# SEDAR 19 South Atlantic Red Grouper Stock Assessment Report

SEDAR53-RD01

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# SEDAR

## Southeast Data, Assessment, and Review

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SEDAR 19
Stock Assessment Report

# South Atlantic Red Grouper

**April 2010**

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

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# SEDAR

## Southeast Data, Assessment, and Review

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# South Atlantic Red Grouper

## SECTION I: Introduction

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# 1. SEDAR PROCESS DESCRIPTION

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

SEDAR is managed by the Caribbean, Gulf of Mexico, and South Atlantic Regional Fishery Management Councils in coordination with NOAA Fisheries and the Atlantic and Gulf States Marine Fisheries Commissions. Oversight is provided by a Steering Committee composed of NOAA Fisheries representatives: Southeast Fisheries Science Center Director and the Southeast Regional Administrator; Regional Council representatives: Executive Directors and Chairs of the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Councils; 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 workshop, 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, 3 reviewers appointed by the Center for Independent Experts (CIE), and one reviewer appointed by each council having jurisdiction over the stocks assessed. The Review Workshop Chair is appointed by the SEFSC director and is usually selected from a NOAA Fisheries regional science center. 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 red grouper fisheries and harvest

*Original Fishery Management Plan*

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

****Measures in the original FMP that would have affected red grouper included the 4" trawl mesh size regulation and a 12 in TL size limit.****

*SAFMC FMP Amendments affecting red grouper*

| Description of Action | FMP/Amendment | Effective Date |
|---|---|---|
| Prohibit trawls | Amendment 1 (SAFMC 1988) | 1/12/89 |
| Prohibit fish traps, entanglement nets & longlines within 50 fathoms; Aggregate bag limit of 5 groupers per person per day excluding Nassau and goliath grouper[1]; Red grouper 20" TL commercial and recreational minimum size limit | Amendment 4 (SAFMC 1991) | 1/1/92 |

| | | |
|---|---|---|
| *Oculina* Experimental Closed Area | Amendment 6<br><br>(SAFMC 1993) | 6/27/94 |
| Limited entry program: transferable permits and 225-lb non-transferable permits | Amendment 8<br><br>(SAFMC 1997) | 12/98 |
| Within the 5 fish aggregate grouper bag limit, no more than 2 fish may be gag or black grouper (individually or in combination); Vessels with longlines may only possess deepwater species | Amendment 9<br><br>(SAFMC 1998a) | 2/24/99 |
| MSY proxy for red grouper is 30% static SPR; OY proxy is 45% static SPR | Amendment 11<br><br>(SAFMC 1998b) | 12/2/99 |
| Establish eight deepwater Type II marine protected areas to protect a portion of the population and habitat of long-lived deepwater snapper grouper species | Amendment 14<br><br>(SAFMC 2007) | 2/12/09 |
| Reduce the 5 aggregate grouper bag limit to 3; Reduce the 2 gag/black bag (individually or in combination) bag limit from 2 to 1; when gag quota met, prohibit harvest of, possession, and retention of shallow water groupers (which includes red grouper) | Amendment 16<br><br>(SAFMC 2008) | **IN NOAA REVIEW – REGULATIONS NOT ESTSABLISHED** |

## 2.2. Control Date Notices

Notice of Control Date 07/30/91 56 FR 36052:

-Anyone entering federal snapper grouper fishery (other than for wreckfish) in the EEZ off S. Atlantic states after 07/30/91 was not assured of future access if limited entry program developed.

Notice of Control Date 10/14/05 70 FR 60058:

-The Council is considering management measures to further limit participation or effort in the commercial fishery for snapper grouper species (excluding Wreckfish).

Notice of Control Date 3/8/07 72 FR 60794:

-The Council may consider measures to limit participation in the snapper grouper for-hire fishery

## 2.3. Management Program Specifications

**Table 2.3.1. General Management Information**

| | |
|---|---|
| Species | Red Grouper (*Epinephelus morio*) |
| Management Unit | Southeastern US |
| Management Unit Definition | All waters within South Atlantic Fishery Management Council Boundaries |
| Management Entity | South Atlantic Fishery Management Council |
| Management Contacts<br>SERO / Council | Jack McGovern/Rick DeVictor |
| Current stock exploitation status | Overfishing |
| Current stock biomass status | Unknown |

**Table 2.3.2. Specific Management Criteria**

| Criteria | Current | | 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 19 |
| MFMT | $F_{MSY}$ | 0.28[1] | $F_{MSY}$ | SEDAR 19 |
| MSY | Yield at $F_{MSY}$ | Not Specified | Yield at $F_{MSY}$ | SEDAR 19 |
| $F_{MSY}$ | $F_{30\%SPR}$ | 0.28[1] | $F_{MAX}$ | SEDAR 19 |
| OY | Yield at $F_{OY}$ | Not Specified | Yield at $F_{OY}$ | SEDAR 19 |
| $F_{OY}$ | $F_{45\%SPR}$ | Not specified[2] | $F_{OY}$ = 65%,75%, 85% $F_{MSY}$ | SEDAR 19 |
| M | n/a | 0.20[1] | M | SEDAR 19 |

[1]Potts and Brennan (2001)

*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 2.3.3. Stock Rebuilding Information**

The current stock biomass status is unknown; no rebuilding plan required.

**Table 2.3.4. 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)*

| Requested Information | Value |
|---|---|
| First Year of Management | 2011 |
| 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) | Average of previous 3 years |

*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 2.3.5. Quota Calculation Details**

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

There is currently not a quota specified for this stock.

## 2.4. Federal Management and Regulatory Timeline

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

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**Table 2.4.1. Federal Annual Commercial Red Grouper Regulatory Summary**

| Year | Fishing Year | Size Limit |
|---|---|---|
| 1983 | Calendar Year | 12 in TL |
| 1984 | Calendar Year | 12 in TL |
| 1985 | Calendar Year | 12 in TL |
| 1986 | Calendar Year | 12 in TL |
| 1987 | Calendar Year | 12 in TL |
| 1988 | Calendar Year | 12 in TL |
| 1989 | Calendar Year | 12 in TL |
| 1990 | Calendar Year | 12 in TL |
| 1991 | Calendar Year | 12 in TL |
| 1992 | Calendar Year | 20 in FL |
| 1993 | Calendar Year | 20 in FL |
| 1994 | Calendar Year | 20 in FL |
| 1995 | Calendar Year | 20 in FL |
| 1996 | Calendar Year | 20 in FL |
| 1997 | Calendar Year | 20 in FL |
| 1998 | Calendar Year | 20 in FL |
| 1999 | Calendar Year | 20 in FL |
| 2000 | Calendar Year | 20 in FL |
| 2001 | Calendar Year | 20 in FL |
| 2002 | Calendar Year | 20 in FL |
| 2003 | Calendar Year | 20 in FL |
| 2004 | Calendar Year | 20 in FL |
| 2005 | Calendar Year | 20 in FL |
| 2006 | Calendar Year | 20 in FL |
| 2007 | Calendar Year | 20 in FL |
| 2008 | Calendar Year | 20 in FL |

**Table 2.4.2. Federal Annual Recreational Red Grouper Regulatory Summary**

| Year | Size Limit | Bag Limit |
|---|---|---|
| 1983 | 12 in TL | -- |
| 1984 | 12 in TL | -- |
| 1985 | 12 in TL | -- |
| 1986 | 12 in TL | -- |
| 1987 | 12 in TL | -- |
| 1988 | 12 in TL | -- |
| 1989 | 12 in TL | -- |
| 1990[3] | 12 in TL | -- |
| 1991 | 12 in TL | -- |
| 1992 | 20 in TL | 5 grouper aggregate[1/]person/day |
| 1993 | 20 in TL | " |
| 1994 | 20 in TL | " |
| 1995 | 20 in TL | " |
| 1996 | 20 in TL | " |
| 1997 | 20 in TL | " |
| 1998 | 20 in TL | " |
| 1999 | 20 in TL | Within the aggregate, not more than 2 fish may be gag or black (individually or in combination) |
| 2000 | 20 in TL | " |
| 2001 | 20 in TL | " |
| 2002 | 20 in TL | " |
| 2003 | 20 in TL | " |
| 2004 | 20 in TL | " |
| 2005 | 20 in TL | " |
| 2006 | 20 in TL | " |
| 2007 | 20 in TL | " |
| 2008 | 20 in TL | |

[1]The following species are included in the grouper aggregate: snowy grouper, gag, black grouper, golden tilefish, misty grouper, red grouper, scamp, tiger grouper, yellowedge grouper, yellowfin grouper, yellowmouth grouper, blueline tilefish, sand tilefish, coney, graysby, red hind, and rock hind.

### 2.5. State Management and Regulatory Timeline

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

**Table 2.5.1. Annual Commercial Red Grouper Regulatory Summary - Florida**

| | Fishing Year | | Minimum Size Limit State Waters | | Possession Limit | |
|---|---|---|---|---|---|---|
| Year | Atlantic | Gulf | Atlantic | Gulf | Atlantic | Gulf |
| 1983 | Calendar Year | Calendar year | **12 in FL[a]** | **12 in FL[a]** | **No more than 10% of individuals may be undersize (FL Statutes Chapter 370.11, effective ~7/1/1977)** | **No more than 10% of individuals may be undersize (FL Statutes Chapter 370.11, effective effective ~7/1/1977)** |
| 1984 | " | " | **12 in FL[a]** | **12 in FL[a]** | " | " |
| 1985 | " | " | **18 in FL** | **18 in FL** | **(effective 7/29/1985)** | **(effective 7/29/1985)** |
| 1986 | " | " | **18 in FL** | **18 in FL** | " | " |
| 1987 | " | " | **18 in FL** | **18 in FL** | **Use of longline gear for reef fish in state waters by commercial fishermen prohibited; bycatch allowance of 5% is permitted harvesters of other species using this gear; use of stab nets (or sink nets) to take snapper or grouper is prohibited in Atlantic waters of Monroe County; 5% of snapper and grouper in possession of harvester may be smaller than the minimum size limit; must be landed in whole condition (head and tail intact) (effective 12/11/1986)** | **Use of longline gear for reef fish in state waters by commercial fishermen prohibited; bycatch allowance of 5% is permitted harvesters of other species using this gear; 5% of snapper and grouper in possession of harvester may be smaller than the minimum size limit; must be landed in whole condition (head and tail intact) (effective 12/11/1986)** |
| 1988 | " | " | **18 in FL** | **18 in FL** | " | " |
| 1989 | " | " | **18 in FL** | **18 in FL** | " | " |
| 1990 | " | " | **20 in TL[b]** | **20 in TL[b]** | **Minimum size 20 in TL; All snapper and grouper designated as "restricted** | **Minimum size 20 in TL; All snapper and grouper designated as "restricted** |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | species"; Allowable gear for snappers and groupers are hook and line, black sea bass traps, spears, gigs, or lance (except powerheads, bangsticks, or explosive devices); all commercial harvest of any species of snapper, grouper, and sea bass is prohibited in state waters whenever harvest of that species is prohibited in adjacent federal waters; snapper and grouper must be landed in whole condition (2/1/1990) | species"; Allowable gear for snappers and groupers are hook and line, black sea bass traps, spears, gigs, or lance (except powerheads, bangsticks, or explosive devices); all commercial harvest of any species of snapper, grouper, and sea bass is prohibited in state waters whenever harvest of that species is prohibited in adjacent federal waters; snapper and grouper must be landed in whole condition (2/1/1990) |
| 1991 | " | " | 20 in TL | 20 in TL | " | " |
| 1992 | " | " | 20 in TL | 20 in TL | " | Requires that a harvester have the appropriate federal permit in order to exceed snapper/grouper bag limits and to purchase or sell snapper/grouper on the state's Gulf Coast (12/31/1992) |
| 1993 | " | " | 20 in TL | 20 in TL | Use of longline gear in state waters prohibited (1/1/1993); allows persons who possess either a Gulf of Mexico or South Atlantic federal reef fish permit to commercially harvest snappers and grouper (except red snapper) in all state waters until July 1, 1995. (10/18/1993) | Use of longline gear in state waters prohibited (1/1/1993); allows persons who possess either a Gulf of Mexico or South Atlantic federal reef fish permit to commercially harvest snappers and grouper (except red snapper) in all state waters until July 1, 1995. (10/18/1993)-- |
| 1994 | " | " | 20 in TL | 20 in TL | Rule language modified to provide the same state and federal definitions of Gulf of Mexico and Atlantic Ocean regions (3/1/1994) | Rule language modified to provide the same state and federal definitions of Gulf of Mexico and Atlantic Ocean regions (3/1/1994) |
| 1995 | " | " | 20 in TL | 20 in TL | Continues the allowance of persons to possess either the proper South Atlantic or Gulf permit to harvest reef fish for commercial purposes through | Continues the allowance of persons to possess either the proper South Atlantic or Gulf permit to harvest reef fish for commercial purposes through |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | **12/31/1995. (7/1/1995)** | **12/31/1995. (7/1/1995)** |
| 1996 | " | " | **20 in TL** | **20 in TL** | **Continues the allowance of persons to possess either the proper South Atlantic or Gulf permit to harvest reef fish for commercial purposes through 12/31/1996. (1/1/1996)** | **Continues the allowance of persons to possess either the proper South Atlantic or Gulf permit to harvest reef fish for commercial purposes through 12/31/1996. (1/1/1996)** |
| 1997 | " | " | **20 in TL** | **20 in TL** | **Continues the allowance of persons to possess either the proper South Atlantic or Gulf permit to harvest reef fish for commercial purposes through 12/31/1997. (11/271996)** | **Continues the allowance of persons to possess either the proper South Atlantic or Gulf permit to harvest reef fish for commercial purposes through 12/31/1997. (11/271996)** |
| 1998 | " | " | **20 in TL** | **20 in TL** | " | " |
| 1999 | " | " | **20 in TL** | **20 in TL** | **No black grouper and gag harvest or possession greater than the bag limit (2 fish daily within the 5 fish daily aggregate limit for all groupers including speckled hind and warsaw) (12/31/1998); 2-fish daily recreational bag limit for black grouper and gag, prohibits the harvest, possession, or landing of black grouper and gag in excess of the recreational bag limit and the purchase, sale, or exchange of black grouper and gag during March and April (3/1/1999)** | **In Monroe County state waters, 2-fish daily recreational bag limit for black grouper and gag within the 5 fish daily aggregate limit for all groupers including speckled hind and warsaw), prohibits the harvest, possession, or landing of black grouper and gag in excess of the recreational bag limit and the purchase, sale, or exchange of black grouper and gag during March and April (3/1/1999)** |
| 2000 | " | " | **20 in TL** | **20 in TL** | **Eliminates the 5-day commercial season closure extension in the reef fish rule, restores documentation requirement for reef fish species possessed during a closure period (Chapter 68B-14, F.A.C.) (1/1/2000)** | **Eliminates the 5-day commercial season closure extension in the reef fish rule, restores documentation requirement for reef fish species possessed during a closure period (Chapter 68B-14, F.A.C.) (1/1/2000)** |
| 2001 | " | " | **20 in TL** | **20 in TL** | “ | **Feb. 15-Mar 15 closed season for the commercial harvest of Gulf gag, black, and red grouper (1/1/2001)** |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2002 | " | " | **20 in TL** | **20 in TL** | " | " |
| 2003 | " | " | **20 in TL** | **20 in TL** | **Imported reef fishes must comply with Florida's legal minimum size limits, includes minimum size limits for 19 reef fish species (1/1/2003)** | **Imported reef fishes must comply with Florida's legal minimum size limits, includes minimum size limits for 19 reef fish species (1/1/2003)** |
| 2004 | " | " | **20 in TL** | **20 in TL** | " | " |
| 2005 | " | " | **20 in TL** | **20 in TL** | " | **2-fish daily recreational bag limit for red grouper (1/3/2005); grouper (includes all grouper species listed in Chap. 68B-14.001(2)(b), F.A.C., except bank sea bass and black sea bass) vessel trip limit for commercial harvesters in state waters of 10,000 pounds until the National Marine Fisheries Service reduces the vessel trip limit in adjacent federal waters. The grouper vessel trip limit shall be restored in state waters to 10,000 pounds on January 1 of the following year (5/20/2005).** |
| 2006 | " | " | **20 in TL** | **20 in TL** | **Specifies total length (TL) measurement means the straight line distance from the most forward point of the head with the mouth closed, to the farthest tip of the tail with the tail compressed or squeezed, while the fish is lying on its side (7/1/2006)** | **1-fish daily recreational bag limit for red grouper (1/1/2006); specifies total length (TL) measurement means the straight line distance from the most forward point of the head with the mouth closed, to the farthest tip of the tail with the tail compressed or squeezed, while the fish is lying on its side (7/1/2006).** |
| 2007 | " | " | **20 in TL** | **20 in TL** | **Commercial trip limits in the Atlantic are set to the same trip limits in federal waters; Commercial fishermen prohibited from harvesting or possessing the recreational bag limit of reef fish species on commercial trips** | **Commercial fishermen prohibited from harvesting or possessing the recreational bag limit of reef fish species on commercial trips (7/1/2007)** |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | **(7/1/2007)** | |
| 2008 | " | " | **20 in TL** | **20 in TL** | " | **Requires all commercial fishermen fishing for Gulf reef fish species to use circle hooks, dehooking devices, and venting tools beginning 6/1/2008. (4/1/2008)** |
| 2009 | " | " | **20 in TL** | **20 in TL** | " | " |

**[a]Measurement specified as "from the tip of the nose to the rear center edge of the tail (i.e., a fork length)."**
**[b]Measurement is a total length.**

**Table 2.5.2. Annual Recreational Red Grouper Regulatory Summary - Florida**

| | Fishing Year | | Size Limit | | Bag Limit | |
|---|---|---|---|---|---|---|
| Year | Atlantic | Gulf | Atlantic | Gulf | Atlantic | Gulf |
| 1983[1] | Calendar Year | Calendar Year | 12 in FL[a] | 12 in FL[a] | No more than 10% of individuals may be undersize (effective ~7/1/1977) | No more than 10% of individuals may be undersize (effective ~7/1/1977) |
| 1984[1] | " | " | 12 in FL | 12 in FL | No more than 10% of individuals may be undersize | No more than 10% of individuals may be undersize |
| 1985[2] | " | " | 18 in FL | 18 in FL | (effective 7/29/1985) | (effective 7/29/1985) |
| 1986 | " | " | 18 in FL | 18 in FL | Grouper aggregate bag limit of 5 per recreational angler daily, with off-the-water possession limit of 10 per recreational angler, for any combination of groupers, excluding rock hind and red hind, 5% of grouper in possession may be smaller than minimum size limit (12/11/1986) | Grouper aggregate bag limit of 5 per recreational angler daily, with off-the-water possession limit of 10 per recreational angler, for any combination of groupers, excluding rock hind and red hind, 5% of grouper in possession may be smaller than minimum size limit (12/11/1986) |
| 1987 | " | " | 18 in FL | 18 in FL | " | " |
| 1988 | " | " | 18 in FL | 18 in FL | " | " |
| 1989 | " | " | 18 in FL | 18 in FL | " | " |
| 1990[3] | " | " | 20 in TL[b] | 20 in TL[b] | Allowable gear: hook and line, spear, gig, or lance (except powerheads, bangsticks, or explosive devices), grouper must be landed in whole condition (2/1/1990) | Allowable gear: hook and line, spear, gig, or lance (except powerheads, bangsticks, or explosive devices), grouper must be landed in whole condition (2/1/1990) (Federal: 5 grouper aggregate[2]/person/day) |
| 1991 | " | " | 20 in TL | 20 in TL | " | " |
| 1992 | " | " | 20 in TL | 20 in TL | (Federal: 5 grouper aggregate[1/]person/day) | " |
| 1993 | " | " | 20 in TL | 20 in TL | " | " |
| 1994 | " | " | 20 in TL | 20 in TL | Allows a two-day possession limit for reef fish statewide for persons aboard charter and head boats on trips exceeding 24 hours provided that the vessel is equipped with a permanent berth for each passenger aboard, and each passenger has a receipt verifying the trip length. Modifies rule language to provide the | Allows a two-day possession limit for reef fish statewide for persons aboard charter and head boats on trips exceeding 24 hours provided that the vessel is equipped with a permanent berth for each passenger aboard, and each passenger has a receipt verifying the trip length. Modifies rule language to provide the same state and |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | same state and federal definitions of Gulf of Mexico and Atlantic Ocean regions (3/1/1994) | federal definitions of Gulf of Mexico and Atlantic Ocean regions (3/1/1994) |
| 1995 | " | " | 20 in TL | 20 in TL | " | " |
| 1996 | " | " | 20 in TL | 20 in TL | " | " |
| 1997 | " | " | 20 in TL | 20 in TL | " | " |
| 1998 | " | " | 20 in TL | 20 in TL | " | " |
| 1999 | " | " | 20 in TL | 20 in TL | Black grouper and gag management modified in Atlantic Ocean state waters to a 2 fish daily recreational bag limit (within the federal 5 fish daily aggregate limit for all groupers including speckled hind and warsaw), harvest and possession prohibited in excess of the bag limit, and purchase and sale of black grouper and gag during March and April (12/31/1998) [Federal: Within the aggregate, not more than 2 fish may be gag or black (individually or in combination)] | Harvest and possession prohibited in excess of the bag limit, and purchase and sale of black grouper and gag during March and April (12/31/1998); Monroe County state waters: a 2 fish daily recreational bag limit (within the 5 fish daily aggregate limit for all groupers including speckled hind and warsaw) for black and gag grouper. Harvest, possession, or landing of black grouper and gag in excess of the recreational bag limit and the purchase, sale, or exchange of black grouper and gag during March and April are prohibited (3/1/1999) |
| 2000 | " | " | 20 in TL | 20 in TL | " | " |
| 2001 | " | " | 20 in TL | 20 in TL | " | " |
| 2002 | " | " | 20 in TL | 20 in TL | " | " |
| 2003 | " | " | 20 in TL | 20 in TL | " | " |
| 2004 | " | " | 20 in TL | 20 in TL | " | " |
| 2005 | " | " | 20 in TL | 20 in TL | " | 2-fish daily recreational bag limit for red grouper (1/3/2005) [Federal: Published 7/05-Limited aggregate grouper bag limit from 5 to 3 grouper per day but, was overturned by 12/05] |
| 2006 | " | " | 20 in TL | 20 in TL | Specifies total length (TL) measurement means the straight line distance from the most forward point of the head with the mouth closed, to the farthest tip of the tail with the | 1-fish daily recreational bag limit for red grouper (1/1/2006); Specifies total length (TL) measurement means the straight line distance from the most forward point of the head with |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | **tail compressed or squeezed, while the fish is lying on its side (7/1/2006)** | **the mouth closed, to the farthest tip of the tail with the tail compressed or squeezed, while the fish is lying on its side (7/1/2006). [Federal: 5 grouper aggregate[2]/person/day]** |
| 2007 | " | " | **20 in TL** | **20 in TL** | **Commercial fishermen prohibited from harvesting or possessing the recreational bag limit of reef fish species on commercial trips (7/1/2007)** | **Zero bag limit for Gulf gag, red and black grouper for captains and crew on for-hire vessels, commercial fishermen prohibited from harvesting or possessing the recreational bag limit of reef fish species on commercial trips (7/1/2007)** |
| 2008 | " | " | **20 in TL** | **20 in TL** | **"** | **Requires all commercial and recreational anglers fishing for any Gulf reef fish species to use circle hooks, dehooking devices and venting tools beginning 6/1/2008 (4/1/2008)** |
| 2009 | " | " | **20 in TL** | **20 in TL** | **"** | **"** |

**[a]Measurement specified as "from the tip of the nose to the rear center edge of the tail (i.e., a fork length)."**

**[b]Measurement is a total length.**

[1]The following species are included in the South Atlantic grouper aggregate: snowy grouper, gag, black grouper, golden tilefish, misty grouper, red grouper, scamp, tiger grouper, yellowedge grouper, yellowfin grouper, yellowmouth grouper, blueline tilefish, sand tilefish, coney, graysby, red hind, and rock hind.

[2]The following species are included in the Gulf of Mexico grouper aggregate. The shallow-water grouper are defined as the follows and includes species are applied to the daily bag limits: black grouper, gag, red grouper (no more than 1 per person), yellowfin grouper, yellowmouth grouper, rock hind, red hind, speckled hind (1 per vessel), and scamp.  Deep-water grouper are defined as misty grouper, snowy grouper, yellowedge grouper, warsaw grouper (1 per vessel), and scamp.

**No other states provided state regulatory tables, as the state regulations did not differ significantly from the federal regulations.**

## 2.6 References

Florida Administrative Code, 1986-2009. Chapter 46-14 Reef Fish (interlibrary loans by year, 1986-1999). Chapter 68B-14 Reef Fish (1999-2009). Current regulations: https://www.flrules.org/default.asp

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## 3. ASSESSMENT HISTORY AND REVIEW

Red grouper have not been formally assessed prior to SEDAR-19. However, the stock has been examined in a trends report using catch curve analysis and catch-per-unit-effort, with data through 1999 (Potts and Brennan, 2001). That report examined several constant, natural mortality rates (M=0.15, 0.20, 0.25, and 0.30), but considered M=0.20 to be the base level. For M=0.20, the most recent static SPR value was estimated at 16%. Possible proxies for $F_{MSY}$ were estimated at $F_{30\%SPR}$=0.28 and $F_{40\%SPR}$=0.17, whereas full F was estimated at F=0.56, which indicated that overfishing was occurring.

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# 4. REGIONAL MAPS

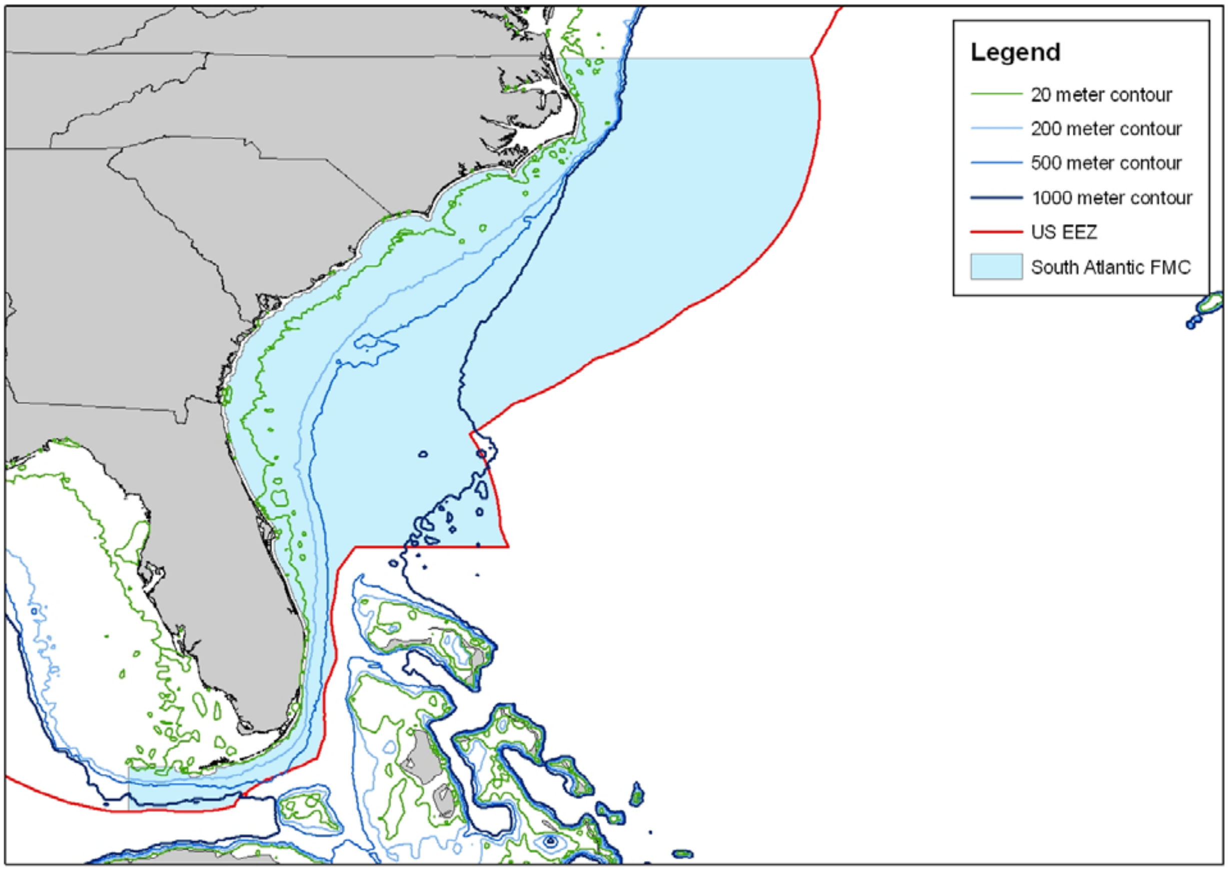



Figure 4.1. South Atlantic Region including Council and EEZ Boundaries

# 5. **ASSESSMENT SUMMARY**

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

## Stock Status and Determination Criteria

Point estimates from the base model indicate that the U.S. southeast stock of red grouper *Epinephelus morio* is currently overfished and is experiencing overfishing.

- Estimated time series of stock status (SSB/MSST) shows decline until the mid-1980s, and then steady increase since, but with a decrease in the terminal year. The increase in stock status appears to have been initially driven by strong recruitment, then reinforced by 1992 management regulations. Base-run estimates of spawning biomass have remained below MSST throughout the time series (overfished status in 1976 is not surprising given the heavy fishing pressure that occurred prior to the start of the assessment period).
- Current stock status was estimated in the base run to be SSB2008/MSST = 0.92; uncertainty in this estimate includes the possibility that the stock is not overfished (i.e., SSB > MSST), but also the possibility that the stock is less healthy than estimated by the base run. Age structure estimated by the base run has become repopulated by older fish during the last decade, approaching the (equilibrium) age structure expected at MSY.
- The estimated time series of *F* /*F*MSY suggests that overfishing has been occurring throughout the assessment period. The series peaked during the 1980s; since 2000, *F* /*F*MSY has been at its lowest levels, but has been increasing since 2005. Current fishery status in the terminal year, with current *F* represented by the geometric mean from 2006–2008, is estimated by the base run to be *F*current/*F*MSY = 1.35. This estimate indicates current overfishing and appears robust across MCB trials.

**Table 1.** Summary of stock status determination criteria.

| Criteria | Recommended Values from SEDAR 19 | |
|---|---|---|
| | Definition | Value |
| M (Instantaneous natural mortality; per year) | Average of Lorenzen M (if used) | 0.14 |
| $F_{2008}$ (per year) | Apical Fishing mortality in 2008 | 0.340 |
| $F_{current}$ (per year) | Geometric mean of the directed fishing mortality rates in 2006 - 2008 | 0.298 |
| $F_{MSY}$ (per year) | $F_{MSY}$ | 0.221 |
| $B_{MSY}$ (metric tons) | Biomass at MSY | 3680 |
| $SSB_{2008}$ (metric tons) | Spawning stock biomass in 2008 | 2051 |
| $SSB_{MSY}$ (metric tons) | $SSB_{MSY}$ | 2592 |
| MSST (metric tons) | (1-M)*SSB $_{MSY}$ | 2229 |
| MFMT (per year) | $F_{MSY}$ | 0.221 |
| MSY (1000 pounds) | Yield at MSY | 1110 |
| OY (1000 pounds) | Yield at $F_{OY}$ | OY (65% $F_{MSY)}$= 1064<br>OY (75% $F_{MSY)}$= 1089<br>OY (85% $F_{MSY}$= 1103 |
| $F_{OY}$ (per year) | $F_{OY}$ = 65%,75%, 85% $F_{MSY}$ | 65% $F_{MSY}$= 0.144<br>75% $F_{MSY}$= 0.166<br>85% $F_{MSY}$= 0.188 |
| Biomass Status | $SSB_{2008}$/MSST | 0.920 |
| Exploitation Status | $F_{current}/F_{MSY}$ | 1.35 |

***All weights are whole weight

**Stock Identification and Management Unit**

The red grouper fishery has been managed in the US as separate Atlantic and Gulf of Mexico stock units with the boundary being U.S. Highway 1 in the Florida Keys. Significant differences in size and age structure and in growth rates of red grouper north and south of 28°N latitude in the Gulf of Mexico have been determined, supporting a hypothesis that red grouper may have some degree of subpopulation structure. Landings data from 1983 through 1995 indicated a possible disjunct distribution of red grouper off the Atlantic coast; with the most catches occurring off NC and off southern FL, with relatively little in between.

The SEDAR12 Life History Data Workshop for the Gulf of Mexico stock of red grouper reviewed the available stock structure information and concluded there is no evidence that suggests different stock management units need to be considered at this time. The SEDAR19 LH DW concurred with that report.

**Species Distribution**:

The red grouper, is associated with reef habitat, especially the adults, in the Western Atlantic from Massachusetts through the Gulf of Mexico and south to Brazil and are reported to occur at depths of 24-120 m.

**Stock Life History** - summary of life history characteristics of the stock under assessment;

- There are no significant identification issues with red grouper and there are no other common names regularly used for red grouper in the region that may complicate data analysis.
- No published information is available on tagging of Atlantic red grouper from the US South Atlantic. Tagging information from the Florida Keys and GOM suggest that adult red grouper only move short distances
- Natural mortality is thought to vary by age so an age-specific Lorenzen mortality curve was used, scaled to provide the same survivorship to the oldest ages as that of the Hoenig estimate of 0.14 per year.
- The maximum observed age was 26 years.
- The LH WG recommends using $L_{inf}$=848.2 (mm), K=0.213 (per year), and $t_o$=-0.66 (yr) in the stock assessment model. These values were obtained using the most appropriate treatment of the data: all available age data with the Diaz et al. (2004) correction applied for fishery dependent samples
- Red grouper is a protogynous hermaphrodite with asynchronous ovarian organization. Eggs are released in batches, but the fecundity pattern (determinate vs. indeterminate) of red grouper is not known.
- Spawning season is from February through June, with a peak in April

**Assessment Methods**

The primary model in this assessment was the Beaufort statistical catch-age model (BAM). The model was implemented with the AD Model Builder software, and its structure and equations are detailed in the document, SEDAR-19 RW-01. 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 populations match available data on the real population. Statistical catch-age models share many attributes with ADAPT-style tuned and untuned VPAs.

**Assessment Data**

The catch-age model included data from four fleets that caught southeastern U.S. red grouper: commercial lines (handline and longline), commercial other (pots, traps, trawl, diving, miscellaneous), recreational headboat, general recreational. The model was fit to data on annual landings (in units of 1000 lb whole weight for commercial fleets, 1000 fish for recreational fleets), annual discard mortalities (in units of 1000 fish for commercial lines and recreational fleets), annual length compositions of landings, annual age compositions of landings, annual length compositions of discards, three fishery dependent indices of abundance (commercial handline, general recreational, and headboat), and one fishery independent index of abundance (MARMAP chevron traps). Not all of the above data sources were available for all fleets in all years. Annual discard mortalities, as fit by the model, were computed by multiplying total discards (tabulated in the DW report) by the release mortality probability of 0.2.

**Release Mortality**

- The Life History Working Group reviewed the scientific studies on release mortality available for red grouper. Values ranged from 8 to 70% depending on the depth of capture and if post-release mortality were included.
- The Commercial workgroup recommended using 20% as the point estimate release mortality for red grouper with a sensitivity range of 10-30%.
- The Recreational workgroup recommended a discard mortality of 20%, with a sensitivity range of 10-30%.

- The Assessment Workshop decided to support the point estimates and range of values recommended by the Data Workshop: 20% (range of 10-30%).
- The Review Panel was concerned with the lack of empirical data to support the discard mortality estimate of 20%. Sensitivity runs were performed that varied this estimate from 10 – 70%. These results support the high impact of this parameter. In the absence of any substantive empirical data the panel did not see a strong basis to change the value from 20%, however, attempts should be made to obtain a more accurate estimate of both immediate and delayed discard mortality.

**Catch Trends**

- Commercial lines reached a peak in the late 1990s, followed by a decline until 2005, when the trend again reversed and began to increase throughout the remainder of the assessment period, with the highest landings reported in 2008.
- Commercial "other" landing showed a general decline throughout the assessment period, with fairly stable landings in the last 4 years of the time series
- Headboat landings have been variable over the assessment period, with peaks in 1998 and 2005.
- Recreational landings showed a large decrease early in the time series, were relatively stable from 1993 to 2004, and have been on the increase since 2005.
- In general, estimated landings have been dominated by commercial lines and general recreational fleets, particularly since 1992. Estimated discard mortalities occur on a smaller scale than landings.

**Fishing Mortality Trends**

- The estimated fishing mortality rates (*F*) peaked during the 1980s, and in the last decade have generally been at their lowest levels of the time series. The two primary contributors are general recreational and commercial line fleets. An increase in fishing mortality rate in the last few years coincides with increased landings from those two fleets.
- In any given year, the maximum *F* at age (i.e., apical F) may be less than that year's sum of fully selected *F*s across fleets. This inequality is due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and several sources of mortality have dome-shaped selectivity.

**Stock Abundance and Biomass Trends** - summary of abundance, biomass, and recruitment over time

- Estimated abundance at age shows truncation of the older ages until the early 1990s, after which older fish began to repopulate. In the most recent years, older fish (6+) appear to be more abundant than in the early years of the assessment period. These older fish are predominantly male. A notably strong year classes was predicted to have occurred in 2004.
- Estimated biomass at age follows a similar pattern as abundance at age. Total biomass and spawning biomass show similar trends— general decline until the mid-1980s, and general increase since the early 1990s but with a downturn at the end of the time series.

**Projections** - results of model runs conducted to estimate stock conditions under various potential future levels of fishing mortality

- Projection scenario 1, in which *F* = 0, predicted the stock to achieve at least 50% chance of recovery by 2013. This duration defines the minimum rebuilding time frame (Tmin). Because the stock can rebuild within 10 years, the maximum rebuilding time frame (Tmax) is 10 years. Thus rebuilding that starts in 2011 should occur by the end of 2020, at the latest. The Tmin and Tmax should bracket the target rebuilding time frame (Ttarget).
- Projections with *F* at 100%, 75%, 50%, or 25% of *F*current predicted recovery by 2020 only if *F* were reduced sufficiently below the current level, as did projections with *F* at 65%, 75%, 85%, or 100% of *F*MSY. The value of *F*rebuild showed little sensitivity to *F* in 2010. In general, higher projected *F* resulted in larger annual and cumulative landings, but smaller biomass with a correspondingly smaller buffer from the MSST.

**Scientific Uncertainty**

- 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. 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.

- In this assessment, the BAM was successively re-fit n=2500 trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of natural mortality and discard mortality. This number of trials was sufficient for convergence of standard errors in management quantities. Of the 2500 trials, approximately 1.3% were discarded, because the model didn't properly converge (in most of these cases a spawner-recruit parameter hit an upper or lower bound, and in one case the optimization did not complete). This left n=2467 trials used to characterize uncertainty.
- Although there is evidence of stock separation (most catches occur off NC and off southern FL, with relatively little in between), the assessment assumed a single unit stock, as suggested by the DW. This assumption imparts an additional and unexplored source of uncertainty. Future assessments could consider spatially explicit assessment models, if data were split accordingly at the DW and if mixing rates could be estimated or assumed. In the meantime, fishery management is not necessarily limited by the assumption of a single unit stock, if managers wished to consider policies that treat portions of the stock distinctly (e.g., regional ABCs).

**Significant Assessment Modifications**

Changes to the base case, as proposed by the assessment workshop, were made at the request of the SEDAR Review Workshop (RW) for application of the Beaufort Assessment Model (BAM) to red grouper. The primary change made at the RW was the removal of the visual survey (RVC) index of abundance and its corresponding length compositions. The BAM base configuration was re-run without the RVC data, as were sensitivity analyses, Monte Carlo/Bootstrap analyses, and projections. Sensitivity analysis included one additional run not considered at the Assessment Workshop, a run with high discard mortality ($\delta = 0.7$). In addition, the rebuilding time frame was revised to have a duration of 10 years (until 2020).

**Sources of Information**

All information was copied directly or generated from the information available in the final Stock Assessment Report for SEDAR 19: South Atlantic Red Grouper.

**Tables**



**Figures**

**Table 2: Summary of Life History Parameters:**

*Table 6.1. Life-history characteristics at age of the population, including average size (mid-year), proportion female, and proportion females mature (all males assumed mature)*

| Age | Total length (mm) | Total length (in) | CV length | Whole weight (kg) | Whole weight (lb) | Prop. female | Female maturity |
|---|---|---|---|---|---|---|---|
| 1 | 313.9 | 12.4 | 0.09 | 0.46 | 1.02 | 1.00 | 0.00 |
| 2 | 416.4 | 16.4 | 0.09 | 1.11 | 2.45 | 0.96 | 0.35 |
| 3 | 499.3 | 19.7 | 0.09 | 1.95 | 4.30 | 0.93 | 0.54 |
| 4 | 566.2 | 22.3 | 0.09 | 2.88 | 6.35 | 0.88 | 0.71 |
| 5 | 620.3 | 24.4 | 0.09 | 3.82 | 8.43 | 0.80 | 0.84 |
| 6 | 664.0 | 26.1 | 0.09 | 4.72 | 10.41 | 0.70 | 0.92 |
| 7 | 699.4 | 27.5 | 0.09 | 5.54 | 12.22 | 0.59 | 0.96 |
| 8 | 727.9 | 28.7 | 0.09 | 6.28 | 13.84 | 0.47 | 0.98 |
| 9 | 751.0 | 29.6 | 0.09 | 6.91 | 15.24 | 0.35 | 0.99 |
| 10 | 769.6 | 30.3 | 0.09 | 7.46 | 16.45 | 0.24 | 1.00 |
| 11 | 784.7 | 30.9 | 0.09 | 7.92 | 17.46 | 0.15 | 1.00 |
| 12 | 796.9 | 31.4 | 0.09 | 8.31 | 18.32 | 0.09 | 1.00 |
| 13 | 806.7 | 31.8 | 0.09 | 8.63 | 19.03 | 0.05 | 1.00 |
| 14 | 814.7 | 32.1 | 0.09 | 8.90 | 19.62 | 0.02 | 1.00 |
| 15 | 821.1 | 32.3 | 0.09 | 9.12 | 20.10 | 0.00 | 1.00 |
| 16 | 826.3 | 32.5 | 0.09 | 9.30 | 20.50 | 0.00 | 1.00 |

**Table 3: Catch and discards by fishery sector**
a) Landings and discards, as fitted by the BAM (i.e., model input).

| | Commercial | | | Recreational | | | |
|---|---|---|---|---|---|---|---|
| | Landings (1000 lb whole weight) | | Discards (1000s) | Landings (1000s) | | Discards (1000s fish) | |
| | Lines (handline, longline) | Misc. (diving, pots, other) | Line | Headboat | MRFSS (smooth) | Headboat | MRFSS |
| 1976 | 263.678 | 171.480 | | 4.60 | | | |
| 1977 | 209.245 | 135.148 | | 5.61 | | | |
| 1978 | 257.966 | 152.356 | | 4.77 | | | |
| 1979 | 234.447 | 135.079 | | 9.38 | | | |
| 1980 | 184.857 | 103.576 | | 8.14 | | | |
| 1981 | 210.664 | 125.994 | | 7.96 | 79.93 | | 15.33 |
| 1982 | 205.599 | 113.021 | | 6.36 | 138.64 | | 17.47 |
| 1983 | 203.609 | 118.816 | | 9.89 | 237.35 | | 154.68 |
| 1984 | 236.620 | 141.385 | | 8.56 | 206.42 | | 175.84 |
| 1985 | 201.470 | 100.637 | | 8.78 | 76.69 | | 7.19 |
| 1986 | 249.957 | 130.830 | | 5.81 | 91.20 | | 34.29 |
| 1987 | 189.755 | 118.235 | | 7.04 | 80.46 | | 114.71 |
| 1988 | 244.353 | 111.014 | | 5.10 | 37.99 | | 54.63 |
| 1989 | 230.244 | 113.742 | | 3.62 | 74.68 | | 11.93 |
| 1990 | 172.989 | 102.009 | | 7.33 | 12.83 | | 21.89 |
| 1991 | 139.206 | 74.863 | | 2.73 | 5.95 | | 163.80 |
| 1992 | 128.888 | 39.960 | 8.915 | 3.98 | 22.65 | | 152.33 |
| 1993 | 168.202 | 16.477 | 8.575 | 4.79 | 50.32 | | 79.55 |
| 1994 | 165.351 | 10.094 | 14.397 | 5.47 | 34.43 | | 146.42 |
| 1995 | 230.109 | 9.413 | 10.489 | 5.25 | 37.21 | | 150.45 |
| 1996 | 279.453 | 19.121 | 11.582 | 5.65 | 46.47 | | 344.66 |
| 1997 | 310.997 | 18.837 | 14.709 | 8.06 | 40.68 | | 352.94 |
| 1998 | 431.654 | 35.487 | 10.461 | 10.90 | 35.31 | | 113.65 |
| 1999 | 404.755 | 17.033 | 12.956 | 7.26 | 19.40 | | 110.38 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2000 | 342.501 | 12.356 | 10.869 | 5.33 | 17.63 | | 226.80 |
| 2001 | 327.783 | 43.889 | 8.423 | 4.94 | 18.37 | | 189.69 |
| 2002 | 331.352 | 31.312 | 21.608 | 4.60 | 39.25 | | 122.95 |
| 2003 | 307.358 | 22.158 | 11.354 | 4.02 | 47.95 | | 159.81 |
| 2004 | 289.084 | 31.624 | 10.850 | 10.76 | 40.40 | | 219.12 |
| 2005 | 202.093 | 13.270 | 9.992 | 11.47 | 35.42 | 88.18 | 230.41 |
| 2006 | 323.546 | 7.659 | 4.933 | 5.24 | 55.80 | 22.44 | 194.77 |
| 2007 | 569.328 | 15.027 | 8.571 | 5.16 | 77.99 | 20.30 | 58.24 |
| 2008 | 590.412 | 9.382 | 1.993 | 2.44 | 89.13 | | 89.94 |

**Table 3: continued**

b) Landings and dead discards in 1000 pounds whole weight, as estimated by the BAM (i.e., model output).

| | Landings (1000 lbs) | | | | Discards (1000 lbs) | | |
|---|---|---|---|---|---|---|---|
| Year | Commercial Lines | Commercial Other | Headboat | MRFSS | Commercial Lines | Headboat | MRFSS |
| 1976 | 262.12 | 170.91 | 26.55 | 1713.36 | 0.00 | 0.00 | 0.00 |
| 1977 | 208.43 | 134.67 | 35.45 | 1517.04 | 0.00 | 0.00 | 0.00 |
| 1978 | 257.53 | 151.64 | 30.38 | 1299.14 | 0.00 | 0.00 | 0.00 |
| 1979 | 234.95 | 134.88 | 57.28 | 1110.18 | 0.00 | 0.00 | 0.00 |
| 1980 | 185.02 | 103.54 | 49.77 | 968.90 | 0.00 | 0.00 | 0.00 |
| 1981 | 210.82 | 125.98 | 49.81 | 486.06 | 0.00 | 0.00 | 4.27 |
| 1982 | 205.78 | 113.12 | 37.32 | 793.97 | 0.00 | 0.00 | 4.58 |
| 1983 | 203.57 | 119.01 | 49.66 | 1163.97 | 0.00 | 0.00 | 42.81 |
| 1984 | 235.87 | 141.99 | 42.76 | 1033.00 | 0.00 | 6.73 | 50.51 |
| 1985 | 200.92 | 100.99 | 39.64 | 347.87 | 0.00 | 6.42 | 1.97 |
| 1986 | 250.03 | 131.15 | 25.53 | 403.06 | 0.00 | 5.95 | 10.19 |
| 1987 | 190.07 | 118.42 | 31.74 | 365.16 | 0.00 | 5.89 | 29.68 |
| 1988 | 244.10 | 111.01 | 22.20 | 165.21 | 0.00 | 6.79 | 16.25 |
| 1989 | 228.88 | 113.86 | 17.08 | 350.67 | 0.00 | 4.48 | 3.66 |
| 1990 | 172.95 | 102.14 | 39.34 | 68.88 | 0.00 | 3.01 | 6.42 |
| 1991 | 139.63 | 74.76 | 16.37 | 35.68 | 0.00 | 3.49 | 42.27 |
| 1992 | 129.29 | 39.95 | 33.00 | 198.81 | 2.82 | 8.58 | 48.21 |
| 1993 | 168.24 | 16.47 | 37.66 | 438.81 | 3.81 | 11.06 | 35.40 |
| 1994 | 165.10 | 10.09 | 38.36 | 266.67 | 6.12 | 9.30 | 62.14 |
| 1995 | 229.03 | 9.41 | 39.35 | 288.19 | 3.44 | 10.50 | 49.36 |
| 1996 | 277.91 | 19.11 | 43.78 | 387.29 | 4.17 | 15.91 | 123.80 |
| 1997 | 311.58 | 18.83 | 58.36 | 326.84 | 7.02 | 15.82 | 168.08 |
| 1998 | 433.52 | 35.47 | 78.09 | 272.43 | 5.42 | 9.54 | 58.88 |
| 1999 | 409.53 | 17.04 | 57.47 | 158.83 | 4.74 | 6.41 | 40.36 |
| 2000 | 348.42 | 12.36 | 47.64 | 163.93 | 3.99 | 7.80 | 83.35 |
| 2001 | 331.70 | 43.93 | 45.42 | 183.16 | 3.19 | 9.39 | 71.92 |
| 2002 | 331.50 | 31.32 | 41.45 | 386.64 | 7.97 | 11.25 | 45.16 |
| 2003 | 307.52 | 22.17 | 34.55 | 454.54 | 4.28 | 13.89 | 60.32 |
| 2004 | 289.41 | 31.65 | 87.33 | 360.59 | 3.69 | 19.17 | 74.72 |
| 2005 | 202.52 | 13.28 | 90.07 | 305.12 | 4.19 | 37.03 | 96.81 |
| 2006 | 325.09 | 7.66 | 39.29 | 462.48 | 2.62 | 11.90 | 103.46 |
| 2007 | 569.40 | 15.03 | 40.62 | 638.96 | 4.18 | 9.89 | 28.62 |
| 2008 | 589.30 | 9.38 | 21.61 | 806.81 | 0.66 | 8.53 | 29.82 |

## Table 4: Fishing mortality estimates

*Table 6.10. 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 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 0.100 | 0.233 | 0.338 | 0.379 | 0.395 | 0.404 | 0.411 | 0.415 | 0.417 | 0.418 | 0.419 | 0.419 | 0.419 | 0.418 | 0.418 | 0.418 |
| 1977 | 0.098 | 0.231 | 0.335 | 0.373 | 0.386 | 0.393 | 0.397 | 0.400 | 0.401 | 0.402 | 0.402 | 0.402 | 0.401 | 0.401 | 0.401 | 0.401 |
| 1978 | 0.109 | 0.249 | 0.356 | 0.396 | 0.410 | 0.418 | 0.423 | 0.427 | 0.428 | 0.429 | 0.429 | 0.428 | 0.428 | 0.428 | 0.427 | 0.427 |
| 1979 | 0.112 | 0.256 | 0.367 | 0.408 | 0.423 | 0.431 | 0.436 | 0.440 | 0.441 | 0.442 | 0.442 | 0.441 | 0.441 | 0.441 | 0.440 | 0.440 |
| 1980 | 0.107 | 0.248 | 0.358 | 0.399 | 0.413 | 0.421 | 0.426 | 0.430 | 0.431 | 0.432 | 0.432 | 0.432 | 0.432 | 0.431 | 0.431 | 0.431 |
| 1981 | 0.096 | 0.198 | 0.260 | 0.287 | 0.299 | 0.307 | 0.313 | 0.317 | 0.319 | 0.319 | 0.319 | 0.318 | 0.318 | 0.318 | 0.317 | 0.317 |
| 1982 | 0.124 | 0.274 | 0.379 | 0.422 | 0.439 | 0.449 | 0.457 | 0.461 | 0.464 | 0.465 | 0.465 | 0.464 | 0.464 | 0.464 | 0.463 | 0.463 |
| 1983 | 0.235 | 0.496 | 0.636 | 0.709 | 0.736 | 0.752 | 0.763 | 0.770 | 0.773 | 0.775 | 0.775 | 0.775 | 0.775 | 0.774 | 0.774 | 0.774 |
| 1984 | 0.215 | 0.662 | 0.938 | 0.997 | 1.026 | 1.054 | 1.076 | 1.091 | 1.100 | 1.104 | 1.106 | 1.106 | 1.106 | 1.106 | 1.105 | 1.105 |
| 1985 | 0.118 | 0.344 | 0.520 | 0.572 | 0.614 | 0.654 | 0.686 | 0.708 | 0.722 | 0.729 | 0.733 | 0.735 | 0.736 | 0.736 | 0.736 | 0.736 |
| 1986 | 0.159 | 0.421 | 0.611 | 0.679 | 0.735 | 0.790 | 0.834 | 0.864 | 0.883 | 0.893 | 0.899 | 0.901 | 0.902 | 0.902 | 0.902 | 0.902 |
| 1987 | 0.172 | 0.425 | 0.561 | 0.614 | 0.657 | 0.697 | 0.730 | 0.753 | 0.767 | 0.774 | 0.778 | 0.779 | 0.780 | 0.780 | 0.780 | 0.779 |
| 1988 | 0.137 | 0.286 | 0.369 | 0.425 | 0.481 | 0.535 | 0.579 | 0.609 | 0.628 | 0.639 | 0.644 | 0.647 | 0.648 | 0.649 | 0.649 | 0.649 |
| 1989 | 0.125 | 0.325 | 0.471 | 0.525 | 0.572 | 0.616 | 0.652 | 0.677 | 0.693 | 0.701 | 0.705 | 0.707 | 0.708 | 0.708 | 0.708 | 0.708 |
| 1990 | 0.111 | 0.208 | 0.240 | 0.268 | 0.295 | 0.322 | 0.344 | 0.359 | 0.368 | 0.372 | 0.374 | 0.375 | 0.375 | 0.375 | 0.375 | 0.375 |
| 1991 | 0.176 | 0.256 | 0.149 | 0.163 | 0.179 | 0.196 | 0.210 | 0.219 | 0.224 | 0.227 | 0.228 | 0.229 | 0.229 | 0.228 | 0.228 | 0.228 |
| 1992 | 0.065 | 0.086 | 0.127 | 0.269 | 0.324 | 0.336 | 0.333 | 0.328 | 0.323 | 0.320 | 0.318 | 0.316 | 0.315 | 0.314 | 0.313 | 0.313 |
| 1993 | 0.042 | 0.059 | 0.174 | 0.501 | 0.590 | 0.611 | 0.612 | 0.611 | 0.609 | 0.607 | 0.606 | 0.606 | 0.605 | 0.605 | 0.604 | 0.604 |
| 1994 | 0.077 | 0.099 | 0.141 | 0.314 | 0.390 | 0.411 | 0.413 | 0.412 | 0.411 | 0.411 | 0.410 | 0.410 | 0.409 | 0.409 | 0.409 | 0.409 |
| 1995 | 0.056 | 0.073 | 0.117 | 0.279 | 0.361 | 0.384 | 0.387 | 0.387 | 0.386 | 0.385 | 0.385 | 0.385 | 0.384 | 0.384 | 0.384 | 0.384 |
| 1996 | 0.083 | 0.108 | 0.158 | 0.360 | 0.448 | 0.472 | 0.474 | 0.473 | 0.471 | 0.470 | 0.470 | 0.469 | 0.469 | 0.468 | 0.468 | 0.468 |
| 1997 | 0.111 | 0.142 | 0.166 | 0.325 | 0.416 | 0.443 | 0.446 | 0.445 | 0.443 | 0.442 | 0.442 | 0.441 | 0.441 | 0.441 | 0.440 | 0.440 |
| 1998 | 0.072 | 0.095 | 0.131 | 0.284 | 0.396 | 0.428 | 0.431 | 0.429 | 0.427 | 0.425 | 0.424 | 0.423 | 0.423 | 0.422 | 0.422 | 0.422 |
| 1999 | 0.074 | 0.095 | 0.101 | 0.182 | 0.260 | 0.284 | 0.287 | 0.286 | 0.285 | 0.285 | 0.284 | 0.284 | 0.283 | 0.283 | 0.283 | 0.283 |
| 2000 | 0.112 | 0.140 | 0.120 | 0.163 | 0.215 | 0.232 | 0.234 | 0.233 | 0.233 | 0.232 | 0.232 | 0.231 | 0.231 | 0.231 | 0.231 | 0.231 |
| 2001 | 0.083 | 0.107 | 0.109 | 0.180 | 0.236 | 0.251 | 0.250 | 0.247 | 0.244 | 0.242 | 0.241 | 0.240 | 0.239 | 0.238 | 0.238 | 0.238 |
| 2002 | 0.053 | 0.070 | 0.109 | 0.256 | 0.324 | 0.341 | 0.342 | 0.340 | 0.338 | 0.336 | 0.335 | 0.334 | 0.334 | 0.333 | 0.333 | 0.333 |
| 2003 | 0.052 | 0.069 | 0.114 | 0.282 | 0.350 | 0.368 | 0.369 | 0.368 | 0.367 | 0.366 | 0.365 | 0.364 | 0.364 | 0.363 | 0.363 | 0.363 |
| 2004 | 0.047 | 0.063 | 0.110 | 0.252 | 0.315 | 0.332 | 0.332 | 0.330 | 0.329 | 0.327 | 0.326 | 0.325 | 0.325 | 0.324 | 0.324 | 0.324 |
| 2005 | 0.053 | 0.068 | 0.091 | 0.176 | 0.212 | 0.222 | 0.223 | 0.223 | 0.222 | 0.222 | 0.221 | 0.221 | 0.221 | 0.221 | 0.221 | 0.221 |
| 2006 | 0.058 | 0.074 | 0.090 | 0.188 | 0.235 | 0.248 | 0.250 | 0.250 | 0.250 | 0.250 | 0.249 | 0.249 | 0.249 | 0.249 | 0.249 | 0.249 |
| 2007 | 0.040 | 0.053 | 0.086 | 0.220 | 0.289 | 0.309 | 0.312 | 0.312 | 0.311 | 0.311 | 0.311 | 0.310 | 0.310 | 0.310 | 0.310 | 0.310 |
| 2008 | 0.042 | 0.055 | 0.095 | 0.251 | 0.318 | 0.337 | 0.340 | 0.340 | 0.339 | 0.339 | 0.339 | 0.339 | 0.339 | 0.339 | 0.339 | 0.339 |

## Table 5: Stock abundance and biomass

*Table 6.2. Estimated total abundance at age (1000 fish) at start of year.*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 387.1 | 361.1 | 169.0 | 542.5 | 160.0 | 34.5 | 24.6 | 11.7 | 12.5 | 4.5 | 2.2 | 1.1 | 0.6 | 0.3 | 0.2 | 0.3 | 1712.2 |
| 1977 | 370.0 | 259.6 | 227.3 | 99.6 | 313.2 | 91.9 | 19.8 | 14.2 | 6.8 | 7.2 | 2.6 | 1.3 | 0.7 | 0.4 | 0.2 | 0.3 | 1415.0 |
| 1978 | 454.7 | 248.5 | 163.8 | 134.5 | 57.9 | 181.4 | 53.4 | 11.6 | 8.3 | 4.0 | 4.3 | 1.5 | 0.7 | 0.4 | 0.2 | 0.3 | 1325.4 |
| 1979 | 411.1 | 302.2 | 154.0 | 94.8 | 76.3 | 32.7 | 102.8 | 30.4 | 6.6 | 4.8 | 2.3 | 2.4 | 0.9 | 0.4 | 0.2 | 0.3 | 1222.3 |
| 1980 | 226.9 | 272.3 | 185.9 | 88.2 | 53.2 | 42.6 | 18.3 | 57.7 | 17.2 | 3.7 | 2.7 | 1.3 | 1.4 | 0.5 | 0.2 | 0.3 | 972.6 |
| 1981 | 267.5 | 151.0 | 168.8 | 107.5 | 50.0 | 30.0 | 24.1 | 10.4 | 33.0 | 9.8 | 2.1 | 1.5 | 0.7 | 0.8 | 0.3 | 0.3 | 857.9 |
| 1982 | 451.5 | 180.0 | 98.5 | 107.6 | 68.0 | 31.6 | 19.0 | 15.3 | 6.6 | 21.1 | 6.3 | 1.4 | 1.0 | 0.5 | 0.5 | 0.4 | 1009.1 |
| 1983 | 492.1 | 295.3 | 108.8 | 55.7 | 59.5 | 37.4 | 17.3 | 10.5 | 8.5 | 3.7 | 11.6 | 3.5 | 0.8 | 0.6 | 0.3 | 0.5 | 1105.9 |
| 1984 | 357.9 | 288.1 | 142.9 | 47.6 | 23.1 | 24.3 | 15.2 | 7.0 | 4.3 | 3.4 | 1.5 | 4.7 | 1.4 | 0.3 | 0.2 | 0.3 | 922.3 |
| 1985 | 380.8 | 213.9 | 118.1 | 46.2 | 14.8 | 7.1 | 7.3 | 4.5 | 2.1 | 1.2 | 1.0 | 0.4 | 1.4 | 0.4 | 0.1 | 0.2 | 799.5 |
| 1986 | 263.1 | 250.7 | 120.5 | 58.1 | 22.0 | 6.8 | 3.2 | 3.2 | 1.9 | 0.9 | 0.5 | 0.4 | 0.2 | 0.6 | 0.2 | 0.1 | 732.4 |
| 1987 | 434.3 | 166.3 | 130.7 | 54.1 | 24.9 | 9.0 | 2.7 | 1.2 | 1.2 | 0.7 | 0.3 | 0.2 | 0.2 | 0.1 | 0.2 | 0.1 | 826.0 |
| 1988 | 296.0 | 270.8 | 86.4 | 61.7 | 24.7 | 11.0 | 3.9 | 1.1 | 0.5 | 0.5 | 0.3 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 757.3 |
| 1989 | 168.1 | 191.1 | 161.6 | 49.4 | 34.0 | 13.0 | 5.5 | 1.9 | 0.5 | 0.2 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 626.1 |
| 1990 | 138.3 | 109.9 | 109.7 | 83.4 | 24.7 | 16.4 | 6.0 | 2.5 | 0.8 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 492.3 |
| 1991 | 256.8 | 91.7 | 70.9 | 71.4 | 53.8 | 15.6 | 10.2 | 3.7 | 1.5 | 0.5 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 576.7 |
| 1992 | 462.6 | 159.5 | 56.4 | 50.6 | 51.2 | 38.3 | 11.1 | 7.2 | 2.6 | 1.1 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 841.2 |
| 1993 | 158.4 | 321.2 | 116.3 | 41.1 | 32.6 | 31.5 | 23.6 | 6.9 | 4.5 | 1.7 | 0.7 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 738.9 |
| 1994 | 257.9 | 112.5 | 240.6 | 80.9 | 21.0 | 15.4 | 14.7 | 11.1 | 3.3 | 2.2 | 0.8 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 760.9 |
| 1995 | 534.5 | 176.9 | 81.0 | 172.8 | 49.8 | 12.1 | 8.8 | 8.5 | 6.5 | 1.9 | 1.3 | 0.5 | 0.2 | 0.1 | 0.0 | 0.0 | 1054.9 |
| 1996 | 601.1 | 374.6 | 130.7 | 59.6 | 110.3 | 29.6 | 7.1 | 5.2 | 5.1 | 3.9 | 1.1 | 0.8 | 0.3 | 0.1 | 0.0 | 0.0 | 1329.4 |
| 1997 | 178.4 | 409.7 | 267.2 | 92.3 | 35.1 | 60.1 | 15.9 | 3.8 | 2.8 | 2.8 | 2.1 | 0.6 | 0.4 | 0.2 | 0.1 | 0.0 | 1071.5 |
| 1998 | 114.4 | 118.3 | 282.5 | 187.2 | 56.3 | 19.7 | 33.2 | 8.9 | 2.2 | 1.6 | 1.6 | 1.2 | 0.4 | 0.2 | 0.1 | 0.1 | 827.6 |
| 1999 | 271.7 | 78.9 | 85.5 | 205.0 | 118.8 | 32.3 | 11.1 | 18.8 | 5.1 | 1.2 | 0.9 | 0.9 | 0.7 | 0.2 | 0.1 | 0.1 | 831.2 |
| 2000 | 281.6 | 186.9 | 57.0 | 63.9 | 144.2 | 78.1 | 20.9 | 7.2 | 12.4 | 3.3 | 0.8 | 0.6 | 0.6 | 0.5 | 0.1 | 0.2 | 858.4 |
| 2001 | 323.4 | 186.5 | 129.1 | 41.8 | 45.8 | 99.1 | 53.3 | 14.4 | 5.0 | 8.6 | 2.3 | 0.6 | 0.4 | 0.4 | 0.3 | 0.2 | 911.3 |
| 2002 | 412.1 | 220.5 | 133.2 | 95.7 | 29.5 | 30.8 | 66.4 | 36.1 | 9.9 | 3.5 | 5.9 | 1.6 | 0.4 | 0.3 | 0.3 | 0.4 | 1046.5 |
| 2003 | 468.7 | 289.5 | 163.3 | 98.8 | 62.5 | 18.2 | 18.9 | 41.0 | 22.6 | 6.2 | 2.2 | 3.7 | 1.0 | 0.3 | 0.2 | 0.4 | 1197.3 |
| 2004 | 884.3 | 329.5 | 214.7 | 120.5 | 62.8 | 37.5 | 10.8 | 11.3 | 24.9 | 13.7 | 3.8 | 1.3 | 2.3 | 0.6 | 0.2 | 0.4 | 1718.7 |
| 2005 | 500.5 | 624.8 | 245.9 | 159.1 | 79.0 | 39.1 | 23.2 | 6.7 | 7.1 | 15.7 | 8.7 | 2.4 | 0.8 | 1.5 | 0.4 | 0.3 | 1715.3 |
| 2006 | 125.2 | 351.5 | 463.7 | 185.6 | 112.5 | 54.4 | 26.9 | 16.1 | 4.7 | 5.0 | 11.1 | 6.1 | 1.7 | 0.6 | 1.0 | 0.5 | 1366.9 |
| 2007 | 179.8 | 87.5 | 259.5 | 350.6 | 129.8 | 75.8 | 36.6 | 18.2 | 11.0 | 3.2 | 3.4 | 7.6 | 4.2 | 1.2 | 0.4 | 1.1 | 1170.0 |
| 2008 | 426.5 | 128.0 | 66.0 | 196.9 | 237.5 | 82.8 | 47.9 | 23.3 | 11.7 | 7.1 | 2.1 | 2.2 | 4.9 | 2.7 | 0.8 | 1.0 | 1241.3 |
| 2009 | 355.8 | 302.9 | 96.2 | 49.6 | 129.2 | 147.2 | 50.9 | 29.7 | 14.5 | 7.3 | 4.4 | 1.3 | 1.4 | 3.1 | 1.7 | 1.1 | 1196.6 |

*Table 6.5. Estimated biomass at age (mt) at start of year*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 179.2 | 401.2 | 329.5 | 1562.5 | 611.6 | 162.9 | 136.2 | 73.7 | 86.6 | 33.2 | 17.3 | 9.3 | 5.2 | 3.0 | 1.7 | 2.6 | 3615.6 |
| 1977 | 171.2 | 288.5 | 443.2 | 287.0 | 1197.2 | 433.7 | 109.9 | 88.9 | 47.1 | 54.0 | 20.4 | 10.5 | 5.6 | 3.1 | 1.8 | 2.5 | 3164.6 |
| 1978 | 210.4 | 276.1 | 319.4 | 387.3 | 221.1 | 856.3 | 295.9 | 72.7 | 57.6 | 29.9 | 33.7 | 12.6 | 6.5 | 3.4 | 1.9 | 2.6 | 2787.4 |
| 1979 | 190.3 | 335.8 | 300.3 | 273.1 | 291.7 | 154.4 | 569.7 | 190.7 | 45.9 | 35.6 | 18.1 | 20.2 | 7.5 | 3.8 | 2.0 | 2.6 | 2442.0 |
| 1980 | 105.0 | 302.6 | 362.5 | 254.1 | 203.3 | 201.2 | 101.5 | 362.4 | 118.8 | 28.0 | 21.3 | 10.7 | 12.0 | 4.4 | 2.2 | 2.7 | 2092.8 |
| 1981 | 123.8 | 167.8 | 329.2 | 309.6 | 191.0 | 141.6 | 133.5 | 65.2 | 228.1 | 73.1 | 16.9 | 12.8 | 6.4 | 7.1 | 2.6 | 2.9 | 1811.6 |
| 1982 | 208.9 | 200.0 | 192.0 | 309.9 | 260.0 | 149.0 | 105.3 | 96.1 | 45.9 | 157.2 | 49.6 | 11.3 | 8.5 | 4.3 | 4.7 | 3.6 | 1806.3 |
| 1983 | 227.7 | 328.1 | 212.1 | 160.5 | 227.5 | 176.5 | 96.1 | 65.6 | 58.6 | 27.4 | 92.1 | 28.7 | 6.6 | 4.9 | 2.4 | 4.7 | 1719.6 |
| 1984 | 165.6 | 320.1 | 278.6 | 137.1 | 88.4 | 114.7 | 84.1 | 44.1 | 29.4 | 25.6 | 11.8 | 39.1 | 12.2 | 2.8 | 2.1 | 2.9 | 1358.6 |
| 1985 | 176.2 | 237.7 | 230.3 | 133.1 | 56.7 | 33.4 | 40.4 | 28.2 | 14.3 | 9.3 | 7.9 | 3.6 | 11.9 | 3.7 | 0.8 | 1.5 | 989.0 |
| 1986 | 121.8 | 278.5 | 234.9 | 167.3 | 84.1 | 32.3 | 17.5 | 20.0 | 13.4 | 6.6 | 4.2 | 3.5 | 1.6 | 5.2 | 1.6 | 1.0 | 993.5 |
| 1987 | 201.0 | 184.8 | 254.8 | 155.8 | 95.0 | 42.4 | 14.8 | 7.5 | 8.2 | 5.3 | 2.5 | 1.6 | 1.3 | 0.6 | 1.9 | 0.9 | 978.4 |
| 1988 | 137.0 | 300.9 | 168.5 | 177.6 | 94.4 | 51.9 | 21.4 | 7.0 | 3.4 | 3.6 | 2.3 | 1.1 | 0.7 | 0.5 | 0.2 | 1.2 | 971.6 |
| 1989 | 77.8 | 212.4 | 315.2 | 142.4 | 129.9 | 61.4 | 30.7 | 11.8 | 3.7 | 1.7 | 1.8 | 1.1 | 0.5 | 0.3 | 0.3 | 0.7 | 991.6 |
| 1990 | 64.0 | 122.1 | 213.9 | 240.3 | 94.3 | 77.2 | 33.5 | 15.7 | 5.8 | 1.8 | 0.8 | 0.8 | 0.5 | 0.2 | 0.1 | 0.4 | 871.5 |
| 1991 | 118.9 | 101.9 | 138.3 | 205.7 | 205.8 | 73.8 | 56.5 | 23.4 | 10.6 | 3.8 | 1.1 | 0.5 | 0.5 | 0.3 | 0.1 | 0.3 | 941.6 |
| 1992 | 214.1 | 177.3 | 110.0 | 145.6 | 195.7 | 181.0 | 61.3 | 45.1 | 18.1 | 8.0 | 2.8 | 0.8 | 0.4 | 0.4 | 0.2 | 0.3 | 1161.3 |
| 1993 | 73.3 | 356.9 | 226.8 | 118.3 | 124.6 | 148.9 | 130.8 | 43.3 | 31.4 | 12.4 | 5.4 | 1.9 | 0.6 | 0.2 | 0.2 | 0.4 | 1275.5 |
| 1994 | 119.4 | 125.0 | 469.2 | 232.9 | 80.2 | 72.7 | 81.7 | 69.8 | 22.7 | 16.2 | 6.3 | 2.7 | 1.0 | 0.3 | 0.1 | 0.3 | 1300.5 |
| 1995 | 247.4 | 196.6 | 157.9 | 497.8 | 190.4 | 57.2 | 48.7 | 53.2 | 44.7 | 14.3 | 10.0 | 3.9 | 1.7 | 0.6 | 0.2 | 0.3 | 1524.8 |
| 1996 | 278.2 | 416.2 | 254.9 | 171.6 | 421.6 | 139.7 | 39.4 | 32.6 | 35.0 | 28.8 | 9.1 | 6.3 | 2.4 | 1.0 | 0.4 | 0.3 | 1837.3 |
| 1997 | 82.6 | 455.2 | 521.0 | 265.9 | 134.1 | 283.6 | 88.1 | 24.1 | 19.6 | 20.7 | 16.8 | 5.2 | 3.6 | 1.4 | 0.6 | 0.3 | 1922.8 |
| 1998 | 52.9 | 131.4 | 551.0 | 539.1 | 215.1 | 93.1 | 184.1 | 55.5 | 15.0 | 11.9 | 12.4 | 9.9 | 3.1 | 2.1 | 0.8 | 0.5 | 1877.9 |
| 1999 | 125.7 | 87.6 | 166.7 | 590.4 | 454.1 | 152.3 | 61.3 | 117.8 | 35.0 | 9.2 | 7.3 | 7.5 | 6.0 | 1.9 | 1.3 | 0.8 | 1824.9 |
| 2000 | 130.3 | 207.7 | 111.1 | 184.0 | 551.2 | 368.5 | 115.9 | 45.3 | 85.6 | 24.9 | 6.5 | 5.0 | 5.2 | 4.1 | 1.3 | 1.4 | 1848.2 |
| 2001 | 149.7 | 207.3 | 251.7 | 120.4 | 175.0 | 467.8 | 295.4 | 90.3 | 34.7 | 64.3 | 18.4 | 4.7 | 3.7 | 3.8 | 3.0 | 1.9 | 1892.0 |
| 2002 | 190.7 | 245.0 | 259.8 | 275.7 | 112.6 | 145.5 | 367.9 | 226.4 | 68.2 | 25.8 | 47.0 | 13.3 | 3.4 | 2.7 | 2.7 | 3.4 | 1990.3 |
| 2003 | 216.9 | 321.6 | 318.5 | 284.5 | 238.9 | 85.7 | 104.5 | 257.2 | 155.9 | 46.1 | 17.2 | 31.0 | 8.8 | 2.3 | 1.7 | 3.9 | 2094.8 |
| 2004 | 409.3 | 366.2 | 418.7 | 347.0 | 240.2 | 177.1 | 60.0 | 71.1 | 172.2 | 102.4 | 29.8 | 11.0 | 19.8 | 5.6 | 1.4 | 3.5 | 2435.3 |
| 2005 | 231.6 | 694.3 | 479.4 | 458.3 | 302.0 | 184.4 | 128.5 | 42.3 | 49.4 | 117.5 | 68.8 | 19.8 | 7.3 | 13.1 | 3.7 | 3.2 | 2803.6 |
| 2006 | 57.9 | 390.6 | 904.3 | 534.7 | 430.1 | 257.0 | 149.2 | 101.1 | 32.8 | 37.5 | 87.7 | 50.8 | 14.6 | 5.4 | 9.6 | 4.9 | 3068.2 |
| 2007 | 83.2 | 97.2 | 506.0 | 1009.9 | 496.0 | 358.0 | 202.6 | 114.4 | 76.2 | 24.2 | 27.2 | 63.0 | 36.5 | 10.4 | 3.8 | 10.1 | 3118.8 |
| 2008 | 197.4 | 142.2 | 128.6 | 567.1 | 907.6 | 390.9 | 265.6 | 146.0 | 81.0 | 52.9 | 16.5 | 18.4 | 42.5 | 24.5 | 7.0 | 9.1 | 2997.3 |
| 2009 | 164.7 | 336.6 | 187.6 | 142.9 | 493.9 | 695.0 | 282.1 | 186.1 | 100.6 | 54.7 | 35.1 | 10.8 | 12.1 | 27.7 | 15.8 | 10.2 | 2756.1 |

**Table 6: Spawning stock biomass and recruitment**

| Year | SSB (mt) | Recruits (1000 fish) |
|---|---|---|
| 1976 | 2158 | 387.1 |
| 1977 | 2002 | 370.0 |
| 1978 | 1749 | 454.7 |
| 1979 | 1492 | 411.1 |
| 1980 | 1290 | 226.9 |
| 1981 | 1152 | 267.5 |
| 1982 | 1054 | 451.5 |
| 1983 | 847 | 492.1 |
| 1984 | 572 | 357.9 |
| 1985 | 415 | 380.8 |
| 1986 | 418 | 263.1 |
| 1987 | 391 | 434.3 |
| 1988 | 427 | 296.0 |
| 1989 | 475 | 168.1 |
| 1990 | 488 | 138.3 |
| 1991 | 552 | 256.8 |
| 1992 | 623 | 462.6 |
| 1993 | 683 | 158.4 |
| 1994 | 717 | 257.9 |
| 1995 | 809 | 534.5 |
| 1996 | 920 | 601.1 |
| 1997 | 1057 | 178.4 |
| 1998 | 1153 | 114.4 |
| 1999 | 1200 | 271.7 |
| 2000 | 1247 | 281.6 |
| 2001 | 1260 | 323.4 |
| 2002 | 1248 | 412.1 |
| 2003 | 1240 | 468.7 |
| 2004 | 1306 | 884.3 |
| 2005 | 1589 | 500.5 |
| 2006 | 1944 | 125.2 |
| 2007 | 2125 | 179.8 |
| 2008 | 2051 | 426.5 |

# Figure 1: Landings by fishery sector

*Figure 6.12. Observed (open circles) and estimated (line, solid circles) commercial lines landings (1000 lb whole weight).*

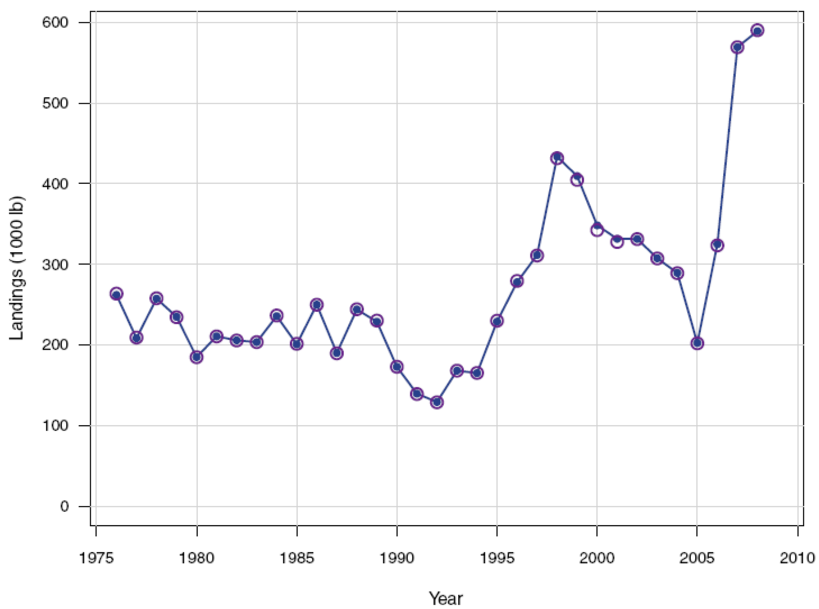



*Figure 6.13. Observed (open circles) and estimated (line, solid circles) commercial other (1000 lb whole weight).*

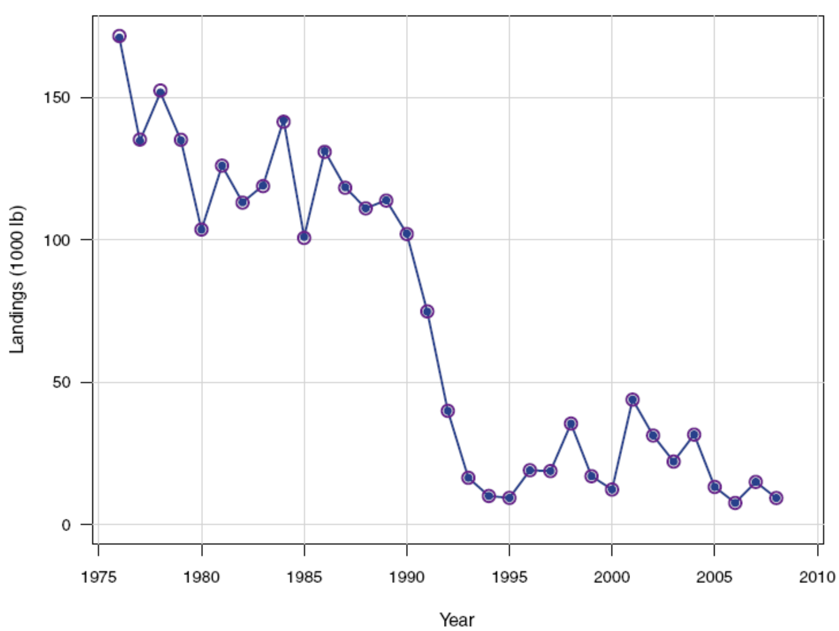


**Figure 1: continued**

*Figure 6.14. Observed (open circles) and estimated (line, solid circles) headboat landings (1000 fish).*

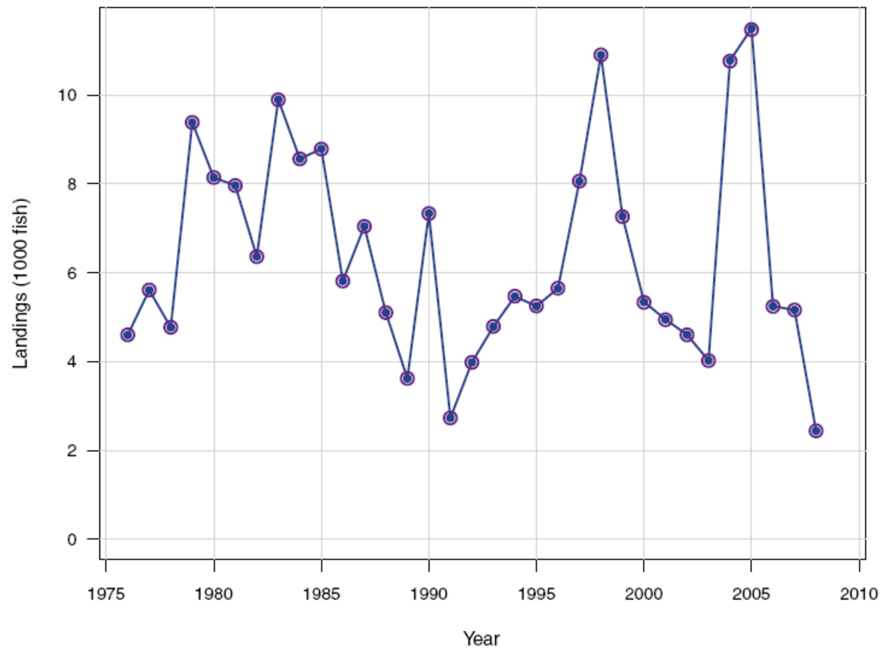



*Figure 6.15. Observed (open circles) and estimated (line, solid circles) general recreational landings (1000 fish). In years without observations, values were predicted using average F (see §III for details).*

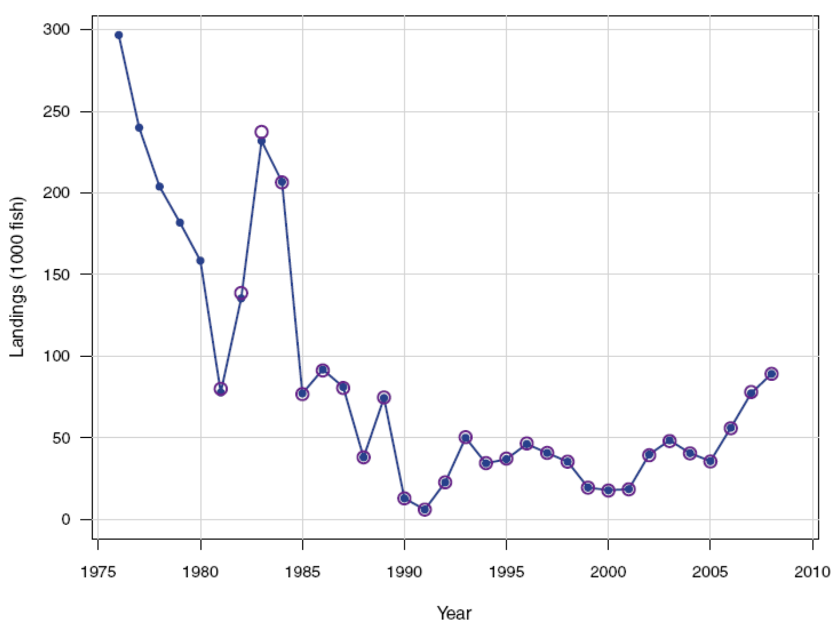


**Figure 2: Discards by fishery sector**

*Figure 6.16. Observed (open circles) and estimated (line, solid circles) commercial handline discard mortalities (1000 dead fish). In years without observations, values were predicted using average F (see §III for details).*

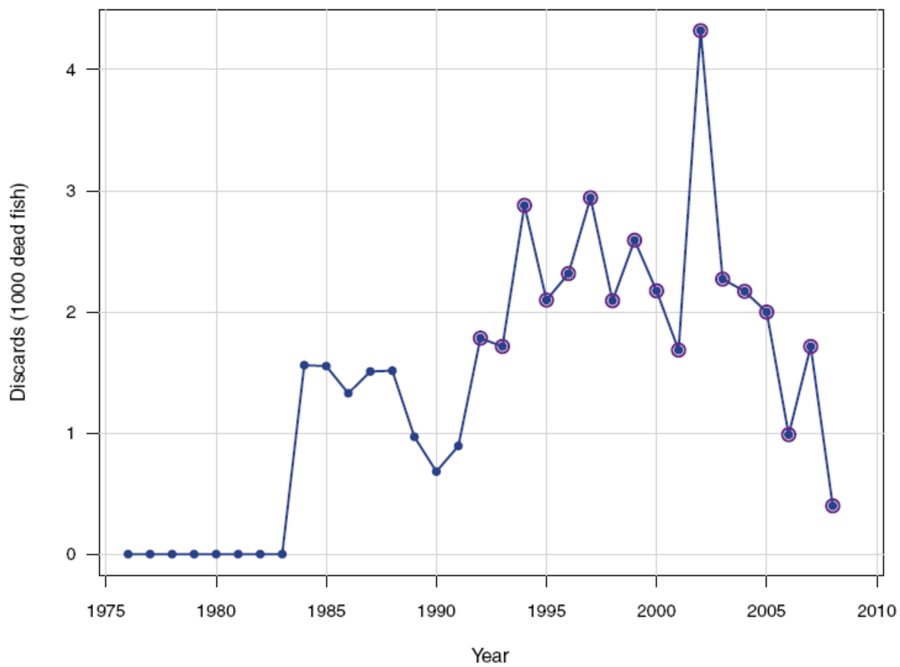



*Figure 6.17. Observed (open circles) and estimated (line, solid circles) headboat discard mortalities (1000 dead fish). In years without observations, values were predicted using average F (see §III for details).*

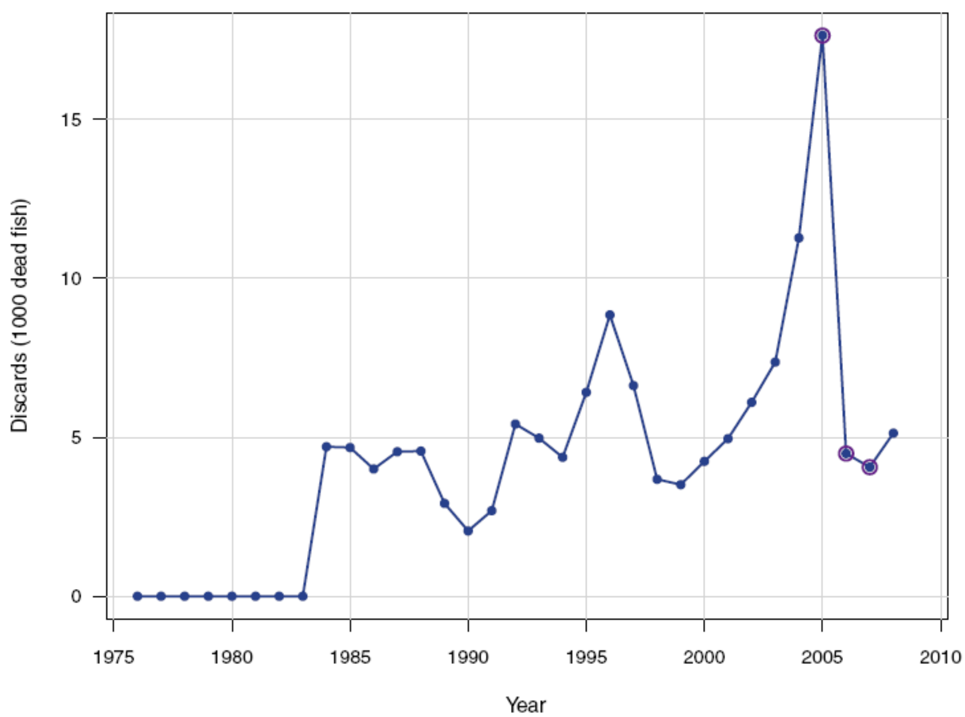



**Figure 2: continued**

*Figure 6.18. Observed (open circles) and estimated (line, solid circles) general recreational discard mortalities (1000 dead fish).*

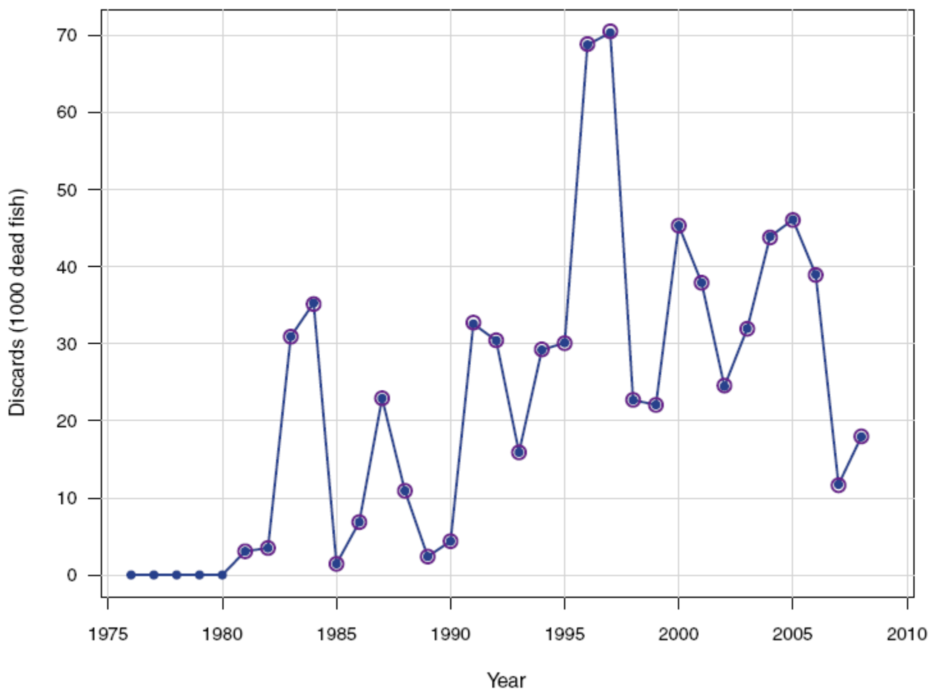
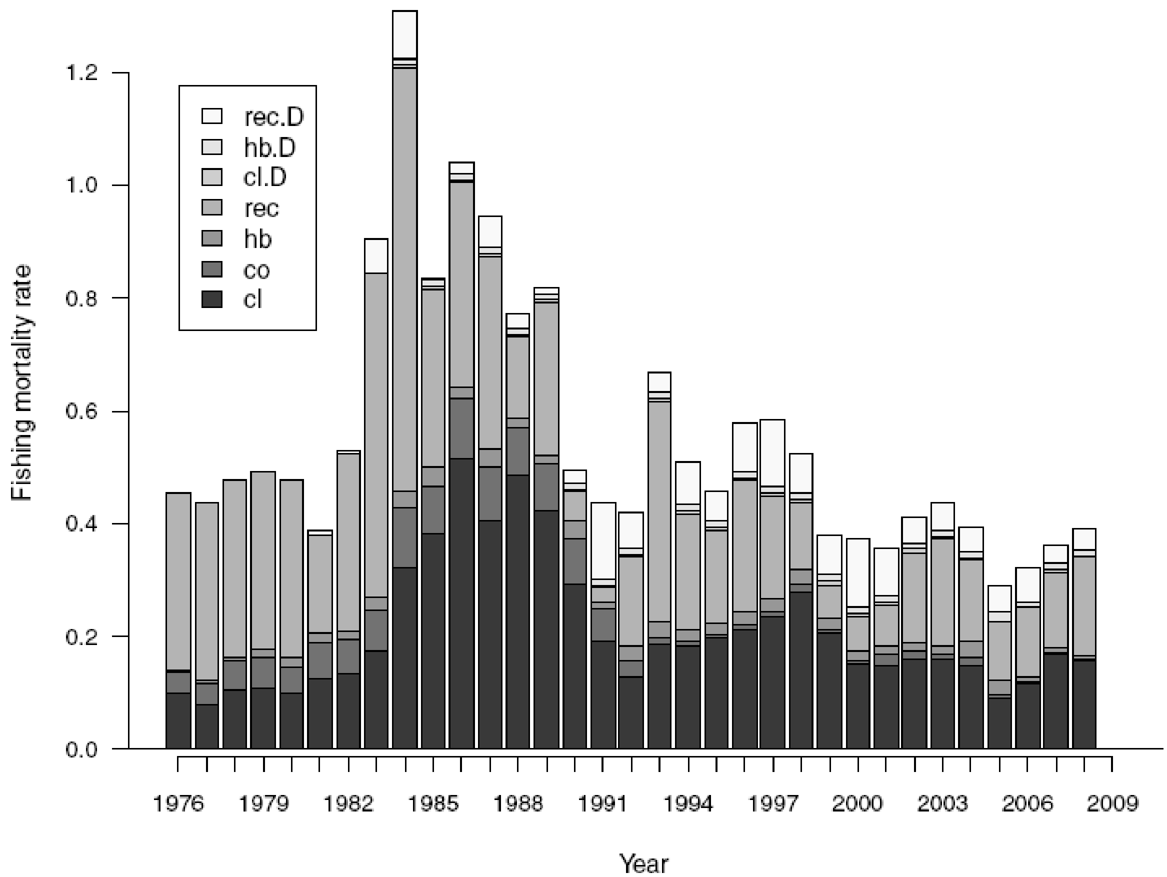


**Figure 3: Fishing Mortality**

*Figure 6.33. Estimated fully selected fishing mortality rate (per year) by fishery. cl refers to commercial lines, co to commercial other, hb to headboat, rec to general recreational, cl.D to commercial discard mortalities, hb.D to headboat discard mortalities, and rec.D to general recreational discard mortalities.*



## Figure 4: Stock Biomass

*Figure 6.25. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates $B_{MSY}$. Bottom panel: Estimated spawning biomass (total mature biomass) at time of peak spawning.*

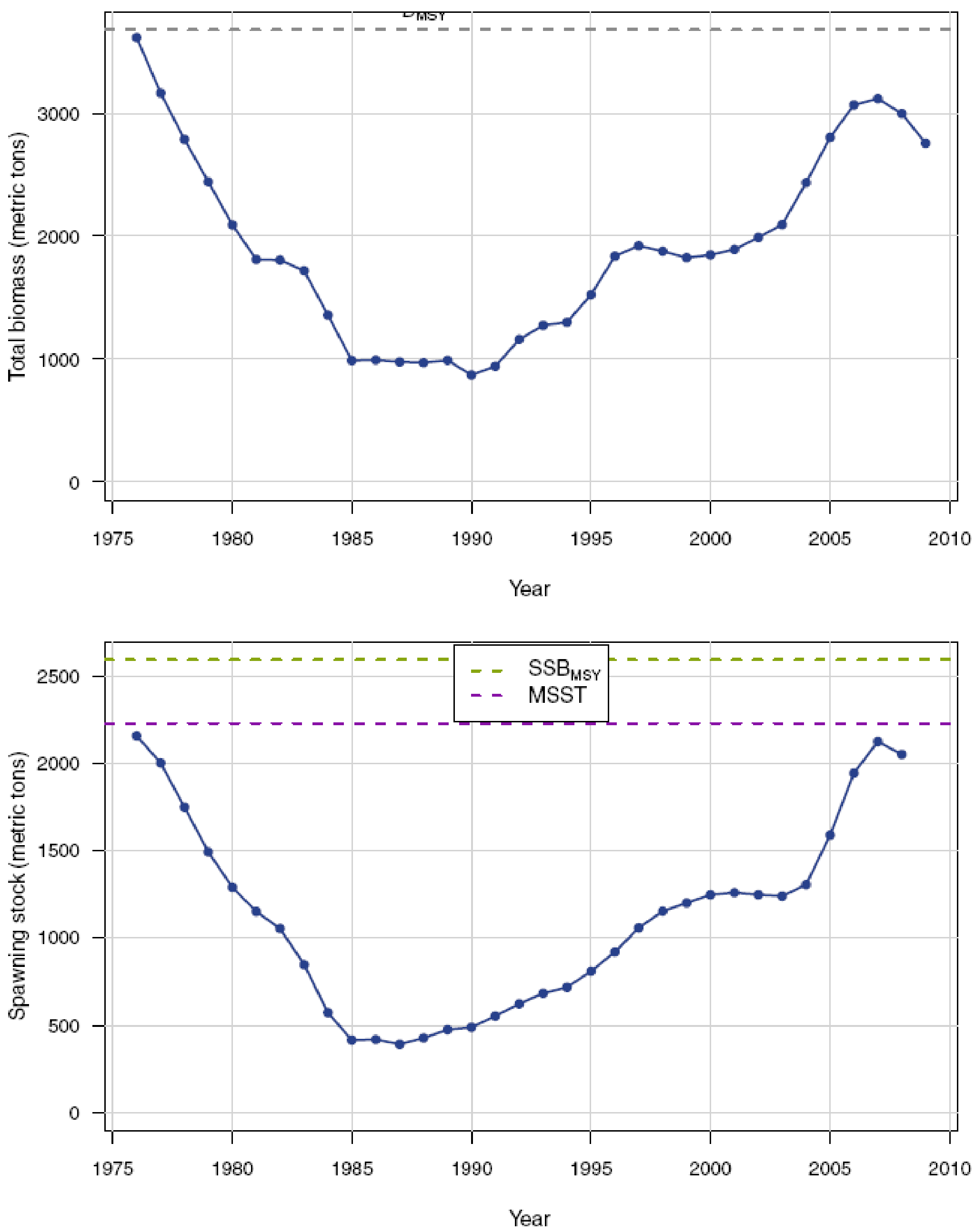
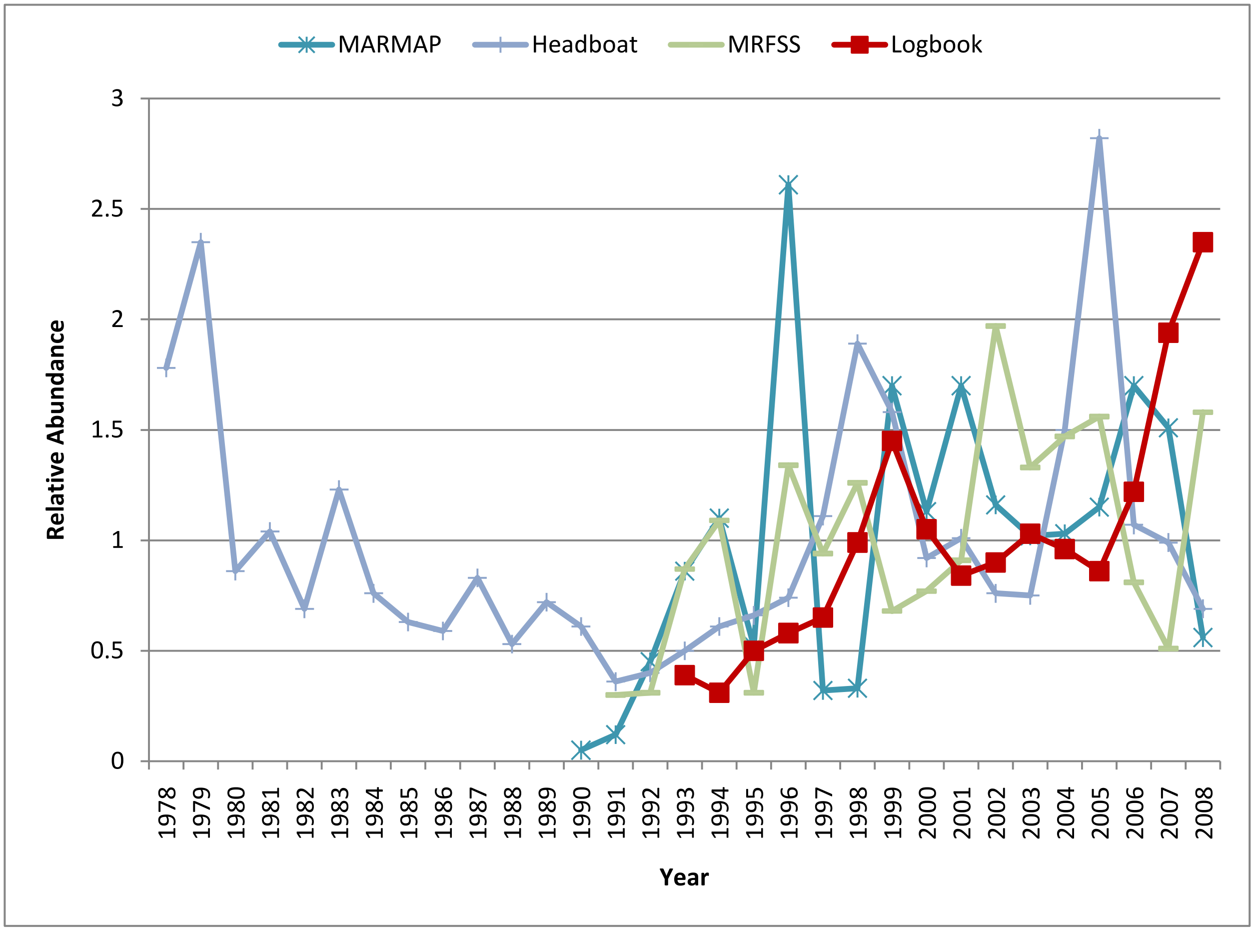


**Figure 5: Abundance Indices**



# Figure 6: Stock-Recruitment

*Figure 6.37. Top panel: Beverton-Holt spawner-recruit curves, with and without lognormal bias correcti*
*Bottom panel: log of recruits (number age-1 fish) per spawner (total mature biomass) as a function of spawne*
*Years on each panel indicate year of recruitment generated from spawning biomass one year prior.*

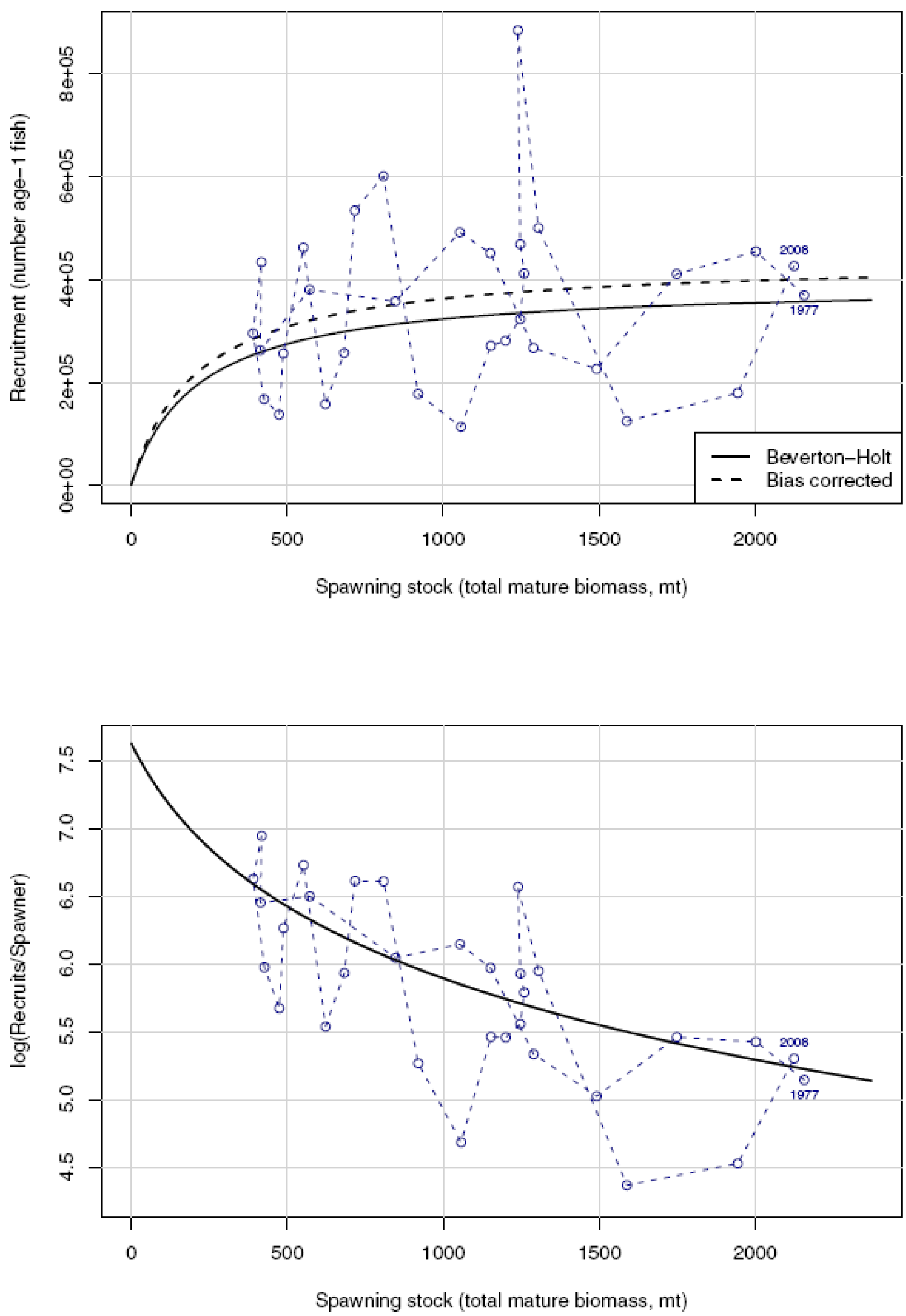
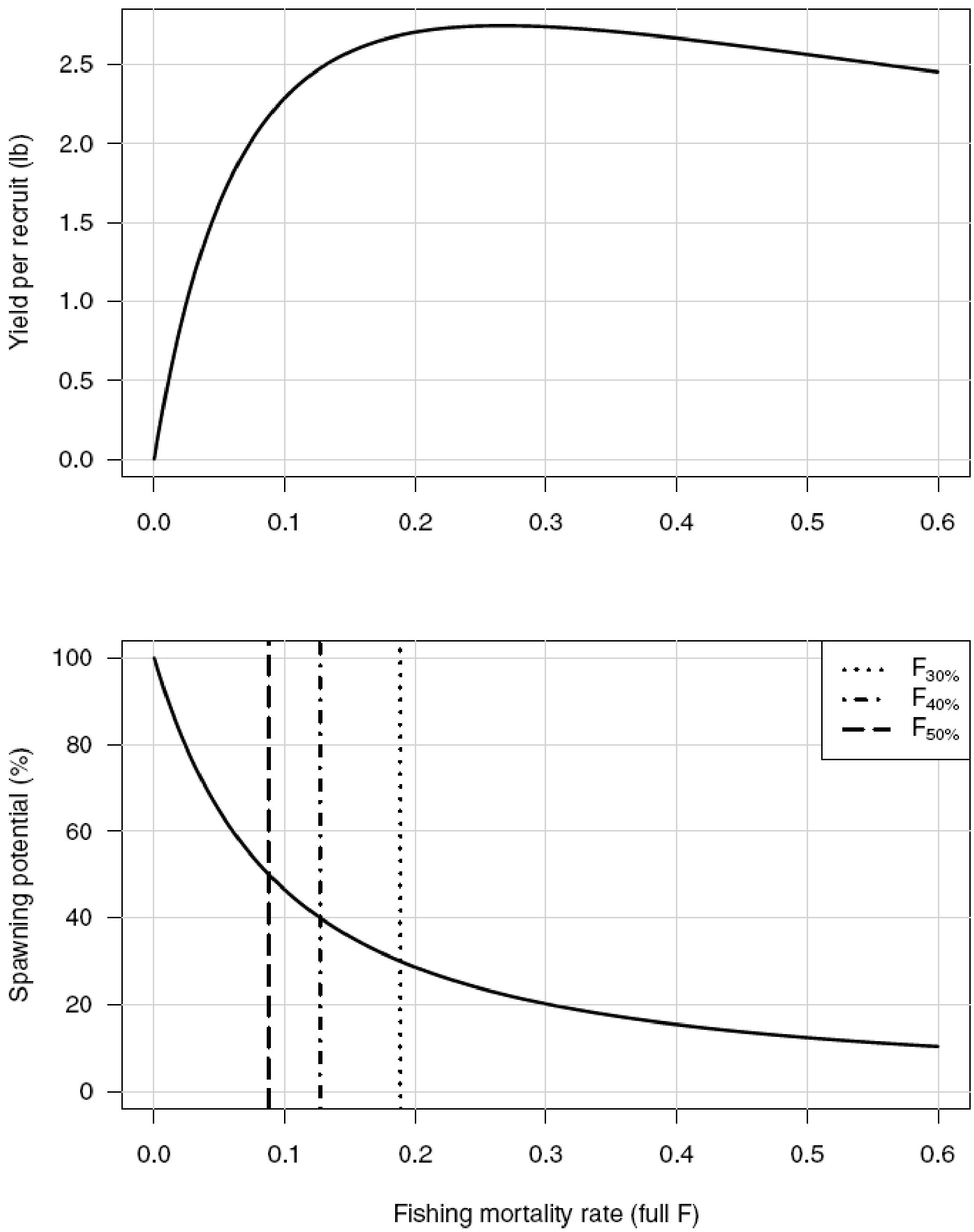


**Figure 7: Yield per Recruit**

*Figure 6.40. Top panel: yield per recruit. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the y% levels provide $F_{y\%}$. Both curves are based on average selectivity from the end of the assessment period.*



## Figure 8: Stock Status and Control Rule

*Figure 6.44. 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). Bottom panel: F relative to $F_{MSY}$.*

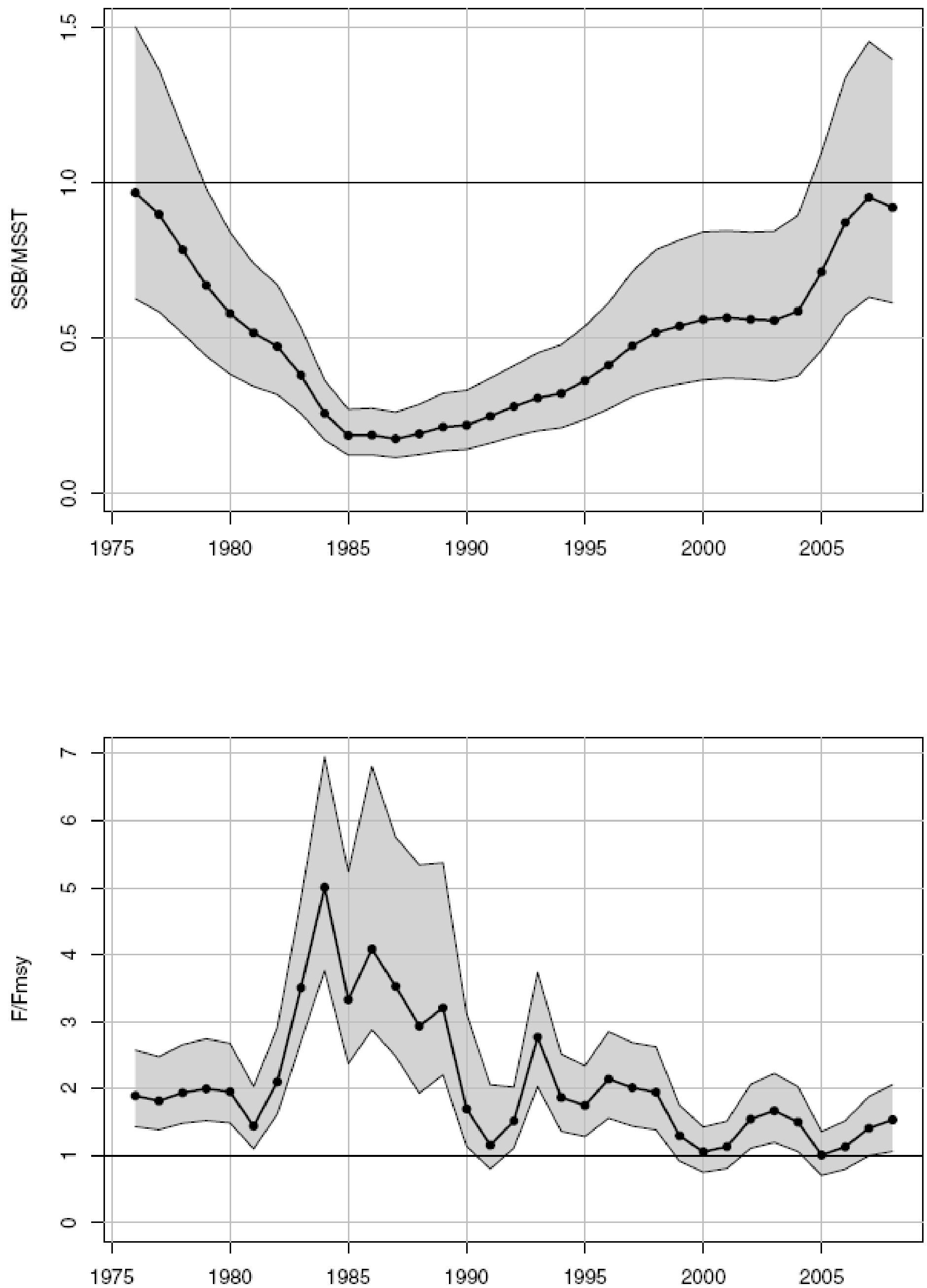
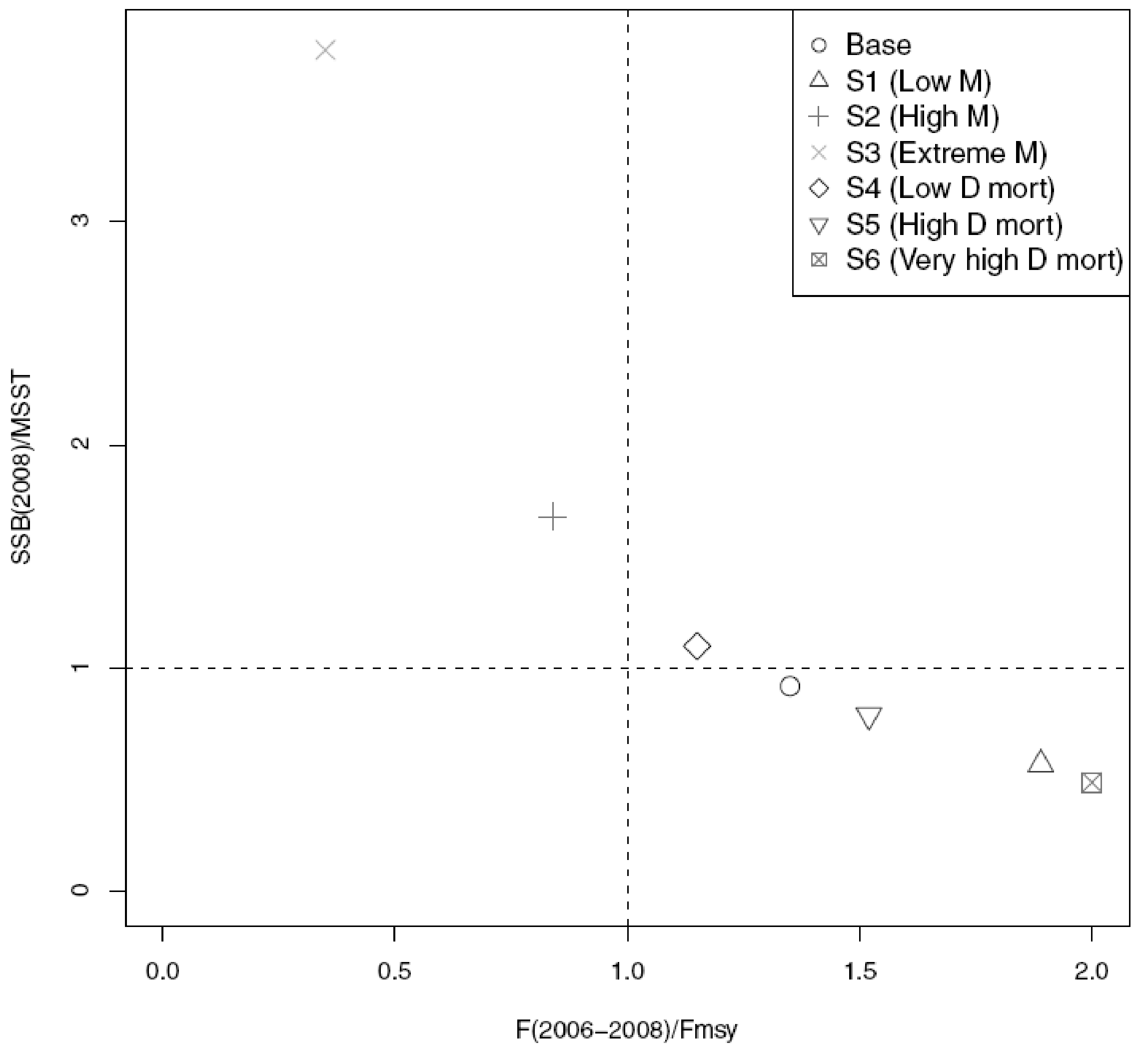


**Figure 8: continued**

*Figure 6.50. Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model.*



# Figure 9: Projections

*Figure 6.51. Projection results under scenario 1—fishing mortality rate fixed at $F = 0$. Curve represents the proportion of projection replicates for which SSB(mid-year) has reached at least $SSB_{MSY} = 2592$ mt.*

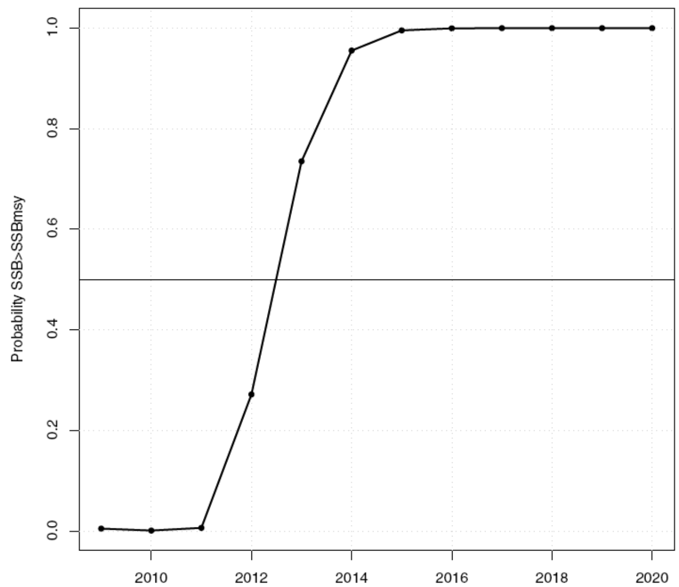



*Figure 6.52. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{current}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.*

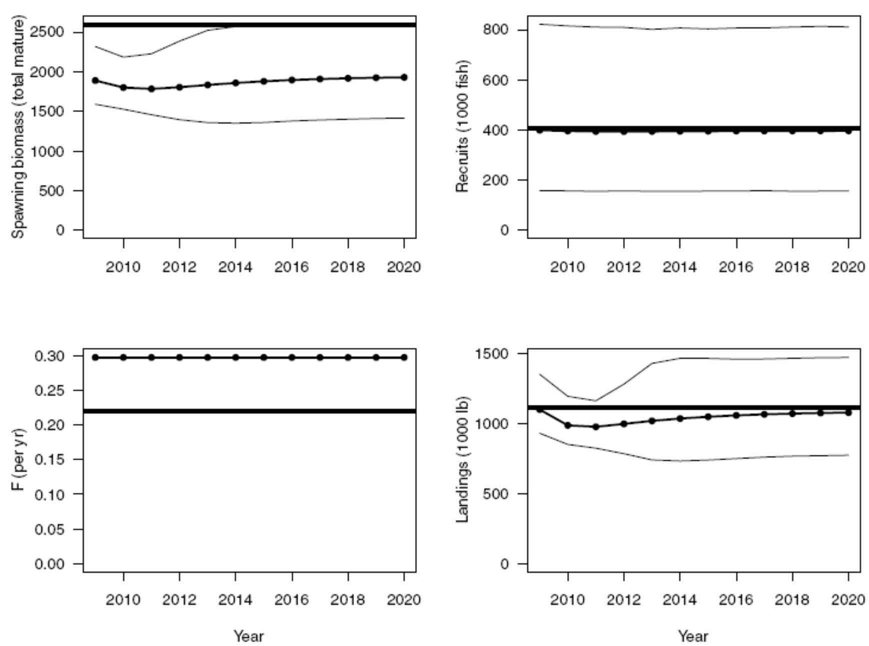


**Figure 9: continued**

*Figure 6.53. Projection results under scenario 3—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and $F = 75\%F_{\text{current}}$ thereafter. 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 mid-year.*

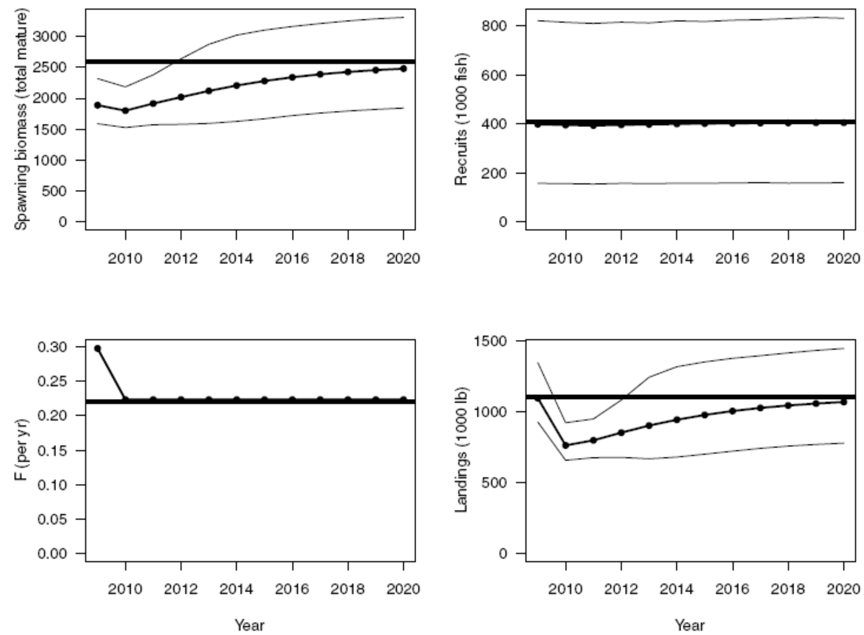



*Figure 6.54. Projection results under scenario 4—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and F 50%$F_{\text{current}}$ thereafter. Expected values represented by dotted solid lines, and uncertainty represented by thi lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark MSY-relate quantities. Spawning stock (SSB) is at mid-year.*

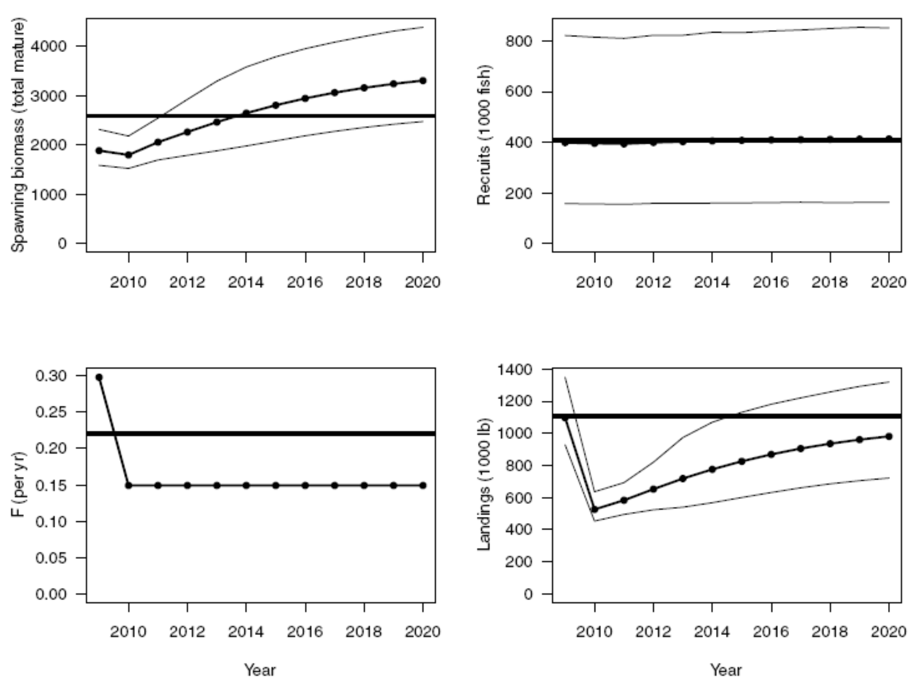


**Figure 9: continued**

*Figure 6.55. Projection results under scenario 5—fishing mortality rate fixed at $F = F_{current}$ in 2009 and F = 25%$F_{current}$ thereafter. Expected values represented by dotted solid lines, and uncertainty represented by thi lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark MSY-relate quantities. Spawning stock (SSB) is at mid-year.*

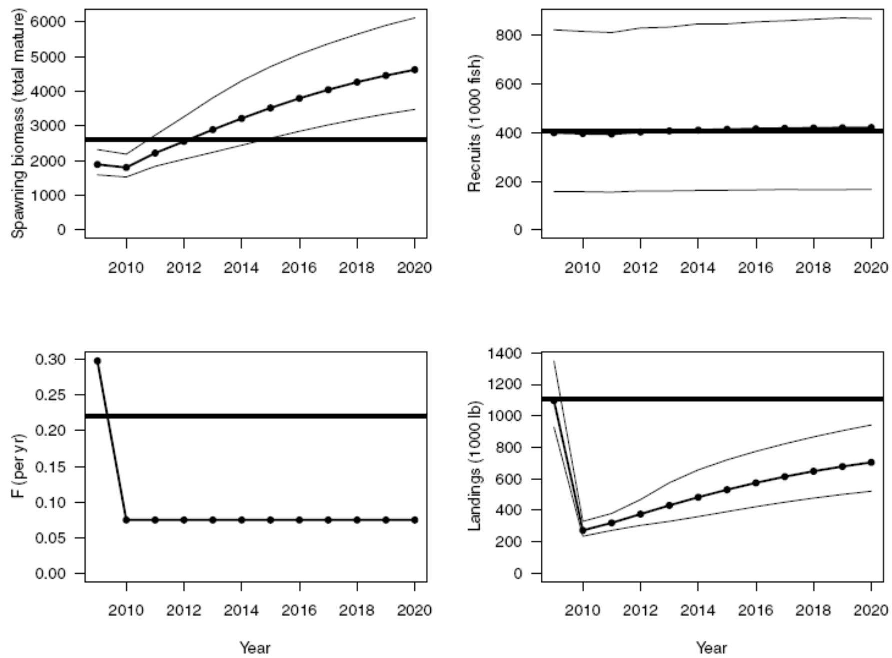



*Figure 6.56. Projection results under scenario 6—fishing mortality rate fixed at F = 65%$F_{MSY}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.*

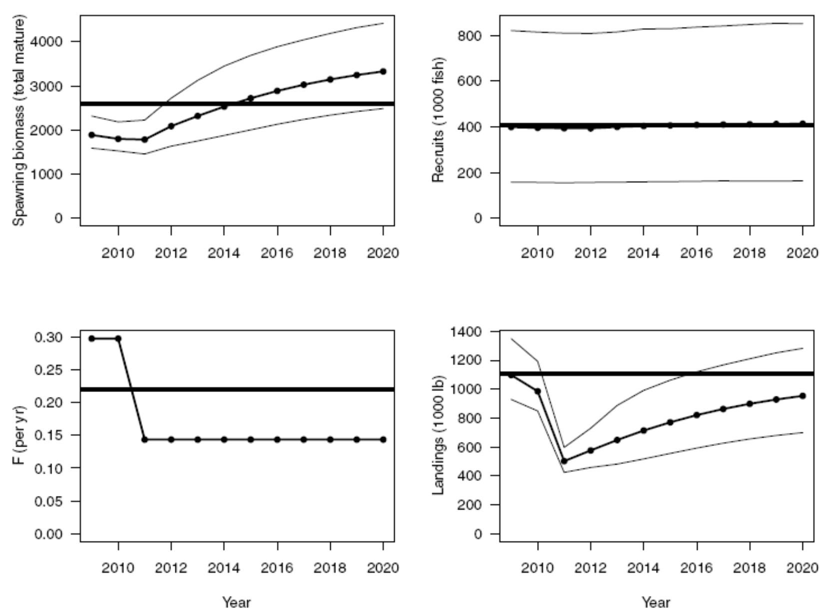


**Figure 9: continued**

*Figure 6.57. Projection results under scenario 7—fishing mortality rate fixed at $F = 75\%F_{MSY}$. 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 mid-year.*

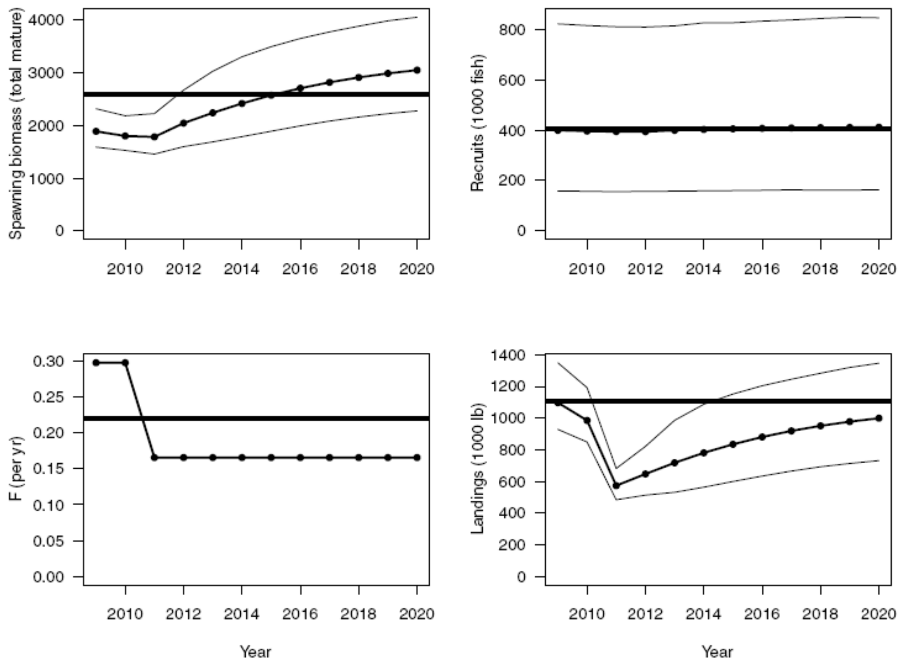
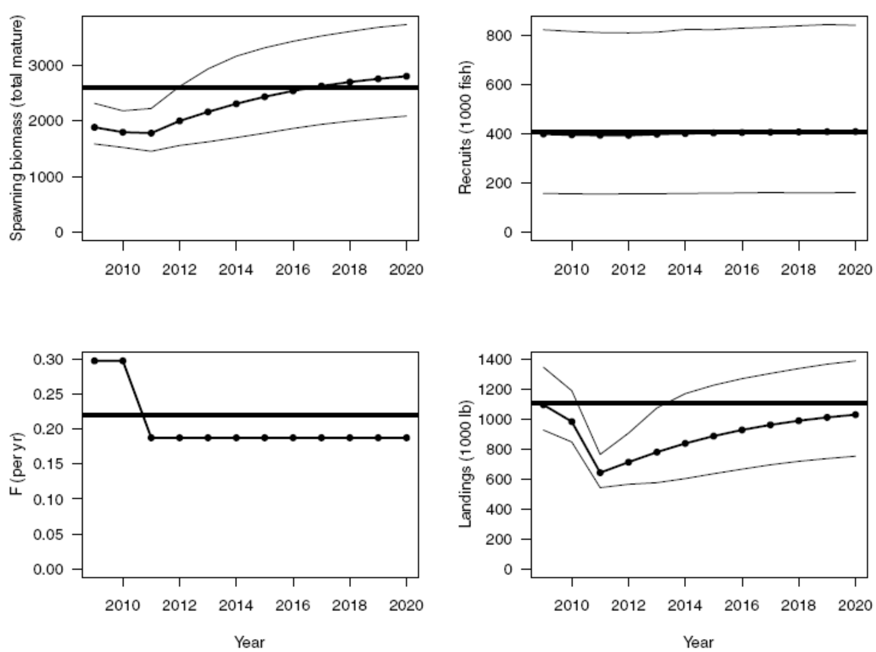



*Figure 6.58. Projection results under scenario 8—fishing mortality rate fixed at $F = 85\%F_{MSY}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.*



# Figure 9: continued

*Figure 6.59. Projection results under scenario 9—fishing mortality rate fixed at $F = F_{MSY}$. 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 mid-year.*

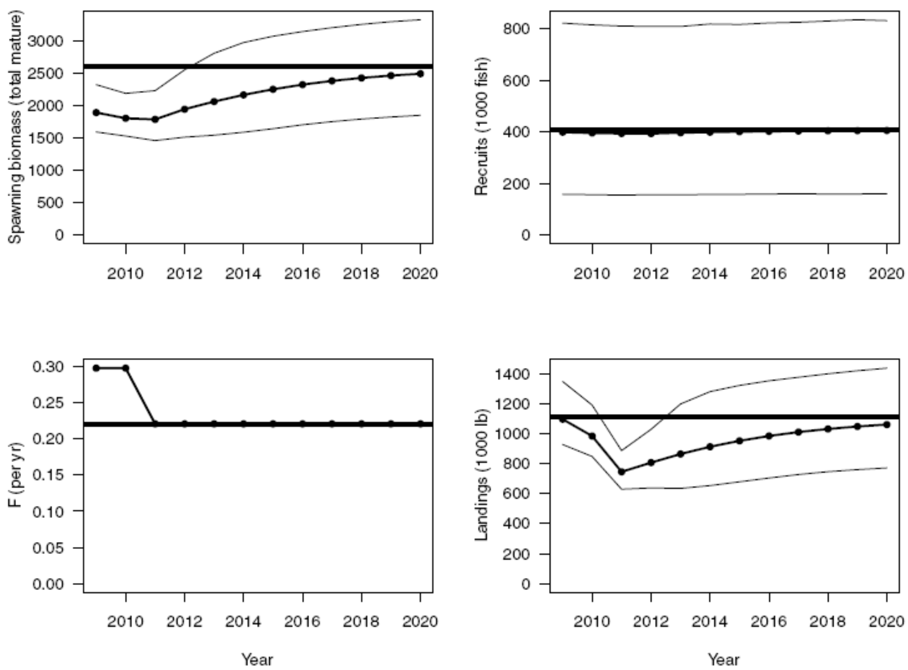



*Figure 6.60. Projection results under scenario 10—fishing mortality rate fixed at $F = F_{rebuild}$, after an initialization period with $F = F_{current}$ in 2009 and 2010. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

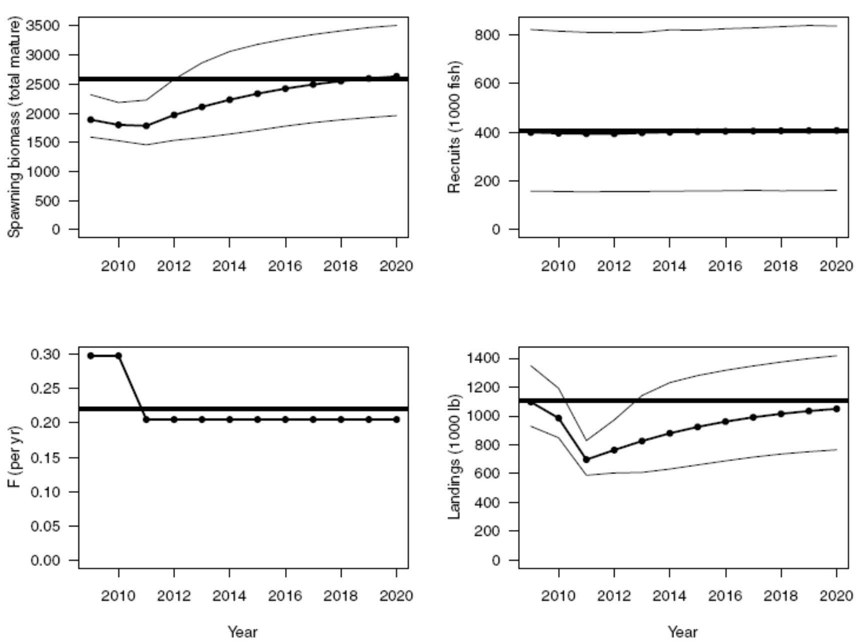


**Figure 9: continued**

*Figure 6.61. Projection results under scenario 11—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, after an initialization period with $F = F_{\text{current}}$ in 2009 and $F = 75\%F_{\text{current}}$ 2010. 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 mid-year.*

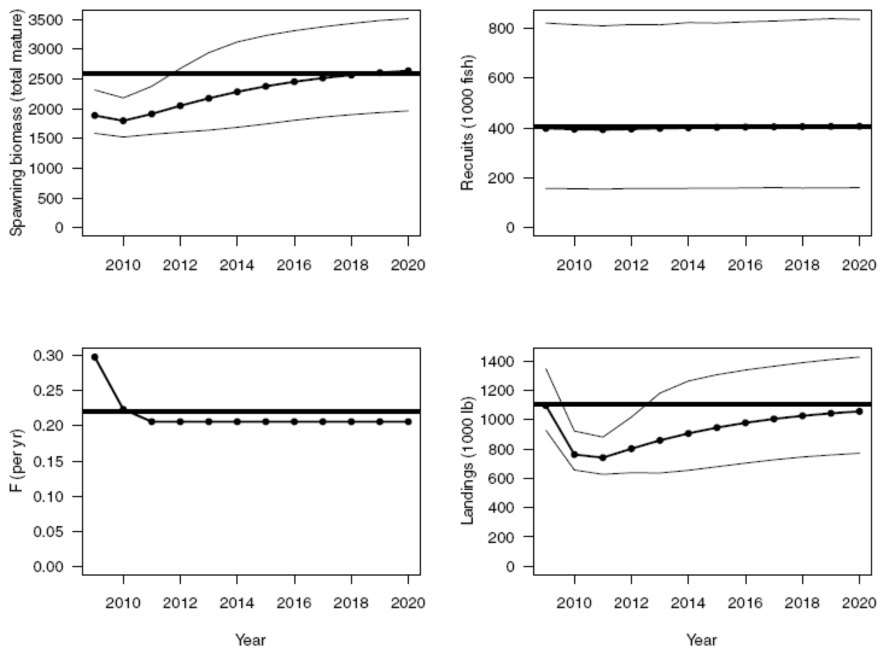



*Figure 6.62. Projection results under scenario 12—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, after an initialization period with $F = F_{\text{current}}$ in 2009 and $F = 50\%F_{\text{current}}$ 2010. Expected values represented by dotted solid lines and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections Horizontal lines mark MSY-related quantities. Spawning stock (SSB) is at mid-year.*

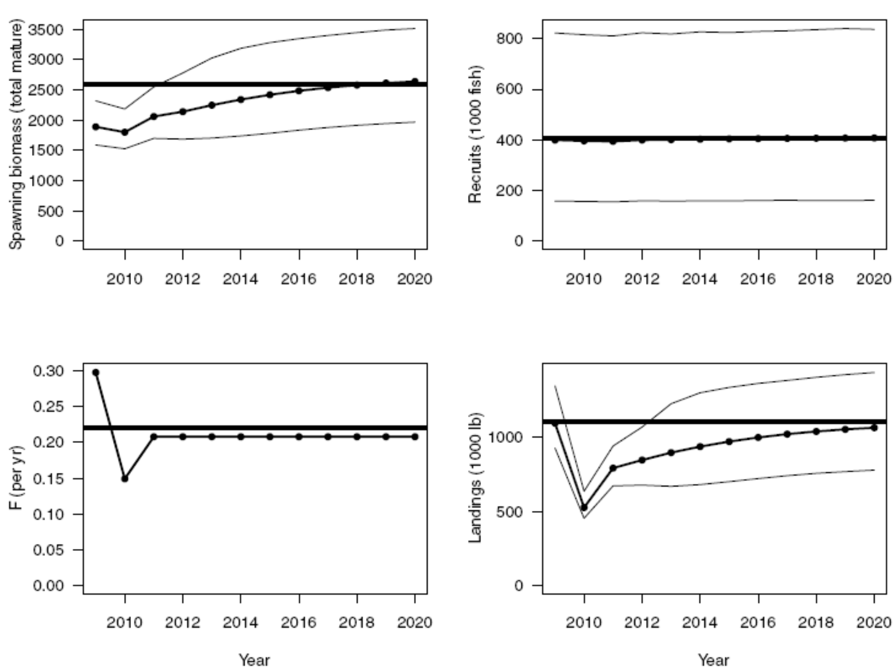
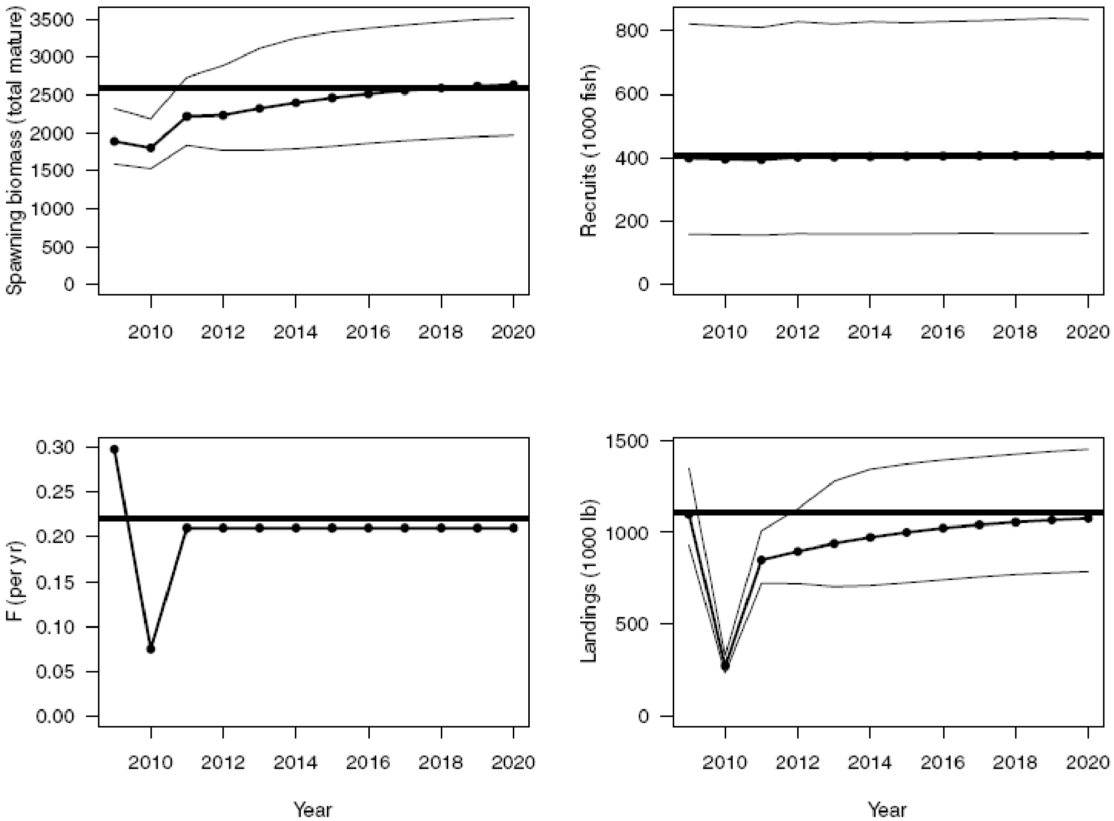


**Figure 9: continued**

*Figure 6.63. Projection results under scenario 13—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, after an initialization period with $F = F_{\text{current}}$ in 2009 and $F = 25\% F_{\text{current}}$ 2010. 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 mid-year.*



# SEDAR

## Southeast Data, Assessment, and Review

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## SEDAR 19

# South Atlantic Red Grouper

## SECTION II: Data Workshop Report

**September 2009**


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

## Table of Contents

# 1. INTRODUCTION

## *1.1. WORKSHOP TIME AND PLACE*

The SEDAR 19 Data Workshop was held June 22 - 26, 2009 in Charleston, South Carolina.

## *1.2. TERMS OF REFERENCE*

1. Characterize stock structure and develop a unit stock definition. Provide maps of species and stock distribution.

2. Tabulate available life history information (e.g., age, growth, natural mortality, reproductive characteristics); 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 all available and relevant fishery dependent and independent data sources. Document all programs evaluated, addressing program objectives, methods, coverage, sampling intensity, and other relevant characteristics. Provide maps of survey coverage. 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 and reliable for use in assessment modeling.

4. Characterize commercial and recreational catch, including both landings and discard, in pounds and number. Evaluate the adequacy of available data for accurately characterizing harvest and discard by species and fishery sector. Provide length and age distributions if feasible. Provide maps of fishery effort and harvest.

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

6. 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 within 6 weeks prior to the Assessment Workshop.

7. Prepare the Data Workshop report providing complete documentation of workshop actions and decisions (Section II. of the SEDAR assessment report). Develop a list of tasks to be completed following the workshop.

## 1.3. LIST OF PARTICIPANTS

***Workshop Panel***

Anne Lange ........ SAFMC SSC
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Bill Tucker ........ GMFMC AP
Bill Lindberg ........ GMFMC SSC
Bob Speath ........ GMFMC AP
Byron White ........ SC DNR
Chip Collier ........ SAFMC SSC/NC DMF
Chris Hayes ........ ACCSP
Daniel Carr ........ NMFS/SEFSC
Dave Gloeckner ........ NMFS/SEFSC
David Player ........ SC DNR
David Wyanski ........ SC DNR
Dennis O'Hern ........ GMFMC AP
Don DeMaria ........ SAFMC AP
Douglas Gregory ........ GMFMC SSC
Jack McGovern ........ SERO
Jennifer Potts ........ NMFS/SEFSC
Jessica Stephen ........ SC DNR
Joe O'Hop ........ FWC FWRI
Julie DeFlippi ........ ACCSP
Ken Brennan ........ NMFS/SEFSC
Kevin McCarthy ........ NMFS/SEFSC
Kyle Shertzer ........ NMFS/SEFSC
Marcel Reichert ........ SAFMC SSC/ SC DNR
Paul Conn ........ NMFS/SEFSC
Richard Stiglitz ........ SAFMC AP
Rob Cheshire ........ NMFS/SEFSC
Robert Muller ........ FWC FWRI
Russell Hudson ........ DSF
Stephanie McInerny ........ NC DMF
Steve Brown ........ FWC FWRI
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Walter Ingram ........ NMFS/SEFSC
Walter Keithly ........ GMFMC SSC

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George Geiger ........ SAFMC
Mark Robison ........ SAFMC/ FL FWRI
Kay Williams ........ GMFMC

***Observers***

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Chad Hanson.......................................................................................................................PEW
Chris Robbins........................................................................................... Ocean Conservancy
David Hoke .......................................................................................................................NOAA
Jerry Ault ............................................................................................... University of Miami
Mark Millikin.............................................................................................................. NMFS/HQ
Richard Hall .......................................................................................................................NOAA

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John Carmichael.........................................................................................SAFMC
Julie Neer .................................................................................................. SEDAR
Rachael Lindsay.......................................................................................... SEDAR
Rick DeVictor .............................................................................................SAFMC
Tyree Davis...................................................................................NMFS Miami

### *1.4. LIST OF DATA WORKSHOP WORKING AND REFERENCE PAPERS*

| Document # | Title | Authors | Working Group |
|---|---|---|---|
| **Documents Prepared for the Data Workshop** | | | |
| SEDAR19-DW-01 | Black grouper, *Mycteroperca bonaci*, standardized catch rates from the Marine Recreational Fisheries Statistics Survey in south Florida,1991-2008 | Robert G. Muller | Indices |
| SEDAR19-DW-02 | A fishery independent index for black grouper, *Mycteroperca bonaci*, from Florida Fish and Wildlife Research Institute's visual survey in the Florida Keys, 1999-2007 | Robert G. Muller and Alejandro Acosta | Indices |
| SEDAR19-DW-03 | Construction of a headboat index for south Atlantic red grouper | Paul Conn | Indices |

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|---|---|---|---|
| SEDAR19-DW-04 | Construction of a headboat index for black grouper | Paul Conn | Indices |
| SEDAR19-DW-05 | Evaluation of the 1960, 1965, and 1970 U.S. Fish and Wildlife Service salt-water angling survey data for use in the stock assessment of red grouper ( Southeast US Atlantic) and black grouper ( Southeast US Atlantic and Gulf of Mexico) | Rob Cheshire and Joe O'Hop | Recreational Statistics |
| SEDAR19-DW-06 | Steepness of spawner-recruit relationships in reef fishes of the southeastern U.S.: A prior distribution for possible use in stock assessment | Sustainable Fisheries Branch | Life History |
| SEDAR19-DW-07 | South Atlantic Region Recreational Fishery Catches of Red and Black Grouper, 1981 - 2008 and Gulf of Mexico Landings of Black Grouper. | Tom Sminkey | Recreational Statistics |
| SEDAR19-DW-08 | Length Frequencies and Condition of Released Red Grouper and Black Grouper from At-Sea Headboat Observer Surveys in the Gulf of Mexico and Atlantic Ocean, 2005 to 2007. | Beverly Sauls | Recreational Statistics |
| SEDAR19-DW-09 | Age, growth, and maturity of black grouper (*Mycteroperca bonaci*) – Crabtree and Bullock (1998) revisited | Joe O'hop and Rick Beaver | Life History |
| SEDAR19-DW-10 | Ault-Smith Notes on Reef-fish Visual Census (RVC) Population Statistics Estimation for Black Grouper (*Mycteroperca bonaci*) and Red Grouper (*Epinephelus mori*) in the Florida Keys and Dry Tortugas Regions | Jerald S. Ault and Steven G. Smith | Indices/Life History |
| SEDAR19-DW-11 | Patterns of annual abundance of black and red grouper in the Florida Keys and Dry Tortugas based on | G. Walter Ingram, Jr. and Douglas E. Harper | Indices |

| | | | |
|---|---|---|---|
| | reef fish visual census conducted by NOAA NMFS. | | |
| SEDAR19-DW-12 | A fishery independent index for red grouper, *Epinephelus morio*, from Florida Fish and Wildlife Research Institute's visual survey in the Florida Keys, 1999-2007 | Robert G. Muller and Alejandro Acosta | Indices |
| SEDAR19-DW-13 | United States Commercial Vertical Line and Longline Vessel Standardized Catch Rates of Black Grouper the Gulf of Mexico and South Atlantic, 1993-2008 | Kevin McCarthy | Indices |
| SEDAR19-DW-14 | United States Commercial Vertical Line Vessel Standardized Catch Rates of Red Grouper in the US South Atlantic, 1993-2008 | Kevin McCarthy | Indices |
| SEDAR19-DW-15 | Calculated discards of black grouper from commercial vertical line and longline fishing vessels in the Gulf of Mexico and US South Atlantic | Kevin McCarthy | Commercial Statistics |
| SEDAR19-DW-16 | Calculated discards of red grouper from commercial vertical line fishing vessels in the US South Atlantic | Kevin McCarthy | Commercial Statistics |
| SEDAR19-DW-17 | Patterns of annual abundance of red grouper observed in chevron traps set during the MARMAP Survey (1990 – 2008) in the U.S. South Atlantic. | G. Walter Ingram, Jr. and Jessica Stephen | Indices |
| SEDAR19-DW-18 | Standardized catch rates of Atlantic red grouper (*Epinephelus morio*) from the North Carolina Commercial Fisheries Trip Ticket Program. | Walter Ingram, Stephanie McInerny, and Alan Bianchi | Indices |

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|---|---|---|---|
| SEDAR19-DW-19 | Red grouper standardized catch rates from the Marine Recreational Fisheries Statistics Survey for the southeastern U.S. Atlantic Ocean, 1991-2008 | Chris Hayes and Robert G. Muller | Indices |
| SEDAR19-DW-20 | Standardized catch rates of black grouper. *Mycteroperca bonaci*, and red grouper, *Epinephelus morio*, from Florida's commercial trip tickets, 1991-2008 | Robert G. Muller | Indices |
| SEDAR19-DW-21 | Estimated Landings and Discards of Red Grouper in the South Atlantic and Black Grouper in the South Atlantic and Gulf of Mexico Headboat Fishery, 2004-2008. | Ken Brennan | Recreational Statistics |
| | | | |

| **Reference Documents** | | |
|---|---|---|
| SEDAR19-RD01 | Reproduction in the protogynous black grouper (*Mycteroperca bonaci* (Poey) from the southern Gulf of Mexico | Thierry Brulé, Ximena Renán, Teresa Colás-Marrufo, Yazmin Hauyon, and Armin N. Tuz-Sulub |
| SEDAR19-RD02 | Life history of red grouper (*Epinephelus morio*) off the coasts of North Carolina and South Carolina | Julian M. Burgos, George R. Sedberry, David M. Wyanski, and Patrick J. Harris |
| SEDAR19-RD03 | Trends in catch data and estimated static SPR values for fifteen species of reef fish landed along the southeastern United States | Jennifer C. Potts and Ken Brennan |
| SEDAR19-RD04 | Density, species and size distribution of groupers (Serranidae) in three habitats at Elbow Reef, Florida Keys | Robert Sluka, Mark Chiappone, Kathleen M. Sullivan, Thomas A. Potts, Jose M. Levy, Emily F. Schmitt and Geoff Meester |
| SEDAR19-RD05 | Population genetic analysis of red grouper, *Epinephelus morio*, and | M. S. Zatcoff, A. O. Ball and G. R. Sedberry |

| | | |
|---|---|---|
| | scamp, *Mycteroperca phenax*, from the southeastern U.S. Atlantic and Gulf of Mexico | |
| SEDAR19-RD06 | The 1960 Salt-Water Angling Survey, USFWS Circular 153 | J. R. Clark |
| SEDAR19-RD07 | The 1965 Salt-Water Angling Survey, USFWS Resource Publication 67 | D. G. Deuel and J. R. Clark |
| SEDAR19-RD08 | 1970 Salt-Water Angling Survey, NMFS Current Fisheries Statistics Number 6200 | D. G. Deuel |
| SEDAR19-RD09 | Age, growth, and reproduction of black grouper, *Mycteroperca bonaci*, in Florida waters | Roy E. Crabtree and Lewis H. Bullock |
| SEDAR19-RD10 | Age and growth of the warsaw grouper and black grouper from the southeast region of the United States | Charles S. Manooch, III and Diane L. Mason |
| SEDAR19-RD11 | The influence of spear fishing on species composition and size of groupers on patch reefs in the upper Florida Keys | Robert D. Sulka and Kathleen M. Sullivan |
| SEDAR19-RD12 | Aspects of fishing and reproduction of the black grouper *Mycteroperca bonaci* (Poey, 1860) (Serranidae: Epinephelinae) in the Northeastern Brazil | Simone Ferreira Teixeira, Beatrice Padovani Ferreira and Isaíras Pereira Padovan** |
| SEDAR19-RD13 | Diet composition of juvenile black grouper (*Mycteroperca bonaci)* from coastal nursery areas of the Yucatan Peninsula, Mexico | Thierry Brulé, Enrique Puerto-Novelo, Esperanza Pérez-Díaz, and Ximena Renán-Galindo |
| SEDAR19-RD14 | Life history of the red grouper *(Epinephelus morio)* off the North Carolina and South Carolina coast | Julian M. Burgos |
| SEDAR19-RD15 | Mean Size at Age: An Evaluation of Sampling Strategies with Simulated | C. Phillip Goodyear |

| | | |
|---|---|---|
| | Red Grouper Data | |
| SEDAR19-RD16 | Evaluation of average length as an estimator of exploitation status for the Florida coral reef fish community. | Ault, J.S., S.G. Smith, and J.A. Bohnsack |
| SEDAR19-RD17 | A retrospective (1979-1996) multispecies assessment of coral reef fish stocks in the Florida Keys | Ault, J.S., J.A. Bohnsack, and G.A. Meester |
| SEDAR19-RD18 | Building sustainable fisheries in Florida's coral reef ecosystem: positive signs in the Dry Tortugas. | Ault, J.S., S.G. Smith, J.A. Bohnsack, J. Luo, D.E. Harper, and D.B. McClellan |
| SEDAR19-RD19 | Are the coral reef finfish fisheries of south Florida sustainable? | Ault, J.S., S.G. Smith and J.T. Tilmant |
| SEDAR19-RD20 | Fishery management analyses for reef fish in Biscayne National Park: bag & size limits | Ault, J.S., S.G. Smith, and J.T. Tilmant |
| SEDAR19-RD21 | Site characterization for Biscayne National Park: assessment of fisheries resources and habitats | Ault, J.S., S.G. Smith, G.A. Meester, J. Luo, and J.A. Bohnsack |
| SEDAR19-RD22 | Baseline Multispecies Coral Reef Fish Stock Assessment for the Dry Tortugas | Jerald S. Ault, Steven G. Smith, Geoffrey A. Meester, Jiangang Luo, James A. Bohnsack, and Steven L. Miller |
| SEDAR19-RD23 | Movement of yellowtail snapper (*Ocyurus chrysurus* Block 1790) and black grouper (*Mycteroperca bonaci* Poey 1860) in the northern Florida Keys National Marine Sanctuary as determined by acoustic telemetry | James Lindholm, Les Kaufman, Steven Miller, Adam Wagschal and Melinda Newville |
| SEDAR19-RD24 | Coral reef fish response to FKNMS management zones: the first ten years (1997-2007) | James A. Bohnsack, Douglas E. Harper, David B. McClellan, and G. Todd Kellison and Jerald S. Ault, Steven G. Smith, Natalia Zurcher |
| SEDAR19-RD25 | Reef fish movements and marine designs | Nick Farmer |
| SEDAR19-RD26 | A Cooperative Multi-agency Reef Fish Monitoring Protocol for the Florida Keys Coral Reef Ecosystem | Marilyn E. Brandt, Natalia Zurcher, Alejandro Acosta, Jerald S. Ault, James A. Bohnsack, Michael W. Feeley, Doug E. Harper, John Hunt, Todd Kellison, David B. McClellan, |

| | | |
|---|---|---|
| | | Matt E. Patterson, Steven G. Smith1 |
| SEDAR19-RD27 | The Natural Mortality Rate of Gag Grouper: A Review of Estimators for Data-Limited Fisheries | Trevor J. Kenchington |
| SEDAR19-RD28 | Population Assessment of the Scamp, *Mycteroperca phenax,* from the Southeastern United States | Charles S.Manooch, III, Jennifer C. Potts, Michael L. Burton, and Patrick J. Harris |
| SEDAR19-RD29 | A Review for Estimating Natural Mortality in Fish Populations | Kate. I. Siegfried & Bruno Sansó |

## 2. LIFE HISTORY

### *2.1. OVERVIEW*

#### 2.1.1. Group membership

| | |
|---|---|
| Marcel Reichert | SC-DNR-MARMAP, WG leader and editor |
| Jennifer Potts | SEFSC Beaufort, Data compiler red grouper |
| Byron White | SC-DNR-MARMAP, Data provider |
| Dave Wyanski | SC-DNR-MARMAP, Data provider |
| Joe O'Hop | FWRI, Data compiler and editor for black grouper |
| Doug Gregory | FL SeaGrant, GMFMC SSC |
| Bill Lindberg | University of Florida, GMFMC SSC |
| Carrie Simmons | GOM Council Staff lead |
| Daniel Carr | SEFSC Beaufort – Data provider |

### *2.2. STOCK DEFINTION AND DESCRIPTION*

The red grouper, *Epinephelus morio*, is a protogynous serranid that is associated with reef habitat, especially the adults, in the Western Atlantic from Massachusetts through the Gulf of Mexico and south to Brazil (Brule and Deniel 1996; Johnson et al. 1998). Red grouper are reported to occur at depths of 24-120 m (Johnson et al. 1998).

#### 2.2.1 Stock structure/definition

The red grouper fishery has been managed in the US as separate Atlantic and Gulf of Mexico stock units with the boundary being U.S. Highway 1 in the Florida Keys. Lombardi-Carlson et al. (2006) found significant differences in size and age structure and in growth rates of red grouper north and south of 28°N latitude in the Gulf of Mexico, supporting a hypothesis that red grouper may have some degree of subpopulation structure. Based on landings data from 1983 through 1995, McGovern et al. (2002) indicated a possible disjunct distribution of red grouper off the Atlantic coast. Landings from more recent years are consistent with these findings (see information of other Data Workshop Working Groups in this report)

The SEDAR12 Life History Data Workshop (LH DW) for the Gulf of Mexico (GOM) reviewed the available stock structure information and concluded there is no evidence that suggests different stock management units need to be considered at this time. The SEDAR19 LH DW concurs with this report and recommends that the status quo be maintained until further studies suggest otherwise.

### 2.2.2. Population genetics

The SEDAR12 LH DW (GOM) reviewed available genetic studies based on mitochondrial DNA (Richardson and Gold 1997) and microsatellite markers (Zatkoff et al. 2004) and found that there was no evidence of stock structure or reproductive isolation among southeastern U.S. Atlantic, northeastern Gulf of Mexico, and southwestern Mexico Gulf of Mexico (Yucatan peninsula) collections of red grouper. Red grouper may have a more complex stock structure, but a longer timescale of generations may be needed to detect genetic differences (Zatcoff et al. 2004). Since the GOM stock assessment, no new published information has become available and the DW recommends that until more detailed information becomes available that suggests otherwise, the red grouper of the S. Atlantic coast of the US be considered one stock.

### 2.2.3. Tagging

No published information is available on tagging of Atlantic red grouper from the US South Atlantic. Tagging information from the Florida Keys (Farmer 2009) and GOM suggest that adult red grouper only move short distances, which could contribute to future stock separation given enough time. The DW of the GOM assessment concluded that it is possible that further research will reveal a more complex subpopulation structure that may not be genetically distinct but are functionally independent units (e.g. red snapper, Fischer et al. 2004).

### 2.2.4. Larval transport and connectivity

The SEDAR 12 DW was not aware of any larval duration estimates specifically for red grouper, and no new information has become available. However, other grouper species have been estimated to have durations of 31-66 days (Lindeman et al. 2000). There are some indications that red grouper, or at least a small part of the population, may have an estuarine dependent component since larval and early juvenile red grouper have been caught in traps in creeks in SC and NC (Ross and Moser 1995, Paulette Mikell, SCDNR, pers.comm.: an ongoing study of gag grouper ingress in the region).

### 2.2.5. Distribution

The red grouper occurs in the western Atlantic from Massachusetts to Rio de Janeiro, Brazil, the Gulf of Mexico and Brazil (Figure 2.14.1 A & B). McGovern et al. (2002) indicated a disjunct distribution of red grouper off the Atlantic coast. Red grouper are commonly caught off NC, northern SC and southern FL but are rare from southern SC to northern FL. They reported that from 1983 through 1995, landings (NC to eastern FL) of grouper increased reaching a peak of 207,000 lbs (Figure 1 in McGovern et al. 2002). Eastern Florida landings dominated the catch through the middle 1980's (Figure 2 in McGovern et al. 2002) when a decline occurred, concurrent with a tremendous increase in North Carolina red grouper landings. During 1986-1995, 45% of the red grouper from the southeastern United States were landed in east Florida and 53% were landed in North Carolina. Red grouper are rarely landed in Georgia or South Carolina (Figure 2 in McGovern et al. 2002).

### 2.2.6. Identification issues

There are no significant identification issues with red grouper and there are no other common names regularly used for red grouper in the region that may complicate data analysis. The LH WG recommended that no adjustments of the data are necessary to correct for possible misidentifications.

### 2.3. NATURAL MORTALITY

The LH WG Natural mortality for red grouper was evaluated using the following methods: Alverson & Carney (1975, as presented in Quinn & Deriso (1999), Beverton (1959), Hoenig (for fish, 1983), Pauly (as presented in Quinn & Deriso, 1999), Ralston (1987), Lorenzen (1992), Jensen (1996), and the "Rule of thumb". The formulas are listed in table 2.13.3A and the estimated M values are provided in Table 2.13.3B.

Since the estimates for Von Bertalanffy parameters K and $L_{inf}$ did not vary much (see Table 2.13.2), the variability in the M estimates that were based on these K and $L_{inf}$ would not vary much either. Considering the size of the age data set, the LH WG recommends using a maximum age ($T_{max}$) of 26 years (see section 2.5.3). For the Beverton estimate of M, the range of the 95% confidence interval for the age at 50% maturity was 2.1-3.2 years. Using a K value of 0.211 resulted in rather high M values between 0.66 to 1.14. We also estimated M based on the Pauly method using 20.9°C (average bottom temperature in the region based on MARMAP data). Estimates of M using this method for 15°C, 25°C, and 30°C are provided in table 2.13.3.B to investigate the effect of the temperature choice on M estimates. Natural mortality estimates using models based on growth and reproductive parameters were highly variable, ranging from 0.09 to 0.78. As was described for the Atlantic red snapper (SEDAR15), among other species, low natural mortality estimates (M = 0.08-0.09) for Atlantic red grouper using the Alverson and Carney (1975) method, and relatively high estimates (M = 0.67-1.14) from the Beverton (1992) equation may be due to the relatively early maturation (2.8 yrs) of red grouper in spite of a relatively long potential life span of 25 years of more. The LH WG concluded that the use of these methods was not appropriate for red grouper.

The DW recommended to use Lorenzen age-specific model for estimates of natural mortality for Ages 1+, as was done in the SEDAR12 for the GOM red grouper assessment. This method allows for the incorporation of age varying natural mortality while constraining the estimates using the biological input of maximum age. The panel further recommended that if desired, a baseline estimate of 0.14 be used for the initial evaluations, with a sensitivity analysis between 0.10 and 0.30. The 0.14 value is an average estimate using the Lorenzen method, as well as the combined “Rule of thumb” and Hoenig estimates. It is also similar to the natural mortality value used in the SEDAR12 GOM red grouper assessment.

### *2.4. DISCARD MORTALITY*

The Working Group reviewed the scientific studies on release mortality available for red grouper. Release mortality for red grouper has been reported at 0-15%, but may potentially be higher under certain scenarios. In the Gulf of Mexico, Wilson & Burns (1996) found that release mortality for red grouper was 9% for depths less than 44 meters. Burns et al. (2002) reported that release mortality for red grouper, was 15% for depths 35-55 meters. However, Burns et al. (2002) state that capture/release mortality was not strongly related to depth. Burns et al. (2002) also reported that red grouper showed a significantly greater ($P< 0.0001$) tag return rate (survival) when unvented. Rudershausen et al. (2007) found that red grouper, in the Atlantic, had an overall release mortality of 8.6%. Those red grouper < 508 mm TL had a release mortality of 10.2% (n=68), and those ≥ 508 mm total length (TL) had release mortality 0.0 % (n=13). Those captured in depths between 25-50 meters had an immediate (release) mortality of 8.6% with a potential delayed mortality of 70.6 % (based on a Monte Carlo probability model).

### *2.5. AGE*

#### 2.5.1 Available age data

Age data were available from SEFSC Beaufort, NC and MARMAP. Each lab provided age information from both fishery dependent and fishery dependent sources. During the DW data were combined and analyses were performed on the combined data set. The LH WG also provided a series of tables with the number of age samples by fishery, year, and state (Table 2.13.1). A significant portion of the SC-DNR/MARMAP otolith data does not include marginal increment information (“edge type”), therefore increment count was used as a proxy for age. In other words, no calendar ages were used in the analysis. The LH WG recommends that MARMAP re-evaluate the available red grouper age data to provide edge types for future assessments. Note that the fishery-independent age frequency data reported by the life-history group is different than that reported by the indices workgroup. The MARMAP life history data represent all red grouper captured with all gear types, under all conditions. The samples used in developing indices are those from Chevron traps only, fished as intended on appropriate habitat.

### 2.5.2. Age procedures, error matrix, and conversion criteria.

SC-DNR/MARMAP and NMFS Beaufort staff met during the SEDAR17 Assessment Workshop to discuss processing and examination of red grouper otoliths. It was concluded that both labs use similar processing techniques and read red grouper otoliths after they have been sectioned. In addition, both labs interpret the increment structure of red grouper otoliths in a similar manner; increments and edge types were characterized in similar way. After the meeting a set of 200 red grouper otolith sections was read by NMFS Beaufort Lab and SC-DNR/MARMAP staff. Annuli counts and edge type for each sample were recorded. Comparisons of the calendar ages of 193 otoliths yielded an absolute agreement between labs of 77%, with an agreement of 99% within 1 calendar year. Average Percent Error (APE) between readings of the two labs was 2.2%, well within the ≤ 5% acceptable APE for relatively easy to read otoliths such as red grouper.

Although the age data were not converted to calendar age, the LH WG recommended the following criteria for possible conversions: Burgos et al. (2007) concluded that annulus (opaque zone) formation is completed by August. For otoliths collected between January 1 and July 31 with a wide translucent zone on the otolith edge, the annuli counts should be advanced by one for calendar age. For samples from the same time period with opaque zones or narrow translucent zones on the edge, annuli counts should be equal to calendar age. For samples collected between August 1 and December 31, annuli counts should be equal to calendar age regardless of edge type.

### 2.5.3. Maximum age

The maximum age of red grouper in the NMFS Beaufort samples (n= 6,541 dating back to 1972) is 26 years. This fish was collected in March of 2003 by a recreational angler. The oldest two fish collected by MARMAP were 20 years (n=2,852, dating back to 1979) and were collected in June and July of 1998 by a commercial fisherman using hook and line. The maximum age for red grouper reported in the Gulf of Mexico was 29 yrs (SEDAR12-DW-03). The LHWG recommends using 26 years at the maximum age for red grouper since this value is based on the largest data set, spanning the longest time period.

### *2.6. GROWTH*

Using several subsets of the combined data set, a series of Von Bertalanffy (VB) growth parameters were estimated (Table 2.13.2). The LH WG recommends using $L_{inf}$=848.2 (mm), K=0.213 (per year), and $t_o$=-0.66 (yr) in the stock assessment model. These values were obtained using the most appropriate treatment of the data: all available age data with the Diaz et al. (2004) correction applied for fishery dependent samples (Figure 2.14.2). The LH WG feels that the selected values are robust, since there was very little variability between the VB parameter estimates between the various iterations (Table 2.13.2). The difference from the general pattern for the MARMAP vertical long line data is due to the low sample size (n=55).

### *2.7. REPRODUCTION*

Red grouper is a protogynous hermaphrodite (Moe 1969; Burgos et al. 2007) with asynchronous ovarian organization. Eggs are released in batches (SEDAR12-DW-4), but the fecundity pattern (determinate vs. indeterminate) of red grouper is not known.

Burgos et al. (SEDAR19-RD02) is the only published reference on the reproductive biology of red grouper along the Atlantic coast of the southeastern U.S. Fishery-independent data collected by the MARMAP program during 1997-2007 were added to the Burgos et al. data set in preparation for the present data workshop. In the workshop data set, sixty-four percent of the 2915 specimens examined histologically came from fishery-dependent sources, primarily the commercial snapper reel fishery. Overall, the majority of specimens were collected with snapper reels (74%) and chevron traps (19%). The information below on spawning seasonality, sexual maturity, sex ratio, and sex transition is based on the most accurate technique (histology) utilized to assess reproductive condition in fishes.

The reproductive information provided to the LH WG was based exclusively on samples collected by the MARMAP program. The LH WG recommends that information provided by MARMAP on spawning seasonality, age at maturity, age at sex transition, and overall sex ratio be used in the assessment for the following reasons: 1) sample sizes in the analyses are large (>1200), 2) this is the only information on the reproductive biology of red grouper along the

Atlantic coast of the southeastern U.S., and 3) the information is based on the most accurate technique (histology) utilized to assess reproductive condition in fishes.

### 2.7.1 Spawning season

Spawning season is from February through June, with a peak in April (Burgos et al. 2007). Burgos et al. (2007) reported the capture of spawning red grouper off the Carolinas between 32°20´N and 34°11´N. Figure 2.14.3 summarizes all available spawning location information collected by MARMAP over the years for both male and female red grouper. The data suggest that spawning is concentrated along the shelf edge.

### 2.7.2 Fecundity

No estimates of annual fecundity at age are available for red grouper along the Atlantic coast of the southeastern U.S. Equations relating age to batch fecundity (BF = 97986*Age – 409775; $r^2$ = 0.49, n=73) and annual fecundity (AF = 416068*Age -1E+06; $r^2$ = 0.26, n=72) were developed for red grouper in the Gulf of Mexico by Fitzhugh et al. (SEDAR12-DW-4), but those equations are limited to ages 5+; for age 4, the equations produce a negative estimate of fecundity. After the Data Workshop, a small amount of gonad weight data (with corresponding age data; n=112, see Figure 2.14.4) was found in the MARMAP data set; however, the relationship between gonad weight age and is weak (simple linear regression, adj. $r^2$ = 0.04), and marginally significant (p = 0.02).

Given the limitations of the fecundity equations and the lack of adequate gonad weight data, the consensus of DW was to recommend the use of total mature biomass (male and female separately) as a proxy for fecundity. It should be noted that gonad weight served as a proxy for fecundity at age in SEDAR12.

### 2.7.3 Age and size at maturity

The smallest mature female was 352 mm TL, and the youngest was age 2 (Figure 2.14.5); age at 50% maturity was 2.8 yr (95% CI = 2.06-3.21) and length at 50% maturity was 488 mm TL (95% CI = 482-493). The largest immature female was 641 mm TL and the oldest was age 9. The logistic equation (1 - 1/(1 + exp(a+b*age)) was used to estimate $A_{50}$ for females (a= -2.1139;

b=0.7569). This value of $A_{50}$ (2.8 yr) is very similar to the value of 2.4 yr (95% CI = 1.77-2.74) reported by Burgos et al. (2007), but it is approximately one year higher than the value of 2 yr applied to data from the 1990s+ during the assessment of Gulf of Mexico red grouper (See Figure 2.5 in SEDAR 12 SAR1). It should be noted that the estimate from SEDAR 12 was based on a methodology that omitted inactive mature females because this reproductive state is most difficult to distinguish from the immature state. In SEDAR19, the classical definition of maturity has been utilized, such that inactive mature females have been included in the numerator and denominator of the proportion mature calculation and the data set has not been temporally restricted. It should be noted that 18.8% of female specimens were classified as "uncertain maturity" because it was difficult to determine whether or not the specimens had spawned previously and therefore reached sexual maturity; therefore, they were omitted from analyses of maturity and sex ratio.

A comparison of age at maturity ogives for 1990-1999 and 2000-2007 with PROBIT analysis revealed a shift toward maturity at later age (period effect, $p<0.0001$), but the overall fit of the model was poor (Logistic model, L.R. chi-square=30.8, $p = 0.021$). Sample size in the latter period was relatively small (440 vs. 1444). Given the limitations of this analysis, the DW recommends the use of the maturity ogive based on all data as reported above.

Concerning the discrepancy between the observed and predicted percentage of mature specimens at age 1, the WG recommends that the observed value of 0% be used in the assessment.

### 2.7.4 Age and size at sex transition.

The smallest male was 402 mm TL, and the youngest was age 2 (Figure 2.14.6.); age at 50% sex transition was 7.7 yr (95% CI = 7.06-8.84) and length at 50% transition was 698 mm TL (95% CI = 684-717).The largest female was 793 mm TL and the oldest was age 13. The normal equation (1-Prob(a+b*age)) was used to estimate $A_{50}$ (a= 2.4115; b= -0.3121). This value of $A_{50}$ (7.7 yr) is very similar to the value of 7.2 yr (95% CI = 6.9-7.7) reported by Burgos et al. (2007), but it's approximately three years lower than the estimate of 10.5 yr applied to data from the 1990s+ during the assessment of Gulf of Mexico red grouper (See Fig 2.6 in SEDAR 12 SAR1). A comparison of $A_{50}$ values based on MARMAP data from two periods (1990-1999 and 2000-

2007) showed that there was no change in age at sex transition (Probit analysis, Normal model; period chi-square=1.08, p=0.299). It should be noted that the overall fit of the model was poor (L.R. chi-square=56.6; p<0.0001); sample size in the latter period was relatively small (381 vs. 1445). Given the limitations of this analysis, the DW recommends the use of the age at sex transition ogive based on all data as reported above.

### 2.7.5 Sex ratio

The percentage of males and transitional specimens in the data set used for SEDAR19 was 21.4%, a value similar to those (22.1 and 22.4%) reported by Coleman et al. (1996) for two studies of Gulf of Mexico red grouper during 1991-1992.

## *2.8. MOVEMENTS AND MIGRATIONS*

Please see Section 2.2.3. – Tagging.

## *2.9. MERISTICS AND CONVERSIONS*

The LH WG recommends the conversions in Table 2.13.5 for length/length weight/weight, and length/weight transformations where needed. The LH WG feels that the conversions are robust since they were established using relatively large data sets with appropriate size ranges.

## *2.10. LIFE HISTORY PARAMETERS AND STEEPNESS*

The LH WG did not have an opportunity to discuss steepness issues related to life history parameters. The LH WG recommends this topic should be addressed in a separate meeting, possibly in conjunction with a future SEDAR DW. The meeting should involve a broad range of individuals with expertise in steepness related life history aspects and include members of the assessment teams.

## *2.11. RESEARCH RECOMMENDATIONS*

- The DW LHWG recognized the value of continuing the age workshops and exchange of otoliths in preparation of SEDAR data workshops. This will be especially important for species that have been recognized as relatively difficult to age.

- The DW LHWG also recognizes the value of similar workshops to discuss the interpretation of reproductive samples, and the possible exchange of histological sections between labs in preparation of SEDAR Data Workshops. This will be especially important for species that have been recognized as relatively difficult to stage.
- Since fecundity information is only available from the GOM and does not include estimates for ages less than 5 years, the DW LH GW recommends initiating a study to estimate fecundity and further identify spawning locations for all age classes in both the GOM and Atlantic populations.
- The data presented at the DW suggest a possible disjunct distribution in the Atlantic stock (NC-FL). The DW LH GW recommends a study to further investigate this by use of genetic, tagging, and other techniques.
- Improved collection and collection strategy for hard parts, in particular from the recreational sector.
- Increase of Fishery Independent data to include the entire area of red grouper distribution in the Atlantic.
- Virtually no information on the life history and distribution of juvenile red grouper (i.e. ages 0-2) is available. The DW LH WG recommends a study to gather information on these early stages.

Procedural recommendation:

- The DW recommends that the report of the natural mortality workshop organized by NMFS (Seattle, WA, August 2009) be a made available to the DW LHW before the next SEDAR as a guide in the discussions concerning natural mortality.

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## *2.13. TABLES*

**Table 2.13.1.A-F.** South Atlantic red grouper annual age (annuli count) composition data presented as sample number and percent frequency for various data sources (fisheries). **A)** Recreational Fishery – number of samples

| Year | Annuli Count | | | | | | | | | | | | | | | | | | | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 20 | 26 | |
| 1977 | | | | | 6 | | | | | | | | | 1 | | | | | | 7 |
| 1978 | | 1 | | | 2 | 9 | | | | | | | | | | | | | | 12 |
| 1979 | | 7 | 4 | 8 | 11 | 2 | 5 | 1 | 1 | | | 1 | | | | | | | | 40 |
| 1980 | | 24 | 30 | 19 | 37 | 30 | 7 | 1 | 4 | | 1 | | | | | | | | | 153 |
| 1981 | 14 | 20 | 39 | 28 | 26 | 29 | 14 | 3 | 4 | 2 | | 1 | | | | | | | | 180 |
| 1982 | 2 | 9 | 18 | 20 | 10 | 5 | 4 | 1 | 1 | 3 | 1 | | | | | | | | | 74 |
| 1983 | 2 | 15 | 4 | 2 | 6 | 2 | | 1 | 1 | 1 | 1 | 2 | 1 | | | | | | | 38 |
| 1984 | 2 | 9 | 11 | 5 | 3 | 1 | 1 | 1 | 2 | 2 | 1 | 2 | 3 | | | 1 | | | | 44 |
| 1985 | | 2 | 2 | 7 | 5 | 1 | | | | 1 | 3 | 1 | 1 | 1 | | | | | | 24 |
| 1986 | | 5 | 1 | 7 | 2 | 1 | 1 | | | | | 1 | | | | | | | | 18 |
| 1987 | 8 | 3 | 3 | 3 | | | | | | | | | | | | | | | | 17 |
| 1988 | | 2 | 15 | 4 | | | | | | | | 1 | | | | | | | | 22 |
| 1989 | | | 1 | 3 | 1 | | | | | | | | | | | | | | | 5 |
| 1990 | | 1 | 4 | 2 | 2 | 1 | | | | | | | | | 1 | | | | | 11 |
| 1991 | | 1 | 6 | 3 | 4 | | 2 | | | | | | | | | | | | | 16 |
| 1992 | | | | 2 | | 1 | | 1 | | | | | | | | | | | | 4 |
| 1993 | | | 3 | 1 | | | | | | | | | | | | | | | | 4 |
| 1994 | | 1 | | 5 | 1 | 1 | | 1 | | | | | | | | | | | | 9 |
| 1996 | | | | 1 | 2 | 5 | | | | | | | | | | | | | | 8 |
| 1997 | | | | 2 | | | | | | | | | | | | | | | | 2 |
| 1998 | | | | 3 | | | | | | | | | | | | | | | | 3 |
| 2001 | | | 10 | 3 | | | 1 | | | | | | | | | | | | | 14 |
| 2002 | | 1 | 23 | 15 | 2 | 1 | 4 | 1 | 1 | 1 | | | | | | | | | | 49 |
| 2003 | | | | 18 | 11 | 2 | 1 | 2 | 1 | 1 | | 1 | | | | | 1 | | 1 | 39 |
| 2004 | | | 17 | 16 | 10 | 6 | | | 1 | | | | | | | 1 | | | | 51 |
| 2005 | | 2 | 34 | 35 | 35 | 4 | 6 | | 2 | 1 | | 1 | | | | | | | | 120 |
| 2006 | | | 19 | 35 | 12 | 8 | 1 | | | 1 | | 1 | | | | | | 1 | | 78 |
| 2007 | | | 5 | 21 | 19 | 7 | | 1 | 1 | | | | | 1 | | | | | | 55 |
| 2008 | | 1 | 3 | 4 | 9 | 13 | 4 | 4 | 1 | | | | | | | | | | | 39 |

**Table 2.13.1.B:** Recreational Fishery – frequency

| Year | Annuli Count | | | | | | | | | | | | | | | | | | | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 20 | 26 | |
| 1977 | 0.000 | 0.000 | 0.000 | 0.000 | 0.857 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.143 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 7 |
| 1978 | 0.000 | 0.083 | 0.000 | 0.000 | 0.167 | 0.750 | 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 | 12 |
| 1979 | 0.000 | 0.175 | 0.100 | 0.200 | 0.275 | 0.050 | 0.125 | 0.025 | 0.025 | 0.000 | 0.000 | 0.025 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 40 |
| 1980 | 0.000 | 0.157 | 0.196 | 0.124 | 0.242 | 0.196 | 0.046 | 0.007 | 0.026 | 0.000 | 0.007 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 153 |
| 1981 | 0.078 | 0.111 | 0.217 | 0.156 | 0.144 | 0.161 | 0.078 | 0.017 | 0.022 | 0.011 | 0.000 | 0.006 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 180 |
| 1982 | 0.027 | 0.122 | 0.243 | 0.270 | 0.135 | 0.068 | 0.054 | 0.014 | 0.014 | 0.041 | 0.014 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 74 |
| 1983 | 0.053 | 0.395 | 0.105 | 0.053 | 0.158 | 0.053 | 0.000 | 0.026 | 0.026 | 0.026 | 0.026 | 0.053 | 0.026 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 38 |
| 1984 | 0.045 | 0.205 | 0.250 | 0.114 | 0.068 | 0.023 | 0.023 | 0.023 | 0.045 | 0.045 | 0.023 | 0.045 | 0.068 | 0.000 | 0.000 | 0.023 | 0.000 | 0.000 | 0.000 | 44 |
| 1985 | 0.000 | 0.083 | 0.083 | 0.292 | 0.208 | 0.042 | 0.000 | 0.000 | 0.000 | 0.042 | 0.125 | 0.042 | 0.042 | 0.042 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 24 |
| 1986 | 0.000 | 0.278 | 0.056 | 0.389 | 0.111 | 0.056 | 0.056 | 0.000 | 0.000 | 0.000 | 0.000 | 0.056 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 18 |
| 1987 | 0.471 | 0.176 | 0.176 | 0.176 | 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 | 17 |
| 1988 | 0.000 | 0.091 | 0.682 | 0.182 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.045 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 22 |
| 1989 | 0.000 | 0.000 | 0.200 | 0.600 | 0.200 | 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 | 5 |
| 1990 | 0.000 | 0.091 | 0.364 | 0.182 | 0.182 | 0.091 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.091 | 0.000 | 0.000 | 0.000 | 0.000 | 11 |
| 1991 | 0.000 | 0.063 | 0.375 | 0.188 | 0.250 | 0.000 | 0.125 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 16 |
| 1992 | 0.000 | 0.000 | 0.000 | 0.500 | 0.000 | 0.250 | 0.000 | 0.250 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4 |
| 1993 | 0.000 | 0.000 | 0.750 | 0.250 | 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 | 4 |
| 1994 | 0.000 | 0.111 | 0.000 | 0.556 | 0.111 | 0.111 | 0.000 | 0.111 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 9 |
| 1996 | 0.000 | 0.000 | 0.000 | 0.125 | 0.250 | 0.625 | 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 | 8 |
| 1997 | 0.000 | 0.000 | 0.000 | 1.000 | 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 | 2 |
| 1998 | 0.000 | 0.000 | 0.000 | 1.000 | 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 | 3 |
| 2001 | 0.000 | 0.000 | 0.714 | 0.214 | 0.000 | 0.000 | 0.071 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 14 |
| 2002 | 0.000 | 0.020 | 0.469 | 0.306 | 0.041 | 0.020 | 0.082 | 0.020 | 0.020 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 49 |
| 2003 | 0.000 | 0.000 | 0.000 | 0.462 | 0.282 | 0.051 | 0.026 | 0.051 | 0.026 | 0.026 | 0.000 | 0.026 | 0.000 | 0.000 | 0.000 | 0.000 | 0.026 | 0.000 | 0.026 | 39 |
| 2004 | 0.000 | 0.000 | 0.333 | 0.314 | 0.196 | 0.118 | 0.000 | 0.000 | 0.020 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.020 | 0.000 | 0.000 | 0.000 | 51 |
| 2005 | 0.000 | 0.017 | 0.283 | 0.292 | 0.292 | 0.033 | 0.050 | 0.000 | 0.017 | 0.008 | 0.000 | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 120 |
| 2006 | 0.000 | 0.000 | 0.244 | 0.449 | 0.154 | 0.103 | 0.013 | 0.000 | 0.000 | 0.013 | 0.000 | 0.013 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.013 | 0.000 | 78 |
| 2007 | 0.000 | 0.000 | 0.091 | 0.382 | 0.345 | 0.127 | 0.000 | 0.018 | 0.018 | 0.000 | 0.000 | 0.000 | 0.000 | 0.018 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 55 |
| 2008 | 0.000 | 0.026 | 0.077 | 0.103 | 0.231 | 0.333 | 0.103 | 0.103 | 0.026 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 39 |

**Table 2.13.1.C:** Commercial Fishery – number of samples

| Year | Annuli Count | | | | | | | | | | | | | | | | | | | | | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 21 | 22 | 23 | 24 | |
| 1988 | | 1 | 1 | 1 | 2 | | | | | | | | | | | | | | | | | | 5 |
| 1997 | | 3 | 8 | 2 | 3 | 1 | 2 | 1 | 1 | | | | | | | | | | | | | | 21 |
| 1998 | | 1 | 20 | 9 | 5 | 5 | 1 | | | | 1 | | | | | | | | | | | | 42 |
| 1999 | | 4 | 12 | 5 | 4 | 1 | 1 | | | | 1 | | | | | | | | | | | | 28 |
| 2000 | 4 | 1 | 1 | 10 | 6 | 2 | | 1 | | | | | | | | | | | | | | | 25 |
| 2001 | | 9 | 8 | 6 | 18 | 9 | 2 | 1 | 1 | | 1 | | | | | | | | | | | | 55 |
| 2002 | | 5 | 12 | | 3 | 3 | 1 | | 1 | | | | | | | | | | | | | | 25 |
| 2003 | | 4 | 4 | 17 | 1 | 4 | 6 | | | 1 | | | | | | | | | | | | | 37 |
| 2004 | 1 | 34 | 101 | 41 | 29 | 7 | 12 | 21 | 15 | 3 | 2 | 1 | | 1 | | | | | | | | | 268 |
| 2005 | 1 | 27 | 155 | 139 | 93 | 32 | 5 | 12 | 29 | 25 | 10 | 3 | 4 | 1 | | | | | | | | | 536 |
| 2006 | | 15 | 291 | 166 | 242 | 29 | 49 | 4 | 7 | 9 | 24 | 9 | 6 | | 3 | 1 | | | | | | | 855 |
| 2007 | | 3 | 165 | 552 | 213 | 162 | 64 | 43 | 8 | 28 | 35 | 28 | 16 | 2 | 4 | 3 | | 1 | | | | 1 | 1328 |
| 2008 | | | 36 | 542 | 901 | 172 | 94 | 73 | 43 | 20 | 41 | 82 | 60 | 26 | 4 | 4 | 3 | 2 | 3 | 1 | 1 | | 2108 |

**Table 2.13.1.D:** Commercial – frequency

| Year | Annuli Count | | | | | | | | | | | | | | | | | | | | | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 21 | 22 | 23 | 24 | |
| 1988 | 0.000 | 0.200 | 0.200 | 0.200 | 0.400 | 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 | 5 |
| 1997 | 0.000 | 0.143 | 0.381 | 0.095 | 0.143 | 0.048 | 0.095 | 0.048 | 0.048 | 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 | 21 |
| 1998 | 0.000 | 0.024 | 0.476 | 0.214 | 0.119 | 0.119 | 0.024 | 0.000 | 0.000 | 0.000 | 0.024 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 42 |
| 1999 | 0.000 | 0.143 | 0.429 | 0.179 | 0.143 | 0.036 | 0.036 | 0.000 | 0.000 | 0.000 | 0.036 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 28 |
| 2000 | 0.160 | 0.040 | 0.040 | 0.400 | 0.240 | 0.080 | 0.000 | 0.040 | 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 | 25 |
| 2001 | 0.000 | 0.164 | 0.145 | 0.109 | 0.327 | 0.164 | 0.036 | 0.018 | 0.018 | 0.000 | 0.018 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 55 |
| 2002 | 0.000 | 0.200 | 0.480 | 0.000 | 0.120 | 0.120 | 0.040 | 0.000 | 0.040 | 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 | 25 |
| 2003 | 0.000 | 0.108 | 0.108 | 0.459 | 0.027 | 0.108 | 0.162 | 0.000 | 0.000 | 0.027 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 37 |
| 2004 | 0.004 | 0.127 | 0.377 | 0.153 | 0.108 | 0.026 | 0.045 | 0.078 | 0.056 | 0.011 | 0.007 | 0.004 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 268 |
| 2005 | 0.002 | 0.050 | 0.289 | 0.259 | 0.174 | 0.060 | 0.009 | 0.022 | 0.054 | 0.047 | 0.019 | 0.006 | 0.007 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 536 |
| 2006 | 0.000 | 0.018 | 0.340 | 0.194 | 0.283 | 0.034 | 0.057 | 0.005 | 0.008 | 0.011 | 0.028 | 0.011 | 0.007 | 0.000 | 0.004 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 855 |
| 2007 | 0.000 | 0.002 | 0.124 | 0.416 | 0.160 | 0.122 | 0.048 | 0.032 | 0.006 | 0.021 | 0.026 | 0.021 | 0.012 | 0.002 | 0.003 | 0.002 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 1328 |
| 2008 | 0.000 | 0.000 | 0.017 | 0.257 | 0.427 | 0.082 | 0.045 | 0.035 | 0.020 | 0.009 | 0.019 | 0.039 | 0.028 | 0.012 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 2108 |

**Table 2.13.1.E:** Fishery-Independent – number of samples (all gears combined).

| Year | Annuli Count | | | | | | | | | | | | | | | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 20 | |
| 1991 | | | 2 | 2 | | | | | | | | | | | | 4 |
| 1992 | | 5 | 1 | 8 | 1 | | | | | | | | | | | 15 |
| 1993 | | 1 | 16 | 1 | 3 | | | | | | | | | | | 21 |
| 1994 | | | | 28 | 1 | | | | | | | | | | | 29 |
| 1995 | | | | | 8 | | | | | | | | | | | 8 |
| 1996 | | 1 | 4 | 2 | 5 | 11 | 1 | | | 1 | | | | | | 25 |
| 1997 | | 6 | 20 | 25 | 28 | 57 | 9 | 2 | | | 1 | | | | | 148 |
| 1998 | | | 198 | 882 | 476 | 60 | 53 | 19 | 11 | 7 | 1 | 4 | | | 2 | 1713 |
| 1999 | | | 7 | 33 | 101 | 24 | 10 | 13 | 2 | 2 | | | | 1 | | 193 |
| 2000 | | 3 | 12 | 49 | 84 | 67 | 38 | 25 | 11 | 6 | 3 | 1 | 1 | | | 300 |
| 2001 | 1 | 2 | 54 | 11 | 9 | 9 | 12 | 2 | 2 | | | | | | | 102 |
| 2002 | | 4 | 9 | 23 | 3 | | 3 | 1 | 1 | | | | | | | 44 |
| 2003 | | 4 | 10 | 6 | 15 | | | | | | | | | 1 | | 36 |
| 2004 | | 9 | 9 | 17 | 3 | 3 | | | 2 | | | | | | | 43 |
| 2005 | | | 8 | 8 | 13 | 4 | 3 | | 1 | | 1 | | | | | 38 |
| 2006 | | | 1 | 28 | 6 | 10 | 3 | 1 | | | | 1 | | | | 50 |
| 2007 | | | 1 | 1 | 44 | 8 | 5 | 4 | 1 | | 1 | | 2 | | | 67 |
| 2008 | | | 1 | | | 14 | 1 | | | | | | | | | 16 |

**Table 2.13.1.F:** Fishery-Independent - frequency (all gears combined).

| Year | Annuli Count | | | | | | | | | | | | | | | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 20 | |
| 1991 | 0.00 | 0.00 | 0.50 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4 |
| 1992 | 0.00 | 0.33 | 0.07 | 0.53 | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 15 |
| 1993 | 0.00 | 0.05 | 0.76 | 0.05 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 21 |
| 1994 | 0.00 | 0.00 | 0.00 | 0.97 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 29 |
| 1995 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8 |
| 1996 | 0.00 | 0.04 | 0.16 | 0.08 | 0.20 | 0.44 | 0.04 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 25 |
| 1997 | 0.00 | 0.04 | 0.14 | 0.17 | 0.19 | 0.39 | 0.06 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 148 |
| 1998 | 0.00 | 0.00 | 0.12 | 0.51 | 0.28 | 0.04 | 0.03 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1713 |
| 1999 | 0.00 | 0.00 | 0.04 | 0.17 | 0.52 | 0.12 | 0.05 | 0.07 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 193 |
| 2000 | 0.00 | 0.01 | 0.04 | 0.16 | 0.28 | 0.22 | 0.13 | 0.08 | 0.04 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 300 |
| 2001 | 0.01 | 0.02 | 0.53 | 0.11 | 0.09 | 0.09 | 0.12 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 102 |
| 2002 | 0.00 | 0.09 | 0.20 | 0.52 | 0.07 | 0.00 | 0.07 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 44 |
| 2003 | 0.00 | 0.11 | 0.28 | 0.17 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 36 |
| 2004 | 0.00 | 0.21 | 0.21 | 0.40 | 0.07 | 0.07 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 43 |
| 2005 | 0.00 | 0.00 | 0.21 | 0.21 | 0.34 | 0.11 | 0.08 | 0.00 | 0.03 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 38 |
| 2006 | 0.00 | 0.00 | 0.02 | 0.56 | 0.12 | 0.20 | 0.06 | 0.02 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 50 |
| 2007 | 0.00 | 0.00 | 0.01 | 0.01 | 0.66 | 0.12 | 0.07 | 0.06 | 0.01 | 0.00 | 0.01 | 0.00 | 0.03 | 0.00 | 0.00 | 67 |
| 2008 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.88 | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 16 |

**Table 2.13.2.** Estimates of Von Bertalanffy (VB) growth parameters using various subsets of the available age data based on non-linear regression analysis. $L_{inf}$= VB asymptotic TL in mm, K=VB growth coefficient, $t_0$=VB theoretical age at length=0 in years, n = sample size, $R^2$= Adjusted $R^2$ from the non-linear regression. The constant CV estimated for the recommended curve fit was 0.090 ± 0.001.

Red Grouper VB Growth Parameters

| Data Source | Parameters | | | | |
|---|---|---|---|---|---|
| | $L_{inf}$ (mm) | K(1/yr) | $t_0$ (yr) | n | $R^2$ (%) |
| All Available age Data | 846.38 | 0.222 | -0.604 | 9386 | 74.47 |
| MARMAP All Fishery Independent (FI) | 832.65 | 0.206 | -0.929 | 2848 | 62.01 |
| MARMAP Chevron (CHV) | 917.38 | 0.194 | 0.028 | 551 | 81.26 |
| MARMAP Vertical Longline (VLL) | 1074.71 | 0.093 | -4.175 | 55 | 69.06 |
| MARMAP (CHV & VLL) | 916.47 | 0.198 | -0.088 | 606 | 81.9 |
| All Fishery Dependent (FD) | 841.41 | 0.231 | -0.565 | 6538 | 75.83 |
| Fishery Dependent (Recreational & Commercial) | 840.99 | 0.230 | -0.586 | 6468 | 75.53 |
| Fishery Dependent Recreational | 872.48 | 0.178 | -1.138 | 1136 | 70.67 |
| Fishery Dependent Commercial | 848.45 | 0.212 | -1.087 | 5332 | 71.85 |
| FD all data Diaz corrected where appropriate | 845.3 | 0.219 | -0.65 | 6243 | N/A |
| FD + FI all data Diaz corrected where appropriate | 848.2 ± 4.412 | 0.213 ± 0.003 | -0.66 ± 0.037 | 9089 | N/A |

**Table 2.13.3.A.** Various published methods used to estimate natural mortality (M).

| **Equations for Estimating M:** | Parameters | | Equation |
|---|---|---|---|
| **Alverson & Carney (1975)** | k, $t_{max}$ | From Quinn & Deriso: | M = 3k/(exp(0.38*$t_{max}$*k)-1) |
| **Beverton (1959)** | k, $a_m$ | ($a_m$ = age at 50% maturity) | M = 3k/(exp($a_m$*k)-1) |
| **Hoenig (1983)** | $t_{max}$ | (for fish) | M=exp(1.46 - 1.01*ln($t_{max}$)) |
| **Pauly (1999)** | $L_{inf}$, k, T | From Quinn & Deriso: | M=exp(-0.0152+0.6543*ln(k)-0.279*ln($L_{inf}$, cm)+0.4634*lnT(oC)) |
| | | from Pauly: | M = 10^(-0.0066-0.279*(log($L_{inf}$))+0.6543*log(K)+0.4634*Log(T)) |
| **Ralston (1987)** | k | | M=0.0189 + 2.06*k |
| **Lorenzen Age-Specific (1996)** | W at age | | M=3.69*W^(-0.305) |
| **Jensen (1996)** | k | | M = 1.5*K |
| **Alagaraja (1984)** | $t_{max}$, survivorship to $t_{max}$ | | M=-ln[S($t_{max}$)]/$t_{max}$; derived from S($t_{max}$)=exp(-M*$t_{max}$) |
| **Rule of thumb** | $t_{max}$ | | M = 2.98/$t_{max}$ |

**Table 2.13.3.B.** Range of natural mortality estimates base on a variety of published methods and subsets of the available data.

| **Data Source** | **Observed Max Age** | **Von Bert* $L_{inf}$ (mm)** | **k** | **Water Temp.** | **age 50% mat. am** | **Alverson & Carney** | **Beverton** | **Hoenig** | **Pauly** | **Ralston** | **Jensen** | **Rule of thumb** | **Alagaraja** *0.01* | *0.02* | *0.05* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All age data with size limit correction | 26 | 849 | 0.211 | 20.9 | 2.1 | 0.09 | 1.14 | 0.16 | 0.42 | 0.45 | 0.32 | 0.11 | 0.18 | 0.15 | 0.12 |
| All age data without no correction | 26 | 846.4 | 0.222 | 20.9 | 2.8 | 0.08 | 0.77 | 0.16 | 0.44 | 0.48 | 0.33 | 0.11 | | | |
| All Fishery-dependent data with size limit correction | 26 | 845.3 | 0.219 | 20.9 | 2.8 | 0.09 | 0.78 | 0.16 | 0.43 | 0.47 | 0.33 | 0.11 | | | |
| varying temperature | 26 | 849 | 0.211 | 15 | | 0.09 | | 0.16 | 0.36 | | | 0.11 | | | |
| varying temperature | 26 | 849 | 0.211 | 25 | | | | | 0.46 | | | | | | |
| varying temperature | 26 | 849 | 0.211 | 30 | | | | | 0.50 | | | | | | |

Note: values in italics under Alagaraja is survivorship

**Table 2.13.3.C.** Lorenzen age specific natural mortality estimates. M is the Lorenzen mortality, Scaled M is the scaled Lorenzen mortality based on a baseline estimate of 0.14, and M low and M high are the results of sensitivity analyses of 0.1 and 0.3, respectively.

| Age | TL (mm) | W (grams) | M | Scaled M | Low M | High M |
|---|---|---|---|---|---|---|
| 0 | 187.10 | 93.04 | 0.93 | 0.49 | 0.35 | 1.04 |
| 1 | 313.93 | 462.80 | 0.57 | 0.30 | 0.21 | 0.64 |
| 2 | 416.43 | 1111.18 | 0.43 | 0.23 | 0.16 | 0.49 |
| 3 | 499.26 | 1949.99 | 0.37 | 0.19 | 0.14 | 0.41 |
| 4 | 566.21 | 2880.26 | 0.33 | 0.17 | 0.12 | 0.37 |
| 5 | 620.31 | 3822.00 | 0.30 | 0.16 | 0.11 | 0.34 |
| 6 | 664.03 | 4720.51 | 0.28 | 0.15 | 0.11 | 0.32 |
| 7 | 699.36 | 5543.54 | 0.27 | 0.14 | 0.10 | 0.30 |
| 8 | 727.92 | 6275.75 | 0.26 | 0.13 | 0.10 | 0.29 |
| 9 | 751.00 | 6913.29 | 0.25 | 0.13 | 0.09 | 0.28 |
| 10 | 769.65 | 7459.51 | 0.24 | 0.13 | 0.09 | 0.27 |
| 11 | 784.72 | 7921.74 | 0.24 | 0.13 | 0.09 | 0.27 |
| 12 | 796.90 | 8309.18 | 0.24 | 0.12 | 0.09 | 0.27 |
| 13 | 806.74 | 8631.51 | 0.23 | 0.12 | 0.09 | 0.26 |
| 14 | 814.70 | 8898.11 | 0.23 | 0.12 | 0.09 | 0.26 |
| 15 | 821.13 | 9117.60 | 0.23 | 0.12 | 0.09 | 0.26 |
| 16 | 826.32 | 9297.64 | 0.23 | 0.12 | 0.09 | 0.26 |
| 17 | 830.52 | 9444.88 | 0.23 | 0.12 | 0.09 | 0.26 |
| 18 | 833.91 | 9565.03 | 0.23 | 0.12 | 0.08 | 0.25 |
| 19 | 836.66 | 9662.88 | 0.22 | 0.12 | 0.08 | 0.25 |
| 20 | 838.87 | 9742.45 | 0.22 | 0.12 | 0.08 | 0.25 |
| 21 | 840.66 | 9807.08 | 0.22 | 0.12 | 0.08 | 0.25 |
| 22 | 842.11 | 9859.52 | 0.22 | 0.12 | 0.08 | 0.25 |
| 23 | 843.28 | 9902.04 | 0.22 | 0.12 | 0.08 | 0.25 |
| 24 | 844.23 | 9936.50 | 0.22 | 0.12 | 0.08 | 0.25 |
| 25 | 844.99 | 9964.40 | 0.22 | 0.12 | 0.08 | 0.25 |
| 26 | 845.61 | 9986.99 | 0.22 | 0.12 | 0.08 | 0.25 |
| Cumulative survival probability | | | 0.00 | 0.03 | 0.07 | 0.00 |

**Table 2.13.4**. Proportion female and proportion of females mature. The assessment uses predicted (statistically fitted) values, with the exception that age 1 maturity is set to zero.

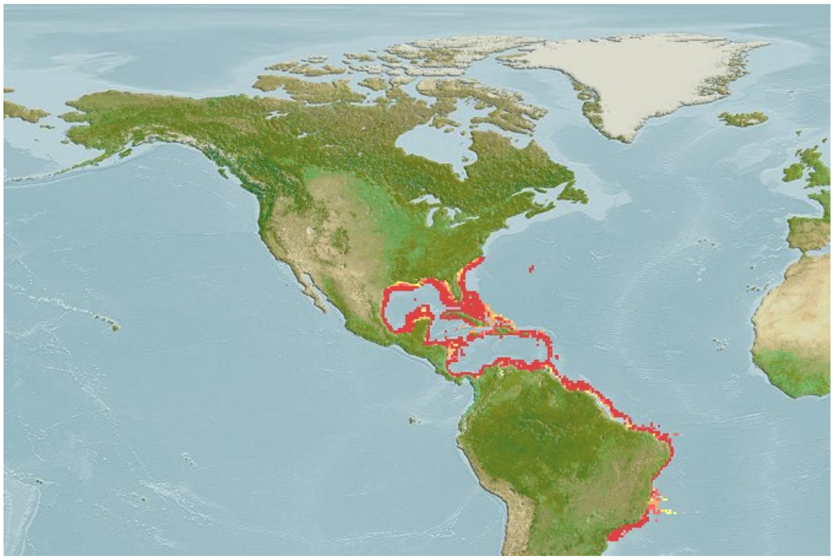
| | Proportion Female | | | Proportion of Females Mature | | |
|---|---|---|---|---|---|---|
| Age | Observed | Predicted | N | Observed | Predicted | N |
| 1 | | 1 | 0 | 0 | 0.205 | 1 |
| 2 | 0.800 | 0.963 | 5 | 0.138 | 0.354 | 29 |
| 3 | 0.860 | 0.930 | 107 | 0.497 | 0.539 | 185 |
| 4 | 0.905 | 0.878 | 685 | 0.737 | 0.714 | 841 |
| 5 | 0.814 | 0.803 | 596 | 0.844 | 0.842 | 575 |
| 6 | 0.603 | 0.705 | 204 | 0.904 | 0.919 | 136 |
| 7 | 0.549 | 0.590 | 113 | 0.939 | 0.960 | 66 |
| 8 | 0.538 | 0.466 | 52 | 0.903 | 0.981 | 31 |
| 9 | 0.433 | 0.346 | 30 | 0.929 | 0.991 | 14 |
| 10 | 0.214 | 0.239 | 14 | 1 | 0.996 | 3 |
| 11 | 0.286 | 0.153 | 7 | 1 | 0.998 | 2 |
| 12 | 0 | 0.091 | 6 | | | |
| 13 | 0.333 | 0.050 | 3 | 1 | 1 | 1 |
| 14 | 0 | 0.025 | 2 | | | |
| 20 | 0 | 0 | 2 | | | |

**Table 2.13.5.** Conversions for red grouper. Lengths (total length=TL, fork length=FL, standard length=SL) in mm, and weights (WW=total wet weight, GW=gutted wet weight) in grams.

| | | |
|---|---|---|
| TL/SL | **TL = 16.15 + 1.1879*SL** | **(adj. $R^2$=98.40%, n = 1,527, TL range: 123-900 mm)** |
| TL/FL | TL = -6.854 + 1.0499*FL | (adj, $R^2$=98.98%, n = 2,378, TL range: 156-900 mm) |
| SL/FL | SL = -15.971 + 0.8778*FL | (adj.$R^2$=98.70%, n = 1,408, SL range: 155-864mm) |
| WW/TL | $WW= 8.418*10^{-6}*TL^{3.100}$ | (adj.$R^2$=93.694%, n = 9,936, TL range 123-961 mm) |
| WW/SL | $WW = 12.948*10^{-6} * SL^{3.134}$ | (adj.$R^2$=93.303%, n = 961, range: SL 100-723 mm) |
| WW/FL | $WW = 6.360*10^{-6}*FL^{3.160}$ | (adj.$R^2$=91.859%, n = 2,785, range: FL 155-878 mm) |
| WW/GW | WW=1.0781*GW | (R2=97.560%, n=111, range: 1,510-8,880 g) |

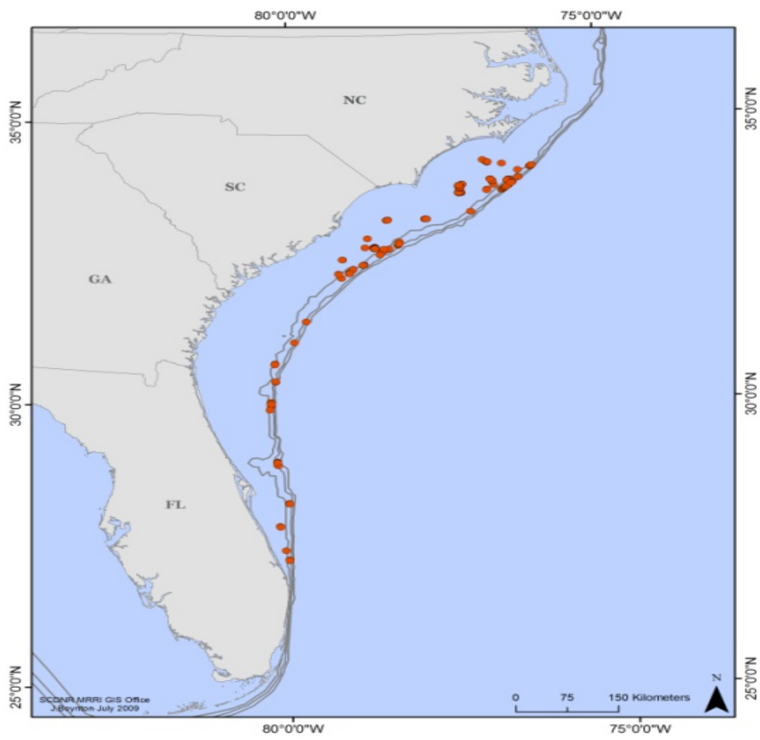
### 2.14. FIGURES

A)



A) Map of N and S. America showing worldwide distribution for red grouper.

B)




B) Locations of red grouper collections made by MARMAP between 1981 and 2008 off the Atlantic coast of Florida, Georgia, S. Carolina and N. Carolina . All years and gears were combined. Red dots indicate collection location and may represent collection of multiple individuals and multiple years.

**Figure 2.14.1.** Distribution maps for red grouper from www.fishbase.org and www.obis.org.au

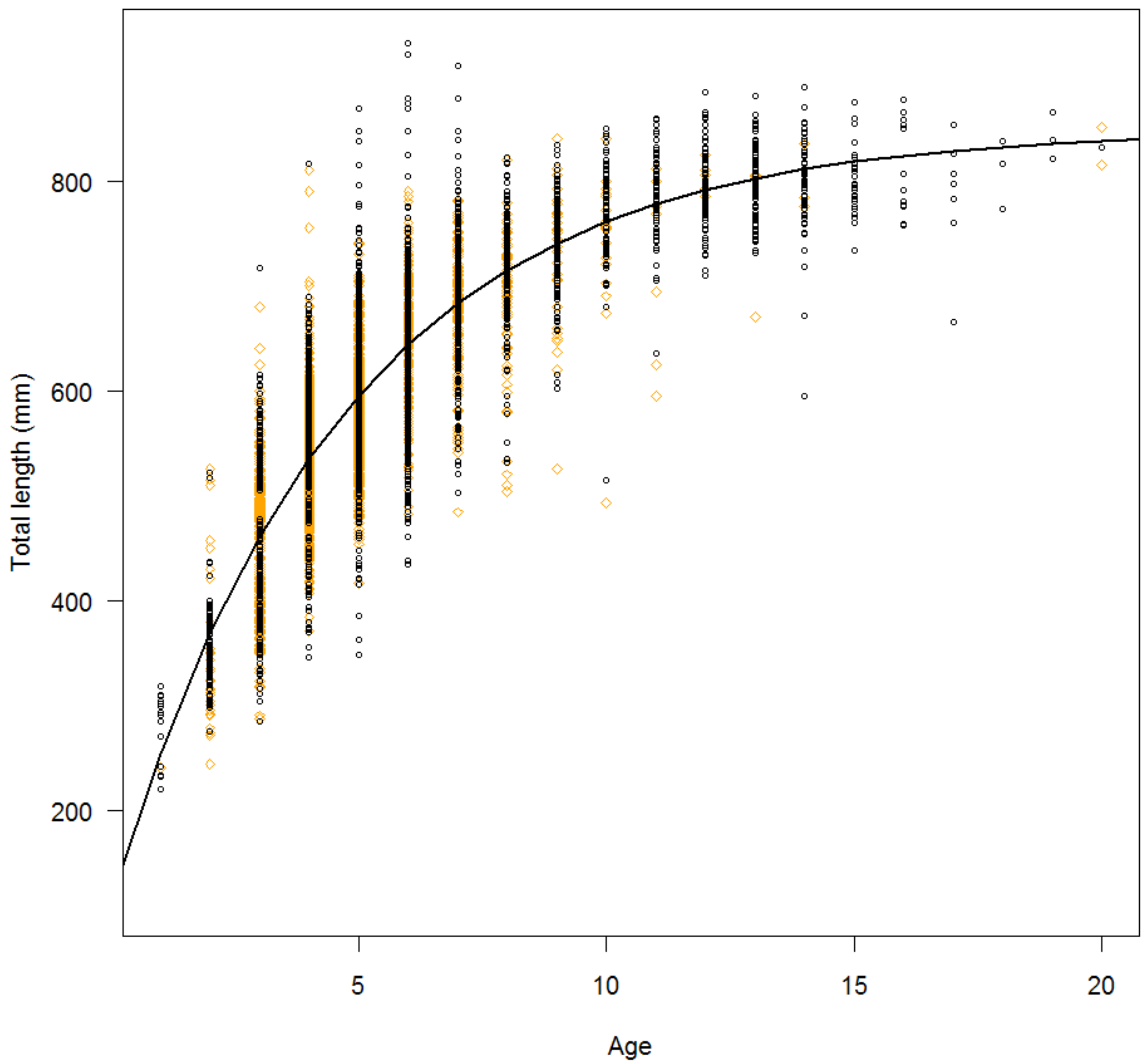



**Figure 2.14.2.** Fitted von Bertalanffy growth curve. The fishery independent samples are shown in black, while the fishery dependent samples are in orange.

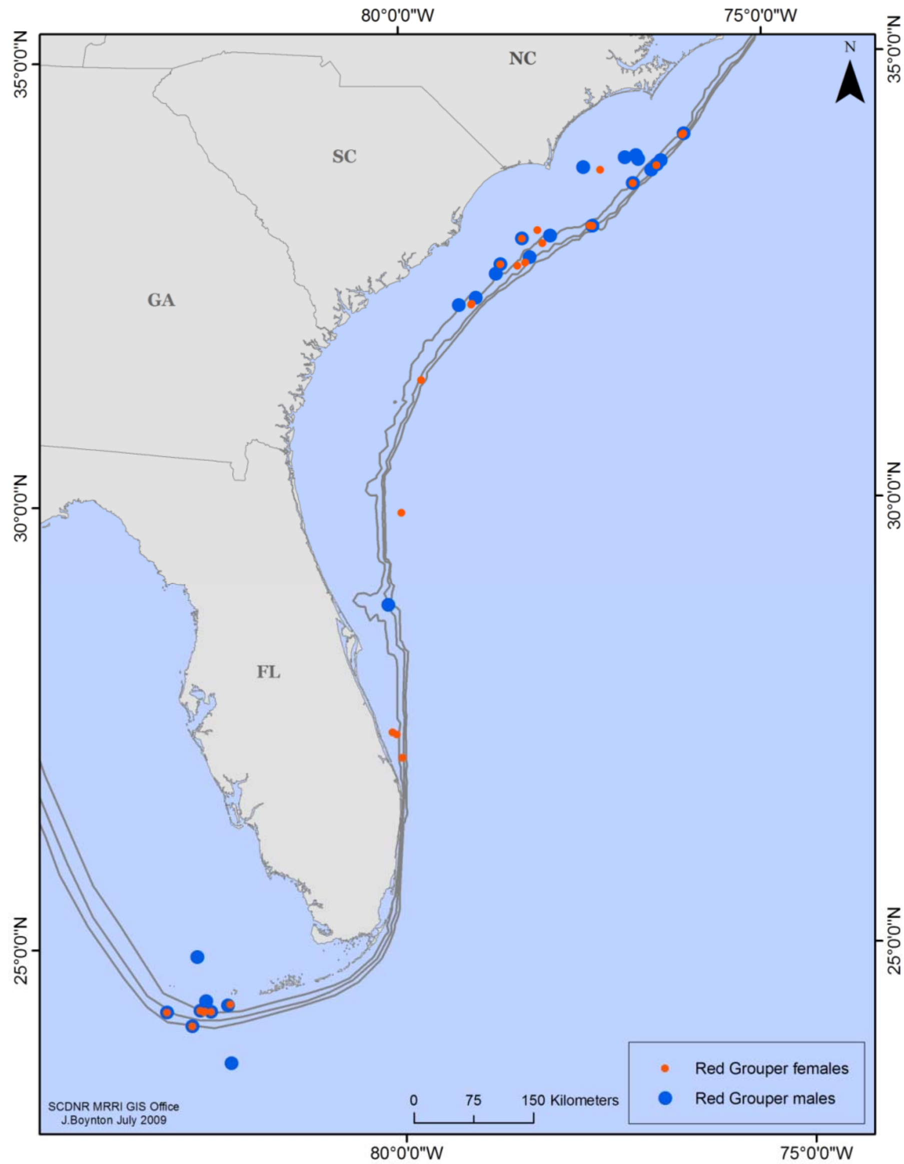



**Figure 2.14.3.** Locations of spawning red grouper in the Southeastern United States in 1993-2007 based on SCDNR-MARMAP information. Spawning is defined as males (large blue dots) with a predominance of spermatozoa and females (small red dots) with hydrated oocytes and/or postovulatory follicles. Note: Samples are from fishery dependent and fishery independent sources. Samples from the Florida Keys were collected from fishery dependent sources by SCDNR personnel (MARFIN). The lines represent the 50, 100, and 150 meter depth contours.

