iyear))/1000.0;
  }


FUNCTION get_landings_wgt
  for (iyear=styr; iyear<=endyr; iyear++)
  {
    L_comm_klb(iyear)=elem_prod(L_comm_num(iyear),wholewgt_comm_klb(iyear));     //in 1000 lb whole weight
//L_cL_klb(iyear)=elem_prod(L_cL_num(iyear),wholewgt_cL_klb(iyear));     //in 1000 lb whole weight
    // L_HB_klb(iyear)=elem_prod(L_HB_num(iyear),wholewgt_HB_klb(iyear));     //in 1000 lb whole weight
    L_GR_klb(iyear)=elem_prod(L_GR_num(iyear),wholewgt_GR_klb(iyear));     //in 1000 lb whole weight

    pred_comm_L_klb(iyear)=sum(L_comm_klb(iyear));
//pred_cL_L_klb(iyear)=sum(L_cL_klb(iyear));
    // pred_HB_L_klb(iyear)=sum(L_HB_klb(iyear));
    pred_GR_L_klb(iyear)=sum(L_GR_klb(iyear));
  }

FUNCTION get_catchability_fcns
 //Get rate increase if estimated, otherwise fixed above
  if (set_q_rate_phase>0.0)
  {

      for (iyear=styr_HB_cpue; iyear<=endyr_HB_cpue; iyear++)
      {   if (iyear>styr_HB_cpue & iyear <=2003)
          {//q_rate_fcn_HB(iyear)=(1.0+q_rate)*q_rate_fcn_HB(iyear-1); //compound
             q_rate_fcn_HB(iyear)=(1.0+(iyear-styr_HB_cpue)*q_rate)*q_rate_fcn_HB(styr_HB_cpue);  //linear
          }
          if (iyear>2003) {q_rate_fcn_HB(iyear)=q_rate_fcn_HB(iyear-1);}
      }
  } //end q_rate conditional

 //Get density dependence scalar (=1.0 if density independent model is used)
  if (q_DD_beta>0.0)
  {
    B_q_DD+=dzero;
    for (iyear=styr;iyear<=endyr;iyear++)
        {q_DD_fcn(iyear)=pow(B0_q_DD,q_DD_beta)*pow(B_q_DD(iyear),-q_DD_beta);}
          //{q_DD_fcn(iyear)=1.0+4.0/(1.0+mfexp(0.75*(B_q_DD(iyear)-0.1*B0_q_DD))); }
  }
```

```
FUNCTION get_indices
//---Predicted CPUEs------------------------

 //HB  cpue
  q_HB(styr_HB_cpue)=mfexp(log_q_HB);
  for (iyear=styr_HB_cpue; iyear<=endyr_HB_cpue; iyear++)
  {
      N_HB(iyear)=elem_prod(N_mdyr(iyear),sel_HB(iyear));
      pred_HB_cpue(iyear)=q_HB(iyear)*q_rate_fcn_HB(iyear)*q_DD_fcn(iyear)*sum(N_HB(iyear));
      if (iyear<endyr_HB_cpue){q_HB(iyear+1)=q_HB(iyear)*mfexp(q_RW_log_dev_HB(iyear));}
  }

FUNCTION get_length_comps

  //comm lines

  for (iyear=1;iyear<=nyr_comm_lenc_pool;iyear++)
   {pred_comm_lenc_yr(iyear)=(L_comm_num(yrs_comm_lenc_pool(iyear))*lenprob_comm)/sum(L_comm_num(yrs_comm_lenc_pool(iyear)));}

  pred_comm_lenc.initialize();
  for (iyear=1;iyear<=nyr_comm_lenc_pool;iyear++)
    {pred_comm_lenc(1) += nfish_comm_lenc_pool(iyear) * pred_comm_lenc_yr(iyear);}
  pred_comm_lenc(1)=pred_comm_lenc(1)/sum(nfish_comm_lenc_pool);


FUNCTION get_age_comps

  //Recreational
  for (iyear=1;iyear<=nyr_GR_agec;iyear++)
  {
    ErrorFree_GR_agec(iyear)=L_GR_num(yrs_GR_agec(iyear))/sum(L_GR_num(yrs_GR_agec(iyear)));
    pred_GR_agec_allages(iyear)=age_error*ErrorFree_GR_agec(iyear);
    for (iage=1; iage<=nages_agec; iage++) {pred_GR_agec(iyear,iage)=pred_GR_agec_allages(iyear,iage);}
    //for (iage=(nages_agec+1); iage<=nages; iage++) {pred_GR_agec(iyear,nages_agec)+=pred_GR_agec_allages(iyear,iage);} //plus group
  }

////-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_weighted_current
  F_temp_sum=0.0;
  F_temp_sum+=mfexp((selpar_n_yrs_wgted*log_avg_F_comm+
        sum(log_F_dev_comm((endyr-selpar_n_yrs_wgted+1),endyr)))/selpar_n_yrs_wgted);

  F_temp_sum+=mfexp((selpar_n_yrs_wgted*log_avg_F_GR+
        sum(log_F_dev_GR((endyr-selpar_n_yrs_wgted+1),endyr)))/selpar_n_yrs_wgted);

  F_comm_prop=mfexp((selpar_n_yrs_wgted*log_avg_F_comm+
        sum(log_F_dev_comm((endyr-selpar_n_yrs_wgted+1),endyr)))/selpar_n_yrs_wgted)/F_temp_sum;

  F_GR_prop=mfexp((selpar_n_yrs_wgted*log_avg_F_GR+
        sum(log_F_dev_GR((endyr-selpar_n_yrs_wgted+1),endyr)))/selpar_n_yrs_wgted)/F_temp_sum;

  log_F_dev_end_comm=sum(log_F_dev_comm((endyr-selpar_n_yrs_wgted+1),endyr))/selpar_n_yrs_wgted;
  log_F_dev_end_GR=sum(log_F_dev_GR((endyr-selpar_n_yrs_wgted+1),endyr))/selpar_n_yrs_wgted;

  F_end_L=sel_comm(endyr)*mfexp(log_avg_F_comm+log_F_dev_end_comm)+
          //sel_cL(endyr)*mfexp(log_avg_F_cL+log_F_dev_end_cL)+
  sel_GR(endyr)*mfexp(log_avg_F_GR+log_F_dev_end_GR);

  F_end=F_end_L;
  F_end_apex=max(F_end);

  sel_wgted_tot=F_end/F_end_apex;
  sel_wgted_L=elem_prod(sel_wgted_tot, elem_div(F_end_L,F_end));

  wgt_wgted_L_denom=F_comm_prop+F_GR_prop;  //+F_HB_prop+F_cL_prop
  wgt_wgted_L_klb=F_comm_prop/wgt_wgted_L_denom*wholewgt_comm_klb(endyr)+
  //F_cL_prop/wgt_wgted_L_denom*wholewgt_cL_klb(endyr)+
  F_GR_prop/wgt_wgted_L_denom*wholewgt_GR_klb(endyr);

FUNCTION get_msy

  //compute values as functions of F
  for(ff=1; ff<=n_iter_msy; ff++)
  {
    //uses fishery-weighted F's
    Z_age_msy=0.0;
    F_L_age_msy=0.0;

    F_L_age_msy=F_msy(ff)*sel_wgted_L;
    Z_age_msy=M+F_L_age_msy;

    N_age_msy(1)=1.0;
    for (iage=2; iage<=nages; iage++)
      {N_age_msy(iage)=N_age_msy(iage-1)*mfexp(-1.*Z_age_msy(iage-1));}
    N_age_msy(nages)=N_age_msy(nages)/(1.0-mfexp(-1.*Z_age_msy(nages)));
    N_age_msy_spawn(1,(nages-1))=elem_prod(N_age_msy(1,(nages-1)),
                                   mfexp((-1.*Z_age_msy(1,(nages-1)))*spawn_time_frac));
    N_age_msy_spawn(nages)=(N_age_msy_spawn(nages-1)*(mfexp(-1.*(Z_age_msy(nages-1)*(1.0-spawn_time_frac) +
                            Z_age_msy(nages)*spawn_time_frac) )))/(1.0-mfexp(-1.*Z_age_msy(nages)));

    spr_msy(ff)=sum(elem_prod(N_age_msy_spawn,reprod));

    R_eq(ff)=SR_eq_func(R0, steep, spr_msy(1), spr_msy(ff), BiasCor, SR_switch);
```

```
    if (R_eq(ff)<dzero) {R_eq(ff)=dzero;}
    N_age_msy*=R_eq(ff);
    N_age_msy_spawn*=R_eq(ff);

    for (iage=1; iage<=nages; iage++)
    {
      L_age_msy(iage)=N_age_msy(iage)*(F_L_age_msy(iage)/Z_age_msy(iage))*
                      (1.-mfexp(-1.*Z_age_msy(iage)));
    }

    SSB_eq(ff)=sum(elem_prod(N_age_msy_spawn,reprod));
SSB_eq_knum(ff)=sum(elem_prod(N_age_msy_spawn,reprodknum));
B_eq(ff)=sum(elem_prod(N_age_msy,wgt_mt));
    L_eq_klb(ff)=sum(elem_prod(L_age_msy,wgt_wgted_L_klb)); //in whole weight
    L_eq_knum(ff)=sum(L_age_msy)/1000.0;
  }

  msy_klb_out=max(L_eq_klb); //msy in whole weight

  for(ff=1; ff<=n_iter_msy; ff++)
  {
   if(L_eq_klb(ff) == msy_klb_out)
      {
        SSB_msy_out=SSB_eq(ff);
        B_msy_out=B_eq(ff);
        R_msy_out=R_eq(ff);
        msy_knum_out=L_eq_knum(ff);
        F_msy_out=F_msy(ff);
        spr_msy_out=spr_msy(ff);
      }
  }
//--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_per_recruit_stuff

  //static per-recruit stuff

  for(iyear=styr; iyear<=endyr; iyear++)
  {
    N_age_spr(1)=1.0;
    for(iage=2; iage<=nages; iage++)
     {N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z(iyear,iage-1));}
    N_age_spr(nages)=N_age_spr(nages)/(1.0-mfexp(-1.*Z(iyear,nages)));
    N_age_spr_spawn(1,(nages-1))=elem_prod(N_age_spr(1,(nages-1)),
                                mfexp(-1.*Z(iyear)(1,(nages-1))*spawn_time_frac));
    N_age_spr_spawn(nages)=(N_age_spr_spawn(nages-1)*
                          (mfexp(-1.*(Z(iyear)(nages-1)*(1.0-spawn_time_frac) + Z(iyear)(nages)*spawn_time_frac) )))
                          /(1.0-mfexp(-1.*Z(iyear)(nages)));
    spr_static(iyear)=sum(elem_prod(N_age_spr_spawn,reprod))/spr_F0;
  }

  //compute SSB/R and YPR as functions of F
  for(ff=1; ff<=n_iter_spr; ff++)
  {
    //uses fishery-weighted F's, same as in MSY calculations
    Z_age_spr=0.0;
    F_L_age_spr=0.0;

    F_L_age_spr=F_spr(ff)*sel_wgted_L;
    Z_age_spr=M+F_L_age_spr;

    N_age_spr(1)=1.0;
    for (iage=2; iage<=nages; iage++)
     {N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z_age_spr(iage-1));}
    N_age_spr(nages)=N_age_spr(nages)/(1-mfexp(-1.*Z_age_spr(nages)));
    N_age_spr_spawn(1,(nages-1))=elem_prod(N_age_spr(1,(nages-1)),
                                   mfexp((-1.*Z_age_spr(1,(nages-1)))*spawn_time_frac));
    N_age_spr_spawn(nages)=(N_age_spr_spawn(nages-1)*
                          (mfexp(-1.*(Z_age_spr(nages-1)*(1.0-spawn_time_frac) + Z_age_spr(nages)*spawn_time_frac) )))
                          /(1.0-mfexp(-1.*Z_age_spr(nages)));
    spr_spr(ff)=sum(elem_prod(N_age_spr_spawn,reprod));
    L_spr(ff)=0.0;
    for (iage=1; iage<=nages; iage++)
    {
      L_age_spr(iage)=N_age_spr(iage)*(F_L_age_spr(iage)/Z_age_spr(iage))*
                      (1.-mfexp(-1.*Z_age_spr(iage)));
      L_spr(ff)+=L_age_spr(iage)*wgt_wgted_L_klb(iage)*1000.0; //in lb whole wgt
    }
  }
  spr_ratio=spr_spr/spr_F0;
  F20_dum=min(fabs(spr_ratio-0.2));
  F30_dum=min(fabs(spr_ratio-0.3));
  F40_dum=min(fabs(spr_ratio-0.4));
  for(ff=1; ff<=n_iter_spr; ff++)
  {
      if (fabs(spr_ratio(ff)-0.2)==F20_dum) {F20_out=F_spr(ff);}
  if (fabs(spr_ratio(ff)-0.3)==F30_dum) {F30_out=F_spr(ff);}
  if (fabs(spr_ratio(ff)-0.4)==F40_dum) {F40_out=F_spr(ff);}
  }
  rec=column(N,1);
  rec_mean=sum(rec(styr_rec_spr, endyr_rec_spr))/nyrs_rec_spr;
  R_F30_out=rec_mean;
  F_L_age_spr=F30_out*sel_wgted_L;
  Z_age_spr=M+F_L_age_spr;
```

```
  N_age_spr(1)=R_F30_out;
  for (iage=2; iage<=nages; iage++)
     {N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z_age_spr(iage-1));}
  N_age_spr(nages)=N_age_spr(nages)/(1-mfexp(-1.*Z_age_spr(nages)));
  N_age_spr_spawn(1,(nages-1))=elem_prod(N_age_spr(1,(nages-1)),
                                   mfexp((-1.*Z_age_spr(1,(nages-1)))*spawn_time_frac));
  N_age_spr_spawn(nages)=(N_age_spr_spawn(nages-1)*
                          (mfexp(-1.*(Z_age_spr(nages-1)*(1.0-spawn_time_frac) + Z_age_spr(nages)*spawn_time_frac) )))
                          /(1.0-mfexp(-1.*Z_age_spr(nages)));

  for (iage=1; iage<=nages; iage++)
    {
      L_age_F30(iage)=N_age_spr(iage)*(F_L_age_spr(iage)/Z_age_spr(iage))*
                      (1.-mfexp(-1.*Z_age_spr(iage)));
    }
  SSB_F30_out=sum(elem_prod(N_age_spr_spawn,reprod));
  SSB_F30_knum_out=sum(elem_prod(N_age_spr_spawn,reprodknum));
  B_F30_out=sum(elem_prod(N_age_spr,wgt_mt));
  L_F30_klb_out=sum(elem_prod(L_age_F30,wgt_wgted_L_klb)); //in whole weight
  L_F30_knum_out=sum(L_age_F30)/1000.0;


 //F40 calcs
  rec=column(N,1);
  rec_mean=sum(rec(styr_rec_spr, endyr_rec_spr))/nyrs_rec_spr;
  R_F40_out=rec_mean;
  F_L_age_spr=F40_out*sel_wgted_L;
  Z_age_spr=M+F_L_age_spr;

  N_age_spr(1)=R_F40_out;
  for (iage=2; iage<=nages; iage++)
     {N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z_age_spr(iage-1));}
  N_age_spr(nages)=N_age_spr(nages)/(1-mfexp(-1.*Z_age_spr(nages)));
  N_age_spr_spawn(1,(nages-1))=elem_prod(N_age_spr(1,(nages-1)),
                                   mfexp((-1.*Z_age_spr(1,(nages-1)))*spawn_time_frac));
  N_age_spr_spawn(nages)=(N_age_spr_spawn(nages-1)*
                          (mfexp(-1.*(Z_age_spr(nages-1)*(1.0-spawn_time_frac) + Z_age_spr(nages)*spawn_time_frac) )))
                          /(1.0-mfexp(-1.*Z_age_spr(nages)));

  for (iage=1; iage<=nages; iage++)
    {
      L_age_F40(iage)=N_age_spr(iage)*(F_L_age_spr(iage)/Z_age_spr(iage))*
                      (1.-mfexp(-1.*Z_age_spr(iage)));
    }
  SSB_F40_out=sum(elem_prod(N_age_spr_spawn,reprod));
  SSB_F40_knum_out=sum(elem_prod(N_age_spr_spawn,reprodknum));
  B_F40_out=sum(elem_prod(N_age_spr,wgt_mt));
  L_F40_klb_out=sum(elem_prod(L_age_F40,wgt_wgted_L_klb)); //in whole weight
  L_F40_knum_out=sum(L_age_F40)/1000.0;


//--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_miscellaneous_stuff

//switch here if var_rec_dev <=dzero
  if(var_rec_dev>0.0)
   {sigma_rec_dev=sqrt(var_rec_dev);} //sample SD of predicted residuals (may not equal rec_sigma)
   else{sigma_rec_dev=0.0;}

  len_cv=elem_div(len_sd,meanlen_TL);
  len_cv_L=elem_div(len_sd_L,meanlen_TL_L);
  len_cv_F=elem_div(len_sd_F,meanlen_TL_F);

  //compute total landings- and discards-at-age in 1000 fish and klb whole weight
  L_total_num.initialize();
  L_total_klb.initialize();
  L_total_knum_yr.initialize();
  L_total_klb_yr.initialize();

  for(iyear=styr; iyear<=endyr; iyear++)
  {
        L_total_klb_yr(iyear)=pred_comm_L_klb(iyear)+pred_GR_L_klb(iyear);//+pred_HB_L_klb(iyear)+pred_cL_L_klb(iyear)
        L_total_knum_yr(iyear)=pred_comm_L_knum(iyear)+pred_GR_L_knum(iyear);//+pred_HB_L_knum(iyear)+pred_cL_L_knum(iyear)

        B(iyear)=elem_prod(N(iyear),wgt_mt);
        totN(iyear)=sum(N(iyear));
        totB(iyear)=sum(B(iyear));
  }

  L_total_num=L_comm_num+L_GR_num;//+L_HB_num+L_cL_num   //landings at age in number fish
  L_total_klb=L_comm_klb+L_GR_klb;//+L_HB_klb+L_cL_klb   //landings at age in klb whole weight

  //Time series of interest
  B(endyr+1)=elem_prod(N(endyr+1),wgt_mt);
  totN(endyr+1)=sum(N(endyr+1));
  totB(endyr+1)=sum(B(endyr+1));
  SdS0=SSB/S0;

  Fend_mean_temp=1.0;
  for (iyear=1; iyear<=selpar_n_yrs_wgted; iyear++) {Fend_mean_temp*=Fapex(endyr-iyear+1);}
  Fend_mean=pow(Fend_mean_temp,(1.0/selpar_n_yrs_wgted));
  if(F_msy_out>0)
    {
      FdF_msy=Fapex/F_msy_out;
      FdF_msy_end=FdF_msy(endyr);
```

```
      FdF_msy_end_mean=Fend_mean/F_msy_out;
    }
  if(SSB_msy_out>0)
    {
      SdSSB_msy=SSB/SSB_msy_out;
      SdSSB_msy_end=SdSSB_msy(endyr);
    }

if(F30_out>0)
    {
  FdF30=Fapex/F30_out;
  FdF30_end_mean=Fend_mean/F30_out;
}
  if(SSB_F30_out>0)
    {
      SdSSB_F30=SSB/SSB_F30_out;
  Sdmsst_F30=SSB/(smsy2msst75*SSB_F30_out);
      SdSSB_F30_end=SdSSB_F30(endyr);
  Sdmsst_F30_end=Sdmsst_F30(endyr);
    }

if(F40_out>0)
    {
  FdF40=Fapex/F40_out;
  FdF40_end_mean=Fend_mean/F40_out;
}
  if(SSB_F40_out>0)
    {
      SdSSB_F40=SSB/SSB_F40_out;
  Sdmsst_F40=SSB/(smsy2msst75*SSB_F40_out);
      SdSSB_F40_end=SdSSB_F40(endyr);
  Sdmsst_F40_end=Sdmsst_F40(endyr);
    }
   //fill in log recruitment deviations for yrs they are nonzero
   for(iyear=styr_rec_dev; iyear<=endyr_rec_dev; iyear++)
     {log_rec_dev_output(iyear)=log_rec_dev(iyear);}
   //fill in log Nage deviations for ages they are nonzero (ages2+)
   for(iage=2; iage<=nages; iage++)
     {log_Nage_dev_output(iage)=log_Nage_dev(iage);}

//--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_projection

    switch(Fproj_switch){
       case 1: //F=Fcurrent
          F_reg_proj=Fend_mean;
          break;
       case 2: //F=Fmsy
          F_reg_proj=F_msy_out;
          break;
       case 3: //F=F30
          F_reg_proj=F30_out;
          break;
       case 4: //F=F40
          F_reg_proj=F40_out;
          break;
       default: // no such switch available
          cout << "Error in input: Projection switch Fproj_switch must be set to 1, 2, 3, or 4." << endl;
          cout << "Presently it is set to " << Fproj_switch <<"."<< endl;
          exit(0);
   }

  N_proj(styr_proj)=N(endyr+1); //initial conditions computed previously

  for (iyear=styr_proj; iyear<=endyr_proj; iyear++) //recruitment follows S-R curve (with bias correction) exactly
  {
        if (iyear<styr_regs) {F_proj(iyear)=Fend_mean;}
else {F_proj(iyear)=Fproj_mult*F_reg_proj;}

FL_age_proj=sel_wgted_L*F_proj(iyear);

        Z_proj(iyear)=M+FL_age_proj;//+FD_age_proj;
        N_spawn_proj(iyear)(1,nages)=elem_prod(N_proj(iyear)(1,nages),(mfexp(-1.*(Z_proj(iyear)(1,nages))*spawn_time_frac))); //peak spawning time
SSB_proj(iyear)= sum(elem_prod(N_spawn_proj(iyear),reprod));
        B_proj(iyear)=sum(elem_prod(N_proj(iyear),wgt_mt)); //uses spawning weight

for (iage=1; iage<=nages; iage++)
{L_age_proj(iyear,iage)=N_proj(iyear,iage)*FL_age_proj(iage)*(1.-mfexp(-1.*Z_proj(iyear,iage)))/Z_proj(iyear,iage);
}
        L_knum_proj(iyear)=sum(L_age_proj(iyear))/1000.0;
    L_klb_proj(iyear)=sum(elem_prod(L_age_proj(iyear),wgt_wgted_L_klb));     //in 1000 lb

if (iyear<endyr_proj) {
N_proj(iyear+1,1)=BiasCor*SR_func(R0, steep, spr_F0, SSB_proj(iyear),SR_switch);
N_proj(iyear+1)(2,nages)=++elem_prod(N_proj(iyear)(1,nages-1),(mfexp(-1.*Z_proj(iyear)(1,nages-1))));
N_proj(iyear+1,nages)+=N_proj(iyear,nages)*mfexp(-1.*Z_proj(iyear,nages)); //plus group
}
  }
   R_proj=column(N_proj,1);
//--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------


FUNCTION evaluate_objective_function
  //fval=square(xdum-9.0);
```

```
  fval=0.0;
  fval_data=0.0;
//---likelihoods---------------------------

//---Indices-------------------------------

  f_HB_cpue=0.0;
  f_HB_cpue=lk_lognormal(pred_HB_cpue, obs_HB_cpue, HB_cpue_cv, w_I_HB);
  fval+=f_HB_cpue;
  fval_data+=f_HB_cpue;

//---Landings-------------------------------

  //f_comm_L in 1000 lb whole wgt
  f_comm_L=lk_lognormal(pred_comm_L_klb(styr_comm_L,endyr_comm_L), obs_comm_L(styr_comm_L,endyr_comm_L),
                      comm_L_cv(styr_comm_L,endyr_comm_L), w_L);
  fval+=f_comm_L;
  fval_data+=f_comm_L;

  //f_GR_L in 1000 fish
  f_GR_L=lk_lognormal(pred_GR_L_knum(styr_GR_L,endyr_GR_L), obs_GR_L(styr_GR_L,endyr_GR_L),
                      GR_L_cv(styr_GR_L,endyr_GR_L), w_L);
  fval+=f_GR_L;
  fval_data+=f_GR_L;

//---Length comps-------------------------------

  f_comm_lenc=lk_dirichlet_multinomial(nsamp_comm_lenc, pred_comm_lenc, obs_comm_lenc, nyr_comm_lenc, double(nlenbins), minSS_comm_lenc, log_dm_comm_lc);
  fval+=f_comm_lenc;
  fval_data+=f_comm_lenc;


//---Age comps-------------------------------

//f_GR_agec
  //f_GR_agec=lk_robust_multinomial(nsamp_GR_agec, pred_GR_agec, obs_GR_agec, nyr_GR_agec, double(nages_agec), minSS_GR_agec, w_ac_GR);
  //f_GR_agec=lk_logistic_normal(nsamp_GR_agec, pred_GR_agec, obs_GR_agec, nyr_GR_agec, double(nages_agec), minSS_GR_agec);
  f_GR_agec=lk_dirichlet_multinomial(nsamp_GR_agec, pred_GR_agec, obs_GR_agec, nyr_GR_agec, double(nages_agec), minSS_GR_agec, log_dm_GR_ac);
  fval+=f_GR_agec;
  fval_data+=f_GR_agec;
//-----------Constraints and penalties--------------------------------

  //Light penalty applied to log_Nage_dev for deviation from zero. If not estimated, this penalty equals zero.
  f_Nage_init=norm2(log_Nage_dev);
  fval+=w_Nage_init*f_Nage_init;

  f_rec_dev=0.0;
  //rec_sigma_sq=square(rec_sigma);
  rec_logL_add=nyrs_rec*log(rec_sigma);
  f_rec_dev=(square(log_rec_dev(styr_rec_dev) + rec_sigma_sq/2.0)/(2.0*rec_sigma_sq));
  for(iyear=(styr_rec_dev+1); iyear<=endyr_rec_dev; iyear++)
  {f_rec_dev+=(square(log_rec_dev(iyear)-R_autocorr*log_rec_dev(iyear-1) + rec_sigma_sq/2.0)/
               (2.0*rec_sigma_sq));}
  f_rec_dev+=rec_logL_add;
  fval+=w_rec*f_rec_dev;

  f_rec_dev_early=0.0; //possible extra constraint on early rec deviations
  if (w_rec_early>0.0)
    { if (styr_rec_dev<endyr_rec_phase1)
        {
          for(iyear=styr_rec_dev; iyear<=endyr_rec_phase1; iyear++)
          //{f_rec_dev_early+=(square(log_rec_dev(iyear)-R_autocorr*log_rec_dev(iyear-1) + rec_sigma_sq/2.0)/
          //                  (2.0*rec_sigma_sq)) + rec_logL_add;}
          {f_rec_dev_early+=square(log_rec_dev(iyear));}
        }
  fval+=w_rec_early*f_rec_dev_early;
  }

  f_rec_dev_end=0.0; //possible extra constraint on ending rec deviations
  if (w_rec_end>0.0)
  { if (endyr_rec_phase2<endyr_rec_dev)
        {
          for(iyear=(endyr_rec_phase2+1); iyear<=endyr_rec_dev; iyear++)
          //{f_rec_dev_end+=(square(log_rec_dev(iyear)-R_autocorr*log_rec_dev(iyear-1) + rec_sigma_sq/2.0)/
          //                 (2.0*rec_sigma_sq)) + rec_logL_add;}
          {f_rec_dev_end+=square(log_rec_dev(iyear));}
        }
      fval+=w_rec_end*f_rec_dev_end;
   }

  //Ftune penalty: does not apply in last phase
  f_Ftune=0.0;
  if (w_Ftune>0.0)
  {if (set_Ftune>0.0 && !last_phase()) {f_Ftune=square(Fapex(set_Ftune_yr)-set_Ftune);}
   fval+=w_Ftune*f_Ftune;
  }

  //Penalty if apical F exceeds 3.0
  f_fullF_constraint=0.0;
  if (w_fullF>0.0)
  {for (iyear=styr; iyear<=endyr; iyear++)
        {if(Fapex(iyear)>3.0) {f_fullF_constraint+=(mfexp(Fapex(iyear)-3.0)-1.0);}}
   fval+=w_fullF*f_fullF_constraint;
  }
```

```
 f_HB_RWq_cpue=0.0;
 for (iyear=styr_HB_cpue; iyear<endyr_HB_cpue; iyear++)
     {f_HB_RWq_cpue+=square(q_RW_log_dev_HB(iyear))/(2.0*set_RWq_var);}
 fval+=f_HB_RWq_cpue;

//---Priors----------------------------------------------------
//neg_log_prior arguments: estimate, prior mean, prior var/-CV, pdf type
//Variance input as a negative value is considered to be CV in arithmetic space (CV=-1 implies loose prior)
//pdf type 1=none, 2=lognormal, 3=normal, 4=beta
  f_priors=0.0;
  f_priors+=neg_log_prior(len_cv_val,set_len_cv(5),set_len_cv(6),set_len_cv(7));

  f_priors+=neg_log_prior(steep,set_steep(5),set_steep(6),set_steep(7));
  f_priors+=neg_log_prior(log_R0,set_log_R0(5),set_log_R0(6),set_log_R0(7));
  f_priors+=neg_log_prior(R_autocorr,set_R_autocorr(5),set_R_autocorr(6),set_R_autocorr(7));
  f_priors+=neg_log_prior(rec_sigma,set_rec_sigma(5),set_rec_sigma(6),set_rec_sigma(7));

  f_priors+=neg_log_prior(selpar_A50_comm1,set_selpar_A50_comm1(5), set_selpar_A50_comm1(6), set_selpar_A50_comm1(7));
  f_priors+=neg_log_prior(selpar_slope_comm1,set_selpar_slope_comm1(5), set_selpar_slope_comm1(6), set_selpar_slope_comm1(7));
  //f_priors+=neg_log_prior(selpar_A50_comm2,set_selpar_A50_comm2(5), set_selpar_A50_comm2(6), set_selpar_A50_comm2(7));
  //f_priors+=neg_log_prior(selpar_slope_comm2,set_selpar_slope_comm2(5), set_selpar_slope_comm2(6), set_selpar_slope_comm2(7));
  // f_priors+=neg_log_prior(selpar_A502_comm2,set_selpar_A502_comm2(5), set_selpar_A502_comm2(6), set_selpar_A502_comm2(7));
  // f_priors+=neg_log_prior(selpar_slope2_comm2,set_selpar_slope2_comm2(5), set_selpar_slope2_comm2(6), set_selpar_slope2_comm2(7));
  //f_priors+=neg_log_prior(selpar_A50_comm3,set_selpar_A50_comm3(5), set_selpar_A50_comm3(6), set_selpar_A50_comm3(7));
  //f_priors+=neg_log_prior(selpar_slope_comm3,set_selpar_slope_comm3(5), set_selpar_slope_comm3(6), set_selpar_slope_comm3(7));


  f_priors+=neg_log_prior(selpar_A50_GR1,set_selpar_A50_GR1(5), set_selpar_A50_GR1(6), set_selpar_A50_GR1(7));
  f_priors+=neg_log_prior(selpar_slope_GR1,set_selpar_slope_GR1(5), set_selpar_slope_GR1(6), set_selpar_slope_GR1(7));
  f_priors+=neg_log_prior(selpar_A50_GR2,set_selpar_A50_GR2(5), set_selpar_A50_GR2(6), set_selpar_A50_GR2(7));
  f_priors+=neg_log_prior(selpar_slope_GR2,set_selpar_slope_GR2(5), set_selpar_slope_GR2(6), set_selpar_slope_GR2(7));

   f_priors+=neg_log_prior(log_q_HB,set_log_q_HB(5),set_log_q_HB(6),set_log_q_HB(7));

  f_priors+=neg_log_prior(log_dm_comm_lc,set_log_dm_comm_lc(5),set_log_dm_comm_lc(6),set_log_dm_comm_lc(7));
  //f_priors+=neg_log_prior(log_dm_cL_lc,set_log_dm_cL_lc(5),set_log_dm_cL_lc(6),set_log_dm_cL_lc(7));
  f_priors+=neg_log_prior(log_dm_GR_ac,set_log_dm_GR_ac(5),set_log_dm_GR_ac(6),set_log_dm_GR_ac(7));
  //f_priors+=neg_log_prior(log_dm_GR_lc,set_log_dm_GR_lc(5),set_log_dm_GR_lc(6),set_log_dm_GR_lc(7));

  f_priors+=neg_log_prior(F_init,set_F_init(5),set_F_init(6),set_F_init(7));

  fval+=f_priors;

//-----------------------------------------------------------------------------------
//Logistic function: 2 parameters
FUNCTION dvar_vector logistic(const dvar_vector& ages, const dvariable& A50, const dvariable& slope)
  //ages=vector of ages, A50=age at 50% selectivity, slope=rate of increase
  RETURN_ARRAYS_INCREMENT();
  dvar_vector Sel_Tmp(ages.indexmin(),ages.indexmax());
  Sel_Tmp=1./(1.+mfexp(-1.*slope*(ages-A50))); //logistic;
  RETURN_ARRAYS_DECREMENT();
  return Sel_Tmp;

//------------------------------------------------------------------------------------
//Logistic-exponential: 4 parameters (but 1 is fixed)
FUNCTION dvar_vector logistic_exponential(const dvar_vector& ages, const dvariable& A50, const dvariable& slope, const dvariable& sigma, const dvariable& joint)
  //ages=vector of ages, A50=age at 50% sel (ascending limb), slope=rate of increase, sigma=controls rate of descent (descending)
  //joint=age to join curves
  RETURN_ARRAYS_INCREMENT();
  dvar_vector Sel_Tmp(ages.indexmin(),ages.indexmax());
  Sel_Tmp=1.0;
  for (iage=1; iage<=nages; iage++)
  {
   if (ages(iage)<joint) {Sel_Tmp(iage)=1./(1.+mfexp(-1.*slope*(ages(iage)-A50)));}
   if (ages(iage)>joint){Sel_Tmp(iage)=mfexp(-1.*square((ages(iage)-joint)/sigma));}
  }
  Sel_Tmp=Sel_Tmp/max(Sel_Tmp);
  RETURN_ARRAYS_DECREMENT();
  return Sel_Tmp;

//------------------------------------------------------------------------------------
//Logistic function: 4 parameters
FUNCTION dvar_vector logistic_double(const dvar_vector& ages, const dvariable& A501, const dvariable& slope1, const dvariable& A502, const dvariable& slope2)
  //ages=vector of ages, A50=age at 50% selectivity, slope=rate of increase, A502=age at 50% decrease additive to A501, slope2=slope of decrease
  RETURN_ARRAYS_INCREMENT();
  dvar_vector Sel_Tmp(ages.indexmin(),ages.indexmax());
  Sel_Tmp=elem_prod( (1./(1.+mfexp(-1.*slope1*(ages-A501)))),(1.-(1./(1.+mfexp(-1.*slope2*(ages-(A501+A502)))))) );
  Sel_Tmp=Sel_Tmp/max(Sel_Tmp);
  RETURN_ARRAYS_DECREMENT();
  return Sel_Tmp;

//------------------------------------------------------------------------------------
//Jointed logistic function: 6 parameters (increasing and decreasing logistics joined at peak selectivity)
FUNCTION dvar_vector logistic_joint(const dvar_vector& ages, const dvariable& A501, const dvariable& slope1, const dvariable& A502, const dvariable& slope2, const dvariable& satval, const dvariable& joint)
  //ages=vector of ages, A501=age at 50% sel (ascending limb), slope1=rate of increase,A502=age at 50% sel (descending), slope1=rate of increase (ascending),
  //satval=saturation value of descending limb, joint=location in age vector to join curves (may equal age or age + 1 if age-0 is included)
  RETURN_ARRAYS_INCREMENT();
  dvar_vector Sel_Tmp(ages.indexmin(),ages.indexmax());
  Sel_Tmp=1.0;
  for (iage=1; iage<=nages; iage++)
  {
   if (double(iage)<joint) {Sel_Tmp(iage)=1./(1.+mfexp(-1.*slope1*(ages(iage)-A501)));}
   if (double(iage)>joint){Sel_Tmp(iage)=1.0-(1.0-satval)/(1.+mfexp(-1.*slope2*(ages(iage)-A502)));}
  }
  Sel_Tmp=Sel_Tmp/max(Sel_Tmp);
```

```
  RETURN_ARRAYS_DECREMENT();
  return Sel_Tmp;

//------------------------------------------------------------------------------------
//Double Gaussian function: 6 parameters (as in SS3)
FUNCTION dvar_vector gaussian_double(const dvar_vector& ages, const dvariable& peak, const dvariable& top, const dvariable& ascwid, const dvariable& deswid, const dvariable& init, const dvariable& final)
  //ages=vector of ages, peak=ascending inflection location (as logistic), top=width of plateau, ascwid=ascent width (as log(width))
  //deswid=descent width (as log(width))
  RETURN_ARRAYS_INCREMENT();
  dvar_vector Sel_Tmp(ages.indexmin(),ages.indexmax());
  dvar_vector sel_step1(ages.indexmin(),ages.indexmax());
  dvar_vector sel_step2(ages.indexmin(),ages.indexmax());
  dvar_vector sel_step3(ages.indexmin(),ages.indexmax());
  dvar_vector sel_step4(ages.indexmin(),ages.indexmax());
  dvar_vector sel_step5(ages.indexmin(),ages.indexmax());
  dvar_vector sel_step6(ages.indexmin(),ages.indexmax());
  dvar_vector pars_tmp(1,6); dvar_vector sel_tmp_iq(1,2);

  pars_tmp(1)=peak;
  pars_tmp(2)=peak+1.0+(0.99*ages(nages)-peak-1.0)/(1.0+mfexp(-top));
  pars_tmp(3)=mfexp(ascwid);
  pars_tmp(4)=mfexp(deswid);
  pars_tmp(5)=1.0/(1.0+mfexp(-init));
  pars_tmp(6)=1.0/(1.0+mfexp(-final));

  sel_tmp_iq(1)=mfexp(-(square(ages(1)-pars_tmp(1))/pars_tmp(3)));
  sel_tmp_iq(2)=mfexp(-(square(ages(nages)-pars_tmp(2))/pars_tmp(4)));

  sel_step1=mfexp(-(square(ages-pars_tmp(1))/pars_tmp(3)));
  sel_step2=pars_tmp(5)+(1.0-pars_tmp(5))*(sel_step1-sel_tmp_iq(1))/(1.0-sel_tmp_iq(1));
  sel_step3=mfexp(-(square(ages-pars_tmp(2))/pars_tmp(4)));
  sel_step4=1.0+(pars_tmp(6)-1.0)*(sel_step3-1.0)/(sel_tmp_iq(2)-1.0);
  sel_step5=1.0/ (1.0+mfexp(-(20.0* elem_div((ages-pars_tmp(1)), (1.0+sfabs(ages-pars_tmp(1)))) )));
  sel_step6=1.0/(1.0+mfexp(-(20.0*elem_div((ages-pars_tmp(2)),(1.0+sfabs(ages-pars_tmp(2)))) )));

  Sel_Tmp=elem_prod(sel_step2,(1.0-sel_step5))+
          elem_prod(sel_step5,((1.0-sel_step6)+ elem_prod(sel_step4,sel_step6)) );

  Sel_Tmp=Sel_Tmp/max(Sel_Tmp);
  RETURN_ARRAYS_DECREMENT();
  return Sel_Tmp;

//------------------------------------------------------------------------------------
//Spawner-recruit function (Beverton-Holt or Ricker)
FUNCTION dvariable SR_func(const dvariable& R0, const dvariable& h, const dvariable& spr_F0, const dvariable& SSB, int func)
  //R0=virgin recruitment, h=steepness, spr_F0=spawners per recruit @ F=0, SSB=spawning biomass
  //func=1 for Beverton-Holt, 2 for Ricker
  RETURN_ARRAYS_INCREMENT();
  dvariable Recruits_Tmp;
  switch(func) {
    case 1: //Beverton-Holt
      Recruits_Tmp=((0.8*R0*h*SSB)/(0.2*R0*spr_F0*(1.0-h)+(h-0.2)*SSB));
    break;
    case 2: //Ricker
      Recruits_Tmp=((SSB/spr_F0)*mfexp(h*(1-SSB/(R0*spr_F0))));
    break;
  }
  RETURN_ARRAYS_DECREMENT();
  return Recruits_Tmp;

//------------------------------------------------------------------------------------
//Spawner-recruit equilibrium function (Beverton-Holt or Ricker)
FUNCTION dvariable SR_eq_func(const dvariable& R0, const dvariable& h, const dvariable& spr_F0, const dvariable& spr_F, const dvariable& BC, int func)
  //R0=virgin recruitment, h=steepness, spr_F0=spawners per recruit @ F=0, spr_F=spawners per recruit @ F, BC=bias correction
  //func=1 for Beverton-Holt, 2 for Ricker
  RETURN_ARRAYS_INCREMENT();
  dvariable Recruits_Tmp;
  switch(func) {
    case 1: //Beverton-Holt
      Recruits_Tmp=(R0/((5.0*h-1.0)*spr_F))*(BC*4.0*h*spr_F-spr_F0*(1.0-h));
    break;
    case 2: //Ricker
      Recruits_Tmp=R0/(spr_F/spr_F0)*(1.0+log(BC*spr_F/spr_F0)/h);
    break;
  }
  RETURN_ARRAYS_DECREMENT();
  return Recruits_Tmp;

//------------------------------------------------------------------------------------
//compute multinomial effective sample size for a single yr
FUNCTION dvariable multinom_eff_N(const dvar_vector& pred_comp, const dvar_vector& obs_comp)
  //pred_comp=vector of predicted comps, obscomp=vector of observed comps
  dvariable EffN_Tmp; dvariable numer; dvariable denom;
  RETURN_ARRAYS_INCREMENT();
  numer=sum( elem_prod(pred_comp,(1.0-pred_comp)) );
  denom=sum( square(obs_comp-pred_comp) );
  if (denom>0.0) {EffN_Tmp=numer/denom;}
  else {EffN_Tmp=-missing;}
  RETURN_ARRAYS_DECREMENT();
  return EffN_Tmp;

//------------------------------------------------------------------------------------
//Likelihood contribution: lognormal
FUNCTION dvariable lk_lognormal(const dvar_vector& pred, const dvar_vector& obs, const dvar_vector& cv, const dvariable& wgt_dat)
  //pred=vector of predicted vals, obs=vector of observed vals, cv=vector of CVs in arithmetic space, wgt_dat=constant scaling of CVs
```

```
  //small_number is small value to avoid log(0) during search
  RETURN_ARRAYS_INCREMENT();
  dvariable LkvalTmp;
  dvariable small_number=0.0001;
  dvar_vector var(cv.indexmin(),cv.indexmax()); //variance in log space
  var=log(1.0+square(cv/wgt_dat));   // convert cv in arithmetic space to variance in log space
  LkvalTmp=sum(0.5*elem_div(square(log(elem_div((pred+small_number),(obs+small_number)))),var) );
  RETURN_ARRAYS_DECREMENT();
  return LkvalTmp;

//-----------------------------------------------------------------------------------
//Likelihood contribution: multinomial
FUNCTION dvariable lk_multinomial(const dvar_vector& nsamp, const dvar_matrix& pred_comp, const dvar_matrix& obs_comp, const double& ncomp, const double& minSS, const dvariable& wgt_dat)
  //nsamp=vector of N's, pred_comp=matrix of predicted comps, obs_comp=matrix of observed comps, ncomp = number of yrs in matrix, minSS=min N threshold, wgt_dat=scaling of N's
  RETURN_ARRAYS_INCREMENT();
  dvariable LkvalTmp;
  dvariable small_number=0.0001;
  LkvalTmp=0.0;
  for (int ii=1; ii<=ncomp; ii++)
  {if (nsamp(ii)>=minSS)
    {LkvalTmp-=wgt_dat*nsamp(ii)*sum(elem_prod((obs_comp(ii)+small_number),
               log(elem_div((pred_comp(ii)+small_number), (obs_comp(ii)+small_number)))));
    }
  }
  RETURN_ARRAYS_DECREMENT();
  return LkvalTmp;

//-----------------------------------------------------------------------------------
//Likelihood contribution: robust multinomial
FUNCTION dvariable lk_robust_multinomial(const dvar_vector& nsamp, const dvar_matrix& pred_comp, const dvar_matrix& obs_comp, const double& ncomp, const dvariable& mbin, const double& minSS, const dvariable& wgt
  //nsamp=vector of N's, pred_comp=matrix of predicted comps, obs_comp=matrix of observed comps, ncomp = number of yrs in matrix, mbin=number of bins, minSS=min N threshold, wgt_dat=scaling of N's
  RETURN_ARRAYS_INCREMENT();
  dvariable LkvalTmp;
  dvariable small_number=0.0001;
  LkvalTmp=0.0;
  dvar_matrix Eprime=elem_prod((1.0-obs_comp), obs_comp)+0.1/mbin; //E' of Francis 2011, p.1131
  dvar_vector nsamp_wgt=nsamp*wgt_dat;
  //cout<<nsamp_wgt<<endl;
  for (int ii=1; ii<=ncomp; ii++)
  {if (nsamp(ii)>=minSS)
    {LkvalTmp+= sum(0.5*log(Eprime(ii))-log(small_number+mfexp(elem_div((-square(obs_comp(ii)-pred_comp(ii))) , (Eprime(ii)*2.0/nsamp_wgt(ii)) ))) );
    }
  }
  RETURN_ARRAYS_DECREMENT();
  return LkvalTmp;

//-----------------------------------------------------------------------------------
//Likelihood contribution: Dirichlet-multinomial
FUNCTION dvariable lk_dirichlet_multinomial(const dvar_vector& nsamp, const dvar_matrix& pred_comp, const dvar_matrix& obs_comp, const double& ncomp, const dvariable& mbin, const double& minSS, const dvariable&
  //nsamp=vector of N's, pred_comp=matrix of predicted comps, obs_comp=matrix of observed comps, ncomp = number of yrs in matrix, mbin=number of bins, minSS=min N threshold, wgt_dat=scaling of N's
  RETURN_ARRAYS_INCREMENT();
  dvariable LkvalTmp;
  dvariable small_number=0.00001;
  LkvalTmp=0.0;
  dvar_vector nsamp_adjust=nsamp*mfexp(log_dir_par);
   //dvar_vector nsamp_adjust=mfexp(log_dir_par);
  for (int ii=1; ii<=ncomp; ii++)
  {
if (nsamp(ii)>=minSS)
    {
LkvalTmp-=gammln(nsamp_adjust(ii))-gammln(nsamp(ii)+nsamp_adjust(ii));
LkvalTmp-=sum(gammln(nsamp(ii)*obs_comp(ii)+nsamp_adjust(ii)*pred_comp(ii)+small_number));
LkvalTmp+=sum(gammln(nsamp_adjust(ii)*pred_comp(ii)+small_number));
    }
  }
  RETURN_ARRAYS_DECREMENT();
  return LkvalTmp;

// //Likelihood contribution: Dirichlet-multinomial
// FUNCTION dvariable lk_dirichlet_multinomial(const dvar_vector& nsamp, const dvar_matrix& pred_comp, const dvar_matrix& obs_comp, const double& ncomp, const dvariable& mbin, const double& minSS, const dvariabl
  // //nsamp=vector of N's, pred_comp=matrix of predicted comps, obs_comp=matrix of observed comps, ncomp = number of yrs in matrix, mbin=number of bins, minSS=min N threshold, wgt_dat=scaling of N's
  // RETURN_ARRAYS_INCREMENT();
  // dvariable LkvalTmp;
  // LkvalTmp=0.0;
  // dvar_vector nsamp_adjust=nsamp*mfexp(log_dir_par);
  // //dvar_vector nsamp_adjust=mfexp(log_dir_par);
  // for (int ii=1; ii<=ncomp; ii++)
  // {
// if (nsamp(ii)>=minSS)
    // {
// LkvalTmp-=gammln(nsamp_adjust(ii))-gammln(nsamp(ii)+nsamp_adjust(ii));
// LkvalTmp-=sum(gammln(nsamp(ii)*obs_comp(ii)+nsamp_adjust(ii)*pred_comp(ii)));
        // LkvalTmp+=sum(gammln(nsamp_adjust(ii)*pred_comp(ii)));
    // }
  // }
  // RETURN_ARRAYS_DECREMENT();
  // return LkvalTmp;


//-----------------------------------------------------------------------------------
//Likelihood contribution: logistic normal (aka multivariate logistic in iSCAM; logistic normal in Francis' terminology)
FUNCTION dvariable lk_logistic_normal(const dvar_vector& nsamp, const dvar_matrix& pred_comp, const dvar_matrix& obs_comp, const double& ncomp, const dvariable& mbin, const double& minSS)
  //nsamp=vector of N's, pred_comp=matrix of predicted comps, obs_comp=matrix of observed comps, ncomp = number of yrs in matrix, mbin=number of bins, minSS=min N threshold
  RETURN_ARRAYS_INCREMENT();
  dvariable LkvalTmp;
```

```
  dvariable small_number=0.0001;
  LkvalTmp=0.0;
  dvar_matrix nu=pred_comp+0.0;
  dvar_matrix pred_plus=pred_comp+small_number;
  dvar_matrix obs_plus=obs_comp+small_number;

  dvariable nu_mean;
  dvariable nu_sum_sq;
  dvariable tau_hat_sq;
  dvariable year_count; //keeps track of years included in likelihood (i.e., that meet the sample size requirement)

  LkvalTmp=0.0;
  nu_sum_sq=0.0;
  year_count=0.0;
  for (int ii=1; ii<=ncomp; ii++)
  {if (nsamp(ii)>=minSS)
    {
year_count+=1.0;
nu_mean=sum( log(obs_plus(ii))-log(pred_plus(ii))  )/mbin; //year-specific mean log residual
for (int jj=1; jj<=mbin;jj++)
{
nu(ii,jj) = log(obs_plus(ii,jj)) - log(pred_plus(ii,jj)) - nu_mean;
nu_sum_sq += square(nu(ii,jj));
}
    }
  }
  if (year_count>0.0)
  {
  tau_hat_sq = nu_sum_sq/((mbin-1.0)*year_count);
  LkvalTmp = (mbin-1.0)*year_count*log(tau_hat_sq);
  }
  RETURN_ARRAYS_DECREMENT();
  return LkvalTmp;

//-----------------------------------------------------------------------------------
//-----------------------------------------------------------------------------------
//Likelihood contribution: priors
FUNCTION  dvariable neg_log_prior(dvariable pred, const double& prior, dvariable var, int pdf)
  //prior=prior point estimate, var=variance (if negative, treated as CV in arithmetic space), pred=predicted value, pdf=prior type (1=none, 2=lognormal, 3=normal, 4=beta)
    dvariable LkvalTmp;
    dvariable alpha, beta, ab_iq;
    dvariable big_number=1e10;
    LkvalTmp=0.0;
    // compute generic pdf's
    switch(pdf) {
        case 1: //option to turn off prior
          LkvalTmp=0.0;
          break;
        case 2: // lognormal
          if(prior<=0.0) cout << "YIKES: Don't use a lognormal distn for a negative prior" << endl;
          else if(pred<=0) LkvalTmp=big_number=1e10;
          else {
            if(var<0.0) var=log(1.0+var*var) ;      // convert cv to variance on log scale
            LkvalTmp= 0.5*( square(log(pred/prior))/var + log(var) );
          }
        break;
        case 3: // normal
          if(var<0.0 && prior!=0.0) var=square(var*prior);      // convert cv to variance on observation scale
          else if(var<0.0 && prior==0.0) var=-var;               // cv not really appropriate if prior value equals zero
          LkvalTmp= 0.5*( square(pred-prior)/var + log(var) );
          break;
        case 4: // beta
          if(var<0.0) var=square(var*prior);          // convert cv to variance on observation scale
          if(prior<=0.0 || prior>=1.0) cout << "YIKES: Don't use a beta distn for a prior outside (0,1)" << endl;
          ab_iq=prior*(1.0-prior)/var - 1.0; alpha=prior*ab_iq; beta=(1.0-prior)*ab_iq;
          if(pred>=0 && pred<=1) LkvalTmp= (1.0-alpha)*log(pred)+(1.0-beta)*log(1.0-pred)-gammln(alpha+beta)+gammln(alpha)+gammln(beta);
          else LkvalTmp=big_number;
          break;
        default: // no such prior pdf currently available
          cout << "The prior must be either 1(lognormal), 2(normal), or 3(beta)." << endl;
          cout << "Presently it is " << pdf << endl;
          exit(0);
    }
    return LkvalTmp;

//-----------------------------------------------------------------------------------
//SDNR: age comp likelihood (assumes fits are done with the robust multinomial function)
FUNCTION dvariable sdnr_multinomial(const double& ncomp, const dvar_vector& ages, const dvar_vector& nsamp,
                                    const dvar_matrix& pred_comp, const dvar_matrix& obs_comp, const dvariable& wgt_dat)
  //ncomp=number of years of data, ages=vector of ages, nsamp=vector of N's,
  //pred_comp=matrix of predicted comps, obs_comp=matrix of observed comps, wgt_dat=likelihood weight for data source
  RETURN_ARRAYS_INCREMENT();
  dvariable SdnrTmp;
  dvar_vector o(1,ncomp);
  dvar_vector p(1,ncomp);
  dvar_vector ose(1,ncomp);
  dvar_vector res(1,ncomp);
  SdnrTmp=0.0;
  for (int ii=1; ii<=ncomp; ii++)
  {
    o(ii)=sum(elem_prod(ages,obs_comp(ii)));
    p(ii)=sum(elem_prod(ages,pred_comp(ii)));
    ose(ii)=sqrt((sum(elem_prod(square(ages),pred_comp(ii)))-square(p(ii)))/(nsamp(ii)*wgt_dat));
  }
  res=elem_div((o-p),ose);
```

```
  SdnrTmp=sqrt(sum(square(res-(sum(res)/ncomp))/(ncomp-1.0)));
  RETURN_ARRAYS_DECREMENT();
  return SdnrTmp;

//------------------------------------------------------------------------------------
//SDNR: lognormal likelihood
FUNCTION dvariable sdnr_lognormal(const dvar_vector& pred, const dvar_vector& obs, const dvar_vector& cv, const dvariable& wgt_dat)
  //nyr=number of years of data, pred=vector of predicted data, obs=vector of observed data, cv=vector of cv's, wgt_dat=likelihood weight for data source
  RETURN_ARRAYS_INCREMENT();
  dvariable SdnrTmp;
  dvariable small_number=0.00001;
  dvariable n;
  dvar_vector res(cv.indexmin(),cv.indexmax());
  SdnrTmp=0.0;
  res=elem_div(log(elem_div(obs+small_number,pred+small_number)),sqrt(log(1+square(cv/wgt_dat))));
  n=cv.indexmax()-cv.indexmin()+1;
  SdnrTmp=sqrt(sum(square(res-(sum(res)/n))/(n-1.0)));
  RETURN_ARRAYS_DECREMENT();
  return SdnrTmp;

//------------------------------------------------------------------------------------
REPORT_SECTION

  if (last_phase())
  {
      cout<<"start report"<<endl;
       //cout<<"xdum = "<<xdum<<endl;
  get_weighted_current();
       cout<<"got weighted"<<endl;
      get_msy();
       cout<<"got msy"<<endl;
      get_per_recruit_stuff();
       cout<<"got per recruit"<<endl;
      get_miscellaneous_stuff();
       cout<<"got misc stuff"<<endl;
  get_projection();
   cout<<"got projection"<<endl;

      grad_max=objective_function_value::pobjfun->gmax;
      time(&finish);
  elapsed_time=difftime(finish,start);
  hour=long(elapsed_time)/3600;
  minute=long(elapsed_time)%3600/60;
  second=(long(elapsed_time)%3600)%60;
  cout<<endl<<endl<<"*******************************************"<<endl;
  cout<<"--Start time: "<<ctime(&start)<<endl;
  cout<<"--Finish time: "<<ctime(&finish)<<endl;
  cout<<"--Runtime: ";
  cout<<hour<<" hours, "<<minute<<" minutes, "<<second<<" seconds"<<endl;
  cout << "--TotalLikelihood: " << fval << endl;
      cout<<"--Final gradient: "<<objective_function_value::pobjfun->gmax << endl;
  cout<<"*******************************************"<<endl;

      cout <<endl;
      cout << "><>--><>--><>--><>--><>--><>--><>--><>--><>--><>"  <<endl;
      cout << "BC Fmsy=" << F_msy_out<< "   BC SSBmsy=" << SSB_msy_out <<endl;
      cout <<"F status="<<FdF_msy_end<<endl;
      cout <<"Pop status="<<SdSSB_msy_end<<endl;
      cout << "h="<<steep<<"   R0="<<R0<<endl;
      //cout << "xdum " << xdum << endl;
      cout << "><>--><>--><>--><>--><>--><>--><>--><>--><>--><>"  <<endl;

      report << "TotalLikelihood " << fval << endl;
      report << "N" << endl;
      report << N<<endl;
      report << "F" << endl;
      report << F <<endl;
      // report << "prob_belowsizelim_block3" << endl;
  // report<<prob_belowsizelim_block3<<endl;

      sdnr_I_HB=sdnr_lognormal(pred_HB_cpue, obs_HB_cpue, HB_cpue_cv, w_I_HB);

      //##################################################################################################
      //##  Passing parameters to vector for bounds check plotting
      //##################################################################################################
       Linf_out(8)=Linf; Linf_out(1,7)=set_Linf;
       K_out(8)=K; K_out(1,7)=set_K;
       t0_out(8)=t0; t0_out(1,7)=set_t0;
       len_cv_val_out(8)=len_cv_val; len_cv_val_out(1,7)=set_len_cv;

   Linf_L_out(8)=Linf_L; Linf_L_out(1,7)=set_Linf_L;
       K_L_out(8)=K_L; K_L_out(1,7)=set_K_L;
       t0_L_out(8)=t0_L; t0_L_out(1,7)=set_t0_L;
       len_cv_val_L_out(8)=len_cv_val_L; len_cv_val_L_out(1,7)=set_len_cv_L;

   Linf_F_out(8)=Linf_F; Linf_F_out(1,7)=set_Linf_F;
       K_F_out(8)=K_F; K_F_out(1,7)=set_K_F;
       t0_F_out(8)=t0_F; t0_F_out(1,7)=set_t0_F;
       len_cv_val_F_out(8)=len_cv_val_F; len_cv_val_F_out(1,7)=set_len_cv_F;

       log_R0_out(8)=log_R0; log_R0_out(1,7)=set_log_R0;
       M_constant_out(8)=M_constant; M_constant_out(1,7)=set_M_constant;
       steep_out(8)=steep; steep_out(1,7)=set_steep;
       rec_sigma_out(8)=rec_sigma; rec_sigma_out(1,7)=set_rec_sigma;
       R_autocorr_out(8)=R_autocorr; R_autocorr_out(1,7)=set_R_autocorr;
```

```
  log_dm_comm_lc_out(8)=log_dm_comm_lc; log_dm_comm_lc_out(1,7)=set_log_dm_comm_lc;
  log_dm_GR_ac_out(8)=log_dm_GR_ac; log_dm_GR_ac_out(1,7)=set_log_dm_GR_ac;

      selpar_A50_comm1_out(8)=selpar_A50_comm1; selpar_A50_comm1_out(1,7)=set_selpar_A50_comm1;
      selpar_slope_comm1_out(8)=selpar_slope_comm1; selpar_slope_comm1_out(1,7)=set_selpar_slope_comm1;

  selpar_A50_GR1_out(8)=selpar_A50_GR1; selpar_A50_GR1_out(1,7)=set_selpar_A50_GR1;
      selpar_slope_GR1_out(8)=selpar_slope_GR1; selpar_slope_GR1_out(1,7)=set_selpar_slope_GR1;
  selpar_A50_GR2_out(8)=selpar_A50_GR2; selpar_A50_GR2_out(1,7)=set_selpar_A50_GR2;
      selpar_slope_GR2_out(8)=selpar_slope_GR2; selpar_slope_GR2_out(1,7)=set_selpar_slope_GR2;

      log_q_HB_out(8)=log_q_HB; log_q_HB_out(1,7)=set_log_q_HB;

      log_avg_F_comm_out(8)=log_avg_F_comm; log_avg_F_comm_out(1,7)=set_log_avg_F_comm;
  log_avg_F_GR_out(8)=log_avg_F_GR; log_avg_F_GR_out(1,7)=set_log_avg_F_GR;
      F_init_out(8)=F_init; F_init_out(1,7)=set_F_init;

      log_rec_dev_out(styr_rec_dev, endyr_rec_dev)=log_rec_dev;
      log_F_dev_comm_out(styr_comm_L,endyr_comm_L)=log_F_dev_comm;
  log_F_dev_GR_out(styr_GR_L,endyr_GR_L)=log_F_dev_GR;

