SEDAR 28 South Atlantic Cobia Stock Assessment Report

SEDAR 28

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Southeast Data, Assessment, and Review

SEDAR 28

Stock Assessment Report

South Atlantic Cobia

January 2013*

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SEDAR
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I. Introduction

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; and Interstate Commission representatives: Executive Directors of the Atlantic States and Gulf States Marine Fisheries Commissions.

SEDAR is organized around three workshops. First is the Data Workshop, during which fisheries, monitoring, and life history data are reviewed and compiled. Second is the Assessment process, which is conducted via a workshop and several webinars, during which assessment models are developed and population parameters are estimated using the information provided from the Data Workshop. Third and final is the Review Workshop, during which independent experts review the input data, assessment methods, and assessment products. The completed assessment, including the reports of all 3 workshops and all supporting documentation, is then forwarded to the Council SSC for certification as 'appropriate for management' and development of specific management recommendations.

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

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

2. Management Overview

2.1. Fishery Management Plan and Amendments

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

Original GMFMC/SAFMC FMP

The Fishery Management Plan (FMP), Final Environmental Impact Statement, Regulatory Impact Review, and Final Regulations for the Coastal Migratory Pelagic Resources (Mackerels), approved in 1983 and implemented effective February 4, 1983, established a management regime for the fishery for mackerels and cobia of the southeastern United States and Gulf of Mexico in the fishery conservation zone (FCZ) under the area of authority of the Gulf of Mexico and South Atlantic Fishery Management Councils and the territorial seas of the states, extending from the North Carolina/Virginia border through Texas.

Measures in the original FMP that would have affected cobia:

1. Cobia (*Rachycentron canadum*) added to fishery management unit.
2. 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.
3. 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.
4. Management Objective: Institute management measures necessary to increase yield per recruit and average size and to prevent overfishing.
5. Possession of cobia less than 33 inches fork length shall be prohibited in the FCZ.

Amendment 1

Final Amendment 1 to the Fishery Management Plan (FMP) and Environmental Impact Statement for the Coastal Migratory Pelagic Resources (Mackerels) was approved in 1985 and regulations effective on September 22, 1985.

Measures in Amendment 1 that would have affected cobia:

1. Establish that the fishing year is January 1st through December 31st.
2. Problem #5. 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.
3. Clarified that minimum size limit is 33” FL or 37” TL.

Amendment 2

Revised Amendment 2 to the Fishery Management Plan (FMP) and Environmental Impact Statement for the Coastal Migratory Pelagic Resources (Mackerels) was approved in 1987 and regulations were effective on June 30, 1987 except for the charter vessel permit requirement which was effective on August 24, 1987.

Measures in Amendment 2 that would have affected cobia:

1. 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.
2. 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 3

Amendment 3 to the Fishery Management Plan (FMP) and Environmental Assessment for the Coastal Migratory Pelagic Resources (Mackerels), with EA, was partially approved in August 1989, revised, resubmitted, and approved in April 1990. Regulations were effective on April 13, 1990.

Measures in Amendment 3 that would have affected cobia:

1. Prohibit drift gillnets for coastal pelagic species.

Amendment 5

Amendment 5 to the Fishery Management Plan (FMP) for the Coastal Migratory Pelagic Resources (Mackerels) was approved in 1990 and regulations were effective on August 20, 1990.

Measures in Amendment 5 that would have affected cobia:

1. Problem #5. The condition of the cobia stock is not known and increased landings over the last ten years have prompted concern about overfishing. Note: Cobia MSY = 1,000,000 pounds and annual catches from 1981-1986 averaged 1,900,000 pounds.
2. Overfishing.
   a. 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.
   b. 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.
   c. 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).
3. Added cobia to the Annual Stock Assessment Procedures.
4. The bag limit for cobia is 2 fish per person per day with a 1-day possession limit.

Amendment 6

Amendment 6 to the Fishery Management Plan (FMP) for the Coastal Migratory Pelagic Resources (Mackerels) was approved in 1992 and regulations were effective on December 3, 1992.

Measures in Amendment 5 that would have affected cobia:

1. Specify the minimum size limit as 33” FL only (i.e., remove the reference to 37” TL).
2. Maximum Sustainable Yield (MSY) changed to 2.2 million pounds based on results from the 1992 Report of the Mackerel Stock Assessment Panel.

Amendment 8

Amendment 8 to the Fishery Management Plan (FMP) for the Coastal Migratory Pelagic Resources (Mackerels) was partially approved on July 23, 1997. Two measures were not approved, namely, the removal of the current prohibition on the use of a drift gillnet in a directed fishery for coastal migratory pelagic fish north of Cape Lookout, NC and revisions of the FMP’s definitions of overfishing and overfished. Regulations were effective on April 3, 1998 except permit changes which were effective on March 4, 1998.

Measures in Amendment 8 that would have affected cobia:

1. Problem #11. Localized reduction of fish abundance due to high fishing pressure.
2. Extend the management area for cobia through New York, i.e., through the jurisdiction of the Mid-Atlantic Fishery Management Council. Note: This action extended the 2 fish bag limit and 33”FL minimum size limit through the Mid-Atlantic Council’s area.
3. Required additional information on each species, including cobia, from the Assessment Panel.
4. Overfishing: 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.
5. Modified the Stock Assessment Panel process.
6. 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 11

Amendment 11 to the Fishery Management Plan (FMP) for the Coastal Migratory Pelagic Resources (Mackerels) was partially approved during 1999 with regulations effective December 2, 1999. Using SPR for biomass parameters was not approved.

Measures in Amendment 11 that would have affected cobia:

1. Maximum sustainable yield for species in the coastal migratory pelagic management unit is unknown. The Council reviewed alternatives and concluded the best available data supports using 30% Static SPR as a proxy for MSY. Note: This was not approved.
2. 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.
3. 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) which is the coastal migratory pelagics MSY proxy. The “threshold level” for all species in the coastal migratory pelagic management unit is defined as 10% Static SPR.

Amendment 18

Final Amendment 18 to the Fishery Management Plan (FMP) for the Coastal Migratory Pelagic Resources in the Gulf of Mexico and Atlantic Region was submitted for formal review and implementation by the Secretary of Commerce on September 26, 2011. Approval of the amendment and implementation of regulations are expected in late 2011 or early 2012.

Measures in Amendment 18 that would have affected cobia:

ACTION 3: Establish Separate Atlantic and Gulf Migratory Groups of Cobia

Preferred Alternative 3. Separate the two migratory groups at the SAFMC/GMFMC boundary

ACTION 19-1: Maximum Sustainable Yield (MSY), Minimum Stock Size Threshold (MSST), and Maximum Fishing Mortality Threshold (MFMT) for Atlantic Migratory Group Cobia The Council has determined that the value for MSY is the value from the most recent stock assessment. Currently MSY is unknown. The Councils will use the ABC for Atlantic Migratory Group Cobia as a proxy for MSY pending results from the SEDAR assessment

The South Atlantic Council has determined that the value for MSST is the value from the most recent stock assessment based on MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}. Currently MSST is unknown

The South Atlantic Council has determined that the value for MFMT is the value of F_{MSY} or proxy of $F_{30\%SPR}$ from the most recent stock assessment. Currently the value for MFMT is unknown

ACTION 19-2: Overfishing Level (OFL) for Atlantic Migratory Group Cobia OFL is unknown. The Councils will use the total ACL for Atlantic Migratory Group Cobia to determine whether overfishing is occurring

ACTION 19-3: Allowable Biological Catch (ABC) Control Rule and ABC for Atlantic Migratory Group Cobia

Preferred Alternative 5. Adopt the Gulf Council's ABC Control Rule as an interim control rule (currently ABC equals the mean plus 1.5 times the standard deviation of the most recent10 years of landings data = 1,571,399 lb whole weight)

ACTION 19-4: Allocations for Atlantic Migratory Group Cobia

Preferred Alternative 3. 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). The allocation would be 8% commercial and 92% recreational. The commercial and recreational allocations specified would remain in effect until modified

ACTION 19-5: Annual Catch Limit (ACL) for Atlantic Migratory Group Cobia

Preferred Alternative 2. ACL = OY = ABC (currently 1,571,399 lb based on the SSC Interim Control Rule; Recreational Sector ACL = 92% = 1,445,687 lb; Commercial Sector ACL = 8% = 125,712 lb)

ACTION 19-6a: Commercial Sector ACT

Preferred Alternative 1. No Action **-**do not specify commercial sector ACTs for Atlantic migratory group cobia

ACTION 19-6b: Recreational Sector ACT

Preferred Alternative 4. The recreational sector ACT equals sector ACL[(1-PSE) or 0.5, whichever is greater] (currently 1,184,688 lb)

ACTION 20. Specify Accountability Measures (AMs) for Atlantic Migratory Group Cobia

Preferred Alternative 3. The commercial AM for this stock is to 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. Implement additional AMs for the recreational sector for this stock. If the recreational sector quota (total ACL x recreational allocation) is exceeded, the Regional Administrator 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. 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

Preferred Option a. Only adjust the recreational season length if the Total ACL is exceeded

Preferred Alternative 4. Commercial payback of any overage

Preferred Option b. 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

Preferred Option c. Only deduct overages if the Total ACL is exceeded

Preferred Alternative 5. Recreational payback of any overage from one year to the next

P**referred Option b.** 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 in Action 19-6

Preferred Option c. Only deduct overages if the Total ACL is exceeded

ACTION 21: Management Measures for Atlantic Migratory Group Cobia

1. **Preferred Alternative 1.** No Action -recreational and commercial fishermen are limited to two cobia per person. This would retain the following regulations that apply to both recreational and commercial fishermen: (a) 33” fork length minimum size limit, (b) two per person per day possession limit (Note: Florida State regulations only allow 1 per person per day for recreational and 2 per person per day for commercial), (c) one day possession limit, (d) must be landed with heads and fins intact, and (e) charter/headboats require a permit for Coastal Migratory Pelagics. Note: The fishing year is January 1 through December 31

GMFMC/SAFMC FMP Amendments affecting cobia

Description of Action	FMP/Amendment	Effective Date
Minimum size limit = 33” FL	Original FMP	2/4/83
Minimum size limit = 33” FL or 37” TL	Amendment 1	9/22/95
Charter boat permit required	Amendment 2	8/24/87
Drift gill nets prohibited for Atlantic king mackerel	Amendment 3	4/13/90
2 cobia/person/day with a 1-day possession limit (applies to recreational & commercial fishermen); must be landed with heads & fins intact	Amendment 5	8/20/90
Minimum size limit changed to FL only (33”FL)	Amendment 6	12/3/92
Allowable Gear: Cobia in the Mid-Atlantic and South Atlantic EEZ --automatic reel, bandit gear, handline, rod and reel, and pelagic longline.	Amendment 8	4/3/98

Include Council Regulatory Amendments in a separate section – None for cobia.

2.2. Emergency and Interim Rules (if any)

None for cobia.

2.3. Secretarial Amendments (if any)

None for cobia.

2.4. Control Date Notices (if any)

None for cobia.

2.5. Management Program Specifications

Table 2.5.1. General Management Information

South Atlantic

Species	**Cobia**
Management Unit	Mid-Atlantic and Southeastern US
Management Unit Definition	All waters within South Atlantic and Mid-Atlantic Fishery Management Council Boundaries (Note: This is the boundary proposed in Amendment 18)
Management Entity	South Atlantic Fishery Management Council (Note: Mid-Atlantic Council participates as voting member on South Atlantic Council's Mackerel Committee.)
Management Contacts SERO / Council	Gregg Waugh (SAFMC); Susan Gerhart (NMFS SERO)
Current stock exploitation status	No overfishing
Current stock biomass status	Not overfished

Table 2.5.2. Specific Management Criteria

Criteria	South Atlantic – Current (Proposed in Amendment 18; anticipate all will be approved)		South Atlantic - Proposed	
	Definition	Value	Definition	Value
MSST	MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}	Unknown	MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}	SEDAR 28
MFMT	F_{MSY} or proxy of $F_{30\%SPR}$	Unknown	F_{MSY}	SEDAR 28
MSY	Value from most recent stock assessment; use ABC as proxy	1,571,399 pounds	Yield at F_{MSY}	SEDAR 28
F_{MSY}	F_{MSY} or proxy of $F_{30\%SPR}$	Unknown	F_{MSY}	SEDAR 28
OY	OY=ABC	1,571,399 pounds	Yield at F_{OY}	SEDAR 28
F_{OY}	n/a	n/a	F_{OY} = 65%,75%, 85% F_{MSY}	SEDAR 28
M	Unknown	Unknown	M	SEDAR 28

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. "Current" is those definitions in place now. Please clarify whether landings parameters are 'landings' or 'catch' (Landings + Discard). If 'landings', please indicate how discards are addressed.

Table 2.5.3. Stock Rebuilding Information

Not overfished currently.

Table 2.5.4. Stock projection information.

(This provides the basic information necessary to bridge the gap between the terminal year of the assessment and the year in which any changes may take place or specific alternative exploitation rates should be evaluated)

South Atlantic

Requested Information	Value
First Year of Management	2013
Projection Criteria during interim years should be based on (e.g., exploitation or harvest)	Fixed Exploitation; Modified Exploitation; Fixed Harvest*
Projection criteria values for interim years should be determined from (e.g., terminal year, avg of X years)	100% ACL, 150% ACL & 200%ACL

*Fixed Exploitation would be $F=F_{MSY}$ (or $F<F_{MSY}$) that would rebuild overfished stock to B_{MSY} in the allowable timeframe. Modified Exploitation would be allow for adjustment in $F<=F_{MSY}$, which would allow for the largest landings that would rebuild the stock to B_{MSY} in the allowable timeframe. Fixed harvest would be maximum fixed harvest with $F<=F_{MSY}$ that would allow the stock to rebuild to B_{MSY} in the allowable timeframe.

First year of Management: Earliest year in which management changes resulting from this assessment are expected to become effective

Interim years: those between the terminal assessment year and the first year that any management could realistically become effective.

Projection Criteria: The parameter which should be used to determine population removals, typically either an exploitation rate or an average landings value or a pre-specified landings target.

Table 2.5.5. Quota Calculation Details
If the stock is managed by quota, please provide the following information

Current Quota Value	None
Next Scheduled Quota Change	Amendment 18: 2011 – Commercial ACL = 125,712 lb ww Recreational ACL = 1,445,687 lb ww
Annual or averaged quota	Annual
If averaged, number of years to average	n/a
Does the quota include bycatch/discard ?	No

How is the quota calculated - conditioned upon exploitation or average landings?
ABC from the SAFMC's SSC = the mean plus 1.5 times the standard deviation of the most recent 10 years of landings data = 1.571,399 lb whole weight.

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

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

2.6. Management and Regulatory Timeline

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

Table 2.6.1. Annual Commercial Cobia Regulatory Summary (Please fill out as appropriate)

	Fishing Year	Size Limit	Possession Limit	Open date	Close date	Other
1983	Calendar Year	33 in FL	-			
1984	Calendar Year	33 in FL	-			
1985	Calendar Year	33 in FL	-			
1986	Calendar Year	33 in FL	-			
1987	Calendar Year	33 in FL	-			
1988	Calendar Year	33 in FL	-			
1989	Calendar Year	33 in FL	-			
1990 onwards	Calendar Year	33 in FL	2/person/day (8/20/90)			Drift gill nets prohibited (4/13/90)

Table 2.6.2. Annual Recreational Cobia Regulatory Summary (Please fill out as appropriate)

	Fishing Year	Size Limit	Bag Limit	Open date	Close date	Other
1983	Calendar Year	33 in FL	-			
1984	Calendar Year	33 in FL	-			
1985	Calendar Year	33 in FL	-			
1986	Calendar Year	33 in FL	-			
1987	Calendar Year	33 in FL	-			Charter boat permits required
1988	Calendar Year	33 in FL	-			
1989	Calendar Year	33 in FL	-			
1990 onwards	Calendar Year	33 in FL	2/person/day (8/20/90)			

Table 7. State Regulatory History

Florida: recreational = 1/person/day; commercial = 2/person/day.

Not sure about others.

References

None provided.

3. Assessment History & Review

South Atlantic cobia has not been previously assessed under the SEDAR process. 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 assessment of South Atlantic cobia was done in 1995 (Thompson 1995). This 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).

References Cited:

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.

4. Regional Maps

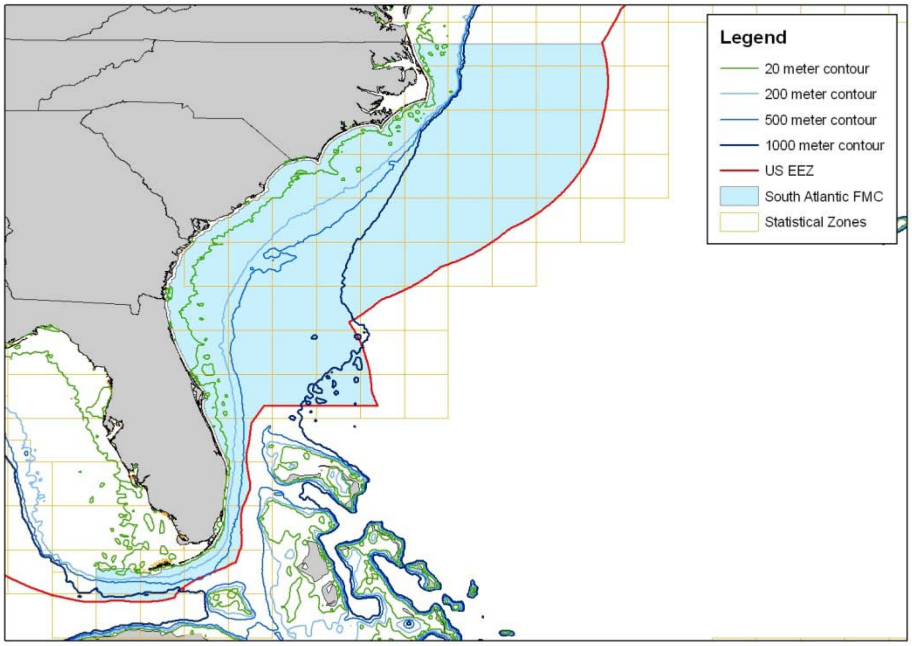


Figure 4.1: South Atlantic Fishery Management Council and EEZ boundaries.

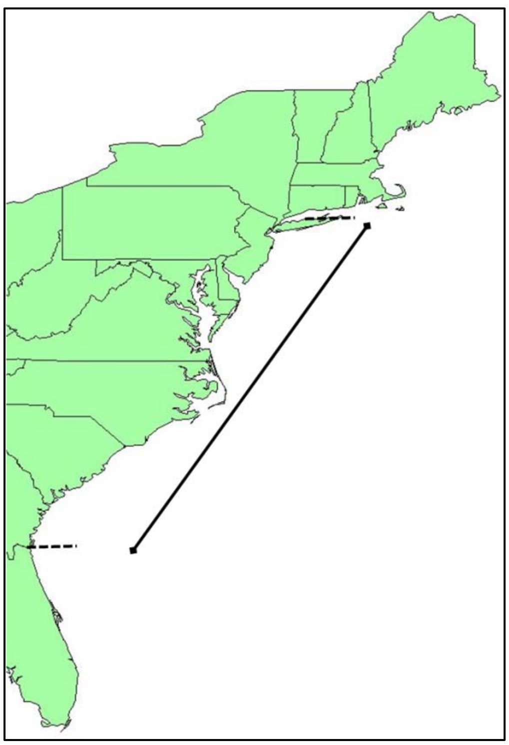


Figure 4.2: SEDAR 28 South Atlantic cobia stock boundaries (New York to GA/FL border).

5. Assessment Summary Report

The Summary Report provides a broad but concise view of the salient aspects of the 2012 South Atlantic cobia stock assessment (SEDAR 28). It recapitulates: (a) the information available to and prepared by the Data Workshop (DW); (b) the application of those data, development and execution of one or more assessment models, and identification of the base-run model configuration by the Assessment Workshop (AW); and (c) the findings and advice determined during the Review Workshop.

Executive Summary

The South Atlantic cobia stock assessment presented by the SEDAR 28 Assessment Workshop (AW) provided the Review Panel (RP) with outputs and results from two assessments models. The primary model was the Beaufort Assessment Model (BAM), while a secondary surplus production model (ASPIC) provided a comparison of model results. The RP concluded that the BAM was the most appropriate model to characterize the stock status for management purposes. The current stock biomass status in the base run was estimated to be SSB_{2011}/MSST=1.75. The current level of fishing (exploitation status) was $F_{2009\text{-}2011}/F_{MSY}$ = 0.599, with F_{2011}/F_{MSY} = 0.423. Therefore, the RP concluded that the stock is not overfished and is not undergoing overfishing. The qualitative results on terminal stock status were similar across presented sensitivity runs, indicating that the stock status results were robust given the provided data and can be used for management. The outcomes of sensitivity analyses were in general agreement with those of the Monte Carlo Bootstrap (MCB) analysis (an additional way to examine uncertainty) in BAM. The RP concluded that the ASPIC model results were not informative for stock status determination and fisheries management.

Stock Status and Determination Criteria

Point estimates from the base model indicated that the U.S. southeast stock of cobia (*Rachycentron canadum*) is currently not overfished and overfishing is not occurring.

Estimated time series of stock status (SSB/MSST, SSB/SSB_{MSY}) showed a general decline through the 1980s, an increase in the late 1980s and early 1990s, followed by a decline in more recent years (Figure 5.7). The increase in stock status in the 1990s may have been driven by several strong year classes and perhaps reinforced by the 2-fish per person bag limit implemented in 1990. Base run estimates of spawning biomass have remained above MSST throughout the time series. Current stock status in the base run was estimated to be SSB_{2011}/MSST = 1.75 (Table 5.1), indicating that the stock is not overfished. Uncertainty from the MCB analysis suggested that the estimate of a stock that is not overfished (i.e., SSB > MSST) is relatively robust. Age structure estimated from the base run shows more older fish than the (equilibrium) age structure expected at MSY. However, in the most recent year, ages 1-7 approached the MSY age structure.

The estimated time series of F/F_{MSY} from the base run suggested that overfishing has not been occurring over the course of the assessment period but with considerable uncertainty, particularly since the mid 2000s, as demonstrated by the MCB analysis (Figure 5.7). Current fishery status, with current F represented by the geometric mean from 2009-2011, is estimated by the base run to be $F_{2009\text{-}2011}/F_{MSY}$ = 0.599 (Table 5.1), but with much uncertainty in that estimate.

Table 5.1 Summary of stock status determination criteria. Estimated status indicators, benchmarks, and related quantities from the Beaufort catch-age model, conditional on estimated current selectivities averaged across fisheries. Rate estimates (F) are in units of y^{-1}; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) and minimum stock size threshold (MSST) are measured by total weight of mature females.

Criteria	Recommended Values from SEDAR 28	
	Definition	Value
M (Instantaneous natural mortality; per year)	Average of Lorenzen M (if used)	0.26
Fcurrent (per year)	Geometric mean of apical fishing mortality rates for 2009-2011 ($F_{2009\text{-}2011}$)	0.276
F_{MSY} (per year)	F_{MSY}	0.461
B_{MSY} (metric tons)	Biomasss at MSY	1991.6
SSB_{2011} (metric tons)	Spawning stock biomass in 2011	693
SSB_{MSY} (metric tons)	Spawning stock biomass at MSY	536.8
MSST (metric tons)	MSST = [(1-M) or 0.5 whichever is greater]*B_{MSY}	397.2
MFMT (per year)	F_{MSY}	0.461
MSY (1000 lb)	Yield at F_{MSY}	808
OY	Yield at F_{OY}	
F_{OY}	F_{OY} = 65%,75%, 85% F_{MSY}	65% F_{MSY} = 0.299 75% F_{MSY}=0.345 85% F_{MSY}=0.391
Biomass Status	SSB_{2011}/MSST	1.75
	SSB_{2011}/SSB_{MSY}	1.29
Exploitation Status	$F_{2009\text{-}2011}/F_{MSY}$	0.599
	F_{2011}/F_{MSY}	0.423

Stock Identification and Management Unit

Microsatellite-based analyses demonstrated that tissue samples collected from NC, SC, east coast Florida (near St. Lucie), MS and TX showed disparate allele frequency distributions and subsequent analysis of molecular variance showed population structuring occurring between the states. Results showed that the Gulf of Mexico stock appeared to be genetically homogeneous and that segment of the population continued around the Florida peninsula to St. Lucie Florida, with a genetic break somewhere between St. Lucie Florida and Port Royal Sound in South Carolina. Tag recapture data suggested two stocks of fish that overlap at Brevard County Florida and corroborated the genetic findings.

The South Atlantic and Gulf stocks were separated at the FL/GA line because genetic data suggested that the split is north of the Brevard/Indian River County line and there was no tagging data to dispute this split. The FL/GA line was selected as the stock boundary based on recommendations from the commercial and recreational work groups and comments that for ease of management the FL/GA line would be the preferable stock boundary and did not conflict with the life history information available. However, there was not enough resolution in the genetic or tagging data to suggest that a biological stock boundary exists specifically at the FL/GA line, only that a mixing zone occurs around Brevard County, FL and potentially to the north. The Atlantic stock extended northward to New York.

Assessment Methods

Following the Terms of Reference, two models of cobia were discussed during the Assessment Workshop (AW): a statistical catch-age model and a surplus-production model (ASPIC). The statistical catch-age was selected at the AW to be the primary assessment model.

The primary model in this assessment was the Beaufort assessment model (BAM), which applies a statistical catch-age formulation. The model was implemented with the AD Model Builder software. In essence, a statistical catch-age model simulates a population forward in time while including fishing processes. Quantities to be estimated are systematically varied until characteristics of the simulated population match available data on the real population. Statistical catch-age models share many attributes with ADAPT-style tuned and untuned VPAs.

A logistic age-aggregated surplus production model, implemented in ASPIC, was considered for cobia by the AW panel. The production model failed to converge under a variety of configurations. The primary difficulty was a lack of contrast in the data, so that very little information was available on the production function for cobia. The production model did converge under a very restricted set of conditions, and gave qualitatively similar results to the catch-age model. The AW panel considered the age structured model to be more appropriate for cobia.

Assessment Data

The catch-age model included data from two fishery dependent surveys, and from both recreational and commercial fisheries that caught southeastern U.S. cobia. The model was fitted to data on annual combined recreational landings and discards, annual combined commercial landings and discards, annual length compositions of recreational landings, annual age compositions of recreational landings, a combined length composition of commercial landings (1982-2011), a combined age composition of commercial landings (1986-2011), and two indices of abundance (the South Atlantic Regional Headboat Survey (SRHS) and the South Carolina logbook program). Discards were a small proportion of landings and no information on size or age of discards was available to estimate discard selectivity; therefore, discards were combined with landings. Not all of the above data sources were available for all fleets that caught cobia in all years.

The recreational landings estimates included headboat landings, developed by the headboat survey, and the general recreational landings for private recreational, charterboat, and shore modes of the Marine Recreational Fishing Statistical Survey (MRFSS). MRFSS began in 1981 and is undergoing modifications, including a change of name to Marine Recreational Information Program (MRIP). The sampling and estimation methodology for this assessment is that of MRFSS from 1981-2003 and MRIP from 2004-2011 as recommended by the DW.

Release Mortality

Discards were a small proportion of landings (mean: 0.048 for recreational discards and 0.013 for commercial discards) and no information was available to estimate discard selectivity. Therefore, dead discards were combined with landings as total recreational removals (landings plus discards) and total commercial removals (landings plus discards). The data workshop provided discard mortality rates for vertical lines (0.05) and for gillnets (0.51) that were used to calculate dead discards prior to combining with landings. Data on commercial discards was available from 1993-2011. Commercial discards were hindcast to 1983 using the mean ratio of discards:landings for 1993-1997. Data on recreational discards were available from 1983-2011. Commercial and recreational discards were assumed negligible prior to 1983 (the first year of regulation).

Catch Trends

The cobia fishery was dominated by the recreational fleet. Observed recreational landings began in 1981 and were variable over the entire time series. Recreational landings peaked in 1986 and again in the early to mid 2000s. Recreational dead discards began in 1983 (the first year of regulation) and were variable with an overall increasing trend over the time series.

Commercial landings peaked in the mid 1990s, followed by a small decline. Commercial landings have remained relatively stable since the early 2000s. Commercial dead discards increased throughout the late 1990s and 2000s, peaking in 2008. See Figures 5.1 and 5.2 for detail on landings and discard trends.

Fishing Mortality Trends

The estimated time series of fishing mortality rates (F) from BAM was highly variable, with F for fully selected ages varying greater than four-fold since the 1980s (Figure 5.3). There was a drop in F in the 1990s following the implementation of the 2-fish per person bag limit, but there has been a notable increase since the early 2000s. In recent years (since 2003), estimates of F have averaged about 0.30. The general recreational fleet has been the largest contributor to total F throughout the time series (Figure 5.3).

Stock Abundance and Biomass Trends

Estimated abundance at age since the 1990s showed a slight truncation of the oldest ages compared to the 1980s, but in general there was little obvious change in age structure over time. Total estimated abundance has varied about two-fold since the 1980s with a general decline since 2005. A strong year class was predicted to have occurred in 2005 comparable to those predicted periodically in the late 1980s and throughout the 1990s. However, predicted recruitment in recent years (2007-2009) has been below average.

Estimated biomass at age followed the same general pattern as estimated abundance at age. Total biomass and spawning biomass showed similar trends - generally higher biomass in the 1990s and early 2000s compared to the 1980s and a decline in more recent years (Figure 5.4). The stock was estimated to be at its lowest point in the late 1980s and was estimated to be at a comparable level now.

Scientific Uncertainty

Sensitivity analysis can be useful for evaluating the consequences of assumptions made in the base assessment model, and for interpreting MCB results in terms of expected effects from input parameters. Time series of F/F_{MSY} and SSB/SSB_{MSY} are plotted in Section III, part 3 of the Stock Assessment Report to demonstrate sensitivity to natural mortality, steepness, model component weights, catchability, the South Carolina cobia stocking program, discard mortality, inclusion or exclusion of indices of abundance, and the measure of reproductive potential. Status indicators were most sensitive to natural mortality, model components weights, and steepness. The qualitative results on terminal stock status were similar across most sensitivity runs, and generally indicated that the stock is not overfished ($SSB/SSB_{MSY} > 1$) and overfishing is not occurring ($F/FMSY < 1$) (Figure 5.8). Sensitivity analyses were in general agreement with the results of the MCB analysis.

Retrospective analyses did not suggest any patterns in F, B, SSB, recruits, SSB/SSB_{MSY}, or F/F_{MSY} and seemed to indicate no retrospective error. The departures in the terminal year for the early retrospectives (terminal year: 2004 - 2007) should be interpreted with caution because they were associated with a large change in sample sizes for recreational age compositions beginning in 2007.

Significant Assessment Modifications

The review panel accepted the base run as developed by the assessment panel. Additional sensitivity runs were conducted during the Review Workshop, including evaluation of dome shaped selectivity, time varying selectivity, a change in model start date (1950 vs. 1981), an alternate stock recruitment model (Ricker), and exploration of growth model assumptions.

Sources of Information

The contents of this summary report were taken from the SEDAR 28 South Atlantic cobia data, assessment, and review reports.

Figures

Figure 5.1: South Atlantic cobia commercial and recreational landings. Commercial landings are in units of pounds whole weight. Recreational landings are in units of pounds whole weight (1981 – 2011) and numbers of fish (1955 – 2011). *(Generated from data in Table 2.6 and Table 2.10 of the Assessment Report.)*

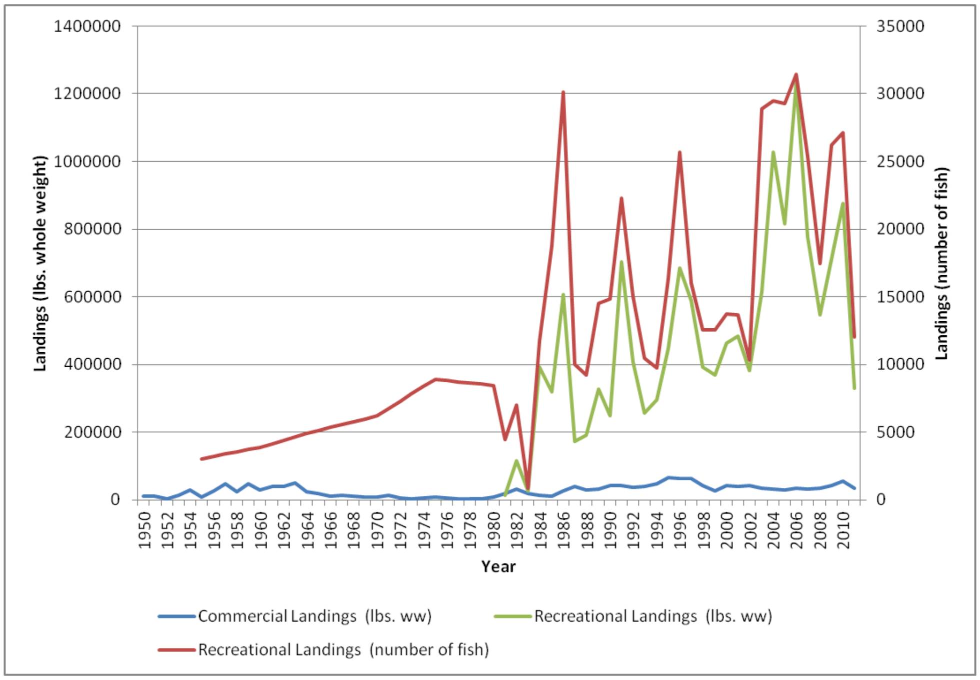


Figure 5.2: South Atlantic cobia commercial and recreational dead discards. Commercial discards are in units of pounds whole weight. Recreational discards are in units of numbers of fish *(Generated from data in Table 2.7 and Table 2.11 of the Assessment Report.)*

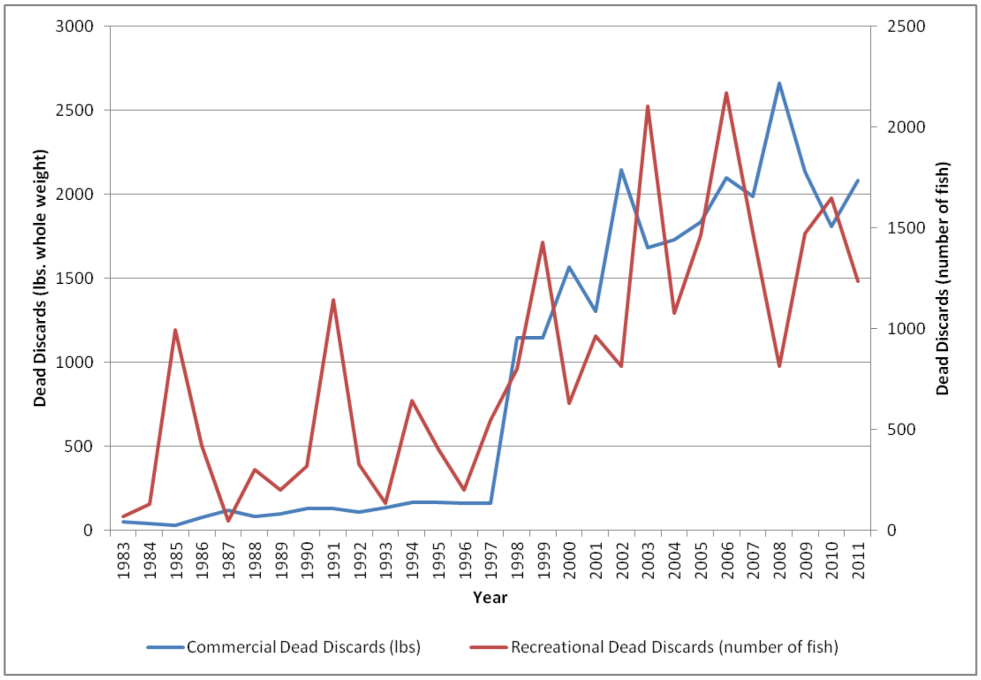


Figure 5.3: Estimated fully selected fishing mortality rate (per year) by fishery. cA refers to commercial, mrip to recreational, both include discards. *(Extracted from Figure 3.17 of the Assessment Report.)*

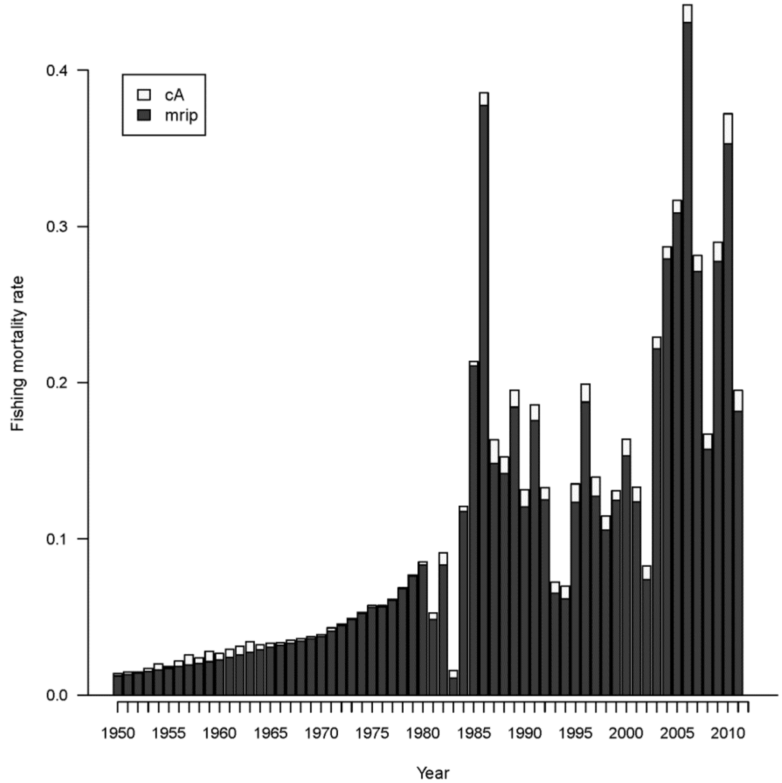


Figure 5.4a: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates B_{MSY}. *(Extracted from Figure 3.14 of the Assessment Report.)*

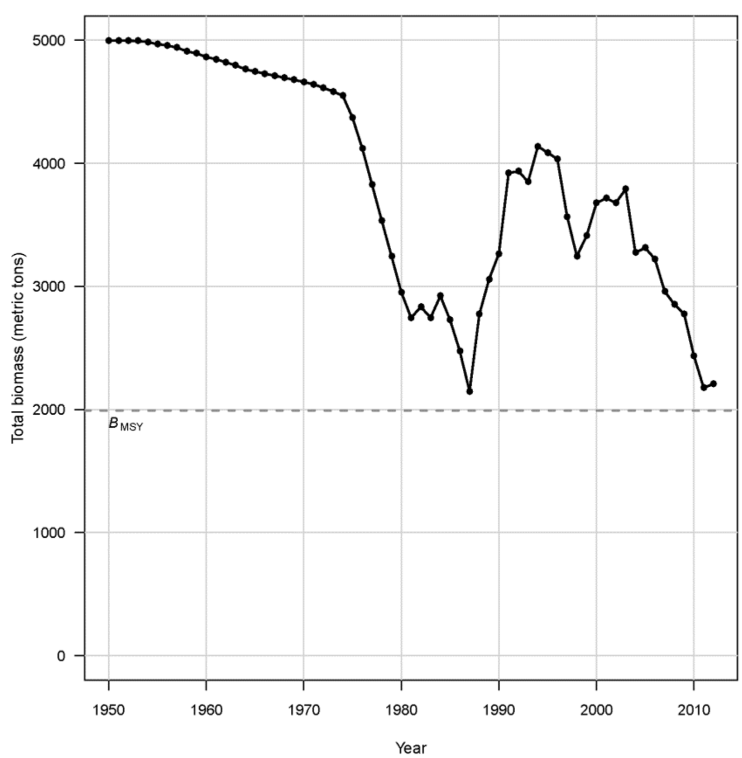


Figure 5.4b: Estimated spawning stock (mature female biomass) at time of peak spawning. *(Extracted from Figure 3.14 of the Assessment Report.)*

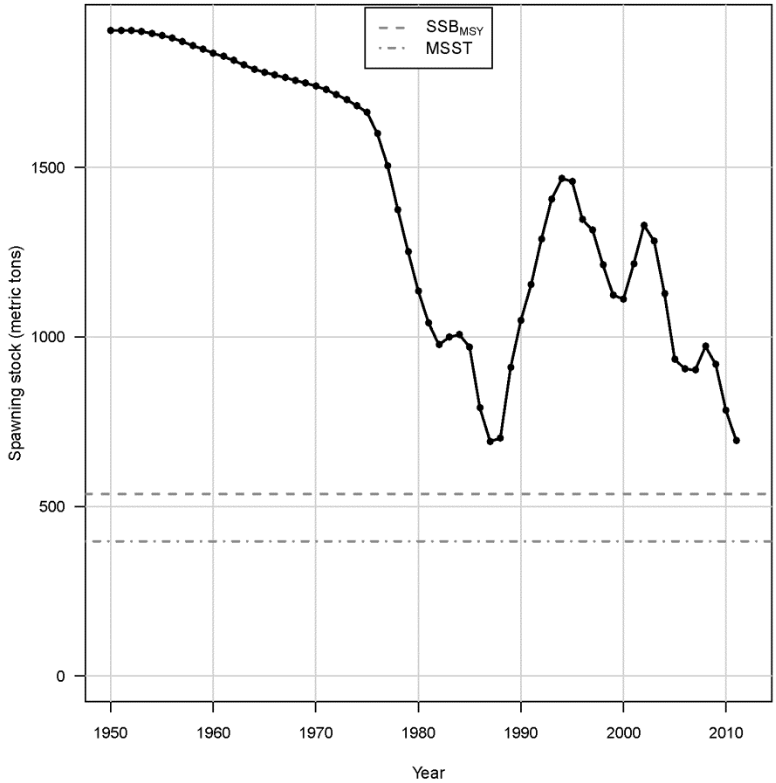


Figure 5.5: South Atlantic cobia indices of abundance from headboat and SC logbook. Each index is scaled to its mean value. *(Generated from data in Table 2.14 of the Assessment Report.)*

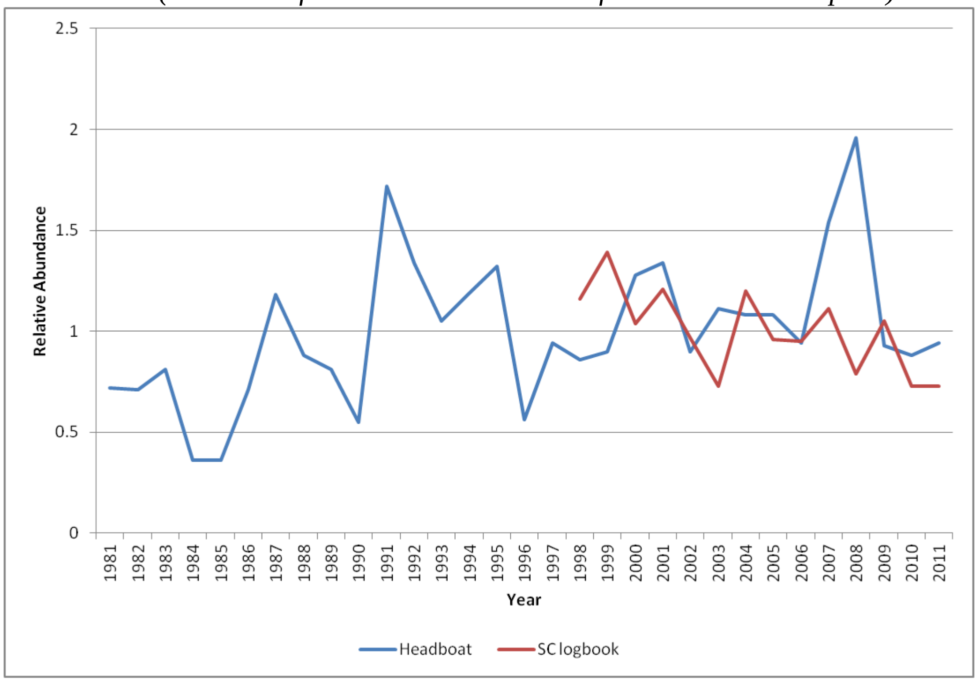


Figure 5.6: Beverton-Holt spawner-recruit curves, with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Years within panel indicate year of recruitment generated from spawning biomass one year prior. *(Extracted from Figure 3.20 of the Assessment Report.)*

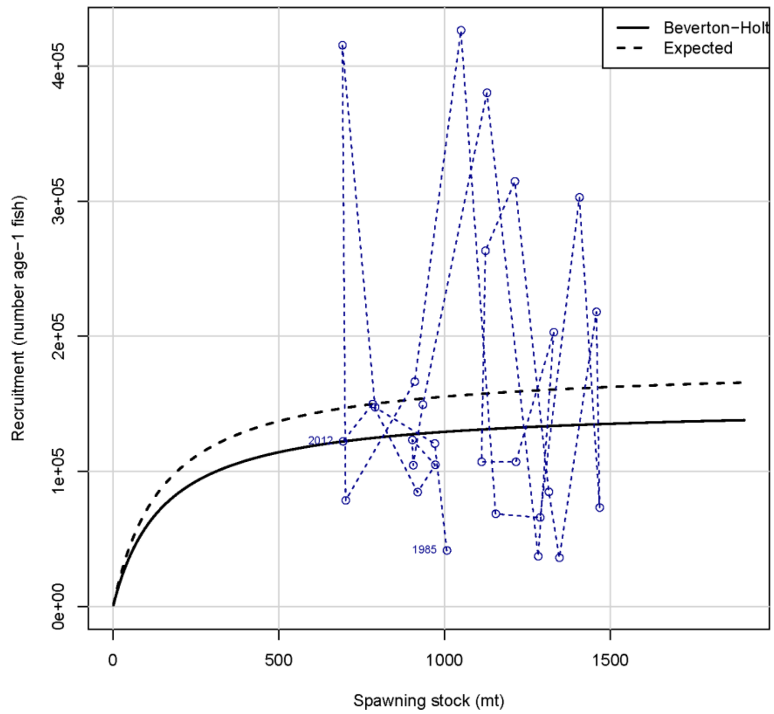


Figure 5.7a: Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5th and 95th percentiles of the MCB trials. Spawning biomass relative to the minimum stock size threshold (MSST). *(Extracted from Figure 3.27 of the Assessment Report.)*

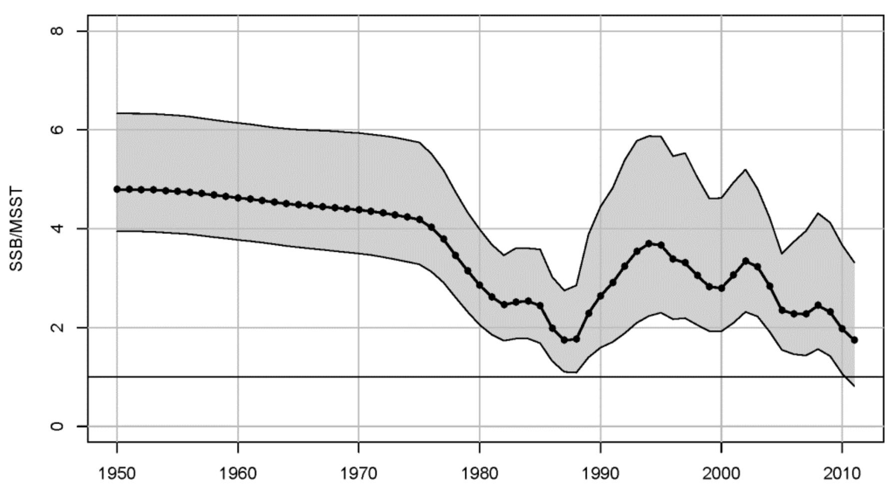


Figure 5.7b: Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5th and 95th percentiles of the MCB trials. Spawning biomass relative to SSB_{MSY}. *(Extracted from Figure 3.27 of the Assessment Report.)*

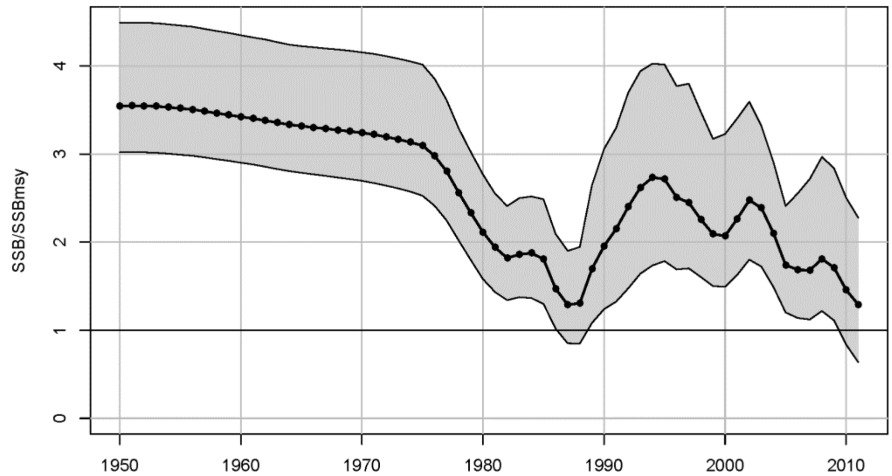


Figure 5.7c: Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5th and 95th percentiles of the MCB trials. F relative to F_{MSY}. *(Extracted from Figure 3.27 of the Assessment Report.)*

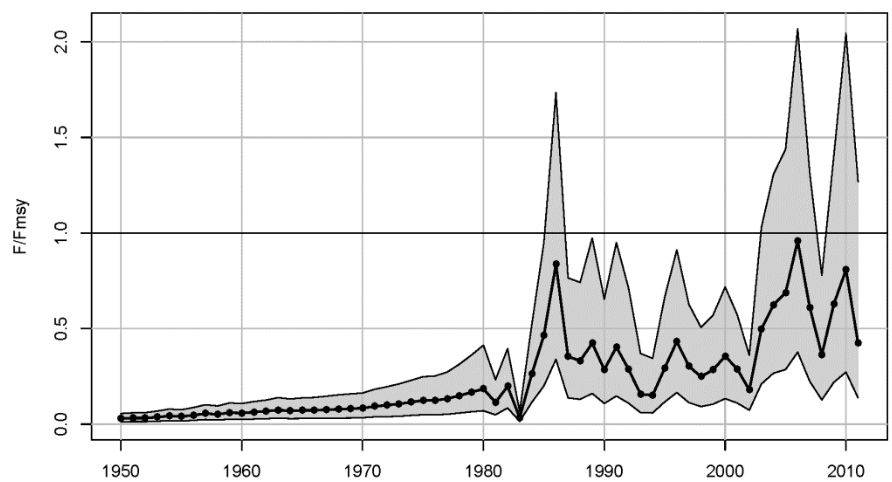
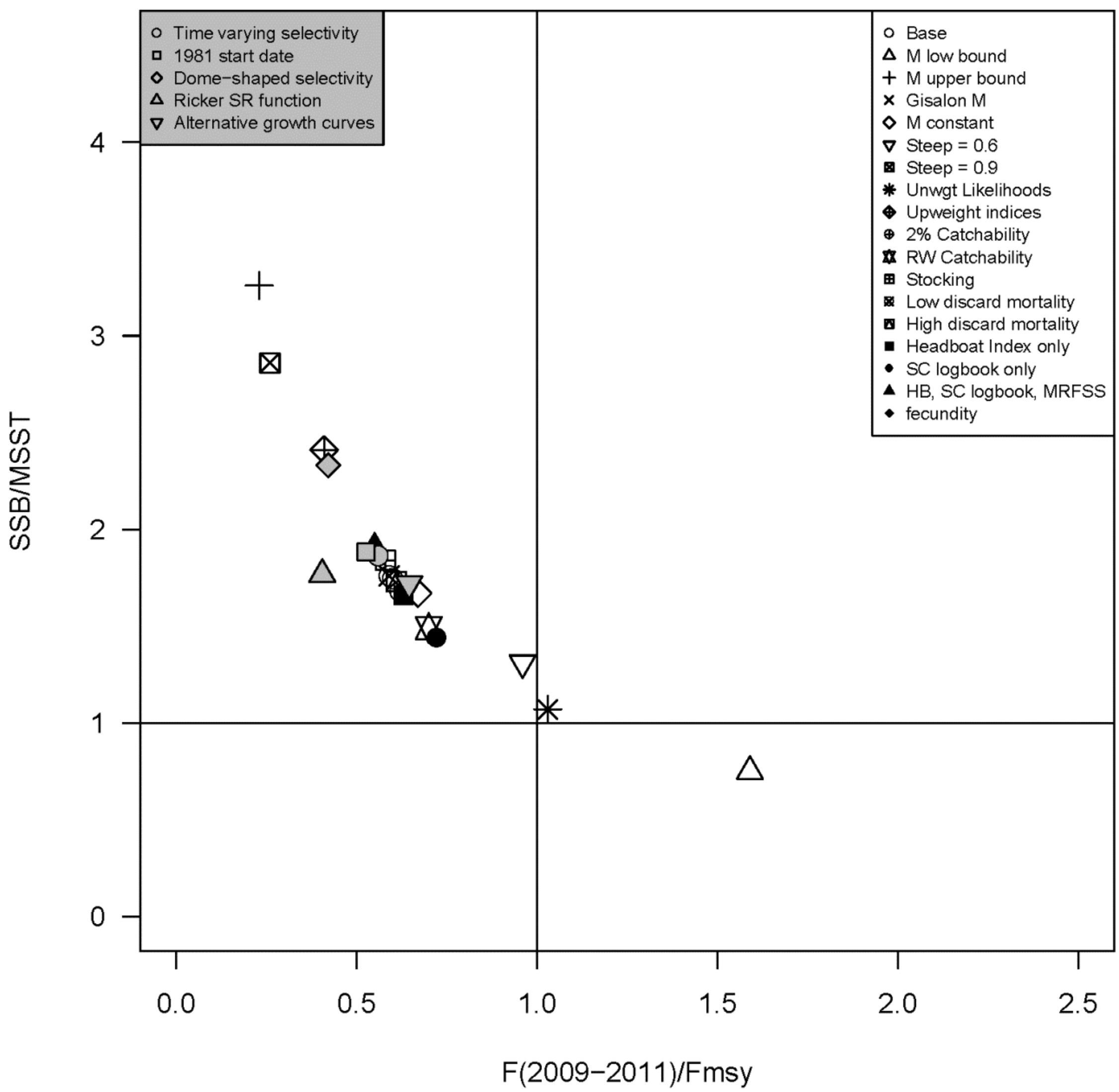


Figure 5.8: Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model. *(Figure 3.39 of the Assessment Report was updated to include sensitivity runs conducted during the Review Workshop. Gray points (legend in upper left corner) identify the additional sensitivity runs conducted at the Review Workshop.)*



6. SEDAR Abbreviations

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
ASMFC	Atlantic States Marine Fisheries Commission
B	stock biomass level
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 Fisheries 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
M	natural mortality (instantaneous)
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
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
SEDAR	Southeast Data, Assessment and Review
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.
Z	total mortality, the sum of M and F

SEDAR

Southeast Data, Assessment, and Review

SEDAR 28

South Atlantic Cobia

SECTION II: Data Workshop Report

May 2012

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

Contents

1 Introduction

1.1 Workshop Time and Place

The SEDAR 28 Data Workshop was held February 6-10, 2012 in Charleston, South Carolina. Webinars were held January 11, 2012 and March 14, 2012.

1.2 Terms of Reference

I. Data Workshop

1. Characterize stock structure and develop an appropriate stock definition. Provide maps of species and stock distribution.
2. Review, discuss and tabulate available life history information.
   - Provide appropriate models to describe growth, maturation, and fecundity by age, sex, or length as applicable
   - Evaluate the adequacy of available life-history information for conducting stock assessments, and recommend life history information for use in population modeling
3. Provide measures of population abundance that are appropriate for stock assessment.
   - Consider and discuss all available and relevant fishery dependent and independent data sources
   - Document all programs evaluated, addressing program objectives, methods, coverage (provide maps), sampling intensity, and other relevant characteristics
   - Develop CPUE and index values by appropriate strata (e.g., age, size, area, and fishery); provide measures of precision and accuracy
   - Evaluate the degree to which available indices adequately represent fishery and population conditions
   - Recommend which data sources are considered adequate for use in assessment modeling.
4. Characterize commercial and recreational catch.
   - Include both landings and discards, in pounds and number
   - Provide estimates of discard mortality rates by fishery and other strata as feasible
   - Evaluate and discuss the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector
   - Provide length and age distributions if feasible, and maps of fishery effort and harvest
   - Provide a single table showing landings by sector in whole weight, using the methods developed by SEFSC for ACL tracking to estimate recreational landings by weight
5. Determine appropriate stock assessment models and/or other methods of evaluating stock status, determining yields, estimating appropriate population benchmarks, and making future projections that are suitable for making management decisions.
6. Provide recommendations for future research, including guidance on sampling design, intensity, and appropriate strata and coverage.

7. Develop a spreadsheet of assessment model input data that reflects the decisions and recommendations of the Data Workshop. Review and approve the contents of the input spreadsheet by TBD.
8. Prepare the Data Workshop report providing complete documentation of workshop actions and decisions (Section II of the SEDAR assessment report), and develop a list of tasks to be completed following the workshop.

II. Assessment Process

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.
   - Consider multiple models, including multispecies models, if data limitations preclude single species assessments
   - ***Consider a model approach that can be applied to Gulf and Atlantic cobia.***
   - Recommend models and configurations considered most reliable or useful for providing advice
   - Document all input data, assumptions, and equations for each model prepared
3. Provide estimates of stock population parameters.
   - Include fishing mortality, abundance, biomass, selectivity, and other parameters as appropriate given data availability and modeling approaches
   - Include appropriate and representative measures of precision for parameter estimates
4. Characterize uncertainty in the assessment and estimated values.
   - Consider uncertainty in input data, modeling approach, and model configuration
   - Consider other sources as appropriate for this assessment
   - Provide appropriate measures of model performance, reliability, and 'goodness of fit'
5. Provide evaluations of yield and productivity
   - Include yield-per-recruit, spawner-per-recruit, and stock-recruitment evaluations
6. 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.
   - Evaluate existing or proposed management criteria as specified in the management summary
   - Recommend proxy values when necessary
7. Provide declarations of stock status relative to management benchmarks or, if necessary, alternative data-poor approaches.
8. Perform a 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, landings, discards and exploitation) and develop rebuilding schedules if warranted; include estimated generation time. Stock projections shall be developed in accordance with the following:
   A) If stock is overfished:

F=0, F=current, F=Fmsy, Ftarget,
F=Frebuild (max that rebuilds in allowed time)

B) If stock is overfishing:
F=Fcurrent, F=Fmsy, F= Ftarget

C) If stock is neither overfished nor overfishing:
F=Fcurrent, F=Fmsy, F=Ftarget

D) If data-limitations preclude classic projections (i.e. A, B, C 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. Prepare an accessible, documented, labeled, and formatted spreadsheet containing all model parameter estimates and all relevant population information resulting from model estimates and any projection and simulation exercises. Include all data included in assessment report tables and all data that support assessment workshop figures.
12. Complete the Assessment Workshop Report for Review (Section III of the SEDAR Stock Assessment Report).

III. Review Workshop

1. Evaluate the quality and applicability of data used in the assessment.
2. Evaluate the quality and applicability of methods used to assess the stock.
3. Evaluate the assessment with respect to the following:
   - 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 quantitative estimates of the status determination criteria for this stock reliable? If not, are there other indicators that may be used to inform managers about stock trends and condition?
4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status with regard to accepted practices and data available for this assessment.
5. If there are significant changes to the base model, or to the choice of alternate states of nature, then provide a probability distribution function for the base model, or a combination of models that represent alternate states of nature, presented for review. Provide justification for the weightings used in producing the combinations of models.
6. Consider how uncertainties in the assessment, and their potential consequences, have been addressed.
   - Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty.
   - Ensure that the implications of uncertainty in technical conclusions are clearly stated.
7. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.

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

8. Prepare a Peer Review Summary summarizing the Panel's evaluation of the stock assessment and 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 the project guidelines.

The review panel may request additional sensitivity analyses, evaluation of alternative assumptions, and correction of errors identified in the assessments provided by the assessment workshop panel; the review panel may not request a new assessment. Additional details regarding the latitude given the review panel to deviate from assessments provided by the assessment workshop panel are provided in the SEDAR Guidelines and the SEDAR Review Panel Overview and Instructions.

** The panel shall ensure that corrected estimates are provided by addenda to the assessment report in the event corrections are made in the assessment, alternative model configurations are recommended, or additional analyses are prepared as a result of review panel findings regarding the TORs above.**

1.3 List of Participants

Amy Dukes
Amy Schueller
Beverly Sauls
Bill Parker
Bob Zales II
Chip Collier
Chris Kalinowski
Chris Palmer
Dave Donaldson
David Gloeckner
Donna Bellais
Doug Devries
Doug Mumford
Eric Fitzpatrick
Erik Williams
Ernst Peebles
Jeanne Boylan
Jeff Isely
Jennifer Potts
Jim Franks
Joe Cimino
Joe Smith
John Ward
Julia Byrd
Julie Defilippi
Justin Yost
Karl Brenkert
Katie Andrews
Kelly Fitzpatrick
Ken Brennan
Kevin Craig
Kevin McCarthy
Kyle Shertzer
Lew Coggins
Liz Scott-Denton
Marcel Reichert
Matt Perkinson
Meaghan Bryan
Mike Denson
Nancie Cummings
Neil Baertlein
Pearse Webster
Read Hendon
Refik Orhum
Rob Cheshire
Robert Johnson
Rusty Hudson
Shannon Calay
Stephanie McInerny
Steve Brown
Ben Hartig
Kari Fenske
Ryan Rindone
Rachael Silvas
Mike Errigo
Sue Gerhart
Gregg Waugh
Clay Porch
Todd Gedamke
Mike Larkin
Steve Saul
Adam Pollack
Steve Turner
Patrick Gilles
John Carmichael
Michael Schirripa
Julie Neer
Tanya Darden
Tim Sartwell
Tom Ogle
Vivian Matter
Walter Ingram
Danielle Chesky
Katie Drew
Erik Hiltz
Frank Hester
Peter Barile
Carly Altizer
Marin Hawk
Mark E Brown
C. Michelle Willis
Carrie Hendrix
Jon Richardsen
Patrick Biando

1.4 List of Data Workshop Working Papers

Gulf and South Atlantic Spanish Mackerel and Cobia
Workshop Document List

Document #	Title	Authors
	Documents Prepared for the Data Workshop	
SEDAR28-DW01	Cobia preliminary data analyses – US Atlantic and GOM genetic population structure	T. Darden 2012
SEDAR28-DW02	South Carolina experimental stocking of cobia *Rachycentron canadum*	M. Denson 2012
SEDAR28-DW03	Spanish Mackerel and Cobia Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico	Pollack and Ingram, 2012
SEDAR28-DW04	Calculated discards of Spanish mackerel and cobia from commercial fishing vessels in the Gulf of	K. McCarthy

	Mexico and US South Atlantic	
SEDAR28-DW05	Evaluation of cobia movement and distribution using tagging data from the Gulf of Mexico and South Atlantic coast of the United States	M. Perkinson and M. Denson 2012
SEDAR28-DW06	Methods for Estimating Shrimp Bycatch of Gulf of Mexico Spanish Mackerel and Cobia	B. Linton 2012
SEDAR28-DW07	Size Frequency Distribution of Spanish Mackerel from Dockside Sampling of Recreational and Commercial Landings in the Gulf of Mexico 1981-2011	N.Cummings and J. Isely
SEDAR28-DW08	Size Frequency Distribution of Cobia from Dockside Sampling of Recreational and Commercial Landings in the Gulf of Mexico 1986-2011	J. Isely and N. Cummings
SEDAR28-DW09	Texas Parks and Wildlife Catch Per unit of Effort Abundance Information for Spanish mackerel	N. Cummings and J. Isely
SEDAR28-DW10	Texas Parks and Wildlife Catch Per unit of Effort Abundance Information for cobia	J. Isely and N. Cummings
SEDAR28-DW11	Size Frequency Distribution of Cobia and Spanish Mackerel from the Galveston, Texas, Reef Fish Observer Program 2006-2011	J Isely and N Cummings
SEDAR28-DW12	Estimated conversion factors for calibrating MRFSS charterboat landings and effort estimates for the South Atlantic and Gulf of Mexico in 1981-1985 with For Hire Survey estimates with application to Spanish mackerel and cobia landings	V. Matter, N Cummings, J Isely, K Brennen, and K Fitzpatrick
SEDAR28-DW13	Constituent based tagging of cobia in the Atlantic and Gulf of Mexico waters	E. Orbesen
SEDAR28-DW14	Recreational Survey Data for Spanish Mackerel and Cobia in the Atlantic and the Gulf of Mexico from the MRFSS and TPWD Surveys	V. Matter
SEDAR28-DW15	Commercial Vertical Line and Gillnet Vessel Standardized Catch Rates of Spanish Mackerel in the US Gulf of Mexico, 1998-2010	N. Baertlein and K. McCarthy
SEDAR28-DW16	Commercial Vertical Line Vessel Standardized Catch Rates of Cobia in the US Gulf of Mexico, 1993-2010	K. McCarthy
SEDAR28-DW17	Standardized Catch Rates of Spanish Mackerel from Commercial Handline, Trolling and Gillnet Fishing Vessels in the US South Atlantic, 1998-2010	K. McCarthy
SEDAR28-DW18	Standardized catch rates of cobia from commercial handline and trolling fishing vessels in the US South Atlantic, 1993-2010	K. McCarthy
SEDAR28-DW19	MRFSS Index for Atlantic Spanish mackerel and	Drew et al.

	cobia	
SEDAR28-DW20	Preliminary standardized catch rates of Southeast US Atlantic cobia (*Rachycentron canadum*) from headboat data.	NMFS Beaufort
SEDAR28-DW21	Spanish mackerel preliminary data summary: SEAMAP-SA Coastal Survey	Boylan and Webster
SEDAR28-DW22	Recreational indices for cobia and Spanish mackerel in the Gulf of Mexico	Bryan and Saul
SEDAR28-DW23	A review of Gulf of Mexico and Atlantic Spanish mackerel (*Scomberomorus maculatus*) age data, 1987-2011, from the Panama City Laboratory, Southeast Fisheries Science Center, NOAA Fisheries Service	Palmer, DeVries, and Fioramonti
SEDAR28-DW24	SCDNR Charterboat Logbook Program Data, 1993 - 2010	Errigo, Hiltz, and Byrd
SEDAR28-DW25	South Carolina Department of Natural Resources State Finfish Survey (SFS)	Hiltz and Byrd
SEDAR28-DW26	Cobia bycatch on the VIMS elasmobranch longline survey:1989-2011	Parsons et al.
Reference Documents		
SEDAR28-RD01	List of documents and working papers for SEDAR 17 (South Atlantic Spanish mackerel) – all documents available on the SEDAR website	SEDAR 17
SEDAR28-RD02	2003 Report of the mackerel Stock Assessment Panel	GMFMC and SAFMC, 2003
SEDAR28-RD03	Assessment of cobia, *Rachycentron canadum*, in the waters of the U.S. Gulf of Mexico	Williams, 2001
SEDAR28-RD04	Biological-statistical census of the species entering fisheries in the Cape Canaveral area	Anderson and Gehringer, 1965
SEDAR28-RD05	A survey of offshore fishing in Florida	Moe 1963
SEDAR28-RD06	Age, growth, maturity, and spawning of Spanish mackerel, *Scomberomorus maculates* (Mitchill), from the Atlantic Coast of the southeastern United States	Schmidt et al. 1993
SEDAR28-RD07	Omnibus amendment to the Interstate Fishery Management Plans for Spanish mackerel, spot, and spotted seatrout	ASMFC 2011
SEDAR28-RD08	Life history of Cobia, *Rachycentron canadum* (Osteichthyes: Rachycentridae), in North Carolina waters	Smith 1995
SEDAR28-RD09	Population genetics of cobia *Rachycentron canadum*: Management implications along the	Darden et al, 2012

	Southeastern US coast	
SEDAR28-RD10	Inshore spawning of cobia (*Rachycentron canadum*) in South Carolina	Lefebvre and Denson, 2012
SEDAR28-RD11	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
SEDAR28-RD12	An assessment of cobia in Southeast US waters	Thompson 1995
SEDAR28-RD13	Reproductive biology of cobia, *Rachycentron canadum*, from coastal waters of the southern United States	Brown-Peterson et al. 2001
SEDAR28-RD14	Larval development, distribution, and ecology of cobia *Rachycentron canadum* (Family: Rachycentridae) in the northern Gulf of Mexico	Ditty and Shaw 1992
SEDAR28-RD15	Age and growth of cobia, *Rachycentron canadum*, from the northeastern Gulf of Mexico	Franks et al 1999
SEDAR28-RD16	Age and growth of Spanish mackerel, *Scomberomorus maculates*, in the Chesapeake Bay region	Gaichas, 1997
SEDAR28-RD17	Status of the South Carolina fisheries for cobia	Hammond, 2001
SEDAR28-RD18	Age, growth and fecundity of the cobia, *Rachycentron canadum*, from Chesapeake Bay and adjacent Mid-Atlantic waters	Richards 1967
SEDAR28-RD19	Cobia (*Rachycentron canadum*) tagging within Cheasapeake Bay and updating of growth equations	Richards 1977
SEDAR28-RD20	Synopsis of biological data on the cobia *Rachycentron canadum* (Pisces: Rachycentridae)	Shaffer and Nakamura 1989
SEDAR28-RD21	South Carolina marine game fish tagging program 1978-2009	Wiggers, 2010
SEDAR28-RD22	Cobia (*Rachycentron canadum*), amberjack (*Seriola dumerili*), and dolphin (*Coryphaena hipurus*) migration and life history study off the southwest coast of Florida	MARFIN 1992
SEDAR28-RD23	Sport fish tag and release in Mississippi coastal water and the adjacent Gulf of Mexico	Hendon and Franks 2010
SEDAR28-RD24	VMRC Cobia otolith preparation protocol	VMRC
SEDAR28-RD25	VMRC Cobia otolith ageing protocol	VMRC

2 Life History

2.1 Overview

State and federal biologist and industry representatives comprised the Life History Work Group (LHWG)
Jennifer Potts – NMFS, Beaufort, NC, Leader of LHWG, South Atlantic Cobia and Spanish Mackerel
Doug Devries – NMFS, Panama City Leader of LHWG, Gulf of Mexico Cobia
Chris Palmer - NMFS, Panama City Leader of LHWG, Gulf of Mexico Spanish Mackerel
Chip Collier – NCDMF, Data provider and SAFMC SSC rep,
Michael Denson – Data provider SCDNR, Charleston, SC
Tanya Darden – Data provider SCDNR, Charleston, SC
Justin Yost – Data provider SCDNR, Charleston, SC
Karl Brenkert – Data provider SCDNR, Charleston, SC
Matt Perkinson – Data provider SCDNR, Charleston, SC,
Jim Franks Data provider, USM/GCRL,
Read Hendon Data provider, USM/GCRL,
Chris Kalinowski Data provider, GA DNR,
Tom Ogle SAFMC AP, Recreational SC,
Bill Parker – Industry Representative, Charterboat, SC,
Robert Johnson – Industry Representative, Florida
Ernst Peebles - USF,
Marcel Reichert - SAFMC SSC,

Not Present:
Joe Smith- Data provider, NMFS Beaufort Lab,
John Ward Gulf socioeconomics Gulf SSC,
Randy Gregory Data provider NC DMF,
Erik Williams - NMFS Beaufort

The LHWG was tasked with combining new age data sets from four sources: National Marine Fisheries Service Beaufort Laboratory (NMFS), South Carolina Department of Natural Resources (SCDNR), Georgia Department of Natural Resources (GADNR), and Florida Fish and Wildlife Conservation Commission (FL FWC). **In order to combine age data from all sources, the LHWG needed to be sure that aging methodology between agencies was consistent.**

2.2 Review of Working Papers

(SEDAR28-DW01) Cobia Preliminary Data Analyses U.S. Atlantic and GOM Genetic Population Structure
Tanya Darden

Abstract
With available data (west FL and northern GOM have low sample sizes), GOM appears to be a genetically homogenous group continuing around the FL peninsula with a genetic break occurring around northern FL and GA. The Atlantic population segment appears to have a genetically homogenous offshore component and genetically unique inshore components.

Critique: The working paper submitted by Darden presented preliminary information on stock structure for cobia in the Gulf of Mexico and U.S. Atlantic Coast using 10 microsatellite loci. The methods and microsatellite loci were based on a report that is currently in review. The study sampled fish from April through July from 2004-2011 with most overlap coming from 2008 to 2010. There was temporal overlap in most samples and had adequate sample sizes for most areas (>100 for NC, SC, SC offshore, FL East Coast, and TX). An increase in the samples off Florida would help provide more resolution in the location of genetic break. Although there is some difference in the collection year by area, the samples were collected from fish during the spawning season and all fish were mature from multiple year classes (described by author later). The methods and data used were appropriate and results can be used for management.

(SEDAR28-DW05) Evaluation of Cobia Movements and Distribution Using Tagging Data from the Gulf of Mexico and South Atlantic Coast of the United States.
Matt Perkinson and M.R. Denson

Abstract
Cobia movement and distribution in the Southeastern United States and the Gulf of Mexico was evaluated using tag-recapture information provided from recreational anglers, commercial fishermen and charterboat captains. Three data sets were provided by the South Carolina Department of Natural resources, the Mote Marine Laboratory, and the Gulf Coast Research Laboratory. A fourth data set of tagged cultured fish from the South Carolina Department of Natural Resources was also evaluated. Cobia were tagged over similar periods, with methodologies and tags that were not appreciably different between programs. Tag-recapture in all four studies yielded similar patterns. Only fish at large for greater than 30 days were included in the analysis. Approximately 79% of tagged fish were recaptured in the region in which they were tagged. Only 1% of cobia tagged in the South Atlantic north of Florida were recaptured in the Gulf, and of those tagged in the Gulf only 1% were recaptured in the Atlantic north of Florida. Cobia tagged on the east coast of Florida are caught North of Florida and in the Gulf of Mexico suggesting a mixed stock off of Florida. Datasets were pooled and partitioned by tag recapture location off of Florida beginning with the Georgia-Florida border and north (GAN), the Georgia Florida border to the Brevard/Volusia County line (N-BR), the Brevard County from Brevard/Volusia County line to Sebastian Inlet (Brevard/Indian River County line)(BR), waters offshore of Sebastian Inlet to Biscayne Bay (S-BR), from Biscayne Bay around the tip of Florida to First Bay on the Gulf side, encompassing all of the Florida Keys (Keys) and the Gulf from First Bay through the Gulf States to the Texas/Mexico line. Cobia tagged south of Brevard County are much more likely to be

recaptured in the Keys or Gulf (95%). These results suggest two stocks of fish that overlap at Brevard county Florida.

Critique
Working paper 05 provides a good overview and comparison of the methods, scope, and results of the three major cobia tagging efforts conducted in the Southeast U.S. since 1974. More importantly it reported the results of an analysis using a pooled data set of all three studies which examined movement patterns between Gulf and Atlantic waters with a special emphasis on fish tagged on the east coast of Florida. The findings presented in this document, which were widely vetted before and during SEDAR28 and well received, were very helpful and influential in defining cobia stock boundaries. This document was recommended for use by the LHWG.

(SEDAR28-DW13) Constituent based tagging of cobia in the Atlantic and Gulf of Mexico waters
E. Orbesen

Abstract
Data used in this analysis were derived from the Southeast Fisheries Science Center's Cooperative Tagging Center conventional tagging program. The data set contains 1510 cobia tag releases and 148 recaptures over 58 years of data collection. Exchange and mixing were examined between six geographical regions.

*Critique: Working paper 13 summarizes the tag recapture data provided by the Southeast Fisheries Science Center's Cooperative Tagging Center conventional tagging program. The time series and methods are comparable with the data included in **SEDAR28-DW05**, v2; fish were tagged by recreational anglers using anchor or dart tags mostly during the 1990's and 2000's. Tag returns (N=148) have also been assigned to the zones (GAN, N-BR, BR, S-BR, KEYS, GULF) used in **SEDAR28-DW05**. The results appear to support the suggestion of separate stocks in the South Atlantic and Gulf, with mixing occurring somewhere around Brevard County, FL. Fish tagged north of Brevard County were largely recaptured north of Brevard County (91%). Fish tagged south or west of Brevard County were largely recaptured south or west of Brevard County (97%). Fish tagged in Brevard County were recaptured to the north (18%), in Brevard (35%), and to the south and west (44%). Recapture percentages are also reported for each zone, but I would be hesitant to include these data in any analyses, as recaptures are often reported without any coinciding tagging data (i.e., anglers may not report all fish they have tagged), leading to an overestimation of recapture rate. The methods appear sound and the data strongly agree with the result of other tagging datasets for the South Atlantic and Gulf of Mexico.*

(SEDAR28-DW02) South Carolina experimental stocking of cobia *Rachycentron canadum*
M.R. Denson 2012

Abstract
The South Carolina Department of Natural Resources has been experimentally spawning wild cobia adults captured in local waters, rearing larvae to a number of juvenile sizes and stocking them back in the same systems. All fish released into the wild are identifiable using a unique genetic tag (microsatellites) and differentiated from wild fish when they are collected in the recreational fishery. Size permitting; fish were also tagged with external dart tags prior to release to make them identifiable to anglers. Fish enter SC waters to spawn in April and are available to recreational anglers at a legal minimum size of 33-inch fork length. This size represents a three- year-old fish (when full recruitment occurs). In order to determine the contribution of stocked fish to the local population, fin clips are removed from fish sampled at fishing tournaments, collected from charterboat captains, recreational fishermen and from SCDNR staff. Stocking contributions are determined and analyzed as a general contribution to the sampled population, as well as to specific yearclasses as determined by otolith-based age determination. Contributions are also evaluated by inshore and offshore collections.

Critique: The paper is a brief overview of the contribution of cobia stocked in 2007 and 2008 by SC-DNR in the Colleton River (SC) has on the wild stock in SC and Georgia, where sampling of the wild stock occurred. Genetic techniques were used to follow this contribution. The paper provides a brief but thorough overview of the data, as well as some limited other information. The data indicate that the contribution of fish stocked to fish in the wild population was at a maximum of 7.3% in 2010, 4.6% in 2011, and is expected be diminish in future years. Paper does not address the potential if and how the stocked fish may affect the population, if an effect exists at all.

The information in this paper seems of limited use for the LH WG.

2.3 Stock Definition and Description

2.3.1 Population genetics

Evidence was presented by Dr. Tanya Darden regarding a genetic-based evaluation of population structure between the South Atlantic and Gulf of Mexico populations described in more detail in SEDAR 28-DW01 (Darden, 2012). Complete methods are documented in SEDAR 28-DW01 and SEDAR 28-RD09 (Darden et al., 2012). Microsatellite-based analyses demonstrated that tissue samples collected from NC, SC, east coast Florida (near St. Lucie), MS and TX show disparate allele frequency distributions and subsequent analysis of molecular variance show population structuring occurring between the states. Results show that the Gulf of Mexico stock appears to be genetically homogeneous and that segment of the population continues around the Florida peninsula to St. Lucie Florida, with a genetic break between where the St. Lucie samples were collected and Port Royal Sound in South Carolina (Figure 2.1). Finer-scale analyses of the sample areas in the South Atlantic segment of the population suggest a genetically homogenous offshore component and genetically unique inshore components.

Following the January 11, 2012 SEDAR 28 webinar, the panel had come to consensus on key points of the South Atlantic and Gulf of Mexico stock Definitions:

- Panel consensus: For South Atlantic cobia, combine estuarine and offshore stocks (data isn't fine enough to split in many cases).
- Panel consensus: Northern boundary for SA should include data through New York.
- Panel consensus: Southern boundary for SA should be Cape Canaveral (based on tagging and genetic data), subject to further review at DW if further data can be examined, Gulf would be South of Cape Canaveral through the Gulf. Consider Volusia/Flagler line for data division of recreational data.

2.3.2 Tagging

Tag-recapture data

Cobia movement and distribution in the Southeastern United States and the Gulf of Mexico was evaluated using tag-recapture information provided from recreational anglers, commercial fishermen and charter boat captains. The South Carolina Department of Natural Resources (Wiggers, 2010), the Mote Marine Laboratory (Burns and Neidig, 1992) and the Gulf Coast Research Laboratory (Hendon and Franks, 2010) provided three data sets. Cobia were tagged over similar periods with methodologies and tags that were not appreciably different between programs. Only fish at large for greater than 30 days were included in the analysis. Tag-recaptures in all three studies yielded similar patterns. Approximately 78% of tagged fish were recaptured in the region in which they were tagged. Only 1% of cobia tagged in the South Atlantic north of Florida were recaptured in the Gulf, and of those tagged in the Gulf, only 1% were recaptured in the Atlantic north of Florida. Cobia tagged on the east coast of Florida are caught north of Florida and in the Gulf of Mexico, suggesting a mixed stock off of Florida. Datasets were pooled and partitioned by initial tagging location beginning with the Georgia/Florida border and north (GAN), the Georgia/Florida border to the Brevard/Volusia County line (N-BR), Brevard County from the Brevard/Volusia County line to Sebastian Inlet (Brevard/Indian River County line)(BR), Sebastian Inlet to Miami (S-BR), Miami around the tip of Florida to Marco Island on the Gulf side, encompassing all of the Florida Keys (Keys), and the Gulf from Marco Island through the Gulf States to the Texas/Mexico line. The combined data show that cobia tagged north of Brevard County are primarily recaptured from Brevard County to the north (99%) (table 2.1). Of cobia tagged in Brevard County, 25% are recaptured north of Brevard County, 39% in Brevard County and 36% in S-BR, the Keys or the Gulf (figure 2.2). Cobia tagged in S-BR, the Keys, or the Gulf are mostly recaptured from Brevard south through the Keys and Gulf (98%)(table 2.2). Additional tagging datasets from the Virginia Institute of Marine Science/VMRC (Susanna Musick, personal communication), SCDNR stock enhancement program (Denson, 2012) and Southeast Fisheries Science Center (Orbesen, 2012) reflect a similar pattern with very little movement between the Gulf and GAN, while fish tagged in BR moved both to the north and to the south through the Keys and Gulf. These results suggest two stocks of fish that overlap at Brevard County Florida and corroborate the genetic findings presented in SEDAR 28-DW01.

It was noted that the recorded location of recaptures were not pin-pointed, but rather given a more general description (e.g., 10 miles off Cape Canaveral). A judgment call was made to assign the recaptured fish to a particular region when the reported location was between regions (e.g. Sebastian Inlet for BR vs. S-BR). A more complete evaluation of the tagging datasets can be found in SEDAR28 DW05 (Perkinson and Denson, 2012).

Discussion of cobia stock definition/delineation between South Atlantic and Gulf of Mexico.
Data workshop LHWG discussions considered specific suggestions to set a stock boundary split at Brevard county Florida based on tagging data evidence that fish tagged in Brevard County are caught both north and south of Brevard County. Discussions of the tagging data pointed out that the available landings data lacked the resolution to separate the stocks within a county.

- A proposal was made to separate the stocks at the FL/GA line because the genetic data suggest that the split is north of the Brevard/Indian River County line and there is no tagging data to dispute this split.
- A second proposal was made suggesting the split at the Brevard County/Indian River County line.

Neither proposal is disputed by the genetic and tagging data.

Recommendation for AW:
During Plenary session the first option FL/GA line was selected based on recommendations from the commercial and recreational work groups and comments that for ease of management the FL/GA line would be the preferable stock boundary and did not conflict with the life history information available. However, there is not enough resolution in the genetic or tagging data to suggest that a biological stock boundary exists specifically at the FL/GA line, only that a mixing zone occurs around Brevard County, FL and potentially to the north.

The Atlantic stock would extend northward to New York.

2.4 Natural Mortality

The LHWG reviewed estimates of total and natural mortality (M) from various equations. Several life history parameters ($L\infty$, k, age at maturity, maximum age) were needed to calculate point estimates of natural mortality (Table 2.3). Maximum age of cobia in the Atlantic stock is 16 years. There was one 16 year old fish from the Virginia age samples, but also several 13-15 year olds from Virginia down to South Carolina (n = 25 out of 2,639 age samples). Maximum age in the Gulf is lower, age 11. It is not uncommon for the same species or close congeners in the Gulf of Mexico and the Atlantic to exhibit a difference in maximum age. Examples include red drum (Beckman et al., 1989; Murphy and Taylor, 1990; Ross et al., 1995) and Gulf menhaden and Atlantic menhaden (Ahrenholz, 1991). Refer to other sections of this life history report for the methodologies used to calculate each of the life history parameters. Because cobia will migrate due to changes in water temperature, cobia's preferred water temperature, 25^{o} C, was used in the Pauly M calculation.

The highest point estimate of M (M = 1.35) was calculated using Ralston's geometric mean method which is based on the value of k from the von Bertalanffy growth model. Other estimates that relied on estimates of k were also high, ranging from 0.58 – 1.13. The LHWG is cautious of using these estimates because of the issues inherent in modeling growth of the species. The L_∞ and k parameters are inversely correlated and can be highly variable depending on the range of the input data and assumptions made when modeling growth. The lowest estimates, M = 0.19, came from Alverson and Carney and from Alagaraja's estimate assuming 5% of the population would attain maximum age.

The LHWG recommends the Hoenig*fish* point estimate of M = 0.26, a value near the average value of M estimates (0.24) that use maximum age in the population. The LHWG also recommends modeling the uncertainty in natural mortality through sensitivity runs with M ranging from 0.20 (the bottom range of the M estimates) to 0.35 (using Hoenig*fish* method with a maximum age of 11, as seen in the Gulf of Mexico). Caution should be taken when selecting maximum age in the population: how many fish were sampled to find that one, old fish; what could be the longevity of the species in an un-fished stock; and what amount of error is associated with the age readings? The LHWG took this question into consideration when selecting the maximum age in the Atlantic population.

Natural mortality rate varies as the fish grows larger; it starts high and decreases with age and size. Based upon LHWG recommendations, Lorenzen (2005) estimates were computed for ages 0+, and scaled to the Hoenig*fish* estimates of M for all fully recruited ages in the fishery, which is age 3+ (Figure 2.3).

Recommendation for AW: Generate a point estimate natural mortality rate from Hoenig's equation using maximum age in the population, which for the Atlantic stock is 16 years. The assessment model should use the age-varying M from the Lorenzen curve scaled to the Hoenig estimate on the fully recruited ages.

For sensitivity runs, one recommendation was made to use a CV of 54% about the Hoenig point estimate (MacCall in Brodziak et al., 2011). Hoenig (Brodziak et al., 2011) felt that that CV was too high, thus the workshop panel recommends the assessment workshop apply a range of CV's about the point estimate of M and scale the Lorenzen curve accordingly.

2.5 Discard Mortality

Discard mortality is an important estimation included in stock assessments and rebuilding projections calculated from a stock assessment. Discard mortality rate can be impacted by several factors including: fish size, sea conditions, temperature, air exposure, handling, light conditions, sea conditions, and delayed mortality (Davis 2002). The longer fish are exposed to most of these factors and the more severe they are, the greater the cumulative stress on the fish (Rummer and Bennett 2007). The impacts of many of these factors are difficult to track or quantify and have led to variability in determining discard mortality rates for a variety of species. Cobia are harvested by several gears, which have varying discard mortality rates. Currently, few data sets are published on discard mortality of cobia (Harrington et al. 2005). Data are collected by the NOAA Southeast Fisheries Science Center on discards in the commercial logbook program. This program randomly samples 20% of commercial vessels operating in the South Atlantic and Gulf of Mexico. From the commercial logbooks, discards were classified into five categories of kept, alive, mostly alive, mostly dead, and dead for gillnets, hook and line, and trolling fisheries. There few data sources that had information on discard mortality. Information was available from logbooks and one observer program. The logbooks reported most cobia released were released alive in bandit (98%) and longline (92%) fisheries. Some anecdotal information on hook and line discard mortality was brought forward during SEDAR 28 including fish recaptured in the VA Marine Resources Commission Tagging Program and SC Department of Natural Resources broodstock collection. The VMRC had 20 fish recaptured that were released in poor condition. The recaptured fish, when initially released, were reported to have been gut hooked, have broken gill arches, bleeding from deep hooking, and one fish was tied off for two hours before tagging. SCDNR collected 60 cobia for brood stock using hook and line and only had one mortality within one week of collection and transportation.

Cobia are also caught in gillnet fisheries. These fisheries target a variety of species including: Spanish mackerel, sharks, sea mullet (*Menticirrhus* spp), Atlantic croaker, and other species. Observers have been onboard boats in the gillnet fishery and reported the number of fish released dead and alive. Of 539 cobia discarded during the observer study, 51% were released dead (Table 2.4., Simon Gulak, personal communication).

Discussion
There was limited discussion on the discard mortality rates of cobia. The panel felt the fish were hardy and not likely to have the barotrauma issues common to many of the snapper and grouper species in the South Atlantic and Gulf of Mexico. A 5% discard mortality rate was estimated for the hook and line fishery with a range of 2 to 8%. The gillnet fishery discard mortality was agreed to be 51% with a range of 36 to 77%. The range was developed from gillnet fisheries with 10 or greater cobia observed released. The discard mortality rate developed for the gillnet fishery may not reflect the discard mortality rate for the remaining gears in the “other gears” category. Informed judgment should be used to develop a discard mortality rate potentially weighted on the number of discards in each fishery as has been done in past SEDARs.

<u>Recommendation for AW:</u>

Hook 5% (2 to 8%) Recreational and Commercial
Gillnet 51% (36-77%)
Other

2.6 Age

Cobia collected in the south Atlantic were aged using similar protocols. Specific cobia ageing procedure as described in SEDAR28-RD25 VMRC cobia aging:

Ageing cobia otoliths involves two steps: 1) Reading the thin-section by counting the number of annuli. 2) Assigning an age to the fish based on sacrifice date and annulus formation period. Once the number of annuli in the otolith "X", has been identified, one of two scenarios determine the estimated age of the fish: 1) there is no growth beyond the last annulus. This means the fish becomes an even "X". This typically happens when a fish has been collected during the annulus deposition period: June 1-June 30 (Richards, C.E. 1967). 2) There is growth beyond the last annulus: The growth is indicated as a "+" after the number of annuli, that is "X+".

If the fish sacrifice date is between January 1, the assigned birth date for all finfish of the Northern hemisphere, and the end of the last month in which the cobia annuli are laid down (July 31), the age of the fish is represented as "X+(X+1)". For example a fish two visible annuli on its thin-section would be assigned the age "2+3" indicating that it belongs to the "age 3" age class.

If the sacrifice date for the fish falls after July 31 and before January 1, the fish has laid down its annulus for the year and has experienced growth since that time. The age of the fish is represented as "X + (X)". A fish with 6 annuli visible on its otolith transverse cross-section would be assigned the age "6 + 6" indicating that it belongs to the "age 6" age class.

Age data were provided by NMFS for 1984-2010 (n=368), VMRC for 1988-2010 (n=813) and SCDNR for 1984-2011 (n=1494).

2.6.1 Age Reader Precision and Aging Error Matrix

The data for the aging error analysis came from otoliths read by four readers, representing each of the four labs contributing data to the South Atlantic. The labs involved included the National Marine Fisheries Service (NMFS), SCDNR, and VMRC. As part of a workshop to improve precision between labs, a set of otoliths from the SCDNR (n=100) reference collection was aged by NMFS personnel. A similar set (n=100 was provided by VMRC to SCDNR. The results of the otolith exchange will be made available to the assessment workshop.

2.7 Growth

Cobia, like many pelagic fish, have very fast growth in the first few years of life. Cobia also exhibit sexually-dimorphic growth with females attaining a larger sizes-at-age and maximum sizes than males. Growth was modeled using the von Bertalanffy growth model. To account for growth of the fish throughout the year, increment counts were converted to calendar ages (Age_{cal}) based on timing of increment formation, and then a fraction of the year was added or subtracted based on the month in which the fish was caught (Age_{frac}). Most of the fish were caught during the time of increment formation, which is in May and June, or later. For those fish caught before June with a wide translucent marginal, the increment counts were bumped by one (1) to get the calendar age. For all fish caught after June, the increment count equaled the calendar age of the fish. Peak spawning, based on maximum GSI, was determined to be in June; thus, the birthdate of each fish was June 1. Fractional age of each fish was computed with the following equation:

$$Age_{frac} = Age_{cal} + ((Month_{capture} - Month_{birth})/12)$$

Because cobia have been subject to a 33 inch minimum size limit regulation since 1985, the fish that recruit to the fishery first tend to be the fastest growers at those early ages, which results in a knife edge size distribution in fishery dependent samples at those affected ages. Dias et al. (2004) developed a correction for that size-selection bias, and that was used for the growth models presented herein. Also, because age samples in the youngest and oldest ages are few, the model incorporated an inverse weighting by sample size at each age. The resulting growth parameters are in table 2.5.

2.8 Reproduction

The majority of the reproductive information is presented in published works by Brown-Peterson et al. (2001) and Franks and Brown-Peterson (2002) and are referenced as such. Where possible, current information collected in the South Atlantic are used. 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.

2.8.1 Spawning Seasonality

Spawning season was determined based on the occurrence of hydrated oocytes and/or postovulatory 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 (figure 2.4). It has also been reported in the literature that cobia spawning peaks in Virginia in July (Joseph et al., 1964; Richards, 1967; Mills, 2000) (table 2.5).

It has been well documented that cobia begin a "migration" or move into nearshore waters in the South Atlantic when temperatures reach 20-25^{o} C (Shaffer and Nakamura, 1989; Biesiot et al., 1994; Smith, 1995). Figures 2.5, 2.6 and 2.7 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 by recreational anglers from 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 may prove an important consideration in estimating the number of spawning days in a spawning season.

2.8.2 Sexual Maturity

Sexual maturity for male cobia in the South Atlantic appears 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 SCDNR study were also limited. Only eight age 0-1 fish were examined and all of these fish were immature (including 4 samples from 2011). Of the age 2 fish (n=27), 70% were sexually mature (Table 2.7). The only caveat regarding these animals was that they were likely the fastest growing and largest two-year olds collected from the fishery. Tables 2.8 and 2.9 both suggest that female cobia above 800 mm FL are likely to be mature, regardless of age. 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.

Recommendation for AW:

The size of cobia appears to more strongly correlate with maturity than age. Due to the paucity of samples at the youngest ages and the influence of the minimum size limit on size at age of those young fish, the LHWG recommends using age-2 for age at 50% maturity. All fish age-3+ in the samples were 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. Thus, a sensitivity run 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+.

2.8.3 Sex ratio

Information on cobia sex ratio by length class (mm FL), year, and age class are available in Tables 2.10, 2.11, and 2.12. The male:female sex ratio for all adult cobia in fishery-independent and fishery-dependent collections from 1983-2012 was **1:1.4**, which was significantly different from a 1:1 ratio based on size (Chi-square= 628.762, 28 df, P =

<0.001, n = 2409), on age (Chi-square= 67.362, 16 df, P = <0.001, n=2409), and on year captured (Chi-square= 124.347, 27 df, P = <0.001, n=2409). When evaluating sex ratio by length the largest fish are skewed towards females.

2.8.4 Spawning Frequency

Spawning frequency estimates range from 4 to 6 days (table 2.13). 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 fishing 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 2.14). Spawning frequency was estimated to be 6.1 days, similar to what was reported by Brown-Peterson et al. (2001) (Table 2.15).

<u>Recommendation for AW:</u>

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

2.8.5 Batch Fecundity (BF)

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 2.8).

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 1). Also, 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:

Use female SSB as an estimate of reproductive potential but to apply a sensitivity analysis on outputs including F_{msy} for the fecundity-weight exponent of b in the range from 1 to 2.4 as suggested by Figure 2.8.

2.9 Movements and Migrations

Covered in section 2.3.2 Tagging

2.10 Meristics and Conversion Factors

Cobia have a strongly forked tail and fork length has been the most consistently used length measurement. Equations to make length-length and weight-length conversions were derived using the simple linear regression model and the power function, respectively (Tables 2.16). Data from the SCDNR, VMRC, NMFS Headboat, and an age study (Smith, 1995) (n=4635) were used to derive the various meristic relationships. For the weight – length relation, the data were linearized by a ln-ln transformation and then converted to the power equation $W = a\mathrm{TL}^b$. All weights are shown in kilograms and all lengths in millimeters. Coefficients of determination (r^2) ranged from 0.969 to 0.976 for the linear length-weight regressions, and 0.952 to 0.985 for the length-length equations. There was a weak suggestion of sexually dimorphic growth in the length-weight model, although it is likely this was driven by sample size and was not biologically significant. There was no evidence of sexually dimorphic growth in the length-length model.

Recommendations for the AW:
1) Use the equations based on combined sources and sexes.

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2. 14 Tables

Table 2.1. Numbers of cobia tagged in a region that were recaptured. Combined SC, GCRL and Mote recaptures.

	Region Recap	GAN	N-BR	BR	S-BR	Keys	Gulf
Region Tagged	N						
GAN	121	110	4	6	0	0	1
N-BR	0	0	0	0	0	0	0
BR	36	5	4	14	2	4	7
S-BR	13	2	0	1	5	2	3
Keys	156	0	0	1	8	88	59
Gulf	744	4	8	12	25	78	617

Table 2.2. Percentages of cobia tagged in a region that were recaptured. Combined SC, GCRL and Mote recaptures.

	Region Recap	GAN	N-BR	BR	S-BR	Keys	Gulf
Region Tagged	N						
GAN	121	91%	3%	5%	0%	0%	1%
N-BR	0	0%	0%	0%	0%	0%	0%
BR	36	14%	11%	39%	6%	11%	19%
S-BR	13	15%	0%	8%	38%	15%	23%
Keys	156	0%	0%	1%	5%	56%	38%
Gulf	745	1%	1%	2%	3%	10%	83%

Table 2.3. Point estimates of natural mortality (M) for Atlantic cobia. Parameter inputs include: L_∞ = 1324.4, k = 0.27, tmax = 16 years, age at 50% maturity = 2 years, and temperature = 25 ^oC.

Method	**Parameter Inputs**	**Estimate**
Alverson & Carney	k, tmax	0.19
Beverton	k, am	1.13
$Hoenig_{fish}$	tmax	0.26
$Hoenig_{alltaxa}$	tmax	0.28
Pauly	L_∞, k, T ^oC	0.48
Ralston	k	0.58
Ralston (geometric mean)	k	1.35
Ralston (method II)	k	1.03
Hewitt & Hoenig	tmax	0.25
Jensen	k	0.41
Rule of thumb	tmax	0.19
Alagaraja 0.01	survivorship to tmax = 0.01	0.29
Alagaraja 0.02	survivorship to tmax = 0.02	0.24
Alagaraja 0.05	survivorship to tmax = 0.05	0.19

Table 2.4. Number, percent kept, and percent discarded dead for cobia caught in gillnet fisheries based on observed trips from 1998-2011. Data were provided by Simon Gulak (NMFS).

Gear Type	Species	Total Number Caught	% Kept	% Discarded Dead
Drift	Cobia	900	69%	63%
Sink	Cobia	309	16%	39%
Strike	Cobia	6	50%	67%
Overall	Cobia	1,215	56%	51%

Table 2.5. Atlantic cobia von Bertalanffy growth parameter estimates.

	Observed		FL, mm		von Bertalanffy growth		
	Max Age	Age range	Length range	n	Linf	K	t_o
ALL FISH: Size-selectivity correction and inverse weighted by sample size at calendar age	16	0 - 16	207 - 1610	2,485	1324.4	0.27	-0.47
ALL FISH: Inverse weighted by sample size at calendar age, no size-limit selectivity correction	16	0 - 16	207 - 1610	2,639	1292.5	0.34	-0.37
FEMALE: Size-selectivity correction and inverse weighted by sample size at calendar age	16	0 - 16	214 - 1610	1,369	1386.6	0.27	-0.43
Female: Inverse weighted by sample size at calendar age, no size-limit selectivity correction	16	0 - 16	214 - 1610	1,410	1368.5	0.33	-0.31
MALE: Size-selectivity correction and inverse weighted by sample size at calendar age	15	0 - 15	207 - 1365	890	1179.1	0.3	-0.49
Male: Inverse weighted by sample size at calendar age, no size-limit selectivity correction	15	0 - 15	207 - 1365	995	111.5	0.43	-0.31

Table 2.6. Published methods for assessing cobia spawning season.

Region	Spawning Season	Method	Reference
Virginia	June-August	GSI, histology	Joseph et al., 1964; Richards, 1967
Virginia	June-August	egg, larval collections	Joseph et al., 1964; Mills, 2000
North Carolina	May-July	GSI	Smith, 1995
North Carolina	May-August	egg, larval collections	Hassler and Rainville, 1975; Smith, 1995
South Carolina	May-August	egg, larval collections	Shaffer and Nakamura, 1989
North central Gulf of Mexico	April-September	GSI, histology	Biesiot et al., 1994; Lotz et al., 1996; Brown-Peterson et al., 2001
North central Gulf of Mexico	May-September	egg, larval collections	Ditty and Shaw, 1992
Louisiana	April-August	GSI, histology	Thompson et al., 1992
Texas	May-September	egg, larval collections	Baughman, 1950; Finucane et al., 1978

Table 2.7. Count of female cobia by age and reproductive phase. Reproductive phase terminology from Brown-Peterson et al., 2011.

Age	Immature	Developing	Spawning Capable	Regressing	Regenerating	POFs	Total
0	1						1
1	7						7
2	8	15	3		1		27
3		142	69	4		25	240
4		41	63	2		30	136
5		28	57	1		28	114
6		26	44	1		21	92
7		22	32	2		11	67
8		11	23	2		1	37
9		9	13	1		4	27
10		6	11			2	19
11		3	7			5	15
12		4	7	1		1	13
13		2	1			1	4
14			2				2
16			1				1
Total	**16**	**309**	**333**	**14**	**1**	**129**	**802**

Table 2.8. Female cobia mean fork length (mm) by age and reproductive phase.

Age	Immature	Developing	Spawning Capable	Regressing	Regenerating	POFs (<24hrs)	POFs (>24hrs)	Total
0	440							440
1	451							451
2	701	788	847		950			771
3		946	931	969		959	945	942
4		1025	1073	1087		1040	1039	1050
5		1098	1134	1178			1097	1116
6		1129	1216	1081		1145	1170	1177
7		1179	1268	1386		1208	1202	1233
8		1249	1267	1318			1164	1261
9		1243	1254				1182	1238
10		1300	1370				1384	1345
11		1316	1422				1290	1357
12		1264	1417	1565			1448	1363
13		1380	1410				1399	1392
14			1384					1384
16			1372					1372
Total	**575**	**1031**	**1133**	**1175**	**950**	**1051**	**1101**	**1076**

Table 2.9. Size at maturity for female cobia fork length (mm).

Female FL (mm)	% Mature	n
≤350	0	0
351-400	0%	2
401-450	0%	3
451-500	0%	2
551-600	0%	1
601-650	33%	3
651-700	100%	1
701-750	44%	9
751-800	75%	4
801-850	100%	24
851-900	100%	53
901-950	100%	73
951-1000	100%	89
1001-1050	100%	93
1051-1100	100%	67
1101-1150	100%	89
1151-1200	100%	80
1201-1250	100%	55
1251-1300	100%	52
1301-1350	100%	27
1351-1400	100%	18
1401-1450	100%	8
1451-1500	100%	10
1551-1600	100%	1
1601-1650	100%	1
Total	**98%**	**765**

Table 2.10 Sex ratio of Atlantic cobia by fork length (mm).

FL (mm)	Male	Female	n	M:F ratio
201-250	2		2	
251-300	2		2	
301-350		1	1	
351-400	4	3	7	01:00.8
401-450	5	4	9	01:00.8
451-500	3	2	5	01:00.7
501-550	2		2	
551-600	4	1	5	01:00.3
601-650	4	3	7	01:00.8
651-700	8	1	9	01:00.1
701-750	13	9	22	01:00.7
751-800	22	9	31	01:00.4
801-850	114	35	149	01:00.3
851-900	233	87	320	01:00.4
901-950	173	121	294	01:00.7
951-1000	173	155	328	01:00.9
1001-1050	117	175	292	01:01.5
1051-1100	69	150	219	01:02.2
1101-1150	33	161	194	01:04.9
1151-1200	21	155	176	01:07.4
1201-1250	5	113	118	01:22.6

1251-1300	1	93	94	0.10625
1301-1350		55	55	
1351-1400	1	35	36	1:35
1401-1450		19	19	
1451-1500		10	10	
1501-1550		1	1	
1551-1600		1	1	
1601-1650		1	1	
Total	**1009**	**1400**	**2409**	**01:01.4**

Table 2.11. Sex ratio of Atlantic cobia by year.

Year captured	Male	Female	n	M:F ratio
1984	1	3	4	1:03
1985		2	2	
1986	17	8	25	01:00.5
1987	12	9	21	01:00.8
1988	8	16	24	1:02
1989	55	39	94	01:00.7
1990	55	55	110	1:01
1991	5	10	15	1:02
1992	7	16	23	01:02.3
1993	4	13	17	01:03.3
1994	8	9	17	01:01.1
1995		10	10	
1996	18	21	39	01:01.2
1997	10	14	24	01:01.4
1998	2	2	4	1:01
1999	11	66	77	1:06
2000	21	76	97	01:03.6
2001	15	49	64	01:03.3
2002	14	45	59	01:03.2
2003	1	8	9	1:08
2004		8	8	
2005	41	92	133	01:02.2
2006	37	49	86	01:01.3
2007	191	201	392	01:01.1
2008	147	180	327	01:01.2
2009	133	156	289	01:01.2
2010	126	195	321	01:01.5
2011	109	126	235	01:01.2
Total	**1048**	**1478**	**2526**	**01:01.4**

Table 2.12. Sex ratio of Atlantic cobia by age in years.

Age	Male	Female	n	M:F ratio
0	7	3	10	01:00.4
1	12	8	20	01:00.7
2	38	41	79	01:01.1
3	318	353	671	01:01.1
4	243	286	529	01:01.2
5	146	209	355	01:01.4
6	84	157	241	01:01.9
7	50	140	190	01:02.8
8	27	64	91	01:02.4
9	26	56	82	01:02.2
10	18	34	52	01:01.9
11	11	27	38	01:02.5
12	4	21	25	01:05.3
13	3	6	9	1:02
14	6	2	8	01:00.3
15	1	2	3	1:02
16		1	1	
Total	**994**	**1410**	**2404**	**01:01.4**

Table 2.13. Spawning frequency of cobia in the Southeastern United States and North Central Gulf of Mexico using POF and FOM analysis.

	Region	
	Southeastern United States (SEUS)	North Central Gulf of Mexico (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 2.14 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 2.15 Mean estimated spawning frequencies of cobia from three regions in the southern United States. Spawning frequencies are 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 2.16 Atlantic stock of cobia meristic conversion equations.

Sex	Model	n	a	SE a	b	SE b	MSE	R2
Male	Ln(Wt) = a+b*Ln(FL)	413	-21.1189	0.180598	3.420446	0.026629	0.13055	0.97564
Female	Ln(Wt) = a+b*Ln(FL)	981	-20.0551	0.1394	3.26078	0.01998	0.13474	0.96451
Combined	Ln(Wt) = a+b*Ln(FL)	4171	-20.181	0.062244	3.275914	0.009046	0.16498	0.96919
	W=aFL^b		2.00E-09		3.28			
Male	FL = a+b*TL	901	25.44165	4.626424	0.862837	0.004402	20.056	0.97711
Female	FL = a+b*TL	1318	7.517172	4.095688	0.883851	0.00335	25.039	0.98143
Combined	FL = a+b*TL	4635	13.52399	1.784063	0.878671	0.001564	24.804	0.98553
Male	FL = a+b*SL	25	-14.3797	32.88142	1.106913	0.036467	24.566	0.97459
Female	FL = a+b*SL	108	60.18683	24.06604	1.039059	0.022473	38.055	0.95231
Combined	FL = a+b*SL	282	35.06659	11.78044	1.060561	0.011413	35.17	0.96848

2.15 Figures

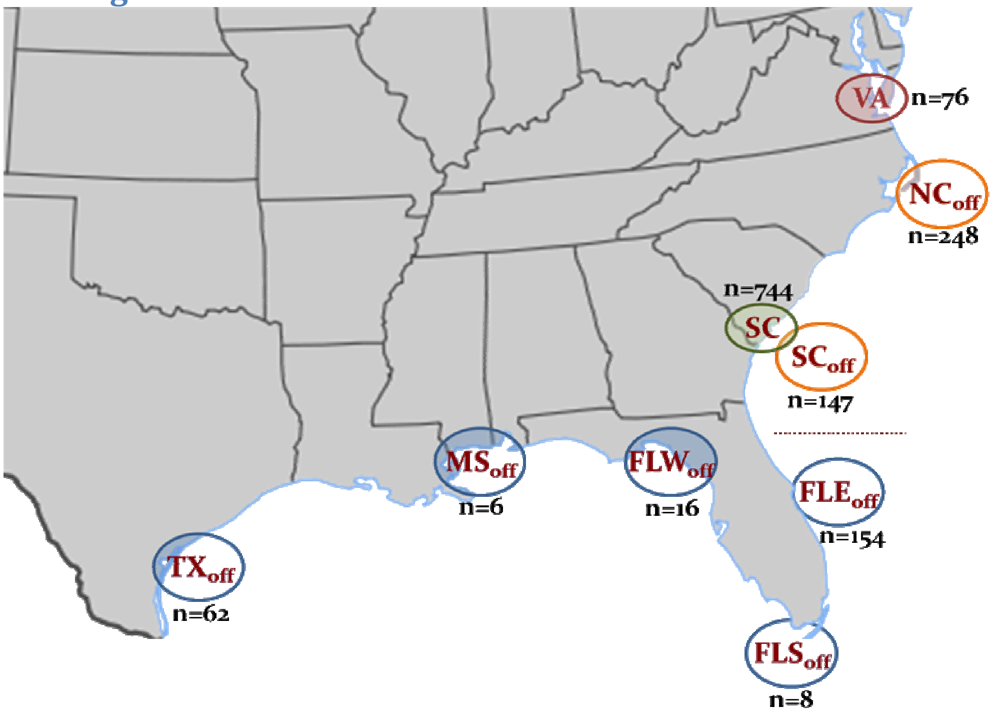

Figure 2.1. Map depicting the approximate sample sites where cobia genetic samples were taken along the south Atlantic and Gulf coast.

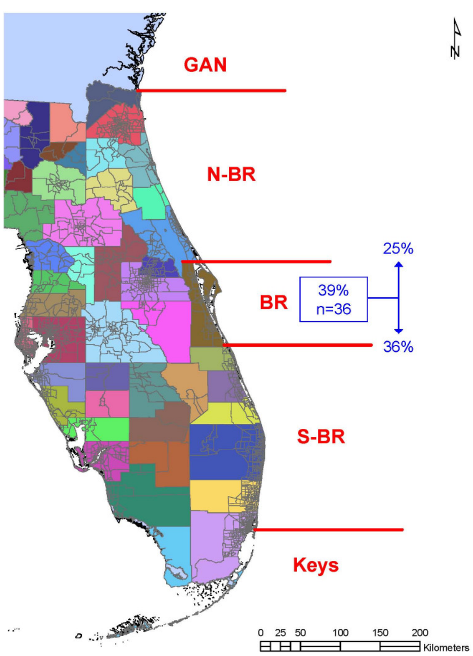

Figure 2.2. Movement of tagged cobia from Brevard County, FL (BR) to the north and south.

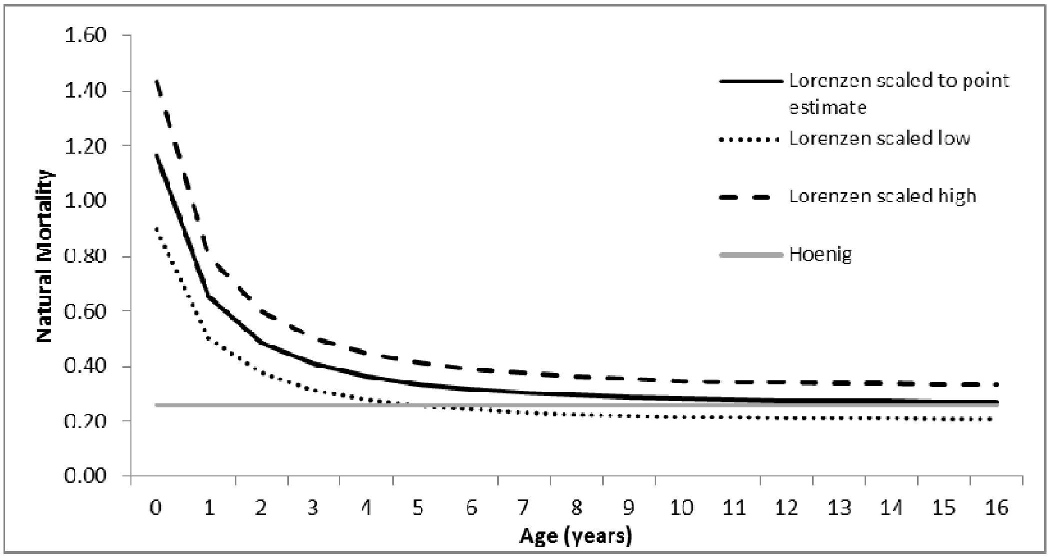

Figure 2.3. Age varying natural mortality (Lorenzen, 2004) for Atlantic cobia, scaled to Hoenig point estimate for the fully recruited ages, 3+.

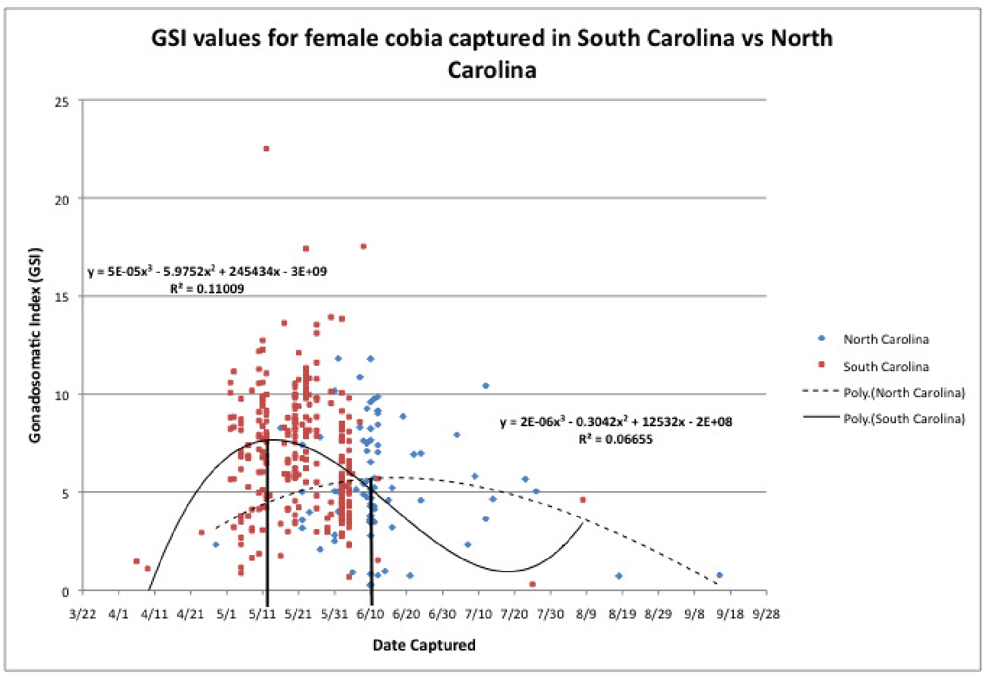

Figure 2.4. Temporal comparison of GSI values for female cobia captured in South Carolina and North Carolina

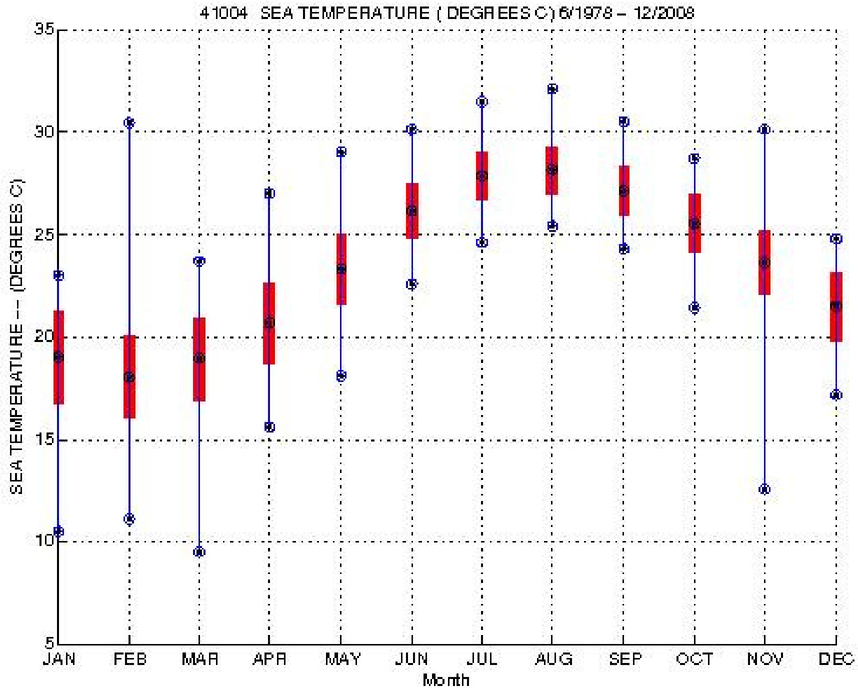

Figure 2.5. Mean monthly temperature profile for waters offshore of South Carolina.

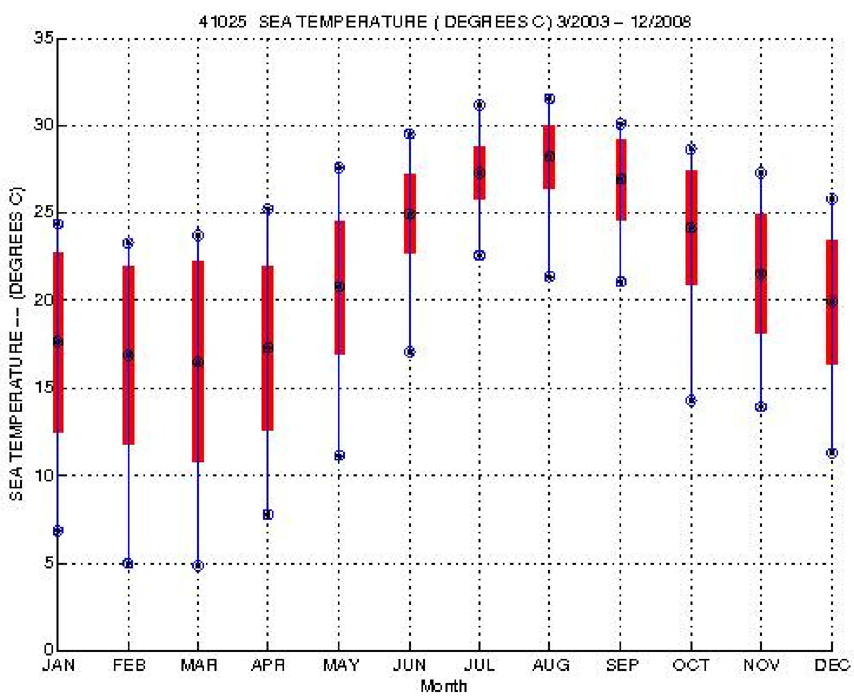

Figure 2.6. Mean monthly temperature profile for waters offshore of North Carolina.

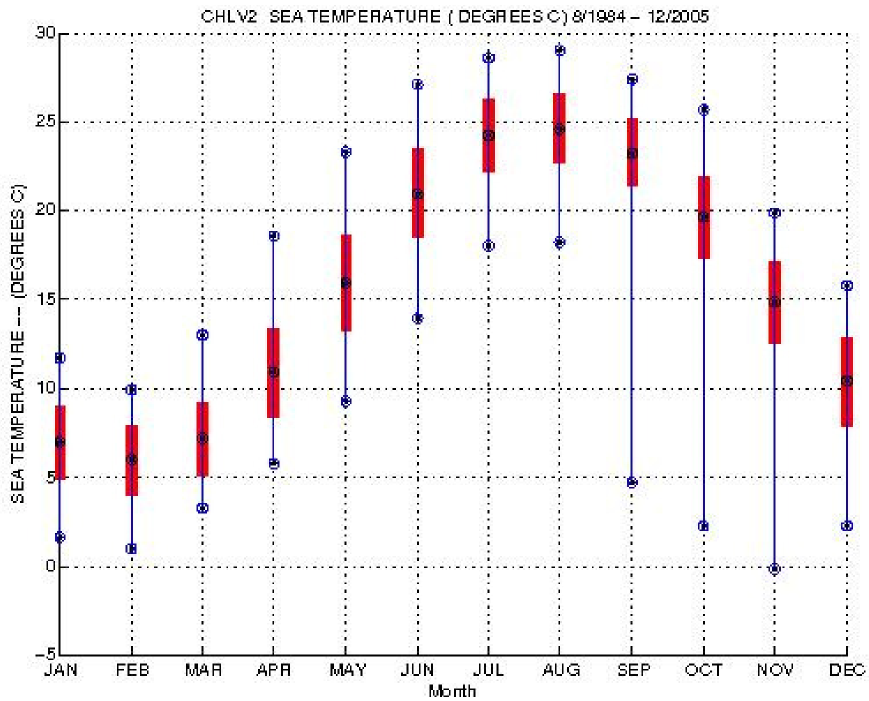

Figure 2.7. Mean monthly temperature profile for waters offshore of Virginia.

