Northeast Fisheries Science Center Reference Document 11-02

51st Northeast Regional Stock Assessment Workshop (51st SAW):

Assessment Report

by Northeast Fisheries Science Center

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10-13 *Black Sea Bass 2010 Stock Assessment Update*, by GR Shepherd and J Nieland. July 2010.

10-14 *Stock Assessment of Summer Flounder for 2010*, by M Terceiro. July 2010.

10-15 *Bluefish 2010 Stock Assessment Update*, by GR Shepherd and J Nieland. July 2010.

10-16 *Stock Assessment of Scup for 2010*, by M Terceiro. July 2010.

10-17 *50th Northeast Regional Stock Assessment Workshop (50th SAW) Assessment Repor*t, by Northeast Fisheries Science Center. August 2010.

10-18 An Updated Spatial Pattern Analysis for the Gulf of Maine-Georges Bank Atlantic Herring Complex During 1963-2009, by JJ Deroba. August 2010.

10-19 Northeast Fisheries Science Center publications, reports, abstracts, and web documents for calendar year 2009, by A Toran. September 2010.

10-20 Northeast Fisheries Science Center publications, reports, abstracts, and web documents for calendar year 2009, by A Toran. September 2010.

10-21 12th Flatfish Biology Conference 2010 Program and Abstracts, by Conference Steering Committee. October 2010.

10-22 Update on Harbor Porpoise Take Reduction Plan Monitoring Initiatives: Compliance and Consequential Bycatch Rates from June 2008 through May 2009, by C D Orphanides. November 2010.

11-01 51st Northeast Regional Stock Assessment Workshop (51st SAW): Assessment Report, by Northeast Fisheries Science Center. January 2011.

Northeast Fisheries Science Center Reference Document 11-02

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Assessment Report

by Northeast Fisheries Science Center

NOAA National Marine Fisheries Service, 166 Water St., Woods Hole, MA 02543.

US DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

March 2011

Northeast Fisheries Science Center Reference Documents

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Editorial Treatment: To distribute this report quickly, it has not undergone the normal technical and copy editing by the Northeast Fisheries Science Center's (NEFSC's) Editorial Office as have most other issues in the NOAA Technical Memorandum NMFS-NE series. Other than the four covers and first two preliminary pages, all writing and editing have been performed by the authors listed within. This report was reviewed by the Stock Assessment Review Committee, a panel of assessment experts from the Center for Independent Experts (CIE), University of Miami.

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A Report of the 51st Northeast Regional Stock Assessment Workshop

51st Northeast Regional Stock Assessment Workshop (51st SAW)

Assessment Report

March 2011

U.S DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

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Foreword

The Northeast Regional Stock Assessment Workshop (SAW) process has three parts: preparation of stock assessments by the SAW Working Groups and/or by ASMFC Technical Committees / Assessment Committees; peer review of the assessments by a panel of outside experts who judge the adequacy of the assessment as a basis for providing scientific advice to managers; and a presentation of the results and reports to the Region's fishery management bodies.

Starting with SAW-39 (June 2004), the process was revised in two fundamental ways. First, the Stock Assessment Review Committee (SARC) became smaller panel with panelists provided by the Independent System for Peer Review (Center of Independent Experts, CIE). Second, the SARC provides little management advice. Instead, Council and Commission teams (e.g., Plan Development Teams, Monitoring and Technical Committees, Science and Statistical Committee) formulate management advice, after an assessment has been accepted by the SARC. Starting with SAW-45 (June 2007) the SARC chairs were from external agencies, but not from the CIE. Starting with SAW-48 (June 2009), SARC chairs are from the Fishery Management Council's Science and Statistics Committee (SSC), and not from the CIE. Also at this time, some assessment Terms of Reference were revised to provide additional science support to the SSCs, as the SSC's are required to make annual ABC recommendations to the fishery management councils.

Reports that are produced following SAW/SARC meetings include: An *Assessment Summary Report* - a summary of the assessment results in a format useful to managers; an *Assessment Report* – a detailed account of the assessments for each stock; and the SARC panelist reports – a summary of the reviewer's opinions and recommendations as well as individual reports from each panelist. SAW/SARC assessment reports are available online at http://www.nefsc.noaa.gov/nefsc/publications/series/crdlist.htm. The CIE review reports and assessment reports can be found at *http://www.nefsc.noaa.gov/nefsc/saw/*".

The 51st SARC was convened in Woods Hole at the Northeast Fisheries Science Center, November 29 – December 3, 2010 to review benchmark stock assessments:
silver hake *(Merluccius bilinearis)*, red hake (*Urophycis chuss*), offshore hake (*Merluccius albidus)* and longfin inshore squid (*Loligo pealeii*). CIE reviews for SARC51 were based on detailed reports produced by NEFSC Assessment Working Groups. This Introduction contains a brief summary of the SARC comments, a list of SARC panelists, the meeting agenda, and a list of attendees (Tables 1 – 3). Maps of the Atlantic coast of the USA and Canada are also provided (Figures 1 - 5).

Outcome of Stock Assessment Review Meeting:

Based on the Review Panel reports (available at http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC 51 Panelist Reports"), the SARC review committee concluded that for **silver hake** none of the ASAP models that were examined provided a consistent assessment of the stock in either the northern (N) or southern (S) area. A key issue was whether to allow a domed selectivity assumption, which creates "cryptic" fish. The ASAP model requires improvement before it can serve as a basis for fishery management advice. In the absence of an accepted assessment model, it was not possible to perform multi-year projections. Work on factors affecting catchability across ages and years in the silver hake surveys is required to ensure that apparent mortality can be assigned to fishing, natural factors, changes in distribution or changes in survey catchability. Inclusion of consumption estimates provided perspective on the magnitude of fishery mortality. Based on newly recommended silver hake biological reference points overfishing is not taking place and the stocks are not overfished in the N or S areas.

The **red hake** assessment moved the understanding of the population and its fisheries forward considerably. Substantial exploratory work was carried out on the age-based data for the survey, fishery and predator consumption using the SS3 and SCALE models, but the diagnostics were not adequate for stock status determination or for provision of management advice. In the absence of an accepted assessment model as a basis for providing management advice, it was not possible to perform multi-year projections. Based on newly recommended red hake biological reference points overfishing is not taking place and the N and S stocks are not overfished.

This was the first time that an **offshore hake** assessment had been attempted. Although the Hake Working Group did a thorough job, the data are insufficient to complete an assessment. The major shortcoming is that the surveys are believed to cover an unknown and variable proportion of the stock. The Panel concluded that sufficient information is not available to determine stock status with confidence, because fishery data are insufficient and one cannot assume that survey data reflect stock trends. The Panel concluded that it is not possible at this time to provide a reliable definition for overfished and overfishing for this stock.

The majority of SARC panelists consider the ***Loligo*** assessment to be adequate for developing annual management advice as long as the exploitation rate stays low. The SARC accepted a newly proposed B_{MSY} proxy, but expressed concerns. During 2009, the *Loligo* stock was not overfished and overfishing was probably not occurring. No overfishing threshold has been recommended, which leaves overfishing status officially unknown. Better understanding of seasonal cohort recruitment, growth rate, mortality, catch and effort, might allow within-season or within-year management schemes.

CIE review reports can be found at http://www.nefsc.noaa.gov/nefsc/saw/ under the heading “SARC 51 Panelist Reports”.

Table 1. 51st Stock Assessment Review Committee Panel.

SARC Chairman (NEFMC SSC):

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Table 2. Agenda, 51st Stock Assessment Review Committee Meeting.

51st Northeast Regional Stock Assessment Workshop (SAW 51)
Stock Assessment Review Committee (SARC) Meeting

November 29 – December 3, 2010

Stephen H. Clark Conference Room – Northeast Fisheries Science Center
Woods Hole, Massachusetts

AGENDA (version: 24 Nov. 2010)

TOPIC	PRESENTER(S)	SARC LEADER	RAPPORTEUR

Monday, Nov. 29

8:45-9 AM			
Welcome	**James Weinberg**, SAW Chair		
Introduction	**J- J Maguire**, SARC Chair		
Agenda			
Conduct of Meeting			
9 - 11 Assessment Presentation (A. Silver hake)			
	Larry Alade	**TBD**	**M. Palmer**
	Jason Link		
	Steve Cadrin		
	(others)		
11- 11:15 Break			
11:15 - 12:30 SARC Discussion w/ presenters (A. Silver hake)			
	J- J Maguire, SARC Chair		**M. Palmer**
12:30 - 1:45 Lunch			
1:45 – 3:30 Assessment Presentation (C. Red hake)			
	Kathy Sosebee	**TBD**	**T. Wood**
	(others)		
3:30 – 3:45 Break			
3:45 – 5 SARC Discussion w/ presenters (C. Red hake)			
	J- J Maguire, SARC Chair		**T. Wood**

Tuesday, Nov. 30

9 - 11 Assessment Presentation (B. *Loligo*)			
	Larry Jacobson	**TBD**	**T. Chute**
	Lisa Hendrickson		
	Jason Link		
11 – 11:15 Break			

11:15 – 12:30	SARC Discussion w/ presenters (B. *Loligo*) **J- J Maguire**, SARC Chair		**T. Chute**
12:30 - 1:45	Lunch		
1:45 – 3:15	Assessment Presentation (D. Offshore hake) **Michele Traver (others)**	**TBD**	**J. Nieland**
3:15 - 3:30	Break		
3:30 - 4:45	SARC Discussion w/ presenters (D. Offshore hake) **J- J Maguire**, SARC Chair		**J. Nieland**

(Evening Social/Dinner at BBC 6:30)

Wednesday, Dec. 1

9 - 10:45	Revisit w/ presenters (A. Silver hake) **J- J Maguire**, SARC Chair	**Mike Palmer**
10:45 - 11	Break	
11 - Noon	Revisit w/ presenters (B. *Loligo*) **J- J Maguire**, SARC Chair	**Toni Chute**
Noon – 1:15	Lunch	
1:15 – 2	cont. Revisit w/ presenters (B. *Loligo*) **J- J Maguire**, SARC Chair	**Toni Chute**
2 – 3:45	Revisit w/ presenters (C. Red hake) **J- J Maguire**, SARC Chair	**T. Wood**
3:45 - 4	Break	
4 - 5:15	Revisit w/ presenters (D. Offshore hake) **J- J Maguire**, SARC Chair	**Julie Nieland**

Thursday, Dec. 2

8:30 - 11	Review/edit Assessment Summary Report (A. Silver hake) **J- J Maguire**, SARC Chair	**Mike Palmer**
11 – 11:15	Break	
11:15 – 12:15	Review/edit Assessment Summary Report (B. *Loligo*) **J- J Maguire**, SARC Chair	**Toni Chute**
12:15 - 1:30	Lunch	
1:30 – 2:30	cont. Review/edit Assessment Summary Report (B. *Loligo*) **J- J Maguire**, SARC Chair	**Toni Chute**

2:30 - 2:45 Break

2:45 – 4:15 Review/edit Assessment Summary Report (C. Red hake)
J- J Maguire, SARC Chair **T. Wood**

4:15 - 5:45 Review/edit Assessment Summary Report (D. Offshore hake)
J- J Maguire, SARC Chair **Julie Nieland**

Friday, Dec. 3

9:00 - 5:30 PM SARC Report writing. (closed meeting)

*All times are approximate, and may be changed at the discretion of the SARC chair. The meeting is open to the public, except where noted.

Table 3. 51st SAW/SARC, List of Attendees

Name	Affiliation	Email
James Weinberg	NEFSC	james.weinberg@noaa.gov
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Ayeisha Brinson	NEFSC	ayeisha.brinson@noaa.gov

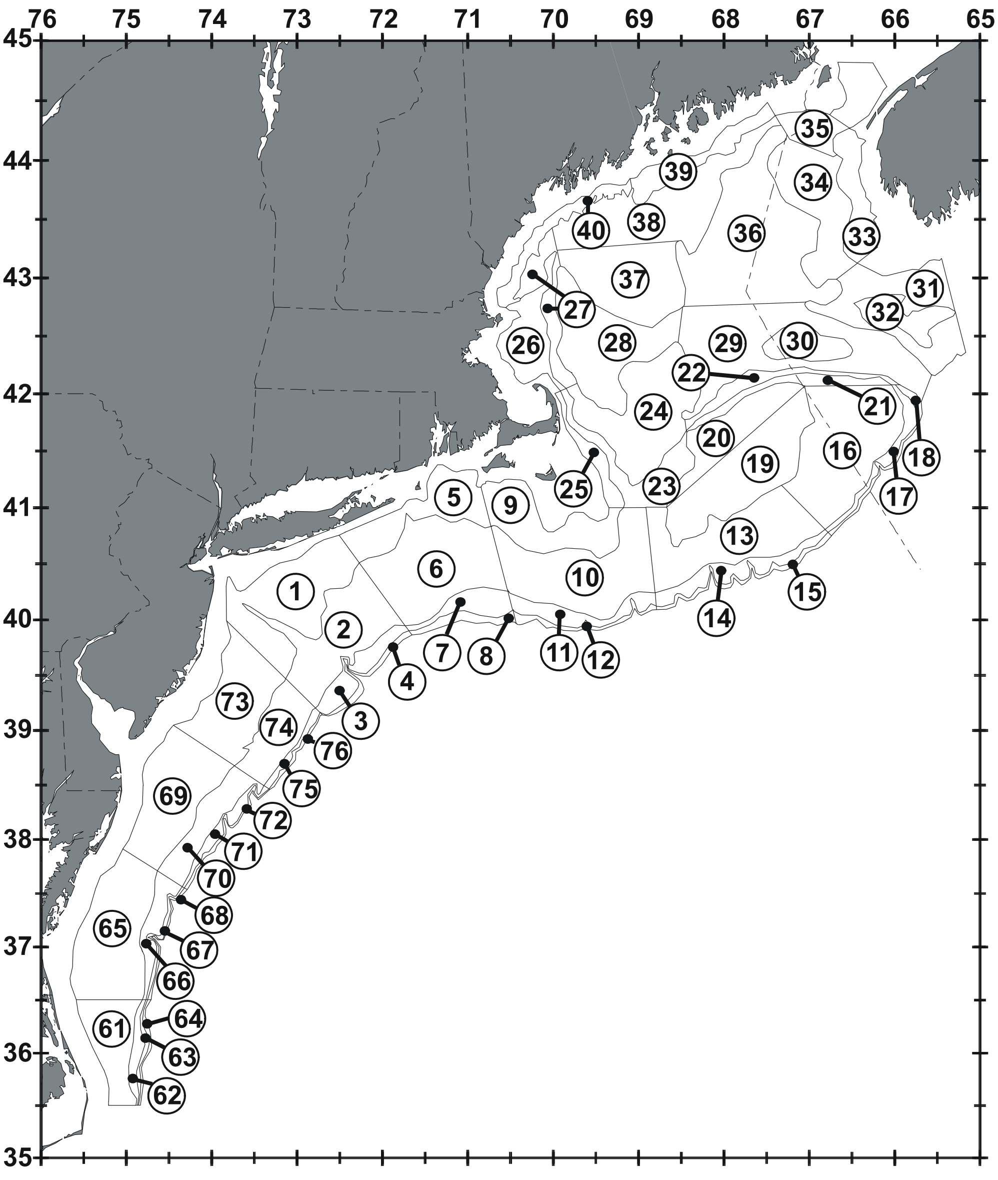

Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

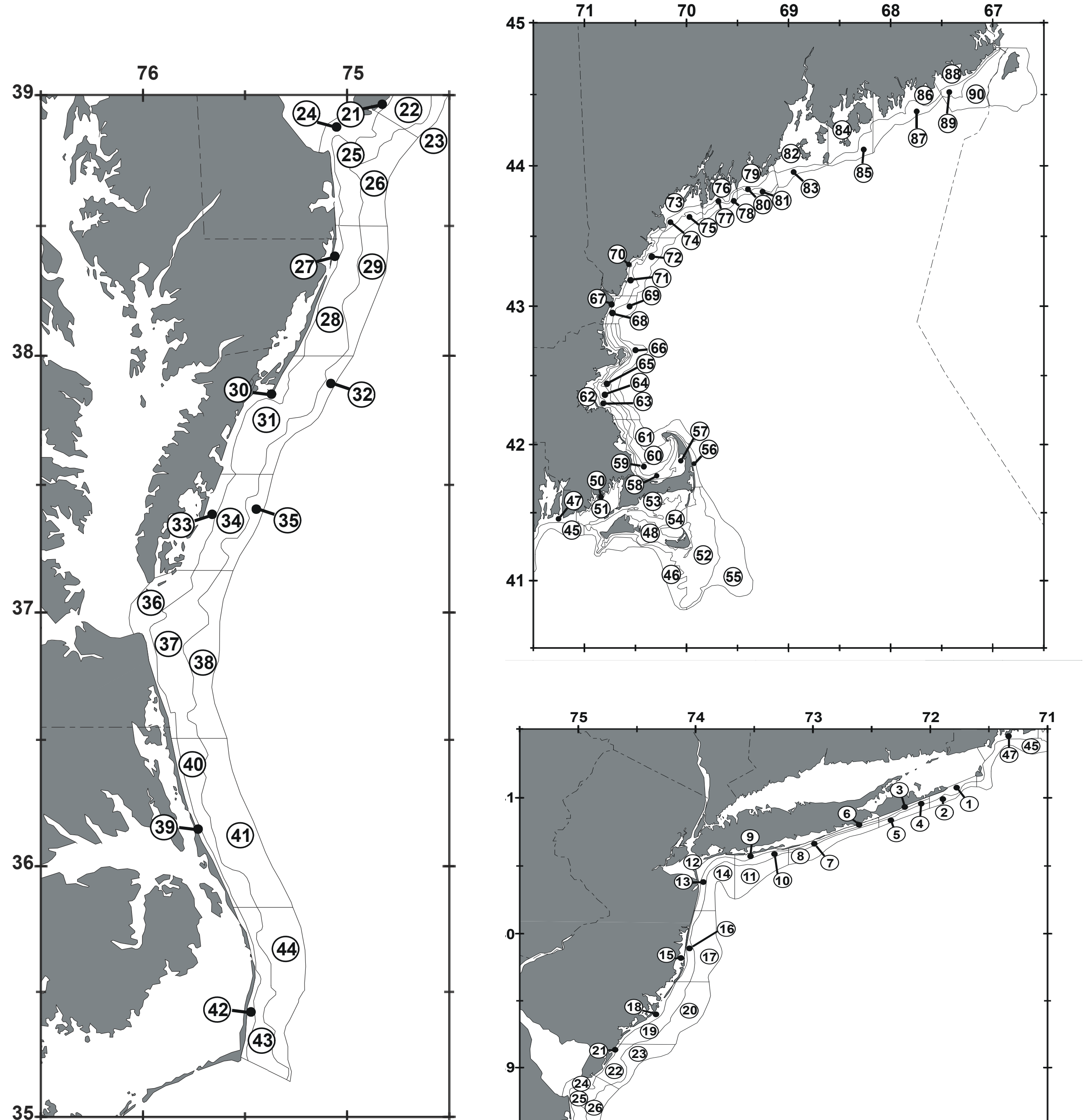

Figure 2. Inshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

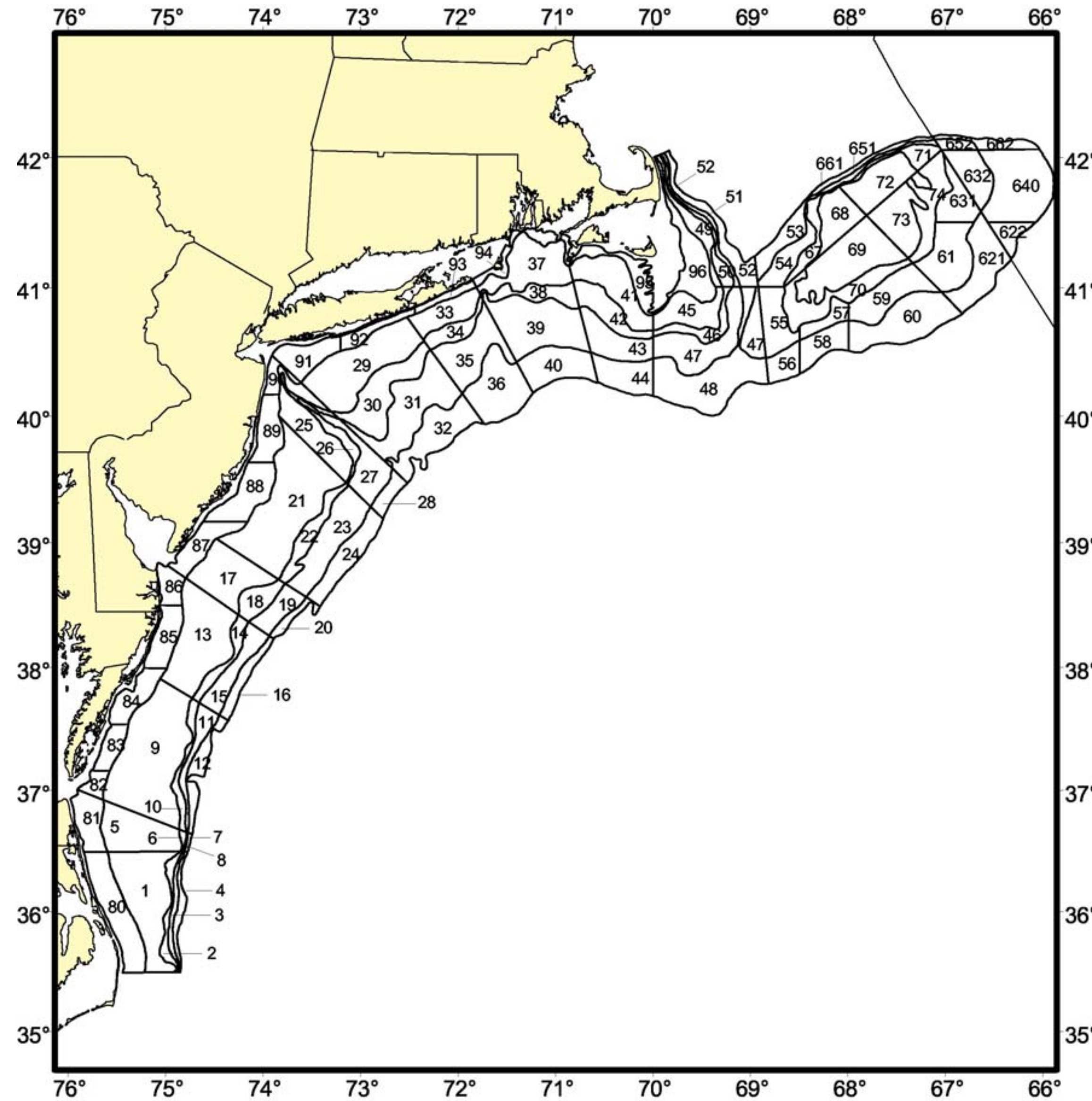

Figure 3. Depth strata sampled during Northeast Fisheries Science Center clam dredge research surveys.

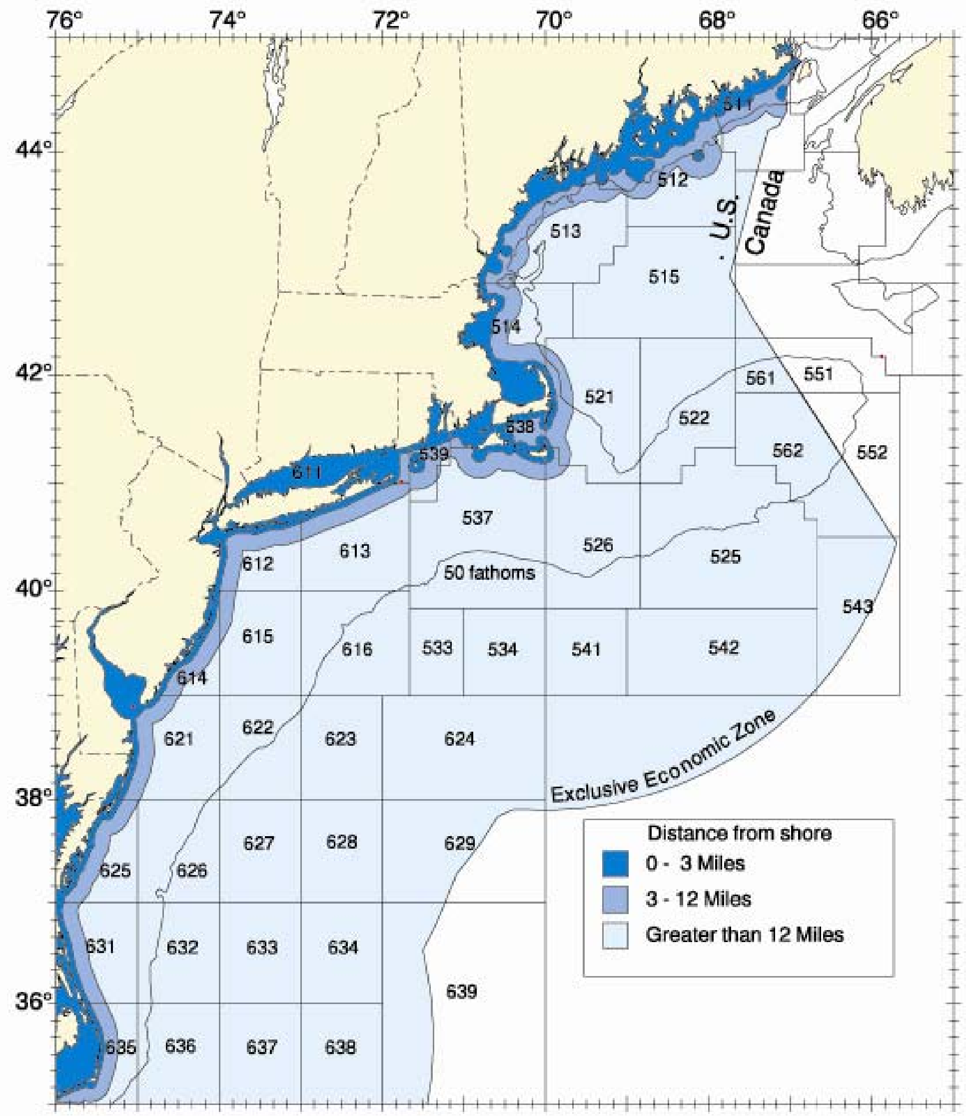

Figure 4. Statistical areas used for reporting commercial catches.

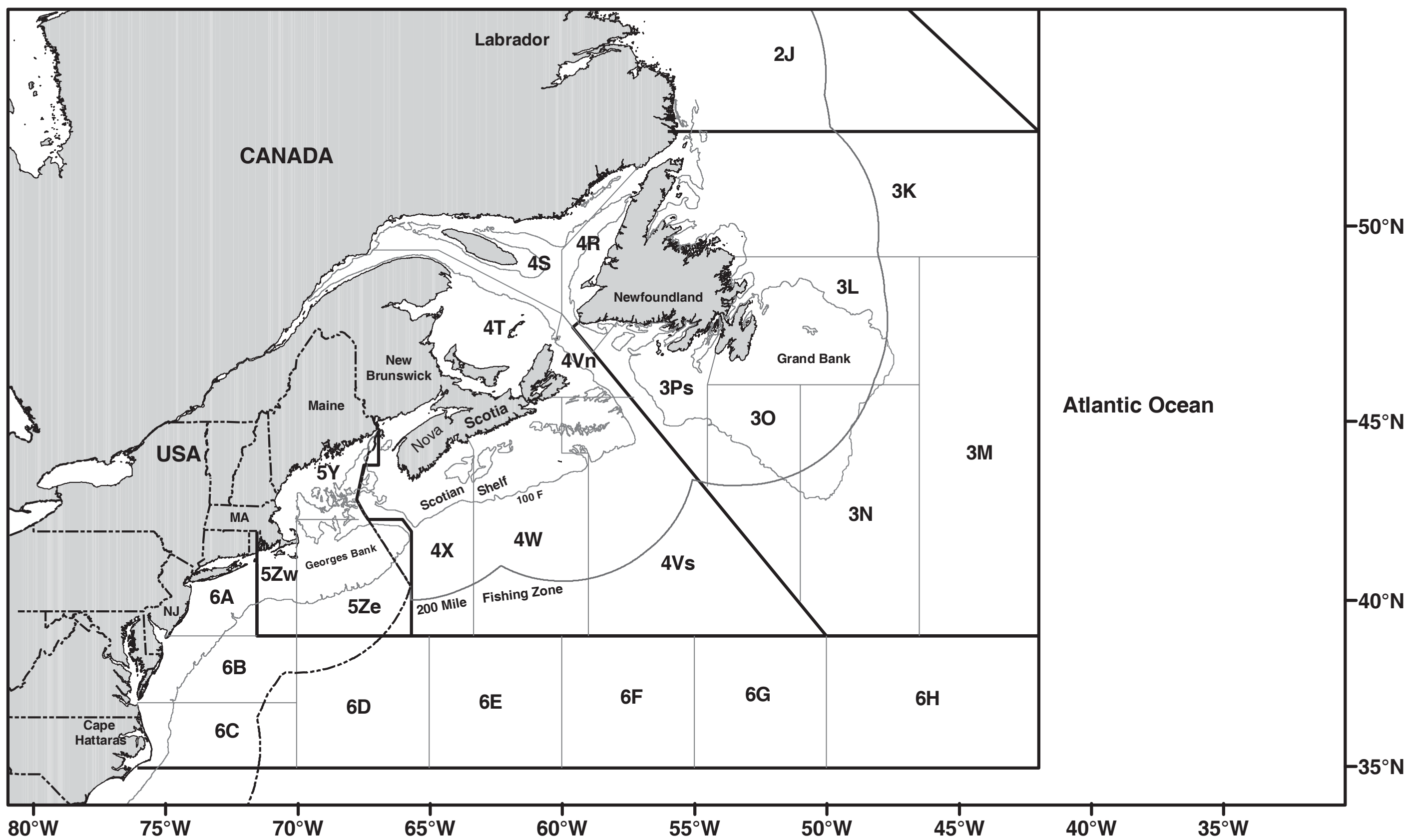

Figure 5. Catch reporting areas of the Northwest Atlantic Fisheries Organization (NAFO) for Subareas 3-6.

A. STOCK ASSESSMENT OF SILVER HAKE FOR 2010

Terms of Reference:

1. Estimate catch from all sources including landings, discards, and effort. Characterize the uncertainty in these sources of data, and estimate LPUE. Analyze and correct for any species mis-identification in these data.

2. Present the survey data being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, etc.). Characterize the uncertainty and any bias in these sources of data.

3. Evaluate the validity of the current stock definition, and determine whether it should be changed. Take into account what is known about migration among stock areas.

4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from Silver hake TOR-5), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results.
5. Evaluate the amount of silver hake consumed by other species as well as the amount due to cannibalism. Include estimates of uncertainty. Relate findings to the stock assessment model.

6. State the existing stock status definitions for “overfished” and “overfishing”. Then update or redefine biological reference points (BRPs; estimates or proxies for BMSY, BTHRESHOLD, and FMSY; and estimates of their uncertainty). If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the “new” (i.e., updated, redefined, or alternative) BRPs.

7. Evaluate stock status (overfished and overfishing) with respect to the existing BRPs, as well as with respect to the “new” BRPs (from Silver hake TOR 6).

8. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).

    a. Provide numerical short-term projections (3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).

b. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.
c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC

9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

Executive Summary

A new assessment model for silver hake (ASAP, Legault and Restrepo 1998) was attempted based on a "combined" (i.e. North + South) assessment area including estimates of fishery landings, discards, and predator consumption, by age class. While the SARC-51 Review Panel felt that the ASAP model represented an advance for the stock assessment, the ASAP results were not accepted due to difficulties in reconciling the inconsistent interpretations from the steep age profiles in the fishery and survey data. An Index Model (AIM) was also explored; however, the diagnostics were not adequate for stock status determination. Therefore, this assessment is based on trends in the three year moving averages for the age-aggregated, fall survey biomass indices (1973-1982) using the arithmetic means rather than the previous delta approach and the three year averages of exploitation indices (total catch/fall survey biomass index). These form the basis for the updated reference points for both the northern and southern management areas.