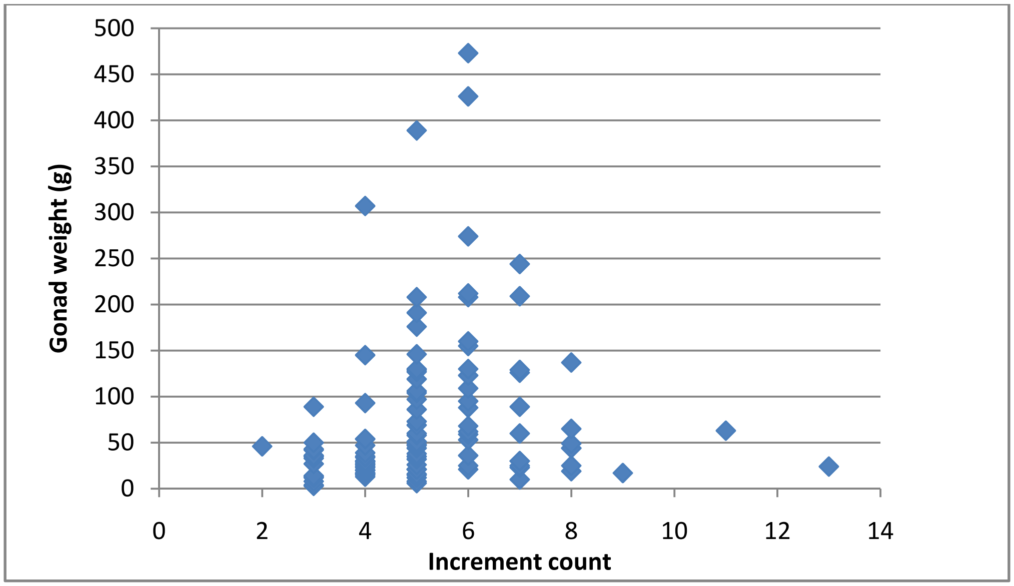



**Figure 2.14.4.** Gonad weight (g) at age (increment count) for female red grouper in fishery-independent and –dependent samples collected by the MARMAP program during 1996-2002. All specimens had at least reached the stage of producing vitellogenic (yolked) oocytes.

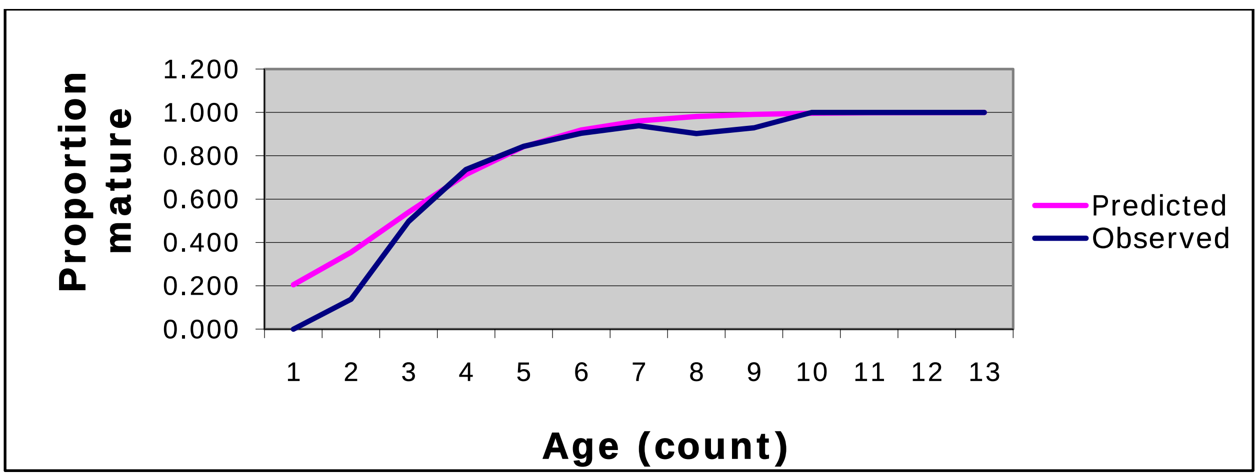



**Figure 2.14.5.** Proportion of sexually mature specimens by age (increment count) class for red grouper in fishery-independent and –dependent samples collected by the MARMAP program during 1980-2007. All specimens (n=1884) examined histologically.

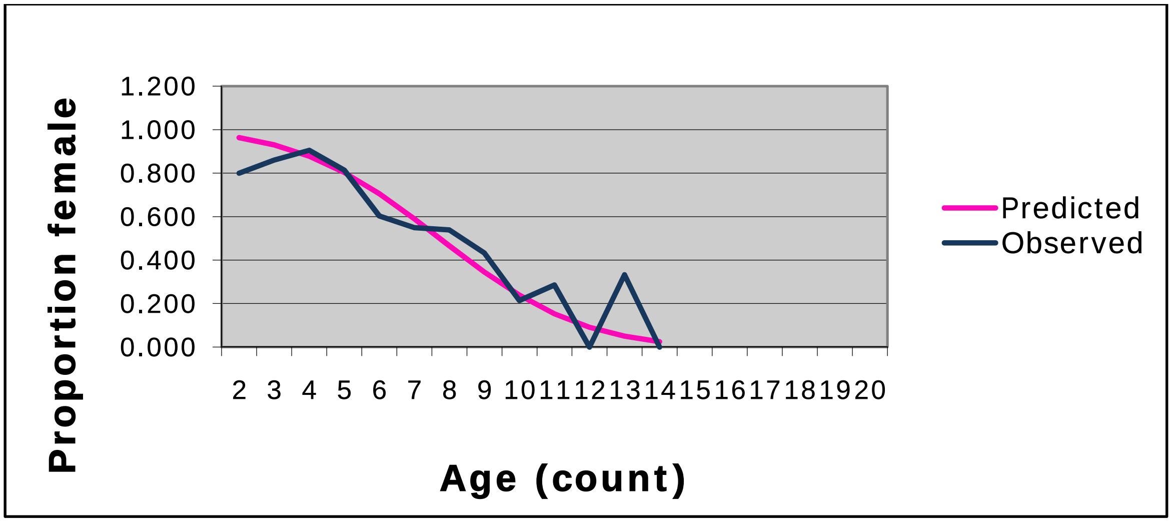



**Figure 2.14.6.** Proportion of adult female specimens by age (increment count) class for red grouper in fishery-independent and –dependent samples collected by the MARMAP program during 1980-2007. All specimens (n=1826) examined histologically.

## 3. COMMERCIAL FISHERY STATISTICS

### *3.1. OVERVIEW*

#### 3.1.1. Group membership

Chair: Dave Gloeckner (SEFSC), Steve Brown (FWC), Stephanie McInerny (NCDMF), David Player (SCDNR), Julie Defilippi (ACCSP), Chris Hayes (ACCSP), Chris Robbins (Ocean Conservancy), Don DeMaria (Fisherman – Keys/SG), Richard Stiglitz (Fisherman – Keys/SG), Bill Tucker (Fisherman – Florida), Bob Spaeth (Fisherman – West Central Florida), Walter Keithly (LSU, GMFMC – SSC).

#### 3.1.2. Issues

Historical commercial landings data for red grouper were explored to address several issues. These issues included: (1) duration of data for the stock assessment, (2) methodology for proportioning Florida landings into Atlantic and Gulf, (3) methodology for proportioning all state 'unclassified' landings prior to the implementation of trip tickets, (4) methodology for proportioning landings by gear, (5) commercial discards, (6) discard mortality, (7) length compositions and (8) research needs.

### *3.2. REVIEW OF WORKING PAPERS*

**Title:** Calculated discards of red grouper from commercial vertical line fishing vessels in the US South Atlantic

**Author:** Kevin McCarthy

**Abstract:** In August 2001, the Southeast Fisheries Science Center (SEFSC) initiated a program to collect commercial fishing vessel discard data from Gulf of Mexico and US South Atlantic fisheries. A reporting form was developed that supplements the existing vessel coastal logbook forms that are currently mandatory for those fisheries (Poffenberger and McCarthy 2004). Discard data from the SEFSC coastal fisheries logbook program were used to calculate the number of red grouper that were discarded during the period January 1, 2002 through December 31, 2008.

Data collection for the discard logbook program involves, each year, a 20% random sample of the vessels with South Atlantic snapper-grouper, Gulf of Mexico reef-fish, king mackerel, Spanish mackerel, or shark permits are selected to report the number of animals discarded by species. To assure that the sample was representative of vessels with those Federal permits, the universe of permitted vessels was stratified by region and gear fished. A random sample was selected, without replacement, from each stratum. Region was defined as the Gulf of Mexico (Gulf-side of the Florida Keys-Dry Tortugas to the Texas-Mexico border) and the South Atlantic (which extends from the North Carolina-Virginia border to the southern/eastern side of the Florida Keys-Dry Tortugas). Fishing gear strata included handline, electric reel (bandit rig), trolling, longline, trap, gillnet, and diving. The selected fishers were instructed to complete a supplemental discard form for every fishing trip that they made. Trips with no discards were reported as such.

Reported data included the numbers of discards by species, estimated condition of the fish when released, reason for release (due to regulations or unmarketable/unwanted), and the

fishing area where the animal was discarded. There are six options for the condition of released fish: all animals are dead, majority of the animals are dead, all animals are alive when released, majority of animals are alive, the fish are kept but not sold, and the condition of the animals is unknown. To calculate species specific discard rates, discard data were matched to the landings and effort data reported (for the appropriate trip) to the coastal logbook program.

## *3.3. COMMERCIAL LANDINGS*

### 3.3.1 Preliminary landings and discussion on methods

Initially, the Accumulated Landings System (ALS) was queried on 20 May 2009 for all grouper landings along the Atlantic coast by state from 1962-2008. This query produced annual landings by grouper species and for unclassified groupers (available by gear) from 1962-2008 for Florida (east coast), Georgia, South Carolina, and North Carolina. Prior to 1986, individual grouper species, other than goliath or Warsaw, were not identified, so landings were for unclassified groupers. Additionally, we queried the Standard Atlantic Fisheries Information System for commercial landings of unclassified grouper from 1950-1961. To obtain any landings from north of North Carolina, we queried the Commercial Fisheries Database at the NEFSC for any records containing red grouper.

The historical data from ACCSP (originally collected by NMFS and DOI) showed no landings for red grouper, but had grouper unclassified landings, which were assumed to include red grouper. The only grouper species identified in the historical data were Warsaw and goliath groupers. The annual data on commercial landings begins in 1950, while previous to that year, data collection was inconsistent, but collected by federal agencies starting 1880. Prior to 1950, there may be gaps of up to 10 years between the collection of landings statistics in some states and even these years may not be complete. The use of interpolation to fill in years where data were not collected has been discouraged because of the annual variations in landings, which could lead to erroneous or misleading estimates (Chestnut & Davis, 1975).

**Decision 1. Because grouper landings were inconsistently collected prior to 1950, the working group recommended that the red grouper time series should not go back further than 1950.**

Only 1,980 pounds were reported as landed by otter trawl or gill net from 2002-2007 north of North Carolina, otherwise no landings were available from Virginia and north that were identified as red grouper. After discussion with the NMFS Northeast Region (NER) it was determined that these landings were most likely purchased by dealers in northern states, but landed in southern states. If so, these landings would have already been reported to the state of landing. Because these landings may have already been reported, they were not included in the landings.

**Decision 2. Because essentially no red grouper landings were reported north of North Carolina, the Workgroup recommended using the VA/NC line as the northern boundary for the South Atlantic red grouper stock.**

Historical data provided by ACCSP for commercial landings (1950-1971) splits Florida into Florida East Coast (Atlantic) and Florida West Coast (Gulf of Mexico). Subsequent data bases post stratify based on the reported area fished.

For the state of Florida, the ALS contains several data tables, one table (ALS_LANDINGS) contains landings by month, gear and area for 1978-present. However, for the period 1977-1996, gear is listed as combined; therefore, gear and area are not identified. The second table (ALS_GENERAL_CANVASS) known as the General Canvass data contains gear and area-specific information for the period 1977-1996, but not corresponding month information. The proportion by gear from the General Canvass was applied to the "combined gear" landings from the first table (ALS_LANDINGS) for the period 1977-1996 to estimate monthly landings by gear and area. The proportioned data for 1977-1996 was appended to the ALS_LANDINGS data for 1997-2008 to create a FL dataset for 1977-2008. This dataset was appended with data from a third table (ALS_LANDINGS7278) containing FL annual summaries by gear and area for 1972-1976 and a fourth table (TALS_GCANV6071) containing FL annual summaries for 1962-1971 by gear and area.

To separate the FL data into east coast and west coast, we used the same methods that were used in SEDAR 17. All Florida landings with water body codes 0010, 0019, and 7xxx (Figure 3.1) were considered South Atlantic red grouper regardless of Florida state code (10, 11, or 12). Also included were the undefined water bodies (0000 and 9999) from ALS state 10 (Atlantic).

For NC-GA, the data in the ALS_LANDINGS table are by gear, area, and month for 1977 to the present. To create a dataset for 1962-2008 for NC-FL, data for NC-FL from the TALS_GCANV6071 table and the ALS_LANDINGS7278 table were appended to the NC-GA data for 1977-2008 from the ALS_ LANDINGS table. These data were then appended to the FL data for 1962-2008, created using the above methods.

**Decision 3. The Workgroup decided to apply the same approach for dividing red grouper into South Atlantic and Gulf of Mexico stocks as was used for the recent vermilion snapper assessment (SEDAR 17). Adjustments to the ALS data are described below.**

Some differences were noted in the landings reported by trip ticket data from NC and FL. Landings from NC were lower in the ALS data compared to the trip ticket data from 1994-2008. There were also differences noted for ALS data compared to FL trip ticket data. Edits that have been made to trip ticket data may not have been made to ALS data, so trip ticket data was used for 1994-2008 for NC and 1986-2008 for FL.

**Decision 4. The Workgroup decided to use trip ticket data instead of ALS data for NC and FL where trip ticket data was available.**

The commercial group also discussed the issue of red grouper landings contained in the unclassified grouper landings.

*North Carolina*

The landings from ALS are lower across the board, which doesn't seem right. Per Stephanie, no proportions should be applied to anything after 1994. Anything before 1981 was unclassified. Per Jack Holland, we shouldn't apply proportions to the 1992 and 1993 landings because of the size limit. These landings are being accurately recorded. From 1994 on, the trip ticket goes through a lot of verification process so anything that is identified to the species level is likely correct. Stephanie contacted Jack about other species that may have been sold as red grouper.

Annual landings of red grouper are actually increasing. Don't know if this is due to the market or if both are increasing. The unclassified landings are going down, but the 'groupers' are increasing as well. As we don't have direct evidence that red grouper are still included in the unclassified landings, the trip ticket data from 1994 to 2008 will not include unclassified landings proportioned by the red grouper landings to other grouper landings.

*South Carolina*

The price of each species is distinctly different so they are usually separated out that way. David Player talked to several dealers and the other species have always been separated out and so no adjustment is needed. The group reached a similar conclusion for SC as for the other states, so no proportion of unclassified will be applied after 2003.

*Georgia*

Per Julie Califf, data in 1997 and 1998 may still have other "red" groupers assigned to the red grouper category. To correct this issue, logbook proportions of red grouper to all grouper landings were applied to all grouper landings for these years to determine red grouper landings for 1997-1998.

*Florida*

There is no reason to look at the unclassified category after 1986 (beginning of FL trip ticket) as red grouper were accurately recorded in the trip ticket data. The group reached a similar conclusion for FL as for the other states.

**Decision 5. The Workgroup decided to only proportion unclassified groupers into red grouper landings before the beginning of trip ticket programs.**

The group also discussed possible misidentification. There are high landings of red grouper from 1986-1989 and then they dropped off. Something caused the landings to drop so dramatically. The group discussed the issues of misidentification. The size limit increased from 18 to 20 inches in FL state waters in 1990 and from 12 to 20 inches in 1992 in federal waters. The group concluded that Nassau grouper could have been reported as red, but the change is likely due to the change in regulations.

An issue in the Gulf of Mexico has been that speckled hind and snowy grouper were paid the same ex-vessel price as red grouper and they were all reported as red grouper. However, there was no evidence presented that indicated that this was happening on the Atlantic side.

With the importance of catch history becoming more prominent it is possible that the proportions are changing over time as species are more accurately reported, so the method of applying proportions to unclassified landings before trip ticket programs were instituted may reflect the increasing reliability of species identification.

**Decision 6. The Workgroup decided that misidentification was at most a very small fraction and no adjustment to the landings was necessary.**

The group discussed primary gears for landings before the workshop. Analysis of the landings data indicated that handline, longline, traps and diving were the primary gears and that all other gears would be assigned to an "other" category.

Assignment of gear to the landings data was discussed. There may be problems with incorrect gear assignments in the ALS or trip ticket data, so this was discussed. There were two options: apply the proportions from logbook or use the gear assignments from trip ticket data.

*North Carolina*

Anything that shows up as long line after the ban (1992) was illegal (and most likely Marine Patrol confiscations) but the trip ticket had already been filled out so these data need to remain in the longline category. Gears weren't reported on the trip ticket until 1992. Prior to that, they were extrapolated from the fishermen's declared gear. In the past, NC has objected to using the logbook gears for years after 1993. There are gear specific assignments for all reef fish on North Carolina trip tickets. Using the logbooks is the same as using the trip tickets.

*South Carolina*

Typically the trip tickets are filled out correctly. The confidence level is pretty high.

*Georgia*

GA has negligible landings and most are handline, so no proportioning was done with logbook data.

*Florida*

FL uses a hierarchy of what gear is most likely for multiple gear trips after 1992. Before that it was based on the licensing data. The logbook methodology has been used for FL in the past. Logbooks report the trip ticket numbers now but the format is currently not consistent, so it's not always possible to match up the trip tickets and the logbooks. So logbook gear proportions were used for FL data from 1992-2008.

**Decision 7. FL will take the gear proportion based on the logbook data and apply that proportion to all landings. The trip ticket gear assignment will be used for NC, GA and SC.**

There are differences between the ALS assignment of area and the trip ticket assignment of area for FL landings in Monroe County. As logbook effort is considered more detailed than trip ticket effort, SEDAR 17 used the logbook proportions of area to assign area to Monroe County landings from trip tickets. Logbook areas are presented in Figure 3.2.

**Decision 8. It was decided to use the logbook areas to proportion Monroe County landings into area fished.**

The group discussed the treatment of unclassified grouper prior to 1981 for NC, GA, and SC and prior to 1986 for FL (first years red grouper was identified in the landings). In 1992, there was a ban on longline gear shoreward of the 50 fathom contour. This could have changed the species composition of landings after this regulation was put in place. Because of this change, it was decided to use the proportion of red grouper to all grouper landings from the first year red grouper was identified in the landings to 1991 to proportion red grouper from unclassified grouper landings.

**Decision 9. Apply the proportion of red grouper to all grouper landings prior to 1992 to the unclassified grouper landings for 1950 – 1980 for NC, GA, and SC and 1950-1985 for FL.**

Landings are originally obtained in gutted weight, and the conversion factors from gutted to whole weight vary b y state; therefore, it was decided that the state landings would be transformed back to their original gutted weight using state specific conversions of whole to gutted weight. SEDAR 12 reported the first year of gutting as 1977, so data after 1977 were converted to gutted weight using state specific conversions, while data from 1977 and before used the conversion calculated by the life history group. Because red grouper were not identified to the species level in the early time periods, landings estimates were considered most reliable starting in 1981 for NC, GA, and SC, and starting in 1986 for FL.

**Decision 10. To remain consistent with FMPs, the group reported landings in gutted weight and decided that landings were most reliable after trip ticket programs started.**

### 3.3.2 Final methods used to develop annual commercial landings by state and gear

*North Carolina*

NCDMF provided landings data from 1950-2008. Data from 1950-1980 were derived from the ALS data and historical data (from NMFS S&T) duplicated in the NCDMF data base. Data from 1981-2008 were collected by NCDMF and the original files are maintained by NCDMF, but duplicated in the ALS. The average proportion of red grouper to all other classified grouper landings (except Warsaw and goliath grouper) from 1981-1991 was applied to unclassified grouper from 1950-1980, the period before red grouper were classified. The annual proportion of red grouper to other classified groupers was applied to unclassified landings within the same year to calculate red grouper that were not classified during 1981-1991. No proportions were applied to red grouper landings from 1992-2008. The proportioned red grouper landings from the unclassified landings were added to the red grouper from 1950-1991 to derive adjusted red grouper landings. The annual proportion of red grouper landings for each gear was applied to the unclassified landings for each year to assign the gear for 1981-1991. For data prior to 1981, the average proportion of red grouper landings for each gear from 1981-1991 was applied to the calculated red grouper landings. Classified red grouper landings from 1981-2008 retained the original gear assignment.

*South Carolina*

SCDNR provided landings data from 2004-2008. Data from 1950-2003 were extracted from the ALS data and historical data (from ACCSP). Data from 1981-2008 were collected by SCDNR and duplicated in the ALS. The average proportion of red grouper to all other classified grouper landings (except Warsaw and goliath grouper) from 1981-1991 was applied to unclassified grouper from 1950-1980, the period before red grouper was classified. The annual proportion of red grouper to other classified groupers was applied to unclassified landings within the same year to calculate red grouper that were not classified during 1981-2003. The proportioned red grouper landings from the unclassified landings were added to the red grouper from

1981-2008 to derive adjusted red grouper landings. The annual proportion of red grouper landings for each gear was applied to the unclassified landings for each year to assign the gear for 1981-2003. For data prior to 1981, the average proportion of red grouper landings for each gear from 1981-1991 was applied to the calculated unclassified red grouper landings. Classified red grouper landings from 1981-2008 retained the original gear assignment.

*Georgia*

GA data from 1950-2008 were extracted from the ALS data and historical data (from ACCSP). Data from 1981-2008 were collected by GADNR and duplicated in the ALS. The average proportion of red grouper to all other classified grouper landings (except Warsaw and goliath grouper) from 1981-1991 was applied to unclassified grouper from 1950-1980, the period before red grouper was classified. The annual proportion of red grouper to other classified groupers was applied to unclassified landings within the same year to calculate red grouper that were not classified during 1981-2008. The proportioned red grouper landings from the unclassified landings were added to the red grouper from 1981-2008 to derive adjusted red grouper landings. Because of a species misidentification issue, logbook proportions of red grouper to all classified groupers were applied to the landings of all classified groupers during 1997-1998 to derive red grouper landings for 1997-1998. The annual proportion of red grouper landings for each gear was applied to the unclassified landings for each year to assign the gear for 1981-2008. For data prior to 1981, the average proportion of red grouper landings for each gear from 1981-1991 was applied to the calculated unclassified red grouper landings. Classified red grouper landings from 1981-2008 retained the original gear assignment.

*Florida*

FL data from 1950-1992 were extracted from the ALS data and historical data (from ACCSP), while FL trip ticket provided landings from 1993-2008. Data from 1986-2008 were collected by FLFWC and duplicated in the ALS. The proportion by gear and area from the General Canvass was applied to the “combined gear” landings from the ALS for the period 1977-1991 and to the FL trip ticket data from 1992-1996 to estimate monthly landings by gear and area. For all data from 1962-1991, landings from water bodies 0010, 0019, 0020, 0029 and 7xxx were assigned to the South Atlantic. For 1950-1961, all landings with state 10 were assigned to South Atlantic. For the data from 1992-2008, all landings from FL, excluding Monroe County, that had water bodies of 0010, 0019, 0020, 0029 and 7xxx were assigned to the South Atlantic. For Monroe County, logbook proportions of South Atlantic to Gulf landings were applied to the county-wide landings from Monroe County to derive South Atlantic landings from Monroe County. The average proportion of red grouper to all other classified grouper landings (except Warsaw and goliath grouper) from 1981-1991 was applied to unclassified grouper from 1950-1985, the period before red grouper was classified. The proportioned red grouper landings from the unclassified landings were added to the red grouper landings from 1986-2008 to derive adjusted red grouper landings. The logbook proportion of red grouper landings by gear was applied to the landings from 1992-2008 to estimate landings by gear. For the 1986 to 1991 data, the gear assignment from the General Canvass was used. For data prior to 1986, the average proportion of red grouper landings for each gear from 1986-1991 was applied to the calculated unclassified red grouper landings.

Final landings estimates in pounds gutted weight by gear are reported in Table 3.1 and are displayed in Figure 3.3. Pots, Diving and other gears are combined into other gear to maintain confidentiality of the landings data. Final landings in numbers (Table 3.2) were calculated with the mean weight derived by TIP data in each strata (year, state, gear) (Table 3.3). When mean weights could not be derived because of no samples or low sample size (N<20), the mean was calculated within each gear across years. Years were separated before 1992 and greater than or equal to 1992 because of size regulations implemented in 1992. If there were no samples for that gear, then the mean weight was calculated across all gears and years before or after 1992.

Estimates of coefficients of variation for each year's landings were developed by reviewing the estimates of SEDAR17 and modifying them to suit the periods when proportioning unclassified landings and the source of the data. Historical landings (proportioned to estimate red grouper landings and gear used) from 1950-1961 were assigned a CV of 0.50, landings estimated by port agents and proportioned for red grouper were assigned a CV of 0.40, landings after red grouper were classified, but had unclassified landings that were believed to include red grouper were assigned a CV of 0.20, and landings after trip ticket programs began were assigned a CV of 0.10 to indicate uncertainty about under-reporting (Table 3.4).

## *3.4. COMMERCIAL DISCARDS*

### 3.4.1 Logbook discards

Discard calculations for South Atlantic red grouper followed the methods described in SEDAR19 DW-16. Only vertical line discards and effort reported from the Florida Keys through North Carolina were included in those analyses. Data reported from other gears were insufficient for discards to be calculated. Five factors were examined with GLM analyses for their possible influence on the red grouper discard rate and proportion of trips with discards. Significant main effects were used to stratify the available discard and total effort data for total discard calculations. Calculated red grouper discards are provided in Table 3.5.

The release condition of discarded red grouper is reported in Table 3.6. In all years except 2005, over 90% of red grouper discards were reported as “alive” or “majority alive” when released. In 2005, 89% of discards were reported as “alive” or “majority alive”. The category “kept” also accounted for a low percentage of red grouper in the discard reports.

The reason “due to regulatory restrictions” accounted for approximately 90% of reported red grouper discards over all years. Beginning in 2008, the regulatory restriction reporting category was expanded to differentiate between fish discarded due to size restriction and those discarded due to fishery closures. Approximately 85% of red grouper discards were reported as discarded due to size restrictions with another 11% discarded due to unspecified regulatory restrictions.

The number of vertical line trips reporting red grouper discards in the US South Atlantic varied from 73 to 149 per year. The total number of annual vertical line trips with discard reports ranged from 1,187 to 4,651 each year, although many of those reports were showed no discards during a trip. The percentage of trips reporting “no discards” increased since the inception of the discard logbook program; nearly doubling from 33.5% to 66%. Given the increasing number of “no discards” reporting trips, red grouper discards from South Atlantic vertical line vessels may be underreported and the generally decreasing trend in number of discards per year since 2002 may be due to lack of reporting.

### 3.4.2 Observer Data

Limited observer data were available for analysis. An observer program was begun in the Gulf of Mexico in July 2006 and is ongoing. South Atlantic observer trips on vertical line vessels began in 2007 (a single 2006 trip had observer coverage). Funding cuts reduced the number of observer trips in both regions during 2008. A total of 219 Gulf of Mexico and South Atlantic vertical line trips had observer reports.

Discard rates from South Atlantic vertical line observer data were calculated for red grouper during 2007 to compare with self-reported discard rates from the discard logbook data. Available data in other years were too few for analysis. All vertical line observer trips reported during 2007 from the South Atlantic were combined to calculate a single overall discard rate because the data were too limited for any stratification. Those observer data were reported by “set”, where set for vertical line gear was defined as the time spent fishing in any single location. When the vessel moved to a new location a new set began. A discard rate was calculated for each set and an overall mean discard rate was then determined. Total vertical line effort reported to the coastal logbook program by vessels fishing in the South Atlantic was summed and applied to the observer reported mean red grouper discard rate to calculate total red grouper discards for 2007.

The observer discard rate was 0.026401 discarded red grouper per hook hour fished with a standard deviation of 0.413604. The mean observer reported discard rate cannot be directly compared to the self reported discard rate for 2007 because the self reported data were stratified by subregion, days at sea, and number of crew. For most strata, however, the self reported discard rates were much lower than the observer reported rate. Those strata with higher self reported discard rates than the observer reported discard rate accounted for only 12.25% of the total vertical line effort and, therefore, had relatively few calculated discards. Total discards calculated using the observer data totaled 26,548 red grouper in 2007. A large number of undersize red grouper were reported as kept: 23 sublegal kept, while 38 discards were reported for the entire data set. Those sublegal kept fish were not included in the total discard calculation. Calculated total discards from observer data were three times the number of discarded fish calculated from the self reported data. South Atlantic red grouper self reported discards may be underreported given the discard calculations based upon observer data. The observer data sample size, however, was low and conclusions based upon those data should be regarded as preliminary.

**Decision 11: The group decided to accept the logbook estimates, although there seems to be a decreasing trend in discard estimates that may be due to under-reporting. The degree of impact of such reporting, resulting in more "no discard" trips, is unknown. Estimated discards are reported in table 3.5.**

### *3.5. DISCARD MORTALITY*

The commercial fishery for red grouper in the South Atlantic primarily utilizes handlines, therefore, release mortality estimates will be estimated based on this primary gear. Release mortality for red grouper was reported by the life history group to be somewhere around 10% based on several manuscripts published within the last 13 years using surface observations. A delayed mortality that estimates mortality after the fish has left the surface was also calculated to be around 70.6% (Rudershausen et al. 2007). Red grouper release morality was roughly estimated from the commercial logbooks at around 15% for handline gear (SEDAR19-DW16). Input from the Gulf of Mexico (GOM) fishermen attending the data workshop confirmed this 10-15% discard mortality for red grouper at the surface. In comparison, SEDAR 12 (GOM red grouper) used 10% release mortality for handline and 40% for longlines for this species in the Gulf (SEDAR 12).

Based on these previously reported estimates of release mortality, the commercial workgroup suggested a point estimate of 15% mortality for red grouper with a sensitivity range of 10-20%. This estimate was discussed at the plenary and was determined to be a low estimate of release mortality for this species because it did not include any measure of delayed mortality. It was suggested that the red grouper release mortality be upped to 25% with sensitivities from 15-35% but some members of the plenary group were not comfortable with this increase so the estimate dropped to 20%. Sensitivities were widened to included 10% (common mortality for surface observation studies) and 30% (a higher estimate for mortality than observed to include more delayed mortality possibilities). Total discards reported for red grouper are relatively low compared to the reported landings. Discards of red grouper and dead discards of red grouper by handline gear are reported in Table 3.7. Landings and dead discards are presented in Figure 3.4.

**Decision 12: The commercial workgroup recommends using 20% as the point estimate for release mortality for red grouper with a sensitivity range of 10-30%.**

### *3.6. COMMERCIAL EFFORT*

Commercial effort and CPUE was presented to the indices group by Kevin McCarthy in SEDAR19 DW14 and will not be presented here.

Trip ticket indices were also calculated and included effort, but this data does not have the temporal resolution of logbook effort and was not used by the indices group. For this reason we do not present that data in this section.

### *3.7. BIOLOGICAL SAMPLING*

Length samples have been collected by the Trip Interview Program (TIP) and several state agencies since 1981. These samples are collected by port agents at docks where commercial catches are landed throughout the US South Atlantic coast. Trips are randomly sampled to obtain trip, effort, catch and length frequency information. Occasionally there has been quota sampling to obtain age structures on fish that are rare in the catch (extremely large and small fish). These non-random samples are identified in the data to allow removal from analyses where non-random samples are not appropriate. Red grouper were not sampled by market category, so exclusion of market category samples or comparison of market category vs. unclassified market category in the samples was not necessary for this species.

Biological sample data were obtained from the TIP sample data (NMFS/SEFSC), which is a data set of sampling data from commercial, recreational, and fishery independent research programs. A subset of these data were used for analyses, which contained commercial samples that were identified as having no sampling bias. These data were further limited to those that could be assigned a year, gear, and state. Data that had an unknown sampling year, gear, or sampling state were deleted from the file. Biological data were joined with landings data by year, gear, and state. Landings data were also limited to only those data that could be assigned a year, gear, and state. Landings and biological data were assigned a state based on landing and sample location. Where no trip landing data were available, the sample was dropped.

### 3.7.1 Sampling Intensity

#### *3.7.1.1 Length samples*

The number of trips sampled ranged from a high of 298 for handline gear in 2007 landed in NC to a low of zero for a great many strata (Table 3.9). The number of trips sampled were consistently greater than 10 trips for handline gear in FL from 1990-2004 and 1998-2003, and handline gear in SC from 1996-2008. Longline, pots and traps, and diving trips were rarely sampled in any state. Handline was the only gear sampled in GA, but even this gear had fewer than 10 trips sampled in any given year.

The number of fish sampled had a high of 2,738 for handline gear in 2007 landed in NC to lows of zero for many of the strata (Table 3.10). Length samples followed the same trends; whereas, the number of lengths sampled were consistently greater than 100 for handline gear in FL from 1993-1995 and 1998-2003, and handline gear in SC from 1996-2008. Longline, pots and traps, and diving trips were rarely sampled in any state. Handline was the only gear sampled in GA, but even this gear had fewer than 100 lengths sampled in 6 out of the 9 years with samples.

*3.7.1.2 Age samples*

The WG had no comments

### 3.7.2 Length/Age Distributions

*3.7.2.1 Length distributions*

Length data were converted to cm total length and binned into one centimeter group with a floor of 0.6 cm and a ceiling of 0.5 cm. Length was converted to weight (gutted weight in pounds) using conversions provided by the life history group. The length data and landings data were divided into handline, longline, traps, diving, and other gears. Length compositions were weighted by the trip landings in numbers and the landings in numbers by strata (state, year, gear).

Annual length compositions of red grouper are summarized in Figures 3.5 – 3.9.

*3.7.2.2 Age Distributions*

Sample size and number of trips sampled for red grouper ages from handline gear were summarized by state from commercial landings in the US Atlantic for 1988-2008 (Table 3.11). Age compositions of samples were only developed for handline (1988-2008, Figure 3.10). Ages were then weighted by 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).

### 3.7.3 Adequacy for characterizing catch

*3.7.3.1 Lengths*

Length sampling has been extensive for red grouper from the handline fishery, with more than 13,983 fish sampled for length. These samples are primarily from NC (13.9% from FL, 22.1% from SC, and 63.6% from NC, and 0.3% from GA). Large longline samples were available for FL from 1986 to 1989 and 1991, but other years were sparse. Other states had sparse and inconsistent samples for the longline fishery. An average of 1,129 fish sampled were available annually from 1984-2008. While handline samples were adequate for the fishery as a whole, longline samples were inconsistently sampled after 1991. Pot and trap samples were only adequate for 1986, 1987, 1989, and 1990, although the number of trips sampled was small. Length sampling percentages are displayed in Table 3.12.

#### *3.7.3.2 Ages*

Of the 5,316 aged red grouper, all of them were from the commercial handline fishery. The ages from handline gear were distributed among the states as follows: 331 from Atlantic Florida, 0 from Georgia, 962 from South Carolina, and 4,293 from North Carolina. It was noted that all samples collected between 1997 and 2002 were from Atlantic Florida and this may be of particular concern because no post-stratification of samples by state is possible for these years. Any age composition for these years is representative of Florida alone, and not necessarily of the coastwide stock. Age sampling percentages are displayed in Table 3.13.

### 3.7.4 Alternatives for characterizing discard length/age

The group discussed alternatives for characterizing lengths and ages of discards. As this data does not exist in any known database, the group suggests using a regulatory approach.

## *3.8. COMMERCIAL CATCH-AT-AGE/LENGTH; DIRECTED AND DISCARD*

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

## *3.9. COMMENTS ON THE ADEQUACY OF DATA FOR ASSESSMENT ANALYSES*

Landings data are reliable since the beginning of trip ticket programs, however: proportioning of unclassified grouper landings to red grouper creates error in these estimates of red grouper landings. For periods where groupers were not classified (prior to 1981 for NC, SC, and GA; prior to 1986 for FL), uncertainty is even higher.

### *3.10. POST WORKSHOP TASKS*

- Discard mortality estimates: McInerny: 7/1/09
- Preliminary documentation of discussions and results: Defillippi, 7/6/09
- TIP length samples: Gloeckner, 7/15/09
- TIP sampling fractions: Gloeckner, 7/15
- TIP length frequencies: Gloeckner, 7/15
- Commercial age sampling fractions: Gloeckner, 7/15
- Commercial age frequencies: Gloeckner, 7/15
- Commercial effort: Gloeckner, 7/15
- Final landings in pounds: Gloeckner, 7/15
- Final landings in numbers: Gloeckner, 7/15
- Workshop document: Gloeckner, 7/24

### *3.11. RESEARCH RECOMMENDATIONS FOR RED GROUPER*

- Still need observer coverage for the snapper-grouper fishery
- 5-10% allocated by strata within states
- get maximum information from fish
- Expand TIP sampling to better cover all statistical strata
- Predominantly by H&L gear
- In that sense, we have decent coverage for lengths
- Trade off with lengths versus ages, need for more ages (i.e., hard parts)
- Workshop to resolve historical commercial landings for a suite of snapper-grouper species
- Monroe County (SA-GoM division)
- Historical species identification (mis-identification and unclassified)

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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 as early as the late1890s. 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 began in 1962.

In addition to 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

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

Beginning in 1986, mandatory reporting by all seafood dealers was implemented by the State of Florida. The State requires 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.

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

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

Marine Fisheries Service to maintain the monthly surveys of North Carolina's major commercial seafood dealers and to obtain data from more dealers.

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

### *3.12. LITERATURE CITED*

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## *3.13. TABLES*

**Table 3.1.** Commercial landings by gear and year in pounds gutted weight. Longline data for 2007 and 2008 are confidential(-).

| | GEAR | | |
|---|---|---|---|
| YEAR | HAND LINES | LONG LINES | OTHER |
| 1950 | 76,199 | 34,795 | 72,419 |
| 1951 | 111,335 | 50,846 | 105,840 |
| 1952 | 76,441 | 34,910 | 72,662 |
| 1953 | 63,476 | 28,989 | 60,338 |
| 1954 | 64,211 | 29,325 | 61,037 |
| 1955 | 32,123 | 14,670 | 30,535 |
| 1956 | 34,524 | 15,248 | 31,738 |
| 1957 | 60,405 | 26,391 | 56,618 |
| 1958 | 19,965 | 8,667 | 18,040 |
| 1959 | 16,759 | 7,484 | 15,576 |
| 1960 | 21,656 | 9,875 | 20,554 |
| 1961 | 21,985 | 10,035 | 20,920 |
| 1962 | 41,147 | 18,783 | 39,104 |
| 1963 | 48,861 | 22,306 | 46,429 |
| 1964 | 50,100 | 22,853 | 47,566 |
| 1965 | 40,921 | 18,672 | 38,852 |
| 1966 | 37,180 | 16,857 | 35,152 |
| 1967 | 61,097 | 27,654 | 57,891 |
| 1968 | 87,021 | 39,203 | 81,609 |
| 1969 | 70,731 | 32,271 | 67,215 |
| 1970 | 96,090 | 43,767 | 91,148 |
| 1971 | 96,975 | 43,914 | 91,450 |
| 1972 | 61,338 | 27,874 | 58,079 |
| 1973 | 77,274 | 34,991 | 73,040 |
| 1974 | 105,036 | 46,542 | 96,982 |
| 1975 | 135,477 | 61,007 | 127,023 |
| 1976 | 168,163 | 76,413 | 159,057 |
| 1977 | 133,876 | 60,211 | 125,358 |
| 1978 | 171,389 | 67,890 | 141,319 |
| 1979 | 157,257 | 60,206 | 125,293 |
| 1980 | 125,049 | 46,416 | 96,073 |
| 1981 | 139,258 | 56,145 | 116,867 |
| 1982 | 140,950 | 49,755 | 104,834 |
| 1983 | 135,912 | 52,947 | 110,208 |
| 1984 | 154,178 | 65,301 | 131,143 |

**Table 3.1.** Continued

| | GEAR | | |
|---|---|---|---|
| YEAR | HAND LINES | LONG LINES | OTHER |
| 1985 | 139,978 | 46,896 | 93,347 |
| 1986 | 164,675 | 67,174 | 121,353 |
| 1987 | 167,487 | 8,522 | 109,670 |
| 1988 | 150,147 | 76,505 | 102,972 |
| 1989 | 146,024 | 67,541 | 105,502 |
| 1990 | 98,873 | 61,584 | 94,620 |
| 1991 | 86,566 | 42,556 | 69,440 |
| 1992 | 99,439 | 20,113 | 37,065 |
| 1993 | 148,320 | 7,697 | 15,283 |
| 1994 | 134,115 | 19,258 | 9,362 |
| 1995 | 185,524 | 27,916 | 8,731 |
| 1996 | 251,245 | 7,964 | 17,736 |
| 1997 | 286,621 | 1,847 | 17,472 |
| 1998 | 375,368 | 25,017 | 32,916 |
| 1999 | 348,293 | 27,140 | 15,799 |
| 2000 | 283,285 | 34,404 | 11,461 |
| 2001 | 267,296 | 36,742 | 40,710 |
| 2002 | 297,107 | 10,241 | 29,044 |
| 2003 | 275,226 | 9,867 | 20,553 |
| 2004 | 251,836 | 16,306 | 29,333 |
| 2005 | 186,072 | 1,381 | 12,308 |
| 2006 | 298,937 | 1,170 | 7,105 |
| 2007 | 528,022 | - | 13,938 |
| 2008 | 547,583 | - | 8,703 |

**Table 3.2.** Commercial landings by gear and year in numbers. Longline data for 2007 and 2008 are confidential(-).

| | GEAR | | |
|---|---|---|---|
| YEAR | HAND LINES | LONG LINES | OTHER |
| 1950 | 15,998 | 6,323 | 17,266 |
| 1951 | 23,375 | 9,240 | 25,234 |
| 1952 | 16,049 | 6,344 | 17,325 |
| 1953 | 13,327 | 5,268 | 14,386 |
| 1954 | 13,481 | 5,329 | 14,553 |
| 1955 | 6,744 | 2,666 | 7,280 |
| 1956 | 7,249 | 2,771 | 7,567 |
| 1957 | 12,682 | 4,796 | 13,409 |
| 1958 | 4,192 | 1,575 | 4,301 |
| 1959 | 3,519 | 1,360 | 3,714 |
| 1960 | 4,547 | 1,794 | 4,900 |
| 1961 | 4,616 | 1,824 | 4,986 |
| 1962 | 8,639 | 3,413 | 9,323 |
| 1963 | 10,259 | 4,054 | 11,070 |
| 1964 | 10,519 | 4,153 | 11,341 |
| 1965 | 8,592 | 3,393 | 9,263 |
| 1966 | 7,806 | 3,063 | 8,379 |
| 1967 | 12,828 | 5,025 | 13,800 |
| 1968 | 18,271 | 7,124 | 19,457 |
| 1969 | 14,850 | 5,864 | 16,023 |
| 1970 | 20,175 | 7,953 | 21,729 |
| 1971 | 20,360 | 7,980 | 21,801 |
| 1972 | 12,878 | 5,065 | 13,844 |
| 1973 | 16,224 | 6,359 | 17,419 |
| 1974 | 22,053 | 8,458 | 23,123 |
| 1975 | 28,444 | 11,086 | 30,286 |
| 1976 | 35,307 | 13,886 | 37,921 |
| 1977 | 28,108 | 10,942 | 29,882 |
| 1978 | 35,984 | 12,337 | 33,682 |
| 1979 | 33,017 | 10,941 | 29,868 |
| 1980 | 26,255 | 8,435 | 22,882 |
| 1981 | 29,238 | 10,203 | 27,864 |
| 1982 | 29,593 | 9,042 | 24,927 |
| 1983 | 28,535 | 9,622 | 26,277 |
| 1984 | 30,396 | 11,867 | 31,268 |
| 1985 | 10,272 | 8,294 | 22,256 |

**Table 3.2.** Continued

| YEAR | GEAR HAND LINES | LONG LINES | OTHER |
|---|---|---|---|
| 1986 | 37,496 | 11,022 | 26,737 |
| 1987 | 35,409 | 1,767 | 31,603 |
| 1988 | 37,044 | 17,053 | 19,576 |
| 1989 | 41,068 | 17,773 | 25,861 |
| 1990 | 15,030 | 10,529 | 15,525 |
| 1991 | 15,015 | 4,606 | 13,105 |
| 1992 | 12,168 | 1,996 | 4,399 |
| 1993 | 14,768 | 764 | 1,848 |
| 1994 | 16,933 | 1,903 | 1,149 |
| 1995 | 22,539 | 2,785 | 1,077 |
| 1996 | 28,320 | 790 | 2,184 |
| 1997 | 32,688 | 183 | 2,156 |
| 1998 | 51,372 | 2,482 | 4,034 |
| 1999 | 43,076 | 2,693 | 1,944 |
| 2000 | 35,194 | 3,414 | 1,362 |
| 2001 | 26,971 | 3,646 | 4,912 |
| 2002 | 29,486 | 1,016 | 3,533 |
| 2003 | 31,707 | 979 | 2,513 |
| 2004 | 27,264 | 1,618 | 3,553 |
| 2005 | 20,825 | 137 | 1,515 |
| 2006 | 34,805 | 116 | 875 |
| 2007 | 62,035 | - | 1,720 |
| 2008 | 57,105 | - | 1,077 |

**Table 3.3.** Mean weights in pounds gutted weight used to derive landings in numbers by year, state and gear.

| STATE | FL | | | | | GA | | | | | NC | | | | | SC | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS |
| 1950 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1951 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1952 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1953 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1954 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1955 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1956 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1957 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1958 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1959 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1960 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1961 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1962 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1963 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1964 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1965 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1966 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1967 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1968 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1969 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1970 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1971 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1972 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1973 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1974 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1975 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |

**Table 3.3.** Continued.

| STATE | FL | | | | | GA | | | | | NC | | | | | SC | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS |
| 1976 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1977 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1978 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1979 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1980 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1981 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1982 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1983 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1984 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 11.627 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1985 | 8.430 | 15.583 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 11.580 | 14.393 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1986 | 8.430 | 4.012 | 6.095 | 5.406 | 4.381 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 10.205 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1987 | 8.430 | 4.469 | 4.256 | 5.406 | 2.739 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 10.780 | 8.785 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1988 | 8.430 | 3.856 | 4.064 | 5.406 | 5.179 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 5.470 | 10.407 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1989 | 8.430 | 3.188 | 3.773 | 5.406 | 3.308 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 7.271 | 5.503 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1990 | 8.430 | 6.180 | 5.503 | 5.406 | 6.872 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 7.229 | 11.738 | 5.406 | 3.665 | 8.430 | 6.554 | 5.503 | 5.406 | 3.665 |
| 1991 | 8.430 | 5.351 | 8.735 | 5.406 | 4.852 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 | 8.430 | 7.101 | 10.429 | 5.406 | 3.665 | 8.430 | 4.763 | 5.503 | 5.406 | 3.665 |
| 1992 | 8.078 | 7.649 | 10.077 | 8.430 | 8.570 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 9.322 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 |
| 1993 | 8.078 | 10.907 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 9.043 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 |
| 1994 | 8.078 | 7.561 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 8.128 | 11.754 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 |
| 1995 | 8.078 | 8.293 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 8.251 | 9.566 | 8.430 | 9.170 | 8.078 | 6.165 | 10.077 | 8.430 | 9.170 |
| 1996 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 8.616 | 10.077 | 8.430 | 9.170 | 8.078 | 8.845 | 10.077 | 8.430 | 9.170 |
| 1997 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 8.630 | 10.077 | 8.430 | 9.170 | 8.078 | 7.383 | 10.077 | 8.430 | 9.170 |
| 1998 | 8.078 | 6.679 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 7.957 | 10.077 | 8.430 | 9.170 | 8.078 | 7.477 | 10.077 | 8.430 | 9.170 |
| 1999 | 8.078 | 7.673 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 8.371 | 10.077 | 8.430 | 9.170 | 8.078 | 7.984 | 10.077 | 8.430 | 9.170 |
| 2000 | 8.078 | 6.506 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 8.741 | 10.077 | 8.430 | 9.170 | 8.078 | 9.355 | 10.077 | 8.430 | 9.170 |
| 2001 | 8.078 | 8.540 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 11.133 | 10.077 | 8.430 | 9.170 | 8.078 | 10.811 | 10.077 | 8.430 | 9.170 |

**Table 3.3.** Continued.

| STATE | FL | | | | | GA | | | | | NC | | | | | SC | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS |
| 2002 | 8.078 | 7.525 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 12.402 | 10.077 | 8.430 | 9.170 | 8.078 | 11.891 | 10.077 | 8.430 | 9.170 |
| 2003 | 8.078 | 5.726 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 12.116 | 10.077 | 8.430 | 9.170 | 8.078 | 11.429 | 10.077 | 8.430 | 9.170 |
| 2004 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 27.460 | 10.077 | 8.430 | 9.170 | 8.078 | 9.662 | 10.077 | 8.430 | 9.170 | 7.224 | 8.451 | 10.077 | 8.430 | 9.170 |
| 2005 | 8.078 | 6.700 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 10.070 | 10.077 | 8.430 | 9.170 | 8.078 | 10.085 | 10.077 | 8.430 | 9.170 |
| 2006 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 8.726 | 10.077 | 8.430 | 9.170 | 8.078 | 7.952 | 10.077 | 8.430 | 9.170 |
| 2007 | 8.078 | 8.108 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 8.817 | 10.077 | 8.430 | 10.259 | 8.078 | 7.863 | 10.077 | 8.430 | 9.170 |
| 2008 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 9.054 | 10.077 | 8.430 | 9.170 | 8.078 | 9.422 | 10.077 | 8.430 | 9.170 | 8.078 | 10.189 | 10.077 | 8.430 | 9.170 |

**Table 3.4.** Estimated coefficients of variation to be applied to commercial landings.

| YEAR | STATE | | | |
|---|---|---|---|---|
| | FL | GA | NC | SC |
| 1950 | 0.50 | 0.50 | 0.50 | 0.50 |
| 1951 | 0.50 | 0.50 | 0.50 | 0.50 |
| 1952 | 0.50 | 0.50 | 0.50 | 0.50 |
| 1953 | 0.50 | 0.50 | 0.50 | 0.50 |
| 1954 | 0.50 | 0.50 | 0.50 | 0.50 |
| 1955 | 0.50 | 0.50 | 0.50 | 0.50 |
| 1956 | 0.50 | 0.50 | 0.50 | 0.50 |
| 1957 | 0.50 | 0.50 | 0.50 | 0.50 |
| 1958 | 0.50 | 0.50 | 0.50 | 0.50 |
| 1959 | 0.50 | 0.50 | 0.50 | 0.50 |
| 1960 | 0.50 | 0.50 | 0.50 | 0.50 |
| 1961 | 0.50 | 0.50 | 0.50 | 0.50 |
| 1962 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1963 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1964 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1965 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1966 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1967 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1968 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1969 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1970 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1971 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1972 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1973 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1974 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1975 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1976 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1977 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1978 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1979 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1980 | 0.40 | 0.40 | 0.40 | 0.40 |
| 1981 | 0.40 | 0.20 | 0.20 | 0.20 |
| 1982 | 0.40 | 0.20 | 0.20 | 0.20 |
| 1983 | 0.40 | 0.20 | 0.20 | 0.20 |
| 1984 | 0.40 | 0.20 | 0.20 | 0.20 |
| 1985 | 0.40 | 0.20 | 0.20 | 0.20 |
| 1986 | 0.20 | 0.20 | 0.20 | 0.20 |
| 1987 | 0.20 | 0.20 | 0.20 | 0.20 |

**Table 3.4** continued

| YEAR | STATE | | | |
|---|---|---|---|---|
| | FL | GA | NC | SC |
| 1988 | 0.20 | 0.20 | 0.20 | 0.20 |
| 1989 | 0.20 | 0.20 | 0.20 | 0.20 |
| 1990 | 0.20 | 0.20 | 0.20 | 0.20 |
| 1991 | 0.20 | 0.20 | 0.20 | 0.20 |
| 1992 | 0.20 | 0.20 | 0.20 | 0.20 |
| 1993 | 0.20 | 0.20 | 0.20 | 0.20 |
| 1994 | 0.20 | 0.10 | 0.20 | 0.20 |
| 1995 | 0.20 | 0.10 | 0.20 | 0.20 |
| 1996 | 0.20 | 0.10 | 0.20 | 0.20 |
| 1997 | 0.10 | 0.10 | 0.20 | 0.20 |
| 1998 | 0.10 | 0.10 | 0.20 | 0.20 |
| 1999 | 0.10 | 0.10 | 0.20 | 0.20 |
| 2000 | 0.10 | 0.10 | 0.20 | 0.20 |
| 2001 | 0.10 | 0.10 | 0.20 | 0.20 |
| 2002 | 0.10 | 0.10 | 0.20 | 0.10 |
| 2003 | 0.10 | 0.10 | 0.20 | 0.10 |
| 2004 | 0.10 | 0.10 | 0.10 | 0.10 |
| 2005 | 0.10 | 0.10 | 0.10 | 0.10 |
| 2006 | 0.10 | 0.10 | 0.10 | 0.10 |
| 2007 | 0.10 | 0.10 | 0.10 | 0.10 |
| 2008 | 0.10 | 0.10 | 0.10 | 0.10 |

**Table 3.5.** Calculated annual commercial vertical line red grouper discards by year. Discards are reported in number of fish.

| Year | Red Grouper Vertical Line Calculated Discards |
|---|---|
| 1992 | 8,915 |
| 1993 | 8,575 |
| 1994 | 14,397 |
| 1995 | 10,489 |
| 1996 | 11,582 |
| 1997 | 14,709 |
| 1998 | 10,461 |
| 1999 | 12,956 |
| 2000 | 10,869 |
| 2001 | 8,423 |
| 2002 | 21,608 |
| 2003 | 11,354 |
| 2004 | 10,850 |
| 2005 | 9,992 |
| 2006 | 4,933 |
| 2007 | 8,571 |
| 2008 | 1,993 |

**Table 3.6.** Estimated condition at release of red grouper commercial vertical line discards. Annual percent of discards reported by release condition category.

| Species/Gear | Year | All Dead | Majority Dead | All Alive | Majority Alive | Kept | Unknown | Unreported | N Fish |
|---|---|---|---|---|---|---|---|---|---|
| Red grouper | 2002 | 0.00% | 0.00% | 87.06% | 9.41% | 3.53% | 0.00% | | **468** |
| Vertical line | 2003 | 0.91% | 5.45% | 76.36% | 16.36% | 0.91% | 0.00% | | **473** |
| | 2004 | 1.90% | 0.00% | 94.29% | 2.86% | 0.95% | 0.00% | | **662** |
| | 2005 | 1.60% | 0.80% | 80.80% | 8.00% | 0.00% | 8.80% | | **628** |
| | 2006 | 0.00% | 0.00% | 82.19% | 16.44% | 1.37% | 0.00% | | **521** |
| | 2007 | 0.00% | 0.00% | 93.29% | 6.04% | 0.67% | 0.00% | | **889** |
| | 2008 | 0.00% | 3.81% | 86.67% | 9.52% | 0.00% | 0.00% | | **525** |
| | **N Fish** | **10** | **142** | **3,447** | **466** | **14** | **87** | | **4,166** |

**Table 3.7.** Estimated handline discards and dead discards in numbers and converted to pounds gutted weight using the TIP handline mean weights for each year.

| Year | Red Grouper Vertical Line Calculated Discards in Numbers | Red Grouper Vertical Line Discards in Pounds | Mortality | Red Grouper Vertical Line Dead Discards in Numbers | Mean Weight | Red Grouper Vertical Line Dead Discards Pounds Gutted |
|---|---|---|---|---|---|---|
| 1992 | 8,915 | 81,490 | 0.20 | 1,783.00 | 9.141 | 81,490 |
| 1993 | 8,575 | 78,621 | 0.20 | 1,715.00 | 9.169 | 78,621 |
| 1994 | 14,397 | 112,230 | 0.20 | 2,879.40 | 7.795 | 112,230 |
| 1995 | 10,489 | 85,751 | 0.20 | 2,097.80 | 8.175 | 85,751 |
| 1996 | 11,582 | 100,856 | 0.20 | 2,316.40 | 8.708 | 100,856 |
| 1997 | 14,709 | 114,717 | 0.20 | 2,941.80 | 7.799 | 114,717 |
| 1998 | 10,461 | 80,711 | 0.20 | 2,092.20 | 7.715 | 80,711 |
| 1999 | 12,956 | 105,566 | 0.20 | 2,591.20 | 8.148 | 105,566 |
| 2000 | 10,869 | 96,874 | 0.20 | 2,173.80 | 8.913 | 96,874 |
| 2001 | 8,423 | 89,473 | 0.20 | 1,684.60 | 10.622 | 89,473 |
| 2002 | 21,608 | 260,577 | 0.20 | 4,321.60 | 12.059 | 260,577 |
| 2003 | 11,354 | 112,607 | 0.20 | 2,270.80 | 9.918 | 112,607 |
| 2004 | 10,850 | 107,200 | 0.20 | 2,170.00 | 9.880 | 107,200 |
| 2005 | 9,992 | 99,461 | 0.20 | 1,998.40 | 9.954 | 99,461 |
| 2006 | 4,933 | 42,641 | 0.20 | 986.60 | 8.644 | 42,641 |
| 2007 | 8,571 | 74,101 | 0.20 | 1,714.20 | 8.646 | 74,101 |
| 2008 | 1,993 | 19,121 | 0.20 | 398.60 | 9.594 | 19,121 |

**Table 3.8.** Vertical line relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for red grouper (1993-2008) in the South Atlantic.

| YEAR | Relative Nominal CPUE | Trips | Proportion Successful Trips | Relative Index | Lower 95% CI (Index) | Upper 95% CI (Index) | CV (Index) |
|---|---|---|---|---|---|---|---|
| 1993 | 0.249802 | 988 | 0.408907 | 0.313331 | 0.220243 | 0.445762 | 0.177641 |
| 1994 | 0.29867 | 1,820 | 0.408242 | 0.296877 | 0.227863 | 0.386794 | 0.132867 |
| 1995 | 0.476702 | 2,024 | 0.479249 | 0.488562 | 0.399869 | 0.596928 | 0.100417 |
| 1996 | 0.362009 | 1,877 | 0.548748 | 0.486361 | 0.403475 | 0.586276 | 0.093624 |
| 1997 | 0.633103 | 2,439 | 0.603936 | 0.626811 | 0.543432 | 0.722983 | 0.071461 |
| 1998 | 0.867402 | 2,423 | 0.685927 | 0.950609 | 0.843615 | 1.071173 | 0.059757 |
| 1999 | 1.165701 | 1,944 | 0.803498 | 1.399444 | 1.257253 | 1.557716 | 0.053611 |
| 2000 | 1.117681 | 1,848 | 0.723485 | 1.069951 | 0.942042 | 1.215229 | 0.063724 |
| 2001 | 0.930686 | 2,236 | 0.637746 | 0.836165 | 0.728358 | 0.959929 | 0.069099 |
| 2002 | 1.006297 | 2,210 | 0.597285 | 0.849904 | 0.735875 | 0.981601 | 0.072125 |
| 2003 | 1.081551 | 1,784 | 0.640135 | 1.039766 | 0.898614 | 1.20309 | 0.073046 |
| 2004 | 0.974075 | 1,664 | 0.671274 | 0.986405 | 0.855541 | 1.137285 | 0.071256 |
| 2005 | 0.86667 | 1,559 | 0.694676 | 0.895343 | 0.772231 | 1.038081 | 0.074063 |
| 2006 | 1.581477 | 1,550 | 0.791613 | 1.399341 | 1.237043 | 1.582932 | 0.061697 |
| 2007 | 2.346077 | 1,841 | 0.785986 | 2.02523 | 1.817331 | 2.256912 | 0.054197 |
| 2008 | 2.042096 | 1,700 | 0.808235 | 2.3359 | 2.095787 | 2.603523 | 0.054274 |

**Table 3.9.** Number of trips sampled by year and gear.

| | GEAR | | | | |
|---|---|---|---|---|---|
| YEAR | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS |
| 1984 | | 18 | 1 | | |
| 1985 | | 26 | 5 | | |
| 1986 | | 24 | 9 | | 13 |
| 1987 | | 29 | 17 | | 6 |
| 1988 | | 53 | 14 | | 1 |
| 1989 | | 60 | 2 | 1 | 8 |
| 1990 | | 70 | 3 | 3 | 6 |
| 1991 | | 66 | 11 | | 5 |
| 1992 | 2 | 42 | | | 2 |
| 1993 | 2 | 71 | | | |
| 1994 | | 74 | 2 | | 1 |
| 1995 | | 85 | 9 | | |
| 1996 | | 79 | | | |
| 1997 | | 64 | | | |
| 1998 | 1 | 103 | 2 | | |
| 1999 | 8 | 176 | | | |
| 2000 | 5 | 214 | | | |
| 2001 | 4 | 149 | | | |
| 2002 | | 115 | 1 | | |
| 2003 | 2 | 135 | | | |
| 2004 | 2 | 181 | | | |
| 2005 | | 240 | | | |
| 2006 | | 283 | | | |
| 2007 | | 399 | | | 4 |
| 2008 | | 362 | | | |

**Table 3.10.** Number of lengths collected by year and gear.

| | GEAR | | | | |
|---|---|---|---|---|---|
| YEAR | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS |
| 1984 | | 69 | 22 | | |
| 1985 | | 79 | 52 | | |
| 1986 | | 328 | 689 | | 1243 |
| 1987 | | 573 | 937 | | 756 |
| 1988 | | 1034 | 941 | | 33 |
| 1989 | | 626 | 148 | 1 | 357 |
| 1990 | | 400 | 203 | 4 | 70 |
| 1991 | | 300 | 327 | | 30 |
| 1992 | 10 | 194 | | | 21 |
| 1993 | 11 | 429 | | | |
| 1994 | | 538 | 38 | | 15 |
| 1995 | | 789 | 275 | | |
| 1996 | | 364 | | | |
| 1997 | | 400 | | | |
| 1998 | 1 | 684 | 4 | | |
| 1999 | 18 | 1636 | | | |
| 2000 | 5 | 1595 | | | |
| 2001 | 5 | 850 | | | |
| 2002 | | 593 | 3 | | |
| 2003 | 2 | 809 | | | |
| 2004 | 6 | 1239 | | | |
| 2005 | | 1299 | | | |
| 2006 | | 2049 | | | |
| 2007 | | 2738 | | | 26 |
| 2008 | | 2356 | | | |

**Table 3.11.** Number of commercial age samples collected and number of trips from which the age samples were collected.

| Year | State | | |
|---|---|---|---|
| | FL | NC | SC |
| 1988 | | 5 (1) | |
| 1989 | | | |
| 1990 | | | |
| 1991 | | | |
| 1992 | | | |
| 1993 | | | |
| 1994 | | | |
| 1995 | | | |
| 1996 | | | |
| 1997 | 21 (9) | | |
| 1998 | 42 (17) | | |
| 1999 | 28 (13) | | |
| 2000 | 25 (11) | | |
| 2001 | 55 (21) | | |
| 2002 | 25 (17) | | |
| 2003 | 18 (6) | 19 (9) | |
| 2004 | 25 (8) | 243 (57) | |
| 2005 | 9 (3) | 496 (130) | 31 (14) |
| 2006 | 12 (5) | 677 (138) | 166 (76) |
| 2007 | 70 (11) | 1032 (274) | 226 (102) |
| 2008 | 9 (6) | 1826 (278) | 273 (111) |

Table 3.12. Commercial length sampling percentage by gear and year.

| | GEAR | | | | |
|---|---|---|---|---|---|
| YEAR | DIVING | HAND LINES | LONG LINES | OTHER | POTS AND TRAPS |
| 1984 | 0.000 | 0.229 | 0.187 | 0.000 | 0.000 |
| 1985 | 0.000 | 0.823 | 0.629 | 0.000 | 0.000 |
| 1986 | 0.000 | 0.886 | 6.251 | 0.000 | 4.922 |
| 1987 | 0.000 | 1.632 | 54.399 | 0.000 | 2.982 |
| 1988 | 0.000 | 2.861 | 5.592 | 0.000 | 0.206 |
| 1989 | 0.000 | 1.552 | 0.835 | 0.011 | 2.125 |
| 1990 | 0.000 | 2.886 | 1.950 | 0.047 | 1.081 |
| 1991 | 0.000 | 2.101 | 7.552 | 0.000 | 0.330 |
| 1992 | 0.800 | 1.694 | 0.000 | 0.000 | 0.697 |
| 1993 | 0.728 | 3.183 | 0.000 | 0.000 | 0.000 |
| 1994 | 0.000 | 3.602 | 2.007 | 0.000 | 24.560 |
| 1995 | 0.000 | 4.038 | 10.086 | 0.000 | 0.000 |
| 1996 | 0.000 | 1.396 | 0.000 | 0.000 | 0.000 |
| 1997 | 0.000 | 1.336 | 0.000 | 0.000 | 0.000 |
| 1998 | 0.032 | 1.460 | 0.162 | 0.000 | 0.000 |
| 1999 | 0.974 | 4.223 | 0.000 | 0.000 | 0.000 |
| 2000 | 0.531 | 5.067 | 0.000 | 0.000 | 0.000 |
| 2001 | 0.242 | 3.485 | 0.000 | 0.000 | 0.000 |
| 2002 | 0.000 | 2.228 | 0.295 | 0.000 | 0.000 |
| 2003 | 0.097 | 2.785 | 0.000 | 0.000 | 0.000 |
| 2004 | 0.346 | 5.030 | 0.000 | 0.000 | 0.000 |
| 2005 | 0.000 | 6.984 | 0.000 | 0.000 | 0.000 |
| 2006 | 0.000 | 6.740 | 0.000 | 0.000 | 0.000 |
| 2007 | 0.000 | 5.079 | 0.000 | 0.000 | 100.000 |
| 2008 | 0.000 | 4.800 | 0.000 | 0.000 | 0.000 |

**Table 3.13.** Commercial age sampling percentage for handline gear by state and year.

| YEAR | STATE | | | |
|---|---|---|---|---|
| | FL | GA | NC | SC |
| 1988 | 0.000 | 0.000 | 0.111 | 0.000 |
| 1989 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1990 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1991 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1992 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1993 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1994 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1995 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1996 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1997 | 0.110 | 0.000 | 0.000 | 0.000 |
| 1998 | 0.131 | 0.000 | 0.000 | 0.000 |
| 1999 | 0.137 | 0.000 | 0.000 | 0.000 |
| 2000 | 0.130 | 0.000 | 0.000 | 0.000 |
| 2001 | 0.255 | 0.000 | 0.000 | 0.000 |
| 2002 | 0.136 | 0.000 | 0.000 | 0.000 |
| 2003 | 0.090 | 0.000 | 0.168 | 0.000 |
| 2004 | 0.176 | 0.000 | 2.295 | 0.000 |
| 2005 | 0.104 | 0.000 | 5.547 | 1.160 |
| 2006 | 0.216 | 0.000 | 3.827 | 2.023 |
| 2007 | 0.907 | 0.000 | 3.169 | 1.468 |
| 2008 | 0.228 | 0.000 | 5.656 | 1.947 |

## *3.14. FIGURES*

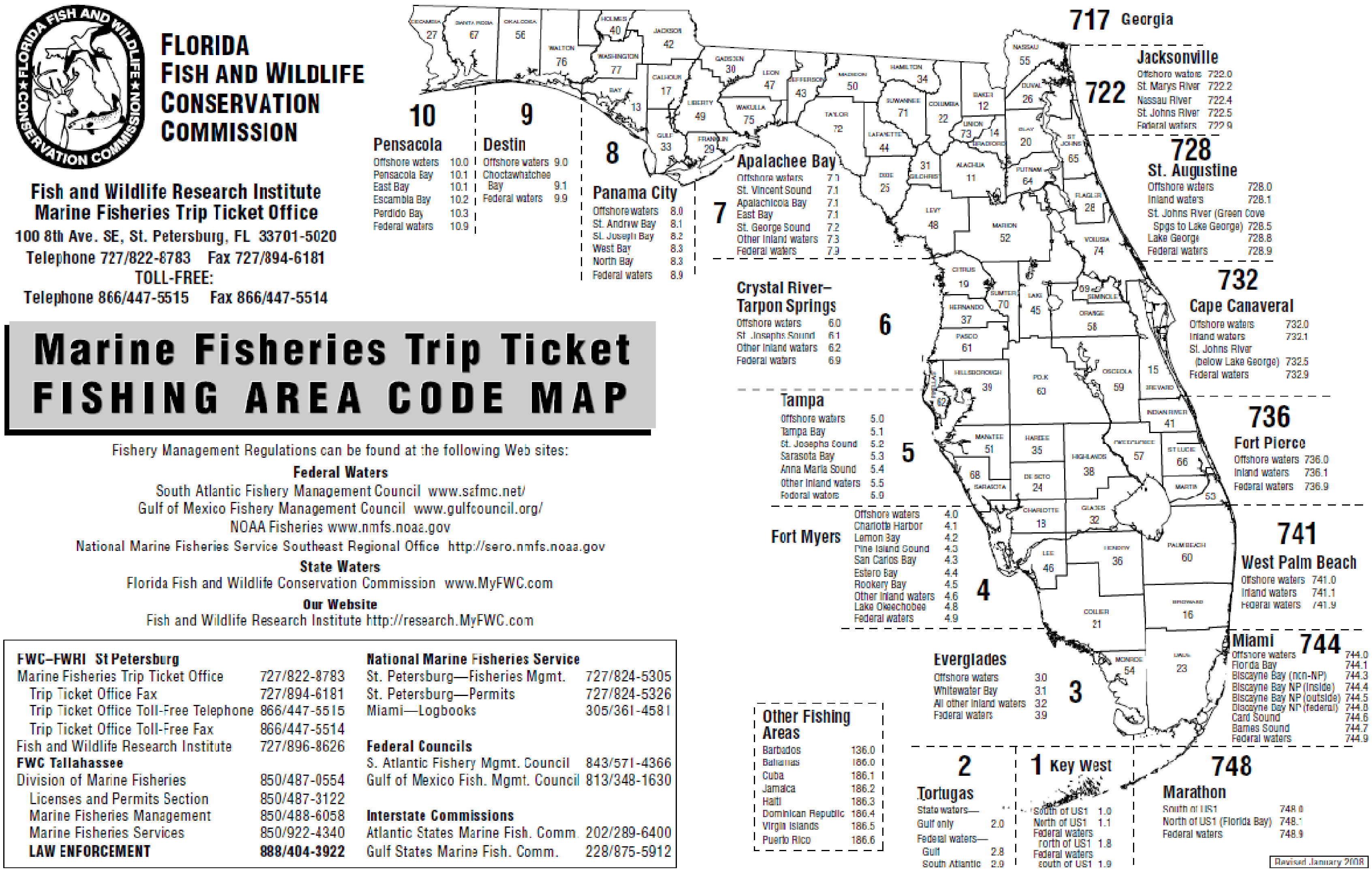
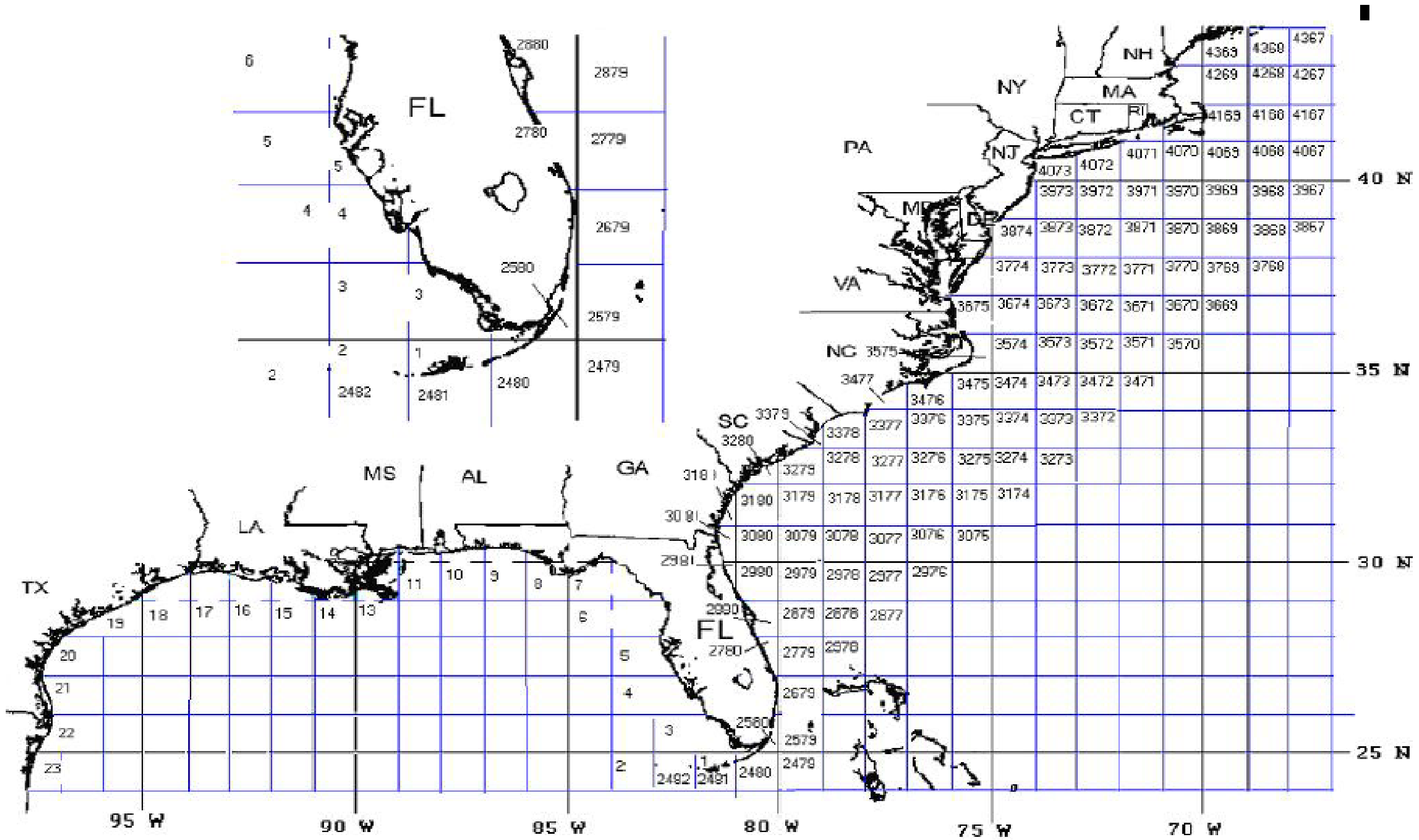



**Figure 3.1.** Map of fishing areas used by the FL trip ticket program.




Area Map: South Atlantic Statistical Grid Map – Grid Numbers follow lines of longitude and latitude. The first two digits in the four digit grid numbers are latitude degrees and the second two digits are longitude degrees.
Gulf of Mexico Statistical Grid Map – Use the grid number of the area you fished. Note that gulf grid numbers do not follow lines of longitude and latitude.
Florida Close-up (See Inset) - The close-up grid map of south Florida shows the 4 digit codes for the South Atlantic Region and the 1 digit code in the Gulf of Mexico Region.

**Figure 3.2.** Map of fishing area designations used in logbook reports.

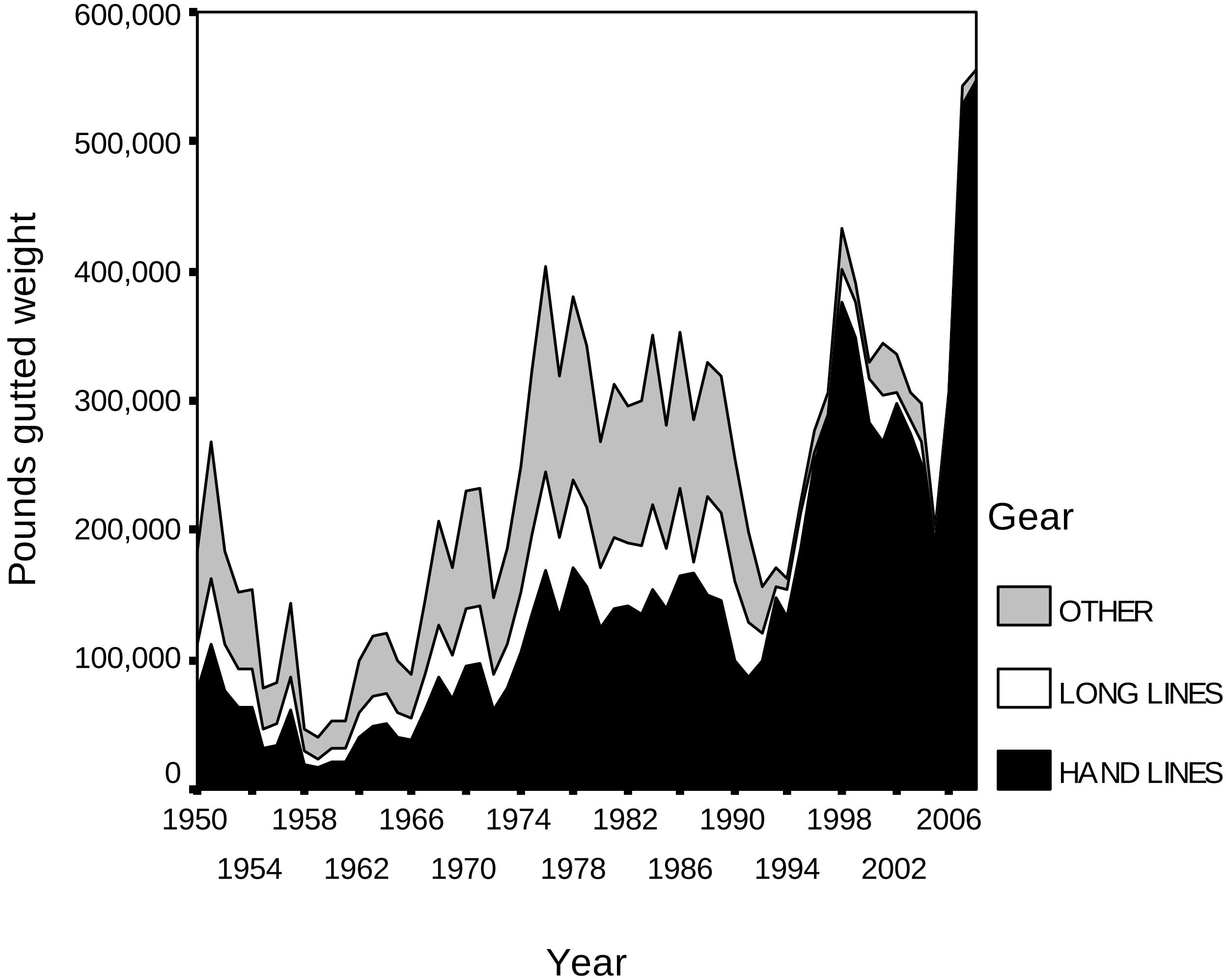



**Figure 3.3.** Commercial landings in pounds gutted weight. Longline landings for 2007 and 2008 have been removed for confidentiality reasons.

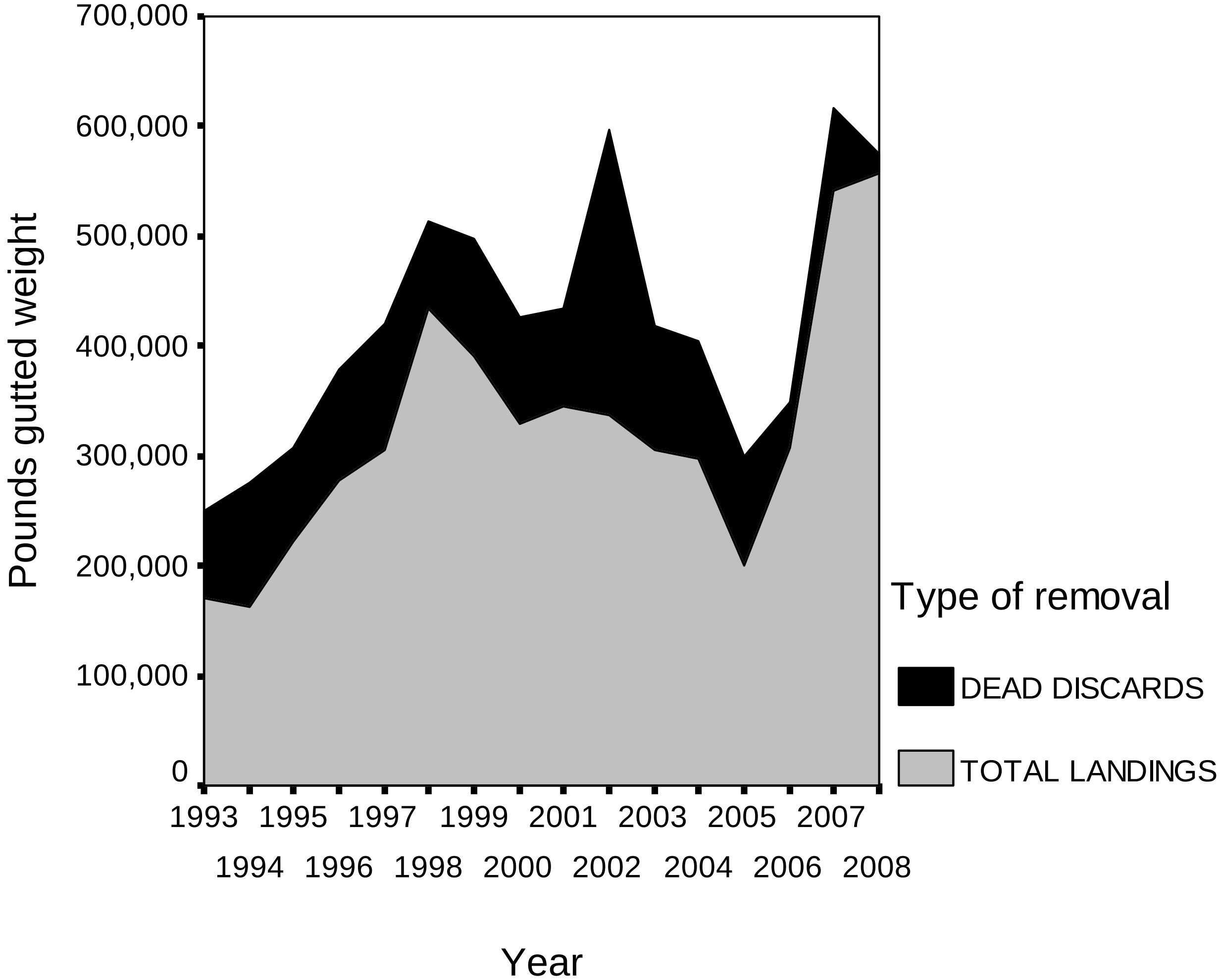



**Figure 3.4.** Landings and dead discards 1993-2008 in pounds gutted weight.

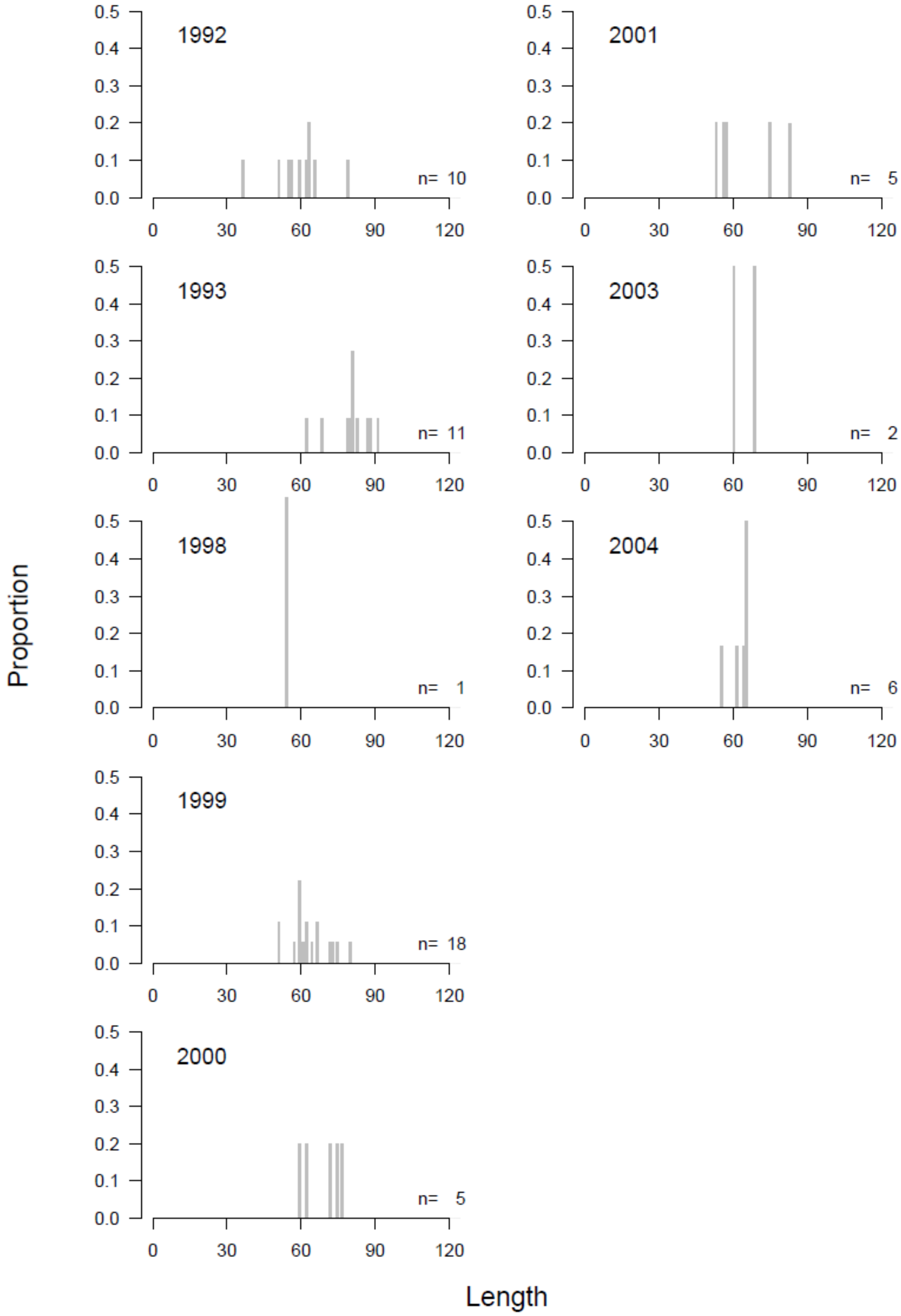



**Figure 3.5.** Relative length composition of commercial length samples by year for diving gear. N is the number of fish measured.

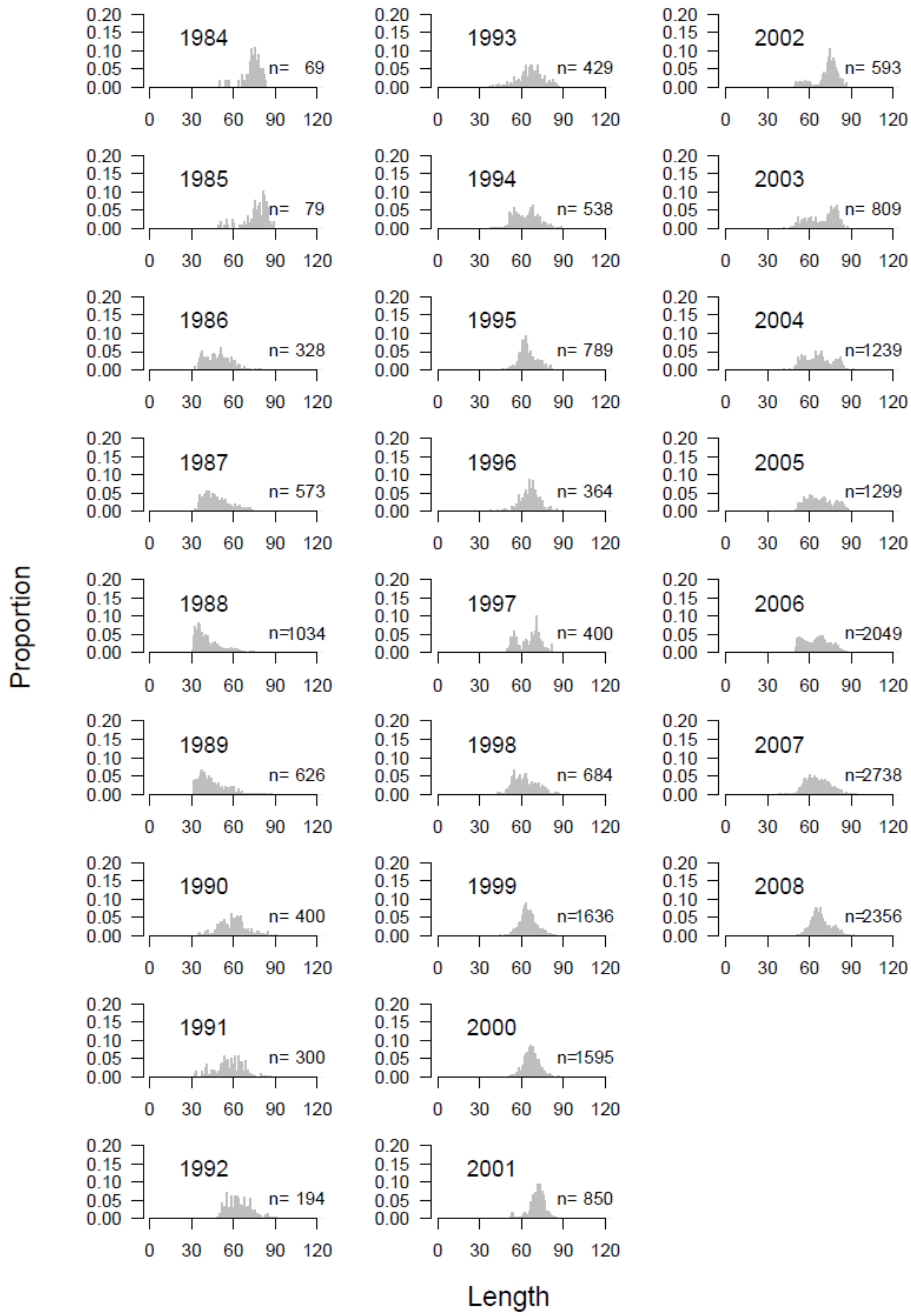



**Figure 3.6.** Relative length composition of commercial length samples by year for handline gear. N is the number of fish measured.

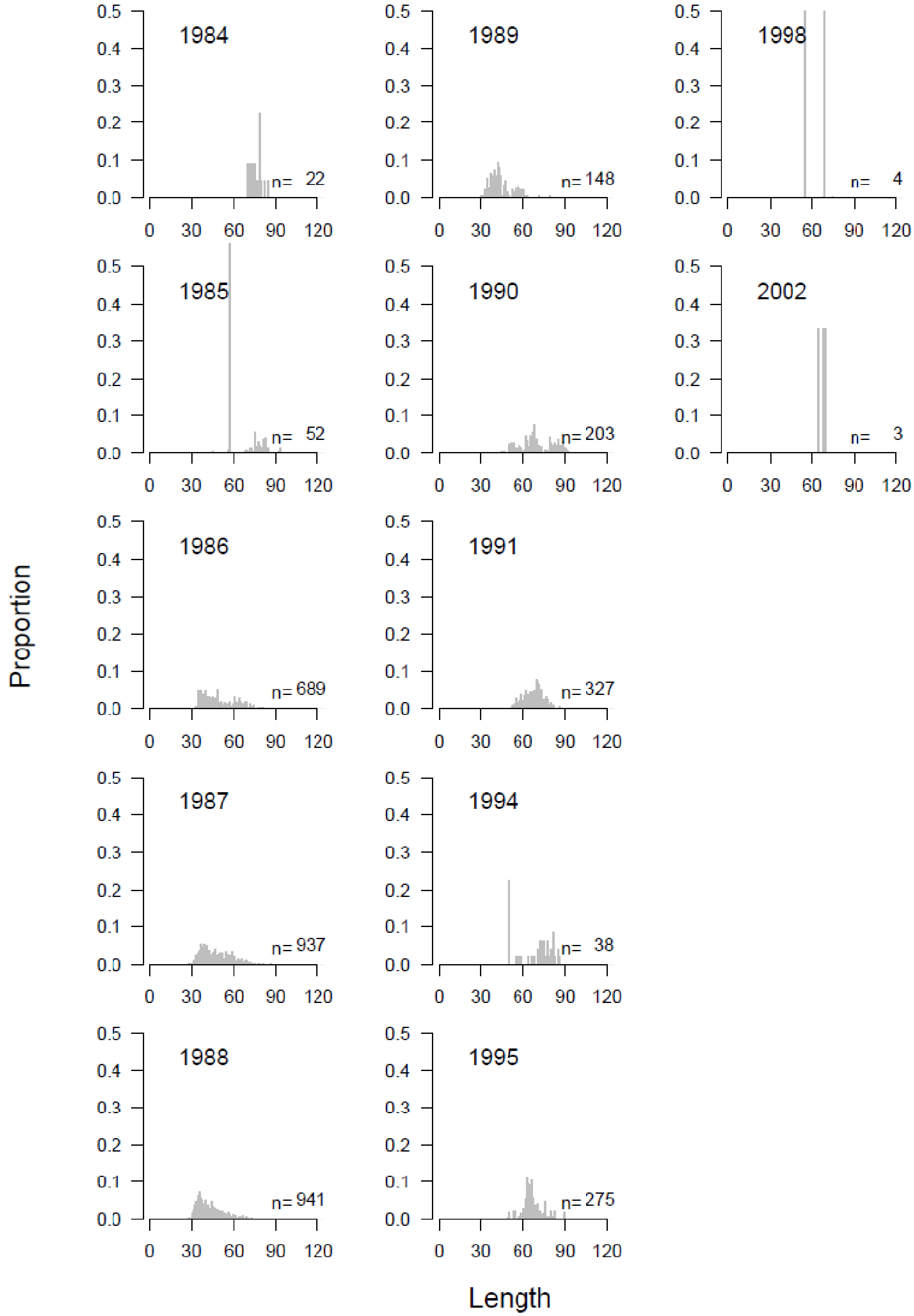



**Figure 3.7.** Relative length composition of commercial length samples by year for longline gear. N is the number of fish measured.

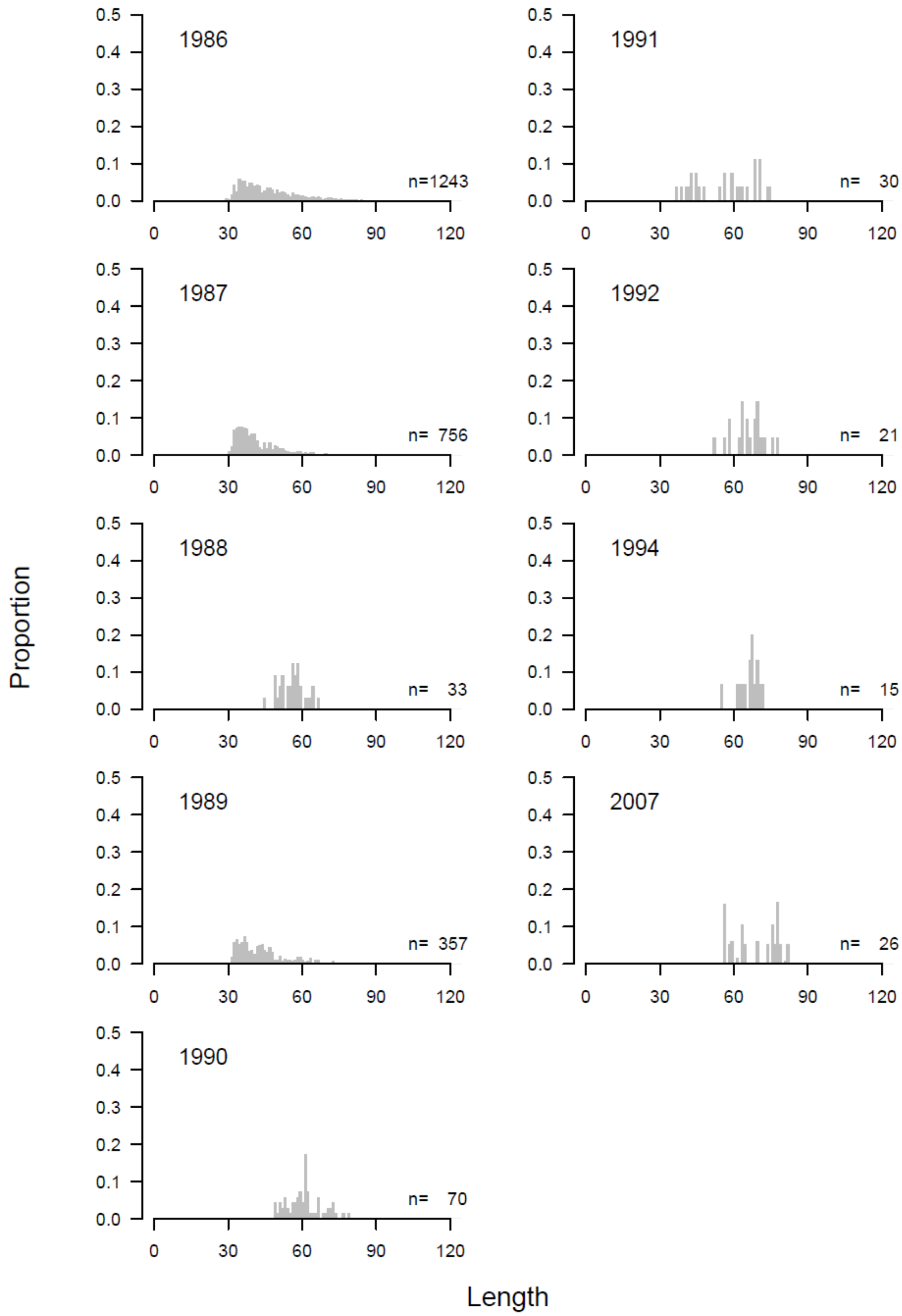



**Figure 3.8.** Relative length composition of commercial length samples by year for pot and trap gear. N is the number of fish measured.

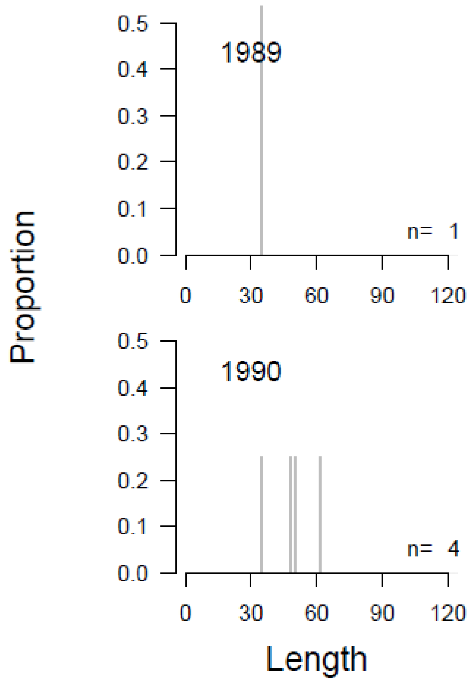



**Figure 3.9.** Relative length composition of commercial length samples by year for other gear. N is the number of fish measured.

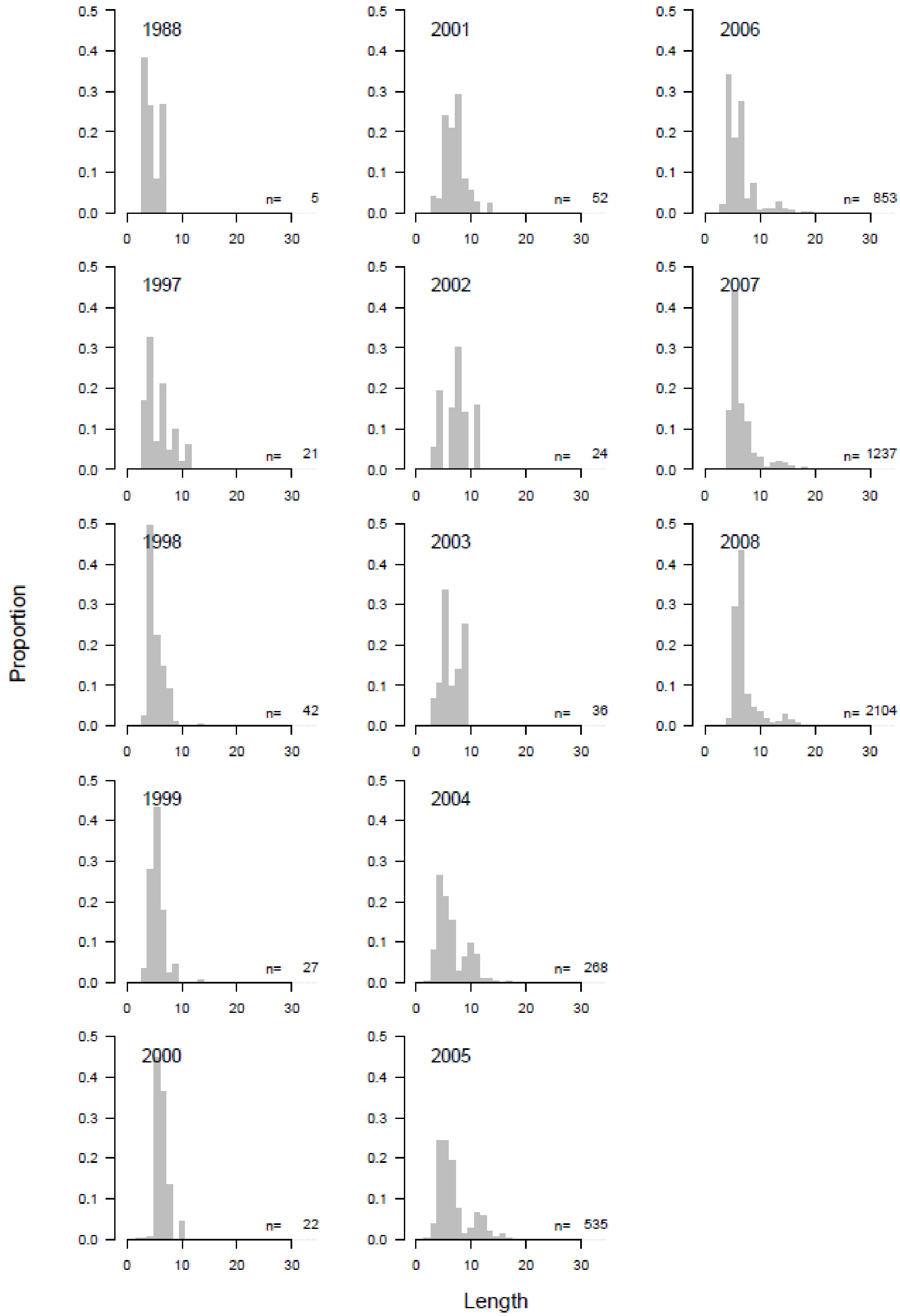



**Figure 3.10.** Relative age composition of age samples by year for handline. N is the number of fish aged.

# 4. RECREATIONAL FISHERY STATISTICS

## *4.1. OVERVIEW*

### 4.1.1. Group membership

Members- Beverly Sauls (FWRC), Tom Sminkey (NMFS Silver Spring), Ken Brennan (NMFS Beaufort), Dennis O'Hern (GMFMC AP/Fisherman rep), Russell Hudson (SAFMC Appointee/Industry rep), Chad Hanson (Observer), Anne Lange (Leader, SAFMC SSC)

### 4.1.2. Issues:

(1) Red Grouper Charter Boat Landings: 1986-2003 & 2004-2008, survey methods changed.

(2) Red Grouper recreational landings in Monroe County, FL (Keys) – MRFSS typically includes Keys with Gulf landings, but coded distance from shore allows evaluation of Atlantic waters vs Gulf waters for trip fishing area during 2005-2008. These data suggest ~91% red grouper landed in Keys taken on trips fishing in Atlantic waters off Keys.

(3) Weight landings for red grouper charter boat mode. The estimated weight landings are for the MRFSS' Random Digit Dialing (RDD) Coastal Household Telephone Survey (CHTS) estimated numbers, not the adjusted charter numbers.

(4) Red Grouper Party/Charter Landings: 1981-1985; headboat landings are used from (Southeast Headboat survey (SEHB) program so we must parse out the headboat from party/charter during period when MRFSS did not stratify.

(5) How to address 1960, 1965, and 1970 U.S. Fish and Wildlife Service (FWS) survey data.

(6) How far back should we generate estimates for the recreational fisheries.

## *4.2. GENERAL RECREATIONAL FISHERY - MRFSS*

### 4.2.1. Review of Working Papers

SEDAR19-DW-07_Groupers_Rec_Landings.pdf, T. R. Sminkey, NMFS, ST1, Silver Spring, MD. 2009 – This paper describes the general linear model regression analysis of Charter boat effort estimates produced by the MRFSS' Coastal Household Telephone Survey and the For-Hire Survey, and how the model can be used to produce a continuous time series of effort and catches (or landings) of fishes when the survey method has changed during that time series. The regression ratios were then applied to the historical time series of effort prior to the overlapping survey methods to produce adjusted charter boat effort for each earlier year. That 'adjusted effort' was substituted for the originally estimated effort and new catch statistics were generated for red grouper. The regression method treats the South Atlantic region and the Gulf region separately, and ratios are provided for each region. The Gulf region analysis and ratios were produced by Diaz and Phares (2004) and applied here to red grouper catch statistics. The recreational statistics workgroup recommends using these adjusted charter boat landings when producing the overall aggregate landings of red grouper, and have included adjusted landings in Table 4.6.1.

### 4.2.2 Recreational Landings - MRFSS

Recreational landings of red grouper were generated from the MRFSS surveys of recreational anglers, conducted from 1981 – 2008 along the Atlantic coast. The area included in these landings encompasses North Carolina to Florida, and it was determined based on field data collected in 2005-2008, to include Monroe County, Florida (the Keys) in this range. Survey area-fished information was modified in 2005 to allow recreational fishing trips returning to the Keys to be characterized as fishing in the Atlantic waters (east and south of the Keys) or the Gulf waters (west and north of the Keys). Of those recreational angling trips landing red grouper in the Keys, the vast majority were fishing in Atlantic waters (91%) so the group recommended inclusion of all red grouper landings from the Keys in this summary. The WG discussed the fact that in previous assessments for Gulf red grouper, landings from the Keys were assumed to be from the Gulf. However, the WG decided that the new data support the change to include these landings in the South Atlantic assessment.

The charter boat survey methods changed during the time series of monitored landings available, so an adjustment was made to produce a uniform time series of landings. This work is detailed in the workshop paper, SEDAR19 DW07, and is discussed above. Weight landings were produced from the adjusted number landed using mean weights by year. There was little mean weight variance within the year.

Total adjusted landings, by numbers and weight (pounds), and live discards are tabulated for the range in Table 4.6.1.

### 4.2.3. Recreational Discards- MRFSS

Live discard information, identification to lowest possible taxon and numbers per angler, are collected during the MRFSS' surveys. These charter boat mode discards are adjusted similar to landings adjustments for the survey method change using relative proportions to total landings (as detailed in SEDAR 19 DW-07), and presented by number for red grouper in Table 4.6.1. We do not have any size or age data available for live discards reported by the MRFSS (all data from angler reports, not observed).

### 4.2.4. Discard Mortality - MRFSS

Given lack of specific studies the recreational WG discussed what would be considered reasonable ranges of discard mortality, based on estimates presented by the commercial and life history WGs. For red grouper the WG recommends a discard mortality of 20%, fishery-wide, with sensitivity analyses run for from 10-30%.

### 4.2.5. Biological Sampling - MRFSS

#### *4.2.5.1. Sampling Intensity Length/Age/Weight*

The MRFSS angler-intercept survey collected lengths and weights of subsamples of landed fishes. The red grouper length frequencies are included in the SEDAR19 DW spreadsheet of statistics (RG_DW_summary.xls) and follow the requested standards (1 cm length groups, Total Length converted from measured Fork Length). The annual sample size of the measured red groupers are reported beside the annual frequencies.

Weights of individual fish are obtained and used to produce average weights per sampled cell (year/wave/sub-region/state/collapsed mode/collapsed area) which are then applied to the harvested (A+B1 catch) catch in numbers to produce the harvested weight estimates. Substitution of mean weight from higher geographically pooled levels (state, then sub-region) may be used to replace missing values within cells if the number of weighed fish per cell is less than 2. If no weights of fish are obtained within the sub-region for a mode during the entire wave then no average weight is available and no weight of landings will be estimated. This potential ‘gap’ in landings estimates may lead to underestimating total harvest if the missing weights are not accounted for in any analysis or stock assessment. Therefore, landed weights from MRFSS should always be compared to landed numbers of fish to evaluate potential missing weight field data.

*4.2.5.2. Length – Age distributions*

The WG had no input on this issue

*4.2.5.3. Adequacy for characterizing catch*

The WG had no input on this issue, see above

*4.2.5.4 Alternatives for characterizing discards*

The WG had no input on this issue

### 4.2.6. Recreational Catch-at-Age/Length; directed and discard

Not discussed by WG

### 4.2.7. Recreational Effort- MRFSS

Marine recreational fishing effort throughout the managed range of red grouper (South Atlantic region plus Florida Keys) is tabulated in Table 4.6.2. Detailed tables of fishing effort by sub-region and mode are provided in the data workshop fishery statistics spreadsheet, RG_DW_summary.xls.

## *4.3. HEADBOAT FISHERY*

### 4.3.1. Review of Working Papers

SEDAR19-DW-21 Estimated Landings and Discards of Red Grouper in the South Atlantic and Black Grouper in the South Atlantic and Gulf of Mexico Headboat Fishery, 2004-2008.pdf, K. J. Brennan, NMFS, Beaufort, NC. This working paper summarizes the estimated landings and discards for both red grouper and black grouper from 2004 to 2008. Prior to 2004 discard information was not collected on the headboat logbook form. Since this self reported data lacks validation the paper recommends continued comparisons to the At-Sea-Observer program.

SEDAR 19-DW-08: Length Frequencies and Condition of Released Red Grouper and Black Grouper from At-Sea Headboat Observer Surveys in the Gulf of Mexico and Atlantic Ocean, 2005 to 2007.pdf, B. Sauls FWC, St. Petersburg, FL. This working paper summarizes information collected on the size, release condition, and final disposition of black and red grouper collected by trained observers during at-sea surveys on board headboats. While this information is specific to the recreational headboat fishery, it provides valuable information on the size of discarded fish from the recreational fishery, which historically has not been collected in other surveys of recreational fishing.

### 4.3.2. Headboat Landings

The Southeast Region Headboat Survey estimates landings and effort for headboats in the South Atlantic and Gulf of Mexico. To determine red grouper landings estimates for the earliest possible year, the recreational working group first considered the areas of coverage in the early years of the Survey. The Headboat Survey was started in 1972; however, logbook reporting did not begin until 1973 and only included vessels from North Carolina and South Carolina until 1975. In 1976 it was expanded to northeast Florida, followed by southeast Florida in 1978 and finally to the Gulf of Mexico in 1986. Landings estimates in the South Atlantic are available beginning in 1981. These estimates were generated using correction factors to account for non- reporting on logbooks.

*Issue 1: The Headboat Survey had partial geographic coverage and reported data available back to 1973; however, estimated landings are not available until 1981.*

Option 1: Include all years (1973–2008).

Option 2: Exclude early years; start the time series in 1978 (begins 100% coverage of logbooks).

Option 3: Exclude early years; start the time series in 1981 when landings estimates are available.

**Decision: Option 1, because most areas are represented throughout the time series. In order to take landings for red grouper back to 1973, a correction factor for non-reporting was derived by calculating the estimated landings to the reported landings for 1981-1983. This correction factor was applied to reported landings from 1978-1980 when full coverage was**

**present. For areas not covered in the Survey an average for the first 3 years of reported landings was calculated for that area. The correction factor was then applied to the average back to 1973. Total pounds landed for years prior to 1981 were calculated by using the average mean weight by area from 1981-1983 and applying this value to numbers landed back to 1973. Results are shown in Table 4.6.3.**

### 4.3.3. Headboat Fishery Discards

Prior to 2004 discard information was not collected on the headboat logbook form. The estimated headboat discards for 2004-2008 from these logbooks are summarized in SEDAR19-DW-21. However, based on past comparisons to the MRFSS AT-Sea Observer data it was concluded that the logbook discards were underreported and the At-Sea data best represented discards ratios for this fishery. In previous SEDARs the MRFSS charterboat discards ratios (i.e., total discards : total removals) were used as a proxy for headboat discards ratios because they most closely resembled the type of fishing that occurs on headboats and they accounted for regulatory changes that were implemented during the time series.

In the case of red grouper four options were considered (Table 4.6.4) using the MRFSS Headboat At Sea observer discard data (2005-2008) and the MRFSS charterboat discard data (1981-2008).

Option 1: The average MRFSS At-Sea discard ratio from 2005 to 2007 was applied to estimated headboat landings starting in 1973 and to 2008. The average was not used for 2005 -2007; rather the actual discard ratios were applied to landings for each of these years. In 2008 the Florida Keys were dropped from the At Sea Observer program causing a low sample size, therefore the average was applied for this year as well. This option does not account for regulatory changes prior to 1992.

Option 2: The MRFSS At-Sea discard data weighted average from 2005 to 2007 was applied to estimated headboat landings starting in 1973 and to 2008. The weighted average would account for differences in sample size and fluctuations that may be due to abundance. The weighted average was not used for 2005 -2007; rather the actual discard ratios were applied to landings for each of these years. In 2008 the Florida Keys were dropped from the At-Sea Observer program causing a low sample size, therefore the weighted average was applied for this year as well. This option does not account for regulatory changes prior to 1992.

Option 3: The MRFSS charterboat discard ratios were used from 1981-2008 and applied to estimated headboat landings. For years 1981, 1984 and 1985 there were no data available. In 1991 the discard values was an extreme outlier to all other years; therefore it was decided not to use these data. As a proxy for these years the average from 1982 and 1983 was used for 1981 and the average from 1984-1988 was used for 1984, 1985 and 1991.

**Option 4 (preferred Option): Combine both sources of data by using the adjusted MRFSS charterboat discard values from Option 3 for the period 1981 to 1991 and the values from Option 2 (At Sea weighted averages) for 1992 to 2008. This method would account for regulatory changes prior to 1992 by using the MRFSS charterboat discard ratios, while in turn using the most representative discard data from the At-Sea-Observer program (SEDAR19-DW-08) for years with a similar regulatory history.**

#### *4.3.3.1. Headboat At-Sea Observer Survey*

An observer survey of the recreational headboat fishery was launched in NC and SC in 2004 and in 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, or each sub-region in Florida. 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 vicinities of the Dry Tortugas. Funding for this data collection was discontinued in the Florida Keys in 2008. While this data set is a short time series, it provides valuable quantitative information on the size distribution and release condition of fish discarded in the recreational fishery. Data from Florida are summarized in SEDAR19-DW-08.

Length frequencies of discards from North Carolina to the Florida Keys were provided for this assessment. Lengths were converted from mid-line length to total length using the length conversion factor provided in the Life History section of this report. Numbers of sampled trips are provided below.

| Year | Northeast FL | Southeast FL | Florida Keys | GA | SC | NC |
|---|---|---|---|---|---|---|
| 2005 | 43 | 95 | 34 | 6 | 97 | 58 |
| 2006 | 38 | 71 | 52 | 7 | 88 | 45 |
| 2007 | 49 | 71 | 46 | 8 | 91 | 52 |
| 2008 | 52 | 76 | 0 | 3 | 78 | 39 |

### 4.3.4. Discard Mortality – Headboat Fishery

Given lack of specific studies the recreational WG discussed what would be considered reasonable ranges of discard mortality, based on estimates presented by the commercial and life history WGs. For red grouper the WG recommends a discard mortality of 20%, fishery-wide, with sensitivity analyses run for from 10-30%.

### 4.3.5. Biological Sampling - Headboat Fishery

#### *4.3.5.1. Sampling Intensity Length/Age/Weight*

The weighed and measured red grouper sample sizes from the headboat fishery by year, region and season are given in Table 4.6.4. The number of headboat trips with weighed and measured red grouper by year, region and season are given in Table 4.6.5. The aged red grouper sample sizes from the headboat fishery by year, state and month are given in Table 4.6.6. The number of headboat trips with aged red grouper by year, region and season are given in Table 4.6.7.

### 4.3.6. Headboat Length – Age distributions

#### *4.3.6.1. Headboat Length Composition*

The length composition from the headboat fishery was generated from 1973-2008. The headboat areas were aggregated to regions of North Carolina, South Carolina, Georgia/North Florida, and South Florida (Florida break at Cape Canaveral). The periods consisted of January-May, June-August, and September –December. These periods were determined by the availability of monthly landings estimates from the early years of the headboat survey. The headboat length composition was weighted by the associated landings by year, region, and period for 1981-2008. The length composition was weighted by year and region only for 1973-1980 because landings were not estimated by month. Eight fish were deleted from the composition from South Florida in September-December because of very small or large lengths. Seven of the removed fish were less than 7 cm and one fish was 555 cm. Length composition values were stored in the RG_DW_summary.xls workbook and are plotted in Figure 4.7.2.

#### *4.3.6.2. Headboat Age Composition*

The headboat ages were weighted by the headboat length composition to overcome potential bias in selecting fish to age and to transfer the weighting given to the length composition based on landings to the age composition. The weighting value for each age record was the proportion from the length composition corresponding to the year and length (1 cm bins) of the aged fish. The weighting values were then summed by age and year to determine the age composition of the fishery. Each value was normalized to sum to 1 across years by dividing each value by the sum for that year. Headboat age composition values were stored in the RG_DW_summary.xls workbook and are plotted in Figure 4.7.3.

#### *4.3.6.3. Adequacy for characterizing catch*

The WG had no input on this issue.

#### *4.3.6.4. Alternatives for characterizing discards*

The WG had no input on this issue.

### **4.3.7. Headboat Catch-at-Age/Length; directed and discard**

The WG had no input on this issue

### 4.3.8. Headboat Fishery Effort

Estimated headboat angler days decreased 24% in the South Atlantic from 2007 to 2008 (Table 4.6.8). The most obvious factor which impacted the headboat fishery in both the Atlantic and Gulf of Mexico was the high price of fuel. The Energy Information Administration reported the price per gallon of diesel fuel reached a high of $4.80/gal in July 2008 compared to $2.90/gal in July 2007 (Figure 4.7.1). The timing of the peak prices coincided with historically the busiest time of year for headboats and tourism for most of the regions included in the Survey. Reports from industry staff, captains\owners, and port agents indicated throughout the 2008 season, this was the factor that most affected the amount of trips, number of passengers, and overall fishing effort.

## *4.4. COMMENTS ON ADEQUACY OF DATA FOR ASSESSMENT ANALYSES*

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

- Landings, as adjusted, appear to be adequate for the time period covered.
- Size data appear to adequately represent the landed catch on an annual basis, for the time period covered.

## *4.5. LITERATURE CITED*

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### *4.6. TABLES*

Table 4.6.1. Red Grouper Recreational Fishery Catch Statistics from the Marine Recreational Fisheries Statistics Survey (MRFSS)

Table 4.6.2. Marine Recreational Information Program (MRIP, formerly MRFSS), angler-effort from the South Atlantic sub-region plus the FL Keys (Monroe County); angler-trips by fishing mode.

Table 4.6.3. Estimated landings of red grouper in the South Atlantic headboat fishery 1973-2008.

Table 4.6.4 Estimated landings and discards of red grouper in the South Atlantic headboat fishery 1973-2008.

Table 4.6.5. Number of red grouper included in the headboat length compositions by region and period.

Table 4.6.6. Number of trips catching red grouper included in the headboat length composition by region and period.

Table 4.6.7 Number of red grouper aged from the headboat fishery by State and Month.

Table 4.6.8. Number of trips from which red grouper were aged from the headboat fishery by state and month.

Table 4.6.9. South Atlantic headboat estimated angler days 1981-2008.

Table 4.6.10. Aged red grouper sample size by year, state, and month for the recreational charter and private mode (MRFSS).

**Table 4.6.1.** Red Grouper Recreational Fishery Catch Statistics from the Marine Recreational Fisheries Statistics Survey (MRFSS)

| | Landings (harvest); adjusted | | | | Live Discards | |
|---|---|---|---|---|---|---|
| Year | Number (x1000) | PSE (CV) | Weight (lbs) | PSE (CV) | Number (x1000) | PSE (CV) |
| 1981 | 80.88 | 24.3 | 206,801 | 28.7 | 15.92 | 98.8 |
| 1982 | 128.95 | 25.1 | 479,044 | 28.7 | 16.87 | 57.8 |
| 1983 | 275.28 | 26.7 | 808,753 | 31.9 | 166.3 | 45.6 |
| 1984 | 1,090.57 | 25.5 | 5,234,186 | 35.9 | 373.18 | 40.3 |
| 1985 | 54.11 | 61.7 | 467,017 | 78.5 | 7.16 | 25 |
| 1986 | 226.01 | 52.8 | 745,811 | 58.3 | 34.44 | 81.2 |
| 1987 | 82.88 | 23.9 | 87,941 | 20.6 | 228.24 | 58.9 |
| 1988 | 36.78 | 23.1 | 137,219 | 16.9 | 51.31 | 53.8 |
| 1989 | 94.9 | 34.4 | 317,134 | 37.9 | 12.52 | 100 |
| 1990 | 12.65 | 30 | 30,286 | 41.2 | 20.3 | 69.2 |
| 1991 | 5.99 | 47 | 33,658 | 51 | 207.92 | 38.4 |
| 1992 | 22.56 | 19.6 | 146,735 | 24.2 | 223.63 | 78.6 |
| 1993 | 50.69 | 14.5 | 306,837 | 16.1 | 74.95 | 28.5 |
| 1994 | 34.3 | 15.9 | 181,503 | 16.5 | 164.6 | 22.8 |
| 1995 | 37.22 | 14.7 | 205,808 | 16.2 | 130.46 | 28.9 |
| 1996 | 46.56 | 14.8 | 295,923 | 15.6 | 355.23 | 12.5 |
| 1997 | 40.6 | 16.3 | 261,072 | 18.1 | 371.62 | 12.1 |
| 1998 | 35.4 | 17.3 | 252,684 | 19.4 | 109.4 | 17.9 |
| 1999 | 19.38 | 15.1 | 129,874 | 15.3 | 109.81 | 20 |
| 2000 | 17.66 | 21.4 | 131,440 | 25.5 | 336.44 | 39.5 |
| 2001 | 18.35 | 15.4 | 148,797 | 18.3 | 176.76 | 79.2 |
| 2002 | 39.3 | 14.1 | 268,474 | 15.2 | 120.92 | 20.8 |
| 2003 | 47.97 | 16.4 | 356,511 | 19.8 | 160.39 | 21.3 |
| 2004 | 40.43 | 16.6 | 348,865 | 24.7 | 224.12 | 24.1 |
| 2005 | 35.34 | 18.4 | 239,215 | 22.7 | 219.3 | 26.8 |
| 2006 | 55.86 | 16.7 | 586,354 | 26 | 225.43 | 28 |
| 2007 | 78.28 | 25.7 | 624,100 | 27.1 | 56.68 | 24.2 |
| 2008 | 88.97 | 23 | 1,104,543 | 25.6 | 90.67 | 16.5 |

**Table 4.6.2.** Marine Recreational Information Program (MRIP, formerly MRFSS), angler-effort from the South Atlantic sub-region plus the FL Keys (Monroe County); angler-trips by fishing mode.

| YEAR | Shore | PSE | Charter | PSE | Priv/Rent | PSE | All Modes | PSE |
|---|---|---|---|---|---|---|---|---|
| 1981 | 5,576,322 | 8.5 | 531,481 | 22.4 | 5,405,193 | 22.8 | 11,512,996 | 11.5 |
| 1982 | 8,415,193 | 9.9 | 947,257 | 8.8 | 5,494,141 | 5.6 | 14,856,591 | 6 |
| 1983 | 9,884,686 | 11.5 | 1,027,631 | 21.6 | 6,244,887 | 5.3 | 17,157,204 | 7 |
| 1984 | 9,794,017 | 7.2 | 954,388 | 8 | 7,597,307 | 5.2 | 18,345,711 | 4.4 |
| 1985 | 8,363,930 | 6.7 | 1,046,927 | 8.7 | 6,831,494 | 6.1 | 16,242,351 | 4.3 |
| 1986 | 7,920,704 | 5.6 | 1,103,100 | 12 | 6,776,294 | 4.9 | 15,800,098 | 3.6 |
| 1987 | 9,576,547 | 9.3 | 813,404 | 13.2 | 8,396,995 | 3.4 | 18,786,946 | 5 |
| 1988 | 10,300,391 | 3.8 | 1,079,778 | 14 | 8,319,329 | 2.9 | 19,699,498 | 2.5 |
| 1989 | 9,011,046 | 4.8 | 895,846 | 12.9 | 7,565,067 | 3.6 | 17,471,959 | 3 |
| 1990 | 7,287,362 | 3.9 | 592,849 | 7.8 | 6,950,072 | 3 | 14,830,283 | 2.4 |
| 1991 | 10,920,021 | 3.5 | 680,219 | 6.1 | 8,295,880 | 2.8 | 19,896,120 | 2.2 |
| 1992 | 9,857,292 | 2.5 | 810,404 | 6.7 | 7,992,459 | 1.8 | 18,660,154 | 1.6 |
| 1993 | 10,197,062 | 2.3 | 1,059,795 | 4.2 | 7,747,208 | 1.8 | 19,004,065 | 1.4 |
| 1994 | 11,503,303 | 2.1 | 1,229,277 | 3.1 | 9,057,769 | 1.7 | 21,790,349 | 1.3 |
| 1995 | 11,089,287 | 2.3 | 1,463,126 | 2.8 | 8,340,534 | 1.7 | 20,892,946 | 1.4 |
| 1996 | 9,811,818 | 2.6 | 1,526,866 | 2.7 | 8,167,399 | 1.8 | 19,506,083 | 1.5 |
| 1997 | 9,850,793 | 2.5 | 1,544,130 | 2.4 | 9,124,057 | 1.8 | 20,518,981 | 1.4 |
| 1998 | 8,996,780 | 2.9 | 1,217,987 | 2.4 | 7,943,540 | 2.1 | 18,158,307 | 1.7 |
| 1999 | 7,082,046 | 3.2 | 1,043,574 | 2.9 | 7,250,243 | 2.2 | 15,375,863 | 1.8 |
| 2000 | 10,600,605 | 3.2 | 777,013 | 2.8 | 9,490,996 | 2.3 | 20,868,615 | 1.9 |
| 2001 | 11,915,640 | 2.9 | 846,327 | 2.7 | 9,868,078 | 2.3 | 22,630,044 | 1.8 |
| 2002 | 9,219,725 | 3.1 | 797,746 | 2.6 | 8,445,698 | 2.2 | 18,463,169 | 1.9 |
| 2003 | 11,099,209 | 3.1 | 776,970 | 2.6 | 10,352,404 | 2.3 | 22,228,584 | 1.9 |
| 2004 | 11,254,419 | 3.5 | 640,572 | 3 | 9,674,023 | 2.5 | 21,569,013 | 2.1 |
| 2005 | 11,255,830 | 3.4 | 646,698 | 3.1 | 10,184,539 | 2.5 | 22,087,067 | 2.1 |
| 2006 | 12,555,398 | 3.4 | 680,665 | 3.8 | 10,950,630 | 2.1 | 24,186,693 | 2 |
| 2007 | 12,025,060 | 3.3 | 738,460 | 3.6 | 13,459,785 | 2.1 | 26,223,305 | 1.9 |
| 2008 | 10,929,879 | 3.3 | 741,078 | 3.6 | 11,360,874 | 2.2 | 23,031,831 | 1.9 |

**Table 4.6.3.** Estimated landings of red grouper in the South Atlantic headboat fishery 1973-2008.

| Area | North Carolina | | South Carolina | | Georgia\NE Florida | | SE Florida | |
|---|---|---|---|---|---|---|---|---|
| Year | Number | Weight(lbs) | Number | Weight(lbs) | Number | Weight(lbs) | Number | Weight(lbs) |
| 1973 | 151 | 1525 | 44 | 471 | 1340 | 18754 | 1306 | 5093 |
| 1974 | 423 | 4276 | 47 | 502 | 1340 | 18754 | 1306 | 5093 |
| 1975 | 228 | 2303 | 41 | 439 | 1340 | 18754 | 1306 | 5093 |
| 1976 | 130 | 1316 | 27 | 282 | 3133 | 43855 | 1306 | 5093 |
| 1977 | 530 | 5353 | 21 | 220 | 3754 | 52560 | 1306 | 5093 |
| 1978 | 1143 | 11543 | 36 | 377 | 2490 | 34860 | 1101 | 4296 |
| 1979 | 2342 | 23654 | 68 | 722 | 1463 | 20477 | 5510 | 21489 |
| 1980 | 406 | 4097 | 74 | 785 | 1208 | 16912 | 6449 | 25150 |
| 1981 | 146 | 1458 | 29 | 278 | 202 | 2981 | 7587 | 32496 |
| 1982 | 497 | 4455 | 39 | 363 | 216 | 3486 | 5610 | 23175 |
| 1983 | 241 | 3013 | 25 | 344 | 263 | 3084 | 9364 | 32466 |
| 1984 | 132 | 1844 | 5 | 60 | 256 | 4009 | 8163 | 34565 |
| 1985 | 150 | 918 | 4 | 24 | 419 | 5755 | 8211 | 36572 |
| 1986 | 68 | 656 | 9 | 87 | 385 | 4367 | 5348 | 24243 |
| 1987 | 137 | 516 | 46 | 96 | 390 | 2368 | 6464 | 31637 |
| 1988 | 374 | 1523 | 391 | 1171 | 1477 | 7665 | 2859 | 13043 |
| 1989 | 187 | 784 | 157 | 564 | 589 | 1710 | 2686 | 14858 |
| 1990 | 1073 | 7294 | 43 | 295 | 692 | 4428 | 5518 | 35895 |
| 1991 | 681 | 4055 | 113 | 544 | 366 | 3080 | 1566 | 9466 |
| 1992 | 458 | 3396 | 85 | 633 | 371 | 2431 | 3062 | 22849 |
| 1993 | 595 | 4709 | 47 | 286 | 264 | 1559 | 3880 | 24519 |
| 1994 | 1267 | 8204 | 87 | 539 | 289 | 2377 | 3822 | 24372 |
| 1995 | 1193 | 7924 | 135 | 1041 | 270 | 2193 | 3652 | 24140 |
| 1996 | 798 | 7362 | 89 | 913 | 387 | 1872 | 4373 | 27006 |
| 1997 | 3020 | 21753 | 137 | 1127 | 768 | 4603 | 4133 | 28151 |
| 1998 | 3554 | 21969 | 704 | 5595 | 942 | 5360 | 5703 | 41475 |
| 1999 | 3126 | 27995 | 709 | 6236 | 572 | 4353 | 2854 | 18899 |
| 2000 | 1155 | 11835 | 273 | 2832 | 408 | 3199 | 3497 | 23126 |
| 2001 | 1062 | 12929 | 140 | 1604 | 373 | 2271 | 3365 | 22589 |
| 2002 | 1099 | 5886 | 80 | 481 | 352 | 2681 | 3073 | 22736 |
| 2003 | 1192 | 9137 | 81 | 704 | 128 | 1001 | 2616 | 15822 |
| 2004 | 937 | 8050 | 145 | 903 | 292 | 1856 | 9382 | 63369 |
| 2005 | 1726 | 17625 | 222 | 1743 | 632 | 3433 | 8890 | 52651 |
| 2006 | 1426 | 11301 | 442 | 3358 | 299 | 1926 | 3074 | 16659 |
| 2007 | 2117 | 21408 | 756 | 7459 | 243 | 2354 | 2043 | 12429 |
| 2008 | 984 | 9606 | 215 | 2103 | 83 | 685 | 1161 | 8391 |

**Table 4.6.4.** Estimated landings and discards of red grouper in the South Atlantic headboat fishery 1973-2008.

| Year | Est. #Landed | Est. # of discards At-Sea avgratio 2005-2007 | Est. # of discards At-Sea weighed avg ratio 2005-2007 | MRFSS_Chtbt ratios | MRFSS_ChtBt_ratios and At-Sea combined |
|---|---|---|---|---|---|
| 1973 | 2841 | 15060 | 16396 | | |
| 1974 | 3116 | 16520 | 17985 | | |
| 1975 | 2915 | 15452 | 16823 | | |
| 1976 | 4595 | 24361 | 26522 | | |
| 1977 | 5611 | 29744 | 32383 | | |
| 1978 | 4770 | 25285 | 27528 | | |
| 1979 | 9383 | 49738 | 54151 | | |
| 1980 | 8136 | 43130 | 46957 | | |
| 1981 | 7964 | 42217 | 45963 | 2823 | 2823 |
| 1982 | 6362 | 33725 | 36717 | 337 | 337 |
| 1983 | 9893 | 52443 | 57095 | 6490 | 6490 |
| 1984 | 8556 | 45355 | 49379 | 26369 | 26369 |
| 1985 | 8784 | 46564 | 50695 | 27072 | 27072 |
| 1986 | 5810 | 30799 | 33531 | 3610 | 3610 |
| 1987 | 7037 | 37303 | 40613 | 42726 | 42726 |
| 1988 | 5101 | 27040 | 29439 | 5885 | 5885 |
| 1989 | 3619 | 19184 | 20886 | 12613 | 12613 |
| 1990 | 7326 | 38835 | 42281 | 29875 | 29875 |
| 1991 | 2726 | 14451 | 15733 | 8402 | 8402 |
| 1992 | 3976 | 21077 | 22947 | 33463 | 22947 |
| 1993 | 4786 | 25371 | 27621 | 5830 | 27621 |
| 1994 | 5465 | 28970 | 31540 | 21105 | 31540 |
| 1995 | 5250 | 27830 | 30299 | 60047 | 30299 |
| 1996 | 5647 | 29935 | 32591 | 30460 | 32591 |
| 1997 | 8058 | 42715 | 46505 | 79869 | 46505 |
| 1998 | 10903 | 57797 | 62924 | 34759 | 62924 |
| 1999 | 7261 | 38491 | 41905 | 45300 | 41905 |
| 2000 | 5333 | 28270 | 30778 | 81450 | 30778 |
| 2001 | 4940 | 26187 | 28510 | 34275 | 28510 |
| 2002 | 4604 | 24406 | 26571 | 26133 | 26571 |
| 2003 | 4017 | 21294 | 23183 | 15415 | 23183 |
| 2004 | 10756 | 57018 | 62076 | 52830 | 62076 |
| 2005 | 11470 | 88181 | 88181 | 66515 | 88181 |
| 2006 | 5241 | 22437 | 22437 | 17785 | 22437 |
| 2007 | 5159 | 20301 | 20301 | 3368 | 20301 |
| 2008 | 2443 | 12950 | 14099 | 1618 | 14099 |

*South Atlantic Red Grouper*

| | North Carolina | | | | | South Carolina | | | | | Georgia - N. Florida | | | | | South Florida | | | | | Grand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Jan.-May | Jun.-Aug. | Sept.-Dec. | Jan.-Dec. | Total | Jan.-May | Jun.-Aug. | Sept.-Dec. | Jan.-Dec. | Total | Jan.-May | Jun.-Aug. | Sept.-Dec. | Jan.-Dec. | Total | Jan.-May | Jun.-Aug. | Sept.-Dec. | Jan.-Dec. | Total | Total |
| 1973 | | | | 9 | 9 | | | | 1 | 1 | | | | | | | | | | | 10 |
| 1974 | | | | 12 | 12 | | | | 2 | 2 | | | | | | | | | | | 14 |
| 1975 | | | | 20 | 20 | | | | 6 | 6 | | | | | | | | | | | 26 |
| 1976 | | | | 20 | 20 | | | | 6 | 6 | | | | 39 | 39 | | | | | | 65 |
| 1977 | | | | 24 | 24 | | | | | | | | | 96 | 96 | | | | | | 120 |
| 1978 | | | | 11 | 11 | | | | 1 | 1 | | | | 39 | 39 | | | | 47 | 47 | 98 |
| 1979 | | | | 20 | 20 | | | | | | | | | 17 | 17 | | | | 121 | 121 | 158 |
| 1980 | | | | 27 | 27 | | | | 1 | 1 | | | | 21 | 21 | | | | 145 | 145 | 194 |
| 1981 | 9 | 1 | 9 | | 19 | | | | | | 7 | 9 | 4 | | 20 | 99 | 30 | 69 | | 198 | 237 |
| 1982 | 5 | 13 | 12 | | 30 | | | | | | 6 | 2 | 3 | | 11 | 89 | 51 | 96 | | 236 | 277 |
| 1983 | 1 | 15 | 8 | | 24 | 1 | | | | 1 | 7 | 3 | 8 | | 18 | 162 | 51 | 126 | | 339 | 382 |
| 1984 | 11 | 3 | 2 | | 16 | | 1 | | | 1 | 10 | 3 | 9 | | 22 | 299 | 53 | 183 | | 535 | 574 |
| 1985 | 3 | 9 | | | 12 | | | | | | 16 | 5 | 9 | | 30 | 297 | 40 | 198 | | 535 | 577 |
| 1986 | 4 | 3 | 3 | | 10 | | | | | | 5 | 5 | 2 | | 12 | 232 | 28 | 102 | | 362 | 384 |
| 1987 | 4 | 3 | 5 | | 12 | | 1 | 7 | | 8 | 6 | 1 | 1 | | 8 | 150 | 20 | 89 | | 259 | 287 |
| 1988 | 2 | 16 | 6 | | 24 | | 10 | | | 10 | 29 | 4 | | | 33 | 111 | 32 | | | 143 | 210 |
| 1989 | 8 | 14 | 7 | | 29 | 1 | 2 | 3 | | 6 | 4 | 1 | 8 | | 13 | 112 | 50 | 34 | | 196 | 244 |
| 1990 | 5 | 14 | 3 | | 22 | | 1 | | | 1 | 9 | 10 | 4 | | 23 | 66 | 9 | 34 | | 109 | 155 |
| 1991 | 2 | 18 | 8 | | 28 | 6 | | | | 6 | 3 | 1 | 3 | | 7 | 17 | 3 | 4 | | 24 | 65 |
| 1992 | 7 | 19 | 20 | | 46 | | 1 | | | 1 | | 1 | 4 | | 5 | 21 | 4 | 6 | | 31 | 83 |
| 1993 | 4 | 7 | 4 | | 15 | 3 | 1 | 1 | | 5 | 4 | 1 | 1 | | 6 | 30 | 25 | 30 | | 85 | 111 |
| 1994 | 9 | 19 | 5 | | 33 | 1 | 1 | 10 | | 12 | 3 | 1 | 6 | | 10 | 48 | 18 | 24 | | 90 | 145 |
| 1995 | 5 | 36 | 19 | | 60 | | 12 | 8 | | 20 | 3 | 2 | 1 | | 6 | 50 | 11 | 41 | | 102 | 188 |
| 1996 | 8 | 20 | 7 | | 35 | 13 | 4 | 45 | | 62 | 5 | 2 | 5 | | 12 | 74 | 15 | 65 | | 154 | 263 |
| 1997 | 3 | 39 | 9 | | 51 | 151 | 4 | 4 | | 159 | 6 | 8 | 2 | | 16 | 75 | 27 | 76 | | 178 | 404 |
| 1998 | 20 | 33 | 65 | | 118 | 18 | 9 | 31 | | 58 | 18 | 9 | 7 | | 34 | 144 | 26 | 87 | | 257 | 467 |
| 1999 | 11 | 66 | 32 | | 109 | 4 | 11 | 11 | | 26 | 9 | 7 | 2 | | 18 | 78 | 22 | 57 | | 157 | 310 |
| 2000 | 12 | 30 | 18 | | 60 | 3 | 5 | | | 8 | 6 | | 2 | | 8 | 54 | 30 | 43 | | 127 | 203 |
| 2001 | 16 | 15 | 10 | | 41 | | | | | | 5 | 4 | 3 | | 12 | 41 | 17 | 49 | | 107 | 160 |
| 2002 | 4 | 17 | | | 21 | | | 2 | | 2 | 15 | 8 | 4 | | 27 | 67 | 33 | 39 | | 139 | 189 |
| 2003 | | 11 | 13 | | 24 | | 3 | 3 | | 6 | 4 | 1 | | | 5 | 47 | 15 | 24 | | 86 | 121 |
| 2004 | 7 | 62 | 2 | | 71 | 1 | 2 | | | 3 | 1 | 1 | 2 | | 4 | 26 | 12 | 36 | | 74 | 152 |
| 2005 | 3 | 40 | 8 | | 51 | | | | | | | 1 | 1 | | 2 | 33 | 26 | 42 | | 101 | 154 |
| 2006 | | 29 | 8 | | 37 | 4 | 5 | 8 | | 17 | 3 | 2 | | | 5 | 52 | 8 | 18 | | 78 | 137 |
| 2007 | | 34 | 2 | | 36 | 6 | 11 | 12 | | 29 | 3 | | 1 | | 4 | 33 | 6 | 18 | | 57 | 126 |
| 2008 | 5 | 11 | 7 | | 23 | 4 | 1 | 2 | | 7 | | 1 | | | 1 | 15 | 3 | 15 | | 33 | 64 |

**Table 4.6.5.** Number of red grouper included in the headboat length compositions by region and period.

**Table 4.6.6.** Number of trips catching red grouper included in the headboat length composition by region and period.

| | North Carolina | | | | | South Carolina | | | | | Georgia - N. Florida | | | | | South Florida | | | | | Grand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Jan.-May | Jun.-Aug. | Sept.-Dec. | Jan.-Dec. | Total | Jan.-May | Jun.-Aug. | Sept.-Dec. | Jan.-Dec. | Total | Jan.-May | Jun.-Aug. | Sept.-Dec. | Jan.-Dec. | Total | Jan.-May | Jun.-Aug. | Sept.-Dec. | Jan.-Dec. | Total | Total |
| 1973 | | | | 8 | 8 | | | | 1 | 1 | | | | | | | | | | | 9 |
| 1974 | | | | 7 | 7 | | | | 2 | 2 | | | | | | | | | | | 9 |
| 1975 | | | | 16 | 16 | | | | 2 | 2 | | | | | | | | | | | 18 |
| 1976 | | | | 17 | 17 | | | | 5 | 5 | | | | 18 | 18 | | | | | | 40 |
| 1977 | | | | 17 | 17 | | | | | | | | | 56 | 56 | | | | | | 73 |
| 1978 | | | | 9 | 9 | | | | 1 | 1 | | | | 23 | 23 | | | | 23 | 23 | 56 |
| 1979 | | | | 11 | 11 | | | | | | | | | 15 | 15 | | | | 63 | 63 | 89 |
| 1980 | | | | 19 | 19 | | | | 1 | 1 | | | | 16 | 16 | | | | 79 | 79 | 115 |
| 1981 | 6 | 1 | 4 | | 11 | | | | | | 7 | 6 | 4 | | 17 | 60 | 19 | 41 | | 120 | 148 |
| 1982 | 3 | 11 | 5 | | 19 | | | | | | 6 | 2 | 2 | | 10 | 47 | 24 | 62 | | 133 | 162 |
| 1983 | 1 | 6 | 7 | | 14 | 1 | | | | 1 | 7 | 3 | 8 | | 18 | 91 | 27 | 73 | | 191 | 224 |
| 1984 | 8 | 3 | 2 | | 13 | | 1 | | | 1 | 9 | 3 | 9 | | 21 | 122 | 40 | 87 | | 249 | 284 |
| 1985 | 3 | 7 | | | 10 | | | | | | 13 | 4 | 7 | | 24 | 98 | 29 | 88 | | 215 | 249 |
| 1986 | 4 | 3 | 3 | | 10 | | | | | | 4 | 2 | 2 | | 8 | 110 | 23 | 52 | | 185 | 203 |
| 1987 | 4 | 2 | 5 | | 11 | | 1 | 2 | | 3 | 4 | 1 | 1 | | 6 | 81 | 13 | 59 | | 153 | 173 |
| 1988 | 2 | 14 | 6 | | 22 | | 4 | | | 4 | 21 | 1 | | | 22 | 69 | 22 | | | 91 | 139 |
| 1989 | 7 | 12 | 4 | | 23 | 1 | 1 | 3 | | 5 | 4 | 1 | 8 | | 13 | 57 | 32 | 23 | | 112 | 153 |
| 1990 | 5 | 9 | 2 | | 16 | | 1 | | | 1 | 7 | 9 | 4 | | 20 | 40 | 7 | 20 | | 67 | 104 |
| 1991 | 2 | 15 | 6 | | 23 | 2 | | | | 2 | 3 | 1 | 3 | | 7 | 15 | 3 | 4 | | 22 | 54 |
| 1992 | 6 | 14 | 14 | | 34 | | 1 | | | 1 | | 1 | 3 | | 4 | 15 | 3 | 2 | | 20 | 59 |
| 1993 | 3 | 7 | 3 | | 13 | 3 | 1 | 1 | | 5 | 3 | 1 | 1 | | 5 | 18 | 16 | 23 | | 57 | 80 |
| 1994 | 7 | 16 | 4 | | 27 | 1 | 1 | 5 | | 7 | 3 | 1 | 5 | | 9 | 32 | 11 | 18 | | 61 | 104 |
| 1995 | 2 | 17 | 12 | | 31 | | 9 | 3 | | 12 | 3 | 2 | 1 | | 6 | 30 | 8 | 24 | | 62 | 111 |
| 1996 | 7 | 13 | 6 | | 26 | 7 | 2 | 15 | | 24 | 4 | 2 | 5 | | 11 | 46 | 10 | 40 | | 96 | 157 |
| 1997 | 3 | 19 | 8 | | 30 | 21 | 4 | 4 | | 29 | 5 | 8 | 2 | | 15 | 44 | 17 | 51 | | 112 | 186 |
| 1998 | 10 | 14 | 31 | | 55 | 13 | 7 | 11 | | 31 | 10 | 8 | 7 | | 25 | 90 | 17 | 55 | | 162 | 273 |
| 1999 | 7 | 33 | 14 | | 54 | 4 | 7 | 4 | | 15 | 7 | 7 | 2 | | 16 | 49 | 18 | 40 | | 107 | 192 |
| 2000 | 8 | 19 | 8 | | 35 | 2 | 4 | | | 6 | 4 | | 2 | | 6 | 37 | 23 | 25 | | 85 | 132 |
| 2001 | 9 | 9 | 8 | | 26 | | | | | | 4 | 4 | 2 | | 10 | 31 | 14 | 38 | | 83 | 119 |
| 2002 | 2 | 7 | | | 9 | | | 2 | | 2 | 10 | 6 | 4 | | 20 | 49 | 29 | 33 | | 111 | 142 |
| 2003 | | 7 | 4 | | 11 | | 3 | 3 | | 6 | 4 | 1 | | | 5 | 37 | 13 | 21 | | 71 | 93 |
| 2004 | 4 | 25 | 2 | | 31 | 1 | 2 | | | 3 | 1 | 1 | 2 | | 4 | 22 | 11 | 26 | | 59 | 97 |

**Table 4.6.6.** continued.

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 3 | 24 | 5 | | 32 | | | | | | | 1 | 1 | | 2 | 20 | 23 | 30 | | 73 | 107 |
| 2006 | | 15 | 5 | | 20 | 4 | 3 | 6 | | 13 | 3 | 2 | | | 5 | 32 | 6 | 17 | | 55 | 93 |
| 2007 | | 12 | 1 | | 13 | 6 | 6 | 9 | | 21 | 3 | | 1 | | 4 | 26 | 4 | 17 | | 47 | 85 |
| 2008 | 3 | 8 | 5 | | 16 | 2 | 1 | 2 | | 5 | | 1 | | | 1 | 12 | 3 | 12 | | 27 | 49 |

**Table 4.6.7.** Number of red grouper aged from the headboat fishery by State and Month.

| | North Carolina | | | | | | | | NC | South Carolina | | | | | | | | | | SC | GA | Florida | | | | | | | | | | | | FL | Grand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | Total | 2 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total | 5 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total | Total |
| 1977 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | 3 | | | 7 | 7 |
| 1978 | | 1 | | | | | | | 1 | | | | | | | | | 1 | | 1 | | | | | | | 1 | | 1 | | 8 | | | 10 | 12 |
| 1979 | | | | | 1 | | | | 1 | | | | | | | | | | | | | | | 1 | | 3 | 8 | 4 | 2 | 4 | 14 | 2 | 1 | 39 | 40 |
| 1980 | | 3 | | | | | | | 3 | | | | | | | | | | | | | 4 | 1 | 8 | 13 | 43 | 11 | 10 | 16 | 9 | 5 | 17 | 13 | 150 | 153 |
| 1981 | | 3 | | | | | 5 | | 8 | | | | | | | | | | | | | 7 | 13 | 20 | 30 | 14 | 5 | 8 | 7 | 11 | 7 | 26 | 24 | 172 | 180 |
| 1982 | | 1 | | 3 | | | | | 4 | | | | | | | | | | | | | 9 | 12 | 11 | 10 | 5 | 8 | 6 | 1 | | 1 | 1 | 6 | 70 | 74 |
| 1983 | | | 2 | | | | | | 2 | | | 1 | | | | | | | | 1 | | 3 | | 1 | 2 | 3 | 2 | 3 | 3 | 4 | 4 | 4 | 6 | 35 | 38 |
| 1984 | | | | | | | 1 | | 1 | | | | | | 1 | | | | | 1 | | 5 | 10 | 5 | 4 | 1 | 1 | 2 | 2 | 3 | 5 | 3 | 1 | 42 | 44 |
| 1985 | | | | | | | | | | | | | | | | | | | | | | 4 | 1 | 4 | | | 2 | 2 | 1 | 2 | 1 | 5 | 2 | 24 | 24 |
| 1986 | | | | | | | | | | | | | | | | | | | | | | 1 | | 1 | 9 | 3 | 2 | 1 | | | | 1 | | 18 | 18 |
| 1987 | | | | | | 1 | 1 | | 2 | | | | 1 | | | 11 | | | | 12 | | 1 | | | | | | | | | | | 2 | 3 | 17 |
| 1988 | | | 1 | 1 | 4 | 2 | 2 | | 10 | | | | 2 | 1 | 7 | | | | | 10 | | | 1 | 1 | | | | | | | | | | 2 | 22 |
| 1989 | | | 2 | | | 1 | | | 3 | | | | | 2 | | | | | | 2 | | | | | | | | | | | | | | | 5 |
| 1990 | | 3 | 1 | 1 | 1 | 3 | | | 9 | | | | | | | | | | | | | | | | | | | 1 | 1 | | | | | 2 | 11 |
| 1991 | | 1 | 4 | 3 | 1 | | 2 | | 11 | | | 3 | | | | | | | | 3 | | | | | | | 1 | | | 1 | | | | 2 | 16 |
| 1992 | | 2 | | 2 | | | | | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 1993 | | | | | | | | | | | 3 | | 1 | | | | | | | 4 | | | | | | | | | | | | | | | 4 |
| 1994 | 1 | | | | | | | | 1 | | | | | | | | 1 | 2 | 3 | 6 | | | | 1 | | | | | | | | 1 | | 2 | 9 |
| 1996 | | | | | | 1 | 1 | | 2 | 1 | | | | | | 1 | | 4 | | 6 | | | | | | | | | | | | | | | 8 |
| 1997 | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | 1 | | | | | | | 2 | 2 |
| 1998 | | | 1 | | | | | | 1 | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | 2 | 3 |
| 2002 | | | | 1 | | | | | 1 | | | | | | | | | 1 | | 1 | | | | | | | | 1 | | | | | | 1 | 3 |
| 2003 | | | | | | 1 | | | 1 | | | | | | | | | | | | | | | | 2 | 1 | | | | 3 | | 2 | | 8 | 9 |
| 2004 | | | 4 | 3 | 3 | 1 | | | 11 | | | | | | | | | | | | | 1 | 1 | | | 1 | | 2 | | 5 | 9 | 2 | 2 | 23 | 34 |
| 2005 | 1 | 1 | 7 | 6 | 4 | 2 | 1 | | 22 | | | | | | | | | | | | | 2 | 8 | | 2 | | 2 | 11 | 6 | 10 | 5 | 10 | 4 | 60 | 82 |
| 2006 | | | | | 2 | 2 | | | 4 | | | | | 1 | 1 | 2 | 2 | | 2 | 8 | | 7 | 5 | 7 | 6 | 4 | 3 | 1 | 2 | 1 | 3 | 5 | 3 | 47 | 59 |
| 2007 | | | 4 | | | | | | 4 | | 1 | 5 | 3 | 2 | | 4 | 3 | 1 | 1 | 20 | 1 | 7 | 6 | | 3 | 2 | | 1 | | 1 | | | 2 | 22 | 47 |
| 2008 | | | | | | | 4 | 4 | 8 | | 1 | 1 | 1 | | | | 2 | | | 5 | | | 1 | 4 | 11 | 1 | 1 | 1 | | 1 | | 2 | 1 | 23 | 36 |

**Table 4.6.8.** Number of trips from which red grouper were aged from the headboat fishery by state and month.

| | North Carolina | | | | | | | | NC | South Carolina | | | | | | | | | | SC | GA | Florida | | | | | | | | | | | | FL | Grand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | Total | 2 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total | 5 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total | Total |
| 1977 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | 2 | | | 6 | 6 |
| 1978 | | 1 | | | | | | | 1 | | | | | | | | | 1 | | 1 | | | | | | | 1 | | 1 | | 3 | | | 5 | 7 |
| 1979 | | | | | 1 | | | | 1 | | | | | | | | | | | | | | | 1 | | 3 | 7 | 3 | 2 | 3 | 8 | 1 | 1 | 29 | 30 |
| 1980 | | 3 | | | | | | | 3 | | | | | | | | | | | | | 3 | 1 | 5 | 7 | 10 | 7 | 8 | 7 | 4 | 4 | 11 | 6 | 73 | 76 |
| 1981 | | 1 | | | | | 2 | | 3 | | | | | | | | | | | | | 6 | 9 | 15 | 17 | 9 | 4 | 5 | 6 | 8 | 6 | 12 | 13 | 110 | 113 |
| 1982 | | 1 | | 2 | | | | | 3 | | | | | | | | | | | | | 7 | 10 | 7 | 4 | 4 | 6 | 4 | 1 | | 1 | 1 | 3 | 48 | 51 |
| 1983 | | | 1 | | | | | | 1 | | | 1 | | | | | | | | 1 | | 3 | | 1 | 2 | 3 | 2 | 3 | 3 | 3 | 4 | 4 | 5 | 33 | 35 |
| 1984 | | | | | | | 1 | | 1 | | | | | | 1 | | | | | 1 | | 4 | 9 | 5 | 4 | 1 | 1 | 2 | 2 | 3 | 4 | 3 | 1 | 39 | 41 |
| 1985 | | | | | | | | | | | | | | | | | | | | | | 4 | 1 | 3 | | | 2 | 1 | 1 | 2 | 1 | 3 | 2 | 20 | 20 |
| 1986 | | | | | | | | | | | | | | | | | | | | | | 1 | | 1 | 5 | 3 | 1 | 1 | | | | 1 | | 13 | 13 |
| 1987 | | | | | | 1 | 1 | | 2 | | | | 1 | | | 2 | | | | 3 | | 1 | | | | | | | | | | | 2 | 3 | 8 |
| 1988 | | | 1 | 1 | 2 | 2 | 2 | | 8 | | | | 1 | 1 | 2 | | | | | 4 | | | 1 | 1 | | | | | | | | | | 2 | 14 |
| 1989 | | | 2 | | | 1 | | | 3 | | | | | 1 | | | | | | 1 | | | | | | | | | | | | | | | 4 |
| 1990 | | 3 | 1 | 1 | 1 | 2 | | | 8 | | | | | | | | | | | | | | | | | | | 1 | 1 | | | | | 2 | 10 |
| 1991 | | 1 | 3 | 2 | 1 | | 2 | | 9 | | | 2 | | | | | | | | 2 | | | | | | | 1 | | | 1 | | | | 2 | 13 |
| 1992 | | 2 | | 1 | | | | | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 1993 | | | | | | | | | | | 3 | | 1 | | | | | | | 4 | | | | | | | | | | | | | | | 4 |
| 1994 | 1 | | | | | | | | 1 | | | | | | | | 1 | 1 | 2 | 4 | | | | 1 | | | | | | | | 1 | | 2 | 7 |
| 1996 | | | | | | 1 | 1 | | 2 | 1 | | | | | | 1 | | 3 | | 5 | | | | | | | | | | | | | | | 7 |
| 1997 | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | 1 | | | | | | | 2 | 2 |
| 1998 | | | 1 | | | | | | 1 | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | 2 | 3 |
| 2002 | | | | 1 | | | | | 1 | | | | | | | | | 1 | | 1 | | | | | | | | 1 | | | | | | 1 | 3 |
| 2003 | | | | | | 1 | | | 1 | | | | | | | | | | | | | | | | 2 | 1 | | | | 2 | | 2 | | 7 | 8 |
| 2004 | | | 4 | 2 | 3 | 1 | | | 10 | | | | | | | | | | | | | 1 | 1 | | | 1 | | 2 | | 3 | 8 | 2 | 2 | 20 | 30 |
| 2005 | 1 | 1 | 7 | 6 | 4 | 2 | 1 | | 22 | | | | | | | | | | | | | 2 | 3 | | 2 | | 2 | 8 | 4 | 7 | 5 | 10 | 3 | 46 | 68 |
| 2006 | | | | | 2 | 1 | | | 3 | | | | | 1 | 1 | 2 | 2 | | 2 | 8 | | 5 | 5 | 6 | 5 | 3 | 3 | 1 | 2 | 1 | 2 | 5 | 3 | 41 | 52 |
| 2007 | | | 2 | | | | | | 2 | | 1 | 5 | 3 | 2 | | 4 | 3 | 1 | 1 | 20 | 1 | 6 | 4 | | 3 | 2 | | 1 | | 1 | | | 2 | 19 | 42 |
| 2008 | | | | | | | 2 | 1 | 3 | | 1 | 1 | 1 | | | | 2 | | | 5 | | | 1 | 3 | 6 | 1 | 1 | 1 | | 1 | | 2 | 1 | 17 | 25 |

**Table 4.6.9.** South Atlantic headboat estimated angler days 1981-2008.

| Year | NC | SC | GA\NEFL | SEFL | Grand Total |
|---|---|---|---|---|---|
| 1981 | 19372 | 59030 | 72069 | 226456 | 376927 |
| 1982 | 26939 | 67539 | 66961 | 226172 | 387611 |
| 1983 | 23830 | 65713 | 83499 | 194364 | 367406 |
| 1984 | 28865 | 67313 | 95234 | 193760 | 385172 |
| 1985 | 31346 | 66001 | 94446 | 186398 | 378191 |
| 1986 | 31187 | 67227 | 113101 | 203960 | 415475 |
| 1987 | 35261 | 78806 | 114144 | 218897 | 447108 |
| 1988 | 42421 | 76468 | 109156 | 192618 | 420663 |
| 1989 | 38678 | 62708 | 102920 | 213944 | 418250 |
| 1990 | 43240 | 57151 | 98234 | 224661 | 423286 |
| 1991 | 40936 | 67982 | 85111 | 194911 | 388940 |
| 1992 | 41177 | 61790 | 90810 | 173714 | 367491 |
| 1993 | 42785 | 64457 | 74494 | 162478 | 344214 |
| 1994 | 36693 | 63231 | 65745 | 177035 | 342704 |
| 1995 | 40294 | 61739 | 59104 | 142507 | 303644 |
| 1996 | 35142 | 54929 | 47236 | 152617 | 289924 |
| 1997 | 37189 | 60147 | 52756 | 120510 | 270602 |
| 1998 | 37399 | 61342 | 51790 | 103551 | 254082 |
| 1999 | 31596 | 55499 | 56770 | 107042 | 250907 |
| 2000 | 31323 | 40291 | 59771 | 122478 | 253863 |
| 2001 | 31779 | 49263 | 55795 | 107592 | 244429 |
| 2002 | 27601 | 42467 | 48911 | 102635 | 221614 |
| 2003 | 22998 | 36556 | 52795 | 92216 | 204565 |
| 2004 | 27255 | 50461 | 50544 | 123157 | 251417 |
| 2005 | 31573 | 34036 | 47778 | 123300 | 236687 |
| 2006 | 25730 | 56070 | 48943 | 126607 | 257350 |
| 2007 | 28997 | 60725 | 53759 | 103386 | 246867 |
| 2008 | 17156 | 47285 | 52338 | 71593 | 188372 |

**Table 4.6.10.** Aged red grouper sample size by year, state, and month for the recreational charter and private mode (MRFSS).

| MRFSS | Florida | | | | | | | | | | | | Grand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
| 2001 | | | | | 3 | | | 1 | | 5 | | 5 | 14 |
| 2002 | 9 | 10 | 6 | 3 | 2 | 2 | 2 | 1 | 3 | 3 | 4 | 1 | 46 |
| 2003 | 2 | | 8 | 5 | 5 | 3 | 1 | 3 | 1 | 1 | 1 | | 30 |
| 2004 | 3 | 2 | 1 | | | 1 | 2 | | | 8 | | | 17 |
| 2005 | 5 | 3 | 8 | 2 | 2 | 1 | 1 | 1 | 4 | 4 | 7 | | 38 |
| 2006 | 1 | 3 | 3 | 9 | | 2 | 1 | | | | | | 19 |
| 2007 | 2 | 5 | | | | | 1 | | | | | | 8 |
| 2008 | 1 | 1 | | | 1 | | | | | | | | 3 |

### *4.7. FIGURES*



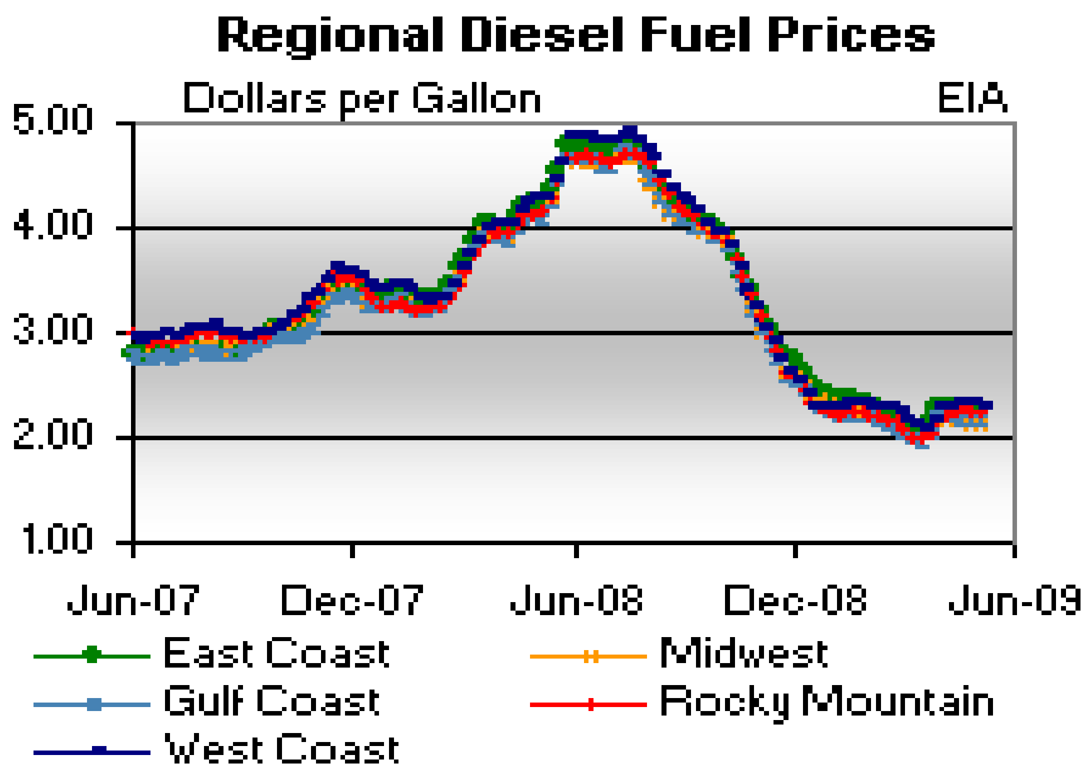


**Fig. 4.7.1.** Regional diesel fuel prices Jun 07-Jun-09.

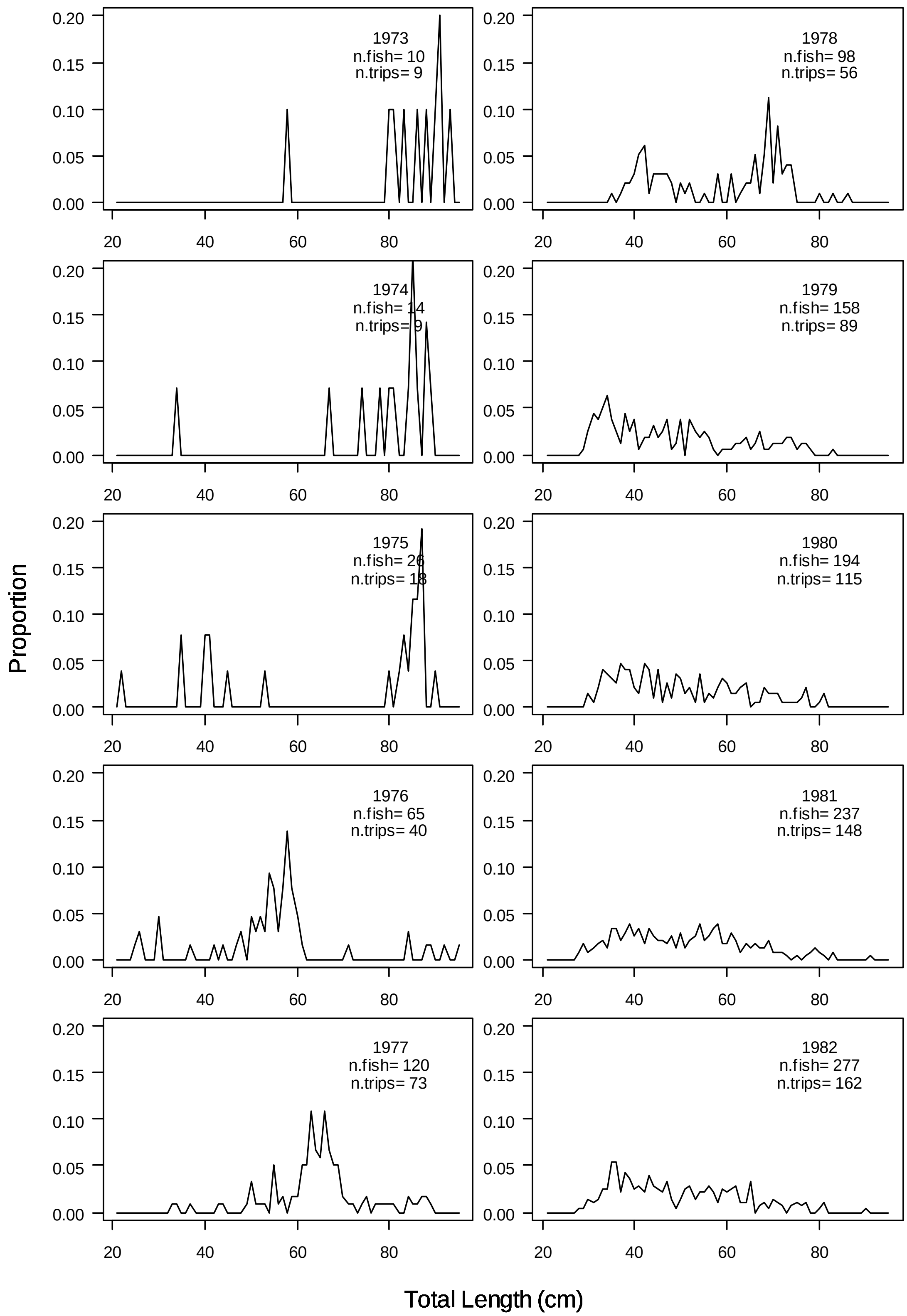


**Figure 4.7.2.** Red grouper length composition from the headboat fishery. Vertical lines represent minimum size limit regulations

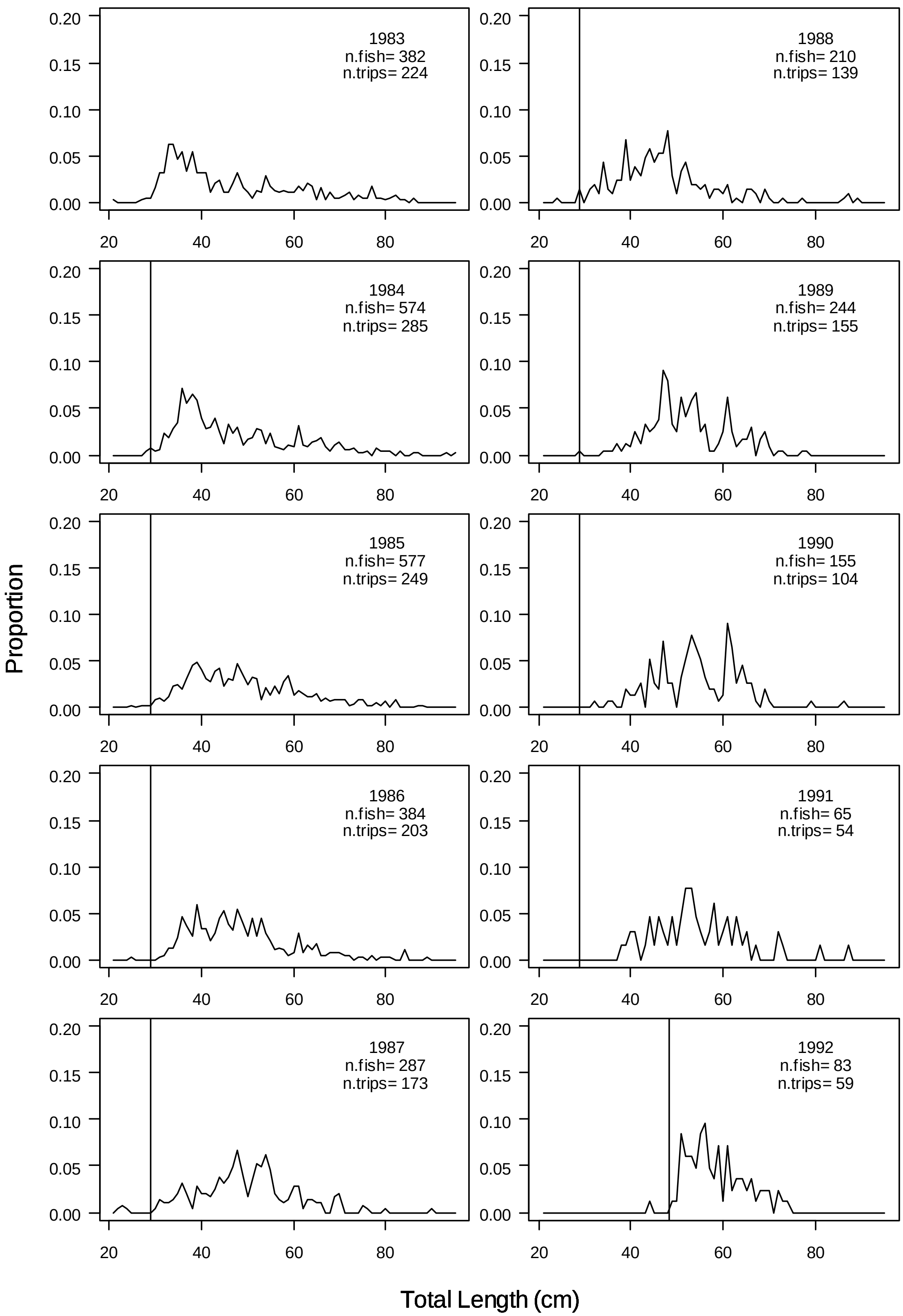


**Figure 4.7.2.** Continued.

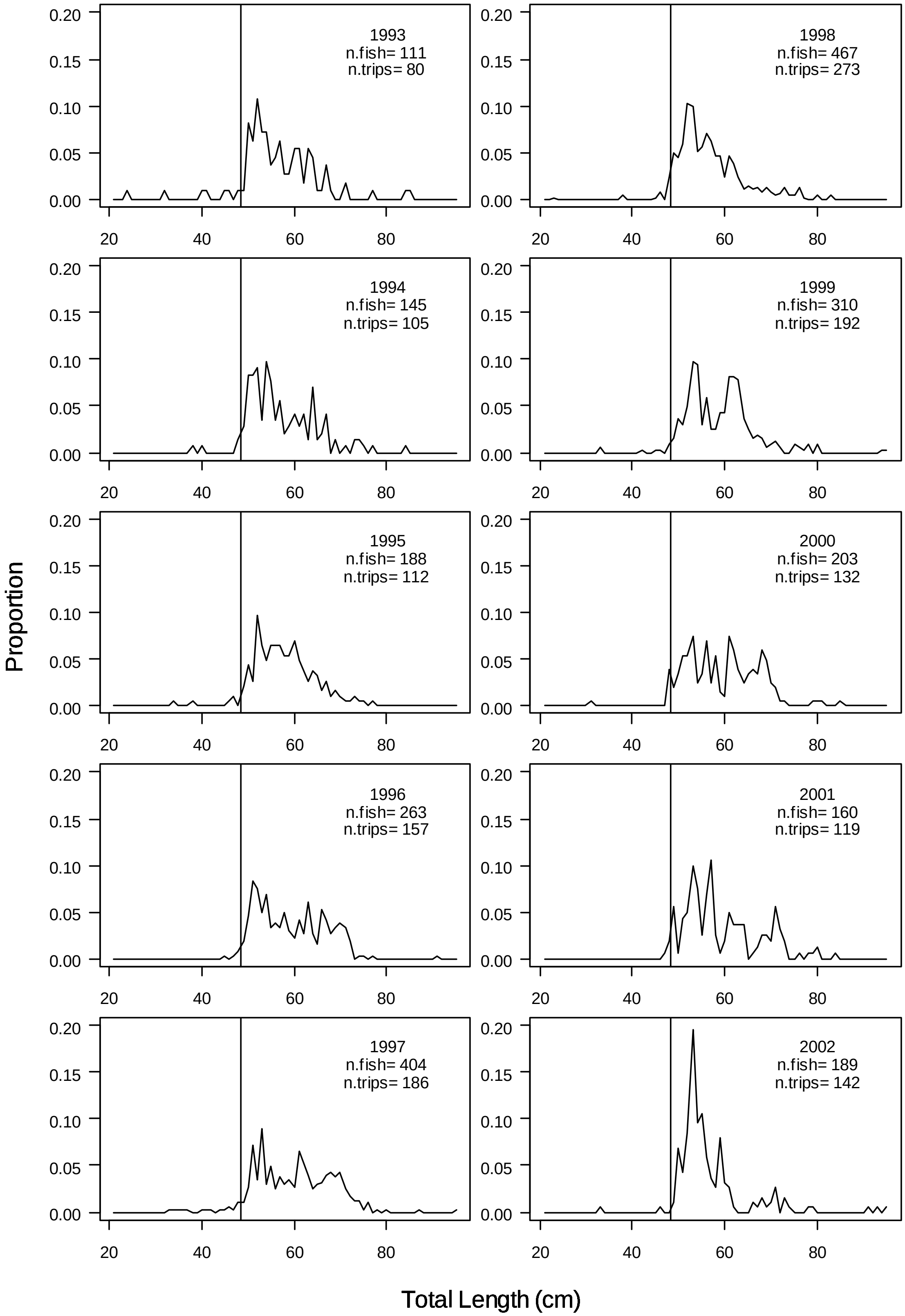


**Figure 4.7.2.** Continued.

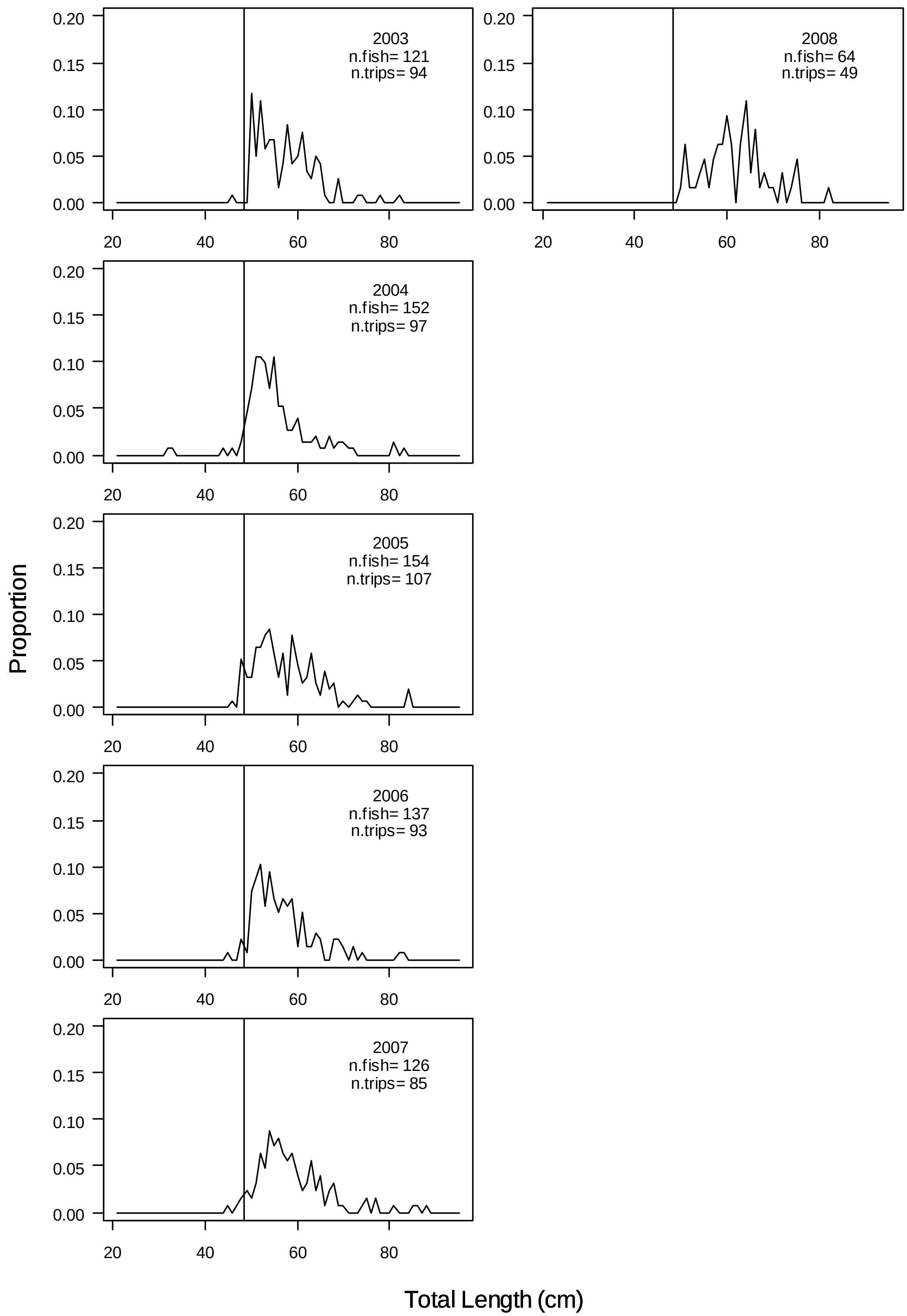


**Figure 4.7.2.** Continued.

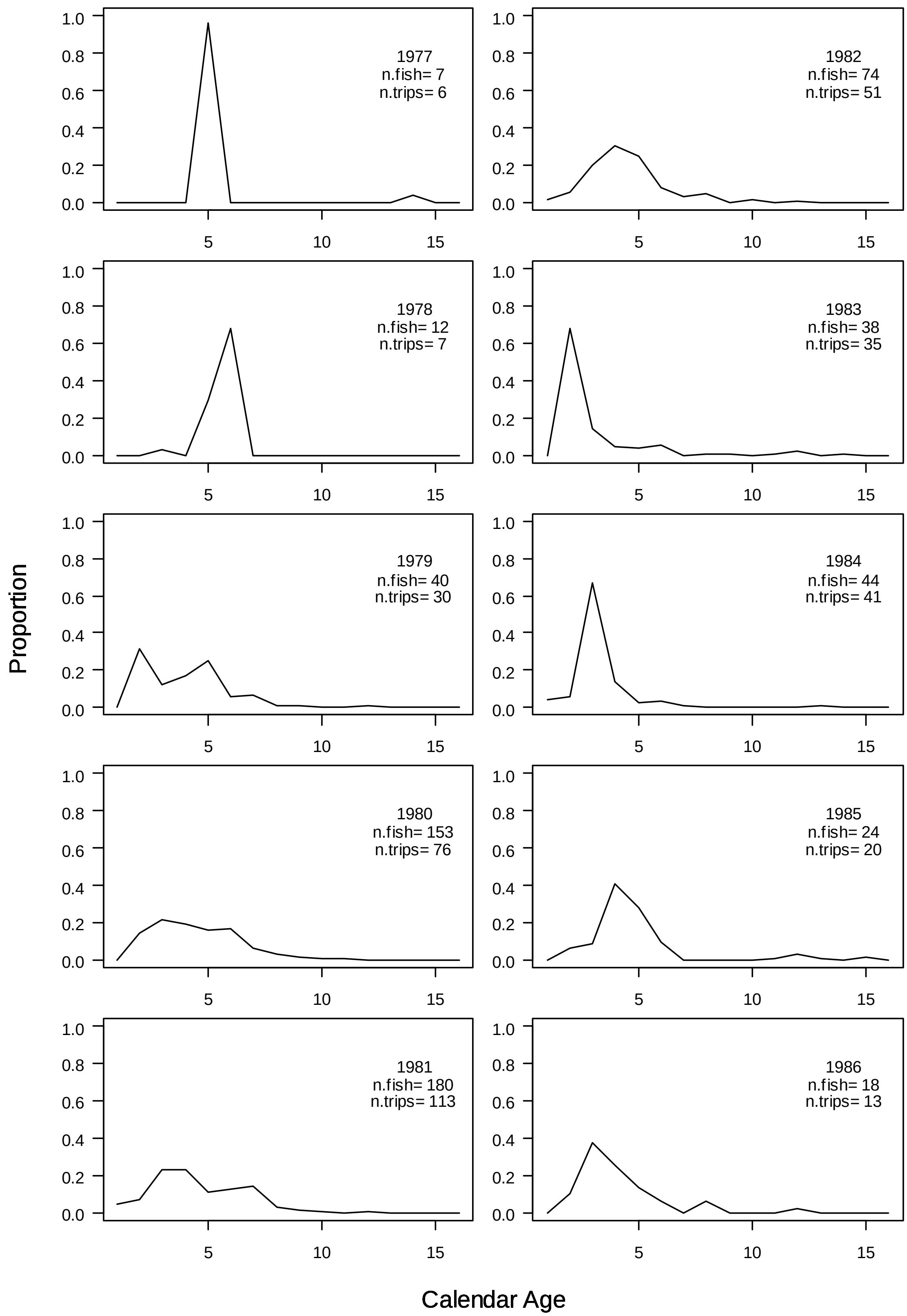


**Figure 4.7.3.** Red grouper age composition from the headboat fishery.

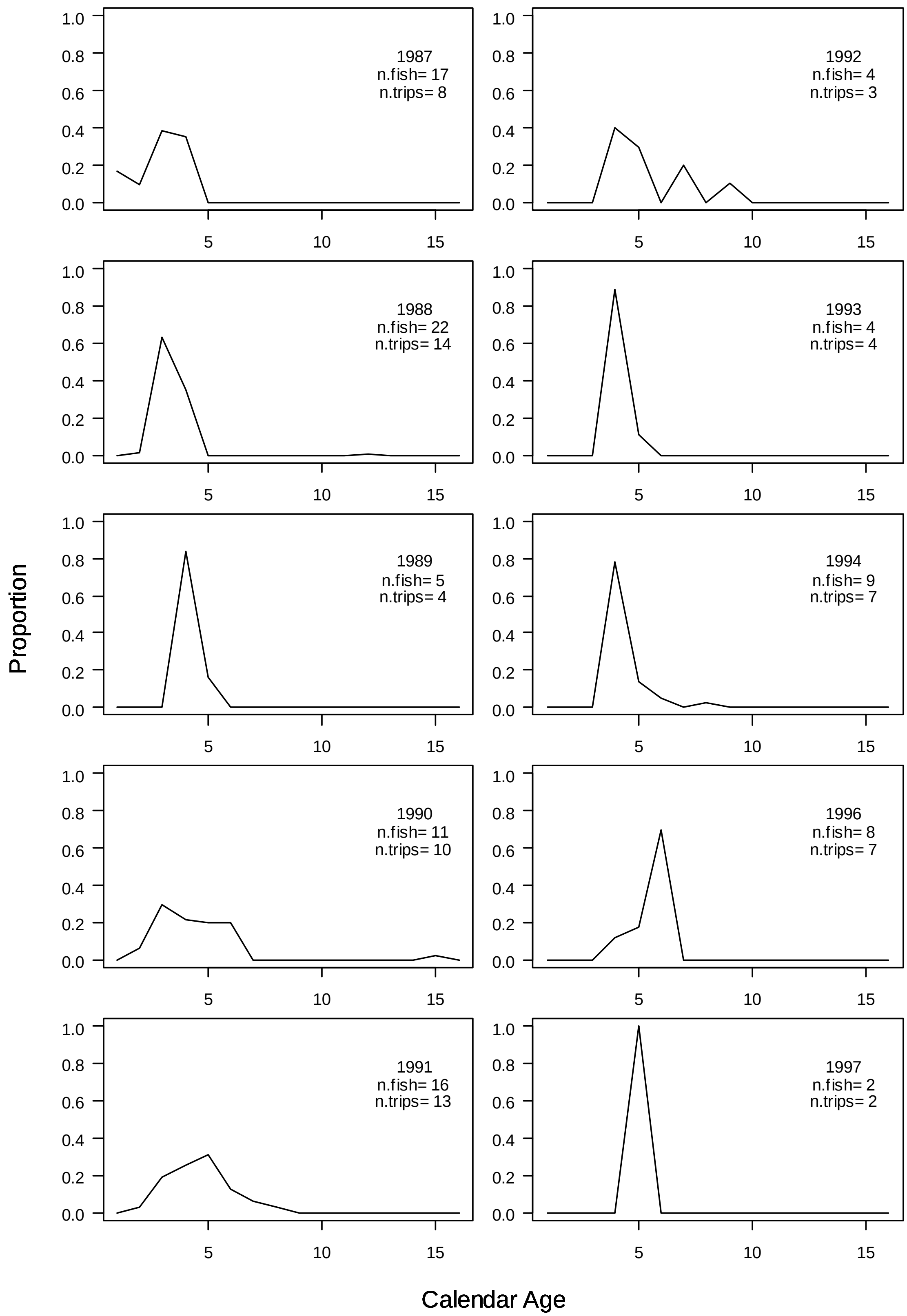


**Figure 4.7.3.** Continued

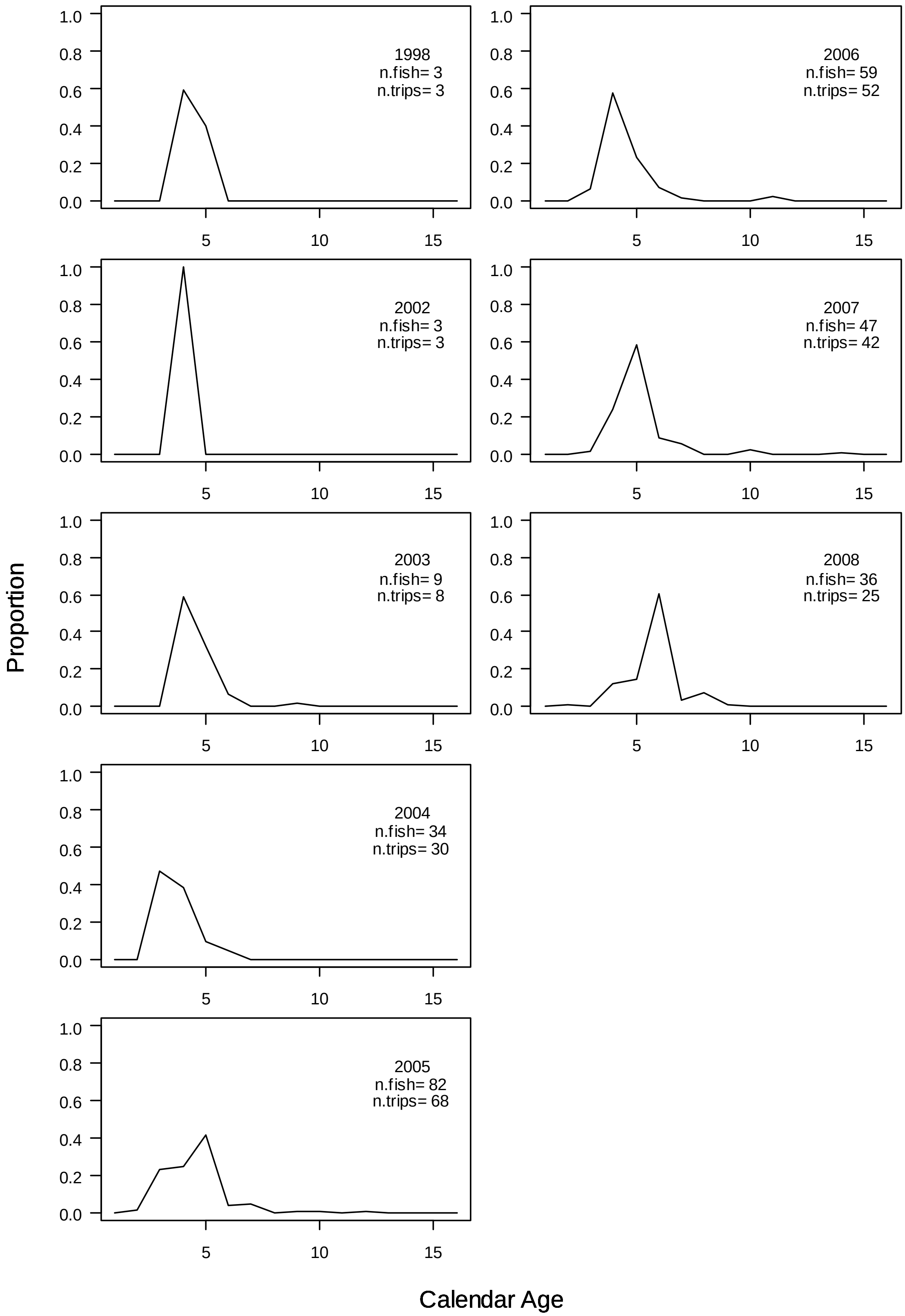


**Figure 4.7.3.** Continued.

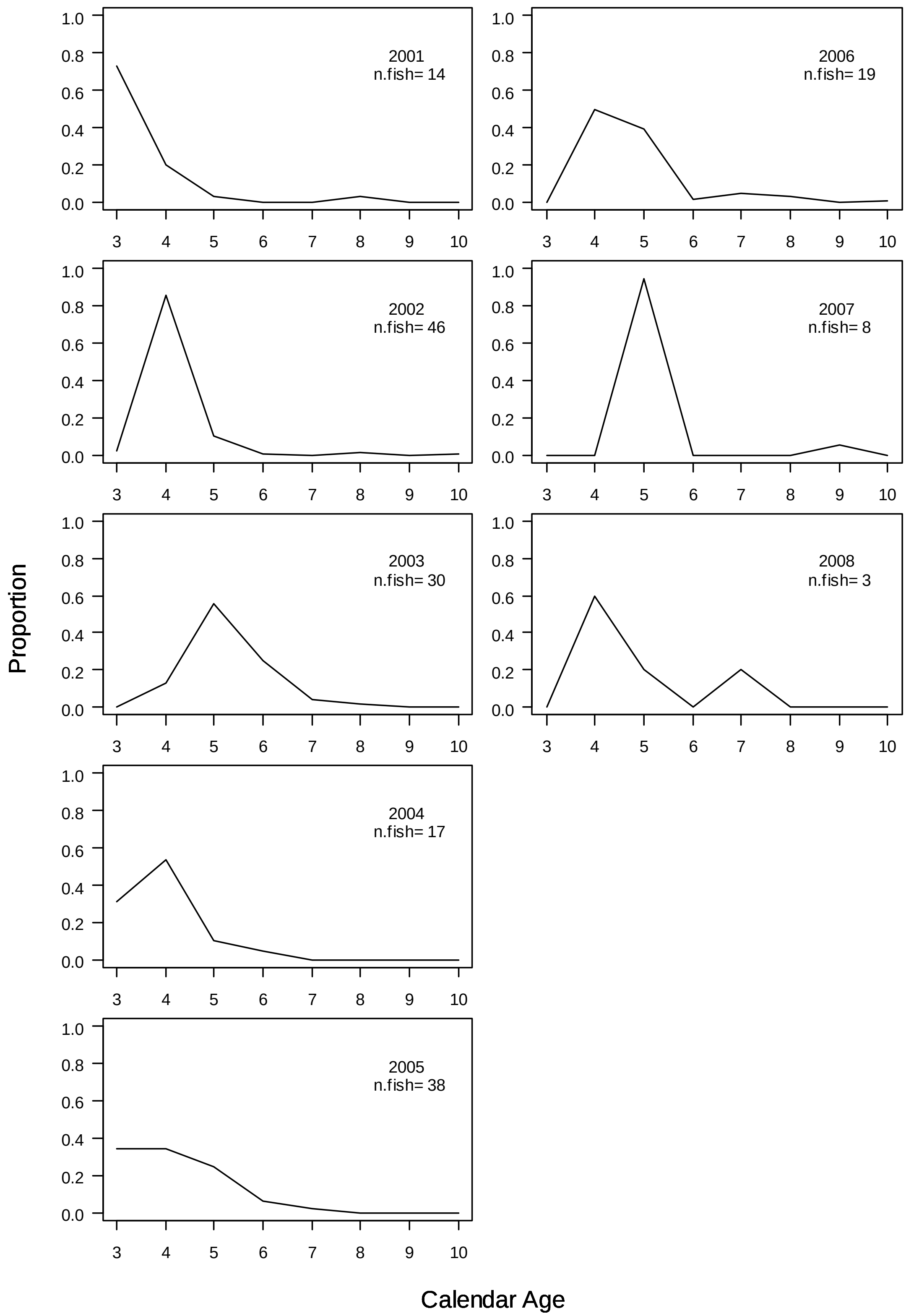


**Figure 4.7.4.** Red grouper age composition from the recreational private and charter modes (MRFSS).

## Appendix I: Historical perspective of recreational grouper fisheries

Historical Records of Red and Black Grouper

Anecdotal and reported catches of grouper, including red and black grouper, have occurred since at least the mid 1800s. While much of the reports of actual landings in select areas, primarily regions or counties in Florida, reflect commercial catches, there are some sporadic reports of catch from sportfish, charter, or party boats. These reports provide evidence of directed effort targeting red and black grouper by sport anglers, particularly in Florida, dating back to at least the 1870s. However, it is unclear through historical records the extent and magnitude of angling activity for red and black grouper over the past 100 years.

Since there are very few and incomplete records of red and black grouper annual catches and effort prior to 1981, it is felt that historical records are inadequate to develop recreational historical landings for the purpose of this stock assessment. For the few records that do detail grouper landings for an area or a state (Florida), the grouper species are lumped together and not separated by species. Additionally, there seems to be some confusion with red grouper, red snapper, and gray ("mangrove") snapper in early accounts. Even more significant, several species of grouper appeared to be called black grouper depending on time period and locality. For instance, Hallock (1876) uses the nomenclature *Serranus nigritus* to describe black grouper which seems to refer to warsaw grouper (*Epinephelus nigritius*) but the description of the species is more similar to goliath grouper which he describes as a favorite target of anglers.

Historical reports of encounters with red and black grouper by sport fishermen occur as early as the 1870s ((Hallock 1876). At that time, red grouper were also called red snapper along the east coast of Florida and were coined *Serranus erythrogaster* by DeKay in 1842 (Hallock 1876, Perry et al 1892). *S. erythrogaster* is a synomym for *Epinephelus morio* (http://www.flmnh.ufl.edu/fish/gallery/Descript/RedGrouper/RedGrouper.html). Hallock (1876) reports of catching *S. erythrogaster* in Mosquito Inlet and Indian River Inlet on the east Coast of Florida. Also reported by Hallock (1876) are catches of "black" grouper (*S. nigritus*) which may indeed been goliath groupers. In early reports, black grouper was used to describe jewfish and it was suggested that what is now known as goliath grouper were actually two different species:

one that lived inshore weighing up to 150 pounds and one that lived offshore getting to 600+ pounds (Goode 1887).

While red grouper seemed to be abundantly caught along Florida's east coast, it was unclear how far north the species occurred (Perry et al 1892, Smith 1907). Black grouper were predominantly known from the Florida Keys, particularly Key West, but sporadic accounts of this species appeared in Beaufort Harbor and Woods Hole (Smith 1907). Early accounts showed that red grouper were the most abundant grouper in the Keys (Schroeder 1895). In the Palm Beach area, "semi-professional boatmen" would take out "pleasure parties" often from out of state to go fish for grouper among others species (Brice 1897). Several other early accounts similarly describe catching grouper species including red and black grouper, in addition to jewfish, dating back to the late 1800s and early 1900s (Goode 1887, Gregg 1902, Turner 1902, Holder 1903).

By the late 1800's a commercial fishery for grouper and other species had developed with some reported landings by gear type in different localities (Brice 1897). Jarvis (1934) reported several years of grouper landings between 1902 and 1934, and described the habitats and habits of some grouper species in Florida.

The earliest available and known record of actual recreational landings and effort occurs in 1955 from charter boats along the east coast of Florida (Ellis 1957). For instance, in 1955 there were 514 charter boats mainly between Stuart and Key West that caught 67,871 grouper (448,847 pounds) during 270,800 fisherman-trips. Grouper in this study was not separated by species and included "predominantly *Epinephalus*, *Mycteroperca*, *Garrupa*, *Cephalopholis*." Effort from the various fishing modes throughout Florida during that same time period was also estimated by Ellis et al 1958. For example, there was an estimated 381,000 trips made on 762 charter boats, 459,000 trips made on 164 party boats, 836,000 fisherman days from shore, and 10,589,000 trips made on private recreational boats for a total of nearly 20 million fisherman-days fishing in salt and brackish water in 1955 in Florida. Much of this activity occurred in southeast Florida and by visitors to the state. Moe (1963) estimated that 32% of the charter boat effort in Florida during the early 1960s occurred on the bottom which provides evidence that this part of the fishery was not likely primarily targeting grouper. However, about 69% of the effort from the party boat fleet fished on the bottom possibly targeting groupers and snappers. However, there is also probable that the party boats were targeting the smaller reef fish species such as grunts. In contrast, the commercial fishery during this time targeted species on the bottom in 99% of their trips (Moe 1963).

Table 4.A.1. Review of Historic State-Level Surveys of Recreational Fishing Effort and Catch.

| Year(s) | Mode and Area | Methods | Effort | Catch | Citation |
|---|---|---|---|---|---|
| 2/1956-2/1957 | Charter, Atlantic coast of Florida, including Keys. | Interviews of 104 charter captains, ~300 interviews of angling parties, 140 charter logbooks. | 514 vessels;<br><br>Estimated 270,820 angler trips | Unclassified grouper species, estimated total catch:<br><br>67,871 fish<br><br>448,847 pounds | Ellis, R.W. Catches of Fish by Charter Boats on Florida's East Coast. Report to Florida State Board of Conservation. Coral Gables, FL. Special Service Bull. 14. |
| 1955-1957 | Private recreational angling, Florida offshore fishing (Gulf and Atlantic) | Mail surveys of 1,100 households, return rate 70%. Monthly panel survey (telephone). | Private boat angling 52% of effort;<br><br>bridge/pier/jetty angling 27%; charter and party angling 5%. | Grouper was not listed as a target species or any portion of recreational catch. | Rosen, A. and R. Ellis. 1961. Catch and Fishing Effort by Anglers in Florida's Coastal and Offshore Waters. Florida State Board of Conservation, Special Service Bull. 18. |
| 1962 | Private recreational boats, charter boats, party boats. Area includes offshore fishing in Florida. | Personal interviews with party/charter vessel operators; post-card survey of 10% (14,000) of private boat owners (33.6% return rate). | Bottom fishing effort (angler days):<br><br>Party: 100,197<br><br>Charter: 24,347 | For-Hire:<br><br>Along Atlantic coast and Keys:<br><br>Charter vessels primarily surface fishing for dolphin, king mackerel, sailfish, etc.;<br><br>Party vessels list red grouper and "black grouper" among primary species taken.<br><br>Private Boats:<br><br>Gulf and Atlantic combined:<br><br>Red grouper the fourth most sought fish by private recreational boat fishery. Black grouper a sport fish primarily in Keys, of minor importance. | 1963, Moe, M. A Survey of Offshore Fishing in Florida. Florida State Board of Conservation. Professional Paper Series, No. 4. |

The possibility of using the Salt-Water Angling Surveys of 1960, 1965, and 1970 (Clark 1962, Deuel and Clark 1968, Deuel 1973) were considered by the Recreational Workgroup for estimating red grouper landings prior to the 1981 implementation of MRFSS. However, those surveys were not advised for extending time series of recreational landings for SEDAR-19 assessments. For grouper species in the South Atlantic region, a major caveat regarded the surveys' wording when asking for the "kinds of saltwater fish" caught by the angler. The grouper category included "sea bass, hinds, etc.", and while there was a separate category for black sea bass, given the way the grouper category was annotated, many of the fish recorded in the grouper category were likely to have been sea bass. Thus, black sea bass, a common species in this region, were reported under one of two categories (groupers or black sea bass) in unknown proportions. The high average weight applied to the grouper category in 1960 could also be a gross overestimation if sea bass were included in the grouper category. Changes in survey procedures among the three years for estimating total weight of fish by species are described in Table Y below.

Table Y. Changes in Salt-Water Angling survey procedures for estimating total weight by species.

| Year | # Groupers | Lbs. Groupers | Notes on Weight Estimates |
|---|---|---|---|
| 1960 | 2,286,000 | 34,290,000 | Interviewed selected charter captains and marine scientists to get an estimated average weight of 15 pounds per grouper in S. Atlantic. |
| 1965 | 6,905,000 | 54,581,000 | Asked respondents to record average weight of fish caught. |
| 1970 | 4,198,000 | 24,121,000 | Manually corrected for respondents that reported estimated total weight rather than average weight for species caught. |

**Annotated Bibliography: historical recreational catch and effort of red and black grouper.**

Compiled: Chad Hanson

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**Hallock 1876**

Charles Hallock. 1876. Camp Life in Florida. A handbook for sportsmen and settlers.

Pg 56-57: [downloaded at www.archive.org]

*Serranus erythogaster* (red snapper or grouper), called by both in different localities.

- East Florida goes by snapper
- At mosquito inlet, small (one to three pounds),
- Indian River inlet, taken at 10-12 pounds, in gulf twice the size

Black grouper (*S. nigritus*) - ??

- Olive brown, dark mottled lines, resembling tortoise shell
- Taken at mosquito inlet from 2 to 10 pounds
- Favorite target of anglers
- Found under mangroves or in holes in banks
- book also mentions Jewfish later on

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**Goode 1887, new edition 1908**

Game and Food Fishes of North American with especial reference to habits and methods of capture. G. Brown Goode.

[Downloaded from google books, electronic copy, paper copy of pages below]

Red grouper: *E. morio* (pp 47-53)

- Up to 40-50 lbs,
- no record north of Florida
- most abundant southern florida,
- west florida, red snapper more abundant, grouper not in demand by small market value
- DeKay writes in 1842: not unusual for "groper" or "red groper" to show up in NY markets ,coming from reefs of Florida, informed by West Indie fishermen that occasionally but rarely taken from off NY
- Holbrooke: brought into Charleston from Florida Jan-Mar
  - o Abundant along whole east coast of florida, florida keys, and gulf of mexico
- Stearns: extremely abundant in GOM, with red snapper, more of a bottom fish than snapper

- S.C. Clarke refers to a fish called "mangrove snapper" or "red grouper"

Black Grouper: *E. nigritus*, called Jew-Fish in Florida and Texas, called Warsaw in Pensacola

- Abundant on east florida and GOM
- Large jew-fish *Promicrops guasa* – adult of black grouper?
- Confusion of which spp black grouper (Pensacola: *M. brunnea, M. microlepis, M.* stomis)

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**Perry et al 1892**

American Game Fishes Their Habits, Habitat, And Peculiarities ; How, When, And Where To Angle For Them. W. A. Perry (" Sillalicum "), A. A. Mosher, W, H. H. Murray,W. D. ToMLiN, A. N. Cheney, Prof. G. Brown Goode, W. N. Haldeman, Francis Endicott, Fred. Mather, S. C. Clarke, Rev. Luther Pardee, Charles Hallock, F. H. Thurston (" Kelpie "), J. Harrington Keene,Prof. David Starr Jordan, William C. Harris, B. C. Milam, G. O. Shields ("Coquina"), J. G. A. Creighton, Dr. J. A. Henshall.

[Downloaded at archive.org, electronic copy]

Red Grouper – E. morio (pg 310) also called *Serranus erythogaster*

- Found on east Florida coast and in abundant and large in West Indies
- Not sure how far north its found
- Found near bottom, in deep holes, near mangrove roots (referring to gray snapper?)
- Image on pg 311 red grouper

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**Schroeder 1895**

William C. Schroeder. 1895. Fisheries of Key West and Clam Industry in Southern Florida

Commercial market in Key West. APPENDIX XII TO THE REPORT OF THE U. S. COMMISSIONER OF FISHERIES FOR 1923. Bureau of Fisheries Document No. 962

[Downloaded at archive.org, electronic copy] pp.3-4, 14-16

- Red grouper – most abundant and best known of Keys groupers, widely distributed, most common during winter but taken throughout year, on rocky, coral, grassy bottoms
    - In shallow water taken 0.5 to 2 lbs, deeper water 2-15 lbs, over 20 lbs not common
    - Ships well alive, transported to Cuba
    - Uncommon north of Florida, rare straggler in North Carolina

- Black grouper (M. bonaci) not sold a lot but highly valued due to size
  - 5-50 lbs, caught deeper than 25 ft , most common Feb-Apr, uncommon over 50lb, average weight 10 lbs, max 100 lbs
- Also mentions, M. microlepis (gag), M. venenosa (yellow-finned grouper, yellow grouper), Promicrops itaiara (jewfish, spotted jewfish), M. falcata phenax (scamp)

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**Brice 1897**

Fish and Fisheries of Coastal Waters of Florida. LETTER FROM THE COMMISSIONER OF FISH AND FISHERIES, TRANSMITTING, IN RESPONSE TO SENATE RESOLUTION OF FEBRUARY 15, 1895, A REPORT ON THE FISH AND FISHERIES OF THE COASTAL WATERS OF FLORIDA. United States Commission ov Fish and Fisheries, Washington, JD. C, January 28, 1897. 54th Congress, 2nd session, document 100.

[downloaded at archive.org, electronic copy] pp.21, 33-36,

- Palm beach, semi-professional boatmen engaged in taking pleasure parties for "grouper"
- "The catch is largely sheepshead, although bluefish, snappers, muttonfish, kingfish, groupers, Spanish mackerel, and other species are also taken in considerable quantities.
- In 1891 this fishery yielded 15,500 pounds, valued at $1,208, and in 1895, 90,852 pounds, worth 62,422."
- "The principal fishes obtained in ocean fishing off Lake Worth are sheepshead, Spanish mackerel, kingfish, red fish, groupers, bluefish, red snapper, and mutton-fish, all of which are comparatively abundant."
  - Biscayne Bay landings (pg 36) 1895:"grouper" = 14,100 pounds
  - Lake worth: table on pp 33-34 of numbers fishermen, landings by gear for 1894 and 1895 ("grouper)"

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**Gregg 1902**

Where, When, and How to Catch Fish on the East Coast of Florida. William H. Gregg.

[downloaded at archive.org, electronic copy]

- Fished in "every State and Territory in the Union but three, and from Siberia and Behring Sea to the Gulfs of California and Mexico, and, all things considered, regard Florida as unequaled in the richness and variety of its attractions for all sorts of sport with rod and reel"
- Snapper Bank furnishes red snapper or red grouper
- Description of species including red grouper, black grouper, jewfish
- Locations and how caught

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**Turner 1902**

Giant Fish of Florida. J. Turner-Turner. 1902.

- Select chapters describing catching tarpon, jewfish, kingfish, etc
- Lots of illustrations

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**Holder 1903**

Charles F. Holder. 1903. Big Game Fishes of the United States

[downloaded at archive.org, electronic copy]

Red grouper: *E. morio* (start pg 211)

- ranging up to 70 lbs (3.5 ft long), largest fish of its kind seen by author,
- caught in 20-100 ft, prefers bases of great coral reefs
- found in abundance in grounds north of Sand, Middle, and East Keys and Tortugas
- chief attraction of sport anglers, caught amongst a wide variety of species
- common of red snapper
- comes inshore in June to spawn, but not migratory

black grouper: *Garrupa nigrita* ---

- the description actually sounds like a jewfish,
- large individuals called jewfish, smaller up to 150 lbs called black grouper
- ranges from Pensacola to mouth of St. Johns River
- attains weight at last 600 pounds

smaller black grouper: *M. bonaci*

- 20-45 pounds

The Florida jewfish – starts at p 298

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**Smith 1907**

The Fishes of North Carolina. Hugh M. Smith. 1907

[downloaded at google books, electronic copy]

Red Grouper: *E. morio* Pp 276

- Biological description
- Abundant Brazil to Florida, regularly extends range up south atlantic coast, occasional straggler up to MA,
- Important food fish in Key West, GOM, and southward,

- attaining 3 ft in length
- NC: does not occur in sufficient abundance or large enough size to have economic value

Black grouper: *M. bonaci* (p.278-9)

- Atlantic coast north of Florida: shows up as straggler from West Indies,
- author reported from Woods Hole, specimens seined in Beaufort Harbor in 1902 and 1904
- attains 50lbs, used for food
- Abundant at key west

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**Holder 1908**

Charles F. Holder. Sportfishing in California and Florida. From BULLETIN OF THE BUREAU OF FISHERIES, Volume XXVIII, 1908 Proceedings of the Fourth International Fishery Congress. Washington, 1908

[downloaded at archive.org, electronic copy]

- Grouper notable food fish: red grouper most valuable, deepwater fish caught on hand line

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**Jarvis 1934**

No mention of recreational, only commercial, GOM

- Description of landings of "grouper" 1902-1932
- Description of species, habitats, markets
- Report of large number of dead fish off Campeche Bay

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**Ellis 1957** (Catches of fish by charter boats on Florida's east coast. Robert W. Ellis. 1957. The Marine Laboratory, University of Miami, Marine Fisheries Research, Special Service Bulletin No. 14. Report to the Florida State Board of Conservation).

[Bev Sauls paper copy]

- Estimated charter boat catches off East Florida using charter boat catch records (logbooks) and interviews of anglers fishing on charter boats
- 514 charter boats in industry centered between Stuart and Key West, with some in Daytona Beach area
    - Dade Co = 182
    - Broward = 100
    - Palm Beach = 68
    - Martin = 26

o Volusia = 17
o St. Johns = 2
- Records of 443 trips during February 1, 1956 and January 31, 1957
- 104 interviews of charter captains (20% of industry)
- "About 300" interviews made of anglers on charter boats
- 90% anglers were tourists, peak activity in winter
- 140 daily trips with catch data from charter boat captain interviews or log books
- Effort estimated for 1955

Results

- 18 trips out of 443 (4%) recorded no catch
- Average catch per angler per trip = 2.6 fish weighing 21.2 pounds
- Dolphin, bonito, kingfish, and "grouper" most frequently caught
- Survey
o Grouper – caught on 40 trips (9.0%), 393 fish (28.5%), 2599 pounds (7.8%), average 6.6 pounds
- Total estimates for time period
o Grouper = 67,871 fish, 448,847 pounds
o Total effort for all charter trips = 270,820 man trips on Florida's east coast
- Grouper: predominantly <u>Epinephalus</u>, <u>Mycteroperca</u>, <u>Garrupa</u>, <u>Cephalopholis</u>

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**Ellis, Rosen and Moffett, 1958**

(Robert W. Ellis, Albert Rosen, and Alan W. Moffett. 1958. <u>A Survey of the Number of Anglers and of Their Fishing Effort and Expenditures in the Coastal Recreational Fishery in Florida.</u> The Marine Laboratory, University of Miami, Virginia Key, Miami 49, Florida. State of Florida Board of Conservation Technical Series No. 24.)

[paper copy in Bev Sauls file; digital copy downloaded at FWRI library]

In 1955:

- estimated 34% Florida residents fished in salt/brackish water, ~7% owned at least one boat
- 762 charter boats made 95,000 trips in FL waters; 381,000 fisherman-days
o ~89% took place in southeast Florida
- 164 party boats made boat 33,000 trips; 459,000 fisherman-days
o ~66% represents visitors
o Greater than half in southeast Florida
- 558 fishing camps around state catering salt/brackish anglers
- 1.5 million fisherman-days from anglers rented skiffs (with rented or angler supplied outboard motors)
- 569,000 fisherman-days spent on 23 paid piers around state
- 5.6 million fisherman-days from 226 bridges, free piers, and jetties
o 39% by visitors
o 40% occurred in southeast Florida

- 267,000 fisherman days from daylight shorefishing; no data on night fishing
  - 37% by visitors
- 10,589,000 fisherman-days from private boat anglers; 14% from visitors
- Total fisherman-days = 20 million all types of salt/brackish fishing
- ➔ No mention of catch type

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**Moe 1963**

A Survey of Offshore Fishing in Florida. Martin A. Moe, Jr. January 1963. Professional Papers Series Number Four. Florida State Board of Conservation, Marine Laboratory, St. Petersburg, Florida. 177pp.

[paper copy in Beverly Sauls, available at FWRI online library, ]

Fishing pressure (pp 66):

- Charter boat: 31.6% of its effort on bottom
- Party boat: 31.3% of effort on surface
- Commercial: 99.3% on bottom
- Descriptions of fishing effort (qualitative) by county and vessel type, and most commonly caught species

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**Milon & Thunberg, 1993**

J. Walter Milon and Eric M. Thunberg. 1993. A regional analysis of current and future florida resident participation in marine recreational fishing. Sea Grant Report Number 112.

- based on the mrfss during July 1991 to June 1992 (76,549 interviews)
- "grouper" trips = 3,114 total (of 51,016, 6.1%) (table 4.1)
  - party = 113 (3.6%)
  - charter = 99 (3.2%)
  - private/rental = 2719 (87.3%)
  - shore = 183 (5.9%)
- grouper not defined

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Holbrook's "Ichthyology of South Carolina

# 5. MEASURES OF POPULATION ABUNDANCE

## *5.1. OVERVIEW*

Several indices of abundance were considered for use in the red grouper assessment model. These indices are listed in Table 5.1, with pros and cons of each in Table 5.2. The possible indices came from fishery independent and fishery dependent data. The DW recommended the use of two fishery independent indices (one from MARMAP chevron traps and one from the University of Miami/NMFS reef fish visual census survey) and three fishery dependent indices (one from commercial logbook data, one from headboat data, and one from general recreational data; Tables 5.1 and 5.2).

### 5.1.1. Group membership

Membership of this DW working group included Jerry Ault, Rob Cheshire, Chip Collier, Paul Conn (leader), Claudia Friess, Chris Hayes, Walter Ingram, Kevin McCarthy, Bob Muller, Kyle Shertzer, and Jessica Stephen.

## *5.2. REVIEW OF WORKING PAPERS*

The working group reviewed a number of working papers and reference documents describing index construction, including:

| | |
|---|---|
| SEDAR19-DW-03 | (Headboat survey) |
| SEDAR19-DW-10 | (U. Miami/NMFS Reef fish visual census) |
| SEDAR19-DW-11 | (U. Miami/NMFS Reef fish visual census) |
| SEDAR19-DW-12 | (FWC visual survey) |
| SEDAR19-DW-14 | (Commercial logbook index) |
| SEDAR19-DW-17 | (Marine Resources Monitoring Assessment and Prediction [MARMAP]) |
| SEDAR19-DW-18 | (North Carolina commercial trip ticket index) |
| SEDAR19-DW-19 | (Marine recreational fisheries statistics survey [MRFSS]) |
| SEDAR19-DW-20 | (Florida commercial trip ticket index) |
| SEDAR19-RD-26 | (Reef monitoring protocols for the RVC survey) |

Several improvements to analyses were identified. In some cases these modifications are described in appendices to original working documents; otherwise, they are reported here. For details on exploratory data analysis, technical analysis, or model diagnostics, we refer the reader to the original working documents.

## *5.3. FISHERY INDEPENDENT INDICES*

Red grouper have been sampled by the MARMAP (Marine Resources Monitoring Assessment and Prediction) program using Chevron traps from 1990-2008. An index of abundance from this survey was recommended for use in the assessment. Other MARMAP gear types were considered, such as blackfish traps, hook & line, and vertical longlines, but sampling effort was low and these traps generally caught too few red grouper to be useful. In addition to MARMAP, we investigated several other potential diver surveys, which primarily occurred off of the Florida Keys and within Dry Tortugas National Park. These included a Florida Wildlife Commission (FWC) visual census survey, a joint University of Miami-NMFS Reef Fish Visual Census (RVC), and a volunteer reef fish survey (Reef.com). Also considered were several smaller scale dive surveys in the Dry Tortugas and Riley's Hump. Of the diver surveys, only the RVC survey was recommended for use.

### 5.3.1 MARMAP Chevron Trap

#### *5.3.1.1 General description*

Chevron traps were baited with cut clupeids and deployed at stations randomly selected by computer from a database of approximately 2,500 live bottom and shelf edge locations and buoyed ("soaked") for approximately 90 minutes. Beginning in the 1990s, additional sites were selected, based on scientific and commercial fisheries sources, off North Carolina and south Florida to facilitate expanding the overall sampling coverage. The site expansion has been ongoing, with a few new sites added each year. As a result, the survey has relatively extensive regional coverage (Figure 5.1); the average number of red grouper collected in the traps each year between 1990 and 2008 was 21.4 (range 0 – 44, n= 450).

### *5.3.1.2 Methods*

The CPUE from MARMAP chevron trap data was computed in units of number fish caught per trap. The duration of the time series was 1990–2008. Spatial coverage included areas from Florida through North Carolina.

Standardized catch rates were estimated using a delta-GLM error structure modified from Lo et al. (1992), in which the binomial distribution describes proportion of positive CPUE, and Poisson distribution describes the positive CPUE. Explanatory variables considered, in addition to year (necessarily included), were bottom temperature (continuous variable), month (categorical variable), latitude degree (categorical variable), depth (continuous variable), and trap set duration (continuous variable). Both model components (binomial and Poisson) included main effects only.