  #include "co22_make_Robject4.cxx"   // write the R-compatible report

 } //endl last phase loop
```

SEDAR

Southeast Data, Assessment, and Review

SEDAR 58

Atlantic Cobia

SECTION IV: Addendum

December 2019

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

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November, 2019 Original release.

December, 2019 Assessment Report Addendum. This release incorporates the corrections made during the Review Workshop, and should be considered the revised final assessment report. All complementary analyses, including sensitivities, ensemble modeling, and the projections have been generated with the model agreed upon during the Review Workshop.

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1 Data Review and Update

In this benchmark assessment, the start year is 1986 and the terminal year is 2017. The composition data and non-hindcasted landings data start in 1986, and the Assessment Panel decided to start the model in the year when the best data become available. The Panel's decision was also based on model runs that demonstrated the fact that including earlier years of hindcasted landings data did not affect model results. Data sources from SEDAR28 were also considered here; however, all data were re–examined and evaluated using current methodologies, including data prior to 2011 (the terminal year of SEDAR28). The input data for this assessment are described below, with focus on modifications from recommendations of the Data Workshop and those used in the last assessment:

1.1 Data Review

In this benchmark assessment, the Beaufort Assessment Model (BAM) was fitted to data sources similar to those used in the SEDAR28 benchmark with some modifications and additions.

- Landings: Commercial (all gears), and General recreational (headboat, charterboat, and private boat modes).
- Discards: Commercial (handline and nets), General recreational (all modes).
- Index of abundance: Headboat CPUE
- Length compositions of landings: Commercial handline
- Age compositions of landings: General recreational

In addition to data fitted by the model, this assessment utilized life-history information that was treated as input. Such inputs, some of which remained the same for this assessment as were used in the last assessment, were provided by the life history working group: natural mortality, female maturity at age, sex ratio, and somatic growth. The discard mortality rates were compiled by the discard mortality working group.

1.2 Data Update

The following is a summarization of the data differences between this benchmark assessment and the last (SEDAR28). Data available for this assessment are summarized in Tables 1–5.

- Discards and discard mortality: The discard mortality working group provide a gillnet discard mortality rate of 0.55, compared to 0.51 in SEDAR28. Commercial and recreational discards were updated through 2017. The estimates for commercial and recreational discards are either model- or ratio-based, therefore the entire time series of estimates were provided.
- Indices of abundance: As per the data workshop recommendations, neither the SCDNR index of abundance, nor the MRFSS index of abundance were used in this assessment, though they were in the SEDAR28 assessment. The headboat index is the sole index used in this benchmark assessment.
- Size/age compositions landings: Commercial and general recreational composition data were corrected and updated through 2017, the terminal year of the assessment, though general recreational length compositions and commercial age compositions were not used. All of the updated composition data are subject to the same minimum sample size used in SEDAR28 (n=30 trips for lengths and n=10 trips for ages) though sample sizes (i.e., trip numbers) were not available for several years and states. The number of fish sampled represented the sample size for general recreational compositions, as often a single fish is caught per trip.

- Growth curves: Additional growth curves were requested by the Assessment Panel, and the analyst and Life History Working Group chairperson conducted the analyses. The Panel requested a female–only and a landings–only growth curve. The landings–only growth curve is meant to represent the average size of the fish captured by the fleet, therefore the fitting procedure did not adjust for the size limit. The females–only growth curve is meant to be used to calculate the female biomass, and therefore needs to reflect the population. Size correction methodology was used for the female–only curve to account for fishery dependent observations (lengths) being truncated by the size limit.
- The iterative reweighting method used in SEDAR28 was not used for composition data, as the Dirichlet multinomial distribution was used. The Dirichlet multinomial is a self-weighting distribution, thus removing the need for weights on the composition data. The index was weighted using the iterative reweighting procedure.
- The Charnov et al. (2013) method was used to calculate natural mortality. The Charnov et al. method is a meta–analysis that includes data from multiple studies that generate methods to estimate natural mortality. The Lorenzen method (Lorenzen 1996) used in SEDAR28 is one method used in the Charnov et al. meta–analysis.

1.2.1 Discard Mortality

The discard mortalities for all the gears were revisited by the discard mortality working group. The group reviewed five data sources from state and federal government agencies. After discussion the observed immediate discard mortality for gillnet gears was 55%. The working group recommended an upper bound of 77% and a lower bound of 36% discard mortality as was recommended during SEDAR28. For lines, the group noted that the overall discard mortality of cobia was relatively low. Estimates of discard mortality ranged from 0% to 12.4%. The group determined that a 0% lower bound estimate was not realistic and therefore adopted the lower bound of 2% from SEDAR28. The group decided that 5% was a reasonable discard mortality estimate based on results from additional data sources and the discard mortality estimate from SEDAR28.

1.2.2 Recreational Landings and Discards

Estimates were available from the recalibrated MRIP data, and were used as input for the landings and discards for all recreational modes except headboat through 2017. Headboat landings were provided through 2017, and headboat discards were calculated using a model-based approach. Headboat and general recreational landings and discards were combined into one general recreational fleet, by applying the discard mortality rate to live discards and combining the result with the landings to create one time series of removals for the general recreational fleet.

1.2.3 Commercial Landings and Discards

The commercial discards were revised for the entire time series, as it is a model-based approach, and provided through 2017. Commercial landings were updated through 2017. Commercial landings and discards were combined into one time series, consistent with SEDAR28, by applying the discard mortality rate to live discards and combining the result with the landings for one time series of removals for the commercial fleet.

1.2.4 Indices of Abundance

The fishery-dependent index was considered in light of new management measures effected since the last assessment. Closures for the recreational season have been intermittent since 2015. The change in closures since SEDAR28 clearly affects catch per effort, and it likely invalidates catch per effort as a meaningful index of abundance. Thus, the headboat index was only updated through 2015 for this assessment. This index was the only index of abundance used in the assessment.

1.2.5 Length Compositions

Length compositions for both fleets were corrected and updated through 2017. The Assessment Panel considered several possible applications of length composition data. The Panel considered including general recreational length compositions in years with no age composition data, or when the age data were sparse. However, no growth curve is estimated internally, and the quality of the age compositions is such that the length compositions were not needed to supplement, and thus they were not used in the assessment. For the commercial fleet, length compositions were inadequate to produce annual length compositions. Therefore, the Assessment Panel agreed to pool the commercial length compositions across years into a single composition.

1.2.6 Age Compositions

The commercial age compositions were discussed by the Assessment Panel, in light of the fact that the samples for ageing were not randomly sampled. The Assessment Panel decided to not use the commercial age compositions, as they did not represent the fleet. The general recreational age compositions were discussed at both the data workshop and during the assessment process. The majority of the samples are from carcass collection programs in Virginia and South Carolina. The general recreational age samples from SEDAR28 were largely carcass samples as well, therefore the discussion focused on whether the samples were different from each state. In order to account for differences, the Assessment Panel decided to weight the age samples by landings in order to provide an age composition representative of the entire fleet across states.

2 Stock Assessment Methods

This assessment updates the primary model applied during the SEDAR28 benchmark for cobia. The methods are reviewed below, and any changes since the SEDAR28 benchmark are noted.

2.1 Overview

This assessment used the Beaufort Assessment Model (BAM, Williams and Shertzer 2015), which applies an integrated catch-age formulation, implemented with the AD Model Builder software (Fournier et al. 2012). In essence, the model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2014). 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). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic such as red porgy, tilefish, blueline tilefish, gag, greater amberjack, snowy grouper, vermilion snapper, and red snapper.

2.2 Data Sources

The catch-age model included data from two fleets that caught cobia in southeastern U.S. waters north of the Georgia Florida border: commercial and general recreational. The model was fitted to data on annual removals (in units of 1000 lb whole weight for commercial and 1000 fish for general recreational), which comprised landings and dead discards. Dead discards were computed using the discard mortalities provided at the Data Workshop. The model was also fitted to pooled length compositions of commercial landings, annual age compositions of general recreational landings, and a fishery-dependent index (headboat). Data used in the model are tabulated in §1 of this report.

2.3 Model Configuration

Model structure and equations of the BAM are detailed in Williams and Shertzer (2015). The assessment time period was 1986–2017. A general description of the assessment model follows.

2.3.1 Stock dynamics

In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The model included age classes $1 - 12^+$, where the oldest age class 12^+ allowed for the accumulation of fish (i.e., plus group).

2.3.2 Initialization

Initial (1986) abundance at age was estimated in the model as follows. First, the equilibrium age structure was computed for ages 2–12 based on natural and initial fishing mortality (F_{init}), where F_{init} is an estimated parameter. Second, lognormal deviations around that equilibrium age structure were estimated. The deviations were lightly penalized, such that the initial abundance of each age could vary from equilibrium if suggested by early composition data, but remain estimable if data were uninformative. Given the initial abundance of ages 2–12, initial (1986) abundance of age-1 fish was computed using the same methods as for recruits in other years (described below).

2.3.3 Growth

Mean size at age of the population (total length, TL) was modeled with the von Bertalanffy equation (Figure 1), and weight at age (whole weight, WW) was modeled as a function of total length. Parameters of growth and conversions (TL-WW) were estimated by the Life History Working Group and were treated as input to the assessment model. The von Bertalanffy parameter estimates for the population from the DW were $L_\infty = 1262$, $K = 0.31$, and $t_0 = -0.53$. However, the Panel decided to use two modified growth curves instead; one to fit to landings (landings only with no size limit correction), and one to calculate spawning stock biomass (females only with a size limit correction) For the landings–only growth curve, $L_\infty = 1287$, $K = 0.26$, and $t_0 = -1.74$, and for the females–only growth curve, $L_\infty = 1334$, $K = 0.32$, and $t_0 = -0.49$. For fitting length composition data, the distribution of size at age was assumed normal with coefficient of variation (CV) estimated by the assessment model. A constant CV, rather than constant standard deviation, was suggested by the size at age data. Only the CV for the landings–only curve is estimated within the model.

2.3.4 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 Charnov et al. (2013). The Charnov et al. (2013) approach relates the natural mortality at age to the von Bertalanffy growth equation parameters (of the whole population) and length at age: $\mathrm{M}_a = K \times [L_a/L_\infty]^{-1.5}$, where L_∞ and K are von Bertalanffy parameters and L_a is length at age.

2.3.5 Female maturity and Spawning stock

Female maturity was modeled with a logistic function; the age at 50% female maturity was estimated to be ~ 1 year. No new data on maturity were available for this assessment, therefore the values from SEDAR28 were applied. Spawning stock was modeled as biomass of mature females measured at the time of peak spawning. For cobia, peak spawning was considered to occur mid–June.

2.3.6 Recruitment

In this assessment, steepness was not estimable, even when applying a prior distribution to inform the estimation (Shertzer and Conn 2012). Likelihood profiles showed no minimum in the likelihood surface either, therefore the Panel concluded that the stock–recruit relationship is not well–defined. In the assessment, annual recruitment was estimated as deviations around an overall average. Expected recruitment of age-1 fish was predicted from the fixed average with annual variation in recruitment assumed to occur with lognormal deviations beginning in 1986.

2.3.7 Landings

The model included time series of landings from two fleets: commercial (all gear) and general recreational (headboat, charterboat, and private boats combined). Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in units of weight (1000 lb whole weight for commercial and 1000 fish for recreational). Observed landings were provided back to the first assessment year (1986) for each fleet.

2.3.8 Discards

Live and dead commercial discards were provided from 1993 to 2017. Live commercial discards were reduced to dead discards using the gear-specific mortality rates, as suggested by the Panel described in §1.2.1, then the dead discards were combined with landings to produce one removal time series. Live discards from the general recreational fleet were available from 1986-2017, and the single removals time series was computed similarly to what was done for the commercial fleet.

2.3.9 Fishing

For each time series of landings, 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.

2.3.10 Selectivities

Selectivity curves were estimated using a parametric approach. This approach applies plausible structure on the shape of the selectivity curves, and achieves greater parsimony than occurs with unique parameters for each age. Selectivities of landings from all fleets were modeled as flat-topped, using a two-parameter logistic function. The selectivity of the fishery-dependent index was the same as that of the general recreational fleet before the size limit regulation.

Age and length composition data are critical for estimating selectivity parameters, and ideally, a model would have sufficient composition data from each fleet over time to estimate distinct selectivities in each time block assumed in the model. The commercial length compositions informed the commercial fleet selectivity, and only one time block was modeled due to lack of regulatory change in the fleet. The general recreational age compositions informed the general recreational fleet selectivities. Two time blocks were modeled due to reports from stakeholders and state scientists that fishing behaviors changed in 2007. The Panel requested multiple runs with different pivotal years for selectivity time blocks (2005–2009), and 2007 was the pivotal year that resulted in the best overall likelihood and best general age composition likelihood. The use of a second time block for the selectivity of the general recreational fleet is a departure from the assumption of time–invariant selectivity in SEDAR28.

2.3.11 Indices of abundance

The model was fit to a fishery–dependent index standardized from headboat logbooks (1991–2015). The predicted index is conditional on selectivity of the general recreational fleet and was computed from abundance at the midpoint of the year.

2.3.12 Catchability

In the BAM, catchability scales indices of relative abundance to estimated population abundance at large. Several options for time-varying catchability were implemented in the BAM following recommendations of the 2009 SEDAR procedural workshop on catchability (SEDAR Procedural Guidance 2009). In particular, the BAM allows for density dependence, linear trends, and random walk, as well as time-invariant catchability. For cobia, catchability of the index was assumed to be constant, as the Panel decided there was little reason to think catchability for cobia on headboats has changed since 1986.

2.3.13 Biological reference points

Biological reference points (benchmarks) were calculated based on the fishing rate that would allow a stock to attain 40% of the maximum spawning potential which would have been obtained in the absence of fishing mortality. Computed benchmarks included $L_{\mathrm{F40\%}}$, fishing mortality rate at $L_{\mathrm{F40\%}}$ ($F_{40\%}$), and spawning stock at $L_{\mathrm{F40\%}}$ ($\mathrm{SSB}_{\mathrm{F40\%}}$)(Gabriel and Mace 1999). In this assessment, spawning stock measures biomass of mature females. 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 fishery estimated as the full F averaged over the last three years of the assessment.

2.3.14 Fitting criterion

The fitting criterion was a penalized likelihood approach in which observed landings were fit closely, and observed composition data and the abundance index were fit to the degree that they were compatible. Landings and index data were fitted using lognormal likelihoods. Length and age composition data were fitted using the Dirichlet-multinomial distribution, with sample size represented by the annual number of fish, adjusted by an estimated variance inflation factor.

The SEDAR28 benchmark fit composition data using the multinomial distribution, and many SEDAR assessments since then have applied a robust version of the multinomial likelihood, as recommended by Francis (2011). More recent work has questioned use of the multinomial distribution in stock assessment models (Francis 2014), and of the alternative distributions, two appear most promising, the Dirichlet-multinomial and logistic-normal (Francis 2017; Thorson et al. 2017). Both are self-weighting and therefore iterative re-weighting (e.g., Francis (2011)) is unnecessary, and both better account for intra-haul correlations (i.e., fish caught in the same set are more alike in length or age than fish caught in a different set). The Dirichlet-multinomial allows for observed zeros (the logistic-normal does not), and has recently been implemented in Stock Synthesis (Methot and Wetzel 2013). This assessment used the Dirichlet-multinomial distribution in the base run.

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 modified the effect of the input CVs. In this application to cobia, CVs of landings (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 to the landings, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). Weights on the index were adjusted iteratively, starting from initial weights in an attempt to achieve standard deviations of normalized residuals (SDNRs) near 1.0.

The compound objective function also included several penalties or prior distributions, applied to CV of growth (based on the empirical estimate), $F_{\text{initratio}}$ (prior of 1.0), and selectivity parameters. Penalties or 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.

2.3.15 Configuration of base run

The base run was configured as described above. However, the base run configuration was not considered to represent all uncertainty. Sensitivities, retrospective analyses, and ensemble modeling was conducted to better characterize the uncertainty in base run point estimates.

2.3.16 Sensitivity analyses

Sensitivity runs were chosen to investigate issues that arose specifically with this benchmark assessment. They were intended to demonstrate directionality of results with changes in inputs or simply to explore model behavior, and not all were considered equally plausible. Sensitivity runs vary from the base run as follows.

- S1: Start model in 1950 to match SEDAR28 start year.
- S2: Include length compositions for the general recreational fleet.
- S3: Use the life history values from SEDAR28. Runs 3a–3e incrementally and additively incorporate each value: length–weight relationship, time of spawn, sex ratio, growth curve, and natural mortality.

- S4: Remove the headboat index.
- S5: Smooth the peak in general recreational removals in 1996 (used the geometric mean of 2 years before and after peak).
- S6: Shift general recreational landings down 3 fold.
- S7: Used the bounds of ensemble parameters that would reach upper bound of status. Runs 7a–c are each parameter, or set of parameters, separately: Landings and discards +1SD, and the upper bound of discard mortality; the lower bound of M using the von Bertalanffy parameters bounds; and the index +1SD.
- S8: Used the bounds of ensemble parameters that would reach lower bound of status. Runs 8a–c are each parameter, or set of parameters, separately: Landings and discards -1SD, and the lower bound of discard mortality; the upper bound of M using the von Bertalanffy parameters bounds; and the index -1SD.
- S9: Runs a–e are the 5 retrospective peels. Retrospective analyses, or peels, were run by incrementally dropping one year at a time for five iterations making the terminal years 2016, 2015, 2014, 2013, and 2012.
- S10: Shift general recreational landings up 3 fold.

2.4 Parameters Estimated

The model estimated annual fishing mortality rates of each fleet (66 parameters), selectivity parameters (6 parameters), Dirichlet-multinomial variance inflation factors (2 parameters), a catchability coefficient associated with the index (1 parameter), initial mean recruitment (1 parameter), initial fishing mortality (1 parameter), variance of the recruitment deviations (1 parameter), annual recruitment deviations (31 parameters), deviations in the initial age structure (15 parameters), and CV of size at age for the landings growth curve (1 parameter).

2.5 Per Recruit and Equilibrium Analyses

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 MSY proxy-related benchmarks (described in §2.6), 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 of the assessment (2015–2017).

2.6 Benchmark/Reference Point Methods

In this assessment of cobia, the quantities $F_{40\%}$, $\mathrm{SSB}_{\mathrm{F}40\%}$, $B_{\mathrm{F}40\%}$, and $L_{\mathrm{F}40\%}$ were estimated as proxies for MSY–based reference points. Steepness was not reliably estimable, so the stock-recruit relationship was not used to identify a maximum yield. Instead, an average level of recruitment was assumed, while estimating deviations around the mean. $F_{40\%}$ was used by consensus of the Panel to generate fishing benchmarks. However, because the stock-recruitment relationship was not estimated, assumptions about recruitment are required to generate biomass benchmarks. Here, equilibrium recruitment was assumed equal to expected recruitment (arithmetic average). On average, expected recruitment is higher than that estimated directly from the spawner-recruit curve, because of lognormal deviation in recruitment. Thus, in this assessment, the method of benchmark estimation accounted for lognormal deviation by including a bias correction in equilibrium average 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}) is the product of R_0 (virgin recruitment) and the bias correction. 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 the highest ASY, and the estimate of $L_{\mathrm{F40\%}}$ is that ASY. The value of $F_{40\%}$ is the F giving 40% spawning potential ratio. The estimates of $L_{\mathrm{F40\%}}$ and $\mathrm{SSB}_{\mathrm{F40\%}}$ follow from the corresponding equilibrium age structure and recruitment.

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 (2015–2017). 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 proposed to be set to $F_{40\%}$, and the minimum stock size threshold (MSST) as $\mathrm{MSST} = 75\%\mathrm{SSB}_{\mathrm{F40\%}}$. Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. Current status of the stock is represented by SSB in the latest assessment year (2017), and current status of the fishery is represented by the geometric mean of F from the latest three years (2015–2017).

2.7 Uncertainty and Measures of Precision

For the base run of the catch-age model (BAM), uncertainty in results and precision of estimates was computed thoroughly through an ensemble modeling approach (Scott et al. 2016) 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 stock assessment (Restrepo et al. 1992; Legault et al. 2001; SEDAR 2004; 2009; 2010). 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 assessment model many times with different values of "observed" data and key input parameters. A chief advantage of the ensemble modeling approach is that the resulting ensemble model describes a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity runs. A minor disadvantage of the approach is that computational demands are relatively high, though parallel computing can somewhat mitigate those demands.

In this assessment, the BAM was successively re-fit in $n = 4000$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. The value of $n = 4000$ was chosen because at least 3000 runs were desired, and it was anticipated that not all runs would be valid. Of the 4000 trials, approximately 0.975% were discarded, based on a 0.5% trim on $R0$ or because the model did not properly converge. This left $n = 3961$ trials used to characterize uncertainty, which was sufficient for convergence of standard errors in management quantities.

The ensemble model should be interpreted as providing an approximation to the uncertainty associated with each output. The results are approximate as all runs are given equal weight in the results, yet some might provide better fits to data than others.

2.7.1 Bootstrap of observed data

To include uncertainty in time series of observed landings, discards, and the index of abundance, multiplicative lognormal errors were applied through a parametric bootstrap. To implement this approach in the ensemble modeling, 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 ($\hat{O}_{s,y}$),

$$O_{s,y} = \hat{O}_{s,y}[\exp(x_{s,y} - \sigma^2_{s,y}/2)] \tag{1}$$

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, $\sigma_{s,y} = \sqrt{\log(1.0 + CV^2_{s,y})}$. As used for fitting the base run, CVs of commercial landings in most years were assumed to be 0.05. The CVs for recreational landings and both commercial and recreational discards were those provided by the data providers(see Table 3). The CVs of indices of abundance were those provided by the data providers (see 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 were drawn at random with replacement using the cell probabilities of the original data. For each year of each data source, the number of individuals sampled was the same as in the original data (number of fish), and the effective sample sizes used for fitting (number of trips) was unmodified.

2.7.2 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 A point estimate of natural mortality at age was provided by the Life History Working Group, though no uncertainty was provided. Because natural mortality is inherently uncertain, the Panel attempted to vary M in the ensemble modeling approach in a way consistent with Charnov et al. (2013). The model in Charnov et al. (2013) is based on a linear regression in log space of the relationship between M and von Bertalanffy growth parameters. Charnov et al. (2013) provides estimates of the standard error of the slope and intercept of that regression. In this step of the ensemble modeling, we used those estimates of uncertainty to regenerate a new slope and intercept, assuming normal distributions, from which we calculated a new natural mortality vector at age for each of the 4000 models. However, at the Review Workshop, the Review Panel determined the resulting level of uncertainty in natural mortality was too small. The Panel recommended double the variance on the estimate of natural mortality be used in the ensemble model.

Discard mortalities Similarly, discard mortalities (δ) were subjected to Monte Carlo variation as follows. The discard mortality working group provided point estimates and an upper and lower bound for each gear type. A new value for commercial and recreational lines discard mortality was drawn for each model from a uniform distribution (range [0.02, 0.12]) with center equal to the point estimate ($\delta = 0.05$). Similarly, a new value for commercial gillnet discard mortality was drawn for each model from a uniform distribution (range [0.36, 0.77]) with center equal to the point estimate ($\delta = 0.55$).

Recreational Landings and Discards CVs The recreational landings and all discards were initially allowed to vary based on the CVs provided. However, the Review Panel recommended the CVs on the commercial fleet discards be capped at 3, because the CVs provided were unreasonably high. Once the landings and discards time series were drawn for each fleet and gear, the discards were decremented by the selected value for discard mortality relevant to the gear, and the result was added to the landings for each fleet.

2.8 Projections—Probabilistic Analysis

Projections were run to predict stock status in years after the assessment, 2018–2024, as requested in the TORs.

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 MSY benchmarks (§2.6).

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.

2.8.1 Initialization of projections