Based on the reference points in the existing FMP, silver hake is not overfished and overfishing is not occurring in both the northern or southern management areas. For the northern area, the three year delta mean biomass index from the NEFSC fall bottom trawl survey in Albatross units during 2007-2009 (6.79 kg/tow) was above the biomass threshold (3.31 kg/tow) and slightly above the biomass target (6.63 kg/tow). The three year average exploitation index (landings divided by survey biomass index for 2007-2009 (0.13) in the north was less than the exploitation threshold and target (2.57). In the southern area, the three year survey biomass index in Albatross units (1.39 kg/tow) was greater than the biomass threshold (0.89 kg/tow) but below the biomass target (1.78 kg/tow). The three year exploitation index for 2007-2009 (4.33) in the south was below the overfishing threshold (34.39) and target (20.63) .

Based on the updated and accepted reference points from SAW/SARC-51 in 2010, the northern stock of silver hake is not overfished and overfishing is not occurring. The three year arithmetic mean fall biomass index for 2007-2009 in Albatross units (6.20 kg/tow), was above the management threshold (3.21 kg/tow) but below the target (6.42 kg/tow). The three year average exploitation index for 2007-2009 (0.20 kt/kg) was below the management threshold (2.78 kt/kg). In the south, silver hake is also not overfished and overfishing is not occurring. The three year average arithmetic mean biomass, also based on the NESFC fall bottom trawl survey data for 2007-2009 in Albatross units (1.11 kg/tow), was above the biomass threshold (0.83 kg/tow) but below the target (1.65

kg/tow). The three year average exploitation index, for 2007-2009 (5.87 kt/kg) (Figure A9) was below the overfishing threshold (34.19 kt/kg)

Given that the ASAP model was not accepted as a basis for providing management advice, ASAP-based multiyear projections are not provided.

The scientific information available on silver stock structure (morphometrics, tagging, discontinuous larva distribution, homogeneous growth and maturity) is equivocal. Therefore, it was concluded that there was no strong biological evidence to support either a separate or combined silver hake assessment. The role of silver hake in the ecosystem was assessed using diet data. It was apparent that silver hake constitute an important link in the food web. Estimates of silver hake removals from the system from predatory based consumption suggest that consumption can be approximately 10 times higher than total catch. These consumption estimates were useful to inform both scaling of biomass estimates and the magnitude of mortalities for silver hake in the system.

Introduction

Hake Working Group Meetings

Three meetings were held in preparation of the 2010 silver hake assessment

1. Hake fishermen's/stakeholder's meeting – August 6, 2010 – UMASS School of Marine Science and Technology (SMAST), Fairhaven, MA. Participants include fishermen Dan Farnham and Bill Phoel. Also in attendance were David Goethel (Oversight Committee chair), Andrew Applegate (staff) Steve Cadrin (SSC and WG chair, SMAST), Pingguo He, Klondike Jonas, Yuying Zhang, Tony Wood, and Daniel Goethel (SMAST), Loretta O'Brien, Michele Traver, Katherine Sosebee and Larry Alade (NEFSC), and Dick Allen (advisor at large). A summary of the discussions is in Appendix A1.

2. Data Meeting – September 7-10, 2010, NEFSC Woods Hole MA. Participants included Steve Cadrin (WG Chair), Assessment leads (Larry Alade, Kathy Sosebee , Michele Traver), Rapporteurs (Jessica Blaylock and Julie Nieland), Mark Showell (DFO), Andy Applegate (NEFMC Staff), NEFSC (Loretta O'Brien, Mark Terceiro, Chris Legault, Tim Miller, Dave Richardson, Ayeisha Brinson, Jiashen Tang, Janet Nye, Mike Palmer, Paul Rago, Josef Idoine, Jon Hare), Moira Kelly (NERO), SMAST(Tony Wood, Yuying Zhang, Saang-Yoon Hyun)

3. Model Meeting – October 25-29, 2010, NEFSC, Woods Hole, MA. Participants included Steve Cadrin (WG chair), Assessment leads ((Larry Alade, Kathy Sosebee , Michele Traver), Rapporteurs (Jessica Blaylock and Julie Nieland), Mark Showell (DFO), Andy Applegate (NEFMC Staff), Dan Farnham (Fisherman and Industry Advisor), NEFSC (Loretta O'Brien, Paul Nitschke, Mark Terceiro, Jay Burnett, Chris Legault, Liz Brooks, Tim Miller, Jon Deroba, Rich McBride, Jim Weinberg, Paul Rago, Josef Idoine, Jon Hare, Janet Nye, Dave Richardson, Laurel Col, Jason Link), SMAST(Tony Wood, Yuying Zhang, Dan

Goethel). The groups met by correspondence after the meetings, including a WebEx meeting on November 5, 2010 to report updates on silver hake analyses, provide guidance on reference points and discuss plans for report development.

This Working Group (WG) report includes products from all three meetings and contributions from all participants. It also has edits which reflect the outcome of the SAW/SARC51 peer review.

Biology

Silver hake also known as whiting, *Merluccius bilinearis* range from Newfoundland to South Carolina. In U.S. waters, silver hake are managed as two separate stocks (Almeida 1987a). The northern silver hake stock inhabits Gulf of Maine - Northern Georges Bank waters, and the southern silver hake stock inhabits Southern Georges Bank - Middle Atlantic Bight waters (Figure A1). Silver hake migrate in response to seasonal changes in water temperatures, moving toward shallow, warmer waters in the spring. They spawn in these shallow waters during late spring and early summer and then return to deeper waters in the autumn (Brodziak et al. 2001). The older, larger silver hake especially prefer deeper waters. During the summer, portions of both stocks can be found on Georges Bank, whereas during the winter, fish in the northern stock move to deep basins in the Gulf of Maine, while fish in the southern stock move to outer continental shelf and slope waters. Silver hake are widely distributed, and have been observed at temperature ranges of 2-17° C (36-63° F) and depth ranges of 11-500 m (36-1,640 ft). However, they are most commonly found between 7-10º C (45-50º F) **(**Lock and Packer 2004).

Female silver hake are serial spawners, producing and releasing up to three batches of eggs in a single spawning season (Collette and Klein-MacPhee eds. 2002). Major spawning areas include the coastal region of the Gulf of Maine from Cape Cod to Grand Manan Island, southern and southeastern Georges Bank, and the southern New England area south of Martha's Vineyard. Peak spawning occurs earlier in the south (May to June) than in the north (July to August). Over one-half of age-2 fish (20 to 30 cm, 8 to 12 in.) and virtually all age-3 fish (25 to 35 cm, 10 to 14 in.) are sexually mature. Silver hake grow to a maximum length of over 70 cm (28 in.) and ages up to 14 years have been observed in U.S. waters, although few fish older than age 6 have been observed in recent years (Brodziak et al. 2001).

Fishery Regulations

The following briefly outlines the current small mesh multispecies regulations (based on the small mesh exemption program) for the New England whiting fishery to provide context for interpreting the fishery and model results.

1. 1994 & 2000 - Exempted fisheries allows vessels to fish for specific species such as whiting or northern shrimp in designated areas using mesh sizes smaller than the minimum mesh size allowed (Gulf of Maine, Georges Bank, Southern New England, Mid-Atlantic : 6.5-inch square or diamond) under the Regulated Mesh Area (RMA) regulations .
2. Permits

    a. Open access Category K Multispecies
    b. Limited Access Category A-F (non Days-at-Sea fishing)
3. No Size Limits
4. 500 lbs at sea transfer limit.
5. 2003 - Possession limits vary by exemption area
    a. 3,500 lbs if mesh < 2.5 inches (63.5mm)
    b. 7,500 lbs if mesh <=3.0 inches (76.2mm)
    c. 30,000 lbs if mesh > 3.0 inches (76.2mm)
    d. No Red Hake possession limit

TOR 1. Estimate catch from all sources including landings, discards, and effort. Characterize the uncertainty in these sources of data, and estimate LPUE. Analyze and correct for any species mis-identification in these data.

Commercial Landings

Silver hake landings (Tables A1, Figures A2-A4) increased substantially during the 1960's due to direct fishing by distant water fleets (DWF) operating in the U.S. waters. Nominal landings of silver hake from the northern stock were significantly higher than those from the southern stock during the mid-1950's through the mid-1960's and fell below the southern stock starting in the late 1960's due to the expansion of the DWF in the southern region. Landings in the north peaked to over 94,000 mt in 1964 and have steadily declined substantially since 1975. Despite the departure of the DWF in 1976, landings continue to further decline and have been less than 10,000mt per year after 2002 (Table A1, Figure A3).

Nominal domestic landings from the southern silver hake stock have varied between 5,000-27,000 mt, (Table A1, Figure A4). However, between 1960 and 1980, distant-water fleet landings of southern silver hake were very high, peaking at about 280,000 mt in 1965 and around 100,000 mt in 1974. Distant-water fleet landings diminished in the mid-1980s, and total landings have since continued to gradually decrease. In 2009, total landings were near a historic low at 7,000 mt.

Maine and Massachusetts have been the primary states in which silver hake from the northern stock have been landed (Table A2). Rhode Island became important in the 1980s and Connecticut in the 1990s. For landings of the southern stock, Rhode Island and Massachusetts were historically important, with New York, New Jersey and Connecticut increasing in importance (Table A3).

The otter trawl has been the principal gear used in the both stocks with some landings in the northern stock coming from the shrimp trawl fishery until the early 1990s with the use of the Nordmore grate (Tables A4-A5, Figures A5-A6). In recent years, sink gill net has increased slightly in importance, although there are significant landings from the other category, which includes unknown gears.

The seasonality of landings from the two stocks is different, with most of the northern stock landings occurring in the second half of the year and the first half of the year accounting for a approximately less than 20% of the annual. Landings from the southern stock appear to be landed more consistently throughout the year than in the north (Tables A6-A8, Figures A7-A8).

Silver hake are landed in seven commercial categories: unclassified round, medium, small, dressed, juvenile, king and large. The vast majorities of landings are reported as round or dressed market category, with other market categories appearing sporadically over time (Tables A9-A10, Figures A9-A10). King silver hake were separated starting in 1981, with smalls appearing in 1982. Large silver hake were further separated in 2004. A juvenile market category appeared in 1994 and was a larger component of the southern stock landings (Tables A9-A10, Figures A11-A12).

A sympatric species of hake, offshore hake, is often landed as silver hake (Garcia-Vazquez et al 2009). In 1991, landings of offshore hake began to be separated, although the extent to which this is actually occurring is still unknown. The geographical distribution of offshore hake is limited to the southern stock of silver hake. Therefore, landings from the northern stock are considered to be silver hake while southern landings are potentially a mixture of silver and offshore hake. In order to estimate landings of silver hake from the southern region, two alternative methods were developed.

Length-based species composition

The first method used the port length samples directly. Length samples of silver and offshore hake were combined by stock (Tables A11-A13). In examining the silver hake length samples by market category, it appeared that most of the market categories were similar in length composition to the round category (Figures A11-A12). Therefore, only three market categories were used for stratification: round, king, and large. Even with the reduction of market categories, pooling over years was required to get an adequate number of fish (Table A14). The length-weight equations by season from Wigley et al 2003 were applied to the samples and used to estimate the landings numbers at length for each market category.

For the southern stock, length compositions for each species were estimated for the spring and fall surveys from 1968-2009. The species length-weight equations were then applied to determine weight-at-length by species. The proportions at length by species for both number and weight were applied to the commercial landings-at-length to estimate landings-at-length by species (Figures A13-A14). The lengths had to be grouped into intervals to avoid zero cells in the survey. To hind-cast the species proportions back to 1955, the average proportion of silver hake for the time series was used and applied to the total silver hake landings.

Depth-based species composition

This method relates survey catch composition to Vessel Monitoring System (VMS) derived commercial landings from 2004-2009 using survey depth as an explanatory factor to develop a model that predicts the hake species landings composition. Offshore and silver hake composition (R_{23}) in the trawl survey tows were modeled as a two parameter logistic function of average depth. Only survey tows with silver hake, offshore hake or both were fitted and mean depth was the dependent variable.

$$R_{23} = \frac{e^{a+b*depth}}{1+e^{a+b*depth}}$$

For each stratum group, survey (winter, spring, and fall), and sets of time series, the catch and depth data were fitted by a non-linear least squares, weighted by the number of positive tows in a stratum, using the Marquardt method (Marquardt 1963) to aide convergence. R^2 and Wald 95% confidence intervals (Cook and Weisberg 1990) were calculated for parameters a, b, D50, and the range to evaluate goodness of fit. Fitting the data with the a two parameter logistic non-linear regression using maximum likelihood estimation and iteratively reweighted least squares approaches was attempted, but did not improve the results.

The parameter estimates for 1985-2009 were applied to the depth association with the VMS-derived commercial landings at depth (Applegate 2010). The model ratio of offshore to silver hake were assigned to landings from each group depth zone, survey season, and survey stratum group and summed for the calendar year (Applegate 2010). The final landings from this method were greater than 90% of the total landings reported by dealers in 2004-2009.

Annual model estimates of silver hake landings for the southern stock area ranged from 4,207 – 6566 mt in 2003-2009, representing 88-95% of the total hake landings **(Table A15)**. Although the depth based landings were derived from VMS effort distribution, hindcast estimates were used for 2003 because the model based estimates appeared to be biased due to small vessels (i.e. fished inshore and catch silver hake) were underrepresented when multispecies VMS requirements first became effective.

Estimates of offshore hake landings ranged between 290 – 893 mt and 5 – 12% of total hake landings **(Table A15)**. These estimates are considerably higher than those reported by either dealers or by fishermen on Vessel Trip Reports (VTR).

Given that VMS data for 2004 – 2009 were deemed acceptable for direct estimation of silver and offshore hake landings composition, landings prior to 2004 (1955 – 2003) were hindcasted to generate longer time series of removal for assessments and for developing biological reference points. Although the hindcast procedure allowed the distribution of catch to vary between statistical areas, the distribution of catch <u>within</u> these intermediate depth statistical areas was assumed to be constant, equal to the average depth distribution observed by VMS during 2004-2009. Details of the hindcasting methodology can be found in Applegate (2010).

The estimated silver hake landings from the depth based logistic model, including the hindcasting, rose from a low of 12,891 mt in 1955 (93% of the total) to over 282,000 mt in 1990 (92% of the total), then declined to 4207 mt in 2006 (90% of the total). Recent landings totaled 5,006-6,406 mt (93 - 95%). Silver hake as a proportion of total hake landings ranged from 87% in 1971, 1976, 1978-1980 to 98% in 1988 and 1996 (Table A16).

Hindcast and model based estimates of offshore hake landings were an order of magnitude greater than that reported by dealers. Landings rose from 951 mt in 1955 (7.0% of the total) to 24,198 mt in 1965 (8% of the total). Offshore hake as a proportion of total hake landings ranged from 2% in 1971, 1976, 1978-1980 to 13% in 1988 and 1996 (Table A16).

The resulting silver hake landings for the two methods are given in Table A15. On average, the two methods gave similar results, with the length-based model averaging 96% silver hake while the depth-based method averaged 94% silver hake. Conversely, there were some differences in the offshore hake estimates with the depth based method averaging approximately 7% and 4% for the length-based method (Table A16, Figure A15).

Given the similarity between both models, the SARC Panel agreed that the results from both methods will have undetectable differences in the assessment results. For the purpose of this assessment, the length-based estimator was considered more suitable primarily due to the number of years hindcasted (1955-1967) relative to the depth-based approach (1955-2003). It was also recognized that the length based approach provided an advantage of estimating fishery age composition which was not readily available in the depth-based method. .

Sampling Intensity

The level of port sampling has generally been strong since the mid-1990's with higher sampling in the south relative to the north. In 2007, over 17,000 length measurements were taken in the southern area resulting in peak sampling intensity of 326 lengths per 100 mt. In the north sampling intensity increases substantially in 2006 and 2007 (115 and 107 lengths per mt respectively). In the recent years, sampling intensity has somewhat declined in both stock areas but more substantially in the north due to very low observed landings (Table A17). Overall, sampling intensity for the silver hake fishery has certainly improved compared to pre-1994 period, particularly in the south.

Commercial Discards

Discard estimates were re-calculated in this assessment. The ratio-estimator used in this assessment is based on the methodology described in Rago et al. (2005) and updated in Wigley et al (2007). It relies on a d/k ratio where the kept component is defined as the total landings of all species within a "fishery". A fishery is defined as a homogeneous group of vessels with respect to gear type (longline, otter trawl, shrimp trawl, sink gill net, and scallop dredge), quarter, and area fished (GOM-NGBK, SGBk-MA), and for otter trawls, mesh size (<= 5.49", > = 5.5 "). All trips were included if they occurred within this stratification regardless of whether or not they caught hakes.

The discard ratio for hakes in stratum h is the sum of discard weight over all trips divided by sum of kept weights over all trips:

$$\hat{R}_h = \frac{\sum_{i=1}^{n_h} d_{ih}}{\sum_{i=1}^{n_h} k_{ih}} \quad (1)$$

Where d_{ih} is the discards for hakes within trip i in stratum h and k_{ih} is the kept component of the catch for all species. R_h is the discard rate in stratum h. The stratum weighted discard to kept ratio is obtained by weighted sum of discard ratios over all strata:

$$\hat{R} = \sum_{h=1}^{H} \left(\frac{N_h}{\sum_{h=1}^{H} N_h} \right) \hat{R}_h \quad (2)$$

The total discard within a strata is simply the product of the estimate discard ratio R and the total landings for the fishery defined as stratum h, i.e., $D_h = R_h K_h$. Cells with < three trips were imputed using annual averages by gear type and region. To hind-cast the discards to 1981 (the first year in which there was no industrial fishery), discards/total landings by half year for the first three years (1989-1991 for otter trawl, sink gill net, and shrimp trawl; 1992-1994 for longline and scallop dredge) were averaged and the rate applied to the total landings from the dealer database. For the otter trawl fisheries, the mesh sizes were combined for the hind-cast.

Discards from the longline and sink gill net fishery were minimal for silver and offshore hake in both stock areas (Table A18-A21). Discards from the otter trawl fisheries have been significant and variable.

The same problem with species identification that exists in the landings was found in the Fisheries Observer Program (FOP) data. There are discards of offshore hake estimated for the north. The geographical distribution of offshore hake is limited to the southern stock of silver hake and therefore, any discards from the northern stock are considered to be silver hake. In order to estimate discards of silver hake from the southern region, only the length-based estimator was employed.

The observer discard length samples of silver and offshore hake were combined by stock (Tables A22-A25). Enough length samples were available for large and small mesh otter trawls in both regions and sink gill net and shrimp trawl in the north. Pooling over years was still required to get an adequate number of fish (Tables A26-A27). The length-weight equations by season from Wigley et al 2003 were applied to the samples and used to estimate the landings numbers at length for each market category. The discards-at-length were raised to the total discards including all the gear types to account for as much of the removals as possible.

For the southern stock, length compositions for each species were estimated for the spring and fall surveys from 1968-2009. The species length-weight equations were then applied to determine weight-at-length by species. The proportions at length by species for both number and weight were applied to the commercial discards-at-length to estimate discards-at-length by species. The lengths had to be grouped into intervals to avoid zero cells in the survey. To hind-cast the species proportions back to 1981, the average proportion of silver hake for the time series was used and applied to the total silver hake discards.

Silver hake discards in the north were approximately 23% of the total catch in years 1981-2009 (Tables A28-A30). Total discards peaked to over 2,900mt in 1982, declined substantially in 1993 to a low of 37mt in 2006 and increased 14% from 2008 (167mt) to 2009 (190mt). In the south, the proportion of discards to total catch in years 1981-2009 was similar to the north (22%), peaked in 1989 (~6500mt), declined substantially in the mid 1990's with a brief increase in 1999 to levels observed in the early 1980's (3500mt). Total discards of silver hake in the south decreased 19% from 2008 (1033mt) to 2009 (839mt).

Catch at age

Due to the lack of commercial age data from the commercial fishery, age compositions for landings and discards were derived from the NEFSC bottom trawl survey age-length keys (ALK) from 1973-2009. Commercial length for both landings and discards frequencies were estimated by half years from the length-based estimator as described above. The silver hake age-length keys were then calculated for both the fall and spring then applied to the length-based landings (1973-2009, Tables A31-A33) and discards (1981-2009, Tables A34-36) by half years (i.e. spring ALK for the half 1 and fall ALK for half2) to capture seasonal differences in the fishery. The fall age-length keys were not available for fall 1974. Therefore adjacent age-length key from 1973 were borrowed to impute commercial landings at ages for half 2 based on minimal differences observed in the mean size at age in the fall survey during the early 1970's.

The catch at age composition of silver hake catches in the fishery has shown a general truncation in the age structure since the late 1980's with fewer availability of fish older than age-6 in the population (Tables A37-A39, Figures A16-A18). In the north, vast majority of the catches were dominated by ages 2-4 in the 1970's, partly supported by the strong 1972 year class. By the early 1980's, ages 2 and 3 declined severely but remained stable through the late 1980's. There were a few strong year classes around the 1990's contributing to moderate expansions in ages 2 and 3. Age-4 continues to decline with further reductions in age-5 in the fishery. However, it appears that there was a 2006 year class which appears to have contributed to the increase in age 3 in 2009 (Table A37, Figure A16).

Similarly in the south, majority of the catches were also dominated by ages 2-4 in the 1970's, supported by the 1972 year class but declined drastically around the early 1980's with moderate expansions in ages 2 and 3 during the 1990's. The age-4 group continues to decline with further truncation in the age structure. However, there have been increased catches of age-1 during the early 1990's probably and recently in the last five years. This is probably due to increased demand for small hake in the Spanish market (comm. Andy Applegate) in the 1990's and more recently, probably related to over the side bait sales (Table A38, Figure A17).

Summary of the combined stock area catches are summarized in Table A39 and in Figure A18. The perception of the age structure does not change relative to the north and south. Similar properties such observed in the north and southern areas such as the truncation of older fish and the dominance of ages 2 and 3 in the recent years still persists.

Mean Weights at age

The overall fishery weights at age were calculated from the landings and discards weighted by the respective catch at age for the north, south and combined area stock. (Tables A40-A42, Figures A19-A21). The mean weight at age (kg) were quite similar but variable between for fish greater than age-4 particularly since the mid 1980's. Only slight variations in mean weights at age were apparent during the mid 1990's - mid 2000's which are likely related to variations in year class strength as they become recruited to the fishery.

Commercial Fishing Effort

There are currently no estimates of CPUE or effort for this species. Given the uncertainties given with species identification above and the major changes in management noted in the introduction, CPUE is not likely to be a good indicator of stock status. In particular, the fishery in the north has been limited in areas they can fish with small mesh. These are not necessarily to good silver hake fishing areas. Over time, the fishery has also changed from one dominated by a distant water fleet that took substantial quantities of everything to a much smaller fishery that may be driven more by prices and regulation than abundance.

TOR 2. Present the survey data being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, etc.). Characterize the uncertainty and any bias in these sources of data.

Data Source: The primary sources of biological information for silver hake are based on the annual fishery independent surveys conducted by the Northeast Fisheries Science Center (NEFSC). The surveys were conducted using a random stratified sampling design which allocates samples relative to the size of the strata, defined by depth. The surveys extend from the Gulf of Maine to Cape Hatteras, in offshore waters at depths 27-365 meters, and have been conducted in the fall since 1963 and in the spring since 1968. The winter bottom trawl survey began in 1992 and was specifically designed for flatfish, however, the deeper survey strata were not sampled until 1998 (Figure A22). The winter trawl survey does not cover the Georges Bank area because the survey was designed specifically for flatfish in the southern region. Details on the stratified random survey design and biological sampling methodology may be found in Grosslein (1969), Azarovitz (1981) and Sosebee and Cadrin (2006). Other surveys used in the analysis of silver hake are NEFSC shrimp survey (1985-2009), Massachusetts Division of Marine Fisheries (1978-2009) fall and spring surveys and Rhode Island (1979-2010), Connecticut (1984-2009), and Maine-New Hampshire (2000-2009) state surveys.

Transform: Survey estimates were computed using both delta transformation and arithmetic means for numbers and weight. The Whiting Plan Development Team (PDT) has used the delta mean for assessing stock status. The delta transformation uses only the positive tows for log transformation given the following equation (syrjala 2000):

$$\hat{M}_{\delta} = \begin{cases} \dfrac{m}{n} e^{\bar{y}} \psi_m\left(\dfrac{1}{2} s_y^2\right) & m > 1, \\ \dfrac{1}{n} x_1 & m = 1, \\ 0 & m = 0 \end{cases}$$

$m =$ number of non - zero tows

$n =$ total number of tows

$$\hat{V}_{\delta} = \begin{cases} \dfrac{m}{n} e^{2\bar{y}} \left[\psi(2s_y^2) - \dfrac{m-1}{n-1} \psi_m\left(\dfrac{m-2}{m-1} s_y^2\right)\right] & m > 1, \\ \dfrac{1}{n} x_1^2 & m = 1, \\ 0 & m = 0 \end{cases}$$

Examination of the differences between the delta and arithmetic means revealed that use of the delta transformation did not reduce the variability of the survey and may have increased interannual variability (See offshore Hake assessment). If a survey has a high variance, the back-transformation may be biased high. The delta transformation was also more sensitive to the handling of missing weights. Prior to 2001, the data for weights were recorded to the nearest 0.1 kg and if a tow contained only a single small fish, the weight was entered into the data as zero. Since the delta transform uses the positive tow, how this is handled has an impact on the result. There were three options: taking out the zeros, leaving in the zeros, and filling in zeros using a length-weight equation. Since these options did not affect the arithmetic as much as the delta mean, the decision was made to use the arithmetic and length-weight options for any new analyses.

Several surveys were explored to provide indices of relative abundance. The properties of each survey are summarized in Table A43. Based on the stock definition provided in TOR 3, survey indices for the assessment was based on data from all strata that have been sampled consistently (NEFSC fall and spring survey). However, future work will explore other surveys as sensitivity analyses in the assessment.

The NEFSC strata set used for the northern area are: 20-30 and 36-40. The NEFSC strata used for the southern management area are: 1-19 and 61-76. The combined strata set are: 1-30, 36-40, and 61-76 (Figure A22). Survey age composition were estimated for the north, south and combined areas from 1973-2009 for when survey ages were available. Of special note, fall 1974 was never aged for both the north and south regions, and therefore age-length key from 1973 was borrowed to impute ages for 1974. As discussed earlier, the mean size at age for both years were similar. The 2009 and 2010 survey values were calibrated to the Albatross IV by using seasonal length-based calibration coefficients. Details on the estimation of the calibration coefficients may be found in Miller et al. 2010. The strata set for the shrimp survey is 1-12, with no calibration needed for 2009. The strata set for the winter surveys are: 1-3, 5-7, 9-11, 13-14, 61-63, 65-67, 69-71, and 73-75. No calibration was also needed for the winter survey, as it was discontinued in 2007. Massachusetts Division of Marine Fisheries data was separated into northern and southern areas. The northern strata set used were 18-36 and the southern strata set used were 11-17 (Figure A23).

Minimum swept area abundance and biomass were calculated by using swept area conversions of 0.0112 for the NEFSC fall and spring surveys, 0.004 for NEFSC shrimp survey, 0.0131 for the NEFSC winter survey, and 0.003846208 for Massachusetts Division of Marine Fisheries (MADMF) fall and spring surveys. Swept area estimates were not calculated for the other state surveys. Swept area estimates at age were also calculated for the NEFSC fall and spring surveys, in the northern, southern, and combined management areas.

Silver hake survey distribution suggests that most of the higher catches for silver hake are in the Gulf of Maine and on Georges Bank in the fall, whereas they are along the shelf edge in the spring. In the spring of the 1970s, most of the silver hake seemed to be in the Gulf of Maine and southern New England, with few on Georges Bank. However, even though the areas did not change through the 1980s and 1990s, the density did. It seems a bit scarcer during this time period. In the fall, there seems to be more silver hake on Georges Bank than in the spring, though most of the catch weight is in the Gulf of Maine (Figures A24-A35).

Calibration: In 2009 the *NOAA* ship *Henry B. Bigelow* replaced the *R/V Albatross IV* as the primary vessel for conducting spring and fall annual bottom trawl surveys for the Northeast Fisheries Science Center (NEFSC). There are many differences in the vessel operation, gear, and towing procedures between the new and old research platforms

(NEFSC Vessel Calibration Working Group 2007). To merge survey information collected in 2009 onward with that collected previously, we need to be able to transform indices (perhaps at size and age) of abundance from the *Henry B. Bigelow* into those that would have been observed had the *Albatross IV* still been in service. The general method for merging information from these two time series is to calibrate the new information to that of the old (Pelletier 1998).

Specifically we need to predict the relative abundance that would have been observed by the *Albatross IV* ($\hat{R}_A$) using the relative abundance from the *Henry B. Bigelow* (R_B) and a "calibration factor" (ρ),

$$\hat{R}_A = \rho R_B . \tag{1}$$

To provide information from which to estimate calibration factors for a broad range of species, 636 paired tows were conducted with the two vessels during 2008. Paired tows occurred at many stations in both the spring and fall surveys. Paired tows were also conducted during the summer and fall at non-random stations to improve the number of non-zero observations for some species. Protocols for the paired tows are described in NEFSC Vessel Calibration Working Group (2007).

The methodology for estimating the calibration factors was proposed by the NEFSC and reviewed by a panel of independent scientists in 2009. The reviewers considered calibration factors that could potentially be specific to either the spring or fall survey (Miller et al. 2010). They recommended using a calibration factor estimator based on a beta-binomial model for the data collected at each station for most species, but also recommended using a ratio-type estimator under certain circumstances and not attempting to estimate calibration factors for species that were not well sampled. In the case of offshore hake, using silver hake calibration factors as a proxy was better than not using any calibration factors.

Since the review, it has become apparent that accounting for size of individuals can be necessary for many species. When there are different selectivity patterns for the two vessels, the fraction of available fish of a given size taken by the two gears is different. Therefore, the ratio of the mean catches by the two vessels will change with size. Under these circumstances, the estimated calibration factor that ignores size reflects an average ratio weighted across sizes where the weights of each size class are at least in part related to the number of individuals at that size and the number of stations where individuals at that size were caught. Applying calibration factors that ignore size effects to surveys conducted in subsequent years when the size composition is unchanged should not produce biased predictions (eq. 1). However, when the size composition changes, the frequency of individuals and number of stations where individuals are observed at each size changes and the implicit weighting across size classes used to obtain the estimated calibration factor will not apply to the new data. Consequently, the predicted numbers per tow that would have been caught by the *Albatross IV* will be biased.

For silver hake, we fit a suite of beta-binomial models that made different assumptions on the relationship of the calibration factor to length. The models ranged from those that were constant with respect to length to logistic and double-logistic functions of length. A season-specific model was chosen based on AIC_c for silver hake where a logistic functional form for the spring and a double-logistic form for the fall provided the best fit (Table A44, Figure A36). To estimate weight per tow for the 2009 and 2010 surveys, the length-weight equations by season from Wigley et al. 2003 were applied to the length frequencies.

North Survey trends:
The NEFSC fall survey biomass steadily increased continuously through the 1970s, peaked in 1998 at 40,462 metric tons and then declined to 3,672 metric tons in 2005, lowest in the time series. Biomass has increased in the last few years and is currently at 14,748 metric tons, a 31% increase from 2008 (11,285 mt; Table A45, Figure A37).

The NEFSC spring survey has been quite variable. There was a large peak in 2001, with 22,309 mt and then considerably declined until 2006, with 915 mt. Since then,the biomass has increased and estimated at 5,673 mt in 2009 (Table A46, Figure A38).

The NEFSC shrimp survey swept area biomass was at its highest early in the time series, in 1987 with 149,508 metric tons. It dropped substantially to 16,302 metric tons in 1988. The survey continued to vary until thereafter, then declined to an all time low of 9,501 metric tons in 2006. Biomass in 2009 was 16,239 mt, a 42% decrease from 2008 (27,980 mt) (Table A47, Figure A39).

The MADMF fall surveys indicate two large spikes in silver hake swept area biomass, 1986 and 2000, with over 2,000 mt. The most recent years have seen a decrease, with 2009 only catching 651 mt (Table A48, Figure A40).

The MADMF spring surveys have much lower values than the fall. Only in 1987 and 2000 were there over 1,000 mt caught. In 2004, the spring survey saw its lowest catch of silver hake in the time series, with only 47 mt. It has since increased to 225 mt in 2009 (Table A49, Figure A41).

The MENH fall survey has been variable without trend but the spring survey peaked in 2002 at approximately 12 kg/tow, declined sharply in 2006 to 1.6 kg/tow and has steadily increased in the last three years (Table A50, Figures A42-A43).