Variable inclusions in both models were based on Type 3 tests of significance. For the binomial submodel, all main effects were significant except bottom temperature ($\alpha$ = 0.05), while both bottom temperature and depth were not significant in the Poisson submodel ($\alpha$ = 0.05).

### *5.3.1.3 Sampling Intensity*

The numbers of chevron trap sets and nominal CPUE are tabulated in Table 5.3, while a map of trap sets and frequency of observations is shown in Figure 5.1. For annual maps, see SEDAR19-DW-17.

### *5.3.1.4 Size/Age Data*

Length and age compositions of chevron trap catches were available for all years of sampling (Tables 5.4 and 5.5). In general, red grouper caught in chevron traps were between 240 and 810 mm of length and 2-14 years old.

### *5.3.1.5 Catch Rates and Measures of Precision*

Model selection results and diagnostic plots from the delta-GLM model fit are in SEDAR19-DW-17. Table 5.3 shows nominal CPUE (fish/trap-hr), standardized CPUE, coefficients of variation (CV), and annual sample sizes (number sets). Figure 5.2 shows standardized and nominal CPUE.

#### *5.3.1.6 Comments on Adequacy for Assessment*

The DW concluded that the geographic coverage and sampling intensity were quite good, and suggested that the chevron trap CPUE be used as an index of abundance in the assessment. There was some concern that the index might be unduly influenced by bottom temperature. However this variable was not a significant predictor of CPUE; ostensibly, variation in bottom temperatures are sufficiently accounted for by using month as a proxy.

### 5.3.2 University of Miami / NMFS RVC Diver Survey

#### *5.3.2.1 General Description*

The reef-fish visual census (RVC) has been conducted in the Florida reef tract since 1979 to the present in a collaboration between NOAA Fisheries SEFSC and the University of Miami. The RVC utilizes standard, non-destructive, in situ visual monitoring methods by highly trained and experienced divers using open circuit SCUBA. The general statistical approach and sampling survey design methodologies incorporating habitat covariates are fully described in Ault et al. (2002, 2005, 2006). Field methods and sampling protocols are detailed in Brandt et al. (2009). In the 2008 survey year, the Florida Fish & Wildlife Conservation Commission and the National Park Service joined on as survey collaborators. The RVC survey is conducted in two principal regions of the south Florida coral reef ecosystem domain: (1) the Florida Keys (Key Biscayne to west of Key West) with a domain size of 559 $km^2$; and, (2) the Dry Tortugas region with a domain size of 339 $km^2$ (Figure 5.3).

Notable milestones for the Florida Keys surveys: (1) 1979-1993: sampling conducted along the Keys reef tract in various reef habitats, but limited in any particular year with respect to geographical coverage and habitats; (2) 1994-2000: sampling coverage expanded to include all geographic regions of the Keys (Biscayne National Park, upper Keys, middle Keys, lower Keys), the full range of reef habitats less than 18 m in depth, and all no-take marine reserves (implemented prior to 1998 survey); (3) 2001-2008: sampling coverage expanded to include forereef habitats ranging from 18-33 m in depth. The survey domain and habitat strata for the Florida Keys surveys are described in Table 5.6. Sample sizes by strata and year are given in Table 5.7. Notable milestones for the

Dry Tortugas surveys: (1) 1999-2000, 2004, 2006, 2008: sampling conducted in all reef habitats less than 33 m in depth in two principal areas, Tortugas Bank and Dry Tortugas National Park, including no-take marine reserves. Habitat strata for the Dry Tortugas surveys are described in Table 5.8, and corresponding sample sizes are given in Table 5.9.

#### *5.3.2.2 Issues Discussed at the Data Workshop*

*Issue 1: Include/exclude design points in the Dry Tortugas*

The Dry Tortugas were not included in the sampling frame every year, and also occurred in a marine reserve.

**Decision: Exclude, because the portion of the population occupying the reserve may not represent population level abundance. For instance, it may be "buffered" from the effects of fishing and may not accurately reflect population level increases or declines. Also, it represents the southernmost "range" of the south Atlantic stock of red grouper.**

*Issue 2: Design or model based analysis*

The survey was designed to estimate abundance across the entire sampling frame (via two-stage stratified random sampling). However, there were gaps in spatial coverage in early years; model based standardization was thus somewhat attractive.

Option 1: Design-based inference from 1994-present.

Option 2: Model-based inference

Option 3: Design-based inference from 1994-present with model-based inference prior to 1994.

**Decision: Option 1 because the survey was designed in a robust fashion and permitted appropriate extrapolation. As such, no assumptions needed to be made about functional forms of delta-GLMs, etc. Model based estimates were examined prior to 1994, but were determined to be too imprecise to be useful.**

*Issue 2: RVC or FWC data?*

There was substantial spatial overlap between the two surveys (FWC survey described in section 5.3.3.4), and both occurred at the southern end of the stock's range (at least with the currently used stock definition).

Option 1. Include both surveys in the assessment

Option 2. Include RVC data only

Option 3. Include FWC data only

**Decision: Option 2, because index working group members reached consensus that including data from two surveys at the southern terminus of the species range would give too much weight to abundance trends in the Florida Keys. Given the choice of one survey in this region, the RVC study design yielded smaller CV's and was the obvious choice. DW members felt including one fishery independent survey in this region was important, however, in that it provides information from an area where red grouper have high relative abundance (the other being North Carolina, which is sampled by the MARMAP survey).**

### *5.3.2.3 Methods*

The census is conducted annually using a two-stage stratified random survey design. Technical descriptions and computational details of this statistical survey design are provided in Ault et al. (2002).

### *5.3.2.4 Sampling Intensity*

A map of survey coverage is provided in Figure 5.3. Sample sizes for the Florida Keys are given in Table 5.7. For annual maps of survey coverage, see SEDAR19-DW-11.

### *5.3.2.4 Size/Age Data*

Since counts of animals were size specific, the design-based estimation approach yielded annual estimates of numbers of individuals in various length bins (Table 5.10). If desired, these numbers could easily be converted to frequencies and sample sizes for use in multinomial models in the assessment. See Figure 5.4 for a visual depiction of these data and for information on annual sample sizes.

### *5.3.2.5 Catch Rates and Measures of Precision*

Catch rates were not computed for this index because survey-wide abundance estimates were available. Instead, key population estimates provided from the RVC for red grouper for the Florida Keys and Dry Tortugas regions are: (1) abundance-at-length by year; (2) total abundance and standard error by year (see Ault et al. 1998, 2005 & 2008 for computational details). Abundance estimates by length category are provided for the years in which the complete domain was surveyed (1994-2008) (Table 5.10; also see Figure 5.4). For the Florida Keys, the deep forereef stratum (18-33 m) was not surveyed prior to 2001. Analysis of surveys from 2001-2008 showed a consistent relationship in density estimates between deep forereef and mid-depth forereef (6-18 m) strata (both strata are principally low-relief habitats) outside of no-take marine reserves. This relationship was used to estimate abundance in the deeper forereef stratum for the years 1994-2000. Thus, abundance estimates comprise the same survey domain in each year. To compare these data with other indices, total abundance was summed over length classes and standardized to its mean (Table 5.18).

### *5.3.2.6 Comments on Adequacy for Assessment*

The DW suggested that the RVC survey be used in the assessment of red grouper. The RVC is a well designed, fishery independent survey, and while it does not cover the whole range of the stock, it covers a large portion of south Florida, and serves as a good compliment to the MARMAP survey farther north. However, the DW suggested it be limited to the Florida Keys, and to the 1994-2008 time period. Several possibilities exist for using it as an index. Perhaps the simplest would be to use the total abundance estimated over all lengths for a given year as an index value (length frequencies could then be used for estimating a selectivity for the index).

### 5.3.3 Other Data Sources Considered

#### *5.3.3.1 MARMAP Florida Snapper Trap*

From 1978 to 1987, Florida snapper traps baited with cut clupeids were soaked for approximately two hours during daylight at 12 study areas with known live-bottom and/or rocky ridges distributed from Onlsow Bay, NC to Fernandina Beach, FL. Only one red grouper was sampled with this gear type, and therefore the DW did not recommend using the MARMAP Florida snapper trap to develop an index of abundance off the southeastern U.S.

#### *5.3.3.2 MARMAP Hook and Line*

Hook and line stations were fished primarily during dawn and dusk periods, one hour preceding and after actual sunrise and sunset, however some fishing was also conducted synoptically with trap sampling. Rods utilizing Electromate motors powered 6/0 Penn Senator reels and 36 kg test monofilament line were fished for 30 minutes by three anglers. The terminal tackle consisted of three 4/0 hooks on 23 kg monofilament leaders 0.25 m long and 0.3 m apart, weighted with 0.5 to 1 kg sinkers. The top and bottom hooks were baited with cut squid and the middle hook baited with cut cigar minnow (*Decapterus sp.*). The same method of sampling was used from 1978 to 2008. However, less emphasis has been placed on hook and line sampling during the 1990s and 2000s to put more effort on tagging of fish at night and running between chevron and long line stations to increase sample coverage.

There were only a few red grouper caught (n=5) between 1991 and 2007, therefore the DW did not recommend using the MARMAP Florida snapper trap to develop an index of abundance off the southeastern U.S. Furthermore, changes in personnel and level of effort have changed over time, compromising the utility of the hook and line survey as an index.

#### *5.3.3.3 MARMAP Short Bottom Long Line (vertical long line)*

The short bottom long line was deployed to catch grouper/snapper over high relief and rough bottom types at depths of 90 to 200 m. This bottom line consisted of 25.6 m of 6.4 mm solid braid dacron groundline dipped in green copper naphenate. The line is deployed by stretching the groundline along the vessel's gunwale with 11 kg weights attached at the ends of the line. Twenty gangions baited with whole squid were placed 1.2 m apart on the groundline which was then attached to an appropriate length of poly warp and buoyed to the surface with a Hi-Flyer. Sets are made for 90 minutes and the gear is retrieved using a pot hauler.

This gear caught very few red grouper (n = 58) over 13 years (1996-2008). Due to this small sample size over a large amount of time, the DW did not recommend using the MARMAP short bottom long line samples to develop an index of abundance for red grouper off the southeastern U.S.

#### *5.3.3.4 Florida Fish and Wildlife Conservation Commission Visual Census*

The description of the Florida Fish and Wildlife Conservation Commission (FWC) visual census and the calculations of the catch rate index are in SEDAR19-DW-12. Briefly, the Florida Keys National Marine Sanctuary (FKNMS) was divided into 6 zones (Figure 5.5) from Key Largo to the Dry Tortugas and the four zones from Key Largo to Key West are sampled monthly from April through October with stationary point counts. A habitat-based, random-stratified site selection procedure, based upon the “Benthic Habitats of the Florida Keys” GIS system, was used to select 39 sample sites each month. A stationary diver records the number of individuals for each of the target species that are observed within an imaginary five-meter radius cylinder and assigns fish to length intervals. On each dive, the two divers conduct two point-counts that are at least 15 m apart. Muller and Acosta (SEDAR19-DW-12) used these data to produce a standardized index with a delta-GLM model, and considered several choices for how data were subsetted prior to analysis.

The DW found the analysis approach to be acceptable, but suggested that this index not be used in the assessment. The primary reason was a desire not to duplicate survey information in the extreme southern end of the stock’s range. Index working group members felt that including two indices from the Florida Keys (RVC and FWC) would give undue influence to patterns of abundance in this region.

*5.3.3.5 Miscellaneous Sources*

Other sources of fishery independent data were considered for possible indices of abundance, including MARMAP trawls, SEAMAP trawls, diver reports (reef.org), and several diver surveys in the Florida Keys. These sources sampled either no or insufficient numbers of red grouper to be useful as an index of abundance, lacked a standardized survey approach, or were redundant to those indices already included in the analysis. An additional factor for diver surveys in and around the Dry Tortugas was that these were conducted in or near a marine protected area, and on the border of a different management area.

## *5.4. FISHERY DEPENDENT INDICES*

### 5.4.1 Recreational Headboat

*5.4.1.1 General Description*

The headboat fishery is sampled separately from other recreational fisheries, and includes an area ranging from North Carolina to the Florida keys (Figure 5.6). The headboat fishery comprises large, for-hire vessels that charge a fee per angler and typically accommodate 6–60 passengers. With simple hook & line gear, passengers on these vessels frequently target hard bottom reefs, sampling many members of the snapper-grouper complex. Headboat records were examined in detail, and catch-per-unit-effort (CPUE) standardization was employed to generate a fishery dependent index from 1978-2008.

*5.4.1.2 Issues Discussed at the DW*

*Issue 1: Include/exclude years prior to full area or vessel coverage*

Early years of headboat sampling did not have full area coverage. All headboats from North Carolina and South Carolina were sampled starting in 1973. Headboats from Georgia and northern Florida were sampled starting in 1976, and from southern Florida starting in 1978. All headboats across all areas were sampled starting in 1978, however there were no port agents in the Florida Keys until 1981.

Option 1: Use data starting in 1973

Option 2: Use data starting in 1976

Option 3: Start the time series in 1978

Option 4: Start the time series in 1981

**Decision: Option 3, because all areas important to this stock were covered. In addition, headboat captains were paid to turn in logs so trip coverage is thought to be high even though no port agent was present in the Florida Keys.**

*Issue 2: Spatial weighting scheme*

Nominal CPUE by appeared to have somewhat different trends for red grouper, indicating a possible year by area interaction (see, e.g., Figure 5.7, Table 5.12).

Option 1: Ignore year by area interactions. This has the effect of giving more weight to trends in south Florida because there were greater sample sizes there.

Option 2: Give equal weight to the three spatial areas used in index construction (NC/SC, Cape Canaveral, FL – South Carolina border, southern Florida). This option makes the assumption that the distribution of virgin biomass in these areas was roughly uniform.

Option 3: An unequal weighting scheme, giving more weight to NC/SC and south FL than other areas.

**Decision: Option 3, giving NC/SC a weight of 0.4, south FL a weight of 0.4 and north FL/GA a weight of 0.2. This decision acknowledges that there appear to be two dominant areas of red grouper abundance: one off NC and one off southern FL.**

*Miscellaneous decisions*

- The DW acknowledged that changes in size limits could be accounted for by the assessment model through estimation of selectivity.
- The DW considered changes in bag limits of groupers in the south Atlantic, but found there to be little evidence that these resulted in few trips where anglers met their collective bag limit (see SEDAR19-DW-03). Therefore, the DW believed there to be little reason for changes in bag limits to have affected CPUE.

*5.4.1.3 Methods*

The CPUE was computed in units of number of fish per hook-hour. The duration of the time series was 1978–2008. Spatial coverage included the entire management area (Figure 5.6). Methods for analyzing headboat CPUE are presented in detail in SEDAR19-DW-03 and are not reproduced in their entirety here.

Effective effort was based on those trips from areas where red grouper were available to be caught. Without fine-scale geographic information on fishing location, trips to be included in the analysis must be inferred. To do so, the method of Stephens and MacCall (2004) was applied. The method uses multiple logistic regression to estimate a probability for each trip that the focal species was caught, given other species caught on that trip. As mentioned previously, the method was applied separately to data from regions north and south of Cape Canaveral, because of differences in species assemblages. Model selection (i.e., choice of predictor species) was based on AIC using a backward stepwise algorithm (Venables and Ripley, 2002). The selected model was used to compute for each trip a probability that red grouper was caught, and a trip was then included if its associated probability was higher than a threshold probability. The threshold was defined to be that which results in the same number of predicted and observed positive trips, as in Stephens and MacCall (2004). Application of Stephens and MacCall (2004) resulted in 12,598 trips in the northern survey region (9.7% of trips), of which ~11% were positive. For the southern region, subsetted data contained 22,793 trips (13.6% of trips), of which ~21% were positive.

Standardized catch rates were estimated using a delta-GLM error structure (Lo et al., 1992; Stefánsson, 1996; Maunder and Punt, 2004), in which the binomial distribution describes positive versus zero CPUE, and either a lognormal or gamma distribution describes the positive CPUE. Successive trials with different transformation of the dependent variable suggested that GLM assumptions were best met when using $CPUE^{-1.0}$ as the response variable within a Gamma model for positive CPUE. Explanatory variables considered, in addition to year (necessarily included), were month, vessel, geographic area, trip type (half-day or full-day trips), and a factor variable for number of anglers (defined by sample quartiles). Both model components (binomial and gamma) included main effects as well as area*month and area*year interactions, both of which were suggested based on exploratory data analysis (e.g., Figure 5.7, Table 5.12). Geographic areas reported were pooled into larger areas to provide adequate sample sizes for each level of this factor—NC and SC combined, GA and north FL combined, and south FL.

Measures of precision were computed by a jackknife routine and summarized by the resulting CV. The jackknife routine iteratively refitted the delta-GLM model N times (N is the total sample size), where each iteration removed a unique record.

#### *5.4.1.4 Sampling Intensity*

The numbers of positive trips by year and area are tabulated in Table 5.11. The method of Stephens and MacCall (2004) does not necessarily select all positive trips. The annual number of selected trips, nominal CPUE, and percent positive for red grouper are shown in Figure 5.8.

#### *5. 4.1.5 Size/Age Data*

Sizes and ages of fish represented by this index are the same as those sampled by the headboat survey (see chapter 4 of this DW report).

#### *5. 4.1.6 Catch Rates and Measures of Precision*

Figure 5.9 shows nominal CPUE (fish/angler-hr) together with standardized CPUE and confidence limits. Standardized CPUE and its coefficient of variation are also available in table form (Table 5.13).

#### *5. 4.1.7 Comments on Adequacy for Assessment*

The headboat index was recommended by the DW for use in the assessment. It had the advantages of wide geographic coverage and reasonable sample sizes. However, the DW did discuss several concerns (Table 5.2). One concern was that it is a fishery dependent index, and is thus subject to problems such as changing catchability over time (including CPUE hyperstability). The DW, however, did note that the headboat fishery is not a directed fishery for red grouper. Rather, it more generally fishes a complex of snapper-grouper species, and does so with only limited search time. Thus, the headboat index may be a more reliable index of abundance than one developed from a fishery that targets red grouper specifically.

### 5.4.2 Recreational Intercepts (MRFSS)

#### *5.4.2.1 General Description*

The Marine Recreational Fisheries Statistics Survey (MRFSS) samples the general recreational fishery. This national survey intercepts anglers fishing from shore, man-made structures, private/rental boats, and charter boats. Headboats are another component of recreational fishing, but they are sampled by a separate headboat survey (see section 5.4.1). Red groupers are a continental shelf species, so only private/rental boats and charter boats were included in calculating the catch rates. Because red groupers in the South Atlantic are considered distinct from those in the Gulf of Mexico for management purposes, only MRFSS intercepts from North Carolina through the Florida Keys were included in this analysis (Figure 5.10). Although MRFSS intercepts began in 1979, MRFSS changed their sampling protocol in 1991 to link additional interviews from the same trip together. Additionally, 1991 was the first full year after the extensive training of samplers had been implemented. Therefore, the index of abundance only uses data from 1991 through 2008.

#### *5.4.2.2 Issues Discussed at DW*

*Issue 1: First year of time series*

Option 1: Start the time series in 1981, the first year of data collection.

Option 2: Start the time series in 1987, because of increased sampling intensity starting in 1987, reflected in the increase in sample sizes.

Option 3: Start the time series in 1991 because of the ability to link all of the intercepts from the same trip to a single trip instead of treating them as independent observations also the species identifications were more accurate beginning in 1991 with the additional training of samplers.

**Decision: Option 3 preferred. The DW decided to start the time series in 1991 when all of the intercepts per trip could aggregated to a single trip.**

*Issue 2: Calculating separate north and south catch rates*

Option 1: Calculate a single index with region as an explanatory variable.

Option 2: Calculate separate red grouper indices for the northern region (North Carolina to Cape Canaveral Florida Brevard county) and the southern region (Florida Keys to Cape Canaveral, Monroe-Indian River counties).

**Decision: Option 1 recommended. There were insufficient positive MRFSS intercepts prior to the Stephens and MacCall selection process from the northern region (273 intercepts over 18 years) to calculate a northern index; therefore, there is a single index with region (North Carolina through Georgia; Nassau County through Flagler County, Florida: Volusia County through Dade County, Florida; and Monroe County, Florida) as an explanatory variable.**

*Issue 3: Calculating nominal catch rates*

Option 1: Use the MRFSS intercepts that caught red grouper (positive trips) to calculate the nominal catch rates as was done in the working paper (SEDAR19-DW-19).

Option 2: Use all of the MRFSS intercepts from South Atlantic region to calculate the nominal catch rate.

**Decision: Option 2 preferred. Using all of the intercepts avoids the bias associated with ignoring those intercepts (97.5%) that did not catch red grouper. However, it also includes many trolling trips for mackerels or tunas which are handled by the subsetting protocols but not when using all trips. Table 5.15 has the revised nominal catch rates.**

*Issue 4: Whether to use MRFSS index in assessment*

**Decision: Use the MRFSS index with the understanding that the selectivity for the index will have to incorporate both landings and discards (live and dead).**

*Miscellaneous decisions*

A 5 groupers/person/day was instituted for the recreational fishery in 1992 in the South Atlantic and in 1999 changed to include no more than 2 black groupers in the bag per day in the South Atlantic which did not affect red grouper; however, the bag limit was not considered to bias the index. The DW examined the occurrence of exceeding the bag limit and noted that only seven trips out of 6,091 trips exceeded the aggregate bag limit. Also, the effect of the bag limit should be minimal because index included discarded fish.

### *5.4.2.3 Methods*

The CPUE was computed in units of number of fish per trip. All of the trips from 1991 through 2008 for the South Atlantic (MRFSS sub region 6) were extracted. There were 91,017 MRFSS intercepts in the charterboat and private/rental boat modes from nearshore (state waters) and offshore waters (federal waters), and 48 species including red grouper occurred on at least 1% of those intercepts. In this analysis, those additional intercepts from the same fishing trip that caught fish but were unavailable to the creel sampler were linked back to the main intercept for the party.

Over the 18 years from 1991 through 2008, there were 2,172 intercepts that caught red grouper in the study area. However, there were additional trips that could have caught red grouper, but didn’t. To identify that effort and include it in the catch rate standardization process, Stephens and MacCall (2004) logistic regressions were employed, as described in SEDAR19-DW-19. Once the MRFSS intercepts for calculating the catch rates were selected, the total number of red grouper caught was calculated for each selected intercept and annual catch rates were estimated with generalized linear models (GLM). A delta-gamma GLM approach (Lo et al. 1992) was then employed to standardize catch rates. Potential explanatory variables were year (1991-2008), wave (two-month time period), mode (charterboat or private/rental boat), area (nearshore or offshore), region (North Carolina through Georgia; Nassau County through Flagler County, Florida: Volusia County through Dade County, Florida; and Monroe County, Florida), hours fished (0, 2, 4, 6, 8, 10, 12+ hr), and the number of anglers on the trip (1, 2, 3, 4, 5, 6, 8, 10, 12+). The variables included in the GLMs were chosen in a stepwise manner using the smallest Akaike Information Criterion (AIC) at each level of the number of predictor variables, provided that the variable was significant at the $\alpha = 0.05$ level in the regression with the significance based on two times the change in log-likelihood (Chi-square distribution).

The annual mean catch per intercept values were calculated with a Monte Carlo method based on the least-squares mean probability of catching a red grouper multiplied by the mean number of red grouper caught per angler in that year. Random variation was added to each outcome by multiplying the standard error of the proportion positive by a random, normal deviate and by multiplying the standard error of the number per intercept by a different random, deviate. After the random deviates were added to the respective least-square means, the terms were back-transformed to their original scales and multiplied together. This process was repeated the same number of times each year as the number of intercepts that caught red grouper in that year and the index was the mean of the outcomes by year.

For further details on methods, including model fitting and diagnostics, the reader is referred to SEDAR19-DW-19.

#### *5.4.2.4 Sampling Intensity*

Sampling intensity (number of intercepted trips) in the study area by region, mode of fishing, area, and year is shown in Table 5.14.

*5.4.2.5 Size/Age Data*

Sizes and ages of fish represented by this index are the same as those of the recreational fishery as sampled by the MRFSS (see chapter 4 of this DW report).

*5.4.2.6 Catch Rates and Measures of Precision*

Table 5.15 and Figure 5.11 show the nominal and standardized red grouper catch rates (number/trip) and their coefficients of variation. The index group questioned calculating nominal catch rates with just the positive intercepts and recommended calculating the nominal catch rates using all of the MRFSS intercepts from the near- and offshore waters of the South Atlantic. The revised nominal catch rates (Table 5.15) are similar to the standardized catch rates (correlation, $r = 0.48$, $df = 16$, $P < 0.05$) but not to the catch rates calculated with just the positive intercepts (correlation, $r = 0.05$, $df = 16$, $P = 0.83$).

*5.4.2.7 Comments on Adequacy for Assessment*

The DW recommended using the standardized MRFSS index in the assessment. However, the DW did discuss several concerns including the effects of regulatory discards. Because the survey measures the discards as well as the landings, the group thought that the MRFSS index was less sensitive to regulatory changes. However, catchability likely changes over time due to both density dependent and independent (e.g., gear improvements) processes.

**5.4.3 Commercial Logbook (Handline)**

*5.4.3.1 General Description*

Commercial fishermen who participate in fisheries managed by the SAFMC began to report catch and effort data in the logbook program to the NMFS in 1990 (Gulf of Mexico) and 1992 (South Atlantic). Logbook data reported for each trip include date, gear, fishing area, days at sea, fishing effort, species caught, and weight of the catch. Logs were originally collected from a random sample representing 20% of vessels in

Florida with 100% reporting from other states; starting in 1993, all commercial fishermen holding snapper-grouper permits were required to submit logs. An index of abundance for red grouper from the logbook data was computed for 1993–2008.

*5.4.3.2 Issues Discussed at the DW*

*Issue 1: Gear selection*

**Decision: Include only vertical lines (composed of handline and electric reels). Very few longline trips were reported in the SA.**

*Issue 2: Year selection*

Option 1: Use data starting in 1993

Option 2: Use data starting in 1990

Option 3: Use data starting in 1992

**Decision: Option 1, because 1992 included only 20% coverage of fishermen, whereas 1993 began 100% coverage.**

*Issue 3:Defining which trips constitute effort*

Option 1: Use method of Stephens and MacCall (2004) to define effort that could have caught the focal species based on the composition of other species in the landings based on four geographical regions as defined in SEDAR 19 DW-14. This method would include trips with effort but zero landings of red grouper.

Option 2: Apply Stephens and MacCall (2004) separately to regions north and south of Cape Canaveral based on species assemblage. The delta-GLM model would have three different geographical areas to include areas from Cape Canaveral south, Georgia to Cape Canaveral, and North Carolina and South Carolina.

**Decision: Option 2. It was likely that not all effective effort was successful at landing red grouper and species assemblage break has been described north and south of Cape Canaveral. The Stephens and MacCall (2004) method was used to select possible trips based on the different assemblage in the two areas. The**

**separate Stephens and MacCall (2004) analyses for north and south of Canaveral addressed the possible habitat differences.**

*Issue 4: Trip tickets versus logbooks*

Commercial logbooks and Florida trip tickets (see section 5.4.4.1) both include information on catch rates of commercial fisheries, with the main differences being that (i) trip tickets more accurately reflect catch for fishers that fish in Florida state waters, (ii) trip tickets are filled out by dealers, while logbooks are filled out by fishermen, (iii) logbooks include finer scale effort information, and (iv) logbook data are available over the spatial extent of the stock while trip tickets are available only at the state level.

Option 1: Use Florida (and possibly North Carolina) trip ticket data to summarize commercial catch rates.

Option 2: Use commercial logbooks.

**Decision: Option 2, because logbooks cover the entire range of the stock with better resolution in effort. Also, the majority of landings were in federal waters, and therefore included in the logbooks.**

### *5.4.3.3 Methods*

Available catch per unit effort (CPUE) data reported to the coastal logbook program from 1993 - 2008 was used to develop a vertical line (handline and electric reel) abundance index for South Atlantic red grouper. A complete description of methodology and initial results are provided in SEDAR19 DW-14. Results from the revised analysis, following the working group's recommendation (section 5.3.1.2, option 2), are included here.

Data were restricted to include only those trips reporting fishing effort by a single gear and area fished. Only trips with landings and effort data reported within 45 days of the completion of the trip were included in the analysis. Approximately 81 percent of vertical line trips were retained.

Clear outliers in the data, e.g. values falling outside the 99.5 percentile of the data, were also excluded from the analyses. Once data exclusions were complete, red grouper trips were identified busing the method of Stephens and MacCall (2004).

Five factors were considered as possible influences on both the proportion of trips that landed red grouper and the catch rate of red grouper. Those factors were: year, season (Jan-Feb, Mar-Apr, etc.), area fished, days at sea, and number of crew. A standardized index of abundance was constructed using the delta lognormal model approach of Lo et al. (1992). Revised diagnostics for construction of the index are presented in Appendix 5.1.

### *5.4.3.4 Sampling Intensity*

The numbers of trips and the proportion of positive trips by year are tabulated in Table 5.16. The method of Stephens and MacCall (2004) does not necessarily select all positive trips.

### *5.4.3.5 Size/Age Data*

Sizes and ages of fish represented by this index are the same as those of the commercial handline fishery (see section 3 of this report).

### *5.4.3.6 Catch Rates and Measures of Precision*

Diagnostic plots from the delta-GLM model fit are in Appendix 5.1. Table 5.16 shows the relative nominal CPUE in weight (called to mean), relative standardized CPUE, coefficients of variation (CV), and annual sample sizes (number trips selected by Stephens and MacCall method). Figure 5.12 shows standardized and nominal CPUE, both scaled to their means.

### *5.4.3.7 Comments on Adequacy for Assessment*

The logbook index was recommended by the DW for use in the assessment. It had the advantages of wide geographic coverage, better estimation of effort than North Carolina and Florida trip tickets, positive correlation with North Carolina CPUE, and very large sample sizes. The DW, however, did express several concerns about this data set (Table 5.1). It was pointed out that there are problems associated with any abundance index and that convincing counter-evidence needs to be presented to not use the logbook data.

Three concerns merit further description. First, commercial fishermen may target different species through time. If changes in targeting have occurred, effective effort can be difficult to estimate. However, the DW recognized that the method of Stephens and MacCall (2004), used here to identify trips for the analysis, can accommodate changes in targeting, as long as species assemblages were consistent.

Second, the data are self-reported and largely unverified. Some attempts at verification have found the data to be reliable, but problems likely remain.

Third and probably foremost, the data are obtained from a directed fishery and therefore the index could contain problems associated with any fishery dependent index. Fishing efficiency of the fleet has likely increased over time due to improved electronics. In addition, overall efficiency may have changed throughout the time series if fishermen of marginal skill have left or entered the fishery at a greater rate than more successful fishermen. Also of concern is whether catch rates in a directed fishery are density-dependent. As fish abundance decreases, fishermen may maintain relatively high catch rates, and as fish abundance increases, catch rates may saturate.

### 5.4.4 Other Data Sources Considered

#### *5.4.4.1 Florida Fish and Wildlife Conservation Commission Marine Resources Information System (Trip Tickets)*

The Florida Fish and Wildlife Conservation Commission (FWC) Marine Resources Information System (trip tickets) began in late 1984 and was adopted by the National Marine Fisheries Service as the official source of Florida’s landings in 1986. The program requires Florida’s commercial fishers to sell their catch to licensed wholesale dealers and each sale is recorded on a trip ticket, a copy of which goes to FWC. Information collected on trip tickets include the fisher’s Saltwater Products License number, wholesale dealer’s license number, date landed, time fished, area fished, county landed, depth, gear fished, number of sets, number of traps pulled, soak time, species codes, size or market categories, amount of catch, and unit price, with these last fields completed for everything landed. Some fields were phased in; for example, beginning in mid-1991, each trip ticket included a series of boxes so that the fishers could indicate the gear used on the trip. Major advantages over the previous monthly dealer reports was that the trip ticket system had species and size codes such that grouper landings could now be reported by species instead of 'Unclassified groupers' and that species assemblages, i.e., species that are frequently caught together, could be identified.

Standardized commercial catch rates were developed from Florida trip tickets using a delta-GLM approach on trips selected by the method of Stephens and MacCall (2004), and are presented in SEDAR19-DW-20. As the DW decided it was more appropriate to use commercial logbook indices, these methods and results are not reproduced here.

A comparison of the FWC trip ticket HL red grouper index values to those from the NMFS Logbook vertical line index showed that the patterns were weakly correlated (correlation coefficient, $r = 0.17$, $df = 14$, $P = 0.53$). However, red grouper appear to have a somewhat bimodal spatial distribution on the Atlantic coast with high red grouper landings in south FL and in the Carolinas, with fewer landings in between. The logbook indices include data from throughout the species' range while the FWC trip tickets only tracked the southern portion of the fishery.

#### *5.4.4.2 North Carolina trip tickets*

Trip ticket records were available in the state of North Carolina from 1994 to 2008, and were used to develop a standardized index for red grouper using offshore rod & reel trips. Methods for index construction and diagnostics are available in SEDAR19-DW-18. the estimated standardized index for red grouper from the commercial fisheries off North Carolina waters indicated that there was an increase in catch rates of red grouper in the early years of the times series through 1999; from 2000 through 2005, there was a relatively stable period. Finally, there was an increase in catch rates during the later years of the time series, with the highest catch rate registered in 2007 (Figure 5.13). The North Carolina trip ticket index was highly correlated with the index developed from logbook records, with a Pearson correlation coefficient of 0.96**.** Recall that the DW favored commercial logbooks over trip tickets for use in the assessment because of broader spatial coverage and more refined effort information.

### *5.5. CATCHABILITY*

Indices of abundance are used in stock assessment to make inference about trends in numbers or biomass of the stock. Typically, models assume that catchability is constant, such that number or biomass is linearly related to the index. However, this assumption can be faulty, particularly for fishery dependent indices, because of changes in catchability that result from changes in such factors as fish abundance, fishing technology, fishers' behavior, and management (Wilberg et al., In review).

In February of 2009, a SEDAR procedural workshop was held to address time-varying catchability (SEDAR, 2009). The workshop recommended that future SEDAR assessments consider time-varying catchability, both qualitatively through discussion at the data workshop and quantitatively in the stock assessment model, if possible.

Based on recommendations from the SEDAR procedural workshop, the SEDAR-19 indices working group, along with fishermen at the DW, discussed possible changes in catchability over time. The starting point for this discussion was the report of the procedural workshop (SEDAR, 2009), in particular, section three of that report. Section three documented sector-specific timelines of factors that could affect catchability in the recreational, headboat, charter/for hire, and commercial sectors; it was compiled primarily by fishermen.

Most of the SEDAR-19 discussion focused on commercial fisheries. It was noted that some commercial fishermen in the Atlantic can target red grouper, which is not necessarily true of all snappers and groupers in this complex of species. Targeting may have the potential to increase density dependence in catchability. GPS on vessels reduced search time for fishing locations, and was adopted by the fleet over time as the technology became more affordable. The fishermen believed that the technology started to become important in 1993 and its effects were fully saturated by 2003. The longline fleet has continued to benefit by interfacing GPS with onboard personal computers. The recreational sector also increased its catchability through GPS, perhaps more so than the commercial sector.

The fishermen discussed several mechanisms that could have led to decreased catchability over time. For example, it was suggested that the overall skill and experience of commercial fishing crews has declined. Also, with greater numbers of fishermen on the water, particularly recreational fishermen, competition for prime fishing locations has increased; thus, fishing effort across the fleet includes more sub-prime locations.

Time-varying catchability of fishery independent indices was also discussed, as it might relate to environmental factors. For MARMAP indices, the standardization explored bottom temperature as a possible covariate of catch rates. For the Florida Keys surveys, hurricane events might have reduced the number of fish in the survey area.

The SEDAR-19 indices group did not discuss modeling approaches for time-varying catchability, but did note previous reviews on this topic (SEDAR, 2009; Wilberg et al., In review). As stated in the executive summary of SEDAR (2009), "…methods should be flexible because no one method will be best for all cases, and because there have not been enough studies testing the performance of alternative catchability models."

### *5.6. CONSENSUS RECOMMENDATIONS AND SURVEY EVALUATIONS*

Two fishery independent indices were recommended for use in the assessment: MARMAP chevron trap and the U. Miami/NMFS RVC in the Florida Keys. Three fishery dependent indices were recommended: commercial handline (logbook), headboat, and MRFSS (Tables 5.1, 5.2). The five indices are compared graphically in Figure 5.14 and their correlations in Table 5.17. A summary of each index and their relative CVs are presented in Table 5.18. A map of the survey area showing the spatial coverage of all indices is also available (Figure 5.15).

Correlations between indices ranged from 0.00 to 0.37, none of which were statistically significant at the $\alpha = 0.05$ level. Weak correlations may be attributable to different selectivities, different trends in catchability, or nonrandom/biased sampling. However, it is difficult to tell on a priori grounds. In addition to previous suggestions for the need to account for time varying changes in catchability, it may be worth considering an approach for estimating an additional component of process error associated with each index, either in the assessment model (Geromont and Butterworth 2001, Wade 2002) or outside of it (Conn, Accepted) to account for this apparent discrepancy.

### *5.7. RESEARCH RECOMMENDATIONS*

1. Expand fishery independent sampling to provide indices of abundance. The DW Panel noted that this recommendation has been the first on the list for virtually all previous SEDAR's in the south Atlantic.
2. Examine variability in catchability
    - Environmental effects
    - Changes over time associated with increases in technology and potential changes in fishing practices. This is of particular importance when considering fishery dependent indices.
    - Potential density-dependent changes in catchability. This is of particular importance for schooling fishes.
3. Conduct studies to examine how the behavior of fisherman changes over time and how these changes relate to factors such as gas prices and economic trends
4. Consider optimal sample allocation for species of interest when designing surveys to increase sample sizes.
5. Examine possible temporal changes in species assemblages. Such changes could influence how the Stephens and MacCall method is applied when determining effective effort.
6. Continue to expand fishery dependent at-sea-observer surveys. Such surveys collects discard information, which would provide for a more accurate index of abundance.

### *5.8. ITEMIZED LIST OF TASKS FOR COMPLETION FOLLOWING WORKSHOP*

- Generate any remaining tables and figures
- Finish writing chapter of DW report
- Submit data to Data Compiler

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## 5.10. TABLES

**Table 5.1.** Red grouper: A summary of catch-effort time series available for the SEDAR 19 data workshop.

| Fishery Type | Data Source | Area | Years | Units | Standardization Method | Size Range | Issues | Use? |
|---|---|---|---|---|---|---|---|---|
| Commercial | Logbook - handline | NC-FL | 1993-2008 | Pounds per hook-hr | Stephens and MacCall; delta-GLM | Same as fishery | Fishery dependent | Y |
| Commercial | FL Trip ticket | FL | 1991-2008 | Pounds per trip | Stephens and MacCall; delta-GLM | Same as fishery | Fishery dependent, trip not a good measure of effort, use logbook | N |
| Commercial | NC Trip ticket | NC | 1994-2008 | Pounds per trip | Stephens and MacCall; delta-GLM | Same as fishery | Fishery dependent, trip not a good measure of effort, use logbook | N |
| Recreational | Headboat | NC-FL | 1978-2008 | Number per angler-hr | Stephens and MacCall; delta-GLM | Same as fishery | Fishery dependent | Y |
| Recreational | MRFSS | NC-FL | 1991-2008 | Number per trip (A+B1+B2). | Stephens and MacCall; delta-GLM | Same as fishery | Fishery dependent | Y |
| Independent | FWC Visual Census | FL Keys | 1999-2004, 2006, 2007 | Number per dive per habitat | delta-GLM | 200mm to 700mm TL; Ages 1-10 | Limited to relatively small segment of stock range; don't want to include two surveys from keys | N |
| Independent | U Miami/NMFS RVC survey | FL Keys | 1994-2008 | Number by length class per survey | Design-based inference | Generally 100mm to 1000mm TL | Limited to relatively small segment of stock range | Y |
| Independent | U Miami/NMFS RVC survey | FL Keys (forereef only) | 1979-1993 | Number per survey | delta-GLM | Same as above | Low sample size for red grouper | N |
| Independent | U Miami/NMFS RVC survey | Tortugas | 1994-1998, 2004, 2006, 2008 | Number per length class per survey | Design-based inference | 100mm to 1200mm TL | Few years, overlaps with Gulf jurisdiction | N |
| Independent | MARMAP Chevron trap | NC-FL | 1990-2008 | Number per trap-hr | delta-GLM | 240-810 mm TL | High variability | Y |
| Independent | MARMAP Florida trap | NC-FL | 1983-1987 | Number per trap-hr | — | — | 1 red grouper caught | N |

| Fishery Type | Data Source | Area | Years | Units | Standardization Method | Size Range | Issues | Use? |
|---|---|---|---|---|---|---|---|---|
| Independent | MARMAP Blackfish trap | NC-FL | 1978-1987 | Number per trap-hr | — | — | No red groupers caught | N |
| Independent | MARMAP Hook and line | NC-FL | 1979-1998 | Number per hook-hr | — | — | Inconsistent sampling effort over time | N |
| Independent | MARMAP Short longline | NC-FL | 1980-2007 | Number per hook-hr | — | — | Very low sample sizes | N |
| Independent | MARMAP trawl | NC-FL | 1980-1987 | | — | — | Low numbers of samples | N |
| Independent | SEAMAP trawl, longline | NC-FL | 1990-2007 | Number per hectare, number per hook-hour | — | — | Very low sample sizes | N |
| Independent | Diver Reports (Reef.org) | NC-FL | 1990-2008 | Numerical category per dive | — | — | Voluntary reporting | N |
| Independent | NOS diver surveys | Tortugas | 2001-2007 | Mean count per survey | — | — | Limited spatial coverage, on border of Gulf , in/around an MPA | N |
| Independent | NMFS-Beaufort | Riley's Hump (Tortugas) | 2001-2008 | Mean count per survey | — | — | Limited spatial coverage, on border of Gulf, in/around an MPA | N |
| Recreational | NC Citation Program | NC | ?-2008 | — | — | — | Voluntary reporting, variable publicity, target species may not be included in program | N |
| Recreational | Online recreational trip reporting (myfish.com) | NC-FL | 2007-2008 | — | — | — | Voluntary reporting, currently only two years of data available | N |

**Table 5.2.** Issues with each data set considered for CPUE.

<u>Fishery dependent indices</u>

Commercial Logbook – Handline (*Recommended for use*)

Pros: Complete census

Covers entire management area

Continuous, 15-year time series

Large annual sample size

Cons: Fishery dependent (targeting)

Data are self-reported and largely unverified

Little information on discard rates

Catchability may vary over time and/or abundance

Issues Addressed:

Possible shift in species preference [Stephens and MacCall (2004) approach]

In some cases, self-reported landings have been compared to TIP data, and they appear reliable

Increases in catchability over time (e.g., due to advances in technology or knowledge) can be addressed in the assessment model

Recreational Headboat (*Recommended for use*)

Pros: Complete census

Covers entire management area

Longest time series available

Data are verified by port samplers

Consistent sampling

Large annual sample size

Generally non-targeted for focal species

Cons: Fishery dependent

Little information on discard rates

Catchability may vary over time and/or abundance

Issues Addressed:

Possible shift in species preference [Stephens and MacCall (2004) approach]

The impression of some people that trip duration has shifted toward half-day trips is not consistent with the data (Exploratory data analysis reveals no such shift on red grouper trips or on headboat trips overall. In addition, trip duration is accounted for as a factor in the GLM.)

Increases in catchability over time (e.g., due to advances in technology or knowledge) can be addressed in the assessment model

MRFSS (*Recommended for use*)

Pros: Relatively long time series

Nearly complete area coverage

Only fishery dependent index to include discard information (A+B1+B2)

Cons: Fishery dependent

High uncertainty in MRFSS unobserved catches

North Carolina Citation Program (*Not recommended for use*)

Pros: May correlate with changes in size over time

Cons: No measure of effort

Fishery dependent

Limited geographic coverage

Not designed to provide information on abundance

Dependent on fishermen to call in and report citations

Online Recreational Logbooks (www.myfish.com) (*Not recommended for use*)

Pros: Ancillary information collected (e.g., weather conditions)

Cons: Voluntary reporting

Fishery dependent

Not designed to provide information on abundance

Only one year (2007) not meaningful as an index

Fishery independent

Diver Reports (www.reef.org) (*Not recommended for use*)

Pros: Trained divers
Visual account of species present

Cons: Not designed with objective of providing an index of abundance
Sample sizes only high in the Florida Keys where there's overlap with two other statistically designed diver studies.
North of the Keys sample sizes decreased rapidly

FWC Visual Census (*Not recommended for use)*

Pros: Fishery independent diver survey
Standardized sampling techniques
Reasonable CVs

Cons: High degree of spatial overlap with RVC survey
Survey occurs at southern terminus of stock range

MARMAP

Chevron Trap Index (*Recommended for use*)

Pros: Fishery independent random hard bottom survey
Adequate spatial coverage
Standardized sampling techniques

Cons: High variability
Unknown if sampling intensity (100s sets per year) is adequate to characterize region-wide abundance of a schooling fish

FL Snapper Trap Index (*Not recommended for use*)

Pros: Fishery independent random hard bottom survey
Adequate spatial coverage, concentrated at center of species' range
Standardized sampling techniques

Cons: High variability
Unacceptably low sample sizes

Blackfish Trap Index (*Not recommended for use*)

Pros: Fishery independent

Cons: Inadequate sample sizes

Hook and Line Index (*Not recommended for use*)

Pros: Fishery independent random hard bottom survey

Adequate regional coverage

Standardized sampling techniques

Cons: Inadequate sample sizes

Short Bottom Longline Index (*Not recommended for use*)

Pros: Fishery independent

Cons: Inadequate sample sizes

Trawl (*Not recommended for use*)

Pros: Fishery independent

Cons: Inadequate sample sizes

NOS Diver surveys (*Not recommended for use*)

Pros: Fishery independent

Cons: Spatially limited

Occur primarily in and around a marine protected area

Issues addressed:

Occurs at border between SA & Gulf management areas

NMFS-Beaufort Riley's Hump diver survey (*Not recommended for use*)

Pros: Fishery independent

Cons: Spatially limited

Occur primarily in and around a marine protected area

Issues addressed:

Occurs at border between SA & Gulf management areas

SEAMAP Trawl Survey (*Not recommended for use*)

Pros: Stratified random sample design

Adequate regional coverage

Standardized sampling techniques

Cons: Limited depth coverage (shallow water survey)

Inadequate sample sizes

U. Miami/NMFS RVC Survey

Florida Keys 1994-Present (*Recommended for use*)

Pros: Well designed survey

Fishery independent

Cons: Spatial coverage limited to southern range of stock

Issues addressed :

Analysis methods (design vs. model-based inference)

Potential of hurricanes to affect CPUE

Florida Keys 1980-1994 (*Not recommended for use*)

Pros: Fishery independent survey

Cons: Range, spatial coverage more limited than later periods

High variability

Tortugas (*Not recommended for use*)

Pros: Well designed survey

Fishery independent

Cons: Survey occurs primarily in marine protected areas

Doubtful that abundance trends in this area will track changes at the population scale

Issues addressed :

On edge of management jurisdiction between South Atlantic/Gulf managment areas

Potential of hurricanes to affect CPUE

**Table 5.3.** Model results for red grouper observed in chevron traps set during the MARMAP Survey (1990 – 2008).

| Survey Year | N | Index (number per trap-hour) | Index (scaled to a mean of one) | CV | LCL | UCL | Nominal Index (scaled to a mean of one) | Nominal Frequency of Occurrence (NFO) | Modeled Frequency of Occurrence (MFO) | CVMFO | LCLMFO | UCLMFO | Modeled Non-Zero CPUE | Nominal Non-Zero CPUE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 351 | 0.001 | 0.047 | 1.125 | 0.008 | 0.289 | 0.087 | 0.009 | 0.002 | 0.807 | 0.000 | 0.009 | 0.367 | 0.500 |
| 1991 | 301 | 0.002 | 0.119 | 0.936 | 0.024 | 0.581 | 0.135 | 0.013 | 0.007 | 0.641 | 0.002 | 0.023 | 0.265 | 0.500 |
| 1992 | 320 | 0.007 | 0.455 | 0.754 | 0.119 | 1.743 | 0.605 | 0.019 | 0.009 | 0.618 | 0.003 | 0.029 | 0.772 | 1.583 |
| 1993 | 411 | 0.013 | 0.865 | 0.654 | 0.262 | 2.854 | 0.595 | 0.019 | 0.013 | 0.522 | 0.005 | 0.037 | 0.957 | 1.500 |
| 1994 | 368 | 0.016 | 1.105 | 0.621 | 0.353 | 3.461 | 0.942 | 0.027 | 0.019 | 0.494 | 0.007 | 0.051 | 0.848 | 1.700 |
| 1995 | 272 | 0.008 | 0.516 | 0.759 | 0.134 | 1.986 | 0.412 | 0.022 | 0.011 | 0.581 | 0.004 | 0.036 | 0.673 | 0.917 |
| 1996 | 321 | 0.039 | 2.607 | 0.608 | 0.849 | 8.010 | 0.286 | 0.025 | 0.061 | 0.366 | 0.029 | 0.122 | 0.641 | 0.563 |
| 1997 | 350 | 0.005 | 0.323 | 0.884 | 0.071 | 1.476 | 0.262 | 0.011 | 0.005 | 0.712 | 0.001 | 0.021 | 0.937 | 1.125 |
| 1998 | 328 | 0.005 | 0.330 | 0.648 | 0.101 | 1.078 | 0.684 | 0.027 | 0.009 | 0.504 | 0.003 | 0.023 | 0.575 | 1.222 |
| 1999 | 225 | 0.025 | 1.698 | 0.525 | 0.633 | 4.556 | 1.404 | 0.071 | 0.039 | 0.376 | 0.019 | 0.081 | 0.643 | 0.969 |
| 2000 | 265 | 0.017 | 1.128 | 0.494 | 0.443 | 2.873 | 1.077 | 0.068 | 0.045 | 0.337 | 0.023 | 0.086 | 0.377 | 0.778 |
| 2001 | 236 | 0.025 | 1.696 | 0.527 | 0.630 | 4.567 | 1.598 | 0.064 | 0.045 | 0.385 | 0.021 | 0.094 | 0.564 | 1.233 |
| 2002 | 218 | 0.017 | 1.157 | 0.516 | 0.438 | 3.055 | 2.197 | 0.092 | 0.031 | 0.381 | 0.015 | 0.066 | 0.549 | 1.175 |
| 2003 | 218 | 0.015 | 1.018 | 0.524 | 0.380 | 2.727 | 1.403 | 0.069 | 0.033 | 0.371 | 0.016 | 0.068 | 0.458 | 1.000 |
| 2004 | 261 | 0.015 | 1.026 | 0.525 | 0.382 | 2.754 | 1.913 | 0.080 | 0.024 | 0.396 | 0.011 | 0.052 | 0.641 | 1.167 |
| 2005 | 303 | 0.017 | 1.147 | 0.476 | 0.465 | 2.830 | 0.975 | 0.076 | 0.038 | 0.339 | 0.019 | 0.073 | 0.450 | 0.630 |
| 2006 | 285 | 0.025 | 1.697 | 0.520 | 0.638 | 4.516 | 1.860 | 0.063 | 0.028 | 0.396 | 0.013 | 0.060 | 0.918 | 1.444 |
| 2007 | 326 | 0.022 | 1.507 | 0.489 | 0.597 | 3.800 | 1.657 | 0.058 | 0.027 | 0.360 | 0.013 | 0.055 | 0.830 | 1.395 |
| 2008 | 303 | 0.008 | 0.560 | 0.655 | 0.169 | 1.850 | 0.908 | 0.040 | 0.012 | 0.525 | 0.004 | 0.033 | 0.707 | 1.125 |

**Table 5.4.** Length compositions (cm) and number of fish sampled (N), and trap sample size (Ntrap; number of trapping events yielding fish that were measured) for red grouper caught in MARMAP chevron traps.

| Year | N | Ntrap | 24 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 2 | 2 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1991 | 3 | 3 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.3333 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1992 | 16 | 6 | 0.0625 | 0.0625 | 0.0000 | 0.0625 | 0.0000 | 0.0000 | 0.0625 | 0.0625 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0625 | 0.1250 | 0.0625 | 0.0000 |
| 1993 | 20 | 8 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1000 | 0.0000 | 0.0000 | 0.0500 | 0.1000 | 0.1000 | 0.2000 | 0.0000 | 0.1000 | 0.0000 | 0.0000 | 0.1000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0500 | 0.0000 | 0.0000 |
| 1994 | 30 | 10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0333 | 0.0000 | 0.0667 | 0.1333 | 0.0000 | 0.1000 | 0.1333 | 0.1000 | 0.0667 | 0.1333 | 0.0667 |
| 1995 | 9 | 6 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1996 | 10 | 9 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.2000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1000 |
| 1997 | 40 | 23 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0250 | 0.0000 | 0.0250 | 0.0750 | 0.0250 | 0.0000 | 0.0250 | 0.0500 | 0.0250 | 0.0500 | 0.0750 | 0.0000 | 0.1250 | 0.0250 | 0.0250 | 0.0250 | 0.0750 | 0.0500 | 0.0500 | 0.0750 |
| 1998 | 78 | 28 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0128 | 0.0128 | 0.0128 | 0.0000 | 0.0128 | 0.0128 | 0.0128 | 0.0385 | 0.0897 | 0.0641 | 0.0897 | 0.1154 | 0.1026 | 0.1026 | 0.0000 |
| 1999 | 48 | 21 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0208 | 0.0625 | 0.0208 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0208 | 0.0417 | 0.0417 |
| 2000 | 38 | 25 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0263 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0263 |
| 2001 | 38 | 20 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0263 | 0.0000 | 0.0263 | 0.0526 | 0.0263 | 0.1053 | 0.0263 | 0.0526 | 0.0526 | 0.0789 | 0.0000 | 0.0000 | 0.0263 | 0.0263 | 0.0000 | 0.0263 | 0.0000 | 0.0000 | 0.0263 |
| 2002 | 37 | 21 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0270 | 0.0000 | 0.0000 | 0.0541 | 0.0270 | 0.0000 | 0.0000 | 0.0270 | 0.0270 | 0.0000 | 0.0000 | 0.0000 | 0.0270 | 0.0270 | 0.0000 | 0.1081 | 0.0000 | 0.0541 | 0.0811 | 0.0811 | 0.1351 |
| 2003 | 37 | 19 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0270 | 0.0541 | 0.0270 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0541 | 0.0000 | 0.0270 | 0.0270 | 0.0270 | 0.1081 | 0.0270 | 0.0270 | 0.0000 | 0.0541 | 0.0000 | 0.0541 | 0.0270 | 0.0000 | 0.0270 |
| 2004 | 40 | 22 | 0.0000 | 0.0250 | 0.0250 | 0.0750 | 0.0750 | 0.0500 | 0.0500 | 0.0000 | 0.0000 | 0.0250 | 0.0000 | 0.0000 | 0.0250 | 0.0250 | 0.0250 | 0.0250 | 0.0500 | 0.0000 | 0.0000 | 0.0000 | 0.0250 | 0.0500 | 0.0000 | 0.0500 | 0.1000 | 0.0750 |
| 2005 | 29 | 25 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0345 | 0.0345 | 0.0000 | 0.0000 | 0.0000 | 0.0345 | 0.1379 | 0.0000 | 0.0690 | 0.0345 | 0.0000 | 0.0345 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0345 | 0.0000 |
| 2006 | 44 | 18 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0227 | 0.0000 | 0.0000 | 0.0000 | 0.0455 | 0.0455 | 0.0682 | 0.0682 | 0.1364 | 0.0455 | 0.1136 | 0.0455 | 0.0000 | 0.0000 | 0.0000 |
| 2007 | 43 | 21 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0233 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0233 | 0.0465 | 0.0465 | 0.0930 | 0.0000 | 0.0000 | 0.0698 |
| 2008 | 24 | 12 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0417 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

| Year | N | Ntrap | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 75 | 76 | 78 | 80 | 81 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 2 | 2 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.5000 | 0.0000 | 0.0000 | 0.0000 | 0.5000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1991 | 3 | 3 | 0.0000 | 0.0000 | 0.3333 | 0.0000 | 0.0000 | 0.3333 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1992 | 16 | 6 | 0.0625 | 0.0625 | 0.0000 | 0.1875 | 0.0000 | 0.0625 | 0.0000 | 0.0000 | 0.0000 | 0.0625 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1993 | 20 | 8 | 0.0000 | 0.0000 | 0.0500 | 0.0000 | 0.0000 | 0.0000 | 0.0500 | 0.0000 | 0.1000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1994 | 30 | 10 | 0.0000 | 0.1000 | 0.0333 | 0.0000 | 0.0000 | 0.0333 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1995 | 9 | 6 | 0.2222 | 0.1111 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.2222 | 0.0000 | 0.2222 | 0.1111 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1111 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1996 | 10 | 9 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1000 | 0.1000 | 0.0000 | 0.1000 | 0.0000 | 0.2000 | 0.0000 | 0.0000 | 0.0000 | 0.1000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1997 | 40 | 23 | 0.0000 | 0.0000 | 0.0250 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0250 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0250 | 0.0000 | 0.0000 | 0.0500 | 0.0000 | 0.0250 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0250 | 0.0000 | 0.0000 |
| 1998 | 78 | 28 | 0.0385 | 0.0385 | 0.0000 | 0.0513 | 0.0256 | 0.0513 | 0.0128 | 0.0128 | 0.0000 | 0.0000 | 0.0000 | 0.0256 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0256 | 0.0000 | 0.0128 | 0.0128 | 0.0000 | 0.0128 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1999 | 48 | 21 | 0.1042 | 0.0833 | 0.0833 | 0.1042 | 0.0208 | 0.0208 | 0.0208 | 0.0625 | 0.0417 | 0.0000 | 0.0417 | 0.0000 | 0.0625 | 0.0000 | 0.0417 | 0.0208 | 0.0417 | 0.0000 | 0.0000 | 0.0208 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0208 | 0.0000 | 0.0000 |
| 2000 | 38 | 25 | 0.0000 | 0.0263 | 0.0263 | 0.0000 | 0.0000 | 0.0000 | 0.0263 | 0.0000 | 0.0263 | 0.0526 | 0.0000 | 0.1316 | 0.0789 | 0.0789 | 0.0263 | 0.0526 | 0.1579 | 0.0263 | 0.1316 | 0.0000 | 0.0526 | 0.0526 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2001 | 38 | 20 | 0.0000 | 0.0000 | 0.0263 | 0.0000 | 0.0000 | 0.0526 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0263 | 0.0000 | 0.0000 | 0.0526 | 0.0263 | 0.0526 | 0.0263 | 0.0000 | 0.1053 | 0.0000 | 0.0526 | 0.0000 | 0.0263 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2002 | 37 | 21 | 0.0541 | 0.0541 | 0.0000 | 0.0541 | 0.0270 | 0.0000 | 0.0000 | 0.0000 | 0.0270 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0541 | 0.0000 | 0.0270 | 0.0000 | 0.0270 | 0.0000 | 0.0000 | 0.0000 |
| 2003 | 37 | 19 | 0.0000 | 0.0541 | 0.0541 | 0.0270 | 0.0000 | 0.0270 | 0.0270 | 0.0541 | 0.0541 | 0.0541 | 0.0000 | 0.0000 | 0.0270 | 0.0270 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0270 | 0.0000 | 0.0000 |
| 2004 | 40 | 22 | 0.0500 | 0.0250 | 0.0000 | 0.0000 | 0.0250 | 0.0250 | 0.0000 | 0.0250 | 0.0000 | 0.0250 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0250 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0250 | 0.0000 | 0.0000 |
| 2005 | 29 | 25 | 0.0345 | 0.0000 | 0.0000 | 0.0000 | 0.0345 | 0.0345 | 0.0000 | 0.0345 | 0.0345 | 0.0690 | 0.0000 | 0.0345 | 0.1379 | 0.0000 | 0.0000 | 0.1034 | 0.0345 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0345 | 0.0000 | 0.0000 |
| 2006 | 44 | 18 | 0.0000 | 0.0455 | 0.0000 | 0.0455 | 0.0000 | 0.0227 | 0.0227 | 0.0000 | 0.0000 | 0.0455 | 0.0000 | 0.0000 | 0.0227 | 0.0000 | 0.0682 | 0.0455 | 0.0455 | 0.0000 | 0.0227 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0227 |
| 2007 | 43 | 21 | 0.1395 | 0.0930 | 0.0698 | 0.0233 | 0.0930 | 0.0465 | 0.0233 | 0.0233 | 0.0000 | 0.0000 | 0.0233 | 0.0233 | 0.0000 | 0.0000 | 0.0233 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0233 | 0.0233 | 0.0233 | 0.0000 | 0.0000 | 0.0233 | 0.0233 |
| 2008 | 24 | 12 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1250 | 0.0000 | 0.0417 | 0.0833 | 0.0417 | 0.0417 | 0.0417 | 0.1250 | 0.0417 | 0.0833 | 0.1250 | 0.0000 | 0.0417 | 0.0000 | 0.0417 | 0.0417 | 0.0417 | 0.0000 | 0.0000 | 0.0417 | 0.0000 | 0.0000 | 0.0000 |

**Table 5.5.** Age compositions and number of fish sampled (N), and trap sample size (Ntrap; number of trapping events yielding fish that were aged) for red grouper caught in MARMAP chevron traps.

| Year | N | Ntrap | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1991 | 3 | 3 | 0.0000 | 0.3333 | 0.6667 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1992 | 15 | 6 | 0.3333 | 0.0667 | 0.5333 | 0.0667 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1993 | 19 | 8 | 0.0526 | 0.7368 | 0.0526 | 0.1579 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1994 | 29 | 10 | 0.0000 | 0.0000 | 0.9655 | 0.0345 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1995 | 7 | 6 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1996 | 9 | 9 | 0.1111 | 0.2222 | 0.0000 | 0.3333 | 0.2222 | 0.0000 | 0.0000 | 0.0000 | 0.1111 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1997 | 36 | 23 | 0.1111 | 0.3611 | 0.3611 | 0.0000 | 0.0278 | 0.1111 | 0.0000 | 0.0000 | 0.0000 | 0.0278 | 0.0000 | 0.0000 | 0.0000 |
| 1998 | 72 | 28 | 0.0000 | 0.0694 | 0.6111 | 0.2361 | 0.0139 | 0.0556 | 0.0139 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1999 | 47 | 21 | 0.0000 | 0.0851 | 0.3830 | 0.4255 | 0.0851 | 0.0000 | 0.0213 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2000 | 33 | 25 | 0.0000 | 0.0303 | 0.0606 | 0.3636 | 0.3030 | 0.1818 | 0.0606 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2001 | 37 | 20 | 0.0000 | 0.4595 | 0.0811 | 0.0811 | 0.1351 | 0.2432 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2002 | 36 | 21 | 0.1111 | 0.0833 | 0.6111 | 0.0833 | 0.0000 | 0.0556 | 0.0278 | 0.0278 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2003 | 36 | 19 | 0.1111 | 0.2778 | 0.1667 | 0.4167 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0278 |
| 2004 | 39 | 22 | 0.2308 | 0.2308 | 0.4103 | 0.0513 | 0.0513 | 0.0000 | 0.0000 | 0.0256 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2005 | 28 | 25 | 0.0000 | 0.2857 | 0.2143 | 0.3571 | 0.0357 | 0.0714 | 0.0000 | 0.0000 | 0.0000 | 0.0357 | 0.0000 | 0.0000 | 0.0000 |
| 2006 | 44 | 18 | 0.0000 | 0.0000 | 0.6136 | 0.1364 | 0.2045 | 0.0227 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0227 | 0.0000 | 0.0000 |
| 2007 | 43 | 21 | 0.0000 | 0.0233 | 0.0233 | 0.7674 | 0.1163 | 0.0233 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0465 | 0.0000 |
| 2008 | 16 | 12 | 0.0000 | 0.0625 | 0.0000 | 0.0000 | 0.8750 | 0.0625 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

**Table 5.6.** Habitat-depth strata for the Florida Keys survey domain (a) prior to implementation of no-take marine reserves, and (b) post-implementation of reserves. Nh is the number of primary sample units (dimensions 200 m by 200 m; 40,000 $m^2$) comprising a stratum; Wh is the corresponding proportion of the domain contained within a stratum.

**(a)**

| Stratum Code | Description | Nh | Wh |
|---|---|---|---|
| PCHR | Hawk's Channel patch reefs | 4914 | 0.3518 |
| HRRF | High-relief habitat (reefs extend >3 m vertically, mostly occurs in shallow forereef) | 345 | 0.0247 |
| FRSH | Forereef, depth 0-6 m, low-relief (reefs extend <2 m vertically from sand base) | 1489 | 0.1066 |
| FRMD | Forereef, depth 6-18 m, low-relief | 5845 | 0.4184 |
| FRDP | Forereef, depth 18-33 m, low-relief | 1376 | 0.0985 |
| | **Total** | **13969** | **1** |

**(b)**

| Stratum Code | Protected | Nh | Wh |
|---|---|---|---|
| PCHR | 0 | 4751 | 0.3401 |
| PCHR | 1 | 163 | 0.0117 |
| HRRF | 0 | 170 | 0.0122 |
| HRRF | 1 | 175 | 0.0125 |
| FRSH | 0 | 1374 | 0.0984 |
| FRSH | 1 | 115 | 0.0082 |
| FRMD | 0 | 5489 | 0.3929 |
| FRMD | 1 | 356 | 0.0255 |
| FRDP | 0 | 1376 | 0.0985 |
| | **Total** | **13969** | **1** |

**Table 5.7.** RVC primary unit sample sizes by strata and year for the period 1994-2008 in the Florida Keys survey domain. The period represents the time when full habitat stratification of the survey domain was employed. The actual number of scientific dives in a year is computed by multiplying the Total by 2.

| | PCHR | | HRRF | | FRSH | | FRMD | | FRDP | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Open | MPA | Open | MPA | Open | MPA | Open | MPA | Open | Total |
| 1994 | 36 | | 43 | | 20 | | 27 | | 0 | 126 |
| 1995 | 76 | | 106 | | 35 | | 74 | | 0 | 291 |
| 1996 | 46 | | 65 | | 26 | | 14 | | 0 | 151 |
| 1997 | 127 | | 117 | | 60 | | 104 | | 0 | 408 |
| 1998 | 110 | 59 | 50 | 97 | 48 | 42 | 43 | 12 | 0 | 461 |
| 1999 | 62 | 22 | 23 | 88 | 26 | 6 | 168 | 45 | 0 | 440 |
| 2000 | 102 | 52 | 22 | 68 | 44 | 20 | 176 | 43 | 0 | 527 |
| 2001 | 145 | 28 | 94 | 134 | 93 | 40 | 138 | 45 | 25 | 742 |
| 2002 | 107 | 24 | 47 | 50 | 18 | 19 | 281 | 53 | 29 | 628 |
| 2003 | 92 | 24 | 53 | 62 | 40 | 21 | 95 | 37 | 24 | 448 |
| 2004 | 42 | 6 | 33 | 54 | 30 | 4 | 48 | 14 | 15 | 246 |
| 2005 | 123 | 19 | 34 | 55 | 49 | 14 | 110 | 48 | 46 | 498 |
| 2006 | 138 | 33 | 43 | 46 | 52 | 42 | 153 | 59 | 42 | 608 |
| 2007 | 137 | 24 | 32 | 62 | 50 | 22 | 204 | 41 | 47 | 619 |
| 2008 | 186 | 30 | 42 | 43 | 75 | 29 | 219 | 65 | 46 | 735 |

**Table 5.8.** Habitat-region strata for the Dry Tortugas survey domain: (a) prior to implementation of no-take marine reserves; and, (b) post-implementation of reserves. Nh is the number of primary sample units (dimensions 200 m by 200 m; 40,000 $m^2$) comprising a stratum; Wh is the corresponding proportion of the domain contained within a stratum.

**(a)**

| Stratum Code | Location | Habitat | Nh | Wh |
|---|---|---|---|---|
| BANK_CONT_LR | Tortugas Bank | Contiguous reef, low-relief | 2584 | 0.3172 |
| BANK_CONT_HR | Tortugas Bank | Contiguous reef, high-relief | 359 | 0.0441 |
| BANK_ISOL_LR | Tortugas Bank | Isolated reef structures, low-relief | 45 | 0.0055 |
| BANK_ISOL_MR | Tortugas Bank | Isolated reef structures, medium-relief | 422 | 0.0518 |
| BANK_ISOL_HR | Tortugas Bank | Isolated reef structures, high-relief | 20 | 0.0025 |
| PARK_CONT_LR | Dry Tortugas National Park | Contiguous reef, low-relief | 2403 | 0.2950 |
| PARK_CONT_MR | Dry Tortugas National Park | Contiguous reef, medium-relief | 211 | 0.0259 |
| PARK_CONT_HR | Dry Tortugas National Park | Contiguous reef, high-relief | 39 | 0.0048 |
| PARK_ISOL_LR | Dry Tortugas National Park | Isolated reef structures, low-relief | 905 | 0.1111 |
| PARK_ISOL_MR | Dry Tortugas National Park | Isolated reef structures, medium-relief | 736 | 0.0903 |
| PARK_ISOL_HR | Dry Tortugas National Park | Isolated reef structures, high-relief | 21 | 0.0026 |
| PARK_SPGR_LR | Dry Tortugas National Park | Spur-groove reef, low-relief | 283 | 0.0347 |
| PARK_SPGR_HR | Dry Tortugas National Park | Spur-groove reef, high-relief | 119 | 0.0146 |
| | | **Total** | **8147** | **1** |

**(b)**

| Stratum Code | Protected | Nh | Wh |
|---|---|---|---|
| BANK_CONT_LR | 0 | 1120 | 0.1375 |
| BANK_CONT_LR | 1 | 1464 | 0.1797 |
| BANK_CONT_HR | 0 | 37 | 0.0045 |
| BANK_CONT_HR | 1 | 322 | 0.0395 |
| BANK_ISOL_LR | 0 | 28 | 0.0034 |
| BANK_ISOL_LR | 1 | 17 | 0.0021 |
| BANK_ISOL_MR | 0 | 133 | 0.0163 |
| BANK_ISOL_MR | 1 | 289 | 0.0355 |
| BANK_ISOL_HR | 1 | 20 | 0.0025 |
| PARK_CONT_LR | 0 | 2403 | 0.2950 |
| PARK_CONT_MR | 0 | 211 | 0.0259 |
| PARK_CONT_HR | 0 | 39 | 0.0048 |
| PARK_ISOL_LR | 0 | 905 | 0.1111 |
| PARK_ISOL_MR | 0 | 736 | 0.0903 |
| PARK_ISOL_HR | 0 | 21 | 0.0026 |
| PARK_SPGR_LR | 0 | 283 | 0.0347 |
| PARK_SPGR_HR | 0 | 119 | 0.0146 |
| | **Total** | **8147** | **1** |

**Table 5.9.** Primary unit sample sizes by strata and year for the Dry Tortugas survey from 1999-2008.

| | BANK_CONT_LR | | BANK_CONT_HR | | BANK_ISOL_LR | | BANK_ISOL_MR | | BANK_ISOL_HR | | PARK CONT_LR | PARK CONT_MR | PARK CONT_HR | PARK ISOL_LR | PARK ISOL_MR | PARK ISOL_HR | PARK SPGR_LR | PARK SPGR_HR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Open** | **MPA** | **Open** | **MPA** | **Open** | **MPA** | **Open** | **MPA** | **Open** | **MPA** | **Open** | **Open** | **Open** | **Open** | **Open** | **Open** | **Open** | **Open** | **Total** |
| 1999 | 51 | | 61 | | 17 | | 31 | | 16 | | 47 | 8 | 10 | 12 | 14 | 6 | 30 | 24 | 327 |
| 2000 | 51 | | 31 | | 40 | | 21 | | 10 | | 64 | 17 | 12 | 45 | 52 | 7 | 9 | 22 | 381 |
| 2004 | 41 | 18 | 9 | 32 | 19 | 4 | 19 | 54 | | 18 | 146 | 39 | 33 | 44 | 45 | 14 | 26 | 8 | 569 |
| 2006 | 43 | 23 | 6 | 32 | 4 | 6 | 15 | 55 | | 8 | 117 | 43 | 24 | 14 | 60 | 14 | 18 | 8 | 490 |
| 2008 | 56 | 47 | 10 | 18 | 10 | 14 | 22 | 48 | | 23 | 108 | 87 | 31 | 56 | 51 | 22 | 36 | 14 | 653 |

**Table 5.10.** Estimates of length-specific abundance for red grouper in the Florida Keys obtained from the U. Miami/NMFS RVC diver survey. Data are in fork lengths.

| FLen (cm) | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2408 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 | 10247 | 4290 | 9804 | 2408 | 0 | 0 | 0 | 0 | 0 | 614 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1134 | 0 | 0 | 0 | 0 | 0 | 0 | 1685 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 899 | 9632 | 0 | 10224 | 0 | 0 | 0 | 614 |
| 13 | 0 | 0 | 0 | 0 | 0 | 30742 | 0 | 2044 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 5132 | 0 | 0 | 0 | 30742 | 0 | 4107 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 81983 | 468 | 6502 | 3943 | 15066 | 0 | 0 | 8072 | 3728 | 0 |
| 16 | 30849 | 0 | 24496 | 0 | 5810 | 23164 | 9985 | 5920 | 2408 | 0 | 12201 | 0 | 0 | 0 | 0 |
| 17 | 15425 | 0 | 0 | 0 | 0 | 94792 | 0 | 1253 | 0 | 0 | 0 | 0 | 0 | 0 | 542 |
| 18 | 0 | 0 | 0 | 0 | 0 | 5231 | 32533 | 1584 | 838 | 11185 | 0 | 0 | 11943 | 0 | 5101 |
| 19 | 0 | 0 | 0 | 0 | 5810 | 41205 | 10916 | 5697 | 2408 | 0 | 0 | 0 | 8072 | 0 | 2930 |
| 20 | 0 | 5132 | 0 | 20129 | 0 | 46226 | 29950 | 11144 | 16039 | 11185 | 12201 | 25840 | 0 | 3728 | 6399 |
| 21 | 15425 | 0 | 12249 | 0 | 33031 | 8716 | 935 | 4107 | 0 | 0 | 0 | 0 | 0 | 0 | 614 |
| 22 | 30849 | 5132 | 0 | 0 | 38033 | 20494 | 8623 | 13804 | 0 | 22370 | 10224 | 0 | 15980 | 3728 | 13721 |
| 23 | 0 | 0 | 0 | 0 | 21737 | 1796 | 11302 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9160 |
| 24 | 0 | 15411 | 0 | 10064 | 5973 | 56473 | 20433 | 4107 | 5603 | 5591 | 0 | 10604 | 0 | 6714 | 8788 |
| 25 | 0 | 8170 | 0 | 19548 | 326 | 56122 | 44154 | 30286 | 26131 | 56660 | 5175 | 12702 | 2986 | 3728 | 25487 |
| 26 | 0 | 0 | 0 | 0 | 38074 | 0 | 13338 | 0 | 4835 | 0 | 0 | 0 | 4333 | 3262 | 8459 |
| 27 | 0 | 1548 | 24496 | 0 | 326 | 15478 | 4290 | 0 | 8062 | 0 | 0 | 0 | 0 | 0 | 3544 |
| 28 | 0 | 0 | 0 | 0 | 5484 | 5124 | 18257 | 18532 | 5583 | 23105 | 52004 | 0 | 4633 | 5971 | 14500 |
| 29 | 0 | 464 | 0 | 0 | 653 | 10463 | 4333 | 11182 | 5627 | 5591 | 12201 | 0 | 597 | 2986 | 2820 |
| 30 | 0 | 20543 | 12249 | 40257 | 41693 | 36189 | 99075 | 37702 | 52209 | 44156 | 30144 | 65084 | 3583 | 22279 | 43823 |
| 31 | 0 | 0 | 0 | 0 | 0 | 20494 | 25617 | 0 | 4835 | 11185 | 0 | 5303 | 0 | 6523 | 14536 |
| 32 | 15425 | 5132 | 0 | 6516 | 5484 | 42791 | 46850 | 48489 | 27600 | 6413 | 0 | 5303 | 11152 | 3728 | 22849 |
| 33 | 0 | 0 | 0 | 455 | 16451 | 14641 | 18262 | 9810 | 9632 | 19072 | 0 | 15572 | 0 | 6990 | 13129 |
| 34 | 0 | 0 | 0 | 0 | 0 | 9410 | 5652 | 14654 | 6492 | 0 | 13473 | 18596 | 0 | 3262 | 17477 |
| 35 | 0 | 23117 | 44902 | 20584 | 18570 | 31174 | 64013 | 142291 | 48016 | 44302 | 30321 | 17908 | 33322 | 17432 | 61231 |
| 36 | 0 | 11141 | 0 | 0 | 21779 | 0 | 8663 | 8213 | 1676 | 1129 | 12201 | 33225 | 0 | 0 | 4063 |
| 37 | 0 | 0 | 0 | 0 | 0 | 184 | 8580 | 0 | 5627 | 822 | 5175 | 0 | 9563 | 11551 | 592 |
| 38 | 0 | 7706 | 0 | 20129 | 653 | 0 | 4333 | 23075 | 7604 | 18643 | 12201 | 13962 | 13001 | 0 | 7363 |
| 39 | 15425 | 7548 | 0 | 0 | 0 | 0 | 4290 | 4107 | 4816 | 0 | 0 | 4330 | 0 | 0 | 2930 |
| 40 | 0 | 6009 | 12249 | 6516 | 26428 | 81046 | 56884 | 68197 | 51881 | 65319 | 85600 | 71952 | 28385 | 50146 | 32871 |
| 41 | 0 | 0 | 0 | 0 | 0 | 10247 | 0 | 0 | 2408 | 0 | 0 | 0 | 0 | 0 | 6342 |
| 42 | 0 | 0 | 0 | 0 | 0 | 0 | 16178 | 17911 | 18993 | 6330 | 10224 | 25403 | 27498 | 1523 | 9160 |
| 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4835 | 6330 | 0 | 534 | 4036 | 3262 | 7063 |
| 44 | 0 | 0 | 0 | 0 | 0 | 0 | 8663 | 283 | 0 | 0 | 10224 | 0 | 0 | 0 | 6472 |
| 45 | 15425 | 464 | 8157 | 17490 | 6136 | 0 | 14181 | 71112 | 51827 | 45651 | 29309 | 63389 | 19125 | 10718 | 23871 |
| 46 | 0 | 0 | 0 | 0 | 0 | 5231 | 0 | 9698 | 3175 | 5591 | 5175 | 837 | 0 | 0 | 5858 |
| 47 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 914 | 0 | 0 | 0 | 8659 | 4825 | 7457 | 5750 |
| 48 | 0 | 0 | 0 | 0 | 0 | 15478 | 9985 | 6365 | 1676 | 6330 | 366 | 0 | 4036 | 0 | 9884 |
| 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 914 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 | 15425 | 0 | 0 | 455 | 5029 | 10463 | 7055 | 35786 | 42130 | 46642 | 12396 | 50106 | 5282 | 15612 | 23212 |
| 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4864 | 0 | 0 | 0 |
| 52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 380 | 0 | 0 | 4330 | 4333 | 3728 | 0 |
| 53 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1548 | 9668 | 1129 | 0 | 0 | 0 | 3728 | 0 |
| 54 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2514 | 0 | 0 | 0 | 0 | 0 | 0 |
| 55 | 0 | 0 | 0 | 0 | 0 | 10463 | 4333 | 9162 | 20554 | 20594 | 8424 | 18122 | 5894 | 4279 | 14930 |
| 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1298 | 0 | 0 |
| 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2408 | 0 | 0 | 0 | 0 | 3262 | 2820 |
| 58 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1688 | 6115 | 5591 | 0 | 0 | 8369 | 6990 | 5858 |
| 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9937 | 0 | 0 | 2930 |
| 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11208 | 30272 | 21822 | 8621 | 20925 | 8721 | 21011 | 28012 |
| 61 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 62 | 0 | 0 | 0 | 0 | 0 | 0 | 5652 | 11182 | 0 | 1129 | 0 | 0 | 0 | 0 | 614 |
| 63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 64 | 0 | 0 | 0 | 6516 | 0 | 0 | 0 | 0 | 0 | 5980 | 0 | 0 | 0 | 0 | 0 |
| 65 | 0 | 0 | 0 | 0 | 0 | 10463 | 0 | 7588 | 14874 | 2601 | 44188 | 8252 | 1947 | 26893 | 8184 |
| 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 761 | 0 | 0 | 4330 | 0 | 0 | 3544 |
| 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12495 | 11186 | 20507 | 10590 | 0 | 4529 | 1273 | 614 |
| 71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6330 | 0 | 0 | 0 | 0 | 0 |
| 72 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 73 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 74 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 75 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27439 | 30344 | 12201 | 0 | 5101 | 6523 | 6472 |
| 76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2930 |
| 78 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 79 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11751 | 0 | 11748 | 10224 | 837 | 0 | 0 | 0 |
| 81 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 83 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 84 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 85 | 0 | 0 | 0 | 0 | 0 | 0 | 4290 | 914 | 0 | 2258 | 0 | 0 | 0 | 0 | 0 |
| 86 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 88 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15000 | 12567 | 0 | 0 | 708 | 0 |
| 91 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 93 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 94 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6330 | 0 | 0 | 0 | 0 | 0 |
| 96 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 97 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 98 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 5.11**. Number of headboat trips reporting red grouper catch by year in the South Atlantic. Zones are south Florida (SF; headboat areas 11, 12, and 17), north Florida & Georgia (NF; areas 6, 7, and 8), South Carolina (SC; areas 4 & 5), and North Carolina (NC; areas 2, 3, 9, 10). Headboat sampling strata 1 (northern NC) was censored due to sampling irregularities.

| Table of year by zone | | | | | |
|---|---|---|---|---|---|
| **year** | **zone** | | | | **Total** |
| **Frequency** | **NC** | **NF** | **SC** | **SF** | |
| **1978** | 97 | 396 | 10 | 83 | 586 |
| **1979** | 142 | 288 | 15 | 685 | 1130 |
| **1980** | 46 | 256 | 20 | 834 | 1156 |
| **1981** | 51 | 128 | 14 | 1067 | 1260 |
| **1982** | 89 | 105 | 10 | 804 | 1008 |
| **1983** | 74 | 113 | 21 | 987 | 1195 |
| **1984** | 28 | 125 | 3 | 930 | 1086 |
| **1985** | 20 | 191 | 3 | 832 | 1046 |
| **1986** | 17 | 169 | 4 | 1062 | 1252 |
| **1987** | 31 | 135 | 23 | 1134 | 1323 |
| **1988** | 58 | 502 | 70 | 632 | 1262 |
| **1989** | 18 | 283 | 32 | 561 | 894 |
| **1990** | 47 | 279 | 21 | 423 | 770 |
| **1991** | 120 | 179 | 28 | 290 | 617 |
| **1992** | 151 | 270 | 37 | 868 | 1326 |
| **1993** | 119 | 194 | 37 | 1122 | 1472 |
| **1994** | 211 | 162 | 40 | 927 | 1340 |
| **1995** | 209 | 203 | 58 | 1011 | 1481 |
| **1996** | 209 | 168 | 63 | 1134 | 1574 |
| **1997** | 150 | 225 | 49 | 810 | 1234 |
| **1998** | 339 | 536 | 210 | 1242 | 2327 |
| **1999** | 297 | 394 | 234 | 617 | 1542 |
| **2000** | 235 | 282 | 164 | 601 | 1282 |
| **2001** | 181 | 271 | 103 | 596 | 1151 |
| **2002** | 129 | 231 | 62 | 458 | 880 |
| **2003** | 182 | 103 | 65 | 444 | 794 |
| **2004** | 183 | 143 | 104 | 598 | 1028 |
| **2005** | 161 | 310 | 79 | 851 | 1401 |
| **2006** | 148 | 234 | 176 | 444 | 1002 |
| **2007** | 118 | 166 | 203 | 420 | 907 |
| **2008** | 119 | 70 | 107 | 398 | 694 |
| **Total** | 3979 | 7111 | 2065 | 22865 | 36020 |

**Table 5.12.** Pairwise Pearson correlation coefficients for time series of nominal headboat CPUE and percentage of positive observations by region (NC: North Carolina; SC: South Carolina; NF: Northern Florida Georgia; SF: Southern Florida). Results are based on subsetted data (e.g., after method of Stephens and MacCall (2004) was used to select trips). An asterisk denotes a significant pairwise positive Pearson correlation at the $\alpha$=0.05 level.

| A. Nominal CPUE | | | | |
|---|---|---|---|---|
| | NC | SC | NF | SF |
| NC | 1 | | | |
| SC | 0.72* | 1 | | |
| NF | 0.32* | 0.34* | 1 | |
| SF | 0.37* | 0.27 | 0.25 | 1 |
| | | | | |
| B. % Positive | | | | |
| NC | 1 | | | |
| SC | 0.46* | 1 | | |
| NF | -0.22 | -0.07 | 1 | |
| SF | 0.47* | 0.45* | 0.03 | 1 |

**Table 5.13.** Standardized CPUE indices for red grouper from the headboat data. The index assumes gives spatial weights of 0.4 to NC/SC, 0.2 to NF, and 0.4 to SF. The CV was borrowed from an estimated index without interactions (SEDAR19-DW-03).

| Year | Index | CV |
|---|---|---|
| 1978 | 1.78 | 19.7 |
| 1979 | 2.35 | 18.1 |
| 1980 | 0.86 | 20.3 |
| 1981 | 1.04 | 20.9 |
| 1982 | 0.69 | 21.7 |
| 1983 | 1.23 | 20.3 |
| 1984 | 0.76 | 20.3 |
| 1985 | 0.63 | 20.7 |
| 1986 | 0.59 | 21.1 |
| 1987 | 0.83 | 20.7 |
| 1988 | 0.53 | 21.9 |
| 1989 | 0.72 | 21.5 |
| 1990 | 0.61 | 22.8 |
| 1991 | 0.36 | 23.4 |
| 1992 | 0.40 | 22.5 |
| 1993 | 0.50 | 21.9 |
| 1994 | 0.61 | 21.8 |
| 1995 | 0.66 | 21.7 |
| 1996 | 0.74 | 21.2 |
| 1997 | 1.11 | 21.2 |
| 1998 | 1.89 | 20.0 |
| 1999 | 1.58 | 20.7 |
| 2000 | 0.92 | 21.9 |
| 2001 | 1.01 | 21.3 |
| 2002 | 0.76 | 21.8 |
| 2003 | 0.75 | 21.7 |
| 2004 | 1.50 | 20.2 |
| 2005 | 2.82 | 18.5 |
| 2006 | 1.07 | 21.7 |
| 2007 | 0.99 | 22.5 |
| 2008 | 0.69 | 23.1 |

**Table 5.14.** The number of MRFSS intercepts in South Atlantic region including Florida Keys by region, mode of fishing, area, and year.

| Region | Mode | Area | Year 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Carolina | Charterboat | <= 3 mi | 92 | 23 | 40 | 110 | 59 | 126 | 175 | 151 | 138 | 80 | 96 | 99 | 100 | 215 | 127 | 82 | 67 | 75 |
| | | > 3 mi | 453 | 485 | 488 | 809 | 740 | 1210 | 1184 | 1036 | 655 | 807 | 795 | 751 | 599 | 439 | 395 | 532 | 394 | 408 |
| | Private/rental | <= 3 mi | 715 | 605 | 634 | 779 | 895 | 554 | 702 | 508 | 581 | 581 | 734 | 473 | 550 | 744 | 665 | 703 | 737 | 631 |
| | | > 3 mi | 360 | 303 | 284 | 432 | 370 | 390 | 336 | 222 | 193 | 321 | 460 | 392 | 370 | 309 | 385 | 439 | 444 | 285 |
| South Carolina | Charterboat | <= 3 mi | 3 | 7 | 1 | 13 | 13 | 11 | 8 | 6 | 3 | 19 | 6 | 18 | 9 | 39 | 31 | 25 | 41 | 18 |
| | | > 3 mi | 78 | 98 | 46 | 35 | 40 | 70 | 86 | 84 | 86 | 165 | 56 | 40 | 30 | 84 | 70 | 64 | 65 | 70 |
| | Private/rental | <= 3 mi | 15 | 17 | 20 | 15 | 23 | 149 | 428 | 415 | 117 | 113 | 90 | 139 | 39 | 104 | 163 | 182 | 189 | 79 |
| | | > 3 mi | 35 | 53 | 61 | 28 | 24 | 62 | 67 | 58 | 30 | 51 | 55 | 63 | 24 | 40 | 32 | 50 | 65 | 54 |
| Georgia | Charterboat | <= 3 mi | 4 | 12 | 6 | 23 | 2 | 9 | 6 | 2 | 17 | 45 | 35 | 29 | 28 | 14 | 36 | 28 | 18 | 25 |
| | | > 3 mi | 2 | 34 | 25 | 23 | 15 | 20 | 17 | 39 | 28 | 21 | 17 | 17 | 61 | 65 | 53 | 50 | 39 | 43 |
| | Private/rental | <= 3 mi | 26 | 47 | 13 | 15 | 24 | 24 | 20 | 17 | 10 | 37 | 17 | 18 | 19 | 20 | 18 | 19 | 11 | 12 |
| | | > 3 mi | 14 | 50 | 26 | 20 | 14 | 17 | 24 | 14 | 9 | 43 | 31 | 22 | 27 | 24 | 21 | 18 | 28 | 32 |
| Northeast Florida | Charterboat | <= 3 mi | 1 | 8 | . | . | . | . | 1 | . | 1 | 1 | . | 6 | 1 | 3 | 3 | . | . | 1 |
| | | > 3 mi | . | 40 | 4 | . | . | . | 1 | . | 5 | 3 | 15 | 31 | 28 | 20 | 15 | 13 | 7 | 9 |
| | Private/rental | <= 3 mi | 77 | 140 | 65 | 110 | 46 | 119 | 75 | 79 | 94 | 95 | 82 | 102 | 85 | 37 | 56 | 49 | 26 | 52 |
| | | > 3 mi | 76 | 103 | 83 | 113 | 57 | 85 | 54 | 97 | 127 | 123 | 199 | 106 | 100 | 81 | 43 | 60 | 51 | 78 |
| Southeast Florida | Charterboat | <= 3 mi | 98 | 195 | 91 | 43 | 69 | 63 | 71 | 93 | 269 | 230 | 350 | 477 | 359 | 214 | 275 | 215 | 234 | 176 |
| | | > 3 mi | 144 | 137 | 86 | 140 | 112 | 150 | 179 | 242 | 238 | 262 | 304 | 247 | 219 | 200 | 162 | 161 | 115 | 96 |
| | Private/rental | <= 3 mi | 374 | 643 | 550 | 598 | 660 | 586 | 624 | 644 | 999 | 785 | 742 | 911 | 859 | 762 | 649 | 861 | 974 | 751 |
| | | > 3 mi | 403 | 732 | 494 | 563 | 618 | 711 | 621 | 731 | 1492 | 1205 | 1099 | 1122 | 1089 | 842 | 693 | 909 | 774 | 725 |
| Florida Keys | Charterboat | <= 3 mi | 61 | 103 | 76 | 93 | 58 | 43 | 98 | 153 | 222 | 194 | 109 | 121 | 165 | 86 | 76 | 48 | 72 | 153 |
| | | > 3 mi | 42 | 81 | 78 | 67 | 93 | 115 | 229 | 464 | 910 | 1013 | 1004 | 972 | 916 | 677 | 647 | 463 | 472 | 655 |
| | Private/rental | <= 3 mi | 125 | 248 | 323 | 302 | 189 | 150 | 260 | 164 | 187 | 73 | 74 | 51 | 76 | 68 | 14 | 51 | 78 | 70 |
| | | > 3 mi | 52 | 99 | 73 | 98 | 85 | 184 | 45 | 44 | 64 | 64 | 66 | 63 | 116 | 67 | 28 | 67 | 109 | 92 |
| | | Total | 3250 | 4263 | 3567 | 4429 | 4206 | 4848 | 5311 | 5263 | 6475 | 6331 | 6436 | 6270 | 5869 | 5154 | 4657 | 5089 | 5010 | 4590 |

**Table 5.15.** Nominal (both positive and all intercepts) and standardized catch rates for red grouper calculated with MRFSS intercepts selected by Stephens and MacCall logistic regression, coefficients of variation, and the indices scaled to their means by year. The Stephens and MacCall estimates were recommended for use in the assessment.

| | Nominal (positive intercepts) | | | | Nominal (all intercepts) | | | | Stephens and MacCall | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| year | N | Mean | CV | Scaled to mean | N | Mean | CV | Scaled to mean | N | Mean | CV | Scaled to mean |
| 1991 | 64 | 4.36 | 0.15 | 0.97 | 3250 | 0.034 | 0.27 | 0.47 | 8 | 0.34 | 0.51 | 0.25 |
| 1992 | 92 | 4.64 | 0.12 | 1.04 | 4263 | 0.084 | 0.57 | 1.13 | 14 | 0.36 | 0.36 | 0.26 |
| 1993 | 77 | 4.03 | 0.16 | 0.90 | 3567 | 0.038 | 0.19 | 0.51 | 9 | 0.98 | 0.84 | 0.72 |
| 1994 | 77 | 4.78 | 0.14 | 1.07 | 4429 | 0.038 | 0.18 | 0.51 | 19 | 1.23 | 0.37 | 0.90 |
| 1995 | 58 | 5.29 | 0.23 | 1.18 | 4206 | 0.026 | 0.19 | 0.35 | 7 | 0.36 | 0.59 | 0.26 |
| 1996 | 74 | 4.81 | 0.13 | 1.07 | 4848 | 0.073 | 0.14 | 0.99 | 20 | 1.52 | 0.35 | 1.11 |
| 1997 | 60 | 5.63 | 0.18 | 1.26 | 5311 | 0.061 | 0.12 | 0.83 | 11 | 1.07 | 0.61 | 0.78 |
| 1998 | 70 | 4.20 | 0.14 | 0.94 | 5263 | 0.040 | 0.13 | 0.54 | 13 | 1.42 | 0.50 | 1.04 |
| 1999 | 90 | 4.12 | 0.20 | 0.92 | 6475 | 0.045 | 0.15 | 0.62 | 21 | 0.76 | 0.32 | 0.56 |
| 2000 | 108 | 5.23 | 0.15 | 1.17 | 6331 | 0.091 | 0.11 | 1.23 | 25 | 0.87 | 0.33 | 0.64 |
| 2001 | 138 | 3.04 | 0.13 | 0.68 | 6436 | 0.082 | 0.16 | 1.11 | 42 | 1.02 | 0.26 | 0.75 |
| 2002 | 201 | 4.80 | 0.11 | 1.07 | 6270 | 0.074 | 0.12 | 1.00 | 53 | 2.23 | 0.25 | 1.63 |
| 2003 | 185 | 4.02 | 0.10 | 0.90 | 5869 | 0.069 | 0.15 | 0.94 | 54 | 1.51 | 0.26 | 1.10 |
| 2004 | 194 | 5.81 | 0.10 | 1.30 | 5153 | 0.126 | 0.12 | 1.70 | 56 | 1.66 | 0.27 | 1.22 |
| 2005 | 159 | 3.81 | 0.10 | 0.85 | 4657 | 0.134 | 0.10 | 1.81 | 68 | 1.76 | 0.22 | 1.29 |
| 2006 | 187 | 4.77 | 0.15 | 1.06 | 5089 | 0.101 | 0.12 | 1.37 | 47 | 0.92 | 0.27 | 0.67 |
| 2007 | 181 | 3.60 | 0.12 | 0.80 | 5010 | 0.073 | 0.19 | 0.99 | 26 | 0.57 | 0.39 | 0.42 |
| 2008 | 180 | 4.52 | 0.09 | 1.01 | 4590 | 0.115 | 0.14 | 1.56 | 48 | 1.79 | 0.28 | 1.31 |
| Total | 2195 | | | | 91017 | | | | 541 | | | |

**Table 5.16.** Revised vertical line relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for red grouper (1993-2008) in the South Atlantic.

| YEAR | Relative Nominal CPUE | Trips | Proportion Successful Trips | Relative Index | Lower 95% CI (Index) | Upper 95% CI (Index) | CV (Index) |
|---|---|---|---|---|---|---|---|
| 1993 | 0.295366 | 993 | 0.386707 | 0.386672 | 0.229068 | 0.652712 | 0.266329 |
| 1994 | 0.311522 | 1,745 | 0.375358 | 0.312842 | 0.187272 | 0.522611 | 0.260849 |
| 1995 | 0.505946 | 1,875 | 0.4672 | 0.502747 | 0.333713 | 0.757399 | 0.207072 |
| 1996 | 0.399508 | 1,889 | 0.516675 | 0.575843 | 0.40723 | 0.814272 | 0.174537 |
| 1997 | 0.707033 | 2,599 | 0.556753 | 0.65357 | 0.483038 | 0.884306 | 0.152045 |
| 1998 | 0.82784 | 2,558 | 0.633698 | 0.985191 | 0.775404 | 1.251736 | 0.120156 |
| 1999 | 1.088635 | 1,970 | 0.738071 | 1.449526 | 1.181416 | 1.778483 | 0.10253 |
| 2000 | 1.139323 | 1,902 | 0.680862 | 1.045295 | 0.811588 | 1.3463 | 0.127039 |
| 2001 | 0.955396 | 2,221 | 0.603332 | 0.836274 | 0.625974 | 1.117227 | 0.145587 |
| 2002 | 1.019031 | 2,149 | 0.565379 | 0.900941 | 0.673673 | 1.204878 | 0.146118 |
| 2003 | 0.950021 | 1,879 | 0.592869 | 1.028567 | 0.775367 | 1.364451 | 0.142001 |
| 2004 | 0.926823 | 1,786 | 0.610302 | 0.959559 | 0.72874 | 1.263487 | 0.138232 |
| 2005 | 0.773892 | 1,596 | 0.630952 | 0.855551 | 0.639818 | 1.144025 | 0.146051 |
| 2006 | 1.423833 | 1,518 | 0.739789 | 1.217362 | 0.939261 | 1.577805 | 0.130221 |
| 2007 | 2.452861 | 1,807 | 0.75927 | 1.93578 | 1.564964 | 2.394459 | 0.106625 |
| 2008 | 2.222968 | 1,623 | 0.796057 | 2.354279 | 1.913195 | 2.897055 | 0.10401 |

**Table 5.17.** Pearson correlation coefficients between indices recommended for the SEDAR 19 assessment of red grouper. Values in parentheses are p-values where the null hypothesis is that the specified indices are uncorrelated (calculated using the function "cor.test" in the R statistical programming platform). Note that the RVC and MARMAP indices were based on all observed fish, not just those in exploitable phases.

| | RVC | MARMAP Trap | Headboat | MRFSS |
|---|---|---|---|---|
| MARMAP Trap | 0.13 (0.65) | 1.00 | | |
| Headboat | 0.24 (0.38) | 0.17 (0.50) | 1.00 | |
| MRFSS | 0.21 (0.45) | 0.20 (0.42) | 0.37 (0.13) | 1.00 |
| Logbook Vertical Line | 0.35 (0.20) | 0.00 (0.99) | 0.08 (0.77) | 0.05 (0.84) |

**Table 5.18.** A summary of all indices recommended for the SEDAR 19 red grouper assessment together with estimated coefficient of variation (CV). All indices have been standardized to their mean. To compute the RVC index, annual estimates of survey-wide abundance was obtained by summing over length bins; these estimates were then standardized to their mean.

| | Independent | | | | Dependent | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | RVC | CV | MARMAP | CV | Headboat | CV | MRFSS | CV | Logbook | CV |
| 1978 | | | | | 1.78 | 0.20 | | | | |
| 1979 | | | | | 2.35 | 0.18 | | | | |
| 1980 | | | | | 0.86 | 0.20 | | | | |
| 1981 | | | | | 1.04 | 0.21 | | | | |
| 1982 | | | | | 0.69 | 0.22 | | | | |
| 1983 | | | | | 1.23 | 0.20 | | | | |
| 1984 | | | | | 0.76 | 0.20 | | | | |
| 1985 | | | | | 0.63 | 0.21 | | | | |
| 1986 | | | | | 0.59 | 0.21 | | | | |
| 1987 | | | | | 0.83 | 0.21 | | | | |
| 1988 | | | | | 0.53 | 0.22 | | | | |
| 1989 | | | | | 0.72 | 0.22 | | | | |
| 1990 | | | 0.05 | 1.13 | 0.61 | 0.23 | | | | |
| 1991 | | | 0.12 | 0.94 | 0.36 | 0.23 | 0.30 | 0.51 | | |
| 1992 | | | 0.45 | 0.75 | 0.40 | 0.23 | 0.31 | 0.36 | | |
| 1993 | | | 0.86 | 0.65 | 0.50 | 0.22 | 0.87 | 0.84 | 0.39 | 0.27 |
| 1994 | 0.37 | 0.65 | 1.10 | 0.62 | 0.61 | 0.22 | 1.09 | 0.37 | 0.31 | 0.26 |
| 1995 | 0.29 | 0.28 | 0.52 | 0.76 | 0.66 | 0.22 | 0.31 | 0.59 | 0.50 | 0.21 |
| 1996 | 0.33 | 0.42 | 2.61 | 0.61 | 0.74 | 0.21 | 1.34 | 0.35 | 0.58 | 0.17 |
| 1997 | 0.40 | 0.42 | 0.32 | 0.88 | 1.11 | 0.21 | 0.94 | 0.61 | 0.65 | 0.15 |
| 1998 | 0.71 | 0.53 | 0.33 | 0.65 | 1.89 | 0.20 | 1.26 | 0.5 | 0.99 | 0.12 |
| 1999 | 2.00 | 0.30 | 1.70 | 0.53 | 1.58 | 0.21 | 0.68 | 0.32 | 1.45 | 0.10 |
| 2000 | 1.50 | 0.13 | 1.13 | 0.49 | 0.92 | 0.22 | 0.77 | 0.33 | 1.05 | 0.13 |
| 2001 | 1.67 | 0.11 | 1.70 | 0.53 | 1.01 | 0.21 | 0.91 | 0.26 | 0.84 | 0.15 |
| 2002 | 1.36 | 0.12 | 1.16 | 0.52 | 0.76 | 0.22 | 1.97 | 0.25 | 0.90 | 0.15 |
| 2003 | 1.51 | 0.12 | 1.02 | 0.52 | 0.75 | 0.22 | 1.33 | 0.26 | 1.03 | 0.14 |
| 2004 | 1.14 | 0.21 | 1.03 | 0.53 | 1.50 | 0.20 | 1.47 | 0.27 | 0.96 | 0.14 |
| 2005 | 1.25 | 0.12 | 1.15 | 0.48 | 2.82 | 0.19 | 1.56 | 0.22 | 0.86 | 0.15 |
| 2006 | 0.62 | 0.17 | 1.70 | 0.52 | 1.07 | 0.22 | 0.81 | 0.27 | 1.22 | 0.13 |
| 2007 | 0.65 | 0.15 | 1.51 | 0.49 | 0.99 | 0.23 | 0.51 | 0.39 | 1.94 | 0.11 |
| 2008 | 1.20 | 0.11 | 0.56 | 0.66 | 0.69 | 0.23 | 1.58 | 0.28 | 2.35 | 0.10 |
| UNITS | Numbers | | Numbers | | Numbers | | Numbers | | Pounds | |

### *5.11. FIGURES*

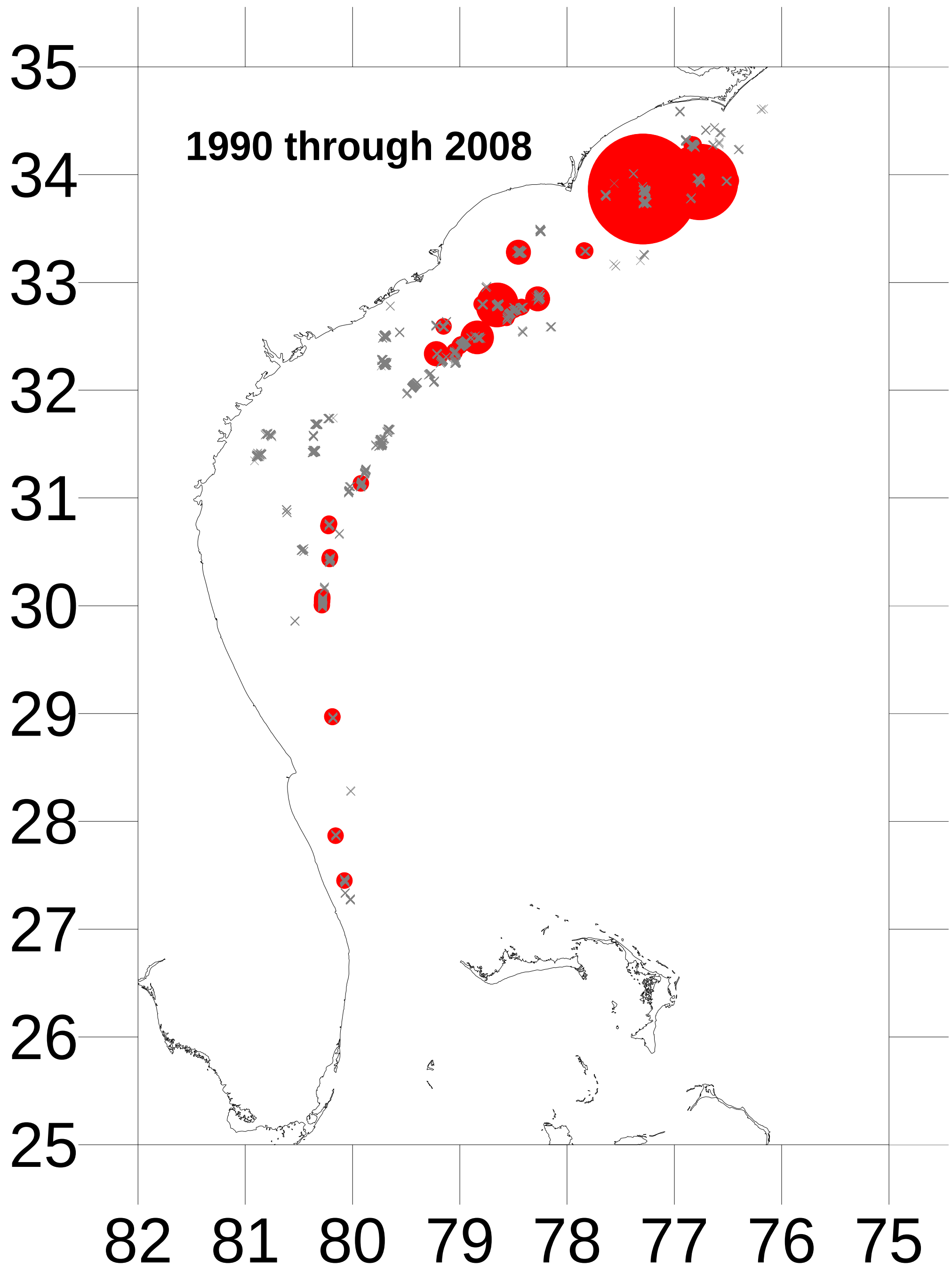



**Figure 5.1.** Effort and number of red grouper observed per chevron trap set during the MARMAP Survey (1990 – 2008). Gray crosses represent effort (5662 chevron trap sets). Red circles indicate trap sets where red grouper were observed. The diameters of the circles are linearly related to the number of red grouper observed during each chevron trap set (non-zero range: 1 – 12 red grouper per chevron trap set).

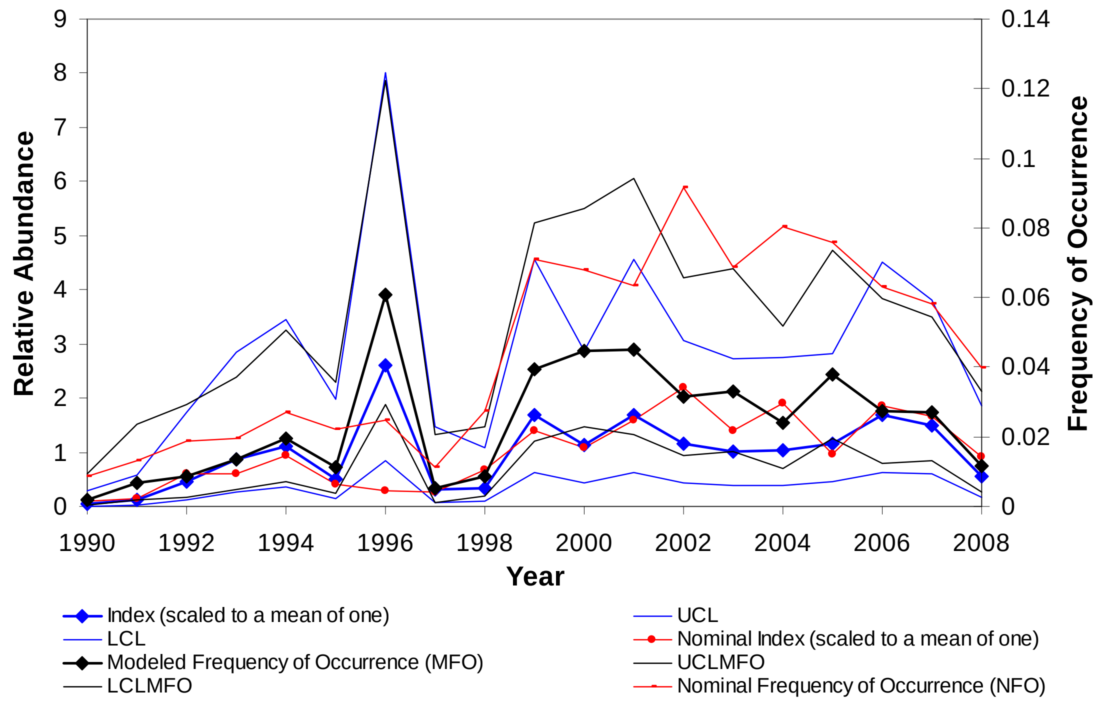



**Figure 5.2.** Model results for red grouper observed in chevron traps set during the MARMAP Survey (1990 – 2008).

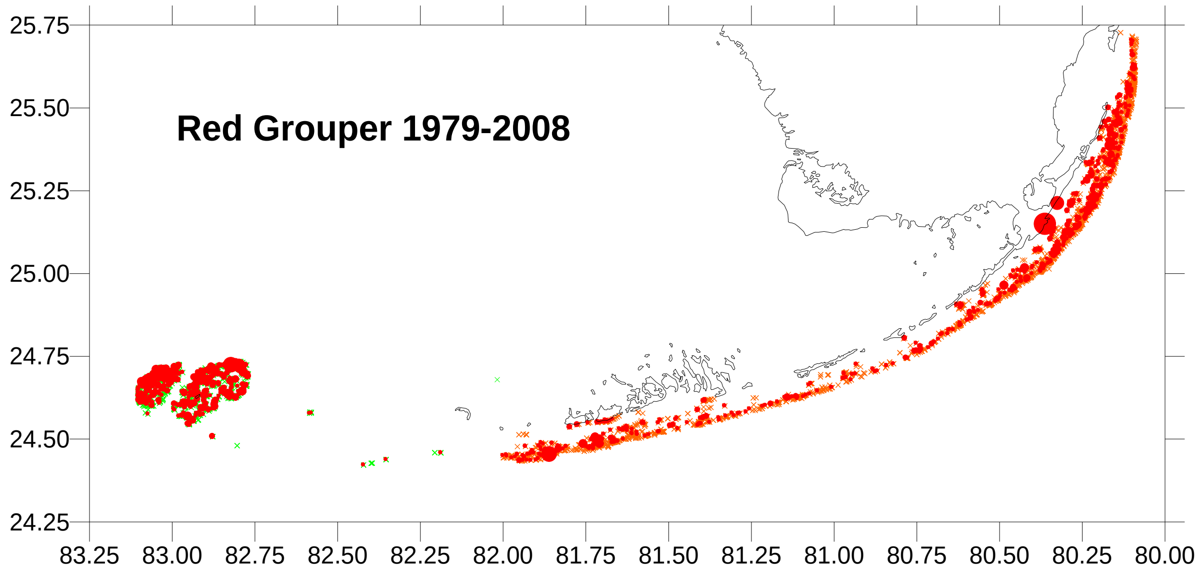



**Figure 5.3.** Effort and number of red grouper observed per sampling plot during the RVC for both the Florida Keys (1979 – 2007) and Dry Tortugas (1994 – 2008). Orange crosses represent RVC effort for the Florida Keys sampling area (14715 sampling plots); while green crosses represent RVC effort for the Dry Tortugas sampling area (4005 sampling plots). Red circles indicate plots where red grouper were observed. The diameters of the circles are linearly related to the number of red grouper observed at each sampling plot (non-zero range: 1 – 10 red grouper per sampling plot).

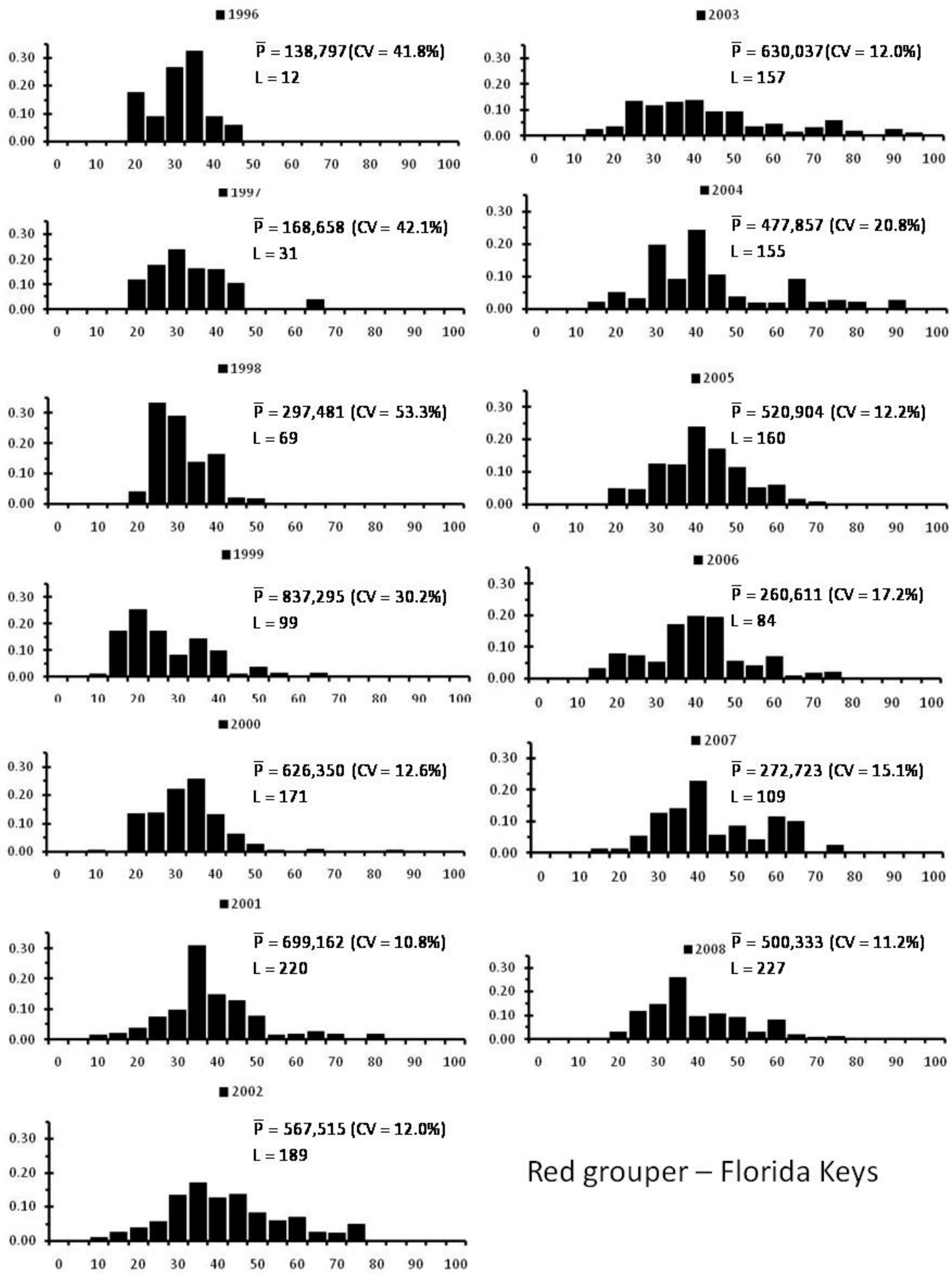



**Figure 5.4.** Proportion of population abundance ( $\overline{P}$ ) at length binned at 5 cm intervals for red grouper (*Epinephelus morio*) in the Florida Keys RVC sampling domain for the years 1996-2008. CV is the coefficient of variation of population abundance, and *L* is the raw number of red grouper observations in the survey.

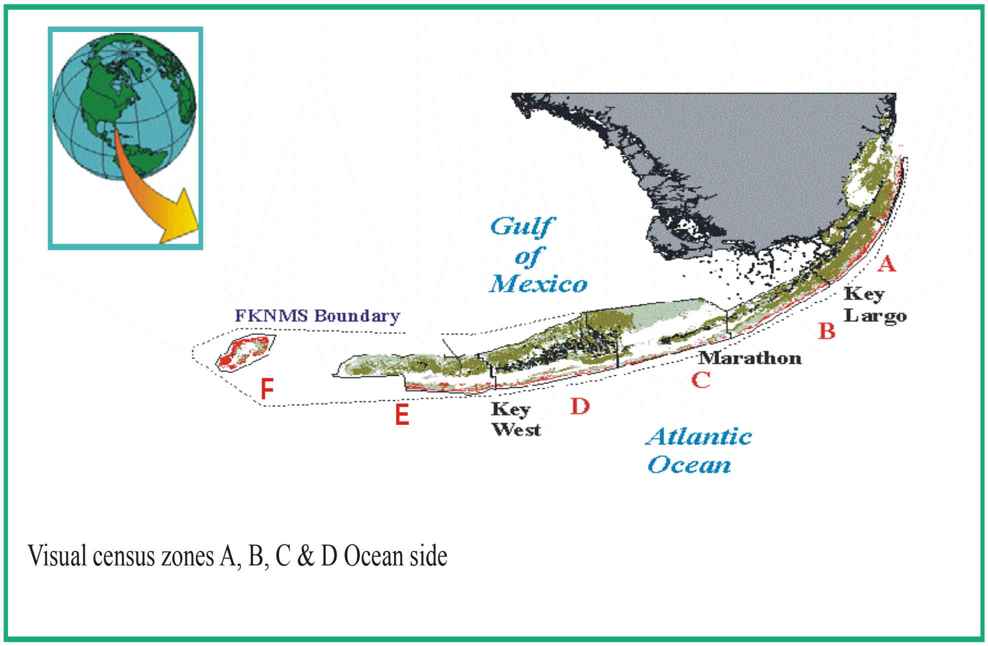



**Figure 5.5.** Map of FWC visual survey sampling areas in the Florida Keys National Marine Sanctuary (FKNMS).

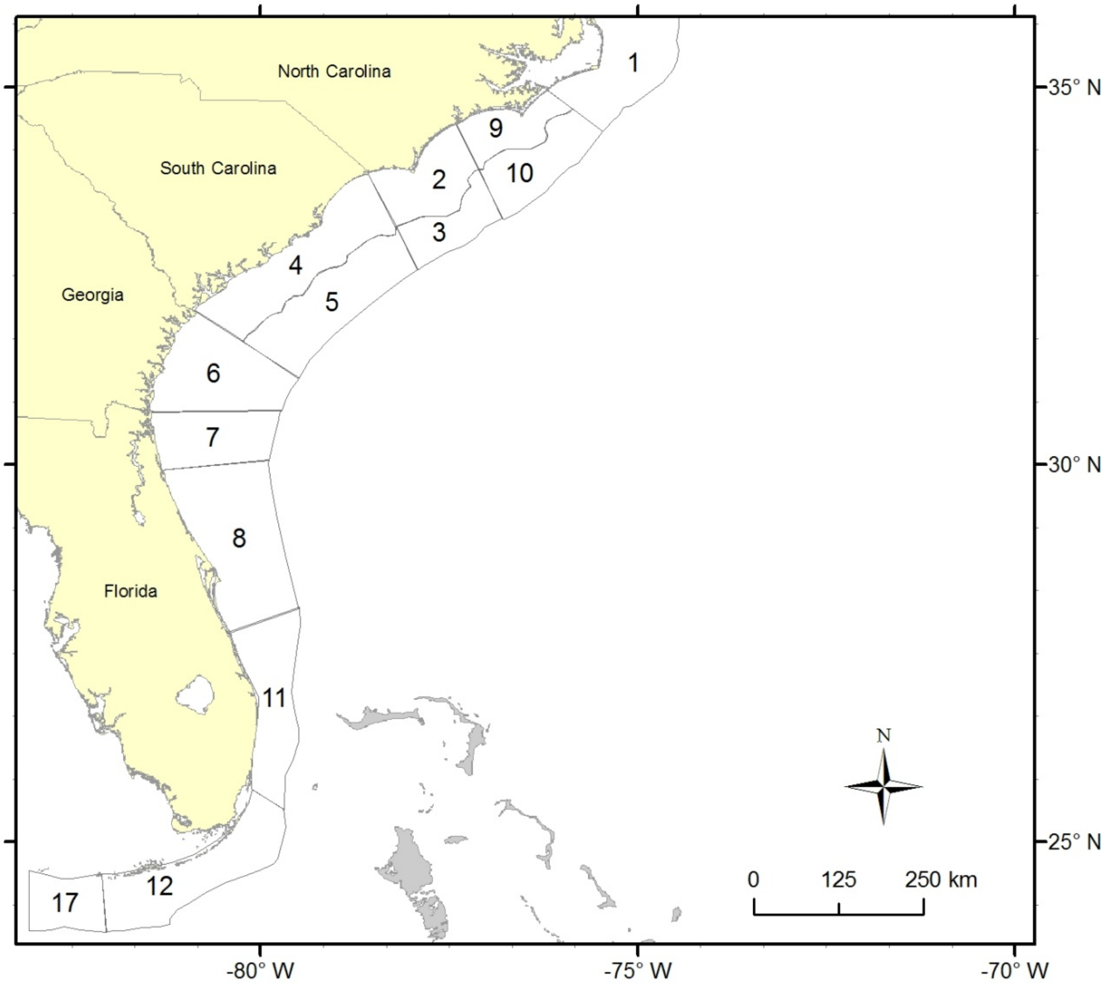



**Figure 5.6.** Spatial sampling strata from the headboat survey off the southeast Atlantic coast of the U.S. Areas 11, 12, and 17 were considered southern Florida (break near Cape Canaveral).

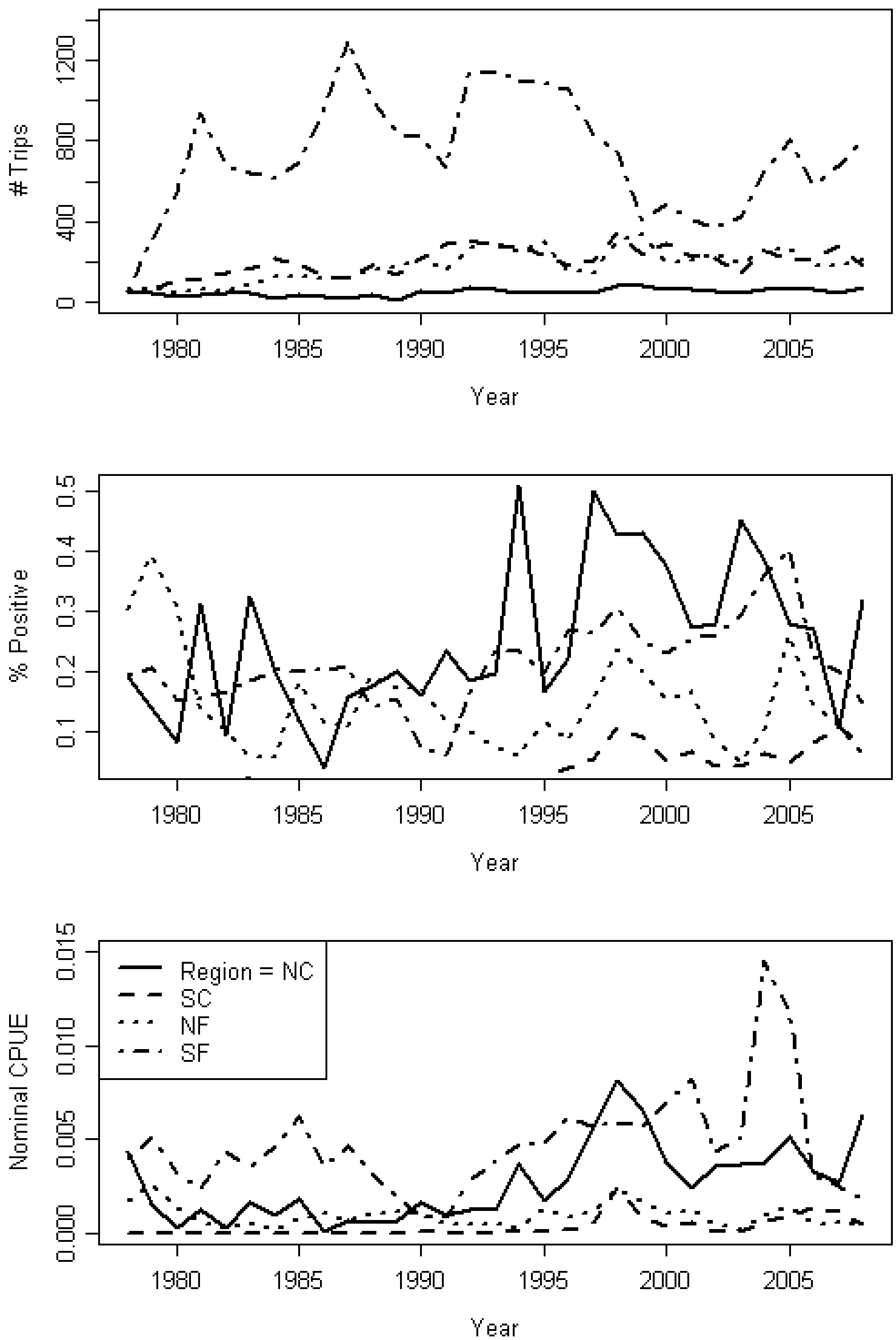



**Figure 5.7.** Sample sizes, percent of positive trips and nominal CPUE (red grouper per angler-hour) as calculated form subsetted data by year and region.

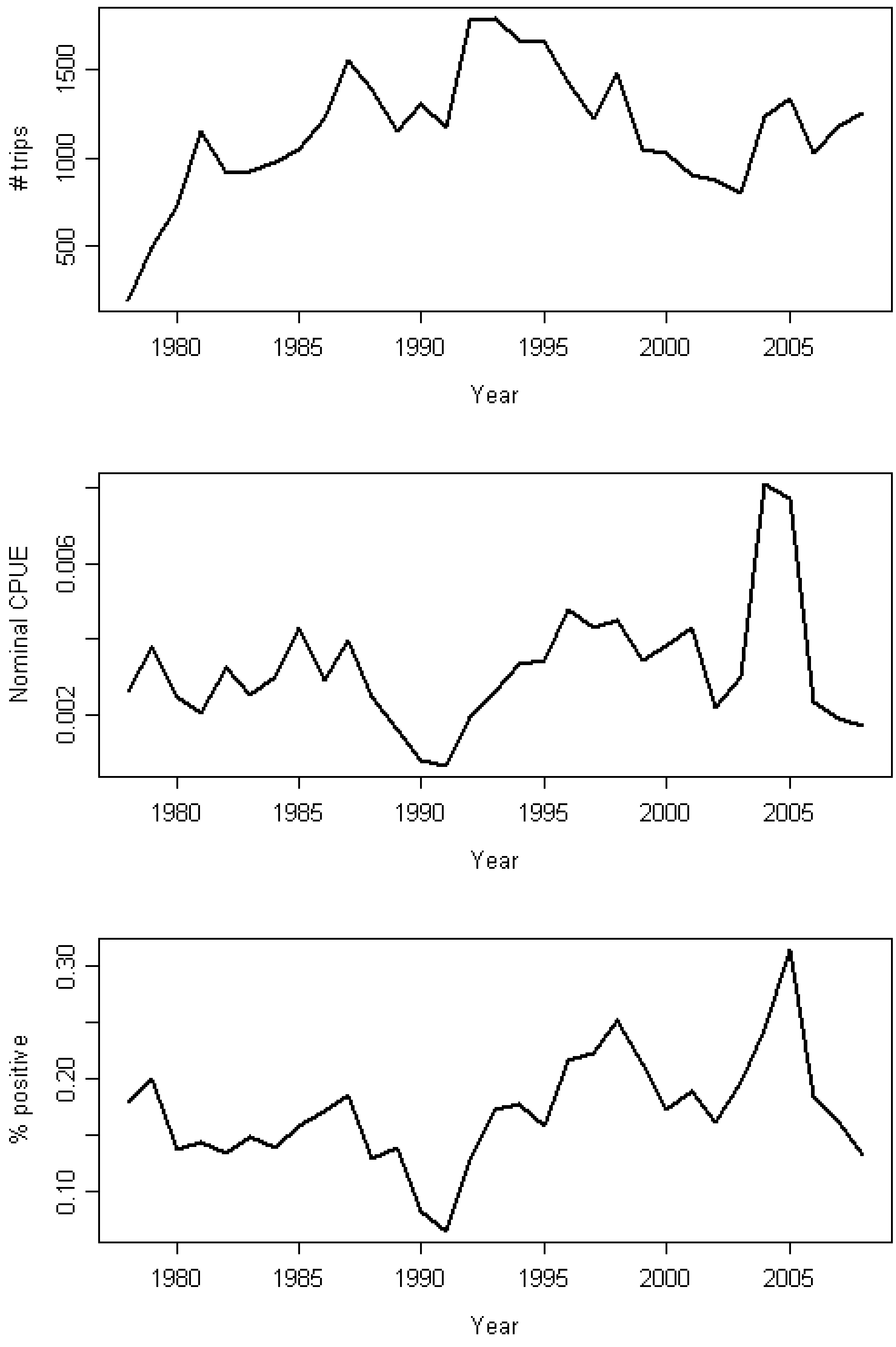



**Figure 5.8.** Sample sizes, nominal CPUE, and % of positive observations by year for trips selected by the method of Stephens and MacCall (2004).

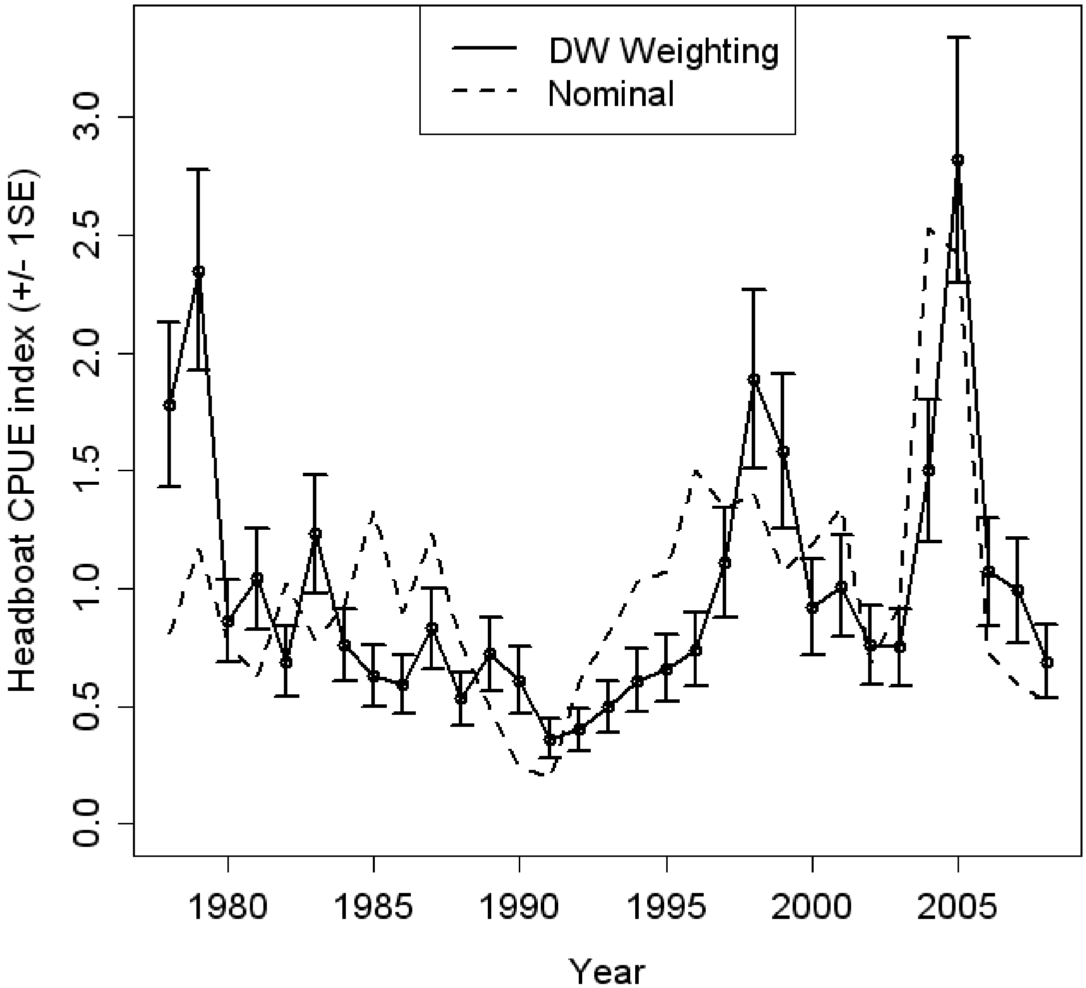



**Figure 5.9.** Modeled versus nominal relative abundance for the headboat index. Black circles and error bars represent values from the standardized indices, while gray dash-dot lines represent nominal CPUE. Modeled CPUE gives results for the set of spatial weights determined by the DW (0.4 for south Florida, 0.2 for northern Florida and Georgia, and 0.4 for north/south Carolina).

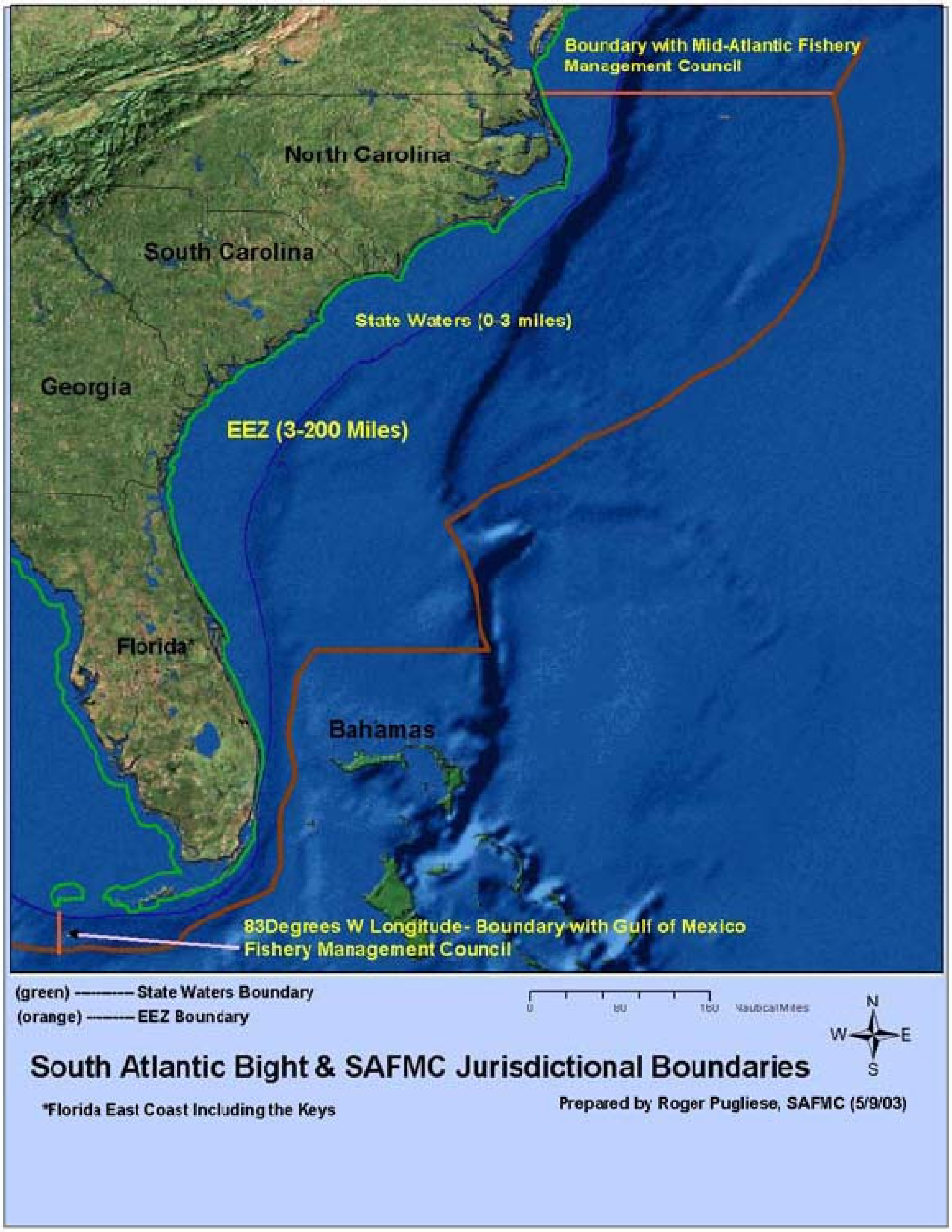



**Figure 5.10.** A map of the study area used for calculation of the MRFSS index.

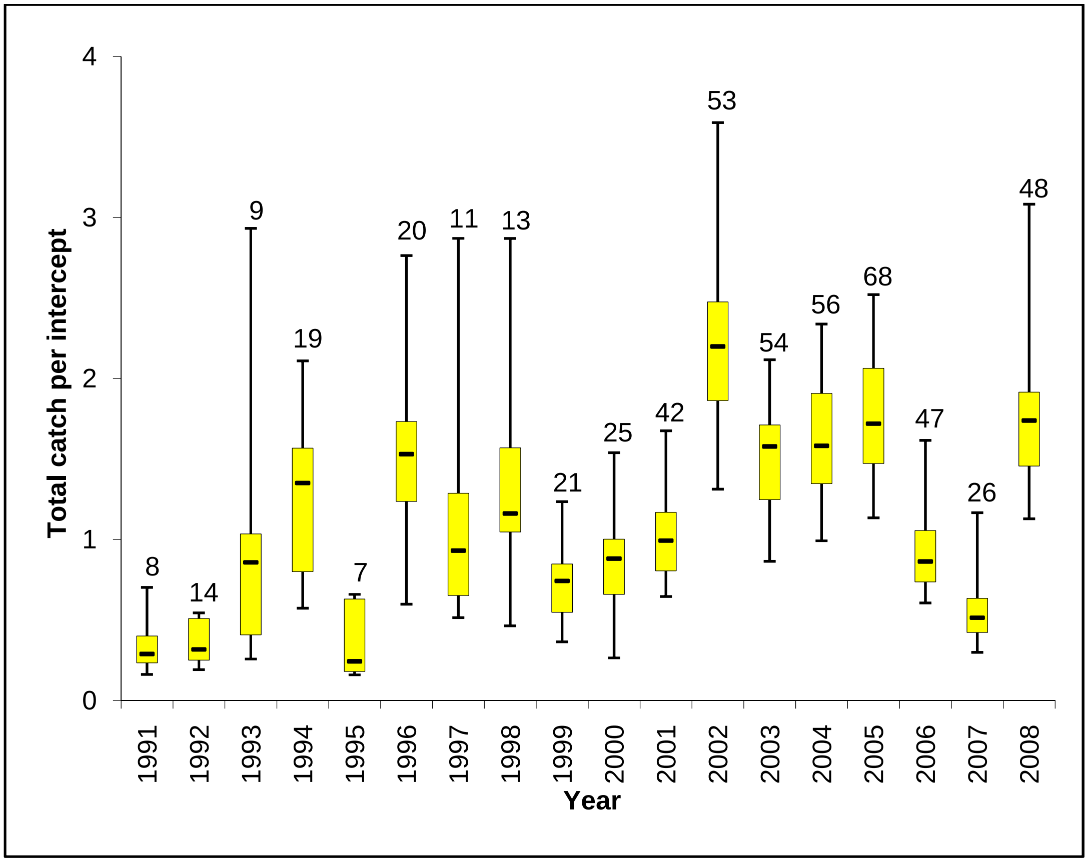



**Figure 5.11.** Standardized annual total catch of red grouper per angler hour per intercept with intercepts selected by Stephens and MacCall's logistic regression. The vertical lines are the 95% confidence interval, the box is the inter-quartile range, the horizontal line is the median of the outcomes and the number above the lines are the number of intercepts that caught red grouper for each year.

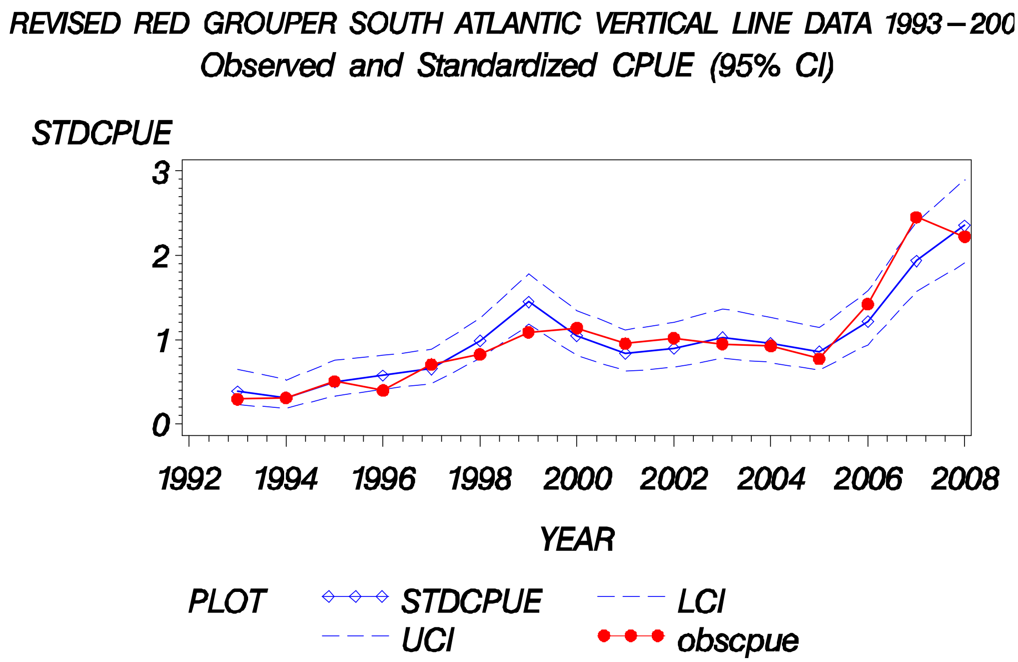



**Figure 5.12.** Revised red grouper nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing vertical line gear in the South Atlantic. The values have been scaled to the nominal mean CPUE or to the standardized mean CPUE.

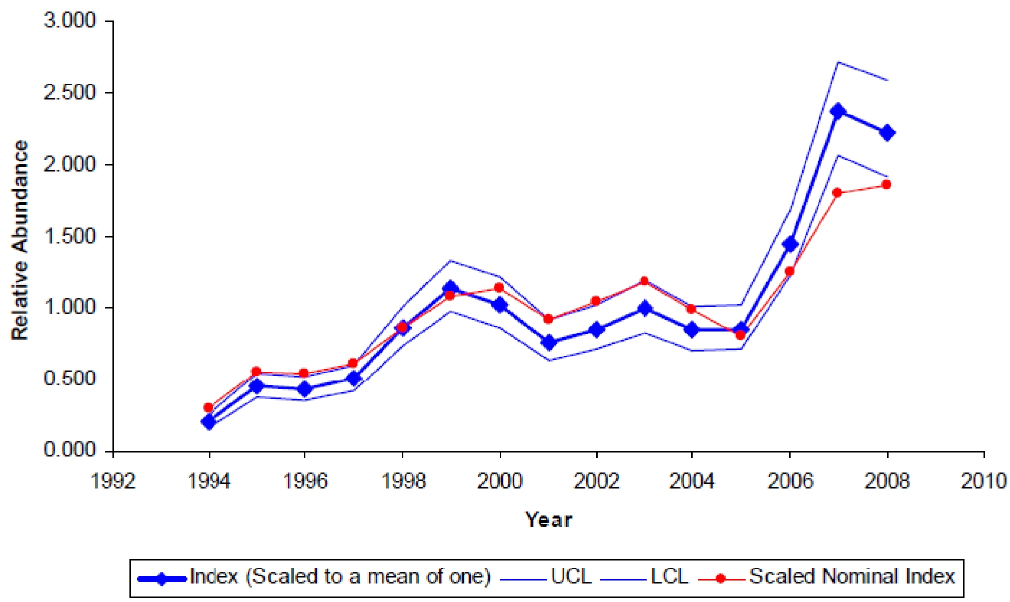



**Figure 5.13.** Estimated standardized index for red grouper from the commercial fishery off North Carolina waters (as estimated using commercial trip tickets). This index was not recommended for use in the assessment.

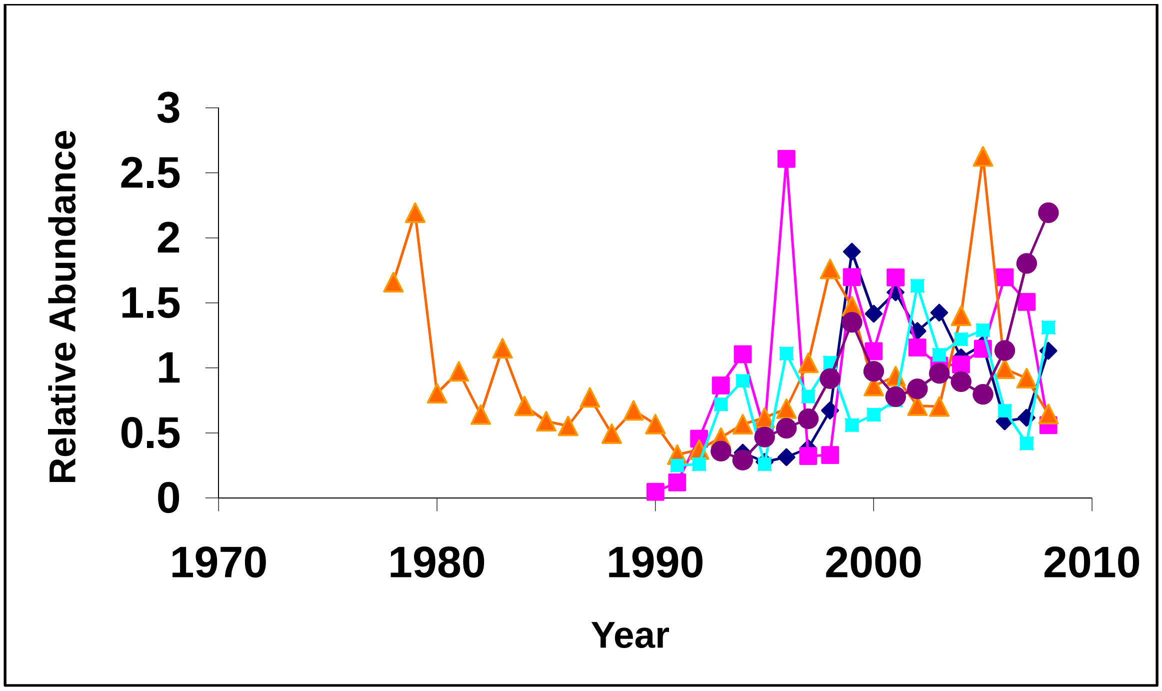



**Figure 5.14.** Red grouper CPUE time series recommended for use in stock assessment. Orange triangles represent recreational headboat, large pink squares represent MARMAP, small aqua squares represent MRFSS, purple circles represent commercial logbooks, and navy diamonds represent the RVC survey. All indices are standardized to a common time scale.

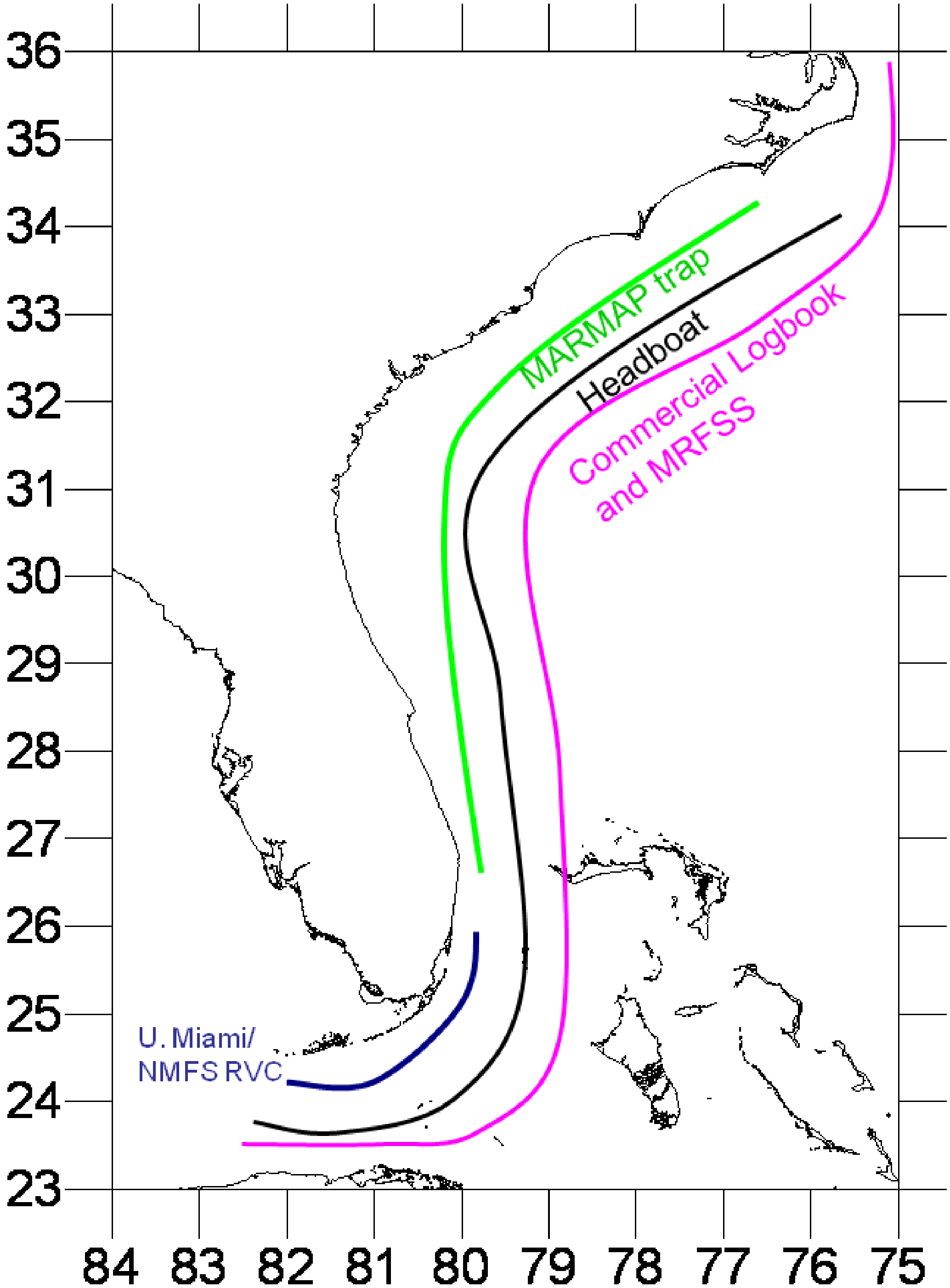
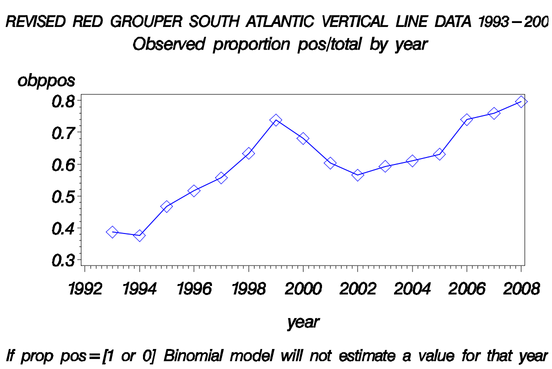



**Figure 5.15.** A map showing the spatial coverage of each survey recommended for use in index construction for SEDAR 19 (red grouper).

**Appendix 5.1.** Additional diagnostics for construction of the logbook vertical line index. Index fits differ from SEDAR19-DW-14 in that separate trip subsetting (i.e., method of Stephens and MacCall [2004]) was performed for areas north and south of Cape Canaveral, FL as suggested by the DW.

**Figure A.1**. Annual trend in **A.** the proportion of positive trips and **B.** nominal CPUE for the South Atlantic1993-2008 red grouper commercial vertical line gear revised model.

**A.**




**B.**

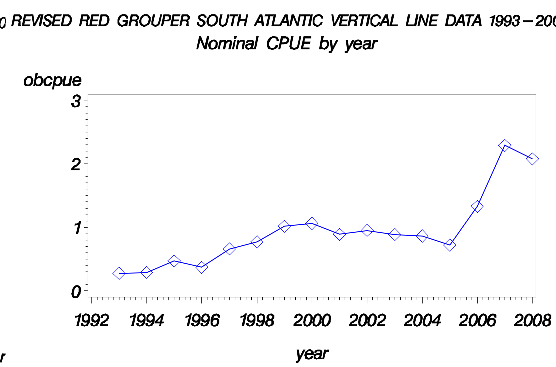
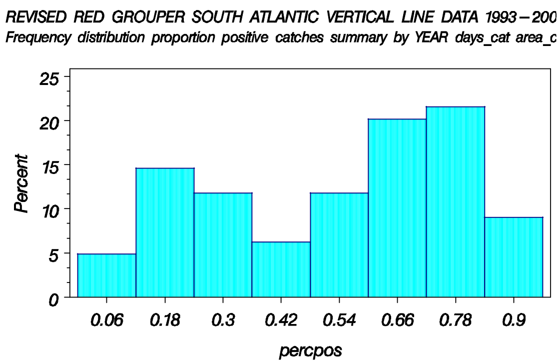
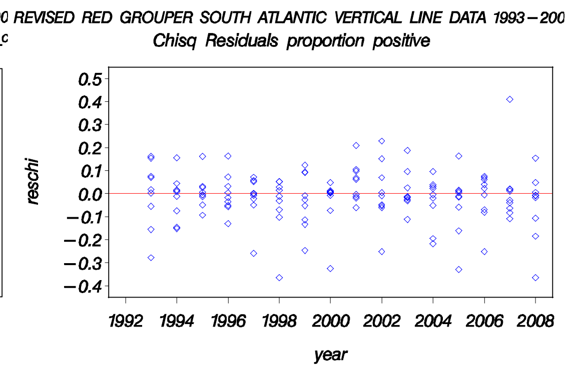


**Figure A.2**. Diagnostic plots for the binomial component of the South Atlantic 1993-2008 red grouper commercial vertical line gear revised model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by area; and **D**. the Chi-Square residuals by days at sea.

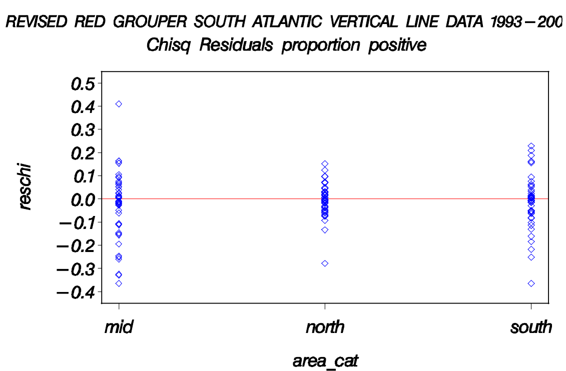
**A.**




**B.**




**C.**




**D.**

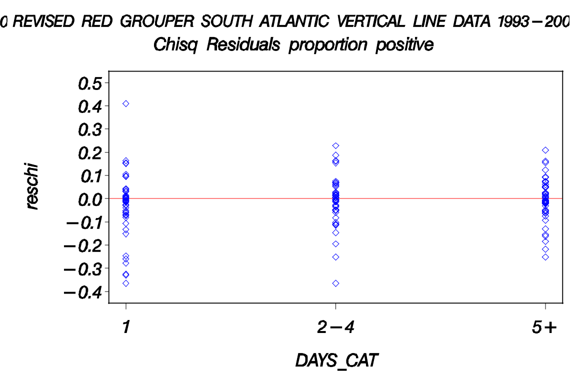


**Figure A.3.** Diagnostic plots for the lognormal component of the South Atlantic 1993-2008 red grouper commercial vertical line gear revised model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

**A.** **B.**

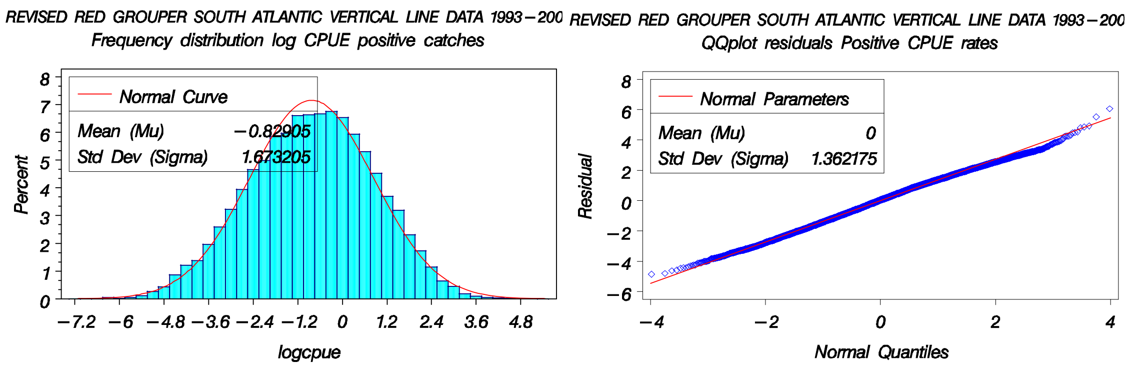
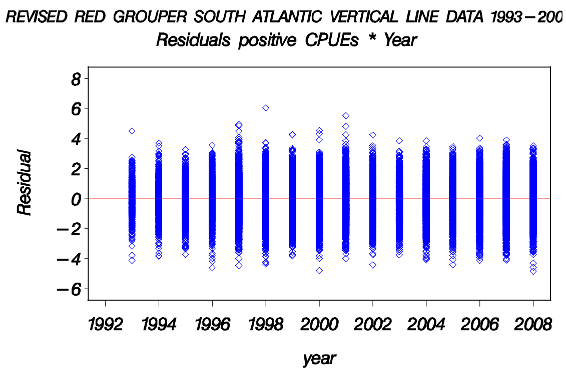
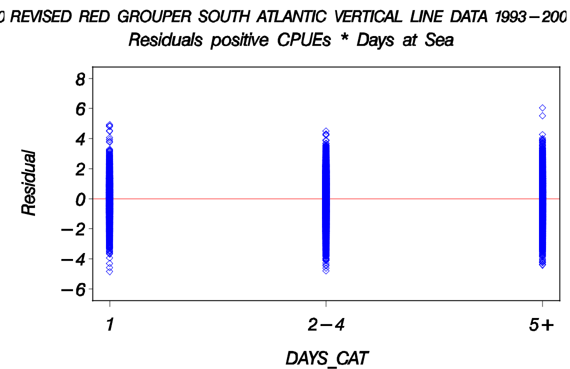


**Figure A.4**. Diagnostic plots for the lognormal component of the South Atlantic 1993-2008 red grouper commercial vertical line gear revised model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by days at sea; **C**. the Chi-Square residuals by area; and **D**. the Chi-Square residuals by number of crew

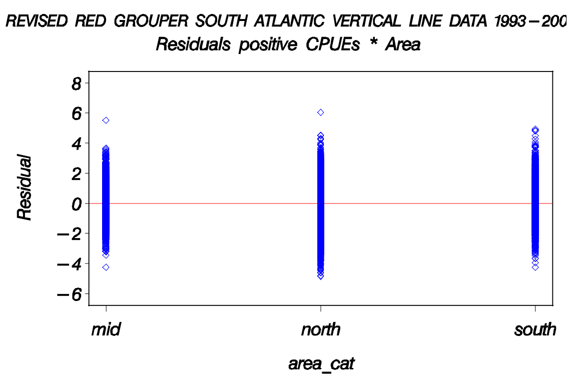
**A.**



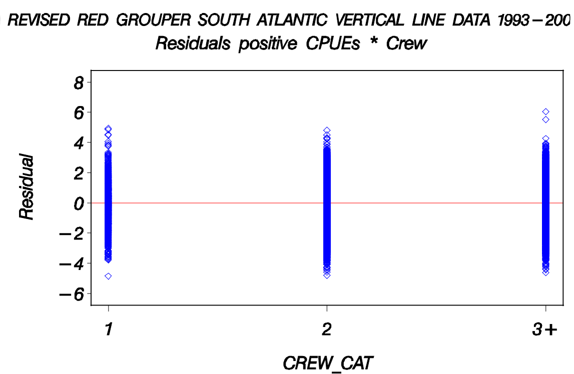

**B.**




**C.**




**D.**



## 6. RESEARCH RECOMMENDATIONS

### *6.1. LIFE HISTORY*

- The DW LHWG recognized the value of continuing the age workshops and exchange of otoliths in preparation of SEDAR data workshops. This will be especially important for species that have been recognized as relatively difficult to age.
- The DW LHWG also recognizes the value of similar workshops to discuss the interpretation of reproductive samples, and the possible exchange of histological sections between labs in preparation of SEDAR Data Workshops. This will be especially important for species that have been recognized as relatively difficult to stage.
- Since fecundity information is only available from the GOM and does not include estimates for ages less than 5 years, the DW LHW recommends initiating a study to estimate fecundity and further identify spawning locations for all age classes in both the GOM and Atlantic populations.
- The data presented at the DW suggest a possible disjunct distribution in the Atlantic stock (NC-FL). The DW LHW recommends a study to further investigate this by use of genetic, tagging, and other techniques.
- Improved collection and collection strategy for hard parts, in particular from the recreational sector.
- Increase of Fishery Independent data to include the entire area of red grouper distribution in the Atlantic.
- Virtually no information on the life history and distribution of juveniles, age one, and age two red grouper is available. The DW LHW recommends a study to gather information on these early stages.

*Procedural recommendation:*

- The DW recommends that the report of the natural mortality workshop organized by NMFS (Seattle, WA, August 2009) be a made available to the DW LHW before the next SEDAR as a guide in the discussions concerning natural mortality.

### *6.2. COMMERCIAL STATISTICS*

- Still need observer coverage for the snapper-grouper fishery
  - 5-10% allocated by strata within states
  - Get maximum information from fish
- Expand TIP sampling to better cover all statistical strata
  - Predominantly by H&L gear
  - In that sense, we have decent coverage for lengths
- Trade off with lengths versus ages, need for more ages (i.e., hard parts)
- Workshop to resolve historical commercial landings for a suite of snapper-grouper species
  - Monroe County (SA-GoM division)
  - Historical species identification (mis-identification and unclassified)

### *6.3. RECREATIONAL STATISTICS*

- Need more detailed information about where the fish are caught (depth, spatial, etc.)
- More detailed information on recreational discards, such as hooking location, depth fished, etc. that are likely to impact discard mortality and discard size/age.
- Additional information on sector (mode) differences.

### *6.4. INDICES OF ABUNDANCE*

1. Expand fishery independent sampling to provide indices of abundance. The DW Panel noted that this recommendation has been the first on the list for virtually all previous SEDAR's in the south Atlantic.
2. Examine variability in catchability
   - Environmental effects
   - Changes over time associated with increases in technology and potential changes in fishing practices. This is of particular importance when considering fishery dependent indices.
   - Potential density-dependent changes in catchability. This is of particular importance for schooling fishes.
3. Conduct studies to examine how the behavior of fisherman changes over time and how these changes relate to factors such as gas prices and economic trends

4. Consider optimal sample allocation for species of interest when designing surveys to increase sample sizes.
5. Examine possible temporal changes in species assemblages. Such changes could influence how the Stephens and MacCall method is applied when determining effective effort.
6. Continue to expand fishery dependent at-sea-observer surveys. Such surveys collects discard information, which would provide for a more accurate index of abundance.

# SEDAR

## Southeast Data, Assessment, and Review

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## SEDAR 19

# South Atlantic Red Grouper

## SECTION III: Assessment Workshop Report

**December 2009**

**NOTE: Modifications to the base model reported in this report were made during the Review Workshop held 25-29 January 2010. For complete results reflecting those changes, please see the Addendum of this Stock Assessment Report (Section VI).**

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 19 Assessment Workshop was held October 5 - 9, 2009 in Saint Petersburg, Florida.

### 1.1.2 Terms of Reference

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

2. Develop population assessment models that are compatible with available data and recommend which model and configuration is deemed most reliable or useful for providing advice. Document all input data, assumptions, and equations.

3. Provide estimates of stock population parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, etc); include appropriate and representative measures of precision for parameter estimates.

4. Characterize uncertainty in the assessment and estimated values, considering components such as input data, modeling approach, and model configuration. Provide appropriate measures of model performance, reliability, and 'goodness of fit'.

5. Provide yield-per-recruit, spawner-per-recruit, and stock-recruitment evaluations, including figures and tables of complete parameters.

6. Provide estimates for SFA criteria consistent with applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards. This may include: evaluating existing SFA benchmarks, estimating alternative SFA benchmarks; and recommending proxy values.
   A. In addition, for black grouper, the Gulf Council requests that the Panel specify OFL, and recommend a range of ABCs for review by its SSC.

7. Provide declarations of stock status relative to SFA benchmarks.

8. Perform a probabilistic analysis of proposed reference points and provide the probability of overfishing at various harvest or exploitation levels.

9. Project future stock conditions (biomass, abundance, 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 (OY),

B) If stock is overfishing
F=Fcurrent, F=Fmsy, F= Ftarget (OY)
C) If stock is neither overfished nor overfishing
F=Fcurrent, F=Fmsy, F=Ftarget (OY)

10. Evaluate the results of past management actions and, if appropriate, probable impacts of current management actions with emphasis on determining progress toward stated management goals.

11. Provide recommendations for future research and data collection (field and assessment); be as specific as practicable in describing sampling design and sampling intensity.

12. 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.

13. Complete the Assessment Workshop Report (Section III of the SEDAR Stock Assessment Report), prepare a first draft of the Summary Report, and develop a list of tasks to be completed following the workshop.

### 1.1.3. List of Participants

***Workshop Panel***

Anne Lange....SAFMC SSC
Bob Speath.... GMFMC AP
Chip Collier.... SAFMC SSC/NC DMF
Dennis O'Hern .... GMFMC AP
Frank Hester.... SFAECFS
Joe O'Hop....FWC FWRI
Kevin McCarthy.... NMFS/SEFSC
Kyle Shertzer .... NMFS/SEFSC
Luiz Barbieri .... SAFMC and GMFMC SSC/FWC FWRI
Paul Conn.... NMFS/SEFSC
Richard Fulford.... GMFMC/USM-GCRC
Rob Cheshire.... NMFS/SEFSC
Robert Muller....FWC FWRI
Sven Kupschus....CIE

***Council Representation***

Brian Cheuvront....SAFMC/NC DMF
George Geiger....SAFMC
Mark Robison.... SAFMC/ FL FWRI
Kay Williams ....GMFMC

***Observers***

Behzad Mahmoudi ........................................ FWC FWRI
Beverly Sauls ........................................ FWC FWRI
Bill Arnold ........................................ NOAA SERO
Bob Shipp ........................................ Univ. of Alabama
Jack McGovern ........................................ NOAA SERO
Joseph Munyandorero ........................................ FWC FWRI
Karen Burns ........................................ GMFMC Staff
Kenny Fex ........................................ SAFMC AP
Nick Framer ........................................ NOAA SERO
Nikhil Mehta ........................................ NOAA SERO
Rich Malinowski ........................................ NOAA SERO
Roy Crabtree ........................................ NOAA SERO
Rusty Hudson ........................................ DSF/SFAECFS
Steve Bortone ........................................ GMFMC Staff

***Staff***

Carrie Simmons ........................................ GMFMC Staff
Julie Neer ........................................ SEDAR
Rick DeVictor ........................................ SAFMC Staff
Tina O'Hern ........................................ GMFMC Staff
Tyree Davis ........................................ NMFS Miami

### 1.1.4. List of Data Workshop Working and Reference Papers

| **Documents Prepared for the Assessment Workshop** | | |
|---|---|---|
| SEDAR19-AW-01 | A hierarchical analysis of red grouper indices. | Paul Conn |
| SEDAR19-AW-02 | Red grouper: Regression and Chapman−Robson estimators of total mortality from catch curve data | Sustainable Fisheries Branch |
| SEDAR19-AW-03 | Additions and Updates to Red Grouper data since the SEDAR 19 Data Workshop | Sustainable Fisheries Branch |
| SEDAR19-AW-04 | Red Grouper: Predecisional Surplus–production Model Results | Sustainable Fisheries Branch |

| | | |
|---|---|---|
| SEDAR19-AW-05 | A non-equilibrium surplus production model of black grouper (*Mycteroperca bonaci*) in southeast United States waters | Robert G. Muller |
| SEDAR19-AW-06 | Catch curves from two periods in the black grouper fishery | Robert G. Muller |
| SEDAR19-AW-07 | A statistical catch-age model for red grouper: mathematical description, implementation details, and computer code. | Sustainable Fisheries Branch |
| SEDAR19-AW-08 | Assessment history of black grouper (*Mycteroperca bonaci*) in the southeast U. S. waters | Robert G. Muller |
| | | |
| **Reference Documents** | | |
| SEDAR19-RD29 | A Review for Estimating Natural Mortality in Fish Populations | Kate. I. Siegfried & Bruno Sansó |
| SEDAR19-RD30 | Bottom longline fishery bycatch of black grouper from observer data | Loraine Hale and John Carlson |
| SEDAR19-RD31 | Characterization of the shark bottom longline fishery: 2007 | Loraine Hale, Lisa D. Hollensead, and John Carlson |
| SEDAR19-RD32 | 2009 Gulf of Mexico Red Grouper Update Report | |

### 1.1.5. Notice of Addenda

## *1.2. PANEL RECOMMENDATIONS AND COMMENT*

### 1.2.1. Term of Reference 1

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

After the analytic team presented a summary of data inputs for the red grouper assessment, they reviewed proposed changes from DW recommendations and lead discussions on those changes.

A number of changes were presented and approved with no discussion, including: starting the model in 1976; conversion of commercial landings to whole pounds; pooling of ages at 16, creating a 16+ age group; smoothing the RVC (visual survey) length compositions (which were converted from fork length) and removing fish <16 cm; and using the ratio of MRFSS numbers and trips to generate estimates for general recreational numbers of trips (this was in order to use numbers of trips, not provided by the DW, as the effective sample size, rather than numbers of fish) for use in age compositions.

Additional changes were discussed by the panel and then approved. The analytic team had pooled the commercial hook and line (HL) and longline (LL) landings and length composition data, noting that the length compositions were similar to start with. A panel member asked if the fact that HLs fish in different (shallower) waters than LLs, would impact pooling of the length data. The analytic team responded that the size compositions seem similar in both data sets, and the panel agreed to use these pooled data.

The other commercial data (dive, trap, and other gears) were also pooled, and a question was raised about whether there were any changes in the proportion of sizes or gears over the time series, which would suggest that pooling may not be appropriate for these gears. Since there were no data to develop separate estimates for these gears, the panel agreed that pooling was justified and appropriate.

MRFSS landings and discard data were smoothed using a cubic smoothing spline. There was discussion as to whether the DW recommended using smoothed data. The DW had not discussed this topic, but the analysts applied the smoothing to adjust the very high 1984 MRFSS value. The Panel agreed to go forward with the smoothing, noting that if results looked questionable, this decision would be reevaluated.

HB discard data were truncated to 2005-2007, even though the DW had provided values for the full assessment time series. However, the data provided by the DW were extrapolated and the Panel agreed that it would be best to use only those years where sampling actually occurred, as input into the model. Discard estimates for years with size limits other than 2005-07 were estimated within the model. Samples were taken in 2008, but since a different sampling method was used, they were not comparable to the 2005-07 series, and were not used in the model.

Panelists also asked why the analysts decided to use 3 cm bins for length compositions instead of the 1 cm bins provided by the DW (grouping lengths from 15 cm to 118 cm, with a $117^{+}$ group). This was done to smooth the frequency distributions, especially for the smaller sample sizes. The Panel concurred with the revised length bins.

Following agreement on the input data and recommended revisions, a Panelist noted that the DW reported that no tagging data were available, and that red grouper don't move great distances. He then raised concern relative to assessing South Atlantic red grouper as a single stock or management unit, given an apparent substantial change in the fishery itself. In the past, the bulk of the fishery occurred off Florida, while in more recent years (2005-08) state trip ticket data show that the North Carolina fishery has increased greatly, while the Florida fishery had declined. It was pointed out that the red grouper are genetically a single stock in the South Atlantic, and the data workshop had recommended the assessment be conducted as a single unit. Also, while a 'two-or-more-area' model could be developed, it would involve a number of assumptions (e.g. mixing rates) where no data are available and the group would have to develop the model based on guesses for these parameters. The panel decided that, at this point, it would move forward with single fishery/stock model and document the two-unit discussion in the report. If it is later determined necessary, an assessment based on the separate fisheries can be pursued. In addition, even though the assessment is conducted without stock separation, managers could possibly manage the areas separately.

The DW panel provided commercial discards in pounds for use in the SS3 and surplus-production model. These values were calculated as the product of the estimated number of discards and the average weight of landed fish. The AW panel rejected these values and instead used the estimated weight of an age-2 fish to represent the size of commercially discarded fish since the discards were most likely 1-3 years old based on the 20-inch size limit.

### 1.2.2. Term of Reference 2

*Develop population assessment models that are compatible with available data and recommend which model and configuration is deemed most reliable or useful for providing advice. Document all input data, assumptions, and equations.*

The analytic team reviewed all inputs and data sources which were then approved by the panel for inclusion. Three models were described and sensitivities were run based on panel inputs and the final base model was selected.

The first model to be discussed was the Beaufort Assessment Model (BAM). Following the presentation, questions were raised regarding selectivity; the graphs presented suggested that we may have poor estimates of input parameters. Discussions followed regarding how it was determined to use flat-topped or dome-shaped selectivity curves for the various input data sets. Questions included: why was selectivity of the MARMAP chevron traps dome-shaped-indicating that this gear was catching smaller, but not larger, fish; and why were LL and HL runs set, a priori, with flat-top selectivity.

The analysts responded that they assumed fisherman would catch large fish if they can, they are fishing deeper and they get better price for larger fish, while trap size, from the fishery independent survey, could restrict larger fish from entering them. Also, the majority of MARMAP trips are in shallower water than the commercial LL would be fishing. It was also noted that the trap runs were not constrained, it was the model that selected the dome-shaped curve for traps, not the analysts. The group requested that the analysts conduct sensitivity runs, including: rerun the line gear model without a priori fixing the model to flat-top, to determine if the model would solve the run with a dome-shape; and rerun the trap data trying to constrain the model to a flat top solution.

The analysts presented the second, stock synthesis (SS) model, and described some of the data issues with the model. The analysts suggested that this model be run as a check of the primary assessment tool, which at this time is recommended to be the BAM.

The Surplus Production model using the combined index and DW-provided commercial discard estimates in weight was presented. Analysts also presented a run with a 2% annual increase in catchability. The model was run again with the revised commercial discard data with the combined and separate indices. Additional runs with the RVC index removed and with just the headboat index were also presented. The general aspects were described and the analysts indicated that it provided a reasonable fit overall, though the fit to the headboat index missed the first few years, showing that the stock decreased in early years, then increased over time.

During the initial presentation questions were raised about catchability, the assumption of a 2% annual increase over time, and why the population never seemed to reach $B_{msy}$. This was possibly due to a very heavy fishery in early years. A Panelist suggested that the runs show that if they let the model run unconstrained rather than an a priori combining of indices, we would get very different results. Combining of indices, based on a Bayesian approach, is described in WP AW3. It was noted that the approach did not account for selectivity, but assumed this was not an issue as long as indices were not from different segments of the population. There was further discussion regarding catchability and whether it is appropriate to use a 2% increase. Analysts noted that economic studies show a 0-4% range of improvements in catchability to be reasonable with 2% being a mid-point, and no less valid then 0, if no change were assumed. It was pointed out that it is reassuring that all the runs show we are near $B_{msy}$ and $F_{msy}$, so no matter which model is used, we are likely not going to get different results.

<u>Base Model</u>

The Panel discussed selection of the base model and what runs should ultimately be used to provide advice. The Panel agreed that the Beaufort Assessment Model (BAM) should be used- it is best suited to the available data sets and is best able to make the most use of those data. While the S-P model appears to work well, quality age data are available and in general, an age-structured model provides more information when age data are available for use. The SS3 model also appears to work, but it is complicated to understand and therefore to explain, with a number of switches to turn on or off, the impacts of which are not clear. Therefore, it is better to use the BAM, which is more fully understood and can be better interpreted and explained. The Panel concurred, and BAM will be the model used for the assessment.

Additional model runs- The Panel next discussed what additional model runs it would like to have completed. The analytic team indicated that they would run a subset of Monte-Carlo runs on the selected model configuration, during the meeting, but any major runs would have to wait until they returned to the lab.

It was decided that sensitivity runs will include:

M- base (0.14), low (0.1), and high (0.2). The DW had suggested a range to 0.3, which was felt to be extreme given the observed maximum age (26) and Z estimates from catch curve analysis, but it was included in the sensitivity runs for completeness, and because it might help provide break points.
Discard mortality rates- run sensitivities;
Measures of SSB- run with percent mature, with just males, and with just females; and
Retrospective analysis

A Panelist asked what we would be providing relative to benchmarks, and was told that we would provide MSY, $F_{msy}$, and $B_{msy}$. The Panelist asked how we could do so without having data that go back to the 1940s, addressing virgin biomass. The models will allow us to provide these estimates without going back to a virgin status, as long as we are comfortable with the M value and a number of assumptions we have included. Sensitivity runs will also address those assumptions.

The analytic team presented the results of the requested sensitivity runs. These showed that, except for the extreme M (0.3), the $F/F_{msy}$ and SSB/MSST plots for each M value (base, low, high) were similar in trends and scale. In addition, when comparing runs by sex, the $F/F_{msy}$ plots were very similar, and the SSB/MSST plots were somewhat similar, by sex. In addition, runs were made with 3 different terminal years (2005, 2006, and 2007). These runs showed that the model may over-estimate F and may under estimate SSB, in the terminal year. Panelists noted that, while the differences in the sensitivity runs may not be great, they likely are outside the confidence intervals from the base runs, and it is difficult to determine the retrospective pattern, it is clear the models are not accounting for all uncertainties. It may be worth looking further at selectivity runs. It was also noted that these runs used just the terminal F, and it was suggested that using a 3-year average may reduce the impact of any retrospective pattern in the Fs (there was less concern for the SSB results). After further discussion, the Panel decided that the model should be run with the existing terminal values, and using a 3-year geometric mean for F.

<u>M</u>- It was noted that the choice of M has a major impact on F and SSB, and the panel asked why 0.14 was chosen for the base run. This is the value recommended by the DW and the Panel decided that unless there was a strong reason to use another value, the DW recommendation should be followed. It is reassuring that the model responds as would be expected with increases or decreases in M, so there is no reason to alter the base M value.

### 1.2.3. Term of Reference 3

*Provide estimates of stock population parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, etc); include appropriate and representative measures of precision for parameter estimates.*

The analytic team completed runs based on panelist recommended inputs. New runs were presented of F, SSB, and recruitment, including CVs of 0.01, 0.05, and 0.1. Results were similar for each, except: F was higher in later years with CV=0.1; and SSB was lower in 2003-08 with CV=0.1.

Further discussion focused on how closely to match observed landings. Previous SEDAR review panels have recommended fitting landings precisely, but one advantage of statistical catch-age models is that they can accommodate error in observed landings. In the model, the degree of fit is controlled by CV, and a range of CVs (0.01−0.1) were examined by the AW panel. Since the model-run results were so similar, it was argued that it would be appropriate to allow the model to use higher, likely more realistic, CVs for the base runs. The Panel decided to have the base runs use 5% CVs, but to also make sensitivity runs to determine where the model convergence is lost. The best runs are those which include the most data sets and allow the model to choose which ones to use, up to the point of convergence. A Panelist pointed out that the SSC needs the best model with the best accounting for uncertainty, while the analyst noted that the SSC has the ability to account for uncertainty in other ways, and provide advice based on knowing that even if there is close model fit, other uncertainties were not accounted for by the model, or that with a poorer fit, those uncertainties were included.

Discussion resumed on the issue of selectivity, beginning with a summary of those obtained in the original model runs, followed by Panel decisions on which to use for subsequent runs for each gear/data set. For the commercial-other gear, the Panel concurred with using dome-shaped selectivity. For the HB and recreational fisheries, a dome-shaped selectivity was considered. However, it was noted that the fleets are focusing on other species, not just red grouper, and the Panel decided to use flat-top selection for both HB and recreational fisheries. They also asked that the model be run with the random walk option turned off so results could be compared to previous runs.

Discussions resumed on catchability after additional runs were completed, using a constant q for fishery independent data sets and four option (constant q, linear increasing q through 2003, density dependent run- with higher q at lower population size, and the random walk with SD set at 0.17). After reviewing the results, it was noted that there was not clear evidence supporting use of the random walk; or that density dependence was a factor, or that there was increasing catchability; suggesting that a constant q should be used. While it was believed that with the recent use of GPS, that catchability would continue to improve, the habitat for this species is just as easily located with depth sounders so the assumption of increasing q may not be valid. In addition, using a constant q would be consistent with how red grouper were modeled in the Gulf of Mexico. It was agreed, that since we do not have data that demonstrate a 'right' number, it is difficult to justify use of a time varying q, so q would be held constant. However, the analysts will make additional runs to ensure all options have been covered. It was also noted that the recommendation of the recent catchability workshop was that "time-variable q should be explored for each future assessment". In this case, it was tested and determined that constant q appears to be more appropriate. After additional test runs the analysts confirmed they were comfortable with a constant q.

The analysts presented a summary of Panel agreed model inputs and results of the subsequent base and sensitivity runs. These outputs included F estimates for the commercial-other, HB, and general recreational landings, and commercial line, HB and recreational discards. The $F/F_{msy}$ plots show an increase in relative F in recent years, while the population (SSB) shows an increase in older age groups in recent years.

Regarding the S-R plots, there were two years where recruitment was very low and the Panel questioned if they were from recent years or from an earlier period where the data were poor. Upon checking, it was determined that they were from 1990, and 1993, and do not reflect current, or recent status.

Results of the new stock synthesis model runs were presented and discussed. These runs appear to match outputs from the BAM runs during peak years, and seem improved over initial runs, although unconstrained, the steepness value went to the upper bound, suggesting there is no S-R relationship. Comparisons of the BAM and SS models were discussed, including similarity in patterns, but differences in scale due to the methods each model uses to weight inputs. It was noted that the BAM results may be more consistent with what we know happened, regarding changes in F in 1992 associated with management changes in that year.

The surplus production model results showed similar F patterns to the BAM and SS3 outputs. It was noted that running the model with separate indices, rather than a single combined index, resulted in tighter CVs. Adding the 2% increase in catchability also resulted in increased CV, though one Panelist indicated he did not believe that the model was capturing all the uncertainty in the data.

<u>Discard mortality rates</u> (.2- base; .1-low; .3-high) - The Panel discussed concerns about the appropriate level of discard mortality. Since this is a shallow water grouper, we expect discard mortality to be low, but it could be anywhere in the suggested range. It was noted that the greatest difference in F estimates from the 3-runs was when the fishery peaked, while the greatest difference in SSB was in the latest years. There was concern that the 0.2 base-value may be too high for this species, since on the water it seems that there is greater survival likelihood. However, delayed mortality would likely increase any on-the-water observations.
The group recommended that future research look at discard mortality.

<u>Additional comments on discard mortality included:</u>
- It would be desirable to consider capture depths when determining discard mortality.
- the GOM red grouper assessment used discard mortalities of 0.45 for LL, and 0.10 for recreational, since the majority are taken in shallow (~80') waters.
- the DW report cited an independent survey that reported up to 70% mortality with HLs, and recommended use of 20% with sensitivity runs at 10% and 30%.

The Panel requested input from a researcher who had conducted a MARFIN catch and release study on impacts of emboli on red grouper. She briefly noted that, in that study, red grouper generally survive capture at 30', and while swim bladders rupture, they are able to hold sufficient air after 2 days, and that after 1 month only a small scar is found where the rupture occurred. In addition, they tried venting and non-venting, and even when brought up from 60 M, some red grouper survived and were recaptured 1000 days later. However, they found variable survival, with H&L gear often having more problems, presumed to be related to the level of struggle a fish displays during capture. They found that the more a fish struggled, the more it demonstrated baritrauma. They also noted that baritrauma is more of a problem for red snapper than for red grouper.

A review of available papers also supports the base discard mortality value and the range, as recommended by the DW- the Panel determined that these values would be used in future runs.

<u>Additional selectivity runs:</u>
Analysts presented plots of the bootstrap runs, showing 200 iterations, bootstrapped only on the data, setting up new time series of landings and indices, with lognormal error, assuming a CV of 0.5. Of the 200 iterations, only one resulted in extreme values and this value will be removed in

future runs. From these runs, steepness appears to be fairly well estimated. The analyst also provided plots of probability functions for SSB, F, and $F_{msy}$, centered on the base-run values.

Discussions on this presentation included:
- we should be more concerned with the range of estimated values, rather than the central tendency for the bootstrap runs;
- comparison of the time series plots for F and SSB, show the greatest uncertainty in F during the times of highest Fs, while this was a period with very tight estimates of SSB. Some Panelists expected to see similar levels of uncertainty in both estimates; while others felt the results were as expected.
- when outputs/results are interpreted, it must be noted that landings were constrained in the model run. At this time, when F is low, it is not a problem, but in the future, if Fs are higher, it will be important.
- sensitivity runs were not made for initial Fs, which were set based on the average of the first 3-years. However, the analyst pointed out that nonequilibrium initial age structure was estimated and that there is information in the length/age composition data in early years, which may dampen any effects that changes in assumed Fs during that time period may produce.
- The Panel decided that the approach addressing uncertainties was useful and asked for a few additional items:
    - show sensitivity runs along with the base runs;
    - run sensitivities on M and discard mortality;
    - run the MRFSS data unsmoothed to evaluate impact of the very high early year (1984);

The analytic team also raised a question about the distribution of $F_{msy}$. When it is determined using the bootstrap runs, it may result in an asymmetric distribution, not a normal distribution. This is important because the SAFMC wants probabilistic outputs, and with asymmetric distributions it could be that the probabilistic $F_{msy}$ could be hit (overfishing would be declared) even though the point estimate has not be reached. The Panel discussed this issue and determined that the assessment should be reported based on what comes out of the model; why run the bootstrap model if the empirical distribution it produces is not going to be used. However, this panel and the SSC should make clear the potential outcome, and prepare the managers so they have options available should this situation arise. Management needs to change the way it looks at the outcomes, rather than change the model outcomes. The Panel recommends that the SSC discuss how uncertainties are derived and interpreted, and how they are presented to managers. For red grouper, it won't make much of a difference in terms of management, but for other stocks these results could be significant, so it should be addressed by the SSC for consistency across future assessments.

Following discussions Panelists were asked if there were any additional runs/configurations that the analysts should complete. It was asked if we needed to provide a rebuilding time frame, and the Chair noted that we are expected to provide a declaration of stock status, based on the preferred/best model, and that once that status is determined the rest of the needed outputs are automatic. If rebuilding is needed we would decide between a 10-year, or other appropriate time frame.

The analytic team also reported on another run of the SS3 model, intended to address Panel concerns about the estimates of steepness. The programmer of SS3 (Rick Methot) assisted in this endeavor, which produced a steepness of 0.89, and suggested that stock recovery was due to an increase in recruitment, not a decrease in F. This run of SS3 included landings data back to 1960 to obtain a full age cycle during an "initialization" period. The analytical team indicated that they would still like to explore further SS3 runs for the AW report.

<u>Additional sensitivity runs:</u>
The analyst reported that using the unsmoothed MRFSS data primarily affected the previous and following years' F values, not the entire series, and values were back to those of previous runs by the end of the time series. For SSB, not smoothing has much greater impact, estimating a much larger virgin recruitment so as time goes by it shows the stock in much worse condition. The unsmoothed data suggests a tremendous increase in F in 1984, with no evidence to suggest that this is realistic. Therefore, it was appropriate to smooth the MRFSS data.

Runs using the geometric mean of Fs in the last 3 years, rather than terminal F from each of the years (2005-2007), provided more stable results, and the Panel agreed that this should be done in future runs.

For future bootstrap and Monte Carlo model runs, the panel was asked which distribution should be used for selecting, M- log normal, triangle, uniform distributions, or any other that the Panel felt was appropriate. After further discussion, the Panel recommended using a normal distribution with the mean set at the DW recommended M=0.14, with SD set to achieve the lower 95% C.I at 0.1, and truncating the normal distribution to provide values between 0.1 and 0.2.

### 1.2.4. Term of Reference 4

*Characterize uncertainty in the assessment and estimated values, considering components such as input data, modeling approach, and model configuration. Provide appropriate measures of model performance, reliability, and 'goodness of fit'.*

Throughout the discussions of each of the models, the issue of uncertainty was raised by the Panel, and those comments are included in summaries of TOR sections, where they occurred. There were also specific discussions of uncertainty and MSY, as follows: Through time, the BAM model seems to be reasonable, even though there is less confidence in recruitment estimates from the recent years. Concerns about the steepness value were discussed further-should a value be fixed, or should the model be allowed to estimate steepness? The model-calculated values were high, implying that recruitment can be high at low stock sizes, but these high values appeared to be consistently estimated. It was noted that the two-way trip in biomass should provide information to estimate steepness. Also, if there were no S-R relationship, why not? Is it habitat restricted, or is there reproductive contribution from other stocks? There is likely some mixing with the GOM population, which is much larger than in the South Atlantic, but the degree of this mixing is not known. After further discussion, the Panel decided that it was appropriate to use the MSY estimates provided by the model, but that the report should include the discussion that MSY estimates are conditional n the estimated S-R relationship. It was further agreed that the status of the stock be determined by what comes out of this work, realizing that changes could occur based on future recommendations of the reviewers.

### 1.2.5. Term of Reference 5

*Provide yield-per-recruit, spawner-per-recruit, and stock-recruitment evaluations, including figures and tables of complete parameters.*

Throughout the Panel deliberations, the analytic team presented various preliminary model outputs. Final outputs will be provided by the analysts in the assessment report, once the final model runs have been completed.

### 1.2.6. Term of Reference 6

*Provide estimates for SFA criteria consistent with applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management programs, and National Standards. This may include: evaluating existing SFA benchmarks, estimating alternative SFA benchmarks; and recommending proxy values.*

The Panel discussed sensitivity runs and benchmarks that would be provided by the final model runs. Benchmarks will include MSY, $F_{msy}$, and $B_{msy}$. A panel member asked how such benchmarks could be derived without the ability to go back to the virgin biomass, such as existed in the 1940's. The analytic team responded that it is not necessary to go back to virgin biomass to estimate benchmarks.

The analytic team will provide benchmarks based on panel discussions/recommendations.

### 1.2.7. Term of Reference 7

*Provide declarations of stock status relative to SFA benchmarks.*

The Panel discussed declaration of stock status, assuming final model runs provided results similar to those found during the AW, and whether it was necessary to recommend a rebuilding time frame. If the stock is declared to be overfished, a rebuilding time frame must be provided. It was assumed that the time frame would be based on SSB reaching $SSB_{msy}$ with probability of 0.5. The declaration of stock status should be based on the 'preferred/best' model. The Panel noted that once stock status is confirmed the rest is automatic; the rebuilding time frame would be one generation time plus the time to rebuild under F=0.

The Panel noted that while the stock may not be in the best condition, it has been improving over time and is near where it should be, and that given the management measures already scheduled for implementation, additional measures may not be necessary. It is therefore important to note the expected impacts of the measures already in place, and suggest that the SSC also make comments on this issue.

The analytic team will include stock status declarations relative to SFA benchmarks after final model runs are completed, as part of the assessment report.

### 1.2.8. Term of Reference 8

*Perform a probabilistic analysis of proposed reference points and provide the probability of overfishing at various harvest or exploitation levels.*

The Panel discussed the need for performing probabilistic analyses if we are doing rebuilding projections; suggesting that those projections would meet the needs for the probabilistic analyses of proposed reference points (i.e., no P-star is required). The question would be what is the probability of recovering the stock? If we were not going into a rebuilding plan, P-star would take place of the rebuilding projections. The Panel concurred that the rebuilding projections which the analytic team will run meet the needs for this TOR.

### 1.2.9. Term of Reference 9

*Project future stock conditions (biomass, abundance, and exploitation) and develop rebuilding schedules if warranted; include estimated generation time.*

The analyst asked the Panel for input on what assumptions for fishing rate (F) should be used in the projections, if the Panel felt projections should be provided in the final assessment. There was considerable discussion as to whether it was appropriate to provide projections at this time, given the number of regulatory changes that have taken place since the final year of input data (2008) and that will occur before management would be able to incorporated assessment results into future measures (2011). The Panel suggested making projections based on the current knowledge, with the intent to rerun the models once the impacts of recent measures are better understood. In addition, the report should include comment on the known new measures and the expected effects of those measures. Concern also was raised to the Panel by a member of the public, regarding the potential impact of the pending end to recreational sales, in 2010. It was suggested that some fish had been double counted- by MRFSS and as part of the commercial fishery.

After Panel discussions, the analytic team suggested, and the Panel concurred with, the following list of projections, which will be run by the analytic team after the AW concludes:

F=0, F=current- 2009, 2010

$F_{current}$

1) $F_{current}$ 2009, 2010
2) $F_{current}$ in 2009, 75% $F_{current}$ 2010
3) $F_{current}$ in 2009, 50% $F_{current}$ 2010
4) $F_{current}$ in 2009, 25% $F_{current}$ 2010

$F_{msy}$

65% $F_{msy}$
75% $F_{msy}$
85% $F_{msy}$
100% $F_{msy}$

$F_{rebuild}$

1) $F_{current}$ 2009, 2010
2) $F_{current}$ in 2009, 75% $F_{current}$ 2010
3) $F_{current}$ in 2009, 50% $F_{current}$ 2010
4) $F_{current}$ in 2009, 25% $F_{current}$ 2010.

## 2. DATA REVIEW AND UPDATE

Processing of data for the assessment is described in the SEDAR 19 Red Grouper Data Workshop Report. This section describes additional processing that occurred since the DW to format the data for use in assessment models. The data used as input to the model are provided in the Microsoft Excel workbook, RG_Input.xlsx available from the SAFMC website. The BAM model input file is provided in SEDAR–19–RW1.

### *2.1. POOLING OF GEARS*

Previous SEDAR assessments have routinely combined gears primarily in the commercial sector to overcome data limitations in the length or age compositions. We evaluated the feasibility of combining the commercial handline and longline gears by comparing the length compositions pooled over the years prior to and after the 1992 size limit of 20 inches (Fig. 1 panels A and B). The previously implemented 12 inch size limit did not appear to have an effect on the length compositions. Each year's contribution to the multi–year length composition was weighted by annual sample size. Based on this analysis, commercial handline and longline gears were combined to overcome gaps in the composition data. We compared the descending portion of the length composition of MARMAP trap (predominantly 1992–2008)to commercial trap (predominantly 1986–1991) as one possible method of supporting the limited commercial trap composition data. Both series were truncated at the peak of the MARMAP survey (49 cm) and re–normalized to sum to 1. (Fig. 1 panel C).

## *2.2. LANDINGS AND DISCARDS*

### 2.2.1. Landings

Commercial fisheries were reduced to two gears: lines (commercial handlines and longlines) and miscellaneous (traps, pots, diving, and miscellaneous). The DW provided commercial landings in gutted weight, which were converted to whole weight using the weight–weight conversion provided by the life–history group. Landings for the recreational data series were input as numbers of fish. The 1973–1975 headboat data, which did not include Southern Florida were omitted as input The commercial landings were taken back to 1976 even though the commercial working group provided data back to 1950. The decision to only take the model back to 1976 was based on the availability of composition data. Sufficient information was not available to get landings back to a virgin stock. Therefore there was no value in modeling landings prior to the first available composition data.

### 2.2.2. Discards

The BAM relied on the discards in number provided by the DW. Headboat discards were sampled in 2005—2008, but 2008 was excluded because of a change in the sampling protocol. There was sufficient headboat discard data from 2005–2007. For headboat and commercial sectors, discards were believed to have occurred outside the years of data. In those years, the BAM applied an average fishing rate to predict discards in numbers, rather than fitting to ratio–generated estimates.

The SS3 data input structure requires consistent units between landings and discards while the surplus–production requires all removals estimated in weight. Due to these requirements, both the surplus–production model and the Stock Synthesis models required the commercial discards to be in weight as model input. The commercial discard estimates in weight were rejected at the SEDAR 19 AW due to an error in the estimated average weight of a discarded fish. The mean weight used to calculate discards in weight (See Red Grouper Final DW Report, Table 3.7) was that of an average landed fish. The AW developed the commercial discard series from 1992–2008 as the product of the discard in numbers and the estimated weight of a two year old red grouper. This was based on the assumption that with a 20–inch size limit most discarded fish would be ages 1–3. This simple method of estimation introduces uncertainty in the model results but reflects the limited understanding of the size of commercial discards. A more thorough description of the conversion of discards in numbers to weight for other gears as used in the surplus–production model is given in Section 3.3.

### 2.2.3. Smoothing of MRFSS

Large fluctuations that are biologically implausible were observed in the landings and discard data provided by MRFSS. Large spikes were suspected to reflect sampling error, and thus both the landings time series and discard time series were smoothed using a cubic smoothing spline (smooth.spline function in R with smoothing parameter set to 0) weighted by the inverse of the annual CVs (Figure 2).

## *2.3. AGE COMPOSITIONS*

Age compositions were pooled at age 16. This was only relevant for the general recreational and commercial handline ages which extended to 21 and 23 years respectively with very low values.

### 2.3.1. General recreational sample size – trips

The appropriate data fields to determine the number of trips were unavailable for the general recreational age compositions. For use in the assessment, the annual number of trips was assumed to be the ratio from MRFSS length comps of total trips (2001–2008) to total fish (2001–2008) applied to annual number of "general recreational" fish aged.

### 2.3.2. General recreational – Examination of potential bias in selecting fish to age

The age compositions for other sectors were adjusted by the DW for potential bias in selecting fish to age by weighting the age compositions by the length compositions using the methods of Chih (2009). It is assumed that the general recreational age compositions follow the MRFSS sampling scheme and adjustments to the age compositions are not necessary. We plotted the length composition of the general recreational aged fish against the corresponding MRFSS length composition to evaluate this potential bias (Figure 3). There does not seem to be a problem with bias in selecting fish to age.

## *2.4. LENGTH COMPOSITION*

The 1–cm bins for length compositions developed during the SEDAR 19 DW were pooled to 3–cm bins for all gears. The commercial handline and longline gear length compositions were pooled annually by summing the sample–size weighted proportion at size for each 3–cm length bin for each gear. The combined commercial handline and longline compositions were then rescaled to sum to 1 annually. The comparison of 1–cm bins and 3–cm bins for the headboat (Figure 4), MRFSS (Figure 5), Commercial lines (Figure 6), Commercial pots and traps (Figure 7), and MARMAP (Figure 8) generally shows a smoother fit without losing the information. The 1–cm plots for all gears were scaled by the ratio of number of 1–cm bins to the number of 3–cm bins (3.029). The annual sample size for the combined commercial handline and longline is the sum of the two sample sizes. The commercial diving and other length compositions had inadequate sampling to be used as model input.

### 2.4.1. RVC length composition

The RVC survey length data were developed in fork length at the SEDAR 19 DW. The raw data were unavailable to make conversions to total length. Without raw data, one possible approach to conversion is simply to convert the bin labels in fork length to total length and then assign the 1–cm bins to the 3–cm bins. However, this causes artificial noise because sometimes the number of bins pooled after rounding is either 2 or 4 instead of 3 which causes artificial noise in the series. In addition the data set already contains considerable lumping of lengths at the 5–cm intervals, especially for larger fish. To smooth the RVC length compositions, we chose to model a distribution of raw length data by generating the population size at each annual bin as a normal distribution with a mean of the individual bin label in total length and with a standard deviation equivalent to a 5–cm spread (sd=5/2.575 where 2.575 is the z score that gives a 99% CI). Figure 9 shows the smoothed RVC length composition (solid line) and the version created by just converting the bin labels to total length and assigning to the 3–cm bin structure (dashed line). The length compositions are truncated at 15 cm TL to remove fish expected to be age 0 (see indices section below).

## *2.5. INDICES*

### 2.5.1. RVC index–remove age 0 fish

The RVC index provided by the DW included age–0 fish which were not included in the Beaufort Assessment Model. The index was recomputed with only the fish greater than 15cm TL, the size used to remove fish likely to be age 0 (Figure 10). The recomputed index is almost identical to the index computed by the DW with the exception of 1999 which was a year with many smaller fish observed (Figure 11).

## *2.6. LIFE HISTORY*

Generation time is not typically computed at the data workshop but may be required for stock projection. Generation time (G) was estimated from Eq. 3.4 in Gotelli (1998, p. 57).

$$G = {\sum l_x b_x x}\Big/{\sum l_x b_x}$$

where summation was over ages x=1 through 100 (by which age cumulative survival is essentially zero), *lx* is the number of fish at age starting with 1 fish at age 1 and decrementing based on natural mortality only, and *bx* is per capita birth rate at age. Because biomass is used as a proxy for reproduction in our model, we substitute the product of [*PfxMfx*+(1-*Pfx*)*Mmx*]*wx* for *bx* in this equation, where *Pfx* is the proportion female at age, *Mfx* is the proportion of females mature at age, *Mmx* is the proportion of males mature at age, and *wx* is expected weight at age. This weighted average of age for mature biomass yields an estimated generation time of 14 years (rounded up from 13.9 yrs.).

## *2.7. ASSESSMENT WORKSHOP DISCUSSION TOPICS*

Several points were raised about the data modifications for use as model input and the data in general. See section 1.2.1 general discussion of the management unit which did not warrant changes to the model input data for SEDAR 19.

• The decision to pool the age composition at 16 years and greater and the length compositions at 95 cm and greater were questioned since the growth curve gives a 16 year old fish a predicted length of about 83 cm. The panelists evaluated the length compositions and determined that there were very few fish in the length compositions greater than 80cm and that this pooling should not cause problems within the model.
• Pooling of the commercial longline and handline data were re–examined. Panelists viewed the length composition data and concluded that there was no strong evidence of differences in the size of fish caught between the two gears.
• The decision to pool the commercial trap, commercial diving, and commercial other gears was discussed. The decision was upheld, as panelists noted the limited amount of age and length information for these gears and the expectation that the primary gears, trap and diving, would have a similar dome–shaped selectivity.
• Smoothing of the MRFSS landings and discard series was discussed in more detail. Panelists were interested if the recreation group at the DW discussed the single large value in 1984 was plausible given the much lower values in 1983 and 1985. One panelist suggested it may not be due to a problem with effort estimate on which landings are expanded if there is not a similar peak in the discards. Analysts examined the discard estimates and there was a peak in 1984 which was not as large relative to surrounding years. Other evidence that the 1984 MRFSS landings were unrealistic was that no other recreational or commercial gears showed this drastic increase in landings for a single year. One panelist considered smoothing the MRFSS data an improvement given the known issues with MRFSS. A decision was made to examine results for a high residual in 1984 MRFSS landings. The AW did examine a sensitivity run without smoothed MRFSS estimates, but decided the estimates were implausible and thus such a run did not merit further consideration

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## *2.8. REFERENCES*

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

Chih, C. 2009. Evaluation of the sampling efficiency of three otolith sampling methods for king mackerel.