Although the terminal year of the assessment is 2017, the assessment model computes abundance at age (N_a) at the start of 2018. For projections, those estimates were used to initialize N_a. However, the assessment has no information to inform the strength of 2018 recruitment, and thus it computes 2018 recruits (N_1) as the expected value, that is, without deviation from the estimate of mean recruitment, 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 (2018) of projections included this variability in N_1. The deterministic projections were not adjusted in this manner, because deterministic recruitment follows mean recruitment.

Fishing rates that define the projections were assumed to start in 2020. Because the assessment period ended in 2017, the projections required an initialization period (2018 and 2019). L_{current} (an average of the last three years of the assessment, 2015-2017) was assumed during the interim period.

2.8.2 Uncertainty of projections

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 2018) 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 mean annual recruitment values ($\bar{R}_y$). Variability is added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{2}$$

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 component.

The procedure generated 20,000 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.

2.8.3 Projection scenarios

The TORs for this assessment described three projections scenarios: $F = F_{40\%}$, $F = 75\% F_{40\%}$, and $F = F_{\text{current}}$. In each, the landings in the interim period (2018–2019) were calculated based on F_{current}.

- Scenario 1: $F = F_{\text{current}}$, with L_{current} assumed for the interim period.
- Scenario 2: $F = F_{40\%}$, with L_{current} assumed for the interim period.
- Scenario 3: $F = 75\% F_{40\%}$, with L_{current} assumed for the interim period.

3 Stock Assessment Results

3.1 Measures of Overall Model Fit

The Beaufort Assessment Model (BAM) fit well to the available data. Predicted length compositions from the commercial fishery were reasonably close to observed data, as were predicted age compositions (Figure 2). The model was configured to fit observed commercial and recreational landings closely (Figures 3–4). The fit to the index of abundance generally captured the observed trend but not all annual fluctuations (Figure 5).

3.2 Parameter Estimates

Estimates of all parameters from the catch-age model are shown in Appendix B. Estimates of management quantities and some key parameters, such as those of the spawner-recruit model, are reported in sections below.

3.3 Stock Abundance and Recruitment

Estimated abundance at age shows little trend, though the last few years are some of the lowest in the time series (Figure 6; Table 6). Total estimated abundance at the end of the assessment period showed a sharp decline since 2013. Annual number of recruits is shown in Table 6 (age-1 column) and in Figure 7. In the most recent decade, a notably strong year class (age-1 fish) was predicted to have occurred in 2010, but the most recent four years had lower than average recruitment.

3.4 Total and Spawning Biomass

Estimated biomass at age, as well as total biomass and spawning biomass followed a similar pattern as abundance at age (Figures 8 and 9 ; Tables 7 and 8).

3.5 Selectivity

Selectivities of landings from commercial and recreational fleets are shown in Figures 10–11. In the general recreational fleet, the selectivity shifted toward younger ages with the reported change in fisher behavior. In the most recent years, full selection occurred near age-4 for both fleets.

Average selectivities of landings were computed from F-weighted selectivities in the most recent period of regulations (Figure 12). These average selectivities were used to compute benchmarks. All selectivities from the most recent period, including average selectivities, are tabulated in Table 9.

3.6 Fishing Mortality and Landings

The estimated fishing mortality rates (F) generally increased through the assessment time period, with a previous peak in 1996 (Figure 13). The general recreational fleet has been the largest contributor to total F (Table 10). Estimates of total F at age are shown in Table 11. Table 12 shows total landings at age in numbers, and Table 13 in weight. In general, the majority of estimated landings were from the general recreational fleet (Figures 14, 15; Tables 14, 15).

3.7 Spawner-Recruitment Parameters

The spawner-recruit relationship with fixed steepness, from which we estimate deviations from the average recruitment, is shown in Figure 16 depicted graphically by recruits per spawner as a function of spawners. Values of recruitment-related parameters were as follows: unfished age-1 recruitment $\widehat{R_0} = 1,559,065$, and standard deviation of recruitment residuals in log space $\widehat{\sigma_R} = 0.53$. Uncertainty in these quantities was estimated through the ensemble modeling (Figure 17).

3.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 18). Per recruit analyses applied the most recent selectivity patterns averaged across fleets, weighted by F from the last three years (2015–2017).

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 19). By definition, the F that provides 40% SPR is $F_{40\%}$, and the corresponding landings and spawning biomass are $L_{\mathrm{F40\%}}$ and $\mathrm{SSB}_{\mathrm{F40\%}}$.

3.9 Benchmarks / Reference Points

As described in §2.6, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the expected recruitment (Figure16). Reference points estimated were $F_{40\%}$, $L_{\mathrm{F40\%}}$, $B_{\mathrm{F40\%}}$ and $\mathrm{SSB}_{\mathrm{F40\%}}$. Standard deviations of benchmarks were approximated as those from ensemble model (§2.7).

Estimates of benchmarks are summarized in Table 16. Point estimates of $L_{\mathrm{F40\%}}$-related quantities were $F_{40\%} = 0.69$ (y^{-1}), $L_{\mathrm{F40\%}} = 4617$ (klb), $B_{\mathrm{F40\%}} = 0.18$ (mt), and $\mathrm{SSB}_{\mathrm{F40\%}} = 3507$ (mt). Distributions of these benchmarks from the ensemble model are shown in Figure 20.

3.9.1 Status of the Stock and Fishery

The estimated time series of spawning stock biomass showed little overall trend, though the terminal year is the lowest in the time series (Figure 9). Current stock status was estimated in the base run to be $\mathrm{SSB}_{2017}/\mathrm{MSST} = 2.58$ and $\mathrm{SSB}_{2017}/\mathrm{SSB}_{\mathrm{F40\%}} = 1.94$ (Table 16 and Figure 21), indicating that the stock is not overfished. Uncertainty from the ensemble modeling suggested that the estimate of SSB relative to both $\mathrm{SSB}_{\mathrm{F40\%}}$ and SSB/MSST is robust (Figures 22, 23). More specifically, about 99.7% of ensemble modeling runs indicate the stock is above MSST, while only 0.3% of the models in the ensemble indicated an overfished status. Age structure estimated by the base run showed slightly fewer younger fish in the last decade than the (equilibrium) age structure expected at $L_{\mathrm{F40\%}}$ (Figure 24), however the rest of the age structure is above expected values in the terminal year (2017).

The estimated time series of fishing mortality rate has a slightly increasing trend, though the peak year was 1996 (Figure 13). Current fishery status in the terminal year, with current F represented by the geometric mean from 2015–2017, was estimated by the base run to be $F_{2015-2017}/F_{40\%} = 0.18$ (Table 16 and Figures 22 and 23). The results of the ensemble model are consistent with those results, as only 3.3% of models within the ensemble estimate the stock is undergoing overfishing.

3.9.2 Comparison to previous assessment

When estimates from this assessment are compared to estimates from the SEDAR28 assessment for cobia, a notable difference is the magnitude of the biomass and spawning stock biomass estimates (Figure 41). In this assessment, updated and recalibrated MRIP estimates of general recreational landings and discards were used. Those estimates are several times higher per year than the estimates used in SEDAR28, and are the result of an improvement in the estimation of recreational effort (for details of how the MRIP is an improvement of MRFSS, see https://www.fisheries.noaa.gov/recreational-fishing-data/how-marine-recreational-information-program-has-improved). Regardless of the magnitude of biomass and SSB, the status benchmarks remain on similar scales (Figure 40). The time trends in abundance, recruitment, and relative status are very similar between this assessment and the last as well (e.g. Figures 40 and 41). Natural mortality estimates provided by the Data Workshop were higher than used for SEDAR28. The higher natural mortality (0.97–0.31 in this assessment compared to 0.56–0.24 in SEDAR28) leads the model to estimate a more productive stock. Length and age composition data are fit better using the Dirichlet-multinomial distribution in this assessment (Figures 2 in both reports), as is the headboat index of abundance using the iterative reweighting process.

3.10 Sensitivity and Retrospective Analyses

Sensitivity runs, described in §2.3, were used for exploring data or model issues that arose during the assessment process, for evaluating implications of assumptions in the base assessment model, and for interpreting ensemble model results in terms of expected effects of input parameters (Figures 25–34). Sensitivity runs are a tool for better understanding model behavior, and therefore should not be used as the basis for management. All runs are not considered equally plausible in the sense of alternative states of nature. Time series of $F/F_{40\%}$ and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{F40\%}}$ demonstrate sensitivity to natural mortality (Figure 31) and the SEDAR28 life history inputs (Figure 27). The majority of the runs agreed with the status indicated by the base run (Figure 34, Table 17). Results appeared to be most sensitive to natural mortality.

Retrospective analyses did not suggest any patterns of substantial over- or underestimation in terminal-year estimates starting in 2017 (Figures 35 and 36).

3.11 Projections

Projections based on $F = F_{40\%}$, which is higher than F_{current} drove the stock towards $L_{\mathrm{F40\%}}$ values (Figures 37 and 38, Tables 18 and 19). The $75\% F_{40\%}$ projection was similar to the $F = F_{40\%}$ scenario (Figure 39, Table 20).

4 Discussion

4.1 Comments on the Assessment

Estimated benchmarks played a central role in this assessment; Values of $\mathrm{SSB}_{\mathrm{F}40\%}$ and $F_{40\%}$ were used to gauge the status of the stock and fishery. Computation of benchmarks was conditional on selectivity, and if selectivity patterns change again 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 ($\mathrm{SSB}_{2017}/\mathrm{MSST} = 2.58$), and that overfishing is not occurring ($F_{2015-2017}/F_{40\%} = 0.18$). The ensemble model indicated that the stock status is most likely above MSST with 99.7% of the runs indicating the stock is not overfished. Only about 0.3% of the ensemble model runs indicate that the stock is experiencing overfishing. The decreasing trend for biomass is dependent on what appears to be below average recruitment in the last four years of the assessment. The stock has been declining over the last few years of the assessment, and this decline will likely continue if recruitment remains low.

The recent low recruitment in 2014 did not continue into the terminal year of the assessment. No mechanism for the recent low recruitment has been identified, and periodic low recruitment events are estimated throughout the time series. Input from the stakeholders suggests the recent low recruitment was short lived, which is consistent with modeling results. Multiple years of low recruitment would likely negatively affect the stock status, however monitoring the age compositions into the future will provide the data needed to make that determination.

In addition to more years of data, this benchmark assessment included several modifications to previous data. First, MRIP recalibrated data were used. Next, the SCDNR and MRFSS indices were excluded after the value of all three indices was re-evaluated. All composition data were updated and any needed corrections were made, including the exclusion of commercial age compositions due to non-random sampling.

In general, fishery dependent indices of abundance may not track actual abundance well, because of factors such as hyperstability. Furthermore, this issue can be exacerbated by management measures. In this assessment, fishery dependent indices were not extended beyond 2015, because of the seasonal closures. Such regulations change fisher behavior, thus altering the portion of the population or habitat represented by the logbook data that would be used to create an index of abundance. As such management measures become more common in the southeast U.S., the continued utility of fishery dependent indices in SEDAR stock assessments will be questionable. This situation amplifies the importance of fishery independent sampling.

4.2 Comments on the 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 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. New management regulations that alter those proportions or selectivities would likely affect projection results.

- The projections assumed that the estimated level of recruitment 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, possibly due to environmental or ecological conditions, stock trajectories may be affected. In this assessment, the lowest recruitment occurred in the terminal four years, and if this is not reversed, the stock projections are overly optimistic.
- 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.

4.3 Research Recommendations

- Develop a fishery independent sampling program for abundance of cobia and other coastal migratory species. Fishery dependent abundance indices used in this assessment were uncertain in part due to the lack of an effective sampling methodology.
- Implement a systematic age sampling program for the general recreational sector. Age samples were important in this assessment for identifying strong year classes but sample sizes were relatively small and disparate in time and space.
- Better characterize reproductive parameters including age at maturity, batch fecundity, spawning seasonality, and spawning frequency.
- Age-dependent natural mortality was estimated by indirect methods for this assessment of cobia. Telemetry- and conventional-tag programs for cobia should be maintained as they may prove useful for estimating mortality.
- Better characterize the migratory dynamics of the stock and the degree of fidelity to spawning areas.

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6 Tables

Table 1. Life-history characteristics at age, including average body length and weight (mid-year), proportion females mature, and natural mortality at age. The CV of length was estimated by the assessment model; other values were treated as input.

Age	Total length (mm)	Total length (in)	CV length	Whole wgt (kg)	Whole wgt (lb)	Fem. mat.	prop. fem.	M
1	589.4	23.2	0.12	2.02	4.44	0.0	0.58	0.97
2	768.7	30.3	0.12	4.82	10.62	0.5	0.58	0.65
3	900.2	35.4	0.12	8.09	17.82	1.0	0.58	0.51
4	996.6	39.2	0.12	11.29	24.89	1.0	0.58	0.44
5	1067.4	42.0	0.12	14.14	31.17	1.0	0.58	0.40
6	1119.2	44.1	0.12	16.52	36.42	1.0	0.58	0.37
7	1157.3	45.6	0.12	18.43	40.64	1.0	0.58	0.35
8	1185.2	46.7	0.12	19.93	43.94	1.0	0.58	0.34
9	1205.7	47.5	0.12	21.08	46.48	1.0	0.58	0.33
10	1220.7	48.1	0.12	21.96	48.40	1.0	0.58	0.33
11	1231.7	48.5	0.12	22.61	49.85	1.0	0.58	0.32
12	1239.8	48.8	0.12	23.10	50.93	1.0	0.58	0.32
13	1245.7	49.0	0.12	23.47	51.73	1.0	0.58	0.32
14	1250.0	49.2	0.12	23.74	52.33	1.0	0.58	0.31
15	1253.2	49.3	0.12	23.93	52.77	1.0	0.58	0.31
16	1255.6	49.4	0.12	24.08	53.09	1.0	0.58	0.31

Table 2. Observed time series of landings (L) and discards (D) combined for the commercial (comm) and general recreational (GR) fleets. Landings are in units of 1000 lb whole weight for commercial landings and discards, and in units of 1000 fish for general recreational landings and discards.

Year	LD.comm	LD.GR
1986	25.734	33.608
1987	40.740	24.930
1988	28.588	12.236
1989	33.453	22.420
1990	44.357	18.605
1991	43.816	23.670
1992	35.933	23.900
1993	39.606	15.991
1994	47.118	13.865
1995	67.648	28.148
1996	62.684	94.424
1997	63.618	20.741
1998	43.700	12.650
1999	27.541	27.283
2000	43.652	14.963
2001	42.593	13.445
2002	45.518	18.645
2003	39.367	55.201
2004	37.783	33.440
2005	29.256	59.899
2006	34.953	53.614
2007	32.733	38.877
2008	35.021	30.785
2009	48.003	57.067
2010	58.689	54.608
2011	36.050	36.904
2012	46.204	50.826
2013	54.060	70.214
2014	70.952	59.131
2015	87.942	115.314
2016	92.754	83.032
2017	68.402	50.597

Table 3. Landings (L), Discards (D, l-D represents live discards and d-D represents dead discards), and CVs used in the ensemble model for the commercial (Comm) and general recreational (GR) fleets. Landings and discards from commercial handline (HL) and commercial gillnet (GN) gear are combined into one commercial removals time series.

Year	GR L	Comm L	Comm HL D	Comm GN d-D	Comm GN l-D	GR D	GR L CVs	Comm L CVs	GR D CVs	Comm D CVs
1986	33.152	25.734	0.000	0.000	0.000	9.1120	0.120	0.10	0.00	0.000
1987	24.893	40.740	0.000	0.000	0.000	0.7360	0.010	0.10	0.46	0.000
1988	11.923	28.588	0.000	0.000	0.000	6.2730	0.100	0.10	0.23	0.000
1989	21.732	33.453	0.000	0.000	0.000	13.767	0.210	0.10	0.12	0.000
1990	18.057	44.357	0.000	0.000	0.000	10.958	0.070	0.10	0.16	0.000
1991	21.504	43.816	0.000	0.000	0.000	43.331	0.110	0.10	0.22	0.000
1992	23.164	35.933	0.000	0.000	0.000	14.733	0.190	0.10	0.19	0.000
1993	15.766	39.526	1.605	0.000	0.000	4.4930	0.160	0.05	0.45	3.00
1994	12.256	47.020	1.959	0.000	0.000	32.179	0.170	0.05	0.05	3.00
1995	27.713	67.557	1.814	0.000	0.000	8.7060	0.340	0.05	0.28	3.00
1996	94.123	62.591	1.856	0.000	0.000	6.0250	0.030	0.05	0.34	3.00
1997	18.938	63.522	1.911	0.000	0.000	36.062	0.050	0.05	0.04	3.00
1998	11.241	43.622	1.563	0.000	0.000	28.186	0.340	0.05	0.18	3.00
1999	23.794	27.474	1.346	0.000	0.000	69.798	0.460	0.05	0.19	3.00
2000	13.665	43.580	1.449	0.000	0.000	25.953	0.280	0.05	0.21	3.00
2001	11.672	42.513	1.592	0.000	0.000	35.464	0.340	0.05	0.16	3.00
2002	16.864	44.375	1.417	0.000	1.950	35.623	0.170	0.05	0.11	3.00
2003	51.969	39.310	1.130	0.000	0.000	64.647	0.500	0.05	0.11	3.00
2004	31.635	32.916	1.040	4.815	0.000	36.095	0.110	0.05	0.17	3.00
2005	57.370	28.884	1.051	0.195	0.226	50.579	0.220	0.05	0.09	3.00
2006	50.908	34.708	1.175	0.186	0.000	54.111	0.230	0.05	0.10	3.00
2007	36.360	31.663	1.194	0.000	1.837	50.351	0.070	0.05	0.08	3.00
2008	28.859	33.876	1.186	0.584	0.913	38.513	0.030	0.05	0.05	3.00
2009	52.657	42.423	1.216	2.911	4.742	88.200	0.170	0.05	0.15	3.00
2010	50.607	56.661	1.040	0.999	1.776	80.012	0.140	0.05	0.09	3.00
2011	31.487	34.222	0.882	0.745	1.889	108.35	0.230	0.05	0.09	3.00
2012	46.387	42.811	0.797	0.999	4.280	88.767	0.020	0.05	0.19	3.00
2013	66.204	53.605	0.869	0.000	0.749	80.211	0.230	0.05	0.28	3.00
2014	52.472	70.064	0.839	0.846	0.000	133.19	0.220	0.05	0.10	3.00
2015	110.42	84.901	0.763	0.000	5.460	97.899	0.120	0.05	0.11	3.00
2016	75.779	92.535	0.776	0.000	0.328	145.07	0.040	0.05	0.10	3.00
2017	39.661	68.365	0.738	0.000	0.000	218.73	0.160	0.05	0.23	3.00

Table 4. Observed index of abundance and CVs from headboats (HB).

Year	HB	HB CV
1991	1.02	0.29
1992	0.95	0.29
1993	0.83	0.23
1994	0.72	0.20
1995	1.14	0.23
1996	0.46	0.19
1997	0.64	0.30
1998	0.78	0.24
1999	0.82	0.21
2000	0.77	0.25
2001	0.70	0.29
2002	1.17	0.28
2003	0.88	0.24
2004	0.89	0.23
2005	1.09	0.23
2006	0.86	0.26
2007	1.59	0.34
2008	1.37	0.18
2009	1.08	0.21
2010	1.00	0.34
2011	0.83	0.28
2012	1.09	0.25
2013	2.04	0.26
2014	1.23	0.21
2015	1.04	0.23
2016	.	.
2017	.	.

Table 5. Sample sizes (number of fish) of length compositions (len) or age compositions (age) by fleet. Data sources are commercial lines (comm) and general recreational (GR).

Year	len.comm	age.GR
1986	.	22
1987	.	18
1988	.	.
1989	.	62
1990	.	80
1991	.	13
1992	.	12
1993	.	.
1994	.	.
1995	.	10
1996	.	31
1997	.	13
1998	.	.
1999	1449	124
2000	.	111
2001	.	52
2002	.	26
2003	.	.
2004	.	.
2005	.	57
2006	.	63
2007	.	203
2008	.	225
2009	.	265
2010	.	293
2011	.	246
2012	.	269
2013	.	445
2014	.	487
2015	.	484
2016	.	386
2017	.	273

Table 6. Estimated total abundance at age (1000 fish) at start of year.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1986	1325.98	307.11	198.34	99.58	141.86	111.43	28.29	31.10	24.90	11.59	9.15	7.20	5.58	4.28	3.27	7.30	2316.96
1987	1591.40	502.45	159.92	117.51	61.15	87.61	70.16	18.14	20.13	16.28	7.58	6.05	4.75	3.69	2.85	7.05	2676.73
1988	2580.01	603.04	261.68	94.87	72.59	38.18	55.87	45.57	11.89	13.34	10.78	5.07	4.04	3.18	2.49	6.69	3809.29
1989	1216.10	977.83	314.40	156.10	59.75	46.86	25.28	37.71	31.06	8.19	9.18	7.50	3.52	2.81	2.23	6.45	2904.98
1990	1611.97	460.84	509.38	186.70	96.73	37.50	30.05	16.52	24.87	20.69	5.46	6.18	5.05	2.37	1.91	5.90	3022.12
1991	2117.04	610.89	240.16	303.17	116.72	61.66	24.48	19.99	11.09	16.87	14.04	3.74	4.23	3.46	1.64	5.41	3554.59
1992	883.41	802.28	318.31	142.81	188.88	73.95	39.97	16.17	13.33	7.47	11.37	9.55	2.54	2.88	2.38	4.85	2520.14
1993	676.16	334.79	418.07	189.35	89.04	119.82	48.00	26.43	10.80	8.99	5.04	7.74	6.51	1.73	1.98	4.97	1949.43
1994	1967.37	256.27	174.54	249.36	119.25	57.48	79.32	32.39	18.01	7.43	6.19	3.50	5.38	4.52	1.22	4.88	2987.13
1995	846.57	745.64	133.61	104.16	157.44	77.34	38.26	53.83	22.20	12.47	5.14	4.33	2.45	3.76	3.20	4.31	2214.71
1996	2126.31	320.78	388.27	79.21	64.31	98.31	49.33	24.85	35.31	14.71	8.26	3.44	2.90	1.64	2.54	5.07	3225.25
1997	681.65	804.96	166.08	222.92	43.47	32.72	49.72	25.28	12.85	18.44	7.68	4.36	1.82	1.53	0.87	4.06	2078.42
1998	1232.22	258.30	419.17	98.49	137.86	27.23	20.94	32.41	16.64	8.55	12.26	5.16	2.93	1.22	1.04	3.34	2277.75
1999	2775.09	467.00	134.64	249.85	61.94	88.82	17.99	14.10	22.04	11.43	5.87	8.51	3.58	2.03	0.85	3.07	3866.82
2000	2081.51	1051.58	243.21	79.82	153.86	38.45	56.25	11.60	9.18	14.50	7.52	3.90	5.65	2.38	1.36	2.63	3763.39
2001	1268.42	788.85	548.09	144.88	50.08	98.72	25.28	37.70	7.85	6.28	9.91	5.19	2.69	3.90	1.66	2.79	3002.30
2002	1490.75	480.73	411.26	326.90	91.26	32.35	65.40	17.07	25.71	5.41	4.32	6.90	3.61	1.87	2.74	3.12	2969.41
2003	2906.73	564.98	250.58	245.04	205.15	58.56	21.27	43.83	11.56	17.57	3.70	2.99	4.76	2.49	1.31	4.09	4344.60
2004	517.92	1101.26	293.90	147.61	147.42	122.31	35.43	13.09	27.24	7.25	11.03	2.34	1.89	3.02	1.60	3.46	2436.76
2005	3248.90	196.26	573.54	174.28	90.99	91.67	77.62	22.90	8.54	17.95	4.78	7.34	1.56	1.26	2.03	3.40	4523.02
2006	2085.47	1230.80	102.05	336.99	103.79	53.28	54.35	46.79	13.94	5.25	11.03	2.97	4.56	0.97	0.79	3.40	4056.43
2007	1459.89	790.11	640.24	60.10	202.55	61.77	32.17	33.38	29.02	8.73	3.29	6.98	1.88	2.88	0.62	2.68	3336.28
2008	2439.09	553.38	411.85	373.02	36.26	126.91	39.88	21.19	22.21	19.50	5.87	2.23	4.74	1.27	1.98	2.26	4061.62
2009	1466.50	924.56	288.56	242.10	229.45	23.18	83.60	26.80	14.38	15.23	13.37	4.06	1.55	3.28	0.89	2.96	3340.46
2010	1475.54	555.87	481.65	166.22	142.48	140.15	14.59	53.68	17.38	9.42	9.97	8.84	2.69	1.02	2.19	2.58	3084.27
2011	4715.81	559.29	289.57	277.75	98.07	87.26	88.44	9.39	34.90	11.41	6.19	6.62	5.87	1.78	0.69	3.20	6196.22
2012	2287.82	1787.55	291.56	169.11	168.40	61.77	56.63	58.56	6.28	23.58	7.71	4.22	4.51	4.00	1.23	2.67	4935.60
2013	2778.18	867.18	931.29	168.12	99.74	103.10	38.97	36.45	38.06	4.12	15.48	5.11	2.80	2.99	2.68	2.61	5096.90
2014	448.71	1053.05	451.73	535.49	98.55	60.68	64.63	24.92	23.54	24.83	2.69	10.20	3.37	1.84	1.99	3.52	2809.76
2015	1659.67	170.08	548.76	262.49	321.25	61.40	38.95	42.32	16.48	15.73	16.59	1.82	6.88	2.27	1.26	3.76	3169.71
2016	1237.97	629.05	88.49	308.30	146.32	185.56	36.54	23.65	25.96	10.21	9.74	10.38	1.14	4.31	1.44	3.17	2722.22
2017	1795.71	469.21	327.33	49.98	173.94	85.57	111.81	22.46	14.68	16.28	6.40	6.17	6.58	0.72	2.76	2.95	3092.56
2018	1795.71	680.62	244.34	187.79	29.17	105.33	53.39	71.17	14.44	9.54	10.57	4.20	4.05	4.31	0.48	3.78	3218.90

Table 7. Estimated biomass at age (1000 lb) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
1986	5892.5	3261.1	3535.3	2478.4	4421.2	4057.8	1149.5	1366.4	1157.2	560.9	456.4	366.6	288.8	223.8	172.6	387.8	29776.3
1987	7072.0	5335.4	2850.6	2924.7	1905.7	3190.5	2851.2	797.0	935.9	788.2	377.7	308.0	245.8	192.9	150.6	374.6	30300.3
1988	11465.1	6403.3	4664.3	2361.2	2262.2	1390.5	2270.1	2002.2	552.9	645.5	537.5	258.2	209.2	166.4	131.4	355.4	35675.7
1989	5404.2	10383.1	5603.9	3885.0	1862.2	1706.6	1027.4	1656.8	1443.6	396.4	457.7	381.8	182.3	147.3	117.9	342.6	34999.1
1990	7163.3	4893.6	9079.5	4646.7	3014.6	1365.8	1221.4	725.8	1156.1	1001.6	272.1	314.6	261.0	124.1	101.0	313.5	35653.8
1991	9407.8	6486.9	4280.7	7545.5	3637.6	2245.4	994.7	878.3	515.7	816.8	699.7	190.5	218.9	181.0	86.6	287.3	38473.1
1992	3925.8	8519.1	5673.6	3554.3	5886.6	2692.9	1624.1	710.3	619.7	361.8	566.6	486.6	131.6	150.8	125.4	257.3	35286.1
1993	3004.7	3555.0	7451.8	4712.6	2775.2	4363.2	1950.7	1161.4	501.8	435.2	251.3	394.4	336.6	90.6	104.5	263.9	31353.0
1994	8742.7	2721.2	3111.2	6206.2	3716.6	2093.3	3223.4	1423.3	837.3	359.8	308.6	178.6	278.4	236.8	64.2	259.3	33760.5
1995	3762.0	7917.7	2381.4	2592.4	4906.8	2816.6	1554.9	2365.1	1031.8	603.6	256.4	220.5	126.8	196.9	168.7	228.6	31130.2
1996	9449.0	3406.4	6920.8	1971.6	2004.4	3580.1	2004.4	1092.2	1641.1	711.9	411.8	175.3	149.9	85.8	134.3	269.2	34007.6
1997	3029.2	8547.5	2960.4	5548.2	1354.7	1191.6	2020.5	1110.9	597.5	892.7	382.9	222.0	93.9	80.0	46.1	215.4	28293.5
1998	5475.8	2742.8	7471.5	2451.3	4296.6	991.4	851.0	1424.2	773.6	413.6	611.1	262.8	151.5	63.7	54.7	177.5	28213.0
1999	12332.0	4958.9	2400.0	6218.4	1930.6	3234.6	730.8	619.5	1024.5	553.4	292.6	433.2	185.2	106.3	45.2	162.9	35228.1
2000	9249.9	11166.4	4335.0	1986.6	4795.1	1400.2	2285.8	509.7	426.8	701.7	374.8	198.6	292.3	124.3	71.9	139.8	38059.1
2001	5636.8	8376.5	9769.3	3605.9	1560.9	3594.9	1027.4	1656.6	364.9	303.8	494.1	264.3	139.3	204.1	87.5	147.9	37234.3
2002	6624.7	5104.6	7330.4	8135.9	2844.4	1177.9	2657.7	750.2	1194.9	261.7	215.6	351.2	187.0	98.1	144.6	165.8	37244.7
2003	12917.1	5999.2	4466.3	6098.6	6393.6	2132.5	864.4	1926.0	537.0	850.8	184.3	152.1	246.3	130.5	69.0	217.2	43185.0
2004	2301.6	11693.8	5238.6	3673.8	4594.4	4453.8	1439.8	575.4	1265.9	351.0	549.8	119.3	97.9	157.9	84.2	183.4	36781.0
2005	14437.6	2084.0	10223.1	4337.6	2835.8	3338.5	3154.2	1006.2	397.1	869.1	238.3	373.9	80.7	65.9	107.1	180.3	43729.1
2006	9267.6	13069.4	1819.0	8387.3	3234.6	1940.3	2208.4	2056.0	647.7	254.2	550.1	151.2	235.9	50.7	41.7	180.6	44094.4
2007	6487.5	8389.9	11411.8	1495.8	6312.5	2249.4	1307.3	1466.7	1348.6	422.4	164.0	355.6	97.2	151.0	32.6	142.2	41834.7
2008	10839.0	5876.2	7341.0	9283.9	1129.9	4621.6	1620.4	931.0	1032.2	943.8	292.3	113.8	245.2	66.6	104.3	119.9	44561.2
2009	6516.9	9817.4	5143.4	6025.7	7150.9	843.9	3397.1	1177.5	668.4	737.0	666.5	206.8	80.0	171.7	47.0	157.4	42807.8
2010	6557.0	5902.4	8585.2	4137.0	4440.6	5103.7	592.8	2358.5	807.8	456.1	497.1	450.4	139.1	53.6	115.7	136.7	40333.6
2011	20956.5	5938.8	5161.5	6912.6	3056.5	3177.5	3593.8	412.7	1622.2	552.5	308.4	336.9	303.6	93.3	36.2	169.5	52632.5
2012	10166.6	18981.4	5196.7	4208.8	5248.3	2249.6	2301.4	2573.0	291.9	1141.1	384.3	215.0	233.5	209.4	64.8	142.0	53608.3
2013	12345.9	9208.3	16599.7	4184.2	3108.5	3754.5	1583.6	1601.4	1769.2	199.5	771.6	260.4	144.8	156.7	141.5	138.9	55968.8
2014	1994.1	11181.8	8051.9	13327.6	3071.5	2209.7	2626.1	1095.0	1094.2	1202.0	134.0	519.4	174.4	96.6	105.2	187.2	47070.7
2015	7375.3	1806.0	9781.3	6533.0	10011.9	2235.9	1582.9	1859.6	766.1	761.3	827.2	92.4	356.0	119.0	66.4	199.7	44374.0
2016	5501.4	6679.6	1577.4	7673.0	4560.3	6757.4	1484.8	1039.3	1206.4	494.3	485.7	528.7	58.9	225.3	75.8	168.4	38516.3
2017	7979.9	4982.2	5834.5	1244.1	5421.2	3116.2	4543.3	987.0	682.6	787.9	319.2	314.4	340.2	37.7	145.3	156.5	36891.9
2018	7979.9	7227.2	4355.2	4673.8	909.2	3835.8	2169.6	3127.0	671.1	461.4	526.9	213.8	209.4	225.8	25.1	200.6	36812.4

Table 8. Estimated time series and status indicators. Fishing mortality rate is apical F*. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB mature female biomass, and SSBknum in 1000s of mature females) at the time of peak spawning (end of March). The* $MSST_{\mathrm{F40}}$ *is defined by* $\mathrm{MSST} = 0.75SSB_{\mathrm{F40}}$*. Prop.fem is proportion of age-*2^{+} *population that is female.*

Year	F	F/F_{40}	B	B/B_{unfished}	SSB	SSBknum	$SSB/SSBB_{\mathrm{F40}}$	$SSB/MSST_{\mathrm{F40}}$	Prop.fem
1986	0.0949	0.1368	13506	0.665	5952	393	1.70	2.26	0.58
1987	0.0820	0.1182	13744	0.677	5345	380	1.52	2.03	0.58
1988	0.0433	0.0624	16182	0.797	5503	424	1.57	2.09	0.58
1989	0.0761	0.1098	15875	0.782	6302	541	1.80	2.40	0.58
1990	0.0580	0.0836	16172	0.796	6795	540	1.94	2.58	0.58
1991	0.0651	0.0939	17451	0.859	6731	517	1.92	2.56	0.58
1992	0.0637	0.0919	16006	0.788	7048	562	2.01	2.68	0.58
1993	0.0435	0.0627	14222	0.700	6989	511	1.99	2.66	0.58
1994	0.0379	0.0547	15313	0.754	6263	416	1.79	2.38	0.58
1995	0.0818	0.1179	14120	0.695	6069	451	1.73	2.31	0.58
1996	0.3196	0.4609	15426	0.759	5569	411	1.59	2.12	0.58
1997	0.0782	0.1128	12834	0.632	5427	449	1.55	2.06	0.58
1998	0.0456	0.0657	12797	0.630	5607	423	1.60	2.13	0.58
1999	0.0890	0.1284	15979	0.787	5296	391	1.51	2.01	0.58
2000	0.0504	0.0727	17263	0.850	6026	521	1.72	2.29	0.58
2001	0.0428	0.0617	16889	0.832	7143	610	2.04	2.72	0.58
2002	0.0504	0.0727	16894	0.832	7349	569	2.10	2.79	0.58
2003	0.1358	0.1959	19588	0.964	6978	522	1.99	2.65	0.58
2004	0.0869	0.1253	16684	0.821	7381	616	2.10	2.81	0.58
2005	0.1567	0.2260	19835	0.977	7220	533	2.06	2.74	0.58
2006	0.1379	0.1989	20001	0.985	7198	604	2.05	2.74	0.58
2007	0.0676	0.0974	18976	0.934	8043	670	2.29	3.06	0.58
2008	0.0475	0.0685	20213	0.995	8031	616	2.29	3.05	0.58
2009	0.0931	0.1342	19417	0.956	8045	634	2.29	3.06	0.58
2010	0.0904	0.1304	18295	0.901	7932	602	2.26	3.02	0.58
2011	0.0623	0.0898	23874	1.175	7468	548	2.13	2.84	0.58
2012	0.0907	0.1308	24316	1.197	8657	780	2.47	3.29	0.58
2013	0.0971	0.1400	25387	1.250	9978	847	2.84	3.79	0.58
2014	0.0733	0.1057	21351	1.051	10171	828	2.90	3.87	0.58
2015	0.1490	0.2149	20128	0.991	9111	638	2.60	3.46	0.58
2016	0.1366	0.1970	17471	0.860	7515	523	2.14	2.86	0.58
2017	0.1017	0.1467	16734	0.824	6795	481	1.94	2.58	0.58
2018	.	.	16698	0.822	.	.	.	.	0.58

Table 9. Selectivity at age for the commercial fleet (comm), general recreational fleet (GR), and landings averaged across fisheries (L.avg). TL is total length. For time-varying selectivities, values shown are from the terminal assessment year.

Age	TL(mm)	TL(in)	comm	GR	L.avg
1	589.4	23.2	0.029	0.000	0.001
2	768.7	30.3	0.171	0.019	0.023
3	900.2	35.4	0.583	0.444	0.448
4	996.6	39.2	0.904	0.971	0.969
5	1067.4	42.0	0.985	0.999	0.999
6	1119.2	44.1	0.998	1.000	1.000
7	1157.3	45.6	1.000	1.000	1.000
8	1185.2	46.7	1.000	1.000	1.000
9	1205.7	47.5	1.000	1.000	1.000
10	1220.7	48.1	1.000	1.000	1.000
11	1231.7	48.5	1.000	1.000	1.000
12	1239.8	48.8	1.000	1.000	1.000
13	1245.7	49.0	1.000	1.000	1.000
14	1250.0	49.2	1.000	1.000	1.000
15	1253.2	49.3	1.000	1.000	1.000
16	1255.6	49.4	1.000	1.000	1.000