North Age Composition: Fall survey age composition shows a general truncation of older age fish with less availability of fish older than age 6. Ages-1 and 2 are the abundant in the survey. The strongest year class over the time series was in 1997 with over 400,000 fish. In 2006, there was a moderate size year class which contributed to the expansion of age-3 in 2009. Since the late 1980’s and early 1990’s, Age 4 and 5 has declined significantly consisting of only 1% of the survey catch (Table A45, Figure A44).

Similar to the fall survey, majority of the spring survey catches consist of ages 1 and 2’s and very few fish older than age-5. There has been several strong year classes since the mid-1980’s contributing to significant expansion of age 2’s and moderately for age-3. A marginal increase was noted for age-4 in the early 2000, but has declined in the recent years (Table A46, Figure A45).

South Survey Trends

The NEFSC fall survey swept area biomass was higher during the 1970's and 1980's than any other part of the time series. Biomass peaked in 1985 at 11,760 metric tons then steadily declined the 1990's to approximately 2,600mt in 1994 then briefly increased in 2001 to over 6,700 metric tons. Biomass has as averaged around 4,000mt in the last 10year and approximately around 3,600 metric tons, a and currently at 3,600 metric tons in 2009, a 20% decrease since 2008 (4,513 metric tons; Table A51, Figure A46).

The NEFSC spring survey had considerably higher biomass than the fall survey. It was fairly high in the 1970s, averaging over 11,000 metric tons. It then decreased through the 1980s and 1990s, with a large spike in 1996 at 20,553 metric tons. In 1997, it fell to 2,142 metric tons. In 2010, it has increased to 3,783 metric tons (Table A52, Figure A47).

The NEFSC winter survey has a very short time series, 1992-2007. The swept area biomass was fairly stable throughout the time series. The largest biomass was in 1993 with almost 8,000 metric tons. It stayed considerably lower than that until it was discontinued in 2007 (Table A53, Figure A48).

The MADMF fall surveys indicate very low swept area biomass. There were only three years in the time series where the catch was over 50 metric tons. In 2007, the biomass plummeted from 25 metric tons down to 0.04 metric tons. The most recent years have increased moderately, with 2009 catching 0.22 metric tons (Table A54, Figure A49).
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The MADMF spring survey has much higher values than the fall, but has generally declined over time. In 1987, there was over 2,000 metric tons caught. In 2003, the spring survey saw its lowest catch of silver hake in the time series, with only 2 metric tons. It has recently increased to 26 metric tons in 2009 (Table A55, Figure A50).

Survey trends for Rhode Island state survey has been variable without trend. The Connecticut survey on the other hand was highest early in the time series but has been low ever since (Table A56, Figures A51-A52).

South Age Composition: Similar to the north, the south has also experienced a general truncation in the age structure with fewer older fish than age-6 in both the fall and the spring survey. Despite the consistent appearance of strong year classes in the last decade, there has been a substantial decline of age 4 and 5 in the surveys. However, the spring survey showed an unusual increase of age-3 in 1989 with approximately 260,000 fish. It is unclear for the sudden increase in age-3. This is likely due to aggregation of this size class during the survey (Tables A51-A52, Figures A53-A54).

Combined North and South

The NEFSC combined area fall survey is driven by the northern region peaking in 1998, with 42,353 metric tons and was extremely low in 2005 at 6,773 metric tons. It has increased recently with biomass at approximately 18,000 metric tons in 2009 (Table A57, Figure A55). In 1975, the spring survey had its highest biomass in the time series, at 37,136 metric tons. Then it hit an extremely low point at 4,725 metric tons in 1997. The survey had smaller spikes in 2000 and 2001 where the catch was over 20,000 metric tons. In 2009, the swept area biomass increased to 13,278 metric tons (Table A58, Figure A56). Similar pattern in the age structure was also observed in the combined stock areas as in the northern region (Tables A57-A58, Figures A57-A58).

TOR 3. Evaluate the validity of the current stock definition, and determine whether it should be changed. Take into account what is known about migration among stock areas.

Two subpopulations of silver hake are assumed to exist within the U.S. EEZ (Almeida 1987a). Analyses of morphometrics (Conover et al. 1961, Almeida 1987a) are the primary basis for this delineation further supported by otolith microconstituent (Bolles and Begg 2000). However, genetic analyses of the population structure have been inconclusive (Schenk 1981). The northern silver hake stock inhabits the Gulf of Maine - Northern Georges Bank waters, and the southern silver hake stock inhabits Southern Georges Bank - Middle Atlantic Bight waters (Figure A22). These boundaries were established at SAW 11(Brodziak et al. 2005).

While it is likely that the northern and the southern stocks mix on Georges Bank, the degree of mixing and movement among the management areas are unknown (Almeida 1987a, Helser et al. 1995, Helser 1996). Silver hake are known to spawn in the Gulf of Maine, southern New England, and on the southern flank of Georges Bank. Therefore, it is likely that silver hake larvae are entrained in the clockwise gyre on Georges Bank leading to larvae settlement in either management areas. Recent analyses of an icthyoplankton survey suggest the southern stock is larger (>90% of the larvae density) than the northern stock (Richardson et al. 2010). This is also consistent with Nye et al. 2009, suggesting a northern shift in the center of biomass for southern stock of silver hake. This is in contrast with the NEFSC trawl survey, which suggests a much larger stock in the northern area (Figure A59). Additionally, in the Gulf of Maine, there were no larvae observed, although adult spawners were present. This further suggests that there is probable transport of silver hake larvae from north to south and adults are migrating across the traditional stock boundaries which also implies that reproductive isolation between the two stock areas is unlikely.

NEFSC trawl surveys indicate a generally continuous distribution of silver hake from the Gulf of Maine to the southern New England/Mid-Atlantic Bight (Figures A24 and A30). However, the relative density of silver hake has varied through time between the northern and southern management areas. Population density as measured by the NEFSC fall bottom trawl survey increased in northern area during the mid-1980's, declined in 2000's and has continue to increase in the recent years. In contrast, density in the southern area showed decreases in the 1990's with a temporary increase in 2000 and declined in the last few years (Figure A60). Relative to the fall survey, the spring survey trends are highly variable and difficult to interpret the trends (Figure A60). This indicates that it is likely that mixing is occurring during the adult life stage. However, the degree of mixing cannot be determined.

Analyses of silver hake size at age data have shown that growth tends to vary in time and among areas (Helser 1996). Particularly, there were consistent differences between growth in the Gulf of Maine and southern New England/Mid Atlantic Bight areas. However, Helser showed that growth patterns on Georges Bank and in the Gulf of Maine were indistinguishable in the 1980's and 1990's and that growth rate changes dynamically on Georges Bank. In the last assessment, Brodziak et al. (2005) reported that there were negligible differences in growth between the northern and southern stock areas. For the purpose of this assessment, a decadal analyses on silver mean size at age from 1973-2009 for the fall and spring by sex was conducted. Results suggest that not only does silver hake exhibit sexually dimorphism but also very little differences were observed in the growth patterns between the northern and the southern stock areas (Figures A61 – A64).

Patterns in silver hake median age at maturity from the spring NEFSC bottom trawl survey (1980-2009) were estimated for both the northern and southern management areas in this assessment. The observed proportion of fish mature at age was fitted a logistic model using a nonlinear least square estimator. Model results in Figure A61 shows that there is no meaningful geographic variation in age at maturity. Annual trends in median age at maturity were also consistently similar between the north and the south management areas with synchronous increases around the early 1990's from 1.6yrs to approximately of 2.3yrs through late 1990's and early parts of 2000 and declined in the recent years to levels estimated in the early 1980's (A50 = 1.6yrs, Figure A65).

In summary, based on the scientific information available on silver stock structure (morphometrics, tagging, discontinuous larva distribution, homogeneous growth and maturity), it was concluded that there were no strong biological evidences to support either a separate or a single stock structure for silver hake. For the purpose of this assessment, a separate north-south and a combined stock model formulation was explored.

TOR 4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from Silver hake TOR-5), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results.

Assessment History

Stock assessments of the silver hake resources were conducted as early as 1968 using catch curves on catch at age data, with more formal assessment methods using Virtual Population Analysis (VPA) during the next two decades. During the next two decades, VPAs were enhanced in various ways using tuning methods with auxiliary research survey data using age-aggregated *ad hoc* techniques. During the early 1990s both Laurec-Shepherd and ADAPT tuning methods based on statistical fitting were attempted and assessment results were accepted with reservation. However, subsequent VPA assessments were rejected due to high degree of uncertainty and instability in parameter estimates (Brodziak et al 2001). Due to these difficulties of the population assessments, the southern and northern stock of silver hake are based on an index of exploitation and biomass derived from NEFSC resource assessment surveys.

In this assessment, two models were attempted, An Index Method (AIM) and the Age Structure Assessment Program (ASAP). While the ASAP model provided major advancement in the assessments, the results were not accepted due difficulties reconciling the inconsistent interpretations of the steep age profiles. The AIM model was also not accepted because it did not provide adequate diagnostics for stock status determination. Thus, this assessments was based on trends in the three year moving averages for the age-aggregated, fall survey biomass indices (1973-1982) using the arithmetic means rather than the previous delta approach (SAFE2003) and the three year averages of exploitation indices (total catch/fall survey biomass index) for both the northern and southern management areas.

A bridge between the current and last assessment

The NEFSC fall Survey biomass (delta mean kg/tow) and the relative exploitation index (landings/delta mean kg/tow) were computed for both the northern and southern stock areas. Survey biomass for the north declined recently and near the target levels used for management while the southern survey biomass has generally increased in recent years and also near the management target. The exploitation rate index for the southern stock is higher than for the northern stock throughout the time series. The exploitation index show high values during 1963-1977 followed by a period of low values during 1978-1993. Since 1994, the northern exploitation continues to decline and the southern values have varied without trend. Overall, the exploitation rate indices suggest that exploitation rates in recent years are much lower than during the 1960's and 1970's when foreign distant water fleets intensively harvested silver hake (Table A59, Figures A66-A67).

For this assessment, the "delta" estimators were replaced with the arithmetic means (i.e. no log transform was applied) because the delta transformation tends to inflate the survey variances and were sensitive to treatment of tows with no catch. Also, the previous exploitation index based on the ratio of landings to the fall delta survey biomass was also updated to include discards to better characterize removals from the commercial catch (landings + discards) relative to the fall survey biomass. Since discards are reliably estimated since 1989, relative exploitation index is now defined as the ratio of the commercial total catch to the arithmetic fall biomass survey (Table 60, Figure A68-69). It is noted that historical discarding, particularly in the Distant Water Fleet, has likely been very small. Therefore, comparison of relative exploitation index based on catch/biomass with reference points based on landings over biomass is justified.

Revised Assessment Method

An Index Method (AIM)

The AIM model is a simple approach for examining the relationship between survey data and catch in data poor stock assessments. AIM is designed to address the question of whether a given rate of fishing mortality is likely to increase or decrease the population size. Survey data are used to define a relative rate of increase and the ratio of catch to survey indices provides a measure of relative fishing mortality. Theoretically the model can identify a stable point about which the stock will neither increase nor decrease in response to a fixed harvest rate. The model assumes that the resource dynamics are approximately linear with relatively minor influence of density dependent effects or variable environmental or ecological factors. Such conditions often typify stocks that have been historically harvested at high fishing rates and are therefore at low population sizes. AIM is both an analytic and graphing approach. The analytical methods can be used to define relative Fs for replacement and the graphical methods can be used to identify transient conditions that are relevant to implementation of any model. The details of the methodology are described below.

- ✓ Population biomass at time t can be written as a linear combination of historical population biomasses
- ✓ Recruitment is proportional to population biomass
- ✓ Fishing mortality is proportional to catch divided by an index of population size (relative F).
- ✓ The rate of change in population biomass is a monotonically decreasing function of relative F.
- ✓ Smoothing methods can be used to identify underlying trends.
- ✓ Randomization methods can be used to develop sampling distributions of test statistics
- ✓ Graphical methods can help identify linkages among variables

Relative F is defined as the ratio of catch to an index of population abundance. A three-year centered average of the abundance index is chosen as the measure of average stock size.

$$relF_{j,s,t} = \left(\frac{C_{s,t}}{\frac{I_{j,s,t-1} + I_{j,s,t} + I_{j,s,t+1}}{3}} \right) \qquad (1)$$

Where $relF_{j,s,t}$ = relative F for relative index j for stock s at time t

$C_{s,t}$ = catch or landings of stock s at time t (in units of weight)
$I_{j,s,t}$= Index of abundance j for stock s at time t expressed in terms of average weight per tow

The population size at any given time can be viewed as a weighted sum of previous recruitment events. For a population with a maximum age of A years, the population in year t consists of the recruits from year t-1, t-2, …t-A. At high levels of total mortality, the contributions from the earliest recruitments, say t-k-1 to t-A will diminish in importance such that the population can be viewed as the sum of recruitments from t-1 to t-k years.

Using the linearity assumption defined above, we can employ basic life history theory to write abundance at time t as a function of the biomasses in previous time periods. The number of recruits at time t (R_t) is assumed to be proportional to the biomass at time t (B_t). More formally,

$$R_t = S_o \, Egg \; B_t \qquad (2)$$

where **Egg** is the number of eggs produced per unit of biomass, and $\mathbf{S_o}$ is the survival rate between the egg and recruit stages. Survival for recruited age groups at age a and time t ($S_{a,t}$) is defined as

$$S_{a,t} = e^{-F_{a,t} - M_{a,t}} \qquad (3)$$

where F and M refer to the instantaneous rates of fishing and natural mortality, respectively. We also need to consider the weight at age a and time t ($W_{a,t}$) and the average longevity (A) of the species.

Using these standard concepts we now write the biomass at time t as a linear combination of the A previous years. Without loss of generality, we can drop the subscripts on the survival terms and assume that average weight at age is invariant with respect to time. Further, set the product S_o Egg equal to the coefficient α. The biomass at time t can now be written as

$$B_t = R_{t-1} S^1 W_1 + R_{t-2} S^2 W_2 + R_{t-3} S^3 W_3 + .. + . R_{t-(A-1)} S^{A-1} W_{A-1} + R_{t-A} S^A W_A \quad (4)$$

Substituting Eq. (2) into Eq. (4) leads to

$$B_t = \alpha B_{t-1} S^1 W_1 + \alpha B_{t-2} S^2 W_2 + \alpha B_{t-3} S^3 W_3 + .. + .\alpha B_{t-(A-1)} S^{A-1} W_{A-1} + \alpha B_{t-A} S^A W_A \, (5)$$

If the population is replacing itself, then the left hand side of Eq. 5 will equal the right hand side. The replacement ratio can then be defined as

$$\Psi_t = \frac{B_t}{\alpha B_{t-1} S^1 W_1 + \alpha B_{t-2} S^2 W_2 + \alpha B_{t-3} S^3 W_3 + .. + .alphaB_{t-(A-1)} S^{A-1} W_{A-1} + \alpha B_{t-A} S^A W_A} \quad (6)$$

Substituting observed values of abundance indices into Eq 6 leads to

$$\Psi_t = \frac{\frac{I_t}{q}}{\alpha \frac{I_{t-1}}{q} S^1 W_1 + \alpha \frac{I_{t-2}}{q} S^2 W_2 + \alpha \frac{I_{t-3}}{q} S^3 W_3 + .. + \alpha \frac{I_{t-(A-1)}}{q} S^{A-1} W_{A-1} + \alpha \frac{I_{t-A}}{q} S^A W_A} \quad (7)$$

By noting that the q's cancel out, and letting $\varphi_j = \alpha S^j W_j$, Eq. 6 simplifies to

$$\Psi_t = \frac{I_t}{\sum_{j=1}^{A} \phi_j \quad I_{t-j}} \quad (8)$$

All of the I_t and φ_j are positive, and at equilibrium $I_t = I_{t+1}$ and $I_t = \sum \varphi_j I_{t-j}$ both hold. Therefore $\sum \varphi_j = 1$. When the population is not at equilibrium the parameter Ψ becomes a measure of the non equilibrium state of the population and a measure of whether the population is increasing or decreasing relative to prevailing fishery and ecosystem conditions.

It would be desirable to express the parameters of φ_j weighting terms as function of the underlying parameters. Analyses of other stocks with more detailed information, such as Georges Bank haddock, has suggested that setting the φ_j to 1/A is a reasonable approximation. Equations 2 to 8 are a long way of justifying that the ratio of current stock size to a moving average of the previous A years of stock size can be used as a measure of population growth rate. This ratio embeds some life history theory into the basis for the ratio and simultaneously provides a way of damping the variations in abundance owing to measurement error. A ratio defined as I_t/I_{t-1} has been found, as expected to be much more noisy measure of population change.
Further details on the AIM methodology may be found in Working Group (2002) and the NOAA Fisheries Toolbox (NFT) 3.1 (2010a) software package http://nft.nefsc.noaa.gov/AIM.html. The relationship between $\mathbf{\Psi_t}$ and $\mathbf{relF_t}$ can be expressed as

$$\ln(\Psi_t) = a + b\ln(relF_t) \quad (9)$$

The usual tests of statistical significance do not apply for the model described in Eq. 9. The relation between $\mathbf{\Psi_t}$ and $\mathbf{relF_t}$ is of the general form of Y/X vs X where X and Y are random variables. The expected correlation between Y/X and X is less than zero and is the basis for the oft stated criticism of spurious correlation. To test for spurious correlation we developed a sampling distribution of the correlation statistic using a randomization test. The randomization test is based on the null hypothesis that the catch and survey time series represent a random ordering of observations with no underlying association. The randomization test was developed as follows:

1. Create a random time series of length **T** of $\mathbf{C_{r,t}}$ from the set $\{\mathbf{C_t}\}$ and $\mathbf{I_{r,t}}$ from the set $\{\mathbf{I_t}\}$ by sampling with replacement.

2. Compute a random time series of relative F ($\mathbf{relF_{r,t}}$) and replacement ratios ($\mathbf{\Psi_{r,t}}$)
3. Compute the r-th correlation coefficient; say $\boldsymbol{\rho_r}$ between ln($\mathbf{relF_{r,t}}$) and ln($\mathbf{\Psi_{r,t}}$).
4. Repeat steps 1 to 3 K times.
5. Compare the observed correlation coefficient $\mathbf{r_{obs}}$ with the sorted set of $\boldsymbol{\rho_r}$
6. The approximate significance level of the observed correlation coefficient $\mathbf{r_{obs}}$ is the fraction of values of $\boldsymbol{\rho_r}$ less than $\mathbf{r_{obs}}$

It should be emphasized that relF is not necessarily an adequate proxy for Fmsy, since this parameter only estimates the average mortality rate at which the stock was capable of replacing itself. Thus, while relF defined as average replacement fishing mortality is a necessary condition for an F_{msy} proxy, it is not sufficient, since the stock could theoretically be brought to the stable point under an infinite array of biomass states. The relF at replacement does however provide some guidance on the contemporary rate of harvesting and its potential impact on future stock abundance.

Application of AIM to Silver Hake

AIM was applied to the combined stock of silver hake using catches and the NEFSC fall and spring bottom trawl survey indices (Table A61). Relative F was defined as the ratio of catch to a centered 3-year average of survey abundance (Eq. 1) and the replacement ratio was defined as a 5-year moving average of previous stock sizes (Eq. 8). The relationship between catch, survey, relative F and the replacement ratio for the fall and spring survey indices are depicted in Figures A70 and A71, respectively. Neither of the randomization tests resulted in significant statistical relationship between the replacement ratio and relative F (Table A61). Bootstrap estimation of the relative F at replacement were imprecise (Table A62, Figure A72) and are not appropriate measures of Fmsy proxies. Graphical results suggest some underlying causes for the absence of a strong statistical relationship. Relative F has been declining continuously for both the fall (Figure A70) and spring (Figure A71) survey indices but the population indices do not suggest any significant rate of change over time. The relationship between replacement ratio is barely negative despite a nearly 60-fold range in catches and a 27-fold range in relative F. The relationship between relative F and survey abundance is instructive (the left center plot in Figures A70-A71). It suggest three temporal stanzas in which the population abundance has declined by comparable amounts from about 8 to 3 kg/tow, when relative F has varied by 30,000 to 70,000 mt/kg/tow between 1968 and 1977 and when relative F varied from 5,000 to 15,000 mt/kg/tow between 1978 and 2000. In the third stanza, from 2001 to 2009 the surveys have fluctuated from 4.0 kg/tow to about 1kg/tow even though relative F has not exceeded 7108 mt/kg/tow for the fall survey and 12,099 mt/kg/tow in the spring survey. At a minimum these stanzas suggest major changes in the population abundance indices and exploitation rates. It is not possible from these data alone to identify causal factors but it does suggest that more advanced modeling will need to account for these changes in apparent productivity and/or natural mortality.

Age Structure Assessment Program (ASAP)

> **[SAW51 Editor's Note: The SARC-51 peer review panel concluded that no single silver hake ASAP model run provided a suitable basis for providing management advice. The silver hake ASAP model and results, which are described here and in Appendices A2-A6, are included in this report mainly to document the ASAP modeling runs that the Hake Working Group provided to the SARC for peer review.]**

Silver hake has been assessed based on survey index of relative exploitation and the 3 year moving average from the survey biomass since 1994(NEFSC 2006). Given some of the changes that have occurred in the fishery (gear, selectivity, targeting, and management), and the change to a new survey vessel (for which a calibration cannot be estimated), the importance of age structure (maturity and growth), and the limited projection capability of the index method, alternative assessment methods were considered for this benchmark. The new assessment model is ASAP (Age Structured Assessment Program v2.0.20, Legault and Restrepo 1998), which can be obtained from the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/). As described at the NFT software website, ASAP is an age-structured model that uses forward computations assuming separability of fishing mortality into year and age components to estimate population sizes given observed catches, catch-at-age, and indices of abundance. Discards can be treated explicitly. The separability assumption is partially relaxed by allowing for fleet-specific computations and by allowing the selectivity at age to change in blocks of years. Weights are input for different components of the objective function which allows for configurations ranging from relatively simple age-structured production models to fully parameterized statistical catch at age models.

The objective function is the sum of the negative log-likelihood of the fit to various model components. Catch at age and survey age composition are modeled assuming a multinomial distribution, while most other model components are assumed to have lognormal error. Specifically, lognormal error is assumed for: total catch in weight by fleet, survey indices, stock recruit relationship, and annual deviations in fishing mortality. Recruitment deviations are also assumed to follow a lognormal distribution, with annual deviations estimated as a bounded vector to force them to sum to zero (this centers the predictions on the expected stock recruit relationship). For more technical details, the reader is referred to the technical manual (Legault 2008).

Model Formulations

The assessment model formulations were structured to consider sensitivity to a number of model inputs. To deal with stock structure, separate North and South stock assessments were considered as well as a single combined stock treatment. These models will subsequently be referred to as North, South, and Combined for brevity. Natural mortality was thought to have a large component due to predation. This was dealt with explicitly by including estimates of consumption in the model as a separate "fishery" fleet (referred to as Consumption model hereafter), or implicitly by considering a single value for natural mortality (referred to as the No-Consumption model hereafter). In the Consumption model formulation, a value of M=0.15 was specified for all ages and all years to comprise all sources of natural mortality *other than* consumption. In the No-Consumption model, a single value of M=0.4 was specified for all ages and all years. The value of M=0.4 was justified by consideration of a maximum observed age of 14. Given M=0.4, the expected cumulative survival to age 14 would be about 0.5%.

Model Inputs

All models considered included catch by a directed fleet beginning in year 1973. Although total landings estimates exist before 1973, there was no age composition, and initial modeling suggested poor identifiability of initial conditions when the model runs started earlier than 1973. All models considered also included estimated discards beginning in 1981. Structurally, discards were included as a separate "fleet" in the model. Treating discards as a separate fleet allowed more flexibility for including total discards in 1981-1988 without any corresponding age composition in addition to years 1989 where estimates of total discards and age composition are both available. These two fleets were the only removals that were modeled for the No Consumption models. For the Consumption models, an additional fleet was modeled to represent removals from predation. The estimated mortality from the "fleet" of predators was then considered to be an additional source of natural mortality (generally termed "M2"). Estimates of total annual natural mortality at age from the Consumption models was then calculated as 0.15+M2 (age, year), and cumulative survival to age 14 could then be compared to the M=0.4 model.

All models included the NEFSC spring and fall bottom trawl surveys. Minimum swept area abundances, annual estimated CV, as well as the age composition for each survey were used in the model.

The model assumed a plus group at age 6. Initial model model runs dealt with the stock as a single unit (Combined runs). An exhausting, albeit not exhaustive, number of model specifications were explored for the Combined run. Exploratory runs examined model sensitivity to estimating a stock recruit function versus estimating an average recruitment with annual deviations; estimating age-specific selectivity for the surveys versus forcing the survey to have a flat-topped selectivity; "breaking" the survey time series into two separate series or maintaining a continuous time series; and adding or removing selectivity "blocks" to the directed and bycatch fleets. In considering these various model iterations, diagnostics were examined to determine if the fit improved. Specifically, the pattern of residuals in age composition for catch and indices, residuals in the fit to total catch and annual index values, components of the objective function in addition to total objective function and number of estimated parameters, as well as the "believability" of the estimated selectivity patterns. With regard to the last criterion ("believability" of estimated selectivity), this was somewhat subjective, however the models tended towards solutions with sharply domed selectivities for both the directed fleet and the surveys (it was also sharply domed for the discard fleet, but that was a sensible result). As there was nothing biological to suggest that fish at ages 5 and beyond would have very low catchability (i.e., no known behavioral aspects, no strong swimming capabilities), nothing gear related that would suggest lower catchability (no outswimming otter trawls, no other known gear interactions), and no known market conditions that would favor smaller fish, the group found it hard to reconcile selectivities of 0.10 on the 6+ group, when fish in the plus group had been estimated in the catch age composition early in the time series.

Model Results—Combined model

Model formulations for both the Consumption and No Consumption model were run in tandem. Although objective function values were not directly comparable between these two model treatments, owing to differences in the underlying data, residual diagnostics, overall fits, and retrospective patterns were compared. After much deliberation, the group agreed to the following base configuration: Consumption model that did not split the survey indices and forced a selectivity=1 for ages 2 and older; two selectivity blocks for the directed fleet (the break occurred between 1988 and 1989) and one single selectivity block for the bycatch fleet. With all models considered, there was a strong correlation between the selectivity estimated for the directed fleet and the selectivity of the surveys. Forcing the flat-top for the survey indices caused the selectivity estimates for the directed fleet to also be flat-topped. For this selectivity pattern, the age composition residuals were acceptable, although the residuals from fits to the total catch and overall index values showed strong time trends. This was a fairly consistent trade-off seen in many of the model diagnostics, wherein improvements in the fit to age composition data were accompanied by a deteriorated fit to the total data (either total catch or total index values). Thus, selecting the 'best' model depended to some extent on the amount of confidence that one had in the age composition data relative to the data streams of total catch and the indices. Complete model diagnostics can be found in the **Appendix A2**. ("Base_model_diagnostics_Consumption_Flat-top Survey").

Retrospective pattern of Base Combined model

A retrospective analysis on the base model using a seven year peel was conducted to examine the stability of the model estimates for fishing mortality, recruitment and spawning stock biomass. Due to the change in selectivity block beginning in 1989, it was difficult to interpret the earliest peels because there was an imbalance in the number of parameters being estimated versus number of years with additional data. However, it was noted that the Consumption models had the lowest retrospective bias (Figures A73-A74, Table A63).

Sensitivity analyses to Base Combined model
For completeness, sensitivity to the model decisions adopted in the base model are summarized in Table A63 and in Figures A75-A77. Eight additional runs are described in this table. Only one run for the No Consumption model is described. While this model offered good diagnostics, and good retrospective analysis results, two of the parameters for selectivity at age were estimated at the upper bound of 1.0. When those parameters were subsequently fixed at 1.0, instead of attempting to estimate them, no hessian was obtained for the model. Because of this instability, the model was not explored further. As an intermediate to the Consumption and No Consumption runs, a model was explored where the natural mortality at age was calculated as 0.15 + $M2_{age,year}$. This model is directly comparable to the No Consumption model as it has exactly the same data, the only difference being the fixed value specified for $M_{age,year}$. Compared to the model with M=0.4 for all years and all ages, the total objective function was 71 points greater, and therefore did not provide a better fit to the data.

The remaining six sensitivity runs were all Consumption models with different numbers of selectivity blocks for the directed and bycatch fleet, and with survey selectivity at age estimated or fixed for ages 2 and older. Model diagnostics and the objective function value favored models that had 2 selectivity blocks for the directed fleet (with the break in 1988/1989) and one selectivity block for the bycatch fleet over the alternatives of 1 selectivity block for each, or 3 selectivity blocks for the directed fleet and 2 selectivity blocks for the bycatch fleet. The motivation for introducing selectivity blocks, and the year that they were introduced, was an attempt to account for changes in the fishery composition (disappearance of foreign fleets) and pertinent regulations (mesh size and trip limits). After the number of selectivity blocks was decided, comparisons were made between a flat-topped survey selectivity (the proposed base model) and a formulation that estimated selectivity at age for the surveys (with only age 2 selectivity fixed at 1.0). The overall objective function for the base model was 4526, while for the model that estimated survey selectivity it was 4491. Thus, the model that estimated survey selectivity improved the objective function by 35 at the cost of adding 8 parameters to the model. And, as mentioned previously, there is the trade-off between fitting age composition data or fitting the total data series better. The other comparison between these two models is the retrospective diagnostics: the Combined base model had relative biases ranging from 26-41% while the sensitivity model that estimated survey selectivity at age had relative biases ranging from 32-62%. Finally, when estimating survey selectivity at age, the model estimated very steep domes with <10% selectivity in the plus group for the directed fleet and both surveys. These two models were considered the best contenders of the models explored, and the working group selected the base model (described above) based on the disbelief of such severe domes and the better retrospective diagnostics.

In general, the No Consumption models had lower retrospective analysis diagnostics compared to the Consumption models. Within the Consumption models, decreasing the selectivity blocks improved the retrospective diagnostics while enforcing a flat-top selectivity worsened the retrospective diagnostics (Table A63).

The intensive examination of model formulations was first explored for the Combined runs, as the likelihood of 'stock' mixing was thought to be high. If stock mixing were occurring, it would result in catch being attributed disproportionately among stocks, and the potential for the survey indices to be more reflective of the seasonal magnitude of mixing rather than any particular stocks' trend in abundance. This was the motivation for the group spending nearly all of the available time on the Combined models. In order to address the terms of reference to explore sensitivity to assumptions of stock structure, some North and South models were explored, but they were simple sensitivities on the structure that had been selected as the base model for the Combined model.

Silver Hake ASAP Results
Attempts were made to assess silver hake by separating the northern and southern data. However, none of the runs examined had assessment diagnostics which were deemed suitable. The working group recommended a combined analysis of data from both areas, meaning a single stock, as the best performing model, but this was ultimately not accepted by the SARC-51 Review Panel as a basis for management advice. Issues encountered in the northern and southern stock assessments are briefly described below, followed by a more detailed description of the recommended model formulation assuming a single stock.

Northern Silver Hake
Four runs were examined for the northern silver hake data. Two of the runs included consumption data while the others did not. Of the set of runs which included consumption forced a flat-topped selectivity patterns in the survey indices while the other allowed domed selectivity. The same selectivity patterns were also assumed for the runs without consumption. All four runs assumed time invariant selectivity patterns for each fleet and assumed recruitment deviations occurred relative to a constant mean, as opposed to being relative to a stock-recruitment relationship (Appendices A3-A6).