## *2.9. FIGURES*

*Figure 1. Red Grouper in Atlantic: Comparison of commercial length composition prior to (panel A) and after (panel B) the 1992 size limit (20 inches). Panel C shows the comparison between the commercial trap (1986–1991) and MARMAP trap (1992–2008). These time periods represent the predominant time periods the data were collected. Both series were truncated to the right of the peak in the MARMAP length composition and normalized to sum to 1, because the primary interest was in the descending limb.*

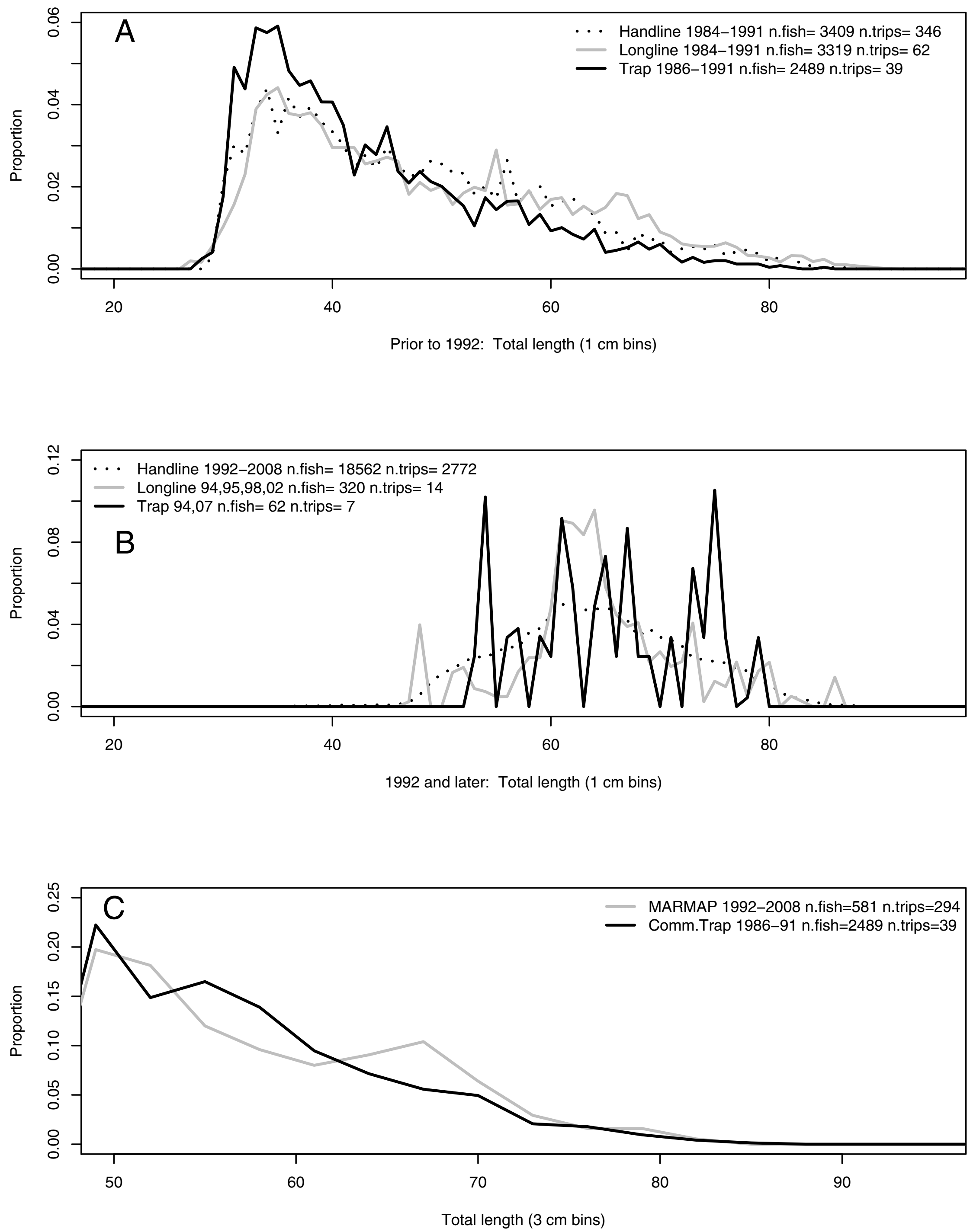


*Figure 2. Red Grouper in Atlantic: Smoothing of MRFSS Landings and Discards.*

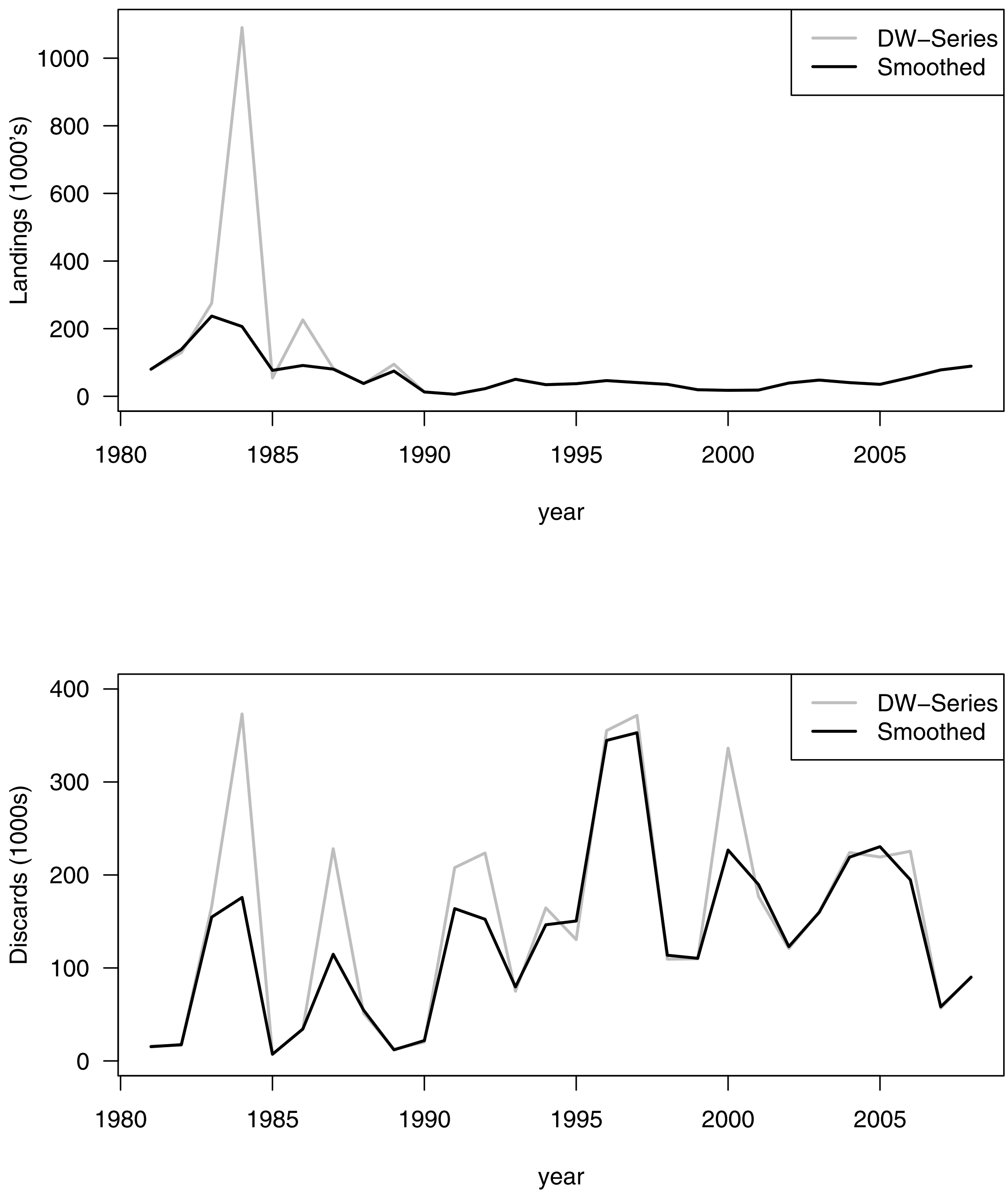


*Figure 3. Red Grouper in Atlantic: Comparison of the length compositions of aged general recreational samples and MRFSS length compositions.*

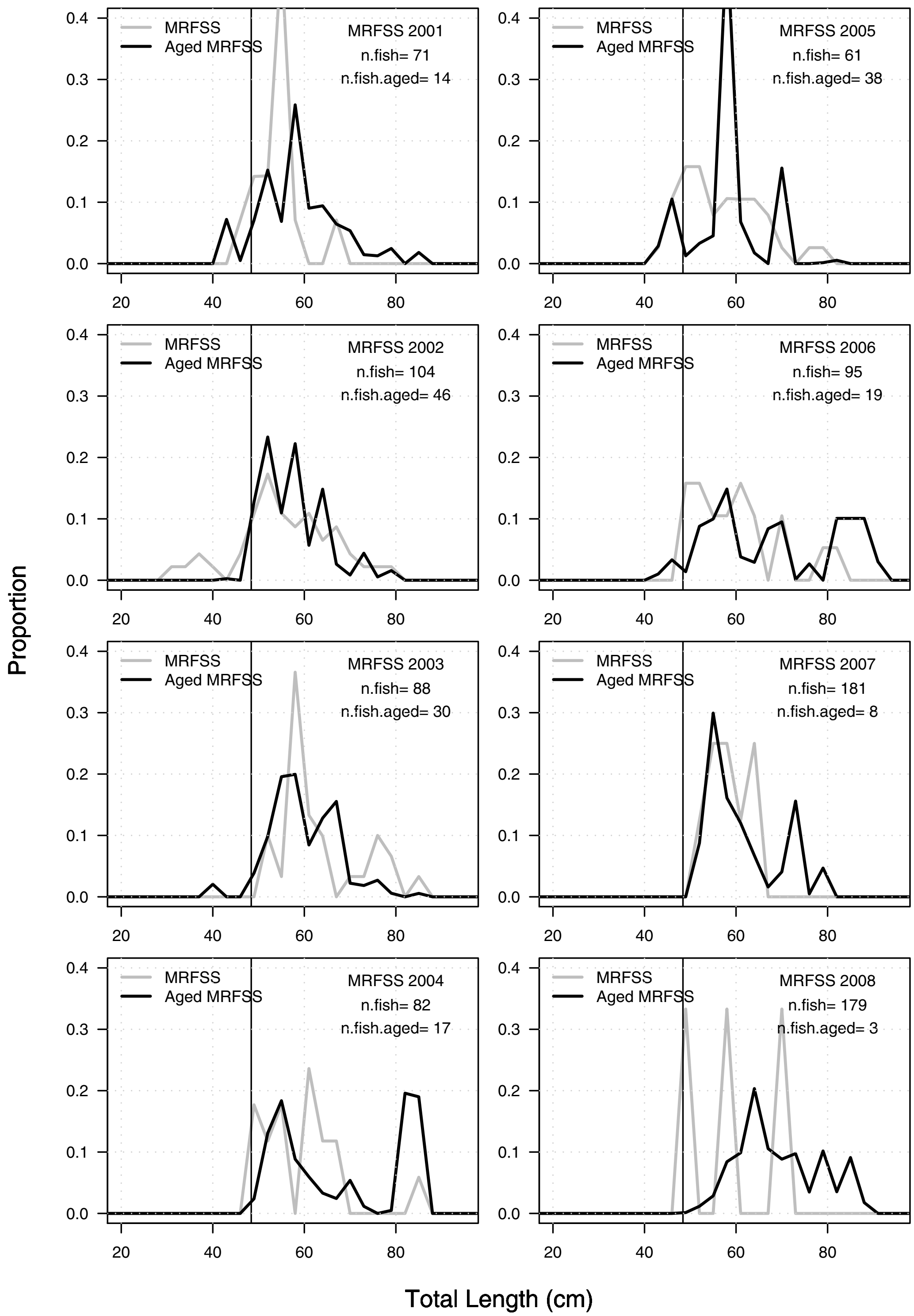


*Figure 4. Red Grouper in Atlantic: Annual headboat length compositions plotted as the 1-cm DW bins and the 3-cm model input. The "y" after the year label indicates inclusion as model input. Years with "n" after the year will be dropped as input because of low sample sizes or other sampling issues. Vertical lines represent federal size limits.*

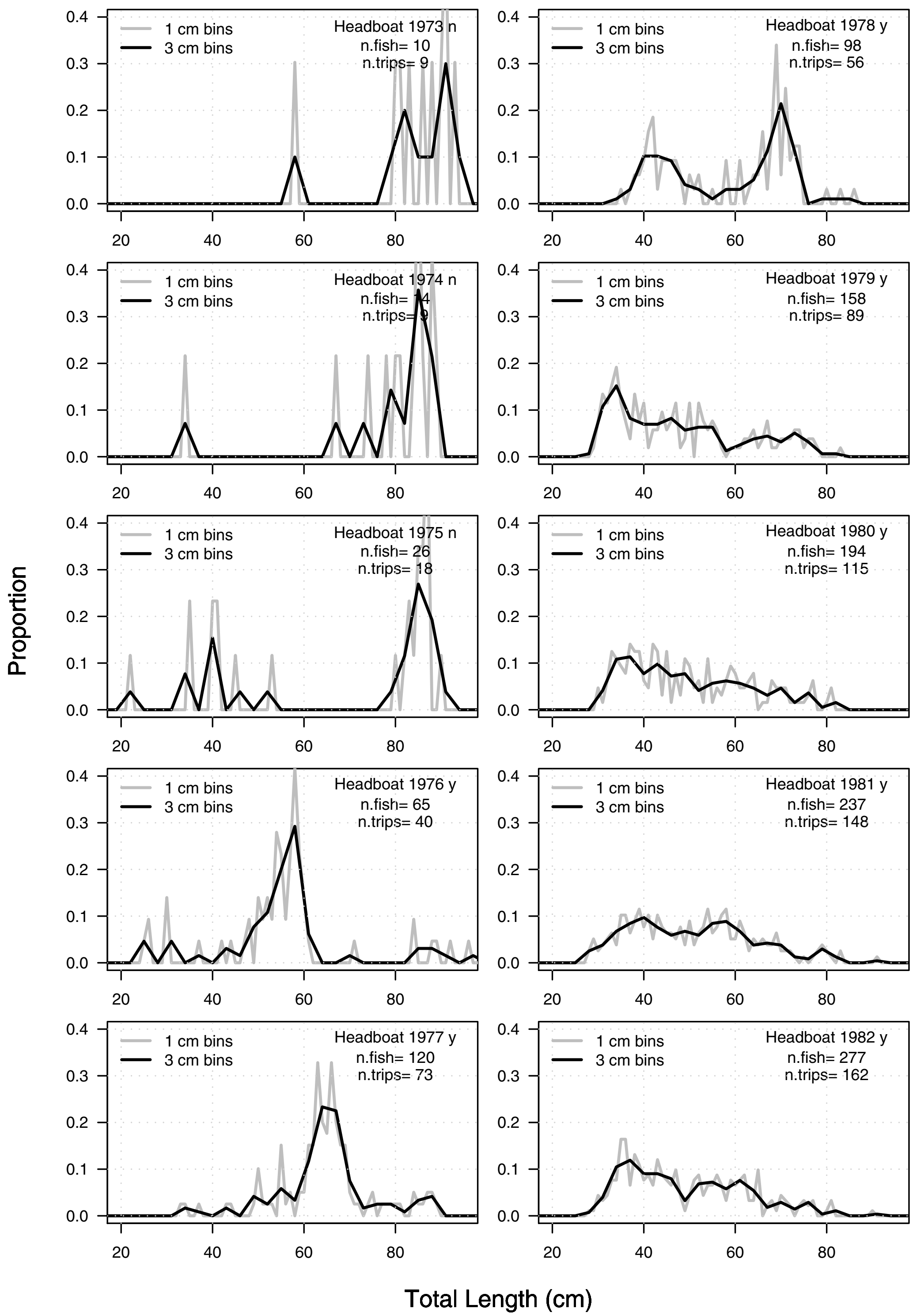


*Figure 4. Continued.*

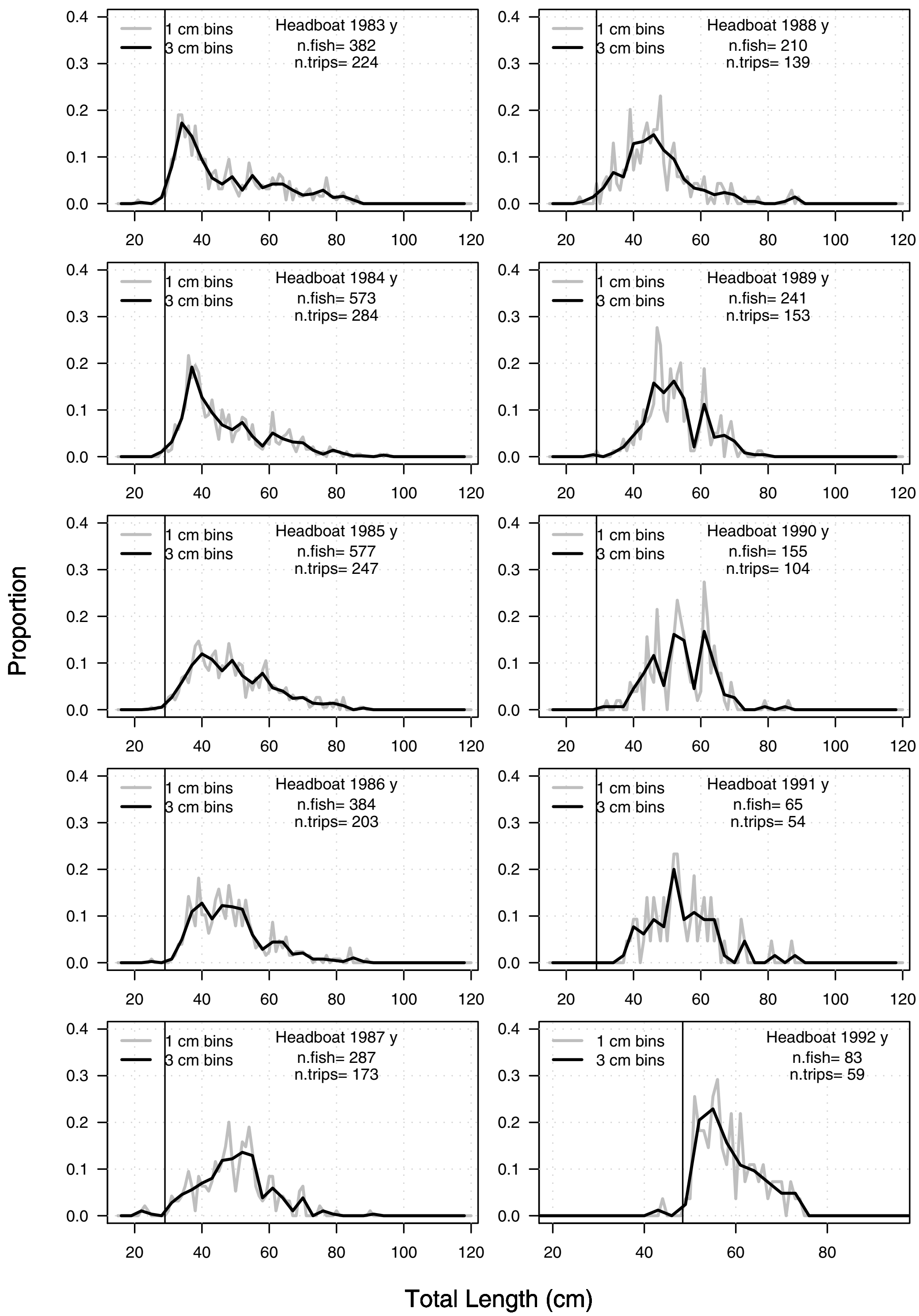


*Figure 4. Continued.*

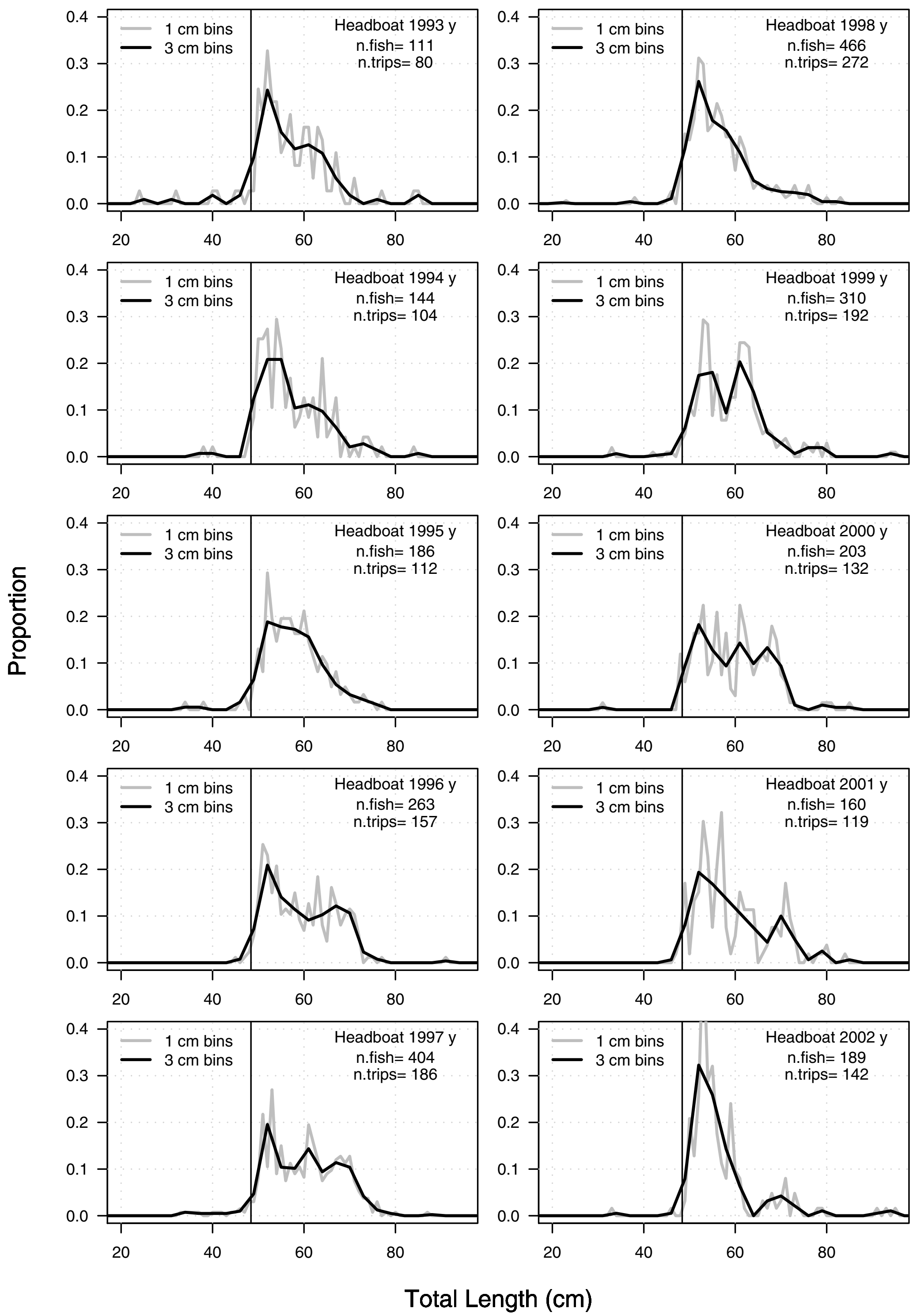


*Figure 4. Continued.*

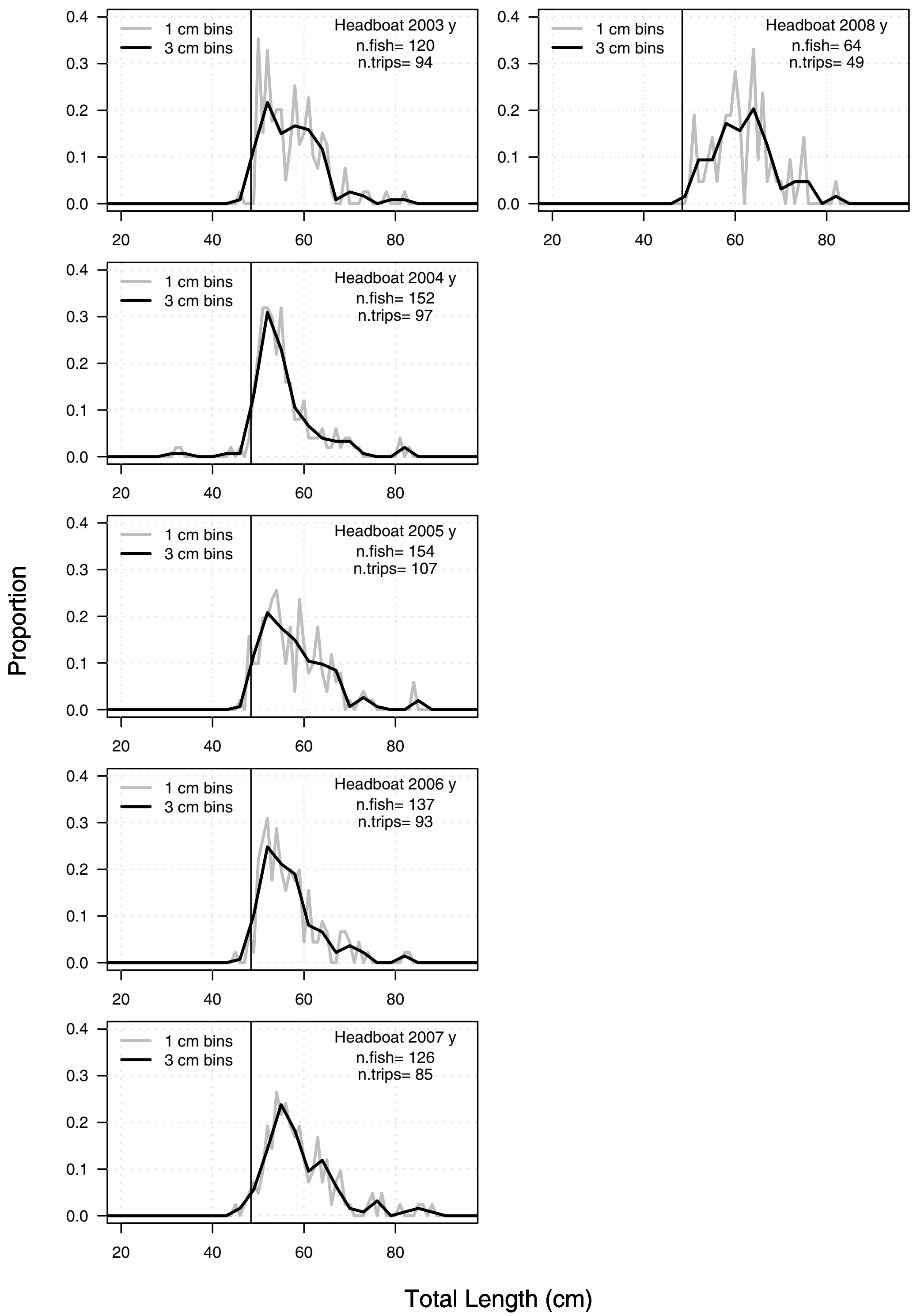


*Figure 5. Red Grouper in Atlantic: Annual MRFSS length compositions plotted as the 1-cm DW bins and the 3-cm model input. The "y" after the year label indicates inclusion as model input. Years with "n" after the year will be dropped as input because of low sample sizes or other sampling issues. Vertical lines represent federal size limits.*

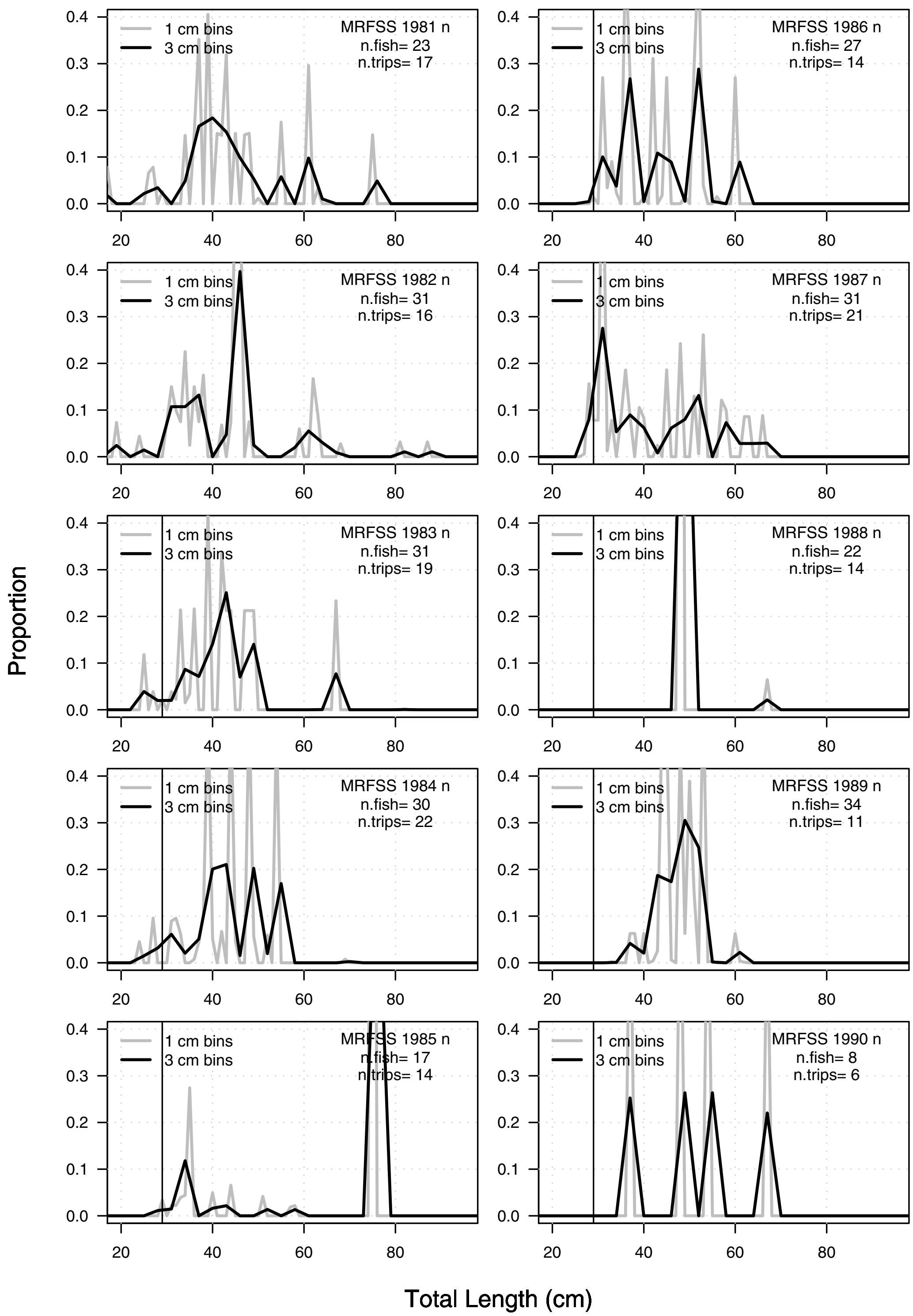


*Figure 5. Continued.*

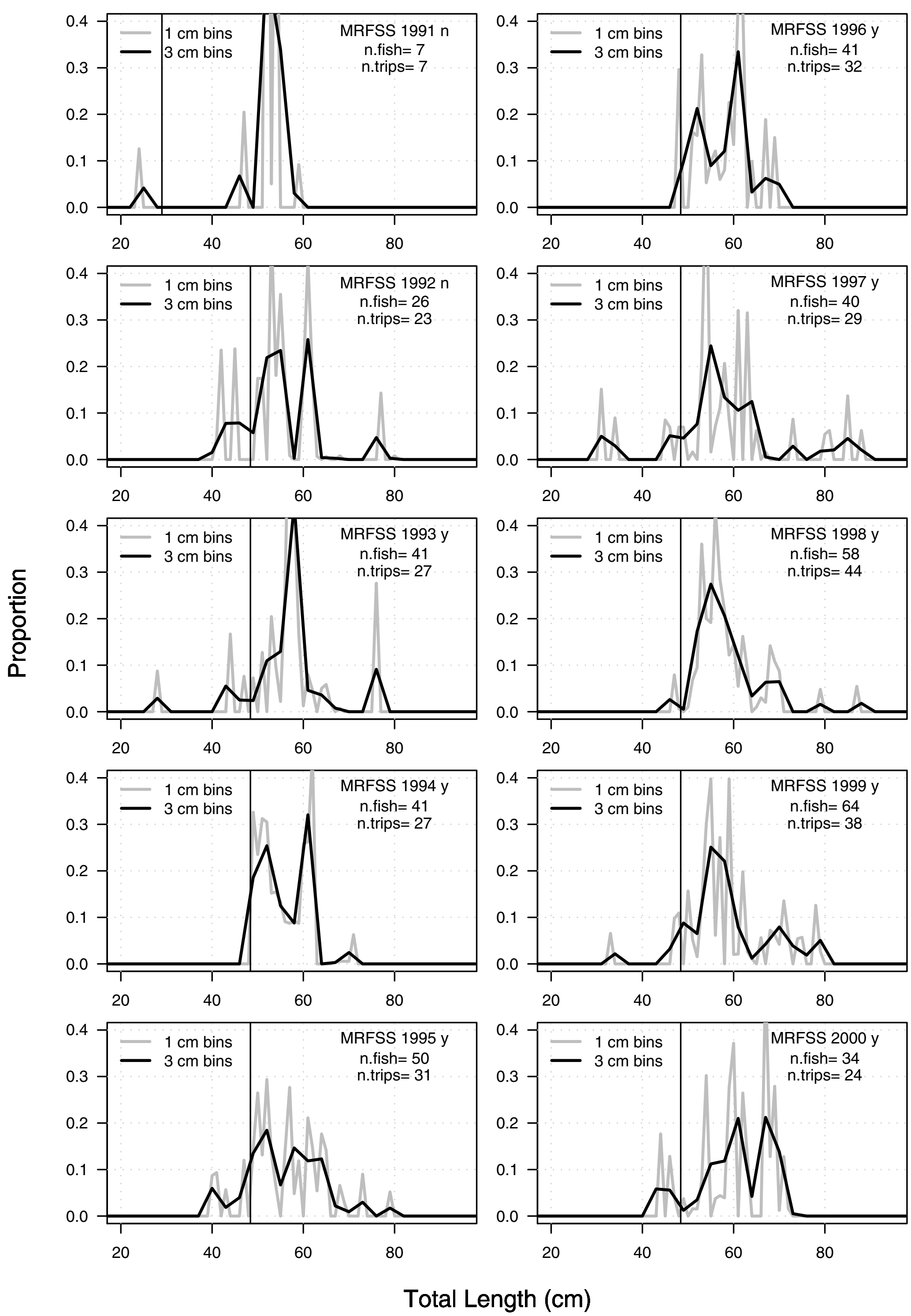


*Figure 5. Continued.*

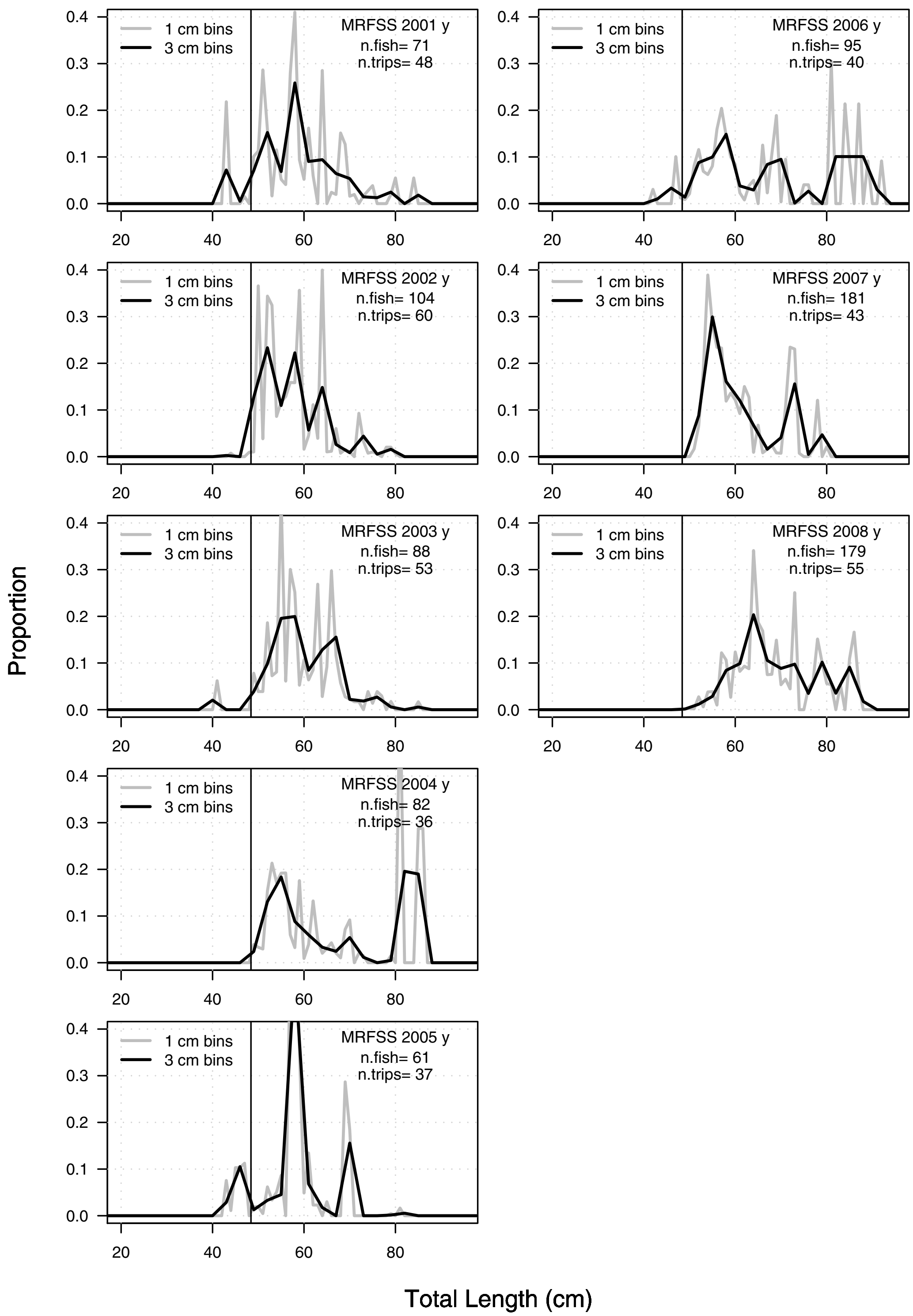


*Figure 6. Red Grouper in Atlantic: Annual commercial handline and longline length compositions plotted as the 1-cm DW bins for longline and handline and the 3-cm combined model input composition. The "y" after the year label indicates inclusion as model input. Years with "n" after the year will be dropped as input because of low sample sizes or other sampling issues. Vertical lines represent federal size limits.*

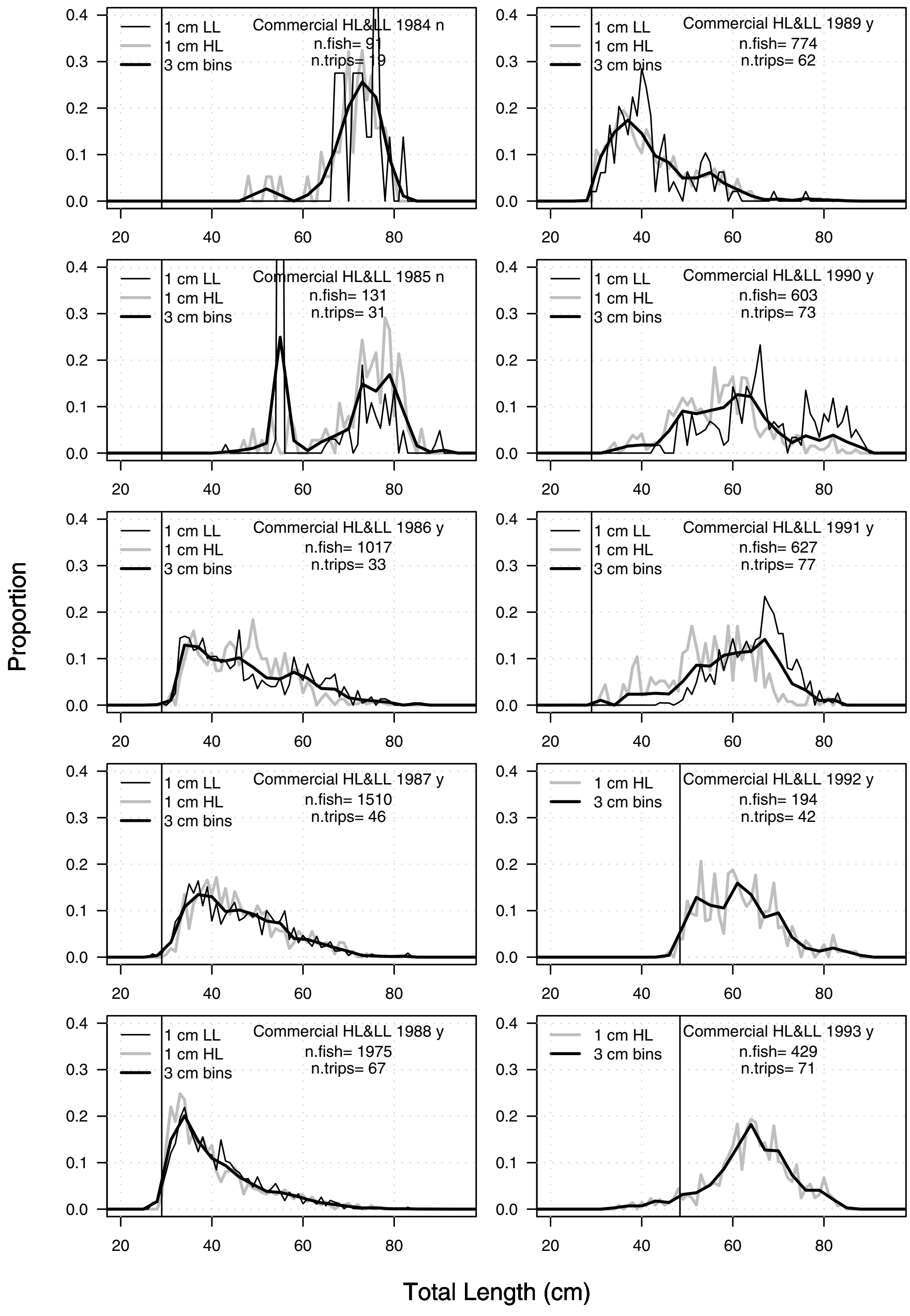


*Figure 6. Continued.*

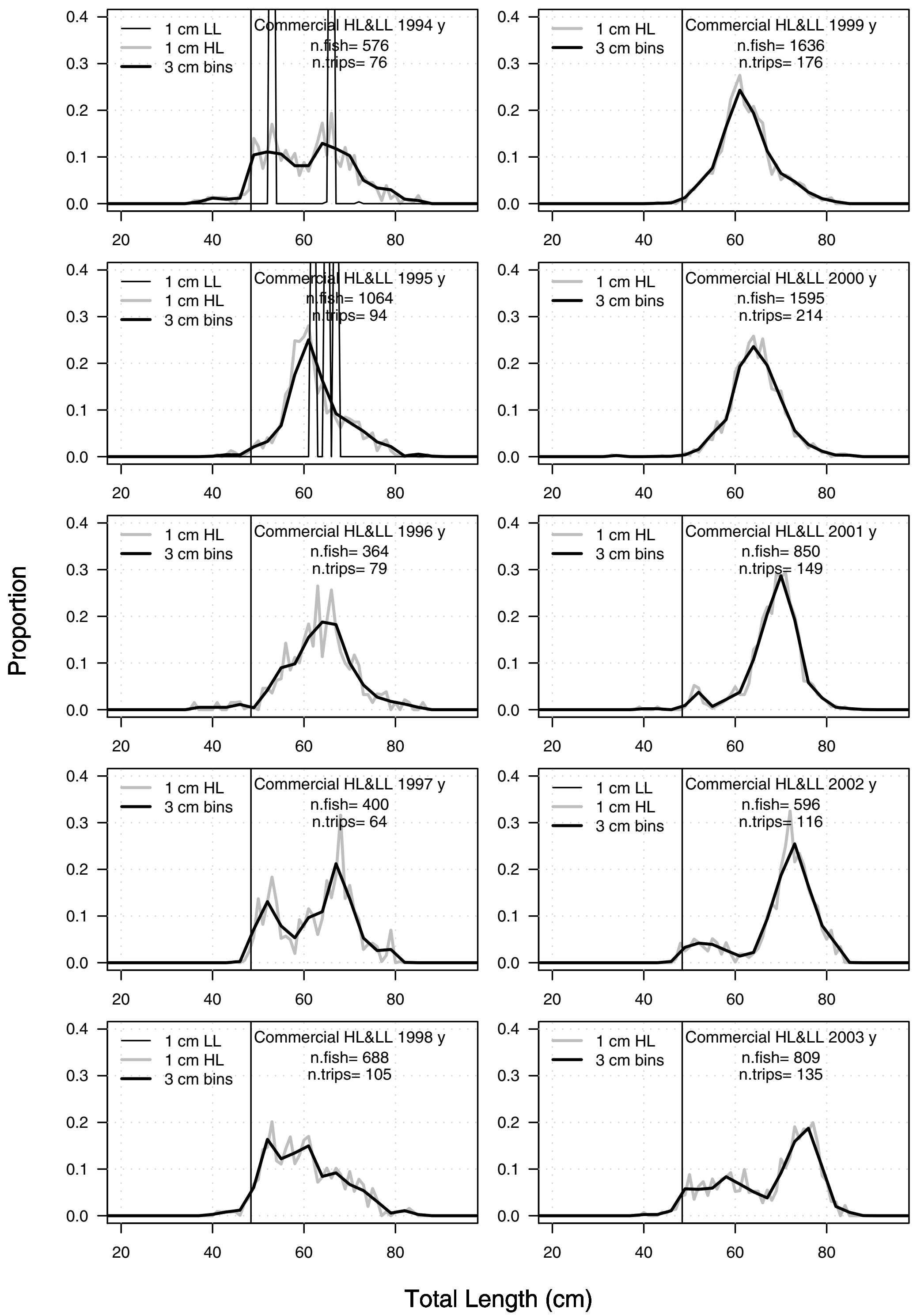


*Figure 6. Continued.*

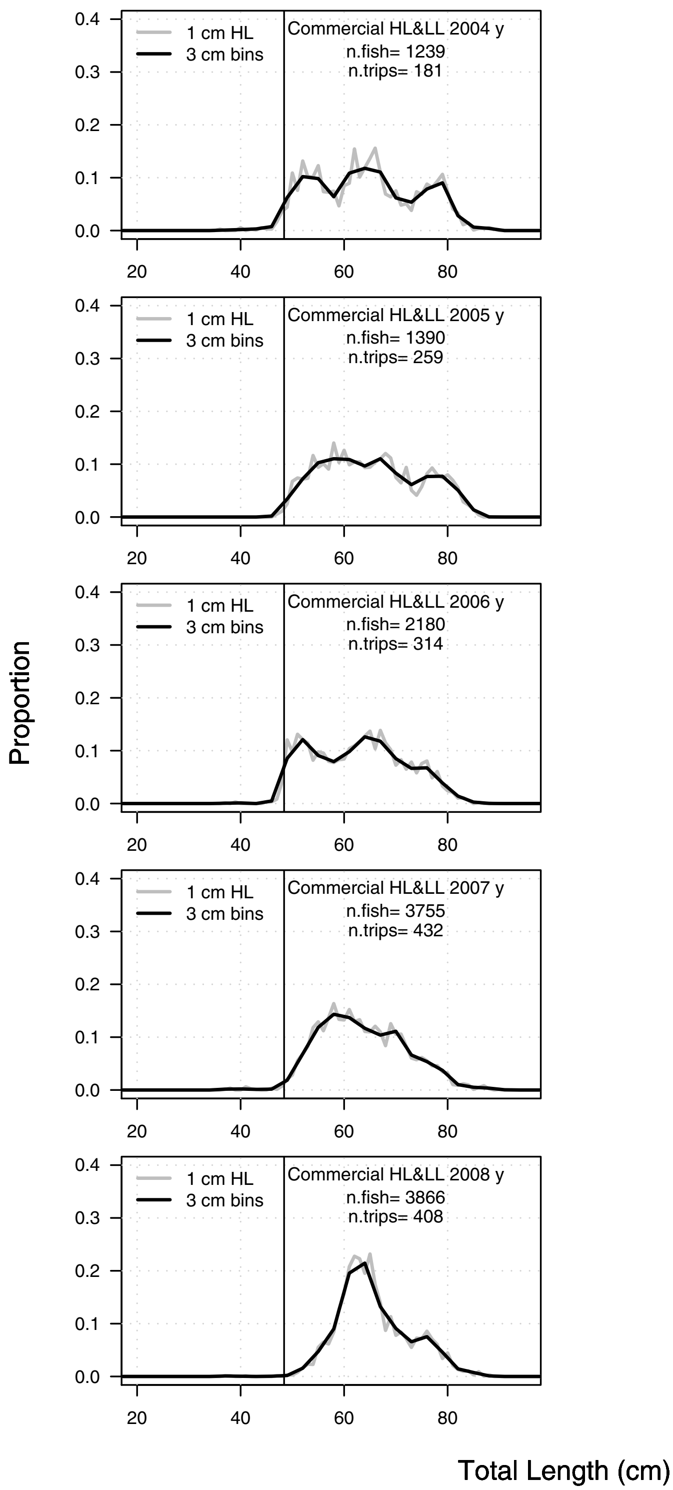


*Figure 7. Red Grouper in Atlantic: Annual commercial pot and trap length compositions plotted as the 1-cm DW bins and the 3-cm model input composition. The "y" after the year label indicates inclusion as model input. Years with "n" after the year will be dropped as input because of low sample sizes or other sampling issues. Vertical lines represent federal size limits.*

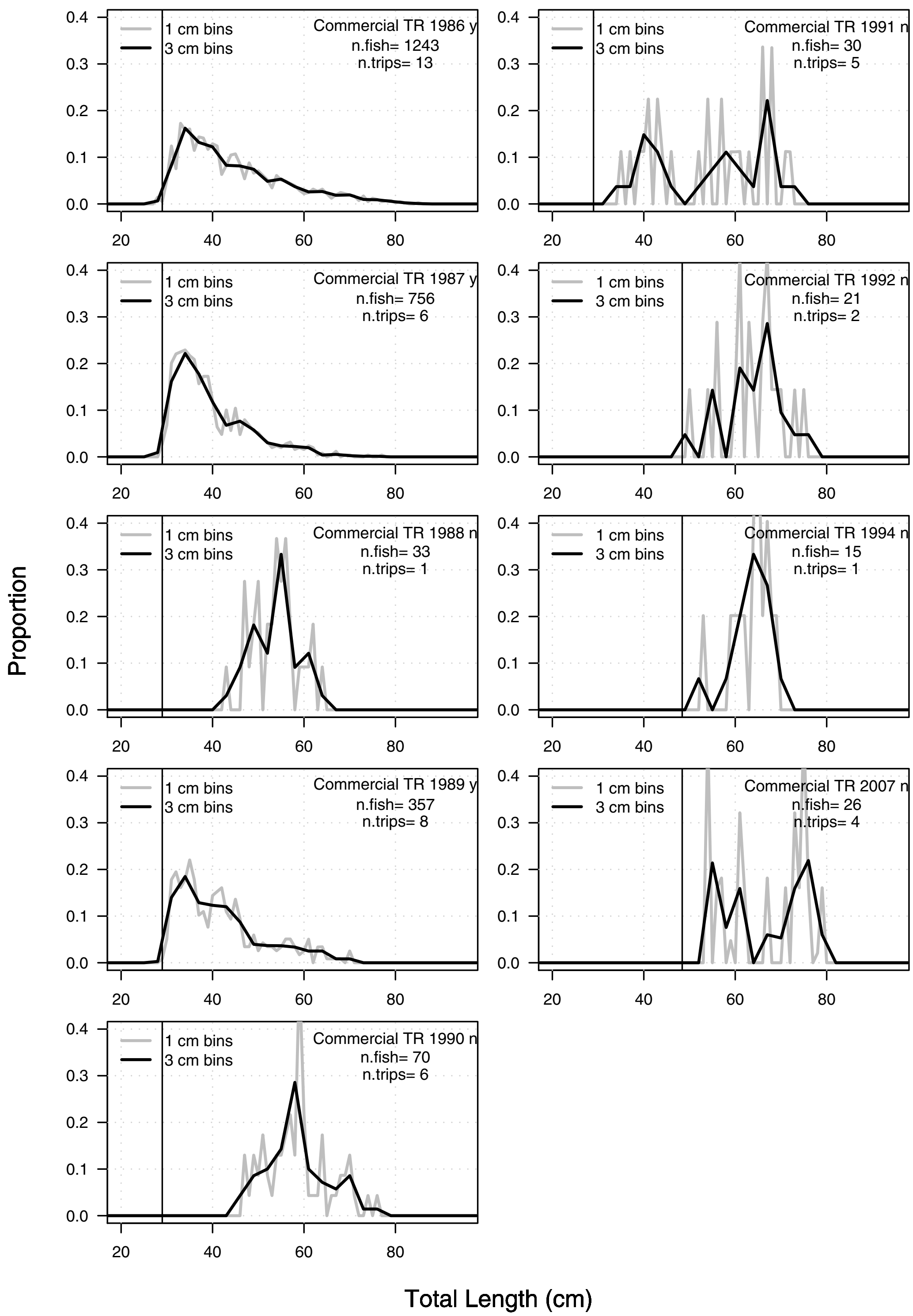


*Figure 8. Red Grouper in Atlantic: Annual MARMAP length compositions plotted as the 1-cm DW bins and the 3-cm model input composition. The "y" after the year label indicates inclusion as model input. Years with "n" after the year will be dropped as input because of low sample sizes or other sampling issues.*

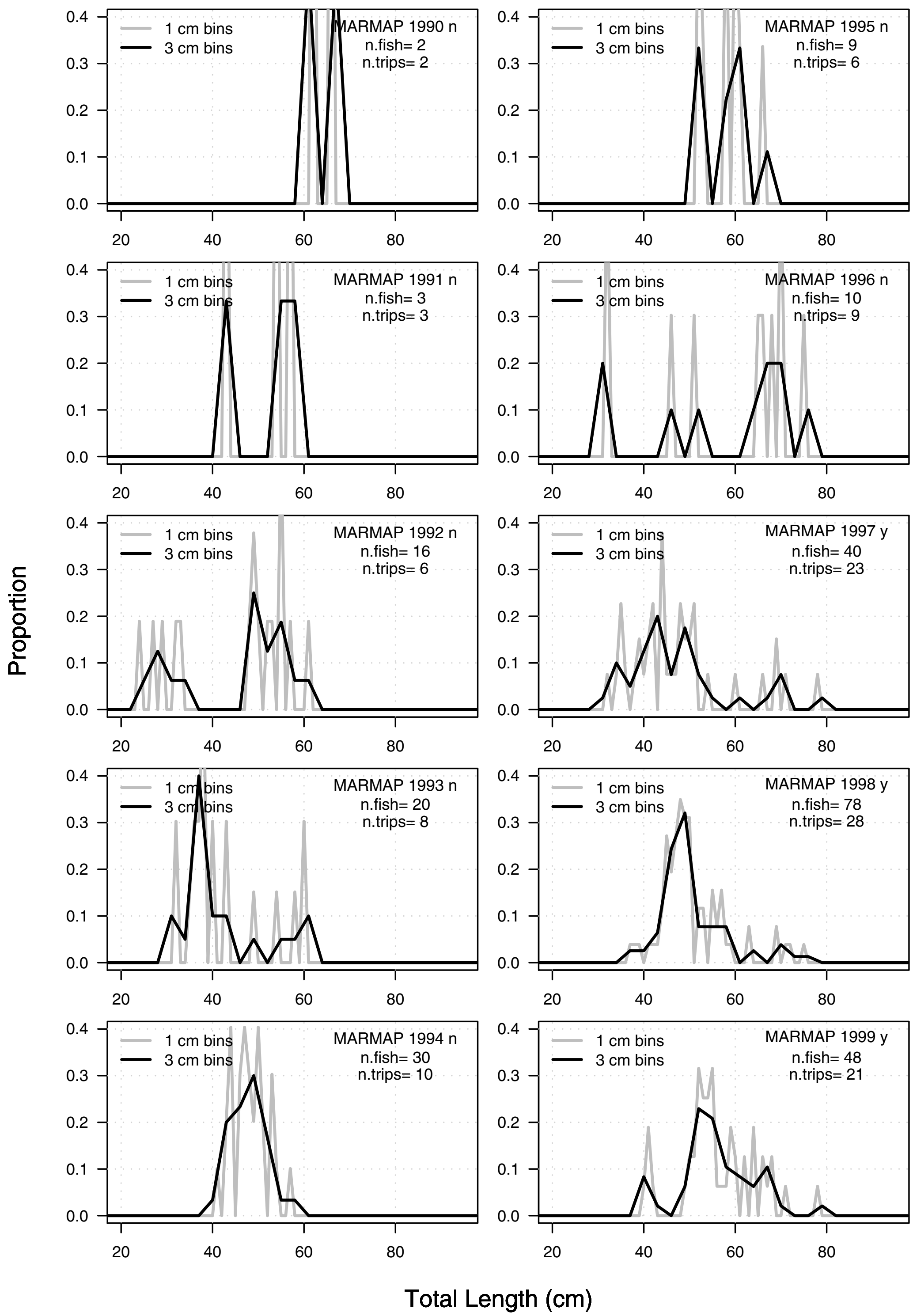


*Figure 8. Continued*

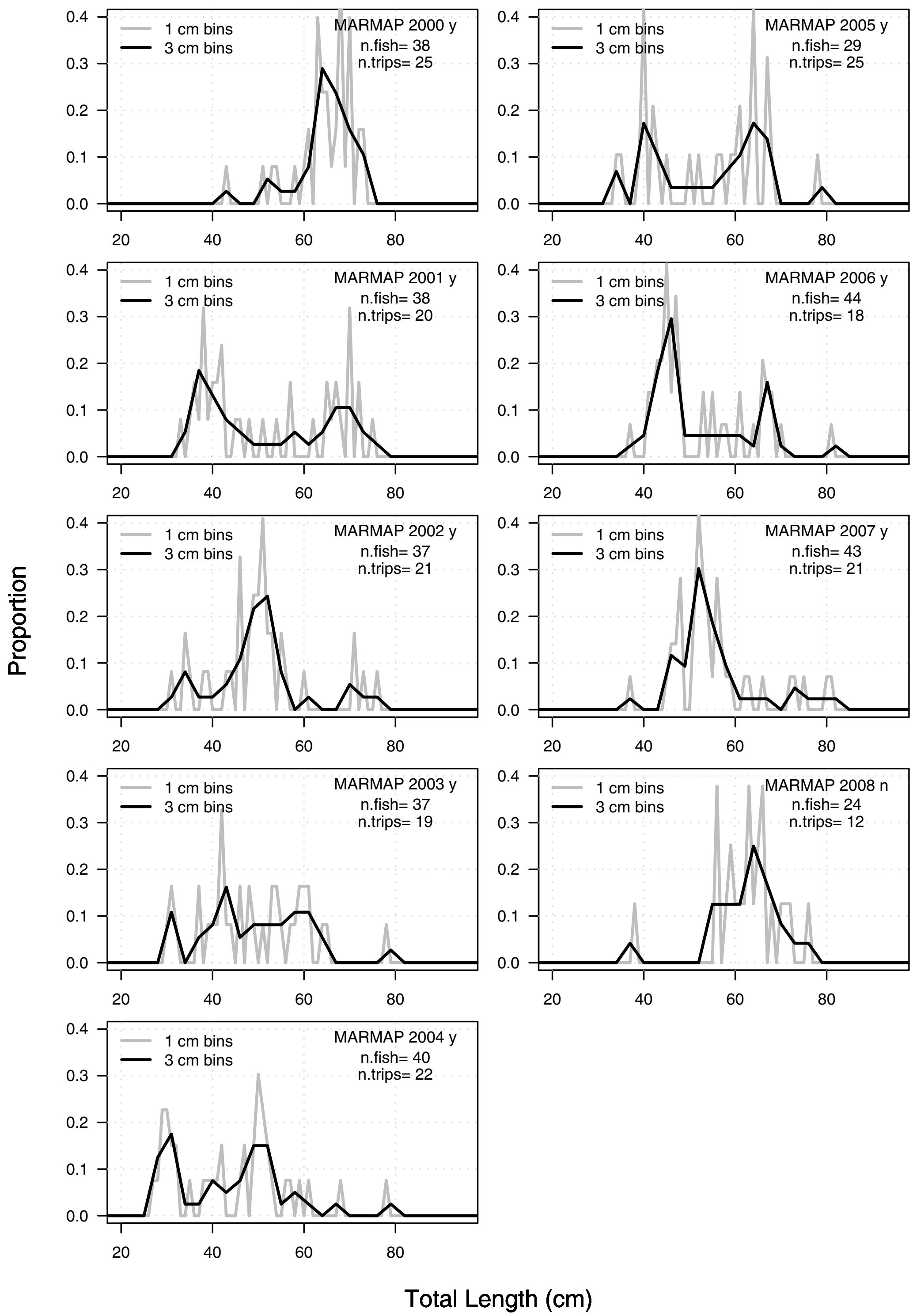


*Figure 9. Red Grouper in Atlantic: Annual RVC length compositions plotted as the 3-cm bins converted from DW input and the 3-cm simulated model input composition. The "y" after the year label indicates inclusion as model input. Years with "n" after the year will be dropped as input because of low sample sizes or other sampling issues.*

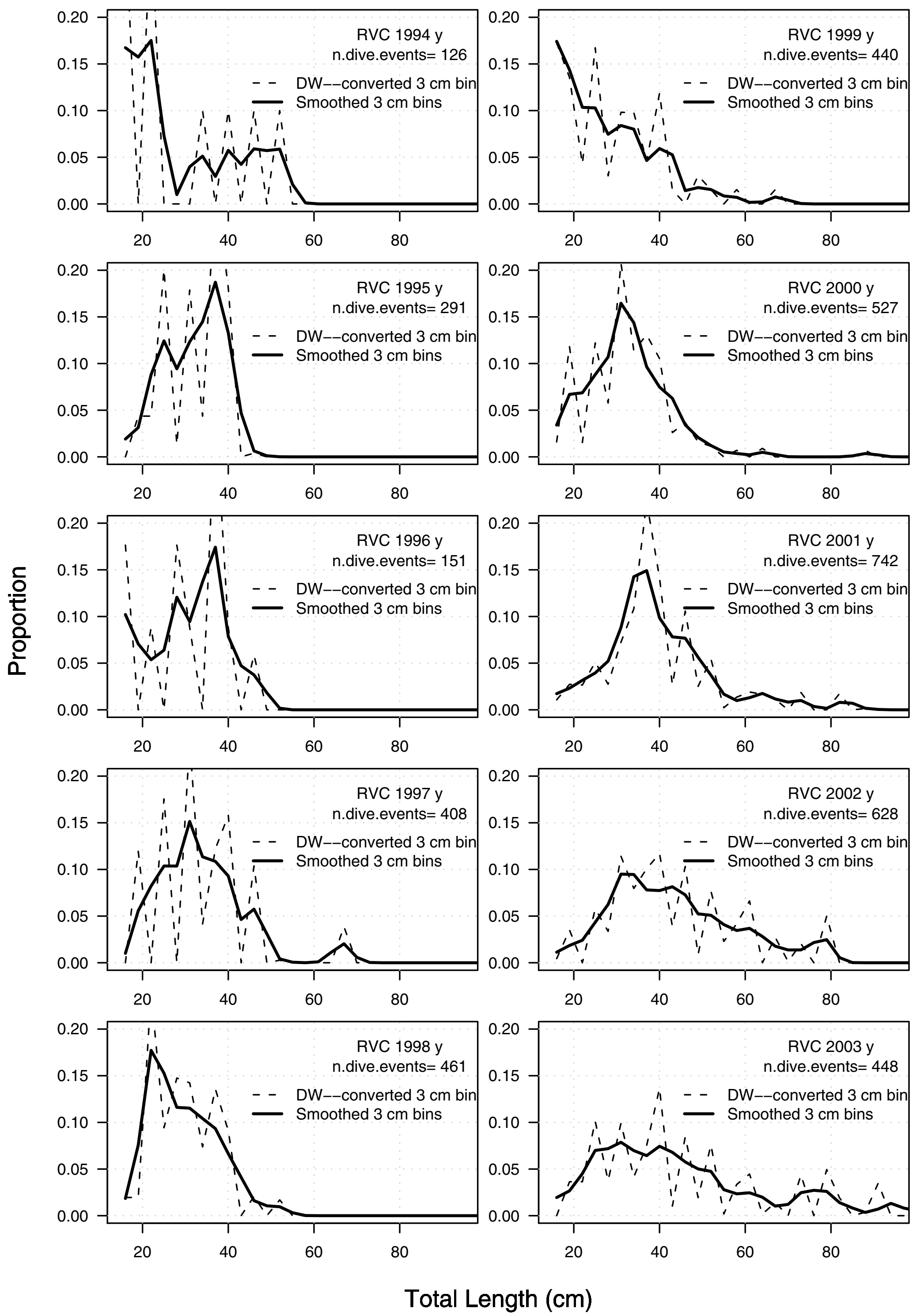


*Figure 9. Continued.*

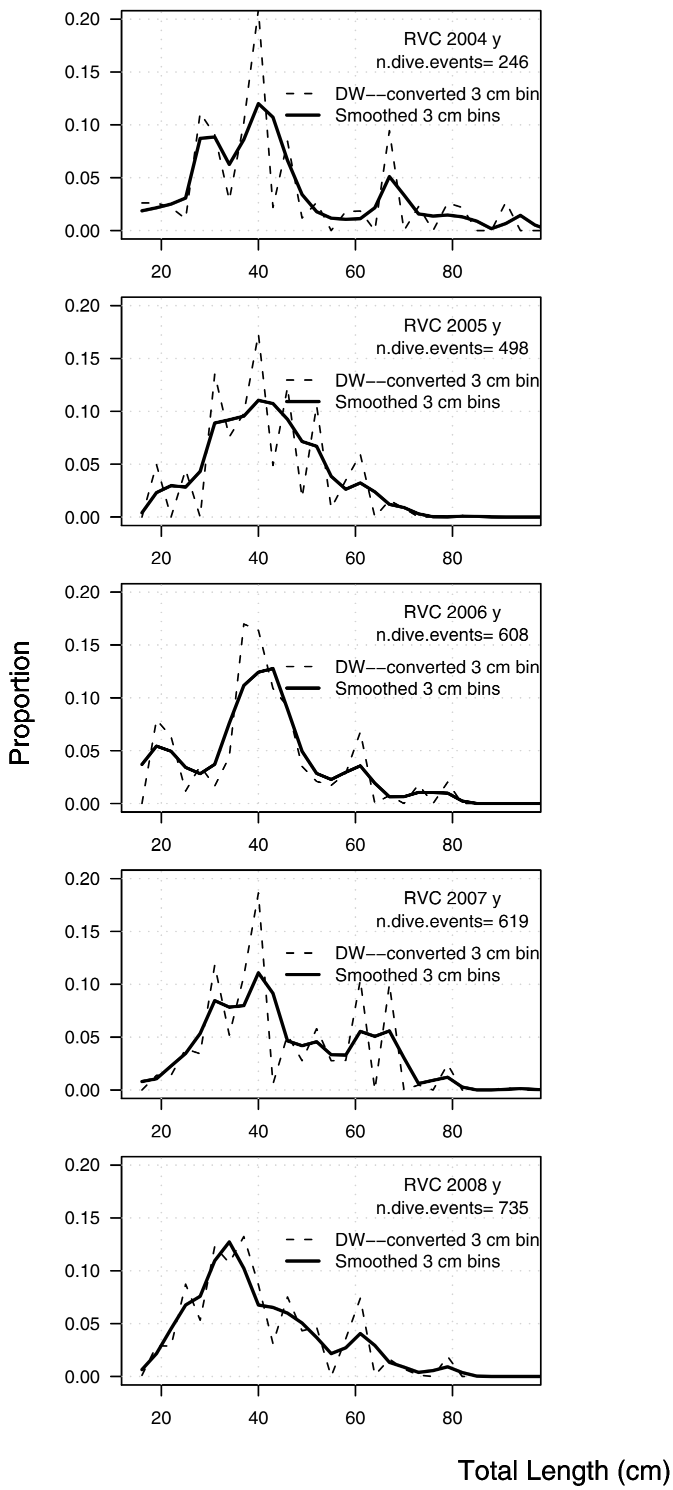


*Figure 10. Red Grouper in Atlantic: vonBertalanffy estimates of expected lengths of age 0 and age 1 fish.*

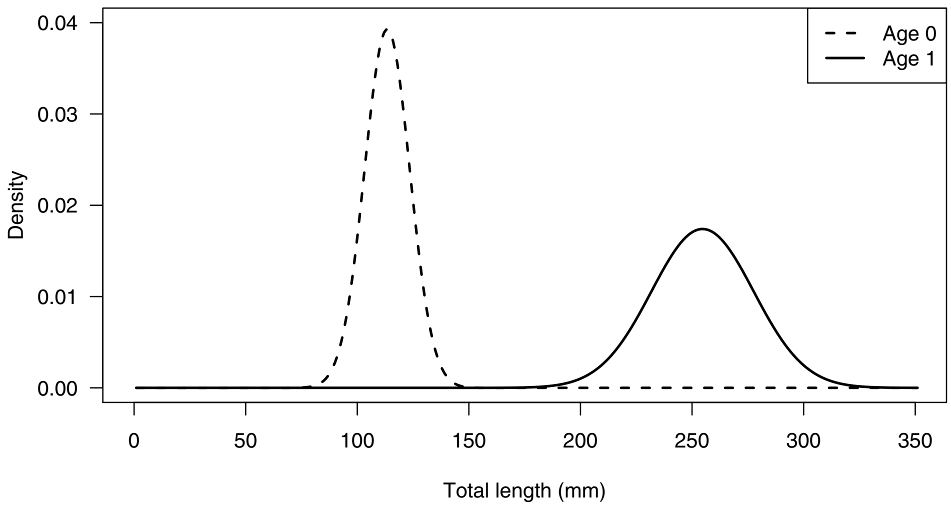
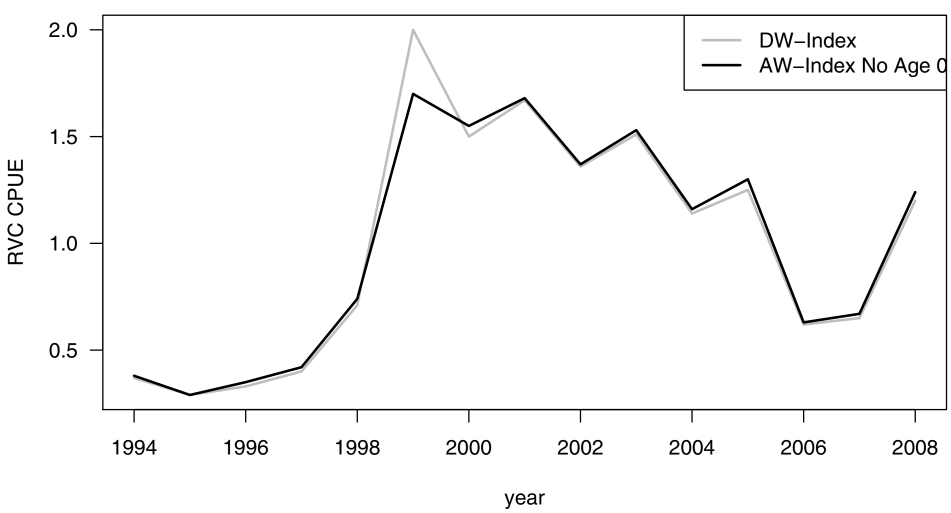



*Figure 11. Red Grouper in Atlantic: RVC index comparison with and without the age-0 fish.*



# 3 Stock Assessment Models and Results

Three different models were considered for red grouper during the Assessment Workshop (AW): the Beaufort statistical catch-age model (BAM), Stock Synthesis version 3 (SS3), and a surplus-production model. In addition, catch curve analysis was used to examine mortality. The BAM was selected at the AW to be the primary assessment model. Abbreviations used in this report 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 statistical catch-age model (BAM). The model was implemented with the AD Model Builder software (ADMB Foundation 2009), and its structure and equations are detailed in the document, SEDAR-19 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 populations 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 used by Fournier and Archibald (1982), Deriso et al. (1985) in their CAGEAN model, and 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 of reef fishes in the U.S. South Atlantic, such as red porgy, black sea bass, tilefish, snowy grouper, gag grouper, greater amberjack, red snapper, vermilion snapper, and Spanish mackerel.

3.1.1.2 **Data Sources** The catch-age model included data from four fleets that caught southeastern U.S. red grouper: commercial lines (handline and longline), commercial other (pots, traps, trawl, diving, miscellaneous), recreational headboat, general recreational. The model was fit to data on annual landings (in units of 1000 lb whole weight for commercial fleets, 1000 fish for recreational fleets), annual discard mortalities (in units of 1000 fish for commercial lines and recreational fleets), annual length compositions of landings, annual age compositions of landings, annual length compositions of discards, three fishery dependent indices of abundance (commercial handline, general recreational, and headboat), and two fishery independent indices of abundance (MARMAP chevron traps, University of Miami Florida Keys visual survey). Not all of the above data sources were available for all fleets in all years. Annual discard mortalities, as fit by the model, were computed by multiplying total discards (tabulated in the DW report) by the release mortality probability of 0.2. Data used in the model are tabulated in the DW report and in §III(2) of this report.

3.1.1.3 **Model Configuration and Equations** Model structure and equations of the BAM are detailed in SEDAR-19-RW01, along with AD Model Builder code for implementation. The assessment time period was 1976–2008. A general description of the assessment model follows:

**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 $\alpha$ is a scale parameter and $\beta$ is a shape parameter. Lorenzen (1996) provided point estimates of $\alpha$ and $\beta$ 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 (2.6% in this case) surviving through the oldest observed age (26 years) as would occur with constant $M = 0.14$ from the DW. This approach using cumulative mortality is consistent with the findings of Hoenig (1983) and Hewitt and Hoenig (2005).

**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 $1 - 16^+$, where the oldest age class $16^+$ allowed for the accumulation of fish (i.e., plus group). Initial (1976) numbers at age were estimated in the model, with penalized deviation from the stable age structure that corresponded to the initial mortality rate (using the geometric mean fishing mortality from 1976–1978).

**Growth** Mean size at age of the population (total length, TL) was modeled with the von Bertalanffy equation, and weight at age (whole weight, WW) was modeled as a function of total length (Figure 3.1, Table 3.1). Parameters of growth and conversions (TL-WW) were estimated by the DW and were treated as input to the assessment model. For fitting length composition data, the distribution of size at age was assumed normal with CV estimated by the assessment model. For fishery length composition data collected under a size limit regulation, the normal distribution of size at age was truncated at the size limit, such that length compositions of landings would include only fish of legal size. Similarly, length compositions of discards would include only fish below a threshold size. Mean length at age of landings and discards were computed from these truncated distributions, and thus average weight at age of landings and discards would differ from those in the population at large.

**Sex transition** Red grouper are a protogynous hermaphrodite. Transition from female to male was modeled with a logistic function, estimated by the DW (Table 3.1).

**Maturity** Female maturity was modeled with a logistic function; parameters for this model were provided by the DW and treated as input to the assessment model (Table 3.1). All males were assumed to be fully mature.

**Spawning biomass** Spawning biomass was modeled as total (males+females) mature biomass at the time of peak spawning, where sex transition and maturity schedules were provided by the DW. For protogynous stocks, use of total mature biomass, rather than that of females or males only, has been found to provide more reliable estimates of management quantities over a broad range of conditions (Brooks et al. 2008). For red grouper, peak spawning was considered to occur in mid-April.

**Recruitment** Estimated recruitment of age-1 fish was predicted from spawning biomass, loosely conditioned on the Beverton–Holt spawner-recruit model. Steepness, $h$, is a key parameter of this model; however, because it is often difficult to estimate steepness ($h$) reliably (Conn et al. In Press), a normal prior distribution was used to inform estimates of $h$ (SEDAR-19-DW06).

**Landings** Time series of landing from four fleets were modeled: commercial line (handline, longline), commercial other (pots, traps, trawl, diving, miscellaneous), headboat, and general recreational (MRFSS). Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in either weight or numbers, depending on how the data were collected (1000 lb whole weight for commercial fleets, and 1000 fish for headboats/recreational fleets). The DW provided observed landings back to the first assessment year (1976) for each fleet except general recreational, because the MRFSS started in 1981. Thus for years 1976–1980, general recreational landings were predicted in the assessment model (but not fit to data), by applying the geometric mean recreational *F* from the years 1981–1983.

**Discards** As with landings, discard mortalities (in units of 1000 fish) were modeled with the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities and release mortality probabilities. Discards were assumed to have a mortality probability of 0.2 for all fisheries, as suggested by the DW. For commercial lines and headboats, discard time series were assumed to begin in 1984, with the start of fishing regulations; for the general recreational fleet, data starting in 1981 were provided by the DW and used in the assessment. In years without observed discards (i.e., 1984–1991 for commercial lines; 1984–2004 and 2008 for headboat), predicted discards were generated in the assessment model, by applying the fleet-specific geometric mean discard *F* from years with data. Although average *F*s were applied, the magnitude of modeled discards would change with regulations because of modifications in discard selectivities (described below).

**Fishing** For each time series of landings and discard mortalities, a separate full fishing mortality rate (*F*) was estimated. 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** In most cases, selectivity curves 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. For most fleets and indices, selectivities were estimated as a two-parameter logistic model (flat-topped). Exceptions were the commercial-other fleet and the MARMAP index, which were modeled with the double logistic formulation (dome-shaped), a four-parameter model. The commercial-other fishing mode partially mirrored the MARMAP selectivity, in that three of the four parameters were assumed equal. The fourth parameter, which controlled the inflection of the ascending limb, was estimated for MARMAP gear (no size limits apply to fishery independent gear), and for commercial-other was set equal to the age associated with a given regulatory period's size limit. The AW examined several other configurations of selectivity by fleet, such as flat-topped for commercial-other and dome-shaped for the recreational and headboat fleets, but did not recommend these other configurations because they lacked both empirical support and *a priori* justification for this Atlantic stock.

Selectivities of fishery dependent indices were the same as those of the relevant fleet. For the recreational index, selectivity included landed and discarded fish; for the commercial and headboat indices, selectivity included only landings.

Selectivity of each fleet was fixed within each period of size-limit regulations, but was permitted to vary among periods. Fisheries experienced three periods of size-limit regulations (no limit prior to 1984, 12-inch limit during 1984–1991, and 20-inch limit from 1992–2008). 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 regulations. That was not the case here, and thus additional assumptions were applied to define selectivities, as follows. Because the MRFSS collected little age or length composition data on red grouper until recently, headboat and general recreational fisheries were assumed to have the same selectivities in the first two regulatory periods. Commercial lines selectivities in the first and second regulatory periods were set equal.

Selectivities of discards were partially estimated, assuming that discards consisted primarily of undersized fish, as implied by observed length compositions of discards. The general approach taken for discard selectivities was that the value for age-1 fish was estimated, age-2 fish were assumed to have full selection, and selectivity for age $2^+$ fish was set equal to the age-specific probability of being below a fixed size (e.g., the size limit) given the estimated normal distribution of size at age. Because little composition data were available on discards, some additional assumptions were necessary; in particular, all fisheries were assumed to have the same discard selectivity function.

Diffuse priors were used on slope parameters of selectivity functions. These priors provide only weak information to help the optimization routine during model execution, by steering parameters away from their bounds. Without these diffuse priors, it is possible during the optimization search that a selectivity parameter could become unimportant, if its bounds were too wide and depending on values of other parameters. When this happens, the likelihood gradient with respect to the aimless parameter approaches zero even if the parameter is not at its globally best value. Diffuse priors help avoid that situation.

**Indices of abundance** The model was fit to two fishery independent indices of abundance (a Florida Keys RVC survey 1994–2008; and a MARMAP chevron trap survey 1991–2008) and to three fishery dependent indices of abundance (headboat 1978–2008; MRFSS 1991–2008; and commercial lines 1993–2008). Predicted indices were conditional on selectivity of the survey/gear and were computed from numbers at age at the midpoint of the year or, in the case of commercial lines, weight at age.

**Catchability** Several options for catchability were implemented for the red grouper assessment following recommendations of a 2009 SEDAR procedural workshop on catchability. In particular, capabilities for including density dependence, linear trends, and random walks were implemented. Parameters for these models could be estimated or fixed based on *a priori* considerations. The AW explored all three options, and found no compelling justification in this case for any of them. Thus, the AW recommended applying constant catchability to each index.

**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. Computed benchmarks included MSY, fishing mortality rate at MSY ($F_{\mathrm{MSY}}$), and spawning biomass (total mature biomass) at MSY ($\mathrm{SSB}_{\mathrm{MSY}}$). These benchmarks are conditional on the estimated selectivity functions. The selectivity pattern used here was the effort-weighted selectivities at age, with effort from each fishery (including discard mortalities) estimated as the full $F$ averaged over the last three years of the assessment.

**Fitting criterion** The fitting criterion was a penalized likelihood approach in which observed landings and discards were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Landings, discards, and index data were fit using lognormal likelihoods. Length and age composition data were fit using multinomial likelihoods. The CVs of landings and discards (in arithmetic space) were assumed equal to 0.05, to achieve a close fit to these time series while allowing some imprecision. The CVs of indices varied annually and were set equal to the values estimated by the DW. Effective sample sizes of the multinomial components were assumed equal to the number of trips sampled annually, rather than the number of fish measured. This approach reflects the belief that individual fish caught per trip do not represent independent samples, but rather the basic sampling unit occurs at the level of trip.

In addition to likelihoods, several penalties and prior distributions were included in the compound objective function. In some cases, as with spawner-recruit steepness and selectivity slope parameters, priors were applied. Penalties on initial age-structure and recruitment deviations were also implemented. Priors and penalties 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.

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 desired data sources). However, in this application to red grouper, all weights were set to 1.0 (with exception of $\omega_7 = 0$ and $\omega_8 = 0$, negating the option for additional penalties on recruitment deviations early and late in the time series).

**Configuration of base run** The base run was configured as described above with data provided by the DW. Some key features include 1) discard mortality of 0.2 across fleets, 2) age-dependent natural mortality scaled to M=0.14, 3) constant catchability, and 4) spawning biomass computed from the mature biomass of both sexes. The AW did not consider this configuration to be a base run in the sense of representing reality better than all other possible configurations, and attempted to portray uncertainty in point estimates through sensitivity analyses and through a Monte-Carlo/bootstrap approach (described below).

**Sensitivity analyses** Sensitivity of results to some key model 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 to constant $M = 0.1$ so as to provide the same cumulative survival of 7.4% through the oldest observed age)
- S2: High $M$ at age (Lorenzen estimates rescaled to constant $M = 0.2$ so as to provide the same cumulative survival of 0.6% through the oldest observed age)
- S3: Extreme $M$ at age (Lorenzen estimates rescaled to constant $M = 0.3$ so as to provide the same cumulative survival of 0.04% through the oldest observed age)
- S4: Low discard mortality rates ($\delta = 0.1$)
- S5: High discard mortality rates ($\delta = 0.3$)
- S6: Spawning biomass computed as mature biomass of females only
- S7: Spawning biomass computed as mature biomass of males only
- S8: Retrospective run with data through 2007
- S9: Retrospective run with data through 2006
- S10: Retrospective run with data through 2005

#### 3.1.1.4 Parameters Estimated

The model estimated annual fishing mortality rates of each fishery, selectivity parameters of fisheries and fishery independent indices of abundance, catchability coefficients associated with indices, Beverton–Holt spawner-recruit parameters, annual recruitment deviations, initial age structure, and CV of size at age. Estimated parameters are described mathematically in the document, SEDAR-19-RW01.

#### 3.1.1.5 Catch Curve Analysis

Catch curve analysis was conducted to provide estimates of total mortality ($Z = F + M$) from age composition data. These analyses are detailed in SEDAR-19-AW02. In short, catch curves were represented by synthetic cohorts (i.e., proportions at age within years), and were analyzed using the Chapman–Robson estimator and using linear regression of the log-transformed proportions at age. Catch curve analysis requires the assumptions that mortality and catchability remain constant with age, and when using synthetic cohorts, that recruitment is constant. These assumptions are rarely met, if ever, by fish populations. Thus, the application of catch curve analysis here is for diagnostic purposes, primarily for comparing the general range of estimated mortality rates of catch curves with those of other models.

3.1.1.6 **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 $F$s 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 represents SPR that would be achieved under an equilibrium age structure at the current $F$ (hence the term *static*).

Yield per recruit and spawning potential ratio were computed as functions of $F$, as were equilibrium landings and spawning biomass. Equilibrium landings and discards were also computed as functions of biomass $B$, which itself is a function of $F$. As in computation of MSY-related benchmarks (described in §3.1.1.7), per recruit and equilibrium analyses applied the most recent selectivity patterns averaged across fisheries, weighted by $F$ from the last three years (2006–2008).

3.1.1.7 **Benchmark/Reference Point Methods** In this assessment of red grouper, the quantities $F_{\text{MSY}}$, $\text{SSB}_{\text{MSY}}$, $B_{\text{MSY}}$, and MSY were estimated by the method of Shepherd (1982). In that 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 $F_{\text{MSY}}$ 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. Thus, in this assessment, the method of benchmark estimation accounted for lognormal deviation by including a bias correction in equilibrium recruitment. The bias correction ($\varsigma$) was computed from the estimated variance ($\sigma^2$) of recruitment deviation: $\varsigma = \exp(\sigma^2/2)$. Then, equilibrium recruitment ($R_{eq}$) associated with any $F$ is,

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

where $R_0$ is virgin recruitment, $h$ is steepness, and $\Phi_F$ is spawning potential ratio given growth, maturity, and total mortality at age (including natural, fishing, and discard mortality rates). The $R_{eq}$ and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of $F_{\text{MSY}}$ is the $F$ giving the highest ASY (excluding discards), and the estimate of MSY is that ASY. The estimate of $\text{SSB}_{\text{MSY}}$ follows from the corresponding equilibrium age structure, as does the estimate of discard mortalities ($D_{\text{MSY}}$), here separated from ASY (and consequently, MSY).

Estimates of MSY and related benchmarks are conditional on selectivity pattern. 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 (2006–2008).

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as $F_{\text{MSY}}$, and the minimum stock size threshold (MSST) as $\text{MSST} = (1 - M)\text{SSB}_{\text{MSY}}$ (Restrepo et al. 1998), with constant M here equated to 0.14. 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 (2008), and current status of the fishery is represented by the geometric mean of $F$ from the latest three years (2006–2008).

In addition to the MSY-related benchmarks, proxies were computed based on per recruit analyses. These proxies include $F_{30\%}$, $F_{40\%}$, and $F_{50\%}$ along with their associated yields. The values of $F_{X\%}$ are defined as those $F$s corresponding to X% spawning potential ratio (i.e., spawners per recruit relative to that at the unfished level). These quantities may serve as proxies for $F_{\text{MSY}}$, 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 of 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).

3.1.1.8 **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). 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=2500 trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of natural mortality and discard mortality, as described below. This number of trials was sufficient for convergence of standard errors in management quantities (Figure 3.2). Of the 2500 trials, approximately 4.6% were discarded, because the model didn't properly converge (in most of these cases a spawner-recruit parameter hit an upper or lower bound, and in one case the optimization did not complete). This left n=2385 trials used to characterize uncertainty.

3.1.1.8.1 **Bootstrap of observed data** To include uncertainty in time series of observed landings, discards, and indices of abundance, multiplicative lognormal errors were applied through a parametric bootstrap. To implement this approach in the 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 logspace 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 landings and discards were assumed to be 0.05, and CVs of indices of abundance were those provided by the DW.

Uncertainty in age and length compositions were included by drawing new distributions for each year of each data source. Ages (or lengths) of individual fish were drawn at random with replacement using the probabilities and sample sizes (number trips) of the original data.

3.1.1.8.2 **Monte Carlo sampling of natural and discard mortalities** Point estimates of natural mortality ($M = 0.14$) and discard mortality ($\delta = 0.2$) were provided by the DW, but with some uncertainty. To carry forward these sources of uncertainty, Monte Carlo sampling was used to generate deviations from the point estimates. For discard mortality, a new $\delta$ value was drawn for each MCB trial from a uniform distribution over the range suggested by the DW [0.1, 0.3]. For natural mortality, a new M value was drawn for each MCB trial from a truncated normal distribution (range [0.1, 0.2]) with mean equal to the point estimate ($M = 0.14$) and standard deviation set to provide a lower 95% confidence limit at 0.1 (the low end of the DW range). Each realized value of M was used to scale the age-specific Lorenzen M, as in the base run.

3.1.1.9 **Acceptable Biological Catch** When a stock is not overfished, acceptable biological catch (ABC) could be computed through probability-based approaches, such as Shertzer et al. (2008*b*), designed to avoid overfishing. However, for overfished stocks, rebuilding projections would likely supersede other approaches for computing ABCs. Because this assessment indicated that the stock is overfished, the AW recommended that ABCs be based on projections.

3.1.1.10 **Projection Methods** Projections were run to predict stock status in years after the assessment, 2009–2028. This time frame of 20 years included two years (2009, 2010) with fishing at the current fishing rate and then eighteen years at the projection rate. Some projections, described below, explored the effects of reduction in the 2010 fishing rate. This reduction is likely to occur with new management regulations scheduled for implementation in 2010 (Amendment 16 of the Snapper-Grouper Fishery Management Plan), but the degree of reduction is yet unknown. The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment results. Time-varying quantities, such as fishery selectivity curves, were fixed to the most recent values of the assessment period. Fully selected $F$ was apportioned between landings and discard mortalities according to the selectivity curves averaged across fisheries, using geometric mean $F$ from the last three years of the assessment period.

**Initialization of projections** Fishing rates that define the projections were assumed to start in 2011, which is the earliest year management could react to this assessment. Because the assessment period ended in 2008, the projections required a two-year initialization period (2009, 2010). Point estimates of initial abundance at age in the projection (start of 2009), other than at age 1, were taken to be the 2008 estimates from the assessment, discounted by 2008 natural and fishing mortalities. The initial abundance at age 1 was computed using the estimated spawner-recruit model and the 2008 estimate of SSB. The fully selected fishing mortality rate applied in the initialization period, $F = F_{\text{current}}$, was taken to be the geometric mean of fully selected $F$ during 2006–2008. In several projections, this rate was decreased in 2010 by 25%, 50%, or 75%, to simulate the currently unknown effect that impending new regulations will have on the fishing rate.

Central tendencies of SSB (mid-year), $F$, recruits, landings, and discards 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 $F_{\text{MSY}}$ would yield MSY from a stock size at $\text{SSB}_{\text{MSY}}$. Uncertainty in future time series was quantified through projections that extended the Monte Carlo/Bootstrap (MCB) fits of the stock assessment model.

**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 and in discard mortality, as well as in estimated quantities such as spawner-recruit parameters, selectivity curves, and in initial (start of 2009) abundance of ages $2^+$. Initial and subsequent recruitment values were generated with stochasticity using a Monte Carlo procedure, in which the estimated Beverton–Holt model (without bias correction) of each MCB fit was used to compute expected annual recruitment values ($\bar{R}_y$). Variability was added to the expected values by choosing multiplicative deviations at random from a lognormal distribution,

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

Here $\epsilon_y$ was drawn from a normal distribution with mean 0 and standard deviation $\hat{\sigma}$, where $\hat{\sigma}$ is the estimated standard deviation from the base assessment model.

The procedure generated 40,000 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 stochastic recruitment streams. Precision of projections was represented graphically by the $5^{th}$ and $95^{th}$ percentiles of the replicate projections.

**Rebuilding time frame** The rebuilding time frame was based on one generation time (14 years) plus the time required to achieve rebuilding under $F = 0$. For this purpose, rebuilding is defined by at least half of projection replicates reaching stock recovery (i.e., SSB ≥ $\text{SSB}_{\text{MSY}}$).

**Projection scenarios** Thirteen constant-$F$ projection scenarios were considered. Unless otherwise stated, the fishing rate in 2009 and 2010 was $F_{\text{current}}$, defined as the geometric mean of $F$ in 2006–2008. The $F_{\text{rebuild}}$ is defined as the maximum $F$ that achieves rebuilding (0.5 probability) in the allowable time frame.

- Scenario 1: $F = 0$
- Scenario 2: $F = F_{\text{current}}$
- Scenario 3: $F = F_{\text{current}}$ in 2009 and $F = 75\%F_{\text{current}}$ thereafter
- Scenario 4: $F = F_{\text{current}}$ in 2009 and $F = 50\%F_{\text{current}}$ thereafter
- Scenario 5: $F = F_{\text{current}}$ in 2009 and $F = 25\%F_{\text{current}}$ thereafter
- Scenario 6: $F = 65\%F_{\text{MSY}}$
- Scenario 7: $F = 75\%F_{\text{MSY}}$
- Scenario 8: $F = 85\%F_{\text{MSY}}$
- Scenario 9: $F = F_{\text{MSY}}$
- Scenario 10: $F = F_{\text{rebuild}}$
- Scenario 11: $F = F_{\text{rebuild}}$, with $F = F_{\text{current}}$ in 2009 and $F = 75\%F_{\text{current}}$ in 2010
- Scenario 12: $F = F_{\text{rebuild}}$, with $F = F_{\text{current}}$ in 2009 and $F = 50\%F_{\text{current}}$ in 2010
- Scenario 13: $F = F_{\text{rebuild}}$, with $F = F_{\text{current}}$ in 2009 and $F = 25\%F_{\text{current}}$ in 2010

### 3.1.2 Model 1 Results

3.1.2.1 **Measures of Overall Model Fit** Overall, the Beaufort Assessment Model (BAM) fit well to the available data. Annual fits to length compositions from each fishery were reasonable in most years, as were fits to age compositions (Figure 3.3). Residuals of these fits, by year and fishery, are summarized with bubble plots; differences between annual observed and predicted vectors are summarized with angular deviation (Figure 3.4–3.14). Angular deviation is defined as the arc cosine of the dot product of two vectors.

The model was configured to fit observed commercial and recreational landings closely (Figures 3.15–3.18), as well as observed discards (Figures 3.19–3.21).

Fits to indices of abundance were reasonable (Figures 3.22–3.26). Since the early 1990s, the general trend in these indices is one of increase.

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 shows truncation of the older ages until the early 1990s, after which older fish began to repopulate (Table 3.2). In the most recent years, older fish ($6^+$) appear to be more abundant than in the early years of the assessment period. These older fish are predominantly male (Tables 3.3, 3.4). Annual number of recruits is shown in Table 3.2 (age-1 column) and in Figure 3.27. A notably strong year classes was predicted to have occurred in 2004.

3.1.2.4 **Total and Spawning Biomass** Estimated biomass at age follows a similar pattern as abundance at age (Tables 3.5,3.6). Total biomass and spawning biomass show similar trends— general decline until the mid-1980s, and general increase since the early 1990s but with a downturn at the end of the time series (Figure 3.28; Table 3.7).

3.1.2.5 **Selectivity** Estimated selectivities of fishery independent surveys are shown in Figure 3.29. Selectivity of landings from commercial lines was estimated to have a gradual slope in earlier years that became more steep with implementation of the 20-inch size limit in 1992 (shown in Figure 3.30). In the most recent period, fish were estimated to be near fully selected by age 5. Selectivity of landings from commercial other was dome-shaped with a shift to older ages at the 1992 regulation change (Figure 3.31). Selectivities of landings from the headboat fleet are shown in Figure 3.32, and those of the general recreational fleet in Figure 3.33. For both of these fleets in the recent period of regulations, fish were estimated to be near fully selected by age 4.

By design, estimated selectivities of discard mortalities were similar across the commercial handline, headboat, and general recreational fisheries (Figure 3.34 – Figure 3.36). In the most recent period of regulations, discards included more fish of ages 3 and 4 than in the earlier period. Few fish age $5^+$ were discarded.

Average selectivities of landings and of discard mortalities were computed from $F$-weighted selectivities in the most recent period of regulations (Figure 3.37). These average selectivities were used to compute benchmarks and projections. All selectivities from the most recent period, including average selectivities, are tabulated in Table 3.8.

3.1.2.6 **Fishing Mortality** The estimated fishing mortality rates ($F$) peaked during the 1980s, and in the last decade have generally been at their lowest levels of the time series (Figure 3.38). The two primary contributors are general recreational and commercial line fleets. An increase in fishing mortality rate in the last few years coincides with increased landings from those two fleets.

Estimates of total $F$ at age are shown in Table 3.10. In any given year, the maximum $F$ at age (i.e., apical F) may be less than that year's sum of fully selected $F$s across fleets. This inequality is due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and several sources of mortality have dome-shaped selectivity.

Table 3.11 shows total landings at age in numbers, and Table 3.12 in 1000 lb. In general, estimated landings have been dominated by commercial lines and general recreational fleets, particularly since 1992 (Figures 3.39, 3.40; Tables 3.13, 3.14). Estimated discard mortalities occur on a smaller scale than landings (Figure 3.41; Tables 3.15, 3.16)

3.1.2.7 **Catch Curve Analysis** Catch curve analysis suggested total mortality rate ($Z = F + M$) ranged from near 0.0 to greater than 1.0, but the bulk of the point estimates were between 0.3 and 0.6 (SEDAR-19-AW02). Based on the constant estimate of natural mortality, $M = 0.14$, these values of $Z$ suggest that fully selected fishing mortality rate is on the scale of $F = 0.16$ to $F = 0.46$, generally consistent with estimates from the catch-age model (Figure 3.38, Table 3.7).

3.1.2.8 **Spawner-Recruitment Parameters** The estimated Beverton–Holt spawner-recruit curve is shown in Figure 3.42, 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: steepness $\widehat{h} = 0.91$, unfished age-1 recruitment $\widehat{R_0} = 399,459$, unfished spawning biomass per recruit $\phi_0 = 0.024$, and standard deviation of recruitment residuals in log space $\widehat{\sigma} = 0.41$ (which resulted in bias correction $\widehat{\varsigma} = 1.09$). Uncertainty in these quantities was estimated through the Monte Carlo/bootstrap (MCB) analysis (Figure 3.43). Although the estimate of steepness is high, it appears to be robust across MCB trials, likely because the two-way trip in spawning biomass provides information on stock productivity (Conn et al. In Press).

3.1.2.9 **Per Recruit and Equilibrium Analyses** Static spawning potential ratio (static SPR) shows a general trend of increase since the mid-1980s, but a decrease in the last several years of the assessment time period (Figure 3.44, Table 3.7).

Yield per recruit and spawning potential ratio were computed as functions of $F$ (Figure 3.45). 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 years (2006–2008). The $F$s that provide 30%, 40%, and 50% SPR are 0.18, 0.12, and 0.08, respectively. For comparison, $F_{\text{MSY}}$ corresponds to about 26% SPR. Although this rate of fishing appears high relative to $F_{X\%}$ proxies, it occurs because the size limit offers protection for spawners and because of the high estimate of steepness.

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of $F$ (Figures 3.46). By definition, the $F$ that maximizes equilibrium landings is $F_{\text{MSY}}$, and the corresponding landings and spawning biomass are MSY and $\text{SSB}_{\text{MSY}}$. Equilibrium landings and discards could also be viewed as functions of biomass $B$, which itself is a function of $F$ (Figure 3.47).

3.1.2.10 **Benchmarks / Reference Points** As described in §3.1.1.7, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the spawner-recruit curve with bias correction (Figure 3.42). This approach is consistent with methods used in rebuilding projections (i.e., fishing at $F_{\text{MSY}}$ yields MSY from a stock size of $\text{SSB}_{\text{MSY}}$). Reference points estimated were $F_{\text{MSY}}$, MSY, $B_{\text{MSY}}$ and $\text{SSB}_{\text{MSY}}$. Based on $F_{\text{MSY}}$, 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 (§3.1.1.8).

Estimates of benchmarks are summarized in Table 3.17. Point estimates of MSY-related quantities were $F_{\text{MSY}} = 0.21\ \text{y}^{-1}$, MSY = 1117 klb, $B_{\text{MSY}} = 3622$ mt, and $\text{SSB}_{\text{MSY}} = 2545$ mt. Distributions of these benchmarks are shown in Figure 3.48.

3.1.2.11 **Status of the Stock and Fishery** Estimated time series of stock status (SSB/MSST) shows decline until the mid-1980s, and then steady increase since, but with a decrease in the terminal year (Figure 3.49, Table 3.7). The increase in stock status appears to have been initially driven by strong recruitment, then reinforced by 1992 management regulations. Base-run estimates of spawning biomass have remained below MSST throughout the time series (overfished status in 1976 is not surprising given the heavy fishing pressure that occurred prior to the start of the assessment period). Current stock status was estimated in the base run to be $SSB_{2008}/MSST = 0.79$ (Table 3.17); uncertainty in this estimate includes the possibility that the stock has fully recovered (i.e., SSB > MSST), but also the possibility that the stock is less healthy than estimated by the base run (Figures 3.50, 3.51). Age structure estimated by the base run has become repopulated by older fish during the last decade, approaching the (equilibrium) age structure expected at MSY (Figure 3.52).

The estimated time series of $F/F_{MSY}$ suggests that overfishing has been occurring throughout the assessment period (Figure 3.49, Table 3.7). The series peaked during the 1980s; since 2000, $F/F_{MSY}$ has been at its lowest levels, but has been increasing since 2005. Current fishery status in the terminal year, with current $F$ represented by the geometric mean from 2006–2008, is estimated by the base run to be $F_{2008}/F_{MSY} = 1.46$ (Table 3.17). This estimate indicates current overfishing and appears robust across MCB trials (Figures 3.50, 3.51).

3.1.2.12 **Sensitivity and Retrospective Analyses** Sensitivity runs, described in §3.1.1.3, may be useful for evaluating implications of assumptions in the base assessment model, and for interpreting MCB results in terms of the effects of natural and discard mortality rates. Plotted are time series of $F/F_{MSY}$ and SSB/MSST for sensitivity to natural mortality (Figure 3.53), discard mortality (Figure 3.54), and measure of spawning biomass (Figure 3.55). In concert, results of sensitivity analyses were similar to those of the base run and MCB analysis: the tendency was toward the status estimate of overfished, and toward the (apparently more robust) estimate of overfishing, although not all runs gave the same qualitative results (Figure 3.57, Table 3.18). Retrospective analyses did not reveal worrying patterns of overestimation or underestimation (Figure 3.56).

3.1.2.13 **Projections** Projection scenario 1, in which $F = 0$, predicted the stock to achieve at least 50% chance of recovery by 2014 (Figure 3.58). This duration defines Tmin, the minimum rebuilding time frame. The maximum rebuilding time frame (Tmax) allows for rebuilding to occur by 2028 (2014 plus 14 years generation time). The Tmin and Tmax should bracket the target rebuilding time frame (Ttarget).

Projections with $F$ at 100%, 75%, 50%, or 25% of $F_{current}$ predicted recovery by 2028 only if $F$ were reduced sufficiently below the current level (Figures 3.59–3.62, Tables 3.19–3.22), as did projections with $F$ at 65%, 75%, 85%, or 100% of $F_{MSY}$ (Figures 3.63–3.66, Tables 3.23–3.26). The value of $F_{rebuild}$ showed little sensitivity to $F$ in 2010 (Figures 3.67–3.70, Tables 3.27–3.30). In general, higher projected $F$ resulted in larger annual and cumulative landings, but smaller biomass with a correspondingly smaller buffer from the MSST.

## 3.2 Model 2: Stock Synthesis

### 3.2.1 Model 2 Methods

3.2.1.1 **Overview** Stock Synthesis 3 (SS3), programmed by Dr. Rick Methot, was added to the NMFS Toolbox in 2009 (Methot 2009). This latest version included an option for protogyny, which was implemented for red grouper. SS3 can handle a wide range of data inputs and model structures, controlled through multiple input files. A primary advantage of SS3 is its great flexibility, but the corresponding complexity requires that users have detailed knowledge of the software for proper application. In this assessment of red grouper, Dr. Methot provided much support and advice. However, nobody on the AW panel considered themselves skilled or experienced with Stock Synthesis. Thus this application was not thoroughly examined at the AW, and SS3 was not recommended by the panel as the assessment model on which to base management. Rather, its use here is intended to complement the Beaufort Assessment Model.

SS3 is described in Methot (2009), provided as a SEDAR-19 RW reference document. Details specific to this application toward red grouper are documented below. Because SS3 did not receive full consideration by the AW panel, the descriptions here of data, model, and results are brief.

3.2.1.2 **Data Sources** Data sources used in SS3 are the same as those used in the BAM, although some modifications were necessary. The model included an initialization period (1960–1975), which required landings as input. For each fleet these initial landings were assumed equal to the geometric mean landings of the first three assessment years (1976–1978).

SS3 required landings and discards by fleet to be in the same units. This conditional was already met by the headboat and recreational fleets, but the commercial discards required conversion from numbers (1000 fish) to weight (mt). As described in §III(2) of this report, this conversion assumed that the average weight of discards was represented by the average weight of age-2 fish.

3.2.1.3 **Model Configuration and Equations** The structure of SS3 is similar to that of the Beaufort Assessment Model (BAM). Both models use statistical catch-age formulations, with similar underlying models of population dynamics and similar components in the likelihood. Some notable differences between this red grouper configuration of SS3 and the BAM include:

- SS3 necessarily models age-0 fish, and thus recruits enter the population at age 0. The BAM models recruits as age-1 fish.
- SS3 computes spawning biomass at the beginning of the year. The BAM computes spawning biomass at the time of peak spawning.
- SS3 models selectivity as a function of age and size, but the primary effect is from size. The BAM models selectivity as a function of age.
- SS3 models selectivity of the entire catch, and allocates catch into landings and discards using a length-based function of retention probability. The BAM estimates separate selectivities and mortality rates for landings and discards.
- In SS3, dome-shaped selectivities are modeled using the double normal function (SS selex type 24); in the BAM, double logistic.
- SS3 models probability of sexual transition with the cumulative normal function; the BAM models proportion male at age with the logistic function.

### 3.2.2 Model 2 Results

**3.2.2.1 Model Fit** Fits to age and length composition data are shown in Figures 3.71–3.73. Landings were fit closely (Figure 3.74), although not always precisely. Discards were fit with more error (Figure 3.75); in particular, headboat discards were underfit. However, given the relatively small scale of headboat discards, this source of mortality is unlikely to have a strong effect on overall population dynamics. Fits to fishery independent indices (Figure 3.76) and fishery dependent indices (Figure 3.77) were similar to those from the Beaufort Assessment Model.

**3.2.2.2 Parameter Estimates and Uncertainty** Estimated parameters and other quantities, along with standard errors, are tabulated in Appendix C. Standard errors assume asymptotic normality, relying on the inverted Hessian matrix. A few key estimates include the following. Steepness of the Beverton–Holt spawner-recruit relationship was estimated to be 0.99, and unfished recruitment was estimated to be 662,486 age-0 fish. After applying the Lorenzen age-0 natural mortality rate (0.49), the unfished recruitment would result in $(662,486 \times e^{-0.49} =)$ 405,856 age-1 fish, an estimate similar to that from the BAM (399,459 age-1 fish). Estimates of management quantities from SS3 were $F_{\mathrm{MSY}} = 0.216$, $\mathrm{SSB}_{\mathrm{MSY}} = 2312$ mt, and MSY $= 1,064,438$ lb. These estimates were also similar to those from the BAM (Table 3.17).

**3.2.2.3 Stock Abundance and Recruitment** The high estimate of steepness corresponds to recruitment that is only weakly related to spawning biomass over its predicted range (Figure 3.78). The spawning biomass was at its lowest in the mid 1980s and has since increased until a drop in the last assessment year (Figure 3.79). SS3 predicts that this increase was driven, at least in part, by strong recruitment events in the early 1990s (Figure 3.79).

**3.2.2.4 Status of the Stock and Fishery** Like the BAM, SS3 predicts that overfishing has been occurring throughout the assessment period, with an increase in the last several years (Figure 3.80). Estimated spawning biomass has remained below MSST, but has been approaching it since the early 1990s. The terminal estimate of fishing status is $F_{2008}/F_{\mathrm{MSY}} = 2.22$ (using the geometric mean of the 2006–2008). The terminal estimate of stock status is $\mathrm{SSB}_{2008}/\mathrm{MSST} = 0.68$.

## 3.3 Model 3: Surplus Production Model

### 3.3.1 Model 3 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 to the data, decomposing population change into a number of processes including growth, mortality, and recruitment. A simplified approach, which may sacrifice some bias in favor of precision, is to aggregate data across age or length classes, and to summarize the relationship between complex population processes by using a simple mathematical model such as a logistic population model.

A logistic surplus production model, implemented in ASPIC (Prager 2005), was used to estimate stock status of red grouper off the southeastern U.S. While primary assessment of the stock was performed via the age-structured BAM, the surplus production approach was intended as a complement, and for additional verification that the age-structured approach was providing reasonable results.

3.3.1.2 **Data Sources** For use in the production model, data developed at the DW required some additional formatting, described below.

**Landings** Headboat and MRFSS recreational landings in numbers and whole pounds were developed at the SEDAR-19 DW. The MRFSS landings in number were subsequently smoothed for input into the age–structured model. The MRFSS landings in weight were not smoothed and were converted to pounds for the MRFSS survey by multiplying by the average annual mean weight, calculated as landings in weight/landings in number, by the smoothed MRFSS landings series from 1981–2008. The unsmoothed MRFSS data were used to determine average size. The 1978–1980 MRFSS landings were calculated as the average of 1981–1983.

Commercial landings were reported by the DW in gutted pounds and were converted to whole pounds using the whole weight–gutted weight conversion supplied by the life-history group.

**Dead Discards** Discard estimates were provided in numbers for commercial and recreational data sources. Weight of discarded individuals was assumed to be the average weight of fish age 1 and 2 prior to the 1992 20–inch size limit, and the weight of age-2 fish (median of fish age 1, 2, and 3) since the 20–inch size limit. The estimated weight of a discarded fish in whole pounds was applied to the discard estimates in numbers to determine the annual weight of discards. The recommended constant discard mortality of 0.2 was applied to the discard estimates. The prior 12–inch size limit did not appear to affect the length compositions and was not considered.

**Indices of Abundance** The indices for red grouper were developed in numbers of landed fish with the exceptions of MRFSS and commercial logbook. MRFSS was developed as numbers of landed and discarded fish and commercial logbook was developed in pounds. The surplus–production model requires input in pounds and therefore the MARMAP, headboat, and RVC indices were converted by multiplying the annual index for each series by an annual mean weight for each gear. There was considerable noise in the MARMAP index in pounds, and it was therefore smoothed using a cubic spline weighted by the inverse of the CV's. MRFSS had the additional step of proportioning the index into landed and discarded fish and applying a mean weight for each. The mean weight for discarded fish was calculated as the mean weight of age-1 and age-2 fish prior to the 20–inch size limit in 1992 and the weight of a age-2 fish after the 20–inch size limit. The mean weight of the landed fish was calculated using the length compositions and the associated estimate of weight at length. The annual mean weight was then calculated as $\sum P_i \, w_i$ where $(P_i)$ is the proportion for each length bin($i$). The length–weight equation provided by the SEDAR-19 DW was used to estimate the weight in whole pounds at each length bin ($w_i$).

These individual indices were combined into a single index (SEDAR-19-AW01), using the hierarchical methods described in Conn (In Press). An additional combined index was generated that incorporates a 2% catchability increase per year until 2003 for use in sensitivity runs.

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

$$\frac{dB_t}{dt} = rB_t - \frac{r}{K}B_t^2, \tag{4}$$

where $B_t$ is biomass in year $t$, $r$ is the intrinsic rate of increase in 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, $F_t$:

$$\frac{dB_t}{dt} = (r - F_t)B_t - \frac{r}{K}B_t^2. \tag{5}$$

By writing 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 bootstrap.

For red grouper, the model was configured using various combinations of indices of abundance. These combinations are defined in Table 3.31. The ASPIC input file for a model run using all indices without catchability increase is provided in Appendix D.

### 3.3.2 Model 3 Results

**3.3.2.1 Model Fit** All runs fit the indices reasonably well except that they had difficulty fitting the first few years of the headboat index (in cases using multiple indices) or the combined index (in cases using this single index). This similarity between cases was not surprising given that the first years of the combined index are solely from the headboat data (Figures 3.81 and 3.82). Because all runs were conditioned on catch, landings were fit exactly.

**3.3.2.2 Parameter Estimates and Uncertainty** Parameter estimates and MSY benchmarks from the base production model run are tabulated in Table 3.31. Output from ASPIC is in Appendix E, along with estimates of bias and precision.

**3.3.2.3 Status of the Stock and Fishery** Across model runs, the tendency of results was toward the estimate of overfishing, with biomass near its threshold. Uncertainty in results was evaluated using 600 bootstrap runs to generate 80% confidence intervals for $B/\text{MSST}$ (Figure 3.83) and $F/F_{\text{MSY}}$ (Figure 3.84). Kernel density plots were generated to evaluate the shape of the distribution of the current relative fishing mortality rate $F/F_{\text{MSY}}$ and biomass relative to the minimum spawning stock threshold $B/\text{MSST}$ (Figures 3.85 and 3.86).

**3.3.2.4 Discussion — Surplus Production Model** The production model estimates that current stock size is near MSST and that the current level of fishing is slightly above the limit reference point $F_{\text{MSY}}$, based on the run with indices input separately and no increase in catchability. This run was most consistent with the age–structured models. There were no large differences in the catchability coefficients estimated by the model runs for each index (Table 3.32). The general effects of combining indices and including an increase in catchability were similar. Both alternatives increased the estimate of current $F/F_{\text{MSY}}$ and associated variability while decreasing the estimate of current stock status $B/\text{MSST}$. Assessment workshop panelists expressed skepticism that the uncertainty was fully captured by the model. The surplus production model, because it omits population age and size structure, does not make use of data on those characteristics. Because such data are available for red grouper, a model that uses them would normally be preferred for a detailed assessment on which to base management.

## 3.4 Discussion

### 3.4.1 Comments on Assessment Results

Estimated benchmarks play a central role in this assessment. Values of $SSB_{MSY}$ and $F_{MSY}$ are used to gauge status of the stock and fishery, and in cases where rebuilding projections are necessary, SSB reaching $SSB_{MSY}$ is the criterion that defines a successfully rebuilt stock. Computation of benchmarks is conditional on selectivity. If selectivity patterns change in the future, for example as a result of new size limits or different catch allocations among sectors, estimates of benchmarks would likely change as well.

The base run of the Beaufort catch-age assessment model indicated that the stock is overfished ($SSB_{2008}/MSST = 0.79$), and that overfishing is occurring ($F_{2008}/F_{MSY} = 1.46$). These results did not appear subject to retrospective error, and were consistent across most, but not all, of the configurations used in sensitivity runs. In addition, the same qualitative findings resulted from the Stock Synthesis application and most production model applications. However, distributions of results from the MCB analysis included realizations spanning other combinations of stock and fishery status (e.g., they included runs where the stock was not overfished and without overfishing). The result that overfishing is occurring appeared to be more robust than the result that the stock is currently overfished (Figures 3.49–3.51, 3.57, 3.85–3.86).

The increase in biomass since the early 1990s would indicate that the federal regulations implemented in 1992 have been effective. The more recent increase in fishing rate may be due, at least in part, to target switching toward red grouper as a result of regulations on other species. The AW panel recognized that imminent regulations on shallow water groupers (Amendment 16 of the Snapper-Grouper Fishery Management Plan), scheduled to take effect in 2010, may be sufficient for reducing the fishing rate below $F_{MSY}$. Thus, even if this stock is declared overfished such that a rebuilding plan becomes mandatory, additional regulations beyond those already scheduled may not be necessary.

### 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 References

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### 3.6 Tables

*Table 3.1. Life-history characteristics at age of the population, including average size (mid-year), proportion female, and proportion females mature (all males assumed mature)*

| Age | Total length (mm) | Total length (in) | CV length | Whole weight (kg) | Whole weight (lb) | Prop. female | Female maturity |
|---|---|---|---|---|---|---|---|
| 1 | 313.9 | 12.4 | 0.12 | 0.46 | 1.02 | 1.00 | 0.00 |
| 2 | 416.4 | 16.4 | 0.12 | 1.11 | 2.45 | 0.96 | 0.35 |
| 3 | 499.3 | 19.7 | 0.12 | 1.95 | 4.30 | 0.93 | 0.54 |
| 4 | 566.2 | 22.3 | 0.12 | 2.88 | 6.35 | 0.88 | 0.71 |
| 5 | 620.3 | 24.4 | 0.12 | 3.82 | 8.43 | 0.80 | 0.84 |
| 6 | 664.0 | 26.1 | 0.12 | 4.72 | 10.41 | 0.70 | 0.92 |
| 7 | 699.4 | 27.5 | 0.12 | 5.54 | 12.22 | 0.59 | 0.96 |
| 8 | 727.9 | 28.7 | 0.12 | 6.28 | 13.84 | 0.47 | 0.98 |
| 9 | 751.0 | 29.6 | 0.12 | 6.91 | 15.24 | 0.35 | 0.99 |
| 10 | 769.6 | 30.3 | 0.12 | 7.46 | 16.45 | 0.24 | 1.00 |
| 11 | 784.7 | 30.9 | 0.12 | 7.92 | 17.46 | 0.15 | 1.00 |
| 12 | 796.9 | 31.4 | 0.12 | 8.31 | 18.32 | 0.09 | 1.00 |
| 13 | 806.7 | 31.8 | 0.12 | 8.63 | 19.03 | 0.05 | 1.00 |
| 14 | 814.7 | 32.1 | 0.12 | 8.90 | 19.62 | 0.02 | 1.00 |
| 15 | 821.1 | 32.3 | 0.12 | 9.12 | 20.10 | 0.00 | 1.00 |
| 16 | 826.3 | 32.5 | 0.12 | 9.30 | 20.50 | 0.00 | 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 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 395.3 | 389.1 | 202.9 | 510.9 | 162.3 | 39.8 | 32.6 | 10.9 | 6.7 | 2.7 | 1.3 | 0.7 | 0.3 | 0.2 | 0.1 | 0.1 | 1756.0 |
| 1977 | 351.5 | 265.8 | 246.0 | 118.6 | 289.4 | 90.9 | 22.2 | 18.0 | 6.0 | 3.6 | 1.5 | 0.7 | 0.4 | 0.2 | 0.1 | 0.1 | 1414.9 |
| 1978 | 467.5 | 236.6 | 168.3 | 144.2 | 67.6 | 163.5 | 51.2 | 12.5 | 10.1 | 3.3 | 2.0 | 0.8 | 0.4 | 0.2 | 0.1 | 0.1 | 1328.5 |
| 1979 | 418.5 | 311.3 | 147.1 | 96.6 | 80.4 | 37.3 | 90.0 | 28.1 | 6.8 | 5.5 | 1.8 | 1.1 | 0.4 | 0.2 | 0.1 | 0.1 | 1225.2 |
| 1980 | 212.4 | 277.8 | 192.1 | 83.5 | 53.2 | 43.9 | 20.3 | 48.7 | 15.1 | 3.6 | 2.9 | 0.9 | 0.6 | 0.2 | 0.1 | 0.1 | 955.5 |
| 1981 | 257.3 | 141.7 | 172.9 | 110.1 | 46.5 | 29.3 | 24.1 | 11.1 | 26.6 | 8.2 | 1.9 | 1.5 | 0.5 | 0.3 | 0.1 | 0.1 | 832.2 |
| 1982 | 474.2 | 173.5 | 92.3 | 109.7 | 69.2 | 29.1 | 18.3 | 14.9 | 6.8 | 16.1 | 4.9 | 1.2 | 0.9 | 0.3 | 0.2 | 0.1 | 1011.7 |
| 1983 | 496.0 | 311.1 | 104.9 | 51.8 | 59.6 | 37.2 | 15.5 | 9.7 | 7.8 | 3.5 | 8.2 | 2.5 | 0.6 | 0.5 | 0.2 | 0.2 | 1109.1 |
| 1984 | 338.5 | 294.2 | 149.5 | 44.9 | 20.6 | 23.2 | 14.2 | 5.8 | 3.6 | 2.8 | 1.3 | 2.9 | 0.9 | 0.2 | 0.2 | 0.1 | 902.9 |
| 1985 | 401.4 | 206.6 | 118.2 | 45.5 | 13.2 | 5.9 | 6.4 | 3.7 | 1.5 | 0.9 | 0.7 | 0.3 | 0.7 | 0.2 | 0.0 | 0.1 | 805.0 |
| 1986 | 230.9 | 265.1 | 115.3 | 56.1 | 20.8 | 5.7 | 2.4 | 2.4 | 1.3 | 0.5 | 0.3 | 0.2 | 0.1 | 0.2 | 0.1 | 0.0 | 701.5 |
| 1987 | 483.3 | 146.4 | 136.2 | 49.7 | 22.9 | 7.9 | 2.0 | 0.8 | 0.7 | 0.4 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 850.4 |
| 1988 | 289.7 | 303.7 | 74.0 | 61.2 | 21.5 | 9.4 | 3.0 | 0.7 | 0.3 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 763.9 |
| 1989 | 165.4 | 188.1 | 179.6 | 41.6 | 33.0 | 10.8 | 4.3 | 1.3 | 0.3 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 624.6 |
| 1990 | 113.2 | 108.7 | 108.1 | 91.8 | 20.5 | 15.4 | 4.7 | 1.7 | 0.5 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 464.7 |
| 1991 | 227.7 | 75.4 | 69.4 | 69.9 | 58.9 | 12.8 | 9.2 | 2.7 | 1.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 527.4 |
| 1992 | 470.8 | 141.3 | 43.1 | 48.7 | 49.9 | 41.6 | 8.9 | 6.3 | 1.8 | 0.6 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 813.3 |
| 1993 | 101.6 | 329.2 | 100.5 | 30.2 | 30.2 | 30.3 | 25.7 | 5.6 | 4.0 | 1.1 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 658.9 |
| 1994 | 314.5 | 72.7 | 243.6 | 65.4 | 14.3 | 13.7 | 13.8 | 11.9 | 2.6 | 1.9 | 0.5 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 755.3 |
| 1995 | 459.8 | 218.8 | 51.3 | 168.2 | 38.5 | 8.2 | 7.9 | 8.1 | 7.0 | 1.5 | 1.1 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 970.8 |
| 1996 | 432.0 | 324.6 | 158.5 | 36.2 | 101.2 | 22.4 | 4.8 | 4.7 | 4.8 | 4.2 | 0.9 | 0.7 | 0.2 | 0.1 | 0.0 | 0.0 | 1095.3 |
| 1997 | 280.0 | 295.1 | 221.2 | 104.8 | 19.6 | 52.7 | 11.8 | 2.6 | 2.5 | 2.6 | 2.3 | 0.5 | 0.4 | 0.1 | 0.0 | 0.0 | 996.1 |
| 1998 | 273.6 | 188.9 | 196.9 | 147.4 | 59.4 | 10.7 | 29.0 | 6.6 | 1.4 | 1.4 | 1.5 | 1.3 | 0.3 | 0.2 | 0.1 | 0.0 | 918.7 |
| 1999 | 333.8 | 194.1 | 137.7 | 138.4 | 86.0 | 32.8 | 5.9 | 16.3 | 3.7 | 0.8 | 0.8 | 0.9 | 0.7 | 0.2 | 0.1 | 0.1 | 952.4 |
| 2000 | 416.0 | 237.0 | 142.1 | 101.2 | 90.8 | 54.2 | 20.8 | 3.8 | 10.6 | 2.4 | 0.5 | 0.5 | 0.6 | 0.5 | 0.1 | 0.1 | 1081.2 |
| 2001 | 313.6 | 288.6 | 166.7 | 103.7 | 69.1 | 60.6 | 36.6 | 14.2 | 2.6 | 7.3 | 1.7 | 0.4 | 0.4 | 0.4 | 0.3 | 0.2 | 1066.5 |
| 2002 | 333.9 | 219.9 | 206.8 | 122.9 | 71.4 | 46.6 | 41.4 | 25.3 | 10.0 | 1.8 | 5.2 | 1.2 | 0.3 | 0.3 | 0.3 | 0.4 | 1087.5 |
| 2003 | 443.0 | 236.9 | 160.9 | 151.6 | 81.0 | 46.1 | 30.4 | 27.3 | 16.9 | 6.7 | 1.2 | 3.5 | 0.8 | 0.2 | 0.2 | 0.4 | 1206.9 |
| 2004 | 655.6 | 313.7 | 172.8 | 117.2 | 99.0 | 52.0 | 29.8 | 19.9 | 18.1 | 11.2 | 4.4 | 0.8 | 2.3 | 0.5 | 0.1 | 0.4 | 1498.0 |
| 2005 | 355.0 | 463.9 | 228.4 | 125.5 | 77.7 | 64.6 | 34.3 | 19.9 | 13.5 | 12.3 | 7.6 | 3.0 | 0.6 | 1.6 | 0.4 | 0.4 | 1408.6 |
| 2006 | 207.9 | 249.5 | 334.0 | 168.1 | 88.1 | 54.5 | 45.8 | 24.6 | 14.5 | 9.8 | 8.9 | 5.5 | 2.2 | 0.4 | 1.2 | 0.5 | 1215.5 |
| 2007 | 190.0 | 146.5 | 180.6 | 246.1 | 114.8 | 59.6 | 37.2 | 31.7 | 17.2 | 10.1 | 6.8 | 6.2 | 3.9 | 1.6 | 0.3 | 1.2 | 1053.9 |
| 2008 | 308.2 | 136.8 | 110.1 | 132.8 | 157.1 | 71.1 | 37.2 | 23.5 | 20.2 | 11.0 | 6.5 | 4.4 | 4.0 | 2.5 | 1.0 | 1.0 | 1027.3 |
| 2009 | 359.6 | 219.8 | 101.0 | 78.4 | 78.8 | 90.0 | 41.0 | 21.7 | 13.8 | 11.9 | 6.5 | 3.8 | 2.6 | 2.4 | 1.5 | 1.2 | 1034.1 |

*Table 3.3. Estimated female abundance at age (1000 fish) at start of year*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 395.3 | 374.7 | 188.7 | 448.6 | 130.3 | 28.1 | 19.2 | 5.1 | 2.3 | 0.6 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1593.3 |
| 1977 | 351.5 | 256.0 | 228.8 | 104.2 | 232.4 | 64.1 | 13.1 | 8.4 | 2.1 | 0.9 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1261.6 |
| 1978 | 467.5 | 227.9 | 156.5 | 126.6 | 54.3 | 115.3 | 30.2 | 5.8 | 3.5 | 0.8 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1188.8 |
| 1979 | 418.5 | 299.8 | 136.8 | 84.8 | 64.5 | 26.3 | 53.1 | 13.1 | 2.4 | 1.3 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1100.9 |
| 1980 | 212.4 | 267.5 | 178.7 | 73.3 | 42.7 | 30.9 | 12.0 | 22.7 | 5.2 | 0.9 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 846.9 |
| 1981 | 257.3 | 136.5 | 160.8 | 96.7 | 37.3 | 20.7 | 14.2 | 5.2 | 9.2 | 2.0 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 740.2 |
| 1982 | 474.2 | 167.1 | 85.8 | 96.3 | 55.6 | 20.5 | 10.8 | 7.0 | 2.4 | 3.9 | 0.8 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 924.3 |
| 1983 | 496.0 | 299.6 | 97.6 | 45.4 | 47.9 | 26.2 | 9.1 | 4.5 | 2.7 | 0.8 | 1.3 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 1031.3 |
| 1984 | 338.5 | 283.3 | 139.0 | 39.4 | 16.6 | 16.3 | 8.4 | 2.7 | 1.2 | 0.7 | 0.2 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 846.7 |
| 1985 | 401.4 | 198.9 | 109.9 | 40.0 | 10.6 | 4.2 | 3.7 | 1.7 | 0.5 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 771.2 |
| 1986 | 230.9 | 255.3 | 107.2 | 49.3 | 16.7 | 4.0 | 1.4 | 1.1 | 0.5 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 666.6 |
| 1987 | 483.3 | 141.0 | 126.6 | 43.6 | 18.4 | 5.6 | 1.2 | 0.4 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 820.3 |
| 1988 | 289.7 | 292.4 | 68.8 | 53.7 | 17.3 | 6.6 | 1.8 | 0.3 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 730.8 |
| 1989 | 165.4 | 181.2 | 167.0 | 36.5 | 26.5 | 7.6 | 2.6 | 0.6 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 587.5 |
| 1990 | 113.2 | 104.7 | 100.5 | 80.6 | 16.4 | 10.8 | 2.8 | 0.8 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 430.0 |
| 1991 | 227.7 | 72.6 | 64.6 | 61.4 | 47.3 | 9.0 | 5.5 | 1.3 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 489.7 |
| 1992 | 470.8 | 136.1 | 40.1 | 42.8 | 40.1 | 29.3 | 5.2 | 2.9 | 0.6 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 768.2 |
| 1993 | 101.6 | 317.0 | 93.4 | 26.5 | 24.2 | 21.4 | 15.1 | 2.6 | 1.4 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 603.7 |
| 1994 | 314.5 | 70.0 | 226.5 | 57.5 | 11.5 | 9.6 | 8.2 | 5.5 | 0.9 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 704.9 |
| 1995 | 459.8 | 210.7 | 47.7 | 147.7 | 30.9 | 5.8 | 4.6 | 3.8 | 2.4 | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 913.9 |
| 1996 | 432.0 | 312.6 | 147.4 | 31.8 | 81.3 | 15.8 | 2.8 | 2.2 | 1.7 | 1.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1028.7 |
| 1997 | 280.0 | 284.2 | 205.8 | 92.0 | 15.7 | 37.1 | 6.9 | 1.2 | 0.9 | 0.6 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 924.8 |
| 1998 | 273.6 | 181.9 | 183.1 | 129.4 | 47.7 | 7.5 | 17.1 | 3.1 | 0.5 | 0.3 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 844.7 |
| 1999 | 333.8 | 186.9 | 128.1 | 121.5 | 69.1 | 23.1 | 3.5 | 7.6 | 1.3 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 875.3 |
| 2000 | 416.0 | 228.2 | 132.2 | 88.8 | 72.9 | 38.2 | 12.3 | 1.8 | 3.7 | 0.6 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 994.8 |
| 2001 | 313.6 | 277.9 | 155.0 | 91.1 | 55.5 | 42.7 | 21.6 | 6.6 | 0.9 | 1.8 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 967.1 |
| 2002 | 333.9 | 211.8 | 192.3 | 107.9 | 57.4 | 32.9 | 24.4 | 11.8 | 3.4 | 0.4 | 0.8 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 977.1 |
| 2003 | 443.0 | 228.1 | 149.7 | 133.1 | 65.1 | 32.5 | 17.9 | 12.7 | 5.8 | 1.6 | 0.2 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 1090.0 |
| 2004 | 655.6 | 302.1 | 160.7 | 102.9 | 79.5 | 36.6 | 17.6 | 9.3 | 6.3 | 2.7 | 0.7 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 1374.1 |
| 2005 | 355.0 | 446.8 | 212.4 | 110.2 | 62.4 | 45.6 | 20.2 | 9.3 | 4.7 | 2.9 | 1.2 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 1270.9 |
| 2006 | 207.9 | 240.2 | 310.7 | 147.6 | 70.7 | 38.4 | 27.0 | 11.5 | 5.0 | 2.3 | 1.4 | 0.5 | 0.1 | 0.0 | 0.0 | 0.0 | 1063.3 |
| 2007 | 190.0 | 141.1 | 168.0 | 216.1 | 92.1 | 42.0 | 22.0 | 14.8 | 5.9 | 2.4 | 1.0 | 0.6 | 0.2 | 0.0 | 0.0 | 0.0 | 896.3 |
| 2008 | 308.2 | 131.7 | 102.4 | 116.6 | 126.1 | 50.1 | 21.9 | 10.9 | 7.0 | 2.6 | 1.0 | 0.4 | 0.2 | 0.1 | 0.0 | 0.0 | 879.3 |
| 2009 | 359.6 | 211.7 | 93.9 | 68.8 | 63.3 | 63.5 | 24.2 | 10.1 | 4.8 | 2.8 | 1.0 | 0.3 | 0.1 | 0.1 | 0.0 | 0.0 | 904.2 |

*Table 3.4. Estimated male abundance at age (1000 fish) at start of year*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 0.0 | 14.4 | 14.2 | 62.3 | 32.0 | 11.8 | 13.3 | 5.8 | 4.4 | 2.1 | 1.1 | 0.6 | 0.3 | 0.2 | 0.1 | 0.1 | 162.7 |
| 1977 | 0.0 | 9.8 | 17.2 | 14.5 | 57.0 | 26.8 | 9.1 | 9.6 | 3.9 | 2.8 | 1.2 | 0.6 | 0.3 | 0.2 | 0.1 | 0.1 | 153.3 |
| 1978 | 0.0 | 8.8 | 11.8 | 17.6 | 13.3 | 48.2 | 21.0 | 6.7 | 6.6 | 2.5 | 1.7 | 0.7 | 0.4 | 0.2 | 0.1 | 0.1 | 139.7 |
| 1979 | 0.0 | 11.5 | 10.3 | 11.8 | 15.8 | 11.0 | 36.9 | 15.0 | 4.5 | 4.2 | 1.5 | 1.0 | 0.4 | 0.2 | 0.1 | 0.1 | 124.2 |
| 1980 | 0.0 | 10.3 | 13.4 | 10.2 | 10.5 | 12.9 | 8.3 | 26.0 | 9.9 | 2.8 | 2.4 | 0.9 | 0.5 | 0.2 | 0.1 | 0.1 | 108.6 |
| 1981 | 0.0 | 5.2 | 12.1 | 13.4 | 9.2 | 8.7 | 9.9 | 5.9 | 17.4 | 6.2 | 1.6 | 1.4 | 0.5 | 0.3 | 0.1 | 0.1 | 92.0 |
| 1982 | 0.0 | 6.4 | 6.5 | 13.4 | 13.6 | 8.6 | 7.5 | 8.0 | 4.5 | 12.3 | 4.2 | 1.1 | 0.9 | 0.3 | 0.2 | 0.1 | 87.4 |
| 1983 | 0.0 | 11.5 | 7.3 | 6.3 | 11.7 | 11.0 | 6.4 | 5.2 | 5.1 | 2.7 | 7.0 | 2.3 | 0.6 | 0.5 | 0.2 | 0.2 | 77.8 |
| 1984 | 0.0 | 10.9 | 10.5 | 5.5 | 4.1 | 6.8 | 5.8 | 3.1 | 2.3 | 2.2 | 1.1 | 2.7 | 0.8 | 0.2 | 0.2 | 0.1 | 56.2 |
| 1985 | 0.0 | 7.6 | 8.3 | 5.6 | 2.6 | 1.7 | 2.6 | 2.0 | 1.0 | 0.7 | 0.6 | 0.3 | 0.6 | 0.2 | 0.0 | 0.1 | 33.8 |
| 1986 | 0.0 | 9.8 | 8.1 | 6.8 | 4.1 | 1.7 | 1.0 | 1.3 | 0.9 | 0.4 | 0.2 | 0.2 | 0.1 | 0.2 | 0.1 | 0.0 | 34.9 |
| 1987 | 0.0 | 5.4 | 9.5 | 6.1 | 4.5 | 2.3 | 0.8 | 0.4 | 0.5 | 0.3 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 30.1 |
| 1988 | 0.0 | 11.2 | 5.2 | 7.5 | 4.2 | 2.8 | 1.2 | 0.4 | 0.2 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 33.0 |
| 1989 | 0.0 | 7.0 | 12.6 | 5.1 | 6.5 | 3.2 | 1.8 | 0.7 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 37.1 |
| 1990 | 0.0 | 4.0 | 7.6 | 11.2 | 4.0 | 4.5 | 1.9 | 0.9 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.7 |
| 1991 | 0.0 | 2.8 | 4.9 | 8.5 | 11.6 | 3.8 | 3.8 | 1.4 | 0.6 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 37.7 |
| 1992 | 0.0 | 5.2 | 3.0 | 5.9 | 9.8 | 12.3 | 3.6 | 3.3 | 1.2 | 0.5 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 45.1 |
| 1993 | 0.0 | 12.2 | 7.0 | 3.7 | 5.9 | 8.9 | 10.5 | 3.0 | 2.6 | 0.9 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 55.2 |
| 1994 | 0.0 | 2.7 | 17.1 | 8.0 | 2.8 | 4.0 | 5.7 | 6.3 | 1.7 | 1.4 | 0.5 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 50.4 |
| 1995 | 0.0 | 8.1 | 3.6 | 20.5 | 7.6 | 2.4 | 3.2 | 4.3 | 4.6 | 1.2 | 0.9 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 56.8 |
| 1996 | 0.0 | 12.0 | 11.1 | 4.4 | 19.9 | 6.6 | 2.0 | 2.5 | 3.2 | 3.2 | 0.8 | 0.6 | 0.2 | 0.1 | 0.0 | 0.0 | 66.6 |
| 1997 | 0.0 | 10.9 | 15.5 | 12.8 | 3.9 | 15.5 | 4.8 | 1.4 | 1.6 | 2.0 | 1.9 | 0.5 | 0.3 | 0.1 | 0.0 | 0.0 | 71.3 |
| 1998 | 0.0 | 7.0 | 13.8 | 18.0 | 11.7 | 3.2 | 11.9 | 3.5 | 0.9 | 1.1 | 1.3 | 1.2 | 0.3 | 0.2 | 0.1 | 0.0 | 74.1 |
| 1999 | 0.0 | 7.2 | 9.6 | 16.9 | 16.9 | 9.7 | 2.4 | 8.7 | 2.5 | 0.6 | 0.7 | 0.8 | 0.7 | 0.2 | 0.1 | 0.1 | 77.1 |
| 2000 | 0.0 | 8.8 | 9.9 | 12.3 | 17.9 | 16.0 | 8.5 | 2.0 | 6.9 | 1.9 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 | 0.1 | 86.5 |
| 2001 | 0.0 | 10.7 | 11.7 | 12.7 | 13.6 | 17.9 | 15.0 | 7.6 | 1.7 | 5.6 | 1.4 | 0.3 | 0.4 | 0.4 | 0.3 | 0.2 | 99.4 |
| 2002 | 0.0 | 8.1 | 14.5 | 15.0 | 14.1 | 13.8 | 17.0 | 13.5 | 6.5 | 1.4 | 4.4 | 1.1 | 0.3 | 0.3 | 0.3 | 0.4 | 110.4 |
| 2003 | 0.0 | 8.8 | 11.3 | 18.5 | 16.0 | 13.6 | 12.4 | 14.6 | 11.0 | 5.1 | 1.0 | 3.1 | 0.8 | 0.2 | 0.2 | 0.4 | 116.9 |
| 2004 | 0.0 | 11.6 | 12.1 | 14.3 | 19.5 | 15.3 | 12.2 | 10.6 | 11.8 | 8.5 | 3.8 | 0.7 | 2.2 | 0.5 | 0.1 | 0.4 | 123.9 |
| 2005 | 0.0 | 17.2 | 16.0 | 15.3 | 15.3 | 19.1 | 14.1 | 10.6 | 8.8 | 9.3 | 6.5 | 2.7 | 0.5 | 1.6 | 0.4 | 0.4 | 137.7 |
| 2006 | 0.0 | 9.2 | 23.4 | 20.5 | 17.4 | 16.1 | 18.8 | 13.1 | 9.5 | 7.4 | 7.6 | 5.0 | 2.1 | 0.4 | 1.2 | 0.5 | 152.2 |
| 2007 | 0.0 | 5.4 | 12.6 | 30.0 | 22.6 | 17.6 | 15.3 | 16.9 | 11.2 | 7.7 | 5.8 | 5.7 | 3.7 | 1.5 | 0.3 | 1.2 | 157.6 |
| 2008 | 0.0 | 5.1 | 7.7 | 16.2 | 30.9 | 21.0 | 15.2 | 12.5 | 13.2 | 8.3 | 5.5 | 4.0 | 3.8 | 2.5 | 1.0 | 1.0 | 147.9 |
| 2009 | 0.0 | 8.1 | 7.1 | 9.6 | 15.5 | 26.6 | 16.8 | 11.6 | 9.1 | 9.1 | 5.5 | 3.5 | 2.5 | 2.3 | 1.5 | 1.2 | 129.8 |

*Table 3.5. Estimated biomass at age (mt) at start of year*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 183.0 | 432.4 | 395.7 | 1471.5 | 620.2 | 188.1 | 180.5 | 68.4 | 46.2 | 20.1 | 10.5 | 5.6 | 3.0 | 1.6 | 0.9 | 1.1 | 3628.7 |
| 1977 | 162.7 | 295.4 | 479.7 | 341.7 | 1106.3 | 428.9 | 122.9 | 112.9 | 41.4 | 27.1 | 11.5 | 5.9 | 3.1 | 1.7 | 0.9 | 1.1 | 3143.0 |
| 1978 | 216.3 | 263.0 | 328.2 | 415.4 | 258.3 | 772.0 | 284.0 | 78.3 | 69.9 | 24.9 | 15.9 | 6.7 | 3.4 | 1.8 | 0.9 | 1.1 | 2740.0 |
| 1979 | 193.7 | 345.9 | 286.8 | 278.2 | 307.2 | 176.2 | 498.8 | 176.1 | 47.1 | 40.7 | 14.2 | 8.9 | 3.7 | 1.9 | 1.0 | 1.1 | 2381.3 |
| 1980 | 98.3 | 308.7 | 374.6 | 240.6 | 203.4 | 207.1 | 112.5 | 305.5 | 104.5 | 27.1 | 22.9 | 7.8 | 4.9 | 2.0 | 1.0 | 1.1 | 2021.9 |
| 1981 | 119.1 | 157.5 | 337.1 | 317.3 | 177.5 | 138.4 | 133.6 | 69.7 | 183.6 | 60.9 | 15.4 | 12.8 | 4.4 | 2.7 | 1.1 | 1.1 | 1732.0 |
| 1982 | 219.5 | 192.8 | 179.9 | 316.0 | 264.5 | 137.2 | 101.3 | 93.6 | 47.2 | 120.4 | 38.9 | 9.7 | 8.0 | 2.7 | 1.7 | 1.4 | 1734.6 |
| 1983 | 229.5 | 345.7 | 204.6 | 149.1 | 227.9 | 175.5 | 85.9 | 60.6 | 54.1 | 26.3 | 65.3 | 20.7 | 5.1 | 4.2 | 1.4 | 1.6 | 1657.4 |
| 1984 | 156.7 | 326.9 | 291.6 | 129.3 | 78.9 | 109.3 | 78.7 | 36.5 | 24.7 | 21.1 | 10.0 | 24.2 | 7.6 | 1.9 | 1.5 | 1.1 | 1299.9 |
| 1985 | 185.8 | 229.5 | 230.5 | 131.1 | 50.3 | 27.8 | 35.2 | 23.3 | 10.1 | 6.4 | 5.2 | 2.4 | 5.7 | 1.8 | 0.4 | 0.6 | 946.2 |
| 1986 | 106.9 | 294.5 | 224.7 | 161.6 | 79.5 | 27.1 | 13.4 | 15.3 | 9.3 | 3.7 | 2.2 | 1.7 | 0.8 | 1.9 | 0.6 | 0.3 | 943.5 |
| 1987 | 223.7 | 162.7 | 265.5 | 143.1 | 87.4 | 37.3 | 11.0 | 4.8 | 4.8 | 2.6 | 1.0 | 0.6 | 0.4 | 0.2 | 0.4 | 0.2 | 945.7 |
| 1988 | 134.1 | 337.4 | 144.2 | 176.2 | 82.2 | 44.4 | 16.8 | 4.5 | 1.7 | 1.6 | 0.8 | 0.3 | 0.2 | 0.1 | 0.1 | 0.2 | 944.9 |
| 1989 | 76.5 | 209.1 | 350.2 | 119.8 | 126.0 | 51.0 | 24.0 | 8.0 | 1.9 | 0.7 | 0.6 | 0.3 | 0.1 | 0.1 | 0.0 | 0.1 | 968.3 |
| 1990 | 52.4 | 120.8 | 210.7 | 264.3 | 78.2 | 72.5 | 26.1 | 11.0 | 3.3 | 0.7 | 0.2 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 840.6 |
| 1991 | 105.4 | 83.7 | 135.4 | 201.5 | 225.3 | 60.4 | 51.2 | 17.0 | 6.7 | 1.9 | 0.4 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 889.1 |
| 1992 | 217.9 | 157.0 | 84.1 | 140.3 | 190.7 | 196.5 | 49.1 | 39.3 | 12.4 | 4.7 | 1.3 | 0.3 | 0.1 | 0.1 | 0.0 | 0.0 | 1093.8 |
| 1993 | 47.0 | 365.8 | 195.9 | 87.0 | 115.3 | 143.1 | 142.3 | 34.9 | 27.6 | 8.6 | 3.2 | 0.9 | 0.2 | 0.1 | 0.0 | 0.0 | 1171.9 |
| 1994 | 145.6 | 80.8 | 475.0 | 188.5 | 54.8 | 64.5 | 76.7 | 74.5 | 18.0 | 14.0 | 4.3 | 1.6 | 0.4 | 0.1 | 0.0 | 0.0 | 1198.8 |
| 1995 | 212.8 | 243.1 | 100.0 | 484.5 | 147.0 | 38.6 | 43.6 | 50.6 | 48.4 | 11.5 | 8.8 | 2.7 | 1.0 | 0.3 | 0.1 | 0.0 | 1392.8 |
| 1996 | 199.9 | 360.7 | 309.1 | 104.2 | 386.9 | 105.7 | 26.6 | 29.3 | 33.5 | 31.4 | 7.3 | 5.5 | 1.7 | 0.6 | 0.2 | 0.1 | 1602.6 |
| 1997 | 129.6 | 327.9 | 431.4 | 301.9 | 74.9 | 248.6 | 65.2 | 16.0 | 17.4 | 19.5 | 18.0 | 4.2 | 3.1 | 0.9 | 0.3 | 0.1 | 1659.1 |
| 1998 | 126.6 | 209.9 | 383.9 | 424.5 | 227.2 | 50.5 | 160.9 | 41.2 | 10.0 | 10.6 | 11.8 | 10.7 | 2.5 | 1.9 | 0.6 | 0.3 | 1673.0 |
| 1999 | 154.5 | 215.7 | 268.6 | 398.6 | 328.8 | 154.7 | 32.9 | 102.5 | 25.9 | 6.2 | 6.5 | 7.1 | 6.5 | 1.5 | 1.1 | 0.5 | 1711.4 |
| 2000 | 192.5 | 263.3 | 277.1 | 291.5 | 346.9 | 255.8 | 115.2 | 23.9 | 73.3 | 18.2 | 4.3 | 4.4 | 4.8 | 4.4 | 1.0 | 1.1 | 1877.8 |
| 2001 | 145.2 | 320.7 | 325.1 | 298.8 | 264.1 | 286.2 | 202.6 | 89.0 | 18.2 | 54.7 | 13.3 | 3.1 | 3.2 | 3.5 | 3.1 | 1.5 | 2032.3 |
| 2002 | 154.5 | 244.4 | 403.2 | 353.9 | 273.0 | 220.1 | 229.3 | 158.7 | 68.8 | 13.8 | 40.9 | 9.9 | 2.3 | 2.4 | 2.5 | 3.3 | 2181.1 |
| 2003 | 205.0 | 263.2 | 313.8 | 436.5 | 309.6 | 217.4 | 168.3 | 171.2 | 116.8 | 49.7 | 9.8 | 28.8 | 7.0 | 1.6 | 1.6 | 4.0 | 2304.3 |
| 2004 | 303.4 | 348.5 | 336.9 | 337.7 | 378.4 | 245.3 | 165.4 | 124.9 | 125.2 | 83.7 | 35.1 | 6.8 | 20.1 | 4.8 | 1.1 | 3.8 | 2521.2 |
| 2005 | 164.3 | 515.5 | 445.4 | 361.5 | 296.8 | 305.0 | 190.1 | 125.2 | 93.1 | 91.5 | 60.3 | 25.0 | 4.9 | 14.2 | 3.4 | 3.4 | 2699.6 |
| 2006 | 96.2 | 277.2 | 651.4 | 484.1 | 336.7 | 257.1 | 254.1 | 154.5 | 100.1 | 73.0 | 70.6 | 46.0 | 19.1 | 3.7 | 10.7 | 5.0 | 2839.5 |
| 2007 | 87.9 | 162.8 | 352.3 | 708.8 | 438.6 | 281.2 | 206.3 | 198.8 | 118.8 | 75.4 | 54.2 | 51.8 | 33.8 | 13.9 | 2.7 | 11.3 | 2798.6 |
| 2008 | 142.7 | 152.0 | 214.6 | 382.6 | 600.3 | 335.5 | 206.1 | 147.3 | 139.7 | 81.8 | 51.2 | 36.3 | 34.7 | 22.5 | 9.2 | 9.0 | 2565.6 |
| 2009 | 166.4 | 244.2 | 196.9 | 225.8 | 301.3 | 424.9 | 227.4 | 136.1 | 95.7 | 88.9 | 51.3 | 31.7 | 22.5 | 21.4 | 13.7 | 11.0 | 2259.3 |

*Table 3.6. Estimated biomass at age (1000 lb) at start of year*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 403.4 | 953.3 | 872.3 | 3244.2 | 1367.3 | 414.6 | 397.8 | 150.8 | 101.9 | 44.4 | 23.0 | 12.2 | 6.6 | 3.6 | 2.0 | 2.4 | 7999.9 |
| 1977 | 358.6 | 651.2 | 1057.5 | 753.3 | 2438.9 | 945.5 | 270.9 | 248.9 | 91.3 | 59.7 | 25.4 | 12.9 | 6.9 | 3.7 | 2.0 | 2.4 | 6929.1 |
| 1978 | 477.0 | 579.7 | 723.6 | 915.8 | 569.4 | 1701.9 | 626.0 | 172.6 | 154.2 | 54.9 | 35.1 | 14.7 | 7.5 | 3.9 | 2.1 | 2.4 | 6040.8 |
| 1979 | 427.0 | 762.6 | 632.2 | 613.4 | 677.3 | 388.5 | 1099.6 | 388.2 | 103.7 | 89.8 | 31.2 | 19.6 | 8.2 | 4.1 | 2.1 | 2.4 | 5250.0 |
| 1980 | 216.7 | 680.5 | 825.8 | 530.4 | 448.4 | 456.6 | 248.0 | 673.5 | 230.5 | 59.6 | 50.4 | 17.2 | 10.8 | 4.4 | 2.2 | 2.4 | 4457.6 |
| 1981 | 262.5 | 347.1 | 743.1 | 699.4 | 391.4 | 305.2 | 294.5 | 153.6 | 404.7 | 134.2 | 33.9 | 28.2 | 9.6 | 6.0 | 2.4 | 2.5 | 3818.4 |
| 1982 | 483.8 | 425.0 | 396.7 | 696.7 | 583.1 | 302.5 | 223.3 | 206.4 | 104.1 | 265.3 | 85.8 | 21.3 | 17.6 | 5.9 | 3.7 | 3.0 | 3824.2 |
| 1983 | 506.0 | 762.0 | 451.0 | 328.6 | 502.4 | 386.9 | 189.3 | 133.6 | 119.2 | 58.1 | 144.1 | 45.7 | 11.3 | 9.2 | 3.1 | 3.4 | 3654.0 |
| 1984 | 345.4 | 720.7 | 642.8 | 285.1 | 173.9 | 240.9 | 173.4 | 80.4 | 54.4 | 46.6 | 22.0 | 53.4 | 16.9 | 4.1 | 3.3 | 2.3 | 2865.8 |
| 1985 | 409.5 | 506.0 | 508.1 | 289.0 | 111.0 | 61.3 | 77.6 | 51.5 | 22.3 | 14.1 | 11.6 | 5.3 | 12.7 | 3.9 | 1.0 | 1.3 | 2086.1 |
| 1986 | 235.6 | 649.4 | 495.5 | 356.3 | 175.3 | 59.8 | 29.5 | 33.7 | 20.4 | 8.2 | 4.9 | 3.9 | 1.7 | 4.1 | 1.3 | 0.7 | 2080.1 |
| 1987 | 493.1 | 358.6 | 585.4 | 315.5 | 192.7 | 82.2 | 24.3 | 10.5 | 10.6 | 5.8 | 2.2 | 1.2 | 0.9 | 0.4 | 1.0 | 0.5 | 2084.9 |
| 1988 | 295.6 | 743.9 | 318.0 | 388.5 | 181.1 | 97.9 | 37.1 | 9.8 | 3.8 | 3.6 | 1.9 | 0.7 | 0.4 | 0.3 | 0.1 | 0.4 | 2083.1 |
| 1989 | 168.7 | 460.9 | 772.0 | 264.1 | 277.7 | 112.5 | 53.0 | 17.6 | 4.2 | 1.5 | 1.3 | 0.6 | 0.2 | 0.1 | 0.1 | 0.2 | 2134.8 |
| 1990 | 115.5 | 266.2 | 464.6 | 582.7 | 172.4 | 159.9 | 57.4 | 24.2 | 7.3 | 1.6 | 0.5 | 0.4 | 0.2 | 0.1 | 0.0 | 0.1 | 1853.2 |
| 1991 | 232.3 | 184.6 | 298.4 | 444.1 | 496.7 | 133.2 | 113.0 | 37.4 | 14.7 | 4.2 | 0.9 | 0.3 | 0.2 | 0.1 | 0.0 | 0.1 | 1960.2 |
| 1992 | 480.4 | 346.2 | 185.4 | 309.4 | 420.4 | 433.2 | 108.4 | 86.6 | 27.3 | 10.3 | 2.8 | 0.6 | 0.2 | 0.1 | 0.1 | 0.1 | 2411.4 |
| 1993 | 103.7 | 806.4 | 431.9 | 191.9 | 254.2 | 315.5 | 313.7 | 76.9 | 60.8 | 18.9 | 7.0 | 1.9 | 0.4 | 0.1 | 0.1 | 0.1 | 2583.6 |
| 1994 | 320.9 | 178.2 | 1047.2 | 415.6 | 120.8 | 142.2 | 169.2 | 164.3 | 39.7 | 30.8 | 9.4 | 3.5 | 0.9 | 0.2 | 0.1 | 0.1 | 2643.0 |
| 1995 | 469.1 | 536.0 | 220.5 | 1068.1 | 324.1 | 85.1 | 96.1 | 111.6 | 106.7 | 25.3 | 19.3 | 5.8 | 2.1 | 0.6 | 0.1 | 0.1 | 3070.6 |
| 1996 | 440.8 | 795.2 | 681.4 | 229.8 | 852.9 | 233.0 | 58.6 | 64.6 | 73.8 | 69.2 | 16.2 | 12.2 | 3.7 | 1.3 | 0.4 | 0.1 | 3533.1 |
| 1997 | 285.6 | 722.9 | 951.1 | 665.7 | 165.0 | 548.1 | 143.7 | 35.3 | 38.4 | 43.0 | 39.7 | 9.2 | 6.9 | 2.1 | 0.8 | 0.3 | 3657.8 |
| 1998 | 279.2 | 462.8 | 846.3 | 935.8 | 500.9 | 111.2 | 354.8 | 90.9 | 22.0 | 23.4 | 25.9 | 23.7 | 5.5 | 4.1 | 1.2 | 0.6 | 3688.3 |
| 1999 | 340.5 | 475.4 | 592.1 | 878.8 | 725.0 | 341.1 | 72.5 | 226.0 | 57.1 | 13.6 | 14.3 | 15.6 | 14.3 | 3.3 | 2.4 | 1.1 | 3773.0 |
| 2000 | 424.4 | 580.6 | 611.0 | 642.6 | 764.7 | 564.0 | 254.1 | 52.7 | 161.7 | 40.1 | 9.4 | 9.7 | 10.7 | 9.7 | 2.2 | 2.3 | 4139.7 |
| 2001 | 320.0 | 707.1 | 716.7 | 658.7 | 582.3 | 631.0 | 446.7 | 196.3 | 40.1 | 120.6 | 29.4 | 6.8 | 7.1 | 7.7 | 6.9 | 3.2 | 4480.4 |
| 2002 | 340.7 | 538.8 | 889.0 | 780.3 | 601.9 | 485.1 | 505.5 | 349.9 | 151.7 | 30.4 | 90.2 | 21.8 | 5.0 | 5.2 | 5.6 | 7.3 | 4808.5 |
| 2003 | 452.0 | 580.3 | 691.8 | 962.3 | 682.6 | 479.3 | 371.0 | 377.5 | 257.4 | 109.5 | 21.6 | 63.4 | 15.3 | 3.5 | 3.6 | 8.9 | 5080.2 |
| 2004 | 668.9 | 768.4 | 742.7 | 744.5 | 834.2 | 540.8 | 364.7 | 275.5 | 275.9 | 184.6 | 77.3 | 15.1 | 44.3 | 10.6 | 2.4 | 8.4 | 5558.4 |
| 2005 | 362.2 | 1136.5 | 981.9 | 796.9 | 654.3 | 672.4 | 419.1 | 275.9 | 205.3 | 201.8 | 133.0 | 55.1 | 10.8 | 31.4 | 7.5 | 7.5 | 5951.7 |
| 2006 | 212.1 | 611.1 | 1436.0 | 1067.3 | 742.3 | 566.8 | 560.2 | 340.6 | 220.6 | 160.9 | 155.8 | 101.4 | 42.0 | 8.2 | 23.6 | 11.1 | 6260.1 |
| 2007 | 193.9 | 358.9 | 776.6 | 1562.7 | 966.9 | 620.0 | 454.8 | 438.2 | 262.0 | 166.3 | 119.4 | 114.2 | 74.4 | 30.6 | 5.9 | 24.9 | 6169.8 |
| 2008 | 314.5 | 335.1 | 473.2 | 843.6 | 1323.5 | 739.7 | 454.4 | 324.8 | 307.9 | 180.4 | 112.8 | 80.0 | 76.6 | 49.5 | 20.2 | 19.9 | 5656.2 |
| 2009 | 366.9 | 538.4 | 434.1 | 497.9 | 664.3 | 936.7 | 501.4 | 300.2 | 211.1 | 196.1 | 113.1 | 69.9 | 49.6 | 47.1 | 30.3 | 24.2 | 4981.0 |

*Table 3.7. 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, mt) in April (time of peak spawning). The* $\mathrm{MSST}$ *is defined by* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{MSY}}$*, with constant* $M = 0.14$*. SPR is static spawning potential ratio, and Prop.male is proportion of the total population that is male.*

| Year | $F$ | $F/F_{\mathrm{MSY}}$ | B | $B/B_{\mathrm{unfished}}$ | SSB | $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ | $SSB/\mathrm{MSST}$ | SPR | Prop.male |
|---|---|---|---|---|---|---|---|---|---|
| 1976 | 0.503 | 2.38 | 3629 | 0.3051 | 2127 | 0.836 | 0.972 | 0.0942 | 0.0927 |
| 1977 | 0.471 | 2.23 | 3143 | 0.2643 | 1957 | 0.769 | 0.894 | 0.0965 | 0.1084 |
| 1978 | 0.508 | 2.40 | 2740 | 0.2304 | 1688 | 0.663 | 0.771 | 0.0887 | 0.1052 |
| 1979 | 0.521 | 2.46 | 2381 | 0.2002 | 1423 | 0.559 | 0.650 | 0.0856 | 0.1014 |
| 1980 | 0.506 | 2.39 | 2022 | 0.1700 | 1220 | 0.479 | 0.557 | 0.0887 | 0.1137 |
| 1981 | 0.392 | 1.85 | 1732 | 0.1456 | 1082 | 0.425 | 0.494 | 0.1275 | 0.1106 |
| 1982 | 0.557 | 2.63 | 1735 | 0.1459 | 982 | 0.386 | 0.448 | 0.0800 | 0.0864 |
| 1983 | 0.923 | 4.36 | 1657 | 0.1394 | 781 | 0.307 | 0.357 | 0.0360 | 0.0701 |
| 1984 | 1.373 | 6.49 | 1300 | 0.1093 | 520 | 0.204 | 0.238 | 0.0234 | 0.0622 |
| 1985 | 1.056 | 4.99 | 946 | 0.0796 | 372 | 0.146 | 0.170 | 0.0526 | 0.0419 |
| 1986 | 1.353 | 6.39 | 944 | 0.0793 | 382 | 0.150 | 0.174 | 0.0404 | 0.0497 |
| 1987 | 1.149 | 5.43 | 946 | 0.0795 | 352 | 0.138 | 0.161 | 0.0424 | 0.0354 |
| 1988 | 1.045 | 4.94 | 945 | 0.0794 | 395 | 0.155 | 0.181 | 0.0698 | 0.0432 |
| 1989 | 1.032 | 4.87 | 968 | 0.0814 | 450 | 0.177 | 0.205 | 0.0597 | 0.0594 |
| 1990 | 0.580 | 2.74 | 841 | 0.0707 | 468 | 0.184 | 0.214 | 0.1186 | 0.0746 |
| 1991 | 0.353 | 1.67 | 889 | 0.0748 | 525 | 0.206 | 0.240 | 0.1463 | 0.0715 |
| 1992 | 0.338 | 1.60 | 1094 | 0.0920 | 580 | 0.228 | 0.265 | 0.1565 | 0.0555 |
| 1993 | 0.634 | 3.00 | 1172 | 0.0985 | 627 | 0.246 | 0.286 | 0.0978 | 0.0838 |
| 1994 | 0.402 | 1.90 | 1199 | 0.1008 | 638 | 0.251 | 0.291 | 0.1324 | 0.0668 |
| 1995 | 0.383 | 1.81 | 1393 | 0.1171 | 723 | 0.284 | 0.330 | 0.1462 | 0.0586 |
| 1996 | 0.494 | 2.33 | 1603 | 0.1348 | 808 | 0.317 | 0.369 | 0.1046 | 0.0608 |
| 1997 | 0.446 | 2.11 | 1659 | 0.1395 | 883 | 0.347 | 0.403 | 0.1100 | 0.0716 |
| 1998 | 0.439 | 2.07 | 1673 | 0.1407 | 946 | 0.372 | 0.432 | 0.1349 | 0.0806 |
| 1999 | 0.305 | 1.44 | 1711 | 0.1439 | 1014 | 0.398 | 0.463 | 0.1853 | 0.0809 |
| 2000 | 0.244 | 1.15 | 1878 | 0.1579 | 1126 | 0.442 | 0.514 | 0.2030 | 0.0800 |
| 2001 | 0.234 | 1.10 | 2032 | 0.1709 | 1265 | 0.497 | 0.578 | 0.2196 | 0.0932 |
| 2002 | 0.279 | 1.32 | 2181 | 0.1834 | 1376 | 0.540 | 0.628 | 0.1954 | 0.1015 |
| 2003 | 0.284 | 1.34 | 2304 | 0.1938 | 1438 | 0.565 | 0.657 | 0.1898 | 0.0969 |
| 2004 | 0.267 | 1.26 | 2521 | 0.2120 | 1507 | 0.592 | 0.688 | 0.1986 | 0.0827 |
| 2005 | 0.195 | 0.92 | 2700 | 0.2270 | 1685 | 0.662 | 0.770 | 0.2469 | 0.0978 |
| 2006 | 0.231 | 1.09 | 2840 | 0.2388 | 1880 | 0.738 | 0.859 | 0.2200 | 0.1252 |
| 2007 | 0.322 | 1.52 | 2799 | 0.2353 | 1917 | 0.753 | 0.876 | 0.1832 | 0.1495 |
| 2008 | 0.400 | 1.89 | 2566 | 0.2157 | 1730 | 0.680 | 0.791 | 0.1468 | 0.1440 |
| 2009 | . | . | 2259 | 0.1900 | . | . | . | . | 0.1256 |

*Table 3.8. Selectivity at age (end-of-assessment time period) for commercial lines (cl), commercial other (co), headboat (hb), general recreational (rec), commercial lines discard mortalities (D.cl), headboat discard mortalities (D.hb), general recreational discard mortalities (D.rec), selectivity of landings averaged across fisheries (L.avg), and selectivity of discard mortalities averaged across fisheries (D.avg). TL is total length.*

| Age | TL(mm) | TL(in) | cl | co | hb | rec | D.cl | D.hb | D.rec | L.avg | D.avg | L.avg+D.avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 313.9 | 12.4 | 0.0012 | 0.0387 | 0.0013 | 0.0002 | 0.5561 | 0.5561 | 0.5561 | 0.0011 | 0.1185 | 0.1196 |
| 2 | 416.4 | 16.4 | 0.0148 | 0.1488 | 0.0601 | 0.0106 | 1.0000 | 1.0000 | 1.0000 | 0.0150 | 0.2131 | 0.2281 |
| 3 | 499.3 | 19.7 | 0.1554 | 0.4602 | 0.7605 | 0.3628 | 0.5402 | 0.5402 | 0.5402 | 0.2832 | 0.1151 | 0.3984 |
| 4 | 566.2 | 22.3 | 0.6932 | 0.8835 | 0.9937 | 0.9681 | 0.1717 | 0.1717 | 0.1717 | 0.8474 | 0.0366 | 0.8840 |
| 5 | 620.3 | 24.4 | 0.9652 | 1.0000 | 0.9999 | 0.9994 | 0.0519 | 0.0519 | 0.0519 | 0.9834 | 0.0111 | 0.9945 |
| 6 | 664.0 | 26.1 | 0.9971 | 0.8536 | 1.0000 | 1.0000 | 0.0181 | 0.0181 | 0.0181 | 0.9961 | 0.0039 | 1.0000 |
| 7 | 699.4 | 27.5 | 0.9998 | 0.6526 | 1.0000 | 1.0000 | 0.0076 | 0.0076 | 0.0076 | 0.9953 | 0.0016 | 0.9969 |
| 8 | 727.9 | 28.7 | 1.0000 | 0.4739 | 1.0000 | 1.0000 | 0.0037 | 0.0037 | 0.0037 | 0.9936 | 0.0008 | 0.9944 |
| 9 | 751.0 | 29.6 | 1.0000 | 0.3334 | 1.0000 | 1.0000 | 0.0021 | 0.0021 | 0.0021 | 0.9922 | 0.0005 | 0.9927 |
| 10 | 769.6 | 30.3 | 1.0000 | 0.2295 | 1.0000 | 1.0000 | 0.0013 | 0.0013 | 0.0013 | 0.9912 | 0.0003 | 0.9915 |
| 11 | 784.7 | 30.9 | 1.0000 | 0.1556 | 1.0000 | 1.0000 | 0.0009 | 0.0009 | 0.0009 | 0.9905 | 0.0002 | 0.9907 |
| 12 | 796.9 | 31.4 | 1.0000 | 0.1044 | 1.0000 | 1.0000 | 0.0007 | 0.0007 | 0.0007 | 0.9900 | 0.0001 | 0.9901 |
| 13 | 806.7 | 31.8 | 1.0000 | 0.0695 | 1.0000 | 1.0000 | 0.0006 | 0.0006 | 0.0006 | 0.9896 | 0.0001 | 0.9897 |
| 14 | 814.7 | 32.1 | 1.0000 | 0.0460 | 1.0000 | 1.0000 | 0.0005 | 0.0005 | 0.0005 | 0.9894 | 0.0001 | 0.9895 |
| 15 | 821.1 | 32.3 | 1.0000 | 0.0304 | 1.0000 | 1.0000 | 0.0004 | 0.0004 | 0.0004 | 0.9892 | 0.0001 | 0.9893 |
| 16 | 826.3 | 32.5 | 1.0000 | 0.0200 | 1.0000 | 1.0000 | 0.0003 | 0.0003 | 0.0003 | 0.9891 | 0.0001 | 0.9892 |

*Table 3.9. Estimated time series of fully selected fishing mortality rates for commercial lines (F.cl), commercial other (F.co), headboat (F.hb), general recreational (F.rec), commercial lines discard mortalities (F.cl.D), headboat discard mortalities (F.hb.D), general recreational discard mortalities (F.rec.D). Also shown is apical F, the maximum F at age summed across fleets, which may not equal the sum of fully selected F's because of dome-shaped selectivities.*

| Year | F.cl | F.co | F.hb | F.rec | F.cl.D | F.hb.D | F.rec.D | Apical F |
|---|---|---|---|---|---|---|---|---|
| 1976 | 0.156 | 0.037 | 0.005 | 0.341 | 0.000 | 0.000 | 0.000 | 0.503 |
| 1977 | 0.122 | 0.038 | 0.008 | 0.341 | 0.000 | 0.000 | 0.000 | 0.471 |
| 1978 | 0.158 | 0.054 | 0.008 | 0.341 | 0.000 | 0.000 | 0.000 | 0.508 |
| 1979 | 0.162 | 0.056 | 0.017 | 0.341 | 0.000 | 0.000 | 0.000 | 0.521 |
| 1980 | 0.147 | 0.048 | 0.017 | 0.341 | 0.000 | 0.000 | 0.000 | 0.506 |
| 1981 | 0.186 | 0.066 | 0.019 | 0.187 | 0.000 | 0.000 | 0.013 | 0.392 |
| 1982 | 0.202 | 0.064 | 0.016 | 0.340 | 0.000 | 0.000 | 0.010 | 0.557 |
| 1983 | 0.268 | 0.074 | 0.027 | 0.627 | 0.000 | 0.000 | 0.070 | 0.923 |
| 1984 | 0.529 | 0.108 | 0.033 | 0.810 | 0.004 | 0.014 | 0.101 | 1.373 |
| 1985 | 0.669 | 0.084 | 0.039 | 0.347 | 0.004 | 0.014 | 0.004 | 1.056 |
| 1986 | 0.934 | 0.108 | 0.025 | 0.393 | 0.004 | 0.014 | 0.023 | 1.353 |
| 1987 | 0.735 | 0.098 | 0.033 | 0.380 | 0.004 | 0.014 | 0.070 | 1.149 |
| 1988 | 0.871 | 0.084 | 0.021 | 0.153 | 0.004 | 0.014 | 0.029 | 1.045 |
| 1989 | 0.736 | 0.086 | 0.014 | 0.281 | 0.004 | 0.014 | 0.010 | 1.032 |
| 1990 | 0.495 | 0.085 | 0.031 | 0.054 | 0.004 | 0.014 | 0.030 | 0.580 |
| 1991 | 0.314 | 0.064 | 0.012 | 0.027 | 0.004 | 0.014 | 0.200 | 0.353 |
| 1992 | 0.117 | 0.032 | 0.025 | 0.163 | 0.005 | 0.014 | 0.083 | 0.338 |
| 1993 | 0.180 | 0.014 | 0.028 | 0.413 | 0.004 | 0.014 | 0.042 | 0.634 |
| 1994 | 0.170 | 0.008 | 0.021 | 0.203 | 0.009 | 0.014 | 0.089 | 0.402 |
| 1995 | 0.174 | 0.006 | 0.023 | 0.181 | 0.005 | 0.014 | 0.067 | 0.383 |
| 1996 | 0.211 | 0.011 | 0.023 | 0.248 | 0.004 | 0.014 | 0.126 | 0.494 |
| 1997 | 0.224 | 0.010 | 0.026 | 0.184 | 0.006 | 0.014 | 0.146 | 0.446 |
| 1998 | 0.257 | 0.018 | 0.032 | 0.133 | 0.005 | 0.014 | 0.057 | 0.439 |
| 1999 | 0.206 | 0.008 | 0.022 | 0.070 | 0.006 | 0.014 | 0.055 | 0.305 |
| 2000 | 0.160 | 0.005 | 0.016 | 0.063 | 0.005 | 0.014 | 0.098 | 0.244 |
| 2001 | 0.141 | 0.018 | 0.013 | 0.061 | 0.003 | 0.014 | 0.080 | 0.234 |
| 2002 | 0.134 | 0.012 | 0.011 | 0.123 | 0.009 | 0.014 | 0.053 | 0.279 |
| 2003 | 0.118 | 0.008 | 0.010 | 0.148 | 0.004 | 0.014 | 0.062 | 0.284 |
| 2004 | 0.107 | 0.011 | 0.026 | 0.122 | 0.003 | 0.014 | 0.064 | 0.267 |
| 2005 | 0.068 | 0.004 | 0.024 | 0.096 | 0.003 | 0.026 | 0.066 | 0.195 |
| 2006 | 0.095 | 0.002 | 0.009 | 0.123 | 0.002 | 0.009 | 0.078 | 0.231 |
| 2007 | 0.149 | 0.004 | 0.009 | 0.159 | 0.005 | 0.012 | 0.034 | 0.322 |
| 2008 | 0.168 | 0.003 | 0.006 | 0.222 | 0.001 | 0.014 | 0.053 | 0.400 |

*Table 3.10. 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 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 0.097 | 0.229 | 0.347 | 0.398 | 0.420 | 0.437 | 0.453 | 0.468 | 0.480 | 0.489 | 0.495 | 0.498 | 0.500 | 0.502 | 0.502 | 0.503 |
| 1977 | 0.096 | 0.227 | 0.344 | 0.393 | 0.411 | 0.423 | 0.435 | 0.446 | 0.455 | 0.461 | 0.465 | 0.468 | 0.469 | 0.470 | 0.471 | 0.471 |
| 1978 | 0.107 | 0.246 | 0.365 | 0.415 | 0.433 | 0.448 | 0.462 | 0.476 | 0.487 | 0.495 | 0.500 | 0.504 | 0.506 | 0.507 | 0.507 | 0.508 |
| 1979 | 0.110 | 0.253 | 0.376 | 0.426 | 0.445 | 0.460 | 0.474 | 0.488 | 0.500 | 0.508 | 0.513 | 0.517 | 0.519 | 0.520 | 0.520 | 0.521 |
| 1980 | 0.105 | 0.244 | 0.366 | 0.417 | 0.436 | 0.449 | 0.463 | 0.476 | 0.487 | 0.494 | 0.499 | 0.502 | 0.504 | 0.505 | 0.506 | 0.506 |
| 1981 | 0.094 | 0.199 | 0.265 | 0.295 | 0.309 | 0.323 | 0.339 | 0.355 | 0.368 | 0.378 | 0.384 | 0.388 | 0.390 | 0.391 | 0.392 | 0.392 |
| 1982 | 0.122 | 0.273 | 0.388 | 0.440 | 0.461 | 0.479 | 0.498 | 0.516 | 0.530 | 0.541 | 0.548 | 0.552 | 0.555 | 0.556 | 0.557 | 0.557 |
| 1983 | 0.222 | 0.503 | 0.659 | 0.749 | 0.786 | 0.813 | 0.840 | 0.865 | 0.885 | 0.900 | 0.910 | 0.916 | 0.919 | 0.921 | 0.922 | 0.923 |
| 1984 | 0.194 | 0.682 | 0.999 | 1.057 | 1.094 | 1.143 | 1.199 | 1.252 | 1.294 | 1.324 | 1.344 | 1.357 | 1.365 | 1.369 | 1.372 | 1.373 |
| 1985 | 0.115 | 0.353 | 0.555 | 0.613 | 0.670 | 0.742 | 0.819 | 0.891 | 0.948 | 0.989 | 1.016 | 1.033 | 1.044 | 1.050 | 1.054 | 1.056 |
| 1986 | 0.156 | 0.436 | 0.652 | 0.727 | 0.808 | 0.910 | 1.020 | 1.121 | 1.201 | 1.259 | 1.297 | 1.321 | 1.336 | 1.345 | 1.350 | 1.353 |
| 1987 | 0.165 | 0.453 | 0.610 | 0.668 | 0.729 | 0.806 | 0.891 | 0.969 | 1.031 | 1.076 | 1.105 | 1.124 | 1.135 | 1.142 | 1.146 | 1.149 |
| 1988 | 0.132 | 0.295 | 0.386 | 0.449 | 0.527 | 0.625 | 0.729 | 0.825 | 0.901 | 0.955 | 0.992 | 1.015 | 1.029 | 1.037 | 1.042 | 1.045 |
| 1989 | 0.120 | 0.324 | 0.481 | 0.540 | 0.603 | 0.683 | 0.770 | 0.849 | 0.912 | 0.957 | 0.988 | 1.007 | 1.018 | 1.025 | 1.029 | 1.032 |
| 1990 | 0.107 | 0.218 | 0.245 | 0.273 | 0.309 | 0.358 | 0.413 | 0.463 | 0.504 | 0.533 | 0.552 | 0.565 | 0.572 | 0.576 | 0.579 | 0.580 |
| 1991 | 0.177 | 0.328 | 0.164 | 0.168 | 0.188 | 0.217 | 0.250 | 0.281 | 0.306 | 0.324 | 0.336 | 0.344 | 0.348 | 0.351 | 0.352 | 0.353 |
| 1992 | 0.058 | 0.111 | 0.166 | 0.309 | 0.338 | 0.334 | 0.326 | 0.320 | 0.316 | 0.312 | 0.310 | 0.308 | 0.307 | 0.306 | 0.306 | 0.305 |
| 1993 | 0.034 | 0.071 | 0.239 | 0.576 | 0.632 | 0.634 | 0.631 | 0.628 | 0.626 | 0.625 | 0.623 | 0.623 | 0.622 | 0.622 | 0.622 | 0.621 |
| 1994 | 0.063 | 0.119 | 0.180 | 0.362 | 0.402 | 0.402 | 0.400 | 0.398 | 0.397 | 0.396 | 0.396 | 0.395 | 0.395 | 0.395 | 0.395 | 0.395 |
| 1995 | 0.048 | 0.092 | 0.159 | 0.338 | 0.381 | 0.383 | 0.382 | 0.380 | 0.379 | 0.379 | 0.378 | 0.378 | 0.378 | 0.377 | 0.377 | 0.377 |
| 1996 | 0.081 | 0.153 | 0.223 | 0.444 | 0.493 | 0.494 | 0.490 | 0.488 | 0.486 | 0.485 | 0.484 | 0.483 | 0.483 | 0.482 | 0.482 | 0.482 |
| 1997 | 0.093 | 0.175 | 0.216 | 0.397 | 0.446 | 0.446 | 0.442 | 0.440 | 0.438 | 0.437 | 0.436 | 0.436 | 0.435 | 0.435 | 0.435 | 0.435 |
| 1998 | 0.044 | 0.086 | 0.162 | 0.368 | 0.435 | 0.439 | 0.435 | 0.432 | 0.429 | 0.427 | 0.426 | 0.425 | 0.424 | 0.424 | 0.423 | 0.423 |
| 1999 | 0.042 | 0.082 | 0.118 | 0.252 | 0.302 | 0.305 | 0.303 | 0.302 | 0.301 | 0.300 | 0.299 | 0.299 | 0.298 | 0.298 | 0.298 | 0.298 |
| 2000 | 0.065 | 0.122 | 0.125 | 0.211 | 0.243 | 0.244 | 0.242 | 0.241 | 0.240 | 0.239 | 0.239 | 0.238 | 0.238 | 0.238 | 0.238 | 0.238 |
| 2001 | 0.055 | 0.103 | 0.115 | 0.203 | 0.234 | 0.232 | 0.228 | 0.225 | 0.222 | 0.220 | 0.219 | 0.218 | 0.217 | 0.217 | 0.216 | 0.216 |
| 2002 | 0.043 | 0.082 | 0.121 | 0.247 | 0.279 | 0.279 | 0.276 | 0.274 | 0.272 | 0.271 | 0.270 | 0.269 | 0.269 | 0.268 | 0.268 | 0.268 |
| 2003 | 0.045 | 0.086 | 0.127 | 0.256 | 0.284 | 0.284 | 0.282 | 0.280 | 0.279 | 0.278 | 0.277 | 0.277 | 0.276 | 0.276 | 0.276 | 0.276 |
| 2004 | 0.046 | 0.087 | 0.130 | 0.242 | 0.267 | 0.266 | 0.263 | 0.261 | 0.259 | 0.258 | 0.257 | 0.256 | 0.256 | 0.256 | 0.255 | 0.255 |
| 2005 | 0.053 | 0.098 | 0.117 | 0.184 | 0.195 | 0.193 | 0.192 | 0.190 | 0.190 | 0.189 | 0.189 | 0.189 | 0.188 | 0.188 | 0.188 | 0.188 |
| 2006 | 0.050 | 0.093 | 0.116 | 0.212 | 0.231 | 0.231 | 0.230 | 0.229 | 0.229 | 0.228 | 0.228 | 0.228 | 0.228 | 0.228 | 0.228 | 0.228 |
| 2007 | 0.029 | 0.056 | 0.117 | 0.279 | 0.319 | 0.322 | 0.321 | 0.320 | 0.319 | 0.318 | 0.318 | 0.318 | 0.318 | 0.318 | 0.318 | 0.318 |
| 2008 | 0.038 | 0.074 | 0.149 | 0.352 | 0.397 | 0.400 | 0.399 | 0.398 | 0.397 | 0.397 | 0.397 | 0.397 | 0.397 | 0.396 | 0.396 | 0.396 |

*Table 3.11. Estimated total landings at age in numbers (1000 fish)*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 31.6 | 71.4 | 54.4 | 155.2 | 51.7 | 13.2 | 11.1 | 3.8 | 2.4 | 1.0 | 0.5 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 |
| 1977 | 27.7 | 48.4 | 65.5 | 35.6 | 90.6 | 29.3 | 7.3 | 6.1 | 2.1 | 1.3 | 0.5 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 |
| 1978 | 40.9 | 46.3 | 47.2 | 45.3 | 22.1 | 55.1 | 17.8 | 4.5 | 3.7 | 1.2 | 0.7 | 0.3 | 0.1 | 0.1 | 0.0 | 0.0 |
| 1979 | 37.7 | 62.4 | 42.2 | 31.0 | 26.9 | 12.8 | 31.9 | 10.2 | 2.5 | 2.0 | 0.7 | 0.4 | 0.2 | 0.1 | 0.0 | 0.0 |
| 1980 | 18.3 | 54.1 | 54.0 | 26.3 | 17.5 | 14.8 | 7.1 | 17.4 | 5.5 | 1.3 | 1.1 | 0.4 | 0.2 | 0.1 | 0.0 | 0.0 |
| 1981 | 18.6 | 21.5 | 36.6 | 26.0 | 11.5 | 7.6 | 6.5 | 3.1 | 7.7 | 2.4 | 0.6 | 0.5 | 0.2 | 0.1 | 0.0 | 0.0 |
| 1982 | 44.9 | 35.9 | 27.2 | 36.1 | 23.8 | 10.3 | 6.7 | 5.7 | 2.7 | 6.4 | 2.0 | 0.5 | 0.4 | 0.1 | 0.1 | 0.1 |
| 1983 | 70.8 | 95.3 | 46.2 | 25.3 | 30.3 | 19.4 | 8.3 | 5.3 | 4.3 | 2.0 | 4.7 | 1.4 | 0.3 | 0.3 | 0.1 | 0.1 |
| 1984 | 34.0 | 108.5 | 86.7 | 27.3 | 12.9 | 14.9 | 9.4 | 3.9 | 2.5 | 2.0 | 0.9 | 2.1 | 0.6 | 0.1 | 0.1 | 0.1 |
| 1985 | 33.6 | 51.8 | 46.1 | 19.3 | 6.0 | 2.9 | 3.3 | 2.1 | 0.8 | 0.5 | 0.4 | 0.2 | 0.4 | 0.1 | 0.0 | 0.0 |
| 1986 | 24.7 | 76.5 | 50.5 | 26.9 | 10.8 | 3.2 | 1.5 | 1.6 | 0.9 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 |
| 1987 | 44.7 | 38.7 | 56.6 | 22.4 | 11.0 | 4.1 | 1.1 | 0.4 | 0.4 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1988 | 24.8 | 58.5 | 21.5 | 20.4 | 8.2 | 4.1 | 1.5 | 0.4 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1989 | 14.0 | 42.7 | 62.7 | 16.1 | 13.9 | 5.0 | 2.2 | 0.7 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1990 | 7.5 | 14.9 | 21.2 | 20.2 | 5.0 | 4.3 | 1.5 | 0.6 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1991 | 10.1 | 6.3 | 8.7 | 9.8 | 9.3 | 2.3 | 1.9 | 0.6 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1992 | 0.6 | 1.2 | 4.0 | 11.3 | 13.1 | 11.0 | 2.3 | 1.6 | 0.5 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1993 | 0.1 | 3.1 | 16.8 | 12.0 | 13.1 | 13.3 | 11.3 | 2.4 | 1.8 | 0.5 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1994 | 0.2 | 0.4 | 24.4 | 17.4 | 4.3 | 4.2 | 4.3 | 3.7 | 0.8 | 0.6 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1995 | 0.2 | 1.3 | 4.9 | 42.6 | 11.2 | 2.4 | 2.3 | 2.4 | 2.1 | 0.5 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1996 | 0.3 | 2.4 | 18.9 | 11.3 | 36.1 | 8.1 | 1.7 | 1.7 | 1.8 | 1.5 | 0.3 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 |
| 1997 | 0.2 | 2.0 | 23.0 | 29.5 | 6.4 | 17.6 | 3.9 | 0.9 | 0.8 | 0.9 | 0.8 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 |
| 1998 | 0.2 | 1.6 | 20.1 | 40.5 | 19.3 | 3.5 | 9.6 | 2.2 | 0.5 | 0.5 | 0.5 | 0.4 | 0.1 | 0.1 | 0.0 | 0.0 |
| 1999 | 0.2 | 1.0 | 9.2 | 27.0 | 20.6 | 8.0 | 1.5 | 4.0 | 0.9 | 0.2 | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 |
| 2000 | 0.2 | 0.9 | 7.5 | 16.1 | 17.7 | 10.8 | 4.2 | 0.8 | 2.1 | 0.5 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 |
| 2001 | 0.2 | 1.5 | 9.0 | 16.1 | 13.1 | 11.6 | 7.0 | 2.7 | 0.5 | 1.4 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| 2002 | 0.2 | 1.1 | 14.1 | 23.5 | 15.9 | 10.5 | 9.3 | 5.7 | 2.2 | 0.4 | 1.1 | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 |
| 2003 | 0.2 | 1.0 | 11.5 | 29.9 | 18.3 | 10.6 | 7.0 | 6.3 | 3.9 | 1.5 | 0.3 | 0.8 | 0.2 | 0.0 | 0.0 | 0.1 |
| 2004 | 0.3 | 1.6 | 12.7 | 21.9 | 21.2 | 11.2 | 6.4 | 4.3 | 3.9 | 2.4 | 0.9 | 0.2 | 0.5 | 0.1 | 0.0 | 0.1 |
| 2005 | 0.1 | 1.6 | 12.9 | 17.7 | 12.4 | 10.5 | 5.6 | 3.2 | 2.2 | 2.0 | 1.2 | 0.5 | 0.1 | 0.3 | 0.1 | 0.1 |
| 2006 | 0.0 | 0.8 | 19.4 | 27.4 | 16.5 | 10.4 | 8.8 | 4.7 | 2.8 | 1.9 | 1.7 | 1.1 | 0.4 | 0.1 | 0.2 | 0.1 |
| 2007 | 0.1 | 0.6 | 14.0 | 53.6 | 28.8 | 15.2 | 9.5 | 8.1 | 4.4 | 2.6 | 1.8 | 1.6 | 1.0 | 0.4 | 0.1 | 0.3 |
| 2008 | 0.1 | 0.7 | 10.5 | 35.2 | 47.4 | 21.8 | 11.4 | 7.3 | 6.2 | 3.4 | 2.0 | 1.4 | 1.2 | 0.8 | 0.3 | 0.3 |

*Table 3.12. Estimated total landings at age in whole weight (1000 lb)*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 32.3 | 174.9 | 234.0 | 985.6 | 435.7 | 136.9 | 135.9 | 53.1 | 36.6 | 16.2 | 8.5 | 4.6 | 2.5 | 1.4 | 0.7 | 0.9 |
| 1977 | 28.3 | 118.7 | 281.8 | 226.3 | 763.6 | 304.5 | 89.6 | 84.4 | 31.4 | 20.8 | 8.9 | 4.6 | 2.4 | 1.3 | 0.7 | 0.8 |
| 1978 | 41.7 | 113.3 | 202.8 | 287.5 | 186.1 | 573.4 | 217.3 | 61.6 | 56.0 | 20.2 | 13.0 | 5.5 | 2.8 | 1.5 | 0.8 | 0.9 |
| 1979 | 38.4 | 152.9 | 181.4 | 196.9 | 226.3 | 133.7 | 389.6 | 141.3 | 38.5 | 33.7 | 11.8 | 7.5 | 3.1 | 1.6 | 0.8 | 0.9 |
| 1980 | 18.7 | 132.4 | 231.9 | 167.2 | 147.2 | 154.4 | 86.3 | 240.5 | 83.7 | 21.9 | 18.7 | 6.4 | 4.0 | 1.7 | 0.8 | 0.9 |
| 1981 | 18.9 | 52.6 | 157.5 | 164.8 | 96.5 | 78.6 | 79.4 | 43.2 | 117.3 | 39.7 | 10.2 | 8.6 | 2.9 | 1.8 | 0.7 | 0.8 |
| 1982 | 45.9 | 87.9 | 116.8 | 229.3 | 200.3 | 107.6 | 82.2 | 78.4 | 40.4 | 104.5 | 34.1 | 8.6 | 7.1 | 2.4 | 1.5 | 1.2 |
| 1983 | 72.2 | 233.6 | 198.7 | 160.8 | 255.3 | 202.0 | 101.4 | 73.2 | 66.3 | 32.6 | 81.5 | 26.1 | 6.5 | 5.3 | 1.8 | 2.0 |
| 1984 | 41.3 | 267.2 | 372.7 | 173.4 | 108.4 | 154.5 | 114.6 | 54.6 | 37.5 | 32.5 | 15.5 | 37.9 | 12.0 | 2.9 | 2.4 | 1.7 |
| 1985 | 40.9 | 127.5 | 198.3 | 122.7 | 50.5 | 30.1 | 40.9 | 28.7 | 12.9 | 8.4 | 7.0 | 3.2 | 7.8 | 2.4 | 0.6 | 0.8 |
| 1986 | 30.0 | 188.3 | 217.3 | 171.0 | 90.8 | 33.5 | 17.8 | 21.5 | 13.6 | 5.6 | 3.4 | 2.7 | 1.2 | 2.9 | 0.9 | 0.5 |
| 1987 | 54.3 | 95.2 | 243.4 | 142.5 | 93.0 | 42.7 | 13.5 | 6.2 | 6.5 | 3.6 | 1.4 | 0.8 | 0.6 | 0.3 | 0.6 | 0.3 |
| 1988 | 30.1 | 144.0 | 92.4 | 129.8 | 69.0 | 42.6 | 18.1 | 5.2 | 2.2 | 2.1 | 1.1 | 0.4 | 0.2 | 0.2 | 0.1 | 0.3 |
| 1989 | 17.0 | 105.1 | 269.7 | 102.0 | 117.2 | 52.2 | 26.8 | 9.5 | 2.4 | 0.9 | 0.8 | 0.4 | 0.1 | 0.1 | 0.1 | 0.1 |
| 1990 | 9.1 | 36.6 | 91.1 | 128.1 | 42.5 | 44.9 | 18.2 | 8.4 | 2.7 | 0.6 | 0.2 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 |
| 1991 | 12.2 | 15.6 | 37.5 | 62.5 | 78.6 | 24.2 | 23.4 | 8.6 | 3.6 | 1.1 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 |
| 1992 | 2.8 | 5.9 | 23.3 | 80.0 | 114.6 | 115.8 | 28.4 | 22.4 | 7.0 | 2.6 | 0.7 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1993 | 0.4 | 15.7 | 97.4 | 85.3 | 115.0 | 140.7 | 138.9 | 34.0 | 26.8 | 8.3 | 3.1 | 0.8 | 0.2 | 0.1 | 0.0 | 0.0 |
| 1994 | 0.7 | 2.2 | 141.1 | 123.0 | 38.1 | 44.5 | 52.6 | 51.0 | 12.3 | 9.5 | 2.9 | 1.1 | 0.3 | 0.1 | 0.0 | 0.0 |
| 1995 | 1.0 | 6.4 | 28.2 | 301.7 | 98.2 | 25.6 | 28.7 | 33.3 | 31.8 | 7.5 | 5.7 | 1.7 | 0.6 | 0.2 | 0.0 | 0.0 |
| 1996 | 1.4 | 12.0 | 109.2 | 80.3 | 316.6 | 85.7 | 21.4 | 23.6 | 26.8 | 25.1 | 5.8 | 4.4 | 1.3 | 0.5 | 0.1 | 0.0 |
| 1997 | 0.8 | 10.3 | 132.9 | 208.9 | 56.3 | 185.8 | 48.4 | 11.9 | 12.8 | 14.4 | 13.2 | 3.1 | 2.3 | 0.7 | 0.3 | 0.1 |
| 1998 | 1.2 | 8.0 | 116.2 | 286.5 | 169.5 | 37.4 | 118.1 | 30.1 | 7.2 | 7.7 | 8.5 | 7.8 | 1.8 | 1.3 | 0.4 | 0.2 |
| 1999 | 0.8 | 5.3 | 53.1 | 191.1 | 180.3 | 84.6 | 17.9 | 55.6 | 14.0 | 3.3 | 3.5 | 3.8 | 3.5 | 0.8 | 0.6 | 0.3 |
| 2000 | 0.7 | 4.8 | 43.6 | 113.9 | 155.4 | 114.5 | 51.3 | 10.6 | 32.4 | 8.0 | 1.9 | 2.0 | 2.1 | 1.9 | 0.4 | 0.5 |
| 2001 | 1.1 | 7.7 | 52.0 | 114.2 | 114.6 | 122.9 | 85.6 | 37.2 | 7.5 | 22.4 | 5.4 | 1.3 | 1.3 | 1.4 | 1.3 | 0.6 |
| 2002 | 0.9 | 5.5 | 81.7 | 166.1 | 139.5 | 111.3 | 114.8 | 79.1 | 34.0 | 6.8 | 20.1 | 4.9 | 1.1 | 1.2 | 1.2 | 1.6 |
| 2003 | 0.9 | 5.3 | 66.4 | 211.4 | 160.6 | 111.6 | 85.7 | 87.0 | 59.0 | 25.0 | 4.9 | 14.5 | 3.5 | 0.8 | 0.8 | 2.0 |
| 2004 | 1.7 | 8.3 | 73.3 | 155.1 | 185.5 | 118.9 | 79.3 | 59.6 | 59.3 | 39.5 | 16.5 | 3.2 | 9.5 | 2.3 | 0.5 | 1.8 |
| 2005 | 0.4 | 8.2 | 74.7 | 125.5 | 108.9 | 110.8 | 68.6 | 45.1 | 33.4 | 32.7 | 21.5 | 8.9 | 1.7 | 5.1 | 1.2 | 1.2 |
| 2006 | 0.2 | 3.9 | 112.2 | 194.2 | 144.8 | 109.8 | 108.1 | 65.7 | 42.4 | 30.9 | 29.9 | 19.5 | 8.1 | 1.6 | 4.5 | 2.1 |
| 2007 | 0.3 | 3.3 | 80.8 | 379.3 | 253.0 | 161.1 | 117.6 | 113.2 | 67.5 | 42.7 | 30.7 | 29.4 | 19.2 | 7.9 | 1.5 | 6.4 |
| 2008 | 0.5 | 3.4 | 60.7 | 249.3 | 415.5 | 230.4 | 141.0 | 100.8 | 95.3 | 55.8 | 34.8 | 24.8 | 23.7 | 15.3 | 6.3 | 6.2 |

*Table 3.13. Estimated time series of landings in numbers (1000 fish) for commercial lines (L.cl), commercial combined (L.co), headboat (L.hb), and general recreational (L.rec)*

| Year | L.cl | L.co | L.hb | L.rec | Total |
|---|---|---|---|---|---|
| 1976 | 39.11 | 39.73 | 4.60 | 313.43 | 396.86 |
| 1977 | 27.49 | 30.57 | 5.61 | 251.37 | 315.03 |
| 1978 | 32.14 | 38.37 | 4.77 | 210.03 | 285.31 |
| 1979 | 28.85 | 37.62 | 9.38 | 185.22 | 261.07 |
| 1980 | 21.98 | 27.14 | 8.14 | 160.76 | 218.03 |
| 1981 | 24.85 | 31.97 | 7.96 | 77.96 | 142.75 |
| 1982 | 26.16 | 34.29 | 6.36 | 135.84 | 202.65 |
| 1983 | 29.69 | 41.79 | 9.89 | 232.81 | 314.19 |
| 1984 | 40.44 | 49.46 | 8.56 | 207.43 | 305.89 |
| 1985 | 43.95 | 37.79 | 8.79 | 77.19 | 167.72 |
| 1986 | 55.54 | 44.20 | 5.81 | 91.90 | 197.46 |
| 1987 | 47.30 | 44.40 | 7.05 | 81.17 | 179.92 |
| 1988 | 57.53 | 39.08 | 5.10 | 37.99 | 139.70 |
| 1989 | 46.18 | 33.42 | 3.62 | 74.34 | 157.57 |
| 1990 | 29.50 | 25.74 | 7.33 | 12.84 | 75.41 |
| 1991 | 21.49 | 19.31 | 2.73 | 5.95 | 49.48 |
| 1992 | 13.98 | 5.10 | 3.98 | 22.61 | 45.67 |
| 1993 | 17.71 | 2.24 | 4.79 | 49.94 | 74.68 |
| 1994 | 19.27 | 1.46 | 5.47 | 34.27 | 60.47 |
| 1995 | 27.20 | 1.32 | 5.24 | 36.53 | 70.29 |
| 1996 | 30.90 | 2.65 | 5.64 | 45.27 | 84.47 |
| 1997 | 35.60 | 2.67 | 8.03 | 39.96 | 86.27 |
| 1998 | 49.01 | 4.91 | 10.81 | 34.30 | 99.04 |
| 1999 | 44.61 | 2.27 | 7.23 | 19.07 | 73.17 |
| 2000 | 36.81 | 1.60 | 5.33 | 17.54 | 61.28 |
| 2001 | 34.64 | 5.63 | 4.95 | 18.42 | 63.64 |
| 2002 | 35.33 | 4.03 | 4.62 | 40.62 | 84.60 |
| 2003 | 33.42 | 2.84 | 4.04 | 51.17 | 91.47 |
| 2004 | 30.73 | 4.08 | 10.85 | 42.16 | 87.82 |
| 2005 | 20.96 | 1.73 | 11.53 | 36.20 | 70.42 |
| 2006 | 33.94 | 0.99 | 5.24 | 56.12 | 96.29 |
| 2007 | 58.61 | 1.88 | 5.15 | 76.56 | 142.20 |
| 2008 | 58.17 | 1.11 | 2.44 | 88.20 | 149.93 |

*Table 3.14. Estimated time series of landings in whole weight (1000 lb) for commercial lines (L.cl), commercial other (L.co), headboat (L.hb), and general recreational (L.rec)*

| Year | L.cl | L.co | L.hb | L.rec | Total |
|---|---|---|---|---|---|
| 1976 | 262.34 | 170.93 | 26.40 | 1800.03 | 2259.70 |
| 1977 | 208.61 | 134.68 | 35.45 | 1589.35 | 1968.10 |
| 1978 | 257.86 | 151.66 | 30.52 | 1344.52 | 1784.56 |
| 1979 | 235.15 | 134.90 | 57.28 | 1131.19 | 1558.52 |
| 1980 | 185.16 | 103.57 | 49.55 | 978.58 | 1316.86 |
| 1981 | 210.93 | 126.00 | 49.73 | 487.05 | 873.71 |
| 1982 | 205.80 | 113.13 | 37.10 | 792.16 | 1148.18 |
| 1983 | 203.50 | 119.02 | 48.78 | 1147.90 | 1519.20 |
| 1984 | 235.81 | 141.99 | 41.67 | 1009.56 | 1429.04 |
| 1985 | 200.96 | 100.97 | 38.93 | 342.02 | 682.88 |
| 1986 | 250.47 | 131.12 | 24.95 | 394.40 | 800.94 |
| 1987 | 190.37 | 118.40 | 31.63 | 364.40 | 704.80 |
| 1988 | 244.66 | 111.01 | 21.55 | 160.50 | 537.71 |
| 1989 | 229.13 | 113.83 | 16.77 | 344.51 | 704.23 |
| 1990 | 172.95 | 102.12 | 39.21 | 68.64 | 382.92 |
| 1991 | 139.61 | 74.77 | 16.79 | 36.59 | 267.76 |
| 1992 | 129.03 | 39.95 | 33.65 | 201.20 | 403.83 |
| 1993 | 167.98 | 16.47 | 38.12 | 444.03 | 666.60 |
| 1994 | 164.85 | 10.09 | 38.74 | 265.72 | 479.40 |
| 1995 | 227.30 | 9.41 | 40.49 | 293.45 | 570.65 |
| 1996 | 273.72 | 19.10 | 43.06 | 378.53 | 714.40 |
| 1997 | 305.86 | 18.82 | 58.90 | 318.67 | 702.25 |
| 1998 | 413.92 | 35.37 | 80.37 | 272.25 | 801.91 |
| 1999 | 387.38 | 17.01 | 56.49 | 157.44 | 618.31 |
| 2000 | 336.15 | 12.35 | 43.44 | 152.20 | 544.15 |
| 2001 | 327.30 | 43.97 | 41.03 | 164.20 | 576.50 |
| 2002 | 337.30 | 31.41 | 38.28 | 362.75 | 769.74 |
| 2003 | 320.49 | 22.23 | 34.29 | 462.52 | 839.53 |
| 2004 | 300.34 | 31.72 | 93.22 | 389.03 | 814.32 |
| 2005 | 205.39 | 13.28 | 97.26 | 332.10 | 648.04 |
| 2006 | 326.82 | 7.66 | 43.08 | 500.44 | 878.00 |
| 2007 | 561.68 | 15.02 | 44.42 | 692.74 | 1313.86 |
| 2008 | 583.85 | 9.38 | 22.48 | 847.97 | 1463.67 |

*Table 3.15. Estimated time series of dead discards in numbers (1000 fish) for commercial handline (D.cl), headboat (D.hb), and general recreational (D.rec)*

| Year | D.cl | D.hb | D.rec | Total |
|---|---|---|---|---|
| 1976 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1977 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1978 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1979 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1980 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1981 | 0.00 | 0.00 | 3.07 | 3.07 |
| 1982 | 0.00 | 0.00 | 3.49 | 3.49 |
| 1983 | 0.00 | 0.00 | 30.96 | 30.96 |
| 1984 | 1.49 | 4.89 | 35.31 | 41.69 |
| 1985 | 1.48 | 4.86 | 1.44 | 7.77 |
| 1986 | 1.29 | 4.25 | 6.86 | 12.41 |
| 1987 | 1.40 | 4.61 | 22.93 | 28.94 |
| 1988 | 1.59 | 5.23 | 10.92 | 17.74 |
| 1989 | 0.98 | 3.22 | 2.39 | 6.59 |
| 1990 | 0.62 | 2.06 | 4.38 | 7.06 |
| 1991 | 0.70 | 2.30 | 32.61 | 35.60 |
| 1992 | 1.78 | 5.19 | 30.43 | 37.41 |
| 1993 | 1.71 | 5.37 | 15.92 | 23.00 |
| 1994 | 2.88 | 4.61 | 29.22 | 36.71 |
| 1995 | 2.10 | 6.34 | 30.19 | 38.63 |
| 1996 | 2.32 | 7.72 | 69.24 | 79.27 |
| 1997 | 2.94 | 6.82 | 70.92 | 80.68 |
| 1998 | 2.09 | 5.66 | 22.98 | 30.74 |
| 1999 | 2.60 | 5.79 | 22.60 | 30.99 |
| 2000 | 2.18 | 6.74 | 47.10 | 56.01 |
| 2001 | 1.69 | 6.88 | 38.97 | 47.54 |
| 2002 | 4.33 | 6.52 | 24.65 | 35.50 |
| 2003 | 2.27 | 7.20 | 31.73 | 41.20 |
| 2004 | 2.17 | 9.55 | 43.36 | 55.08 |
| 2005 | 2.00 | 17.67 | 45.55 | 65.22 |
| 2006 | 0.99 | 4.51 | 38.67 | 44.17 |
| 2007 | 1.71 | 4.08 | 11.59 | 17.39 |
| 2008 | 0.40 | 4.77 | 17.89 | 23.06 |

*Table 3.16. Estimated time series of dead discards in whole weight (1000 lb) for commercial handline (D.cl), headboat (D.hb), and general recreational (D.rec)*

| Year | D.cl | D.hb | D.rec | Total |
|---|---|---|---|---|
| 1976 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1977 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1978 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1979 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1980 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1981 | 0.00 | 0.00 | 4.37 | 4.37 |
| 1982 | 0.00 | 0.00 | 4.64 | 4.64 |
| 1983 | 0.00 | 0.00 | 43.88 | 43.88 |
| 1984 | 0.00 | 7.17 | 51.74 | 58.91 |
| 1985 | 0.00 | 6.73 | 1.99 | 8.73 |
| 1986 | 0.00 | 6.52 | 10.51 | 17.03 |
| 1987 | 0.00 | 5.94 | 29.55 | 35.49 |
| 1988 | 0.00 | 7.96 | 16.63 | 24.59 |
| 1989 | 0.00 | 4.98 | 3.69 | 8.67 |
| 1990 | 0.00 | 3.14 | 6.69 | 9.82 |
| 1991 | 0.00 | 3.03 | 43.04 | 46.07 |
| 1992 | 2.94 | 8.55 | 50.15 | 61.64 |
| 1993 | 4.00 | 12.53 | 37.13 | 53.65 |
| 1994 | 6.05 | 9.69 | 61.41 | 77.15 |
| 1995 | 3.86 | 11.67 | 55.55 | 71.08 |
| 1996 | 4.68 | 15.59 | 139.88 | 160.15 |
| 1997 | 6.58 | 15.27 | 158.69 | 180.53 |
| 1998 | 4.62 | 12.51 | 50.74 | 67.87 |
| 1999 | 5.37 | 11.97 | 46.72 | 64.06 |
| 2000 | 4.36 | 13.48 | 94.25 | 112.09 |
| 2001 | 3.64 | 14.86 | 84.21 | 102.72 |
| 2002 | 9.34 | 14.07 | 53.19 | 76.60 |
| 2003 | 4.58 | 14.51 | 63.97 | 83.05 |
| 2004 | 4.14 | 18.21 | 82.67 | 105.02 |
| 2005 | 4.46 | 39.42 | 101.63 | 145.50 |
| 2006 | 2.43 | 11.09 | 95.13 | 108.65 |
| 2007 | 4.08 | 9.71 | 27.56 | 41.35 |
| 2008 | 0.80 | 9.64 | 36.12 | 46.56 |

*Table 3.17. Estimated status indicators, benchmarks, and related quantities from the Beaufort catch-age model, conditional on estimated current selectivities averaged across fisheries. Precision is represented by standard errors (SE) approximated from Monte Carlo/Bootstrap analysis. Estimates of yield do not include discards; $D_{MSY}$ represents discard mortalities expected when fishing at $F_{MSY}$. 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. Symbols, abbreviations, and acronyms are listed in Appendix A.*

| Quantity | Units | Estimate | SE |
|---|---|---|---|
| $F_{MSY}$ | $y^{-1}$ | 0.212 | 0.027 |
| $85\%F_{MSY}$ | $y^{-1}$ | 0.180 | 0.023 |
| $75\%F_{MSY}$ | $y^{-1}$ | 0.159 | 0.020 |
| $65\%F_{MSY}$ | $y^{-1}$ | 0.138 | 0.018 |
| $F_{30\%}$ | $y^{-1}$ | 0.178 | 0.024 |
| $F_{40\%}$ | $y^{-1}$ | 0.121 | 0.016 |
| $F_{50\%}$ | $y^{-1}$ | 0.084 | 0.011 |
| $B_{MSY}$ | mt | 3622 | 530 |
| $SSB_{MSY}$ | mt | 2545 | 488 |
| MSST | mt | 2189 | 459 |
| MSY | 1000 lb | 1117 | 86 |
| $D_{MSY}$ | 1000 fish | 26 | 7 |
| $R_{MSY}$ | 1000 age-1 fish | 406 | 50 |
| Y at $85\%F_{MSY}$ | 1000 lb | 1110 | 85 |
| Y at $75\%F_{MSY}$ | 1000 lb | 1095 | 83 |
| Y at $65\%F_{MSY}$ | 1000 lb | 1069 | 81 |
| $F_{2008}/F_{MSY}$ | — | 1.46 | 0.27 |
| $SSB_{2008}/MSST$ | — | 0.79 | 0.22 |

*Table 3.18. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last three assessment years.*

| Run | Description | $F_{MSY}$ | $SSB_{MSY}$ (mt) | MSY(1000 lb) | $F_{2008}/F_{MSY}$ | $SSB_{2008}$/MSST | steep | R0(1000) |
|---|---|---|---|---|---|---|---|---|
| Base | — | 0.212 | 2545 | 1117 | 1.46 | 0.79 | 0.91 | 399 |
| S1 | Low M | 0.171 | 3501 | 1270 | 2.03 | 0.49 | 0.95 | 306 |
| S2 | High M | 0.274 | 1825 | 987 | 0.92 | 1.47 | 0.85 | 589 |
| S3 | Extreme M | 0.421 | 1413 | 1004 | 0.41 | 3.29 | 0.76 | 1175 |
| S4 | Low D mort | 0.248 | 2085 | 1069 | 1.22 | 0.99 | 0.92 | 357 |
| S5 | High D mort | 0.19 | 3019 | 1187 | 1.67 | 0.66 | 0.90 | 447 |
| S6 | SSB female | 0.222 | 1356 | 1075 | 1.39 | 0.94 | 0.80 | 376 |
| S7 | SSB male | 0.222 | 1027 | 1121 | 1.40 | 0.72 | 0.97 | 390 |
| S8 | Retro 2004 | 0.188 | 2521 | 1001 | 1.49 | 0.72 | 0.92 | 375 |
| S9 | Retro 2006 | 0.168 | 2806 | 979 | 1.69 | 0.58 | 0.91 | 394 |
| S10 | Retro 2005 | 0.15 | 3443 | 1063 | 1.36 | 0.65 | 0.89 | 461 |

*Table 3.19. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{current}$. F = fishing mortality rate (per year), Pr(*SSB > SSB$_{MSY}$*) = proportion of stochastic projection replicates exceeding* SSB$_{MSY}$*, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000* lb *whole weight), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are* $F_{MSY}$ = 0.21 *(per yr),* SSB$_{MSY}$ = 2545 *(mt), and* MSY = 1117 *(klb). Expected values presented are from deterministic projections.*

| Year | F(per yr) | Pr(SSB > SSB$_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.31 | 0 | 1509.83 | 391 | 29 | 56 | 93 | 956 | 956 |
| 2010 | 0.31 | 0 | 1437.68 | 384 | 34 | 70 | 85 | 868 | 1824 |
| 2011 | 0.31 | 0 | 1432.92 | 381 | 35 | 74 | 89 | 866 | 2689 |
| 2012 | 0.31 | 0 | 1470.2 | 381 | 35 | 75 | 97 | 908 | 3597 |
| 2013 | 0.31 | 0 | 1517.58 | 382 | 35 | 75 | 103 | 946 | 4543 |
| 2014 | 0.31 | 0 | 1560.63 | 384 | 35 | 75 | 106 | 976 | 5519 |
| 2015 | 0.31 | 0 | 1596 | 385 | 36 | 76 | 108 | 998 | 6517 |
| 2016 | 0.31 | 0 | 1624.13 | 387 | 36 | 76 | 109 | 1016 | 7533 |
| 2017 | 0.31 | 0 | 1646.12 | 387 | 36 | 76 | 110 | 1030 | 8562 |
| 2018 | 0.31 | 0 | 1663.14 | 388 | 36 | 76 | 111 | 1041 | 9603 |
| 2019 | 0.31 | 0 | 1676.3 | 389 | 36 | 77 | 112 | 1049 | 10,652 |
| 2020 | 0.31 | 0 | 1686.49 | 389 | 36 | 77 | 112 | 1055 | 11,707 |
| 2021 | 0.31 | 0 | 1694.45 | 389 | 36 | 77 | 113 | 1061 | 12,768 |
| 2022 | 0.31 | 0 | 1700.64 | 390 | 36 | 77 | 113 | 1065 | 13,833 |
| 2023 | 0.31 | 0.01 | 1705.44 | 390 | 36 | 77 | 113 | 1068 | 14,900 |
| 2024 | 0.31 | 0.01 | 1709.13 | 390 | 36 | 77 | 113 | 1070 | 15,970 |
| 2025 | 0.31 | 0.01 | 1711.95 | 390 | 36 | 77 | 114 | 1072 | 17,042 |
| 2026 | 0.31 | 0.01 | 1714.11 | 390 | 36 | 77 | 114 | 1073 | 18,115 |
| 2027 | 0.31 | 0.01 | 1715.77 | 390 | 36 | 77 | 114 | 1074 | 19,190 |
| 2028 | 0.31 | 0.01 | 1717.05 | 390 | 36 | 77 | 114 | 1075 | 20,265 |

*Table 3.20. Projection results under scenario 3—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and $F = 75\%F_{\text{current}}$ thereafter. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY}$ = 0.21 (per yr), $SSB_{MSY}$ = 2545 (mt), and MSY = 1117 (klb). Expected values presented are from deterministic projections.*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.31 | 0 | 1509.83 | 391 | 29 | 56 | 93 | 956 | 956 |
| 2010 | 0.232 | 0 | 1437.68 | 384 | 26 | 53 | 66 | 673 | 1629 |
| 2011 | 0.232 | 0 | 1546.59 | 381 | 27 | 57 | 73 | 712 | 2341 |
| 2012 | 0.232 | 0.01 | 1656.23 | 385 | 27 | 58 | 82 | 781 | 3123 |
| 2013 | 0.232 | 0.02 | 1769.49 | 388 | 27 | 59 | 89 | 844 | 3967 |
| 2014 | 0.232 | 0.04 | 1871.69 | 392 | 28 | 59 | 94 | 895 | 4862 |
| 2015 | 0.232 | 0.06 | 1959.09 | 394 | 28 | 60 | 97 | 938 | 5799 |
| 2016 | 0.232 | 0.08 | 2032 | 396 | 28 | 60 | 100 | 973 | 6772 |
| 2017 | 0.232 | 0.1 | 2091.69 | 398 | 28 | 60 | 102 | 1002 | 7773 |
| 2018 | 0.232 | 0.12 | 2139.88 | 399 | 28 | 61 | 104 | 1025 | 8798 |
| 2019 | 0.232 | 0.15 | 2178.5 | 400 | 28 | 61 | 105 | 1043 | 9842 |
| 2020 | 0.232 | 0.16 | 2209.35 | 401 | 28 | 61 | 106 | 1058 | 10,900 |
| 2021 | 0.232 | 0.18 | 2234.04 | 401 | 28 | 61 | 107 | 1070 | 11,970 |
| 2022 | 0.232 | 0.2 | 2253.72 | 402 | 28 | 61 | 108 | 1080 | 13,050 |
| 2023 | 0.232 | 0.21 | 2269.33 | 402 | 28 | 61 | 108 | 1087 | 14,138 |
| 2024 | 0.232 | 0.22 | 2281.6 | 402 | 28 | 61 | 109 | 1093 | 15,231 |
| 2025 | 0.232 | 0.23 | 2291.2 | 402 | 29 | 61 | 109 | 1098 | 16,329 |
| 2026 | 0.232 | 0.23 | 2298.72 | 403 | 29 | 61 | 109 | 1102 | 17,431 |
| 2027 | 0.232 | 0.24 | 2304.62 | 403 | 29 | 61 | 109 | 1105 | 18,536 |
| 2028 | 0.232 | 0.24 | 2309.23 | 403 | 29 | 61 | 110 | 1107 | 19,642 |

*Table 3.21. Projection results under scenario 4—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and $F$ = 50%$F_{\text{current}}$ thereafter. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY}$ = 0.21 (per yr), $SSB_{MSY}$ = 2545 (mt), and MSY = 1117 (klb). Expected values presented are from deterministic projections.*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.31 | 0 | 1509.83 | 391 | 29 | 56 | 93 | 956 | 956 |
| 2010 | 0.155 | 0 | 1437.68 | 384 | 17 | 36 | 45 | 464 | 1420 |
| 2011 | 0.155 | 0 | 1671.01 | 381 | 18 | 39 | 53 | 522 | 1942 |
| 2012 | 0.155 | 0.02 | 1872.51 | 389 | 18 | 40 | 62 | 600 | 2542 |
| 2013 | 0.155 | 0.1 | 2078.23 | 394 | 19 | 41 | 69 | 674 | 3215 |
| 2014 | 0.155 | 0.23 | 2270.88 | 399 | 19 | 41 | 75 | 738 | 3953 |
| 2015 | 0.155 | 0.38 | 2444.05 | 402 | 19 | 42 | 79 | 795 | 4748 |
| 2016 | 0.155 | 0.53 | 2596.09 | 405 | 19 | 42 | 83 | 844 | 5592 |
| 2017 | 0.155 | 0.66 | 2726.96 | 407 | 20 | 42 | 86 | 887 | 6479 |
| 2018 | 0.155 | 0.75 | 2837.83 | 409 | 20 | 43 | 88 | 923 | 7402 |
| 2019 | 0.155 | 0.82 | 2930.81 | 410 | 20 | 43 | 90 | 953 | 8356 |
| 2020 | 0.155 | 0.87 | 3008.25 | 411 | 20 | 43 | 92 | 979 | 9334 |
| 2021 | 0.155 | 0.9 | 3072.66 | 412 | 20 | 43 | 93 | 1000 | 10,334 |
| 2022 | 0.155 | 0.92 | 3125.97 | 412 | 20 | 43 | 94 | 1017 | 11,351 |
| 2023 | 0.155 | 0.93 | 3169.8 | 413 | 20 | 43 | 95 | 1031 | 12,382 |
| 2024 | 0.155 | 0.94 | 3205.53 | 413 | 20 | 43 | 96 | 1043 | 13,425 |
| 2025 | 0.155 | 0.95 | 3234.47 | 414 | 20 | 43 | 96 | 1052 | 14,477 |
| 2026 | 0.155 | 0.95 | 3257.9 | 414 | 20 | 43 | 97 | 1060 | 15,537 |
| 2027 | 0.155 | 0.96 | 3276.87 | 414 | 20 | 43 | 97 | 1066 | 16,603 |
| 2028 | 0.155 | 0.96 | 3292.2 | 414 | 20 | 43 | 98 | 1071 | 17,673 |

*Table 3.22. Projection results under scenario 5—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and $F = 25\%F_{\text{current}}$ thereafter. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY} = 0.21$ (per yr), $SSB_{MSY} = 2545$ (mt), and MSY = 1117 (klb). Expected values presented are from deterministic projections.*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.31 | 0 | 1509.83 | 391 | 29 | 56 | 93 | 956 | 956 |
| 2010 | 0.077 | 0 | 1437.68 | 384 | 9 | 18 | 23 | 240 | 1196 |
| 2011 | 0.077 | 0 | 1807.28 | 381 | 9 | 20 | 29 | 287 | 1483 |
| 2012 | 0.077 | 0.1 | 2124.43 | 393 | 9 | 21 | 35 | 347 | 1830 |
| 2013 | 0.077 | 0.39 | 2458.25 | 400 | 10 | 21 | 41 | 406 | 2235 |
| 2014 | 0.077 | 0.71 | 2787.26 | 405 | 10 | 21 | 45 | 461 | 2697 |
| 2015 | 0.077 | 0.9 | 3100.02 | 409 | 10 | 22 | 49 | 513 | 3210 |
| 2016 | 0.077 | 0.97 | 3390.56 | 413 | 10 | 22 | 52 | 561 | 3771 |
| 2017 | 0.077 | 0.99 | 3655.09 | 415 | 10 | 22 | 55 | 605 | 4376 |
| 2018 | 0.077 | 1 | 3891.98 | 417 | 10 | 22 | 58 | 644 | 5019 |
| 2019 | 0.077 | 1 | 4101.67 | 419 | 10 | 23 | 60 | 678 | 5698 |
| 2020 | 0.077 | 1 | 4285.72 | 420 | 10 | 23 | 62 | 709 | 6406 |
| 2021 | 0.077 | 1 | 4446.75 | 421 | 10 | 23 | 63 | 735 | 7141 |
| 2022 | 0.077 | 1 | 4586.81 | 422 | 10 | 23 | 65 | 758 | 7899 |
| 2023 | 0.077 | 1 | 4707.8 | 423 | 10 | 23 | 66 | 778 | 8677 |
| 2024 | 0.077 | 1 | 4811.37 | 423 | 10 | 23 | 67 | 795 | 9472 |
| 2025 | 0.077 | 1 | 4899.39 | 424 | 10 | 23 | 67 | 809 | 10,281 |
| 2026 | 0.077 | 1 | 4974.11 | 424 | 10 | 23 | 68 | 821 | 11,102 |
| 2027 | 0.077 | 1 | 5037.49 | 424 | 10 | 23 | 69 | 832 | 11,934 |
| 2028 | 0.077 | 1 | 5091.15 | 424 | 11 | 23 | 69 | 841 | 12,775 |

*Table 3.23. Projection results under scenario 6—fishing mortality rate fixed at $F = 65\%F_{MSY}$. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY} = 0.21$ (per yr), $SSB_{MSY} = 2545$ (mt), and MSY = 1117 (klb). Expected values presented are from deterministic projections.*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.31 | 0 | 1509.83 | 391 | 29 | 56 | 93 | 956 | 956 |
| 2010 | 0.31 | 0 | 1437.68 | 384 | 34 | 70 | 85 | 868 | 1824 |
| 2011 | 0.138 | 0 | 1432.92 | 381 | 16 | 34 | 42 | 414 | 2237 |
| 2012 | 0.138 | 0.01 | 1738.09 | 381 | 16 | 35 | 52 | 494 | 2731 |
| 2013 | 0.138 | 0.07 | 1985.92 | 391 | 17 | 36 | 60 | 573 | 3305 |
| 2014 | 0.138 | 0.19 | 2223.19 | 397 | 17 | 36 | 66 | 645 | 3949 |
| 2015 | 0.138 | 0.37 | 2440.08 | 401 | 17 | 37 | 71 | 708 | 4657 |
| 2016 | 0.138 | 0.56 | 2633.81 | 405 | 17 | 37 | 75 | 764 | 5421 |
| 2017 | 0.138 | 0.72 | 2803.64 | 408 | 17 | 38 | 79 | 813 | 6234 |
| 2018 | 0.138 | 0.83 | 2950.2 | 410 | 18 | 38 | 81 | 856 | 7090 |
| 2019 | 0.138 | 0.89 | 3075.24 | 411 | 18 | 38 | 84 | 892 | 7982 |
| 2020 | 0.138 | 0.93 | 3181.08 | 413 | 18 | 39 | 86 | 923 | 8905 |
| 2021 | 0.138 | 0.95 | 3270.36 | 414 | 18 | 39 | 87 | 949 | 9853 |
| 2022 | 0.138 | 0.97 | 3345.21 | 414 | 18 | 39 | 89 | 970 | 10,824 |
| 2023 | 0.138 | 0.98 | 3407.56 | 415 | 18 | 39 | 90 | 988 | 11,812 |
| 2024 | 0.138 | 0.98 | 3459 | 415 | 18 | 39 | 91 | 1003 | 12,815 |
| 2025 | 0.138 | 0.99 | 3501.17 | 416 | 18 | 39 | 91 | 1015 | 13,831 |
| 2026 | 0.138 | 0.99 | 3535.7 | 416 | 18 | 39 | 92 | 1025 | 14,856 |
| 2027 | 0.138 | 0.99 | 3563.92 | 416 | 18 | 39 | 93 | 1034 | 15,890 |
| 2028 | 0.138 | 0.99 | 3586.99 | 417 | 18 | 39 | 93 | 1040 | 16,930 |

*Table 3.24. Projection results under scenario 7—fishing mortality rate fixed at $F = 75\%F_{MSY}$. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY}$ = 0.21 (per yr), $SSB_{MSY}$ = 2545 (mt), and MSY = 1117 (klb). Expected values presented are from deterministic projections.*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.31 | 0 | 1509.83 | 391 | 29 | 56 | 93 | 956 | 956 |
| 2010 | 0.31 | 0 | 1437.68 | 384 | 34 | 70 | 85 | 868 | 1824 |
| 2011 | 0.159 | 0 | 1432.92 | 381 | 18 | 39 | 48 | 473 | 2297 |
| 2012 | 0.159 | 0.01 | 1702.23 | 381 | 19 | 40 | 58 | 556 | 2853 |
| 2013 | 0.159 | 0.05 | 1919.6 | 390 | 19 | 41 | 67 | 636 | 3489 |
| 2014 | 0.159 | 0.13 | 2124.59 | 395 | 19 | 42 | 73 | 707 | 4196 |
| 2015 | 0.159 | 0.26 | 2308.92 | 400 | 20 | 42 | 78 | 769 | 4964 |
| 2016 | 0.159 | 0.41 | 2470.95 | 403 | 20 | 43 | 82 | 823 | 5787 |
| 2017 | 0.159 | 0.55 | 2610.83 | 405 | 20 | 43 | 85 | 870 | 6657 |
| 2018 | 0.159 | 0.66 | 2729.76 | 407 | 20 | 43 | 88 | 909 | 7566 |
| 2019 | 0.159 | 0.75 | 2829.78 | 409 | 20 | 44 | 90 | 943 | 8508 |
| 2020 | 0.159 | 0.81 | 2913.3 | 410 | 20 | 44 | 92 | 971 | 9479 |
| 2021 | 0.159 | 0.85 | 2982.84 | 411 | 20 | 44 | 93 | 994 | 10,473 |
| 2022 | 0.159 | 0.88 | 3040.41 | 412 | 20 | 44 | 95 | 1013 | 11,486 |
| 2023 | 0.159 | 0.9 | 3087.77 | 412 | 20 | 44 | 96 | 1029 | 12,515 |
| 2024 | 0.159 | 0.92 | 3126.37 | 413 | 20 | 44 | 96 | 1042 | 13,556 |
| 2025 | 0.159 | 0.92 | 3157.65 | 413 | 20 | 44 | 97 | 1052 | 14,608 |
| 2026 | 0.159 | 0.93 | 3182.95 | 413 | 20 | 44 | 98 | 1060 | 15,668 |
| 2027 | 0.159 | 0.94 | 3203.41 | 414 | 20 | 44 | 98 | 1067 | 16,736 |
| 2028 | 0.159 | 0.94 | 3219.95 | 414 | 20 | 44 | 98 | 1073 | 17,808 |

*Table 3.25. Projection results under scenario 8—fishing mortality rate fixed at $F = 85\%F_{MSY}$. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY} = 0.21$ (per yr), $SSB_{MSY} = 2545$ (mt), and MSY = 1117 (klb). Expected values presented are from deterministic projections.*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.31 | 0 | 1509.83 | 391 | 29 | 56 | 93 | 956 | 956 |
| 2010 | 0.31 | 0 | 1437.68 | 384 | 34 | 70 | 85 | 868 | 1824 |
| 2011 | 0.18 | 0 | 1432.92 | 381 | 21 | 44 | 54 | 531 | 2355 |
| 2012 | 0.18 | 0.01 | 1667.24 | 381 | 21 | 45 | 65 | 614 | 2969 |
| 2013 | 0.18 | 0.04 | 1855.96 | 389 | 21 | 46 | 73 | 693 | 3663 |
| 2014 | 0.18 | 0.09 | 2031.41 | 394 | 22 | 47 | 79 | 762 | 4425 |
| 2015 | 0.18 | 0.17 | 2186.67 | 398 | 22 | 47 | 84 | 821 | 5246 |
| 2016 | 0.18 | 0.27 | 2321.05 | 401 | 22 | 48 | 88 | 871 | 6117 |
| 2017 | 0.18 | 0.37 | 2435.33 | 403 | 22 | 48 | 91 | 915 | 7032 |
| 2018 | 0.18 | 0.47 | 2531.1 | 405 | 22 | 48 | 93 | 951 | 7982 |
| 2019 | 0.18 | 0.55 | 2610.56 | 406 | 23 | 49 | 95 | 981 | 8963 |
| 2020 | 0.18 | 0.62 | 2676.05 | 407 | 23 | 49 | 97 | 1005 | 9969 |
| 2021 | 0.18 | 0.67 | 2729.92 | 408 | 23 | 49 | 98 | 1026 | 10,994 |
| 2022 | 0.18 | 0.71 | 2774.01 | 409 | 23 | 49 | 99 | 1042 | 12,037 |
| 2023 | 0.18 | 0.74 | 2809.85 | 409 | 23 | 49 | 100 | 1056 | 13,093 |
| 2024 | 0.18 | 0.76 | 2838.75 | 410 | 23 | 49 | 101 | 1067 | 14,160 |
| 2025 | 0.18 | 0.78 | 2861.91 | 410 | 23 | 49 | 101 | 1076 | 15,235 |
| 2026 | 0.18 | 0.79 | 2880.45 | 410 | 23 | 49 | 102 | 1082 | 16,318 |
| 2027 | 0.18 | 0.8 | 2895.29 | 411 | 23 | 49 | 102 | 1088 | 17,406 |
| 2028 | 0.18 | 0.81 | 2907.17 | 411 | 23 | 49 | 103 | 1093 | 18,498 |

*Table 3.26. Projection results under scenario 9—fishing mortality rate fixed at $F = F_{MSY}$. F = fishing mortality rate (per year), Pr(*$SSB > SSB_{MSY}$*) = proportion of stochastic projection replicates exceeding* $SSB_{MSY}$*, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000* lb *whole weight), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are* $F_{MSY} = 0.21$ *(per yr),* $SSB_{MSY} = 2545$ *(mt), and* MSY = 1117 *(klb). Expected values presented are from deterministic projections.*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.31 | 0 | 1509.83 | 391 | 29 | 56 | 93 | 956 | 956 |
| 2010 | 0.31 | 0 | 1437.68 | 384 | 34 | 70 | 85 | 868 | 1824 |
| 2011 | 0.212 | 0 | 1432.92 | 381 | 24 | 52 | 63 | 617 | 2440 |
| 2012 | 0.212 | 0 | 1616.32 | 381 | 25 | 53 | 74 | 696 | 3136 |
| 2013 | 0.212 | 0.02 | 1765.25 | 387 | 25 | 53 | 82 | 770 | 3906 |
| 2014 | 0.212 | 0.05 | 1901.1 | 392 | 25 | 54 | 87 | 833 | 4739 |
| 2015 | 0.212 | 0.08 | 2018.58 | 395 | 25 | 55 | 92 | 884 | 5623 |
| 2016 | 0.212 | 0.12 | 2117.99 | 397 | 26 | 55 | 95 | 928 | 6552 |
| 2017 | 0.212 | 0.17 | 2200.73 | 399 | 26 | 56 | 98 | 965 | 7516 |
| 2018 | 0.212 | 0.22 | 2268.64 | 401 | 26 | 56 | 100 | 995 | 8511 |
| 2019 | 0.212 | 0.26 | 2323.91 | 402 | 26 | 56 | 101 | 1019 | 9531 |
| 2020 | 0.212 | 0.3 | 2368.66 | 403 | 26 | 56 | 103 | 1039 | 10,570 |
| 2021 | 0.212 | 0.34 | 2404.86 | 404 | 26 | 56 | 104 | 1055 | 11,625 |
| 2022 | 0.212 | 0.37 | 2434.02 | 404 | 26 | 57 | 105 | 1068 | 12,693 |
| 2023 | 0.212 | 0.39 | 2457.38 | 405 | 26 | 57 | 105 | 1078 | 13,771 |
| 2024 | 0.212 | 0.41 | 2475.92 | 405 | 26 | 57 | 106 | 1087 | 14,858 |
| 2025 | 0.212 | 0.42 | 2490.57 | 405 | 26 | 57 | 106 | 1093 | 15,951 |
| 2026 | 0.212 | 0.43 | 2502.14 | 406 | 26 | 57 | 107 | 1098 | 17,049 |
| 2027 | 0.212 | 0.44 | 2511.28 | 406 | 26 | 57 | 107 | 1102 | 18,151 |
| 2028 | 0.212 | 0.45 | 2518.5 | 406 | 26 | 57 | 107 | 1105 | 19,256 |

*Table 3.27. Projection results under scenario 10—fishing mortality rate fixed at $F = F_{\text{rebuild}}$. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY} = 0.21$ (per yr), $SSB_{MSY} = 2545$ (mt), and MSY = 1117 (klb). Expected values presented are from deterministic projections.*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.31 | 0 | 1509.83 | 391 | 29 | 56 | 93 | 956 | 956 |
| 2010 | 0.31 | 0 | 1437.68 | 384 | 34 | 70 | 85 | 868 | 1824 |
| 2011 | 0.207 | 0 | 1432.92 | 381 | 24 | 51 | 62 | 604 | 2428 |
| 2012 | 0.207 | 0.01 | 1623.59 | 381 | 24 | 52 | 72 | 684 | 3112 |
| 2013 | 0.207 | 0.02 | 1778.06 | 387 | 24 | 52 | 80 | 760 | 3872 |
| 2014 | 0.207 | 0.05 | 1919.31 | 392 | 25 | 53 | 86 | 823 | 4695 |
| 2015 | 0.207 | 0.09 | 2041.87 | 395 | 25 | 54 | 91 | 876 | 5572 |
| 2016 | 0.207 | 0.14 | 2145.91 | 398 | 25 | 54 | 94 | 921 | 6493 |
| 2017 | 0.207 | 0.19 | 2232.76 | 400 | 25 | 54 | 97 | 959 | 7451 |
| 2018 | 0.207 | 0.25 | 2304.27 | 402 | 25 | 55 | 99 | 990 | 8441 |
| 2019 | 0.207 | 0.3 | 2362.62 | 403 | 26 | 55 | 101 | 1015 | 9456 |
| 2020 | 0.207 | 0.35 | 2409.97 | 404 | 26 | 55 | 102 | 1035 | 10,491 |
| 2021 | 0.207 | 0.38 | 2448.38 | 404 | 26 | 55 | 103 | 1052 | 11,543 |
| 2022 | 0.207 | 0.41 | 2479.38 | 405 | 26 | 55 | 104 | 1065 | 12,609 |
| 2023 | 0.207 | 0.44 | 2504.25 | 405 | 26 | 56 | 105 | 1076 | 13,685 |
| 2024 | 0.207 | 0.46 | 2524.05 | 406 | 26 | 56 | 105 | 1085 | 14,770 |
| 2025 | 0.207 | 0.47 | 2539.72 | 406 | 26 | 56 | 106 | 1092 | 15,862 |
| 2026 | 0.207 | 0.49 | 2552.12 | 406 | 26 | 56 | 106 | 1097 | 16,958 |
| 2027 | 0.207 | 0.5 | 2561.93 | 406 | 26 | 56 | 106 | 1101 | 18,060 |
| 2028 | 0.207 | 0.51 | 2569.69 | 407 | 26 | 56 | 107 | 1104 | 19,164 |