Table 10. Estimated time series of fully selected fishing mortality rates for the commercial fleet (F.comm) and the general recreational fleet (F.GR). Also shown is apical F, the maximum F at age summed across fleets.

Year	F.comm	F.GR	Apical F
1986	0.002	0.093	0.095
1987	0.003	0.079	0.082
1988	0.002	0.041	0.043
1989	0.002	0.074	0.076
1990	0.002	0.056	0.058
1991	0.002	0.063	0.065
1992	0.002	0.062	0.064
1993	0.002	0.041	0.043
1994	0.003	0.035	0.038
1995	0.004	0.078	0.082
1996	0.004	0.316	0.320
1997	0.004	0.074	0.078
1998	0.003	0.043	0.046
1999	0.002	0.087	0.089
2000	0.003	0.048	0.050
2001	0.002	0.040	0.043
2002	0.002	0.048	0.050
2003	0.002	0.134	0.136
2004	0.002	0.085	0.087
2005	0.001	0.155	0.157
2006	0.002	0.136	0.138
2007	0.002	0.066	0.068
2008	0.002	0.046	0.047
2009	0.002	0.091	0.093
2010	0.003	0.088	0.090
2011	0.002	0.061	0.062
2012	0.002	0.089	0.091
2013	0.002	0.095	0.097
2014	0.003	0.071	0.073
2015	0.003	0.146	0.149
2016	0.004	0.132	0.137
2017	0.004	0.098	0.102
2018	.	.	.

Table 11. Estimated instantaneous fishing mortality rate (per yr) at age

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1986	0.000	0.003	0.013	0.048	0.082	0.093	0.094	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095
1987	0.000	0.002	0.012	0.042	0.071	0.080	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
1988	0.000	0.001	0.007	0.022	0.038	0.042	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
1989	0.000	0.002	0.011	0.039	0.066	0.074	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076
1990	0.000	0.002	0.009	0.030	0.050	0.057	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
1991	0.000	0.002	0.010	0.033	0.056	0.064	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
1992	0.000	0.002	0.009	0.032	0.055	0.062	0.063	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064
1993	0.000	0.001	0.007	0.022	0.038	0.042	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
1994	0.000	0.001	0.006	0.020	0.033	0.037	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
1995	0.000	0.003	0.013	0.042	0.071	0.080	0.081	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
1996	0.001	0.008	0.045	0.160	0.276	0.312	0.318	0.319	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320
1997	0.000	0.003	0.012	0.041	0.068	0.076	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078
1998	0.000	0.002	0.007	0.024	0.040	0.045	0.045	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046
1999	0.000	0.002	0.013	0.045	0.077	0.087	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089
2000	0.000	0.002	0.008	0.026	0.044	0.049	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
2001	0.000	0.001	0.007	0.022	0.037	0.042	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
2002	0.000	0.002	0.008	0.026	0.044	0.049	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
2003	0.001	0.004	0.019	0.068	0.117	0.132	0.135	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136	0.136
2004	0.000	0.002	0.013	0.044	0.075	0.085	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087
2005	0.001	0.004	0.022	0.078	0.135	0.153	0.156	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157
2006	0.001	0.004	0.019	0.069	0.119	0.134	0.137	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
2007	0.000	0.002	0.030	0.065	0.067	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
2008	0.000	0.001	0.021	0.046	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
2009	0.000	0.002	0.042	0.090	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093
2010	0.000	0.002	0.041	0.088	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090
2011	0.000	0.001	0.028	0.060	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
2012	0.000	0.002	0.041	0.088	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
2013	0.000	0.002	0.043	0.094	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097	0.097
2014	0.000	0.002	0.033	0.071	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073
2015	0.000	0.003	0.067	0.144	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149	0.149
2016	0.000	0.003	0.061	0.132	0.136	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137	0.137
2017	0.000	0.002	0.046	0.099	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102

Table 12. Estimated total landings at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1986	0.35	0.57	2.08	3.76	9.22	8.26	2.16	2.39	1.92	0.90	0.71	0.56	0.43	0.33	0.26	0.57
1987	0.39	0.87	1.52	3.89	3.46	5.64	4.65	1.21	1.35	1.09	0.51	0.41	0.32	0.25	0.19	0.48
1988	0.36	0.58	1.36	1.69	2.21	1.32	1.99	1.64	0.43	0.48	0.39	0.18	0.15	0.12	0.09	0.24
1989	0.27	1.53	2.74	4.79	3.14	2.81	1.56	2.35	1.94	0.51	0.58	0.47	0.22	0.18	0.14	0.41
1990	0.30	0.59	3.54	4.43	3.91	1.73	1.43	0.79	1.20	0.99	0.26	0.30	0.24	0.12	0.09	0.29
1991	0.42	0.85	1.84	8.02	5.28	3.18	1.30	1.07	0.60	0.91	0.76	0.20	0.23	0.19	0.09	0.29
1992	0.17	1.07	2.34	3.68	8.37	3.73	2.08	0.85	0.70	0.39	0.60	0.51	0.13	0.15	0.13	0.26
1993	0.10	0.33	2.21	3.39	2.72	4.16	1.72	0.95	0.39	0.33	0.18	0.28	0.24	0.06	0.07	0.18
1994	0.27	0.24	0.85	3.96	3.19	1.75	2.48	1.02	0.57	0.24	0.20	0.11	0.17	0.14	0.04	0.16
1995	0.23	1.39	1.33	3.48	8.90	4.97	2.53	3.59	1.49	0.84	0.35	0.29	0.16	0.25	0.22	0.29
1996	1.83	1.95	13.38	9.54	12.89	22.22	11.45	5.81	8.30	3.46	1.95	0.81	0.68	0.39	0.60	1.20
1997	0.18	1.49	1.61	7.18	2.36	2.02	3.15	1.62	0.83	1.18	0.50	0.28	0.12	0.10	0.06	0.26
1998	0.20	0.29	2.42	1.87	4.42	0.99	0.79	1.23	0.63	0.32	0.47	0.20	0.11	0.05	0.04	0.13
1999	0.70	0.82	1.34	8.88	3.79	6.19	1.29	1.02	1.60	0.83	0.43	0.62	0.26	0.15	0.06	0.23
2000	0.35	1.25	1.52	1.66	5.43	1.55	2.33	0.48	0.38	0.61	0.32	0.16	0.24	0.10	0.06	0.11
2001	0.18	0.79	2.91	2.57	1.51	3.38	0.89	1.34	0.28	0.22	0.36	0.19	0.10	0.14	0.06	0.10
2002	0.24	0.54	2.50	6.77	3.22	1.30	2.71	0.71	1.08	0.23	0.18	0.29	0.15	0.08	0.12	0.13
2003	1.08	1.48	3.73	13.09	18.77	6.10	2.28	4.73	1.25	1.91	0.40	0.33	0.52	0.27	0.14	0.45
2004	0.13	1.92	2.88	5.13	8.81	8.33	2.48	0.93	1.93	0.52	0.79	0.17	0.14	0.22	0.11	0.25
2005	1.35	0.57	9.69	10.65	9.52	10.91	9.51	2.83	1.06	2.23	0.60	0.92	0.19	0.16	0.25	0.43
2006	0.78	3.23	1.54	18.25	9.63	5.63	5.91	5.13	1.53	0.58	1.22	0.33	0.50	0.11	0.09	0.38
2007	0.07	0.88	14.94	3.09	10.92	3.38	1.78	1.85	1.62	0.49	0.18	0.39	0.11	0.16	0.03	0.15
2008	0.10	0.46	6.80	13.58	1.39	4.92	1.56	0.83	0.88	0.77	0.23	0.09	0.19	0.05	0.08	0.09
2009	0.10	1.42	9.23	16.94	16.84	1.73	6.28	2.02	1.09	1.16	1.02	0.31	0.12	0.25	0.07	0.23
2010	0.11	0.87	15.01	11.31	10.17	10.16	1.07	3.94	1.28	0.70	0.74	0.66	0.20	0.08	0.16	0.19
2011	0.23	0.59	6.24	13.19	4.89	4.41	4.51	0.48	1.80	0.59	0.32	0.34	0.30	0.09	0.04	0.17
2012	0.15	2.67	9.09	11.55	12.06	4.49	4.16	4.32	0.47	1.75	0.57	0.31	0.34	0.30	0.09	0.20
2013	0.19	1.38	31.03	12.26	7.62	8.00	3.05	2.87	3.01	0.33	1.23	0.41	0.22	0.24	0.21	0.21
2014	0.03	1.38	11.47	29.76	5.75	3.59	3.86	1.50	1.42	1.50	0.16	0.62	0.20	0.11	0.12	0.21
2015	0.18	0.42	27.77	28.70	36.79	7.14	4.57	4.99	1.95	1.86	1.97	0.22	0.82	0.27	0.15	0.45
2016	0.15	1.49	4.13	31.06	15.45	19.89	3.95	2.57	2.83	1.11	1.07	1.14	0.12	0.47	0.16	0.35
2017	0.17	0.85	11.46	3.81	13.90	6.94	9.15	1.85	1.21	1.34	0.53	0.51	0.55	0.06	0.23	0.25

Table 13. Estimated total landings at age in whole weight (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1986	3.14	8.67	45.38	105.11	308.75	315.58	91.02	108.58	92.40	44.87	36.78	29.65	23.44	18.30	14.15	31.87
1987	3.58	13.36	33.26	108.91	115.87	215.77	196.28	55.06	64.96	54.81	26.47	21.65	17.35	13.72	10.73	26.76
1988	3.24	8.93	29.74	47.24	73.87	50.54	84.01	74.36	20.63	24.14	20.25	9.76	7.94	6.36	5.04	13.66
1989	2.46	23.45	59.72	133.94	105.32	107.46	65.86	106.59	93.33	25.68	29.87	25.01	11.98	9.74	7.83	22.80
1990	2.69	9.08	77.17	124.01	131.09	66.07	60.15	35.87	57.41	49.84	13.64	15.83	13.18	6.31	5.14	16.03
1991	3.84	13.09	40.05	224.51	176.88	121.51	54.80	48.56	28.65	45.46	39.25	10.71	12.37	10.30	4.94	16.43
1992	1.52	16.34	51.08	103.11	280.20	142.77	87.67	38.48	33.73	19.73	31.14	26.82	7.28	8.40	7.01	14.42
1993	0.87	5.06	48.18	94.92	91.00	159.20	72.45	43.30	18.80	16.34	9.50	14.97	12.82	3.48	4.02	10.18
1994	2.42	3.70	18.54	110.85	106.82	66.81	104.71	46.40	27.43	11.81	10.21	5.92	9.27	7.94	2.16	8.74
1995	2.06	21.36	29.02	97.48	298.21	190.05	106.76	162.97	71.44	41.87	17.93	15.46	8.92	13.97	11.99	16.30
1996	16.64	29.85	291.89	266.89	431.78	849.34	482.99	263.95	398.46	173.18	100.93	43.11	36.96	21.33	33.46	67.26
1997	1.64	22.81	35.23	200.90	78.97	77.07	132.98	73.37	39.65	59.35	25.65	14.92	6.34	5.43	3.14	14.72
1998	1.79	4.40	52.90	52.40	148.00	37.93	33.13	55.65	30.37	16.27	24.23	10.45	6.04	2.57	2.20	7.18
1999	6.32	12.64	29.27	248.55	126.86	236.67	54.45	46.32	76.96	41.65	22.19	32.96	14.13	8.17	3.48	12.60
2000	3.21	19.08	33.17	46.60	182.03	59.07	98.16	21.96	18.48	30.45	16.39	8.71	12.86	5.52	3.20	6.23
2001	1.66	12.14	63.45	71.91	50.45	129.19	37.58	60.81	13.46	11.23	18.40	9.88	5.22	7.71	3.31	5.62
2002	2.19	8.34	54.58	189.42	107.86	49.70	114.15	32.34	51.76	11.36	9.43	15.41	8.23	4.35	6.44	7.39
2003	9.78	22.61	81.46	366.36	628.84	233.12	96.16	214.98	60.24	95.60	20.87	17.27	28.07	14.99	7.94	25.07
2004	1.17	29.42	62.78	143.63	294.99	318.37	104.78	42.02	92.90	25.81	40.74	8.87	7.30	11.87	6.35	13.86
2005	12.22	8.80	211.40	298.06	319.02	417.20	401.07	128.38	50.92	111.62	30.84	48.56	10.51	8.66	14.10	23.80
2006	7.05	49.57	33.51	510.63	322.66	215.12	249.18	232.79	73.69	28.98	63.17	17.42	27.27	5.90	4.87	21.16
2007	0.65	13.50	326.08	86.44	365.75	129.20	74.95	84.12	77.68	24.38	9.53	20.74	5.68	8.90	1.93	8.43
2008	0.95	7.08	148.41	380.06	46.42	188.25	65.88	37.87	42.17	38.62	12.06	4.70	10.17	2.79	4.38	5.05
2009	0.90	21.77	201.38	474.19	564.01	65.99	265.07	91.92	52.41	57.88	52.74	16.42	6.37	13.78	3.79	12.70
2010	1.03	13.27	327.50	316.64	340.77	388.28	45.01	179.14	61.62	34.85	38.29	34.80	10.78	4.18	9.06	10.74
2011	2.11	9.02	136.26	369.05	163.66	168.67	190.40	21.87	86.35	29.47	16.58	18.17	16.42	5.09	1.98	9.30
2012	1.35	40.89	198.45	323.30	404.06	171.67	175.28	196.04	22.34	87.49	29.69	16.66	18.16	16.41	5.09	11.18
2013	1.71	21.08	677.22	342.98	255.34	305.70	128.68	130.18	144.44	16.32	63.59	21.53	12.02	13.10	11.86	11.66
2014	0.28	21.10	250.25	832.83	192.54	137.34	162.92	67.95	68.20	75.06	8.44	32.79	11.04	6.16	6.73	12.01
2015	1.61	6.38	606.12	803.14	1232.42	272.77	192.71	226.49	93.71	93.29	102.11	11.45	44.25	14.90	8.33	25.14
2016	1.33	22.83	90.08	869.36	517.66	760.33	166.73	116.73	136.09	55.86	55.30	60.40	6.73	26.03	8.78	19.55
2017	1.56	13.02	250.19	106.55	465.55	265.30	386.05	83.89	58.26	67.38	27.51	27.17	29.50	3.29	12.74	13.75

Table 14. Estimated time series of landings in numbers (1000 fish) for the commercial fleet (L.comm) and general recreational (L.GR))

Year	L.comm	L.GR	Total
1986	0.80	33.65	34.45
1987	1.31	24.95	26.26
1988	0.99	12.24	13.23
1989	1.20	22.44	23.64
1990	1.59	18.62	20.20
1991	1.54	23.69	25.23
1992	1.24	23.92	25.16
1993	1.32	16.00	17.32
1994	1.52	13.87	15.39
1995	2.17	28.15	30.32
1996	2.14	94.32	96.46
1997	2.21	20.71	22.93
1998	1.51	12.64	14.15
1999	0.96	27.25	28.21
2000	1.59	14.96	16.56
2001	1.57	13.45	15.01
2002	1.61	18.64	20.25
2003	1.37	55.16	56.54
2004	1.31	33.41	34.72
2005	1.04	59.82	60.86
2006	1.25	53.57	54.83
2007	1.19	38.86	40.04
2008	1.24	30.79	32.03
2009	1.66	57.15	58.80
2010	2.01	54.64	56.65
2011	1.27	36.92	38.19
2012	1.70	50.81	52.52
2013	2.03	70.21	72.24
2014	2.51	59.18	61.68
2015	2.94	115.30	118.24
2016	2.96	83.00	85.96
2017	2.22	50.60	52.81
.	.	.	.

Table 15. Estimated time series of landings in whole weight (1000 lb) for the commercial fleet (L.comm) and general recreational (L.GR).

Year	L.comm	L.GR	Total
1986	25.74	1251.95	1277.69
1987	40.75	937.80	978.55
1988	28.59	451.12	479.71
1989	33.46	797.59	831.05
1990	44.36	639.15	683.51
1991	43.82	807.53	851.35
1992	35.94	833.76	869.70
1993	39.61	565.48	605.09
1994	47.12	496.62	543.74
1995	67.65	1038.15	1105.79
1996	62.68	3445.34	3508.02
1997	63.61	728.56	792.17
1998	43.70	441.79	485.49
1999	27.54	945.68	973.22
2000	43.65	521.47	565.12
2001	42.59	459.45	502.04
2002	45.52	627.41	672.93
2003	39.37	1883.99	1923.36
2004	37.78	1167.08	1204.86
2005	29.26	2065.92	2095.17
2006	34.95	1828.02	1862.97
2007	32.73	1205.26	1237.99
2008	35.02	959.83	994.86
2009	48.00	1853.31	1901.31
2010	58.69	1757.28	1815.97
2011	36.05	1208.33	1244.38
2012	46.20	1671.88	1718.09
2013	54.06	2103.35	2157.41
2014	70.95	1814.68	1885.63
2015	87.94	3646.88	3734.82
2016	92.75	2821.04	2913.80
2017	68.40	1743.32	1811.72
.	.	.	.

Table 16. Estimated status indicators, benchmarks, and related quantities from the base run of the Beaufort Assessment Model, conditional on estimated current selectivities averaged across fleets. Median values and standard deviations (SD) approximated from the ensemble model are also provided. Rate estimates (F) are in units of y^{-1}*; status indicators are dimensionless; and biomass estimates are whole weight in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured as mature female biomass.*

Quantity	Units	Estimate	Median	SD
$F_{40\%}$	y^{-1}	0.69	0.65	0.19
$B_{\mathrm{F40\%}}$	mt	12523	11028	9140
$\mathrm{SSB}_{\mathrm{F40\%}}$	mt	3507	3199	1872
MSST	mt	2631	2658	1007
$L_{\mathrm{F40\%}}$	1000 lb	4617	4010	3428
$Lknum_{\mathrm{F40\%}}$	1000 fish	176.461	151	141
$R_{\mathrm{F40\%}}$	1000 age-1 fish	1781121	1525734	1688
$F_{2015-2017}/F_{40\%}$	—	0.18	0.24	0.28
$\mathrm{SSB}_{2017}/\mathrm{MSST}$	—	2.58	2.41	0.51
$\mathrm{SSB}_{2017}/\mathrm{SSB}_{\mathrm{F40\%}}$	—	1.94	1.81	0.38

Table 17. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last two assessment years.

Run	Description	$F_{40\%}$	$\mathrm{SSB}_{\mathrm{F40\%}}$ (mt)	LFforty(1000 lb)	LFforty(1000s)	$\mathrm{F}_{\mathrm{current}}/f_{40\%}$	$\mathrm{SSB}_{2017}/\mathrm{SSB}_{\mathrm{F40\%}}$	R0(1000)
Base	—	0.693	3507.39	4617	176	0.18	1.94	1559
S1	early start year	0.696	3387.54	4460	170	0.19	1.91	1450
S2	Include length comps	0.714	2951.28	3886	149	0.22	1.88	1220
S3	S28 LH values all	0.319	1846.34	1967	61	0.92	1.21	326
S4	S28 l-w	0.695	4213.39	5546	175	0.18	1.95	1552
S5	S28 + time of spawn	0.725	3717.09	4868	154	0.27	1.46	1353
S6	S28 and sex ratio	0.724	3694.84	5613	178	0.18	1.95	1552
S7	S28 and growth	0.627	3009.4	4491	168	0.2	1.97	1591
S8	S28 and M	0.341	1899.46	2004	63	0.86	1.24	326
S9	Remove index	0.707	3339.82	4397	168	0.23	1.63	1491
S10	smooth MRIP peaks	0.693	3154.33	4153	159	0.17	1.96	1403
S11	lower GR landings	0.682	1225.51	1615	62	0.19	1.94	547
S12	upper GR landings	0.698	10293.18	13544	516	0.18	1.95	4595
S13	Upper values of ensemble parms	0.908	6588.87	10039	399	0.07	2.23	4157
S14	Lower values of ensemble parms	0.502	1958.7	2124	77	0.43	1.55	565
S15	Upper Ensemble L/D/DiscM	0.691	3903.01	5138	197	0.17	1.99	1742
S16	Upper Ensemble Index	0.502	2511.75	2724	99	0.42	1.58	724
S17	Lower Ensemble L/D/DiscM	0.693	3487.61	4591	175	0.18	1.94	1557
S18	Lower Ensemble Index	0.693	2712.45	3571	137	0.19	1.91	1211
S19	Upper Ensemble M	0.91	5839.93	8897	354	0.08	2.2	3683
S20	Lower Ensemble M	0.694	3498.23	4606	176	0.18	1.95	1562
S21	alt. maturity	0.616	3330.01	4436	167	0.21	1.93	1559

*Table 18. Projection results with fishing mortality rate fixed at $F = F_{\text{current}}$ starting in 2020. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = removals (landings and dead discards) expressed in numbers (n, in 1000s) or whole weight (w, in 1000*lb*). The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)
2018	1796	1399	0.16	0.22	6647	5333	82	87	2820	2908
2019	1796	1377	0.19	0.24	6060	5117	84	91	2820	2908
2020	1796	1389	0.10	0.15	6089	5112	46	58	1479	1817
2021	1796	1382	0.10	0.15	6306	5225	49	60	1553	1857
2022	1796	1385	0.10	0.15	6478	5327	51	62	1612	1905
2023	1796	1380	0.10	0.15	6606	5394	53	63	1653	1944
2024	1796	1383	0.10	0.15	6697	5443	54	64	1683	1967

Table 19. Projection results with fishing mortality rate fixed at $F = F_{40\%}$ starting in 2020. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = removals (landings and dead discards) expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*). The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)
2018	1796	1399	0.16	0.22	6647	5333	82	87	2820	2908
2019	1796	1377	0.19	0.24	6060	5117	84	91	2820	2908
2020	1796	1389	0.69	0.65	5046	4361	254	212	8041	6507
2021	1796	1382	0.69	0.65	4109	3618	205	171	5945	4980
2022	1796	1385	0.69	0.65	3751	3338	188	156	5141	4315
2023	1796	1380	0.69	0.65	3616	3234	181	151	4836	4082
2024	1796	1383	0.69	0.65	3566	3201	179	149	4722	3981

Table 20. Projection results with fishing mortality rate fixed at $F = 75\%F_{40\%}$ starting in 2020. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = removals (landings and dead discards) expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb*). The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)
2018	1796	1399	0.16	0.22	6647	5333	82	87	2820	2908
2019	1796	1377	0.19	0.24	6060	5117	84	91	2820	2908
2020	1796	1389	0.52	0.49	5326	4591	202	168	6426	5188
2021	1796	1382	0.52	0.49	4602	4041	176	147	5222	4341
2022	1796	1385	0.52	0.49	4277	3804	165	137	4680	3921
2023	1796	1380	0.52	0.49	4132	3697	160	133	4437	3739
2024	1796	1383	0.52	0.49	4069	3656	158	131	4329	3659

7 Figures

Figure 1. Mean length at age (mm) and estimated upper and lower 95% confidence intervals of the population.

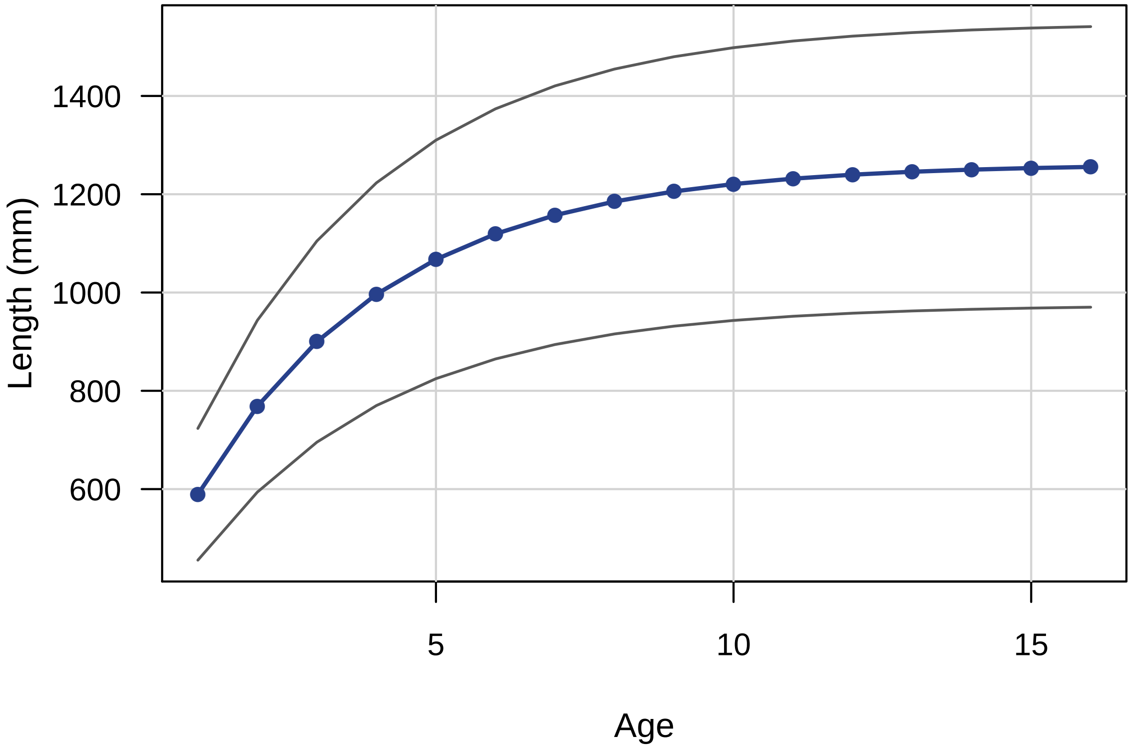


Figure 2. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet from the base run. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, comm to the commercial fleet, and GR to the general recreational fleet. N indicates the number of fish samples taken. For the commercial fleet, length compositions from 1986–2017 were pooled.

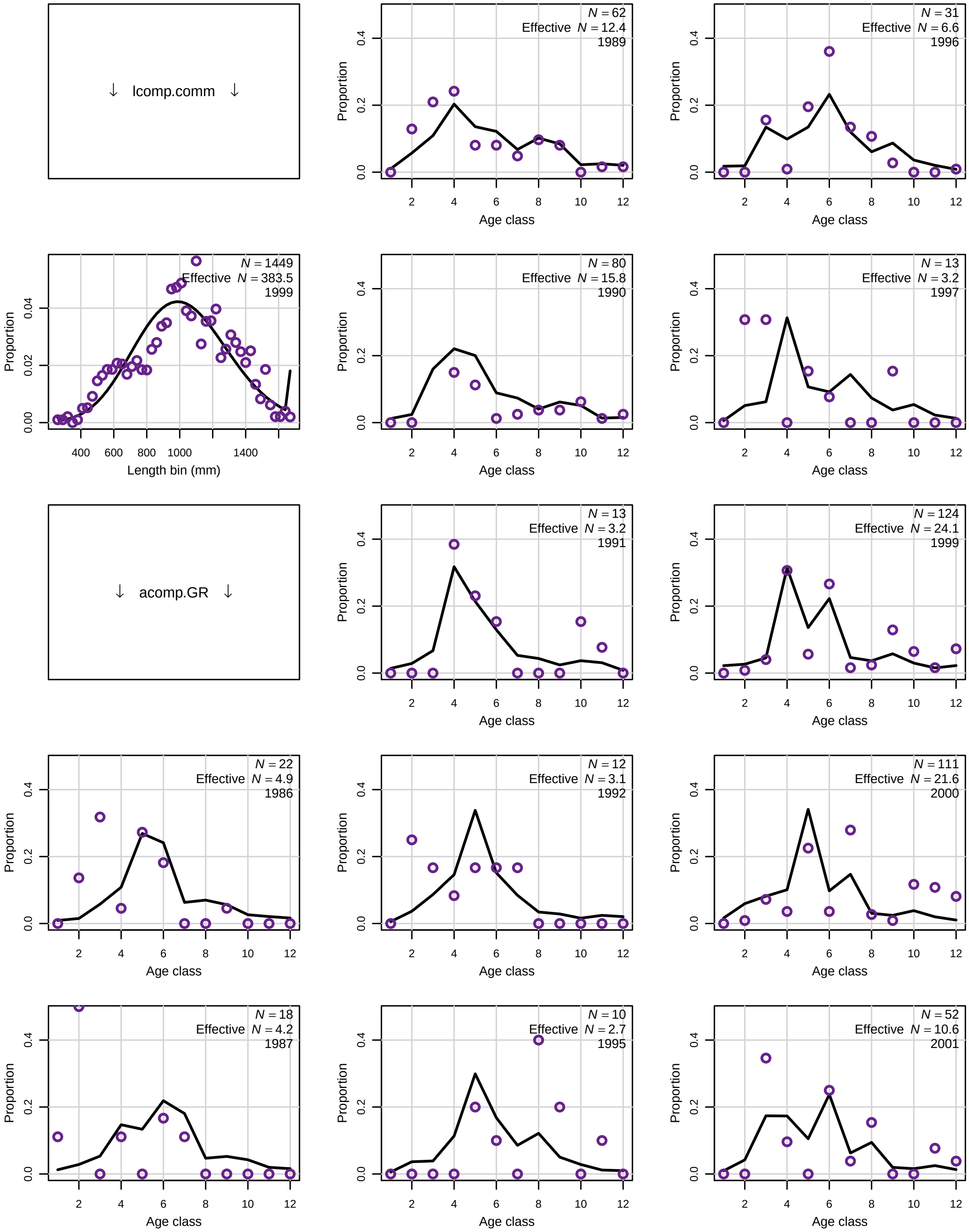


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey from the base run.

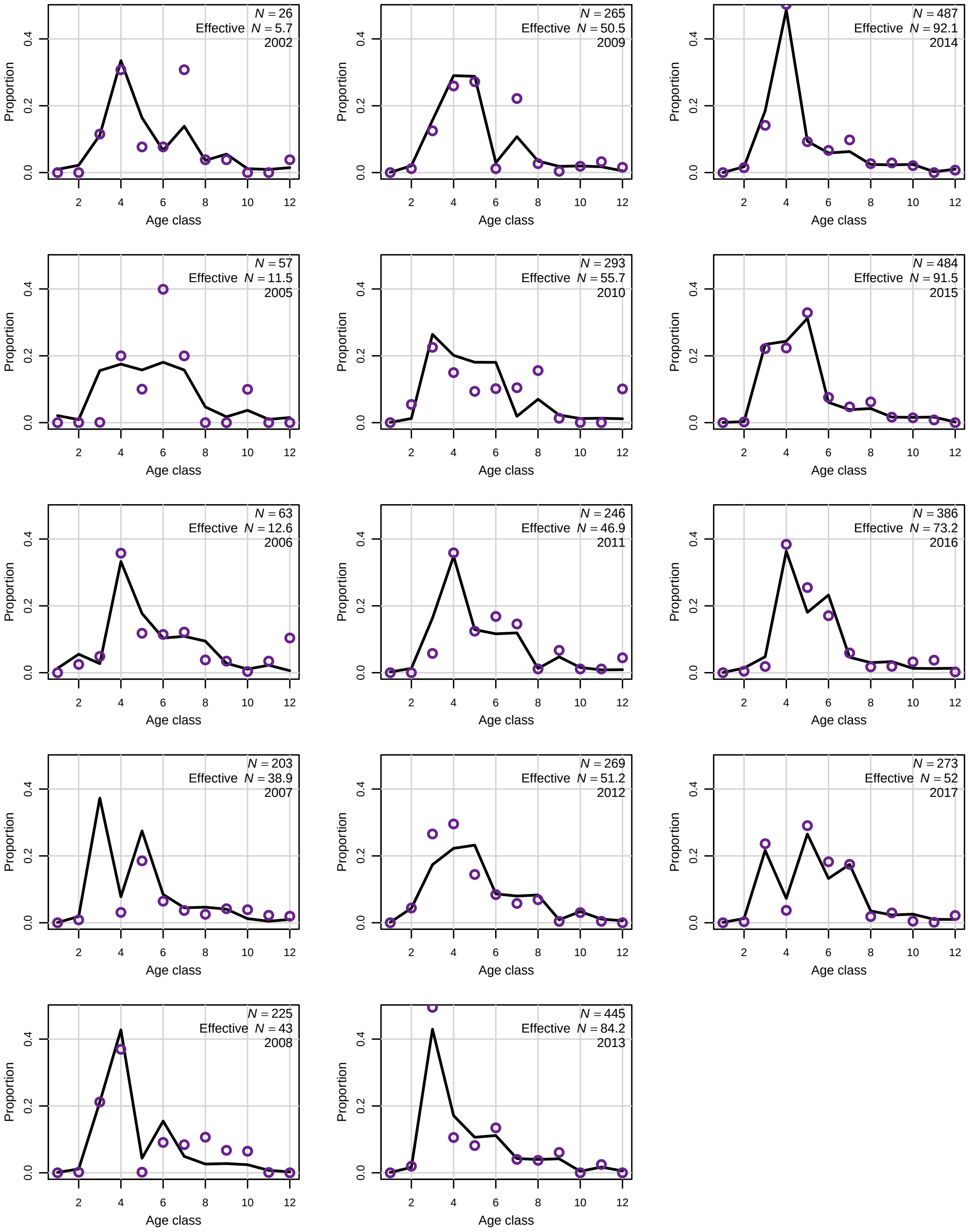


Figure 3. Observed (open circles) and estimated (line, solid circles) commercial landings (1000 lb whole weight).

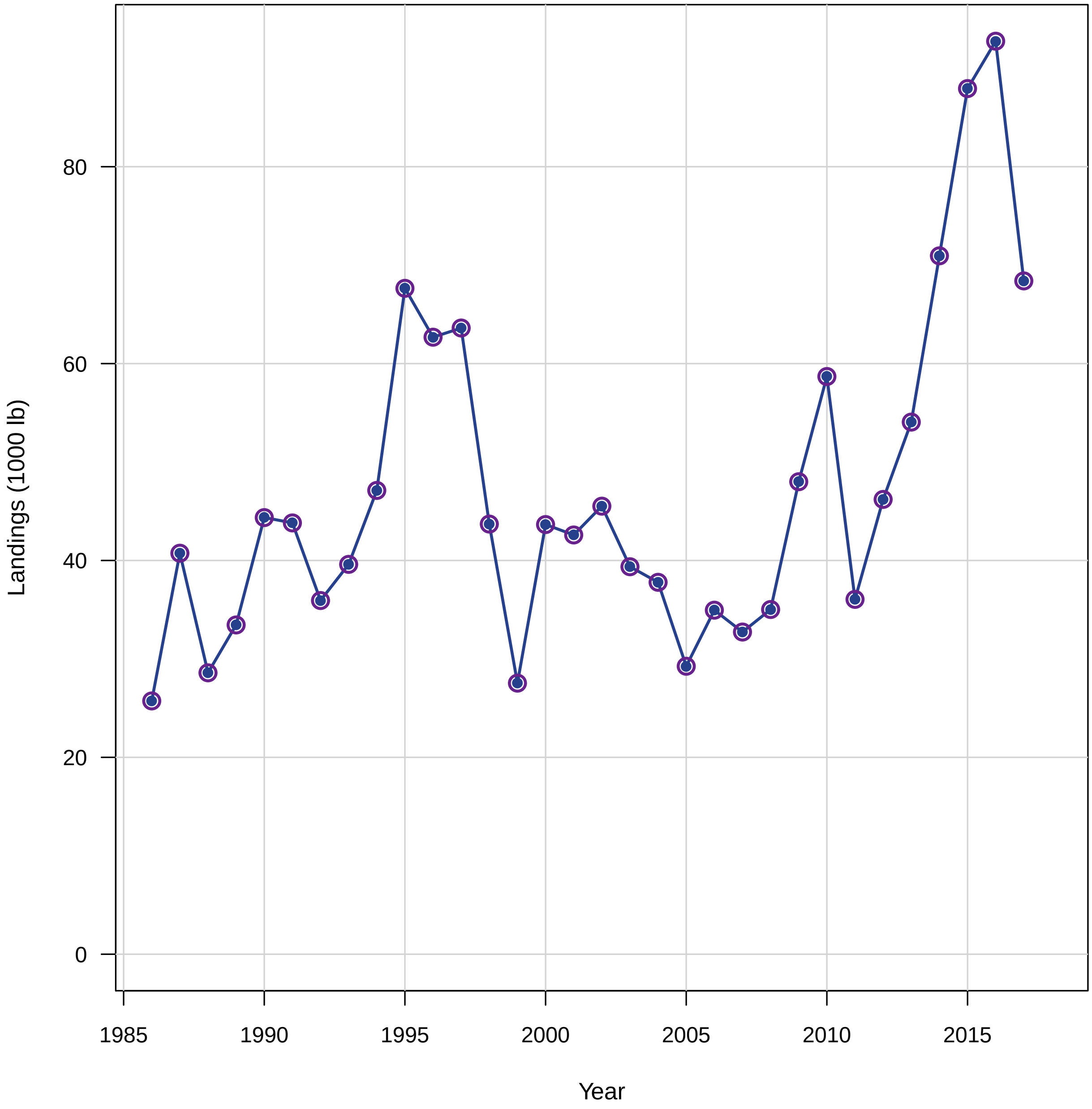


Figure 4. Observed (open circles) and estimated (line, solid circles) general recreational landings (1000 fish).

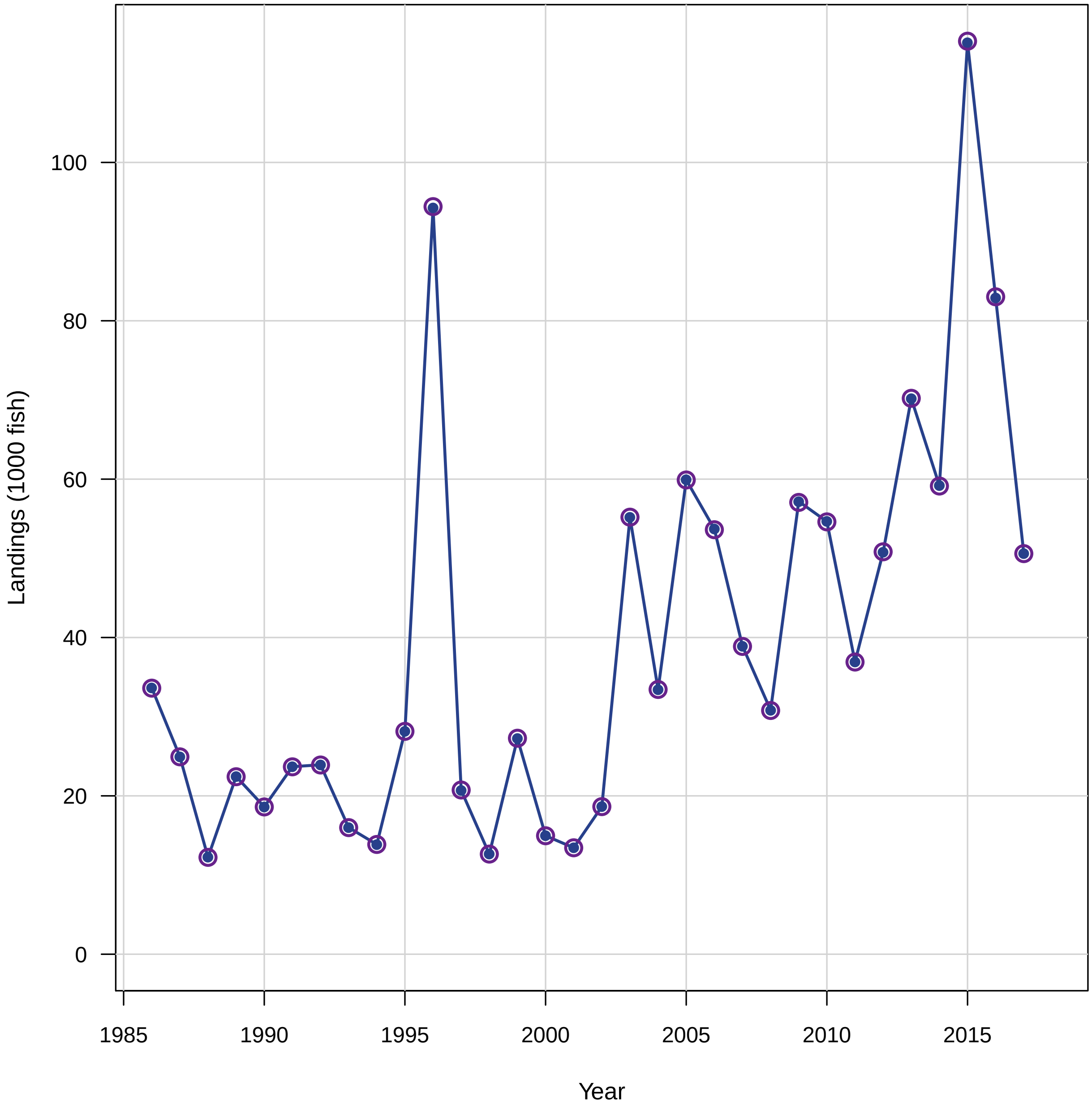


Figure 5. Observed (open circles) and estimated (line, solid circles) index of abundance from the headboat fleet.

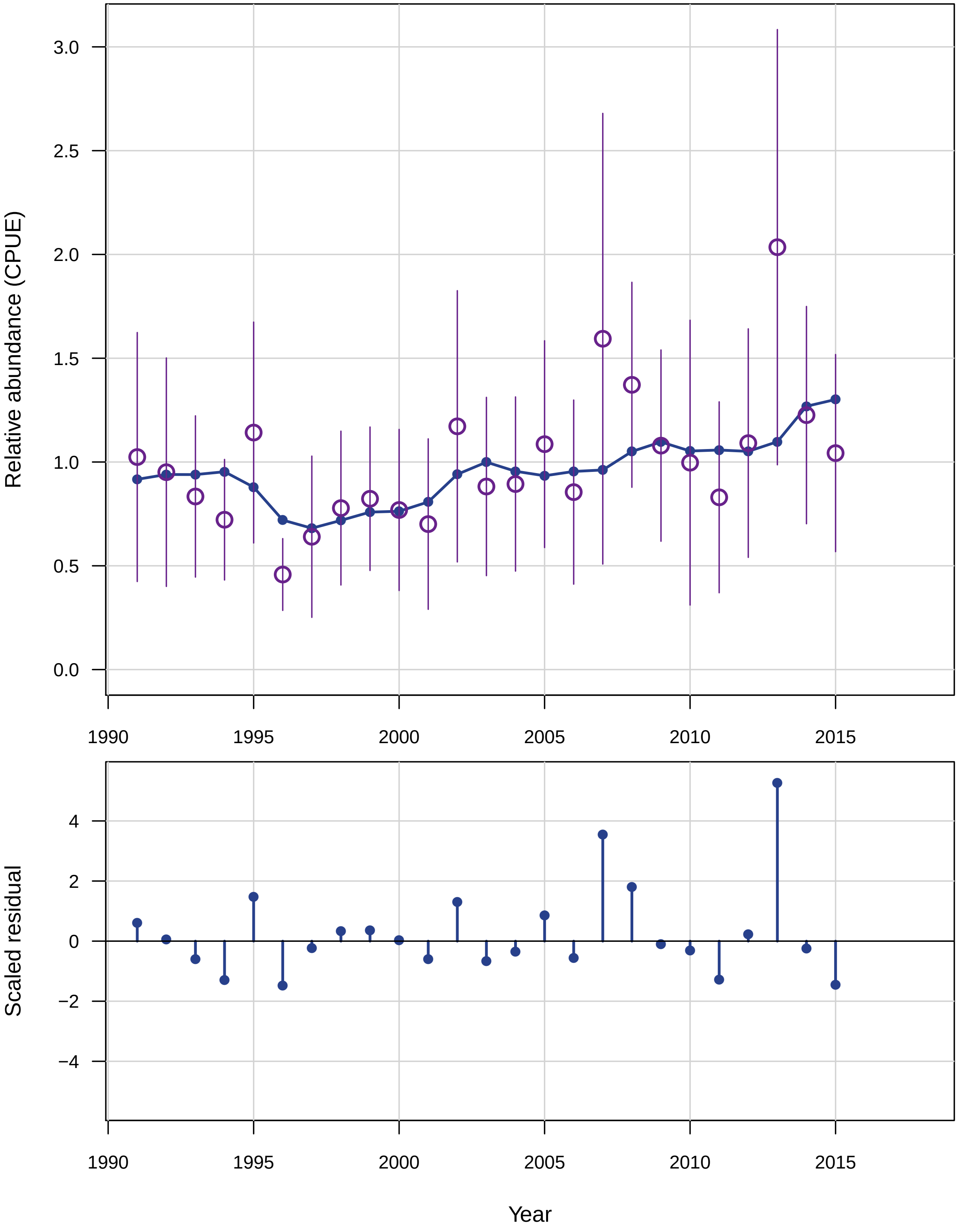


Figure 6. Estimated abundance at age at start of year.

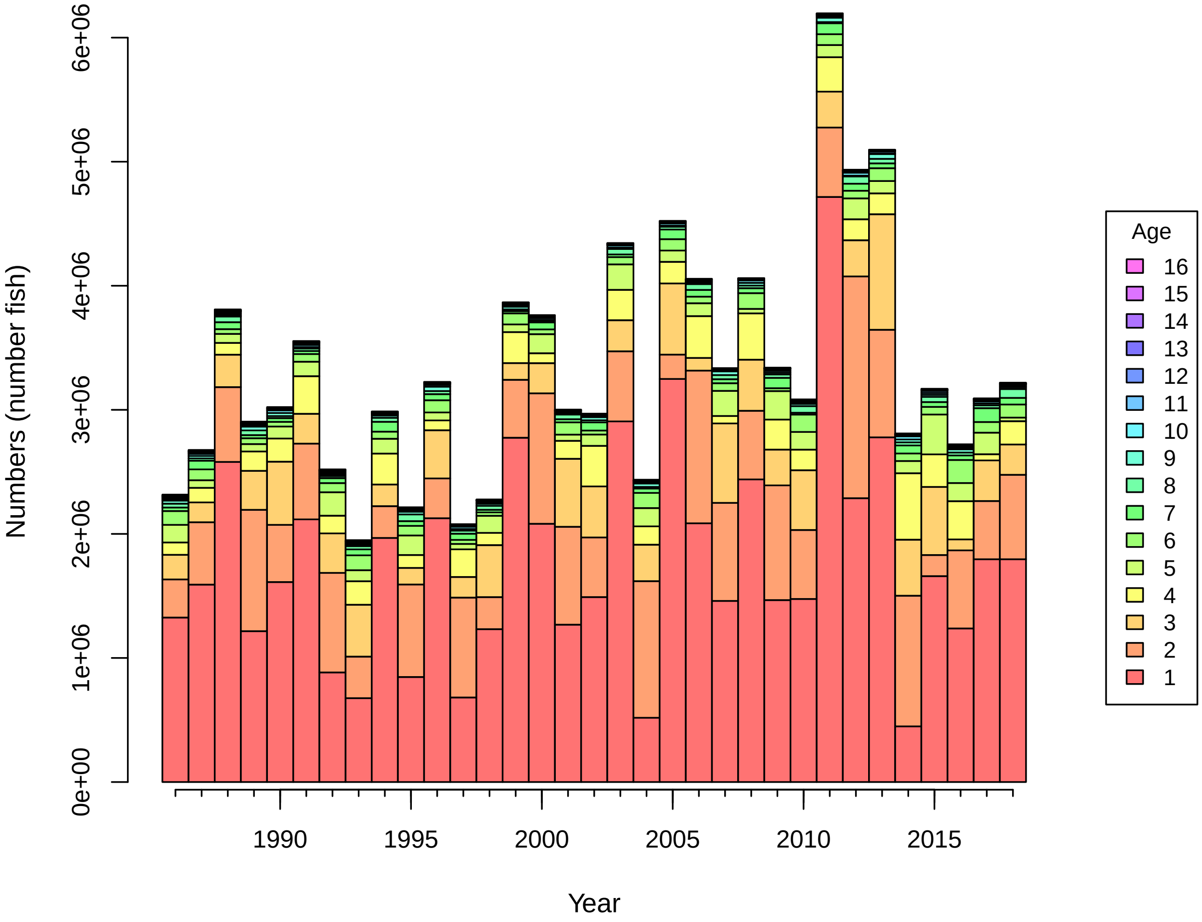


Figure 7. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates $R_{\mathrm{F40\%}}$. *Bottom panel: log recruitment residuals.*

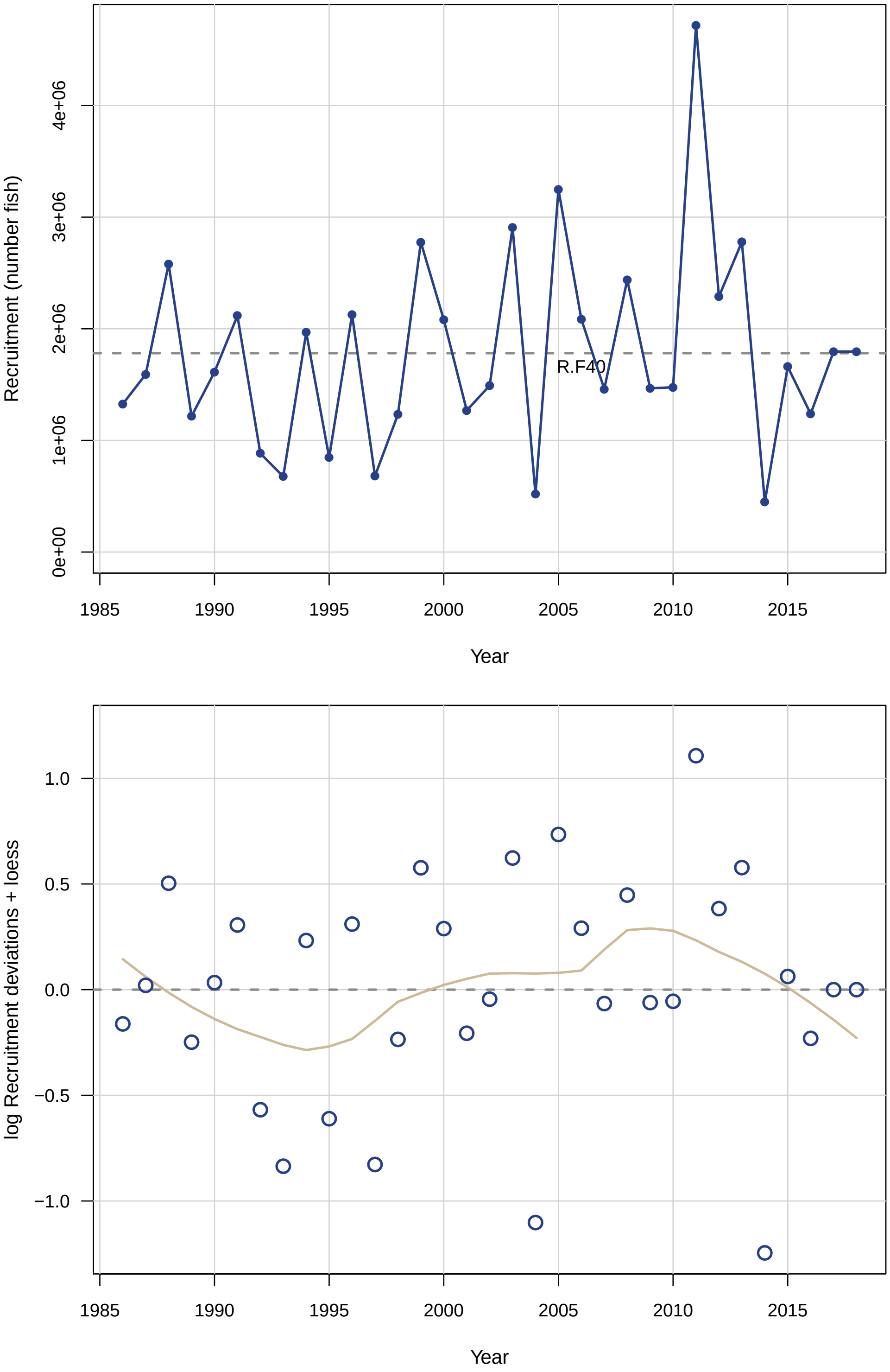


Figure 8. Estimated biomass at age at start of year.

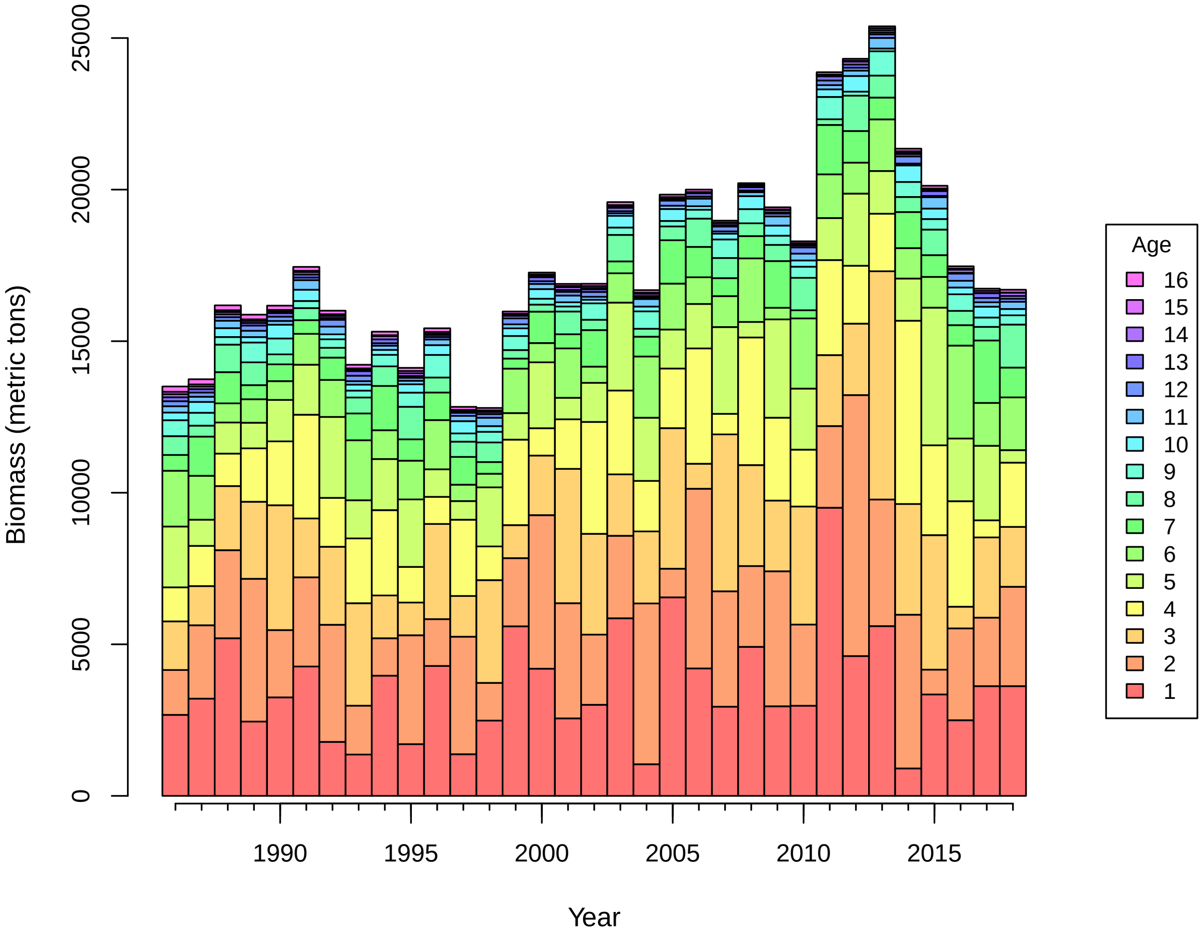


Figure 9. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates $B_{\mathrm{F40\%}}$*. Bottom panel: Estimated spawning stock (mature female biomass) at time of peak spawning.*

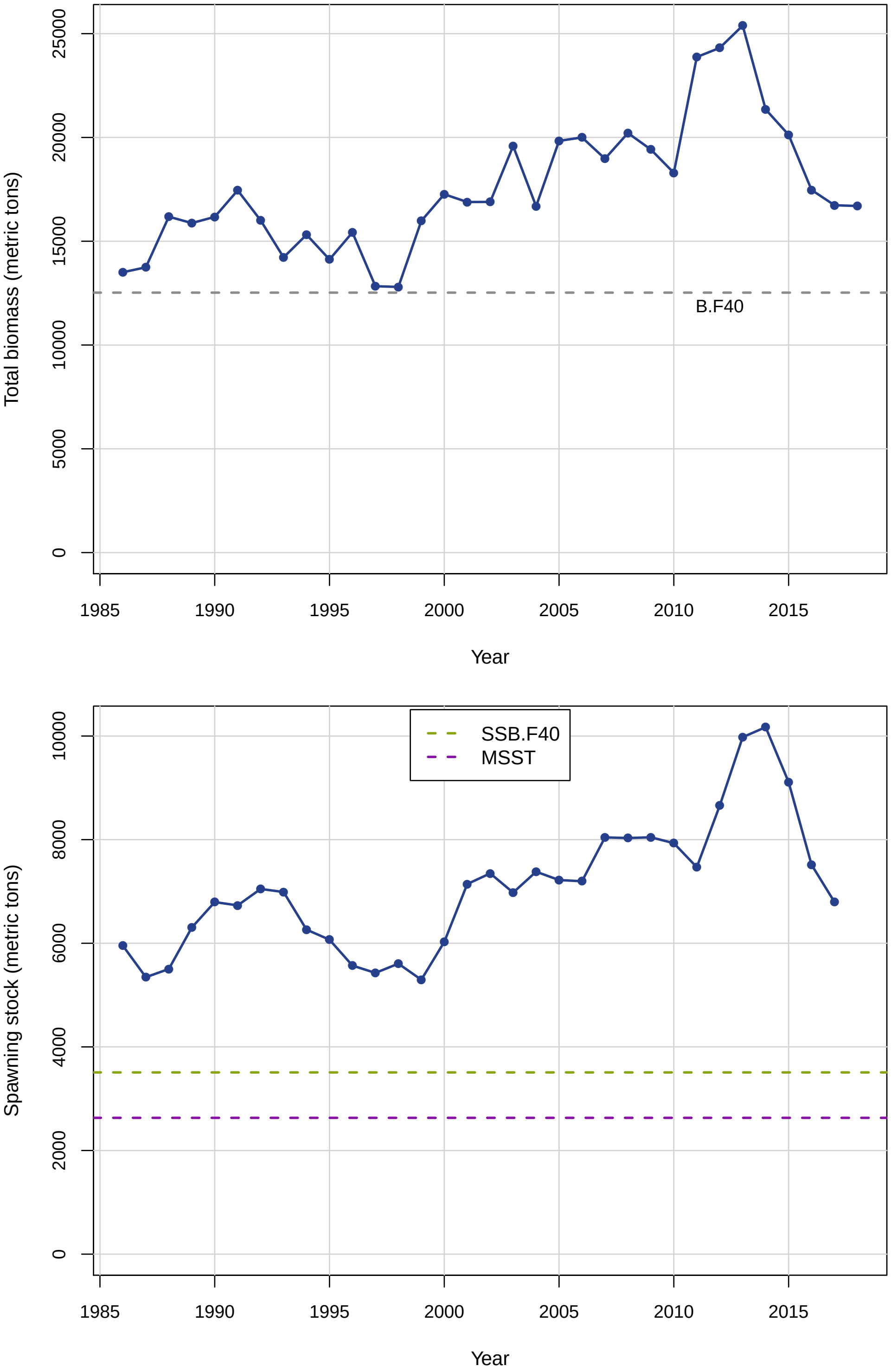


Figure 10. Estimated selectivity of the commercial fleet. Years indicated on plot signify the first year of a time block.

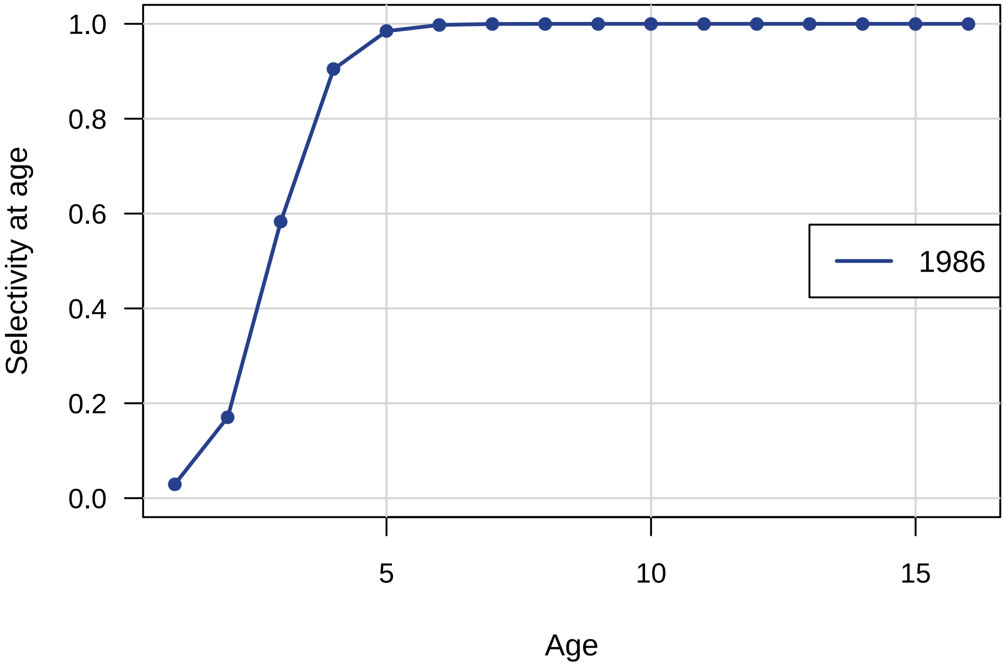


Figure 11. Estimated selectivities of the general recreational fleet. Years indicated on plot signify the first year of a time block.

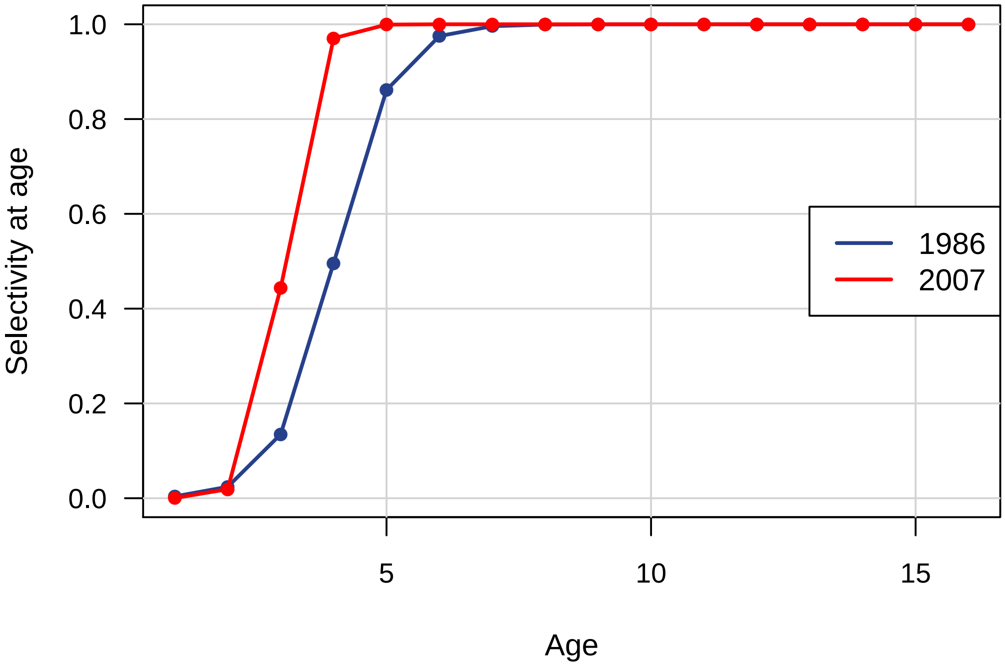


Figure 12. Average selectivity from the terminal assessment years, weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and projections.

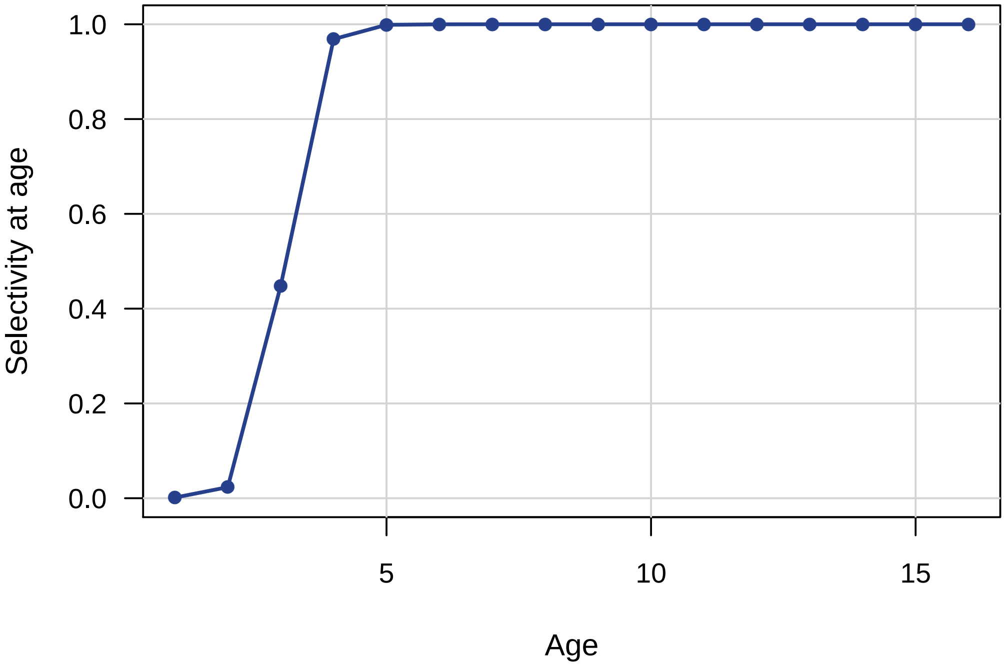


Figure 13. Estimated fully selected fishing mortality rate (per year) by fishery. comm refers to the commercial fleet, and GR to the general recreational fleet.

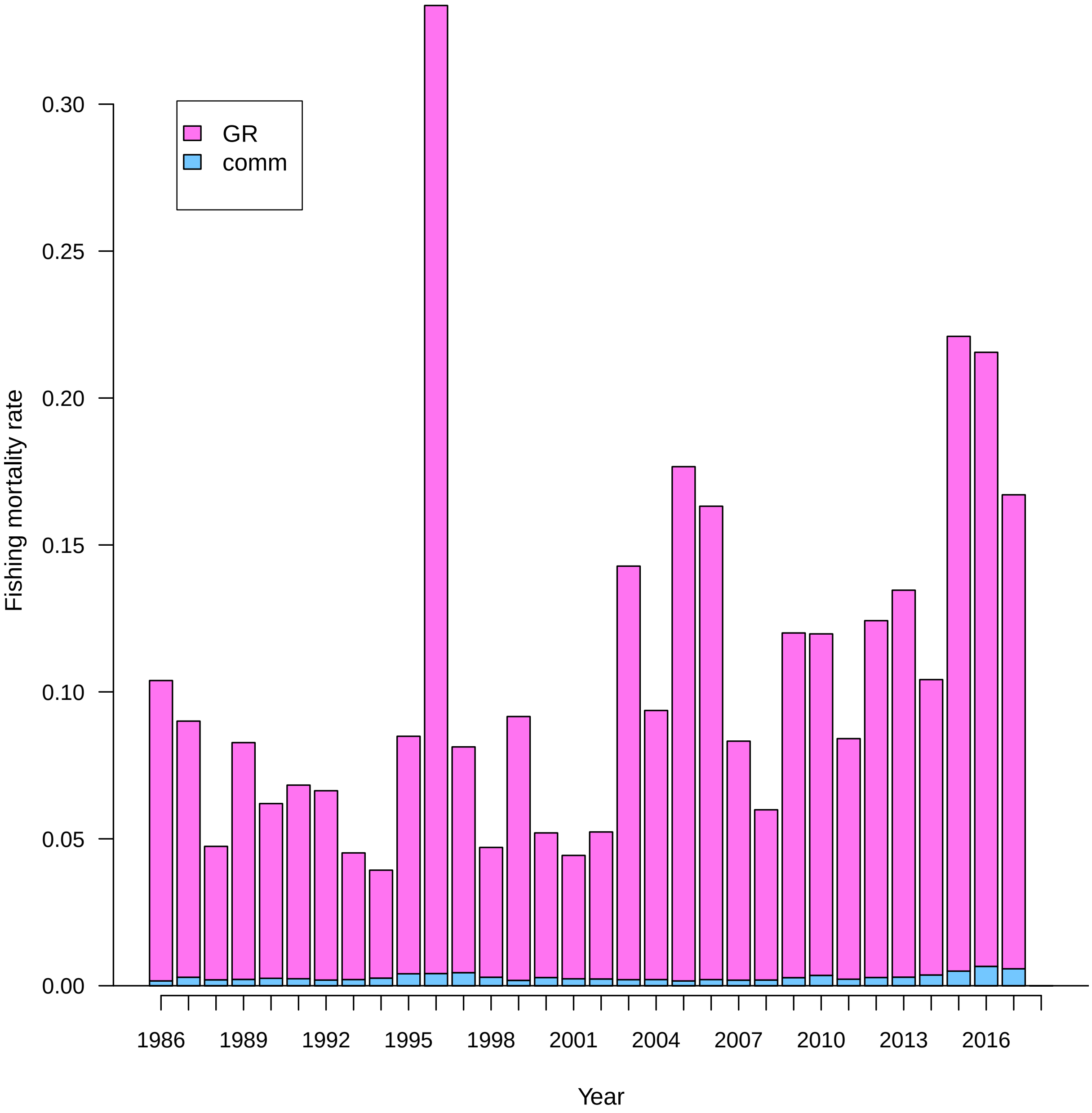


Figure 14. Estimated landings in numbers by fishery from the catch-age model. comm refers to the commercial fleet, and GR to the general recreational fleet.

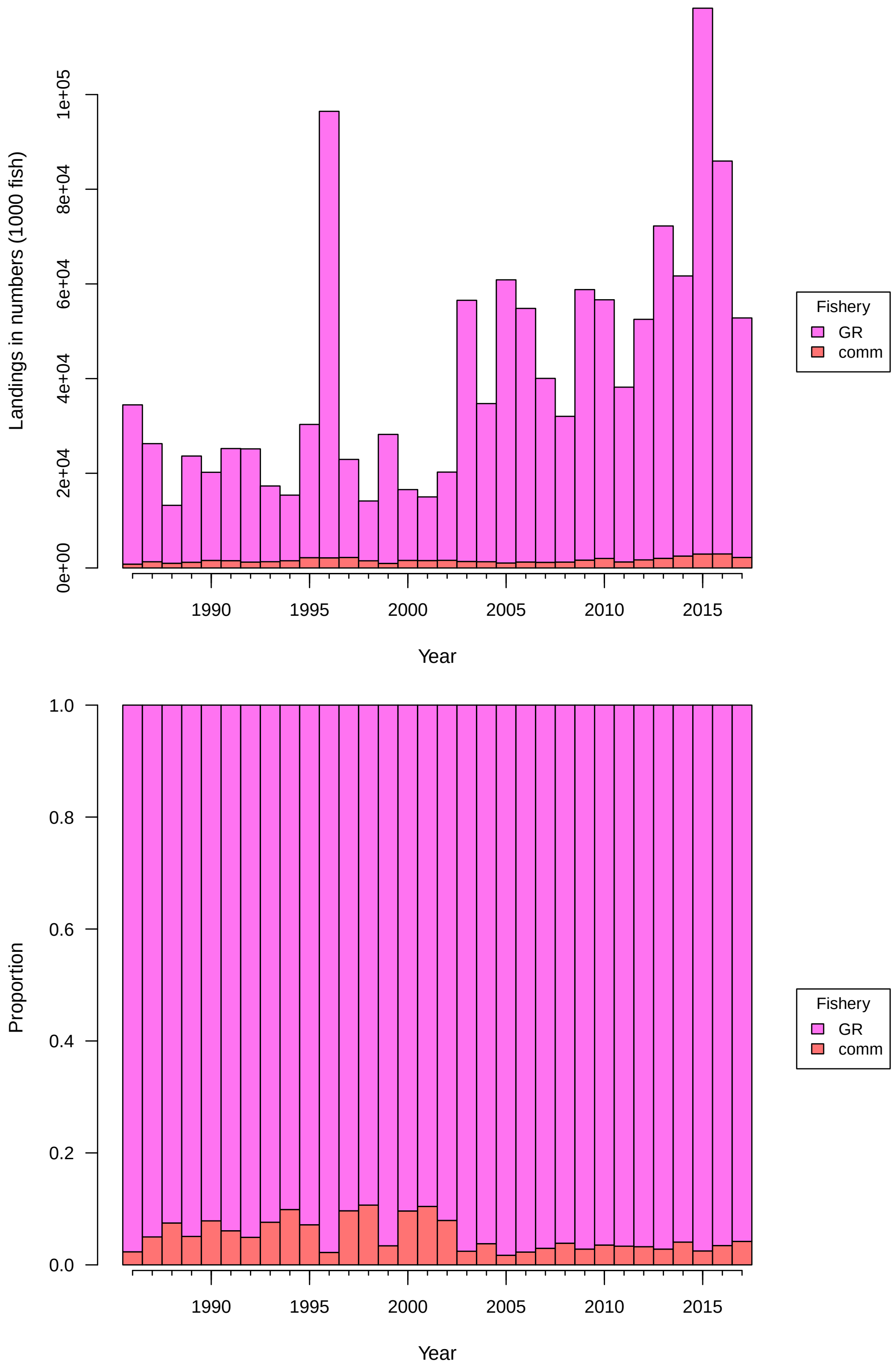


Figure 15. Estimated landings in whole weight by fishery from the catch-age model. comm refers to the commercial fleet, and GR to the general recreational fleet.

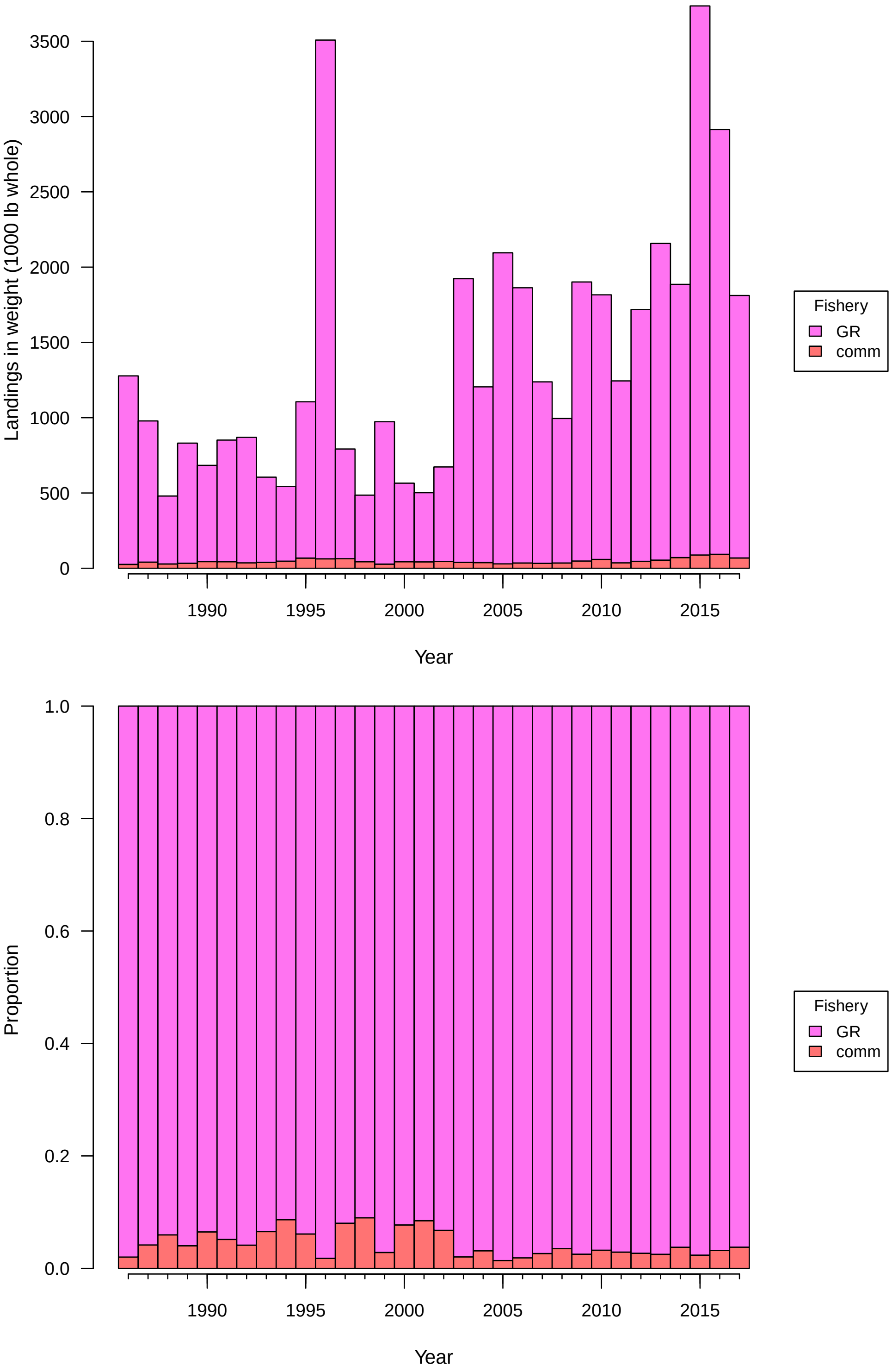


Figure 16. Top panel: Spawner-recruit relationship, with and without lognormal bias correction. The expected curve was used for computing management benchmarks. Years within panel indicate year of recruitment generated from spawning biomass. Bottom panel: log of recruits (number age-1 fish) per spawner as a function of spawners.

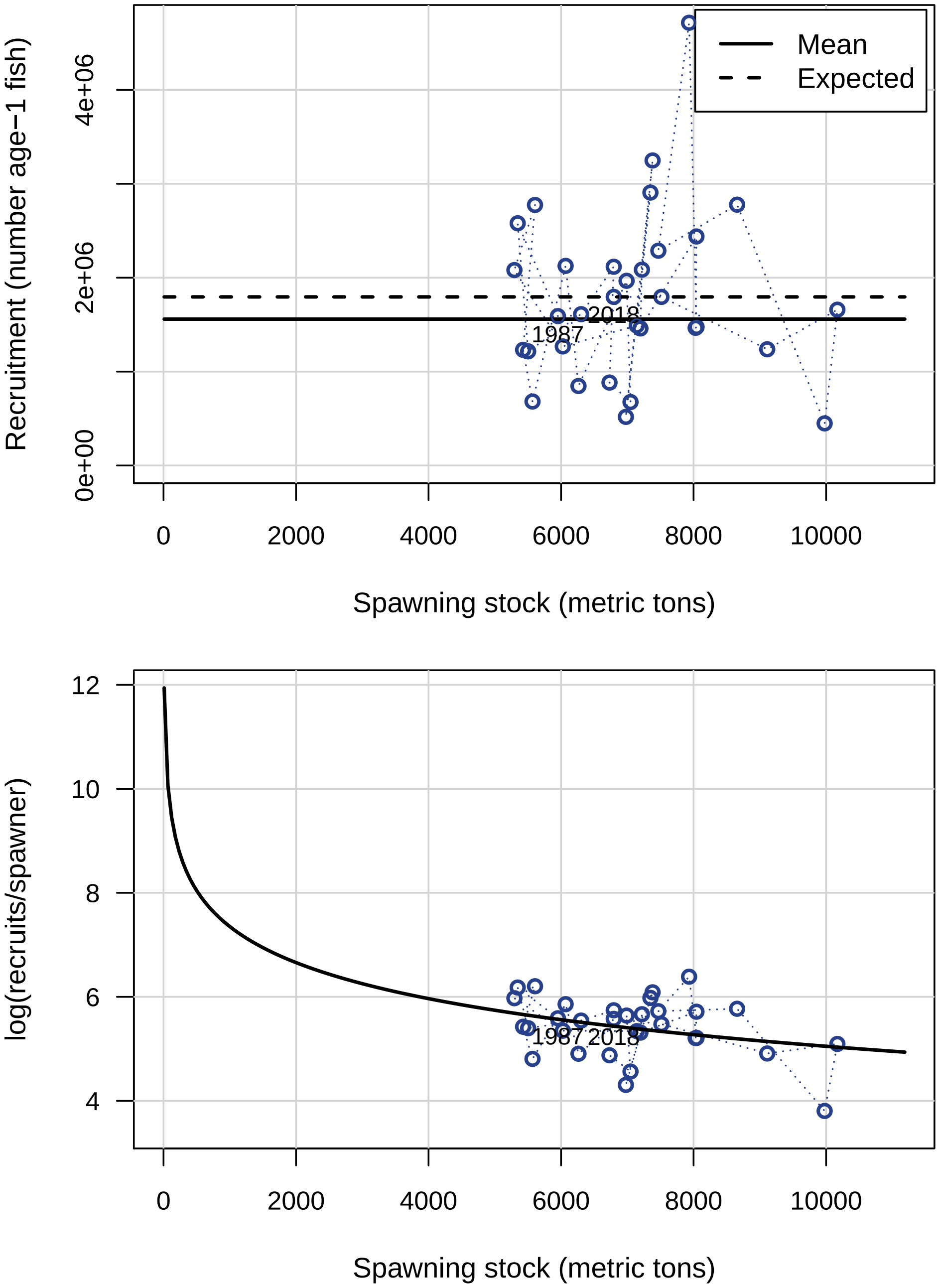


Figure 17. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), the SD of recruitment residuals, and unfished spawners per recruit. Vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model.

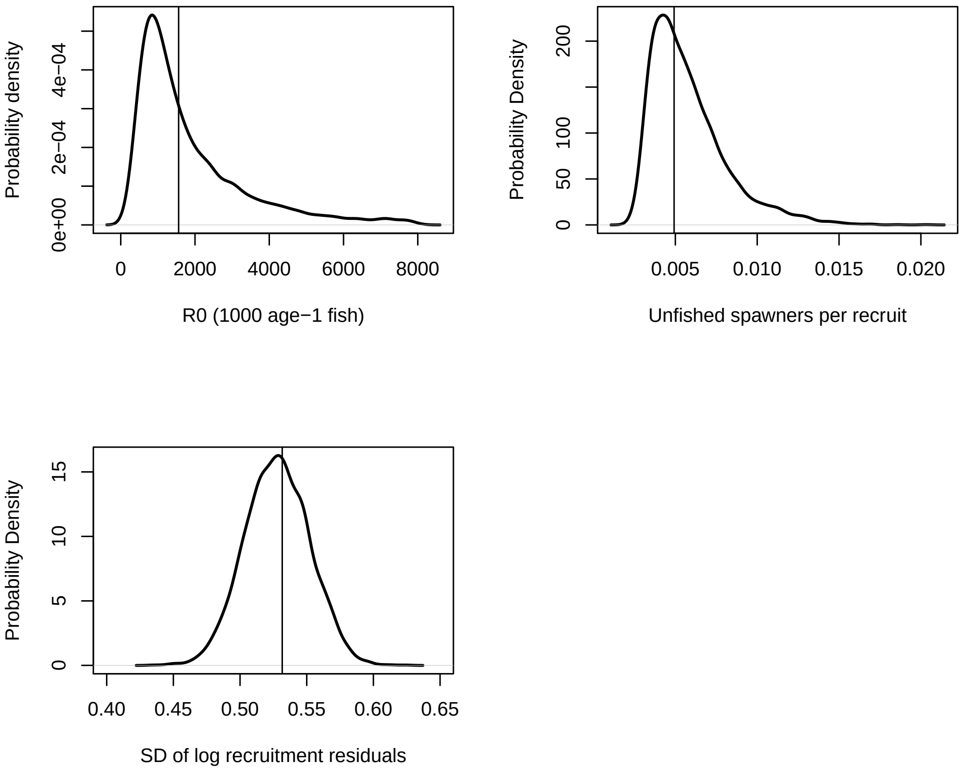


Figure 18. Top panel: yield per recruit (kg). Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. *Both curves are based on average selectivity from the end of the assessment period.*

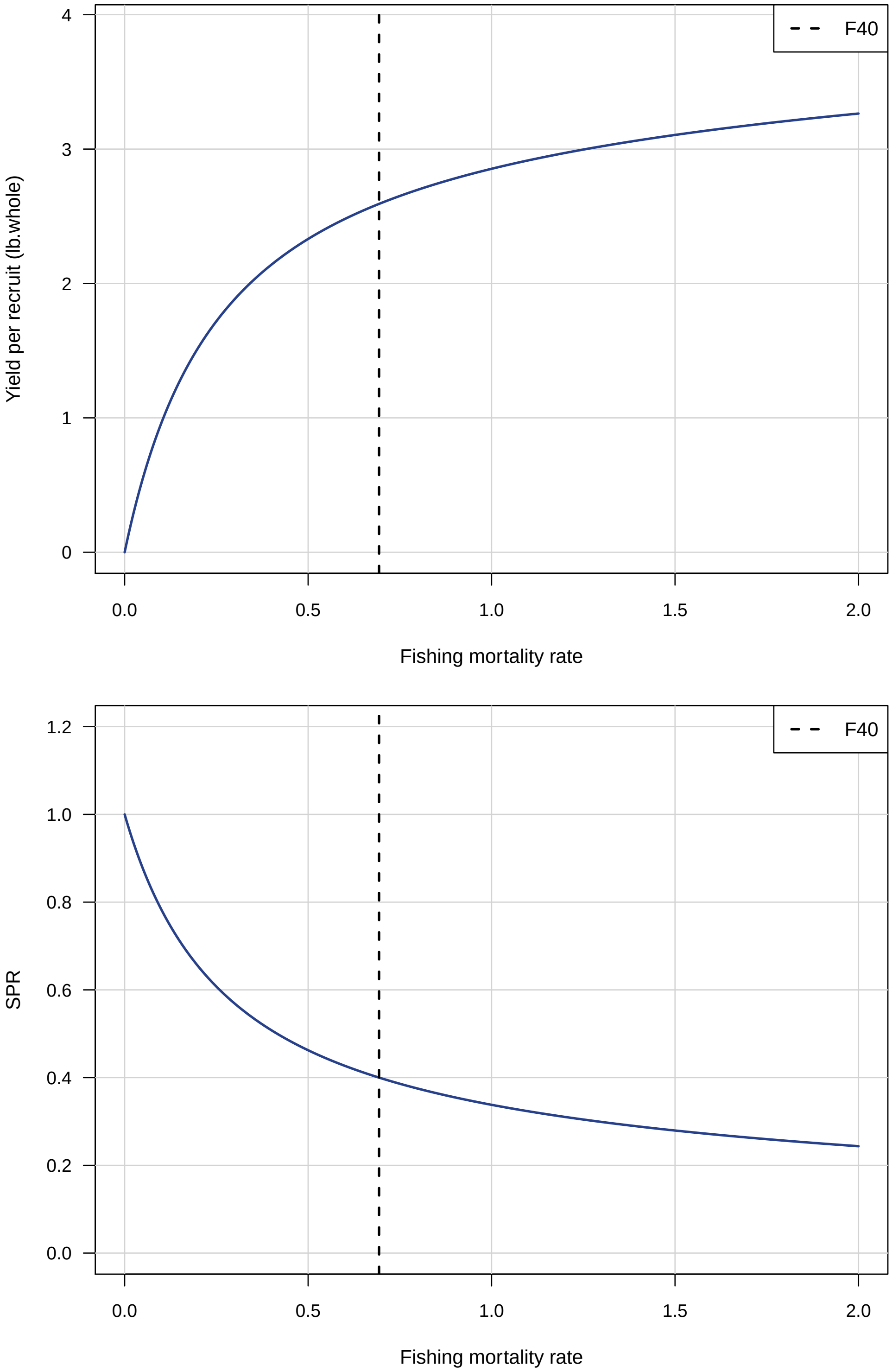


Figure 19. Top panel: equilibrium landings. The vertical dashed line occurs where fishing rate is $F_{40\%} = 0.69$ *and equilibrium landings are* $L_{F40\%}$ *(1000 lb). Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.*

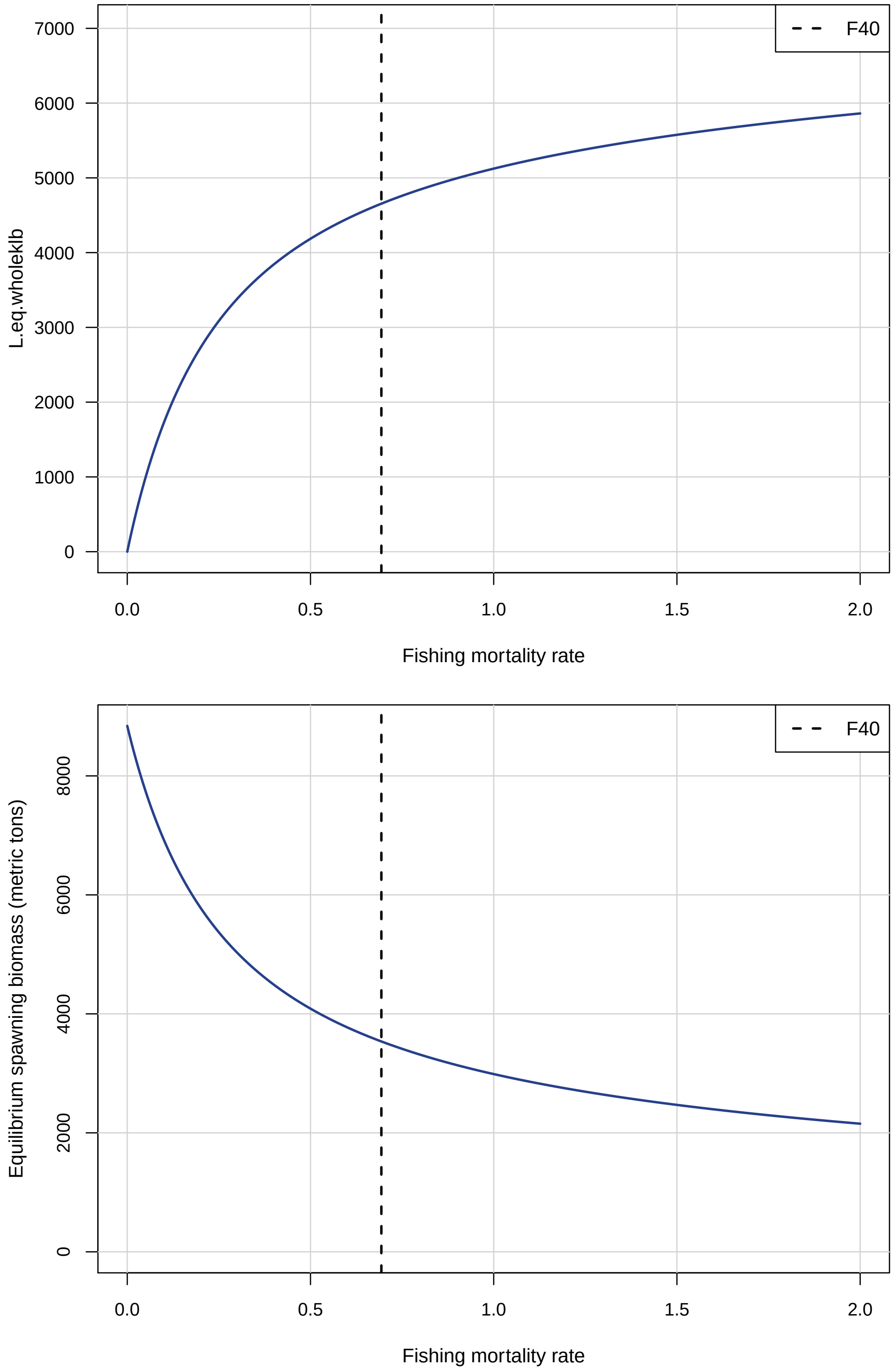


Figure 20. Probability densities of $F_{40\%}$-related benchmarks from the ensemble model of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.

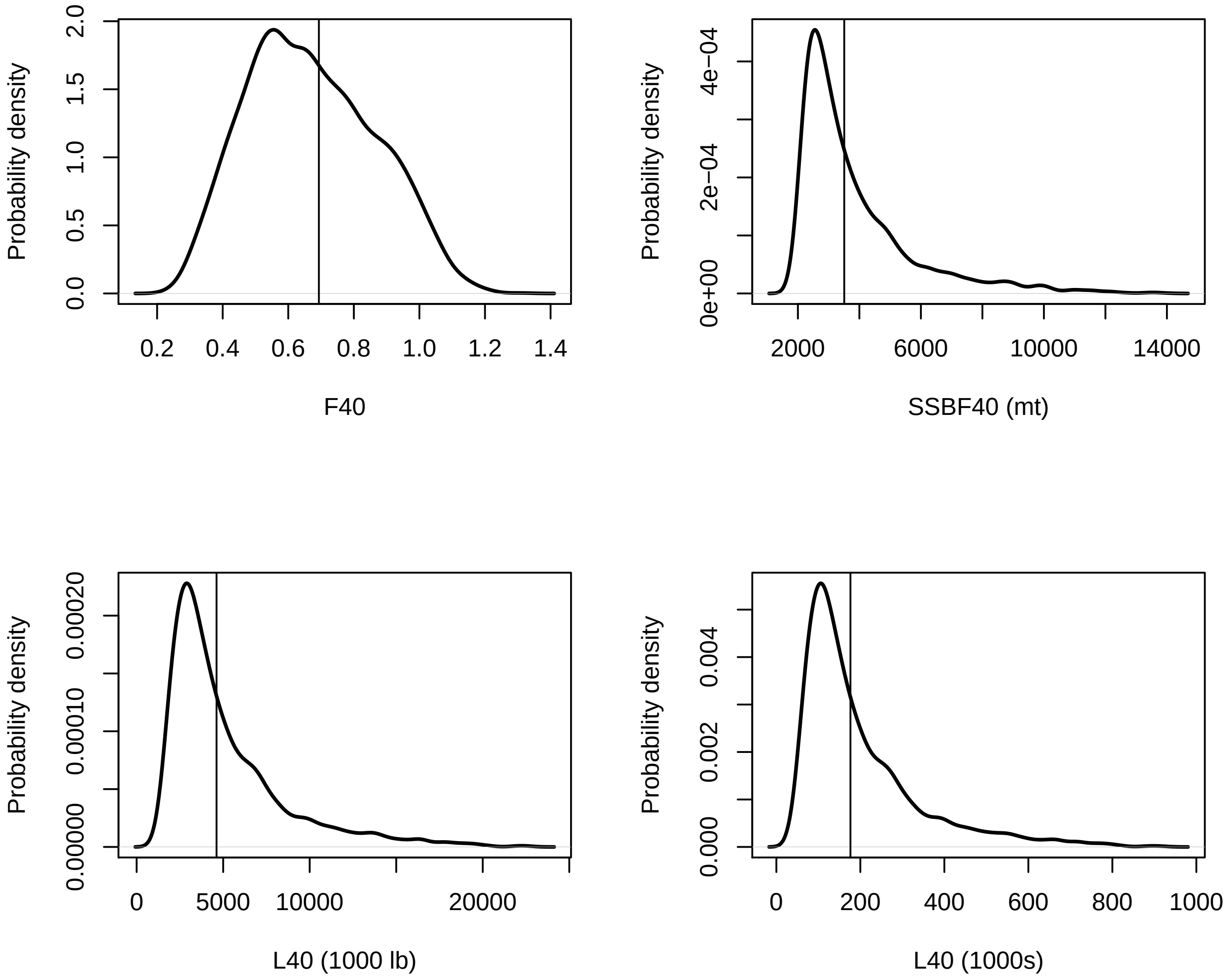


Figure 21. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5^{th} *and* 95^{th} *percentiles of the ensemble modeling. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Middle panel: spawning biomass relative to* $\mathrm{SSB}_{\mathrm{F}40\%}$. *Bottom panel: F relative to* $F_{40\%}$.

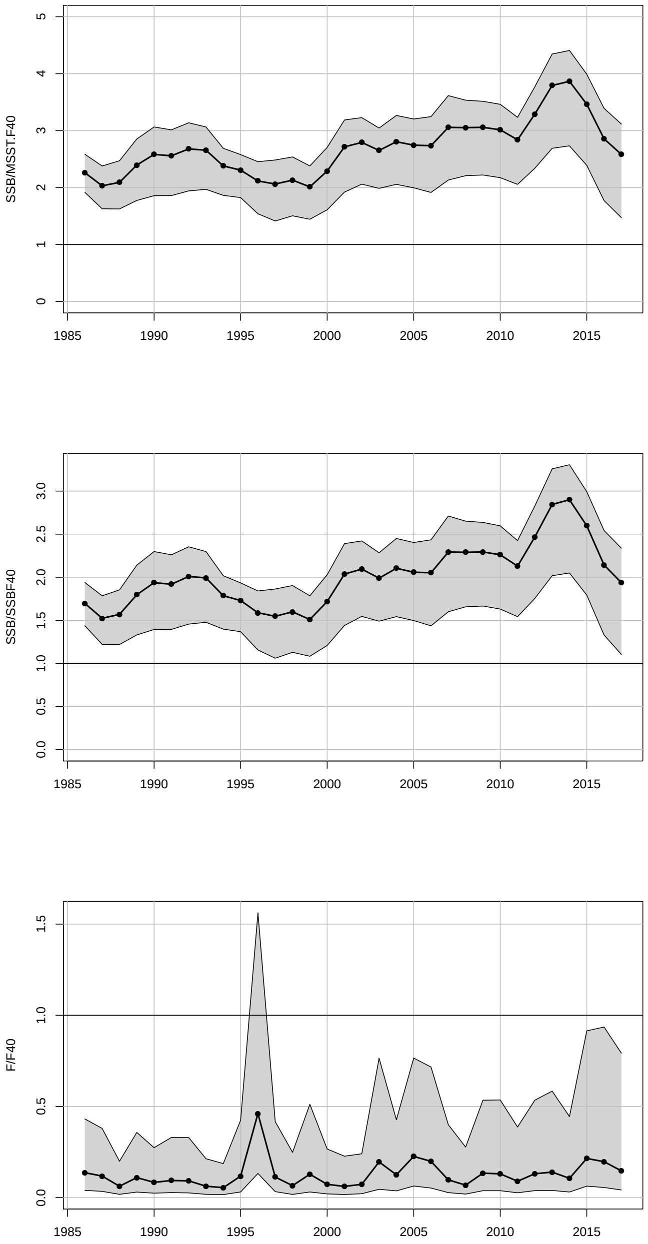


Figure 22. Probability densities of terminal status estimates from ensemble model of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.

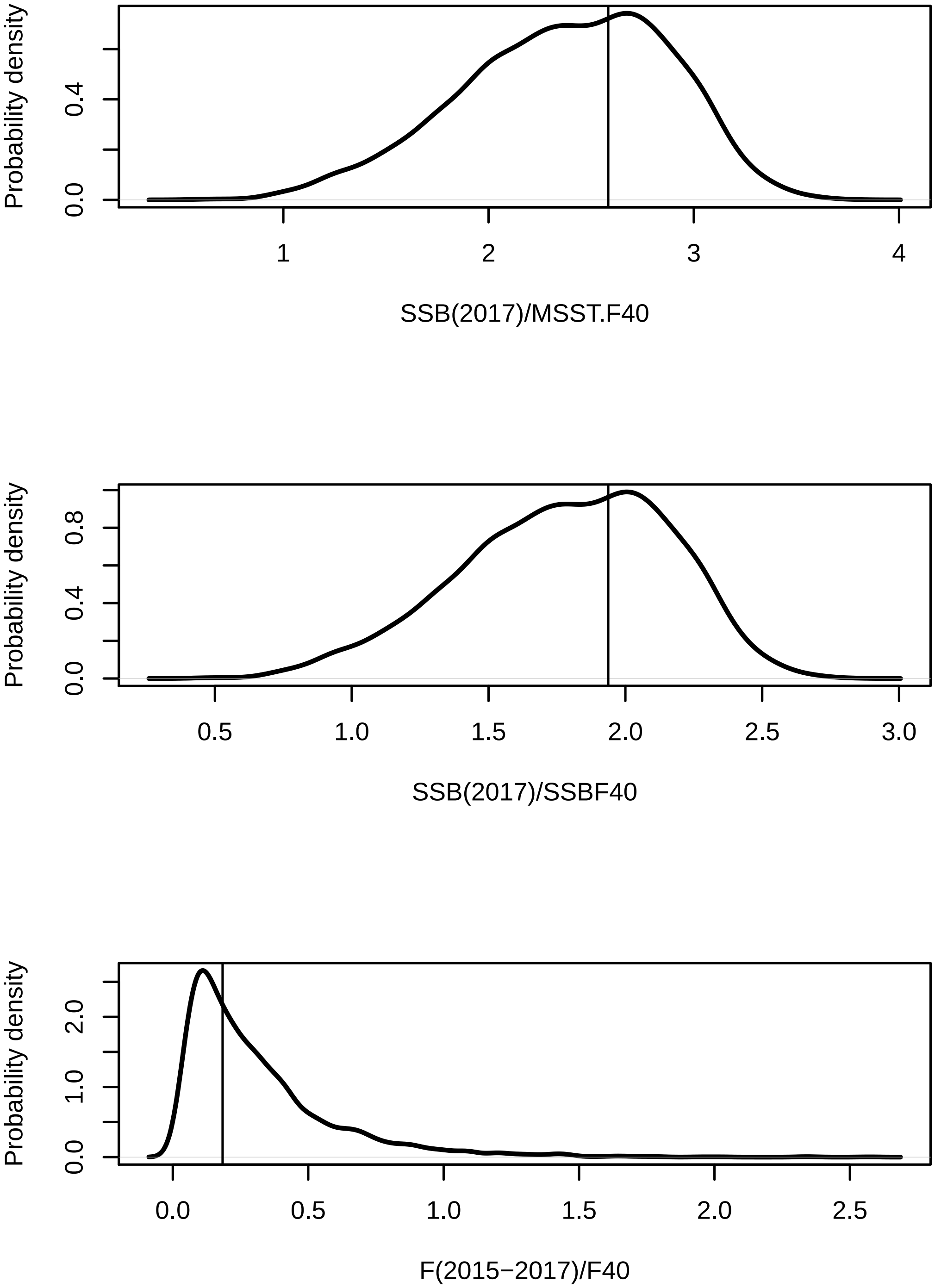


Figure 23. Phase plots of terminal status estimates from the ensemble model of the Beaufort Assessment Model. Top panel is status relative to MSST, *and the bottom panel is status relative to* $\mathrm{SSB}_{\mathrm{F40\%}}$. *The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by* 5^{th} *and* 95^{th} *percentiles.*

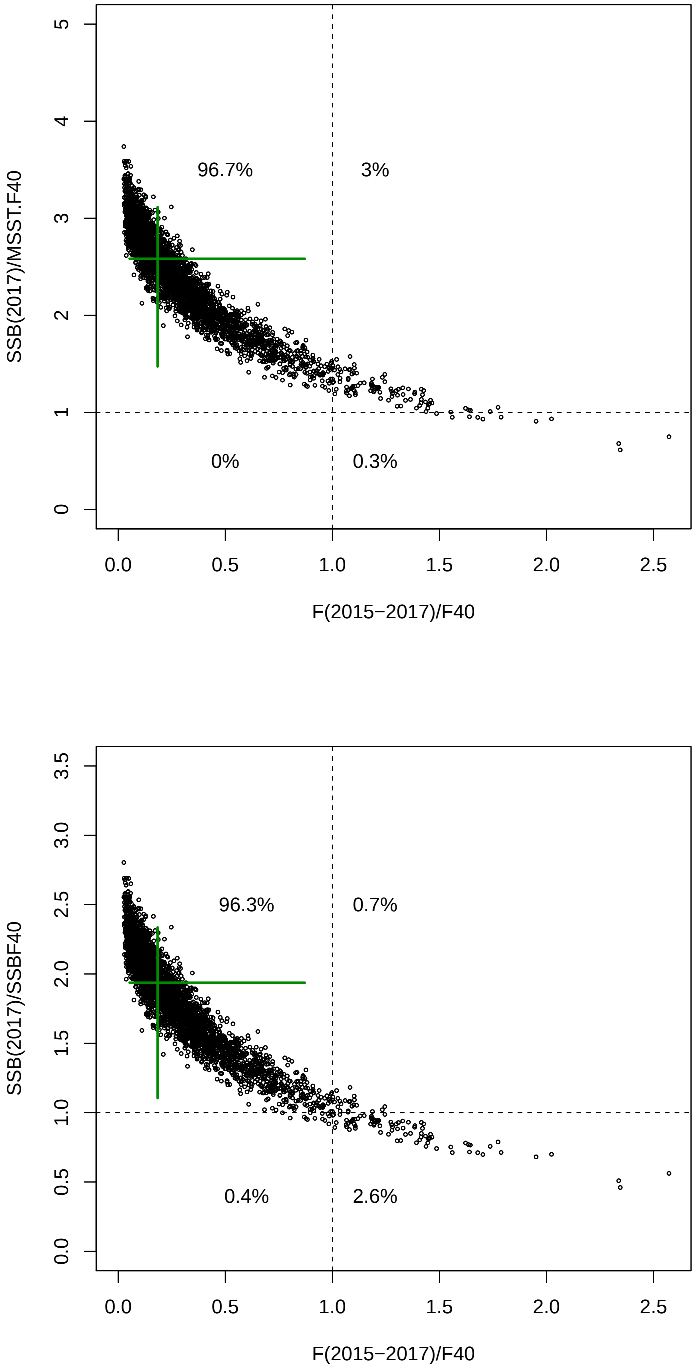


Figure 24. Age structure relative to the equilibrium expected at $L_{\mathrm{F40\%}}$.

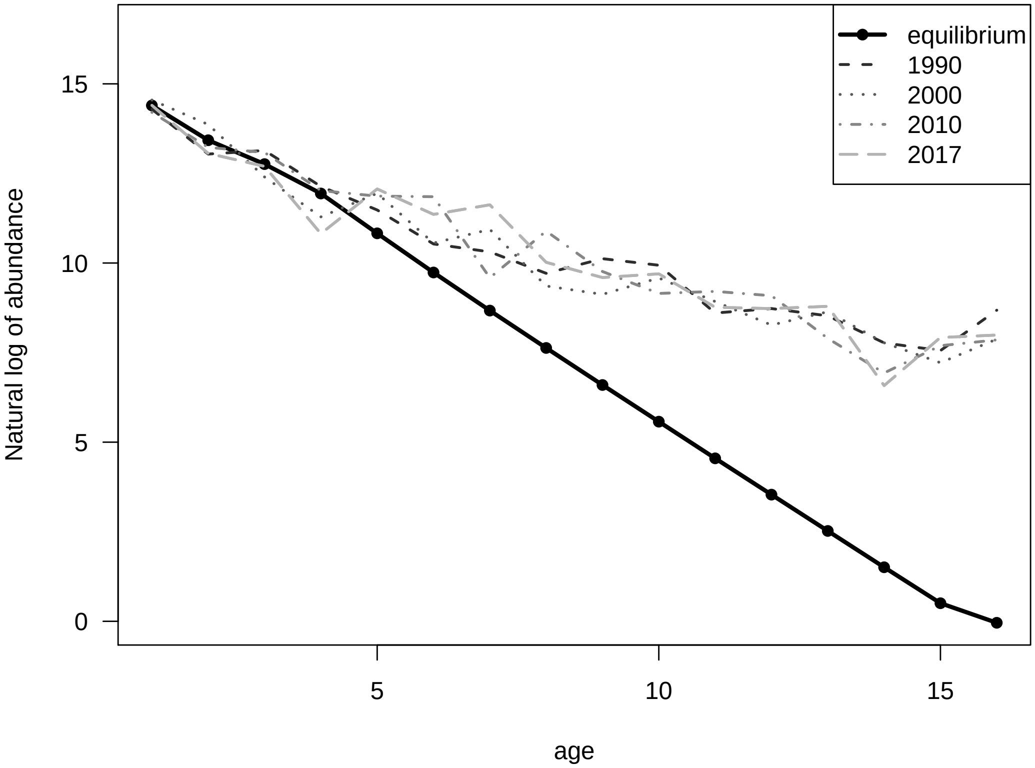


Figure 25. Sensitivity to an earlier start year (sensitivity run S1). Top panel: Ratio of F to $F_{40\%}$. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.

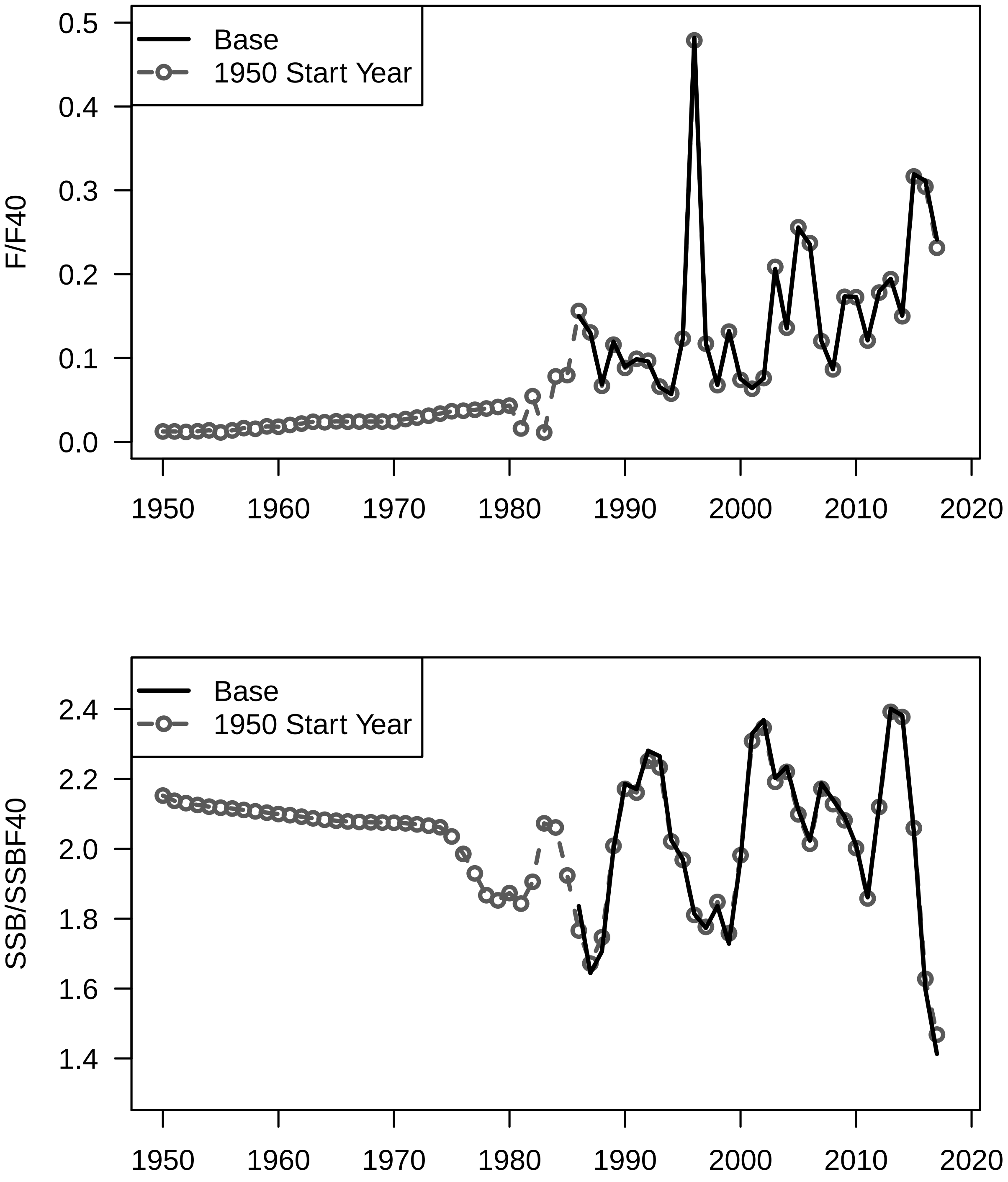


Figure 26. Sensitivity to including recreational length compositions (sensitivity run S2). Top panel: Ratio of F to $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F}40\%}$*.*

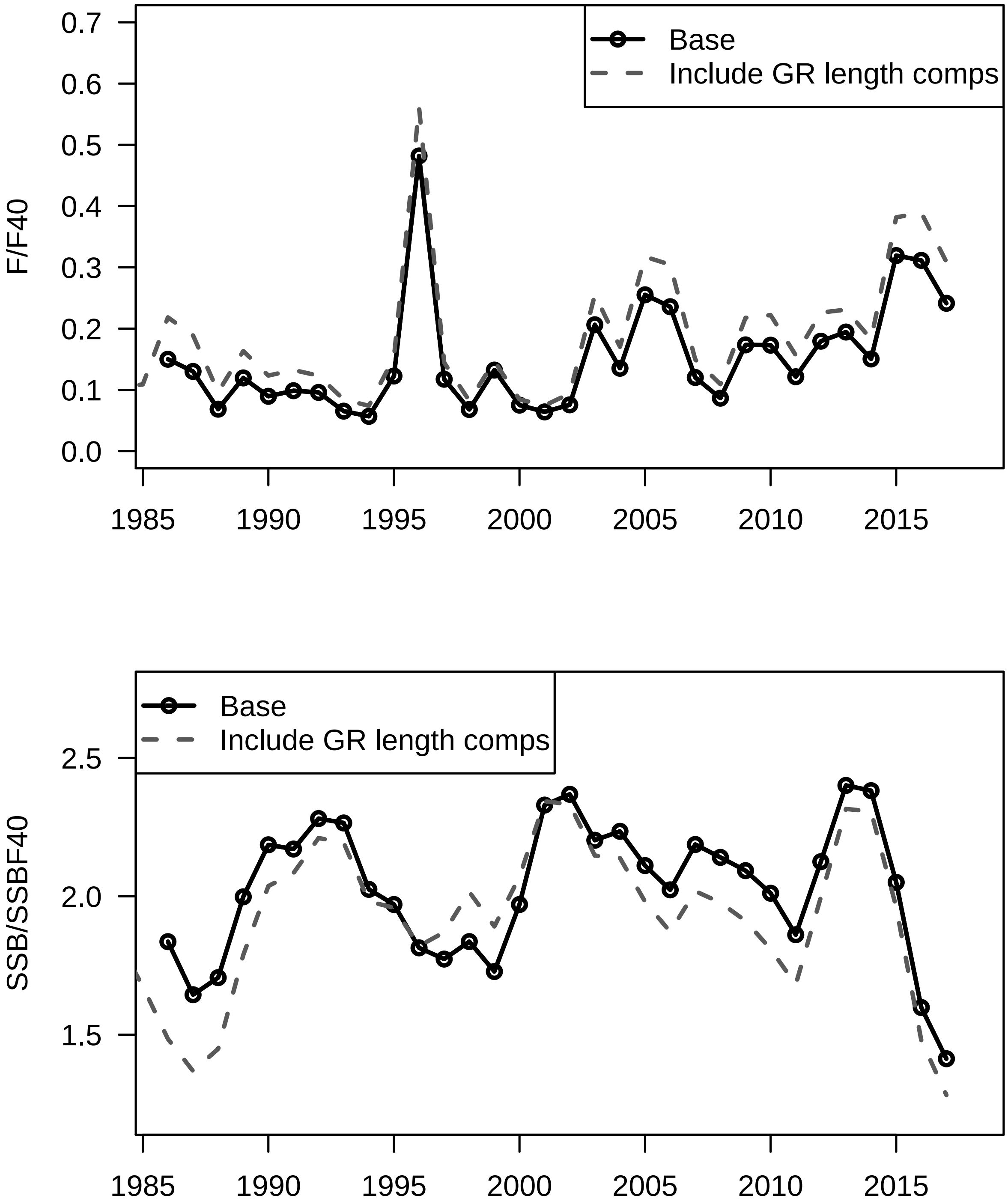


Figure 27. Sensitivity to SEDAR 28 life history values (sensitivity runs S3a-e). Top panel: Ratio of F *to* $F_{40\%}$. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F}40\%}$.

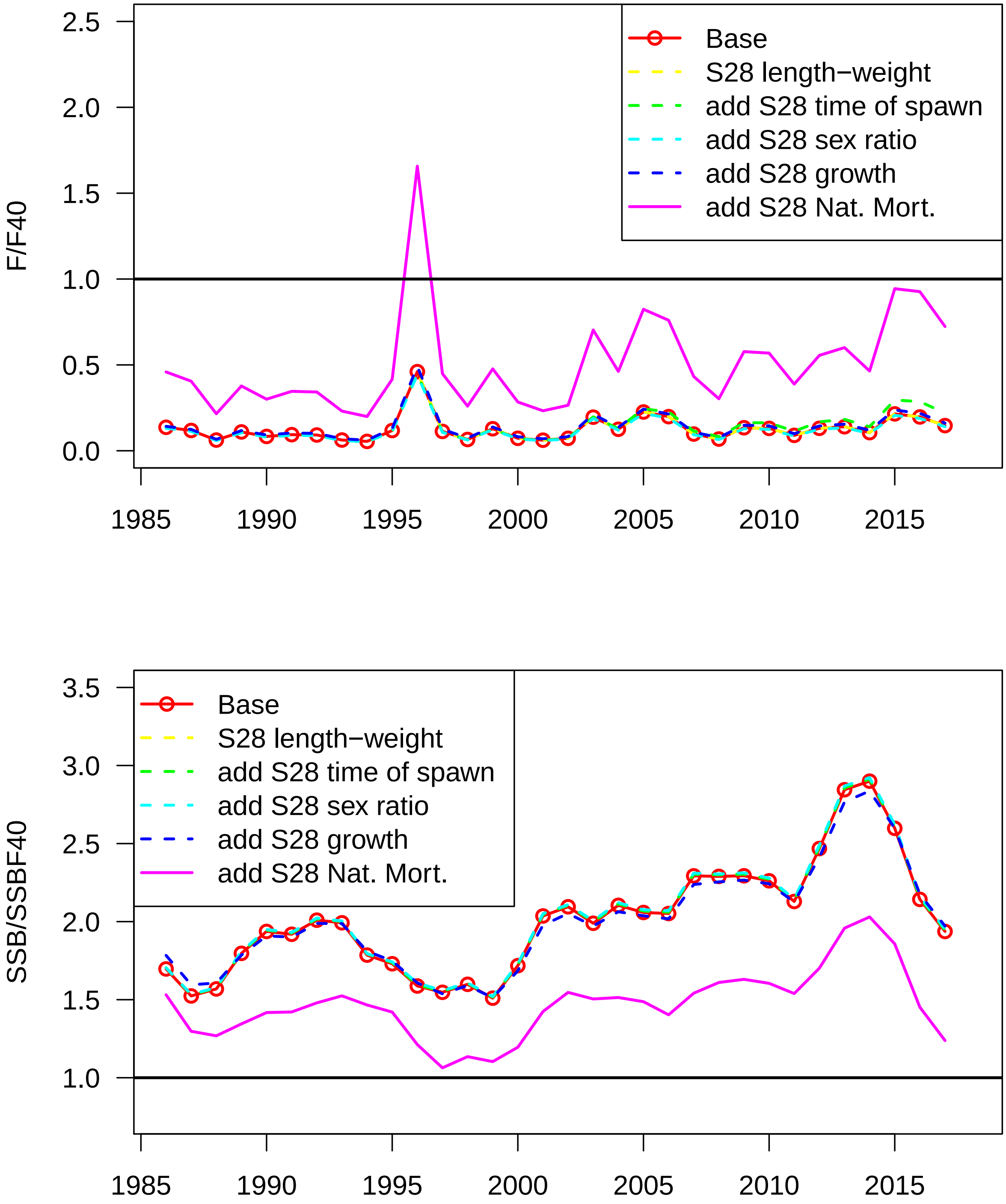


Figure 28. Sensitivity to including the headboat index (sensitivity run S4). Top panel: Ratio of F to $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $\text{SSB}_{\text{F40\%}}$.

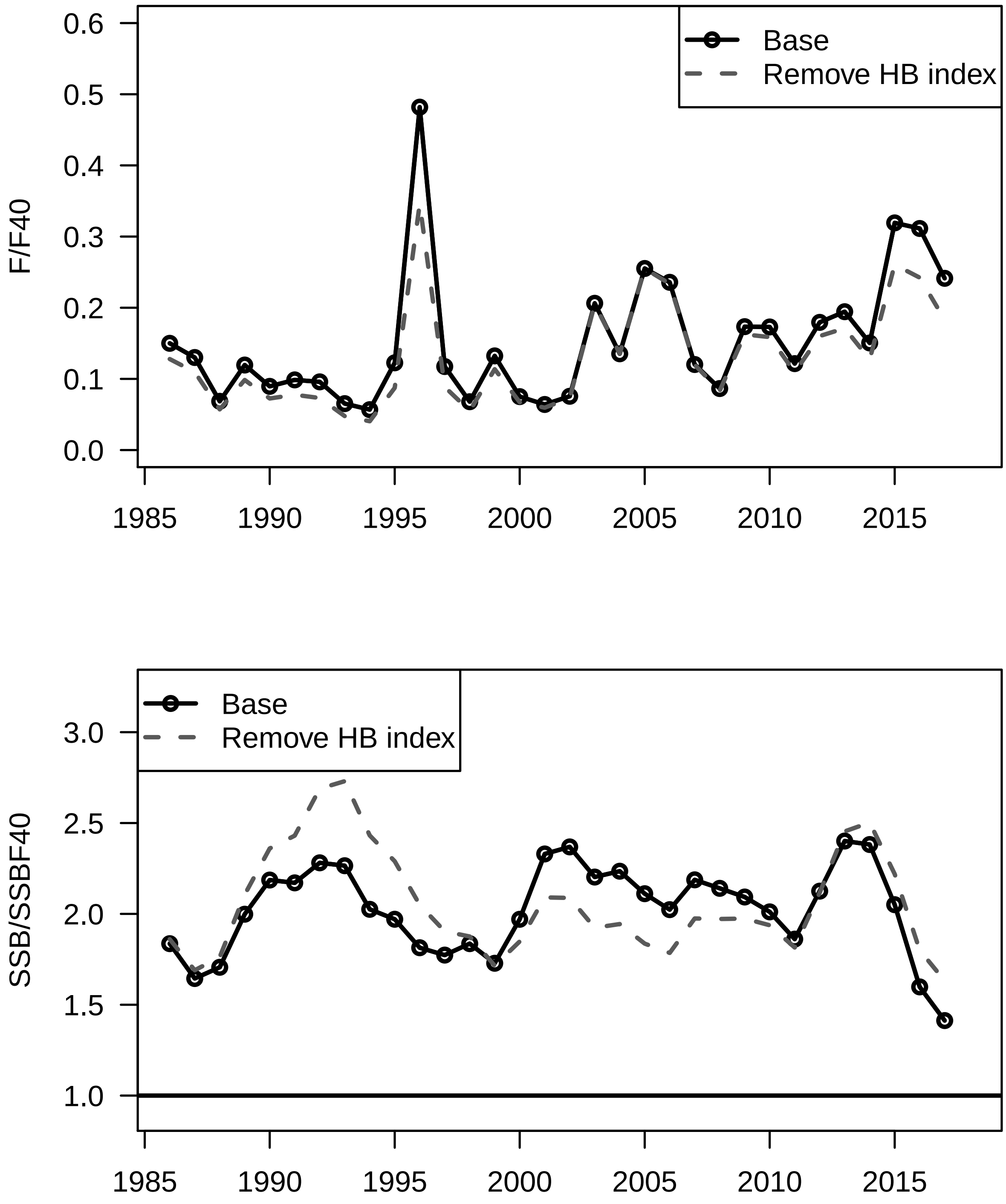


Figure 29. Sensitivity to smoothing the general recreational peaks (sensitivity run S5). Top panel: Ratio of F *to* $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.

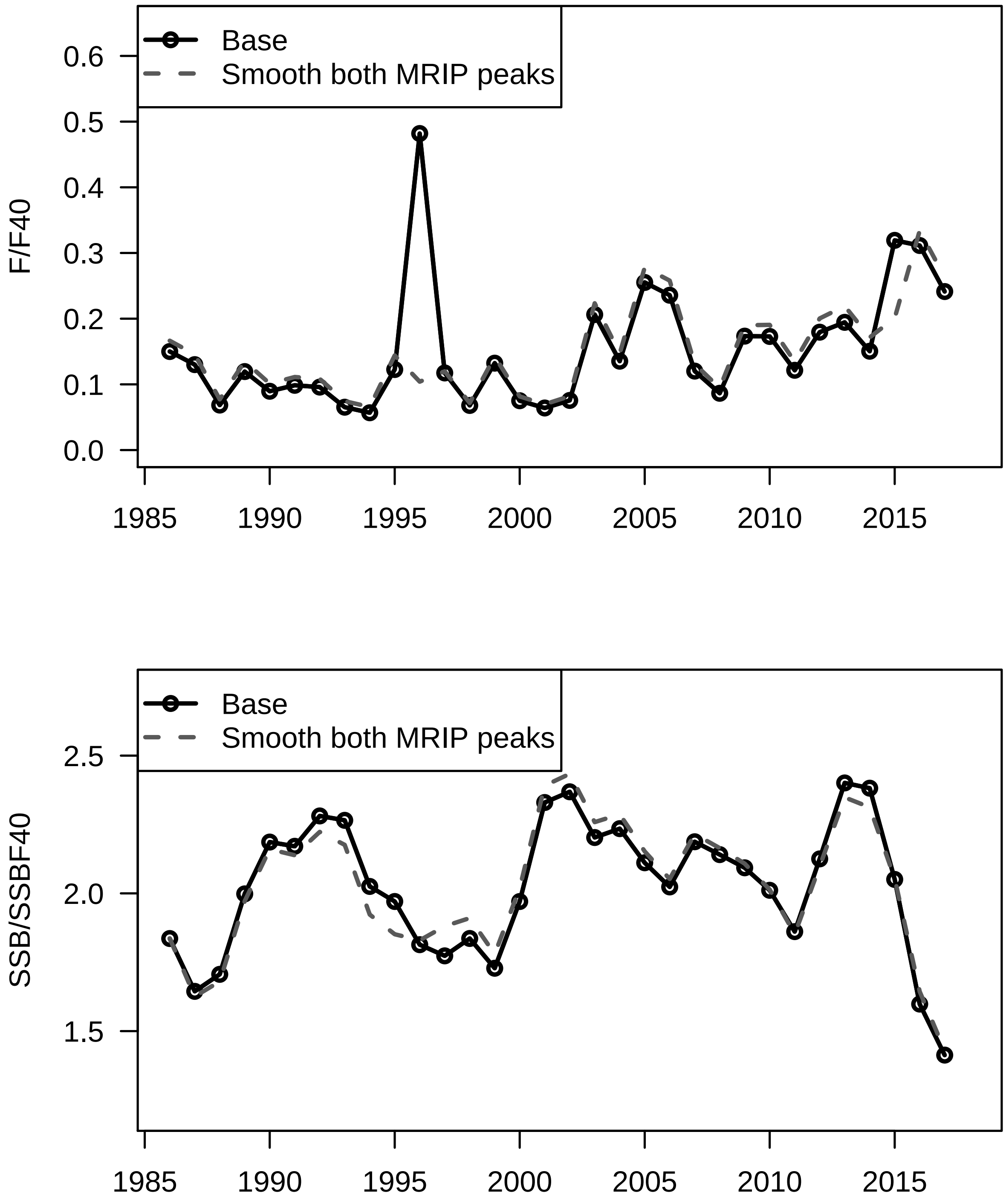


Figure 30. Sensitivity to higher and lower recreational landings (sensitivity runs S6 and S10). Top panel: Ratio of F *to* $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$*. Any lines not visible overlap results of the base run.*

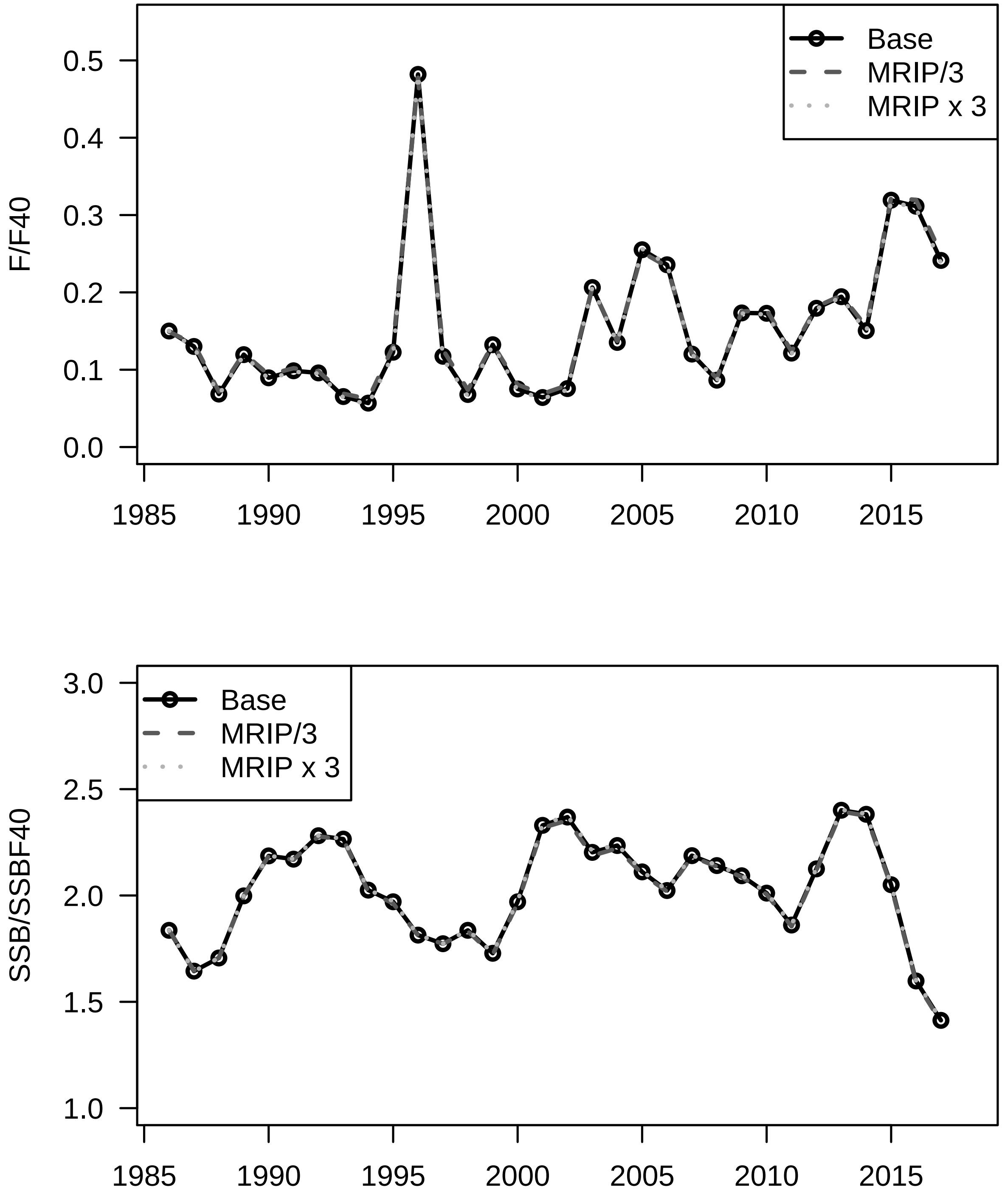


Figure 31. Sensitivity to changes in natural mortality (sensitivity runs S7b–S8b). Top panel: Ratio of F to $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.

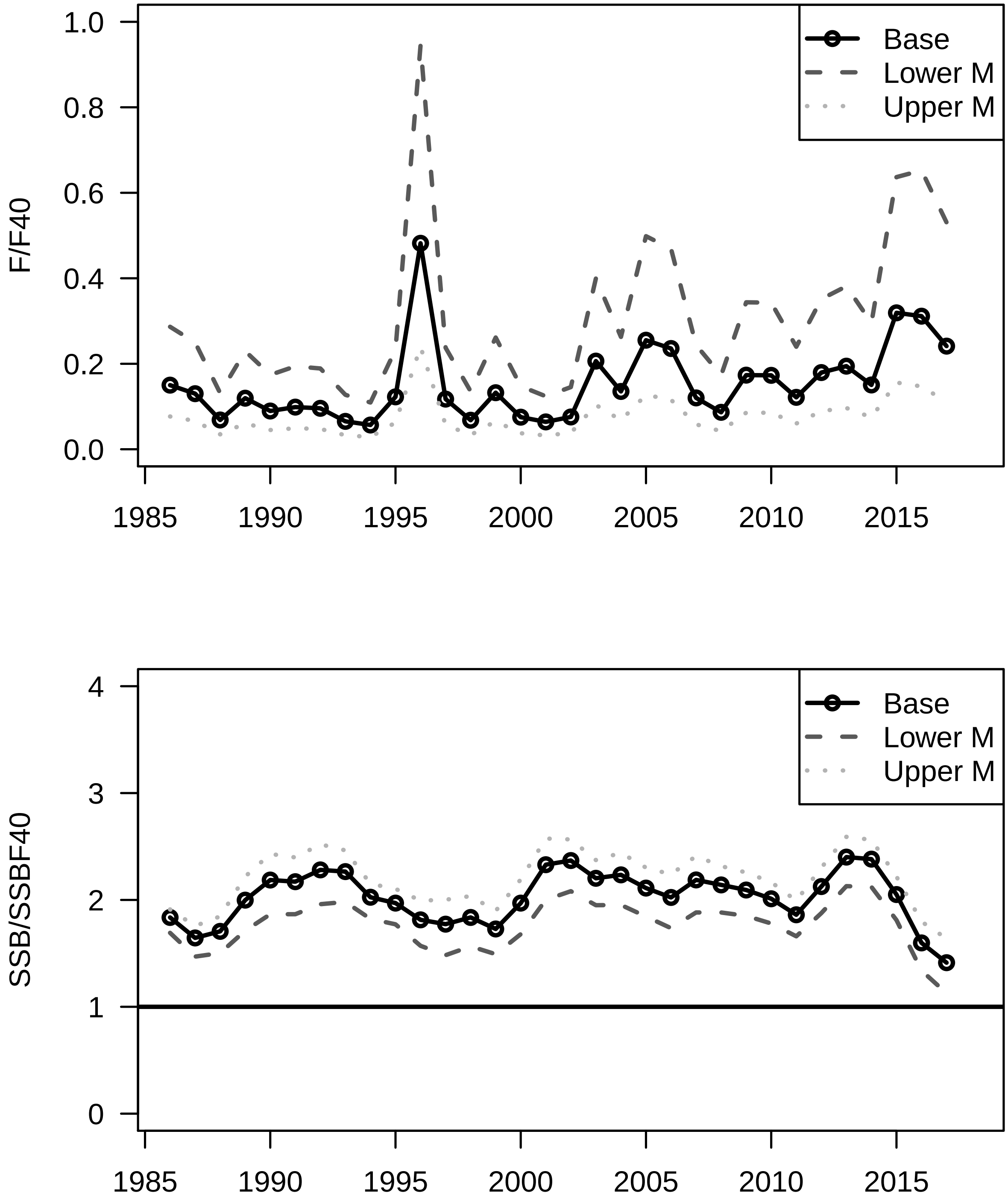


Figure 32. Individual sensitivity comparison of the parameters values provided to the ensemble model. This variation contains the upper and lower bounds for landings, discards, and discard mortality. (sensitivity run S7a–c and S8a–c). Top panel: Ratio of F *to* $F_{40\%}$. *Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F40\%}}$.

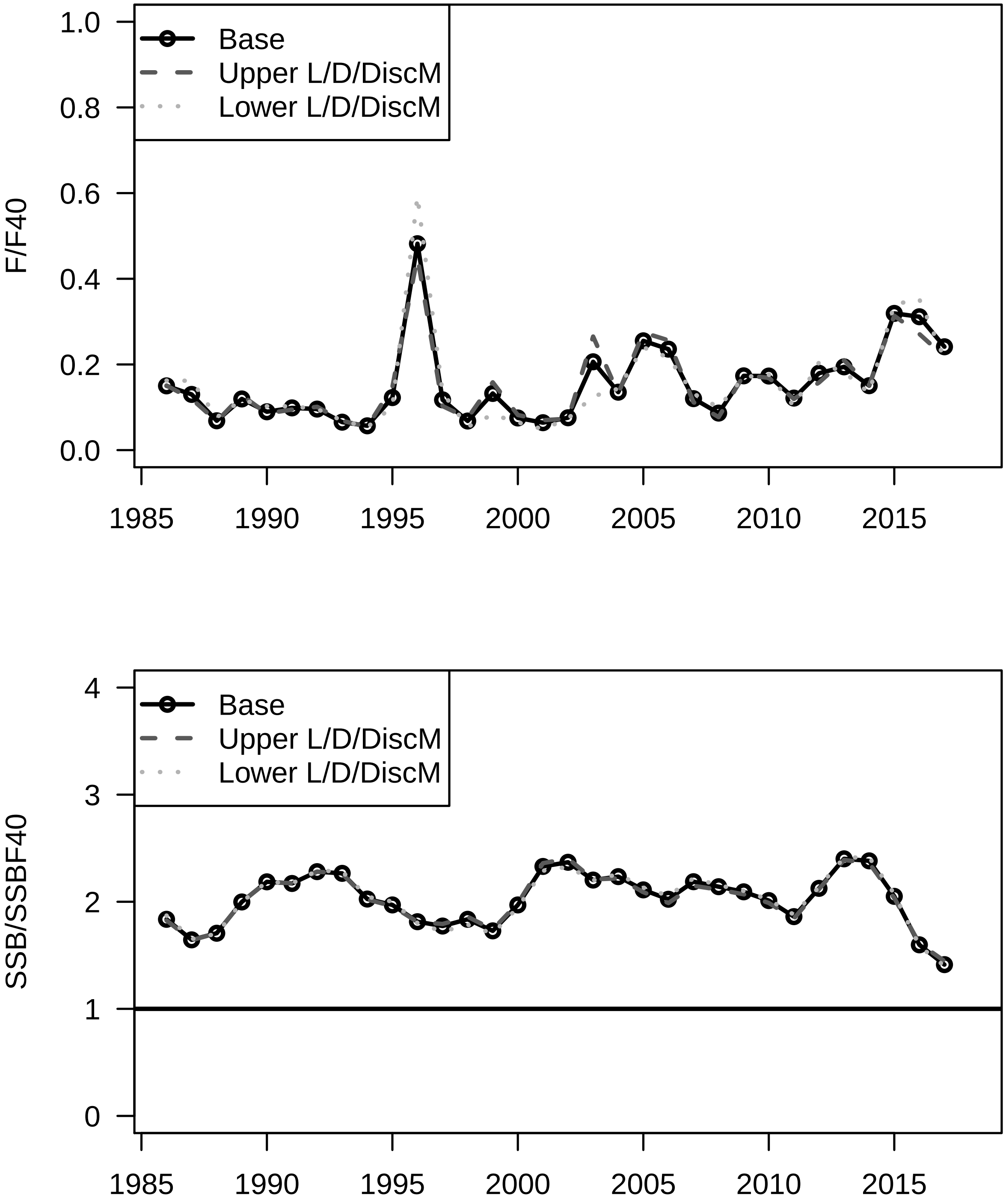


Figure 33. Sensitivity to an alternative maturity schedule (sensitivity runs S12). Top panel: Ratio of F to $F_{40\%}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{F}40\%}$.

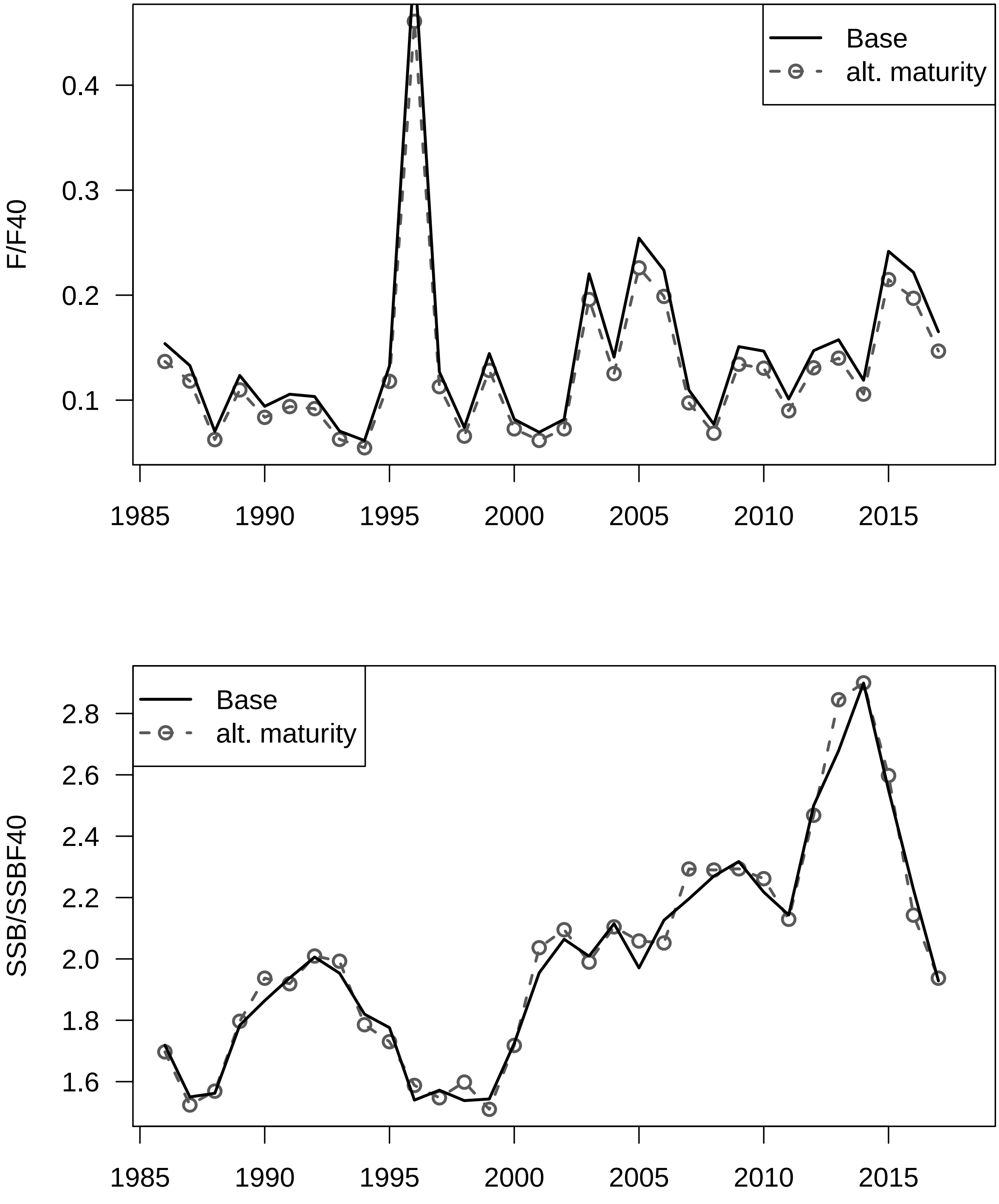


Figure 34. Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model.

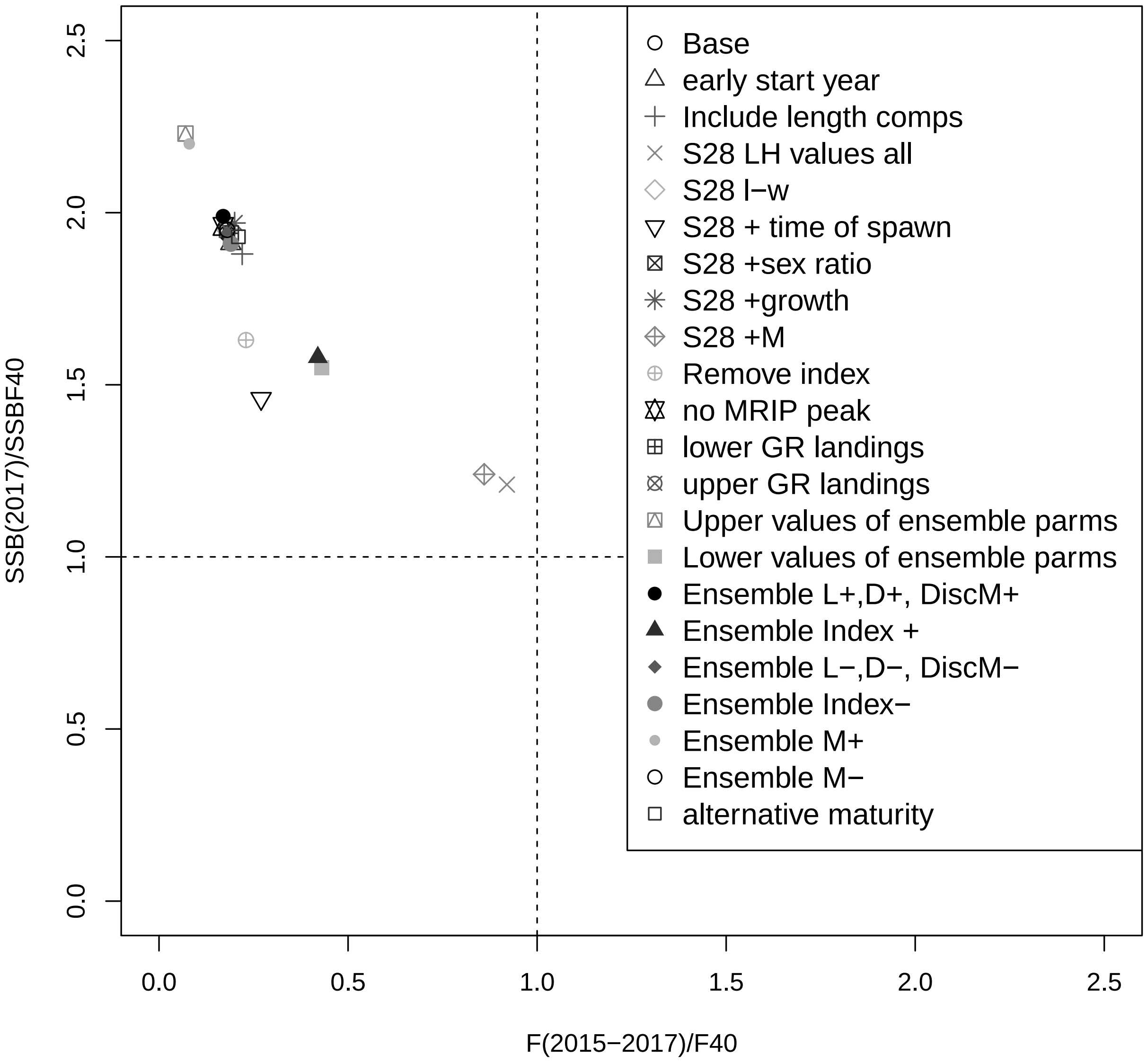


Figure 35. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S9a–e). Top panel: Recruits. Bottom panel: Spawning biomass. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

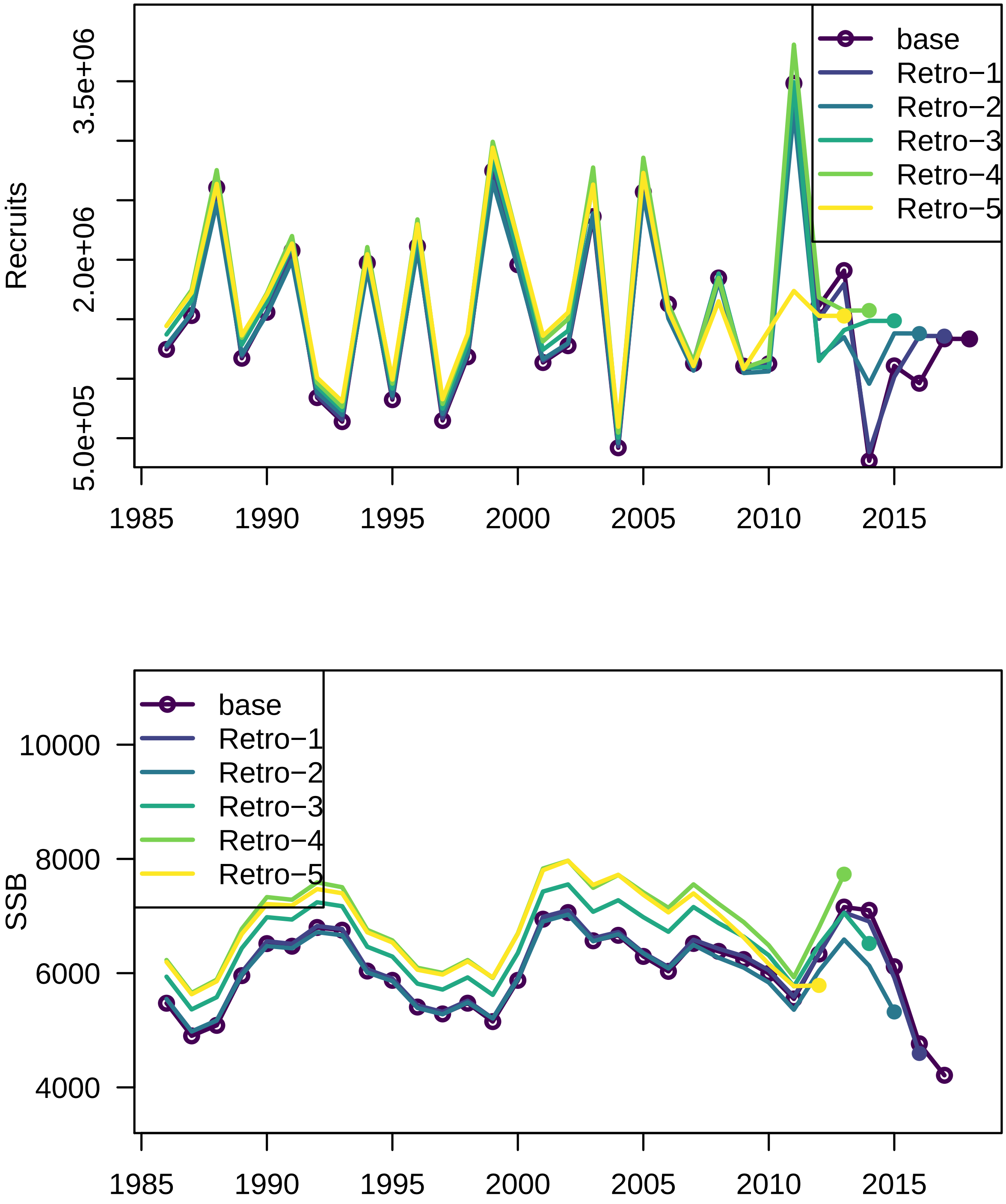


Figure 36. Retrospective status analyses. Sensitivity to terminal year of data (sensitivity runs S9a–e). Top panel: Fishing status. Bottom panel: Biomass status. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

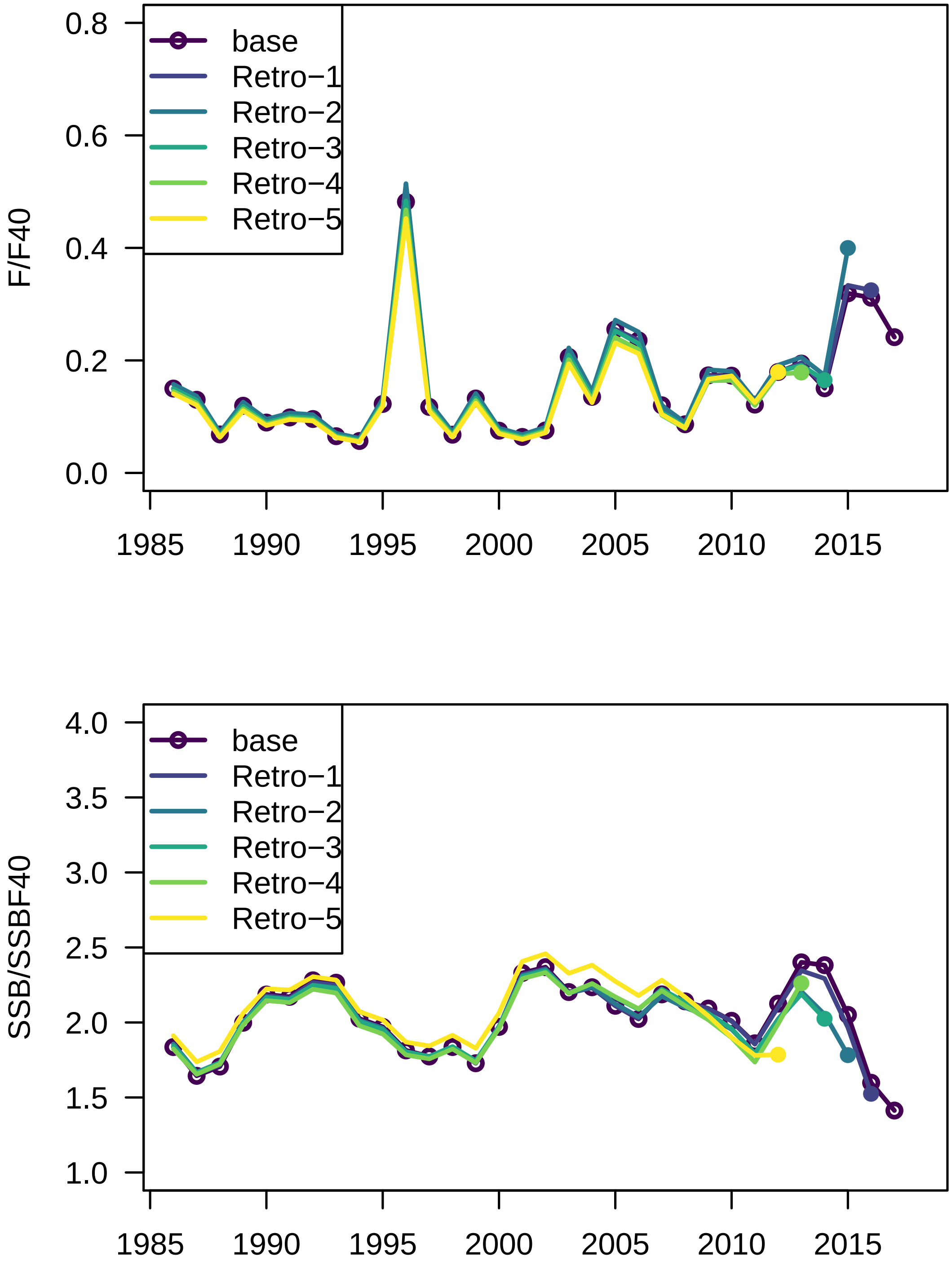


Figure 37. Projection results under scenario 1—fishing mortality rate fixed at F_{current}*, with 2020 as the first year of new regulations. The interim years (2018–2019) use a mean of the 2014–2017 landings. In all panels, expected values represented by solid lines, median values represented by dashed lines, and uncertainty represented by thin lines corresponding to* 5^{th} *and* 95^{th} *percentiles of replicate projections. Horizontal lines mark* $L_{\mathrm{F40\%}}$*-related quantities from the base run (solid blue lines) and medians from the MCB runs(dashed green lines). Spawning stock (SSB) is at time of peak spawning.*

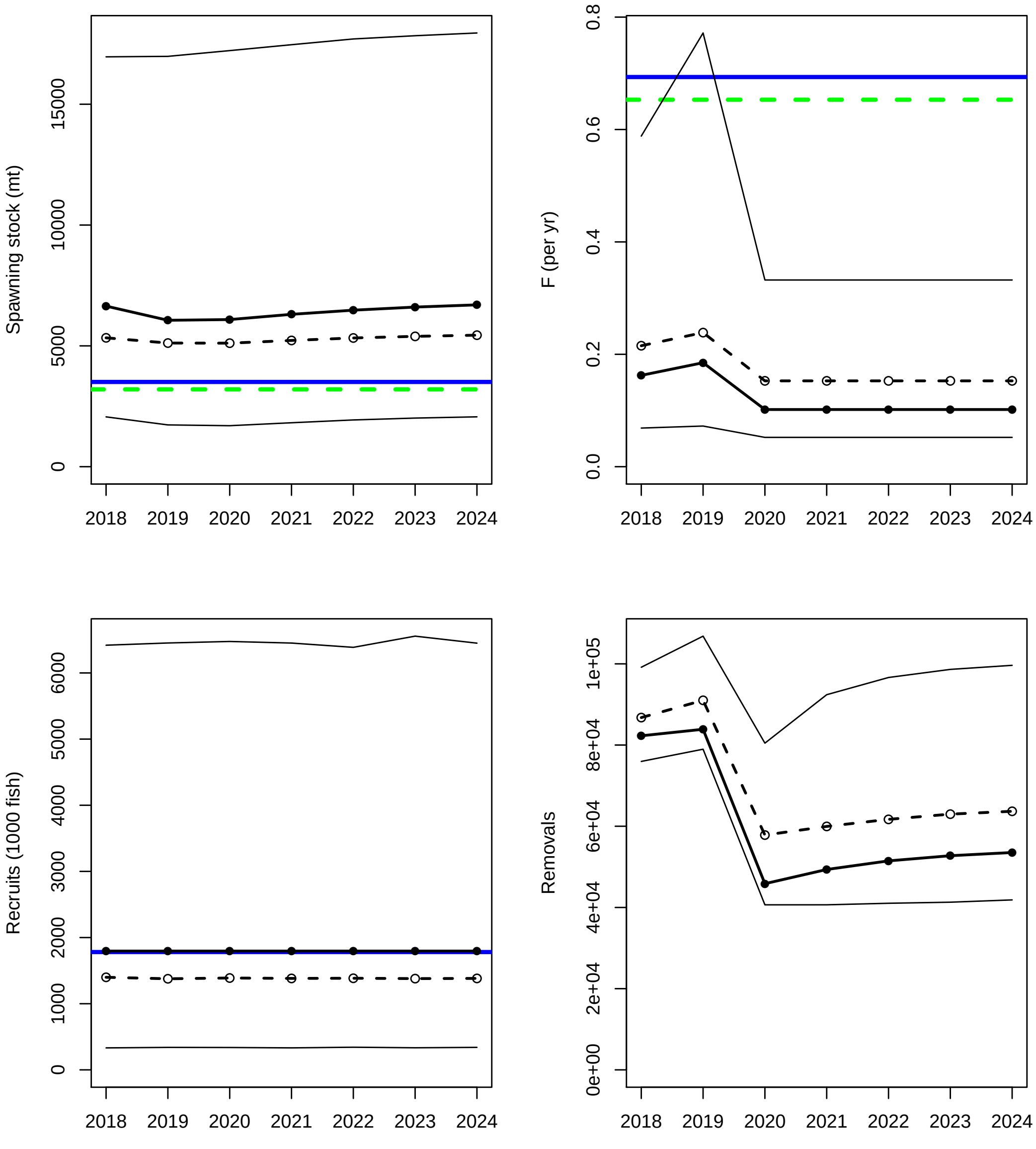


Figure 38. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{40\%}$*, with 2020 as the first year of new regulations. The interim years (2018–2019) use a mean of the 2014–2017 landings. In all panels, expected values represented by solid lines, median values represented by dashed lines, and uncertainty represented by thin lines corresponding to* 5^{th} *and* 95^{th} *percentiles of replicate projections. Horizontal lines mark* $L_{\mathrm{F}40\%}$*-related quantities from the base run (solid blue lines) and medians from the MCB runs(dashed green lines). Spawning stock (SSB) is at time of peak spawning.*

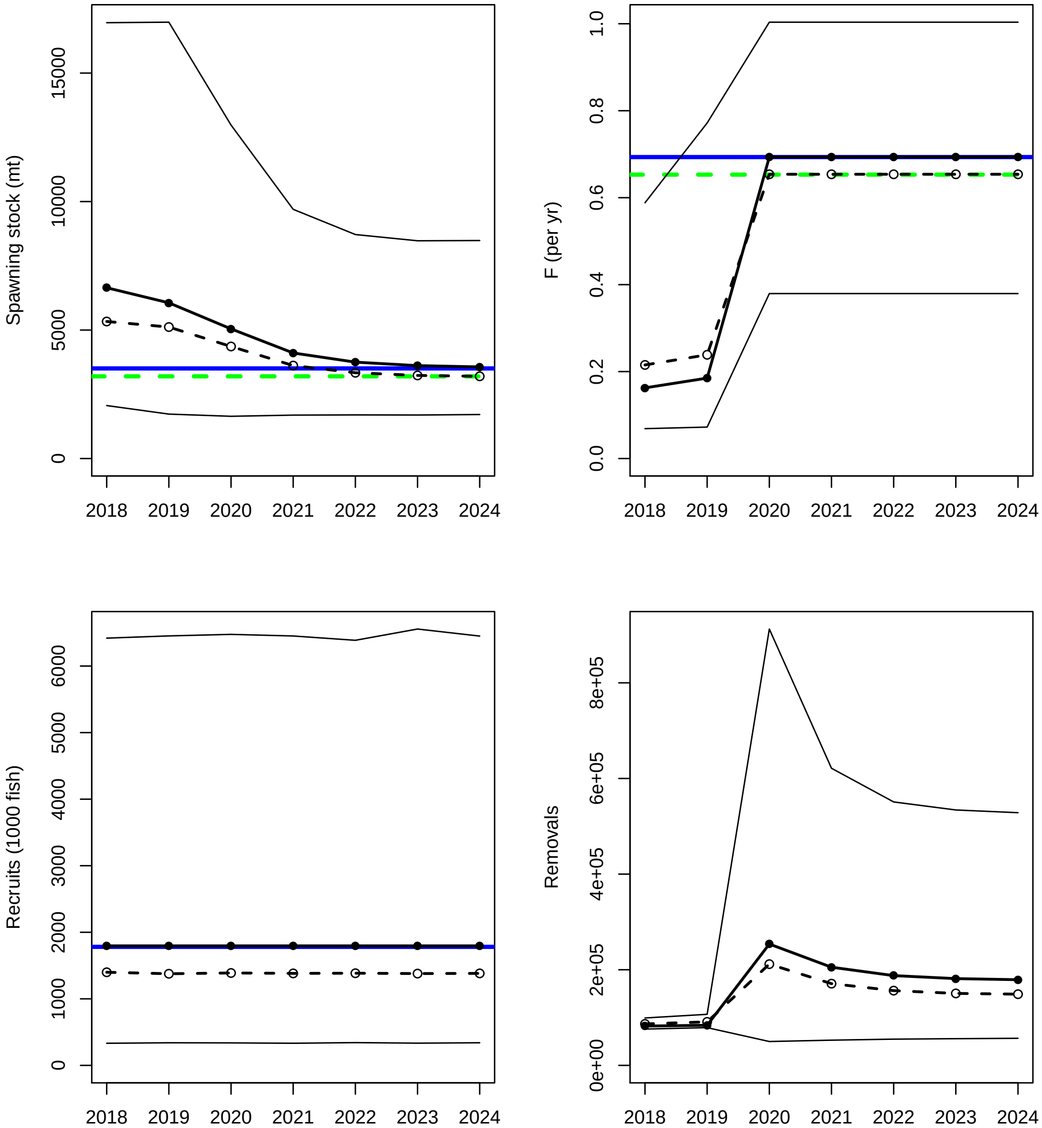


Figure 39. Projection results under scenario 3—fishing mortality rate fixed at $F = 75\% F_{40\%}$*, with 2020 as the first year of new regulations. The interim years (2018–2019) use a mean of the 2014–2017 landings. In all panels, expected values represented by solid lines, median values represented by dashed lines, and uncertainty represented by thin lines corresponding to* 5^{th} *and* 95^{th} *percentiles of replicate projections. Horizontal lines mark* $L_{\mathrm{F}40\%}$*-related quantities from the base run (solid blue lines) and medians from the MCB runs(dashed green lines). Spawning stock (SSB) is at time of peak spawning.*

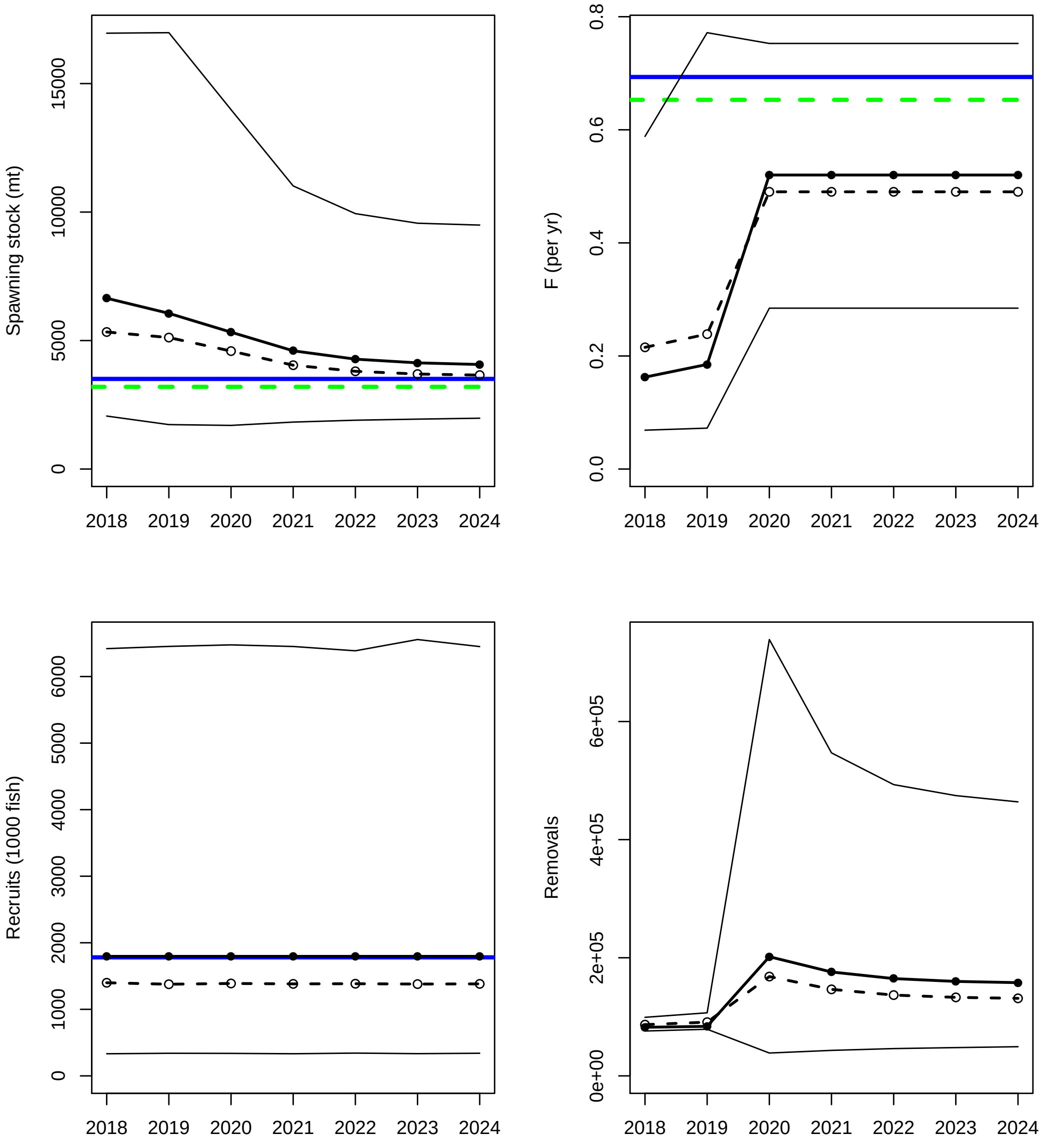


Figure 40. Comparing benchmark time series from current and last assessment. Solid line represents the base run of the current benchmark assessment and the dashed line represents the base run from the last assessment. Top panel: The biomass status time series. Bottom panel: The fishing status time series. The current benchmark assessment used $F_{40\%}$ *as an MSY proxy, while the last assessment benchmarks are relative to MSY.*

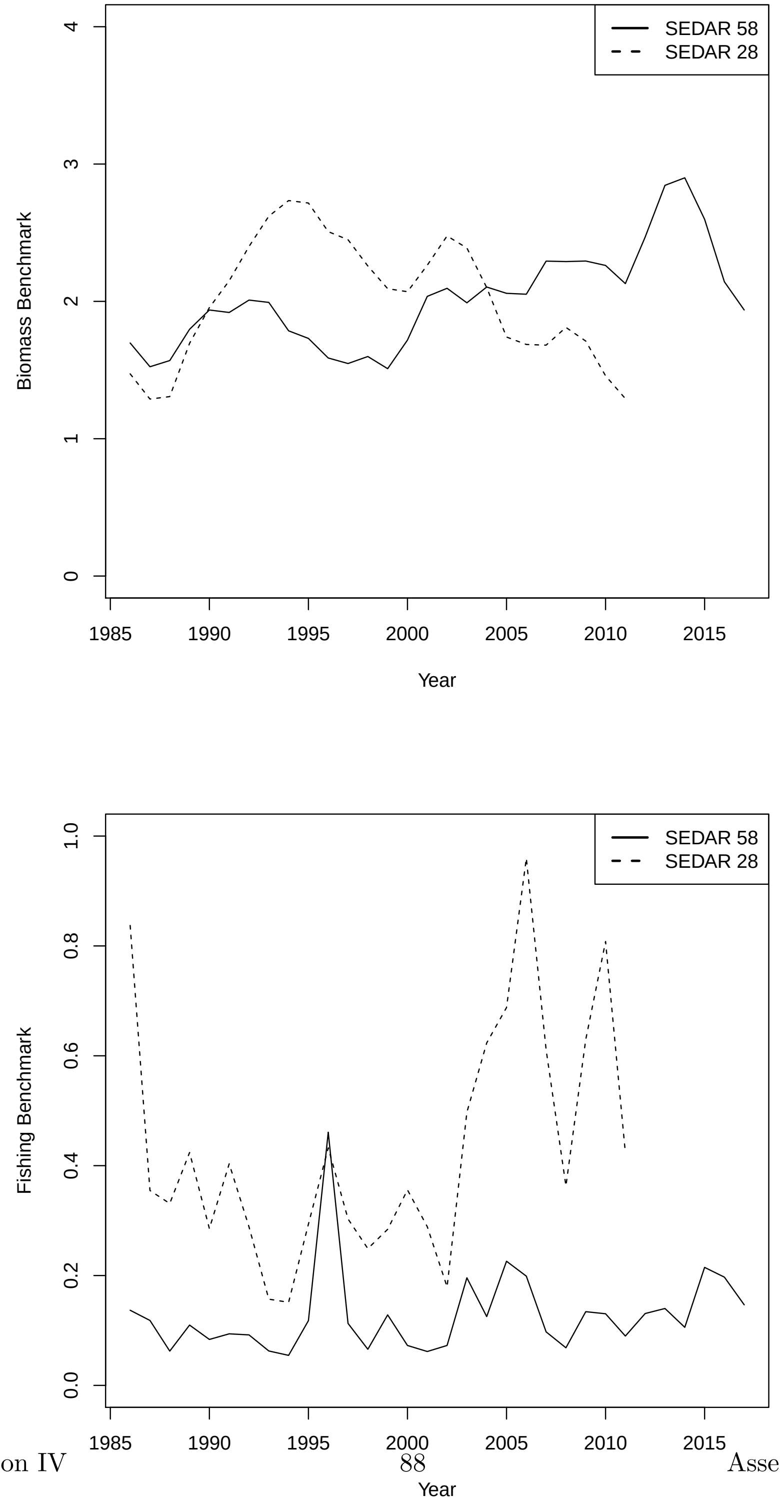
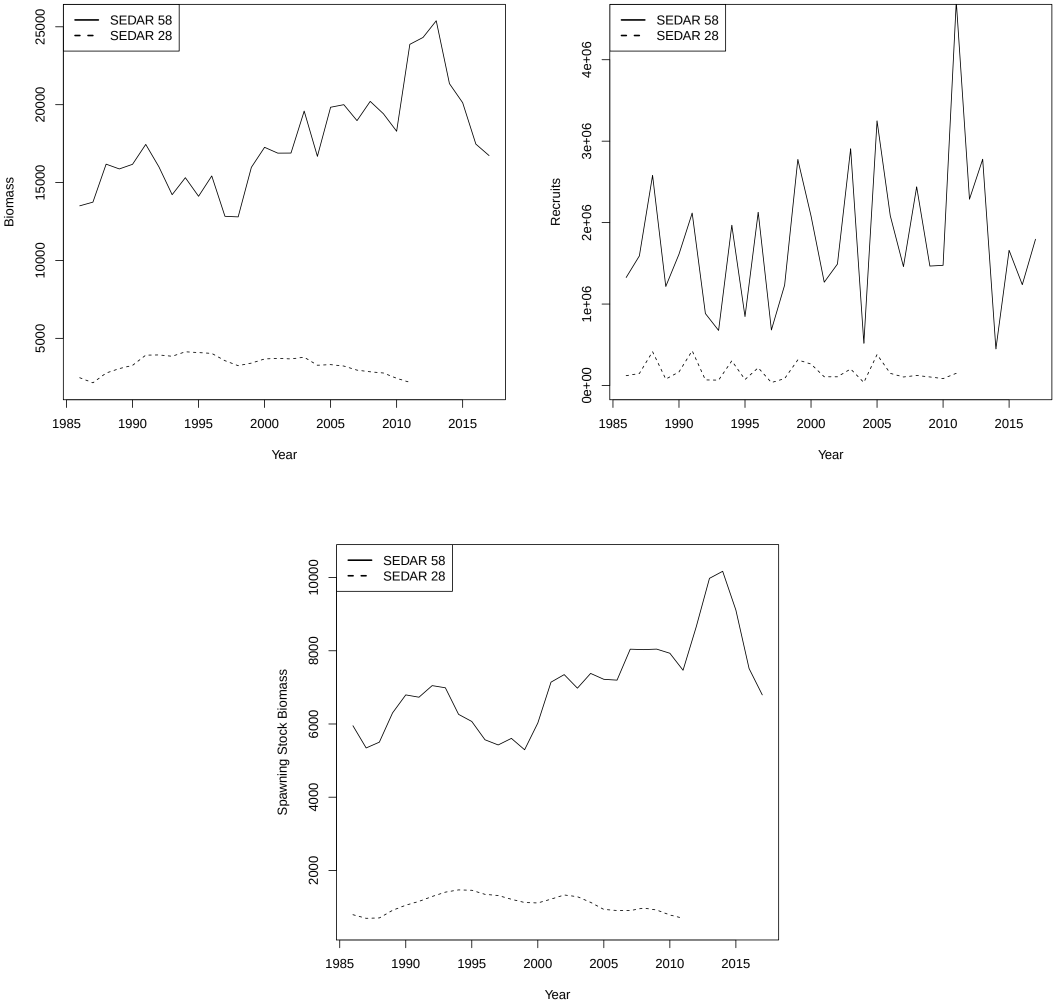


Figure 41. Comparing biological time series from current and last assessment. Solid line represents the base run of the current benchmark assessment and the dashed line represents the base run from the last assessment. Top left panel: The biomass time series. Top right panel: The recruits time series. Bottom panel: The spawning stock biomass time series.



Appendix A Abbreviations and symbols

Table 21. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for cobia)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1r
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 cobia)
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
MCB	Monte Carlo/Bootstrap, 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 cobia as $(1 - M)\text{SSB}_{\text{MSY}} = 0.7\text{SSB}_{\text{MSY}}$.
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
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
SSB_{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)

Appendix B Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 125  Objective function value = 13081.0  Maximum gradient component = 3.71966e-005
# Linf:
1262.00000000
# K:
0.310000000000
# t0:
-0.530000000000
# len_cv_val:
0.116000000000
# Linf_L:
1287.00000000
# K_L:
0.260000000000
# t0_L:
-1.74000000000
# len_cv_val_L:
0.245818304825
# Linf_F:
1334.00000000
# K_F:
0.320000000000
# t0_F:
-0.500000000000
# len_cv_val_F:
0.0820000000000
# log_Nage_dev:
 -0.654606338343 -0.441705938715 -0.619957311353 0.176467046709 0.339404359345 -0.656543149543 -0.206782890707
 -0.0840897095860 -0.513959621286 -0.414635309252 -0.329974414368 -0.258789190181 -0.200518485752 -0.153648100868
 -0.343450521296
# log_R0:
14.2595966272
# steep:
0.990000000000
# rec_sigma:
0.531632919938
# R_autocorr:
0.00000000000
# log_rec_dev:
 -0.161932496243 0.0205253511603 0.503706776325 -0.248438173459 0.0333688981026 0.305931790396 -0.568047801597
 -0.835406816529 0.232612759621 -0.610653211406 0.310301391756 -0.827317950002 -0.235267474544 0.576597323894
 0.289006143057 -0.206309975810 -0.0448039037301 0.622943441840 -1.10201589514 0.734229257077 0.290908719265
 -0.0657253518860 0.447539090944 -0.0612092267582 -0.0550598410519 1.10683518523 0.383511976197 0.577708090873
 -1.24545797456 0.0625324840168 -0.230612587042
# log_dm_comm_lc:
-1.02432279118
# log_dm_GR_ac:
-1.46674441375
# selpar_A50_comm1:
2.82590807557
# selpar_slope_comm1:
1.91389775589
# selpar_A50_GR1:
4.00896043328
# selpar_slope_GR1:
1.84230846787
# selpar_A50_GR2:
3.06054251474
# selpar_slope_GR2:
3.71958042115
# log_q_HB:
-12.9183541549
# log_avg_F_comm:
-6.07314681773
# log_F_dev_comm:
 -0.424069815234 0.135797947850 -0.216544352021 -0.133787336457 0.0435327739423 -0.00955281294585 -0.214978379226
 -0.131867283604 0.0833504793268 0.532828030995 0.555213745278 0.627229754565 0.200520044140 -0.264880706964
 0.162002846803 -0.00550720158837 -0.0367627593564 -0.169361776664 -0.187492099025 -0.472726076068 -0.273336756815
  -0.399168892170 -0.398993439407 -0.0742960074569 0.145063909500 -0.336327178662 -0.121858601971 -0.101247872650
  0.103846413447 0.369578318374 0.591669551699 0.422125532362
# log_avg_F_GR:
-2.57187349680
# log_F_dev_GR:
 0.200503557442 0.0378909967745 -0.611845664864 -0.0301237470240 -0.317811086908 -0.195665551427 -0.210585874736
  -0.611835804826 -0.769342704285 0.0187052190295 1.41841397805 -0.0328960856420 -0.580030482082 0.132723076871
  -0.471309715880 -0.634965404137 -0.460862395590 0.560945162946 0.106221150008 0.709479170126 0.577734731641
  -0.145984434067 -0.508972871794 0.174024726979 0.138884783626 -0.230930697233 0.149279159448 0.218034114960
  -0.0767711988528 0.645291772347 0.550443945020 0.251358174081
# F_init:
0.00506529251796
```