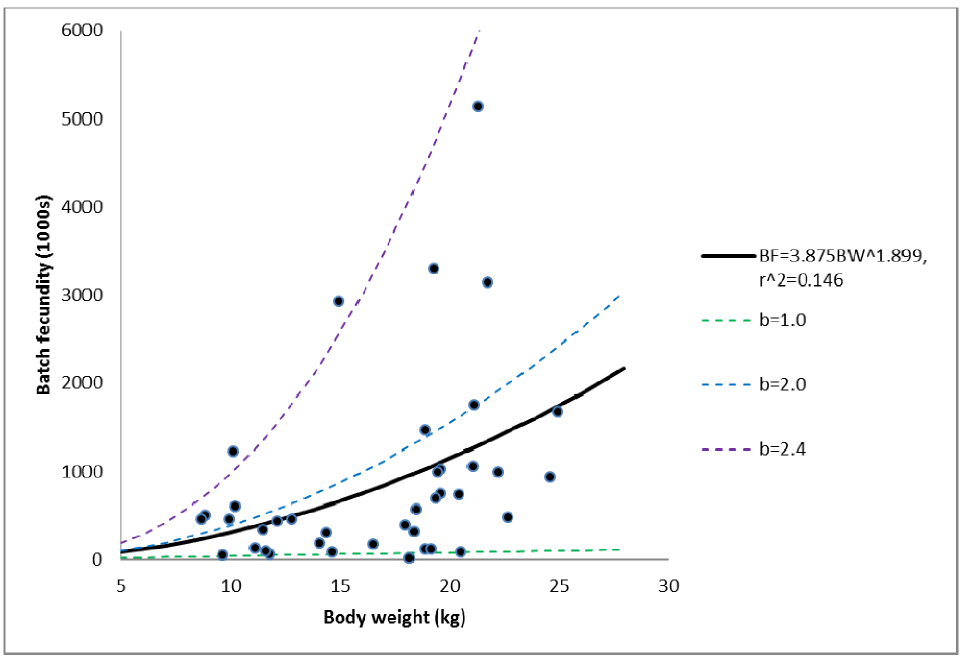

Figure 2.8. Power function of cobia batch fecundity and female body weight. Best fit shown by solid line. Range in values of exponent b represented by dashed lines.

3 Commercial Fishery Statistics

3.1 Overview

Commercial landings for the U.S. South Atlantic cobia stock were developed in whole weight for the period 1928–2010 based on federal and state databases. Corresponding landings in numbers were based on mean weights estimated from TIP by state and year.

Commercial discards were calculated from vessels fishing in the US South Atlantic. Shrimp bycatch of cobia was examined but found to be too rare to pursue estimates.

Sampling intensity for lengths and age by year were considered, and length and age compositions were developed by year for which sample size was deemed adequate.

3.1.1 Participants

David Gloeckner	Workgroup leader; Gulf	NMFS Miami
Kyle Shertzer	Workgroup leader; SA	NMFS Beaufort
Stephanie McInerney	Rapporteur/Data Provider	NC DMF
Steve Brown	Data Provider	FL MRRI
Julie Califf*	Data Provider	GADNR
Julie Defilippi	Data Provider	ACCSP
Tim Sartwell	Data Provider	ACCSP
Joe Cimino	Data Provider	VMRC
Amy Dukes	Data Provider	SC DMF
Donna Bellais	Data Provider	GSMFC
Liz Scott-Denton*	Data Provider	NMFS Galveston
Rusty Hudson	Commercial Fisherman	FL
Ben Hartig	SAFMC; Commercial Fisherman	FL
Kevin McCarthy	Data Provider	NMFS Miami
Rob Cheshire*	Data provider	NMFS Beaufort
Brian Linton*	Data Provider	NMFS Miami

* Did not attend data workshop

3.2 Review of Working Papers

The Working Group (WG) reviewed three working papers. All three of these papers were focused on Gulf of Mexico (GoM) stocks.

SEDAR28-DW6: This working paper described a Bayesian approach to estimating shrimp bycatch in the GoM of both cobia and Spanish mackerel. The group found the methods to be sound, but questioned whether sample sizes for cobia were adequate to support the Bayesian model.

SEDAR28-DW7: This working paper described length frequency distributions of Spanish mackerel from commercial and recreational fleets in the GoM. Length frequencies of commercial landings were compiled from TIP data, and these data were considered adequate for use in the assessment.

SEDAR28-DW8: This working paper described length frequency distributions of cobia from commercial and recreational fleets in the GoM. Length frequencies of commercial landings were compiled from TIP data, and these data were considered adequate for use in the assessment.

3.3 Commercial Landings

3.3.1 Time Series Duration

The WG made the decision to examine landings as far back in time as possible, because the longer time period might shed light on stock resilience and potential. Landings were compiled starting in 1928, the first year of available data, but the reliability of information improved substantially in 1950 with several additional improvements since (described along with methods).

The terminal year considered for this report was 2010. However, the intent is to provide data through 2011 in time for the assessment workshop, if feasible. Several data streams (e.g., discards) depend on statistics computed across years and could therefore change throughout the time series with the inclusion of 2011.

3.3.2 Stock Boundaries

Commercial landings were compiled from GA through ME (Figure 3.1). The southern boundary was the FL-GA state boundary. Landings north of the boundary were considered to be from the Atlantic stock, and landings south of the boundary were considered to be from the Gulf of Mexico stock.

3.3.3 Identification Issues

Cobia are not easily confused with other species. Identification was not considered to be an issue.

3.3.4 Commercial Gears

The WG evaluated the distribution of gears in the landings and in the TIP data. Handline is the most popular gear, although gillnets, poundnets, and seines are also common (Figure 3.2). Because these other gears were seldom sampled for biological information (lengths, ages), the DW recommended combining all commercial gears into a single time series.

3.3.5 Commercial Landings

Landings prior to 1950 were compiled from reports by the Bureau of Commercial Fisheries or US Fish and Fisheries Commission, available from the NMFS office of Science and Technology. These historical landings are also reported in NMFS (1990).

Statistics on commercial landings (1950 to present) for all species on the Atlantic coast are maintained in the Atlantic Coastal Cooperative Statistics Program (ACCSP) Data Warehouse. The Data Warehouse is an on-line database of fisheries dependent data provided by the ACCSP state and federal partners. Data sources and collection methods are illustrated by state in Figure 3.3. The Data Warehouse was queried in February 2012 for all cobia landings (annual summaries by gear category) from 1950–2010 from Georgia through Maine (ACCSP, 2012). Data are presented as a single time series of commercial landings, as decided at the DW. The specific gears (ACCSP codes) that caught cobia are listed in Table 3.1. Commercial landings in pounds (whole weight) were developed based on methodologies as defined by the WG for each state for 1950–2010.

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 –The landings data for South Carolina come from two different sources. The first, 1980–2003, is from the old NMFS Canvass data system. This system involved wholesale seafood dealers reporting total monthly landings by species to the state. The second source, 2004–present, is the SC Trip Ticket Program with data available in the ACCSP data warehouse. The Trip Ticket Program requires wholesale seafood dealers to fill out an individual trip ticket for each trip made. The landings are broken down by species, gear type, and area fished. The ALS data base was used to extend landings back to 1962.

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

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

Virginia – The Virginia Marine Resources Commission provided VA landings data from 1993 through current. Mandatory daily harvest reporting for commercial harvest began in 1993. Virginia landings from prior to 1993 were provided by ACCSP.

Combined State Results – Commercial landings of cobia are distributed in the Atlantic (GA-ME) with low incidence relative to many other species (Figure 3.4A,B). The geographic distribution of effort was similar to that of landings (Figure 3.5A,B). Annual landings are presented in Table 3.2 and Figure 3.6.

The Workgroup made the following decisions for reporting of commercial landings:

- Landings should be reported as whole weight (rather than gutted)
- Landings would be presented by calendar year/gear and as far back as monthly data are available across all states
- Final landings data (1950–2010) would come from the following sources:

North of Virginia:
ACCSP 1950–2010
Virginia:
ACCSP 1950–1993
VA 1993–2010
North Carolina:
ACCSP 1950–1971, 1978–1993
NC 1972–1977, 1994–2010
South Carolina:
ACCSP 1950–2010
Georgia:
ACCSP 1950–2010

Confidentiality – Issues of confidentiality often arise when landings are reported by area (e.g., state). This was not done here, and landings reported by gear met the "rule of 3," so there is no breach of confidentiality.

3.3.6 Converting Landings in Weight to Landings in Numbers

The weight in pounds for each sample was calculated using the mean weight of fish by gear and year. Mean weights of fish were weighted by the weight of fish in the sample, trip weight, and strata landing weight (all in pounds whole weight). When the annual sample size was fewer than 20 (most years), the mean across all years was used (Table 3.3). The landings in pounds whole weight were then divided by the mean weight by year to derive landings in numbers (Table 3.4).

Although landings are supplied here in numbers of fish (to satisfy TOR 5), the WG recommends that the assessment fit to commercial landings in weight. Landings in weight are considered to be more reliable, because 1) landings data were collected in units of weight, and 2) landings in number include the additional uncertainty imposed by calculations or assumptions of the applied average weights.

3.4 Commercial Discards

3.4.1 Discards from Commercial Fishing

Cobia commercial discards were calculated for vessels fishing vertical lines (handline, electric reel/bandit rig), trolling, and gillnets in the US South Atlantic and Gulf of Mexico using methods described in SEDAR 28-DW04. Available data included the number of discards and fishing effort from self-reported discard logbooks for the years 2002-2010 from vessels with federal fishing permits (other than tuna and swordfish permits). Less than 2.5 percent of cobia discard reports for the period 2002–2010 was from trips reporting fishing a gear other than vertical lines, trolling, or gillnets. Data from vessels reporting fishing those other gears were not included in the discard calculations.

Cobia discards from the commercial vertical line, trolling, and gillnet fisheries were calculated for the US South Atlantic (statistical areas 2900-3700; Figure 3.1) and Gulf of Mexico (statistical areas 1-21 and South Atlantic areas 2300-2900; Figure 3.1). As with the Spanish mackerel discard calculations, small sample size (Table 3.5) prevented complex analysis. Cobia discards were calculated for the years 1993–2010 using methods identical to those used in calculating Spanish mackerel discards. Those years include the first year of full reporting of federally permitted vessels to the coastal logbook program. It should be noted that gillnet effort was not reported to the coastal logbook until 1998. Without fully reported effort, calculated discards would likely be biased low.

Yearly total gear specific calculated discards (in number of fish) are provided in Table 3.6. Those totals included all discards reported to the discard logbook program including those reported as “kept, not sold.” Calculated discards in the South Atlantic, as spatially defined here, were fewer than 1,300 fish per year. The same data concerns associated with the Spanish mackerel discard calculations are applicable to the cobia calculations. Results should be used with caution and discards calculated here may represent the minimum number of discards from the commercial fishery.

A high percentage of cobia discards were reported as “all alive” or “majority alive” when released regardless of the gear used (Table 3.7). In the Gulf of Mexico region trolling fishery, 29% of fish that might otherwise have been discarded were reported as “kept, not sold.” Only in the South Atlantic gillnet fishery were more than five percent of discards reported as “majority dead” or “all dead,” however only 87 discarded fish were observed in that fishery.

3.4.2 Discards from Shrimp Bycatch

Shrimp bycatch of Atlantic cobia appeared to be negligible, and thus the DW did not pursue calculating estimates. This decision was based on information from observer coverage of commercial shrimping. Over the period 1998–2010, only five cobia were observed to be caught in approximately 1700 shrimp nets in the Atlantic. Three of the five were caught within the stock boundaries (north of the GA-FL border).

3.5 Commercial Effort

The geographic distribution of fishing effort is plotted in Figure 3.5 and tabulated in Table 3.8. North Carolina is the dominant area for number of trips with cobia landings.

3.6 Biological Sampling

Biological sample data were obtained from the TIP sample data at NMFS/SEFSC. Data that were not already in the TIP database were also incorporated from NCDMF, as well as sample data from VMRC covering Virginia commercial fisheries. Data were filtered to eliminate those records that included a size or effort bias, were known to be collected non-randomly, were not from commercial trips, were selected by quota sampling, or were not collected shore-side (observer data). These data were further limited to those that could be assigned a year, gear, and state. Data that had an unknown landing year, gear, or state were deleted from the file. Additionally, samples were removed if they were drawn from market categories to mitigate the potential for bias in sampling.

Length samples were weighted spatially by the landings for the particular year, state, and gear stratum, and thus were limited to where those strata could be identified in the corresponding landings. Landings and biological data were assigned a state based on landing location or sample location if there was no landing location assigned.

3.6.1 Sampling Intensity

The number of trips sampled for lengths ranged from a high of 33 in 1992 to a low of zero in 1983 and before 1982 (Table 3.9). The number of fish sampled for lengths ranged from a high of 75 in 1992 to a low of zero in 1983 and before 1982 (Table 3.9). In year-by-gear cells where fish were measured, the sample size was typically on the order of tens of fish.

The number of trips sampled for ages was not provided; the number of fish sampled for ages was zero in many strata. In years when fish were aged, the sample size was typically fewer than ten fish (Table 3.10).

3.6.2 Length and Age Compositions of Commercial Landings

Lengths, measured in fork length (cm), were binned into one centimeter groups with a floor of 0.6 cm and a ceiling of 0.5 cm. Length compositions by gear and year were weighted by the trip landings in numbers and the landings in numbers by strata (state, year, gear). Annual length compositions of cobia are summarized in Figure 3.7.

Raw age compositions are summarized by year and gear (Figure 3.8). In some assessments, ages are weighted length compositions to address potential bias in the age compositions. When possible, the commercial group suggests that ages be weighted by the length composition with the formula:

$$RW_i = \frac{NLi \big/ TN}{OLi \big/ TO},$$

where NLi is the number of fish measured with length i, TN is the total number of fish measured in that strata, OLi is the number of ages sampled at length i, and TO is the total number of ages sampled within the strata (Chih, 2009). This weighting corrects for a potential sampling bias of age samples relative to length samples (Chih, 2009), which have already been corrected. The age compositions presented in Figure 3.8 are un-weighted. Weighting by length composition was not pursued here because of the low sample sizes in length compositions.

3.7 Comments on Adequacy of Data for Assessment Analyses

Landings data appear to be adequate to support the assessment, with landings reports beginning for cobia in the late 1920s. Landings have greatest certainty since the individual state's trip ticket programs were initiated. Landings prior to 1950 are considered highly uncertain.

Discard estimates have greater uncertainty than the landings, as there are very few trips where cobia discards were observed by the Reeffish Observer Program. Additionally, the NMFS logbook doesn't capture the entire fishery, so the discards reported to this program should be considered a minimum estimate.

Commercial discards are based on estimated encounter rates and effort. In years when multi-year averages are used to compute encounter rates, these estimates do not account for year-specific age structure in the cobia stock.

Sample sizes for developing length compositions were small, as were those for developing age compositions. The annual proportion of commercial trips sampled for lengths is less than 5% in all years, and in many years is less than 1% (Table 3.9).

Because of the low sample sizes in length and age compositions, the DW discussed how these data might be used in the assessment. One possible approach discussed by DW panelists was that, rather than using annual compositions, the assessment could fit to compositions pooled across years (shown in Figures 3.7 and 3.8). In general, this approach facilitates estimation of selectivity, but precludes using these data to estimate year-class strength. However in this case, composition data provide little, if any, signal on year-class strength.

3.8 Literature Cited

Atlantic Coastal Cooperative Statistics Program. 2012. Annual landings by custom gear category; generated by Tim Sartwell using ACCSP Data Warehouse, Arlington, VA: accessed February, 2012.

Chih, C. 2009. The effects of otolith sampling methods on the precision of growth curves. *North American Journal of Fisheries Management* 29:1519–1528.

NMFS (National Marine Fisheries Service). 1990. Historical Catch Statistics, Atlantic and Gulf Coast States: 1879-1989; Current Fishery Statistics No. 9010; Historical Series Nos. 5-9 revised. Washington, DC: U.S. Government Printing Office. Original Bureau reports are available: http://docs.lib.noaa.gov/rescue/cof/data_rescue_fish_commission_annual_reports.html.

SEDAR. 2008. SEDAR17 Stock Assessment Report: South Atlantic Spanish Mackerel. (http://www.sefsc.noaa.gov/sedar/download/S17%20SM%20SAR%201.pdf?id=DOCUMENT).

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Addendum to Commercial Landings (Section 3.3):

NMFS SEFIN Accumulated Landings (ALS)

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

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

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

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

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

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

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

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

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

There are two problems with the commercial fishery statistics that were collected from seafood dealers. First, dealers do not always record the specific species that are caught and second, fish or shellfish are not always purchased at the same location where they are unloaded, i.e., landed.

Dealers have always recorded fishery products in ways that meet their needs, which sometimes make it ambiguous for scientific uses. Although the port agents can readily identify individual species, they usually were not at the fish house when fish were being unloaded and thus, could not observe and identify the fish.

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

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

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

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

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

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

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

Georgia
=======
Prior to 1977, the National Marine Fisheries Service collected commercial landings data Georgia. From 1977 to 2001 state port agents visited dealers and docks to collect the information on a regular basis. Compliance was mandatory for the fishing industry. To collect more timely and accurate data, Georgia

initiated a trip ticket program in 1999, but the program was not fully implemented to allow complete coverage until 2001. All sales of seafood products landed in Georgia must be recorded on a trip ticket at the time of the sale. Both the seafood dealer and the seafood harvester are responsible for insuring the ticket is completed in full.

South Carolina
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Prior to 1972, commercial landings data were collected by various federal fisheries agents based in South Carolina, either U.S. Fish or Wildlife or National Marine Fisheries Service personnel. In 1972, South Carolina began collecting landings data from coastal dealers in cooperation with federal agents. Mandatory monthly landings reports on forms supplied by the Department are required from all licensed wholesale dealers in South Carolina. Until fall of 2003, those 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. Target species and length quotas were supplied by NMFS and sampling targets of 10% of monthly commercial trips by gear were set to collect those species and length frequencies. In 2005, South Carolina began collecting age structures (otoliths) in addition to length frequencies, using ACCSP funding to supplement CSP funding.

North Carolina

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

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

NMFS SEFIN Annual Canvas Data for Florida

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

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

3.9 Tables

Table 3.1. Specific ACCSP gears in each gear category for cobia commercial landings. For SEDAR28, all commercial landings (handlines and other) were combined into a single time series.

ACCSP GEAR CODE	ACCSP GEAR NAME	ACCSP TYPE NAME	SEDAR 28 Gear Group
300	HOOK AND LINE	HOOK AND LINE	HAND LINES
301	HOOK AND LINE, MANUAL	HOOK AND LINE	HAND LINES
302	HOOK AND LINE, ELECTRIC	HOOK AND LINE	HAND LINES
303	ELECTRIC/HYDRAULIC, BANDIT REELS	HOOK AND LINE	HAND LINES
320	TROLL LINES	HOOK AND LINE	HAND LINES
700	HAND LINE	HAND LINE	HAND LINES
701	TROLL AND HAND LINES CMB	HAND LINE	HAND LINES
000	NOT CODED	NOT CODED	OTHER
010	HAUL SEINES	HAUL SEINES	OTHER
020	OTHER SEINES	HAUL SEINES	OTHER
022	COMMON SEINE	HAUL SEINES	OTHER
030	PURSE SEINE	PURSE SEINES	OTHER
050	POUND NETS	FIXED NETS	OTHER
060	FYKE NETS	FIXED NETS	OTHER
090	OTTER TRAWLS	TRAWLS	OTHER
091	OTTER TRAWL BOTTOM, CRAB	TRAWLS	OTHER
092	OTTER TRAWL BOTTOM, FISH	TRAWLS	OTHER
095	OTTER TRAWL BOTTOM, SHRIMP	TRAWLS	OTHER
096	OTTER TRAWL BOTTOM, OTHER	TRAWLS	OTHER
097	OTTER TRAWL MIDWATER	TRAWLS	OTHER
110	OTHER TRAWLS	TRAWLS	OTHER
120	FLY NET	TRAWLS	OTHER
130	POTS AND TRAPS	POTS AND TRAPS	OTHER
131	POTS AND TRAPS, CONCH	POTS AND TRAPS	OTHER
132	POTS AND TRAPS, BLUE CRAB	POTS AND TRAPS	OTHER
139	POTS AND TRAPS, FISH	POTS AND TRAPS	OTHER
140	POTS AND TRAPS, SPINY LOBSTER	POTS AND TRAPS	OTHER

200	GILL NETS	GILL NETS	OTHER
201	GILL NETS, FLOATING DRIFT	GILL NETS	OTHER
203	GILL NETS, FLOATING ANCHOR	GILL NETS	OTHER
204	GILL NETS, SINK ANCHOR	GILL NETS	OTHER
205	GILL NETS, RUNAROUND	GILL NETS	OTHER
207	GILL NETS, OTHER	GILL NETS	OTHER
400	LONG LINES	LONG LINES	OTHER
401	LONG LINES, VERTICAL	LONG LINES	OTHER
402	LONG LINES, SURFACE	LONG LINES	OTHER
403	LONG LINES, BOTTOM	LONG LINES	OTHER
404	LONG LINES, SURFACE, MIDWATER	LONG LINES	OTHER
405	LONG LINES, TROT	LONG LINES	OTHER
500	DREDGE	DREDGE	OTHER
511	DREDGE, NEW BEDFORD	DREDGE	OTHER
602	PATENT TONGS	RAKES, HOES, AND TONGS	OTHER
660	SPEARS	SPEARS AND GIGS	OTHER
661	SPEARS, DIVING	SPEARS AND GIGS	OTHER
662	GIGS	SPEARS AND GIGS	OTHER
750	BY HAND, DIVING GEAR	BY HAND	OTHER
760	BY HAND, NO DIVING GEAR	BY HAND	OTHER
800	OTHER GEARS	OTHER GEARS	OTHER
801	UNSPECIFIED GEAR	OTHER GEARS	OTHER
802	COMBINED GEARS	OTHER GEARS	OTHER

Table 3.2. Cobia landings in weight (pounds whole weight) from the U.S. South Atlantic, 1928–2010. Empty cells indicate missing information (not zeros).

Year	Landings	Year	Landings
1928	250[1]	1972	7000
1929	350	1973	4600
1930	200	1974	5500
1931	300	1975	8100
1932	4515	1976	5900
1933		1977	3500
1934	25300	1978	2747
1935		1979	4540
1936	9300	1980	8388
1937	22400	1981	17923
1938	23500	1982	31264
1939	11700	1983	18033
1940	2500	1984	13694
1941	1000	1985	11115
1942		1986	25754
1943		1987	40495
1944		1988	28638
1945		1989	33273
1946		1990	43736
1947	1800	1991	43816
1948		1992	36675
1949		1993	39502
1950	11400	1994	46912
1951	11800	1995	67047
1952	3800	1996	62378
1953	13700	1997	62279
1954	28200	1998	43499
1955	9200	1999	27451
1956	27100	2000	43532
1957	48600	2001	40791
1958	25500	2002	42236
1959	48900	2003	35305
1960	30700	2004	32650
1961	38700	2005	28675
1962	41100	2006	33785
1963	49900	2007	31576
1964	24500	2008	33783
1965	19900	2009	42278
1966	12100	2010	56544
1967	12800		
1968	10900		
1969	9000		
1970	9200		
1971	14400		

[1] In 1928, only NC data were available.

Table 3.3. Mean weights in pounds whole weight used to derive landings in numbers by year.

Year	Mean weight (lb whole weight)	Standard deviation
1928–1989	40.42	134.38
1990	27.31	59.90
1991	40.42	134.38
1992	40.42	134.38
1993	40.42	134.38
1994	40.42	134.38
1995	40.42	134.38
1996	40.42	134.38
1997	40.42	134.38
1998	40.42	134.38
1999	40.42	134.38
2000	40.42	134.38
2001	40.42	134.38
2002	40.42	134.38
2003	40.42	134.38
2004	24.35	53.57
2005	41.45	98.59
2006	23.45	39.23
2007	28.55	64.92
2008	35.77	90.66
2009	30.01	49.54
2010	40.42	134.38

Table 3.4. Cobia landings in numbers (thousands of fish) from the U.S. Atlantic, 1928–2010.

Year	Landings (1000 fish)	Year	Landings (1000 fish)
1928	0.006	1972	0.173
1929	0.009	1973	0.114
1930	0.005	1974	0.136
1931	0.007	1975	0.200
1932	0.112	1976	0.146
1933		1977	0.087
1934	0.626	1978	0.068
1935		1979	0.112
1936	0.230	1980	0.208
1937	0.554	1981	0.443
1938	0.581	1982	0.773
1939	0.289	1983	0.446
1940	0.062	1984	0.339
1941	0.025	1985	0.275
1942		1986	0.637
1943		1987	1.002
1944		1988	0.709
1945		1989	0.823
1946		1990	1.601
1947	0.045	1991	1.084
1948		1992	0.907
1949		1993	0.977
1950	0.282	1994	1.161
1951	0.292	1995	1.659
1952	0.094	1996	1.543
1953	0.339	1997	1.541
1954	0.698	1998	1.076
1955	0.228	1999	0.679
1956	0.670	2000	1.077
1957	1.202	2001	1.009
1958	0.631	2002	1.045
1959	1.210	2003	0.873
1960	0.760	2004	1.341
1961	0.957	2005	0.692
1962	1.017	2006	1.441
1963	1.235	2007	1.106
1964	0.606	2008	0.944
1965	0.492	2009	1.409
1966	0.299	2010	1.399
1967	0.317		
1968	0.270		
1969	0.223		
1970	0.228		
1971	0.356		

Table 3.5. Number of trips reporting cobia discards by region and gear fished; all years combined (2002–2010). "Other species" totals include all other reports to the discard logbook program. Also included in "other species" totals are trips with no reported discards. Trips with multiple gears fished reported or that fished in both regions may be counted more than once. Totals include only those vessels with federal fishing permits.

Region	Species	Gillnet	Vertical line	Trolling	All other gears
GOM	Cobia	0	349	83	29
	Other species (cobia boundaries)	586	32,072	13,224	4,203
SA	Cobia	43	44	13	6
	Other species (cobia boundaries)	1,952	6,049	2,165	1,838

Table 3.6. Cobia yearly total calculated discards from commercial gillnet, vertical line, and trolling vessels with federal fishing permits in the US South Atlantic (29°N to 37°N latitude). Discards are reported as number of fish.

Year	Gillnet	Vertical line	Trolling	Calculated discards
1993		384	13	397
1994		479	20	499
1995		472	19	491
1996		455	20	475
1997		448	24	472
1998	453	336	47	836
1999	474	282	53	809
2000	714	303	49	1,066
2001	708	325	40	1,074
2002	963	301	32	1,296
2003	777	243	27	1,047
2004	690	225	26	941
2005	778	217	25	1,020
2006	919	237	25	1,181
2007	817	256	33	1,107
2008	766	255	26	1,047
2009	652	263	32	946
2010	760	218	19	997

Table 3.7. Self-reported discard mortality/disposition of cobia caught on commercial fishing vessels with federal fishing permits, 2002-2010. No cobia discards were reported from gillnet vessels in the Gulf of Mexico.

Region	Gear	Disposition							Number of fish
		All Dead	Majority Dead	All Alive	Majority Alive	Kept	Unable to Determine	Unreported	
South Atlantic	Gillnet	3%	23%	43%	28%	3%	0%	3%	87
	Handline/Electric	5%	2%	88%	6%	0%	0%	5%	65
	Trolling	0%	0%	93%	0%	7%	0%	0%	27
Gulf of Mexico	Gillnet	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0
	Handline/Electric	0%	1%	86%	4%	9%	0%	0%	774
	Trolling	1%	0%	66%	5%	29%	0%	1%	132

Table 3.8. Number of commercial trips that caught cobia by year and area.

YEAR	NORTH (VA-NY)	NC	GA-SC
1994	162	674	
1995	133	614	
1996	133	484	
1997	139	539	
1998	124	375	
1999	123	253	
2000	131	400	
2001	125	482	
2002	79	382	
2003	98	381	
2004	80	382	
2005	164	368	108
2006	165	412	75
2007	139	428	130
2008	89	492	120
2009	134	659	75
2010	47	639	67

Table 3.9. Number of commercial cobia (n.fish) and trips (n.trips) sampled for lengths by year. Sample sizes represent the number of valid samples (i.e., biased samples removed). Total trips, used to compute proportion trips sampled, does not include GA-SC in 1994–2004 (prior to SC trip tickets).

Year	n.fish	n.trips	Proportion trips sampled
1982	12	2	
1984	12	12	
1985	12	9	
1987	5	5	
1988	15	14	
1989	10	4	
1990	24	3	
1991	13	10	
1992	1	1	
1993	10	5	
1994	7	6	0.007
1995	5	3	0.004
1997	9	3	0.004
1999	12	5	0.013
2000	11	4	0.008
2001	11	7	0.012
2002	5	3	0.007
2003	13	6	0.013
2004	42	17	0.037
2005	39	21	0.033
2006	23	13	0.020
2007	21	12	0.017
2008	75	33	0.047
2009	30	18	0.021
2010	7	7	0.009

Table 3.10. Number of commercial cobia (n.fish) sampled for ages by year.

Year	n.fish
1986	1
1989	4
1990	3
1991	1
1998	5
1999	9
2000	7
2001	7
2002	36
2003	2
2004	2
2005	6
2006	2
2007	11
2008	5
2009	3
2010	5

3.10 Figures

Figure 3.1. Map of U.S. Atlantic and Gulf coast with shrimp area designations.

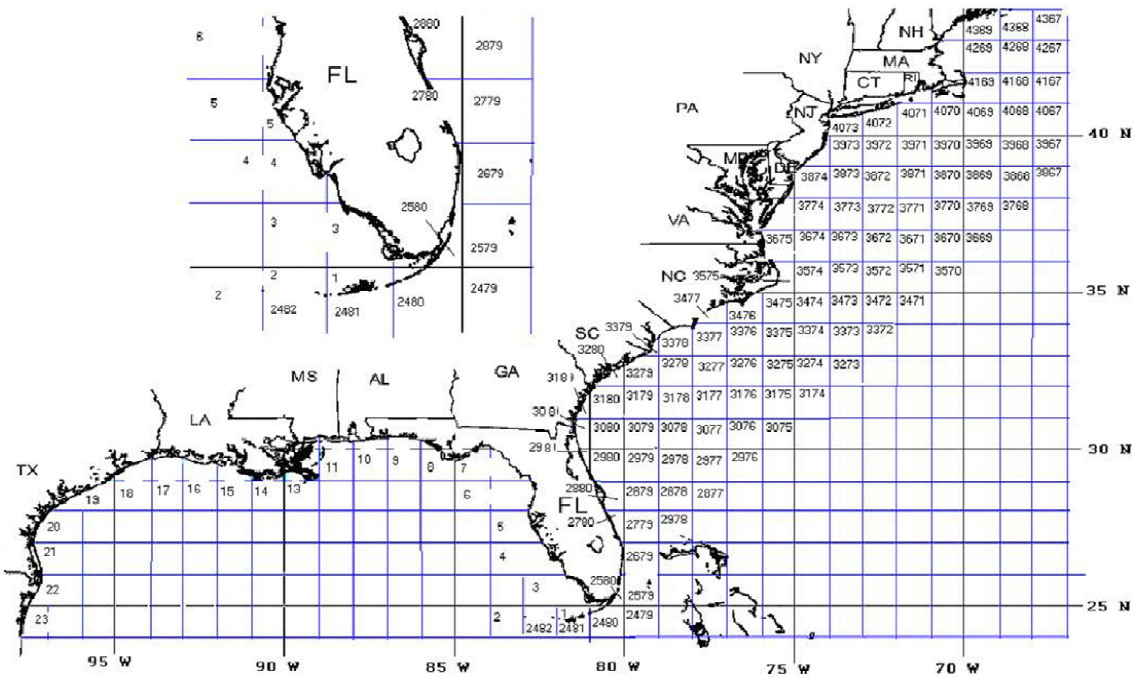
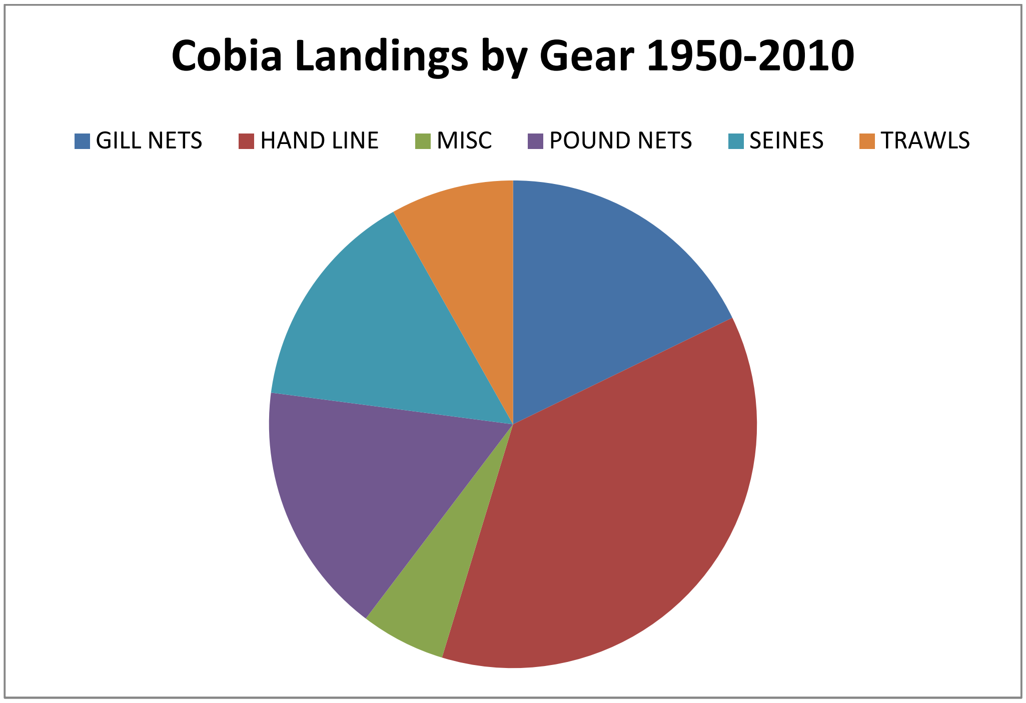


Figure 3.2. Distribution of gears used to land cobia. Top panel: 1950–2010. Bottom panel: 1990–2010.



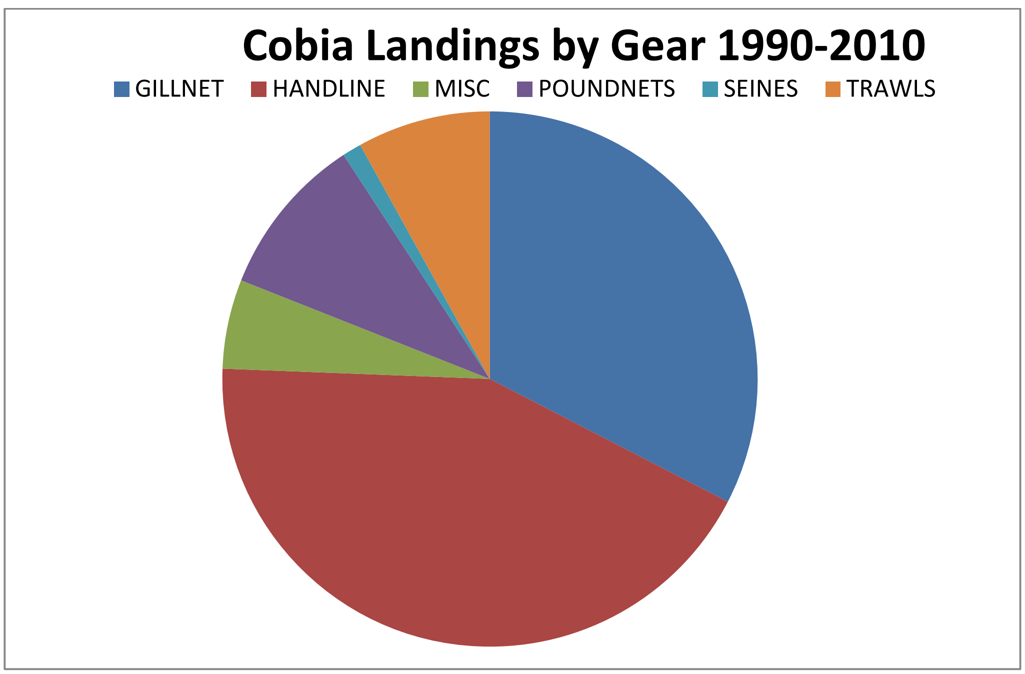


Figure 3.3. Atlantic Coastal Cooperative Statistics Program (ACCSP) Data Warehouse - data sources and collection methods by state. Early summaries provided by NMFS.

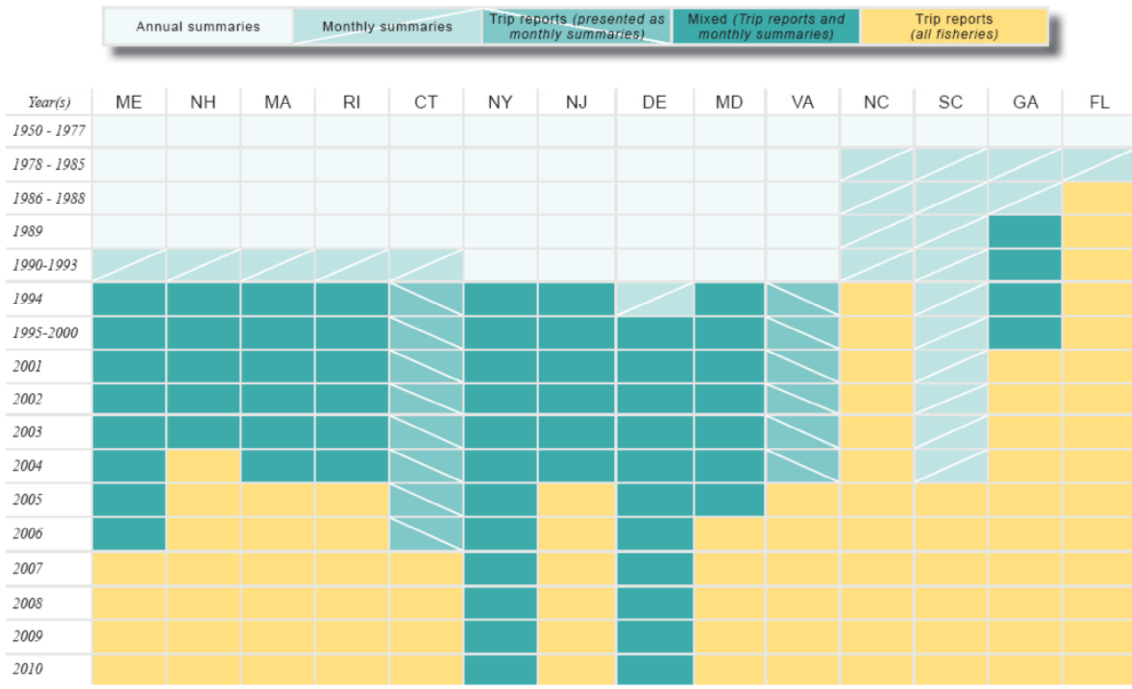


Figure 3.4A. Geographic distribution of cobia landings (lb gutted weight) reported in logbooks during 1990–1999. Areas north of NC were not part of this data set.

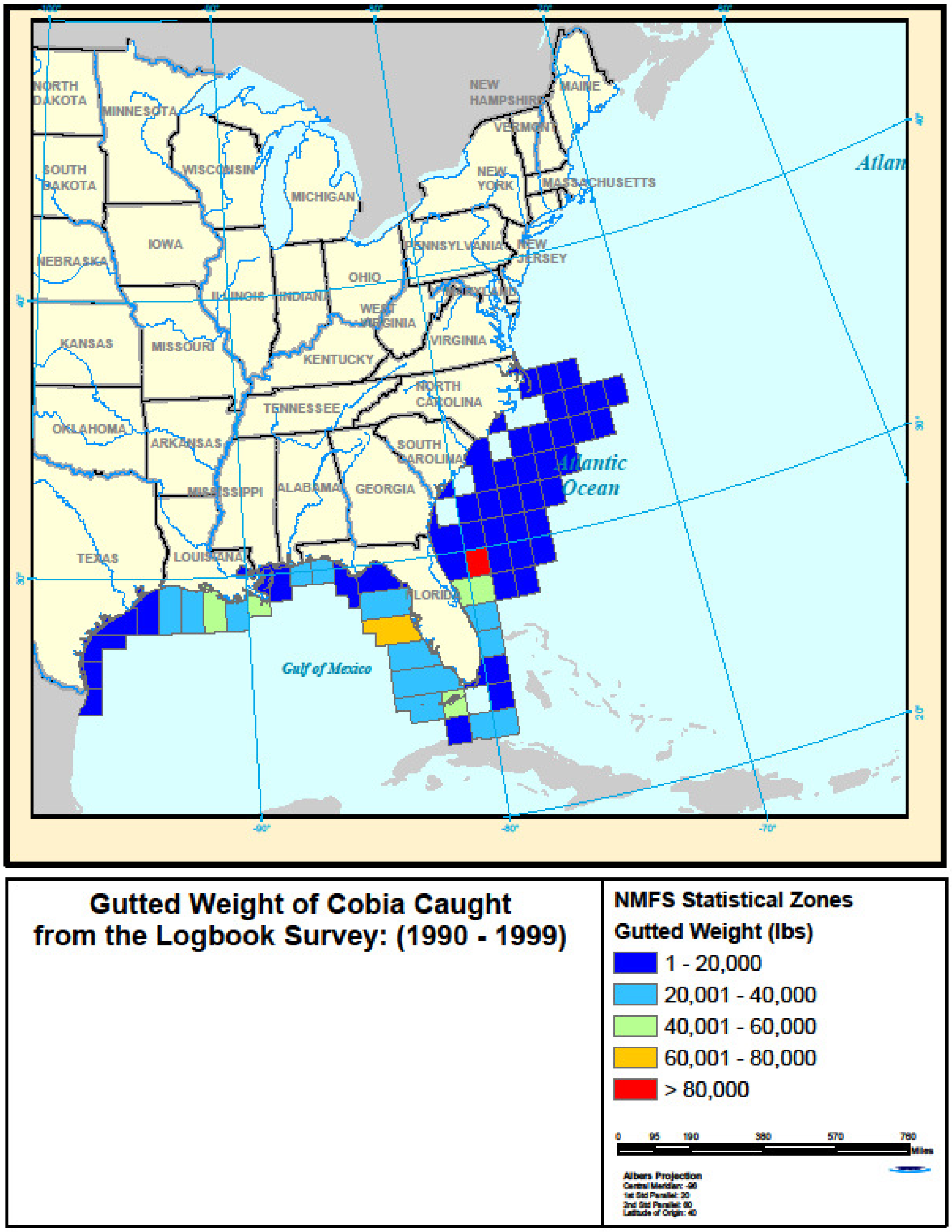


Figure 3.4B. Geographic distribution of cobia landings (lb gutted weight) reported in logbooks during 2000–2010. Areas north of NC were not part of this data set.

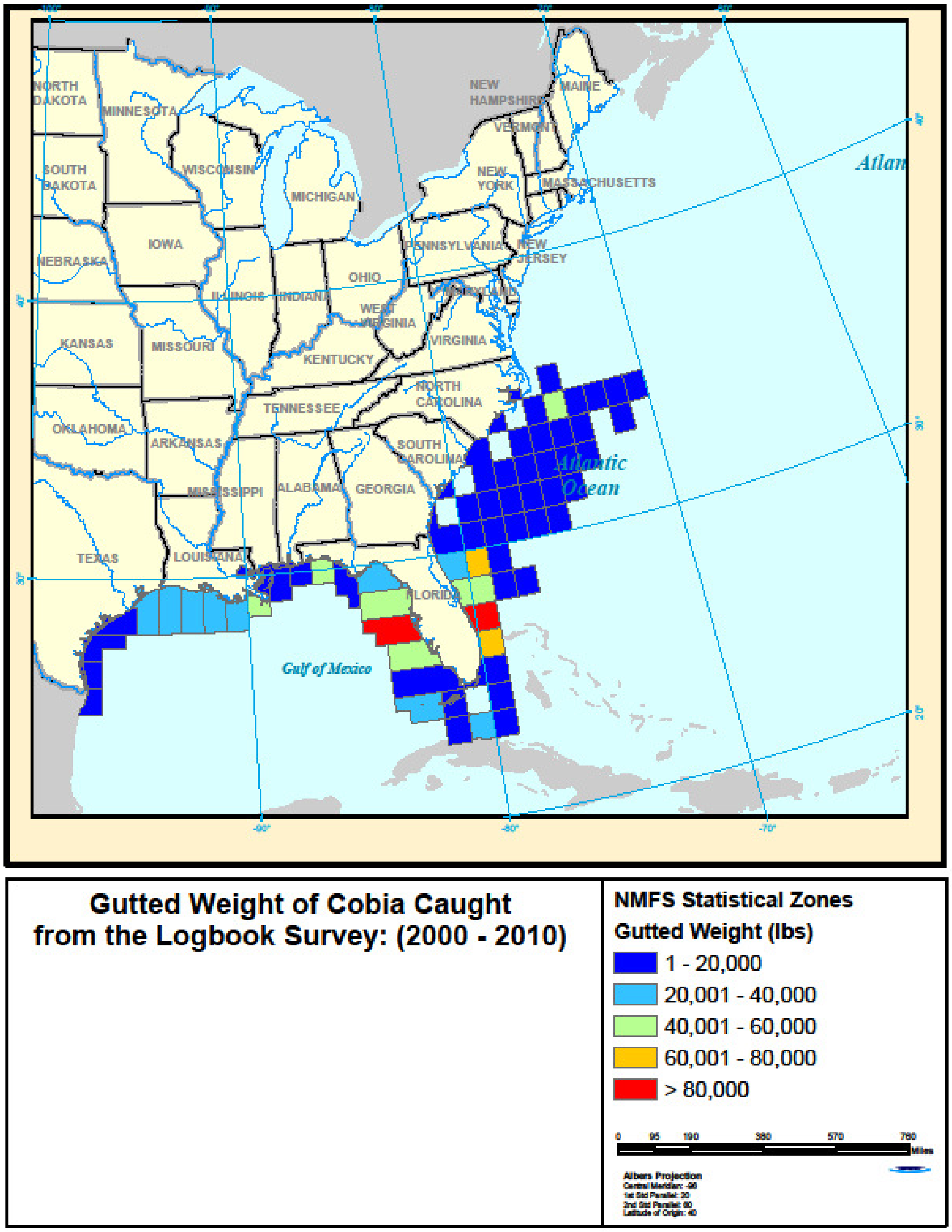


Figure 3.5A. Geographic distribution of cobia fishing effort (number trips) reported in logbooks during 1990–1999. Areas north of NC were not part of this data set.

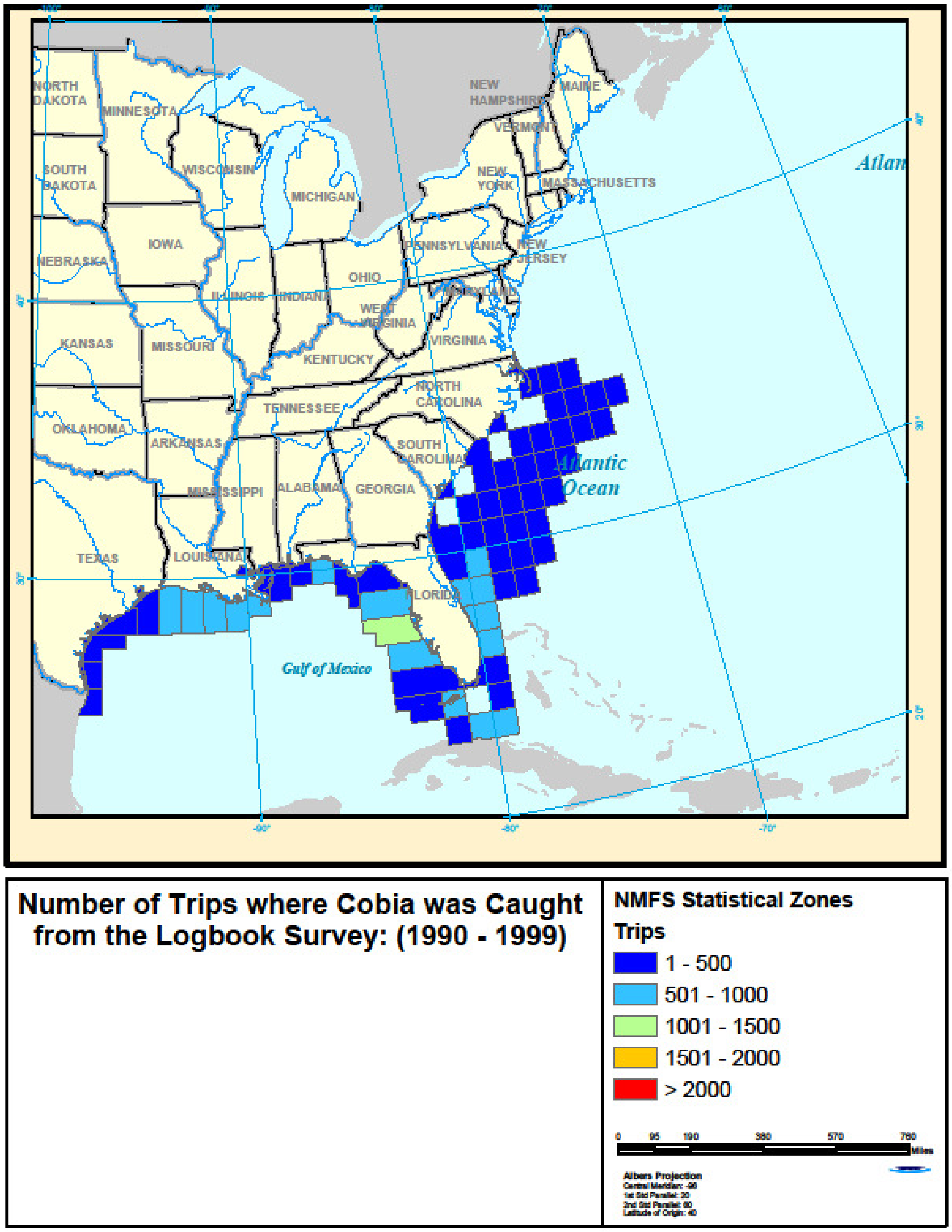


Figure 3.5B. Geographic distribution of cobia fishing effort (number trips) reported in logbooks during 2000–2010. Areas north of NC were not part of this data set.

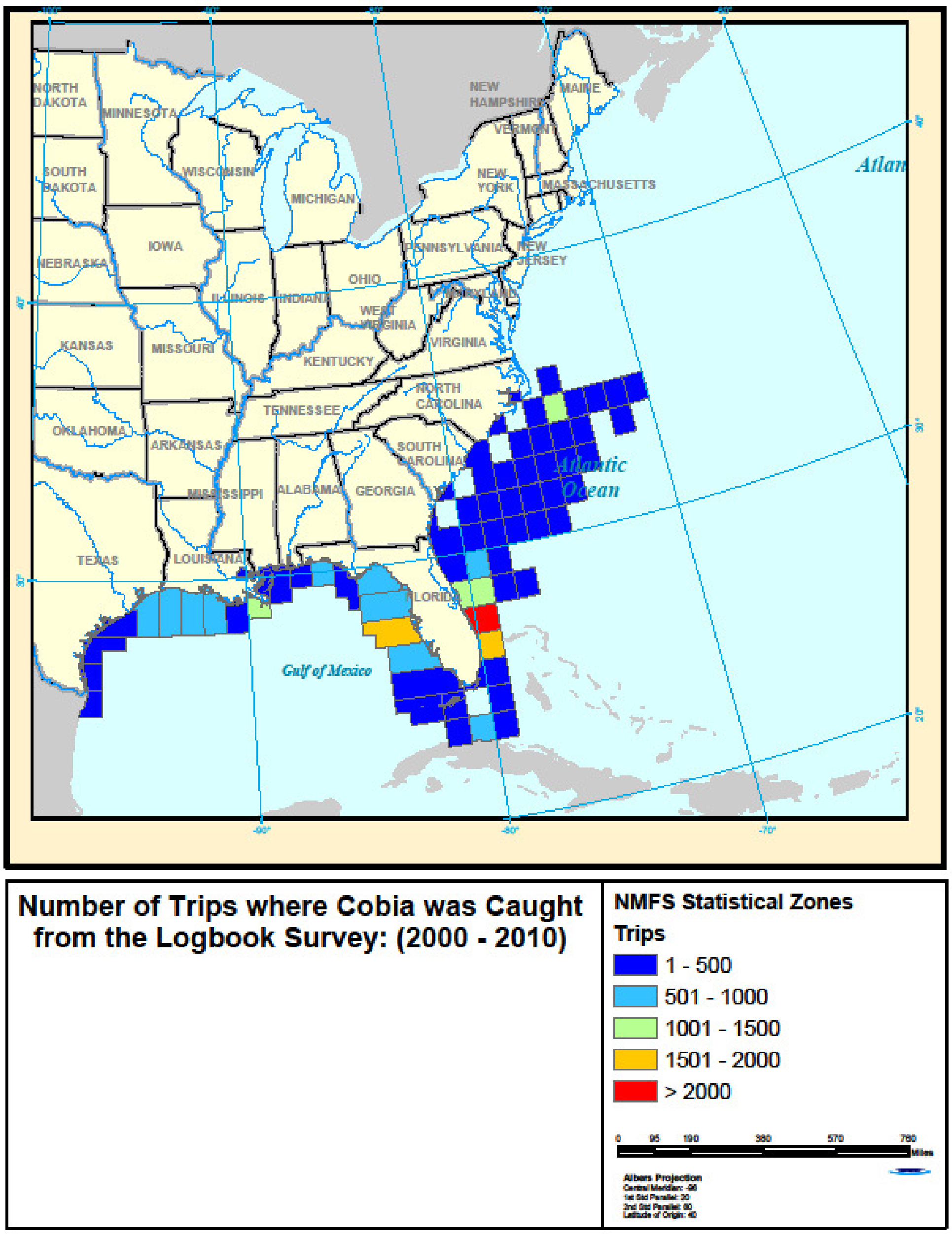


Figure 3.6. Total (all gears) commercial landings (pounds whole weight) of cobia in the U.S. South Atlantic, 1928–2010.

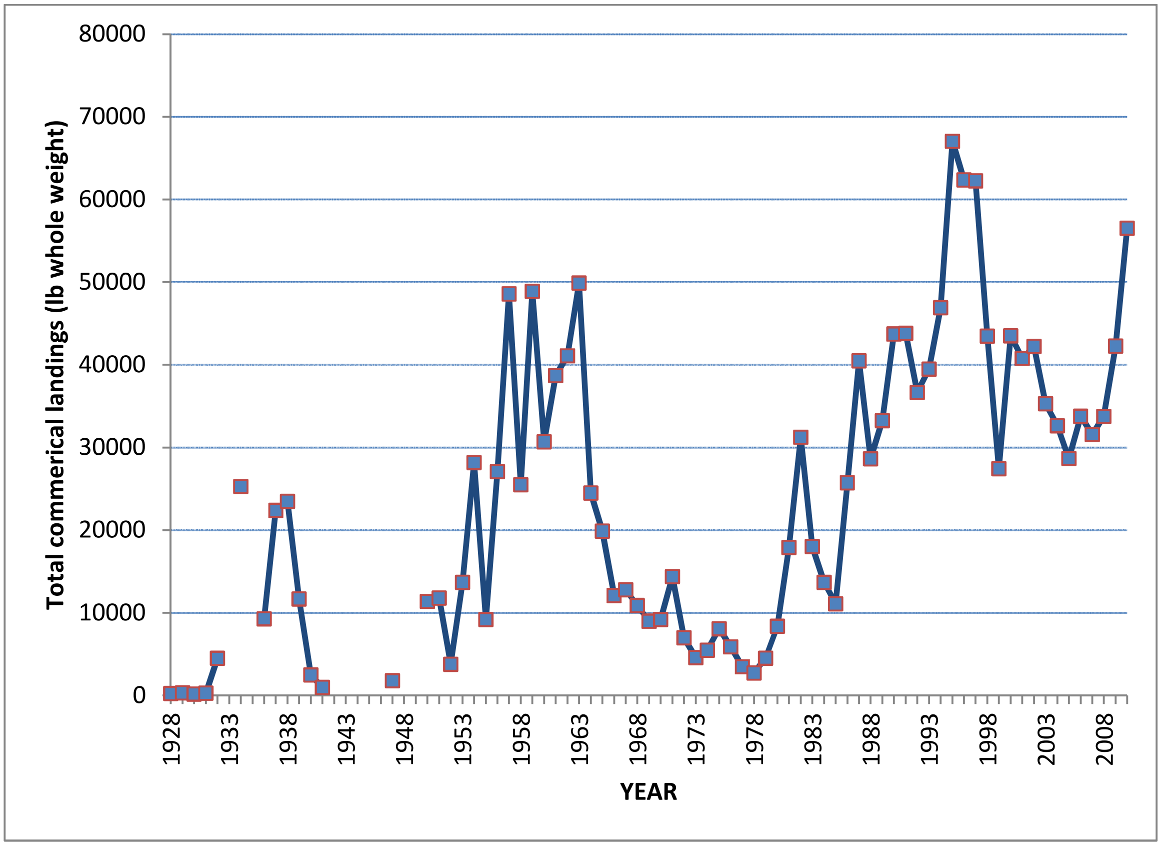
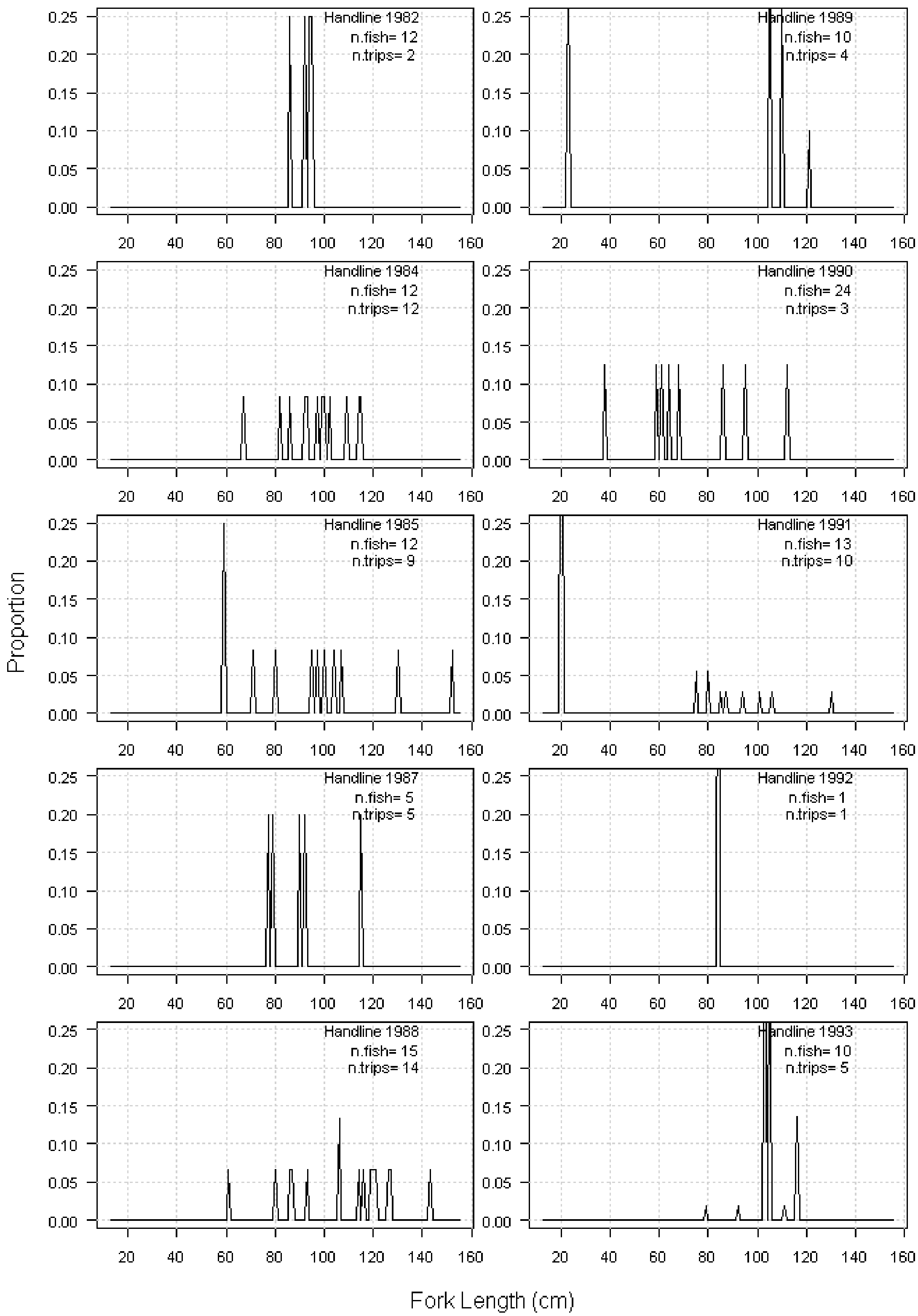
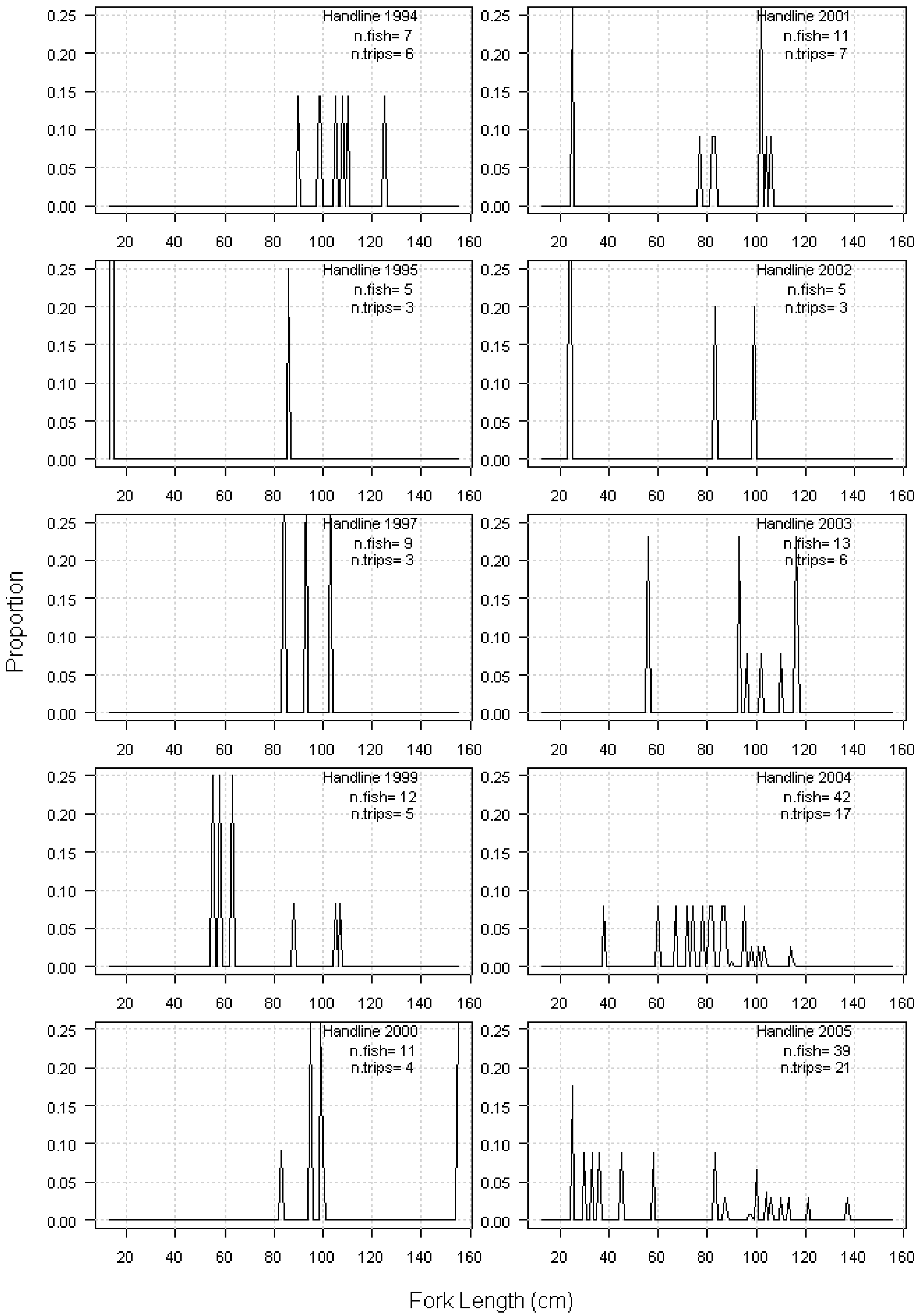


Figure 3.7. Relative length compositions of commercial length (FL in cm) samples by year. Sample size indicated on each panel (n.fish = number of fish, n.trips = number of trips). Last panel shows the length composition pooled across years.




Handline 1994
n.fish= 7
n.trips= 6
Handline 2001
n.fish= 11
n.trips= 7
Handline 1995
n.fish= 5
n.trips= 3
Handline 2002
n.fish= 5
n.trips= 3
Handline 1997
n.fish= 9
n.trips= 3
Handline 2003
n.fish= 13
n.trips= 6
Handline 1999
n.fish= 12
n.trips= 5
Handline 2004
n.fish= 42
n.trips= 17
Handline 2000
n.fish= 11
n.trips= 4
Handline 2005
n.fish= 39
n.trips= 21
Proportion
Fork Length (cm)

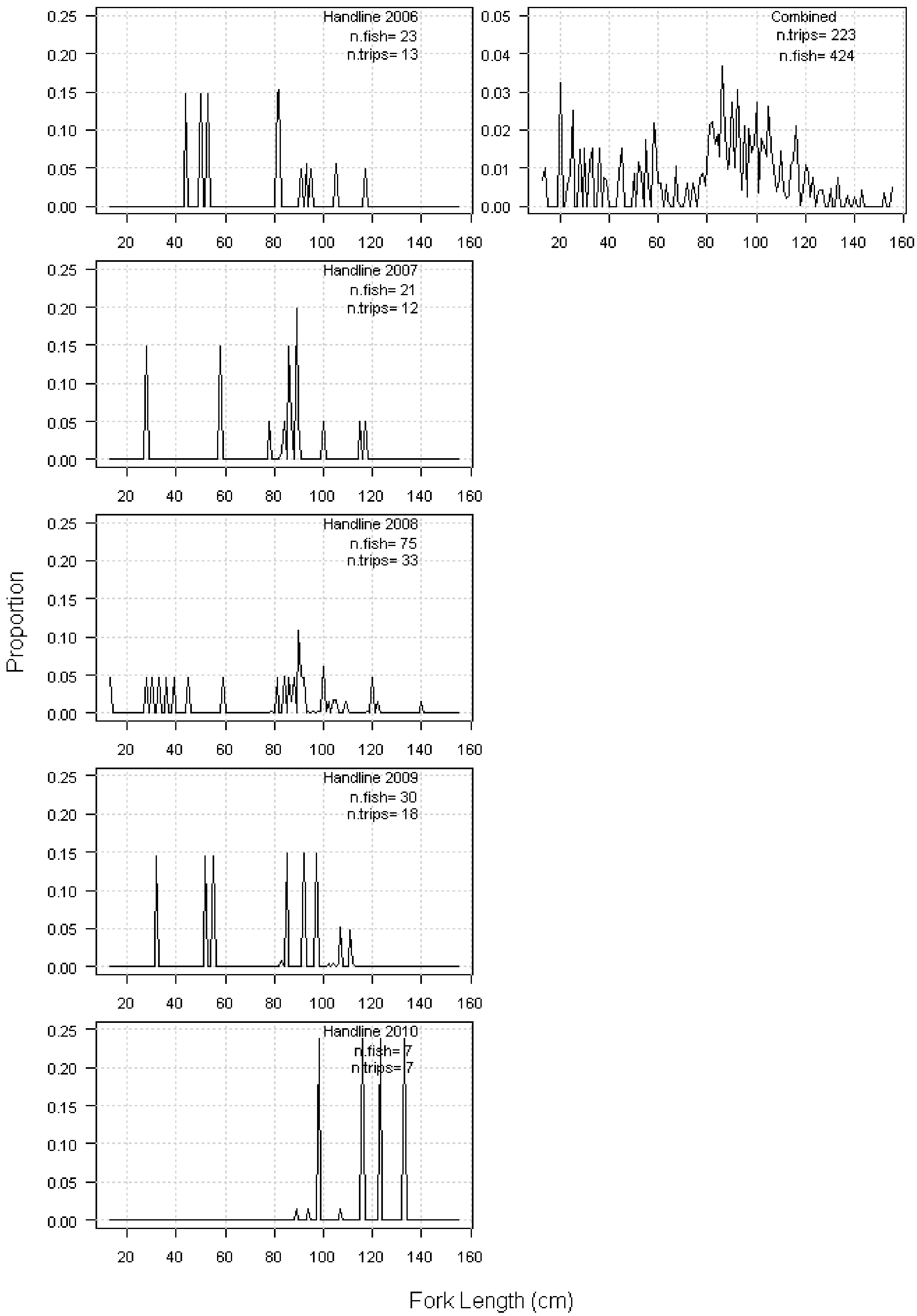
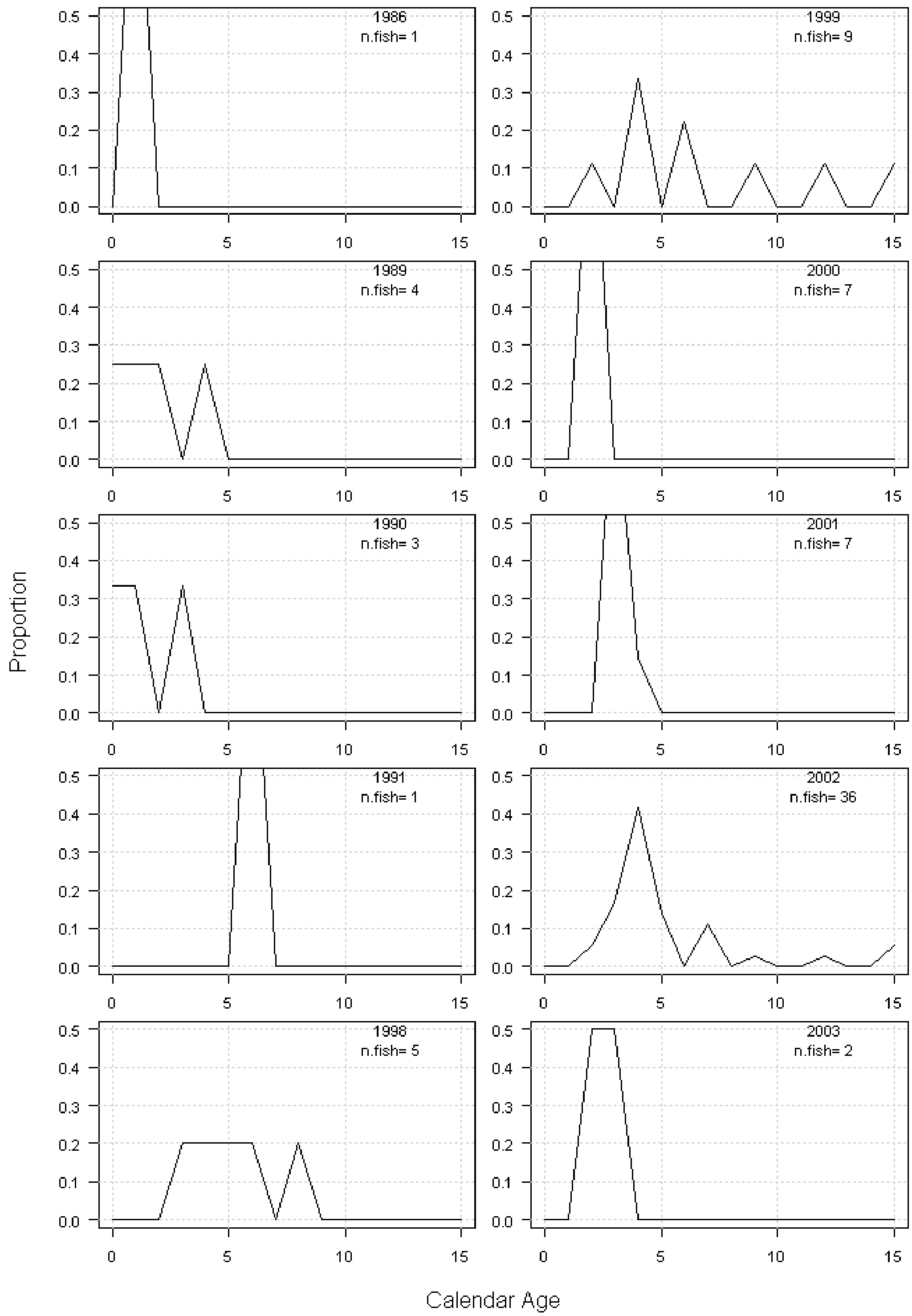
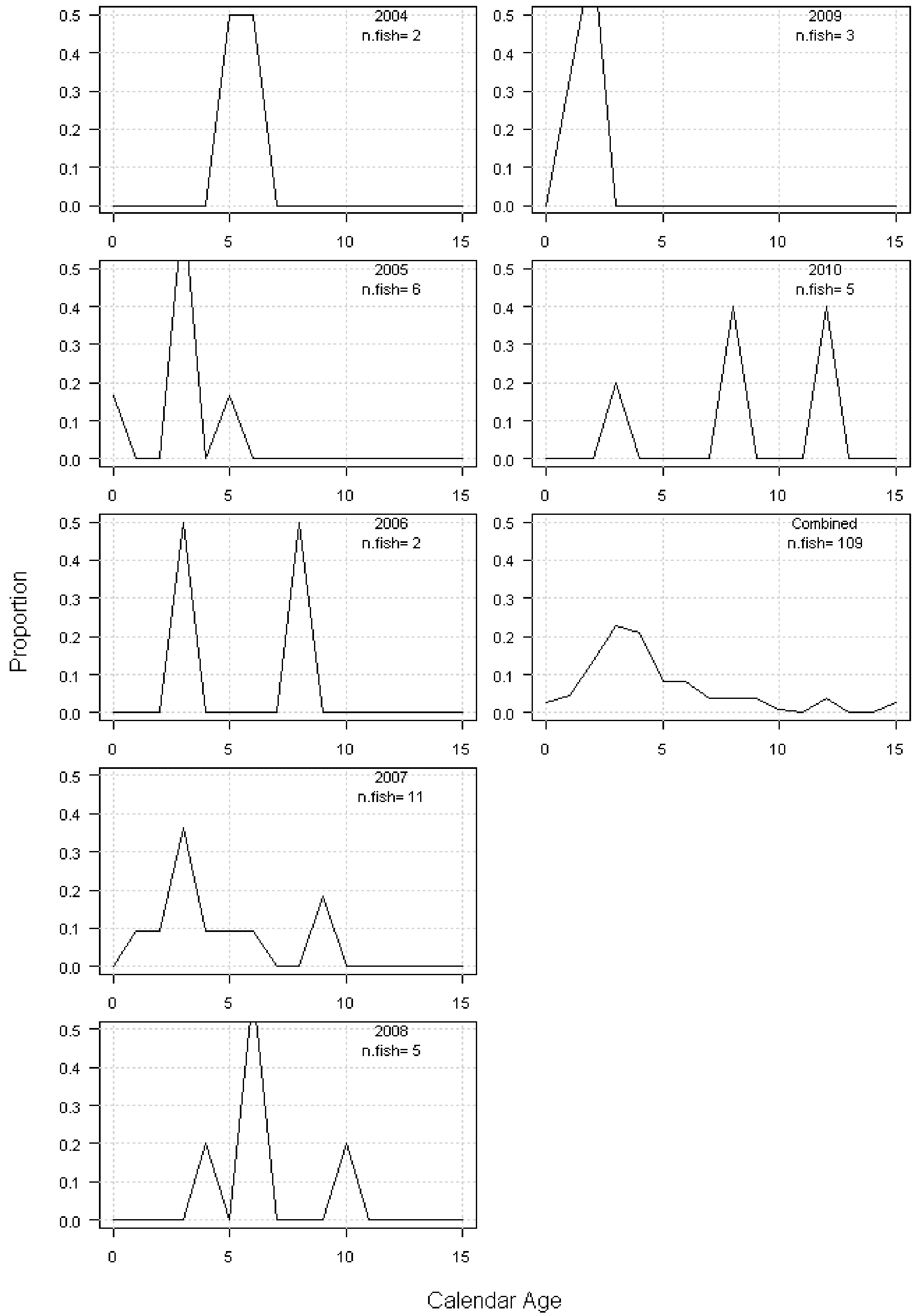

Handline 2006
n.fish= 23
n.trips= 13
Combined
n.trips= 223
n.fish= 424
Handline 2007
n.fish= 21
n.trips= 12
Handline 2008
n.fish= 75
n.trips= 33
Handline 2009
n.fish= 30
n.trips= 18
Handline 2010
n.fish= 7
n.trips= 7
Proportion
Fork Length (cm)

Figure 3.8. Relative age compositions of commercial age samples by year (n.fish = number of fish). These compositions are raw (unweighted). Last panel shows the age composition pooled across years.




2004
n.fish= 2
2009
n.fish= 3
2005
n.fish= 6
2010
n.fish= 5
2006
n.fish= 2
Combined
n.fish= 109
2007
n.fish= 11
2008
n.fish= 5
Proportion
Calendar Age

4 Recreational Fishery Statistics

4.1 Overview

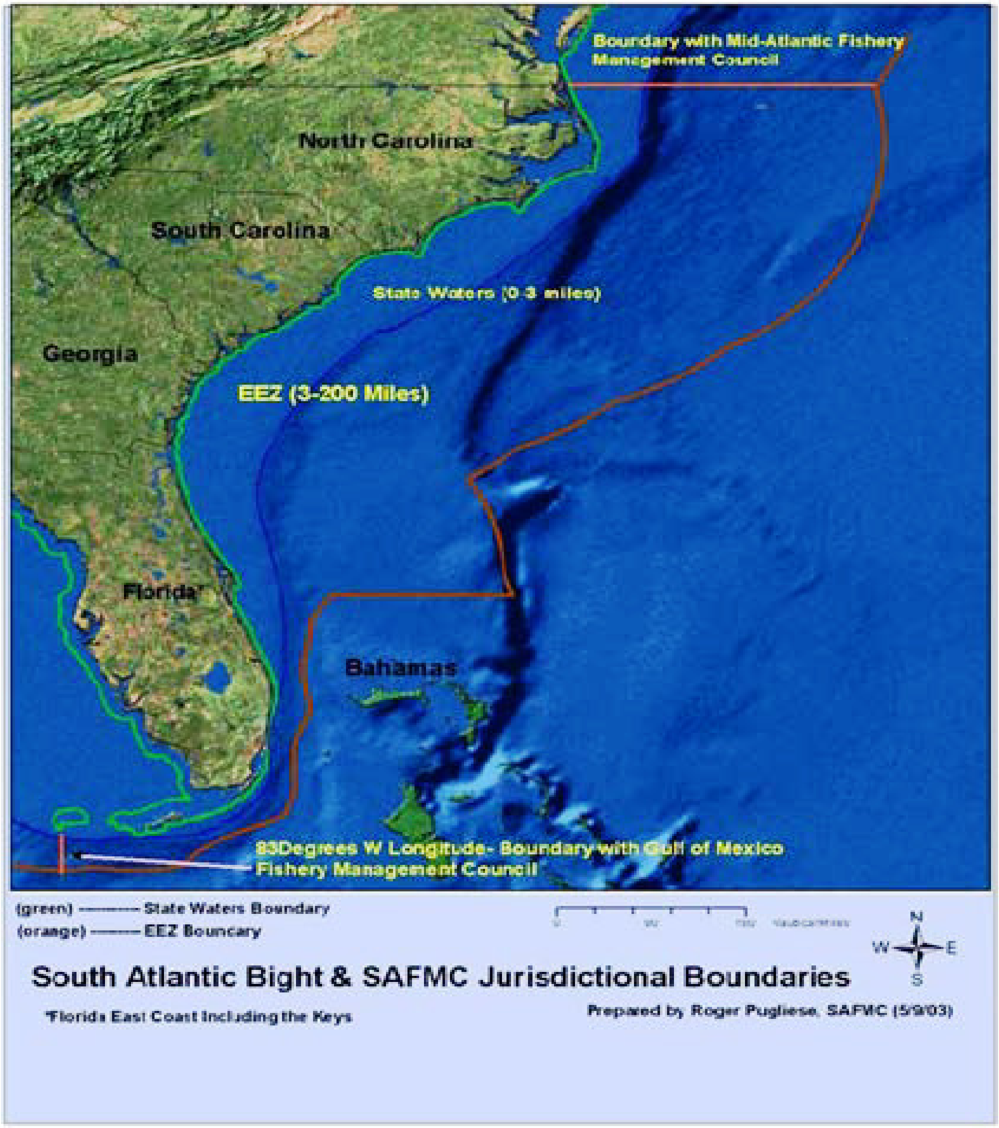
4.1.1 Group membership

Members- Ken Brennan (Leader South Atlantic\NMFS Beaufort), Julia Byrd (SCDNR), Kelly Fitzpatrick (NMFS Beaufort), Eric Hiltz (SCDNR), Robert Johnson (SAFMC Appointee\ Industry rep FL), Vivian Matter (Leader Gulf of Mexico\NMFS SEFSC), Bill Parker (SAFMC Appointee/Industry rep SC), Tom Ogle (SAFMC Appointee/Industry rep SC), Bob Zales (GMFMC Appointee/Industry rep FL).

4.1.2 Issues

1) Division of the stock between the Atlantic and Gulf of Mexico along the East Florida coast: may vary by data source depending on differing spatial resolutions of the datasets.
2) Headboat logbook forms did not include cobia on a universal form until 1984 in the South Atlantic.
3) Missing weight estimates for some recreational "cells" (i.e., specific year, state, fishing mode, wave combinations).
4) 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.
5) Charter boat landings: MRFSS charter survey methods changed in 2004 for Georgia and north.
6) Combined charter boat/headboat landings, 1981-1985: Official headboat landings are available from the SRHS. Therefore, the headboat component of the MRFSS combined charter boat/headboat mode must be parsed out.
7) Usefulness of historical data sources such as the 1960, 1965, and 1970 U.S. Fish and Wildlife Service (FWS) surveys to generate estimates of landings prior to 1981. Review whether other data sources are also available.
8) New MRIP weighted estimates are available for 2004-2011: Determine appropriate use of datasets to cover the entire period from 1981-2011.

4.1.3 South Atlantic Fishery Management Council Jurisdictional Boundaries



4.2 Review of Working Papers

SEDAR28-DW12, *Estimated conversion factors for calibrating MRFSS charter boat landings and effort estimates for the South Atlantic and Gulf of Mexico in 1981-1985 with For Hire Survey estimates with application to Spanish mackerel and cobia landings. Vivian M. Matter, Nancie Cummings, John Jeffrey Isely, Kenneth Brennan, and Kelly Fitzpatrick.*

This working paper presents correction factors to calibrate the traditional MRFSS charter boat/headboat combined mode estimates with the For-Hire Survey for 1981-1985. These calibration factors are based on equivalent units of effort and consistent methodologies across both sub regions.

SEDAR28-DW14, *Recreational Survey Data for Spanish Mackerel and Cobia in the Atlantic and the Gulf of Mexico from the MRFSS and TPWD Surveys. Vivian Matter*

This working paper presents recreational survey data for Spanish mackerel and cobia from the Marine Recreational Fishery Statistics Survey (MRFSS) and the Texas Parks and Wildlife Department (TPWD) surveys in the Atlantic and the Gulf of Mexico. Issues addressed include the allocation of the Spanish mackerel landings in the Keys into the Gulf of Mexico or Atlantic Ocean, the split of cobia landings along the east coast of Florida, the calibration of MRFSS charter boat estimates back in time, 1981-1985 adjustments and substitutions, MRIP vs MRFSS estimates for 2004-2011, and estimating recreational landings in weight from the surveys.

SEDAR28-DW24 *South Carolina Department of Natural Resources (SCDNR) Charter boat Logbook Program. Mike Errigo, Eric Hiltz and Julia Byrd.*

This working paper presents an index of abundance that was developed from the South Carolina Department of Natural Resources (SCDNR) charter boat logbook program for 1998-2010. The index of abundance developed is standardized catch per unit effort (CPUE; catch per angler hour) of cobia using a delta-GLM model. Three explanatory variables were used in the delta-GLM model (year, locale, and month). The analysis is meant to describe the population trends of fish caught by V1 (6-pack) charter vessels in estuarine, nearshore, and offshore waters operating in or off of South Carolina. These data represent 85,357 fishing trips where anglers caught 10,949 and harvested 4,896 cobia. The catch data presented in this working paper was further discussed by the Recreational Fisheries Working Group and the index was further discussed by the Indices Working Group.

SEDAR28-DW25, *South Carolina Department of Natural Resources (SCDNR) State Finfish Survey. Eric Hiltz and Julia Byrd*

This working paper presents a summary of the cobia catch, disposition, and size information collected through the South Carolina Department of Natural Resources (SCDNR) State Finfish Survey (SFS) from 1988 to 2011. 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) using a questionnaire and interview procedure similar to those of the intercept portion of the MRFSS. Prior to any analyses, all interviews of fishing parties participating in cobia fishing tournaments (or fishing parties assumed to be participating in cobia fishing tournaments) were removed to account for any biases. (From 2008, 2009, and 2011 a total of 33 interviews with 48 length measurements were removed from the dataset). From 1988-2011 a total of 452 fishing parties were interviewed where cobia were caught, representing between 0.06% - 3.09% of the total number of interviews in each year. Fishing parties interviewed through the SFS caught 700 cobia from 1988 to 2011. Of those fish, a total of 423 were harvested and 360 length measurements were obtained. The length frequency data presented in this working paper were further discussed by the Recreational Fisheries Working Group to potentially be used to supplement the MRFSS data for length compositions.

4.3 Recreational Landings

4.3.1 Marine Recreational Fisheries Statistics Survey (MRFSS)

Introduction

The Marine Recreational Fisheries Statistics Survey (MRFSS) provides a long time series of estimated catch per unit effort, total effort, landings, and discards for six two-month periods (waves) each year. The survey provides estimates for three recreational fishing modes: shore-based fishing (SH), private and rental boat fishing (PR), and for-hire charter and guide fishing (CH). 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.

The MRFSS survey covers coastal Atlantic states from Maine to Florida. The state of Florida is sampled as two sub-regions. The east Florida sub-region includes counties adjacent to the Atlantic coast from Nassau County south through Miami-Dade County, and the west Florida sub-region includes Monroe County (Florida Keys) and counties adjacent to the Gulf of Mexico. Separate estimates are generated for each Florida sub-region, and those estimates may be post-stratified into smaller regions based on proportional sampling. 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.

The MRFSS design incorporates three complementary survey methods for estimating catch and effort. Catch data are collected through angler interviews during dockside intercept surveys of recreational fishing trips after they have been completed. Effort data are collected using two telephone surveys. The Coastal Household Telephone Survey (CHTS) uses random digit dialing of coastal households to obtain detailed information about the previous two months of recreational fishing trips from the anglers. The weekly For-Hire Survey interviews charter boat operators (captains or owners) to obtain the trip information with only one-week recall period. These effort data and estimates are aggregated to produce the wave estimates. 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. Full survey documentation and ongoing efforts to review and improve survey methods are available on the MRFSS website at: http://www.st.nmfs.gov/st1/recreational.

Survey methods for the for-hire fishing mode have seen the most improvement over time. Catch rate data has improved through increased sample quotas and additional sampling (requested and funded by the states) to the intercept portion of the survey. It was also recognized that the random household telephone survey was intercepting relatively few anglers in the for-hire fishing mode and the For-Hire Telephone Survey (FHS) was developed to estimate effort in the for-hire mode. The new method draws a random sample of known for-hire charter and guide vessels each week and vessel operators are called and asked directly to report their fishing activity. The FHS was pilot tested in east Florida in 2000 and officially adopted in 2003. The FHS was then expanded to the rest of the Atlantic (GA and north) in 2005, wave 2. There is one unofficial year of FHS for this group of states from 2004, which has been used in SEDARs for other species (SEDAR 16 king mackerel).

A further improvement in the FHS method was the pre-stratification of Florida into smaller sub-regions for estimating effort. Pre-stratification defines the sample unit on a sub-state level to produce separate effort estimates by these finer geographical regions. The FHS sub-regions include three distinct regions bordering the Atlantic coast: Monroe County (sub-region 3), SE Florida from Dade through Indian River counties (sub-region 4), and NE Florida from Martin through Nassau counties (sub-region 5). The coastal household telephone survey method for the for-hire fishing mode continues to run concurrently with the newer FHS method.

Calibration of traditional MRFSS charter boat estimates
Conversion factors have been estimated to calibrate the traditional MRFSS charter boat estimates with the FHS for 1986-1997 in the Gulf of Mexico (SEDAR7-AW03, Diaz and Phares, 2004), for 1986-2003 in the South Atlantic (SEDAR16-DW15, Sminkey, 2008), and for 1981-2003 in the mid-Atlantic (SEDAR17 Data Workshop Report, 2008). 1986-2003 South Atlantic calibration factors were updated in 2011 (SEDAR25 Data Workshop Report, 2011). These calibration factors are tabulated in SEDAR 28-DW14. The relationship between the old charter boat method estimates of angler trips and the FHS estimates of angler trips was used to estimate the conversion factors. Since these factors are based on effort, they can be applied to all species' landings. In the Gulf of Mexico and South Atlantic, the period of 1981-1985 could not be calibrated with the same ratios developed for 1986+ because in the earlier 1981-1985 time period, MRFSS considered charter boat and headboat as a single combined mode in both regions. Thus, in order to properly calibrate the estimates from 1981-1985, headboat data from the Southeast Region Headboat Survey (SRHS) must be included in the analysis. To calibrate the MRFSS combined charter boat and headboat mode effort estimates in 1981-1985, conversion factors were estimated using 1986-1990 effort estimates from both modes, in equivalent effort units, and angler trip (SEDAR 28-DW12).

New MRIP weighted estimates
Revised catch and effort estimates, based on an improved estimation method, were released on January 25, 2012. These estimates are available for the Atlantic and Gulf Coasts for January 2004 through October 2011. This new estimation method, developed as part of the Marine Recreational Information Program (MRIP), provides more accurate data by removing potential biases that were included in the previous estimates. Since new MRIP estimates are only available for a portion of the recreational time series that the MRFSS covers, calibration factors between the MRFSS estimates and the MRIP estimates must be developed in order to maintain one consistent time series for the recreational estimates. To that end a calibration workshop is planned for the spring that will address this important data need.

Figure 4.12.1 shows the comparison of the MRIP and MRFSS estimates for 2004-2011. At the SEDAR 28 DW plenary, the MRFSS estimates were identified as the best available data for 1981-2003. The MRIP estimates were identified as the best available data for 2004-2011. If the calibration workshop is able to produce correction factors that can be applied to the data in time for the SEDAR 28 Assessment Workshop in May, then these correction factors will be used to adjust the MRFSS estimates from 1981-2003. If the calibration workshop is not able to produce results in time then MRFSS estimates will be used from 1981-2003 and MRIP estimates will be used from 2004-2011.

Division of stock along East Florida coast
The MRFSS Florida estimates can be post-stratified into finer scale geographical regions. Post-stratification proportionally distributes the state-wide (FLE and FLW) effort into finer scale sub-regions and then produces effort estimates at this finer geographical scale. This is needed for the private and shore modes (all years) and charter boat mode (prior to FHS). FHS charter boat mode estimates are already pre-stratified, as discussed above. East Florida can be post-stratified into two Florida sub-regions: SE Florida from Dade through Indian River counties (sub-region 4) and NE Florida from Martin through Nassau counties (sub-region 5). It was decided at the SEDAR 28 DW plenary to split the stock at the Georgia/Florida border. Therefore, no post-stratified estimates are required. Official MRFSS East Florida estimates are included in the Gulf of Mexico stock.

Separation of SA combined charter/headboat mode
In the South Atlantic, 1981-1985 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 MRFSS combined charter/headboat mode must be split in order to not double estimate the headboat mode for these years. MRFSS charter/headboat mode was split in these years by using a ratio of SRHS headboat angler trip estimates to MRFSS charter boat angler trip estimates for 1986-1990. A similar method (using landings data instead of effort data) has been used in the past (SEDAR 25- black sea bass). The mean ratio was calculated by state (or state equivalent to match SRHS areas to MRFSS 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 MRFSS charter/headboat mode was split for all years 1981-1985 and the headboat component was deleted from the MRFSS dataset to avoid duplication with the SRHS.

Missing cells in MRFSS weight estimates
MRFSS landings estimates in weight must be treated with caution due to the occurrence of missing fish mean weight estimates in some strata. MRFSS weight estimates are calculated by multiplying the estimated number harvested in a cell (year/wave/state/mode/area/species) by the mean weight of the measured fish in that cell. When there are no fish measured in the cell (fish were gutted or too big for the sampler to weigh, harvest was all self-reported, etc.) estimates of landings in number are provided but there are no corresponding estimates of landings in weight.

The MRFSS cobia estimates of landings in weight are used when provided by the survey. In cases where there is an estimate of landings in number but not weight, the Southeast Fisheries Science Center has used the MRFSS sample data to obtain an average weight using the following hierarchy: species, region, year, state, mode, and wave (SEDAR 22-DW-16). The minimum number of weights used at each level of substitution is 30 fish, except for the final species level, where the minimum is one fish. In some cases, the MRFSS sample data records length, but not weight. These lengths were converted to weights using length weight equations developed by the Life History Working Group. These converted weights were used only in cases where having these additional converted weights would increase the number of weights available at each hierarchy level to meet the 30 fish minimum. 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 MRFSS/MRIP landings estimates are shown in tables 4.11.1 and 4.11.2 by year and mode and in Figure 4.12.2.

Maps
Figures 4.12.3, 4.12.4, and 4.12.5 show the number of cobia intercepted by the MRFSS from 1981-1989, 1990-1999, and 2000-2010 respectively. Numbers of fish mapped are intercepted by the survey as an A fish (seen by the interviewer) or a B1 fish (reported dead but not seen by the interviewer). Latitude and longitudes of the intercept site are mapped when available; otherwise, the mid-point of the county of intercept is mapped. Intercepted fish are shown for the Gulf of Mexico and Atlantic Ocean.

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. Due to headboat area definitions and confidentiality issues, Georgia and South Carolina landings must be combined. The SRHS began in the Gulf of Mexico in 1986 and extends from Naples, FL to South Padre Island, TX. The South Atlantic and Gulf of Mexico Headboat Surveys generally include 70-80 vessels participating in each region annually.

The Headboat Survey incorporates two components for estimating catch and effort. 1) Information about the size of fishes 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 was routinely written in by captains, this was evident by examining numerous logbooks from 1980 to 1983, this 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. MFRSS headboat landings will be used 1981-1983.

Option 2: Use estimated headboat landings based on available logbook data 1981- 2010.

Decision: Option 2

Catch Estimates
Final SRHS landings estimates are shown in Table 4.11.3. by year and state, and in Figure 4.12.6. SRHS areas 1-6 and 9-10 are included in the Atlantic cobia stock. Figures 4.12.7, 4.12.8, 4.12.9, and 4.12.10 show the South Atlantic reported cobia headboat landings from 1973-1979, 1980-1989, 1990-1999, and 2000-2011 respectively. Reported headboat landings of cobia in the South Atlantic in the 1970's were concentrated between Cape Lookout and Cape Fear, NC. However, from the 1980's to present reported landings were spread throughout North and South Carolina, with few reported landings in Georgia.

4.3.3 Historic Recreational Landings

Introduction
The historic recreational landings time period is defined as pre-1981 for the charter boat, 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 other potential historical sources and methods to compile landings of cobia prior to the available time series of MRFSS and headboat estimated landings.

The sources of historical landings that were reviewed for potential use are as follows:

- Salt Water Angler Surveys (SWAS), 1960, 1965 &1970.
- The U.S Fish and Wildlife Service (USFWS), 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation Survey (FHWAR).

SWAS
During the SEDAR 28 data workshop the RWG reviewed the Salt Water Angler Surveys (SWAS) from 1960, 1965 &1970. Cobia was not listed on the SWAS for the South Atlantic until 1970. Cobia estimates in 1970 SWAS were subject to a one year recall bias, similar to the 1960 and 1965 SWAS. Completed interview records were obtained from 1,947 persons classified as substantial saltwater anglers, this represented only 0.00021% of the total estimated saltwater anglers in the United States in 1970.

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 conduct 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 South 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 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 South Atlantic from the MRFSS 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).

A bootstrap analysis was used to capture the range of uncertainty in the historic recreational catch estimates. More specifically, the historic catch estimates are based on the average CPUE and the ratio of MRFSS effort to historic effort estimates. These two quantities were bootstrapped 200 times using the empirical estimates that went into each of them. The 5th and 95th percentiles were then computed from the distribution of bootstrap estimates to characterize the uncertainty (Figure 4.12.11).

Issue: Available historical cobia landings limited 1950-1980.

Option 1: Use the Adjusted SWAS estimates.

Option 2: Use average ratio from entire time series (1981-2010) applied to commercial landings to estimate recreational landings (1950-1980).

Option 3: Use available recreational time series for the MRFSS\MRIP and headboat estimates 1981- 2010.

Option 4: Total cobia landings using the FHWAR census method (South Atlantic 1955-1980) are presented with the total estimated cobia landings (MRFSS/MRIP and SRHS landings) (South Atlantic 1981-2011) in Table 4.11.5 and Figure 4.12.12.

Decision: *Option 4*

4.3.4 Potential Sources for Additional Landings Data

SCDNR Charter boat Logbook Program Data, 1993 – 2011
The Recreational Fisheries Working Group discussed the possibility of replacing the MRFSS charter mode estimates for South Carolina from 1993 to 2011 with the SCDNR Charter boat Logbook Program estimates. The SCDNR Charter boat Logbook Program is a mandatory logbook program and is a complete census. However, the data is self-reported and no field validation is done on catch or effort. SCDNR charter boat logbook data were compared with MRFSS charter mode estimates (Figure 4.12.13). The Recreational Fisheries Working Group recommended not replacing the MRFSS/MRIP charter boat estimates with the SCDNR Charter boat Logbook Program estimates for 1993 – 2011. The MRFSS estimates represent a longer time series and concern was expressed about replacing the MRFSS/MRIP dataset with the SCDNR Charterboat logbook dataset because the data would only be replaced for one state (SC) and one mode (charter). Additionally since MRFSS/MRIP estimates are currently used to monitor annual catch limits (ACL's), the group thought it would be appropriate to use these estimates for the recreational landings data.

4.4 Recreational Discards

4.4.1 MRFSS discards

Discarded live fish are reported by the anglers interviewed by the MRFSS so both the identity and quantities reported are unverified. Discarded fish size is unknown for all modes of fishing covered by the MRFSS. 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 Beaufort, NC Logbook program (SRHS) produces estimates of total discards in the headboat fishery since that class of caught fish was added to their logbook (2004). All estimates of live released fish (B2 fish) in charter or charter boat/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 MRFSS. Final MRFSS/MRIP discard estimates are shown in Table 4.11.6 by year and mode and in Figure 4.12.14.

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 MRFSS At-Sea Observer Headboat program, it was determined that the logbook discard data would be used from 2004-2011. The RWG further concluded that a proxy should be used to estimate the headboat cobia discards for previous years. The RWG considered the following three possible data sources to be used as a proxy for estimated headboat discards for 1981-2003 (Figure 4.12.15).

- MRFSS charter boat discard estimates (corrected for FHS adjustment) applied– Extend back to 1981.
- MRFSS private boat discard ratio estimates– Extend back to 1981 and follows the pattern exhibited in the Southeast Region Headboat Survey in later years.

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

Option 1: Apply the MRFSS charter boat discard:landings ratio to estimated headboat landings in order to estimate headboat discards from 1981-2003.
Option 2: Apply the MRFSS private boat discard:landings ratio to estimated headboat landings in order to estimate headboat discards from 1981-2003.
Option 3: Calculate a ratio of the mean ratio of SRHS discard:landings (2004-2011) to the mean ratio of MRFSS CH discard:landings (2004-2011). Apply this ratio to the yearly MRFSS charter boat discard:landings ratio (1981-2003) in order to estimate 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).

- Decision: **Option 3:** Calculate a ratio of the mean ratio of SRHS discard:landings (2004-2010) to the mean MRFSS CH discard:landings ratio (2004-2010). Apply this ratio to the yearly MRFSS charter boat discard:landings ratio (1981-2003) in order to estimate 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). The MRFSS charter boat discard estimates followed the pattern exhibited in the Southeast Region Headboat Survey in later years. Because the MRFSS charter boat discard ratio was greater than the SRHS discard ratio, using the MRFSS charter boat ratio without the adjustment described in Option 3 could result in overestimating the SRHS discards. The resulting discard estimates for headboats from 1981 to 2003 are represented in Table 4.11.7. The final estimated headboat discard estimates 1981-2011 as well as the discards:landings ratio are presented in Figure 4.12.16.

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, and the east coast of Florida is further stratified into northern and southern sample regions. 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, and the release condition of discarded fish (FL only). Data are also collected on the length of the trip, area fished (inland, state, and federal waters) and, in Florida, the minimum and maximum depth fished. In the Florida Keys (sub-region 3) some vessels that run trips that span more than 24 hours are also sampled to collect information on trips that fish farther offshore and for longer durations, primarily in the vicinity of the Dry Tortugas. Due to low cobia sample sizes the MRFSS At-Sea Observer data was not used in this assessment.

4.4.4 Alternatives for characterizing discards

Due to low cobia sample sizes in the MRFSS At-Sea Observer data it was concluded that the headboat logbook discard estimates should be used from 2004-2011 for the South Atlantic headboat fishery. Further, the group decided to use the charter mode as a proxy to calculate headboat discards for 1981-2003, since the discard rates from the longer time series of MRFSS reflect historic changes in discard rates. These rates include the impacts from changes in recreational size limits and bag limits for cobia over time.

4.5 Biological Sampling

4.5.1 Sampling Intensity Length/Age/Weight

MRFSS Charter, Private, and Shore

The MRFSS' 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 center line (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 MRFSS assignments because of concerns over the introduction of bias to survey data collection.

The number of cobia measured or weighed in the Atlantic (NY-GA) in the MRFSS 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 in the Atlantic (NY-GA) in the MRFSS 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. The number of MRFSS intercept trips conducted in the Atlantic (NY-GA) and the percentage of intercepts that encountered cobia are summarized by year and mode in Table 4.11.14. Dockside mean weights of cobia weighed from the MRFSS in the Atlantic (NY-GA) are tabulated for 1981-2011 in Table 4.11.15.

Headboat Survey Biological Sampling
Lengths were collected from 1972 to 2011 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 for the entire range of Atlantic waters along the 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 4.11.16. The number of cobia aged from the headboat fleet by year and state are summarized in Table 4.11.17. Dockside mean weights for the headboat fishery are tabulated for 1973-2010 in Table 4.11.18.

SCDNR State Finfish Survey (SFS)
Cobia lengths were collected through the SCDNR State Finfish Survey (SFS) from 1988 to 2011. 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) using a questionnaire and interview procedure similar to the intercept portion of the MRFSS. From 1988 through March 2009 mid-line lengths were measured and from April 2009 to 2011 total lengths were measured. From 1988 to 2011 360 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 MRFSS length data for length compositions. Total length measurements from 2009-2011 were converted to fork length measurements using the following equation derived by the Life History Working Group for the South Atlantic stock at the SEDAR 28 data workshop:

$FL = 13.52399 + 0.87867TL$ ($N = 4635$, $R^2 = 0.9855$)

Summarized length data from 1988 – 2011 can be found in Table 4.11.19.

Aging data
The number of cobia aged from the SRHS by year and state is summarized in Table 4.11.17. Age samples collected from the private/rental boat, charter boat, and shore modes are not typically collected as part of the MRFSS sampling protocol. These samples come from a number of sources including state agencies, special projects, and sometimes as add-ons to the MRFSS survey. The number of cobia aged from the charter boat fleet by year and state is summarized in Table 4.11.20. The number of cobia aged from the private fleet by year and state is summarized in Table 4.11.21. The number of cobia aged from the recreational fishery (mode unknown) by year and state is summarized in Table 4.11.22. 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.

4.5.2 Length – Age distributions

MRFSS and SCDNR SFS Length Frequency Analysis Protocol
The angler intercept survey is stratified by wave (2-month period), state, and fishing mode (shore, charter boat, party boat, private or rental boat) so simple aggregations of fish lengths across strata cannot be used to characterize a regional, annual length distribution of landed fish; a weighting scheme is needed to representatively include the distributions of each stratum value. The MRFSS' angler intercept length frequency analysis produces unbiased estimates of length-class frequencies for more than one stratum by summing respectively weighted relative length-class frequencies across strata. The steps used are:

1) Output a distribution of measured fish among state/mode/wave strata,
2) Output a distribution of estimated catch among state/mode/wave strata,
3) Calculate and output relative length-class frequencies for each state/mode/wave stratum,
4) Calculate appropriate relative weighting factors to be applied to the length-class frequencies for each state/mode/wave stratum prior to pooling among strata,
5) Sum across strata as defined, e.g., annual, sub-region length frequencies, by year in 1-cm length bins.
6) Convert to annual proportion in each size bin (Figure 4.12.17).

Lengths were taken from the MRFSS (charter boat, private/rental boat, and shore modes) during 1981 to 2011. Lengths were taken from the SCDNR SFS during 1988 to 2011. The number of vessel trips sampled were not available from the MRFSS. However, the number of trips sampled in the SCDNR SFS are vessel trips. Therefore the total number of trips with cobia length measurements taken is an amalgam of vessel and angler trips during 1988 to 2011.

Southeast Region Headboat Survey Length Frequency Analysis Protocol
Headboat landings (1981to 2011) were pooled across five time intervals (Jan-May, Jun, July, Aug, Sep-Dec) because landings were not estimated by month until 1996. Spatial weighting was developed by region for the headboat survey by pooling landings by region; NC, SC, and GA. For each measured fish a landings value was assigned based on month of capture and region. The landings associated with each length measurement were summed by year in 1-cm length bins. These landings are typically then converted to annual proportion in each size bin (Figure 4.12.18).

Recreational Age Frequency
Due to low age sample sizes in the headboat sector unweighted age compositions were calculated for the entire recreational fishery. (Figure 4.12.19, see SEDAR 28 data summary workbook for data). Ages 0-16 were plotted.

4.6 Recreational Catch-at-Age/Length; directed and discard

Catch at age is handled within the assessment model and does not require discussion or presentation here.

4.7 Recreational Effort

4.7.1 MRFSS Recreational & Charter Effort

Effort estimation for the recreational fishery surveys are produced via telephone surveys of both anglers (private/rental boats and shore fishers) and for-hire boat operators (charter boat anglers, and in early years, party or charter anglers). 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 4.11.23 and 4.11.24 by year and mode. An angler-trip is a single day of fishing in the specified mode, not to exceed 24 hours.

Figures 4.12.20, 4.12.21, and 4.12.22 show the number of angler trips that intercepted cobia from the MRFSS from 1981-1989, 1990-1999, and 2000-2010 respectively. Latitude and longitudes of the intercept site are mapped when available; otherwise, the mid-point of the county of intercept is mapped. Intercepted trips that caught cobia are shown for the Gulf of Mexico and Atlantic Ocean.

4.7.2 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 all available information. This information is used to provide estimates of total catch by month and area, along with estimates of effort.

SRHS areas 1-6 and 9-10 are included in the Atlantic cobia stock. Figures 4.12.23, 4.12.24, 4.12.25, and 4.12.26 show the South Atlantic reported cobia trips from 1973-1979, 1980-1989, 1990-1999, and 2000-2011 respectively. Reported cobia positive headboat trips in the South Atlantic in the 1970's were concentrated between Cape Lookout and Cape Fear, NC. However, from the 1980's to present reported cobia positive headboat trips were spread throughout North and South Carolina, with few reported trips in Georgia.

Estimated headboat angler days have decreased in the South Atlantic in recent years (Table 4.11.25). 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.

4.8 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 the charter and headboat sector.

4.9 Literature Cited

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4.10 Tables

Table 4.11.1. Atlantic (NY-GA) cobia landings (numbers of fish and whole weight in pounds) for charter boat mode and charter boat/headboat mode (MRFSS, NMFS, 1981-2003; MRIP, NMFS, 2004-2011). 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. 2011 data is preliminary and through October.

	Estimated CH Landings			Estimated CH/HB Landings		
YEAR	Number	CV	Pounds	Number	CV	Pounds
1981	0	0.00	0	0	0.00	0
1982	0	0.00	0	0	0.00	0
1983	0	0.00	0	150	1.11	4,375
1984	343	1.22	6,438	0	0.00	0
1985	891	1.65	19,831	7,058	0.71	95,590
1986	7,271	0.60	134,153	1,472	0.58	11,068
1987	737	0.40	16,176	0	0.00	0
1988	779	0.48	17,123	0	0.00	0
1989	262	0.85	3,120	105	0.87	347
1990	629	0.39	9,457	0	0.00	0
1991	1,555	0.95	29,056	971	0.65	35,176
1992	1,507	0.33	31,456	0	0.00	0
1993	3,850	0.40	96,818	0	0.00	0
1994	370	0.36	9,222	0	0.00	0
1995	5,037	0.50	114,050	0	0.00	0
1996	6,381	0.76	115,158	0	0.00	0
1997	2,793	0.59	72,617	0	0.00	0
1998	4,757	0.37	150,576	0	0.00	0
1999	1,132	0.57	50,298	0	0.00	0
2000	824	0.56	27,111	0	0.00	0
2001	1,555	0.51	47,360	0	0.00	0
2002	1,804	0.48	53,966	108	1.08	5,095
2003	3,077	0.42	50,015	74	1.08	2,154
2004	2,756	0.38	93,962			
2005	2,137	0.47	71,734			
2006	1,491	0.60	63,733			
2007	2,307	0.46	61,486			
2008	1,072	0.77	27,271			
2009	1,051	0.44	26,641			
2010	3,648	0.34	121,353			
2011	1,026	0.48	29,866			

Table 4.11.2. Atlantic (NY-GA) cobia landings (numbers of fish and whole weight in pounds) for private/rental boat mode and shore mode (MRFSS, NMFS, 1981-2003; MRIP, NMFS, 2004-2011). 2011 data is preliminary and through October.

	Estimated PR Landings			Estimated SH Landings		
YEAR	Number	CV	Pounds	Number	CV	Pounds
1981	4,364	0.71	11,189	0	0.00	0
1982	6,969	0.46	113,554	0	0.00	0
1983	687	1.00	20,894	0	0.00	0
1984	11,284	0.42	383,565	0	0.00	0
1985	10,769	0.28	204,223	0	0.00	0
1986	15,936	0.35	361,911	5,364	1.00	98,941
1987	5,685	0.26	94,248	3,439	0.69	60,681
1988	7,896	0.26	155,207	397	1.00	14,170
1989	13,034	0.17	290,999	987	0.49	28,587
1990	14,029	0.19	233,744	0	0.00	0
1991	17,304	0.30	563,413	2,124	0.35	69,405
1992	12,469	0.22	350,236	747	0.58	19,419
1993	5,933	0.36	140,623	475	1.00	13,383
1994	8,286	0.25	261,823	807	0.72	19,500
1995	9,613	0.34	278,310	1,394	0.52	46,786
1996	18,995	0.35	560,745	195	1.00	5,520
1997	9,002	0.37	340,841	3,896	1.00	167,045
1998	7,329	0.30	226,514	226	1.00	9,052
1999	10,993	0.30	306,591	302	1.00	9,160
2000	12,694	0.43	432,743	0	0.00	0
2001	11,466	0.34	418,739	367	1.00	11,874
2002	5,025	0.37	199,264	3,123	0.62	117,357
2003	25,017	0.30	547,700	622	1.00	13,115
2004	26,510	0.40	927,873	0	0.00	0
2005	20,137	0.42	703,995	6,827	0.82	35,743
2006	29,818	0.38	1,164,948	0	0.00	0
2007	22,469	0.35	704,483	0	0.00	0
2008	15,127	0.42	466,875	1,024	0.71	45,240
2009	23,379	0.26	640,422	1,645	0.71	41,832
2010	22,987	0.19	745,214	323	1.01	6,411
2011	8,801	0.33	265,025	1,448	0.68	37,314

Table 4.11.3. Estimated headboat landings of cobia in the South Atlantic 1981-2011. Due to headboat area definitions and confidentiality issues, Georgia and South Carolina landings must be combined.

	North Carolina		South Carolina/ Georgia	
Year	Number	Weight (lbs)	Number	Weight (lbs)
1981	85	1,565	-	-
1982	37	644	13	227
1983	44	1,308	13	228
1984	43	1,077	25	626
1985	16	357	32	713
1986	53	910	55	821
1987	43	710	97	1,601
1988	82	1,984	82	1,796
1989	79	1,535	70	1,477
1990	154	4,403	49	1,319
1991	203	3,856	160	3,126
1992	201	4,505	101	2,231
1993	116	2,243	114	2,486
1994	180	3,512	118	2,300
1995	184	3,896	147	3,110
1996	46	1,347	76	2,192
1997	91	2,179	216	5,117
1998	51	1,286	200	4,907
1999	48	971	113	2,342
2000	66	1,397	141	2,985
2001	95	2,190	156	3,764
2002	75	1,739	197	4,428
2003	48	1,040	69	1,496
2004	82	2,552	125	3,843
2005	83	1,857	101	2,271
2006	40	808	96	1,925
2007	32	544	574	9,666
2008	32	775	203	6,136
2009	5	90	148	2,836
2010	20	492	116	3,036
2011	19	332	104	1,869

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	0.0004	1.29	7,793,267	3,048
1960	80,602,000	0.29	7,712,294	0.0004	1.29	9,939,565	3,887
1965	95,837,000	0.33	10,201,818	0.0004	1.29	13,148,051	5,142
1970	113,694,000	0.33	12,305,878	0.0004	1.29	15,859,752	6,202
1975	167,499,000	0.33	17,679,316	0.0004	1.29	22,785,012	8,910
1980	164,040,000	0.32	16,783,303	0.0004	1.29	21,630,235	8,459
1985	171,055,000	0.33	18,099,435	0.0004	1.29	23,326,458	9,122

Table 4.11.5. Estimated cobia landings (number) using FHWAR census method (1955-1984), MRFSS (1985-2003), and MRIP (2004-2011) estimation methods.

Year	Estimated landings (n)	Year	Estimated landings (n)
1955	978	1984	11,695
1956	1,032	1985	18,766
1957	1,086	1986	30,151
1958	1,140	1987	10,001
1959	1,194	1988	9,236
1960	1,248	1989	14,536
1961	1,328	1990	14,861
1962	1,409	1991	22,316
1963	1,490	1992	15,025
1964	1,570	1993	10,488
1965	1,651	1994	9,760
1966	1,719	1995	16,375
1967	1,787	1996	25,693
1968	1,855	1997	15,997
1969	1,923	1998	12,563
1970	1,991	1999	12,588
1971	2,165	2000	13,725
1972	2,339	2001	13,639
1973	2,513	2002	10,332
1974	2,687	2003	28,906
1975	2,861	2004	29,473
1976	2,832	2005	29,285
1977	2,803	2006	31,445
1978	2,774	2007	25,382
1979	2,745	2008	17,458
1980	2,716	2009	26,228
1981	4,449	2010	27,094
1982	7,019	2011	11,398
1983	894		

Table 4.11.6. Atlantic (NY-GA) cobia discards for the recreational fishing modes by year (MRFSS, NMFS, 1981-2003; MRIP, NMFS, 2004-2011). 2011 data is preliminary and through October. 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. 2011 data is preliminary and through October.

	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	0	0.00			0	0.00	0	0.00
1982	0	0.00	0	0.00			0	0.00	0	0.00
1983	0	0.00	0	0.00			0	0.00	1,423	1.00
1984	0	0.00	0	0.00			0	0.00	2,612	1.00
1985	0	0.00	394	1.08			4,628	0.47	14,860	0.58
1986	0	0.00	0	0.00			8,422	0.78	0	0.00
1987	0	0.00	0	0.00			920	0.59	0	0.00
1988	228	0.70	0	0.00			5,766	0.34	0	0.00
1989	625	1.02	0	0.00			2,618	0.66	760	0.71
1990	0	0.00	0	0.00			6,084	0.44	316	1.00
1991	144	0.77	1,049	0.80			17,082	0.32	4,487	0.36
1992	46	1.07	0	0.00			5,265	0.41	1,237	0.65
1993	129	1.07	0	0.00			2,041	0.72	480	1.00
1994	56	1.14	1,525	0.60			7,241	0.31	4,052	0.42
1995	1,659	0.90	0	0.00			5,288	0.46	1,099	0.59
1996	431	0.69	0	0.00			3,432	0.34	196	1.00
1997	0	0.00	0	0.00			4,803	0.30	6,182	0.39
1998	1,808	0.46	0	0.00			11,042	0.38	3,100	0.55
1999	0	0.00	0	0.00			21,540	0.26	7,014	0.47
2000	330	0.55	0	0.00			9,886	0.34	2,270	0.61
2001	0	0.00	0	0.00			16,623	0.26	2,662	0.60
2002	158	1.05	707	0.59			13,992	0.29	1,461	0.52
2003	719	0.89	0	0.00			31,901	0.28	9,196	0.43
2004	5,798	0.53			40	0.99	14,752	0.29	926	0.78
2005	1,115	0.36			0	0.00	22,833	0.32	5,253	0.64
2006	489	0.71			0	0.00	42,888	0.33	0	0.00
2007	139	0.88			0	0.00	27,884	0.54	1,414	0.61
2008	703	0.38			0	0.00	12,231	0.30	3,296	0.50
2009	948	0.83			0	0.00	22,065	0.34	6,282	0.36
2010	1,557	0.62			0	0.00	22,685	0.24	8,514	0.47
2011	683	0.47			0	0.00	20,725	0.26	6,605	0.44

Table 4.11.7. Estimated South Atlantic cobia discards for SRHS by year and state.† Due to headboat area definitions and confidentiality issues, Georgia and South Carolina landings must be combined.

Year	North Carolina	South Carolina/Georgia	South Atlantic
1981	-	-	-
1982	-	-	-
1983	-	-	-
1984	-	-	-
1985	-	-	-
1986	-	-	-
1987	-	-	-
1988	-	5	5
1989	-	-	-
1990	-	-	-
1991	55	-	55
1992	-	3	3
1993	1	-	1
1994	10	-	10
1995	5	16	22
1996	1	2	3
1997	-	-	-
1998	6	74	79
1999	-	-	-
2000	-	130	130
2001	-	-	-
2002	4	-	4
2003	1	243	243
2004	2	14	16
2005	-	10	10
2006	-	12	12
2007	-	36	36
2008	-	22	22
2009	5	157	162
2010	-	151	151
2011	3	28	31

†1981-2003 HB mode uses MRFSS CH discard ratio.

Table 4.11.8. Number of cobia measured or weighed in the Atlantic (NY-GA) in the MRFSS charter fleet by year and state.