*Table 3.28. Projection results under scenario 11—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009, $F = 75\%F_{\text{current}}$ in 2010, and $F_{\text{rebuild}}$ thereafter. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY}$ = 0.21 (per yr), $SSB_{MSY}$ = 2545 (mt), and MSY = 1117 (klb). Expected values presented are from deterministic projections.*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.31 | 0 | 1509.83 | 391 | 29 | 56 | 93 | 956 | 956 |
| 2010 | 0.232 | 0 | 1437.68 | 384 | 26 | 53 | 66 | 673 | 1629 |
| 2011 | 0.208 | 0 | 1546.59 | 381 | 24 | 51 | 66 | 645 | 2274 |
| 2012 | 0.208 | 0.01 | 1696.22 | 385 | 24 | 52 | 75 | 720 | 2994 |
| 2013 | 0.208 | 0.03 | 1838.76 | 390 | 25 | 53 | 83 | 790 | 3784 |
| 2014 | 0.208 | 0.07 | 1968.69 | 393 | 25 | 54 | 88 | 848 | 4632 |
| 2015 | 0.208 | 0.11 | 2081.43 | 396 | 25 | 54 | 92 | 897 | 5530 |
| 2016 | 0.208 | 0.16 | 2176.97 | 399 | 25 | 54 | 95 | 939 | 6469 |
| 2017 | 0.208 | 0.21 | 2256.44 | 401 | 25 | 55 | 98 | 973 | 7442 |
| 2018 | 0.208 | 0.26 | 2321.59 | 402 | 26 | 55 | 100 | 1002 | 8444 |
| 2019 | 0.208 | 0.31 | 2374.56 | 403 | 26 | 55 | 101 | 1025 | 9469 |
| 2020 | 0.208 | 0.35 | 2417.41 | 404 | 26 | 56 | 103 | 1043 | 10,512 |
| 2021 | 0.208 | 0.39 | 2452.08 | 405 | 26 | 56 | 104 | 1059 | 11,571 |
| 2022 | 0.208 | 0.41 | 2480.02 | 405 | 26 | 56 | 105 | 1071 | 12,641 |
| 2023 | 0.208 | 0.44 | 2502.4 | 405 | 26 | 56 | 105 | 1080 | 13,722 |
| 2024 | 0.208 | 0.46 | 2520.19 | 406 | 26 | 56 | 106 | 1088 | 14,810 |
| 2025 | 0.208 | 0.47 | 2534.24 | 406 | 26 | 56 | 106 | 1094 | 15,904 |
| 2026 | 0.208 | 0.48 | 2545.34 | 406 | 26 | 56 | 106 | 1099 | 17,003 |
| 2027 | 0.208 | 0.49 | 2554.12 | 406 | 26 | 56 | 107 | 1103 | 18,106 |
| 2028 | 0.208 | 0.5 | 2561.06 | 407 | 26 | 56 | 107 | 1106 | 19,212 |

*Table 3.29. Projection results under scenario 12—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009, $F = 50\%F_{\text{current}}$ in 2010, and $F_{\text{rebuild}}$ thereafter. F = fishing mortality rate (per year), Pr(SSB > SSB$_{\text{MSY}}$) = proportion of stochastic projection replicates exceeding SSB$_{\text{MSY}}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{\text{MSY}} = 0.21$ (per yr), SSB$_{\text{MSY}}$ = 2545 (mt), and MSY = 1117 (klb). Expected values presented are from deterministic projections.*

| Year | F(per yr) | Pr(SSB > SSB$_{\text{MSY}}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.31 | 0 | 1509.83 | 391 | 29 | 56 | 93 | 956 | 956 |
| 2010 | 0.155 | 0 | 1437.68 | 384 | 17 | 36 | 45 | 464 | 1420 |
| 2011 | 0.208 | 0 | 1671.01 | 381 | 24 | 52 | 69 | 685 | 2105 |
| 2012 | 0.208 | 0.01 | 1775.43 | 389 | 25 | 53 | 78 | 756 | 2861 |
| 2013 | 0.208 | 0.04 | 1906.22 | 392 | 25 | 53 | 85 | 820 | 3681 |
| 2014 | 0.208 | 0.08 | 2025.08 | 395 | 25 | 54 | 90 | 873 | 4553 |
| 2015 | 0.208 | 0.13 | 2128.34 | 398 | 25 | 54 | 94 | 918 | 5471 |
| 2016 | 0.208 | 0.18 | 2215.79 | 400 | 25 | 55 | 97 | 956 | 6427 |
| 2017 | 0.208 | 0.23 | 2288.33 | 401 | 26 | 55 | 99 | 987 | 7414 |
| 2018 | 0.208 | 0.28 | 2347.61 | 403 | 26 | 55 | 101 | 1013 | 8427 |
| 2019 | 0.208 | 0.33 | 2395.64 | 403 | 26 | 55 | 102 | 1034 | 9461 |
| 2020 | 0.208 | 0.37 | 2434.39 | 404 | 26 | 56 | 103 | 1051 | 10,512 |
| 2021 | 0.208 | 0.4 | 2465.7 | 405 | 26 | 56 | 104 | 1064 | 11,577 |
| 2022 | 0.208 | 0.43 | 2490.89 | 405 | 26 | 56 | 105 | 1075 | 12,652 |
| 2023 | 0.208 | 0.45 | 2511.05 | 406 | 26 | 56 | 105 | 1084 | 13,736 |
| 2024 | 0.208 | 0.46 | 2527.06 | 406 | 26 | 56 | 106 | 1091 | 14,827 |
| 2025 | 0.208 | 0.48 | 2539.68 | 406 | 26 | 56 | 106 | 1097 | 15,924 |
| 2026 | 0.208 | 0.48 | 2549.65 | 406 | 26 | 56 | 107 | 1101 | 17,025 |
| 2027 | 0.208 | 0.49 | 2557.53 | 406 | 26 | 56 | 107 | 1104 | 18,129 |
| 2028 | 0.208 | 0.5 | 2563.75 | 407 | 26 | 56 | 107 | 1107 | 19,236 |

*Table 3.30. Projection results under scenario 13—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009, $F = 25\%F_{\text{current}}$ in 2010, and $F_{\text{rebuild}}$ thereafter. F = fishing mortality rate (per year), Pr(SSB > $\text{SSB}_{\text{MSY}}$) = proportion of stochastic projection replicates exceeding $\text{SSB}_{\text{MSY}}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{\text{MSY}} = 0.21$ (per yr), $\text{SSB}_{\text{MSY}} = 2545$ (mt), and MSY = 1117 (klb). Expected values presented are from deterministic projections.*

| Year | F(per yr) | Pr(SSB > $\text{SSB}_{\text{MSY}}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.31 | 0 | 1509.83 | 391 | 29 | 56 | 93 | 956 | 956 |
| 2010 | 0.077 | 0 | 1437.68 | 384 | 9 | 18 | 23 | 240 | 1196 |
| 2011 | 0.208 | 0 | 1807.28 | 381 | 24 | 53 | 73 | 729 | 1924 |
| 2012 | 0.208 | 0.02 | 1860.03 | 393 | 25 | 53 | 82 | 794 | 2718 |
| 2013 | 0.208 | 0.06 | 1977.93 | 394 | 25 | 54 | 88 | 851 | 3570 |
| 2014 | 0.208 | 0.11 | 2084.72 | 397 | 25 | 54 | 92 | 898 | 4468 |
| 2015 | 0.208 | 0.16 | 2177.66 | 399 | 25 | 55 | 95 | 939 | 5407 |
| 2016 | 0.208 | 0.21 | 2256.38 | 401 | 25 | 55 | 98 | 974 | 6381 |
| 2017 | 0.208 | 0.26 | 2321.52 | 402 | 26 | 55 | 100 | 1002 | 7382 |
| 2018 | 0.208 | 0.31 | 2374.57 | 403 | 26 | 55 | 101 | 1025 | 8407 |
| 2019 | 0.208 | 0.35 | 2417.42 | 404 | 26 | 56 | 103 | 1043 | 9451 |
| 2020 | 0.208 | 0.39 | 2451.89 | 405 | 26 | 56 | 104 | 1058 | 10,509 |
| 2021 | 0.208 | 0.42 | 2479.7 | 405 | 26 | 56 | 105 | 1071 | 11,580 |
| 2022 | 0.208 | 0.44 | 2502.05 | 405 | 26 | 56 | 105 | 1080 | 12,660 |
| 2023 | 0.208 | 0.46 | 2519.92 | 406 | 26 | 56 | 106 | 1088 | 13,748 |
| 2024 | 0.208 | 0.47 | 2534.09 | 406 | 26 | 56 | 106 | 1094 | 14,842 |
| 2025 | 0.208 | 0.48 | 2545.25 | 406 | 26 | 56 | 106 | 1099 | 15,941 |
| 2026 | 0.208 | 0.49 | 2554.05 | 406 | 26 | 56 | 107 | 1103 | 17,044 |
| 2027 | 0.208 | 0.5 | 2561.01 | 407 | 26 | 56 | 107 | 1106 | 18,150 |
| 2028 | 0.208 | 0.51 | 2566.5 | 407 | 26 | 56 | 107 | 1108 | 19,258 |

### 3.6.1 Tables

*Table 3.31. ASPIC model results with $B_1/K$ estimated and with indices input separately or combined. The effect of a hypothesized 2% catchability increase per year (t–var q) was evaluated for two of the runs with all indices included. Additional runs without the RVC index which was negatively correlated with the RVC and headboat indices, and with only the headboat index were evaluated to determine the influence of the index on the results. Biomass quantities (MSY, $B_{MSY}$, K) are in units of pounds whole weight.*

| Run | t–var q | $B_1/K$ | MSY | $F_{MSY}$ | $B_{MSY}$ | K | r | $B/B_{MSY}$ | $F/F_{MSY}$ | like.val |
|---|---|---|---|---|---|---|---|---|---|---|
| Separate | no | 0.280 | 1122656 | 0.431 | 2603865 | 5207730 | 0.862 | 1.036 | 1.377 | 2.750 |
| Separate | yes | 0.346 | 999832 | 0.464 | 2154379 | 4308757 | 0.928 | 0.763 | 1.932 | 3.177 |
| Combined | no | 0.252 | 1175633 | 0.249 | 4727339 | 9454678 | 0.497 | 0.790 | 1.777 | 3.106 |
| Combined | yes | 0.228 | 1266533 | 0.270 | 4696007 | 9392015 | 0.539 | 0.533 | 2.332 | 3.597 |
| Separate-noRVC | no | 0.308 | 1061664 | 0.447 | 2373619 | 4747238 | 0.895 | 0.939 | 1.563 | 1.932 |
| Separate-HB only | no | 0.396 | 909375 | 0.300 | 3029596 | 6059191 | 0.600 | 0.677 | 2.413 | 4.88 |

*Table 3.32. Comparison of the model estimated catchability coefficients for headboat (hb.q), commercial (c.q), MRFSS (MRFSS.q), MARMAP (MARMAP.q), and RVC (RVC.q).*

| Run | t–var q | hb.q | c.q | MRFSS.q | MARMAP.q | RVC.q |
|---|---|---|---|---|---|---|
| Separate | no | 4.08E-07 | 3.42E-07 | 3.18E-07 | 2.99E-07 | 2.46E-07 |
| Separate | yes | 3.26E-07 | 3.85E-07 | 3.33E-07 | 3.78E-07 | 3.23E-07 |
| Combined | no | 3.89E-07 | | | | |
| Combined | yes | 4.74E-07 | | | | |
| Separate-noRVC | no | 4.03E-07 | 3.37E-07 | 3.12E-07 | 2.93E-07 | |
| Separate-HB only | no | 3.12E-07 | | | | |

### 3.7 Figures

*Figure 3.1. Mean length at age (mm) and estimated 95% confidence interval of the population.*

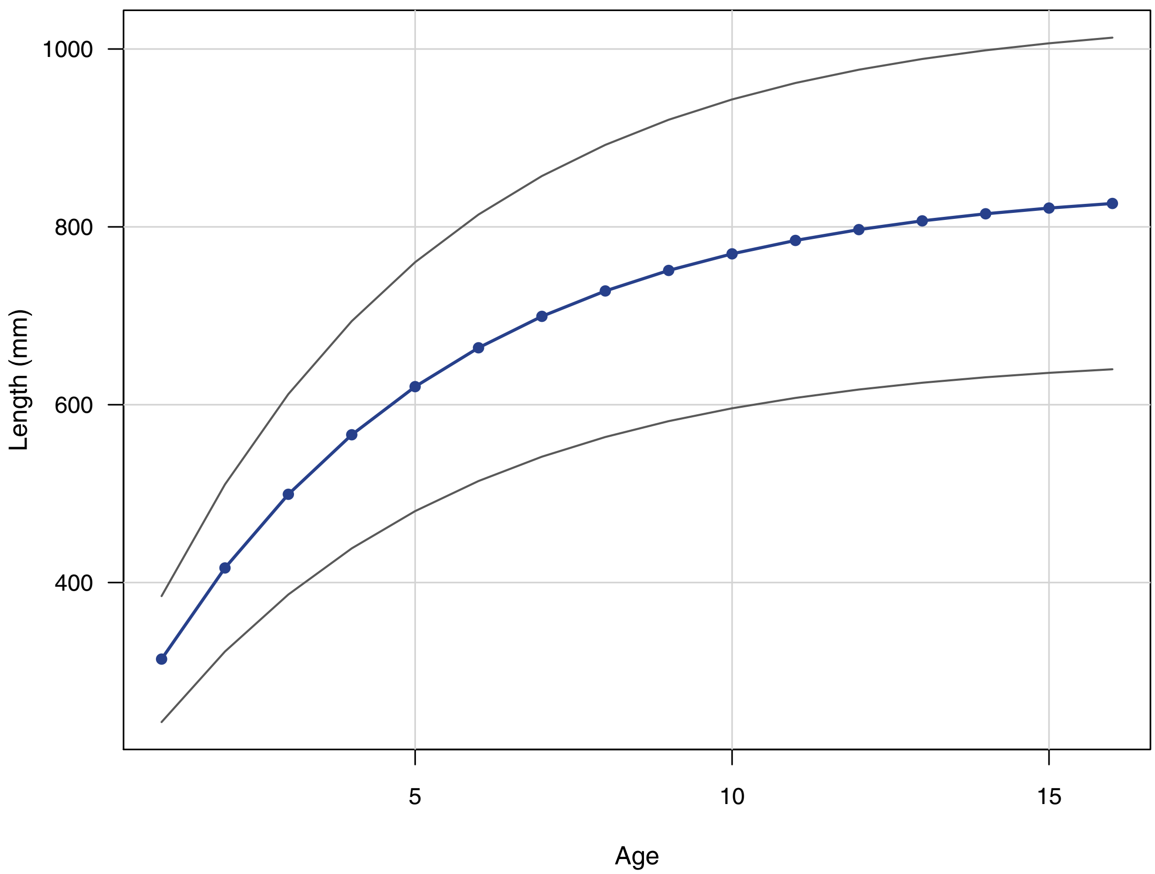


*Figure 3.2. Standard errors of management quantities with increased number of Monte Carlo/bootstrap trials.*

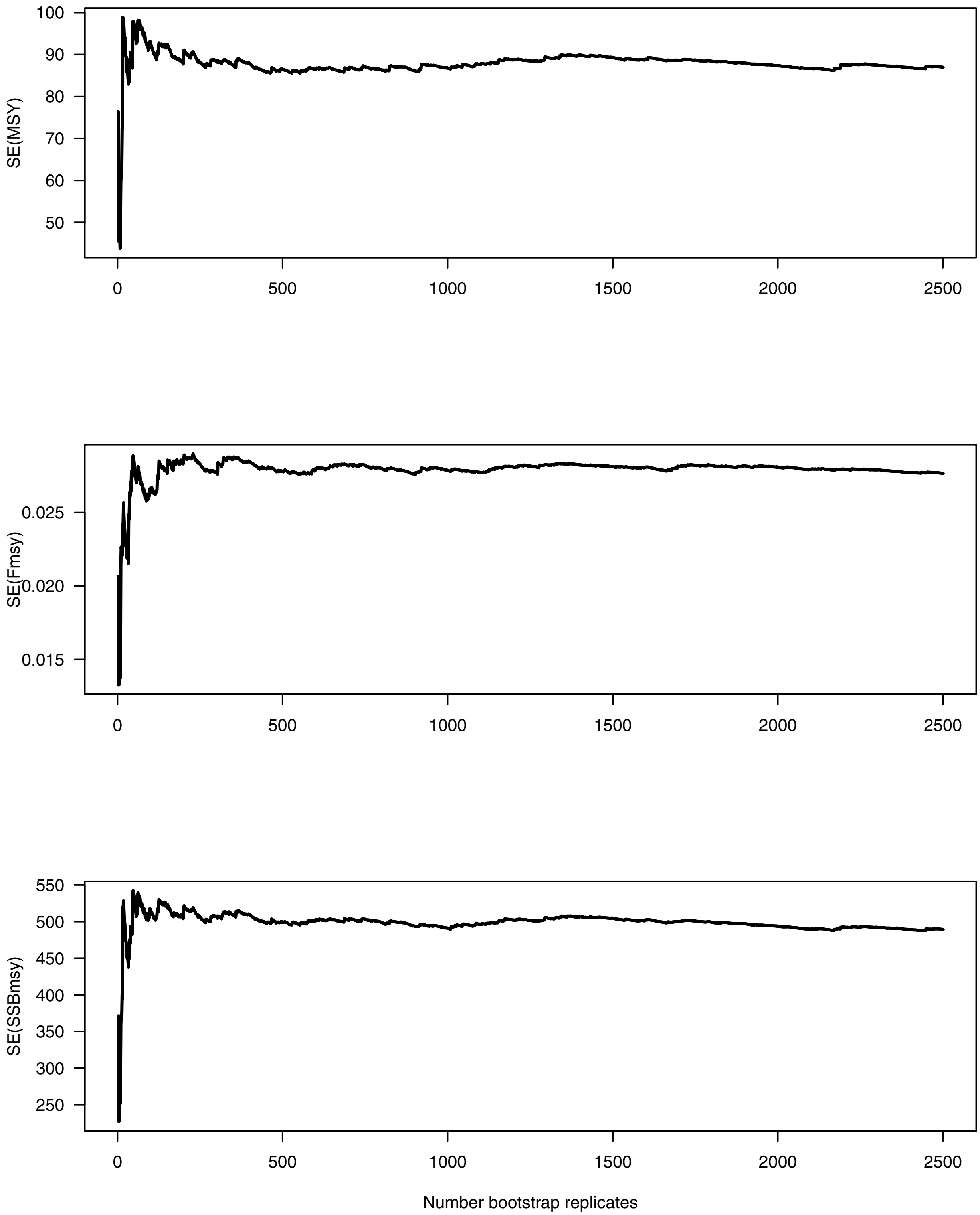


*Figure 3.3. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, rvc refers to the visual survey, cvt to chevron trap, cl to commercial lines, co to commercial other, hb to headboat, rec to general recreational (MRFSS), and hb.D to headboat discards. N indicates the number of trips from which individual fish samples were taken.*

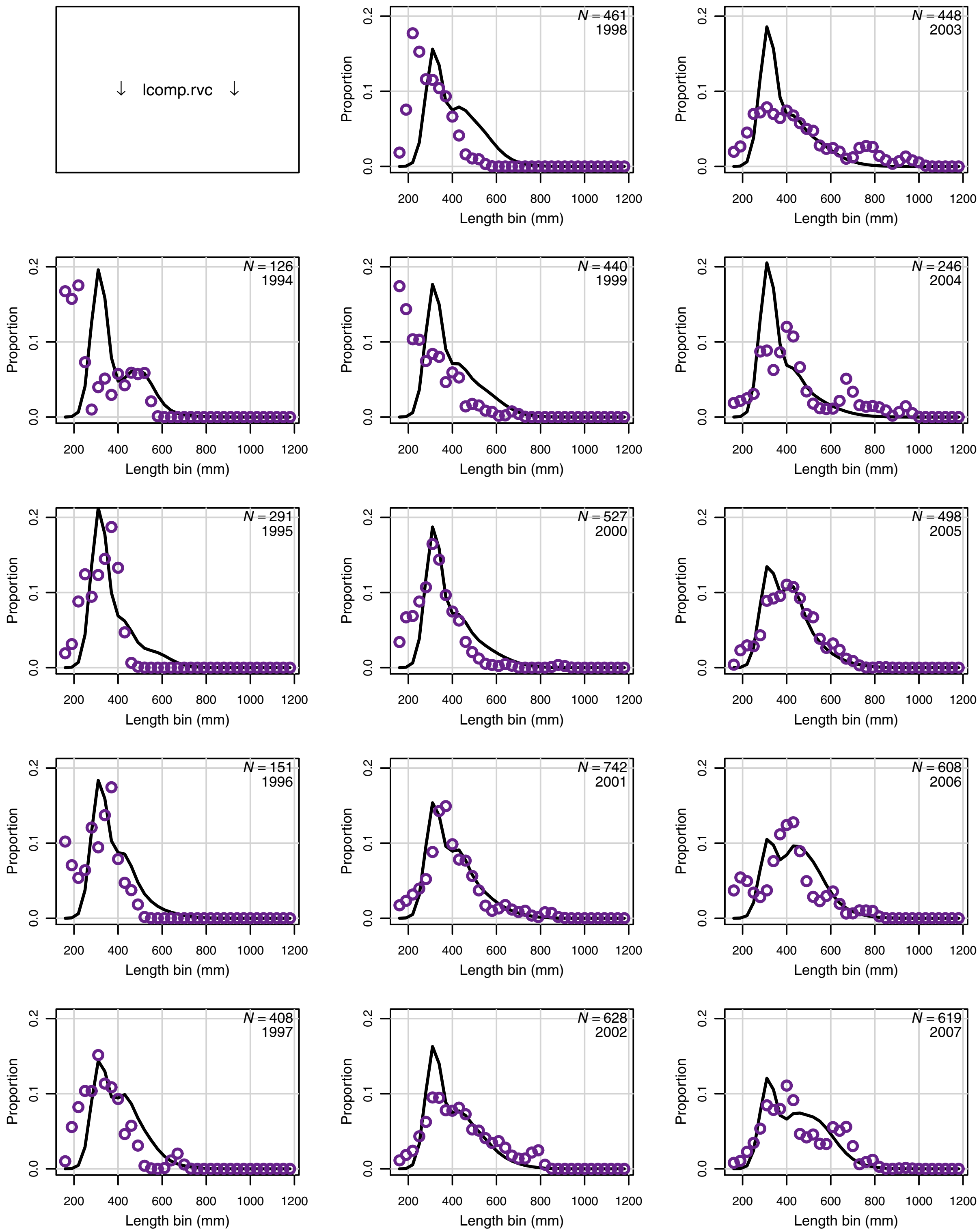


*Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

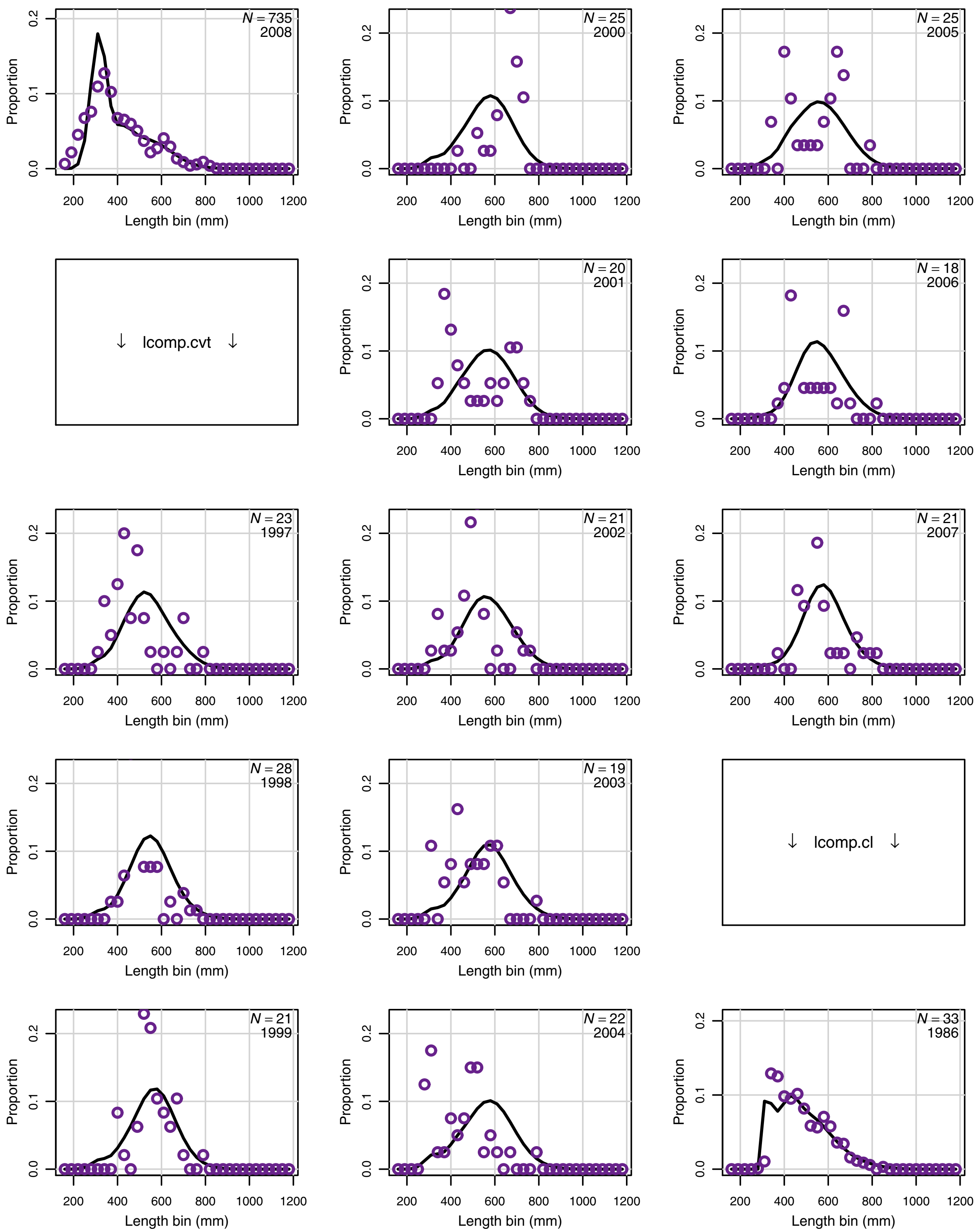


*Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

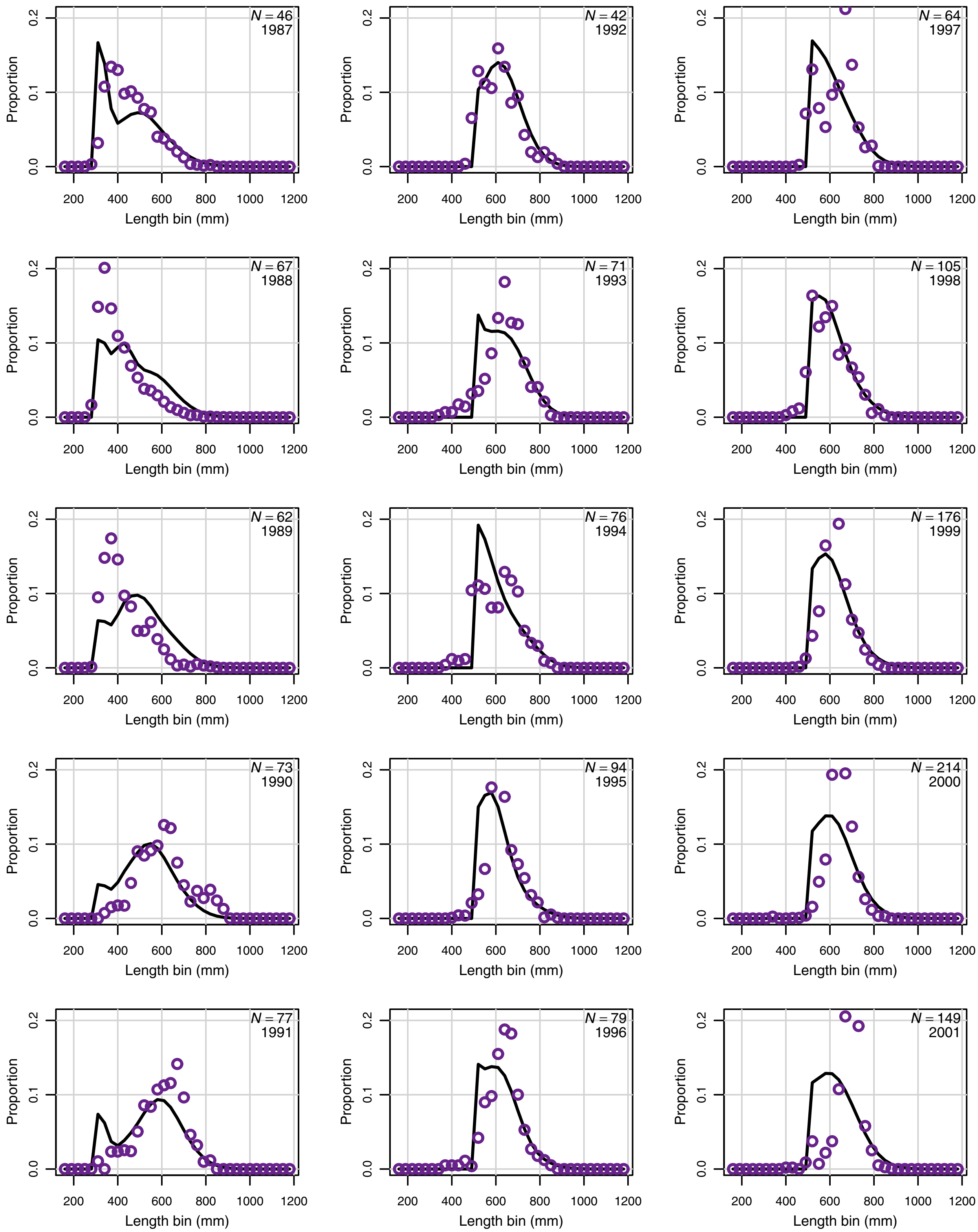


*Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

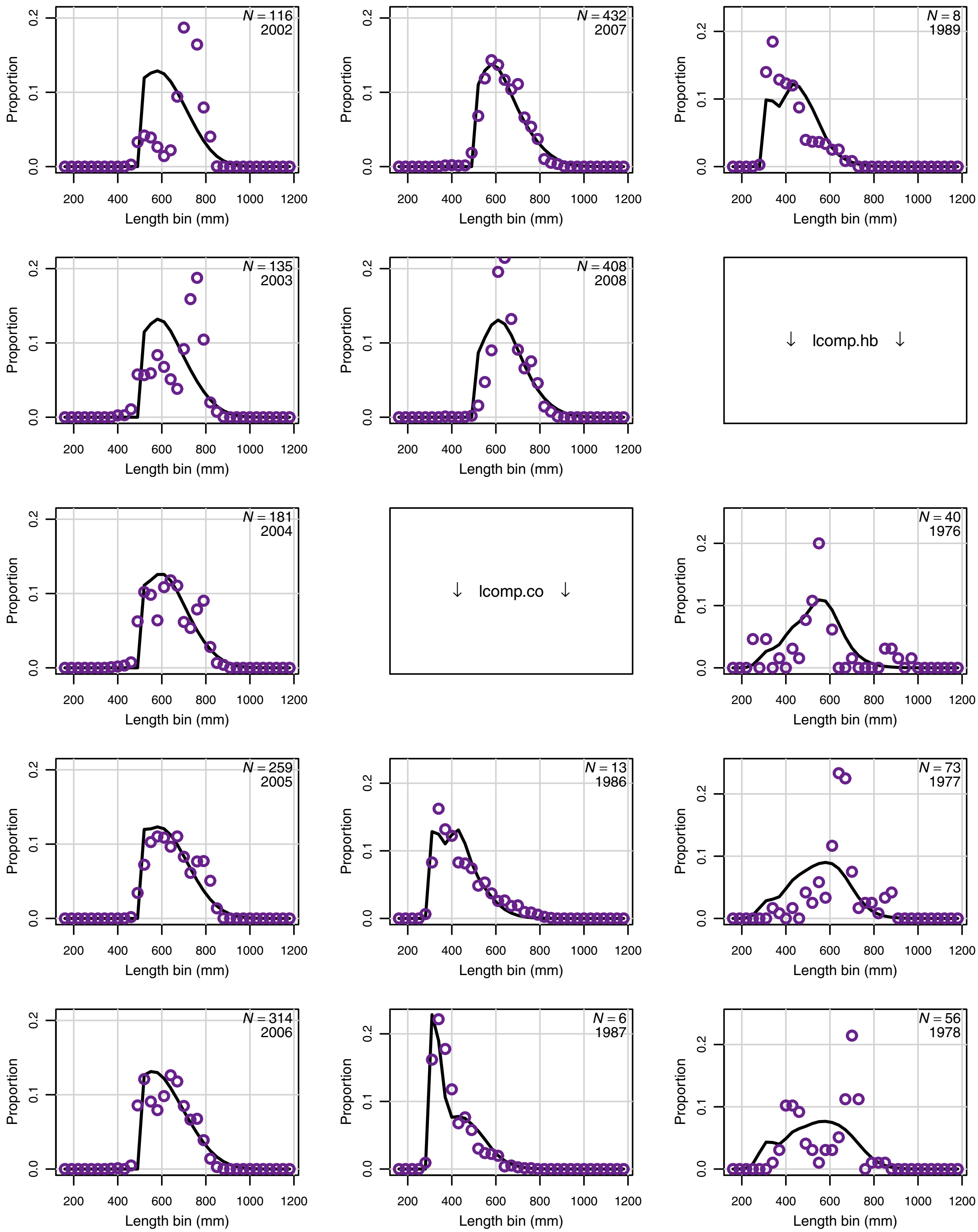


*Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

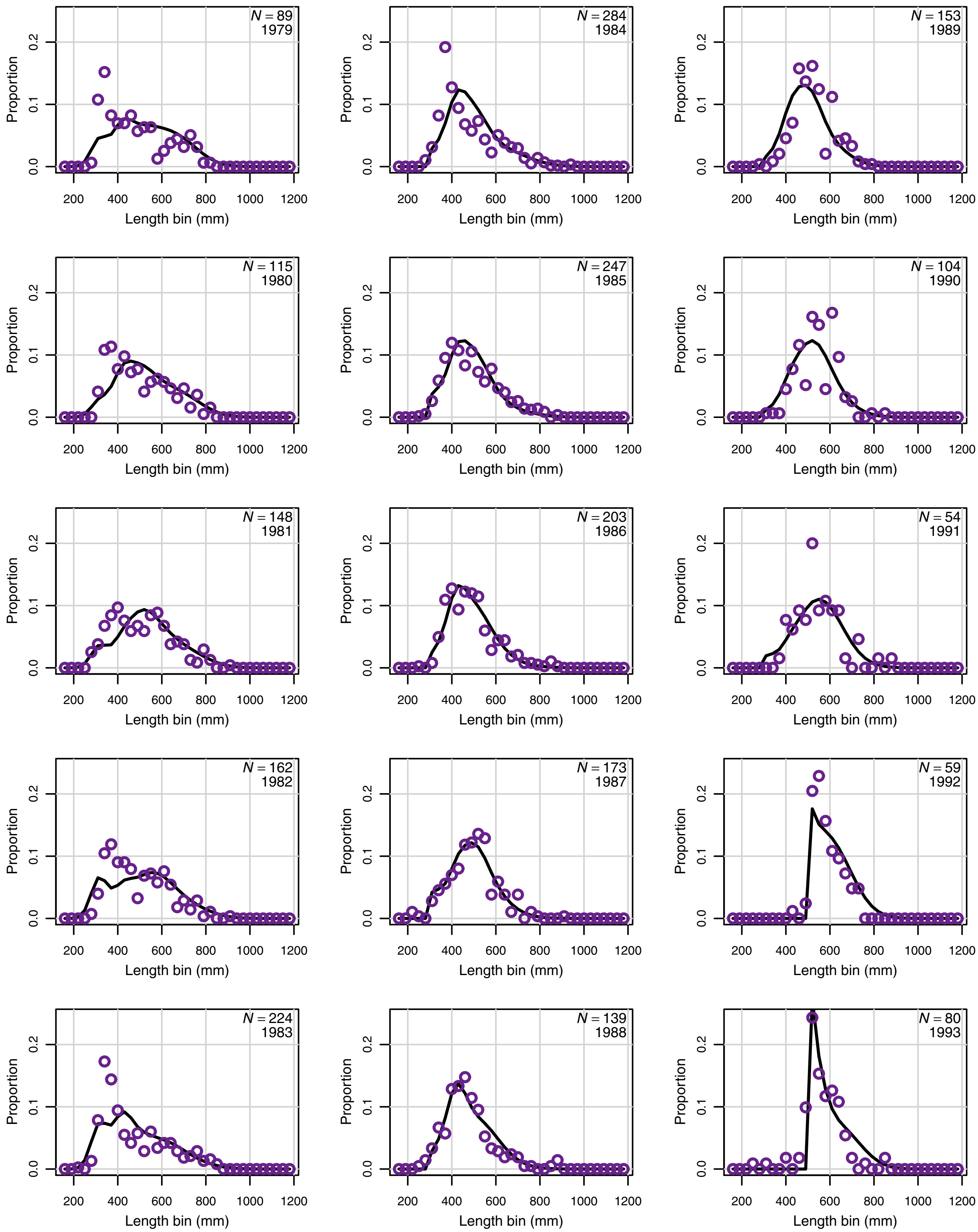


*Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

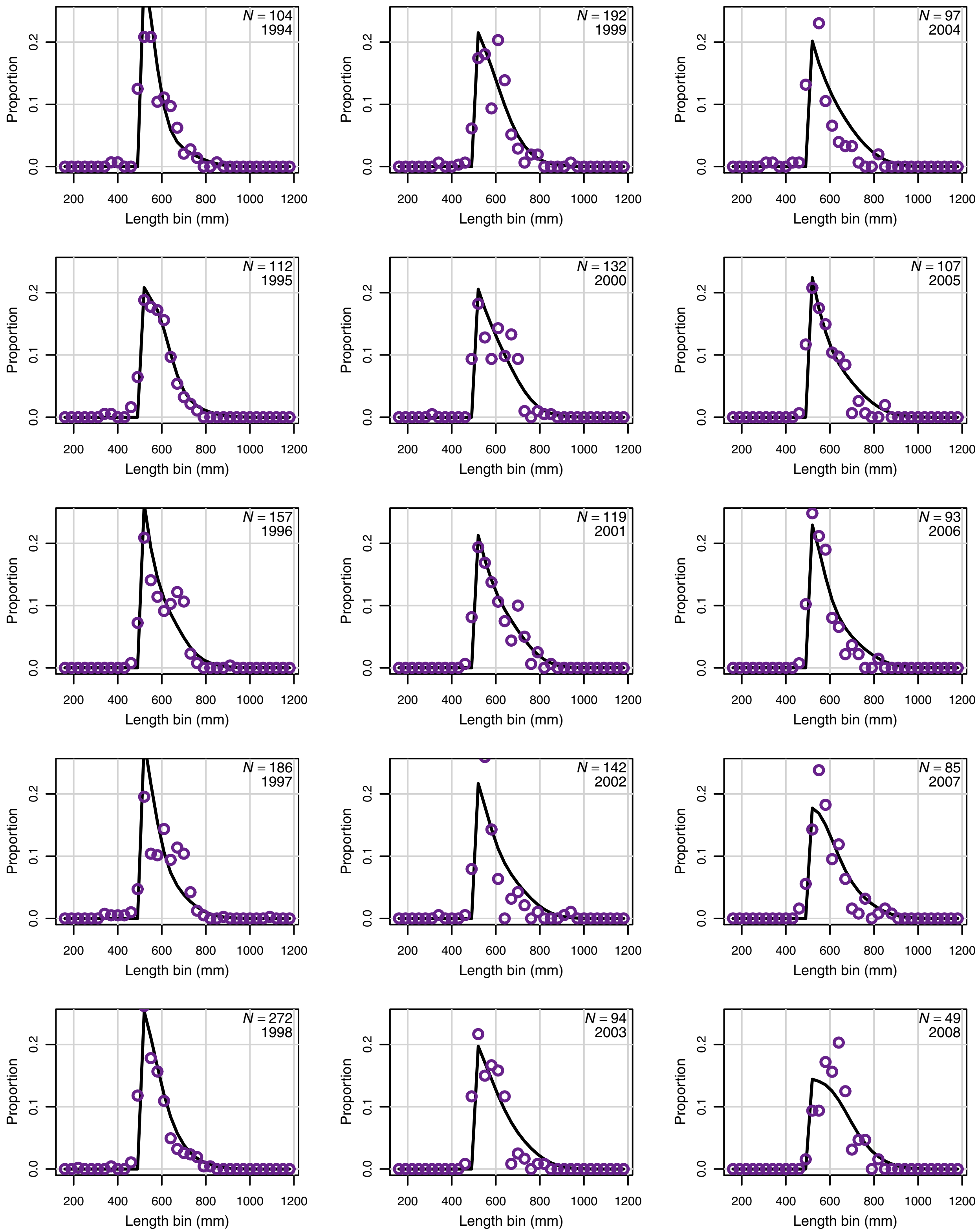


*Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

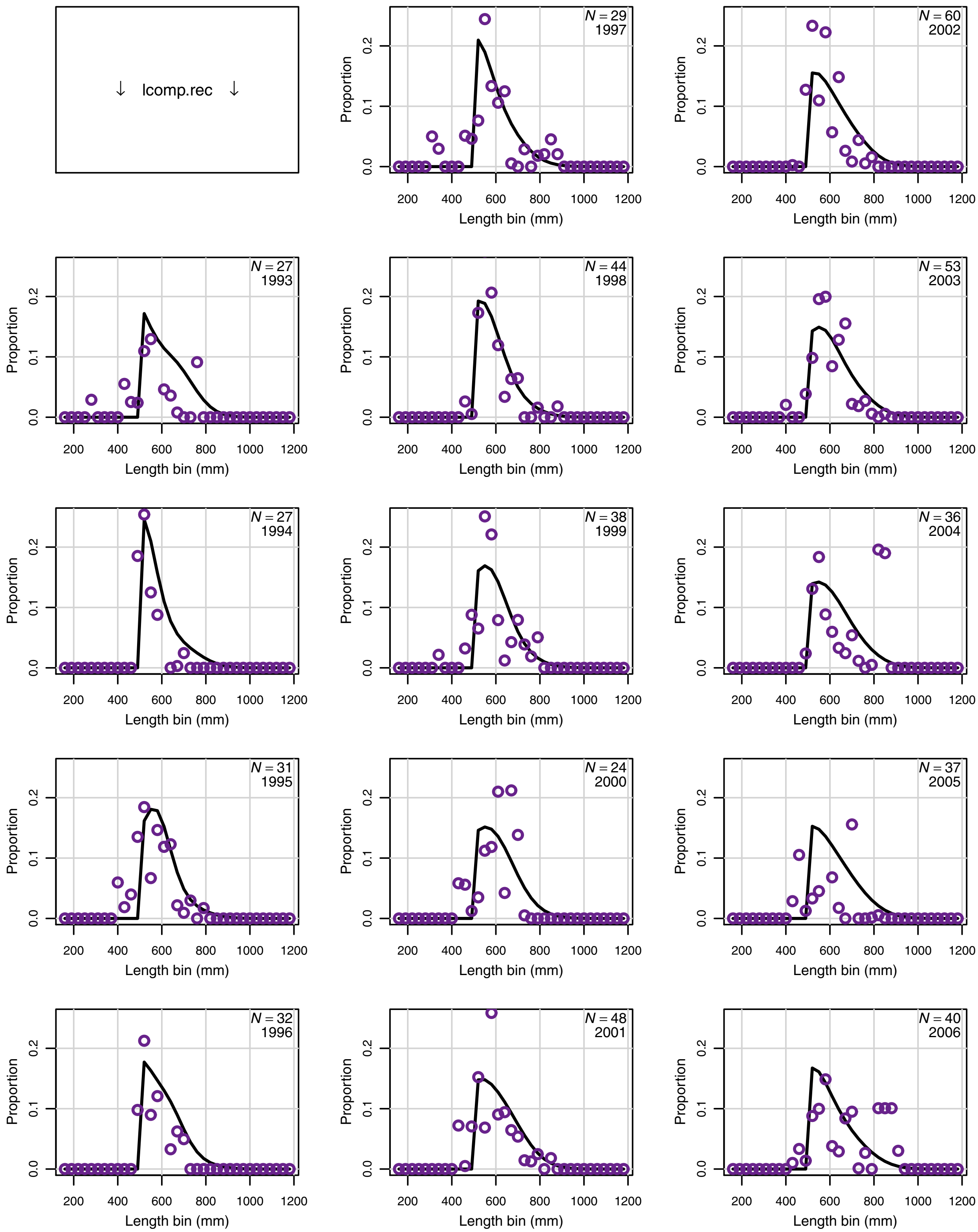


*Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

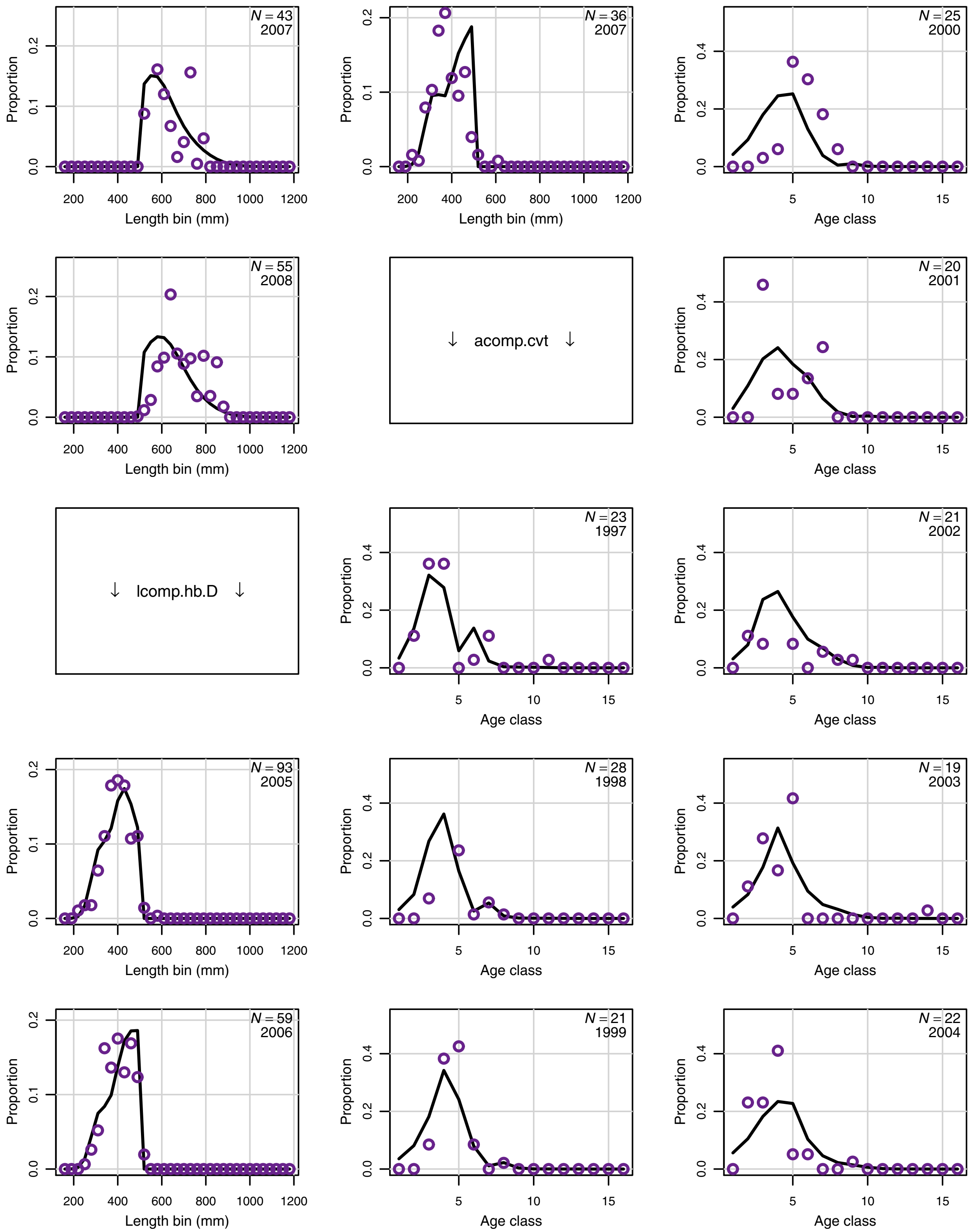


*Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

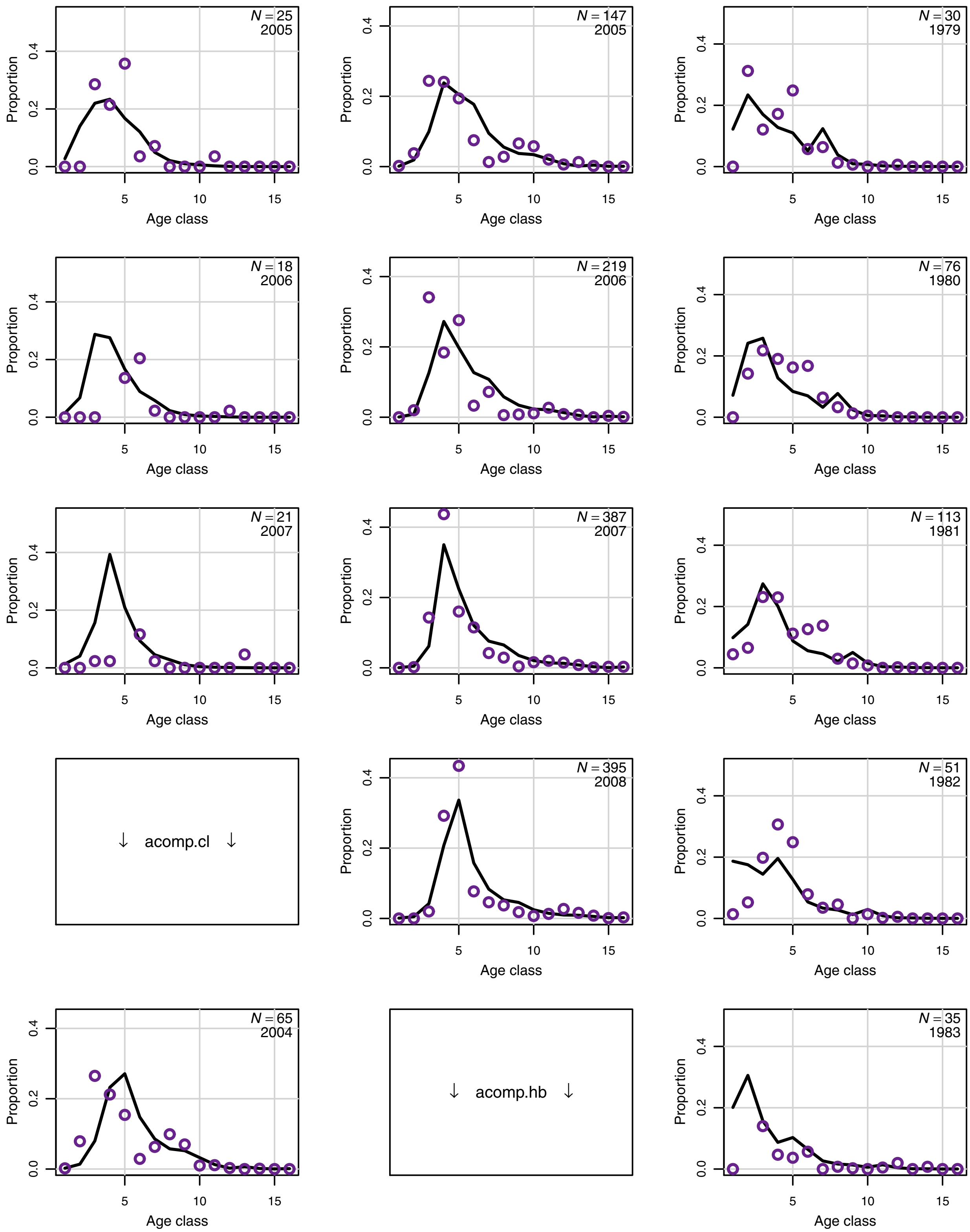


*Figure 3.3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

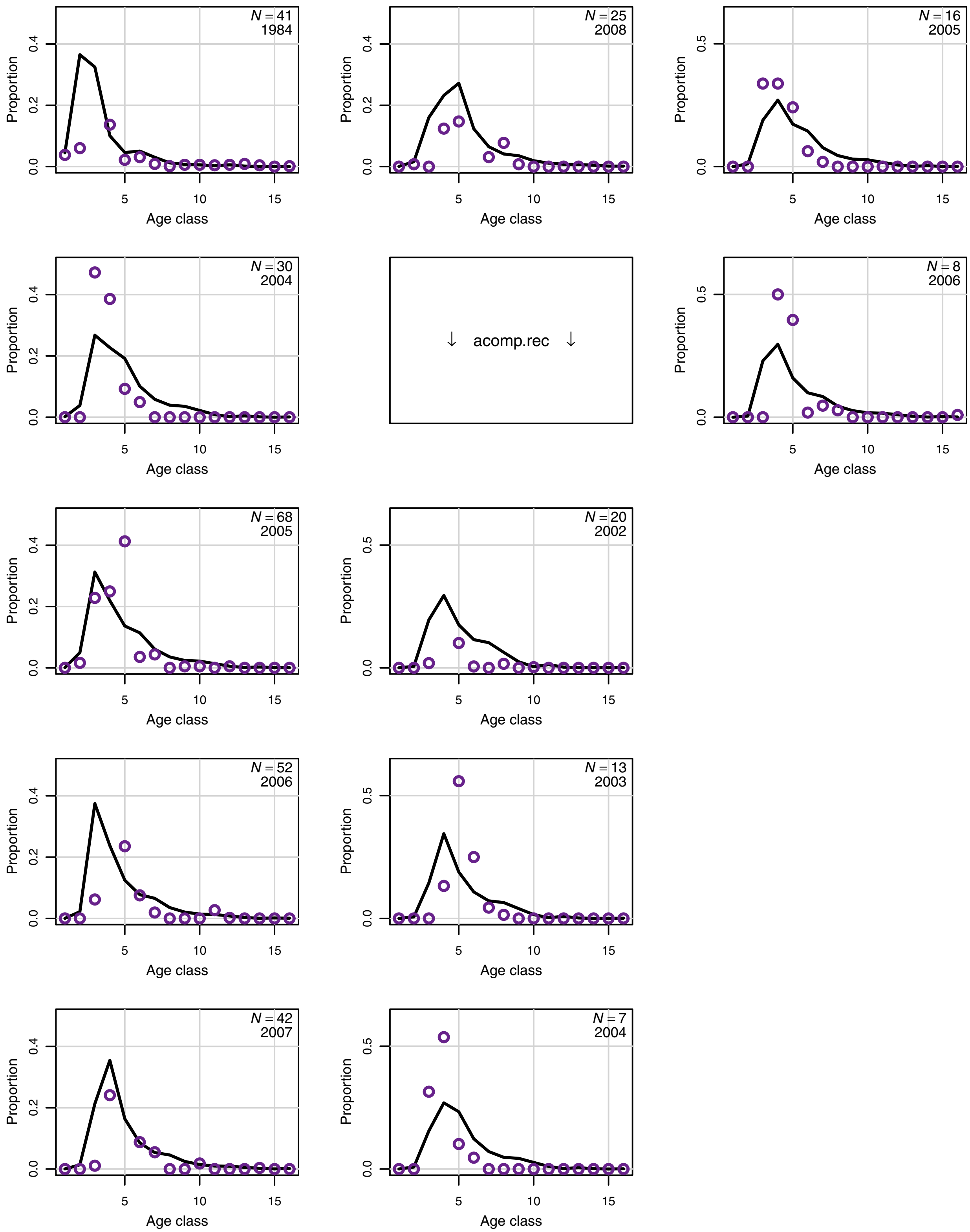


*Figure 3.4. Top panel is a bubble plot of length composition residuals from the visual survey; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

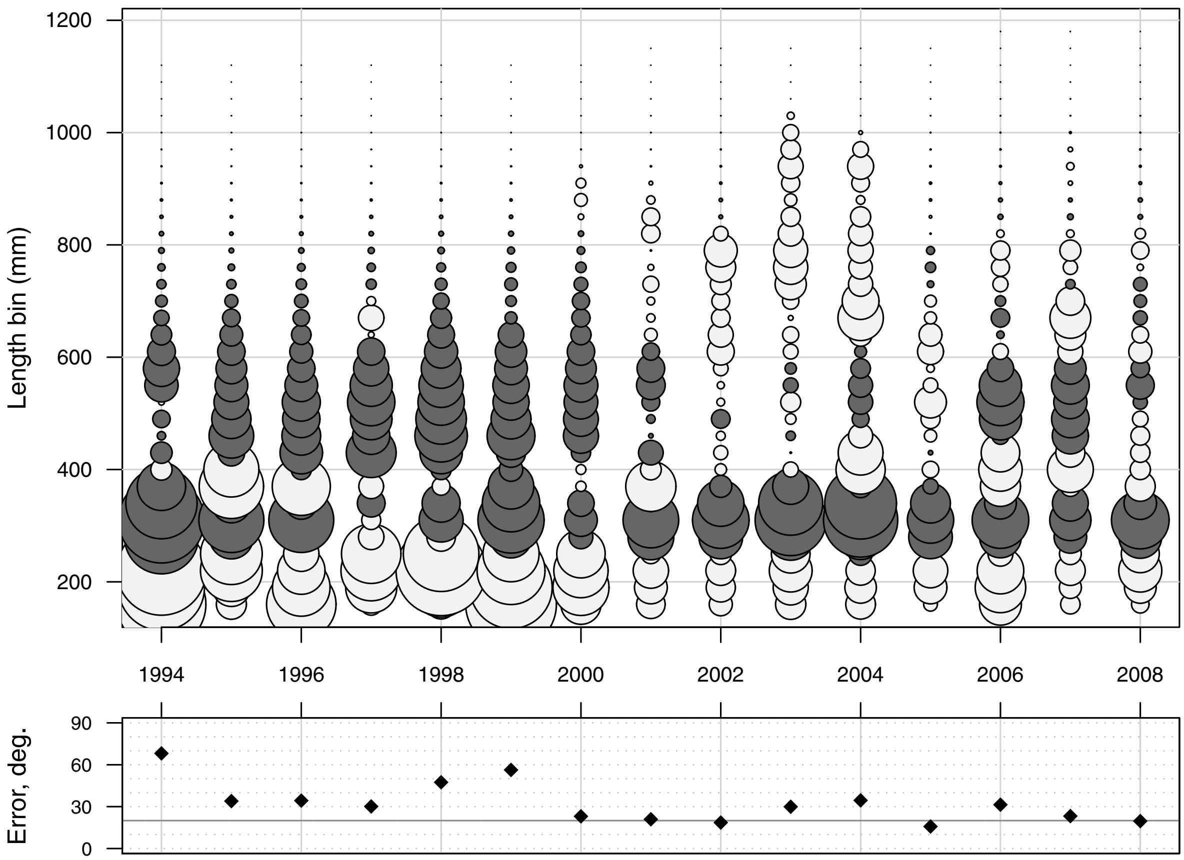


*Figure 3.5. Top panel is a bubble plot of length composition residuals from MARMAP Florida snapper trap; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

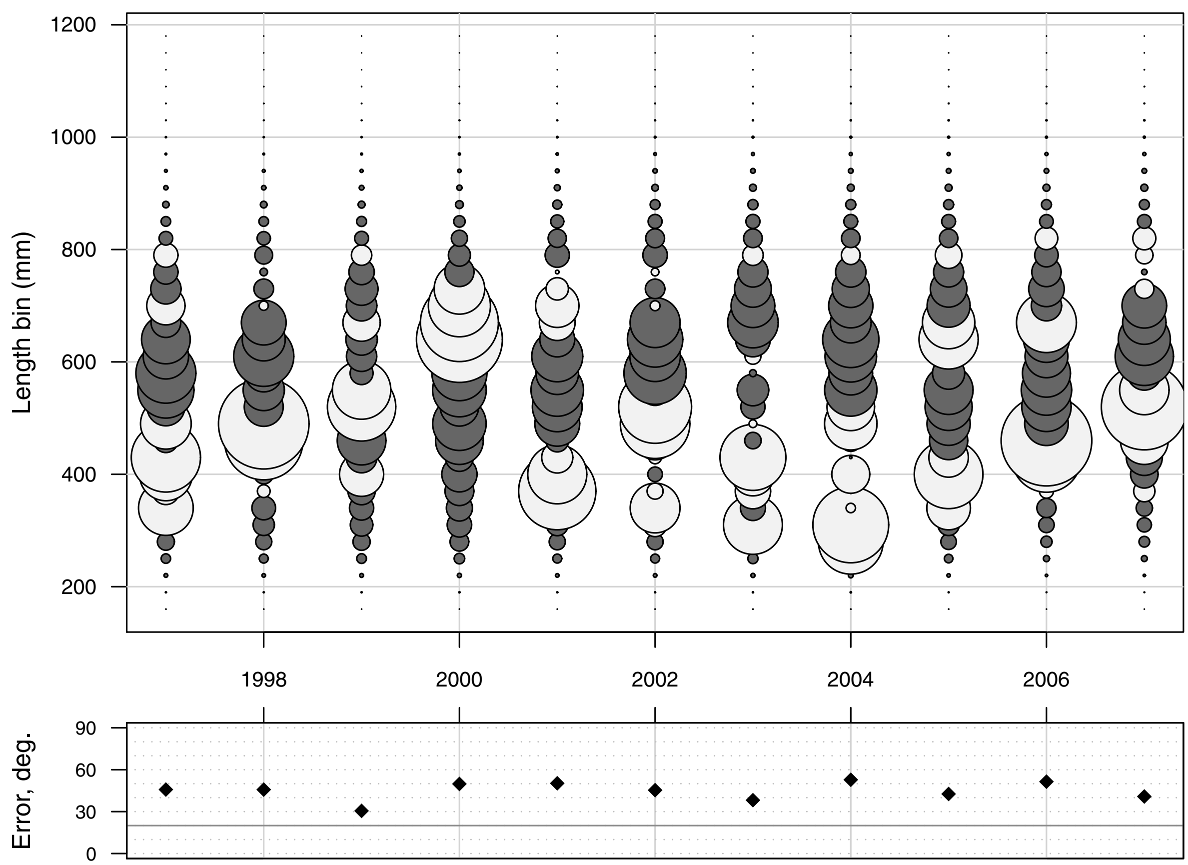


*Figure 3.6. Top panel is a bubble plot of length composition residuals from commercial lines; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

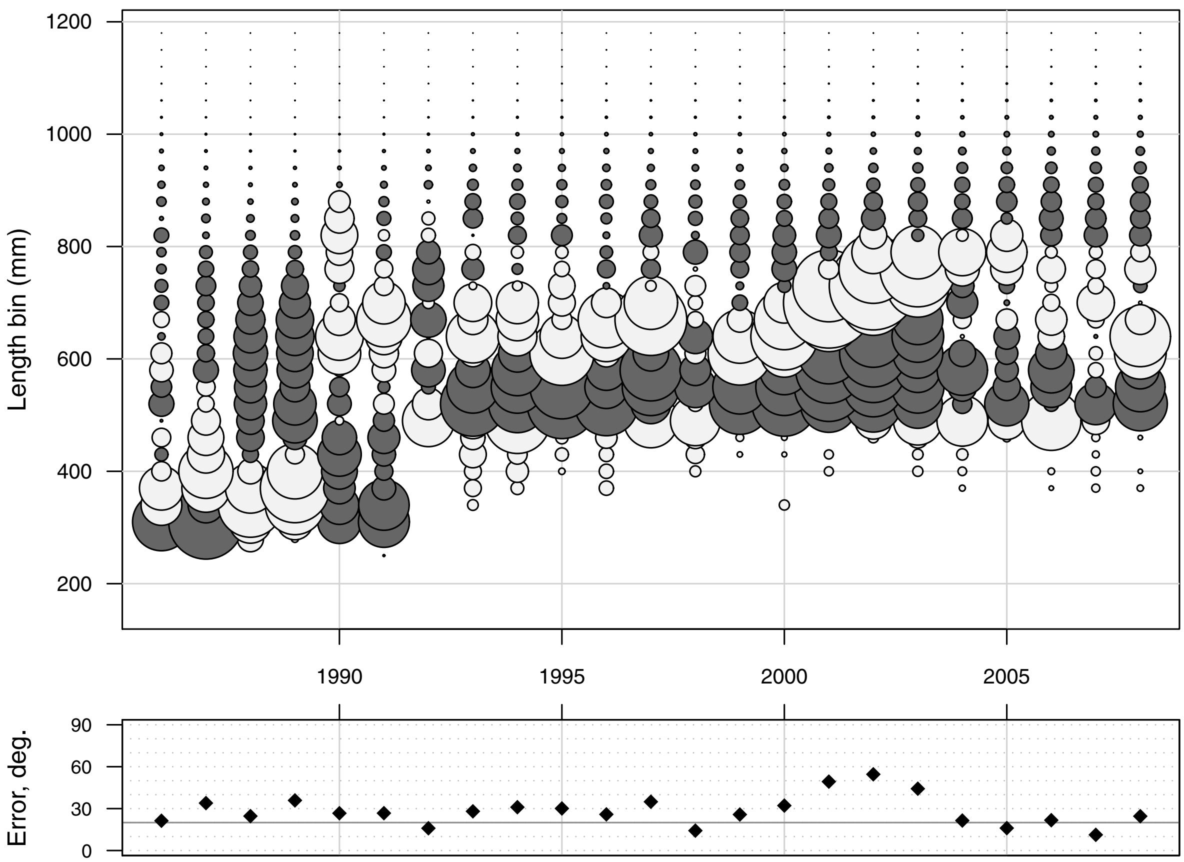


*Figure 3.7. Top panel is a bubble plot of length composition residuals from the commercial other; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

*Figure 3.8. Top panel is a bubble plot of length composition residuals from headboats; Dark represents overestimates and light 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.*

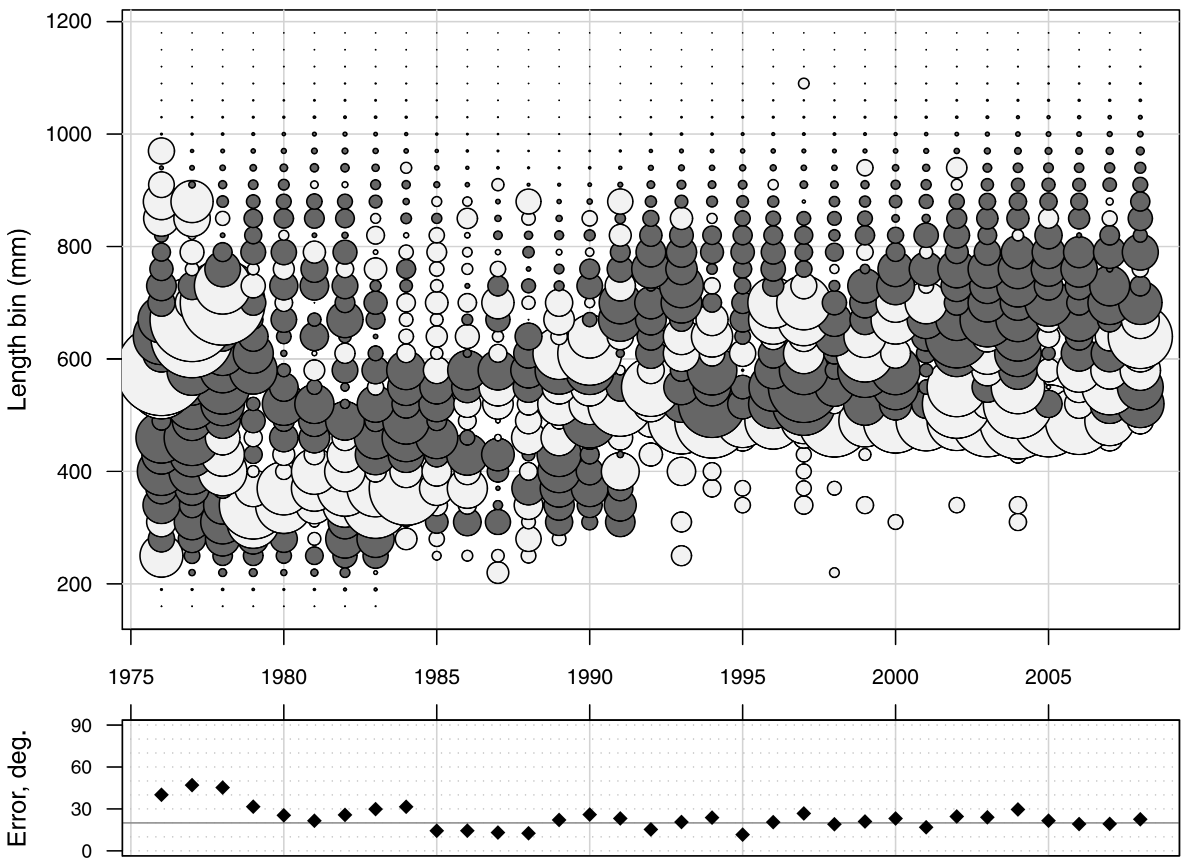


*Figure 3.9. Top panel is a bubble plot of length composition residuals from the recreational fleet (MRFSS); Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

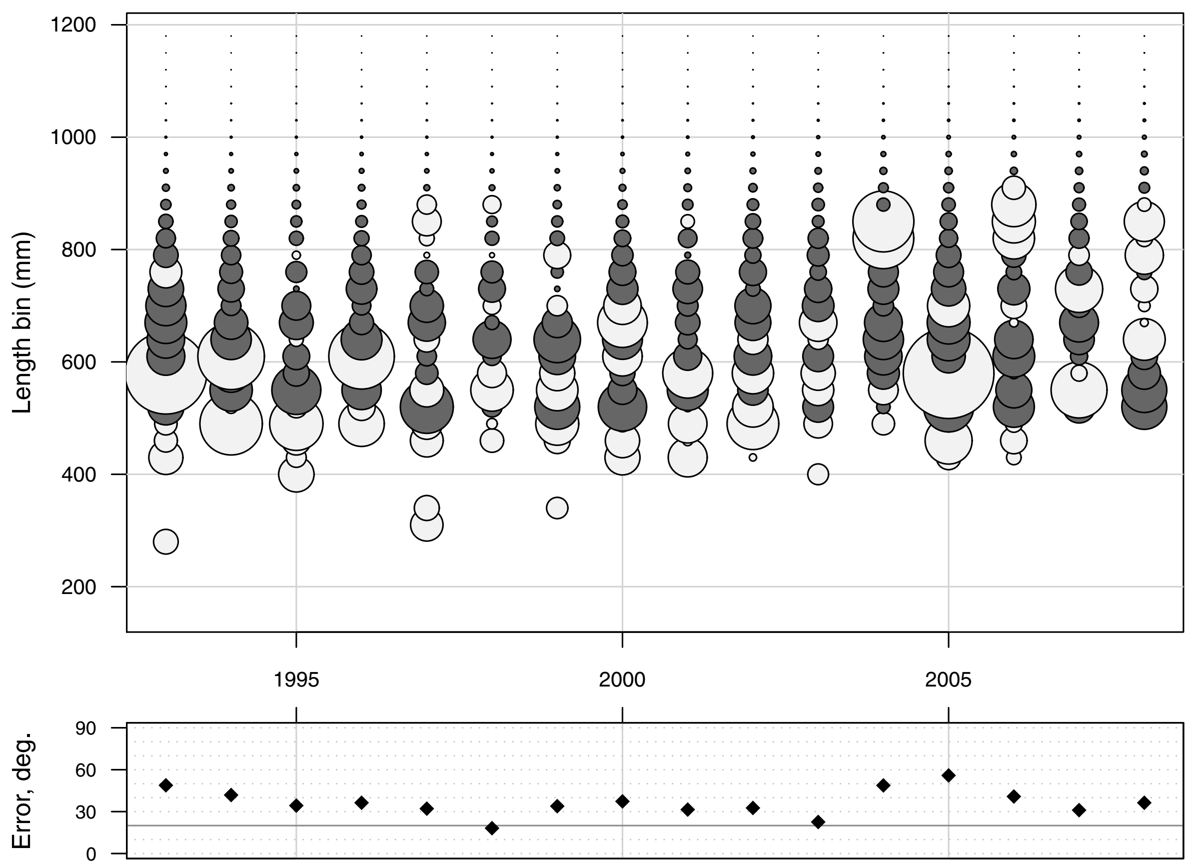


*Figure 3.10. Top panel is a bubble plot of length composition residuals from headboat discards; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

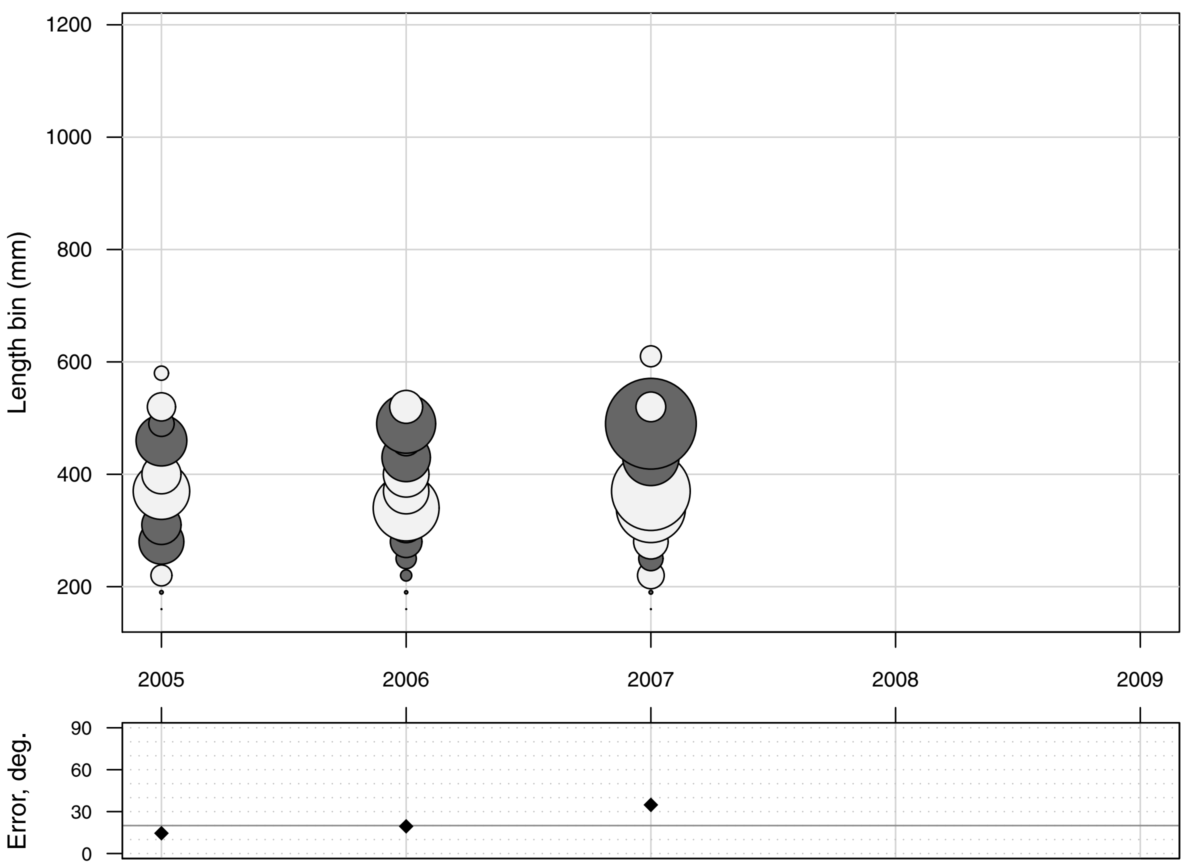


*Figure 3.11. Top panel is a bubble plot of age composition residuals from MARMAP chevron trap; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

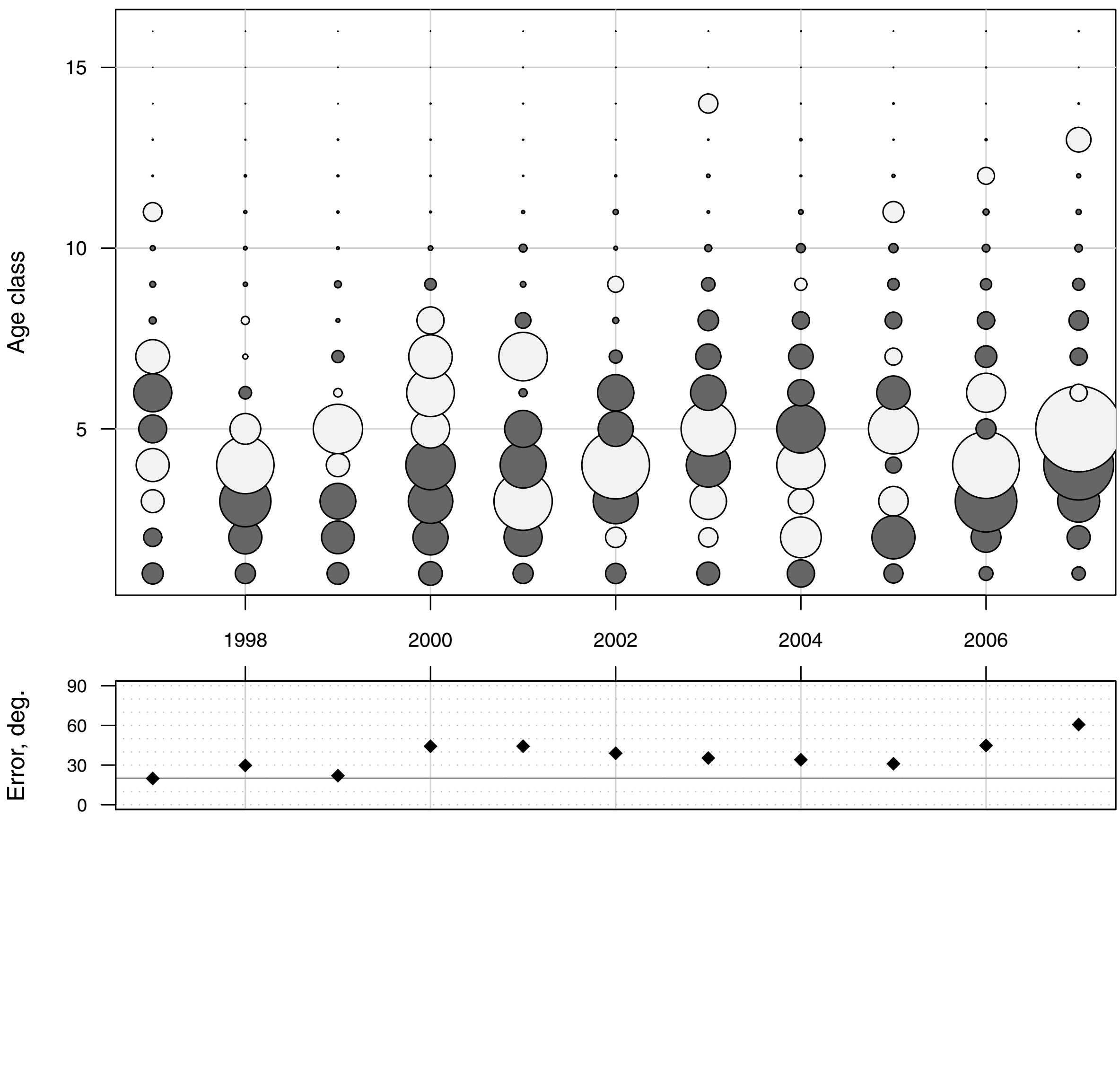


*Figure 3.12. Top panel is a bubble plot of age composition residuals from commercial lines; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

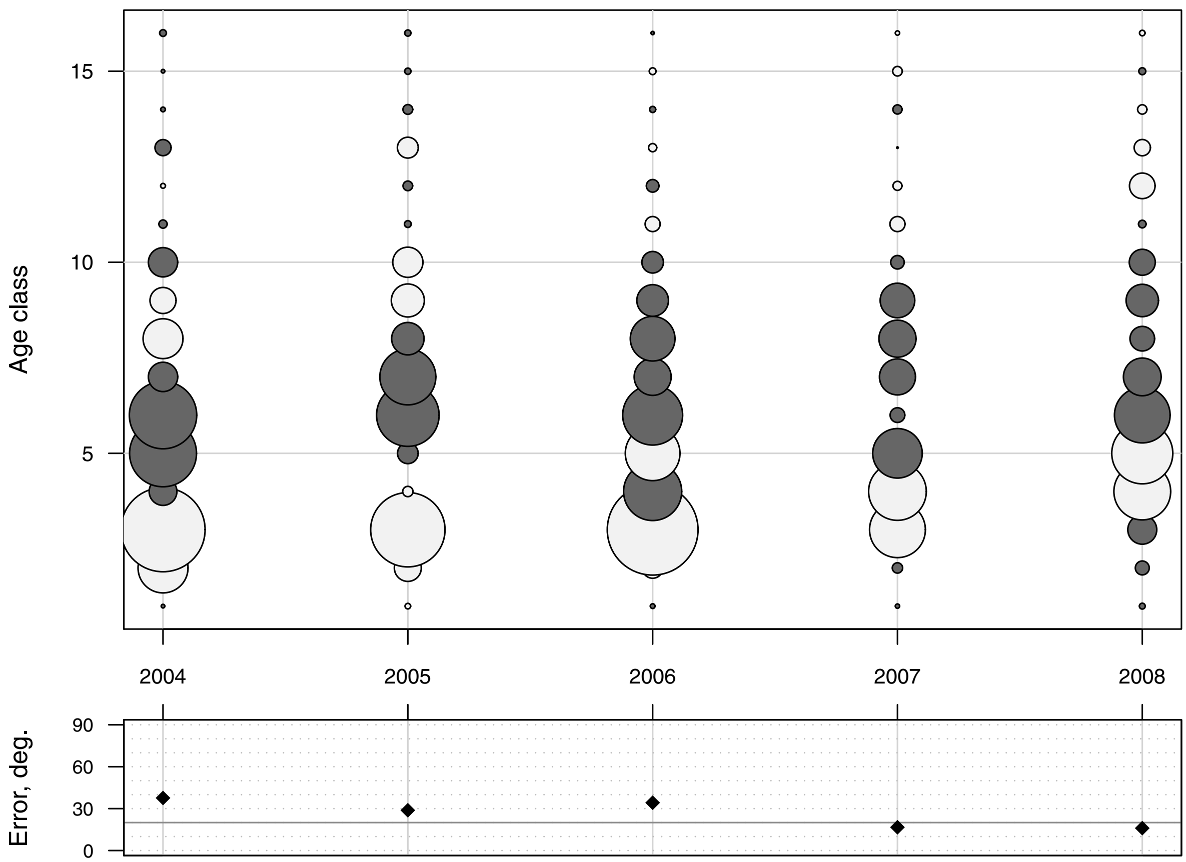


*Figure 3.13. Top panel is a bubble plot of age composition residuals from headboats; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

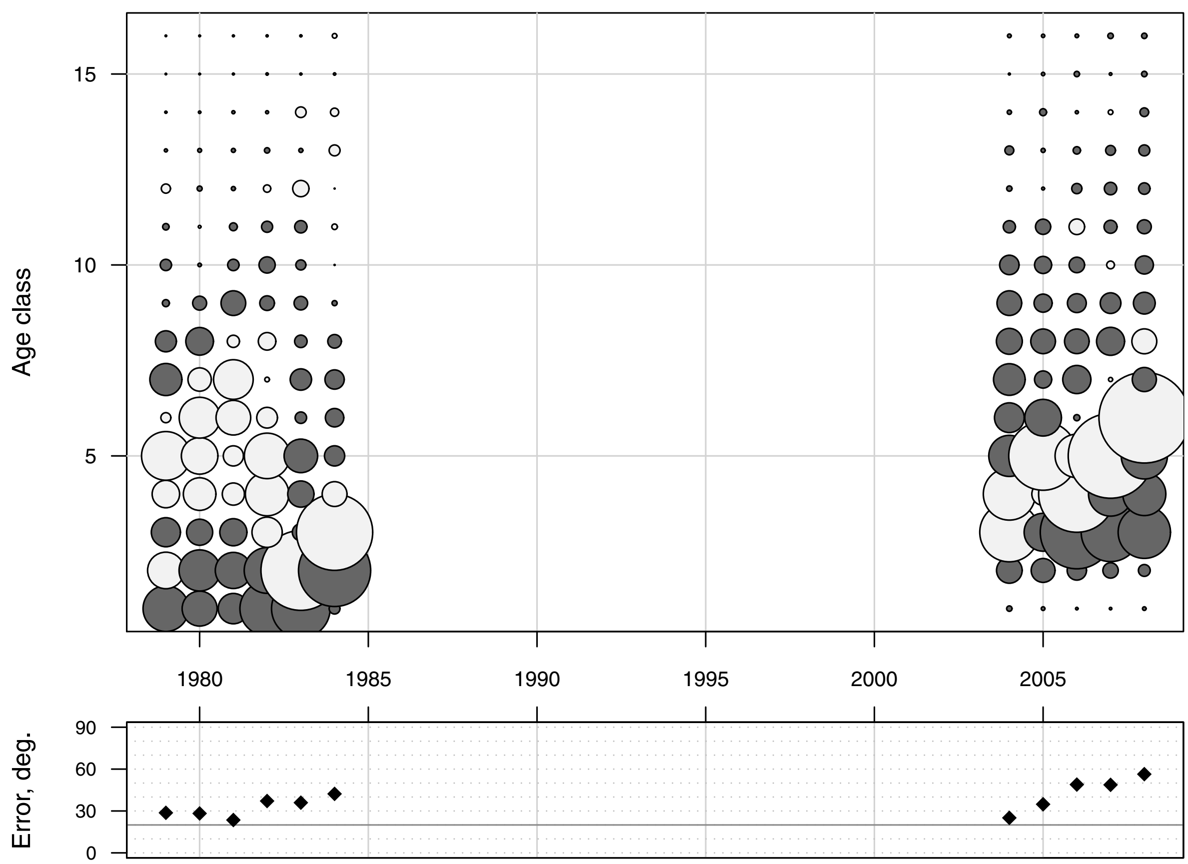


*Figure 3.14. Top panel is a bubble plot of age composition residuals from the recreational fleet (MRFSS); Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

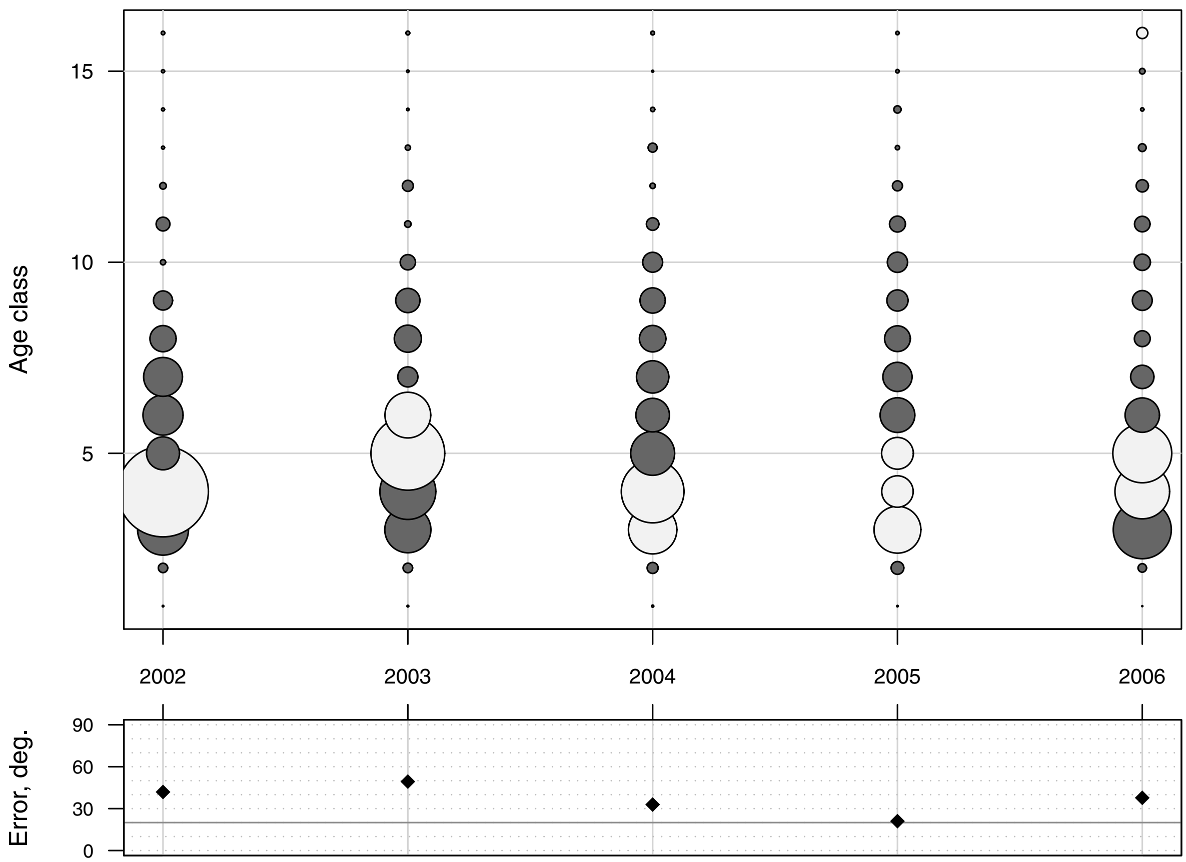


*Figure 3.15. Observed (open circles) and estimated (line, solid circles) commercial lines landings (1000 lb whole weight).*

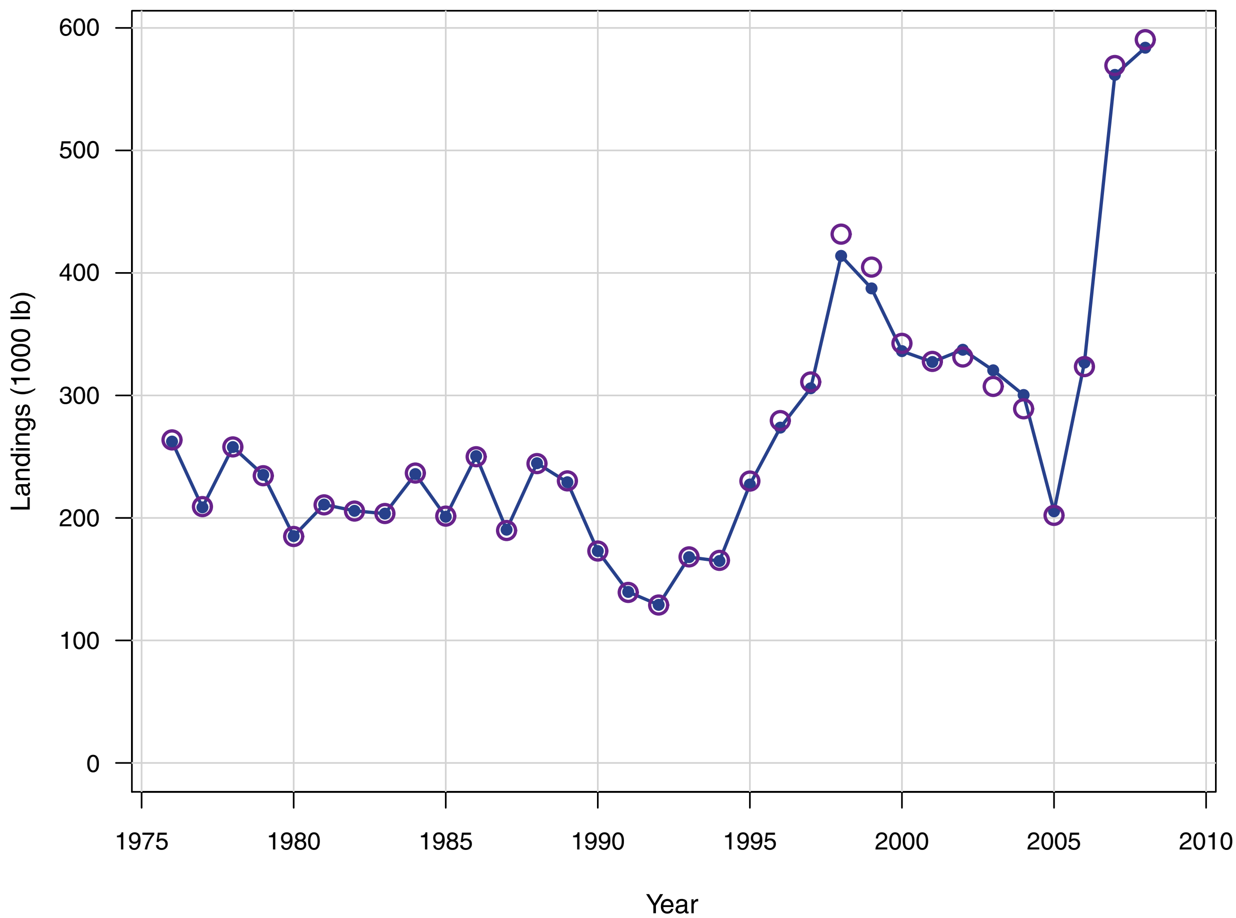


*Figure 3.16. Observed (open circles) and estimated (line, solid circles) commercial other (1000 lb whole weight).*

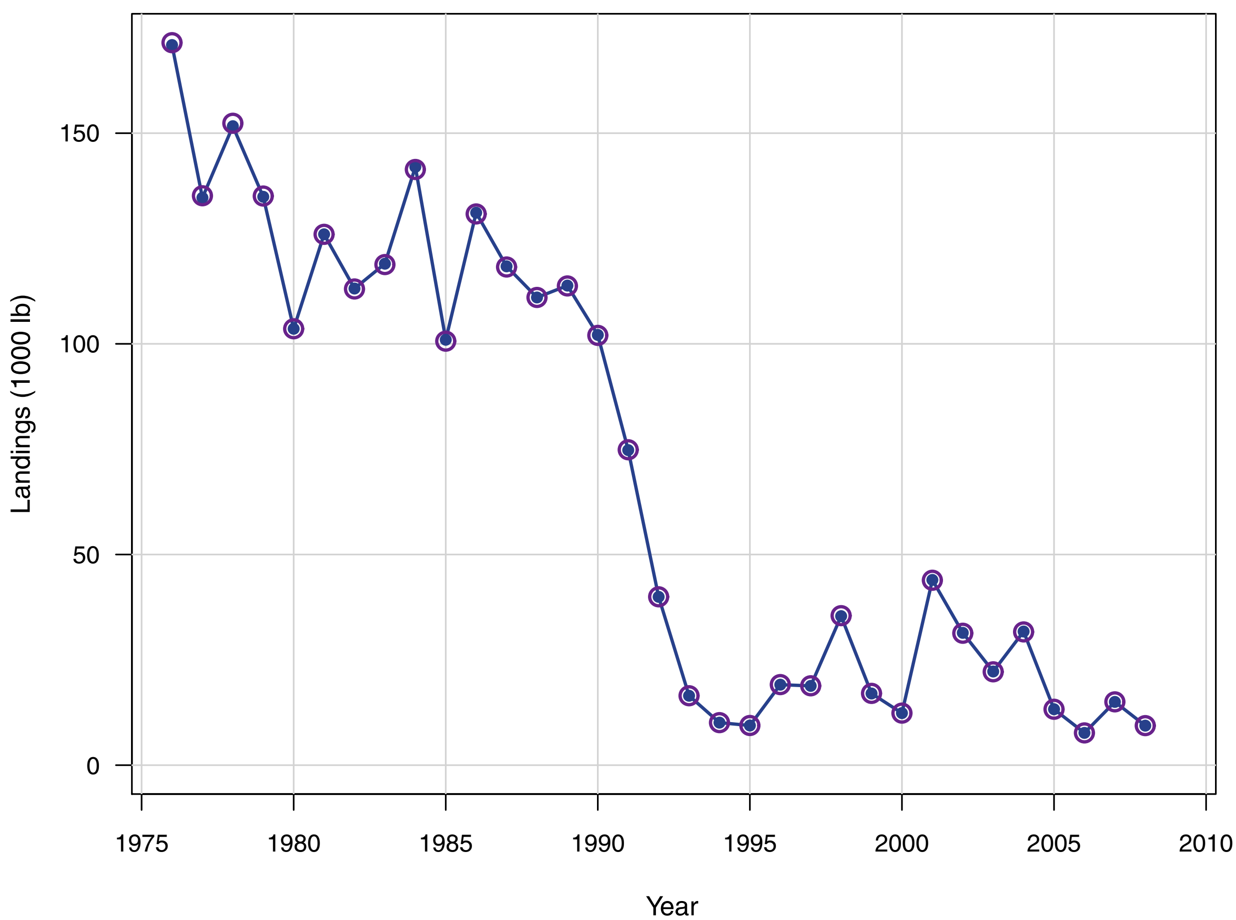


*Figure 3.17. Observed (open circles) and estimated (line, solid circles) headboat landings (1000 fish).*

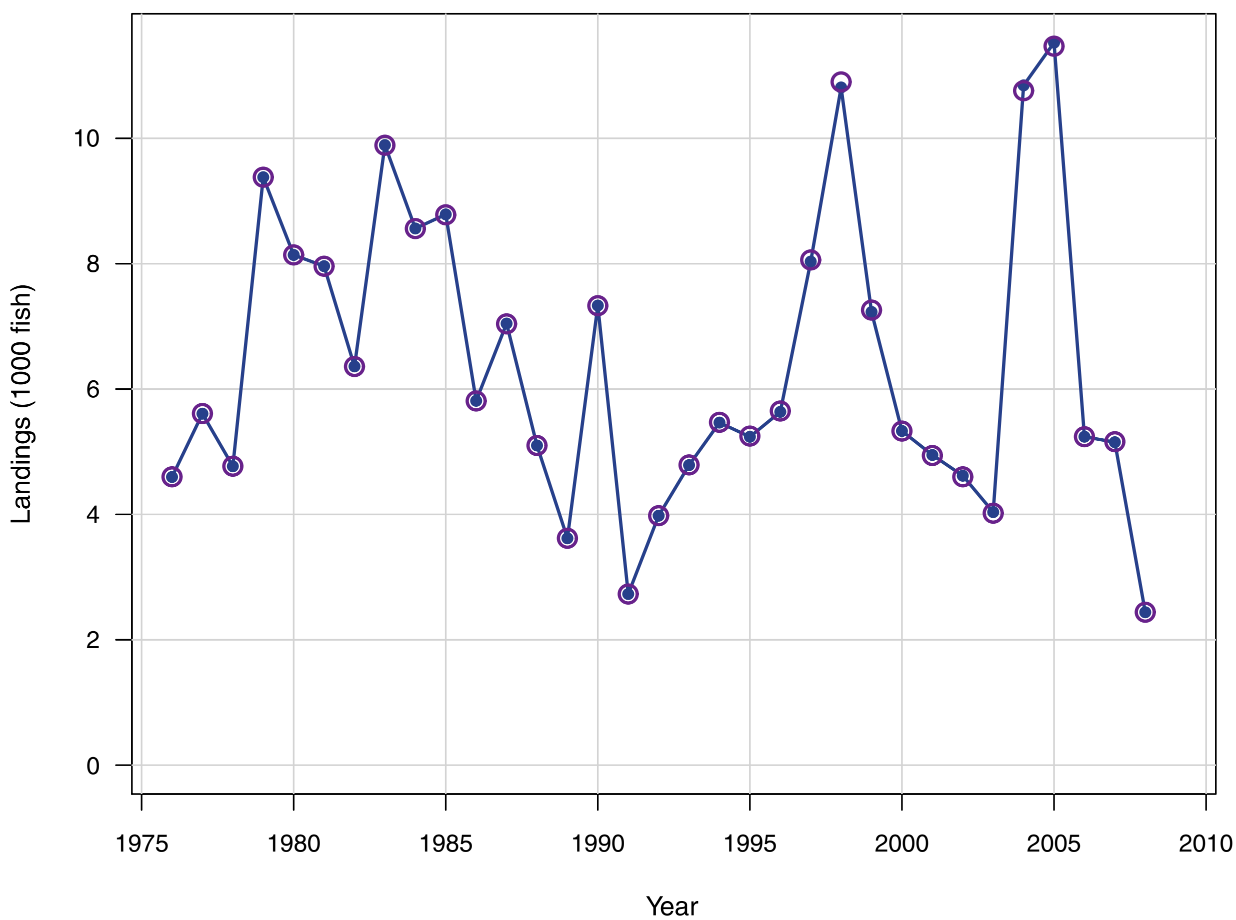


*Figure 3.18. Observed (open circles) and estimated (line, solid circles) general recreational landings (1000 fish). In years without observations, values were predicted using average F (see §3.1.1.3 for details).*

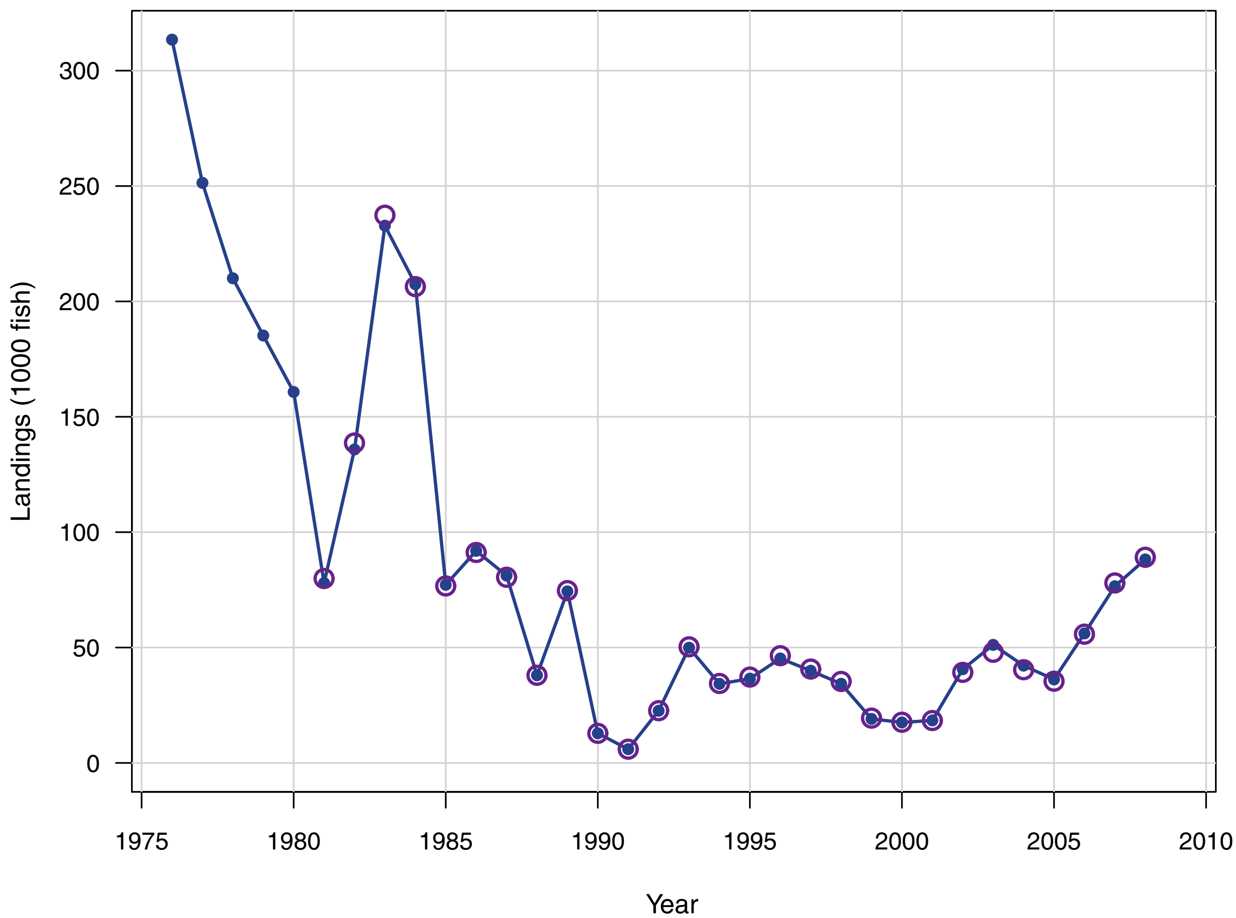


*Figure 3.19. Observed (open circles) and estimated (line, solid circles) commercial handline discard mortalities (1000 dead fish). In years without observations, values were predicted using average F (see §3.1.1.3 for details).*

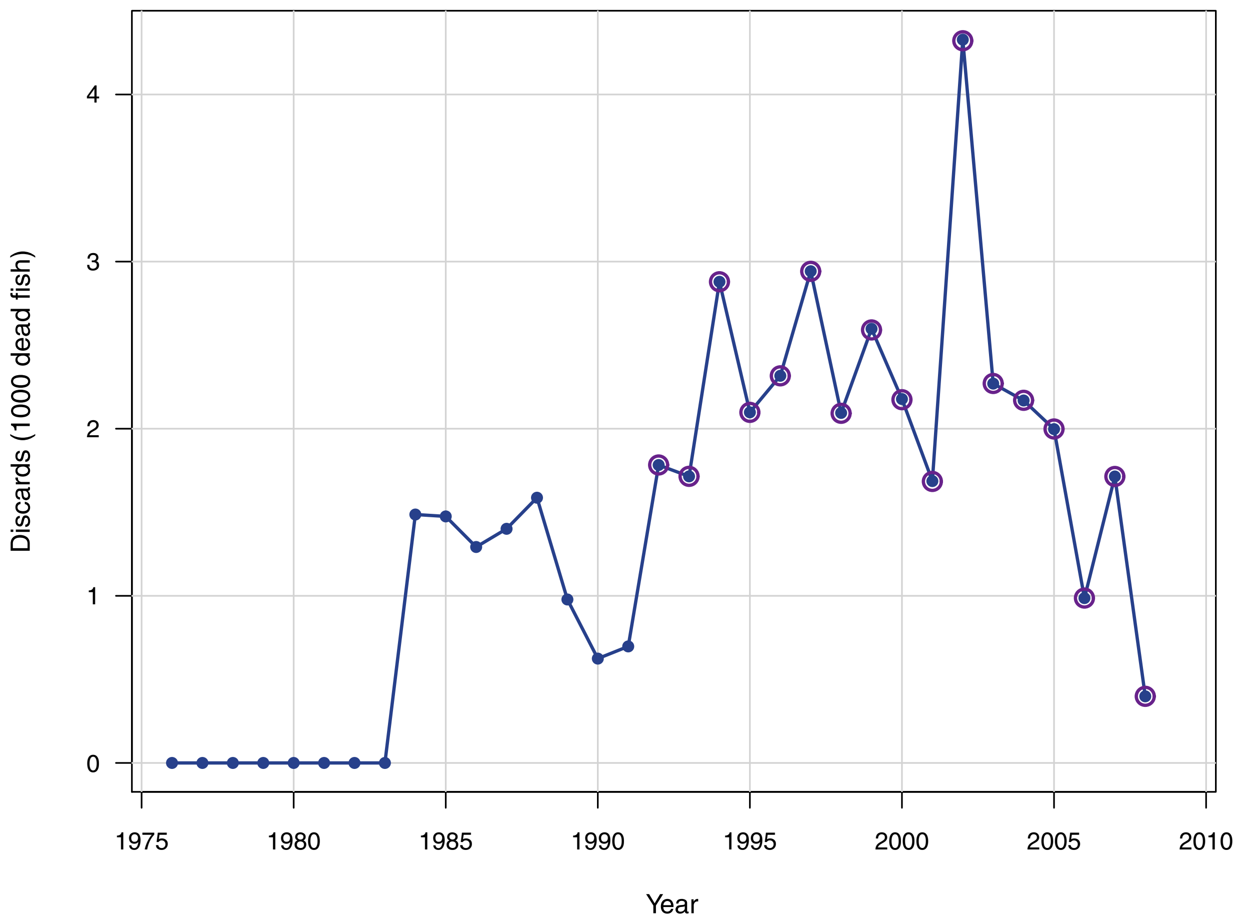


*Figure 3.20. Observed (open circles) and estimated (line, solid circles) headboat discard mortalities (1000 dead fish). In years without observations, values were predicted using average F (see §3.1.1.3 for details).*

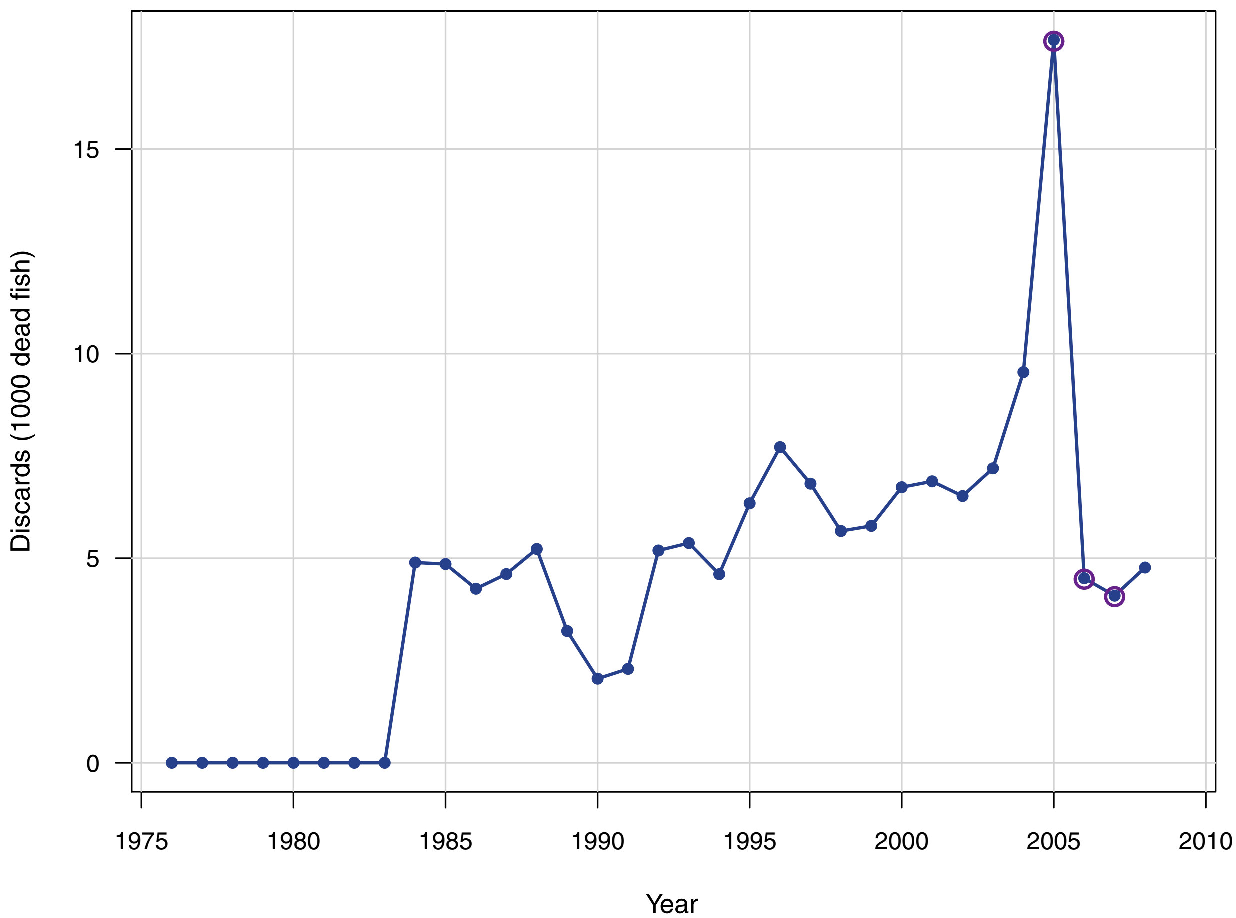


*Figure 3.21. Observed (open circles) and estimated (line, solid circles) general recreational discard mortalities (1000 dead fish).*

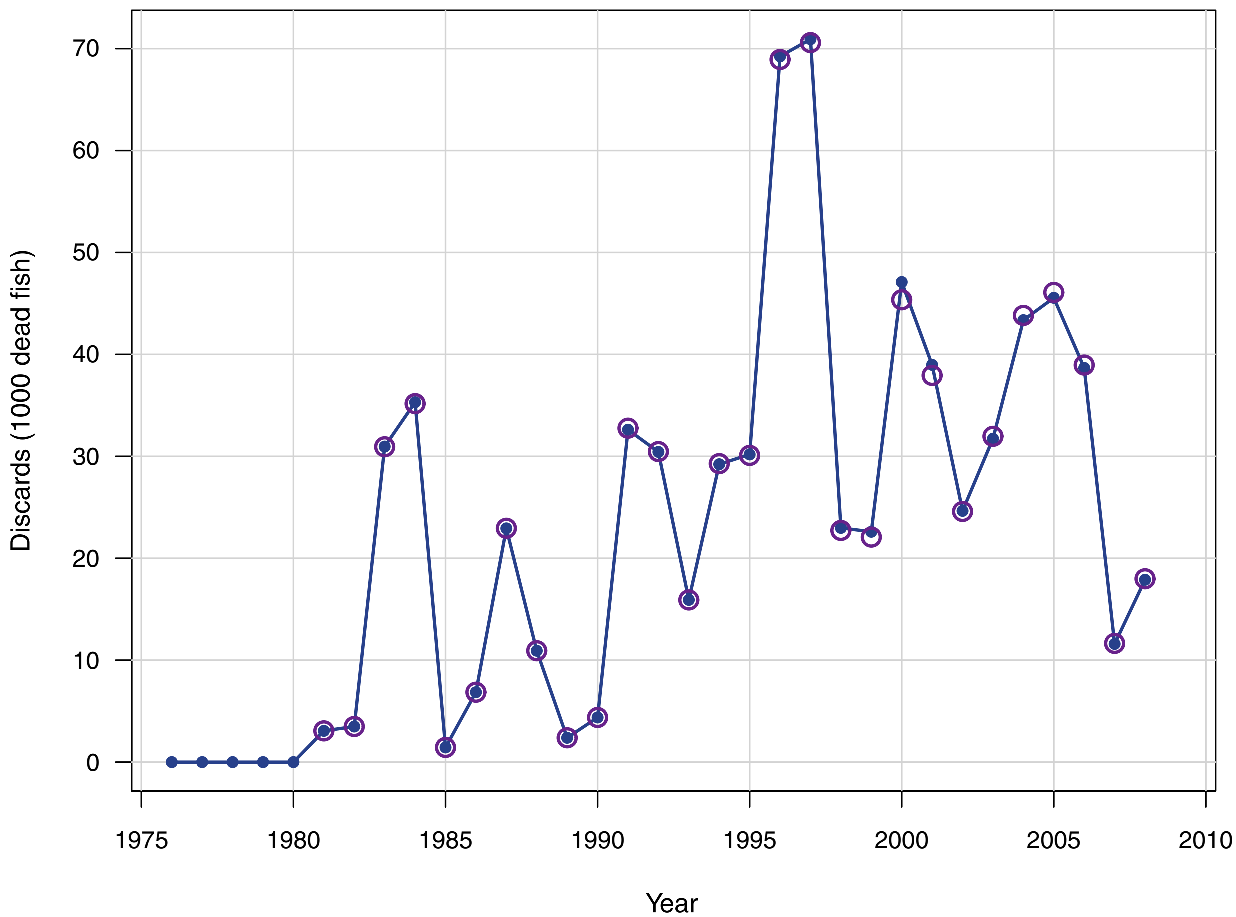


*Figure 3.22. Observed (open circles) and estimated (line, solid circles) index of abundance from FL Keys visual survey (RVC).*

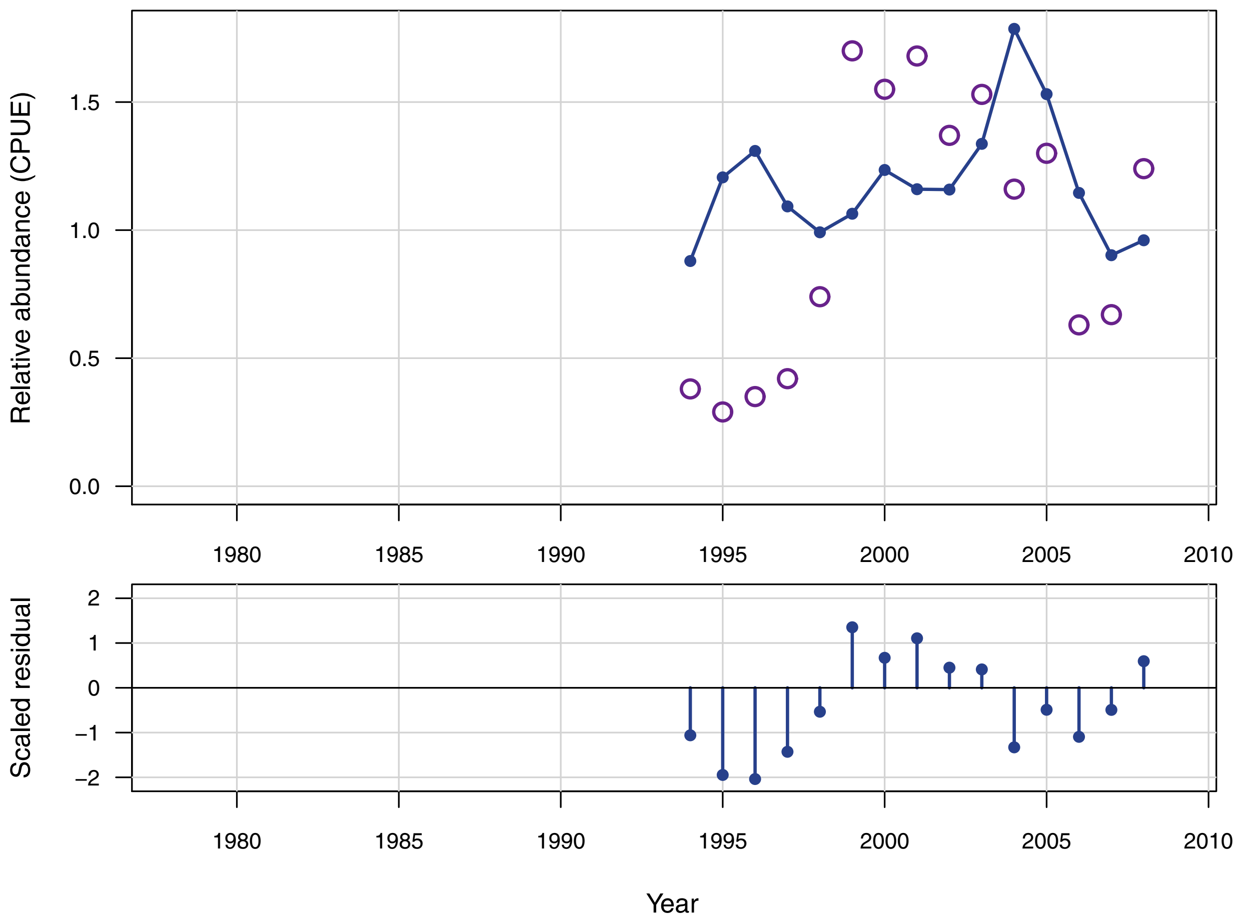


*Figure 3.23. Observed (open circles) and estimated (line, solid circles) index of abundance from MARMAP chevron trap.*

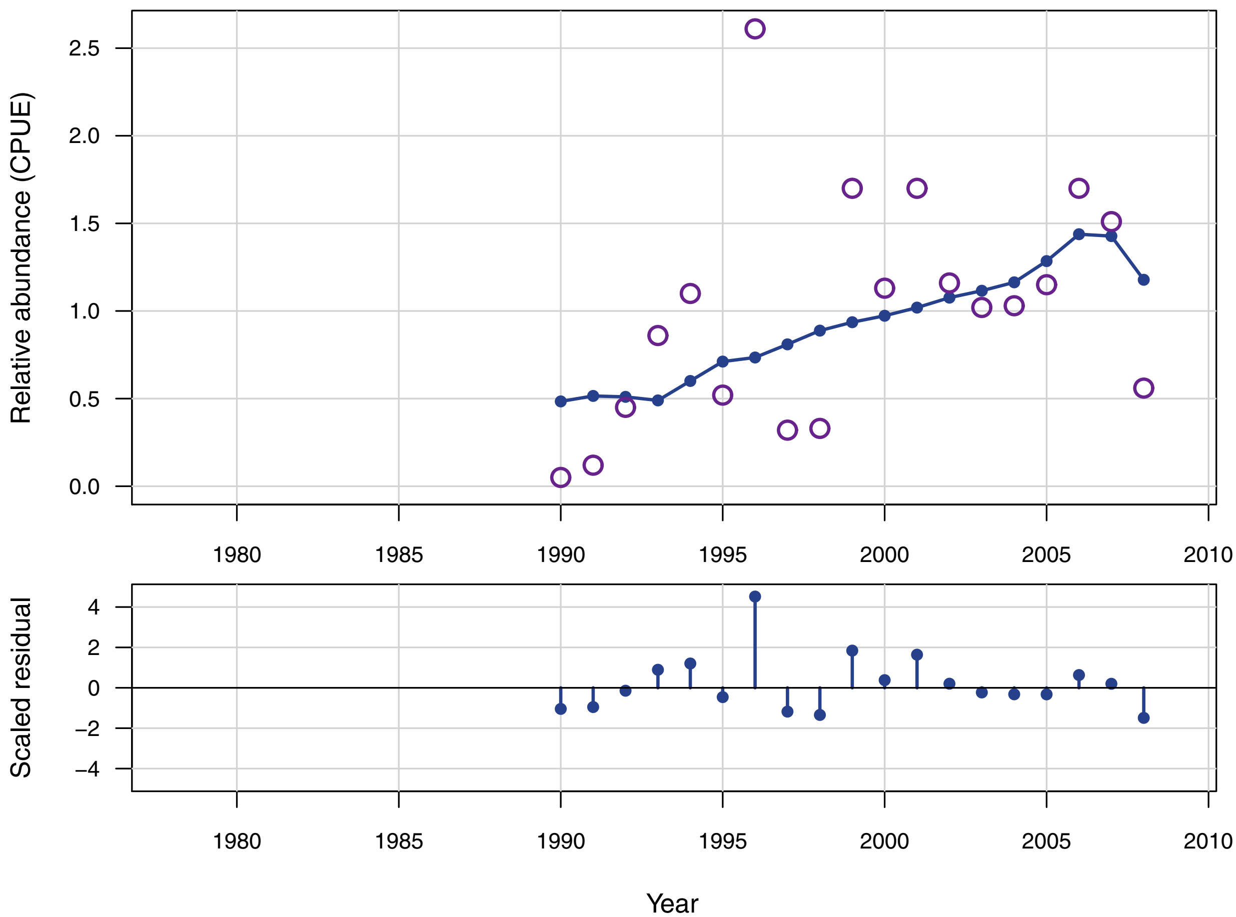


*Figure 3.24. Observed (open circles) and estimated (line, solid circles) index of abundance from commercial handline.*

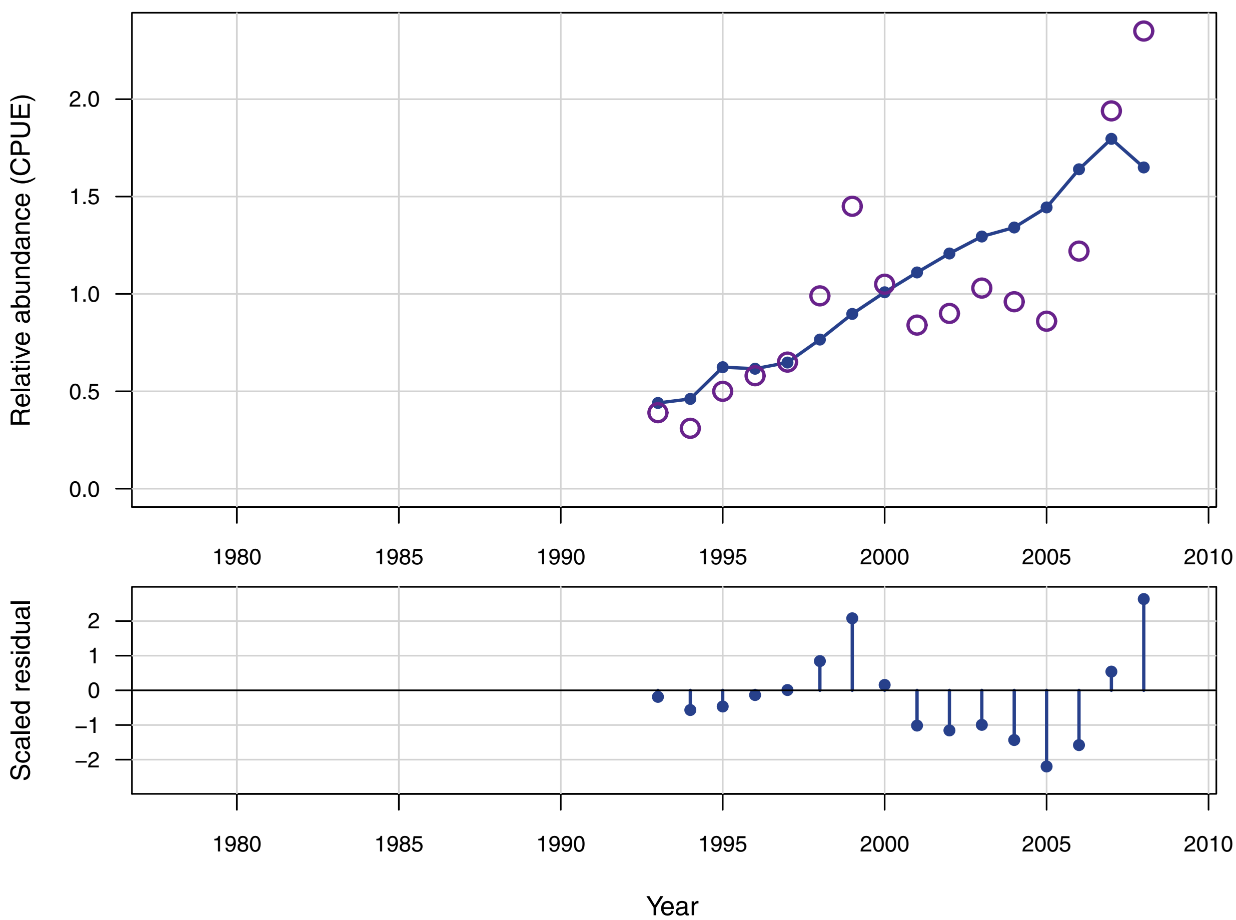


*Figure 3.25. Observed (open circles) and estimated (line, solid circles) index of abundance from headboat.*

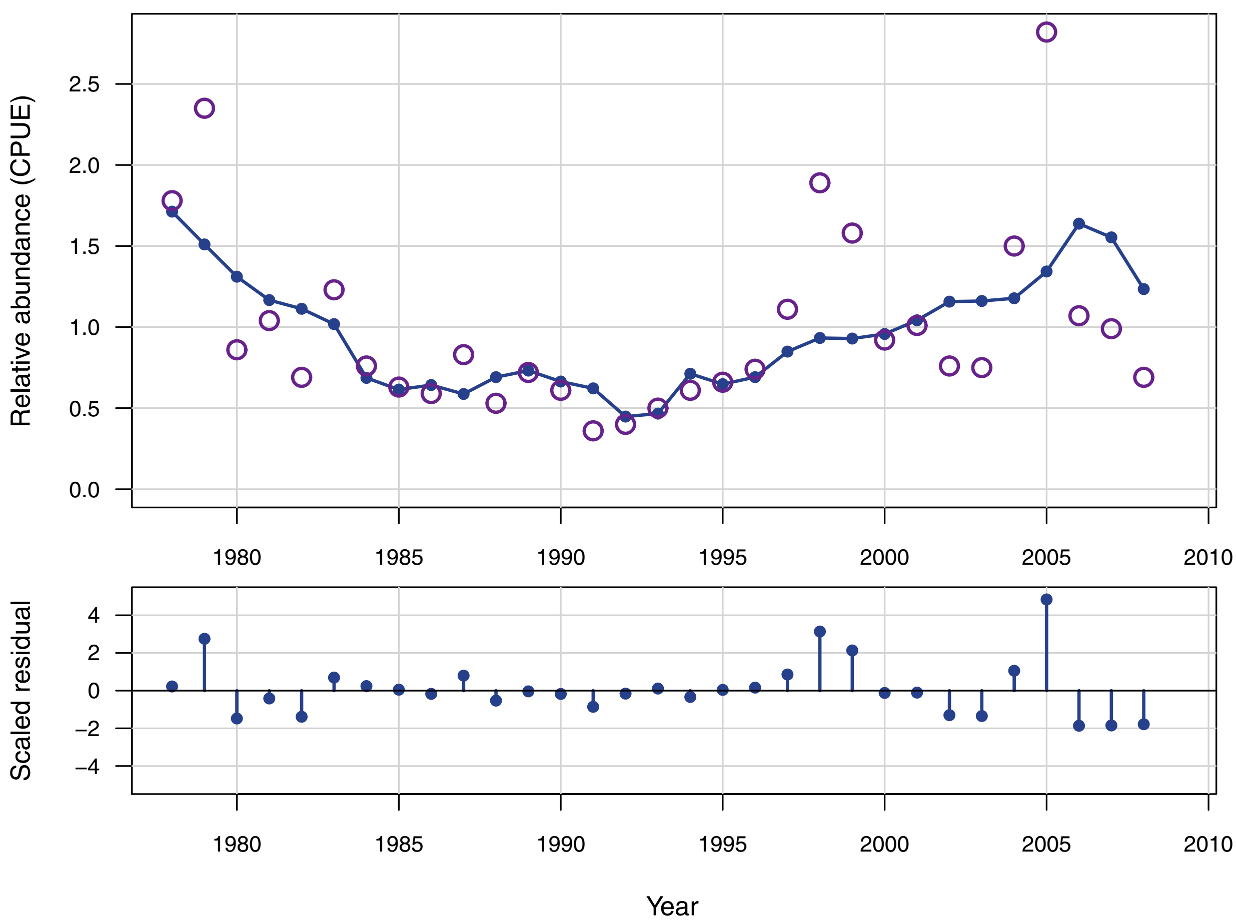


*Figure 3.26. Observed (open circles) and estimated (line, solid circles) abundance from general recreational (MRFSS).*

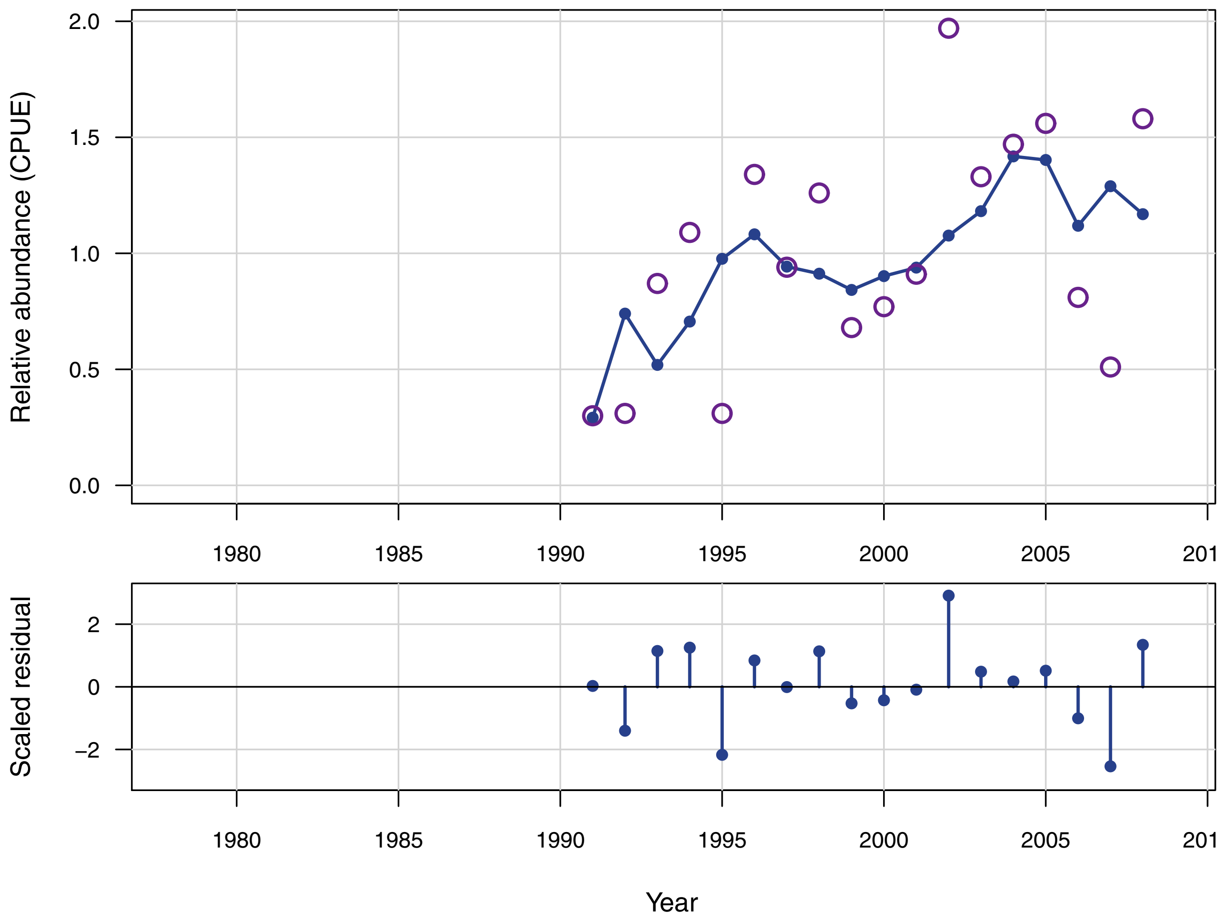
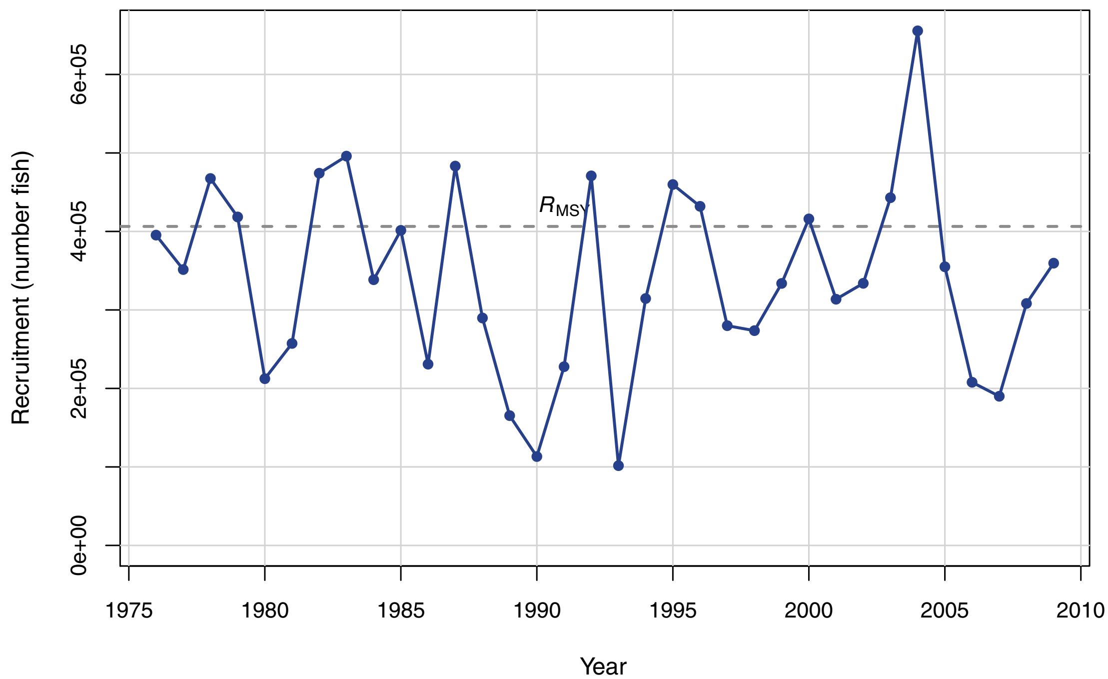


*Figure 3.27. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates $R_{MSY}$. Bottom panel: log recruitment residuals.*



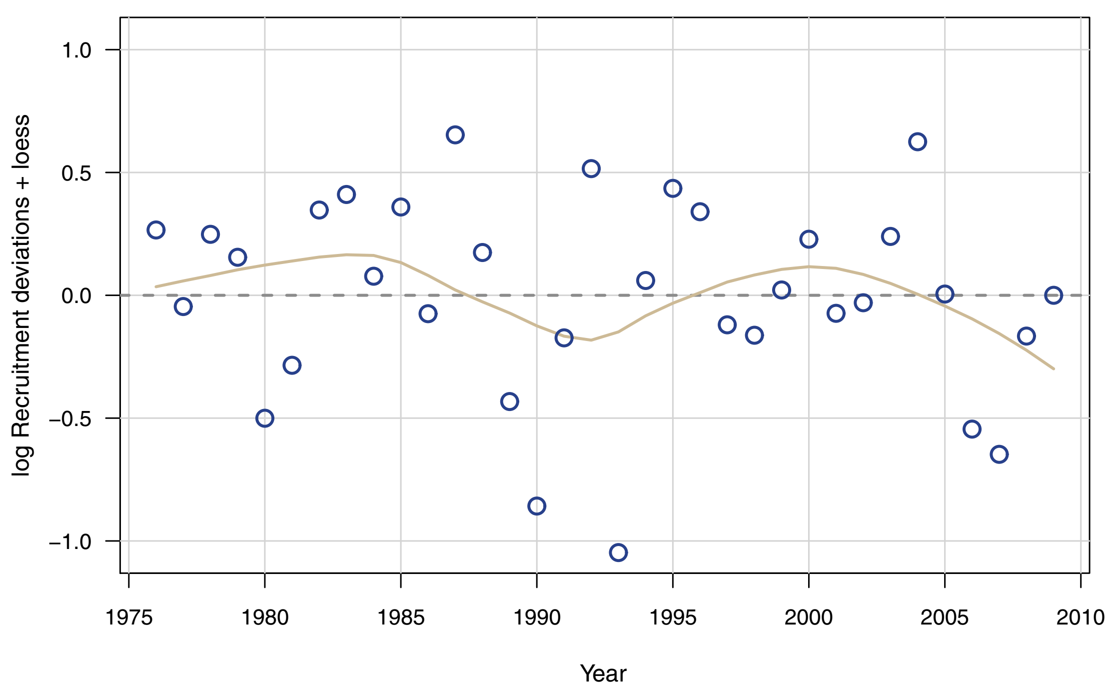



*Figure 3.28. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates $B_{MSY}$. Bottom panel: Estimated spawning biomass (total mature biomass) at time of peak spawning.*

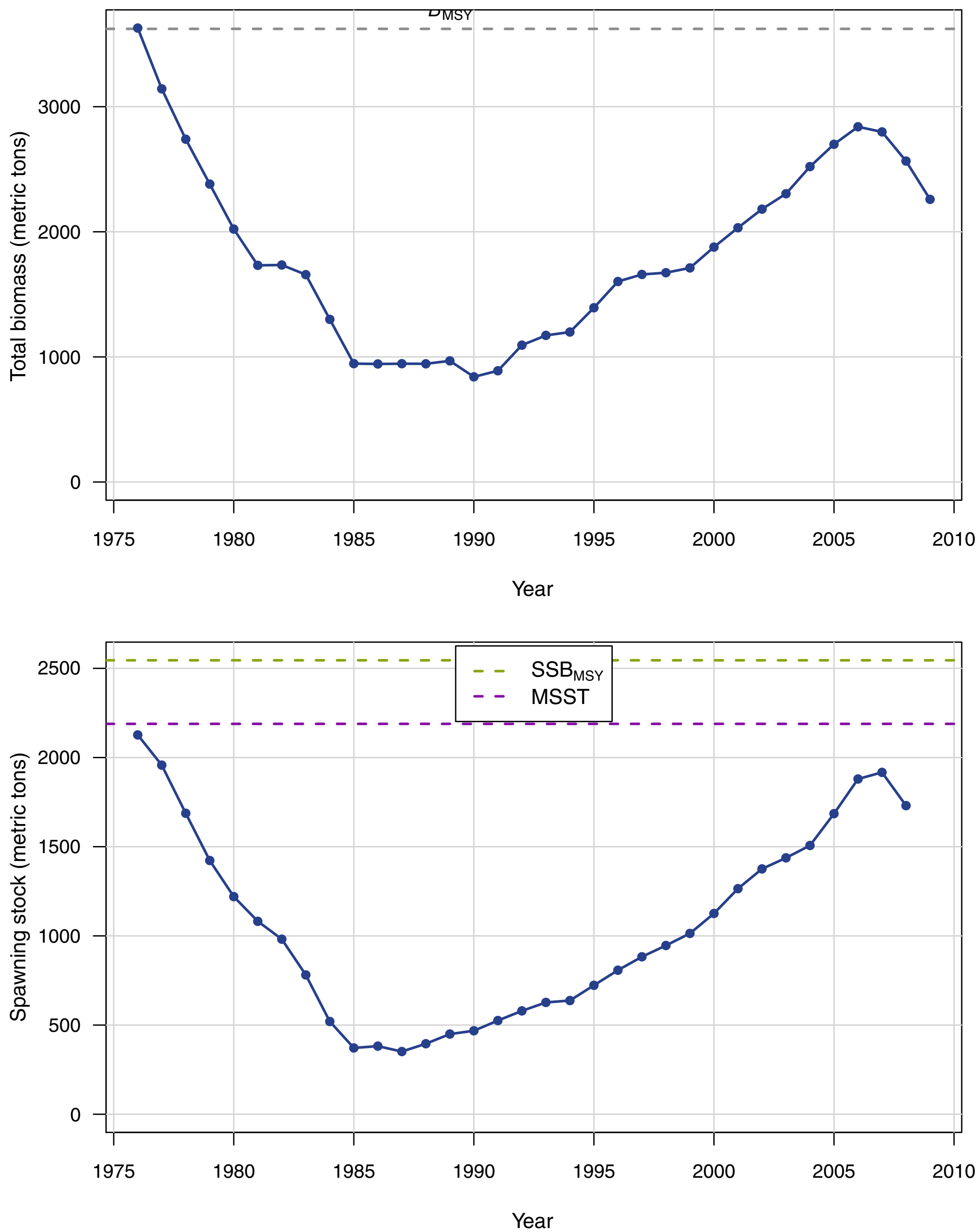


*Figure 3.29. Selectivities of fishery independent surveys. Top panel: Florida Keys visual survey (RVC). Bottom panel: MARMAP chevron traps.*

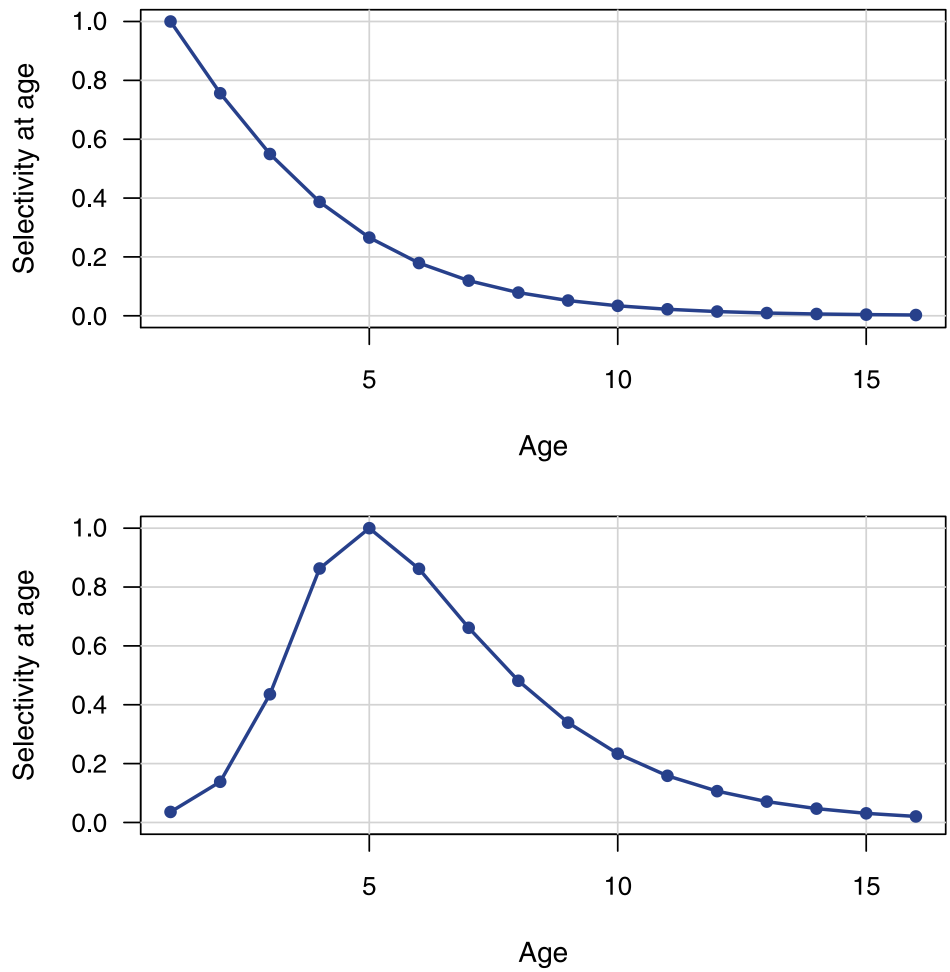


*Figure 3.30. Selectivities of commercial lines. Top panel: 1976–1991. Bottom panel: 1992–2008.*

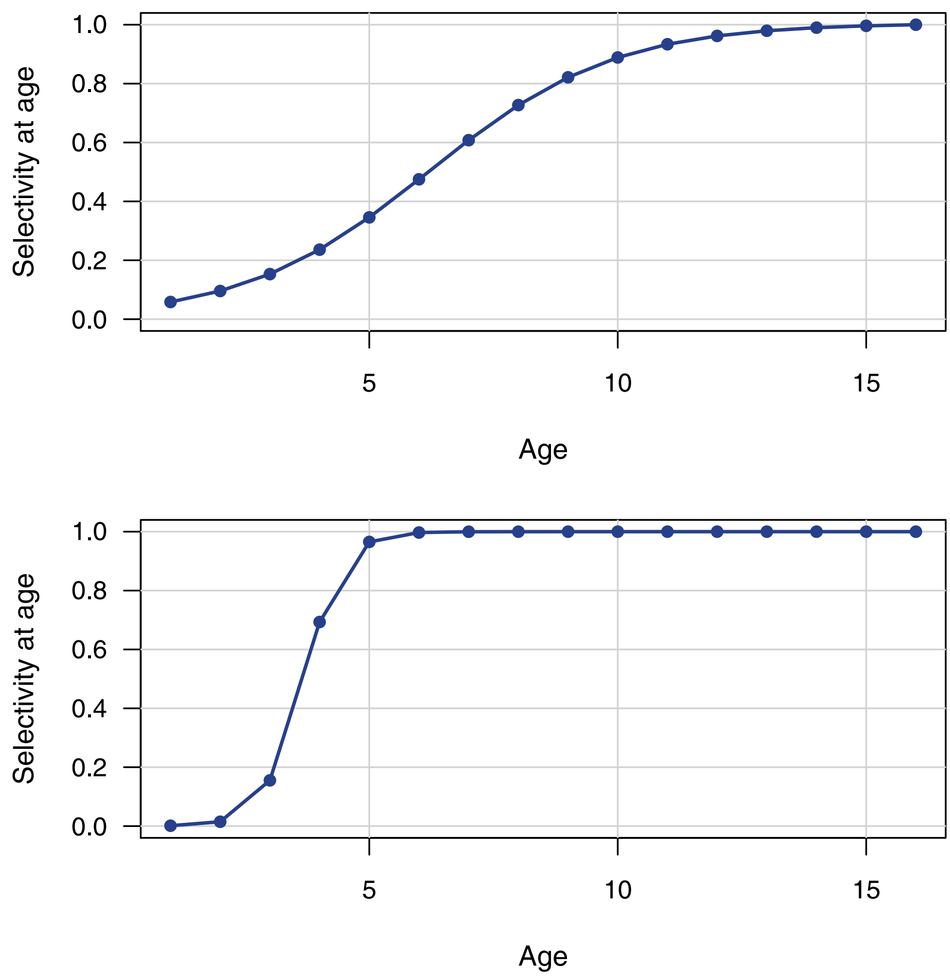


*Figure 3.31. Selectivities of commercial other gears. Top panel: 1976–1991. Bottom panel: 1992–2008.*

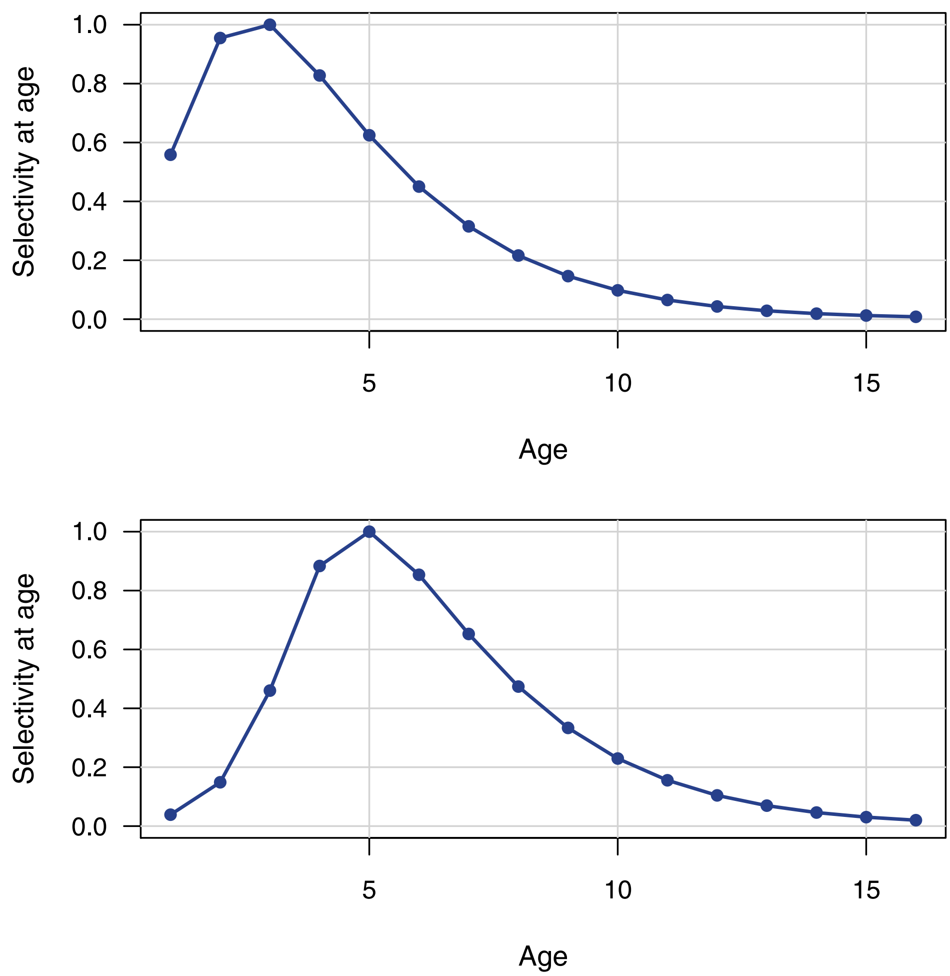


*Figure 3.32. Selectivities of the headboat fleet. Top panel: 1976–1983. Middle panel: 1984–1991. Bottom panel: 1992–2008.*

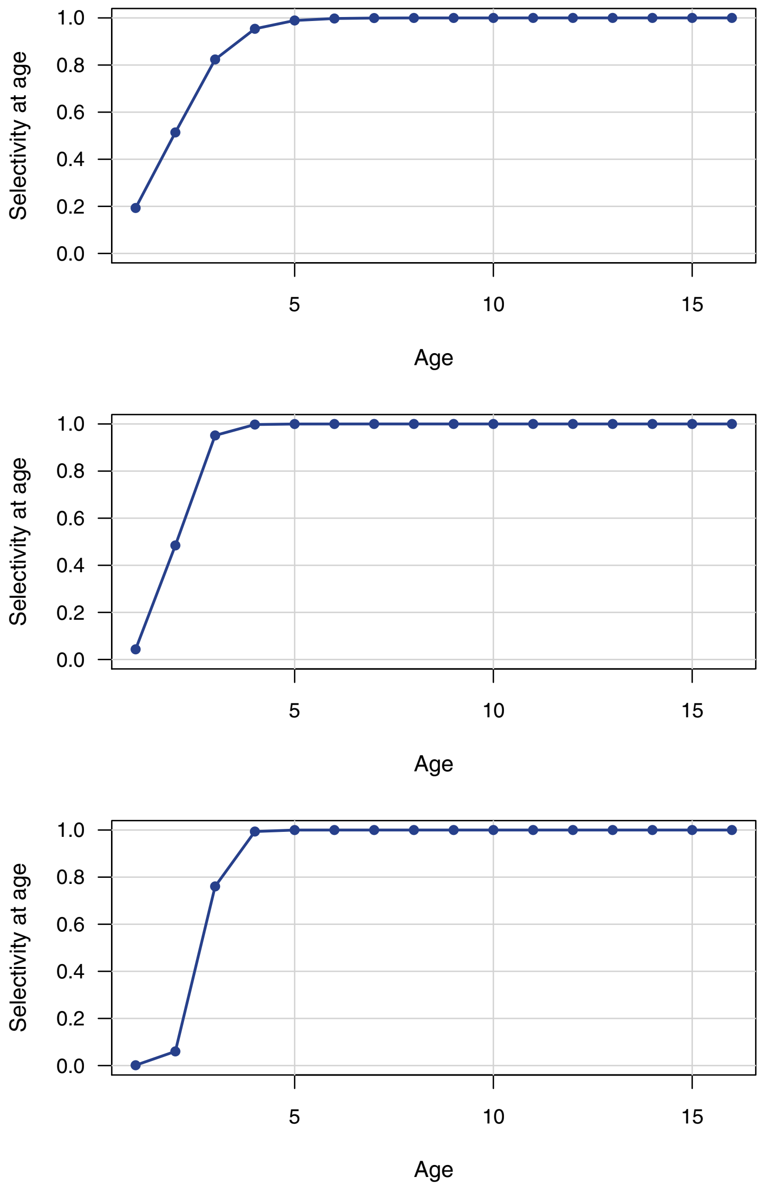


*Figure 3.33. Selectivities of the general recreational fleet. Top panel: 1976–1983. Middle panel: 1984–1991. Bottom panel: 1992–2008.*

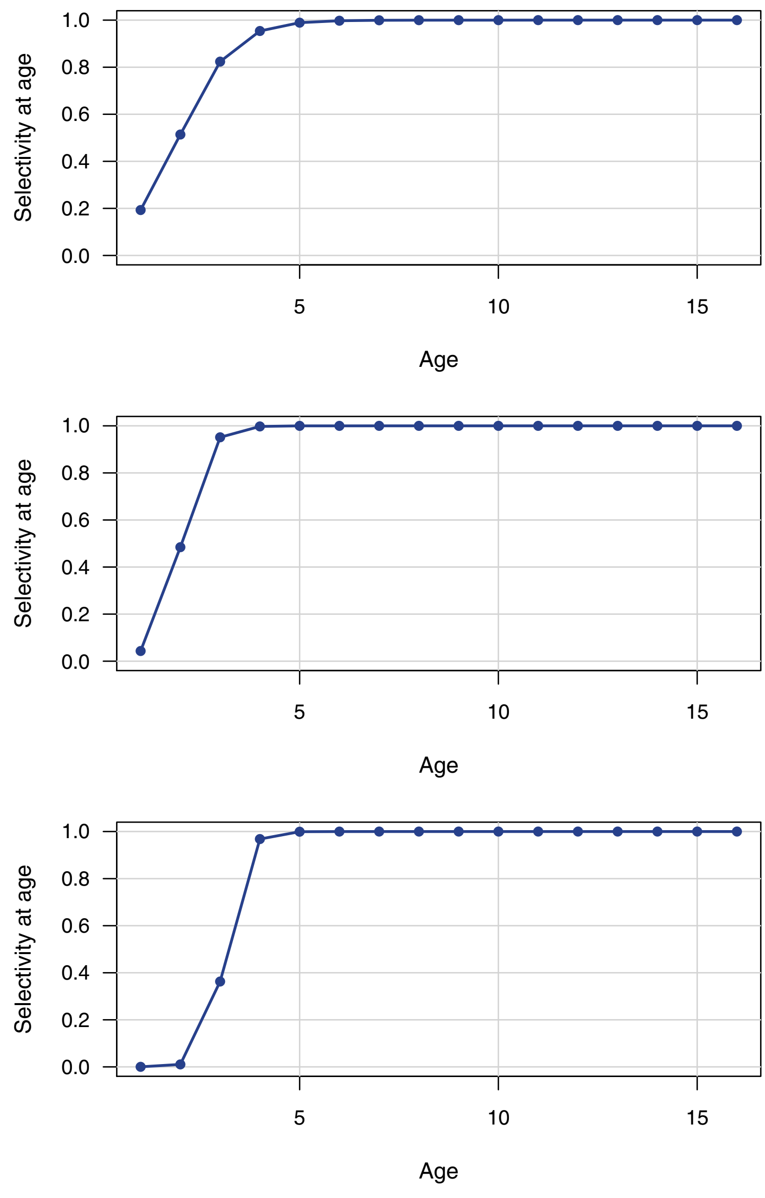


*Figure 3.34. Selectivities of discard mortalities from commercial lines. Top panel: 1984–1991. Bottom panel: 1992–2008.*

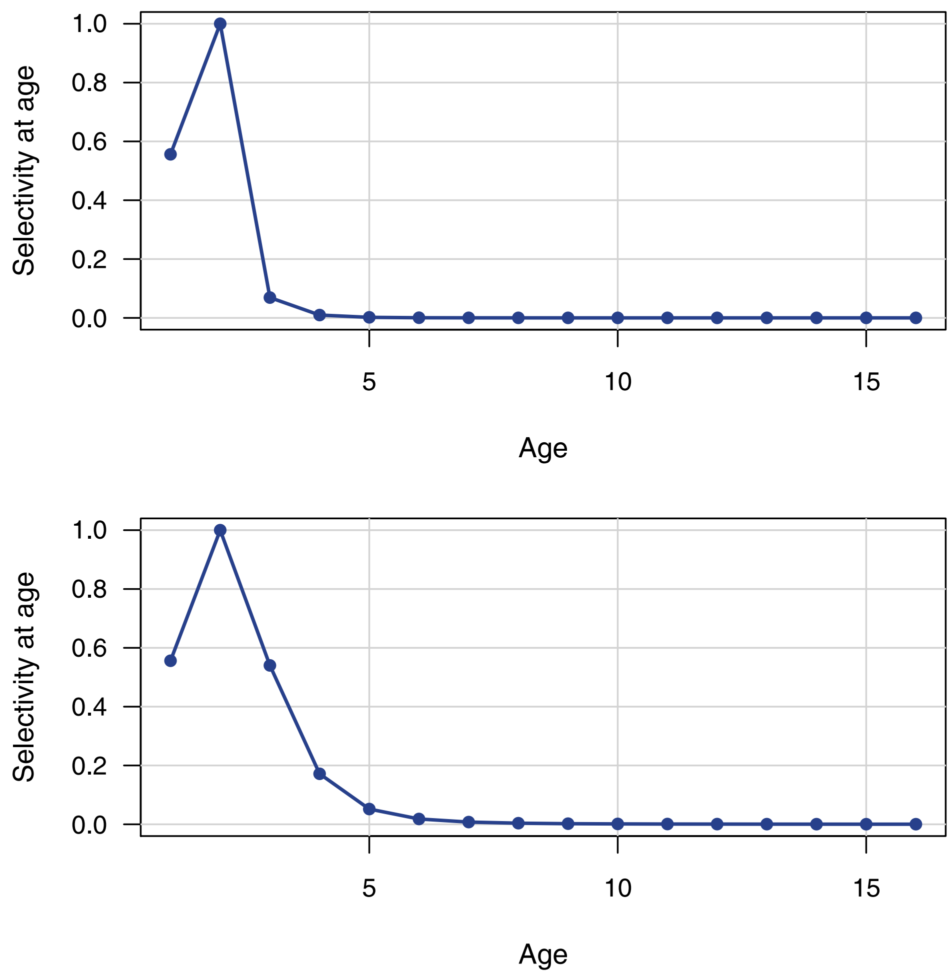


*Figure 3.35. Selectivities of discard mortalities from the headboat fleet. Top panel: 1984–1991. Bottom panel: 1992–2008.*

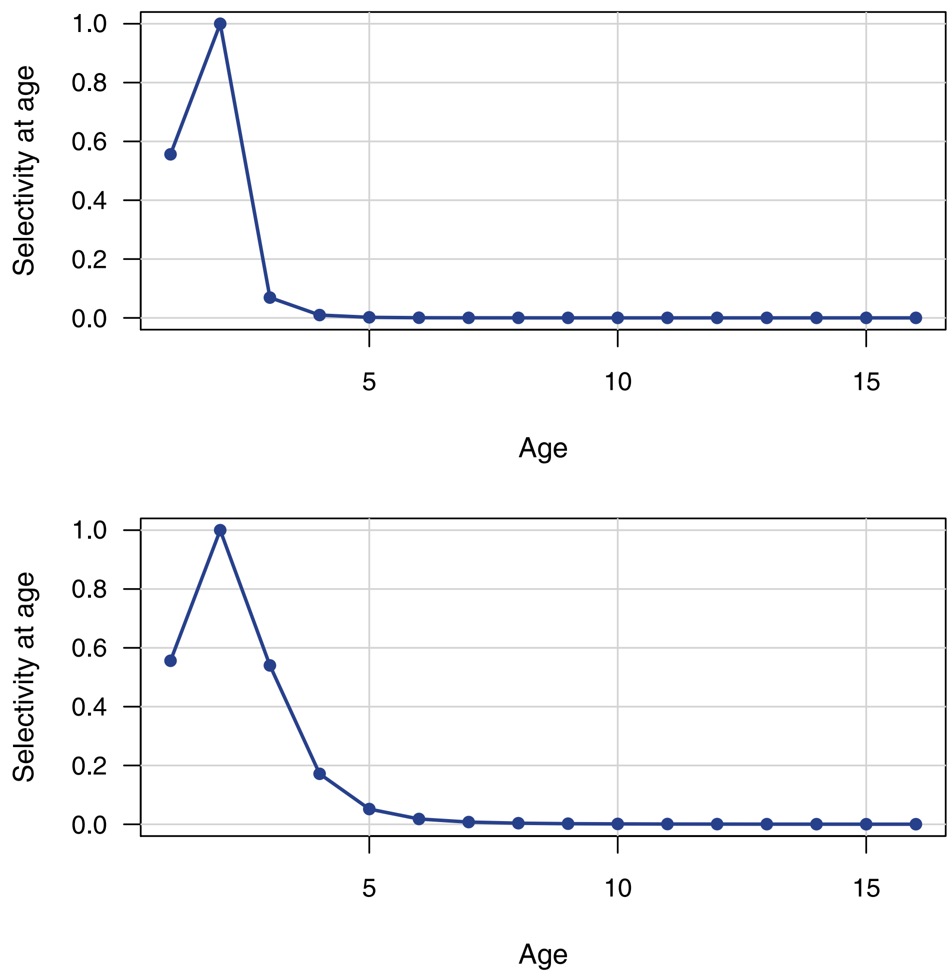


*Figure 3.36. Selectivities of discard mortalities from the general recreational fleet. Top panel: 1981–1991. Bottom panel: 1992–2008.*

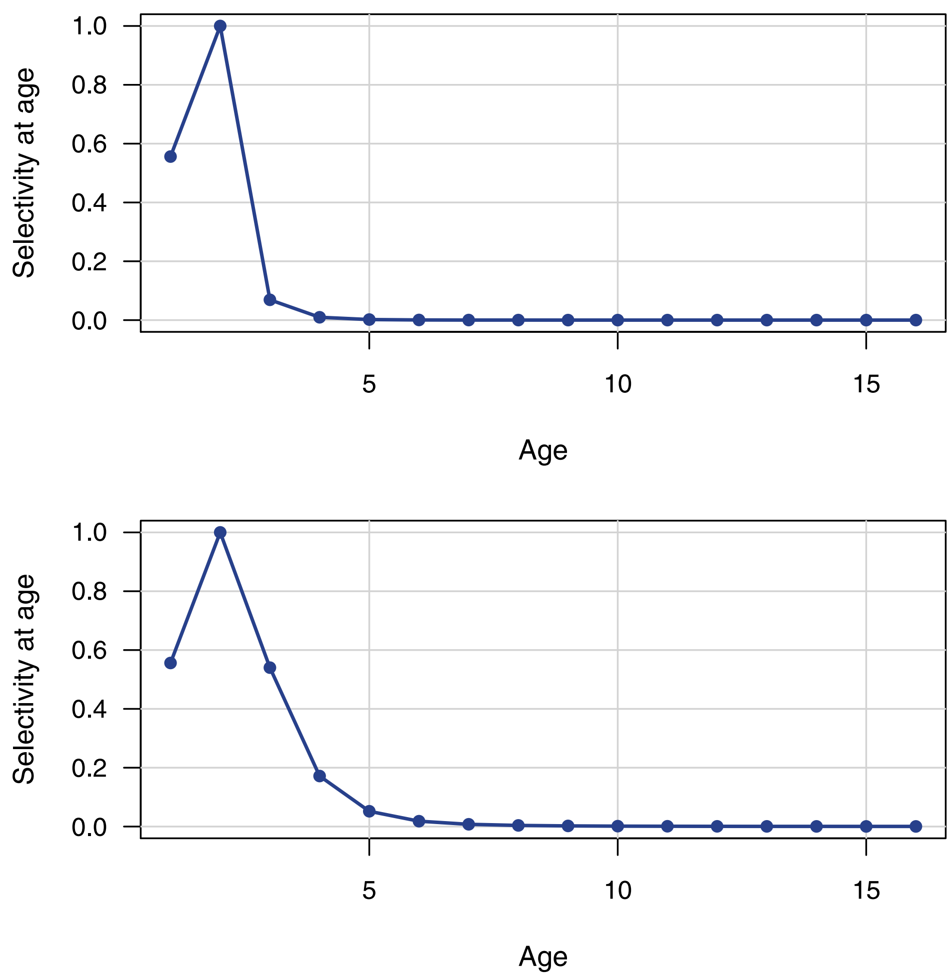


*Figure 3.37. Average selectivities from the terminal assessment year (2008, 20-inch limit), weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and base-run projections. Top panel: average selectivity applied to landings. Middle panel: average selectivity applied to discard mortalities. Bottom panel: total average selectivity.*

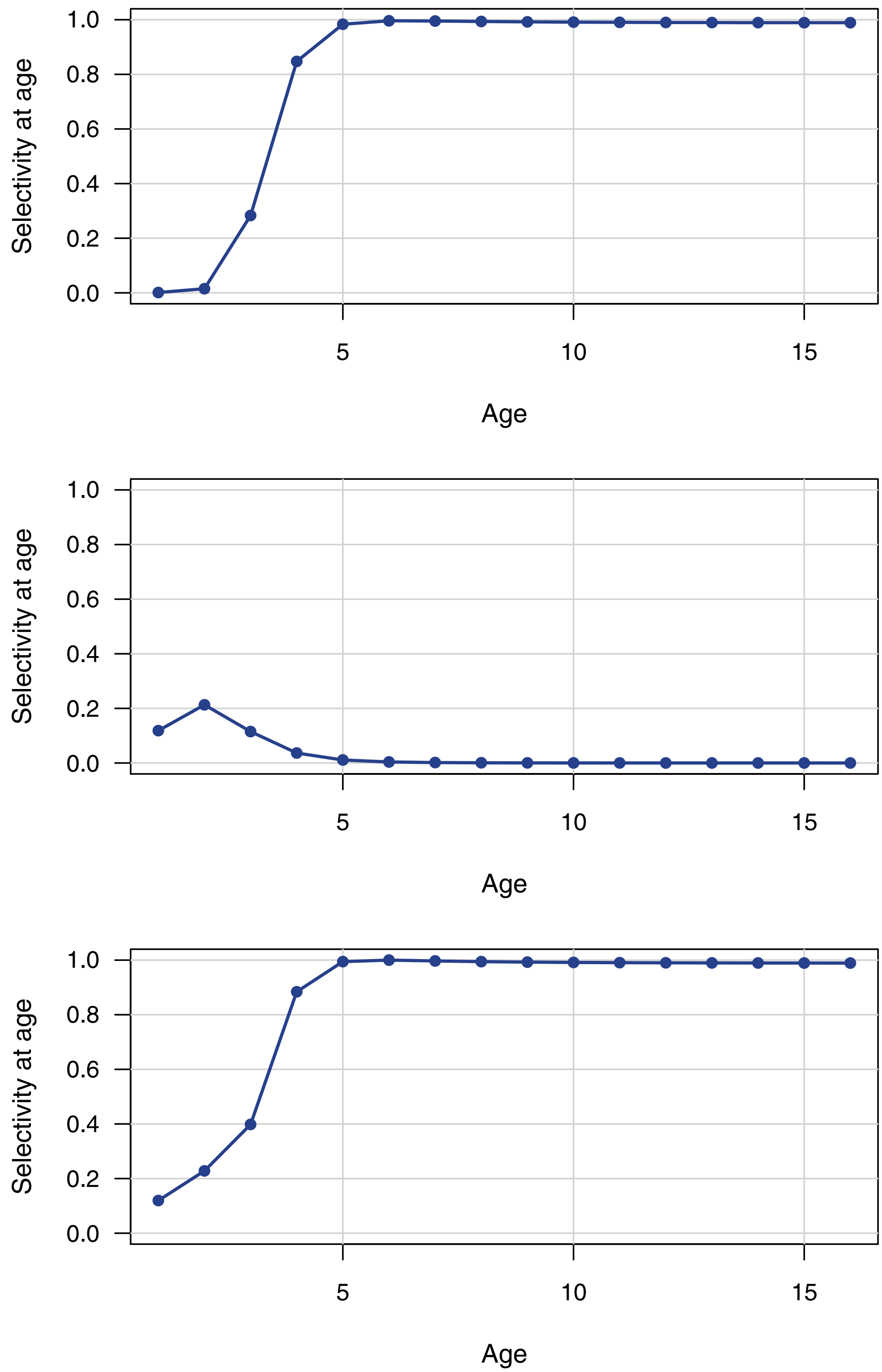


*Figure 3.38. Estimated fully selected fishing mortality rate (per year) by fishery. cl refers to commercial lines, co to commercial other, hb to headboat, rec to general recreational, cl.D to commercial discard mortalities, hb.D to headboat discard mortalities, and rec.D to general recreational discard mortalities.*

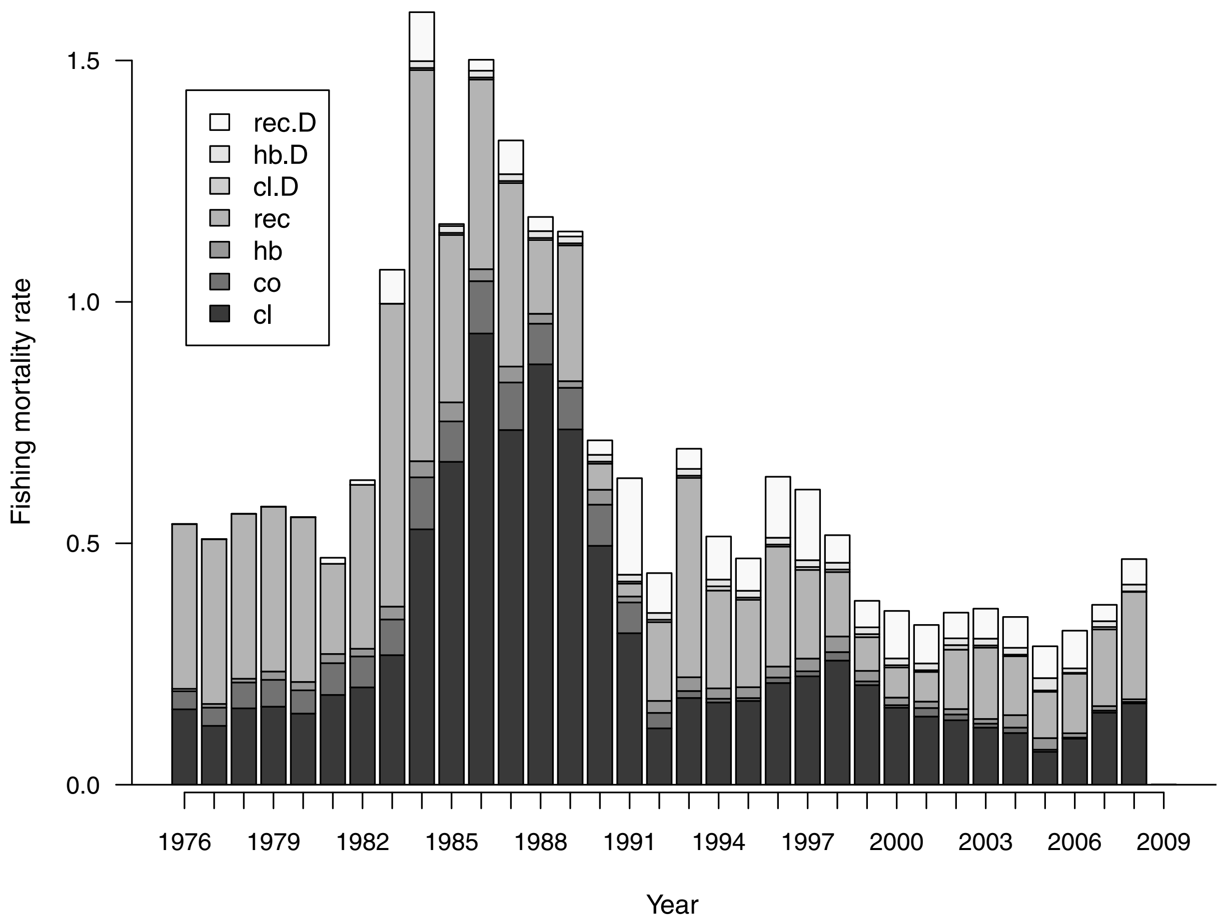


*Figure 3.39. Estimated landings in numbers by fishery from the Beaufort catch-age model. cl refers to commercial lines, co to commercial other, hb to headboat, rec to general recreational.*

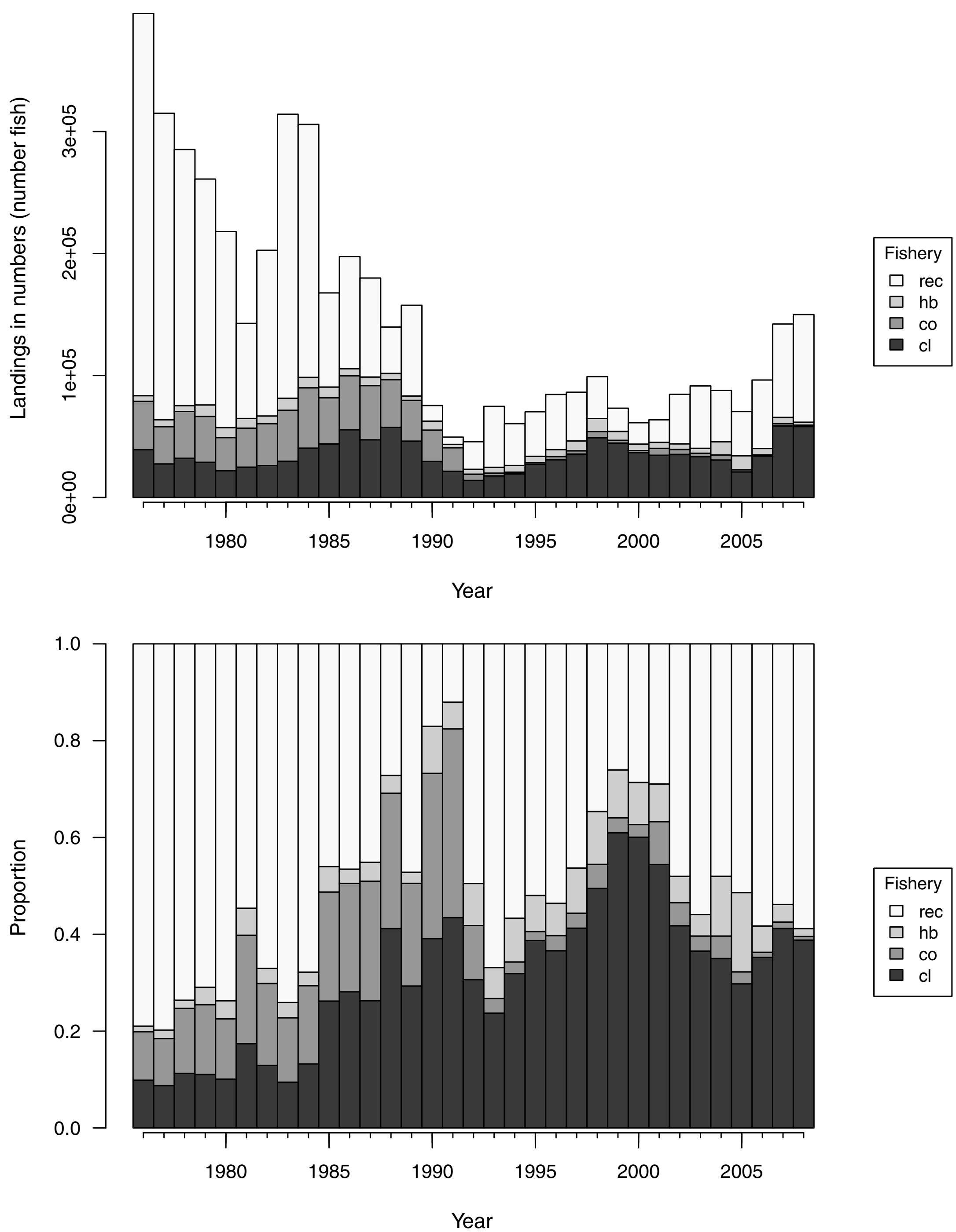
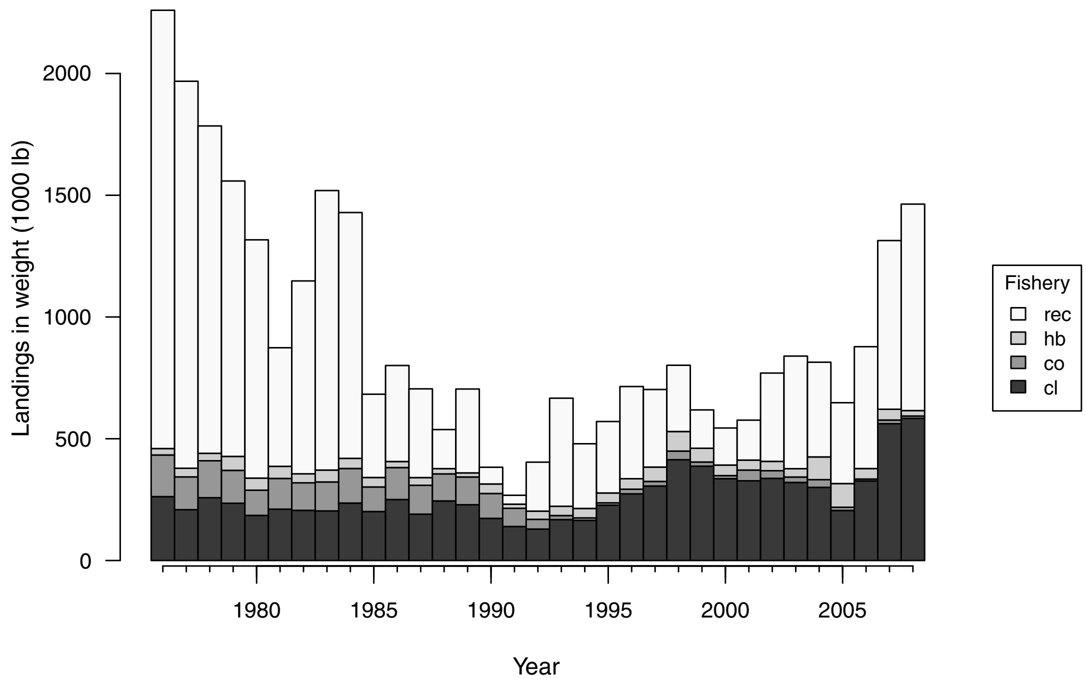


*Figure 3.40. Estimated landings in whole weight by fishery from the Beaufort catch-age model. cl refers to commercial lines, co to commercial other, hb to headboat, rec to general recreational.*



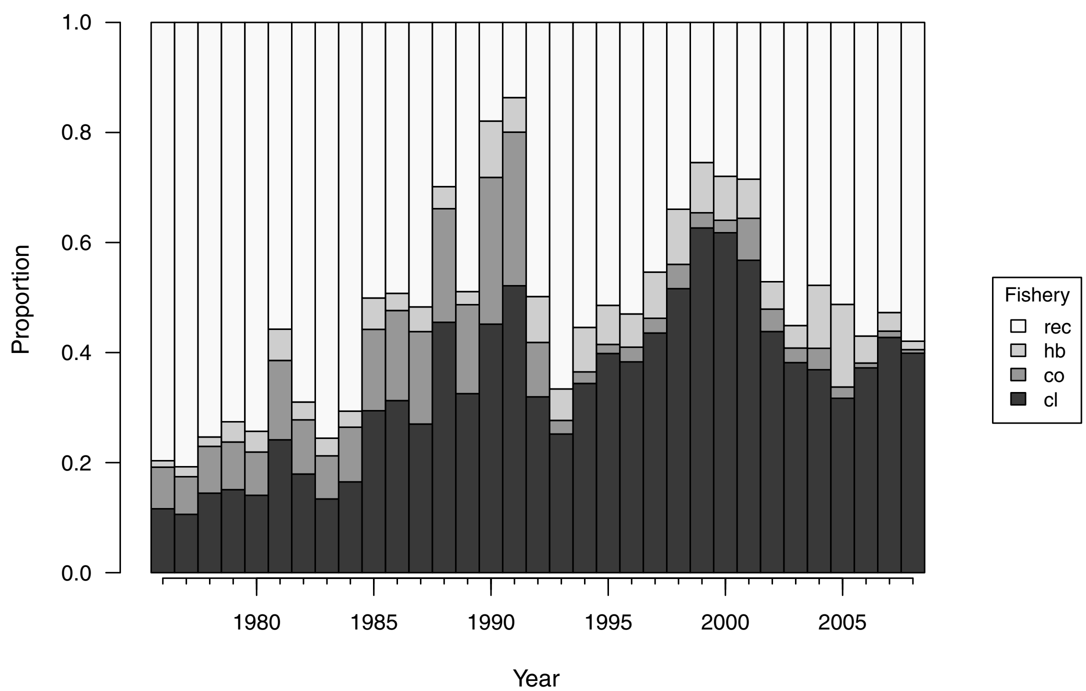



*Figure 3.41. Estimated discard mortalities by fishery from the Beaufort catch-age model. cl refers to commercial lines, hb to headboat, rec to general recreational.*

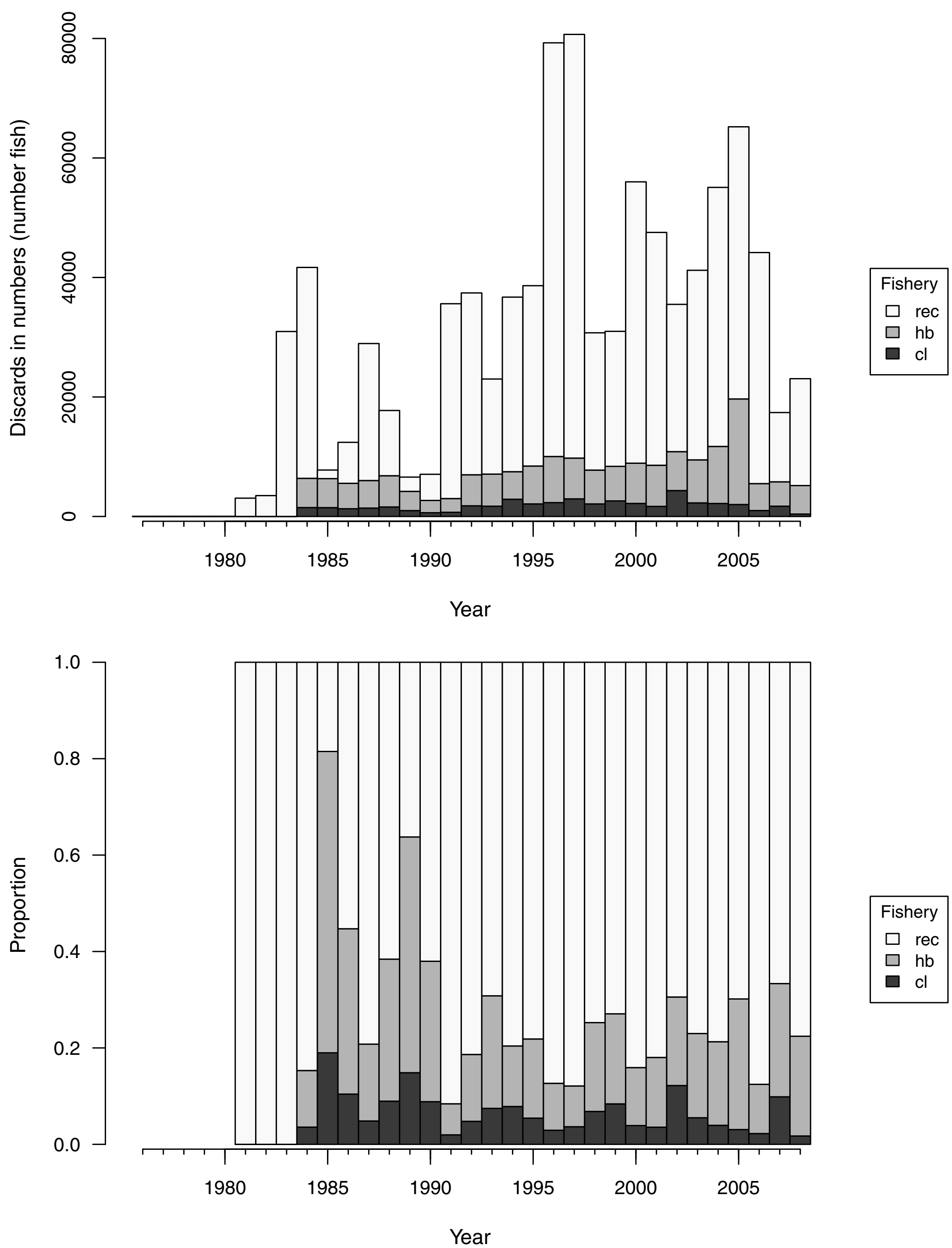


*Figure 3.42. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. Bottom panel: log of recruits (number age-1 fish) per spawner (total mature biomass) as a function of spawners. Years on each panel indicate year of recruitment generated from spawning biomass one year prior.*

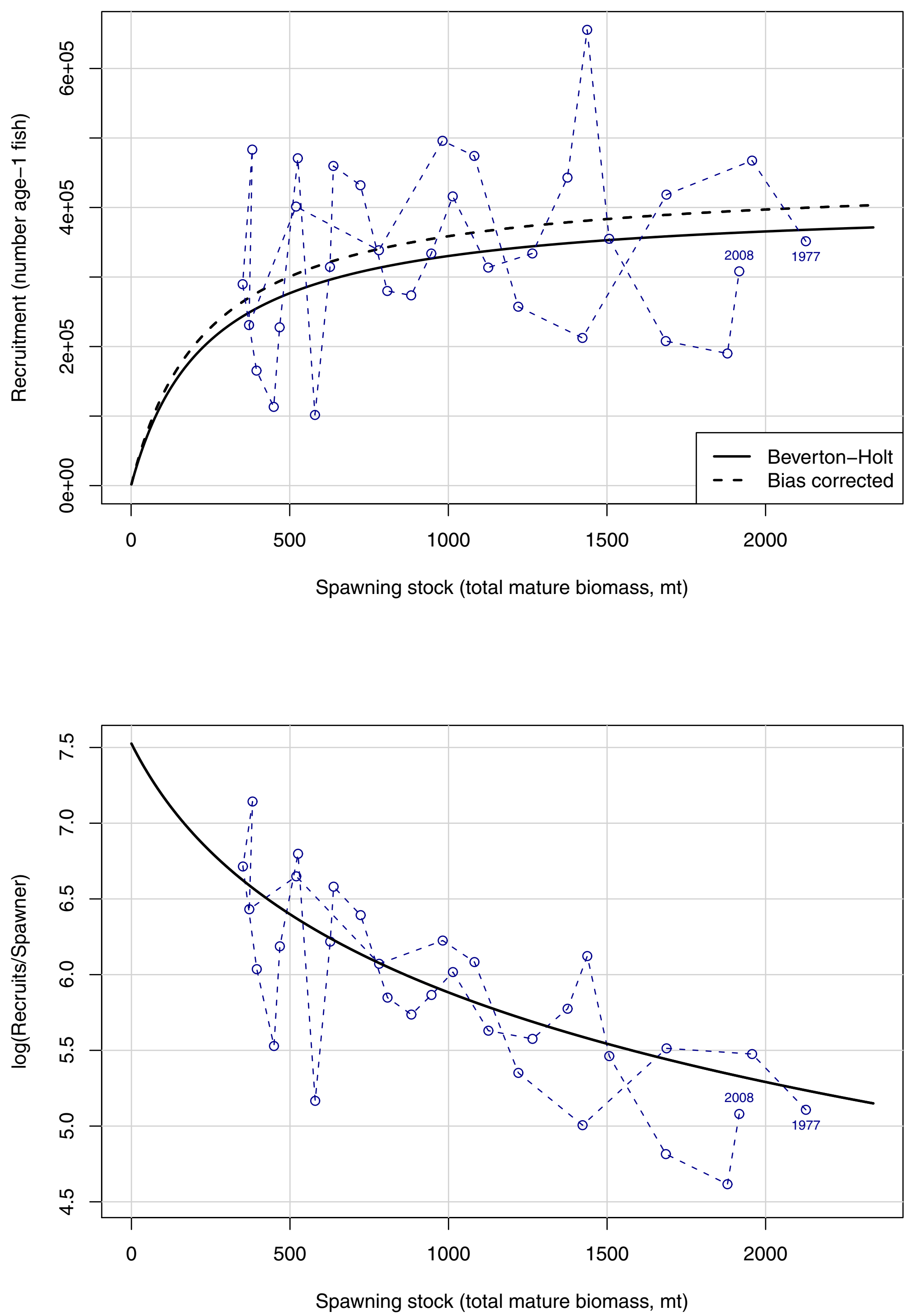


*Figure 3.43. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model.*

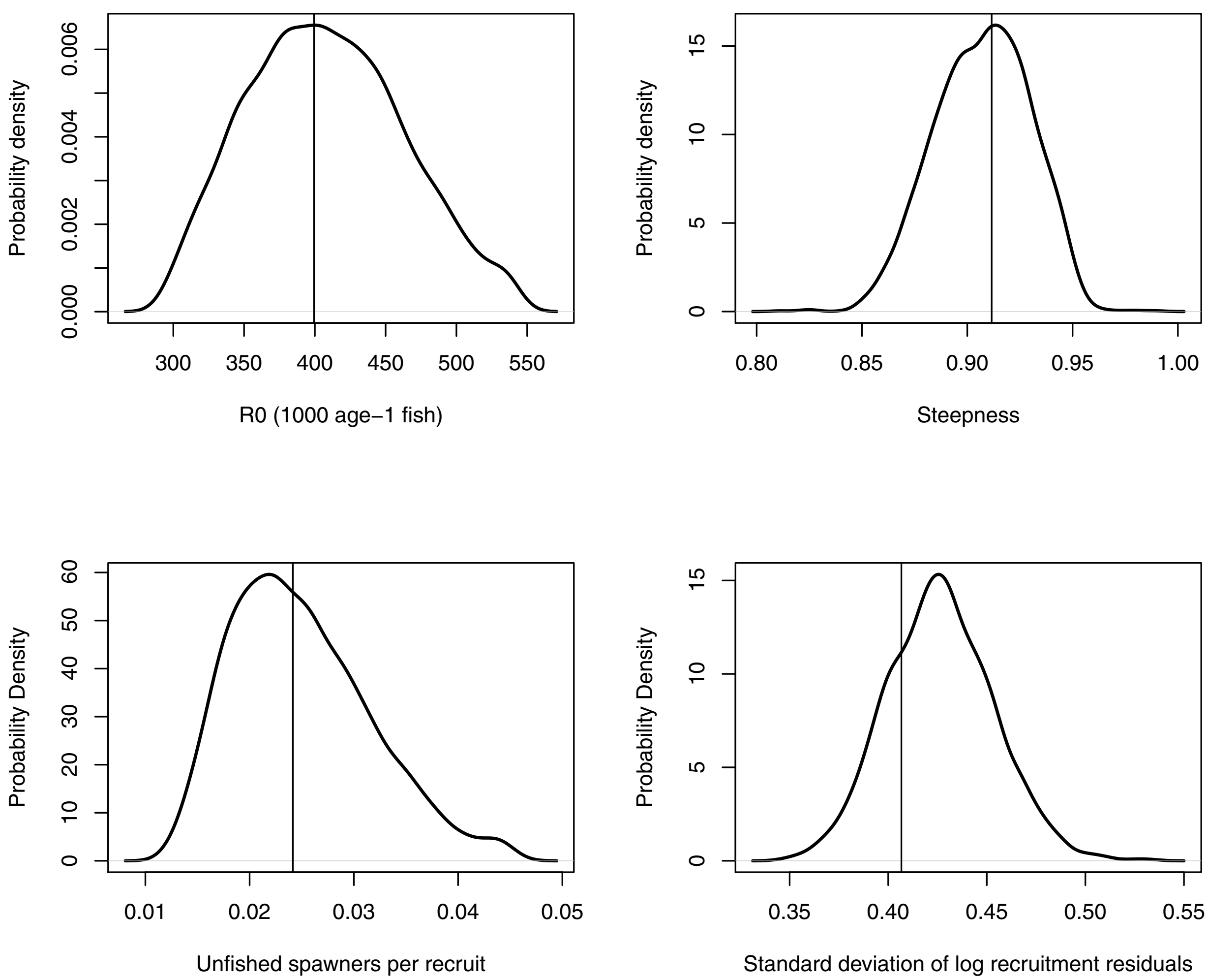


*Figure 3.44. Estimated time series of static spawning potential ratio, the annual equilibrium spawners per recruit relative to that at the unfished level.*

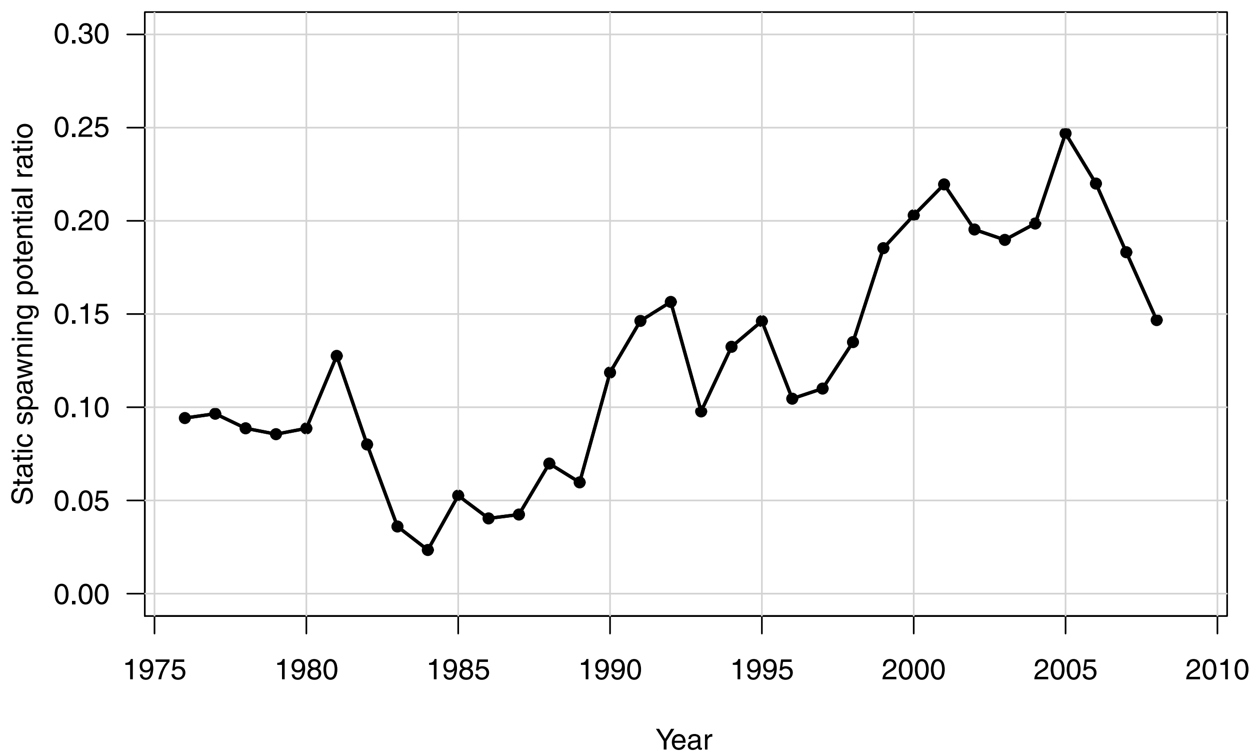


*Figure 3.45. Top panel: yield per recruit. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the y% levels provide $F_{y\%}$. Both curves are based on average selectivity from the end of the assessment period.*

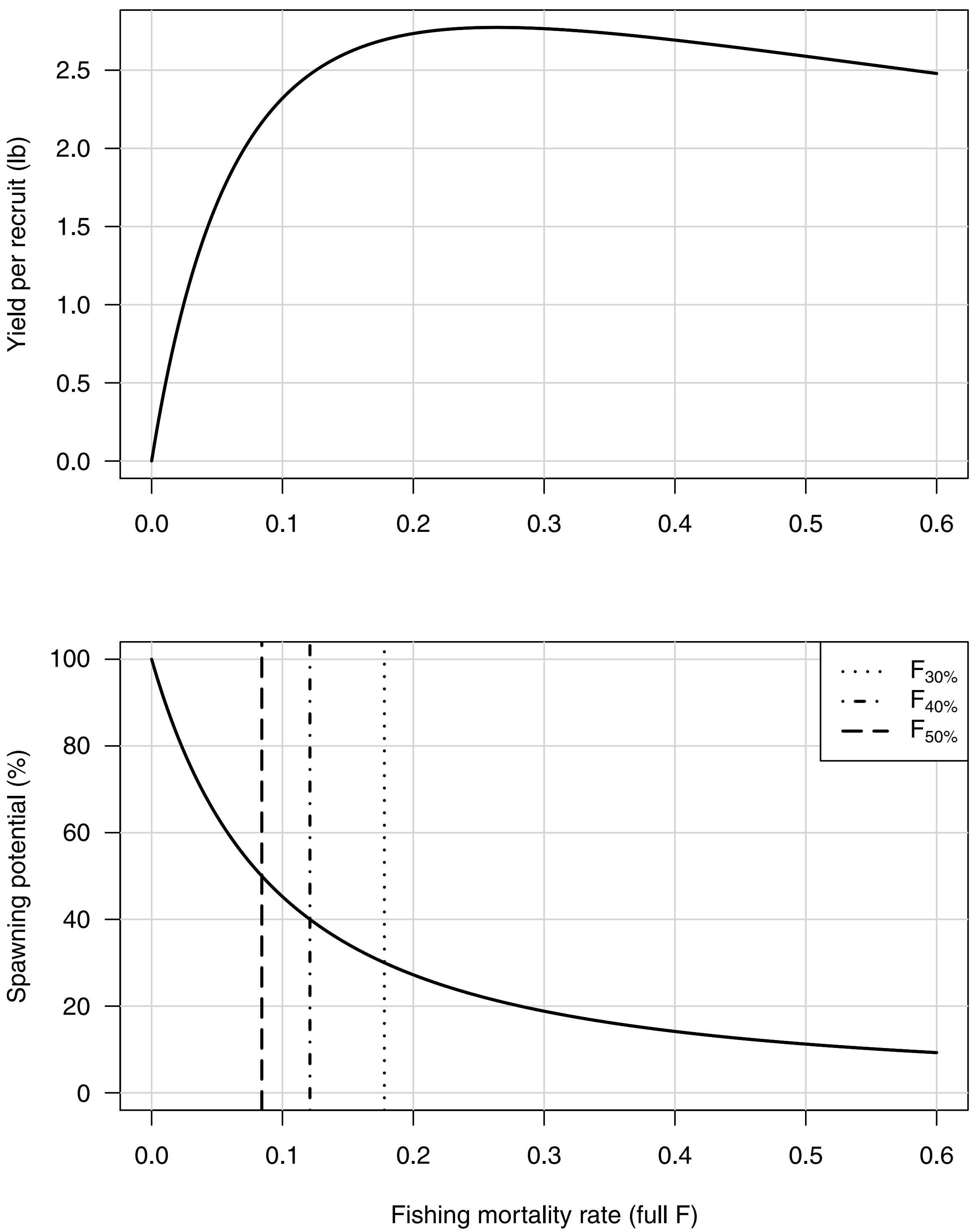


*Figure 3.46. Top panel: equilibrium landings. The peak occurs where fishing rate is* $F_{MSY} = 0.21$ *and equilibrium landings are* MSY = 1117 *(1000 lb). Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.*

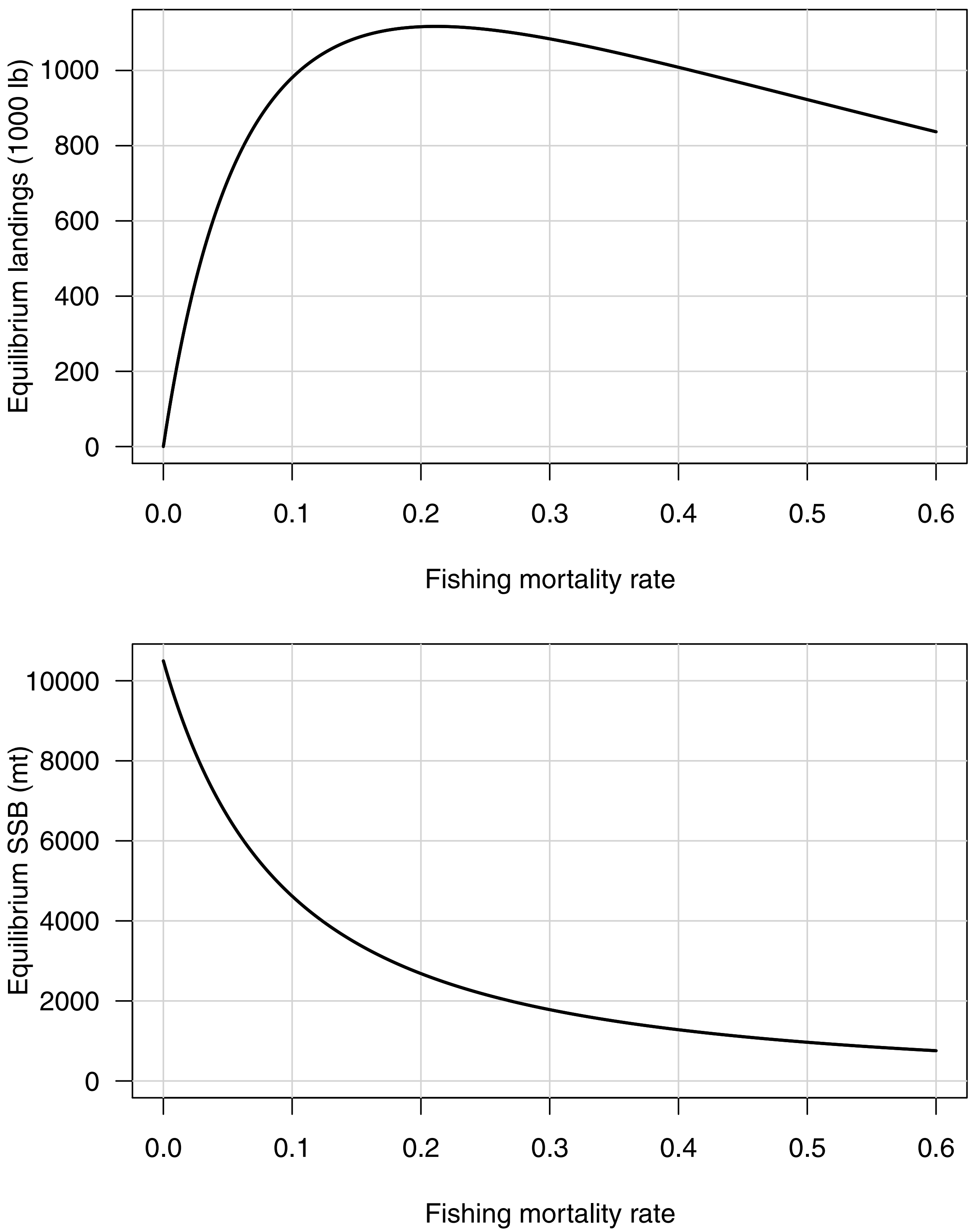


*Figure 3.47. Top panel: equilibrium landings as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is* $B_{\mathrm{MSY}} = 3622$ *mt and equilibrium landings are* MSY = 1117 *(1000 lb). Bottom panel: equilibrium discard mortality as a function of equilibrium biomass.*

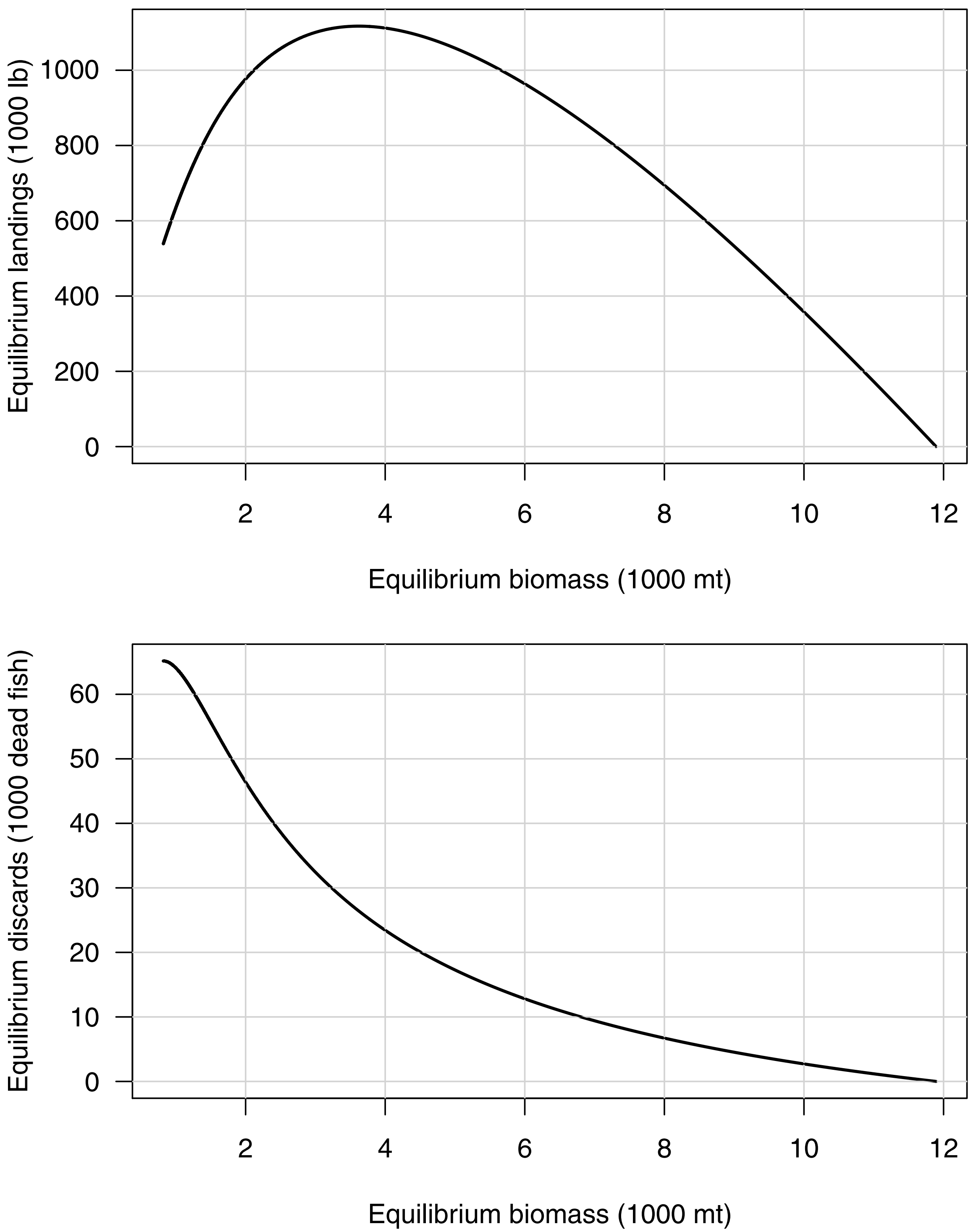


*Figure 3.48. Probability densities of* MSY*-related benchmarks from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.*

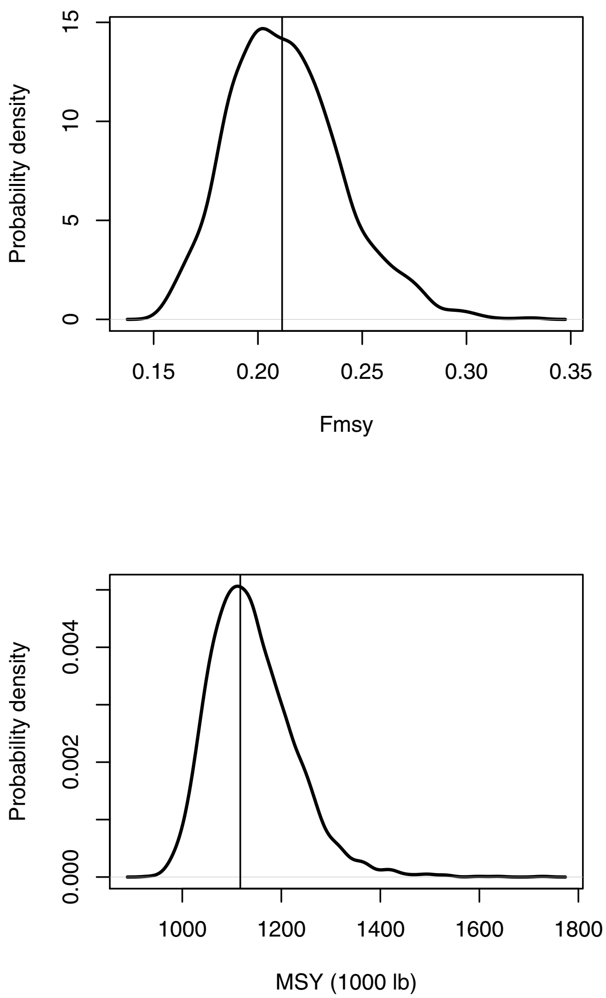
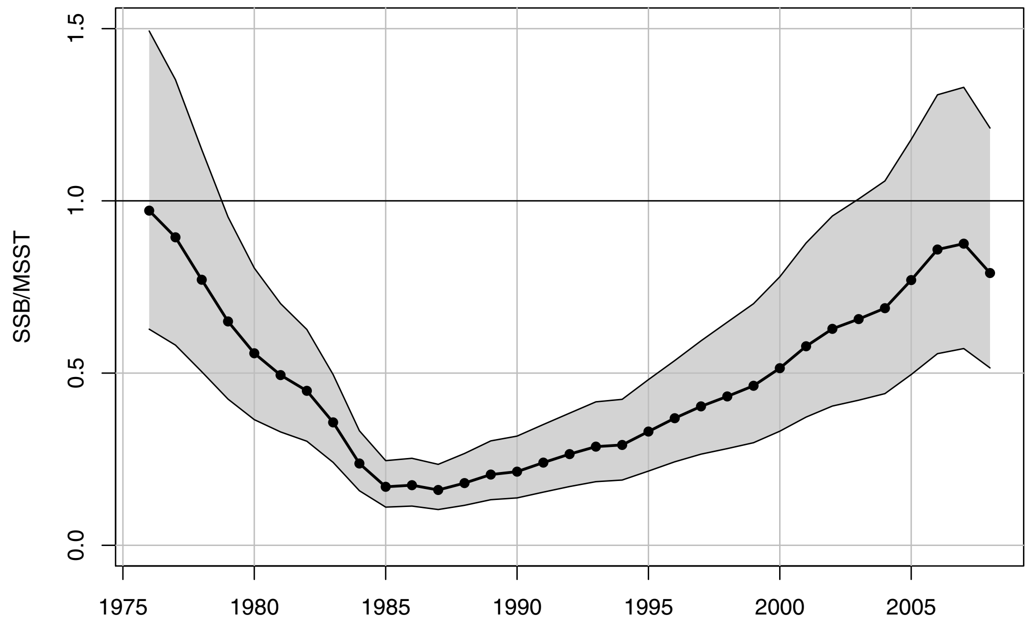


*Figure 3.49. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate $5^{th}$ and $95^{th}$ percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Bottom panel: F relative to $F_{\mathrm{MSY}}$.*



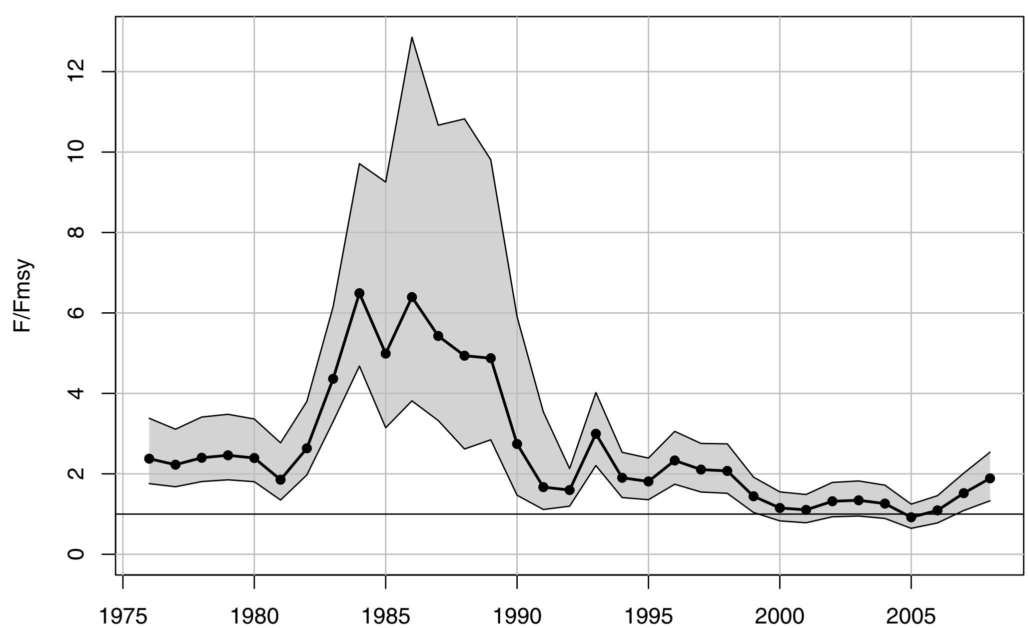
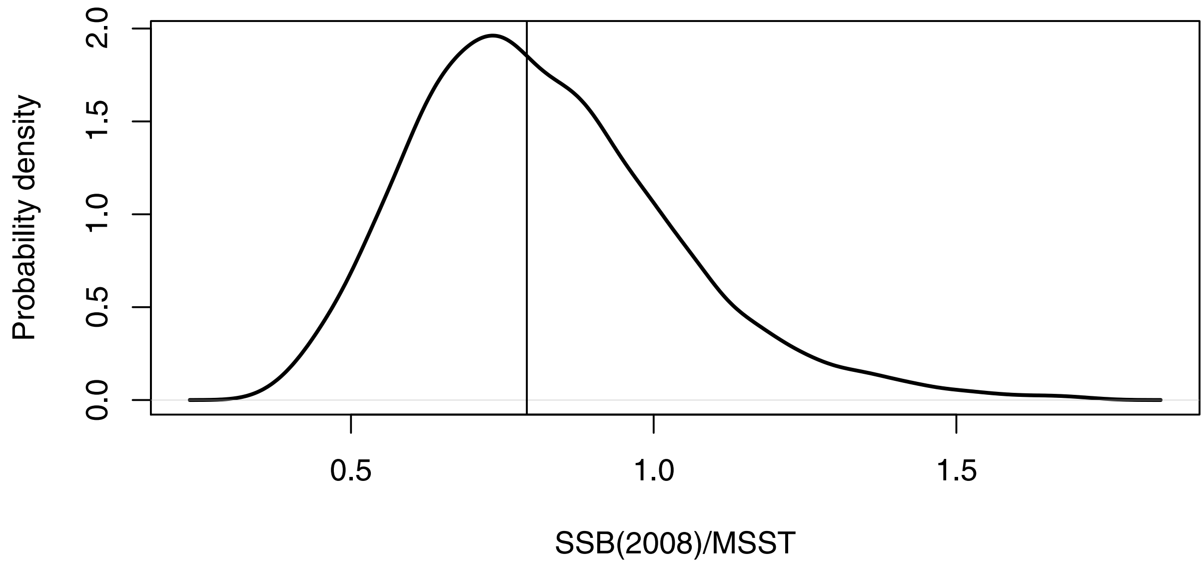



*Figure 3.50. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.*



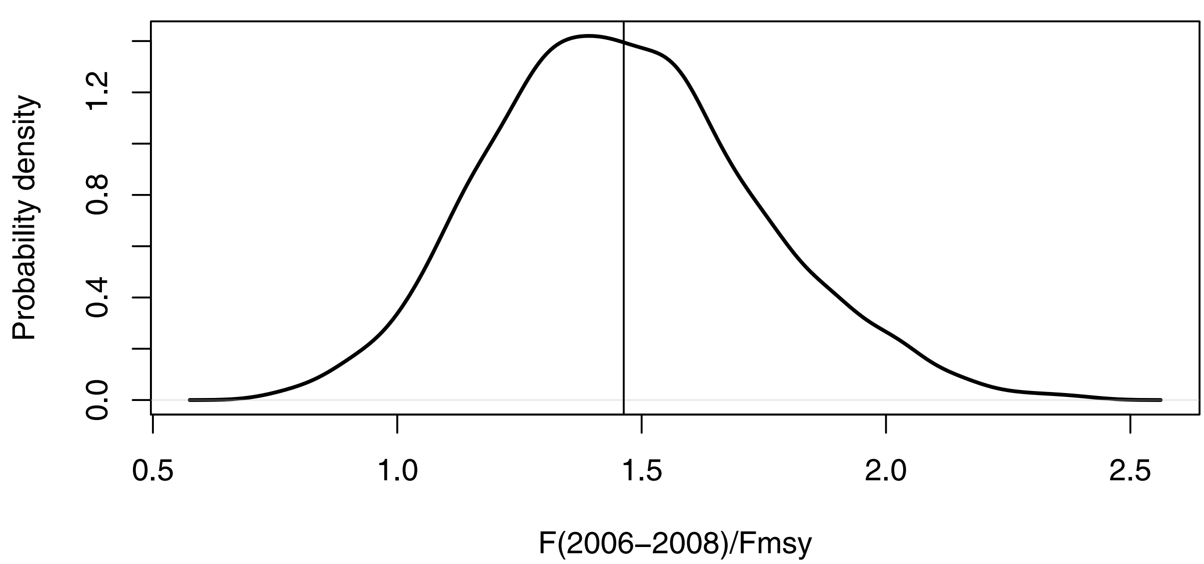



*Figure 3.51. Phase plot of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by* $5^{th}$ *and* $95^{th}$ *percentiles.*

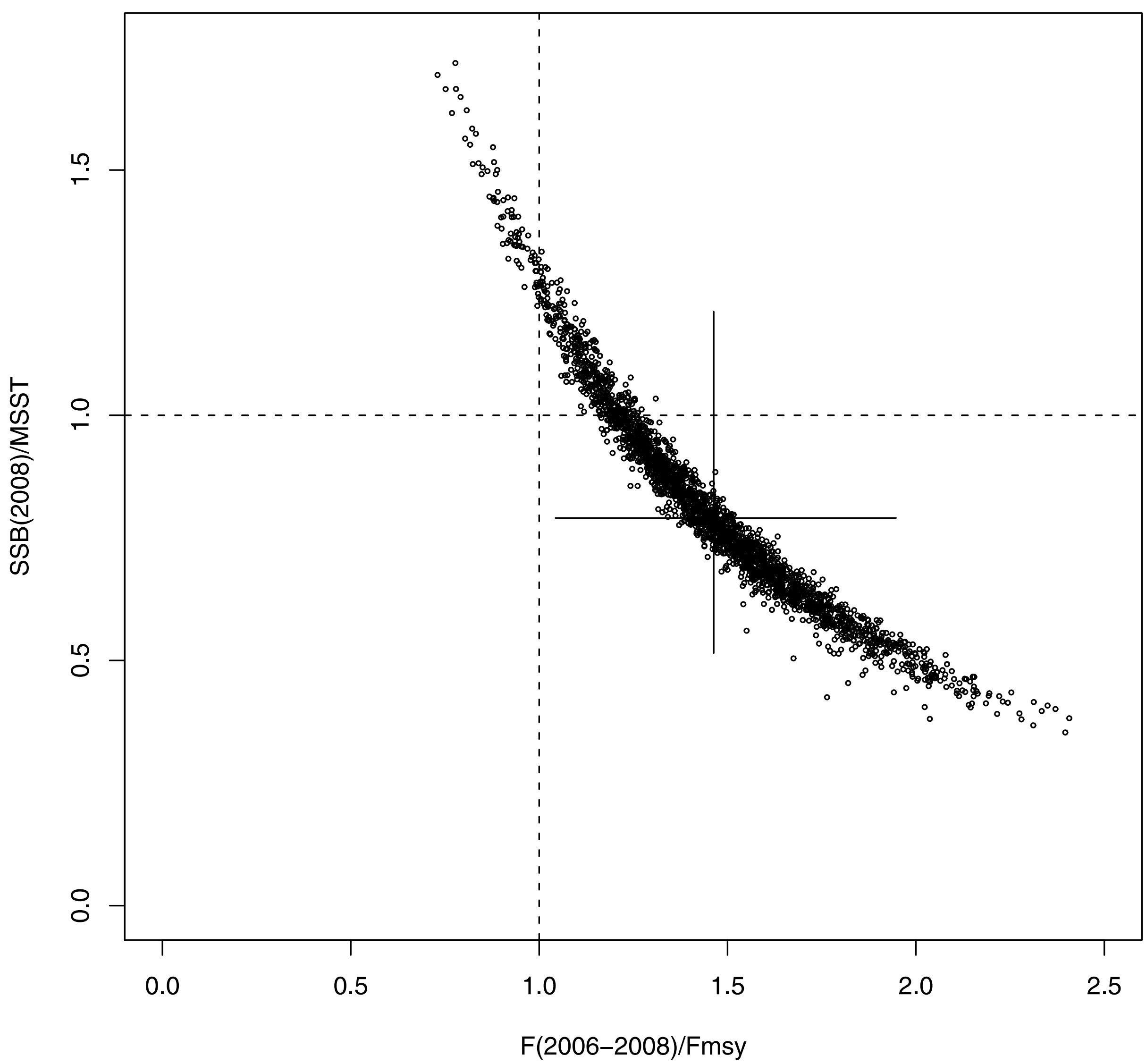


*Figure 3.52. Age structure relative to the equilibrium expected at* MSY.