Appendix C Beaufort Assessment Model code for Cobia

```
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##
//##  SEDAR 58  SA Cobia, 2019
//##  (Modified from: SEDAR 50  SA BLT assessment model, 2017)
//##  NMFS, Beaufort Lab, Sustainable Fisheries Branch
//##
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
DATA_SECTION

!!cout << "Starting Beaufort Assessment Model" << endl;
!!cout << endl;
!!cout << "                BAM!" << endl;
!!cout << endl;

//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//-- BAM DATA_SECTION: set-up section
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>

// Starting and ending years of the model (year data starts)
init_int styr;
init_int endyr;

// Starting and ending years to estimate recruitment deviations from S-R curve
init_int styr_rec_dev;
init_int endyr_rec_dev;
// Ending years of 3 phases of constraints on recruitment deviations
// (allows possible heavier constraint (weights defined later) in early and late period, with lighter constraint in the middle)
init_int endyr_rec_phase1;
init_int endyr_rec_phase2;
// ending years of selectivity block 1
//init_int endyr_selex_phase1_comm; // comm
init_int endyr_selex_phase1_GR; // GR
// ending years of selectivity block 2
//init_int endyr_selex_phase2_comm; // comm
//init_int endyr_selex_phase2_cL; // cL
//init_int endyr_selex_phase2_GR; // GR

//number assessment years
number nyrs;
number nyrs_rec;

//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   nyrs=endyr-styr+1.;
   nyrs_rec=endyr_rec_dev-styr_rec_dev+1.;
 END_CALCS

// Number of ages in population model(classes are 1,...,N+; assumes last age is plus group
init_int nages;
// Vector of ages for age bins in population model, last is a plus group
init_vector agebins(1,nages);

//Total number of ages used to match age comps: plus group may differ from popn, first age must not
init_int nages_agec;

//Vector of ages for age bins in age comps
init_vector agebins_agec(1,nages_agec);

// Number length bins used to match length comps and width of bins (mm)
init_int nlenbins;          //used to match data
init_number lenbins_width;  //width of length bins (mm)

// Vector of length bins (mm; midpoint of bin) used to match length comps and bins used to compute plus group
init_vector lenbins(1,nlenbins);

// Max value of F used in spr and msy calculations
init_number max_F_spr_msy;
// Number of iterations in spr calculations
init_int n_iter_spr;
//Total number of iterations for msy calcs
int n_iter_msy;
 LOCAL_CALCS
n_iter_msy=n_iter_spr;
 END_CALCS

// Starting and ending years to compute arithmetic average recruitment for SPR-related values
init_int styr_rec_spr;
init_int endyr_rec_spr;
//Arithmetic average recruitment for SPR-related values
number nyrs_rec_spr;
 LOCAL_CALCS
   nyrs_rec_spr=endyr_rec_spr-styr_rec_spr+1.;
 END_CALCS


// Number of years at end of time series over which to average sector Fs, for weighted selectivities
init_int selpar_n_yrs_wgted;
// Multiplicative bias correction of recruitment (may set to 1.0 for none or negative to compute from recruitment variance)
init_number set_BiasCor;
```

```
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//-- BAM DATA_SECTION: observed data section
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>

//######################################################################################################
//## Commercial Handline
//######################################################################################################
//## comm ######## INDEX ########
//## comm ## Starting and ending years of CPUE index
//init_int styr_comm_cpue;
//init_int endyr_comm_cpue;
//## comm ## Observed index CPUE and CVs
//init_vector obs_comm_cpue(styr_comm_cpue,endyr_comm_cpue);
//init_vector comm_cpue_cv(styr_comm_cpue,endyr_comm_cpue);

//## comm ######## LANDINGS ########
//## comm ## Starting and ending years of landings (bt50 landings+discards; includes comm and c0 (commercial other))
init_int styr_comm_L;
init_int endyr_comm_L;
//## comm ## Observed landings (1000 lbs) and assumed CVs
init_vector obs_comm_L(styr_comm_L,endyr_comm_L);
init_vector comm_L_cv(styr_comm_L,endyr_comm_L);

//## comm ######## LENGTH COMPS ########
//## comm ## Number and vector of years of length compositions to be pooled
init_int nyr_comm_lenc_pool;
init_ivector yrs_comm_lenc_pool(1,nyr_comm_lenc_pool);
//# Annual sample size (nfish) of length comp data; used to weight years for pooling
init_vector nfish_comm_lenc_pool(1,nyr_comm_lenc_pool);
//## comm ## Number and vector of years of length compositions, after pooling
init_int nyr_comm_lenc;
init_ivector yrs_comm_lenc(1,nyr_comm_lenc);
//## comm ## Sample size of length comp data (first row observed n.trips, second row n.fish)
init_vector nsamp_comm_lenc(1,nyr_comm_lenc);
init_vector nfish_comm_lenc(1,nyr_comm_lenc);
//## comm ## Observed length comps (3cm bins; proportions by year)
init_matrix obs_comm_lenc(1,nyr_comm_lenc,1,nlenbins);

//######################################################################################################
//## Recreational Headboat
//######################################################################################################
//## HB ######## INDEX ########
//## HB ## Starting and ending years of CPUE index
init_int styr_HB_cpue;
init_int endyr_HB_cpue;
//## HB ## Observed index CPUE and CVs
init_vector obs_HB_cpue(styr_HB_cpue,endyr_HB_cpue);//Observed CPUE
init_vector HB_cpue_cv(styr_HB_cpue,endyr_HB_cpue); //CV of cpue

//######################################################################################################
//## General Recreational
//######################################################################################################
//## GR ######## LANDINGS ########
//## GR ## Starting and ending years of landings (bt50 landings+discards)
init_int styr_GR_L;
init_int endyr_GR_L;
//## GR ## Observed landings (1000 lbs) and assumed CVs
init_vector obs_GR_L(styr_GR_L,endyr_GR_L);   //vector of observed landings by year
init_vector GR_L_cv(styr_GR_L,endyr_GR_L);    //vector of CV of landings by year

//## GR ######## LENGTH COMPS ########
//## GR ## Number and vector of years of length compositions
//init_int nyr_GR_lenc;
//init_ivector yrs_GR_lenc(1,nyr_GR_lenc);
//## GR ## Sample size of length comp data (first row observed n.trips, second row n.fish)
//nit_vector nsamp_GR_lenc(1,nyr_GR_lenc);
//init_vector nfish_GR_lenc(1,nyr_GR_lenc);
//## GR ## Observed length comps (3cm bins; proportions by year)
//init_matrix obs_GR_lenc(1,nyr_GR_lenc,1,nlenbins);

//  Age compositions
init_int nyr_GR_agec;
init_ivector yrs_GR_agec(1,nyr_GR_agec);
init_vector nsamp_GR_agec(1,nyr_GR_agec);
init_vector nfish_GR_agec(1,nyr_GR_agec);
init_matrix obs_GR_agec(1,nyr_GR_agec,1,nages_agec);

//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//-- BAM DATA_SECTION: parameter section
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//######################################################################################################
//## Parameter values and initial guesses
//######################################################################################################
//######## Population ########
init_vector set_Linf(1,7); // VonBert Linf (mmFL)
init_vector set_K(1,7); // VonBert K
init_vector set_t0(1,7); // VonBert t0
init_vector set_len_cv(1,7); // CV of length at age
//########Landings growth curve
init_vector set_Linf_L(1,7);            // VonBert Linf (mmFL)
init_vector set_K_L(1,7);               // VonBert K
init_vector set_t0_L(1,7);              // VonBert t0
init_vector set_len_cv_L(1,7);          // CV of length at age
//########Female only growth curve (popl and landings)
```

```
init_vector set_Linf_F(1,7);            // VonBert Linf (mmFL)
init_vector set_K_F(1,7);               // VonBert K
init_vector set_t0_F(1,7);              // VonBert t0
init_vector set_len_cv_F(1,7);          // CV of length at age
//######## Constant M ########
init_vector set_M_constant(1,7); // constant M (used only to compute MSST=(1-M)SSBmsy)
//######## StockRecruitment ########
init_vector set_steep(1,7);          // SR steepness parameter
init_vector set_log_R0(1,7);         // SR log_R0 parameter
init_vector set_R_autocorr(1,7);     // SR recruitment autocorrelation (lag 1)
init_vector set_rec_sigma(1,7);      // standard deviation of recruitment in log space
//######## DirichletMultinomial ########
init_vector set_log_dm_comm_lc(1,7);   // Dirichlet-multinomial overdispersion parameter (log-space): comm length comps
//init_vector set_log_dm_cL_lc(1,7);  // Dirichlet-multinomial overdispersion parameter (log-space): cL length comps
//init_vector set_log_dm_HB_lc(1,7);   // Dirichlet-multinomial overdispersion parameter (log-space): HB length comps
//init_vector set_log_dm_GR_lc(1,7);   // Dirichlet-multinomial overdispersion parameter (log-space): GR length comps
init_vector set_log_dm_GR_ac(1,7);    //Dirichlet-multinomial overdispersion parameter
//######## Selectivity ########
init_vector set_selpar_A50_comm1(1,7); // comm age at 0.5 selectivity
init_vector set_selpar_slope_comm1(1,7); // comm slope of ascending limb
//init_vector set_selpar_A50_comm2(1,7); // comm age at 0.5 selectivity (block 2)
//init_vector set_selpar_slope_comm2(1,7); // comm slope of ascending limb (block 2)
// init_vector set_selpar_A502_comm2(1,7); // comm L502 (block 2)
// init_vector set_selpar_slope2_comm2(1,7); // comm slope of descending limb (block 2)
//init_vector set_selpar_A50_comm3(1,7); // comm age at 0.5 selectivity (block 3)
//init_vector set_selpar_slope_comm3(1,7); // comm slope of ascending limb (block 3)
//init_vector set_selpar_A50_cL1(1,7); // cL age at 0.5 selectivity
//init_vector set_selpar_slope_cL1(1,7); // cL slope of ascending limb
//init_vector set_selpar_A50_cL2(1,7); // cL age at 0.5 selectivity (block 2)
//init_vector set_selpar_slope_cL2(1,7); // cL slope of ascending limb (block 2)
//// init_vector set_selpar_A502_cL2(1,7); // cL L502 (block 2)
//// init_vector set_selpar_slope2_cL2(1,7); // cL slope of descending limb (block 2)
//init_vector set_selpar_A50_cL3(1,7); // cL age at 0.5 selectivity (block 3)
//init_vector set_selpar_slope_cL3(1,7); // cL slope of ascending limb (block 3)
init_vector set_selpar_A50_GR1(1,7);  // GR age at 0.5 selectivity
init_vector set_selpar_slope_GR1(1,7); // GR slope of ascending limb
init_vector set_selpar_A50_GR2(1,7); // GR age at 0.5 selectivity (block 2)
init_vector set_selpar_slope_GR2(1,7); // GR slope of ascending limb (block 2)
// init_vector set_selpar_A502_GR2(1,7); // GR L502 (block 2)
// init_vector set_selpar_slope2_GR2(1,7); // GR slope of descending limb (block 2)
//init_vector set_selpar_A50_GR3(1,7); // GR age at 0.5 selectivity (block 3)
//init_vector set_selpar_slope_GR3(1,7); // GR slope of ascending limb (block 3)
//######## IndexCatchability ########
//init_vector set_log_q_comm(1,7);       // comm CPUE (log q)
//init_vector set_log_q_cL(1,7);       // cL CPUE (log q)
init_vector set_log_q_HB(1,7);       // HB CPUE (log q)
//######## FishingMortality ########
init_vector set_F_init(1,7);   // initial F (not log space)
init_vector set_log_avg_F_comm(1,7); // comm log mean F
//init_vector set_log_avg_F_cL(1,7); // cL log mean F
init_vector set_log_avg_F_GR(1,7); // GR log mean F

//######################################################################################################
//## Dev vectors
//######################################################################################################
init_vector set_log_F_dev_comm(1,3);  // comm F devs
//init_vector set_log_F_dev_cL(1,3); // cL F devs
init_vector set_log_F_dev_GR(1,3); // GR F devs
init_vector set_log_RWq_dev(1,3); // Random walk on q
init_vector set_log_rec_dev(1,3); // recruitment devs
init_vector set_log_Nage_dev(1,3); // Nage devs

//######## F dev initial guesses ########
//## comm (1962 - 2015)
init_vector set_log_F_dev_comm_vals(styr_comm_L,endyr_comm_L);
//## cL (1958 - 2015)
//init_vector set_log_F_dev_cL_vals(styr_cL_L,endyr_cL_L);
// ## GR (1973 - 2015)
init_vector set_log_F_dev_GR_vals(styr_GR_L,endyr_GR_L);

//######## Rec dev initial guesses (1958 - 2015) ########
init_vector set_log_rec_dev_vals(styr_rec_dev,endyr_rec_dev);

//######## initial N age devs, all ages but the first one (2 to 15) ########
init_vector set_log_Nage_dev_vals(2,nages);

//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//-- BAM DATA_SECTION: likelihood weights section
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
init_number set_w_L; // landings

//init_number set_w_I_comm;         // comm index
//init_number set_w_I_cL;         // cL index
init_number set_w_I_HB;         // HB index
init_number set_w_lc_comm;        // comm length comps
//init_number set_w_lc_cL;        // cL length comps
//init_number set_w_lc_GR; // GR length comps
init_number set_w_ac_GR; //weight for the Recreational age comps
init_number set_w_Nage_init;    // log N.age.dev residuals (initial abundance)for fitting initial abundance at age (excluding first age)
init_number set_w_rec;            // SR residuals (for fitting SR curve)
init_number set_w_rec_early;      // constraint on early recruitment deviations
init_number set_w_rec_end;        // constraint on ending recruitment deviations
init_number set_w_fullF;          // penalty if F exceeds 3.0 (reduced by factor of 10 each phase, not applied in final phase of optimization) full F summed over fisheries
init_number set_w_Ftune;          // weight on tuning F (penalty not applied in final phase of optimization)
```

```
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//-- BAM DATA_SECTION: miscellaneous stuff section
//--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>

// Length-weight parameter a (W=aL^b); mm to kg
init_number wgtpar_a;
// Length-weight parameter b (W=aL^b); mm to kg
init_number wgtpar_b;

// Length-batchFecundity parameter a (BF=a + bL); mm to eggs
//init_number batchfecpar_a;
// Length-batchFecundity b (BF=a + bL); mm to eggs
//init_number batchfecpar_b;
// Number of batches spawned per mature female per year
//init_number nbatch;
// Value by which to scale fecundity unit (e.g. 1000000 to diplay fecundity in millions)
//init_number fecpar_scale;

// vector of maturity-at-age for females (ages 1 - 15 )
init_vector maturity_f_obs(1,nages);
// Proportion female by age (assumed 50:50 sex ratio)
init_vector prop_f_obs(1,nages);
// time of year (as fraction) for spawning
init_number spawn_time_frac;
// age-dependent natural mortality at age (ages 1 - 15 )
init_vector set_M(1,nages);

// Spawner-recruit parameters:  SR function switch (integer 1=Beverton-Holt, 2=Ricker)
init_int SR_switch;

// switch for rate increase in q: Integer value (choose estimation phase, negative value turns it off)
init_int set_q_rate_phase;
// annual positive rate of increase on all fishery dependent q's due to technology creep
init_number set_q_rate;

// density dependence on fishery catchability coefficients (DDq) switch: Integer value (choose estimation phase of random walk, negative value turns it off)
init_int set_q_DD_phase;
// q_DD exponent, value of zero is density independent, est range is (0.1,0.9)
init_number set_q_DD_beta;
// SE of q_DD exponent (0.128 provides 95% CI in range 0.5)
init_number set_q_DD_beta_se;
// Age to begin counting q_DD (should be age near full exploitation)
init_int set_q_DD_stage;      //age to begin counting biomass, should be near full exploitation

// Variance (sd^2) of fishery dependent random walk catchabilities (0.03 is near the sd=0.17 of Wilberg and Bence)
init_number set_RWq_var;     //assumed variance of RW q

// Tuning F (not applied in last phase of optimization, or not applied at all if penalty weight=0)
init_number set_Ftune;
// Year for tuning F
init_int set_Ftune_yr;

// threshold sample sizes ntrips (>=)for length comps (set to 99999.0 if sel is fixed):
init_number minSS_comm_lenc; // comm len comps
//init_number minSS_cL_lenc; // cL len comps
// init_number minSS_HB_lenc; // HB len comps (to be removed for bt50)
//init_number minSS_GR_lenc; // GR len comps
//threshold sample sizes for age comps
init_number minSS_GR_agec;

// Input for deterministic F-based projections
// Last year of projections, must be later than assessment endyr by default
init_int endyr_proj; // Projection end year (must be later than assessment endyr)
init_int styr_regs;   // Apply current F until styr_regs, then the projection F
init_int Fproj_switch;  // Switching indicating value to use for defining projection F: 1=Fcurrent, 2=Fmsy, 3=F30, 4=F40
init_number Fproj_mult; // Multiplier 'c' applied to compute projection F, for example Fproj=cFmsy
// Calculate projection start year
int styr_proj;
 LOCAL_CALCS
   styr_proj=endyr+1;
 END_CALCS

// Aging error matrix (columns are true age 1- 15 , rows are ages as read for age comps: columns should sum to one)
init_matrix age_error(1,nages,1,nages);

//------------------------------------<< 999 >>-------------------------------------
// END OF READING IN VALUES FROM .dat file
//------------------------------------<< 999 >>-------------------------------------


// #######Indexing integers for year(iyear), age(iage),length(ilen) ###############
int iyear;
int iage;
int ilen;
int ff;

number sqrt2pi;
number g2mt;                    //conversion of grams to metric tons
number g2kg;                    //conversion of grams to kg
number g2klb;                   //conversion of grams to 1000 lb
number mt2klb;                  //conversion of metric tons to 1000 lb
number mt2lb;                   //conversion of metric tons to lb
number dzero;                   //small additive constant to prevent division by zero
number huge_number;             //huge number, to avoid irregular parameter space
```

```
init_number end_of_data_file;
//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   if(end_of_data_file!=999)
   {
       cout << "*** WARNING: Data File NOT READ CORRECTLY ****" << endl;
       exit(0);
   }
   else
   {cout << "Data File read correctly" << endl;}
 END_CALCS

//##################################################################################################
PARAMETER_SECTION //##################################################################################################
//##################################################################################################

 LOCAL_CALCS
  const double Linf_LO=set_Linf(2); const double Linf_HI=set_Linf(3); const double Linf_PH=set_Linf(4);
  const double K_LO=set_K(2); const double K_HI=set_K(3); const double K_PH=set_K(4);
  const double t0_LO=set_t0(2); const double t0_HI=set_t0(3); const double t0_PH=set_t0(4);
  const double len_cv_LO=set_len_cv(2); const double len_cv_HI=set_len_cv(3); const double len_cv_PH=set_len_cv(4);

  const double Linf_L_LO=set_Linf_L(2); const double Linf_L_HI=set_Linf_L(3); const double Linf_L_PH=set_Linf_L(4);
  const double K_L_LO=set_K_L(2); const double K_L_HI=set_K_L(3); const double K_L_PH=set_K_L(4);
  const double t0_L_LO=set_t0_L(2); const double t0_L_HI=set_t0_L(3); const double t0_L_PH=set_t0_L(4);
  const double len_cv_L_LO=set_len_cv_L(2); const double len_cv_L_HI=set_len_cv_L(3); const double len_cv_L_PH=set_len_cv_L(4);

  const double Linf_F_LO=set_Linf_F(2); const double Linf_F_HI=set_Linf_F(3); const double Linf_F_PH=set_Linf_F(4);
  const double K_F_LO=set_K_F(2); const double K_F_HI=set_K_F(3); const double K_F_PH=set_K_F(4);
  const double t0_F_LO=set_t0_F(2); const double t0_F_HI=set_t0_F(3); const double t0_F_PH=set_t0_F(4);
  const double len_cv_F_LO=set_len_cv_F(2); const double len_cv_F_HI=set_len_cv_F(3); const double len_cv_F_PH=set_len_cv_F(4);

  const double M_constant_LO=set_M_constant(2); const double M_constant_HI=set_M_constant(3); const double M_constant_PH=set_M_constant(4);
  const double steep_LO=set_steep(2); const double steep_HI=set_steep(3); const double steep_PH=set_steep(4);
  const double log_R0_LO=set_log_R0(2); const double log_R0_HI=set_log_R0(3); const double log_R0_PH=set_log_R0(4);
  const double R_autocorr_LO=set_R_autocorr(2); const double R_autocorr_HI=set_R_autocorr(3); const double R_autocorr_PH=set_R_autocorr(4);
  const double rec_sigma_LO=set_rec_sigma(2); const double rec_sigma_HI=set_rec_sigma(3); const double rec_sigma_PH=set_rec_sigma(4);

  const double log_dm_comm_lc_LO=set_log_dm_comm_lc(2); const double log_dm_comm_lc_HI=set_log_dm_comm_lc(3); const double log_dm_comm_lc_PH=set_log_dm_comm_lc(4);
  //const double log_dm_cL_lc_LO=set_log_dm_cL_lc(2); const double log_dm_cL_lc_HI=set_log_dm_cL_lc(3); const double log_dm_cL_lc_PH=set_log_dm_cL_lc(4);
  //const double log_dm_GR_lc_LO=set_log_dm_GR_lc(2); const double log_dm_GR_lc_HI=set_log_dm_GR_lc(3); const double log_dm_GR_lc_PH=set_log_dm_GR_lc(4);
  const double log_dm_GR_ac_LO=set_log_dm_GR_ac(2); const double log_dm_GR_ac_HI=set_log_dm_GR_ac(3); const double log_dm_GR_ac_PH=set_log_dm_GR_ac(4);

  const double selpar_A50_comm1_LO=set_selpar_A50_comm1(2); const double selpar_A50_comm1_HI=set_selpar_A50_comm1(3); const double selpar_A50_comm1_PH=set_selpar_A50_comm1(4);
  const double selpar_slope_comm1_LO=set_selpar_slope_comm1(2); const double selpar_slope_comm1_HI=set_selpar_slope_comm1(3); const double selpar_slope_comm1_PH=set_selpar_slope_comm1(4);
  //const double selpar_A50_comm2_LO=set_selpar_A50_comm2(2); const double selpar_A50_comm2_HI=set_selpar_A50_comm2(3); const double selpar_A50_comm2_PH=set_selpar_A50_comm2(4);
  //const double selpar_slope_comm2_LO=set_selpar_slope_comm2(2); const double selpar_slope_comm2_HI=set_selpar_slope_comm2(3); const double selpar_slope_comm2_PH=set_selpar_slope_comm2(4);
  // const double selpar_A502_comm2_LO=set_selpar_A502_comm2(2); const double selpar_A502_comm2_HI=set_selpar_A502_comm2(3); const double selpar_A502_comm2_PH=set_selpar_A502_comm2(4);
  // const double selpar_slope2_comm2_LO=set_selpar_slope2_comm2(2); const double selpar_slope2_comm2_HI=set_selpar_slope2_comm2(3); const double selpar_slope2_comm2_PH=set_selpar_slope2_comm2(4);
  //const double selpar_A50_comm3_LO=set_selpar_A50_comm3(2); const double selpar_A50_comm3_HI=set_selpar_A50_comm3(3); const double selpar_A50_comm3_PH=set_selpar_A50_comm3(4);
  //const double selpar_slope_comm3_LO=set_selpar_slope_comm3(2); const double selpar_slope_comm3_HI=set_selpar_slope_comm3(3); const double selpar_slope_comm3_PH=set_selpar_slope_comm3(4);

  const double selpar_A50_GR1_LO=set_selpar_A50_GR1(2); const double selpar_A50_GR1_HI=set_selpar_A50_GR1(3); const double selpar_A50_GR1_PH=set_selpar_A50_GR1(4);
  const double selpar_slope_GR1_LO=set_selpar_slope_GR1(2); const double selpar_slope_GR1_HI=set_selpar_slope_GR1(3); const double selpar_slope_GR1_PH=set_selpar_slope_GR1(4);
  const double selpar_A50_GR2_LO=set_selpar_A50_GR2(2); const double selpar_A50_GR2_HI=set_selpar_A50_GR2(3); const double selpar_A50_GR2_PH=set_selpar_A50_GR2(4);
  const double selpar_slope_GR2_LO=set_selpar_slope_GR2(2); const double selpar_slope_GR2_HI=set_selpar_slope_GR2(3); const double selpar_slope_GR2_PH=set_selpar_slope_GR2(4);
  // const double selpar_A502_GR2_LO=set_selpar_A502_GR2(2); const double selpar_A502_GR2_HI=set_selpar_A502_GR2(3); const double selpar_A502_GR2_PH=set_selpar_A502_GR2(4);
  // const double selpar_slope2_GR2_LO=set_selpar_slope2_GR2(2); const double selpar_slope2_GR2_HI=set_selpar_slope2_GR2(3); const double selpar_slope2_GR2_PH=set_selpar_slope2_GR2(4);
  //const double selpar_A50_GR3_LO=set_selpar_A50_GR3(2); const double selpar_A50_GR3_HI=set_selpar_A50_GR3(3); const double selpar_A50_GR3_PH=set_selpar_A50_GR3(4);
  //const double selpar_slope_GR3_LO=set_selpar_slope_GR3(2); const double selpar_slope_GR3_HI=set_selpar_slope_GR3(3); const double selpar_slope_GR3_PH=set_selpar_slope_GR3(4);


  //const double log_q_comm_LO=set_log_q_comm(2); const double log_q_comm_HI=set_log_q_comm(3); const double log_q_comm_PH=set_log_q_comm(4);
  //const double log_q_cL_LO=set_log_q_cL(2); const double log_q_cL_HI=set_log_q_cL(3); const double log_q_cL_PH=set_log_q_cL(4);
  const double log_q_HB_LO=set_log_q_HB(2); const double log_q_HB_HI=set_log_q_HB(3); const double log_q_HB_PH=set_log_q_HB(4);

  const double F_init_LO=set_F_init(2); const double F_init_HI=set_F_init(3); const double F_init_PH=set_F_init(4);
  const double log_avg_F_comm_LO=set_log_avg_F_comm(2); const double log_avg_F_comm_HI=set_log_avg_F_comm(3); const double log_avg_F_comm_PH=set_log_avg_F_comm(4);
  //const double log_avg_F_cL_LO=set_log_avg_F_cL(2); const double log_avg_F_cL_HI=set_log_avg_F_cL(3); const double log_avg_F_cL_PH=set_log_avg_F_cL(4);
  const double log_avg_F_GR_LO=set_log_avg_F_GR(2); const double log_avg_F_GR_HI=set_log_avg_F_GR(3); const double log_avg_F_GR_PH=set_log_avg_F_GR(4);

  //-dev vectors-----------------------------------------------------------------------------------------------------------
  const double log_F_dev_comm_LO=set_log_F_dev_comm(1); const double log_F_dev_comm_HI=set_log_F_dev_comm(2); const double log_F_dev_comm_PH=set_log_F_dev_comm(3);
  //const double log_F_dev_cL_LO=set_log_F_dev_cL(1); const double log_F_dev_cL_HI=set_log_F_dev_cL(2); const double log_F_dev_cL_PH=set_log_F_dev_cL(3);
  const double log_F_dev_GR_LO=set_log_F_dev_GR(1); const double log_F_dev_GR_HI=set_log_F_dev_GR(2); const double log_F_dev_GR_PH=set_log_F_dev_GR(3);

  const double log_RWq_LO=set_log_RWq_dev(1); const double log_RWq_HI=set_log_RWq_dev(2); const double log_RWq_PH=set_log_RWq_dev(3);

  const double log_rec_dev_LO=set_log_rec_dev(1); const double log_rec_dev_HI=set_log_rec_dev(2); const double log_rec_dev_PH=set_log_rec_dev(3);
  const double log_Nage_dev_LO=set_log_Nage_dev(1); const double log_Nage_dev_HI=set_log_Nage_dev(2); const double log_Nage_dev_PH=set_log_Nage_dev(3);

 END_CALCS

////--------------Growth---------------------------------------------------------------------------
  //Population growth parms and conversions
  init_bounded_number Linf(Linf_LO,Linf_HI,Linf_PH);
  init_bounded_number K(K_LO,K_HI,K_PH);
  init_bounded_number t0(t0_LO,t0_HI,t0_PH);
  init_bounded_number len_cv_val(len_cv_LO,len_cv_HI,len_cv_PH);
  vector Linf_out(1,8);
  vector K_out(1,8);
  vector t0_out(1,8);
  vector len_cv_val_out(1,8);

  vector meanlen_TL(1,nages);   //mean total length (mm) at age all fish
```

```
  vector wgt_g(1,nages);        //whole wgt in g
  vector wgt_kg(1,nages);       //whole wgt in kg
  vector wgt_mt(1,nages);       //whole wgt in mt
  vector wgt_klb(1,nages);      //whole wgt in 1000 lb
  vector wgt_lb(1,nages);       //whole wgt in lb

  init_bounded_number Linf_L(Linf_L_LO,Linf_L_HI,Linf_L_PH);
  init_bounded_number K_L(K_L_LO,K_L_HI,K_L_PH);
  init_bounded_number t0_L(t0_L_LO,t0_L_HI,t0_L_PH);
  init_bounded_number len_cv_val_L(len_cv_L_LO,len_cv_L_HI,len_cv_L_PH);
  vector Linf_L_out(1,8);
  vector K_L_out(1,8);
  vector t0_L_out(1,8);
  vector len_cv_val_L_out(1,8);
  vector meanlen_TL_L(1,nages);   //mean total length (mm) at age all fish

  vector wgt_g_L(1,nages);        //whole wgt in g
  vector wgt_kg_L(1,nages);       //whole wgt in kg
  vector wgt_mt_L(1,nages);       //whole wgt in mt
  vector wgt_klb_L(1,nages);      //whole wgt in 1000 lb
  vector wgt_lb_L(1,nages);       //whole wgt in lb
  vector wgt_klb_gut_L(1,nages);  //gutted wgt in 1000 lb
  vector wgt_lb_gut_L(1,nages);   //gutted wgt in lb

  init_bounded_number Linf_F(Linf_F_LO,Linf_F_HI,Linf_F_PH);
  init_bounded_number K_F(K_F_LO,K_F_HI,K_F_PH);
  init_bounded_number t0_F(t0_F_LO,t0_F_HI,t0_F_PH);
  init_bounded_number len_cv_val_F(len_cv_F_LO,len_cv_F_HI,len_cv_F_PH);
  vector Linf_F_out(1,8);
  vector K_F_out(1,8);
  vector t0_F_out(1,8);
  vector len_cv_val_F_out(1,8);
  vector meanlen_TL_F(1,nages);   //mean total length (mm) at age all fish

  vector wgt_g_F(1,nages);        //whole wgt in g
  vector wgt_kg_F(1,nages);       //whole wgt in kg
  vector wgt_mt_F(1,nages);       //whole wgt in mt
  vector wgt_klb_F(1,nages);      //whole wgt in 1000 lb
  vector wgt_lb_F(1,nages);       //whole wgt in lb


  //vector batchfec(1,nages);     //batch fecundity at age
  //vector fec(1,nages);          //annual fecundity at age

  matrix len_comm_mm(styr,endyr,1,nages);          //mean length at age of commercial handline landings in mm
  matrix wholewgt_comm_klb(styr,endyr,1,nages);    //whole wgt of commercial handline landings in 1000 lb
  //matrix len_cL_mm(styr,endyr,1,nages);          //mean length at age of commercial longline landings in mm
  //matrix wholewgt_cL_klb(styr,endyr,1,nages);    //whole wgt of commercial longline landings in 1000 lb
  matrix len_HB_mm(styr,endyr,1,nages);          //mean length at age of HB landings in mm
  matrix wholewgt_HB_klb(styr,endyr,1,nages);    //whole wgt of HB landings in 1000 lb
  matrix len_GR_mm(styr,endyr,1,nages);          //mean length at age of GR landings in mm
  matrix wholewgt_GR_klb(styr,endyr,1,nages);    //whole wgt of GR landings in 1000 lb

  matrix lenprob(1,nages,1,nlenbins);           //distn of size at age (age-length key, 3 cm bins) in population
  number zscore_len;                            //standardized normal values used for computing lenprob
  vector cprob_lenvec(1,nlenbins);              //cumulative probabilities used for computing lenprob
  number zscore_lzero;                          //standardized normal values for length = 0
  number cprob_lzero;                           //length probability mass below zero, used for computing lenprob

  matrix lenprob_L(1,nages,1,nlenbins);
  number zscore_len_L;                            //standardized normal values used for computing lenprob
  vector cprob_lenvec_L(1,nlenbins);              //cumulative probabilities used for computing lenprob
  number zscore_lzero_L;                          //standardized normal values for length = 0
  number cprob_lzero_L;                           //length probability mass below zero, used for computing lenprob

  matrix lenprob_F(1,nages,1,nlenbins);
  number zscore_len_F;                            //standardized normal values used for computing lenprob
  vector cprob_lenvec_F(1,nlenbins);              //cumulative probabilities used for computing lenprob
  number zscore_lzero_F;                          //standardized normal values for length = 0
  number cprob_lzero_F;                           //length probability mass below zero, used for computing lenprob


  //matrices below are used to match length comps
  matrix lenprob_comm(1,nages,1,nlenbins);     //distn of size at age in comm
  //matrix lenprob_cL(1,nages,1,nlenbins);     //distn of size at age in cL
  matrix lenprob_HB(1,nages,1,nlenbins);     //distn of size at age in HB
  matrix lenprob_GR(1,nages,1,nlenbins);     //distn of size at age in GR

  vector len_sd(1,nages);
  vector len_cv(1,nages); //for fishgraph
  //All Fishery-dependent
  vector len_sd_L(1,nages);
  vector len_cv_L(1,nages); //for fishgraph
  //Females
  vector len_sd_F(1,nages);
  vector len_cv_F(1,nages);

//----Predicted length and age compositions
  matrix pred_comm_lenc(1,nyr_comm_lenc,1,nlenbins); //predicted length comps pooled across years
  matrix pred_comm_lenc_yr(1,nyr_comm_lenc_pool,1,nlenbins); //annual predicted length comps
  //matrix pred_cL_lenc(1,nyr_cL_lenc,1,nlenbins);
  //matrix pred_HB_lenc(1,nyr_HB_lenc,1,nlenbins);
  //matrix pred_GR_lenc(1,nyr_GR_lenc,1,nlenbins);
  matrix pred_GR_agec(1,nyr_GR_agec,1,nages_agec);
```

```
  matrix pred_GR_agec_allages(1,nyr_GR_agec,1,nages);
  matrix ErrorFree_GR_agec(1,nyr_GR_agec,1,nages);

//Sample size (perhaps adjusted herein) used in fitting comp data
  vector nsamp_comm_lenc_allyr(styr,endyr);
  //vector nsamp_cL_lenc_allyr(styr,endyr);
  // vector nsamp_HB_lenc_allyr(styr,endyr);
  //vector nsamp_GR_lenc_allyr(styr,endyr);
  vector nsamp_GR_agec_allyr(styr,endyr);

//Nfish used in MCB analysis (not used in fitting)
  vector nfish_comm_lenc_allyr(styr,endyr);
  //vector nfish_cL_lenc_allyr(styr,endyr);
  // vector nfish_HB_lenc_allyr(styr,endyr);
  //vector nfish_GR_lenc_allyr(styr,endyr);
  vector nfish_GR_agec_allyr(styr,endyr);

//Computed effective sample size for output (not used in fitting)
  vector neff_comm_lenc_allyr(styr,endyr);
  //vector neff_cL_lenc_allyr(styr,endyr);
  // vector neff_HB_lenc_allyr(styr,endyr);
  //vector neff_GR_lenc_allyr(styr,endyr);
  vector neff_GR_agec_allyr(styr,endyr);

//-----Population------------------------------------------------------------------------------------
  matrix N(styr,endyr+1,1,nages);           //Population numbers by year and age at start of yr
  matrix N_mdyr(styr,endyr,1,nages);        //Population numbers by year and age at mdpt of yr: used for comps and cpue
  matrix N_spawn(styr,endyr,1,nages);       //Population numbers by year and age at peaking spawning: used for SSB
  init_bounded_vector log_Nage_dev(2,nages,log_Nage_dev_LO,log_Nage_dev_HI,log_Nage_dev_PH);
  vector log_Nage_dev_output(1,nages);      //used in output. equals zero for first age
  matrix B(styr,endyr+1,1,nages);           //Population biomass by year and age at start of yr
  vector totB(styr,endyr+1);                //Total biomass by year
  vector totN(styr,endyr+1);                //Total abundance by year
  vector SSB(styr,endyr);                   //Total spawning biomass by year (female mature biomass)
  vector SSB_knum(styr,endyr);              //Total spawning numbers by year (number of mature females)
  vector rec(styr,endyr+1);                 //Recruits by year
  vector prop_f(1,nages);
  //vector prop_m(1,nages);
  vector maturity_f(1,nages);
  //vector maturity_m(1,nages);
  vector reprod(1,nages);
  vector reprodknum(1,nages);

//---Stock-Recruit Function (Beverton-Holt, steepness parameterization)----------
  init_bounded_number log_R0(log_R0_LO,log_R0_HI,log_R0_PH);        //log(virgin Recruitment)
  vector log_R0_out(1,8);
  number R0;                                  //virgin recruitment
  init_bounded_number steep(steep_LO,steep_HI,steep_PH); //steepness
  vector steep_out(1,8);
  init_bounded_number rec_sigma(rec_sigma_LO,rec_sigma_HI,rec_sigma_PH);  //sd recruitment residuals
  vector rec_sigma_out(1,8);
  init_bounded_number R_autocorr(R_autocorr_LO,R_autocorr_HI,R_autocorr_PH);  //autocorrelation in SR
  vector R_autocorr_out(1,8);

  number rec_sigma_sq;                        //square of rec_sigma
  number rec_logL_add;                        //additive term in -logL term

  init_bounded_dev_vector log_rec_dev(styr_rec_dev,endyr_rec_dev,log_rec_dev_LO,log_rec_dev_HI,log_rec_dev_PH);
  vector log_rec_dev_output(styr,endyr+1);             //used in t.series output. equals zero except for yrs in log_rec_dev
  vector log_rec_dev_out(styr_rec_dev,endyr_rec_dev);  //used in output for bound checking

  number var_rec_dev;                           //variance of log recruitment deviations, from yrs with unconstrainted S-R(XXXX-XXXX)
  number sigma_rec_dev;                         //sample SD of log residuals (may not equal rec_sigma
  number BiasCor;                               //Bias correction in equilibrium recruits
  number S0;                                    //equal to spr_F0*R0 = virgin SSB
  number B0;                                    //equal to bpr_F0*R0 = virgin B
  number R1;                                    //Recruits in styr
  number R_virgin;                              //unfished recruitment with bias correction
  vector SdS0(styr,endyr);                      //Spawners relative to the unfished level


  init_bounded_number log_dm_comm_lc(log_dm_comm_lc_LO,log_dm_comm_lc_HI,log_dm_comm_lc_PH);
  //init_bounded_number log_dm_cL_lc(log_dm_cL_lc_LO,log_dm_cL_lc_HI,log_dm_cL_lc_PH);
  // init_bounded_number log_dm_HB_lc(log_dm_HB_lc_LO,log_dm_HB_lc_HI,log_dm_HB_lc_PH);
  //init_bounded_number log_dm_GR_lc(log_dm_GR_lc_LO,log_dm_GR_lc_HI,log_dm_GR_lc_PH);
  init_bounded_number log_dm_GR_ac(log_dm_GR_ac_LO,log_dm_GR_ac_HI,log_dm_GR_ac_PH);

  vector log_dm_comm_lc_out(1,8);
  //vector log_dm_cL_lc_out(1,8);
  // vector log_dm_HB_lc_out(1,8);
  //vector log_dm_GR_lc_out(1,8);
  vector log_dm_GR_ac_out(1,8);
//------------------------------------------------------------------------------------------------------------------------------------------------
////---Selectivity-------------------------------------------------------------------------

//Commercial handline-------------------------------------------------
  matrix sel_comm(styr,endyr,1,nages);
  vector sel_comm_vec(1,nages);
  //vector sel_comm_block1(1,nages);
  //vector sel_comm_block2(1,nages);
  //vector sel_comm_block3(1,nages);

  init_bounded_number selpar_A50_comm1(selpar_A50_comm1_LO,selpar_A50_comm1_HI,selpar_A50_comm1_PH);
  init_bounded_number selpar_slope_comm1(selpar_slope_comm1_LO,selpar_slope_comm1_HI,selpar_slope_comm1_PH);
  //init_bounded_number //selpar_A50_comm2(selpar_A50_comm2_LO,selpar_A50_comm2_HI,selpar_A50_comm2_PH);
```

```
  //init_bounded_number selpar_slope_comm2(selpar_slope_comm2_LO,selpar_slope_comm2_HI,selpar_slope_comm2_PH);
  // init_bounded_number selpar_A502_comm2(selpar_A502_comm2_LO,selpar_A502_comm2_HI,selpar_A502_comm2_PH);
  // init_bounded_number selpar_slope2_comm2(selpar_slope2_comm2_LO,selpar_slope2_comm2_HI,selpar_slope2_comm2_PH);
  //init_bounded_number selpar_A50_comm3(selpar_A50_comm3_LO,selpar_A50_comm3_HI,selpar_A50_comm3_PH);
  //init_bounded_number selpar_slope_comm3(selpar_slope_comm3_LO,selpar_slope_comm3_HI,selpar_slope_comm3_PH);

  vector selpar_A50_comm1_out(1,8);
  vector selpar_slope_comm1_out(1,8);
  //vector selpar_A50_comm2_out(1,8);
  //vector selpar_slope_comm2_out(1,8);
  // vector selpar_A502_comm2_out(1,8);
  // vector selpar_slope2_comm2_out(1,8);
  //vector selpar_A50_comm3_out(1,8);
  //vector selpar_slope_comm3_out(1,8);

  //Headboat -------------------------------------------------
  matrix sel_HB(styr,endyr,1,nages); // Still need to define sel_HB to associate with HB index, but can just set equal to sel_GR below
  vector sel_HB_block1(1,nages);
  vector sel_HB_block2(1,nages);
  //vector sel_HB_block3(1,nages);

  //General Rec
  matrix sel_GR(styr,endyr,1,nages);
  vector sel_GR_block1(1,nages);
  vector sel_GR_block2(1,nages);
  //vector sel_GR_block3(1,nages);

  init_bounded_number selpar_A50_GR1(selpar_A50_GR1_LO,selpar_A50_GR1_HI,selpar_A50_GR1_PH);
  init_bounded_number selpar_slope_GR1(selpar_slope_GR1_LO,selpar_slope_GR1_HI,selpar_slope_GR1_PH);
  init_bounded_number selpar_A50_GR2(selpar_A50_GR2_LO,selpar_A50_GR2_HI,selpar_A50_GR2_PH);
  init_bounded_number selpar_slope_GR2(selpar_slope_GR2_LO,selpar_slope_GR2_HI,selpar_slope_GR2_PH);
  // init_bounded_number selpar_A502_GR2(selpar_A502_GR2_LO,selpar_A502_GR2_HI,selpar_A502_GR2_PH);
  // init_bounded_number selpar_slope2_GR2(selpar_slope2_GR2_LO,selpar_slope2_GR2_HI,selpar_slope2_GR2_PH);
  //init_bounded_number selpar_A50_GR3(selpar_A50_GR3_LO,selpar_A50_GR3_HI,selpar_A50_GR3_PH);
  //init_bounded_number selpar_slope_GR3(selpar_slope_GR3_LO,selpar_slope_GR3_HI,selpar_slope_GR3_PH);

  vector selpar_A50_GR1_out(1,8);
  vector selpar_slope_GR1_out(1,8);
  vector selpar_A50_GR2_out(1,8);
  vector selpar_slope_GR2_out(1,8);
  // vector selpar_A502_GR2_out(1,8);
  // vector selpar_slope2_GR2_out(1,8);
 //vector selpar_A50_GR3_out(1,8);
 //vector selpar_slope_GR3_out(1,8);

//Weighted total selectivity--------------------------------------------
  //effort-weighted, recent selectivities
  vector sel_wgted_L(1,nages);  //toward landings
  vector sel_wgted_tot(1,nages);//toward Z, landings plus deads discards

//-----------------------------------------------------------------------------------------------------------------------------------------------
//-------CPUE Predictions--------------------------------
  //vector pred_comm_cpue(styr_comm_cpue,endyr_comm_cpue);                   //predicted comm index (weight fish per effort)
  //matrix N_comm(styr_comm_cpue,endyr_comm_cpue,1,nages);                   //used to compute comm index
  //vector pred_cL_cpue(styr_cL_cpue,endyr_cL_cpue);                   //predicted cL index (weight fish per effort)
 // matrix N_cL(styr_cL_cpue,endyr_cL_cpue,1,nages);                   //used to compute cL index
  vector pred_HB_cpue(styr_HB_cpue,endyr_HB_cpue);                   //predicted HB index (number fish per effort)
  matrix N_HB(styr_HB_cpue,endyr_HB_cpue,1,nages);                   //used to compute HB index

//---Catchability (CPUE q's)----------------------------------------------------------
  //init_bounded_number log_q_comm(log_q_comm_LO,log_q_comm_HI,log_q_comm_PH);
  //init_bounded_number log_q_cL(log_q_cL_LO,log_q_cL_HI,log_q_cL_PH);
  init_bounded_number log_q_HB(log_q_HB_LO,log_q_HB_HI,log_q_HB_PH);

  //vector log_q_comm_out(1,8);
 // vector log_q_cL_out(1,8);
  vector log_q_HB_out(1,8);

  number q_rate;
  //vector q_rate_fcn_comm(styr_comm_cpue,endyr_comm_cpue);         //increase due to technology creep (saturates in 2003)
  //vector q_rate_fcn_cL(styr_cL_cpue,endyr_cL_cpue);         //increase due to technology creep (saturates in 2003)
  vector q_rate_fcn_HB(styr_HB_cpue,endyr_HB_cpue);         //increase due to technology creep (saturates in 2003)

//  init_bounded_number q_DD_beta(0.1,0.9,set_q_DD_phase);    //not estimated so commented out and declared as number (below)
  number q_DD_beta;
  vector q_DD_fcn(styr,endyr);    //density dependent function as a multiple of q (scaled a la Katsukawa and Matsuda. 2003)
  number B0_q_DD;                 //B0 of ages q_DD_age plus
  vector B_q_DD(styr,endyr);      //annual biomass of ages q_DD_age plus

//Fishery dependent random walk catchability
 //init_bounded_vector q_RW_log_dev_comm(styr_comm_cpue,endyr_comm_cpue-1,log_RWq_LO,log_RWq_HI,log_RWq_PH);
 //init_bounded_vector q_RW_log_dev_cL(styr_cL_cpue,endyr_cL_cpue-1,log_RWq_LO,log_RWq_HI,log_RWq_PH);
 init_bounded_vector q_RW_log_dev_HB(styr_HB_cpue,endyr_HB_cpue-1,log_RWq_LO,log_RWq_HI,log_RWq_PH);

//Fishery dependent catchability over time, may be constant
 //vector q_comm(styr_comm_cpue,endyr_comm_cpue);
 //vector q_cL(styr_cL_cpue,endyr_cL_cpue);
 vector q_HB(styr_HB_cpue,endyr_HB_cpue);

//-----------------------------------------------------------------------------------------------------------------------------------------------
//---Landings in numbers (total or 1000 fish) and in wgt (whole klb)--------------------------------------------------
  matrix L_comm_num(styr,endyr,1,nages);   //landings (numbers) at age
  matrix L_comm_klb(styr,endyr,1,nages);   //landings (1000 lb whole weight) at age
  vector pred_comm_L_knum(styr,endyr);     //yearly landings in 1000 fish summed over ages
  vector pred_comm_L_klb(styr,endyr);      //yearly landings in 1000 lb whole summed over ages
```

```
  //matrix L_cL_num(styr,endyr,1,nages);   //landings (numbers) at age
  //matrix L_cL_klb(styr,endyr,1,nages);   //landings (1000 lb whole weight) at age
  //vector pred_cL_L_knum(styr,endyr);     //yearly landings in 1000 fish summed over ages
  //vector pred_cL_L_klb(styr,endyr);      //yearly landings in 1000 lb whole summed over ages

  matrix L_GR_num(styr,endyr,1,nages);   //landings (numbers) at age
  matrix L_GR_klb(styr,endyr,1,nages);   //landings (1000 lb whole weight) at age
  vector pred_GR_L_knum(styr,endyr);     //yearly landings in 1000 fish summed over ages
  vector pred_GR_L_klb(styr,endyr);      //yearly landings in 1000 lb whole summed over ages

  matrix L_total_num(styr,endyr,1,nages);//total landings in number at age
  matrix L_total_klb(styr,endyr,1,nages);//landings in klb whole wgt at age
  vector L_total_knum_yr(styr,endyr);    //total landings in 1000 fish by yr summed over ages
  vector L_total_klb_yr(styr,endyr);     //total landings (klb whole wgt) by yr summed over ages

////---MSY calcs---------------------------------------------------------------------------
  number F_comm_prop;       //proportion of F_sum attributable to comm, last X=selpar_n_yrs_wgted yrs
  //number F_cL_prop;       //proportion of F_sum attributable to comm, last X=selpar_n_yrs_wgted yrs
  number F_GR_prop;       //proportion of F_sum attributable to GR, last X=selpar_n_yrs_wgted yrs

  number F_init_comm_prop;  //proportion of F_init attributable to comm, first X yrs
  //number F_init_cL_prop;  //proportion of F_init attributable to cL, first X yrs
  number F_init_GR_prop;  //proportion of F_init attributable to GR, first X yrs

  number F_temp_sum;      //sum of geom mean Fsum's in last X yrs, used to compute F_fishery_prop

  vector F_end(1,nages);
  vector F_end_L(1,nages);
  number F_end_apex;

  number SSB_msy_out;           //SSB (total mature biomass) at msy
  number F_msy_out;             //F at msy
  number msy_klb_out;           //max sustainable yield (1000 lb whole wgt)
  number msy_knum_out;          //max sustainable yield (1000 fish)
  number B_msy_out;             //total biomass at MSY
  number R_msy_out;             //equilibrium recruitment at F=Fmsy
  number spr_msy_out;           //spr at F=Fmsy

  number F20_dum; //intermediate calculation for F20
  number F30_dum; //intermediate calculation for F30
  number F40_dum; //intermediate calculation for F40
  number F20_out;               //F20
  number F30_out;               //F30
  number F40_out;               //F40
  number SSB_F30_out;
  number SSB_F30_knum_out;
  number B_F30_out;
  number R_F30_out;
  number L_F30_knum_out;
  number L_F30_klb_out;

  number SSB_F40_out;
  number SSB_F40_knum_out;
  number B_F40_out;
  number R_F40_out;
  number L_F40_knum_out;
  number L_F40_klb_out;
  number rec_mean;   //arithmetic average recruitment used in SPR-related quantities

  vector N_age_msy(1,nages);         //numbers at age for MSY calculations: beginning of yr
  vector N_age_msy_spawn(1,nages);   //numbers at age for MSY calculations: time of peak spawning
  vector L_age_msy(1,nages);         //landings at age for MSY calculations
  vector Z_age_msy(1,nages);         //total mortality at age for MSY calculations
  vector F_L_age_msy(1,nages);       //fishing mortality landings (not discards) at age for MSY calculations
  vector F_msy(1,n_iter_msy);        //values of full F to be used in equilibrium calculations
  vector spr_msy(1,n_iter_msy);      //reproductive capacity-per-recruit values corresponding to F values in F_msy
  vector R_eq(1,n_iter_msy);         //equilibrium recruitment values corresponding to F values in F_msy
  vector L_eq_klb(1,n_iter_msy);     //equilibrium landings(klb whole wgt) values corresponding to F values in F_msy
  vector L_eq_knum(1,n_iter_msy);    //equilibrium landings(1000 fish) values corresponding to F values in F_msy
  vector SSB_eq(1,n_iter_msy);       //equilibrium reproductive capacity values corresponding to F values in F_msy
  vector SSB_eq_knum(1,n_iter_msy);
  vector B_eq(1,n_iter_msy);         //equilibrium biomass values corresponding to F values in F_msy

  vector FdF_msy(styr,endyr);
  vector FdF30(styr,endyr);
  vector FdF40(styr,endyr);
  vector SdSSB_msy(styr,endyr);
  number SdSSB_msy_end;
  number FdF_msy_end;
  number FdF_msy_end_mean;           //geometric mean of last X yrs

  vector SdSSB_F30(styr,endyr);
  vector Sdmsst_F30(styr,endyr);
  number SdSSB_F30_end;
  number Sdmsst_F30_end;
  number FdF30_end_mean;             //geometric mean of last selpar_n_yrs_wgted yrs
  vector L_age_F30(1,nages);         //landings at age for F30 calculations

  vector SdSSB_F40(styr,endyr);
  vector Sdmsst_F40(styr,endyr);
  number SdSSB_F40_end;
  number Sdmsst_F40_end;
  number FdF40_end_mean;             //geometric mean of last selpar_n_yrs_wgted yrs
  number Fend_mean_temp;  //intermediate calc for geometric mean of last selpar_n_yrs_wgted yrs
```

```
  number Fend_mean;  //geometric mean of last selpar_n_yrs_wgted yrs
  vector L_age_F40(1,nages);         //landings at age for F40 calculations

  vector wgt_wgted_L_klb(1,nages);   //fishery-weighted average weight at age of landings in whole weight
  number wgt_wgted_L_denom;          //used in intermediate calculations

  number iter_inc_msy;               //increments used to compute msy, equals 1/(n_iter_msy-1)

////--------Mortality------------------------------------------------------------------

  vector M(1,nages);                         //age-dependent natural mortality
  init_bounded_number M_constant(M_constant_LO,M_constant_HI,M_constant_PH);   //age-indpendent: used only for MSST
  vector M_constant_out(1,8);
  number smsy2msstM;                         //scales Smsy to get msst using (1-M). Used only in output.
  number smsy2msst75;                        //scales Smsy to get msst using 75%. Used only in output.

  matrix F(styr,endyr,1,nages);
  vector Fsum(styr,endyr);                   //Full fishing mortality rate by year
  vector Fapex(styr,endyr);                  //Max across ages, fishing mortality rate by year (may differ from Fsum bc of dome-shaped sel
  matrix Z(styr,endyr,1,nages);

  init_bounded_number log_avg_F_comm(log_avg_F_comm_LO,log_avg_F_comm_HI,log_avg_F_comm_PH);
  vector log_avg_F_comm_out(1,8);
  init_bounded_dev_vector log_F_dev_comm(styr_comm_L,endyr_comm_L,log_F_dev_comm_LO,log_F_dev_comm_HI,log_F_dev_comm_PH);
  vector log_F_dev_comm_out(styr_comm_L,endyr_comm_L);
  matrix F_comm(styr,endyr,1,nages);
  vector F_comm_out(styr,endyr);        //used for intermediate calculations in fcn get_mortality
  number log_F_dev_init_comm;
  number log_F_dev_end_comm;

  init_bounded_number log_avg_F_GR(log_avg_F_GR_LO,log_avg_F_GR_HI,log_avg_F_GR_PH);
  vector log_avg_F_GR_out(1,8);
  init_bounded_dev_vector log_F_dev_GR(styr_GR_L,endyr_GR_L,log_F_dev_GR_LO,log_F_dev_GR_HI,log_F_dev_GR_PH);
  vector log_F_dev_GR_out(styr_GR_L,endyr_GR_L);
  matrix F_GR(styr,endyr,1,nages);
  vector F_GR_out(styr,endyr); //used for intermediate calculations in fcn get_mortality
  number log_F_dev_init_GR;
  number log_F_dev_end_GR;

  init_bounded_number F_init(F_init_LO,F_init_HI,F_init_PH); //scales early F for initialization
  vector F_init_out(1,8);
  number F_init_denom;  //interim calculation. From Erik's red snapper ASPM

  //number F_init_ratio;   //scales initial F, which is read in as a fixed value
  //vector sel_initial(1,nages);       //initial selectivity (a combination of recreational and commercial selectivities)

//---Per-recruit stuff----------------------------------------------------------------------------------
  vector N_age_spr(1,nages);         //numbers at age for SPR calculations: beginning of year
  vector N_age_spr_spawn(1,nages);   //numbers at age for SPR calculations: time of peak spawning
  vector L_age_spr(1,nages);         //catch at age for SPR calculations
  vector Z_age_spr(1,nages);         //total mortality at age for SPR calculations
  vector spr_static(styr,endyr);     //vector of static SPR values by year
  vector F_L_age_spr(1,nages);       //fishing mortality of landings (not discards) at age for SPR calculations
  vector F_spr(1,n_iter_spr);        //values of full F to be used in per-recruit calculations
  vector spr_spr(1,n_iter_spr);      //reproductive capacity-per-recruit values corresponding to F values in F_spr
  vector spr_ratio(1,n_iter_spr);    //reproductive capacity-per-recruit relative to spr_F0 values corresponding to F values in F_spr
  vector L_spr(1,n_iter_spr);        //landings(lb)-per-recruit (ypr) values corresponding to F values in F_spr

  vector N_spr_F0(1,nages);          //Used to compute spr at F=0: at time of peak spawning
  vector N_bpr_F0(1,nages);          //Used to compute bpr at F=0: at start of year
  vector N_spr_initial(1,nages);     //Initial spawners per recruit at age given initial F
  vector N_initial_eq(1,nages);      //Initial equilibrium abundance at age
  vector F_initial(1,nages);         //initial F at age
  vector Z_initial(1,nages);         //initial Z at age
  number spr_initial;                //initial spawners per recruit
  number spr_F0;                     //Spawning biomass per recruit at F=0
  number bpr_F0;                     //Biomass per recruit at F=0

  number iter_inc_spr;               //increments used to compute msy, equals max_F_spr_msy/(n_iter_spr-1)

////-------SDNR output-----------------------------------------------------------------------------

  number sdnr_lc_comm;
  //number sdnr_lc_cL;
  //number sdnr_lc_HB;
  //number sdnr_lc_GR;
  number sdnr_ac_GR;
 // number sdnr_I_comm;
 // number sdnr_I_cL;
  number sdnr_I_HB;

////-------Objective function components-----------------------------------------------------------------------------
  number w_L;

 // number w_I_comm;
 // number w_I_cL;
  number w_I_HB;

  number w_lc_comm;
  //number w_lc_cL;
  //number w_lc_HB;
  //number w_lc_GR;
  number w_ac_GR;

  number w_Nage_init;
```

```
  number w_rec;
  number w_rec_early;
  number w_rec_end;
  number w_fullF;
  number w_Ftune;

  number f_comm_L;
  //number f_cL_L;
  // number f_HB_L;
  number f_GR_L;

  //number f_comm_cpue;
  //number f_cL_cpue;
  number f_HB_cpue;

  //number f_comm_RWq_cpue;
  //number f_cL_RWq_cpue;
  number f_HB_RWq_cpue;

  number f_comm_lenc;
  //number f_cL_lenc;
  // number f_HB_lenc;
  number f_GR_lenc;

  number f_GR_agec;

//  Penalties and constraints. Not all are used.
  number f_Nage_init;              //weight on log devs to estimate initial abundance (excluding first age)
  number f_rec_dev;                //weight on recruitment deviations to fit S-R curve
  number f_rec_dev_early;          //extra weight on deviations in first recruitment stanza
  number f_rec_dev_end;            //extra weight on deviations in ending recruitment stanza
  number f_fullF_constraint;       //penalty for Fapex>X
  number f_Ftune;                  //penalty for tuning F in Ftune yr.  Not applied in final optimization phase.
  number f_priors;                 //prior information on parameters

   //init_number xdum;
   objective_function_value fval;
   number fval_data;
   number grad_max;

 //--Dummy variables ----
   number denom;                   //denominator used in some calculations
   number numer;                   //numerator used in some calculations

  //---------- Projection quantities---------------------------------------------------------------
  number F_reg_proj;    //value used to define the projections
  vector F_proj(styr_proj,endyr_proj);         //F by yr for projections (=F_reg_proj after regulations start, current F till then)
  vector L_knum_proj(styr_proj,endyr_proj);    //total landings in 1000 fish for projections
  vector L_klb_proj(styr_proj,endyr_proj);     //total landings in weight (1000 lb) for projections

  vector B_proj(styr_proj,endyr_proj);         //Biomass for projections
  vector SSB_proj(styr_proj,endyr_proj);       //SSB for projections
  vector R_proj(styr_proj,endyr_proj);         //recruits for projections
  vector FL_age_proj(1,nages);          //F (landings) by age for projections

  matrix N_proj(styr_proj,endyr_proj,1,nages);           //Population numbers by year and age at start of yr
  matrix N_spawn_proj(styr_proj,endyr_proj,1,nages);     //Population numbers by year and age at peaking spawning: used for SSB in projections
  matrix Z_proj(styr_proj,endyr_proj,1,nages);           //Z by year and age for projections
  matrix L_age_proj(styr_proj,endyr_proj,1,nages);       //Projected landings at age in numbers

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//INITIALIZATION_SECTION
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
GLOBALS_SECTION
  #include "admodel.h"          // Include AD class definitions
  #include "admb2r.cpp"         // Include S-compatible output functions (needs preceding)
  #include <time.h>
time_t start,finish;
long hour,minute,second;
double elapsed_time;

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
RUNTIME_SECTION
 maximum_function_evaluations 1000, 2000,3000, 5000, 10000;//, 10000, 10000;
 convergence_criteria 1e-2, 1e-2,1e-3, 1e-3, 1e-4;//, 1e-4, 1e-4;

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
PRELIMINARY_CALCS_SECTION

// Set values of fixed parameters or set initial guess of estimated parameters

 //Population
  Linf=set_Linf(1);
  K=set_K(1);
  t0=set_t0(1);
  len_cv_val=set_len_cv(1);

  //All fisheries
  Linf_L=set_Linf_L(1);
  K_L=set_K_L(1);
  t0_L=set_t0_L(1);
  len_cv_val_L=set_len_cv_L(1);
```

```
 //Females
 Linf_F=set_Linf_F(1);
 K_F=set_K_F(1);
 t0_F=set_t0_F(1);
 len_cv_val_F=set_len_cv_F(1);

 M=set_M;
 M_constant=set_M_constant(1);
 smsy2msstM=1.0-M_constant;
 smsy2msst75=0.75;

 log_R0=set_log_R0(1);
 steep=set_steep(1);
 R_autocorr=set_R_autocorr(1);
 rec_sigma=set_rec_sigma(1);

 log_dm_comm_lc=set_log_dm_comm_lc(1);
 //log_dm_cL_lc=set_log_dm_cL_lc(1);
 // log_dm_HB_lc=set_log_dm_HB_lc(1);
 //log_dm_GR_lc=set_log_dm_GR_lc(1);
 log_dm_GR_ac=set_log_dm_GR_ac(1);

// log_q_comm=set_log_q_comm(1);
 //log_q_cL=set_log_q_cL(1);
 log_q_HB=set_log_q_HB(1);

 q_rate=set_q_rate;
 //q_rate_fcn_comm=1.0;
 //q_rate_fcn_cL=1.0;
 q_rate_fcn_HB=1.0;
 q_DD_beta=set_q_DD_beta;
 q_DD_fcn=1.0;

 //q_RW_log_dev_comm.initialize();
// q_RW_log_dev_cL.initialize();
 q_RW_log_dev_HB.initialize();

  if (set_q_rate_phase<0 & q_rate!=0.0)
 {

   for (iyear=styr_HB_cpue; iyear<=endyr_HB_cpue; iyear++)
     {   if (iyear>styr_HB_cpue & iyear <=2003)
         {//q_rate_fcn_HB(iyear)=(1.0+q_rate)*q_rate_fcn_HB(iyear-1); //compound
            q_rate_fcn_HB(iyear)=(1.0+(iyear-styr_HB_cpue)*q_rate)*q_rate_fcn_HB(styr_HB_cpue);  //linear
         }
         if (iyear>2003) {q_rate_fcn_HB(iyear)=q_rate_fcn_HB(iyear-1);}
     }
 } //end q_rate conditional

 w_L=set_w_L;

// w_I_comm=set_w_I_comm;
// w_I_cL=set_w_I_cL;
 w_I_HB=set_w_I_HB;

 w_lc_comm=set_w_lc_comm;
 //w_lc_cL=set_w_lc_cL;
 //w_lc_HB=set_w_lc_HB;
 //w_lc_GR=set_w_lc_GR;
 w_ac_GR=set_w_ac_GR;

 w_Nage_init=set_w_Nage_init;
 w_rec=set_w_rec;
 w_rec_early=set_w_rec_early;
 w_rec_end=set_w_rec_end;
 w_fullF=set_w_fullF;
 w_Ftune=set_w_Ftune;

 F_init=set_F_init(1);

 log_avg_F_comm=set_log_avg_F_comm(1);
 //log_avg_F_cL=set_log_avg_F_cL(1);
 // log_avg_F_HB=set_log_avg_F_HB(1);
 log_avg_F_GR=set_log_avg_F_GR(1);

 log_F_dev_comm=set_log_F_dev_comm_vals;
 //log_F_dev_cL=set_log_F_dev_cL_vals;
 // log_F_dev_HB=set_log_F_dev_HB_vals;
 log_F_dev_GR=set_log_F_dev_GR_vals;

 selpar_A50_comm1=set_selpar_A50_comm1(1);
 selpar_slope_comm1=set_selpar_slope_comm1(1);
 //selpar_A50_comm2=set_selpar_A50_comm2(1);
 //selpar_slope_comm2=set_selpar_slope_comm2(1);
 // selpar_A502_comm2=set_selpar_A502_comm2(1);
 // selpar_slope2_comm2=set_selpar_slope2_comm2(1);
 //selpar_A50_comm3=set_selpar_A50_comm3(1);
 //selpar_slope_comm3=set_selpar_slope_comm3(1);

 selpar_A50_GR1=set_selpar_A50_GR1(1);
 selpar_slope_GR1=set_selpar_slope_GR1(1);
 selpar_A50_GR2=set_selpar_A50_GR2(1);
 selpar_slope_GR2=set_selpar_slope_GR2(1);
 // selpar_A502_GR2=set_selpar_A502_GR2(1);
 // selpar_slope2_GR2=set_selpar_slope2_GR2(1);
```

```
  //selpar_A50_GR3=set_selpar_A50_GR3(1);
  //selpar_slope_GR3=set_selpar_slope_GR3(1);

 sqrt2pi=sqrt(2.*3.14159265);
 g2mt=0.000001;         //conversion of grams to metric tons
 g2kg=0.001;            //conversion of grams to kg
 mt2klb=2.20462;        //conversion of metric tons to 1000 lb
 mt2lb=mt2klb*1000.0;   //conversion of metric tons to lb
 g2klb=g2mt*mt2klb;     //conversion of grams to 1000 lb
 dzero=0.00001;
 huge_number=1.0e+10;

 SSB_msy_out=0.0;

 iter_inc_msy=max_F_spr_msy/(n_iter_msy-1);
 iter_inc_spr=max_F_spr_msy/(n_iter_spr-1);

 maturity_f=maturity_f_obs;

 prop_f=prop_f_obs;

//Fill in sample sizes of comps, possibly sampled in nonconsec yrs
//Used primarily for output in R object

      nsamp_comm_lenc_allyr=missing;
  //nsamp_cL_lenc_allyr=missing;
  //nsamp_GR_lenc_allyr=missing;
  nsamp_GR_agec_allyr=missing;

      nfish_comm_lenc_allyr=missing;
  //nfish_cL_lenc_allyr=missing;
  //nfish_GR_lenc_allyr=missing;
  nfish_GR_agec_allyr=missing;

      for (iyear=1; iyear<=nyr_comm_lenc; iyear++)
         {if (nsamp_comm_lenc(iyear)>=minSS_comm_lenc)
           {nsamp_comm_lenc_allyr(yrs_comm_lenc(iyear))=nsamp_comm_lenc(iyear);
            nfish_comm_lenc_allyr(yrs_comm_lenc(iyear))=nfish_comm_lenc(iyear);}}
      //for (iyear=1; iyear<=nyr_cL_lenc; iyear++)
      //   {if (nsamp_cL_lenc(iyear)>=minSS_cL_lenc)
      //     {nsamp_cL_lenc_allyr(yrs_cL_lenc(iyear))=nsamp_cL_lenc(iyear);
      //      nfish_cL_lenc_allyr(yrs_cL_lenc(iyear))=nfish_cL_lenc(iyear);}}
  //for (iyear=1; iyear<=nyr_GR_lenc; iyear++)
      //   {if (nsamp_GR_lenc(iyear)>=minSS_GR_lenc)
      //      {nsamp_GR_lenc_allyr(yrs_GR_lenc(iyear))=nsamp_GR_lenc(iyear);
      //       nfish_GR_lenc_allyr(yrs_GR_lenc(iyear))=nfish_GR_lenc(iyear);}}
  for (iyear=1; iyear<=nyr_GR_agec; iyear++)
         {if (nsamp_GR_agec(iyear)>=minSS_GR_agec)
           {nsamp_GR_agec_allyr(yrs_GR_agec(iyear))=nsamp_GR_agec(iyear);
             nfish_GR_agec_allyr(yrs_GR_agec(iyear))=nfish_GR_agec(iyear);}}

//fill in Fs for msy and per-recruit analyses
  F_msy(1)=0.0;
  for (ff=2;ff<=n_iter_msy;ff++) {F_msy(ff)=F_msy(ff-1)+iter_inc_msy;}
  F_spr(1)=0.0;
  for (ff=2;ff<=n_iter_spr;ff++) {F_spr(ff)=F_spr(ff-1)+iter_inc_spr;}


//fill in F’s, Catch matrices, and log rec dev with zero’s
  F_comm.initialize(); L_comm_num.initialize();
  //F_cL.initialize(); L_cL_num.initialize();
  // F_HB.initialize(); L_HB_num.initialize();
  F_GR.initialize(); L_GR_num.initialize();

  F_comm_out.initialize();
  //F_cL_out.initialize();
  // F_HB_out.initialize();
  F_GR_out.initialize();

  sel_comm.initialize();
  sel_comm_vec.initialize();
  sel_HB.initialize();
  sel_GR.initialize();


  //sel_comm_block1.initialize();
  //sel_comm_block2.initialize();
  //sel_cL_block1.initialize();
  //sel_cL_block2.initialize();
  sel_HB_block1.initialize();
  sel_HB_block2.initialize();
  sel_GR_block1.initialize();
  sel_GR_block2.initialize();


  log_rec_dev_output.initialize();
  log_rec_dev=set_log_rec_dev_vals;
  log_Nage_dev_output.initialize();
  log_Nage_dev=set_log_Nage_dev_vals;


//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
TOP_OF_MAIN_SECTION
  time(&start);
```

```
  arrmblsize=20000000;
  gradient_structure::set_MAX_NVAR_OFFSET(1600);
  gradient_structure::set_GRADSTACK_BUFFER_SIZE(2000000);
  gradient_structure::set_CMPDIF_BUFFER_SIZE(2000000);
  gradient_structure::set_NUM_DEPENDENT_VARIABLES(10000);

//>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
PROCEDURE_SECTION

 //cout<<"start"<<endl;

 //get_M_at_age(); //Needed only if M is estimated

  get_length_weight_at_age();