The run which did not include consumption estimates set natural mortality to 0.4 for all years and ages. The predicted commercial landings are well below the observed values at the start of the time series when the foreign fleets were operating, but then well above the observed values near the end of the time series. These are large deviations in both absolute and relative terms and are a strong indication that the model is not fitting the data well. However, when a domed selectivity is allowed, the fit the landings show an improvement in the absolute and relative magnitude of the residuals. The fit to the discards also exhibits a pattern of underestimating the observed values early in the time series and overestimating them recently. However, these deviations are small in both absolute and relative terms and so are less of a concern. The opposite is true early in the time series when domed selectivity is allowed in the survey with a good fit to the time series in the recent years. The landings and discards at age both have patterns in the residuals, especially at ages one and two. The input effective sample size appears to be a bit high for the commercial landings, where only approximately 20% of the output effective sample sizes are greater than the input values. The input and output effective sample sizes for the discards are better matched. Neither of the survey indices are fit well, with patterns in the residuals and large magnitudes for the standardized residuals, but to a lesser degree when domed selectivity is allowed in the survey. The observed magnitude and patterning of the residuals is an indication that the input CV for the surveys is too small relative to the ability to fit the indices. The age composition for both indices is not fit well, with long periods of the same sign of residuals for ages one and two especially. The input effective sample sizes for both indices are too high relative to the output effective sample sizes. The catchability coefficients for both indices are above one, indicating that the estimated population is smaller than the minimum swept area biomass estimated from the surveys. This can occur if the assumed swept area of a tow is too small, for example due to herding of fish, but is generally an indication that there may be a problem in the run. In contrast, when domed selectivity is allowed the catchabilities estimates were well below one which agrees with the very strong dome estimated in the survey with less than 5% of ages 5 and 6 selected in the survey. The implication of such selectivity pattern resulted in unrealistic estimate of spawning stock biomass reaching approximately 6million metric tons in the recent years and an expansion of age 6+ in the population which is contradictory to the both the fishery and the survey. Thus, these runs were not considered acceptable by the working group.

The two runs which did include consumption set the base natural mortality to 0.15 and then entered the consumption time series as an additional fleet. The main difference between these two runs is the selectivity pattern for the two indices where the run which allowed a dome did in fact estimate a strong dome for both indices. However, qualitatively the results from the two runs were still quite similar and are described together here. These runs fit the commercial landings and discards much better than the runs which did not include consumption. The fit to the consumption time series was not fit as well and the landing or discards. The absolute magnitude of the lack of fit to the consumption time series is quite high, but the relatively small standardized deviations indicate that the uncertainty in the consumption values is being appropriately modeled. The age composition for the commercial landings and discards still exhibit patterns in the residuals, especially at ages one and two. There are no age composition residuals for the consumption fleet, meaning that the selectivity patterns should not be estimated. However, the two runs did in fact estimate selectivity patterns based on a double logistic form. These parameters could be estimated because priors were set on the values. However, the resulting selectivity patterns do not make intuitive sense with low selectivity at age one, the age which typically has the highest consumption selectivity. The input effective sample size for the commercial landings is slightly high relative to the output effective sample size, but more closely matched for the commercial discards. The survey indices are fit better than the runs without consumption in terms of there not being a strong pattern in the residuals. However, the magnitude of the standardized residuals is still quite large, indicating that the input CV for the indices is too small relative to how closely the indices can be modeled. The age composition for index 1 is fit reasonably well while index two shows patterns in the residuals for ages one and two. The input effective sample size for both the indices is too high relative to the output effective sample size. The catchability coefficients are more reasonable than the runs without consumption, indicating a relative efficiency of the net around 0.5. The catch due to the consumption fleet appears to be quite small in five of the first six years in the time series, which is due to low sampling of predators during this time period instead of a true change in consumption. The mortality rate due to consumption is generally greater than one after the first six years in the time series, with some years above two. This high mortality contrasts with the fishing mortality rates of less than 0.3 for most years. Note that the plot showing the relative spawners (SSB/S0) is treating consumption as a mortality that is not included when computing S0, which it typically would be since it is a form of natural mortality. If this plot was made including consumption mortality as a natural mortality, then the relative spawners would be much closer to one than currently shown.

Southern Silver Hake Stock
For the southern region, similar model runs were conducted as in the northern region. However, the models in the south had convergence problem which is likely attributed to model mis-specification (i.e. inaccurate definition of stock boundaries). One possible hypothesis is that the model is having difficulties resolving the lack of coherence between the removals from the fishery and the trends in the survey due to possible migration patterns of silver hake to the northern region. The shift in the population density over time will then reflect seasonal distribution in the survey rather than stock specific trend of abundance as explained above.

Combined Silver Hake Stock
A number of the issues seen in the northern silver hake runs are also apparent in this combined run. Specifically, commercial landings are not fit well at the start of the time series, consumption landings are mostly underestimated, strong patterns are seen in the age composition residuals for all three fleets, the indices are not well fit in terms of either trends in residuals or the magnitude of the standardized residuals, strong patterns are seen in the age composition residuals for index, the relative spawners plot has the same issue as the northern silver hake assessment with consumption, and consumption in the early years appears low. The inclusion of age composition data for the consumption fleet is an improvement relative to the northern silver hake runs, as now there is information to estimate selectivity for this fleet. The estimated selectivity pattern for the consumption fleet is more traditional than the northern silver hake runs, with highest selectivity at age one and decreasing selectivity at older ages. This means that the effect of consumption will be mainly to increase recruitment to account for this additional mortality, but it will not have a large impact on the adult population. However, there is an indirect impact caused by this selectivity pattern because the base natural mortality is 0.15 compared to 0.4 when consumption is not included. Since there is essentially no consumption mortality at old ages, the net effect is to reduce natural mortality on the old fish, which means fishing mortality must be high to prevent old fish from appearing in the age composition.

Given the series of model exploration for North, South and the combined management area formulation, the working group recommended the Consumption model with 2 selectivity block in the directed fleet with a single selectivity in the bycatch fleet. However, this was not accepted by the SARC-51 Review Panel as a basis for management advice.

Fishing Mortality
Fishing mortality on ages 3+ varied between 0.5 and 1.0 from 1973 to 1995 then increased and varied between 1.0 and 2.0 from 1996 to 2008. The fishing mortality rate in 2009 is estimated to be 0.77 (80% confidence interval 0.58 – 0.95). Note that the variance estimates include some consumption based mortality estimates. Given the very low mortality on older ages in the population, the influence of consumption on the variance is minimal to negligible (Appendix A2, Table A64).

Recruitment
Recruitment at age-1 was relatively low in the early part of the time series, which may be an artifact of consumption mortality being underestimated during this time period. Since then, recruitment has varied without trend between 400 million and 1.1 billion fish annually. The number of age-1 fish in 2009 is estimated to be 742 million fish (80% confidence interval 616 – 867 million fish (Appendix A2, Table A65).

Spawning Stock Biomass
Spawning stock biomass varied around 70 thousand mt during the early part of the time series, but this again could be an artifact due to the low consumption mortality during this time. Spawning stock biomass decreased to approximately 33 thousand mt in 1978 and slowly declined to 55 thousand mt in 2006, but has since increased. Spawning stock biomass in 2009 is estimated to be 23 thousand mt (80% confidence interval 19.5-26.8 thousand mt (Appendix A2, Table A65).

Natural Mortality
Estimate of Natural mortality (M1+M2) was highest and most variable for age-1 ranging between 0.2 and 1.5 from 1973-1995. Natural mortality declined substantially in 1997 by approximately 70% resulting in natural mortality estimate of 0.5. This was also when consumption was relatively low due to very low recruitment. The natural mortality rate in 2009 is estimated to be 1.2 (Appendix 2 and Table A66).

TOR 5. Evaluate the amount of silver hake consumed by other species as well as the amount due to cannibalism. Include estimates of uncertainty. Relate findings to the stock assessment model.

Food habits were evaluated for a wide range (14) of fish predators that eat silver hake and commonly occur in NEFSC bottom trawl surveys. The amount of food eaten and the type of food eaten were the primary food habits data examined. From these data, per capita consumption, total consumption of silver hake, and an estimate of the amount of silver hake removed by these fish predators were calculated. Combined with abundance estimates of these predators, an amount of silver hake removed by these predators was then calculated. Consumption estimates of silver hake were presented as an estimate that is biased towards conservative values because consumption by birds, marine mammals, large pelagic fish and organisms outside of the survey area were not included. Moreover, swept-area biomass estimates for many of predators were based on bottom trawl survey data (without adjustments for bottom trawl catchability), although stock assessment results were used for some predators, such that predator abundance estimates and associated silver hake consumption would be mostly underestimates as well.

Methods

Every predator that contained silver hake was identified from the NEFSC FHDBS. From that original list, a subset of predators (Table A67) was examined to elucidate which predators consistently ate silver hake, determined by "rules of thumb" that include having a diet composition of >1% for any five year block, and with >5tows for each two year block and > 10 stomachs for each three year block.

Annual consumption estimates were calculated on a seasonal basis (two 6 month periods) based on spring and fall bottom trawl surveys and for each predator species. Although the food habits data collections started quantitatively in 1973, not all species of silver hake predators were sampled during the full extent of this sampling program, thus we start our time series here in 1977 (Link and Almeida (2000). This sampling program was a part of the NEFSC bottom trawl survey program (Azarovitz 1981; NEFC 1988). There are various ways to integrate seasonally, but we took the simple sum of the two seasonal estimates in this analysis. We have also done the analyses for various size classes of predators in other instances, but here we have integrated across all predator size classes to come up with a total consumption of silver hake for each predator.

This approach followed previously established and described methods for estimating consumption, using an evacuation rate model methodology. For further details, see Durbin et al. (1983), Ursin et al. (1985), Pennington (1985), Overholtz et al. (1991, 1999, 2000, 2008), Tsou & Collie (2001a, 2001b), Link & Garrison (2002), Link et al. (2006, 2008, 2009), Methratta & Link (2006), Link & Sosebee (2008), Overholtz & Link (2007, 2009), Tyrrell et al. (2007, 2008), Link and Idoine (2009), Moustahfid et al. (2009a, 2009b), and NEFSC (e.g., 2006, 2007a, 2007b, 2008, 2010a, 2010b). The main data inputs are mean stomach contents (S_i) for each silver hake predator i, diet composition (D_{ij}) where the subscript j refers to silver hake as a prey item, and T is the bottom temperature taken from the bottom trawl surveys (Taylor et al. 2005). Units for stomach estimates are in g. We note that we estimated S and D for two-year time blocks to ensure data-density sufficiency for all predators in both seasons and for both stocks; temperature (T) was estimated annually for both seasons and both stock areas.

As noted, to estimate per capita consumption, the gastric evacuation rate method was used (Eggers 1977, Elliott and Persson 1978). There has been copious experience in this region using these models (see references listed above). The two main parameters, α and β, were set to 0.004 and 0.115 respectively based upon prior studies and sensitivity analyses (NEFSC 2007a, 2007b). The exception is that α was set to 0.002 for elasmobranch predators consistent with and to reflect their slightly lower metabolism than teleost fishes.

Using the evacuation rate model to calculate consumption requires two variables and two parameters. The per capita consumption rate, C_{it} is calculated as:

$$C_{it} = 24 \cdot E_{it} \cdot \overline{S_{it}}^{\gamma}$$

where 24 is the number of hours in a day and the evacuation rate E_{it} is:

$$E_{it} = \alpha e^{\beta T} \qquad ;$$

and is formulated such that estimates of mean stomach contents (S_{it}) and ambient temperature (T; here used as bottom temperature from the NEFSC bottom trawl surveys for either season (Taylor & Bascuñán 2000, Taylor et al. 2005)) are the only data required. This was done for each predator i (species) for each time period t (season and year). The parameters α and β are set as values chosen noted above. The parameter γ is a shape function is almost always set to 1 (Gerking 1994).

Once daily per capita consumption rates were estimated for each silver hake predator, those estimates were then scaled up to a seasonal estimate. This was done by multiplying the number days in each half year, which were then multiplied by the diet composition D_{ij} that was silver hake, to estimate the seasonal per capita consumption of silver hake. That is, once per capita consumption rates were estimated for each silver hake predator in a temporal period (t), those estimates were then scaled up to a seasonal estimate ($C'_{it} = C_{fall}$ or C_{spr}) by multiplying the number days in each half year:

$$C'_{it} = C_{it} \cdot 182.5$$

These were then multiplied by the diet composition D_{ijt} that was silver hake, to estimate the seasonal per capita consumption of this fish C_{ijt}:

$$C_{ijt} = C'_{it} \cdot D_{ijt}$$

These were then summed to provide an annual estimate, C'_{ij}:

$$C'_{ij} = C_{ij,fall} + C_{ij,spring}$$

Once these were summed to provide an annual estimate (or the following could be done seasonally and the summed), they were then scaled by the total stock abundance of each predator to estimate the amount of silver hake removed by any of the predators included in the study. We used a swept area estimate of abundance from bottom trawl survey estimates for most predators and recent stock assessment estimates for five of the fourteen (Table A57). Those predators that had stock assessment values were used directly. These consumption estimates were then scaled by the total stock abundance to estimate a total amount of silver hake (j) removed by any predator i, C_{ij}:

$$C_{ij} = C'_{ij} \cdot N_i \qquad ,$$

where N_i is the estimate of abundance for each predator for each year.

We note that there are several ways to combine variance estimators in these consumption approaches. Estimates of variance for each variable and data type were calculated, namely about *S*, *DC*, and *N*. Further particulars of these estimators for the stomach contents and diet composition can be found in Link and Almeida (2000). There are three main ways to present variance about the estimates of consumption. One is to calculate a triple variance estimator that scales to the mean of each parameter (*S*, *DC*, and *N*). Another is to evaluate the maximal CV across all three parameters, across both seasons, and across all species of predator and then carry the largest value for each annual estimate of consumption. Finally, since from prior studies we know that the largest source of variance is associated with the estimates of abundance (scaled to the number), one can take the maximal CV across all predators and seasons for abundance and use that as a proxy for the variance about the consumption estimate. Here we adopted a modification of the third option, using the maximal CVs (associated with abundance estimates) and adopted mild adjustments for D_{ij} and S_i on a percentage basis (again, those CVs and means usually are minimized by the scale of the abundance means). The maximum from all predator sets were then used to portray variance for the total amount of silver hake consumed by these fishes. These range from 0.1 to 1.0 and in practice most were on the order of 0.35-0.50.

These predator species-specific consumptions were then summed across all *i* predators to estimate a total amount of silver hake removed by the predators included in this study. Upon further inspection by season, stock area, and predator species, it was determined that pollock *DC* were excessively variable, resulting in some notably anomalous and indefensible outputs; thus we removed pollock as a predator from the final estimates of consumption. Thus, these C_{ij} were then summed across all *i* predators (excluding pollock) to obtain an estimate a total amount of silver hake removed by these silver hake predators, C_j:

$$C_j = \sum_i C_{ij} \quad .$$

We show both the total consumption, total by species, and total by stock area. We also contrast these estimates with silver hake landings to provide a sense of contrast and magnitude. We also present these consumption estimates as 3 year moving averages to smooth the high degree of inter-annual variability common for these food habits data.

Sizes of silver hake in predators were also calculated as proportions by length in 5 cm bins for each year (combined across predators) across the time series. These can be used to inform the allocation of consumption to those size classes of fish overlapping with the fishery (or survey estimates). In this assessment, the consumption estimates were rescaled to conform with the current model formulation (i.e. age 1-6+). Survey age length keys were used to derive the proportion at length for Age-0 to adjust the consumption at length for each year. This makes the assumption that the survey length distribution within a given age is similar to consumption. For simplicity purposes, a constant probability was used based on an aggregated age-length key across seasons and geographical areas for the combined assessment. Table A68 summarizes the probability used in the analyses. On average, this resulted in a 40% decrease from the original consumption estimates (Figure A78).

Total consumption was modeled as a separate fleet in the Age Structured Assessment Program (Legault, 2008) to provide estimate of natural mortality based consumption (M2). Detail on the model structure and assumption regarding natural mortality and selectivity are provided in TOR4.

Results

Total consumptive removals by all consistent silver hake predators, using swept area abundance estimates of the predators, has varied through time ranging between peaking at 4,000 mt in 1975 and peaking at 165,000mt in 1985. This was followed by a brief decline during the early to mid 1990s and increased substantially in 1999 to approximately 135,000 mt. In the last decade, consumption has declined and averaged approximately 70,000 mt in the last five years (Figure A79, Table A69).

Spatially the consumption was approximately equally distributed between the northern and southern stocks (Figure A80), with higher peak values observed in the northern stock.

Although the consumption of silver hake occurred in thirteen predators, the majority of the consumption was attributable to goosefish (Figures A81-A82). For predators with swept area estimated abundance, these were generally lower than those stocks with abundance estimates obtained from stock assessments (summer flounder, goosefish, bluefish, cod), but were dominated by spiny dogfish (Figure A81-A82). These findings were consistent for both the northern and southern stocks combined (Figure A81)

The size of most of the silver hake consumed was <20 cm (Figure A83), yet some large fishes were also eaten. Over 50% of the silver hake eaten in most years were < 15 cm. We note that this loosely corresponds to the age 0 size class. The proportions also varied by size over the years (Table A70, Figure A81).

These estimates of silver hake consumed by the consistent fish predators in this study were compared to total catch (Figures A79-A80). Silver hake catches and consumption estimates were distinct for much of the time series, with landings higher earlier in the time series (1970s), but with consumption the dominant source of removal since the 1980s. Given this caveat, we note that consumption is approximately 10 times higher than catch in the 2000s.

TOR 6. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; estimates or proxies for BMSY, BTHRESHOLD, and FMSY; and estimates of their uncertainty). If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

Existing Reference Points

The northern silver hake stock overfishing definition (NEFMC 2003) uses a relative exploitation index (total landings divided by NEFSC autumn survey biomass index) as a proxy for fishing mortality. The northern stock is considered ***overfished*** *when the 3-year average biomass is less than ½ the B_{MSY} proxy (B_{MSY} proxy = 6.63 kg/tow).* ***Overfishing*** *occurs when the 3-year average exploitation index is greater than 2.57, the F_{MSY} proxy (the average exploitation index during 1973-1982), and is used as both a target and threshold value for fishing mortality for the northern stock (NEFSC 2006)*

The southern silver hake stock is considered to be ***overfished*** *when the three-year moving average of the NMFS autumn survey weight per tow index is less than half of the B_{MSY} proxy (B_{MSY} proxy = 1.78 kg/tow) (NEFMC 2003).* ***Overfishing*** *is considered to be occurring in the silver hake southern stock when the exploitation index (landings divided by the three-year moving average of the delta-distributed fall survey biomass index) exceeds the F_{MSY} threshold proxy of 34.39 (NEFMC 2002).*

There are currently no BRPs for a combined (i.e., north + south) stock.

New Reference Points

In the absence of an agreed ASAP model run, the newly accepted reference points (in kg/tow in Albatross units) for both the northern and southern silver hake stocks are as follows:

> *Silver hake is overfished when the three-year moving average of the fall survey weight per tow (i.e. the biomass threshold) is less than one half the B_{MSY} proxy, where the B_{MSY} proxy is defined as the average observed from 1973-1982. The most recent estimates of the biomass thresholds are 3.21 kg/tow for the northern stock and 0.83 kg/tow for the southern stock.*
>
> *Overfishing occurs when the ratio between the catch and the arithmetic fall survey biomass index from the most recent three years exceeds the overfishing threshold. The most recent estimates of the overfishing threshold, are 2.78 kt/kg for the northern stock and 34.19 kt/kg for the southern stock of silver hake.*

Overfishing threshold estimates were based on annual exploitation ratios (catch divided by arithmetic fall survey biomass) averaged from 1973-1982. Catch per tow is in "Albatross" units.

TOR7. Evaluate stock status (overfished and overfishing) with respect to the existing BRPs, as well as with respect to the "new" BRPs (from Silver hake TOR 6).

Based on the biological reference points in the existing FMP, the northern stock of silver hake is not overfished and overfishing is not occurring. The three year delta mean biomass index (Figure A66), based on NEFSC fall bottom trawl survey data for 2007-2009 (6.79 kg/tow), was above the management threshold level (3.31 kg/tow) and slightly above the target level (6.63 kg/tow). The three year average exploitation index (landings divided by biomass index, Figure A66) for 2007-2009 (0.15) was below the single management threshold/target (2.57).

Similarly, based on the existing BRPs the southern stock of silver hake is not overfished and overfishing is not occurring. The three year delta mean biomass index (Figure A67) based on NEFSC fall bottom trawl survey data for 2007-2009 (1.39 kg/tow) was above the management threshold level (0.89 kg/tow) but below the target level (1.78 kg/tow). The three year average exploitation index (Figure A67) for 2007-2009 (4.33) was below both the management threshold (34.39) and the management target level (20.63).

Based on new biological reference points from SARC 51, the northern stock of silver hake is not overfished and overfishing is not occurring. The three year arithmetic mean biomass index (Figure A68), based on NEFSC fall bottom trawl survey data in Albatross units for 2007-2009 (6.20 kg/tow), was above the management threshold (3.21 kg/tow) and below the target (6.42 kg/tow). The three year average exploitation index (catch divided by biomass index, Figure A68) for 2007-2009 (0.20 kt/kg) was below the overfishing threshold (2.78 kt/kg).

Based on new biological reference points from SARC 51, the southern stock of silver hake is not overfished and overfishing is not occurring. The three year arithmetic mean biomass index (Figure A69), based on NEFSC fall bottom trawl survey data in Albatross units for 2007-2009 (1.11 kg/tow), was above the management threshold (0.83 kg/tow) and below the target (1.65 kg/tow). The three year average exploitation index (catch divided by biomass index, Figure A69) for 2007-2009 (5.87 kt/kg) was below the overfishing threshold (34.19 kt/kg).

TOR 8. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).

> *a. Provide numerical short-term projections (3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).*
>
> *b. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.*
>
> *c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.*

Stock projections were not carried out because the results from the ASAP model were not accepted for stock determination. However, with recent increases in stock biomass in the north, relatively stable biomass in the south and average recruitments in both areas, with low fishing mortality rates; qualitative analyses suggest that it is unlikely that the northern and southern stocks of silver hake will decline significantly in the short-term. Despite this assertion, uncertainties in the assessment exist due to the unknown cause of age truncation in the age-structure and the unknown magnitude of species mixing in the catch.

Summary

The population dynamics of silver hake in the northwest Atlantic have changed through time. In particular, patterns in growth and spatial distribution have changed substantially over the last 40years. Age structure, fish growth and spatial distribution reflect stock productivity. The current age structure indicates very little rebuilding of age-6 and older has occurred. It is likely that the lack of rebuilding of the age structure may have resulted from the continued high fishing mortality rates following the cessation of the distant water fleet.

Survey trends indicate that biomass in the northern area is high and low for the southern stock area. The incoherence of the survey trends relative to the levels of removals in the southern area is likely due to movement and therefore the survey trend may reflect seasonal abundances rather that trends for the southern stock. Although the evidence for silver hake stock structure is equivocal, a combined area model formulation appears to be more robust and stable relative to the north-south split.

Silver hake population constitutes an important link in the food web. Estimates of consumption of silver hake is on the same order of magnitude as estimates of silver hake stock landings, but consistently higher than landings. This is true for the combined evaluation and for both stocks. Estimates of predatory removal of silver hake via consumption are likely conservative given nature of these consumption estimates. These consumption estimates should be useful to inform both the scaling of biomass estimates and the magnitude of mortalities for silver hake. These estimates are likely to be quite informative to the dynamics of silver hake, as they represent a major source of removals and internal dynamics (cannibalism) that is being accounted for.

Silver hake are cannibalistic. Over 870 occurrences occurred out of over 49,000 silver hake stomachs sampled and recorded in the Food Habits Database, or roughly 2% of every hake caught consumed hake. For perspective, another species thought to be highly cannibalistic, the goosefish (*Lophius americanus*), only had 0.1% incidence of cannibalism. On average, silver hake comprised 12% of the silver hake diet composition (by weight), a significant, consistent and important prey item. This poses some potential tautologies of estimating silver hake abundance to then estimate silver hake cannibalism, which in turn can inform assessment models to estimate silver hake abundance. To accommodate this, we used swept area abundance estimates for silver hake as a predator of silver hake to help scale the total silver hake consumed by silver hake. Cannibalism has implications for recruitment as well, and we are exploring alternative models of stock-recruit relationships to ascertain how much cannibalism can influence those dynamics.

The accepted catch and survey index-based BRPs do not incorporate age structure and do not provide any measures of uncertainty. No age-based analytical model formulations (ASAP) were accepted, nonetheless, the model results were informative. Based on the collective knowledge of the fishery and the surveys, the most likely model (Run 6) did provide indications of trend that were in agreement with the declining age 3+ spawning numbers from the autumn NEFSC survey. Status quo BRPs are not considered appropriate to set ABC. Recent catches have been considerably less than historical ones, however, 3+ numbers in the autumn surveys have been declining since the early 1990s under such catches possibly for reasons other than only fishing (Figures A86-A87).

Research to address fishery selectivity and stock composition (mixing of northern and southern components) and the extent of stock distribution is needed to reconcile the issues regarding selectivity in the current ASAP model formulation.

TOR 9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

SAW1 (1985)

- Re-analysis of VPA incorporating new stock definitions is currently underway
- By-catch and discard of young silver hake in the shrimp fishery a potential source of significant juvenile mortality
- CPUE indices for southern-and northern stocks need to be reconstructed with different standard fleets
- Consistency of surveys and analytical assessments for tracking cohorts will be examined
- Predatory impact of silver hake is likely significant

SAW17 (1994)

- The subcommittee strongly recommends that the stock structure of this resource be closely examined in order to determine the most appropriate aggregation of landings at age and survey data.
- The subcommittee recommends that the survey series be evaluated to 1) determine appropriate strata sets to account for possible differences in distribution between years, 2) determine evidence of mixing between stocks, 3) determine effect of transformations (e.g., logarithmic or delta) in reducing the impact of unusually high tows.
- The subcommittee recommends that the adequacy of the statistical design of the sea sampling program for estimating discards of silver hake be evaluated. The subcommittee notes that this evaluation should be done across several species and that sampling designs need to reflect the priorities given to each species.
- Sea sampling is not yet substitutable for port sampling. Thus, port samples for length composition are essential to estimate landings at age. Since age-structures collected in the survey do not adequately cover commercially caught fish, the

subcommittee recommends that age structures be collected from either the port sampling or sea sampling programs.

- The subcommittee recommends that the spring and summer Canadian surveys be evaluated for use as tuning indices and as indicators of silver hake geographical distribution.
- The developing fishery for juvenile silver hake should be carefully monitored to establish whether it is targeting concentrations of small fish or sampling landing catches that otherwise would have been discarded. From a scientific basis it would be beneficial to take observers aboard that target silver hake, optimally when participating in an experimental fisheries program. This data collection effort is needed to accumulate catch statistics, measure the length composition of landings and discards, and provide adequate sea sampling to determine discard rate.
- There is a need for a market category designation and adequate sampling for small silver hake (<18cm) to properly quantify the magnitude of the landings of these juvenile fish.
- MARMAP data should be examined to gain information on egg and larval silver hake distribution with respect to aggregation of spawning adults.

SAW32 (2001) and SAW42 (2006)

- Develop survey information that covers the offshore range of the population.
- Conduct surveys of spawning aggregations on the southern flank of Georges Bank.
- Investigate bathymetric demography of population.
- Investigate spatial distribution, stock structure and movements of silver hake within Georges Bank, the Gulf of Maine, and the Scotian shelf in relation to physical oceanography.
- Quantify age-specific fecundity of silver hake.

New Research Recommendations (from data and model meetings)

- Studies to estimate discard mortality should be conducted.
- Investigate silver and offshore hake data in deepwater surveys (e.g., monkfish survey).
- Consider hydrographic information in conjunction with the larval indices. This is not currently available, but work is in progress to be able to back-calculate spawning areas.
- Information on consumption by more predators (including mammals, highly migratory species (HMS)) needs to be included.
- Examine diel (day/night) variation in consumption of hakes.
- Validation of the ageing method for silver hake via tagging, radiocarbon, or tetracyclin research needs to be conducted.
- More comprehensive analysis of silver hake stock structure based on DNA (expanded genetic analysis) needs to be conducted.

- Investigate stock identification questions for silver hake by using samples from Tom Helser and Bill Phoel.
- Take M matrix from consumption model and put into model without consumption.

Sources of Uncertainty

1. The mis-reporting of silver hake in thee landings as offshore hale and vice-versa introduces considerable uncertainty in removals. Landings of silver hake may be over-reported and landings of offshore hake may be under-reported.
2. Survey data indicate relatively large silver hake may move around Georges Bank from South stock area to the northern. Uncertainty about north-south movements of adult silver hake is important because of uncertainty about linkages between the northern and southern stock areas.
3. The decreasing trend in abundance of relatively old and larger individuals. These reductions have occurred despite normal growth patterns, low fishing mortality rates and relative high biomass. This possibility of increased natural mortality due to predation is likely which was explored in this assessment.
4. Consumption
    a. Minimum swept area estimates for some predator abundance does not account for q for all predators; these are likely lower estimates of predator abundance and thus these consumption estimates should be viewed as conservative estimates. Although stock assessment estimates of abundance were used for some predators, using a full range of abundance estimates from stock assessments for more predators would also likely increase the estimates noted here.
    b. Is the α too low compared to literature? These too may be somewhat conservative, but are within the range of those generally reported. Again, these should be viewed as conservative estimates.
    c. Some fish predators that did not consistently eat silver hake (e.g. pollock, some of the skates) were not included in the analysis.
    d. Also, these estimates did not include a wide range of other (non-fish) predators known to consume silver hake (e.g., seabirds, squids, marine mammals), nor did they include silver hake cannibalism, which is suspected to be significant. Collectively this relatively limited set of predators thus may result in these being fairly conservative estimates of overall predatory removals of silver hake.
    e. Spatio-temporal overlap considerations between predators and silver hake were assumed.
    f. The degree of tautology due to silver hake cannibalism (i.e. estimating consumption based upon silver hake abundance, to better estimate silver hake abundance) is worth noting and addressing in further detail at some point in the future.

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Table A1. Nominal landings of silver hake by stock from 1955-2009.

	Northern Stock			Southern Stock			Combined Stock		
Year	US	DWF	Total	US	DWF	Total	US	DWF	Total
1955	53,361		53,361	13,842		13,842	67,203		67,203
1956	42,150		42,150	14,871		14,871	57,021		57,021
1957	62,750		62,750	17,153		17,153	79,903		79,903
1958	49,903		49,903	13,473		13,473	63,376		63,376
1959	50,608		50,608	17,112		17,112	67,720		67,720
1960	45,543		45,543	9,206		9,206	54,749		54,749
1961	39,688		39,688	13,209		13,209	52,897		52,897
1962	42,427	36,575	79,002	13,408	5,325	18,733	55,835	41,900	97,735
1963	36,399	37,525	73,924	19,359	74,023	93,382	55,758	111,548	167,306
1964	37,222	57,240	94,462	26,518	127,036	153,554	63,740	184,276	248,016
1965	29,512	15,793	45,305	23,765	283,366	307,131	53,278	299,159	352,437
1966	33,569	14,239	47,808	11,212	200,058	211,270	44,781	214,297	259,078
1967	26,489	6,882	33,371	9,500	81,749	91,249	35,989	88,631	124,620
1968	30,873	10,506	41,379	9,074	49,422	58,496	39,947	59,928	99,875
1969	16,008	8,047	24,055	8,165	67,396	75,561	24,173	75,443	99,616
1970	15,223	12,305	27,528	6,879	20,633	27,512	22,102	32,938	55,040
1971	11,158	25,243	36,401	5,546	66,344	71,890	16,704	91,587	108,291
1972	6,440	18,784	25,224	5,973	88,381	94,354	12,413	107,165	119,578
1973	14,005	18,086	32,091	6,604	97,989	104,593	20,609	116,075	136,684
1974	6,907	13,775	20,682	7,751	102,112	109,863	14,658	115,887	130,545
1975	12,566	27,308	39,874	8,441	65,812	74,253	21,007	93,120	114,127
1976	13,483	151	13,634	10,434	58,307	68,741	23,917	58,458	82,375
1977	12,455	2	12,457	11,458	47,850	59,308	23,913	47,852	71,765
1978	12,609		12,609	12,779	14,353	27,132	25,388	14,353	39,741
1979	3,415		3,415	13,498	4,877	18,375	16,913	4,877	21,790
1980	4,730		4,730	11,848	1,698	13,546	16,578	1,698	18,276
1981	4,416		4,416	11,783	3,043	14,826	16,199	3,043	19,242
1982	4,664		4,664	12,164	2,397	14,561	16,828	2,397	19,225
1983	5,312		5,312	11,520	620	12,140	16,832	620	17,452
1984	8,289		8,289	12,731	412	13,143	21,020	412	21,432
1985	8,297		8,297	11,843	1,321	13,164	20,140	1,321	21,461
1986	8,502		8,502	9,573	550	10,123	18,075	550	18,625
1987	5,658		5,658	10,121	2	10,123	15,779	2	15,781
1988	6,789		6,789	9,195		9,195	15,984		15,984
1989	4,648		4,648	13,428		13,428	18,076		18,076
1990	6,377		6,377	13,610		13,610	19,987		19,987
1991	6,055		6,055	10,492		10,492	16,547		16,547
1992	5,306		5,306	10,873		10,873	16,179		16,179
1993	4,364		4,364	12,942		12,942	17,306		17,306
1994	3,899		3,899	12,159		12,159	16,058		16,058
1995	2,594		2,594	12,102		12,102	14,696		14,696
1996	3,619		3,619	12,561		12,561	16,180		16,180
1997	2,802		2,802	12,763		12,763	15,565		15,565
1998	2,045		2,045	12,828		12,828	14,873		14,873
1999	3,444		3,444	10,577		10,577	14,021		14,021
2000	2,592		2,592	9,769		9,769	12,361		12,361
2001	3,391		3,391	9,517		9,517	12,908		12,908
2002	2,593		2,593	5,344		5,344	7,937		7,937
2003	1,808		1,808	6,835		6,835	8,643		8,643
2004	1,049		1,049	7,436		7,436	8,485		8,485
2005	827		827	6,670		6,670	7,497		7,497
2006	903		903	4,629		4,629	5,532		5,532
2007	1,014		1,014	5,345		5,345	6,359		6,359
2008	620		620	5,638		5,638	6,258		6,258
2009	1,038		1,038	6,720		6,720	7,755		7,758

Table A2. Landings of silver hake in metric tons from the northern region by state.