YEAR	GA	SC	NC	VA	MD	TOTAL
1984		2				2
1985		3				3
1986			1	1	1	3
1987	10		4			14
1988	1	4	1			6
1989			3	1	1	5
1990			8			8
1991		1	3	1		5
1992		1	9			10
1993			10			10
1994			5			5
1995		2	12			14
1996		2	26			28
1997	1	2	8			11
1998		1	22			23
1999			3			3
2000			7			7
2001			5			5
2002	2		3	1		6
2003	1		12			13
2004	1	4	13			18
2005			8	1		9
2006	1		3			4
2007	4		5			9
2008	1	1	2			4
2009	2	1	3	2		8
2010	2	2	35	3	1	43
2011	1		17			18
Grand Total	27	26	228	10	3	294

Table 4.11.9. Number of cobia measured or weighed in the Atlantic (NY-GA) in the MRFSS private fleet by year and state.

YEAR	GA	SC	NC	VA	MD	TOTAL
1981			1	1		2
1982	3	2	1			6
1983	2					2
1984	2	3	2			7
1985	6	3		11		20
1986	3	4	5	9		21
1987	2		7	1		10
1988		4	8			12
1989	1	10	15	4		30
1990	1	5	20	4		30
1991		3	9	3	1	16
1992	1	4	10	10		25
1993			5	4		9
1994		1	13	10		24
1995			10	5		15
1996	1	1	10	5		17
1997		1	12	3		16
1998		3	5	4		12
1999		8	1	5	1	15
2000			4	6		10
2001			6	11		17
2002			9	2		11
2003		9	6	3	1	19
2004		3	13	3		19
2005		1	21	5		27
2006		1	9	5		15
2007	1		3	12		16
2008	7	1	2	2		12
2009		4	4	9		17
2010	3	3	24	8		38
2011	4		6	2		12
Grand Total	37	74	241	147	3	502

Table 4.11.10. Number of cobia measured or weighed in the Atlantic (NY-GA) in the MRFSS shore mode by year and state.

YEAR	SC	NC	VA	TOTAL
1986		1		1
1987	1	2		3
1988		1		1
1989		3		3
1991		8		8
1992		2		2
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		4
2003		1		1
2005		2	1	3
2008		1	1	2
2009		1		1
2010		1		1
2011		4		4
Grand Total	1	42	3	46

Table 4.11.11 Number of angler trips with measured or weighed cobia in the Atlantic (NY-GA) in the MRFSS charter fleet by year and state.

YEAR	GA	SC	NC	VA	MD	TOTAL
1984		2				2
1985		3				3
1986			1	1	1	3
1987	6		4			10
1988	1	3	1			5
1989			3	1	1	5
1990			5			5
1991		1	3	1		5
1992		1	8			9
1993			7			7
1994			4			4
1995		1	9			10
1996		2	12			14
1997	1	2	5			8
1998		1	7			8
1999			1			1
2000			4			4
2001			4			4
2002	2		2	1		5
2003	1		8			9
2004	1	3	7			11
2005			3	1		4
2006	1		2			3
2007	3		4			7
2008	1	1	2			4
2009	1	1	3	2		7
2010	2	2	17	1	1	23
2011	1		9			10
Grand Total	21	23	135	8	3	190

Table 4.11.12. Number of angler trips with measured or weighed cobia in the Atlantic (NY-GA) in the MRFSS private fleet by year and state.

YEAR	GA	SC	NC	VA	MD	TOTAL
1981			1	1		2
1982	3	2	1			6
1983	1					1
1984	2	3	1			6
1985	3	3		9		15
1986	1	4	5	8		18
1987	2		7	1		10
1988		4	8			12
1989	1	8	13	4		26
1990	1	5	18	3		27
1991		3	9	3	1	16
1992	1	4	9	5		19
1993			5	4		9
1994		1	11	7		19
1995			9	5		14
1996	1	1	8	5		15
1997		1	8	3		12
1998		3	4	4		11
1999		6	1	4	1	12
2000			4	4		8
2001			6	8		14
2002			6	2		8
2003		8	6	3	1	18
2004		3	8	2		13
2005		1	9	5		15
2006		1	7	5		13
2007	1		3	11		15
2008	3	1	2	2		8
2009		3	4	9		16
2010	2	3	20	7		32
2011	4		4	2		10
Grand Total	26	68	197	126	3	420

Table 4.11.13. Number of angler trips with measured or weighed cobia in the Atlantic (NY-GA) in the MRFSS shore fleet by year and state.

YEAR	SC	NC	VA	TOTAL
1986		1		1
1987	1	2		3
1988		1		1
1989		3		3
1991		8		8
1992		2		2
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		4
2003		1		1
2005		2	1	3
2008		1	1	2
2009		1		1
2010		1		1
2011		4		4
Grand Total	1	42	3	46

Table 4.11.14. Number of MRFSS intercept angler trips conducted in the Atlantic (NY-GA) by year and mode with the percentage of intercepts that encountered cobia.

	Shore			Cbt			Priv		
YEAR	TOT int	COB int	%cob	TOT int	COB int	%cob	TOT int	COB int	%cob
1981	3,685		0.00%	929		0.00%	4,648	2	0.04%
1982	4,892		0.00%	287		0.00%	5,627	6	0.11%
1983	6,168	1	0.02%	1,006		0.00%	7,049	1	0.01%
1984	4,616	1	0.02%	782	2	0.26%	3,536	7	0.20%
1985	8,850	4	0.05%	2,029	3	0.15%	8,582	25	0.29%
1986	3,995	1	0.03%	2,477	7	0.28%	12,673	22	0.17%
1987	5,278	3	0.06%	3,795	16	0.42%	12,472	19	0.15%
1988	6,402	1	0.02%	3,197	10	0.31%	12,038	24	0.20%
1989	10,377	5	0.05%	4,921	6	0.12%	16,971	40	0.24%
1990	8,607	1	0.01%	3,740	5	0.13%	20,305	46	0.23%
1991	14,097	19	0.13%	4,454	8	0.18%	21,138	37	0.18%
1992	12,277	6	0.05%	4,607	13	0.28%	21,046	32	0.15%
1993	12,745	2	0.02%	4,226	8	0.19%	17,515	11	0.06%
1994	15,442	9	0.06%	5,940	10	0.17%	20,086	32	0.16%
1995	15,835	7	0.04%	5,283	12	0.23%	16,242	27	0.17%
1996	16,995	2	0.01%	7,965	18	0.23%	18,304	30	0.16%
1997	15,604	10	0.06%	7,975	8	0.10%	20,069	29	0.14%
1998	15,280	7	0.05%	7,515	18	0.24%	18,367	27	0.15%
1999	14,975	9	0.06%	5,357	7	0.13%	16,215	28	0.17%
2000	14,177	3	0.02%	6,264	9	0.14%	16,216	21	0.13%
2001	16,756	5	0.03%	6,174	9	0.15%	23,608	37	0.16%
2002	15,945	9	0.06%	5,306	15	0.28%	19,549	26	0.13%
2003	15,093	11	0.07%	5,887	17	0.29%	18,609	42	0.23%
2004	12,813	3	0.02%	6,193	16	0.26%	17,870	35	0.20%
2005	10,106	8	0.08%	7,501	12	0.16%	14,673	38	0.26%
2006	9,114		0.00%	6,513	9	0.14%	16,687	39	0.23%
2007	10,900	3	0.03%	6,441	11	0.17%	18,263	43	0.24%
2008	12,372	8	0.06%	6,869	17	0.25%	18,535	31	0.17%
2009	9,558	8	0.08%	5,930	10	0.17%	16,409	42	0.26%
2010	13,932	13	0.09%	7,317	38	0.52%	19,392	86	0.44%

Table 4.11.15. Mean weight (lb) of cobia weighed from the MRFSS in the Atlantic (NY-GA) by year and mode, 1981-2011.

	Cbt				Priv				Shore			
YEAR	N	Mean (lbs)	Min (lbs)	Max (lbs)	N	Mean (lbs)	Min (lbs)	Max (lbs)	N	Mean (lbs)	Min (lbs)	Max (lbs)
1981					2	2.76	2.20	3.31				
1982					4	8.87	1.32	27.56				
1983					2	30.42	24.25	36.60				
1984	2	12.46	8.38	16.53	5	32.41	16.98	60.19				
1985	3	19.33	16.09	23.15	16	22.31	2.20	56.00				
1986	3	30.42	23.81	38.36	17	19.21	1.54	50.93	1	41.01	41.01	41.01
1987	12	24.34	12.13	42.11	10	16.53	0.44	33.07	2	1.76	0.44	3.09
1988	6	22.19	9.92	42.99	10	20.57	1.10	50.04	1	48.72	48.72	48.72
1989	5	11.33	0.66	26.46	22	20.23	0.44	65.48	3	24.25	0.88	52.69
1990	7	16.60	2.87	33.07	16	15.02	0.22	42.11				
1991	3	22.63	16.31	26.46	12	19.38	1.76	67.90	8	30.86	0.88	71.65
1992	10	21.89	13.67	35.71	16	27.43	5.07	54.23	1	52.03	52.03	52.03
1993	10	23.26	7.72	40.79	9	26.82	15.87	61.07	1	33.29	33.29	33.29
1994	3	31.89	22.05	42.55	21	30.59	1.65	50.71	2	24.47	18.30	30.64
1995	13	32.22	11.90	59.97	12	27.19	6.61	59.97	4	38.77	27.67	51.15
1996	25	16.57	1.98	66.14	11	25.94	12.13	56.22	1	31.97	31.97	31.97
1997	10	29.48	19.84	54.01	10	35.90	24.25	55.12	1	34.83	34.83	34.83
1998	23	35.51	12.79	62.28	10	28.47	10.58	55.23	1	52.03	52.03	52.03
1999	3	52.07	31.97	67.13	7	15.16	2.09	27.12	1	48.06	48.06	48.06
2000	7	33.48	12.02	62.28	7	38.63	6.61	68.89				
2001	5	24.10	10.58	50.71	13	32.53	14.33	60.19	1	67.24	67.24	67.24
2002	5	32.39	11.46	50.93	11	36.66	17.64	52.91	4	48.39	27.34	72.97
2003	12	18.10	10.80	40.79	12	22.14	17.02	36.38	1	38.58	38.58	38.58
2004	14	37.35	14.55	61.73	16	32.74	13.67	61.18				
2005	8	41.51	13.76	77.16	27	26.86	2.87	57.01	3	20.61	0.66	39.13
2006	4	23.84	16.53	27.56	9	28.43	14.77	49.05				
2007	8	22.93	14.77	44.20	11	32.05	16.53	64.99				
2008	3	32.96	12.35	60.08	10	28.08	14.33	45.19	2	40.90	20.06	61.73
2009	5	23.59	15.21	35.82	12	24.43	9.26	55.12	1	31.97	31.97	31.97
2010	27	28.49	10.14	60.12	30	33.46	4.63	81.57	1	19.84	19.84	19.84
2011	18	32.64	9.26	103.02	10	51.00	11.90	131.61	3	29.47	13.45	44.09

Table 4.11.16. Number of cobia and positive trips in the SRHS by year and state.

	Fish (N)			Trips (N)		
Year	North Carolina	South Carolina/Georgia	Total	North Carolina	South Carolina/Georgia	Total
1972	-	-	-	-	-	-
1973	-	-	-	-	-	-
1974	-	3	-	-	3	3
1975	-	-	-	-	-	-
1976	-	-	-	-	-	-
1977	-	-	-	-	-	-
1978	1	-	1	1	-	1
1979	2	-	2	2	-	2
1980	1	-	1	1	-	1
1981	1	-	1	1	-	1
1982	3	-	3	3	-	3
1983	4	-	4	4	-	4
1984	4	2	6	4	2	6
1985	6	1	7	6	1	7
1986	3	3	6	3	3	6
1987	3	4	7	4	3	7
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	8	2	10	7	2	9
1993	4	9	13	4	7	11
1994	-	9	9	-	7	7
1995	7	8	15	7	8	15
1996	2	6	8	2	5	8
1997	5	4	9	5	4	9
1998	3	6	9	3	5	8
1999	4	1	5	4	1	5
2000	-	1	1	-	1	1
2001	6	-	6	6	-	6
2002	5	1	6	4	1	5
2003	2	1	3	2	1	3
2004	4	-	4	3	-	3
2005	4	-	4	4	-	4
2006	2	2	4	2	2	4
2007	-	7	7	-	7	7
2008	2	1	3	2	1	3
2009	-	2	2	-	2	2
2010	1	7	8	1	5	6
2011	1	1	2	1	1	2

Table 4.11.17. Number of South Atlantic cobia aged from the SRHS by year and state. Due to headboat area definitions and confidentiality issues, Georgia and South Carolina landings must be combined. States not shown did not age any cobia for this time period.

Year	North Carolina	South Carolina/Georgia
1981	-	-
1982	-	-
1983	-	-
1984	-	-
1985	-	-
1986	-	-
1987	-	-
1988	-	-
1989	-	-
1990	-	-
1991	-	-
1992	-	-
1993	-	-
1994	-	-
1995	-	-
1996	-	-
1997	-	-
1998	-	-
1999	-	-
2000	-	-
2001	-	-
2002	-	-
2003	-	-
2004	-	-
2005	1	-
2006	1	2
2007	-	-
2008	-	-
2009	-	-
2010	-	-
2011	-	-

Table 4.11.18. Mean weight (kg) of cobia measured in the SRHS by year and state, 1972-2011.

	NC				SC/GA			
Year	N	Mean(kg)	Min(kg)	Max(kg)	N	Mean(kg)	Min(kg)	Max(kg)
1972	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-
1974	-	-	-	-	3	0.24	0.23	0.27
1975	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	-
1978	1	9.52	9.52	9.52	-	-	-	-
1979	2	12.35	11.70	12.99	-	-	-	-
1980	1	5.96	5.96	5.96	-	-	-	-
1981	1	4.25	4.25	4.25	-	-	-	-
1982	3	9.10	3.70	16.80	-	-	-	-
1983	4	8.81	6.50	12.93	-	-	-	-
1984	4	10.48	7.38	12.70	2	14.95	6.80	23.10
1985	6	9.70	3.00	17.44	1	12.60	12.60	12.60
1986	4	4.48	0.15	6.20	3	8.27	5.60	11.80
1987	6	5.95	0.10	13.45	4	9.80	5.50	14.30
1988	2	10.51	10.11	10.90	5	9.19	1.10	17.10
1989	5	8.96	6.19	12.52	2	13.33	12.38	14.28
1990	3	10.82	7.31	13.61	6	8.50	5.37	11.73
1991	5	6.69	4.15	10.36	8	9.19	3.81	14.38
1992	9	10.73	5.15	18.18	2	7.76	7.15	8.37
1993	4	9.51	7.14	12.82	9	9.98	5.51	15.30
1994	-	-	-	-	9	8.70	4.66	15.25
1995	7	9.14	6.20	12.65	9	9.70	5.03	15.43
1996	3	13.74	12.71	15.43	6	12.38	4.74	23.81
1997	5	8.93	5.94	12.29	4	10.46	7.67	13.05
1998	3	11.25	6.05	15.27	6	10.67	5.34	17.72
1999	4	10.86	9.16	12.55	1	10.39	10.39	10.39
2000	-	-	-	-	1	10.06	10.06	10.06
2001	6	10.74	4.79	14.88	-	-	-	-
2002	5	12.33	7.29	19.02	1	7.74	7.74	7.74
2003	2	14.07	10.53	17.60	1	5.66	5.66	5.66
2004	4	16.26	11.95	20.24	-	-	-	-
2005	4	10.37	6.83	15.20	-	-	-	-
2006	2	7.52	6.04	9.00	2	9.89	8.02	11.76
2007	-	-	-	-	7	9.35	6.93	14.83
2008	2	9.86	9.55	10.17	1	16.78	16.78	16.78
2009	-	-	-	-	2	16.06	5.91	26.21
2010	1	11.16	11.16	11.16	7	9.56	6.85	13.80
2011	1	10.32	10.32	10.32	1	5.52	5.52	5.52

Table 4.11.19. 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. Total length measurements from 2009-2011 were converted to fork length using the following equation developed for the South Atlantic stock at the SEDAR 28 data workshop: FL = 13.52399 + 0.87867TL (N = 4635, R^2 = 0.9855).

Year	Cobia (n)	Fish (n) Charter	Private	Shore	Mean FL (mm)	Std Dev FL (mm)	Min FL (mm)	Max FL (mm)
1988	3	-	3	-	916.70	76.90	865	1,005
1989	-	-	-	-	-	-	-	-
1990	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-
1992	4	-	4	-	1,122.50	146.50	986	1,305
1993	2	-	2	-	600.50	340.10	360	841
1994	-	-	-	-	-	-	-	-
1995	-	-	-	-	-	-	-	-
1996	2	-	2	-	1,496.00	33.90	1,472	1,520
1997	-	-	-	-	-	-	-	-
1998	11	-	10	1	994.20	220.90	463	1,260
1999	31	-	31	-	1,002.60	85.90	912	1,418
2000	4	-	4	-	917.30	52.70	878	995
2001	8	-	8	-	1,010.30	59.80	935	1,135
2002	22	-	22	-	1,048.10	126.30	865	1,255
2003	14	1	13	-	926.40	167.60	580	1,349
2004	16	1	15	-	968.30	188.80	835	1,452
2005	21	-	21	-	908.70	42.10	830	1,000
2006	18	-	18	-	982.00	163.60	845	1,502
2007	80	-	80	-	909.20	50.30	810	1,060
2008	64	-	64	-	957.70	129.50	410	1,350
2009	33	-	33	-	909.20	139.00	720	1,336
2010	10	-	10	-	838.30	72.70	760	976
2011	17	1	16	-	814.50	33.90	770	886

Table 4.11.20. Number of cobia aged in the Atlantic (NY-GA) from the charter boat fleet by year and state. States not shown did not age any cobia for this time period.

Year	South Carolina
1981	-
1982	-
1983	-
1984	-
1985	-
1986	-
1987	-
1988	-
1989	-
1990	-
1991	-
1992	-
1993	-
1994	-
1995	-
1996	-
1997	-
1998	-
1999	-
2000	-
2001	-
2002	-
2003	-
2004	-
2005	40
2006	36
2007	27
2008	120
2009	131
2010	145
2011	130

Table 4.11.21. Number of cobia aged in the Atlantic (NY-GA) from the private/rental fleet by year and state. States not shown did not age any cobia for this time period.

Year	North Carolina	South Carolina
1981	-	-
1982	-	-
1983	-	-
1984	-	-
1985	-	-
1986	-	-
1987	-	-
1988	-	-
1989	-	-
1990	-	-
1991	-	-
1992	-	-
1993	-	-
1994	-	-
1995	-	-
1996	-	-
1997	-	-
1998	-	-
1999	-	-
2000	-	-
2001	-	-
2002	-	-
2003	-	-
2004	-	-
2005	-	73
2006	-	17
2007	-	207
2008	-	153
2009	-	68
2010	9	67
2011	-	88

Table 4.11.22. Number of cobia aged in the Atlantic (NY-GA) from the recreational fishery (mode unknown) by year and state. States not shown did not age any cobia for this time period.

Year	North Carolina	South Carolina	Virginia
1981	-	-	-
1982	-	-	-
1983	-	-	-
1984	3	-	-
1985	2	-	-
1986	22	-	-
1987	18	-	-
1988	15	1	-
1989	78	-	-
1990	99	2	-
1991	16	-	-
1992	19	-	-
1993	16	-	-
1994	16	-	-
1995	-	-	-
1996	-	-	-
1997	-	-	-
1998	-	-	-
1999	-	-	122
2000	-	-	104
2001	-	-	71
2002	-	-	26
2003	-	-	7
2004	-	-	7
2005	-	1	9
2006	-	-	21
2007	-	98	55
2008	-	-	46
2009	-	-	102
2010	-	-	106
2011	-	-	-

Table 4.11.23. Atlantic (NY-GA) estimated number of angler trips for charter boat mode, headboat mode, and charter boat/headboat mode (MRFSS, NMFS, 1981-2003; MRIP, NMFS, 2004-2011). 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-region 5. 2011 data is preliminary and through October.

	Estimated CH Angler Trips		Estimated CH/HB Angler Trips		Estimated HB Angler Trips	
YEAR	Trips	CV	Trips	CV	Trips	CV
1981			4,146,778	0.10		
1982			5,439,882	0.17		
1983			5,663,227	0.12		
1984			4,036,577	0.10		
1985			4,723,731	0.13		
1986	706,073	0.23	3,762,777	0.11		
1987	393,266	0.23	2,954,897	0.09		
1988	546,250	0.18	2,344,332	0.09		
1989	447,998	0.18	2,003,865	0.08		
1990	282,405	0.18	2,093,201	0.07		
1991	322,411	0.16	2,606,588	0.08		
1992	369,145	0.15	1,813,034	0.08		
1993	479,656	0.13	3,160,377	0.09		
1994	645,260	0.11	2,725,381	0.08		
1995	762,281	0.11	2,457,942	0.09		
1996	852,372	0.11	1,766,195	0.08		
1997	842,398	0.11	2,331,586	0.08		
1998	699,936	0.11	1,428,132	0.08		
1999	558,006	0.12	1,311,598	0.08		
2000	447,280	0.14	1,678,258	0.08		
2001	478,030	0.13	1,913,617	0.07		
2002	451,770	0.13	1,425,642	0.07		
2003	432,334	0.14	1,707,580	0.07		
2004	877,116	0.06			507,746	0.10
2005	1,161,048	0.10			417,724	0.06
2006	997,737	0.05			624,432	0.04
2007	1,353,163	0.04			670,723	0.05
2008	874,280	0.03			547,183	0.03
2009	831,722	0.04			520,687	0.02
2010	736,384	0.04			386,172	0.01
2011	766,585	0.06			388,117	0.10

Table 4.11.24. Atlantic (NY-GA) estimated number of angler trips for private/rental boat mode and shore mode (MRFSS, NMFS, 1981-2003; MRIP, NMFS, 2004-2011). 2011 data is preliminary and through October.

	Estimated PR Angler Trips		Estimated SH Angler Trips	
YEAR	Trips	CV	Trips	CV
1981	7,101,843	0.05	7,282,174	0.09
1982	7,994,625	0.05	8,749,367	0.07
1983	10,713,696	0.05	10,672,537	0.09
1984	9,950,250	0.05	9,235,357	0.09
1985	8,923,798	0.05	7,768,772	0.08
1986	12,107,268	0.04	8,764,770	0.06
1987	11,263,226	0.03	7,605,243	0.05
1988	11,748,478	0.03	8,586,272	0.04
1989	8,946,356	0.03	7,172,346	0.06
1990	10,286,830	0.03	6,950,138	0.04
1991	11,196,471	0.03	9,020,267	0.04
1992	9,353,482	0.03	7,781,211	0.04
1993	11,433,826	0.04	8,658,703	0.03
1994	12,017,506	0.03	10,107,300	0.04
1995	11,005,471	0.03	9,985,246	0.04
1996	11,179,203	0.03	9,746,242	0.03
1997	12,379,154	0.03	9,866,222	0.03
1998	11,274,774	0.03	8,603,162	0.04
1999	10,674,520	0.03	8,467,486	0.04
2000	14,690,732	0.03	11,981,224	0.03
2001	15,552,729	0.02	13,215,203	0.03
2002	12,387,281	0.02	10,470,263	0.03
2003	15,036,635	0.02	13,210,273	0.03
2004	15,601,291	0.03	11,927,499	0.04
2005	15,731,509	0.03	13,195,098	0.04
2006	15,771,604	0.03	13,075,952	0.04
2007	16,750,654	0.03	12,803,517	0.04
2008	16,023,305	0.03	13,822,973	0.04
2009	13,237,092	0.03	10,989,648	0.05
2010	13,173,589	0.03	11,137,084	0.04
2011	10,326,490	0.03	9,097,855	0.05

Table 4.11.25. South Atlantic headboat estimated angler days by year and state, 1981-2011.

Year	North Carolina	South Carolina/Georgia	South Atlantic
1981	38,746	118,060	156,806
1982	53,878	135,078	188,956
1983	47,660	131,446	179,106
1984	57,730	134,627	192,357
1985	62,730	132,002	194,732
1986	62,374	134,454	196,828
1987	70,522	157,612	228,134
1988	84,842	152,936	237,778
1989	77,356	125,416	202,772
1990	86,480	114,302	200,782
1991	81,872	135,964	217,836
1992	82,353	123,580	205,933
1993	85,571	128,914	214,485
1994	73,384	127,432	200,816
1995	80,589	129,905	210,494
1996	70,284	115,224	185,508
1997	74,378	126,107	200,485
1998	74,798	126,688	201,486
1999	63,192	114,472	177,664
2000	62,674	84,886	147,560
2001	63,558	103,202	166,760
2002	55,202	89,478	144,680
2003	45,996	75,964	121,960
2004	54,510	100,924	155,434
2005	63,146	71,594	134,740
2006	51,466	115,979	167,445
2007	57,999	125,385	183,384
2008	34,314	97,718	132,032
2009	38,931	86,014	124,945
2010	42,137	93,811	135,948
2011	36,910	92,414	129,324

4.11 Figures

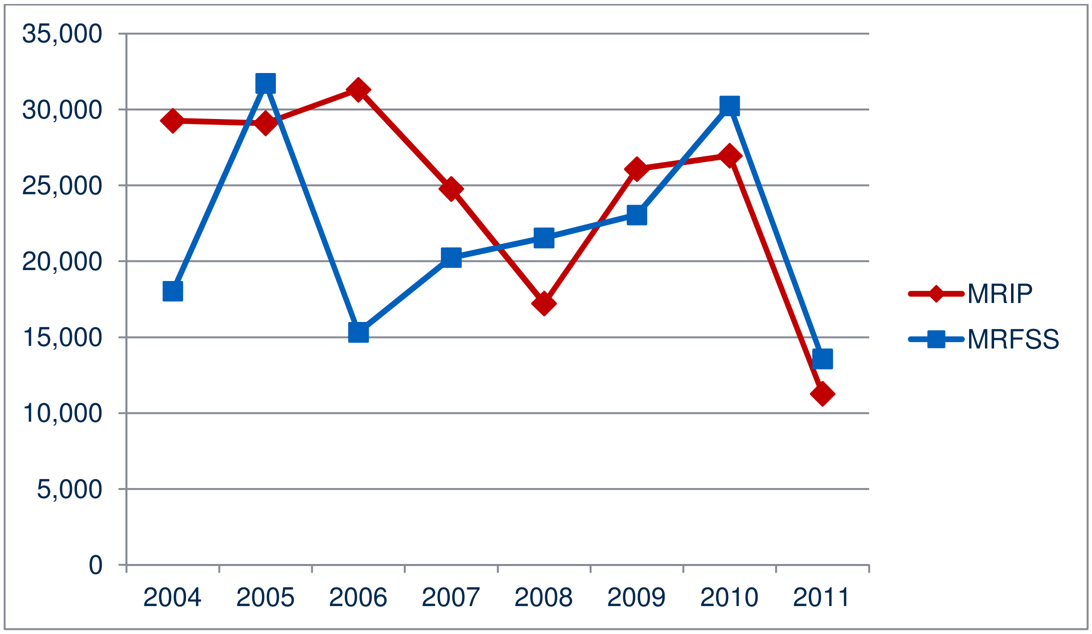

Figure 4.12.1. Comparison of MRIP and MRFSS landings (A+B1) for Atlantic cobia (NY-GA).

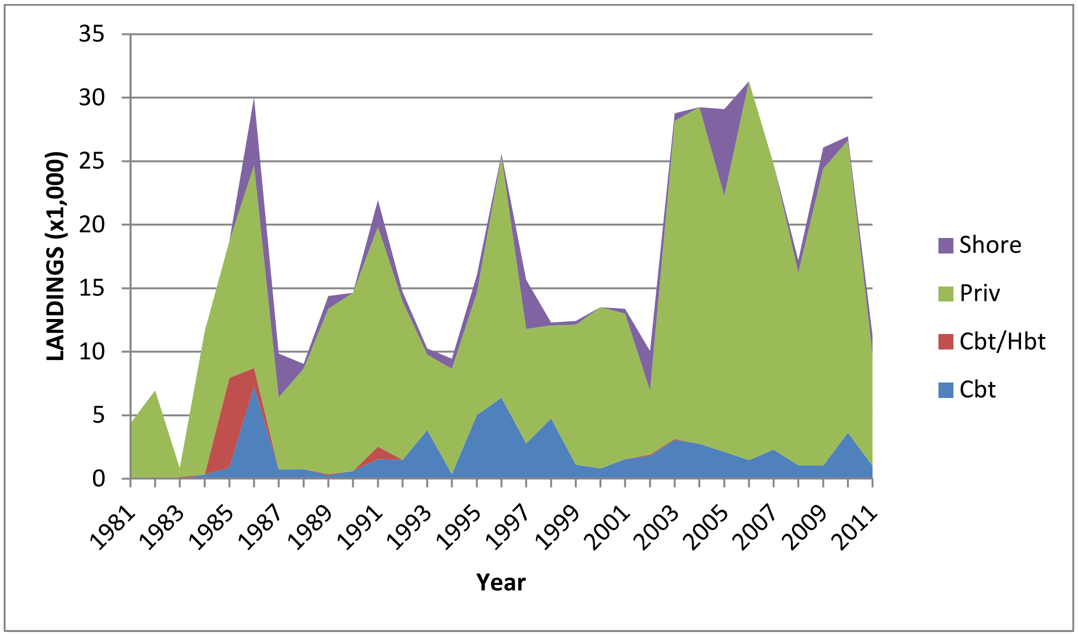

Figure 4.12.2. Atlantic (NY-GA) cobia landings (numbers of fish) by year and mode (MRFSS, NMFS, 1981-2003; MRIP, NMFS, 2004-2011). 2011 data is preliminary and through October.

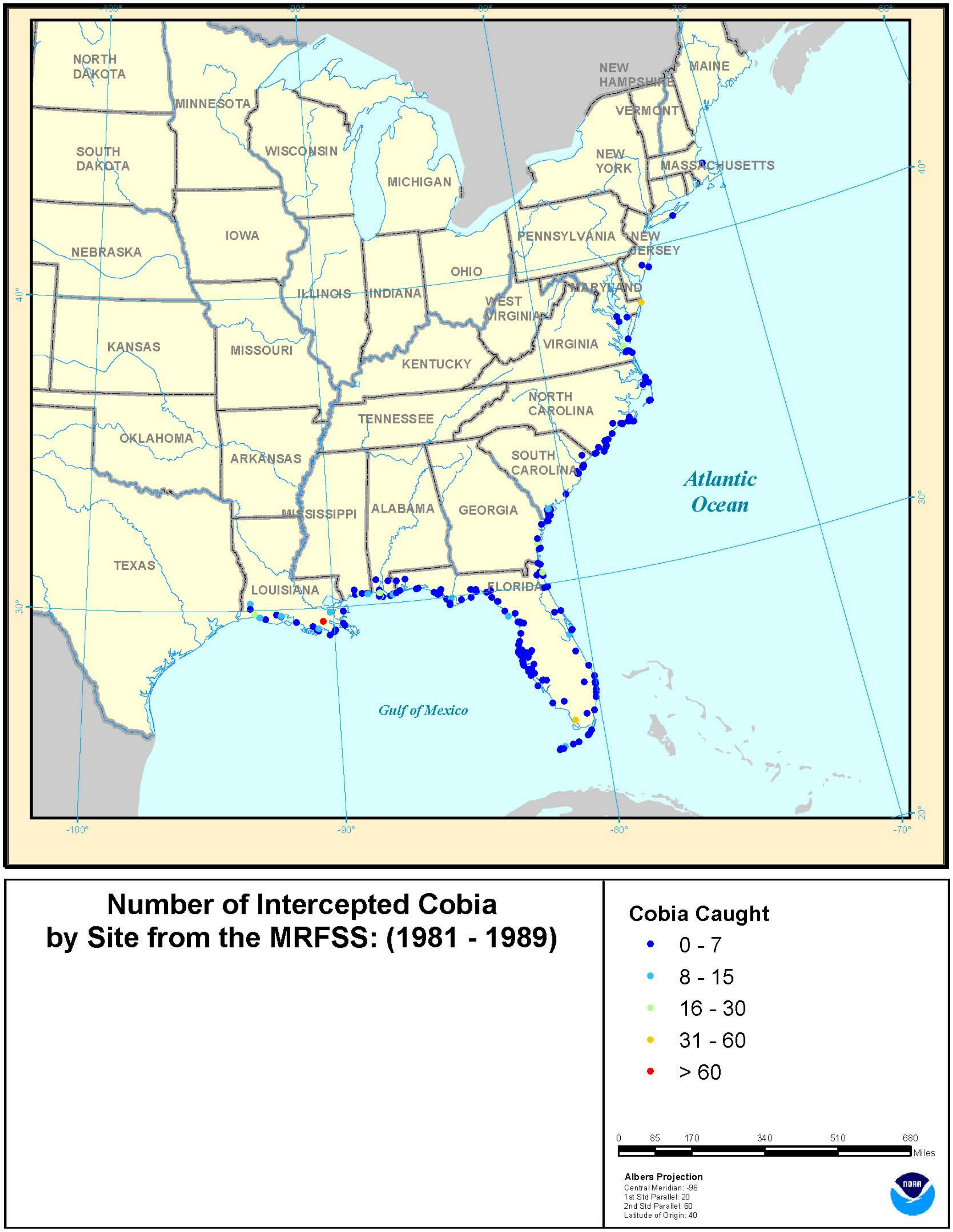

Figure 4.12.3. The number of cobia intercepted by the MRFSS from 1981-1989.

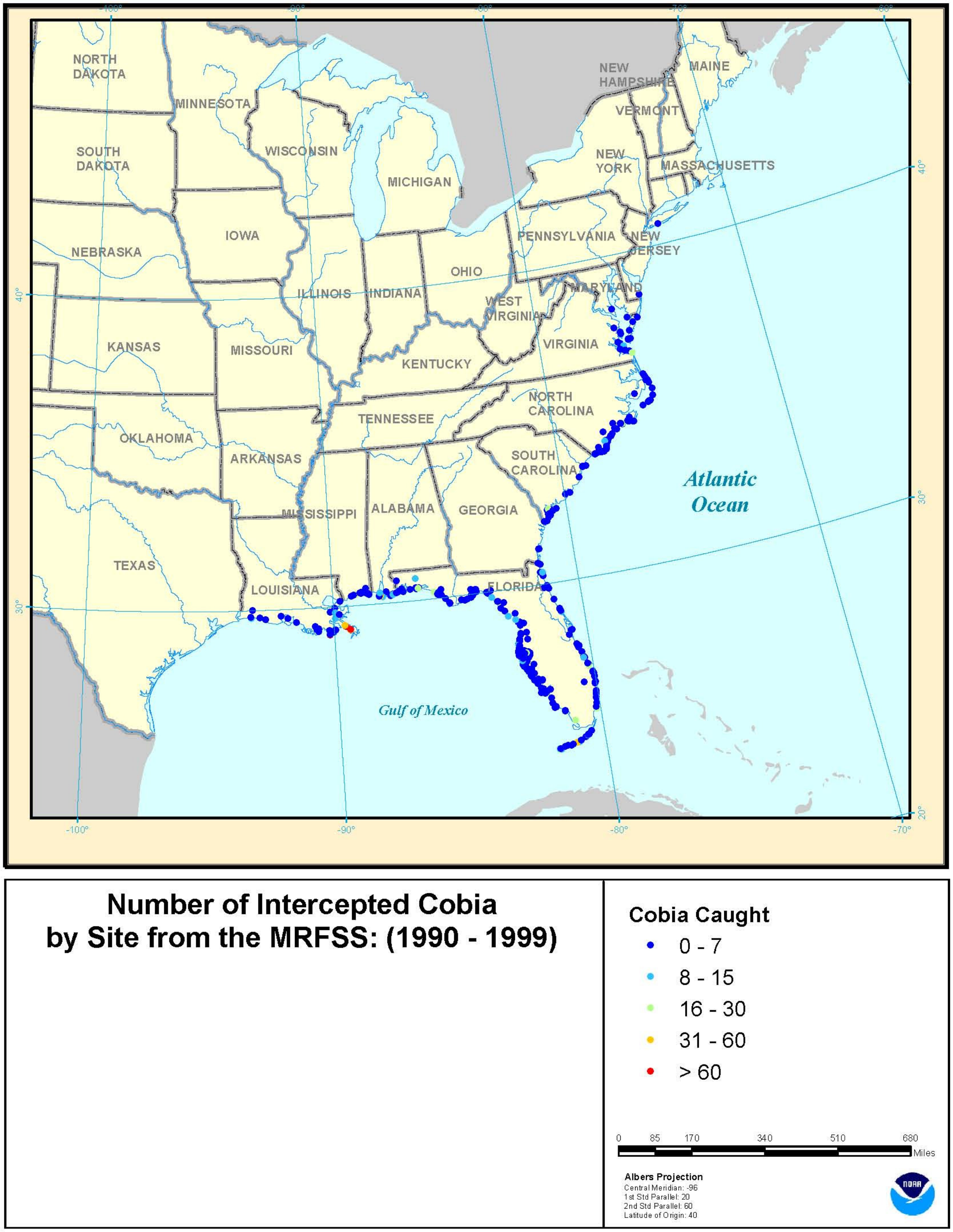

Figure 4.12.4. The number of cobia intercepted by the MRFSS from 1990-1999.

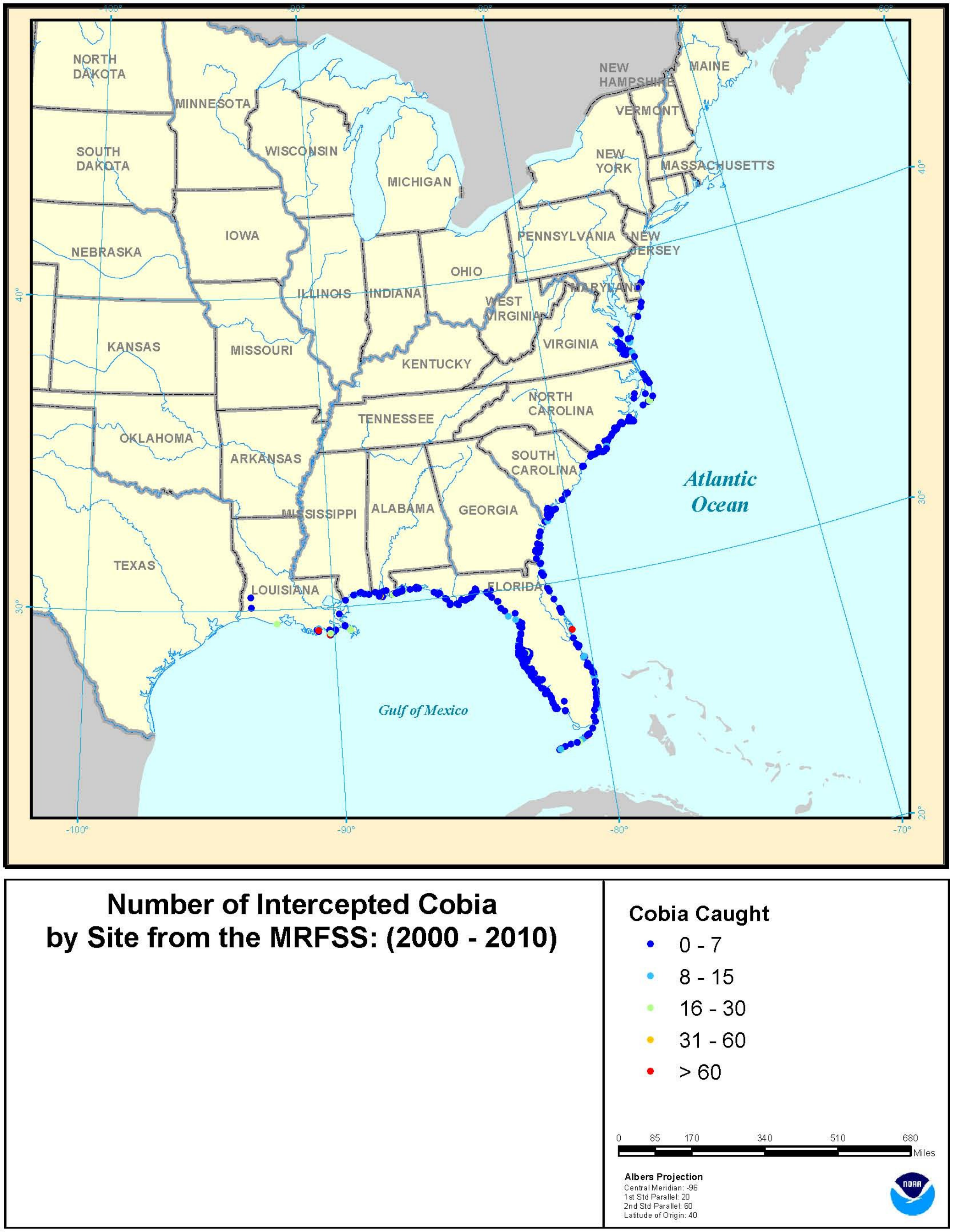

Figure 4.12.5. The number of cobia intercepted by the MRFSS from 2000-2010.

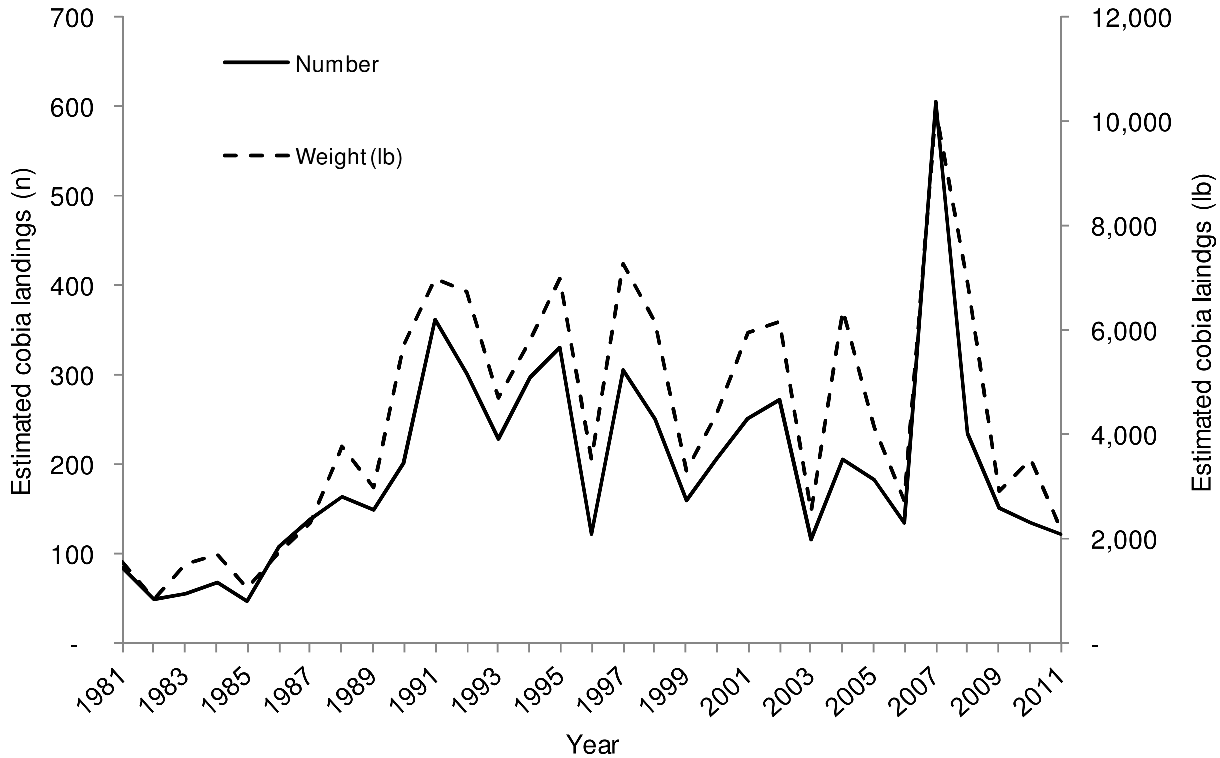

Figure 4.12.6. South Atlantic estimated cobia landings (number and pounds) for the headboat fishery, 1981-2011.

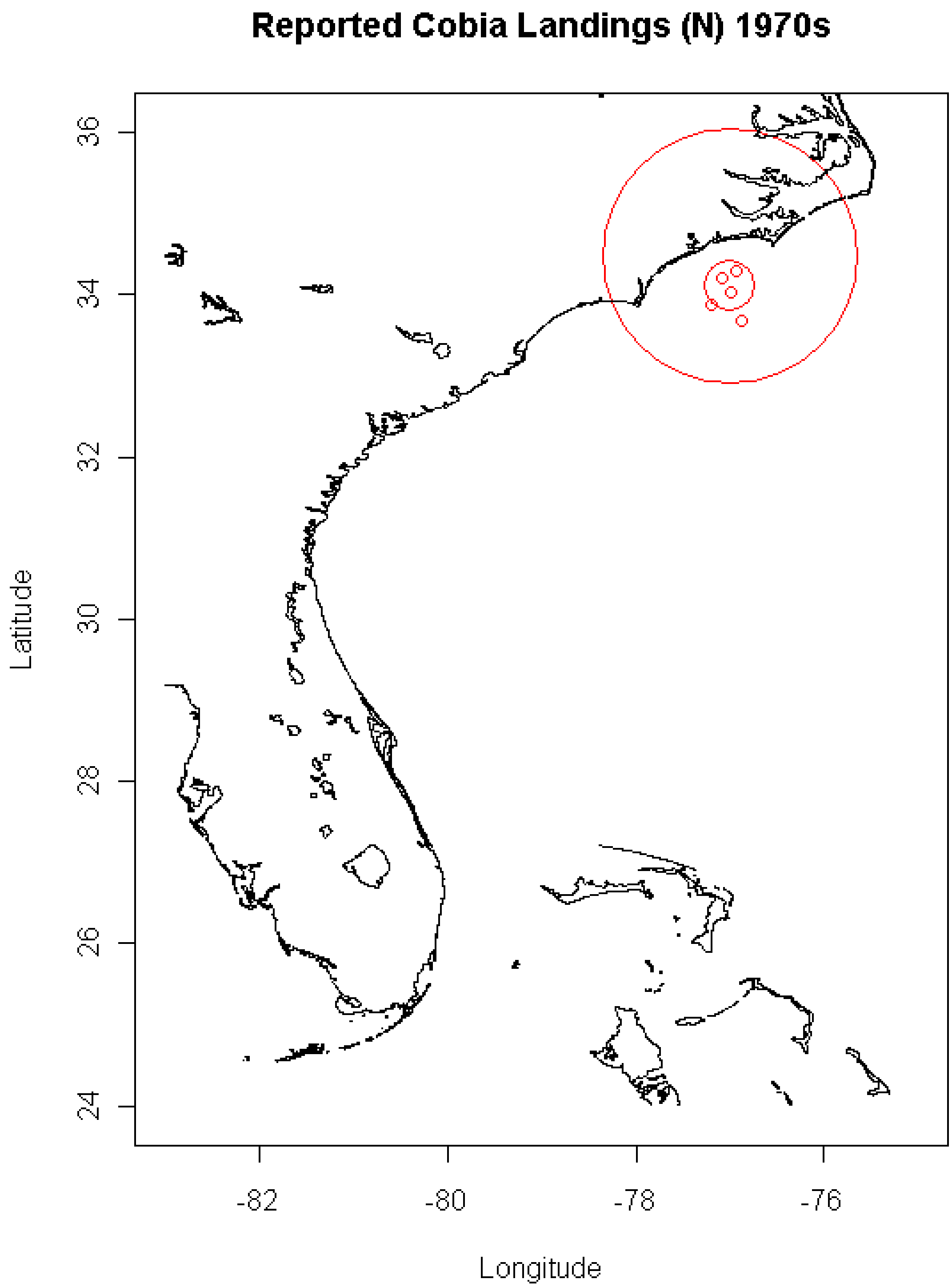

Figure 4.12.7. Reported cobia landings (numbers of fish) in the South Atlantic from SRHS, 1973-1979. The size of each point is proportional to the reported landings (N) at the given location.

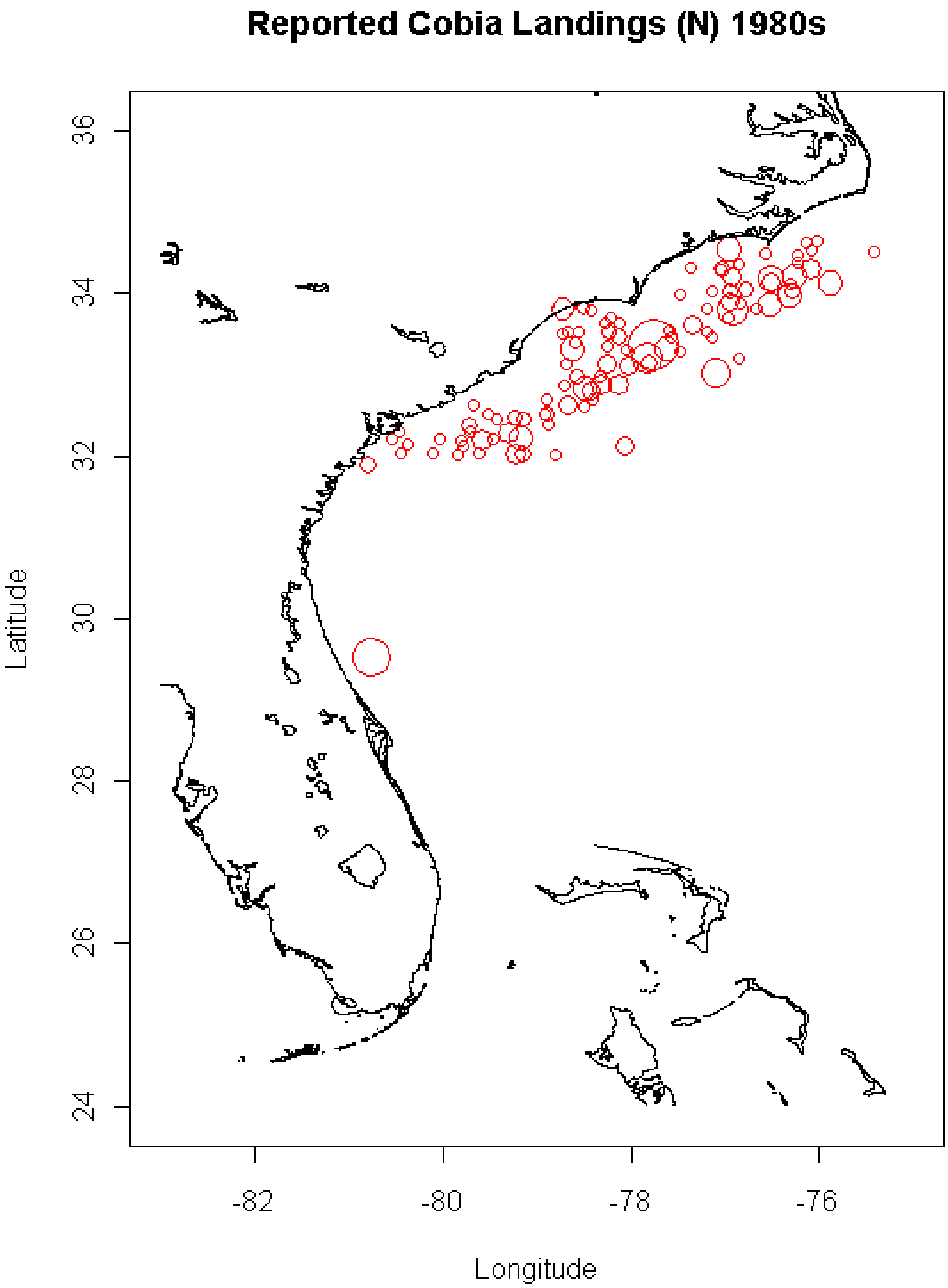

Figure 4.12.8. Reported cobia landings (numbers of fish) in the South Atlantic from SRHS, 1980-1989. The size of each point is proportional to the reported landings (N) at the given location.

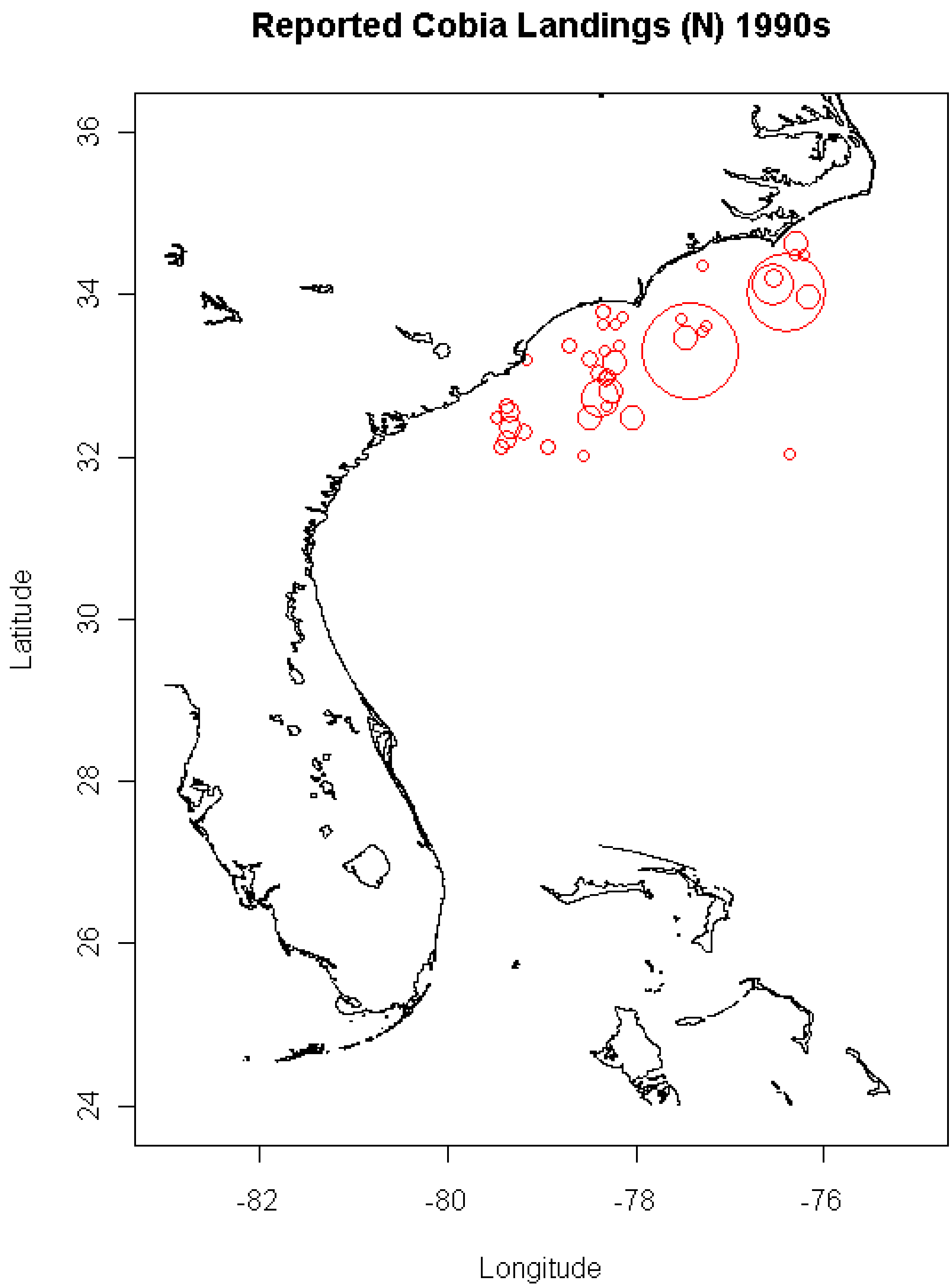

Figure 4.12.9. Reported cobia landings (numbers of fish) in the South Atlantic from SRHS, 1990-1999. The size of each point is proportional to the reported landings (N) at the given location.

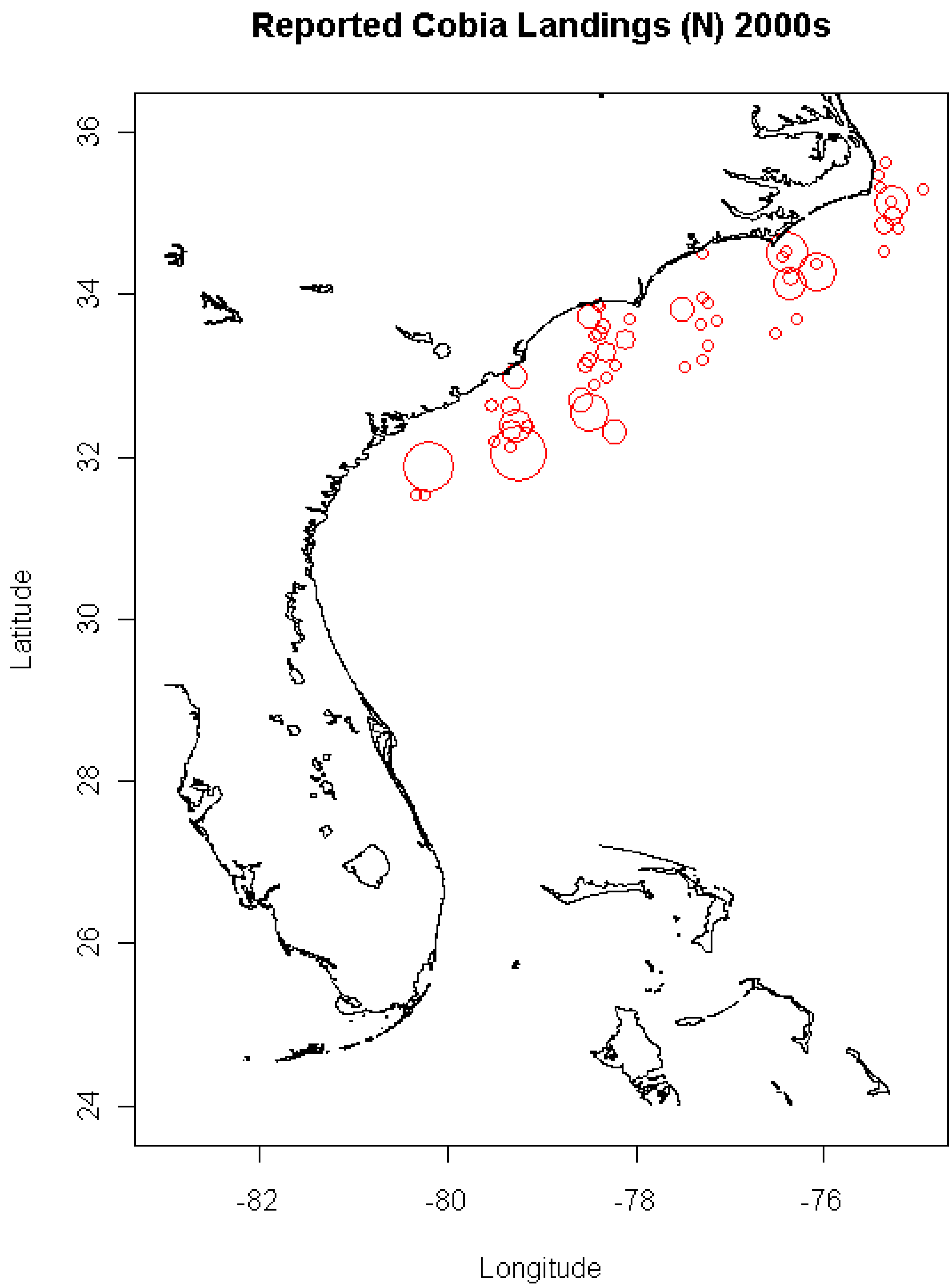

Figure 4.12.10. Reported cobia landings (numbers of fish) in the South Atlantic from SRHS, 2000-2011. The size of each point is proportional to the reported landings (N) at the given location.

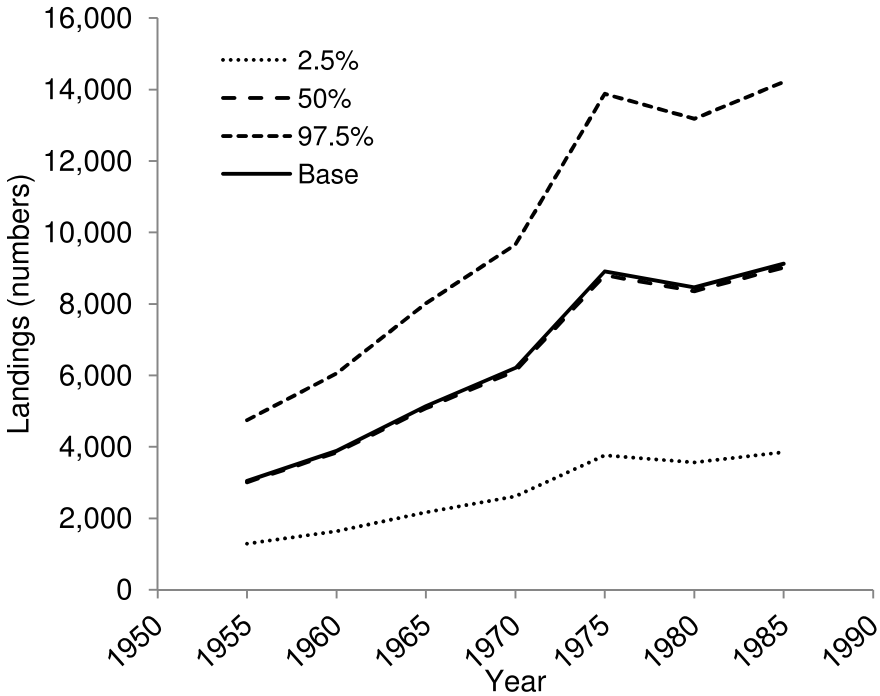

Figure 4.12.11. Bootstrap analysis of FHWAR census method (1955-1984) cobia landings estimates.

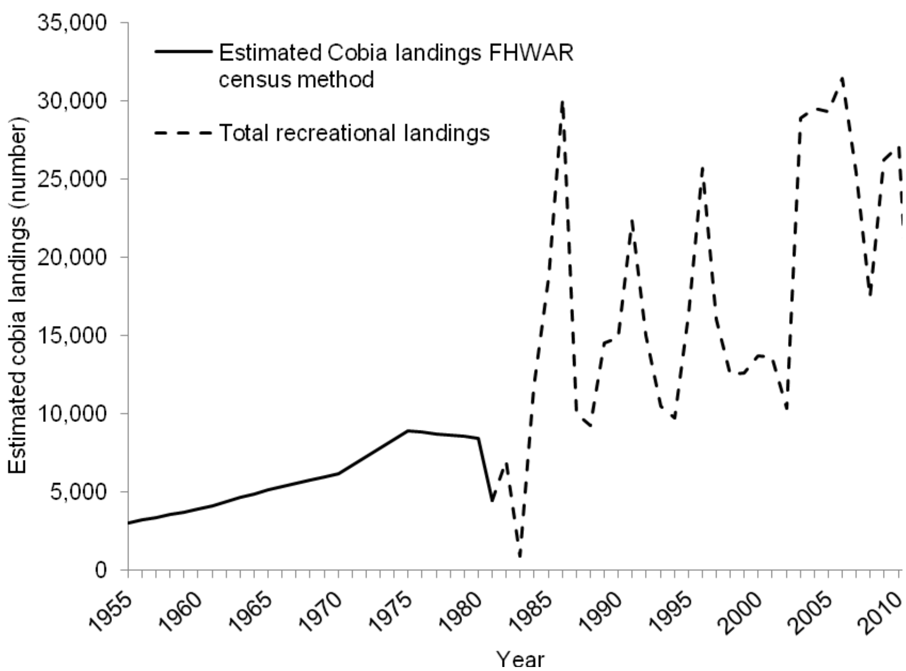

Figure 4.12.12. Estimated cobia landings (number) using FHWAR census method (1955-1984), MRFSS (1985-2003), and MRIP (2004-2011) estimation methods.

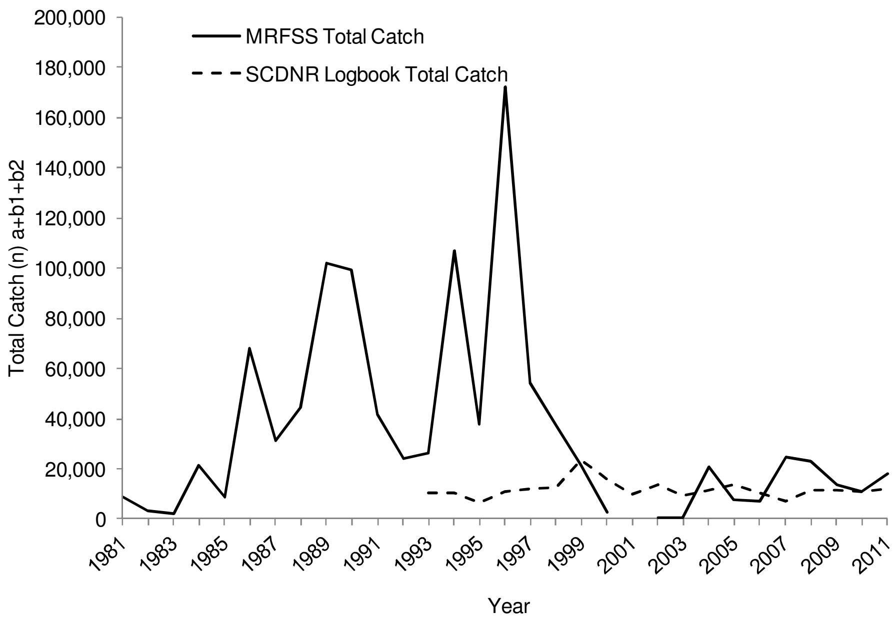

Figure 4.12.13. Comparison of South Carolina total catch (a+b1+b2) from MRFSS charter mode and SCDNR charter boat logbook program, 1993-2011. 2011 data is preliminary for both datasets.

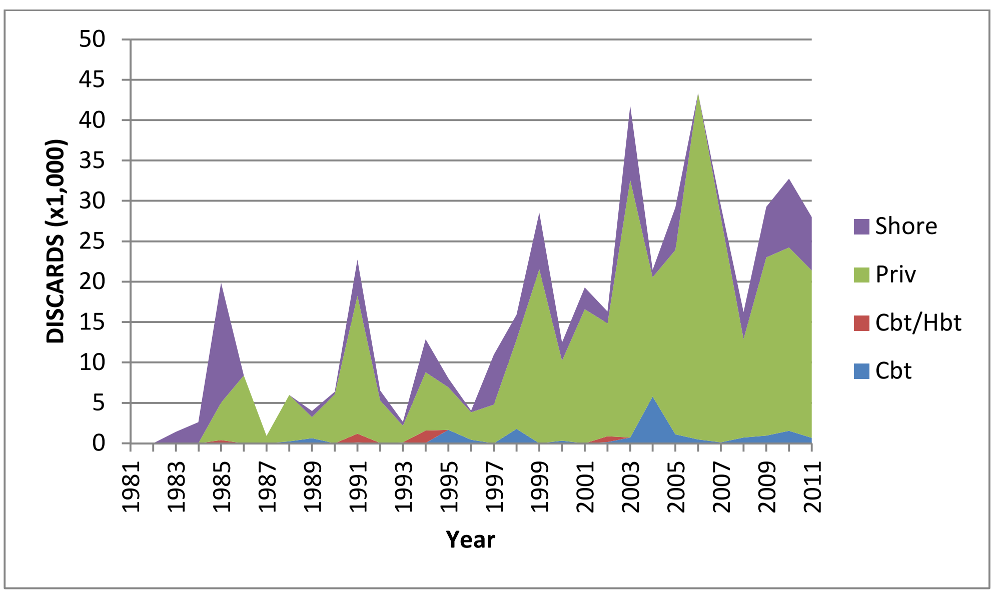

Figure 4.12.14. Atlantic (NY-GA) cobia discards (numbers of fish) by year and mode (MRFSS, NMFS, 1981-2003; MRIP, NMFS, 2004-2011). 2011 data is preliminary and through October.

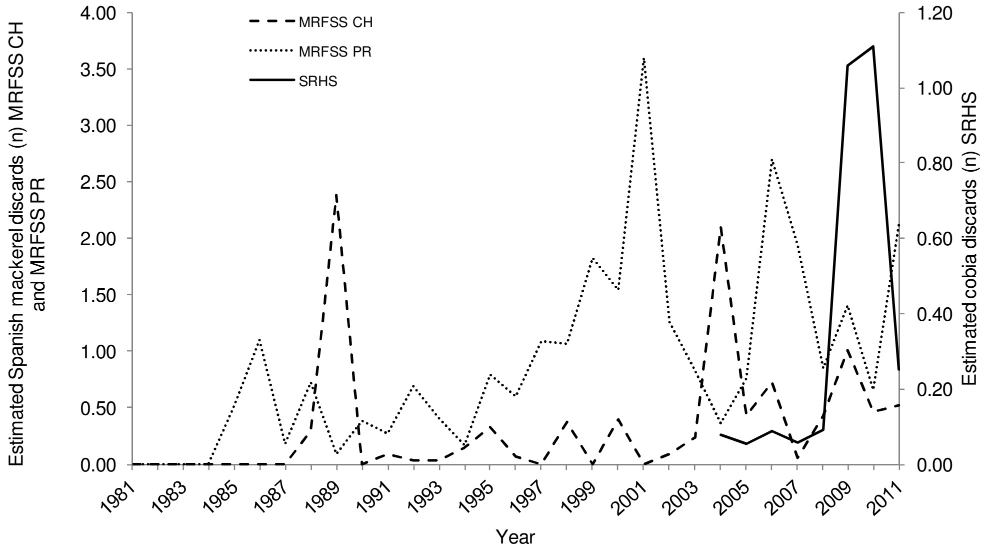

Figure 4.12.15. Percentage of cobia discards in the recreational fishery, 1981-2011.

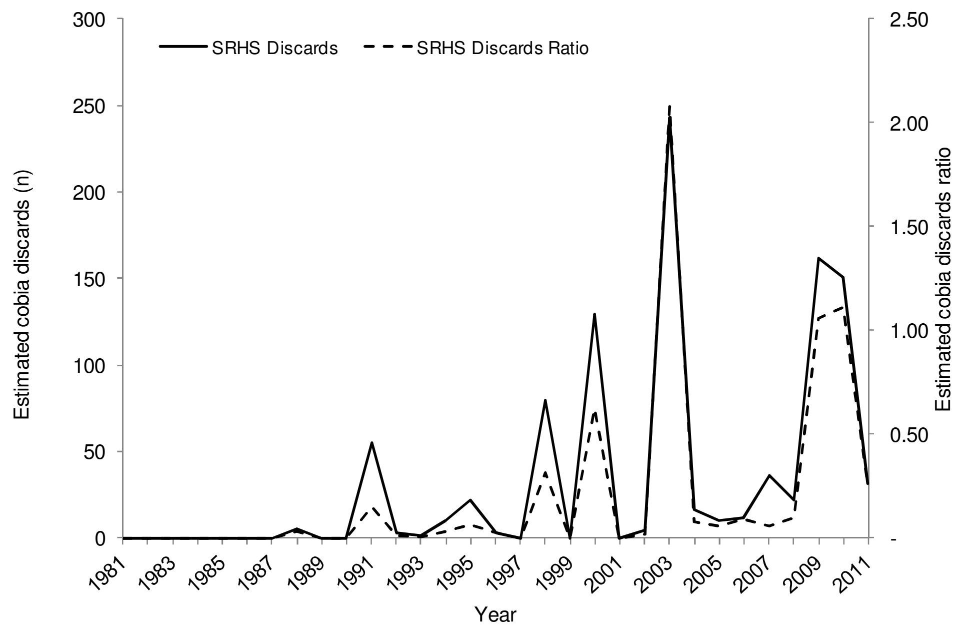

Figure 4.12.16. South Atlantic estimated cobia discards and discard ratio for the headboat fishery (MRFSS proxy 1981-2003; SRHS 2004-2011).

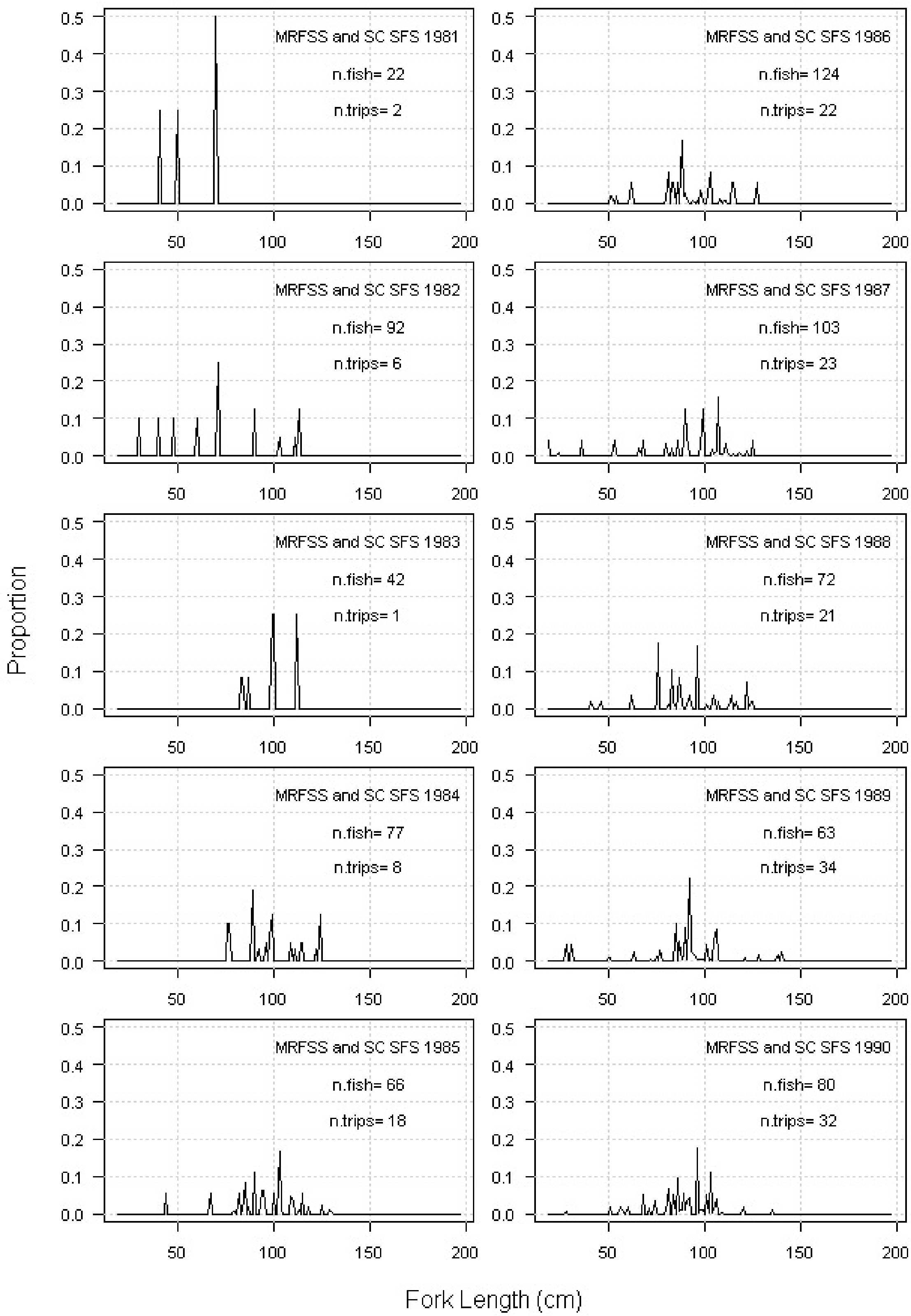

Figure 4.12.17. Length composition from the MRFSS (1981-2011) and SCDNR SFS (1988-2011). The number of trips reported includes both angler and vessel trips for years 1988-2011.

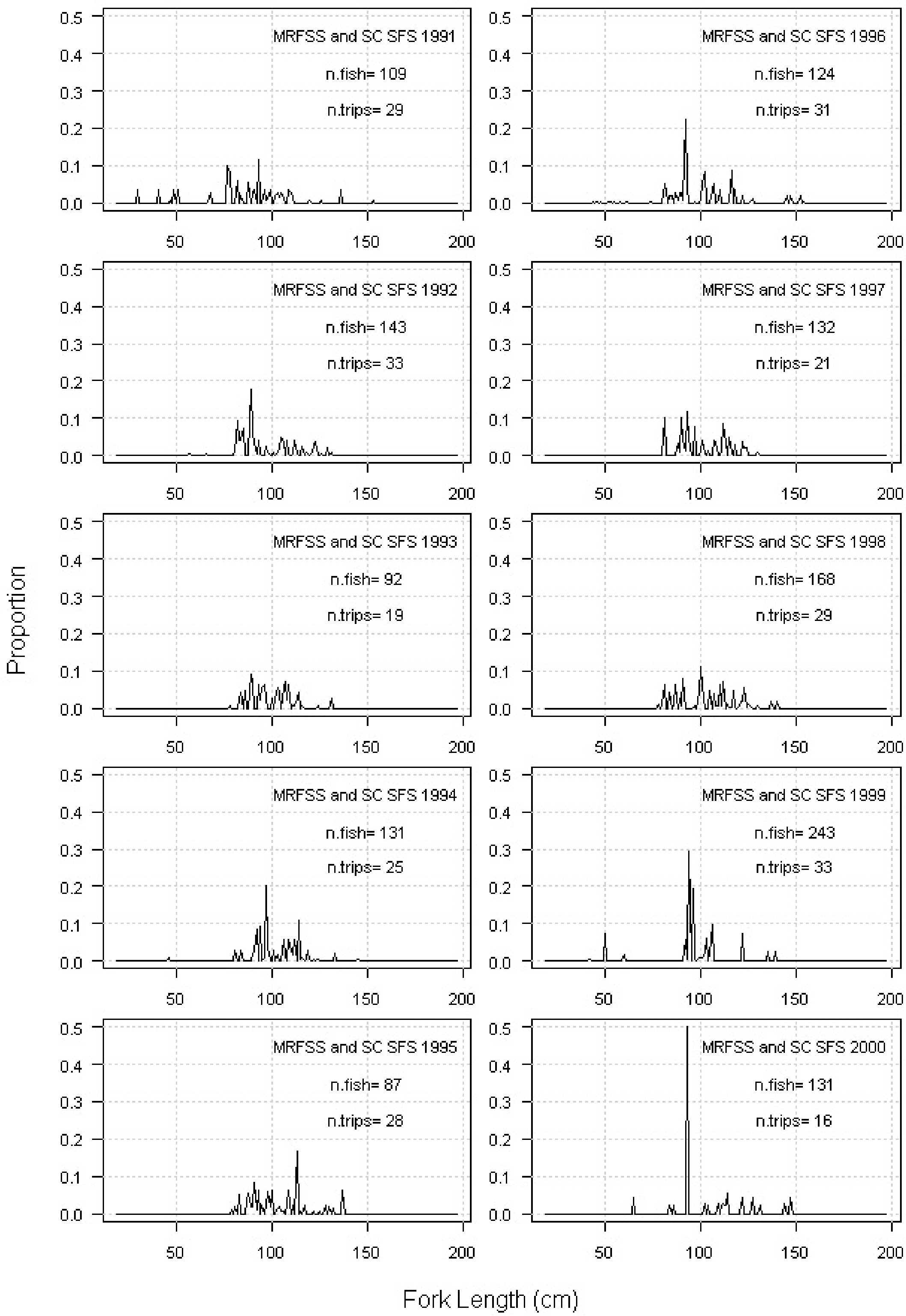

Figure 4.12.17. Length composition from the MRFSS (1981-2011) and SCDNR SFS (1988-2011) (continued). The number of trips reported includes both angler and vessel trips for years 1988-2011.

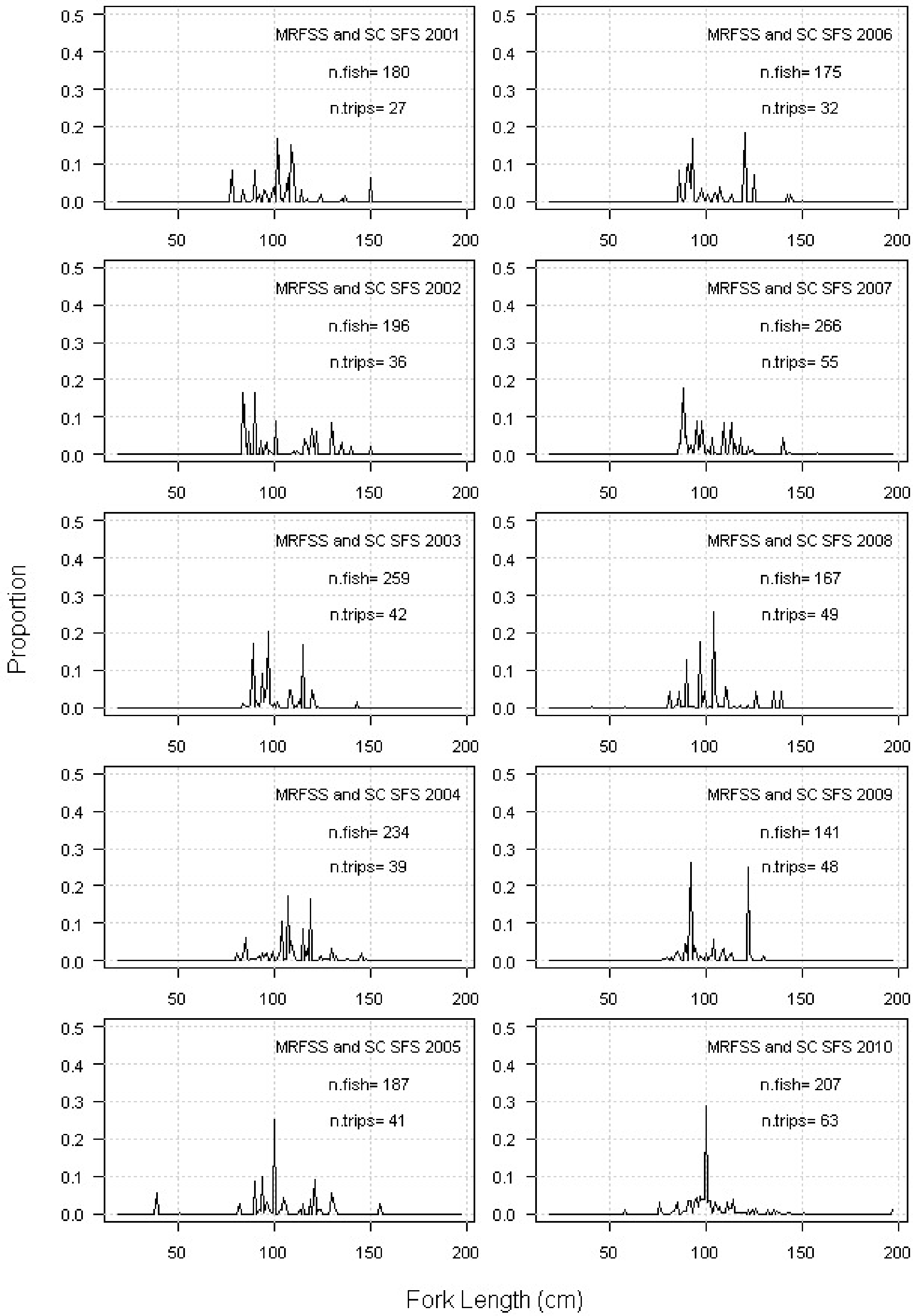

Figure 4.12.17. Length composition from the MRFSS (1981-2011) and SCDNR SFS (1988-2011) (continued). The number of trips reported includes both angler and vessel trips for years 1988-2011.

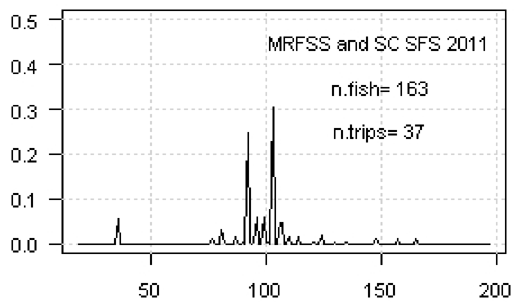

Figure 4.12.17. Length composition from the MRFSS (1981-2011) and SCDNR SFS (1988-2011) (continued). The number of trips reported includes both angler and vessel trips for years 1988-2011.

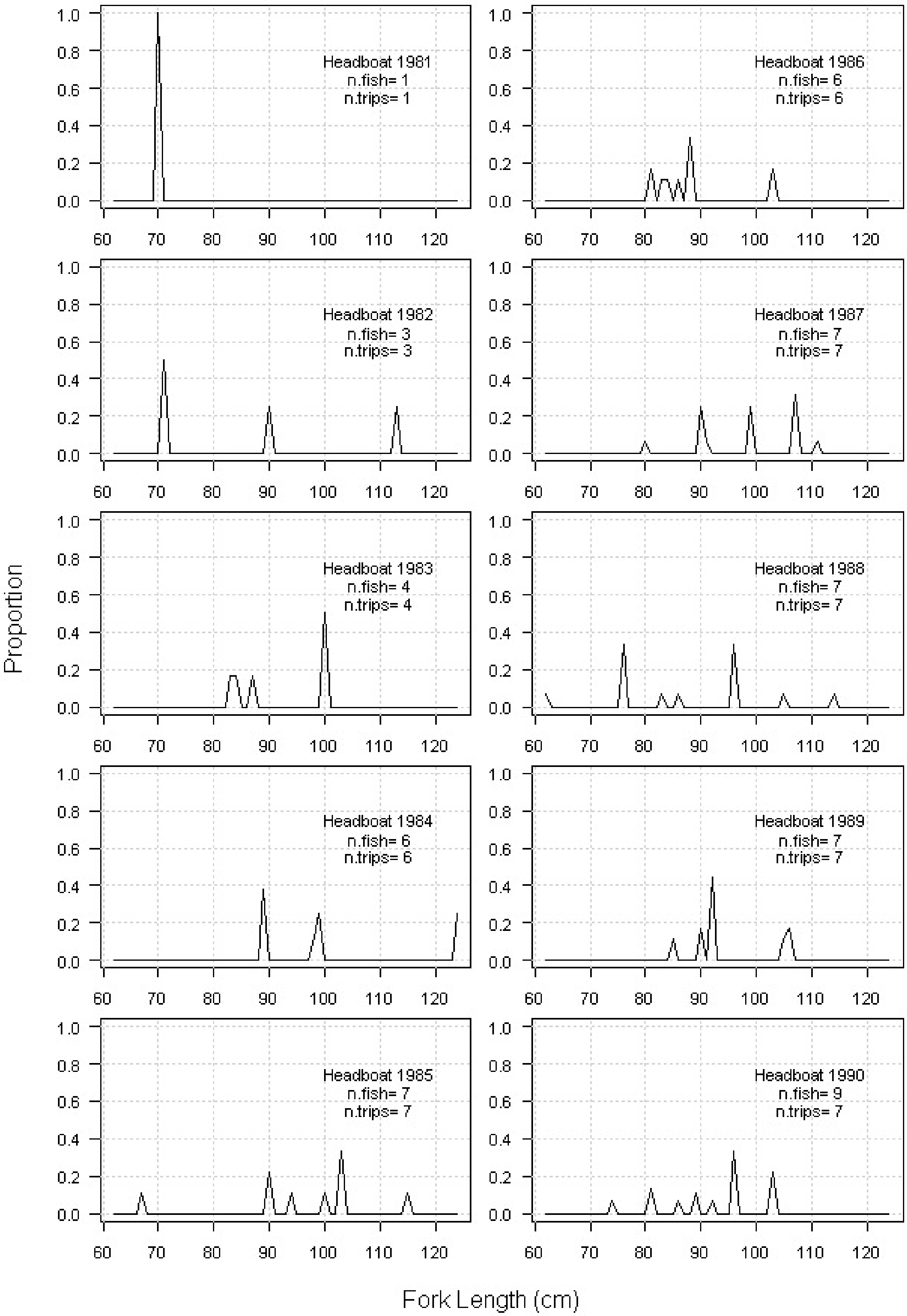

Figure 4.12.18. Headboat length composition 1981-2011.

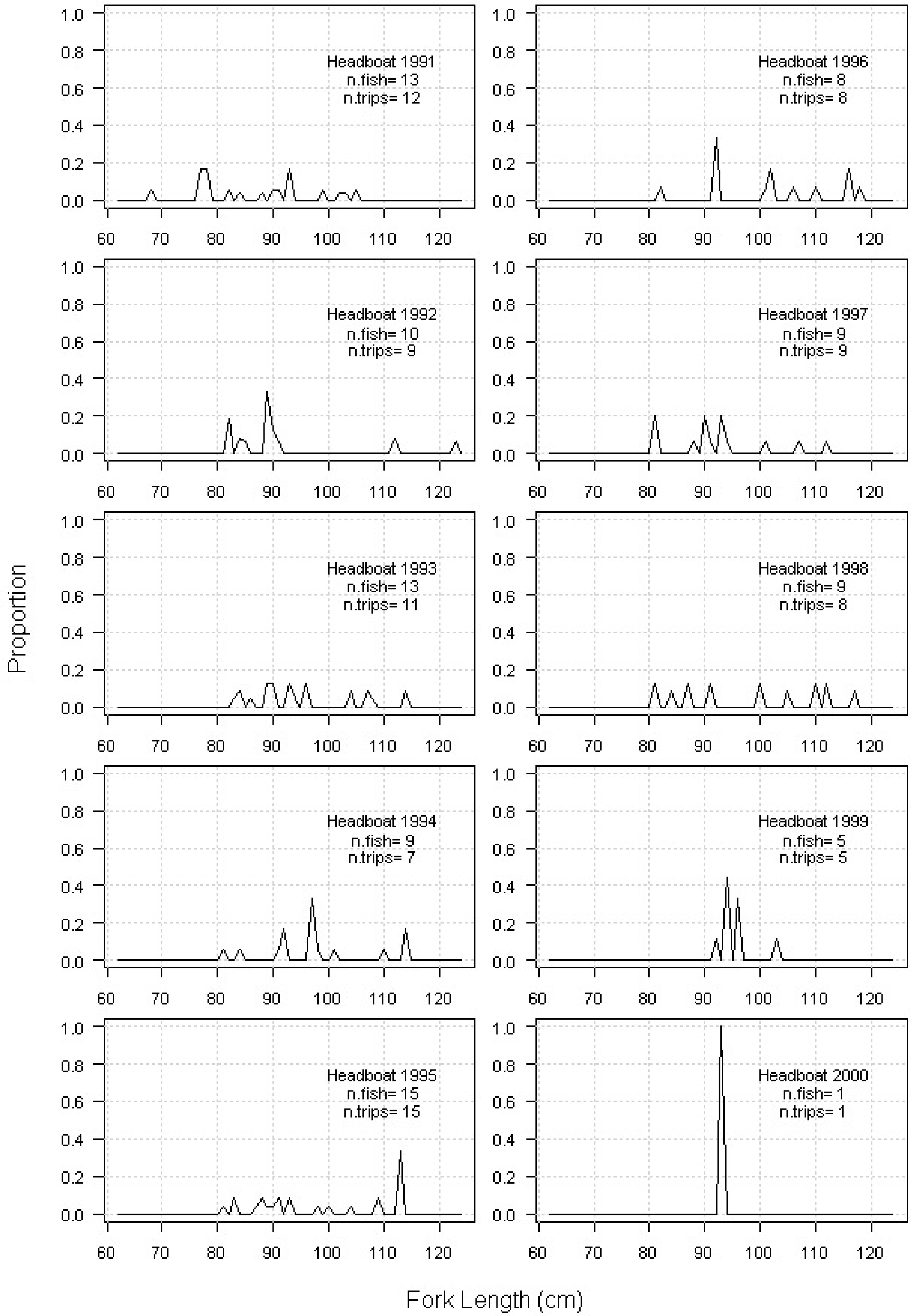

Figure 4.12.18. Headboat length composition 1981-2011 (Continued).

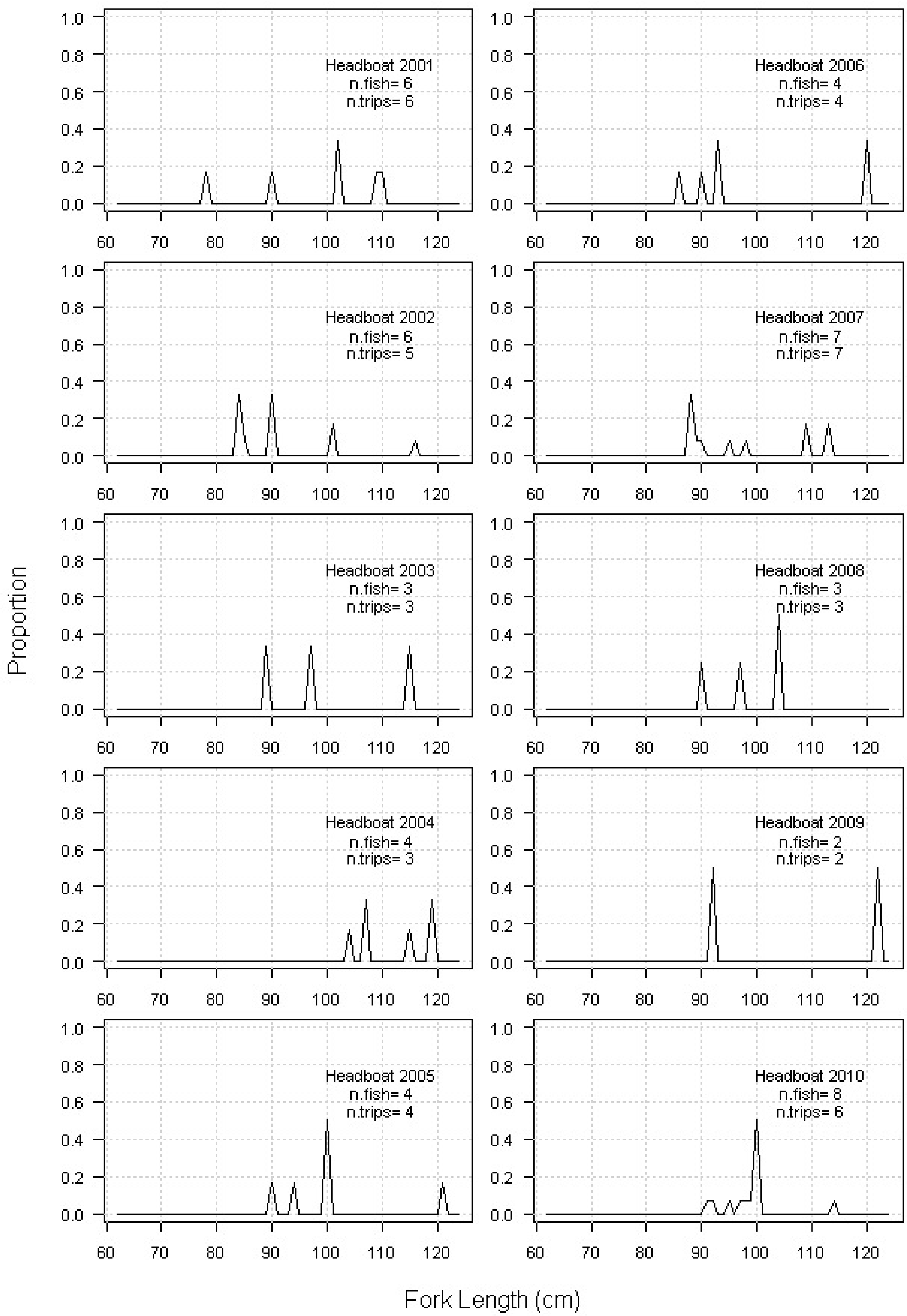

Figure 4.12.18. Headboat length composition 1981-2011 (Continued).

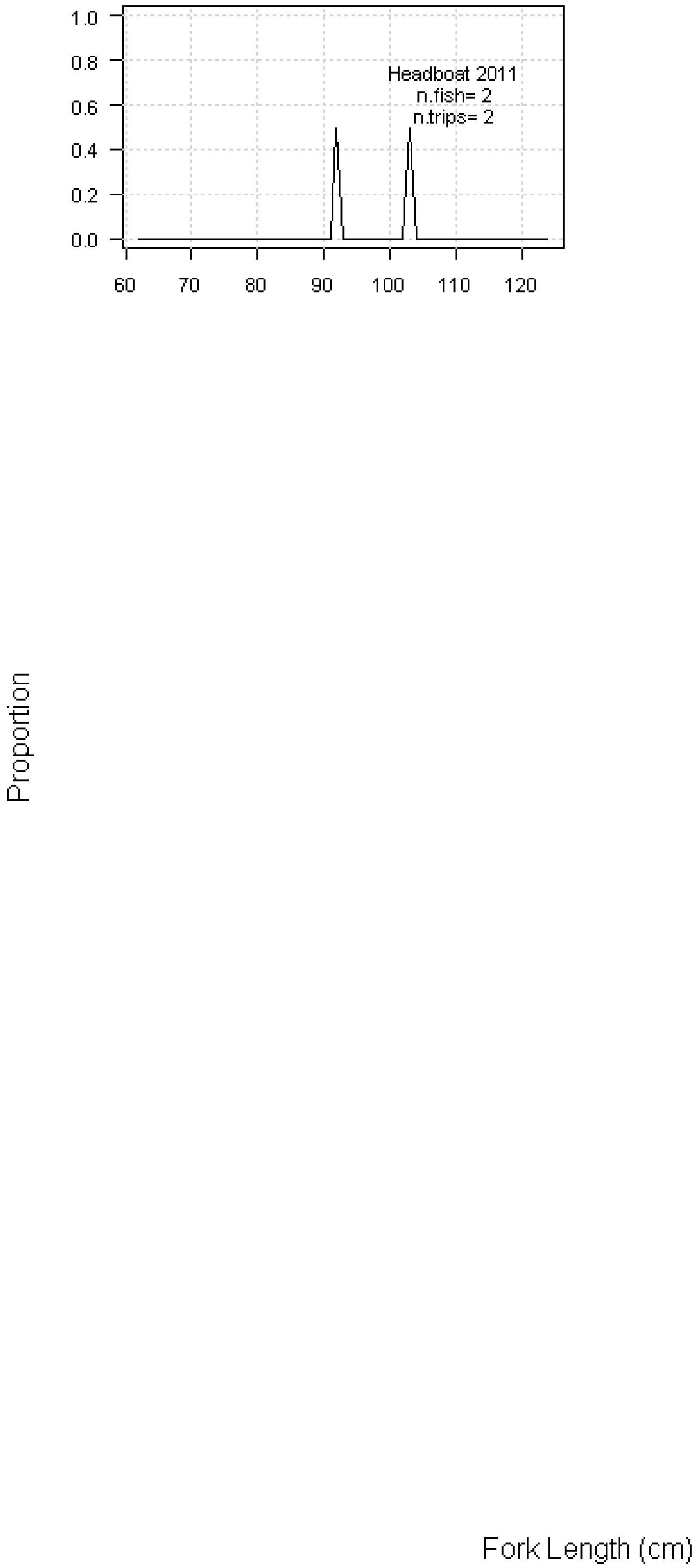

Figure 4.12.18. Headboat length composition 1981-2011 (Continued).

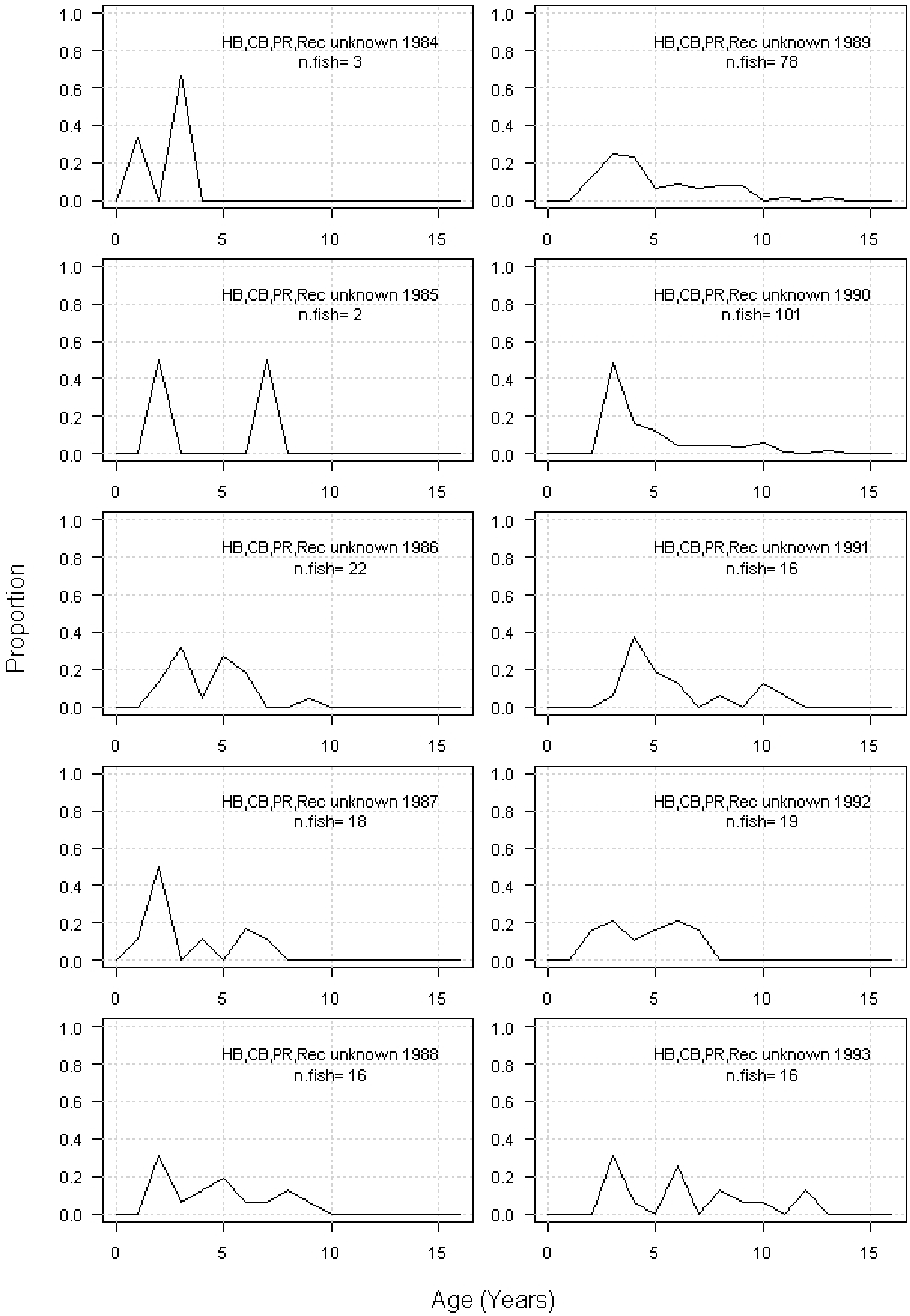

Figure 4.12.19. Age composition of cobia from the headboat, charter boat, private/rental boat, recreational fishery (mode unknown) (1984-1994, 1999-2011).

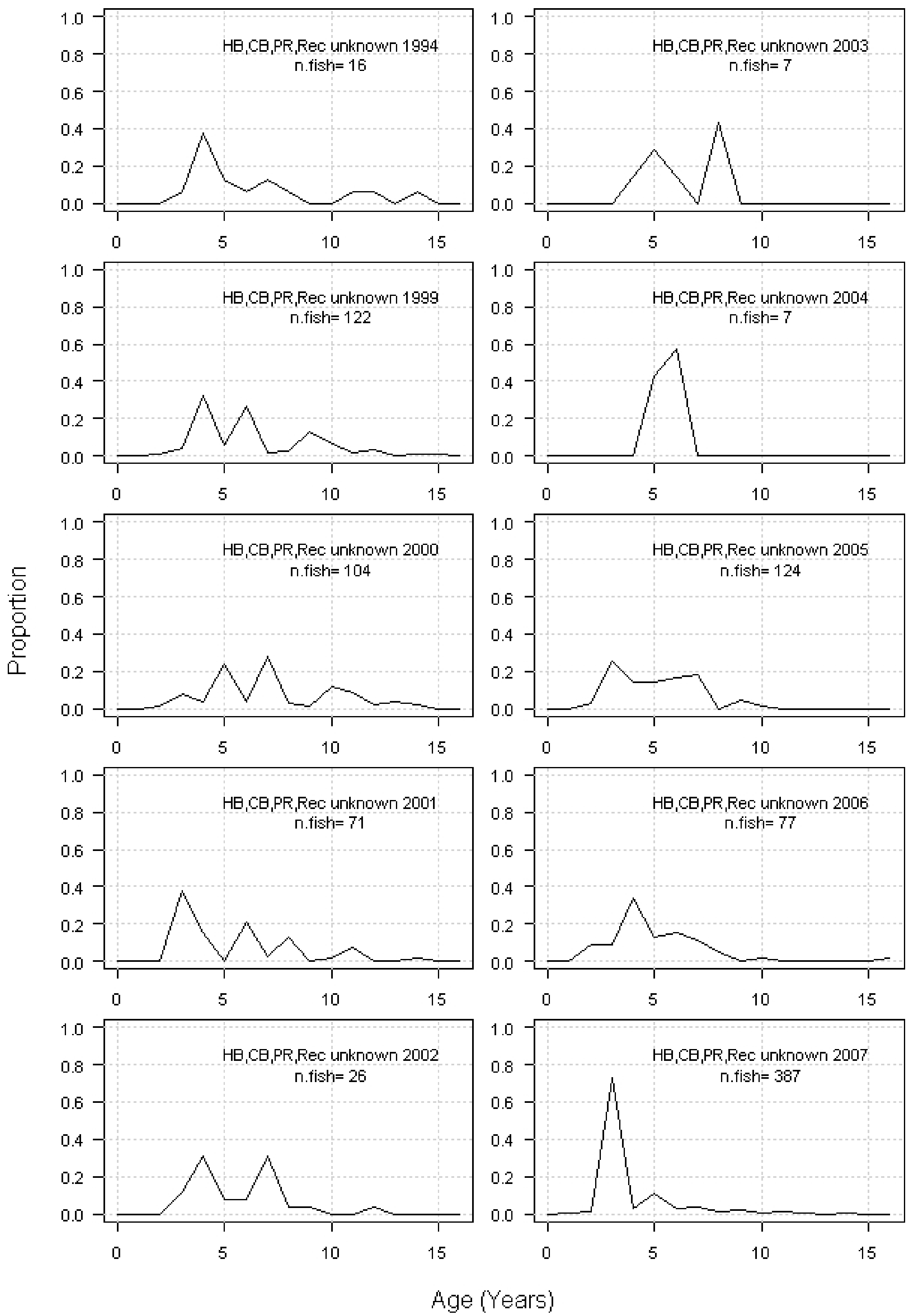

Figure 4.12.19. Age composition of cobia mackerel from the headboat, charter boat, private/rental boat, recreational fishery (mode unknown) (1984-1994, 1999-2011) (continued).

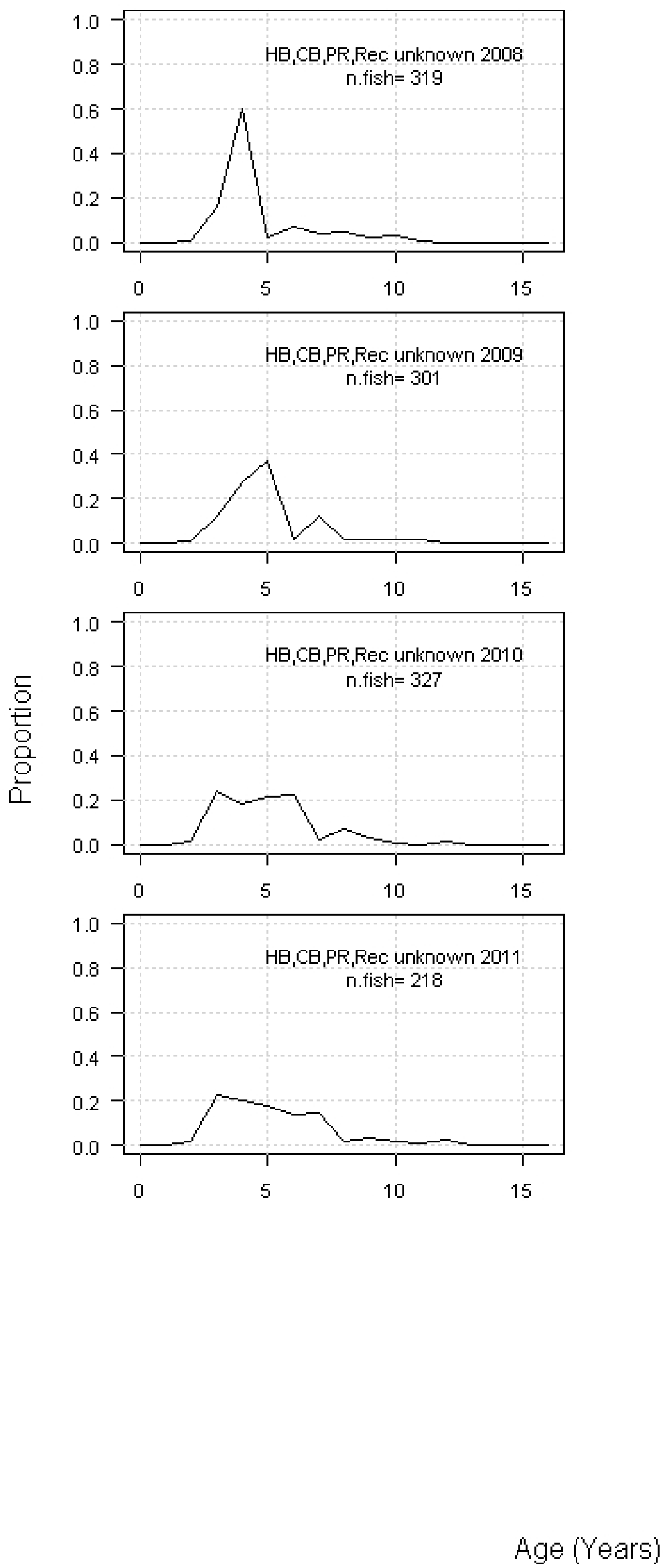

Figure 4.12.19. Age composition of cobia from the headboat, charter boat, private/rental boat, recreational fishery (mode unknown) (1984-1994, 1999-2011) (continued).

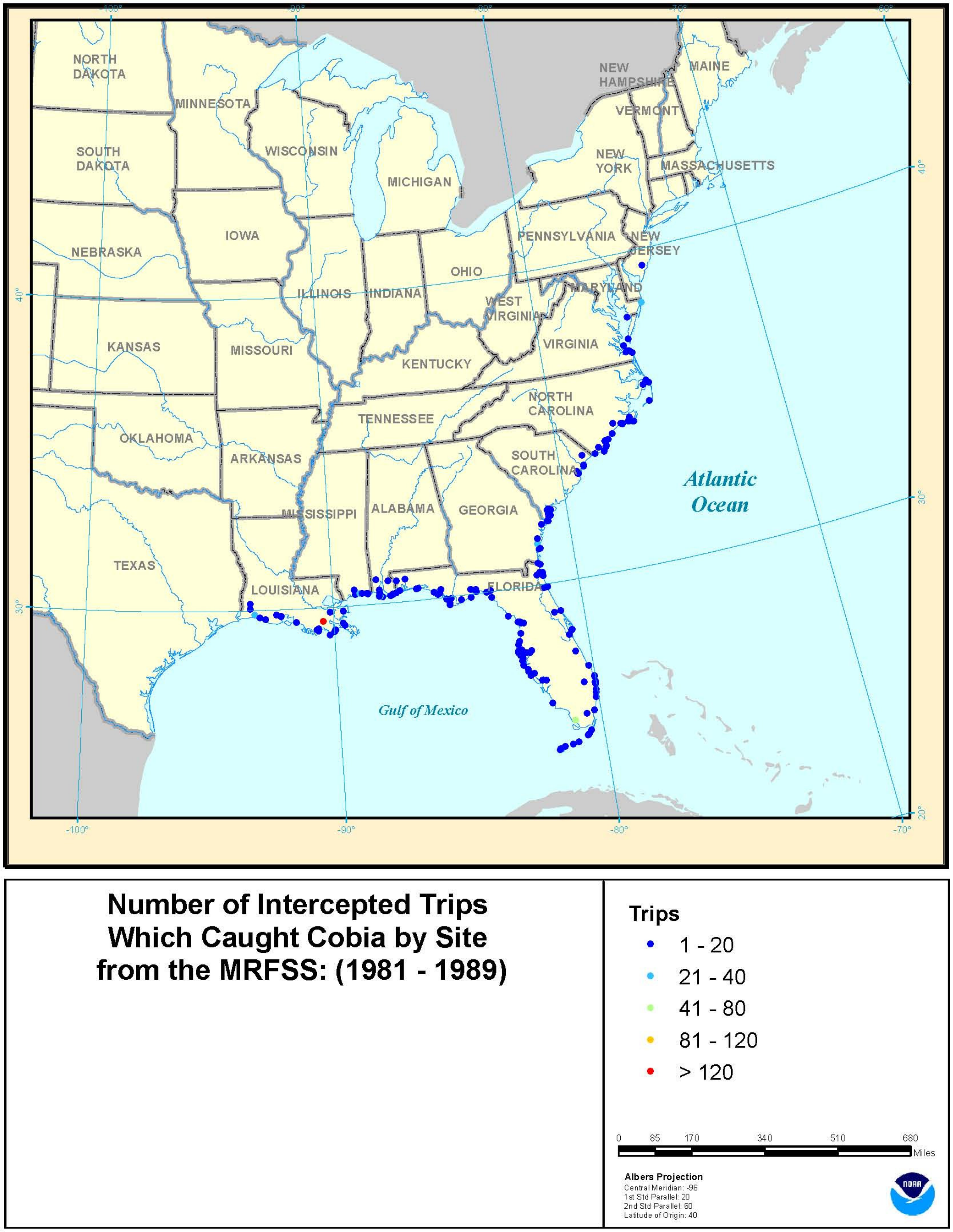

Figure 4.12.20. The number MRFSS intercepted trips which caught cobia from 1981-1989.

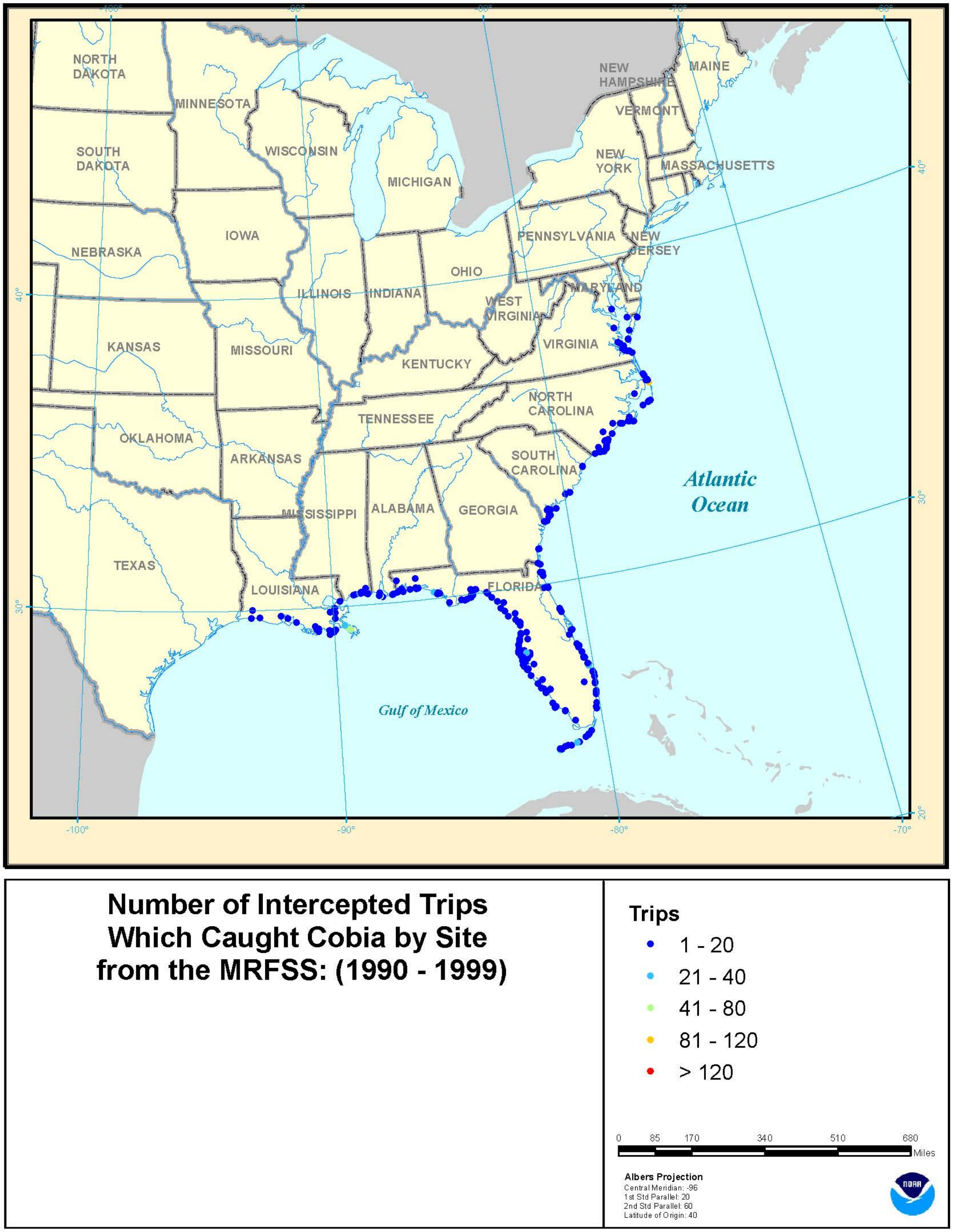

Figure 4.12.21. The number MRFSS intercepted trips which caught cobia from 1990-1999.

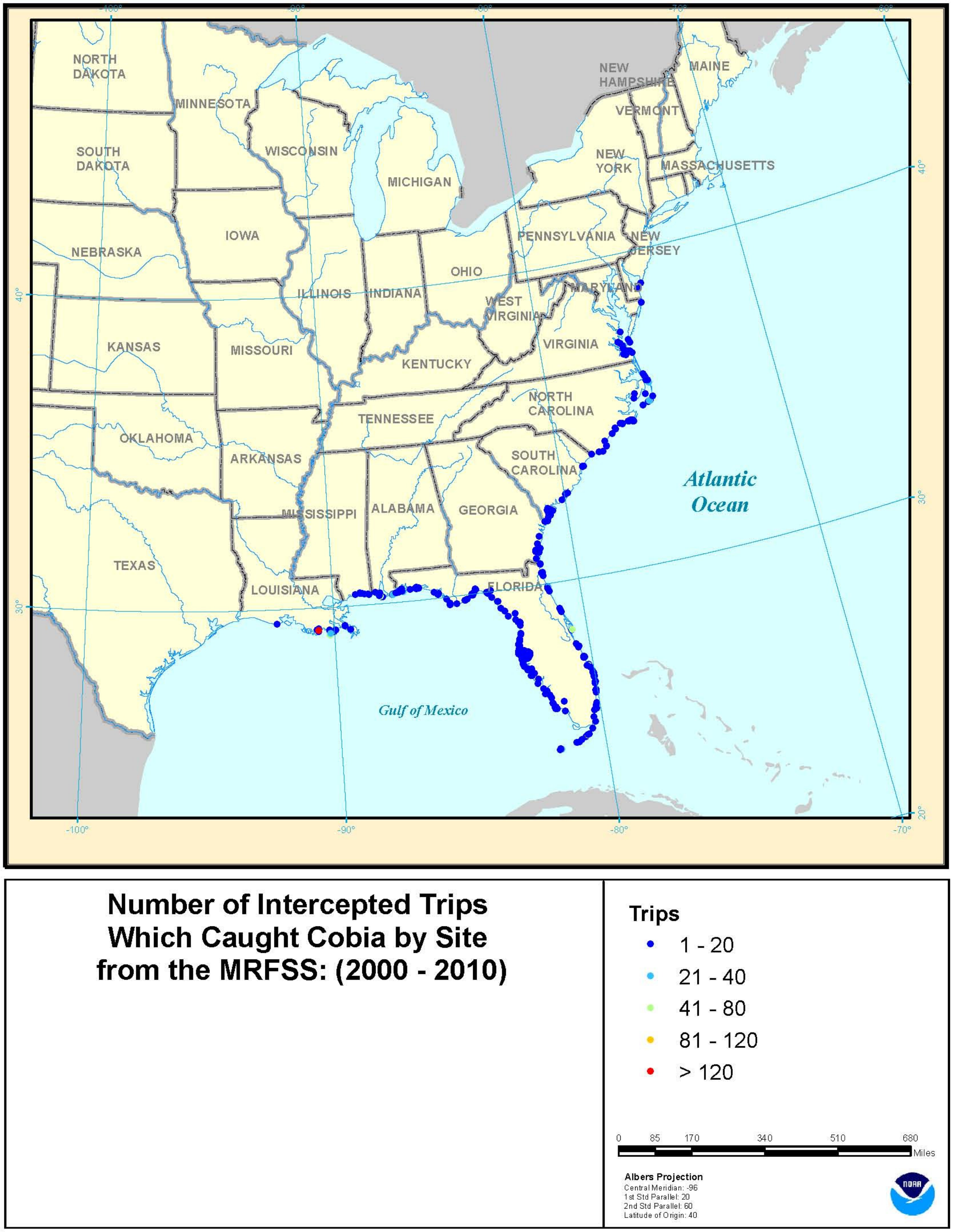

Figure 4.12.22. The number MRFSS intercepted trips which caught cobia from 2000-2010.