  //cout << "got length, weight, fecundity transitions" <<endl;
  get_reprod();
  //cout << "got reprod" << endl;
  get_length_at_age_dist();
  //cout<< "got predicted length at age distribution"<<endl;
  get_weight_at_age_landings();
  //cout<< "got weight at age of landings"<<endl;
  get_spr_F0();
  //cout << "got F0 spr" << endl;
  get_selectivity();
  //cout << "got selectivity" << endl;
  get_mortality();
  // cout << "got mortalities" << endl;
  get_bias_corr();
  //cout<< "got recruitment bias correction" << endl;
  get_numbers_at_age();
  //cout << "got numbers at age" << endl;
  get_landings_numbers();
  //cout << "got landings in numbers" << endl;
  get_landings_wgt();
  //cout << "got landings in wgt" << endl;
  // get_dead_discards();
  //cout << "got dead discards in num and wgt" << endl;
  get_catchability_fcns();
  //cout << "got catchability_fcns" << endl;
  get_indices();
  //cout << "got indices" << endl;
  get_length_comps();
  // cout<< "got length comps"<< endl;
   get_age_comps();
  //cout<< "got age comps"<< endl;
   evaluate_objective_function();
   //cout << "objective function calculations complete" << endl;


FUNCTION get_length_weight_at_age
//population total length in mm
    //compute mean length (mm TL) and weight (whole) at age
    meanlen_TL=Linf*(1.0-mfexp(-K*(agebins-t0+0.5))); //Actually fork length
    wgt_kg=wgtpar_a*pow(meanlen_TL,wgtpar_b);             //whole wgt in kg
    wgt_g=wgt_kg/g2kg;                                    //convert wgt in kg to weight in g
    wgt_mt=wgt_g*g2mt;                                    //convert weight in g to weight in mt
    wgt_klb=mt2klb*wgt_mt;                                //1000 lb of whole wgt
    wgt_lb=mt2lb*wgt_mt;                                  //lb of whole wgt

//All fisheries
meanlen_TL_L=Linf_L*(1.0-mfexp(-K_L*(agebins-t0_L+0.5)));    //Landings total length in mm
    wgt_kg_L=wgtpar_a*pow(meanlen_TL_L,wgtpar_b);             //whole wgt in kg
    wgt_g_L=wgt_kg_L/g2kg;                                    //convert wgt in kg to weight in g
    wgt_mt_L=wgt_g_L*g2mt;                                    //convert weight in g to weight in mt
    wgt_klb_L=mt2klb*wgt_mt_L;                               //1000 lb of whole wgt
    wgt_lb_L=mt2lb*wgt_mt_L;                                 //1000 lb of whole wgt

//Females
meanlen_TL_F=Linf_F*(1.0-mfexp(-K_F*(agebins-t0_F+0.5)));    //Landings total length in mm
    wgt_kg_F=wgtpar_a*pow(meanlen_TL_F,wgtpar_b);             //whole wgt in kg
    wgt_g_F=wgt_kg_F/g2kg;                                    //convert wgt in kg to weight in g
    wgt_mt_F=wgt_g_F*g2mt;                                    //convert weight in g to weight in mt
    wgt_klb_F=mt2klb*wgt_mt_F;                               //1000 lb of whole wgt
    wgt_lb_F=mt2lb*wgt_mt_F;                                 //1000 lb of whole wgt

//batchfec = mfexp(batchfecpar_a + batchfecpar_b*meanlen_TL);  // batch fecundity at length [should be batchfec = exp(a+bL) based on Harris 2004]
//fec = batchfec*nbatch/fecpar_scale;                          // annual fecundity at length scaled to fecpar_scale units

FUNCTION get_reprod

    //reprod=elem_prod(prop_f,elem_prod(maturity_f,fec));
reprod=elem_prod(elem_prod(prop_f,maturity_f),wgt_mt_F);
reprodknum=elem_prod(prop_f,maturity_f)/1000.0;
//+elem_prod(prop_m,maturity_m)),wg_mt);

FUNCTION get_length_at_age_dist
  //compute matrix of length at age, based on the normal distribution
    //population
for (iage=1;iage<=nages;iage++)
   {len_cv(iage)=len_cv_val;
    len_sd(iage)=meanlen_TL(iage)*len_cv(iage);
zscore_lzero=(0.0-meanlen_TL(iage))/len_sd(iage);
cprob_lzero=cumd_norm(zscore_lzero);
```

```
    //All fishery dependent
//len_cv_L(iage)=mfexp(log_len_cv_L+log_len_cv_dev_L(iage));
    len_cv_L(iage)=len_cv_val_L;
    len_sd_L(iage)=meanlen_TL_L(iage)*len_cv_L(iage);
zscore_lzero_L=(0.0-meanlen_TL_L(iage))/len_sd_L(iage);
cprob_lzero_L=cumd_norm(zscore_lzero_L);

//Females
//len_cv_L(iage)=mfexp(log_len_cv_L+log_len_cv_dev_L(iage));
    len_cv_F(iage)=len_cv_val_F;
    len_sd_F(iage)=meanlen_TL_F(iage)*len_cv_F(iage);
zscore_lzero_F=(0.0-meanlen_TL_F(iage))/len_sd_F(iage);
cprob_lzero_F=cumd_norm(zscore_lzero_F);

    //first length bin
//population
    zscore_len=((lenbins(1)+0.5*lenbins_width)-meanlen_TL(iage)) / len_sd(iage);
    cprob_lenvec(1)=cumd_norm(zscore_len);          //includes any probability mass below zero
    lenprob(iage,1)=cprob_lenvec(1)-cprob_lzero;    //removes any probability mass below zero

//All fishery dependent
    zscore_len_L=((lenbins(1)+0.5*lenbins_width)-meanlen_TL_L(iage)) / len_sd_L(iage);
    cprob_lenvec_L(1)=cumd_norm(zscore_len_L);          //includes any probability mass below zero
    lenprob_L(iage,1)=cprob_lenvec_L(1)-cprob_lzero_L;    //removes any probability mass below zero

//Females
    zscore_len_F=((lenbins(1)+0.5*lenbins_width)-meanlen_TL_F(iage)) / len_sd_F(iage);
    cprob_lenvec_F(1)=cumd_norm(zscore_len_F);          //includes any probability mass below zero
    lenprob_F(iage,1)=cprob_lenvec_F(1)-cprob_lzero_F;    //removes any probability mass below zero

    //most other length bins
    //population
    for (ilen=2;ilen<nlenbins;ilen++)
      {
        zscore_len=((lenbins(ilen)+0.5*lenbins_width)-meanlen_TL(iage)) / len_sd(iage);
cprob_lenvec(ilen)=cumd_norm(zscore_len);
        lenprob(iage,ilen)=cprob_lenvec(ilen)-cprob_lenvec(ilen-1);
      }

//All fishery dependent
    for (ilen=2;ilen<nlenbins;ilen++)
      {
        zscore_len_L=((lenbins(ilen)+0.5*lenbins_width)-meanlen_TL_L(iage)) / len_sd_L(iage);
cprob_lenvec_L(ilen)=cumd_norm(zscore_len_L);
        lenprob_L(iage,ilen)=cprob_lenvec_L(ilen)-cprob_lenvec_L(ilen-1);
      }

//Females
    for (ilen=2;ilen<nlenbins;ilen++)
      {
        zscore_len_F=((lenbins(ilen)+0.5*lenbins_width)-meanlen_TL_F(iage)) / len_sd_F(iage);
cprob_lenvec_F(ilen)=cumd_norm(zscore_len_F);
        lenprob_F(iage,ilen)=cprob_lenvec_F(ilen)-cprob_lenvec_F(ilen-1);
      }

    //last length bin is a plus group
//population
    zscore_len=((lenbins(nlenbins)-0.5*lenbins_width)-meanlen_TL(iage)) / len_sd(iage);
lenprob(iage,nlenbins)=1.0-cumd_norm(zscore_len);
      lenprob(iage)=lenprob(iage)/(1.0-cprob_lzero);  //renormalize to account for any prob mass below size=0

//All fishery dependent
    zscore_len_L=((lenbins(nlenbins)-0.5*lenbins_width)-meanlen_TL_L(iage)) / len_sd_L(iage);
lenprob_L(iage,nlenbins)=1.0-cumd_norm(zscore_len_L);
      lenprob_L(iage)=lenprob_L(iage)/(1.0-cprob_lzero_L);  //renormalize to account for any prob mass below size=0

//Females
    zscore_len_F=((lenbins(nlenbins)-0.5*lenbins_width)-meanlen_TL_F(iage)) / len_sd_F(iage);
lenprob_F(iage,nlenbins)=1.0-cumd_norm(zscore_len_F);
      lenprob_F(iage)=lenprob_F(iage)/(1.0-cprob_lzero_F);  //renormalize to account for any prob mass below size=0
   }

  //fleet and survey specific length probs, all assumed here to equal the popn
  lenprob_comm=lenprob_L;
  //lenprob_cL=lenprob;
  lenprob_HB=lenprob;
  //lenprob_GR=lenprob;

FUNCTION get_weight_at_age_landings  ///***in whole weight

  for (iyear=styr; iyear<=endyr; iyear++)
  {
    len_comm_mm(iyear)=meanlen_TL_L;
    wholewgt_comm_klb(iyear)=wgt_klb_L;
    //len_cL_mm(iyear)=meanlen_TL;
    //wholewgt_cL_klb(iyear)=wgt_klb;
    len_HB_mm(iyear)=meanlen_TL_L;
    wholewgt_HB_klb(iyear)=wgt_klb_L;
    len_GR_mm(iyear)=meanlen_TL_L;
    wholewgt_GR_klb(iyear)=wgt_klb_L;
  }


FUNCTION get_spr_F0
  //at mdyr, apply half this yr's mortality, half next yr's
```

```
  N_spr_F0(1)=1.0*mfexp(-1.0*M(1)*spawn_time_frac); //at peak spawning time
  N_bpr_F0(1)=1.0;      //at start of year
  for (iage=2; iage<=nages; iage++)
  { N_spr_F0(iage)=N_spr_F0(iage-1)*mfexp(-1.0*(M(iage-1)*(1.0-spawn_time_frac) + M(iage)*spawn_time_frac));
    N_bpr_F0(iage)=N_bpr_F0(iage-1)*mfexp(-1.0*(M(iage-1)));
  }
  N_spr_F0(nages)=N_spr_F0(nages)/(1.0-mfexp(-1.0*M(nages))); //plus group (sum of geometric series)
  N_bpr_F0(nages)=N_bpr_F0(nages)/(1.0-mfexp(-1.0*M(nages)));

  spr_F0=sum(elem_prod(N_spr_F0,reprod));
  bpr_F0=sum(elem_prod(N_bpr_F0,wgt_mt));



FUNCTION get_selectivity
  sel_comm_vec=logistic(agebins, selpar_A50_comm1, selpar_slope_comm1);
  sel_GR_block1=logistic(agebins, selpar_A50_GR1, selpar_slope_GR1);
  sel_GR_block2=logistic(agebins, selpar_A50_GR2, selpar_slope_GR2);
  sel_HB_block1=sel_GR_block1; // Use GR selectivity for HB
  sel_HB_block2=sel_GR_block1; // Use GR selectivity for HB

  //-------- comm --------//
  for (iyear=styr; iyear<=endyr; iyear++)
{sel_comm(iyear) = sel_comm_vec;}

  //---- GR and HB ----//
  //BLOCK 1 for selex
  for (iyear=styr; iyear<=endyr_selex_phase1_GR; iyear++)
   {
    sel_HB(iyear)=sel_HB_block1;
    sel_GR(iyear)=sel_GR_block1;
   }
  //BLOCK 2 for selex
  for (iyear=(endyr_selex_phase1_GR+1); iyear<=endyr; iyear++)//iyear<=endyr_selex_phase2_GR; iyear++)
   {
    sel_HB(iyear)=sel_HB_block2;
    sel_GR(iyear)=sel_GR_block2;
   }


FUNCTION get_mortality
  Fsum.initialize();
  Fapex.initialize();
  F.initialize();
  //initialization F is avg from first 3 yrs of observed landings
  log_F_dev_init_comm=sum(log_F_dev_comm(styr_comm_L,(styr_comm_L+2)))/3.0;
  //log_F_dev_init_cL=sum(log_F_dev_cL(styr_cL_L,(styr_cL_L+2)))/3.0;
  log_F_dev_init_GR=sum(log_F_dev_GR(styr_GR_L,(styr_GR_L+2)))/3.0;

  for (iyear=styr; iyear<=endyr; iyear++)
  {
    if(iyear>=styr_comm_L & iyear<=endyr_comm_L) //spans full time series
{F_comm_out(iyear)=mfexp(log_avg_F_comm+log_F_dev_comm(iyear));}
    F_comm(iyear)=sel_comm(iyear)*F_comm_out(iyear);
    Fsum(iyear)+=F_comm_out(iyear);


if(iyear>=styr_GR_L & iyear<=endyr_GR_L) //starts in 1981
{F_GR_out(iyear)=mfexp(log_avg_F_GR+log_F_dev_GR(iyear));}
    if (iyear<styr_GR_L)
{F_GR_out(iyear)=mfexp(log_avg_F_GR+log_F_dev_init_GR);}
F_GR(iyear)=sel_GR(iyear)*F_GR_out(iyear);
    Fsum(iyear)+=F_GR_out(iyear);

    //Total F at age
    F(iyear)=F_comm(iyear);  //first in additive series (NO +=)
    //F(iyear)+=F_cL(iyear);
    // F(iyear)+=F_HB(iyear);
    F(iyear)+=F_GR(iyear);

    Fapex(iyear)=max(F(iyear));
    Z(iyear)=M+F(iyear);

   }  //end iyear

FUNCTION get_bias_corr
  var_rec_dev=norm2(log_rec_dev(styr_rec_dev,endyr_rec_dev)-
              sum(log_rec_dev(styr_rec_dev,endyr_rec_dev))/nyrs_rec)
              /(nyrs_rec-1.0);
  //if (set_BiasCor <= 0.0) {BiasCor=mfexp(var_rec_dev/2.0);}   //bias correction based on empirical residuals
  rec_sigma_sq=square(rec_sigma);
  if (set_BiasCor <= 0.0) {BiasCor=mfexp(rec_sigma_sq/2.0);}   //bias correction based on Rsigma
  else {BiasCor=set_BiasCor;}

FUNCTION get_numbers_at_age
//Initialization
  R0=mfexp(log_R0);
  S0=spr_F0*R0;
  //R_virgin=SR_eq_func(R0, steep, spr_F0, spr_F0, BiasCor, SR_switch);
  R_virgin=BiasCor*R0; //changed to move away from an SR relationship
  B0=bpr_F0*R_virgin;
  B0_q_DD=R_virgin*sum(elem_prod(N_bpr_F0(set_q_DD_stage,nages),wgt_mt(set_q_DD_stage,nages)));

  // Commented out code block from Erik’s ASPM for red snapper
  F_init_denom=mfexp(log_avg_F_comm+log_F_dev_init_comm)+mfexp(log_avg_F_GR+log_F_dev_init_GR); //+mfexp(log_avg_F_cL+log_F_dev_init_cL)
```

```
  F_init_comm_prop= mfexp(log_avg_F_comm+log_F_dev_init_comm)/F_init_denom;
  //F_init_cL_prop= mfexp(log_avg_F_cL+log_F_dev_init_cL)/F_init_denom;
  F_init_GR_prop= mfexp(log_avg_F_GR+log_F_dev_init_GR)/F_init_denom;

  F_initial=sel_comm(styr)*F_init*F_init_comm_prop+
            //sel_cL(styr)*F_init*F_init_cL_prop+
            sel_GR(styr)*F_init*F_init_GR_prop;

//F_initial=sel_initial*F_init;
  Z_initial=M+F_initial;

//Initial equilibrium age structure
  N_spr_initial(1)=1.0*mfexp(-1.0*Z_initial(1)*spawn_time_frac); //at peak spawning time;
  for (iage=2; iage<=nages; iage++)
    {
      N_spr_initial(iage)=N_spr_initial(iage-1)*
                   mfexp(-1.0*(Z_initial(iage-1)*(1.0-spawn_time_frac) + Z_initial(iage)*spawn_time_frac));
    }
  N_spr_initial(nages)=N_spr_initial(nages)/(1.0-mfexp(-1.0*Z_initial(nages))); //plus group
  spr_initial=sum(elem_prod(N_spr_initial,reprod));
  //if (styr==styr_rec_dev) {R1=SR_eq_func(R0, steep, spr_F0, spr_initial, 1.0, SR_switch);} //without bias correction (deviation added later)
  //else {R1=SR_eq_func(R0, steep, spr_F0, spr_initial, BiasCor, SR_switch);} //with bias correction
  if (styr==styr_rec_dev) {R1=R0;} //without bias correction (deviation added later)
  else {R1=BiasCor*R0;} //with bias correction

  if(R1<10.0) {R1=10.0;} //Avoid unrealistically low popn sizes during search algorithm

//Compute equilibrium age structure for first year
  N_initial_eq(1)=R1;
  for (iage=2; iage<=nages; iage++)
  {
    N_initial_eq(iage)=N_initial_eq(iage-1)*
        mfexp(-1.0*(Z_initial(iage-1)));
  }
  //plus group calculation
  N_initial_eq(nages)=N_initial_eq(nages)/(1.0-mfexp(-1.0*Z_initial(nages))); //plus group

//Add deviations to initial equilibrium N
  N(styr)(2,nages)=elem_prod(N_initial_eq(2,nages),mfexp(log_Nage_dev));

  if (styr==styr_rec_dev) {N(styr,1)=N_initial_eq(1)*mfexp(log_rec_dev(styr_rec_dev));}
  else {N(styr,1)=N_initial_eq(1);}

  N_mdyr(styr)(1,nages)=elem_prod(N(styr)(1,nages),(mfexp(-1.*(Z_initial(1,nages))*0.5))); //mid year
  N_spawn(styr)(1,nages)=elem_prod(N(styr)(1,nages),(mfexp(-1.*(Z_initial(1,nages))*spawn_time_frac))); //peak spawning time

  SSB(styr)=sum(elem_prod(N_spawn(styr),reprod));
  SSB_knum(styr)=sum(elem_prod(N_spawn(styr),reprodknum));
  B_q_DD(styr)=sum(elem_prod(N(styr)(set_q_DD_stage,nages),wgt_mt(set_q_DD_stage,nages)));

//Rest of years
  for (iyear=styr; iyear<endyr; iyear++)
  {
    if(iyear<(styr_rec_dev-1)||iyear>(endyr_rec_dev-1)) //recruitment follows S-R curve (with bias correction) exactly
    {
N(iyear+1,1)=BiasCor*R0; //Changed to use ave rec instead of SR relationship
//N(iyear+1,1)=BiasCor*SR_func(R0, steep, spr_F0, SSB(iyear),SR_switch);
        N(iyear+1)(2,nages)=++elem_prod(N(iyear)(1,nages-1),(mfexp(-1.*Z(iyear)(1,nages-1))));
        N(iyear+1,nages)+=N(iyear,nages)*mfexp(-1.*Z(iyear,nages)); //plus group
        N_mdyr(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-1.*(Z(iyear+1)(1,nages))*0.5))); //mid year
        N_spawn(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-1.*(Z(iyear+1)(1,nages))*spawn_time_frac))); //peak spawning time
        SSB(iyear+1)=sum(elem_prod(N_spawn(iyear+1),reprod));
SSB_knum(iyear+1)=sum(elem_prod(N_spawn(iyear+1),reprodknum));
B_q_DD(iyear+1)=sum(elem_prod(N(iyear+1)(set_q_DD_stage,nages),wgt_mt(set_q_DD_stage,nages)));
    }
    else   //recruitment follows S-R curve with lognormal deviation
    {
        N(iyear+1,1)=R0*mfexp(log_rec_dev(iyear+1)); //Changed to use ave rec instead of SR relationship
        //N(iyear+1,1)=SR_func(R0, steep, spr_F0, SSB(iyear),SR_switch)*mfexp(log_rec_dev(iyear+1));
        N(iyear+1)(2,nages)=++elem_prod(N(iyear)(1,nages-1),(mfexp(-1.*Z(iyear)(1,nages-1))));
        N(iyear+1,nages)+=N(iyear,nages)*mfexp(-1.*Z(iyear,nages)); //plus group
        N_mdyr(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-1.*(Z(iyear+1)(1,nages))*0.5))); //mid year
        N_spawn(iyear+1)(1,nages)=elem_prod(N(iyear+1)(1,nages),(mfexp(-1.*(Z(iyear+1)(1,nages))*spawn_time_frac))); //peak spawning time
        SSB(iyear+1)=sum(elem_prod(N_spawn(iyear+1),reprod));
SSB_knum(iyear+1)=sum(elem_prod(N_spawn(iyear+1),reprodknum));
        B_q_DD(iyear+1)=sum(elem_prod(N(iyear+1)(set_q_DD_stage,nages),wgt_mt(set_q_DD_stage,nages)));
    }
  }

  //last year (projection) has no recruitment variability
  N(endyr+1,1)=BiasCor*R0; //Changed to use ave rec instead of SR relationship
  //N(endyr+1,1)=BiasCor*SR_func(R0, steep, spr_F0, SSB(endyr),SR_switch);
  N(endyr+1)(2,nages)=++elem_prod(N(endyr)(1,nages-1),(mfexp(-1.*Z(endyr)(1,nages-1))));
  N(endyr+1,nages)+=N(endyr,nages)*mfexp(-1.*Z(endyr,nages)); //plus group


FUNCTION get_landings_numbers //Baranov catch eqn
  for (iyear=styr; iyear<=endyr; iyear++)
  {
    for (iage=1; iage<=nages; iage++)
    {
      L_comm_num(iyear,iage)=N(iyear,iage)*F_comm(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
      //L_cL_num(iyear,iage)=N(iyear,iage)*F_cL(iyear,iage)*
        //(1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
```

```
      L_GR_num(iyear,iage)=N(iyear,iage)*F_GR(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
    }
    pred_comm_L_knum(iyear)=sum(L_comm_num(iyear))/1000.0;
//pred_cL_L_knum(iyear)=sum(L_cL_num(iyear))/1000.0;
    pred_GR_L_knum(iyear)=sum(L_GR_num(iyear))/1000.0;
  }


FUNCTION get_landings_wgt
  for (iyear=styr; iyear<=endyr; iyear++)
  {
    L_comm_klb(iyear)=elem_prod(L_comm_num(iyear),wholewgt_comm_klb(iyear));     //in 1000 lb whole weight
//L_cL_klb(iyear)=elem_prod(L_cL_num(iyear),wholewgt_cL_klb(iyear));     //in 1000 lb whole weight
    // L_HB_klb(iyear)=elem_prod(L_HB_num(iyear),wholewgt_HB_klb(iyear));     //in 1000 lb whole weight
    L_GR_klb(iyear)=elem_prod(L_GR_num(iyear),wholewgt_GR_klb(iyear));     //in 1000 lb whole weight

    pred_comm_L_klb(iyear)=sum(L_comm_klb(iyear));
//pred_cL_L_klb(iyear)=sum(L_cL_klb(iyear));
    // pred_HB_L_klb(iyear)=sum(L_HB_klb(iyear));
    pred_GR_L_klb(iyear)=sum(L_GR_klb(iyear));
  }

FUNCTION get_catchability_fcns
 //Get rate increase if estimated, otherwise fixed above
  if (set_q_rate_phase>0.0)
  {

      for (iyear=styr_HB_cpue; iyear<=endyr_HB_cpue; iyear++)
      {   if (iyear>styr_HB_cpue & iyear <=2003)
          {//q_rate_fcn_HB(iyear)=(1.0+q_rate)*q_rate_fcn_HB(iyear-1); //compound
             q_rate_fcn_HB(iyear)=(1.0+(iyear-styr_HB_cpue)*q_rate)*q_rate_fcn_HB(styr_HB_cpue);  //linear
          }
          if (iyear>2003) {q_rate_fcn_HB(iyear)=q_rate_fcn_HB(iyear-1);}
      }
  } //end q_rate conditional

 //Get density dependence scalar (=1.0 if density independent model is used)
  if (q_DD_beta>0.0)
  {
    B_q_DD+=dzero;
    for (iyear=styr;iyear<=endyr;iyear++)
        {q_DD_fcn(iyear)=pow(B0_q_DD,q_DD_beta)*pow(B_q_DD(iyear),-q_DD_beta);}
          //{q_DD_fcn(iyear)=1.0+4.0/(1.0+mfexp(0.75*(B_q_DD(iyear)-0.1*B0_q_DD))); }
  }


FUNCTION get_indices
//---Predicted CPUEs------------------------

 //HB  cpue
  q_HB(styr_HB_cpue)=mfexp(log_q_HB);
  for (iyear=styr_HB_cpue; iyear<=endyr_HB_cpue; iyear++)
  {
      N_HB(iyear)=elem_prod(N_mdyr(iyear),sel_HB(iyear));
      pred_HB_cpue(iyear)=q_HB(iyear)*q_rate_fcn_HB(iyear)*q_DD_fcn(iyear)*sum(N_HB(iyear));
      if (iyear<endyr_HB_cpue){q_HB(iyear+1)=q_HB(iyear)*mfexp(q_RW_log_dev_HB(iyear));}
  }

FUNCTION get_length_comps

  //comm lines

  for (iyear=1;iyear<=nyr_comm_lenc_pool;iyear++)
   {pred_comm_lenc_yr(iyear)=(L_comm_num(yrs_comm_lenc_pool(iyear))*lenprob_comm)/sum(L_comm_num(yrs_comm_lenc_pool(iyear)));}

  pred_comm_lenc.initialize();
  for (iyear=1;iyear<=nyr_comm_lenc_pool;iyear++)
    {pred_comm_lenc(1) += nfish_comm_lenc_pool(iyear) * pred_comm_lenc_yr(iyear);}
  pred_comm_lenc(1)=pred_comm_lenc(1)/sum(nfish_comm_lenc_pool);

  ////comm longline
  //for (iyear=1;iyear<=nyr_cL_lenc;iyear++)
  //{pred_cL_lenc(iyear)=(L_cL_num(yrs_cL_lenc(iyear))*lenprob_cL)/sum(L_cL_num(yrs_cL_lenc(iyear)));}

  //general rec
  //for (iyear=1;iyear<=nyr_GR_lenc;iyear++)
  //{pred_GR_lenc(iyear)=(L_GR_num(yrs_GR_lenc(iyear))*lenprob_GR)/sum(L_GR_num(yrs_GR_lenc(iyear)));}

FUNCTION get_age_comps

  //Recreational
  for (iyear=1;iyear<=nyr_GR_agec;iyear++)
  {
    ErrorFree_GR_agec(iyear)=L_GR_num(yrs_GR_agec(iyear))/sum(L_GR_num(yrs_GR_agec(iyear)));
    pred_GR_agec_allages(iyear)=age_error*ErrorFree_GR_agec(iyear);
    for (iage=1; iage<=nages_agec; iage++) {pred_GR_agec(iyear,iage)=pred_GR_agec_allages(iyear,iage);}
    //for (iage=(nages_agec+1); iage<=nages; iage++) {pred_GR_agec(iyear,nages_agec)+=pred_GR_agec_allages(iyear,iage);} //plus group
  }

////--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_weighted_current
  F_temp_sum=0.0;
  F_temp_sum+=mfexp((selpar_n_yrs_wgted*log_avg_F_comm+
        sum(log_F_dev_comm((endyr-selpar_n_yrs_wgted+1),endyr)))/selpar_n_yrs_wgted);
```

```
  F_temp_sum+=mfexp((selpar_n_yrs_wgted*log_avg_F_GR+
        sum(log_F_dev_GR((endyr-selpar_n_yrs_wgted+1),endyr)))/selpar_n_yrs_wgted);

  F_comm_prop=mfexp((selpar_n_yrs_wgted*log_avg_F_comm+
        sum(log_F_dev_comm((endyr-selpar_n_yrs_wgted+1),endyr)))/selpar_n_yrs_wgted)/F_temp_sum;

  F_GR_prop=mfexp((selpar_n_yrs_wgted*log_avg_F_GR+
        sum(log_F_dev_GR((endyr-selpar_n_yrs_wgted+1),endyr)))/selpar_n_yrs_wgted)/F_temp_sum;

  log_F_dev_end_comm=sum(log_F_dev_comm((endyr-selpar_n_yrs_wgted+1),endyr))/selpar_n_yrs_wgted;
  //log_F_dev_end_cL=sum(log_F_dev_cL((endyr-selpar_n_yrs_wgted+1),endyr))/selpar_n_yrs_wgted;
  log_F_dev_end_GR=sum(log_F_dev_GR((endyr-selpar_n_yrs_wgted+1),endyr))/selpar_n_yrs_wgted;

  F_end_L=sel_comm(endyr)*mfexp(log_avg_F_comm+log_F_dev_end_comm)+
          //sel_cL(endyr)*mfexp(log_avg_F_cL+log_F_dev_end_cL)+
  sel_GR(endyr)*mfexp(log_avg_F_GR+log_F_dev_end_GR);

  F_end=F_end_L;
  F_end_apex=max(F_end);

  sel_wgted_tot=F_end/F_end_apex;
  sel_wgted_L=elem_prod(sel_wgted_tot, elem_div(F_end_L,F_end));

  wgt_wgted_L_denom=F_comm_prop+F_GR_prop;  //+F_HB_prop+F_cL_prop
  wgt_wgted_L_klb=F_comm_prop/wgt_wgted_L_denom*wholewgt_comm_klb(endyr)+
  //F_cL_prop/wgt_wgted_L_denom*wholewgt_cL_klb(endyr)+
  F_GR_prop/wgt_wgted_L_denom*wholewgt_GR_klb(endyr);

FUNCTION get_msy

  //compute values as functions of F
  for(ff=1; ff<=n_iter_msy; ff++)
  {
    //uses fishery-weighted F's
    Z_age_msy=0.0;
    F_L_age_msy=0.0;

    F_L_age_msy=F_msy(ff)*sel_wgted_L;
    Z_age_msy=M+F_L_age_msy;

    N_age_msy(1)=1.0;
    for (iage=2; iage<=nages; iage++)
      {N_age_msy(iage)=N_age_msy(iage-1)*mfexp(-1.*Z_age_msy(iage-1));}
    N_age_msy(nages)=N_age_msy(nages)/(1.0-mfexp(-1.*Z_age_msy(nages)));
    N_age_msy_spawn(1,(nages-1))=elem_prod(N_age_msy(1,(nages-1)),
                                   mfexp((-1.*Z_age_msy(1,(nages-1)))*spawn_time_frac));
    N_age_msy_spawn(nages)=(N_age_msy_spawn(nages-1)*(mfexp(-1.*(Z_age_msy(nages-1)*(1.0-spawn_time_frac) +
                            Z_age_msy(nages)*spawn_time_frac) )))/(1.0-mfexp(-1.*Z_age_msy(nages)));

    spr_msy(ff)=sum(elem_prod(N_age_msy_spawn,reprod));

    //R_eq(ff)=SR_eq_func(R0, steep, spr_msy(1), spr_msy(ff), BiasCor, SR_switch);
    R_eq(ff)=BiasCor*R0;

    if (R_eq(ff)<dzero) {R_eq(ff)=dzero;}
    N_age_msy*=R_eq(ff);
    N_age_msy_spawn*=R_eq(ff);

    for (iage=1; iage<=nages; iage++)
    {
      L_age_msy(iage)=N_age_msy(iage)*(F_L_age_msy(iage)/Z_age_msy(iage))*
                      (1.-mfexp(-1.*Z_age_msy(iage)));
    }

    SSB_eq(ff)=sum(elem_prod(N_age_msy_spawn,reprod));
SSB_eq_knum(ff)=sum(elem_prod(N_age_msy_spawn,reprodknum));
B_eq(ff)=sum(elem_prod(N_age_msy,wgt_mt));
    L_eq_klb(ff)=sum(elem_prod(L_age_msy,wgt_wgted_L_klb)); //in whole weight
    L_eq_knum(ff)=sum(L_age_msy)/1000.0;
  }

  msy_klb_out=max(L_eq_klb); //msy in whole weight

  for(ff=1; ff<=n_iter_msy; ff++)
  {
   if(L_eq_klb(ff) == msy_klb_out)
      {
        SSB_msy_out=SSB_eq(ff);
        B_msy_out=B_eq(ff);
        R_msy_out=R_eq(ff);
        msy_knum_out=L_eq_knum(ff);
        F_msy_out=F_msy(ff);
        spr_msy_out=spr_msy(ff);
      }
  }

//--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_per_recruit_stuff

  //static per-recruit stuff

  for(iyear=styr; iyear<=endyr; iyear++)
  {
    N_age_spr(1)=1.0;
```

```
   for(iage=2; iage<=nages; iage++)
    {N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z(iyear,iage-1));}
   N_age_spr(nages)=N_age_spr(nages)/(1.0-mfexp(-1.*Z(iyear,nages)));
   N_age_spr_spawn(1,(nages-1))=elem_prod(N_age_spr(1,(nages-1)),
                                mfexp(-1.*Z(iyear)(1,(nages-1))*spawn_time_frac));
   N_age_spr_spawn(nages)=(N_age_spr_spawn(nages-1)*
                          (mfexp(-1.*(Z(iyear)(nages-1)*(1.0-spawn_time_frac) + Z(iyear)(nages)*spawn_time_frac) )))
                          /(1.0-mfexp(-1.*Z(iyear)(nages)));
   spr_static(iyear)=sum(elem_prod(N_age_spr_spawn,reprod))/spr_F0;
 }

 //compute SSB/R and YPR as functions of F
 for(ff=1; ff<=n_iter_spr; ff++)
 {
   //uses fishery-weighted F's, same as in MSY calculations
   Z_age_spr=0.0;
   F_L_age_spr=0.0;

   F_L_age_spr=F_spr(ff)*sel_wgted_L;
   Z_age_spr=M+F_L_age_spr;

   N_age_spr(1)=1.0;
   for (iage=2; iage<=nages; iage++)
    {N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z_age_spr(iage-1));}
   N_age_spr(nages)=N_age_spr(nages)/(1-mfexp(-1.*Z_age_spr(nages)));
   N_age_spr_spawn(1,(nages-1))=elem_prod(N_age_spr(1,(nages-1)),
                                   mfexp((-1.*Z_age_spr(1,(nages-1)))*spawn_time_frac));
   N_age_spr_spawn(nages)=(N_age_spr_spawn(nages-1)*
                          (mfexp(-1.*(Z_age_spr(nages-1)*(1.0-spawn_time_frac) + Z_age_spr(nages)*spawn_time_frac) )))
                          /(1.0-mfexp(-1.*Z_age_spr(nages)));
   spr_spr(ff)=sum(elem_prod(N_age_spr_spawn,reprod));
   L_spr(ff)=0.0;
   for (iage=1; iage<=nages; iage++)
   {
     L_age_spr(iage)=N_age_spr(iage)*(F_L_age_spr(iage)/Z_age_spr(iage))*
                      (1.-mfexp(-1.*Z_age_spr(iage)));
     L_spr(ff)+=L_age_spr(iage)*wgt_wgted_L_klb(iage)*1000.0; //in lb whole wgt
   }
 }
 spr_ratio=spr_spr/spr_F0;
 F20_dum=min(fabs(spr_ratio-0.2));
 F30_dum=min(fabs(spr_ratio-0.3));
 F40_dum=min(fabs(spr_ratio-0.4));
 for(ff=1; ff<=n_iter_spr; ff++)
 {
     if (fabs(spr_ratio(ff)-0.2)==F20_dum) {F20_out=F_spr(ff);}
 if (fabs(spr_ratio(ff)-0.3)==F30_dum) {F30_out=F_spr(ff);}
 if (fabs(spr_ratio(ff)-0.4)==F40_dum) {F40_out=F_spr(ff);}
 }
 rec=column(N,1);
 rec_mean=sum(rec(styr_rec_spr, endyr_rec_spr))/nyrs_rec_spr;
 R_F30_out=rec_mean;
 F_L_age_spr=F30_out*sel_wgted_L;
 Z_age_spr=M+F_L_age_spr;

 N_age_spr(1)=R_F30_out;
 for (iage=2; iage<=nages; iage++)
    {N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z_age_spr(iage-1));}
 N_age_spr(nages)=N_age_spr(nages)/(1-mfexp(-1.*Z_age_spr(nages)));
 N_age_spr_spawn(1,(nages-1))=elem_prod(N_age_spr(1,(nages-1)),
                                   mfexp((-1.*Z_age_spr(1,(nages-1)))*spawn_time_frac));
 N_age_spr_spawn(nages)=(N_age_spr_spawn(nages-1)*
                          (mfexp(-1.*(Z_age_spr(nages-1)*(1.0-spawn_time_frac) + Z_age_spr(nages)*spawn_time_frac) )))
                          /(1.0-mfexp(-1.*Z_age_spr(nages)));

 for (iage=1; iage<=nages; iage++)
   {
     L_age_F30(iage)=N_age_spr(iage)*(F_L_age_spr(iage)/Z_age_spr(iage))*
                      (1.-mfexp(-1.*Z_age_spr(iage)));
   }
 SSB_F30_out=sum(elem_prod(N_age_spr_spawn,reprod));
 SSB_F30_knum_out=sum(elem_prod(N_age_spr_spawn,reprodknum));
 B_F30_out=sum(elem_prod(N_age_spr,wgt_mt));
 L_F30_klb_out=sum(elem_prod(L_age_F30,wgt_wgted_L_klb)); //in whole weight
 L_F30_knum_out=sum(L_age_F30)/1000.0;


//F40 calcs
 rec=column(N,1);
 rec_mean=sum(rec(styr_rec_spr, endyr_rec_spr))/nyrs_rec_spr;
 R_F40_out=rec_mean;
 F_L_age_spr=F40_out*sel_wgted_L;
 Z_age_spr=M+F_L_age_spr;

 N_age_spr(1)=R_F40_out;
 for (iage=2; iage<=nages; iage++)
    {N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z_age_spr(iage-1));}
 N_age_spr(nages)=N_age_spr(nages)/(1-mfexp(-1.*Z_age_spr(nages)));
 N_age_spr_spawn(1,(nages-1))=elem_prod(N_age_spr(1,(nages-1)),
                                   mfexp((-1.*Z_age_spr(1,(nages-1)))*spawn_time_frac));
 N_age_spr_spawn(nages)=(N_age_spr_spawn(nages-1)*
                          (mfexp(-1.*(Z_age_spr(nages-1)*(1.0-spawn_time_frac) + Z_age_spr(nages)*spawn_time_frac) )))
                          /(1.0-mfexp(-1.*Z_age_spr(nages)));

 for (iage=1; iage<=nages; iage++)
```

```
    {
      L_age_F40(iage)=N_age_spr(iage)*(F_L_age_spr(iage)/Z_age_spr(iage))*
                      (1.-mfexp(-1.*Z_age_spr(iage)));
    }
  SSB_F40_out=sum(elem_prod(N_age_spr_spawn,reprod));
  SSB_F40_knum_out=sum(elem_prod(N_age_spr_spawn,reprodknum));
  B_F40_out=sum(elem_prod(N_age_spr,wgt_mt));
  L_F40_klb_out=sum(elem_prod(L_age_F40,wgt_wgted_L_klb)); //in whole weight
  L_F40_knum_out=sum(L_age_F40)/1000.0;


//---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_miscellaneous_stuff

//switch here if var_rec_dev <=dzero
  if(var_rec_dev>0.0)
   {sigma_rec_dev=sqrt(var_rec_dev);} //sample SD of predicted residuals (may not equal rec_sigma)
   else{sigma_rec_dev=0.0;}

  len_cv=elem_div(len_sd,meanlen_TL);
  len_cv_L=elem_div(len_sd_L,meanlen_TL_L);
  len_cv_F=elem_div(len_sd_F,meanlen_TL_F);

  //compute total landings- and discards-at-age in 1000 fish and klb whole weight
  L_total_num.initialize();
  L_total_klb.initialize();
  L_total_knum_yr.initialize();
  L_total_klb_yr.initialize();

  for(iyear=styr; iyear<=endyr; iyear++)
  {
        L_total_klb_yr(iyear)=pred_comm_L_klb(iyear)+pred_GR_L_klb(iyear);//+pred_HB_L_klb(iyear)+pred_cL_L_klb(iyear)
        L_total_knum_yr(iyear)=pred_comm_L_knum(iyear)+pred_GR_L_knum(iyear);//+pred_HB_L_knum(iyear)+pred_cL_L_knum(iyear)

        B(iyear)=elem_prod(N(iyear),wgt_mt);
        totN(iyear)=sum(N(iyear));
        totB(iyear)=sum(B(iyear));
  }

  L_total_num=L_comm_num+L_GR_num;//+L_HB_num+L_cL_num   //landings at age in number fish
  L_total_klb=L_comm_klb+L_GR_klb;//+L_HB_klb+L_cL_klb   //landings at age in klb whole weight

  //Time series of interest
  B(endyr+1)=elem_prod(N(endyr+1),wgt_mt);
  totN(endyr+1)=sum(N(endyr+1));
  totB(endyr+1)=sum(B(endyr+1));
  SdS0=SSB/S0;

  Fend_mean_temp=1.0;
  for (iyear=1; iyear<=selpar_n_yrs_wgted; iyear++) {Fend_mean_temp*=Fapex(endyr-iyear+1);}
  Fend_mean=pow(Fend_mean_temp,(1.0/selpar_n_yrs_wgted));
  if(F_msy_out>0)
    {
      FdF_msy=Fapex/F_msy_out;
      FdF_msy_end=FdF_msy(endyr);
      FdF_msy_end_mean=Fend_mean/F_msy_out;
    }
  if(SSB_msy_out>0)
    {
      SdSSB_msy=SSB/SSB_msy_out;
      SdSSB_msy_end=SdSSB_msy(endyr);
    }

if(F30_out>0)
    {
  FdF30=Fapex/F30_out;
  FdF30_end_mean=Fend_mean/F30_out;
}
  if(SSB_F30_out>0)
    {
      SdSSB_F30=SSB/SSB_F30_out;
  Sdmsst_F30=SSB/(smsy2msst75*SSB_F30_out);
      SdSSB_F30_end=SdSSB_F30(endyr);
  Sdmsst_F30_end=Sdmsst_F30(endyr);
    }

if(F40_out>0)
    {
  FdF40=Fapex/F40_out;
  FdF40_end_mean=Fend_mean/F40_out;
}
  if(SSB_F40_out>0)
    {
      SdSSB_F40=SSB/SSB_F40_out;
  Sdmsst_F40=SSB/(smsy2msst75*SSB_F40_out);
      SdSSB_F40_end=SdSSB_F40(endyr);
  Sdmsst_F40_end=Sdmsst_F40(endyr);
    }
   //fill in log recruitment deviations for yrs they are nonzero
   for(iyear=styr_rec_dev; iyear<=endyr_rec_dev; iyear++)
     {log_rec_dev_output(iyear)=log_rec_dev(iyear);}
   //fill in log Nage deviations for ages they are nonzero (ages2+)
   for(iage=2; iage<=nages; iage++)
     {log_Nage_dev_output(iage)=log_Nage_dev(iage);}
```

```
//-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_projection

    switch(Fproj_switch){
       case 1: //F=Fcurrent
          F_reg_proj=Fend_mean;
          break;
       case 2: //F=Fmsy
          F_reg_proj=F_msy_out;
          break;
       case 3: //F=F30
          F_reg_proj=F30_out;
          break;
       case 4: //F=F40
          F_reg_proj=F40_out;
          break;
       default: // no such switch available
          cout << "Error in input: Projection switch Fproj_switch must be set to 1, 2, 3, or 4." << endl;
          cout << "Presently it is set to " << Fproj_switch <<"."<< endl;
          exit(0);
   }

  N_proj(styr_proj)=N(endyr+1); //initial conditions computed previously

  for (iyear=styr_proj; iyear<=endyr_proj; iyear++) //recruitment follows S-R curve (with bias correction) exactly
  {
        if (iyear<styr_regs) {F_proj(iyear)=Fend_mean;}
else {F_proj(iyear)=Fproj_mult*F_reg_proj;}

FL_age_proj=sel_wgted_L*F_proj(iyear);

        Z_proj(iyear)=M+FL_age_proj;//+FD_age_proj;
        N_spawn_proj(iyear)(1,nages)=elem_prod(N_proj(iyear)(1,nages),(mfexp(-1.*(Z_proj(iyear)(1,nages))*spawn_time_frac))); //peak spawning time
SSB_proj(iyear)= sum(elem_prod(N_spawn_proj(iyear),reprod));
        B_proj(iyear)=sum(elem_prod(N_proj(iyear),wgt_mt)); //uses spawning weight

for (iage=1; iage<=nages; iage++)
{L_age_proj(iyear,iage)=N_proj(iyear,iage)*FL_age_proj(iage)*(1.-mfexp(-1.*Z_proj(iyear,iage)))/Z_proj(iyear,iage);
}
        L_knum_proj(iyear)=sum(L_age_proj(iyear))/1000.0;
    L_klb_proj(iyear)=sum(elem_prod(L_age_proj(iyear),wgt_wgted_L_klb));     //in 1000 lb

if (iyear<endyr_proj) {
N_proj(iyear+1,1)=BiasCor*R0; //Changed to move away from an SR relationship
//N_proj(iyear+1,1)=BiasCor*SR_func(R0, steep, spr_F0, SSB_proj(iyear),SR_switch);
N_proj(iyear+1)(2,nages)=++elem_prod(N_proj(iyear)(1,nages-1),(mfexp(-1.*Z_proj(iyear)(1,nages-1))));
N_proj(iyear+1,nages)+=N_proj(iyear,nages)*mfexp(-1.*Z_proj(iyear,nages)); //plus group
}
  }
   R_proj=column(N_proj,1);
//-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------


FUNCTION evaluate_objective_function
  //fval=square(xdum-9.0);

  fval=0.0;
  fval_data=0.0;
//---likelihoods---------------------------

//---Indices-------------------------------

  f_HB_cpue=0.0;
  f_HB_cpue=lk_lognormal(pred_HB_cpue, obs_HB_cpue, HB_cpue_cv, w_I_HB);
  fval+=f_HB_cpue;
  fval_data+=f_HB_cpue;

//---Landings-------------------------------

  //f_comm_L in 1000 lb whole wgt
  f_comm_L=lk_lognormal(pred_comm_L_klb(styr_comm_L,endyr_comm_L), obs_comm_L(styr_comm_L,endyr_comm_L),
                      comm_L_cv(styr_comm_L,endyr_comm_L), w_L);
  fval+=f_comm_L;
  fval_data+=f_comm_L;

  //f_GR_L in 1000 fish
  f_GR_L=lk_lognormal(pred_GR_L_knum(styr_GR_L,endyr_GR_L), obs_GR_L(styr_GR_L,endyr_GR_L),
                      GR_L_cv(styr_GR_L,endyr_GR_L), w_L);
  fval+=f_GR_L;
  fval_data+=f_GR_L;

//---Length comps-------------------------------

  //f_comm_lenc
  //f_comm_lenc=lk_robust_multinomial(nsamp_comm_lenc, pred_comm_lenc, obs_comm_lenc, nyr_comm_lenc, double(nlenbins), minSS_comm_lenc, w_lc_comm);
  //f_comm_lenc=lk_logistic_normal(nsamp_comm_lenc, pred_comm_lenc, obs_comm_lenc, nyr_comm_lenc, double(nlenbins), minSS_comm_lenc);
  f_comm_lenc=lk_dirichlet_multinomial(nsamp_comm_lenc, pred_comm_lenc, obs_comm_lenc, nyr_comm_lenc, double(nlenbins), minSS_comm_lenc, log_dm_comm_lc);
  fval+=f_comm_lenc;
  fval_data+=f_comm_lenc;


//---Age comps-------------------------------

//f_GR_agec
  //f_GR_agec=lk_robust_multinomial(nsamp_GR_agec, pred_GR_agec, obs_GR_agec, nyr_GR_agec, double(nages_agec), minSS_GR_agec, w_ac_GR);
```

```
  //f_GR_agec=lk_logistic_normal(nsamp_GR_agec, pred_GR_agec, obs_GR_agec, nyr_GR_agec, double(nages_agec), minSS_GR_agec);
  f_GR_agec=lk_dirichlet_multinomial(nsamp_GR_agec, pred_GR_agec, obs_GR_agec, nyr_GR_agec, double(nages_agec), minSS_GR_agec, log_dm_GR_ac);
  fval+=f_GR_agec;
  fval_data+=f_GR_agec;
//-----------Constraints and penalties--------------------------------

  //Light penalty applied to log_Nage_dev for deviation from zero. If not estimated, this penalty equals zero.
  f_Nage_init=norm2(log_Nage_dev);
  fval+=w_Nage_init*f_Nage_init;

  f_rec_dev=0.0;
  //rec_sigma_sq=square(rec_sigma);
  rec_logL_add=nyrs_rec*log(rec_sigma);
  f_rec_dev=(square(log_rec_dev(styr_rec_dev) + rec_sigma_sq/2.0)/(2.0*rec_sigma_sq));
  for(iyear=(styr_rec_dev+1); iyear<=endyr_rec_dev; iyear++)
  {f_rec_dev+=(square(log_rec_dev(iyear)-R_autocorr*log_rec_dev(iyear-1) + rec_sigma_sq/2.0)/
               (2.0*rec_sigma_sq));}
  f_rec_dev+=rec_logL_add;
  fval+=w_rec*f_rec_dev;

  f_rec_dev_early=0.0; //possible extra constraint on early rec deviations
  if (w_rec_early>0.0)
    { if (styr_rec_dev<endyr_rec_phase1)
        {
          for(iyear=styr_rec_dev; iyear<=endyr_rec_phase1; iyear++)
          //{f_rec_dev_early+=(square(log_rec_dev(iyear)-R_autocorr*log_rec_dev(iyear-1) + rec_sigma_sq/2.0)/
          //                  (2.0*rec_sigma_sq)) + rec_logL_add;}
          {f_rec_dev_early+=square(log_rec_dev(iyear));}
        }
  fval+=w_rec_early*f_rec_dev_early;
  }

  f_rec_dev_end=0.0; //possible extra constraint on ending rec deviations
  if (w_rec_end>0.0)
  { if (endyr_rec_phase2<endyr_rec_dev)
        {
          for(iyear=(endyr_rec_phase2+1); iyear<=endyr_rec_dev; iyear++)
          //{f_rec_dev_end+=(square(log_rec_dev(iyear)-R_autocorr*log_rec_dev(iyear-1) + rec_sigma_sq/2.0)/
          //                 (2.0*rec_sigma_sq)) + rec_logL_add;}
          {f_rec_dev_end+=square(log_rec_dev(iyear));}
        }
      fval+=w_rec_end*f_rec_dev_end;
   }

  //Ftune penalty: does not apply in last phase
  f_Ftune=0.0;
  if (w_Ftune>0.0)
  {if (set_Ftune>0.0 && !last_phase()) {f_Ftune=square(Fapex(set_Ftune_yr)-set_Ftune);}
   fval+=w_Ftune*f_Ftune;
  }

  //Penalty if apical F exceeds 3.0
  f_fullF_constraint=0.0;
  if (w_fullF>0.0)
  {for (iyear=styr; iyear<=endyr; iyear++)
        {if(Fapex(iyear)>3.0) {f_fullF_constraint+=(mfexp(Fapex(iyear)-3.0)-1.0);}}
   fval+=w_fullF*f_fullF_constraint;
  }

 //Random walk components of fishery dependent indices
 //f_comm_RWq_cpue=0.0;
 //for (iyear=styr_comm_cpue; iyear<endyr_comm_cpue; iyear++)
 //     {f_comm_RWq_cpue+=square(q_RW_log_dev_comm(iyear))/(2.0*set_RWq_var);}
 //fval+=f_comm_RWq_cpue;
 //
 //f_cL_RWq_cpue=0.0;
 //for (iyear=styr_cL_cpue; iyear<endyr_cL_cpue; iyear++)
 //     {f_cL_RWq_cpue+=square(q_RW_log_dev_cL(iyear))/(2.0*set_RWq_var);}
 //fval+=f_cL_RWq_cpue;
 //
 f_HB_RWq_cpue=0.0;
 for (iyear=styr_HB_cpue; iyear<endyr_HB_cpue; iyear++)
     {f_HB_RWq_cpue+=square(q_RW_log_dev_HB(iyear))/(2.0*set_RWq_var);}
 fval+=f_HB_RWq_cpue;

//---Priors---------------------------------------------------
//neg_log_prior arguments: estimate, prior mean, prior var/-CV, pdf type
//Variance input as a negative value is considered to be CV in arithmetic space (CV=-1 implies loose prior)
//pdf type 1=none, 2=lognormal, 3=normal, 4=beta
  f_priors=0.0;
  f_priors+=neg_log_prior(len_cv_val,set_len_cv(5),set_len_cv(6),set_len_cv(7));

  f_priors+=neg_log_prior(steep,set_steep(5),set_steep(6),set_steep(7));
  f_priors+=neg_log_prior(log_R0,set_log_R0(5),set_log_R0(6),set_log_R0(7));
  f_priors+=neg_log_prior(R_autocorr,set_R_autocorr(5),set_R_autocorr(6),set_R_autocorr(7));
  f_priors+=neg_log_prior(rec_sigma,set_rec_sigma(5),set_rec_sigma(6),set_rec_sigma(7));

  f_priors+=neg_log_prior(selpar_A50_comm1,set_selpar_A50_comm1(5), set_selpar_A50_comm1(6), set_selpar_A50_comm1(7));
  f_priors+=neg_log_prior(selpar_slope_comm1,set_selpar_slope_comm1(5), set_selpar_slope_comm1(6), set_selpar_slope_comm1(7));
  //f_priors+=neg_log_prior(selpar_A50_comm2,set_selpar_A50_comm2(5), set_selpar_A50_comm2(6), set_selpar_A50_comm2(7));
  //f_priors+=neg_log_prior(selpar_slope_comm2,set_selpar_slope_comm2(5), set_selpar_slope_comm2(6), set_selpar_slope_comm2(7));
  // f_priors+=neg_log_prior(selpar_A502_comm2,set_selpar_A502_comm2(5), set_selpar_A502_comm2(6), set_selpar_A502_comm2(7));
  // f_priors+=neg_log_prior(selpar_slope2_comm2,set_selpar_slope2_comm2(5), set_selpar_slope2_comm2(6), set_selpar_slope2_comm2(7));
  //f_priors+=neg_log_prior(selpar_A50_comm3,set_selpar_A50_comm3(5), set_selpar_A50_comm3(6), set_selpar_A50_comm3(7));
  //f_priors+=neg_log_prior(selpar_slope_comm3,set_selpar_slope_comm3(5), set_selpar_slope_comm3(6), set_selpar_slope_comm3(7));
```

```
  f_priors+=neg_log_prior(selpar_A50_GR1,set_selpar_A50_GR1(5), set_selpar_A50_GR1(6), set_selpar_A50_GR1(7));
  f_priors+=neg_log_prior(selpar_slope_GR1,set_selpar_slope_GR1(5), set_selpar_slope_GR1(6), set_selpar_slope_GR1(7));
  f_priors+=neg_log_prior(selpar_A50_GR2,set_selpar_A50_GR2(5), set_selpar_A50_GR2(6), set_selpar_A50_GR2(7));
  f_priors+=neg_log_prior(selpar_slope_GR2,set_selpar_slope_GR2(5), set_selpar_slope_GR2(6), set_selpar_slope_GR2(7));

   f_priors+=neg_log_prior(log_q_HB,set_log_q_HB(5),set_log_q_HB(6),set_log_q_HB(7));

  f_priors+=neg_log_prior(log_dm_comm_lc,set_log_dm_comm_lc(5),set_log_dm_comm_lc(6),set_log_dm_comm_lc(7));
  //f_priors+=neg_log_prior(log_dm_cL_lc,set_log_dm_cL_lc(5),set_log_dm_cL_lc(6),set_log_dm_cL_lc(7));
  f_priors+=neg_log_prior(log_dm_GR_ac,set_log_dm_GR_ac(5),set_log_dm_GR_ac(6),set_log_dm_GR_ac(7));
  //f_priors+=neg_log_prior(log_dm_GR_lc,set_log_dm_GR_lc(5),set_log_dm_GR_lc(6),set_log_dm_GR_lc(7));

  f_priors+=neg_log_prior(F_init,set_F_init(5),set_F_init(6),set_F_init(7));

  fval+=f_priors;

//------------------------------------------------------------------------------
//Logistic function: 2 parameters
FUNCTION dvar_vector logistic(const dvar_vector& ages, const dvariable& A50, const dvariable& slope)
  //ages=vector of ages, A50=age at 50% selectivity, slope=rate of increase
  RETURN_ARRAYS_INCREMENT();
  dvar_vector Sel_Tmp(ages.indexmin(),ages.indexmax());
  Sel_Tmp=1./(1.+mfexp(-1.*slope*(ages-A50))); //logistic;
  RETURN_ARRAYS_DECREMENT();
  return Sel_Tmp;

//-------------------------------------------------------------------------------
//Logistic-exponential: 4 parameters (but 1 is fixed)
FUNCTION dvar_vector logistic_exponential(const dvar_vector& ages, const dvariable& A50, const dvariable& slope, const dvariable& sigma, const dvariable& joint)
  //ages=vector of ages, A50=age at 50% sel (ascending limb), slope=rate of increase, sigma=controls rate of descent (descending)
  //joint=age to join curves
  RETURN_ARRAYS_INCREMENT();
  dvar_vector Sel_Tmp(ages.indexmin(),ages.indexmax());
  Sel_Tmp=1.0;
  for (iage=1; iage<=nages; iage++)
  {
   if (ages(iage)<joint) {Sel_Tmp(iage)=1./(1.+mfexp(-1.*slope*(ages(iage)-A50)));}
   if (ages(iage)>joint){Sel_Tmp(iage)=mfexp(-1.*square((ages(iage)-joint)/sigma));}
  }
  Sel_Tmp=Sel_Tmp/max(Sel_Tmp);
  RETURN_ARRAYS_DECREMENT();
  return Sel_Tmp;

//-------------------------------------------------------------------------------
//Logistic function: 4 parameters
FUNCTION dvar_vector logistic_double(const dvar_vector& ages, const dvariable& A501, const dvariable& slope1, const dvariable& A502, const dvariable& slope2)
  //ages=vector of ages, A50=age at 50% selectivity, slope=rate of increase, A502=age at 50% decrease additive to A501, slope2=slope of decrease
  RETURN_ARRAYS_INCREMENT();
  dvar_vector Sel_Tmp(ages.indexmin(),ages.indexmax());
  Sel_Tmp=elem_prod( (1./(1.+mfexp(-1.*slope1*(ages-A501)))),(1.-(1./(1.+mfexp(-1.*slope2*(ages-(A501+A502)))))) );
  Sel_Tmp=Sel_Tmp/max(Sel_Tmp);
  RETURN_ARRAYS_DECREMENT();
  return Sel_Tmp;

//-------------------------------------------------------------------------------
//Jointed logistic function: 6 parameters (increasing and decreasing logistics joined at peak selectivity)
FUNCTION dvar_vector logistic_joint(const dvar_vector& ages, const dvariable& A501, const dvariable& slope1, const dvariable& A502, const dvariable& slope2, const dvariable& satval, const dvariable& joint)
  //ages=vector of ages, A501=age at 50% sel (ascending limb), slope1=rate of increase,A502=age at 50% sel (descending), slope1=rate of increase (ascending),
  //satval=saturation value of descending limb, joint=location in age vector to join curves (may equal age or age + 1 if age-0 is included)
  RETURN_ARRAYS_INCREMENT();
  dvar_vector Sel_Tmp(ages.indexmin(),ages.indexmax());
  Sel_Tmp=1.0;
  for (iage=1; iage<=nages; iage++)
  {
   if (double(iage)<joint) {Sel_Tmp(iage)=1./(1.+mfexp(-1.*slope1*(ages(iage)-A501)));}
   if (double(iage)>joint){Sel_Tmp(iage)=1.0-(1.0-satval)/(1.+mfexp(-1.*slope2*(ages(iage)-A502)));}
  }
  Sel_Tmp=Sel_Tmp/max(Sel_Tmp);
  RETURN_ARRAYS_DECREMENT();
  return Sel_Tmp;

//-------------------------------------------------------------------------------
//Double Gaussian function: 6 parameters (as in SS3)
FUNCTION dvar_vector gaussian_double(const dvar_vector& ages, const dvariable& peak, const dvariable& top, const dvariable& ascwid, const dvariable& deswid, const dvariable& init, const dvariable& final)
  //ages=vector of ages, peak=ascending inflection location (as logistic), top=width of plateau, ascwid=ascent width (as log(width))
  //deswid=descent width (as log(width))
  RETURN_ARRAYS_INCREMENT();
  dvar_vector Sel_Tmp(ages.indexmin(),ages.indexmax());
  dvar_vector sel_step1(ages.indexmin(),ages.indexmax());
  dvar_vector sel_step2(ages.indexmin(),ages.indexmax());
  dvar_vector sel_step3(ages.indexmin(),ages.indexmax());
  dvar_vector sel_step4(ages.indexmin(),ages.indexmax());
  dvar_vector sel_step5(ages.indexmin(),ages.indexmax());
  dvar_vector sel_step6(ages.indexmin(),ages.indexmax());
  dvar_vector pars_tmp(1,6); dvar_vector sel_tmp_iq(1,2);

  pars_tmp(1)=peak;
  pars_tmp(2)=peak+1.0+(0.99*ages(nages)-peak-1.0)/(1.0+mfexp(-top));
  pars_tmp(3)=mfexp(ascwid);
  pars_tmp(4)=mfexp(deswid);
  pars_tmp(5)=1.0/(1.0+mfexp(-init));
  pars_tmp(6)=1.0/(1.0+mfexp(-final));
```

```
  sel_tmp_iq(1)=mfexp(-(square(ages(1)-pars_tmp(1))/pars_tmp(3)));
  sel_tmp_iq(2)=mfexp(-(square(ages(nages)-pars_tmp(2))/pars_tmp(4)));

  sel_step1=mfexp(-(square(ages-pars_tmp(1))/pars_tmp(3)));
  sel_step2=pars_tmp(5)+(1.0-pars_tmp(5))*(sel_step1-sel_tmp_iq(1))/(1.0-sel_tmp_iq(1));
  sel_step3=mfexp(-(square(ages-pars_tmp(2))/pars_tmp(4)));
  sel_step4=1.0+(pars_tmp(6)-1.0)*(sel_step3-1.0)/(sel_tmp_iq(2)-1.0);
  sel_step5=1.0/ (1.0+mfexp(-(20.0* elem_div((ages-pars_tmp(1)), (1.0+sfabs(ages-pars_tmp(1)))) )));
  sel_step6=1.0/(1.0+mfexp(-(20.0*elem_div((ages-pars_tmp(2)),(1.0+sfabs(ages-pars_tmp(2)))) )));

  Sel_Tmp=elem_prod(sel_step2,(1.0-sel_step5))+
          elem_prod(sel_step5,((1.0-sel_step6)+ elem_prod(sel_step4,sel_step6)) );

  Sel_Tmp=Sel_Tmp/max(Sel_Tmp);
  RETURN_ARRAYS_DECREMENT();
  return Sel_Tmp;

//-----------------------------------------------------------------------------------
//Spawner-recruit function (Beverton-Holt or Ricker)
FUNCTION dvariable SR_func(const dvariable& R0, const dvariable& h, const dvariable& spr_F0, const dvariable& SSB, int func)
  //R0=virgin recruitment, h=steepness, spr_F0=spawners per recruit @ F=0, SSB=spawning biomass
  //func=1 for Beverton-Holt, 2 for Ricker
  RETURN_ARRAYS_INCREMENT();
  dvariable Recruits_Tmp;
  switch(func) {
    case 1: //Beverton-Holt
      Recruits_Tmp=((0.8*R0*h*SSB)/(0.2*R0*spr_F0*(1.0-h)+(h-0.2)*SSB));
    break;
    case 2: //Ricker
      Recruits_Tmp=((SSB/spr_F0)*mfexp(h*(1-SSB/(R0*spr_F0))));
    break;
  }
  RETURN_ARRAYS_DECREMENT();
  return Recruits_Tmp;

//-----------------------------------------------------------------------------------
//Spawner-recruit equilibrium function (Beverton-Holt or Ricker)
FUNCTION dvariable SR_eq_func(const dvariable& R0, const dvariable& h, const dvariable& spr_F0, const dvariable& spr_F, const dvariable& BC, int func)
  //R0=virgin recruitment, h=steepness, spr_F0=spawners per recruit @ F=0, spr_F=spawners per recruit @ F, BC=bias correction
  //func=1 for Beverton-Holt, 2 for Ricker
  RETURN_ARRAYS_INCREMENT();
  dvariable Recruits_Tmp;
  switch(func) {
    case 1: //Beverton-Holt
      Recruits_Tmp=(R0/((5.0*h-1.0)*spr_F))*(BC*4.0*h*spr_F-spr_F0*(1.0-h));
    break;
    case 2: //Ricker
      Recruits_Tmp=R0/(spr_F/spr_F0)*(1.0+log(BC*spr_F/spr_F0)/h);
    break;
  }
  RETURN_ARRAYS_DECREMENT();
  return Recruits_Tmp;

//-----------------------------------------------------------------------------------
//compute multinomial effective sample size for a single yr
FUNCTION dvariable multinom_eff_N(const dvar_vector& pred_comp, const dvar_vector& obs_comp)
  //pred_comp=vector of predicted comps, obscomp=vector of observed comps
  dvariable EffN_Tmp; dvariable numer; dvariable denom;
  RETURN_ARRAYS_INCREMENT();
  numer=sum( elem_prod(pred_comp,(1.0-pred_comp)) );
  denom=sum( square(obs_comp-pred_comp) );
  if (denom>0.0) {EffN_Tmp=numer/denom;}
  else {EffN_Tmp=-missing;}
  RETURN_ARRAYS_DECREMENT();
  return EffN_Tmp;

//-----------------------------------------------------------------------------------
//Likelihood contribution: lognormal
FUNCTION dvariable lk_lognormal(const dvar_vector& pred, const dvar_vector& obs, const dvar_vector& cv, const dvariable& wgt_dat)
  //pred=vector of predicted vals, obs=vector of observed vals, cv=vector of CVs in arithmetic space, wgt_dat=constant scaling of CVs
  //small_number is small value to avoid log(0) during search
  RETURN_ARRAYS_INCREMENT();
  dvariable LkvalTmp;
  dvariable small_number=0.0001;
  dvar_vector var(cv.indexmin(),cv.indexmax()); //variance in log space
  var=log(1.0+square(cv/wgt_dat));   // convert cv in arithmetic space to variance in log space
  LkvalTmp=sum(0.5*elem_div(square(log(elem_div((pred+small_number),(obs+small_number)))),var) );
  RETURN_ARRAYS_DECREMENT();
  return LkvalTmp;

//-----------------------------------------------------------------------------------
//Likelihood contribution: multinomial
FUNCTION dvariable lk_multinomial(const dvar_vector& nsamp, const dvar_matrix& pred_comp, const dvar_matrix& obs_comp, const double& ncomp, const double& minSS, const dvariable& wgt_dat)
  //nsamp=vector of N's, pred_comp=matrix of predicted comps, obs_comp=matrix of observed comps, ncomp = number of yrs in matrix, minSS=min N threshold, wgt_dat=scaling of N's
  RETURN_ARRAYS_INCREMENT();
  dvariable LkvalTmp;
  dvariable small_number=0.0001;
  LkvalTmp=0.0;
  for (int ii=1; ii<=ncomp; ii++)
  {if (nsamp(ii)>=minSS)
    {LkvalTmp-=wgt_dat*nsamp(ii)*sum(elem_prod((obs_comp(ii)+small_number),
               log(elem_div((pred_comp(ii)+small_number), (obs_comp(ii)+small_number)))));
    }
  }
  RETURN_ARRAYS_DECREMENT();
```

```
  return LkvalTmp;

//-------------------------------------------------------------------------------------
//Likelihood contribution: robust multinomial
FUNCTION dvariable lk_robust_multinomial(const dvar_vector& nsamp, const dvar_matrix& pred_comp, const dvar_matrix& obs_comp, const double& ncomp, const dvariable& mbin, const double& minSS, const dvariable& wgt
  //nsamp=vector of N’s, pred_comp=matrix of predicted comps, obs_comp=matrix of observed comps, ncomp = number of yrs in matrix, mbin=number of bins, minSS=min N threshold, wgt_dat=scaling of N’s
  RETURN_ARRAYS_INCREMENT();
  dvariable LkvalTmp;
  dvariable small_number=0.0001;
  LkvalTmp=0.0;
  dvar_matrix Eprime=elem_prod((1.0-obs_comp), obs_comp)+0.1/mbin; //E’ of Francis 2011, p.1131
  dvar_vector nsamp_wgt=nsamp*wgt_dat;
  //cout<<nsamp_wgt<<endl;
  for (int ii=1; ii<=ncomp; ii++)
  {if (nsamp(ii)>=minSS)
    {LkvalTmp+= sum(0.5*log(Eprime(ii))-log(small_number+mfexp(elem_div((-square(obs_comp(ii)-pred_comp(ii))) , (Eprime(ii)*2.0/nsamp_wgt(ii)) ))) );
    }
  }
  RETURN_ARRAYS_DECREMENT();
  return LkvalTmp;

//-------------------------------------------------------------------------------------
//Likelihood contribution: Dirichlet-multinomial
FUNCTION dvariable lk_dirichlet_multinomial(const dvar_vector& nsamp, const dvar_matrix& pred_comp, const dvar_matrix& obs_comp, const double& ncomp, const dvariable& mbin, const double& minSS, const dvariable&
  //nsamp=vector of N’s, pred_comp=matrix of predicted comps, obs_comp=matrix of observed comps, ncomp = number of yrs in matrix, mbin=number of bins, minSS=min N threshold, wgt_dat=scaling of N’s
  RETURN_ARRAYS_INCREMENT();
  dvariable LkvalTmp;
  dvariable small_number=0.00001;
  LkvalTmp=0.0;
  dvar_vector nsamp_adjust=nsamp*mfexp(log_dir_par);
   //dvar_vector nsamp_adjust=mfexp(log_dir_par);
  for (int ii=1; ii<=ncomp; ii++)
  {
if (nsamp(ii)>=minSS)
    {
LkvalTmp-=gammln(nsamp_adjust(ii))-gammln(nsamp(ii)+nsamp_adjust(ii));
LkvalTmp-=sum(gammln(nsamp(ii)*obs_comp(ii)+nsamp_adjust(ii)*pred_comp(ii)+small_number));
LkvalTmp+=sum(gammln(nsamp_adjust(ii)*pred_comp(ii)+small_number));
    }
  }
  RETURN_ARRAYS_DECREMENT();
  return LkvalTmp;

// //Likelihood contribution: Dirichlet-multinomial
// FUNCTION dvariable lk_dirichlet_multinomial(const dvar_vector& nsamp, const dvar_matrix& pred_comp, const dvar_matrix& obs_comp, const double& ncomp, const dvariable& mbin, const double& minSS, const dvariabl
  // //nsamp=vector of N’s, pred_comp=matrix of predicted comps, obs_comp=matrix of observed comps, ncomp = number of yrs in matrix, mbin=number of bins, minSS=min N threshold, wgt_dat=scaling of N’s
  // RETURN_ARRAYS_INCREMENT();
  // dvariable LkvalTmp;
  // LkvalTmp=0.0;
  // dvar_vector nsamp_adjust=nsamp*mfexp(log_dir_par);
  // //dvar_vector nsamp_adjust=mfexp(log_dir_par);
  // for (int ii=1; ii<=ncomp; ii++)
  // {
// if (nsamp(ii)>=minSS)
    // {
// LkvalTmp-=gammln(nsamp_adjust(ii))-gammln(nsamp(ii)+nsamp_adjust(ii));
// LkvalTmp-=sum(gammln(nsamp(ii)*obs_comp(ii)+nsamp_adjust(ii)*pred_comp(ii)));
        // LkvalTmp+=sum(gammln(nsamp_adjust(ii)*pred_comp(ii)));
    // }
  // }
  // RETURN_ARRAYS_DECREMENT();
  // return LkvalTmp;


//-------------------------------------------------------------------------------------
//Likelihood contribution: logistic normal (aka multivariate logistic in iSCAM; logistic normal in Francis’ terminology)
FUNCTION dvariable lk_logistic_normal(const dvar_vector& nsamp, const dvar_matrix& pred_comp, const dvar_matrix& obs_comp, const double& ncomp, const dvariable& mbin, const double& minSS)
  //nsamp=vector of N’s, pred_comp=matrix of predicted comps, obs_comp=matrix of observed comps, ncomp = number of yrs in matrix, mbin=number of bins, minSS=min N threshold
  RETURN_ARRAYS_INCREMENT();
  dvariable LkvalTmp;
  dvariable small_number=0.0001;
  LkvalTmp=0.0;
  dvar_matrix nu=pred_comp+0.0;
  dvar_matrix pred_plus=pred_comp+small_number;
  dvar_matrix obs_plus=obs_comp+small_number;

  dvariable nu_mean;
  dvariable nu_sum_sq;
  dvariable tau_hat_sq;
  dvariable year_count; //keeps track of years included in likelihood (i.e., that meet the sample size requirement)

  LkvalTmp=0.0;
  nu_sum_sq=0.0;
  year_count=0.0;
  for (int ii=1; ii<=ncomp; ii++)
  {if (nsamp(ii)>=minSS)
    {
year_count+=1.0;
nu_mean=sum( log(obs_plus(ii))-log(pred_plus(ii))  )/mbin; //year-specific mean log residual
for (int jj=1; jj<=mbin;jj++)
{
nu(ii,jj) = log(obs_plus(ii,jj)) - log(pred_plus(ii,jj)) - nu_mean;
nu_sum_sq += square(nu(ii,jj));
}
    }
```

```
  }
  if (year_count>0.0)
  {
  tau_hat_sq = nu_sum_sq/((mbin-1.0)*year_count);
  LkvalTmp = (mbin-1.0)*year_count*log(tau_hat_sq);
  }
  RETURN_ARRAYS_DECREMENT();
  return LkvalTmp;

//-----------------------------------------------------------------------------------
//-----------------------------------------------------------------------------------
//Likelihood contribution: priors
FUNCTION  dvariable neg_log_prior(dvariable pred, const double& prior, dvariable var, int pdf)
  //prior=prior point estimate, var=variance (if negative, treated as CV in arithmetic space), pred=predicted value, pdf=prior type (1=none, 2=lognormal, 3=normal, 4=beta)
    dvariable LkvalTmp;
    dvariable alpha, beta, ab_iq;
    dvariable big_number=1e10;
    LkvalTmp=0.0;
    // compute generic pdf's
    switch(pdf) {
        case 1: //option to turn off prior
          LkvalTmp=0.0;
          break;
        case 2: // lognormal
          if(prior<=0.0) cout << "YIKES: Don't use a lognormal distn for a negative prior" << endl;
          else if(pred<=0) LkvalTmp=big_number=1e10;
          else {
            if(var<0.0) var=log(1.0+var*var) ;      // convert cv to variance on log scale
            LkvalTmp= 0.5*( square(log(pred/prior))/var + log(var) );
          }
        break;
        case 3: // normal
          if(var<0.0 && prior!=0.0) var=square(var*prior);       // convert cv to variance on observation scale
          else if(var<0.0 && prior==0.0) var=-var;               // cv not really appropriate if prior value equals zero
          LkvalTmp= 0.5*( square(pred-prior)/var + log(var) );
          break;
        case 4: // beta
          if(var<0.0) var=square(var*prior);          // convert cv to variance on observation scale
          if(prior<=0.0 || prior>=1.0) cout << "YIKES: Don't use a beta distn for a prior outside (0,1)" << endl;
          ab_iq=prior*(1.0-prior)/var - 1.0; alpha=prior*ab_iq; beta=(1.0-prior)*ab_iq;
          if(pred>=0 && pred<=1) LkvalTmp= (1.0-alpha)*log(pred)+(1.0-beta)*log(1.0-pred)-gammln(alpha+beta)+gammln(alpha)+gammln(beta);
          else LkvalTmp=big_number;
          break;
        default: // no such prior pdf currently available
          cout << "The prior must be either 1(lognormal), 2(normal), or 3(beta)." << endl;
          cout << "Presently it is " << pdf << endl;
          exit(0);
    }
    return LkvalTmp;

//-----------------------------------------------------------------------------------
//SDNR: age comp likelihood (assumes fits are done with the robust multinomial function)
FUNCTION dvariable sdnr_multinomial(const double& ncomp, const dvar_vector& ages, const dvar_vector& nsamp,
                                    const dvar_matrix& pred_comp, const dvar_matrix& obs_comp, const dvariable& wgt_dat)
  //ncomp=number of years of data, ages=vector of ages, nsamp=vector of N's,
  //pred_comp=matrix of predicted comps, obs_comp=matrix of observed comps, wgt_dat=likelihood weight for data source
  RETURN_ARRAYS_INCREMENT();
  dvariable SdnrTmp;
  dvar_vector o(1,ncomp);
  dvar_vector p(1,ncomp);
  dvar_vector ose(1,ncomp);
  dvar_vector res(1,ncomp);
  SdnrTmp=0.0;
  for (int ii=1; ii<=ncomp; ii++)
  {
    o(ii)=sum(elem_prod(ages,obs_comp(ii)));
    p(ii)=sum(elem_prod(ages,pred_comp(ii)));
    ose(ii)=sqrt((sum(elem_prod(square(ages),pred_comp(ii)))-square(p(ii)))/(nsamp(ii)*wgt_dat));
  }
  res=elem_div((o-p),ose);
  SdnrTmp=sqrt(sum(square(res-(sum(res)/ncomp))/(ncomp-1.0)));
  RETURN_ARRAYS_DECREMENT();
  return SdnrTmp;

//-----------------------------------------------------------------------------------
//SDNR: lognormal likelihood
FUNCTION dvariable sdnr_lognormal(const dvar_vector& pred, const dvar_vector& obs, const dvar_vector& cv, const dvariable& wgt_dat)
  //nyr=number of years of data, pred=vector of predicted data, obs=vector of observed data, cv=vector of cv's, wgt_dat=likelihood weight for data source
  RETURN_ARRAYS_INCREMENT();
  dvariable SdnrTmp;
  dvariable small_number=0.00001;
  dvariable n;
  dvar_vector res(cv.indexmin(),cv.indexmax());
  SdnrTmp=0.0;
  res=elem_div(log(elem_div(obs+small_number,pred+small_number)),sqrt(log(1+square(cv/wgt_dat))));
  n=cv.indexmax()-cv.indexmin()+1;
  SdnrTmp=sqrt(sum(square(res-(sum(res)/n))/(n-1.0)));
  RETURN_ARRAYS_DECREMENT();
  return SdnrTmp;

//-----------------------------------------------------------------------------------
REPORT_SECTION

  if (last_phase())
  {
```

```
    cout<<"start report"<<endl;
     //cout<<"xdum = "<<xdum<<endl;
get_weighted_current();
     cout<<"got weighted"<<endl;
    get_msy();
     cout<<"got msy"<<endl;
    get_per_recruit_stuff();
     cout<<"got per recruit"<<endl;
    get_miscellaneous_stuff();
     cout<<"got misc stuff"<<endl;
get_projection();
 cout<<"got projection"<<endl;

    grad_max=objective_function_value::pobjfun->gmax;
    time(&finish);
elapsed_time=difftime(finish,start);
hour=long(elapsed_time)/3600;
minute=long(elapsed_time)%3600/60;
second=(long(elapsed_time)%3600)%60;
cout<<endl<<endl<<"*******************************************"<<endl;
cout<<"--Start time: "<<ctime(&start)<<endl;
cout<<"--Finish time: "<<ctime(&finish)<<endl;
cout<<"--Runtime: ";
cout<<hour<<" hours, "<<minute<<" minutes, "<<second<<" seconds"<<endl;
cout << "--TotalLikelihood: " << fval << endl;
    cout<<"--Final gradient: "<<objective_function_value::pobjfun->gmax << endl;
cout<<"*******************************************"<<endl;

    cout <<endl;
    cout << "><>--><>--><>--><>--><>--><>--><>--><>--><>--><>"  <<endl;
    cout << "F40=" << F40_out<< "   SSB.F40=" << SSB_F40_out <<endl;
    cout <<"F status="<<FdF_msy_end<<endl;
    cout <<"Pop status="<<SdSSB_msy_end<<endl;
    cout << "R0="<<R0<<endl;
    //cout << "xdum " << xdum << endl;
    cout << "><>--><>--><>--><>--><>--><>--><>--><>--><>--><>"  <<endl;

    report << "TotalLikelihood " << fval << endl;
    report << "N" << endl;
    report << N<<endl;
    report << "F" << endl;
    report << F <<endl;
    // report << "prob_belowsizelim_block3" << endl;
// report<<prob_belowsizelim_block3<<endl;

    sdnr_I_HB=sdnr_lognormal(pred_HB_cpue, obs_HB_cpue, HB_cpue_cv, w_I_HB);

    //#################################################################################################
    //##  Passing parameters to vector for bounds check plotting
    //#################################################################################################
     Linf_out(8)=Linf; Linf_out(1,7)=set_Linf;
     K_out(8)=K; K_out(1,7)=set_K;
     t0_out(8)=t0; t0_out(1,7)=set_t0;
     len_cv_val_out(8)=len_cv_val; len_cv_val_out(1,7)=set_len_cv;

 Linf_L_out(8)=Linf_L; Linf_L_out(1,7)=set_Linf_L;
     K_L_out(8)=K_L; K_L_out(1,7)=set_K_L;
     t0_L_out(8)=t0_L; t0_L_out(1,7)=set_t0_L;
     len_cv_val_L_out(8)=len_cv_val_L; len_cv_val_L_out(1,7)=set_len_cv_L;

 Linf_F_out(8)=Linf_F; Linf_F_out(1,7)=set_Linf_F;
     K_F_out(8)=K_F; K_F_out(1,7)=set_K_F;
     t0_F_out(8)=t0_F; t0_F_out(1,7)=set_t0_F;
     len_cv_val_F_out(8)=len_cv_val_F; len_cv_val_F_out(1,7)=set_len_cv_F;

     log_R0_out(8)=log_R0; log_R0_out(1,7)=set_log_R0;
     M_constant_out(8)=M_constant; M_constant_out(1,7)=set_M_constant;
     steep_out(8)=steep; steep_out(1,7)=set_steep;
     rec_sigma_out(8)=rec_sigma; rec_sigma_out(1,7)=set_rec_sigma;
     R_autocorr_out(8)=R_autocorr; R_autocorr_out(1,7)=set_R_autocorr;

 log_dm_comm_lc_out(8)=log_dm_comm_lc; log_dm_comm_lc_out(1,7)=set_log_dm_comm_lc;
 //log_dm_cL_lc_out(8)=log_dm_cL_lc; log_dm_cL_lc_out(1,7)=set_log_dm_cL_lc;
 //log_dm_GR_lc_out(8)=log_dm_GR_lc; log_dm_GR_lc_out(1,7)=set_log_dm_GR_lc;
     log_dm_GR_ac_out(8)=log_dm_GR_ac; log_dm_GR_ac_out(1,7)=set_log_dm_GR_ac;

     selpar_A50_comm1_out(8)=selpar_A50_comm1; selpar_A50_comm1_out(1,7)=set_selpar_A50_comm1;
     selpar_slope_comm1_out(8)=selpar_slope_comm1; selpar_slope_comm1_out(1,7)=set_selpar_slope_comm1;

 selpar_A50_GR1_out(8)=selpar_A50_GR1; selpar_A50_GR1_out(1,7)=set_selpar_A50_GR1;
     selpar_slope_GR1_out(8)=selpar_slope_GR1; selpar_slope_GR1_out(1,7)=set_selpar_slope_GR1;
 selpar_A50_GR2_out(8)=selpar_A50_GR2; selpar_A50_GR2_out(1,7)=set_selpar_A50_GR2;
     selpar_slope_GR2_out(8)=selpar_slope_GR2; selpar_slope_GR2_out(1,7)=set_selpar_slope_GR2;

     log_q_HB_out(8)=log_q_HB; log_q_HB_out(1,7)=set_log_q_HB;

     log_avg_F_comm_out(8)=log_avg_F_comm; log_avg_F_comm_out(1,7)=set_log_avg_F_comm;
 //log_avg_F_cL_out(8)=log_avg_F_cL; log_avg_F_cL_out(1,7)=set_log_avg_F_cL;
     log_avg_F_GR_out(8)=log_avg_F_GR; log_avg_F_GR_out(1,7)=set_log_avg_F_GR;
     F_init_out(8)=F_init; F_init_out(1,7)=set_F_init;

     log_rec_dev_out(styr_rec_dev, endyr_rec_dev)=log_rec_dev;
     log_F_dev_comm_out(styr_comm_L,endyr_comm_L)=log_F_dev_comm;
 //log_F_dev_cL_out(styr_cL_L,endyr_cL_L)=log_F_dev_cL;
     log_F_dev_GR_out(styr_GR_L,endyr_GR_L)=log_F_dev_GR;
```

```
  #include "co22_make_Robject4.cxx"   // write the R-compatible report

 } //endl last phase loop
```