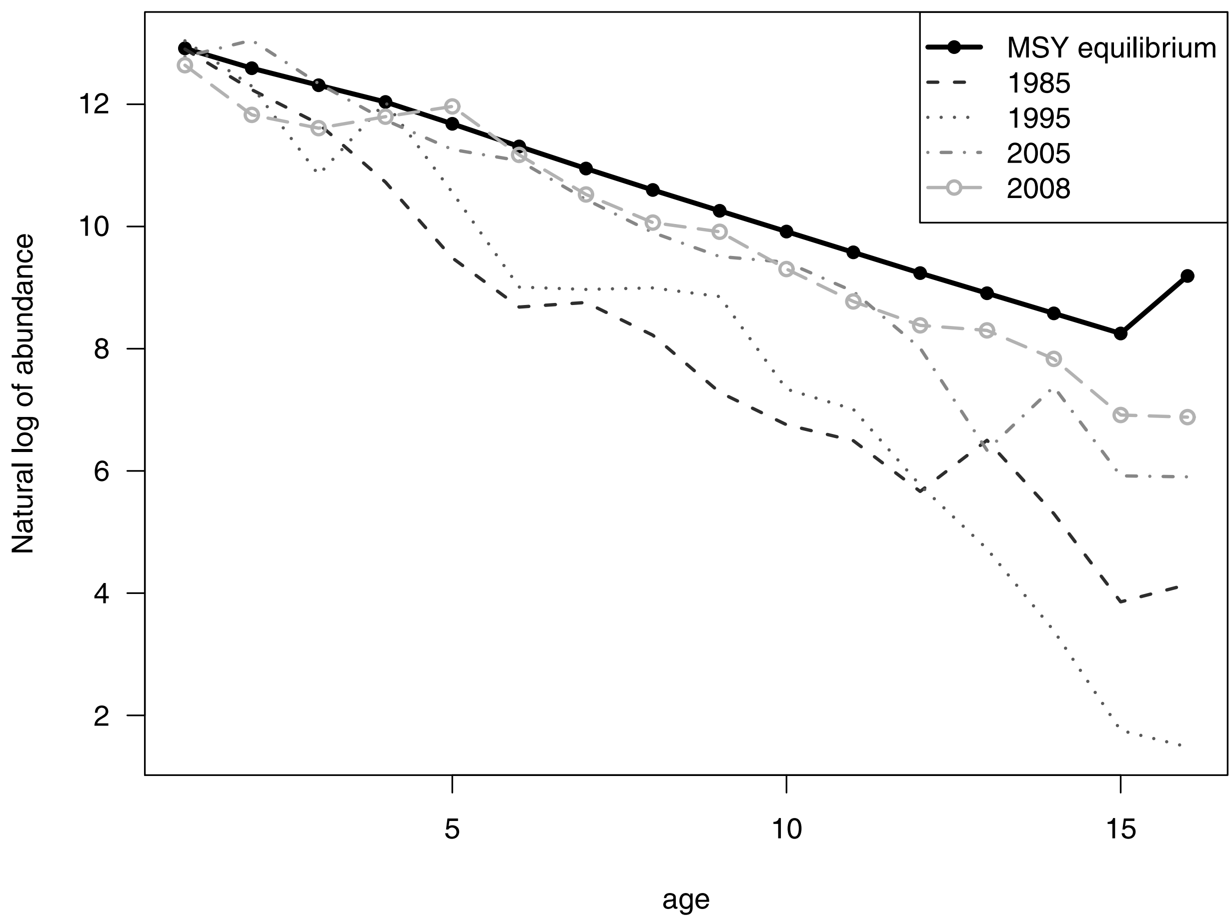


*Figure 3.53. Sensitivity to changes in natural mortality (sensitivity runs S1–S3). Top panel: Ratio of $F$ to $F_{\mathrm{MSY}}$. Bottom panel: Ratio of* SSB *to* MSST.

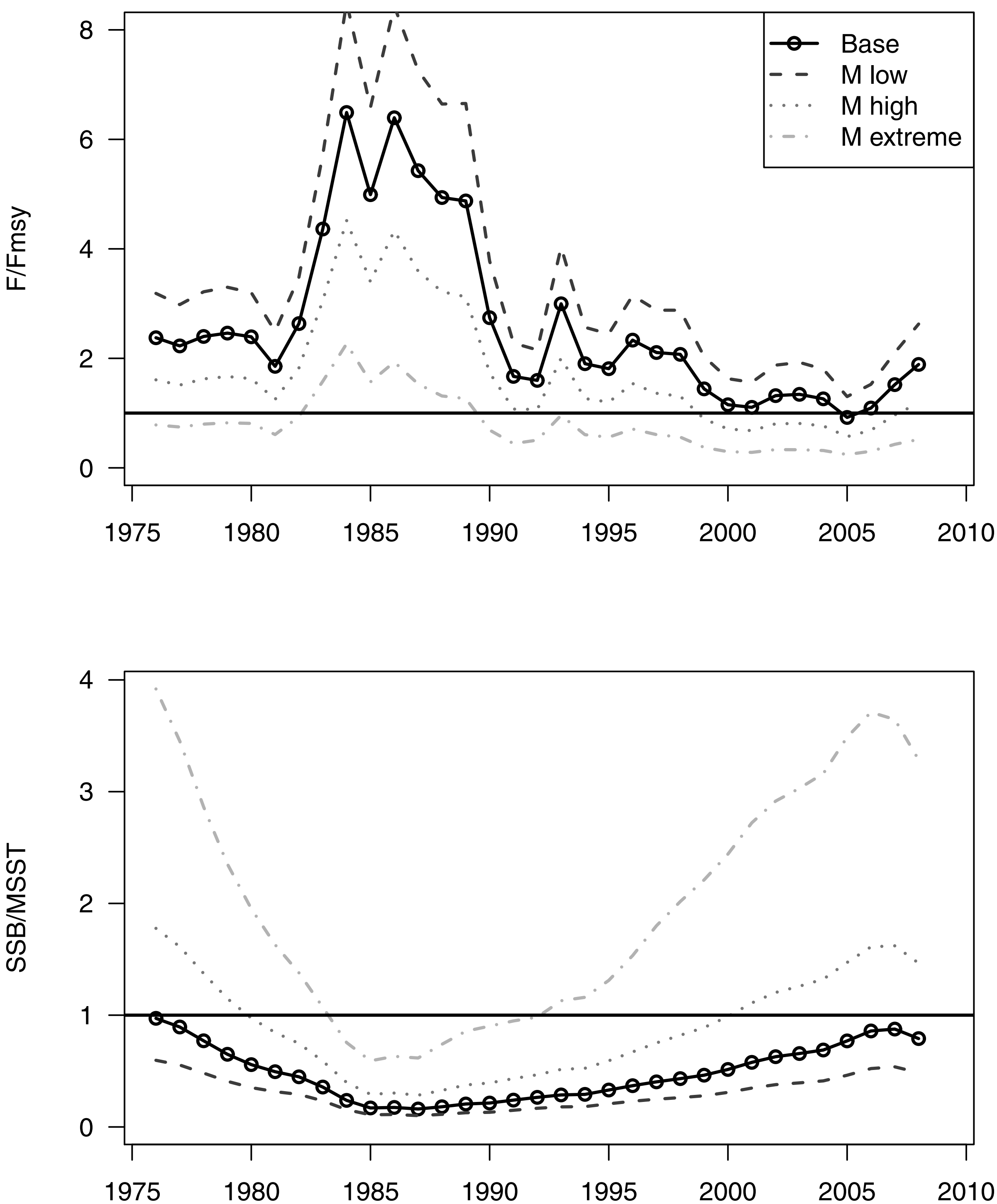
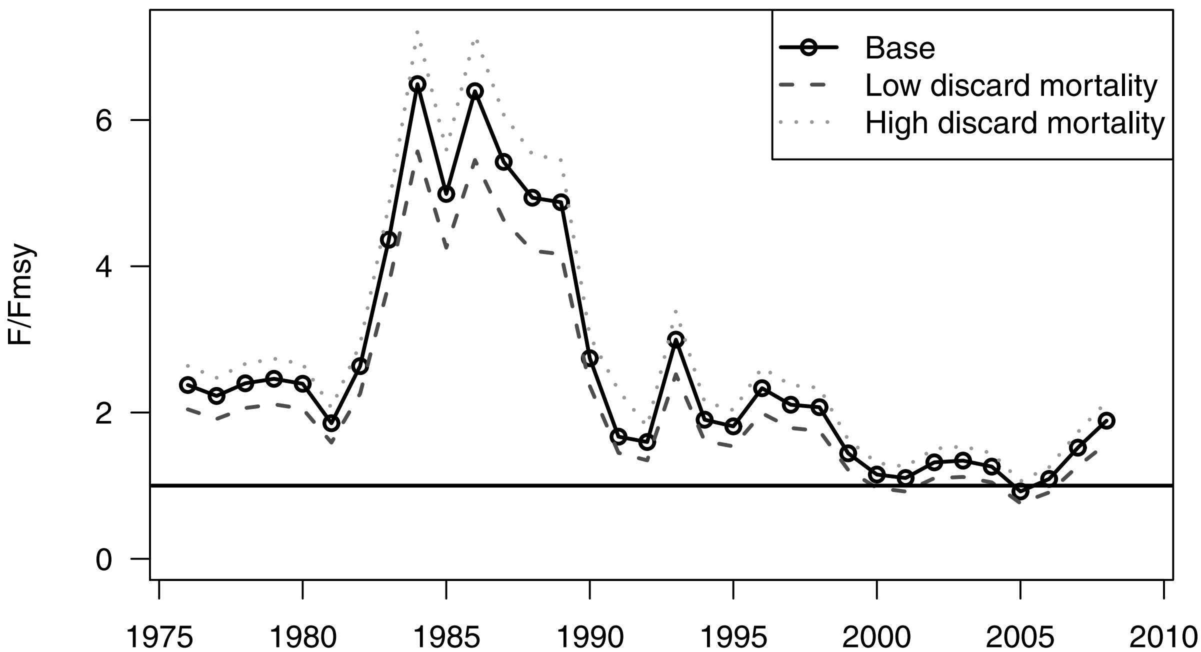


*Figure 3.54. Sensitivity to discard mortality rates (sensitivity runs S4 and S5). Top panel:Ratio of $F$ to $F_{MSY}$. Bottom panel:Ratio of* SSB *to* MSST.



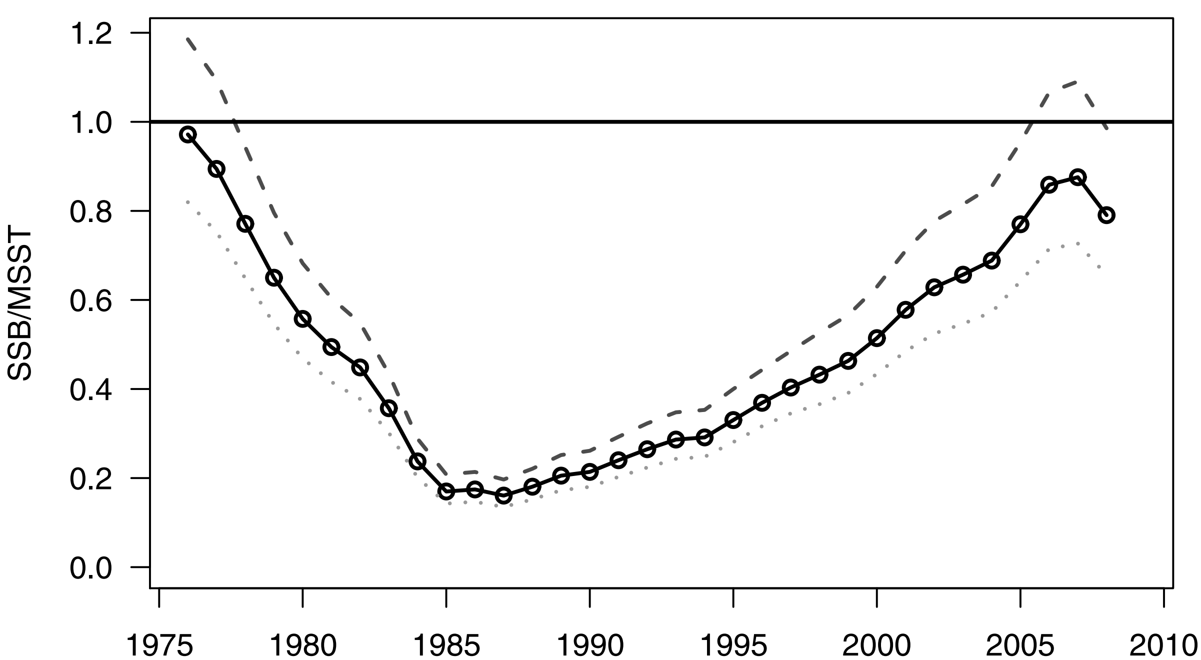



*Figure 3.55. Sensitivity to the measure of spawning biomass (sensitivity runs S6 – S7). Top panel: Ratio of F to* $F_{MSY}$*. Bottom panel: Ratio of* SSB *to* MSST.

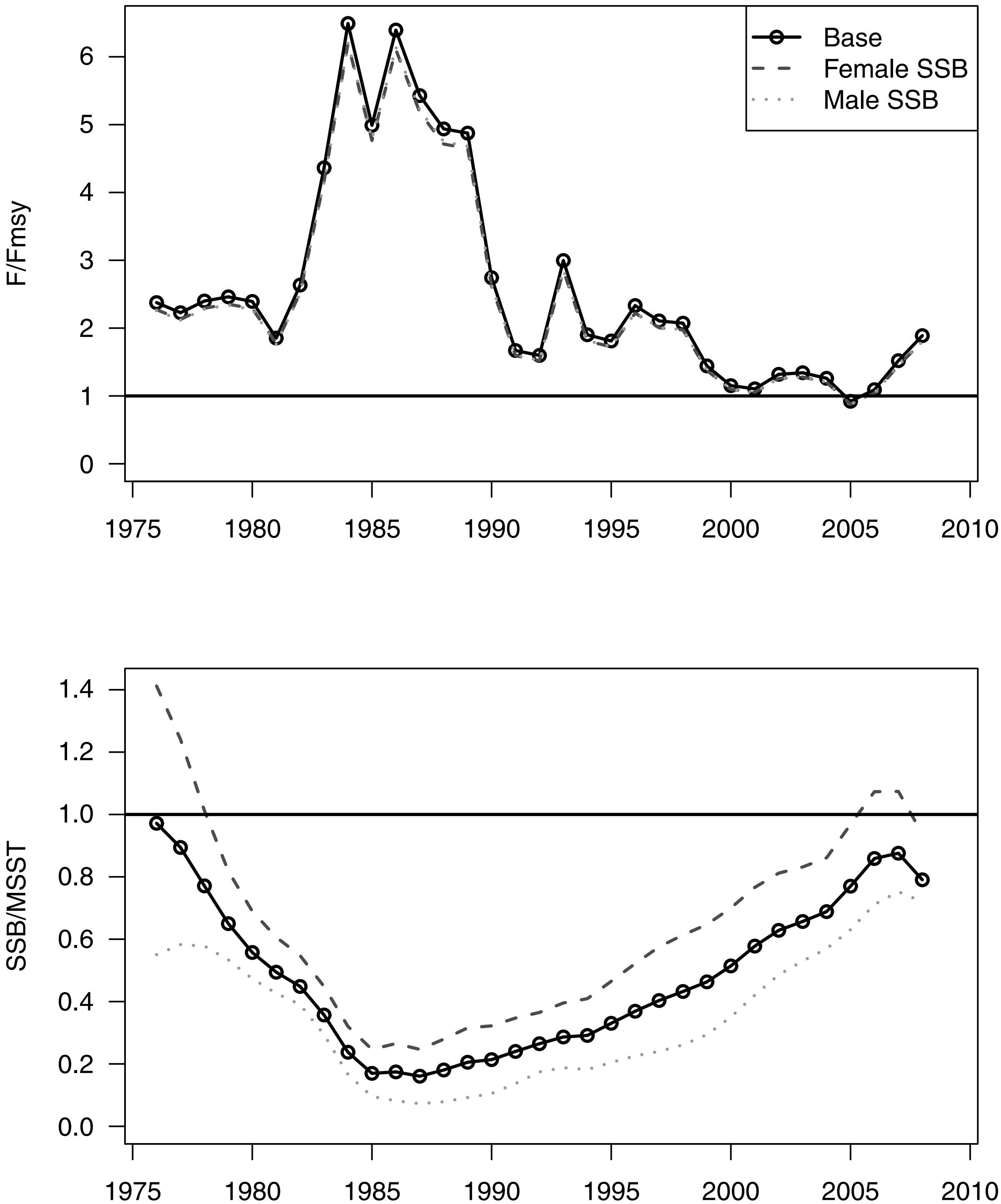


*Figure 3.56. Retrospective analyses. Sensitivity to terminal year of data (sensitivity runs S8–S10). Top panel: Fishing mortality rate. Bottom panel: Spawning biomass.*

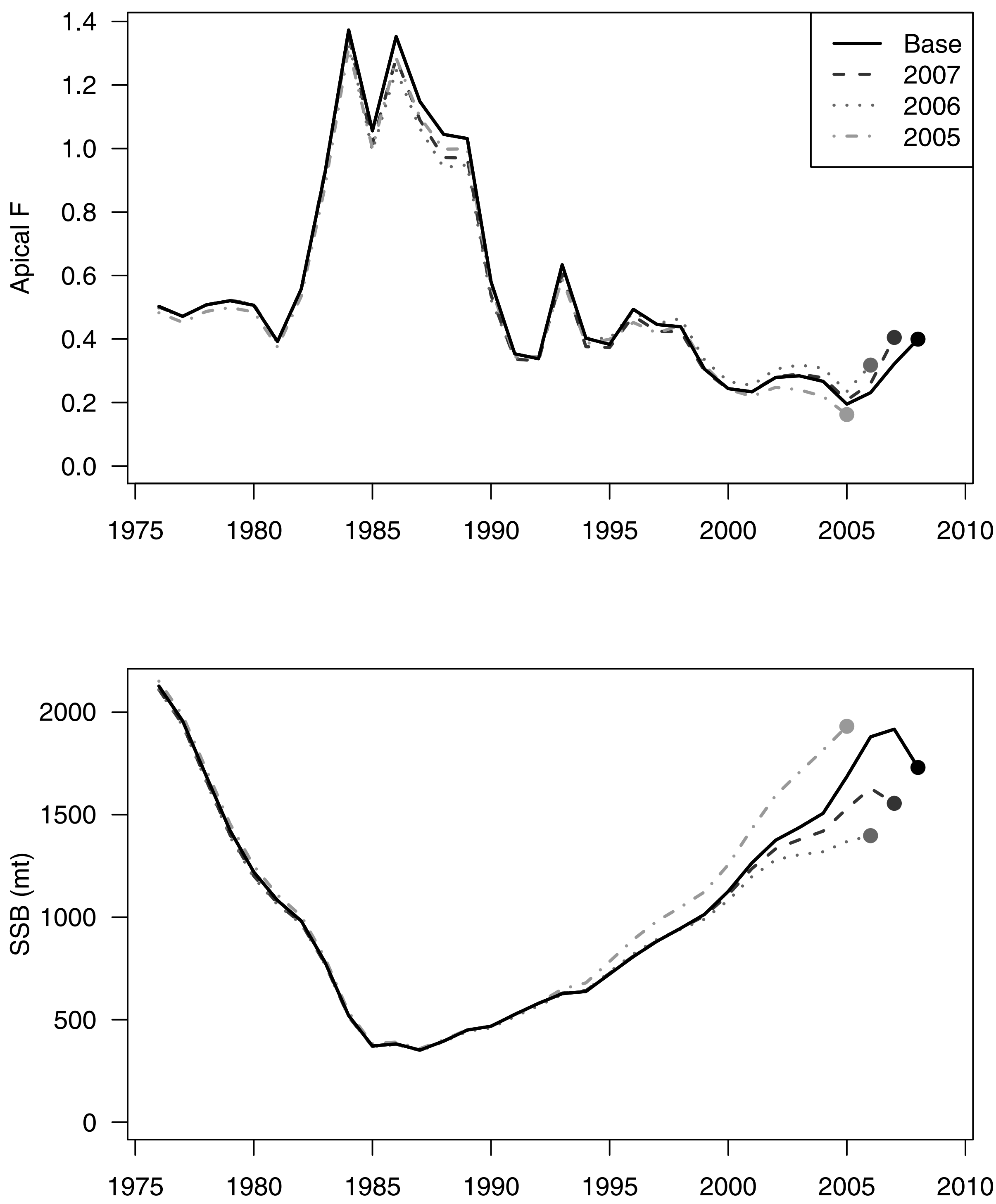


*Figure 3.57. Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model.*

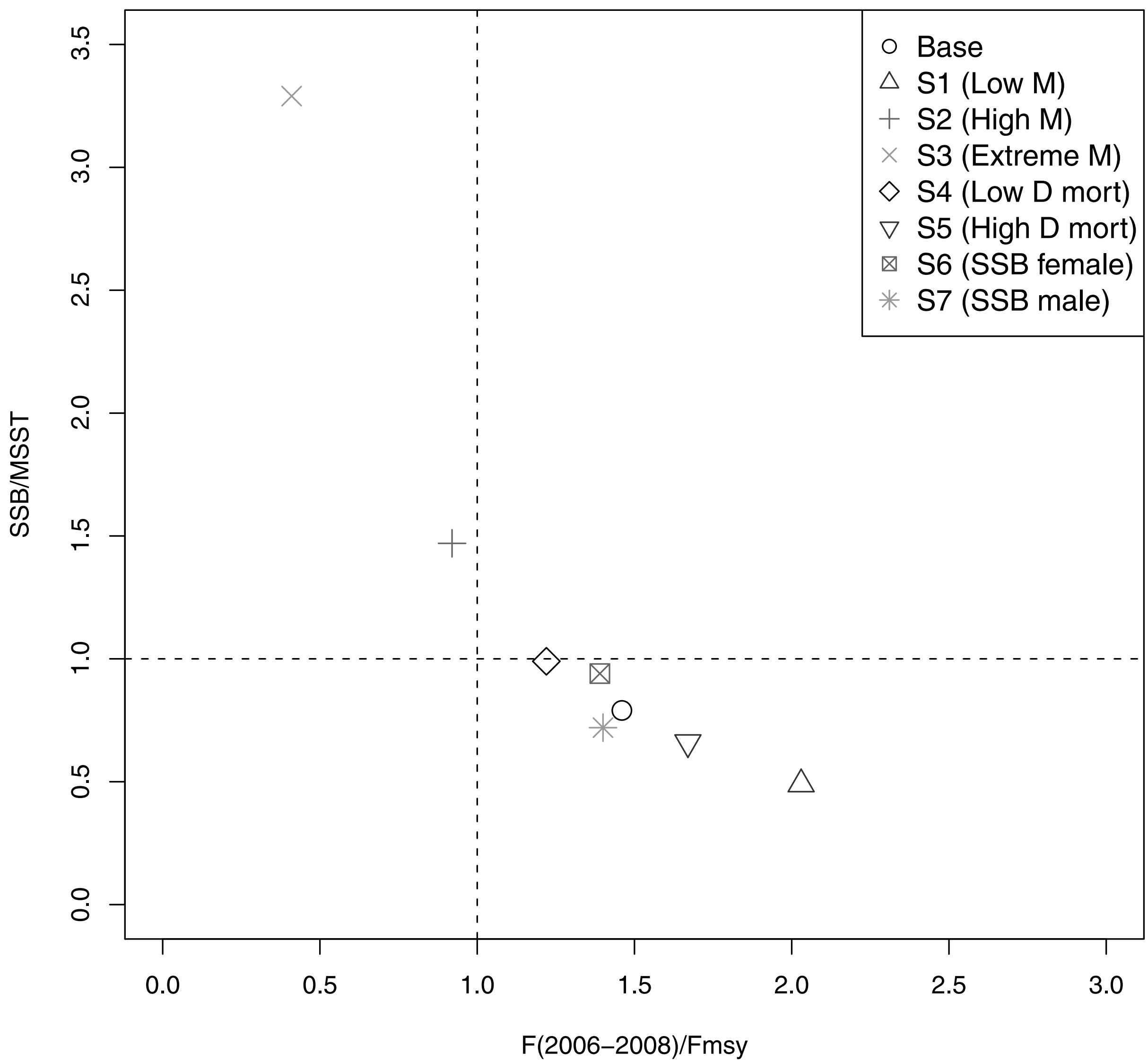


*Figure 3.58. Projection results under scenario 1—fishing mortality rate fixed at F = 0. Curve represents the proportion of projection replicates for which SSB(mid-year) has reached at least* $SSB_{MSY} = 2545$.

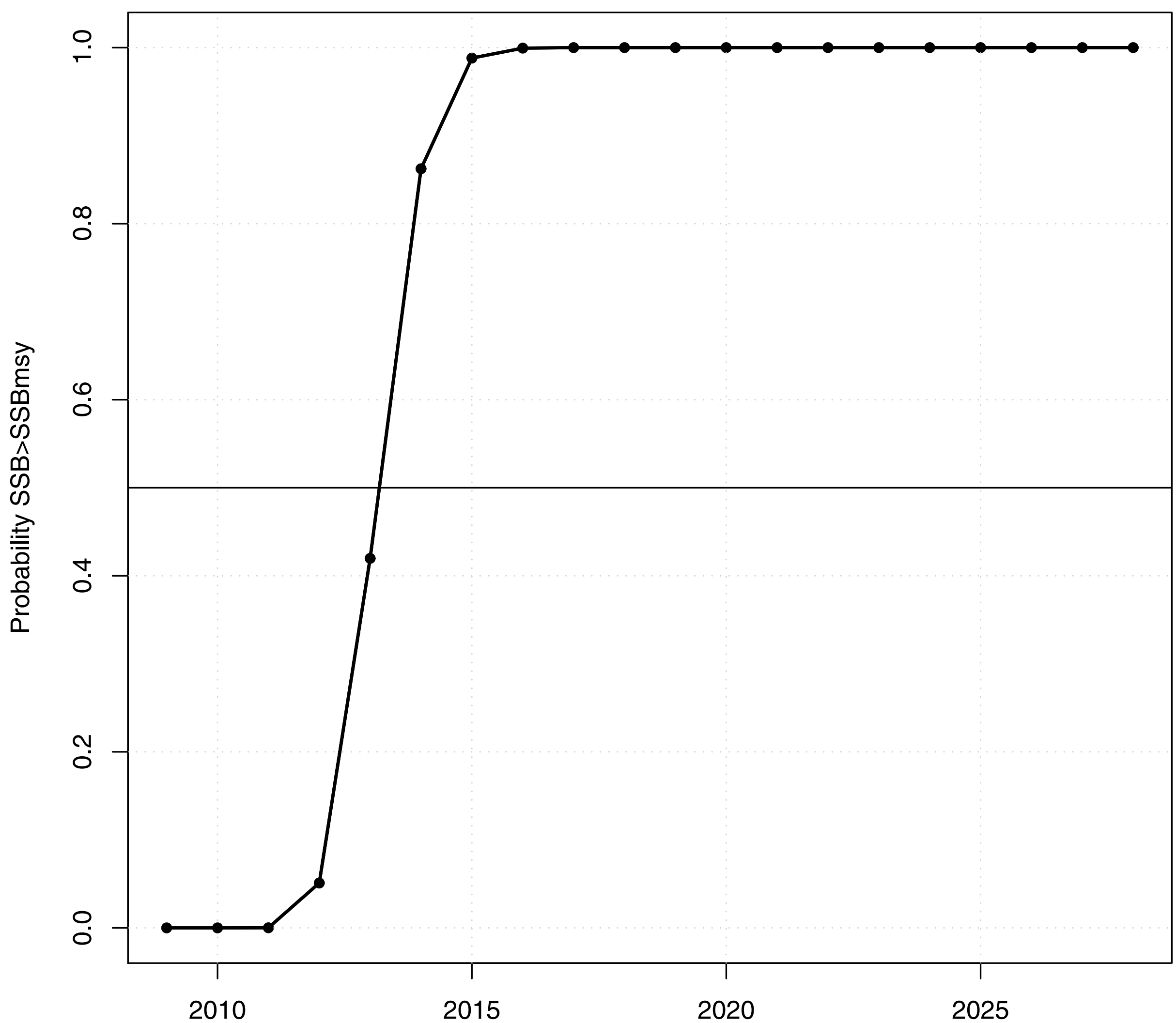


*Figure 3.59. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{\text{current}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

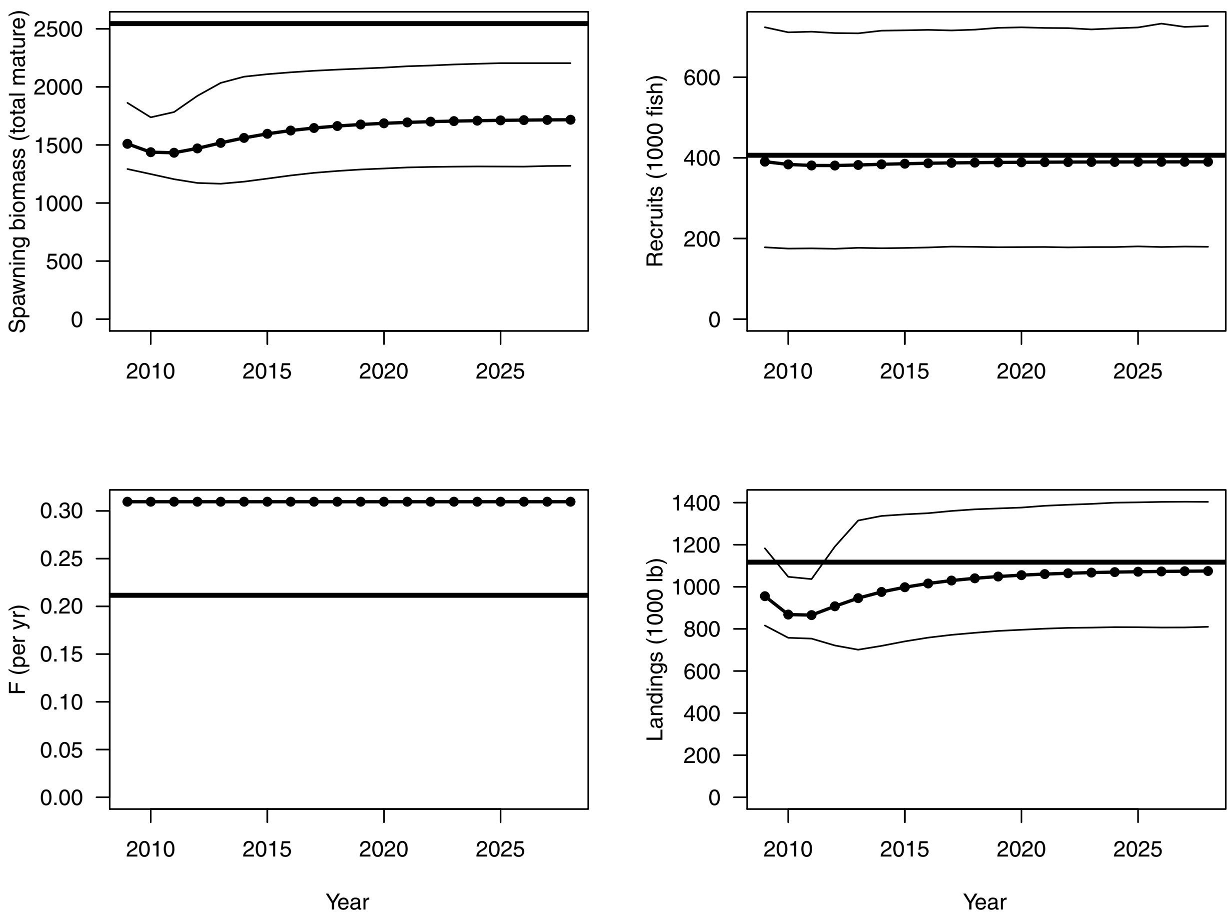


*Figure 3.60. Projection results under scenario 3—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and $F = 75\%F_{\text{current}}$ thereafter. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

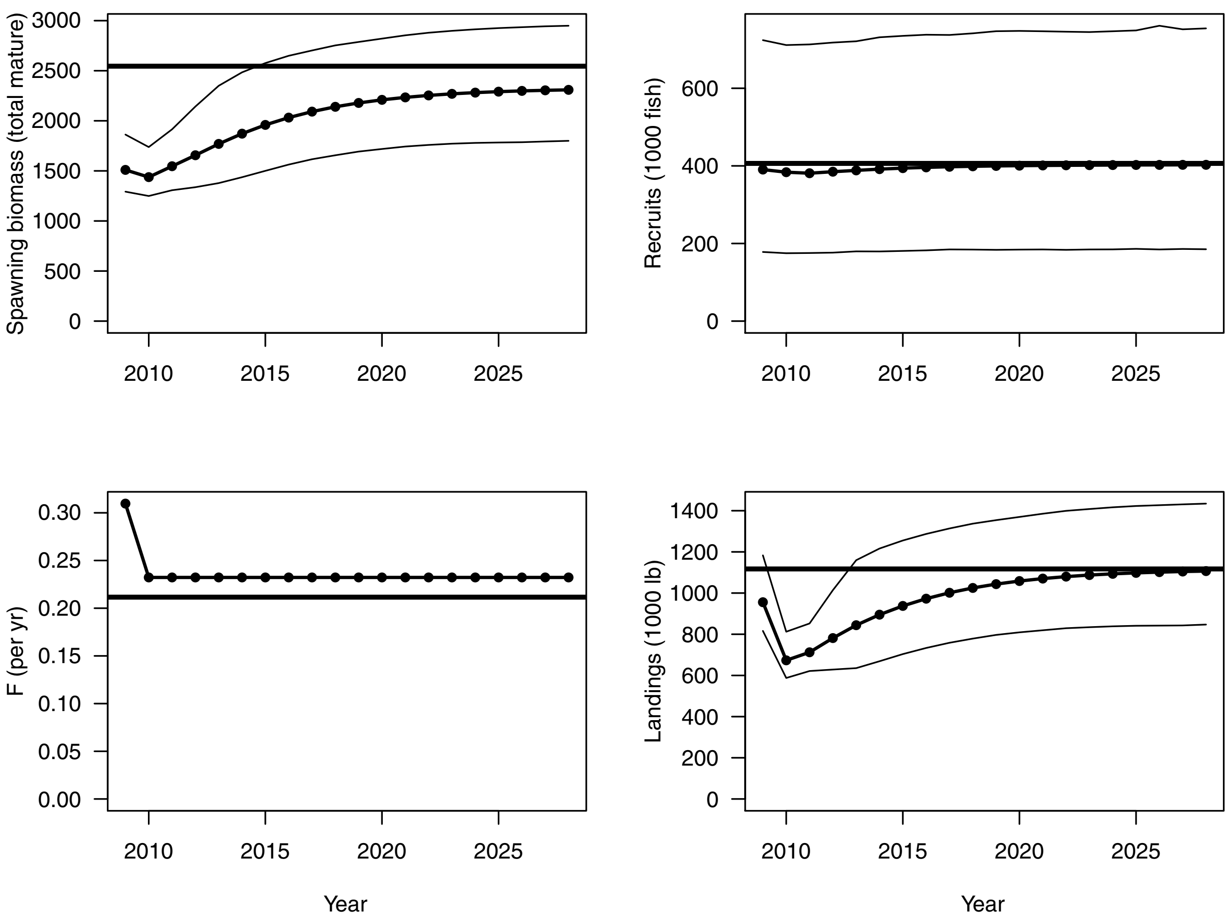


*Figure 3.61. Projection results under scenario 4—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and $F = 50\% F_{\text{current}}$ thereafter. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

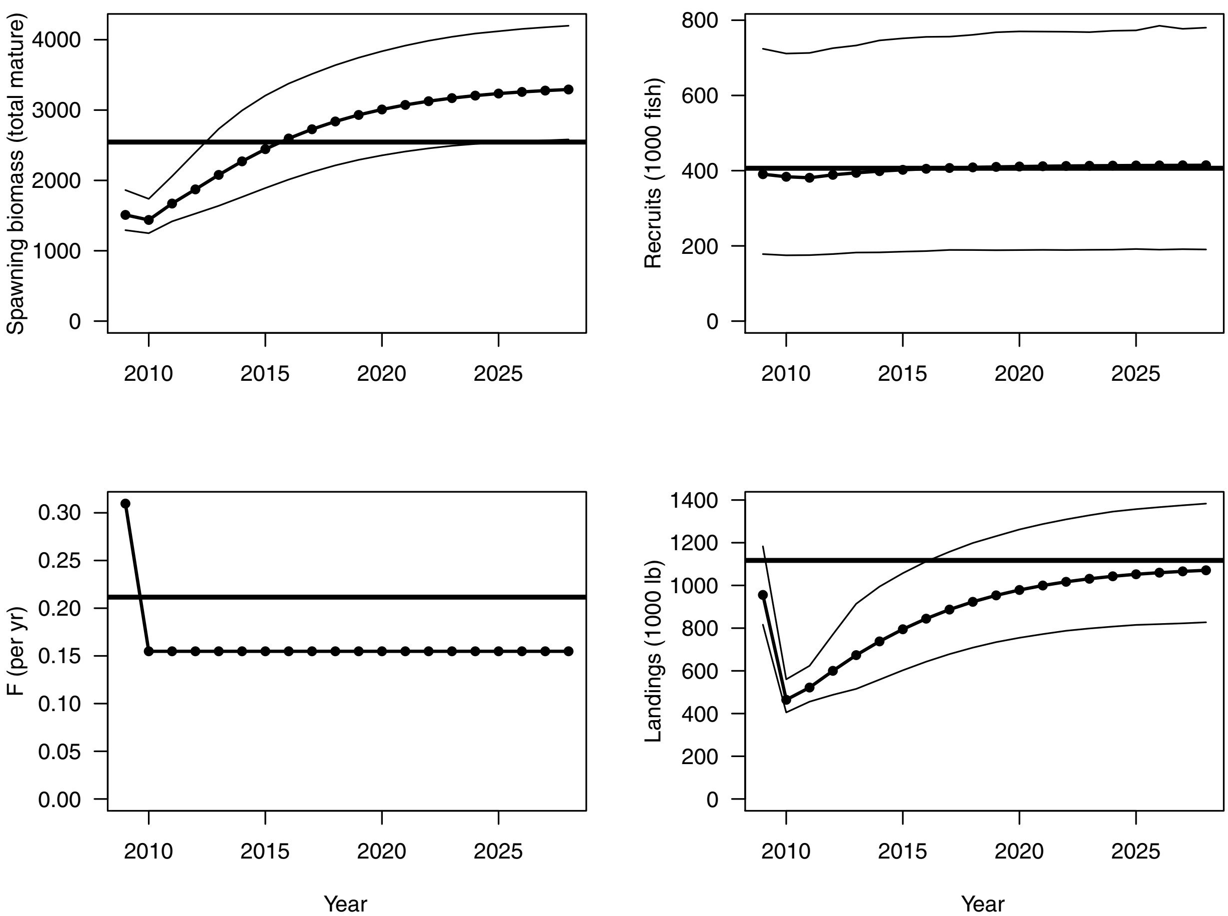


*Figure 3.62. Projection results under scenario 5—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and $F = 25\%F_{\text{current}}$ thereafter. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

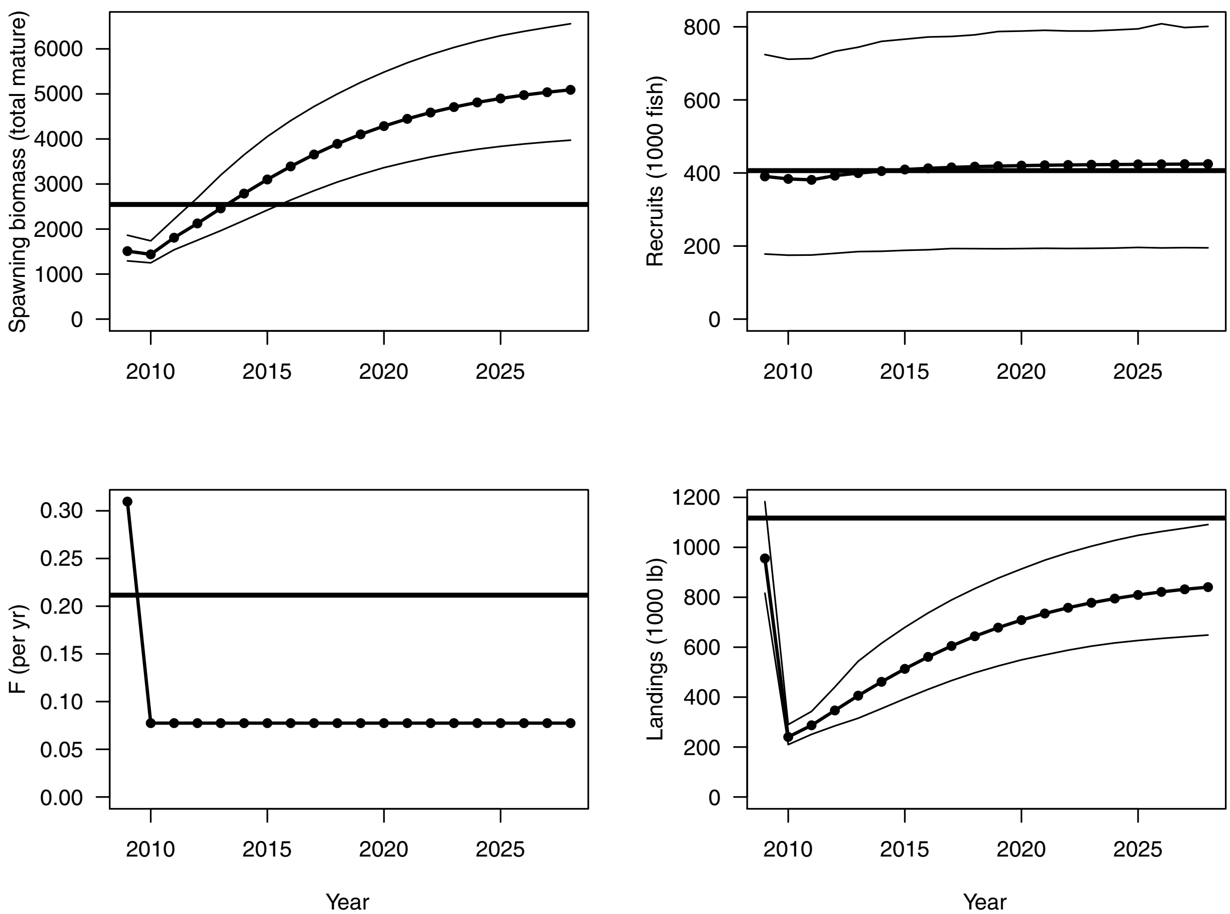


*Figure 3.63. Projection results under scenario 6—fishing mortality rate fixed at $F = 65\%F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

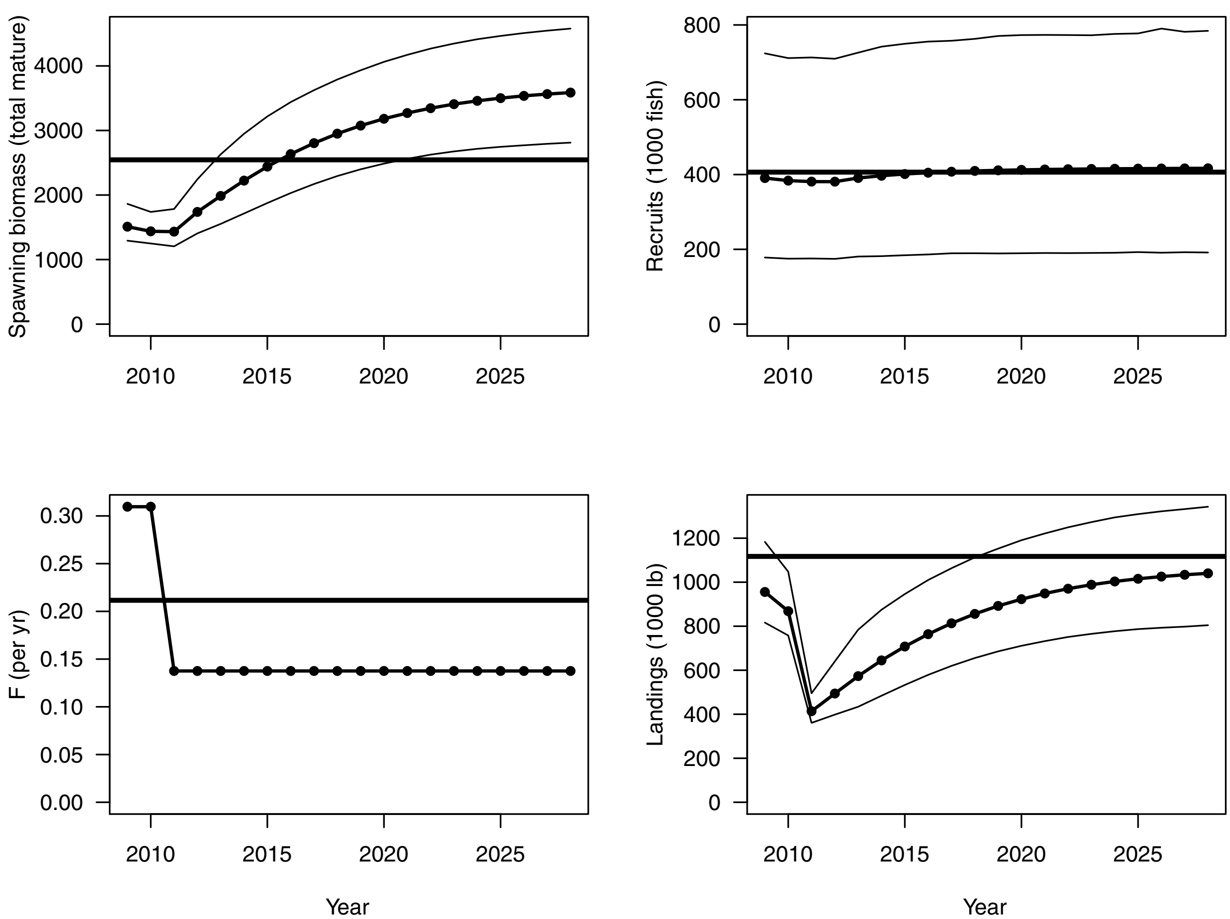


*Figure 3.64. Projection results under scenario 7—fishing mortality rate fixed at $F = 75\%F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

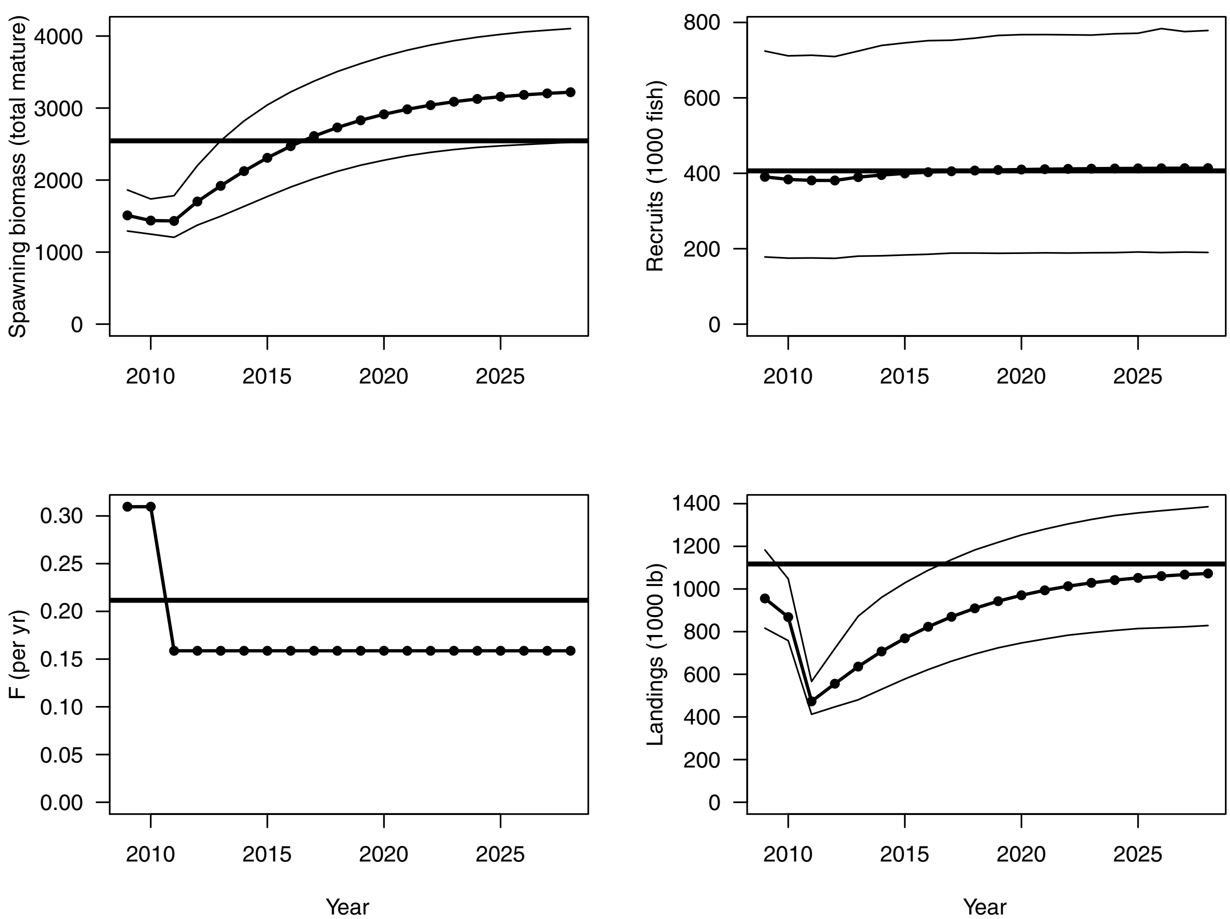


*Figure 3.65. Projection results under scenario 8—fishing mortality rate fixed at $F = 85\% F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

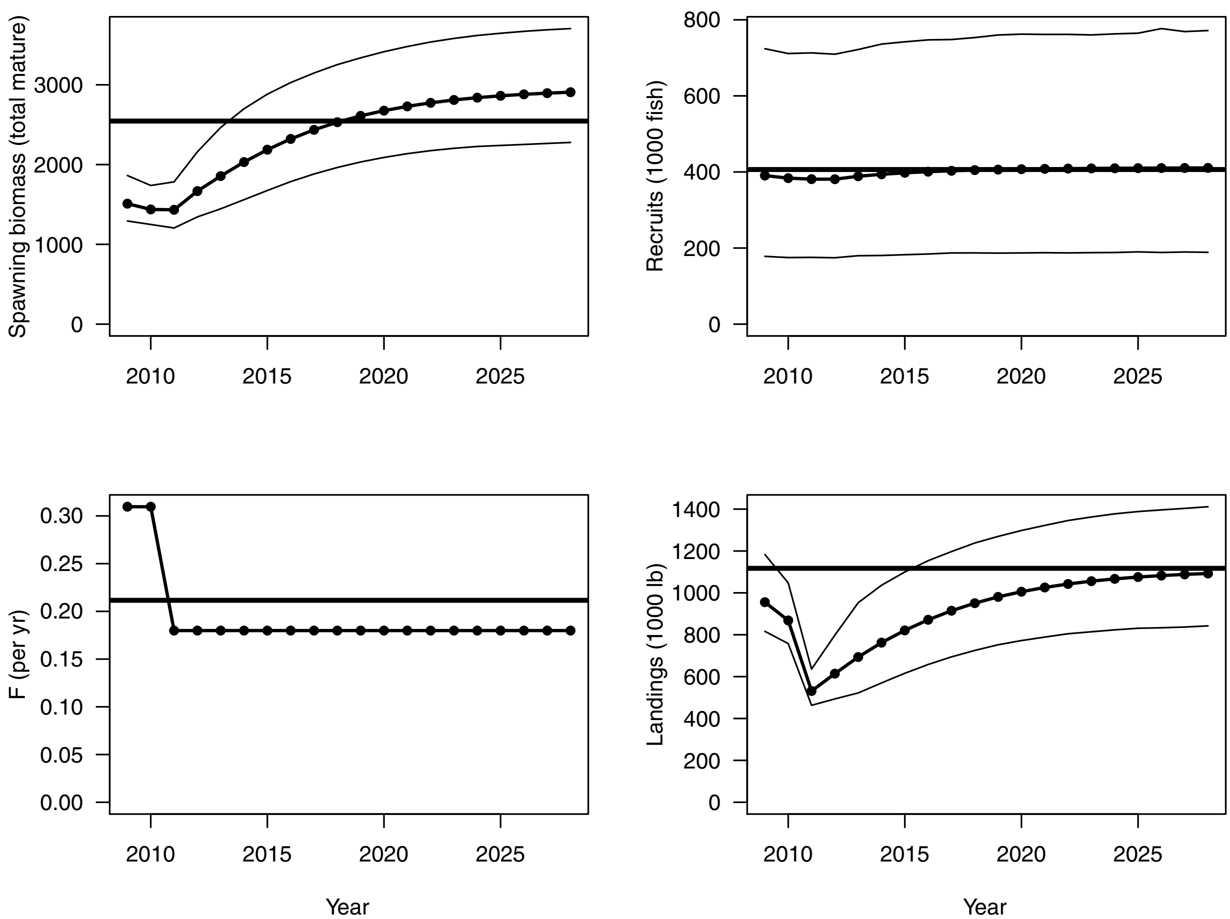


*Figure 3.66. Projection results under scenario 9—fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

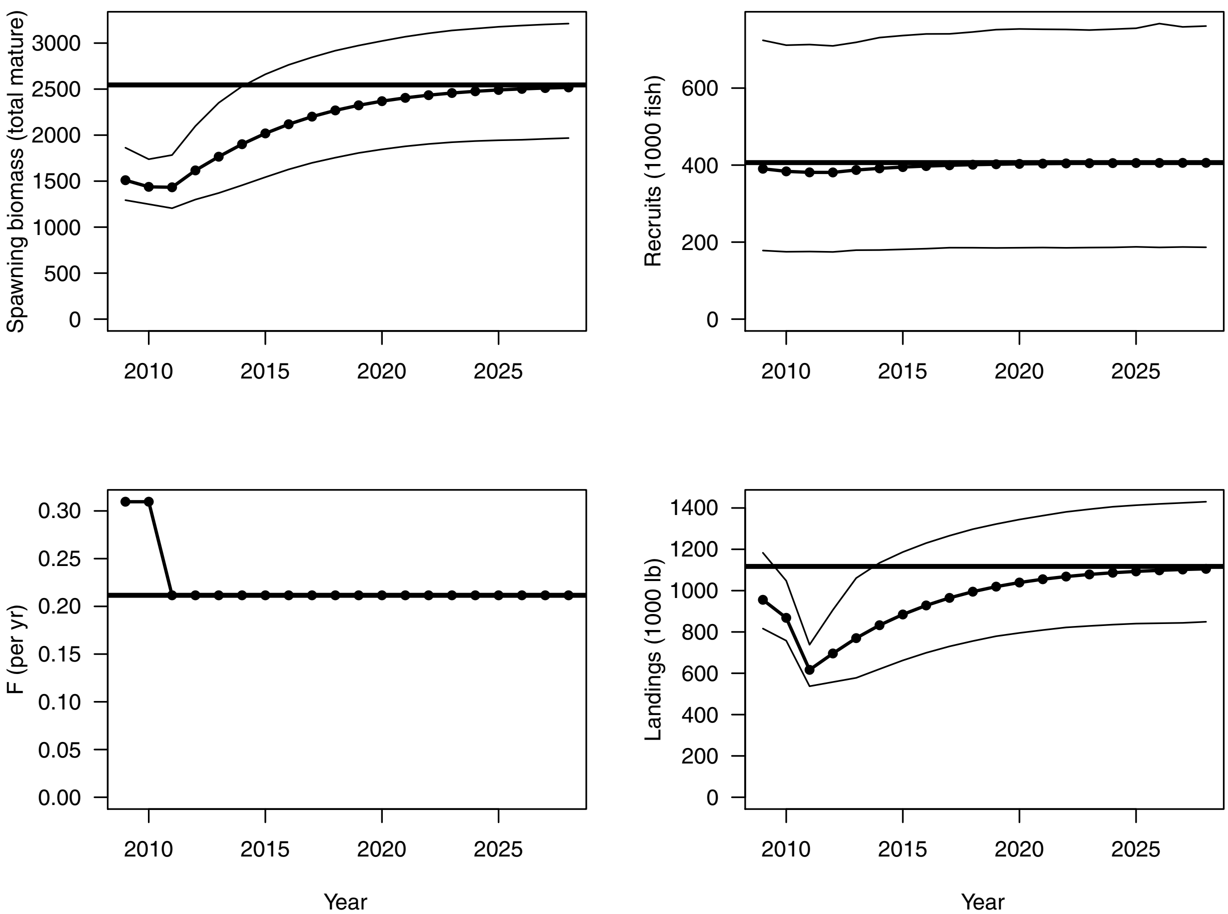


*Figure 3.67. Projection results under scenario 10—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, after an initialization period with $F = F_{\text{current}}$ in 2009 and 2010. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

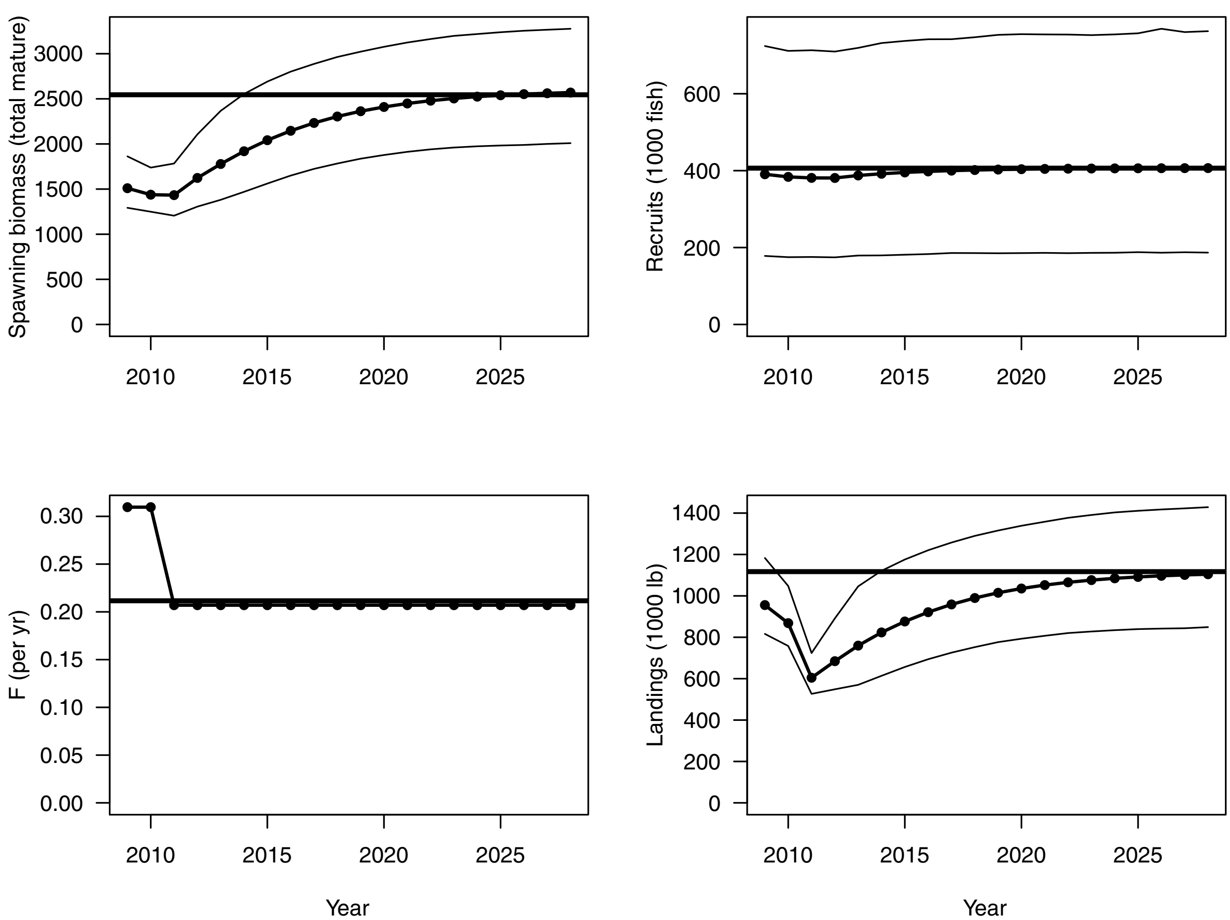


*Figure 3.68. Projection results under scenario 11—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, after an initialization period with $F = F_{\text{current}}$ in 2009 and $F = 75\%F_{\text{current}}$ 2010. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

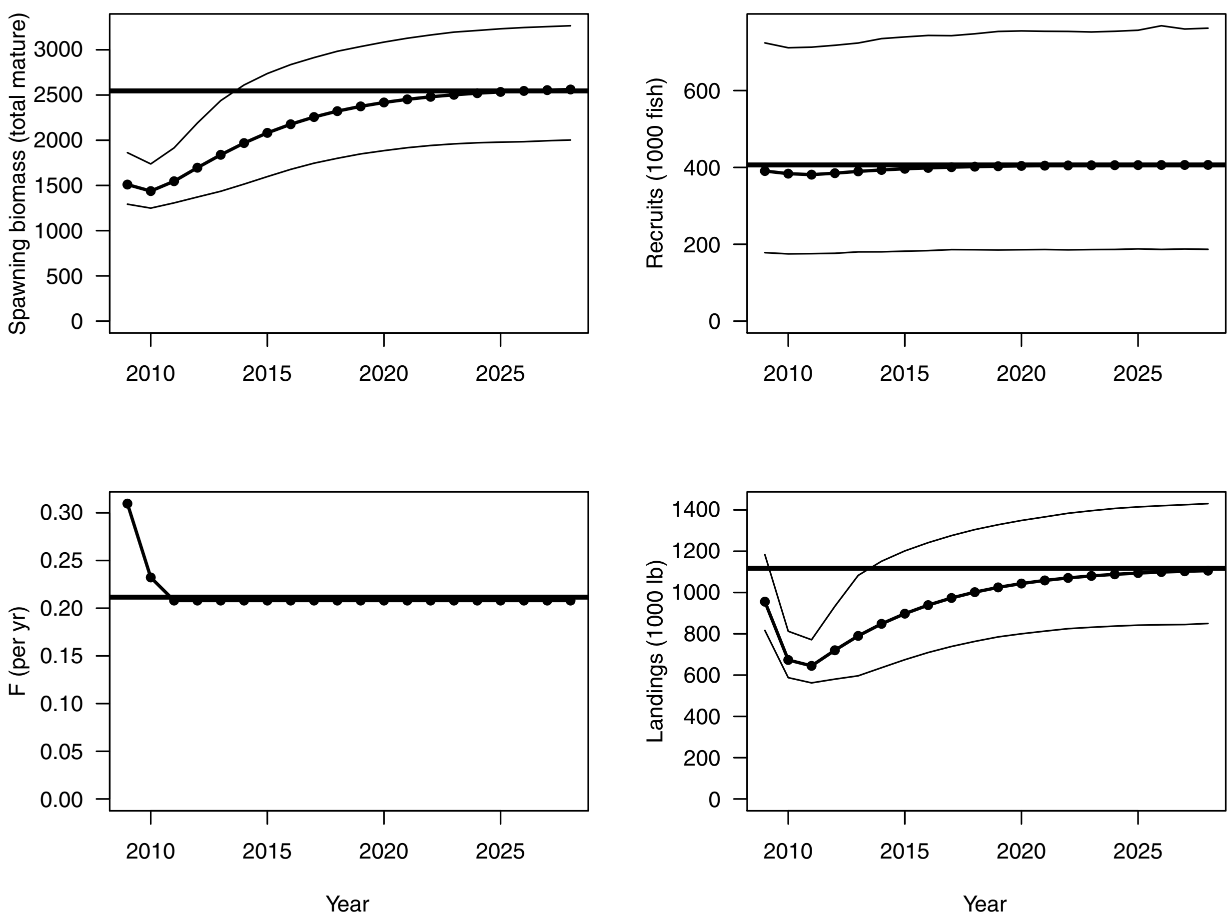


*Figure 3.69. Projection results under scenario 12—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, after an initialization period with $F = F_{\text{current}}$ in 2009 and $F = 50\% F_{\text{current}}$ 2010. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

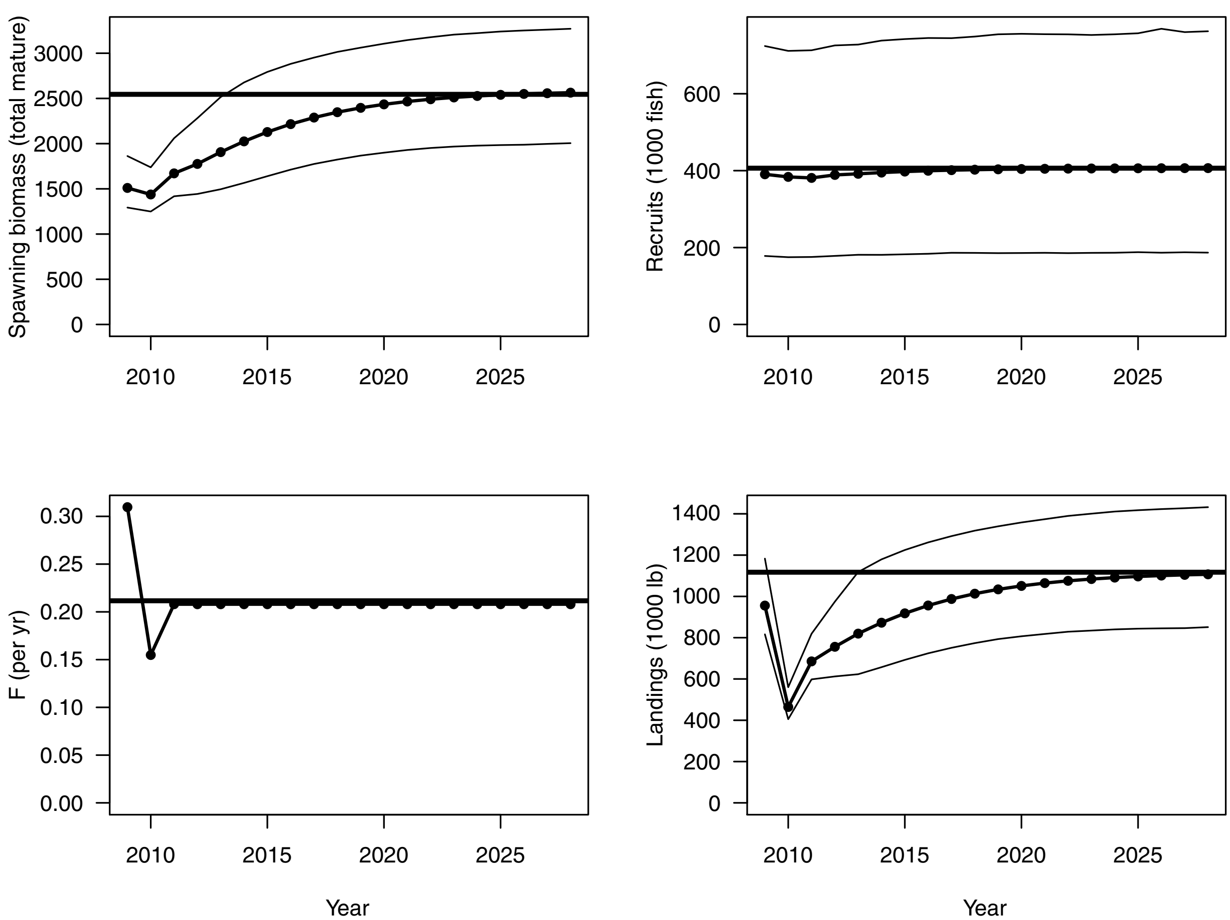


*Figure 3.70. Projection results under scenario 13—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, after an initialization period with $F = F_{\text{current}}$ in 2009 and $F = 25\%F_{\text{current}}$ 2010. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

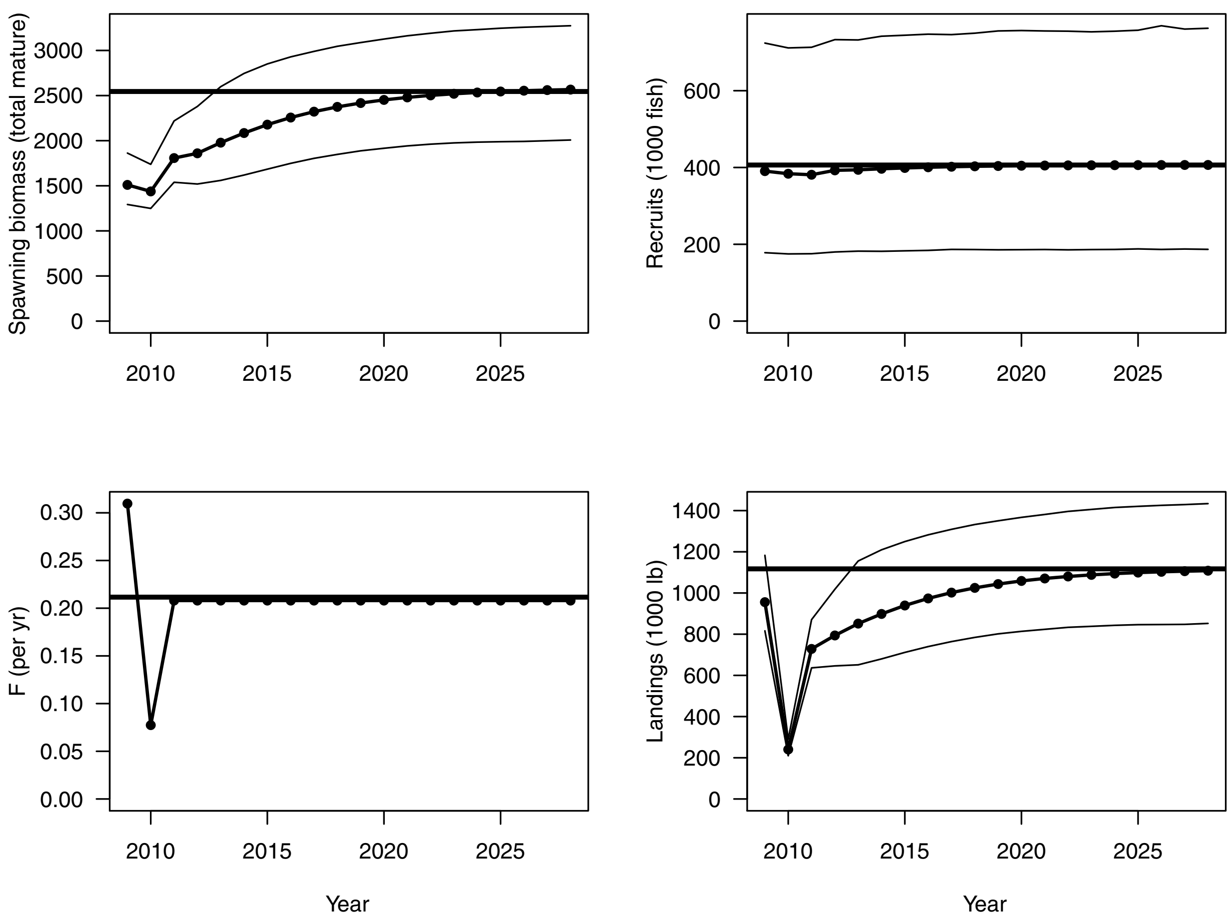
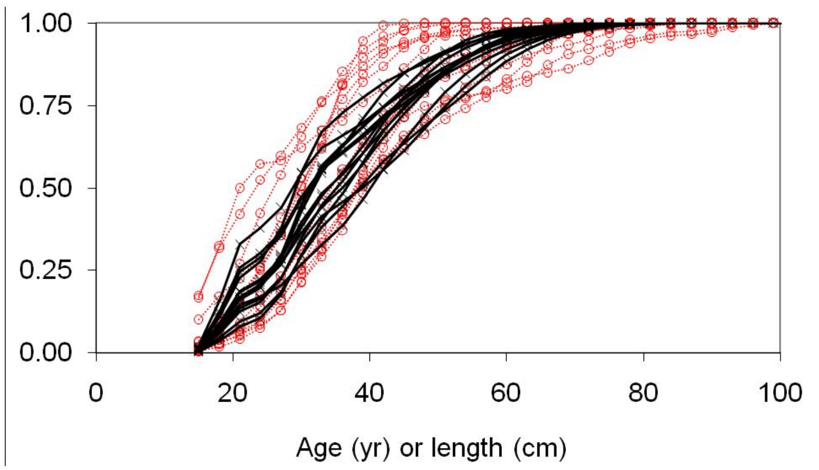


*Figure 3.71. SS3 predicted (heavy black lines, ×) and observed (thin dotted red lines,* o*) age and length compositions from fishery independent sources. Fits are of cumulative distributions, with ages on the left and lengths on the right. Top panel: Florida Keys visual survey (RVC, no age comps available). Bottom panel: MARMAP chevron trap.*



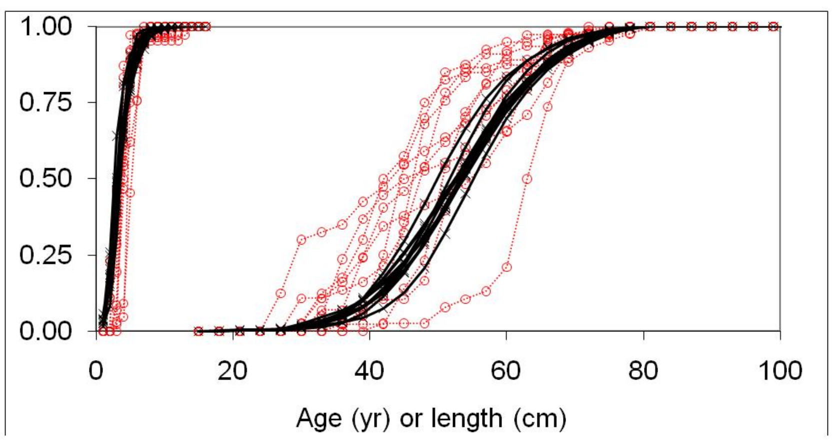
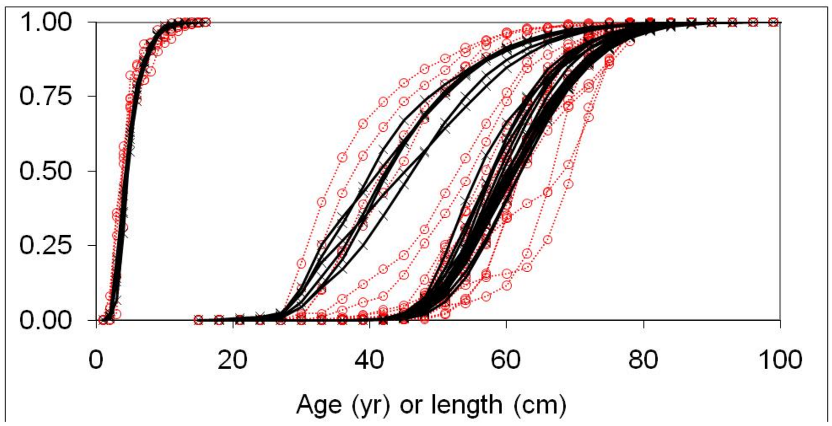



*Figure 3.72. SS3 predicted (heavy black lines, ×) and observed (thin dotted red lines, o) age and length compositions from commercial fleets. Fits are of cumulative distributions, with ages on the left and lengths on the right. Top panel: Commercial lines (cl). Bottom panel: Commercial other (co, no age comps available).*



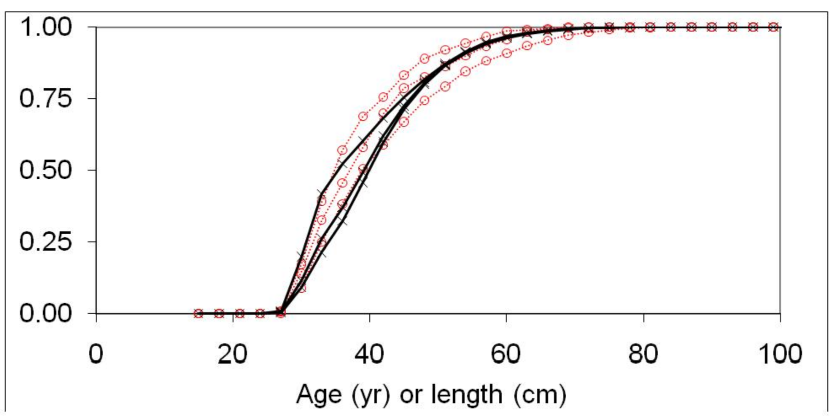
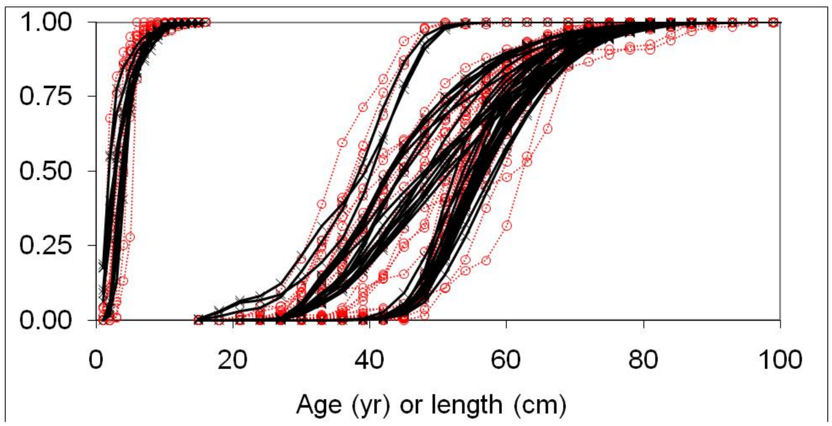



*Figure 3.73. SS3 predicted (heavy black lines, ×) and observed (thin dotted red lines, o) age and length compositions from headboat and general recreational fleets. Fits are of cumulative distributions, with ages on the left and lengths on the right. Top panel: Headboats (hb). Bottom panel: General recreational (rec).*



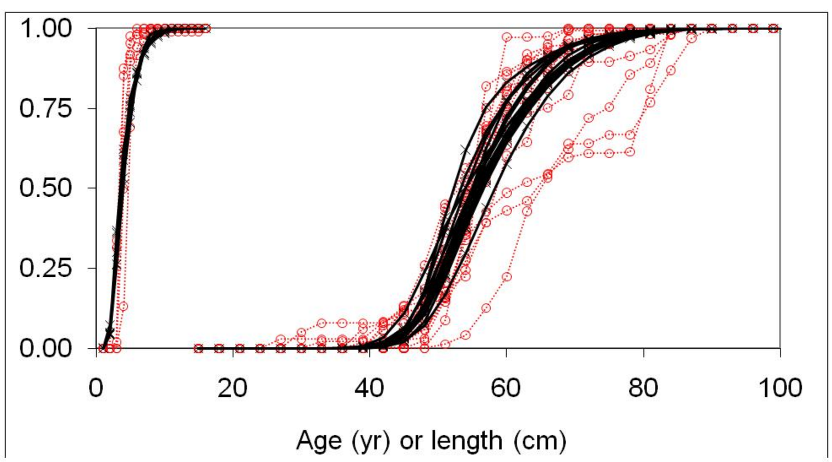



*Figure 3.74. SS3 fits to landings time series. Dark lines with solid circles represent predicted; and open circles, observed.*

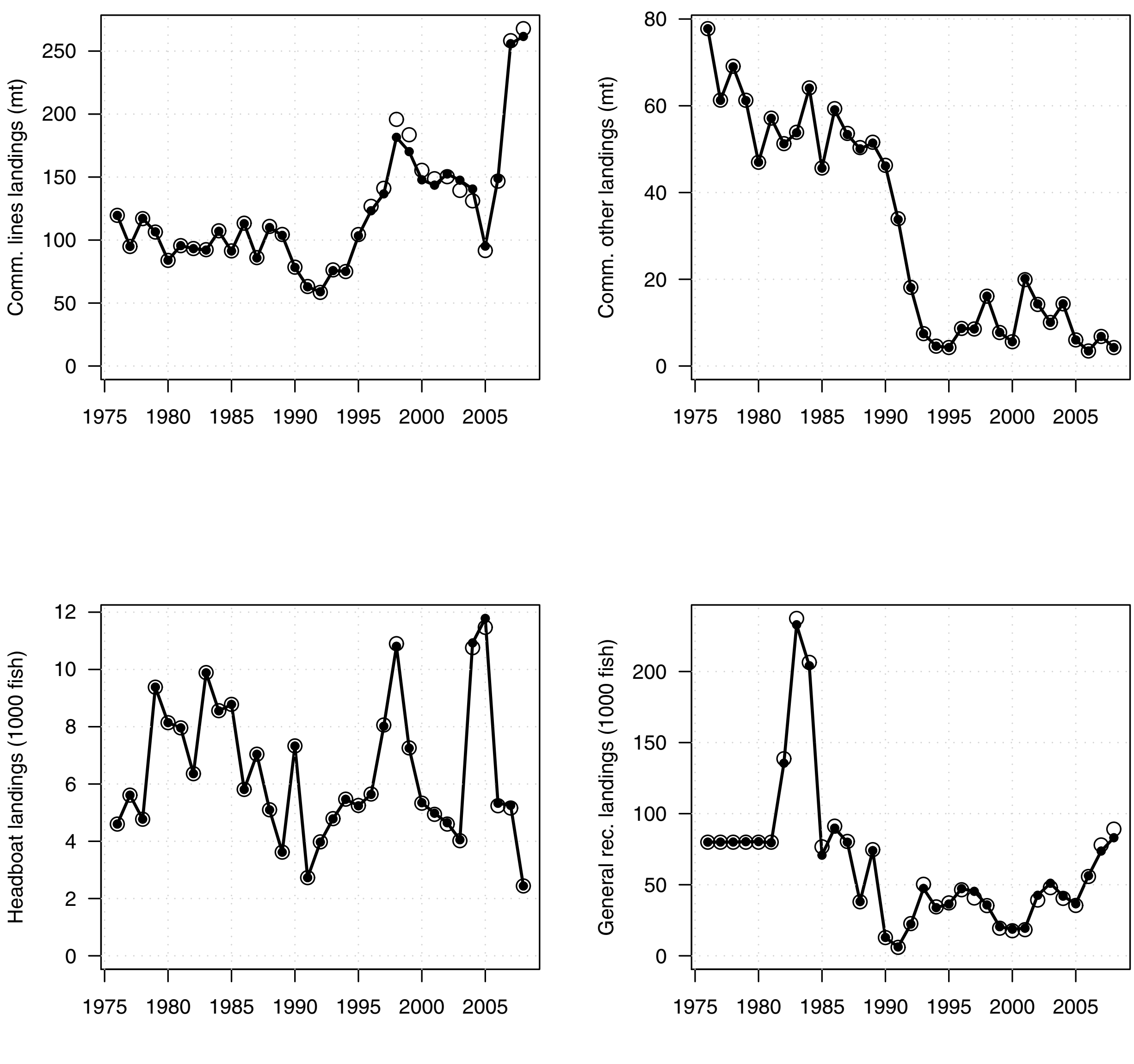


*Figure 3.75. SS3 fits to discard time series. Dark line represents predicted; circles, observed; bars, ±2 SE of observations. Top panel: Commercial lines. Middle panel: Headboat. Bottom panel: General recreational (MRFSS).*

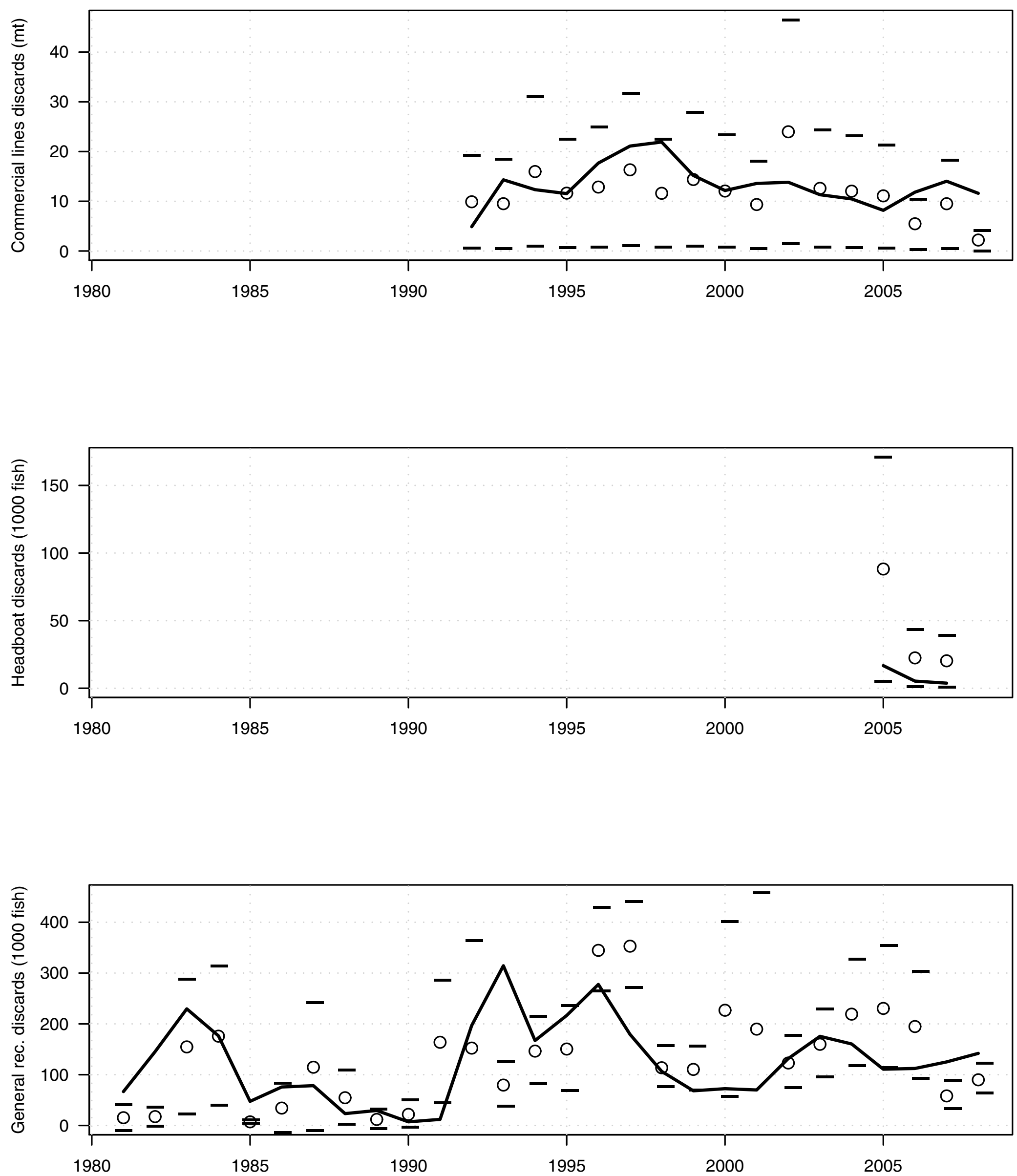


*Figure 3.76. SS3 fits to fishery independent indices of abundance (left y-axis). Dark line represents predicted; circles, observed; bars, ±2 SE of observations. Horizontal line indicates estimate of catchability (right y-axis). Top panel: Florida Keys visual survey (RVC). Bottom panel: MARMAP chevron trap.*

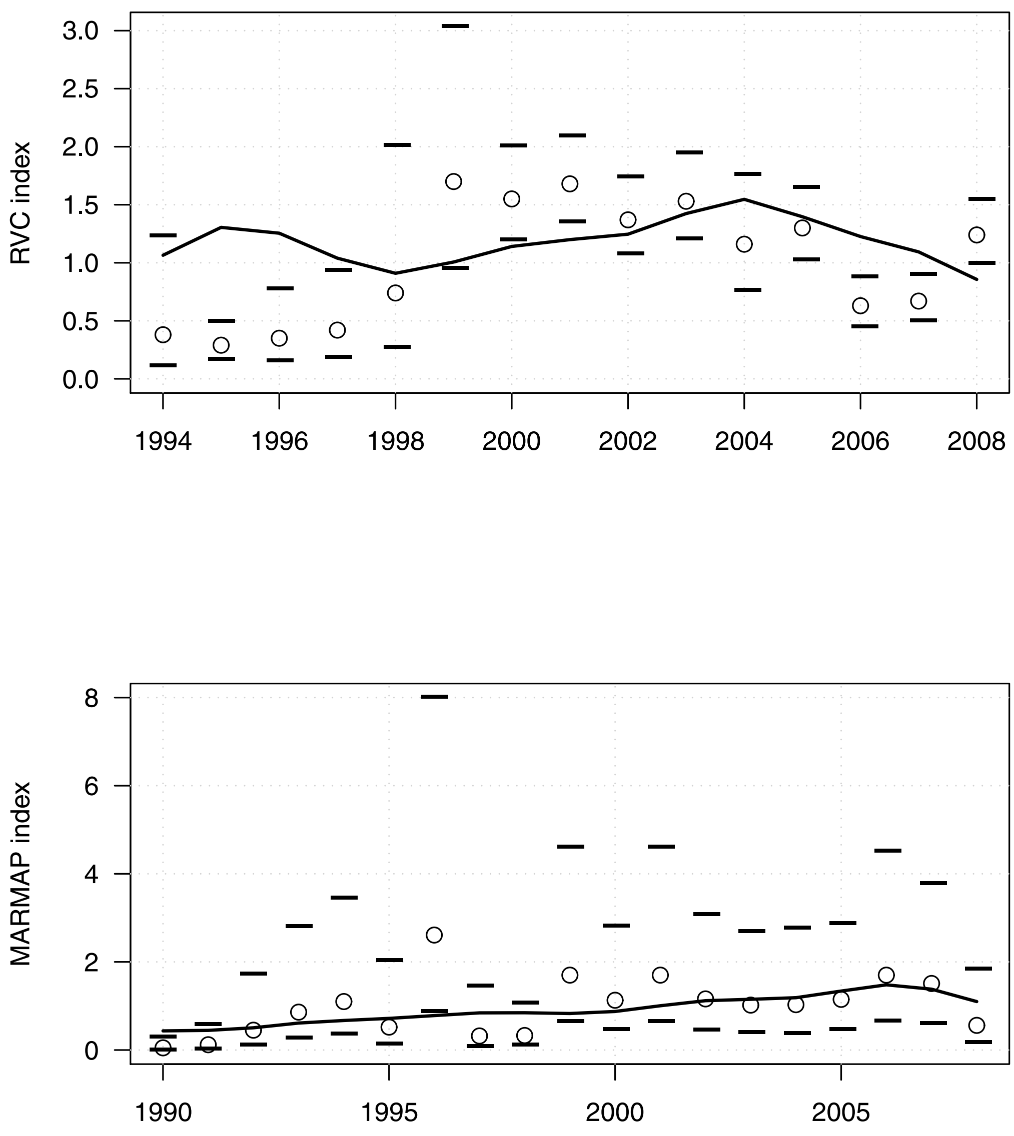


*Figure 3.77. SS3 fits to fishery dependent indices of abundance (left y-axis). Dark line represents predicted; circles, observed; bars, ±2 SE of observations. Top panel: Commercial handlines. Middle panel: Headboat. Bottom panel: General recreational (MRFSS).*

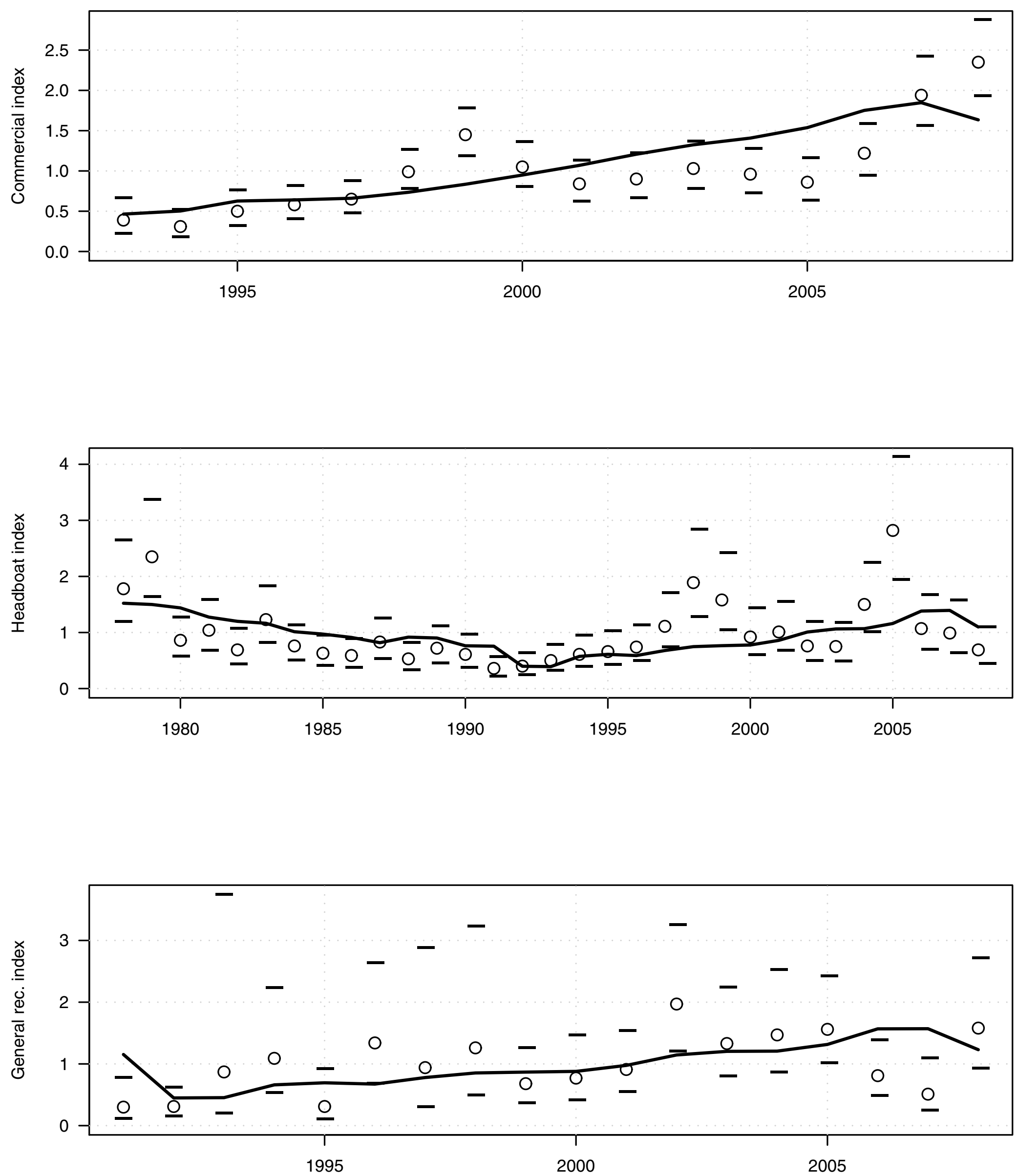


*Figure 3.78. Beverton-Holt spawner-recruit curve and recruits (circles) estimated by SS3.*

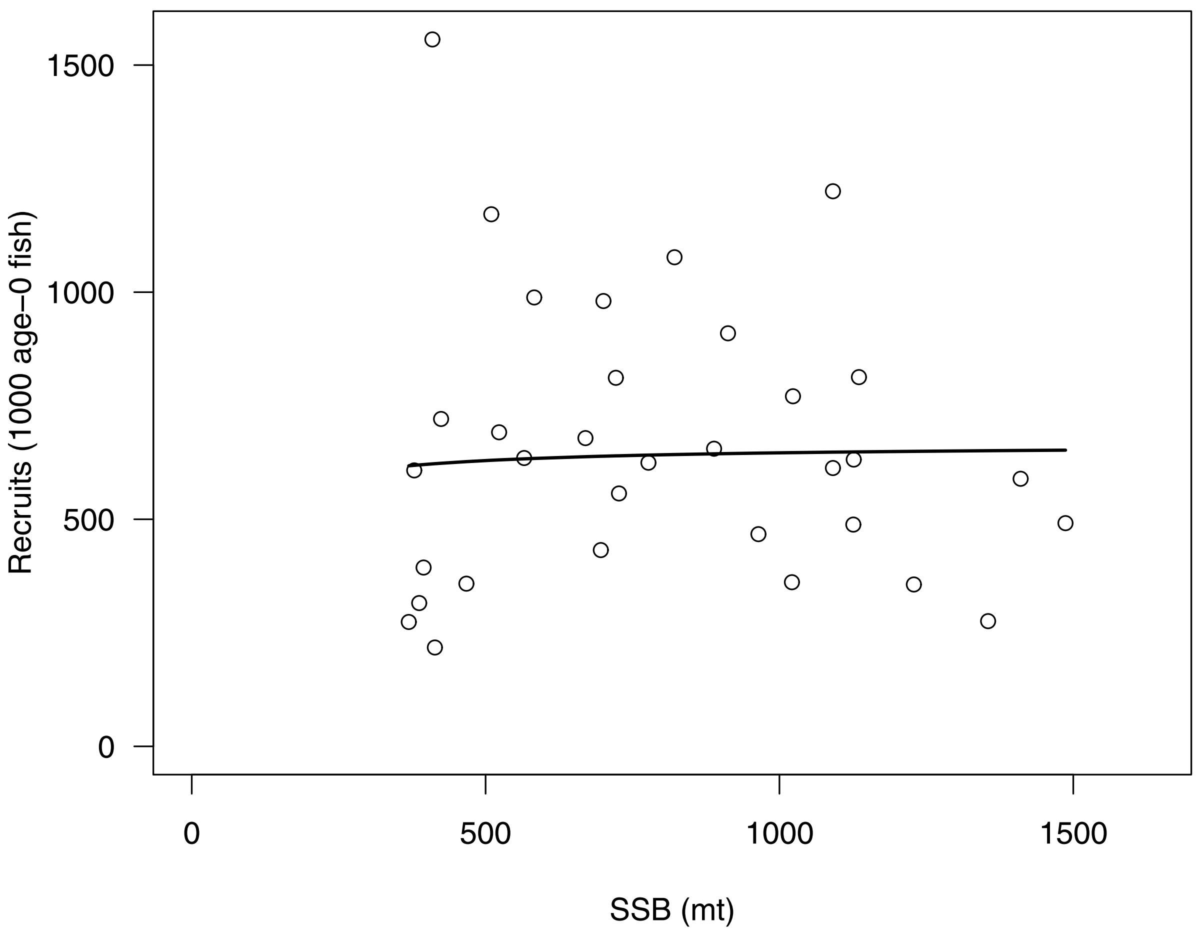


*Figure 3.79. Time series of spawning biomass (top panel) and recruitment (bottom panel) estimated by SS3. Gray regions represent 95 percent confidence bands.*

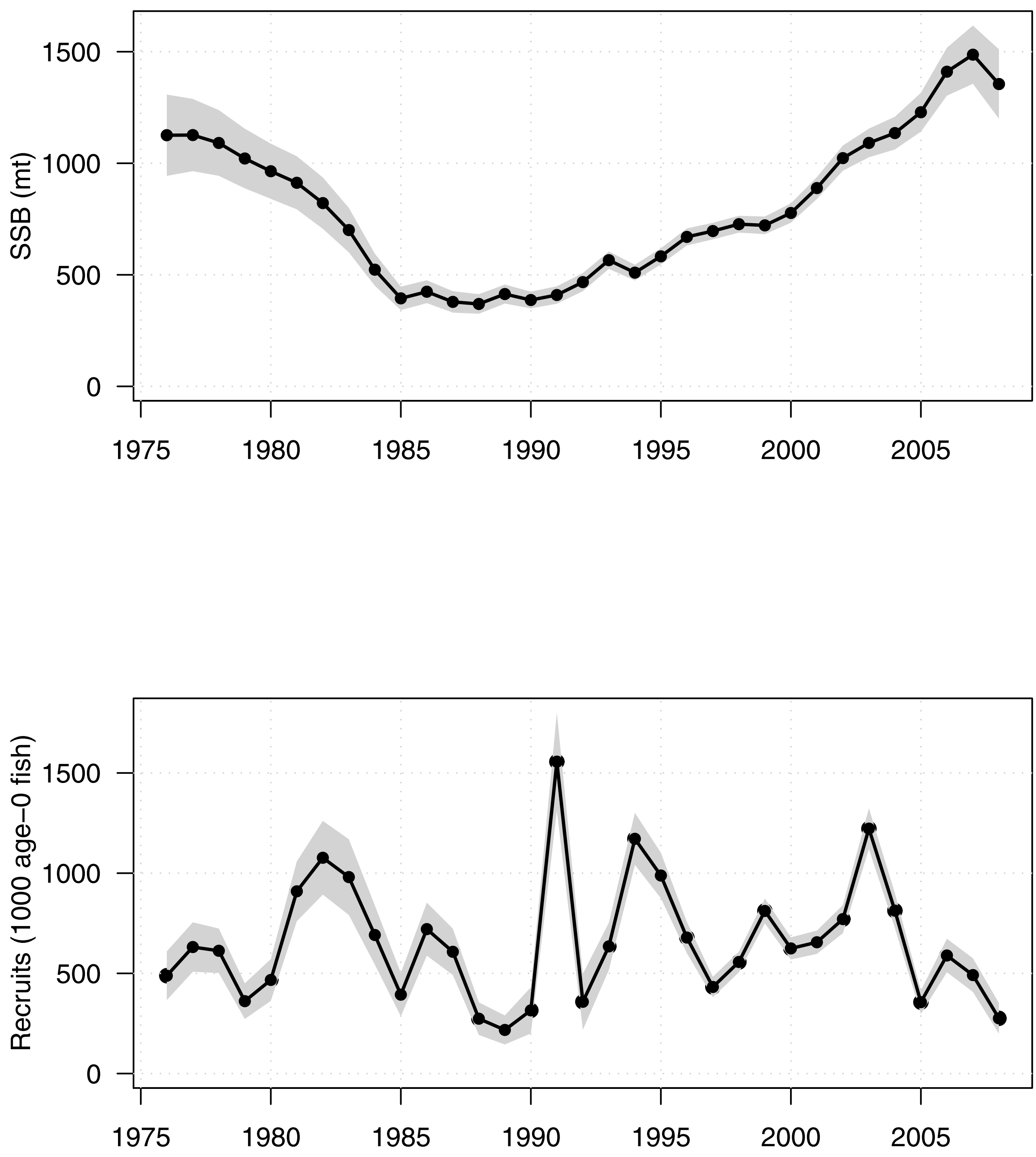


*Figure 3.80. Time series of $F/F_{\text{MSY}}$ (top panel) and* SSB/MSST *(bottom panel) estimated by SS3. Gray regions represent 95 percent confidence bands.*

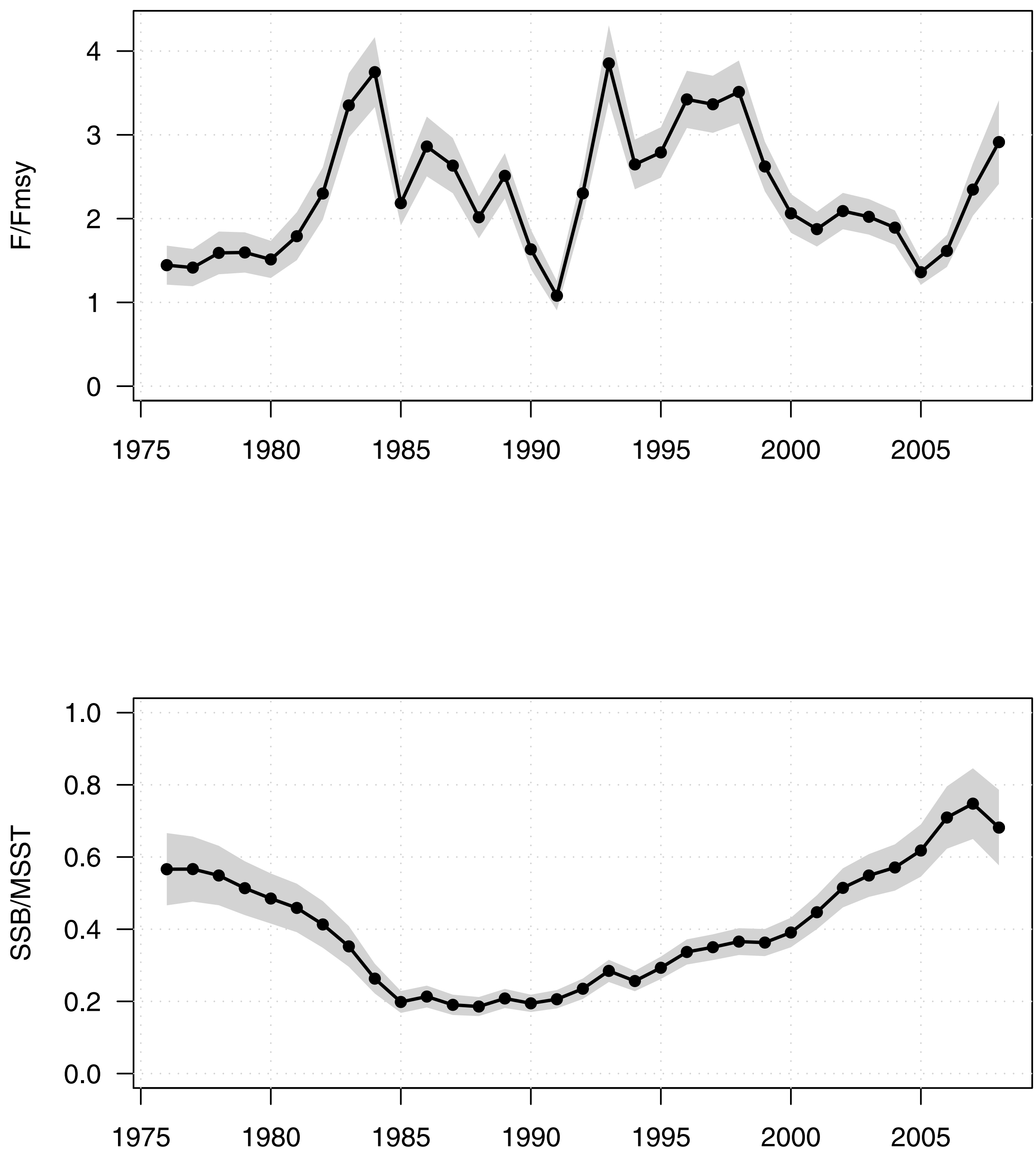


*Figure 3.81. Red Grouper in Atlantic: Fit of production model to separate indices without time-varying catchability.*

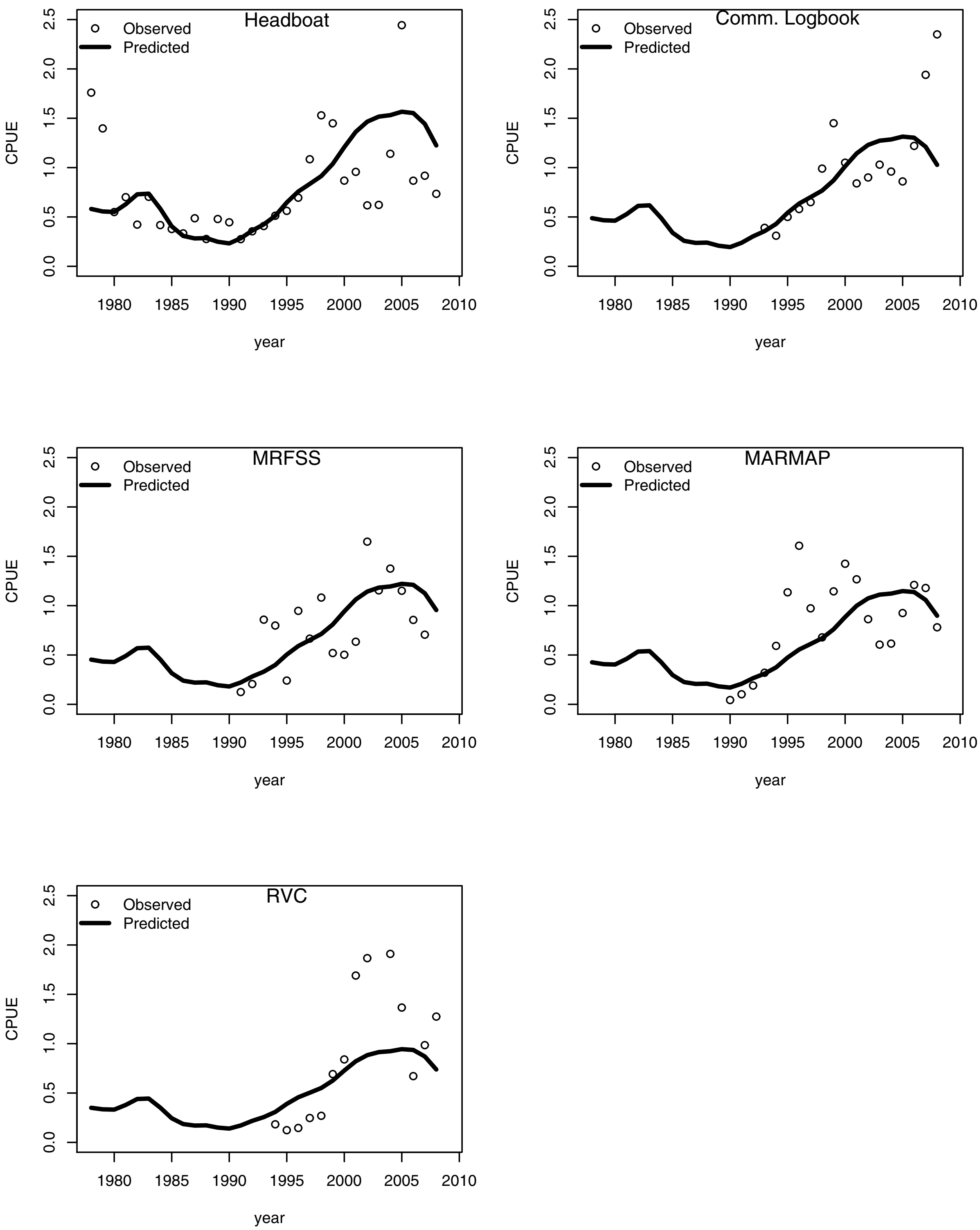


*Figure 3.82. Red Grouper in Atlantic: Fit of production model to combined indices with and without time-varying catchability.*

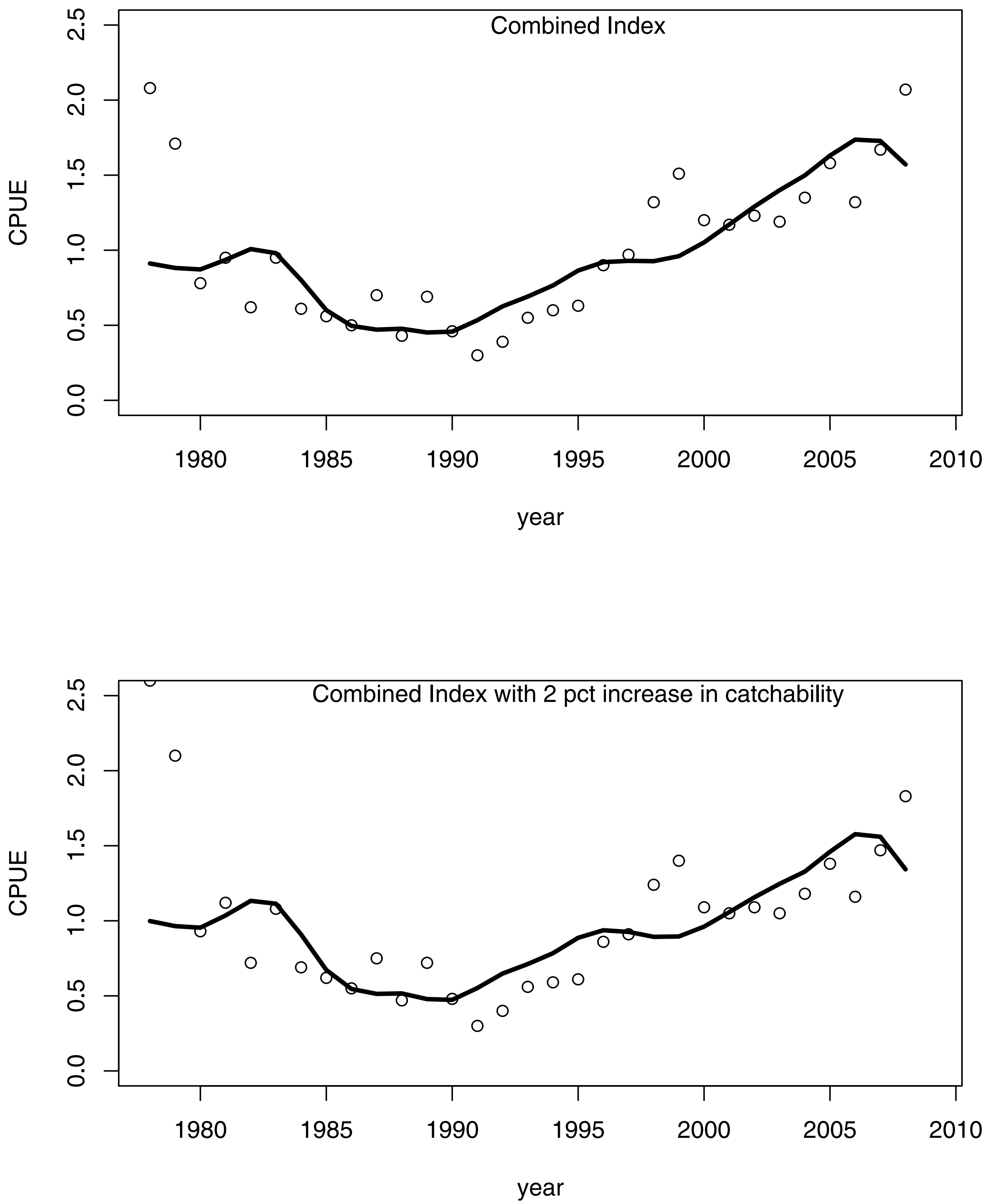


*Figure 3.83. Red Grouper in Atlantic: Production model estimates of relative biomass. The runs were made with separate and combined indices with and without a 2% catchability increase since 1978, as indicated on panels. Dotted lines represent $10^{th}$ and $90^{th}$ percentiles from 600 bootstrap replicates.*

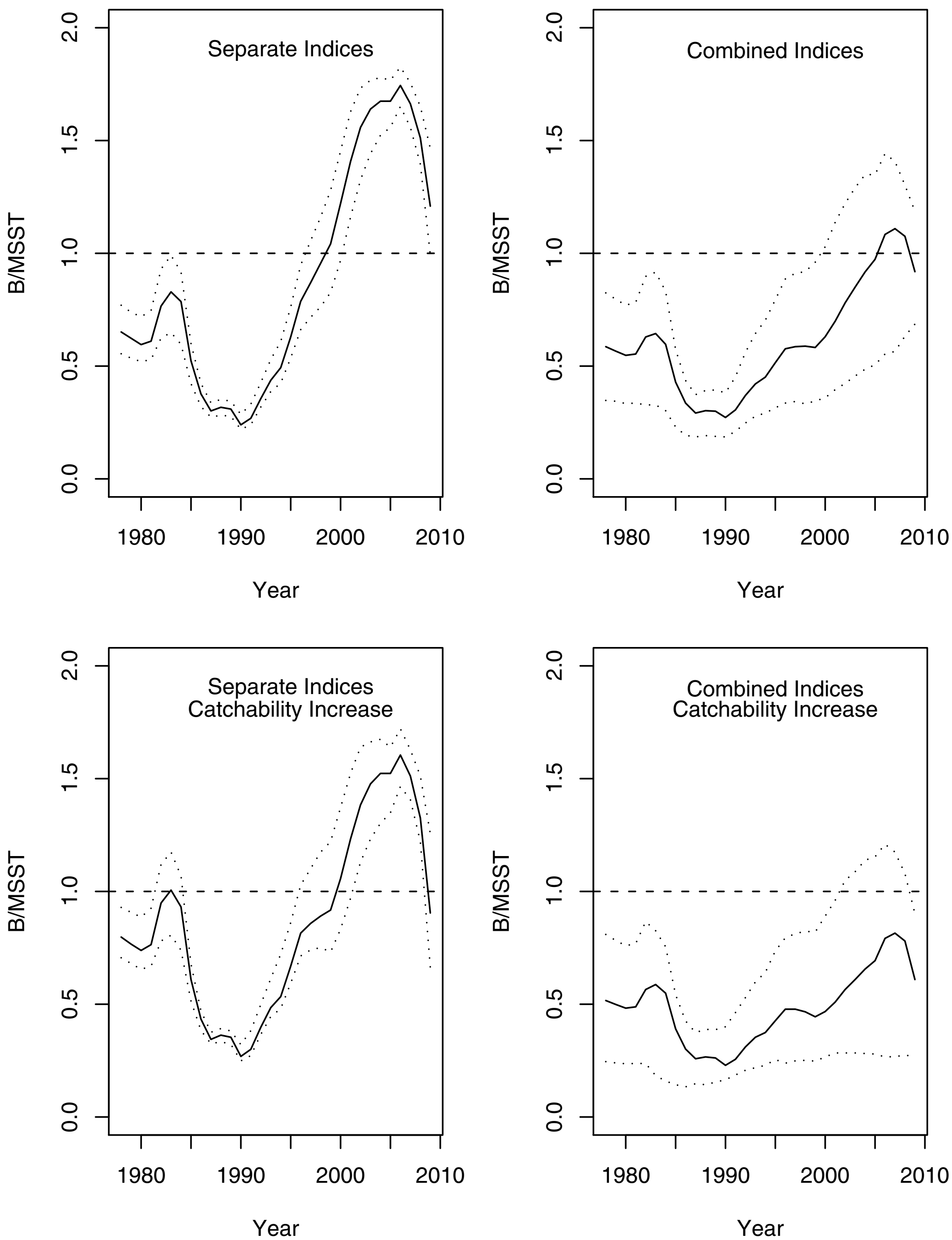


*Figure 3.84. Red Grouper in Atlantic: Production model estimates of relative fishing mortality rate. The runs were made with separate and combined indices with and without a 2% catchability increase since 1978, as indicated on panels. Dotted lines represent $10^{th}$ and $90^{th}$ percentiles from 600 bootstrap replicates.*

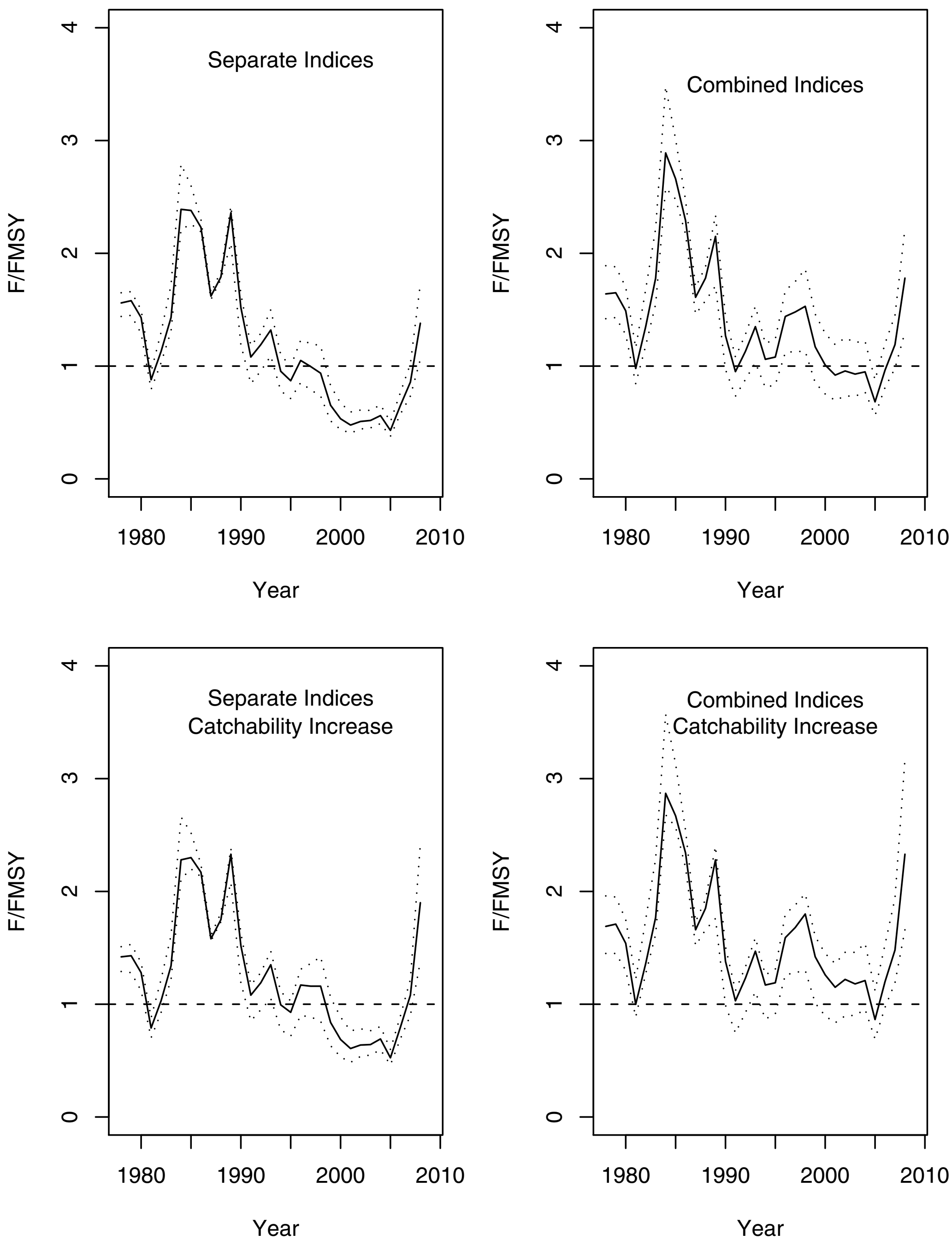


*Figure 3.85. Red Grouper in Atlantic: Kernel density plots of 600 bootstrap runs of the base model for the current B/MSST estimate.*

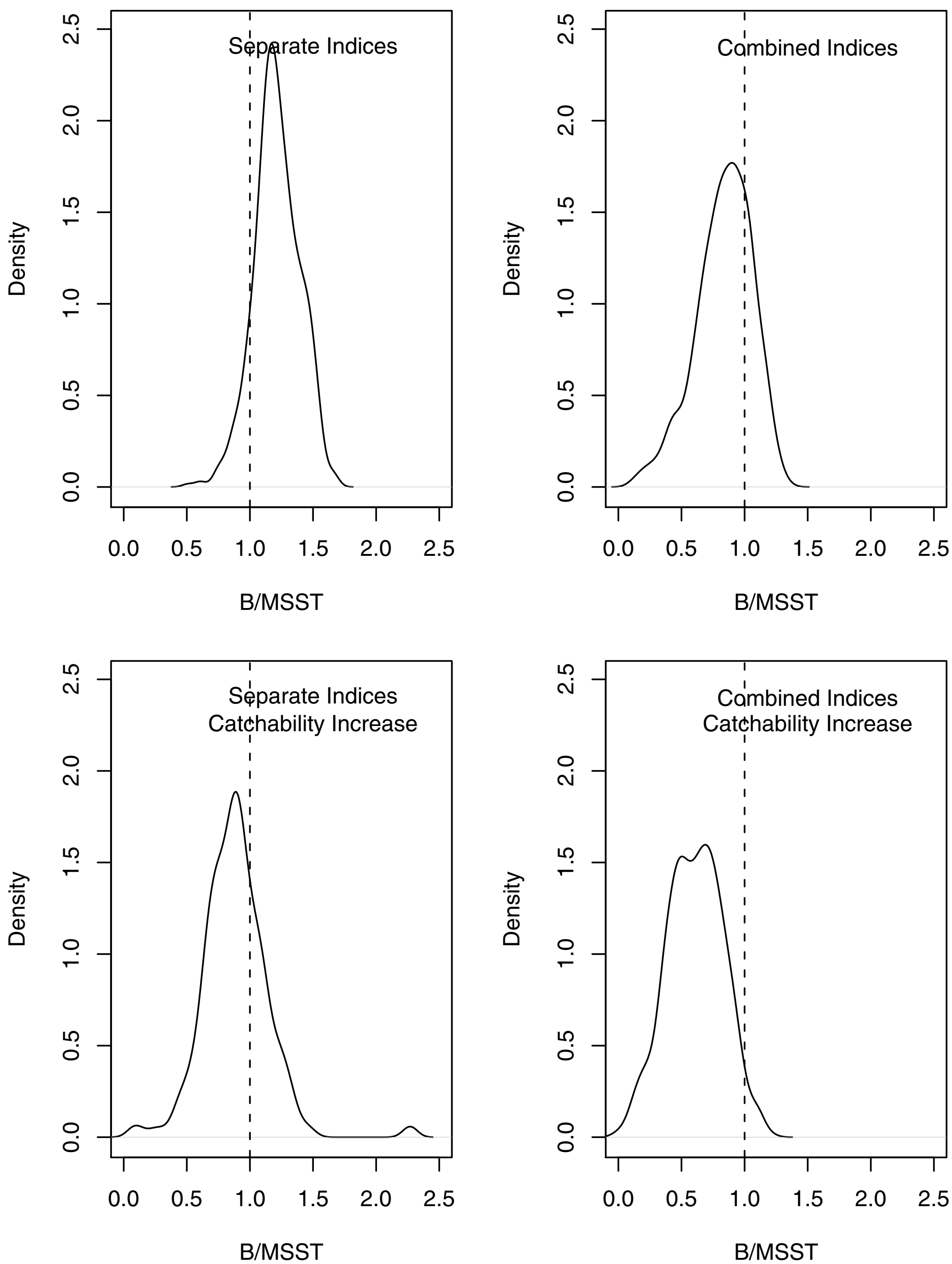
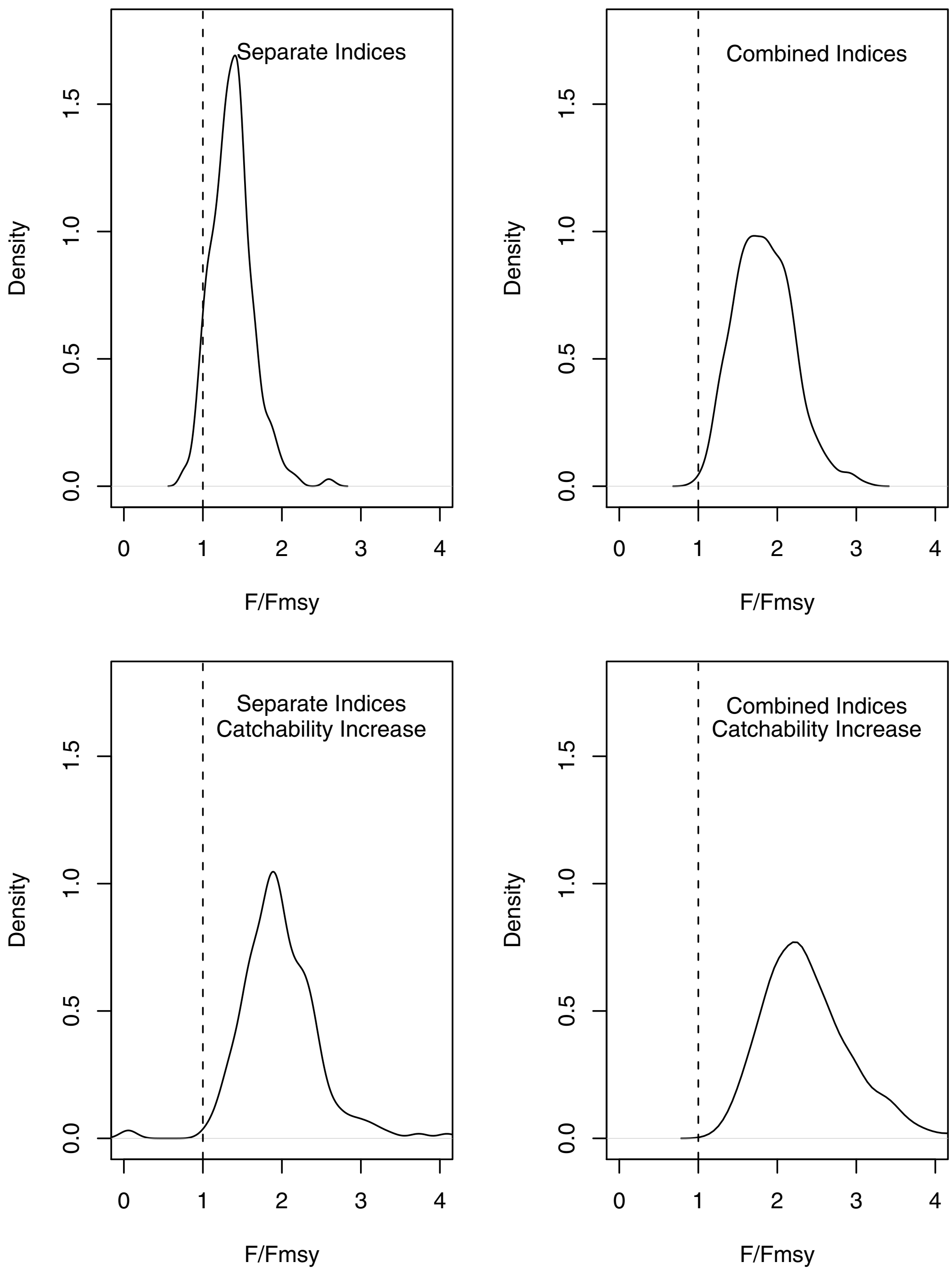


*Figure 3.86. Red Grouper in Atlantic: Kernel density plots of 600 bootstrap runs of the base model for the current $F/F_{MSY}$ estimate.*



## 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 red grouper) |
| ASY | Average Sustainable Yield |
| $B$ | Total biomass of stock, conventionally on January 1r |
| BAM | Beaufort Assessment Model (a statistical catch-age formulation) |
| CPUE | Catch per unit effort; used after adjustment as an index of abundance |
| CV | Coefficient of variation |
| DW | Data Workshop (here, for red grouper) |
| $F$ | Instantaneous rate of fishing mortality |
| $F_{\text{MSY}}$ | 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 |
| MFMT | Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on $F_{\text{MSY}}$ |
| mm | Millimeter(s); 1 inch = 25.4 mm |
| MRFSS | Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS |
| MSST | Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for red grouper as $(1 - M)\text{SSB}_{\text{MSY}} = 0.7\text{SSB}_{\text{MSY}}$. |
| MSY | Maximum sustainable yield (per year) |
| mt | Metric ton(s). One mt is 1000 kg, or about 2205 lb. |
| $N$ | Number of fish in a stock, conventionally on January 1 |
| NC | State of North Carolina |
| NMFS | National Marine Fisheries Service, same as "NOAA Fisheries Service" |
| NOAA | National Oceanic and Atmospheric Administration; parent agency of NMFS |
| OY | Optimum yield; SFA specifies that OY ≤ 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 |
| 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 |
| SRA | Stock reduction analysis |
| SS3 | Stock Synthesis version 3, stock assessment software |
| SSB | Spawning stock biomass; mature biomass of males and females |
| $\text{SSB}_{\text{MSY}}$ | Level of SSB at which MSY can be attained |
| SW | Scoping workshop; first of 3 workshops in SEDAR updates |
| 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 = 256  Objective function value = 10845.9  Maximum gradient component = 0.000242801
# log_len_cv:
-2.16168948204
# log_Nage_dev:
 0.669372497215 0.505789495003 1.97976679189 1.40689581623 0.584508773672 0.968566355507 0.464307117100 0.571293832621
 0.269094683172 0.165932197872 0.0994767360386 0.0583217003759 0.0336625177489 0.0192036064677 0.0238976964339
# log_R0:
12.8978672659
# steep:
0.911579235467
# log_rec_dev:
 0.265842969196 -0.0457456319852 0.248194141287 0.154752220146 -0.500476397869 -0.284954452952 0.347119103185
 0.410354208986 0.0775882505167 0.359429555579 -0.0749417973618 0.653137366289 0.174151078209 -0.432501753505
 -0.857901254655 -0.173225867486 0.515699509404 -1.04733367690 0.0602573425244 0.435271810529 0.340133091175
 -0.120114240097 -0.162622705957 0.0216347466844 0.228215518812 -0.0733567044243 -0.0302612839703 0.239626040608
 0.625092592769 0.00508502292778 -0.544734803531 -0.647458233573 -0.165955764561
# R_autocorr:
0.00000000000
# selpar_slope_RVC:
0.432297633577
# selpar_L50_CVT:
3.67526739068
# selpar_slope_CVT:
1.50003938707
# selpar_L502_CVT:
1.00000057746
# selpar_slope2_CVT:
0.421639162166
# selpar_L50_cL2:
6.20586446572
# selpar_slope_cL2:
0.535656888970
# selpar_L50_cL3:
3.67502177371
# selpar_slope_cL3:
2.50808768944
# selpar_L50_HB1:
1.96258256174
# selpar_slope_HB1:
1.48592854246
# selpar_L50_HB2:
2.02054644978
# selpar_slope_HB2:
3.03603272480
# selpar_L50_HB3:
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# selpar_slope_HB3:
3.90620345078
# selpar_Age1_HB_D3:
0.556065863700
# selpar_L50_MRFSS3:
3.14164030809
# selpar_slope_MRFSS3:
3.97674798012
# log_q_RVC:
-13.1368856031
# log_q_CVT:
-12.6187229516
# log_q_cL:
-7.63847637712
# log_q_HB:
-12.7792813710
# log_q_MRFSS:
-13.2475213608
# q_rate:
0.00000000000
```

```
# q_DD_beta:
0.00000000000
# q_RW_log_dev_cL:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
# q_RW_log_dev_HB:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
# q_RW_log_dev_MRFSS:
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 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000
# log_avg_F_cL:
-1.51920044260
# log_F_dev_cL:
 -0.337817399317 -0.585153702247 -0.324671337305 -0.303322469866 -0.395873789107 -0.163139601236 -0.0824064882830
 0.203728250652 0.882294630734 1.11688144358 1.45145564368 1.21082786937 1.38074167012 1.21246535848 0.815456089112
 0.360073281996 -0.628703081289 -0.197555816295 -0.250571600706 -0.232065152330 -0.0385064639916 0.0251410700527
 0.160983506940 -0.0594202267075 -0.316326389866 -0.438769364392 -0.494118621132 -0.615183988024 -0.714689945601
 -1.16670359592 -0.830327784542 -0.382682113822 -0.262039882738
# log_avg_F_cO:
-3.76681902954
# log_F_dev_cO:
 0.482115924421 0.490067011366 0.839305855047 0.876323717617 0.734433734725 1.04538531643 1.01949617883 1.16158869976
 1.53847519706 1.28584398693 1.54502231272 1.44850866841 1.29167694170 1.31619189647 1.30552930152 1.01434992483
 0.326283607194 -0.472150336286 -1.09986211781 -1.36874062541 -0.705410851654 -0.797410374928 -0.274390942844
 -1.09152562701 -1.47832829467 -0.265741882568 -0.656287418011 -1.04085297215 -0.722519219786 -1.67900462172
 -2.34433971143 -1.69843701394 -2.02559626483
# log_avg_F_HB:
-4.05503421718
# log_F_dev_HB:
 -1.24178177109 -0.822595774636 -0.805041626564 -0.00275909888122 -0.00285053463106 0.0953217650770 -0.0864290842268
 0.430560842578 0.657011115145 0.823019215798 0.359823915328 0.643509891125 0.168455901705 -0.235787152389 0.576879256026
 -0.343419864389 0.359059563213 0.496174601482 0.213003893699 0.263776092147 0.269676266952 0.420681507453 0.623870342014
 0.228303229308 -0.104939178454 -0.263844692838 -0.438645594806 -0.576871962167 0.397434274271 0.328546938122
 -0.658871701213 -0.625127964429 -1.14614261073
# log_avg_F_MRFSS:
-1.76074366337
# log_F_dev_MRFSS:
 0.0827517728821 0.680476760610 1.29470258639 1.55021636949 0.701802504540 0.826148605179 0.793413718106 -0.117777049599
 0.492363745300 -1.15738309141 -1.85848065675 -0.0518234362780 0.876542788459 0.164072454943 0.0513058993324
 0.368414180591 0.0656342748270 -0.253210796136 -0.901857544660 -1.01175483886 -1.02880699531 -0.334352079840
 -0.151080569340 -0.341973565668 -0.584740058675 -0.332862864776 -0.0789026636940 0.257160550341
# F_init_ratio:
1.00000000000
# log_avg_F_cL_D:
-5.45540494240
# log_F_dev_cL_D:
 0.123289383460 0.0501053916401 0.721003809256 0.0855131959145 -0.0113143044745 0.350713991306 0.196725489445
 0.390377178324 0.0625311808784 -0.214066303072 0.782002206887 0.0376654983242 -0.290439276698 -0.390719117071
 -0.763393260361 0.160955000688 -1.29095006445
# log_avg_F_HB_D:
-4.26368790597
# log_F_dev_HB_D:
 0.597513324856 -0.435027517454 -0.162485807402
# log_avg_F_MRFSS_D:
-3.01923657991
# log_F_dev_MRFSS_D:
 -1.35754448846 -1.60803446069 0.363612898847 0.731457029889 -2.46167771609 -0.767059887478 0.359113199025 -0.507072293871
 -1.54409836290 -0.488495750230 1.40915261724 0.524589035741 -0.158065096795 0.602243672065 0.315754754399 0.949900223038
 1.09686333120 0.155886821069 0.117318670240 0.700332599200 0.489917703603 0.0854859907258 0.239143310646 0.268694649057
 0.300065046749 0.469265412229 -0.363662113684 0.0769132052355
```

## Appendix C Parameter estimates and standard errors from SS3 application toward red grouper.

| index | name | value | std dev |
|---|---|---|---|
| 1 | MGparm[4] | 1.0479e-001 | 7.8086e-004 |
| 2 | SR_parm[1] | 6.4960e+000 | 2.9968e-002 |
| 3 | SR_parm[2] | 9.8902e-001 | 9.7435e-003 |
| 4 | recdev_early | 1.2850e-002 | 3.7502e-001 |
| 5 | recdev_early | 1.1371e-002 | 3.7428e-001 |
| 6 | recdev_early | 8.0332e-003 | 3.7329e-001 |
| 7 | recdev_early | 2.0651e-003 | 3.7205e-001 |
| 8 | recdev_early | -8.4765e-003 | 3.7040e-001 |
| 9 | recdev_early | -2.6222e-002 | 3.6806e-001 |
| 10 | recdev_early | -5.4776e-002 | 3.6450e-001 |
| 11 | recdev_early | -7.0968e-002 | 3.5839e-001 |
| 12 | recdev_early | -1.5311e-001 | 3.5092e-001 |
| 13 | recdev_early | -1.0318e-001 | 3.3749e-001 |
| 14 | recdev_early | -1.0140e-001 | 3.3084e-001 |
| 15 | recdev_early | 2.9756e-001 | 3.1473e-001 |
| 16 | recdev_early | 7.6691e-001 | 2.0410e-001 |
| 17 | recdev_early | -2.0494e-001 | 2.2073e-001 |
| 18 | recdev_early | -5.7926e-002 | 1.3690e-001 |
| 19 | recdev_early | -3.1780e-001 | 1.3786e-001 |
| 20 | recdev1 | -2.1144e-001 | 1.2546e-001 |
| 21 | recdev1 | 4.5662e-002 | 9.8005e-002 |
| 22 | recdev1 | 1.6503e-002 | 9.1134e-002 |
| 23 | recdev1 | -5.0989e-001 | 1.2378e-001 |
| 24 | recdev1 | -2.5146e-001 | 1.1205e-001 |
| 25 | recdev1 | 4.1619e-001 | 8.2125e-002 |
| 26 | recdev1 | 5.8846e-001 | 8.5098e-002 |
| 27 | recdev1 | 5.0031e-001 | 9.5020e-002 |
| 28 | recdev1 | 1.6408e-001 | 1.0849e-001 |
| 29 | recdev1 | -3.8284e-001 | 1.4126e-001 |
| 30 | recdev1 | 2.1731e-001 | 9.7104e-002 |
| 31 | recdev1 | 5.3895e-002 | 1.0431e-001 |
| 32 | recdev1 | -7.4131e-001 | 1.5249e-001 |
| 33 | recdev1 | -9.7859e-001 | 1.7014e-001 |
| 34 | recdev1 | -6.0304e-001 | 1.8382e-001 |
| 35 | recdev1 | 9.8931e-001 | 9.2689e-002 |
| 36 | recdev1 | -4.8770e-001 | 1.9188e-001 |
| 37 | recdev1 | 7.4721e-002 | 9.5333e-002 |
| 38 | recdev1 | 6.9259e-001 | 5.9971e-002 |
| 39 | recdev1 | 5.1604e-001 | 6.0672e-002 |
| 40 | recdev1 | 1.3422e-001 | 5.9410e-002 |
| 41 | recdev1 | -3.1868e-001 | 5.9760e-002 |
| 42 | recdev1 | -6.6814e-002 | 4.8372e-002 |
| 43 | recdev1 | 3.1000e-001 | 4.0398e-002 |
| 44 | recdev1 | 4.5424e-002 | 4.5492e-002 |
| 45 | recdev1 | 8.9239e-002 | 4.5541e-002 |
| 46 | recdev1 | 2.4755e-001 | 4.6902e-002 |
| 47 | recdev1 | 7.0687e-001 | 4.2908e-002 |
| 48 | recdev1 | 2.9815e-001 | 5.4833e-002 |
| 49 | recdev1 | -5.2828e-001 | 8.3005e-002 |
| 50 | recdev1 | -2.8544e-002 | 7.2817e-002 |
| 51 | recdev1 | -2.1085e-001 | 8.7503e-002 |
| 52 | recdev1 | -7.8711e-001 | 1.3955e-001 |
| 53 | init_F[1] | 8.5877e-002 | 1.4300e-002 |
| 54 | init_F[2] | 7.7304e-002 | 1.5908e-002 |
| 55 | init_F[3] | 1.0292e-002 | 1.2289e-003 |
| 56 | init_F[4] | 1.4870e-001 | 1.3513e-002 |
| 57 | F_rate[1] | 8.6038e-002 | 1.3470e-002 |
| 58 | F_rate[2] | 8.5116e-002 | 1.3042e-002 |
| 59 | F_rate[3] | 8.4553e-002 | 1.3790e-002 |
| 60 | F_rate[4] | 8.4305e-002 | 1.5569e-002 |
| 61 | F_rate[5] | 8.4350e-002 | 1.7468e-002 |
| 62 | F_rate[6] | 8.4730e-002 | 1.8980e-002 |
| 63 | F_rate[7] | 8.5557e-002 | 1.9953e-002 |

| | | | |
|---|---|---|---|
| 64 | F_rate[8] | 8.7050e-002 | 2.0438e-002 |
| 65 | F_rate[9] | 8.9450e-002 | 2.0535e-002 |
| 66 | F_rate[10] | 9.3217e-002 | 2.0533e-002 |
| 67 | F_rate[11] | 9.8869e-002 | 2.0767e-002 |
| 68 | F_rate[12] | 1.0570e-001 | 2.1038e-002 |
| 69 | F_rate[13] | 1.0995e-001 | 2.0130e-002 |
| 70 | F_rate[14] | 1.0052e-001 | 1.4963e-002 |
| 71 | F_rate[15] | 8.4912e-002 | 9.1408e-003 |
| 72 | F_rate[16] | 7.9334e-002 | 7.1803e-003 |
| 73 | F_rate[17] | 8.6047e-002 | 7.1515e-003 |
| 74 | F_rate[18] | 7.1597e-002 | 5.7942e-003 |
| 75 | F_rate[19] | 9.3566e-002 | 7.4258e-003 |
| 76 | F_rate[20] | 8.9338e-002 | 7.0465e-003 |
| 77 | F_rate[21] | 7.3715e-002 | 5.8534e-003 |
| 78 | F_rate[22] | 9.1768e-002 | 7.5162e-003 |
| 79 | F_rate[23] | 1.0094e-001 | 8.5154e-003 |
| 80 | F_rate[24] | 1.1670e-001 | 9.7373e-003 |
| 81 | F_rate[25] | 1.7018e-001 | 1.4051e-002 |
| 82 | F_rate[26] | 1.6000e-001 | 1.3173e-002 |
| 83 | F_rate[27] | 2.0187e-001 | 1.6048e-002 |
| 84 | F_rate[28] | 1.6937e-001 | 1.3797e-002 |
| 85 | F_rate[29] | 2.0400e-001 | 1.5843e-002 |
| 86 | F_rate[30] | 1.8670e-001 | 1.3114e-002 |
| 87 | F_rate[31] | 1.5059e-001 | 1.0205e-002 |
| 88 | F_rate[32] | 1.1287e-001 | 7.0710e-003 |
| 89 | F_rate[33] | 2.1198e-001 | 1.8730e-002 |
| 90 | F_rate[34] | 3.2685e-001 | 3.0322e-002 |
| 91 | F_rate[35] | 3.0466e-001 | 2.7361e-002 |
| 92 | F_rate[36] | 3.3588e-001 | 2.7976e-002 |
| 93 | F_rate[37] | 3.8932e-001 | 3.1121e-002 |
| 94 | F_rate[38] | 4.1924e-001 | 3.3202e-002 |
| 95 | F_rate[39] | 5.0089e-001 | 3.9037e-002 |
| 96 | F_rate[40] | 4.1656e-001 | 3.1866e-002 |
| 97 | F_rate[41] | 3.1906e-001 | 2.4040e-002 |
| 98 | F_rate[42] | 2.7530e-001 | 2.0582e-002 |
| 99 | F_rate[43] | 2.5826e-001 | 1.9642e-002 |
| 100 | F_rate[44] | 2.2782e-001 | 1.8045e-002 |
| 101 | F_rate[45] | 2.0429e-001 | 1.6747e-002 |
| 102 | F_rate[46] | 1.2713e-001 | 1.0545e-002 |
| 103 | F_rate[47] | 1.7416e-001 | 1.4587e-002 |
| 104 | F_rate[48] | 2.8267e-001 | 2.4518e-002 |
| 105 | F_rate[49] | 3.2487e-001 | 3.3271e-002 |
| 106 | F_rate[50] | 7.6773e-002 | 1.5502e-002 |
| 107 | F_rate[51] | 7.6166e-002 | 1.5645e-002 |
| 108 | F_rate[52] | 7.6044e-002 | 1.7425e-002 |
| 109 | F_rate[53] | 7.6212e-002 | 1.9398e-002 |
| 110 | F_rate[54] | 7.6603e-002 | 2.0792e-002 |
| 111 | F_rate[55] | 7.7255e-002 | 2.1583e-002 |
| 112 | F_rate[56] | 7.8311e-002 | 2.1983e-002 |
| 113 | F_rate[57] | 8.0020e-002 | 2.2251e-002 |
| 114 | F_rate[58] | 8.2520e-002 | 2.2513e-002 |
| 115 | F_rate[59] | 8.6473e-002 | 2.3276e-002 |
| 116 | F_rate[60] | 9.1721e-002 | 2.4367e-002 |
| 117 | F_rate[61] | 9.7208e-002 | 2.5395e-002 |
| 118 | F_rate[62] | 9.6348e-002 | 2.3298e-002 |
| 119 | F_rate[63] | 7.9447e-002 | 1.5170e-002 |
| 120 | F_rate[64] | 6.7272e-002 | 1.1085e-002 |
| 121 | F_rate[65] | 6.6211e-002 | 1.2190e-002 |
| 122 | F_rate[66] | 7.9417e-002 | 1.6544e-002 |
| 123 | F_rate[67] | 6.9303e-002 | 1.5713e-002 |
| 124 | F_rate[68] | 8.3889e-002 | 1.8951e-002 |
| 125 | F_rate[69] | 7.6982e-002 | 1.6427e-002 |
| 126 | F_rate[70] | 6.2262e-002 | 1.3209e-002 |
| 127 | F_rate[71] | 8.3735e-002 | 1.8534e-002 |
| 128 | F_rate[72] | 7.9249e-002 | 1.6106e-002 |
| 129 | F_rate[73] | 8.6919e-002 | 1.4254e-002 |
| 130 | F_rate[74] | 1.1947e-001 | 1.6853e-002 |
| 131 | F_rate[75] | 9.0684e-002 | 1.2106e-002 |
| 132 | F_rate[76] | 1.2353e-001 | 1.7408e-002 |
| 133 | F_rate[77] | 1.2107e-001 | 1.7661e-002 |
| 134 | F_rate[78] | 1.0467e-001 | 1.3760e-002 |

| | | | |
|---|---|---|---|
| 135 | F_rate[79] | 1.0951e-001 | 1.4986e-002 |
| 136 | F_rate[80] | 1.1333e-001 | 1.8650e-002 |
| 137 | F_rate[81] | 8.2636e-002 | 1.5028e-002 |
| 138 | F_rate[82] | 2.9877e-002 | 4.2753e-003 |
| 139 | F_rate[83] | 1.0294e-002 | 1.1027e-003 |
| 140 | F_rate[84] | 6.8319e-003 | 8.9147e-004 |
| 141 | F_rate[85] | 5.6075e-003 | 7.5839e-004 |
| 142 | F_rate[86] | 9.9330e-003 | 1.2102e-003 |
| 143 | F_rate[87] | 9.6560e-003 | 1.2191e-003 |
| 144 | F_rate[88] | 1.9620e-002 | 2.8580e-003 |
| 145 | F_rate[89] | 9.9180e-003 | 1.6123e-003 |
| 146 | F_rate[90] | 6.5060e-003 | 1.0413e-003 |
| 147 | F_rate[91] | 2.0168e-002 | 3.1333e-003 |
| 148 | F_rate[92] | 1.3346e-002 | 2.1665e-003 |
| 149 | F_rate[93] | 9.2725e-003 | 1.5815e-003 |
| 150 | F_rate[94] | 1.2250e-002 | 2.0311e-003 |
| 151 | F_rate[95] | 4.5363e-003 | 7.2794e-004 |
| 152 | F_rate[96] | 2.5600e-003 | 4.5805e-004 |
| 153 | F_rate[97] | 5.6625e-003 | 1.1734e-003 |
| 154 | F_rate[98] | 4.3689e-003 | 9.7515e-004 |
| 155 | F_rate[99] | 1.1766e-002 | 1.3923e-003 |
| 156 | F_rate[100] | 1.1669e-002 | 1.4123e-003 |
| 157 | F_rate[101] | 1.1669e-002 | 1.8911e-003 |
| 158 | F_rate[102] | 1.1703e-002 | 2.2439e-003 |
| 159 | F_rate[103] | 1.1762e-002 | 2.4227e-003 |
| 160 | F_rate[104] | 1.1860e-002 | 2.4860e-003 |
| 161 | F_rate[105] | 1.2021e-002 | 2.4739e-003 |
| 162 | F_rate[106] | 1.2283e-002 | 2.4188e-003 |
| 163 | F_rate[107] | 1.2671e-002 | 2.3362e-003 |
| 164 | F_rate[108] | 1.3266e-002 | 2.2942e-003 |
| 165 | F_rate[109] | 1.4096e-002 | 2.2988e-003 |
| 166 | F_rate[110] | 1.4889e-002 | 2.3432e-003 |
| 167 | F_rate[111] | 1.4762e-002 | 2.1706e-003 |
| 168 | F_rate[112] | 1.2057e-002 | 1.4586e-003 |
| 169 | F_rate[113] | 9.8922e-003 | 9.2657e-004 |
| 170 | F_rate[114] | 1.0171e-002 | 8.5933e-004 |
| 171 | F_rate[115] | 1.0210e-002 | 8.3253e-004 |
| 172 | F_rate[116] | 1.3892e-002 | 1.1261e-003 |
| 173 | F_rate[117] | 1.2604e-002 | 1.0260e-003 |
| 174 | F_rate[118] | 2.5151e-002 | 2.0834e-003 |
| 175 | F_rate[119] | 2.2762e-002 | 1.9064e-003 |
| 176 | F_rate[120] | 2.5066e-002 | 2.1289e-003 |
| 177 | F_rate[121] | 2.1163e-002 | 1.8340e-003 |
| 178 | F_rate[122] | 3.3376e-002 | 2.8980e-003 |
| 179 | F_rate[123] | 3.2995e-002 | 2.8482e-003 |
| 180 | F_rate[124] | 3.6096e-002 | 3.0456e-003 |
| 181 | F_rate[125] | 2.5238e-002 | 2.0596e-003 |
| 182 | F_rate[126] | 3.4212e-002 | 2.7521e-003 |
| 183 | F_rate[127] | 2.2240e-002 | 1.7304e-003 |
| 184 | F_rate[128] | 1.5958e-002 | 1.1624e-003 |
| 185 | F_rate[129] | 3.8595e-002 | 2.7223e-003 |
| 186 | F_rate[130] | 1.4567e-002 | 1.0126e-003 |
| 187 | F_rate[131] | 4.0052e-002 | 2.8807e-003 |
| 188 | F_rate[132] | 4.8243e-002 | 3.4432e-003 |
| 189 | F_rate[133] | 3.8227e-002 | 2.4616e-003 |
| 190 | F_rate[134] | 3.4360e-002 | 2.1616e-003 |
| 191 | F_rate[135] | 3.8149e-002 | 2.3452e-003 |
| 192 | F_rate[136] | 4.7186e-002 | 2.8382e-003 |
| 193 | F_rate[137] | 5.7798e-002 | 3.3915e-003 |
| 194 | F_rate[138] | 3.8108e-002 | 2.2418e-003 |
| 195 | F_rate[139] | 2.7717e-002 | 1.6425e-003 |
| 196 | F_rate[140] | 2.3350e-002 | 1.3875e-003 |
| 197 | F_rate[141] | 1.8542e-002 | 1.1061e-003 |
| 198 | F_rate[142] | 1.5335e-002 | 9.3169e-004 |
| 199 | F_rate[143] | 4.1169e-002 | 2.5742e-003 |
| 200 | F_rate[144] | 4.0981e-002 | 2.6158e-003 |
| 201 | F_rate[145] | 1.5534e-002 | 1.0227e-003 |
| 202 | F_rate[146] | 1.5132e-002 | 1.0812e-003 |
| 203 | F_rate[147] | 8.8710e-003 | 7.7730e-004 |
| 204 | F_rate[148] | 1.3587e-001 | 1.2302e-002 |
| 205 | F_rate[149] | 1.3548e-001 | 1.6014e-002 |

| | | | |
|---|---|---|---|
| 206 | F_rate[150] | 1.3593e-001 | 2.2387e-002 |
| 207 | F_rate[151] | 1.3650e-001 | 2.4912e-002 |
| 208 | F_rate[152] | 1.3733e-001 | 2.5767e-002 |
| 209 | F_rate[153] | 1.3863e-001 | 2.5684e-002 |
| 210 | F_rate[154] | 1.4075e-001 | 2.5020e-002 |
| 211 | F_rate[155] | 1.4416e-001 | 2.4093e-002 |
| 212 | F_rate[156] | 1.4876e-001 | 2.2939e-002 |
| 213 | F_rate[157] | 1.5657e-001 | 2.2785e-002 |
| 214 | F_rate[158] | 1.6484e-001 | 2.2569e-002 |
| 215 | F_rate[159] | 1.7180e-001 | 2.3373e-002 |
| 216 | F_rate[160] | 1.5920e-001 | 2.0737e-002 |
| 217 | F_rate[161] | 1.1999e-001 | 1.0245e-002 |
| 218 | F_rate[162] | 1.1242e-001 | 8.0752e-003 |
| 219 | F_rate[163] | 1.2317e-001 | 8.0333e-003 |
| 220 | F_rate[164] | 1.3695e-001 | 8.7830e-003 |
| 221 | F_rate[165] | 1.5156e-001 | 9.5499e-003 |
| 222 | F_rate[166] | 1.5426e-001 | 9.5651e-003 |
| 223 | F_rate[167] | 1.5394e-001 | 9.5119e-003 |
| 224 | F_rate[168] | 1.6875e-001 | 1.0671e-002 |
| 225 | F_rate[169] | 1.8679e-001 | 1.2013e-002 |
| 226 | F_rate[170] | 2.9636e-001 | 1.8115e-002 |
| 227 | F_rate[171] | 4.8838e-001 | 2.7288e-002 |
| 228 | F_rate[172] | 4.8860e-001 | 2.7018e-002 |
| 229 | F_rate[173] | 1.8598e-001 | 1.1144e-002 |
| 230 | F_rate[174] | 2.6849e-001 | 1.6318e-002 |
| 231 | F_rate[175] | 2.4507e-001 | 1.5589e-002 |
| 232 | F_rate[176] | 1.0536e-001 | 6.5476e-003 |
| 233 | F_rate[177] | 2.3123e-001 | 1.3272e-002 |
| 234 | F_rate[178] | 5.1060e-002 | 3.2821e-003 |
| 235 | F_rate[179] | 2.3646e-002 | 1.5782e-003 |
| 236 | F_rate[180] | 2.1630e-001 | 1.4335e-002 |
| 237 | F_rate[181] | 4.4845e-001 | 2.6964e-002 |
| 238 | F_rate[182] | 2.2312e-001 | 1.2481e-002 |
| 239 | F_rate[183] | 2.2797e-001 | 1.2628e-002 |
| 240 | F_rate[184] | 3.0341e-001 | 1.4714e-002 |
| 241 | F_rate[185] | 2.5210e-001 | 1.2163e-002 |
| 242 | F_rate[186] | 1.8179e-001 | 9.4243e-003 |
| 243 | F_rate[187] | 1.0289e-001 | 5.6027e-003 |
| 244 | F_rate[188] | 9.3153e-002 | 5.2877e-003 |
| 245 | F_rate[189] | 8.6846e-002 | 4.9843e-003 |
| 246 | F_rate[190] | 1.6222e-001 | 8.9760e-003 |
| 247 | F_rate[191] | 1.8503e-001 | 1.0253e-002 |
| 248 | F_rate[192] | 1.5182e-001 | 8.6228e-003 |
| 249 | F_rate[193] | 1.2182e-001 | 7.1448e-003 |
| 250 | F_rate[194] | 1.5704e-001 | 9.3814e-003 |
| 251 | F_rate[195] | 2.0440e-001 | 1.3381e-002 |
| 252 | F_rate[196] | 2.9238e-001 | 2.4297e-002 |
| 253 | Q_parm[1] | -6.1816e+000 | 7.1601e-002 |
| 254 | Q_parm[2] | -5.5061e+000 | 5.3469e-002 |
| 255 | Q_parm[3] | -5.4252e+000 | 8.0540e-002 |
| 256 | Q_parm[4] | -6.6926e+000 | 5.0383e-002 |
| 257 | Q_parm[5] | -5.6383e+000 | 1.5132e-001 |
| 258 | selparm[2] | 1.8901e+001 | 1.0242e+000 |
| 259 | selparm[4] | 1.9950e+000 | 7.2796e-002 |
| 260 | selparm[11] | 3.3456e+001 | 1.2898e+000 |
| 261 | selparm[12] | -2.6078e+000 | 1.0706e+000 |
| 262 | selparm[13] | 2.0490e+000 | 6.8245e-001 |
| 263 | selparm[14] | 6.8531e+000 | 5.3491e-001 |
| 264 | selparm[17] | 3.8037e+001 | 8.8295e-001 |
| 265 | selparm[18] | 1.6930e+001 | 1.2992e+000 |
| 266 | selparm[19] | 2.2191e+001 | 7.2276e-001 |
| 267 | selparm[20] | 6.7660e+000 | 2.8193e+000 |
| 268 | selparm[21] | 3.3536e+001 | 6.8718e-001 |
| 269 | selparm[22] | -4.9986e+000 | 4.6141e-002 |
| 270 | selparm[23] | 5.0654e+000 | 1.0138e-001 |
| 271 | selparm[24] | 8.0000e+000 | 6.1067e-004 |
| 272 | selparm[27] | 6.2785e+001 | 2.3167e+000 |
| 273 | selparm[28] | -8.3215e-001 | 2.2237e-001 |
| 274 | selparm[29] | 5.5965e+000 | 1.6016e-001 |
| 275 | selparm[30] | 9.8821e-001 | 1.9134e+000 |
| 276 | selparm[45] | 2.9198e+001 | 2.9721e+000 |

| | | | |
|---|---|---|---|
| 277 | selparm[46] | 5.9145e+001 | 7.8004e-001 |
| 278 | selparm[47] | 3.2298e+001 | 4.5222e-001 |
| 279 | selparm[48] | 5.0562e+001 | 1.5333e-001 |
| 280 | spbio_std | 1.0036e+004 | 3.0073e+002 |
| 281 | spbio_std | 1.0307e+003 | 1.7121e+002 |
| 282 | spbio_std | 1.0307e+003 | 1.7121e+002 |
| 283 | spbio_std | 1.0429e+003 | 1.6954e+002 |
| 284 | spbio_std | 1.0540e+003 | 1.6903e+002 |
| 285 | spbio_std | 1.0619e+003 | 1.8120e+002 |
| 286 | spbio_std | 1.0656e+003 | 2.0689e+002 |
| 287 | spbio_std | 1.0647e+003 | 2.3463e+002 |
| 288 | spbio_std | 1.0589e+003 | 2.5486e+002 |
| 289 | spbio_std | 1.0467e+003 | 2.6377e+002 |
| 290 | spbio_std | 1.0254e+003 | 2.6104e+002 |
| 291 | spbio_std | 9.9392e+002 | 2.4749e+002 |
| 292 | spbio_std | 9.4567e+002 | 2.2713e+002 |
| 293 | spbio_std | 8.8600e+002 | 2.0234e+002 |
| 294 | spbio_std | 8.2092e+002 | 1.7823e+002 |
| 295 | spbio_std | 8.0133e+002 | 1.5465e+002 |
| 296 | spbio_std | 9.1055e+002 | 1.2941e+002 |
| 297 | spbio_std | 1.0333e+003 | 1.0877e+002 |
| 298 | spbio_std | 1.1257e+003 | 9.2983e+001 |
| 299 | spbio_std | 1.1265e+003 | 8.2593e+001 |
| 300 | spbio_std | 1.0910e+003 | 7.5178e+001 |
| 301 | spbio_std | 1.0213e+003 | 6.8196e+001 |
| 302 | spbio_std | 9.6426e+002 | 6.3089e+001 |
| 303 | spbio_std | 9.1247e+002 | 6.0813e+001 |
| 304 | spbio_std | 8.2150e+002 | 5.8768e+001 |
| 305 | spbio_std | 7.0053e+002 | 5.0863e+001 |
| 306 | spbio_std | 5.2298e+002 | 3.6683e+001 |
| 307 | spbio_std | 3.9445e+002 | 2.6884e+001 |
| 308 | spbio_std | 4.2423e+002 | 2.6118e+001 |
| 309 | spbio_std | 3.7861e+002 | 2.4511e+001 |
| 310 | spbio_std | 3.6928e+002 | 2.2420e+001 |
| 311 | spbio_std | 4.1371e+002 | 2.1687e+001 |
| 312 | spbio_std | 3.8700e+002 | 1.9183e+001 |
| 313 | spbio_std | 4.0951e+002 | 1.9961e+001 |
| 314 | spbio_std | 4.6733e+002 | 2.0795e+001 |
| 315 | spbio_std | 5.6565e+002 | 1.9925e+001 |
| 316 | spbio_std | 5.0969e+002 | 1.8021e+001 |
| 317 | spbio_std | 5.8277e+002 | 1.8506e+001 |
| 318 | spbio_std | 6.6991e+002 | 1.9540e+001 |
| 319 | spbio_std | 6.9609e+002 | 1.8989e+001 |
| 320 | spbio_std | 7.2698e+002 | 1.9228e+001 |
| 321 | spbio_std | 7.2164e+002 | 2.0146e+001 |
| 322 | spbio_std | 7.7711e+002 | 2.2210e+001 |
| 323 | spbio_std | 8.8878e+002 | 2.5119e+001 |
| 324 | spbio_std | 1.0230e+003 | 2.8853e+001 |
| 325 | spbio_std | 1.0911e+003 | 3.2736e+001 |
| 326 | spbio_std | 1.1353e+003 | 3.7423e+001 |
| 327 | spbio_std | 1.2288e+003 | 4.4479e+001 |
| 328 | spbio_std | 1.4104e+003 | 5.4833e+001 |
| 329 | spbio_std | 1.4868e+003 | 6.6606e+001 |
| 330 | spbio_std | 1.3551e+003 | 7.9377e+001 |
| 331 | recr_std | 6.6251e+002 | 1.9854e+001 |
| 332 | recr_std | 6.6251e+002 | 1.9854e+001 |
| 333 | recr_std | 6.3730e+002 | 2.3874e+002 |
| 334 | recr_std | 6.3479e+002 | 2.3730e+002 |
| 335 | recr_std | 6.3110e+002 | 2.3521e+002 |
| 336 | recr_std | 6.2573e+002 | 2.3230e+002 |
| 337 | recr_std | 6.1751e+002 | 2.2805e+002 |
| 338 | recr_std | 6.0496e+002 | 2.2185e+002 |
| 339 | recr_std | 5.8622e+002 | 2.1283e+002 |
| 340 | recr_std | 5.7504e+002 | 2.0518e+002 |
| 341 | recr_std | 5.2794e+002 | 1.8480e+002 |
| 342 | recr_std | 5.5297e+002 | 1.8610e+002 |
| 343 | recr_std | 5.5166e+002 | 1.8241e+002 |
| 344 | recr_std | 8.1827e+002 | 2.5652e+002 |
| 345 | recr_std | 1.3016e+003 | 2.6249e+002 |
| 346 | recr_std | 4.9074e+002 | 1.0888e+002 |
| 347 | recr_std | 5.6919e+002 | 7.8325e+001 |

| | | | |
|---|---|---|---|
| 348 | recr_std | 4.3927e+002 | 6.1234e+001 |
| 349 | recr_std | 4.8827e+002 | 6.2062e+001 |
| 350 | recr_std | 6.3143e+002 | 6.2929e+001 |
| 351 | recr_std | 6.1280e+002 | 5.6678e+001 |
| 352 | recr_std | 3.6139e+002 | 4.5368e+001 |
| 353 | recr_std | 4.6722e+002 | 5.3251e+001 |
| 354 | recr_std | 9.0946e+002 | 7.6134e+001 |
| 355 | recr_std | 1.0769e+003 | 9.3902e+001 |
| 356 | recr_std | 9.8046e+002 | 9.6417e+001 |
| 357 | recr_std | 6.9150e+002 | 7.5303e+001 |
| 358 | recr_std | 3.9369e+002 | 5.4988e+001 |
| 359 | recr_std | 7.2081e+002 | 6.7536e+001 |
| 360 | recr_std | 6.0761e+002 | 5.8961e+001 |
| 361 | recr_std | 2.7386e+002 | 4.1476e+001 |
| 362 | recr_std | 2.1765e+002 | 3.7007e+001 |
| 363 | recr_std | 3.1548e+002 | 5.8863e+001 |
| 364 | recr_std | 1.5564e+003 | 1.2454e+002 |
| 365 | recr_std | 3.5819e+002 | 7.1205e+001 |
| 366 | recr_std | 6.3482e+002 | 6.0186e+001 |
| 367 | recr_std | 1.1715e+003 | 6.6207e+001 |
| 368 | recr_std | 9.8836e+002 | 5.7962e+001 |
| 369 | recr_std | 6.7871e+002 | 3.9839e+001 |
| 370 | recr_std | 4.3216e+002 | 2.5832e+001 |
| 371 | recr_std | 5.5685e+002 | 2.6365e+001 |
| 372 | recr_std | 8.1146e+002 | 3.1680e+001 |
| 373 | recr_std | 6.2449e+002 | 2.8263e+001 |
| 374 | recr_std | 6.5531e+002 | 2.9712e+001 |
| 375 | recr_std | 7.7080e+002 | 3.5876e+001 |
| 376 | recr_std | 1.2222e+003 | 5.1869e+001 |
| 377 | recr_std | 8.1295e+002 | 4.4407e+001 |
| 378 | recr_std | 3.5640e+002 | 2.9723e+001 |
| 379 | recr_std | 5.8914e+002 | 4.2604e+001 |
| 380 | recr_std | 4.9145e+002 | 4.2951e+001 |
| 381 | recr_std | 2.7570e+002 | 3.8927e+001 |
| 382 | SPR_std | 1.4833e+000 | 2.8270e-002 |
| 383 | SPR_std | 1.4816e+000 | 3.1285e-002 |
| 384 | SPR_std | 1.4815e+000 | 4.1469e-002 |
| 385 | SPR_std | 1.4821e+000 | 4.8069e-002 |
| 386 | SPR_std | 1.4833e+000 | 5.1486e-002 |
| 387 | SPR_std | 1.4855e+000 | 5.2246e-002 |
| 388 | SPR_std | 1.4892e+000 | 5.0764e-002 |
| 389 | SPR_std | 1.4951e+000 | 4.7494e-002 |
| 390 | SPR_std | 1.5030e+000 | 4.2850e-002 |
| 391 | SPR_std | 1.5150e+000 | 3.8125e-002 |
| 392 | SPR_std | 1.5281e+000 | 3.3417e-002 |
| 393 | SPR_std | 1.5394e+000 | 3.0296e-002 |
| 394 | SPR_std | 1.5327e+000 | 2.8466e-002 |
| 395 | SPR_std | 1.4808e+000 | 2.4310e-002 |
| 396 | SPR_std | 1.4448e+000 | 1.9531e-002 |
| 397 | SPR_std | 1.4526e+000 | 1.7289e-002 |
| 398 | SPR_std | 1.4850e+000 | 1.5702e-002 |
| 399 | SPR_std | 1.4843e+000 | 1.5698e-002 |
| 400 | SPR_std | 1.5115e+000 | 1.3673e-002 |
| 401 | SPR_std | 1.5123e+000 | 1.3148e-002 |
| 402 | SPR_std | 1.5046e+000 | 1.4295e-002 |
| 403 | SPR_std | 1.5411e+000 | 1.2539e-002 |
| 404 | SPR_std | 1.5919e+000 | 7.6934e-003 |
| 405 | SPR_std | 1.6337e+000 | 3.4820e-003 |
| 406 | SPR_std | 1.6393e+000 | 2.7816e-003 |
| 407 | SPR_std | 1.5740e+000 | 7.5063e-003 |
| 408 | SPR_std | 1.6121e+000 | 5.1080e-003 |
| 409 | SPR_std | 1.6022e+000 | 5.7767e-003 |
| 410 | SPR_std | 1.5511e+000 | 8.4320e-003 |
| 411 | SPR_std | 1.5965e+000 | 5.4358e-003 |
| 412 | SPR_std | 1.4933e+000 | 1.2070e-002 |
| 413 | SPR_std | 1.3600e+000 | 1.7829e-002 |
| 414 | SPR_std | 1.5349e+000 | 1.0767e-002 |
| 415 | SPR_std | 1.6177e+000 | 5.0746e-003 |
| 416 | SPR_std | 1.5417e+000 | 8.2400e-003 |
| 417 | SPR_std | 1.5461e+000 | 7.7655e-003 |
| 418 | SPR_std | 1.5840e+000 | 5.1717e-003 |

| | | | |
|---|---|---|---|
| 419 | SPR_std | 1.5697e+000 | 5.3832e-003 |
| 420 | SPR_std | 1.5520e+000 | 5.6223e-003 |
| 421 | SPR_std | 1.4760e+000 | 8.1485e-003 |
| 422 | SPR_std | 1.4292e+000 | 1.0372e-002 |
| 423 | SPR_std | 1.4124e+000 | 1.1017e-002 |
| 424 | SPR_std | 1.4832e+000 | 9.8179e-003 |
| 425 | SPR_std | 1.4918e+000 | 1.0276e-002 |
| 426 | SPR_std | 1.4734e+000 | 1.0950e-002 |
| 427 | SPR_std | 1.3982e+000 | 1.4885e-002 |
| 428 | SPR_std | 1.4415e+000 | 1.4313e-002 |
| 429 | SPR_std | 1.5164e+000 | 1.1805e-002 |
| 430 | SPR_std | 1.5671e+000 | 1.2135e-002 |
| 431 | F_std | 1.4345e+000 | 1.5368e-001 |
| 432 | F_std | 1.4252e+000 | 1.6430e-001 |
| 433 | F_std | 1.4241e+000 | 2.1422e-001 |
| 434 | F_std | 1.4265e+000 | 2.5098e-001 |
| 435 | F_std | 1.4326e+000 | 2.7369e-001 |
| 436 | F_std | 1.4439e+000 | 2.8489e-001 |
| 437 | F_std | 1.4631e+000 | 2.8743e-001 |
| 438 | F_std | 1.4949e+000 | 2.8461e-001 |
| 439 | F_std | 1.5406e+000 | 2.7765e-001 |
| 440 | F_std | 1.6151e+000 | 2.7665e-001 |
| 441 | F_std | 1.7075e+000 | 2.7698e-001 |
| 442 | F_std | 1.8003e+000 | 2.8229e-001 |
| 443 | F_std | 1.7571e+000 | 2.5162e-001 |
| 444 | F_std | 1.4418e+000 | 1.5269e-001 |
| 445 | F_std | 1.2684e+000 | 1.0470e-001 |
| 446 | F_std | 1.2887e+000 | 1.0094e-001 |
| 447 | F_std | 1.4446e+000 | 1.1887e-001 |
| 448 | F_std | 1.4156e+000 | 1.1355e-001 |
| 449 | F_std | 1.5910e+000 | 1.3010e-001 |
| 450 | F_std | 1.5961e+000 | 1.2249e-001 |
| 451 | F_std | 1.5132e+000 | 1.1329e-001 |
| 452 | F_std | 1.7899e+000 | 1.4594e-001 |
| 453 | F_std | 2.2998e+000 | 1.5934e-001 |
| 454 | F_std | 3.3518e+000 | 1.9559e-001 |
| 455 | F_std | 3.7486e+000 | 2.1305e-001 |
| 456 | F_std | 2.1845e+000 | 1.3521e-001 |
| 457 | F_std | 2.8609e+000 | 1.8188e-001 |
| 458 | F_std | 2.6326e+000 | 1.6795e-001 |
| 459 | F_std | 2.0159e+000 | 1.2808e-001 |
| 460 | F_std | 2.5109e+000 | 1.3790e-001 |
| 461 | F_std | 1.6338e+000 | 1.2031e-001 |
| 462 | F_std | 1.0800e+000 | 8.9291e-002 |
| 463 | F_std | 2.3021e+000 | 1.4024e-001 |
| 464 | F_std | 3.8530e+000 | 2.3214e-001 |
| 465 | F_std | 2.6470e+000 | 1.5155e-001 |
| 466 | F_std | 2.7902e+000 | 1.5346e-001 |
| 467 | F_std | 3.4231e+000 | 1.7427e-001 |
| 468 | F_std | 3.3648e+000 | 1.7379e-001 |
| 469 | F_std | 3.5123e+000 | 1.9135e-001 |
| 470 | F_std | 2.6222e+000 | 1.5139e-001 |
| 471 | F_std | 2.0629e+000 | 1.1807e-001 |
| 472 | F_std | 1.8745e+000 | 1.0597e-001 |
| 473 | F_std | 2.0903e+000 | 1.1072e-001 |
| 474 | F_std | 2.0214e+000 | 1.0825e-001 |
| 475 | F_std | 1.8924e+000 | 1.0476e-001 |
| 476 | F_std | 1.3607e+000 | 7.6514e-002 |
| 477 | F_std | 1.6140e+000 | 9.7577e-002 |
| 478 | F_std | 2.3468e+000 | 1.5964e-001 |
| 479 | F_std | 2.9134e+000 | 2.5478e-001 |
| 480 | depletion | 5.1844e-001 | 8.4099e-002 |
| 481 | depletion | 5.2454e-001 | 8.2382e-002 |
| 482 | depletion | 5.3015e-001 | 8.1618e-002 |
| 483 | depletion | 5.3412e-001 | 8.8071e-002 |
| 484 | depletion | 5.3596e-001 | 1.0192e-001 |
| 485 | depletion | 5.3555e-001 | 1.1686e-001 |
| 486 | depletion | 5.3262e-001 | 1.2788e-001 |
| 487 | depletion | 5.2648e-001 | 1.3306e-001 |
| 488 | depletion | 5.1579e-001 | 1.3224e-001 |
| 489 | depletion | 4.9993e-001 | 1.2582e-001 |

| | | | |
|---|---|---|---|
| 490 | depletion | 4.7566e-001 | 1.1570e-001 |
| 491 | depletion | 4.4564e-001 | 1.0305e-001 |
| 492 | depletion | 4.1291e-001 | 9.0381e-002 |
| 493 | depletion | 4.0306e-001 | 7.8008e-002 |
| 494 | depletion | 4.5800e-001 | 6.6165e-002 |
| 495 | depletion | 5.1975e-001 | 5.7327e-002 |
| 496 | depletion | 5.6623e-001 | 5.1059e-002 |
| 497 | depletion | 5.6660e-001 | 4.6015e-002 |
| 498 | depletion | 5.4877e-001 | 4.1993e-002 |
| 499 | depletion | 5.1370e-001 | 3.8077e-002 |
| 500 | depletion | 4.8501e-001 | 3.5405e-002 |
| 501 | depletion | 4.5896e-001 | 3.4319e-002 |
| 502 | depletion | 4.1321e-001 | 3.3017e-002 |
| 503 | depletion | 3.5236e-001 | 2.8787e-002 |
| 504 | depletion | 2.6305e-001 | 2.1071e-002 |
| 505 | depletion | 1.9840e-001 | 1.5488e-002 |
| 506 | depletion | 2.1338e-001 | 1.5442e-002 |
| 507 | depletion | 1.9043e-001 | 1.4365e-002 |
| 508 | depletion | 1.8574e-001 | 1.3449e-002 |
| 509 | depletion | 2.0809e-001 | 1.3524e-002 |
| 510 | depletion | 1.9465e-001 | 1.2233e-002 |
| 511 | depletion | 2.0598e-001 | 1.3029e-002 |
| 512 | depletion | 2.3506e-001 | 1.4439e-002 |
| 513 | depletion | 2.8452e-001 | 1.5733e-002 |
| 514 | depletion | 2.5637e-001 | 1.4370e-002 |
| 515 | depletion | 2.9313e-001 | 1.5813e-002 |
| 516 | depletion | 3.3695e-001 | 1.7782e-002 |
| 517 | depletion | 3.5013e-001 | 1.8232e-002 |
| 518 | depletion | 3.6566e-001 | 1.8941e-002 |
| 519 | depletion | 3.6297e-001 | 1.9157e-002 |
| 520 | depletion | 3.9087e-001 | 2.0891e-002 |
| 521 | depletion | 4.4704e-001 | 2.3928e-002 |
| 522 | depletion | 5.1457e-001 | 2.7631e-002 |
| 523 | depletion | 5.4879e-001 | 3.0240e-002 |
| 524 | depletion | 5.7103e-001 | 3.2742e-002 |
| 525 | depletion | 6.1805e-001 | 3.6989e-002 |
| 526 | depletion | 7.0942e-001 | 4.4063e-002 |
| 527 | depletion | 7.4783e-001 | 4.9980e-002 |
| 528 | depletion | 6.8159e-001 | 5.3319e-002 |
| 529 | Mgmt_quant | 1.0036e+004 | 3.0073e+002 |
| 530 | Mgmt_quant | 1.0780e+004 | 3.2303e+002 |
| 531 | Mgmt_quant | 1.0738e+004 | 3.2176e+002 |
| 532 | Mgmt_quant | 6.6251e+002 | 1.9854e+001 |
| 533 | Mgmt_quant | 4.0143e+003 | 1.2029e+002 |
| 534 | Mgmt_quant | 4.0167e-001 | 1.4942e-003 |
| 535 | Mgmt_quant | 1.1413e-001 | 2.4389e-003 |
| 536 | Mgmt_quant | 4.4012e+002 | 1.2136e+001 |
| 537 | Mgmt_quant | 3.9976e+003 | 1.0817e+002 |
| 538 | Mgmt_quant | 1.1480e-001 | 2.4522e-003 |
| 539 | Mgmt_quant | 4.4085e+002 | 1.2641e+001 |
| 540 | Mgmt_quant | 2.3118e+003 | 9.9276e+001 |
| 541 | Mgmt_quant | 2.3249e-001 | 5.3771e-003 |
| 542 | Mgmt_quant | 2.1641e-001 | 6.9508e-003 |
| 543 | Mgmt_quant | 4.8282e+002 | 1.2466e+001 |
| 544 | Mgmt_quant | 4.1949e+002 | 1.2038e+001 |
| 545 | Extra_Std | 1.0036e+004 | 3.0073e+002 |

## Appendix D ASPIC Input: Computer input file for production model run using individual indices without catchability increase.

```
BOT                           Run Mode
'SAFMC Red Grouper (2009) Landings and Indices'
LOGISTIC YLD SSE              Modeltype, conditioning, loss fn
112                           Verbosity
600                           N Bootstraps
0  100000                     Monte Carlo
1d-8                          Conv (fit)
3d-8  8                       Conv (restart), N restarts
1d-4  6                       Conv (F), steps/yr for generalized
4d0                           Max F allowed
1                             Weight for B1>K
5                             Number of series
1d0 1d0 1d0 1d0 1d0           Series weights
0.5d0                         B1/K guess
9.0e5                         MSY guess
9.0e6                         K guess
5d-8 5d-8 5d-8 5d-8 5d-8      q guess
1 1 1 1 1 1 1 1               Estimate flags
2e4  2e7                      MSY bounds
1e5  1e8                      K bounds
82184571                      Random seed
31                            Number of years
"Headboat Index, Total Ldgs whole pounds"
"CC"

1978 1.759765983 955335
1979 1.369317406 929805
1980 0.527515634 829313
1981 0.658599284 584541
1982 0.388530901 871342
1983 0.633433256 1114579
1984 0.367429492 1479356
1985 0.324836811 1019164
1986 0.280150751 724227
1987 0.399154722 482606
1988 0.221327883 541470
1989 0.373735687 619986
1990 0.338876903 371613
1991 0.20358095 324400
1992 0.255114431 453168
1993 0.285489448 593866
1994 0.348457277 515613
1995 0.370812018 594858
1996 0.444732077 844324
1997 0.672490345 878851
1998 0.917816313 905773
1999 0.840206303 715666
2000 0.486162002 679897
2001 0.516703334 687601
2002 0.321141336 788800
2003 0.311031315 830012
2004 0.570024897 907905
2005 1.221625687 711155
2006 0.433775103 1068654
2007 0.458986632 1309290
2008 0.367187045 1782947



"Commercial Logbook Index"
"I1"
1978 -1
1979 -1
```

```
1980 -1
1981 -1
1982 -1
1983 -1
1984 -1
1985 -1
1986 -1
1987 -1
1988 -1
1989 -1
1990 -1
1991 -1
1992 -1
1993 0.39
1994 0.3038
1995 0.48
1996 0.5452
1997 0.598
1998 0.891
1999 1.276
2000 0.903
2001 0.7056
2002 0.738
2003 0.824
2004 0.768
2005 0.688
2006 0.976
2007 1.552
2008 1.88


"MRFSS Index"
"I1"

1978 -1
1979 -1
1980 -1
1981 -1
1982 -1
1983 -1
1984 -1
1985 -1
1986 -1
1987 -1
1988 -1
1989 -1
1990 -1
1991 0.12219232
1992 0.19747501
1993 0.806359175
1994 0.734547416
1995 0.216969493
1996 0.833591466
1997 0.572721991
1998 0.908719612
1999 0.426161777
2000 0.402048766
2001 0.494951681
2002 1.252698979
2003 0.854345093
2004 1.017738616
2005 0.851616957
2006 0.633080003
2007 0.522388708
2008 2.011498337


"MARMAP Index"
"I1"

1978 -1
```

```
1979 -1
1980 -1
1981 -1
1982 -1
1983 -1
1984 -1
1985 -1
1986 -1
1987 -1
1988 -1
1989 -1
1990 0.04355279
1991 0.102022907
1992 0.190107099
1993 0.320250535
1994 0.592514007
1995 1.135130711
1996 1.607233002
1997 0.972868199
1998 0.678605981
1999 1.144846829
2000 1.424535852
2001 1.266821077
2002 0.862626707
2003 0.604988559
2004 0.615216272
2005 0.925008455
2006 1.209910708
2007    1.179062583
2008    0.780631057

"RVC Index"
"I1"

1978 -1
1979 -1
1980 -1
1981 -1
1982 -1
1983 -1
1984 -1
1985 -1
1986 -1
1987 -1
1988 -1
1989 -1
1990 -1
1991 -1
1992 -1
1993 -1
1994 0.183201916
1995 0.123695774
1996 0.146035457
1997 0.24682348
1998 0.269257885
1999 0.692052319
2000 0.840447751
2001 1.690301549
2002 1.866716773
2003 2.734947113
2004 1.909778879
2005 1.365996721
2006 0.671344164
2007    0.985064057
2008    1.27433616
Note: Source of data is file "RG_INPUT_ASPIC.xls" dated 15 SEP 2009, prepared by RTC
```

## Appendix E ASPIC Output: Results of production model run using individual indices without catchability increase.

```
SAFMC Red Grouper (2009) Landings and Indices                                                         Page 1
                                                                                Thursday, 08 Oct 2009 at 00:35:03
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.31)
                                                                                                 BOT program mode
Author:     Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research          LOGISTIC model mode
            101 Pivers Island Road; Beaufort, North Carolina  28516  USA                        YLD conditioning
            Mike.Prager@noaa.gov                                                                SSE 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: e:\rg\assessment\aspic\rg2009_001ci_boot.inp
------------------------------------------------------------------------------------------------------------------------
Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization with bootstrap.
Number of years analyzed:                       31          Number of bootstrap trials:                         600
Number of data series:                           5          Bounds on MSY (min, max):       2.000E+04     2.000E+07
Objective function:                  Least squares          Bounds on K (min, max):         1.000E+05     1.000E+08
Relative conv. criterion (simplex):      1.000E-08          Monte Carlo search mode, trials:        0        100000
Relative conv. criterion (restart):      3.000E-08          Random number seed:                            82184571
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.


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
------------------------------------------------------------------------------------------------------------------------
                                       |
 1  Headboat Index, Tota...            |   1.000
                                       |      31
                                       |
 2  Commercial Logbook Index           |   0.057   1.000
                                       |      16      16
                                       |
 3  MRFSS Index                        |   0.068   0.425   1.000
                                       |      18      16      18
                                       |
 4  MARMAP Index                       |   0.329   0.152   0.000   1.000
                                       |      19      16      18      19
                                       |
 5  RVC Index                          |  -0.143   0.197   0.352  -0.371   1.000
                                       |      15      15      15      15      15
                                       --------------------------------------------------
                                               1       2       3       4       5


GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)
------------------------------------------------------------------------------------------------------------------------
                                                    Weighted               Weighted       Current      Inv. var.     R-squared
Loss component number and title                          SSE        N           MSE        weight         weight       in CPUE

Loss(-1)  SSE in yield                             0.000E+00
Loss(0)   Penalty for B1 > K                       0.000E+00        1           N/A     1.000E+00            N/A
Loss(1)   Headboat Index (1947-2006), Total Ldgs   9.182E+00       31     3.166E-01     1.000E+00      9.601E-01        -0.162
Loss(2)   Commercial Logbook Index                 2.205E+00       16     1.575E-01     1.000E+00      1.930E+00         0.074
Loss(3)   MRFSS Index                              5.283E+00       18     3.302E-01     1.000E+00      9.207E-01         0.072
Loss(4)   MARMAP Index                             6.652E+00       19     3.913E-01     1.000E+00      7.768E-01         0.213
```

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Loss(5) | RVC Index | 8.443E+00 | 15 | 6.494E-01 | 1.000E+00 | 4.681E-01 | 0.165 |

| | | | |
|---|---|---|---|
| TOTAL OBJECTIVE FUNCTION, MSE, RMSE: | 3.17647942E+01 | 3.491E-01 | 5.908E-01 |
| Estimated contrast index (ideal = 1.0): | 0.5768 | C* = (Bmax-Bmin)/K | |
| Estimated nearness index (ideal = 1.0): | 1.0000 | N* = 1 - \|min(B-Bmsy)\|/K | |



MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

| Parameter | | Estimate | User/pgm guess | 2nd guess | Estimated | User guess |
|---|---|---|---|---|---|---|
| B1/K | Starting relative biomass (in 1978) | 3.430E-01 | 5.000E-01 | 9.000E-01 | 1 | 1 |
| MSY | Maximum sustainable yield | 1.004E+06 | 9.000E+05 | 6.887E+05 | 1 | 1 |
| K | Maximum population size | 4.382E+06 | 9.000E+06 | 4.132E+06 | 1 | 1 |
| phi | Shape of production curve (Bmsy/K) | 0.5000 | 0.5000 | ---- | 0 | 1 |
| --------- | Catchability Coefficients by Data Series --------------- | | | | | |
| q(1) | Headboat Index (1947-2006), Total Ldgs | 3.213E-07 | 5.000E-08 | 4.750E-06 | 1 | 1 |
| q(2) | Commercial Logbook Index | 3.786E-07 | 5.000E-08 | 4.750E-06 | 1 | 1 |
| q(3) | MRFSS Index | 3.275E-07 | 5.000E-08 | 4.750E-06 | 1 | 1 |
| q(4) | MARMAP Index | 3.709E-07 | 5.000E-08 | 4.750E-06 | 1 | 1 |
| q(5) | RVC Index | 3.176E-07 | 5.000E-08 | 4.750E-06 | 1 | 1 |

MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

| Parameter | | Estimate | Logistic formula | General formula |
|---|---|---|---|---|
| MSY | Maximum sustainable yield | 1.004E+06 | ---- | ---- |
| Bmsy | Stock biomass giving MSY | 2.191E+06 | K/2 | K*n**(1/(1-n)) |
| Fmsy | Fishing mortality rate at MSY | 4.581E-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(2009)/Bmsy | 7.782E-01 | ---- | ---- |
| F./Fmsy | Ratio: F(2008)/Fmsy | 1.900E+00 | ---- | ---- |
| Fmsy/F. | Ratio: Fmsy/F(2008) | 5.264E-01 | ---- | ---- |
| Y.(Fmsy) | Approx. yield available at Fmsy in 2009 | 7.810E+05 | MSY*B./Bmsy | MSY*B./Bmsy |
| | ...as proportion of MSY | 7.782E-01 | ---- | ---- |
| Ye. | Equilibrium yield available in 2009 | 9.542E+05 | 4*MSY*(B/K-(B/K)**2) | g*MSY*(B/K-(B/K)**n) |
| | ...as proportion of MSY | 9.508E-01 | ---- | ---- |
| --------- | Fishing effort rate at MSY in units of each CE or CC series --------- | | | |
| fmsy(1) | Headboat Index (1947-2006), Total Ldgs | 1.426E+06 | Fmsy/q( 1) | Fmsy/q( 1) |



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 | 1978 | 0.649 | 1.503E+06 | 1.471E+06 | 9.553E+05 | 9.553E+05 | 8.953E+05 | 1.417E+00 | 6.861E-01 |
| 2 | 1979 | 0.657 | 1.443E+06 | 1.416E+06 | 9.298E+05 | 9.298E+05 | 8.780E+05 | 1.434E+00 | 6.587E-01 |
| 3 | 1980 | 0.585 | 1.391E+06 | 1.417E+06 | 8.293E+05 | 8.293E+05 | 8.783E+05 | 1.278E+00 | 6.350E-01 |
| 4 | 1981 | 0.361 | 1.440E+06 | 1.618E+06 | 5.845E+05 | 5.845E+05 | 9.329E+05 | 7.887E-01 | 6.574E-01 |
| 5 | 1982 | 0.472 | 1.788E+06 | 1.845E+06 | 8.713E+05 | 8.713E+05 | 9.784E+05 | 1.031E+00 | 8.164E-01 |
| 6 | 1983 | 0.612 | 1.896E+06 | 1.820E+06 | 1.115E+06 | 1.115E+06 | 9.746E+05 | 1.337E+00 | 8.652E-01 |
| 7 | 1984 | 1.045 | 1.756E+06 | 1.415E+06 | 1.479E+06 | 1.479E+06 | 8.714E+05 | 2.282E+00 | 8.013E-01 |
| 8 | 1985 | 1.053 | 1.148E+06 | 9.677E+05 | 1.019E+06 | 1.019E+06 | 6.889E+05 | 2.299E+00 | 5.239E-01 |
| 9 | 1986 | 0.995 | 8.174E+05 | 7.277E+05 | 7.242E+05 | 7.242E+05 | 5.555E+05 | 2.173E+00 | 3.731E-01 |
| 10 | 1987 | 0.724 | 6.487E+05 | 6.665E+05 | 4.826E+05 | 4.826E+05 | 5.178E+05 | 1.581E+00 | 2.961E-01 |
| 11 | 1988 | 0.803 | 6.838E+05 | 6.741E+05 | 5.415E+05 | 5.415E+05 | 5.226E+05 | 1.753E+00 | 3.121E-01 |
| 12 | 1989 | 1.069 | 6.650E+05 | 5.801E+05 | 6.200E+05 | 6.200E+05 | 4.607E+05 | 2.333E+00 | 3.035E-01 |
| 13 | 1990 | 0.695 | 5.057E+05 | 5.351E+05 | 3.716E+05 | 3.716E+05 | 4.303E+05 | 1.516E+00 | 2.308E-01 |
| 14 | 1991 | 0.495 | 5.644E+05 | 6.548E+05 | 3.244E+05 | 3.244E+05 | 5.097E+05 | 1.082E+00 | 2.576E-01 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15 | 1992 | 0.545 | 7.497E+05 | 8.310E+05 | 4.532E+05 | 4.532E+05 | 6.165E+05 | 1.190E+00 | 3.422E-01 |
| 16 | 1993 | 0.618 | 9.130E+05 | 9.603E+05 | 5.939E+05 | 5.939E+05 | 6.869E+05 | 1.350E+00 | 4.168E-01 |
| 17 | 1994 | 0.455 | 1.006E+06 | 1.133E+06 | 5.156E+05 | 5.156E+05 | 7.684E+05 | 9.937E-01 | 4.592E-01 |
| 18 | 1995 | 0.425 | 1.259E+06 | 1.399E+06 | 5.949E+05 | 5.949E+05 | 8.712E+05 | 9.281E-01 | 5.746E-01 |
| 19 | 1996 | 0.535 | 1.535E+06 | 1.577E+06 | 8.443E+05 | 8.443E+05 | 9.248E+05 | 1.169E+00 | 7.008E-01 |
| 20 | 1997 | 0.533 | 1.616E+06 | 1.649E+06 | 8.789E+05 | 8.789E+05 | 9.422E+05 | 1.163E+00 | 7.375E-01 |
| 21 | 1998 | 0.531 | 1.679E+06 | 1.704E+06 | 9.058E+05 | 9.058E+05 | 9.541E+05 | 1.160E+00 | 7.664E-01 |
| 22 | 1999 | 0.384 | 1.727E+06 | 1.865E+06 | 7.157E+05 | 7.157E+05 | 9.802E+05 | 8.376E-01 | 7.885E-01 |
| 23 | 2000 | 0.315 | 1.992E+06 | 2.161E+06 | 6.799E+05 | 6.799E+05 | 1.002E+06 | 6.869E-01 | 9.092E-01 |
| 24 | 2001 | 0.278 | 2.314E+06 | 2.472E+06 | 6.876E+05 | 6.876E+05 | 9.855E+05 | 6.071E-01 | 1.056E+00 |
| 25 | 2002 | 0.292 | 2.611E+06 | 2.698E+06 | 7.888E+05 | 7.888E+05 | 9.493E+05 | 6.381E-01 | 1.192E+00 |
| 26 | 2003 | 0.294 | 2.772E+06 | 2.821E+06 | 8.300E+05 | 8.300E+05 | 9.203E+05 | 6.422E-01 | 1.265E+00 |
| 27 | 2004 | 0.317 | 2.862E+06 | 2.863E+06 | 9.079E+05 | 9.079E+05 | 9.091E+05 | 6.923E-01 | 1.307E+00 |
| 28 | 2005 | 0.241 | 2.863E+06 | 2.956E+06 | 7.112E+05 | 7.112E+05 | 8.806E+05 | 5.252E-01 | 1.307E+00 |
| 29 | 2006 | 0.364 | 3.033E+06 | 2.932E+06 | 1.069E+06 | 1.069E+06 | 8.880E+05 | 7.955E-01 | 1.384E+00 |
| 30 | 2007 | 0.493 | 2.852E+06 | 2.656E+06 | 1.309E+06 | 1.309E+06 | 9.563E+05 | 1.076E+00 | 1.302E+00 |
| 31 | 2008 | 0.870 | 2.499E+06 | 2.049E+06 | 1.783E+06 | 1.783E+06 | 9.886E+05 | 1.900E+00 | 1.141E+00 |
| 32 | 2009 | | 1.705E+06 | | | | | | 7.782E-01 |

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RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) Headboat Index (1947-2006), Total Ldgs w

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 | 1978 | 1.760E+00 | 4.728E-01 | 0.6493 | 9.553E+05 | 9.553E+05 | -1.31431 | 1.000E+00 |
| 2 | 1979 | 1.369E+00 | 4.549E-01 | 0.6568 | 9.298E+05 | 9.298E+05 | -1.10198 | 1.000E+00 |
| 3 | 1980 | 5.275E-01 | 4.552E-01 | 0.5854 | 8.293E+05 | 8.293E+05 | -0.14735 | 1.000E+00 |
| 4 | 1981 | 6.586E-01 | 5.199E-01 | 0.3613 | 5.845E+05 | 5.845E+05 | -0.23655 | 1.000E+00 |
| 5 | 1982 | 3.885E-01 | 5.928E-01 | 0.4723 | 8.713E+05 | 8.713E+05 | 0.42252 | 1.000E+00 |
| 6 | 1983 | 6.334E-01 | 5.849E-01 | 0.6123 | 1.115E+06 | 1.115E+06 | -0.07972 | 1.000E+00 |
| 7 | 1984 | 3.674E-01 | 4.547E-01 | 1.0454 | 1.479E+06 | 1.479E+06 | 0.21317 | 1.000E+00 |
| 8 | 1985 | 3.248E-01 | 3.109E-01 | 1.0532 | 1.019E+06 | 1.019E+06 | -0.04374 | 1.000E+00 |
| 9 | 1986 | 2.802E-01 | 2.338E-01 | 0.9953 | 7.242E+05 | 7.242E+05 | -0.18078 | 1.000E+00 |
| 10 | 1987 | 3.992E-01 | 2.142E-01 | 0.7241 | 4.826E+05 | 4.826E+05 | -0.62260 | 1.000E+00 |
| 11 | 1988 | 2.213E-01 | 2.166E-01 | 0.8032 | 5.415E+05 | 5.415E+05 | -0.02151 | 1.000E+00 |
| 12 | 1989 | 3.737E-01 | 1.864E-01 | 1.0687 | 6.200E+05 | 6.200E+05 | -0.69560 | 1.000E+00 |
| 13 | 1990 | 3.389E-01 | 1.719E-01 | 0.6945 | 3.716E+05 | 3.716E+05 | -0.67852 | 1.000E+00 |
| 14 | 1991 | 2.036E-01 | 2.104E-01 | 0.4954 | 3.244E+05 | 3.244E+05 | 0.03291 | 1.000E+00 |
| 15 | 1992 | 2.551E-01 | 2.670E-01 | 0.5453 | 4.532E+05 | 4.532E+05 | 0.04565 | 1.000E+00 |
| 16 | 1993 | 2.855E-01 | 3.086E-01 | 0.6184 | 5.939E+05 | 5.939E+05 | 0.07778 | 1.000E+00 |
| 17 | 1994 | 3.485E-01 | 3.640E-01 | 0.4552 | 5.156E+05 | 5.156E+05 | 0.04353 | 1.000E+00 |
| 18 | 1995 | 3.708E-01 | 4.496E-01 | 0.4252 | 5.949E+05 | 5.949E+05 | 0.19263 | 1.000E+00 |
| 19 | 1996 | 4.447E-01 | 5.068E-01 | 0.5353 | 8.443E+05 | 8.443E+05 | 0.13067 | 1.000E+00 |
| 20 | 1997 | 6.725E-01 | 5.298E-01 | 0.5330 | 8.789E+05 | 8.789E+05 | -0.23840 | 1.000E+00 |
| 21 | 1998 | 9.178E-01 | 5.477E-01 | 0.5314 | 9.058E+05 | 9.058E+05 | -0.51628 | 1.000E+00 |
| 22 | 1999 | 8.402E-01 | 5.993E-01 | 0.3837 | 7.157E+05 | 7.157E+05 | -0.33791 | 1.000E+00 |
| 23 | 2000 | 4.862E-01 | 6.943E-01 | 0.3147 | 6.799E+05 | 6.799E+05 | 0.35638 | 1.000E+00 |
| 24 | 2001 | 5.167E-01 | 7.944E-01 | 0.2781 | 6.876E+05 | 6.876E+05 | 0.43012 | 1.000E+00 |
| 25 | 2002 | 3.211E-01 | 8.671E-01 | 0.2923 | 7.888E+05 | 7.888E+05 | 0.99322 | 1.000E+00 |
| 26 | 2003 | 3.110E-01 | 9.065E-01 | 0.2942 | 8.300E+05 | 8.300E+05 | 1.06973 | 1.000E+00 |
| 27 | 2004 | 5.700E-01 | 9.199E-01 | 0.3171 | 9.079E+05 | 9.079E+05 | 0.47860 | 1.000E+00 |
| 28 | 2005 | 1.222E+00 | 9.499E-01 | 0.2406 | 7.112E+05 | 7.112E+05 | -0.25163 | 1.000E+00 |
| 29 | 2006 | 4.338E-01 | 9.423E-01 | 0.3644 | 1.069E+06 | 1.069E+06 | 0.77576 | 1.000E+00 |
| 30 | 2007 | 4.590E-01 | 8.533E-01 | 0.4930 | 1.309E+06 | 1.309E+06 | 0.62009 | 1.000E+00 |
| 31 | 2008 | 3.672E-01 | 6.583E-01 | 0.8703 | 1.783E+06 | 1.783E+06 | 0.58374 | 1.000E+00 |

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RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED) Commercial Logbook Index

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 | 1978 | 0.000E+00 | 0.000E+00 | -- | * | 5.571E-01 | 0.00000 | 1.000E+00 |
| 2 | 1979 | 0.000E+00 | 0.000E+00 | -- | * | 5.360E-01 | 0.00000 | 1.000E+00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | 1980 | 0.000E+00 | 0.000E+00 | -- | * | 5.364E-01 | 0.00000 | 1.000E+00 |
| 4 | 1981 | 0.000E+00 | 0.000E+00 | -- | * | 6.125E-01 | 0.00000 | 1.000E+00 |
| 5 | 1982 | 0.000E+00 | 0.000E+00 | -- | * | 6.985E-01 | 0.00000 | 1.000E+00 |
| 6 | 1983 | 0.000E+00 | 0.000E+00 | -- | * | 6.892E-01 | 0.00000 | 1.000E+00 |
| 7 | 1984 | 0.000E+00 | 0.000E+00 | -- | * | 5.358E-01 | 0.00000 | 1.000E+00 |
| 8 | 1985 | 0.000E+00 | 0.000E+00 | -- | * | 3.664E-01 | 0.00000 | 1.000E+00 |
| 9 | 1986 | 0.000E+00 | 0.000E+00 | -- | * | 2.755E-01 | 0.00000 | 1.000E+00 |
| 10 | 1987 | 0.000E+00 | 0.000E+00 | -- | * | 2.523E-01 | 0.00000 | 1.000E+00 |
| 11 | 1988 | 0.000E+00 | 0.000E+00 | -- | * | 2.552E-01 | 0.00000 | 1.000E+00 |
| 12 | 1989 | 0.000E+00 | 0.000E+00 | -- | * | 2.196E-01 | 0.00000 | 1.000E+00 |
| 13 | 1990 | 0.000E+00 | 0.000E+00 | -- | * | 2.026E-01 | 0.00000 | 1.000E+00 |
| 14 | 1991 | 0.000E+00 | 0.000E+00 | -- | * | 2.479E-01 | 0.00000 | 1.000E+00 |
| 15 | 1992 | 0.000E+00 | 0.000E+00 | -- | * | 3.146E-01 | 0.00000 | 1.000E+00 |
| 16 | 1993 | 1.000E+00 | 1.000E+00 | -- | 3.900E-01 | 3.636E-01 | 0.07013 | 1.000E+00 |
| 17 | 1994 | 1.000E+00 | 1.000E+00 | -- | 3.038E-01 | 4.288E-01 | -0.34471 | 1.000E+00 |
| 18 | 1995 | 1.000E+00 | 1.000E+00 | -- | 4.800E-01 | 5.297E-01 | -0.09858 | 1.000E+00 |
| 19 | 1996 | 1.000E+00 | 1.000E+00 | -- | 5.452E-01 | 5.972E-01 | -0.09103 | 1.000E+00 |
| 20 | 1997 | 1.000E+00 | 1.000E+00 | -- | 5.980E-01 | 6.243E-01 | -0.04303 | 1.000E+00 |
| 21 | 1998 | 1.000E+00 | 1.000E+00 | -- | 8.910E-01 | 6.453E-01 | 0.32259 | 1.000E+00 |
| 22 | 1999 | 1.000E+00 | 1.000E+00 | -- | 1.276E+00 | 7.061E-01 | 0.59171 | 1.000E+00 |
| 23 | 2000 | 1.000E+00 | 1.000E+00 | -- | 9.030E-01 | 8.181E-01 | 0.09877 | 1.000E+00 |
| 24 | 2001 | 1.000E+00 | 1.000E+00 | -- | 7.056E-01 | 9.360E-01 | -0.28258 | 1.000E+00 |
| 25 | 2002 | 1.000E+00 | 1.000E+00 | -- | 7.380E-01 | 1.022E+00 | -0.32519 | 1.000E+00 |
| 26 | 2003 | 1.000E+00 | 1.000E+00 | -- | 8.240E-01 | 1.068E+00 | -0.25949 | 1.000E+00 |
| 27 | 2004 | 1.000E+00 | 1.000E+00 | -- | 7.680E-01 | 1.084E+00 | -0.34453 | 1.000E+00 |
| 28 | 2005 | 1.000E+00 | 1.000E+00 | -- | 6.880E-01 | 1.119E+00 | -0.48656 | 1.000E+00 |
| 29 | 2006 | 1.000E+00 | 1.000E+00 | -- | 9.760E-01 | 1.110E+00 | -0.12886 | 1.000E+00 |
| 30 | 2007 | 1.000E+00 | 1.000E+00 | -- | 1.552E+00 | 1.005E+00 | 0.43415 | 1.000E+00 |
| 31 | 2008 | 1.000E+00 | 1.000E+00 | -- | 1.880E+00 | 7.756E-01 | 0.88538 | 1.000E+00 |

* Asterisk indicates missing value(s).

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RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED) MRFSS Index

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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 | 1978 | 0.000E+00 | 0.000E+00 | -- | * | 4.818E-01 | 0.00000 | 1.000E+00 |
| 2 | 1979 | 0.000E+00 | 0.000E+00 | -- | * | 4.636E-01 | 0.00000 | 1.000E+00 |
| 3 | 1980 | 0.000E+00 | 0.000E+00 | -- | * | 4.639E-01 | 0.00000 | 1.000E+00 |
| 4 | 1981 | 0.000E+00 | 0.000E+00 | -- | * | 5.298E-01 | 0.00000 | 1.000E+00 |
| 5 | 1982 | 0.000E+00 | 0.000E+00 | -- | * | 6.041E-01 | 0.00000 | 1.000E+00 |
| 6 | 1983 | 0.000E+00 | 0.000E+00 | -- | * | 5.961E-01 | 0.00000 | 1.000E+00 |
| 7 | 1984 | 0.000E+00 | 0.000E+00 | -- | * | 4.634E-01 | 0.00000 | 1.000E+00 |
| 8 | 1985 | 0.000E+00 | 0.000E+00 | -- | * | 3.169E-01 | 0.00000 | 1.000E+00 |
| 9 | 1986 | 0.000E+00 | 0.000E+00 | -- | * | 2.383E-01 | 0.00000 | 1.000E+00 |
| 10 | 1987 | 0.000E+00 | 0.000E+00 | -- | * | 2.183E-01 | 0.00000 | 1.000E+00 |
| 11 | 1988 | 0.000E+00 | 0.000E+00 | -- | * | 2.208E-01 | 0.00000 | 1.000E+00 |
| 12 | 1989 | 0.000E+00 | 0.000E+00 | -- | * | 1.900E-01 | 0.00000 | 1.000E+00 |
| 13 | 1990 | 0.000E+00 | 0.000E+00 | -- | * | 1.752E-01 | 0.00000 | 1.000E+00 |
| 14 | 1991 | 1.000E+00 | 1.000E+00 | -- | 1.222E-01 | 2.144E-01 | -0.56230 | 1.000E+00 |
| 15 | 1992 | 1.000E+00 | 1.000E+00 | -- | 1.975E-01 | 2.721E-01 | -0.32067 | 1.000E+00 |
| 16 | 1993 | 1.000E+00 | 1.000E+00 | -- | 8.064E-01 | 3.145E-01 | 0.94163 | 1.000E+00 |
| 17 | 1994 | 1.000E+00 | 1.000E+00 | -- | 7.345E-01 | 3.709E-01 | 0.68329 | 1.000E+00 |
| 18 | 1995 | 1.000E+00 | 1.000E+00 | -- | 2.170E-01 | 4.582E-01 | -0.74749 | 1.000E+00 |
| 19 | 1996 | 1.000E+00 | 1.000E+00 | -- | 8.336E-01 | 5.165E-01 | 0.47868 | 1.000E+00 |
| 20 | 1997 | 1.000E+00 | 1.000E+00 | -- | 5.727E-01 | 5.400E-01 | 0.05889 | 1.000E+00 |
| 21 | 1998 | 1.000E+00 | 1.000E+00 | -- | 9.087E-01 | 5.582E-01 | 0.48740 | 1.000E+00 |
| 22 | 1999 | 1.000E+00 | 1.000E+00 | -- | 4.262E-01 | 6.107E-01 | -0.35984 | 1.000E+00 |
| 23 | 2000 | 1.000E+00 | 1.000E+00 | -- | 4.020E-01 | 7.076E-01 | -0.56527 | 1.000E+00 |
| 24 | 2001 | 1.000E+00 | 1.000E+00 | -- | 4.950E-01 | 8.096E-01 | -0.49206 | 1.000E+00 |
| 25 | 2002 | 1.000E+00 | 1.000E+00 | -- | 1.253E+00 | 8.836E-01 | 0.34903 | 1.000E+00 |
| 26 | 2003 | 1.000E+00 | 1.000E+00 | -- | 8.543E-01 | 9.238E-01 | -0.07821 | 1.000E+00 |
| 27 | 2004 | 1.000E+00 | 1.000E+00 | -- | 1.018E+00 | 9.375E-01 | 0.08213 | 1.000E+00 |
| 28 | 2005 | 1.000E+00 | 1.000E+00 | -- | 8.516E-01 | 9.680E-01 | -0.12809 | 1.000E+00 |
| 29 | 2006 | 1.000E+00 | 1.000E+00 | -- | 6.331E-01 | 9.603E-01 | -0.41662 | 1.000E+00 |
| 30 | 2007 | 1.000E+00 | 1.000E+00 | -- | 5.224E-01 | 8.696E-01 | -0.50963 | 1.000E+00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 31 | 2008 | 1.000E+00 | 1.000E+00 | -- | 2.011E+00 | 6.708E-01 | 1.09810 | 1.000E+00 |

* Asterisk indicates missing value(s).
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RESULTS FOR DATA SERIES # 4 (NON-BOOTSTRAPPED) MARMAP Index

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 | 1978 | 0.000E+00 | 0.000E+00 | -- | * | 5.457E-01 | 0.00000 | 1.000E+00 |
| 2 | 1979 | 0.000E+00 | 0.000E+00 | -- | * | 5.251E-01 | 0.00000 | 1.000E+00 |
| 3 | 1980 | 0.000E+00 | 0.000E+00 | -- | * | 5.255E-01 | 0.00000 | 1.000E+00 |
| 4 | 1981 | 0.000E+00 | 0.000E+00 | -- | * | 6.001E-01 | 0.00000 | 1.000E+00 |
| 5 | 1982 | 0.000E+00 | 0.000E+00 | -- | * | 6.843E-01 | 0.00000 | 1.000E+00 |
| 6 | 1983 | 0.000E+00 | 0.000E+00 | -- | * | 6.751E-01 | 0.00000 | 1.000E+00 |
| 7 | 1984 | 0.000E+00 | 0.000E+00 | -- | * | 5.249E-01 | 0.00000 | 1.000E+00 |
| 8 | 1985 | 0.000E+00 | 0.000E+00 | -- | * | 3.589E-01 | 0.00000 | 1.000E+00 |
| 9 | 1986 | 0.000E+00 | 0.000E+00 | -- | * | 2.699E-01 | 0.00000 | 1.000E+00 |
| 10 | 1987 | 0.000E+00 | 0.000E+00 | -- | * | 2.472E-01 | 0.00000 | 1.000E+00 |
| 11 | 1988 | 0.000E+00 | 0.000E+00 | -- | * | 2.500E-01 | 0.00000 | 1.000E+00 |
| 12 | 1989 | 0.000E+00 | 0.000E+00 | -- | * | 2.152E-01 | 0.00000 | 1.000E+00 |
| 13 | 1990 | 1.000E+00 | 1.000E+00 | -- | 4.355E-02 | 1.985E-01 | -1.51661 | 1.000E+00 |
| 14 | 1991 | 1.000E+00 | 1.000E+00 | -- | 1.020E-01 | 2.428E-01 | -0.86725 | 1.000E+00 |
| 15 | 1992 | 1.000E+00 | 1.000E+00 | -- | 1.901E-01 | 3.082E-01 | -0.48324 | 1.000E+00 |
| 16 | 1993 | 1.000E+00 | 1.000E+00 | -- | 3.203E-01 | 3.562E-01 | -0.10635 | 1.000E+00 |
| 17 | 1994 | 1.000E+00 | 1.000E+00 | -- | 5.925E-01 | 4.201E-01 | 0.34386 | 1.000E+00 |
| 18 | 1995 | 1.000E+00 | 1.000E+00 | -- | 1.135E+00 | 5.189E-01 | 0.78271 | 1.000E+00 |
| 19 | 1996 | 1.000E+00 | 1.000E+00 | -- | 1.607E+00 | 5.850E-01 | 1.01065 | 1.000E+00 |
| 20 | 1997 | 1.000E+00 | 1.000E+00 | -- | 9.729E-01 | 6.116E-01 | 0.46419 | 1.000E+00 |
| 21 | 1998 | 1.000E+00 | 1.000E+00 | -- | 6.786E-01 | 6.322E-01 | 0.07086 | 1.000E+00 |
| 22 | 1999 | 1.000E+00 | 1.000E+00 | -- | 1.145E+00 | 6.917E-01 | 0.50382 | 1.000E+00 |
| 23 | 2000 | 1.000E+00 | 1.000E+00 | -- | 1.425E+00 | 8.014E-01 | 0.57521 | 1.000E+00 |
| 24 | 2001 | 1.000E+00 | 1.000E+00 | -- | 1.267E+00 | 9.170E-01 | 0.32320 | 1.000E+00 |
| 25 | 2002 | 1.000E+00 | 1.000E+00 | -- | 8.626E-01 | 1.001E+00 | -0.14859 | 1.000E+00 |
| 26 | 2003 | 1.000E+00 | 1.000E+00 | -- | 6.050E-01 | 1.046E+00 | -0.54788 | 1.000E+00 |
| 27 | 2004 | 1.000E+00 | 1.000E+00 | -- | 6.152E-01 | 1.062E+00 | -0.54578 | 1.000E+00 |
| 28 | 2005 | 1.000E+00 | 1.000E+00 | -- | 9.250E-01 | 1.096E+00 | -0.16997 | 1.000E+00 |
| 29 | 2006 | 1.000E+00 | 1.000E+00 | -- | 1.210E+00 | 1.088E+00 | 0.10654 | 1.000E+00 |
| 30 | 2007 | 1.000E+00 | 1.000E+00 | -- | 1.179E+00 | 9.849E-01 | 0.17989 | 1.000E+00 |
| 31 | 2008 | 1.000E+00 | 1.000E+00 | -- | 7.806E-01 | 7.598E-01 | 0.02702 | 1.000E+00 |

* Asterisk indicates missing value(s).
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RESULTS FOR DATA SERIES # 5 (NON-BOOTSTRAPPED) RVC Index

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 | 1978 | 0.000E+00 | 0.000E+00 | -- | * | 4.673E-01 | 0.00000 | 1.000E+00 |
| 2 | 1979 | 0.000E+00 | 0.000E+00 | -- | * | 4.496E-01 | 0.00000 | 1.000E+00 |
| 3 | 1980 | 0.000E+00 | 0.000E+00 | -- | * | 4.499E-01 | 0.00000 | 1.000E+00 |
| 4 | 1981 | 0.000E+00 | 0.000E+00 | -- | * | 5.138E-01 | 0.00000 | 1.000E+00 |
| 5 | 1982 | 0.000E+00 | 0.000E+00 | -- | * | 5.859E-01 | 0.00000 | 1.000E+00 |
| 6 | 1983 | 0.000E+00 | 0.000E+00 | -- | * | 5.781E-01 | 0.00000 | 1.000E+00 |
| 7 | 1984 | 0.000E+00 | 0.000E+00 | -- | * | 4.494E-01 | 0.00000 | 1.000E+00 |
| 8 | 1985 | 0.000E+00 | 0.000E+00 | -- | * | 3.073E-01 | 0.00000 | 1.000E+00 |
| 9 | 1986 | 0.000E+00 | 0.000E+00 | -- | * | 2.311E-01 | 0.00000 | 1.000E+00 |
| 10 | 1987 | 0.000E+00 | 0.000E+00 | -- | * | 2.117E-01 | 0.00000 | 1.000E+00 |
| 11 | 1988 | 0.000E+00 | 0.000E+00 | -- | * | 2.141E-01 | 0.00000 | 1.000E+00 |
| 12 | 1989 | 0.000E+00 | 0.000E+00 | -- | * | 1.842E-01 | 0.00000 | 1.000E+00 |
| 13 | 1990 | 0.000E+00 | 0.000E+00 | -- | * | 1.699E-01 | 0.00000 | 1.000E+00 |
| 14 | 1991 | 0.000E+00 | 0.000E+00 | -- | * | 2.079E-01 | 0.00000 | 1.000E+00 |
| 15 | 1992 | 0.000E+00 | 0.000E+00 | -- | * | 2.639E-01 | 0.00000 | 1.000E+00 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 16 | 1993 | 0.000E+00 | 0.000E+00 | -- | * | 3.050E-01 | 0.00000 | 1.000E+00 |
| 17 | 1994 | 1.000E+00 | 1.000E+00 | -- | 1.832E-01 | 3.597E-01 | -0.67474 | 1.000E+00 |
| 18 | 1995 | 1.000E+00 | 1.000E+00 | -- | 1.237E-01 | 4.444E-01 | -1.27879 | 1.000E+00 |
| 19 | 1996 | 1.000E+00 | 1.000E+00 | -- | 1.460E-01 | 5.009E-01 | -1.23258 | 1.000E+00 |
| 20 | 1997 | 1.000E+00 | 1.000E+00 | -- | 2.468E-01 | 5.237E-01 | -0.75220 | 1.000E+00 |
| 21 | 1998 | 1.000E+00 | 1.000E+00 | -- | 2.693E-01 | 5.413E-01 | -0.69833 | 1.000E+00 |
| 22 | 1999 | 1.000E+00 | 1.000E+00 | -- | 6.921E-01 | 5.923E-01 | 0.15564 | 1.000E+00 |
| 23 | 2000 | 1.000E+00 | 1.000E+00 | -- | 8.404E-01 | 6.862E-01 | 0.20273 | 1.000E+00 |
| 24 | 2001 | 1.000E+00 | 1.000E+00 | -- | 1.690E+00 | 7.852E-01 | 0.76678 | 1.000E+00 |
| 25 | 2002 | 1.000E+00 | 1.000E+00 | -- | 1.867E+00 | 8.570E-01 | 0.77855 | 1.000E+00 |
| 26 | 2003 | 1.000E+00 | 1.000E+00 | -- | 2.735E+00 | 8.960E-01 | 1.11596 | 1.000E+00 |
| 27 | 2004 | 1.000E+00 | 1.000E+00 | -- | 1.910E+00 | 9.092E-01 | 0.74217 | 1.000E+00 |
| 28 | 2005 | 1.000E+00 | 1.000E+00 | -- | 1.366E+00 | 9.388E-01 | 0.37504 | 1.000E+00 |
| 29 | 2006 | 1.000E+00 | 1.000E+00 | -- | 6.713E-01 | 9.313E-01 | -0.32730 | 1.000E+00 |
| 30 | 2007 | 1.000E+00 | 1.000E+00 | -- | 9.851E-01 | 8.434E-01 | 0.15530 | 1.000E+00 |
| 31 | 2008 | 1.000E+00 | 1.000E+00 | -- | 1.274E+00 | 6.506E-01 | 0.67228 | 1.000E+00 |

* Asterisk indicates missing value(s).
SAFMC Red Grouper (2009) Landings and Indices Page 9

ESTIMATES FROM BOOTSTRAPPED ANALYSIS

| Param name | Point estimate | Estimated bias in pt estimate | Estimated relative bias | Bias-corrected approximate confidence limits 80% lower | 80% upper | 50% lower | 50% upper | Inter-quartile range | Relative IQ range |
|---|---|---|---|---|---|---|---|---|---|
| B1/K | 3.430E-01 | 7.164E-04 | 0.21% | 3.032E-01 | 3.999E-01 | 3.281E-01 | 3.757E-01 | 4.758E-02 | 0.139 |
| K | 4.382E+06 | 9.101E+05 | 20.77% | 3.554E+06 | 7.290E+06 | 3.905E+06 | 5.574E+06 | 1.669E+06 | 0.381 |
| q(1) | 3.213E-07 | 6.878E-09 | 2.14% | 1.931E-07 | 4.000E-07 | 2.508E-07 | 3.584E-07 | 1.075E-07 | 0.335 |
| q(2) | 3.786E-07 | 1.152E-08 | 3.04% | 2.275E-07 | 5.366E-07 | 2.978E-07 | 4.561E-07 | 1.583E-07 | 0.418 |
| q(3) | 3.275E-07 | 1.046E-08 | 3.19% | 1.982E-07 | 4.550E-07 | 2.524E-07 | 3.912E-07 | 1.389E-07 | 0.424 |
| q(4) | 3.709E-07 | 1.275E-08 | 3.44% | 2.208E-07 | 5.081E-07 | 2.832E-07 | 4.335E-07 | 1.502E-07 | 0.405 |
| q(5) | 3.176E-07 | 1.837E-08 | 5.78% | 1.776E-07 | 4.388E-07 | 2.388E-07 | 3.700E-07 | 1.312E-07 | 0.413 |
| MSY | 1.004E+06 | 2.466E+05 | 24.57% | 9.419E+05 | 1.062E+06 | 9.642E+05 | 1.022E+06 | 5.819E+04 | 0.058 |
| Ye(2009) | 9.542E+05 | -1.968E+04 | -2.06% | 7.640E+05 | 1.108E+06 | 8.528E+05 | 1.040E+06 | 1.868E+05 | 0.196 |
| Y.@Fmsy | 7.810E+05 | 4.553E+05 | 58.30% | 5.368E+05 | 1.182E+06 | 6.388E+05 | 9.724E+05 | 3.335E+05 | 0.427 |
| Bmsy | 2.191E+06 | 4.550E+05 | 20.77% | 1.777E+06 | 3.645E+06 | 1.952E+06 | 2.787E+06 | 8.346E+05 | 0.381 |
| Fmsy | 4.581E-01 | 1.919E-02 | 4.19% | 2.964E-01 | 5.521E-01 | 3.657E-01 | 5.081E-01 | 1.424E-01 | 0.311 |
| fmsy(1) | 1.426E+06 | 1.175E+06 | 82.42% | 1.227E+06 | 1.705E+06 | 1.324E+06 | 1.562E+06 | 2.376E+05 | 0.167 |
| fmsy(2) | 1.210E+06 | 6.234E+05 | 51.52% | 9.379E+05 | 1.573E+06 | 1.053E+06 | 1.379E+06 | 3.260E+05 | 0.269 |
| fmsy(3) | 1.399E+06 | 7.998E+05 | 57.17% | 1.080E+06 | 1.799E+06 | 1.216E+06 | 1.583E+06 | 3.673E+05 | 0.263 |
| fmsy(4) | 1.235E+06 | 7.526E+05 | 60.94% | 9.581E+05 | 1.554E+06 | 1.077E+06 | 1.378E+06 | 3.008E+05 | 0.244 |
| fmsy(5) | 1.442E+06 | 7.091E+05 | 49.16% | 1.114E+06 | 1.901E+06 | 1.247E+06 | 1.657E+06 | 4.093E+05 | 0.284 |
| B./Bmsy | 7.782E-01 | -1.065E-02 | -1.37% | 5.670E-01 | 1.077E+00 | 6.771E-01 | 9.432E-01 | 2.661E-01 | 0.342 |
| F./Fmsy | 1.900E+00 | 7.246E-02 | 3.81% | 1.371E+00 | 2.423E+00 | 1.617E+00 | 2.175E+00 | 5.581E-01 | 0.294 |
| Ye./MSY | 9.508E-01 | -6.213E-02 | -6.53% | 8.169E-01 | 9.989E-01 | 9.038E-01 | 9.923E-01 | 8.850E-02 | 0.093 |
| q2/q1 | 1.178E+00 | 2.462E-02 | 2.09% | 8.909E-01 | 1.518E+00 | 1.006E+00 | 1.341E+00 | 3.341E-01 | 0.284 |
| q3/q1 | 1.019E+00 | 2.013E-02 | 1.98% | 7.835E-01 | 1.281E+00 | 8.838E-01 | 1.153E+00 | 2.690E-01 | 0.264 |
| q4/q1 | 1.154E+00 | 2.027E-02 | 1.76% | 9.273E-01 | 1.539E+00 | 1.041E+00 | 1.342E+00 | 3.012E-01 | 0.261 |
| q5/q1 | 9.884E-01 | 4.450E-02 | 4.50% | 7.364E-01 | 1.281E+00 | 8.558E-01 | 1.113E+00 | 2.576E-01 | 0.261 |

INFORMATION FOR REPAST (Prager, Porch, Shertzer, & Caddy. 2003. NAJFM 23: 349-361)

| | |
|---|---|
| Unitless limit reference point in F (Fmsy/F.): | 0.5264 |
| CV of above (from bootstrap distribution): | 4.240 |

NOTES ON BOOTSTRAPPED ESTIMATES:

- Bootstrap results were computed from 600 trials.
- Results are conditional on bounds set on MSY and K in the input file.
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The default 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.