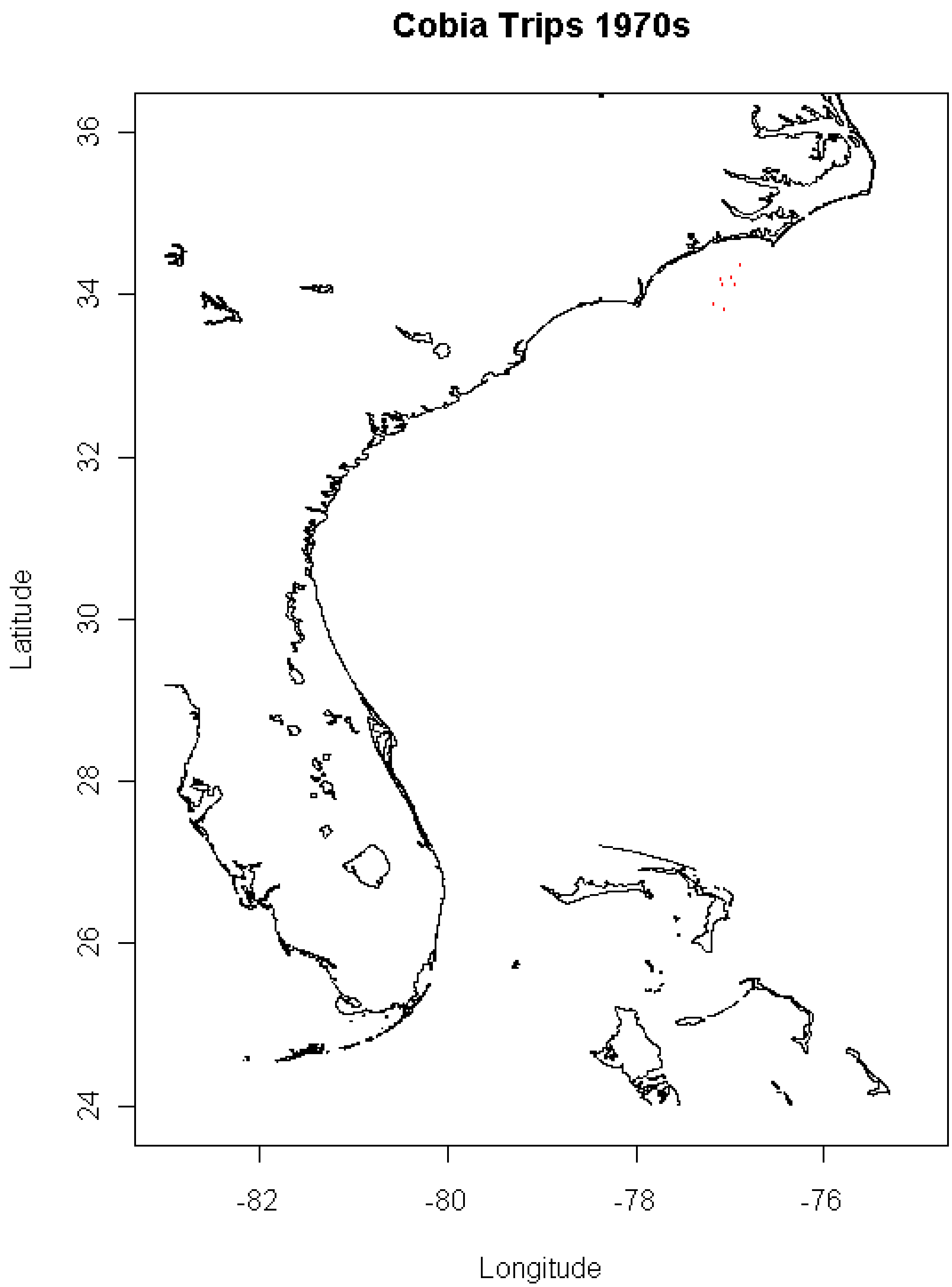

Figure 4.12.23. Reported cobia trips in the South Atlantic from SRHS, 1973-1979. The size of each point is proportional to the frequency of reported trips at the given location.

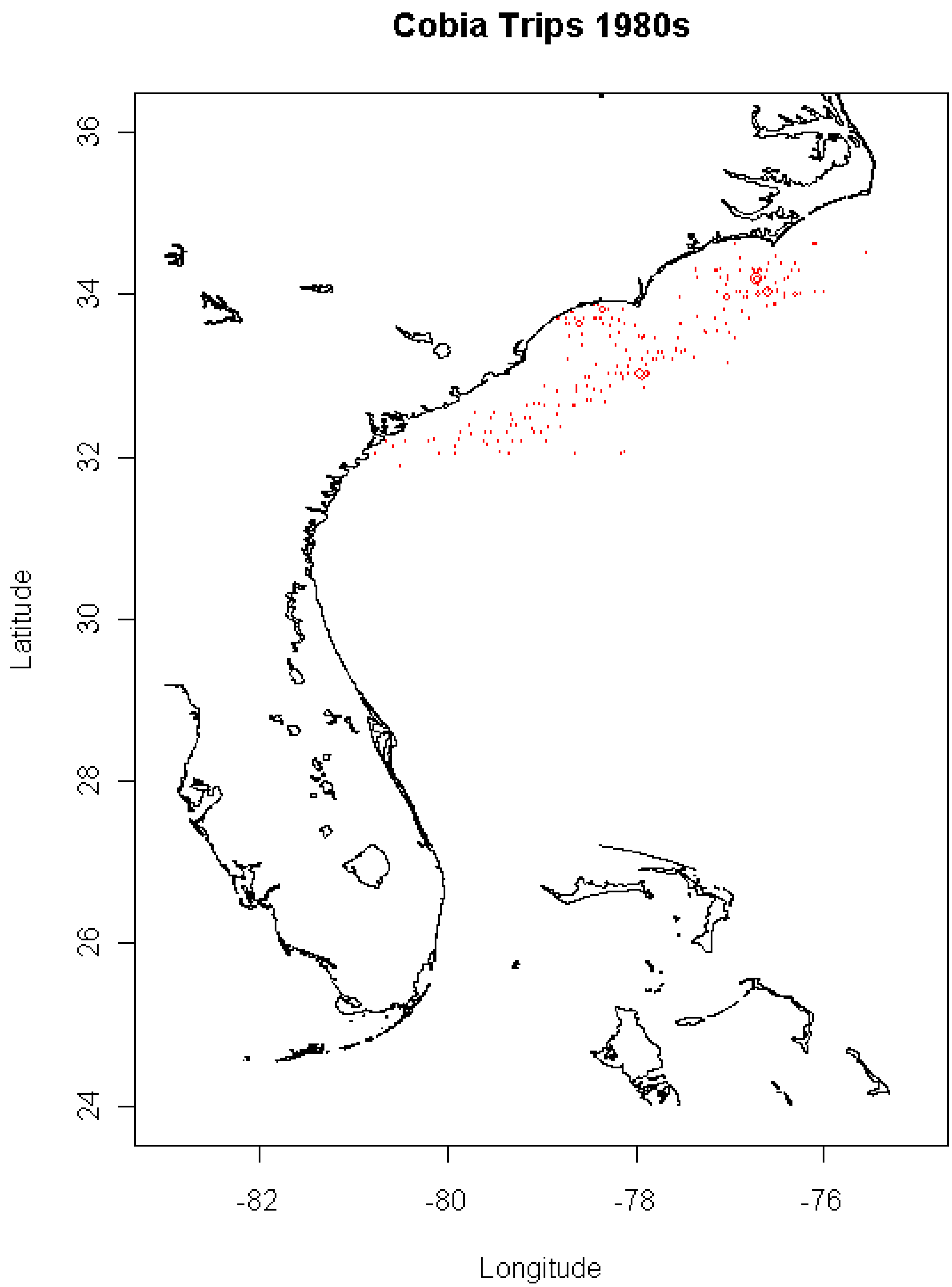

Figure 4.12.24. Reported cobia trips in the South Atlantic from SRHS, 1980-1989. The size of each point is proportional to the frequency of reported trips at the given location.

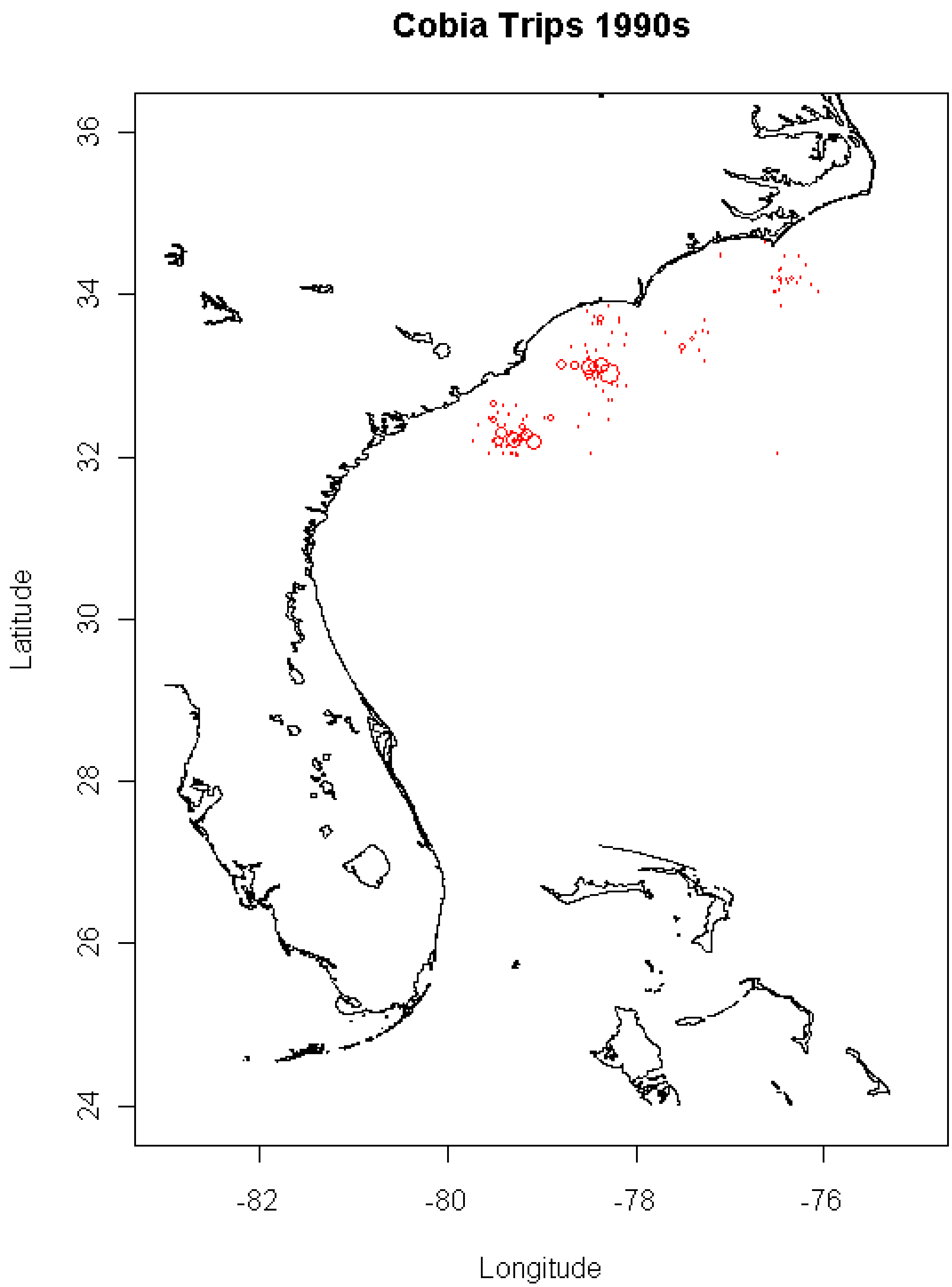

Figure 4.12.25. Reported cobia trips in the South Atlantic from SRHS, 1990-1999. The size of each point is proportional to the frequency of reported trips at the given location.

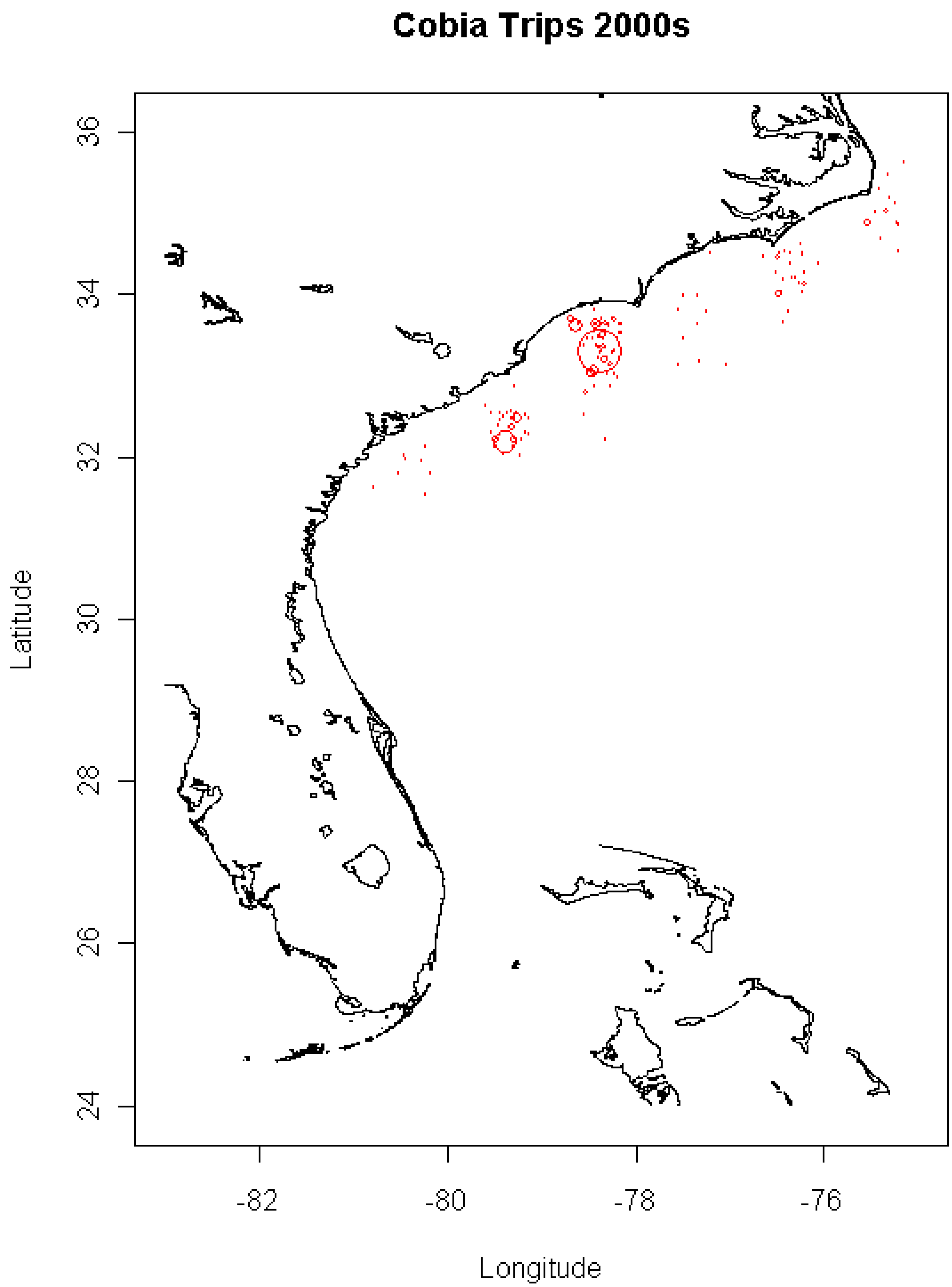

Figure 4.12.26. Reported cobia trips in the South Atlantic from SRHS, 2000-2011. The size of each point is proportional to the frequency of reported trips at the given location.

5 Measures of Population Abundance

5.1 Overview

Several fishery independent 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. The NMFS bottom longline survey, MARMAP, and SEAMAP were not further considered due to extremely low catches of cobia in all years.

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.

Several indices of abundance were considered for use in the South Atlantic cobia assessment model. These indices are listed in Table 5.1.1, with pros and cons of each in Table 5.1.2. Due to the lack of data, a fishery independent index for cobia was not developed. The DW recommended three fishery dependent indices (recreational headboat index, recreational South Carolina Charterboat index, and recreational MRFSS index) for potential use in the cobia stock assessment.

Group membership

Membership of this DW Index Working Group (IWG) included Amy Schueller (work group leader), Eric Fitzpatrick (Rapporteur), Walter Ingram, Jeanne Boylan, Pearse Webster, Clay Porch, Neil Baertlein, Kevin McCarthy, Steve Saul, Meaghan Bryan, Katie Andrews, Kevin Craig, Michael Schirripa, Nancie Cummings, Julia Byrd, and Mike Errigo. Several other participants of the data workshop contributed in the IWG discussions throughout the week.

5.2 Review of Working Papers

The working group reviewed four working papers describing index construction, including: SEDAR28-DW18; SEDAR28-DW19; SEDAR28-DW20; and SEDAR28-DW24. SEDAR28-DW18 described the computation of a fishery dependent index from the commercial logbook vertical line data. SEDAR28-DW19 described the computation of a fishery dependent index from the MRFSS recreational data. SEDAR28-DW20 described the computation of fishery dependent data from the recreational headboat fishery. SEDAR28-DW24 described the computation of a fishery dependent index from the SCDNR charterboat data.

These working papers were helpful for determining which indices should be recommended for use and addendums to each working paper (if applicable) are described below in each index description.

Index report cards for all fishery dependent data considered at the data workshop can be found in Appendix 5.

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

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 5.4.1.1). 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 (areas 1- 17).

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 development of the CPUE index is described in more detail in SEDAR28-DW20. The appendix to the working paper describes decisions made by the SEDAR 28 DW panel with updated tables and figures. The SEDAR 28 DW index working group decisions summarized in SEDAR28-DW20 (Appendix 1) include:

- Begin data series in 1981 due to increased write-ins by captains. Data suggests write-in reporting of cobia prior to 1984 was similar to cobia reporting after 1984.
- At plenary, the Georgia/Florida line was chosen as the stock boundary. This boundary change removed north Florida from the analysis.

5.4.1.1 Methods of Estimation

Data Filtering Techniques

While exploring headboat data to develop a standardized index for cobia in the south Atlantic, the following methods were investigated.

Stephens & McCall

Applying methods described by Stephens & McCall (2004) to cobia resulted in a 67% reduction in positive cobia trips while identifying approximately 11,000 trips that were unsuccessful at catching cobia. A large reduction in positive cobia trips and an inflation of zero cobia trips was anticipated due to the infrequency of cobia in the headboat fishery, therefore a more appropriate method was pursued.

Positive Trips

Headboat trips that caught cobia were investigated. This method underestimates the amount of effort directed at cobia in the headboat fishery by disregarding trips that were unsuccessful at catching cobia. Due to the nature of the cobia fishery a more appropriate method was pursued.

Core Vessels

To identify headboat trips that best characterize the cobia fishery, vessels that consistently caught cobia were selected. A subset identifying data from 15 headboats representing 90% of cobia effort and landings was selected. Positive cobia trips from these core vessels increased from 1.6% (entire fleet) to 6%. By identifying vessels that encounter cobia more frequently, the remaining vessels that infrequently encountered cobia and the associated zero trips were removed. Selecting data using a core group of vessels while removing vessels that inconsistently or never reported cobia more appropriately reflected cobia effort in the headboat fishery.

Spatial distributions of core vessel headboat cobia trips and catch per angler-hour in the south Atlantic by decade are presented in Figures 5.4.1.2 and 5.4.1.3 (both of these figures include eastern Florida, while the stock boundary has been delineated at the Georgia-Florida border). In order to present confidential information spatially, specific locations were shifted from their original position using a jitter function to randomly redistribute plot points by 3 nautical miles. Plot points located on land may be due to the jitter function or misreported location code.

Subsetting trips

The annual catch records were combined, selecting headboat trips that were in the geographical boundaries (North Carolina-Georgia).

Area & Trip Type

Trips from area codes within the geographical boundaries were selected. Multiday trips and trips with less than five anglers per trip were removed eliminating 138,353 records.

Years

1981-2011.

Core Vessel, Month by Vessel

Data from 15 headboats representing 90% of cobia effort and landings were selected. Trips taken by each core vessel that did not catch cobia, but were within the months that typically encountered cobia, were included in the analysis. These ‘zero’ trips represent additional cobia effort to be included in the binomial portion of the analysis. For each vessel, if zero cobia were caught in a specific month, trips from that month were removed (ex. exclusion of winter months for vessels in the northern range). Several vessels caught cobia from April – September, while other vessels caught cobia year around.

Outliers

Trips defined by the upper 0.01% of cobia catch were removed as they likely represent misreporting or data entry errors (i.e., catches greater than 12 cobia per trip).

Model Input

Response and explanatory variables

CPUE – catch per unit effort (CPUE) has units of fish/angler-hour and was calculated as the number of cobia caught divided by the number of anglers times the number of trip hours.

Year- A summary of the total number of trips with cobia effort per year and trips with positive cobia catch is provided in Table 5.4.1.1. Density plots of cobia catch by year are provided in Figure 5.4.1.4.

Trip Type- Trip types of half, ¾, and full day trips were included in the analysis. Multi-day trips were removed.

Vessel-Since each vessel targeted cobia differently (whether by state, season, mean number of anglers), vessel was included in the analysis as an explanatory variable. The number of records with positive cobia effort ranged from 36 trips to 239 trips per year. All vessel information is confidential.

Standardization

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

BERNOULLI SUBMODEL

One component of the delta-GLM is a logistic regression model that attempts to explain the probability of either catching or not catching cobia on a particular trip. First, a model was fit with all main effects in order to determine which effects should remain in the binomial component of the delta-GLM. Stepwise AIC (Venables and Ripley1997) with a backwards selection algorithm was then used to eliminate those that did not improve model fit. In this case, the stepwise AIC procedure did not remove any predictor variables. Recognizable patterns were not apparent in the randomized quantile residuals (Figures 5.4.1.5 – 5.4.1.10).

POSITIVE CPUE SUBMODEL

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

Both components of the model were then fit together (with the code adapted from Dick 2004) using the lognormal and gamma distributions and compared using AIC. With CPUE as the dependent variable, the gamma distribution outperformed the lognormal distribution with lower AIC values when all factors were included and when using only those factors that were selected in the previous step.

Thus, the gamma model with all factors was used for computing the positive component of the index, and the binomial with all factors was used for computing the Bernoulli component of the index. Standard model diagnostics appeared reasonable for the positive component of the model using raw residuals (Dunn and Smyth 1996).

5.4.1.2 Sampling Intensity

The resulting data set contained 27,243 trips with 6% positive cobia trips.

5.4.1.3 Size/Age data

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

5.4.1.4 Catch Rates

Standardized catch rates and associated error bars are shown in Figure 5.4.1.11 and are tabulated in Table 5.4.1.1.

5.4.1.5 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 5.4.1.1 and applied to the estimated index to develop error estimates.

5.4.1.6 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 full range of the stock as described for the South Atlantic and is a complete census of the headboats. 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 was 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 data.

5.4.2 SCDNR Charterboat Logbook Program

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 represents 6-pack charter vessels only and is self-reported with no field validation.

5.4.2.1 Methods of Estimation

Data
All SCDNR charterboat logbook entries which reported using bottom fishing as the method of fishing for that trip were included in the index calculation. 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 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 1998-2010 (Figure 5.4.2.1).

Methods
The CPUE index was standardized using a Delta-GLM approach following the methods of Dick (2004). The factors include in the model that were significant are Year (1998-2010), Locale (Estuarine, Nearshore (0-3 miles), Offshore (outside of 3 miles)), and either Month (1-12) or Season (Winter, Spring, Summer, Fall). The Indices Working Group decided to use Month as a factor over Season due to the lower CVs and better fit when Month was used in the model. A Jackknife approach was used to estimate the amount of variation in the model run as per Dick (2004).

5.4.2.2 Sampling Intensity

Data represents SC licensed 6-pack charter vessel trips operating in or off of SC from 1998 – 2010. 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 85,357 fishing trips in which anglers caught 10,949 cobia and harvested 4,896 cobia (Table 5.4.2.1).

5.4.2.3 Size/Age data

Size and age data specific to charter boats are not 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).

5.4.2.4 Catch Rates

Catch per unit effort was calculated as the number of fish caught per angler-hour. Table 5.4.2.2 and Figure 5.4.2.2 show the nominal and standardized cobia catch rates. The nominal index is above the standardized index because of the way zero catch trips were selected. The subset of trips that were used for the cobia index included all reported bottom fishing trips in estuarine, nearshore (0-3 miles), and offshore (3+) waters. Data were available from 1993 – 2010; however, only data from 1998 – 2010 were used for the index due to a change in effort in the fishery. The percentage of trips targeting cobia increased in 1998 and has remained relatively stable since then. The index was calculated using data from all months.

5.4.2.5 Uncertainty and Measures of Precision

Table 5.4.2.2 shows the coefficients of variation.

5.4.2.5 Comments on Adequacy for Assessment

The index of abundance created from the SC charterboat logbook data was considered by the indices working group to be adequate for potential use in the cobia assessment. The dataset covers a large portion of the South Atlantic stock's geographic range. The index 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. Data were available from 1993 to 2010, however it was decided that the dataset should be truncated to only include data from 1998 onwards due to a change in effort in the fishery (increase in the percentage of trips targeting cobia from 1997 to 1998). The Index Working Group decided that although the MRFSS index could be reproduced to include charter mode, since cobia is a rare event species in MRFSS the SCDNR charterboat logbook dataset would be better to use as an index for this mode of fishing.

5.4.3 MRFSS

The MRFSS access-point angler intercept survey is conducted at public marine fishing access points to collect data on the individual catch of fishers, including species identification, total number and disposition of each species, and length and weight measurements of retained fish, as well as information about the fishing trip and the angler's fishing behavior. For more information on the methodology and variables collected, see the MRFSS Data User's Manual (available at http://www.st.nmfs.noaa.gov/st1/recreational/pubs/data_users/index.html).

5.4.3.1 Methods of Estimation

Data from 1985 – 2010 were used. After sub-setting the sample sizes in 1981-1984 were too small and data for 2011 were not yet finalized.

The unit of effort used was directed angler-hour. The MRFSS intercept database was subset to trips that either targeted or caught (regardless of disposition) the cobia and by hook-and-line gear. Total available catch (Type A catch) was divided by the number of A-anglers that contributed to that catch multiplied by the number of hours fished to obtain Type A catch-per-angler-hour. The number of unavailable fish (Type B1 + B2 catch) was summed over all Type B records in the group trip set and divided by the number of unavailable catch records for that group trip multiplied by the number of hours fished to obtain Type B catch-per-angler-hour. The Type A and Type B catch per angler-hour estimates were added together to get total catch per angler-hour.

The MRFSS intercept survey only counts anglers who contribute to the total catch, thus estimates of total catch per angler-hour may be biased high in cases where anglers in the group fished but did not catch anything. In addition, the directed trips designation may not adequately identify zero trips. Anglers targeting other species or who do not report a target species may still have taken a trip that could have caught the species of interest, and that zero trip would not be included in the directed trips subset.

Atlantic observations were defined as the FL/GA state line north to NY. The index reflects private/rental boats and shore modes, hook and line gear and waves 2-5.

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

A delta-lognormal approach (Lo *et al.,* 1992) was used to standardize the index. A forward selection method was used to select the factors based on reductions in deviance for each component of the model. Factors considered included year, region, area fished, wave, mode and hours fished. A factor was included in the model if it reduced the deviance by 5% or more.

5.4.3.2 Sampling Intensity

In the Atlantic, a total of 4,740 interviews were conducted from 1985 – 2010 in waves 2-5 that caught or targeted cobia and used hook-and-line gear.

5.4.3.3 Size/Age data

The recreational fisheries target adult fish of both species. The median fork length for cobia was 98 cm, with individuals ranging from 11 to 197 cm (Figure 5.4.3.1). 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).

5.4.3.4 Catch Rates

Both the nominal and standardized indices were flat, varying without trend (Figure 5.4.3.2, Table 5.4.3.1).

5.4.3.5 Uncertainty and Measures of Precision

For cobia, year, area fished, mode and wave provided the greatest reductions in deviance for the positive trips model (Table 5.4.3.2). Year, area fished, wave, region and mode provided the greatest reductions in deviance for the proportion positive model (Table 5.4.3.3). Cobia positive intercepts deviated slightly from the lognormal distribution (Figure 5.4.3.3). Standard errors were derived from the estimated covariance matrix of the estimated coefficients.

5.4.3.6 Comments on Adequacy for Assessment

The index of abundance created from the MRFSS data was 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 South 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. While the index created from MRFSS is based on fishery dependent data, the recommendation based on the pros was to consider this as an index for potential use in the assessment.

5.4.4 Other Data Sources Considered

Several datasets were introduced at the SEDAR 28 data workshop that were considered but not recommended for potential use in the cobia stock assessment.

5.4.4.1 South Atlantic Commercial Logbook – hook and line

Self-reported commercial logbook hook and line (handline, electric and hydraulic reel, and trolling) catch per unit effort (CPUE) data were used to construct standardized abundance indices for cobia in the US South Atlantic. Cobia data were sufficient to construct indices including the years 1993-2010. Prior to 1993, only a 20% sample of vessels in Florida was required to report landings and effort data to the coastal logbook program. Methods and results of the analyses are described in SEDAR28-DW18.

Two hook and line indices were constructed using handline (including electric reels) combined with trolling data: a lognormal model including only data from positive cobia hook and line trips and a delta-lognormal index including all South Atlantic hook and line data. The spatial coverage of both indices included the region 28^{o}N to 37^{o}N latitude.

Data were filtered to remove records missing landings or effort data, records with logical inconsistencies (e.g., fishing more than 24 hours/day), and records with obvious data entry errors (vessels reporting 50 lines fished, for example). Data were also filtered to remove records from reports submitted more than 45 days following the fishing trip. Such lengthy delays in reporting may have resulted in less accurate data than that reported with less delay.

Commercial logbook data reported from fishing trips with cobia landings were used in lognormal models on catch rates to construct standardized indices of abundance. Parameterization of the model was accomplished using a GLM procedure (GENMOD; Version 9.1 of the SAS System for Windows © 2002-03. SAS Institute Inc., Cary, NC, USA). The final lognormal model was fit using a mixed model (PROC MIXED; Version 9.1 of the SAS System for Windows © 2002-03. SAS Institute Inc., Cary, NC, USA).

A second standardized index of abundance was constructed using a delta lognormal model approach (Lo et al. 1992). This method combines separate general linear model (GLM) analyses of the proportion of successful trips (trips that landed cobia) and the catch rates on successful trips to construct a single standardized CPUE index. Parameterization of the models was accomplished using a GLM analysis (GENMOD; Version 8.02 of the SAS System for Windows © 2000. SAS Institute Inc., Cary, NC, USA). The final delta-lognormal model was fit using a SAS macro, GLIMMIX (Russ Wolfinger, SAS Institute).

The final model for the lognormal on CPUE of successful trips:

LOG(CPUE) = Year + Gear Fished + Quarter + Year*Quarter + Gear Fished*Year

The final models for the binomial on proportion positive trips (PPT) and the lognormal on CPUE of successful trips were:

PPT = Year + Subregion + Gear Fished

LOG(CPUE) = Year + Gear Fished + Quarter + Year*Quarter + Gear Fished*Year

Relative nominal CPUE, number of trips, and relative abundance indices are provided in Tables 5.4.4.1 and 5.4.4.2 for each of the cobia hook and line analyses. The lognormal and delta-lognormal abundance indices are shown in Figures 5.4.4.1 and Figure 5.4.4.2.

No change in yearly mean cpue was apparent in the lognormal cobia index. A small increase in cpue was found in the final two years of the delta-lognormal index, however confidence intervals around the mean values were large.

5.4.4.2. Comments on Adequacy for Assessment

Neither commercial logbook index of South Atlantic cobia was recommended for use in the cobia stock assessment. Concerns were raised regarding the very restrictive trip limits of the fishery (two cobia per person per day) and the often opportunistic fishing effort practiced by the fishery, which prevented the construction of a CPUE series that reflected cobia population abundance because the unit of effort could not be defined. Additionally, cobia were not consistently reported on the logbook form and sample sizes were low.

5.5 Consensus Recommendations and Survey Evaluations

Three fishery dependent indices were recommended for potential use in the cobia stock assessment: recreational headboat index, SC charterboat index, and the MRFSS index. All indices that have been computed are compared graphically in Figure 5.5.1. Pearson correlations and significance values (p-value) among indices are presented in Table 5.5.1. Correlations were completed for all overlapping years of data between two data sets. Indices recommended for potential use are presented in Table 5.5.3.

The relative ranking of the ability of each index to represent true population abundance was discussed. Based on these discussions, the indices recommended for the assessment were ranked as follows with a bulleted list of discussion points below each index:

1. Headboat index
    - Longest time series
    - Operates in a manner more similar to fishery independent data collection because the fishery targets the snapper-grouper complex in general rather than the focal species specifically
2. MRFSS index
    - Potential bag limit issue, however, the index does include discards
    - Prim1 and Prim2, often only report these fields when a cobia was caught
    - Potential issue using MRFSS methodology instead of MRIP to develop index
3. SC Charterboat logbook index
    - Shorter time series
    - Doesn’t match up with a fleet from any of the landings time series, therefore, the assessment panel will have to borrow a selectivity curve from another source or fleet
    - Limited spatial extent

5.6 Literature Cited

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5.7 Tables

Table 5.1.1. Table of the data considered for the construction of a CPUE index.

Fishery Type	Data Source	Area	Years	Units	Standardization Method	Issues	Use?
Recreational	Headboat	NC-GA	1981-2011	Number/angler-hour	Delta-GLM	Fishery dependent, self reported	Yes
Recreational	SCDNR Charter Logbooks	All of SC	1998-2010	Number / angler-hour	Delta-GLM	Overlap with MRFSS, self reported with no field validation	Yes
Commercial	Commercial Logbook Vertical Line	NC-GA	1993-2010	Lb kept/hook hour	Delta–GLM	Fishery dependent, self reported, effort unit difficult to define, problems with trip limits, low sample sizes	No
Recreational	MRFSS	NY-GA	1985-2010	Number/angler-hour	Delta-GLM	Fishery dependent.	Yes

Table 5.1.2. Table of the pros and cons for each data set considered at the data workshop.

Fishery dependent indices
Recreational Headboat (*Recommended for use*)
Pros:
- Complete census
- Covers entire 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
- Concerns about stocking effects
- Mostly presence/absence

SCDNR Charterboat *(Recommended for use)*
Pros:
- Census of charter boats (rare species)
- Reasonable spatial coverage
- No bag limit issue
- Includes discards

Cons:
- No field validation, self reported data
- Potential stocking effects
- Data reproducible in MRFSS at larger scale

MRFSS *(Recommended for use)*
Pros:
- Includes discards
- Good spatial coverage
- Long time series
- Target known
- No bag limit issues

Cons:
- MRFSS sampling design considerations
- Fishery dependent

Commercial Logbook – Vertical Line (*Not recommended for use*)
Pros:
- Complete census

Cons:
- Can't define unit of effort relevant to cobia
- Problems with limiting out (bag limit is 2/person/day)

- Not consistently reported on form
- Uncertainty in ability to estimate number of cobia caught from weight
- Extremely low sample sizes for cobia
- Only federally permitted vessels required to report

Table 5.4.1.1. The relative nominal CPUE, number of trips with positive cobia catch, core vessel trips, percentage of trips positive for cobia capture (% positive cobia), standardized index, and CV for the cobia headboat fishery in the south Atlantic.

Year	nominal CPUE	cobia trips	Vessel Trips	% positive cobia	Standardized index	CV (index)
1981	0.42	23	307	7%	0.72	0.25
1982	0.56	28	459	6%	0.71	0.26
1983	0.56	27	484	6%	0.81	0.25
1984	0.55	14	500	3%	0.36	0.31
1985	0.98	7	455	2%	0.36	0.56
1986	0.76	21	508	4%	0.71	0.27
1987	0.77	42	869	5%	1.18	0.19
1988	0.66	44	995	4%	0.88	0.21
1989	0.88	22	542	4%	0.81	0.25
1990	0.56	21	562	4%	0.55	0.26
1991	0.85	70	938	7%	1.72	0.17
1992	0.91	81	1,189	7%	1.34	0.16
1993	0.74	82	1,248	7%	1.05	0.15
1994	0.86	88	1,185	7%	1.19	0.15
1995	0.87	113	1,230	9%	1.32	0.14
1996	0.75	48	1,204	4%	0.56	0.20
1997	0.88	58	816	7%	0.94	0.17
1998	0.94	76	1,281	6%	0.86	0.15
1999	1.11	58	1,152	5%	0.90	0.18
2000	1.13	84	1,339	6%	1.28	0.17
2001	1.71	74	1,047	7%	1.34	0.17
2002	1.39	70	1,007	7%	0.90	0.16
2003	1.41	57	965	6%	1.11	0.19
2004	1.12	80	1,270	6%	1.08	0.16
2005	1.43	55	902	6%	1.08	0.19
2006	1.17	55	1,093	5%	0.94	0.20
2007	1.04	100	1,063	9%	1.54	0.14
2008	1.20	87	795	11%	1.96	0.15
2009	2.43	42	822	5%	0.93	0.21
2010	1.36	58	1,016	6%	0.88	0.17
2011	1.12	41	831	5%	0.94	0.22

Table 5.4.2.1. Annual number of vessel trips, percentage of trips with cobia catch, total cobia catch in number of fish, and cobia harvest in number of fish from SCDNR Charterboat Logbook Program, 1998-2010.

Year	Vessel Trips	% Trips with Cobia Catch	Cobia Total Catch (# fish)	Cobia Harvest (# fish)
1998	5050	5.17	780	178
1999	5294	7.10	1046	509
2000	6222	5.98	720	311
2001	6357	6.09	967	433
2002	6515	5.39	698	347
2003	6560	4.83	605	374
2004	6588	5.46	734	439
2005	6927	4.89	676	403
2006	7064	5.22	881	212
2007	7662	6.17	1284	482
2008	7242	4.98	901	433
2009	6976	4.97	858	390
2010	6900	4.52	799	385

Table 5.4.2.2. Nominal cobia catch per unit effort in number of fish per angler hour, standardized CPUE, and the associated CV and SE for the SCDNR charterboat logbook program, 1998-2010.

Year	Nominal CPUE	Standardized CPUE	CV	SE
1998	0.01217	0.00584	0.31088	0.00181
1999	0.01587	0.00712	0.30511	0.00217
2000	0.00938	0.00532	0.23432	0.00125
2001	0.01228	0.00618	0.25334	0.00156
2002	0.00847	0.00492	0.33630	0.00166
2003	0.00721	0.00371	0.21724	0.00081
2004	0.00876	0.00610	0.25642	0.00156
2005	0.00724	0.00486	0.23719	0.00115
2006	0.00915	0.00481	0.20822	0.00100
2007	0.01218	0.00574	0.24121	0.00138
2008	0.00864	0.00407	0.23494	0.00096
2009	0.00889	0.00534	0.23311	0.00124
2010	0.00817	0.00370	0.28015	0.00104

Table 5.4.3.1. Standardized index, CV, nominal index, and sample size for south Atlantic cobia from MRFSS for 1985 to 2010.

Year	Standardized Index	CV	Nominal Index	Sample Size
1985	0.028	0.70	0.037	111
1986	0.019	0.74	0.026	100
1987	0.016	0.79	0.038	106
1988	0.013	0.61	0.019	92
1989	0.054	0.60	0.074	125
1990	0.013	0.68	0.019	159
1991	0.017	0.65	0.020	161
1992	0.018	0.68	0.023	179
1993	0.013	0.60	0.027	100
1994	0.021	0.59	0.044	301
1995	0.026	0.59	0.032	229
1996	0.025	0.59	0.028	245
1997	0.038	0.57	0.042	189
1998	0.043	0.56	0.067	149
1999	0.062	0.57	0.075	150
2000	0.038	0.55	0.039	119
2001	0.054	0.55	0.065	167
2002	0.034	0.56	0.037	212
2003	0.051	0.53	0.063	214
2004	0.051	0.53	0.049	179
2005	0.050	0.55	0.064	184
2006	0.054	0.52	0.060	144
2007	0.038	0.54	0.047	245
2008	0.038	0.55	0.045	219
2009	0.052	0.51	0.063	251
2010	0.055	0.62	0.078	410

Table 5.4.3.2. Deviance table for positive trips model for Atlantic cobia from MRFSS.

	D.F.	Deviance	Resid. D.F.	Resid. Dev	Pr(>Chi)	Percent Deviance Explained
NULL	.	.	855	348.3	.	.
YEAR	25	7.89	855	340.4	0.7767	57.7
AREA_FISHED	2	2.92	828	337.5	0.0274	21.4
WAVE	3	1.52	825	336.0	0.2898	11.1
REGION	1	0.14	824	335.8	0.5565	1.0
MODE	1	1.20	823	334.6	0.0856	8.8

Table 5.4.3.3. Deviance table for proportion positive model for Atlantic cobia from MRFSS.

	D.F.	Deviance	Resid. D.F.	Resid. Dev	Pr(>Chi)	Percent Deviance Explained
NULL	.	.	4739	4477.3	.	.
YEAR	25	137.98	4714	4339.3	0.0000	36.4
AREA_FISHED	2	76.49	4712	4262.8	0.0000	20.2
WAVE	3	111.01	4709	4151.8	0.0000	29.3
REGION	1	24.67	4708	4127.1	0.0000	6.5
MODE	1	28.64	4707	4098.5	0.0000	7.6
HOURS_FISHED	1	0.01	4706	4098.5	0.0000	0.0

Table 5.4.4.1. Commercial logbook cobia handline and trolling relative nominal CPUE, number of trips, standardized abundance index, and associated upper and lower confidence intervals (CI) and CVs for the South Atlantic lognormal index, 1993-2010.

YEAR	Normalized Nominal CPUE	Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1993	0.925	49	0.906	0.518	1.583	0.285
1994	1.067	103	1.090	0.656	1.809	0.258
1995	0.991	59	0.812	0.471	1.399	0.278
1996	1.279	55	1.219	0.714	2.081	0.272
1997	1.100	73	0.962	0.578	1.602	0.259
1998	0.740	136	0.951	0.588	1.537	0.244
1999	0.888	130	0.907	0.561	1.468	0.244
2000	0.679	127	0.801	0.495	1.297	0.244
2001	0.628	155	0.716	0.445	1.154	0.242
2002	0.659	168	0.799	0.497	1.284	0.241
2003	0.863	146	0.951	0.590	1.533	0.242
2004	1.162	134	1.291	0.796	2.095	0.246
2005	1.245	138	1.167	0.722	1.886	0.244
2006	1.024	165	1.063	0.661	1.708	0.241
2007	1.278	166	1.111	0.690	1.788	0.241
2008	0.985	190	0.926	0.576	1.488	0.241
2009	1.060	300	1.083	0.678	1.730	0.237
2010	1.428	266	1.247	0.779	1.997	0.239

Table 5.4.4.2. Commercial cobia handline relative nominal CPUE, number of trips, proportion positive trips, standardized abundance index, and associated confidence interval (CI) and CV for the South Atlantic delta-lognormal index from 1993 to 2010.

YEAR	Normalized Nominal CPUE	Trips	Proportion Positive	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1993	0.925	939	0.052	0.945	0.369	2.424	0.498
1994	1.067	1,823	0.057	1.302	0.603	2.815	0.400
1995	0.991	1,637	0.036	0.654	0.267	1.602	0.471
1996	1.279	1,220	0.045	1.208	0.491	2.971	0.474
1997	1.100	1,795	0.041	0.895	0.391	2.048	0.432
1998	0.740	4,512	0.030	0.624	0.307	1.269	0.366
1999	0.888	4,252	0.031	0.638	0.312	1.307	0.370
2000	0.679	4,647	0.027	0.487	0.237	1.001	0.372
2001	0.628	4,196	0.037	0.594	0.298	1.183	0.355
2002	0.659	3,889	0.043	0.731	0.371	1.441	0.349
2003	0.863	3,327	0.044	0.897	0.447	1.800	0.359
2004	1.162	3,048	0.044	1.268	0.622	2.584	0.368
2005	1.245	3,059	0.045	1.129	0.558	2.287	0.364
2006	1.024	3,285	0.050	1.110	0.562	2.189	0.350
2007	1.278	3,798	0.044	1.039	0.526	2.051	0.350
2008	0.985	4,003	0.047	0.874	0.449	1.700	0.342
2009	1.060	4,345	0.069	1.402	0.756	2.601	0.317
2010	1.428	2,728	0.098	2.201	1.173	4.131	0.323

Table 5.5.1. Pearson correlation analysis (p-value) for indices recommended for use. Correlations are for 1985-2010 for the headboat-MRFSS comparison and for 1998-2010 for the headboat-SC logbook and MRFSS-SC logbook comparisons.

	SA Headboat	MRFSS	SCDNR Charterboat logbook
SA Headboat	1		
MRFSS	0.001 (0.996)	1	
SCDNR Charterboat logbook	-0.158 (0.60)	0.23 (0.44)	1

Table 5.5.3. SEDAR 28 south Atlantic cobia indices recommended for potential use in the cobia stock assessment scaled to their mean and the associated CVs.

Year	Headboat	SC logbook	MRFSS	Headboat cv	SC logbook cv	MRFSS cv
1981	0.72			0.25		
1982	0.71			0.26		
1983	0.81			0.25		
1984	0.36			0.31		
1985	0.36		0.79	0.56		0.70
1986	0.71		0.54	0.27		0.74
1987	1.18		0.45	0.19		0.79
1988	0.88		0.37	0.21		0.61
1989	0.81		1.52	0.25		0.60
1990	0.55		0.37	0.26		0.68
1991	1.72		0.48	0.17		0.65
1992	1.34		0.51	0.16		0.68
1993	1.05		0.37	0.15		0.60
1994	1.19		0.59	0.15		0.59
1995	1.32		0.73	0.14		0.59
1996	0.56		0.71	0.2		0.59
1997	0.94		1.07	0.17		0.57
1998	0.86	1.12	1.21	0.15	0.31	0.56
1999	0.9	1.37	1.75	0.18	0.31	0.57
2000	1.28	1.02	1.07	0.17	0.23	0.55
2001	1.34	1.19	1.52	0.17	0.25	0.55
2002	0.9	0.94	0.96	0.16	0.34	0.56
2003	1.11	0.71	1.44	0.19	0.22	0.53
2004	1.08	1.17	1.44	0.16	0.26	0.53
2005	1.08	0.93	1.41	0.19	0.24	0.55
2006	0.94	0.92	1.52	0.2	0.21	0.52
2007	1.54	1.10	1.07	0.14	0.24	0.54
2008	1.96	0.78	1.07	0.15	0.23	0.55
2009	0.93	1.03	1.47	0.21	0.23	0.51
2010	0.88	0.71	1.55	0.17	0.28	0.62
2011	0.94			0.22		

5.8 Figures

Figure 5.4.1.1. Map of headboat sampling area definition. These areas were pooled into regions of North Carolina (NC=1,2,3,9,10), South Carolina (SC=4,5), and Georgia (GA=6).

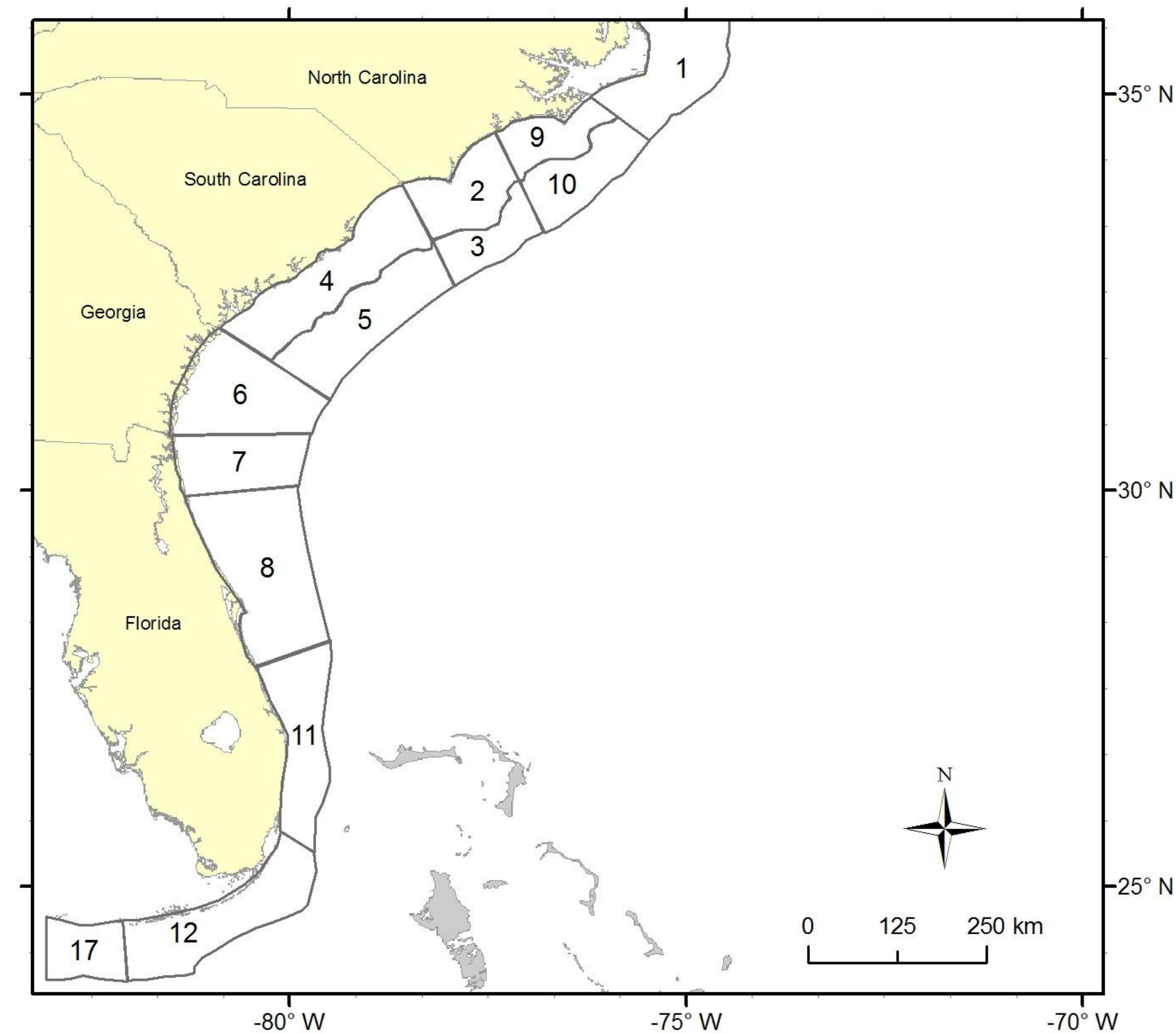


Figure 5.4.1.2. Cobia CPUE (catch/angler-hr) distribution in south Atlantic and east coast of Florida headboat fishery, 1984-2010. These locations were jittered for confidentiality reasons. Locations on land are either misreported or data entry errors. The southern stock boundary for cobia was the Georgia-Florida state line.

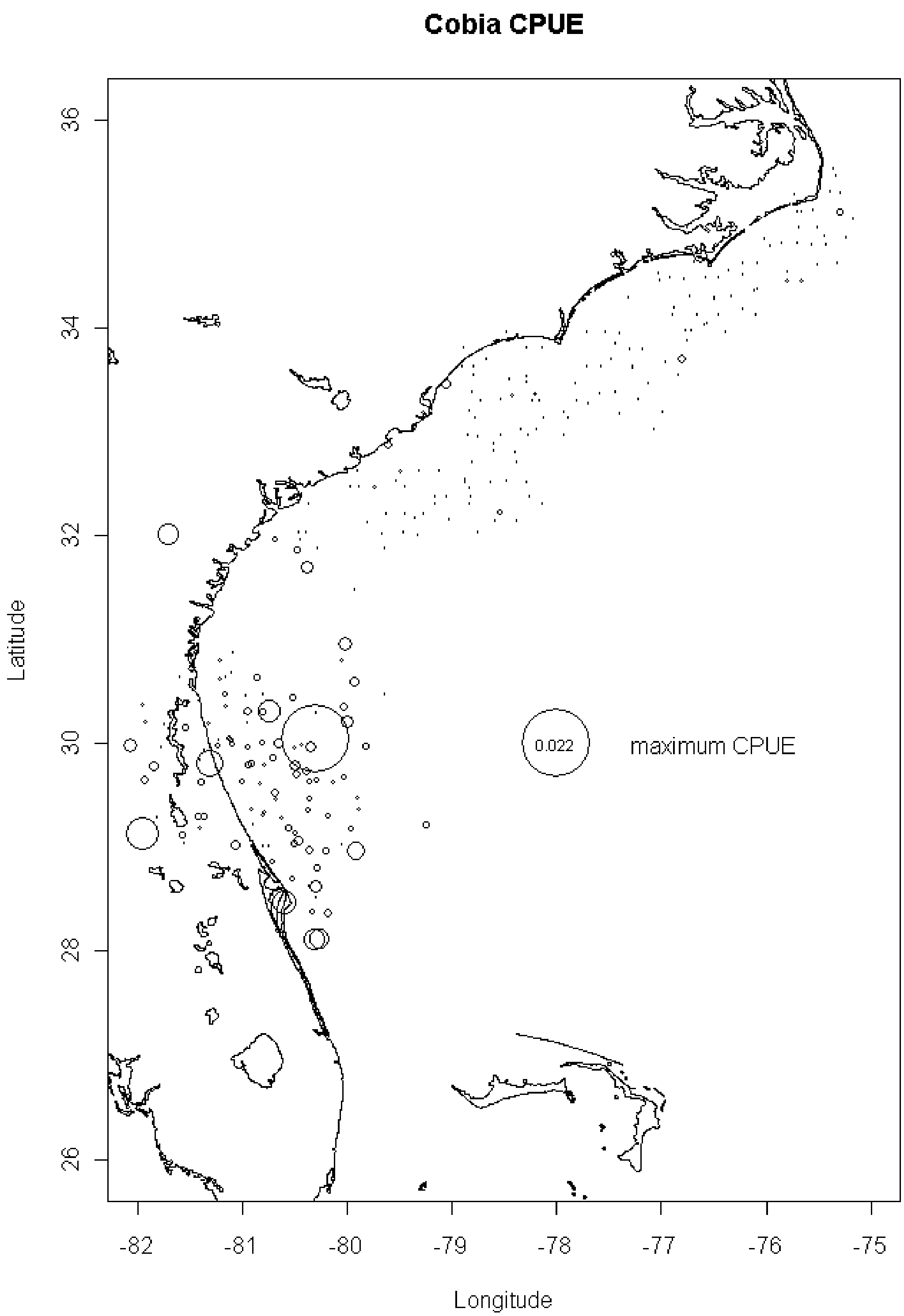


Figure 5.4.1.3. Distribution of headboat trips by identified core vessel in the south Atlantic, 1984-2011. Locations were jittered for confidentiality reasons. Locations on land are either misreported or data entry errors. The southern stock boundary for cobia was the Georgia-Florida state line.

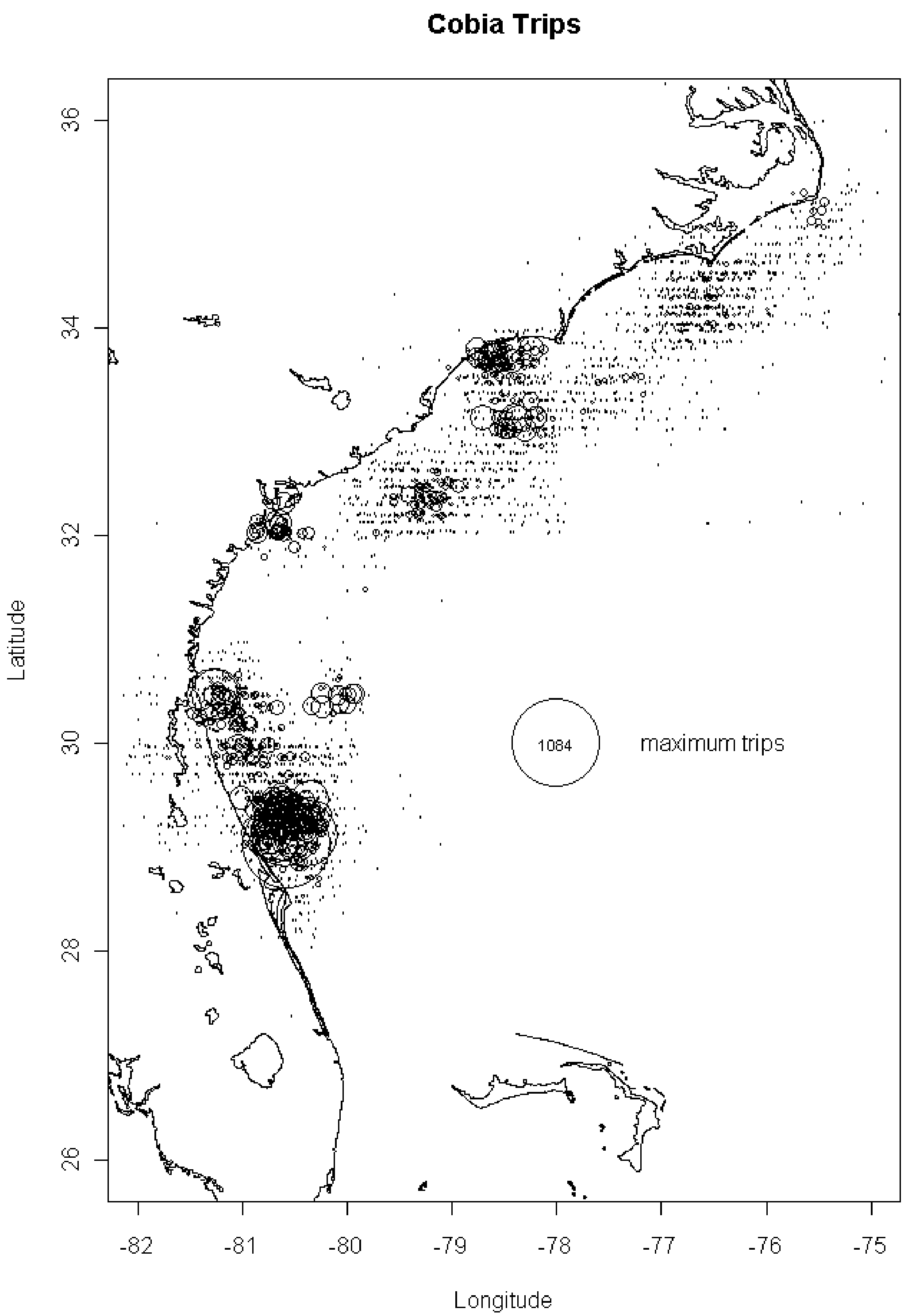


Figure 5.4.1.4. Density plot of non-zero cobia catch per year for the core vessels in the south Atlantic headboat fishery, 1981-2011.

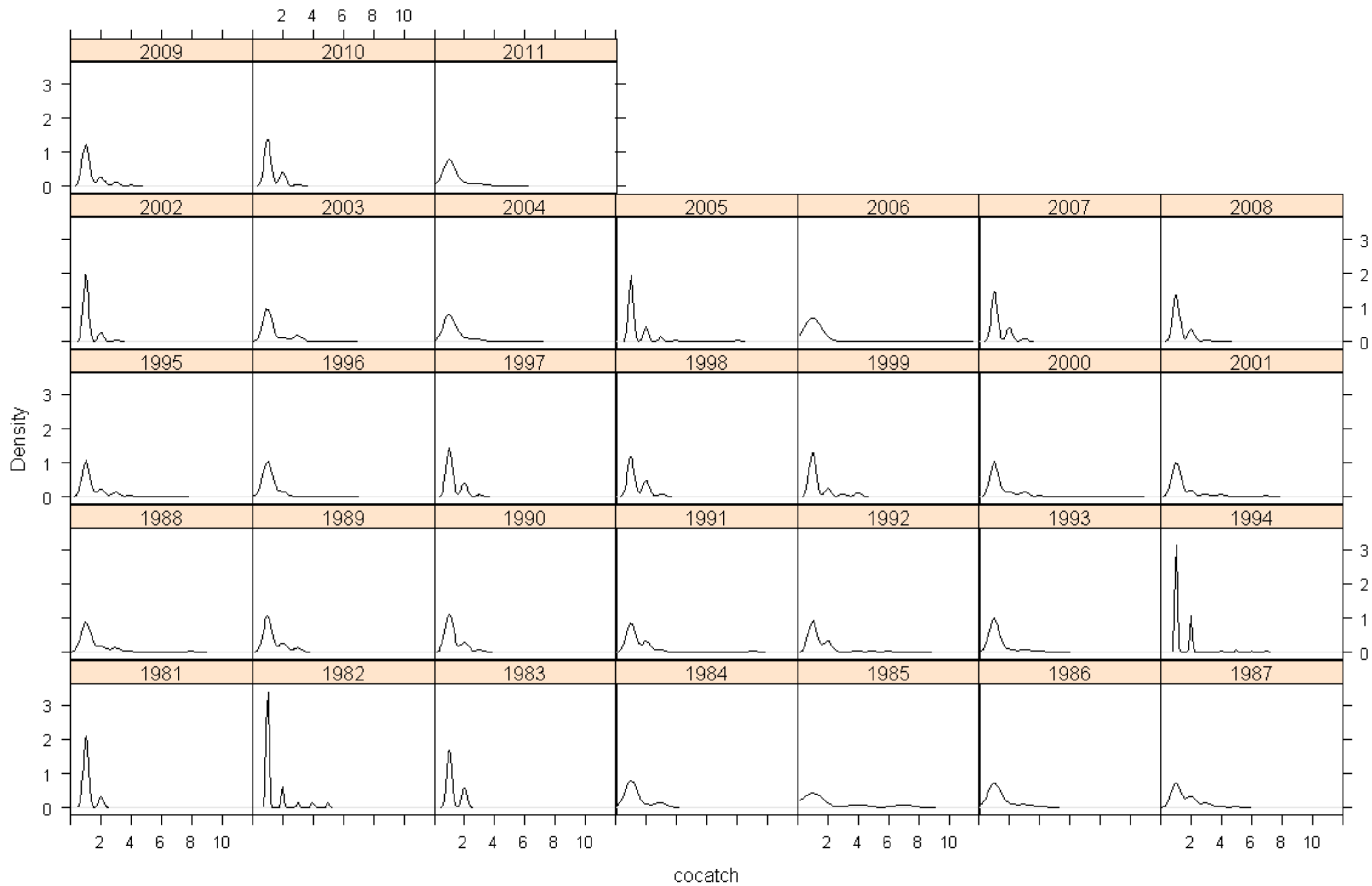


Figure 5.4.1.5. Observed CPUE for cobia by year from 1981-2011 for the south Atlantic headboat fishery with sample size reported above the plot.

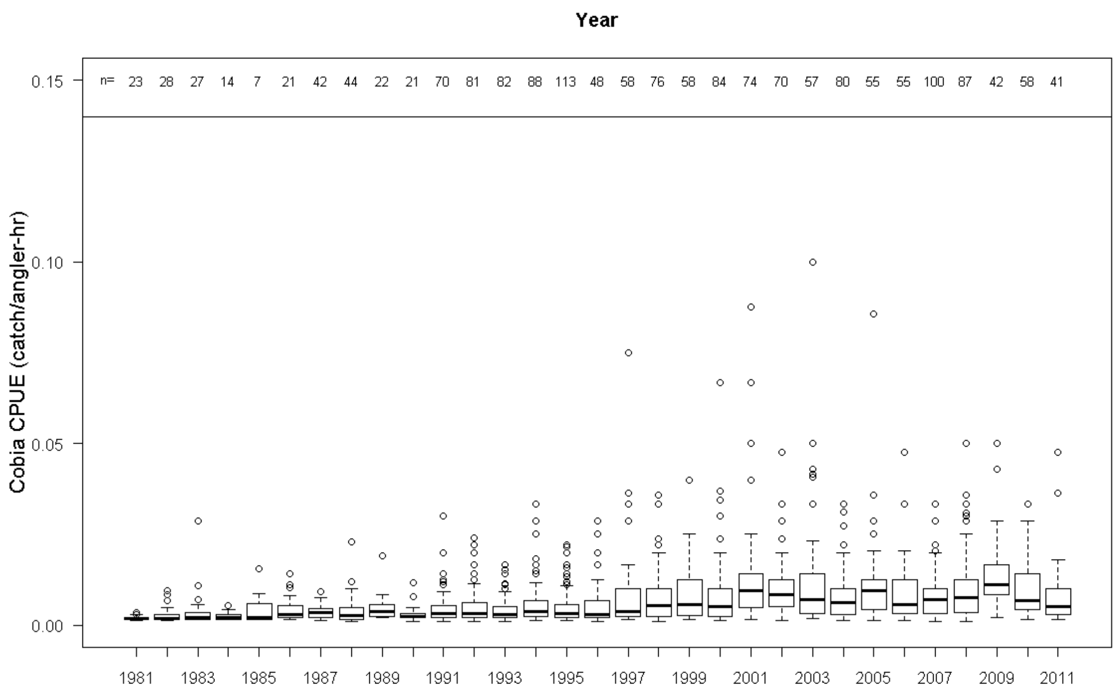


Figure 5.4.1.6. Observed CPUE for cobia by trip type from the south Atlantic headboat fishery with sample size reported above the plot.

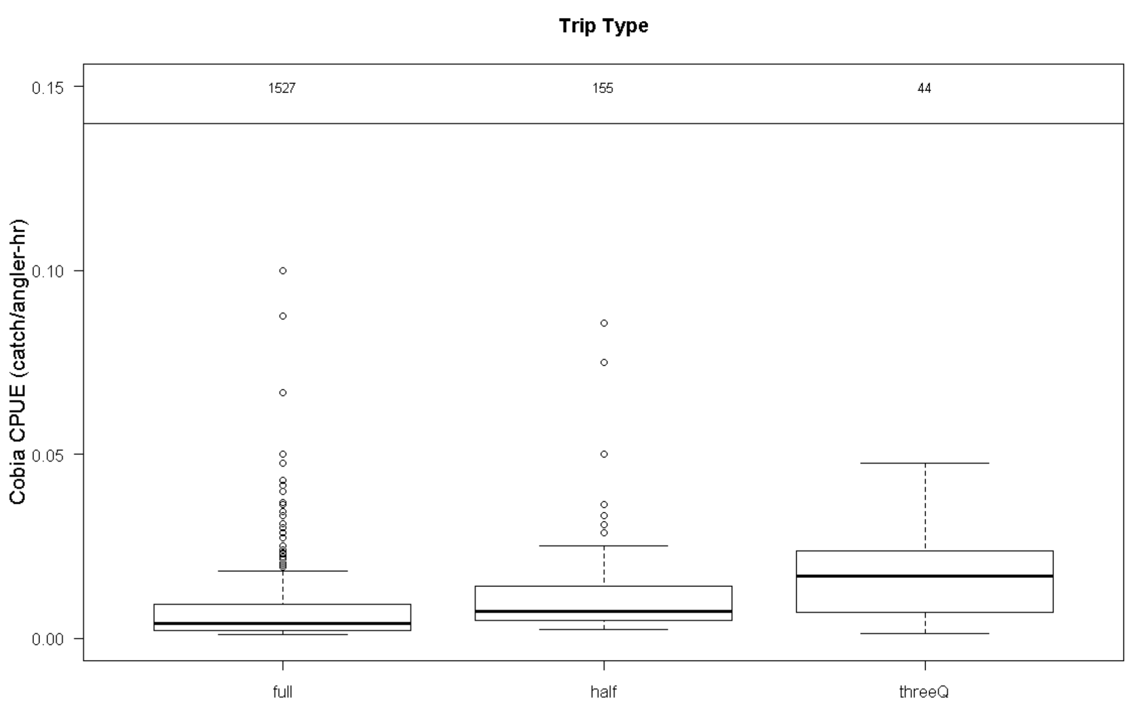


Figure 5.4.1.7. Observed CPUE for cobia by vessel from the south Atlantic headboat fishery. Vessel and number of trips not identified due to confidentiality.

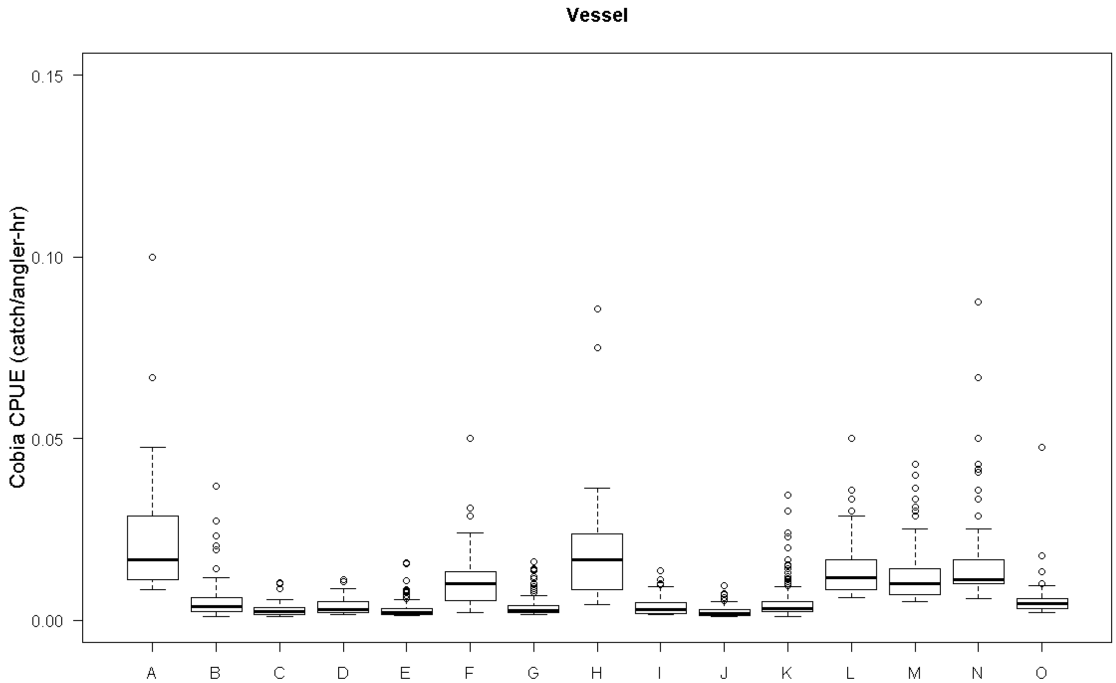


Figure 5.4.1.8. Gamma distribution of CPUE for cobia in the south Atlantic headboat fishery.

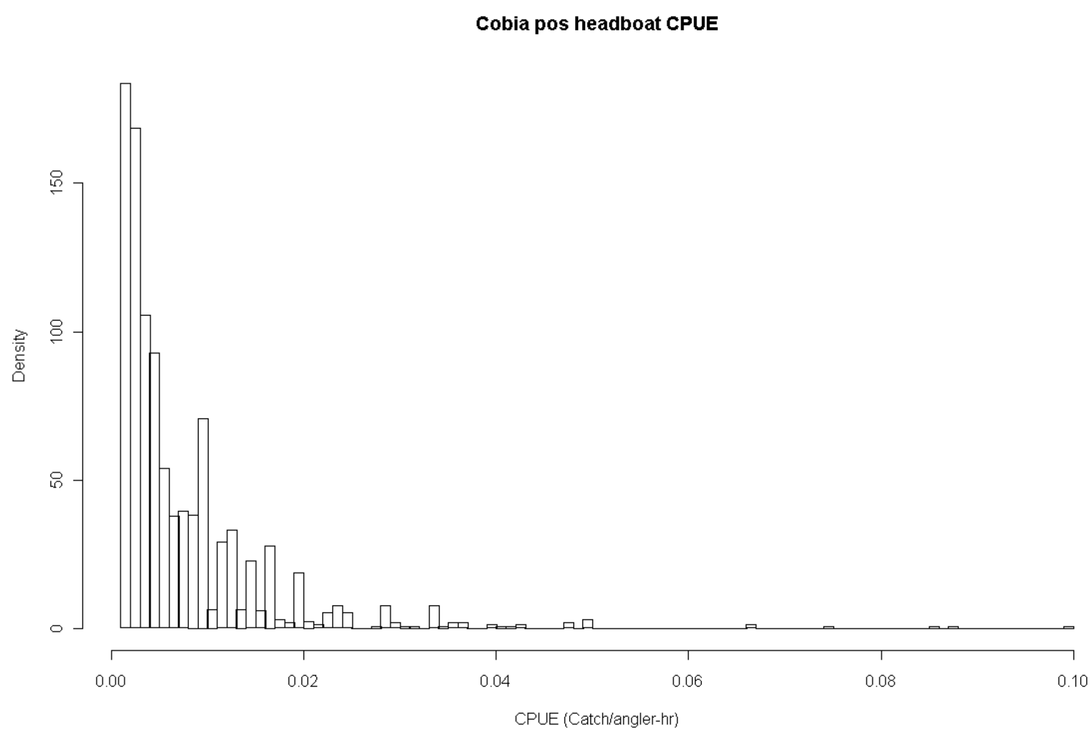
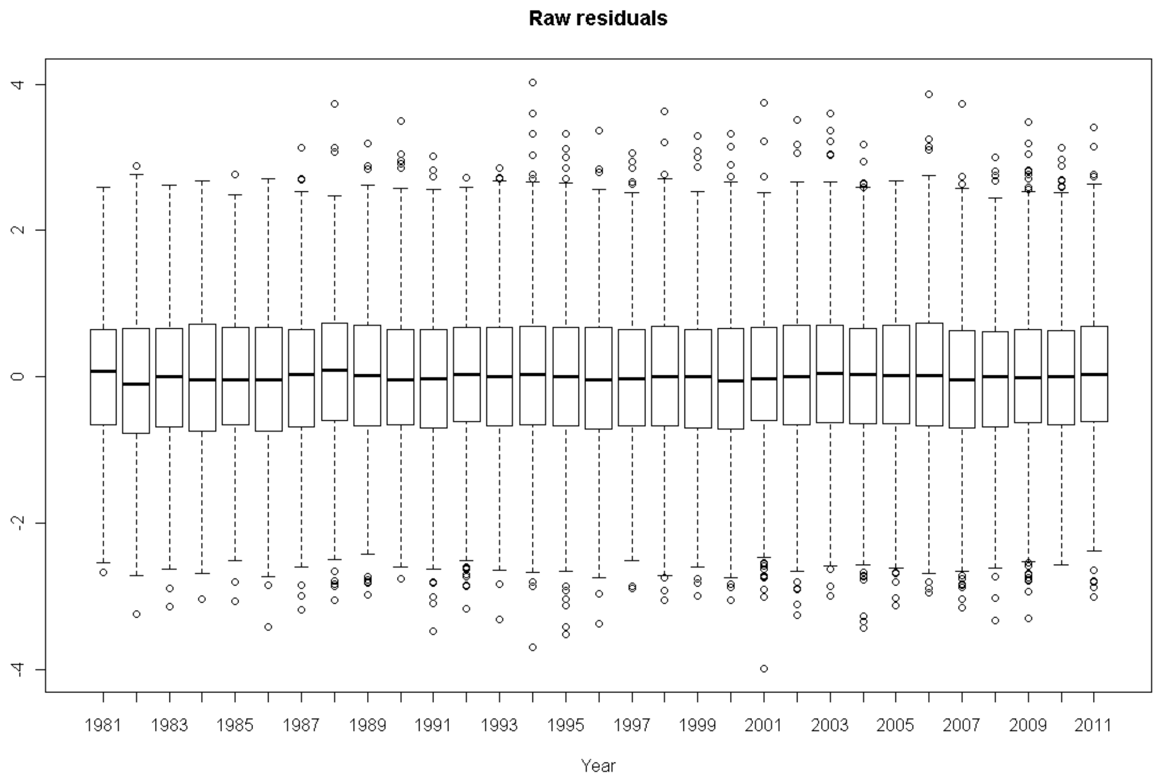
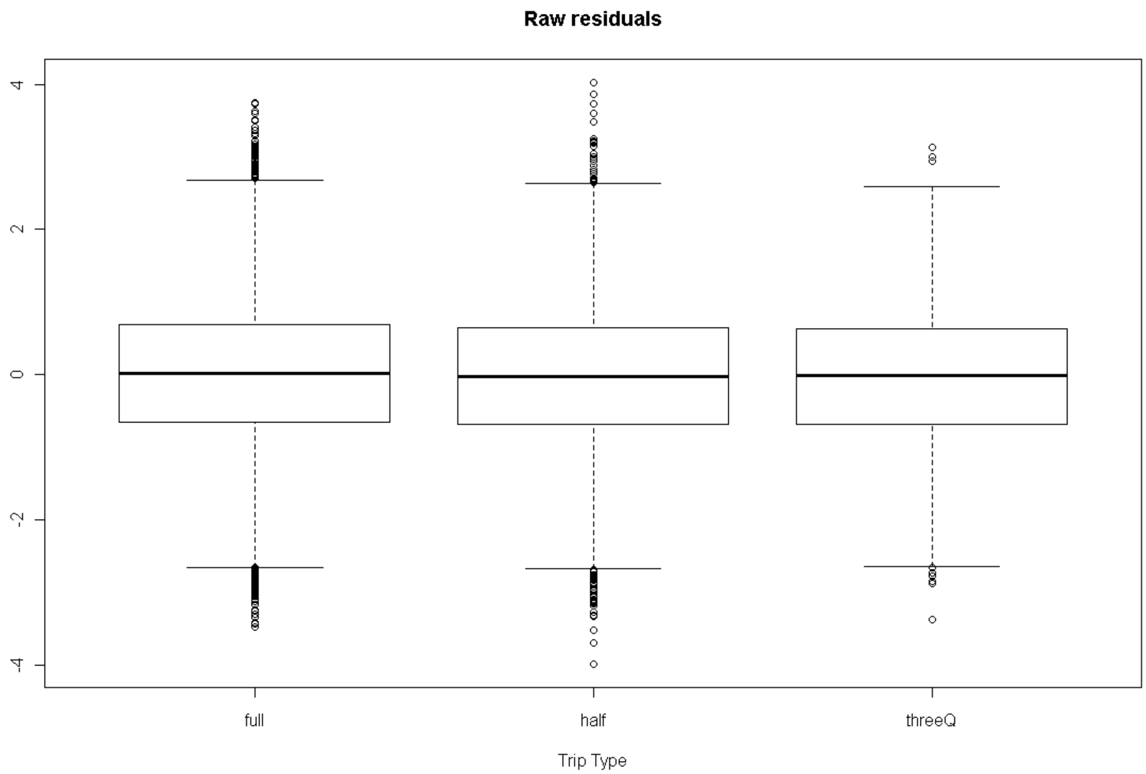


Figure 5.4.1.9. CPUE binomial residuals for the headboat fishery for year (top panel), trip (middle panel), and vessel (bottom panel).




Raw residuals
4
2
0
-2
-4
full
half
threeQ
Trip Type

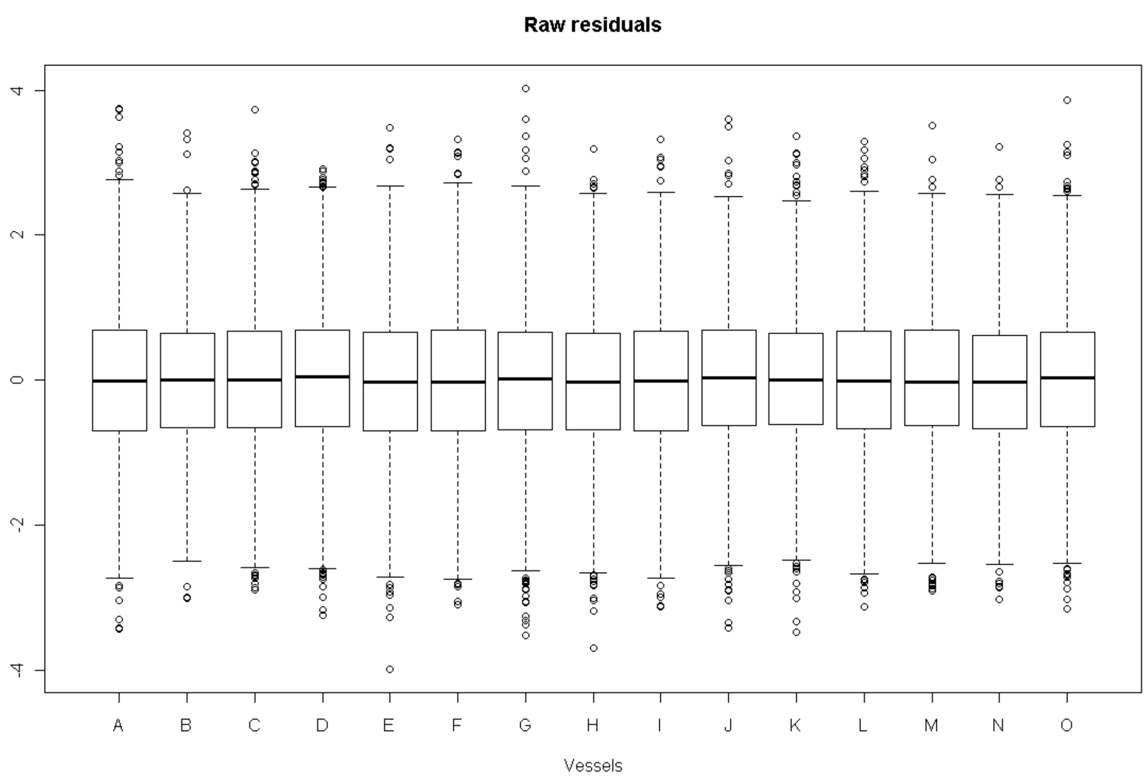

Raw residuals
4
2
0
-2
-4
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
Vessels

Figure 5.4.1.10. QQ plot of gamma residuals for cobia headboat CPUE.

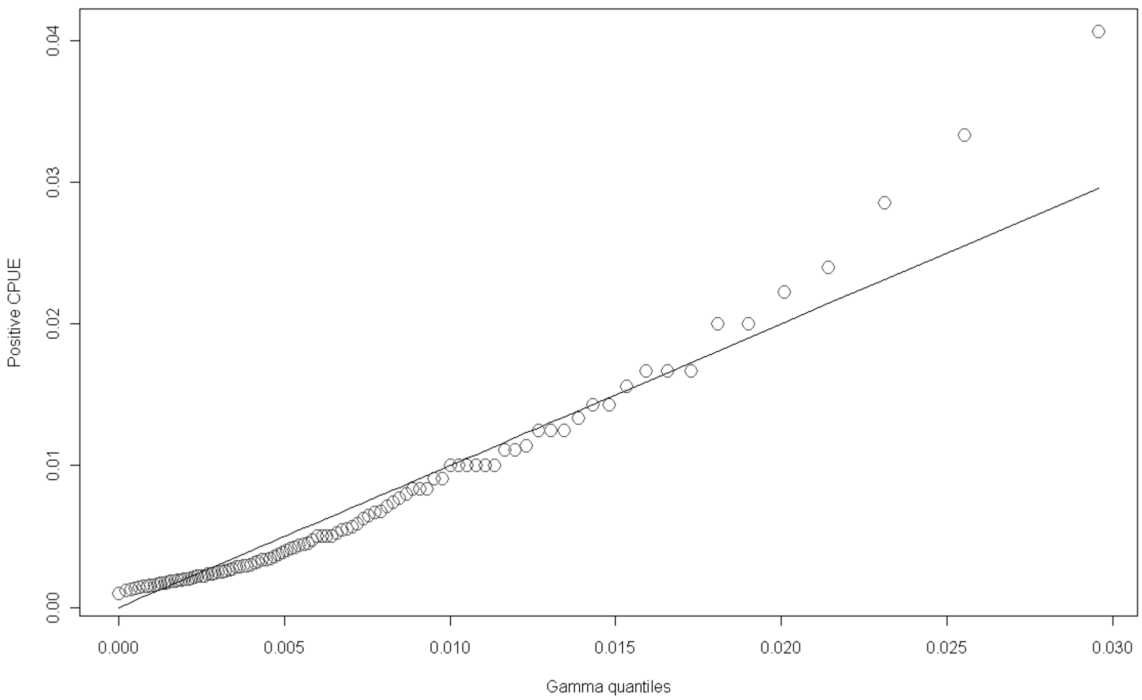


Figure 5.4.1.11. The standardized and nominal headboat index computed for cobia in the south Atlantic during 1981-2011.

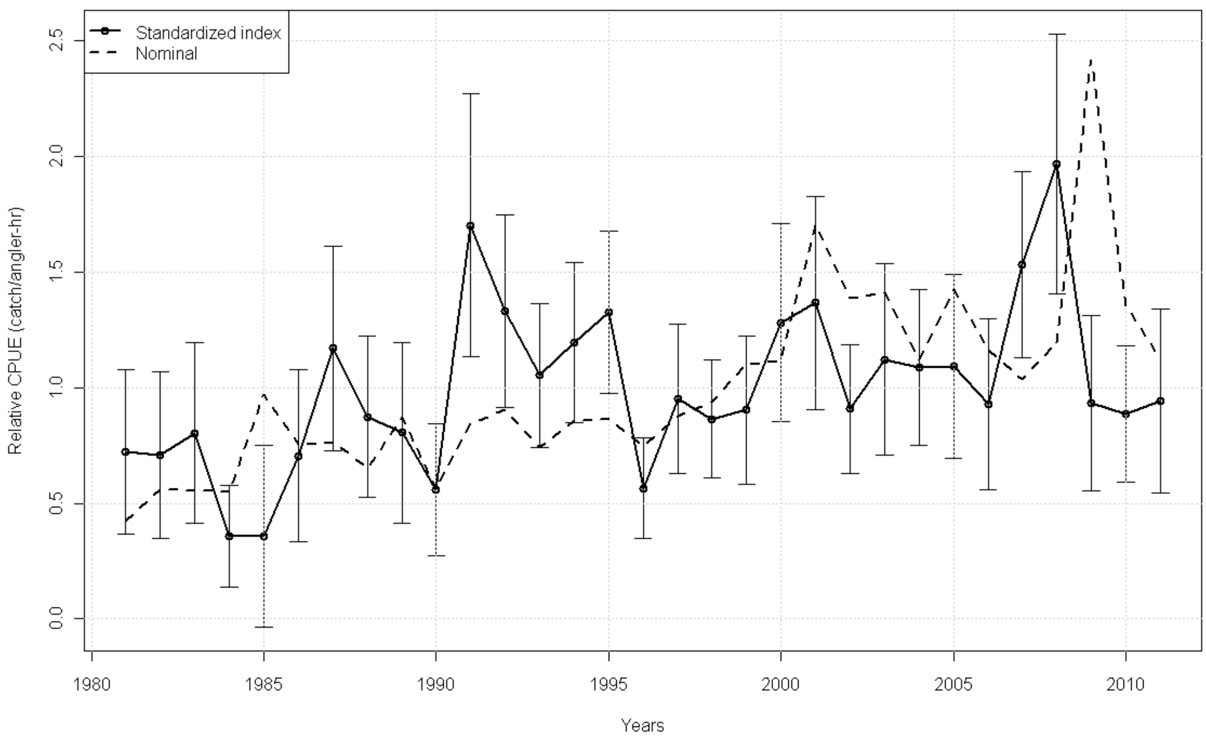


Figure 5.4.2.1. Percentage of SCDNR Charterboat Logbook bottom fishing trips that reported targeting cobia from 1993 – 2010.

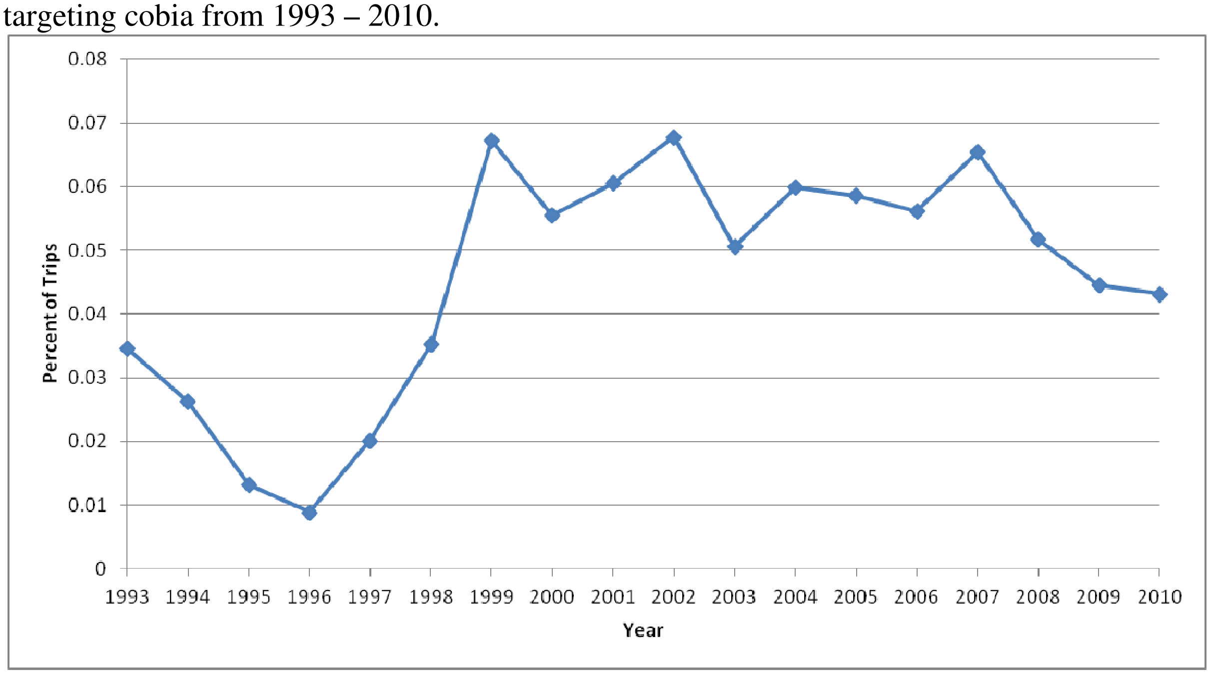


Figure 5.4.2.2. Cobia CPUE from SCDNR Charterboat Logbook data from 1998-2010. Nominal (blue) and Standardized (red) catch per angler-hour are shown with the dotted line showing one standard error from the standardized CPUE.

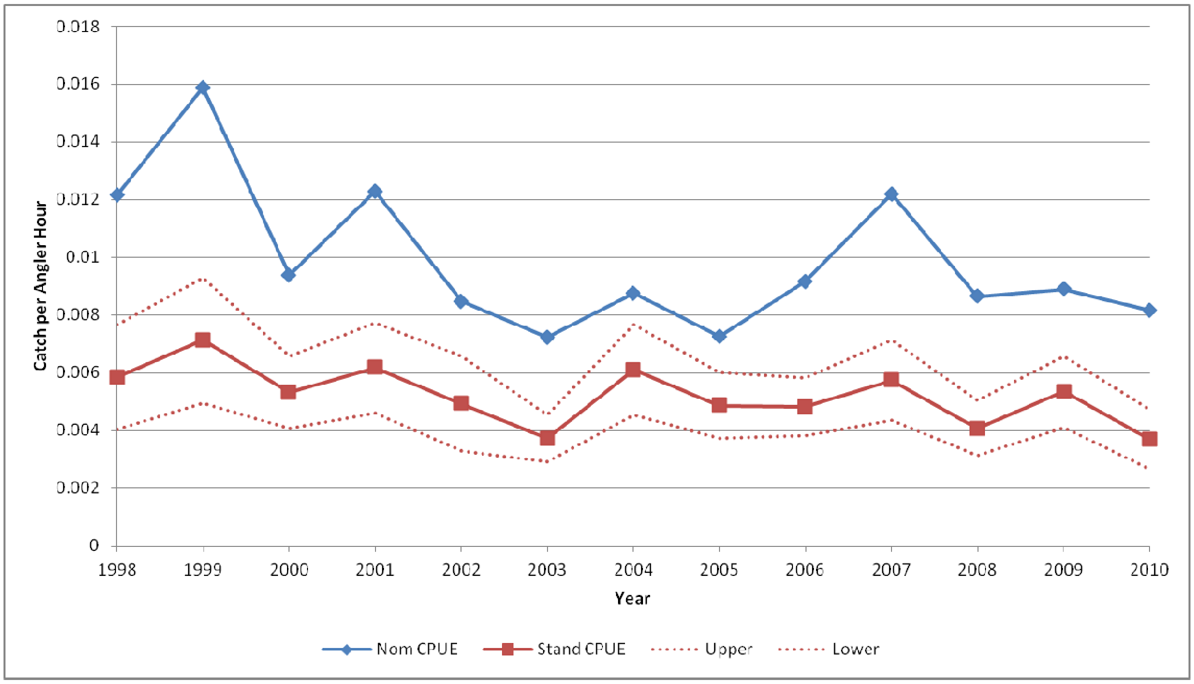


Figure 5.4.3.1. Length frequency of landed cobia from the Atlantic by year from MRFSS.

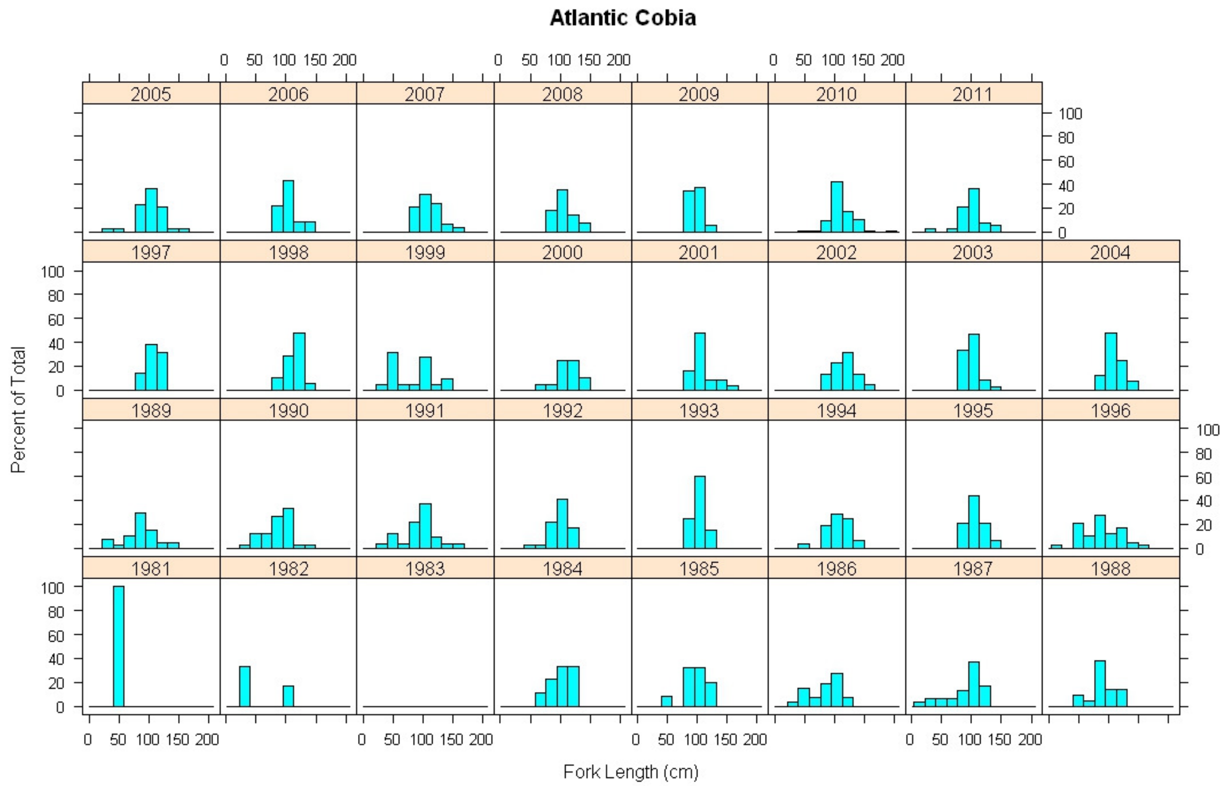


Figure 5.4.3.2. The Nominal and standardized MRFSS CPUE for south Atlantic cobia.

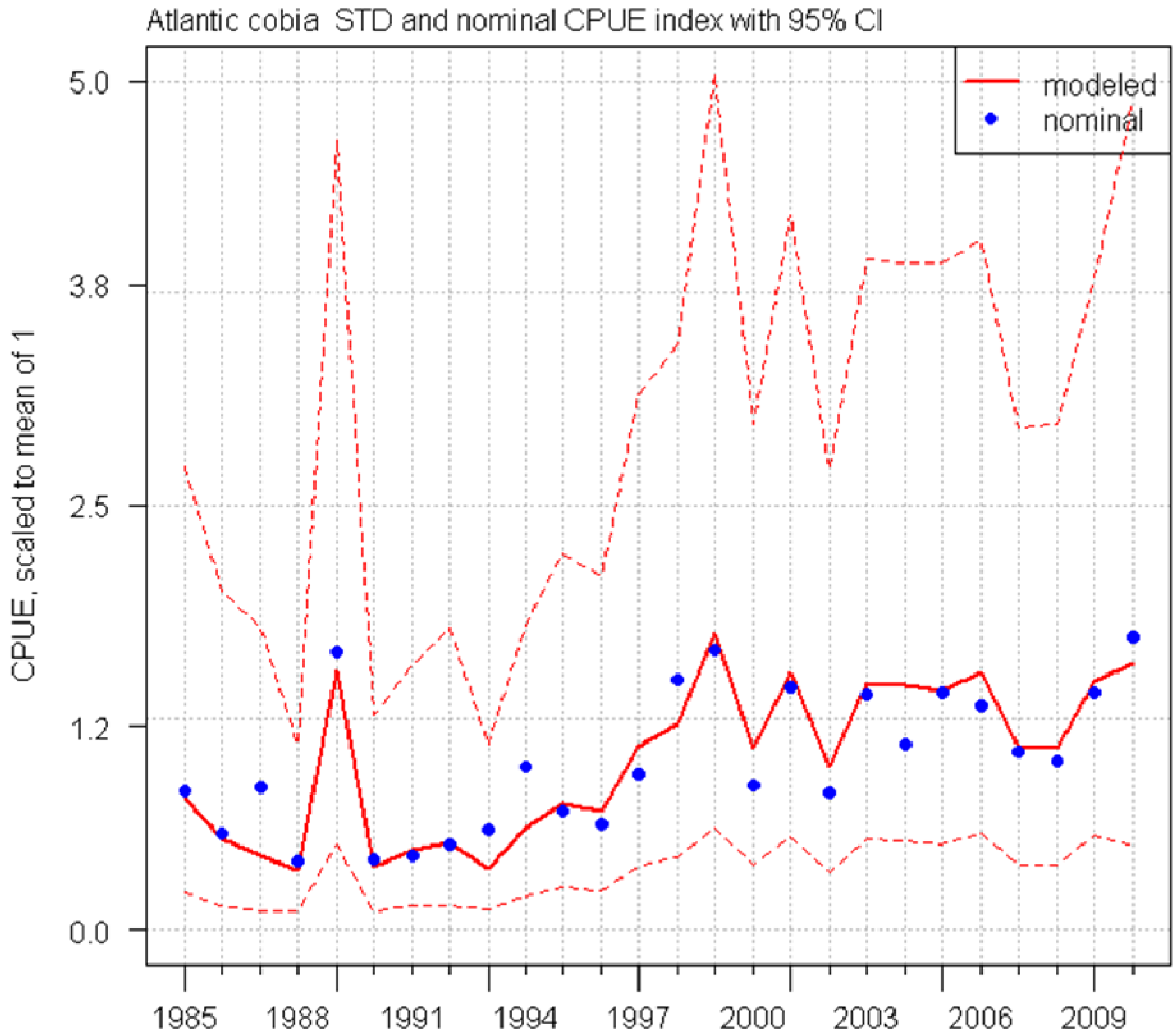


Figure 5.4.3.3. Residuals for Atlantic cobia delta-lognormal model based on MRFSS.

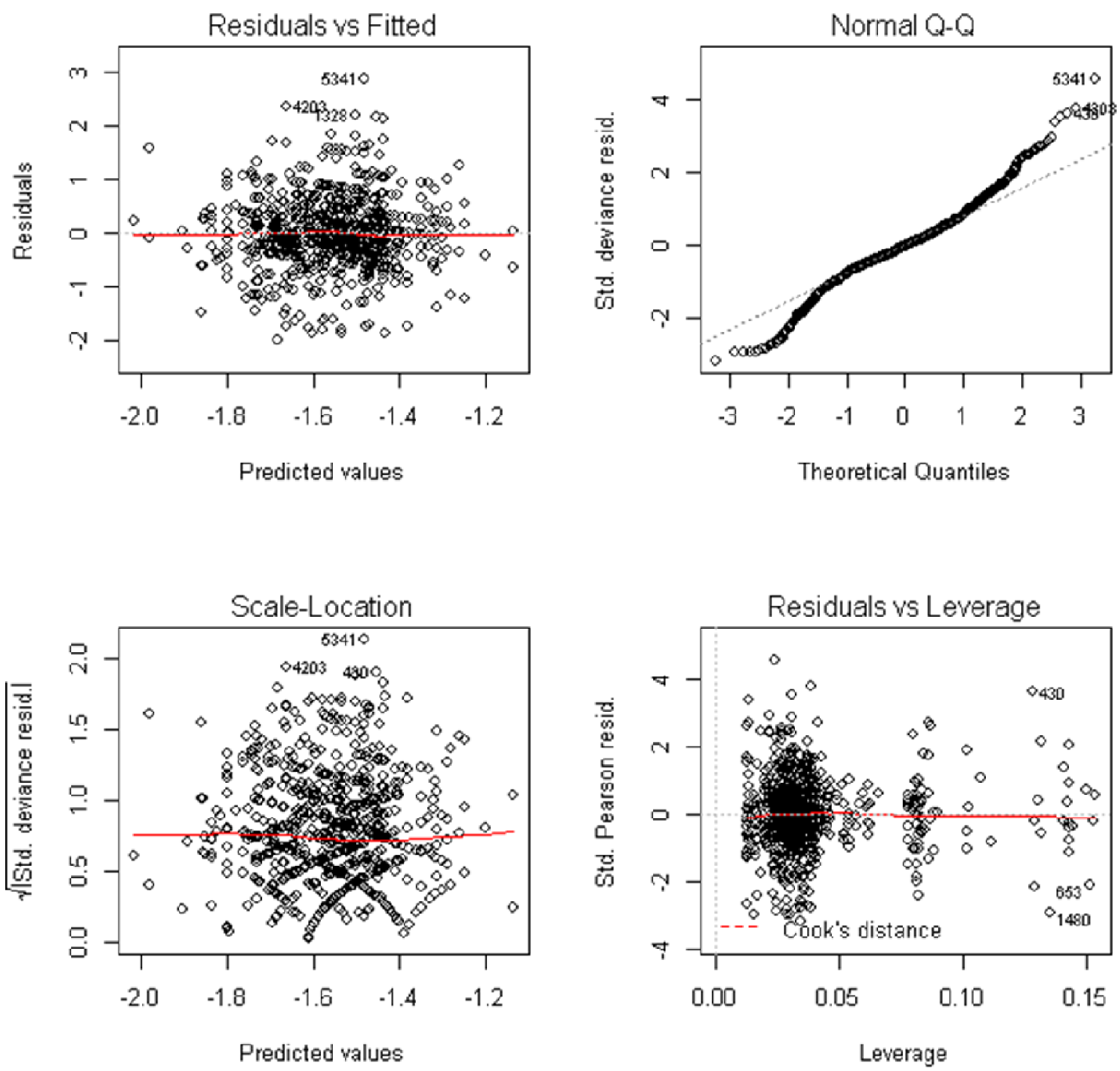


Figure 5.4.4.1. Cobia nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits (dashed lines) for commercial handline and trolling fishing vessels in the South Atlantic lognormal index. CPUE = pounds cobia/hook hour fished.

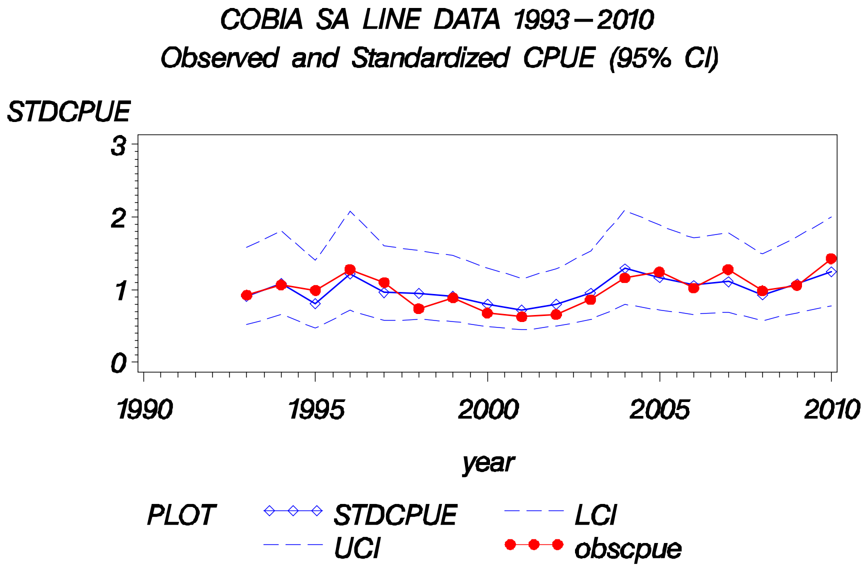


Figure 5.4.4.2. Cobia nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits (dashed lines) for commercial gillnet fishing vessels in the South Atlantic delta-lognormal index. CPUE = pounds cobia per hook hour fished.

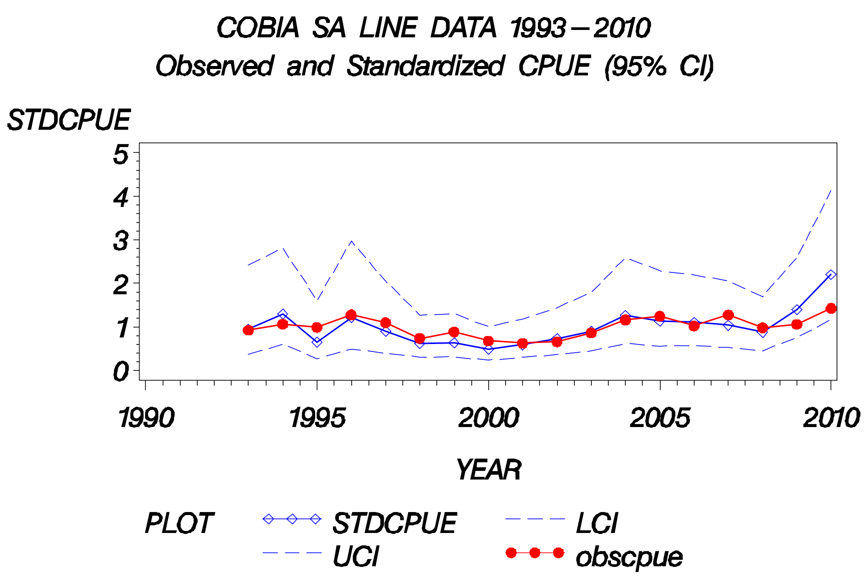
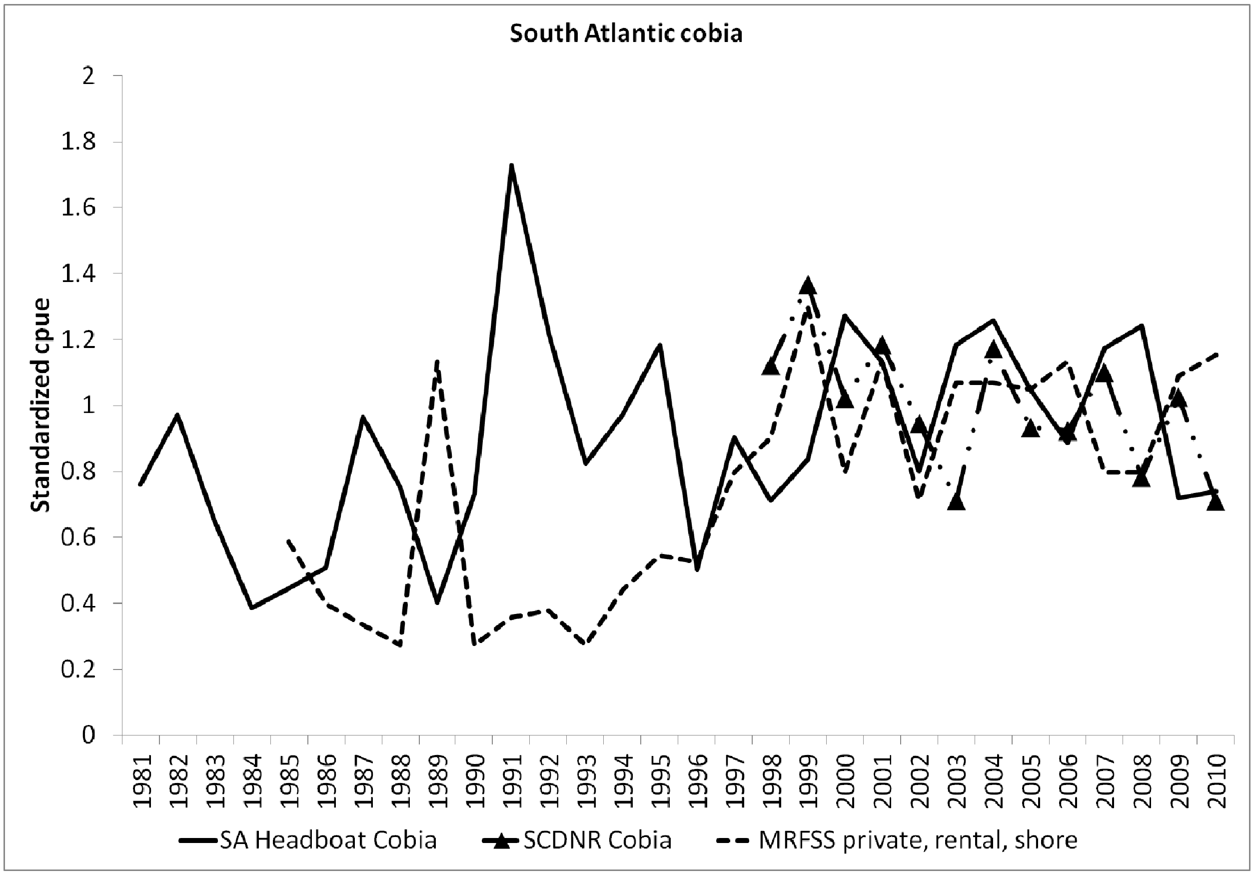


Figure 5.5.1. All indices (scaled to respective means) discussed and recommended for potential use in the south Atlantic cobia stock assessment at the SEDAR 28 Data Workshop.



6 Analytic Approach

Suggested analytic approach given the data – South Atlantic cobia

Based on the data workshop and subsequent discussions, data for South Atlantic cobia appear sufficient to construct an age-aggregated surplus production model (landings and CPUE time series). ASPIC 5.0 is designed specifically for surplus production models and will be used as the modeling platform. The lack of adequate age and length composition data preclude the development of a full statistical catch-at-age model. However, it may be possible to incorporate some age-dependent processes (mortality, fecundity, selectivity) in a highly constrained, age-structured production model. The Beaufort Assessment Model (BAM) will be explored as a platform for developing an age-structured production model.

7 Research Recommendations

7.1 Life History

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.

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.

Explore the feasibility of satellite tags for Cobia movement studies.

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.

Further research is needed on Cobia and Spanish mackerel release mortality.

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.

7.2 Commercial

Although under the category of research recommendations, this list is not research per se, but rather suggestions to improve data collection. The first three recommendations were modified from the SEDAR17 DW report.

1. Need to expand observer coverage
2. Expand TIP sampling to better cover all statistical strata

3. Trade off with lengths versus ages, need for more ages (i.e., hard parts)
4. Consider the use of VMS to improve spatial resolution of data
5. During discussions 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)
6. Uniformity between state and federal reporting systems/forms would vastly improve the ease and efficiency of data compilation.
7. Establish online reporting and use logbooks as a backup.
8. Establish a mechanism for identifying age samples that were collected by length or market categories, so as to better address any potential bias in age compositions.
9. Compiling commercial data is surprisingly complex. As this is the 28th SEDAR, one might expect that many of the complications would have been resolved by now through better coordination among NMFS, ACCSP, and the states. Increased attention should be given toward the goal of "one-stop shopping" for commercial data.

7.3 Recreational Statistics

1) Increase proportion of fish with biological data within MRFSS sampling.

2) Continue to develop methods to collect a higher degree of information on released fish (length, condition, etc.) in the recreational fishery.

3) Require mandatory reporting for all charter boats state and federal.

4) Continue development of electronic mandatory reporting for for-hire sector.

5) Continued research efforts to incorporate/require logbook reporting from recreational anglers.

6) Establish a review panel to evaluate methods for reconstructing historical landings (SWAS, FWS, etc.).

7) Quantify historical fishing photos for use in reconstructing recreational historical landings.

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.

9) Continue and expand fishery dependent at-sea-observer surveys to collect discard information, which would provide for a more accurate index of abundance.

7.4 Indices

- Explore SEFIS video data as a potential fishery independent index of abundance for cobia

- 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

Section 5 Appendix - Index Report Cards

Appendix 5.1 Headboat

Appendix 5.2 SC Charterboat logbook

Appendix 5.3 MRFSS

Appendix 5.4a Commercial logbook vertical line (Delta lognormal)

Appendix 5.4b Commercial logbook (Positive trips only)

Appendix 5.1
South Atlantic Cobia
Headboat Index

DESCRIPTION OF THE DATA SOURCE

Working Group Comments:

1. Fishery Independent Indices

	Not Applicable	Absent	Incomplete	Complete
A. Describe the survey design (e.g. fixed sampling sites, random stratified sampling), location, seasons/months and years of sampling.	✓			
B. Describe sampling methodology (e.g. gear, vessel, soak time etc.)	✓			
C. Describe any changes in sampling methodology (e.g. gear, vessel, sample design etc.)	✓			
D. Describe the variables reported in the data set (e.g. location, time, temperature, catch, effort etc.).	✓			
E. What species or species assemblages are targeted by this survey (e.g. red snapper, reef fish, pelagic).	✓			
F. Describe the size/age range that the index applies to. Include supporting figures (e.g. size comp) if available.	✓			

2. Fishery Dependent Indices

	Not Applicable	Absent	Incomplete	Complete
A. Describe the data source and type of fishery (e.g. commercial handline, commercial longline, recreational hook and line etc.).				✓
B. Describe any changes to reporting requirements, variables reported, etc.				✓
C. Describe the variables reported in the data set (e.g. location, time, temperature, catch, effort etc.).				✓
D Describe the size/age range that the index applies to. Include supporting figures (e.g. size comp) if available.				✓

METHODS

1. Data Reduction and Exclusions

	Not Applicable	Absent	Incomplete	Complete
A. Describe any data exclusions (e.g. gears, fishing modes, sampling areas etc.). Report the number of records removed and justify removal.				✓
B. Describe data reduction techniques (if any) used to address targeting (e.g. Stephens and MacCall, 2004; gear configuration, species assemblage etc).				✓
C. Discuss procedures used to identify outliers. How many were identified? Were they excluded?				✓

2. Management Regulations (for FD Indices)	Not Applicable	Absent	Incomplete	Complete
A. Provide (or cite) history of management regulations (e.g. bag limits, size limits, trip limits, closures etc.).				✓
B. Describe the effects (if any) of management regulations on CPUE				✓
C. Discuss methods used (if any) to minimize the effects of management measures on the CPUE series.	✓			

Working Group Comments:

3. Describe Analysis Dataset (after exclusions and other treatments)

	Not Applicable	Absent	Incomplete	Complete
A. Provide tables and/or figures of number of observations by factors (including year, area, etc.) and interaction terms.				✓
B. Include tables and/or figures of number of positive observations by factors and interaction terms.	✓			
C. Include tables and/or figures of the proportion positive observations by factors and interaction terms.	✓			
D. Include tables and/or figures of average (unstandardized) CPUE by factors and interaction terms.			✓	
E. Include annual maps of locations of survey sites (or fishing trips) and associated catch rates ***OR*** supply the raw data needed to construct these maps (Observation, Year, Latitude, Longitude (or statistical grid, area), Catch, Effort).				✓
F. Describe the effort variable and the units. If more than one effort variable is present in the dataset, justify selection.				✓
G. What are the units of catch (e.g. numbers or biomass, whole weight, gutted weight, kilograms, pounds).				✓

4. Model Standardization

	Not Applicable	Absent	Incomplete	Complete
A. Describe model structure (e.g. delta-lognormal)				✓
B. Describe construction of GLM components (e.g. forward selection from null etc.)				✓
C. Describe inclusion criteria for factors and interactions terms.				✓
D. Were YEAR*FACTOR interactions included in the model? If so, how (e.g. fixed effect, random effect)? Were random effects tested for significance using a likelihood ratio test?	✓			
E. Provide a table summarizing the construction of the GLM components.				✓
F. Summarize model statistics of the mixed model formulation(s) (e.g. log likelihood, AIC, BIC etc.)	✓			
G. Report convergence statistics.		✓		

MODEL DIAGNOSTICS

Comment: Other model structures are possible and acceptable. Please provide appropriate diagnostics to the CPUE indices working group.

	Not Applicable	Absent	Incomplete	Complete	Working Group Comments:
1. Binomial Component					
A. Include plots of the chi-square residuals by factor.	✓				
B. Include plots of predicted and observed proportion of positive trips by year and factor (e.g. year*area)	✓				
C. Report overdispersion parameter and other fit statistics (e.g. chi-square / degrees of freedom).	✓				
2. Lognormal/Gamma Component					
A. Include histogram of log(CPUE) or a histogram of the residuals of the model on CPUE. Overlay the expected distribution.				✓	
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor.	✓				
C. Include QQ-plot – (e.g. Student deviance residuals vs. theoretical quantiles), Overlay expected distribution.				✓	
D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.		✓			
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.	✓				
F. Include plots of the residuals by factor				✓	
3. Poisson Component					
A. Report overdispersion parameter and other fit statistics (e.g. chi-square / degrees of freedom).	✓				
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor.	✓				
C. Include QQ-plot – (e.g. Student deviance residuals vs. theoretical quantiles), Overlay expected distribution.	✓				
D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.	✓				
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.	✓				***The feasibility of this diagnostic is still under review.***
4. Zero-inflated model					
A. Include ROC curve to quantify goodness of fit.	✓				
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor).	✓				
C. Include QQ-plot (e.g. Student dev. residuals vs. theoretical quantiles), Overlay expected distribution.	✓				

MODEL DIAGNOSTICS (CONT.)

	Not Applicable	Absent	Incomplete	Complete	Working Group Comments:

D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.	✓			
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.	✓			

MODEL RESULTS

A. Tables of Nominal CPUE, Standardized CPUE, Observations, Positive Observations, Proportion Positive Observations and Coefficients of Variation (CVs). Other statistics may also be appropriate to report				✓
B. Figure of Nominal and Standardized Indices with measure of variance (i.e. CVs).				✓

IF MULTIPLE MODEL STRUCTURES WERE CONSIDERED:

(***Note: this is always recommended but required when model diagnostics are poor***.)