SEDAR

Southeast Data, Assessment, and Review

SEDAR 58

Atlantic Cobia

SECTION V: Research Recommendations

December 2019

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

Table of Contents

1. Stock ID Workshop

1.1 Genetics

- Collect and analyze more samples from Jacksonville, Florida through Brunswick, Georgia along the Atlantic coast.
- Evaluate potential substructure within the Gulf of Mexico stock, including potential population substructure in Tampa Bay, along the Florida panhandle, and in the existing sample distribution gap off of Louisiana.
- Additional life history studies to document spawning locations outside of coastal South Carolina.
- Examine inshore versus offshore genetic structure in other states that harbor year-round inshore populations.
- Samples should be distributed temporally throughout the spawning season, which can vary by location. Samples obtained outside of the spawning season may not reflect the genetic stock being sampled, given observed movement of some individuals from spawning grounds.

1.2 Life History/Biology

1. More, randomly-collected age samples throughout the range of Cobia are needed.

   Cobia are exploited primarily by the charter boat fleet and private recreational fishery. Randomly collected biological samples of Cobia from the recreational fishery will provide essential data inputs to stock assessments. Only 130 new age data points spanning 18 years from the GOM have been made available since SEDAR 28. The majority of all age samples were collected from South Carolina and Virginia. Most of those samples were from carcass collection programs from the recreational fishery, which may not be able to be used to characterize the fishery landings due to the non-random sample collection method.

2. Reproductive biological information throughout the range of Cobia are needed. No reproductive data exists for the east coast of Florida and the Florida Keys. More specific information on the locations of spawning is needed, and in particular from both estuarine and offshore waters. Estimates of fecundity need to be made throughout the range of Cobia.

   Since SEDAR 28, no significant additional reproductive sampling has been conducted. The majority of the data used in that assessment was published in 2001 and 2002 with some newer data from South Carolina. In SEDAR 28, it was noted that few fish were sampled at small sizes (ages 0-2) before they enter the fishery at age 3 and that even the 3 year olds may have been the largest 3 year olds due to the size regulations. Relying on fishery dependent sampling, where the recreational minimum size limit is 33 inches FL in the Gulf of Mexico and increasing to 36 inches FL in the south Atlantic, results in only sampling fish likely to be mature. Additional sampling, particularly at smaller sizes and younger ages, would help to better define the steepness of the maturity curve and the proportion mature at age. Fish in this size range have traditionally been difficult to locate and sample so having information on fish at these sizes would also help to delineate habitat requirements for juvenile fish.

It was also noted in the stock ID workshop that none of the samples collected for Brown-Peterson et al. (2001) were from the southeastern portion of Florida or the Florida Keys (Figure 13) and sampling was likely minimal from the east coast of Florida in general. This data gap is important to fill, particularly given the acoustic tagging data that suggests the possibility of a resident Florida group and not having clear information on from where these east coast Florida fish recruit (e.g. are they migrants from other areas or is there reproduction occurring in this area?).

3. Information on larval dispersion is needed to elucidate stock structure of Cobia.

   While larval data was submitted late to the workshop (see SEDAR 58 Working Paper S58-SID09), most of the larval data collected at this point comes from the Gulf of Mexico with less effort conducted in the Atlantic. While Cobia larvae were present in many of the Gulf of Mexico samples, very few positive Cobia larvae tows were observed in the South Atlantic. Previous work in South Carolina (Lefebvre and Denson 2012) and Chesapeake Bay (Joseph et al. 1964) suggest that Cobia on the east coast use some estuaries for spawning, although there is likely an offshore spawning contingent also. More information on larval presence/absence, particularly from the east coast of the United States, could help to better define where fish are spawning and suggest other unique spawning sub-groups. A better understanding of spawning locations may also allow for predictions on how and where larvae are dispersed, providing support for the observed genetic differences, and possibly helping to define the stock boundary area.

4. A fishery-independent survey is needed to monitor Cobia and obtain biological information on Cobia below the minimum size limits imposed on the fishery.

5. Ecosystem studies are needed for Cobia with regards to prey availability and energetics to better understand growth differences of the species throughout its range.

1.3 Spatial Distribution / Movement

Priorities

- Refine understanding of ATL-GOM boundary and zone of uncertainty by installing acoustic arrays between Canaveral FL and Brunswick GA, plus more tagging in this region.
- Try to detect overwintering fish by extending acoustic arrays to shelf break
- Determine spawning grounds by sampling for ripe adults / ichthyoplankton
- The Spatial Working Group felt that it was important to undertake another stock ID process in approximately three years, and before the next assessment, to incorporate data that is anticipated in the next few years (there are many acoustically-tagged cobia presently at large).

Telemetry

Stock boundary and zone of uncertainty

- Improve spatial resolution near the existing stock boundary (GA-FL line) by adding additional acoustic arrays between Canaveral FL and Brunswick GA.
- Tag additional fish in the same area and extend tagging to Savannah GA using acoustic, conventional, and PSAT tags, with distribution of tagging effort across seasons.

Onshore-offshore movement and overwintering

- Extend existing acoustic receiver arrays to the shelf break and add additional receiver arrays between Canaveral FL and Brunswick GA. In some cases this will mean that acoustic receivers cannot be deployed and recovered by divers, but there may be buoys that can be attached to. In addition, acoustic releases can be used to deploy and recover receivers in deep water, depending on presence of bottom-trawl fisheries or other hazards.
- PSAT tagging of fish from FL to VA, and northern GOM, to understand over-wintering habitat, which can provide locations where there are no receivers and no fishing effort.
- Since there is presently decreased fishing effort in the putative over-wintering areas (e.g., offshore), increased sampling in these areas could be useful.

Existing detection network

- It is very important that the existing acoustic network remains in place and functional, which will require ongoing funding and effort (e.g., Chesapeake Bay, Pensacola Bay, offshore areas of NC). Some of the existing receiver arrays may be in projects that are closing down, so there is some risk that portions of the tracking network will be removed in the near future (e.g., Navy array at Chesapeake Bay mouth).

Conventional tagging

- More conventional tagging data is needed in data poor areas of Georgia and North Florida, along with the Cape Canaveral area, where little recent tagging data is available. In areas where cobia are available for much of the year, programs should focus on tagging over multiple seasons to ensure that any differing movement behaviors are represented.
- Cooperative tagging programs exist in VA and NC and in GOM; increase cooperative tagging in SC, and begin tagging in GA and the FL east coast.
- Ideally, auxiliary experiments to estimate tag shedding (e.g. double tagging) and tag reporting (e.g. high and low reward tags) are done as part of new or ongoing conventional tagging studies. This auxiliary information allows for estimation of fishing and natural mortality rates from the conventional tag returns.

Other topics

- Analyze existing PSAT data to get environmental preferences, particularly for overwintering individuals.
- Use oceanographic databases to determine temperature for time-location detections of cobia in acoustic dataset, and fishery presence-absence survey data.
- Look for existing plankton survey data. Determine if new ichthyoplankton research is planned or possible.
- Establish/continue collection programs to help identify spawning locations in all regions. This would include collecting gonads, otoliths, and genetics. NC and SC are collecting from dock sampling programs (genetics) and carcass collection programs (gonads). Similar programs in other regions would yield useful data.

Overall

- In addition to the research recommendations above, the Panel recommends that Cobia stock ID should be re-evaluated in three to five years.

1.4 Stock ID Review Workshop

1.) An enhanced understanding of the spatial distribution and interannual variability in recreational fishing effort is needed to understand if recent increases in landings have been driven by changes in stock abundance, effort, or spatial distribution of the exploited stocks. This appears to be a critical element to determine if recent harvest levels represent overfishing or a growing stock. The commercial landings data are minimally informative given short seasons, limited harvest allocations, and that most landings are the result of incidental catch during other targeted fisheries.

2.) Future research should further explore if discrete genetic stocks exist along the Atlantic Coast and Gulf of Mexico. Existing data supports at least some population substructure along the Atlantic Coast, and there are some indications of additional substructure along the Gulf Coast. Concerns were voiced from the public that local stocks may be overexploited under a coastwide management framework. If substructure occurs, the overall abundance of coastwide stocks are expected to show increased stability (e.g., a portfolio effect *sensu* Shindler *et al*. 2010), but overfishing of specific stocks may lead to reduced overall catch.

3.) Existing fishery independent surveys encounter few cobia, and offer little information on trends in abundance. It would be very beneficial to develop a survey design that characterizes temporal trends in the abundance of stocks. At the present, it is very difficult to distinguish changes in abundances versus changes in fishing effort.

4.) Genomic markers for stock delineation should be considered. The microsatellite studies to date estimated large effective population sizes, which suggests slow rates of neutral genetic drift among populations, especially if some gene flow occurs. As a result, relatively small levels of genetic differentiation exist between units, and the power of genetic assignment testing is limited. A genomic approach with a much larger number of SNP loci may offer enhanced resolution of stocks. In particular SNP loci that are under selection may show much higher levels of differentiation (and thus discriminatory ability) than microsatellites. Several new population genomics approaches (e.g. Genotyping-by-thousands and Rapture) and rapidly decreasing sequencing costs are making population-scale genomics increasingly tractable.

5.) Additional studies are needed to understand the migratory patterns of cobia, particularly during the winter months when offshore habitat use may be more prevalent. Studies using offshore receiver arrays or pop-off satellite archival tags may be particularly instructive. Stable isotope analysis of bony structures may also be informative.

2. Data Workshop

2.1 Life History Research Recommendations

Carcass donations

- Validate the carcass collection programs as representing the recreational fishery. E.g., Side-by-side comparison to a random port sampling program.
- State agencies should work together to achieve more consistency in their programs.
- Increase public education for the importance of the programs.
- Expand the geographic range of the donation sites.

Reproductive recommendations

- Histological processing of all gonad tissue to better estimate the maturity schedule of Atlantic Cobia. In particular, focus on the fish aged 0 – 3 years and cover full geographic range of the species.

  - Determine the contribution to the population from the inshore spawning stock and the offshore spawning stock.
  - Obtain estimates of fecundity and periodicity of the Atlantic Cobia stock.

Stock ID

  - Use otolith chemistry techniques to elucidate the contribution of inshore and offshore spawned Cobia to the Atlantic population.
  - Expand genetics studies to refine the possible stock separation of the inshore and offshore segments of the population.

Tagging studies

  - Direct tagging studies to obtain estimates of mortality
  - Determine tag retention and reporting rates
  - Hold a workshop to ensure consistent tagging methods across states at the program level.

2.2 Commercial Research Recommendations

- Programmatic funding should be allocated to expand existing observer coverage to ensure complete spatial coverage for the South Atlantic.
- Funding should be allocated towards the development of standardized map products.
- This includes various federal and state logbook grids from Maine to Texas.
- All grids need to include SDO registration.
- Includes translation tables between each grid.
- Creation of map products that compare commercial fishing effort between the CFLP and state trip ticket data.
- Develop statistically robust discard estimation techniques.
- Standardize how effort data are collected, processed, and utilized in relation to catch.
- There may be inconsistencies among commercial data sets for effort, since there is not a vessel permit required for cobia rather an individual catch limit.
- A single trip ticket may group multiple individual catches together with total effort, while multiple trip tickets may separate individual catch yet replicate the vessel effort.
- Create outreach strategies to further enhance the implementation plan for the commercial electronic logbook and include state partners. This will increase the data validity.
- This data collection effort will greatly improve reporting periodicity, reduce recall basis, provide increased spatial trends, provide more robust discard data, this list is endless, but should address where this data will fill in data gaps within a SEDAR
- The group recommends a workshop to establish a best practice for converting landings (e.g., gutted to whole weight).
- This workshop should address multiple species and jurisdictions.
- The group suggests that the partners include cobia in an RFP for updating federal and state specific conversion factors.
- The group recommends a workshop to establish a best practice for assigning uncertainty to landing series, as recommended in the best practices workshop.

2.3 Recreational Research recommendations

- Increase proportion of fish with biological data within MRFSS sampling.
- Efforts are ongoing to collect more biological data such as length and weight for fish sampled within MRIP.
- Continue to develop methods to collect a higher degree of information on released fish (length, condition, etc.) in the recreational fishery.
- In 2016, Virginia developed a Cobia permit data application that specifically collects information on released fish. Full description of this program can be found in section 4.3.4.
- North Carolina is also working on a coast-wide discard application that could provide information in the future.
- Require mandatory reporting for all charterboats state and federal.
- Establishment of federal logbooks for charter captains that have valid federal finfish permits is pending approval and implementation is expected in summer of 2019.
- State logbook are still a work in progress with no current actions pending.
- Continue development of electronic mandatory reporting for for-hire sector.
- Southeast For-Hire Integrated Electronic Reporting (SEFHIER) is currently working to provide more robust for-hire data that is timely and can be integrated with existing programs.
- Continued research efforts to incorporate/require logbook reporting from recreational anglers.
- Two applications that have been created and are currently used by the recreational fishery along the Atlantic coast are My Fish Count and VA cobia permit. There is one pending application from North Carolina that will be a coast-wide application for released fish.
- Establish a review panel to evaluate methods for reconstructing historical landings (SWAS, FWS, etc.).
- FHWAR method was reviewed by assessment panels and established as “Best Practice” in SEDAR Data Best Practices procedural workshop.
- Quantify historical fishing photos for use in reconstructing recreational historical landings.
- SAFMC FIS funded 2018-2019
- Narrow down the sampling universe. Identify angler preference and effort. Require a reef fish stamp for anglers targeting reef fish, pelagic stamp for migratory species, and deep water complex stamp for deep-water species. The program would be similar to the federal duck stamp required of hunters. This would allow the managers to identify what anglers were fishing for.
- National Saltwater Angler Registry
- VA cobia permit
- Continue and expand fishery dependent at-sea-observer surveys to collect discard information, which would provide for a more accurate index of abundance.
- Continued in Atlantic but expansion is funding limited
- Research recommendations
- Improve recreational reporting applications –

- Standardized across states (i.e., Harbor Light Scamp app, My Fish Count app).
- Capable of capturing length with photo.
- Standardize carcass collection protocols across states.
- Increase recreational biological sampling (i.e., NC, GA).
- Increase citizen Science involvement in tagging and tissue collection efforts.

2.4 Indices research recommendations

- SEDAR 28 DW - Explore SEFIS video data as a potential fishery independent index of abundance for cobia.
- The SEFIS video data are collected in association with the chevron trap survey and were evaluated for use in SEDAR 58. This survey focuses on bottom species and takes place outside of the primary cobia season. Cobia have been observed on very few occasions (1-3%) in the videos. It is unlikely that this survey would provide a useful index of cobia abundance.

- SEDAR 28 DW - Using simulation analysis, evaluate the utility of including interaction terms in the development of a standardized index and identify the potential effects these interaction terms have on stock assessments.
- Simulation analyses evaluating the utility of including interaction terms in developing a standardized index, to our group's knowledge, have not been attempted for cobia.

- SEDAR 28 AW - Develop a fishery-independent sampling program for abundance of cobia and other coastal migratory species. Fishery -dependent abundance indices used in this assessment were uncertain in part due to the lack of an effective sampling methodology.
- No new fishery-independent surveys have been implemented for cobia and other coastal migratory species.
- Research Recommendations
- Develop a fishery-independent sampling program for abundance of cobia and other coastal migratory species.
- Improve MRIP coverage for rare event species
- Improve validation methods for SC Charter Logbook
- Improve effort definition of gear and target species within trips (mixed effort)

2.5 Discard mortality Research recommendations

- SEDAR 28-During discussion at the data workshop it was noted that the logbook categories for discards (all dead, majority dead, majority alive, all alive) are not useful for informing discard mortality. Consider simplified logbook language in regard to discards (e.g., list them as dead or alive).
- New recommendation based on same concern: The group recommends that the SEDAR send a recommendation to the Southeast Fisheries Science Center (SEFSC) Fisheries Statistics Division Director clarifying the discard disposition. The group also noted that

obtaining adequate discard data is best achieved by collaboration with stakeholder and state/federal partners.

- SEDAR 28- Further research is needed on cobia release mortality.
- The discard mortality ad-hoc group addressed this recommendation from SEDAR 28 and agree that additional research is still needed on cobia release mortality.
- New SEDAR 58 recommendations:
- The group recommends continuing electronic tagging to estimate release mortality and total mortality. Increases in spatial coverage (i.e. receiver arrays) and the number of tags both spatially and temporally to increase the precision of mortality estimates. Furthermore, elucidating the effect of temperature on discard mortality through the use of temperature tags.
- The group recommends the use of conventional tagging. The tagging of telemetered fish informs the fates (i.e. harvest or catch and release of the telemetered fish). For all conventionally tagged fish, high value tags are need to estimate tag reporting rate and estimates of tag loss.
- The group recommends a SEDAR/council/state or regional management (ASMFC) sponsored tagging workshop to codify methodologies.

2.6 Ecosystem research recommendations

- Determine locations of all genetically distinct population segments
- Identify spawning aggregations and duration and timing of spawning
- Further characterize spawning habitat: salinity, water temperature, day length, habitat type (i.e. structured, vegetated, sandy)
- Identify the habitat of 0-2 year olds juveniles and sub-adults
- Determine habitat use during the winter
- Document the distribution and mechanism for transport of eggs, larvae and post-larvae
- Evaluate the impacts of increased temperature, increased eutrophication of estuarine and nearshore waters, and decreased salinity on egg, larvae and juvenile survival
- Evaluate the impacts of increased temperature, increased eutrophication of estuarine and nearshore waters, and decreased salinity on the food web supporting larvae and juveniles
- Determine factors affecting changes in growth, maturity at age, egg production, and sex ratio as temperature increases forcing a change in habitat use
- Identify threats to different life stages by invasive species
- Better understand the relationship between prey species and co-occurring species (blue crab, calico crab, hardhead catfish, eels, cownose rays etc.)
- Identify levels of pollutants (mercury, microplastics, ethinyl-estradiol) affecting cobia and determine the impacts on growth, maturity at age, egg production, sex ratio and behavior

2.7 Socio economic research recommendations

- Obtain better data (e.g., more comprehensive and timely) to estimate the annual economic impacts, net benefits, and economic contributions of recreational and commercial Atlantic cobia fishing on coastal communities and regions.

- Obtain cost and expenditure data for recreational fishing trips targeting cobia by fishing mode, for different states, and for anglers returning to private sites, who would not be sampled by the MRIP.
- Estimate willingness-to-pay associated with recreational cobia angling.

3. Assessment Process

1. Develop a fishery independent sampling program for abundance of cobia and other coastal migratory species.
2. Fishery dependent abundance indices used in this assessment were uncertain in part due to the lack of an effective sampling methodology.
3. Implement a systematic age sampling program for the general recreational sector. Age samples were important in this assessment for identifying strong year classes but sample sizes were relatively small and disparate in time and space.
4. Better characterize reproductive parameters including age at maturity, batch fecundity, spawning seasonality, and spawning frequency.
5. Age-dependent natural mortality was estimated by indirect methods for this assessment of cobia. Telemetry- and conventional-tag programs for cobia should be maintained as they may prove useful for estimating mortality.
6. Better characterize the migratory dynamics of the stock and the degree of fidelity to spawning areas.

4. Review Workshop

The RP reviewed the large list of research recommendations made by the DW and AW groups. The RP recommends that the following DA and AW research recommendations should be given high priority because of the importance to the stock assessment model:

1. Because the fishery-dependent index ended in 2015, development of a new index, either fishery-dependent or preferably fishery-independent, should be given top priority. Without an index of abundance, it is unlikely that stock status would be able to be estimated with any reliability in future. The RP recommend exploring other fisheries-dependent CPUE sources if available, developing fisheries-independent surveys such as egg/larvae surveys or close-kin methods, expanding analysis of the ten-year SERFS baited trap-video survey for cobia, or exploring the use of tag-data as potential indices of abundance.
2. Given that age composition data are an important source of information for the assessment model, methods to increase sample size (such as expanding carcass collection locations and establishing similar programs in other states) should be implemented. In addition, development of sampling programs to collect size and age information on fish released in the recreational fishery should be a priority.
3. The uncertainty in the stock status would be improved if better information on age-at-maturity and annual sex ratios were collected.
4. Natural mortality is an important parameter that affects model estimates of recruitment and spawning stock biomass. The RP recommends that estimates of natural mortality be made using tagging data or other analytical approaches (e.g., meta-analysis, catch-curves, etc.) for use in the model or to ground-truth the life-history invariant method used currently.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 58

Atlantic Cobia

SECTION VI: Review Workshop Report

December 2019

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

1. Introduction

1.1. Workshop Time and Place

The Review Workshop for SEDAR-58 Atlantic cobia stock assessment was held on November 19-21, 2019 in Beaufort, NC.

1.2. Terms of Reference

1. Evaluate the data used in the assessment addressing the following:
   - Are data decisions made by the DW and AW sound and robust?
   - Are data uncertainties acknowledged, reported, and within normal or expected levels?
   - Are data applied appropriately within the assessment model?
   - Are input data series reliable and sufficient to support the assessment approach and findings?

2. Evaluate the methods used to assess the stock, taking into account the available data.
   - Are methods scientifically sound and robust? Do the methods follow accepted scientific practices?
   - Are assessment models configured appropriately and applied consistent with accepted scientific practices?
   - Are the methods appropriate for the available data?

3. Evaluate the assessment findings with respect to the following:
   - Are population estimates (model output – e.g. abundance, exploitation, biomass) reliable, consistent with input data and population biological characteristics, and useful to support status inferences?
   - Is the stock overfished? What information helps you reach this conclusion?
   - Is the stock undergoing overfishing? What information helps you reach this conclusion?
   - Is there an informative stock recruitment relationship? Is the stock recruitment curve reliable and useful for evaluation of productivity and future stock conditions?
   - Are the quantitative estimates of the status determination criteria for this stock appropriate for management use? If not, are there other indicators that may be used to inform managers about stock trends and conditions?

4. Evaluate the stock projections, addressing the following:
   - Are the methods consistent with accepted practices and available data?
   - Are the methods appropriate for the assessment model and outputs?
   - Are the results informative and robust, and useful to support inferences of probably future conditions?
   - Are key uncertainties acknowledged, discussed, and reflected in projection results?

5. Consider how uncertainties in the assessment, and their potential consequences, are addressed.
   - Comment on the degree to which methods used to evaluate uncertainty reflect and capture all sources of uncertainty in the population, data sources, and assessment methods.
   - Are the implications of uncertainty in technical conclusions clearly stated?

6. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.
    - Clearly denote research and monitoring that could improve the reliability of, and information provided by, future assessments.
    - Provide recommendations on possible ways to improve the SEDAR process.

7. Provide suggestions on improvements in data or modeling approaches which should be considered when scheduling the next assessment.

8. Prepare a Peer Review Summary of the Panel's evaluation of the stock assessment, addressing each Term of Reference. Develop a list of tasks to be completed following the workshop. Complete and submit the Peer Review Summary Report in accordance with project guidelines.

1.3. List of Participants

Review Panelist

Jeff Buckel	ASMFC Review Panel Chair
Gary Nelson	ASMFC Reviewer
Alistair Dunn	CIE Reviewer
John Casey	CIE Reviewer
Matt Cieri	CIE Reviewer

Appointed Observers

Collins Doughtie*	SAFMC Mack/Cobia AP
Bill Gorham	SAFMC Mack/Cobia AP
Wes Blow	SAFMC Mack/Cobia AP

Analytical Representatives

Katie Siegfried	SEFSC Beaufort Lead analyst
Kyle Shertzer	SEFSC Beaufort
Erik Williams	SEFSC Beaufort
Rob Cheshire	SEFSC Beaufort

Council and Agency Staff

Kathleen Howington	SEDAR
Cierra Graham	SAFMC
Mike Schmidtke	ASMFC

Review Workshop Attendees

Jie Cao	NC State	Morehead City, NC
Erik Fitzpatrick	NOAA	Beaufort, NC
Amy Scheuller	NOAA	Beaufort, NC
Matt Damiano	NC State	Morehead City, NC
Riley Gallagher	NC State	Morehead City, NC
Joseph W. Smith	Morehead City, NC	
Amanda Tong	NCDMF	Morehead City, NC
Chris Batsavage	NCDMF	Morehead City, NC

**Participants noted with an Asterix were unable to attend the workshop*

1.4. List of Review Workshop Working Papers & Documents

Documents Prepared for the Review Workshop		
SEDAR58-RW01	An Age Structured Production Model for Atlantic Cobia	Siegfried, 2019
SEDAR58-RW02	Public Comment Forum	SEDAR 2019
Reference Documents		
SEDAR58-RD46	The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural systems and aquaculture	Lorenzen, 1996
SEDAR58-RD47	Bias in common catch-curve methods applied to age frequency data from fish surveys	Nelson, 2019

2. Review Panel Report

2.1. Executive Summary

The Review Workshop for SEDAR-58 Atlantic cobia stock assessment was held on November 19-21, 2019 in Beaufort, NC. The Atlantic cobia assessment team (AT) provided an assessment report and presentations that were reviewed by the Review Panel (RP). The RP consisted of three CIE reviewers, an ASMFC appointed reviewer, and an ASMFC appointed chair. The AT provided presentations on the background of the stock assessment, sensitivities, and projections. Additionally, the RP requested other sensitivities and ensemble runs that were addressed during the review workshop and are described below. The RP responded to seven Terms of Reference (ToRs, see above) that covered data used, assessment methods, assessment findings and projections, uncertainty, research recommendations, and improvements to data or modeling approaches.

The Data Workshop (DW) satisfactorily assembled data, time series, and the necessary life history information needed for the model; however, the RP did not see justification for certain data decisions made by the DW (e.g., change in methodology to estimate natural mortality). The uncertainty in data inputs was well described and the RP identified four major sources of data uncertainty: commercial and recreational removals, age compositions for the recreation fishery before 2007, length compositions for the commercial fishery, and the assumed rate of natural mortality. Additionally, the RP recommended further examination of the 1996 and 2015 recreational removals.

Data were used appropriately in the age-structured assessment (Beaufort Assessment Model) and the methods were scientifically sound, followed accepted scientific practices, were configured appropriately, and were appropriate for the available data. There was no clear stock-recruitment relationship and the use of mean recruitment with deviations was appropriate. The RP asked why the time-block selectivity (i.e., two selectivities, one for the early and one for the late period of the head-boat index) was applied to the head-boat index given that the explanation for time-varying selectivity in the targeted fishery would likely not apply to the non-targeted head-boat fishery. The AT agreed and compared age-composition fits with and without time-block selectivity. The time-invariant selectivity for the head-boat index had better fits in recent years and was consistent with the fishery; this model was chosen as the revised base model for Atlantic Cobia.

The modeled population estimates (e.g., abundance, exploitation, and biomass estimates) were reliable given the assessment assumptions and observations. The assessment panel proposed reference points of $F_{40\%}$ as a proxy for F_{MSY}, $\mathrm{SSB}_{\mathrm{F}40\%}$ as a proxy for $\mathrm{SSB}_{\mathrm{MSY}}$, and 75% of $F_{40\%}$ and 75%SSB as target reference points. The estimates of SSB and *F* for Atlantic Cobia show the population has been above $\mathrm{SSB}_{\mathrm{F}40\%}$ and below $F_{40\%}$ since the beginning of the modeled period (1986); thus, the stock is not overfished and overfishing is not occurring. The RP noted that the model estimates of population size, status, and trend were consistent with the known and assumed population parameters, and that the model used the best available science and was adequate to support stock biomass and stock status inferences. For example, the trends in biomass estimates from the assessment were consistent with the head-boat index.

Projections were carried out appropriately using accepted practices given the data available and were appropriate for the assessment model and required outputs. Projections for removals in numbers, *F*, SSB (mt) and recruits (numbers at age 1) were carried out for the years 2020-2024 at $F = F_{current}$, $F = F_{40\%}$, and $F = 75\%\ F_{40\%}$. The mean deterministic and median stochastic estimates of SSB were greater than $\mathrm{SSB}_{40\%}$ for these years. However, given the uncertainty around inputs, there was a small (12%, $F_{current}$) to moderate (50%, $F = F_{40\%}$) percentage of stochastic simulations that resulted in an overfished status ($\mathrm{SSB} < \mathrm{SSB}_{\mathrm{F}40\%}$). The RP concluded that the projection results are informative and robust and are useful to support inferences of future stock status and biomass. The key uncertainties were reflected in projection results.

The key uncertainties within the assessment model were well described by the AT in the assessment document (SEDAR-58-addendum). The main uncertainty was in estimates of natural mortality (*M*) and less significant uncertainties in the choice of steepness (*h*) of the stock-recruit relationship and the estimated maturation ogive. Ensemble model bootstraps used estimates of M based on 2x the standard error of the *M* around the regression line for the estimated mean size of Cobia at age. The RP noted that that while the estimates of *M* were very uncertain, the outcomes of the assessment showed that the stock was highly unlikely to be below the $\mathrm{SSB}_{\mathrm{F}40\%}$ reference point.

The following research recommendations should be given high priority because of the importance to the stock assessment model: develop a new index of abundance, increase sample size (such as expanding carcass collection locations and establishing similar programs in other states) of size- and age-compositions in harvested and released fish, improve information on age-at-maturity and annual sex ratios, and use tagging data or other analytical approaches (e.g., meta-analysis, catch-curves, etc.) to ground-truth the estimate of natural mortality. Additionally, the RP recommended that additional research on steepness (*h*) and a full description of landings changes from SEDAR-28 through SEDAR-58 be conducted. Lastly, there was small evidence of lack of fit to age-composition data and the RP recommended that the AT consider alternative selectivity shapes in future assessments.

The assessment has only a single index of abundance (the head-boat CPUE index). Due to recent management closures, this index was not available for years since 2015. The RP noted that if there were future closures then this index of abundance will not be available in future years. Currently there are no other suitable indices of abundance available. The RP strongly recommended that additional indices of abundance be developed and that preferably, these be fishery-independent.

The RP noted that the SEDAR stock assessment review process would be improved if the Chair of the Data Working Group were to attend the review panel meeting, and be available to assist the AT describe decisions relating to the choice of data. The RP recommends that SEDAR request a document or DW report section that summarizes main decisions and descriptions of why that decision was made at the data workshop. Additionally, a separate document that contains information pertaining to final data streams used in the assessment, including the summary of the rationale for the data choices, would be helpful.

While the AT has proposed $SSB_{40\%}$ and $F_{40\%}$ reference points for this stock that are based on a long history of use in other locations and for similar stocks, further work with fishery managers on goals and objectives is advised prior to conducting a new benchmark. Proposed reference points could then be fully evaluated while a new assessment is conducted. The reference points proposed are based on MSY proxies and management could consider reference points consistent with levels of risk tolerance.

The RP reached consensus on all its recommendations and conclusions and there is no minority report.

2.2. Statements addressing each TOR

1. Evaluate the data used in the assessment, addressing the following:

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

Details on data processing were provided to the RP through Data Workshop (DW) and Assessment Workshop (AW) reports. The DW and AW groups made considerable efforts to provide the best data for use in the assessment. The primary data sources used in the assessment were commercial landings assembled through ACCSP/State records, commercial dead discards derived from standard live discard/landings ratios and a constant discard mortality of 0.55, the MRIP harvest and dead releases derived from live releases and a constant release mortality of 0.05, and length and age data collected primarily through state carcass collection programs.

The relative ratio of recreational to commercial landings are approximately 95:5. The AW had low confidence in data collected prior to 1986, so only data from 1986-2017 were used in the assessment. The RP agreed that the decisions made by the DW and AW during data analysis and assembly were reasonable and sound.

The RP concluded that data working groups satisfactorily assembled data and the necessary life history information needed for the model.

However, the RP noted that the justification for some of the data decisions that may have major influences on the assessment results were not well described; these were the choice of abundance indices, the rate of natural mortality (i.e., switching the value of *M* from Lorenzen (1996) to Charnov et al. (2013)), and the maturity ogive. In a few cases, there were no descriptions of how data were derived (e.g., state gutted to total weight conversion factors).

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

The DW and AW identified the major sources of data uncertainty and provided adequate information in the data and assessment reports for the panel to judge the quality of the data sources. In addition, the DW and AW had provided parameter error bounds for use in the sensitivity and ensemble model runs.

The RP identified that the major sources of uncertainty in the assessment were:

1. *Uncertainty in commercial and recreational landings and discards;*
2. *Uncertainty in the age compositions for the recreational fishery for years before 2007 due to small sample sizes;*
3. *Uncertainty in the length compositions for the commercial fishery due to very small sample sizes; and*
4. *The assumed rate of natural mortality (M).*

Coefficients of variation for the commercial landings, recreational landings and discards, and head-boat index were within ranges considered realistic and adequate for assessment purposes. However, CVs for the commercial discards appeared unrealistically high and the RP noted that the values of these CVs should be investigated in the future to ensure that they were correctly estimated. The RP noted that the revised base case (co23, SEDAR-58-Addendum) applied a maximum cap on the CV for commercial discards of 3.0 in the ensemble modeling analysis. However, the RP noted that due to the very small amount of removals associated with commercial discards, that this revision would not have any significant impact on the ensemble modeling outcomes.

The RP identified that the distribution and bounds on the values of the plausible rates of natural mortality (*M*) used in the ensemble modeling were based on the standard error estimates from Charnov et al. (2013) and were likely to be unrealistically narrow. Hence the RP recommended that the distribution and bounds for *M* for the new base ensemble modeling (co23, SEDAR-58-Addendum) use the values from the Charnov et al. (2013) regression equation when the equation slope and intercept were adjusted using ±2 standard errors.

- *Are data applied appropriately within the assessment model?*

The RP concluded that, based on assessment model diagnostics and output, the time series of removals (i.e. catch and dead discard estimates), length and age composition data, and the head-boat CPUE index of abundance were used appropriately in the BAM model.

- *Are input data series reliable and sufficient to support the assessment approach and findings?*

The RP agreed that the data used in the stock assessment were the best available data, and that the working groups satisfactorily characterized removals from all data sources.

The RP had concerns about the reliability of recreational removals in the 1996 and 2015 years, as recreational catch estimates for these where unusually high when compared with the neighboring years. A sensitivity run (SEDAR-58-Addendum) in which the values were replaced with the mean values from the neighboring four years showed these values had little influence on the model results. However, the RP suggested that these high catches should be investigated further to determine the underlying cause for the increases.

The RP noted that the age composition data appeared sufficient and reliable because several cohorts could be tracked through the data over time.

The RP noted that only a single index of abundance was available for this assessment (the head-boat CPUE index), and due to recent management closures of the recreational fishery, this index was not available for years since 2015. The RP noted that if there were future closures then this index of abundance will not be available in future years. Currently, there are no other suitable indices of abundance available.

The RP strongly recommended that additional indices of abundance be developed and that preferably, these be fishery independent. The RP noted that spatial/temporal analyses of catch and effort data (i.e., using gaussian random fields as, for example, implemented in VAST (Thorson 2019)) may provide a means to develop an index of abundance using the recreational catch and effort data. However, the RP recommended that approaches using, for example, the baited trap-camera time series (SERFS) that has been carried out in the region may provide a useful index of abundance if these data were analyzed for Atlantic Cobia.

2. Evaluate the methods used to assess the stock, taking into account the available data.

- *Are methods scientifically sound and robust? Do the methods follow accepted scientific practices?*

The Beaufort Assessment Model (BAM) (Williams & Shertzer 2015) was the primary assessment model, which was implemented with AD-Model Builder software. This model estimated biomass and selectivity parameters using assumed catches and productivity parameters. The estimates were obtained by minimizing an objective function consisting of likelihoods applied to CPUE, age composition data, and length composition data, along with uniform priors on estimated parameters with exception of those that had an assumed functional form. BAM has previously been used in

SEDAR assessments, and has been simulation tested. The version of BAM was set up to match the data availability of Atlantic Cobia.

The AT demonstrated they were familiar with the modeling software and were competent in its application. The model was documented in the assessment report (SEDAR-58-addendum) and the AD-Model Builder code was supplied as an appendix to the assessment report. The RP was confident that the model was scientifically sound, robust, and appropriate for the available data.

The RP closely reviewed output from the non-revised base case run (co22) and revised base case run (co23, see SEDAR-58-addendum). Model diagnostics, model sensitivities, analyses to investigate uncertainties, ensemble models, projections, and some supplementary analyses were examined by the RP (see Section 2.3 for a list of supplementary analyses). A full description of the revised base case assessment model is given in SEDAR-58-addendum.

Model observations were a CPUE index from recreational catch and effort for head-boats, comprising of about 5% of the total catch from recreational fishers, age composition data obtained from carcass samples of recreational landings, and a length composition data for commercial landings. The head-boat CPUE indices suggested a small increase in abundance over the time period of the index (1991-2015).

Estimates of removals (landings and dead discards) were via two fleets: the commercial fleet (comprising of a minority of removals) and the recreational fleet. The model estimated the removals with a low CV to resolve the Baranov catch equation and not to model the uncertainty in removals. Estimated removals from the model were almost identical to the observed removals (Figure 1).

Commercial catch was modelled with a selectivity fitted to the commercial length frequency compositions. The length composition data were an aggregate over the years due to the low annual sample sizes. The RP noted the lack of age data for the commercial catch, but given the low level of commercial catch (about 5% of total catch), the review panel considered that the use of length composition data was adequate for determining the selectivity pattern for the commercial fleet in the assessment model.