```
- Bias estimates are typically of high variance and therefore may be misleading.

Trials replaced for lack of convergence:      0          Trials replaced for MSY out of bounds:              125
Trials replaced for q out-of-bounds:          0
Trials replaced for K out-of-bounds:         28          Residual-adjustment factor:                      1.0430

Elapsed time: 1 hours, 36 minutes, 7 seconds.
```

# SEDAR

## Southeast Data, Assessment, and Review

---

## SEDAR 19

# South Atlantic Red Grouper

## SECTION IV: Research Recommendations

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

# 1. DATA WORKSHOP RESEARCH RECOMMENDATIONS

## *1.1 LIFE HISTORY WORKING GROUP*

Research recommendations.

- The DW LH WG recognized the value of continuing the age workshops and exchange of otoliths in preparation of SEDAR data workshops. This will be especially important for species that have been recognized as relatively difficult to age.
- The DW LH WG also recognizes the value of similar workshops to discuss the interpretation of reproductive samples, and the possible exchange of histological sections between labs in preparation of SEDAR Data Workshops. This will be especially important for species that have been recognized as relatively difficult to stage.
- Since fecundity information is only available from the GOM and does not include estimates for ages less than 5 years, the DW LH WG recommends initiating a study to estimate fecundity and further identify spawning locations for all age classes in both the GOM and Atlantic populations.
- The data presented at the DW suggest a possible disjunct distribution in the Atlantic stock (NC-FL). The DW LH WG recommends a study to further investigate this by use of genetic, tagging, and other techniques.
- Improved collection and collection strategy for hard parts, in particular from the recreational sector.
- Increase of Fishery Independent data to include the entire area of red grouper distribution in the Atlantic.
- Virtually no information on the life history and distribution of juvenile red grouper (i.e. ages 0-2) is available. The DW LH WG recommends a study to gather information on these early stages.

Procedural recommendation:

- The DW recommends that the report of the natural mortality workshop organized by NMFS (Seattle, WA, August 2009) be a made available to the DW LHW before the next SEDAR as a guide in the discussions concerning natural mortality.

### *1.2 COMMERCIAL STATISTICS WORKING GROUP*

• Still need observer coverage for the snapper-grouper fishery

– 5-10% allocated by strata within states

– get maximum information from fish

• Expand TIP sampling to better cover all statistical strata

– Predominantly by H&L gear

– In that sense, we have decent coverage for lengths

• Trade off with lengths versus ages, need for more ages (i.e., hard parts)

• Workshop to resolve historical commercial landings for a suite of snapper-grouper species

– Monroe County (SA-GoM division)

– Historical species identification (mis-identification and unclassified)

### *1.3 RECREATIONAL STATISTICS WORKING GROUP*

-Need more detailed information about where the fish are caught (depth, spatial, etc.)

-More detailed information on recreational discards, such as hooking location, depth fished, etc. that are likely to impact discard mortality and discard size/age.

- Additional information on sector (mode) differences.

### *1.4 INDICES OF ABUNDANCE WORKING GROUP*

1. Expand fishery independent sampling to provide indices of abundance. The DW Panel noted that this recommendation has been the first on the list for virtually all previous SEDAR's in the south Atlantic.

2. Examine variability in catchability
    - Environmental effects
    - Changes over time associated with increases in technology and potential changes in fishing practices. This is of particular importance when considering fishery dependent indices.
    - Potential density-dependent changes in catchability. This is of particular importance for schooling fishes.

3. Conduct studies to examine how the behavior of fisherman changes over time and how these changes relate to factors such as gas prices and economic trends

4. Consider optimal sample allocation for species of interest when designing surveys to increase sample sizes.

5. Examine possible temporal changes in species assemblages.  Such changes could influence how the Stephens and MacCall method is applied when determining effective effort.

6. Continue to expand fishery dependent at-sea-observer surveys.  Such surveys collects discard information, which would provide for a more accurate index of abundance.

## 2. ASSESSMENT WORKSHOP RESEARCH RECOMMENDATIONS

1. Expanded fishery independent surveys of reef fishes in the Southeast, including red grouper, would greatly improve stock assessments.
2. More information on age/length composition of discards from various fleets would improve stock assessment of reef fishes in the Southeast, including red grouper.
3. More information on discard mortality rates would improve stock assessment of reef fishes in the Southeast, including red grouper.
4. The apparent stock separation of red grouper deserves further consideration.  It may be desirable to develop appropriate spatial assessment models, if corresponding data requirements could be met.  It may be desirable to research methods of spatial management (whether or not the assessment is spatially explicit).
5. More detailed spatial resolution of fishing effort would likely improve assessments.
6. Information on historical landings of reef fishes in the Southeast could lead to improved understanding of stock productivity and dynamics of stock assemblages.
7. Methods to characterize uncertainty in assessment results deserve further consideration.  For avoiding overfishing, characterizing uncertainty is more than an academic exercise, particularly when relying on probabilistic methods to set catch levels.
8. Effects of new management measures (Amendment 16, seasonal closure) should be monitored.

## 3. REVIEW PANEL RESEARCH RECOMMENDATIONS

Members of the Data and Assessment workshops identified a number of shortcomings in the data available for red grouper, and the Review Panel (RP) felt that future research efforts should be focused on obtaining more precise estimates for parameters that displayed a strong potential effect and high uncertainty on the output of the assessment models.  This opinion was reinforced by the fact that red grouper are not abundant, nor do they represent substantial fisheries; hence data acquisition efforts are hampered by both low abundances and low availability of samples from fishery sources. Many of the research recommendations have a reasonable biological basis, but a number are not directly linked to the assessment models used in the stock assessment. The RP felt that future research should focus on discard mortality, especially from the recreational fishery, acquiring better fishery-independent abundance estimates, improved methods for estimating catch by recreational anglers, improved age and growth data, and efforts to quantify linkages (i.e., recruitment effects) between western Caribbean and US stocks of red grouper. Given that fecundity data are not currently used in the stock assessment models, nor are histological gonadal stages utilized other than to distinguish mature from immature specimens, we suggest that these studies have lower priority than the research needs identified above. Studies directed towards identifying locations of spawning aggregations may be difficult to conduct for a species with low abundance, although such studies would be useful if spatially-based fisheries closures were to be employed for red grouper.

The RP recommends a strategic approach should be taken towards research for the snapper-grouper complex. The criteria which would be used to evaluate the strategy should be:

- Efficiency: for example sampling for sex ratio, length, and age could cover a range of species simultaneously.
- Impact: the resulting information should have clear implications for decision making.

To achieve this, managers and scientists will both need to be involved in developing a strategic research plan.

The RP recommends future research to determine which F metric behaves best under this management system.

# SEDAR

## Southeast Data, Assessment, and Review

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## SEDAR 19

# South Atlantic Red Grouper

## SECTION V: Review Workshop Report

SEDAR
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North Charleston, SC 29405

# 1. INTRODUCTION

## 1.1. Workshop Time and Place

The SEDAR 19 Review Workshop was held January 25-29, 2010 in Savannah, Georgia.

## 1.2. Terms of Reference

1. Evaluate the adequacy, appropriateness, and application of data used in the assessment.
2. Evaluate the adequacy, appropriateness, and application of methods used to assess the stock.
3. Recommend appropriate estimates of stock abundance, biomass, and exploitation.
4. Evaluate the methods used to estimate population benchmarks and management parameters (*e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies*); recommend appropriate management benchmarks and provide estimated values for management benchmarks, a range of ABC, and declarations of stock status.
   A. In addition, for black grouper, the Gulf Council requests that the Panel evaluate the methods used to estimate OFL.
5. Evaluate the adequacy, appropriateness, and application of the methods used to project future population status; recommend appropriate estimates of future stock condition (e.g., exploitation, abundance, biomass).
6. Evaluate the adequacy, appropriateness, and application of methods used to characterize uncertainty in estimated parameters. Provide measures of uncertainty for estimated parameters*. Ensure that the implications of uncertainty in technical conclusions are clearly stated.
7. Ensure that stock assessment results are clearly and accurately presented in the Stock Assessment Report, including the Summary Report, and that reported results are consistent with Review Panel recommendations**.
8. Evaluate the SEDAR Process as applied to the reviewed assessments and identify any Terms of Reference which were inadequately addressed by the Data or Assessment Workshops.
9. 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 future assessments. Recommend an appropriate interval for the next assessment, and whether a benchmark or update assessment is warranted.
10. Prepare a Peer Review Consensus 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 Consensus Report within 3 weeks of workshop conclusion.

* 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

| Appointee | Function | Affiliation |
|---|---|---|
| ***Review Panel*** | | |
| Chris Legault | Review Panel Chair | NEFSC |
| Paul Medley | CIE Reviewer | |
| Stuart Reeves | CIE Reviewer | CEFAS |
| Neil Klaer | CIE Reviewer | CSIRO |
| Gary Grossman | Council Appointed Reviewer | SAFMC |
| Sean Powers | Council Appointed Reviewer | GMFMC |
| | | |
| ***Analytical Team Representation*** | | |
| Kyle Sherzter | Red grouper lead analyst | NMFS Beaufort |
| Bob Muller | Black grouper lead analyst | FWRI |
| Rob Cheshire | Analytic support | NMFS Beaufort |
| Joe O'Hop | Analytic support | FWRI |
| | | |
| ***Official Observers*** | | |
| Dennis O'Hern | AP/Fisherman rep – Black grouper (GMFMC) | West Central FL/private |
| | | |
| ***Council Representation*** | | |
| Brian Cheuvront | South Atlantic Council Member | SAFMC |
| George Geiger | South Atlantic Council Member | SAFMC |
| Bob Gill | Gulf of Mexico Council Member | GMFMC |
| Luiz Barbieri | AW Rep– Black grouper | SAFMC and GMFMC SSC |
| Anne Lange | AW Rep – Red grouper | SAFMC SSC |
| | | |
| ***Staff*** | | |
| Julie A Neer | SEDAR Coordinator | SEDAR |
| Rachael Lindsay | Administrative Assistant | SEDAR |
| Carrie Simmons | Gulf of Mexico Council Staff | GMFMC |

| | | |
|---|---|---|
| | Lead | |
| John Carmichael | South Atlantic Council Staff | SAFMC |
| Kari Fenske | South Atlantic Council Staff | SAFMC |
| Gregg Waugh | South Atlantic Council Staff | SAFMC |
| Patrick Gilles | IT Support | NMFS Miami |
| | | |
| ***Other Observers*** | | |
| Rusty Hudson | | DSF, Inc. |
| Marcus Drymon | | NMFS - Pascagoula |

## 1.4. List of Data Workshop Working Papers

| Document # | Title | Authors |
|---|---|---|
| **Documents Prepared for the Review Workshop** | | |
| SEDAR19-RW-01 | A statistical catch-age model for red grouper: mathematical description, implementation details, and computer code | Sustainable Fisheries Branch |

## 2. Red Grouper Review Panel Summary Report

The stock assessment presented by the Assessment Workshop (AW) was accepted after minor modifications made during the review meeting. It was concluded that overfishing was occurring and the stock was overfished in 2008. All terms of reference were addressed by the Data Workshop (DW) and AW. The Review Panel (RP) thanked all the members of the DW and AW for their diligence in preparing their reports and willingness to respond to questions from the RP.

### 2.1 Terms of Reference

#### 2.1.1 Evaluate the adequacy, appropriateness, and application of data used in the assessment.

The majority of information for red grouper was derived from landings data because few fishery independent indices were available. The RP identified several areas of concern relative to the quality and reliability of the fishery-dependent data. Many of these issues were noted by the DW as well as the AW, but deserve re-examination here because they weighed heavily in the RP review. The least problematic of the fishery-dependent data was the commercial long-line data and the index of abundance derived from these data and effort as reported in the logbooks. The RP discussed potential problems with unknown or changing selectivity and catchability of the long-line data where changes in the long-line fishery were made as a result of regulations. Similar to the longline data, the head boat data, a fairly small component of the grouper fishery, was viewed as reliable.

The RP was very concerned about the recreational landings derived from the MRFSS data set. Central to this problem for red grouper was the lack of species-specific landings in earlier data sets (grouper was treated as an aggregate category prior to 1986). Further inspection of landings data for red grouper indicated disproportionally higher recreational catches during this early period. The RP discussed the validity and reasoning behind estimating landings for years prior to the start of the MRFSS program. The estimated data for MRFSS landings was higher than many observed years. It was thought that stock size was higher for earlier years which resulted in higher landings. Additionally, the unusually high estimated landings in 1984 were smoothed through a process that reduced its magnitude but also reduced high landings in 1986. The weight of MRFSS data in the model and the validity of the MRFSS data were questioned. However, lacking an alternative, the data were accepted for use in stock assessment models.

The RP was concerned with the lack of empirical data to support the discard mortality estimate of 20%. Given that discards are much greater than the catch, relatively small changes in discard mortality could have major implications. The 20% value was arrived by consensus in the DW and AW. Sensitivity runs were performed that varied this estimate from 10 – 70%, which bracketed published estimates. These results support the high impact of this parameter. In the absence of any substantive empirical data the panel did not see a strong basis to change the value from 20%, however attempts should be made to obtain a more accurate estimate of both acute and chronic discard mortality.

Generally, the sample sizes for red grouper ages were low. This limited the ability to estimate cohort strength within the models and added uncertainty to the results. Given the apparent break in distribution between North Carolina and Florida, the RP requested age and length compositions be split by these regions to examine whether growth differences were present. These were not provided but should be investigated in the future as a possible method for refining stock identification.

Four fisheries-dependent abundance indices were used in the assessment: 1) commercial longline data, 2) commercial hook and line data, 3) headboat data, and 4) MRFSS data. The RP expressed concern regarding the effort data used in the CPUE indices. The RP felt that effort data should have been presented more prominently in the report. Further, recent declines in indices of abundance were assumed to be related to decreases in effort; however, besides the imposition of more stringent trip limits in the longline fishery, little evidence was presented to support the assumption. The fishery-dependent indices relied on a sub-setting technique based on species composition to determine which observations to include in the index. This approach may be influenced by changes in relative abundance of the associated species.

The DW and AW have examined catchability changes through time for the snapper-grouper fishery complex and have concluded that increased use of GPS may have caused an increase in fishing efficiency. A simple approach for including the effect on fishery-dependent indices was to assume a 2% increase per year in catchability. The RP accepts that it is useful to examine plausible scenarios of catchability change as sensitivities to the base run, and note the difficulty in assigning relative probabilities to such scenarios.

The red grouper assessment used two fishery-independent abundance indices: 1) Marmap survey data, and 2) NMFS-UM Reef Visual Census (RVC). Although the panel recognized that fishery-independent data are difficult to obtain, both sets of data had shortcomings warranting discussion. For example, neither fishery-independent abundance index was significantly correlated with any other abundance index, and CV's for both indices were very high. Consequently their contribution to the assessment models was questionable. This lack of agreement probably was a function of several factors. For example, neither MARMAP nor RVC data were collected from depths that were representative of the fishery, and trap data (MARMAP) have a gear selectivity curve (dome-shaped) that differs from typical gear used in the fishery, which probably contributed to the fact that the actual numbers of fish sampled by fishery-independent gear was not high. In addition, RVC data come from a spatially restricted area that was not representative of the fishery. There also appeared to be problems in the RVC length data and aging data, because length-frequency histograms produced by this method displayed patterns that were suggestive of biased sampling. The DW could not obtain sample sizes for these histograms. Finally, there were changes in RVC sampling methodology in 1998 that made comparability of early and late samples questionable. Consequently, the panel recommended removal of RVC data from the models. Although the MARMAP data were imprecise, the panel felt that they should be included in the model as they should provide an index of abundance unaffected by management controls.

The RP recommends that future management actions affect the monitoring data as little as possible, and where monitoring is affected, changes should be accounted for by implementing controls in a way that allows the effect to be estimated. Fishery-dependent abundance indices in particular may be compromised as measures of population abundance when affected by management actions, making it difficult or impossible to evaluate whether the management is achieving its objectives. It appears that the longline index, which is probably the most important abundance index for this fishery, has been compromised through the use of trip limits. Alternatively, the RP recommends that new and better sources of fishery independent indices be developed.

2.1.2 Evaluate the adequacy, appropriateness, and application of methods used to assess the stock.

Catch curves

Catch curves use available age and/or length data to provide a useful upper bound on natural mortality, particularly if data are available from periods when fishing intensity is low. However, the method assumes logistic flat-topped selectivity and equilibrium over the ages of fish being used in the assessment. Where domed selectivity or non-equilibrium is suspected, estimates should not be used. A standard approach, developed by Hoenig (1983), was used to estimate natural mortality for red grouper.

The estimated Z from the catch curve did not take account of the Lorenzen (1996) natural mortality model used in the age-structured models, but assumed constant mortality with age. Although this is not likely to affect the estimate much because the Lorenzen natural mortality is fairly constant over the ages used in the catch curve, the two approaches are not entirely consistent.

ASPIC

The production model stock assessment provided a useful comparison with age-structured models. ASPIC provides a standard maximum likelihood method to fit models with multiple indices. The data for this assessment were adequate for the use of this method. Production models ignore age and length information, but use catch weight and indices of abundance only. Therefore, where age and length information are available, production models are not the preferred assessment method.

Beaufort Assessment Model (BAM)

Efforts of the AW were primarily directed towards the development of the BAM. This statistical catch at age model was implemented with AD Model Builder software and has been applied in a number of previous SEDAR South Atlantic reef fish assessments. It used a penalized likelihood approach to fit to observed landings, discards, abundance indices and length/age composition data. The general approach is standard and the core BAM implementation has been simulation tested and shown to provide unbiased estimates. The RP concluded that the method was adequate for the stock assessment of red grouper, and that it had been appropriately applied to the available data.

Stock Synthesis 3 (SS3)

The AW made an effort to develop an assessment comparable to BAM using Stock Synthesis 3. A model of protogynous hermaphrodism was recently implemented in the software to allow all of the options required by the red grouper assessment. However, because males and females were assumed to contribute equally by weight to the spawning biomass, modeling of transfer of females to males had little impact on assessment results. SS3 is very flexible software that allows a wide range of configurations so that it can be applied to a wide range of fisheries stock assessments. With this flexibility also comes complexity, and for reasons of limited familiarity with the approach, the AW was unwilling to recommend the SS3 model for the provision of management advice at this stage. The RP agreed with this position.

There were several differences in the SS3 implementation compared to BAM, including the age at recruitment, time of the year for computation of spawning biomass, modeling of retention and discarding, and modeling of sexual transition. The RP believed that these implementation differences were relatively minor, and represented equally valid methods. Advantages in using SS3 over BAM are that there is no requirement to fit growth curves external to the model and that selectivity can be specified to apply by age, or by length. Fishing gear is normally length-selective, so it is preferable to directly model selectivity in the same manner. Growth parameters are fitted by the model, allowing the interaction of selectivity and growth parameters to be more effectively accounted for. The RP recommended that efforts continue in moving the red grouper assessment to a method that includes length-based selectivity and permits integrated growth modeling.

2.1.3 Recommend appropriate estimates of stock abundance, biomass, and exploitation.

The RP notes the different approaches used to estimate current exploitation levels between the black grouper and red grouper AW. Specifically, the current F for black grouper was determined from the F at age 5 in 2008 whereas the red grouper current F was determined as the average of the apical F over the years 2006 through 2008. The RP recognized that different metrics can be used, as long as they are consistent with the reference point calculations, as they were in both cases. However, if the method were the same among stocks, it would facilitate review and comparison. The RP recommends future research to determine which metric behaves best under this management system.

Current estimates of stock abundance, biomass, and exploitation are summarized in the table below. See the addendum for the full time series of each parameter.

| Parameter | Metric | Year | Units | Value |
|---|---|---|---|---|
| Stock Abundance | N (all ages) | 2008 | thousands of fish | 1240 |
| Biomass | SSB | 2008 | thousand metric tons | 2.1 |
| Exploitation | apical F | 2006-08 | per year | 0.34 |

2.1.4 Evaluate the methods used to estimate population benchmarks and management parameters (e.g., MSY, Fmsy, Bmsy, MSST, MFMT, or their proxies); recommend appropriate management benchmarks and provide estimated values for management benchmarks, a range of ABC, and declarations of stock status.

Fmsy can be estimated within stock assessment models, but will depend on the estimate of steepness for the Beverton and Holt stock-recruitment relationship. Steepness can rarely be estimated with high precision unless data cover a period of extreme depletion from which the stock has recovered. Alternatively, spawner-per-recruit benchmarks can be used as proxies for the MSY based benchmarks. Choice of the spawner-per-recruit benchmark will depend on the expected decline in recruitment associated with that level of spawning stock biomass. A steepness of 0.9, implies 90% unexploited recruitment at SPR20%. Where lower steepness is suspected, higher SPR benchmarks would be needed to achieve the same performance.

Despite the above caveats, the RP agrees with the AW that steepness for red grouper can be estimated (0.92) within the base-case stock assessment model. Consequently, MSY, SSBmsy, and Fmsy can be estimated directly. Current benchmarks for red grouper are provided in the table below. However, when considering between-model uncertainty, the RP believed that a proxy, such as F30%SPR = 0.19, should also be considered for red grouper.

| Parameter | Units | Value |
|---|---|---|
| MSY | million pounds | 1.1 |
| Bmsy | thousand metric tons | 2.6 |
| Fmsy | per year | 0.22 |

2.1.5 Evaluate the adequacy, appropriateness, and application of the methods used to project future population status; recommend appropriate estimates of future stock condition (e.g., exploitation, abundance, biomass).

Projections were made from 2009 to 2020 using a standard age-structured forward catch equation method. The fully selected fishing mortality rate in 2009 and 2010 was assumed to be the geometric mean of the fully selected fishing mortalities 2006 to 2008 from the BAM assessment. The start year for catches affected by future management actions was 2011. Uncertainty in initial stock abundance was captured in projection by using replicate Monte Carlo Bootstrap fits as starting points. Additional uncertainty was introduced in projections by stochastic selection of annual recruitment values from the fitted stock-recruitment relationship. The RP agreed with this standard approach

(Shertzer et al. 2008). The RP also agreed that projections correctly modeled the time series of future F and biomass values required for evaluation of the various management options examined (see addendum). The P* software package is the preferred method for projection of the probability of overfishing, and was used for projections.

2.1.6 Evaluate the adequacy, appropriateness, and application of methods used to characterize uncertainty in estimated parameters. Provide measures of uncertainty for estimated parameters. Ensure that the implications of uncertainty in technical conclusions are clearly stated.

The methods used to quantify uncertainty in the red grouper assessment were Monte Carlo Bootstrap simulations and sensitivity analyses which are standard and appropriate methods. The analyst also indicated that Markov Chain Monte Carlo methods also were explored but did not yield additional or more precise information than the Monte Carlo Bootstrap method. The RP felt that there was substantial uncertainty in the assessment that was produced by weaknesses in the data set and by the fact that the assessment models did not provide strong fits to the existing data. The sensitivity analysis was particularly helpful in identifying structural uncertainty in the assessment models and further analyses should focus on model structures that displayed high uncertainty such as discard survivorship rates, natural mortality rates and the interpretation of abundance index data.

2.1.7 Ensure that stock assessment results are clearly and accurately presented in the Stock Assessment Report, including the Summary Report, and that reported results are consistent with Review Panel recommendations.

There is a need to develop standard diagnostics for the different models and data used in the assessment. Diagnostic plots should include fits of all observed to expected data, and also residual plots that emphasize systematic patterns. For age and length composition residuals, bubble plots are effective as a check on the modeling of the cohorts. Where the likelihood function is composed of a number of separate components, their unweighted contributions to the likelihood should be routinely reported. Typically, detailed graphical diagnostics are examined at least for the base case, and a table of unweighted likelihood components should be prepared that includes the base case and all sensitivity analyses.

Standard diagnostic tables and figures were provided on request and the AW provided sufficient information about the assessment model fits and results. The RP noted that this TOR seems unnecessary, as the RP must meet it in order to meet the other TOR. The RP suggests that this TOR not be included in future SEDAR TOR.

2.1.8 Evaluate the SEDAR Process as applied to the reviewed assessments and identify any Terms of Reference which were inadequately addressed by the Data or Assessment Workshops.

Prior to the SEDAR 19 Review meeting, the DW had delivered a comprehensive set of data for both stocks considered. These data enabled the AW to develop assessments of the state of the stock using a range of different approaches in both cases. As a result it was clear to the RP that the SEDAR process that preceded the review meeting had been effective in achieving its intended purpose. The RP noted one term of reference which the DW did not appear to have addressed, which was the provision of maps of effort and harvest. While these might have been useful to inform some of the RP's discussions, their absence did not hinder the main purpose of the work, i.e. the provision of agreed stock assessments for the two stocks of concern.

The DW was asked to "Recommend which data sources are considered adequate and reliable for use in assessment modeling". The RP noted that choices related to the use of data within stock assessments are typically more complex than simply the inclusion/exclusion of particular datasets, because even noisy data may inform an assessment with an appropriate weighting. Consequently, the RP recommends that future DW provide a semi-quantitative evaluation (e.g. score) of the relative reliability of each data set. This information could then be used to inform the weightings used in stock assessments.

The focus of the SEDAR 19 review was two species of grouper, red and black. These two species are not targeted fisheries. Instead, they are caught as relatively minor components of a general reef-fish fishery. To some extent this is reflected in their inclusion in a general snapper/grouper management plan rather than being the subject of specific management plans. The RP had some reservations about the amount of effort and resources being focused on these two species through the SEDAR review process. These reflected both the relatively small contribution these species make to the area's fisheries, and the fact that these two species were being considered in isolation of all other components of the snapper/grouper complex. An efficient multispecies approach to managing the snapper/grouper complex fisheries could pave the way to developing a comprehensive ecosystem approach required for responsible fisheries management[1].

Vessels that are fishing on the mixed snapper/grouper complex generally are not specifically targeting black or red grouper. Consequently, it is difficult to interpret how vessels are likely to respond to management measures intended to protect these species. Similarly, vessels may also change their behavior in response to management measures that are directed towards other species in the complex, which complicates the use of fishery-dependent data in this assessment. This information might be lost through not addressing the full assemblage of target species within the same review. Although it may not be practical or desirable to attempt full assessments of all species in the complex at the same time, other approaches might be considered. In particular, it might be possible to identify one or two key species within the assemblage, and focus on these, while providing information about the complex as a whole as well. The key species might be

[1] FAO (1995) Code of Conduct for Responsible Fisheries. FAO, Rome.
FAO (2003) Fisheries Management FAO Technical Guidelines for Responsible Fisheries 4 Suppl. 2. FAO, Rome.

those of highest commercial value and/or of greatest vulnerability in terms of their life-history characteristics. Such an approach would facilitate a more integrated perspective of the fishery and also help focus resources where they would be most effectively used.

2.1.9 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 future assessments. Recommend an appropriate interval for the next assessment, and whether a benchmark or update assessment is warranted.

Members of the Data and Assessment workshops identified a number of shortcomings in the data available for red grouper, and the RP felt that future research efforts should be focused on obtaining more precise estimates for parameters that displayed a strong potential effect and high uncertainty on the output of the assessment models. This opinion was reinforced by the fact that red grouper are not abundant, nor do they represent substantial fisheries; hence data acquisition efforts are hampered by both low abundances and low availability of samples from fishery sources. Many of the research recommendations have a reasonable biological basis, but a number are not directly linked to the assessment models used in the stock assessment. The RP felt that future research should focus on discard mortality, especially from the recreational fishery, acquiring better fishery-independent abundance estimates, improved methods for estimating catch by recreational anglers, improved age and growth data, and efforts to quantify linkages (i.e., recruitment effects) between western Caribbean and US stocks of red grouper. Given that fecundity data are not currently used in the stock assessment models, nor are histological gonadal stages utilized other than to distinguish mature from immature specimens, we suggest that these studies have lower priority than the research needs identified above. Studies directed towards identifying locations of spawning aggregations may be difficult to conduct for a species with low abundance, although such studies would be useful if spatially-based fisheries closures were to be employed for red grouper.

The RP recommends a strategic approach should be taken towards research for the snapper-grouper complex. The criteria which would be used to evaluate the strategy should be:

- Efficiency: for example sampling for sex ratio, length, and age could cover a range of species simultaneously.
- Impact: the resulting information should have clear implications for decision making.

To achieve this, managers and scientists will both need to be involved in developing a strategic research plan.

As noted in section 2.1.3, the RP recommends future research to determine which F metric behaves best under this management system.

The RP recommends that the time frame for the next assessment be set according to the requirements of the main target and/or most vulnerable species within the snapper/grouper complex. The current assessment is sufficiently strong for red grouper that the next assessment could be just an update. However, consideration should be given to either joint assessments or assessments based on those species constraining fishing activity, which would then determine the time frame for the next assessment of this stock.

2.1.10 Prepare a Peer Review Consensus 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 Consensus Report within 3 weeks of workshop conclusion.

No response needed.

2.2 Summary of RP discussions and resultant changes to assessments

The main focus was on the BAM model suggested by the AW as the approach to use for the final assessment.
Main initial problems: Early years of MRFSS data; block of very high Fs in years 1985-1990.
Other issues: lack of clarity of potential impacts of protogyny; how well steepness was estimated.

Approaches suggested:

- Replace MRFSS catch data estimates for years prior to 1991, with estimates based on the ratio between MRFSS & recreational/commercial since 1991 (effectively 50:50)
- Explore same issue by applying a higher CV (0.3 rather than 0.1) to the MRFFS estimates over 1976-1990
- Add a penalty function to reduce the chance of estimates of F above 1
- Runs with changes to the sex ratio parameters to explore the impacts of protogyny
- A run with steepness fixed at 0.8
- Runs with weightings on each of the indices increased (to 10) and decreased (to 0.1)
- A run assuming no changes in selectivity in the commercial fleets over time, reflecting concerns that changes in minimum landing size wouldn't necessarily influence fishing practices, and that the block of high Fs corresponded roughly to the second regulatory period assumed in the catchability changes.

The RP also requested that the results be presented in terms of a table of the likelihood contributions associated with each parameter in order to better understand the impacts of each change on the model fit.

Examination of the likelihood contribution table from all of the requested runs indicated that both the indices and the length composition data from the RVC survey were in conflict with other sources of information in the model fit. For this reason, the RP requested another run with these data omitted. This run reduced the magnitude of fishing mortality over the 1985-1990 period as it resulted in a leftward shift of the selectivity of the commercial longlines. This configuration of the model was accepted as the final one.

## 2.3 References


Hoenig, J. M. 1983. Empirical use of longevity data to estimate mortality rates. Fishery Bulletin 81: 898-903.

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.

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.

# SEDAR

## Southeast Data, Assessment, and Review

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## SEDAR 19

# South Atlantic Red Grouper

## SECTION VI: Addenda

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# 6 Revisions

This addendum documents several changes made at the SEDAR Review Workshop (RW) for application of the Beaufort Assessment Model (BAM) to red grouper. The primary change made at the RW was the removal of the visual survey (RVC) index of abundance and its corresponding length compositions. The BAM base configuration was re-run without the RVC data, as were sensitivity analyses, Monte Carlo/Bootstrap analyses, and projections. Sensitivity analysis included one additional run not considered at the Assessment Workshop, a run with high discard mortality ($\delta = 0.7$). In addition, the rebuilding time frame is revised here to have a duration of 10 years (until 2020).

## 6.1 Model Configurations

Unless otherwise noted in this addendum, methods and configurations were the same as described in the Assessment Workshop Report (Section III of this document).

### 6.1.1 Sensitivity Analyses

The base run of the BAM applied Lorenzen age-based natural mortality scaled to $M = 0.14$, and discard mortality of $\delta = 0.2$. Sensitivity of results to these values was examined through sensitivity analyses. These model runs vary from the base run as follows:

- S1: Low $M$ at age (Lorenzen estimates rescaled to constant $M = 0.1$ so as to provide the same cumulative survival of 7.4% through the oldest observed age)
- S2: High $M$ at age (Lorenzen estimates rescaled to constant $M = 0.2$ so as to provide the same cumulative survival of 0.6% through the oldest observed age)
- S3: Extreme $M$ at age (Lorenzen estimates rescaled to constant $M = 0.3$ so as to provide the same cumulative survival of 0.04% through the oldest observed age)
- S4: Low discard mortality rates ($\delta = 0.1$)
- S5: High discard mortality rates ($\delta = 0.3$)
- S6: Very high discard mortality rates ($\delta = 0.7$)

### 6.1.2 Projection Scenarios

Thirteen constant-$F$ projection scenarios were considered. Unless otherwise stated, the fishing rate in 2009 and 2010 was $F_{\text{current}}$, defined as the geometric mean of $F$ in 2006–2008. The $F_{\text{rebuild}}$ is defined as the maximum $F$ that achieves rebuilding (0.5 probability) in the allowable time frame.

- Scenario 1: $F = 0$
- Scenario 2: $F = F_{\text{current}}$
- Scenario 3: $F = F_{\text{current}}$ in 2009 and $F = 75\% F_{\text{current}}$ thereafter
- Scenario 4: $F = F_{\text{current}}$ in 2009 and $F = 50\% F_{\text{current}}$ thereafter

- Scenario 5: $F = F_{\text{current}}$ in 2009 and $F = 25\% F_{\text{current}}$ thereafter
- Scenario 6: $F = 65\% F_{\text{MSY}}$
- Scenario 7: $F = 75\% F_{\text{MSY}}$
- Scenario 8: $F = 85\% F_{\text{MSY}}$
- Scenario 9: $F = F_{\text{MSY}}$
- Scenario 10: $F = F_{\text{rebuild}}$
- Scenario 11: $F = F_{\text{rebuild}}$, with $F = F_{\text{current}}$ in 2009 and $F = 75\% F_{\text{current}}$ in 2010
- Scenario 12: $F = F_{\text{rebuild}}$, with $F = F_{\text{current}}$ in 2009 and $F = 50\% F_{\text{current}}$ in 2010
- Scenario 13: $F = F_{\text{rebuild}}$, with $F = F_{\text{current}}$ in 2009 and $F = 25\% F_{\text{current}}$ in 2010

## 6.2 BAM Results

### 6.2.1 Measures of Overall Model Fit

Overall, the Beaufort Assessment Model (BAM) fit well to the available data. Annual fits to length compositions from each fishery were reasonable in most years, as were fits to age compositions (Figure 6.1). Residuals of these fits, by year and fishery, are summarized with bubble plots; differences between annual observed and predicted vectors are summarized with angular deviation (Figure 6.2–6.11). Angular deviation is defined as the arc cosine of the dot product of two vectors.

The model was configured to fit observed commercial and recreational landings closely (Figures 6.12–6.15), as well as observed discards (Figures 6.16–6.18).

Fits to indices of abundance were reasonable (Figures 6.19–6.22). Since the early 1990s, the general trend in these indices is one of increase.

### 6.2.2 Parameter Estimates

Estimates of all parameters from the catch-age model are shown in Appendix A. The parameter controlling variation in size at age was estimated to be near its prior, $CV = 0.09$ (Figure 6.23, Table 6.1). Estimates of management quantities and some key parameters, such as those of the spawner-recruit model, are reported in sections below.

### 6.2.3 Stock Abundance and Recruitment

Estimated abundance at age shows truncation of the older ages until the early 1990s, after which older fish began to repopulate (Table 6.2). In the most recent years, older fish ($6^+$) appear to be more abundant than in the early years of the assessment period. These older fish are predominantly male (Tables 6.3, 6.4). Annual number of recruits is shown in Table 6.2 (age-1 column) and in Figure 6.24. A notably strong year classes was predicted to have occurred in 2004.

### 6.2.4 **Total and Spawning Biomass**

Estimated biomass at age follows a similar pattern as abundance at age (Tables 6.5,6.6). Total biomass and spawning biomass show similar trends— general decline until the mid-1980s, and general increase since the early 1990s but with a downturn at the end of the time series (Figure 6.25; Table 6.7).

### 6.2.5 **Selectivity**

Estimated selectivity of MARMAP chevron traps (fishery independent survey) is shown in Figure 6.26. Selectivity of landings from commercial lines was estimated to have a gradual slope in earlier years that became more steep with implementation of the 20-inch size limit in 1992 (shown in Figure 6.27). In the most recent period, fish were estimated to be near fully selected by age 5. Selectivity of landings from commercial other was dome-shaped with a shift to older ages at the 1992 regulation change (Figure 6.28). Selectivities of landings from the headboat fleet are shown in Figure 6.29, and those of the general recreational fleet in Figure 6.30. For both of these fleets in the recent period of regulations, fish were estimated to be near fully selected by age 4.

By design, estimated selectivities of discard mortalities were similar across the commercial handline, headboat, and general recreational fisheries (Figure 6.31). In the most recent period of regulations, discards included more fish of ages 3 and 4 than in the earlier period. Few fish age $5^+$ were discarded.

Average selectivities of landings and of discard mortalities were computed from $F$-weighted selectivities in the most recent period of regulations (Figure 6.32). These average selectivities were used to compute benchmarks and projections. All fishery selectivities from the most recent period, including average selectivities, are tabulated in Table 6.8.

### 6.2.6 **Fishing Mortality**

The estimated fishing mortality rates ($F$) peaked during the 1980s, and in the last decade have generally been at their lowest levels of the time series (Figure 6.33). The two primary contributors are general recreational and commercial line fleets. An increase in fishing mortality rate in the last few years coincides with increased landings from those two fleets (Figures 6.34, 6.35).

Estimates of total $F$ at age are shown in Table 6.10. In any given year, the maximum $F$ at age (i.e., apical F) may be less than that year's sum of fully selected $F$s across fleets. This inequality is due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and several sources of mortality have dome-shaped selectivity.

Table 6.11 shows total landings at age in numbers, and Table 6.12 in 1000 lb. In general, estimated landings have been dominated by commercial lines and general recreational fleets, particularly since 1992 (Figures 6.34, 6.35; Tables 6.13, 6.14). Estimated discard mortalities occur on a smaller scale than landings (Figure 6.36; Tables 6.15, 6.16)

### 6.2.7 Spawner-Recruitment Parameters

The estimated Beverton–Holt spawner-recruit curve is shown in Figure 6.37, 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: steepness $\widehat{h} = 0.92$, unfished age-1 recruitment $\widehat{R_0} = 384,122$, unfished spawning biomass per recruit $\phi_0 = 0.024$, and standard deviation of recruitment residuals in log space $\hat{\sigma} = 0.48$ (which resulted in bias correction $\hat{\varsigma} = 1.12$). Uncertainty in these quantities was estimated through the Monte Carlo/bootstrap (MCB) analysis (Figure 6.38). Although the estimate of steepness is high, it appears to be robust across MCB trials, likely because the two-way trip in spawning biomass provides information on stock productivity (Conn et al. In Press).

### 6.2.8 Per Recruit and Equilibrium Analyses

Static spawning potential ratio (static SPR) shows a general trend of increase since the mid-1980s, but a decrease in the last several years of the assessment time period (Figure 6.39, Table 6.7).

Yield per recruit and spawning potential ratio were computed as functions of $F$ (Figure 6.40). 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 years (2006–2008). The $F$s that provide 30%, 40%, and 50% SPR are 0.19, 0.13, and 0.09, respectively. For comparison, $F_{\mathrm{MSY}}$ corresponds to about 26% SPR. Although this rate of fishing appears high relative to $F_{X\%}$ proxies, it occurs here because the size limit offers protection for spawners and because of the high estimate of steepness.

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of $F$ (Figures 6.41). By definition, the $F$ that maximizes equilibrium landings is $F_{\mathrm{MSY}}$, and the corresponding landings and spawning biomass are MSY and $\mathrm{SSB}_{\mathrm{MSY}}$. Equilibrium landings and discards could also be viewed as functions of biomass $B$, which itself is a function of $F$ (Figure 6.42).

### 6.2.9 Benchmarks / Reference Points

As described in the AW Report, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the spawner-recruit curve with bias correction (Figure 6.37). This approach is consistent with methods used in rebuilding projections (i.e., fishing at $F_{\mathrm{MSY}}$ yields MSY from a stock size of $\mathrm{SSB}_{\mathrm{MSY}}$). Reference points estimated were $F_{\mathrm{MSY}}$, MSY, $B_{\mathrm{MSY}}$ and $\mathrm{SSB}_{\mathrm{MSY}}$. Based on $F_{\mathrm{MSY}}$, three possible values of $F$ at optimum yield (OY) were considered—$F_{\mathrm{OY}} = 65\% F_{\mathrm{MSY}}$, $F_{\mathrm{OY}} = 75\% F_{\mathrm{MSY}}$, and $F_{\mathrm{OY}} = 85\% F_{\mathrm{MSY}}$—and for each, the corresponding yield was computed. Standard errors of benchmarks were approximated as those from Monte Carlo/bootstrap analysis (detailed in AW Report).

Estimates of benchmarks are summarized in Table 6.17. Point estimates of MSY-related quantities were $F_{\mathrm{MSY}} = 0.22\ \mathrm{y}^{-1}$, MSY = 1110 klb, $B_{\mathrm{MSY}} = 3680$ mt, and $\mathrm{SSB}_{\mathrm{MSY}} = 2592$ mt. Distributions of these benchmarks are shown in Figure 6.43.

### 6.2.10 Status of the Stock and Fishery

Estimated time series of stock status (SSB/MSST) shows decline until the mid-1980s, and then steady increase since, but with a decrease in the terminal year (Figure 6.44, Table 6.7). The increase in stock status appears to have been initially driven by strong recruitment, then reinforced by 1992 management regulations. Base-run estimates of spawning biomass have remained below MSST throughout the time series (overfished status in 1976 is not surprising given the heavy fishing pressure that occurred prior to the start of the assessment period). Current stock status was estimated in the base run to be $SSB_{2008}/MSST = 0.92$ (Table 6.17); uncertainty in this estimate includes the possibility that the stock is not overfished (i.e., SSB > MSST), but also the possibility that the stock is less healthy than estimated by the base run (Figures 6.45, 6.46). Age structure estimated by the base run has become repopulated by older fish during the last decade, approaching the (equilibrium) age structure expected at MSY (Figure 6.47).

The estimated time series of $F/F_{MSY}$ suggests that overfishing has been occurring throughout the assessment period (Figure 6.44, Table 6.7). The series peaked during the 1980s; since 2000, $F/F_{MSY}$ has been at its lowest levels, but has been increasing since 2005. Current fishery status in the terminal year, with current $F$ represented by the geometric mean from 2006–2008, is estimated by the base run to be $F_{2008}/F_{MSY} = 1.35$ (Table 6.17). This estimate indicates current overfishing and appears robust across MCB trials (Figures 6.45, 6.46).

### 6.2.11 Sensitivity Analyses

Sensitivity runs may be useful for evaluating implications of assumptions in the base assessment model, and for interpreting MCB results in terms of the effects of natural and discard mortality rates. Plotted are time series of $F/F_{MSY}$ and SSB/MSST for sensitivity to natural mortality (Figure 6.48) and discard mortality (Figure 6.49). In concert, results of sensitivity analyses were similar to those of the base run and MCB analysis: the tendency was toward the status estimate of overfished, and toward the (apparently more robust) estimate of overfishing, although not all runs gave the same qualitative results (Figure 6.50, Table 6.18).

### 6.2.12 Projections

Projection scenario 1, in which $F = 0$, predicted the stock to achieve at least 50% chance of recovery by 2013 (Figure 6.51). This duration defines the minimum rebuilding time frame (Tmin). Because the stock can rebuild within 10 years, the maximum rebuilding time frame (Tmax) is 10 years. Thus rebuilding that starts in 2011 should occur by the end of 2020, at the latest. The Tmin and Tmax should bracket the target rebuilding time frame (Ttarget).

Projections with $F$ at 100%, 75%, 50%, or 25% of $F_{current}$ predicted recovery by 2020 only if $F$ were reduced sufficiently below the current level (Figures 6.52–6.55, Tables 6.19–6.22), as did projections with $F$ at 65%, 75%, 85%, or 100% of $F_{MSY}$ (Figures 6.56–6.59, Tables 6.23–6.26). The value of $F_{rebuild}$ showed little sensitivity to $F$ in 2010 (Figures 6.60–6.63, Tables 6.27–6.30). In general, higher projected $F$ resulted in larger annual and cumulative landings, but smaller biomass with a correspondingly smaller buffer from the MSST.

## 6.3 Discussion

### 6.3.1 Comments on Assessment Results

Estimated benchmarks play a central role in this assessment. Values of $SSB_{MSY}$ and $F_{MSY}$ are used to gauge status of the stock and fishery, and in cases where rebuilding projections are necessary, SSB reaching $SSB_{MSY}$ is the criterion that defines a successfully rebuilt stock. Computation of benchmarks is conditional on selectivity. If selectivity patterns change in the future, for example as a result of new size limits or different catch allocations among sectors, estimates of benchmarks would likely change as well.

The base run of the Beaufort catch-age assessment model indicated that the stock is overfished yet near MSST ($SSB_{2008}/MSST = 0.92$), and that overfishing is occurring ($F_{2008}/F_{MSY} = 1.35$). These results did not appear subject to retrospective error, and were consistent across the majority, but not all, of the configurations used in sensitivity runs. In addition, the same qualitative findings resulted from the Stock Synthesis application and most production model applications (see Section III). However, distributions of results from the MCB analysis included realizations spanning other combinations of stock and fishery status (e.g., they included runs where the stock was not overfished and without overfishing). The result that overfishing is occurring appeared to be more robust than the result that the stock is currently overfished (Figures 6.44–6.46, 6.50).

The increase in biomass since the early 1990s would indicate that the federal regulations implemented in 1992 have been effective. The more recent increase in fishing rate may be due, at least in part, to target switching toward red grouper as a result of regulations on other species. The AW panel recognized that imminent regulations on shallow water groupers (Amendment 16 of the Snapper-Grouper Fishery Management Plan), scheduled to take effect in 2010, may be sufficient for reducing the fishing rate below $F_{MSY}$. Thus, even if this stock is declared overfished such that a rebuilding plan becomes mandatory, additional regulations beyond those already scheduled may not be necessary.

### 6.3.2 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.

### 6.4 References

## References

Conn, P. B., E. H. Williams, and K. W. Shertzer. In Press. When can we reliably estimate the productivity of fish stocks? Canadian Journal of Fisheries and Aquatic Sciences .

## 6.5 Tables

*Table 6.1. Life-history characteristics at age of the population, including average size (mid-year), proportion female, and proportion females mature (all males assumed mature)*

| Age | Total length (mm) | Total length (in) | CV length | Whole weight (kg) | Whole weight (lb) | Prop. female | Female maturity |
|---|---|---|---|---|---|---|---|
| 1 | 313.9 | 12.4 | 0.09 | 0.46 | 1.02 | 1.00 | 0.00 |
| 2 | 416.4 | 16.4 | 0.09 | 1.11 | 2.45 | 0.96 | 0.35 |
| 3 | 499.3 | 19.7 | 0.09 | 1.95 | 4.30 | 0.93 | 0.54 |
| 4 | 566.2 | 22.3 | 0.09 | 2.88 | 6.35 | 0.88 | 0.71 |
| 5 | 620.3 | 24.4 | 0.09 | 3.82 | 8.43 | 0.80 | 0.84 |
| 6 | 664.0 | 26.1 | 0.09 | 4.72 | 10.41 | 0.70 | 0.92 |
| 7 | 699.4 | 27.5 | 0.09 | 5.54 | 12.22 | 0.59 | 0.96 |
| 8 | 727.9 | 28.7 | 0.09 | 6.28 | 13.84 | 0.47 | 0.98 |
| 9 | 751.0 | 29.6 | 0.09 | 6.91 | 15.24 | 0.35 | 0.99 |
| 10 | 769.6 | 30.3 | 0.09 | 7.46 | 16.45 | 0.24 | 1.00 |
| 11 | 784.7 | 30.9 | 0.09 | 7.92 | 17.46 | 0.15 | 1.00 |
| 12 | 796.9 | 31.4 | 0.09 | 8.31 | 18.32 | 0.09 | 1.00 |
| 13 | 806.7 | 31.8 | 0.09 | 8.63 | 19.03 | 0.05 | 1.00 |
| 14 | 814.7 | 32.1 | 0.09 | 8.90 | 19.62 | 0.02 | 1.00 |
| 15 | 821.1 | 32.3 | 0.09 | 9.12 | 20.10 | 0.00 | 1.00 |
| 16 | 826.3 | 32.5 | 0.09 | 9.30 | 20.50 | 0.00 | 1.00 |

*Table 6.2. Estimated total abundance at age (1000 fish) at start of year.*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 387.1 | 361.1 | 169.0 | 542.5 | 160.0 | 34.5 | 24.6 | 11.7 | 12.5 | 4.5 | 2.2 | 1.1 | 0.6 | 0.3 | 0.2 | 0.3 | 1712.2 |
| 1977 | 370.0 | 259.6 | 227.3 | 99.6 | 313.2 | 91.9 | 19.8 | 14.2 | 6.8 | 7.2 | 2.6 | 1.3 | 0.7 | 0.4 | 0.2 | 0.3 | 1415.0 |
| 1978 | 454.7 | 248.5 | 163.8 | 134.5 | 57.9 | 181.4 | 53.4 | 11.6 | 8.3 | 4.0 | 4.3 | 1.5 | 0.7 | 0.4 | 0.2 | 0.3 | 1325.4 |
| 1979 | 411.1 | 302.2 | 154.0 | 94.8 | 76.3 | 32.7 | 102.8 | 30.4 | 6.6 | 4.8 | 2.3 | 2.4 | 0.9 | 0.4 | 0.2 | 0.3 | 1222.3 |
| 1980 | 226.9 | 272.3 | 185.9 | 88.2 | 53.2 | 42.6 | 18.3 | 57.7 | 17.2 | 3.7 | 2.7 | 1.3 | 1.4 | 0.5 | 0.2 | 0.3 | 972.6 |
| 1981 | 267.5 | 151.0 | 168.8 | 107.5 | 50.0 | 30.0 | 24.1 | 10.4 | 33.0 | 9.8 | 2.1 | 1.5 | 0.7 | 0.8 | 0.3 | 0.3 | 857.9 |
| 1982 | 451.5 | 180.0 | 98.5 | 107.6 | 68.0 | 31.6 | 19.0 | 15.3 | 6.6 | 21.1 | 6.3 | 1.4 | 1.0 | 0.5 | 0.5 | 0.4 | 1009.1 |
| 1983 | 492.1 | 295.3 | 108.8 | 55.7 | 59.5 | 37.4 | 17.3 | 10.5 | 8.5 | 3.7 | 11.6 | 3.5 | 0.8 | 0.6 | 0.3 | 0.5 | 1105.9 |
| 1984 | 357.9 | 288.1 | 142.9 | 47.6 | 23.1 | 24.3 | 15.2 | 7.0 | 4.3 | 3.4 | 1.5 | 4.7 | 1.4 | 0.3 | 0.2 | 0.3 | 922.3 |
| 1985 | 380.8 | 213.9 | 118.1 | 46.2 | 14.8 | 7.1 | 7.3 | 4.5 | 2.1 | 1.2 | 1.0 | 0.4 | 1.4 | 0.4 | 0.1 | 0.2 | 799.5 |
| 1986 | 263.1 | 250.7 | 120.5 | 58.1 | 22.0 | 6.8 | 3.2 | 3.2 | 1.9 | 0.9 | 0.5 | 0.4 | 0.2 | 0.6 | 0.2 | 0.1 | 732.4 |
| 1987 | 434.3 | 166.3 | 130.7 | 54.1 | 24.9 | 9.0 | 2.7 | 1.2 | 1.2 | 0.7 | 0.3 | 0.2 | 0.2 | 0.1 | 0.2 | 0.1 | 826.0 |
| 1988 | 296.0 | 270.8 | 86.4 | 61.7 | 24.7 | 11.0 | 3.9 | 1.1 | 0.5 | 0.5 | 0.3 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 757.3 |
| 1989 | 168.1 | 191.1 | 161.6 | 49.4 | 34.0 | 13.0 | 5.5 | 1.9 | 0.5 | 0.2 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 626.1 |
| 1990 | 138.3 | 109.9 | 109.7 | 83.4 | 24.7 | 16.4 | 6.0 | 2.5 | 0.8 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 492.3 |
| 1991 | 256.8 | 91.7 | 70.9 | 71.4 | 53.8 | 15.6 | 10.2 | 3.7 | 1.5 | 0.5 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 576.7 |
| 1992 | 462.6 | 159.5 | 56.4 | 50.6 | 51.2 | 38.3 | 11.1 | 7.2 | 2.6 | 1.1 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 841.2 |
| 1993 | 158.4 | 321.2 | 116.3 | 41.1 | 32.6 | 31.5 | 23.6 | 6.9 | 4.5 | 1.7 | 0.7 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 738.9 |
| 1994 | 257.9 | 112.5 | 240.6 | 80.9 | 21.0 | 15.4 | 14.7 | 11.1 | 3.3 | 2.2 | 0.8 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 760.9 |
| 1995 | 534.5 | 176.9 | 81.0 | 172.8 | 49.8 | 12.1 | 8.8 | 8.5 | 6.5 | 1.9 | 1.3 | 0.5 | 0.2 | 0.1 | 0.0 | 0.0 | 1054.9 |
| 1996 | 601.1 | 374.6 | 130.7 | 59.6 | 110.3 | 29.6 | 7.1 | 5.2 | 5.1 | 3.9 | 1.1 | 0.8 | 0.3 | 0.1 | 0.0 | 0.0 | 1329.4 |
| 1997 | 178.4 | 409.7 | 267.2 | 92.3 | 35.1 | 60.1 | 15.9 | 3.8 | 2.8 | 2.8 | 2.1 | 0.6 | 0.4 | 0.2 | 0.1 | 0.0 | 1071.5 |
| 1998 | 114.4 | 118.3 | 282.5 | 187.2 | 56.3 | 19.7 | 33.2 | 8.9 | 2.2 | 1.6 | 1.6 | 1.2 | 0.4 | 0.2 | 0.1 | 0.1 | 827.6 |
| 1999 | 271.7 | 78.9 | 85.5 | 205.0 | 118.8 | 32.3 | 11.1 | 18.8 | 5.1 | 1.2 | 0.9 | 0.9 | 0.7 | 0.2 | 0.1 | 0.1 | 831.2 |
| 2000 | 281.6 | 186.9 | 57.0 | 63.9 | 144.2 | 78.1 | 20.9 | 7.2 | 12.4 | 3.3 | 0.8 | 0.6 | 0.6 | 0.5 | 0.1 | 0.2 | 858.4 |
| 2001 | 323.4 | 186.5 | 129.1 | 41.8 | 45.8 | 99.1 | 53.3 | 14.4 | 5.0 | 8.6 | 2.3 | 0.6 | 0.4 | 0.4 | 0.3 | 0.2 | 911.3 |
| 2002 | 412.1 | 220.5 | 133.2 | 95.7 | 29.5 | 30.8 | 66.4 | 36.1 | 9.9 | 3.5 | 5.9 | 1.6 | 0.4 | 0.3 | 0.3 | 0.4 | 1046.5 |
| 2003 | 468.7 | 289.5 | 163.3 | 98.8 | 62.5 | 18.2 | 18.9 | 41.0 | 22.6 | 6.2 | 2.2 | 3.7 | 1.0 | 0.3 | 0.2 | 0.4 | 1197.3 |
| 2004 | 884.3 | 329.5 | 214.7 | 120.5 | 62.8 | 37.5 | 10.8 | 11.3 | 24.9 | 13.7 | 3.8 | 1.3 | 2.3 | 0.6 | 0.2 | 0.4 | 1718.7 |
| 2005 | 500.5 | 624.8 | 245.9 | 159.1 | 79.0 | 39.1 | 23.2 | 6.7 | 7.1 | 15.7 | 8.7 | 2.4 | 0.8 | 1.5 | 0.4 | 0.3 | 1715.3 |
| 2006 | 125.2 | 351.5 | 463.7 | 185.6 | 112.5 | 54.4 | 26.9 | 16.1 | 4.7 | 5.0 | 11.1 | 6.1 | 1.7 | 0.6 | 1.0 | 0.5 | 1366.9 |
| 2007 | 179.8 | 87.5 | 259.5 | 350.6 | 129.8 | 75.8 | 36.6 | 18.2 | 11.0 | 3.2 | 3.4 | 7.6 | 4.2 | 1.2 | 0.4 | 1.1 | 1170.0 |
| 2008 | 426.5 | 128.0 | 66.0 | 196.9 | 237.5 | 82.8 | 47.9 | 23.3 | 11.7 | 7.1 | 2.1 | 2.2 | 4.9 | 2.7 | 0.8 | 1.0 | 1241.3 |
| 2009 | 355.8 | 302.9 | 96.2 | 49.6 | 129.2 | 147.2 | 50.9 | 29.7 | 14.5 | 7.3 | 4.4 | 1.3 | 1.4 | 3.1 | 1.7 | 1.1 | 1196.6 |

*Table 6.3. Estimated female abundance at age (1000 fish) at start of year*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 387.1 | 347.7 | 157.2 | 476.3 | 128.5 | 24.3 | 14.5 | 5.5 | 4.3 | 1.1 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1547.0 |
| 1977 | 370.0 | 250.0 | 211.4 | 87.5 | 251.5 | 64.8 | 11.7 | 6.6 | 2.4 | 1.7 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1258.1 |
| 1978 | 454.7 | 239.3 | 152.3 | 118.1 | 46.5 | 127.9 | 31.5 | 5.4 | 2.9 | 1.0 | 0.7 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1180.3 |
| 1979 | 411.1 | 291.0 | 143.2 | 83.3 | 61.3 | 23.1 | 60.6 | 14.2 | 2.3 | 1.1 | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 1091.9 |
| 1980 | 226.9 | 262.3 | 172.9 | 77.5 | 42.7 | 30.1 | 10.8 | 26.9 | 5.9 | 0.9 | 0.4 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 857.5 |
| 1981 | 267.5 | 145.4 | 157.0 | 94.4 | 40.1 | 21.1 | 14.2 | 4.8 | 11.4 | 2.3 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 758.9 |
| 1982 | 451.5 | 173.3 | 91.6 | 94.5 | 54.6 | 22.3 | 11.2 | 7.1 | 2.3 | 5.0 | 1.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 914.5 |
| 1983 | 492.1 | 284.4 | 101.1 | 48.9 | 47.8 | 26.4 | 10.2 | 4.9 | 2.9 | 0.9 | 1.8 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 1021.7 |
| 1984 | 357.9 | 277.5 | 132.9 | 41.8 | 18.6 | 17.1 | 9.0 | 3.3 | 1.5 | 0.8 | 0.2 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 861.0 |
| 1985 | 380.8 | 206.0 | 109.8 | 40.6 | 11.9 | 5.0 | 4.3 | 2.1 | 0.7 | 0.3 | 0.2 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 761.8 |
| 1986 | 263.1 | 241.4 | 112.0 | 51.0 | 17.7 | 4.8 | 1.9 | 1.5 | 0.7 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 694.4 |
| 1987 | 434.3 | 160.1 | 121.5 | 47.5 | 20.0 | 6.3 | 1.6 | 0.6 | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 792.6 |
| 1988 | 296.0 | 260.8 | 80.4 | 54.1 | 19.8 | 7.7 | 2.3 | 0.5 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 722.1 |
| 1989 | 168.1 | 184.1 | 150.3 | 43.4 | 27.3 | 9.2 | 3.3 | 0.9 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 586.8 |
| 1990 | 138.3 | 105.8 | 102.0 | 73.3 | 19.8 | 11.5 | 3.6 | 1.2 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 455.9 |
| 1991 | 256.8 | 88.3 | 66.0 | 62.7 | 43.2 | 11.0 | 6.0 | 1.7 | 0.5 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 536.5 |
| 1992 | 462.6 | 153.6 | 52.5 | 44.4 | 41.1 | 27.0 | 6.5 | 3.3 | 0.9 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 792.4 |
| 1993 | 158.4 | 309.3 | 108.2 | 36.1 | 26.2 | 22.2 | 13.9 | 3.2 | 1.6 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 679.6 |
| 1994 | 257.9 | 108.3 | 223.8 | 71.0 | 16.9 | 10.9 | 8.7 | 5.2 | 1.1 | 0.5 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 704.4 |
| 1995 | 534.5 | 170.4 | 75.3 | 151.8 | 40.0 | 8.5 | 5.2 | 4.0 | 2.2 | 0.5 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 992.6 |
| 1996 | 601.1 | 360.7 | 121.6 | 52.3 | 88.6 | 20.9 | 4.2 | 2.4 | 1.7 | 0.9 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1254.6 |
| 1997 | 178.4 | 394.5 | 248.5 | 81.0 | 28.2 | 42.4 | 9.4 | 1.8 | 1.0 | 0.7 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 986.2 |
| 1998 | 114.4 | 113.9 | 262.8 | 164.3 | 45.2 | 13.9 | 19.6 | 4.1 | 0.7 | 0.4 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 739.6 |
| 1999 | 271.7 | 75.9 | 79.5 | 180.0 | 95.4 | 22.8 | 6.5 | 8.7 | 1.8 | 0.3 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 742.8 |
| 2000 | 281.6 | 180.0 | 53.0 | 56.1 | 115.8 | 55.0 | 12.3 | 3.4 | 4.3 | 0.8 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 762.6 |
| 2001 | 323.4 | 179.6 | 120.1 | 36.7 | 36.8 | 69.9 | 31.4 | 6.7 | 1.7 | 2.1 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 808.8 |
| 2002 | 412.1 | 212.3 | 123.9 | 84.1 | 23.7 | 21.7 | 39.2 | 16.8 | 3.4 | 0.8 | 0.9 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 939.0 |
| 2003 | 468.7 | 278.7 | 151.9 | 86.7 | 50.2 | 12.8 | 11.1 | 19.1 | 7.8 | 1.5 | 0.3 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 1089.3 |
| 2004 | 884.3 | 317.4 | 199.7 | 105.8 | 50.5 | 26.5 | 6.4 | 5.3 | 8.6 | 3.3 | 0.6 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 1608.4 |
| 2005 | 500.5 | 601.7 | 228.6 | 139.7 | 63.4 | 27.5 | 13.7 | 3.1 | 2.5 | 3.8 | 1.3 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 1586.2 |
| 2006 | 125.2 | 338.5 | 431.3 | 163.0 | 90.4 | 38.4 | 15.9 | 7.5 | 1.6 | 1.2 | 1.7 | 0.6 | 0.1 | 0.0 | 0.0 | 0.0 | 1215.3 |
| 2007 | 179.8 | 84.3 | 241.3 | 307.8 | 104.2 | 53.5 | 21.6 | 8.5 | 3.8 | 0.8 | 0.5 | 0.7 | 0.2 | 0.0 | 0.0 | 0.0 | 1007.0 |
| 2008 | 426.5 | 123.2 | 61.3 | 172.9 | 190.7 | 58.4 | 28.3 | 10.8 | 4.1 | 1.7 | 0.3 | 0.2 | 0.2 | 0.1 | 0.0 | 0.0 | 1078.7 |
| 2009 | 355.8 | 291.7 | 89.5 | 43.6 | 103.8 | 103.8 | 30.0 | 13.8 | 5.0 | 1.8 | 0.7 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 1039.7 |

*Table 6.4. Estimated male abundance at age (1000 fish) at start of year*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 0.0 | 13.4 | 11.8 | 66.2 | 31.5 | 10.2 | 10.1 | 6.3 | 8.2 | 3.4 | 1.8 | 1.0 | 0.6 | 0.3 | 0.2 | 0.3 | 165.2 |
| 1977 | 0.0 | 9.6 | 15.9 | 12.2 | 61.7 | 27.1 | 8.1 | 7.6 | 4.5 | 5.5 | 2.2 | 1.1 | 0.6 | 0.3 | 0.2 | 0.3 | 156.9 |
| 1978 | 0.0 | 9.2 | 11.5 | 16.4 | 11.4 | 53.5 | 21.9 | 6.2 | 5.5 | 3.0 | 3.6 | 1.4 | 0.7 | 0.4 | 0.2 | 0.3 | 145.1 |
| 1979 | 0.0 | 11.2 | 10.8 | 11.6 | 15.0 | 9.7 | 42.1 | 16.2 | 4.3 | 3.6 | 1.9 | 2.2 | 0.8 | 0.4 | 0.2 | 0.3 | 130.5 |
| 1980 | 0.0 | 10.1 | 13.0 | 10.8 | 10.5 | 12.6 | 7.5 | 30.8 | 11.2 | 2.9 | 2.3 | 1.2 | 1.3 | 0.5 | 0.2 | 0.3 | 115.1 |
| 1981 | 0.0 | 5.6 | 11.8 | 13.1 | 9.8 | 8.8 | 9.9 | 5.5 | 21.6 | 7.5 | 1.8 | 1.4 | 0.7 | 0.8 | 0.3 | 0.3 | 99.0 |
| 1982 | 0.0 | 6.7 | 6.9 | 13.1 | 13.4 | 9.3 | 7.8 | 8.2 | 4.3 | 16.0 | 5.3 | 1.2 | 0.9 | 0.5 | 0.5 | 0.4 | 94.6 |
| 1983 | 0.0 | 10.9 | 7.6 | 6.8 | 11.7 | 11.0 | 7.1 | 5.6 | 5.5 | 2.8 | 9.8 | 3.1 | 0.7 | 0.5 | 0.3 | 0.5 | 84.1 |
| 1984 | 0.0 | 10.7 | 10.0 | 5.8 | 4.6 | 7.2 | 6.2 | 3.8 | 2.8 | 2.6 | 1.3 | 4.3 | 1.3 | 0.3 | 0.2 | 0.3 | 61.3 |
| 1985 | 0.0 | 7.9 | 8.3 | 5.6 | 2.9 | 2.1 | 3.0 | 2.4 | 1.4 | 0.9 | 0.8 | 0.4 | 1.3 | 0.4 | 0.1 | 0.2 | 37.7 |
| 1986 | 0.0 | 9.3 | 8.4 | 7.1 | 4.3 | 2.0 | 1.3 | 1.7 | 1.3 | 0.7 | 0.4 | 0.4 | 0.2 | 0.6 | 0.2 | 0.1 | 37.9 |
| 1987 | 0.0 | 6.2 | 9.1 | 6.6 | 4.9 | 2.7 | 1.1 | 0.6 | 0.8 | 0.5 | 0.3 | 0.2 | 0.1 | 0.1 | 0.2 | 0.1 | 33.5 |
| 1988 | 0.0 | 10.0 | 6.0 | 7.5 | 4.9 | 3.2 | 1.6 | 0.6 | 0.3 | 0.4 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 35.2 |
| 1989 | 0.0 | 7.1 | 11.3 | 6.0 | 6.7 | 3.8 | 2.3 | 1.0 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 | 39.2 |
| 1990 | 0.0 | 4.1 | 7.7 | 10.2 | 4.9 | 4.8 | 2.5 | 1.3 | 0.5 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 36.5 |
| 1991 | 0.0 | 3.4 | 5.0 | 8.7 | 10.6 | 4.6 | 4.2 | 2.0 | 1.0 | 0.4 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 40.2 |
| 1992 | 0.0 | 5.9 | 3.9 | 6.2 | 10.1 | 11.3 | 4.5 | 3.8 | 1.7 | 0.8 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 48.9 |
| 1993 | 0.0 | 11.9 | 8.1 | 5.0 | 6.4 | 9.3 | 9.7 | 3.7 | 3.0 | 1.3 | 0.6 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 59.3 |
| 1994 | 0.0 | 4.2 | 16.8 | 9.9 | 4.1 | 4.5 | 6.0 | 5.9 | 2.2 | 1.7 | 0.7 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 56.5 |
| 1995 | 0.0 | 6.5 | 5.7 | 21.1 | 9.8 | 3.6 | 3.6 | 4.5 | 4.2 | 1.5 | 1.1 | 0.4 | 0.2 | 0.1 | 0.0 | 0.0 | 62.3 |
| 1996 | 0.0 | 13.9 | 9.1 | 7.3 | 21.7 | 8.7 | 2.9 | 2.8 | 3.3 | 2.9 | 1.0 | 0.7 | 0.3 | 0.1 | 0.0 | 0.0 | 74.8 |
| 1997 | 0.0 | 15.2 | 18.7 | 11.3 | 6.9 | 17.7 | 6.5 | 2.1 | 1.9 | 2.1 | 1.8 | 0.6 | 0.4 | 0.2 | 0.1 | 0.0 | 85.3 |
| 1998 | 0.0 | 4.4 | 19.8 | 22.8 | 11.1 | 5.8 | 13.6 | 4.7 | 1.4 | 1.2 | 1.3 | 1.1 | 0.3 | 0.2 | 0.1 | 0.1 | 88.0 |
| 1999 | 0.0 | 2.9 | 6.0 | 25.0 | 23.4 | 9.5 | 4.5 | 10.0 | 3.3 | 0.9 | 0.8 | 0.8 | 0.7 | 0.2 | 0.1 | 0.1 | 88.3 |
| 2000 | 0.0 | 6.9 | 4.0 | 7.8 | 28.4 | 23.0 | 8.6 | 3.9 | 8.1 | 2.5 | 0.7 | 0.6 | 0.6 | 0.5 | 0.1 | 0.2 | 95.8 |
| 2001 | 0.0 | 6.9 | 9.0 | 5.1 | 9.0 | 29.2 | 21.8 | 7.7 | 3.3 | 6.6 | 2.0 | 0.5 | 0.4 | 0.4 | 0.3 | 0.2 | 102.5 |
| 2002 | 0.0 | 8.2 | 9.3 | 11.7 | 5.8 | 9.1 | 27.2 | 19.3 | 6.5 | 2.6 | 5.0 | 1.5 | 0.4 | 0.3 | 0.3 | 0.4 | 107.4 |
| 2003 | 0.0 | 10.7 | 11.4 | 12.0 | 12.3 | 5.4 | 7.7 | 21.9 | 14.7 | 4.7 | 1.8 | 3.4 | 1.0 | 0.2 | 0.2 | 0.4 | 108.0 |
| 2004 | 0.0 | 12.2 | 15.0 | 14.7 | 12.4 | 11.1 | 4.4 | 6.0 | 16.3 | 10.4 | 3.2 | 1.2 | 2.2 | 0.6 | 0.2 | 0.4 | 110.3 |
| 2005 | 0.0 | 23.1 | 17.2 | 19.4 | 15.6 | 11.5 | 9.5 | 3.6 | 4.7 | 12.0 | 7.4 | 2.2 | 0.8 | 1.4 | 0.4 | 0.3 | 129.1 |
| 2006 | 0.0 | 13.0 | 32.5 | 22.6 | 22.2 | 16.1 | 11.0 | 8.6 | 3.1 | 3.8 | 9.4 | 5.6 | 1.6 | 0.6 | 1.0 | 0.5 | 151.6 |
| 2007 | 0.0 | 3.2 | 18.2 | 42.8 | 25.6 | 22.4 | 15.0 | 9.7 | 7.2 | 2.5 | 2.9 | 6.9 | 4.0 | 1.1 | 0.4 | 1.1 | 163.0 |
| 2008 | 0.0 | 4.7 | 4.6 | 24.0 | 46.8 | 24.4 | 19.6 | 12.4 | 7.7 | 5.4 | 1.8 | 2.0 | 4.7 | 2.7 | 0.8 | 1.0 | 162.6 |
| 2009 | 0.0 | 11.2 | 6.7 | 6.1 | 25.5 | 43.4 | 20.9 | 15.8 | 9.5 | 5.6 | 3.8 | 1.2 | 1.3 | 3.0 | 1.7 | 1.1 | 156.8 |

*Table 6.5. Estimated biomass at age (mt) at start of year*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 179.2 | 401.2 | 329.5 | 1562.5 | 611.6 | 162.9 | 136.2 | 73.7 | 86.6 | 33.2 | 17.3 | 9.3 | 5.2 | 3.0 | 1.7 | 2.6 | 3615.6 |
| 1977 | 171.2 | 288.5 | 443.2 | 287.0 | 1197.2 | 433.7 | 109.9 | 88.9 | 47.1 | 54.0 | 20.4 | 10.5 | 5.6 | 3.1 | 1.8 | 2.5 | 3164.6 |
| 1978 | 210.4 | 276.1 | 319.4 | 387.3 | 221.1 | 856.3 | 295.9 | 72.7 | 57.6 | 29.9 | 33.7 | 12.6 | 6.5 | 3.4 | 1.9 | 2.6 | 2787.4 |
| 1979 | 190.3 | 335.8 | 300.3 | 273.1 | 291.7 | 154.4 | 569.7 | 190.7 | 45.9 | 35.6 | 18.1 | 20.2 | 7.5 | 3.8 | 2.0 | 2.6 | 2442.0 |
| 1980 | 105.0 | 302.6 | 362.5 | 254.1 | 203.3 | 201.2 | 101.5 | 362.4 | 118.8 | 28.0 | 21.3 | 10.7 | 12.0 | 4.4 | 2.2 | 2.7 | 2092.8 |
| 1981 | 123.8 | 167.8 | 329.2 | 309.6 | 191.0 | 141.6 | 133.5 | 65.2 | 228.1 | 73.1 | 16.9 | 12.8 | 6.4 | 7.1 | 2.6 | 2.9 | 1811.6 |
| 1982 | 208.9 | 200.0 | 192.0 | 309.9 | 260.0 | 149.0 | 105.3 | 96.1 | 45.9 | 157.2 | 49.6 | 11.3 | 8.5 | 4.3 | 4.7 | 3.6 | 1806.3 |
| 1983 | 227.7 | 328.1 | 212.1 | 160.5 | 227.5 | 176.5 | 96.1 | 65.6 | 58.6 | 27.4 | 92.1 | 28.7 | 6.6 | 4.9 | 2.4 | 4.7 | 1719.6 |
| 1984 | 165.6 | 320.1 | 278.6 | 137.1 | 88.4 | 114.7 | 84.1 | 44.1 | 29.4 | 25.6 | 11.8 | 39.1 | 12.2 | 2.8 | 2.1 | 2.9 | 1358.6 |
| 1985 | 176.2 | 237.7 | 230.3 | 133.1 | 56.7 | 33.4 | 40.4 | 28.2 | 14.3 | 9.3 | 7.9 | 3.6 | 11.9 | 3.7 | 0.8 | 1.5 | 989.0 |
| 1986 | 121.8 | 278.5 | 234.9 | 167.3 | 84.1 | 32.3 | 17.5 | 20.0 | 13.4 | 6.6 | 4.2 | 3.5 | 1.6 | 5.2 | 1.6 | 1.0 | 993.5 |
| 1987 | 201.0 | 184.8 | 254.8 | 155.8 | 95.0 | 42.4 | 14.8 | 7.5 | 8.2 | 5.3 | 2.5 | 1.6 | 1.3 | 0.6 | 1.9 | 0.9 | 978.4 |