1. Plot of resulting indices and estimates of variance				✓
2. Table of model statistics (e.g. AIC criteria)		✓		

	Date Received	*Workshop Recommendation*	*Revision Deadline* ***	*Author and Rapporteur Signatures*
First Submission				
Revision				

*The revision deadline is negotiated by the author, the SEDAR coordinator and the CPUE rapporteur. The author **DOES NOT** commit to any **LEGAL OBLIGATION** by agreeing to submit a manuscript before this deadline. The maximum penalty for failure to submit a revised document prior to the submission deadline is rejection of the CPUE series.*

Justification of Working Group Recommendation

1. Headboat index
• Longest time series
• Operates in a manner more similar to fishery independent data collection because the fishery targets the snapper-grouper complex in general rather than the focal species specifically

Reset Fields

Appendix 5.2
South Atlantic Cobia
SC DNR Index

DESCRIPTION OF THE DATA SOURCE

Working Group Comments:

1. Fishery Independent Indices

	Not Applicable	Absent	Incomplete	Complete
A. Describe the survey design (e.g. fixed sampling sites, random stratified sampling), location, seasons/months and years of sampling.	✓			
B. Describe sampling methodology (e.g. gear, vessel, soak time etc.)	✓			
C. Describe any changes in sampling methodology (e.g. gear, vessel, sample design etc.)	✓			
D. Describe the variables reported in the data set (e.g. location, time, temperature, catch, effort etc.).	✓			
E. What species or species assemblages are targeted by this survey (e.g. red snapper, reef fish, pelagic).	✓			
F. Describe the size/age range that the index applies to. Include supporting figures (e.g. size comp) if available.	✓			

2. Fishery Dependent Indices

	Not Applicable	Absent	Incomplete	Complete
A. Describe the data source and type of fishery (e.g. commercial handline, commercial longline, recreational hook and line etc.).				✓
B. Describe any changes to reporting requirements, variables reported, etc.				✓
C. Describe the variables reported in the data set (e.g. location, time, temperature, catch, effort etc.).				✓
D Describe the size/age range that the index applies to. Include supporting figures (e.g. size comp) if available.	✓			

METHODS

1. Data Reduction and Exclusions

	Not Applicable	Absent	Incomplete	Complete
A. Describe any data exclusions (e.g. gears, fishing modes, sampling areas etc.). Report the number of records removed and justify removal.				✓
B. Describe data reduction techniques (if any) used to address targeting (e.g. Stephens and MacCall, 2004; gear configuration, species assemblage etc).				✓
C. Discuss procedures used to identify outliers. How many were identified? Were they excluded?	✓			

	Not Applicable	Absent	Incomplete	Complete	Working Group Comments:
2. Management Regulations (for FD Indices)					
A. Provide (or cite) history of management regulations (e.g. bag limits, size limits, trip limits, closures etc.).				✓	
B. Describe the effects (if any) of management regulations on CPUE				✓	
C. Discuss methods used (if any) to minimize the effects of management measures on the CPUE series.				✓	
3. Describe Analysis Dataset (after exclusions and other treatments)					
A. Provide tables and/or figures of number of observations by factors (including year, area, etc.) and interaction terms.				✓	
B. Include tables and/or figures of number of positive observations by factors and interaction terms.				✓	
C. Include tables and/or figures of the proportion positive observations by factors and interaction terms.			✓		Available upon request.
D. Include tables and/or figures of average (unstandardized) CPUE by factors and interaction terms.				✓	
E. Include annual maps of locations of survey sites (or fishing trips) and associated catch rates ***OR*** supply the raw data needed to construct these maps (Observation, Year, Latitude, Longitude (or statistical grid, area), Catch, Effort).				✓	
F. Describe the effort variable and the units. If more than one effort variable is present in the dataset, justify selection.				✓	
G. What are the units of catch (e.g. numbers or biomass, whole weight, gutted weight, kilograms, pounds).				✓	
4. Model Standardization					
A. Describe model structure (e.g. delta-lognormal)				✓	
B. Describe construction of GLM components (e.g. forward selection from null etc.)				✓	
C. Describe inclusion criteria for factors and interactions terms.				✓	
D. Were YEAR*FACTOR interactions included in the model? If so, how (e.g. fixed effect, random effect)? Were random effects tested for significance using a likelihood ratio test?		✓			Available upon request.
E. Provide a table summarizing the construction of the GLM components.		✓			
F. Summarize model statistics of the mixed model formulation(s) (e.g. log likelihood, AIC, BIC etc.)				✓	
G. Report convergence statistics.				✓	

MODEL DIAGNOSTICS

Comment: Other model structures are possible and acceptable. Please provide appropriate diagnostics to the CPUE indices working group.

Item	Not Applicable	Absent	Incomplete	Complete	Working Group Comments:
1. Binomial Component					
A. Include plots of the chi-square residuals by factor.				✓	
B. Include plots of predicted and observed proportion of positive trips by year and factor (e.g. year*area)				✓	
C. Report overdispersion parameter and other fit statistics (e.g. chi-square / degrees of freedom).				✓	
2. Lognormal/Gamma Component					
A. Include histogram of log(CPUE) or a histogram of the residuals of the model on CPUE. Overlay the expected distribution.				✓	
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor.				✓	
C. Include QQ-plot – (e.g. Student deviance residuals vs. theoretical quantiles), Overlay expected distribution.				✓	
D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.				✓	
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.				✓	
F. Include plots of the residuals by factor				✓	
3. Poisson Component					
A. Report overdispersion parameter and other fit statistics (e.g. chi-square / degrees of freedom).	✓				
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor.	✓				
C. Include QQ-plot – (e.g. Student deviance residuals vs. theoretical quantiles), Overlay expected distribution.	✓				
D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.	✓				
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.	✓				***The feasibility of this diagnostic is still under review.***
4. Zero-inflated model					
A. Include ROC curve to quantify goodness of fit.	✓				
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor).	✓				
C. Include QQ-plot (e.g. Student dev. residuals vs. theoretical quantiles), Overlay expected distribution.	✓				

MODEL DIAGNOSTICS (CONT.)

	Not Applicable	Absent	Incomplete	Complete	Working Group Comments:

D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.	✓			
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.	✓			

MODEL RESULTS

A. Tables of Nominal CPUE, Standardized CPUE, Observations, Positive Observations, Proportion Positive Observations and Coefficients of Variation (CVs). Other statistics may also be appropriate to report				✓
B. Figure of Nominal and Standardized Indices with measure of variance (i.e. CVs).				✓

IF MULTIPLE MODEL STRUCTURES WERE CONSIDERED:

(***Note: this is always recommended but required when model diagnostics are poor***.)

1. Plot of resulting indices and estimates of variance				✓
2. Table of model statistics (e.g. AIC criteria)				✓

	Date Received	*Workshop Recommendation*	*Revision Deadline* ***	*Author and Rapporteur Signatures*
First Submission	2/3/2012	Revision		
Revision	2/10/2012	Recommended		

The revision deadline is negotiated by the author, the SEDAR coordinator and the CPUE rapporteur. The author ***DOES NOT*** *commit to any* ***LEGAL OBLIGATION*** *by agreeing to submit a manuscript before this deadline. The maximum penalty for failure to submit a revised document prior to the submission deadline is rejection of the CPUE series.*

Justification of Working Group Recommendation

The data workshop accepted this index to be included in the stock assessment. The dataset covers a large portion of the South Atlantic stock's geographic range. The index 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. Data were available from 1993 to 2010, however it was decided that the dataset should be truncated to only include data from 1998 onwards due to a change in effort in the fishery (increase in the percentage of trips targeting Cobia from 1997 to 1998). The Index Working Group decided that although the MRFSS index could be reproduced to include charter mode, since cobia is a rare event species in MRFSS the SCDNR charterboat logbook dataset would be better to use as an index for charter mode.

Reset Fields

Evaluation of Abundance Indices of list species: List data set (SEDAR28-DW-##)

Appendix 5.3
South Atlantic Cobia
MRFSS Index

Working Group Comments:

DESCRIPTION OF THE DATA SOURCE

1. Fishery Independent Indices

Item	Not Applicable	Absent	Incomplete	Complete
A. Describe the survey design (e.g. fixed sampling sites, random stratified sampling), location, seasons/months and years of sampling.				
B. Describe sampling methodology (e.g. gear, vessel, soak time etc.)				
C. Describe any changes in sampling methodology (e.g. gear, vessel, sample design etc.)				
D. Describe the variables reported in the data set (e.g. location, time, temperature, catch, effort etc.).				
E. What species or species assemblages are targeted by this survey (e.g. red snapper, reef fish, pelagic).				
F. Describe the size/age range that the index applies to. Include supporting figures (e.g. size comp) if available.				

2. Fishery Dependent Indices

Item	Not Applicable	Absent	Incomplete	Complete
A. Describe the data source and type of fishery (e.g. commercial handline, commercial longline, recreational hook and line etc.).				✓
B. Describe any changes to reporting requirements, variables reported, etc.	✓			
C. Describe the variables reported in the data set (e.g. location, time, temperature, catch, effort etc.).			✓	
D Describe the size/age range that the index applies to. Include supporting figures (e.g. size comp) if available.				✓

METHODS

1. Data Reduction and Exclusions

Item	Not Applicable	Absent	Incomplete	Complete
A. Describe any data exclusions (e.g. gears, fishing modes, sampling areas etc.). Report the number of records removed and justify removal.				✓
B. Describe data reduction techniques (if any) used to address targeting (e.g. Stephens and MacCall, 2004; gear configuration, species assemblage etc).				✓
C. Discuss procedures used to identify outliers. How many were identified? Were they excluded?		✓		

	Not Applicable	Absent	Incomplete	Complete
2. Management Regulations (for FD Indices)				
A. Provide (or cite) history of management regulations (e.g. bag limits, size limits, trip limits, closures etc.).			✓	
B. Describe the effects (if any) of management regulations on CPUE				✓
C. Discuss methods used (if any) to minimize the effects of management measures on the CPUE series.				✓
3. Describe Analysis Dataset (after exclusions and other treatments)				
A. Provide tables and/or figures of number of observations by factors (including year, area, etc.) and interaction terms.		✓		
B. Include tables and/or figures of number of positive observations by factors and interaction terms.			✓	
C. Include tables and/or figures of the proportion positive observations by factors and interaction terms.				✓
D. Include tables and/or figures of average (unstandardized) CPUE by factors and interaction terms.		✓		
E. Include annual maps of locations of survey sites (or fishing trips) and associated catch rates ***OR*** supply the raw data needed to construct these maps (Observation, Year, Latitude, Longitude (or statistical grid, area), Catch, Effort).		✓		
F. Describe the effort variable and the units. If more than one effort variable is present in the dataset, justify selection.				✓
G. What are the units of catch (e.g. numbers or biomass, whole weight, gutted weight, kilograms, pounds).				✓
4. Model Standardization				
A. Describe model structure (e.g. delta-lognormal)				✓
B. Describe construction of GLM components (e.g. forward selection from null etc.)				✓
C. Describe inclusion criteria for factors and interactions terms.				✓
D. Were YEAR*FACTOR interactions included in the model? If so, how (e.g. fixed effect, random effect)? Were random effects tested for significance using a likelihood ratio test?	✓			
E. Provide a table summarizing the construction of the GLM components.				✓
F. Summarize model statistics of the mixed model formulation(s) (e.g. log likelihood, AIC, BIC etc.)				✓
G. Report convergence statistics.				✓

Working Group Comments:

MODEL DIAGNOSTICS

Comment: Other model structures are possible and acceptable. Please provide appropriate diagnostics to the CPUE indices working group.

	Not Applicable	Absent	Incomplete	Complete
1. Binomial Component				
A. Include plots of the chi-square residuals by factor.				✓
B. Include plots of predicted and observed proportion of positive trips by year and factor (e.g. year*area)				✓
C. Report overdispersion parameter and other fit statistics (e.g. chi-square / degrees of freedom).				✓
2. Lognormal/Gamma Component				
A. Include histogram of log(CPUE) or a histogram of the residuals of the model on CPUE. Overlay the expected distribution.		✓		
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor.				✓
C. Include QQ-plot – (e.g. Student deviance residuals vs. theoretical quantiles), Overlay expected distribution.				✓
D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.				✓
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.				✓
F. Include plots of the residuals by factor				✓
3. Poisson Component				
A. Report overdispersion parameter and other fit statistics (e.g. chi-square / degrees of freedom).				
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor.				
C. Include QQ-plot – (e.g. Student deviance residuals vs. theoretical quantiles), Overlay expected distribution.				
D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.				
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.				
4. Zero-inflated model				
A. Include ROC curve to quantify goodness of fit.				
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor).				
C. Include QQ-plot (e.g. Student dev. residuals vs. theoretical quantiles), Overlay expected distribution.				

Working Group Comments:

The feasibility of this diagnostic is still under review.

MODEL DIAGNOSTICS (CONT.)

	Not Applicable	Absent	Incomplete	Complete

Working Group Comments:

D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.				
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.				

MODEL RESULTS

A. Tables of Nominal CPUE, Standardized CPUE, Observations, Positive Observations, Proportion Positive Observations and Coefficients of Variation (CVs). Other statistics may also be appropriate to report			✓	
B. Figure of Nominal and Standardized Indices with measure of variance (i.e. CVs).				✓

IF MULTIPLE MODEL STRUCTURES WERE CONSIDERED:

(***Note: this is always recommended but required when model diagnostics are poor***.)

1. Plot of resulting indices and estimates of variance				
2. Table of model statistics (e.g. AIC criteria)				

	Date Received	*Workshop Recommendation*	*Revision Deadline ****	*Author and Rapporteur Signatures*
First Submission				
Revision				

The revision deadline is negotiated by the author, the SEDAR coordinator and the CPUE rapporteur. The author ***DOES NOT*** *commit to any* ***LEGAL OBLIGATION*** *by agreeing to submit a manuscript before this deadline. The maximum penalty for failure to submit a revised document prior to the submission deadline is rejection of the CPUE series.*

Justification of Working Group Recommendation

Appendix 5.4a
South Atlantic Cobia
Comm. Log., Hook and Line, DeltaLN

DESCRIPTION OF THE DATA SOURCE

1. Fishery Independent Indices

Item	Not Applicable	Absent	Incomplete	Complete
A. Describe the survey design (e.g. fixed sampling sites, random stratified sampling), location, seasons/months and years of sampling.				
B. Describe sampling methodology (e.g. gear, vessel, soak time etc.)				
C. Describe any changes in sampling methodology (e.g. gear, vessel, sample design etc.)				
D. Describe the variables reported in the data set (e.g. location, time, temperature, catch, effort etc.).				
E. What species or species assemblages are targeted by this survey (e.g. red snapper, reef fish, pelagic).				
F. Describe the size/age range that the index applies to. Include supporting figures (e.g. size comp) if available.				

2. Fishery Dependent Indices

Item	Not Applicable	Absent	Incomplete	Complete
A. Describe the data source and type of fishery (e.g. commercial handline, commercial longline, recreational hook and line etc.).				✓
B. Describe any changes to reporting requirements, variables reported, etc.				✓
C. Describe the variables reported in the data set (e.g. location, time, temperature, catch, effort etc.).				✓
D Describe the size/age range that the index applies to. Include supporting figures (e.g. size comp) if available.	✓			✓

METHODS

1. Data Reduction and Exclusions

Item	Not Applicable	Absent	Incomplete	Complete
A. Describe any data exclusions (e.g. gears, fishing modes, sampling areas etc.). Report the number of records removed and justify removal.				✓
B. Describe data reduction techniques (if any) used to address targeting (e.g. Stephens and MacCall, 2004; gear configuration, species assemblage etc).				✓
C. Discuss procedures used to identify outliers. How many were identified? Were they excluded?				✓

Working Group Comments:

2D unknown, data are pounds landed no size data reported - presume legal size with few sublegal

2. Management Regulations (for FD Indices)

	Not Applicable	Absent	Incomplete	Complete
A. Provide (or cite) history of management regulations (e.g. bag limits, size limits, trip limits, closures etc.).				✓
B. Describe the effects (if any) of management regulations on CPUE				✓
C. Discuss methods used (if any) to minimize the effects of management measures on the CPUE series.		✓		

3. Describe Analysis Dataset (after exclusions and other treatments)

	Not Applicable	Absent	Incomplete	Complete
A. Provide tables and/or figures of number of observations by factors (including year, area, etc.) and interaction terms.			✓	
B. Include tables and/or figures of number of positive observations by factors and interaction terms.			✓	
C. Include tables and/or figures of the proportion positive observations by factors and interaction terms.			✓	
D. Include tables and/or figures of average (unstandardized) CPUE by factors and interaction terms.			✓	
E. Include annual maps of locations of survey sites (or fishing trips) and associated catch rates ***OR*** supply the raw data needed to construct these maps (Observation, Year, Latitude, Longitude (or statistical grid, area), Catch, Effort).			✓	
F. Describe the effort variable and the units. If more than one effort variable is present in the dataset, justify selection.				✓
G. What are the units of catch (e.g. numbers or biomass, whole weight, gutted weight, kilograms, pounds).				✓

4. Model Standardization

	Not Applicable	Absent	Incomplete	Complete
A. Describe model structure (e.g. delta-lognormal)				✓
B. Describe construction of GLM components (e.g. forward selection from null etc.)				✓
C. Describe inclusion criteria for factors and interactions terms.				✓
D. Were YEAR*FACTOR interactions included in the model? If so, how (e.g. fixed effect, random effect)? Were random effects tested for significance using a likelihood ratio test?				✓
E. Provide a table summarizing the construction of the GLM components.				✓
F. Summarize model statistics of the mixed model formulation(s) (e.g. log likelihood, AIC, BIC etc.)				✓
G. Report convergence statistics.			✓	

Working Group Comments:

3A-E. confidential data
4G. Available on demand

MODEL DIAGNOSTICS

Comment: Other model structures are possible and acceptable. Please provide appropriate diagnostics to the CPUE indices working group.

	Not Applicable	Absent	Incomplete	Complete	Working Group Comments:
1. Binomial Component					
A. Include plots of the chi-square residuals by factor.				✓	1B, C. Available on demand 2B,D,E. Available on demand
B. Include plots of predicted and observed proportion of positive trips by year and factor (e.g. year*area)			✓		
C. Report overdispersion parameter and other fit statistics (e.g. chi-square / degrees of freedom).			✓		
2. Lognormal/Gamma Component					
A. Include histogram of log(CPUE) or a histogram of the residuals of the model on CPUE. Overlay the expected distribution.				✓	
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor.			✓		
C. Include QQ-plot – (e.g. Student deviance residuals vs. theoretical quantiles), Overlay expected distribution.				✓	
D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.			✓		
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.			✓		
F. Include plots of the residuals by factor				✓	
3. Poisson Component					
A. Report overdispersion parameter and other fit statistics (e.g. chi-square / degrees of freedom).					
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor.					
C. Include QQ-plot – (e.g. Student deviance residuals vs. theoretical quantiles), Overlay expected distribution.					
D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.					
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.					***The feasibility of this diagnostic is still under review.***
4. Zero-inflated model					
A. Include ROC curve to quantify goodness of fit.					
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor).					
C. Include QQ-plot (e.g. Student dev. residuals vs. theoretical quantiles), Overlay expected distribution.					

MODEL DIAGNOSTICS (CONT.)

	Not Applicable	Absent	Incomplete	Complete	Working Group Comments:

D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.				
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.				

MODEL RESULTS

A. Tables of Nominal CPUE, Standardized CPUE, Observations, Positive Observations, Proportion Positive Observations and Coefficients of Variation (CVs). Other statistics may also be appropriate to report				✓
B. Figure of Nominal and Standardized Indices with measure of variance (i.e. CVs).				✓

IF MULTIPLE MODEL STRUCTURES WERE CONSIDERED:

(***Note: this is always recommended but required when model diagnostics are poor***.)

1. Plot of resulting indices and estimates of variance				
2. Table of model statistics (e.g. AIC criteria)				

	Date Received	*Workshop Recommendation*	*Revision Deadline* ***	*Author and Rapporteur Signatures*
First Submission	2/6/12	not recommended		
Revision				

The revision deadline is negotiated by the author, the SEDAR coordinator and the CPUE rapporteur. The author ***DOES NOT*** *commit to any* ***LEGAL OBLIGATION*** *by agreeing to submit a manuscript before this deadline. The maximum penalty for failure to submit a revised document prior to the submission deadline is rejection of the CPUE series.*

Justification of Working Group Recommendation

This index was not recommended for use. The working group had concerns that the very restrictive trip limits of the fishery (two cobia per person per day) and the often opportunistic fishing effort practiced by the fishery prevented the construction of a cpue series that reflected cobia population abundance.

Reset Fields

Appendix 5.4b
South Atlantic Cobia
Comm. Lob., Hook and Line, Pos.

DESCRIPTION OF THE DATA SOURCE

1. Fishery Independent Indices

Item	Not Applicable	Absent	Incomplete	Complete
A. Describe the survey design (e.g. fixed sampling sites, random stratified sampling), location, seasons/months and years of sampling.				
B. Describe sampling methodology (e.g. gear, vessel, soak time etc.)				
C. Describe any changes in sampling methodology (e.g. gear, vessel, sample design etc.)				
D. Describe the variables reported in the data set (e.g. location, time, temperature, catch, effort etc.).				
E. What species or species assemblages are targeted by this survey (e.g. red snapper, reef fish, pelagic).				
F. Describe the size/age range that the index applies to. Include supporting figures (e.g. size comp) if available.				

2. Fishery Dependent Indices

Item	Not Applicable	Absent	Incomplete	Complete
A. Describe the data source and type of fishery (e.g. commercial handline, commercial longline, recreational hook and line etc.).				✓
B. Describe any changes to reporting requirements, variables reported, etc.				✓
C. Describe the variables reported in the data set (e.g. location, time, temperature, catch, effort etc.).				✓
D Describe the size/age range that the index applies to. Include supporting figures (e.g. size comp) if available.	✓			✓

METHODS

1. Data Reduction and Exclusions

Item	Not Applicable	Absent	Incomplete	Complete
A. Describe any data exclusions (e.g. gears, fishing modes, sampling areas etc.). Report the number of records removed and justify removal.				✓
B. Describe data reduction techniques (if any) used to address targeting (e.g. Stephens and MacCall, 2004; gear configuration, species assemblage etc).				✓
C. Discuss procedures used to identify outliers. How many were identified? Were they excluded?				✓

Working Group Comments:

2D unknown, data are pounds landed no size data reported - presume legal size with few sublegal

2. Management Regulations (for FD Indices)

Item	Not Applicable	Absent	Incomplete	Complete
A. Provide (or cite) history of management regulations (e.g. bag limits, size limits, trip limits, closures etc.).				✓
B. Describe the effects (if any) of management regulations on CPUE				✓
C. Discuss methods used (if any) to minimize the effects of management measures on the CPUE series.		✓		

3. Describe Analysis Dataset (after exclusions and other treatments)

Item	Not Applicable	Absent	Incomplete	Complete
A. Provide tables and/or figures of number of observations by factors (including year, area, etc.) and interaction terms.			✓	
B. Include tables and/or figures of number of positive observations by factors and interaction terms.			✓	
C. Include tables and/or figures of the proportion positive observations by factors and interaction terms.			✓	
D. Include tables and/or figures of average (unstandardized) CPUE by factors and interaction terms.			✓	
E. Include annual maps of locations of survey sites (or fishing trips) and associated catch rates ***OR*** supply the raw data needed to construct these maps (Observation, Year, Latitude, Longitude (or statistical grid, area), Catch, Effort).			✓	
F. Describe the effort variable and the units. If more than one effort variable is present in the dataset, justify selection.				✓
G. What are the units of catch (e.g. numbers or biomass, whole weight, gutted weight, kilograms, pounds).				✓

4. Model Standardization

Item	Not Applicable	Absent	Incomplete	Complete
A. Describe model structure (e.g. delta-lognormal)				✓
B. Describe construction of GLM components (e.g. forward selection from null etc.)				✓
C. Describe inclusion criteria for factors and interactions terms.				✓
D. Were YEAR*FACTOR interactions included in the model? If so, how (e.g. fixed effect, random effect)? Were random effects tested for significance using a likelihood ratio test?				✓
E. Provide a table summarizing the construction of the GLM components.				✓
F. Summarize model statistics of the mixed model formulation(s) (e.g. log likelihood, AIC, BIC etc.)				✓
G. Report convergence statistics.			✓	

Working Group Comments:

3A-E. confidential data
4G. Available on demand

MODEL DIAGNOSTICS

Comment: Other model structures are possible and acceptable. Please provide appropriate diagnostics to the CPUE indices working group.

	Not Applicable	Absent	Incomplete	Complete
1. Binomial Component				
A. Include plots of the chi-square residuals by factor.	✓			
B. Include plots of predicted and observed proportion of positive trips by year and factor (e.g. year*area)	✓			
C. Report overdispersion parameter and other fit statistics (e.g. chi-square / degrees of freedom).	✓			
2. Lognormal/Gamma Component				
A. Include histogram of log(CPUE) or a histogram of the residuals of the model on CPUE. Overlay the expected distribution.				✓
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor.			✓	
C. Include QQ-plot – (e.g. Student deviance residuals vs. theoretical quantiles), Overlay expected distribution.				✓
D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.			✓	
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.			✓	
F. Include plots of the residuals by factor				✓
3. Poisson Component				
A. Report overdispersion parameter and other fit statistics (e.g. chi-square / degrees of freedom).				
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor.				
C. Include QQ-plot – (e.g. Student deviance residuals vs. theoretical quantiles), Overlay expected distribution.				
D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.				
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.				
4. Zero-inflated model				
A. Include ROC curve to quantify goodness of fit.				
B. Include plots describing error distribution (e.g. Studentized residuals vs. linear predictor).				
C. Include QQ-plot (e.g. Student dev. residuals vs. theoretical quantiles), Overlay expected distribution.				

Working Group Comments:

1. positive trips only

2B,D,E. Available on demand

The feasibility of this diagnostic is still under review.

MODEL DIAGNOSTICS (CONT.)

	Not Applicable	Absent	Incomplete	Complete

Working Group Comments:

D. Include diagnostic plot for variance function (e.g. square root of std residuals vs. fitted values). Overlay expected distribution.				
E. Include diagnostic plot for link function (e.g. linear response variable vs. linear predictor). Overlay expected distribution.				

MODEL RESULTS

A. Tables of Nominal CPUE, Standardized CPUE, Observations, Positive Observations, Proportion Positive Observations and Coefficients of Variation (CVs). Other statistics may also be appropriate to report				✓
B. Figure of Nominal and Standardized Indices with measure of variance (i.e. CVs).				✓

IF MULTIPLE MODEL STRUCTURES WERE CONSIDERED:

(***Note: this is always recommended but required when model diagnostics are poor***.)

1. Plot of resulting indices and estimates of variance				
2. Table of model statistics (e.g. AIC criteria)				

	Date Received	*Workshop Recommendation*	*Revision Deadline ****	*Author and Rapporteur Signatures*
First Submission	2/6/12	not recommended		
Revision				

The revision deadline is negotiated by the author, the SEDAR coordinator and the CPUE rapporteur. The author ***DOES NOT*** *commit to any* ***LEGAL OBLIGATION*** *by agreeing to submit a manuscript before this deadline. The maximum penalty for failure to submit a revised document prior to the submission deadline is rejection of the CPUE series.*

Justification of Working Group Recommendation

This index was not recommended for use. The working group had concerns that the very restrictive trip limits of the fishery (two cobia per person per day) and the often opportunistic fishing effort practiced by the fishery prevented the construction of a cpue series that reflected cobia population abundance.

Reset Fields

SEDAR

Southeast Data, Assessment, and Review

SEDAR 28

South Atlantic Cobia

SECTION III: Assessment Workshop Report
October 2012

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

Table of Contents

1 Workshop Proceedings

1.1 Introduction

1.1.1 Workshop Time and Place

The SEDAR 28 Assessment Workshop for Gulf of Mexico and South Atlantic Spanish Mackerel (*Scomberomorus maculatus*) and Cobia (*Rachycentron canadum*) was conducted as a workshop held May 7-11 2012 at the Courtyard by Marriott in Miami, FL and eight webinars. Webinars were held on May 22, June 19, July 10, July 24, August 9, August 17, August 30, and September 12th.

1.1.2 Terms of Reference

Panel Responses are italicized

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.

   Data are summarized in the DW report and updates to data are described in section 2 of the AW report.

2. Develop population assessment models that are compatible with available data.
   - Consider multiple models, including multispecies models, if data limitations preclude single species assessments
   - ***Consider a model approach that can be applied to Gulf and Atlantic cobia.***
   - Recommend models and configurations considered most reliable or useful for
   - providing advice
   - Document all input data, assumptions, and equations for each model prepared

   A catch-age model (BAM and a surplus production model (ASPIC) are described in section 3 of the AW report. Similar models were considered for both the Gulf and South Atlantic stocks. The BAM was considered most reliable for providing management advice. Input data are documented in the DW report and in section 2 of the AW report. Model assumptions and equations of BAM are documented in SEDAR28-RW01 and those of ASPIC in Prager (2005).

3. Provide estimates of stock population parameters.
   - Include fishing mortality, abundance, biomass, selectivity, and other parameters as appropriate given data availability and modeling approaches
   - Include appropriate and representative measures of precision for parameter estimates

   These estimates and measures of precision are described in section 3 of the AW report.

4. Characterize uncertainty in the assessment and estimated values.
   - Consider uncertainty in input data, modeling approach, and model configuration
   - Consider other sources as appropriate for this assessment

- Provide appropriate measures of model performance, reliability, and 'goodness of fit'

Measures of uncertainty are described in section 3 of the AW report.

5. Provide evaluations of yield and productivity
   - Include yield-per-recruit, spawner-per-recruit, and stock-recruitment evaluations

   These estimates are provided in section 3 of the AW report.

6. 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.
   - Evaluate existing or proposed management criteria as specified in the management
   - summary
   - Recommend proxy values when necessary

   Estimated management benchmarks and alternatives are provided in section 3 of the AW report.

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

   Estimates of stock status are provided in section 3 of the AW report.

8. Perform a 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

   Probabilistic analyses are described in section 3 of the AW report.

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

   A) If stock is overfished:
   F=0, F=current, F=Fmsy, Ftarget,
   F=Frebuild (max that rebuilds in allowed time)
   B) If stock is overfishing:
   F=Fcurrent, F=Fmsy, F= Ftarget
   C) If stock is neither overfished nor overfishing:
   F=Fcurrent, F=Fmsy, F=Ftarget
   D) If data-limitations preclude classic projections (i.e. A, B, C above), explore alternate models to provide management advice.

Projections are described in section 3 of the AW report. A re-building schedule does not appear warranted.

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

    Provided in the report.

11. Prepare an accessible, documented, labeled, and formatted spreadsheet containing all model parameter estimates and all relevant population information resulting from model estimates and any projection and simulation exercises. Include all data included in assessment report tables and all data that support assessment workshop figures.

    An Excel file of model input and output was supplied. Most values are also reported in the DW report and in section 2 of the AW report.

12. Complete the Assessment Workshop Report for Review (Section III of the SEDAR Stock Assessment Report).

    This report was provided within the specified time frame.

1.1.3 List of Participants

Panelists

Katie Andrews	Kevin Craig	Nancie Cummings	Jeff Isely
Rob Cheshire	Meaghan Bryan	Eric Fitzpatrick	Mike Denson
Read Hendon	Marcel Reichert	Scott Crosson	Bob Muller
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Steve Saul	Adam Pollack	Kevin McCarthy	Neil Baertlein
Michael Schirripa	Todd Gedamke	Walt Ingram	Shannon Calay
Andrea Grabman			

1.1.4 List of Assessment Workshop Working Papers

Documents Prepared for the Assessment Workshop		
SEDAR28-AW01	Florida Trip Tickets	S. Brown
SEDAR28-AW02	SEDAR 28 Spanish mackerel bycatch estimates from US Atlantic coast shrimp trawls	NMFS Beaufort

2 Data Review and Update

Processing of data for this assessment is described in the SEDAR 28South Atlantic Cobia Data Workshop Report. This section summarizes the data input for the Beaufort Assessment Model (BAM) base run and describes additional processing prior to and during the Assessment Workshop (AW). In particular, data for 2011, which were not available at the DW, were added. In some cases the addition of the final year of data changed estimates for the earlier years. The data were also used for the surplus production model. A summary of the model input is given in Tables 2.1-2.15.

2.1 Additional Data

Several data elements were discussed and recommended at the SEDAR 28 DW but were not completed by the Data Workshop (DW) panel. These data elements were addressed prior to the AW and included in the DW report. The following refer to data updates that have not been included in the DW report but were included as input to the BAM base model.

2.2 Life History

The relationship between weight and length ($Wt = aFL^{b}$) for sexes combined was developed at the DW and used as model input (Table 2.1).

The von Bertalanffy equation (sexes combined) was used to model growth of cobia (Table 2.2).

An age-specific maturity vector was developed using length-specific maturity and the von Bertalanffy growth curve that was provided at the DW (Table 2.3). Female growth parameters were used to develop the maturity vector because reproductive potential was represented by mature female biomass in the model.

A scaled Lorenzen age-specific natural mortality vector was developed at the DW but was updated after the DW (Table 2.4). The cumulative survival of ages 3-16 based on a point estimate of natural mortality (M=0.26) was used to scale the age-based estimates of natural mortality.

Generation time (G) is not typically computed at the DW but may be required for stock projections. Generation time was estimated from Eq. 3.4 in Gotelli (1998) using female growth parameters.

$G = \Sigma l_x b_x x / \Sigma l_x b_x$

where summation was over ages x=0 through 16 (by which age cumulative survival is near zero), l_x is the number of fish at age starting with 1 fish at age zero and decrementing based on natural mortality only, and b_x is per capita birth rate at age. We substituted the product of m_x and w_x for b_x in this equation, where m_x is the proportion of females mature at age, and w_x is the expected weight of females at age calculated from the von Bertalanffy growth curve and the length to weight conversion equations (females only). This weighted average of age for mature female biomass yields an estimated generation time of 7 years.

An aging error matrix was developed for cobia using the AGEMAT software (Table 2.5; Punt et al. 2008). Four independent readers from three different laboratories aged the same 106 cobia otoliths. Ages reported ranged from age 2 – 13. Percent agreement among readers was typically > 90%.

2.3 Commercial Landings and Discards

Total commercial landings (1950-2011) were updated to include 2011 data (Table 2.6, 1000s lbs whole weight). The number of commercial discards (alive and dead) was available for 1993-2011. The number of dead commercial discards was calculated assuming a 0.05 discard mortality rate for fish caught by vertical line and trolling and a 0.51 discard mortality rate for fish caught by gillnet, as recommended by the DW. The number of dead commercial discards was converted to weight assuming a mean weight of discarded fish of 6.8 lbs (see section 2.5 below for estimation of mean weight). The ratio of dead commercial discards to total commercial landings (based on weight)was used to hindcast commercial discards to 1983 (when regulations were first put in place). The mean ratio of dead commercial discards to landings from 1993-1997 (mean: 0.0030; range: 0.0025 to 0.0036) was used for hindcasting. Estimates of dead commercial discards (1000s lbs whole weight) are shown in Table 2.7. Commercial discards were assumed to be zero prior to 1983 when regulation began. Estimates of dead commercial discards averaged only 2.4% of commercial landings and were combined with landings as total commercial removals.

2.4 Commercial Length and Age Composition

Cobia commercial length compositions were updated to 2011 (Table 2.8).Annual length compositions (originally 1-cm bins) were combined into 3-cm bins with a minimum size of 20 cm and a maximum size of 149 cm. Commercial length compositions were pooled across all years (1982 - 2011) and weighted by the annual number of trips sampled due to low sample sizes.

Commercial age compositions were also pooled across years (1986 – 2011) due to low sample sizes and weighted by the annual number of fish sampled (number of trips was not available for age compositions). Cobia age 12-15were pooled as a plus group(12+, Table 2.9).

2.5 Recreational Landings and Discards

Recreational landings and discards (number of fish)were updated to include2011 (Table 2.10, Table 2.11). Recreational landings from the Southeast Regional Headboat Survey (SRHS) were pooled with those from MRFSS (all modes). Discard estimates from 1983-2003 SRHS and total discard estimates changed from that available at the DW with the addition of 2011 data. Discard estimates were computed using a more recent (2004-2010) discards to landings ratio. The number of dead recreational discards was estimated for 1983 -2011 assuming a discard mortality rate of 0.05, as recommended by the DW. Recreational discards were assumed to be zero prior to 1983 (the year regulation began). Similar to commercial data, estimates of dead recreational discards were small relative to recreational landings (mean for 1983 – 2011: 4.6%) and were combined with recreational landings as recreational removals.

Prior to 1981 landings were estimated in number. However, input for the surplus production model required estimated removals in weight. To estimate total removals in weight, a mean weight was calculated for the recreational cobia fishery by pooling data by fleet and weighting by sample size. The mean weight used prior to 1981 was 11.8 lbs.

A similar calculation was required to estimate the mean weight of discarded cobia. Using combined MRFSS and headboat length composition data from a period with no minimum length limit in place (1981 and 1982), the weight of recreationally discarded fish was determined by calculating the sum of the products of the mean weight at each length bin (using the length-weight relationship) by the proportion of fish in that bin up to the size limit (33 inches). The mean weight of discarded cobia was 6.8 lbs. For ASPIC, the dead discards were combined with landings as total removals.

2.6 Recreational Length and Age composition

Cobia recreational length compositions were updated to include 2011 (Table 2.12). Length compositions for MRFSS and headboat (SRHS) were combined. Recreational length compositions (originally 1 cm bins) were combined into 3-cm bins with a minimum size of 20 cm and a maximum size limit of 149 cm.

Cobia recreational age compositions were updated to include 2011 (Table 2.13). Recreational age compositions from the headboat survey (SRHS) and MRFSS were combined. Considerable discussion occurred at the AW regarding weighting of the recreational age compositions. The AW panel recommended not weighting the annual recreational age compositions because many aged fish could not be assigned to particular trips, and because there were a large number of missing cells in the annual length compositions (which are typically used to weight the annual age compositions). Attempted weighting of the annual age compositions resulted in the exclusion of > 50% of the aged fish and the loss of several years of age composition data. Weighting age composition data for cobia is probably not as important as for some other species because cobia are mostly harvested as one or possibly two fish per trip. Therefore, unweighted age compositions with annual sample sizes equal to the number of fish were used in the statistical catch-at-age model.

2.7 Indices

The head boat (SRHS) index, South Carolina charter boat logbook index, the MRFSS index, and the associated CVs were updated through 2011 using the same methods discussed above in Section 5 of the Data Workshop report. All finalized indices for potential use in the cobia stock assessment and associated CVs are in Table 2.14.

2.8 South Carolina cobia stocking program

Cobia were stocked in South Carolina waters as part of an experimental stocking program from 2005-2009. The program and the number of fish stocked are described in SEDAR28-DW02. The potential effect of these stocked fish was evaluated via sensitivity analysis (sensitivity 10). Stocked fish were considered an external source of age-1 recruits and added to the model for the relevant years. To generate the number of age-1 recruits, an age was assigned to each group of stocked fish based on their mean length, the von Bertalanffy growth function, and the month of stocking. Most stocked fish were age-0. The age-0 natural mortality rate from the scaled Lorenzen vector was applied to each group of stocked fish for the remainder of the calendar year after stocking. These fish were then added to the model at the beginning of the calendar year as age-1 recruits. Stocked fish were considered identical to wild fish in terms of their mortality, growth, and reproductive dynamics. The number of external (stocked) age-1 recruits added is shown in Table 2.15.

2.9 References

Gotelli, N.J. 1998. A Primer of Ecology 2nd Edition. Sinauer Associates, Inc., Sunderland, MA, 236p.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology 49:627-642.

Punt, A.E., Smith, D.C., Krusic-Golub, K. and Robertson, S. 2008. Quantifying age-reading error for use in fisheries stock assessments, with application to species in Australia's Southern and Eastern Scalefish and Shark Fishery. *Can. J. Fish. Aquat. Sci.* 65:1991-2005.

2.10 Tables

Table 2.1. Meristic conversions for South Atlantic cobia. FL= fork length (mm), TL = total length (mm), SL=standard length (mm), Wt= whole body weight (kg).

Sex	Model	n	a	SE a	b	SE b	MSE	R2
Male	Ln(Wt) = a+b*Ln(FL)	413	-21.12	0.18	3.42	0.03	0.13	0.98
Female	Ln(Wt) = a+b*Ln(FL)	981	-20.06	0.14	3.26	0.02	0.13	0.96
Combined	Ln(Wt) = a+b*Ln(FL)	4171	-20.18	0.06	3.28	0.01	0.16	0.97
	Wt=aFL^b		2.0 e-09		3.28			
Male	FL = a+b*TL	901	25.44	4.63	0.86	0.004	20.06	0.98
Female	FL = a+b*TL	1318	7.52	4.10	0.88	0.003	25.04	0.98
Combined	FL = a+b*TL	4635	13.52	1.78	0.88	0.002	24.80	0.99
Male	FL = a+b*SL	25	-14.38	32.88	1.11	0.04	24.57	0.97
Female	FL = a+b*SL	108	60.19	24.07	1.04	0.02	38.06	0.95
Combined	FL = a+b*SL	282	35.07	11.78	1.06	0.01	35.17	0.97

Table 2.2. Von Bertalanffy growth model parameter estimates for South Atlantic cobia. Standard errors in ().

Atlantic Cobia Growth (VB):	Observed Max Age	Age range	FL, mm Length range	n	von Bertalanffy growth Linf (SE)	K (SE)	t_o	CV
ALL FISH: Size-selectivity correction and inverse weighted by sample size at calendar age	16	0 - 16	207 - 1610	2,485	1324.4 (115.71)	0.27 (0.0732)	-0.47 (0.192)	0.131 (0.0308)
ALL FISH: Inverse weighted by sample size at calendar age, no size-limit selectivity correction	16	0 - 16	207 - 1610	2,639	1292.5	0.34	-0.37	
FEMALE: Size-selectivity correction and inverse weighted by sample size at calendar age	16	0 - 16	214 - 1610	1,369	1386.6 (112.7)	0.27 (0.0668)	0.43 (0.161)	0.124 (0.0277)
Female: Inverse weighted by sample size at calendar age, no size-limit selectivity correction	16	0 - 16	214 - 1610	1,410	1368.5	0.33	-0.31	
MALE: Size-selectivity correction and inverse weighted by sample size at calendar age	15	0 - 15	207 - 1365	890	1179.1 (90.88)	0.3 (0.0805)	-0.49 (0.205)	0.125 (0.031)
Male: Inverse weighted by sample size at calendar age, no size-limit selectivity correction	15	0 - 15	207 - 1365	995	111.5	0.43	-0.31	

Table 2.3. South Atlantic cobia age specific maturity vector (females only).

Age	% mature
0	0
1	0
2	50
3	75
4	100
5	100
6	100
7	100
8	100
9	100
10	100
11	100
12	100
13	100
14	100
15	100
16	100

Table 2.4. Age-specific natural mortality of South Atlantic cobia based on the Lorenzen (1996) method for all data combined.

Age	Scaled Lorenzen base
1	0.559
2	0.418
3	0.350
4	0.312
5	0.288
6	0.272
7	0.261
8	0.253
9	0.247
10	0.242
11	0.239
12	0.238
13	0.236
14	0.235
15	0.234
16	0.233

Table 2.5. South Atlantic cobia aging error matrix.

Age	1	2	3	4	5	6	7	8	9	10	11	12
1	0.982	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.018	0.964	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.018	0.964	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.018	0.964	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.018	0.964	0.018	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.018	0.964	0.018	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.018	0.964	0.018	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.964	0.018	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.964	0.018	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.964	0.018	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.964	0.018
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.982

Table 2.6. South Atlantic cobia commercial landings updated to include 2011.

Year	Landings (1000 lb)	Year	Landings (1000 lb)
1950	11.4	1981	17.9
1951	11.8	1982	31.3
1952	3.8	1983	18.0
1953	13.7	1984	13.7
1954	28.2	1985	11.1
1955	9.2	1986	25.8
1956	27.1	1987	40.5
1957	48.6	1988	28.6
1958	25.5	1989	33.3
1959	48.9	1990	43.7
1960	30.7	1991	43.8
1961	38.7	1992	36.7
1962	41.1	1993	39.5
1963	49.9	1994	46.9
1964	24.5	1995	67.0
1965	19.9	1996	62.4
1966	12.1	1997	62.3
1967	12.8	1998	43.5
1968	10.9	1999	27.5
1969	9.0	2000	43.5
1970	9.2	2001	40.8
1971	14.4	2002	42.2
1972	7.0	2003	35.3
1973	4.6	2004	32.6
1974	5.5	2005	28.7
1975	8.1	2006	33.8
1976	5.9	2007	31.6
1977	3.5	2008	33.8
1978	2.7	2009	42.3
1979	4.5	2010	56.5
1980	8.4	2011	34.0

Table 2.7. South Atlantic cobia commercial discards, including 2011.

Year	Dead Discards (1000s lbs)
1983	0.053
1984	0.041
1985	0.033
1986	0.076
1987	0.120
1988	0.085
1989	0.099
1990	0.130
1991	0.130
1992	0.109
1993	0.136
1994	0.170
1995	0.170
1996	0.163
1997	0.163
1998	1.147
1999	1.147
2000	1.568
2001	1.303
2002	2.145
2003	1.684
2004	1.731
2005	1.833
2006	2.098
2007	1.989
2008	2.661
2009	2.132
2010	1.806
2011	2.084

Table 2.8. South Atlantic cobia pooled (1981-2011) commercial length compositions updated to include 2011.

Year	n.fish	n.trips	FL (cm)																					
all years	438	237	20	23	26	29	32	35	38	41	44	47	50	53	56	59	62	65	68	71	74	77	80	83
			0.03	0.01	0.02	0.03	0.03	0.01	0.01	0.00	0.02	0.01	0.01	0.02	0.02	0.04	0.01	0.00	0.01	0.01	0.01	0.02	0.04	0.06
Year	n.fish	n.trips	FL (cm)																					
all years	438	237	86	89	92	95	98	101	104	107	110	113	116	119	122	125	128	131	134	137	140	143	146	149
			0.07	0.05	0.07	0.03	0.06	0.06	0.06	0.03	0.02	0.01	0.04	0.02	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00

Table 2.9. South Atlantic cobia pooled (1986-2011) commercial age compositions updated to include 2011 data.

age	proportion
1	0.043
2	0.128
3	0.222
4	0.231
5	0.077
6	0.085
7	0.051
8	0.043
9	0.043
10	0.009
11	0.000
12	0.068

Table 2.10. South Atlantic cobia recreational landings updated to include 2011.

Year	Total Recreational*	
	Number	Weight (lb)
1955	3,048	
1956	3,215	
1957	3,383	
1958	3,551	
1959	3,719	
1960	3,887	
1961	4,138	
1962	4,389	
1963	4,640	
1964	4,891	
1965	5,142	
1966	5,354	
1967	5,566	
1968	5,778	
1969	5,990	
1970	6,202	
1971	6,744	
1972	7,285	
1973	7,827	
1974	8,369	
1975	8,910	
1976	8,820	
1977	8,730	
1978	8,639	
1979	8,549	
1980	8,459	
1981	4,449	12,753
1982	7,019	114,425
1983	894	26,805
1984	11,695	391,706
1985	18,766	320,714
1986	30,151	607,805
1987	10,001	173,416
1988	9,236	190,261
1989	14,536	326,065
1990	14,861	248,922
1991	22,316	704,031
1992	15,025	407,847
1993	10,488	255,553
1994	9,760	296,357
1995	16,375	446,152
1996	25,693	684,962
1997	15,997	587,799
1998	12,563	392,335
1999	12,588	369,362
2000	13,725	464,236
2001	13,639	483,926
2002	10,332	381,849
2003	28,906	615,522
2004	29,473	1,028,231
2005	29,285	815,600
2006	31,445	1,231,415
2007	25,382	776,180
2008	17,458	546,297
2009	26,228	711,821
2010	27,094	876,505
2011	12,024	330,071

Table 2.11. South Atlantic cobia recreational discards updated to include 2011.

Year	Total Discards (number)	Dead Discards (number)
1983	1,423	71
1984	2,612	131
1985	19,882	994
1986	8,422	421
1987	920	46
1988	5,999	300
1989	4,003	200
1990	6,401	320
1991	22,816	1,141
1992	6,551	328
1993	2,652	133
1994	12,883	644
1995	8,067	403
1996	4,061	203
1997	10,985	549
1998	16,030	801
1999	28,554	1,428
2000	12,616	631
2001	19,284	964
2002	16,323	816
2003	42,059	2,103
2004	21,533	1,077
2005	29,211	1,461
2006	43,388	2,169
2007	29,473	1,474
2008	16,252	813
2009	29,457	1,473
2010	32,906	1,645
2011	24,665	1,233

Table 2.12. South Atlantic cobia recreational length compositions updated to include 2011.

YEAR	n.fish	n.trips	Length Bins (mm)																					
			200	230	260	290	320	350	380	410	440	470	500	530	560	590	620	650	680	710	740	770	800	830
1981	3	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.000	0.000	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.000	0.000	0.000	0.000
1982	9	9	0.000	0.000	0.000	0.133	0.000	0.000	0.000	0.133	0.000	0.133	0.000	0.000	0.000	0.133	0.000	0.000	0.000	0.167	0.000	0.000	0.000	0.000
1983	6	5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.222
1984	15	14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.240	0.000	0.000
1985	30	25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.085	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.000	0.000	0.000	0.024	0.097
1986	31	28	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.060	0.000	0.000	0.119	0.000	0.000	0.000	0.000	0.000	0.050	0.043
1987	34	30	0.066	0.017	0.000	0.000	0.000	0.066	0.000	0.000	0.000	0.000	0.000	0.083	0.000	0.000	0.000	0.033	0.066	0.000	0.000	0.000	0.013	0.033
1988	29	28	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.027	0.000	0.027	0.000	0.000	0.000	0.000	0.016	0.000	0.000	0.000	0.027	0.108	0.027	0.152
1989	45	41	0.000	0.000	0.000	0.077	0.077	0.000	0.000	0.000	0.000	0.000	0.026	0.000	0.000	0.000	0.038	0.000	0.000	0.010	0.022	0.051	0.000	0.000
1990	47	39	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.000	0.043	0.039	0.000	0.000	0.081	0.023	0.020	0.000	0.037	0.081
1991	42	41	0.000	0.000	0.000	0.046	0.000	0.000	0.000	0.046	0.000	0.009	0.093	0.000	0.000	0.000	0.000	0.000	0.033	0.000	0.000	0.127	0.000	0.072
1992	51	42	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.017	0.120
1993	35	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.046
1994	40	32	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.013
1995	48	43	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.023	0.038
1996	55	39	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.000	0.016	0.004	0.004	0.016	0.000	0.000	0.000	0.004	0.000	0.088	0.039
1997	37	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.049	0.000
1998	56	37	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042	0.062	0.013
1999	55	38	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.049	0.000	0.000	0.146	0.016	0.016	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	22	17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.080	0.000	0.000	0.000	0.000	0.000	0.045
2001	37	33	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.027	0.000	0.052
2002	49	41	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.041
2003	50	45	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.017
2004	57	42	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.039	0.000
2005	64	45	0.000	0.000	0.000	0.000	0.000	0.000	0.110	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.055
2006	41	36	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2007	112	62	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2008	85	52	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.080	0.000
2009	61	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.040	0.000
2010	100	69	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.000	0.000	0.000	0.000	0.000	0.055	0.000	0.007
2011	52	38	0.000	0.000	0.000	0.000	0.000	0.112	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.030	0.065	0.007

Table 2.12. South Atlantic cobia recreational length compositions updated to include 2011. (cont.)

YEAR	n.fish	n.trips	860	890	920	950	980	1010	1040	1070	1100	1130	1160	1190	1220	1250	1280	1310	1340	1370	1400	1430	1460	1490
			0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1981	3	3	0.000	0.083	0.000	0.000	0.000	0.000	0.067	0.000	0.067	0.083	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1982	9	9	0.111	0.000	0.000	0.000	0.167	0.333	0.000	0.000	0.000	0.167	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1983	6	5	0.000	0.150	0.040	0.060	0.150	0.000	0.000	0.000	0.100	0.060	0.060	0.000	0.040	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	15	14	0.156	0.052	0.043	0.135	0.000	0.026	0.095	0.000	0.126	0.017	0.026	0.028	0.000	0.034	0.017	0.012	0.000	0.000	0.000	0.000	0.000	0.000
1985	30	25	0.022	0.138	0.018	0.022	0.067	0.090	0.032	0.018	0.022	0.090	0.090	0.000	0.000	0.000	0.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1986	31	28	0.066	0.118	0.046	0.000	0.092	0.000	0.037	0.094	0.035	0.017	0.007	0.024	0.022	0.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	34	30	0.124	0.000	0.108	0.080	0.000	0.000	0.043	0.027	0.000	0.043	0.027	0.000	0.108	0.054	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	29	28	0.186	0.066	0.115	0.064	0.025	0.077	0.025	0.039	0.000	0.000	0.000	0.000	0.013	0.000	0.026	0.000	0.000	0.026	0.038	0.000	0.000	0.000
1989	45	41	0.121	0.051	0.086	0.077	0.036	0.088	0.065	0.063	0.007	0.000	0.000	0.027	0.000	0.000	0.000	0.000	0.016	0.000	0.000	0.000	0.000	0.000
1990	47	39	0.000	0.077	0.125	0.046	0.051	0.013	0.063	0.023	0.108	0.000	0.000	0.009	0.000	0.009	0.000	0.000	0.000	0.046	0.000	0.000	0.000	0.000
1991	42	41	0.079	0.109	0.097	0.010	0.060	0.013	0.124	0.125	0.018	0.033	0.043	0.008	0.084	0.008	0.033	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	51	42	0.050	0.138	0.046	0.132	0.035	0.070	0.101	0.151	0.090	0.076	0.010	0.000	0.000	0.010	0.000	0.035	0.000	0.000	0.000	0.000	0.000	0.000
1993	35	30	0.000	0.028	0.050	0.152	0.152	0.013	0.027	0.114	0.125	0.163	0.020	0.062	0.010	0.010	0.000	0.000	0.029	0.000	0.000	0.000	0.010	0.000
1994	40	32	0.030	0.067	0.149	0.029	0.121	0.075	0.037	0.035	0.085	0.104	0.035	0.000	0.006	0.006	0.029	0.045	0.000	0.086	0.000	0.000	0.000	0.000
1995	48	43	0.131	0.098	0.242	0.000	0.004	0.080	0.000	0.097	0.021	0.000	0.040	0.010	0.029	0.004	0.022	0.000	0.000	0.000	0.000	0.000	0.035	0.000
1996	55	39	0.000	0.077	0.125	0.036	0.116	0.062	0.019	0.086	0.019	0.152	0.087	0.041	0.087	0.029	0.000	0.015	0.000	0.000	0.000	0.000	0.000	0.000
1997	37	30	0.020	0.042	0.048	0.006	0.040	0.200	0.025	0.054	0.116	0.050	0.030	0.017	0.157	0.011	0.000	0.011	0.000	0.028	0.028	0.000	0.000	0.000
1998	56	37	0.000	0.000	0.010	0.233	0.000	0.032	0.043	0.173	0.016	0.000	0.000	0.000	0.130	0.000	0.000	0.000	0.043	0.000	0.043	0.000	0.000	0.000
1999	55	38	0.045	0.000	0.045	0.000	0.000	0.053	0.045	0.000	0.098	0.205	0.000	0.000	0.125	0.000	0.080	0.045	0.000	0.000	0.000	0.053	0.080	0.000
2000	22	17	0.000	0.039	0.035	0.087	0.049	0.118	0.023	0.157	0.170	0.052	0.012	0.000	0.000	0.035	0.000	0.000	0.012	0.026	0.000	0.000	0.000	0.105
2001	37	33	0.120	0.041	0.067	0.055	0.012	0.033	0.000	0.000	0.012	0.012	0.047	0.177	0.110	0.000	0.000	0.146	0.055	0.000	0.037	0.000	0.000	0.037
2002	49	41	0.009	0.048	0.072	0.314	0.100	0.055	0.000	0.085	0.085	0.052	0.020	0.085	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.000	0.000
2003	50	45	0.116	0.000	0.022	0.116	0.034	0.011	0.152	0.084	0.136	0.000	0.070	0.023	0.000	0.062	0.022	0.101	0.000	0.000	0.000	0.000	0.000	0.012
2004	57	42	0.000	0.018	0.034	0.109	0.064	0.040	0.117	0.037	0.000	0.018	0.055	0.077	0.051	0.022	0.018	0.168	0.000	0.000	0.000	0.000	0.000	0.000
2005	64	45	0.016	0.016	0.271	0.000	0.198	0.032	0.075	0.101	0.000	0.032	0.000	0.065	0.000	0.129	0.000	0.000	0.000	0.000	0.000	0.064	0.000	0.000
2006	41	36	0.095	0.055	0.057	0.124	0.147	0.024	0.104	0.000	0.020	0.020	0.066	0.095	0.057	0.024	0.000	0.000	0.000	0.000	0.095	0.019	0.000	0.000
2007	112	62	0.092	0.009	0.000	0.000	0.181	0.000	0.110	0.000	0.184	0.080	0.000	0.011	0.011	0.080	0.000	0.000	0.080	0.000	0.080	0.000	0.000	0.000
2008	85	52	0.094	0.161	0.077	0.107	0.081	0.060	0.134	0.040	0.060	0.060	0.000	0.000	0.057	0.000	0.000	0.027	0.000	0.000	0.000	0.000	0.000	0.000
2009	61	50	0.055	0.030	0.014	0.097	0.051	0.237	0.069	0.080	0.065	0.051	0.011	0.011	0.016	0.048	0.000	0.020	0.018	0.040	0.000	0.007	0.000	0.000
2010	100	69	0.028	0.015	0.028	0.126	0.119	0.015	0.132	0.184	0.030	0.028	0.000	0.000	0.000	0.037	0.000	0.007	0.007	0.000	0.000	0.000	0.007	0.022

Table 2.13. South Atlantic cobia recreational age compositions updated to include 2011.

Year	n.fish	1	2	3	4	5	6	7	8	9	10	11	12
1984	3	0.333	0.000	0.667	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1985	2	0.000	0.500	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000
1986	22	0.000	0.136	0.318	0.045	0.273	0.182	0.000	0.000	0.045	0.000	0.000	0.000
1987	18	0.111	0.500	0.000	0.111	0.000	0.167	0.111	0.000	0.000	0.000	0.000	0.000
1988	17	0.000	0.294	0.059	0.118	0.235	0.059	0.059	0.118	0.059	0.000	0.000	0.000
1989	78	0.000	0.128	0.244	0.231	0.064	0.090	0.064	0.077	0.077	0.000	0.013	0.013
1990	103	0.000	0.000	0.485	0.165	0.117	0.039	0.039	0.039	0.029	0.058	0.010	0.019
1991	16	0.000	0.000	0.063	0.375	0.188	0.125	0.000	0.063	0.000	0.125	0.063	0.000
1992	20	0.000	0.150	0.200	0.100	0.150	0.200	0.200	0.000	0.000	0.000	0.000	0.000
1993	16	0.000	0.000	0.313	0.063	0.000	0.250	0.000	0.125	0.063	0.063	0.000	0.125
1994	16	0.000	0.000	0.063	0.375	0.125	0.063	0.125	0.063	0.000	0.000	0.063	0.125
1995	10	0.000	0.000	0.000	0.000	0.200	0.100	0.000	0.400	0.200	0.000	0.100	0.000
1996	31	0.000	0.000	0.129	0.032	0.129	0.290	0.194	0.097	0.097	0.000	0.000	0.032
1997	20	0.000	0.250	0.200	0.100	0.100	0.100	0.050	0.000	0.100	0.000	0.100	0.000
1998													
1999	130	0.000	0.008	0.038	0.315	0.054	0.262	0.015	0.023	0.138	0.062	0.015	0.069
2000	111	0.000	0.009	0.072	0.036	0.225	0.036	0.279	0.027	0.009	0.117	0.108	0.081
2001	72	0.000	0.000	0.375	0.153	0.000	0.208	0.028	0.125	0.000	0.014	0.069	0.028
2002	27	0.000	0.000	0.111	0.296	0.074	0.074	0.333	0.037	0.037	0.000	0.000	0.037
2003	7	0.000	0.000	0.000	0.143	0.286	0.143	0.000	0.429	0.000	0.000	0.000	0.000
2004	7	0.000	0.000	0.000	0.000	0.429	0.571	0.000	0.000	0.000	0.000	0.000	0.000
2005	125	0.000	0.032	0.256	0.144	0.144	0.176	0.184	0.000	0.048	0.016	0.000	0.000
2006	81	0.000	0.086	0.086	0.321	0.123	0.148	0.111	0.049	0.012	0.012	0.012	0.037
2007	397	0.003	0.010	0.730	0.025	0.108	0.028	0.035	0.015	0.020	0.008	0.013	0.005
2008	327	0.000	0.006	0.153	0.609	0.021	0.067	0.040	0.043	0.028	0.028	0.003	0.003
2009	311	0.000	0.013	0.119	0.273	0.363	0.019	0.119	0.019	0.019	0.023	0.023	0.010
2010	330	0.000	0.012	0.245	0.182	0.212	0.221	0.018	0.067	0.030	0.003	0.000	0.009
2011	307	0.000	0.013	0.179	0.248	0.160	0.147	0.147	0.013	0.042	0.013	0.010	0.029

Table 2.14. South Atlantic cobia indices and associated CVs recommended for potential use. Each index is scaled to its mean value.

Year	Headboat	SC logbook	MRFSS	CV Headboat	CV SC logbook	CV MRFSS
1981	0.72			0.25		
1982	0.71			0.26		
1983	0.81			0.25		
1984	0.36			0.31		
1985	0.36		0.76	0.56		0.67
1986	0.71		0.53	0.27		0.72
1987	1.18		0.43	0.19		0.77
1988	0.88		0.35	0.21		0.59
1989	0.81		1.49	0.25		0.58
1990	0.55		0.37	0.26		0.65
1991	1.72		0.47	0.17		0.62
1992	1.34		0.51	0.16		0.66
1993	1.05		0.36	0.15		0.57
1994	1.19		0.60	0.15		0.57
1995	1.32		0.74	0.14		0.56
1996	0.56		0.69	0.2		0.56
1997	0.94		1.08	0.17		0.55
1998	0.86	1.16	1.20	0.15	0.32	0.53
1999	0.9	1.39	1.73	0.18	0.31	0.54
2000	1.28	1.04	1.06	0.17	0.24	0.52
2001	1.34	1.21	1.49	0.17	0.25	0.52
2002	0.9	0.97	0.95	0.16	0.33	0.53
2003	1.11	0.73	1.45	0.19	0.22	0.51
2004	1.08	1.20	1.41	0.16	0.25	0.51
2005	1.08	0.96	1.39	0.19	0.23	0.52
2006	0.94	0.95	1.49	0.2	0.21	0.50
2007	1.54	1.11	1.06	0.14	0.24	0.52
2008	1.96	0.79	1.07	0.15	0.23	0.52
2009	0.93	1.05	1.46	0.21	0.23	0.49
2010	0.88	0.73	1.60	0.17	0.27	0.50
2011	0.94	0.73	1.26	0.22	0.23	0.61

Table 2.15. Number of cobia added as age-1 recruits to represent the effect of stocking for sensitivity 10.

Year enter model	Age enter model	Number fish
2006	1	2,310
2008	1	31,373
2009	1	1,693
2010	1	1,126

3 Stock Assessment Models and Results

Several stock assessment models of cobia were discussed during the Assessment Workshop (AW) including a catch-age model (the Beaufort assessment model, BAM) and an age-aggregated surplus production model (ASPIC). In addition, alternative methods of catch curve analysis that made different assumptions about selectivity and natural mortality, as well a method based on variation in mean length were used to estimate total mortality.

The BAM was selected by the AW panelists to be the primary assessment model, although descriptions and results from all models considered are reported here. Abbreviations used herein are defined in Appendix A.

3.1 Model 1: Beaufort Assessment Model

3.1.1 Model 1 Methods

3.1.1.1 Overview The primary model in this assessment was the Beaufort assessment model (BAM), which applies a statistical catch-age formulation. The model was implemented with the AD Model Builder software (Fournier et al. 2012), and its structure and equations are detailed in SEDAR-28-RW-01. In essence, a statistical catch-age model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008*a*). Quantities to be estimated are systematically varied until characteristics of the simulated population match available data on the real population. Statistical catch-age models share many attributes with ADAPT-style tuned and untuned VPAs.

The method of forward projection has a long history in fishery models. It was introduced by Pella and Tomlinson (1969) for fitting production models and then, among many applications, used by Fournier and Archibald (1982), by Deriso et al. (1985) in their CAGEAN model, and by Methot (1989; 2009) in his Stock Synthesis model. The catch-age model of this assessment is similar in structure to the CAGEAN and Stock Synthesis models. Versions of this assessment model have been used in previous SEDAR assessments in the U.S. South Atlantic, such as red porgy, black seabass, snowy grouper, gag grouper, greater amberjack, vermilion snapper, Spanish mackerel, red grouper, red snapper, and tilefish.

3.1.1.2 Data Sources The catch-age model included data from two fishery dependent surveys, and from both recreational and commercial fisheries that caught southeastern U.S. cobia. The model was fitted to data on annual combined recreational landings and discards, annual combined commercial landings and discards, annual length compositions of recreational landings, annual age compositions of recreational landings, a combined length composition of commercial landings (1982-2011), a combined age composition of commercial landings (1986-2011), and two indices of abundance (the South Atlantic Regional Headboat Survey (SRHS) and the South Carolina logbook program). Discards were a small proportion of landings and no information on size or age of discards was available to estimate discard selectivity; therefore, discards were combined with landings. Not all of the above data sources were available for all fleets that caught cobia in all years. Data used in the model are tabulated in the DW report and in §II of this assessment report.

The recreational landings estimates include headboat landings, developed by the headboat survey, and the general recreational landings for private recreational, charterboat, and shore modes of the Marine Recreational Fishing Statistical Survey (MRFSS). MRFSS began in 1981 and is undergoing modifications, including a change of name to Marine Recreational Information Program (MRIP). In this report, the acronyms MRFSS and MRIP are used synonymously to refer to sampling of the general recreational fleet. The sampling and estimation methodology for this assessment is that of MRFSS from 1981-2003 and MRIP from 2004-2011 as recommended by the DW.

3.1.1.3 **Model Configuration and Equations** Model structure and equations of the BAM are detailed in SEDAR-28-RW01, along with AD Model Builder code for implementation. The assessment time period was 1950–2011. A general description of the assessment model follows.

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). The age to start the plus group (12) was chosen based on inspection of age composition data and where estimates of life history parameters (size-at-age and age-based natural mortality) approached an asymptote.

Initialization Initial (1950) abundance at age was computed in the model assuming an equilibrium age structure and fishing mortality rate. The equilibrium age structure was computed for ages $1-12^{+}$ based on natural and fishing mortality (F), where F was set equal to the geometric mean fishing mortality from the first three assessment years (1950-1952). This was based on the assumption by the AW panel that the stock was lightly exploited prior to the 1950s, particularly during the years following WWII.

Natural mortality rate The natural mortality rate (M) was assumed constant over time, but decreasing with age. The form of M as a function of age was based on Lorenzen (1996). The Lorenzen (1996) approach inversely relates the natural mortality at age to mean weight at age W_a by the power function $M_a = \alpha W_a^{\beta}$, where α is a scale parameter and β is a shape parameter. Lorenzen (1996) provided point estimates of α and β for oceanic fishes, which were used for this assessment. As in previous SEDAR assessments, the Lorenzen estimates of M_a were rescaled to provide the same fraction of fish surviving from age-1 through the oldest observed age (16 yr) as would occur with constant $M = 0.26$ from the DW. This approach using cumulative mortality is consistent with the findings of Hoenig (1983) and Hewitt and Hoenig (2005).

Growth Mean size at age of the population (fork length, FL) was modeled with the von Bertalanffy equation, and weight at age (whole weight, WW) was modeled as a function of fork length (Figure 3.1, Table 3.1). Parameters of growth and conversions (FL-WW) were estimated by the DW and were treated as input to the assessment model. The von Bertalanffy parameter estimates from the DW were $L_{\infty} = 1324.4$ mm, $k = 0.27$, and $t_0 = -0.47$ yr. 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.

Female maturity Females were modeled to be fully mature at age 4 and the proportion mature at ages 1, 2, and 3 were assumed to be 0.0, 0.5, and 0.75 respectively (Table 3.1).

Spawning stock Spawning stock (units of mt) was modeled using total mature female biomass measured at the time of peak spawning. For cobia, peak spawning was considered to occur in May. In cases when reliable estimates of fecundity are unavailable, spawning biomass is commonly used as a proxy for population fecundity. This assumption was investigated via sensitivity analysis using limited information on fecundity of cobia.

Recruitment Expected recruitment of age-1 fish was predicted from spawning stock using the Beverton–Holt spawner-recruit model. Annual variation in recruitment was assumed to occur with lognormal deviations for the years 1975–2009. These deviations were constrained to sum to to 1.0 for the period 1984-2009 when annual age compositions and other data sources providing information on year class strength were available. Estimated recruitment deviations for 1975-1983 were not constrained, and provided a bridge between the data poor period beginning in 1950 and the period when data became available (Methot and Taylor 2011). The ending year of estimated recruitment residuals (2009) was based on the selectivity curves for the recreational and commercial fisheries and the last year of age composition data. Because the age at full selection for cobia generally occurs at age 4 with high selectivity for age 3, and the last year of composition data in the model is 2011, the AW panel agreed that this was a reasonable period over which to estimate recruitment deviations.

Landings and Discards The model included two time series of combined landings plus discards from 1950-2011: a general recreational fleet and a general commercial fleet. There is little directed commercial harvest of cobia, and fish are generally harvested incidentally during other fishing activities. Therefore, commercial landings were pooled across all commercial gears in the model. Discards were a small proportion of landings (mean: 0.048 for recreational discards and 0.013 for commercial discards) and no information was available to estimate discard selectivity. Therefore, dead discards were combined with landings as total recreational removals (landings plus discards) and total commercial removals (landings plus discards). The DW provided discard mortality rates for vertical lines (0.05) and for gillnets (0.51) that were used to calculate dead discards prior to combining with landings. Data on commercial discards was available from 1993-2011. Commercial discards were hindcast to 1983 using the mean ratio of discards:landings for 1993-1997. Data on recreational discards were available from 1983-2011. Commercial and recreational discards were assumed negligible prior to 1983 (the first year of regulation).

The combined landings and discards were modeled with the Baranov catch equation (Baranov 1918) and were fitted in units of weight (1000 lb whole weight, commercial) or numbers of fish (1000 fish, recreational). The DW provided observed commercial landings back to the first assessment year (1950). Estimates of general recreational landings were provided by the DW back to 1955 based on estimated landings from MRFSS and the regional headboat survey (1981-2011), and a hindcasting method to estimate historical recreational landings (1955-1980) that is described in the DW report. The historical recreational landings were estimated back to the start year of the model (1950) by extending the hindcasting method an additional five years.

Fishing Mortality 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.

Selectivities Selectivity curves applied to landings and CPUE series were estimated using a parametric approach. This approach applies plausible structure on the shape of the curves, and achieves greater parsimony than occurs with unique parameters for each age. Selectivity of landings from the commerical and recreational fleets were modeled as flat-topped, using a two parameter logistic function. Selectivities of the fishery dependent indices (Headboat and South Carolina logbook) were assumed the same as that of the general recreational fleet because all use hook and line gear.

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 period of regulation. For South Atlantic cobia a 33-inch minimum size limit was implemented in 1983 and a 2-fish per person bag limit was implemented in 1990. Commercial age and length composition data were only sufficient to develop a single pooled age (1986-2011; no data for 1987-88 and 1992-97) or length (1982-2011; no data for 1983, 1986, 1996, and 1998) composition. For the recreational fleet, sufficient data were available to develop annual age (1984-2011; no data for 1998) and length (1981-2011) compositions, though sample sizes were low in many years. No age data and minimal length data were available for the recreational fleet prior to the implementation of the 33-inch size limit in 1983. Therefore, the AW panel recommended assuming constant selectivities for the recreational and commercial fleets. This is reasonable given that cobia is mostly harvested by hook and line and mostly incidental to other fishing activities.

Indices of abundance Three indices of abundance based on CPUE were recommended for consideration by the DW: (1) the headboat index, (2) the South Carolina charterboat logbook index, and (3) the MRFSS recreational index. In initial model runs, the three indices could not be fit simultaneously due to lack of correlation among the indices (range R: -0.11 to 0.19; no correlations statistically significant). In response, the AW panel recommended the MRFSS index be excluded from the base run. The basis for exclusion was that compared to the other two indices, the MRFSS index did not (1) reflect strong year classes that were evident in the age composition data, (2) showed large swings in abundance (5-fold) in consecutive years that the AW panel thought were unreasonable, and (3) appeared to track the amount of sampling effort in the MRFSS program. Hence, the model was fit to two indices of relative abundance: the headboat survey (1981-2011) and the South Carolina charterboat logbook survey (1998-2011). The consequences of inclusion or exclusion of abundance indices (including the MRFSS index) were investigated via sensitivity analysis. Predicted indices were conditional on selectivities, which were assumed the same for the headboat and South Carolina logbook indices, and were computed from abundance at the midpoint of the year.

Catchability In the BAM, catchability scales indices of relative abundance to estimated population abundance. 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. Parameters for these models could be estimated or fixed based on *a priori* considerations. The AW agreed that time-varying catchability was unlikely to be an issue for cobia, and recommended that catchability be assumed constant over time for each index. As a sensitivity run, linearly increasing catchability with a slope of 2% up to 2003 and assumed constant thereafter was conducted. Choice of the year 2003 was based on recommendations from fishermen regarding when the effects of Global Positioning Systems likely saturated in the southeast U.S. Atlantic (SEDAR 2009). This trend reflects the belief that catchability has generally increased over time as a result of improved technology (SEDAR Procedural Guidance 2009) and as estimated for reef fishes in the Gulf of Mexico (Thorson and Berkson 2010). Another sensitivity run applied a random walk approach to estimating to catchability, where catchability for a particular year was a function of that in the previous year and a random component.

Biological reference points Biological reference points (benchmarks) were calculated based on maximum sustainable yield (MSY) estimates from the Beverton–Holt spawner-recruit model with bias correction (expected values in arithmetic space). Computed benchmarks included MSY, fishing mortality rate at MSY (F_{MSY}), and spawning stock at MSY ($\mathrm{SSB}_{\mathrm{MSY}}$). In this assessment, spawning stock measures total 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.

Fitting criterion The fitting criterion was a penalized log-likelihood approach in which combined landings and discards were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Landings and indices were fitted using lognormal likelihoods. Length and age composition data were fitted using robust multinomial likelihoods.

For the observed commercial age and length compositions, which were pooled over multiple years, the model predicted an annual age (or length) composition weighted by the observed effective sample size for the relevant year. These annual predicted compositions were then combined in the same way that the observed commercial age and length compositions were combined to generate a single composition prior to fitting.

The model includes the capability for each component of the likelihood to be weighted by user-supplied values (for instance, to give more influence to stronger data sources). For data components, these weights were applied by either adjusting CVs (lognormal components) or adjusting effective sample sizes (multinomial components). In this application to cobia, CVs of combined landings and discards (in arithmetic space) were assumed equal to 0.05, to achieve a close fit to these time series yet allow some imprecision. In practice, the small CVs are a matter of computational convenience, as they help achieve the desired result of close fits to the landings, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). Weights on other data components (indices, age and length compositions) were adjusted iteratively, starting from initial weights as follows. The CVs of indices were set equal to the values estimated by the DW. Effective sample sizes of the annual length compositions were assumed equal to the annual number of trips sampled, reflecting the belief that the basic sampling unit occurs at the level of trip. Only number of fish (not number of trips) was available for annual age compositions; therefore, effective sample sizes were set to the annual number of fish sampled. Because cobia are caught mostly as one individual fish per trip, the number of fish landed is a good approximation of the number of trips. The effective sample size for recreational age compositions was capped at 200 as recommended by the AW panel. For the pooled commercial age and length composition, effective sample sizes were set to the average number of trips for length compositions and the average number of fish for age compositions over the years sampled. These initial weights were then adjusted until standard deviations of normalized residuals (SDNRs) were near 1.0 (SEDAR25-RW04, SEDAR25-RW06). The method used was identical to that of (Francis 2011) and used the method of computing SDNRs that accounts for potential correlations in the composition data (TA1.8 in Table A1 of (Francis 2011)). Because commercial age and length compositions were pooled over years due to limited sample sizes, this approach could not be used to derive weights for these data sources. Therefore, weights on commercial age and length compositions were assumed to be the same as those for the comparable recreational data source. As a sensitivity run, the weight on the indices were adjusted upward to a value of 2.5 (SEDAR25-RW06), in accordance with the principle that abundance data should be given primacy (Francis 2011). Upweighting of the abundance indices was not recommended for the base run because the indices were not highly correlated, and were not developed from fishery-independent data or from fisheries that primarily target cobia.

In addition, the compound objective function included several penalties or prior distributions, applied to CV of growth (based on the empirical estimate), the slope of selectivity parameters, and recruitment standard deviation based on Beddington and Cooke (1983) and Mertz and Myers (1996). 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.

Configuration of base run The base run was configured as described above with data provided by the DW. Uncertainty in parameter estimates and management quantities was evaluated through sensitivity analyses and a Monte-Carlo/bootstrap approach (described below). Steepness could not be estimated for cobia. When the model was allowed to estimate steepness under a variety of conditions, it consistently reached the upper bound (0.99). When a prior was used, the prior had to be highly informative ($CV < 0.1$) for the estimate to be pulled downward from the upper bound. Therefore, the assessment panel agreed to fix steepness at 0.75. This value is based on the modal value for species with a similar life history reported in Myers et al. (2002).

Sensitivity and retrospective analyses Sensitivity of results to some key model inputs and assumptions was examined through sensitivity analyses. These model runs, as well as retrospective analyses, vary from the base run as follows.

- S1: Low M at age (Lorenzen estimates rescaled so as to provide the same cumulative survival through the oldest observed age as would constant $M = 0.20$)
- S2: High M at age (Lorenzen estimates rescaled so as to provide the same cumulative survival through the oldest observed age as would constant $M = 0.35$)
- S3: Constant $M = 0.26$ across ages
- S4: Steepness $h = 0.60$
- S5: Steepness $h = 0.90$
- S6: Model component weights unadjusted (e.g. all weight multipliers set to 1.0)
- S7: Upweight index weights to 2.50 from those based on iterative reweighting
- S8: Linearly increasing catchability with slope of 2% until 2003 and constant thereafter

- S9: Random walk catchability
- S10: South Carolina stocked fish as an external recruitment source
- S11: Low discard mortality (Vertical lines: 0.02; gillnets: 0.36)
- S12: High discard mortality (Vertical lines: 0.08; gillnets: 0.77)
- S13: Headboat index only
- S14: South Carolina logbook index only
- S15: Headboat, South Carolina logbook, and MRFSS indices
- S16: Fecundity as the measure of reproductive potential
- S17: Retrospective run with data through 2010
- S18: Retrospective run with data through 2009
- S19: Retrospective run with data through 2008
- S20: Retrospective run with data through 2007
- S21: Retrospective run with data through 2006
- S22: Retrospective run with data through 2005
- S23: Retrospective run with data through 2004

Retrospective analyses should be interpreted with caution because several data sources and changes in sampling effort appear only near the end of the full time series. In particular, sample sizes for annual recreational age composition increase almost six-fold beginning in 2007 compared to the earlier years.

3.1.1.4 **Parameters Estimated** The model estimated annual fishing mortality rates of each fishery, selectivity parameters, catchability coefficients associated with indices, parameters of the spawner-recruit model, annual recruitment deviations, and CV of size at age. Estimated parameters are described mathematically in the document, SEDAR-28-RW01.

3.1.1.5 **Per Recruit and Equilibrium Analyses** Static spawning potential ratio (static SPR) of each year was computed as the asymptotic spawners per recruit given that year's fishery-specific Fs and selectivities, divided by spawners per recruit that would be obtained in an unexploited stock. In this form, static SPR ranges between zero and one, and it represents SPR that would be achieved under an equilibrium age structure given the year-specific F (hence the word *static*).

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-related benchmarks (described in §3.1.1.6), per recruit and equilibrium analyses applied the most recent selectivity patterns averaged across fisheries, weighted by each fleet's F from the last three years (2009–2011).

3.1.1.6 Benchmark/Reference Point Methods

In this assessment of cobia, the quantities F_{MSY}, $\mathrm{SSB}_{\mathrm{MSY}}$, B_{MSY}, and MSY were estimated by the method of Shepherd (1982). In this method, the point of maximum yield is identified from the spawner-recruit curve and parameters describing growth, natural mortality, maturity, and selectivity. The value of F_{MSY} is the F that maximizes equilibrium landings.

On average, expected recruitment is higher than that estimated directly from the spawner-recruit curve because of lognormal deviation in recruitment. 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,

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

where R_0 is virgin recruitment, h is steepness, and Φ_F is spawning potential ratio (ϕ_F/ϕ_0) given growth, maturity, and total mortality at age (including natural and fishing mortality rates). The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of F_{MSY} is the F giving the highest ASY and the estimate of MSY is that ASY. The estimate of $\mathrm{SSB}_{\mathrm{MSY}}$ follows from the corresponding equilibrium age structure.

Estimates of MSY and related benchmarks are conditional on selectivity patterns. The selectivity pattern used here was an average of terminal-year selectivities from each fishery, where each fishery-specific selectivity was weighted in proportion to its corresponding estimate of F averaged over the last three years (2009–2011). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of MSY and related benchmarks.

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as F_{MSY}, and the minimum stock size threshold (MSST) as MSST $= (1-M)\mathrm{SSB}_{\mathrm{MSY}}$ (Restrepo et al. 1998), with constant M here equal to 0.26. 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 (2011), and current status of the fishery is represented by the geometric mean of F from the latest three years (2009–2011).

In addition to the MSY-related benchmarks, the assessment considered proxies based on per recruit analyses (e.g., $F_{40\%}$). The values of $F_{X\%}$ are defined as those Fs corresponding to X% spawning potential ratio, i.e., spawners (population fecundity) per recruit relative to that at the unfished level. These quantities may serve as proxies for F_{MSY}, if the spawner-recruit relationship cannot be estimated reliably. Mace (1994) recommended $F_{40\%}$ as a proxy; however, later studies have found that $F_{40\%}$ is too high a fishing rate across many life-history strategies (Williams and Shertzer 2003; Brooks et al. 2009) and can lead to undesirably low levels of biomass and recruitment (Clark 2002).

3.1.1.7 Uncertainty and Measures of Precision

Uncertainty was in part examined through use of multiple models and sensitivity runs. For the base run of the catch-age model (BAM), uncertainty in results and precision of estimates was computed more thoroughly through a mixed Monte Carlo and bootstrap (MCB) approach. Monte Carlo and bootstrap methods (Efron and Tibshirani 1993; Manly 1997) 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 model many times with different values of "observed" data and key input parameters. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or handful of sensitivity runs. A minor disadvantage of the approach is that computational demands are relatively high.

In this assessment, the BAM was successively re-fit n=3200 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 3200 was chosen because at least 3000 runs were desired to characterize variability in input dat and parameters, and not all runs were likely to be valid. Of the 3200 trials, four were discarded because of unusually low estimates of R_0 or high estimates of σ^2_{rec}. This left 3196 trials used to characterize uncertainty, which was sufficient for convergence of standard errors in management quantities.

The MCB analysis should be interpreted as providing an approximation to the uncertainty associated with each output. The results are approximate for two related reasons. First, not all combinations of Monte Carlo parameter inputs are equally likely, as biological parameters might be correlated. Second, all runs are given equal weight in the results, yet some might provide better fits to data than others.

3.1.1.7.1 **Bootstrap of observed data** To include uncertainty in time series of observed landings plus discards, and indices of abundance, multiplicative lognormal errors were applied through a parametric bootstrap. To implement this approach in the MCB trials, random variables ($x_{s,y}$) were drawn for each year y of time series s from a normal distribution with mean 0 and variance $\sigma^2_{s,y}$ [that is, $x_{s,y} \sim N(0, \sigma^2_{s,y})$]. Annual observations were then perturbed from their original values ($\hat{O}_{s,y}$),

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

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 pooled landings and discards were assumed to be 0.05, and CVs of indices of abundance were those provided by the DW (tabulated in §III(2) of this assessment report).

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.

3.1.1.7.2 **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.

Steepness The steepness stock–recruit parameter was fixed at 0.75 in the base run. Uncertainty in this parameter was characterized by drawing random values from a truncated normal distribution (range [0.60, 0.90]) with mean equal to 0.75 and standard deviation=0.19. The standard deviation is that estimated from meta analysis (Shertzer and Conn 2012). The upper and lower bounds were based on inspection of a profile over steepness that suggested this range as plausible values.

Natural mortality Point estimates of natural mortality ($M = 0.26$) were provided by the DW, but with some uncertainty. To carry forward this source of uncertainty, Monte Carlo sampling was used to generate deviations from the point estimate. A new M value was drawn for each MCB trial from a truncated normal distribution (range [0.20, 0.35]) with mean equal to the point estimate ($M = 0.26$) and standard deviation set to provide an upper 95% confidence limit at 0.35 (the high end of the DW range). Each realized value of M was used to scale the age-specific Lorenzen M, as in the base run.

Historical recreational landings Annual estimates of historical recreational landings (1950-1980) were provided by the DW with associated 95% confidence limits. Monte carlo sampling was used to generate deviations from the annual point estimates by drawing a multiplier from a truncated normal distribution (range [0.542, 1.458]) with mean=1.0 and standard deviation=0.234. The upper and lower bounds are the 95% confidence intervals provided by the DW and the standard deviation was set to provide 95% confidence limits at these bounds.

3.1.1.8 **Acceptable Biological Catch** When a stock is not overfished, acceptable biological catch (ABC) could be computed through probability-based approaches, such as that of Shertzer et al. (2008*b*), designed to avoid overfishing. However, for overfished stocks, rebuilding projections would likely supersede other approaches for computing ABCs.

3.1.1.9 **Projection Methods** Projections were run to predict stock status in years after the assessment, 2012–2016. The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment. Fully selected F was apportioned between landings according to the selectivity curves averaged across fisheries, using geometric mean F from the last three years of the assessment period.

Central tendencies 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_{MSY} would yield MSY from a stock size at SSB_{MSY}. Uncertainty in future time series was quantified through projections that extended the Monte Carlo/Bootstrap (MCB) fits of the stock assessment model.

Initialization of projections Point estimates of initial abundance at age in the projection (start of 2012), other than at age 1, were taken to be the 2011 estimates from the assessment, discounted by 2011 natural and fishing mortalities. The initial abundance at age 1 was computed using the estimated spawner-recruit model and a 2011 estimate of SSB. In the assessment, the terminal two years of recruitment did not deviate from the spawner-recruit curve, which influenced the abundances of ages 1–2 (N_{1-2}) in 2011. In the projections, lognormal stochasticity was applied to these abundances based on recruitment variation σ_R. Thus, the initial abundance in year one (2012) of the projections included this variability in N_{2-3}, as well as in the SSB_{2011} used to compute initial recruits, N_1.

Because the assessment period ended in 2011, the projections required an initialization period (2012). The fully selected fishing mortality rate during the initialization period was taken to be the geometric mean of fully selected F from 2009-2011. Any changes in fishing effort were assumed to begin in 2013.

Uncertainty of projections To characterize uncertainty in future stock dynamics, stochasticity was included in replicate projections, each an extension of a single MCB assessment model fit. Thus, projections carried forward uncertainties in natural mortality, steepness, and historical recreational landings, as well as in estimated quantities such as spawner-recruit parameters, selectivity curves, and in initial (start of 2012) abundance at age. Initial and subsequent recruitment values were generated with stochasticity using a Monte Carlo procedure, in which the estimated Beverton–Holt model of each MCB fit was used to compute mean annual recruitment values ($\bar{R}_y$). Variability was added to the mean values by choosing multiplicative deviations at random from the recruitment deviations estimated for that chosen MCB run.

Because the base run model assumed no recruitment deviation for years 2010–2012, the initial projection year (start of 2012) ages 1–3 included additional variability in recruitment following the same method for subsequent years as age–1.

The procedure generated 10,000 replicate projections of MCB model fits drawn at random (with replacement) from the MCB runs. In cases where the same MCB run was drawn, projections would still differ as a result of stochasticity in projected recruitment streams. Precision of projections was represented graphically by the 5^{th} and 95^{th} percentiles of the replicate projections.

Rebuilding time frame Cobia does not appear to be overfished and no rebuilding plan is necessary.

Projection scenarios Five constant-F projection scenarios were considered.

- Scenario 1: $F = F_{\mathrm{MSY}}$
- Scenario 2: $F = F_{\mathrm{current}}$ as the geometric mean F from 2009-2011
- Scenario 3: $F = 65\% F_{\mathrm{MSY}}$
- Scenario 4: $F = 75\% F_{\mathrm{MSY}}$
- Scenario 5: $F = 85\% F_{\mathrm{MSY}}$

3.1.2 Model 1 Results

3.1.2.1 Measures of Overall Model Fit

Generally, the Beaufort Assessment Model (BAM) fit well to the available data. Predicted length compositions were reasonably close to observed data in most years, as were predicted age compositions (Figure 3.2).

There was considerable discussion during the AW about the presence of small (sublegal) fish in the observed length compositions. These were evident in the residuals of fits to the length compositions, particularly in the 1980s (Figure 3.3–3.4). Some questions were raised as to the validity of these samples, such as possible incorrect species identification or data entered in the incorrect units. These fish did not significantly influence the model fits, however. As a result, the AW agreed to retain them in the data.

Similarly, the annual recreational age compositions were fit reasonably well, particularly since 2005 when sampling increased (Figure 3.5). The fit to the pooled commercial age composition was reasonable as well (Figure 3.6).

The model was configured to fit observed commercial and recreational removals closely (Figures 3.7–3.8).

Fits to indices of abundance captured the general trends but not all annual fluctuations (Figures 3.9–3.10). The model fits suggested a general downward trend in abundance of cobia since the late 1990s though with considerable annual variability.

3.1.2.2 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.

3.1.2.3 Stock Abundance and Recruitment

Estimated abundance at age since the 1990s showed a slight truncation of the oldest ages compared to the 1980s, but in general there was little obvious change in age structure over time (Figure 3.11, Table 3.2). Total estimated abundance has varied about two-fold since the 1980s with a general decline since 2005. Annual number of recruits is shown in Table 3.2 (age-1 column) and in Figure 3.12. A strong year class was predicted to have occurred in 2005 comparable to those predicted periodically in the late 1980s and throughout the 1990s. However, predicted recruitment in recent years (2007-2009) has been below average.

3.1.2.4 Total and Spawning Biomass

Estimated biomass at age follows the same general pattern as estimated abundance at age (Figure 3.13; Table 3.3). Total biomass and spawning biomass showed similar trends–generally higher biomass in the 1990s and early 2000s compared to the 1980s and a decline in more recent years (Figure 3.14, Table 3.4). The stock was estimated to be at its lowest point in the late 1980s and is estimated to be at a comparable level now.

3.1.2.5 Selectivity Selectivity estimates of the general recreational and commercial fleets are very similar, with perhaps slightly higher selectivity on smaller fish in the commerical fleet (Figure 3.15). Fish were estimated to be near fully selected by age 4. Average selectivities of landings were computed from F-weighted selectivities in the most recent years (Figure 3.16). These average selectivities were used to compute benchmarks and central-tendency projections. All selectivities from the most recent period, including average selectivities, are tabulated in Table 3.5.

3.1.2.6 Fishing Mortality The estimated time series of fishing mortality rates (F) from BAM was highly variable, with F for fully selected ages varying greater than four-fold since the 1980s (Figure 3.17). There was a drop in F in the 1990s following the implementation of the 2-fish per person bag limit, but there has been a notable increase since the early 2000s. In recent years (since 2003), estimates of F have averaged about 0.30. The general recreational fleet has been the largest contributor to total F throughout the time series (Table 3.6, Figure 3.17). Estimates of F from the catch-age model were generally consistent with those based on catch curve analysis (see below).

Estimates of total F at age are shown in Table 3.7.

Table 3.8 shows total landings at age in numbers, and Table 3.9 in weight. In general, the majority of estimated landings were from the general recreational fleet (Figures 3.18, 3.19; Tables 3.10, 3.11).

3.1.2.7 Spawner-Recruitment Parameters The estimated Beverton–Holt spawner-recruit curve is shown in Figure 3.20, along with the effect of density dependence on recruitment, depicted graphically by recruits per spawner as a function of spawners. Values of recruitment-related parameters were as follows: assumed steepness $h = 0.75$, unfished age-1 recruitment $\widehat{R_0} = 136,548$, unfished spawning biomass (mt) per recruit $\phi_0 = 1.228e{-2}$, and standard deviation of recruitment residuals in log space $\sigma = 0.61$ (which resulted in bias correction $\varsigma = 1.20$). The empirical standard deviation of recruitment residuals in log space was $\widehat{\sigma} = 0.66$. Uncertainty in these quantities was estimated through the Monte Carlo/bootstrap (MCB) analysis (Figure 3.21).

3.1.2.8 Per Recruit and Equilibrium Analyses Static spawning potential ratio (static SPR) was variable but showed a general trend of decline during the 1970s and early 1980s, followed by a relatively stable period in the 1990s, and a decline since the early to mid 2000s (Figure 3.22, Table 3.4). Values lower than the MSY level imply that, given estimated fishing rates, population equilibria would be lower than desirable (as defined by MSY). Values near the end of the time series approach the MSY level in some years.

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 3.23). As in computation of MSY-related benchmarks, per recruit analyses applied the most recent selectivity patterns averaged across fisheries, weighted by F from the last three assessment years (2009–2011). The yield per recruit curve peaked at $F_{max} = 2.0$, but a wide range of F provided nearly identical yield per recruit. The Fs that provide 30%, 40%, and 50% SPR are 0.49, 0.31, and 0.20, respectively. For comparison, F_{MSY} corresponds to about 32% SPR. Although this rate of fishing appears high relative to $F_{X\%}$ proxies, it occurs here because cobia mature relatively quickly relative to the size limit and because the assumed steepness of $h = 0.75$ implies a relatively productive stock.

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 3.24). By definition, the F that maximizes equilibrium landings is F_{MSY}, and the corresponding landings and spawning biomass are MSY and SSB_{MSY}. Equilibrium landings and discards could also be viewed as functions of biomass B, which itself is a function of F (Figure 3.25).

3.1.2.9 **Benchmarks / Reference Points** As described in §3.1.1.6, biological reference points (benchmarks) were derived assuming equilibrium dynamics, corresponding to the expected spawner-recruit curve (Figure 3.20). This approach is consistent with methods used in rebuilding projections (i.e., fishing at F_{MSY} yields MSY from a stock size of SSB_{MSY}). Reference points estimated were F_{MSY}, MSY, B_{MSY} and SSB_{MSY}. Based on F_{MSY}, three possible values of F at optimum yield (OY) were considered—$F_{\text{OY}} = 65\%F_{\text{MSY}}$, $F_{\text{OY}} = 75\%F_{\text{MSY}}$, and $F_{\text{OY}} = 85\%F_{\text{MSY}}$—and for each, the corresponding yield was computed. Standard errors of benchmarks were approximated as those from Monte Carlo/bootstrap analysis (§3.1.1.7).

Estimates of benchmarks are summarized in Table 3.12. Point estimates of MSY-related quantities were $F_{\text{MSY}} = 0.461\ \text{y}^{-1}$, MSY = 808 klb, $B_{\text{MSY}} = 1991.6$ mt, and $\text{SSB}_{\text{MSY}} = 536.8$ mt. Distributions of these benchmarks are shown in Figure 3.26.

3.1.2.10 **Status of the Stock and Fishery** Estimated time series of stock status (SSB/MSST, $\text{SSB}/\text{SSB}_{\text{MSY}}$) showed a general decline through the 1980s, an increase in the late 1980s and early 1990s, followed by a decline in more recent years (Figure 3.27, Table 3.4). The increase in stock status in the 1990s may have been driven by several strong year classes (Figure 3.12) and perhaps reinforced by the 2-fish per person bag limit implemented in 1990. Base run estimates of spawning biomass have remained above MSST throughout the time series. Current stock status in the base run was estimated to be $\text{SSB}_{2011}/\text{MSST} = 1.75$ (Table 3.12), indicating that the stock is not overfished. Uncertainty from the MCB analysis suggests that the estimate of a stock that is not overfished (i.e., SSB > MSST) is relatively robust (Figures 3.28, 3.29). Age structure estimated from the base run shows more older fish than the (equilibrium) age structure expected at MSY (Figure 3.30). However, in the most recent year, ages 1–7 approached the MSY age structure.

The estimated time series of F/F_{MSY} from the base run suggests that overfishing has not been occurring over the course of the assessment period but with considerable uncertainty, particularly since the mid 2000s, as demonstrated by the MCB analysis (Figure 3.27, Table 3.4). Current fishery status, with current F represented by the geometric mean from 2009–2011, is estimated by the base run to be $F_{2009-2011}/F_{\text{MSY}} = 0.599$ (Table 3.12), but with much uncertainty in that estimate (Figures 3.28, 3.29).

3.1.2.11 **Sensitivity and Retrospective Analyses** Sensitivity analysis, described in §3.1.1.3, can be useful for evaluating the consequences of assumptions made in the base assessment model, and for interpreting MCB results in terms of expected effects from input parameters. Time series of F/F_{MSY} and $\text{SSB}/\text{SSB}_{\text{MSY}}$ are plotted to demonstrate sensitivity to natural mortality (Figure 3.31), steepness (Figure 3.32), model component weights (Figure 3.33), catchability (Figure 3.34), the South Carolina cobia stocking program (Figure 3.35), discard mortality (Figure 3.36), inclusion or exclusion of indices of abundance (Figure 3.37), and the measure of reproductive potential (Figure 3.38). Status indicators were most sensitive to natural mortality, model components weights, and steepness. The qualitative results on terminal stock status were similar across most sensitivity runs, and generally indicated that the stock is not overfished ($\text{SSB}/\text{SSB}_{\text{MSY}} > 1$) and overfishing is not occurring ($F/F_{\text{MSY}} < 1$) (Table 3.13, Figure 3.39). Sensitivity analyses were in general agreement with the results of the MCB analysis.

Retrospective analyses did not suggest any patterns in F, B, SSB, recruits, $\text{SSB}/\text{SSB}_{\text{MSY}}$, or F/F_{MSY} and seemed to indicate no retrospective error (Figures 3.40 – 3.44). The departures in the terminal year for the early retrospectives (terminal year: $2004 - 2007$) should be interpreted with caution because they were associated with a large change in sample sizes for recreational age compositions beginning in 2007.

3.1.2.12 **Projections** There were only slight differences in the F_{MSY}, $F_{65\%MSY}$, $F_{75\%MSY}$, and $F_{85\%MSY}$ projection scenarios (Figures 3.46–3.50 and Tables 3.14–3.18). The $F_{current}$ projection maintained SSB above SSB_{MSY} and landings slightly below landings at MSY (Table 3.15 and Figure 3.47).

3.2 Total Mortality Estimation

3.2.1 Methods: Total Mortality

3.2.1.1 Overview Total Mortality ($Z = F + M$) of cobia was estimated from age composition data using conventional catch curve analysis and a more recent catch curve method (Thorson and Prager 2011), and from length composition using a mean length estimator (Gedamke and Hoenig 2006). Full fishing mortality (F) was calculated from Z assuming the constant natural mortality rate (M=0.26) provided by the DW. These estimates of fishing mortality were compared to those from the base run of the catch-age model (BAM). The application of catch curve analysis is for diagnostic purposes to ensure that estimates of mortality from the catch-age model are within a reasonable range.

3.2.1.2 Catch Curve Analysis Conventional catch curve analysis was conducted on synthetic cohorts using linear regression on the log-transformed proportions of cobia catch at age from the recreational fishery, and on several true cohorts using the numbers of cobia landed at age. Analysis of synthetic cohorts was limited to years when the number of aged fish was greater than 70 individuals. For both synthetic and true cohorts, catch curve analysis requires the assumptions that mortality and catchability are constant above some chosen fully selected age. An additional assumption for synthetic cohorts is that recruitment is constant over time. Under these assumptions, total mortality (Z) is the slope of the descending limb of the age composition from a chosen age at full selection to the maximum age.

Catch curve analysis was also conducted using a method developed by (Thorson and Prager 2011) that relaxes some of the assumptions of conventional catch curve analysis. In addition to estimating total mortality, this method simultaneously estimates logistic selectivity parameters from the ascending limb of the catch curve, avoiding the need to choose an age at full selection from visual inspection. In addition, this method relaxes the assumption of constant natural mortality for all vulnerable ages by assuming Lorenzen age-based natural mortality, with M decreasing with increasing age.

3.2.1.3 Mean Length Estimator Changes in mean length of fish that are fully vulnerable to fishing gear can be used to estimate total mortality (Z) and test for changes in Z over time from basic growth parameters and a known length at first capture (Gedamke and Hoenig 2006). Mean annual length of cobia from the recreational fishery (1984-2011), the von Bertalanffy growth coeficient ($k = 0.27$) and the asymptotic length ($L_\infty = 1324.4$ mm), and an assumed length at full selection were used to estimate total mortality of cobia. The model was run with three alternative sizes (fork length) at full selection (975 mm, 1025 mm, and 1075 mm; Figure 3.51). The possibility of up to four annual changes in Z since 1984 were allowed. Akaike's Information Criteria (AIC) was used to determine the most parsimonious model.

3.2.2 Results: Total Mortality

Conventional catch curve analysis on synthetic cohorts suggested the total mortality rate ($Z = F + M$) of cobia ranged from 0.10 to 0.55 with a mean over years of $Z = 0.34$ (Table 3.22). Analysis of true cohorts suggested similar mortality rates with a range over years of 0.26 to 0.51 and a mean of $Z = 0.40$. Based on the constant estimate of natural mortality, $M = 0.26$, these values of Z suggest the fully selected fishing mortality rate of cobia is on the scale of $F < 0.10$ to $F = 0.51$, with a mean $F = 0.11$ based on synthetic cohorts and mean $F = 0.15$ based on true cohorts. These estimates of F are similar to those based on the method of (Thorson and Prager 2011), where estimates of F ranged from 0.02 to 0.55 with a mean of $F = 0.14$.

Mortality estimates from catch curve analysis were generally consistent with those from the mean length estimator (Gedamke and Hoenig 2006) (Table 3.19–Table 3.21). Based on annual changes in mean length and an assumed age at full vulnerability of 925 mm or 975 mm, there was the most support for a constant $Z = 0.39$ (or $F = 0.13$) (Figure 3.52, Table 3.19–Table 3.20). With an assumed length at full vulnerability of 1025 mm there was support for a decrease in mortality in 1990, the year the 2-fish per person bag limit was implemented, with $Z = 0.47$ prior to 1990 and $Z = 0.22$ subsequent to 1990 (Figure 3.53, Table 3.21).

Estimates of fishing mortality derived from catch curve analysis and the mean length estimator were generally consistent with those estimated by the catch-age model over a similar time period (Figure 3.54).

3.3 Model 2: Surplus Production Model

3.3.1 Model 2 Methods

3.3.1.1 Overview Assessments based on age or length structure are often favored because they incorporate more data on the structure of the population. However, these approaches typically involve fitting a large number of parameters and decomposing population dynamics into multiple processes including growth, mortality, and recruitment. A simplified approach is to aggregate data across age or length classes, and to summarize the relationship among complex population processes by using a simple mathematical model such as a logistic population model.

A logistic age-aggregated surplus production model, implemented in ASPIC (Prager 2005), was considered for cobia by the AW panel. The production model failed to converge under a variety of configurations. The primary difficulty was a lack of contrast in the data, so that very little information was available on the production function for cobia. The production model did converge under a very restricted set of conditions. This run is described below and qualitative comparisons are made to the catch-age model, but the AW panel considered the age structured model to be more appropriate for cobia. The data sources and model structure relevant to production modeling are described below and in Appendix C.

3.3.1.2 Data Sources The surplus production model was fit using a single time series of removals, which included commercial and recreational landings and dead discards, and two abundance indices, the headboat index and the South Carolina charterboat logbook index. All updates to the data after the DW, including the addition of 2011 data, were included in the ASPIC model input. The time series of removals was based on the same input data used for the catch-age model, converted from numbers to biomass where appropriate.

Landings and Dead Discards All landings and dead discards were combined into a single times series in units of pounds. Where landings or discards were provided in numbers, they were converted to biomass by multiplying numbers by an annual mean weight as described previously.

Indices of Abundance Three indices of abundance, the headboat index, the South Carolina charterboat logbook index, and MRFSS index, were provided by the DW. Similar to the catch-age model, only the headboat index and South Carolina logbook index were used in the production model. The two indices were converted from units of number of fish per angler-hour to pounds per angler-hour using annual estimates of individual mean weight and re-scaling to the mean.

The data input to the production model run is provided in Table 3.23.

3.3.1.3 Model Configuration and Equations

Production modeling used the model formulation and ASPIC software of Prager (1994; 2005). This is an observation-error estimator of the continuous-time form of the Schaefer (logistic) production model (Schaefer 1954; 1957). Estimation was conditioned on catch.

The logistic model for population growth is the simplest form of a differential equation which satisfies a number of ecologically realistic constraints, such as a carrying capacity (a consequence of limited resources). When written in terms of stock biomass, this model specifies that

$$\frac{dB_t}{dt} = rB_t - \frac{r}{K}B_t^2, \tag{3}$$

where B_t is biomass in year t, r is the intrinsic rate of increase in the absence of density dependence, and K is carrying capacity (Schaefer 1954; 1957). This equation may be rewritten to account for the effects of fishing by introducing an instantaneous fishing mortality term, F_t:

$$\frac{dB_t}{dt} = (r - F_t)B_t - \frac{r}{K}B_t^2. \tag{4}$$

By expressing the term F_t as a function of catchability coefficients and effort expended by fishermen in different fisheries, Prager (1994) showed how to estimate model parameters from time series of yield and effort. Nonparametric confidence intervals on parameters were estimated through bootstrapping.

3.3.2 Model 2 Results

3.3.2.1 Model Fit

The age aggregated surplus production model hit bounds or failed to converge under a variety of scenarios. In general, estimates of B_1/K for models that did converge were very low (e.g., < 0.01) and were considered highly unrealistic by the AW panel for a species with little directed harvest. Over most of the time series landings have been increasing. In addition, the indices show a general increase until the late 1990s, after which there is some indication of a decline. As a result, there is very little contrast in the available data to provide information on the production function. In an attempt to address these issues, an alternative start date (1981) when abundance indices began was considered. Models failed to converged with the later start date as well, probably due to the general lack of correlation among the indices and the large amount of variability during the first few years of the headboat index. Convergence was obtained with a start date of 1985 and an assumed B_1/K of 0.5. Fits to the indices for this run are shown in Figure 3.55. The model captured the general trends in the indices but tended to overestimate the early years of the headboat index and did not capture the annual variability in either index.

3.3.2.2 Status of the Stock and Fishery

Given the restricted conditions under which the production model converged and the relatively poor fits to the indices, estimates of stock status based on the production model should be interpreted with caution. Even so, the results regarding stock status were qualitatively similar to those of the catch-age model (Figure 3.56). $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ suggest the stock is not overfished though there has been a declining trend in recent years, similar to the catch-age model. Similarly estimates of F/F_{MSY} have been increasing in recent years, but do not indicate that overfishing is occurring.

3.3.2.3 Discussion — Surplus Production Model

The surplus production model, because it omits population age and size structure, does not make use of data for those characteristics. Because such data are available for cobia, a model that uses them would normally be preferred for a detailed assessment on which to base management. The fundamental problem was a lack of contrast in the data so that information on the productivity of the stock was limited. In addition, the inability of production models to estimate annual recruitment resulted in poor fits to the available abundance indices. In response the AW panel recommended limited use of production modeling for this assessment.

3.4 Discussion

3.4.1 Comments on Assessment Results

Estimated benchmarks played a central role in this assessment. Values of $\mathrm{SSB}_{\mathrm{MSY}}$ and F_{MSY} were used to gauge the status of the stock and fishery. Computation of benchmarks was conditional on selectivity. If selectivity patterns change in the future, for example as a result of new size limits or different relative catch allocations among sectors, estimates of benchmarks would likely change as well.

The base run of the Beaufort assessment model (BAM) indicated that the stock is not overfished ($\mathrm{SSB}_{2011}/\mathrm{MSST} = 1.75$), and that overfishing is not occurring ($F_{2009-2011}/F_{\mathrm{MSY}} = 0.599$). These qualitative conclusions were consistent across most model configurations used in sensitivity runs. It should be noted that the sensitivity runs and the mode of the MCB runs tended toward values that were similar to the base run in terms of overfished and overfishing indicators.

Cobia is a 'rare event' fishery and so there is a lack of reliable indices of abundance. There is no fishery independent index of abundance, and the three available indices were developed from fishery dependent sampling programs that rarely target cobia. This can be an advantage in that changes in targeting and fishing practices are less likely to effect the use of the index as an indicator of cobia abundance. However, cobia are harvested mostly as one or two individual fish per trip, so the indices are sensitive to the method by which trips that had the potential to catch cobia are selected. This was an important topic of discussion at the DW, and efforts were made to develop the most reliable indices of abundance. Even so, these indices were highly variable and not well correlated.

Perhaps the greatest uncertainty in this assessment was the spawner-recruit relationship. Steepness could not be estimated reliably (tended toward the upper bound), and, therefore, had to be fixed at a value agreed on by the AW ($h = 0.75$). Hence, MSY-based management quantities are conditional on this particular value of steepness. An alternative approach would be to choose a proxy for F_{MSY}, most likely $F_{X\%}$ (such as $F_{30\%}$ or $F_{40\%}$). However, such proxies do not provide biomass-based benchmarks. If managers wish to gauge stock status, further assumptions about equilibrium recruitment levels would be necessary. Furthermore, choice of X% implies an underlying steepness, as described by Brooks et al. (2009). Thus, choosing a proxy equates to choosing steepness. Given the two alternative approaches, it seems preferable to focus on steepness, as its value is less arbitrary, and can be evaluated relative to other species by comparison to previous meta-analysis (Myers et al. 2002; Shertzer and Conn 2012).

Of the sensitivity runs conducted with the BAM, results were least sensitive to assumptions about catchability, addition of stocked fish from the South Carolina stocking program as an external source of age-1 recruits, discard mortality, and the inclusion or exclusion of the indices (including the MRFSS index that was not used in the base run). Results were most sensitive to natural mortality, steepness, and model component weights. Sensitivity to the measure of reproductive potential (mature female spawning biomass vs. female fecundity) was intermedate. Sensitivity to natural mortality and steepness is common in stock assessment. Sensitivity to model component weights occurred here primarily because alternative data sources (length compositions and age compositions) were given more weight relative to the indices compared to that in the base run. Upweighting the indices further (beyond that from iterative re-weighting) had little effect on the results. The effect of alternative weighting schemes on status indicators was most pronounced during the early years of the data sources (1980s) with smaller differences in the more recent years (2000s).

The assessment predicted relatively low abundance in the 1980s, relatively high abundance in the 1990s, and a decline since 2000. The high abundance in the 1990s may have been due to a combination of the 2-fish per person bag limit implemented in 1990 and several strong year classes in the late 1980s and early 1990s. The last strong year class predicted by the model occurred in 2005 and both indices have shown declines over the last decade. There have been reports of increased fishing pressure on cobia in recent years, including an increasing number of cobia tournaments and a developing charterboat industry. While MCB and sensitivity analyses indicate stock status (in terms of biomass) has been relatively robust over the last decade, there is considerably more uncertainty in fishery status (in terms of fishing mortality), with a large proportion of the MCB runs suggesting overfishing may be occurring. These estimates are conditional on assumptions about steepness with a higher value of steepness implying greater resilience to fishing mortality.

Most assessed stocks in the southeastern U.S. have shown histories of heavy exploitation. Cobia are not a particularly common species and so do not support a large commercial fishery. The recreational fishery is prosecuted during short windows (weeks to a month) during the spring and summer as the fish become more available, presumably during seasonal alongshore and cross shelf migrations. Hence, the fishery is not heavily concentrated on the entire stock at any particular location or time. This characteristic of the fishery along with the relatively early age at maturation may afford some resilience to fishing. On the other hand, there is some evidence of genetic structure at spatial scales smaller than the entire stock (e.g., among estuaries). If so, then distinct subcomponents of the stock may be experiencing very different levels of fishing pressure with possible consequences for population productivity.

3.4.2 Comments on Projections

As usual, projections should be interpreted in light of the model assumptions and key aspects of the data. Some major considerations are the following:

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5–10 years).
- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock trajectories may be affected.

3.5 Research Recommendations

The assessment panel made the following 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.
- Better characterize the genetic structure of the stock and evaluate the possibility of local population structure.
- Better characterize the migratory dynamics of the stock and the degree of fidelity to spawning areas.
- Age-dependent natural mortality was estimated by indirect methods for this assessment of cobia. Tag-recapture programs for cobia exist and may prove useful for estimating mortality.
- Obtain MRIP intercept numbers at the DW for cobia and other rarely caught species.

3.6 References

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3.7 Tables

Table 3.1. Life-history characteristics at age of the population, including average body size and weight (mid-year), and proportion females mature.

Age	Fork length (mm)	Fork length (in)	CV length	Whole weight (kg)	Whole weight (lb)	Female maturity
1	546.3	21.5	0.13	1.90	4.20	0.00
2	730.4	28.8	0.13	4.94	10.89	0.50
3	871.0	34.3	0.13	8.80	19.39	0.75
4	978.3	38.5	0.13	12.87	28.38	1.00
5	1060.2	41.7	0.13	16.76	36.95	1.00
6	1122.7	44.2	0.13	20.22	44.59	1.00
7	1170.4	46.1	0.13	23.18	51.11	1.00
8	1206.9	47.5	0.13	25.64	56.52	1.00
9	1234.7	48.6	0.13	27.63	60.90	1.00
10	1255.9	49.4	0.13	29.21	64.41	1.00
11	1272.1	50.1	0.13	30.47	67.17	1.00
12	1284.5	50.6	0.13	31.45	69.34	1.00

Table 3.2. Estimated total abundance at age (1000 fish) at start of year.

Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1950	165.71	94.75	62.34	43.62	31.49	23.27	17.50	13.29	10.17	7.83	6.06	21.09	497.12
1951	165.71	94.75	62.34	43.63	31.50	23.28	17.50	13.29	10.17	7.83	6.06	21.10	497.18
1952	165.72	94.75	62.34	43.60	31.48	23.27	17.50	13.28	10.17	7.83	6.06	21.09	497.08
1953	165.71	94.75	62.35	43.61	31.46	23.26	17.49	13.28	10.16	7.83	6.06	21.08	497.03
1954	165.70	94.74	62.34	43.56	31.40	23.19	17.44	13.24	10.14	7.81	6.04	21.03	496.62
1955	165.66	94.73	62.31	43.48	31.28	23.08	17.34	13.17	10.08	7.76	6.01	20.91	495.80
1956	165.61	94.71	62.32	43.50	31.26	23.03	17.28	13.11	10.04	7.73	5.98	20.82	495.41
1957	165.57	94.68	62.29	43.43	31.18	22.94	17.18	13.02	9.96	7.67	5.94	20.67	494.54
1958	165.50	94.65	62.23	43.31	31.02	22.79	17.05	12.90	9.86	7.58	5.87	20.44	493.19
1959	165.42	94.62	62.24	43.33	30.98	22.71	16.97	12.82	9.78	7.52	5.81	20.25	492.46
1960	165.35	94.56	62.18	43.23	30.87	22.59	16.84	12.71	9.68	7.43	5.74	19.97	491.17
1961	165.27	94.53	62.17	43.23	30.84	22.54	16.78	12.63	9.61	7.37	5.68	19.73	490.38
1962	165.20	94.48	62.14	43.16	30.76	22.46	16.70	12.55	9.53	7.29	5.62	19.45	489.31
1963	165.11	94.44	62.10	43.09	30.65	22.36	16.60	12.46	9.45	7.21	5.55	19.14	488.16
1964	165.02	94.39	62.05	42.99	30.52	22.21	16.48	12.36	9.35	7.13	5.47	18.80	486.78
1965	164.93	94.34	62.06	43.02	30.50	22.16	16.40	12.29	9.29	7.07	5.42	18.52	486.01
1966	164.87	94.29	62.03	43.00	30.49	22.12	16.34	12.22	9.23	7.02	5.37	18.25	485.24
1967	164.81	94.26	62.01	42.98	30.47	22.11	16.31	12.17	9.18	6.97	5.33	18.00	484.60
1968	164.75	94.23	61.98	42.94	30.41	22.06	16.28	12.13	9.13	6.92	5.28	17.75	483.86
1969	164.69	94.19	61.96	42.90	30.34	21.99	16.22	12.09	9.09	6.88	5.24	17.51	483.11
1970	164.63	94.16	61.94	42.86	30.28	21.92	16.16	12.04	9.05	6.84	5.20	17.27	482.34
1971	164.56	94.12	61.92	42.81	30.21	21.84	16.08	11.97	8.99	6.80	5.16	17.03	481.50
1972	164.48	94.09	61.88	42.70	30.06	21.70	15.95	11.86	8.90	6.73	5.11	16.75	480.21
1973	164.37	94.04	61.86	42.63	29.90	21.53	15.81	11.74	8.80	6.64	5.05	16.46	478.83
1974	164.25	93.98	61.83	42.54	29.75	21.35	15.63	11.60	8.68	6.55	4.97	16.14	477.26
1975	90.37	93.91	61.78	42.44	29.58	21.16	15.44	11.42	8.54	6.43	4.87	15.77	401.71
1976	92.67	51.67	61.72	42.31	29.38	20.94	15.24	11.23	8.37	6.30	4.77	15.36	359.96
1977	80.98	52.98	33.96	42.27	29.29	20.80	15.08	11.08	8.23	6.18	4.67	14.98	320.51
1978	88.87	46.30	34.82	23.21	29.15	20.66	14.92	10.93	8.09	6.05	4.56	14.56	302.12
1979	81.45	50.81	30.43	23.72	15.89	20.41	14.71	10.73	7.92	5.90	4.43	14.07	280.46
1980	69.05	46.57	33.38	20.64	16.11	11.03	14.41	10.49	7.71	5.73	4.29	13.50	252.91
1981	101.56	39.48	30.58	22.55	13.91	11.09	7.73	10.19	7.48	5.53	4.13	12.87	267.11
1982	189.19	58.06	25.94	20.99	15.68	9.89	8.03	5.65	7.51	5.54	4.12	12.71	363.31
1983	65.92	108.14	38.09	17.46	14.06	10.74	6.89	5.64	4.00	5.35	3.97	12.11	292.37
1984	156.93	37.68	71.12	26.62	12.59	10.38	8.06	5.22	4.31	3.08	4.14	12.47	352.61
1985	41.38	89.71	24.72	47.19	17.33	8.36	7.02	5.50	3.59	2.99	2.14	11.60	261.53
1986	120.49	23.66	58.71	15.67	28.06	10.49	5.15	4.36	3.45	2.27	1.89	8.75	282.95
1987	147.37	68.86	15.40	34.15	7.88	14.31	5.44	2.70	2.30	1.83	1.21	5.70	307.17
1988	415.32	84.22	45.03	9.99	21.34	5.02	9.27	3.56	1.78	1.53	1.22	4.63	602.92
1989	78.44	237.37	55.13	29.39	6.31	13.74	3.29	6.13	2.37	1.19	1.03	3.96	438.36
1990	166.35	44.83	155.22	35.23	17.80	3.89	8.62	2.08	3.92	1.53	0.77	3.23	443.47
1991	426.35	95.08	29.36	102.36	22.71	11.71	2.60	5.82	1.42	2.68	1.05	2.77	703.91
1992	68.51	243.68	62.20	18.85	62.57	14.14	7.41	1.66	3.75	0.92	1.75	2.50	487.95
1993	65.76	39.16	159.67	41.00	12.13	41.09	9.44	5.00	1.13	2.57	0.63	2.93	380.52
1994	302.72	37.59	25.70	108.47	27.98	8.46	29.15	6.77	3.61	0.82	1.88	2.61	555.77
1995	73.10	173.04	24.67	17.48	74.23	19.57	6.02	20.94	4.90	2.63	0.60	3.30	420.50
1996	217.91	41.78	113.31	16.24	11.23	48.63	13.04	4.05	14.20	3.34	1.80	2.68	488.23
1997	35.95	124.54	27.31	72.25	9.80	6.90	30.39	8.23	2.58	9.09	2.15	2.90	332.09
1998	84.69	20.54	81.54	17.94	46.21	6.39	4.58	20.36	5.56	1.75	6.21	3.46	299.23
1999	314.55	48.41	13.47	54.23	11.75	30.90	4.35	3.14	14.10	3.87	1.23	6.79	506.78
2000	263.14	179.80	31.73	8.89	34.96	7.73	20.67	2.94	2.14	9.66	2.67	5.54	569.89
2001	106.97	150.39	117.67	20.59	5.55	22.26	5.00	13.52	1.94	1.42	6.44	5.49	457.24
2002	106.95	61.14	98.53	77.55	13.25	3.64	14.86	3.37	9.19	1.32	0.98	8.23	399.01
2003	202.84	61.13	40.11	66.58	52.41	9.15	2.56	10.54	2.41	6.61	0.96	6.68	461.98
2004	37.05	115.93	39.96	25.22	39.02	31.26	5.55	1.57	6.51	1.50	4.13	4.79	312.49
2005	380.10	21.18	75.66	24.41	13.97	21.96	17.89	3.21	0.91	3.82	0.88	5.27	569.26
2006	149.27	217.23	13.81	45.54	13.13	7.63	12.20	10.04	1.81	0.52	2.18	3.53	476.90
2007	104.43	85.29	141.12	7.81	21.70	6.33	3.74	6.04	5.01	0.91	0.26	2.89	385.55
2008	123.20	59.68	55.65	86.42	4.35	12.28	3.65	2.18	3.54	2.95	0.54	1.88	356.32
2009	104.75	70.41	39.06	36.06	53.79	2.76	7.93	2.38	1.43	2.34	1.96	1.61	324.48
2010	84.52	59.86	45.92	23.81	19.92	30.19	1.58	4.57	1.38	0.84	1.37	2.11	276.07
2011	149.80	48.29	38.91	26.85	12.15	10.30	15.87	0.84	2.45	0.74	0.45	1.89	308.54
2012	122.11	85.61	31.56	24.86	16.27	7.50	6.46	10.06	0.53	1.57	0.48	1.52	308.54

Table 3.3. Estimated biomass at age (1000 lb) at start of year

Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1950	696.0	1031.5	1209.0	1238.1	1163.4	1037.7	894.2	750.9	619.3	504.4	407.0	1462.5	11014.1
1951	696.0	1031.5	1208.8	1238.3	1164.0	1038.2	894.6	751.3	619.7	504.6	407.2	1463.2	11017.4
1952	696.0	1031.5	1208.8	1237.7	1163.2	1037.7	894.2	750.9	619.3	504.4	407.0	1462.5	11013.0
1953	696.0	1031.5	1209.0	1237.7	1162.5	1037.1	894.0	750.5	619.1	504.2	407.0	1461.9	11010.1
1954	695.8	1031.5	1208.8	1236.4	1160.1	1034.2	891.3	748.5	617.3	502.7	405.9	1457.9	10990.5
1955	695.8	1031.3	1208.1	1234.1	1155.7	1029.1	886.3	744.3	614.0	500.0	403.4	1450.0	10952.1
1956	695.6	1031.1	1208.6	1234.8	1155.0	1026.7	883.2	741.2	611.3	498.0	401.9	1444.0	10931.4
1957	695.3	1030.9	1207.7	1232.8	1152.1	1022.7	878.3	736.1	606.7	494.1	399.0	1433.2	10889.1
1958	695.1	1030.4	1206.8	1229.3	1146.0	1016.1	871.5	729.1	600.3	488.5	394.4	1417.1	10824.5
1959	694.7	1030.0	1207.0	1229.7	1144.9	1012.8	867.5	724.9	595.7	484.4	390.7	1403.9	10785.7
1960	694.5	1029.6	1205.7	1226.9	1140.7	1007.3	860.9	718.5	589.7	478.6	385.6	1384.7	10723.1
1961	694.0	1029.1	1205.5	1226.9	1139.6	1005.1	857.6	714.1	585.5	474.4	381.6	1368.0	10681.4
1962	693.8	1028.7	1204.8	1224.9	1136.5	1001.3	853.4	709.2	580.3	469.6	377.2	1348.3	10628.3
1963	693.4	1028.2	1204.2	1222.9	1132.7	996.9	848.6	704.6	575.2	464.5	372.8	1327.2	10570.9
1964	693.1	1027.6	1203.3	1220.3	1127.7	990.5	842.2	698.4	569.7	459.2	367.7	1303.8	10503.5
1965	692.7	1027.1	1203.3	1220.9	1127.0	987.9	838.4	694.5	565.9	455.7	364.0	1284.4	10462.0
1966	692.5	1026.7	1202.8	1220.5	1126.6	986.3	835.3	690.7	562.2	452.2	360.9	1265.5	10422.1
1967	692.3	1026.3	1202.4	1220.0	1125.7	985.7	833.8	688.1	558.9	449.1	358.0	1248.0	10388.2
1968	691.8	1025.8	1202.0	1218.7	1123.7	983.5	832.0	685.9	556.0	445.8	354.9	1230.8	10350.9
1969	691.6	1025.6	1201.5	1217.6	1121.3	980.6	829.2	683.4	553.4	442.9	352.1	1213.9	10313.0
1970	691.4	1025.1	1201.1	1216.5	1118.8	977.3	825.9	680.3	550.9	440.5	349.4	1197.3	10274.6
1971	691.1	1024.7	1200.6	1215.2	1116.2	973.8	821.9	676.6	547.6	437.8	346.8	1181.0	10233.6
1972	690.7	1024.3	1200.0	1212.1	1110.5	967.4	815.5	670.4	542.3	433.4	343.3	1161.6	10171.5
1973	690.3	1023.8	1199.5	1209.9	1104.7	959.9	808.0	663.6	535.9	427.9	339.1	1141.3	10104.2
1974	689.8	1023.2	1198.9	1207.5	1099.2	952.0	799.2	655.4	528.7	421.5	333.6	1119.1	10027.9
1975	379.4	1022.5	1198.0	1204.6	1092.8	943.4	789.3	645.5	520.1	414.2	327.4	1093.7	9630.7
1976	389.1	562.4	1196.9	1200.9	1085.6	933.9	778.7	634.7	510.1	405.7	320.3	1065.3	9083.5
1977	340.2	576.7	658.5	1200.0	1082.2	927.5	770.7	626.3	501.6	397.9	313.7	1038.8	8434.0
1978	373.2	504.0	675.3	658.7	1077.0	921.1	762.6	617.5	493.0	389.6	306.4	1009.7	7788.0
1979	342.2	553.1	590.0	673.1	587.3	909.8	751.6	606.5	482.4	380.1	297.8	975.5	7149.2
1980	289.9	507.1	647.3	585.8	595.2	492.1	736.6	592.8	469.8	368.8	288.1	936.1	6509.4
1981	426.6	429.9	593.0	640.0	513.9	494.5	395.1	576.1	455.5	356.5	277.3	892.7	6050.8
1982	794.5	632.1	502.9	595.7	579.4	441.1	410.3	319.2	457.2	356.9	276.9	881.4	6247.7
1983	276.9	1177.3	738.5	495.4	519.6	478.6	352.1	319.0	243.8	344.8	266.8	839.7	6052.6
1984	659.2	410.3	1379.0	755.5	465.2	463.0	412.0	295.2	262.8	198.2	278.0	865.1	6443.0
1985	173.7	976.6	479.3	1339.3	640.2	373.0	358.7	311.1	218.9	192.2	143.7	804.5	6011.3
1986	506.0	257.5	1138.5	444.7	1036.8	468.0	263.2	246.7	210.1	145.9	127.2	606.5	5451.4
1987	618.8	749.6	298.5	969.4	291.2	638.2	278.2	152.6	140.4	118.2	81.4	395.5	4732.0
1988	1744.3	916.9	873.3	283.5	788.6	224.0	474.0	201.3	108.5	98.5	82.0	320.8	6115.4
1989	329.4	2584.3	1069.0	834.2	233.0	612.7	168.0	346.6	144.6	76.9	69.2	274.5	6742.6
1990	698.6	488.1	3009.8	999.8	657.9	173.5	440.7	117.7	238.5	98.3	51.8	224.2	7199.0
1991	1790.6	1035.1	569.5	2905.3	838.9	522.1	132.9	329.2	86.4	172.8	70.5	191.8	8645.0
1992	287.7	2653.0	1205.9	535.1	2312.0	630.5	379.0	94.1	228.6	59.3	117.5	173.3	8676.1
1993	276.2	426.4	3096.2	1163.8	448.2	1831.8	482.6	282.6	69.0	165.3	42.5	203.0	8487.8
1994	1271.4	409.2	498.5	3079.0	1034.0	377.2	1489.9	382.5	220.0	52.9	125.9	181.0	9121.4
1995	307.1	1883.9	478.4	496.3	2742.8	872.8	307.8	1183.7	298.5	169.5	40.6	228.6	9009.4
1996	915.1	454.8	2197.1	461.0	414.9	2168.2	666.5	228.8	865.1	215.4	121.3	186.1	8894.5
1997	151.0	1355.8	529.6	2051.0	362.0	307.8	1553.4	465.2	157.0	585.5	144.4	201.1	7863.7
1998	355.6	223.8	1580.9	509.0	1707.5	285.1	233.9	1150.8	338.6	112.9	417.1	239.9	7155.1
1999	1321.0	527.1	261.0	1539.3	434.1	1377.7	222.2	177.7	858.5	249.3	82.2	470.9	7521.3
2000	1105.2	1957.5	615.3	252.2	1291.9	344.8	1056.7	166.0	130.5	622.4	179.2	384.3	8105.7
2001	449.3	1637.4	2281.8	584.4	205.0	992.5	255.7	764.1	117.9	91.5	432.5	380.7	8192.8
2002	449.1	665.6	1910.5	2201.3	489.6	162.5	759.5	190.7	559.5	85.3	65.5	570.6	8109.7
2003	851.9	665.6	777.8	1889.8	1936.5	407.9	130.7	595.7	147.0	425.7	64.4	463.0	8356.0
2004	155.6	1262.1	774.9	715.6	1441.8	1394.0	283.7	88.6	396.4	96.6	277.1	331.8	7218.6
2005	1596.4	230.6	1467.2	692.7	516.1	979.3	914.5	181.2	55.6	245.8	59.3	365.3	7304.1
2006	626.8	2365.1	267.9	1292.6	485.2	340.2	623.7	567.5	110.5	33.5	146.6	244.9	7104.6
2007	438.5	928.6	2736.4	221.6	801.8	282.4	191.1	341.5	305.3	58.6	17.6	200.6	6524.4
2008	517.4	649.7	1079.2	2452.9	160.7	547.6	186.3	123.0	215.6	190.3	36.4	130.3	6289.3
2009	439.8	766.5	757.5	1023.6	1987.5	123.0	405.2	134.3	87.1	150.8	131.8	111.8	6118.9
2010	354.9	651.7	890.4	675.9	736.1	1346.1	80.5	258.2	84.0	53.8	92.4	146.2	5370.5
2011	629.2	525.8	754.4	762.1	448.9	459.4	811.3	47.2	149.0	47.8	30.4	131.2	4796.6
2012	512.8	932.1	612.0	705.5	601.2	334.2	330.5	568.6	32.6	101.2	32.2	105.4	4868.2

Table 3.4. Estimated time series and status indicators. Fishing mortality rate is apical F, which includes discard mortalities. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, mature female weight, mt) at the end of May (time of peak spawning). The MSST *is defined by* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{MSY}}$*, with constant* $M = 0.26$*. SPR is static spawning potential ratio.*

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	SSB/SSB$_{\mathrm{MSY}}$	SSB/MSST	SPR
1950	0.0138	0.0301	4996	0.944	1904	3.55	4.79	0.937
1951	0.0148	0.0322	4997	0.944	1904	3.55	4.79	0.933
1952	0.0147	0.0320	4995	0.944	1903	3.55	4.79	0.934
1953	0.0170	0.0369	4994	0.944	1901	3.54	4.79	0.924
1954	0.0199	0.0432	4985	0.942	1895	3.53	4.77	0.912
1955	0.0184	0.0400	4968	0.939	1889	3.52	4.75	0.918
1956	0.0218	0.0473	4958	0.937	1882	3.51	4.74	0.904
1957	0.0257	0.0558	4939	0.933	1871	3.49	4.71	0.889
1958	0.0237	0.0515	4910	0.928	1859	3.46	4.68	0.897
1959	0.0279	0.0606	4892	0.924	1849	3.44	4.65	0.880
1960	0.0266	0.0578	4864	0.919	1837	3.42	4.62	0.886
1961	0.0293	0.0636	4845	0.915	1827	3.40	4.60	0.875
1962	0.0312	0.0678	4821	0.911	1815	3.38	4.57	0.868
1963	0.0341	0.0741	4795	0.906	1802	3.36	4.54	0.857
1964	0.0323	0.0701	4764	0.900	1790	3.33	4.51	0.865
1965	0.0333	0.0723	4745	0.897	1781	3.32	4.48	0.861
1966	0.0336	0.0729	4727	0.893	1773	3.30	4.46	0.860
1967	0.0350	0.0761	4712	0.890	1765	3.29	4.44	0.855
1968	0.0362	0.0786	4695	0.887	1757	3.27	4.42	0.851
1969	0.0373	0.0811	4678	0.884	1749	3.26	4.40	0.847
1970	0.0388	0.0843	4660	0.881	1740	3.24	4.38	0.842
1971	0.0431	0.0935	4642	0.877	1729	3.22	4.35	0.827
1972	0.0456	0.0991	4614	0.872	1715	3.20	4.32	0.819
1973	0.0490	0.1064	4583	0.866	1700	3.17	4.28	0.808
1974	0.0530	0.1150	4549	0.859	1682	3.13	4.23	0.796
1975	0.0573	0.1245	4368	0.825	1662	3.10	4.18	0.783
1976	0.0573	0.1245	4120	0.779	1599	2.98	4.03	0.783
1977	0.0614	0.1333	3826	0.723	1505	2.80	3.79	0.771
1978	0.0687	0.1492	3533	0.667	1375	2.56	3.46	0.750
1979	0.0770	0.1671	3243	0.613	1252	2.33	3.15	0.728
1980	0.0851	0.1849	2953	0.558	1135	2.11	2.86	0.707
1981	0.0527	0.1145	2745	0.519	1041	1.94	2.62	0.796
1982	0.0911	0.1979	2834	0.535	977	1.82	2.46	0.692
1983	0.0157	0.0341	2745	0.519	999	1.86	2.51	0.929
1984	0.1208	0.2624	2922	0.552	1007	1.88	2.53	0.629
1985	0.2136	0.4638	2727	0.515	970	1.81	2.44	0.490
1986	0.3856	0.8373	2473	0.467	790	1.47	1.99	0.351
1987	0.1634	0.3548	2146	0.406	692	1.29	1.74	0.555
1988	0.1525	0.3311	2774	0.524	701	1.31	1.77	0.573
1989	0.1952	0.4239	3058	0.578	910	1.69	2.29	0.512
1990	0.1314	0.2854	3265	0.617	1049	1.95	2.64	0.608
1991	0.1858	0.4034	3921	0.741	1154	2.15	2.91	0.524
1992	0.1329	0.2885	3935	0.744	1288	2.40	3.24	0.606
1993	0.0723	0.1570	3850	0.727	1407	2.62	3.54	0.739
1994	0.0697	0.1513	4137	0.782	1468	2.73	3.69	0.746
1995	0.1352	0.2936	4087	0.772	1458	2.72	3.67	0.601
1996	0.1991	0.4325	4034	0.762	1346	2.51	3.39	0.507
1997	0.1395	0.3029	3567	0.674	1315	2.45	3.31	0.594
1998	0.1147	0.2490	3245	0.613	1212	2.26	3.05	0.641
1999	0.1308	0.2841	3412	0.645	1123	2.09	2.83	0.610
2000	0.1639	0.3559	3677	0.695	1111	2.07	2.80	0.555
2001	0.1330	0.2889	3716	0.702	1215	2.26	3.06	0.606
2002	0.0826	0.1793	3679	0.695	1329	2.48	3.35	0.712
2003	0.2290	0.4972	3790	0.716	1282	2.39	3.23	0.473
2004	0.2871	0.6234	3274	0.619	1128	2.10	2.84	0.418
2005	0.3167	0.6878	3313	0.626	934	1.74	2.35	0.395
2006	0.4419	0.9595	3223	0.609	905	1.69	2.28	0.323
2007	0.2813	0.6109	2959	0.559	902	1.68	2.27	0.423
2008	0.1672	0.3630	2853	0.539	972	1.81	2.45	0.550
2009	0.2899	0.6295	2775	0.524	918	1.71	2.31	0.415
2010	0.3721	0.8081	2436	0.460	783	1.46	1.97	0.358
2011	0.1950	0.4235	2176	0.411	693	1.29	1.75	0.512
2012	.	.	2208	0.417	.	.	.	.

Table 3.5. Selectivity at age (end-of-assessment time period) for pooled commercial (cA), pooled recreational (mrip), and selectivity of landings averaged across fisheries (L.avg). FL is fork length.

Age	FL(mm)	FL(in)	cA	mrip	L.avg
1	546.3	21.5	0.031	0.001	0.002
2	730.4	28.8	0.182	0.026	0.034
3	871.0	34.3	0.609	0.495	0.501
4	978.3	38.5	0.916	0.973	0.970
5	1060.2	41.7	0.987	0.999	0.999
6	1122.7	44.2	0.998	1.000	1.000
7	1170.4	46.1	1.000	1.000	1.000
8	1206.9	47.5	1.000	1.000	1.000
9	1234.7	48.6	1.000	1.000	1.000
10	1255.9	49.4	1.000	1.000	1.000
11	1272.1	50.1	1.000	1.000	1.000
12	1284.5	50.6	1.000	1.000	1.000

Table 3.6. Estimated time series of fully selected fishing mortality rates for the general commercial (F.cA) and general recreational (F.mrip) fleets. Also shown is apical F, the maximum F at age summed across fleets.

Year	F.cA	F.mrip	Apical F
1950	0.001	0.012	0.014
1951	0.002	0.013	0.015
1952	0.000	0.014	0.015
1953	0.002	0.015	0.017
1954	0.004	0.016	0.020
1955	0.001	0.017	0.018
1956	0.004	0.018	0.022
1957	0.006	0.019	0.026
1958	0.003	0.020	0.024
1959	0.007	0.021	0.028
1960	0.004	0.022	0.027
1961	0.005	0.024	0.029
1962	0.006	0.026	0.031
1963	0.007	0.027	0.034
1964	0.003	0.029	0.032
1965	0.003	0.031	0.033
1966	0.002	0.032	0.034
1967	0.002	0.033	0.035
1968	0.002	0.035	0.036
1969	0.001	0.036	0.037
1970	0.001	0.037	0.039
1971	0.002	0.041	0.043
1972	0.001	0.045	0.046
1973	0.001	0.048	0.049
1974	0.001	0.052	0.053
1975	0.001	0.056	0.057
1976	0.001	0.056	0.057
1977	0.001	0.061	0.061
1978	0.000	0.068	0.069
1979	0.001	0.076	0.077
1980	0.002	0.083	0.085
1981	0.004	0.049	0.053
1982	0.008	0.083	0.091
1983	0.005	0.011	0.016
1984	0.003	0.117	0.121
1985	0.003	0.211	0.214
1986	0.008	0.377	0.386
1987	0.015	0.148	0.163
1988	0.011	0.142	0.152
1989	0.011	0.184	0.195
1990	0.011	0.120	0.131
1991	0.010	0.176	0.186
1992	0.008	0.125	0.133
1993	0.007	0.065	0.072
1994	0.008	0.062	0.070
1995	0.012	0.123	0.135
1996	0.012	0.188	0.199
1997	0.012	0.127	0.139
1998	0.009	0.106	0.115
1999	0.006	0.125	0.131
2000	0.011	0.153	0.164
2001	0.009	0.124	0.133
2002	0.009	0.074	0.083
2003	0.007	0.222	0.229
2004	0.008	0.279	0.287
2005	0.008	0.309	0.317
2006	0.011	0.430	0.442
2007	0.010	0.271	0.281
2008	0.010	0.157	0.167
2009	0.012	0.277	0.290
2010	0.019	0.353	0.372
2011	0.013	0.182	0.195

Table 3.7. Estimated instantaneous fishing mortality rate (per yr) at age, including discard mortality

Year	1	2	3	4	5	6	7	8	9	10	11	12
1950	0.000	0.001	0.007	0.013	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014
1951	0.000	0.001	0.008	0.014	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
1952	0.000	0.000	0.007	0.014	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
1953	0.000	0.001	0.009	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
1954	0.000	0.001	0.010	0.019	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
1955	0.000	0.001	0.009	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
1956	0.000	0.001	0.011	0.021	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
1957	0.000	0.002	0.013	0.025	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026
1958	0.000	0.001	0.012	0.023	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
1959	0.000	0.002	0.015	0.027	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
1960	0.000	0.001	0.014	0.026	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
1961	0.000	0.002	0.015	0.028	0.029	0.029	0.029	0.029	0.029	0.029	0.029	0.029
1962	0.000	0.002	0.016	0.030	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
1963	0.000	0.002	0.018	0.033	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
1964	0.000	0.001	0.016	0.031	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
1965	0.000	0.001	0.017	0.032	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
1966	0.000	0.001	0.017	0.033	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
1967	0.000	0.001	0.018	0.034	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
1968	0.000	0.001	0.018	0.035	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
1969	0.000	0.001	0.019	0.036	0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
1970	0.000	0.001	0.019	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
1971	0.000	0.001	0.022	0.042	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
1972	0.000	0.001	0.023	0.044	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046
1973	0.000	0.001	0.024	0.048	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049
1974	0.000	0.002	0.026	0.051	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053
1975	0.000	0.002	0.029	0.056	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
1976	0.000	0.002	0.028	0.056	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
1977	0.000	0.002	0.030	0.060	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
1978	0.000	0.002	0.034	0.067	0.069	0.069	0.069	0.069	0.069	0.069	0.069	0.069
1979	0.000	0.002	0.038	0.075	0.077	0.077	0.077	0.077	0.077	0.077	0.077	0.077
1980	0.000	0.003	0.042	0.083	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
1981	0.000	0.002	0.027	0.051	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053
1982	0.000	0.004	0.046	0.088	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
1983	0.000	0.001	0.008	0.015	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
1984	0.000	0.004	0.060	0.117	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121
1985	0.000	0.006	0.106	0.208	0.213	0.214	0.214	0.214	0.214	0.214	0.214	0.214
1986	0.001	0.011	0.192	0.375	0.385	0.386	0.386	0.386	0.386	0.386	0.386	0.386
1987	0.001	0.007	0.083	0.158	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.163
1988	0.000	0.006	0.077	0.148	0.152	0.152	0.152	0.152	0.152	0.152	0.152	0.152
1989	0.000	0.007	0.098	0.189	0.195	0.195	0.195	0.195	0.195	0.195	0.195	0.195
1990	0.000	0.005	0.066	0.127	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131
1991	0.000	0.006	0.093	0.180	0.186	0.186	0.186	0.186	0.186	0.186	0.186	0.186
1992	0.000	0.005	0.067	0.129	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133
1993	0.000	0.003	0.037	0.070	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072
1994	0.000	0.003	0.035	0.067	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
1995	0.000	0.005	0.068	0.131	0.135	0.135	0.135	0.135	0.135	0.135	0.135	0.135
1996	0.000	0.007	0.100	0.193	0.199	0.199	0.199	0.199	0.199	0.199	0.199	0.199
1997	0.000	0.006	0.070	0.135	0.139	0.139	0.139	0.139	0.139	0.139	0.139	0.139
1998	0.000	0.004	0.058	0.111	0.114	0.115	0.115	0.115	0.115	0.115	0.115	0.115
1999	0.000	0.004	0.065	0.127	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131
2000	0.000	0.006	0.082	0.159	0.164	0.164	0.164	0.164	0.164	0.164	0.164	0.164
2001	0.000	0.005	0.067	0.129	0.133	0.133	0.133	0.133	0.133	0.133	0.133	0.133
2002	0.000	0.003	0.042	0.080	0.082	0.083	0.083	0.083	0.083	0.083	0.083	0.083
2003	0.000	0.007	0.114	0.222	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229
2004	0.000	0.009	0.143	0.279	0.287	0.287	0.287	0.287	0.287	0.287	0.287	0.287
2005	0.000	0.010	0.158	0.308	0.316	0.317	0.317	0.317	0.317	0.317	0.317	0.317
2006	0.001	0.013	0.220	0.429	0.441	0.442	0.442	0.442	0.442	0.442	0.442	0.442
2007	0.001	0.009	0.140	0.273	0.281	0.281	0.281	0.281	0.281	0.281	0.281	0.281
2008	0.000	0.006	0.084	0.162	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167
2009	0.001	0.010	0.145	0.281	0.290	0.290	0.290	0.290	0.290	0.290	0.290	0.290
2010	0.001	0.013	0.186	0.361	0.372	0.372	0.372	0.372	0.372	0.372	0.372	0.372
2011	0.001	0.007	0.098	0.189	0.195	0.195	0.195	0.195	0.195	0.195	0.195	0.195

Table 3.8. Estimated total landings at age in numbers (1000 fish)

Year	1	2	3	4	5	6	7	8	9	10	11	12
1950	0.01	0.05	0.37	0.50	0.38	0.28	0.21	0.16	0.12	0.10	0.07	0.26
1951	0.01	0.05	0.39	0.53	0.40	0.30	0.23	0.17	0.13	0.10	0.08	0.28
1952	0.00	0.04	0.39	0.53	0.40	0.30	0.23	0.17	0.13	0.10	0.08	0.27
1953	0.01	0.06	0.45	0.61	0.46	0.34	0.26	0.20	0.15	0.12	0.09	0.32
1954	0.02	0.08	0.54	0.71	0.54	0.40	0.30	0.23	0.18	0.14	0.11	0.37
1955	0.01	0.05	0.48	0.66	0.50	0.37	0.28	0.21	0.16	0.13	0.10	0.34
1956	0.02	0.09	0.58	0.78	0.58	0.43	0.33	0.25	0.19	0.15	0.11	0.40
1957	0.03	0.13	0.70	0.91	0.68	0.51	0.38	0.29	0.22	0.17	0.13	0.47
1958	0.02	0.09	0.63	0.84	0.63	0.47	0.35	0.27	0.20	0.16	0.12	0.43
1959	0.03	0.14	0.76	0.98	0.74	0.55	0.41	0.31	0.24	0.18	0.14	0.50
1960	0.02	0.10	0.71	0.94	0.70	0.52	0.39	0.30	0.23	0.17	0.13	0.47
1961	0.02	0.12	0.79	1.03	0.77	0.57	0.43	0.32	0.25	0.19	0.15	0.51
1962	0.02	0.13	0.84	1.10	0.82	0.61	0.45	0.34	0.26	0.20	0.15	0.53
1963	0.03	0.15	0.92	1.20	0.89	0.66	0.49	0.37	0.28	0.22	0.17	0.57
1964	0.02	0.11	0.85	1.14	0.84	0.62	0.46	0.35	0.26	0.20	0.15	0.53
1965	0.01	0.10	0.87	1.17	0.87	0.64	0.47	0.36	0.27	0.21	0.16	0.54
1966	0.01	0.09	0.87	1.18	0.87	0.64	0.48	0.36	0.27	0.21	0.16	0.54
1967	0.01	0.09	0.91	1.24	0.91	0.67	0.49	0.37	0.28	0.21	0.16	0.55
1968	0.01	0.09	0.94	1.27	0.94	0.69	0.51	0.38	0.29	0.22	0.17	0.56
1969	0.01	0.09	0.97	1.31	0.97	0.71	0.52	0.39	0.30	0.22	0.17	0.57
1970	0.01	0.09	1.00	1.36	1.00	0.73	0.54	0.41	0.31	0.23	0.18	0.59
1971	0.01	0.11	1.12	1.51	1.11	0.81	0.60	0.45	0.34	0.25	0.19	0.64
1972	0.01	0.10	1.17	1.59	1.16	0.85	0.63	0.47	0.35	0.27	0.20	0.67
1973	0.01	0.11	1.26	1.71	1.24	0.90	0.67	0.50	0.37	0.28	0.21	0.70
1974	0.01	0.12	1.36	1.84	1.33	0.97	0.71	0.53	0.40	0.30	0.23	0.74
1975	0.01	0.13	1.47	1.98	1.43	1.03	0.76	0.56	0.42	0.32	0.24	0.78
1976	0.00	0.07	1.46	1.97	1.42	1.02	0.75	0.55	0.41	0.31	0.24	0.76
1977	0.00	0.07	0.86	2.11	1.52	1.09	0.79	0.58	0.44	0.33	0.25	0.79
1978	0.00	0.07	0.99	1.29	1.68	1.20	0.87	0.64	0.48	0.36	0.27	0.86
1979	0.01	0.09	0.96	1.47	1.02	1.33	0.96	0.70	0.52	0.39	0.29	0.93
1980	0.01	0.10	1.17	1.41	1.14	0.79	1.04	0.76	0.56	0.42	0.31	0.98
1981	0.01	0.07	0.68	0.97	0.62	0.50	0.35	0.46	0.34	0.25	0.19	0.59
1982	0.04	0.17	0.99	1.53	1.19	0.76	0.62	0.44	0.58	0.43	0.32	0.99
1983	0.01	0.10	0.27	0.22	0.19	0.15	0.09	0.08	0.06	0.07	0.06	0.17
1984	0.02	0.11	3.51	2.54	1.25	1.04	0.81	0.53	0.44	0.31	0.42	1.27
1985	0.01	0.44	2.11	7.64	2.91	1.42	1.19	0.94	0.62	0.51	0.37	1.99
1986	0.05	0.22	8.70	4.25	7.87	2.97	1.46	1.24	0.99	0.65	0.54	2.51
1987	0.07	0.37	1.03	4.31	1.03	1.90	0.72	0.36	0.31	0.25	0.16	0.77
1988	0.14	0.39	2.81	1.18	2.63	0.62	1.16	0.45	0.22	0.19	0.15	0.58
1989	0.03	1.32	4.35	4.38	0.98	2.14	0.52	0.96	0.37	0.19	0.16	0.63
1990	0.05	0.19	8.42	3.63	1.91	0.42	0.94	0.23	0.43	0.17	0.08	0.36
1991	0.14	0.50	2.21	14.56	3.36	1.75	0.39	0.88	0.21	0.41	0.16	0.42
1992	0.02	0.94	3.39	1.96	6.78	1.55	0.81	0.18	0.42	0.10	0.19	0.28
1993	0.01	0.10	4.85	2.38	0.74	2.51	0.58	0.31	0.07	0.16	0.04	0.18
1994	0.07	0.09	0.75	6.08	1.64	0.50	1.73	0.40	0.22	0.05	0.11	0.16
1995	0.03	0.76	1.38	1.85	8.17	2.17	0.67	2.35	0.55	0.30	0.07	0.37
1996	0.08	0.24	9.12	2.46	1.77	7.73	2.08	0.65	2.28	0.54	0.29	0.43
1997	0.01	0.56	1.57	7.87	1.11	0.79	3.49	0.95	0.30	1.05	0.25	0.34
1998	0.02	0.07	3.87	1.62	4.35	0.61	0.44	1.95	0.53	0.17	0.60	0.33
1999	0.07	0.17	0.72	5.57	1.25	3.33	0.47	0.34	1.54	0.42	0.13	0.74
2000	0.09	0.87	2.12	1.13	4.60	1.03	2.76	0.39	0.29	1.30	0.36	0.75
2001	0.03	0.61	6.44	2.15	0.60	2.44	0.55	1.49	0.21	0.16	0.72	0.61
2002	0.03	0.17	3.41	5.12	0.91	0.25	1.04	0.24	0.65	0.09	0.07	0.58
2003	0.06	0.35	3.66	11.47	9.36	1.65	0.46	1.91	0.44	1.21	0.18	1.22
2004	0.01	0.82	4.51	5.31	8.51	6.88	1.23	0.35	1.45	0.33	0.92	1.07
2005	0.14	0.16	9.36	5.60	3.32	5.26	4.30	0.77	0.22	0.93	0.21	1.28
2006	0.08	2.35	2.32	13.80	4.12	2.41	3.87	3.20	0.58	0.17	0.70	1.13
2007	0.04	0.62	15.67	1.61	4.65	1.37	0.81	1.32	1.10	0.20	0.06	0.64
2008	0.04	0.29	3.79	11.15	0.58	1.66	0.50	0.30	0.48	0.41	0.07	0.26
2009	0.05	0.55	4.47	7.65	11.83	0.61	1.77	0.53	0.32	0.53	0.44	0.36
2010	0.06	0.62	6.63	6.26	5.42	8.29	0.43	1.26	0.38	0.23	0.38	0.59
2011	0.06	0.28	3.08	3.99	1.88	1.61	2.49	0.13	0.39	0.12	0.07	0.30

Table 3.9. Estimated total landings at age in whole weight (1000 lb)

Year	1	2	3	4	5	6	7	8	9	10	11	12
1950	0.03	0.50	7.14	14.14	13.87	12.50	10.82	9.12	7.55	6.16	4.98	17.90
1951	0.03	0.53	7.64	15.16	14.87	13.39	11.60	9.78	8.09	6.60	5.34	19.18
1952	0.01	0.39	7.48	15.12	14.78	13.31	11.53	9.72	8.04	6.56	5.30	19.06
1953	0.04	0.61	8.75	17.33	16.99	15.31	13.26	11.18	9.25	7.55	6.10	21.93
1954	0.07	0.92	10.41	20.13	19.79	17.83	15.44	13.02	10.77	8.79	7.11	25.55
1955	0.03	0.56	9.39	18.75	18.30	16.45	14.23	12.00	9.93	8.10	6.55	23.55
1956	0.07	0.95	11.34	22.02	21.55	19.36	16.74	14.10	11.66	9.52	7.70	27.67
1957	0.11	1.41	13.61	25.76	25.30	22.71	19.60	16.49	13.63	11.13	9.00	32.35
1958	0.06	0.97	12.28	23.89	23.29	20.86	17.98	15.10	12.47	10.17	8.22	29.57
1959	0.12	1.47	14.74	27.95	27.31	24.43	21.04	17.65	14.55	11.85	9.57	34.42
1960	0.08	1.13	13.79	26.71	25.97	23.17	19.90	16.68	13.73	11.17	9.01	32.37
1961	0.10	1.33	15.24	29.31	28.50	25.41	21.79	18.21	14.97	12.16	9.80	35.14
1962	0.10	1.42	16.25	31.19	30.30	26.98	23.11	19.28	15.82	12.84	10.32	36.92
1963	0.12	1.65	17.81	33.94	32.94	29.31	25.07	20.90	17.11	13.85	11.13	39.66
1964	0.07	1.15	16.50	32.25	31.10	27.59	23.57	19.62	16.05	12.97	10.40	36.90
1965	0.06	1.09	16.91	33.28	32.02	28.34	24.17	20.10	16.42	13.25	10.61	37.43
1966	0.04	0.96	16.93	33.62	32.29	28.54	24.29	20.16	16.45	13.26	10.60	37.20
1967	0.04	1.00	17.67	35.06	33.67	29.76	25.30	20.95	17.07	13.75	10.97	38.28
1968	0.04	0.99	18.19	36.16	34.69	30.64	26.05	21.55	17.52	14.08	11.23	38.96
1969	0.03	0.98	18.73	37.27	35.70	31.51	26.77	22.15	17.99	14.43	11.48	39.62
1970	0.04	1.02	19.45	38.68	36.99	32.61	27.69	22.90	18.60	14.90	11.84	40.59
1971	0.05	1.21	21.62	42.76	40.87	35.99	30.52	25.22	20.47	16.41	13.02	44.34
1972	0.03	1.13	22.74	45.20	43.04	37.83	32.04	26.45	21.45	17.18	13.63	46.15
1973	0.03	1.16	24.35	48.39	45.91	40.25	34.04	28.06	22.73	18.19	14.43	48.61
1974	0.03	1.26	26.29	52.11	49.28	43.05	36.32	29.90	24.19	19.33	15.32	51.41
1975	0.02	1.41	28.45	56.14	52.93	46.09	38.75	31.82	25.70	20.52	16.24	54.29
1976	0.02	0.75	28.38	55.99	52.57	45.62	38.23	31.28	25.21	20.10	15.89	52.88
1977	0.02	0.80	16.69	59.83	56.04	48.45	40.46	33.00	26.50	21.07	16.64	55.12
1978	0.02	0.77	19.11	36.65	62.20	53.66	44.64	36.29	29.04	23.02	18.12	59.76
1979	0.02	0.97	18.68	41.77	37.83	59.14	49.09	39.75	31.71	25.05	19.65	64.40
1980	0.03	1.04	22.68	40.03	42.25	35.24	53.00	42.82	34.03	26.79	20.95	68.10
1981	0.05	0.71	13.13	27.39	22.91	22.27	17.87	26.17	20.75	16.27	12.68	40.84
1982	0.19	1.87	19.11	43.29	43.87	33.71	31.51	24.61	35.36	27.67	21.49	68.44
1983	0.03	1.09	5.15	6.34	7.00	6.53	4.82	4.39	3.36	4.77	3.70	11.63
1984	0.10	1.24	68.12	72.10	46.08	46.28	41.38	29.76	26.56	20.09	28.21	87.83
1985	0.03	4.81	40.83	216.86	107.44	63.13	60.98	53.08	37.46	32.99	24.71	138.25
1986	0.21	2.38	168.61	120.50	290.65	132.27	74.77	70.30	60.05	41.81	36.47	174.00
1987	0.27	4.05	20.02	122.24	38.23	84.56	37.03	20.38	18.81	15.86	10.94	53.21
1988	0.58	4.23	54.53	33.58	97.11	27.83	59.18	25.23	13.63	12.41	10.36	40.50
1989	0.12	14.33	84.37	124.20	36.04	95.60	26.34	54.53	22.81	12.16	10.96	43.48
1990	0.23	2.05	163.31	102.96	70.50	18.78	47.90	12.85	26.10	10.78	5.69	24.64
1991	0.60	5.40	42.82	413.38	123.97	77.83	19.93	49.49	13.03	26.12	10.68	29.05
1992	0.07	10.19	65.77	55.74	250.38	68.92	41.62	10.37	25.28	6.57	13.04	19.23
1993	0.06	1.05	94.03	67.64	27.16	112.08	29.67	17.44	4.27	10.26	2.64	12.63
1994	0.28	1.02	14.64	172.50	60.43	22.27	88.37	22.77	13.14	3.17	7.55	10.86
1995	0.11	8.27	26.70	52.46	301.82	96.95	34.34	132.61	33.53	19.09	4.56	25.80
1996	0.35	2.60	176.81	69.87	65.31	344.47	106.38	36.67	138.98	34.68	19.55	30.03
1997	0.05	6.15	30.47	223.27	41.03	35.19	178.53	53.67	18.16	67.91	16.78	23.35
1998	0.10	0.81	75.06	46.10	160.90	27.11	22.36	110.42	32.57	10.88	40.28	23.18
1999	0.29	1.89	13.99	158.14	46.35	148.43	24.05	19.31	93.55	27.23	9.00	51.52
2000	0.38	9.52	41.15	31.95	170.09	45.80	141.08	22.25	17.53	83.82	24.16	51.87
2001	0.13	6.59	124.90	60.93	22.23	108.60	28.13	84.33	13.05	10.15	48.05	42.32
2002	0.11	1.90	66.16	145.38	33.71	11.30	53.07	13.38	39.36	6.01	4.63	40.29
2003	0.25	3.86	71.05	325.50	345.85	73.50	23.67	108.22	26.77	77.72	11.76	84.71
2004	0.05	8.98	87.51	150.69	314.47	306.66	62.69	19.65	88.17	21.52	61.88	74.12
2005	0.58	1.79	181.48	158.87	122.53	234.53	220.01	43.78	13.47	59.63	14.42	88.83
2006	0.32	25.61	44.92	391.79	152.06	107.51	197.95	180.75	35.30	10.72	46.98	78.54
2007	0.17	6.76	303.79	45.83	171.80	61.04	41.52	74.43	66.71	12.86	3.87	44.04
2008	0.17	3.12	73.45	316.59	21.56	74.13	25.34	16.78	29.52	26.11	4.98	17.90
2009	0.20	5.94	86.60	217.17	437.10	27.30	90.29	30.04	19.52	33.89	29.68	25.18
2010	0.23	6.74	128.47	177.54	200.29	369.45	22.20	71.45	23.33	14.96	25.72	40.70
2011	0.26	3.07	59.64	113.29	69.33	71.59	127.04	7.43	23.47	7.56	4.80	20.76

Table 3.10. Estimated time series of landings in numbers (1000 fish) for the general commercial (L.cA) and general recreational (L.mrip) fleet

Year	L.cA	L.mrip	Total
1950	0.29	2.21	2.50
1951	0.30	2.38	2.68
1952	0.10	2.54	2.64
1953	0.35	2.71	3.06
1954	0.72	2.88	3.60
1955	0.24	3.05	3.28
1956	0.70	3.22	3.91
1957	1.25	3.38	4.63
1958	0.66	3.55	4.21
1959	1.26	3.72	4.98
1960	0.79	3.89	4.68
1961	1.00	4.14	5.14
1962	1.07	4.39	5.46
1963	1.30	4.64	5.94
1964	0.64	4.89	5.53
1965	0.52	5.14	5.66
1966	0.32	5.35	5.67
1967	0.34	5.57	5.90
1968	0.29	5.78	6.06
1969	0.24	5.99	6.23
1970	0.24	6.20	6.45
1971	0.38	6.75	7.13
1972	0.18	7.29	7.47
1973	0.12	7.83	7.95
1974	0.15	8.37	8.52
1975	0.21	8.92	9.13
1976	0.15	8.83	8.98
1977	0.09	8.74	8.83
1978	0.07	8.65	8.72
1979	0.11	8.57	8.67
1980	0.20	8.48	8.68
1981	0.44	4.59	5.02
1982	0.79	7.25	8.04
1983	0.49	0.97	1.46
1984	0.39	11.85	12.25
1985	0.32	19.83	20.14
1986	0.75	30.69	31.44
1987	1.21	10.07	11.28
1988	0.97	9.56	10.53
1989	1.26	14.76	16.02
1990	1.64	15.19	16.82
1991	1.51	23.46	24.97
1992	1.26	15.35	16.62
1993	1.31	10.62	11.93
1994	1.40	10.40	11.79
1995	1.90	16.76	18.66
1996	1.83	25.84	27.67
1997	1.78	16.51	18.30
1998	1.24	13.34	14.58
1999	0.78	13.99	14.77
2000	1.34	14.35	15.69
2001	1.40	14.60	16.00
2002	1.42	11.14	12.56
2003	1.10	30.88	31.98
2004	1.00	30.39	31.39
2005	0.94	30.61	31.56
2006	1.23	33.49	34.72
2007	1.26	26.82	28.08
2008	1.25	18.28	19.53
2009	1.40	27.70	29.10
2010	1.81	28.74	30.55
2011	1.13	13.26	14.38

Table 3.11. Estimated time series of landings in whole weight (1000 lb) forthe general commercial (L.cA) and general recreational (L.mrip) fleet

Year	L.cA	L.mrip	Total
1950	11.40	93.30	104.70
1951	11.80	100.41	112.21
1952	3.80	107.50	111.30
1953	13.70	114.59	128.29
1954	28.20	121.64	149.84
1955	9.20	128.64	137.84
1956	27.10	135.58	162.68
1957	48.60	142.51	191.11
1958	25.50	149.37	174.87
1959	48.90	156.20	205.10
1960	30.70	162.99	193.69
1961	38.70	173.24	211.94
1962	41.10	183.45	224.55
1963	49.90	193.59	243.49
1964	24.50	203.68	228.18
1965	19.90	213.76	233.66
1966	12.10	222.24	234.34
1967	12.80	230.72	243.52
1968	10.90	239.20	250.10
1969	9.00	247.66	256.66
1970	9.20	256.10	265.30
1971	14.40	278.10	292.50
1972	7.00	299.89	306.89
1973	4.60	321.54	326.14
1974	5.50	342.99	348.49
1975	8.10	364.26	372.36
1976	5.90	361.02	366.92
1977	3.50	371.11	374.61
1978	2.75	380.54	383.28
1979	4.54	383.54	388.08
1980	8.39	378.58	386.97
1981	17.98	203.08	221.06
1982	31.36	319.74	351.11
1983	18.09	40.72	58.81
1984	13.74	454.02	467.76
1985	11.15	769.43	780.58
1986	25.83	1146.18	1172.02
1987	40.62	384.98	425.60
1988	28.73	350.44	379.16
1989	33.37	491.56	524.94
1990	43.87	441.93	485.79
1991	43.95	768.33	812.28
1992	36.78	530.38	567.17
1993	39.64	339.29	378.93
1994	47.08	369.92	417.00
1995	67.21	669.05	736.26
1996	62.53	963.16	1025.70
1997	62.43	632.12	694.55
1998	44.64	505.12	549.76
1999	28.60	565.16	593.75
2000	45.10	594.49	639.59
2001	42.09	507.32	549.41
2002	44.38	370.92	415.30
2003	36.98	1115.88	1152.86
2004	34.38	1162.02	1196.39
2005	30.50	1109.41	1139.91
2006	35.88	1236.56	1272.44
2007	33.56	799.25	832.81
2008	36.44	573.21	609.65
2009	44.41	958.51	1002.92
2010	58.35	1022.73	1081.08
2011	36.06	472.18	508.24

Table 3.12. Estimated status indicators, benchmarks, and related quantities from the Beaufort catch-age model, conditional on estimated current selectivities averaged across fisheries. Rate estimates (F) are in units of y^{-1}*; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) and minimum stock size threshold (MSST) are measured by total weight of mature females. Symbols, abbreviations, and acronyms are listed in Appendix A.*

Quantity	Units	Estimate
F_{MSY}	y^{-1}	0.461
$85\%F_{\mathrm{MSY}}$	y^{-1}	0.391
$75\%F_{\mathrm{MSY}}$	y^{-1}	0.345
$65\%F_{\mathrm{MSY}}$	y^{-1}	0.299
$F_{30\%}$	y^{-1}	0.493
$F_{40\%}$	y^{-1}	0.309
$F_{50\%}$	y^{-1}	0.205
B_{MSY}	mt	1991.6
$\mathrm{SSB}_{\mathrm{MSY}}$	mt	536.8
MSST	mt	397.2
MSY	1000 lb	808
R_{MSY}	1000 age-1 fish	139
Y at $85\%F_{\mathrm{MSY}}$	1000 lb	803
Y at $75\%F_{\mathrm{MSY}}$	1000 lb	794
Y at $65\%F_{\mathrm{MSY}}$	1000 lb	777
$F_{2009-2011}/F_{\mathrm{MSY}}$	—	0.599
$F_{2011}/F_{\mathrm{MSY}}$	—	0.423
$\mathrm{SSB}_{2011}/\mathrm{MSST}$	—	1.75

Table 3.13. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last three assessment years. Spawning stock was based on total biomass (mt) of mature females. See text for full description of sensitivity runs.

Run	Description	F_{MSY}	SSB_{MSY} (mt)	B_{MSY} (mt)	MSY(1000 lb)	$F_{2009-2011}/F_{MSY}$	$SSB_{2011}/MSST$	SSB_{2011}/SSB_{MSY}	steep	R0(1000)
Base	—	0.46	537	1992	808	0.6	1.75	1.29	0.75	137
S1	M=0.20	0.31	549	1693	617	1.59	0.75	0.6	0.75	74
S2	M=0.35	0.697	612	2806	1207	0.23	3.26	2.12	0.75	275
S3	constant M=0.26	0.403	559	1826	795	0.67	1.67	1.24	0.75	76
S4	h=0.6	0.299	677	2264	708	0.96	1.31	0.97	0.6	142
S5	h=0.9	1.046	340	1639	953	0.26	2.86	2.12	0.95	132
S6	Unweighted	0.538	320	1224	526	1.03	1.07	0.79	0.75	71
S7	upweight indices	0.446	620	2286	917	0.41	2.41	1.79	0.75	160
S8	q 0.02	0.46	534	1981	804	0.62	1.68	1.25	0.75	136
S9	RW q	0.462	522	1938	787	0.7	1.49	1.1	0.75	133
S10	SC stocking	0.461	534	1983	805	0.58	1.84	1.36	0.75	136
S11	Low discard mortality	0.461	523	1939	787	0.59	1.76	1.31	0.75	133
S12	High discard mortality	0.461	549	2039	827	0.61	1.73	1.28	0.75	140
S13	HB index only	0.462	526	1951	793	0.63	1.66	1.23	0.75	133
S14	SC logbook index only	0.464	515	1912	778	0.72	1.44	1.06	0.75	130
S15	HB, SC logbook, MRFSS indices	0.46	545	2020	819	0.55	1.91	1.41	0.75	139
S16	Fecundity	0.321		2254	738	0.87	1.58	1.17	0.75	140

Table 3.14. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$ starting in 2013. F = fishing mortality rate (per year), Pr(SSB > $\mathrm{SSB}_{\mathrm{MSY}}$) = proportion of stochastic projection replicates exceeding $\mathrm{SSB}_{\mathrm{MSY}}$, SSB = spawning stock (mt) at peak spawning time, R = recruits (1000 age-1 fish), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{\mathrm{MSY}} = 0.461$ (per yr), $\mathrm{SSB}_{\mathrm{MSY}} = 536.8$ (mt), and MSY = 808 (1000 lb). Expected values presented are from deterministic projections.

Year	F(per yr)	Pr(SSB > $\mathrm{SSB}_{\mathrm{MSY}}$)	SSB(mt)	R(1000)	L(1000)	L(1000 lb)	Sum L(1000 lb)
2012	0.204	0.65	695.8	147	14	508	508
2013	0.46	0.61	664.3	147	31	1045	1553
2014	0.46	0.53	615.7	146	30	950	2503
2015	0.46	0.48	589.7	143	30	900	3403
2016	0.46	0.46	574.7	142	29	874	4276

Table 3.15. Projection results with fishing mortality rate fixed at $F = F_{\text{current}}$ starting in 2013. F = fishing mortality rate (per year), Pr($\text{SSB} > \text{SSB}_{\text{MSY}}$*) = proportion of stochastic projection replicates exceeding* SSB_{MSY}*, SSB = spawning stock (mt) at peak spawning time, R = recruits (1000 age-1 fish), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are* $F_{\text{MSY}} = 0.461$ *(per yr),* $\text{SSB}_{\text{MSY}} = 536.8$ *(mt), and* $\text{MSY} = 808$ *(1000 lb). Expected values presented are from deterministic projections.*

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(mt)	R(1000)	L(1000)	L(1000 lb)	Sum L(1000 lb)
2012	0.204	0.65	695.8	147	14	508	508
2013	0.276	0.67	704.9	147	20	675	1183
2014	0.276	0.7	721.4	147	21	693	1875
2015	0.276	0.71	735.7	148	22	709	2585
2016	0.276	0.73	747.5	148	22	723	3307

*Table 3.16. Projection results with fishing mortality rate fixed at $F = 65\% F_{\text{MSY}}$ starting in 2013. F = fishing mortality rate (per year), Pr(*SSB > SSB_{MSY}*) = proportion of stochastic projection replicates exceeding* SSB_{MSY}*, SSB = spawning stock (mt) at peak spawning time, R = recruits (1000 age-1 fish), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are* $F_{\text{MSY}} = 0.461$ *(per yr),* $\text{SSB}_{\text{MSY}} = 536.8$ *(mt), and* MSY = 808 *(1000 lb). Expected values presented are from deterministic projections.*

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(mt)	R(1000)	L(1000)	L(1000 lb)	Sum L(1000 lb)
2012	0.204	0.65	695.8	147	14	508	508
2013	0.299	0.66	699.6	147	21	724	1233
2014	0.299	0.68	706.7	147	23	732	1965
2015	0.299	0.68	714.3	147	23	742	2707
2016	0.299	0.69	721.2	147	24	750	3457

Table 3.17. Projection results with fishing mortality rate fixed at $F = 75\% F_{\mathrm{MSY}}$ starting in 2013. F = fishing mortality rate (per year), Pr($\mathrm{SSB} > \mathrm{SSB}_{\mathrm{MSY}}$*) = proportion of stochastic projection replicates exceeding* $\mathrm{SSB}_{\mathrm{MSY}}$*, SSB = spawning stock (mt) at peak spawning time, R = recruits (1000 age-1 fish), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are* $F_{\mathrm{MSY}} = 0.461$ *(per yr),* $\mathrm{SSB}_{\mathrm{MSY}} = 536.8$ *(mt), and* MSY = 808 *(1000 lb). Expected values presented are from deterministic projections.*

Year	F(per yr)	Pr(SSB > $\mathrm{SSB}_{\mathrm{MSY}}$)	SSB(mt)	R(1000)	L(1000)	L(1000 lb)	Sum L(1000 lb)
2012	0.204	0.65	695.8	147	14	508	508
2013	0.345	0.65	689.3	147	24	821	1329
2014	0.345	0.65	678.9	147	25	804	2133
2015	0.345	0.63	674.8	146	25	798	2931
2016	0.345	0.62	673.5	146	26	797	3728

Table 3.18. Projection results with fishing mortality rate fixed at $F = 85\% F_{\text{MSY}}$ starting in 2013. F = fishing mortality rate (per year), Pr($\text{SSB} > \text{SSB}_{\text{MSY}}$*) = proportion of stochastic projection replicates exceeding* SSB_{MSY}*, SSB = spawning stock (mt) at peak spawning time, R = recruits (1000 age-1 fish), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are* $F_{\text{MSY}} = 0.461$ *(per yr),* $\text{SSB}_{\text{MSY}} = 536.8$ *(mt), and* MSY = 808 *(1000 lb). Expected values presented are from deterministic projections.*

Year	F(per yr)	Pr(SSB > SSB_{MSY})	SSB(mt)	R(1000)	L(1000)	L(1000 lb)	Sum L(1000 lb)
2012	0.204	0.65	695.8	147	14	508	508
2013	0.391	0.63	679.2	147	27	913	1421
2014	0.391	0.6	652.6	146	27	868	2289
2015	0.391	0.57	638.5	145	27	845	3134
2016	0.391	0.55	630.7	144	27	833	3967

Table 3.19. AIC and total mortality estimates. The von Bertalanffy growth coefficient, the asymptotic length, and the length at full vulnerability were set to 0.27, 1324.4mm, and 925mm, respectively. Note Z values = 0.001 are hitting the lower bound placed on the Z-estimates.

Changes in Z	Npar	Nobs	AIC	LLIKE	Z	Z1	Change Year 1	Z2	Change Year 2	Z3	Change Year 3	Z4	Change Year 4	Z5
0	2	32	341.742	168.664	0.385	-	-	-	-	-	-	-	-	-
1	4	32	343.231	166.875	-	0.401	2008	0.001	-	-	-	-	-	-
2	6	32	344.400	164.520	-	0.373	2004	0.725	2007	0.001	-	-	-	-
3	8	32	349.566	163.652	-	0.448	1989	0.342	2004	0.760	2007	0.001	-	-
4	10	32	356.087	162.806	-	0.440	1992	0.132	1995	0.408	2004	0.697	2007	0.001

Table 3.20. AIC and total mortality estimates. The von Bertalanffy growth coefficient, the asymptotic length, and the length at full vulnerability were set to 0.27, 1324.4mm, and 975mm, respectively. Note Z values = 0.001 are hitting the lower bound placed on the Z-estimates.

Changes in Z	Npar	Nobs	AIC	LLIKE	Z	Z1	Change Year 1	Z2	Change Year 2	Z3	Change Year 3	Z4	Change Year 4	Z5
0	2	32	341.742	168.664	0.385	-	-	-	-	-	-	-	-	-
1	4	32	343.231	166.875	-	0.401	2008	0.001	-	-	-	-	-	-
2	6	32	344.400	164.520	-	0.373	2004	0.725	2007	0.001	-	-	-	-
3	8	32	349.566	163.652	-	0.448	1989	0.342	2004	0.760	2007	0.001	-	-
4	10	32	356.087	162.806	-	0.440	1992	0.132	1995	0.408	2004	0.697	2007	0.001

Table 3.21. AIC and total mortality estimates. The von Bertalanffy growth coefficient, the asymptotic length, and the length at full vulnerability were set to 0.27, 1324.4mm, and 1025mm, respectively. Note Z values = 0.001 are hitting the lower bound placed on the Z-estimates.

Changes in Z	Npar	Nobs	AIC	LLIKE	Z	Z1	Change Year 1	Z2	Change Year 2	Z3	Change Year 3	Z4	Change Year 4	Z5
0	2	30	317.832	156.694	0.281	-	-	-	-	-	-	-	-	-
1	4	30	314.693	152.547	-	0.468	1990	0.223	-	-	-	-	-	-
2	6	30	318.575	151.461	-	0.490	1991	0.029	1995	0.256	-	-	-	-
3	8	30	323.498	150.32	-	0.493	1991	0.001	1995	0.281	2008	0.001	-	-
4	10	30	331.182	149.802	-	0.453	1992	0.001	1995	0.236	2005	0.582	2007	0.001

Table 3.22. Summary of catch curve analysis for south Atantic cobia.

Year	Natural Mortality (M)	Traditional Method Synthetic cohort all ages (F)	(Z)	Traditional Method True cohort all ages (F)	(Z)	Thorson and Prager Synthetic cohort all ages (F)	(Z)
1984	0.26						
1985	0.26						
1986	0.26						
1987	0.26						
1988	0.26			0.02	0.28		
1989	0.26	0.07	0.33			0.03	0.29
1990	0.26	0.10	0.36			0.44	0.70
1991	0.26			0.00	0.26		
1992	0.26						
1993	0.26						
1994	0.26						
1995	0.26						
1996	0.26	0.00	0.15	0.25	0.51	0.55	0.81
1997	0.26						
1998	0.26			0.16	0.42		
1999	0.26	0.00	0.20	0.13	0.39	0.05	0.31
2000	0.26	0.00	0.10	0.24	0.50	0.03	0.29
2001	0.26	0.00	0.18			0.11	0.37
2002	0.26			0.22	0.48		
2003	0.26			0.17	0.33		
2004	0.26			0.16	0.42		
2005	0.26	0.09	0.35	0.16	0.42	0.02	0.28
2006	0.26	0.19	0.45			0.13	0.39
2007	0.26	0.17	0.43				
2008	0.26	0.23	0.49				
2009	0.26	0.18	0.44				
2010	0.26	0.29	0.55			0.03	0.29
2011	0.26	0.15	0.41			0.05	0.31
Average		0.11	0.34	0.15	0.40	0.14	0.40

Table 3.23. Input for Surplus–production model runs. Total removals in pounds. The indices are in units of pounds per angler hour.

Year	Commercial Discards	Recreational Discards	Commercial Landings	Recreational Landings	Headboat	SC logbook	MRFSS
1955			9,200	35,962			
1956			27,100	37,942			
1957			48,600	39,923			
1958			25,500	41,904			
1959			48,900	43,885			
1960			30,700	45,866			
1961			38,700	48,827			
1962			41,100	51,788			
1963			49,900	54,749			
1964			24,500	57,710			
1965			19,900	60,671			
1966			12,100	63,173			
1967			12,800	65,676			
1968			10,900	68,179			
1969			9,000	70,681			
1970			9,200	73,184			
1971			14,400	79,575			
1972			7,000	85,966			
1973			4,600	92,358			
1974			5,500	98,749			
1975			8,100	105,140			
1976			5,900	104,074			
1977			3,500	103,009			
1978			2,747	101,943			
1979			4,540	100,877			
1980			8,388	32,043			
1981			17,923	12,753	0.72		
1982			31,264	114,425	0.71		
1983	541	484	18,033	26,805	0.81		
1984	411	888	13,694	391,706	0.36		
1985	333	6,760	11,115	320,714	0.36		0.76
1986	773	2,864	25,754	607,805	0.71		0.53
1987	1,215	313	40,495	173,416	1.18		0.43
1988	859	2,040	28,638	190,280	0.88		0.35
1989	998	1,361	33,273	326,065	0.81		1.49
1990	1,312	2,176	43,736	248,922	0.55		0.37
1991	1,314	7,758	43,816	704,031	1.72		0.47
1992	1,100	2,227	36,675	407,847	1.34		0.51
1993	135	902	39,502	255,553	1.05		0.36
1994	170	4,380	46,912	296,357	1.19		0.60
1995	167	2,743	67,047	446,152	1.32		0.74
1996	162	1,381	62,378	684,962	0.56		0.69
1997	160	3,735	62,279	587,799	0.94		1.08
1998	1,146	5,450	43,499	392,335	0.86	1.16	1.20
1999	1,149	9,708	27,451	369,362	0.9	1.39	1.73
2000	1,568	4,289	43,532	464,236	1.28	1.04	1.06
2001	1,303	6,557	40,791	483,926	1.34	1.21	1.49
2002	2,147	5,550	42,236	381,849	0.9	0.97	0.95
2003	1,686	14,300	35,305	615,522	1.11	0.73	1.45
2004	1,732	7,321	32,650	1,028,231	1.08	1.20	1.41
2005	1,836	9,932	28,675	815,600	1.08	0.96	1.39
2006	2,100	14,752	33,785	1,231,415	0.94	0.95	1.49
2007	1,990	10,021	31,576	776,180	1.54	1.11	1.06
2008	2,666	5,526	33,783	546,297	1.96	0.79	1.07
2009	2,136	10,015	42,278	711,821	0.93	1.05	1.46
2010	1,811	11,188	56,544	876,505	0.88	0.73	1.60
2011	2,085	9,535	33,978	330,071	0.94	0.73	1.26

3.8 Figures

Figure 3.1. Mean length at age (mm) and estimated 95% confidence interval of the population.

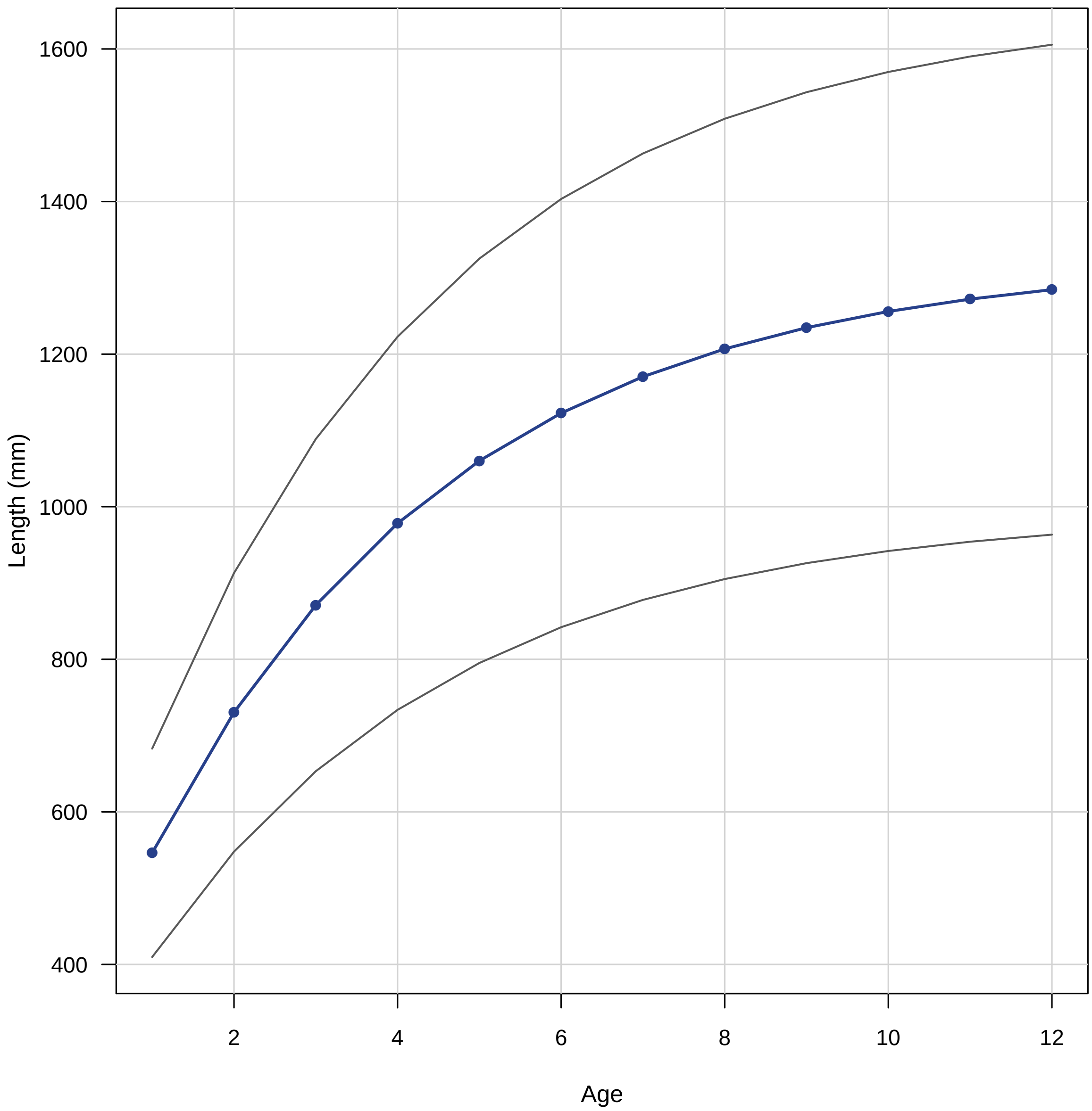


Figure 3.2. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, mrip to pooled recreational landings and discards, cA to pooled commercial landings and discards. N indicates the number of trips from which individual fish samples were taken.

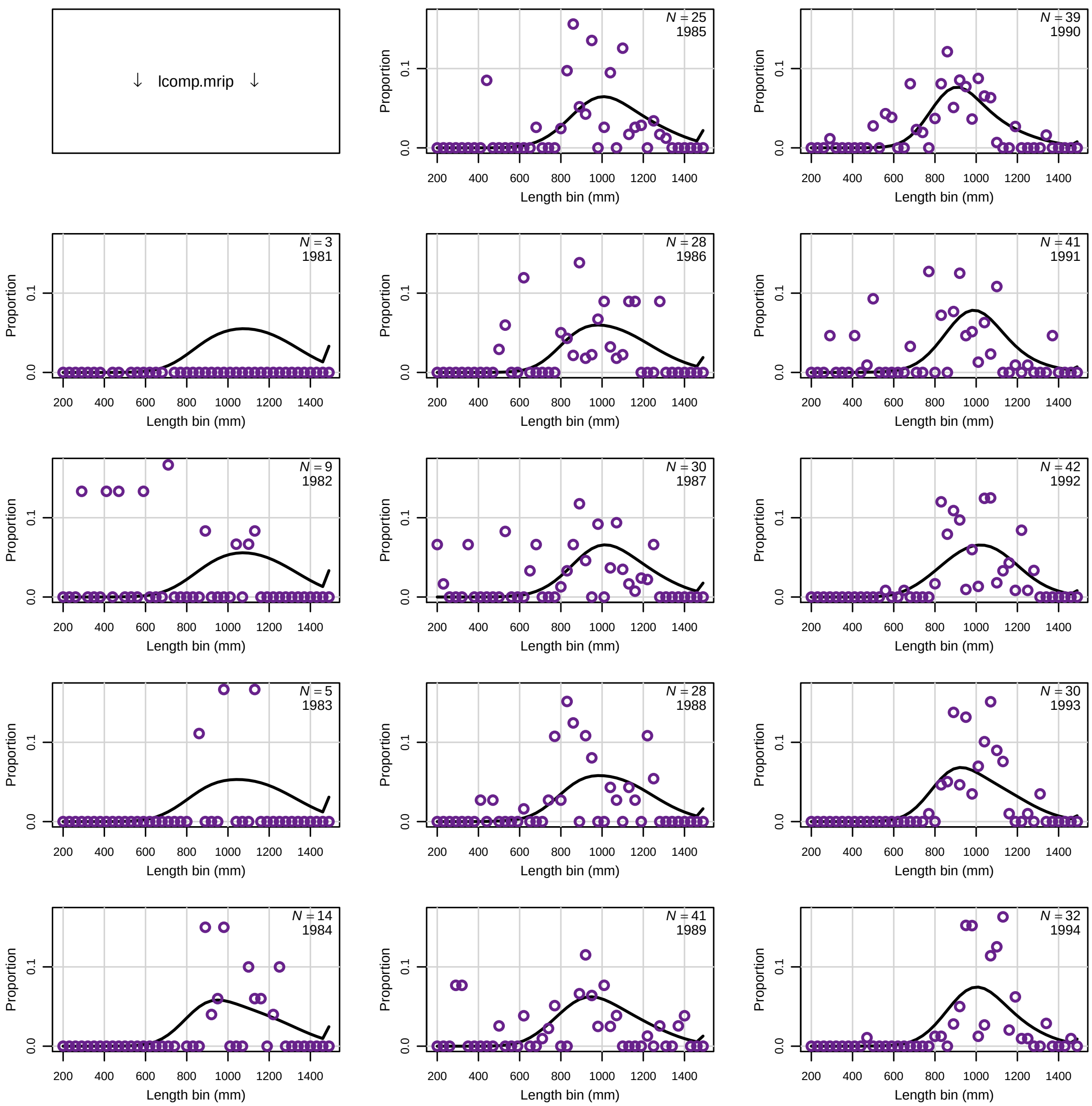


Figure 3.2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

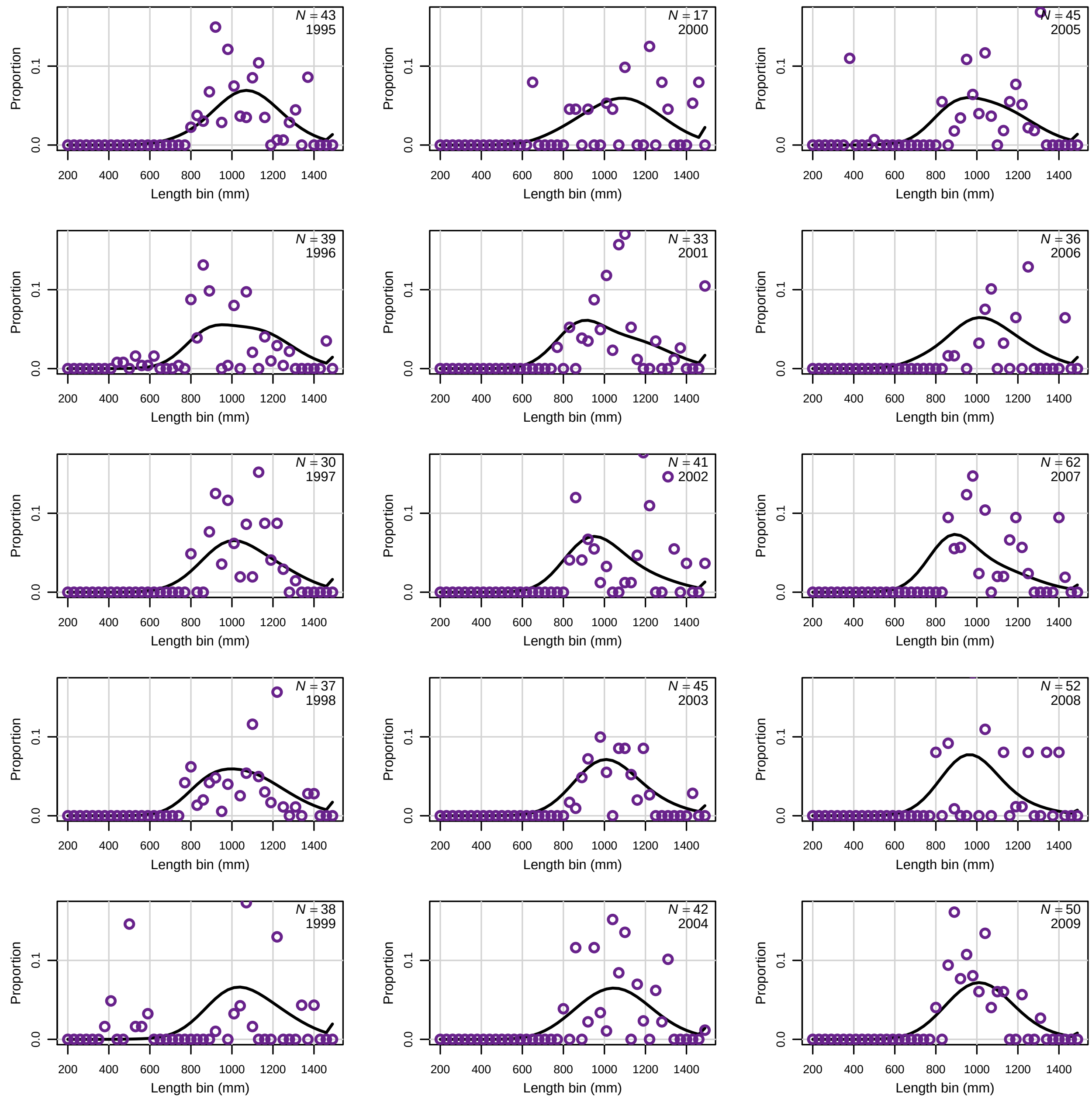


Figure 3.2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

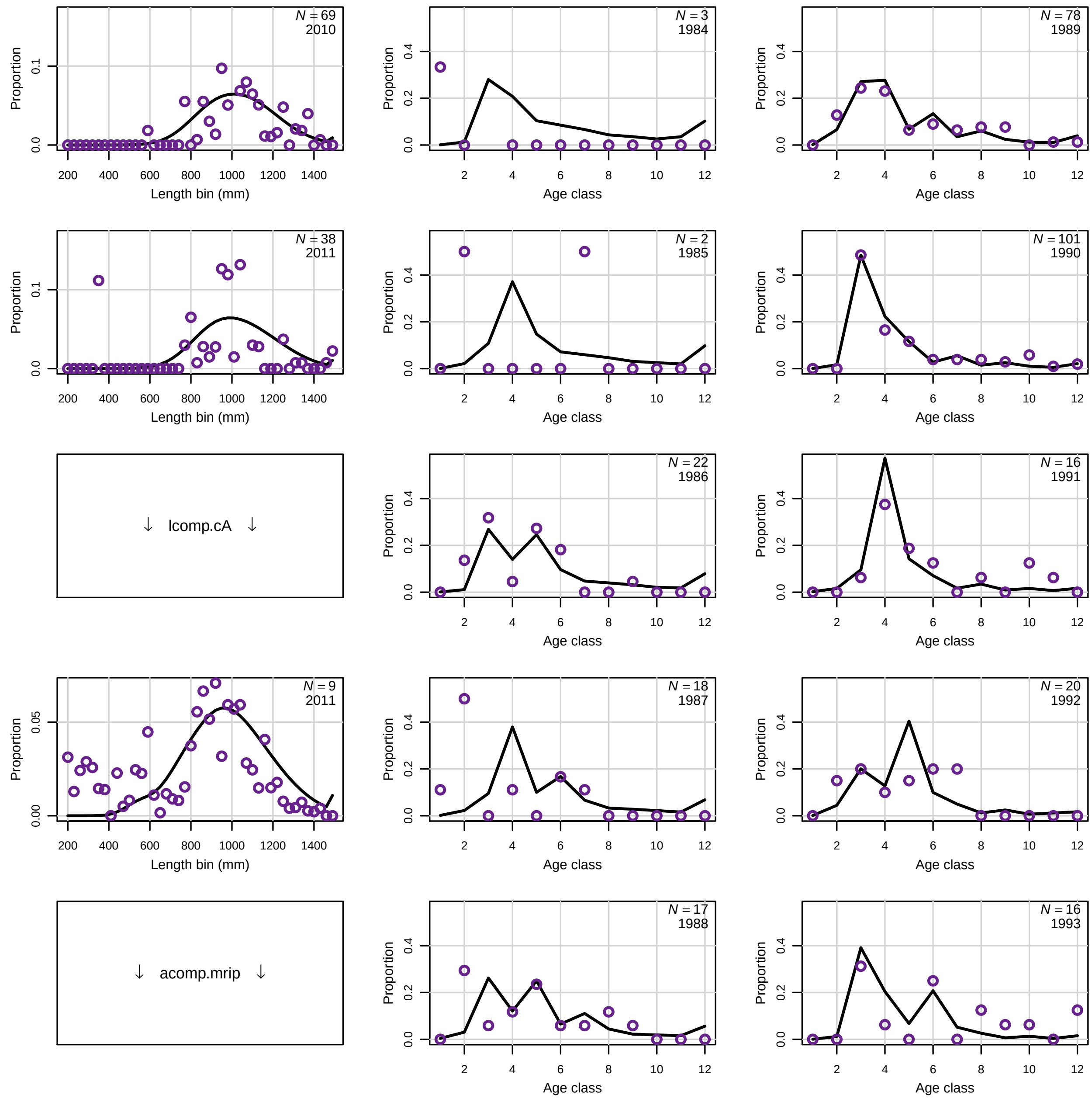


Figure 3.2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

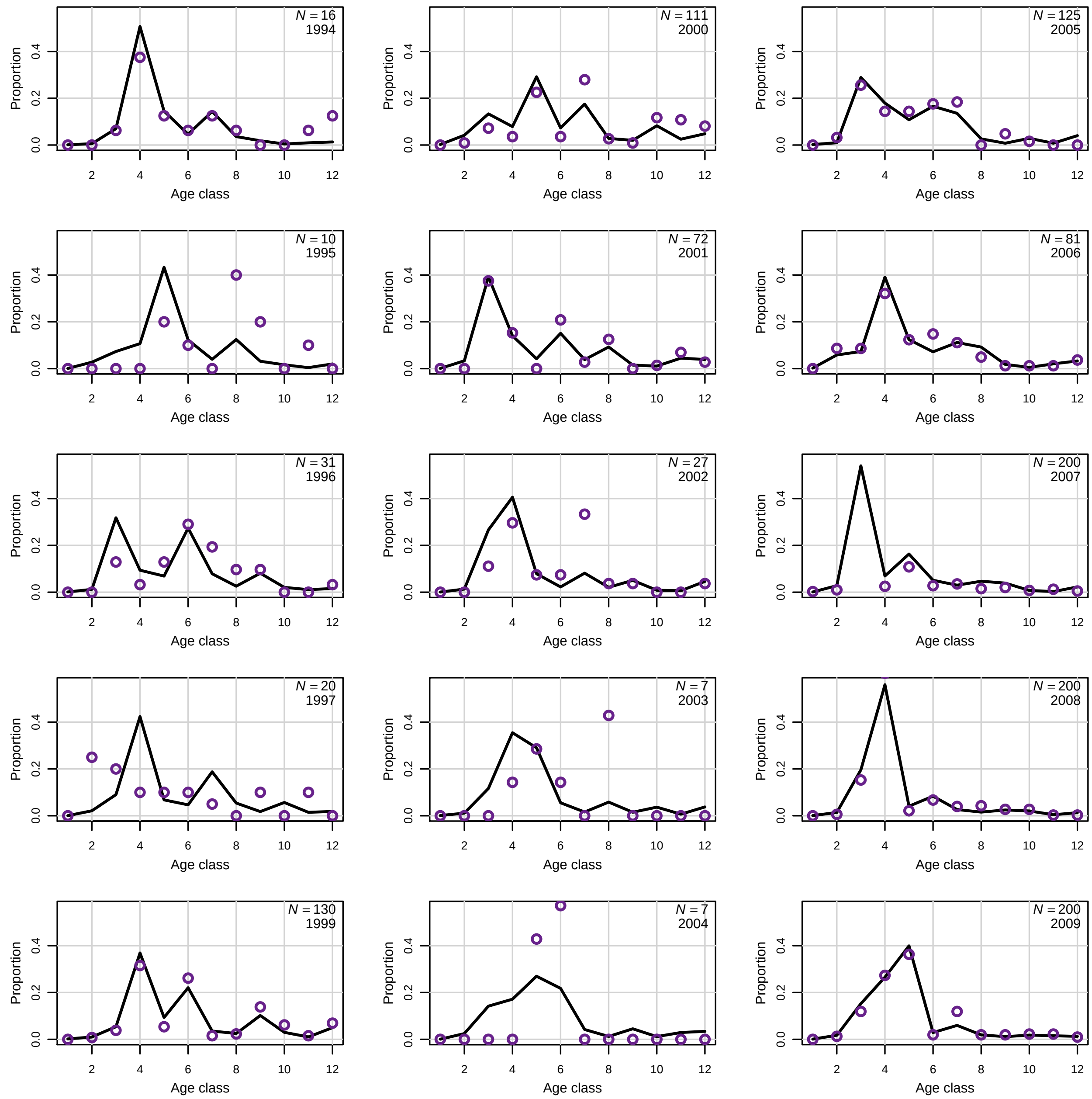


Figure 3.2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

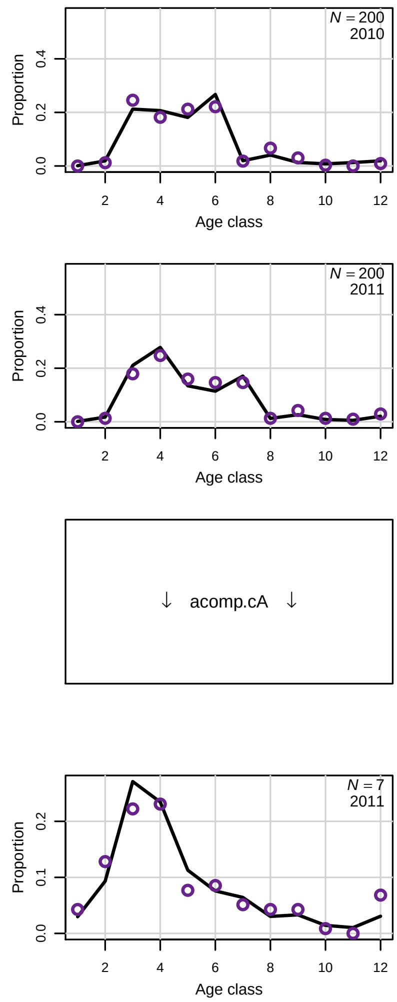


Figure 3.3. Top panel is a bubble plot of length composition residuals from the general recreational fishery. Dark represents overestimates and light indicates underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

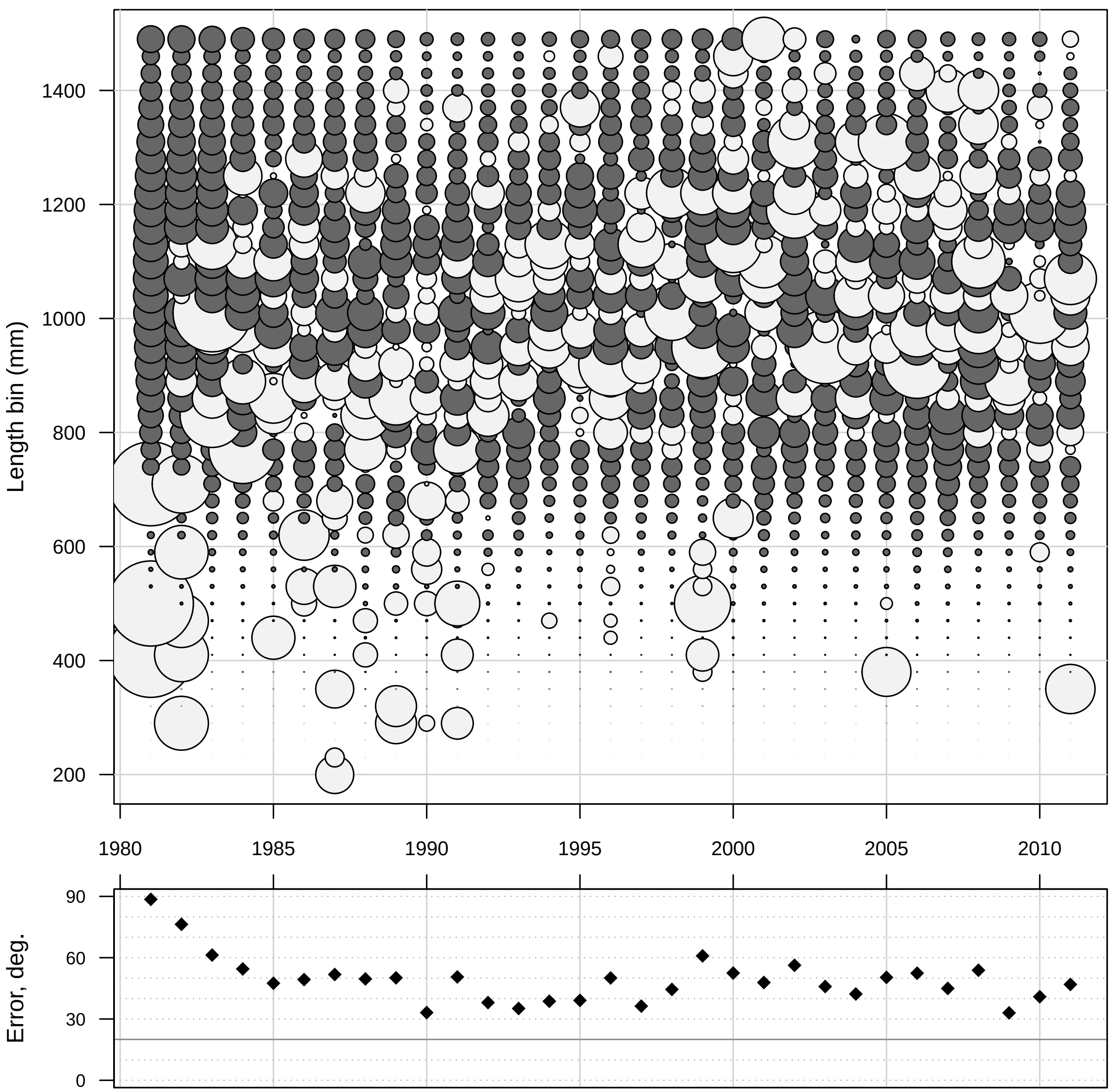


Figure 3.4. Top panel is a bubble plot of length composition residuals from the general commercial fishery (pooled over years). Dark represents overestimates and light indicates underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

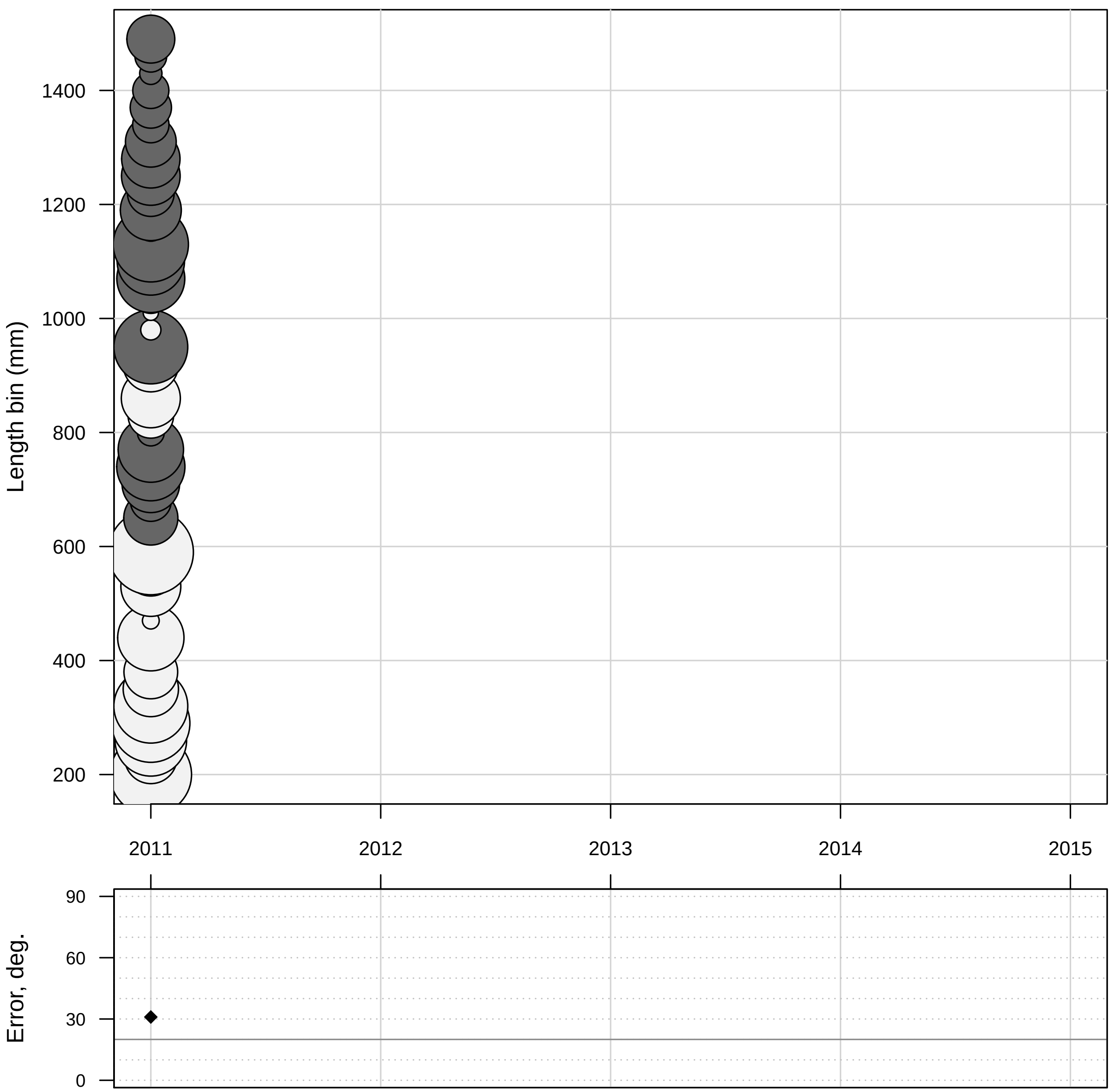


Figure 3.5. Top panel is a bubble plot of age composition residuals from the general recreational fishery. Dark represents overestimates and light indicates underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

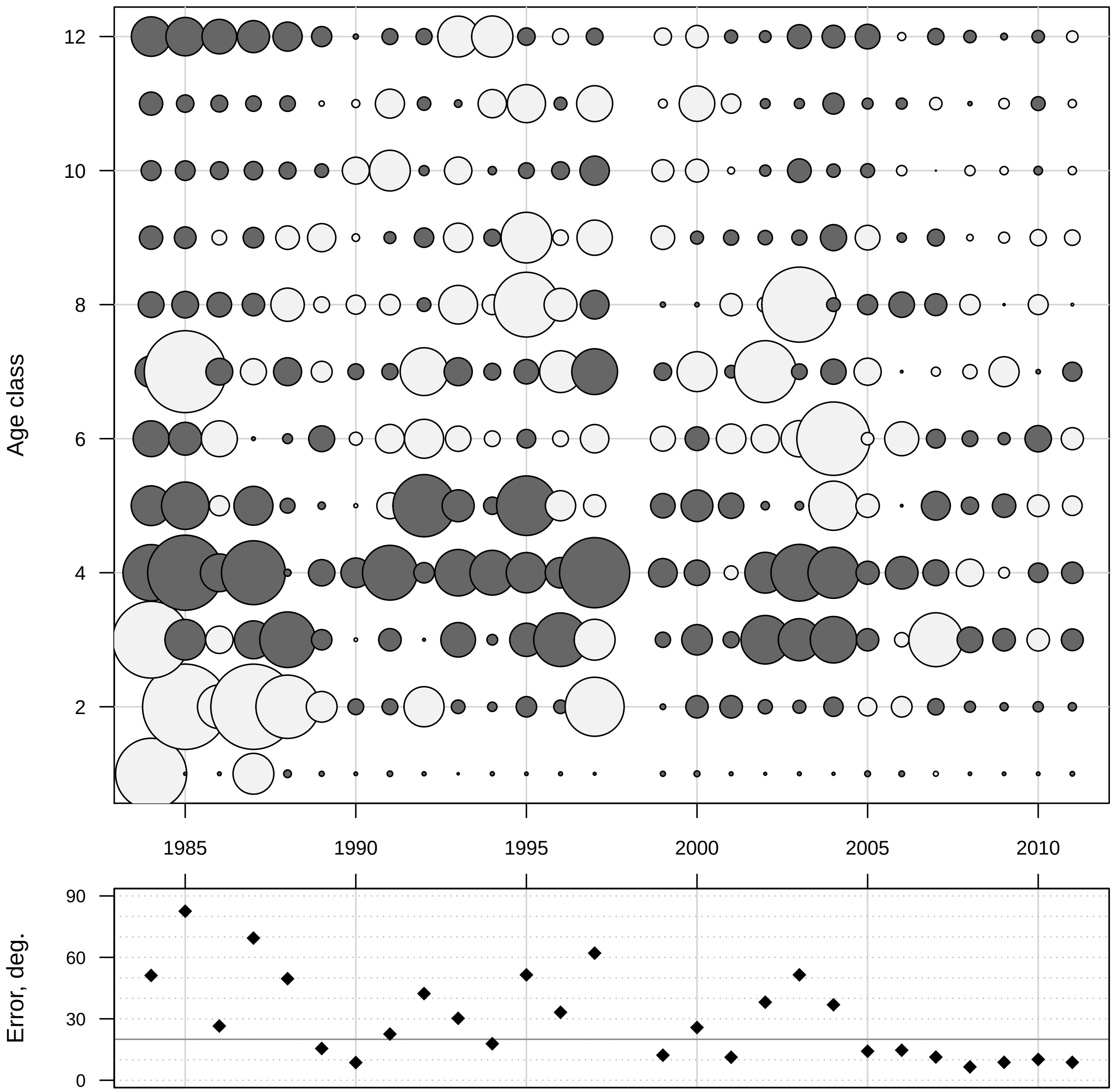


Figure 3.6. Top panel is a bubble plot of age composition residuals from the general commercial fishery (pooled over years). Dark represents overestimates and light indicates underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.

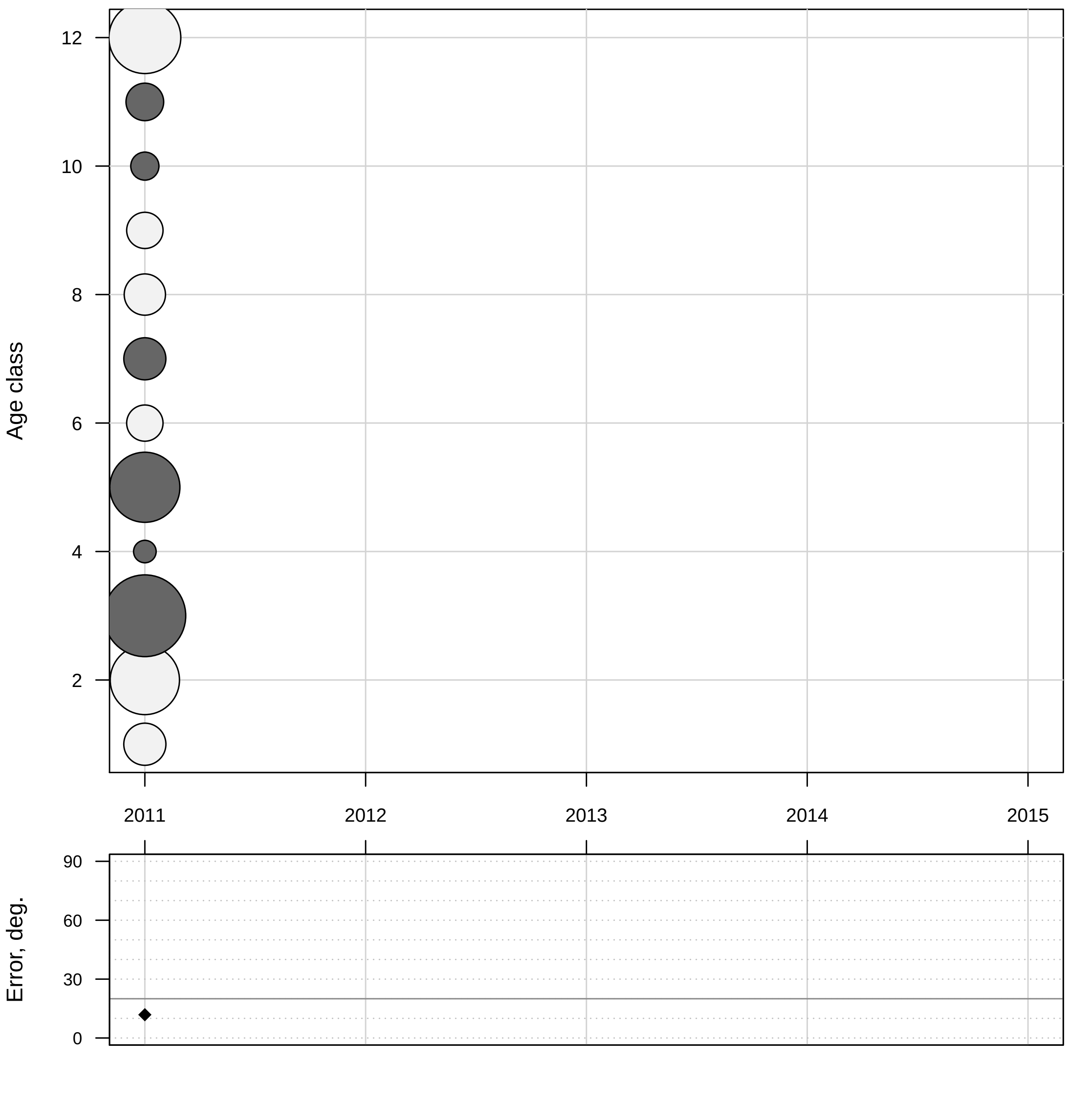


Figure 3.7. Observed (open circles) and estimated (line, solid circles) combined commercial landings and discards (1000 lb whole weight).

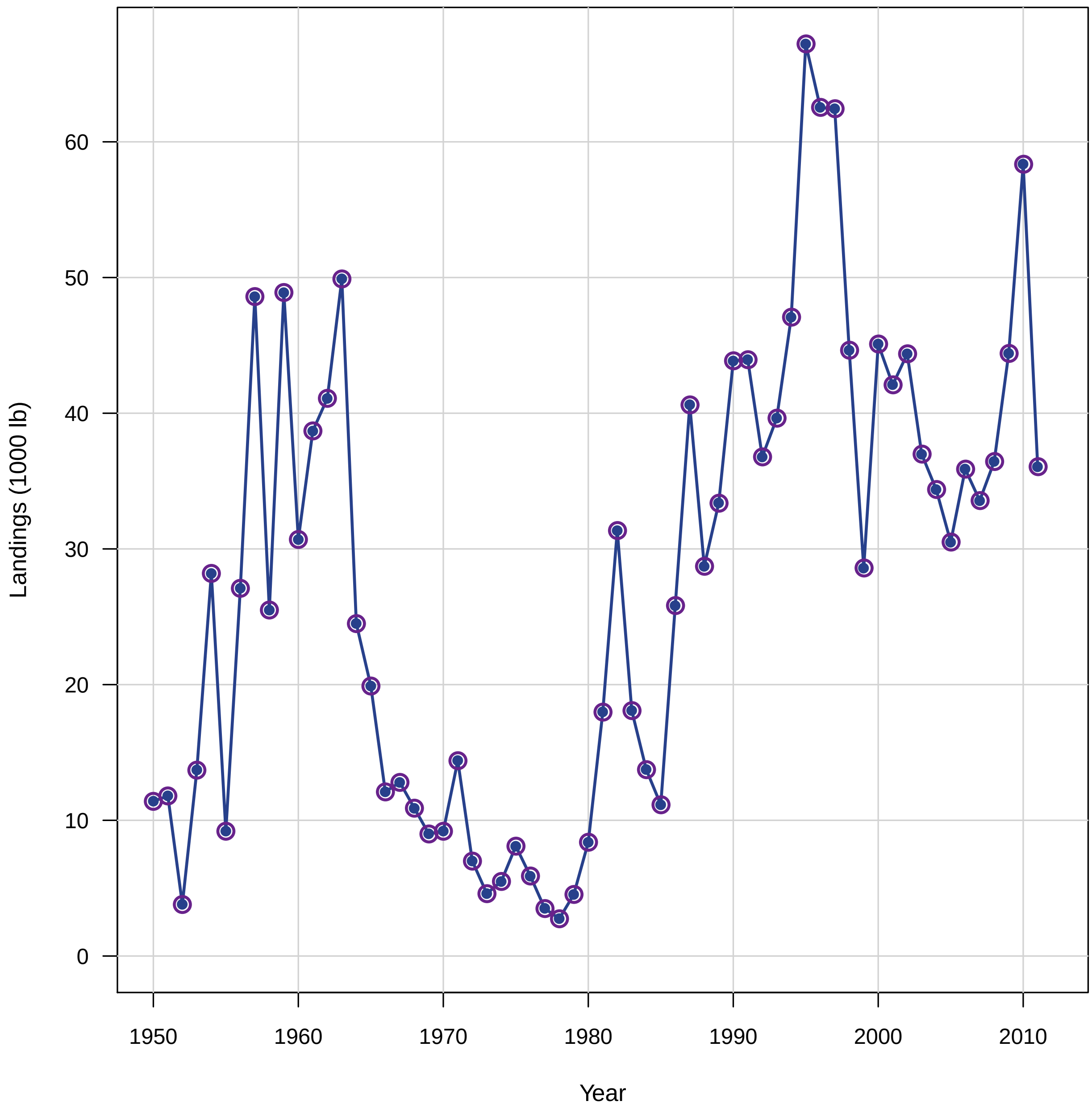


Figure 3.8. Observed (open circles) and estimated (line, solid circles) combined recreational landings and discards (1000 fish).

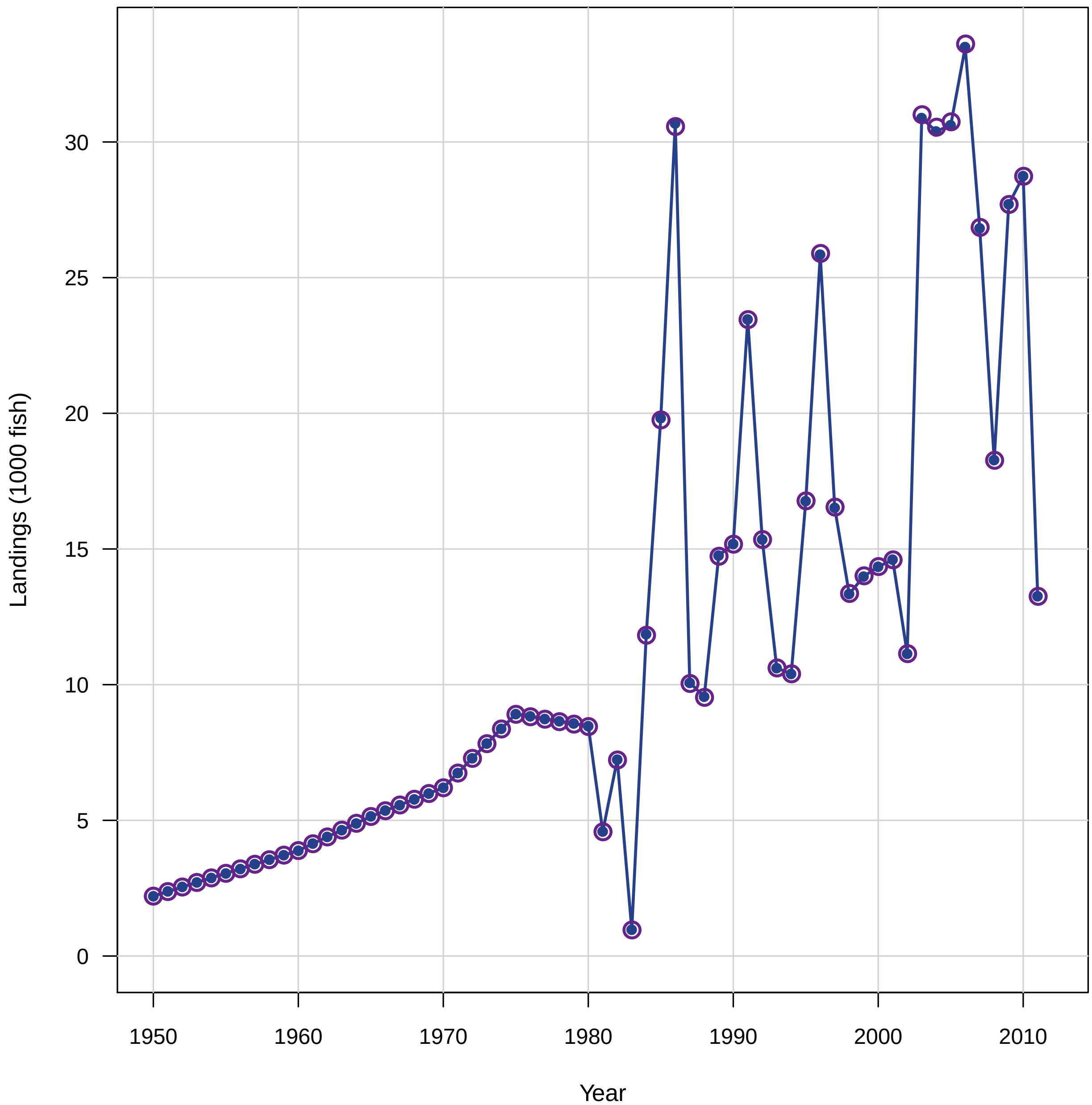


Figure 3.9. Observed (open circles) and estimated (line, solid circles) index of abundance- headboat.

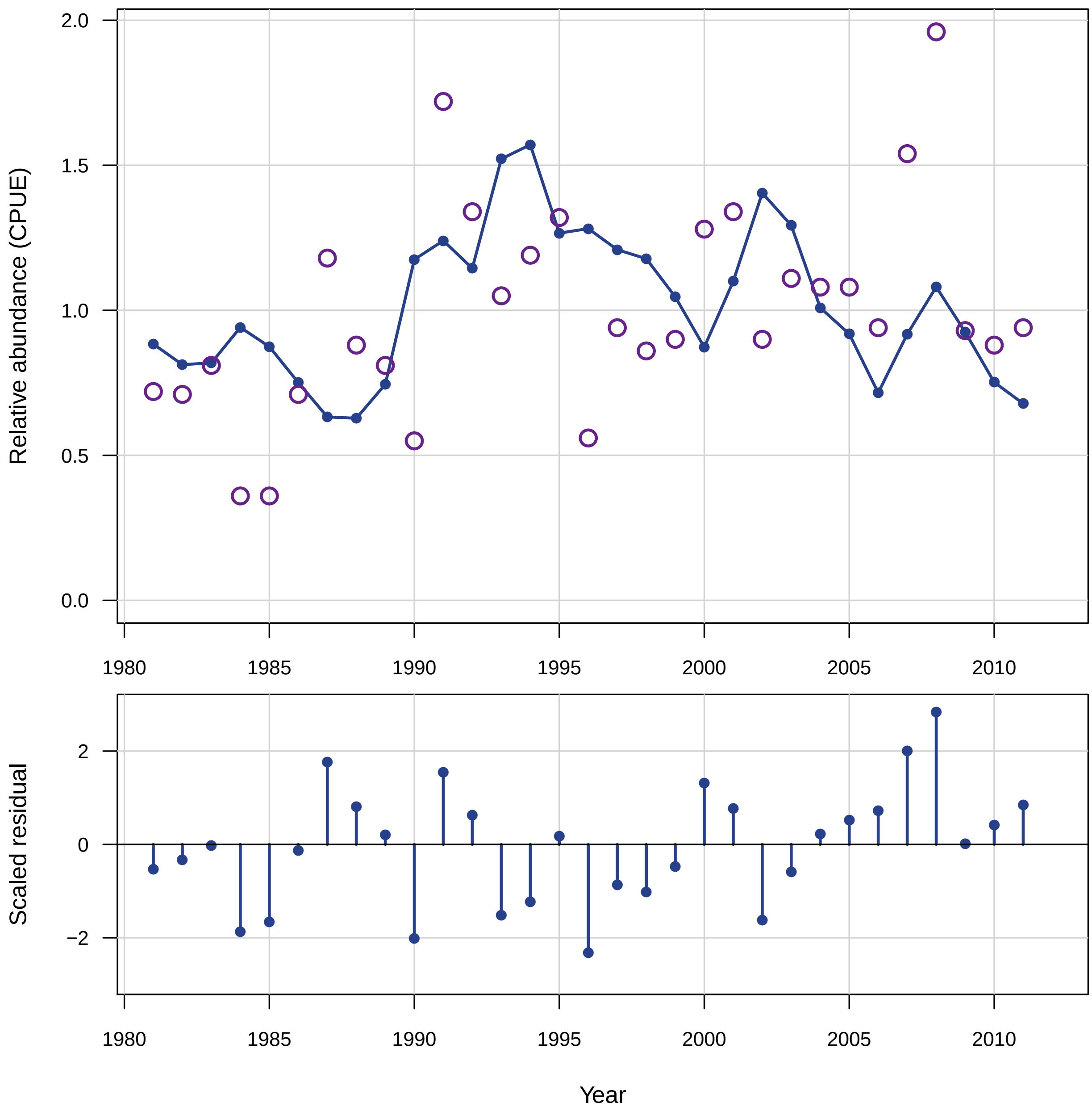


Figure 3.10. Observed (open circles) and estimated (line, solid circles) index of abundance- South Carolina charterboat logbook.

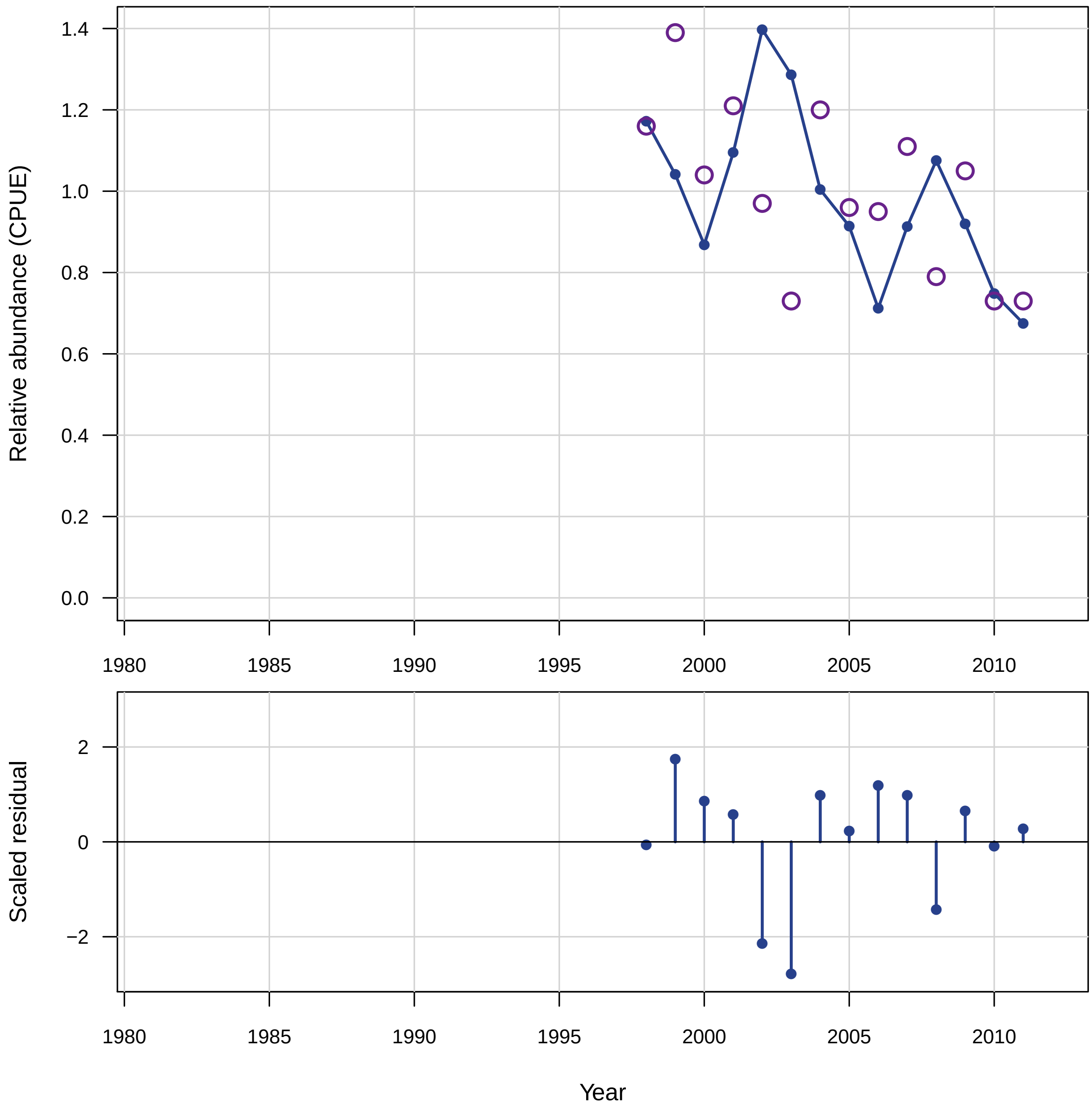


Figure 3.11. Estimated abundance at age at start of year.

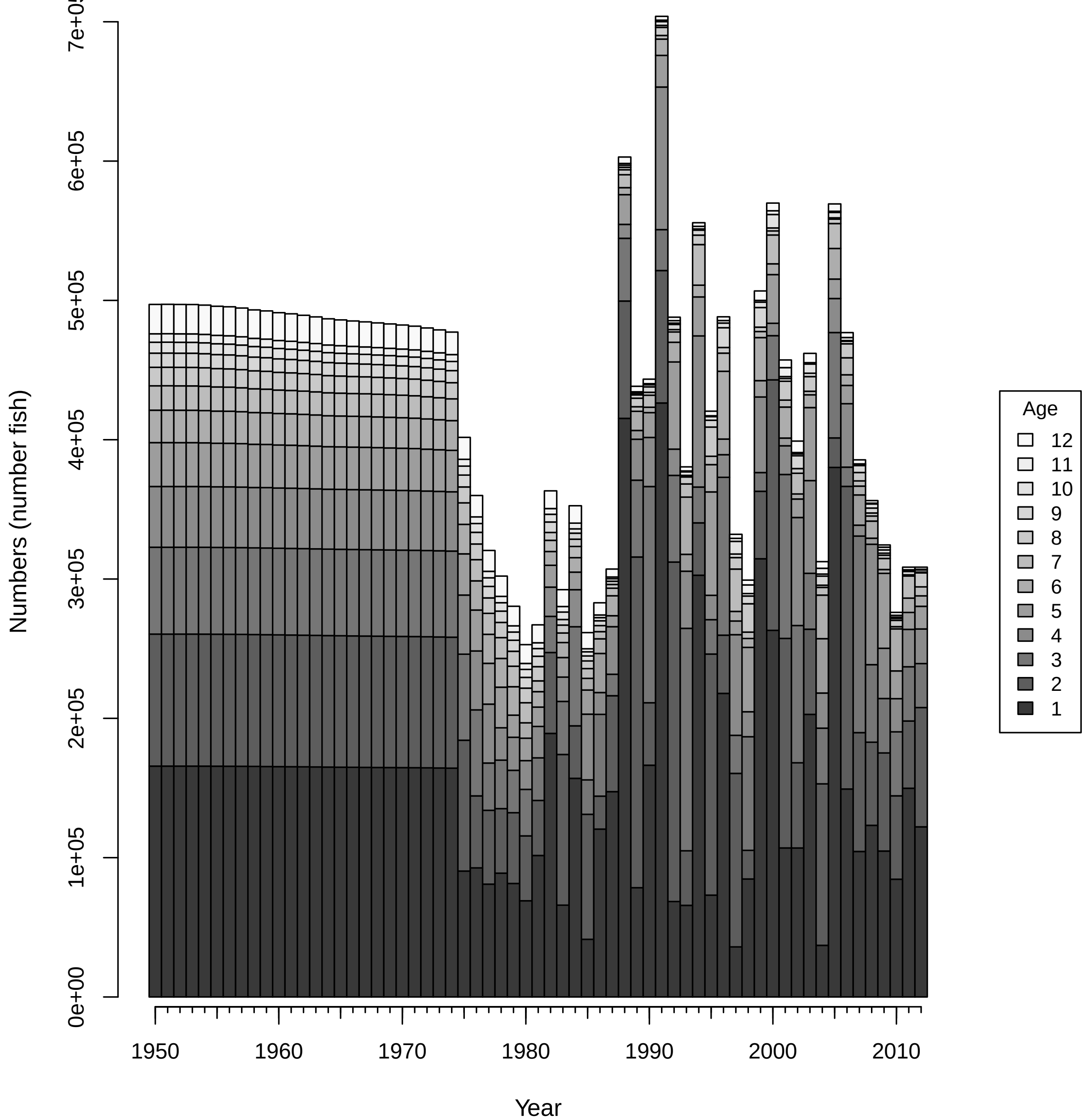


Figure 3.12. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates R_{MSY}. Bottom panel: log recruitment residuals.

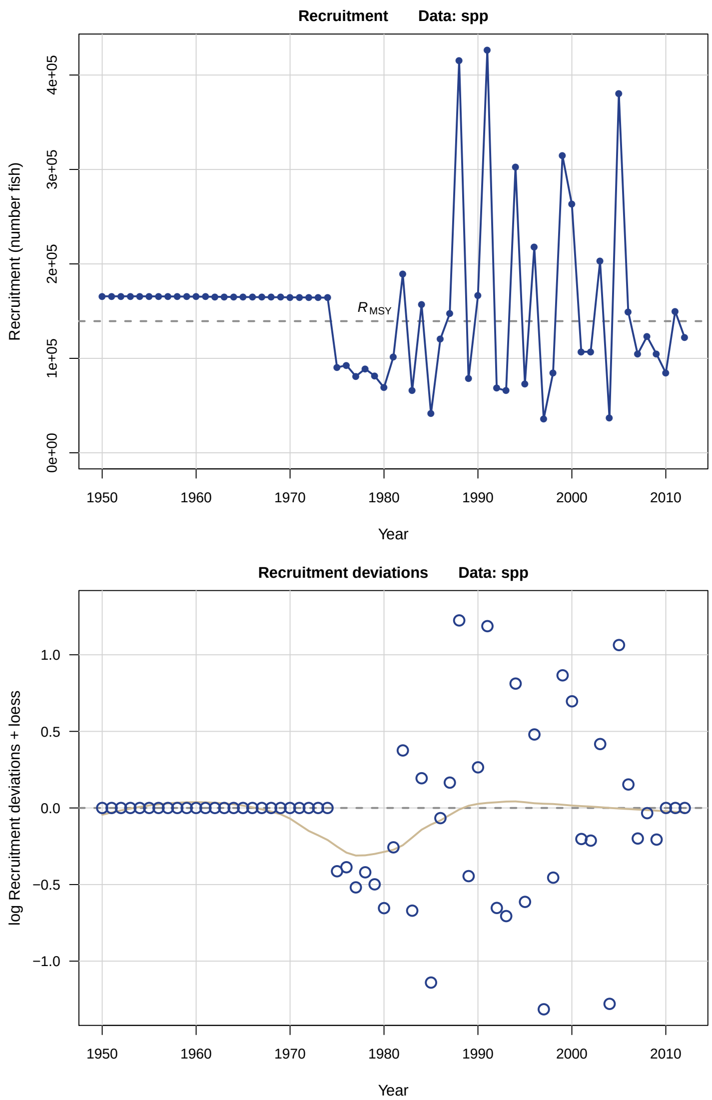


Figure 3.13. Estimated biomass at age at start of year.

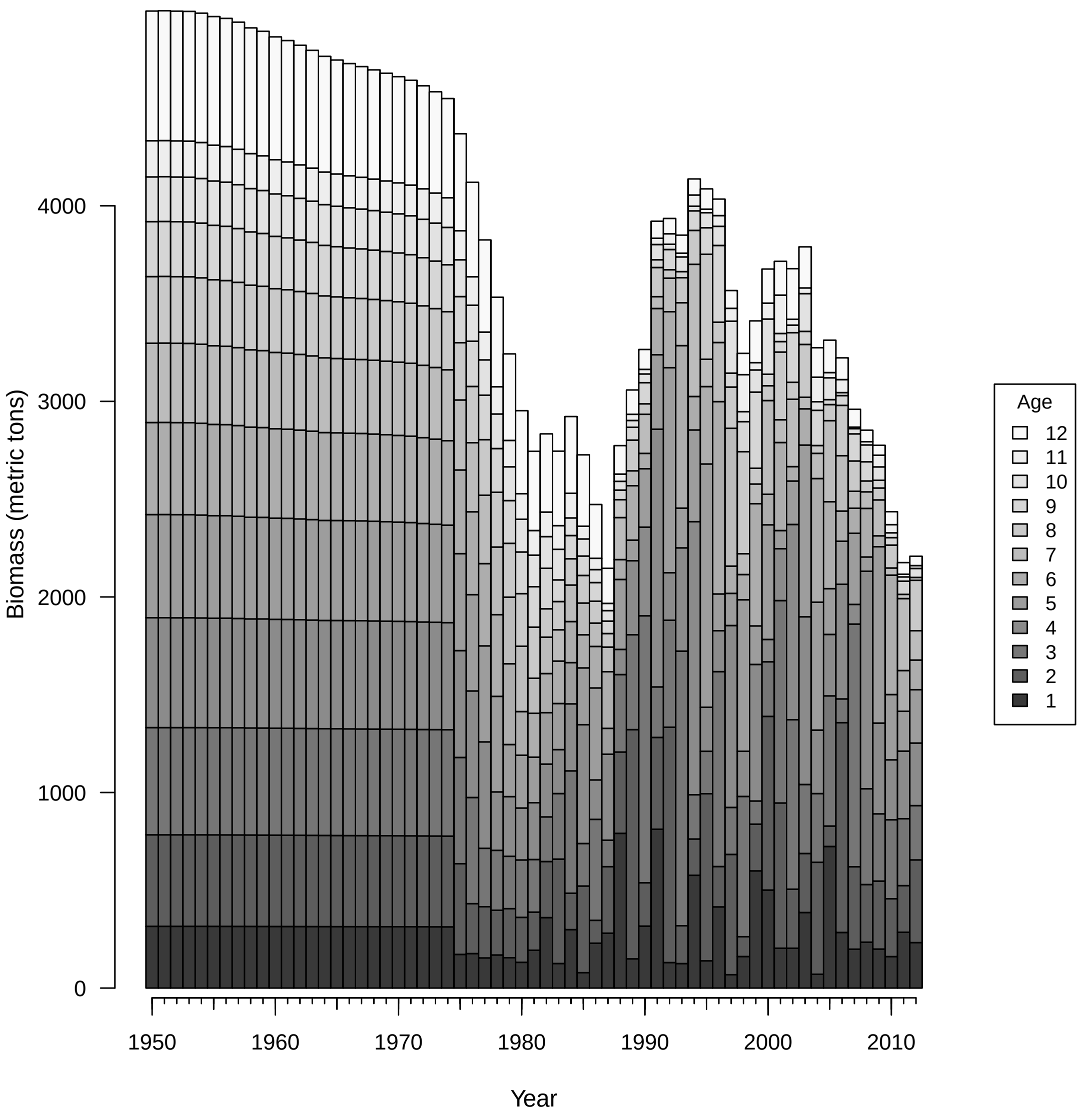


Figure 3.14. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates B_{MSY}. Bottom panel: Estimated spawning stock (mature female biomass) at time of peak spawning.