Year	CT	ME	MD	MA	NH	NJ	NY	RI	VA	Unknown	Total
1964		11499		24722				<1		1000	37,222
1965		12625		16887							29,512
1966		13357		20212							33,569
1967		9368		16855				1		265	26,489
1968		13068		17789				<1		16	30,873
1969		8115		7893							16,008
1970		6730		8489				<1		4	15,223
1971		4491		6659				1		7	11,158
1972		1857		4568				1		14	6,440
1973		2503		11502				<1			14,005
1974		1301		5604				1			6,907
1975		544		12022				<1			12,566
1976		185		13284				1		14	13,483
1977		116		12324				<1		15	12,455
1978		527		12054				<1		28	12,609
1979		65		3334				4		12	3,415
1980		245		4448				3		34	4,730
1981		1280		2994	7	2		80		53	4,416
1982		871		3747	16	17		13			4,664
1983		1051		4209	48			4			5,312
1984		1644		6388	64			193			8,289
1985		1131		6691	99			371		5	8,297
1986		876		7496	85			45			8,502
1987		580		4885	72			119		2	5,658
1988		972		4075	69	<1		1673			6,789
1989		342		2794	57			1455			4,648
1990		120		3747	103	<1		2408			6,377
1991		57		3561	78			2359			6,055
1992		46		3165	84			2010			5,306
1993		28		2247	64			2025			4,364
1994		875		2045	92			887			3,899
1995	243	896	<1	1211	80	10	19	135	<1		2,594
1996	318	1452		1144	110		137	459			3,619
1997	131	558		1258	148	5	116	585			2,802
1998	118	76		1153	49	<1	332	317			2,045
1999	540	64		1804	111		380	546			3,444
2000	240	9		1953	163		1	227			2,592
2001	438	14		2199	136		105	499			3,391
2002	251	6		1701	79		106	450			2,593
2003	67	1		1205	83		141	311			1,808
2004	173	1		753	71		31	20			1,049
2005	54	1		644	39		17	71			827
2006	148	<1		538	44		34	140			903
2007	1	<1	3	665	93		24	228			1,014
2008	<1	<1		444	83		<1	21	72		620
2009	10	<1		882	144	<1		1			1,038

Table A3 Landings of silver hake in metric tons from the southern region by state.

	CT	ME	MD	MA	NH	NJ	NY	NC	PA	RI	VA	Unknown	Total
1964				709						1677		24132	26,518
1965				3481						1077		19207	23,765
1966		23		3139						1080		6970	11,212
1967		12		296						552		8640	9,500
1968				579						976		7519	9,074
1969				435						1274		6456	8,165
1970				1304						1629		3946	6,879
1971				179						1318		4049	5,546
1972				525						1219		4229	5,973
1973				53						1397		5154	6,604
1974				6						2337		5408	7,751
1975				52						2400		5989	8,441
1976				70						3249		7115	10,434
1977				4						2469		8985	11,458
1978				298		5021				2981		4479	12,779
1979				62		5356				3776		4304	13,498
1980		2		12		5362				3132		3340	11,848
1981		<1		11		4113				4520		3138	11,783
1982		<1	5	92		3204				6811	80	1971	12,164
1983			15	157		3000				6101	36	2211	11,520
1984			12	2		3720				6620	76	2300	12,731
1985			4	8		4087				5653	25	2066	11,843
1986			1	13		2676	1072			5633	12	165	9,573
1987		1	<1	1		1897	2052			5926	30	214	10,121
1988		<1	3	<1		2765	1900			4483	9	35	9,195
1989	351	1	6	2		3719	4109			5220	20		13,428
1990	238		10	236		3913	3354			5833	26		13,610
1991	385	<1	7	397		1976	2769			4945	14		10,492
1992	572	<1	1	436		943	2693			6226	3		10,873
1993	1088	<1	6	228		1098	5534			4982	5		12,942
1994	857	3	1	86		1214	5055			4918	5	20	12,159
1995	1352	2	2	70	<1	1229	5118			4325	4		12,102
1996	2242	2	1	89	<1	816	5633			3773	5		12,561
1997	1757	7	1	35	<1	981	5319			4661	2		12,763
1998	1643	4	<1	39		701	6081	<1		4353	6		12,828
1999	2404	<1	1	120	<1	336	3879			3836	1		10,577
2000	2573	1	1	307		299	2048	2		4540	<1		9,770
2001	1926	1	1	290	1	361	3248	1		3686	3		9,517
2002	898	14	<1	458	<1	425	1693	2		1855	<1		5,345
2003	1046	<1	<1	1518		68	1891	1		2310	<1		6,835
2004	1207	<1	<1	1917	<1	116	2098	<1	<1	2097	1		7,436
2005	1493	1	<1	1865		140	1100			2073			6,671
2006	1049	1		1132		90	761			1596			4,629
2007	824		<1	796		491	1119			2114			5,345
2008	607	<1	<1	1104		432	1188			2265	42		5,638
2009	302			1579		1070	1233			2535	1		6,720

Table A4. Landings of silver hake in metric tons from the northern region by gear.

Year	LL	OTF	OTS	SGN	OTH	Total
1964	<1	37215		<1	7	37,222
1965		29512		<1	<1	29,512
1966	<1	33551		<1	18	33,569
1967		26488			1	26,489
1968		30871			2	30,873
1969	<1	16008				16,008
1970		15223		<1	<1	15,223
1971	1	11157		<1	<1	11,158
1972	<1	6439		1	<1	6,440
1973	<1	13976		1	28	14,005
1974	<1	6890		11	5	6,907
1975	1	12270	282	13		12,566
1976	3	13405	24	48	3	13,483
1977	3	12368	26	54	4	12,455
1978	1	12471		64	73	12,609
1979	1	3386	1	19	8	3,415
1980	1	4666	5	50	8	4,730
1981	1	4187	175	50	3	4,416
1982	<1	4503	124	27	8	4,664
1983	1	5000	254	29	28	5,312
1984	<1	8035	133	39	81	8,289
1985	<1	7697	464	30	106	8,297
1986	<1	7585	736	49	133	8,502
1987	<1	5008	423	60	167	5,658
1988	<1	6211	395	24	158	6,789
1989	<1	4322	240	38	48	4,648
1990	1	6041	258	73	3	6,377
1991	<1	5756	170	55	73	6,055
1992	1	5078	100	44	82	5,306
1993	2	4195	4	42	121	4,364
1994	<1	3723	21	72	82	3,899
1995	<1	2257	20	56	260	2,594
1996	<1	3516	45	56	2	3,619
1997	<1	2599	131	45	26	2,802
1998	5	1998	9	30	3	2,045
1999	1	3389	16	22	16	3,444
2000	<1	2457	22	41	72	2,592
2001	<1	3293	1	24	73	3,391
2002	<1	2565	<1	20	7	2,593
2003	<1	1753		15	40	1,808
2004	<1	969	<1	26	54	1,049
2005	<1	733	<1	37	57	827
2006		883	1	17	2	903
2007	<1	1005	1	8		1,014
2008	<1	575	3	41	1	620
2009	<1	820	8	200	10	1,038

Table A5. Landings of silver hake in metric tons from the southern region by gear.

Year	LL	OTF	SGN	OTH	Total
1964		26518		<1	26,518
1965		23765		<1	23,765
1966		11212			11,212
1967		9499		01	9,500
1968		9073		1	9,074
1969		8165		<1	8,165
1970		6879			6,879
1971		5546		<1	5,546
1972		5862	1	109	5,973
1973		6593		11	6,604
1974		7747		4	7,751
1975		8440	<1	1	8,441
1976		10430	<1	4	10,434
1977		11457		1	11,458
1978	<1	12746	4	29	12,779
1979		13459	6	33	13,498
1980	<1	11828	6	14	11,848
1981	<1	11772	6	5	11,783
1982		12147	3	14	12,164
1983		11500	14	6	11,520
1984		12689	18	24	12,731
1985		11828	8	6	11,843
1986		9564	3	6	9,573
1987	1	10113	2	5	10,121
1988	<1	9191	1	3	9,195
1989		13422	1	5	13,428
1990		13605	1	4	13,610
1991	<1	10484	2	6	10,492
1992	<1	10872	1	<1	10,873
1993	<1	12927	1	14	12,942
1994	3	11288	1	867	12,159
1995	<1	10731	1	1371	12,102
1996	<1	12543	1	12.81	12,561
1997		12741	1	21	12,763
1998		12786	10	32	12,828
1999	3	10557	2	15	10,577
2000	<1	9755	8	6	9,769
2001	<1	9509	2	6	9,517
2002		5330	3	12	5,345
2003		6818	13	4	6,835
2004	<1	7146	49	241	7,436
2005	60	6211	30	370	6,671
2006	30	4273	68	258	4,629
2007		5053	78	214	5,345
2008	17	4998	143	480	5,638
2009	<1	4735	168	1817	6,720

Table A6. Landings of silver hake in metric tons from the northern region by month.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
1964	1000	4	<1		<1	360	5168	15031	7953	3999	2405	1202	99	37,222
1965		1	1		12	7	2614	12088	7411	5084	1603	649	41	29,512
1966				<1	<1	60	3868	9305	13307	4237	2185	577	30	33,569
1967	265	<1	1			<1	1179	11176	8279	2813	2183	582	12	26,489
1968	15			<1	1	279	3076	11202	9609	4498	2047	140	6	30,873
1969		<1				24	2308	6563	3701	1677	1278	367	91	16,008
1970	3	5	4	21	21	287	1737	4657	5050	1898	901	554	85	15,223
1971	8	2	1	11	7	7	596	4759	2541	607	1016	1447	156	11,158
1972	14	10	1	1	3	225	240	1332	1231	670	1231	1018	464	6,440
1973		9	9	17	54	138	1078	3478	3326	2356	2188	823	529	14,005
1974		18	2	3	8	140	481	1128	1949	1029	711	1139	299	6,907
1975		43	42	24	37	1487	1092	3521	1875	1137	1921	1117	274	12,566
1976	15	99	693	1091	314	302	520	2517	2832	2820	1303	757	220	13,483
1977	15	46	16	87	1404	544	434	1299	3707	2096	1809	601	397	12,455
1978	27	46	356	53	343	625	358	2630	4846	1364	1066	754	141	12,609
1979	12	21	3	21	81	32	87	679	520	510	539	807	103	3,415
1980	34	29	14	16	17	30	229	519	561	1085	1691	392	113	4,730
1981	53	40	46	73	200	108	221	463	803	693	1037	525	154	4,416
1982		57	24	78	42	81	94	318	1251	984	805	598	332	4,664
1983		98	18	62	199	54	288	709	1205	669	652	729	629	5,312
1984	1	72	22	78	74	40	116	582	1869	1431	1580	1549	875	8,289
1985	5	165	96	290	74	161	347	800	1471	1476	1221	1293	898	8,297
1986	2	324	383	223	124	172	317	1274	1278	1054	1414	1261	676	8,502
1987	1	148	75	103	94	180	235	535	457	1062	948	1289	531	5,658
1988		272	148	158	67	182	388	963	1436	1131	957	751	336	6,789
1989		169	31	29	61	94	210	552	1755	611	651	359	127	4,648
1990		90	46	37	47	46	51	1113	1839	853	921	922	413	6,377
1991		110	52	17	16	22	191	2271	1109	694	802	567	204	6,055
1992	2	123	32	11	1	8	71	1227	1301	856	860	688	126	5,306
1993	3	55	7	19	<1	43	127	1476	1086	495	475	443	135	4,364
1994		52	8	20	30	26	199	758	778	884	614	416	114	3,899
1995	2	9	1	1	1	24	49	387	859	595	441	202	23	2,594
1996		4	1	4	2	48	55	415	1071	965	807	214	33	3,619
1997	1	16	14	31	52	94	73	442	683	686	485	208	16	2,802
1998		4	1	2	26	1	29	371	601	413	232	333	33	2,045
1999		8	1	24	6	1	74	659	926	634	520	507	85	3,444
2000		51	57	117	5	4	85	430	451	372	608	368	43	2,592
2001		70	67	65	3	9	37	450	842	804	461	428	156	3,391
2002		32	21	2	2	1	59	472	630	663	472	197	42	2,593
2003		11	1	<1	<1	9	35	410	668	331	178	153	12	1,808
2004		3	<1	<1	2	16	22	70	263	491	120	43	20	1,049
2005		<1	1	<1	<1	44	38	139	396	151	44	9	4	827
2006		2	12	1	<1	<1	<1	42	456	368	7	11	4	903
2007		<1	<1	8	<1	<1	1	94	310	318	247	22	12	1,014
2008		<1	2	1	7	13	7	108	115	81	107	157	22	620
2009		22	<1	2	2	11	8	251	165	167	50	298	63	1,038

Table A7. Landings of silver hake in metric tons from the southern region by month.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	Total
1964	24,133	15	10	4	105	308	876	183	177	118	266	183	140	26,518
1965	19,208	22	4	15	481	1670	1768	196	111	38	90	86	76	23,765
1966	6,961	24	40	22	484	1329	782	394	741	78	201	94	62	11,212
1967	8,637	15	6	15	69	77	393	48	47	32	47	64	50	9,500
1968	7,519	22	27	53	36	170	650	136	118	85	120	75	63	9,074
1969	6,455	21	13	20	103	413	434	160	124	187	90	88	57	8,165
1970	3,947	13	23	25	29	1055	750	285	365	201	78	60	48	6,879
1971	4,050	9	11	50	35	101	358	364	245	109	46	36	132	5,546
1972	4,230	78	9	15	20	412	562	145	275	81	6	69	71	5,973
1973	5,154	59	14	18	23	261	322	156	120	75	84	138	180	6,604
1974	5,406	172	186	160	205	366	363	273	42	46	51	77	404	7,751
1975	5,988	313	89	119	169	324	280	158	161	96	132	131	481	8,441
1976	7,117	298	185	129	362	338	399	298	221	329	103	358	297	10,434
1977	8,986	56	36	49	36	270	465	270	297	231	103	170	489	11,458
1978	4,478	871	1018	1124	848	1153	786	134	111	164	264	642	1186	12,779
1979	4,303	1492	779	991	741	798	496	438	357	383	508	839	1373	13,498
1980	3,340	1131	896	737	1095	968	456	300	285	373	443	608	1216	11,848
1981	3,138	1193	382	673	842	1071	1118	533	429	330	340	854	880	11,783
1982	1,972	953	729	1074	590	1359	1642	715	613	505	546	577	889	12,164
1983	2,212	1145	753	599	721	856	979	871	734	743	493	564	850	11,520
1984	2,301	1214	780	1388	976	1153	1258	1300	356	298	493	381	833	12,731
1985	2,067	1318	1079	840	1209	1391	1077	959	465	214	451	269	504	11,843
1986	165	895	429	828	1567	1351	1133	484	452	603	383	350	933	9,573
1987	213	919	815	1219	1199	1359	938	704	877	505	307	246	820	10,121
1988	35	920	1292	1449	1229	1197	1165	395	70	69	242	432	700	9,195
1989	11	1315	1160	1180	1430	1651	1355	1322	390	564	826	998	1226	13,428
1990		1807	1035	1293	1350	1828	1486	881	591	827	584	743	1185	13,610
1991	11	953	1190	974	1498	1675	1240	172	539	591	355	562	732	10,492
1992	104	953	761	1037	1474	1089	1942	780	350	595	660	491	637	10,873
1993	3	598	986	1397	1380	1510	1194	372	604	1181	1437	1356	924	12,942
1994		1154	1041	1237	1156	1170	1294	913	611	1002	1090	720	771	12,159
1995	4	940	1065	1350	1178	1316	1139	1078	780	884	739	816	813	12,102
1996	2	1194	1340	1250	1320	1433	1278	935	402	637	605	1072	1093	12,561
1997	10	1228	1025	1196	1558	1527	1385	899	526	808	772	827	1002	12,763
1998	1	1058	1145	1393	1243	1255	1487	1036	583	1094	858	835	840	12,828
1999		1071	1034	1365	1469	1474	1149	519	467	406	561	452	610	10,577
2000		1032	992	991	910	923	893	749	878	879	486	386	651	9,769
2001	27	1203	955	1088	911	1208	1209	831	632	280	410	362	401	9,517
2002	22	489	845	683	496	823	556	281	135	144	172	323	376	5,345
2003		524	478	560	361	543	766	668	384	901	601	437	613	6,835
2004		528	780	960	681	684	758	753	665	449	397	491	290	7,436
2005		444	409	822	604	635	850	787	512	657	340	282	328	6,671
2006		318	403	595	393	550	559	530	215	192	313	249	313	4,629
2007		339	342	454	373	556	654	469	615	521	330	316	374	5,338
2008		526	389	626	455	530	401	364	516	585	379	493	373	5,638
2009		420	517	619	488	868	677	613	547	627	604	379	362	6,720

Table A8. Nominal landings of silver hake by region and half year.

	North				South			
Year	1	2	Unknown	Total	1	2	Unknown	Total
1964	5532	30689	1000	37,222	1318	1067	24,133	26,518
1965	2635	26876		29,512	3960	597	19,208	23,765
1966	3928	29641		33,569	2681	1570	6,961	11,212
1967	1180	25045	265	26,489	575	288	8,637	9,500
1968	3356	27502	15	30,873	958	597	7,519	9,074
1969	2332	13677		16,008	1004	706	6,455	8,165
1970	2075	13145	3	15,223	1895	1037	3,947	6,879
1971	624	10526	8	11,158	564	932	4,050	5,546
1972	480	5946	14	6,440	1096	647	4,230	5,973
1973	1305	12700		14,005	697	753	5,154	6,604
1974	652	6255		6,907	1452	893	5,406	7,751
1975	2724	9843		12,566	1294	1159	5,988	8,441
1976	3019	10449	15	13,483	1711	1606	7,117	10,434
1977	2531	9909	15	12,455	912	1560	8,986	11,458
1978	1781	10801	27	12,609	5800	2501	4,478	12,779
1979	245	3158	12	3,415	5297	3898	4,303	13,498
1980	335	4361	34	4,730	5283	3225	3,340	11,848
1981	688	3675	53	4,416	5279	3366	3,138	11,783
1982	376	4288		4,664	6347	3845	1,972	12,164
1983	719	4593		5,312	5053	4255	2,212	11,520
1984	402	7886	1	8,289	6769	3661	2,301	12,731
1985	1133	7159	5	8,297	6914	2862	2,067	11,843
1986	1543	6957	2	8,502	6203	3205	165	9,573
1987	835	4822	1	5,658	6449	3459	213	10,121
1988	1215	5574		6,789	7252	1908	35	9,195
1989	594	4055		4,648	8091	5326	11	13,428
1990	317	6061		6,377	8799	4811		13,610
1991	408	5647		6,055	7530	2951	11	10,492
1992	246	5058	2	5,306	7256	3513	104	10,873
1993	251	4110	3	4,364	7065	5874	3	12,942
1994	335	3564		3,899	7052	5107		12,159
1995	85	2507	2	2,594	6988	5110	4	12,102
1996	114	3505		3,619	7815	4744	2	12,561
1997	280	2520	1	2,802	7919	4834	10	12,763
1998	63	1983		2,045	7581	5246	1	12,828
1999	114	3331		3,444	7562	3015		10,577
2000	319	2272		2,592	5741	4029		9,769
2001	251	3141		3,391	6574	2916	27	9,517
2002	117	2476		2,593	3892	1431	22	5,345
2003	56	1752		1,808	3232	3604		6,835
2004	43	1007		1,049	4391	3045		7,436
2005	83	743		827	3764	2906		6,671
2006	15	888		903	2818	1812		4,629
2007	9	1003		1,014	2718	2625		5,338
2008	30	590		620	2927	2710		5,638
2009	45	994		1,038	3589	3132		6,720

Table A9. Landings of silver hake by market category from the northern region.

	Half 1							Half 2						
Year	Round	Med	Small	Dressed	Juv	King	Large	Round	Med	Small	Dressed	Juv	King	Large
1964	5350			183				30023			666			
1965	2633			2				26626			225			
1966	3916			11				29510			131			
1967	1179			1				24410			634			
1968	3300			55				26867			634			
1969	2331			<1				13314			362			
1970	2052			23				13095			50			
1971	581			43				10415			113			
1972	471			8				5917			29			
1973	1292			13				12600			99			
1974	648			4				6222			33			
1975	2691			28				9678			168			
1976	3010			8				10447			3			
1977	2530			<1				9847			49			
1978	1779			1				10739			62			
1979	241			4				3125			33			
1980	333			4				4341			19			
1981	667			20		1		3591			28		53	
1982	366			6		3		3986		163	63		74	
1983	414		241	18		46		4047		348	16		183	
1984	199		121	2		81		6436		1234	10		206	
1985	788		232	<1		113		5995		606	61		496	
1986	1147		280	2		114		5826		360	355		418	
1987	680		118	1		35		4234		323	6		260	
1988	1027		167	1		19		5030		344	<1		201	
1989	520		51	<1		22		3818		51	16		166	
1990	258		53	<1		6		5776		17	1		263	
1991	394		5	<1		7		5373		9	<1		263	
1992	236		8			3		4692		40			323	
1993	250		1			1		3913		47			148	
1994	275		49		6	4		2774		521		143	113	
1995	73		5	<1		1		1954		162			36	
1996	84		27			1		2755		442			87	
1997	191		87			2		1825		548			148	
1998	54		3			6		1489		188	16	73	212	
1999	79		35			5		2545		289		236	255	
2000	279		8	<1		31		1890		189			193	
2001	206		5			39		2405		416			302	
2002	94		15			5		1801		501			146	
2003	20		34			2		1177		481			93	
2004	13		8	21		1	<1	359		76	362	24	20	100
2005	71		<1	1		<1	1	363		20	303	<1	4	17
2006	10		1	<1	3	<1	<1	291		110	329	41	12	67
2007	9		<1	1		<1	<1	525	72	169	57	50	20	67
2008	17	<1	2	3	<1	1	3	337	48	18	93	3	13	27
2009	1	<1	<1	4		<1	<1	436	43	3	6		9	35

Table A10. Landings of silver hake by market category from the southern region.

	Half 1							Half 2						
Year	Round	Med	Small	Dressed	Juv	King	Large	Round	Med	Small	Dressed	Juv	King	Large
1964	1243			76				548			519			
1965	3934			26				540			59			
1966	2449			223				1374			196			
1967	557			17				259			28			
1968	909			48				560			37			
1969	980			24				701			4			
1970	1864			32				1028			10			
1971	536			29				925			7			
1972	1037			59				644			4			
1973	676			20				743			11			
1974	1388			63				879			13			
1975	1265			28				1121			38			
1976	1674			38				1574			32			
1977	907			5				1561			<1			
1978	5791			8				2496			5			
1979	5294			3				3897			1			
1980	5282			<1				3225			1			
1981	5028			107		145		3253			1		112	
1982	6153			35		160		3718		<1	8		120	
1983	4928			3		122		3994			36		225	
1984	6491		1	12		265		3407		1	1		252	
1985	6662			19		232		2667		10	<1		185	
1986	6005		50	<1		147		3094		1			110	
1987	6291		22			137		3387		<1			72	
1988	7135		<1			117		1853		1	<1		54	
1989	7922		<1			61		4763			4		71	
1990	8564			4		110		4542		1	<1		127	
1991	7168		3	2		154		2643		4	<1		121	
1992	6856		12	<1		155		3187		14	<1		65	
1993	6897		<1			124		3447		1197	1	75	114	
1994	3606		2533	1	361	229		2529		1672	<1	277	75	
1995	5142		1375	<1	33	385		4091		680	<1		328	
1996	5999		1474	<1	2	335		3070		1369	1	23	283	
1997	4620		2583		61	606		3210		1369	<1		251	
1998	5411		1542		75	552		3159		1756		45	282	
1999	4817		1989		338	418		2108		767		4	128	
2000	3793		1571	2	44	299		2438		1187		<1	403	
2001	4335		1214		6	908		1905		602			355	
2002	2355		1059	<1	178	228		916		413			88	
2003	1917		1064			248		1959		1524			118	
2004	2403	<1	1101	406	54	206	63	1203		566	410	267	162	150
2005	1587		640	746	293	85	109	1303		443	551	344	38	49
2006	1103		701	445	209	86	92	739	<1	405	260	143	53	43
2007	1153	128	582		163	128	218	996	101	759	228	53	126	153
2008	864	240	652	318	14	127	198	731	378	367	288	3	179	132
2009	955	592	472	144		160	228	684	338	730	75	20	117	166

Table A11. Summary of number of silver hake measured by port samplers by market category and half in the northern region.

	Round		Small		Dressed		King		Large	
Year	1	2	1	2	1	2	1	2	1	2
1969	202	2135								
1970	218	1838								
1971	243	2481				218				
1972		1221								
1973	320	3572			614					
1974	191	1409			84					
1975	799	855								
1976	1789	2126								
1977	878	3795								
1978	1217	1808								
1979	103	1362								
1980		775								
1981	98	1577								
1982		2007		117						
1983	210	3003		200						
1984	433	1829		519						
1985	221	1946	515	1130			125	338		
1986	974	3183	290	586						
1987	367	2717		839				324		
1988	691	2400	300	728			201	519		
1989	763	1146	106					100		
1990	466	1467								
1991	634	1232					114	129		
1992	215							262		
1993		886								
1995	348	344	202							
1997		207		209						
1998		514								
1999	100	45						113		
2000	269	407						102		
2001	1255	800	218				263	217		
2002	103		98				76	106		
2003	19	426						95		
2004	134	488		201				93		
2005		100		100				4		
2006	110	521						9	108	293
2007		547						189		344
2008		200						12		
2009	87	100								

Table A12. Summary of number of silver hake measured by port samplers by market category and half in the southern region.

	Round		Small		Dressed		Juv		King		Large	
Year	1	2	1	2	1	2	1	2	1	2	1	2
1969	50											
1970	316											
1971	98	311										
1972	216											
1975		793										
1976	200	1268			61							
1977	1418	685										
1978	1039	378										
1979	882	1321										
1980	2128	1995										
1981	1270	2570								154		
1982	3159	2699							472	190		
1983	4246	2067							256	541		
1984	3302	1716							323	306		
1985	5048	2025		110					344	186		
1986	3565	3118							201	468		
1987	5004	2539							167	182		
1988	4778	2922							87			
1989	3643	2594							167	104		
1990	5147	4069							201	100		
1991	3004	2397							95	198		
1992	2610	1023							96			
1993	1414	900		212					41	100		
1994	1003		303									
1995	1489		308						236			
1997	2535	236	1396	317					1475	157		
1998	2877	1585	411	32			104		781	410		
1999	2563	603	102	536			413		526	396		
2000	919	542	526	410					223	182		
2001	3598	2131	1178	555					2201	1021		
2002	3243	1274	1139	221			121		958	98		
2003	3088	1536	981	1309					713	618		
2004	1888	2129	1177	319					515	1163		
2005	2646	4512	539	517					1980	526		696
2006	5634	3341							632	461	1503	1256
2007	7499	3575		102					1209	614	1833	2585
2008	5432	3828	109						997	964	2376	1331
2009	4013	2890					100		1498	683	1339	1340

Table A13. Summary of number of offshore hake measured by port samplers by market category, half and region.

	North	South		
	Round	Round		King
Year	Half 1	Half 1	Half 2	Half 1
1993			103	
1994				
1997		135		
2003				31
2004				337
2005	1			
2006		29		

Table A14. Pooling of silver/offshore hake port length samples to estimate length and species composition of the commercial landings by region and market category.

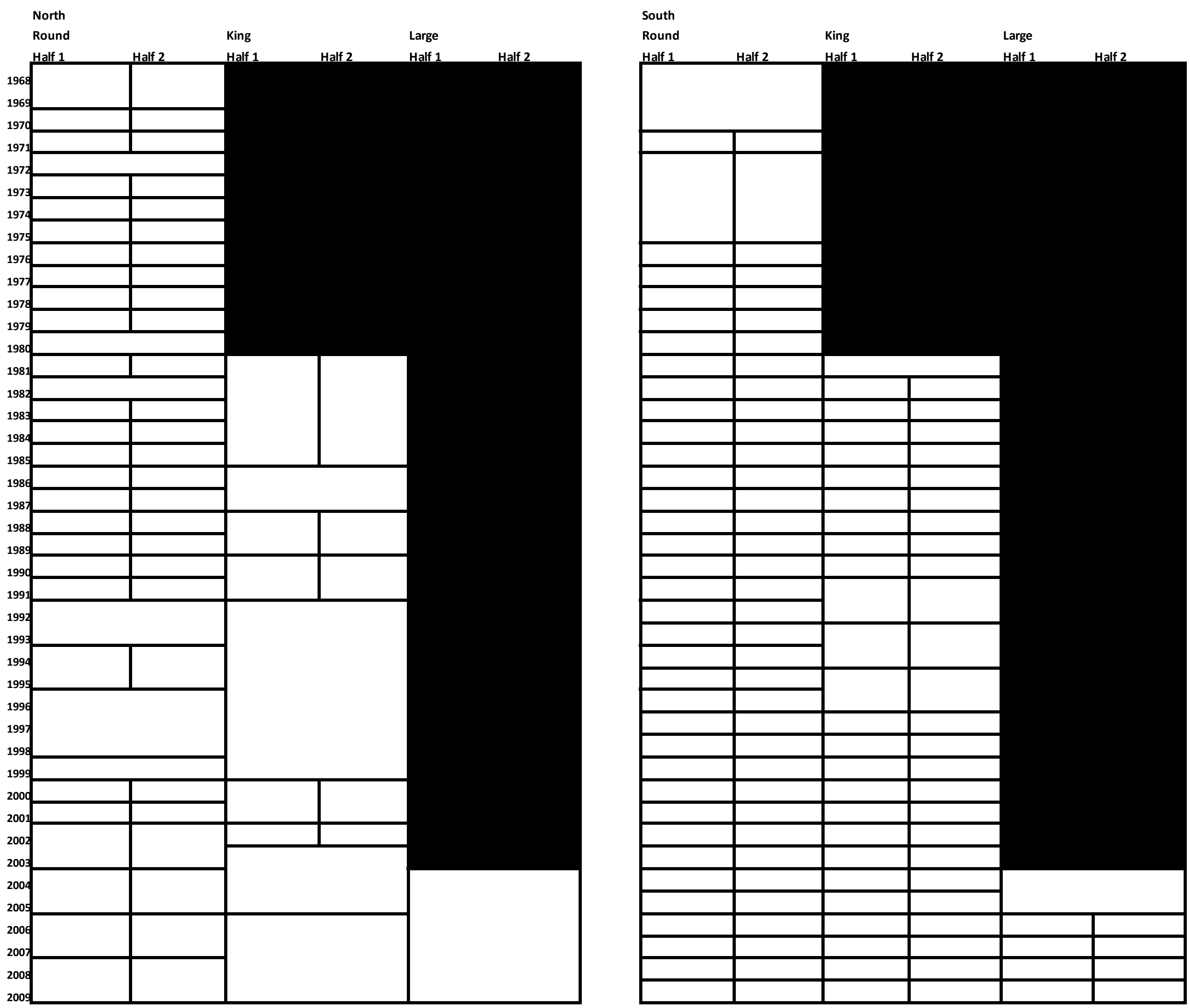

Table A15: Comparison of estimated and reported offshore and silver hake landings, 2004-2009. Red values reflect revisions from the original working paper. Differences are less than 1%.