| 1988 | 137.0 | 300.9 | 168.5 | 177.6 | 94.4 | 51.9 | 21.4 | 7.0 | 3.4 | 3.6 | 2.3 | 1.1 | 0.7 | 0.5 | 0.2 | 1.2 | 971.6 |
| 1989 | 77.8 | 212.4 | 315.2 | 142.4 | 129.9 | 61.4 | 30.7 | 11.8 | 3.7 | 1.7 | 1.8 | 1.1 | 0.5 | 0.3 | 0.3 | 0.7 | 991.6 |
| 1990 | 64.0 | 122.1 | 213.9 | 240.3 | 94.3 | 77.2 | 33.5 | 15.7 | 5.8 | 1.8 | 0.8 | 0.8 | 0.5 | 0.2 | 0.1 | 0.4 | 871.5 |
| 1991 | 118.9 | 101.9 | 138.3 | 205.7 | 205.8 | 73.8 | 56.5 | 23.4 | 10.6 | 3.8 | 1.1 | 0.5 | 0.5 | 0.3 | 0.1 | 0.3 | 941.6 |
| 1992 | 214.1 | 177.3 | 110.0 | 145.6 | 195.7 | 181.0 | 61.3 | 45.1 | 18.1 | 8.0 | 2.8 | 0.8 | 0.4 | 0.4 | 0.2 | 0.3 | 1161.3 |
| 1993 | 73.3 | 356.9 | 226.8 | 118.3 | 124.6 | 148.9 | 130.8 | 43.3 | 31.4 | 12.4 | 5.4 | 1.9 | 0.6 | 0.2 | 0.2 | 0.4 | 1275.5 |
| 1994 | 119.4 | 125.0 | 469.2 | 232.9 | 80.2 | 72.7 | 81.7 | 69.8 | 22.7 | 16.2 | 6.3 | 2.7 | 1.0 | 0.3 | 0.1 | 0.3 | 1300.5 |
| 1995 | 247.4 | 196.6 | 157.9 | 497.8 | 190.4 | 57.2 | 48.7 | 53.2 | 44.7 | 14.3 | 10.0 | 3.9 | 1.7 | 0.6 | 0.2 | 0.3 | 1524.8 |
| 1996 | 278.2 | 416.2 | 254.9 | 171.6 | 421.6 | 139.7 | 39.4 | 32.6 | 35.0 | 28.8 | 9.1 | 6.3 | 2.4 | 1.0 | 0.4 | 0.3 | 1837.3 |
| 1997 | 82.6 | 455.2 | 521.0 | 265.9 | 134.1 | 283.6 | 88.1 | 24.1 | 19.6 | 20.7 | 16.8 | 5.2 | 3.6 | 1.4 | 0.6 | 0.3 | 1922.8 |
| 1998 | 52.9 | 131.4 | 551.0 | 539.1 | 215.1 | 93.1 | 184.1 | 55.5 | 15.0 | 11.9 | 12.4 | 9.9 | 3.1 | 2.1 | 0.8 | 0.5 | 1877.9 |
| 1999 | 125.7 | 87.6 | 166.7 | 590.4 | 454.1 | 152.3 | 61.3 | 117.8 | 35.0 | 9.2 | 7.3 | 7.5 | 6.0 | 1.9 | 1.3 | 0.8 | 1824.9 |
| 2000 | 130.3 | 207.7 | 111.1 | 184.0 | 551.2 | 368.5 | 115.9 | 45.3 | 85.6 | 24.9 | 6.5 | 5.0 | 5.2 | 4.1 | 1.3 | 1.4 | 1848.2 |
| 2001 | 149.7 | 207.3 | 251.7 | 120.4 | 175.0 | 467.8 | 295.4 | 90.3 | 34.7 | 64.3 | 18.4 | 4.7 | 3.7 | 3.8 | 3.0 | 1.9 | 1892.0 |
| 2002 | 190.7 | 245.0 | 259.8 | 275.7 | 112.6 | 145.5 | 367.9 | 226.4 | 68.2 | 25.8 | 47.0 | 13.3 | 3.4 | 2.7 | 2.7 | 3.4 | 1990.3 |
| 2003 | 216.9 | 321.6 | 318.5 | 284.5 | 238.9 | 85.7 | 104.5 | 257.2 | 155.9 | 46.1 | 17.2 | 31.0 | 8.8 | 2.3 | 1.7 | 3.9 | 2094.8 |
| 2004 | 409.3 | 366.2 | 418.7 | 347.0 | 240.2 | 177.1 | 60.0 | 71.1 | 172.2 | 102.4 | 29.8 | 11.0 | 19.8 | 5.6 | 1.4 | 3.5 | 2435.3 |
| 2005 | 231.6 | 694.3 | 479.4 | 458.3 | 302.0 | 184.4 | 128.5 | 42.3 | 49.4 | 117.5 | 68.8 | 19.8 | 7.3 | 13.1 | 3.7 | 3.2 | 2803.6 |
| 2006 | 57.9 | 390.6 | 904.3 | 534.7 | 430.1 | 257.0 | 149.2 | 101.1 | 32.8 | 37.5 | 87.7 | 50.8 | 14.6 | 5.4 | 9.6 | 4.9 | 3068.2 |
| 2007 | 83.2 | 97.2 | 506.0 | 1009.9 | 496.0 | 358.0 | 202.6 | 114.4 | 76.2 | 24.2 | 27.2 | 63.0 | 36.5 | 10.4 | 3.8 | 10.1 | 3118.8 |
| 2008 | 197.4 | 142.2 | 128.6 | 567.1 | 907.6 | 390.9 | 265.6 | 146.0 | 81.0 | 52.9 | 16.5 | 18.4 | 42.5 | 24.5 | 7.0 | 9.1 | 2997.3 |
| 2009 | 164.7 | 336.6 | 187.6 | 142.9 | 493.9 | 695.0 | 282.1 | 186.1 | 100.6 | 54.7 | 35.1 | 10.8 | 12.1 | 27.7 | 15.8 | 10.2 | 2756.1 |

*Table 6.6. Estimated biomass at age (1000 lb) at start of year*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 395.0 | 884.6 | 726.5 | 3444.7 | 1348.3 | 359.0 | 300.3 | 162.6 | 190.9 | 73.3 | 38.1 | 20.5 | 11.5 | 6.5 | 3.8 | 5.7 | 7971.1 |
| 1977 | 377.5 | 635.9 | 977.2 | 632.6 | 2639.4 | 956.1 | 242.2 | 196.0 | 103.8 | 119.1 | 45.0 | 23.1 | 12.4 | 6.9 | 3.9 | 5.6 | 6976.8 |
| 1978 | 463.9 | 608.8 | 704.1 | 853.8 | 487.5 | 1887.7 | 652.3 | 160.2 | 127.1 | 65.9 | 74.3 | 27.7 | 14.2 | 7.6 | 4.2 | 5.7 | 6145.1 |
| 1979 | 419.5 | 740.4 | 662.0 | 602.2 | 643.2 | 340.4 | 1256.0 | 420.4 | 101.1 | 78.5 | 40.0 | 44.6 | 16.6 | 8.5 | 4.5 | 5.8 | 5383.7 |
| 1980 | 231.6 | 667.1 | 799.1 | 560.2 | 448.2 | 443.6 | 223.7 | 799.0 | 261.9 | 61.6 | 47.0 | 23.7 | 26.4 | 9.8 | 5.0 | 5.9 | 4613.8 |
| 1981 | 272.9 | 370.0 | 725.8 | 682.5 | 421.0 | 312.2 | 294.3 | 143.7 | 502.8 | 161.2 | 37.3 | 28.1 | 14.2 | 15.7 | 5.8 | 6.3 | 3993.9 |
| 1982 | 460.6 | 440.9 | 423.3 | 683.3 | 573.3 | 328.6 | 232.1 | 211.8 | 101.3 | 346.5 | 109.3 | 25.0 | 18.8 | 9.4 | 10.4 | 7.9 | 3982.3 |
| 1983 | 502.1 | 723.4 | 467.5 | 353.9 | 501.7 | 389.1 | 211.9 | 144.7 | 129.2 | 60.3 | 203.0 | 63.2 | 14.5 | 10.8 | 5.4 | 10.3 | 3791.0 |
| 1984 | 365.2 | 705.8 | 614.2 | 302.3 | 194.9 | 252.8 | 185.4 | 97.3 | 64.8 | 56.5 | 25.9 | 86.1 | 26.8 | 6.1 | 4.5 | 6.5 | 2995.3 |
| 1985 | 388.5 | 524.0 | 507.7 | 293.5 | 124.9 | 73.5 | 89.1 | 62.2 | 31.6 | 20.4 | 17.5 | 7.9 | 26.3 | 8.1 | 1.8 | 3.3 | 2180.4 |
| 1986 | 268.5 | 614.1 | 517.9 | 368.8 | 185.4 | 71.2 | 38.6 | 44.1 | 29.6 | 14.5 | 9.2 | 7.7 | 3.5 | 11.5 | 3.5 | 2.2 | 2190.4 |
| 1987 | 443.1 | 407.4 | 561.8 | 343.4 | 209.5 | 93.5 | 32.6 | 16.5 | 18.0 | 11.6 | 5.6 | 3.4 | 2.9 | 1.3 | 4.2 | 2.1 | 2157.1 |
| 1988 | 302.0 | 663.4 | 371.5 | 391.6 | 208.0 | 114.3 | 47.1 | 15.5 | 7.5 | 7.9 | 5.0 | 2.3 | 1.5 | 1.2 | 0.5 | 2.6 | 2142.1 |
| 1989 | 171.5 | 468.2 | 694.9 | 313.9 | 286.5 | 135.3 | 67.7 | 26.0 | 8.1 | 3.8 | 3.9 | 2.4 | 1.1 | 0.7 | 0.6 | 1.5 | 2186.1 |
| 1990 | 141.1 | 269.2 | 471.7 | 529.8 | 207.8 | 170.2 | 73.8 | 34.7 | 12.8 | 3.9 | 1.8 | 1.8 | 1.1 | 0.5 | 0.3 | 0.9 | 1921.3 |
| 1991 | 262.1 | 224.6 | 305.0 | 453.4 | 453.7 | 162.8 | 124.6 | 51.5 | 23.4 | 8.4 | 2.5 | 1.1 | 1.1 | 0.7 | 0.3 | 0.7 | 2076.0 |
| 1992 | 472.0 | 390.8 | 242.5 | 321.0 | 431.4 | 399.1 | 135.2 | 99.4 | 40.0 | 17.7 | 6.2 | 1.8 | 0.8 | 0.8 | 0.5 | 0.8 | 2560.2 |
| 1993 | 161.7 | 786.8 | 500.1 | 260.8 | 274.7 | 328.3 | 288.3 | 95.4 | 69.3 | 27.4 | 12.0 | 4.2 | 1.2 | 0.5 | 0.5 | 0.8 | 2812.0 |
| 1994 | 263.2 | 275.6 | 1034.4 | 513.4 | 176.8 | 160.3 | 180.1 | 153.8 | 50.1 | 35.7 | 13.9 | 6.0 | 2.1 | 0.6 | 0.3 | 0.7 | 2867.0 |
| 1995 | 545.4 | 433.4 | 348.1 | 1097.5 | 419.8 | 126.0 | 107.4 | 117.3 | 98.5 | 31.5 | 22.1 | 8.5 | 3.7 | 1.3 | 0.4 | 0.6 | 3361.5 |
| 1996 | 613.3 | 917.6 | 561.9 | 378.4 | 929.5 | 308.0 | 86.8 | 71.8 | 77.1 | 63.5 | 20.0 | 13.8 | 5.3 | 2.3 | 0.8 | 0.6 | 4050.6 |
| 1997 | 182.0 | 1003.6 | 1148.7 | 586.2 | 295.6 | 625.3 | 194.3 | 53.2 | 43.3 | 45.6 | 37.0 | 11.5 | 8.0 | 3.1 | 1.3 | 0.8 | 4239.1 |
| 1998 | 116.7 | 289.7 | 1214.6 | 1188.4 | 474.1 | 205.1 | 405.9 | 122.5 | 33.0 | 26.3 | 27.3 | 21.9 | 6.8 | 4.7 | 1.8 | 1.2 | 4140.1 |
| 1999 | 277.2 | 193.2 | 367.5 | 1301.6 | 1001.2 | 335.9 | 135.2 | 259.7 | 77.1 | 20.4 | 16.0 | 16.5 | 13.2 | 4.1 | 2.8 | 1.8 | 4023.3 |
| 2000 | 287.3 | 457.9 | 245.0 | 405.7 | 1215.3 | 812.4 | 255.6 | 99.9 | 188.7 | 55.0 | 14.3 | 11.1 | 11.4 | 9.1 | 2.8 | 3.1 | 4074.6 |
| 2001 | 330.0 | 457.0 | 555.0 | 265.4 | 385.9 | 1031.2 | 651.2 | 199.1 | 76.5 | 141.7 | 40.6 | 10.4 | 8.1 | 8.3 | 6.6 | 4.2 | 4171.3 |
| 2002 | 420.4 | 540.1 | 572.8 | 607.9 | 248.3 | 320.8 | 811.2 | 499.1 | 150.4 | 56.8 | 103.7 | 29.4 | 7.6 | 5.9 | 5.9 | 7.6 | 4387.8 |
| 2003 | 478.3 | 709.1 | 702.1 | 627.1 | 526.6 | 189.0 | 230.4 | 567.1 | 343.7 | 101.7 | 37.8 | 68.3 | 19.4 | 5.0 | 3.8 | 8.7 | 4618.2 |
| 2004 | 902.3 | 807.3 | 923.1 | 765.0 | 529.5 | 390.5 | 132.2 | 156.8 | 379.7 | 225.7 | 65.8 | 24.2 | 43.7 | 12.3 | 3.1 | 7.8 | 5368.9 |
| 2005 | 510.6 | 1530.6 | 1056.9 | 1010.3 | 665.7 | 406.6 | 283.3 | 93.3 | 109.0 | 259.0 | 151.7 | 43.7 | 16.1 | 28.9 | 8.1 | 7.0 | 6180.9 |
| 2006 | 127.7 | 861.2 | 1993.6 | 1178.8 | 948.1 | 566.5 | 329.0 | 223.0 | 72.2 | 82.7 | 193.4 | 112.0 | 32.3 | 11.8 | 21.1 | 10.9 | 6764.3 |
| 2007 | 183.5 | 214.4 | 1115.5 | 2226.4 | 1093.5 | 789.2 | 446.8 | 252.1 | 168.0 | 53.3 | 60.1 | 138.8 | 80.4 | 23.0 | 8.4 | 22.4 | 6875.7 |
| 2008 | 435.2 | 313.4 | 283.6 | 1250.3 | 2000.9 | 861.9 | 585.5 | 321.9 | 178.6 | 116.6 | 36.4 | 40.5 | 93.8 | 53.9 | 15.3 | 20.1 | 6607.9 |
| 2009 | 363.0 | 742.1 | 413.7 | 315.1 | 1089.0 | 1532.3 | 622.0 | 410.4 | 221.7 | 120.5 | 77.4 | 23.9 | 26.6 | 61.1 | 34.9 | 22.6 | 6076.2 |

*Table 6.7. 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, mt) in April (time of peak spawning). The* MSST *is defined by* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{MSY}}$, *with constant* $M = 0.14$. *SPR is static spawning potential ratio, and Prop.male is proportion of the total population that is male.*

| Year | $F$ | $F/F_{\mathrm{MSY}}$ | B | $B/B_{\mathrm{unfished}}$ | SSB | $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ | $SSB/\mathrm{MSST}$ | SPR | Prop.male |
|---|---|---|---|---|---|---|---|---|---|
| 1976 | 0.419 | 1.89 | 3616 | 0.3059 | 2158 | 0.832 | 0.968 | 0.0994 | 0.0965 |
| 1977 | 0.402 | 1.82 | 3165 | 0.2678 | 2002 | 0.772 | 0.898 | 0.1019 | 0.1109 |
| 1978 | 0.429 | 1.94 | 2787 | 0.2359 | 1749 | 0.675 | 0.785 | 0.0933 | 0.1095 |
| 1979 | 0.442 | 2.00 | 2442 | 0.2066 | 1492 | 0.576 | 0.669 | 0.0897 | 0.1067 |
| 1980 | 0.432 | 1.96 | 2093 | 0.1771 | 1290 | 0.498 | 0.579 | 0.0929 | 0.1184 |
| 1981 | 0.319 | 1.44 | 1812 | 0.1533 | 1152 | 0.444 | 0.517 | 0.1343 | 0.1153 |
| 1982 | 0.465 | 2.10 | 1806 | 0.1528 | 1054 | 0.406 | 0.473 | 0.0839 | 0.0937 |
| 1983 | 0.775 | 3.51 | 1720 | 0.1455 | 847 | 0.327 | 0.380 | 0.0375 | 0.0761 |
| 1984 | 1.106 | 5.01 | 1359 | 0.1150 | 572 | 0.221 | 0.257 | 0.0245 | 0.0664 |
| 1985 | 0.736 | 3.33 | 989 | 0.0837 | 415 | 0.160 | 0.186 | 0.0572 | 0.0472 |
| 1986 | 0.902 | 4.08 | 994 | 0.0841 | 418 | 0.161 | 0.187 | 0.0439 | 0.0518 |
| 1987 | 0.780 | 3.53 | 978 | 0.0828 | 391 | 0.151 | 0.175 | 0.0473 | 0.0405 |
| 1988 | 0.649 | 2.94 | 972 | 0.0822 | 427 | 0.165 | 0.191 | 0.0763 | 0.0465 |
| 1989 | 0.708 | 3.21 | 992 | 0.0839 | 475 | 0.183 | 0.213 | 0.0624 | 0.0627 |
| 1990 | 0.375 | 1.70 | 871 | 0.0737 | 488 | 0.188 | 0.219 | 0.1303 | 0.0741 |
| 1991 | 0.256 | 1.16 | 942 | 0.0797 | 552 | 0.213 | 0.248 | 0.1775 | 0.0697 |
| 1992 | 0.336 | 1.52 | 1161 | 0.0983 | 623 | 0.240 | 0.279 | 0.1691 | 0.0581 |
| 1993 | 0.612 | 2.77 | 1276 | 0.1079 | 683 | 0.264 | 0.306 | 0.1092 | 0.0803 |
| 1994 | 0.413 | 1.87 | 1300 | 0.1100 | 717 | 0.277 | 0.322 | 0.1411 | 0.0742 |
| 1995 | 0.387 | 1.75 | 1525 | 0.1290 | 809 | 0.312 | 0.363 | 0.1601 | 0.0590 |
| 1996 | 0.474 | 2.14 | 1837 | 0.1555 | 920 | 0.355 | 0.413 | 0.1241 | 0.0562 |
| 1997 | 0.446 | 2.02 | 1923 | 0.1627 | 1057 | 0.408 | 0.474 | 0.1228 | 0.0796 |
| 1998 | 0.431 | 1.95 | 1878 | 0.1589 | 1153 | 0.445 | 0.517 | 0.1440 | 0.1063 |
| 1999 | 0.287 | 1.30 | 1825 | 0.1544 | 1200 | 0.463 | 0.538 | 0.1988 | 0.1063 |
| 2000 | 0.234 | 1.06 | 1848 | 0.1564 | 1247 | 0.481 | 0.559 | 0.2050 | 0.1116 |
| 2001 | 0.251 | 1.13 | 1892 | 0.1601 | 1260 | 0.486 | 0.565 | 0.2091 | 0.1125 |
| 2002 | 0.342 | 1.55 | 1990 | 0.1684 | 1248 | 0.481 | 0.560 | 0.1758 | 0.1027 |
| 2003 | 0.369 | 1.67 | 2095 | 0.1773 | 1240 | 0.478 | 0.556 | 0.1650 | 0.0902 |
| 2004 | 0.332 | 1.50 | 2435 | 0.2061 | 1306 | 0.504 | 0.586 | 0.1813 | 0.0642 |
| 2005 | 0.223 | 1.01 | 2804 | 0.2372 | 1589 | 0.613 | 0.713 | 0.2418 | 0.0753 |
| 2006 | 0.250 | 1.13 | 3068 | 0.2596 | 1944 | 0.750 | 0.872 | 0.2228 | 0.1109 |
| 2007 | 0.312 | 1.41 | 3119 | 0.2639 | 2125 | 0.820 | 0.953 | 0.2001 | 0.1393 |
| 2008 | 0.340 | 1.54 | 2997 | 0.2536 | 2051 | 0.791 | 0.920 | 0.1840 | 0.1310 |
| 2009 | . | . | 2756 | 0.2332 | . | . | . | . | 0.1311 |

*Table 6.8. Selectivity at age (end-of-assessment time period) for commercial lines (cl), commercial other (co), headboat (hb), general recreational (rec), commercial lines discard mortalities (D.cl), headboat discard mortalities (D.hb), general recreational discard mortalities (D.rec), selectivity of landings averaged across fisheries (L.avg), and selectivity of discard mortalities averaged across fisheries (D.avg). TL is total length.*

| Age | TL(mm) | TL(in) | cl | co | hb | rec | D.cl | D.hb | D.rec | L.avg | D.avg | L.avg+D.avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 313.9 | 12.4 | 0.0023 | 0.0412 | 0.0008 | 0.0001 | 0.8187 | 0.8187 | 0.8187 | 0.0015 | 0.1497 | 0.1512 |
| 2 | 416.4 | 16.4 | 0.0159 | 0.1523 | 0.0369 | 0.0057 | 1.0000 | 1.0000 | 1.0000 | 0.0127 | 0.1828 | 0.1955 |
| 3 | 499.3 | 19.7 | 0.1022 | 0.4559 | 0.6487 | 0.2636 | 0.5516 | 0.5516 | 0.5516 | 0.1955 | 0.1008 | 0.2964 |
| 4 | 566.2 | 22.3 | 0.4458 | 0.8671 | 0.9889 | 0.9570 | 0.1122 | 0.1122 | 0.1122 | 0.7093 | 0.0205 | 0.7298 |
| 5 | 620.3 | 24.4 | 0.8504 | 1.0000 | 0.9998 | 0.9993 | 0.0186 | 0.0186 | 0.0186 | 0.9302 | 0.0034 | 0.9336 |
| 6 | 664.0 | 26.1 | 0.9757 | 0.8802 | 1.0000 | 1.0000 | 0.0037 | 0.0037 | 0.0037 | 0.9912 | 0.0007 | 0.9918 |
| 7 | 699.4 | 27.5 | 0.9965 | 0.6976 | 1.0000 | 1.0000 | 0.0009 | 0.0009 | 0.0009 | 0.9998 | 0.0002 | 1.0000 |
| 8 | 727.9 | 28.7 | 0.9995 | 0.5273 | 1.0000 | 1.0000 | 0.0003 | 0.0003 | 0.0003 | 0.9998 | 0.0001 | 0.9999 |
| 9 | 751.0 | 29.6 | 0.9999 | 0.3873 | 1.0000 | 1.0000 | 0.0001 | 0.0001 | 0.0001 | 0.9988 | 0.0000 | 0.9989 |
| 10 | 769.6 | 30.3 | 1.0000 | 0.2787 | 1.0000 | 1.0000 | 0.0001 | 0.0001 | 0.0001 | 0.9979 | 0.0000 | 0.9979 |
| 11 | 784.7 | 30.9 | 1.0000 | 0.1976 | 1.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.9972 | 0.0000 | 0.9972 |
| 12 | 796.9 | 31.4 | 1.0000 | 0.1386 | 1.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.9967 | 0.0000 | 0.9967 |
| 13 | 806.7 | 31.8 | 1.0000 | 0.0964 | 1.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.9964 | 0.0000 | 0.9964 |
| 14 | 814.7 | 32.1 | 1.0000 | 0.0667 | 1.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.9961 | 0.0000 | 0.9961 |
| 15 | 821.1 | 32.3 | 1.0000 | 0.0460 | 1.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.9959 | 0.0000 | 0.9959 |
| 16 | 826.3 | 32.5 | 1.0000 | 0.0316 | 1.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.9958 | 0.0000 | 0.9958 |

*Table 6.9. Estimated time series of fully selected fishing mortality rates for commercial lines (F.cl), commercial other (F.co), headboat (F.hb), general recreational (F.rec), commercial lines discard mortalities (F.cl.D), headboat discard mortalities (F.hb.D), general recreational discard mortalities (F.rec.D). Also shown is apical F, the maximum F at age summed across fleets, which may not equal the sum of fully selected F's because of dome-shaped selectivities.*

| Year | F.cl | F.co | F.hb | F.rec | F.cl.D | F.hb.D | F.rec.D | Apical F |
|---|---|---|---|---|---|---|---|---|
| 1976 | 0.099 | 0.037 | 0.005 | 0.314 | 0.000 | 0.000 | 0.000 | 0.419 |
| 1977 | 0.079 | 0.036 | 0.007 | 0.314 | 0.000 | 0.000 | 0.000 | 0.402 |
| 1978 | 0.105 | 0.051 | 0.007 | 0.314 | 0.000 | 0.000 | 0.000 | 0.429 |
| 1979 | 0.109 | 0.053 | 0.016 | 0.314 | 0.000 | 0.000 | 0.000 | 0.442 |
| 1980 | 0.100 | 0.046 | 0.016 | 0.314 | 0.000 | 0.000 | 0.000 | 0.432 |
| 1981 | 0.126 | 0.062 | 0.018 | 0.173 | 0.000 | 0.000 | 0.010 | 0.319 |
| 1982 | 0.135 | 0.061 | 0.015 | 0.312 | 0.000 | 0.000 | 0.008 | 0.465 |
| 1983 | 0.174 | 0.071 | 0.024 | 0.574 | 0.000 | 0.000 | 0.059 | 0.775 |
| 1984 | 0.323 | 0.105 | 0.031 | 0.750 | 0.004 | 0.011 | 0.084 | 1.106 |
| 1985 | 0.383 | 0.082 | 0.036 | 0.316 | 0.004 | 0.011 | 0.003 | 0.736 |
| 1986 | 0.515 | 0.105 | 0.023 | 0.362 | 0.004 | 0.011 | 0.019 | 0.902 |
| 1987 | 0.406 | 0.096 | 0.030 | 0.343 | 0.004 | 0.011 | 0.056 | 0.780 |
| 1988 | 0.485 | 0.083 | 0.019 | 0.143 | 0.004 | 0.011 | 0.027 | 0.649 |
| 1989 | 0.421 | 0.086 | 0.013 | 0.273 | 0.004 | 0.011 | 0.009 | 0.708 |
| 1990 | 0.292 | 0.083 | 0.030 | 0.052 | 0.004 | 0.011 | 0.024 | 0.375 |
| 1991 | 0.191 | 0.059 | 0.011 | 0.025 | 0.004 | 0.011 | 0.135 | 0.256 |
| 1992 | 0.128 | 0.031 | 0.024 | 0.160 | 0.004 | 0.011 | 0.063 | 0.336 |
| 1993 | 0.185 | 0.013 | 0.027 | 0.392 | 0.004 | 0.011 | 0.036 | 0.612 |
| 1994 | 0.184 | 0.007 | 0.022 | 0.203 | 0.007 | 0.011 | 0.074 | 0.413 |
| 1995 | 0.198 | 0.005 | 0.020 | 0.166 | 0.004 | 0.011 | 0.052 | 0.387 |
| 1996 | 0.212 | 0.010 | 0.022 | 0.233 | 0.003 | 0.011 | 0.087 | 0.474 |
| 1997 | 0.234 | 0.009 | 0.025 | 0.181 | 0.005 | 0.011 | 0.118 | 0.446 |
| 1998 | 0.278 | 0.015 | 0.027 | 0.116 | 0.006 | 0.011 | 0.069 | 0.431 |
| 1999 | 0.206 | 0.007 | 0.019 | 0.057 | 0.008 | 0.011 | 0.070 | 0.287 |
| 2000 | 0.153 | 0.005 | 0.017 | 0.061 | 0.006 | 0.011 | 0.119 | 0.234 |
| 2001 | 0.148 | 0.019 | 0.016 | 0.073 | 0.004 | 0.011 | 0.085 | 0.251 |
| 2002 | 0.160 | 0.015 | 0.015 | 0.157 | 0.008 | 0.011 | 0.045 | 0.342 |
| 2003 | 0.159 | 0.010 | 0.013 | 0.191 | 0.003 | 0.011 | 0.048 | 0.369 |
| 2004 | 0.149 | 0.013 | 0.030 | 0.145 | 0.002 | 0.011 | 0.043 | 0.332 |
| 2005 | 0.091 | 0.004 | 0.026 | 0.104 | 0.002 | 0.017 | 0.045 | 0.223 |
| 2006 | 0.118 | 0.002 | 0.008 | 0.123 | 0.002 | 0.007 | 0.062 | 0.250 |
| 2007 | 0.168 | 0.004 | 0.008 | 0.135 | 0.005 | 0.011 | 0.033 | 0.312 |
| 2008 | 0.158 | 0.002 | 0.005 | 0.176 | 0.001 | 0.011 | 0.039 | 0.340 |

*Table 6.10. 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 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 0.100 | 0.233 | 0.338 | 0.379 | 0.395 | 0.404 | 0.411 | 0.415 | 0.417 | 0.418 | 0.419 | 0.419 | 0.419 | 0.418 | 0.418 | 0.418 |
| 1977 | 0.098 | 0.231 | 0.335 | 0.373 | 0.386 | 0.393 | 0.397 | 0.400 | 0.401 | 0.402 | 0.402 | 0.402 | 0.401 | 0.401 | 0.401 | 0.401 |
| 1978 | 0.109 | 0.249 | 0.356 | 0.396 | 0.410 | 0.418 | 0.423 | 0.427 | 0.428 | 0.429 | 0.429 | 0.428 | 0.428 | 0.428 | 0.427 | 0.427 |
| 1979 | 0.112 | 0.256 | 0.367 | 0.408 | 0.423 | 0.431 | 0.436 | 0.440 | 0.441 | 0.442 | 0.442 | 0.441 | 0.441 | 0.441 | 0.440 | 0.440 |
| 1980 | 0.107 | 0.248 | 0.358 | 0.399 | 0.413 | 0.421 | 0.426 | 0.430 | 0.431 | 0.432 | 0.432 | 0.432 | 0.432 | 0.431 | 0.431 | 0.431 |
| 1981 | 0.096 | 0.198 | 0.260 | 0.287 | 0.299 | 0.307 | 0.313 | 0.317 | 0.319 | 0.319 | 0.319 | 0.318 | 0.318 | 0.318 | 0.317 | 0.317 |
| 1982 | 0.124 | 0.274 | 0.379 | 0.422 | 0.439 | 0.449 | 0.457 | 0.461 | 0.464 | 0.465 | 0.465 | 0.464 | 0.464 | 0.464 | 0.463 | 0.463 |
| 1983 | 0.235 | 0.496 | 0.636 | 0.709 | 0.736 | 0.752 | 0.763 | 0.770 | 0.773 | 0.775 | 0.775 | 0.775 | 0.775 | 0.774 | 0.774 | 0.774 |
| 1984 | 0.215 | 0.662 | 0.938 | 0.997 | 1.026 | 1.054 | 1.076 | 1.091 | 1.100 | 1.104 | 1.106 | 1.106 | 1.106 | 1.106 | 1.105 | 1.105 |
| 1985 | 0.118 | 0.344 | 0.520 | 0.572 | 0.614 | 0.654 | 0.686 | 0.708 | 0.722 | 0.729 | 0.733 | 0.735 | 0.736 | 0.736 | 0.736 | 0.736 |
| 1986 | 0.159 | 0.421 | 0.611 | 0.679 | 0.735 | 0.790 | 0.834 | 0.864 | 0.883 | 0.893 | 0.899 | 0.901 | 0.902 | 0.902 | 0.902 | 0.902 |
| 1987 | 0.172 | 0.425 | 0.561 | 0.614 | 0.657 | 0.697 | 0.730 | 0.753 | 0.767 | 0.774 | 0.778 | 0.779 | 0.780 | 0.780 | 0.780 | 0.779 |
| 1988 | 0.137 | 0.286 | 0.369 | 0.425 | 0.481 | 0.535 | 0.579 | 0.609 | 0.628 | 0.639 | 0.644 | 0.647 | 0.648 | 0.649 | 0.649 | 0.649 |
| 1989 | 0.125 | 0.325 | 0.471 | 0.525 | 0.572 | 0.616 | 0.652 | 0.677 | 0.693 | 0.701 | 0.705 | 0.707 | 0.708 | 0.708 | 0.708 | 0.708 |
| 1990 | 0.111 | 0.208 | 0.240 | 0.268 | 0.295 | 0.322 | 0.344 | 0.359 | 0.368 | 0.372 | 0.374 | 0.375 | 0.375 | 0.375 | 0.375 | 0.375 |
| 1991 | 0.176 | 0.256 | 0.149 | 0.163 | 0.179 | 0.196 | 0.210 | 0.219 | 0.224 | 0.227 | 0.228 | 0.229 | 0.229 | 0.228 | 0.228 | 0.228 |
| 1992 | 0.065 | 0.086 | 0.127 | 0.269 | 0.324 | 0.336 | 0.333 | 0.328 | 0.323 | 0.320 | 0.318 | 0.316 | 0.315 | 0.314 | 0.313 | 0.313 |
| 1993 | 0.042 | 0.059 | 0.174 | 0.501 | 0.590 | 0.611 | 0.612 | 0.611 | 0.609 | 0.607 | 0.606 | 0.606 | 0.605 | 0.605 | 0.604 | 0.604 |
| 1994 | 0.077 | 0.099 | 0.141 | 0.314 | 0.390 | 0.411 | 0.413 | 0.412 | 0.411 | 0.411 | 0.410 | 0.410 | 0.409 | 0.409 | 0.409 | 0.409 |
| 1995 | 0.056 | 0.073 | 0.117 | 0.279 | 0.361 | 0.384 | 0.387 | 0.387 | 0.386 | 0.385 | 0.385 | 0.385 | 0.384 | 0.384 | 0.384 | 0.384 |
| 1996 | 0.083 | 0.108 | 0.158 | 0.360 | 0.448 | 0.472 | 0.474 | 0.473 | 0.471 | 0.470 | 0.470 | 0.469 | 0.469 | 0.468 | 0.468 | 0.468 |
| 1997 | 0.111 | 0.142 | 0.166 | 0.325 | 0.416 | 0.443 | 0.446 | 0.445 | 0.443 | 0.442 | 0.442 | 0.441 | 0.441 | 0.441 | 0.440 | 0.440 |
| 1998 | 0.072 | 0.095 | 0.131 | 0.284 | 0.396 | 0.428 | 0.431 | 0.429 | 0.427 | 0.425 | 0.424 | 0.423 | 0.423 | 0.422 | 0.422 | 0.422 |
| 1999 | 0.074 | 0.095 | 0.101 | 0.182 | 0.260 | 0.284 | 0.287 | 0.286 | 0.285 | 0.285 | 0.284 | 0.284 | 0.283 | 0.283 | 0.283 | 0.283 |
| 2000 | 0.112 | 0.140 | 0.120 | 0.163 | 0.215 | 0.232 | 0.234 | 0.233 | 0.233 | 0.232 | 0.232 | 0.231 | 0.231 | 0.231 | 0.231 | 0.231 |
| 2001 | 0.083 | 0.107 | 0.109 | 0.180 | 0.236 | 0.251 | 0.250 | 0.247 | 0.244 | 0.242 | 0.241 | 0.240 | 0.239 | 0.238 | 0.238 | 0.238 |
| 2002 | 0.053 | 0.070 | 0.109 | 0.256 | 0.324 | 0.341 | 0.342 | 0.340 | 0.338 | 0.336 | 0.335 | 0.334 | 0.334 | 0.333 | 0.333 | 0.333 |
| 2003 | 0.052 | 0.069 | 0.114 | 0.282 | 0.350 | 0.368 | 0.369 | 0.368 | 0.367 | 0.366 | 0.365 | 0.364 | 0.364 | 0.363 | 0.363 | 0.363 |
| 2004 | 0.047 | 0.063 | 0.110 | 0.252 | 0.315 | 0.332 | 0.332 | 0.330 | 0.329 | 0.327 | 0.326 | 0.325 | 0.325 | 0.324 | 0.324 | 0.324 |
| 2005 | 0.053 | 0.068 | 0.091 | 0.176 | 0.212 | 0.222 | 0.223 | 0.223 | 0.222 | 0.222 | 0.221 | 0.221 | 0.221 | 0.221 | 0.221 | 0.221 |
| 2006 | 0.058 | 0.074 | 0.090 | 0.188 | 0.235 | 0.248 | 0.250 | 0.250 | 0.250 | 0.250 | 0.249 | 0.249 | 0.249 | 0.249 | 0.249 | 0.249 |
| 2007 | 0.040 | 0.053 | 0.086 | 0.220 | 0.289 | 0.309 | 0.312 | 0.312 | 0.311 | 0.311 | 0.311 | 0.310 | 0.310 | 0.310 | 0.310 | 0.310 |
| 2008 | 0.042 | 0.055 | 0.095 | 0.251 | 0.318 | 0.337 | 0.340 | 0.340 | 0.339 | 0.339 | 0.339 | 0.339 | 0.339 | 0.339 | 0.339 | 0.339 |

*Table 6.11. Estimated total landings at age in numbers (1000 fish)*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 31.8 | 67.3 | 44.4 | 158.3 | 48.5 | 10.7 | 7.8 | 3.8 | 4.0 | 1.4 | 0.7 | 0.4 | 0.2 | 0.1 | 0.1 | 0.1 |
| 1977 | 29.9 | 48.0 | 59.2 | 28.7 | 93.2 | 27.9 | 6.1 | 4.4 | 2.1 | 2.3 | 0.8 | 0.4 | 0.2 | 0.1 | 0.1 | 0.1 |
| 1978 | 40.5 | 49.1 | 45.0 | 40.7 | 18.1 | 57.9 | 17.3 | 3.8 | 2.7 | 1.3 | 1.4 | 0.5 | 0.2 | 0.1 | 0.1 | 0.1 |
| 1979 | 37.7 | 61.3 | 43.3 | 29.4 | 24.4 | 10.7 | 34.1 | 10.2 | 2.2 | 1.6 | 0.8 | 0.8 | 0.3 | 0.1 | 0.1 | 0.1 |
| 1980 | 20.0 | 53.7 | 51.2 | 26.8 | 16.7 | 13.7 | 6.0 | 19.0 | 5.7 | 1.2 | 0.9 | 0.4 | 0.5 | 0.2 | 0.1 | 0.1 |
| 1981 | 19.5 | 23.1 | 35.4 | 24.8 | 12.0 | 7.4 | 6.1 | 2.7 | 8.5 | 2.5 | 0.5 | 0.4 | 0.2 | 0.2 | 0.1 | 0.1 |
| 1982 | 43.4 | 37.6 | 28.5 | 34.3 | 22.5 | 10.7 | 6.5 | 5.3 | 2.3 | 7.4 | 2.2 | 0.5 | 0.3 | 0.2 | 0.2 | 0.1 |
| 1983 | 71.2 | 91.7 | 46.9 | 26.3 | 29.0 | 18.5 | 8.7 | 5.3 | 4.3 | 1.9 | 5.9 | 1.8 | 0.4 | 0.3 | 0.1 | 0.3 |
| 1984 | 37.5 | 107.4 | 80.1 | 28.0 | 13.9 | 14.9 | 9.4 | 4.4 | 2.7 | 2.2 | 0.9 | 3.0 | 0.9 | 0.2 | 0.1 | 0.2 |
| 1985 | 32.1 | 53.0 | 43.9 | 18.7 | 6.3 | 3.2 | 3.4 | 2.2 | 1.0 | 0.6 | 0.5 | 0.2 | 0.7 | 0.2 | 0.0 | 0.1 |
| 1986 | 27.6 | 71.4 | 50.6 | 26.6 | 10.7 | 3.5 | 1.7 | 1.7 | 1.1 | 0.5 | 0.3 | 0.2 | 0.1 | 0.3 | 0.1 | 0.1 |
| 1987 | 39.5 | 43.1 | 51.4 | 23.0 | 11.2 | 4.2 | 1.3 | 0.6 | 0.6 | 0.4 | 0.2 | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 |
| 1988 | 24.8 | 51.7 | 24.3 | 19.8 | 8.8 | 4.3 | 1.6 | 0.5 | 0.2 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 |
| 1989 | 14.4 | 44.2 | 55.7 | 18.7 | 13.8 | 5.6 | 2.5 | 0.9 | 0.3 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1990 | 9.0 | 15.1 | 21.3 | 18.1 | 5.9 | 4.2 | 1.6 | 0.7 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1991 | 11.0 | 7.7 | 8.7 | 9.9 | 8.2 | 2.6 | 1.8 | 0.7 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1992 | 0.6 | 1.2 | 4.1 | 10.6 | 13.1 | 10.2 | 2.9 | 1.9 | 0.7 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1993 | 0.1 | 2.3 | 14.2 | 14.8 | 13.5 | 13.5 | 10.2 | 3.0 | 2.0 | 0.7 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1994 | 0.2 | 0.6 | 18.3 | 19.5 | 6.3 | 4.8 | 4.7 | 3.5 | 1.0 | 0.7 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1995 | 0.3 | 0.9 | 5.5 | 37.8 | 14.0 | 3.6 | 2.6 | 2.6 | 1.9 | 0.6 | 0.4 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 |
| 1996 | 0.5 | 2.2 | 11.3 | 16.1 | 36.8 | 10.4 | 2.5 | 1.8 | 1.8 | 1.4 | 0.4 | 0.3 | 0.1 | 0.0 | 0.0 | 0.0 |
| 1997 | 0.1 | 2.4 | 20.7 | 22.6 | 11.0 | 20.0 | 5.4 | 1.3 | 1.0 | 0.9 | 0.7 | 0.2 | 0.1 | 0.1 | 0.0 | 0.0 |
| 1998 | 0.1 | 0.8 | 20.1 | 41.3 | 17.0 | 6.4 | 10.9 | 2.9 | 0.7 | 0.5 | 0.5 | 0.4 | 0.1 | 0.1 | 0.0 | 0.0 |
| 1999 | 0.2 | 0.4 | 3.8 | 29.6 | 25.1 | 7.4 | 2.6 | 4.4 | 1.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 |
| 2000 | 0.1 | 0.6 | 2.2 | 8.0 | 25.6 | 15.0 | 4.1 | 1.4 | 2.4 | 0.7 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 |
| 2001 | 0.3 | 1.0 | 6.0 | 5.9 | 8.9 | 20.4 | 11.0 | 3.0 | 1.0 | 1.7 | 0.5 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 |
| 2002 | 0.3 | 1.2 | 8.5 | 19.4 | 7.5 | 8.3 | 18.0 | 9.8 | 2.7 | 0.9 | 1.6 | 0.4 | 0.1 | 0.1 | 0.1 | 0.1 |
| 2003 | 0.3 | 1.4 | 11.2 | 21.9 | 17.1 | 5.2 | 5.5 | 11.9 | 6.5 | 1.8 | 0.6 | 1.1 | 0.3 | 0.1 | 0.1 | 0.1 |
| 2004 | 0.7 | 1.8 | 14.6 | 24.1 | 15.7 | 9.9 | 2.9 | 3.0 | 6.6 | 3.6 | 1.0 | 0.3 | 0.6 | 0.2 | 0.0 | 0.1 |
| 2005 | 0.2 | 2.0 | 11.9 | 22.8 | 13.9 | 7.2 | 4.3 | 1.3 | 1.3 | 2.9 | 1.6 | 0.4 | 0.2 | 0.3 | 0.1 | 0.1 |
| 2006 | 0.0 | 1.0 | 20.5 | 28.1 | 21.7 | 11.1 | 5.6 | 3.4 | 1.0 | 1.0 | 2.3 | 1.3 | 0.4 | 0.1 | 0.2 | 0.1 |
| 2007 | 0.1 | 0.3 | 13.4 | 62.2 | 30.1 | 18.8 | 9.2 | 4.6 | 2.8 | 0.8 | 0.9 | 1.9 | 1.1 | 0.3 | 0.1 | 0.3 |
| 2008 | 0.2 | 0.4 | 3.8 | 39.4 | 59.8 | 22.1 | 12.9 | 6.3 | 3.2 | 1.9 | 0.6 | 0.6 | 1.3 | 0.7 | 0.2 | 0.3 |

*Table 6.12. Estimated total landings at age in whole weight (1000 lb)*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 32.4 | 164.8 | 191.0 | 1005.1 | 408.6 | 111.4 | 94.9 | 52.0 | 61.3 | 23.6 | 12.3 | 6.6 | 3.7 | 2.1 | 1.2 | 1.8 |
| 1977 | 30.5 | 117.5 | 254.7 | 182.3 | 785.7 | 290.0 | 74.5 | 60.9 | 32.3 | 37.1 | 14.0 | 7.2 | 3.9 | 2.2 | 1.2 | 1.7 |
| 1978 | 41.3 | 120.2 | 193.3 | 258.3 | 152.4 | 602.1 | 211.2 | 52.4 | 41.7 | 21.6 | 24.4 | 9.1 | 4.7 | 2.5 | 1.4 | 1.9 |
| 1979 | 38.5 | 150.2 | 186.3 | 186.6 | 206.0 | 111.3 | 416.6 | 140.9 | 34.0 | 26.4 | 13.5 | 15.1 | 5.6 | 2.9 | 1.5 | 1.9 |
| 1980 | 20.4 | 131.6 | 220.1 | 170.3 | 140.9 | 142.3 | 72.8 | 263.0 | 86.5 | 20.4 | 15.5 | 7.9 | 8.8 | 3.2 | 1.6 | 2.0 |
| 1981 | 19.9 | 56.5 | 152.0 | 157.4 | 100.9 | 77.0 | 74.1 | 36.7 | 129.1 | 41.4 | 9.6 | 7.3 | 3.6 | 4.0 | 1.5 | 1.6 |
| 1982 | 44.3 | 92.1 | 122.3 | 217.6 | 189.2 | 111.0 | 79.8 | 73.8 | 35.4 | 121.3 | 38.3 | 8.8 | 6.6 | 3.3 | 3.6 | 2.8 |
| 1983 | 72.7 | 224.8 | 201.8 | 166.9 | 243.9 | 192.8 | 106.5 | 73.4 | 65.8 | 30.8 | 103.5 | 32.4 | 7.4 | 5.5 | 2.8 | 5.3 |
| 1984 | 43.1 | 263.2 | 344.5 | 177.8 | 117.1 | 154.9 | 115.4 | 61.3 | 41.0 | 35.8 | 16.5 | 54.9 | 17.1 | 3.9 | 2.9 | 4.1 |
| 1985 | 36.9 | 129.9 | 188.8 | 118.6 | 53.4 | 33.0 | 41.6 | 29.8 | 15.4 | 10.0 | 8.6 | 3.9 | 13.0 | 4.0 | 0.9 | 1.6 |
| 1986 | 31.8 | 174.9 | 217.4 | 168.7 | 90.1 | 36.4 | 20.6 | 24.2 | 16.4 | 8.1 | 5.2 | 4.4 | 2.0 | 6.5 | 2.0 | 1.2 |
| 1987 | 45.4 | 105.7 | 220.9 | 146.2 | 94.0 | 44.0 | 15.9 | 8.3 | 9.1 | 5.9 | 2.8 | 1.8 | 1.5 | 0.7 | 2.2 | 1.1 |
| 1988 | 28.5 | 126.8 | 104.6 | 125.5 | 73.9 | 44.3 | 19.4 | 6.7 | 3.3 | 3.5 | 2.2 | 1.1 | 0.7 | 0.5 | 0.2 | 1.2 |
| 1989 | 16.6 | 108.3 | 239.3 | 118.9 | 116.2 | 58.2 | 30.5 | 12.1 | 3.8 | 1.8 | 1.9 | 1.2 | 0.5 | 0.3 | 0.3 | 0.7 |
| 1990 | 10.3 | 36.9 | 91.4 | 114.9 | 49.3 | 43.7 | 20.1 | 9.8 | 3.7 | 1.1 | 0.5 | 0.5 | 0.3 | 0.2 | 0.1 | 0.3 |
| 1991 | 12.6 | 18.9 | 37.4 | 62.6 | 69.0 | 27.0 | 22.1 | 9.5 | 4.4 | 1.6 | 0.5 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 |
| 1992 | 3.0 | 5.8 | 22.4 | 71.8 | 111.9 | 106.4 | 35.9 | 26.1 | 10.4 | 4.6 | 1.6 | 0.5 | 0.2 | 0.2 | 0.1 | 0.2 |
| 1993 | 0.7 | 11.3 | 77.9 | 100.0 | 115.3 | 140.8 | 124.2 | 41.2 | 29.8 | 11.8 | 5.2 | 1.8 | 0.5 | 0.2 | 0.2 | 0.4 |
| 1994 | 0.8 | 2.8 | 100.4 | 131.3 | 53.5 | 50.5 | 57.2 | 49.0 | 15.9 | 11.3 | 4.4 | 1.9 | 0.7 | 0.2 | 0.1 | 0.2 |
| 1995 | 1.5 | 4.3 | 30.4 | 255.0 | 119.2 | 37.6 | 32.3 | 35.4 | 29.7 | 9.5 | 6.6 | 2.6 | 1.1 | 0.4 | 0.1 | 0.2 |
| 1996 | 2.3 | 11.1 | 61.8 | 108.8 | 314.6 | 108.4 | 30.8 | 25.5 | 27.3 | 22.4 | 7.0 | 4.9 | 1.9 | 0.8 | 0.3 | 0.2 |
| 1997 | 0.7 | 11.9 | 113.1 | 152.2 | 94.2 | 209.3 | 65.6 | 18.0 | 14.6 | 15.4 | 12.4 | 3.9 | 2.7 | 1.0 | 0.4 | 0.3 |
| 1998 | 0.6 | 4.2 | 110.3 | 278.7 | 145.3 | 66.8 | 133.3 | 40.2 | 10.8 | 8.6 | 8.9 | 7.1 | 2.2 | 1.5 | 0.6 | 0.4 |
| 1999 | 0.8 | 1.8 | 21.0 | 199.9 | 214.0 | 77.5 | 31.6 | 60.8 | 18.0 | 4.7 | 3.7 | 3.8 | 3.1 | 1.0 | 0.7 | 0.4 |
| 2000 | 0.6 | 3.2 | 12.1 | 54.1 | 218.5 | 156.7 | 49.9 | 19.5 | 36.8 | 10.7 | 2.8 | 2.2 | 2.2 | 1.8 | 0.5 | 0.6 |
| 2001 | 1.5 | 5.0 | 32.8 | 40.1 | 75.6 | 213.4 | 134.9 | 41.0 | 15.6 | 28.7 | 8.2 | 2.1 | 1.6 | 1.7 | 1.3 | 0.8 |
| 2002 | 1.7 | 5.9 | 46.8 | 131.0 | 64.4 | 86.7 | 220.2 | 135.4 | 40.6 | 15.3 | 27.8 | 7.9 | 2.0 | 1.6 | 1.6 | 2.0 |
| 2003 | 1.6 | 7.0 | 61.3 | 147.4 | 145.9 | 54.4 | 66.8 | 164.5 | 99.3 | 29.3 | 10.9 | 19.7 | 5.6 | 1.4 | 1.1 | 2.5 |
| 2004 | 3.3 | 8.9 | 79.8 | 162.8 | 134.1 | 103.0 | 35.0 | 41.5 | 100.1 | 59.3 | 17.2 | 6.4 | 11.5 | 3.2 | 0.8 | 2.0 |
| 2005 | 0.9 | 9.8 | 65.0 | 153.5 | 119.0 | 75.7 | 53.1 | 17.5 | 20.4 | 48.4 | 28.3 | 8.2 | 3.0 | 5.4 | 1.5 | 1.3 |
| 2006 | 0.2 | 4.8 | 112.5 | 189.5 | 185.2 | 116.2 | 68.2 | 46.4 | 15.0 | 17.2 | 40.2 | 23.3 | 6.7 | 2.5 | 4.4 | 2.3 |
| 2007 | 0.4 | 1.6 | 73.5 | 419.7 | 257.3 | 196.1 | 112.2 | 63.6 | 42.3 | 13.4 | 15.1 | 35.0 | 20.3 | 5.8 | 2.1 | 5.6 |
| 2008 | 0.8 | 2.2 | 20.9 | 265.9 | 510.9 | 230.4 | 158.1 | 87.3 | 48.4 | 31.6 | 9.9 | 11.0 | 25.5 | 14.6 | 4.2 | 5.5 |

*Table 6.13. Estimated time series of landings in numbers (1000 fish) for commercial lines (L.cl), commercial combined (L.co), headboat (L.hb), and general recreational (L.rec)*

| Year | L.cl | L.co | L.hb | L.rec | Total |
|---|---|---|---|---|---|
| 1976 | 39.98 | 38.17 | 4.60 | 296.72 | 379.47 |
| 1977 | 28.32 | 29.57 | 5.61 | 239.95 | 303.45 |
| 1978 | 33.41 | 36.70 | 4.77 | 203.85 | 278.73 |
| 1979 | 30.37 | 35.68 | 9.38 | 181.78 | 257.20 |
| 1980 | 23.37 | 26.14 | 8.14 | 158.47 | 216.12 |
| 1981 | 26.54 | 31.11 | 7.96 | 77.67 | 143.28 |
| 1982 | 27.77 | 32.43 | 6.36 | 135.35 | 201.91 |
| 1983 | 31.31 | 39.58 | 9.89 | 231.86 | 312.63 |
| 1984 | 42.12 | 48.49 | 8.56 | 206.80 | 305.97 |
| 1985 | 43.63 | 36.61 | 8.79 | 77.09 | 166.12 |
| 1986 | 55.09 | 43.79 | 5.81 | 91.76 | 196.45 |
| 1987 | 45.38 | 42.38 | 7.04 | 81.05 | 175.85 |
| 1988 | 55.79 | 37.66 | 5.10 | 37.96 | 136.50 |
| 1989 | 45.62 | 32.79 | 3.62 | 74.32 | 156.35 |
| 1990 | 30.08 | 25.98 | 7.33 | 12.84 | 76.23 |
| 1991 | 22.58 | 19.71 | 2.73 | 5.95 | 50.97 |
| 1992 | 13.85 | 5.28 | 3.98 | 22.64 | 45.75 |
| 1993 | 17.66 | 2.31 | 4.79 | 49.96 | 74.72 |
| 1994 | 18.77 | 1.50 | 5.47 | 34.27 | 60.00 |
| 1995 | 26.99 | 1.35 | 5.25 | 36.85 | 70.44 |
| 1996 | 31.24 | 2.70 | 5.65 | 46.11 | 85.71 |
| 1997 | 35.11 | 2.75 | 8.06 | 40.64 | 86.55 |
| 1998 | 50.73 | 5.07 | 10.90 | 35.32 | 102.01 |
| 1999 | 46.62 | 2.24 | 7.27 | 19.50 | 75.63 |
| 2000 | 36.12 | 1.49 | 5.34 | 17.77 | 60.72 |
| 2001 | 31.52 | 5.20 | 4.95 | 18.49 | 60.16 |
| 2002 | 30.92 | 3.92 | 4.60 | 39.68 | 79.12 |
| 2003 | 29.59 | 2.96 | 4.02 | 48.41 | 84.99 |
| 2004 | 29.27 | 4.47 | 10.77 | 40.53 | 85.04 |
| 2005 | 21.45 | 1.91 | 11.49 | 35.64 | 70.49 |
| 2006 | 35.39 | 1.08 | 5.24 | 56.10 | 97.81 |
| 2007 | 62.43 | 1.99 | 5.16 | 77.27 | 146.85 |
| 2008 | 61.14 | 1.14 | 2.44 | 89.11 | 153.83 |

*Table 6.14. Estimated time series of landings in whole weight (1000 lb) for commercial lines (L.cl), commercial other (L.co), headboat (L.hb), and general recreational (L.rec)*

| Year | L.cl | L.co | L.hb | L.rec | Total |
|---|---|---|---|---|---|
| 1976 | 262.12 | 170.91 | 26.55 | 1713.36 | 2172.94 |
| 1977 | 208.43 | 134.67 | 35.45 | 1517.04 | 1895.59 |
| 1978 | 257.53 | 151.64 | 30.38 | 1299.14 | 1738.70 |
| 1979 | 234.95 | 134.88 | 57.28 | 1110.18 | 1537.29 |
| 1980 | 185.02 | 103.54 | 49.77 | 968.90 | 1307.23 |
| 1981 | 210.82 | 125.98 | 49.81 | 486.06 | 872.67 |
| 1982 | 205.78 | 113.12 | 37.32 | 793.97 | 1150.19 |
| 1983 | 203.57 | 119.01 | 49.66 | 1163.97 | 1536.21 |
| 1984 | 235.87 | 141.99 | 42.76 | 1033.00 | 1453.61 |
| 1985 | 200.92 | 100.99 | 39.64 | 347.87 | 689.42 |
| 1986 | 250.03 | 131.15 | 25.53 | 403.06 | 809.77 |
| 1987 | 190.07 | 118.42 | 31.74 | 365.16 | 705.39 |
| 1988 | 244.10 | 111.01 | 22.20 | 165.21 | 542.52 |
| 1989 | 228.88 | 113.86 | 17.08 | 350.67 | 710.49 |
| 1990 | 172.95 | 102.14 | 39.34 | 68.88 | 383.31 |
| 1991 | 139.63 | 74.76 | 16.37 | 35.68 | 266.44 |
| 1992 | 129.29 | 39.95 | 33.00 | 198.81 | 401.05 |
| 1993 | 168.24 | 16.47 | 37.66 | 438.81 | 661.19 |
| 1994 | 165.10 | 10.09 | 38.36 | 266.67 | 480.23 |
| 1995 | 229.03 | 9.41 | 39.35 | 288.19 | 565.98 |
| 1996 | 277.91 | 19.11 | 43.78 | 387.29 | 728.09 |
| 1997 | 311.58 | 18.83 | 58.36 | 326.84 | 715.62 |
| 1998 | 433.52 | 35.47 | 78.09 | 272.43 | 819.51 |
| 1999 | 409.53 | 17.04 | 57.47 | 158.83 | 642.86 |
| 2000 | 348.42 | 12.36 | 47.64 | 163.93 | 572.36 |
| 2001 | 331.70 | 43.93 | 45.42 | 183.16 | 604.22 |
| 2002 | 331.50 | 31.32 | 41.45 | 386.64 | 790.90 |
| 2003 | 307.52 | 22.17 | 34.55 | 454.54 | 818.79 |
| 2004 | 289.41 | 31.65 | 87.33 | 360.59 | 768.99 |
| 2005 | 202.52 | 13.28 | 90.07 | 305.12 | 610.99 |
| 2006 | 325.09 | 7.66 | 39.29 | 462.48 | 834.53 |
| 2007 | 569.40 | 15.03 | 40.62 | 638.96 | 1264.01 |
| 2008 | 589.30 | 9.38 | 21.61 | 806.81 | 1427.10 |

*Table 6.15. Estimated time series of dead discards in numbers (1000 fish) for commercial handline (D.cl), headboat (D.hb), and general recreational (D.rec)*

| Year | D.cl | D.hb | D.rec | Total |
|---|---|---|---|---|
| 1976 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1977 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1978 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1979 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1980 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1981 | 0.00 | 0.00 | 3.07 | 3.07 |
| 1982 | 0.00 | 0.00 | 3.49 | 3.49 |
| 1983 | 0.00 | 0.00 | 30.96 | 30.96 |
| 1984 | 1.56 | 4.70 | 35.31 | 41.58 |
| 1985 | 1.55 | 4.68 | 1.44 | 7.67 |
| 1986 | 1.33 | 4.00 | 6.86 | 12.19 |
| 1987 | 1.51 | 4.55 | 22.93 | 28.98 |
| 1988 | 1.51 | 4.57 | 10.93 | 17.01 |
| 1989 | 0.97 | 2.92 | 2.39 | 6.28 |
| 1990 | 0.68 | 2.06 | 4.38 | 7.11 |
| 1991 | 0.89 | 2.69 | 32.60 | 36.18 |
| 1992 | 1.78 | 5.42 | 30.44 | 37.64 |
| 1993 | 1.71 | 4.97 | 15.92 | 22.61 |
| 1994 | 2.88 | 4.37 | 29.22 | 36.47 |
| 1995 | 2.10 | 6.41 | 30.14 | 38.65 |
| 1996 | 2.32 | 8.85 | 68.84 | 80.00 |
| 1997 | 2.94 | 6.63 | 70.40 | 79.97 |
| 1998 | 2.09 | 3.68 | 22.71 | 28.48 |
| 1999 | 2.59 | 3.51 | 22.09 | 28.19 |
| 2000 | 2.17 | 4.24 | 45.37 | 51.78 |
| 2001 | 1.68 | 4.96 | 37.95 | 44.59 |
| 2002 | 4.32 | 6.10 | 24.49 | 34.91 |
| 2003 | 2.27 | 7.37 | 31.99 | 41.63 |
| 2004 | 2.17 | 11.27 | 43.92 | 57.37 |
| 2005 | 2.00 | 17.64 | 46.13 | 65.77 |
| 2006 | 0.99 | 4.49 | 39.02 | 44.50 |
| 2007 | 1.71 | 4.06 | 11.75 | 17.53 |
| 2008 | 0.40 | 5.13 | 17.94 | 23.47 |

*Table 6.16. Estimated time series of dead discards in whole weight (1000 lb) for commercial handline (D.cl), headboat (D.hb), and general recreational (D.rec)*

| Year | D.cl | D.hb | D.rec | Total |
|---|---|---|---|---|
| 1976 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1977 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1978 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1979 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1980 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1981 | 0.00 | 0.00 | 4.27 | 4.27 |
| 1982 | 0.00 | 0.00 | 4.58 | 4.58 |
| 1983 | 0.00 | 0.00 | 42.81 | 42.81 |
| 1984 | 0.00 | 6.73 | 50.51 | 57.24 |
| 1985 | 0.00 | 6.42 | 1.97 | 8.40 |
| 1986 | 0.00 | 5.95 | 10.19 | 16.14 |
| 1987 | 0.00 | 5.89 | 29.68 | 35.56 |
| 1988 | 0.00 | 6.79 | 16.25 | 23.04 |
| 1989 | 0.00 | 4.48 | 3.66 | 8.14 |
| 1990 | 0.00 | 3.01 | 6.42 | 9.44 |
| 1991 | 0.00 | 3.49 | 42.27 | 45.76 |
| 1992 | 2.82 | 8.58 | 48.21 | 59.61 |
| 1993 | 3.81 | 11.06 | 35.40 | 50.28 |
| 1994 | 6.12 | 9.30 | 62.14 | 77.56 |
| 1995 | 3.44 | 10.50 | 49.36 | 63.30 |
| 1996 | 4.17 | 15.91 | 123.80 | 143.88 |
| 1997 | 7.02 | 15.82 | 168.08 | 190.92 |
| 1998 | 5.42 | 9.54 | 58.88 | 73.84 |
| 1999 | 4.74 | 6.41 | 40.36 | 51.51 |
| 2000 | 3.99 | 7.80 | 83.35 | 95.14 |
| 2001 | 3.19 | 9.39 | 71.92 | 84.50 |
| 2002 | 7.97 | 11.25 | 45.16 | 64.38 |
| 2003 | 4.28 | 13.89 | 60.32 | 78.49 |
| 2004 | 3.69 | 19.17 | 74.72 | 97.59 |
| 2005 | 4.19 | 37.03 | 96.81 | 138.03 |
| 2006 | 2.62 | 11.90 | 103.46 | 117.98 |
| 2007 | 4.18 | 9.89 | 28.62 | 42.69 |
| 2008 | 0.66 | 8.53 | 29.82 | 39.01 |

*Table 6.17. Estimated status indicators, benchmarks, and related quantities from the Beaufort catch-age model, conditional on estimated current selectivities averaged across fisheries. Precision is represented by standard errors (SE) approximated from Monte Carlo/Bootstrap analysis. Estimates of yield do not include discards; $D_{MSY}$ represents discard mortalities expected when fishing at $F_{MSY}$. 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.*

| Quantity | Units | Estimate | SE |
|---|---|---|---|
| $F_{MSY}$ | $y^{-1}$ | 0.221 | 0.030 |
| $85\%F_{MSY}$ | $y^{-1}$ | 0.188 | 0.026 |
| $75\%F_{MSY}$ | $y^{-1}$ | 0.166 | 0.023 |
| $65\%F_{MSY}$ | $y^{-1}$ | 0.144 | 0.020 |
| $F_{30\%}$ | $y^{-1}$ | 0.189 | 0.029 |
| $F_{40\%}$ | $y^{-1}$ | 0.127 | 0.019 |
| $F_{50\%}$ | $y^{-1}$ | 0.088 | 0.012 |
| $B_{MSY}$ | mt | 3680 | 569 |
| $SSB_{MSY}$ | mt | 2592 | 519 |
| MSST | mt | 2229 | 487 |
| MSY | 1000 lb | 1110 | 102 |
| $D_{MSY}$ | 1000 fish | 27 | 8 |
| $R_{MSY}$ | 1000 age-1 fish | 407 | 58 |
| Y at $85\%F_{MSY}$ | 1000 lb | 1103 | 101 |
| Y at $75\%F_{MSY}$ | 1000 lb | 1089 | 99 |
| Y at $65\%F_{MSY}$ | 1000 lb | 1064 | 96 |
| $F_{2008}/F_{MSY}$ | — | 1.35 | 0.26 |
| $SSB_{2008}/MSST$ | — | 0.92 | 0.25 |

*Table 6.18. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last three assessment years.*

| Run | Description | $F_{MSY}$ | $SSB_{MSY}$ (mt) | MSY(1000 lb) | $F_{2008}/F_{MSY}$ | $SSB_{2008}$/MSST | steep | R0(1000) |
|---|---|---|---|---|---|---|---|---|
| Base | — | 0.221 | 2592 | 1110 | 1.35 | 0.92 | 0.92 | 384 |
| S1 | Low M | 0.177 | 3543 | 1267 | 1.89 | 0.57 | 0.95 | 294 |
| S2 | High M | 0.292 | 1855 | 972 | 0.84 | 1.68 | 0.86 | 564 |
| S3 | Extreme M | 0.464 | 1449 | 985 | 0.35 | 3.77 | 0.78 | 1139 |
| S4 | Low D mort | 0.261 | 2153 | 1072 | 1.15 | 1.1 | 0.93 | 347 |
| S5 | High D mort | 0.196 | 3026 | 1161 | 1.52 | 0.79 | 0.91 | 424 |
| S6 | Very high D mort | 0.147 | 4919 | 1437 | 2 | 0.49 | 0.88 | 605 |

*Table 6.19. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{current}$. F = fishing mortality rate (per year), Pr(*SSB > $SSB_{MSY}$*) = proportion of stochastic projection replicates exceeding* $SSB_{MSY}$*, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000* lb *whole weight), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are $F_{MSY}$ = 0.22 (per yr),* $SSB_{MSY}$ = 2592 *(mt), and* MSY = 1110 *(1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.298 | 0 | 1888.74 | 399 | 32 | 61 | 107 | 1098 | 1098 |
| 2010 | 0.298 | 0 | 1800.36 | 396 | 35 | 70 | 94 | 985 | 2083 |
| 2011 | 0.298 | 0.01 | 1783.42 | 394 | 35 | 70 | 98 | 975 | 3058 |
| 2012 | 0.298 | 0.02 | 1804.56 | 394 | 34 | 70 | 103 | 996 | 4053 |
| 2013 | 0.298 | 0.04 | 1833.04 | 394 | 34 | 70 | 106 | 1017 | 5070 |
| 2014 | 0.298 | 0.05 | 1858.24 | 395 | 34 | 70 | 108 | 1034 | 6104 |
| 2015 | 0.298 | 0.05 | 1878.85 | 395 | 35 | 70 | 109 | 1046 | 7150 |
| 2016 | 0.298 | 0.05 | 1895.25 | 396 | 35 | 70 | 110 | 1056 | 8206 |
| 2017 | 0.298 | 0.05 | 1907.71 | 396 | 35 | 70 | 110 | 1064 | 9270 |
| 2018 | 0.298 | 0.05 | 1916.95 | 396 | 35 | 70 | 110 | 1069 | 10,339 |
| 2019 | 0.298 | 0.05 | 1923.94 | 397 | 35 | 70 | 111 | 1073 | 11,412 |
| 2020 | 0.298 | 0.05 | 1929.25 | 397 | 35 | 70 | 111 | 1076 | 12,489 |

*Table 6.20. Projection results under scenario 3—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and $F = 75\%F_{\text{current}}$ thereafter. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY} = 0.22$ (per yr), $SSB_{MSY} = 2592$ (mt), and MSY = 1110 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.298 | 0 | 1888.74 | 399 | 32 | 61 | 107 | 1098 | 1098 |
| 2010 | 0.224 | 0 | 1800.36 | 396 | 26 | 53 | 72 | 763 | 1861 |
| 2011 | 0.224 | 0.02 | 1915.38 | 394 | 26 | 54 | 79 | 799 | 2660 |
| 2012 | 0.224 | 0.06 | 2018.84 | 397 | 26 | 54 | 86 | 853 | 3513 |
| 2013 | 0.224 | 0.12 | 2119.48 | 399 | 27 | 54 | 92 | 904 | 4416 |
| 2014 | 0.224 | 0.17 | 2206.66 | 400 | 27 | 54 | 95 | 945 | 5361 |
| 2015 | 0.224 | 0.22 | 2279.68 | 402 | 27 | 54 | 98 | 979 | 6340 |
| 2016 | 0.224 | 0.26 | 2339.83 | 403 | 27 | 55 | 100 | 1006 | 7346 |
| 2017 | 0.224 | 0.29 | 2388.07 | 404 | 27 | 55 | 101 | 1028 | 8375 |
| 2018 | 0.224 | 0.32 | 2426.1 | 405 | 27 | 55 | 102 | 1046 | 9421 |
| 2019 | 0.224 | 0.35 | 2456.1 | 405 | 27 | 55 | 103 | 1060 | 10,480 |
| 2020 | 0.224 | 0.37 | 2479.68 | 405 | 27 | 55 | 104 | 1071 | 11,551 |

*Table 6.21. Projection results under scenario 4—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and $F$ = 50%$F_{\text{current}}$ thereafter. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY}$ = 0.22 (per yr), $SSB_{MSY}$ = 2592 (mt), and MSY = 1110 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.298 | 0 | 1888.74 | 399 | 32 | 61 | 107 | 1098 | 1098 |
| 2010 | 0.149 | 0 | 1800.36 | 396 | 18 | 36 | 50 | 525 | 1623 |
| 2011 | 0.149 | 0.04 | 2059.22 | 394 | 18 | 37 | 57 | 583 | 2206 |
| 2012 | 0.149 | 0.17 | 2266.12 | 399 | 18 | 37 | 65 | 652 | 2858 |
| 2013 | 0.149 | 0.34 | 2467.23 | 403 | 18 | 37 | 71 | 718 | 3576 |
| 2014 | 0.149 | 0.49 | 2649.17 | 406 | 18 | 37 | 75 | 776 | 4352 |
| 2015 | 0.149 | 0.63 | 2809.34 | 408 | 18 | 38 | 79 | 826 | 5177 |
| 2016 | 0.149 | 0.73 | 2948.03 | 410 | 18 | 38 | 82 | 869 | 6046 |
| 2017 | 0.149 | 0.81 | 3065.34 | 411 | 19 | 38 | 84 | 905 | 6951 |
| 2018 | 0.149 | 0.86 | 3162.9 | 412 | 19 | 38 | 86 | 936 | 7887 |
| 2019 | 0.149 | 0.89 | 3243.67 | 413 | 19 | 38 | 88 | 961 | 8848 |
| 2020 | 0.149 | 0.92 | 3310.09 | 414 | 19 | 38 | 89 | 982 | 9830 |

*Table 6.22. Projection results under scenario 5—fishing mortality rate fixed at $F = F_{current}$ in 2009 and $F$ = 25%$F_{current}$ thereafter. F = fishing mortality rate (per year), Pr(*SSB > $SSB_{MSY}$*) = proportion of stochastic projection replicates exceeding* $SSB_{MSY}$*, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000* lb *whole weight), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are* $F_{MSY}$ = 0.22 *(per yr),* $SSB_{MSY}$ = 2592 *(mt), and* MSY = 1110 *(1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.298 | 0 | 1888.74 | 399 | 32 | 61 | 107 | 1098 | 1098 |
| 2010 | 0.075 | 0 | 1800.36 | 396 | 9 | 18 | 26 | 272 | 1369 |
| 2011 | 0.075 | 0.1 | 2216.11 | 394 | 9 | 19 | 31 | 319 | 1688 |
| 2012 | 0.075 | 0.42 | 2552.06 | 402 | 9 | 19 | 36 | 375 | 2063 |
| 2013 | 0.075 | 0.72 | 2891.21 | 407 | 9 | 19 | 41 | 430 | 2494 |
| 2014 | 0.075 | 0.89 | 3215.46 | 410 | 9 | 19 | 45 | 482 | 2976 |
| 2015 | 0.075 | 0.96 | 3517.68 | 413 | 9 | 19 | 49 | 530 | 3506 |
| 2016 | 0.075 | 0.99 | 3794.6 | 416 | 10 | 20 | 52 | 574 | 4080 |
| 2017 | 0.075 | 1 | 4042.86 | 417 | 10 | 20 | 54 | 613 | 4694 |
| 2018 | 0.075 | 1 | 4261.73 | 419 | 10 | 20 | 56 | 648 | 5341 |
| 2019 | 0.075 | 1 | 4453.33 | 420 | 10 | 20 | 58 | 678 | 6019 |
| 2020 | 0.075 | 1 | 4619.65 | 421 | 10 | 20 | 59 | 704 | 6724 |

*Table 6.23. Projection results under scenario 6—fishing mortality rate fixed at $F = 65\%F_{MSY}$. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY} = 0.22$ (per yr), $SSB_{MSY} = 2592$ (mt), and MSY = 1110 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.298 | 0 | 1888.74 | 399 | 32 | 61 | 107 | 1098 | 1098 |
| 2010 | 0.298 | 0 | 1800.36 | 396 | 35 | 70 | 94 | 985 | 2083 |
| 2011 | 0.144 | 0.01 | 1783.42 | 394 | 17 | 34 | 50 | 501 | 2584 |
| 2012 | 0.144 | 0.08 | 2088.75 | 394 | 17 | 35 | 58 | 575 | 3159 |
| 2013 | 0.144 | 0.23 | 2319.46 | 400 | 17 | 35 | 65 | 648 | 3807 |
| 2014 | 0.144 | 0.4 | 2532.28 | 404 | 17 | 36 | 70 | 713 | 4520 |
| 2015 | 0.144 | 0.56 | 2721.91 | 406 | 18 | 36 | 75 | 770 | 5291 |
| 2016 | 0.144 | 0.69 | 2887.64 | 409 | 18 | 36 | 78 | 820 | 6111 |
| 2017 | 0.144 | 0.78 | 3029.34 | 410 | 18 | 37 | 81 | 863 | 6973 |
| 2018 | 0.144 | 0.85 | 3148.58 | 412 | 18 | 37 | 83 | 898 | 7872 |
| 2019 | 0.144 | 0.89 | 3248.27 | 413 | 18 | 37 | 85 | 928 | 8800 |
| 2020 | 0.144 | 0.92 | 3331.03 | 414 | 18 | 37 | 87 | 953 | 9753 |

*Table 6.24. Projection results under scenario 7—fishing mortality rate fixed at $F = 75\%F_{MSY}$. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY}$ = 0.22 (per yr), $SSB_{MSY}$ = 2592 (mt), and MSY = 1110 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.298 | 0 | 1888.74 | 399 | 32 | 61 | 107 | 1098 | 1098 |
| 2010 | 0.298 | 0 | 1800.36 | 396 | 35 | 70 | 94 | 985 | 2083 |
| 2011 | 0.166 | 0.01 | 1783.42 | 394 | 20 | 40 | 57 | 573 | 2656 |
| 2012 | 0.166 | 0.07 | 2044.99 | 394 | 20 | 40 | 66 | 647 | 3302 |
| 2013 | 0.166 | 0.18 | 2240.79 | 399 | 20 | 41 | 72 | 718 | 4020 |
| 2014 | 0.166 | 0.31 | 2418.43 | 402 | 20 | 41 | 78 | 780 | 4800 |
| 2015 | 0.166 | 0.44 | 2573.95 | 405 | 20 | 41 | 82 | 834 | 5635 |
| 2016 | 0.166 | 0.55 | 2707.57 | 407 | 20 | 42 | 85 | 880 | 6515 |
| 2017 | 0.166 | 0.64 | 2819.87 | 409 | 20 | 42 | 87 | 919 | 7434 |
| 2018 | 0.166 | 0.72 | 2912.78 | 410 | 21 | 42 | 90 | 951 | 8385 |
| 2019 | 0.166 | 0.77 | 2989.25 | 411 | 21 | 42 | 91 | 977 | 9363 |
| 2020 | 0.166 | 0.81 | 3051.77 | 411 | 21 | 42 | 93 | 999 | 10,362 |

*Table 6.25. Projection results under scenario 8—fishing mortality rate fixed at $F = 85\%F_{MSY}$. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY} = 0.22$ (per yr), $SSB_{MSY} = 2592$ (mt), and MSY = 1110 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.298 | 0 | 1888.74 | 399 | 32 | 61 | 107 | 1098 | 1098 |
| 2010 | 0.298 | 0 | 1800.36 | 396 | 35 | 70 | 94 | 985 | 2083 |
| 2011 | 0.188 | 0.01 | 1783.42 | 394 | 22 | 45 | 64 | 643 | 2726 |
| 2012 | 0.188 | 0.06 | 2002.31 | 394 | 22 | 45 | 73 | 714 | 3440 |
| 2013 | 0.188 | 0.14 | 2165.39 | 398 | 22 | 46 | 79 | 781 | 4221 |
| 2014 | 0.188 | 0.23 | 2311.01 | 401 | 23 | 46 | 84 | 839 | 5060 |
| 2015 | 0.188 | 0.33 | 2436.35 | 403 | 23 | 46 | 88 | 888 | 5949 |
| 2016 | 0.188 | 0.42 | 2542.28 | 405 | 23 | 47 | 91 | 930 | 6878 |
| 2017 | 0.188 | 0.49 | 2629.82 | 407 | 23 | 47 | 93 | 964 | 7842 |
| 2018 | 0.188 | 0.55 | 2701.06 | 408 | 23 | 47 | 95 | 991 | 8833 |
| 2019 | 0.188 | 0.6 | 2758.8 | 408 | 23 | 47 | 96 | 1014 | 9847 |
| 2020 | 0.188 | 0.64 | 2805.35 | 409 | 23 | 47 | 98 | 1032 | 10,879 |

*Table 6.26. Projection results under scenario 9—fishing mortality rate fixed at $F = F_{MSY}$. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY}$ = 0.22 (per yr), $SSB_{MSY}$ = 2592 (mt), and MSY = 1110 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.298 | 0 | 1888.74 | 399 | 32 | 61 | 107 | 1098 | 1098 |
| 2010 | 0.298 | 0 | 1800.36 | 396 | 35 | 70 | 94 | 985 | 2083 |
| 2011 | 0.221 | 0.01 | 1783.42 | 394 | 26 | 53 | 75 | 746 | 2829 |
| 2012 | 0.221 | 0.04 | 1940.25 | 394 | 26 | 53 | 82 | 808 | 3637 |
| 2013 | 0.221 | 0.1 | 2058.07 | 397 | 26 | 53 | 88 | 865 | 4502 |
| 2014 | 0.221 | 0.15 | 2161.08 | 399 | 26 | 53 | 93 | 914 | 5416 |
| 2015 | 0.221 | 0.2 | 2247.64 | 401 | 26 | 54 | 96 | 953 | 6369 |
| 2016 | 0.221 | 0.24 | 2319.1 | 403 | 26 | 54 | 98 | 986 | 7355 |
| 2017 | 0.221 | 0.28 | 2376.71 | 404 | 27 | 54 | 100 | 1012 | 8367 |
| 2018 | 0.221 | 0.32 | 2422.47 | 404 | 27 | 54 | 101 | 1033 | 9399 |
| 2019 | 0.221 | 0.35 | 2458.77 | 405 | 27 | 54 | 102 | 1049 | 10,449 |
| 2020 | 0.221 | 0.37 | 2487.46 | 406 | 27 | 55 | 103 | 1062 | 11,511 |

*Table 6.27. Projection results under scenario 10—fishing mortality rate fixed at $F = F_{\text{rebuild}}$. F = fishing mortality rate (per year), Pr(*SSB > $\text{SSB}_{\text{MSY}}$*) = proportion of stochastic projection replicates exceeding* $\text{SSB}_{\text{MSY}}$*, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000* lb *whole weight), L = landings (1000 fish or 1000* lb *whole weight), and Sum L = cumulative landings (1000* lb*). For reference, estimated benchmarks are $F_{\text{MSY}}$ = 0.22 (per yr),* $\text{SSB}_{\text{MSY}}$ = 2592 *(mt), and* MSY = 1110 *(1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

| Year | F(per yr) | Pr(SSB > $\text{SSB}_{\text{MSY}}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.298 | 0 | 1888.74 | 399 | 32 | 61 | 107 | 1098 | 1098 |
| 2010 | 0.298 | 0 | 1800.36 | 396 | 35 | 70 | 94 | 985 | 2083 |
| 2011 | 0.205 | 0.01 | 1783.42 | 394 | 24 | 49 | 70 | 697 | 2780 |
| 2012 | 0.205 | 0.05 | 1969.91 | 394 | 24 | 49 | 78 | 763 | 3543 |
| 2013 | 0.205 | 0.11 | 2109.02 | 398 | 24 | 50 | 84 | 826 | 4369 |
| 2014 | 0.205 | 0.19 | 2231.83 | 400 | 24 | 50 | 89 | 880 | 5249 |
| 2015 | 0.205 | 0.26 | 2336.2 | 402 | 25 | 50 | 92 | 924 | 6173 |
| 2016 | 0.205 | 0.32 | 2423.32 | 404 | 25 | 50 | 95 | 961 | 7134 |
| 2017 | 0.205 | 0.38 | 2494.4 | 405 | 25 | 51 | 97 | 991 | 8126 |
| 2018 | 0.205 | 0.43 | 2551.51 | 406 | 25 | 51 | 98 | 1015 | 9141 |
| 2019 | 0.205 | 0.47 | 2597.29 | 407 | 25 | 51 | 100 | 1035 | 10,175 |
| 2020 | 0.205 | 0.5 | 2633.8 | 407 | 25 | 51 | 101 | 1050 | 11,225 |

*Table 6.28. Projection results under scenario 11—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009, $F = 75\%F_{\text{current}}$ in 2010, and $F_{\text{rebuild}}$ thereafter. F = fishing mortality rate (per year), Pr(SSB > $\text{SSB}_{\text{MSY}}$) = proportion of stochastic projection replicates exceeding $\text{SSB}_{\text{MSY}}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{\text{MSY}} = 0.22$ (per yr), $\text{SSB}_{\text{MSY}} = 2592$ (mt), and MSY = 1110 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

| Year | F(per yr) | Pr(SSB > $\text{SSB}_{\text{MSY}}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.298 | 0 | 1888.74 | 399 | 32 | 61 | 107 | 1098 | 1098 |
| 2010 | 0.224 | 0 | 1800.36 | 396 | 26 | 53 | 72 | 763 | 1861 |
| 2011 | 0.206 | 0.02 | 1915.38 | 394 | 24 | 50 | 74 | 742 | 2602 |
| 2012 | 0.206 | 0.07 | 2053.13 | 397 | 24 | 50 | 81 | 803 | 3405 |
| 2013 | 0.206 | 0.14 | 2177.85 | 399 | 25 | 50 | 87 | 860 | 4265 |
| 2014 | 0.206 | 0.22 | 2287.01 | 401 | 25 | 50 | 91 | 907 | 5172 |
| 2015 | 0.206 | 0.29 | 2379.49 | 403 | 25 | 51 | 94 | 947 | 6119 |
| 2016 | 0.206 | 0.35 | 2456.54 | 404 | 25 | 51 | 96 | 980 | 7099 |
| 2017 | 0.206 | 0.4 | 2519.13 | 406 | 25 | 51 | 98 | 1006 | 8105 |
| 2018 | 0.206 | 0.44 | 2569.15 | 406 | 25 | 51 | 99 | 1027 | 9132 |
| 2019 | 0.206 | 0.48 | 2609.06 | 407 | 25 | 51 | 100 | 1044 | 10,177 |
| 2020 | 0.206 | 0.51 | 2640.78 | 407 | 25 | 51 | 101 | 1058 | 11,235 |

*Table 6.29. Projection results under scenario 12—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009, $F = 50\%F_{\text{current}}$ in 2010, and $F_{\text{rebuild}}$ thereafter. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY}$ = 0.22 (per yr), $SSB_{MSY}$ = 2592 (mt), and MSY = 1110 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.298 | 0 | 1888.74 | 399 | 32 | 61 | 107 | 1098 | 1098 |
| 2010 | 0.149 | 0 | 1800.36 | 396 | 18 | 36 | 50 | 525 | 1623 |
| 2011 | 0.208 | 0.04 | 2059.22 | 394 | 25 | 51 | 78 | 793 | 2416 |
| 2012 | 0.208 | 0.1 | 2139.52 | 399 | 25 | 50 | 85 | 848 | 3264 |
| 2013 | 0.208 | 0.18 | 2247.14 | 401 | 25 | 51 | 90 | 898 | 4162 |
| 2014 | 0.208 | 0.25 | 2340.29 | 402 | 25 | 51 | 93 | 939 | 5101 |
| 2015 | 0.208 | 0.32 | 2418.88 | 404 | 25 | 51 | 96 | 973 | 6073 |
| 2016 | 0.208 | 0.37 | 2484.22 | 405 | 25 | 51 | 98 | 1001 | 7074 |
| 2017 | 0.208 | 0.41 | 2537.01 | 406 | 25 | 52 | 99 | 1023 | 8097 |
| 2018 | 0.208 | 0.45 | 2578.91 | 407 | 25 | 52 | 100 | 1041 | 9139 |
| 2019 | 0.208 | 0.48 | 2612.16 | 407 | 25 | 52 | 101 | 1056 | 10,194 |
| 2020 | 0.208 | 0.51 | 2638.46 | 407 | 25 | 52 | 102 | 1067 | 11,261 |

*Table 6.30. Projection results under scenario 13—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009, $F = 25\%F_{\text{current}}$ in 2010, and $F_{\text{rebuild}}$ thereafter. F = fishing mortality rate (per year), Pr(SSB > $SSB_{MSY}$) = proportion of stochastic projection replicates exceeding $SSB_{MSY}$, SSB = mid-year spawning stock (mt), R = recruits (1000 age-1 fish), D = discard mortalities (1000 fish or 1000 lb whole weight), L = landings (1000 fish or 1000 lb whole weight), and Sum L = cumulative landings (1000 lb). For reference, estimated benchmarks are $F_{MSY} = 0.22$ (per yr), $SSB_{MSY} = 2592$ (mt), and MSY = 1110 (1000 lb). Expected values presented are from deterministic projections (klb = 1000 lb).*

| Year | F(per yr) | Pr(SSB > $SSB_{MSY}$) | SSB(mt) | R(1000) | D(1000) | D(klb) | L(1000) | L(klb) | Sum L(klb) |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 0.298 | 0 | 1888.74 | 399 | 32 | 61 | 107 | 1098 | 1098 |
| 2010 | 0.075 | 0 | 1800.36 | 396 | 9 | 18 | 26 | 272 | 1369 |
| 2011 | 0.21 | 0.1 | 2216.11 | 394 | 25 | 52 | 83 | 848 | 2218 |
| 2012 | 0.21 | 0.15 | 2231.31 | 402 | 25 | 51 | 89 | 896 | 3113 |
| 2013 | 0.21 | 0.23 | 2320.39 | 402 | 25 | 51 | 93 | 938 | 4052 |
| 2014 | 0.21 | 0.29 | 2396.36 | 404 | 25 | 52 | 96 | 972 | 5024 |
| 2015 | 0.21 | 0.35 | 2460.16 | 405 | 25 | 52 | 98 | 1000 | 6023 |
| 2016 | 0.21 | 0.39 | 2513.16 | 406 | 25 | 52 | 99 | 1023 | 7046 |
| 2017 | 0.21 | 0.43 | 2555.73 | 406 | 26 | 52 | 101 | 1041 | 8087 |
| 2018 | 0.21 | 0.46 | 2589.23 | 407 | 26 | 52 | 102 | 1055 | 9142 |
| 2019 | 0.21 | 0.49 | 2615.65 | 407 | 26 | 52 | 102 | 1067 | 10,209 |
| 2020 | 0.21 | 0.5 | 2636.42 | 407 | 26 | 52 | 103 | 1076 | 11,285 |

### 6.6 Figures

*Figure 6.1. 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, cvt to chevron trap, cl to commercial lines, co to commercial other, hb to headboat, rec to general recreational (MRFSS), and hb.D to headboat discards. N indicates the number of trips from which individual fish samples were taken.*

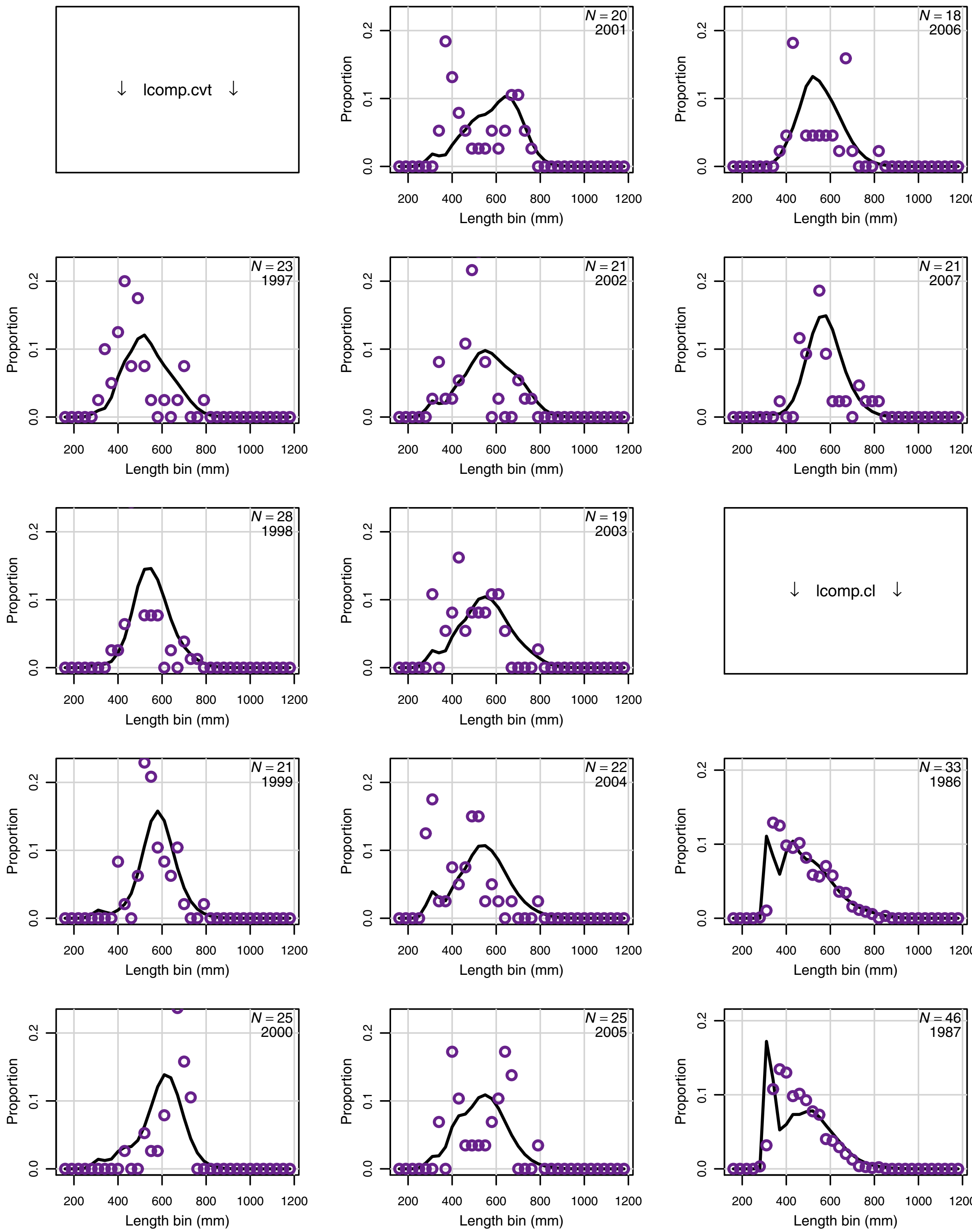


*Figure 6.1. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

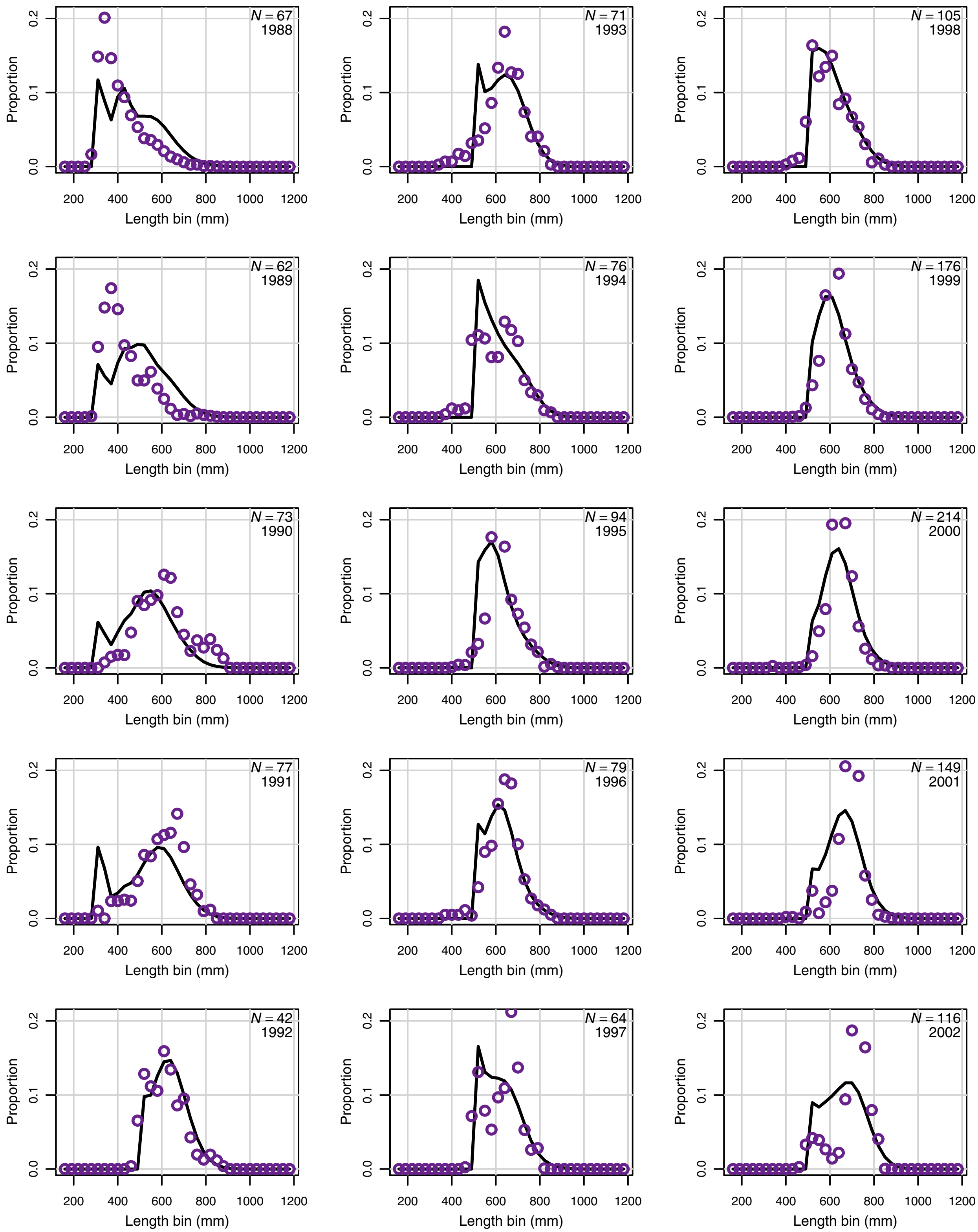


*Figure 6.1. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

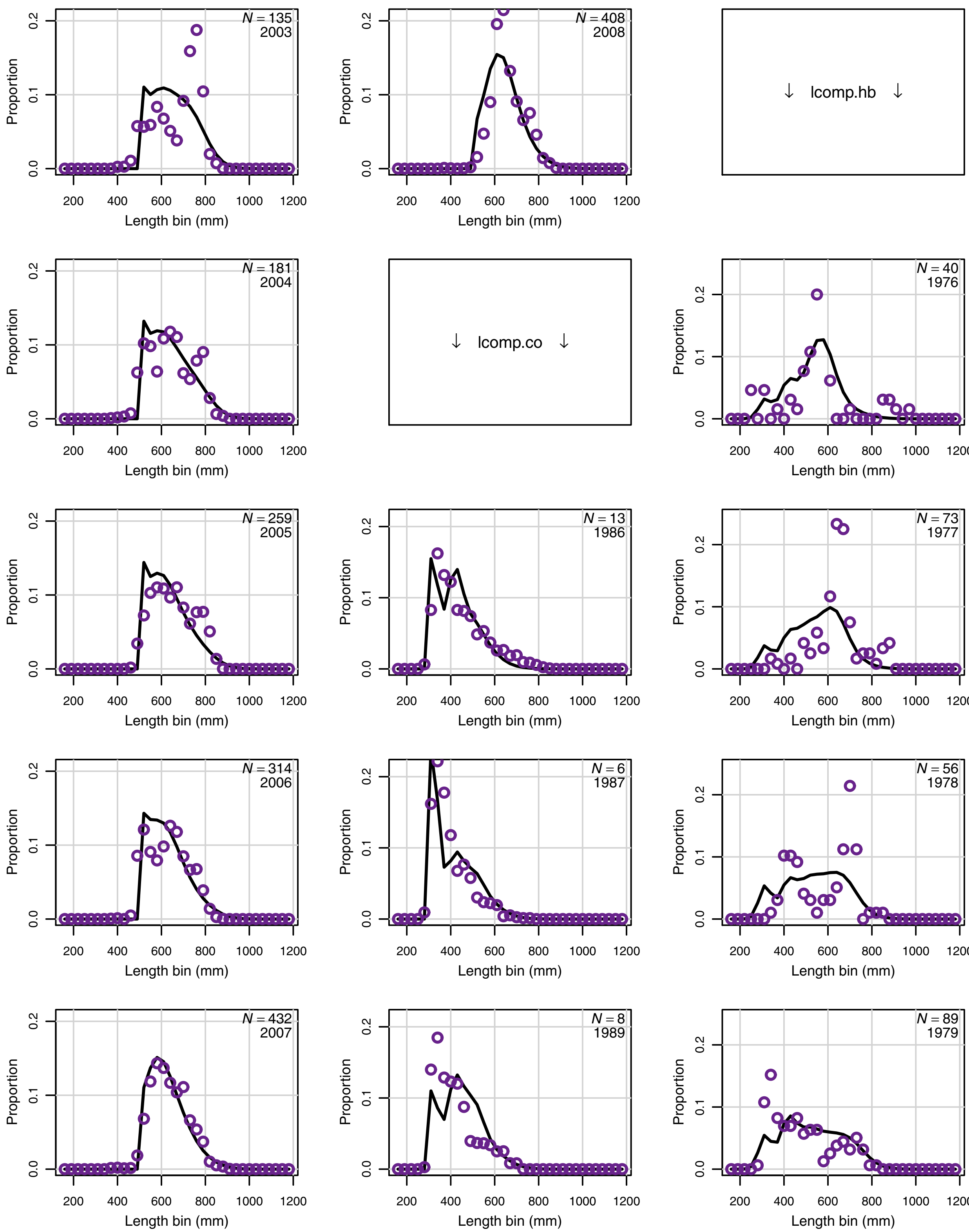


*Figure 6.1. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

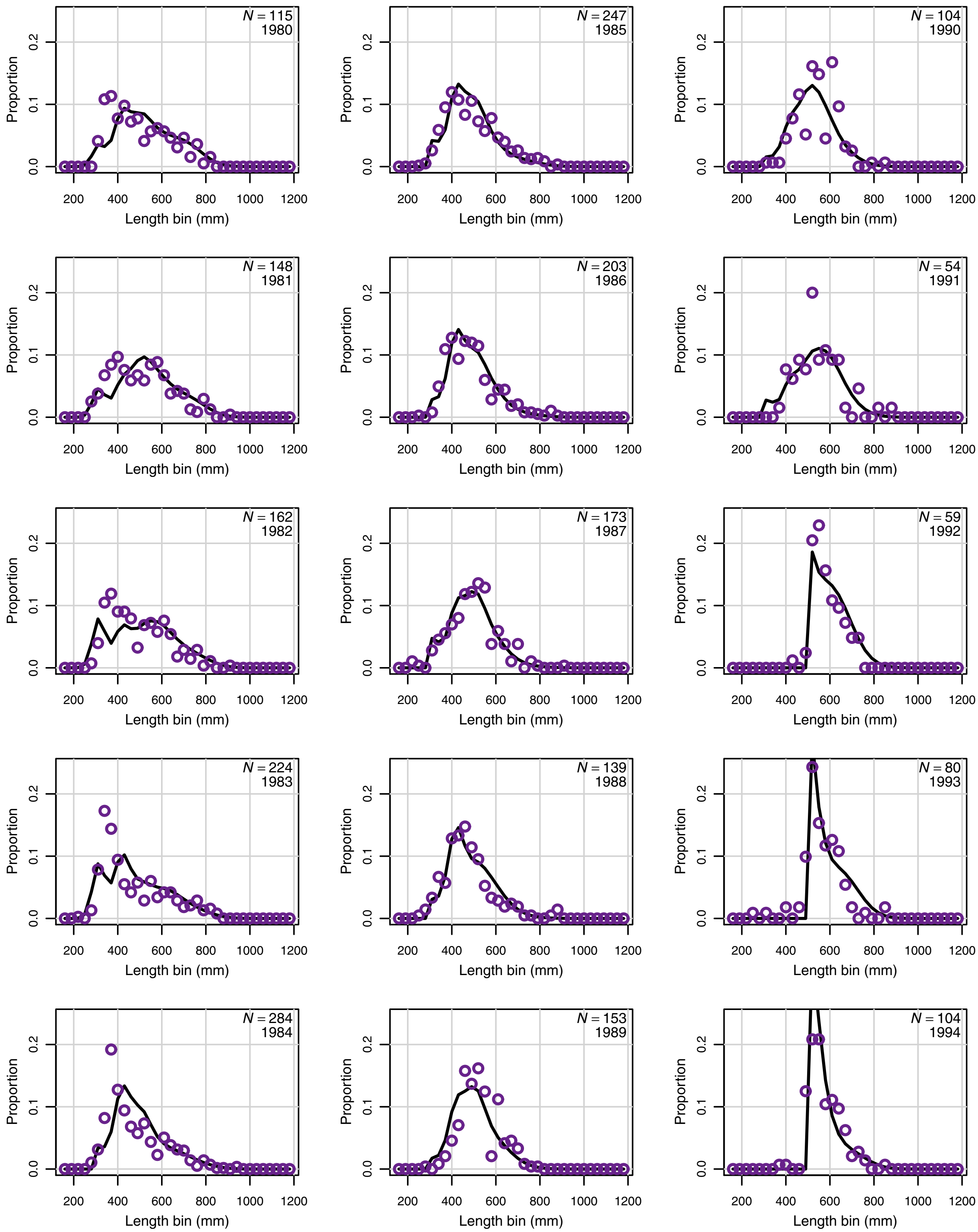


*Figure 6.1. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

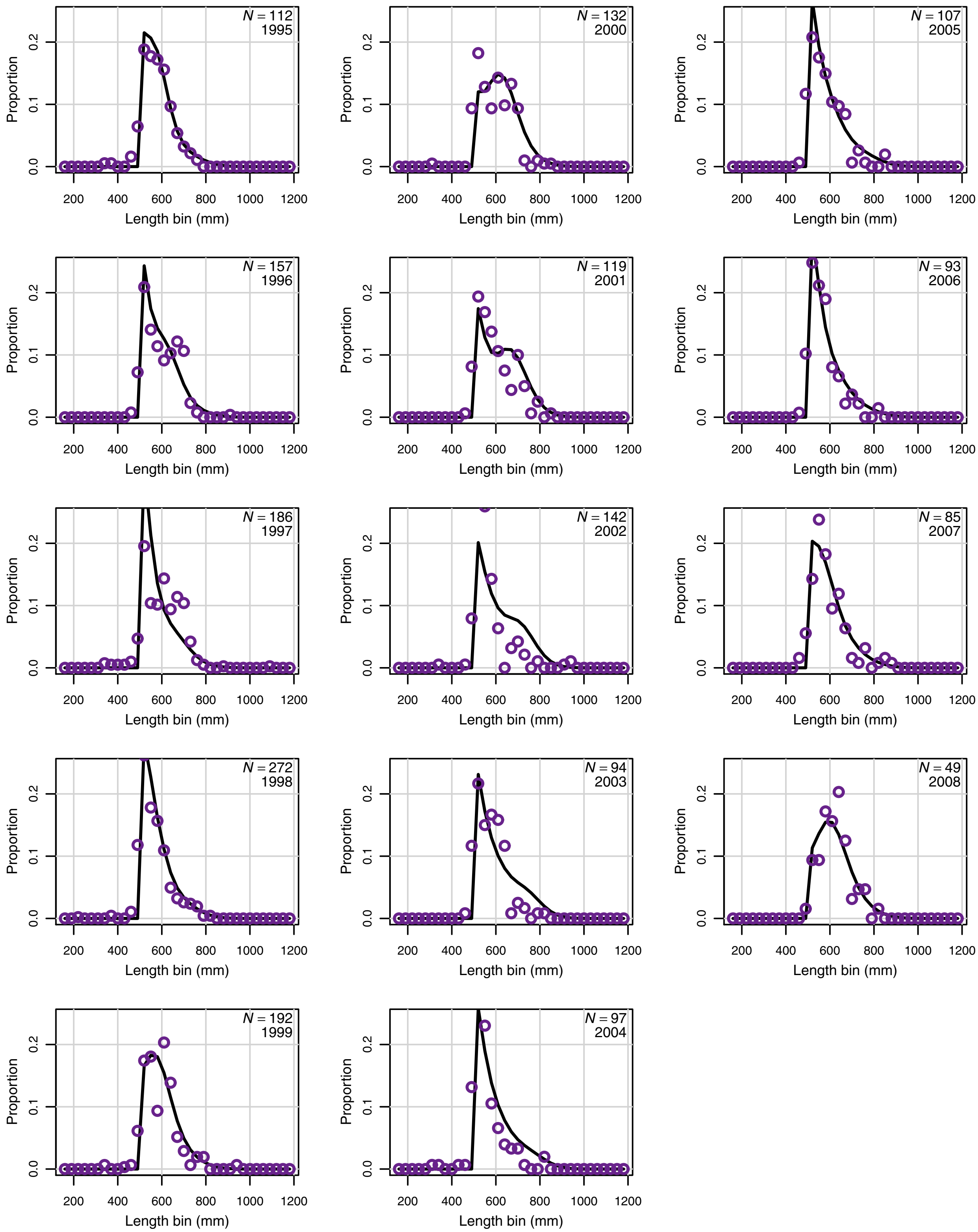


*Figure 6.1. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

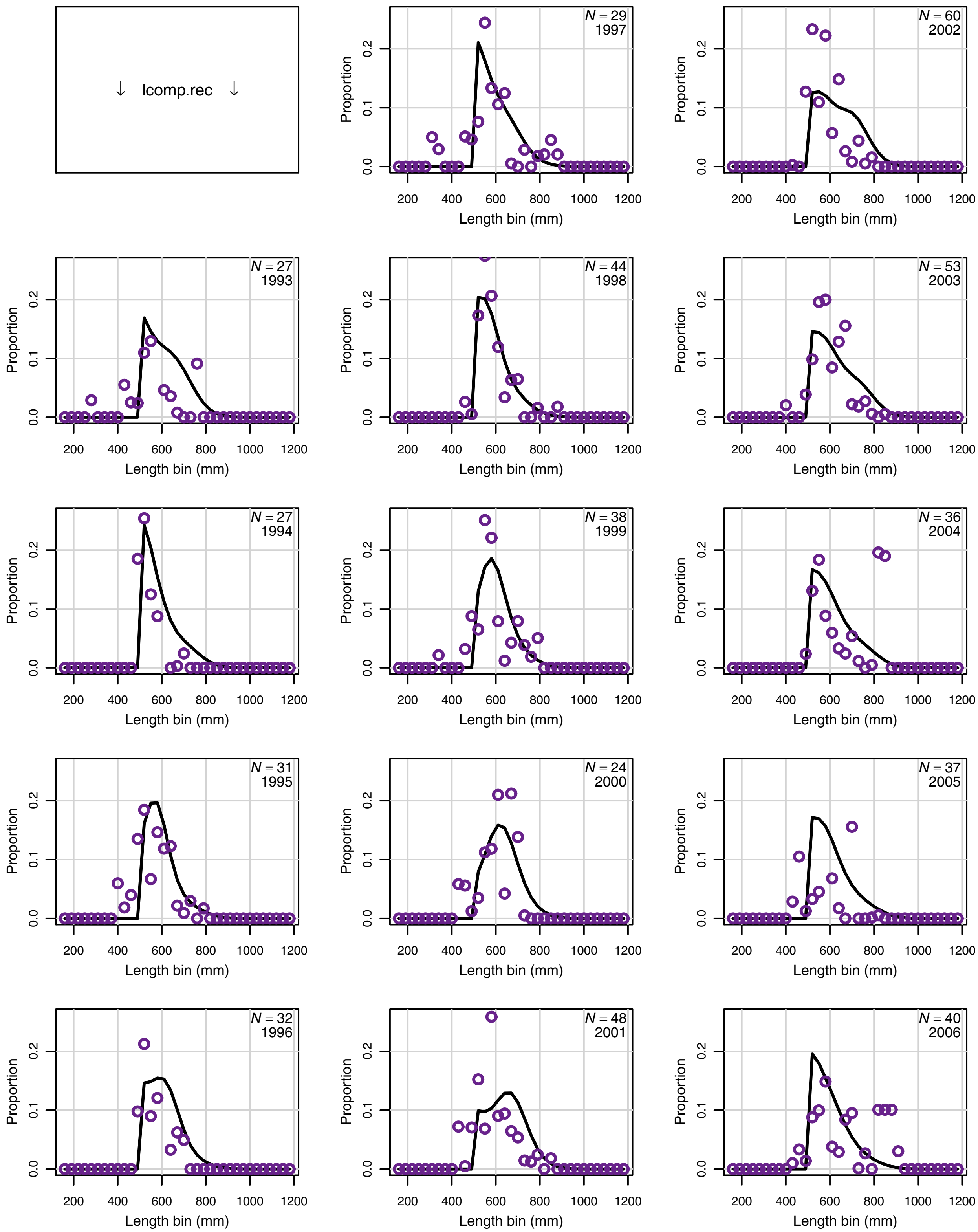


*Figure 6.1. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

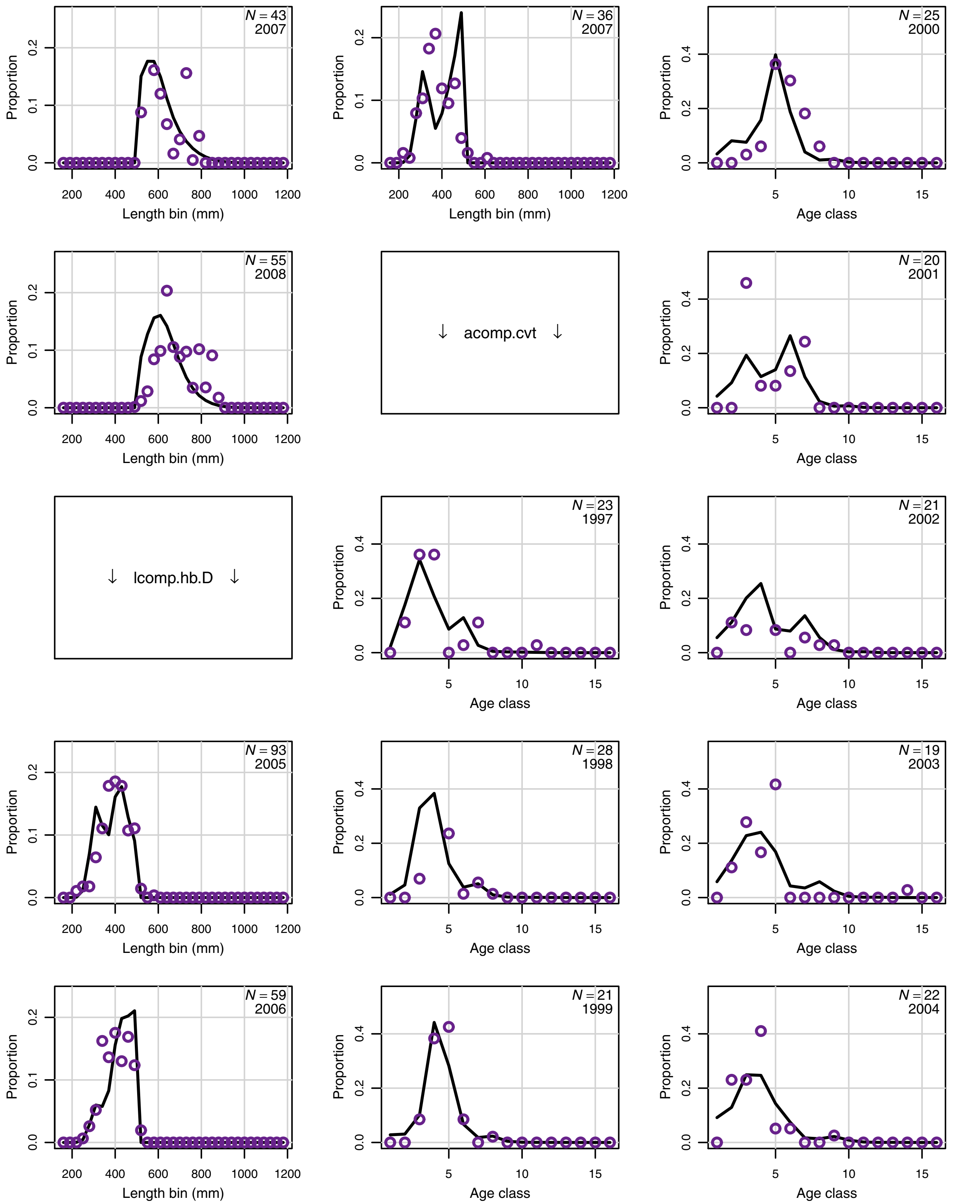


*Figure 6.1. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

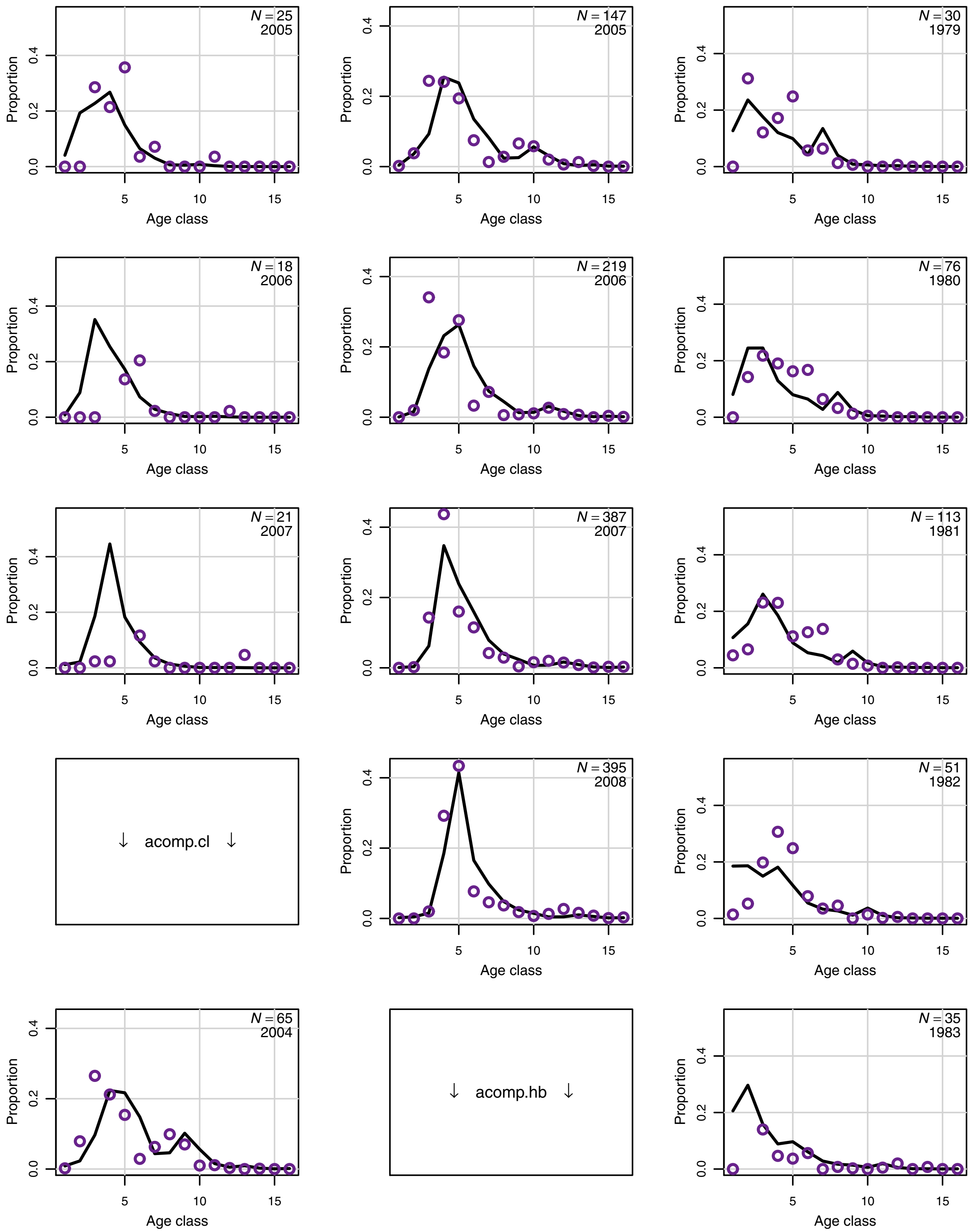


*Figure 6.1. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

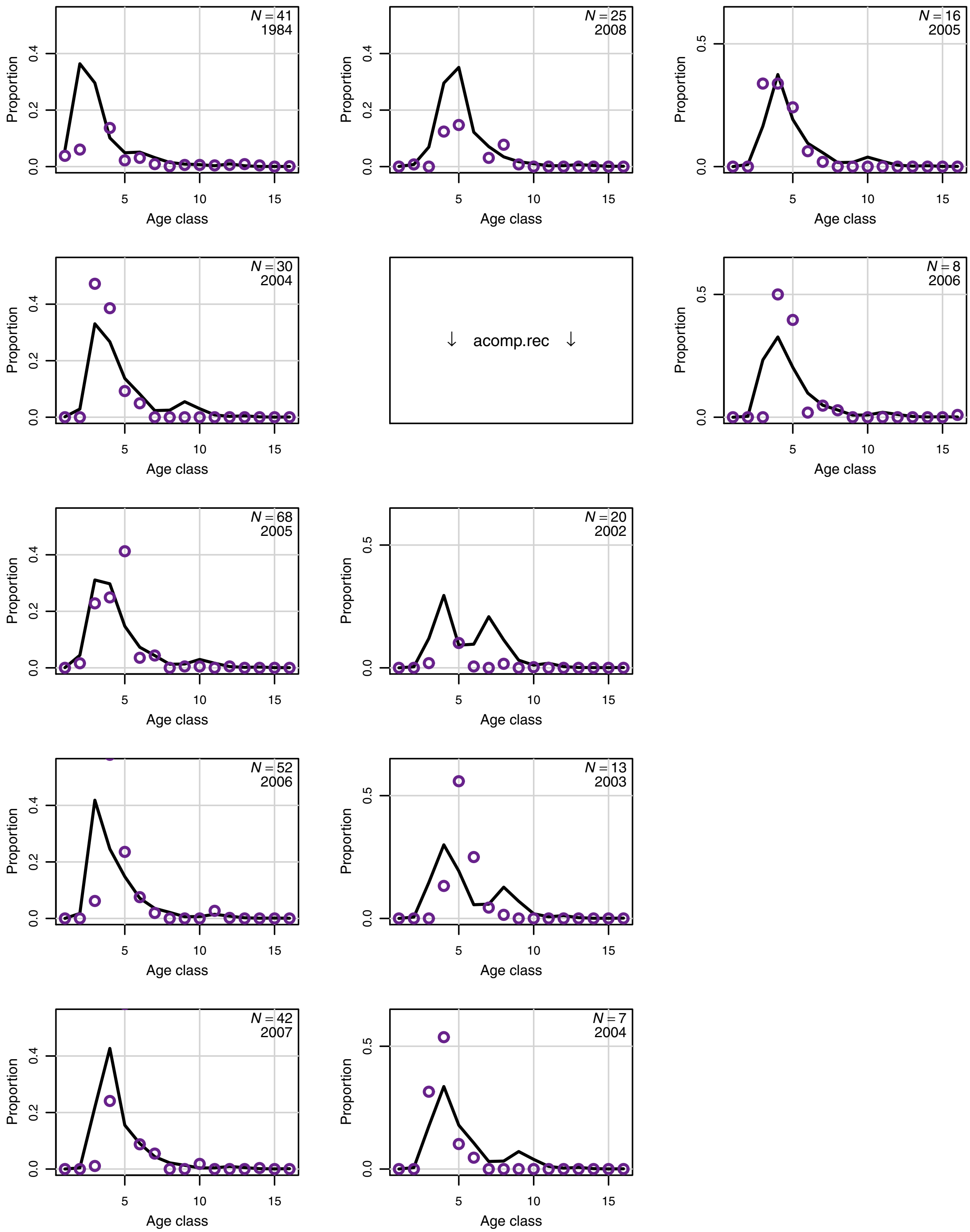


*Figure 6.2. Top panel is a bubble plot of length composition residuals from MARMAP Florida snapper trap; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

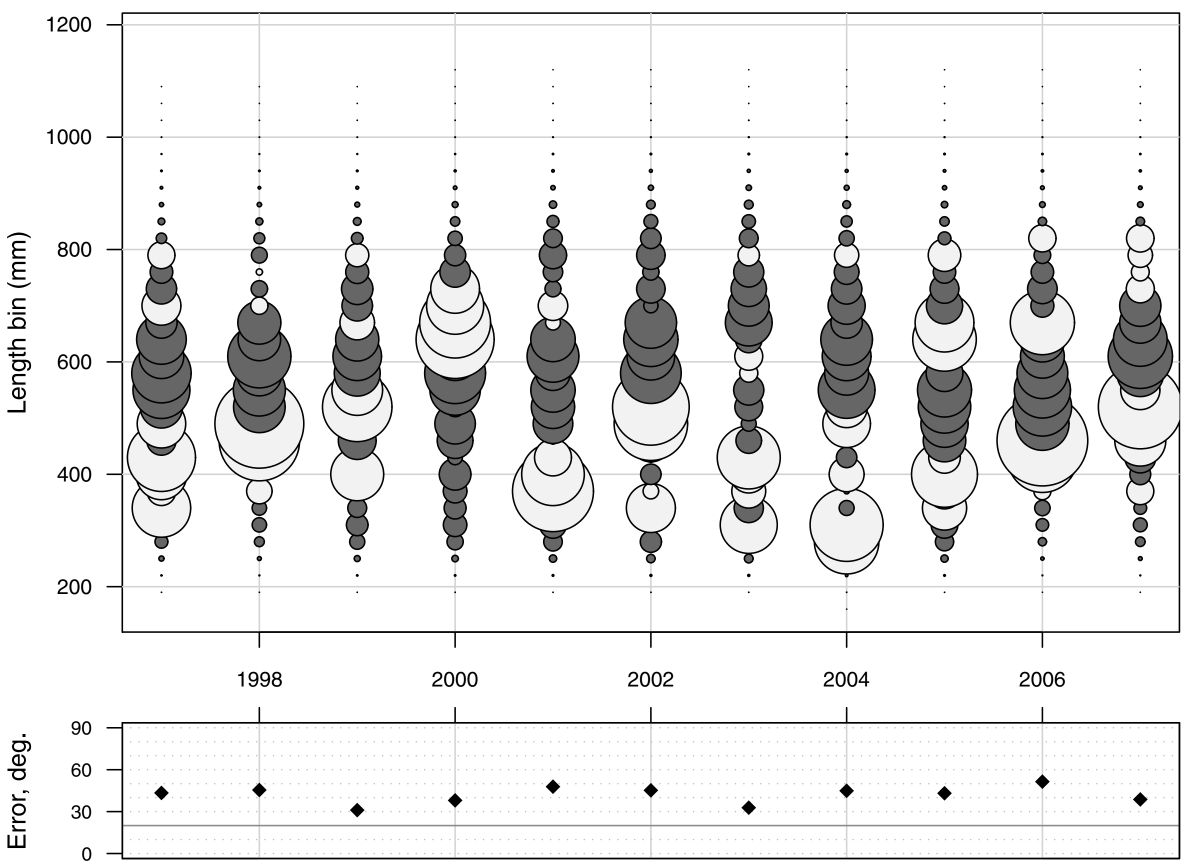


*Figure 6.3. Top panel is a bubble plot of length composition residuals from commercial lines; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

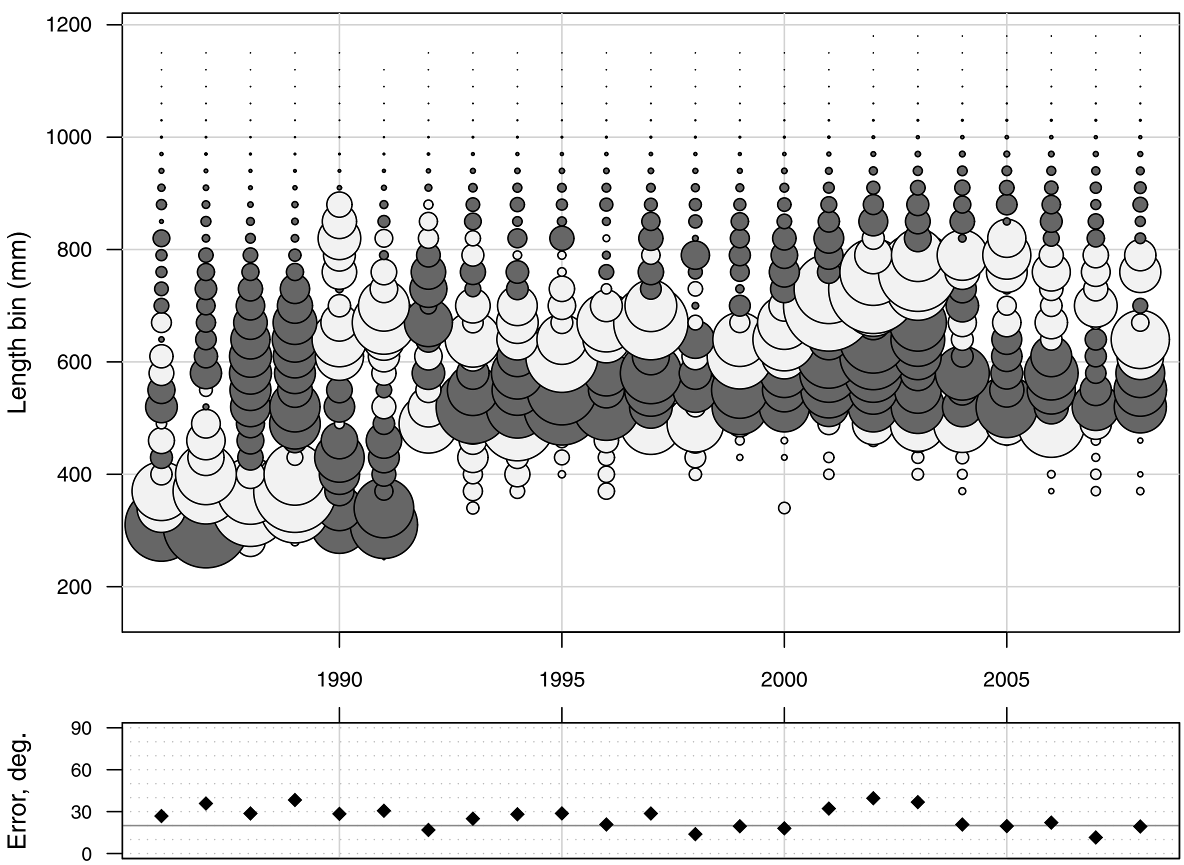


*Figure 6.4. Top panel is a bubble plot of length composition residuals from the commercial other; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

*Figure 6.5. Top panel is a bubble plot of length composition residuals from headboats; Dark represents overestimates and light 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.*

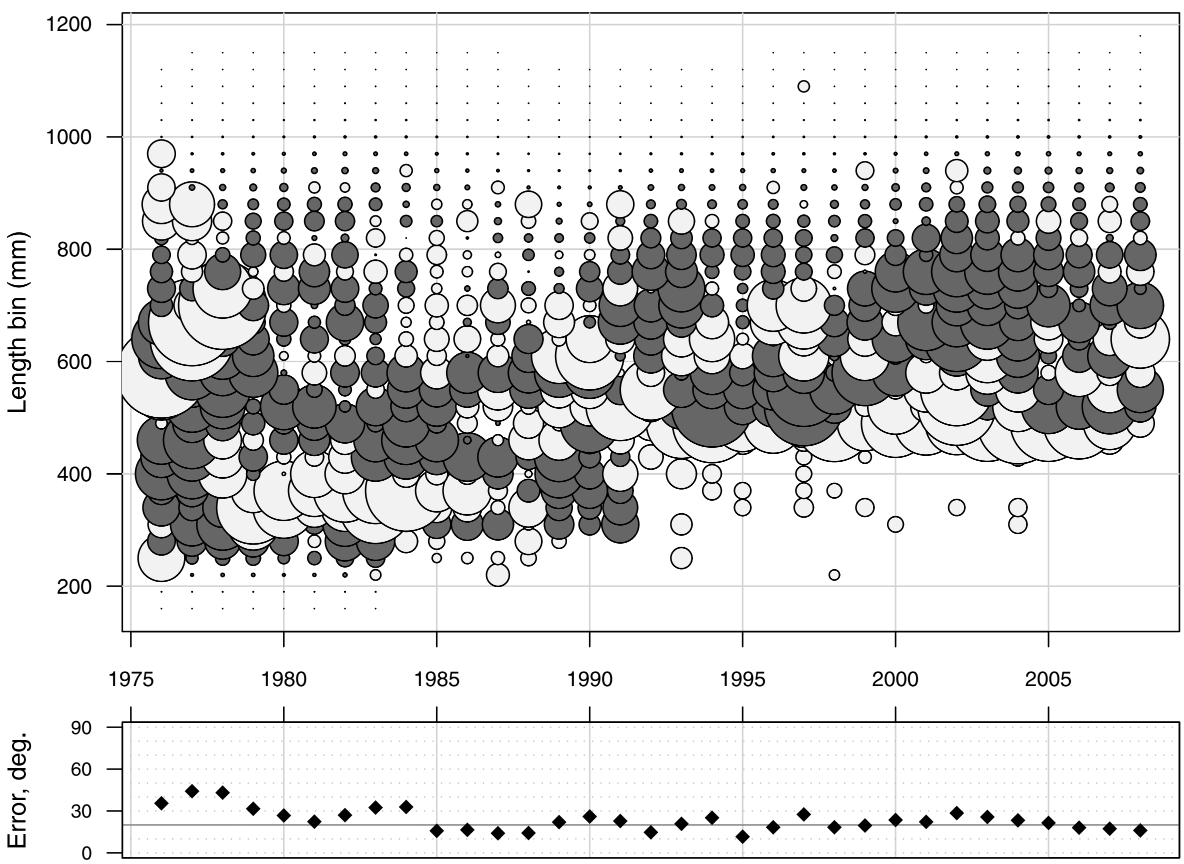


*Figure 6.6. Top panel is a bubble plot of length composition residuals from the recreational fleet (MRFSS); Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

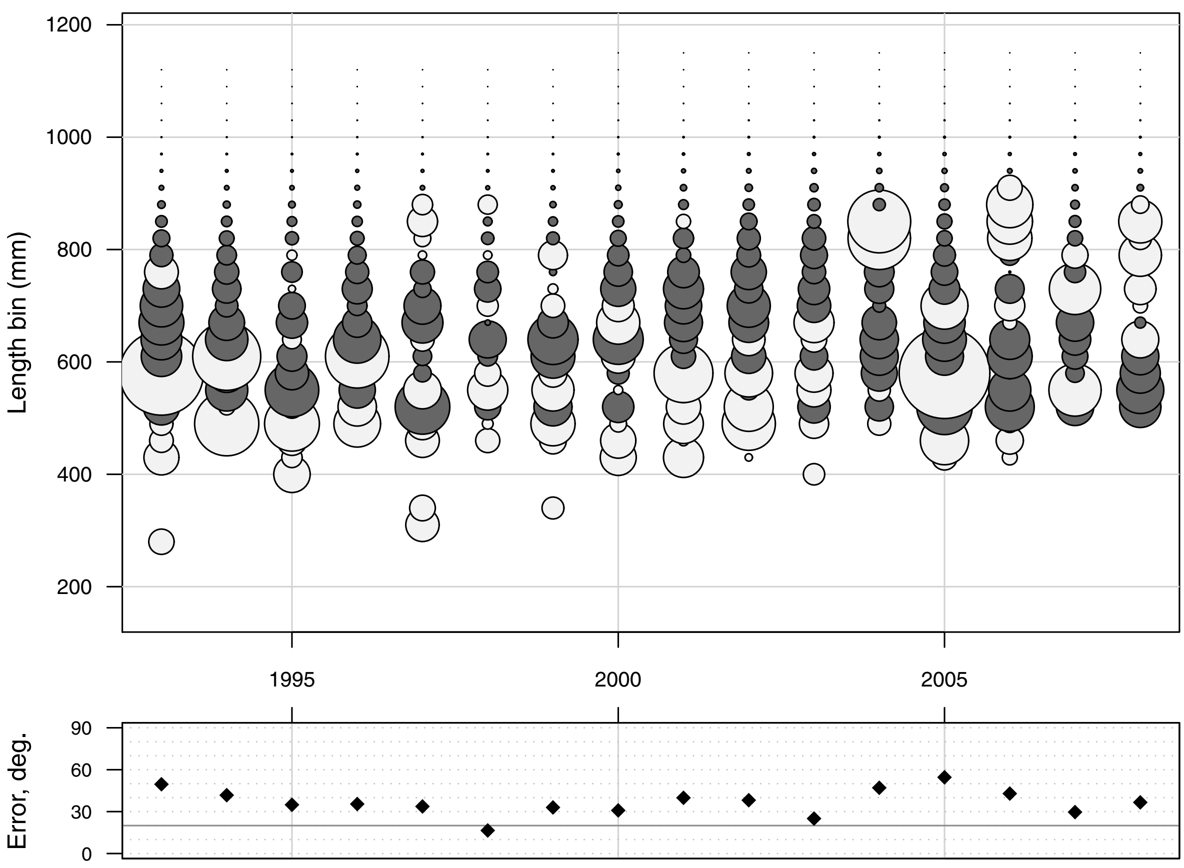


*Figure 6.7. Top panel is a bubble plot of length composition residuals from headboat discards; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

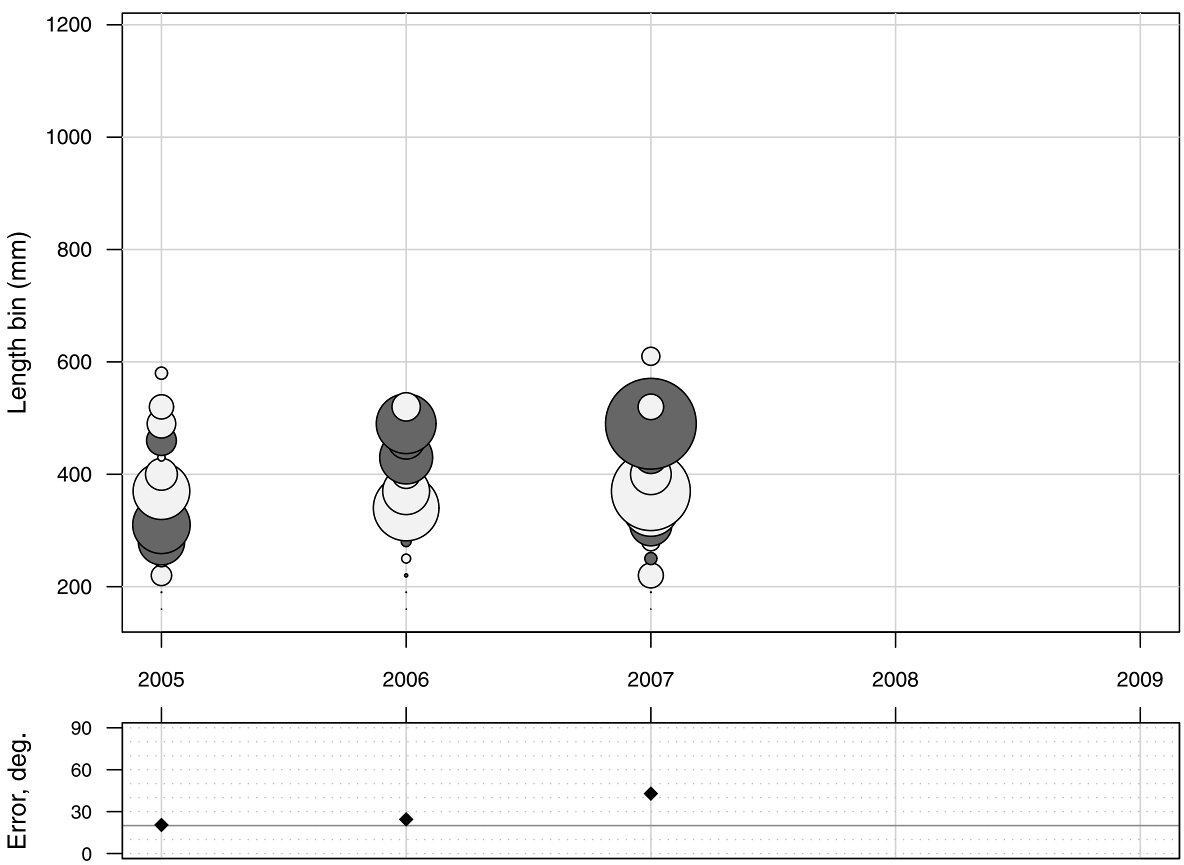


*Figure 6.8. Top panel is a bubble plot of age composition residuals from MARMAP chevron trap; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

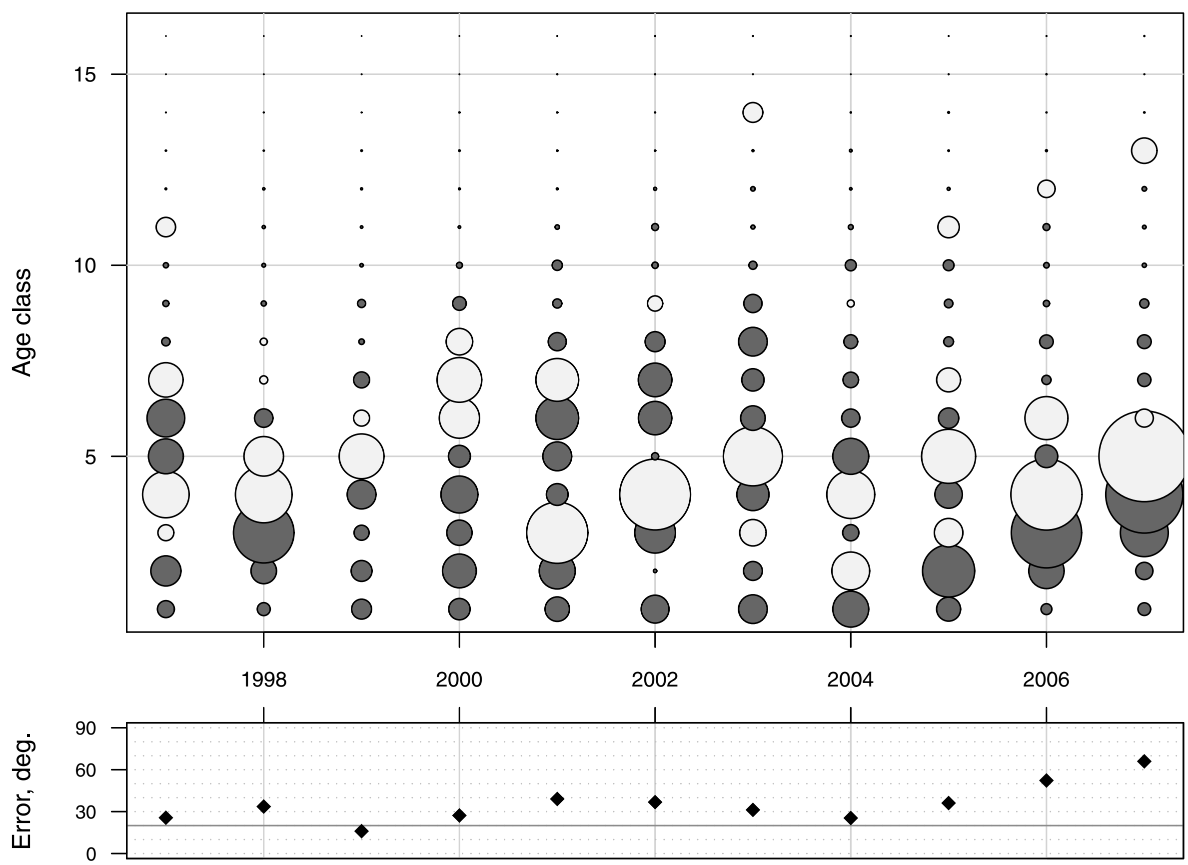


*Figure 6.9. Top panel is a bubble plot of age composition residuals from commercial lines; Dark represents over-estimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

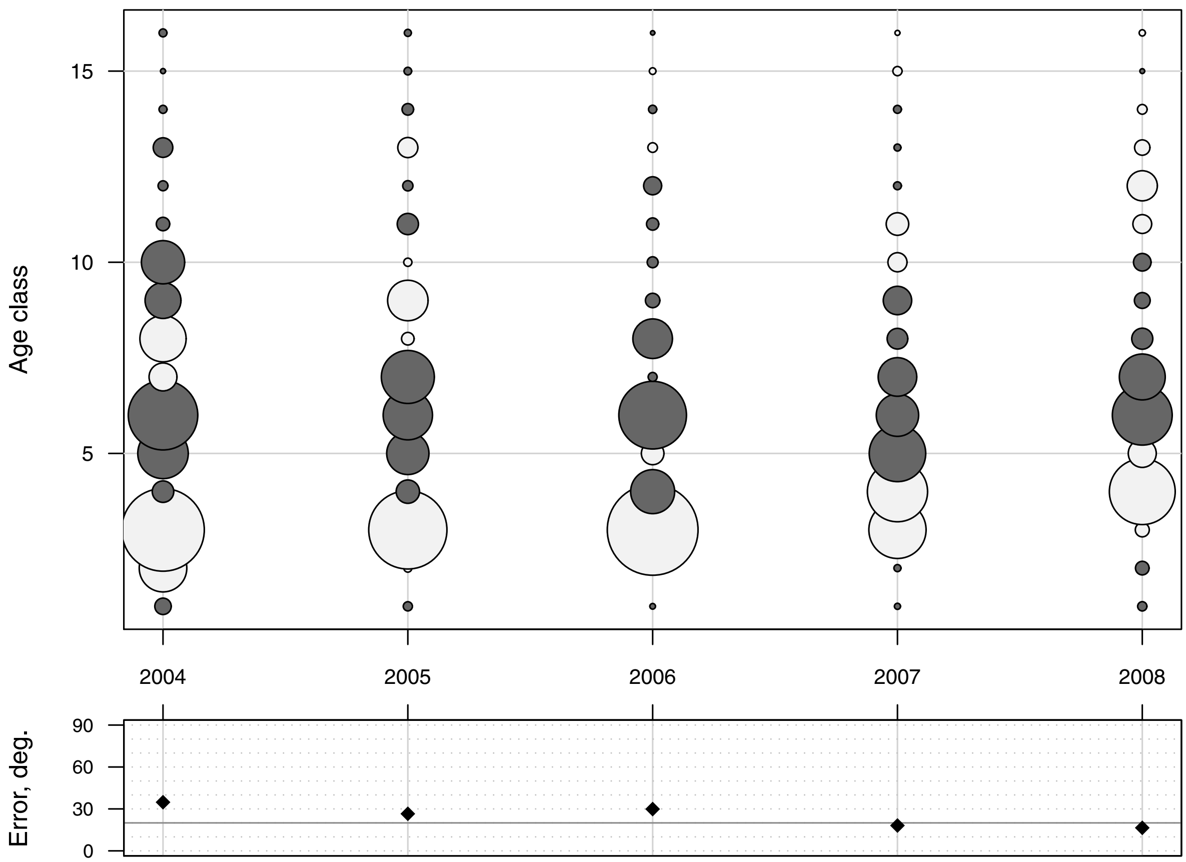


*Figure 6.10. Top panel is a bubble plot of age composition residuals from headboats; Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

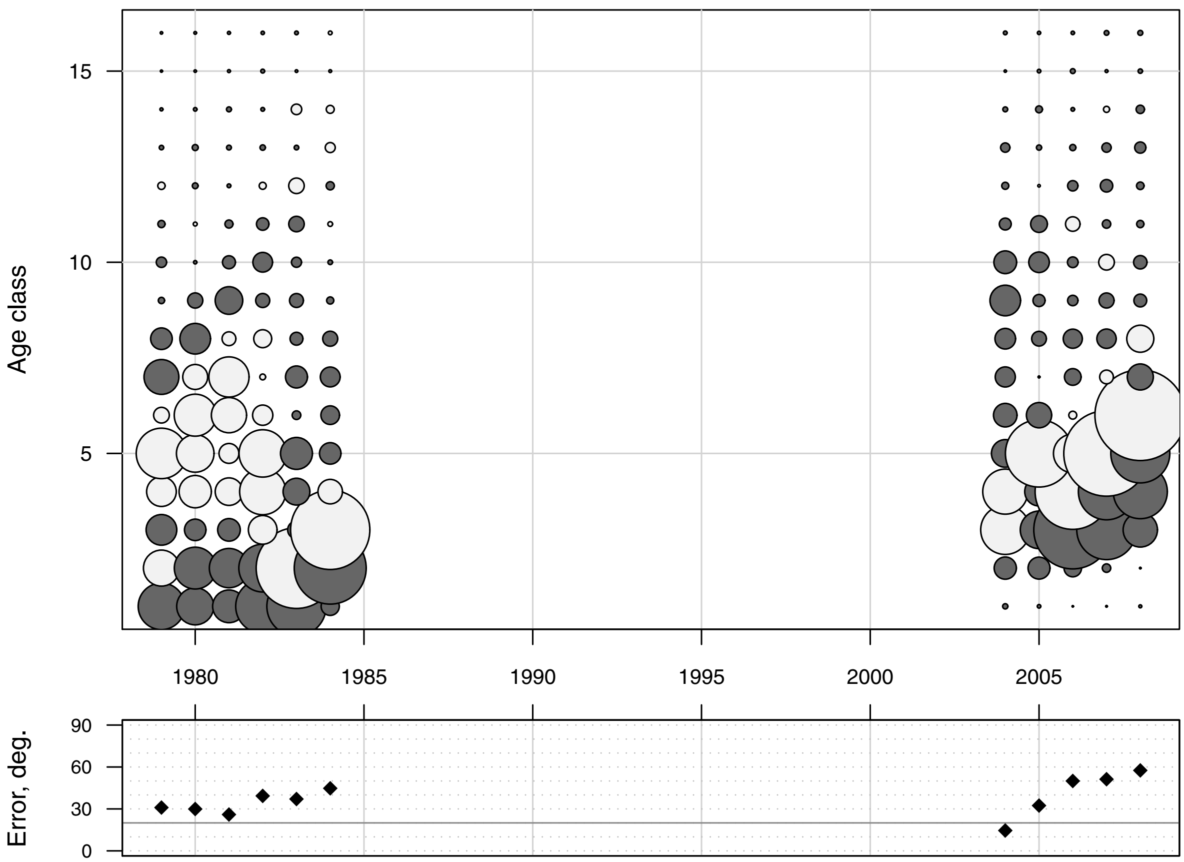


*Figure 6.11. Top panel is a bubble plot of age composition residuals from the recreational fleet (MRFSS); Dark represents overestimates and light underestimates. Bottom panel shows the angle (in degrees) between vectors of observations and estimates, with a reference line at 20 degrees. Error is bounded between 0 and 90 degrees, with 0 indicating a perfect fit.*

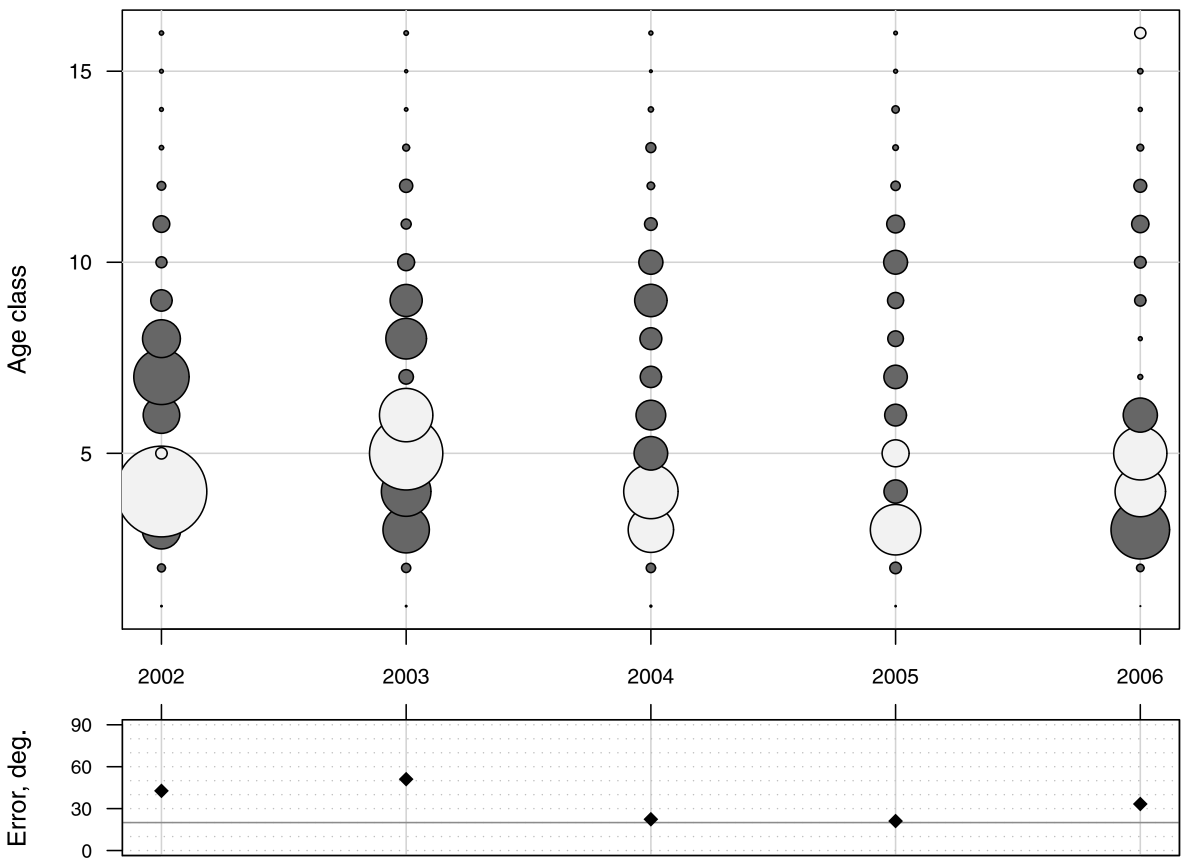


*Figure 6.12. Observed (open circles) and estimated (line, solid circles) commercial lines landings (1000 lb whole weight).*

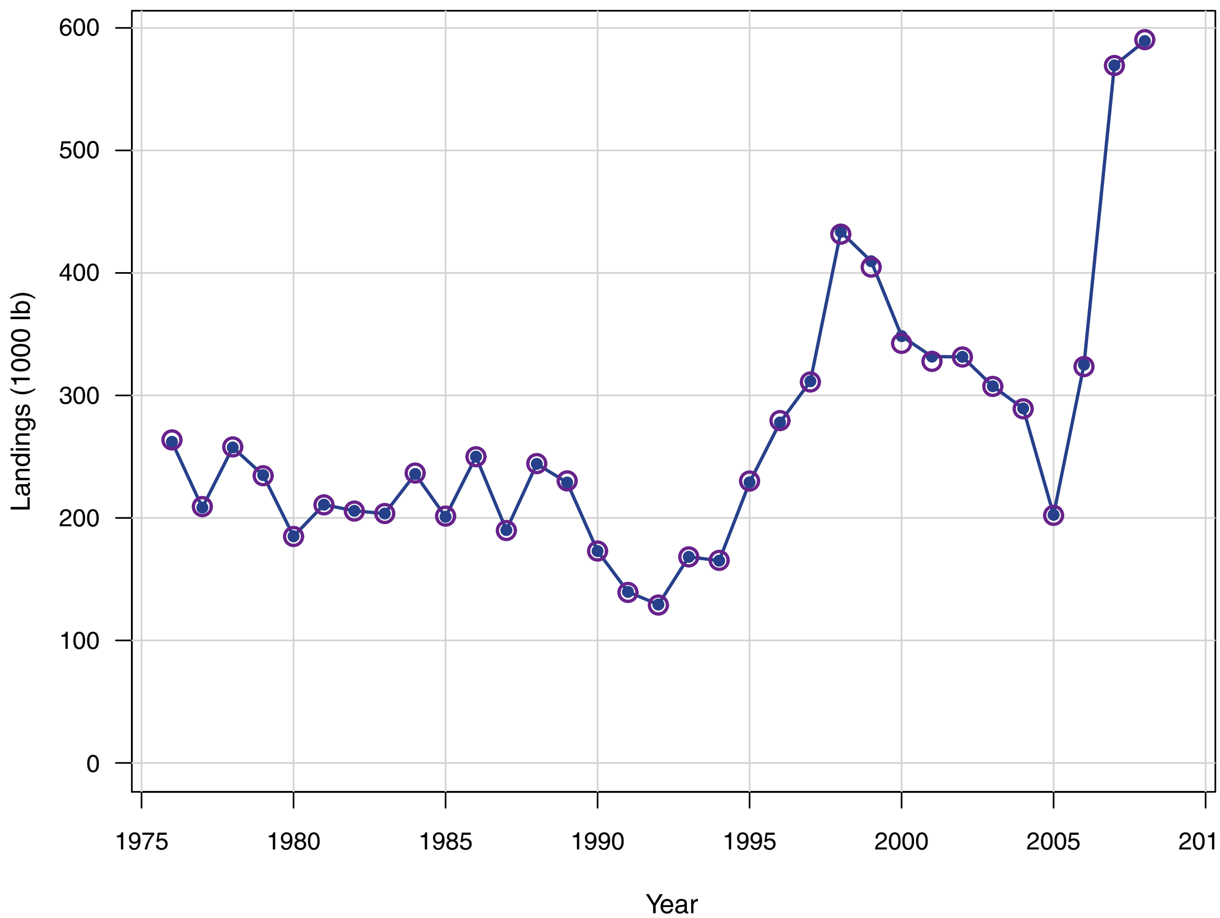


*Figure 6.13. Observed (open circles) and estimated (line, solid circles) commercial other (1000 lb whole weight).*

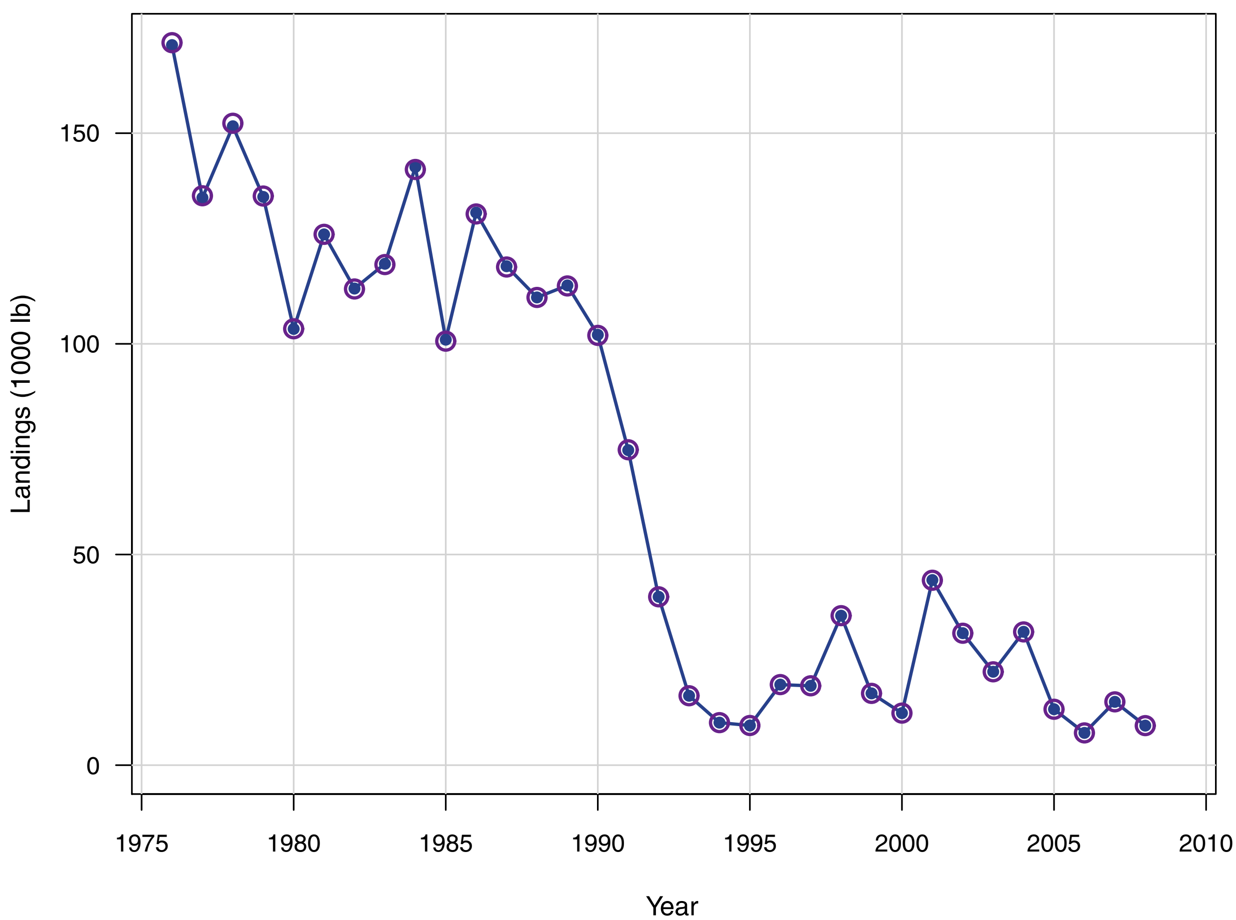


*Figure 6.14. Observed (open circles) and estimated (line, solid circles) headboat landings (1000 fish).*

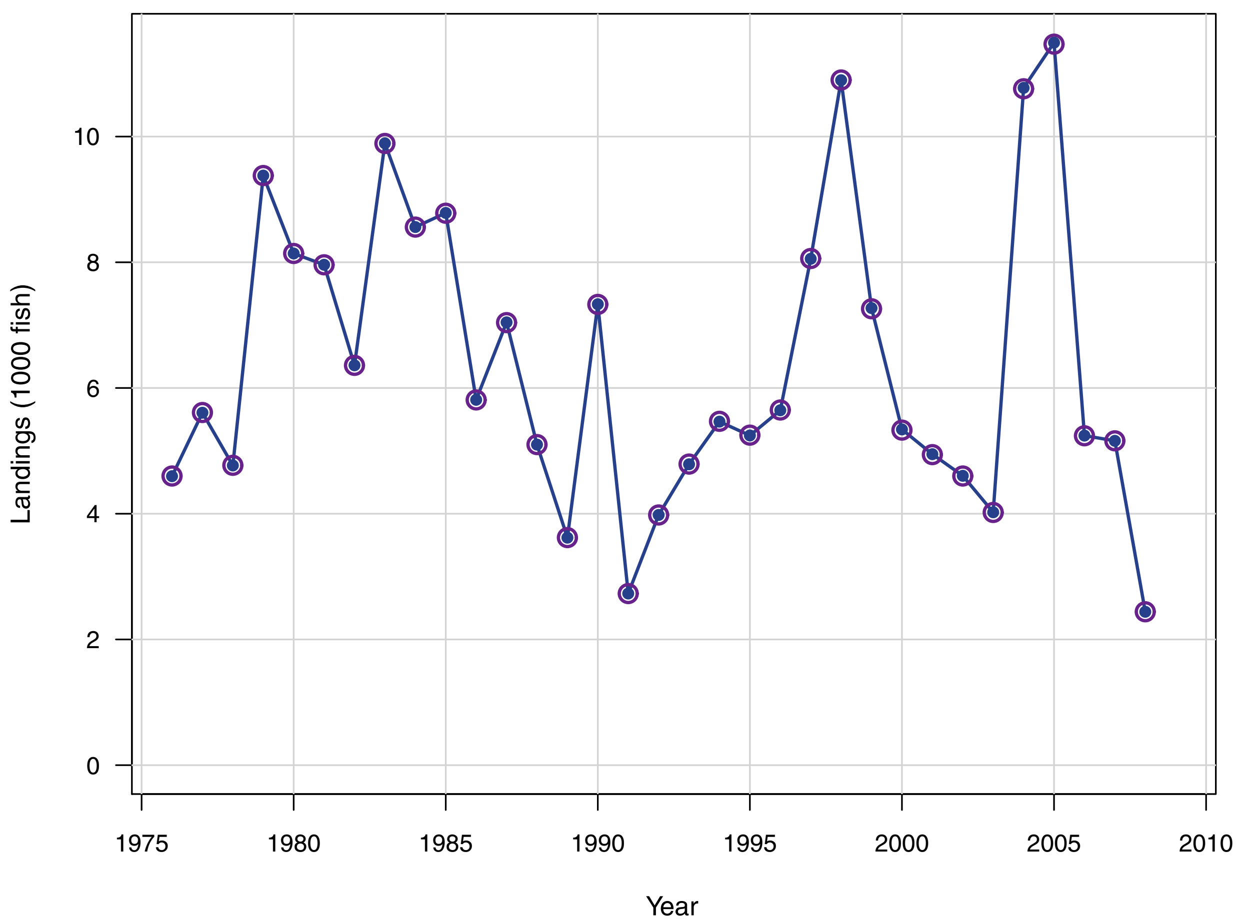


*Figure 6.15. Observed (open circles) and estimated (line, solid circles) general recreational landings (1000 fish). In years without observations, values were predicted using average F (see §III for details).*

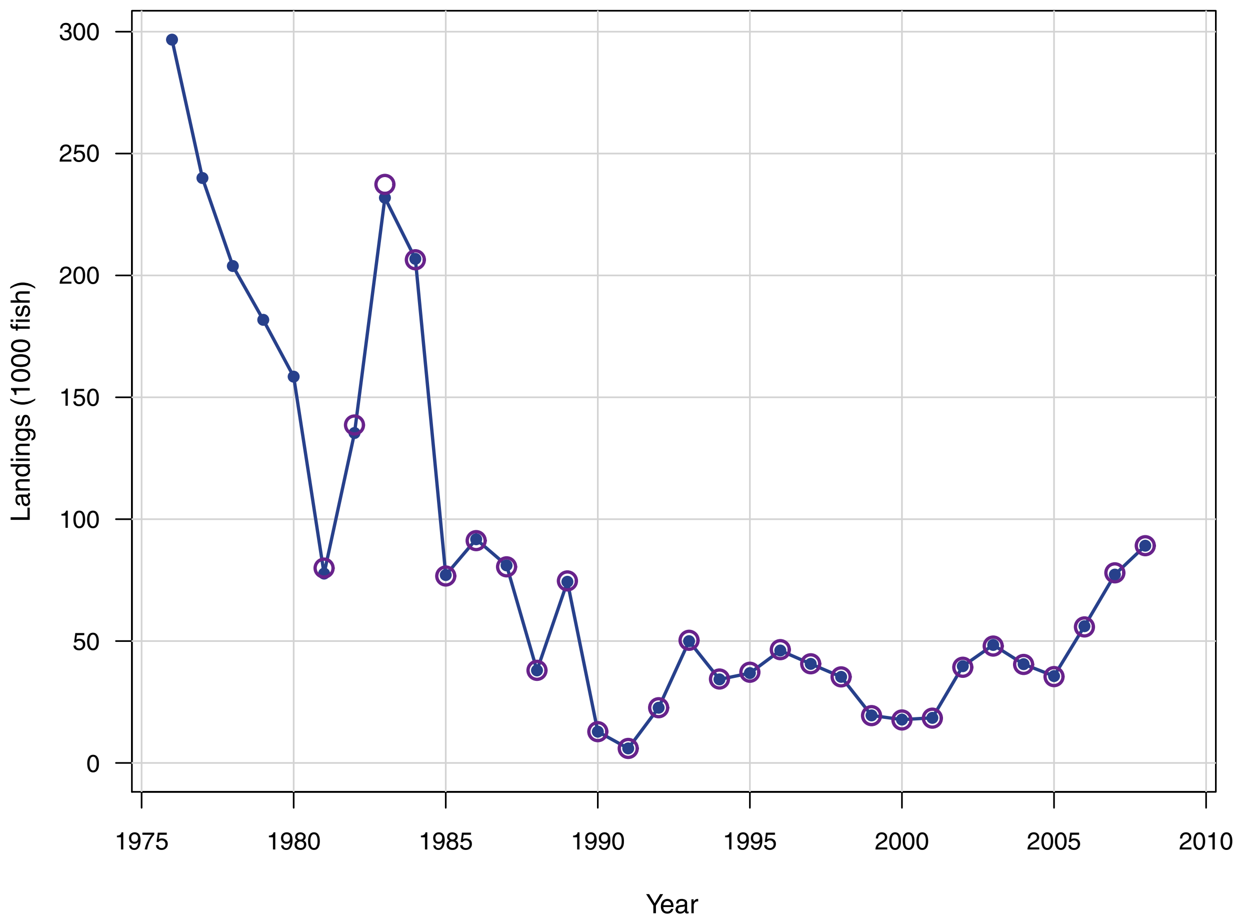


*Figure 6.16. Observed (open circles) and estimated (line, solid circles) commercial handline discard mortalities (1000 dead fish). In years without observations, values were predicted using average F (see §III for details).*

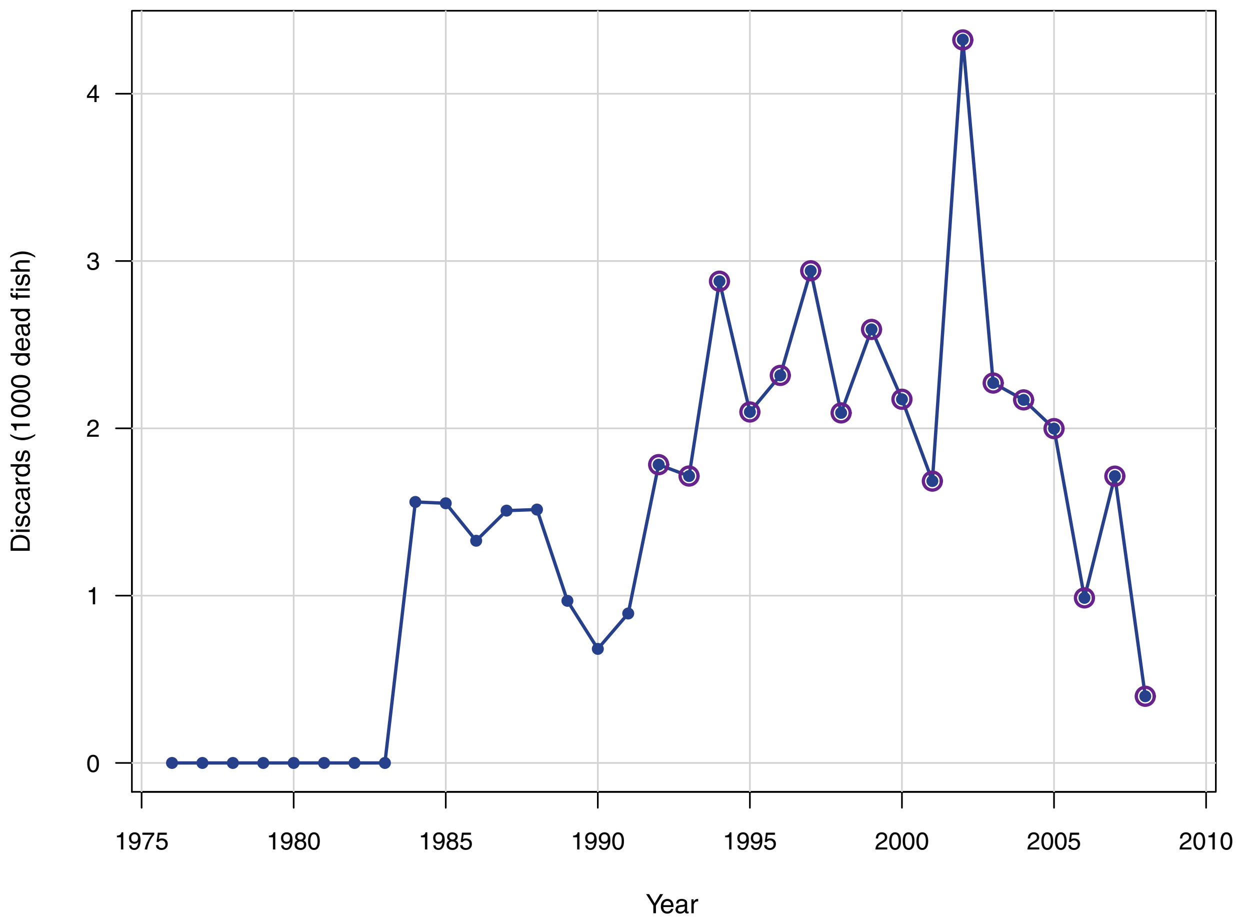


*Figure 6.17. Observed (open circles) and estimated (line, solid circles) headboat discard mortalities (1000 dead fish). In years without observations, values were predicted using average F (see §III for details).*

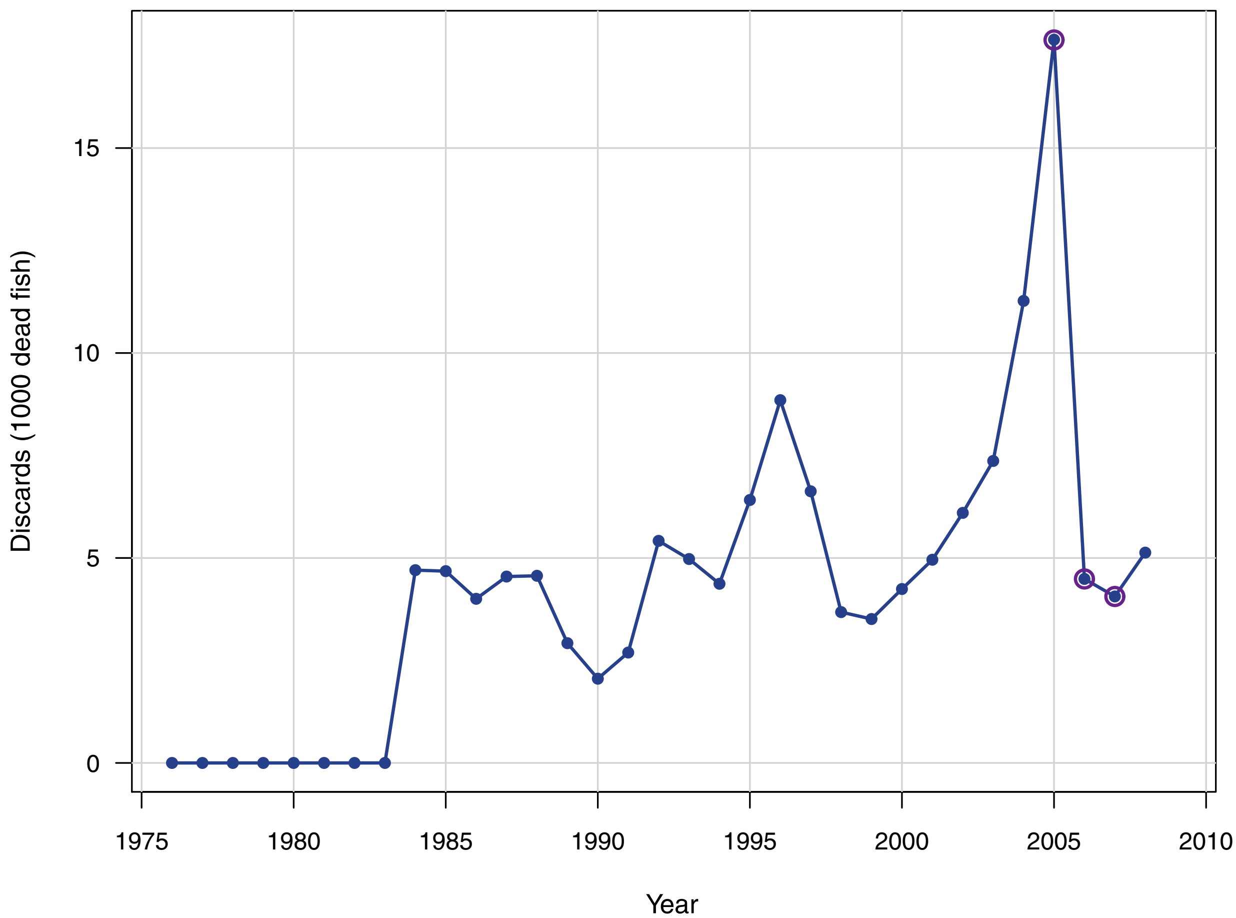


*Figure 6.18. Observed (open circles) and estimated (line, solid circles) general recreational discard mortalities (1000 dead fish).*

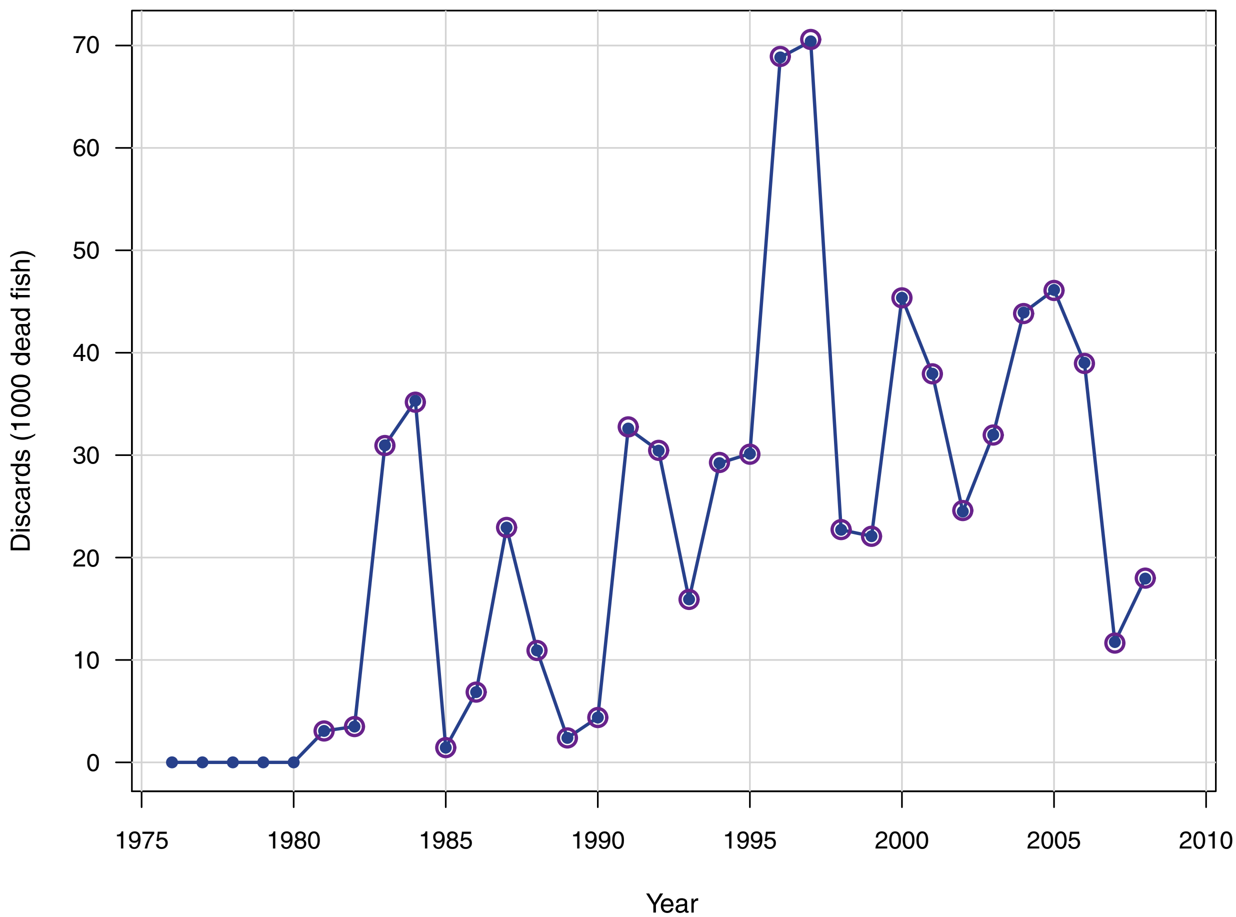


*Figure 6.19. Observed (open circles) and estimated (line, solid circles) index of abundance from MARMAP chevron trap.*

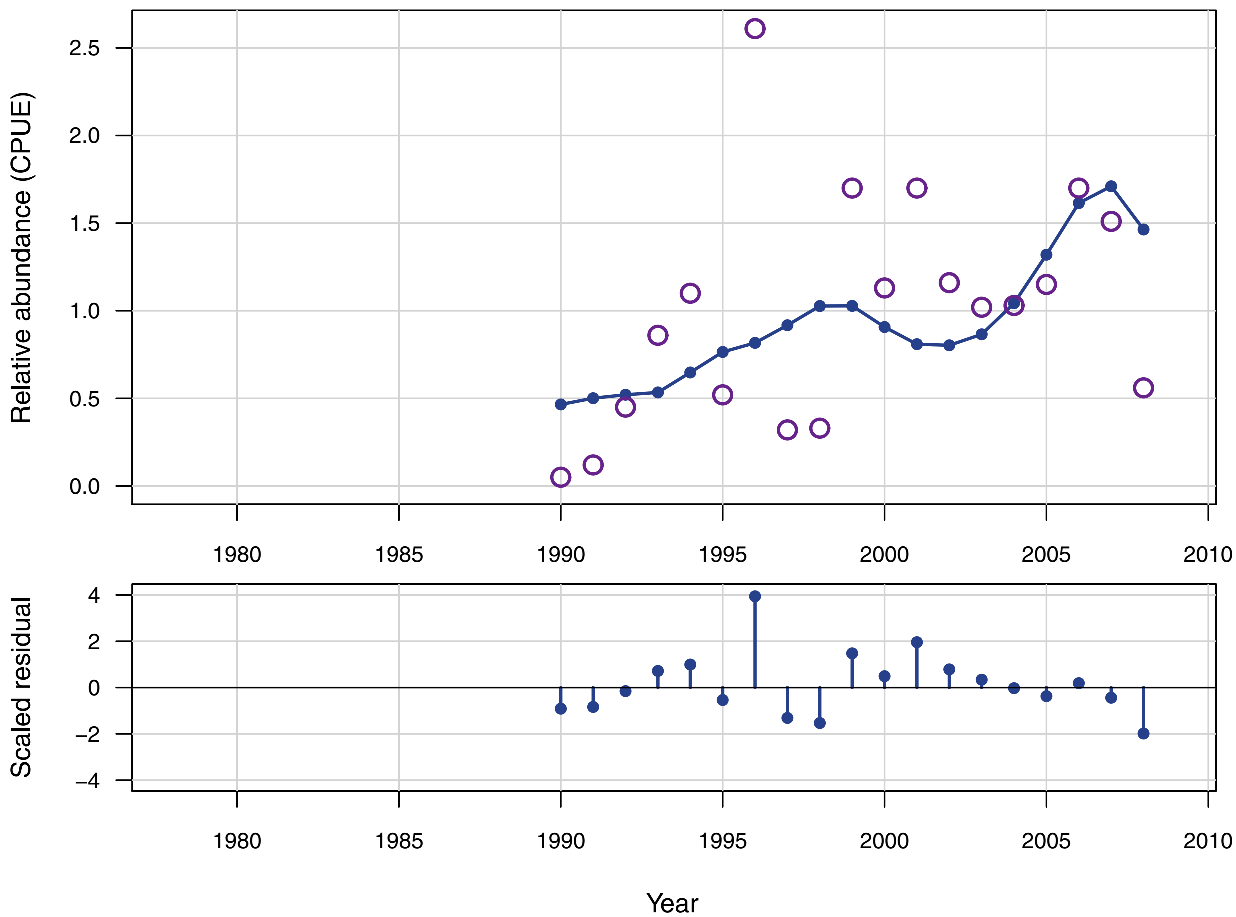


*Figure 6.20. Observed (open circles) and estimated (line, solid circles) index of abundance from commercial handline.*

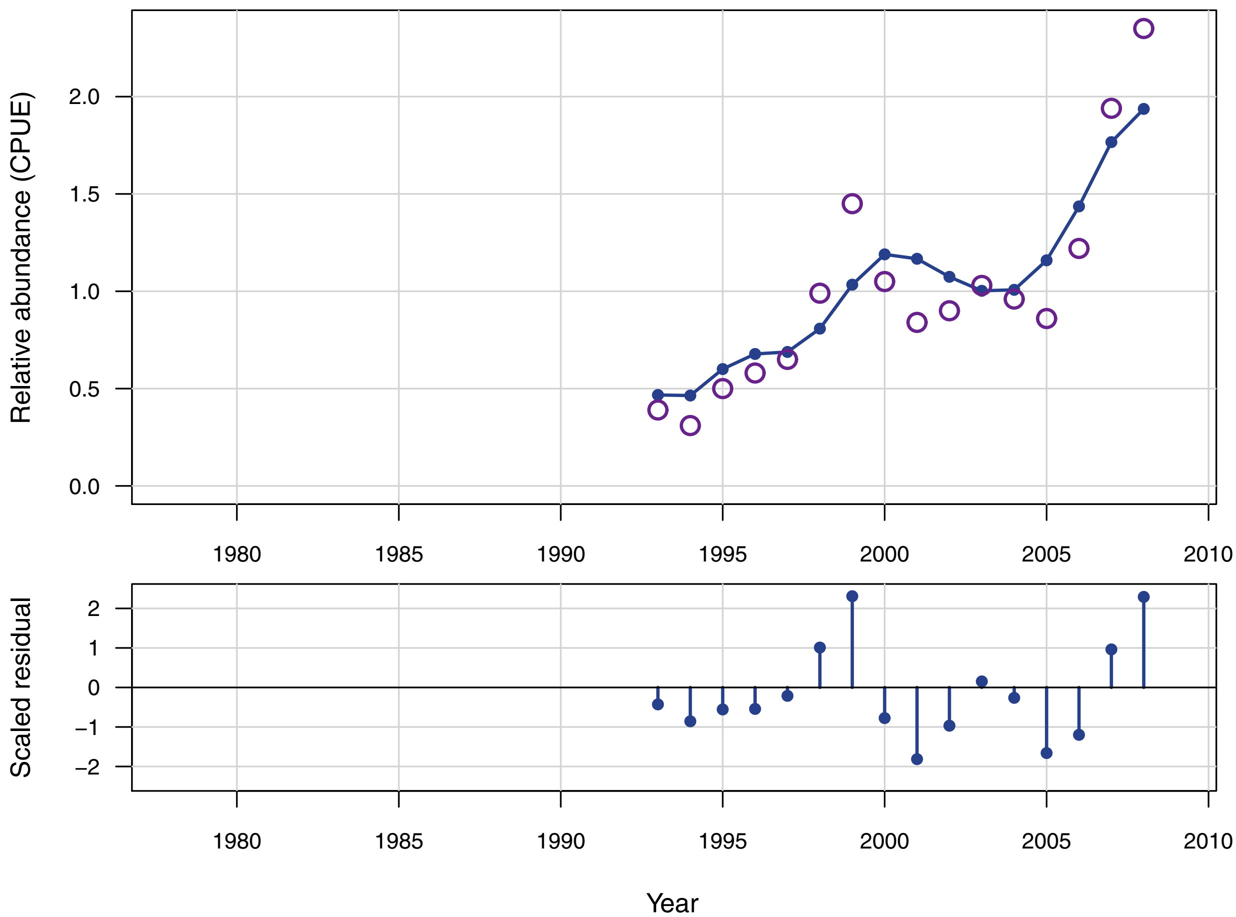


*Figure 6.21. Observed (open circles) and estimated (line, solid circles) index of abundance from headboat.*

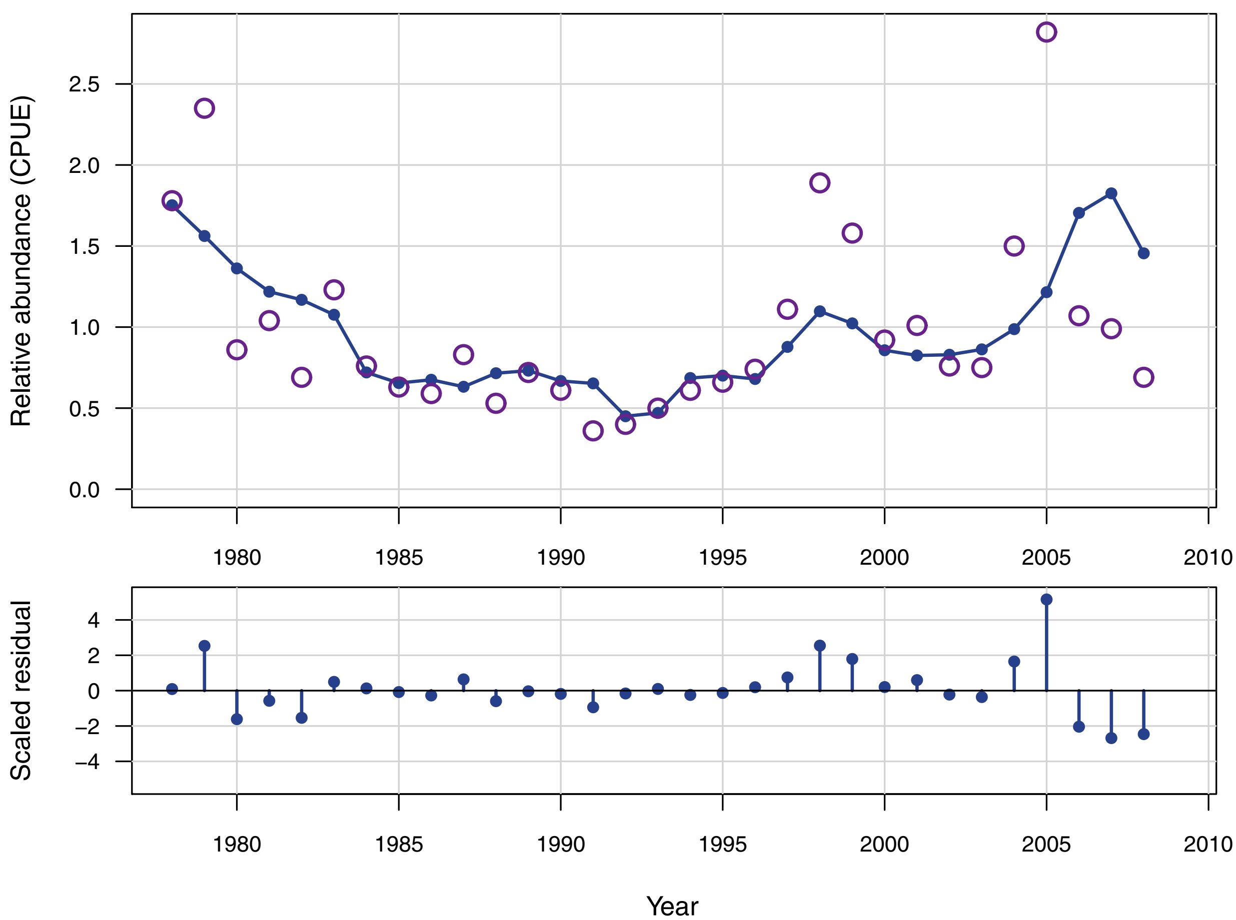


*Figure 6.22. Observed (open circles) and estimated (line, solid circles) abundance from general recreational (MRFSS).*

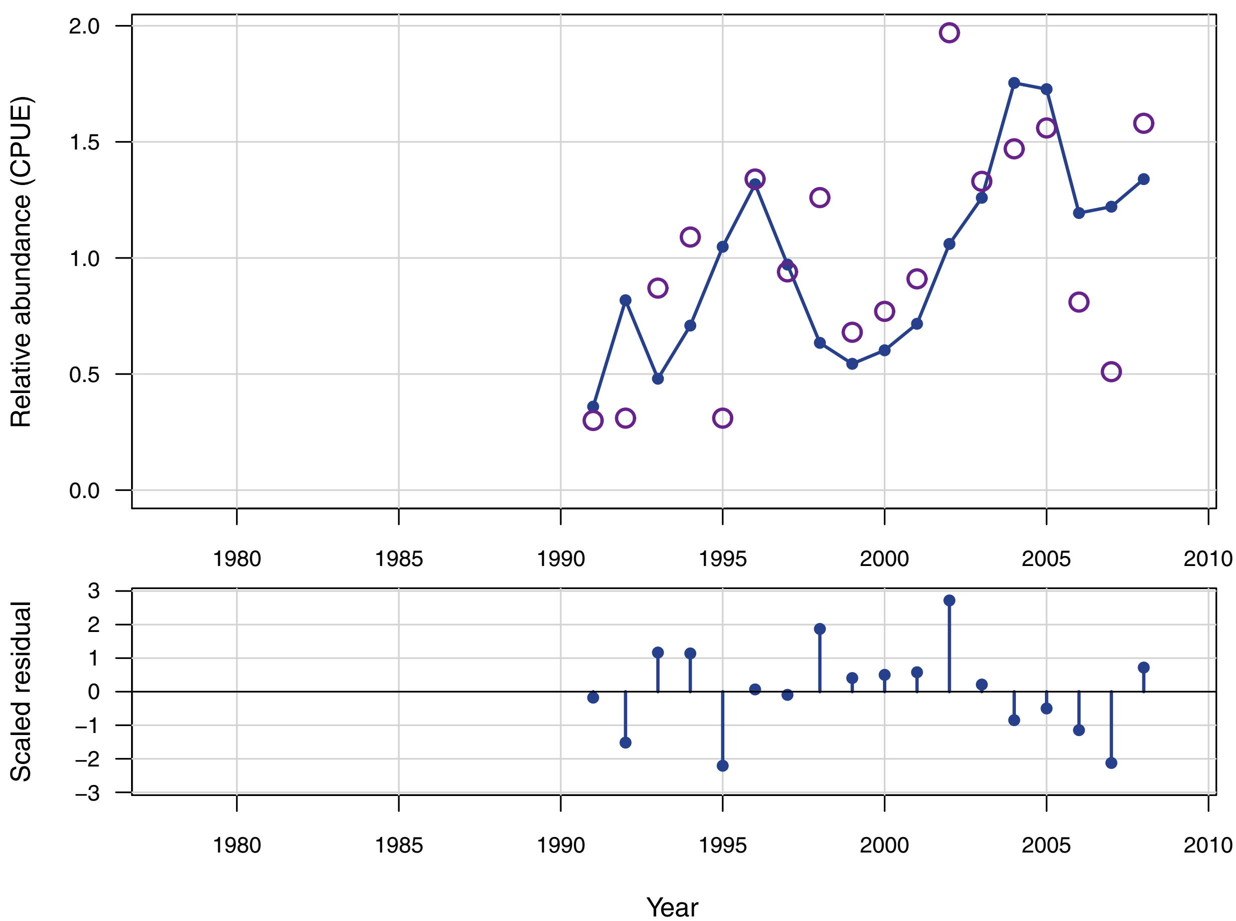


*Figure 6.23. Mean length at age (mm) and estimated 95% confidence interval of the population.*

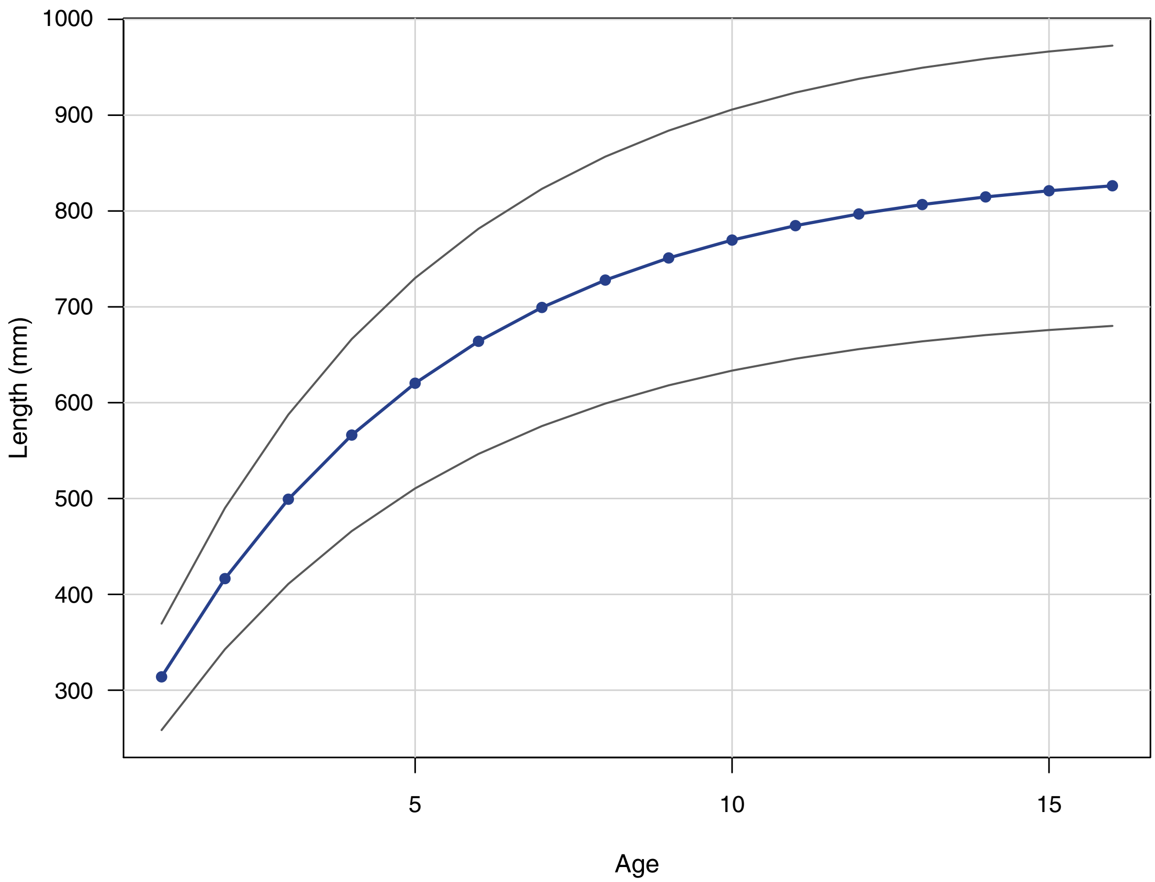


*Figure 6.24. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates $R_{MSY}$. Bottom panel: log recruitment residuals.*

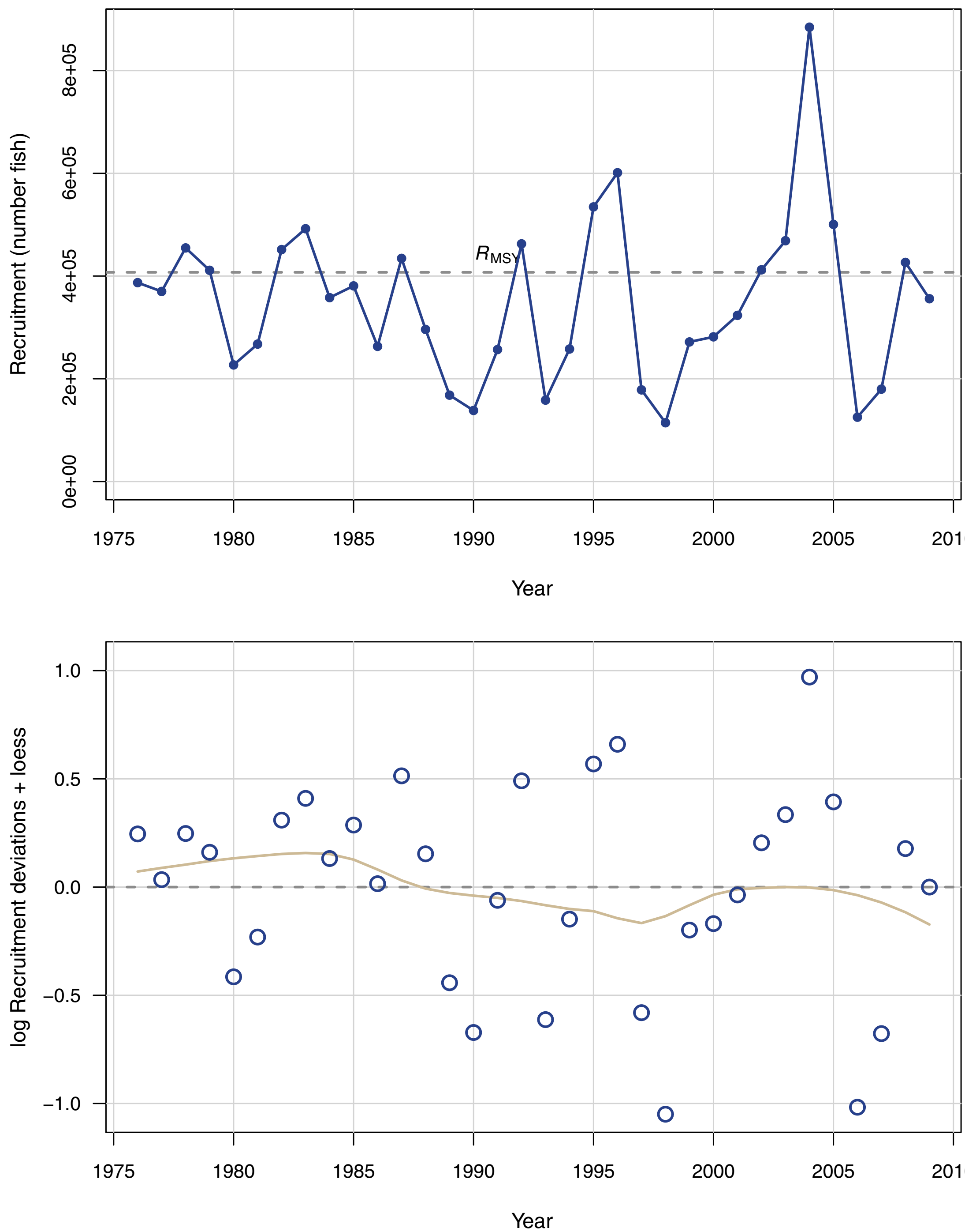
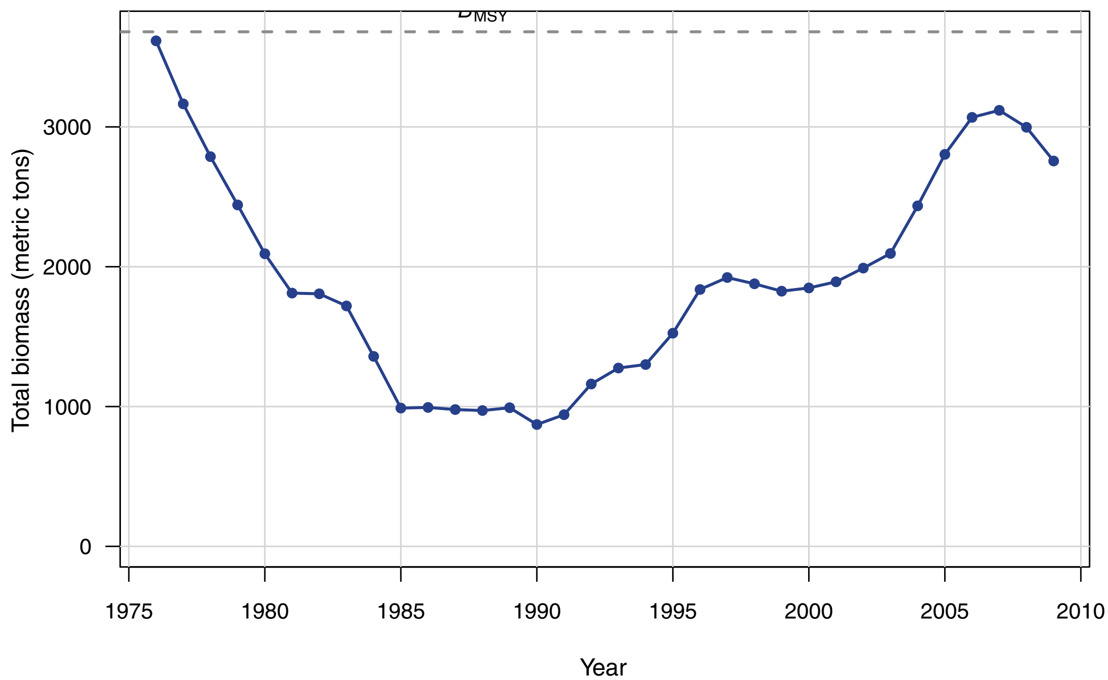


*Figure 6.25. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates $B_{MSY}$. Bottom panel: Estimated spawning biomass (total mature biomass) at time of peak spawning.*



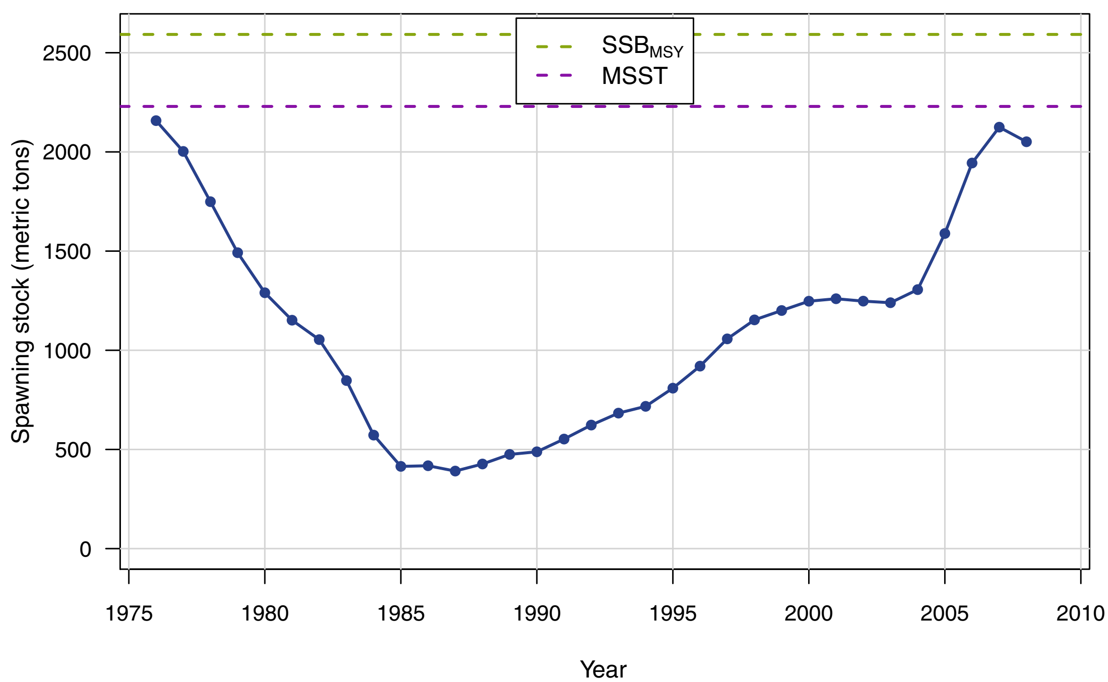



*Figure 6.26. Selectivities of the MARMAP chevron traps (fishery independent survey).*

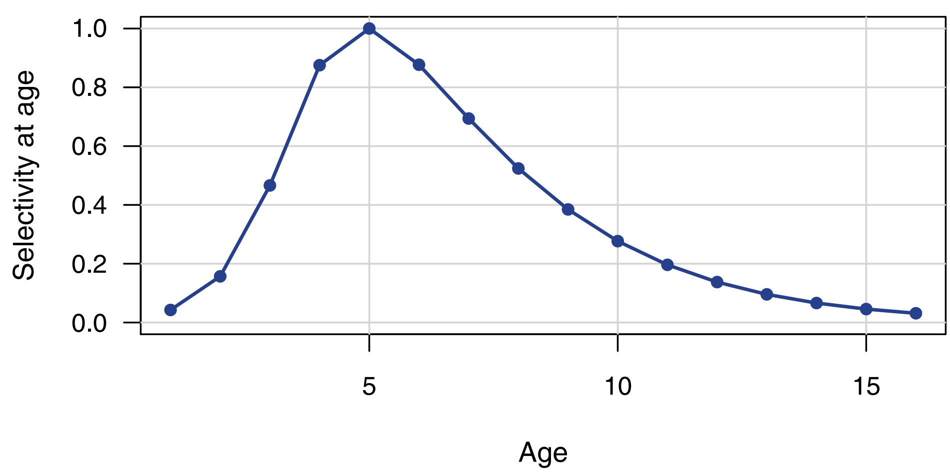


*Figure 6.27. Selectivities of commercial lines. Top panel: 1976–1991. Bottom panel: 1992–2008.*

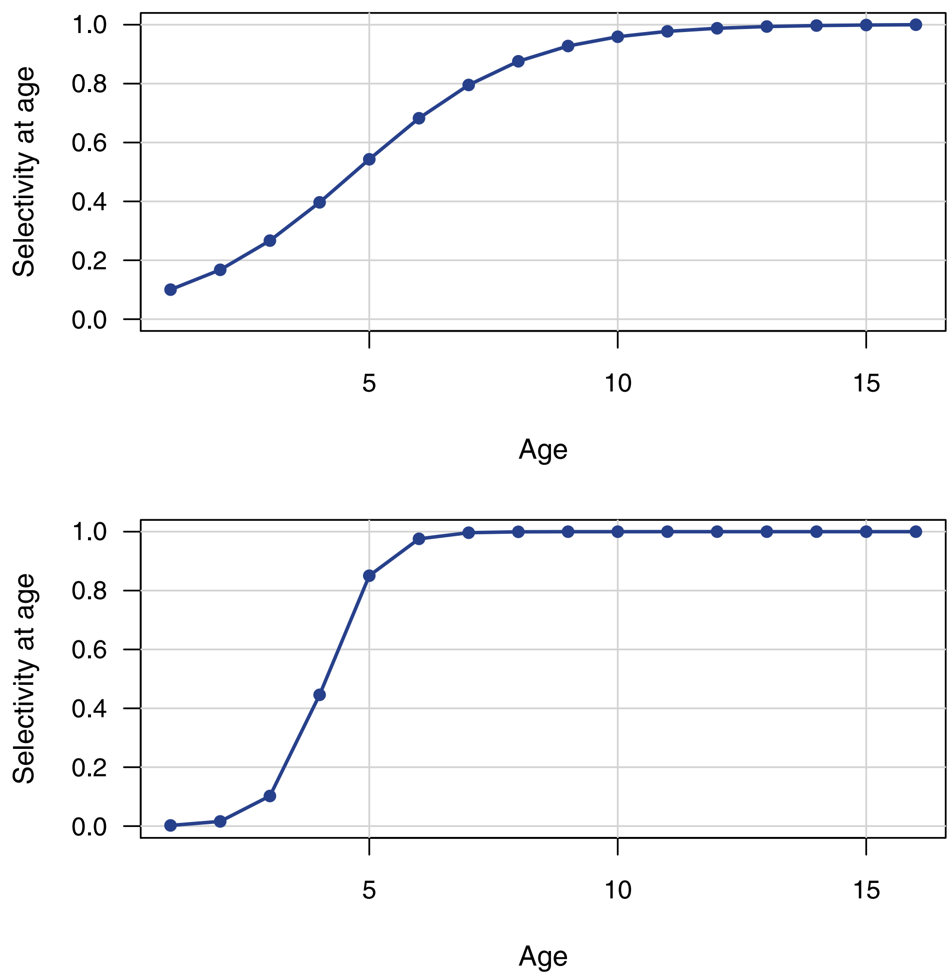


*Figure 6.28. Selectivities of commercial other gears. Top panel: 1976–1991. Bottom panel: 1992–2008.*

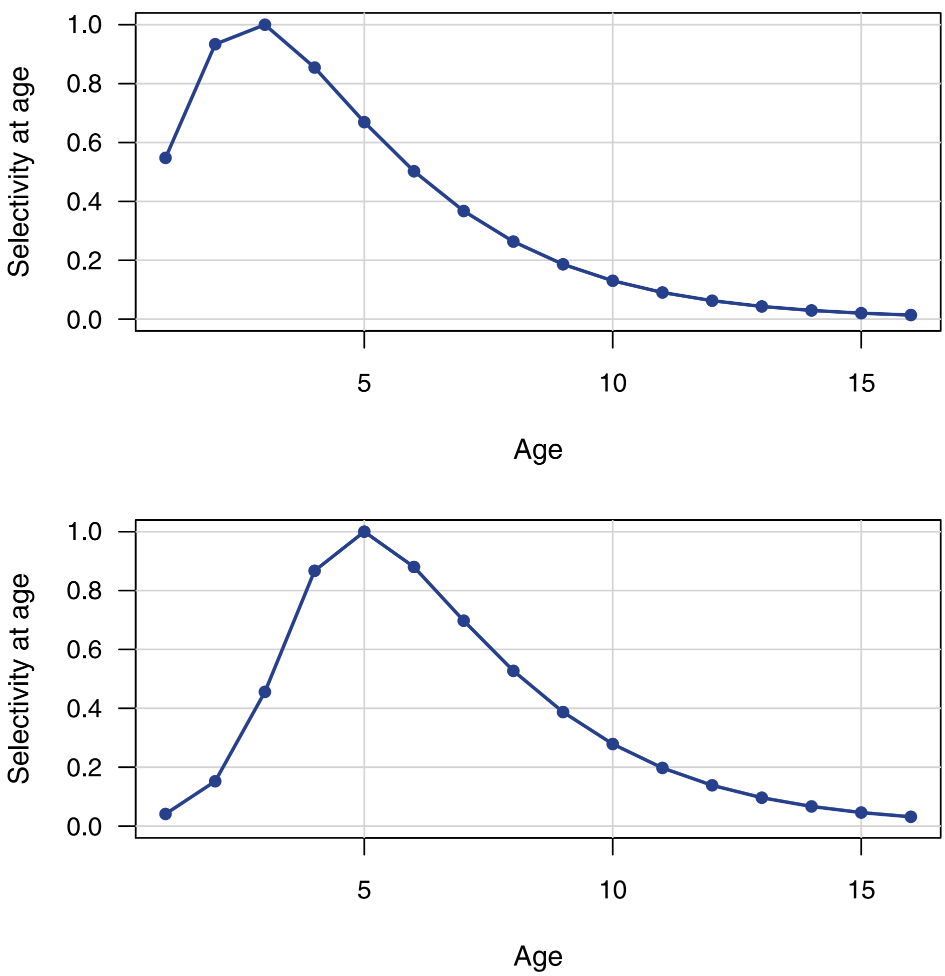


*Figure 6.29. Selectivities of the headboat fleet. Top panel: 1976–1983. Middle panel: 1984–1991. Bottom panel: 1992–2008.*

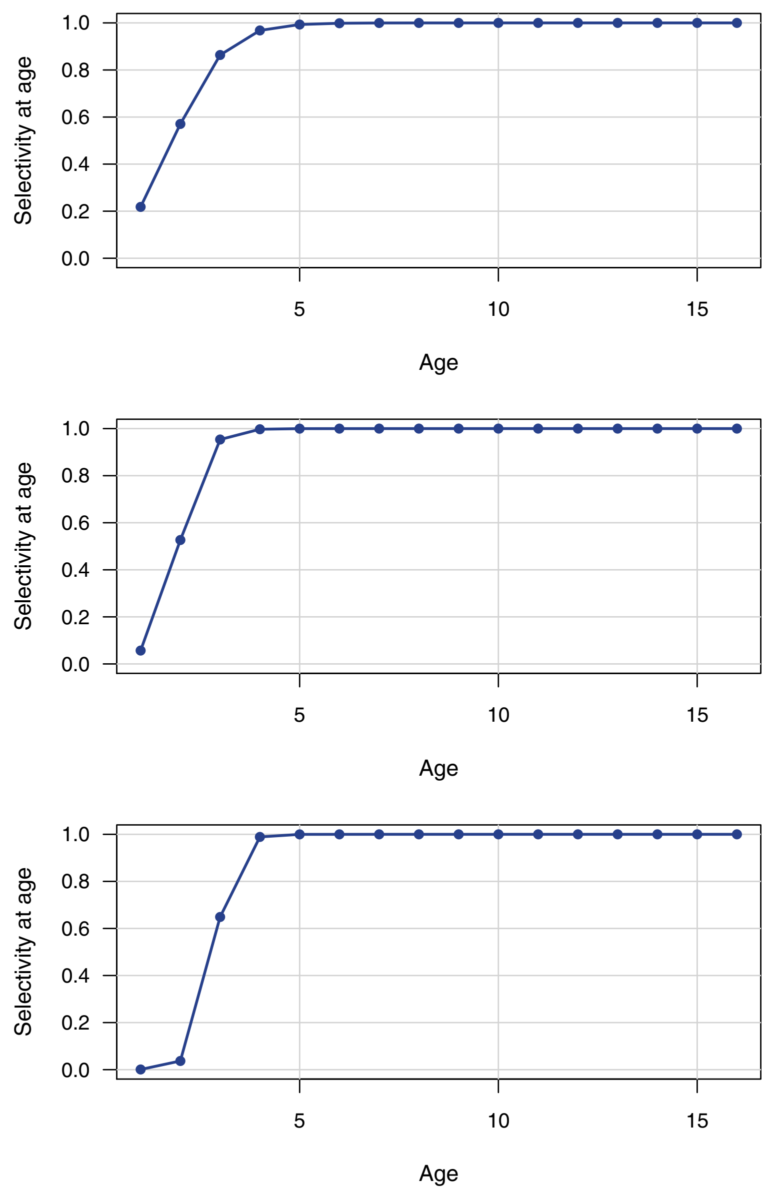


*Figure 6.30. Selectivities of the general recreational fleet. Top panel: 1976–1983. Middle panel: 1984–1991. Bottom panel: 1992–2008.*

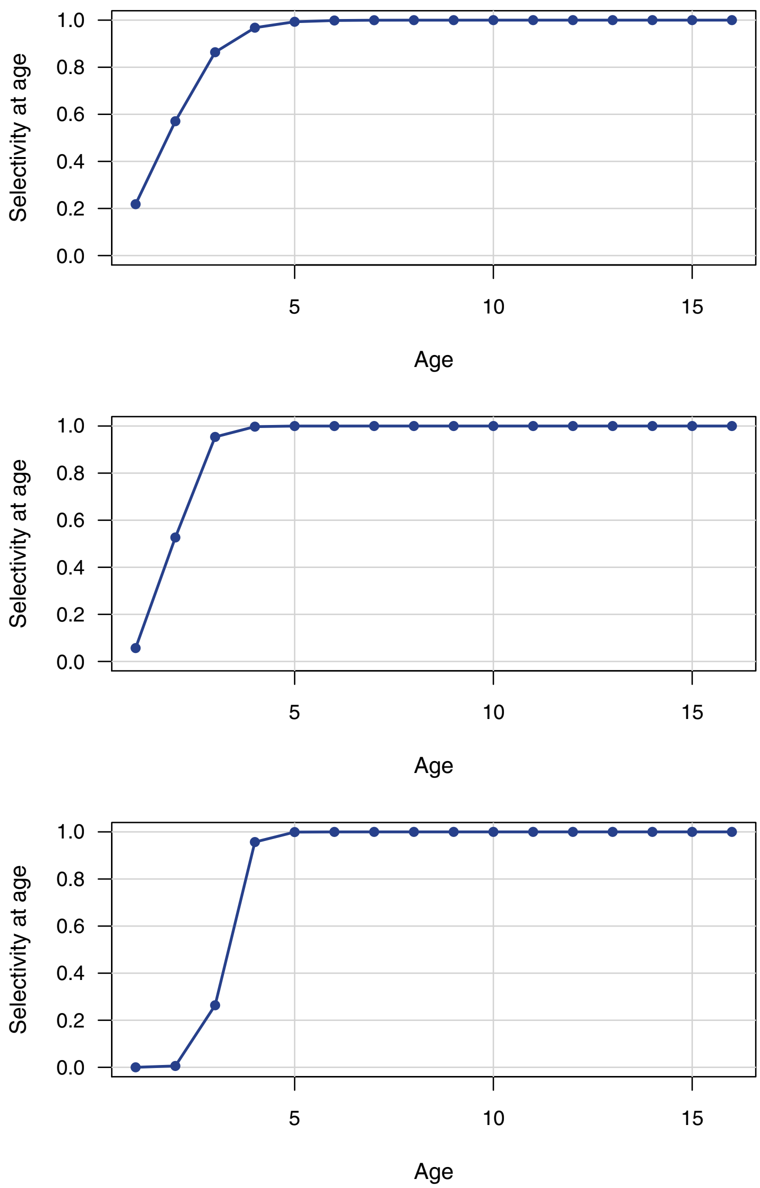


*Figure 6.31. Selectivities of discard mortalities for commercial lines, headboat, and recreational fleets. Top panel: Prior to 1992. Bottom panel: 1992–2008.*

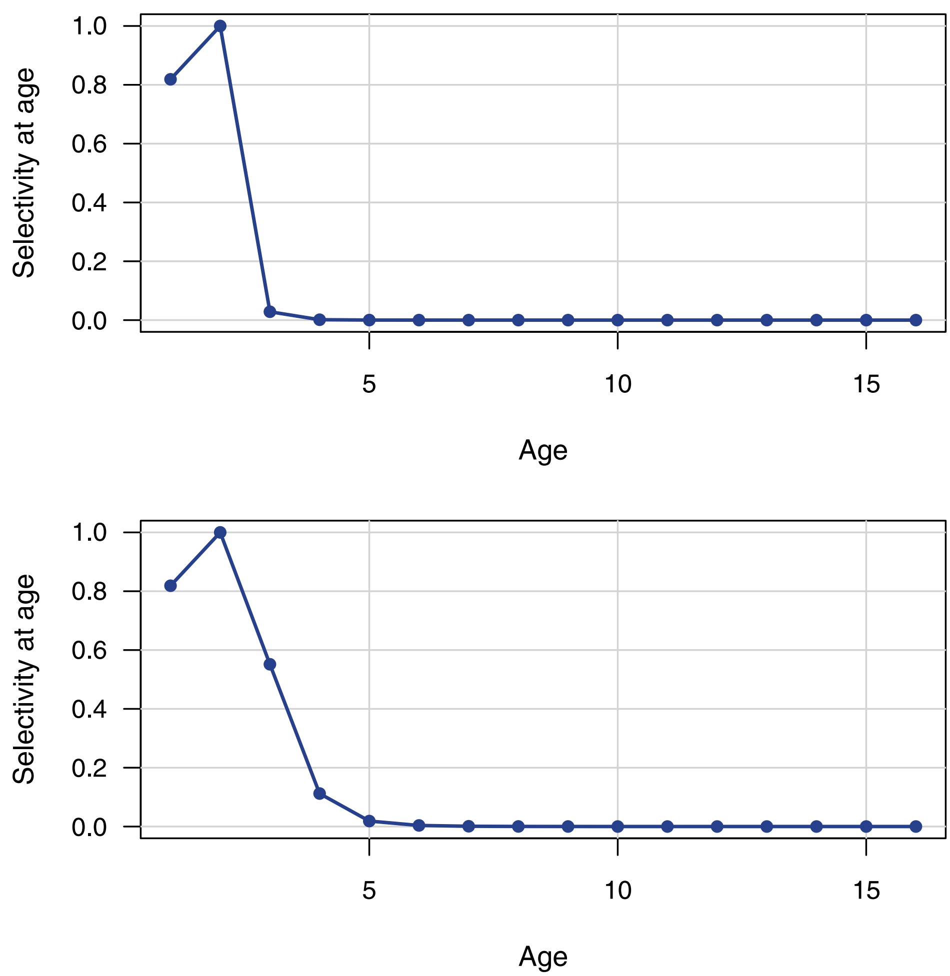


*Figure 6.32. Average selectivities from the terminal assessment year (2008, 20-inch limit), weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and base-run projections. Top panel: average selectivity applied to landings. Middle panel: average selectivity applied to discard mortalities. Bottom panel: total average selectivity.*

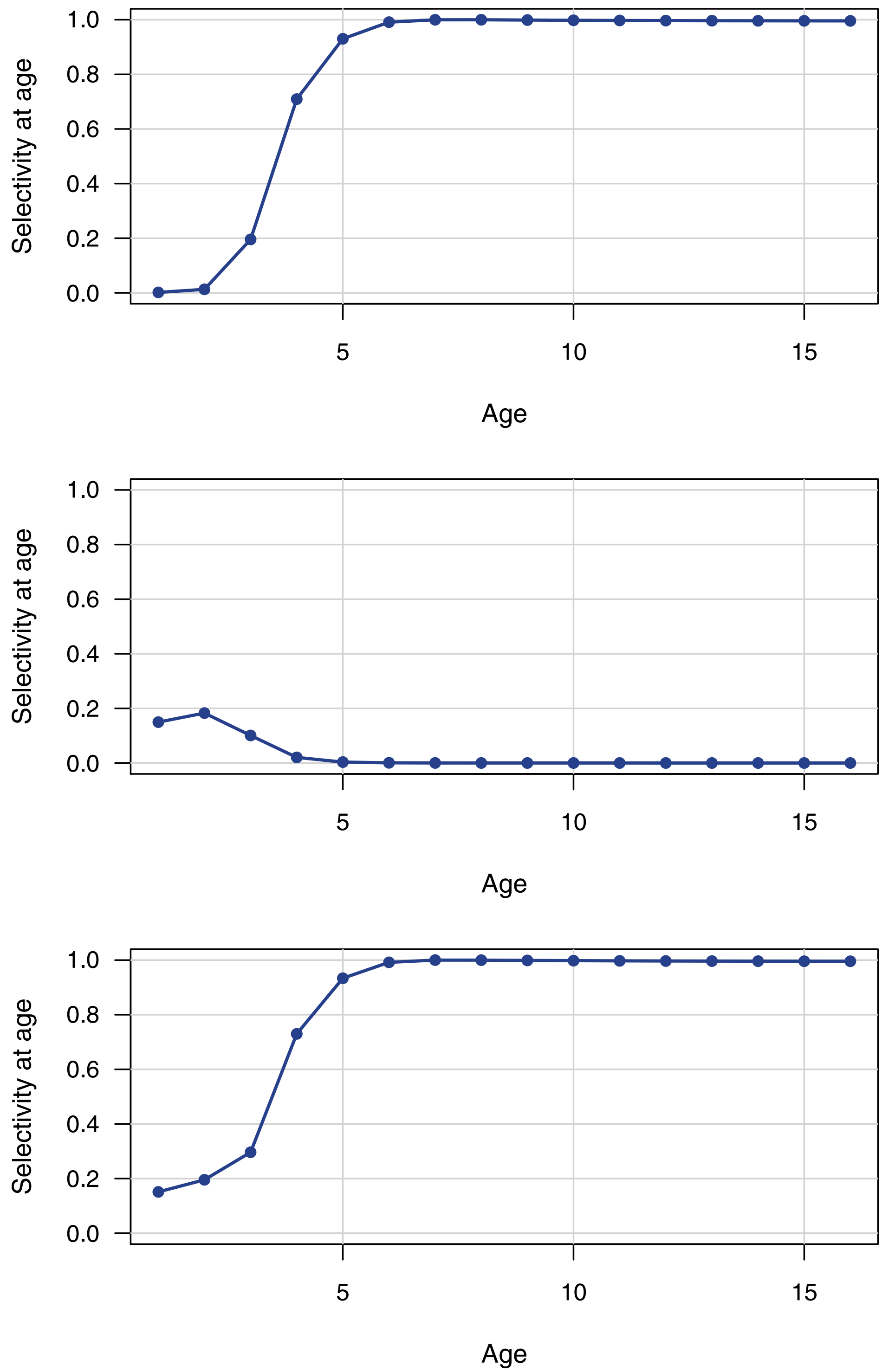


*Figure 6.33. Estimated fully selected fishing mortality rate (per year) by fishery. cl refers to commercial lines, co to commercial other, hb to headboat, rec to general recreational, cl.D to commercial discard mortalities, hb.D to headboat discard mortalities, and rec.D to general recreational discard mortalities.*

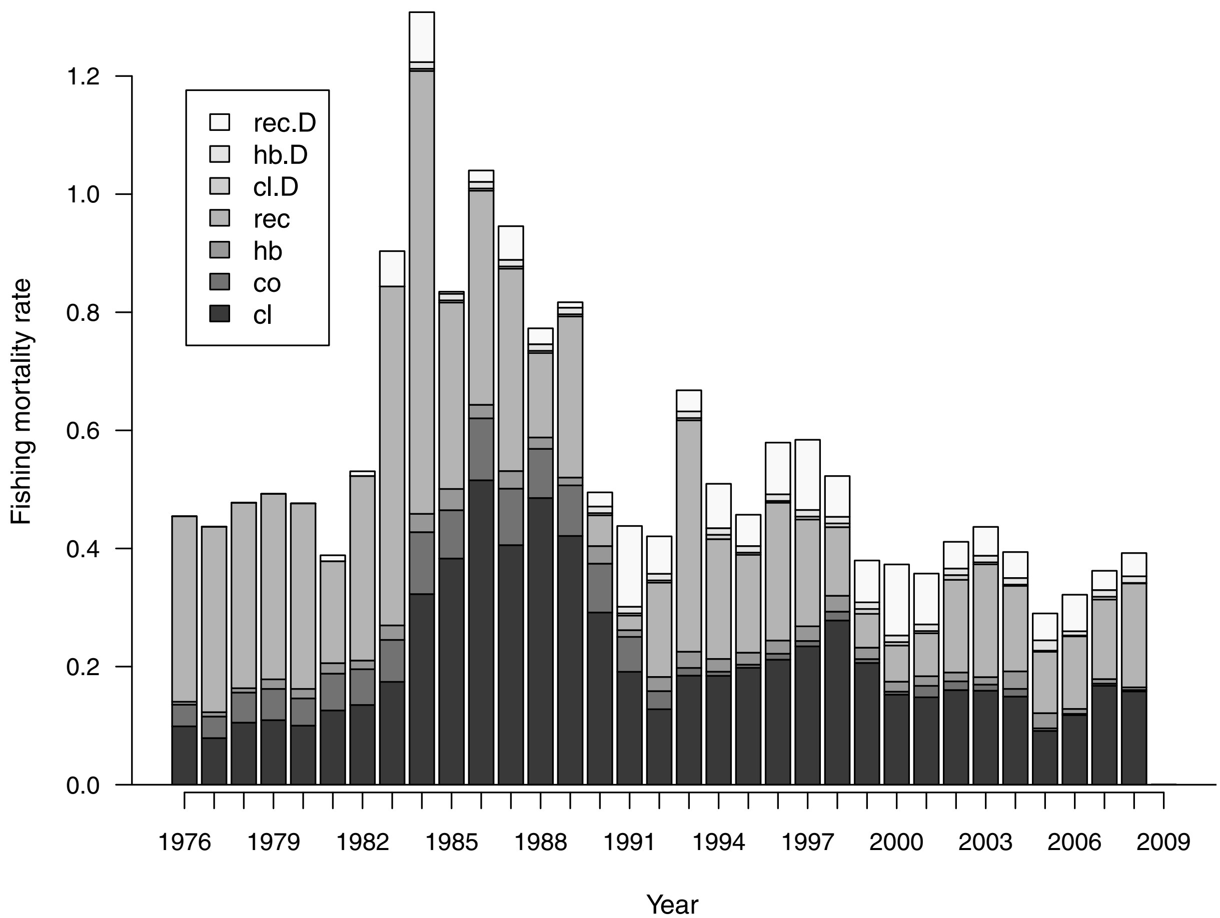
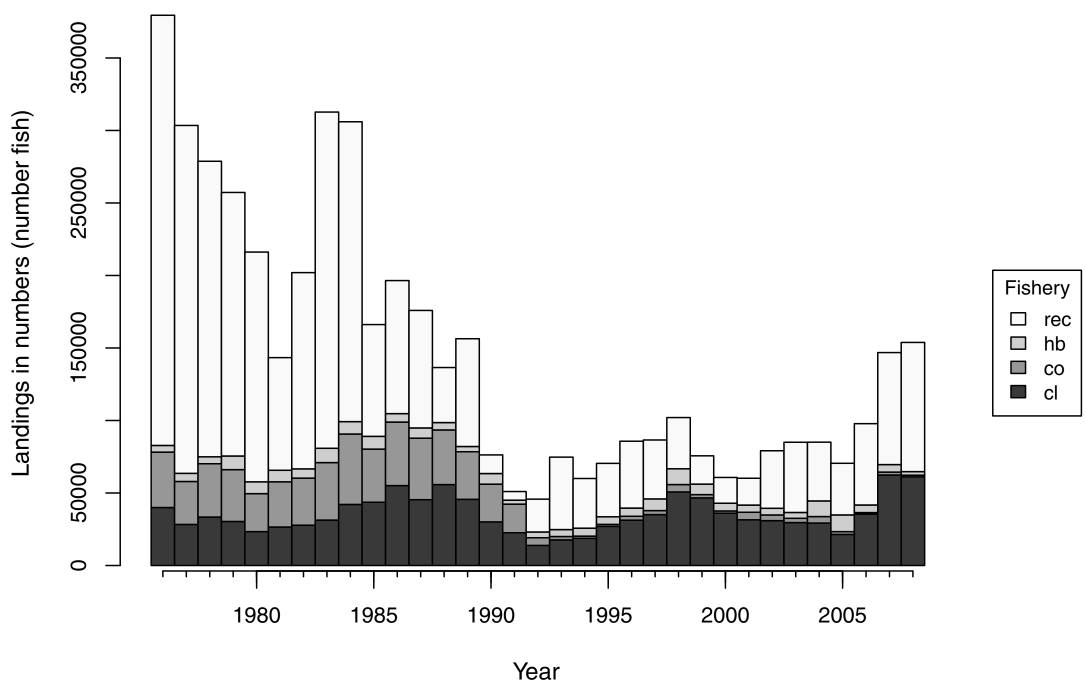


*Figure 6.34. Estimated landings in numbers by fishery from the Beaufort catch-age model. cl refers to commercial lines, co to commercial other, hb to headboat, rec to general recreational.*



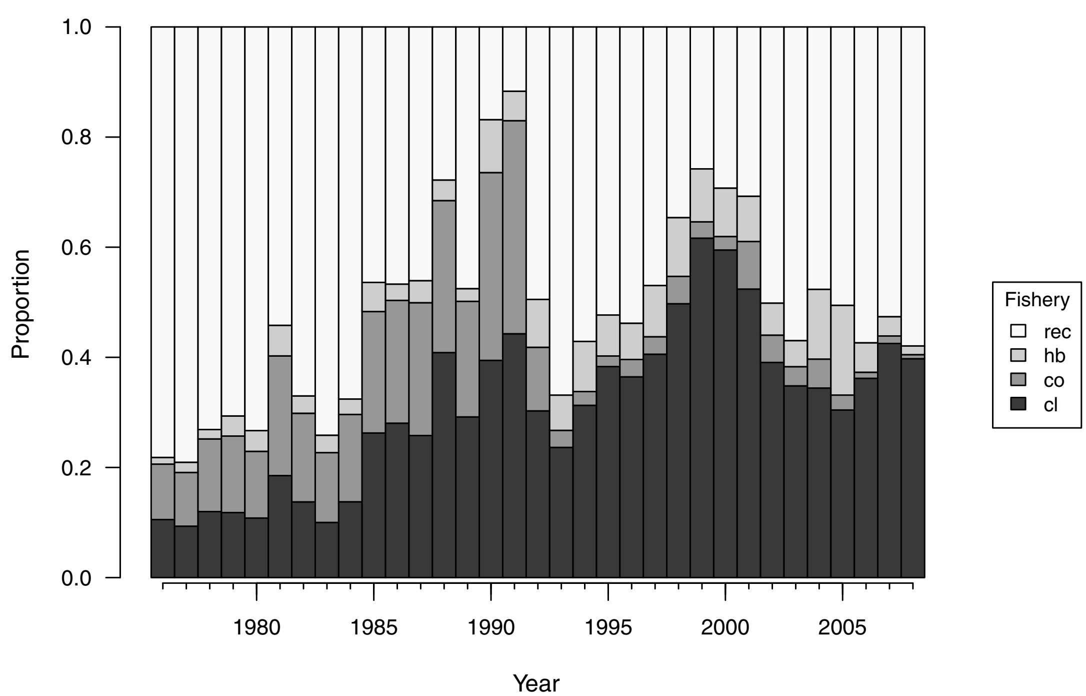



*Figure 6.35. Estimated landings in whole weight by fishery from the Beaufort catch-age model. cl refers to commercial lines, co to commercial other, hb to headboat, rec to general recreational.*

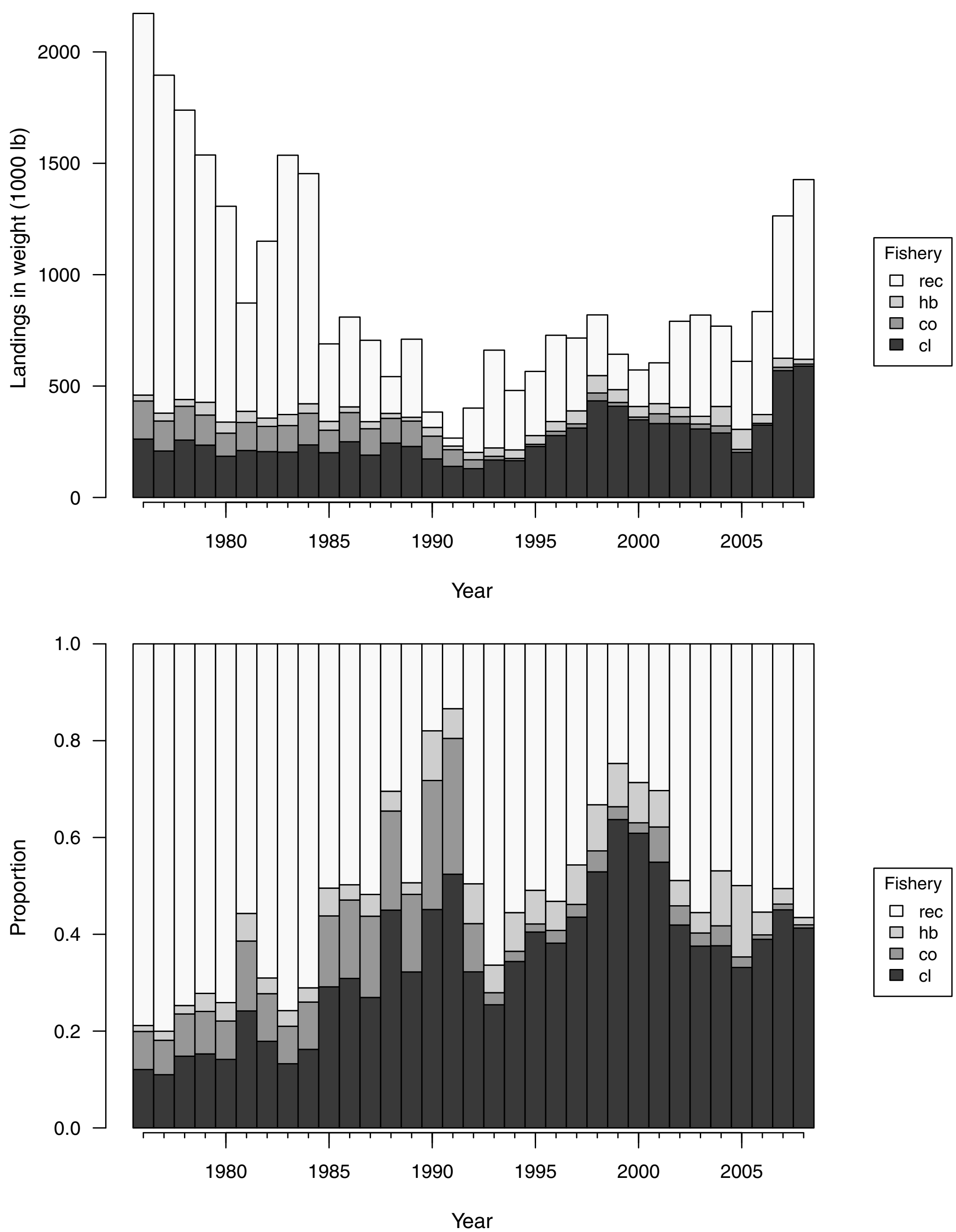


*Figure 6.36. Estimated discard mortalities by fishery from the Beaufort catch-age model. cl refers to commercial lines, hb to headboat, rec to general recreational.*

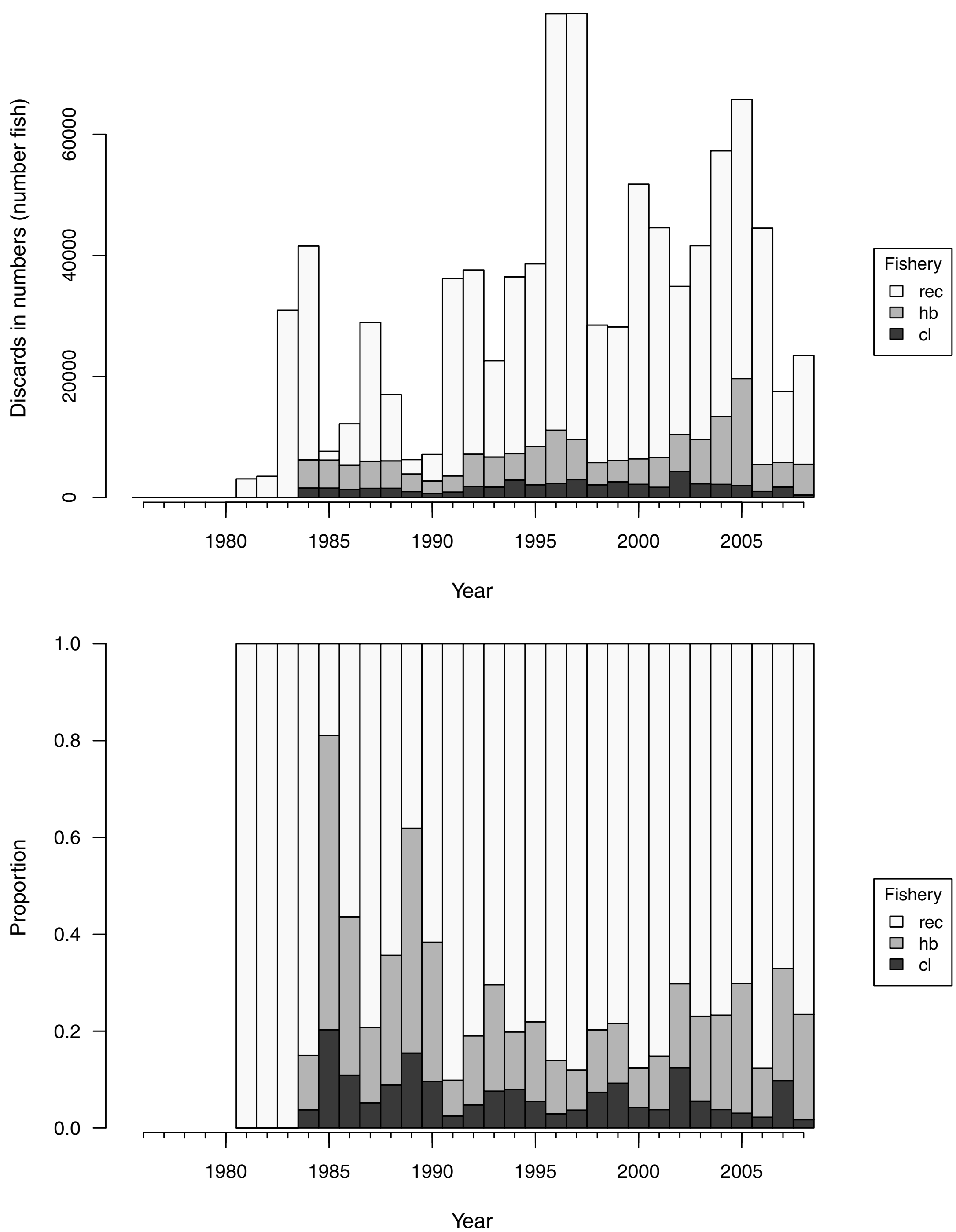


*Figure 6.37. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. Bottom panel: log of recruits (number age-1 fish) per spawner (total mature biomass) as a function of spawners. Years on each panel indicate year of recruitment generated from spawning biomass one year prior.*

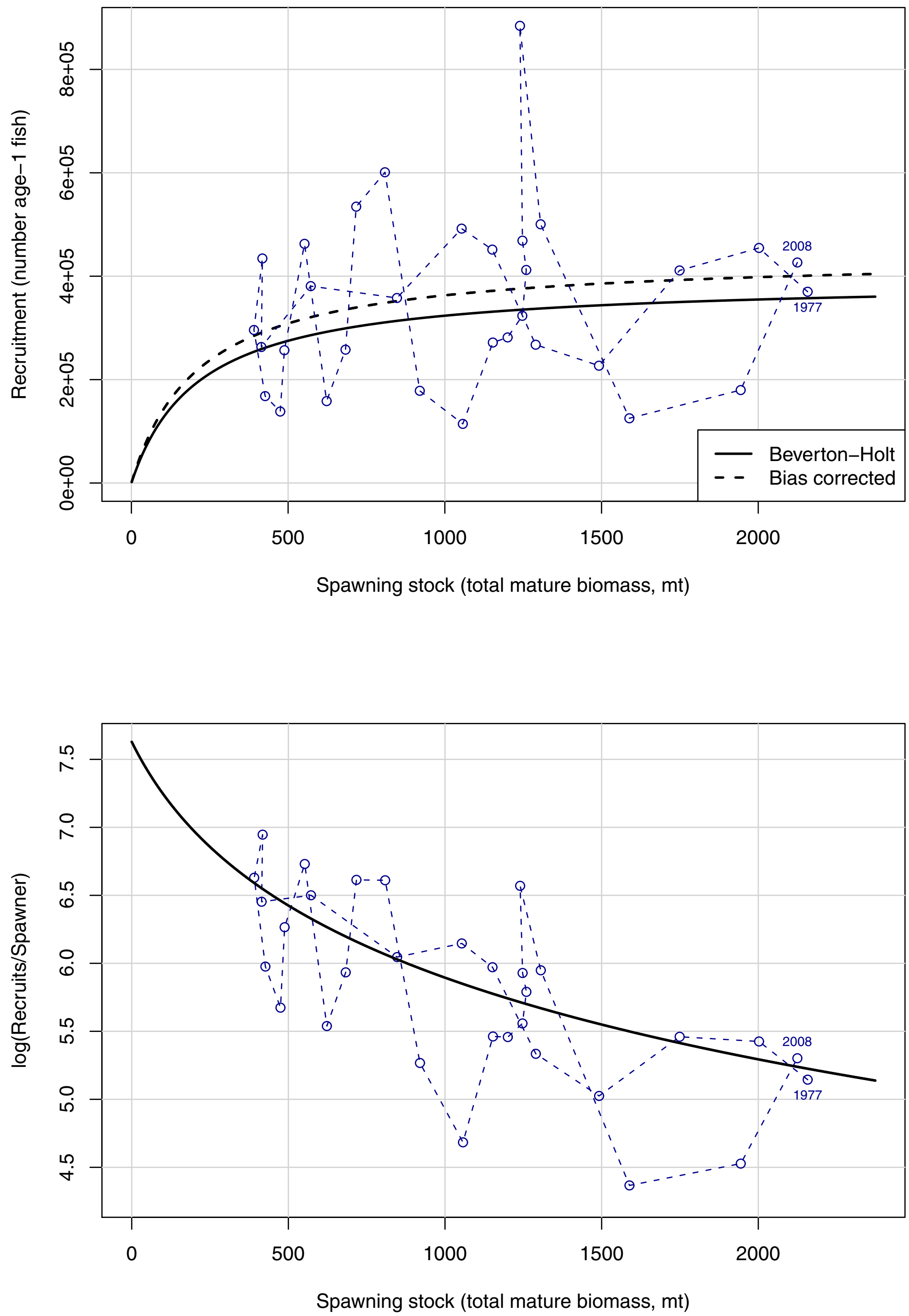


*Figure 6.38. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model.*

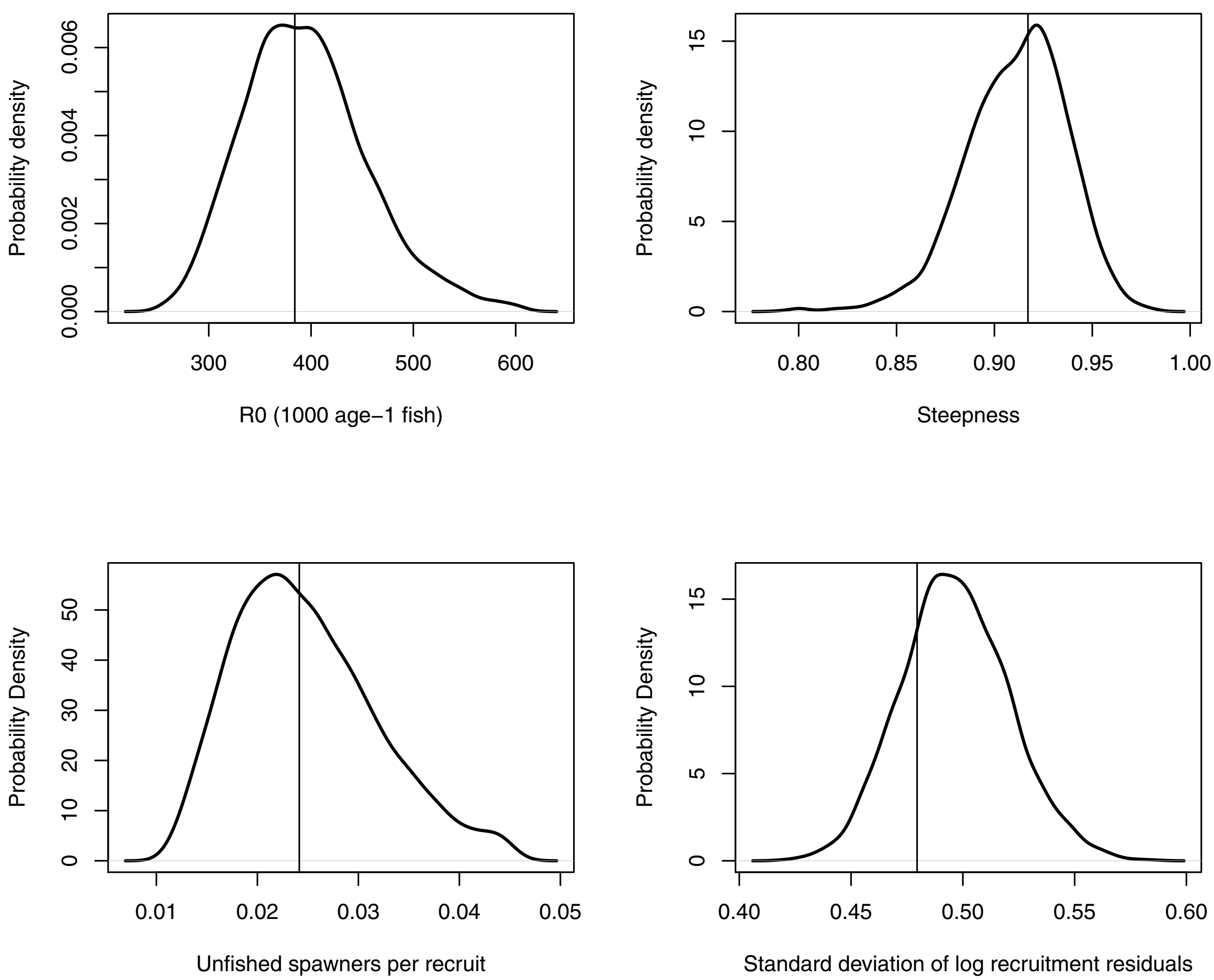


*Figure 6.39. Estimated time series of static spawning potential ratio, the annual equilibrium spawners per recruit relative to that at the unfished level.*

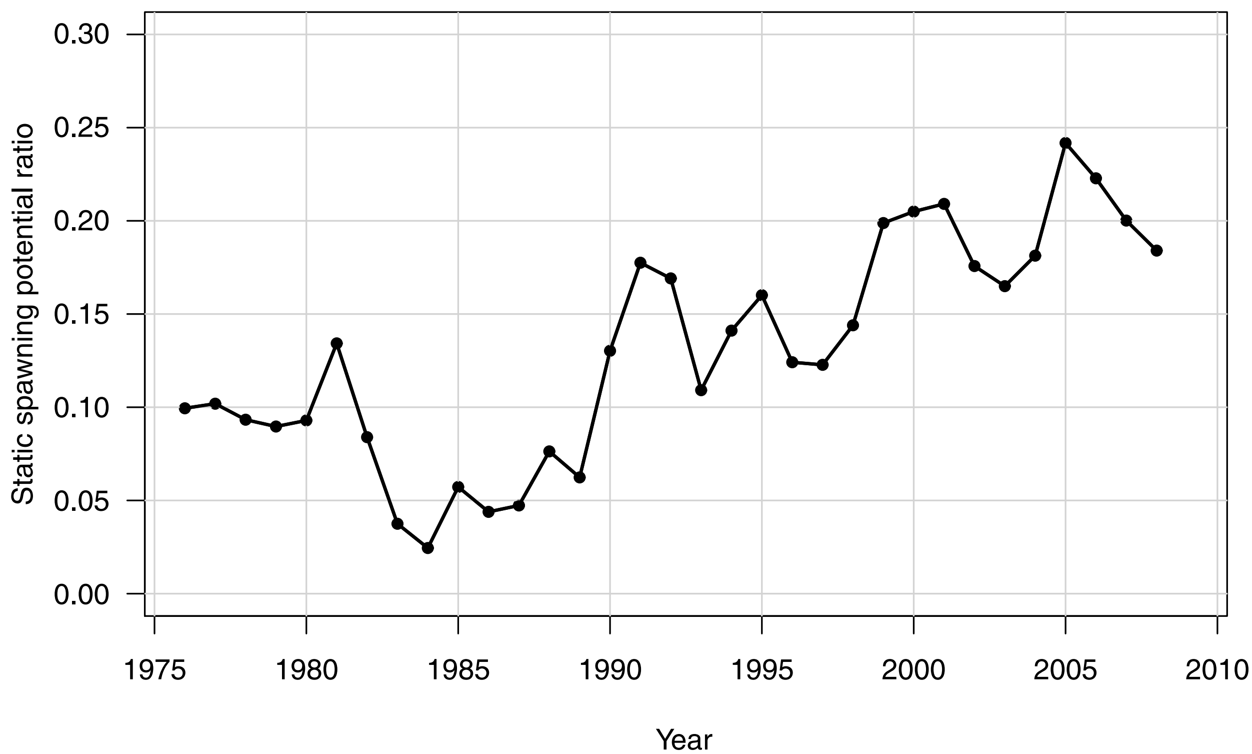


*Figure 6.40. Top panel: yield per recruit. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the y% levels provide $F_{y\%}$. Both curves are based on average selectivity from the end of the assessment period.*

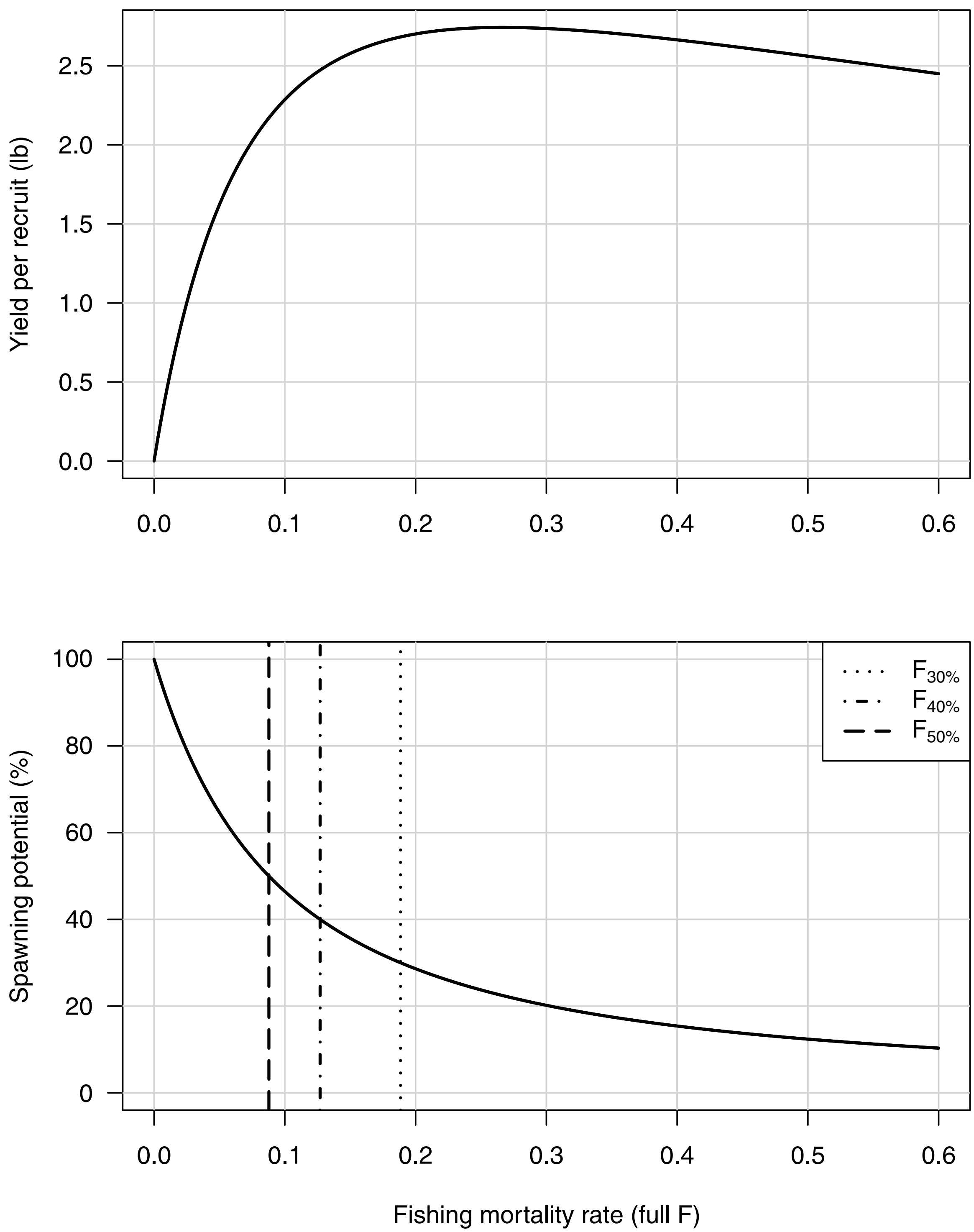


*Figure 6.41. Top panel: equilibrium landings. The peak occurs where fishing rate is* $F_{MSY} = 0.22$ *and equilibrium landings are* MSY = 1110 *(1000 lb). Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.*

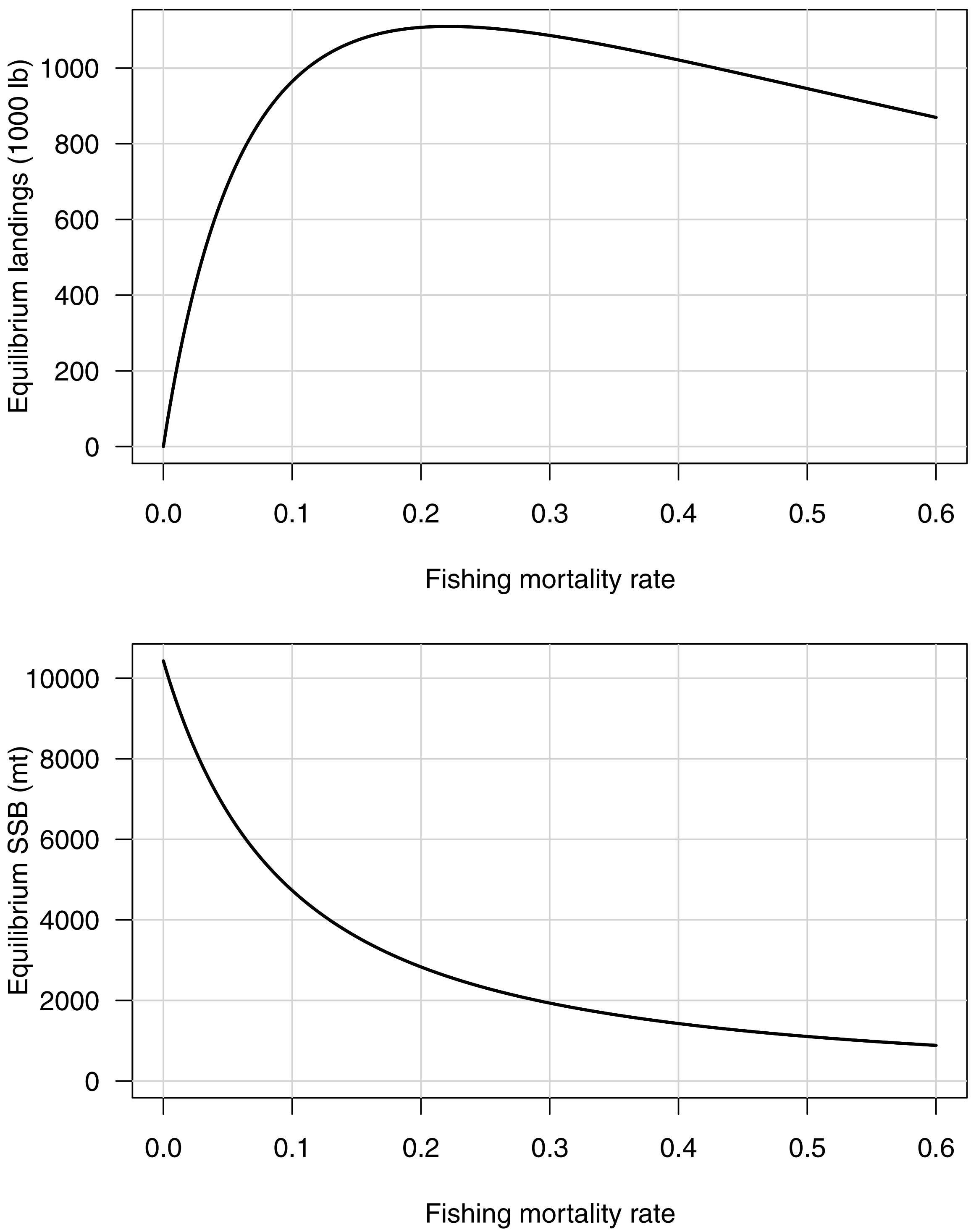


*Figure 6.42. Top panel: equilibrium landings as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is* $B_{\mathrm{MSY}} = 3680$ *mt and equilibrium landings are* MSY = 1110 *(1000 lb). Bottom panel: equilibrium discard mortality as a function of equilibrium biomass.*

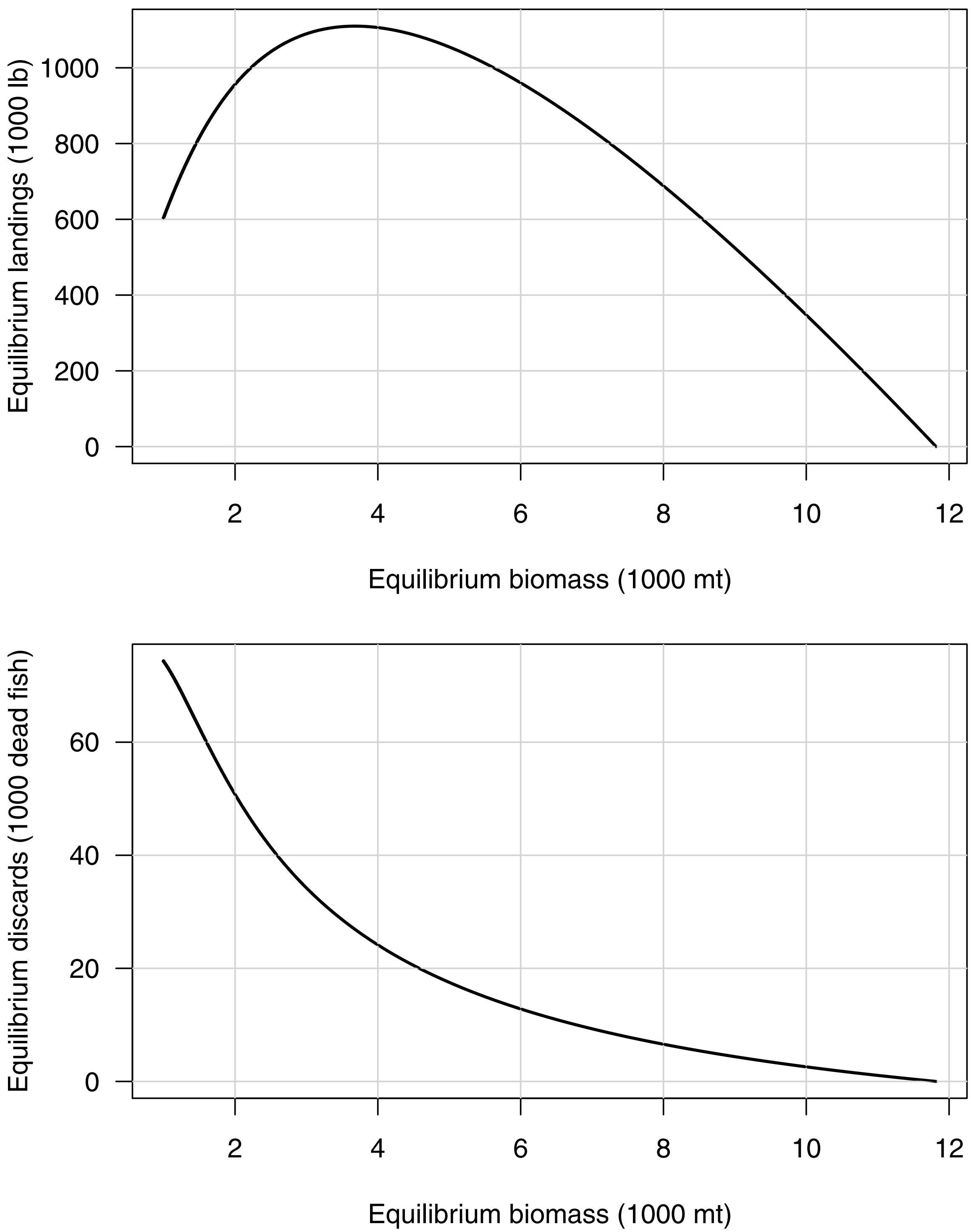


*Figure 6.43. Probability densities of* MSY*-related benchmarks from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.*

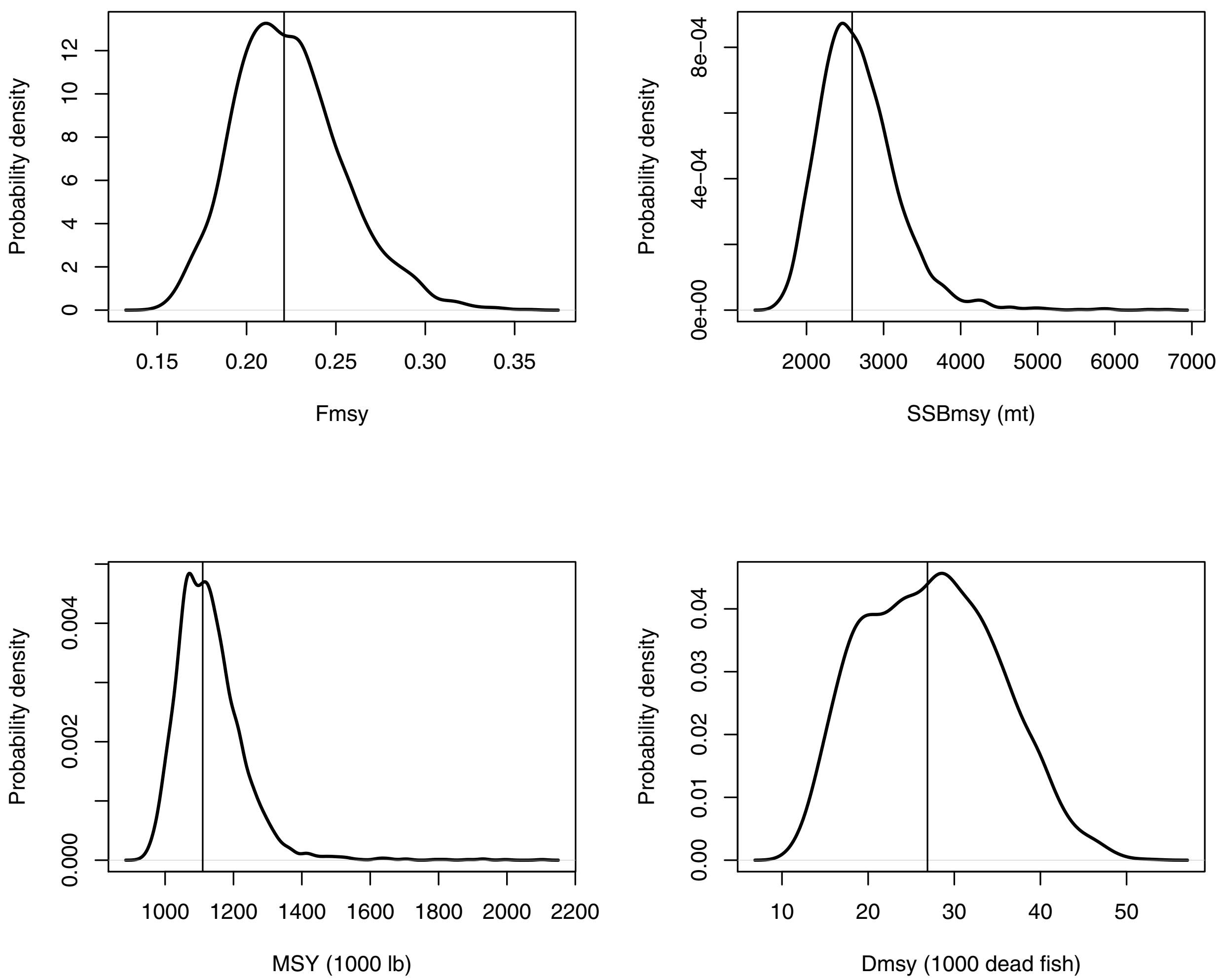


*Figure 6.44. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate $5^{th}$ and $95^{th}$ percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Bottom panel: F relative to $F_{\mathrm{MSY}}$.*

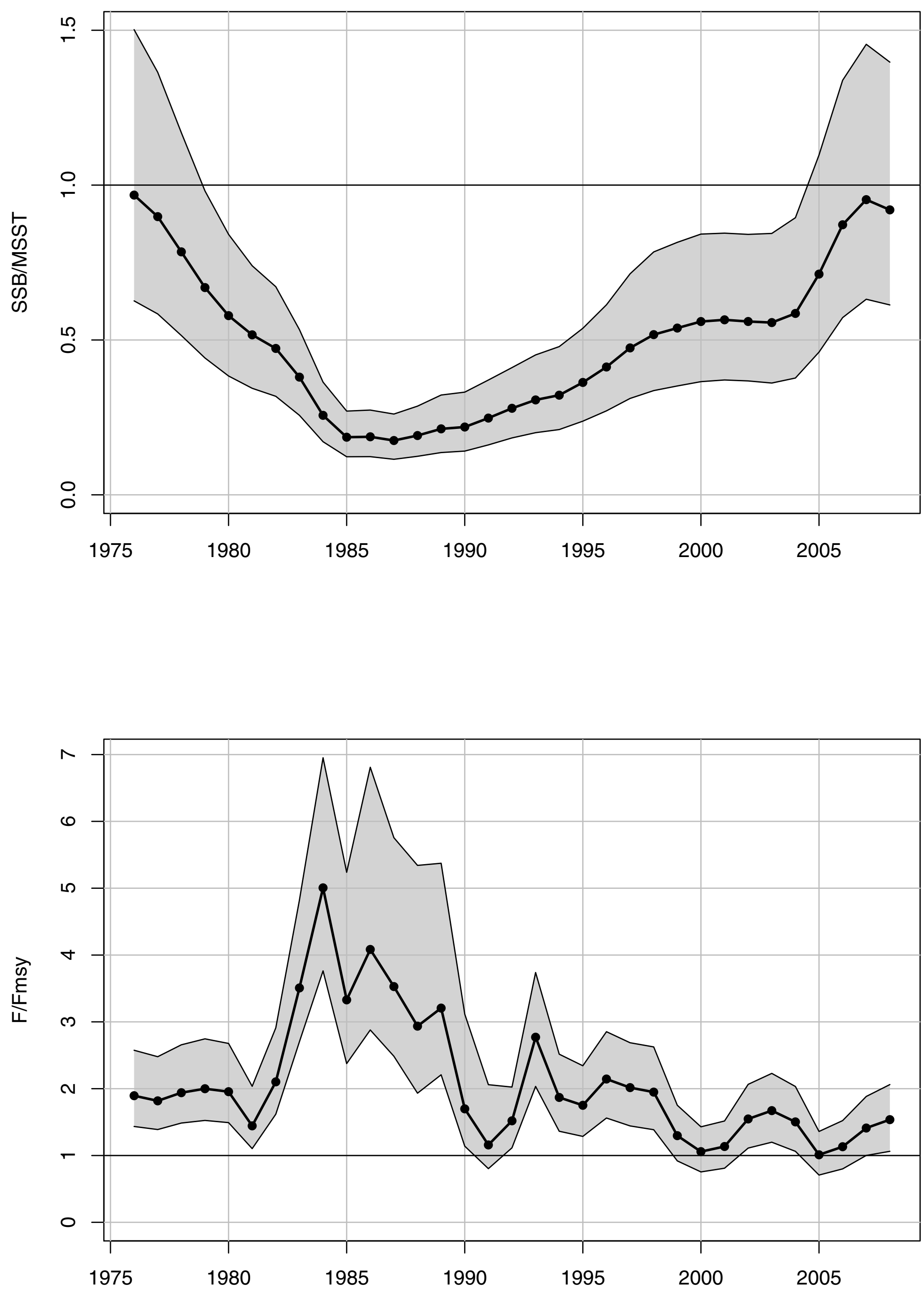


*Figure 6.45. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.*

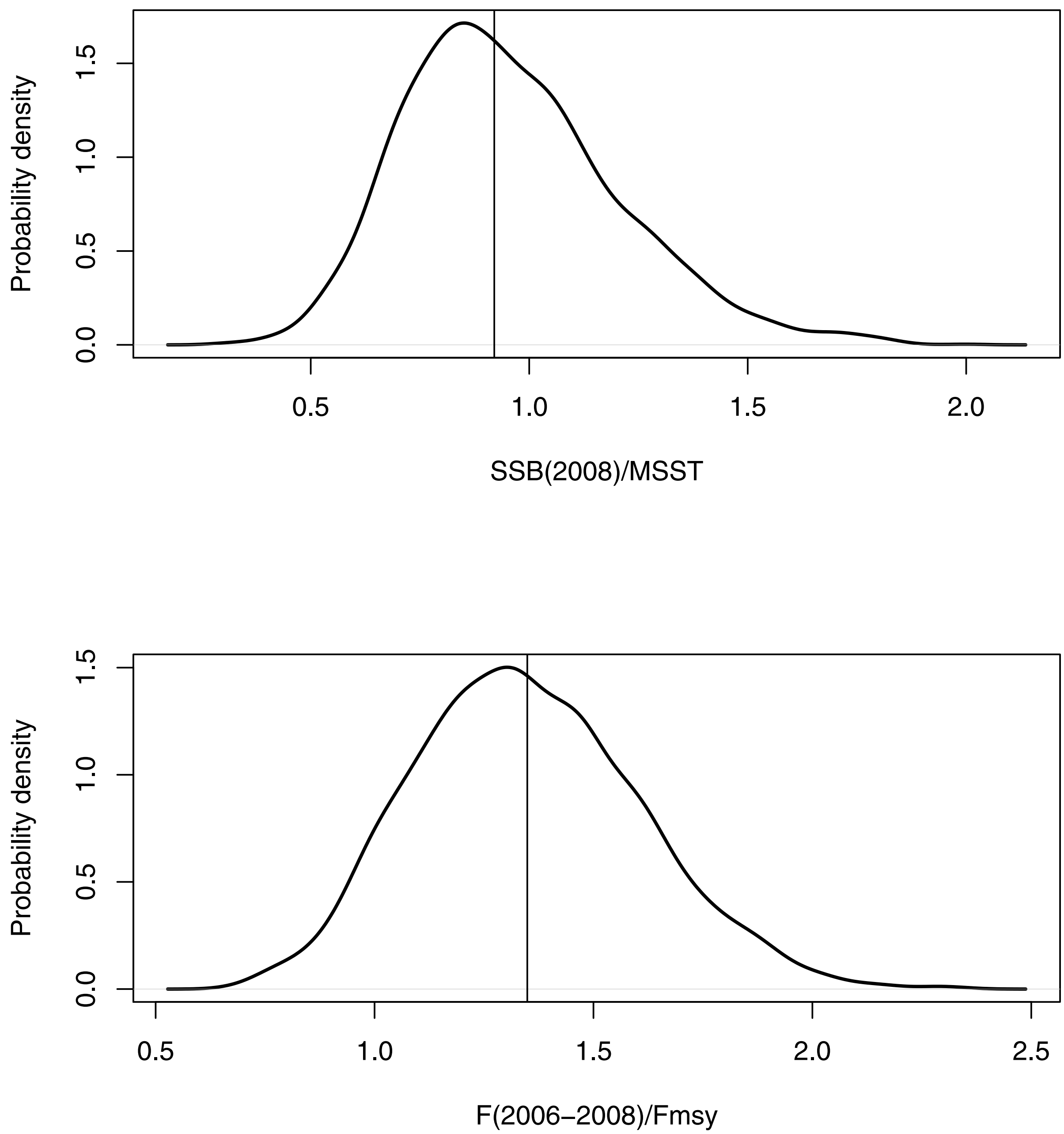


*Figure 6.46. Phase plot of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by $5^{th}$ and $95^{th}$ percentiles.*

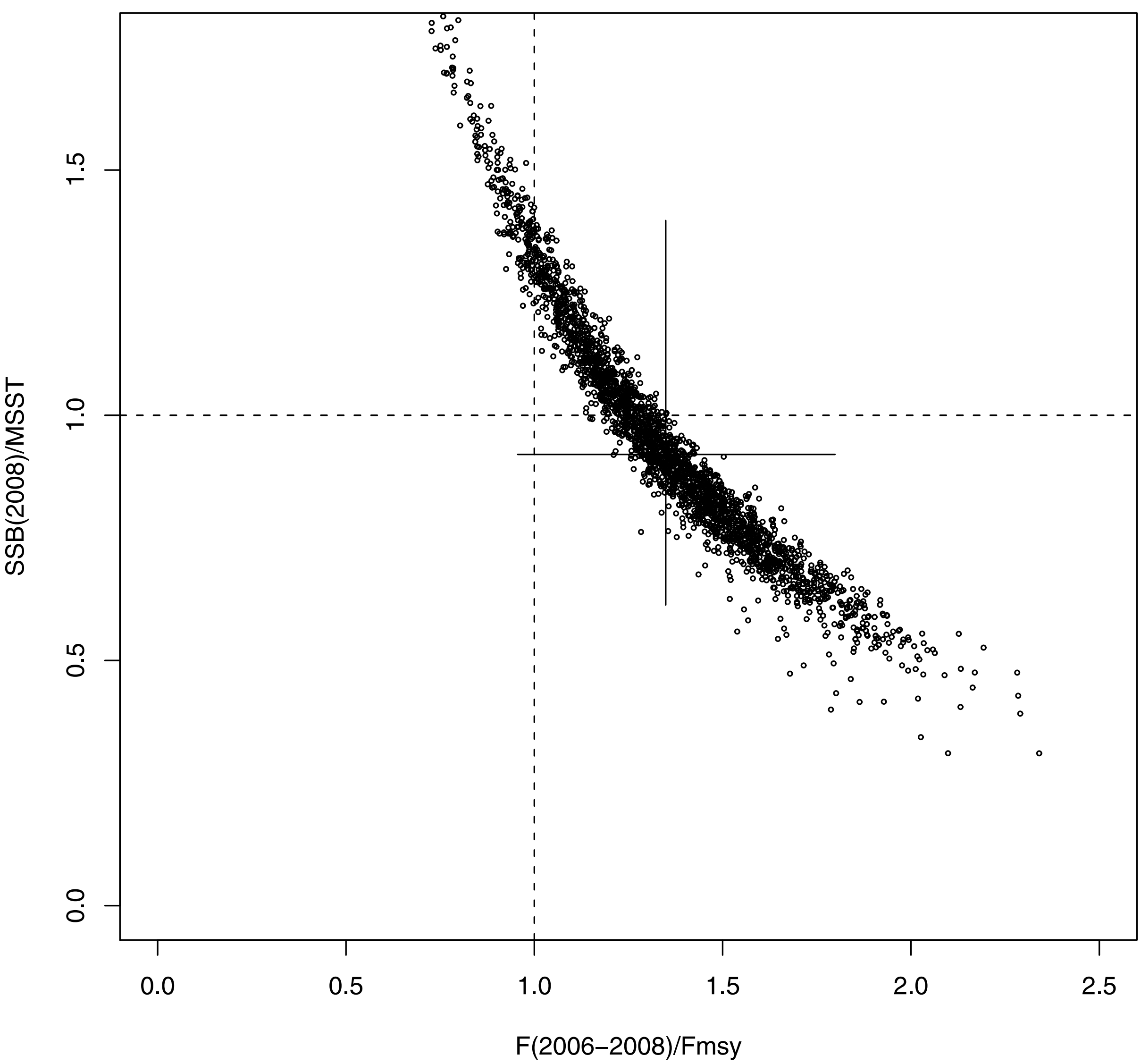


*Figure 6.47. Age structure relative to the equilibrium expected at* MSY.

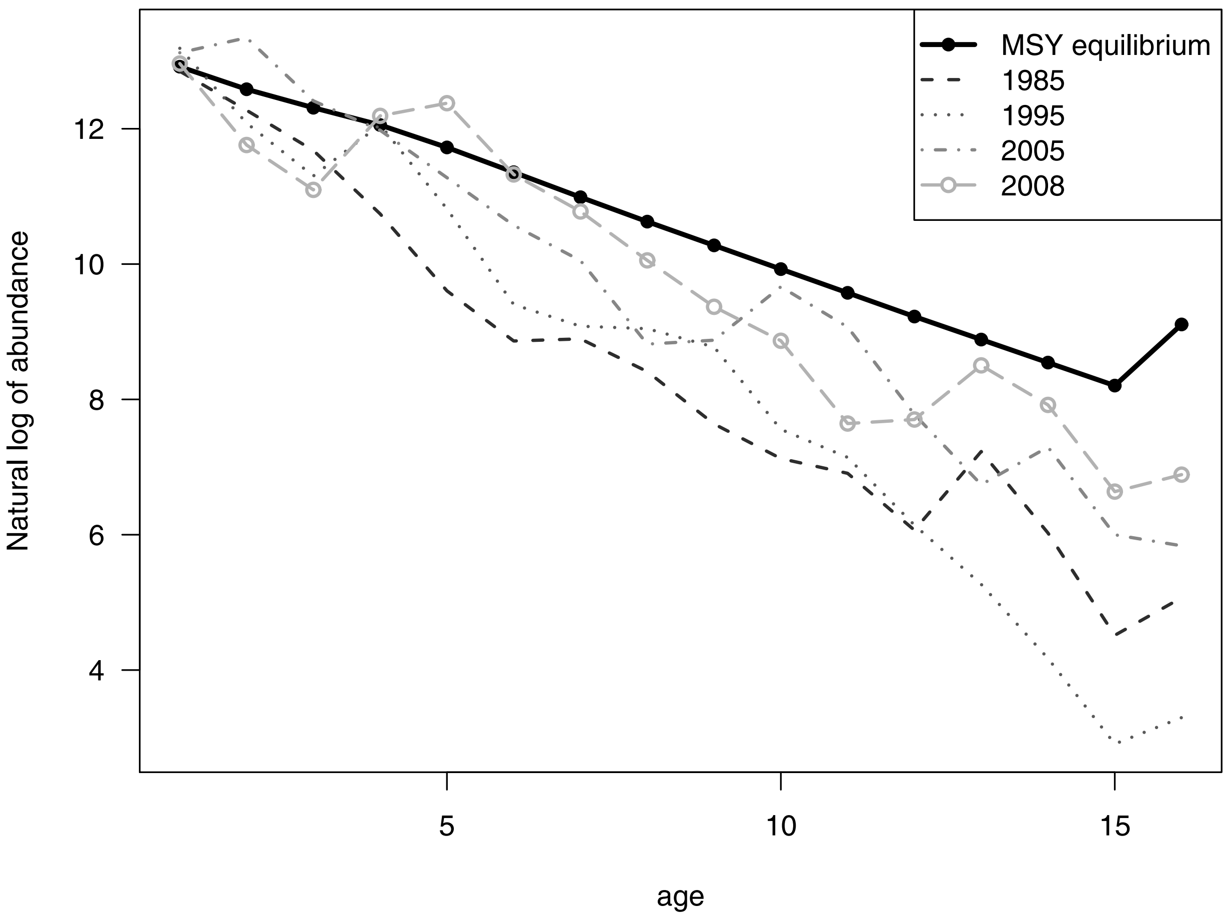
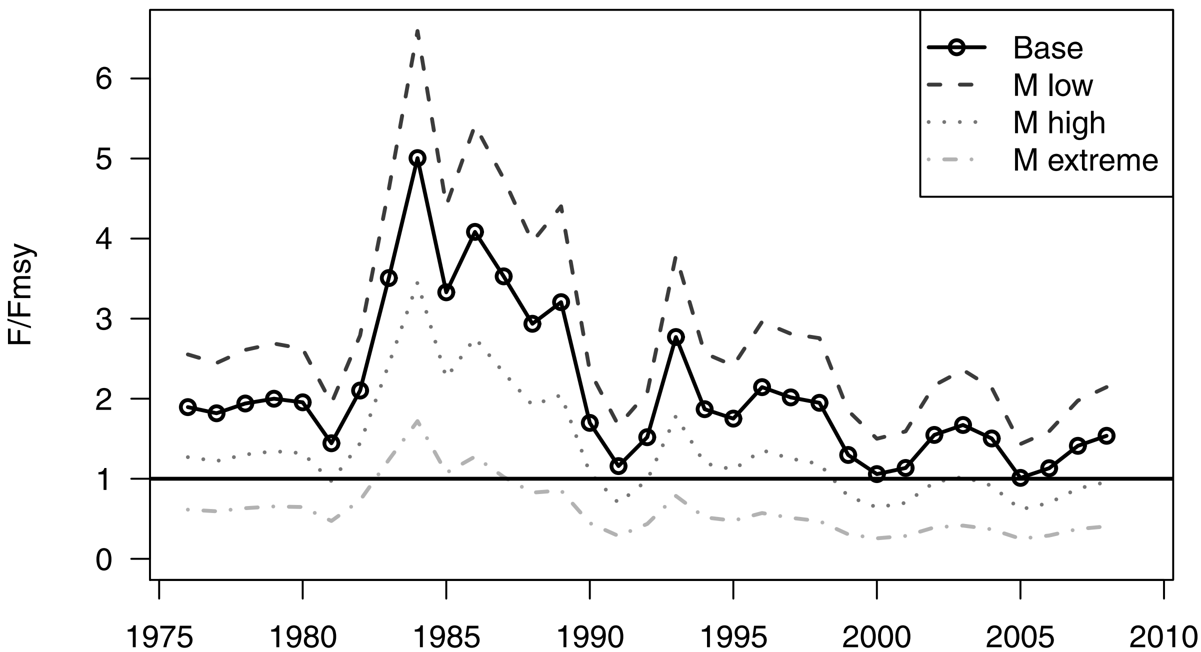


*Figure 6.48. Sensitivity to changes in natural mortality (sensitivity runs S1–S3). Top panel: Ratio of $F$ to $F_{MSY}$. Bottom panel: Ratio of* SSB *to* MSST.



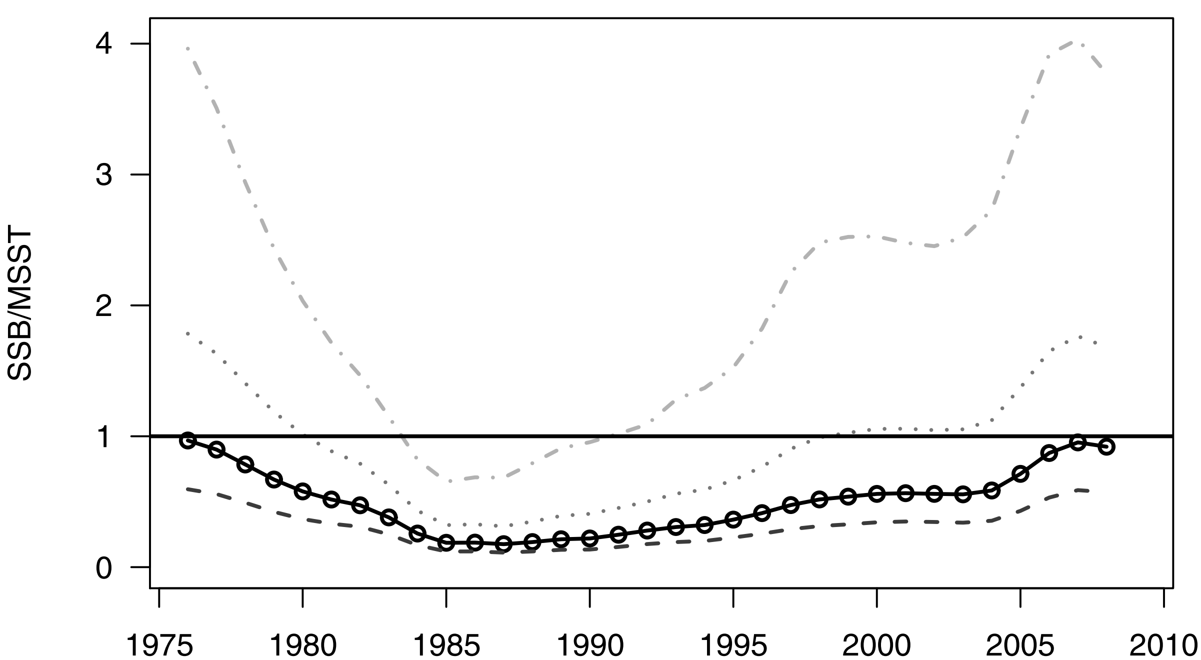



*Figure 6.49. Sensitivity to discard mortality rates (sensitivity runs S4 and S5). Top panel:Ratio of $F$ to $F_{MSY}$. Bottom panel:Ratio of* SSB *to* MSST.

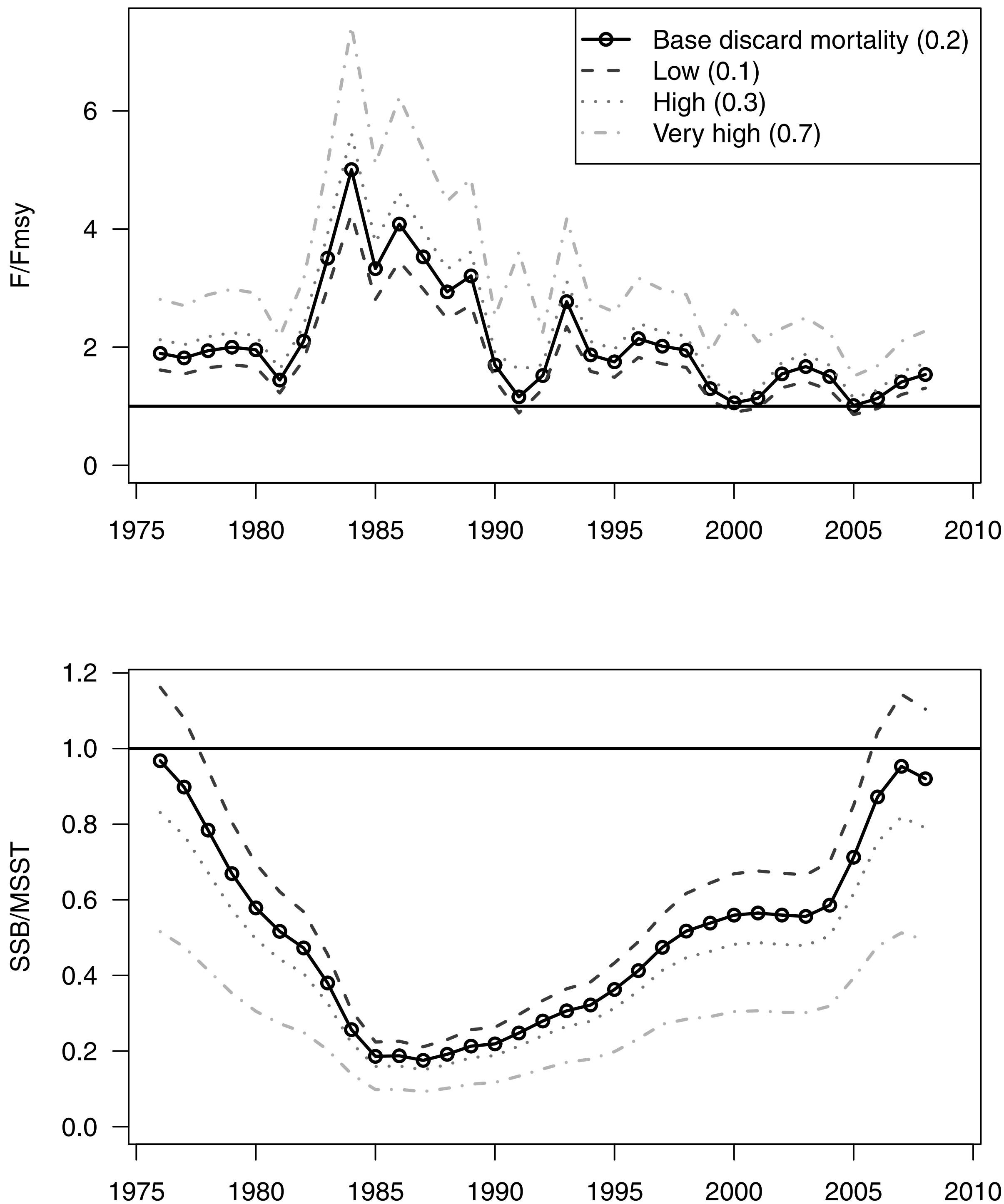


*Figure 6.50. Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model.*

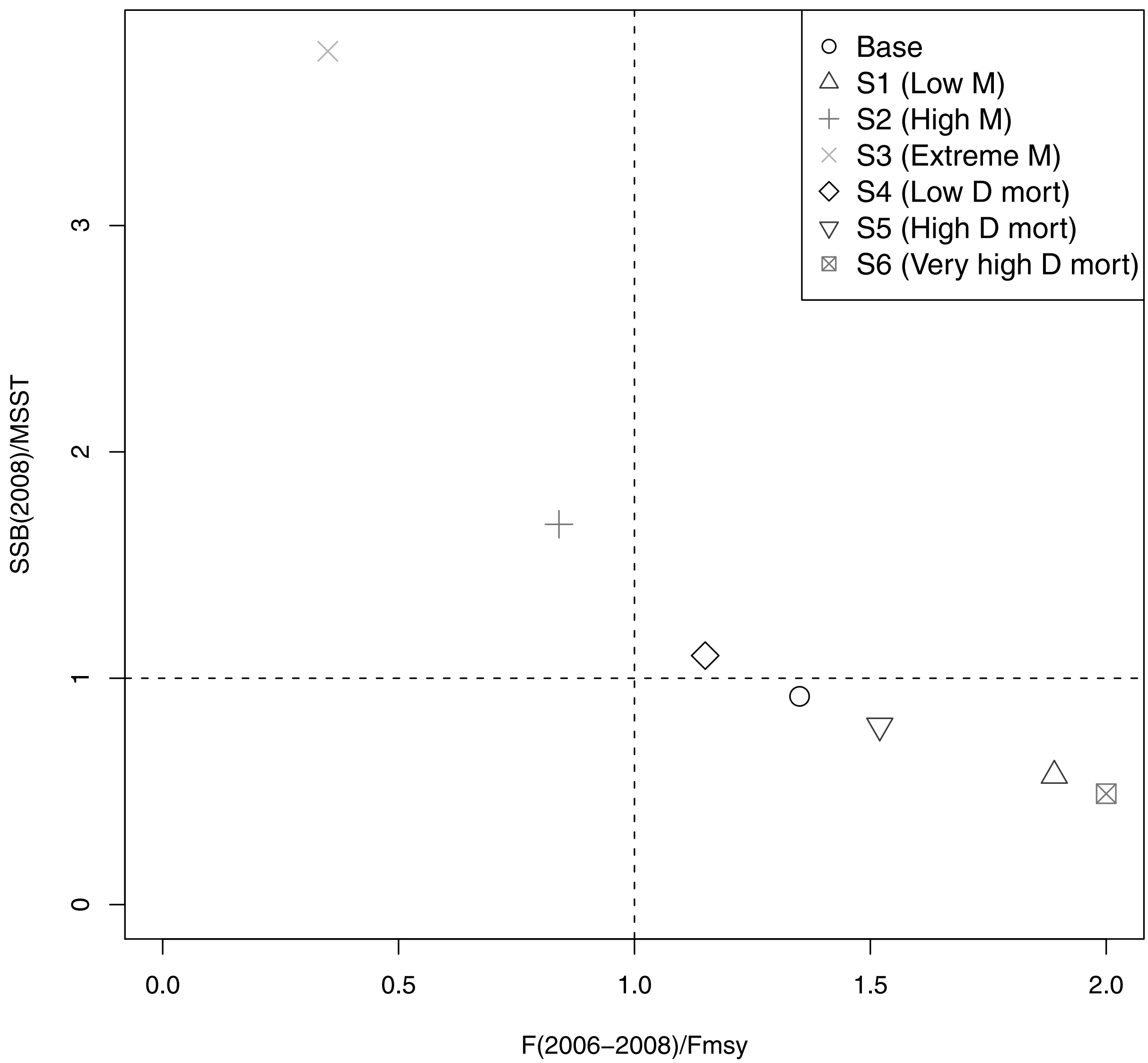


*Figure 6.51. Projection results under scenario 1—fishing mortality rate fixed at $F = 0$. Curve represents the proportion of projection replicates for which SSB(mid-year) has reached at least* $\mathrm{SSB}_{\mathrm{MSY}} = 2592$ *mt.*

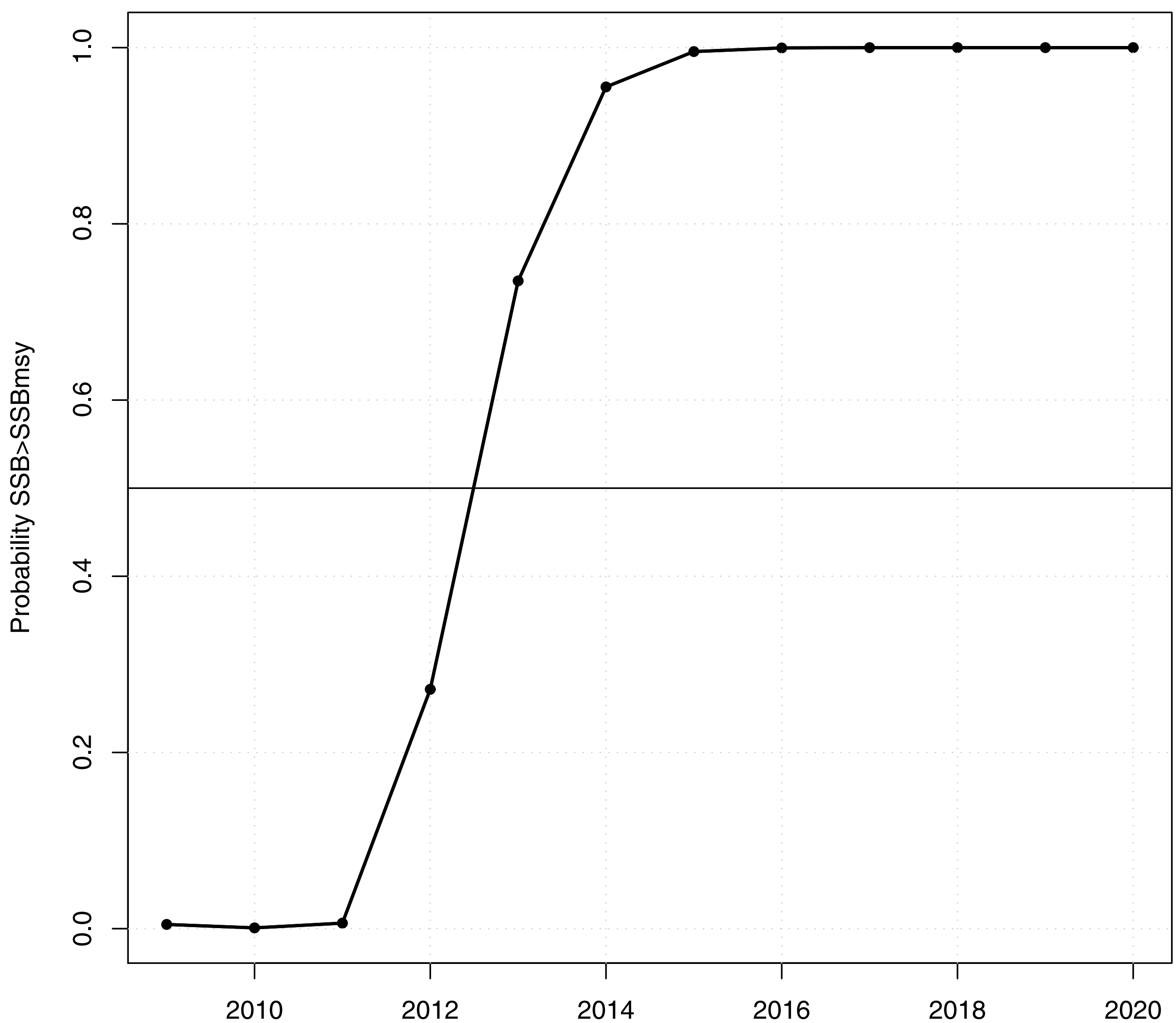


*Figure 6.52. Projection results under scenario 2—fishing mortality rate fixed at $F = F_{\text{current}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

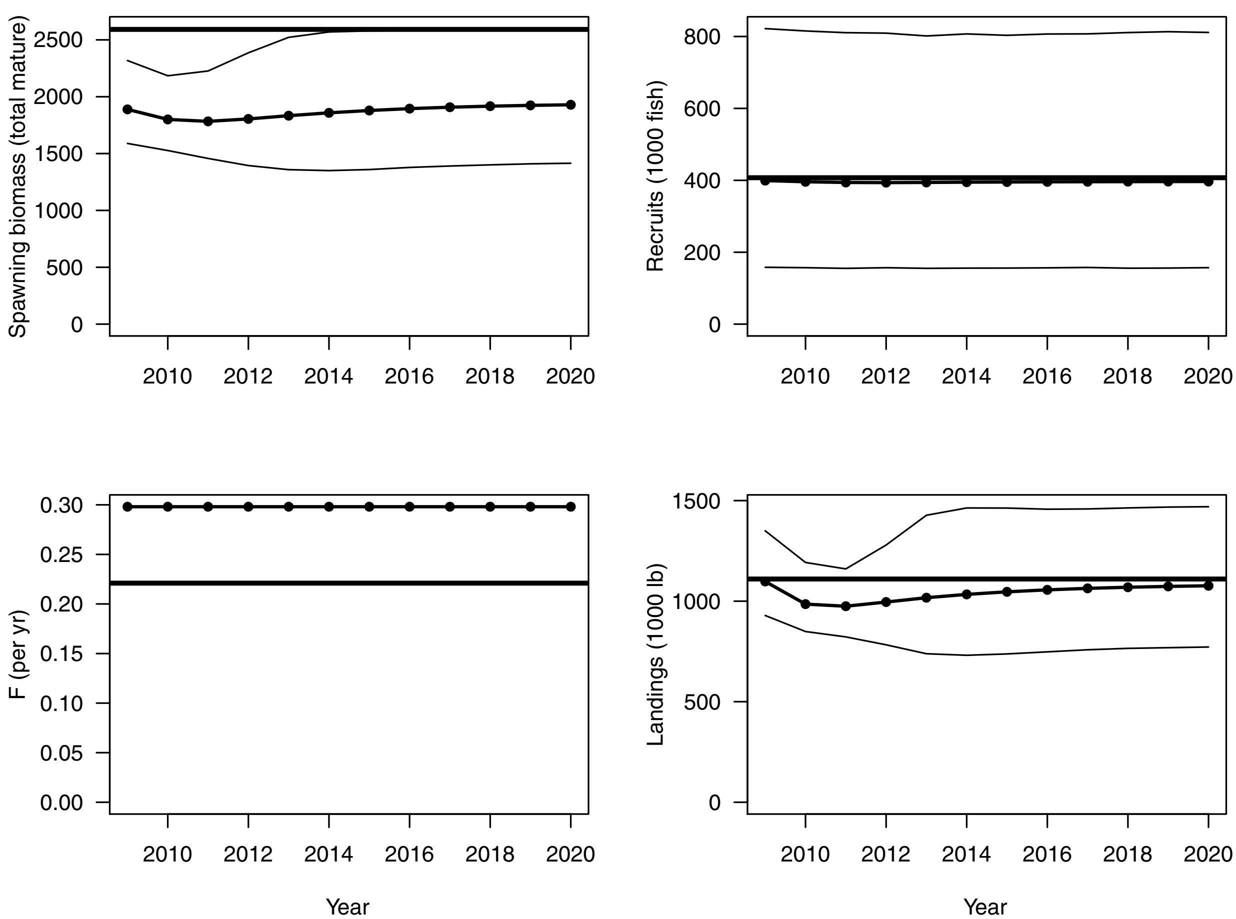


*Figure 6.53. Projection results under scenario 3—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and $F = 75\%F_{\text{current}}$ thereafter. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

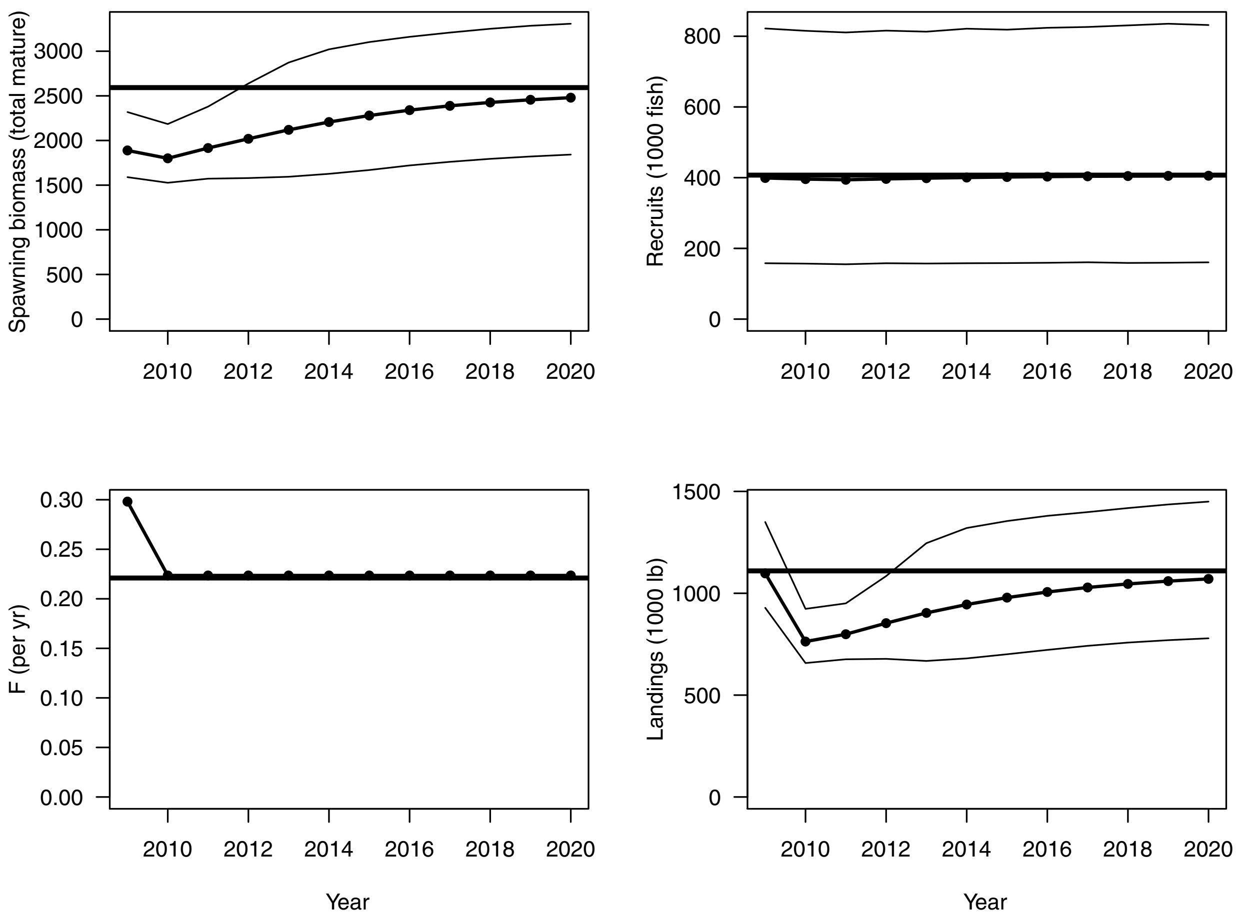


*Figure 6.54. Projection results under scenario 4—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and $F = 50\%F_{\text{current}}$ thereafter. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

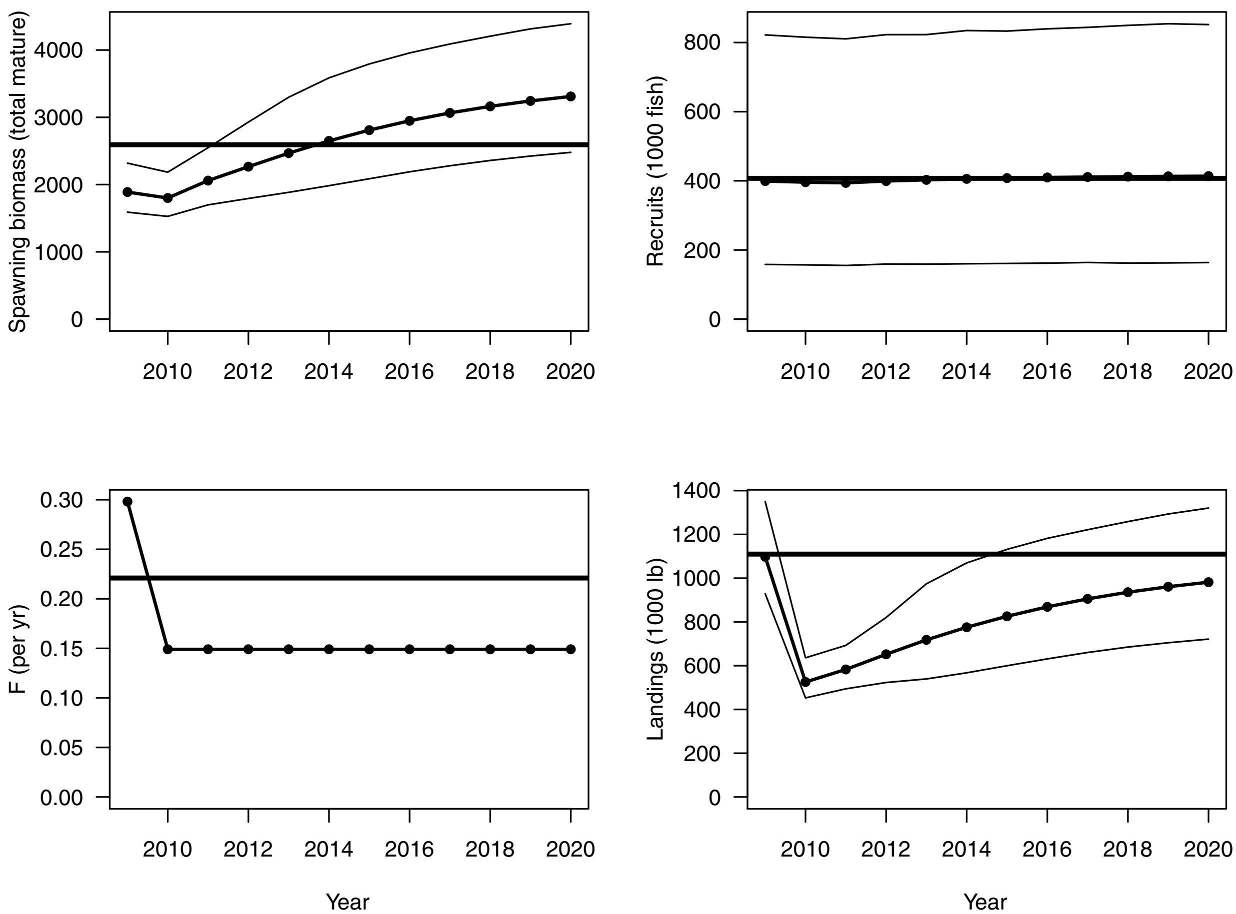


*Figure 6.55. Projection results under scenario 5—fishing mortality rate fixed at $F = F_{\text{current}}$ in 2009 and $F = 25\%F_{\text{current}}$ thereafter. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

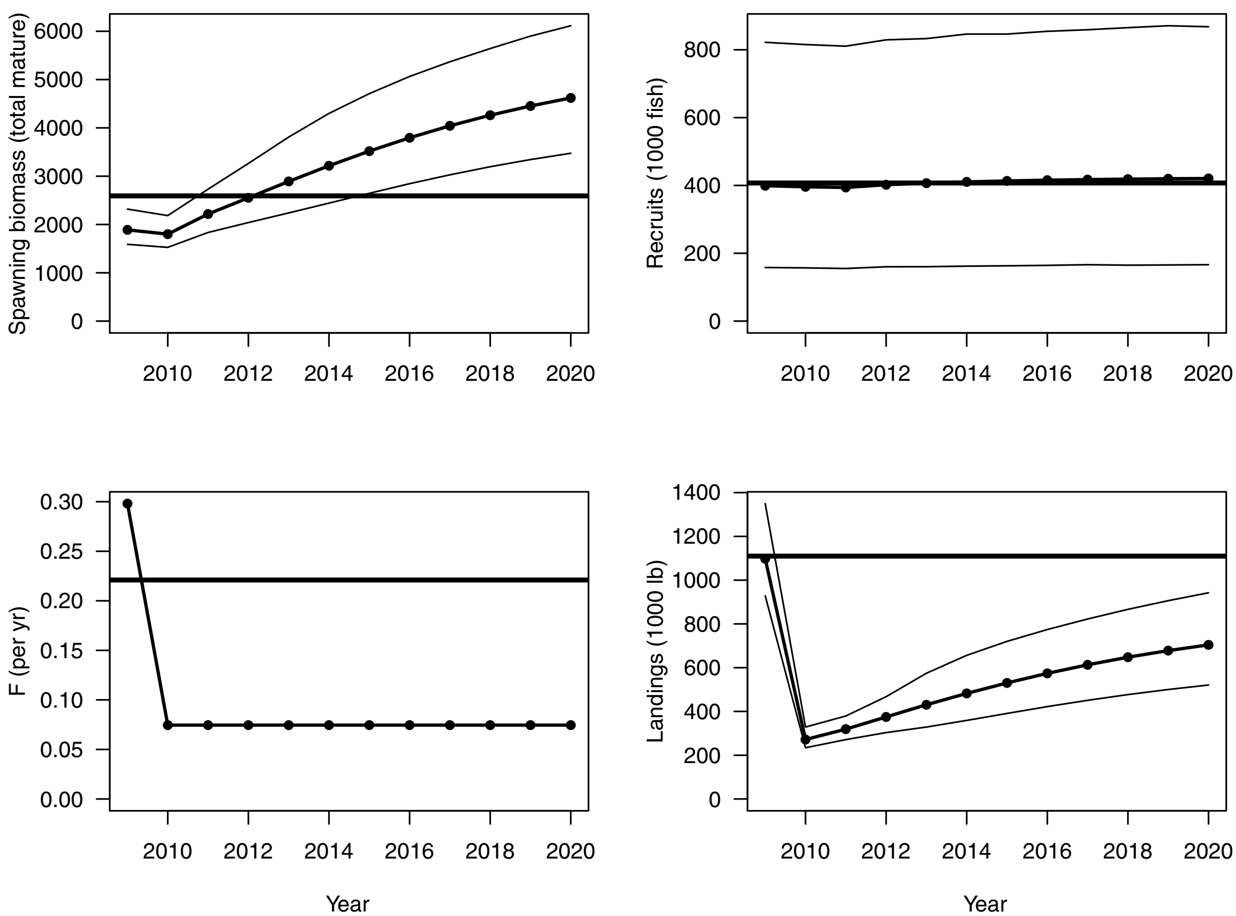


*Figure 6.56. Projection results under scenario 6—fishing mortality rate fixed at $F = 65\%F_{\mathrm{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

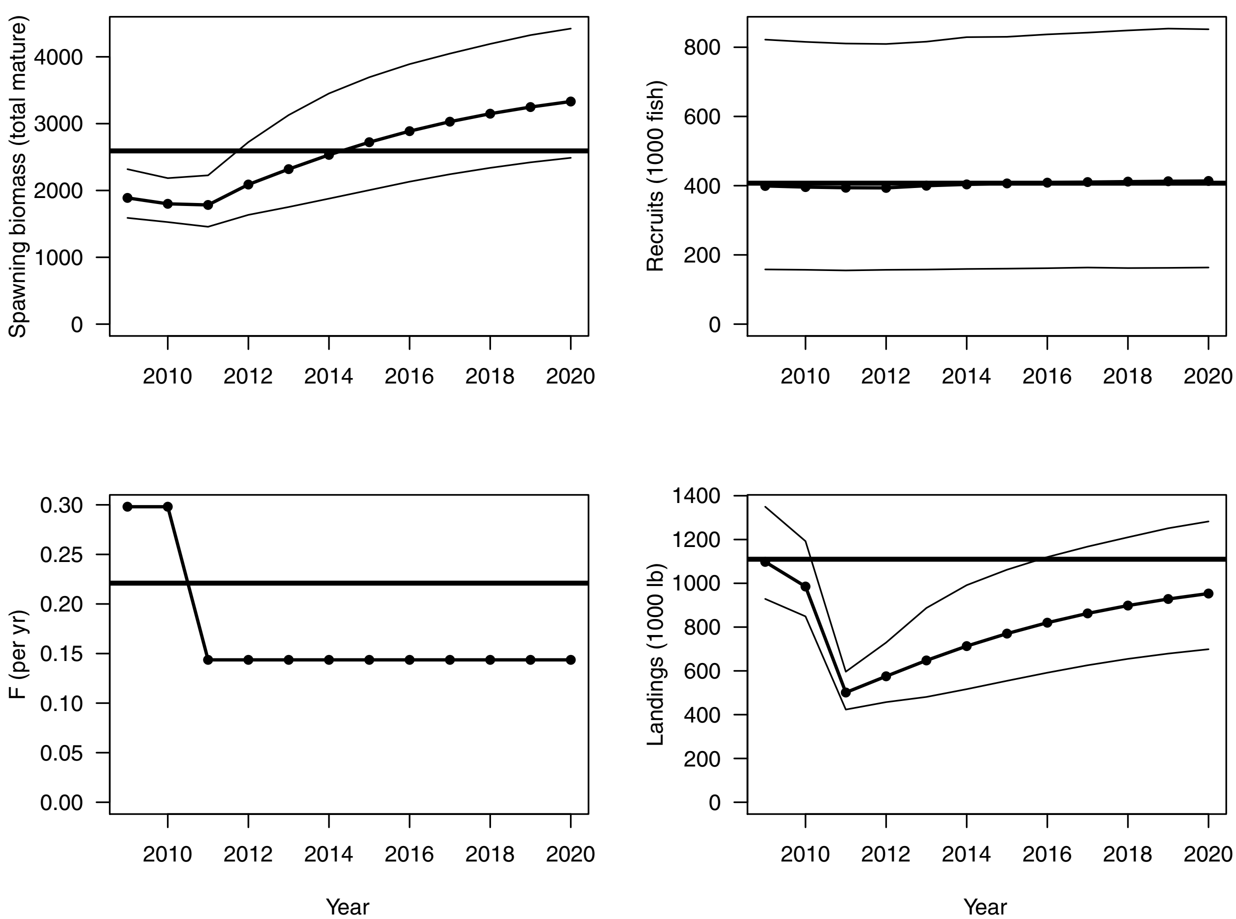


*Figure 6.57. Projection results under scenario 7—fishing mortality rate fixed at $F = 75\%F_{\text{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

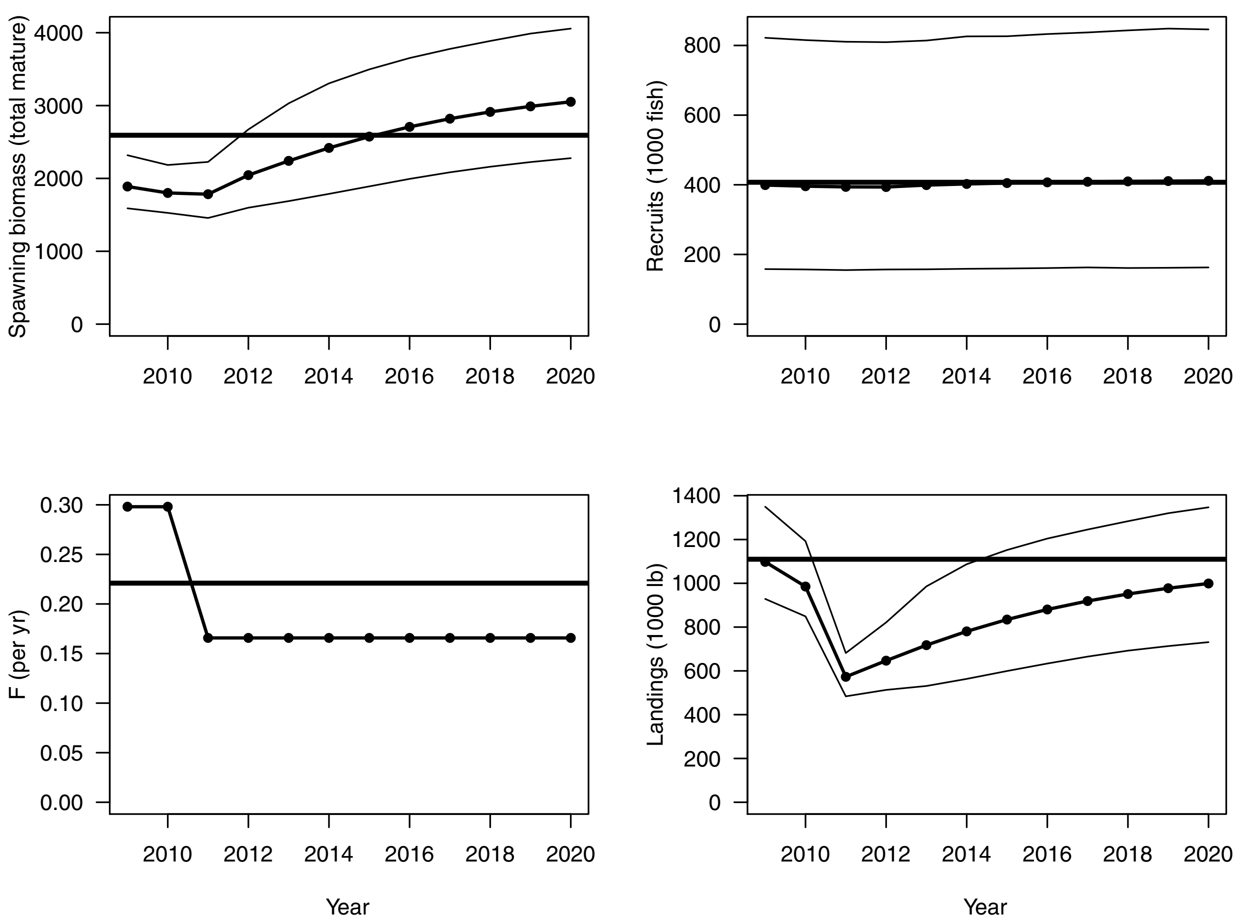


*Figure 6.58. Projection results under scenario 8—fishing mortality rate fixed at* $F = 85\%F_{\text{MSY}}$*. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to* $5^{th}$ *and* $95^{th}$ *percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

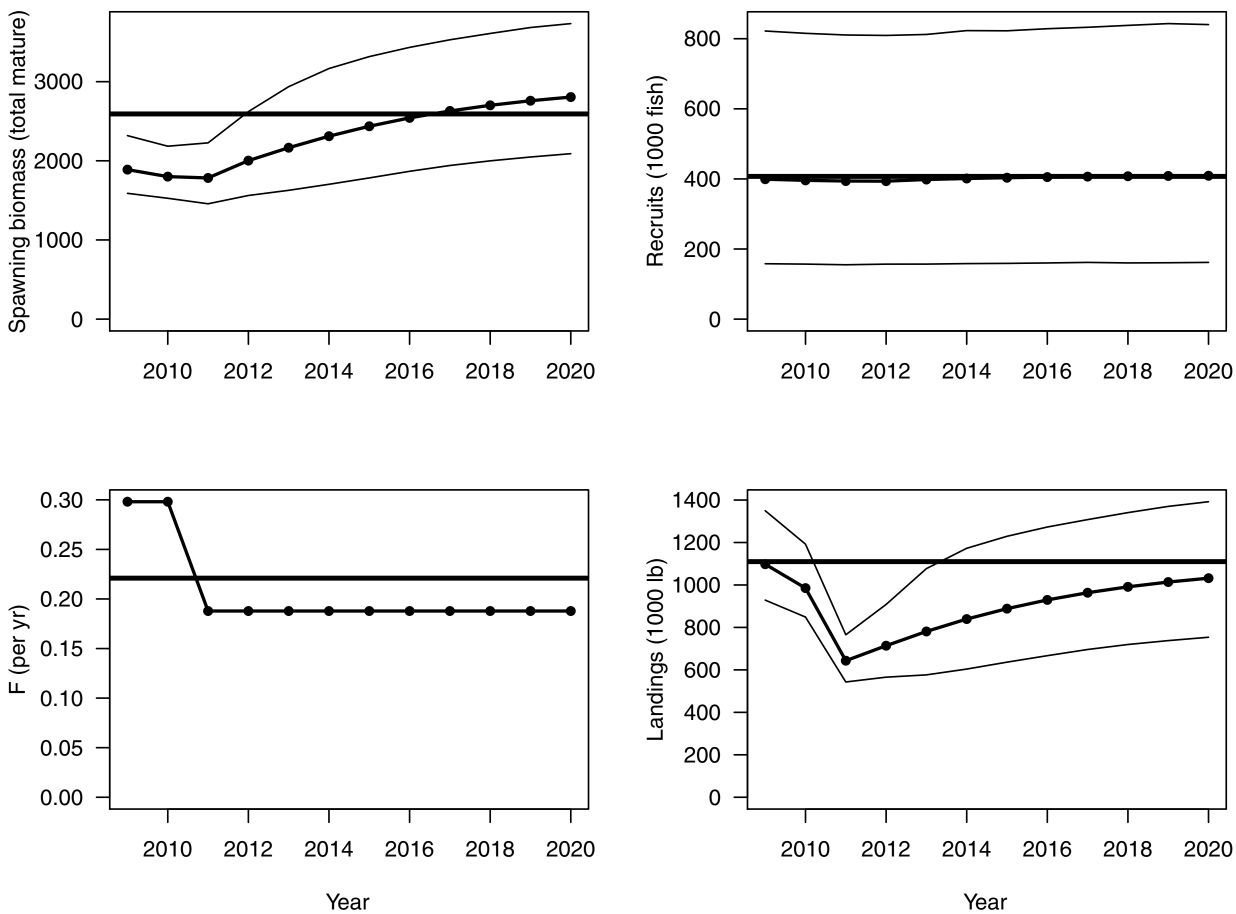


*Figure 6.59. Projection results under scenario 9—fishing mortality rate fixed at $F = F_{\text{MSY}}$. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

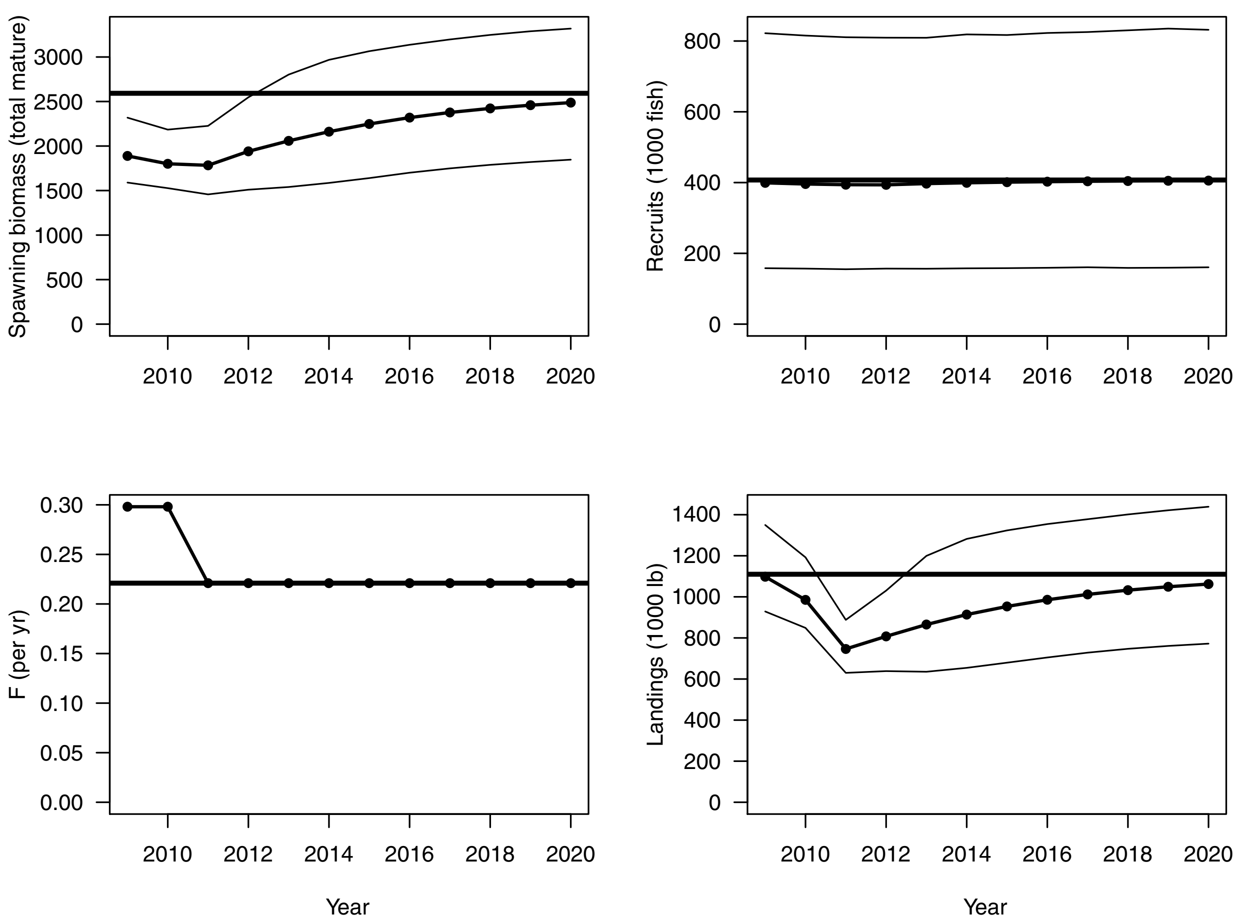


*Figure 6.60. Projection results under scenario 10—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, after an initialization period with $F = F_{\text{current}}$ in 2009 and 2010. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

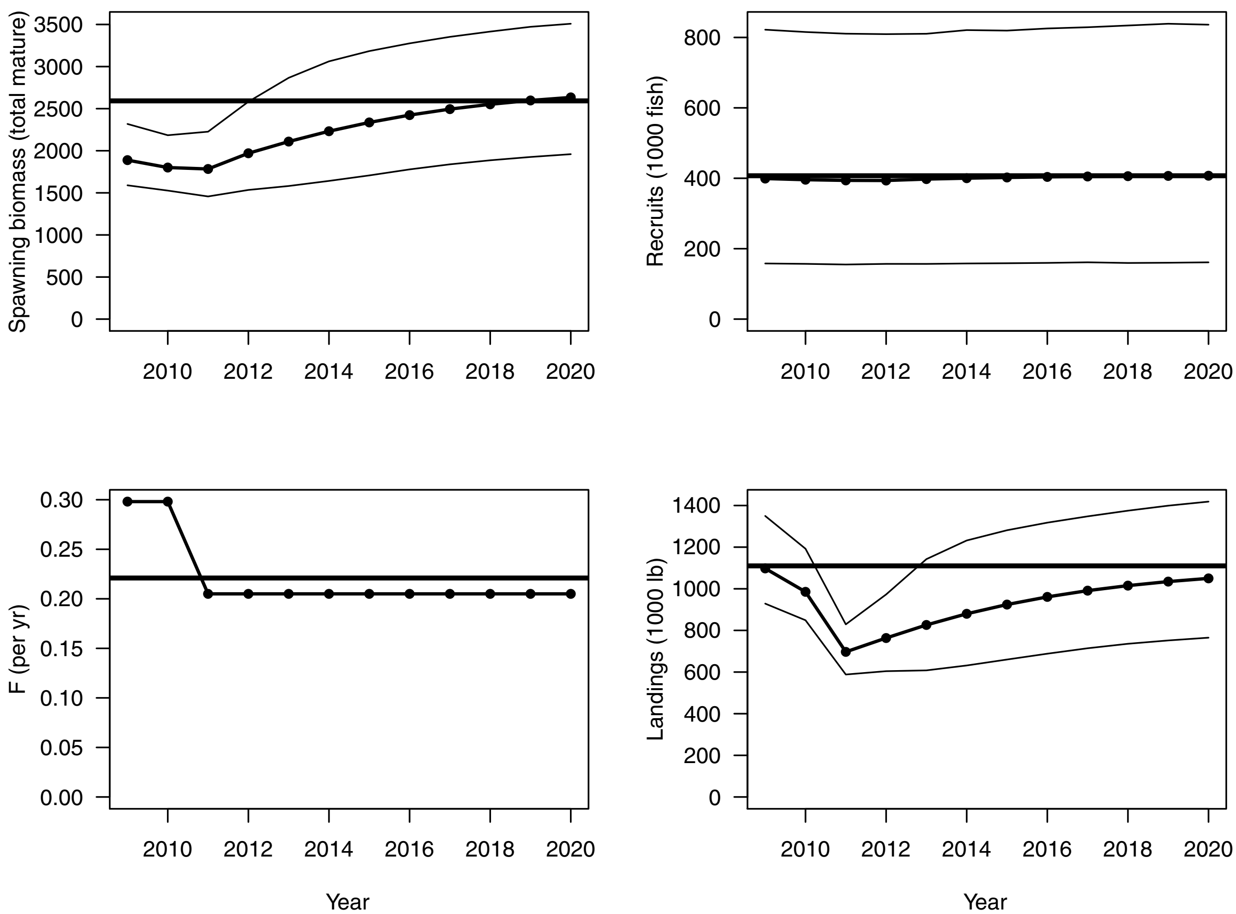


*Figure 6.61. Projection results under scenario 11—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, after an initialization period with $F = F_{\text{current}}$ in 2009 and $F = 75\% F_{\text{current}}$ 2010. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*

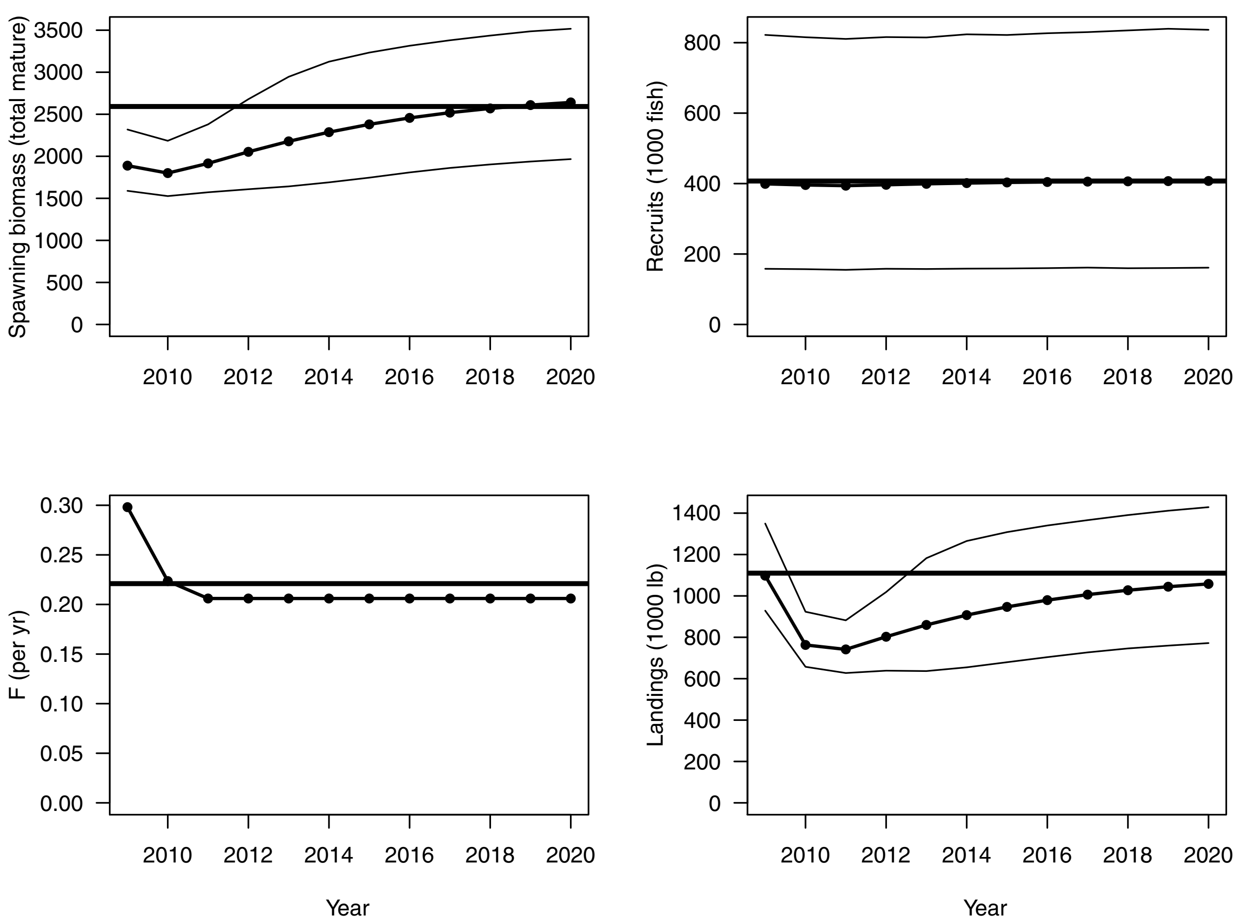


*Figure 6.62. Projection results under scenario 12—fishing mortality rate fixed at $F = F_{\mathrm{rebuild}}$, after an initialization period with $F = F_{\mathrm{current}}$ in 2009 and $F = 50\% F_{\mathrm{current}}$ 2010. Expected values represented by dotted solid lines, and uncertainty represented 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 mid-year.*

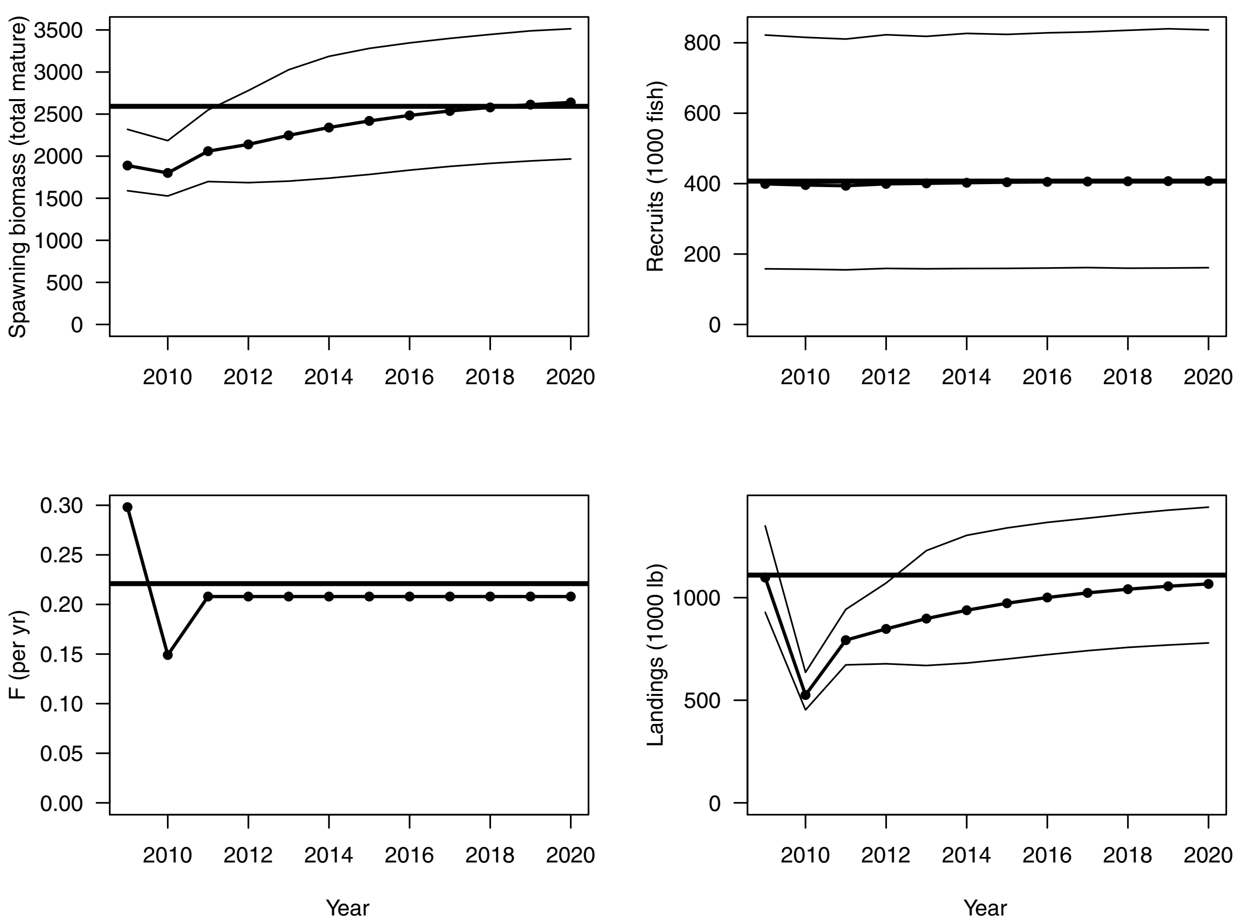
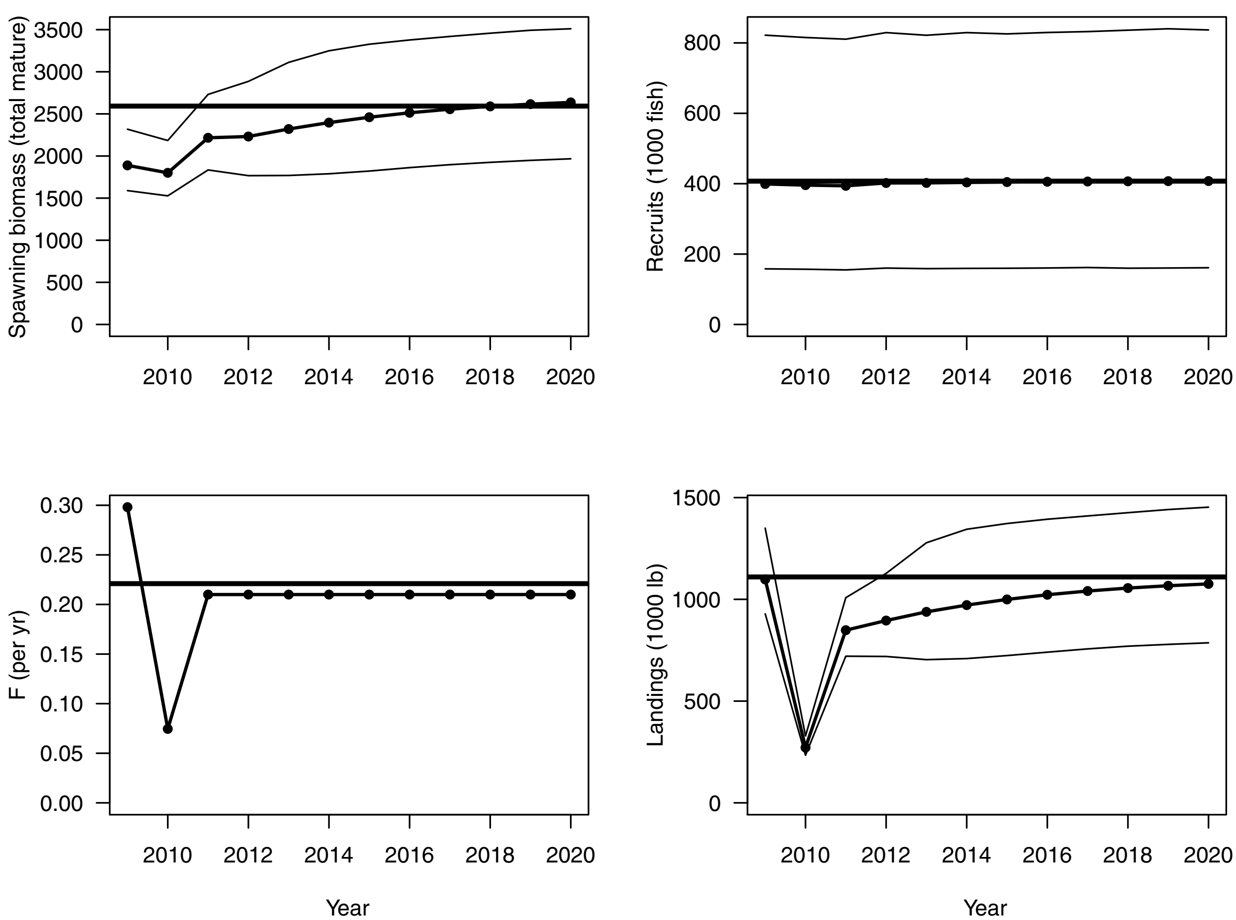


*Figure 6.63. Projection results under scenario 13—fishing mortality rate fixed at $F = F_{\text{rebuild}}$, after an initialization period with $F = F_{\text{current}}$ in 2009 and $F = 25\%F_{\text{current}}$ 2010. Expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Horizontal lines mark* MSY*-related quantities. Spawning stock (SSB) is at mid-year.*



## Appendix A Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 254  Objective function value = 5067.12  Maximum gradient component = 0.00280377
# log_len_cv:
-2.40480051188
# log_Nage_dev:
 0.597628460616 0.325805510556 2.03063793052 1.36308747281 0.384800288526 0.598389193161 0.408210523307
 1.01542701606 0.527564875775 0.358255044932 0.233314349800 0.148684071880 0.0935451375447 0.0582572078106
 0.0908609446995
# log_R0:
12.8598929967
# steep:
0.916972170477
# log_rec_dev:
 0.245177703120 0.0335314265748 0.246833623857 0.160111981391 -0.415268815854 -0.231400953047 0.309314073281
 0.409669421511 0.130952056662 0.286415755744 0.0158142926754 0.514001211959 0.153705479108 -0.441816558518
 -0.671062494858 -0.0614499266886 0.491562435185 -0.613119954840 -0.149152624634 0.569707525720 0.659160620084
 -0.582059942375 -1.05004363202 -0.198242366943 -0.169730148399 -0.0369902804898 0.203880401355 0.334122038011
 0.969214702992 0.393528271007 -1.01634907046 -0.666964071103 0.176947819992
# R_autocorr:
0.00000000000
# selpar_L50_CVT:
3.60226607587
# selpar_slope_CVT:
1.46174879502
# selpar_L502_CVT:
1.00000092135
# selpar_slope2_CVT:
0.382551431393
# selpar_L50_cL2:
4.71273642004
# selpar_slope_cL2:
0.591460461342
# selpar_L50_cL3:
4.11134766247
# selpar_slope_cL3:
1.95564845363
# selpar_L50_HB1:
1.81834935887
# selpar_slope_HB1:
1.56079256331
# selpar_L50_HB2:
1.96365341384
# selpar_slope_HB2:
2.91618547050
# selpar_L50_HB3:
2.84203662244
# selpar_slope_HB3:
3.87631146799
# selpar_Age1_HB_D3:
0.801707264951
# selpar_L50_MRFSS3:
3.24880589302
# selpar_slope_MRFSS3:
4.12924889168
# log_q_CVT:
-12.7094820408
# log_q_cL:
-7.55399366282
# log_q_HB:
-12.8109013688
# log_q_MRFSS:
-13.4169852521
# q_rate:
0.00000000000
# q_DD_beta:
0.00000000000
# q_RW_log_dev_cL:
```

```
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
# q_RW_log_dev_HB:
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 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
# q_RW_log_dev_MRFSS:
 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000 0.00000000000
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 0.00000000000
# log_avg_F_cL:
-1.69757983652
# log_F_dev_cL:
 -0.616760944037 -0.841449806180 -0.555477058686 -0.516035915732 -0.604531894077 -0.375775127754 -0.304640924596
 -0.0500450954159 0.566628366976 0.737885400746 1.03494086866 0.795352269968 0.974955960018 0.833078242902
 0.465389674490 0.0430831640034 -0.359598751069 0.00877696440500 0.00670776214062 0.0777707213536 0.145193007591
 0.246323982830 0.417749306205 0.118473862615 -0.182576125677 -0.212889545482 -0.133500648194 -0.140238777486
 -0.204386999994 -0.698400474395 -0.439951800890 -0.0883601196985 -0.147689545540
# log_avg_F_cO:
-3.80916168821
# log_F_dev_cO:
 0.505401866685 0.498575864453 0.832855989807 0.869992238133 0.731443361416 1.03389520781 1.00527912108 1.16479524152
 1.55438528066 1.30623341425 1.55412760344 1.46224494177 1.32325168968 1.35108334750 1.31625629140 0.981745397535
 0.324758824845 -0.527470226905 -1.14777984239 -1.42313526995 -0.795971400250 -0.892897492917 -0.394646958702
 -1.21325126492 -1.50012710265 -0.132078125634 -0.405242479833 -0.759262660303 -0.532316730924 -1.61669835504
 -2.38696836836 -1.83817708272 -2.25030232051
# log_avg_F_HB:
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# log_F_dev_HB:
 -1.23963567497 -0.828758220865 -0.827864528861 -0.0365641818513 -0.0411108899991 0.0514264933532 -0.135005152171
 0.376333764065 0.613527191980 0.760708411973 0.312078827175 0.572277732491 0.133909675893 -0.235478560911
 0.570949461485 -0.392270715922 0.354464153226 0.488079653311 0.250586042532 0.187316355704 0.288114861368
 0.390420008260 0.470227756526 0.138115109427 0.00691855186638 -0.0317808579177 -0.110784805626 -0.285424743015
 0.566046149745 0.424973616140 -0.698099328038 -0.784444536009 -1.30925162036
# log_avg_F_MRFSS:
-1.79278060309
# log_F_dev_MRFSS:
 0.0363977963832 0.629552614258 1.23764163539 1.50504005314 0.639570299600 0.778262751218 0.722007774864
 -0.151842233636 0.493594384729 -1.16200832929 -1.90609173682 -0.0409820391597 0.855866082710 0.197380084911
 -0.00462492974971 0.337903188951 0.0829226872456 -0.359974791126 -1.06696834564 -0.999182002168 -0.829367633943
 -0.0594547944053 0.136997008101 -0.139921161389 -0.471984099969 -0.304388935740 -0.211688556494 0.0553432280314
# F_init_ratio:
1.00000000000
# log_avg_F_cL_D:
-5.59222418601
# log_F_dev_cL_D:
 -0.00350951332435 0.0345005687663 0.686668120564 -0.0101166447426 -0.235042453927 0.286864541581 0.535134009354
 0.802760890357 0.435947036391 0.0257131359780 0.761196329526 -0.0717967174407 -0.539619844524 -0.636174657859
 -0.867889590596 0.245039667034 -1.44967487714
# log_avg_F_HB_D:
-4.49335834779
# log_F_dev_HB_D:
 0.442959596980 -0.451689720028 0.00873012304721
# log_avg_F_MRFSS_D:
-3.18062430962
# log_F_dev_MRFSS_D:
 -1.41592646905 -1.65225095531 0.363711702087 0.710915217088 -2.48369383867 -0.768502762968 0.315763422966
 -0.433936873933 -1.50995139042 -0.550707598577 1.19103703244 0.422394097348 -0.149025861752 0.592290141546
 0.243280204653 0.745117694289 1.05055227078 0.507976194060 0.533793699552 1.06258272171 0.728813505947
 0.0837765107785 0.161799023427 0.0564522212589 0.0913374674686 0.398161556566 -0.241520321246 -0.0542386120466
```