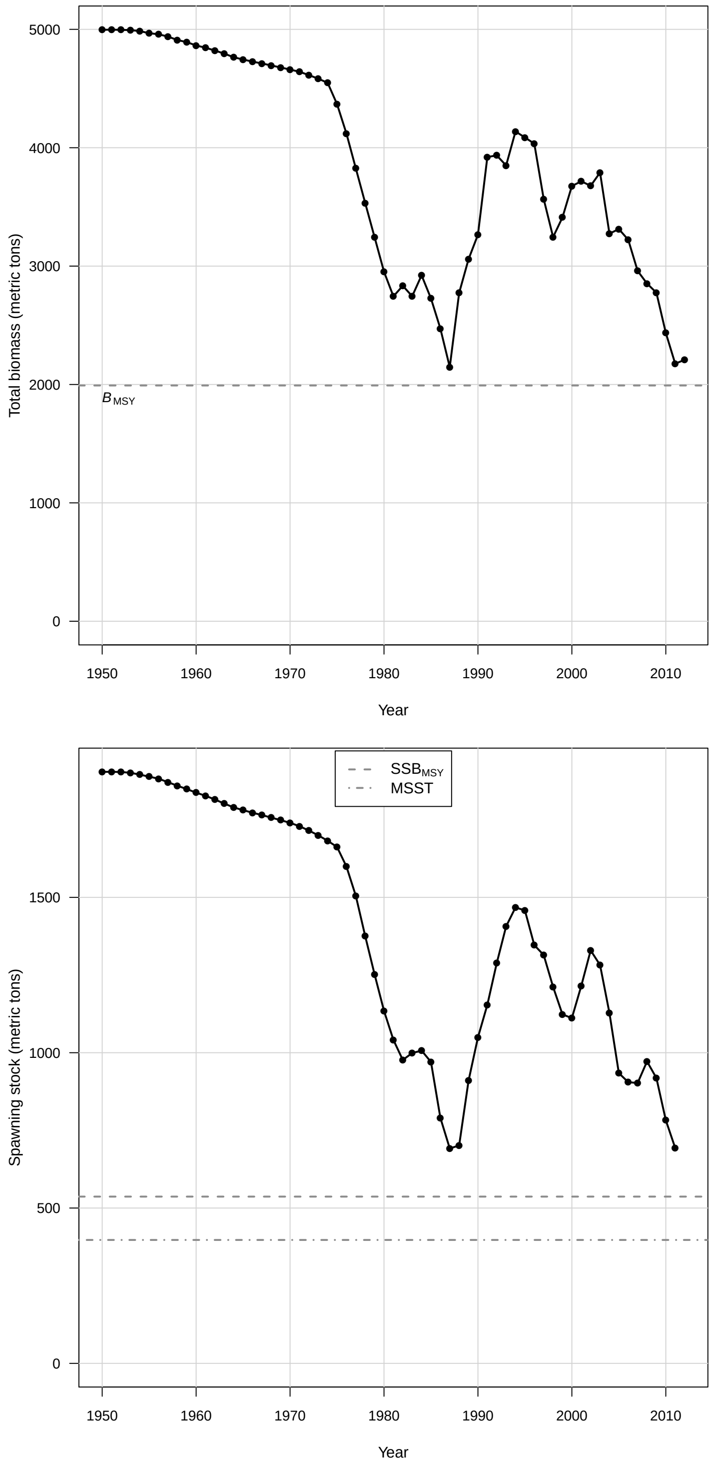


Figure 3.15. Selectivities of fleets 1950–2011. Top panel: pooled commercial including landings and discards. Second panel: pooled recreational including landings and discards.

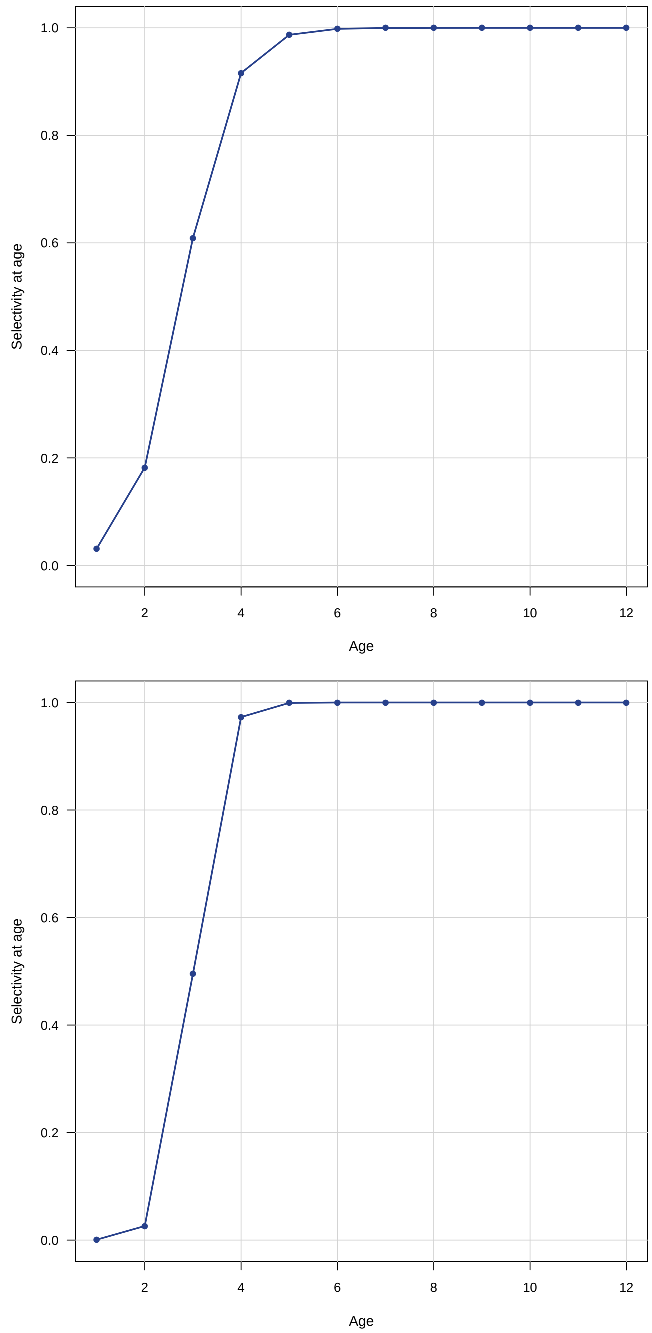


Figure 3.16. Average selectivity from the terminal assessment year weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and central-tendency projections.

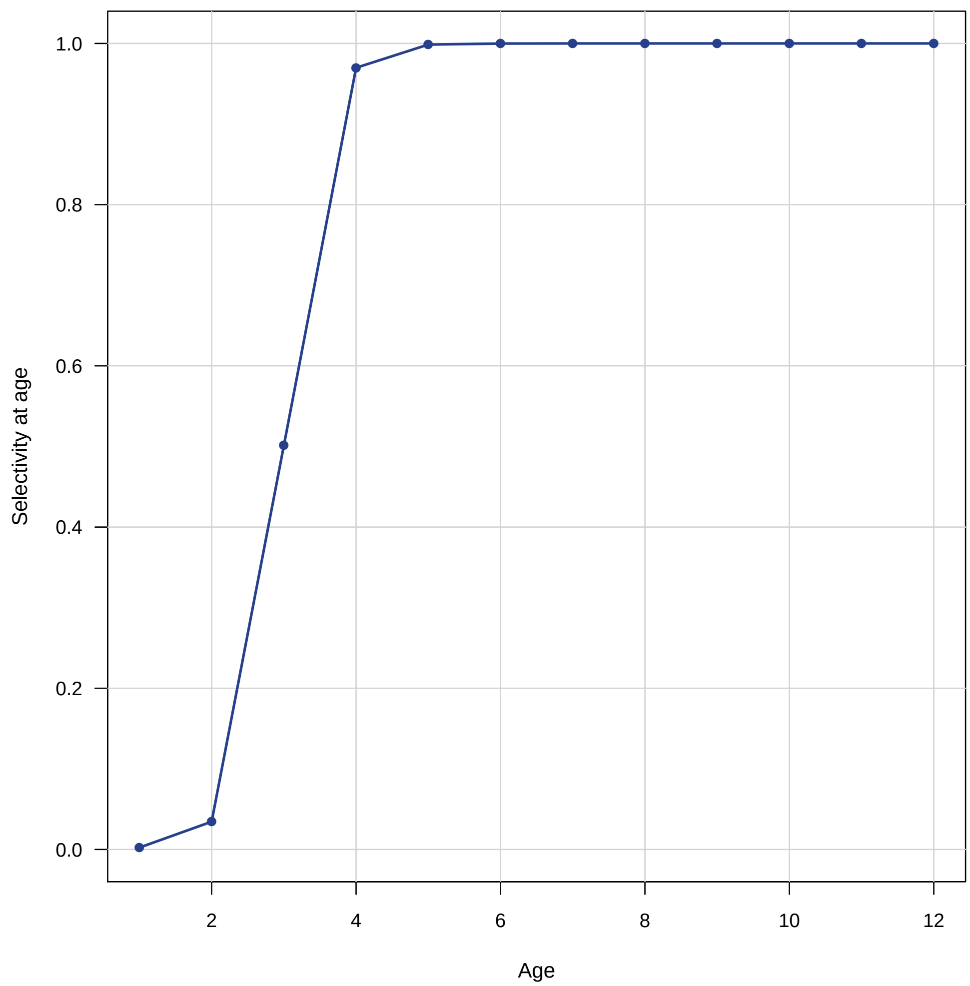


Figure 3.17. Estimated fully selected fishing mortality rate (per year) by fishery. cA refers to commercial, mrip to recreational, both include discards.

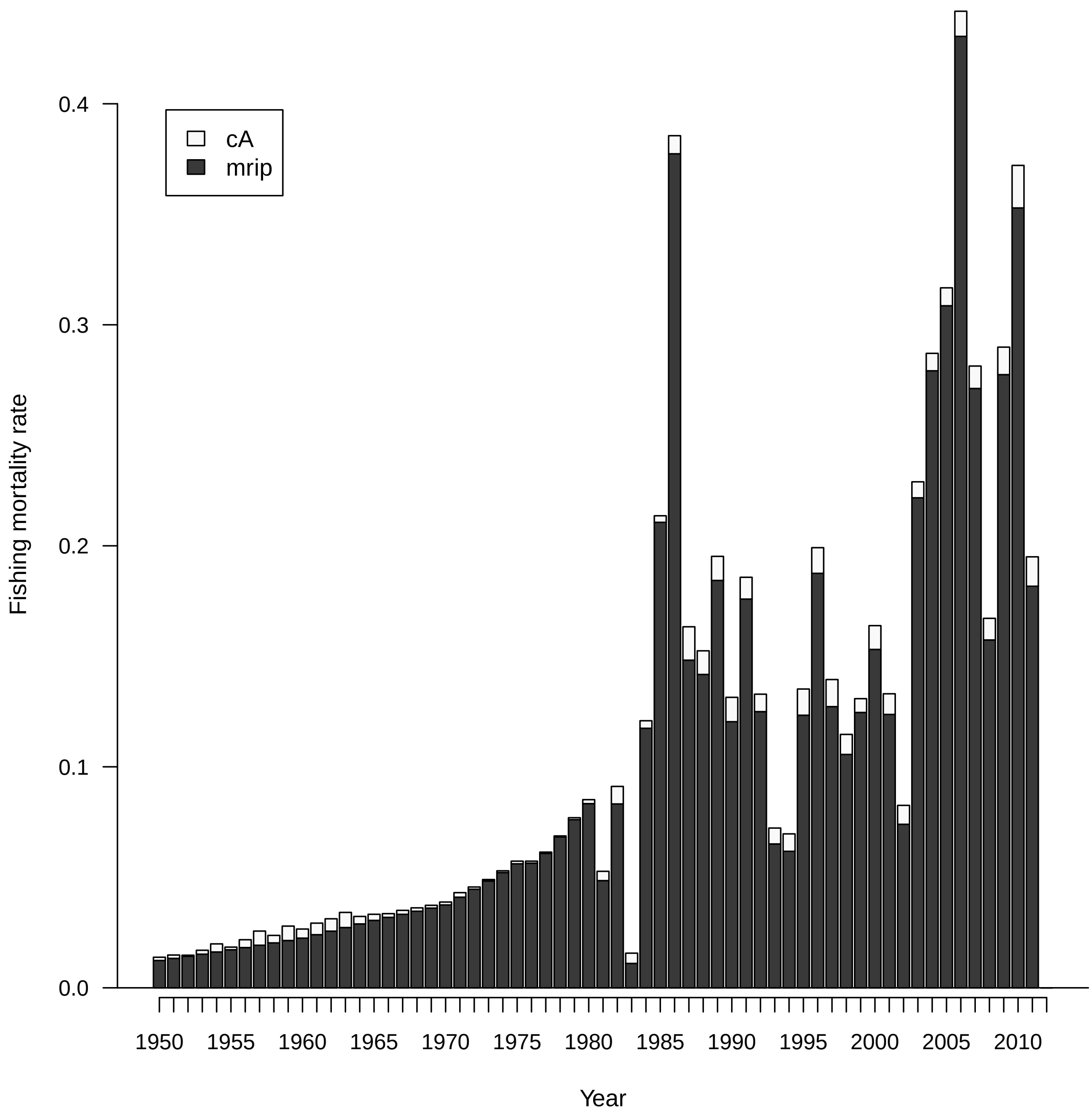


Figure 3.18. Estimated removals in numbers by fishery from the catch-age model. cA refers to the commercial fleet and mrip refers to the recreational fleet.

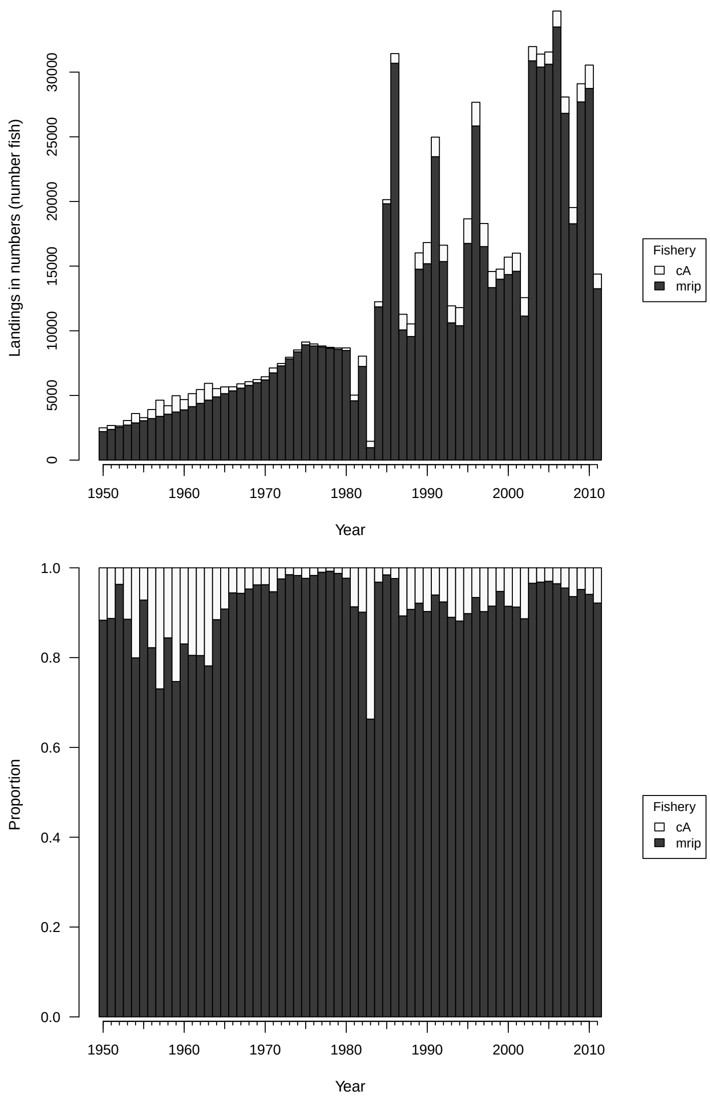


Figure 3.19. Estimated removals in whole weight by fishery from the catch-age model. cA refers to the commercial fleet and mrip refers to the recreational fleet.

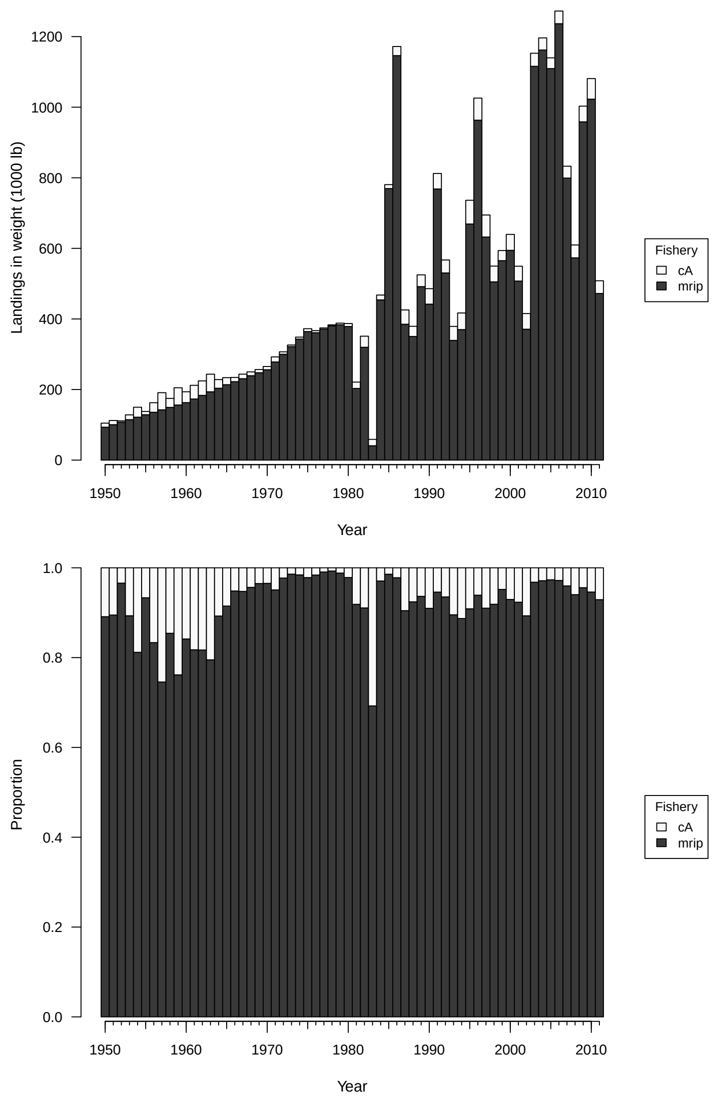
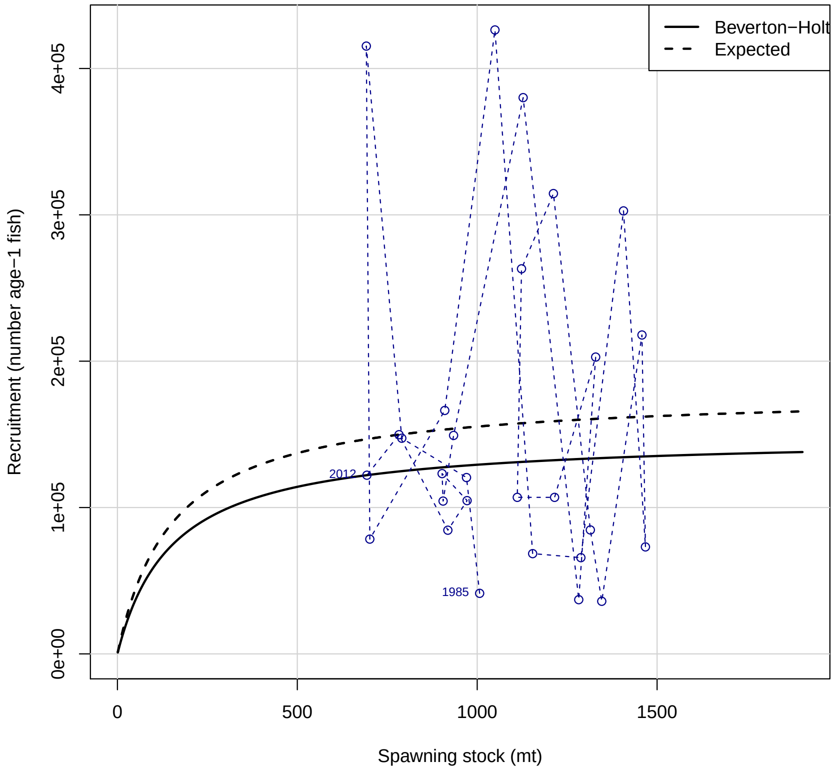


Figure 3.20. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Years within panel indicate year of recruitment generated from spawning biomass one year prior. Bottom panel: log of recruits (number age-1 fish) per spawner (biomass of mature females) as a function of spawners.



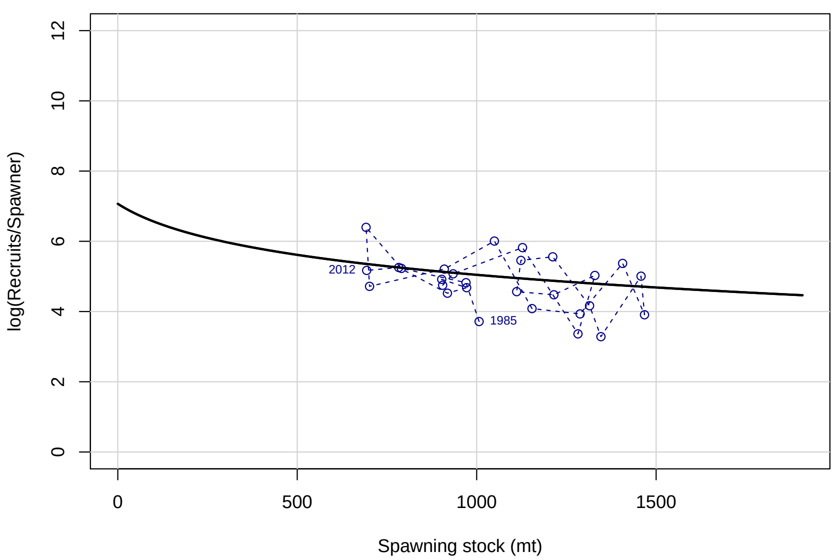


Figure 3.21. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model.

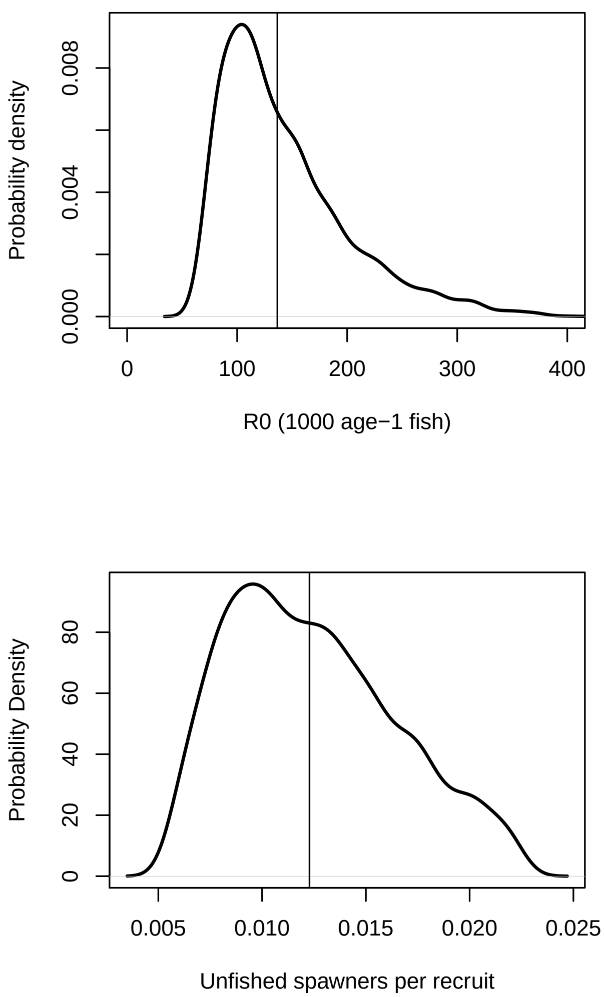


Figure 3.22. Estimated time series of static spawning potential ratio, the annual equilibrium spawners per recruit relative to that at the unfished level. Horizontal dashed line indicates the equilibrium MSY level.

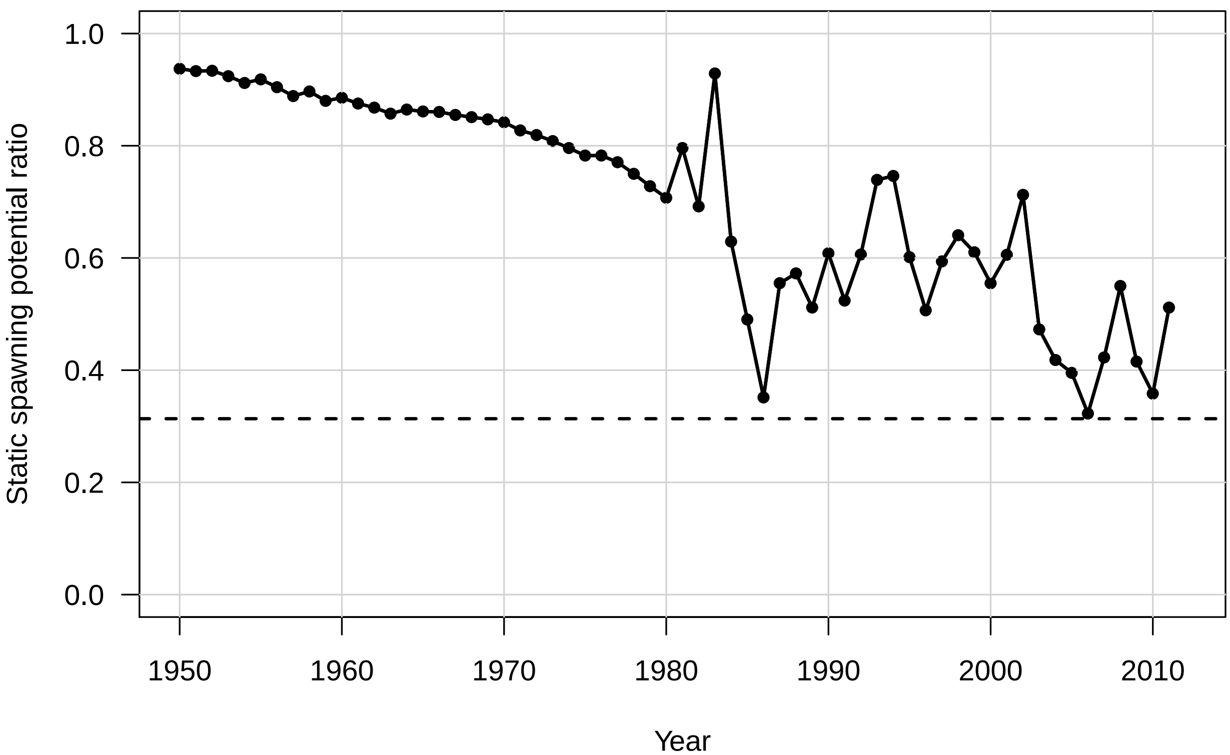


Figure 3.23. Top panel: yield per recruit. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the x% levels provide $F_{x\%}$. Both curves are based on average selectivity from the end of the assessment period.

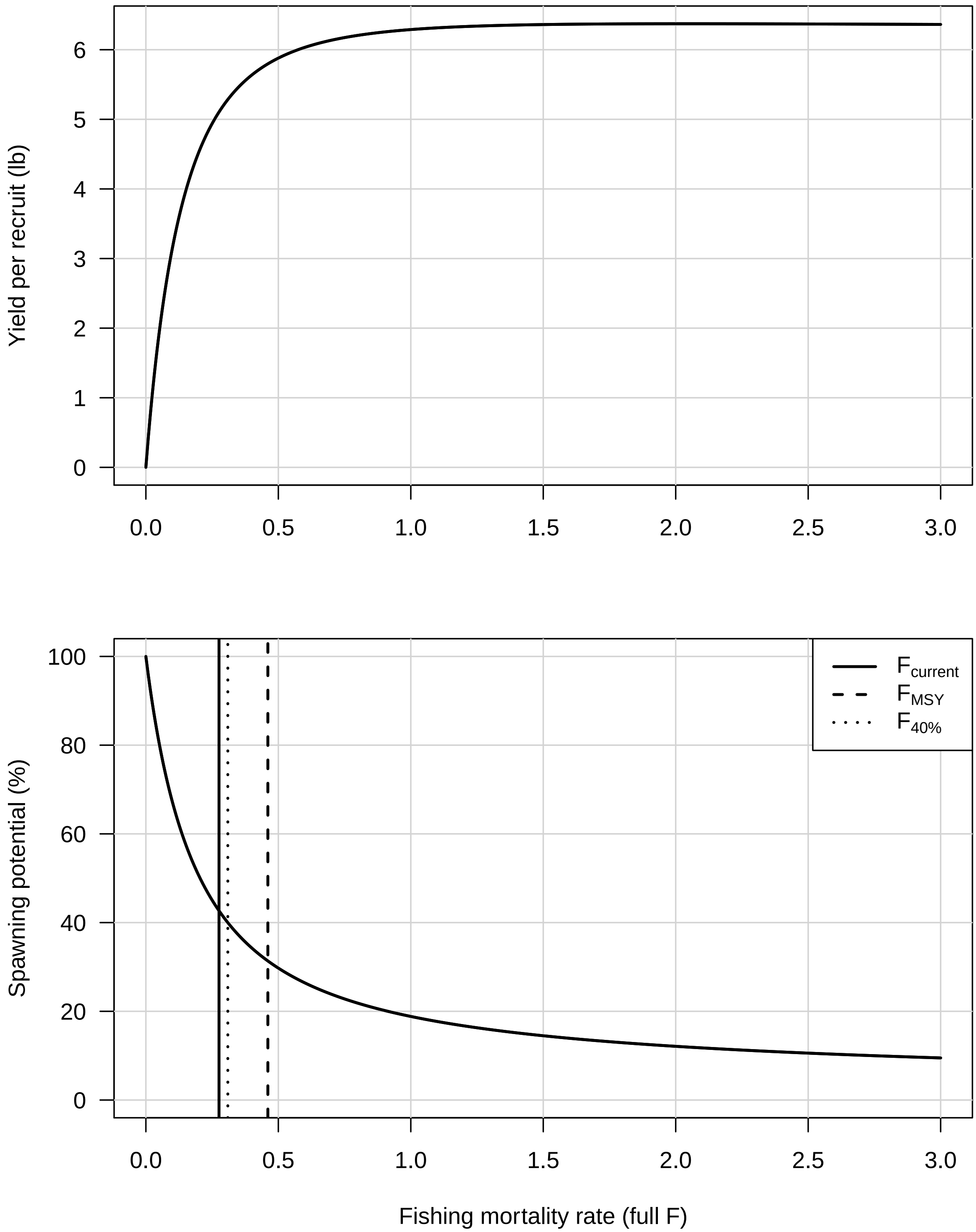


Figure 3.24. Top panel: equilibrium landings. The peak occurs where fishing rate is $F_{\mathrm{MSY}} = 0.461$ *and equilibrium landings are* $\mathrm{MSY} = 808$ *(1000 lb). Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.*

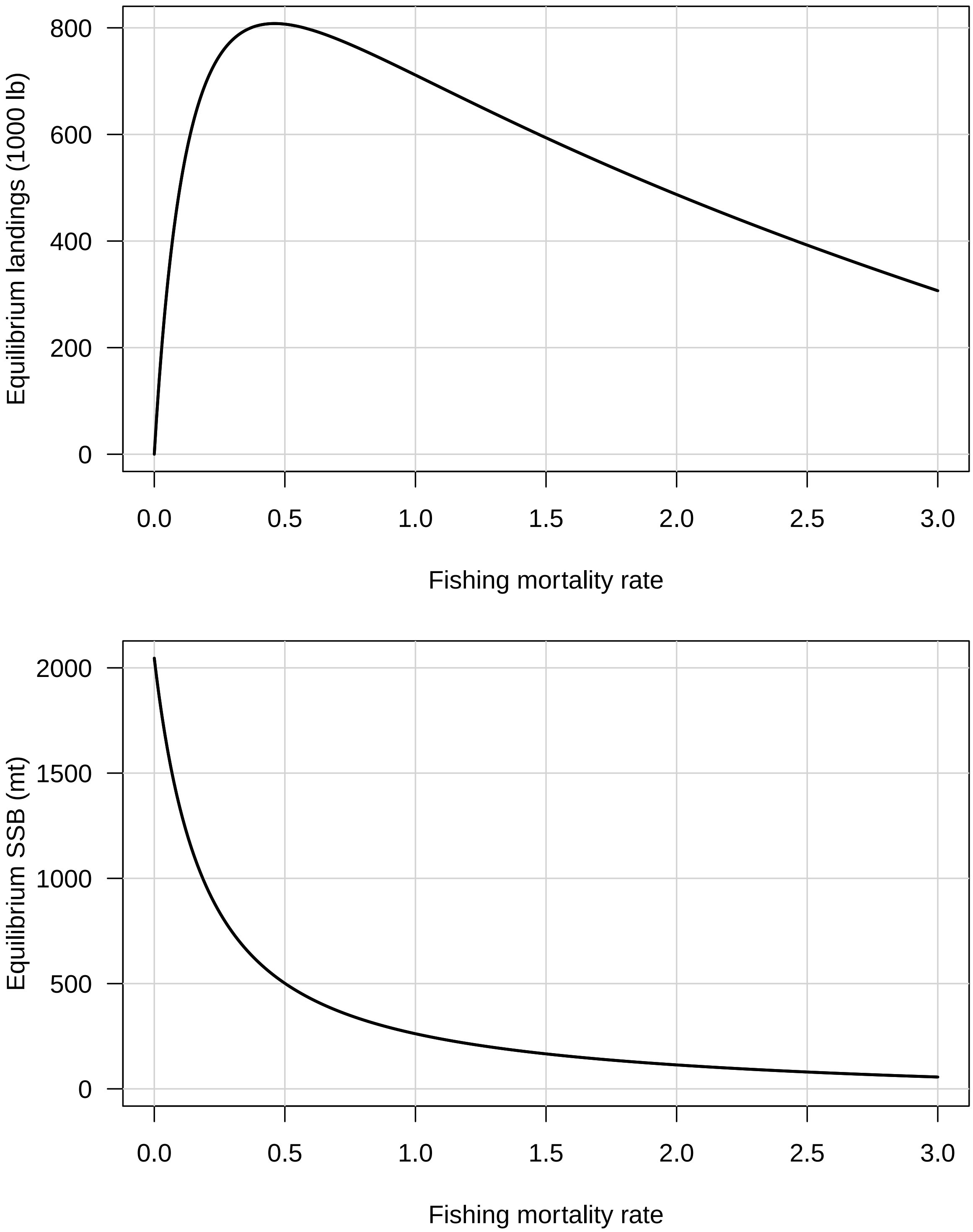


Figure 3.25. Equilibrium landings as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is $B_{\mathrm{MSY}} = 1991.6$ *mt and equilibrium landings are* MSY = 808 *(1000 lb).*

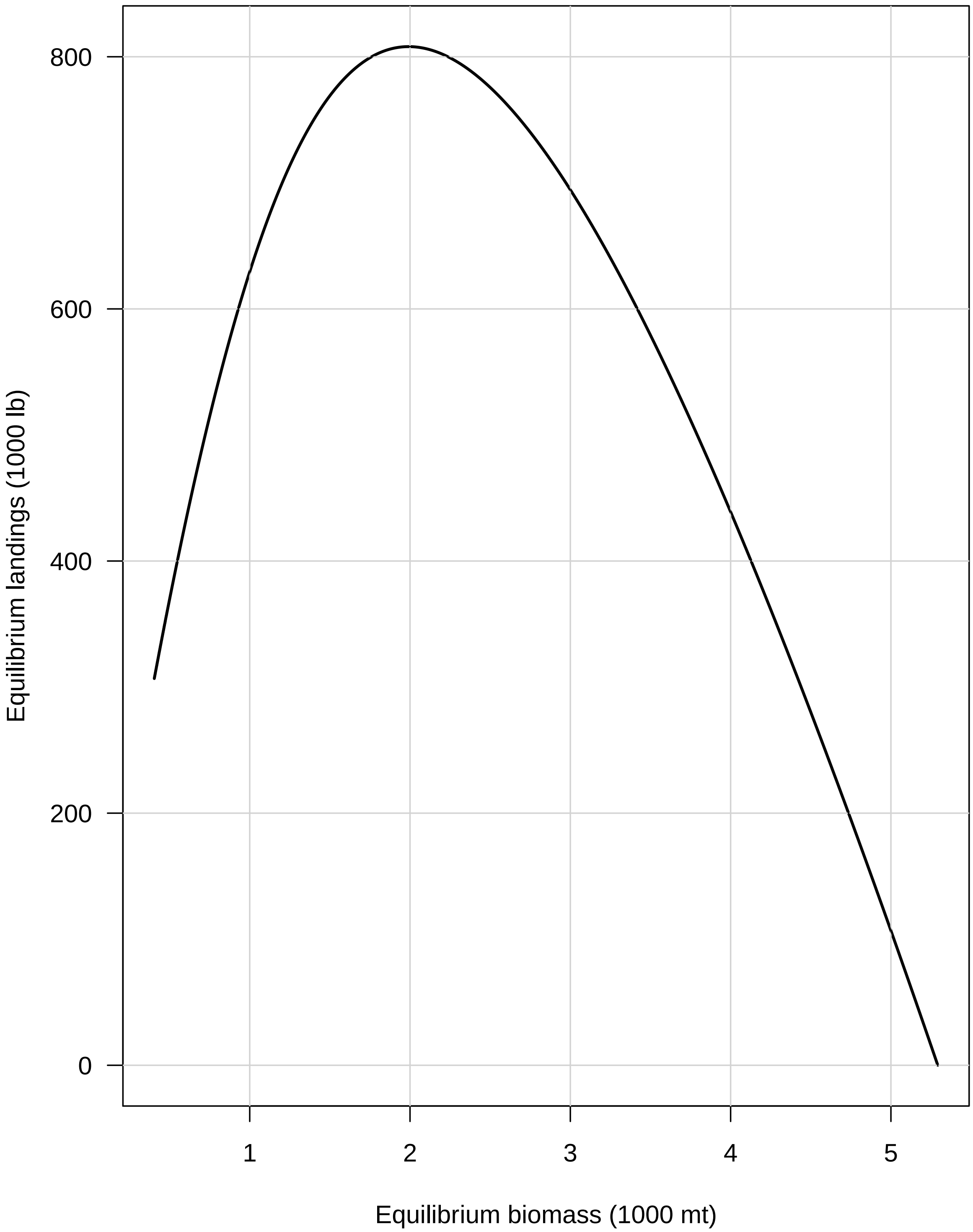


Figure 3.26. Probability densities of MSY*-related benchmarks from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.*

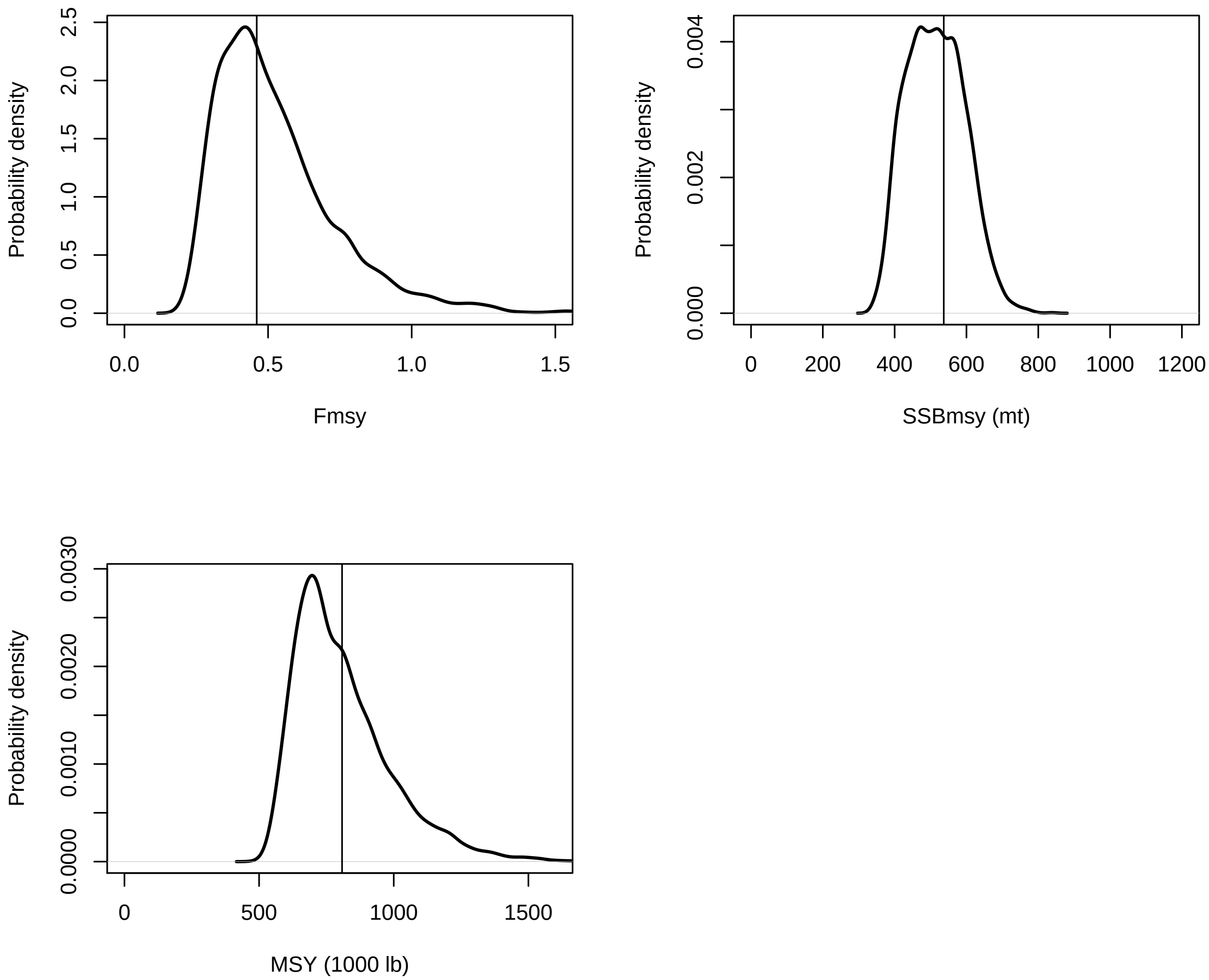
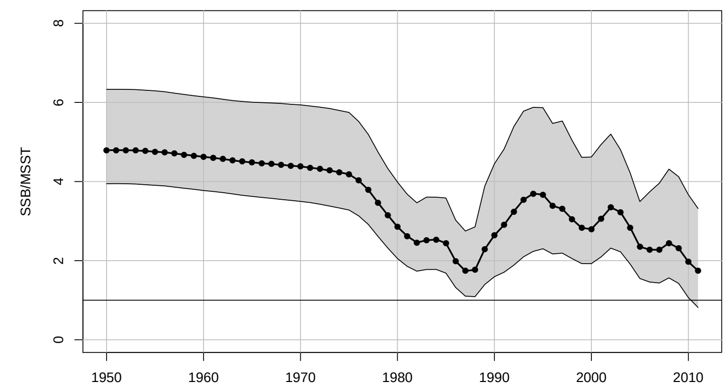
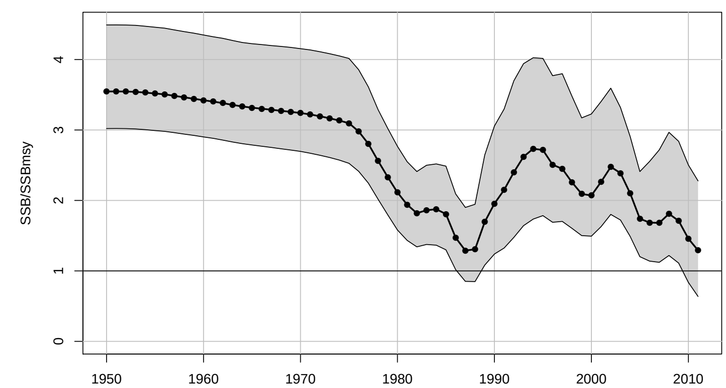


Figure 3.27. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5^{th} and 95^{th} percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (MSST). Middle panel: spawning biomass relative to SSBmsy. Bottom panel: F relative to F_{MSY}.





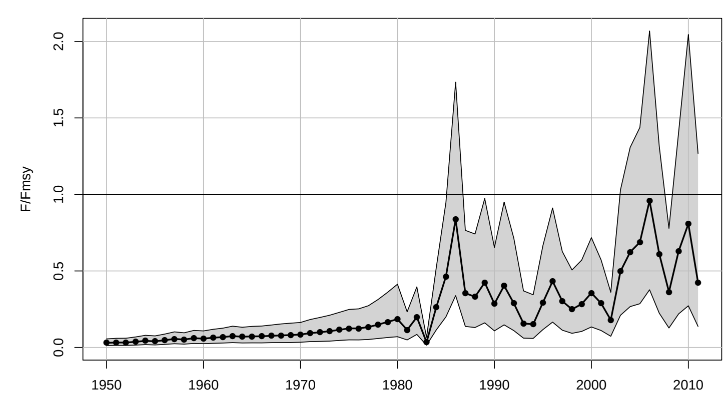


Figure 3.28. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.

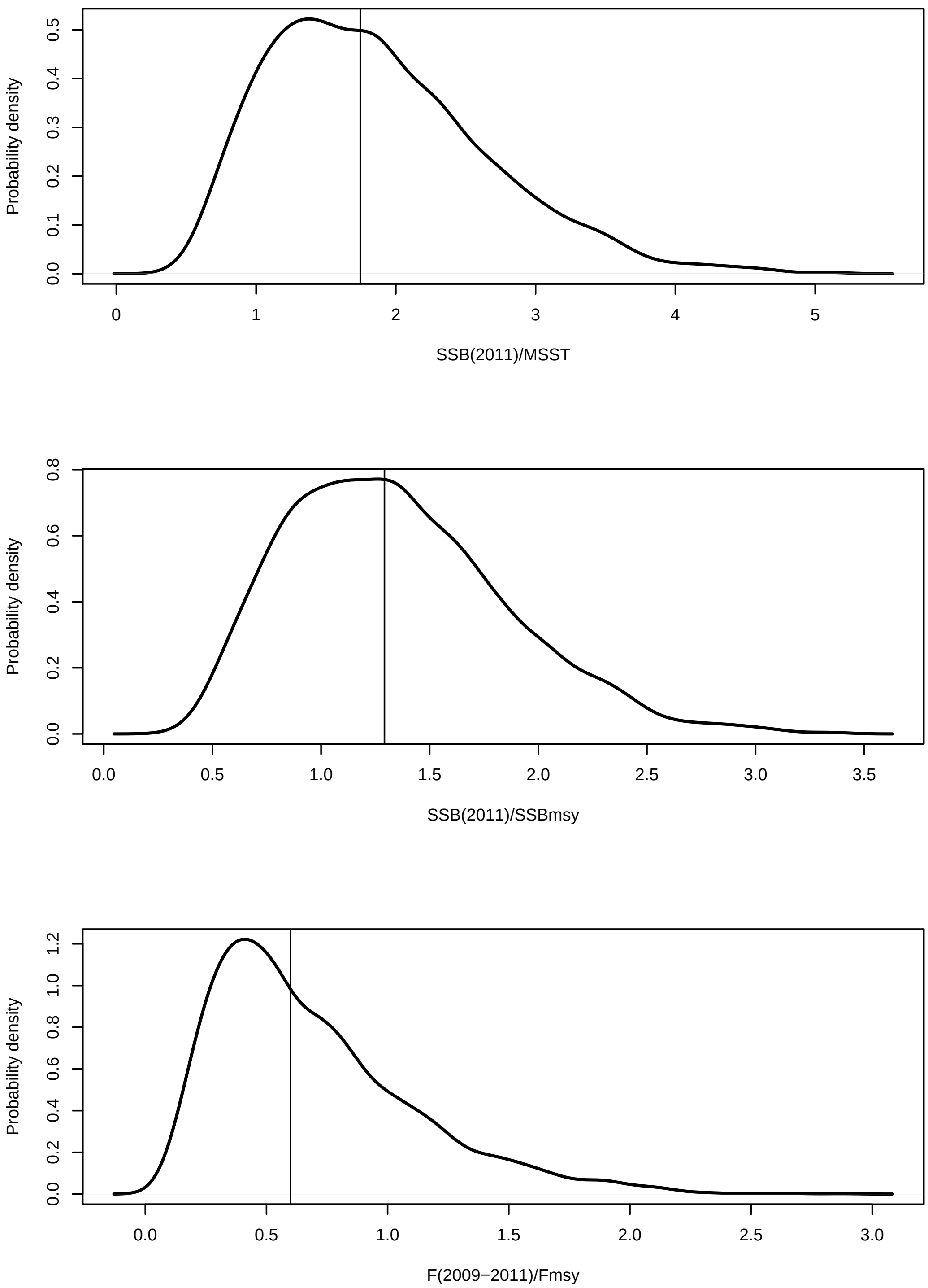
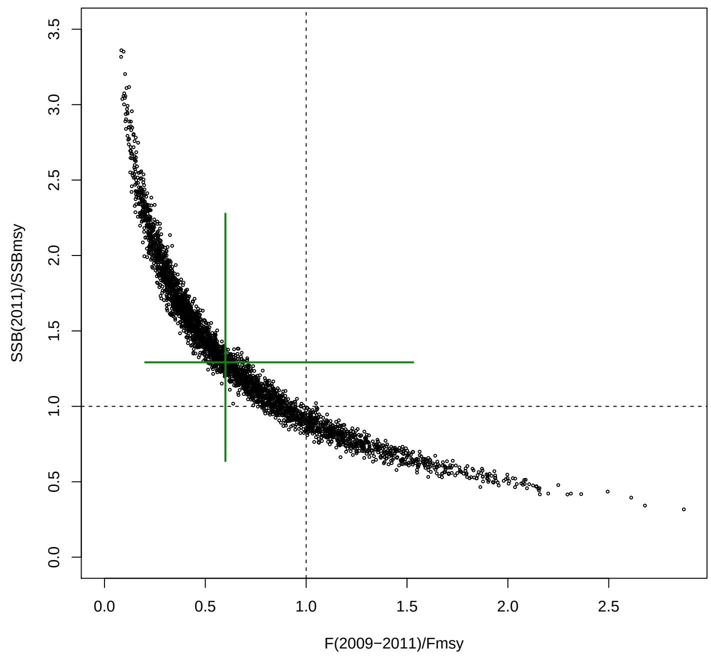


Figure 3.29. Phase plot of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5^{th} *and* 95^{th} *percentiles.*



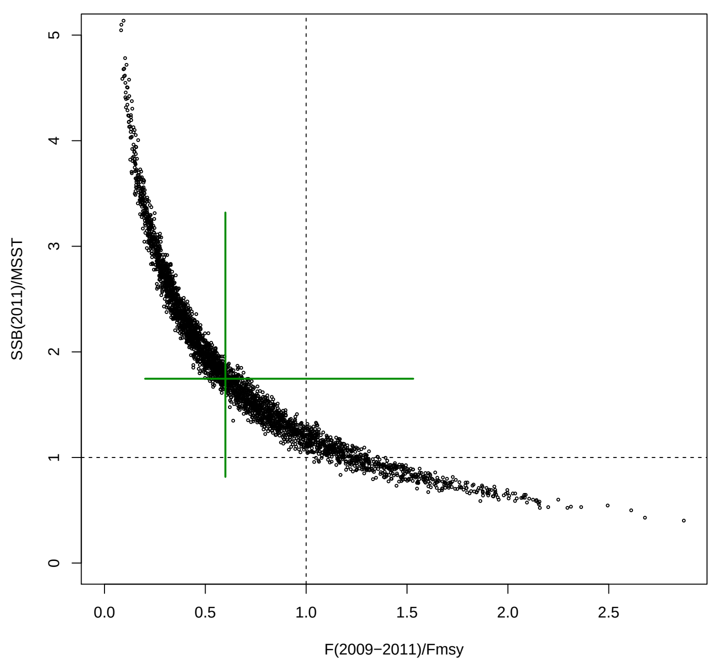


Figure 3.30. Age structure relative to the equilibrium expected at MSY*.*

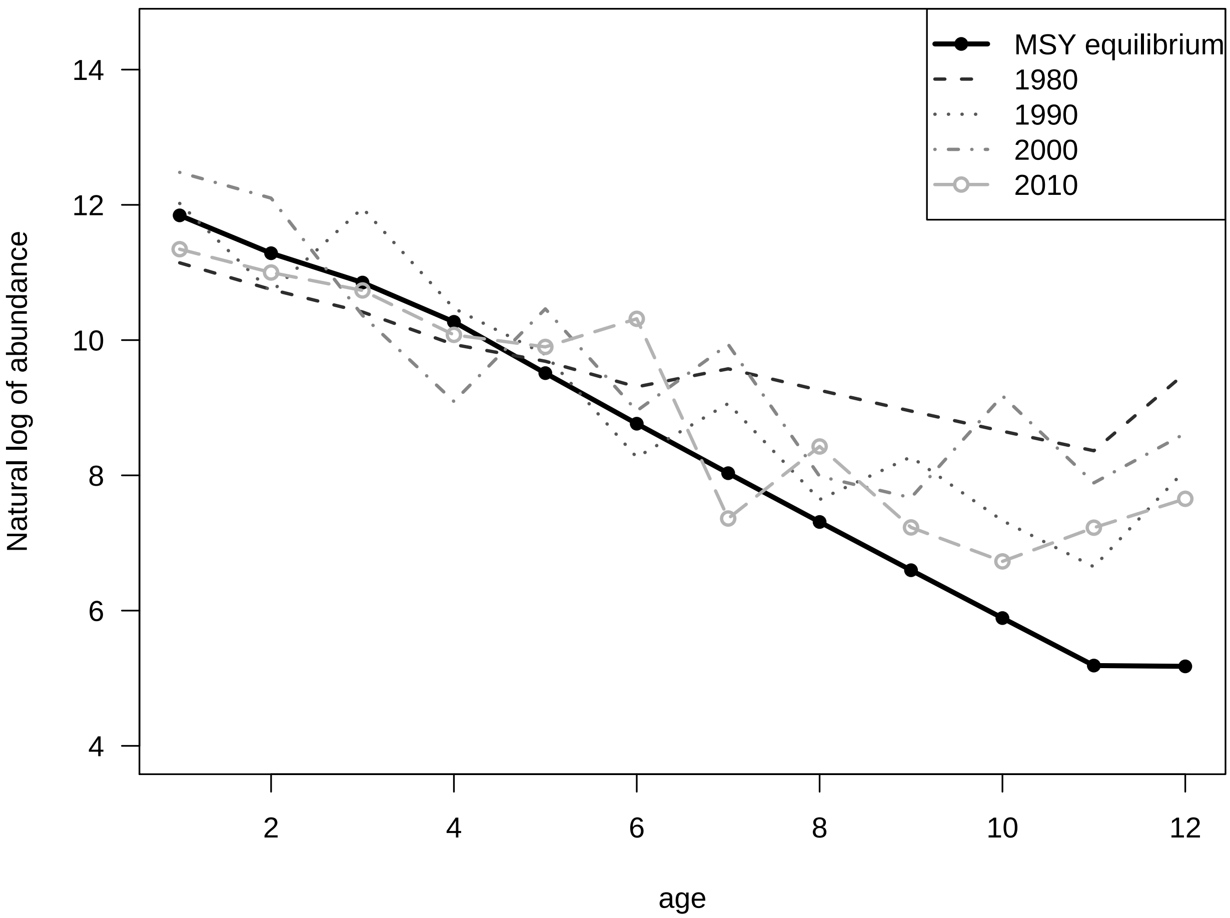


Figure 3.31. Sensitivity to changes in natural mortality (sensitivity runs S1–S3). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$*. Any lines not visible overlap results of the base run.*

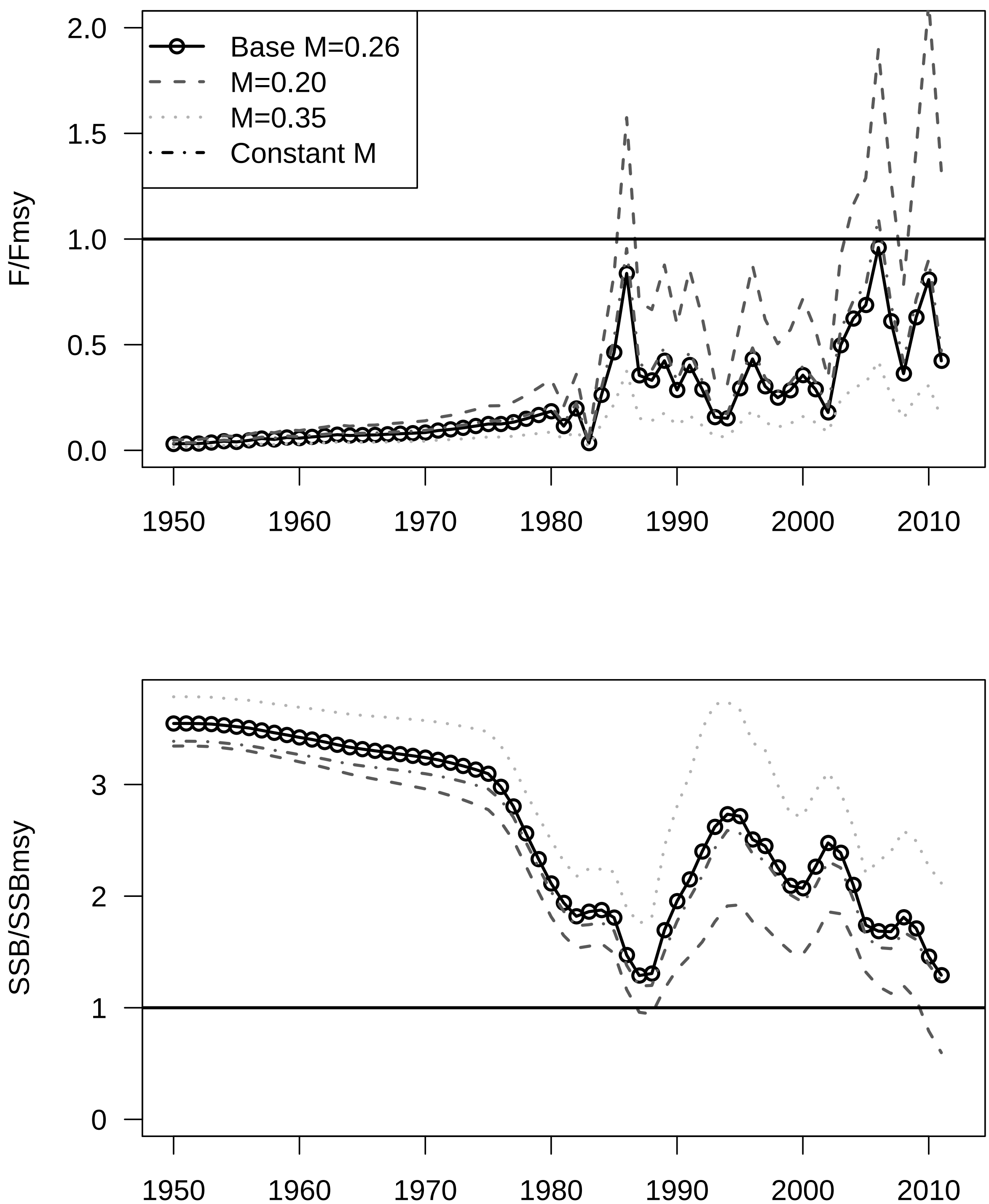


Figure 3.32. Sensitivity to steepness (sensitivity runs S4–S5). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB to $\mathrm{SSB}_{\mathrm{MSY}}$. Any lines not visible overlap results of the base run.

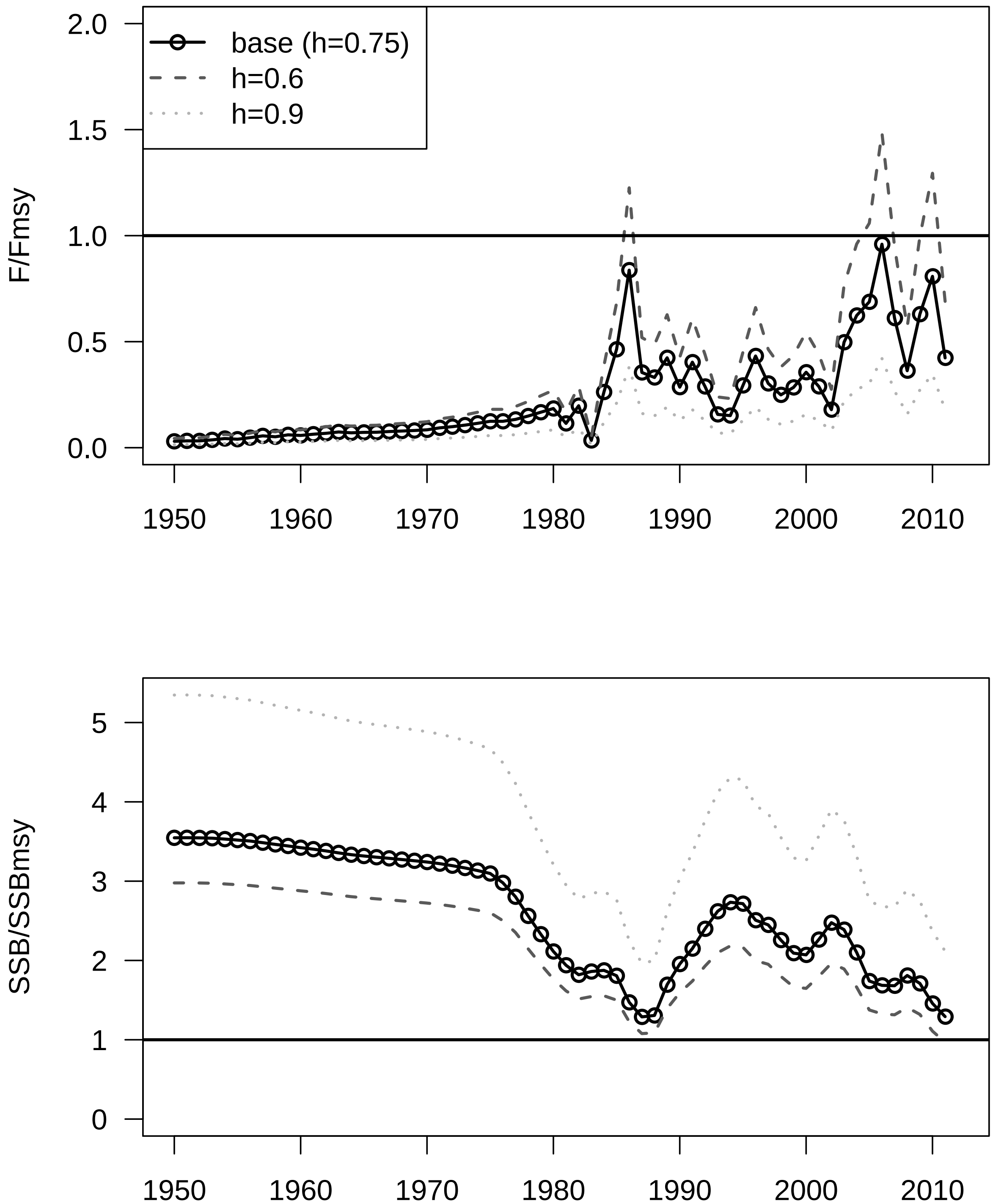
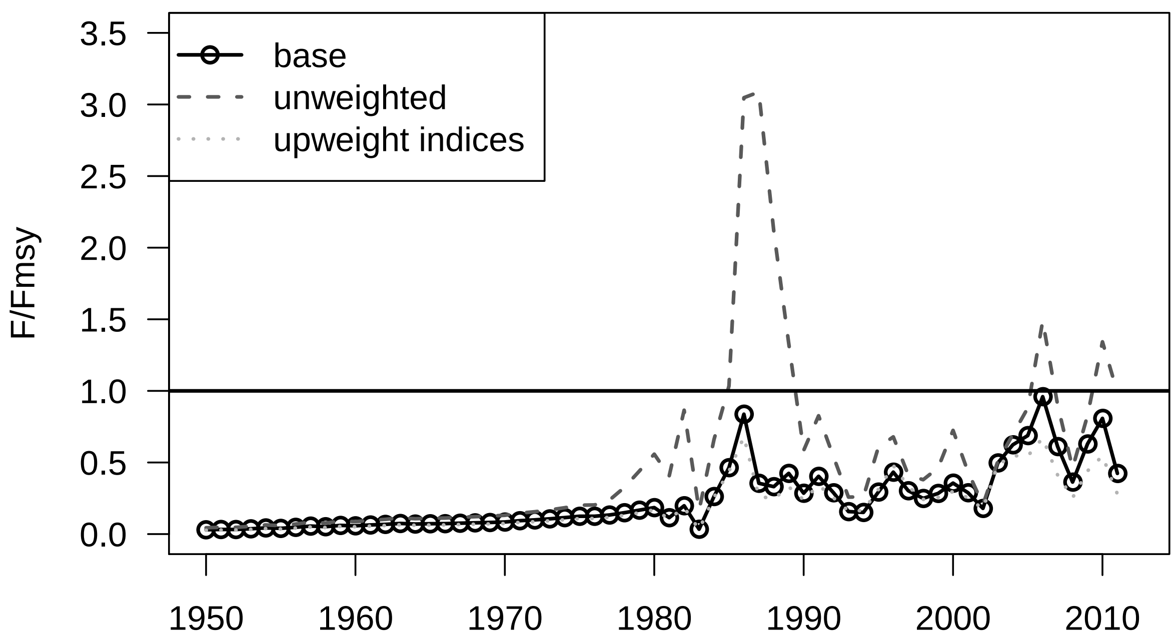


Figure 3.33. Sensitivity to model component weights (sensitivity runs S6–S7). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$*. Any lines not visible overlap results of the base run.*



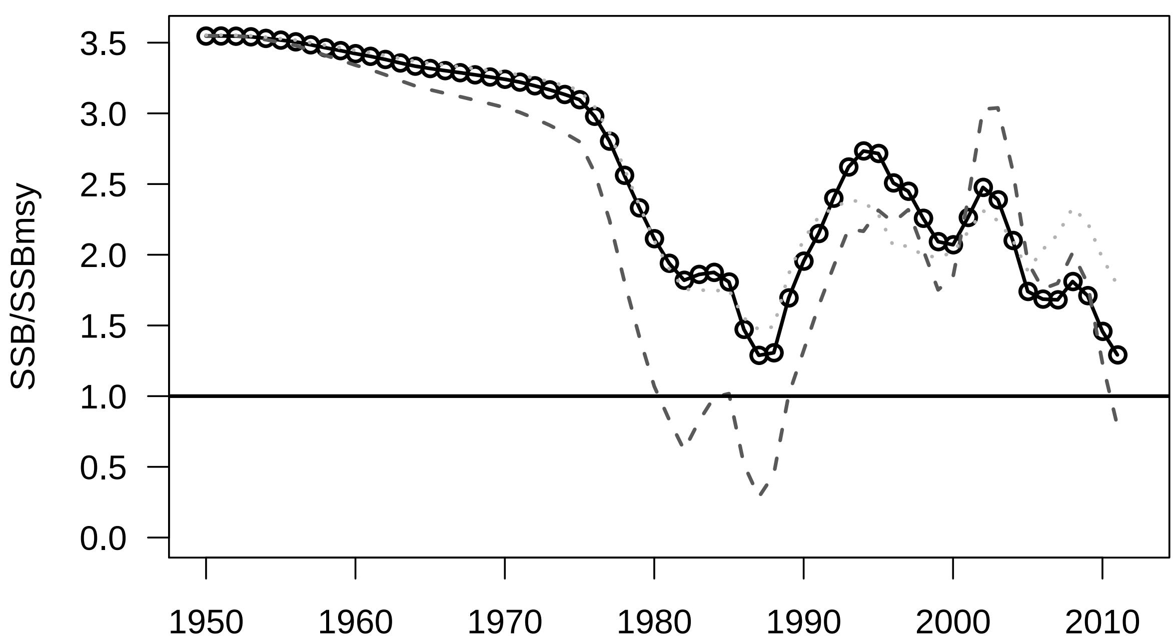


Figure 3.34. Sensitivity to catchability assumptions (sensitivity run S8–S9). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* SSB_{MSY}*. Any lines not visible overlap results of the base run.*

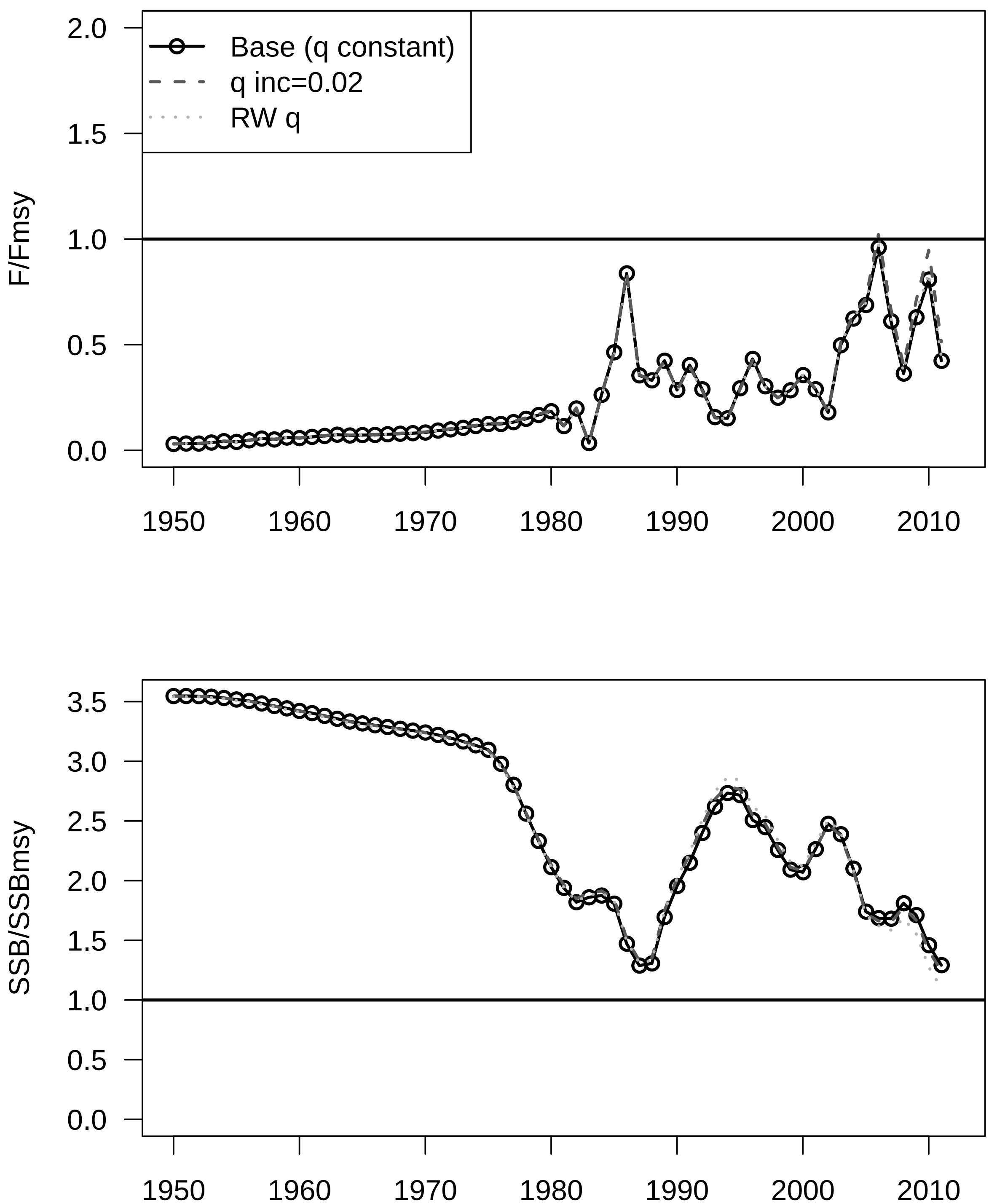
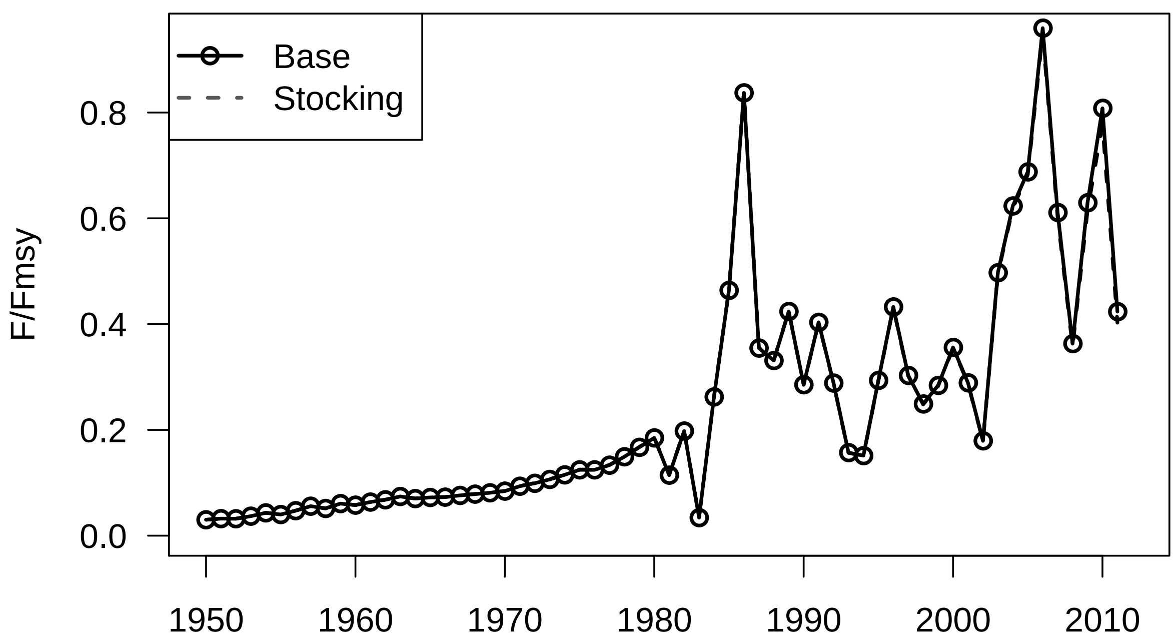


Figure 3.35. Sensitivity to South Carolina cobia stocking program (sensitivity run S10). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB to SSB_{MSY}. Any lines not visible overlap results of the base run.



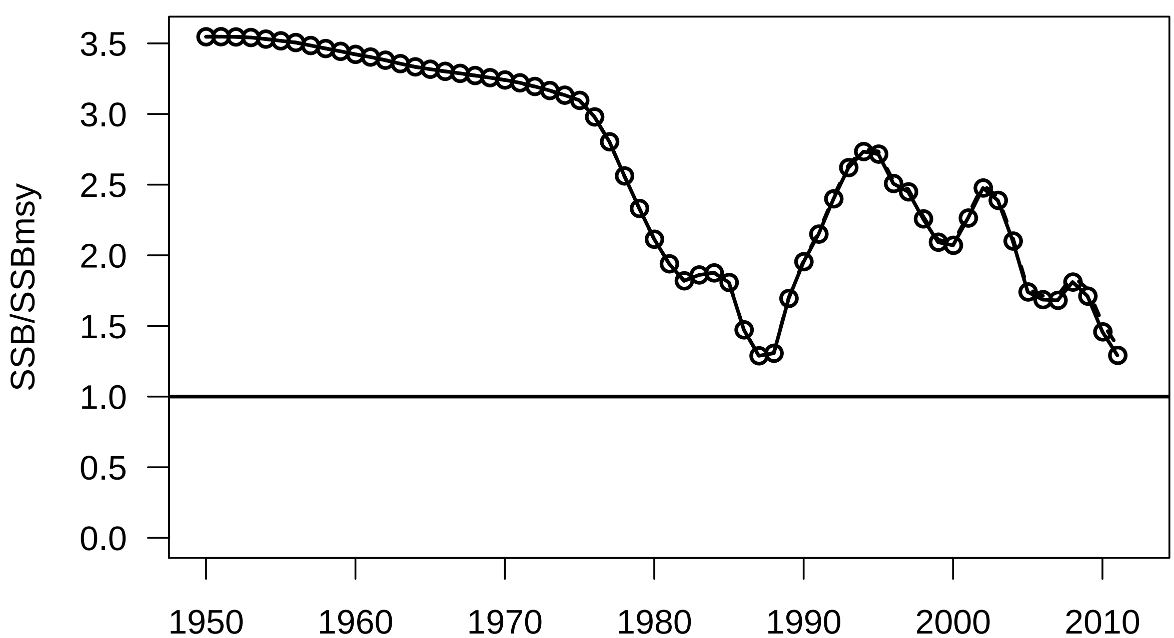
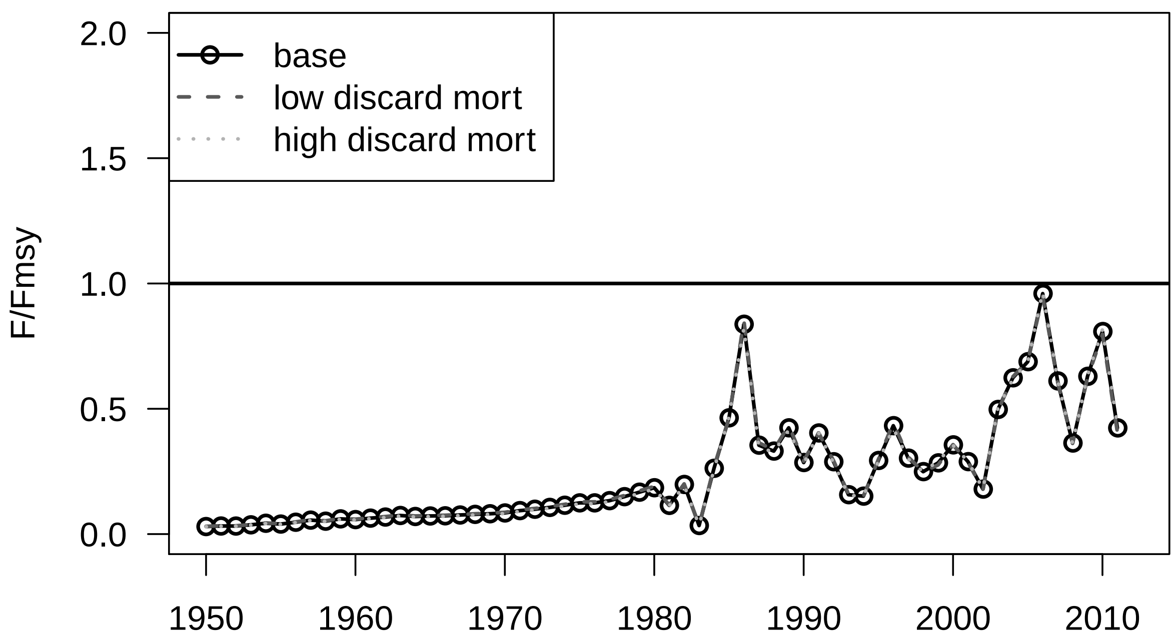


Figure 3.36. Sensitivity to discard mortality (sensitivity runs S11–S12). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$*. Any lines not visible overlap results of the base run.*



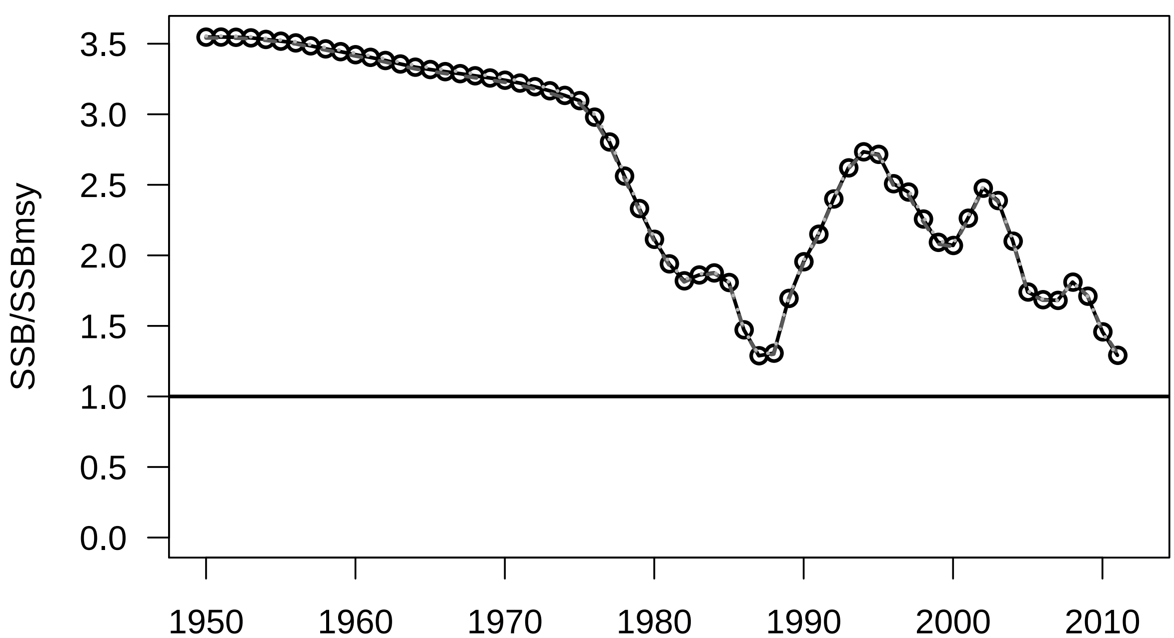
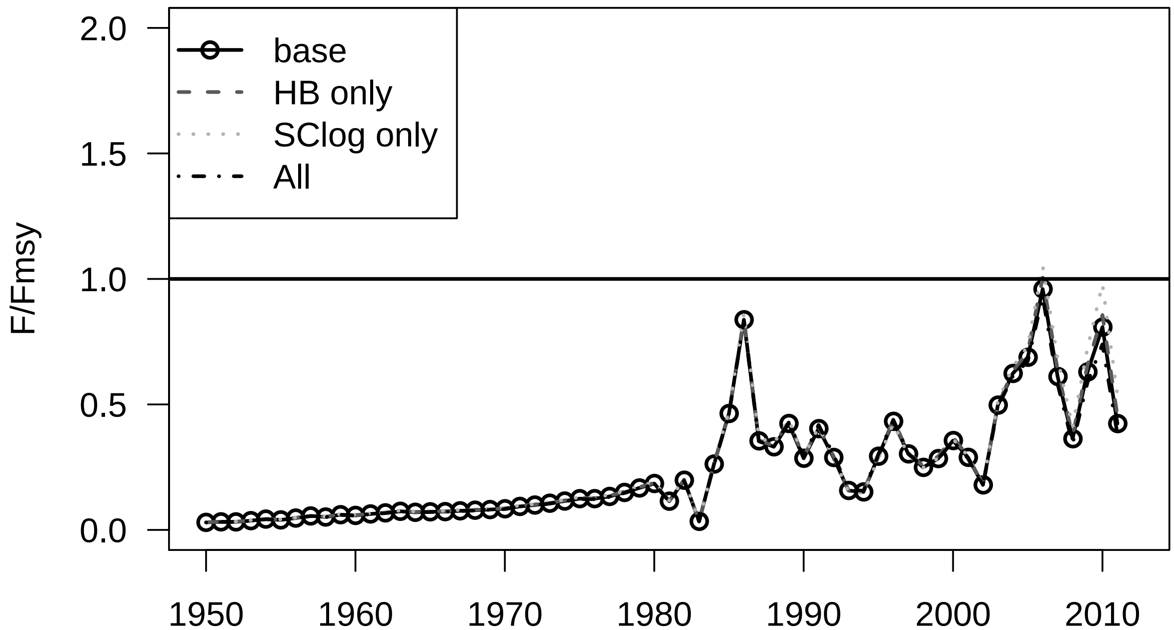


Figure 3.37. Sensitivity to indices (sensitivity runs S13–S15). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB to SSB_{MSY}. Any lines not visible overlap results of the base run.



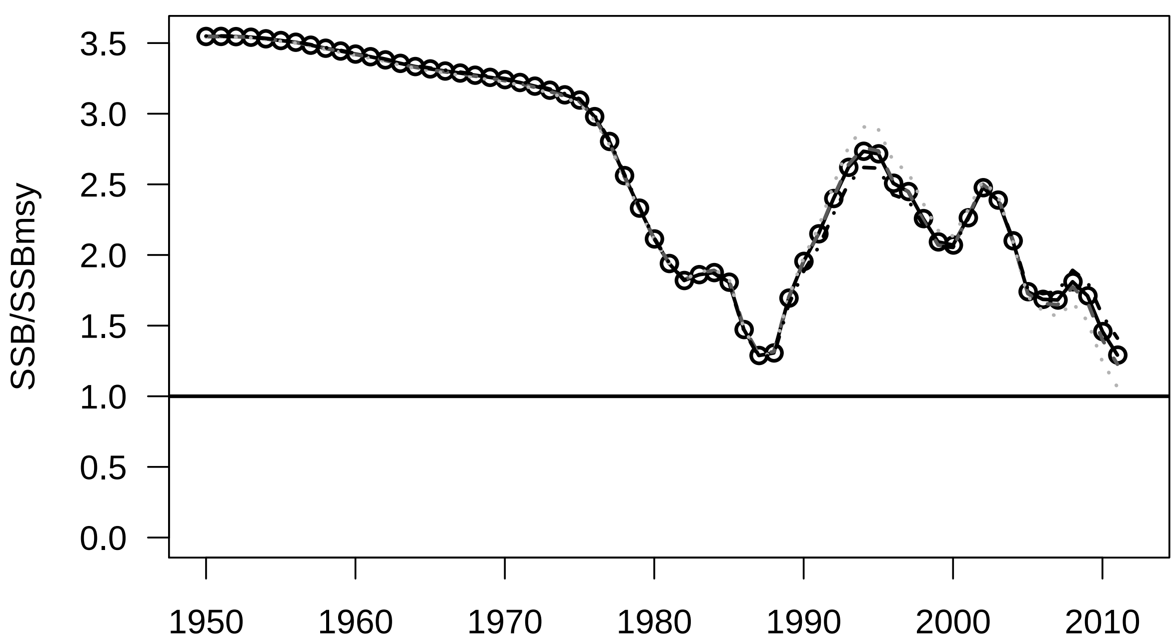


Figure 3.38. Sensitivity to measure of reproductive output (sensitivity run S16). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$. *Any lines not visible overlap results of the base run.*

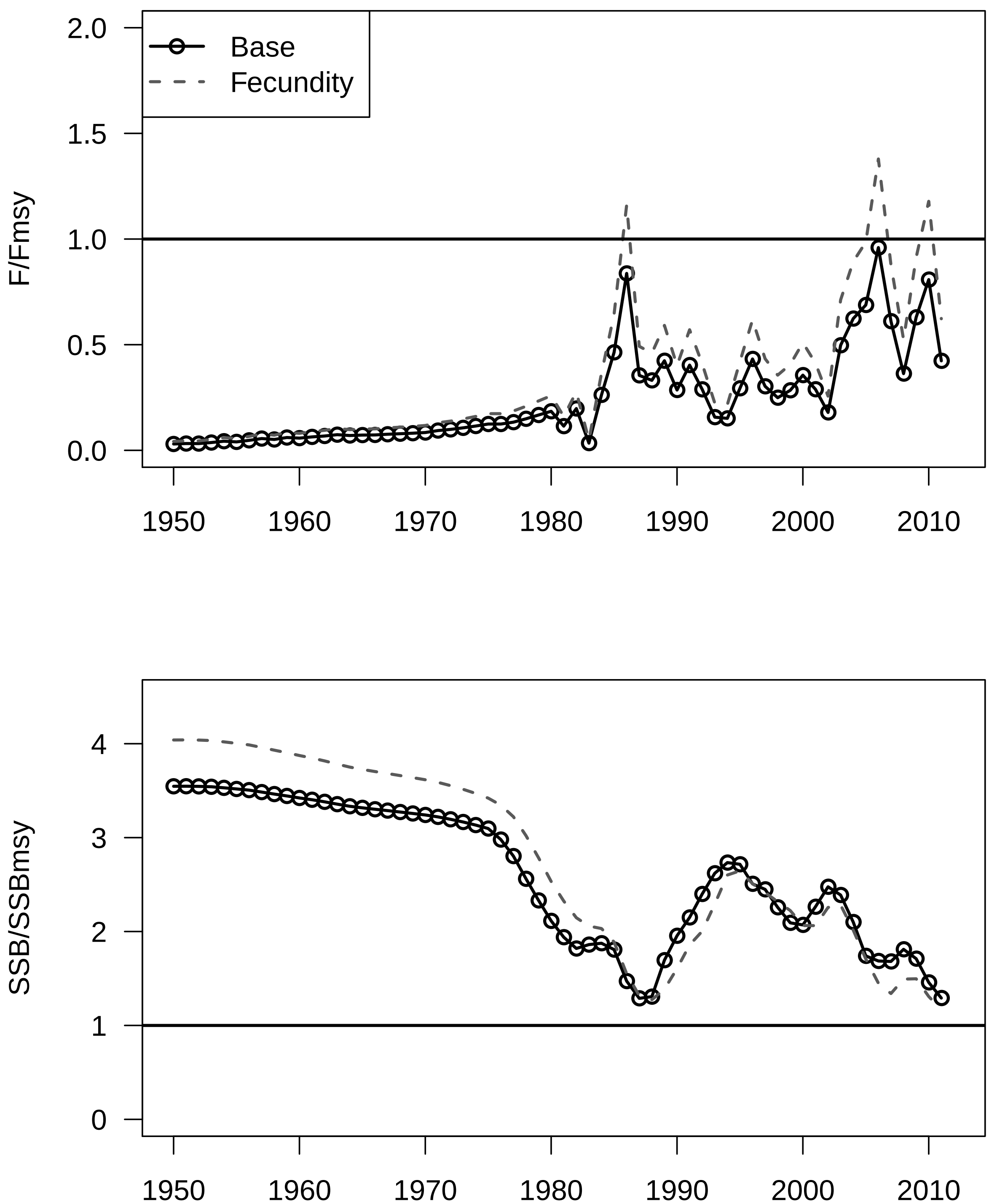


Figure 3.39. Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model.

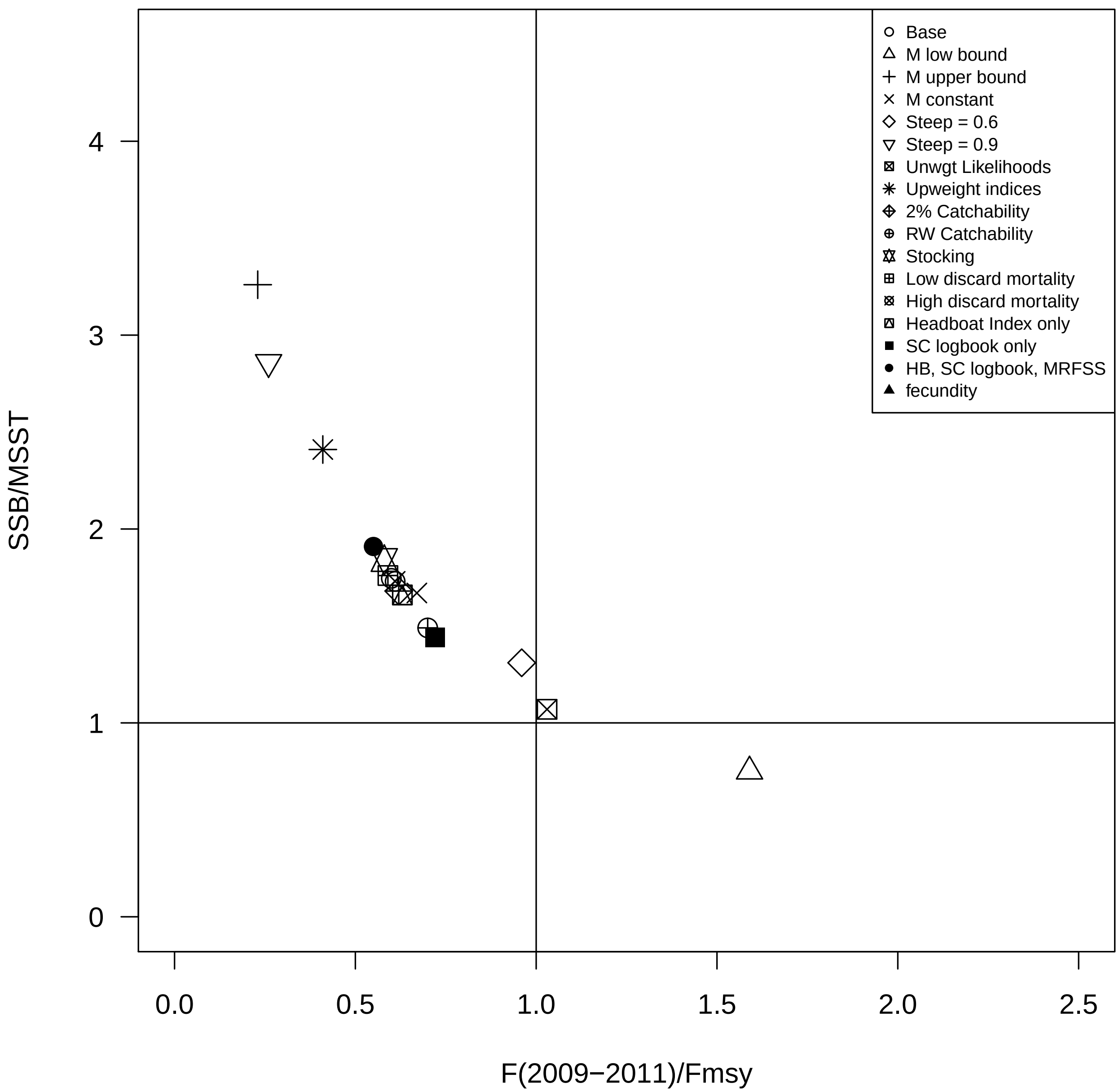


Figure 3.40. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S17–S23). Fishing mortality rate, where solid circles show geometric mean of terminal three years, as used to compute fishing status.

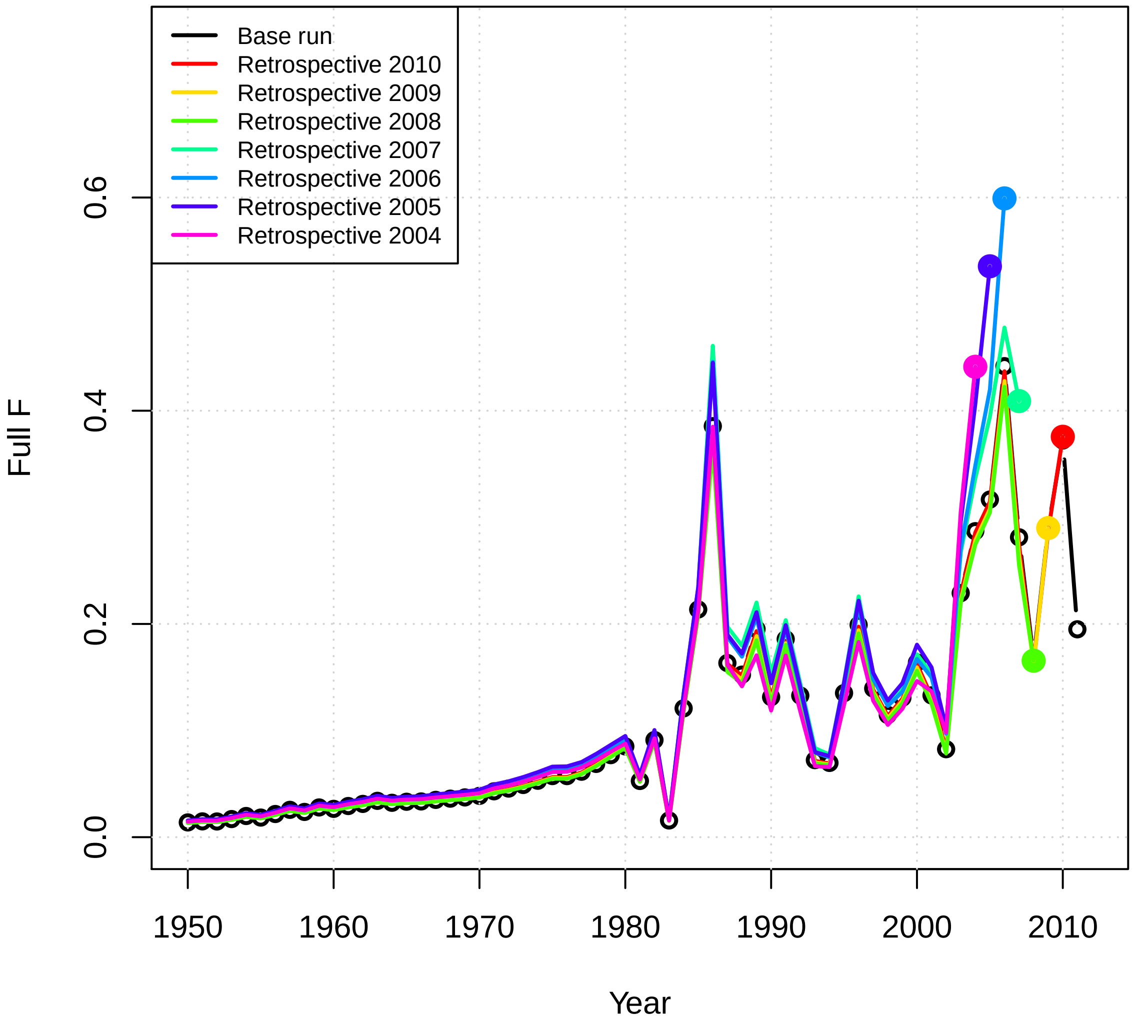


Figure 3.41. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S17–S23). Biomass time series.

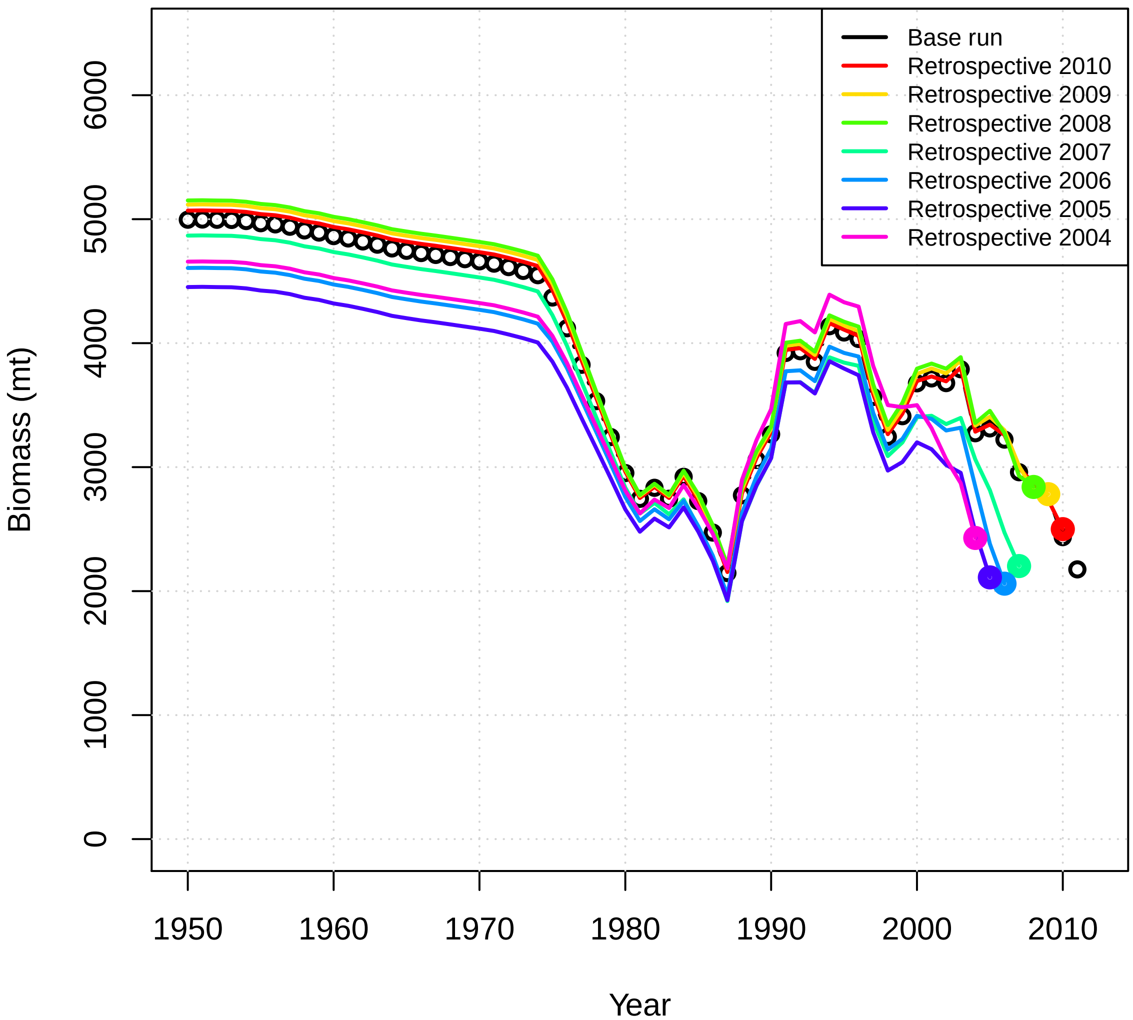


Figure 3.42. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S17–S23). Spawning stock biomass time series.

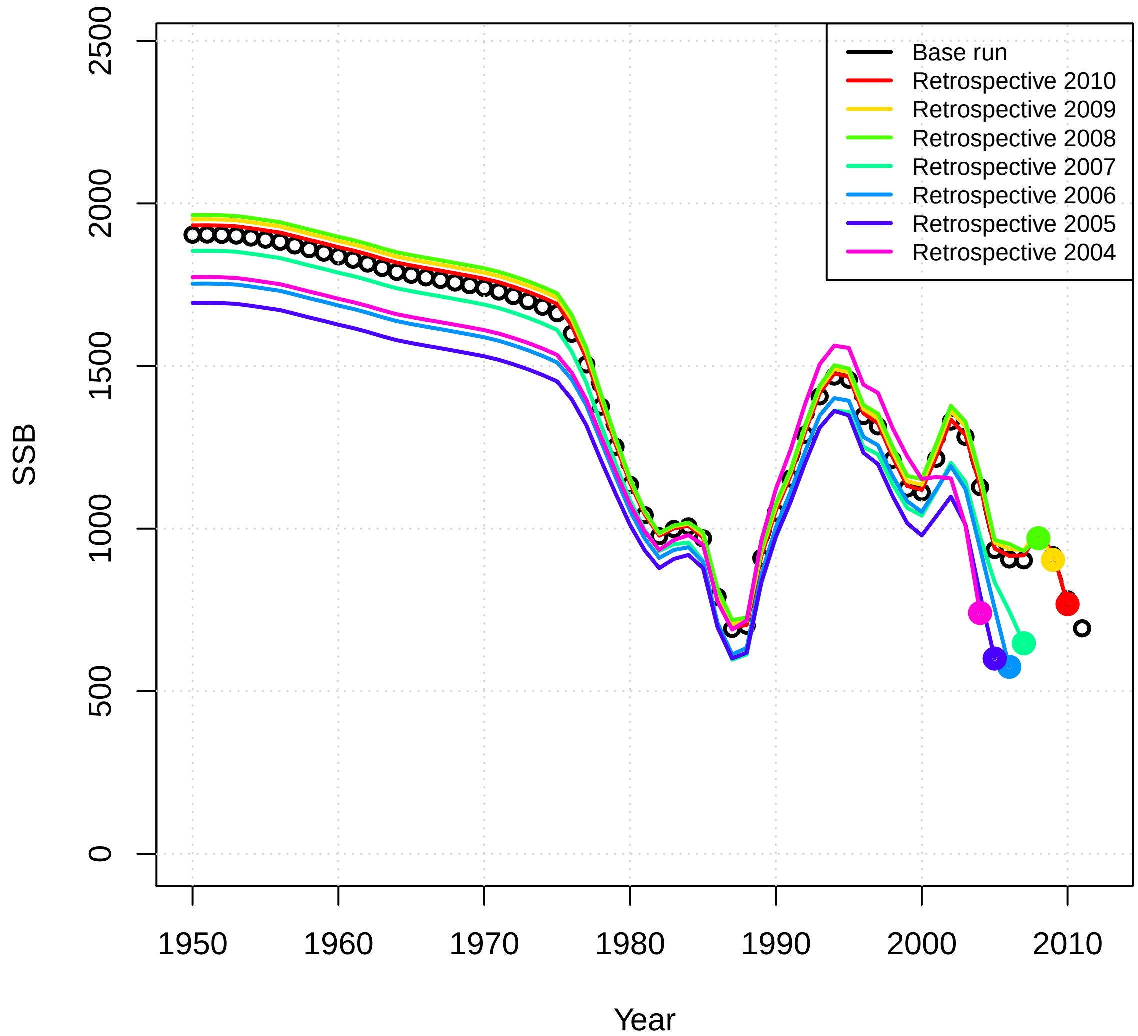


Figure 3.43. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S17–S23). Recruitment time series.

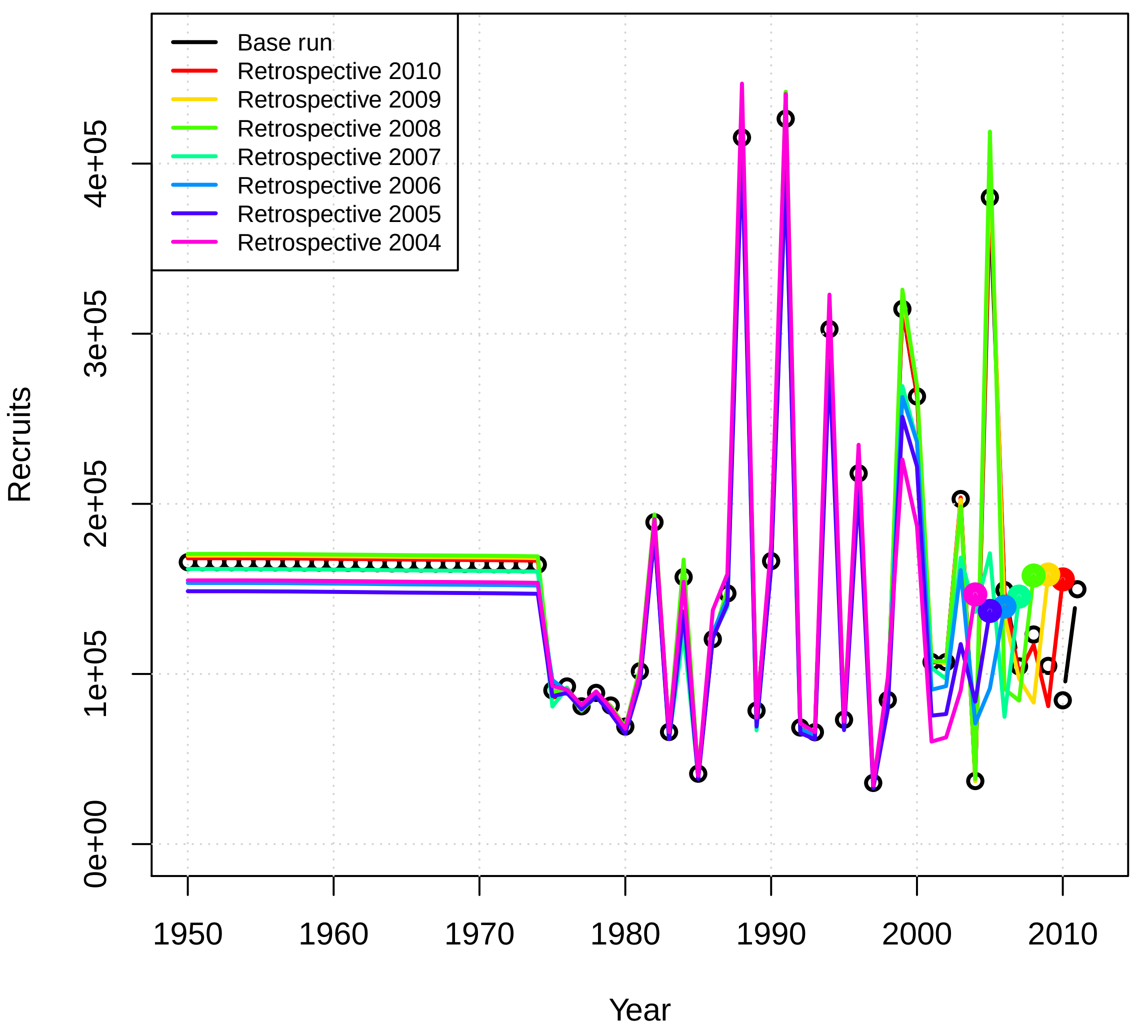


Figure 3.44. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S17–S23). Relative spawning stock biomass time series.

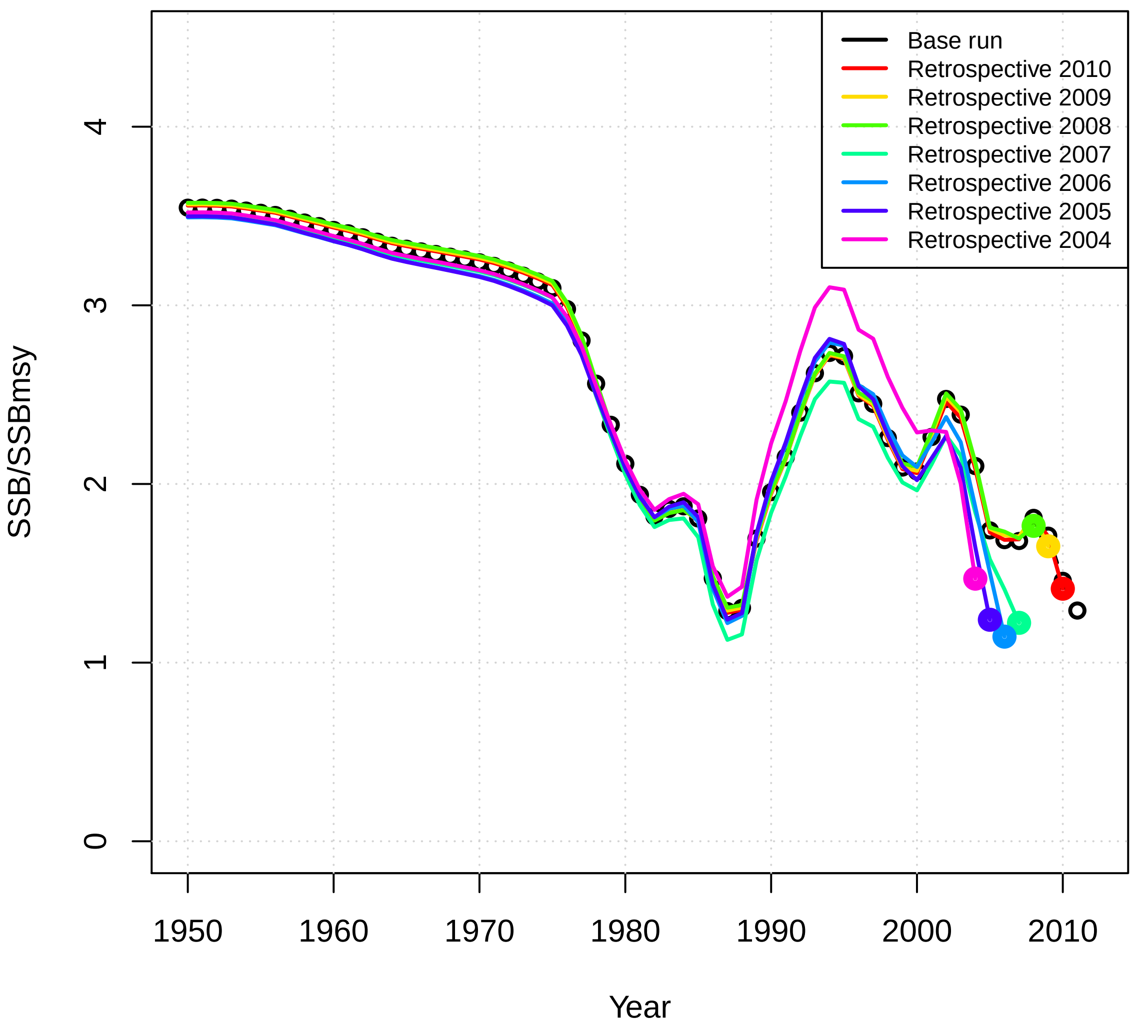


Figure 3.45. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S17–S23). Relative fishing mortality rate time series.