Recreational catch was fitted using two selectivity patterns – the first for years between 1986 and 2006, and the second for years since 2007. The head-boat index was initially modelled as the vulnerable abundance using the early period recreational selectivity for the period up to 2006, and the later period selectivity for the period from 2007 (co22, SEDAR-58-assessment model). However, as the head-boat index was only for a small proportion of the recreational fishery that did not target Cobia and was unlikely to have changed its fishing pattern over that period, the RP recommended that the head-boat index be interpreted using the vulnerable abundance from the pre-2007 selectivity pattern (co23, SEDAR-58-Addendum). This revised base case assessment model (co23) was recommended by the RP for the assessment of Atlantic Cobia.

The RP noted that the model convergence was good with analyses of the alternative starting values showing no evidence of failure to converge for the non-revised base model (co22).

While the model was sensitive to the choice of *M*, the RP noted that the Charnov et al. (2013) approach was supported from both external sources as well and internal diagnostics when compared to lower Lorenzen (1996) estimates. Use of *M* lower than the current approach resulted in inferior model diagnostics (Figure 2). However, the Review Panel suggested examination of *M* is warranted for future assessments and recommended starting with the 2015 SEDAR data best practices document.

Recruitment was highly variable with no clear stock-recruitment relationship (see SEDAR-58-addendum). As such the use of mean recruitment with deviations was appropriate.

- *Are assessment models configured appropriately and applied consistent with accepted scientific practices?*

The RP concluded that the model was configured appropriately and applied consistently with accepted scientific practices after recommended changes were made to the base model

The RP supported the use of two fleets with a time block of selectivity for the recreational fleet at 1986- 2006 and a second time block 2007-2017. Changes in management measures and an increase in the VA catch likely increased the targeting of smaller fish since 2007. This change is reflected in the estimated selectivities (Figure 3)

Diagnostics suggested that the starting year of 1986 was appropriate. Data prior to 1986 are likely unreliable. Further sensitivity analysis supported the AT's use of 1986 as a start year for the assessment as there wasn't a clear difference when pushing the start year back to SEDAR-28 value of 1950 (Figure 4).

The RP did recommend changing the base model to have only one block for selectivity (1986 to 2006 recreational selectivity) in the head boat fishery dependent index of abundance. This resulted in a new base case run (revised base case assessment; Co23). The revised base case assessment was more consistent as it was unlikely that the management changes would have affected the head-boat CPUE index, given that it was not targeting cobia. When compared to the base run as recommended by the AT, the revised base case had some small differences in the diagnostics of model fit, but the changes were minor. Further, the revised base case model (with non-revised base case HB weights; sens14a) typically had a lower negative log likelihood for the age composition fits in the most recent years (Table 1).

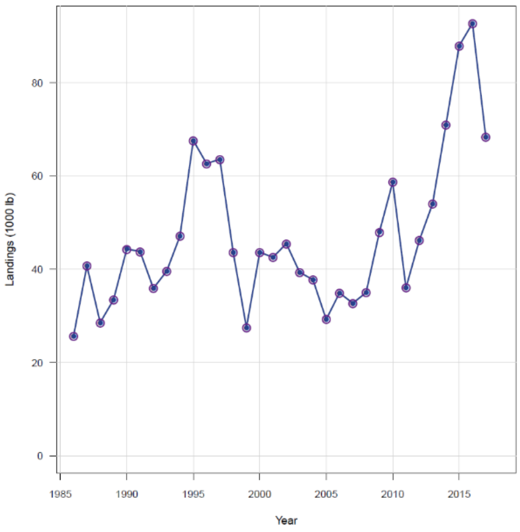
- *Are the methods appropriate for the available data?*

Given that most of the data are catch-at-age composition data, a statistical catch-at-age approach such as the BAM, which fully utilizes these data is likely the best approach. The RP did discuss the potential of other approaches, but these were even less likely to be successful given the importance of compositional age data and the lack of a current index of abundance (the head-boat CPUE index of abundance time series ended two years prior to terminal year).

As such the use of the age data in the assessment seems appropriate and was applied using acceptable methods, especially after moving to the revised base case as recommended by the RP.

Table 1: Yearly negative log likelihoods for age-composition fits from three runs examining selectivity: co22 (non-revised base case), sens14a (2 time blocks for selectivity with first time block applied to head-boat index of abundance), and sens15 (1 time block for selectivity). Sens14a is the revised base case but with likelihood weight on head-boat index from non-revised base case.

	co22	sens14a	sens15
1986	44.778	44.803	43.831
1987	36.087	36.098	38.667
1989	137.910	138.060	137.870
1990	141.306	141.483	138.400
1991	26.599	26.586	27.256
1992	28.823	28.849	29.101
1995	23.531	23.544	24.596
1996	60.886	60.993	61.464
1997	30.925	30.769	30.523
1999	249.833	250.169	251.431
2000	240.678	240.981	242.119
2001	99.538	99.776	98.903
2002	54.123	54.248	55.387
2005	95.815	96.362	99.389
2006	137.570	137.730	137.547
2007	341.990	342.178	342.064
2008	410.445	410.879	410.493
2009	484.010	484.044	485.065
2010	627.468	627.281	628.063
2011	469.958	469.662	469.736
2012	507.673	507.711	508.450
2013	749.187	748.787	749.533
2014	805.321	805.013	804.939
2015	848.079	848.063	847.913
2016	663.435	663.177	663.284
2017	490.955	490.818	491.071



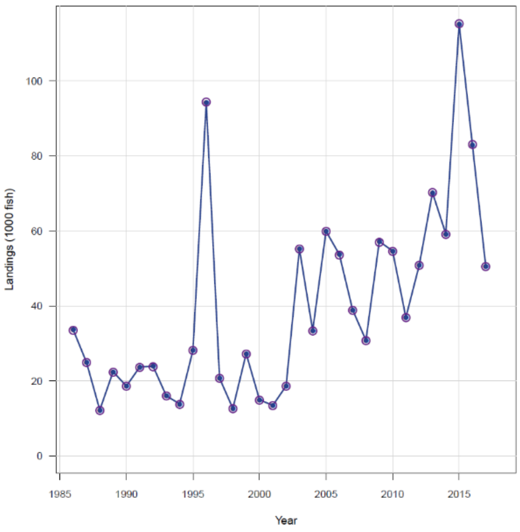


Figure 1: Comparison of estimates verses observed removals for (left) the commercial removals, and (right) the recreational removals. Open circles indicate observed removals and closed circles the estimated removals from the model.

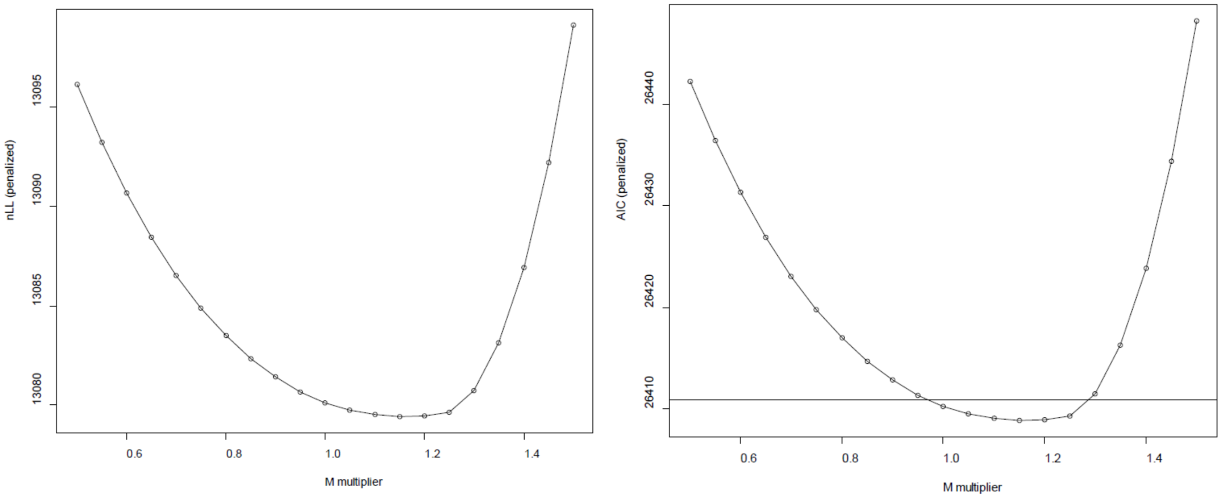
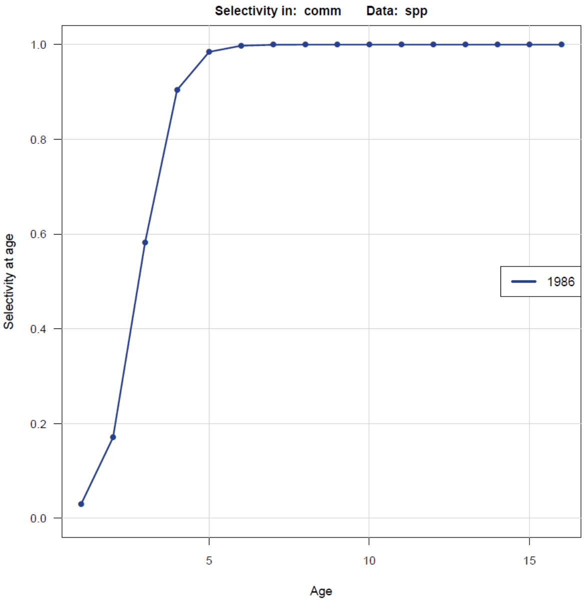


Figure 2: Negative Log likelihood and AIC at various values of natural mortality, shown as a multiplier on the value of M



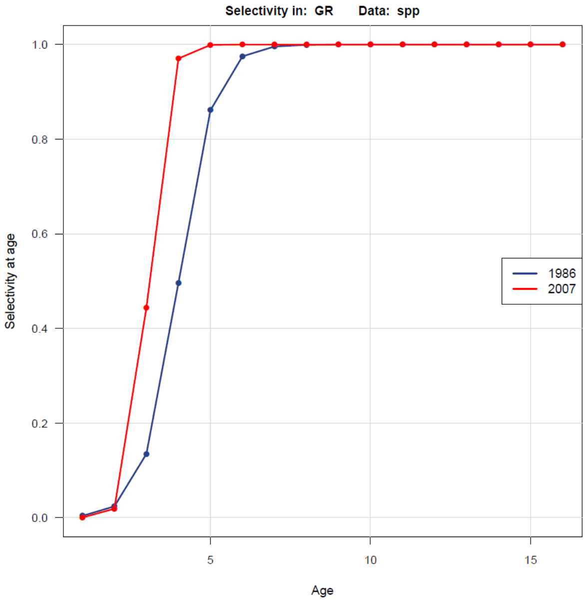


Figure 3: Selectivity curve for the commercial (top) and recreational fishery (bottom). Note that two time blocks on fishery selectivity are used 1986-2006 (blue) and 2007-2017 (red).

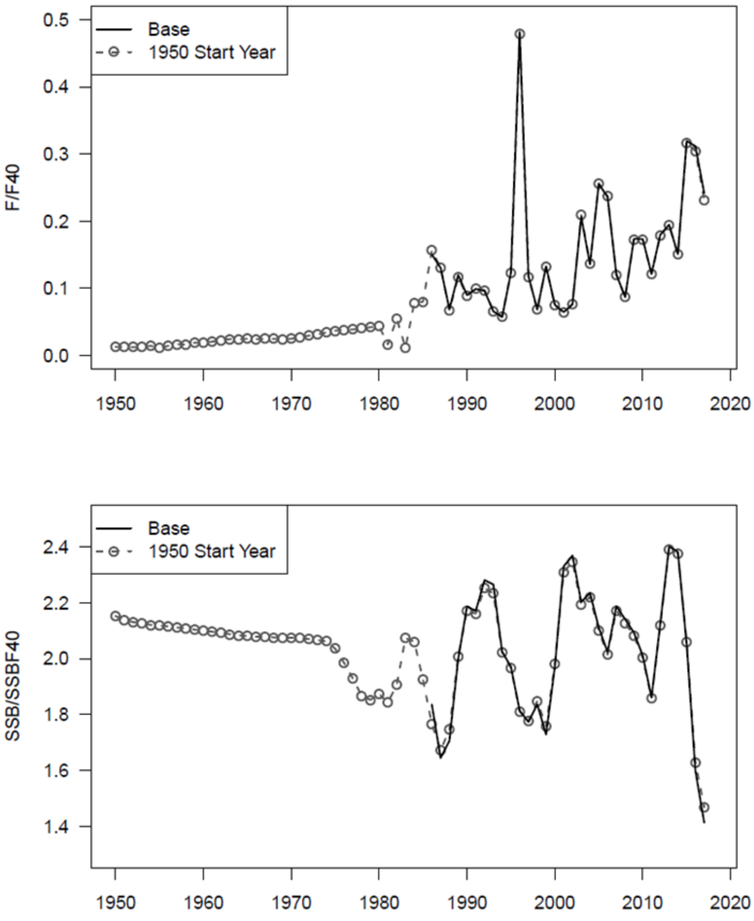


Figure 4: Start year value sensitivity. ratio of F to F40% (top), ratio of SSB to SSBF40% (bottom)

3. Evaluate the assessment findings with respect to the following:

- *Are population estimates (model output – e.g., abundance, exploitation, biomass) reliable, consistent with input data and population biological characteristics, and useful to support status inferences?*

The RP concluded that the modelled population estimates (e.g., abundance, exploitation, and biomass estimates) were reliable given the assessment assumptions and observations.

The RP noted that the AT had recommended reference points of $F_{40\%}$ as a proxy for F_{MSY} and $SSB_{F40\%}$ as a proxy for SSB_{MSY}. The RP also noted that the AT had provided model outcomes based on 75% of $F_{40\%}$ as the target reference point as this provided an uncertainty buffer around the B_{MSY} proxy.

The AT provided estimates of SSB and F for Atlantic Cobia that showed the population had been above $SSBF_{40\%}$ since the beginning of the modeled period (1986) and had trended up over that time from about 1.5 x $SSB_{F40\%}$ to about 2 x $SSB_{F40\%}$. However, in the most recent three years the biomass had reduced to about 1.5 x $SSB_{F40\%}$ in the terminal year in 2017 (Figure 5 and Figure 6).

The RP found that the biomass estimates were consistent with the head-boat index with no evidence of departure from the assumptions of constant variance or trend in residuals (Figure 6).

Model fits to the recreational catch age composition data were adequate over the time period where these data were available and no evidence of systematic trend in the annual age composition fits (Figure 7). Model fits across ages suggested some small evidence of lack of fit, specifically for ages 4-5 (Figure 8), and the RP panel recommended that the AT consider alternative selectivity shapes that may account for this pattern in future assessments.

The RP noted that only a single index of abundance was available for this fishery (the head-boat CPUE index), and that due to recent management closures of the recreational fishery, this index was not available for years since 2015. The RP noted that if there were future closures then this index of abundance will not be available in future years. Currently there are no other suitable indices of abundance available.

The RP strongly recommended that additional indices of abundance should be developed and that preferably, these be fishery-independent. The RP noted that spatial/temporal analyses of catch and effort data (i.e., using gaussian random fields as, for example, implemented in VAST Thorsen (2019)) may provide a means to develop an index of abundance using recreational data. However, the RP recommended that approaches using, for example, the baited trap camera time series (SERFS) that has been carried out in the region may provide a useful index of abundance if these data were analyzed for Atlantic Cobia.

The RP noted that the model estimates of population size, status, and trend were consistent with the known and assumed population parameters, and that the model used the best available science and was adequate to support stock biomass and stock status inferences.

The key uncertainties within the assessment model were well described by the AT in the assessment document (SEDAR-58-addendum), with the main uncertainty on the assessment outcomes were the estimates of natural mortality (M), and less significant uncertainties in the choice of steepness (h) of the stock-recruit relationship (see later) and the estimated maturation ogive.

Estimates of M were age-dependent, based on the life-history invariant assumptions using the regressions in Charnov et al. (2013). Ensemble model bootstraps used estimates of M based on 2x the standard error of the M around the regression line for the estimated mean size of Cobia at age. The RP noted that that while the estimates of M were very uncertain within the assessment model (co23, SEDAR-58-addendum), the outcomes of the assessment showed that the stock was highly unlikely to be below the $SSB_{F40\%}$ reference point.

The RP noted that the estimates of the maturation ogive in the model were uncertain but noted that a sensitivity that used a slightly right-shifted ogive (model sensitivity 11, see SEDAR-58-Addendum) showed that the model outcomes were relatively insensitive to the choice of the maturity ogive.

- *Is the stock overfished? What information helps you reach this conclusion?*

The reference points were not provided by the current management body to determine stock status. However, the RP noted $SSB_{F40\%}$was recommended as a reference point by the assessment panel. SSBF40% is commonly used in this region and globally as an appropriate management reference point.

The RP concluded that the results of the assessment model showed that the stock was highly unlikely to be below the $SSB_{F40\%}$ reference point for the period 2015 to 2017 (i.e., the terminal years of the model) (Figure 10). The assessment model stock projections (see later) also showed that it was highly unlikely that the stock was below the $SSB_{F40\%}$ reference point in the most recent years (2017—2019).

The RP concludes that in relation to the reference point recommended by the assessment panel ($SSB_{F40\%}$) the stock is not overfished.

- *Is the stock undergoing overfishing? What information helps you reach this conclusion?*

The reference points were not provided by the current management body to determine stock status. The RP noted $F_{40\%}$ was recommended from the assessment panel. $F_{40\%}$ is commonly used in this region and globally as an appropriate management reference point.

The assessment model showed that it was highly unlikely that the stock was above $F_{40\%}$ reference point for the period 2015 to 2017 (i.e., the terminal years of the model) (Figure 10). The assessment model stock projections (see later) also showed that it was highly unlikely that the stock was above $F_{40\%}$ reference point in the most recent years (2017—2019).

The RP concludes that in relation to the reference point recommended by the assessment panel ($F_{40\%}$), overfishing is not occurring.

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

The revised base case assessment model (co23) and all sensitivities assumed a steepness of h=1 (i.e., no relationship between spawning stock abundance and the mean number of recruits). The RP noted that there was no available information to support estimation of the value of h in the model, as stock size had remained high over the modeled period. Further, given the stock status the RP concluded that the choice of h was unlikely to affect the stock status estimates in the model nor the projections given the current and historical stock status. However, the RP noted that the choice of steepness would affect the value of the target and hence the stock status relative to the target reference points.

The RP recommended that additional research be conducted for the next assessment to consider evidence for the choice of h, for example from meta-analyses or similar approaches to determine plausible values on h to evaluate as sensitivities to the revised base case model

- *Are the quantitative estimates of the status determination criteria for this stock appropriate for management use? If not, are there other indicators that may be used to inform managers about stock trends and conditions?*

The RP noted that the quantitative estimates of the status determination criteria for this stock were appropriate for management, but also noted that there were no defined and approved management targets or thresholds by the current management body. However, the RP noted that this assessment used a proposed reference point of 75% $SSB_{F40\%}$ and $F_{40\%}$, and that $SSB_{F40\%}$ and $F_{40\%}$ were appropriate choices as proxies for Bmsy and MSY, with 75% $SSB_{F40\%}$ and $F_{40\%}$ likely to be appropriate proxies for management targets.

The RP noted that additional work by the AT on catch curve analyses (using regression estimators, Chapman-Robson estimators, and Poisson regression estimators) showed a similar pattern of a slight increase in total mortality Z (i.e., $F + M$) over time with values that were consistent with the assessment modeling results (Figure 11).

The RP did not identify other status indicators that may be appropriate to inform managers.

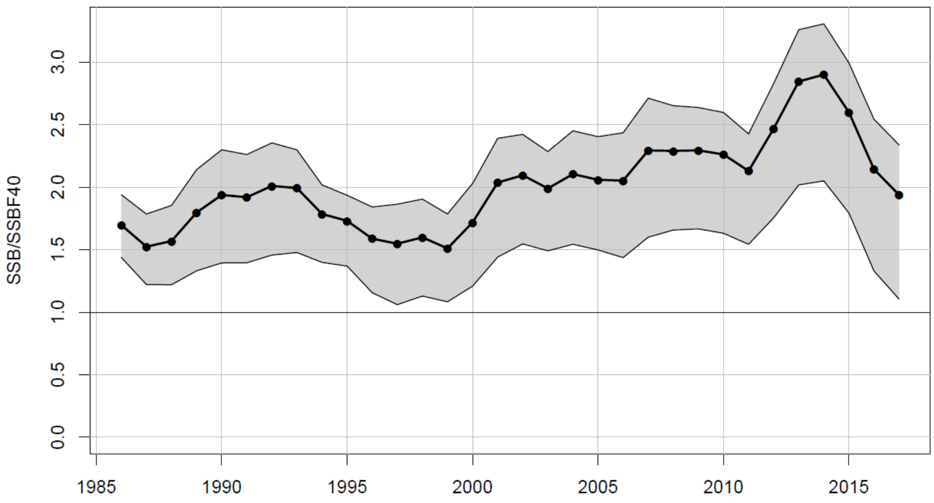


Figure 5: The 95% range for the estimates of SSB/SSBF40 from the ensemble models (grey shaded region) with the revised base case (co23, solid line) for the assessment model for 1986-2017.

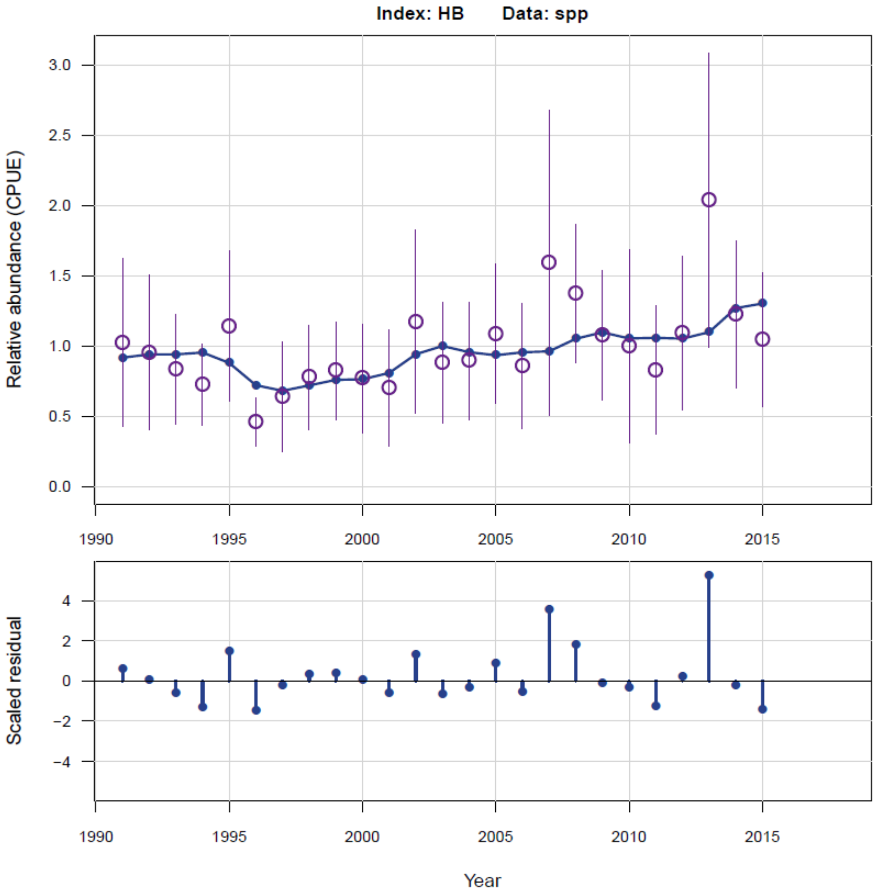


Figure 6: Revised base case model (co23) fits (top) and residuals (bottom) to the head-boat CPUE index of abundance for 1991-2015.

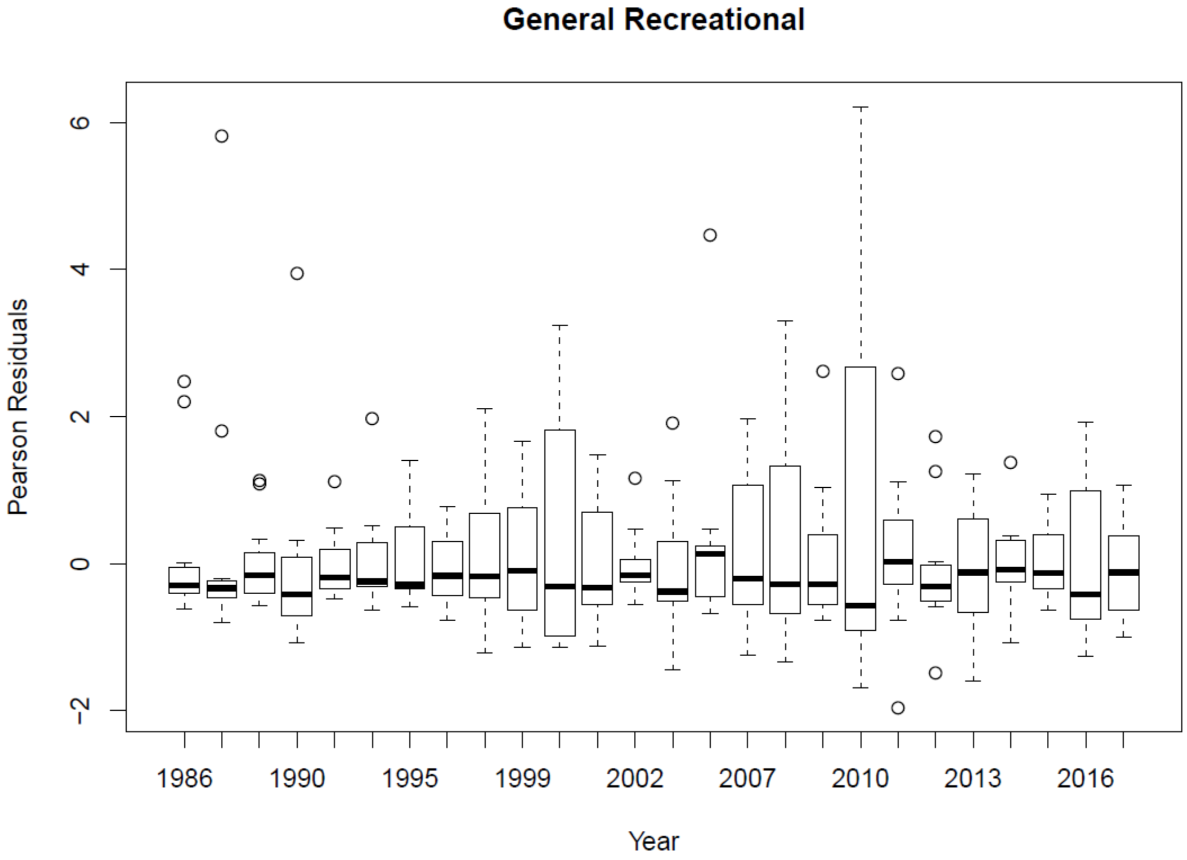


Figure 7: Pearson residuals for the age composition fits for years 1986-2017 for the revised base case model (co23)

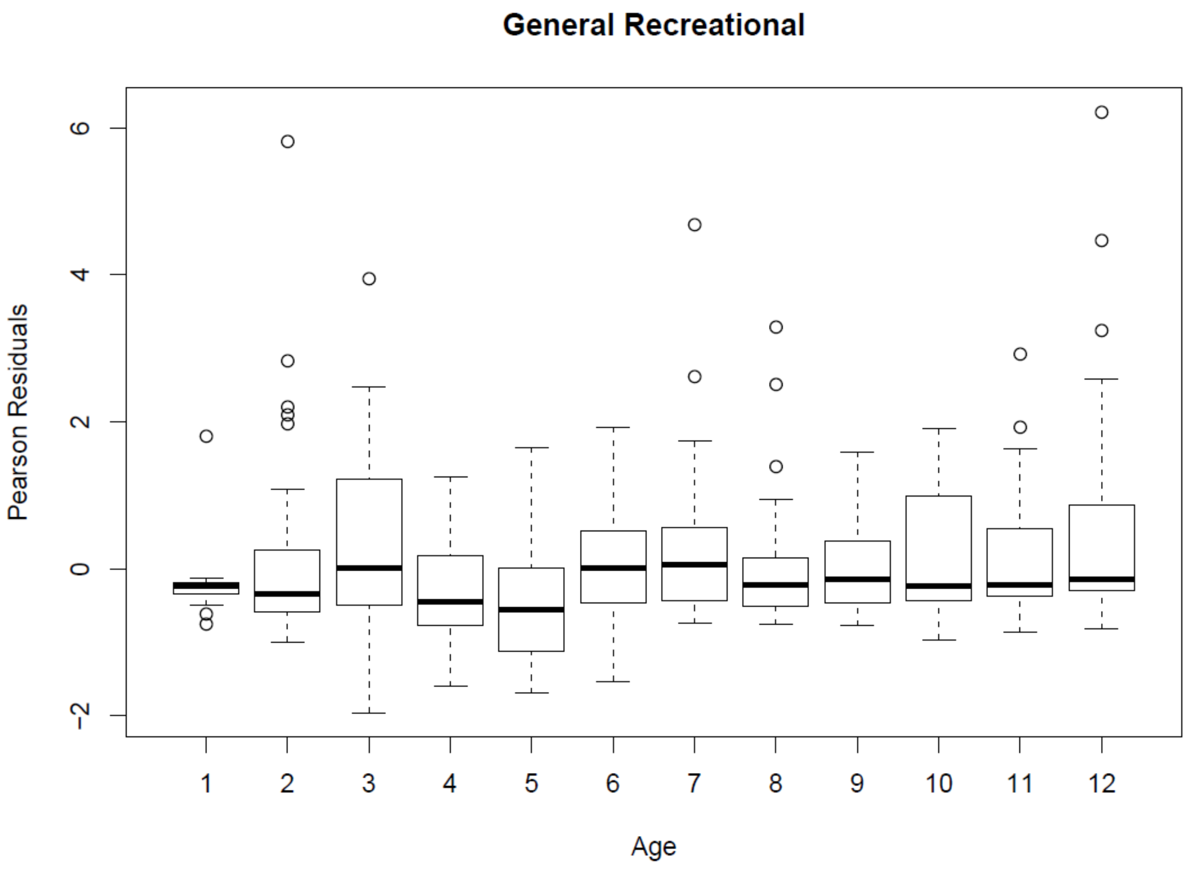


Figure 8: Pearson residuals for the age composition fits for ages 1-12 over the years 1986-2017 for the revised base case model (co23)

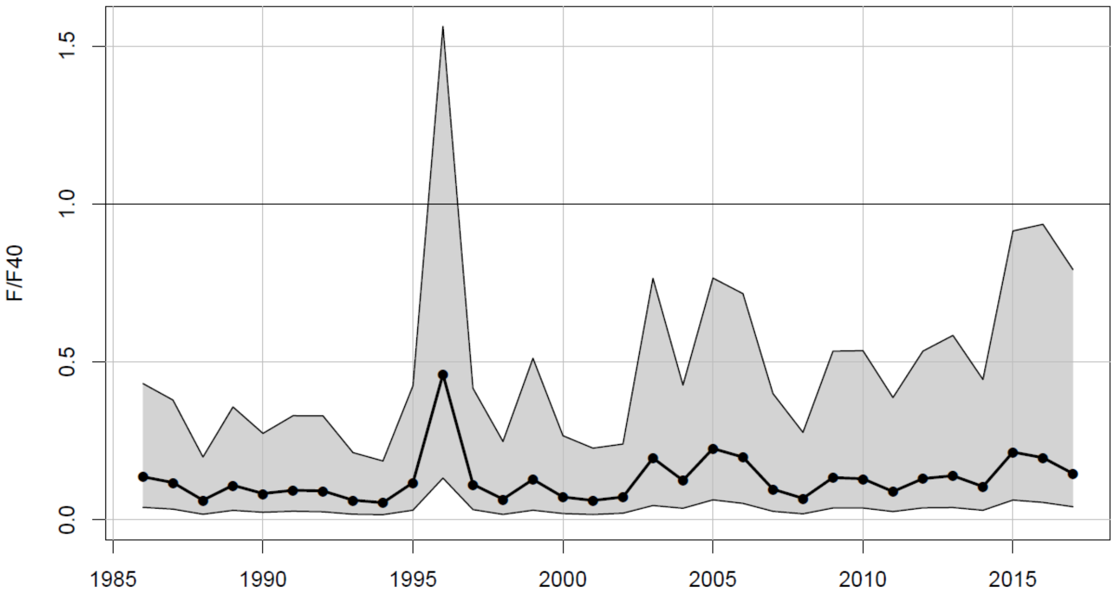


Figure 9: The 95% range for the estimates of F/F40 from the ensemble models (grey shaded region) with the revised base case (co23, solid line) for the assessment model for 1986-2017.

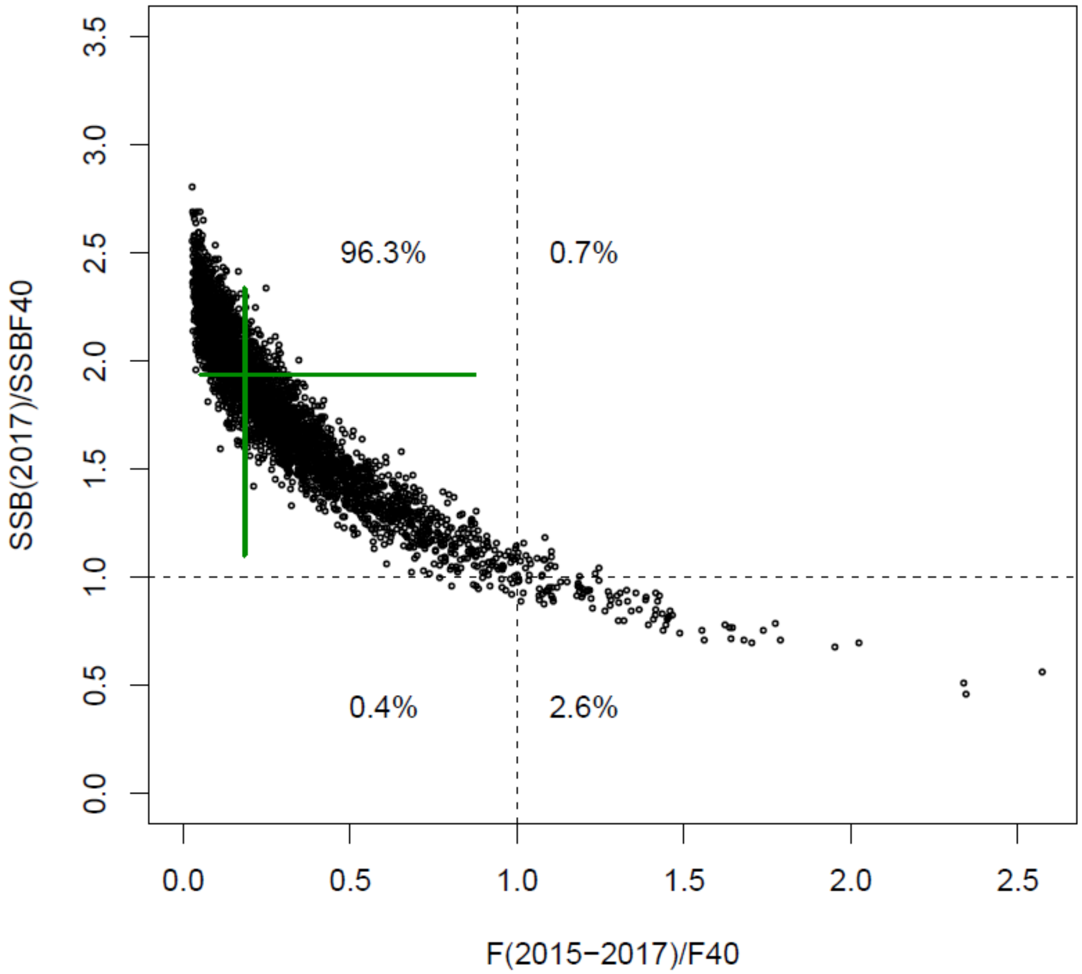


Figure 10: Ensemble model estimates of SSB(2017)/SSBF40 versus F(2015-2017)/F40 showing the proportion of ensemble model runs above and below the potential over-fishing and overfished reference points for Atlantic Cobia from the revised base case model (co23).

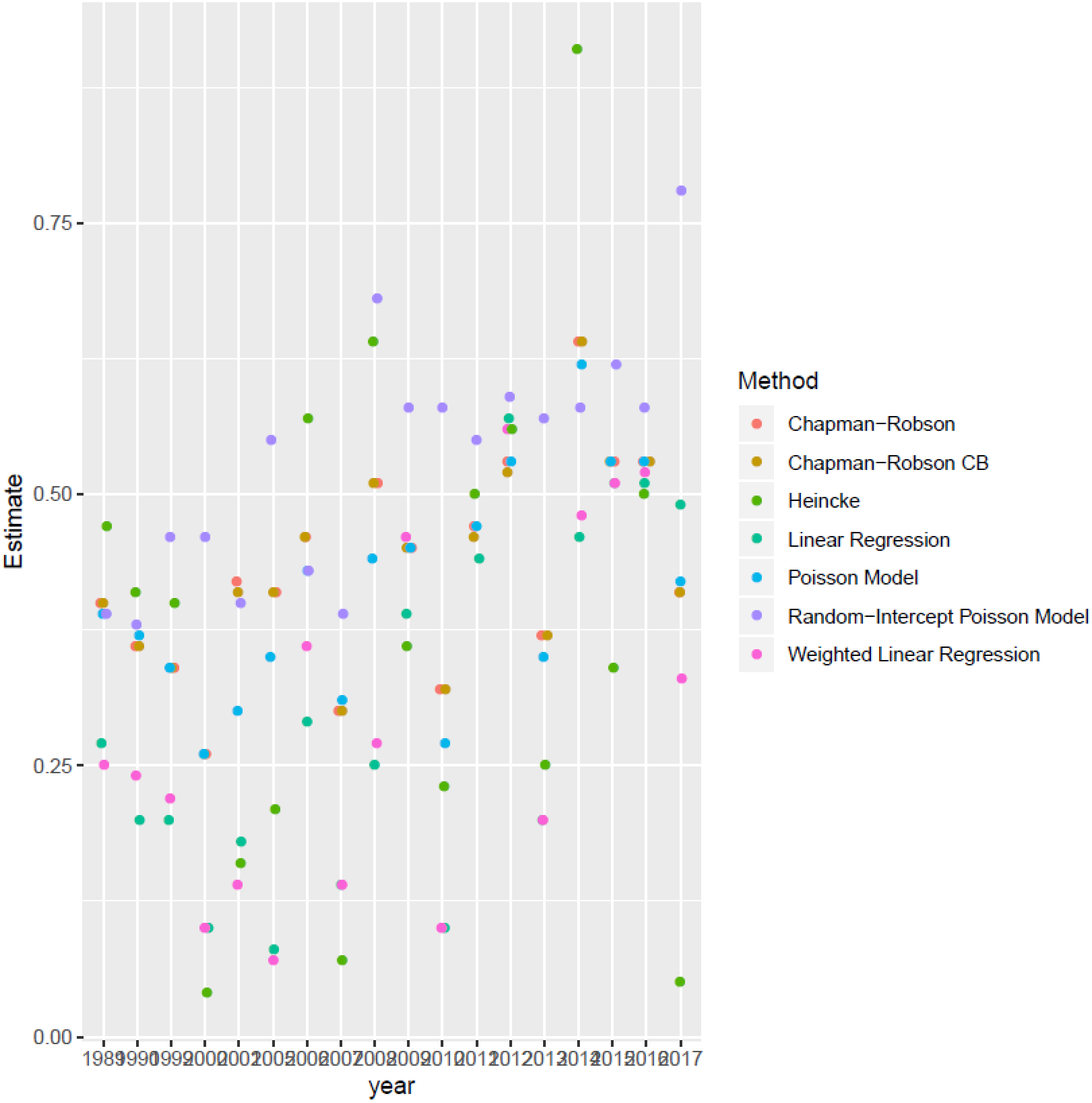


Figure 11: Catch curve estimates for 1989-2017 using regression Chapman-Robson, and Poisson regression estimators for Atlantic Cobia.

4. Evaluate the stock projections, addressing the following:

- *Are the methods consistent with accepted practices and available data?*
- *Are the methods appropriate for the assessment model and outputs?*

The RP concluded that projections were carried out appropriately using accepted practices given the data available and were appropriate for the assessment model and required outputs.

Projections for removals in number, F, SSB (000 mt) and recruits (000's at age 1) were carried out for the years 2020-2024 under 3 different scenarios:

1. *Scenario 1: F = Fcurrent, (where F current is computed as the geometric mean $F_{2015\text{-}2017}$)*
2. *Scenario 2: F = $F_{40\%}$,*
3. *Scenario 3: F = 75% $F_{40\%}$,*

Because the assessment period ended in 2017, the projections required an initialization period (2018 and 2019) for which it was assumed that total removals in weight were the mean removals in weight observed for the years 2015-2017. Given this mean removal in weight, the projection code determined the removal in numbers for 2018 and 2019 based on population attributes using the same equations used in the revised base model. Thus, there is a slight increase in the number of removals in 2019 relative to 2018 because the age- and size-structure of the population differed between the two years.

For each scenario, deterministic and stochastic projections were performed.

Population numbers at ages 2 and older in 2018 were derived from the assessment base run. For deterministic projections numbers at age 1 was arithmetic mean recruitment. For stochastic projections age 1 recruits were drawn from the lognormal distribution of recruitment values.

- *Are the results informative and robust, and useful to support inferences of probably future conditions?*
- *Are key uncertainties acknowledged, discussed, and reflected in projection results?*

The RP concluded that the projection results are informative and robust and are useful to support inferences of future stock status and biomass. The key uncertainties were well described and were reflected in projection results.

Results of projections are given in the Tables below (Tables 18 to 20 from SEDAR-58-Addendum) and Figures 12 to Figure 14.

Projection results for Scenario 1 ($F = F_{current}$), scenario 2 ($F = F_{40\%}$), and scenario 3 ($F = 75\% F_{40\%}$).

Table 18. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{current}}$ *starting in 2020.* R *= number of age-1 recruits (in 1000s),* F *= fishing mortality rate (per year),* S *= spawning stock (mt),* L *= removals (landings and dead discards) expressed in numbers (n, in 1000s) or whole weight (w, in 1000*lb*). The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)
2018	1796	1399	0.16	0.22	6647	5333	82	87	2820	2908
2019	1796	1377	0.19	0.24	6060	5117	84	91	2820	2908
2020	1796	1389	0.10	0.15	6089	5112	46	58	1479	1817
2021	1796	1382	0.10	0.15	6306	5225	49	60	1553	1857
2022	1796	1385	0.10	0.15	6478	5327	51	62	1612	1905
2023	1796	1380	0.10	0.15	6606	5394	53	63	1653	1944
2024	1796	1383	0.10	0.15	6697	5443	54	64	1683	1967

Table 19. Projection results with fishing mortality rate fixed at $F = F_{40\%}$ *starting in 2020.* R *= number of age-1 recruits (in 1000s),* F *= fishing mortality rate (per year),* S *= spawning stock (mt),* L *= removals (landings and dead discards) expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*). The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)
2018	1796	1399	0.16	0.22	6647	5333	82	87	2820	2908
2019	1796	1377	0.19	0.24	6060	5117	84	91	2820	2908
2020	1796	1389	0.69	0.65	5046	4361	254	212	8041	6507
2021	1796	1382	0.69	0.65	4109	3618	205	171	5945	4980
2022	1796	1385	0.69	0.65	3751	3338	188	156	5141	4315
2023	1796	1380	0.69	0.65	3616	3234	181	151	4836	4082
2024	1796	1383	0.69	0.65	3566	3201	179	149	4722	3981

Table 20. Projection results with fishing mortality rate fixed at $F = 75\%F_{40\%}$ *starting in 2020.* R *= number of age-1 recruits (in 1000s),* F *= fishing mortality rate (per year),* S *= spawning stock (mt),* L *= removals (landings and dead discards) expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*). The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b(mt)	S.med(mt)	L.b(n)	L.med(n)	L.b(w)	L.med(w)
2018	1796	1399	0.16	0.22	6647	5333	82	87	2820	2908
2019	1796	1377	0.19	0.24	6060	5117	84	91	2820	2908
2020	1796	1389	0.52	0.49	5326	4591	202	168	6426	5188
2021	1796	1382	0.52	0.49	4602	4041	176	147	5222	4341
2022	1796	1385	0.52	0.49	4277	3804	165	137	4680	3921
2023	1796	1380	0.52	0.49	4132	3697	160	133	4437	3739
2024	1796	1383	0.52	0.49	4069	3656	158	131	4329	3659

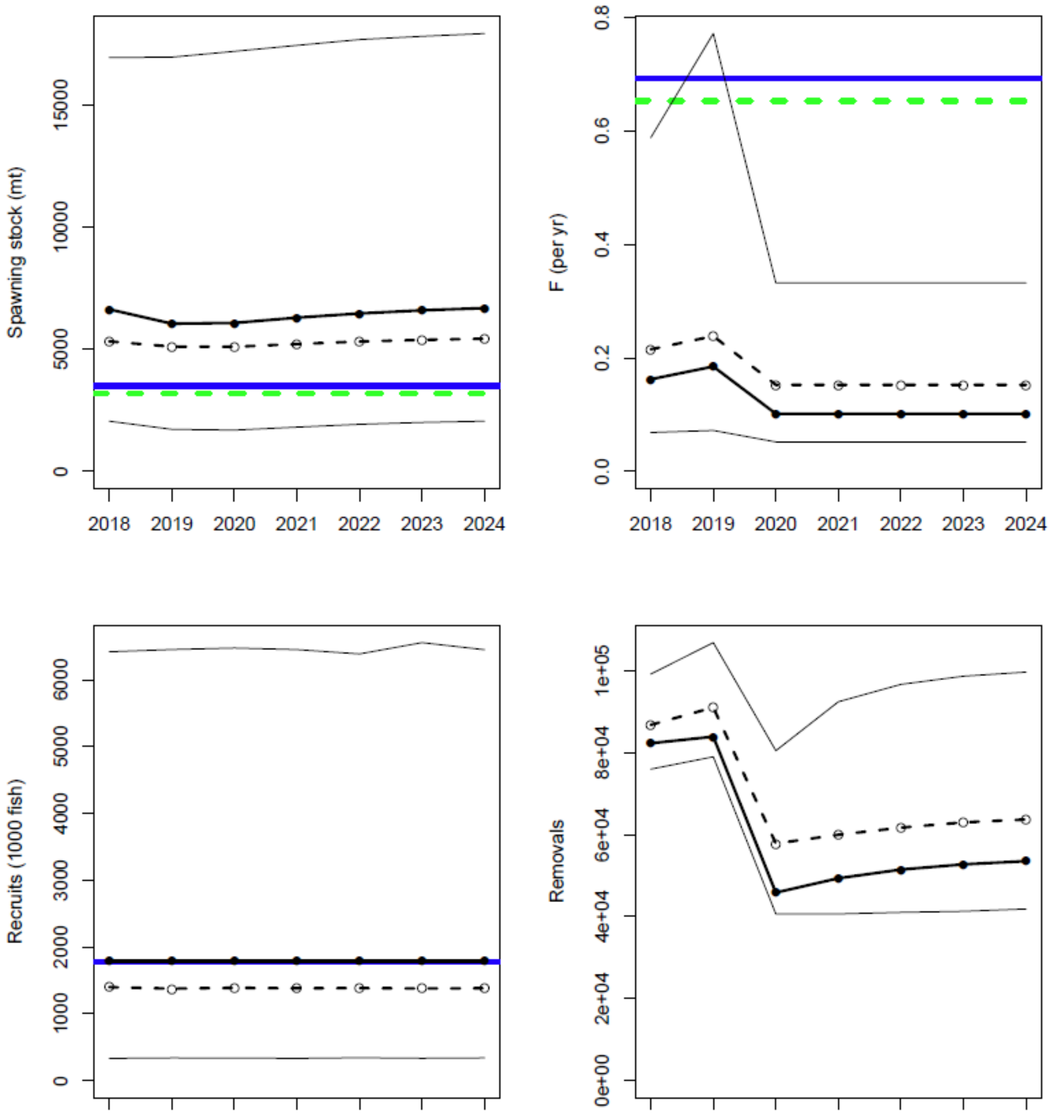


Figure 12: Results of projections for Scenario 1, F=Fcurrent. Solid black line = deterministic projection; dashes black line = median of stochastic simulations; thin black lines = lower (5%) and upper (95%) confidence intervals; green and blue horizontal lines = stochastic and deterministic reference levels respectively. Removals are in numbers.

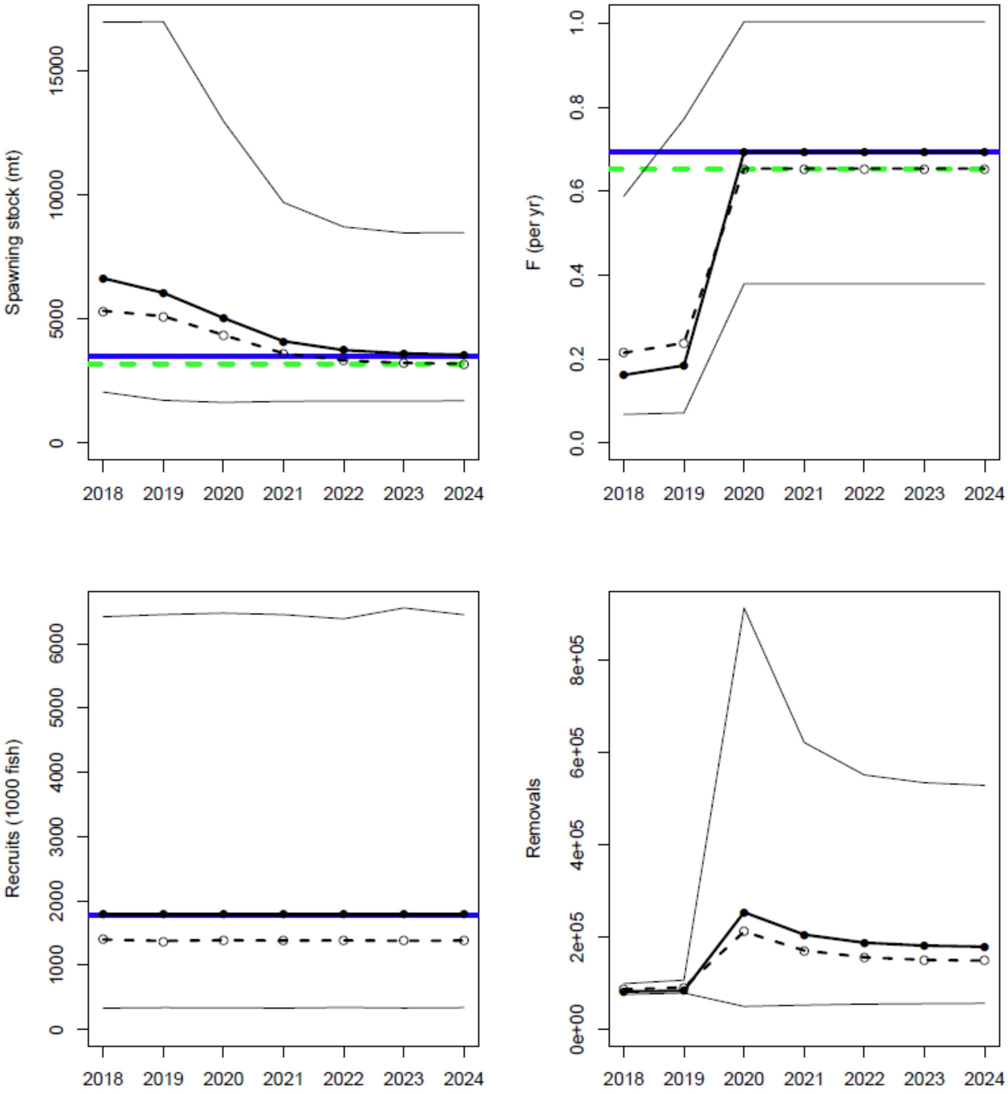


Figure 13: Results of projections for Scenario 2, F=F40%. Solid black line = deterministic projection; dashes black line = median of stochastic simulations; thin black lines = lower (5%) and upper (95%) confidence intervals; green and blue horizontal lines = stochastic and deterministic reference levels respectively. Removals are in numbers.

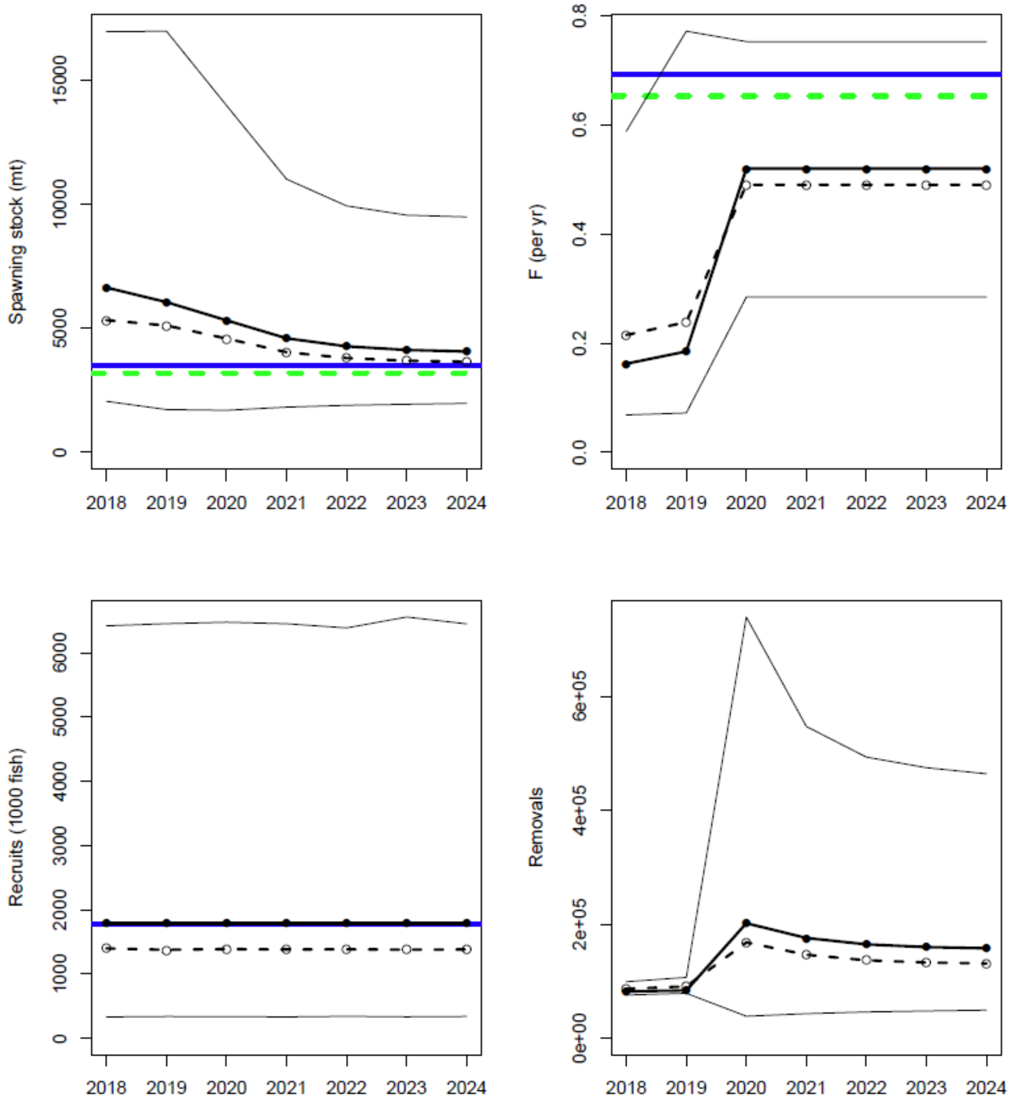


Figure 14: Results of projections for Scenario 3, F=75%F40%. Solid black line = deterministic projection; dashes black line = median of stochastic simulations; thin black lines = lower (5%) and upper (95%) confidence intervals; green and blue horizontal lines = stochastic and deterministic reference levels respectively. Removals are in numbers.

Results of deterministic and median estimates from stochastic projections were broadly similar although the 95% confidence intervals on stochastic estimates were relatively large indicating the uncertainty associated with the projection results. Such uncertainty was primarily driven by future recruit estimates being drawn from the historical variation about the mean recruitment because of an absence of a meaningful stock/recruit relationship. Nevertheless, examination of the proportion of stochastic projections runs where SSB falls below the SSBF40% reference point (Table 2) indicated that,

1. *If F=Fcurrent, the probability of the SSB falling below the biomass corresponding to* $SSB_{F40\%}$ *between 2020 and 2024 was less than 12%*
2. *If* $F=75\%F_{40\%}$*, the probability of the SSB falling below the biomass corresponding to* $SSB_{F40\%}$ *between 2020 and 2024 was less than 35%*
3. *If* $F = F_{40\%}$*, the probability of the SSB falling below the biomass corresponding to* $SSB_{F40\%}$ *tended to 50% by 2024.*

Table 2: Proportion of stochastic projections where SSB< $SSB_{F40\%}$.

	F40	75% F_{40}	$F_{current}$
2018	0.19	0.07	0.07
2019	0.23	0.11	0.11
2020	0.3	0.14	0.12
2021	0.4	0.23	0.11
2022	0.46	0.31	0.09
2023	0.49	0.34	0.08
2024	0.5	0.35	0.08

5.Consider how uncertainties in the assessment, and their potential consequences, are addressed.

The RP noted that considerable efforts were made by the AW to address uncertainty in assessment model output through sensitivities and using the ensemble modeling approach. For the ensemble modeling, a total of 4000 simulation runs were made (with ~3200 usable) involving bootstrapping of observed input variables (landings, discard, head-boat index estimates, age and length composition data) and fixed variables (natural mortality, discard mortality and recreational landings and discards) using Monte Carlo sampling with the relevant uncertainties.

Sensitivity runs were performed to investigate responses in model output to changes in inputs and to investigate model behavior. Ten alternative sensitivity runs were initially presented. Most of the model runs had a similar status as the base-case run presented in the assessment report (SEDAR-58 assessment report). The sensitivity and ensemble analyses showed that the results were most sensitive to the choice of natural mortality (M). While uncertainty in the value of M did not significantly impact the status of the stock with regard to the proposed reference points, the RP noted that choice of *M* is important as the stock status will be sensitive to its value.

The RP requested additional sensitivity runs to investigate uncertainty in the input natural mortality at age, maturity at age, and the assumption of 2 time blocks for selectivity for the head-boat index. The sensitivity analyses presented in the assessment report are appropriate, informative, and highlight the sensitivity of model output to *M* at age. This result was further confirmed by the additional sensitivity runs carried out during the review meeting.

Figure 10 summarizes the results of ensemble runs with respect to the reference points for F and SSB. 97% of ensemble runs indicate that the stock of Atlantic cobia is not overfished with respect to the proxy reference point for B_{MSY} ($SSB_{F40\%}$) and that 96.7% indicate that with respect to the F_{MSY} proxy ($F_{40\%}$) that overfishing is not taking place (Figure 10). The small percentage of runs that indicated overfished or overfishing occurred when natural mortality was assumed to be at the very low end of its plausible range.

6.Consider the research recommendations provided by the Data and Assessment Workshops and make any additional recommendations or prioritizations warranted.

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

The RP reviewed the large list of research recommendations made by the DW and AW groups. The RP recommends that the following DA and AW research recommendations should be given high priority because of the importance to the stock assessment model:

1. *Because the fishery-dependent index ended in 2015, development of a new index, either fishery-dependent or preferably fishery-independent, should be given top priority. Without an index of abundance, it is unlikely that stock status would be able to be estimated with any reliability in future. The RP recommend exploring other fisheries-dependent CPUE sources if available, developing fisheries-independent surveys such as egg/larvae surveys or close-kin methods, expanding analysis of the ten-year SERFS baited trap-video survey for cobia, or exploring the use of tag-data as potential indices of abundance.*
2. *Given that age composition data are an important source of information for the assessment model, methods to increase sample size (such as expanding carcass collection locations and establishing similar programs in other states) should be implemented. In addition, development of sampling programs to collect size and age information on fish released in the recreational fishery should be a priority.*
3. *The uncertainty in the stock status would be improved if better information on age-at-maturity and annual sex ratios were collected.*
4. *Natural mortality is an important parameter that affects model estimates of recruitment and spawning stock biomass. The RP recommends that estimates of natural mortality be made using tagging data or other analytical approaches (e.g., meta-analysis, catch-curves, etc.) for use in the model or to ground-truth the life-history invariant method used currently.*

- *Provide recommendations on possible ways to improve the SEDAR process.*

The RP noted that the SEDAR stock assessment review process would be improved if the Chair of the Data Working Group were to attend the review panel meeting, and be available to assist the AT describe decisions relating to the choice of data.

The RP noted that the DW report may be improved if summaries of descriptions of the reasons for data choices were provided. In the future, the RP noted that a separate document that contained only information pertaining to final data streams used in the assessment, including the summary of the rationale for the data choices, would be helpful. In this case, where the RP required additional detail on what has been done, then the workshop documents could be consulted. The RP recommends that SEDAR request a document or DW report section that summarizes main decisions and descriptions of why that decision was made at the data workshop.

7. Provide suggestions on improvements in data or modeling approaches which should be considered when scheduling the next assessment.

While the AT has proposed SSB40% and F40% reference points for this stock that are based on a long history of use in other locations and for similar stocks, further work with fishery managers on goals and objectives is advised prior to conducting a new benchmark. Proposed reference points could then be fully evaluated while a new assessment is conducted. The reference points proposed are based on MSY proxies and management could consider reference points consistent with levels of risk tolerance.

During the RW the RP noted some inconsistencies with regards to recreational landings; most notably the 1996 and 2015 catch. Further examination by the AT during the workshop provided no clear answers as to whether this was the result of the MRIP calibration or the result of other changes in the rec catch stream. Prior to the next assessment, a full description of landings changes from SEDAR-28 through SEDAR-58 should be conducted. This examination should be fully and completely documented in time for the next benchmark.

Work on an appropriate fishery-dependent or independent abundance index should be a priority. The current head-boat index as formulated through 2015 may not be useful after SEDAR-58. Additionally, development of a fishery-independent index is preferred. Lack of an appropriate index would likely prevent a quantitative assessment of this stock from moving forward.

The assessment method used and thus stock status is highly sensitive to assumptions of M. As such, a full suite of potential M estimates, based on life history or other approaches, should be investigated and fully documented in future assessments.

The RP recommended that given the recent break in the head-boat index an additional three years of head-boat index would be required to produce a robust assessment using only that index. This implies that if the head-boat index were to re-commence in 2020, the next assessment would be in

2024 at the earliest. However, the Atlantic Cobia assessment could be done sooner if other information (low recruitment, change in catch) points to issues with the stock.

The RP recommends a more thorough comparison between old and new stock assessments. This comparison would describe model changes and the consequential changes in stock status estimates between assessments. Such a comparison would be valuable to allow the RP to identify those components of the analysis that resulted in changes in stock status between assessments.

The RP recommend that any uncertainty in the maturity ogive be included in future ensemble modeling.

2.3. Summary results of analytical

The RP made a several requests for additional graphs and tables of input data, additional model sensitivity and ensemble runs, and modified projections during the workshop. The requests are listed below along with summaries when appropriate. The AT fulfilled all of these requests during the workshop and the results were instrumental in reaching the conclusions summarized in this report.

List of requests for AT

Model sensitivities and exploration

1. *Undertake a comparison between Lorenzen and Charnov estimates of M using the new population-level VBGF parameters for Lorenzen. Two Lorenzen M versus age curves (SEDAR-28 and with SEDAR-58 VBGF size at age) and the Charnov estimated M versus age with SEDAR-58 VBGF parameters were provided to the RP.*
2. *Evaluate uncertainty in maturity; 75% of age-3 and 100% of age-4 for life history incremental analysis. This sensitivity run gave a similar result as the revised base case model.*
3. *Examine PSEs for recreational landings and discards; captured in ensemble models (see SEDAR-58-addendum).*
4. *Provide a raw time series of F40 and SSB40 (instead of those values relative to benchmarks). RP agreed that R0 values in SEDAR-58-addendum provide the scaling differences between the various sensitivity runs and met request.*
5. *Provide the CVs of the head-boat index. The AT provided these as pre- and post-weighted values; they are given in Table 5.5 of AW report.*
6. *Provide boxplots and bubble plots of absolute and Pearson residuals for age composition data for the previous (SEDAR-28), and the SEDAR-58 base case, and revised base case models; the RP did not find any major concerns resulting from consideration of the diagnostic plots (see RW report above).*
7. *Undertake a model run using a single selectivity for the head-boat index. The AT provided this sensitivity and it was decided by RP and AT that this should be the base case run. Further details are provided in RP report sections addressing the TORs above.*
8. *Provide CPUE index and catch-at-age residual patterns for original and revised base case models.*

9. *Undertake a sensitivity of model results to the relative weighting of the age composition data for the revised base model, by multiplying the Dirichlet N's by 0.5 and 2.0 as sensitivity runs (see report above).*
10. *Provide a likelihood profile for R0 and M (see report above).*
11. *Provide boxplots of the age composition residuals to provide information on whether a robustified distribution (e.g. robust multinomial) would be appropriate to model the age composition data (see report above).*
12. *Provide information on if the 1996 spike in estimated recreational catch was a result of the MRIP calibration*
13. *Provide a plot of distribution of M when standard error of the Charnov regression estimated model slope and intercept was doubled from that provided by Charnov et al. (2013).*
14. *Provide the proportion of total catch that was head-boat catch; less than about 1% in most years, with the highest in any one year of about 3%.*
15. *Describe the numbers of vessels and locations that made up the head-boat index: vessels and locations in Table 4.11.3 in the DW report; Number of cobia in Table 4.11.15 in the DW report; All modes Table 4.11.19 in the DW report; Year and state level summaries in Table 4.11.20 in the DW report; and the head-boat index in Table 5.3 in the DW report.*
16. *Update the ensemble models with revised base case (see SEDAR 58 addendum).*
17. *Cap the commercial discard CV at 3.0 for the ensemble modeling.*
18. *Show the values of the observation and prior likelihood components for the revised base case and the old base case (i.e., for the choice of one vs two selectivity blocks to fit the head-boat index) (see report above).*

Projection comments and requests

1. *Describe the assumption of recent landings for first two years relative to constant F; any means to determine which is best. Recent fishing closures were used as justification for the use of current landings in first two years of projections. Time series of historic F, projected F and time series of historic catch and projected catch.*
2. *Provide tables on the probability of stock status being above and below targets in the projection period (see report above).*
3. *Provide a description of the assumptions on future recruitment used for projections.*
4. *Question on targets. Is there a threshold level for ASMFC? Varies by species.*
5. *Is F40% appropriate?*
6. *Provide analyses to check that SSB goes below target because of low recruitment in 2014; this resulting in the identification of an error in the projections where the bias correction was not applied to the future recruitment deviations; this was corrected by the AT for the projections described in this report.*

2.4. Additional comments

No additional comments were made by the RP.

3. Submitted Comment

The following statements were submitted to the review as comments.

Comments from Bill Gorman (1 of 2):

Hello, I would like to start out by expressing my disappointment in being unable to attend the review workshop due to illness. I have spent a long time waiting for this processes and truly enjoyed being a part of the stock ID workshop. Being an observer at the stock ID workshop I must voice my objection to parts of the summary documents. For example in the genetics work groups they concluded that "the current stock boundary or one that came as a result of SEDAR28 could not be refuted." When reviewing the rational for the current stock boundary, that ultimately being "...for ease of management, and there was no tagging or life history to dispute.." However, it goes on to clearly disclose that genetic did not "prove" nor narrow down the area in that location of the FL/GA boarder. I contend that the current stock ID CAN be refuted with new tagging from VA, both Atags and Sat tags both have fish going into NEFL with a 3rd making it's was prior to a premature release in South GA. Two different studies, both with yes limited samples, but if it were such a small fraction to went and wintered off NEFL than two studies with extremely small samples shouldn't have captured these fish in back to back years. That is BEST AVAILABLE SCIENCE, you cannot tell me nor will anyone accept that these tagged fish are merely "strayers" and are to be overlooked and labeled "it's low sample size" when two UNSEEN fish can account for over 400,000lb of catch, resulting to federal waters being closed the following year and further restricting citizens access to their public resource. This migration pattern is also consistent with Spanish. The NEFL area accounts for the largest area of commercial catch and up to 45% of the EFL annual catch. I agree for ease of management it is likely best to keep the boundary where it is, however, I strongly believe science shows what we fishermen have known, NY to NEFL should be assessed as one management group and even when SC and GA Atag fish go off radar, the fishery in NEFL picks up, and it is shown again in the timing of the VA fish. If fish are leave one fishery and enter into another, they should either be managed or assessed together.

Comment from Bill Gorman (2 of 2):

Reviewers Please take note of the MRIP 2015 and or 2016 catch totals. They were discussed, and addressed in the data workshop report section 4.3.1 (page 73-74, specifically in the catch estimates section), and graphs in section 4.12.1-3 (pg. 104 - 106). However, these data points are important on two ends, if you recall there was one year GA had zero or next to zero reported landings, that is as troubling as catch estimates that reflect daily effort in one day that isn't practical. Reviewers should also recognize that VMRC took over the surveying from subcontractors during this time period. These are important notes, since this assessment is working with extremely limited data, catch data will play a larger roll than one with more data such as independent surveys and or consistent caucus/age sampling across the entire management range. Thank you for your time Bill Gorham

Comment from Collins Doughtie:

I am very sorry for missing this event but hopefully my comments about cobia, and that fishery itself, will finally be taken to heart. I realize some of you rely on your job compiling statistics and such but being out on the ocean as much as I am plus being heavily involved in the cobia research that has, and is, being done here at the Waddell Mariculture Center in Bluffton, SC, I feel the solution to insure healthy cobia populations for the future starts with one change. That is an across the board limit revision. For example, right here in SC there is a six fish per boat, per day limit. With the ever growing coastal population and popularity of cobia, this insanely liberal limit is unsustainable. I realize many of you are not fisherman but one cobia can feed a lot of folks. The yield per fish is substantial. I have caught a whole lot of cobia over the years and though I have pretty much gone to catch and release now, a two fish per boat per day limit is all anyone needs to satisfy those onboard. I know that a three fish limit has floated out there and that would be a good start but it has to be for all our Atlantic coastal states. My comments here are not based on statistics but rather observation and many years of catching these wonderful creatures. I have watched what over fishing has done to our area and unless changes are made quite quickly, I fear the rest of you will experience this very sad scenario in the not so distant future. Thank you for being involved!

4. References

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