	Model based estimate			Dealer reported landings			VTR hail weights			
	Offshore hake	Silver hake	Percent offshore	Offshore hake	Silver hake	Percent offshore	Reporting vessels	Offshore hake	Silver hake	Percent offshore
2004	894	6,566	12.00%	18	6,096	0.30%	371	169	6,124	2.70%
2005	819	5,865	12.20%	9	5,886	0.10%	321	213	6,439	3.20%
2006	459	4,207	9.80%	35	3,973	0.90%	405	121	4,170	2.80%
2007	350	5,006	6.50%	11	4,316	0.30%	384	180	4,677	3.70%
2008	290	5,376	5.10%	19	4,127	0.50%	370	194	4,544	4.10%
2009	331	6,406	4.90%	13	4,328	0.30%	382	139	5,363	2.50%

Table A16. Comparison of alternative methods of landings estimation for silver hake. Bold values reflect hindcasted estimates (bold black fonts are hindecast values using historical landings while the bold red fonts are based on dealer landings).

Year	Nominal	Length-Based	Depth-Based
1955	13842	**13255**	**12891**
1956	14871	**14241**	**13849**
1957	17153	**16426**	**15974**
1958	13473	**12902**	**12547**
1959	17112	**16387**	**15936**
1960	9206	**8816**	**8573**
1961	13209	**12649**	**12301**
1962	18733	**17939**	**17446**
1963	93382	**89425**	**86966**
1964	153554	**147048**	**148312**
1965	307131	**294117**	**282942**
1966	211270	**202318**	**193000**
1967	91249	**87383**	**86163**
1968	58496	58157	**56120**
1969	75561	74891	**72817**
1970	27512	26832	**25642**
1971	71890	70506	**70459**
1972	94354	88178	**89047**
1973	104593	102078	**100176**
1974	109863	102396	**105904**
1975	74253	72164	**71706**
1976	68741	64608	**67395**
1977	59308	57160	**57550**
1978	27132	25834	**26655**
1979	18375	16398	**18052**
1980	13546	11684	**13295**
1981	14826	13429	**14316**
1982	14561	14152	**13634**
1983	12140	11860	**11499**
1984	13143	12955	**12531**
1985	13164	12820	**12468**
1986	10123	9697	**9500**
1987	10123	9552	**9219**
1988	9195	8950	**8017**
1989	13428	12995	**12656**
1990	13610	13020	**12784**
1991	10492	9740	**9731**
1992	10873	10531	**9912**
1993	12942	12487	**11517**
1994	12159	12181	**10851**
1995	12102	11992	**10810**
1996	12561	12134	**10925**
1997	12763	12548	**11413**
1998	12828	12558	**11499**
1999	10577	10417	**9667**
2000	9769	9472	**8918**
2001	9517	8884	**8585**
2002	5344	4888	**4773**
2003	6835	6281	**6363**
2004	7436	6965	6566
2005	6670	6395	5865
2006	4629	4584	4207
2007	5345	5067	5006
2008	5638	5582	5376
2009	6720	6595	6406

Table A17. Port Samples (sampling intensity) for Silver hake in the northern and southern regions

NORTH				SOUTH		
Year	Number of Lengths	Commercial Landings (mt)	Lengths per 100mt	Number of Lengths	Commercial Landings (mt)	Lengths per 100mt
1969	2337	24055	10	50	75561	0
1970	2056	27528	7	316	27512	1
1971	2942	36401	8	409	71890	1
1972	1221	25224	5	216	94354	0
1973	4506	32091	14	0	104593	0
1974	1684	20682	8	0	109863	0
1975	1654	39874	4	793	74253	1
1976	3915	13634	29	1529	68741	2
1977	4673	12457	38	2103	59308	4
1978	3025	12609	24	1417	27132	5
1979	1465	3415	43	2203	18375	12
1980	775	4730	16	4123	13546	30
1981	1675	4416	38	3994	14826	27
1982	2124	4664	46	6520	14561	45
1983	3413	5312	64	7110	12140	59
1984	2781	8289	34	5647	13143	43
1985	4275	8297	52	7713	13164	59
1986	5033	8502	59	7352	10123	73
1987	4247	5658	75	7892	10123	78
1988	4839	6789	71	7787	9195	85
1989	2115	4648	46	6508	13428	48
1990	1933	6377	30	9517	13610	70
1991	2109	6055	35	5694	10492	54
1992	477	5306	9	3729	10873	34
1993	886	4364	20	2667	12942	21
1994	0	3899	0	1306	12159	11
1995	894	2594	34	2033	12102	17
1996	0	3619	0	0	12561	0
1997	416	2802	15	6116	12763	48
1998	514	2045	25	6200	12828	48
1999	258	3444	7	5139	10577	49
2000	778	2592	30	2802	9769	29
2001	2753	3391	81	10684	9517	112
2002	383	2593	15	7054	5344	132
2003	540	1808	30	8245	6835	121
2004	916	1049	87	7191	7436	97
2005	204	827	25	11416	6670	171
2006	1041	903	115	12827	4629	277
2007	1080	1014	107	17417	5345	326
2008	212	620	34	15037	5638	267
2009	187	1038	18	11863	6720	177

Table A18. Silver hake discards from the northern region by gear and half. The discards from 1981-1988 (91 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

	Longline			Large Mesh Otter Trawl			Small Mesh Otter Trawl			Sink Gill Net			Scallop Dredge			Shrimp Trawl		
	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total
1981	0	0	0	417.9	1898.6	2316.4	Na			13.4	53.2	66.6	2.7	28.4	31.1	223.4	0.6	224.0
1982	0	0	0	411.8	2116.1	2527.9	Na			5.9	47.9	53.7	1.6	21.9	23.6	282.0	17.7	299.7
1983	0	0	0	453.9	1783.5	2237.4	Na			6.2	39.8	46.0	1.4	17.2	18.6	285.6	54.1	339.7
1984	0	0	0	379.2	1640.3	2019.4	Na			5.9	52.4	58.3	0.8	10.3	11.1	372.6	130.1	502.7
1985	0	0	0	331.3	1476.8	1808.2	Na			6.4	44.8	51.2	0.6	9.9	10.5	520.1	171.7	691.8
1986	0	0	0	289.6	1159.9	1449.5	Na			7.8	46.9	54.7	1.0	10.6	11.6	634.7	203.5	838.1
1987	0	0	0	243.7	1031.4	1275.1	Na			7.0	47.7	54.6	1.2	20.4	21.6	642.8	112.5	755.4
1988	0	0	0	227.0	982.0	1209.0	Na			7.8	48.6	56.4	1.5	26.0	27.5	379.9	111.7	491.6
1989	0	0	0	56.2	241.6	297.8	183.2	1005.1	1188.3	17.9	34.5	52.4	1.7	29.9	31.6	612.7	159.0	771.7
1990	0	0	0	271.4	415.8	687.2	18.8	611.2	630.0	6.2	81.8	88.0	0.6	31.9	32.5	420.0	130.9	551.0
1991	0	0	0	19.4	372.9	392.3	28.0	486.5	514.5	3.6	40.1	43.8	2.7	3.5	6.2	262.6	31.6	294.2
1992	0	0	0	99.8	271.9	371.8	28.1	555.0	583.0	5.1	37.4	42.4	0.0	5.2	5.2	378.4	48.7	427.1
1993	0	0	0	94.7	165.3	260.1	9.7	179.2	189.0	5.2	55.2	60.4	1.5	58.5	60.0	62.2	108.4	170.6
1994	0	0	0	29.0	15.6	44.7	3.8	63.0	66.8	2.8	41.0	43.8	0.6	0.5	1.1	25.5	58.3	83.8
1995	0.008	0.010	0.019	56.5	64.2	120.7	2.7	17.6	20.2	5.6	23.5	29.1	1.9	5.7	7.6	216.7	239.5	456.1
1996	0.008	0.008	0.016	55.7	9.3	65.1	1.2	19.5	20.7	3.6	52.9	56.5	0.0	2.1	2.1	576.3	105.0	681.3
1997	0.008	0.008	0.017	28.1	28.8	56.8	1.8	14.3	16.1	14.1	13.3	27.4	0.5	6.9	7.4	126.4	15.1	141.5
1998	0.006	0.010	0.016	116.8	21.5	138.3	23.0	269.3	292.3	4.6	4.4	9.0	19.2	17.3	36.6	206.2	11.2	217.4
1999	0.006	0.008	0.015	26.9	143.1	170.0	20.4	395.6	415.9	8.9	9.3	18.2	8.9	10.6	19.5	93.6	2.2	95.8
2000	0.004	0.009	0.013	102.2	83.3	185.5	0.1	0.7	0.9	9.3	15.1	24.4	1.4	2.7	4.1	137.8	2.3	140.1
2001	0.005	0.006	0.011	182.7	221.2	404.0	3.5	14.3	17.7	3.7	8.9	12.6	1.8	1.4	3.2	39.4		39.4
2002	0	0	0	291.6	95.8	387.4	0	103.0	103.0	3.5	5.7	9.2	1.7	2.2	3.9	9.7		9.7
2003	0	0	0	40.5	34.7	75.2	0.3	90.3	90.6	7.3	2.9	10.2	0	4.4	4.4	22.0		22.0
2004	0	0	0	22.1	44.5	66.5	0.1	29.6	29.6	1.2	1.8	2.9	0.1	0.0	0.1	13.4	0.6	13.9
2005	0	0.019	0.019	5.2	35.4	40.6	0.2	9.1	9.3	0.1	0.9	1.0	0.0	0.6	0.6	10.3	0.5	10.7
2006	0	0	0	3.7	17.3	21.1	0	4.9	5.0	0.7	0.4	1.1	0	1.1	1.1	2.5	7.3	9.8
2007	0.002	0	0.002	4.1	14.9	18.9	42.3	669.7	712.0	0.8	0.6	1.5	0.2	1.9	2.1	11.7	2.8	14.5
2008	0	0.002	0.002	12.6	32.2	44.8	8.1	63.6	71.7	1.4	4.7	6.2	0.2	0.1	0.3	35.1	9.0	44.1
2009	0	0	0	13.9	54.5	68.4	11.9	83.7	95.6	2.0	4.3	6.4	0.1	2.7	2.8	14.6	28.3	42.9

Table A19. Silver hake discards from the southern region by gear and half. The discards from 1981-1988 (91 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

	Longline				Large Mesh Otter Trawl				Small Mesh Otter Trawl				Sink Gill Net				Scallop Dredge		
	1	2	Total		1	2	Total		1	2	Total		1	2	Total		1	2	Total
1981	0	0	0		2332.4	1176.2	3508.5		Na				0.0	0.1	0.1		6.1	87.9	94.0
1982	0	0	0		2646.2	2069.8	4716.0		Na				0.0	0.1	0.1		3.6	67.9	71.6
1983	0	0	0		2869.3	2026.3	4895.7		Na				0.0	0.1	0.1		3.1	53.3	56.4
1984	0	0	0		3124.7	1864.3	4989.1		Na				0.0	0.2	0.2		1.8	31.9	33.7
1985	0	0	0		2580.7	1369.7	3950.3		Na				0.0	0.1	0.1		1.2	30.7	31.9
1986	0	0	0		2598.7	1822.2	4420.9		Na				0.0	0.2	0.2		2.3	32.9	35.2
1987	0	0	0		2664.5	1643.3	4307.8		Na				0.0	0.2	0.2		2.7	63.2	65.9
1988	0	0	0		2971.7	1570.4	4542.1		Na				0.0	0.2	0.2		3.4	80.5	83.9
1989	0	0	0		31.1	81.0	112.1		5295.8	1085.1	6380.9		0	0	0		12.5	136.8	149.3
1990	0	0	0		2342.0	420.7	2762.6		1211.4	1961.3	3172.7		0	0	0		20.5	237.5	258.0
1991	0	0	0		201.0	993.0	1194.0		539.8	1480.5	2020.3		0	0.1	0.1		12.8	6.8	19.6
1992	0	0	0		443.9	211.2	655.1		244.7	2559.4	2804.1		0.6	2.7	3.3		9.8	7.4	17.2
1993	0	0	0		250.5	15.7	266.2		3144.5	1475.9	4620.4		1.4	3.4	4.8		6.9	346.2	353.1
1994	0	0	0		549.7	11.0	560.7		3067.1	2335.5	5402.7		0.4	0.3	0.7		15.0	12.4	27.4
1995	0	0	0		136.9	5.8	142.7		83.1	1087.9	1171.0		0.2	0.3	0.4		64.5	60.5	125.0
1996	0.058	0.041	0.099		9.2	10.4	19.6		386.0	52.6	438.6		0.2	0	0.2		19.7	12.7	32.4
1997	0.066	0.057	0.123		26.7	341.4	368.2		220.7	0.1	220.8		1.7	0.4	2.1		33.6	14.5	48.1
1998	0.064	0.044	0.108		2.0	0	2.0		322.0	14.2	336.2		0.3	0.2	0.5		2.5	12.5	15.0
1999	0.049	0.023	0.072		0	18.9	18.9		3461.8	29.5	3491.4		0.9	0	0.9		22.1	18.5	40.6
2000	0.033	0.028	0.061		7.4	1.9	9.4		29.7	161.2	190.9		7.6	0	7.6		80.2	44.7	124.9
2001	0.046	0.046	0.092		2.9	0.3	3.2		25.3	152.0	177.4		0	0	0		6.1	5.7	11.8
2002	0	0	0		5.9	1.3	7.2		160.5	96.8	257.3		0.4	0	0.4		11.4	3.6	14.9
2003	0	0	0		3.8	11.0	14.8		137.2	515.7	652.9		1.2	0.0	1.3		1.7	5.2	7.0
2004	0	0	0		25.2	63.9	89.1		380.4	760.5	1141.0		0.4	0	0.4		4.5	9.0	13.5
2005	0	0	0		19.5	31.2	50.7		825.6	685.9	1511.5		0.1	0.2	0.2		3.4	8.4	11.8
2006	0.045	0.028	0.073		8.9	15.7	24.5		95.7	28.0	123.7		0.0	0	0.0		1.0	11.2	12.2
2007	0.140	0.190	0.331		8.0	13.5	21.5		47.5	53.8	101.3		0	0	0		5.3	3.5	8.8
2008	0.165	0.160	0.325		12.6	12.1	24.7		713.7	299.3	1013.1		0.0	0	0.0		3.7	3.5	7.2
2009	0.121	0.209	0.330		33.2	24.9	58.2		185.9	562.2	748.1		0.1	0.0	0.1		14.5	6.3	20.8

Table A20. Offshore hake discards from the northern region by gear and half. The hind-cast discards for offshore hake are zero.

	Large Mesh Otter Trawl				Small Mesh Otter Trawl				Sink Gill Net				Scallop Dredge		
	1	2	Total		1	2	Total		1	2	Total		1	2	Total
1989	0	0	0		0	0	0		0	0	0		0	0	0
1990	0	0	0		0	0	0		0	0	0		0	0	0
1991	0	0	0		0	0	0		0	0	0		0	0	0
1992	0	0	0		0	0	0		0	0	0		0	0	0
1993	0	0	0		0	0	0		0	0.023	0.023		0	0	0
1994	0	0	0		0	0	0		0	0	0		0	0	0
1995	0	0	0		0	0	0		0	0	0		0	0	0
1996	0	0	0		0	0	0		0	0	0		0	0	0
1997	0	0	0		0	0	0		0	0	0		0	0	0
1998	0	0	0		0	0	0		0	0	0		0	0	0
1999	0	0	0		0	0	0		0	0	0		0	0	0
2000	0	6.544	6.544		0	0	0		0	0	0		0	0	0
2001	0	0.065	0.065		0	0	0		0	0	0		0	0	0
2002	0.428	0.028	0.457		0	0	0		0.272	0	0.272		0.016	0.021	0.038
2003	0.028	0	0.028		0	0	0		0	0.085	0.085		0	0.339	0.339
2004	2.169	0.023	2.192		0	0	0		0	0	0		0	0	0
2005	0.168	0.025	0.192		0	0	0		0	0.032	0.032		0	0	0
2006	0	0.520	0.520		0	0	0		0	0	0		0	0	0
2007	0.089	0.630	0.719		0	0	0		0	0.004	0.004		0	0.027	0.027
2008	0.079	0.007	0.086		0	0	0		0	0	0		0	0	0
2009	0.915	4.311	5.226		0.013	0.089	0.102		0	0	0		0	0	0

Table A21. Offshore hake discards from the southern region by gear and half. The hind-cast discards for offshore hake are zero.

	Large Mesh Otter Trawl				Small Mesh Otter Trawl				Sink Gill Net				Scallop Dredge		
	1	2	Total		1	2	Total		1	2	Total		1	2	Total
1989	0	0	0		0	0	0		0	0	0		0	0	0
1990	0	0	0		0	0	0		0	0	0		0	0	0
1991	0	0	0		0	0	0		0	0	0		0	0	0
1992	0	0	0		0	0	0		0	0	0		0	0	0
1993	0	0	0		0	0	0		0	0	0		0	0	0
1994	0	0	0		0	0	0		0	0	0		0	0	0
1995	0	0	0		0	0	0		0	0	0		0.064	0.001	0.064
1996	0	0	0		0	0	0		0	0	0		0	0	0
1997	0	0	0		0.019	1.810	1.828		0.028	0	0.028		1.028	0.435	1.463
1998	0	0	0		170.494	0	170.494		0	0	0		3.386	0	3.386
1999	0	0	0		0	1.168	1.168		0	0	0		0	0.571	0.571
2000	0	0.619	0.619		0.183	0.239	0.422		0	0	0		0	0.056	0.056
2001	0	0.065	0.065		0	9.685	9.685		0	0	0		0	0	0
2002	0	0	0		143.674	0	143.674		0	0	0		0	2.563	2.563
2003	0	0	0		0	0	0		0	0	0		2.183	0.015	2.199
2004	0.036	0.030	0.066		2.131	0.909	3.040		0	0	0		1.618	0.219	1.837
2005	0	0	0		0	6.384	6.384		0	0	0		0	0	0
2006	0	0.416	0.416		0	4.109	4.109		0	0	0		0	0.012	0.012
2007	0.510	0.685	1.195		19.386	0	19.386		0	0	0		0	0.036	0.036
2008	0.926	0.176	1.102		0.006	0	0.006		0	0	0		0.001	0.035	0.035
2009	0.440	4.941	5.381		0.025	20.262	20.287		0.050	0	0.050		0	0	0

Table A22. Number of discarded silver hake sampled from the FOP in the northern region by gear type.

	Large Mesh				Small Mesh				Sink Gill Net				Scallop Dredge				Shrimp Trawl			
	Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2	
	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len
1989	2	213	10	779	3	1543	23	6445	-	-	-	-	-	-	-	-	16	3590	4	546
1990	-	-	5	362	1	84	7	1130	1	4	-	-	-	-	-	-	8	1221	-	-
1991	1	31	1	150	-	-	27	8063	2	5	4	10	-	-	-	-	8	1055	-	-
1992	1	1	-	-	1	100	19	3888	4	24	5	22	-	-	-	-	-	-	-	-
1993	2	222	1	70	-	-	2	371	2	19	2	7	-	-	-	-	13	2383	2	224
1994	-	-	1	11	-	-	-	-	-	-	6	63	-	-	1	1	9	446	2	459
1995	3	32	1	48	-	-	1	81	1	1	-	-	-	-	-	-	4	404	5	728
1996	1	1	-	-	-	-	4	343	1	3	3	31	-	-	-	-	9	470	1	149
1997	1	1	2	66	1	20	-	-	-	-	-	-	-	-	1	1	9	739	-	-
1998	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	9	218	1	2	6	85	-	-	-	-	-	-	-	-
2000	-	-	-	-	-	-	-	-	6	60	2	22	-	-	-	-	-	-	-	-
2001	-	-	1	14	-	-	-	-	2	2	2	3	-	-	-	-	-	-	-	-
2002	-	-	11	265	-	-	9	542	3	4	3	7	-	-	-	-	-	-	-	-
2003	13	565	13	255	-	-	5	241	11	229	12	39	-	-	1	113	5	372	-	-
2004	4	9	23	749	1	5	9	325	6	12	22	65	-	-	-	-	3	284	-	-
2005	13	105	17	259	2	5	9	97	1	1	10	66	-	-	1	2	2	66	-	-
2006	9	69	5	30	-	-	4	1028	1	1	1	1	-	-	-	-	-	-	-	-
2007	9	127	15	195	-	-	2	733	3	14	3	4	-	-	-	-	4	444	-	-
2008	5	155	16	255	-	-	1	144	6	7	6	62	1	3	-	-	6	206	-	-
2009	7	34	16	260	-	-	3	180	3	15	1	1	-	-	-	-	-	-	-	-

Table A23. Number of discarded silver hake sampled from the FOP in the southern region by gear type.

	Large Mesh					Small Mesh					Sink Gill Net					Scallop Dredge			
	Half 1		Half 2			Half 1		Half 2			Half 1		Half 2			Half 1		Half 2	
Year	trips	len	trips	len		trips	len	trips	len		trips	len	trips	len		trips	len	trips	len
1989	2	40	1	150		12	2265	10	1659		-	-	-	-		-	-	-	-
1990	2	399	-	-		8	2090	2	95		-	-	-	-		-	-	-	-
1991	-	-	2	29		5	657	7	860		-	-	-	-		-	-	-	-
1992	-	-	-	-		1	20	5	459		1	1	-	-		-	-	-	-
1993	1	127	-	-		-	-	-	-		1	12	-	-		1	2	-	-
1994	2	49	-	-		1	20	5	239		-	-	-	-		2	5	2	6
1995	1	3	1	11		2	73	-	-		-	-	1	3		4	50	-	-
1996	-	-	-	-		4	290	8	494		2	2	-	-		2	31	3	17
1997	-	-	1	216		7	371	1	2		7	69	1	4		2	112	1	1
1998	-	-	-	-		3	656	-	-		-	-	-	-		-	-	-	-
1999	-	-	-	-		2	309	4	97		-	-	-	-		1	2	-	-
2000	-	-	1	19		1	198	3	88		-	-	-	-		3	456	1	1
2001	-	-	-	-		2	160	3	13		-	-	-	-		-	-	-	-
2002	-	-	-	-		3	139	-	-		-	-	-	-		-	-	-	-
2003	-	-	2	2		3	76	3	40		1	2	-	-		2	3	4	140
2004	6	150	16	359		6	293	24	2007		2	4	-	-		1	17	15	224
2005	9	118	12	471		15	1191	11	1346		-	-	-	-		-	-	5	53
2006	7	48	4	24		10	762	15	764		-	-	-	-		-	-	1	1
2007	3	13	7	106		7	130	14	479		-	-	-	-		4	13	2	10
2008	6	38	10	110		6	580	12	626		-	-	-	-		4	31	7	36
2009	2	19	1	1		10	832	30	1998		1	1	-	-		12	91	6	37

Table A24. Number of kept and discarded offshore hake sampled in all gears from the FOP in the northern region.

	Large Mesh Trawl			Sink Gill Net			
	Half 2			Half 1		Half 2	
	Discards			Discards		Discards	
Year	ntrips	numlen		ntrips	numlen	ntrips	numlen
2002				1	19		
2004	1	1					
2005	2	3				1	1
2006	1	9					
2009	1	1					

Table A25. Number of kept and discarded offshore hake sampled in all gears from the FOP in the southern region.

	Large Mesh Trawl		Small Mesh Trawl				Scallop Dredge	
	Half 1		Half 1		Half 2		Half 1	
	Discards		Discards		Discards		Discards	
Year	ntrips	numlen	ntrips	numlen	ntrips	numlen	ntrips	numlen
1997					1	7		
2001	1	1						
2002								
2004					1	8	1	3
2007								
2009			1	1	1	1		

Table A26. Pooling of silver/offshore hake observer length samples to estimate length and species composition of the commercial discards by gear from the north.

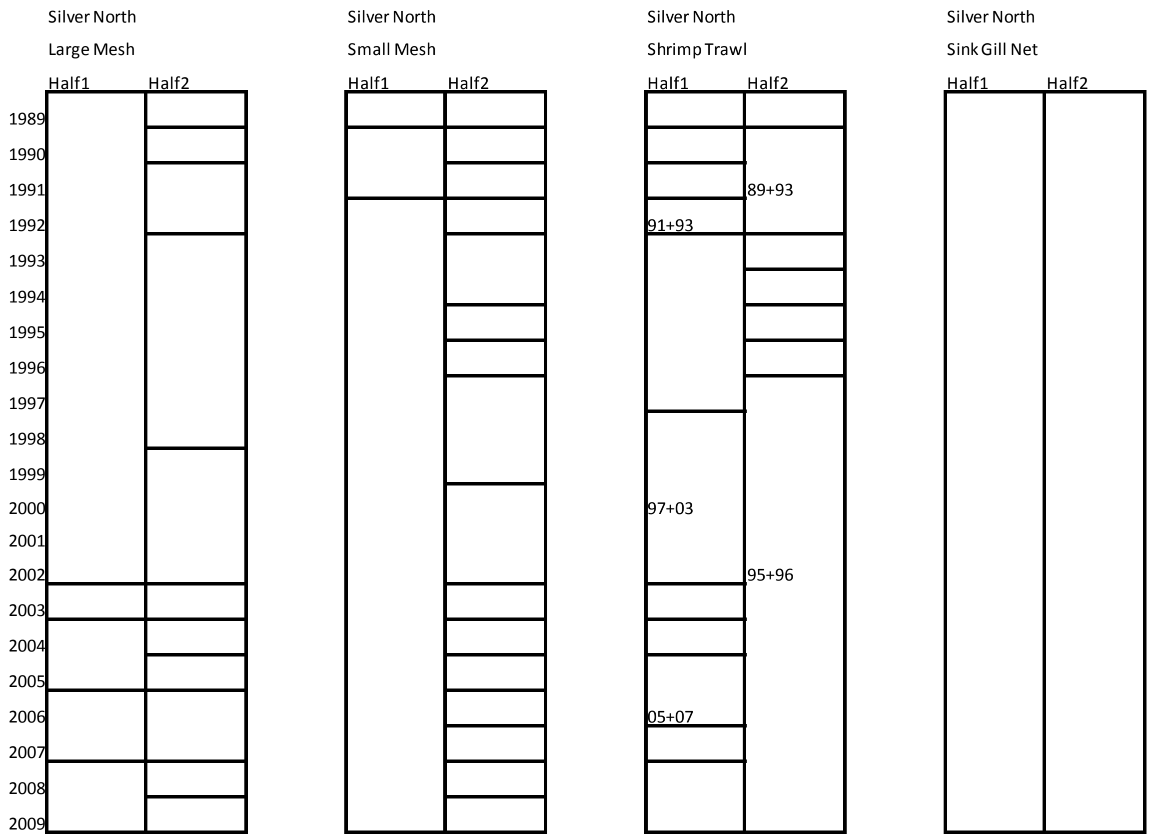

Table A27. Pooling of silver/offshore hake observer length samples to estimate length and species composition of the commercial discards by gear from the south.

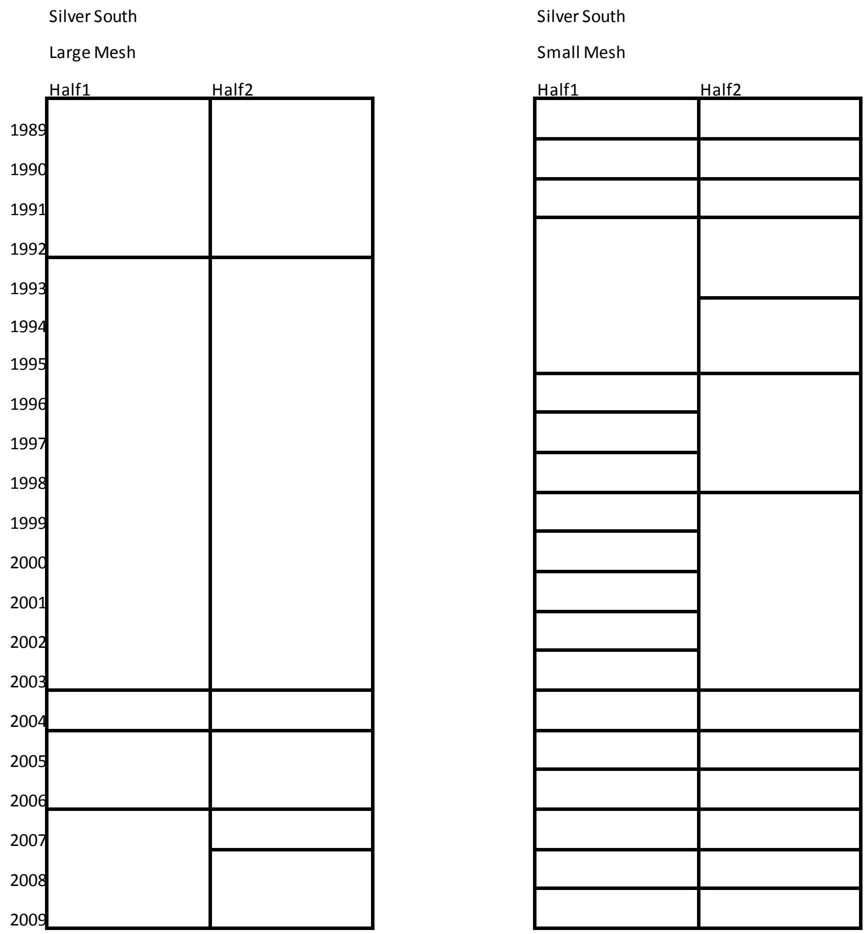

Table A28: Silver hake annual catch in metric tons from the northern stock area.

Year	Domestic	Foreign	Total landings	discards	Total Catch	% discards
1955			53361	0	53361	0%
1956			42150	0	42150	0%
1957			62750	0	62750	0%
1958			49903	0	49903	0%
1959			50608	0	50608	0%
1960			45543	0	45543	0%
1961			39688	0	39688	0%
1962			79002	0	79002	0%
1963			73924	0	73924	0%
1964			94462	0	94462	0%
1965			45279	0	45279	0%
1966			47808	0	47808	0%
1967			33371	0	33371	0%
1968			41379	0	41378.94	0%
1969			24055	0	24054.96	0%
1970			27528	0	27527.97	0%
1971			36398	0	36398.22	0%
1972			25224	0	25223.95	0%
1973	14005	18086	32091	0	32090.95	0%
1974	6,907	13,775	20,682	0	20682	0%
1975	12,566	27,308	39874	0	39874	0%
1976	13,483	151	13634	0	13634	0%
1977	12,455	2	12457	0	12457	0%
1978	12,609	0	12609	0	12609	0%
1979	3415	0	3415	0	3415	0%
1980	4730	0	4730	0	4730	0%
1981	4416	0	4416	2638	7054	37%
1982	4664	0	4664	2905	7569	38%
1983	5312	0	5312	2642	7954	33%
1984	8289	0	8289	2591	10880	24%
1985	8297	0	8297	2562	10859	24%
1986	8502	0	8502	2354	10856	22%
1987	5658	0	5658	2107	7765	27%
1988	6789	0	6789	1785	8574	21%
1989	4648	0	4648	2315	6963	33%
1990	6377	0	6377	1958	8335	23%
1991	6055	0	6055	1256	7311	17%
1992	5306	0	5306	1424	6730	21%
1993	4364	0	4364	686	5050	14%
1994	3899	0	3899	241	4140	6%
1995	2594	0	2594	630	3224	20%
1996	3619	0	3619	824	4443	19%
1997	2802	0	2802	243	3045	8%
1998	2045	0	2045	693	2738	25%
1999	3449	0	3449	742	4190	18%
2000	2592	0	2592	359	2952	12%
2001	3391	0	3391	477	3868	12%
2002	2593	0	2593	513	3106	17%
2003	1808	0	1808	198	2006	10%
2004	1049	0	1049	115	1165	10%
2005	828	0	828	62	890	7%
2006	904	0	904	37	941	4%
2007	1014	0	1014	750	1764	43%
2008	620	0	620	167	788	21%
2009	1042	0	1042	190	1232	15%

Table A29: Silver hake annual catches in metric tons in from the Southern stock area.