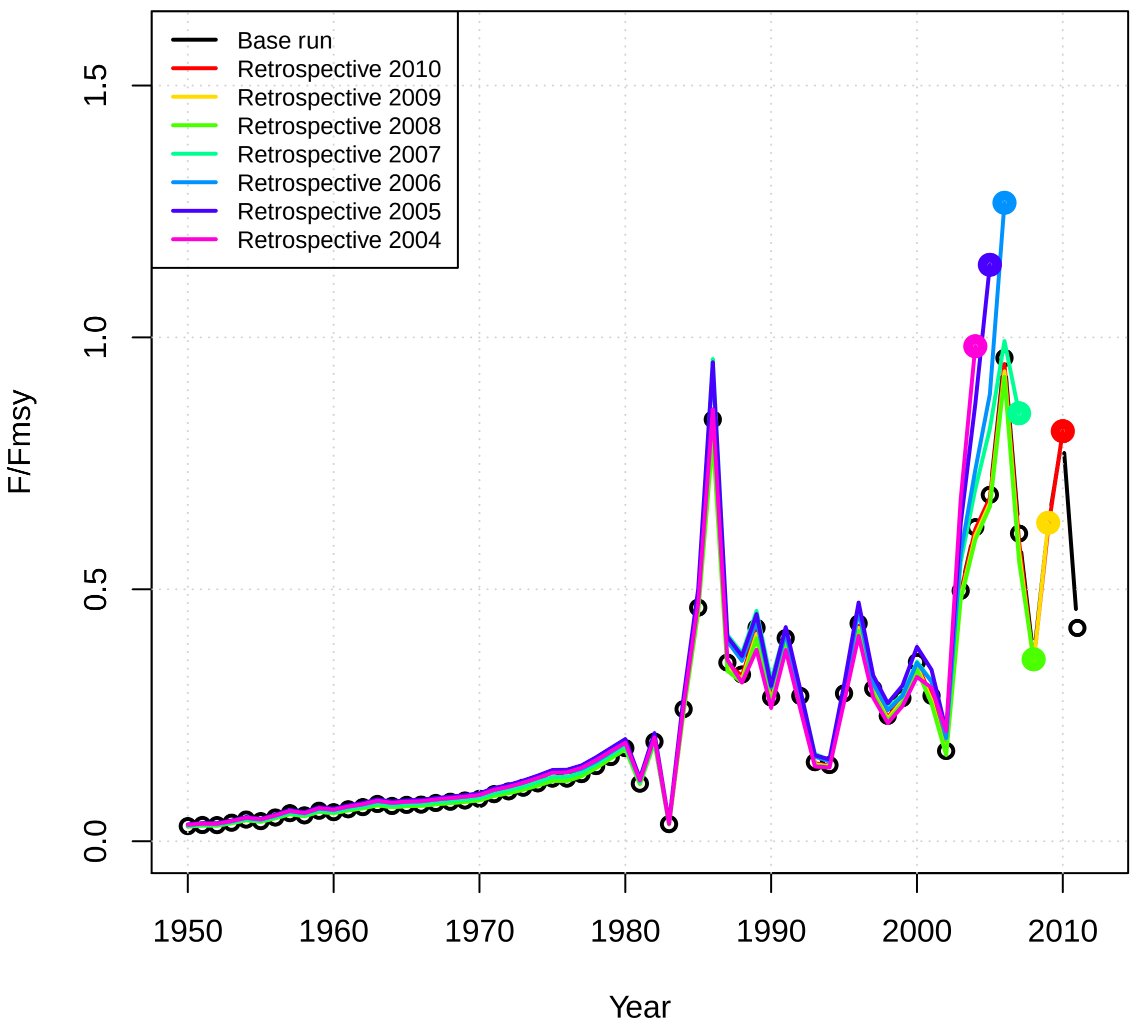


Figure 3.46. Projection results under scenario 1—fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at time of peak spawning.*

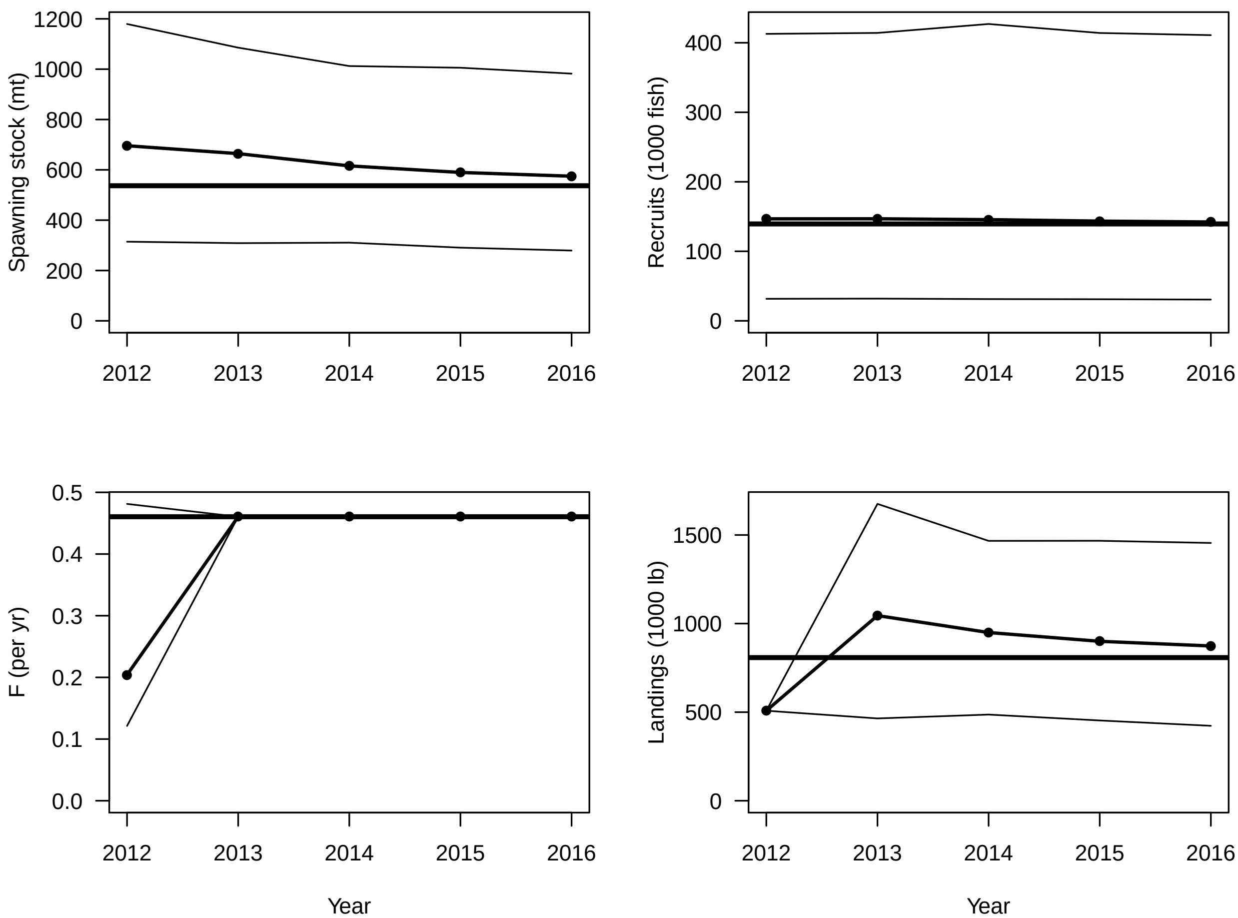


Figure 3.47. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{\text{current}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at time of peak spawning.*

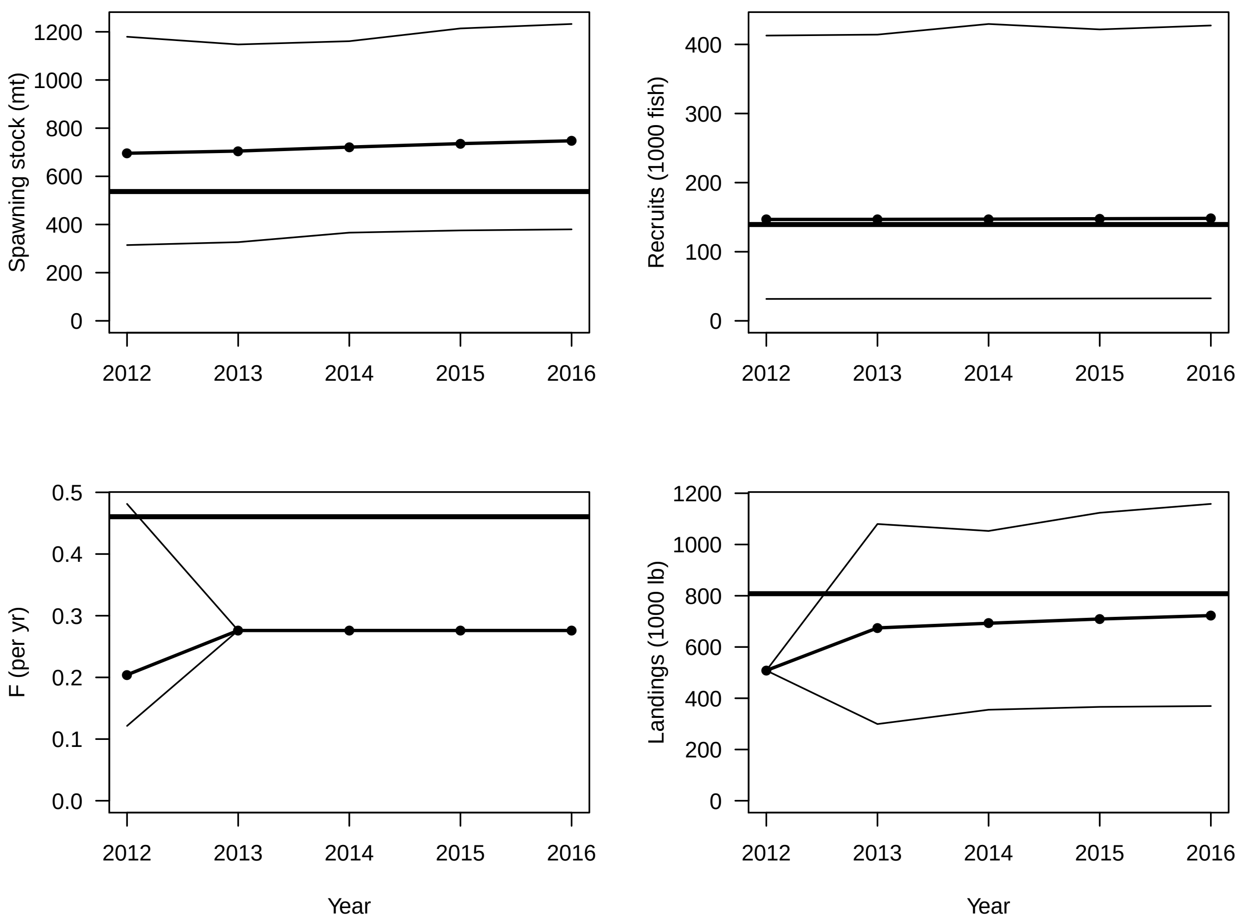


Figure 3.48. Projection results under scenario 3—fishing mortality rate fixed at $F = 65\% F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at time of peak spawning.*

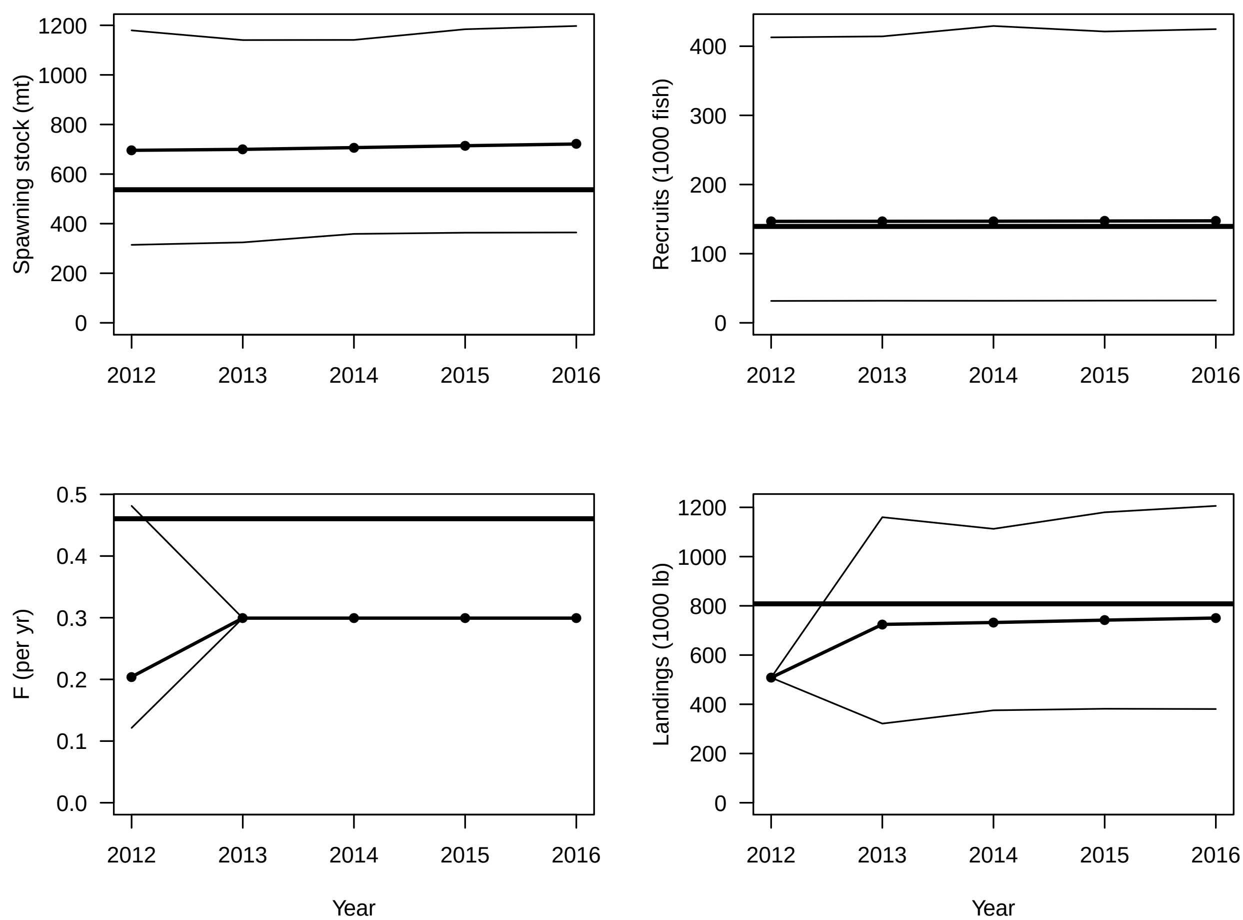


Figure 3.49. Projection results under scenario 4—fishing mortality rate fixed at $F = 75\% F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at time of peak spawning.*

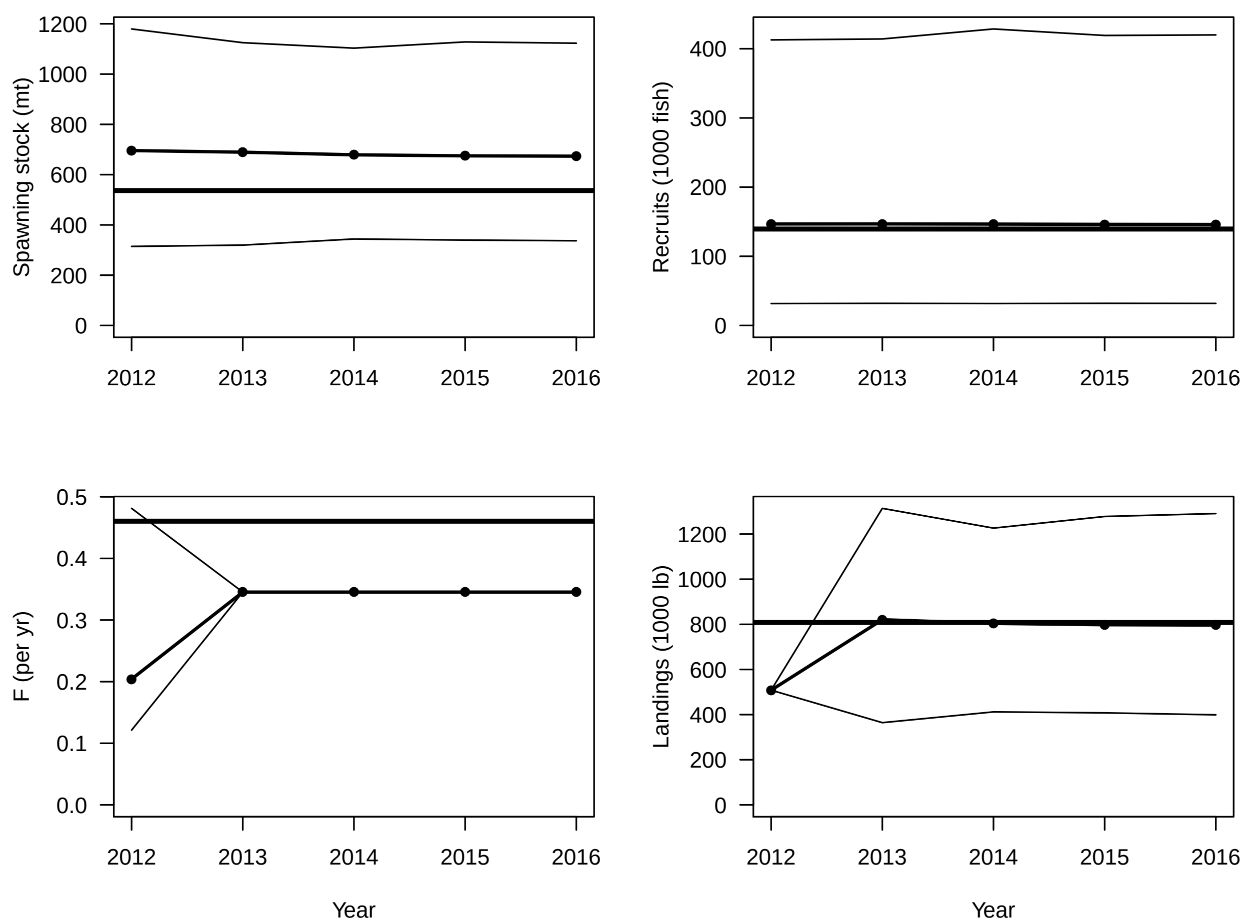


Figure 3.50. Projection results under scenario 5—fishing mortality rate fixed at $F = 85\%F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5^{th} and 95^{th} percentiles of replicate projections. Horizontal lines mark MSY*-related quantities. Spawning stock (SSB) is at time of peak spawning.*

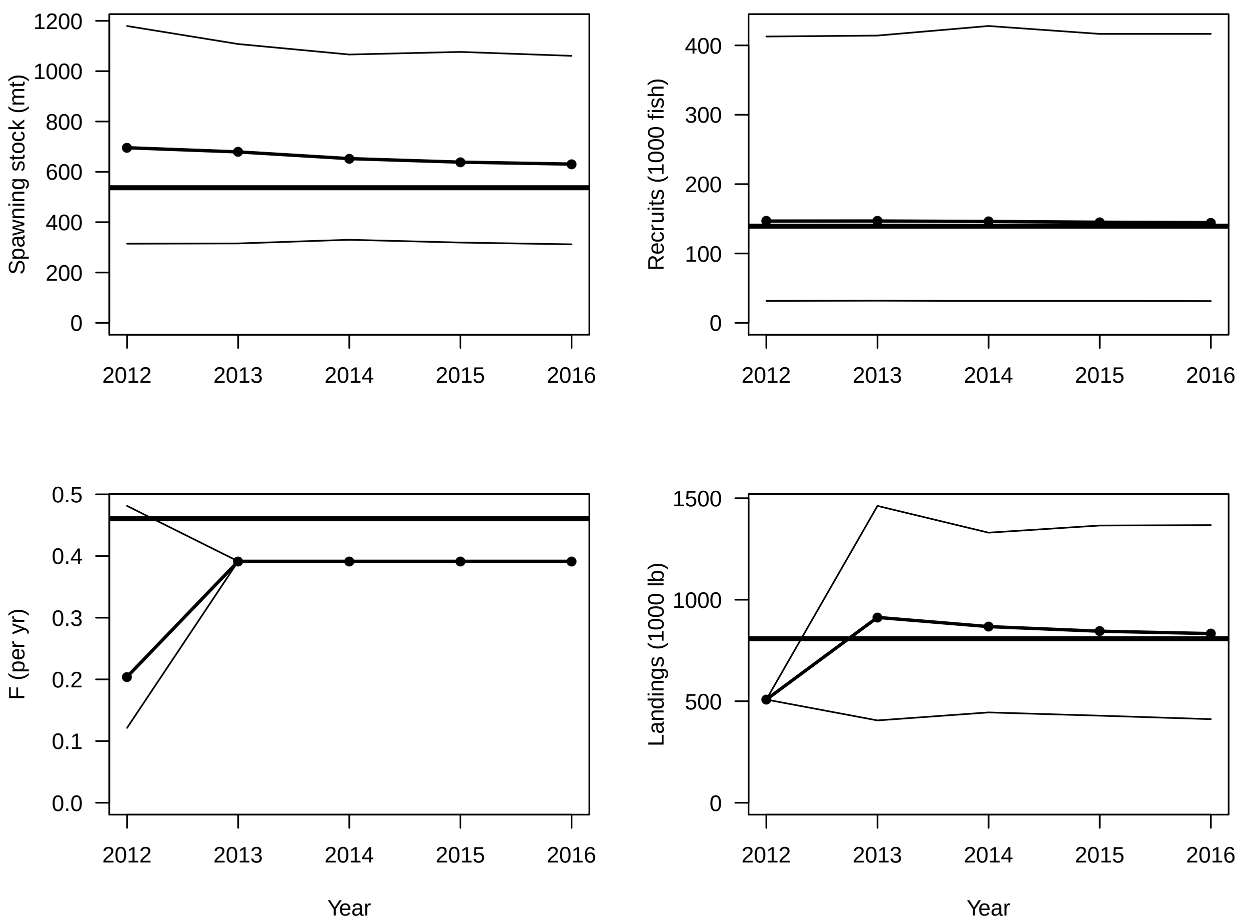


Figure 3.51. Length-frequency plot for cobia caught in the South Atlantic recreational fishery. Data were aggregated across years, months, waves and states. N denotes the total number of fish measured. The distribution was used to characterize length-at-full vulnerability. 975 mm represents the peak of the frequency plot.

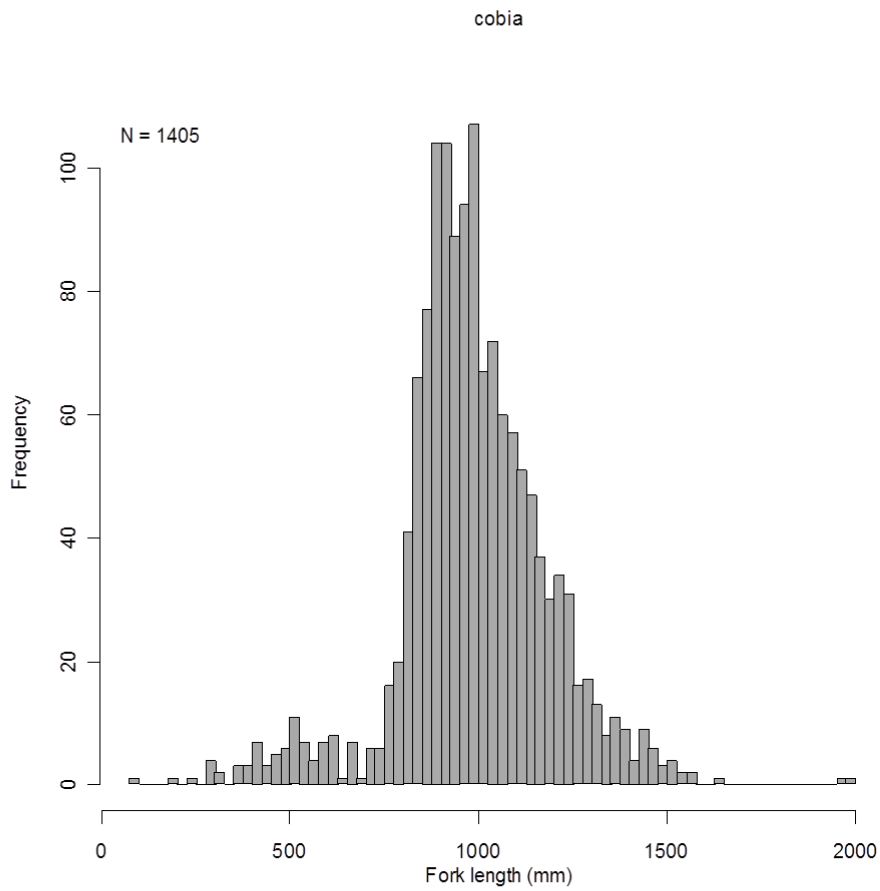


Figure 3.52. Annual mean length estimates (mm), where length-at-full vulnerability was assumed equal to 975 mm. Bubble size was determined by scaling the annual sample size relative to the minimum and maximum number of annual samples. The plot shows the best fit line for the most parsimonious model (constant Z over time) assuming this length at full vulnerability.

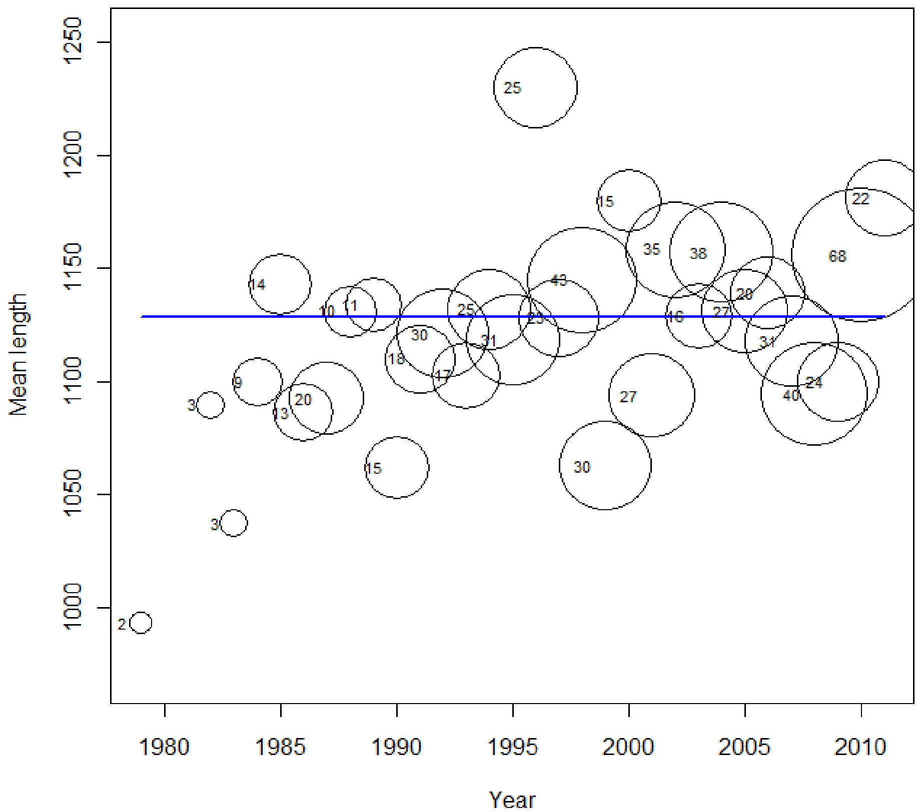


Figure 3.53. Annual mean length estimates (mm), where length-at-full vulnerability was assumed equal to 1025 mm. Bubble size was determined by scaling the annual sample size relative to the minimum and maximum number of annual samples. The best fit line is shown for the most parsimonious model (decline in Z from 0.47 to 0.22 after 1990) assuming this length at full vulnerability.

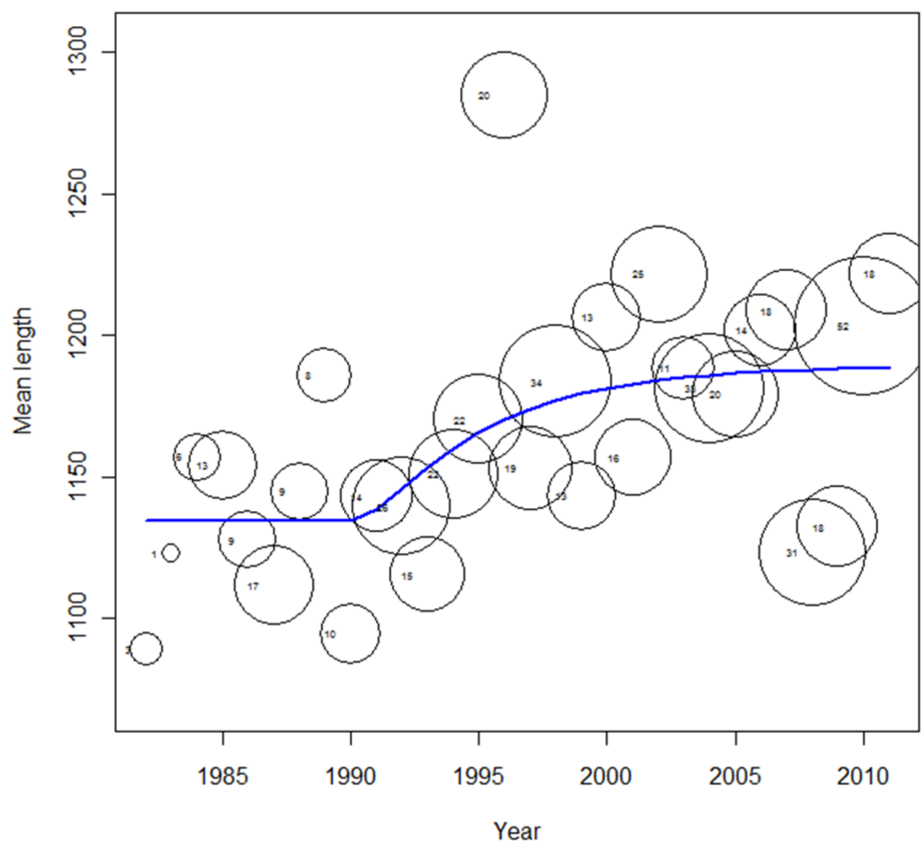


Figure 3.54. Comparison of F estimates from catch curve analysis to the Beaufort Assesment Model.

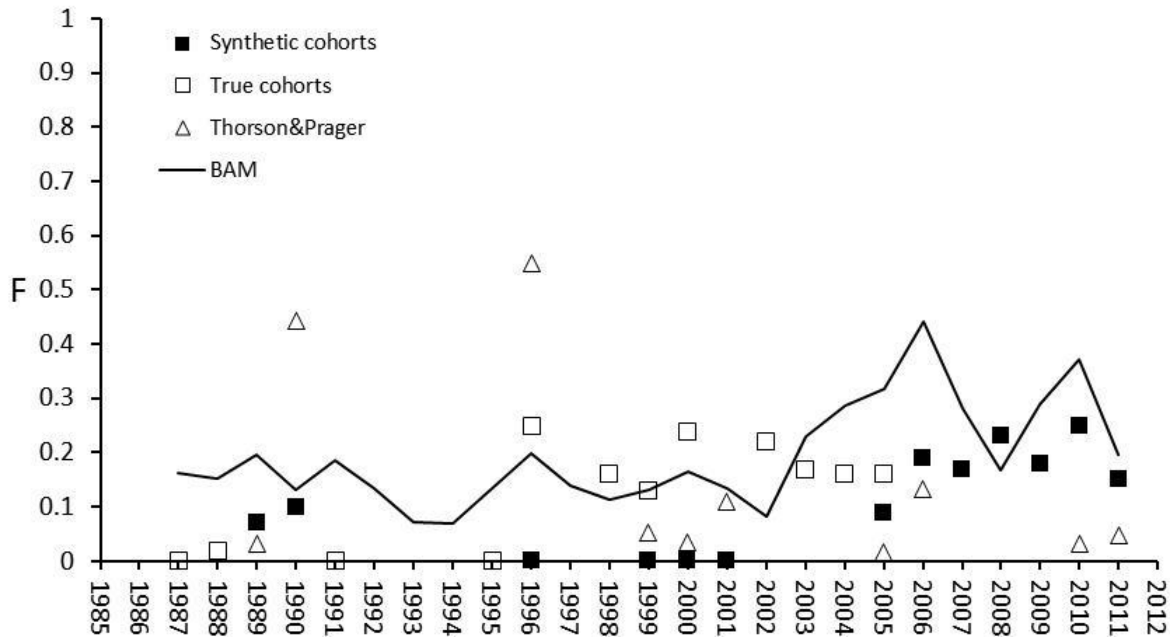


Figure 3.55. Cobia production model: Observed (closed circles) and model fit (open diamonds) for two fishery-dependent (headboat and SC charterboat logbook) indices of abundance.

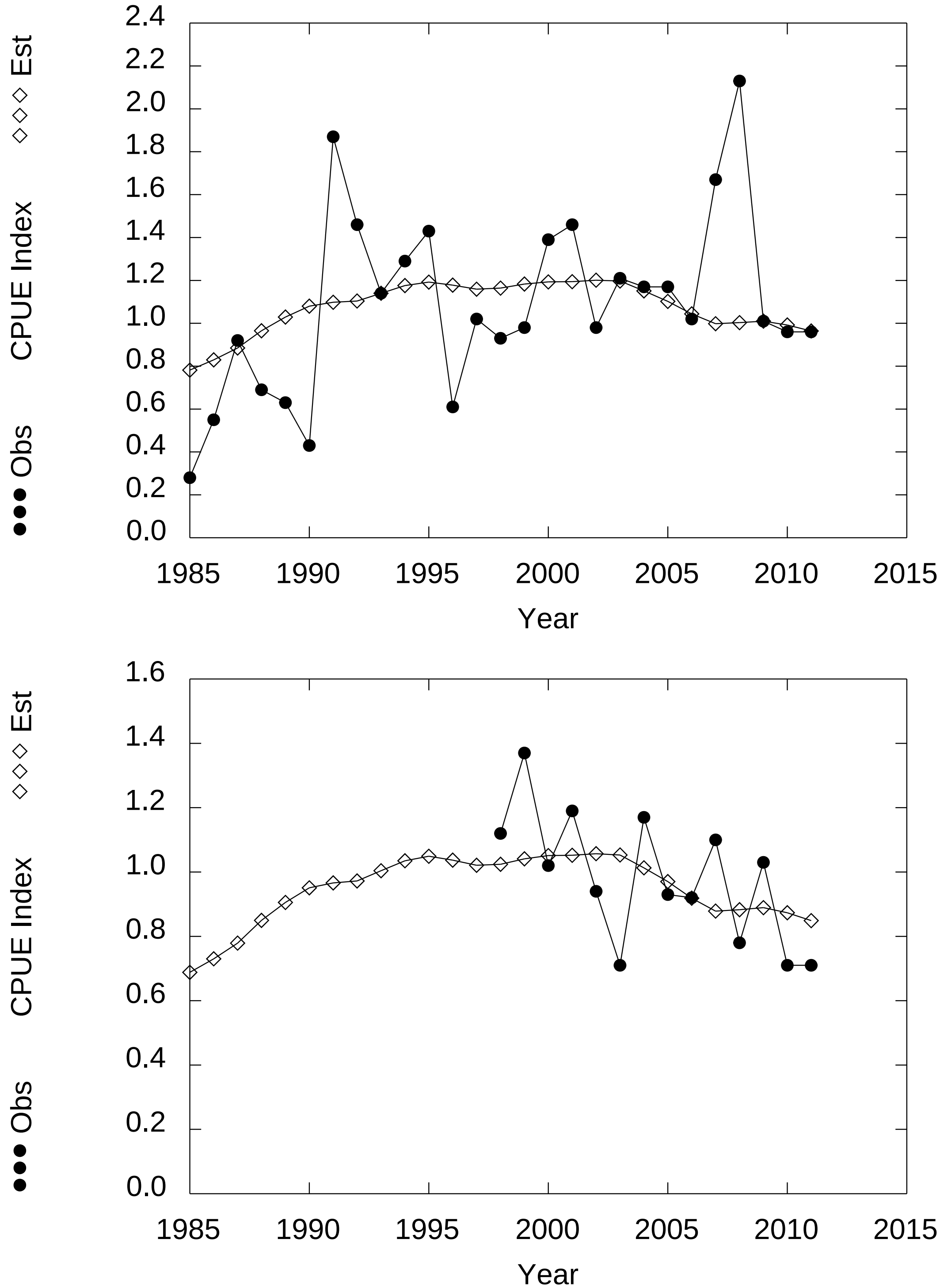
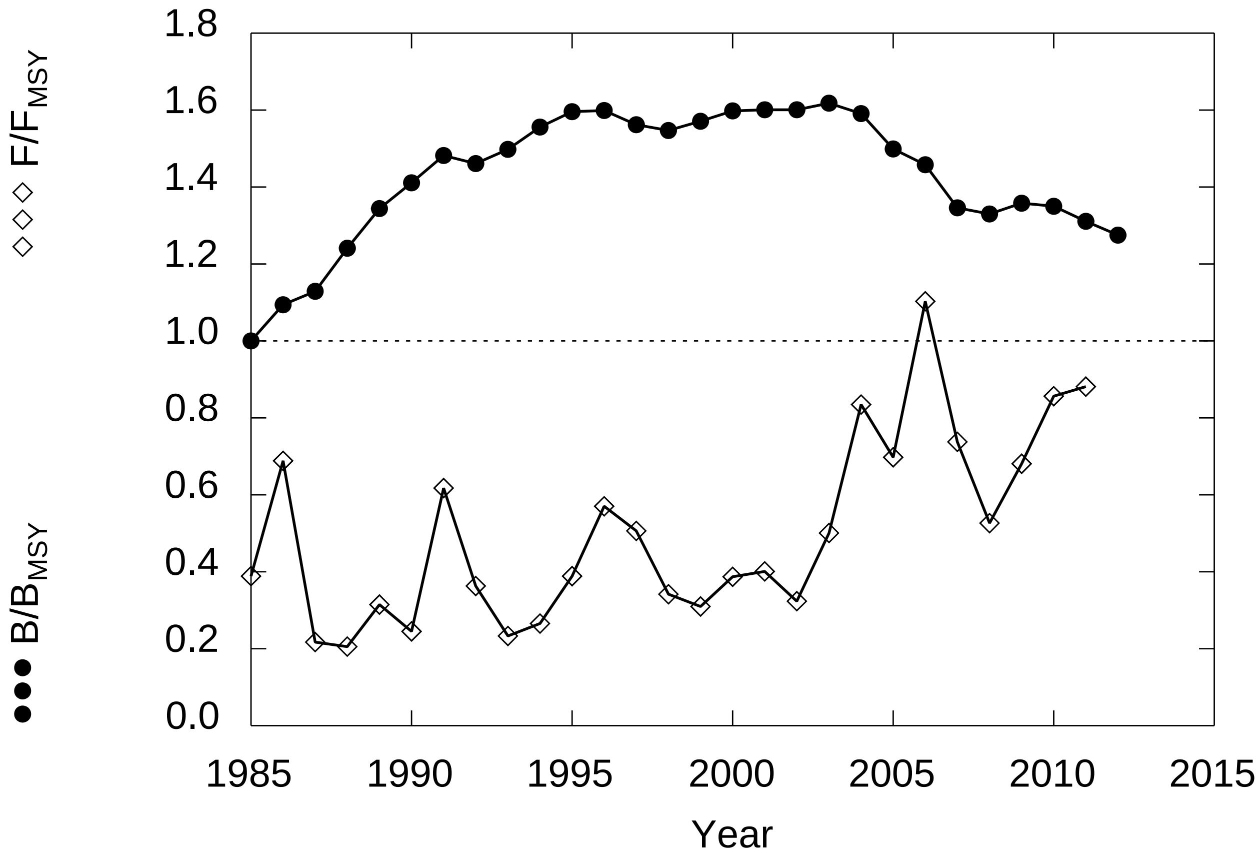


Figure 3.56. Cobia production model: Trends in relative fishing mortality (F/F_{MSY}, top panel) and relative biomass (B/B_{MSY}, bottom panel) estimated by the production model.



Appendix A Abbreviations and symbols

Table A.1. 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 1
BAM	Beaufort Assessment Model (a statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
DW	Data Workshop (here, for 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/Boostrap, 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
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 = 170  Objective function value = -3668.66  Maximum gradient component = 0.000318345
# len_cv_val:
0.127542359795
# log_R0:
11.8244283856
# rec_sigma:
0.605997768765
# log_rec_dev1:
 -0.413054352287 -0.386909067947 -0.518412505872 -0.419948782223 -0.498547781615 -0.653844183075 -0.256898214518 0.375724133276 -0.670243156462
# log_rec_dev2:
 0.194201111886 -1.13978478939 -0.0661388106143 0.165700304946 1.22456944710 -0.444668148641 0.265368070225 1.18726157682 -0.652591080236 -0.705755253699
 0.812035361192 -0.612963572894 0.479884734830 -1.31433184136 -0.454881981172 0.865970614135 0.696316486505 -0.202581252128 -0.213110635976 0.417301422426
-1.27894953389 1.06357468718 0.153222099384 -0.199440583255 -0.0337988093946 -0.206409623974
# selpar_L50_mrip:
3.00539693262
# selpar_slope_mrip:
3.59802225556
# selpar_L50_cA:
2.77213422828
# selpar_slope_cA:
1.94448059202
# log_q_mrip:
-10.0000000000
# log_q_hb:
-11.5764477364
# log_q_sc:
-11.5813676103
# log_avg_F_mrip:
-2.72042974597
# log_F_dev_mrip:
 -1.67222403071 -1.59880268257 -1.53003732453 -1.46484809148 -1.40160106482 -1.34187427116 -1.28539715100 -1.22891896632 -1.17527883036 -1.12406892691
 -1.07479213292 -1.00764268639 -0.943226356126 -0.881225298631 -0.823151703433 -0.769323070393 -0.725474427739 -0.683184460767 -0.641991128254 -0.602025365775
 -0.563094538360 -0.473650736599 -0.389267852103 -0.309515271447 -0.233393525870 -0.159961456300 -0.154550548593 -0.0791328234758 0.0356805895781 0.144481383977
 0.235486666654 -0.305651019223 0.233855678943 -1.78632825332 0.578525524612 1.16274237019 1.74589265057 0.811514203228 0.767052796444 1.02935783431 0.603528796199
 0.982571575281 0.640660306968 -0.0114737927059 -0.0639889764727 0.627562022985 1.04667319986 0.658712387449 0.472369805927 0.637725582852 0.843838689633 0.630488288118
 0.116623960627 1.21404034912 1.44450135881 1.54473766355 1.87760512404 1.41542438087 0.871368810487 1.43827272648 1.67875344544 1.01504859156
# log_avg_F_cA:
-5.52078002214
# log_F_dev_cA:
 -0.998866200050 -0.964330384297 -2.09696840320 -0.813228156948 -0.0878470676808 -1.20434001462 -0.120151297089 0.470424740542 -0.168108681465 0.489311135032
 0.0303548928172 0.267938210317 0.335107549738 0.537082681925 -0.167181105267 -0.369761280436 -0.862415047585 -0.801482832221 -0.957201114093 -1.14367728010 -1.11641052623
 -0.661528352012 -1.37417519401 -1.78427481426 -1.59435942332 -1.19327723704 -1.48733911432 -1.95453791520 -2.11151472317 -1.51024254741 -0.794999748967 0.0503448546949
 0.683719052773 0.150553317611 -0.158749492155 -0.299795716249 0.716133533008 1.32921188147 0.982030212257 1.00221504439 1.01394764607 0.902241127263 0.680714484004 0.587546397117
 0.679727889370 1.08662156348 1.06449029459 1.11887941974 0.817059141338 0.444484228199 0.989355642151 0.848379000425 0.761147820266 0.593155396236 0.680268045000 0.707462408147
 1.04478606317 0.931246043906 0.894378541583 1.13456676639 1.57052382150 1.20135482287
```

Appendix C ASPIC Output: Results of production model run for cobia.

```
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                                                                                     Wednesday, 03 Oct 2012 at 10:32:10
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.47)
                                                                                                      FIT program mode
Author:    Michael H. Prager                                                                      LOGISTIC model mode
           Prager Consulting                                                                         YLD conditioning
           mike.prager@mhprager.com                                                                  LAV optimization

Reference: Prager, M. H. 1994. A suite of extensions to a nonequilibrium             ASPIC User's Manual is available
           surplus-production model.  Fishery Bulletin 92: 374-389.                            gratis from the author.

CONTROL PARAMETERS (FROM INPUT FILE)          Input file: P:/...Production_Cobia/ASPIC Suite/OCT 2012/S28_co_OCT_9.inp
-----------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization.
Number of years analyzed:                      27           Number of bootstrap trials:                             0
Number of data series:                          2           Bounds on MSY (min, max):       1.000E+03     1.000E+06
Objective function:           Least absolute values         Bounds on K (min, max):         1.100E+06     1.000E+08
Relative conv. criterion (simplex):      1.000E-08          Monte Carlo search mode, trials:        1         10000
Relative conv. criterion (restart):      3.000E-08          Random number seed:                               1952385
Relative conv. criterion (effort):       1.000E-04          Identical convergences required in fitting:             8
Maximum F allowed in fitting:               4.000


PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)                                                   error code   0
-----------------------------------------------------------------------------------------------------------------------
Normal convergence

WARNING: Negative correlations detected between some indices.  A fundamental assumption of ASPIC is that all indices
        represent the abundance of the stock. That assumption should be checked.
Number of restarts required for convergence:     12


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
-----------------------------------------------------------------------------------------------------------------------
                                       |
 1  HB Index (WPUE), Yield             |   1.000
                                       |      27
                                       |
 2  SC logbook                         |  -0.064   1.000
                                       |      14      14
                                       --------------------------------------------------
                                               1       2


GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)
-----------------------------------------------------------------------------------------------------------------------
                                                     Weighted            Weighted      Current    Inv. var.    R-squared
Loss component number and title                           LAV     N           MSE       weight       weight      in CPUE

Loss(-1)  LAV in yield                              0.000E+00
Loss(0)   Penalty for B1 > K                        0.000E+00     1           N/A    0.000E+00          N/A
Loss(1)   HB Index (WPUE), Yield                    7.480E+00    27           N/A    1.000E+00          N/A        0.124
Loss(2)   SC logbook                                2.098E+00    14           N/A    1.000E+00          N/A        0.216
..............................................................
TOTAL OBJECTIVE FUNCTION:                      9.57843136E+00
Estimated contrast index (ideal = 1.0):            0.3089          C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):            1.0000          N* = 1 - |min(B-Bmsy)|/K
SEDAR 28 - South Atlantic Cobia                                                                              Page 2


MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
-----------------------------------------------------------------------------------------------------------------------
Parameter                                            Estimate     User/pgm guess    2nd guess    Estimated   User guess

B1/K      Starting relative biomass (in 1985)       5.000E-01          5.000E-01    2.920E-01            0            1
MSY       Maximum sustainable yield                 8.317E+05          6.400E+05    5.072E+05            1            1
```

K	Maximum population size	1.047E+07	2.000E+07	3.043E+06	1	1
phi	Shape of production curve (Bmsy/K)	0.5000	0.5000	----	0	1

--------- Catchability Coefficients by Data Series ---------------

q(1)	HB Index (WPUE), Yield	1.425E-07	1.000E-06	3.238E-07	1	1
q(2)	SC logbook	1.254E-07	1.000E-06	9.500E-05	1	1

MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Logistic formula	General formula
MSY	Maximum sustainable yield	8.317E+05	----	----
Bmsy	Stock biomass giving MSY	5.236E+06	K/2	K*n**(1/(1-n))
Fmsy	Fishing mortality rate at MSY	1.588E-01	MSY/Bmsy	MSY/Bmsy
n	Exponent in production function	2.0000	----	----
g	Fletcher's gamma	4.000E+00	----	[n**(n/(n-1))]/[n-1]
B./Bmsy	Ratio: B(2012)/Bmsy	1.275E+00	----	----
F./Fmsy	Ratio: F(2011)/Fmsy	8.811E-01	----	----
Fmsy/F.	Ratio: Fmsy/F(2011)	1.135E+00	----	----
Y.(Fmsy)	Approx. yield available at Fmsy in 2012	1.039E+06	MSY*B./Bmsy	MSY*B./Bmsy
	...as proportion of MSY	1.249E+00	----	----
Ye.	Equilibrium yield available in 2012	7.687E+05	4*MSY*(B/K-(B/K)**2)	g*MSY*(B/K-(B/K)**n)
	...as proportion of MSY	9.243E-01	----	----

--------- Fishing effort rate at MSY in units of each CE or CC series ---------

fmsy(1)	HB Index (WPUE), Yield	1.115E+06	Fmsy/q(1)	Fmsy/q(1)

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ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1985	0.062	5.236E+06	5.484E+06	3.386E+05	3.386E+05	8.292E+05	3.887E-01	1.000E+00
2	1986	0.109	5.727E+06	5.821E+06	6.364E+05	6.364E+05	8.212E+05	6.883E-01	1.094E+00
3	1987	0.034	5.911E+06	6.210E+06	2.142E+05	2.142E+05	8.020E+05	2.172E-01	1.129E+00
4	1988	0.033	6.499E+06	6.774E+06	2.210E+05	2.210E+05	7.592E+05	2.054E-01	1.241E+00
5	1989	0.050	7.037E+06	7.218E+06	3.607E+05	3.607E+05	7.122E+05	3.146E-01	1.344E+00
6	1990	0.039	7.389E+06	7.579E+06	2.948E+05	2.948E+05	6.647E+05	2.449E-01	1.411E+00
7	1991	0.098	7.759E+06	7.702E+06	7.556E+05	7.556E+05	6.471E+05	6.176E-01	1.482E+00
8	1992	0.058	7.650E+06	7.750E+06	4.467E+05	4.467E+05	6.398E+05	3.629E-01	1.461E+00
9	1993	0.037	7.843E+06	8.000E+06	2.961E+05	2.961E+05	5.996E+05	2.330E-01	1.498E+00
10	1994	0.042	8.147E+06	8.254E+06	3.478E+05	3.478E+05	5.552E+05	2.653E-01	1.556E+00
11	1995	0.062	8.354E+06	8.364E+06	5.161E+05	5.161E+05	5.348E+05	3.885E-01	1.596E+00
12	1996	0.091	8.373E+06	8.270E+06	7.489E+05	7.489E+05	5.523E+05	5.701E-01	1.599E+00
13	1997	0.080	8.176E+06	8.136E+06	6.540E+05	6.540E+05	5.765E+05	5.061E-01	1.562E+00
14	1998	0.054	8.099E+06	8.165E+06	4.430E+05	4.430E+05	5.713E+05	3.415E-01	1.547E+00
15	1999	0.049	8.227E+06	8.299E+06	4.083E+05	4.083E+05	5.470E+05	3.097E-01	1.571E+00
16	2000	0.061	8.366E+06	8.375E+06	5.147E+05	5.147E+05	5.327E+05	3.869E-01	1.598E+00
17	2001	0.064	8.384E+06	8.383E+06	5.339E+05	5.339E+05	5.313E+05	4.009E-01	1.601E+00
18	2002	0.051	8.381E+06	8.428E+06	4.331E+05	4.331E+05	5.226E+05	3.235E-01	1.601E+00
19	2003	0.080	8.471E+06	8.398E+06	6.679E+05	6.679E+05	5.283E+05	5.007E-01	1.618E+00
20	2004	0.133	8.331E+06	8.077E+06	1.071E+06	1.071E+06	5.863E+05	8.346E-01	1.591E+00
21	2005	0.111	7.847E+06	7.735E+06	8.570E+05	8.570E+05	6.421E+05	6.975E-01	1.499E+00
22	2006	0.175	7.632E+06	7.325E+06	1.283E+06	1.283E+06	6.984E+05	1.103E+00	1.458E+00
23	2007	0.117	7.047E+06	7.004E+06	8.207E+05	8.207E+05	7.369E+05	7.377E-01	1.346E+00
24	2008	0.084	6.963E+06	7.038E+06	5.884E+05	5.884E+05	7.331E+05	5.263E-01	1.330E+00
25	2009	0.108	7.108E+06	7.088E+06	7.665E+05	7.665E+05	7.276E+05	6.808E-01	1.358E+00
26	2010	0.136	7.069E+06	6.962E+06	9.470E+05	9.470E+05	7.412E+05	8.563E-01	1.350E+00
27	2011	0.140	6.863E+06	6.767E+06	9.470E+05	9.470E+05	7.605E+05	8.811E-01	1.311E+00
28	2012		6.677E+06						1.275E+00

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RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED)   HB Index (WPUE), Yield

Data type CC: CPUE-catch series   Series weight: 1.000

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Statist weight
1	1985	2.800E-01	7.815E-01	0.0617	3.386E+05	3.386E+05	1.02642	1.000E+00
2	1986	5.500E-01	8.295E-01	0.1093	6.364E+05	6.364E+05	0.41089	1.000E+00
3	1987	9.200E-01	8.849E-01	0.0345	2.142E+05	2.142E+05	-0.03893	1.000E+00
4	1988	6.900E-01	9.652E-01	0.0326	2.210E+05	2.210E+05	0.33569	1.000E+00
5	1989	6.300E-01	1.029E+00	0.0500	3.607E+05	3.607E+05	0.49018	1.000E+00
6	1990	4.300E-01	1.080E+00	0.0389	2.948E+05	2.948E+05	0.92095	1.000E+00
7	1991	1.870E+00	1.098E+00	0.0981	7.556E+05	7.556E+05	-0.53287	1.000E+00
8	1992	1.460E+00	1.104E+00	0.0576	4.467E+05	4.467E+05	-0.27917	1.000E+00
9	1993	1.140E+00	1.140E+00	0.0370	2.961E+05	2.961E+05	0.00000	1.000E+00
10	1994	1.290E+00	1.176E+00	0.0421	3.478E+05	3.478E+05	-0.09234	1.000E+00
11	1995	1.430E+00	1.192E+00	0.0617	5.161E+05	5.161E+05	-0.18219	1.000E+00
12	1996	6.100E-01	1.178E+00	0.0906	7.489E+05	7.489E+05	0.65850	1.000E+00
13	1997	1.020E+00	1.159E+00	0.0804	6.540E+05	6.540E+05	0.12805	1.000E+00
14	1998	9.300E-01	1.164E+00	0.0543	4.430E+05	4.430E+05	0.22405	1.000E+00
15	1999	9.800E-01	1.183E+00	0.0492	4.083E+05	4.083E+05	0.18792	1.000E+00
16	2000	1.390E+00	1.193E+00	0.0614	5.147E+05	5.147E+05	-0.15247	1.000E+00
17	2001	1.460E+00	1.194E+00	0.0637	5.339E+05	5.339E+05	-0.20073	1.000E+00
18	2002	9.800E-01	1.201E+00	0.0514	4.331E+05	4.331E+05	0.20331	1.000E+00
19	2003	1.210E+00	1.197E+00	0.0795	6.679E+05	6.679E+05	-0.01108	1.000E+00
20	2004	1.170E+00	1.151E+00	0.1326	1.071E+06	1.071E+06	-0.01646	1.000E+00
21	2005	1.170E+00	1.102E+00	0.1108	8.570E+05	8.570E+05	-0.05973	1.000E+00
22	2006	1.020E+00	1.044E+00	0.1752	1.283E+06	1.283E+06	0.02303	1.000E+00
23	2007	1.670E+00	9.980E-01	0.1172	8.207E+05	8.207E+05	-0.51483	1.000E+00
24	2008	2.130E+00	1.003E+00	0.0836	5.884E+05	5.884E+05	-0.75324	1.000E+00
25	2009	1.010E+00	1.010E+00	0.1081	7.665E+05	7.665E+05	0.00000	1.000E+00
26	2010	9.600E-01	9.921E-01	0.1360	9.470E+05	9.470E+05	0.03287	1.000E+00
27	2011	9.600E-01	9.642E-01	0.1399	9.470E+05	9.470E+05	0.00437	1.000E+00

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1

```
                   -2       -1.5       -1       -0.5        0        0.5        1        1.5        2
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year    Residual   ------------------------------------------------------------------------------------
1985      1.0264                                            |=====================
1986      0.4109                                            |========
1987     -0.0389                                           =|
1988      0.3357                                            |=======
1989      0.4902                                            |==========
1990      0.9210                                            |==================
1991     -0.5329                                 ===========|
1992     -0.2792                                      ======|
1993      0.0000                                            |
1994     -0.0923                                          ==|
1995     -0.1822                                        ====|
1996      0.6585                                            |=============
1997      0.1280                                            |===
1998      0.2240                                            |====
1999      0.1879                                            |====
2000     -0.1525                                         ===|
2001     -0.2007                                        ====|
2002      0.2033                                            |====
2003     -0.0111                                            |
2004     -0.0165                                            |
2005     -0.0597                                           =|
2006      0.0230                                            |
2007     -0.5148                                  ==========|
2008     -0.7532                             ===============|
2009      0.0000                                            |
2010      0.0329                                            |=
2011      0.0044                                            |
                   ------------------------------------------------------------------------------------
```

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RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED)   SC logbook

Data type I1: Abundance index (annual average) Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Statist weight
1	1985	0.000E+00	0.000E+00	--	*	6.880E-01	0.00000	1.000E+00
2	1986	0.000E+00	0.000E+00	--	*	7.302E-01	0.00000	1.000E+00
3	1987	0.000E+00	0.000E+00	--	*	7.790E-01	0.00000	1.000E+00
4	1988	0.000E+00	0.000E+00	--	*	8.497E-01	0.00000	1.000E+00
5	1989	0.000E+00	0.000E+00	--	*	9.054E-01	0.00000	1.000E+00
6	1990	0.000E+00	0.000E+00	--	*	9.508E-01	0.00000	1.000E+00
7	1991	0.000E+00	0.000E+00	--	*	9.662E-01	0.00000	1.000E+00
8	1992	0.000E+00	0.000E+00	--	*	9.722E-01	0.00000	1.000E+00
9	1993	0.000E+00	0.000E+00	--	*	1.004E+00	0.00000	1.000E+00
10	1994	0.000E+00	0.000E+00	--	*	1.035E+00	0.00000	1.000E+00
11	1995	0.000E+00	0.000E+00	--	*	1.049E+00	0.00000	1.000E+00
12	1996	0.000E+00	0.000E+00	--	*	1.037E+00	0.00000	1.000E+00
13	1997	0.000E+00	0.000E+00	--	*	1.021E+00	0.00000	1.000E+00
14	1998	1.000E+00	1.000E+00	--	1.120E+00	1.024E+00	0.08933	1.000E+00
15	1999	1.000E+00	1.000E+00	--	1.370E+00	1.041E+00	0.27456	1.000E+00
16	2000	1.000E+00	1.000E+00	--	1.020E+00	1.051E+00	-0.02956	1.000E+00
17	2001	1.000E+00	1.000E+00	--	1.190E+00	1.052E+00	0.12371	1.000E+00
18	2002	1.000E+00	1.000E+00	--	9.400E-01	1.057E+00	-0.11751	1.000E+00
19	2003	1.000E+00	1.000E+00	--	7.100E-01	1.053E+00	-0.39455	1.000E+00
20	2004	1.000E+00	1.000E+00	--	1.170E+00	1.013E+00	0.14393	1.000E+00
21	2005	1.000E+00	1.000E+00	--	9.300E-01	9.703E-01	-0.04237	1.000E+00
22	2006	1.000E+00	1.000E+00	--	9.200E-01	9.188E-01	0.00126	1.000E+00
23	2007	1.000E+00	1.000E+00	--	1.100E+00	8.786E-01	0.22479	1.000E+00
24	2008	1.000E+00	1.000E+00	--	7.800E-01	8.829E-01	-0.12388	1.000E+00
25	2009	1.000E+00	1.000E+00	--	1.030E+00	8.891E-01	0.14708	1.000E+00
26	2010	1.000E+00	1.000E+00	--	7.100E-01	8.733E-01	-0.20707	1.000E+00
27	2011	1.000E+00	1.000E+00	--	7.100E-01	8.488E-01	-0.17857	1.000E+00

* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2

```
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    -------------------------------------------------------------------------------------
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.0000                                             |
1991     0.0000                                             |
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998     0.0893                                             |====
1999     0.2746                                             |===========
2000    -0.0296                                            =|
2001     0.1237                                             |=====
2002    -0.1175                                        =====|
2003    -0.3946                             ================|
2004     0.1439                                             |======
2005    -0.0424                                           ==|
2006     0.0013                                             |
2007     0.2248                                             |=========
2008    -0.1239                                        =====|
2009     0.1471                                             |======
2010    -0.2071                                     ========|
2011    -0.1786                                      =======|
                   -------------------------------------------------------------------------------------
```

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Observed (O) and Estimated (*) CPUE for Data Series # 1 -- HB Index (WPUE), Yield

```
     :
2.4 -:
     :
     :
     :                                                                      O
     :
2.0 -:
     :
     :                            O
     :
     :                                                                    O
1.6 -:
     :
     :                              O       O              O
     :                                                  O
     :                                   O
1.2 -:                                   *  * *    *  * *  * *  2 O  O
     :                         *  * *  2         *                *  *
     :                       *                   O                     2    *  2
     :                  O *                        O  O      O            *      2  2
     :                  *
0.8 -:             * *
     :                    O
     :                       O                O
     :               O
     :
0.4 -:                         O
     :             O
     :
     :
     :
0.0 -:
     :........................................................................................................
      :         :         :         :         :         :         :         :         :         :         :
   1980.     1984.     1988.     1992.     1996.     2000.     2004.     2008.     2012.     2016.     2020.


          Observed (O) and Estimated (*) CPUE for Data Series # 2 -- SC logbook
     :
1.6 -:
     :
     :
     :
     :
1.4 -:
     :                                                O
     :
     :
     :
1.2 -:                                                     O
     :                                                            O
     :                                             O                      O
     :
     :                                   *  * *  * *  * 2  * *  *              O
1.0 -:                                 *                          *
     :                         *  * *                        O       *
     :                       *                                       O 2
     :                                                                    * *  * *
     :                    *                                                         *
0.8 -:                                                                      O
     :                  *
     :               *                                          O                O  O
     :             *
     :
0.6 -:
     :
     :
     :
     :
0.4 -:
```

```
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1980.     1984.     1988.     1992.     1996.     2000.     2004.     2008.     2012.     2016.     2020.
SEDAR 28 - South Atlantic Cobia                                                                                 Page  7

                                   Time Plot of Estimated F/Fmsy and B/Bmsy (dashed line = 1.0)
           :
      2.4 -:
           :
           :
           :
           :
      2.0 -:
           :
           :
           :
           :
      1.6 -:                                      B B  B    B B  B B  B B
           :                            B    B B         B                 B
           :                         B    B                                  B
           :                       B                                            B B  B B
           :                    B                                                         B B
      1.2 -:
           :               B  B                                              F
           :-  - -  - -  - -  - -  - -  - -  - -  - -  - -  - -  - -  - -  - -  - -  - -  - -  - -  - -  - -  - -
           :             B
           :                                                                           F  F
      0.8 -:                                                            F
           :               F                                               F    F    F
           :                            F
           :                                        F                             F
           :                                           F              F
      0.4 -:             F                F       F           F  F
           :                       F                     F  F      F
           :                  F F    F       F F
           :
           :
      0.0 -:
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1980.     1984.     1988.     1992.     1996.     2000.     2004.     2008.     2012.     2016.     2020.

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Southeast Data, Assessment, and Review

SEDAR 28

South Atlantic Cobia

SECTION IV: Research Recommendations

December 2012

SEDAR
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North Charleston, SC 29405

Section IV. Research Recommendations

Contents

Data Workshop Research Recommendations

Life History

- 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.
- 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.
- Explore the feasibility of satellite tags for Cobia movement studies.
- 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.
- Further research is needed on Cobia and Spanish mackerel release mortality.
- 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.

Commercial Statistics

Although under the category of research recommendations, this list is not research per se, but rather suggestions to improve data collection. The first three recommendations were modified from the SEDAR17 DW report.

- Need to expand observer coverage.
- Expand TIP sampling to better cover all statistical strata.
- Trade off with lengths versus ages, need for more ages (i.e., hard parts).
- Consider the use of VMS to improve spatial resolution of data.
- During discussions 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).
- Uniformity between state and federal reporting systems/forms would vastly improve the ease and efficiency of data compilation.
- Establish online reporting and use logbooks as a backup.
- Establish a mechanism for identifying age samples that were collected by length or market categories, so as to better address any potential bias in age compositions.
- Compiling commercial data is surprisingly complex. As this is the 28th SEDAR, one might expect that many of the complications would have been resolved by now through better coordination among NMFS, ACCSP, and the states. Increased attention should be given toward the goal of "one-stop shopping" for commercial data.

Recreational Statistics

- Increase proportion of fish with biological data within MRFSS sampling.
- Continue to develop methods to collect a higher degree of information on released fish (length, condition, etc.) in the recreational fishery.
- Require mandatory reporting for all charter boats state and federal.
- Continue development of electronic mandatory reporting for for-hire sector.
- Continued research efforts to incorporate/require logbook reporting from recreational anglers.
- Establish a review panel to evaluate methods for reconstructing historical landings (SWAS, FWS, etc.).
- Quantify historical fishing photos for use in reconstructing recreational historical landings.
- 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 deepwater 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.
- Continue and expand fishery dependent at-sea-observer surveys to collect discard information, which would provide for a more accurate index of abundance.

Indices

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

Assessment Workshop Research Recommendations

The assessment panel made the following 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.
- Better characterize the genetic structure of the stock and evaluate the possibility of local population structure.
- Better characterize the migratory dynamics of the stock and the degree of fidelity to spawning areas.
- Age-dependent natural mortality was estimated by indirect methods for this assessment of cobia. Tag-recapture programs for cobia exist and may prove useful for estimating mortality.
- Obtain MRIP intercept numbers at the DW for cobia and other rarely caught species.

Review Workshop Research Recommendations

- Motives and selectivity of discarding fish by fishers. The current data compilation exercises appear to concentrate on estimating discard mortality, without any consideration of the selective impact of discarding. It would be beneficial to broaden our understanding on the motives for discarding and the selectivity imposed by the behavior to aid considerations of size at age and what appropriate assumptions could be included in the assessment model.
- II. Further analysis of the interactions of length/age and maturity of Cobia. The number of observations that drive the maturity ogive is very low, even relative to the total number of Cobia aged. The minimum landing length appears to impact on the collection of potential samples and is above the likely length of 50% mature. A research approach needs to be developed that strengthens the estimation of the maturity ogive by considering the interaction of size and age and the impact of variability in female maturity on the estimation of benchmarks/reference points. This research will probably have to increase the number of observations of maturity status of 1, 2, 3 and 4 year old fish by sex.
- The DW recommended tagging to study movement patterns. The RW suggests that a tagging program may also help to inform the cobia stock assessment. The fishery and biology of cobia seems to be conducive for a successful tagging program. The fishery for cobia is currently dominated by a recreational fishery with a two-fish bag limit and a minimum landing size, resulting in a large portion of discarded catch. Discarded cobia appear to have high survival (e.g., 95% discard survival assumed in the assessment). Therefore, a tagging program conducted as an industry partnership could release tagged fish from normal fishing operations. Few cobia are discarded per trip, so the additional costs and resources required per trip would be expected to be small, and the data recording aspects at sea would be minimal. The impact on the fishing operations would be anticipated to be negligible. The major costs would be organization, tags, data collation, outreach, a reporting system for recaptured tags, and subsequent data analysis. Industry participation rates might be high if information is provided back to participants, and their collaboration improves stock assessment and fishery management. This information should improve estimates of discard numbers and potentially fish sizes. Estimates of discard mortality may be possible from initial Z from early returns compared with Z on later returns, though this will be compounded with selection. Estimates of Z or tag recovery rate on older ages will help to inform on the appropriate selection function to be used in the assessments could be obtained from ratio of tag returns on from one year to the next. Using tag return data the total mortality Z(i,j,y) between year i and year j, of fish belonging to year class y is obtained using the Jolly-Seber estimator (see Ricker, 1975):

  $$Z(i,j,y) = \log\{\_r(i,k,y)/\_r(j,k,y)*R(j,y)/R(i,y)\} \quad (1)$$

  where R(i,y) is the number of tagged fish of year class y that were released in year i , R(j,y) is the number of tagged fish of the same year class that were released in year j (j>i) and *_r(j,k,y)* is the numbers of such tagged fish that were recaptured in the years k summed over all k > j. Though variability may be caused by variation in initial tagging losses, small numbers of recovered tags and errors in ageing (Antsalo, 2006). If resources are available consideration should be given to coupling two types of tagging: 1) high volume, low cost tagging would be most informative for estimates of Z that would help with population level estimates of total mortality and possibly selection and natural mortality; 2) high cost, electronic tagging might give more detail on migration. Of the two methods, the high volume approaches are more likely to be informative for management parameters at a population level.

References:

Antsalo, M. 2006. Abundance estimation of the Northeast Atlantic mackerel (*Scomberscombrus*) with use of Norwegian tag data. University of Bergen, Department of Biology Bergen Norway. Dissertation 64 pp.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 1–382.

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South Atlantic Cobia

SECTION V: Review Workshop Report
November 2012

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1. Workshop Proceedings

1.1 Introduction

1.1.1 Workshop Time and Place

The SEDAR 28 Review Workshop for South Atlantic Spanish Mackerel (*Scomberomorus maculatus*) and Cobia (*Rachycentron canadum*) was conducted as a workshop held October 29 to November 2, 2012 at the Doubletree Hotel in Atlanta, GA.

1.1.2 Terms of Reference

1. Evaluate the quality and applicability of data used in the assessment.
2. Evaluate the quality and applicability of methods used to assess the stock.
3. Evaluate the assessment with respect to the following:
    - 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 quantitative estimates of the status determination criteria for this stock reliable? If not, are there other indicators that may be used to inform managers about stock trends and condition?
4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status with regard to accepted practices and data available for this assessment.
5. If there are significant changes to the base model, or to the choice of alternate states of nature, then provide a probability distribution function for the base model, or a combination of models that represent alternate states of nature, presented for review. Provide justification for the weightings used in producing the combinations of models.
6. Consider how uncertainties in the assessment, and their potential consequences, have been addressed.
    - Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty.
    - Ensure that the implications of uncertainty in technical conclusions are clearly stated.
7. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.
    - Clearly denote research and monitoring needs that could improve the reliability of, and information provided by, future assessments.
8. Prepare a Peer Review Summary summarizing the Panel's evaluation of the stock assessment and 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 the project guidelines.

The review panel may request additional sensitivity analyses, evaluation of alternative assumptions, and correction of errors identified in the assessments provided by the assessment workshop panel; the review panel may not request a new assessment. Additional details regarding the latitude given the review panel to deviate from assessments provided by the assessment workshop panel are provided in the SEDAR Guidelines and the SEDAR Review Panel Overview and Instructions.

** The panel shall ensure that corrected estimates are provided by addenda to the assessment report in the event corrections are made in the assessment, alternative model configurations are recommended, or additional analyses are prepared as a result of review panel findings regarding the TORs above.**

1.1.3 List of Participants

Panelists		
Marcel Reichert	Review Panel Chair	SA SSC
Steve Cadrin	Reviewer	SA SSC
Matt Cieri	Reviewer	CIE
Mark Dickey-Collas	Reviewer	CIE
John Simmonds	Reviewer	CIE
Analytical Team		
Katie Andrews	Lead Analyst SASM	NMFS Beaufort
Kevin Craig	Lead Analyst SAC	NMFS Beaufort
Kyle Shertzer	Analyst	NMFS Beaufort
Erik Williams	Analyst	NMFS Beaufort
Council Members		
Ben Hartig	Council Rep	SAFMC
Anna Beckwith	Council Rep	SAFMC
Observers		
None		
Staff and Agency		
Ryan Rindone	SEDAR 28 RW Coordinator	SEDAR
Julia Byrd	SEDAR Coordinator	SEDAR
Andrea Grabman	Administrative Support	SEDAR
Mike Errigo	Fishery Biologist	SAFMC

1.1.4 List of Review Workshop Working Papers

Documents Prepared for the Review Workshop		
SEDAR28-RW01	The Beaufort Assessment Model (BAM) with application to cobia: mathematical description, implementation details, and computer code	Craig
SEDAR28-RW02	Development and diagnostics of the Beaufort assessment model applied to Cobia	Craig
SEDAR28-RW03	The Beaufort Assessment Model (BAM) with application to Spanish mackerel: mathematical description, implementation details, and computer code	Andrews
SEDAR28-RW04	Development and diagnostics of the Beaufort assessment model applied to Spanish mackerel	Andrews

2. Review Panel Report

Executive summary

The South Atlantic cobia stock assessment presented by the SEDAR 28 Assessment Workshop (AW) provided the Review Panel (RP) with outputs and results from two assessments models. The primary model was the Beaufort Assessment Model (BAM), while a secondary, surplus-production model (ASPIC) provided a comparison of model results. The RP concluded that the BAM was the most appropriate model to characterize the stock status for management purposes. The current stock status in the base run was estimated to be $SSB_{2011}/MSST=1.75$. The current level of fishing is $F_{2009\text{-}2011}/F_{MSY} = 0.599$, with $F_{2011}/F_{MSY} = 0.423$. Therefore, the RP concludes that the stock is not overfished and is not undergoing overfishing. The qualitative results on terminal stock status were similar across presented sensitivity runs, indicating that the stock status results were robust given the provided data and can be used for management. The outcomes of sensitivity analyses were in general agreement with those of the Monte Carlo Bootstrap analysis in BAM. The RP concluded that the ASPIC model results were not informative for stock status determination and fisheries management.

2.2. Statements addressing each Term of Reference.

2.2.1. Evaluate the quality and applicability of data used in the assessment.

The RP concluded that the data used in the assessment was overall best available, but there was some concern that the assessment team may have tried to do too much with limited available data. The paucity of age and discard information was noted. However the clear progression of some cohorts through the time series of age composition persuaded the RP that an age based model could be appropriate considering the data sources. Some concern was expressed about the impact of the minimum landing size on t he bias of the data, despite the use of the Diaz correction. The impact of the minimum landing size on the selectivity of discards should also be considered.

Add strengths and weaknesses of each category of data.

Strengths and weaknesses of the data related to life history strategies:

The strengths of the data used were

- The stock identity was considered and fish movement was also examined though tag studies, estimates of age varying natural mortality were considered and provided,
- Discard mortality was considered,
- The report highlighted and provided information on sexual dimorphism in growth, and
- Information to derive alternative stock reproduction potential indices was considered.

The weaknesses of the data used were

- That the potential for tagging studies or juvenile release events to monitor mortality had not been fully explored,
- Age sampling was very poor,
- Whilst discard mortality was considered, discard selectivity was not assessed,
- Size of individuals at age in the catches and the size of individuals at age in the population were assumed to be synonymous,
- The number of observations that drive the maturity ogive was very low, even relative to the total number of cobia aged,
- If management was to use an alternative reproductive potential proxy than female biomass, the existing information base appears weak, especially as cobia is an indeterminate spawner,
- There was no provision of information in the report of time trends in growth, maturity and weight to inform on environmentally driven changes in sustainable exploitation benchmarks.

The strengths and weaknesses of the used landings data:

Strengths included commercial and recreational landings. Commercial landings were available back to 1950 a nd a combination of MRFSS and MRIP were used to examine recreational removals to 1983. Commercial discards were of a concern, as these are not well estimated given due low sample sizes. Additionally discards were reconstructed from 1983 to 1993 using a static kept to discard ratio further compounding this uncertainty. However, it was noted that commercial landings represented a small part of the recent catch with discards a smaller portion of that. This suggests that overall importance of discards to the assessment was minimal given other inputs.

Strengths and weaknesses of length and age composition data:

Cobia commercial length compositions were updated to 2011 (Table 2.8). Annual length compositions (originally 1-cm bins) were combined into 3-cm bins with a minimum size of 20 cm and a maximum size of 149 cm. Commercial length compositions were pooled across all years (1982 - 2011) and weighted by the annual number of trips sampled due to low sample sizes. Commercial age compositions were also pooled across years (1986 – 2011) due to low sample sizes and weighted by the annual number of fish sampled (number of trips was not available for age compositions). Cobia age 12-15 were pooled as a plus group (12+, Table 2.9). This procedure removes any contrast in age and length data by year, allowing only mean age structure for the period to be estimated. This is clearly a weakness, but given the proportion of catch taken in the commercial fishery may not be a major problem. Cobia recreational age compositions were updated to include 2011 data. Recreational age compositions from the headboat survey (SRHS) and MRFSS were combined. Following a review unweighted age compositions with annual sample sizes equal to the number of fish were used in the statistical catch-at-age model. The provision of age data for the assessment is regarded as a particularly important part of the information on catches. Modeling population growth and mortality through length alone for cobia is unlikely to lead to precise estimates of population parameters as there is considerable overlap between lengths at age 2 and older making the separation of cohorts difficult. Information on catch at age in the recreational fishery has improved considerably with increased sampling to a level of 200 trips in 2007 onwards. Before this the numbers aged where lower and in some years inadequate. However, 200 trips is still a relatively small number of aged individuals as often trips only catch single individuals with which to apportion among 12 age classes. Increasing the number of individuals used to estimate age proportions in the recreational fishery is identified as one of the ways to improve the assessment.

The strengths and weaknesses of the used indices of abundance:

The strengths of the indices of abundance used were:

- Three fishery dependent indices were available for potential use in the cobia stock assessment, with the recreational headboat index being available since 1981,
- Indices cover the entire stock area (recreational headboat and MRFSS indices) or the central portion of the stock (SCDNR charterboat index),
- Fishery-dependent indices are based on selected data (e.g., selected headboat vessels with consistent catches of cobia),
- Fishery-dependent indices are standardized to account for factors not related to relative abundance using conventional statistical analyses (e.g., delta-GLM with year, location, season effects and bootstrap estimates of precision),
- Trends in the recreational headboat index are considered to represent resource trends, because the fishery does not target cobia, and
- The recreational headboat index and SCDNR charterboat logbook program are considered to be a census of effort for those fleets.

The weaknesses of the indices data used were

- There are no fishery-independent indices of abundance available,
- Fishery catchability may not be constant or linear, as assumed in the assessment,
- Standardization of fishery-dependent indices does not remove the effect of technological improvements in fishing efficiency,
- Regulatory changes may influence fishery catch rates,
- MRFSS statistics for rarely caught species, like cobia, are less reliable,
- MRFSS statistics are not necessarily relevant to fishing effort directed toward cobia,
- MRFSS and MRIP statistics are combined into a single series, but CPUE from the two programs may not be comparable,
- Correlation among indices is poor, such that one index (MRFSS) needed to be removed from the stock assessment, and
- Assessment results (e.g., stock status) are sensitive to the relative weighting of indices.

2.2.2. Evaluate the quality and applicability of methods used to assess the stock.

The RP concluded that the BAM and presented methods were the best available considering the data. BAM can utilize the dynamics between cohorts whereas the ASPIC model cannot, as it is biomass based. There was some concern that the conclusion on stock status and other assessment results from the BAM are substantively based on the steepness assumption.

2.2.3. Evaluate the assessment with respect to the following:

Is the stock overfished and what information helps you reach this conclusion?

The RP concluded that there is a high probability that stock is not overfished. The base model conclusions combined with the sensitivity analyses were the basis for the RP's conclusion.

Is the stock undergoing overfishing and what information helps you reach this conclusion?

The RP concluded that there is a good probability that stock is not undergoing overfishing, but the RP is less certain about the status of F than SSB. The base model conclusions combined with the sensitivity analyses were the basis for the RP's 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 quantitative estimates of the status determination criteria for this stock reliable? The RP interpreted the latter question as: How reliable are the reference points?

The RP found the stock recruit relationship was not informative in the context of the parameters needed for management against MSY criteria. However, the stock seems to be in state of reasonable, not impaired recruitment, and in that sense, it is informative.

The analysis of different stock recruit relationship did not have a effect on trends, but did change F/SSB status, and the results of this extra analysis are documented below (section 2.3).

The RP recommended that further exploration could be useful to understand dynamics (see research recommendations below), but was aware that additional insight may not necessarily lead to better informed models or management.

There was some concern by the RP that the status is sensitive to steepness estimates. However, analyses indicated that this may not change status determination. The assumed estimates of steepness appeared to be justified when the characteristics of cobia where compared to other estimates given in the literature.

Recommendation for P*'s using SAFMC tiered approach, applying additive penalties to P* = 0.5: cobia (P* = 0.325 = 0.5 - 0.175).

I. Assessment Information – Tier 2: Quantitative assessment provides estimates of either exploitation or biomass, but not MSY benchmarks; requires proxy reference points. (P* penalty = -0.025; steepness was fixed at h = 0.75)

II. Uncertainty – Tier 3: Medium: This tier represents assessments in which key uncertainties are addressed via statistical techniques and sensitivities, but the full uncertainties are not carried forward into the projections and reference point calculations. Projections may, however, reflect uncertainty in recruitment and population abundance. Although outputs include distributions of F, F_{MSY} as in the 'High' category above, in this category fewer uncertainties are addressed in developing such distributions. One example for this level is a distribution of F_{MSY} which only reflects uncertainty in recruitment. (P* penalty = -0.05).

III. Stock Status – Tier 1: Neither overfished nor overfishing, and stock is at high biomass and low exploitation relative to benchmark values. (P* penalty = 0).

IV. Productivity-Susceptibility Analysis – Tier 3: High Risk. Low productivity, high vulnerability and susceptibility, score >3.181 (P* penalty = -0.1; PSA score = 3.29, MRAG 2009).

2.2.4. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status with regard to accepted practices and data available for this assessment.

The RP concluded that since accepted practices were followed, it was adequate and appropriate.

2.2.5. If there are significant changes to the base model, or to the choice of alternate states of nature, then provide a probability distribution function for the base model, or a combination of models that represent alternate states of nature, presented for review. Provide justification for the weightings used in producing the combinations of models.

The RP explored some additional sensitivity to other states of nature, but did not propose any changes.

2.2.6. Consider how uncertainties in the assessment, and their potential consequences, have been addressed.

There were two ways in which this was addressed in the assessment: MC and Alternatives to assumptions.
The RP asked for several additional runs to explore this issue (see section 2.3. below).

Comment on the degree to which methods used to evaluate uncertainty reflect and capture the significant sources of uncertainty.

The RP concluded that the degree is sufficient to address scientific uncertainty for management (ABC) recommendations. However, they are conditional to the overall choice of the model dynamics, but this is acceptable practice. The RP also noted that the management uncertainty is not included, but this was also not required.

Ensure that the implications of uncertainty in technical conclusions are clearly stated (in the assessment document).

The RP concluded that they were clearly stated.

2.2.7. Consider the research recommendations provided by the Data and Assessment workshops and make any additional recommendations or prioritizations warranted.
Clearly denote research and monitoring needs that could improve the reliability of, and information provided by, future assessments.

I. Motives and selectivity of discarding fish by fishers. The current data compilation exercises appear to concentrate on estimating discard mortality, without any consideration of the selective impact of discarding. It would be beneficial to broaden our understanding on the motives for discarding and the selectivity imposed by the behavior to aid considerations of size at age and what appropriate assumptions could be included in the assessment model.

II. Further analysis of the interactions of length/age and maturity of Cobia. The number of observations that drive the maturity ogive is very low, even relative to the total number of Cobia aged. The minimum landing length appears to impact on the collection of potential samples and is above the likely length of 50% mature. A research approach needs to be developed that strengthens the estimation of the maturity ogive by considering the interaction of size and age and the impact of variability in female maturity on the estimation of benchmarks/reference points. This research will probably have to increase the number of observations of maturity status of 1, 2, 3 and 4 year old fish by sex.

III. The DW recommended tagging to study movement patterns. The RW suggests that a tagging program may also help to inform the cobia stock assessment. The fishery and biology of cobia seems to be conducive for a successful tagging program. The fishery for cobia is currently dominated by a recreational fishery with a two-fish bag limit and a minimum landing size, resulting in a large portion of discarded catch. Discarded cobia appear to have high survival (e.g., 95% discard survival assumed in the assessment). Therefore, a tagging program conducted as an industry partnership could release tagged fish from normal fishing operations. Few cobia are discarded per trip, so the additional costs and resources required per trip would be expected to be small, and the data recording aspects at sea would be minimal. The impact on the fishing operations would be anticipated to be negligible. The major costs would be organization, tags, data collation, outreach, a reporting system for recaptured tags, and subsequent data analysis. Industry participation rates might be high if information is provided back to participants, and their collaboration improves stock assessment and fishery management. This information should improve estimates of discard numbers and potentially fish sizes. Estimates of discard mortality may be possible from initial Z from early returns compared with Z on later returns, though this will be compounded with selection. Estimates of Z or tag recovery rate on older ages will help to inform on the appropriate selection function to be used in the assessments could be obtained from ratio of tag returns on from one year to the next. Using tag return data the total mortality Z(i,j,y) between year i and year j, of fish belonging to year class y is obtained using the Jolly-Seber estimator (see Ricker, 1975):

$$Z(i,j,y) = \log\{\Sigma r(i,k,y)/\Sigma r(j,k,y)*R(j,y)/R(i,y)\} \qquad (1)$$

where R(i,y) is the number of tagged fish of year class y that were released in year i , R(j,y) is the number of tagged fish of the same year class that were released in year j (j>i) and $\Sigma r(j,k,y)$ is the numbers of such tagged fish that were recaptured in the years k summed over all k > j. Though variability may be caused by variation in initial tagging losses, small numbers of recovered tags and errors in ageing (Antsalo, 2006). If resources are available consideration should be given to coupling two types of tagging: 1) high volume, low cost tagging would be most informative for estimates of Z that would help with population level estimates of total mortality and possibly selection and natural mortality; 2) high cost, electronic tagging might give more detail on migration. Of the two methods, the high volume approaches are more likely to be informative for management parameters at a population level.

References:

Antsalo, M. 2006. A bundance estimation of the Northeast Atlantic mackerel (*Scomber scombrus*) with use of Norwegian tag data. University of Bergen, Department of Biology Bergen Norway. Dissertation 64 pp.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 1–382.

2.3. Summary Results of Analytical Requests (Sensitivities, corrections, etc).

I. Evaluation of dome-shaped selectivity for cobia assessment.

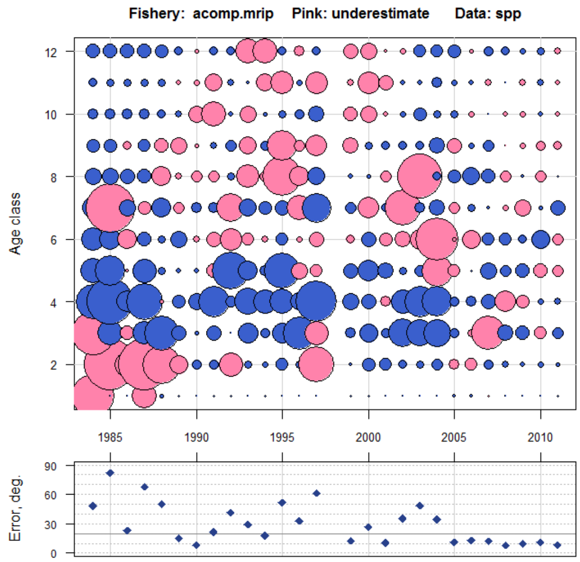
Rational: It was noted that the proposed assessment model was based on an assumption that the dominant fishery, the recreational fishery, was modeled with a selectivity at age based on a logistic curve asymptotic to full selection. However, the fishery was reported to be diverse with respect to variation in population density, season, latitude, and onshore-offshore variability. Such variability might be expected to be characterized by a dome shaped selection function even though the gear interaction could be considered logistic.

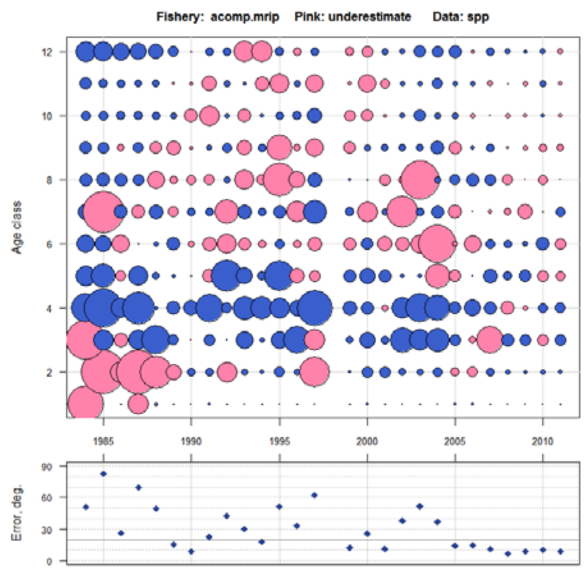
Objective: Evaluate the sensitivity of F/F_{msy} and SSB/SSB_{msy} to the selectivity assumption.

Outcome: Initially a fixed decline in selection with age was tested and secondly some alternative fitting methods were tested. The alternative assumption on selection resulted in very similar residual patterns and very similar overall fit, indicating that the data may not be sufficient to differentiate between the two alternatives. Further exploration using a single parameter to determine the rate of decline in selection above the fitted peak suggests a rather flat likelihood surface but does show a minimum that occurs with some doming. Dome shaped selection does not change the general perception of stock status with respect to 'over fished' or 'over fishing' criteria however, use of dome shaped selection supports a perception that F/F_{msy} is lower and SSB/SSB_{msy} is greater.

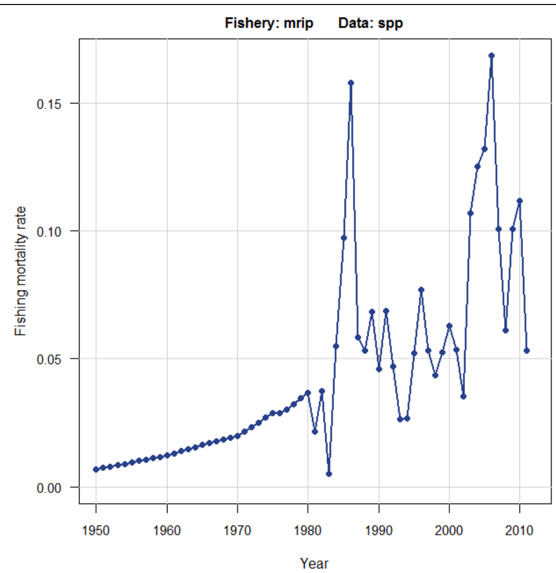
	Fmsy	SSBmsy	MSY	Fend/Fmsy	SSBend/MSST	steep	R0
Logistic	0.46	536.8	808	0.599	1.75	0.75	136548
Dome-fit	0.466	1072.7	1624	0.188	3.58	0.75	288706

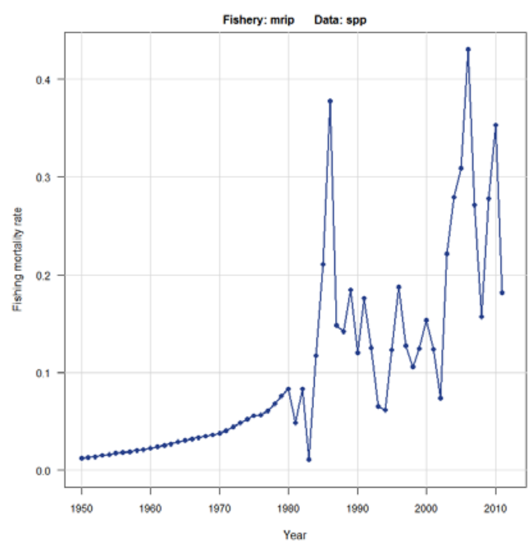
Residuals on dome shaped logistic selection functions fishery data.

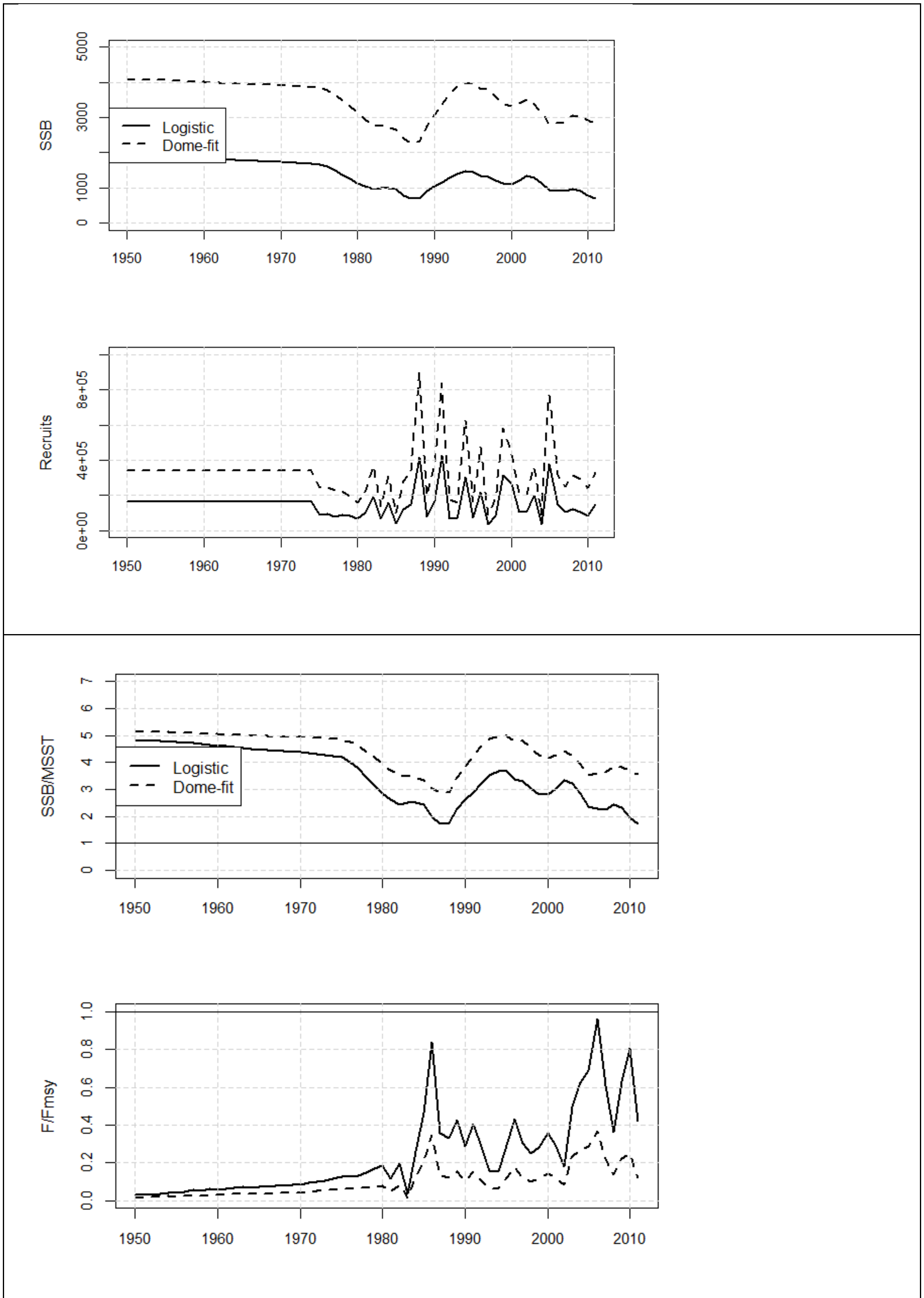




Mean F dome shaped logistic selection functions.



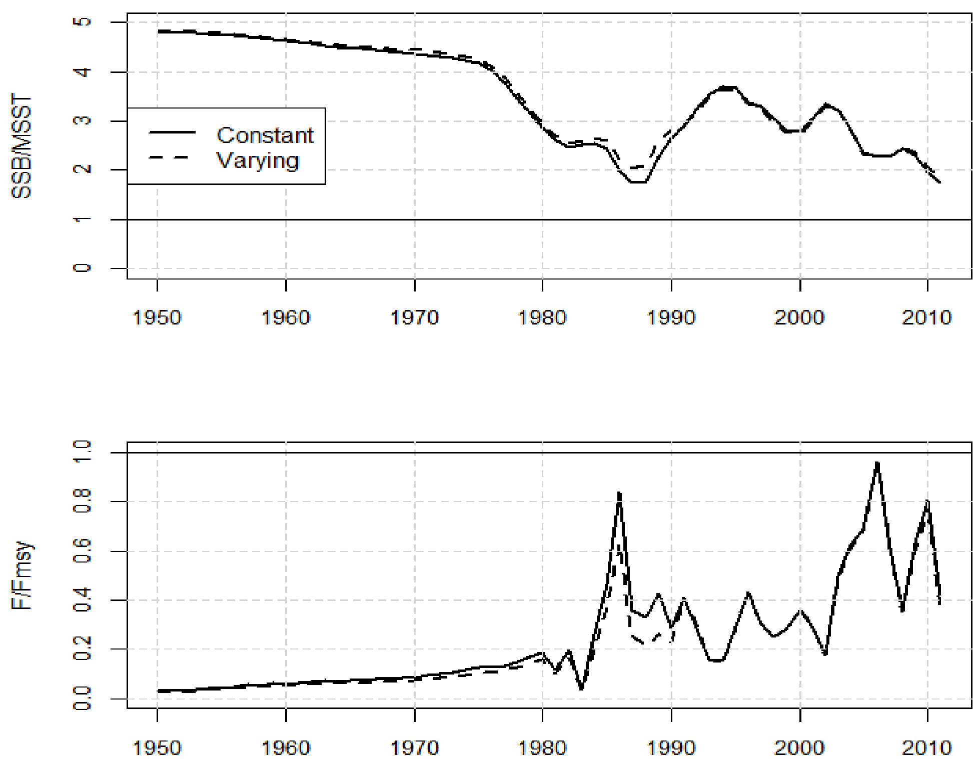




Comparison of stock and status for domed and logistic functions

II. Time varying selectivity

The RP requested a sensitivity analysis to evaluate the effects of assuming constant selectivity. The most reasonable basis for a change in selectivity was the 1990 regulation for a two-fish bag limit. Accordingly, an alternative BAM configuration was developed with two selectivity periods (1950-1990 and 1991-2011) for the recreational fleet. The additional model parameters produced only a slightly improved fit to early age composition data, and minor changes in relative stock size and fishing mortality in the late 1990s, but negligible changes to more recent estimates and no change in stock status. Therefore, the RP concluded that the constant selectivity assumption was the most parsimonious model, and results were not sensitive to a change in selectivity from the bag limit regulation.



III. Start date (1950 vs. 1981)

The RP requested a run with the initialization year for the BAM be move to 1981 rather than 1950 (base).

Justification: The RP noted that with the exception of commercial and reconstructed recreational landings, much of the observational data did not start until 1981. A s such the RP thought it would be useful to test sensitivity of the model by setting the start year to the 1st year of complete data

Results: Overall the model was not sensitive to changes in the start year. Neither stock status nor reference points changed significantly.

Run	Fmsy	SSBmsy	MSY	Fend/Fmsy	SSBend/MSST	Steepness	R0
Start 1950	0.461	536.8	808	0.599	1.75	0.75	136548
Start 1981	0.471	570	873	0.527	1.88	0.75	140414

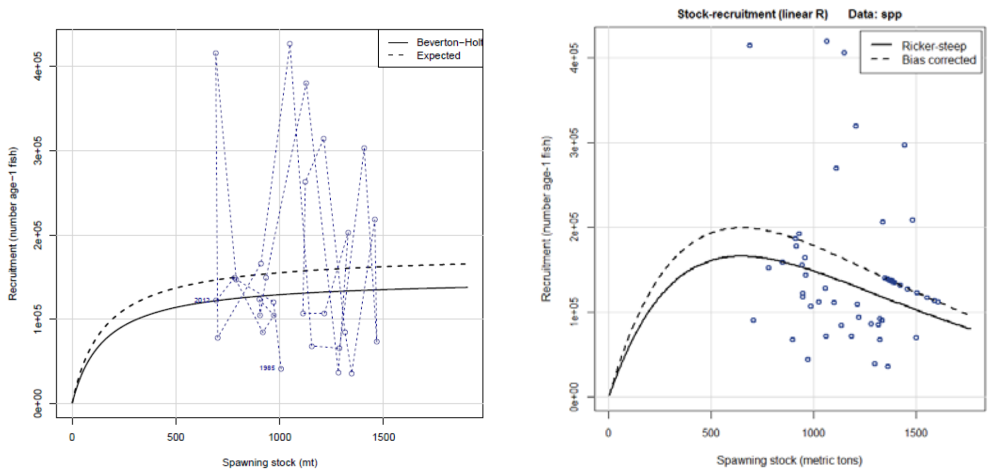
IV. Evaluation of alternative (Ricker) S-R model.

Rational: It was noted that the proposed assessment model was based on an assumption that the S-R model was Beverton/Holt form. Examination of the SSB Rec pairs indicate a significant fall in recruitment with increasing SSB and a difficulty in S-R model fitting with inability to estimate steepness for the BH model.

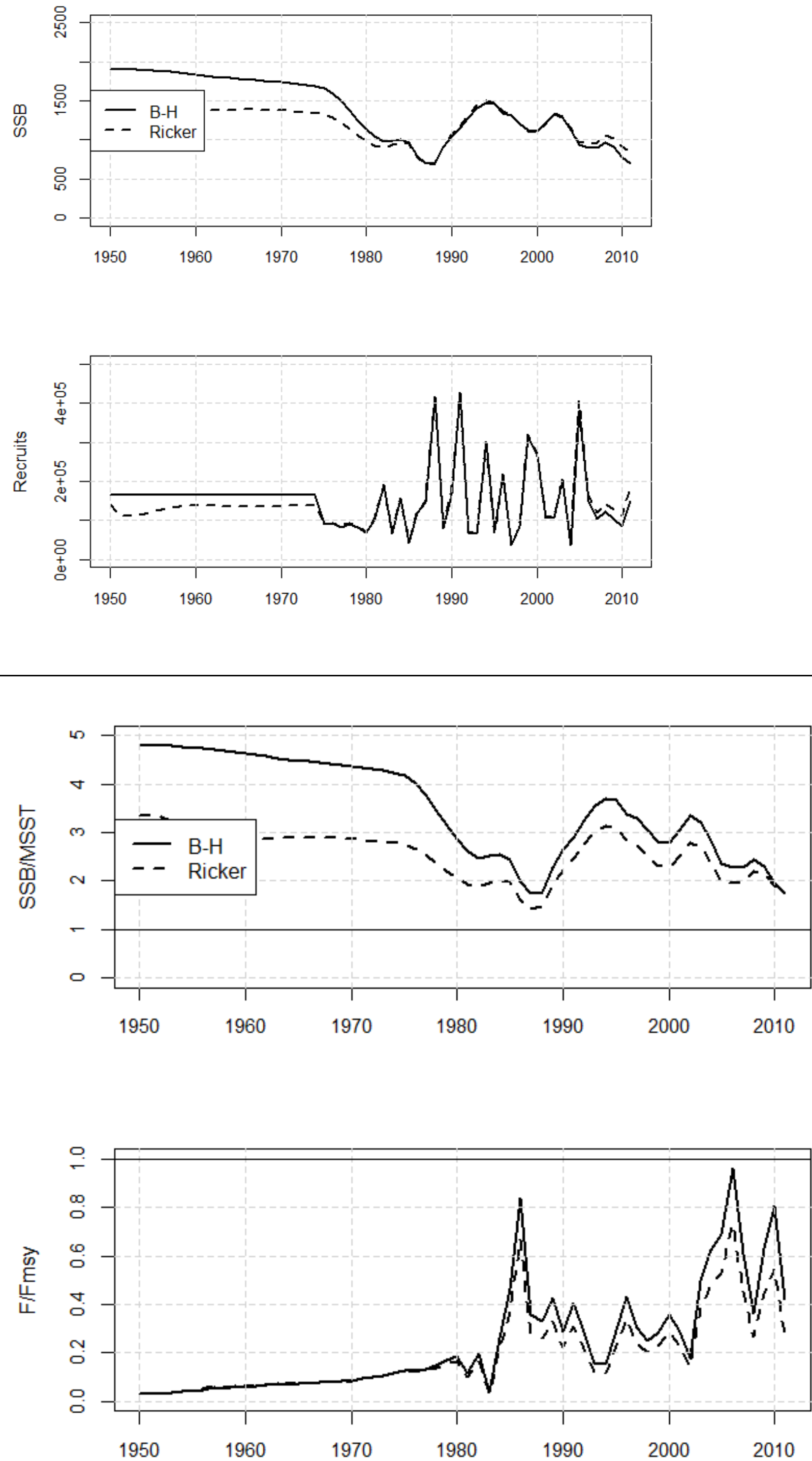
Objective: Evaluate the sensitivity of F/F_{msy} and SSB/SSB_{msy} to an alternative S-R assumption.

Outcome: The alternative assumption on S -R model resulted in closer fit to the S-R pairs, slightly poorer overall fit but because an additional parameter estimating steepness could now be fitted in the model, increasing the number of fitted parameters. However, the newly estimated steepness parameter does not come from information on s lope to the origin, rather from the mathematical construct of the Ricker model and the information on the decline in recruitment at high biomass that mathematically implies the steepness. The perception of stock status with respect to 'over fished' or 'over fishing' criteria was unchanged, however, the use of Ricker S-R model results in a perception that F/F_{msy} is slightly lower and SSB/SSB_{msy} is slightly greater. The greatest changes in the assessment are found in the early years where there is little informative data. The unexploited biomass is particularly sensitive to choice of S-R functional form. It is suggested that S-R model choice is best selected based on an understanding of population biology rather than just fit criteria alone.

Run	Fmsy	SSBmsy	MSY	Fend/Fmsy	SSBend/MSST	Steepness	R0
B-H	0.461	536.8	808	0.599	1.75	0.75	136548
Ricker	0.586	649.2	1182	0.405	1.77	2.15	-



Comparison of BH and Ricker S-R.



Comparison of stock status and exploitation status with alternative BH or Ricker S-R relationships.

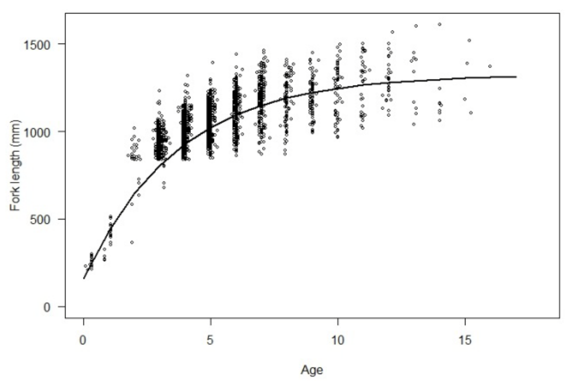
V. Exploration of growth model assumptions.

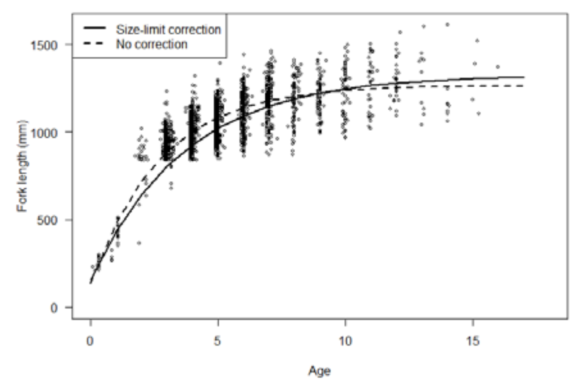
Rational: There were a number of interlinking issues associated with data preparation and modeling of growth maturation ogive and fraction discarded. There were some indications in the data that mean weight at age 3 might be underestimated as growth before and after maturation appears to follow fit different V-B growth models. The truncation should also be linked to estimated discard rates and the uses of maturity data.

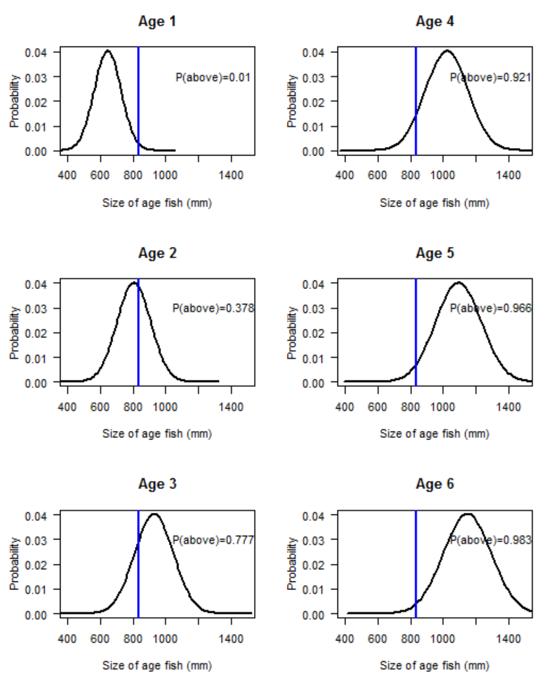
Objective: Evaluate the sensitivity of F/F_{msy} and SSB/SSB_{msy} to alternative growth assumptions.

Outcome: The change in growth modelling resulted in changes in model results with small changes in selectivity and stock status. The changes in context of stock status are negligible.

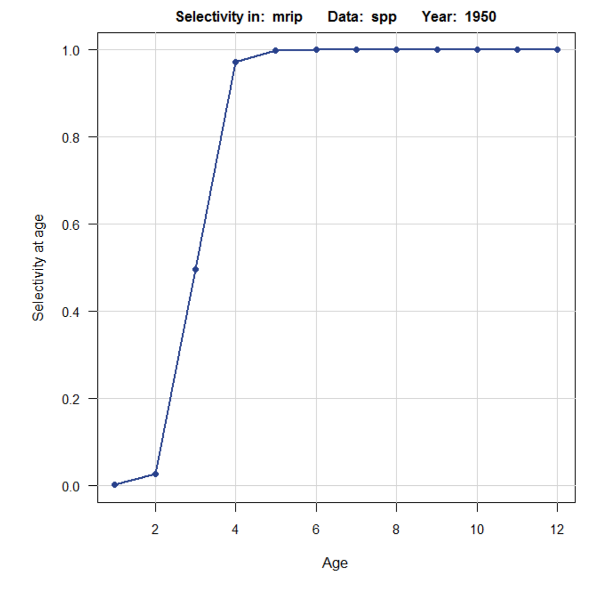
	Fmsy	SSBmsy	MSY	Fend/Fmsy	SSBend/MSST	steep	R0
one VB curve	0.461	536.8	808	0.599	1.75	0.75	136548
two VB curve	0.495	421	871.6	0.646	1.72	0.75	120175

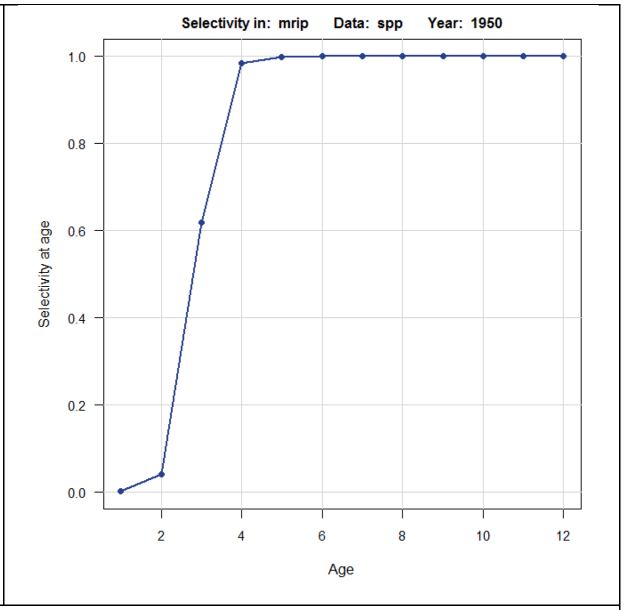




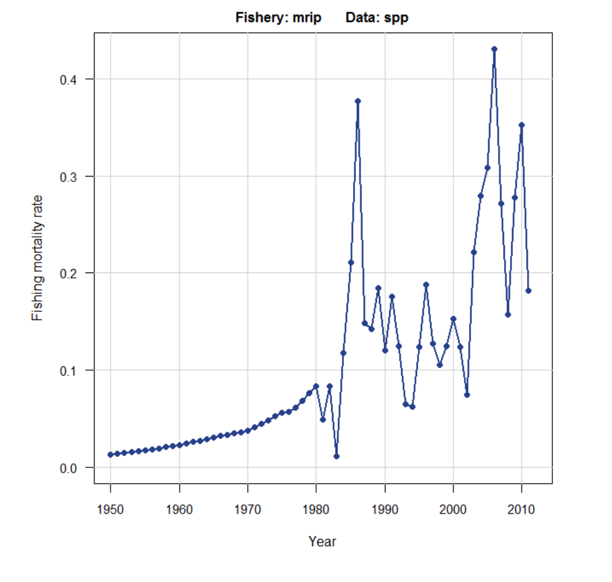


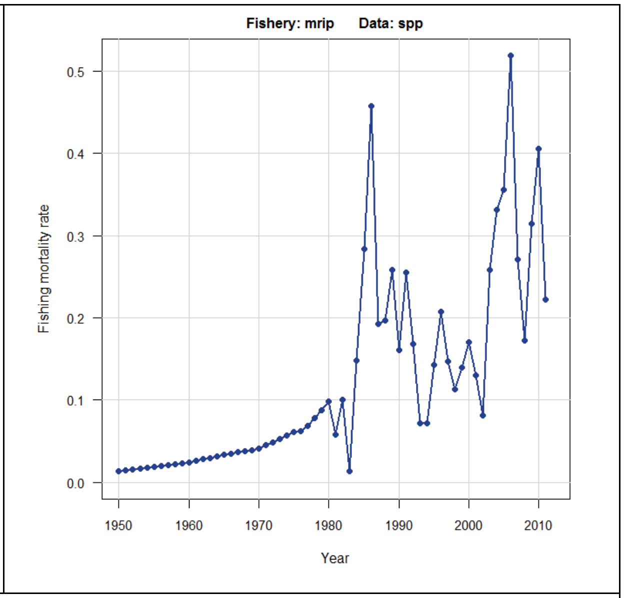
Single and dual growth function models for growth, and truncation at age due to minimum landing size





Comparison of logistic selectivity functions with single and dual growth functions.





Comparison between single and two growth functions

3. Submitted comments

No additional comments were submitted.

SEDAR

Southeast Data, Assessment, and Review

SEDAR 28

South Atlantic Cobia

SECTION VI: Addendum

May 2013

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

P* and Associated Analyses for South Atlantic Cobia SEDAR 28 Stock Assessment

Sustainable Fisheries Branch, National Marine Fisheries Service,
Southeast Fisheries Science Center,
101 Pivers Island Rd, Beaufort, NC 28516
April 15, 2013

Introduction

This document responds to requests for P* projections and related information from the SEDAR 28 South Atlantic cobia stock assessment following the April 2013 meeting of the SSC. The SSC requested the following additional information from the Monte Carlo Bootstrap (MCB) uncertainty analysis described in the assessment report: 1) The percentage of runs with SSB > MSST; 2) the percentage of runs with F < MFMT; and 3) the median values of F_{msy}, MSST, and MSY from the uncertainty runs. P* projections were also requested with specified probabilities of exceeding the overfishing limit in any projection year of P*=0.4 and P*=0.5.

Uncertainty Analysis

The MCB analysis is fully described in the assessment report (SEDAR 2012). The median values requested from the MCB runs are shown in Table 1 along with the point estimates from the base run. The percentage of MCB runs with SSB > MSST was 89.7%. The percentage of MCB runs with F < MFMT was 93.8%.

Table 1. Management quantities from the SEDAR 28 South Atlantic cobia stock assessment. "Estimate" refers to the point estimate from the base run of the cobia catch-age model. "MCB value" refers to the median of the 3196 MCB runs that were retained and used to characterize uncertainty.

Quantity	Units	Estimate	MCB value
F_{MSY}	y^{-1}	0.461	0.480
MSST	mt	397.2	379.2
MSY	1000 lb	808	772.6
$F_{2009-2011}/F_{MSY}$	—	0.599	—
SSB_{2011}/MSST	—	1.75	—

P Analysis*

Acceptable biological catch (ABC) was computed using the sequential PASCL approach of Shertzer et al. (2010), a refinement of the probability-based approach described in Shertzer et al. (2008). This approach solves for annual levels of projected landings that are consistent with a preset acceptable probability of overfishing (P*) in any year of the projection time period. The method considers uncertainty in F_{MSY} as characterized by the MCB analysis described in the SEDAR 28 South Atlantic cobia stock assessment report (SEDAR 2012). No implementation uncertainty is included so that annual catch targets are considered to be centered on the ABC. Two 5-yr projections were run with P* = 0.5 and P* = 0.4. These values were recommended by the SSC following review of the assessment, which showed the stock is not overfished nor experiencing overfishing.

Projections were run for the five years following the terminal year of the assessment (2012-2016). The structure of the projection model is described in SEDAR (2012). The first year of new management is assumed to be 2013, which is the earliest year that management could respond to this assessment. Point estimates of initial abundance at age in the projection (start of 2012), other than at age 1, were taken to be the 2011 estimates from the assessment, discounted by 2011 natural and fishing mortalities. The initial abundance at age 1 was computed using the estimated spawner-recruit model and a 2011 estimate of SSB. In the assessment, the terminal two years of recruitment did not deviate from the spawner-recruit curve, which influenced the abundances of ages 1-2 ($N_{1\text{-}2}$) in 2011. In the projections, lognormal stochasticity was applied to these abundances based on recruitment variation (σ_R). Thus, the initial abundance in year one (2012) of the projections included this variability in $N_{2\text{-}3}$, as well as in the SSB_{2011} used to compute initial recruits, N_1. Because the assessment ended in 2011, the projections required an initialization period (2012). The fully selected fishing mortality rate during the initialization period was taken to be the geometric mean of fully selected F from 2009-2011. Any changes in fishing effort were assumed to begin in 2013.

To characterize uncertainty in future stock dynamics, stochasticity was included in replicate projections, each an extension of a single MCB assessment model fit. Thus, projections carried forward uncertainties in natural mortality, steepness, and historical recreational landings, as well as in estimated quantities such as spawner-recruit parameters, selectivity curves, and in initial (2012) abundance at age. Initial and subsequent recruitment values were generated with stochasticity using a Monte Carlo procedure, in which the estimated Beverton-Holt model of each MCB fit was used to compute mean annual recruitment values. Variability was added to the mean values by choosing multiplicative deviations at random from the recruitment deviations estimated for that chosen MCB run.

The procedure generated 10,000 replicate projections of MCB model fits drawn at random (with replacement) from the MCB runs. In cases where the same MCB run was drawn, projections would still differ as a result of stochasticity in projected recruitment streams. Precision of projections was represented graphically by the 5^{th} and 95^{th} percentiles of the replicate projections.

Annual ABC (landings plus discard mortalities in 1000 lb whole weight) was computed for the years 2013-2016. Projected values from this assessment are show in Figure 1 and 2 and Table 2 and 3. In general, ABC increased with a higher acceptable probability of overfishing (P*) while spawning stock biomass decreased. Because implementation uncertainty was considered zero, these ABC values should be considered possible catch limits. Implementation uncertainty could be included in which case these values would be adjusted downward in setting annual catch targets (ACTs).

The projection method applied here assumed the catch taken from the stock was the annual ABC. If the projection had applied a catch level lower than the ABC, say at ACT < ABC, then the corresponding reduction in applied F would have resulted in higher stock sizes, and higher ABCs in subsequent years.

Comments on Projections:

- In general, projections of fish stocks are highly uncertain, particularly in the long-term (> 3-5 years). The large confidence intervals on estimated F and associated spawning stock biomass in 2015-2016 (Figure 1-2), suggests projections beyond 3 years are highly uncertain for this stock.
- Although these projections included many 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 fishing effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- These projections did not consider any error in implementing regulations (e.g., landings in excess of the ABC). If implementation error were included the projections would be altered.
- The projections assume that the estimated spawner-recruit relationship applies in the future and that past residuals reflect future uncertainty in recruitment. If future recruitment changes, due to environment or harvest effects, then stock trajectories will be altered.

References

SEDAR, 2012. SEDAR 28 Stock Assessment Report for South Atlantic Cobia.

Shertzer, K.W., M.H. Prager, and E.H. Williams. 2008. A probability-based approach to setting annual catch levels. Fishery Bulletin 106:225-232.

Shertzer, K.W., M.H. Prager, and E.H. Williams. 2010. Probabilistic approaches to setting acceptable biological catch and annual catch targets for multiple years: Reconciling methodology with National Standards Guidelines. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 2:451-458.

Table 2. Acceptable biological catch (ABC) in units of 1000 lb whole weight based on the annual probability of overfishing P* = 0.4. F = fishing mortality rate (per yr), SSB = mid-year spawning stock biomass (mature female biomass in metric tons whole weight), Pr(SSB > SSB_{MSY}) = proportion of replicates where SSB was above the point estimate of SSB_{MSY} = 536.8 mt, R = recruits (1000 age-1 fish), and L = Landings plus discards (1000 lb whole weight). ABC (1000 lb whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity while other values presented are medians.

Year	F	P*	SSB	Pr(SSB > SSBmsy)	R	ABC (1000 lb)
2013	0.412	0.4	587.2	0.57	114132	815.1
2014	0.404	0.4	567.5	0.54	114869	768.6
2015	0.388	0.4	561.4	0.53	110234	726.7
2016	0.379	0.4	563.5	0.53	108437	706.5

Table 3. Acceptable biological catch (ABC) in units of 1000 lb whole weight based on the annual probability of overfishing P* = 0.5. F = fishing mortality rate (per yr), SSB = mid-year spawning stock biomass (mature female biomass in metric tons whole weight), Pr(SSB > SSB_{MSY}) = proportion of replicates where SSB was above the point estimate of SSB_{MSY} = 536.8 mt, R = recruits (1000 age-1 fish), and L = Landings plus discards (1000 lb whole weight). ABC (1000 lb whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity while other values presented are medians.

Year	F	P*	SSB	Pr(SSB > SSBmsy)	R	ABC (1000 lb)
2013	0.478	0.5	575.0	0.55	114132	922.7
2014	0.478	0.5	536.4	0.50	114136	845.5
2015	0.472	0.5	517.3	0.48	108420	792.8
2016	0.469	0.5	508.1	0.47	105306	766.7

Figure 1. P* = 0.4 projection results. For this assessment, discards were combined with landings so the ABC reflects both landings and dead discards. Annual ABCs (panel F) are a single quantity while other values presented are medians. Error bars represent the 5th and 95th percentiles of the 10,000 projection runs.

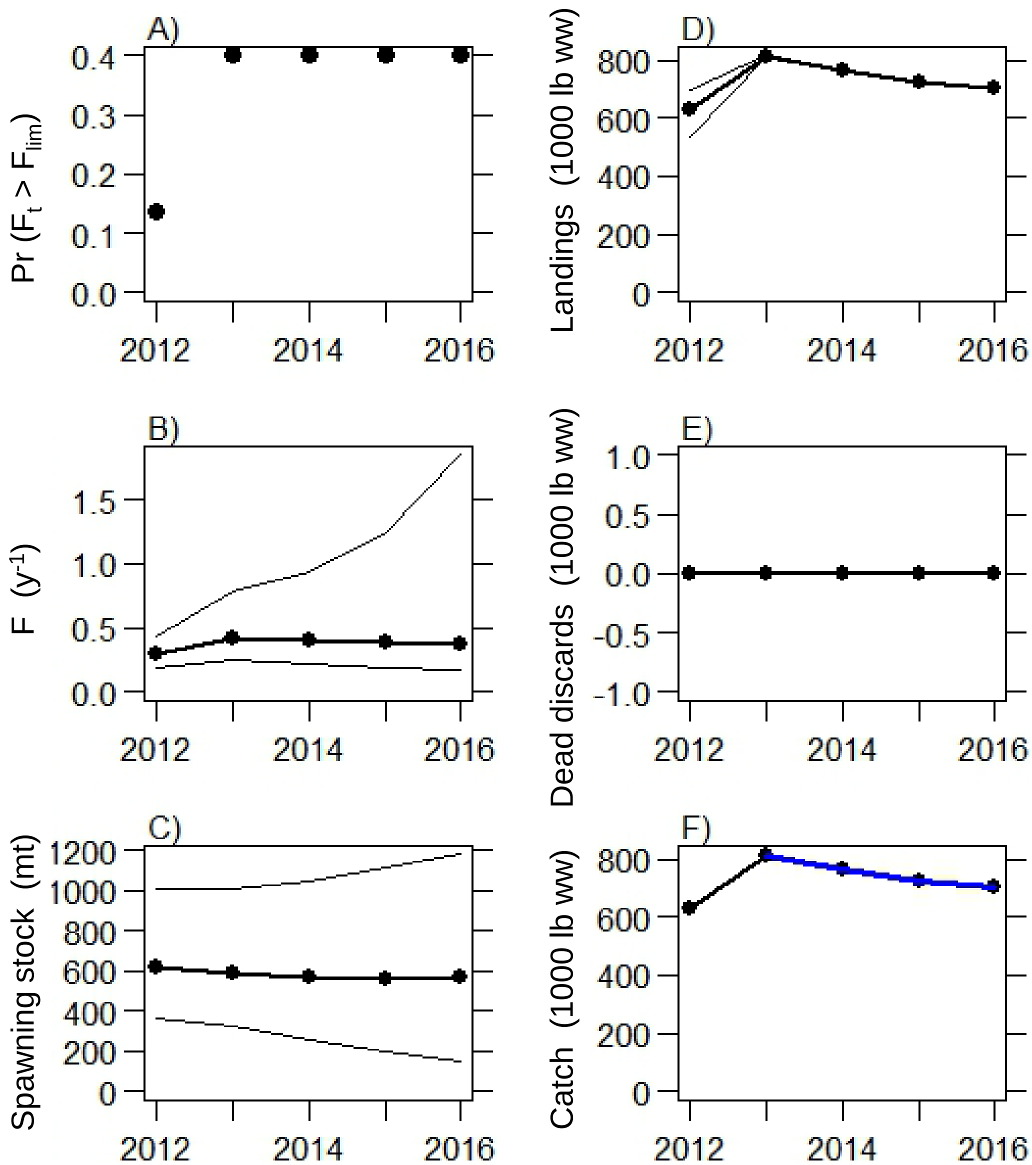


Figure 2. P* = 0.5 projection results. For this assessment, discards were combined with landings so the ABC reflects both landings and dead discards. Annual ABCs (panel F) are a single quantity while other values presented are medians. Error bars represent the 5th and 95th percentiles of the 10,000 projection runs.