Year	Domestic	Foreign	Total landings	discards	Total Catch	% discards
1955			13255	0	13255	0%
1956			14241	0	14241	0%
1957			16426	0	16426	0%
1958			12902	0	12902	0%
1959			16387	0	16387	0%
1960			8816	0	8816	0%
1961			12649	0	12649	0%
1962			17939	0	17939	0%
1963			89425	0	89425	0%
1964			147048	0	147048	0%
1965			294117	0	294117	0%
1966			202318	0	202318	0%
1967			87383	0	87383	0%
1968			58157	0	58157	0%
1969			74891	0	74891	0%
1970			26832	0	26832	0%
1971			70506	0	70506	0%
1972			88179	0	88179	0%
1973	6445	95633	102078	0	102078	0%
1974	7224	95171	102396	0	102396	0%
1975	8204	63961	72164	0	72164	0%
1976	9807	54802	64608	0	64608	0%
1977	11043	46117	57160	0	57160	0%
1978	12168	13666	25834	0	25834	0%
1979	12046	4352	16398	0	16398	0%
1980	10219	1465	11684	0	11684	0%
1981	10672	2756	13429	3502	16931	21%
1982	11822	2330	14152	4654	18806	25%
1983	11254	606	11860	4814	16674	29%
1984	12549	406	12955	4883	17838	27%
1985	11533	1286	12820	3872	16691	23%
1986	9170	527	9697	4332	14029	31%
1987	9550	2	9552	4252	13804	31%
1988	8950	0	8950	4497	13447	33%
1989	12995	0	12995	6573	19568	34%
1990	13020	0	13020	5972	18992	31%
1991	9740	0	9740	3081	12821	24%
1992	10531	0	10531	3446	13977	25%
1993	12487	0	12487	5166	17653	29%
1994	12181	0	12181	5936	18118	33%
1995	11992	0	11992	1402	13394	10%
1996	12134	0	12134	479	12613	4%
1997	12548	0	12548	624	13172	5%
1998	12558	0	12558	526	13084	4%
1999	10417	0	10417	3549	13965	25%
2000	9472	0	9472	329	9800	3%
2001	8884	0	8884	188	9072	2%
2002	4888	0	4888	410	5298	8%
2003	6281	0	6281	604	6884	9%
2004	6965	0	6965	1203	8168	15%
2005	6395	0	6395	1576	7971	20%
2006	4583	0	4583	161	4745	3%
2007	5067	0	5067	146	5212	3%
2008	5582	0	5582	1033	6616	16%
2009	6595	0	6595	839	7434	11%

Table A30 Silver hake annual catch in metric tons for the combined areas.

Year	Domestic	Foreign	Total landings	discards	Total Catch	% discards
1955			66616	0	66616	0%
1956			56391	0	56391	0%
1957			79176	0	79176	0%
1958			62805	0	62805	0%
1959			66995	0	66995	0%
1960			54359	0	54359	0%
1961			52337	0	52337	0%
1962			96941	0	96941	0%
1963			163349	0	163349	0%
1964			241510	0	241510	0%
1965			339396	0	339396	0%
1966			250126	0	250126	0%
1967			120754	0	120754	0%
1968			99536	0	99536	0%
1969			98946	0	98946	0%
1970			54360	0	54360	0%
1971			106905	0	106905	0%
1972			113403	0	113403	0%
1973	20,450	113,719	134,169	0	134169	0%
1974	14,131	108,946	123,078	0	123078	0%
1975	20,770	91,269	112,038	0	112038	0%
1976	23,290	54,953	78,242	0	78242	0%
1977	23,498	46,119	69,617	0	69617	0%
1978	24,777	13,666	38,443	0	38443	0%
1979	15,461	4,352	19,813	0	19813	0%
1980	14,949	1,465	16,414	0	16414	0%
1981	15,088	2,756	17,845	6140.438	23985	26%
1982	16,486	2,330	18,816	7559.343	26375	29%
1983	16,566	606	17,172	7455.982	24628	30%
1984	20,838	406	21,244	7474.685	28718	26%
1985	19,830	1,286	21,117	6433.169	27550	23%
1986	17,672	527	18,199	6686.172	24885	27%
1987	15,208	2	15,210	6359	21569	29%
1988	15739	0	15,739	6282	22021	29%
1989	17643	0	17,643	8888	26530	34%
1990	19397	0	19,397	7930	27327	29%
1991	15794	0	15,794	4337	20131	22%
1992	15837	0	15,837	4870	20707	24%
1993	16851	0	16,851	5852	22703	26%
1994	16080	0	16,080	6178	22258	28%
1995	14586	0	14,586	2032	16618	12%
1996	15753	0	15,753	1302	17055	8%
1997	15350	0	15,350	867	16217	5%
1998	14603	0	14,603	1219	15822	8%
1999	13866	0	13,866	4290	18156	24%
2000	12064	0	12,064	688	12752	5%
2001	12275	0	12,275	665	12941	5%
2002	7481	0	7,481	923	8404	11%
2003	8089	0	8,089	802	8890	9%
2004	8015	0	8,015	1318	9333	14%
2005	7223	0	7,223	1638	8861	18%
2006	5487	0	5,487	199	5686	3%
2007	6081	0	6,081	896	6977	13%
2008	6203	0	6,203	1201	7403	16%
2009	7636	0	7,636	1030	8666	12%

Table A31. Commercial landings at Age (in thousands of fish) of Silver hake in the northern stock.

year	age-1	age-2	age-3	age-4	age-5	age-6	age-7	age-8	age-9	age-10	age-11	age-12	age-13	age-14
1973	37000	96406	27096	3454	1856	899	123	0	0	240	0	22	185	0
1974	12400	40532	25154	4244	2087	937	54	0	0	52	54	0	81	0
1975	4830	57091	77841	23950	8358	2549	430	117	0	0	0	0	0	0
1976	2016	19716	23193	9460	2422	1501	359	20	0	0	0	0	0	0
1977	1027	7540	21532	14176	3152	472	271	25	9	0	0	0	0	0
1978	1593	7550	6950	10922	13525	2465	311	271	0	7	5	0	0	0
1979	532	2599	2233	1441	1759	2262	419	25	0	0	0	0	0	0
1980	1506	11469	10300	1899	532	437	866	348	49	44	0	3	0	0
1981	4366	9008	7668	3937	689	155	231	185	21	0	0	0	0	0
1982	4679	7989	2937	2864	2773	266	71	471	92	1	2	0	0	0
1983	2944	11947	2801	1447	1924	880	180	51	17	0	0	0	0	0
1984	5183	16108	6503	3325	920	817	8	0	51	0	0	0	0	0
1985	8979	5508	12908	3977	531	713	141	0	0	0	0	0	0	0
1986	3905	15321	3927	4907	1382	516	23	38	0	0	0	0	0	0
1987	851	13368	9831	1456	948	71	3	0	0	0	0	0	0	0
1988	1312	6242	20269	3349	521	624	0	0	0	0	0	0	0	0
1989	3184	5770	10242	2758	344	43	0	0	0	0	0	0	0	0
1990	3528	15845	6989	4840	1140	15	0	0	0	0	0	0	0	0
1991	1186	13900	7701	2537	1074	9	0	0	0	0	0	0	0	0
1992	6149	15882	8256	1206	143	11	2	0	0	0	0	0	0	0
1993	4062	14565	5674	2045	187	8	0	0	0	0	0	0	0	0
1994	2053	10017	6551	1898	38	3	0	0	0	0	0	0	0	0
1995	630	1769	910	1912	531	25	0	0	0	0	0	0	0	0
1996	1842	13844	6984	1026	54	16	0	0	0	0	0	0	0	0
1997	2787	13552	3167	205	101	7	0	0	0	0	0	0	0	0
1998	1033	5539	1842	1001	32	77	0	0	0	0	0	0	0	0
1999	63	4212	3875	2126	244	108	0	0	0	0	0	0	0	0
2000	630	4922	4152	814	273	4	3	0	0	0	0	0	0	0
2001	233	1829	1752	1822	978	241	5	0	0	0	0	0	0	0
2002	441	5674	3600	707	60	74	0	0	0	0	0	0	0	0
2003	189	2634	3742	632	63	31	10	0	0	0	0	0	0	0
2004	1168	2838	1975	191	16	1	1	0	0	0	0	0	0	0
2005	1288	1927	1598	209	32	13	3	0	0	0	0	0	0	0
2006	4839	795	482	511	14	14	0	0	0	0	0	0	0	0
2007	4072	2211	214	218	117	0	0	0	0	0	0	0	0	0
2008	2141	2210	130	61	2	7	0	0	0	0	0	0	0	0
2009	584	2370	1510	346	19	0	1	0	0	0	0	0	0	0

Table A32. Silver hake commercial landings at Age (in thousands of fish) for the southern stock.

year	age-1	age-2	age-3	age-4	age-5	age-6	age-7	age-8	age-9	age-10	age-11	age-12	age-13	age-14	Total
1973	3470	164329	134686	55533	13498	3410	1524	0	0	0	0	0	0	0	376669
1974	6213	65952	172266	108329	34225	10484	2576	0	455	0	0	0	0	0	400665
1975	5223	49456	128180	63861	20200	2694	396	0	96	0	0	0	0	0	270243
1976	383	51663	48274	39785	18228	8141	3881	412	0	0	0	0	0	0	170766
1977	2044	16736	62794	35481	14643	5894	5004	1312	0	0	0	0	0	0	143908
1978	1383	20549	18263	26284	11708	3412	458	61	0	0	0	0	0	72	82191
1979	1716	12338	12825	6390	9503	5726	998	197	0	0	0	0	0	0	49693
1980	1793	17101	17433	7962	3778	1793	2257	414	168	1	0	0	0	0	52701
1981	5739	12437	17517	12679	5443	2190	1015	1275	666	0	13	0	0	0	58973
1982	4968	26448	10550	8833	6558	2070	1033	369	299	133	0	0	0	0	61260
1983	7861	19351	11352	5583	2531	1733	816	59	71	273	0	0	0	0	49629
1984	2129	29479	15330	5535	1091	421	346	0	0	0	0	0	0	0	54332
1985	3098	23434	21909	8077	1377	236	311	63	65	0	0	0	0	0	58571
1986	5545	27377	9665	8122	1524	205	21	0	0	0	0	0	0	0	52464
1987	4791	21647	14036	5113	3369	69	0	0	39	0	0	0	0	0	49062
1988	1331	17531	27692	7243	579	27	0	0	0	0	0	0	0	0	54404
1989	1204	20708	38294	10594	1034	182	0	0	0	0	0	0	0	0	72036
1990	716	21207	32891	10819	1793	31	19	0	0	0	0	0	0	0	67475
1991	341	3601	22108	17717	3723	1124	62	0	0	0	0	0	0	0	48677
1992	2318	19170	24496	13147	793	3	0	0	0	0	0	0	0	0	59928
1993	3120	19023	24621	15399	2579	0	0	0	0	0	0	0	0	0	64742
1994	1161	21801	33190	9522	355	0	0	0	0	0	0	0	0	0	66028
1995	1479	17014	27007	16578	436	0	0	0	0	0	0	0	0	0	62513
1996	2220	25222	42727	7537	1229	2	0	0	0	0	0	0	0	0	78937
1997	14558	23930	36763	7045	124	0	0	0	0	0	0	0	0	0	83538
1998	4970	29969	43918	3510	10	0	0	0	0	0	0	0	0	0	84559
1999	2697	32190	37657	3405	94	0	0	0	0	0	0	0	0	0	76042
2000	1089	22309	36529	3064	35	0	0	0	0	0	0	0	0	0	63026
2001	1615	9840	22302	9767	765	36	0	0	0	0	0	0	0	0	44325
2002	832	10883	20010	2696	108	0	0	0	0	0	0	0	0	0	34528
2003	7130	13441	18738	5432	18	0	0	0	0	0	0	0	0	0	45364
2004	2917	11052	27476	5139	21	0	0	0	0	0	0	0	0	0	46611
2005	13692	14352	15447	5051	144	0	0	0	0	0	0	0	0	0	48697
2006	11545	16527	8551	1080	35	1	0	0	0	0	0	0	0	0	37738
2007	10627	17887	5919	1526	171	4	0	0	0	30	0	0	0	0	36167
2008	13215	27207	3266	828	73	0	0	0	0	0	0	0	0	0	44603
2009	6886	31886	8431	807	124	0	0	0	0	0	0	0	0	0	48137

Table A33. Silver hake commercial landings at Age (in thousands of fish) for the combined stock area.

year	age-1	age-2	age-3	age-4	age-5	age-6	age-7	age-8	age-9	age-10	age-11	age-12	age-13	age-14
1973	40470	260734	161782	58987	15354	4310	1647	0	0	240	0	22	185	0
1974	18614	106484	197420	112573	36311	11421	2630	0	455	52	54	0	81	0
1975	10053	106547	206021	87810	28557	5243	826	117	96	0	0	0	0	0
1976	2399	71378	71467	49245	20650	9642	4239	431	0	0	0	0	0	0
1977	3071	24276	84326	49656	17795	6365	5275	1336	9	0	0	0	0	0
1978	2975	28099	25213	37205	25233	5877	769	333	0	7	5	0	0	72
1979	2248	14938	15059	7831	11262	7988	1417	222	0	0	0	0	0	0
1980	3300	28571	27734	9861	4310	2230	3123	761	216	45	0	3	0	0
1981	10105	21445	25185	16616	6132	2344	1246	1459	687	0	13	0	0	0
1982	9647	34437	13487	11697	9331	2336	1104	839	391	134	2	0	0	0
1983	10804	31298	14153	7030	4454	2613	996	110	88	273	0	0	0	0
1984	7312	45587	21833	8860	2011	1238	355	0	51	0	0	0	0	0
1985	12077	28943	34817	12054	1908	950	451	63	65	0	0	0	0	0
1986	9450	42698	13593	13029	2906	720	44	38	0	0	0	0	0	0
1987	5642	35015	23866	6569	4317	140	3	0	39	0	0	0	0	0
1988	2643	23773	47960	10592	1100	651	0	0	0	0	0	0	0	0
1989	4388	26478	48536	13352	1378	225	0	0	0	0	0	0	0	0
1990	4244	37052	39880	15659	2932	46	19	0	0	0	0	0	0	0
1991	1526	17501	29808	20254	4797	1133	62	0	0	0	0	0	0	0
1992	8467	35052	32751	14353	937	14	2	0	0	0	0	0	0	0
1993	7182	33588	30295	17443	2766	8	0	0	0	0	0	0	0	0
1994	3214	31818	39741	11419	393	3	0	0	0	0	0	0	0	0
1995	2109	18783	27917	18490	967	25	0	0	0	0	0	0	0	0
1996	4062	39066	49711	8563	1283	18	0	0	0	0	0	0	0	0
1997	17344	37482	39930	7250	225	7	0	0	0	0	0	0	0	0
1998	6004	35508	45759	4511	41	77	0	0	0	0	0	0	0	0
1999	2760	36401	41532	5531	338	108	0	0	0	0	0	0	0	0
2000	1719	27231	40680	3878	308	4	3	0	0	0	0	0	0	0
2001	1848	11669	24053	11589	1743	277	5	0	0	0	0	0	0	0
2002	1273	16556	23610	3402	168	74	0	0	0	0	0	0	0	0
2003	7318	16074	22480	6064	80	31	10	0	0	0	0	0	0	0
2004	4084	13890	29450	5330	36	1	1	0	0	0	0	0	0	0
2005	14980	16279	17045	5260	176	13	3	0	0	0	0	0	0	0
2006	16384	17321	9033	1591	48	14	0	0	0	0	0	0	0	0
2007	14698	20099	6133	1744	287	4	0	0	0	30	0	0	0	0
2008	15355	29416	3396	889	75	7	0	0	0	0	0	0	0	0
2009	7469	34256	9941	1153	143	0	1	0	0	0	0	0	0	0

Table A34. Silver hake commercial discards at age (in thousands of fish) for the northern stock.

year	age-1	age-2	age-3	age-4	age-5	age-6	age-7	age-8	age-9	age-10	age-11	age-12	age-13	age-14
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	34529	3279	1442	629	44	2	0	0	0	0	0	0	0	0
1990	8113	7223	1550	818	340	23	0	0	0	0	0	0	0	0
1991	7800	4315	1102	277	40	5	0	0	0	0	0	0	0	0
1992	11045	6942	1802	322	48	5	0	0	0	0	0	0	0	0
1993	5725	2262	452	275	79	7	0	0	0	0	0	0	0	0
1994	1894	1067	140	69	11	4	0	0	0	0	0	0	0	0
1995	9688	4188	433	136	25	5	0	0	0	0	0	0	0	0
1996	14927	7047	2159	175	10	4	0	0	0	0	0	0	0	0
1997	2270	2068	242	39	26	8	0	0	0	0	0	0	0	0
1998	4734	4809	1209	245	25	13	0	0	0	0	0	0	0	0
1999	2075	3559	1177	113	25	2	0	0	0	0	0	0	0	0
2000	2610	3434	489	148	40	5	0	0	0	0	0	0	0	0
2001	975	2054	713	304	67	11	0	0	0	0	0	0	0	0
2002	1246	1253	709	479	95	40	0	0	0	0	0	0	0	0
2003	2895	691	142	89	17	4	2	0	0	0	0	0	0	0
2004	536	554	121	39	5	6	0	0	0	0	0	0	0	0
2005	1204	225	76	7	3	2	0	0	0	0	0	0	0	0
2006	542	27	16	23	1	0	0	0	0	0	0	0	0	0
2007	8724	1155	109	66	122	0	0	0	0	0	0	0	0	0
2008	2196	679	26	11	4	1	0	0	0	0	0	0	0	0
2009	2346	348	99	17	4	0	1	0	0	0	0	0	0	0

Table A35. Silver hake commercial discards at age (in thousands of fish) for the southern stock.

year	age-1	age-2	age-3	age-4	age-5	age-6	age-7	age-8	age-9	age-10	age-11	age-12	age-13	age-14
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	4958	16357	19820	5162	407	112	0	0	0	0	0	0	0	0
1990	5688	27591	11822	2303	170	6	3	0	0	0	0	0	0	0
1991	3135	11326	6831	1442	204	34	0	0	0	0	0	0	0	0
1992	17293	14333	3295	724	15	0	0	0	0	0	0	0	0	0
1993	11733	14866	8778	5663	1075	0	0	0	0	0	0	0	0	0
1994	1172	13170	15618	5120	117	0	0	0	0	0	0	0	0	0
1995	986	3789	2401	717	35	0	0	0	0	0	0	0	0	0
1996	384	837	2001	382	48	0	0	0	0	0	0	0	0	0
1997	604	1640	1626	159	12	0	0	0	0	0	0	0	0	0
1998	174	841	3176	65	0	0	0	0	0	0	0	0	0	0
1999	113	18144	17372	32	0	0	0	0	0	0	0	0	0	0
2000	340	1188	856	62	3	0	0	0	0	0	0	0	0	0
2001	827	987	274	15	0	0	0	0	0	0	0	0	0	0
2002	490	2019	1878	65	0	0	0	0	0	0	0	0	0	0
2003	1182	1780	1590	115	1	0	0	0	0	0	0	0	0	0
2004	5936	3506	2209	504	12	0	0	0	0	0	0	0	0	0
2005	5577	6210	4992	142	2	0	0	0	0	0	0	0	0	0
2006	441	588	293	46	0	0	0	0	0	0	0	0	0	0
2007	551	364	181	34	6	0	0	0	0	0	0	0	0	0
2008	2841	6586	494	68	5	0	0	0	0	0	0	0	0	0
2009	5572	3479	511	21	6	0	0	0	0	0	0	0	0	0

Table A36. Silver hake commercial discards at age (in thousands of fish) for the combined stock areas.

year	age-1	age-2	age-3	age-4	age-5	age-6	age-7	age-8	age-9	age-10	age-11	age-12	age-13	age-14
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	39487	19636	21262	5791	451	114	0	0	0	0	0	0	0	0
1990	13801	34814	13372	3121	510	29	3	0	0	0	0	0	0	0
1991	10935	15641	7933	1720	244	40	0	0	0	0	0	0	0	0
1992	28338	21276	5097	1046	63	5	0	0	0	0	0	0	0	0
1993	17458	17128	9230	5938	1154	7	0	0	0	0	0	0	0	0
1994	3067	14236	15758	5189	127	4	0	0	0	0	0	0	0	0
1995	10673	7978	2835	853	61	5	0	0	0	0	0	0	0	0
1996	15311	7884	4160	557	58	4	0	0	0	0	0	0	0	0
1997	2874	3708	1868	197	38	8	0	0	0	0	0	0	0	0
1998	4907	5651	4386	310	25	13	0	0	0	0	0	0	0	0
1999	2188	21703	18548	145	25	2	0	0	0	0	0	0	0	0
2000	2950	4623	1345	210	43	5	0	0	0	0	0	0	0	0
2001	1801	3041	988	319	68	11	0	0	0	0	0	0	0	0
2002	1736	3272	2587	543	95	40	0	0	0	0	0	0	0	0
2003	4077	2471	1732	204	18	4	2	0	0	0	0	0	0	0
2004	6473	4060	2330	543	17	6	0	0	0	0	0	0	0	0
2005	6781	6435	5069	149	5	2	0	0	0	0	0	0	0	0
2006	983	615	309	69	1	0	0	0	0	0	0	0	0	0
2007	9275	1519	291	99	128	0	0	0	0	0	0	0	0	0
2008	5037	7265	519	80	9	1	0	0	0	0	0	0	0	0
2009	7918	3828	611	37	10	0	1	0	0	0	0	0	0	0

Table A37. Silver hake catch at age (in thousands of fish) for the northern stock.

year	age-1	age-2	age-3	age-4	age-5	age-6	age-7	age-8	age-9	age-10	age-11	age-12	age-13	age-14
1973	37000	96406	27096	3454	1856	899	123	0	0	240	0	22	185	0
1974	12400	40532	25154	4244	2087	937	54	0	0	52	54	0	81	0
1975	4830	57091	77841	23950	8358	2549	430	117	0	0	0	0	0	0
1976	2016	19716	23193	9460	2422	1501	359	20	0	0	0	0	0	0
1977	1027	7540	21532	14176	3152	472	271	25	9	0	0	0	0	0
1978	1593	7550	6950	10922	13525	2465	311	271	0	7	5	0	0	0
1979	532	2599	2233	1441	1759	2262	419	25	0	0	0	0	0	0
1980	1506	11469	10300	1899	532	437	866	348	49	44	0	3	0	0
1981	4366	9008	7668	3937	689	155	231	185	21	0	0	0	0	0
1982	4679	7989	2937	2864	2773	266	71	471	92	1	2	0	0	0
1983	2944	11947	2801	1447	1924	880	180	51	17	0	0	0	0	0
1984	5183	16108	6503	3325	920	817	8	0	51	0	0	0	0	0
1985	8979	5508	12908	3977	531	713	141	0	0	0	0	0	0	0
1986	3905	15321	3927	4907	1382	516	23	38	0	0	0	0	0	0
1987	851	13368	9831	1456	948	71	3	0	0	0	0	0	0	0
1988	1312	6242	20269	3349	521	624	0	0	0	0	0	0	0	0
1989	37713	9049	11684	3387	388	45	0	0	0	0	0	0	0	0
1990	11640	23068	8539	5658	1480	37	0	0	0	0	0	0	0	0
1991	8985	18215	8803	2814	1114	14	0	0	0	0	0	0	0	0
1992	17193	22825	10058	1528	191	16	2	0	0	0	0	0	0	0
1993	9787	16827	6126	2320	266	15	0	0	0	0	0	0	0	0
1994	3948	11084	6691	1966	49	7	0	0	0	0	0	0	0	0
1995	10318	5957	1344	2048	556	30	0	0	0	0	0	0	0	0
1996	16769	20891	9143	1202	64	20	0	0	0	0	0	0	0	0
1997	5056	15620	3409	243	127	15	0	0	0	0	0	0	0	0
1998	5767	10348	3051	1246	57	90	0	0	0	0	0	0	0	0
1999	2138	7771	5052	2240	270	110	0	0	0	0	0	0	0	0
2000	3239	8356	4640	962	313	9	3	0	0	0	0	0	0	0
2001	1208	3883	2465	2126	1045	252	5	0	0	0	0	0	0	0
2002	1687	6927	4309	1185	155	114	0	0	0	0	0	0	0	0
2003	3083	3325	3884	721	80	36	12	0	0	0	0	0	0	0
2004	1704	3392	2095	230	21	7	1	0	0	0	0	0	0	0
2005	2492	2151	1674	216	35	15	3	0	0	0	0	0	0	0
2006	5381	821	498	534	15	14	0	0	0	0	0	0	0	0
2007	12796	3366	324	284	239	0	0	0	0	0	0	0	0	0
2008	4337	2889	156	72	6	8	0	0	0	0	0	0	0	0
2009	2930	2718	1609	363	23	0	1	0	0	0	0	0	0	0

Table A38. Silver hake catch at age (in thousands of fish) for the southern stock.

year	age-1	age-2	age-3	age-4	age-5	age-6	age-7	age-8	age-9	age-10	age-11	age-12	age-13	age-14
1973	3470	164329	134686	55533	13498	3410	1524	0	0	0	0	0	0	0
1974	6213	65952	172266	108329	34225	10484	2576	0	455	0	0	0	0	0
1975	5223	49456	128180	63861	20200	2694	396	0	96	0	0	0	0	0
1976	383	51663	48274	39785	18228	8141	3881	412	0	0	0	0	0	0
1977	2044	16736	62794	35481	14643	5894	5004	1312	0	0	0	0	0	0
1978	1383	20549	18263	26284	11708	3412	458	61	0	0	0	0	0	72
1979	1716	12338	12825	6390	9503	5726	998	197	0	0	0	0	0	0
1980	1793	17101	17433	7962	3778	1793	2257	414	168	1	0	0	0	0
1981	5739	12437	17517	12679	5443	2190	1015	1275	666	0	13	0	0	0
1982	4968	26448	10550	8833	6558	2070	1033	369	299	133	0	0	0	0
1983	7861	19351	11352	5583	2531	1733	816	59	71	273	0	0	0	0
1984	2129	29479	15330	5535	1091	421	346	0	0	0	0	0	0	0
1985	3098	23434	21909	8077	1377	236	311	63	65	0	0	0	0	0
1986	5545	27377	9665	8122	1524	205	21	0	0	0	0	0	0	0
1987	4791	21647	14036	5113	3369	69	0	0	39	0	0	0	0	0
1988	1331	17531	27692	7243	579	27	0	0	0	0	0	0	0	0
1989	6162	37065	58113	15756	1441	294	0	0	0	0	0	0	0	0
1990	6404	48799	44712	13122	1962	37	22	0	0	0	0	0	0	0
1991	3476	14927	28939	19159	3927	1159	62	0	0	0	0	0	0	0
1992	19611	33504	27791	13871	809	3	0	0	0	0	0	0	0	0
1993	14853	33889	33400	21062	3654	0	0	0	0	0	0	0	0	0
1994	2333	34970	48808	14642	472	0	0	0	0	0	0	0	0	0
1995	2464	20804	29408	17295	471	0	0	0	0	0	0	0	0	0
1996	2604	26059	44729	7919	1277	2	0	0	0	0	0	0	0	0
1997	15162	25570	38389	7204	136	0	0	0	0	0	0	0	0	0
1998	5144	30811	47094	3576	10	0	0	0	0	0	0	0	0	0
1999	2810	50334	55028	3437	94	0	0	0	0	0	0	0	0	0
2000	1429	23497	37385	3126	38	0	0	0	0	0	0	0	0	0
2001	2442	10827	22576	9782	765	36	0	0	0	0	0	0	0	0
2002	1322	12901	21888	2760	108	0	0	0	0	0	0	0	0	0
2003	8312	15220	20327	5547	18	0	0	0	0	0	0	0	0	0
2004	8853	14559	29685	5643	33	0	0	0	0	0	0	0	0	0
2005	19269	20562	20439	5193	147	0	0	0	0	0	0	0	0	0
2006	11986	17115	8844	1126	35	1	0	0	0	0	0	0	0	0
2007	11178	18252	6100	1559	177	4	0	0	0	31	0	0	0	0
2008	16055	33793	3759	896	78	0	0	0	0	0	0	0	0	0
2009	12458	35366	8942	827	130	0	0	0	0	0	0	0	0	0

Table A39. Silver hake catch at age (in thousands of fish) for the combined stock areas.

year	age-1	age-2	age-3	age-4	age-5	age-6	age-7	age-8	age-9	age-10	age-11	age-12	age-13	age-14
1973	40470	260734	161782	58987	15354	4310	1647	0	0	240	0	22	185	0
1974	18614	106484	197420	112573	36311	11421	2630	0	455	52	54	0	81	0
1975	10053	106547	206021	87810	28557	5243	826	117	96	0	0	0	0	0
1976	2399	71378	71467	49245	20650	9642	4239	431	0	0	0	0	0	0
1977	3071	24276	84326	49656	17795	6365	5275	1336	9	0	0	0	0	0
1978	2975	28099	25213	37205	25233	5877	769	333	0	7	5	0	0	72
1979	2248	14938	15059	7831	11262	7988	1417	222	0	0	0	0	0	0
1980	3300	28571	27734	9861	4310	2230	3123	761	216	45	0	3	0	0
1981	10105	21445	25185	16616	6132	2344	1246	1459	687	0	13	0	0	0
1982	9647	34437	13487	11697	9331	2336	1104	839	391	134	2	0	0	0
1983	10804	31298	14153	7030	4454	2613	996	110	88	273	0	0	0	0
1984	7312	45587	21833	8860	2011	1238	355	0	51	0	0	0	0	0
1985	12077	28943	34817	12054	1908	950	451	63	65	0	0	0	0	0
1986	9450	42698	13593	13029	2906	720	44	38	0	0	0	0	0	0
1987	5642	35015	23866	6569	4317	140	3	0	39	0	0	0	0	0
1988	2643	23773	47960	10592	1100	651	0	0	0	0	0	0	0	0
1989	43875	46114	69798	19143	1829	339	0	0	0	0	0	0	0	0
1990	18045	71866	53252	18780	3442	74	22	0	0	0	0	0	0	0
1991	12461	33142	37742	21973	5041	1172	62	0	0	0	0	0	0	0
1992	36804	56328	37849	15399	1000	19	2	0	0	0	0	0	0	0
1993	24640	50716	39525	23382	3920	15	0	0	0	0	0	0	0	0
1994	6281	46054	55499	16608	521	7	0	0	0	0	0	0	0	0
1995	12782	26761	30752	19343	1027	30	0	0	0	0	0	0	0	0
1996	19373	46950	53871	9120	1341	22	0	0	0	0	0	0	0	0
1997	20218	41190	41798	7447	263	15	0	0	0	0	0	0	0	0
1998	10911	41159	50145	4822	67	90	0	0	0	0	0	0	0	0
1999	4948	58104	60080	5676	364	110	0	0	0	0	0	0	0	0
2000	4668	31853	42025	4087	351	9	3	0	0	0	0	0	0	0
2001	3650	14709	25041	11908	1811	288	5	0	0	0	0	0	0	0
2002	3009	19828	26197	3945	263	114	0	0	0	0	0	0	0	0
2003	11395	18545	24212	6268	98	36	12	0	0	0	0	0	0	0
2004	10557	17950	31780	5873	54	7	1	0	0	0	0	0	0	0
2005	21761	22713	22113	5409	181	15	3	0	0	0	0	0	0	0
2006	17367	17936	9343	1660	49	15	0	0	0	0	0	0	0	0
2007	23974	21618	6424	1843	416	4	0	0	0	31	0	0	0	0
2008	20392	36681	3915	968	84	8	0	0	0	0	0	0	0	0
2009	15388	38084	10552	1190	153	0	1	0	0	0	0	0	0	0

Table A40. Silver hake catch weight at age for the northern stock (kg).

year	age-1	age-2	age-3	age-4	age-5	age-6	age-7	age-8	age-9	age-10	age-11	age-12	age-13	age-14
1973	0.1232	0.1730	0.2557	0.4812	0.5760	0.6304	1.3418	0	0	1.1065	0	1.5049	0.8503	0
1974	0.1086	0.2086	0.2856	0.4209	0.5113	0.6522	0.6635	0	0	0.8537	1.4930	0	0.8479	0
1975	0.0845	0.1426	0.2117	0.3529	0.4732	0.7730	0.8541	0.8503	0	0	0	0	0	0
1976	0.0806	0.1519	0.2129	0.3369	0.4962	0.5890	0.6476	1.7126	0	0	0	0	0	0
1977	0.1227	0.1803	0.2294	0.2859	0.4489	0.6075	0.9102	0.8939	0.9586	0	0	0	0	0
1978	0.1167	0.2110	0.2448	0.2883	0.3236	0.4981	0.5365	0.7281	0	0.9017	0.9586	0	0	0
1979	0.1363	0.2126	0.2817	0.3397	0.3510	0.3655	0.4756	1.0956	0	0	0	0	0	0
1980	0.0960	0.1346	0.1689	0.2160	0.3041	0.3532	0.3083	0.4826	1.0829	1.8496	0	2.4460	0	0
1981	0.1099	0.1383	0.1780	0.2258	0.2935	0.3490	0.4612	0.3617	0.3282	0	0	0	0	0
1982	0.1109	0.1630	0.2068	0.3004	0.3150	0.3347	0.3768	0.6137	0.9944	1.5090	1.6687	2.0320	0	0
1983	0.1293	0.1911	0.2906	0.3329	0.3918	0.5613	0.4510	0.2854	0.5359	0	0	0	0	0
1984	0.1242	0.1925	0.2971	0.4626	0.4736	0.7454	1.5651	0	0.3111	0	0	0	0	0
1985	0.1410	0.2052	0.2619	0.3762	0.4645	0.9337	0.6524	0	0	0	0	0	0	0
1986	0.1257	0.2281	0.3306	0.3757	0.5430	1.0947	2.0009	0.3005	0	0	0	0	0	0
1987	0.0903	0.1539	0.2679	0.3407	0.3579	0.6826	1.7468	0	0	0	0	0	0	0
1988	0.1001	0.1409	0.1930	0.3411	0.4072	0.8203	0	0	0	0	0	0	0	0
1989	0.0474	0.1487	0.2174	0.3043	0.4352	1.2695	0	0	0	0	0	0	0	0
1990	0.0648	0.1417	0.2294	0.2869	0.4627	0.8688	0	0	0	0	0	0	0	0
1991	0.0675	0.1498	0.2149	0.2853	1.1251	0.8025	0	0	0	0	0	0	0	0
1992	0.0576	0.1224	0.2228	0.3462	0.7570	1.2611	3.8648	0	0	0	0	0	0	0
1993	0.0603	0.1300	0.2233	0.3077	0.6194	1.5227	2.9826	0	0	0	0	0	0	0
1994	0.0697	0.1318	0.2435	0.3618	1.0404	1.7938	2.3271	0	0	0	0	0	0	0
1995	0.0354	0.0759	0.2045	0.6955	1.1767	1.7207	0	0	0	0	0	0	0	0
1996	0.0210	0.1009	0.1713	0.2751	0.7922	1.3982	3.3621	0	0	0	0	0	0	0
1997	0.0623	0.1262	0.1681	0.2849	0.7734	1.1201	1.5205	0	0	0	0	0	0	0
1998	0.0250	0.1047	0.2592	0.4631	0.6507	1.1736	2.6742	0	0	0	0	0	0	0
1999	0.0157	0.1443	0.3103	0.5187	0.7310	0.9842	1.5045	0	0	0	0	0	0	0
2000	0.0275	0.1180	0.2511	0.4529	0.8244	1.4221	1.4473	0	0	0	0	0	0	0
2001	0.0324	0.1161	0.3010	0.5716	0.9876	1.5147	1.7181	0	0	0	0	0	0	0
2002	0.0762	0.1576	0.2679	0.4301	0.6001	1.1045	2.1307	0	0	0	0	0	0	0
2003	0.0348	0.1338	0.2434	0.5180	0.9793	1.0626	1.5786	2.1307	0	0	0	0	0	0
2004	0.0620	0.1191	0.2631	0.2836	0.9794	2.0800	1.7304	0	0	0	0	0	0	0
2005	0.0466	0.1386	0.2308	0.3075	0.3634	0.3484	1.7543	0	0	0	0	0	0	0
2006	0.1007	0.1784	0.1847	0.2651	1.0386	0.1753	1.8087	0	0	0	0	0	0	0
2007	0.0717	0.1848	0.2308	0.2906	0.2756	1.8087	0.2359	0	0	0	0	0	0	0
2008	0.0667	0.1451	0.2292	0.4476	0.8437	0.7874	1.8087	0	0	0	0	0	0	0
2009	0.0642	0.1589	0.2403	0.5676	0.5001	2.0215	0.4448	0	0	0	0	0	0	0

Table A41. Silver hake catch weight at age for the southern stock (kg).

year	age-1	age-2	age-3	age-4	age-5	age-6	age-7	age-8	age-9	age-10	age-11	age-12	age-13	age-14
1973	0.1102	0.2002	0.2795	0.3898	0.4967	0.5898	0.5125	0	0	0	0	0	0	0
1974	0.1362	0.1872	0.2263	0.3065	0.3433	0.3767	0.4480	0	0.3271	0	0	0	0	0
1975	0.1363	0.1927	0.2312	0.3531	0.4162	0.4345	0.2943	0	0.4383	0	0	0	0	0
1976	0.1063	0.2132	0.2660	0.4318	0.7257	0.8034	0.8772	0.8802	0	0	0	0	0	0
1977	0.1487	0.2365	0.3146	0.3922	0.5951	0.8713	0.8184	0.9788	0	0	0	0	0	0
1978	0.1434	0.2082	0.2816	0.3553	0.3564	0.6986	0.5444	0.7697	0	0	0	0	0	0.3273
1979	0.1494	0.2159	0.2669	0.3164	0.4980	0.4376	0.6086	0.9545	0	0	0	0	0	0
1980	0.1172	0.1895	0.2163	0.2605	0.2752	0.3078	0.2723	0.3256	0.2761	0.6516	0	0	0	0
1981	0.1187	0.1889	0.2139	0.2490	0.2903	0.3502	0.3504	0.3930	0.4192	0	0.8959	0	0	0
1982	0.1364	0.1902	0.2691	0.2662	0.2856	0.3225	0.3791	0.3954	0.4054	0.4021	0	0	0	0
1983	0.1677	0.2019	0.2752	0.3016	0.3392	0.3186	0.3143	0.2506	0.5700	0.3831	0	0	0	0
1984	0.1522	0.1991	0.2536	0.3985	0.3472	0.4259	0.3178	0	0	0	0	0	0	0
1985	0.1371	0.1749	0.2295	0.3164	0.3773	0.2988	0.2871	0.2739	0.2500	0	0	0	0	0
1986	0.1387	0.1555	0.2190	0.2504	0.2931	0.3239	0.3268	0	0	0	0	0	0	0
1987	0.1338	0.1521	0.2097	0.2763	0.3653	0.3325	0	0	0.2280	0	0	0	0	0
1988	0.0608	0.1476	0.1574	0.2408	0.2785	0.6306	0	0	0	0	0	0	0	0
1989	0.0882	0.1311	0.1716	0.2291	0.3326	0.2510	0	0	0	0	0	0	0	0
1990	0.0742	0.1260	0.1864	0.2558	0.3304	0.4163	0.5621	0	0	0	0	0	0	0
1991	0.0668	0.1196	0.1736	0.2177	0.3123	0.3114	0.3537	0	0	0	0	0	0	0
1992	0.0730	0.1269	0.1761	0.2274	0.2613	1.3141	0	0	0	0	0	0	0	0
1993	0.0688	0.1158	0.1958	0.2369	0.3218	0	0	0	0	0	0	0	0	0
1994	0.0696	0.1472	0.1781	0.2616	0.6066	0	0	0	0	0	0	0	0	0
1995	0.0901	0.1610	0.1869	0.2323	0.6541	0	0	0	0	0	0	0	0	0
1996	0.0822	0.1272	0.1430	0.2696	0.4288	1.5012	0	0	0	0	0	0	0	0
1997	0.0843	0.1312	0.1683	0.2783	0.4143	0	0	0	0	0	0	0	0	0
1998	0.0832	0.1347	0.1533	0.3480	0.8411	0	0	0	0	0	0	0	0	0
1999	0.0699	0.0976	0.1399	0.3240	0.4891	0	0	0	0	0	0	0	0	0
2000	0.0935	0.1388	0.1483	0.2680	0.5868	0	0	0	0	0	0	0	0	0
2001	0.0722	0.1350	0.1717	0.3047	0.6768	1.6357	0	0	0	0	0	0	0	0
2002	0.0773	0.1172	0.1274	0.2928	0.8062	0	0	0	0	0	0	0	0	0
2003	0.0762	0.1333	0.1501	0.2077	0.6676	0	0	0	0	0	0	0	0	0
2004	0.0674	0.1069	0.1529	0.2558	1.0052	0	0	0	0	0	0	0	0	0
2005	0.0991	0.1045	0.1189	0.2738	0.4053	0	0	0	0	0	0	0	0	0
2006	0.0961	0.1252	0.1352	0.2019	0.7299	1.3809	0	0	0	0	0	0	0	0
2007	0.0959	0.1393	0.1884	0.2224	0.5065	1.1264	0	0	0	0.2369	0	0	0	0
2008	0.0907	0.1173	0.2107	0.4058	0.5134	0	0	0	0	0	0	0	0	0
2009	0.0920	0.1242	0.1629	0.4140	0.7106	0	0	0	0	0	0	0	0	0

Table A42 Silver hake catch weight at age for the combined stock areas (kg).

year	age-1	age-2	age-3	age-4	age-5	age-6	age-7	age-8	age-9	age-10	age-11	age-12	age-13	age-14
1973	0.1221	0.1902	0.2755	0.3952	0.5063	0.5983	0.5745	0	0	1.1065	0	1.5049	0.8503	0
1974	0.1178	0.1954	0.2339	0.3108	0.3530	0.3993	0.4525	0	0.3271	0.8537	1.4930	0	0.8479	0
1975	0.1114	0.1659	0.2238	0.3530	0.4329	0.5991	0.5859	0.8503	0.4383	0	0	0	0	0
1976	0.0847	0.1962	0.2488	0.4136	0.6988	0.7700	0.8578	0.9179	0	0	0	0	0	0
1977	0.1400	0.2190	0.2928	0.3619	0.5692	0.8518	0.8231	0.9772	0.9586	0	0	0	0	0
1978	0.1291	0.2089	0.2715	0.3356	0.3388	0.6145	0.5412	0.7358	0	0.9017	0.9586	0	0	0.3273
1979	0.1463	0.2153	0.2691	0.3206	0.4751	0.4172	0.5693	0.9706	0	0	0	0	0	0
1980	0.1075	0.1675	0.1987	0.2519	0.2788	0.3167	0.2823	0.3973	0.4580	1.8180	0	2.4460	0	0
1981	0.1149	0.1676	0.2030	0.2435	0.2906	0.3501	0.3710	0.3890	0.4164	0	0.8959	0	0	0
1982	0.1240	0.1839	0.2556	0.2746	0.2944	0.3239	0.3789	0.5178	0.5435	0.4109	1.6687	2.0320	0	0
1983	0.1572	0.1978	0.2782	0.3081	0.3619	0.4004	0.3391	0.2666	0.5634	0.3831	0	0	0	0
1984	0.1323	0.1968	0.2666	0.4226	0.4050	0.6367	0.3476	0	0.3111	0	0	0	0	0
1985	0.1400	0.1807	0.2415	0.3361	0.4016	0.7757	0.4009	0.2739	0.2500	0	0	0	0	0
1986	0.1334	0.1816	0.2512	0.2976	0.4120	0.8756	1.2022	0.3005	0	0	0	0	0	0
1987	0.1272	0.1528	0.2337	0.2906	0.3637	0.5107	1.7468	0	0.2280	0	0	0	0	0
1988	0.0803	0.1458	0.1724	0.2725	0.3395	0.8123	0	0	0	0	0	0	0	0
1989	0.0531	0.1346	0.1792	0.2424	0.3544	0.3861	0	0	0	0	0	0	0	0
1990	0.0681	0.1310	0.1933	0.2652	0.3873	0.6436	0.5621	0	0	0	0	0	0	0
1991	0.0673	0.1362	0.1832	0.2264	0.4918	0.3172	0.3537	0	0	0	0	0	0	0
1992	0.0658	0.1250	0.1885	0.2392	0.3562	1.2704	3.8648	0	0	0	0	0	0	0
1993	0.0654	0.1205	0.2001	0.2440	0.3420	1.5227	2.9826	0	0	0	0	0	0	0
1994	0.0697	0.1435	0.1859	0.2735	0.6470	1.7938	2.3271	0	0	0	0	0	0	0
1995	0.0459	0.1421	0.1877	0.2813	0.9371	1.7207	0	0	0	0	0	0	0	0
1996	0.0292	0.1155	0.1478	0.2704	0.4462	1.4061	3.3621	0	0	0	0	0	0	0
1997	0.0788	0.1293	0.1683	0.2785	0.5876	1.1201	1.5205	0	0	0	0	0	0	0
1998	0.0524	0.1272	0.1597	0.3778	0.6780	1.1736	2.6742	0	0	0	0	0	0	0
1999	0.0465	0.1038	0.1542	0.4008	0.6685	0.9842	1.5045	0	0	0	0	0	0	0
2000	0.0477	0.1333	0.1597	0.3115	0.7990	1.4221	1.4473	0	0	0	0	0	0	0
2001	0.0591	0.1300	0.1844	0.3523	0.8562	1.5298	1.7181	0	0	0	0	0	0	0
2002	0.0767	0.1313	0.1505	0.3341	0.6847	1.1045	2.1307	0	0	0	0	0	0	0
2003	0.0650	0.1334	0.1651	0.2434	0.9217	1.0626	1.5786	2.1307	0	0	0	0	0	0
2004	0.0665	0.1092	0.1601	0.2569	0.9951	2.0800	1.7304	0	0	0	0	0	0	0
2005	0.0930	0.1077	0.1274	0.2752	0.3973	0.3484	1.7543	0	0	0	0	0	0	0
2006	0.0976	0.1276	0.1379	0.2222	0.8232	0.2517	1.8087	0	0	0	0	0	0	0
2007	0.0830	0.1464	0.1906	0.2329	0.3737	1.1763	0.2359	0	0	0.2369	0	0	0	0
2008	0.0856	0.1194	0.2115	0.4089	0.5376	0.7874	1.8087	0	0	0	0	0	0	0
2009	0.0867	0.1267	0.1747	0.4608	0.6791	2.0215	0.4448	0	0	0	0	0	0	0

Table A43. Survey attributes. The years where age structure is available pertains to silver hake specifically (Some age information is available earlier in the time series for other stocks).

Survey	Index	Years	Precision	Area	depth(m)	Speed (kn)	duration (min)	Height (m)	Changes	Comments
Fall	abundance	1973-2009		GOM, SGB, NGB, SNE, MA	>30	3.8	30	1-2	D85, V~	
	age Structure	1973-2009								
Spring	abundance	1973-2009		GOM, SGB, NGB, SNE, MA	>30	3.8	30	1-2	5, V~, N73-81, V~	
	age Structure	1973-2009								
Shrimp	abundance	1985-2009	?	W.GOM	?	2	15	3	none	no ages
Larval	SSB	1977-2008	IQR~?	SW.GOM-GB	>30	NA		NA	mesh93	
ME-NH	Recruitment	2000-2009	?	Inshore ME	<30	2.5	20	3	none	no ages
Maspring	Recruitment	(1978)1982-2009	?	Inshore MA			15	3	V82	Intermittent ages
Mafall	Recruitment	(1978)1982-2009	?	Inshore MA	<100~	2	15	3		intermittent ages

Table A44. negative log-likelihood, number of model parameters, AIC_c measures for beta-binomial models with the specified relationship of the calibration factor to length fit to silver hake catch data from the 2008 *Albatross IV*/*Henry B. Bigelow* calibration experiment.

Model	Model	-LL	# parameters	AIC_c	Δ (AIC_c)	AIC_c Weights
1	**All stations, constant (no length effect)**	9341.745	2	18687.49	494.4465	0
2	**Survey, S-S, constant**	9322.744	4	18653.49	460.4489	0
3	**S,F,S-S, constant model**	9305.244	6	18622.5	429.4549	0
4	**All stations, logistic model**	9186.488	5	18382.99	189.9405	0
5	**Survey, S-S logistic**	9163.663	10	18347.36	154.3148	0
6	**S, F, S-S, logistic**	9146.738	15	18323.55	130.5072	0
7	**All stations, double logistic model**	9115.248	8	18246.52	53.4731	0
8	**Survey, S-S, double-logistic model**	9089.773	16	18211.63	18.5858	1.00E-04
9	**S,F,S-S, double-logistic model**	9073.961	24	18196.11	3.0675	0.1774
10	**Spring logistic model**	9076.506	21	18195.16	2.1138	NA
11	**No minimum of ascending logistic for Fall**	9073.981	23	18194.14	1.0926	NA
12	**No minima for ascending or descending logistic for Fall**	9074.917	22	18194	0.9499	NA
13	**Spring logistic, no minima for ascending or descending logistic for Fall**	9076.527	19	18193.05	0	0.8225

Table A45: NEFSC fall survey indices of minimum swept area abundance for northern silver hake stock in thousands of fish and thousand of metric tons (Note that 2009a are raw Bigelow Values and 2009b are converted Bigelow values to Albatross units)

Year	CV	Age1	Age2	Age3	Age4	Age5	Age6+	B(000mt)
1973	12%	14436.5	17065.9	6506.6	956.3	640.4	384.7	8.818
1974	16%	0.0	0.0	0.0	0.0	0.0	0.0	7.374
1975	17%	35678.7	65288.3	15495.3	4861.7	1785.7	1324.1	17.312
1976	15%	15459.1	33747.8	35380.2	13317.2	2055.5	2303.5	24.070
1977	21%	11894.0	11472.0	19658.5	12447.3	2127.2	519.8	14.381
1978	10%	22603.4	7793.0	4901.3	7013.1	9481.1	2681.8	13.527
1979	14%	54164.4	35852.5	4038.5	1873.8	2241.7	3455.2	13.222
1980	21%	8020.5	27275.0	26790.4	6152.2	2286.6	6611.8	15.460
1981	24%	16369.2	10221.9	11695.4	9707.7	1530.8	2594.7	9.667
1982	38%	32671.9	18255.7	6595.6	6801.4	6221.3	1512.4	13.443
1983	20%	85804.5	59343.2	2440.3	1256.5	1284.5	820.2	18.735
1984	16%	12838.7	15684.7	4775.2	1077.8	396.1	248.0	7.185
1985	12%	84813.3	7705.9	14376.6	2885.3	210.8	51.6	17.718
1986	11%	171009.8	46817.8	6360.4	6077.7	742.5	0.0	27.902
1987	13%	7056.1	88792.7	21521.0	2330.5	1818.8	229.0	20.949
1988	13%	8381.9	13019.5	37131.3	2667.3	319.7	79.6	12.939
1989	14%	115415.1	26960.7	28799.9	2886.6	141.0	17.1	22.539
1990	21%	45324.0	116639.3	29578.5	13340.3	1629.7	0.0	33.397
1991	19%	76098.0	61390.6	21634.0	4048.5	230.2	0.0	22.515
1992	13%	79017.2	80694.6	25106.3	840.5	0.0	0.0	21.925
1993	15%	103221.8	62864.1	9868.4	1885.8	112.1	0.0	16.051
1994	12%	41373.7	78996.9	7439.5	226.2	0.0	0.0	14.644
1995	14%	174259.8	75106.4	18922.2	772.3	0.0	0.0	27.592
1996	14%	30675.8	75793.5	19831.7	1861.6	119.4	39.6	16.191
1997	17%	24796.9	39185.3	11025.0	855.9	53.9	17.8	12.108
1998	20%	437056.4	85750.8	10686.5	1411.6	45.2	86.0	40.462
1999	13%	82209.2	124230.5	3951.8	837.5	106.8	20.1	23.853
2000	13%	216280.5	92445.2	14006.8	860.2	55.4	0.0	28.903
2001	13%	26200.2	111742.1	7411.1	1307.6	224.5	0.0	17.820
2002	12%	55376.4	64790.2	4901.0	628.7	38.3	0.0	17.093
2003	13%	135899.8	34640.5	15642.5	537.1	55.8	0.0	17.745
2004	17%	39525.1	28282.0	3761.0	390.3	36.2	0.0	7.014
2005	16%	8989.2	15479.3	4467.7	170.5	88.6	55.6	3.672
2006	39%	56340.2	4048.3	3011.8	2338.8	0.0	65.1	7.903
2007	12%	163771.4	6655.9	818.1	500.7	444.0	0.0	13.786
2008	13%	73158.4	32141.6	1132.8	208.0	0.0	0.0	11.285
2009a	13%	349370.4	132034.0	55391.2	932.5	1458.7	32.7	67.300
2009b	NA	71712.5	30640.6	13550.5	285.8	357.7	11.9	14.748

Table A46: NEFSC spring survey indices of minimum swept area abundance for northern silver hake stock in thousands of fish and thousands of metric tons (Note that 2009a are raw Bigelow Values and 2009b are converted Bigelow values to Albatross units).

Year	CV	Age1	Age2	Age3	Age4	Age5	Age6+	B(000mt)
1973	17%	11417.2	25745.9	2586.8	336.2	113.2	40.7	5.760
1974	21%	80728.8	8416.8	4048.8	1116.6	218.9	153.0	5.789
1975	24%	103639.2	163802.8	17115.2	2873.8	937.9	119.7	18.268
1976	13%	25532.1	57159.3	30964.7	3593.2	1243.0	833.2	17.952
1977	14%	12742.4	12445.0	10823.9	4368.0	873.5	719.0	7.796
1978	26%	10279.1	4439.9	840.5	449.6	448.3	164.6	1.720
1979	23%	20114.1	30356.8	1037.8	288.7	147.6	304.7	3.693
1980	14%	9743.9	44268.4	15180.1	1065.2	305.4	615.4	8.565
1981	15%	24465.0	12678.4	8566.6	2805.3	348.4	144.4	4.607
1982	15%	23899.0	12213.5	3437.4	1493.6	1156.8	286.3	3.047
1983	16%	23320.0	17971.3	1880.7	546.5	766.9	266.6	3.273
1984	22%	8586.5	12281.1	1891.8	403.1	107.6	133.1	2.370
1985	29%	70390.3	7367.8	4209.5	1578.5	456.2	313.3	5.004
1986	20%	162634.1	12302.0	1595.9	1455.1	311.3	182.3	6.321
1987	19%	6462.3	72239.3	7050.9	961.0	460.9	96.7	7.906
1988	16%	1956.9	3583.3	10439.5	1317.5	218.5	97.4	2.641
1989	21%	236852.6	7336.2	1499.6	3118.6	250.1	0.0	7.353
1990	18%	30459.7	19804.3	3243.8	736.5	413.6	41.9	3.363
1991	12%	85192.9	10244.0	2636.3	1228.0	89.9	46.9	2.850
1992	26%	237761.6	91109.7	12132.1	3703.4	189.4	16.0	11.639
1993	25%	80010.3	49913.7	6632.8	2830.6	281.8	0.0	5.513
1994	31%	15457.9	139351.6	22783.5	2405.6	25.3	33.4	11.254
1995	19%	92548.6	113790.1	14160.7	2347.8	125.0	37.0	6.998
1996	19%	7746.6	43529.7	29157.0	2431.9	37.7	45.4	6.436
1997	14%	5291.4	13944.4	7595.3	579.5	172.5	37.7	2.583
1998	12%	156694.2	212364.9	4923.3	1076.5	190.0	47.3	8.357
1999	16%	24723.9	123620.3	11145.9	1487.2	461.6	16.0	8.751
2000	17%	38275.9	357605.0	49393.7	5192.7	557.6	126.7	20.285
2001	13%	8371.0	261511.6	72584.2	6256.4	614.6	65.3	22.309
2002	15%	14365.3	79166.5	30560.5	3707.2	350.3	240.3	7.457
2003	19%	104133.8	160288.7	13610.3	2901.2	166.9	73.6	7.496
2004	19%	10608.0	111844.0	7763.1	2773.9	236.0	33.0	6.541
2005	16%	5128.1	21365.7	7241.4	555.5	36.2	0.0	2.436
2006	13%	18462.6	2344.0	630.8	1038.0	59.5	36.2	0.915
2007	19%	160220.6	12298.6	1249.9	384.1	338.5	43.7	4.716
2008	18%	23538.5	64374.8	1957.3	282.0	28.5	161.6	6.290
2009a	14%	458004.4	131703.7	65939.2	1601.0	304.9	958.9	75.190
2009b	NA	52960.0	27848.6	13993.6	339.8	64.7	203.5	5.673

Table A47: Swept area abundance and biomass for silver hake from the Shrimp survey

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1985	9675	775.78	1218.38	333.18	68474.09	107632.44	29315.49
1986	12022	2242.04	2740.04	1744.04	105899.39	130566.43	81232.65
1987	11595	1151.27	1439.34	863.19	149508.25	187774.65	111241.56
1988	6574	95.94	117.43	74.45	16302.04	19623.88	12980.20
1989	9167	1452.78	1981.00	924.56	82533.48	121208.59	43858.37
1990	9167	761.40	851.82	670.98	92028.43	102836.78	81220.08
1991	10401	852.50	955.33	749.67	62591.40	72070.35	53112.45
1992	8983	1542.04	1827.99	1256.09	82456.75	94660.16	70253.12
1993	10629	1964.33	2160.56	1768.11	85261.32	91638.99	78883.65
1994	6574	399.06	533.46	264.66	32765.14	46107.41	19423.05
1995	6147	554.31	691.27	417.35	30770.35	38115.24	23425.29
1996	6574	506.71	654.17	359.25	34179.38	43632.79	24726.13
1997	6147	154.76	200.29	109.23	10644.45	13005.05	8283.85
1998	7241	2060.04	2831.16	1288.92	72296.68	98166.24	46427.12
1999	8195	741.92	875.53	608.31	46540.63	56341.44	36739.62
2000	8195	1892.18	2206.53	1577.83	81988.72	93634.84	70342.81
2001	7749	617.70	730.27	505.14	46869.83	55068.85	38670.80
2002	8500	1063.57	1149.30	977.84	66092.60	71205.56	60979.64
2003	9167	2324.57	2974.95	1674.18	81179.51	108300.31	54058.72
2004	10788	875.95	1053.75	698.15	42106.37	50668.00	33544.75
2005	10788	244.07	295.65	192.50	17895.40	20879.63	14911.17
2006	7241	136.78	177.41	96.15	9501.46	12106.05	6896.87
2007	9370	773.15	950.45	595.84	32559.34	40137.80	24980.65
2008	9370	575.56	668.92	482.21	27980.69	33357.67	22603.95
2009	9370	286.63	343.30	229.97	16239.62	20030.72	12448.51

Table A48. Fall survey Swept area abundance and biomass with 95% Confidence interval for silver from the Massachusetts Division of Fisheries Fall North Survey

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1978	948	16.03	23.30	8.77	767.75	1373.74	161.79
1979	969	18.10	20.35	15.84	1327.45	1548.98	1105.90
1980	969	15.11	23.96	6.26	1522.93	3150.82	-104.96
1981	969	11.05	13.71	8.38	1450.37	1821.45	1079.30
1982	969	14.38	17.12	11.64	794.94	924.46	665.39
1983	969	8.72	10.10	7.33	845.40	979.33	711.47
1984	969	3.74	4.33	3.15	595.07	723.94	466.18
1985	948	13.93	16.01	11.85	1477.26	1797.31	1157.18
1986	969	32.75	36.69	28.81	2115.96	2435.27	1796.68
1987	933	3.47	4.59	2.35	274.01	328.50	219.51
1988	933	3.57	4.26	2.88	552.66	718.88	386.45
1989	875	9.75	11.30	8.21	695.98	802.75	589.24
1990	969	4.37	5.21	3.52	483.49	610.52	356.44
1991	914	20.69	24.40	16.98	1399.73	1635.34	1164.13
1992	969	59.66	68.32	51.00	1657.29	1974.05	1340.50
1993	969	8.27	9.91	6.64	549.88	656.52	443.21
1994	969	11.89	14.74	9.05	1099.07	1376.58	821.54
1995	969	14.41	17.89	10.93	1041.30	1299.77	782.84
1996	969	10.82	12.89	8.74	1111.37	1274.32	948.41
1997	969	7.99	11.02	4.96	507.48	677.86	337.07
1998	969	12.70	15.58	9.83	666.70	820.48	512.92
1999	969	14.15	19.27	9.02	1210.00	1590.30	829.73
2000	969	21.69	25.38	18.01	2231.55	2596.94	1866.14
2001	969	4.94	6.64	3.24	759.74	1147.77	371.71
2002	969	13.74	15.65	11.82	1018.45	1133.66	903.27
2003	969	10.69	13.45	7.94	718.47	996.69	440.26
2004	969	7.39	10.58	4.20	434.49	527.73	341.27
2005	969	1.77	2.12	1.42	171.75	207.57	135.92
2006	969	5.92	7.16	4.68	508.06	643.22	372.92
2007	948	4.27	4.93	3.60	412.63	500.96	324.29
2008	969	6.09	7.20	4.98	481.80	576.23	387.35
2009	948	7.74	10.18	5.30	651.17	892.02	410.28

Table A49: Spring survey swept area abundance and biomass with 95% Confidence interval for silver from the Massachusetts Division of Fisheries in the northern management area

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1978	930	1.15	1.75	0.55	227.17	357.30	97.03
1979	969	1.76	2.43	1.10	79.41	142.42	16.40
1980	969	2.11	2.87	1.36	268.44	375.11	161.77
1981	969	4.47	6.14	2.81	560.31	1114.59	6.02
1982	969	0.64	0.78	0.51	80.39	100.85	59.94
1983	969	4.73	5.69	3.76	677.13	833.78	520.50
1984	969	1.97	2.46	1.48	299.96	392.84	207.07
1985	969	5.65	7.06	4.24	322.13	469.99	174.26
1986	969	10.12	11.73	8.52	753.77	1069.50	438.04
1987	969	11.83	39.84	-16.17	1470.43	4825.34	-1884.51
1988	969	1.24	1.55	0.94	198.78	244.81	152.75
1989	969	4.00	5.32	2.68	204.22	282.52	125.92
1990	969	1.25	2.90	-0.40	112.26	238.94	-14.41
1991	969	1.56	2.12	1.00	112.19	160.91	63.44
1992	969	3.99	5.62	2.37	386.24	676.58	95.91
1993	969	0.84	1.60	0.07	32.22	44.52	19.93
1994	969	1.96	4.30	-0.38	73.87	117.88	29.85
1995	969	5.44	6.91	3.96	273.60	324.29	222.91
1996	969	1.88	2.36	1.41	70.27	94.60	45.95
1997	969	6.34	10.92	1.76	644.38	1191.00	97.73
1998	969	2.24	3.03	1.45	124.83	191.85	57.84
1999	969	4.91	6.63	3.20	231.43	373.14	89.74
2000	969	13.12	17.61	8.62	1031.18	1478.87	583.48
2001	969	2.86	3.67	2.05	314.19	410.05	218.35
2002	969	4.53	5.68	3.37	406.30	498.86	313.74
2003	969	3.67	4.46	2.88	149.90	182.30	117.50
2004	969	0.95	1.21	0.68	47.19	73.09	21.26
2005	969	1.00	1.26	0.74	52.76	65.98	39.53
2006	969	3.90	5.09	2.72	186.03	313.33	58.73
2007	969	2.36	2.87	1.85	162.57	198.80	126.35
2008	969	2.08	2.61	1.55	138.44	182.98	93.87
2009	969	4.80	6.14	3.45	225.05	256.62	193.51

Table A50: Stratified mean number and weight per tow (kg) for silver hake from the fall and spring Maine_New Hampshire State surveys, 2000-2009

	MENH Fall	MENH Fall	MENH Spring	MENH Spring
Year	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)
2000	786.49	34.77		
2001	687.67	52.88	97.74	3.68
2002	476.28	13.47	302.44	13.34
2003	1046.25	49.97	503.71	11.63
2004	413.66	24.85	131.82	5.25
2005	44.93	3.77	43.34	1.91
2006	82.59	7.13	40.47	1.58
2007	605.57	37.14	223.16	5.68
2008	467.93	30.66	145.21	4.67
2009	498.48	25.73	277.21	8.54

Table A51: NEFSC fall survey indices of minimum swept area abundance for southern silver hake stock in thousands of fish and thousand of metric tons (Note that 2009a are raw Bigelow Values and 2009b are converted Bigelow values to Albatross units)

Year	CV	Age1	Age2	Age3	Age4	Age5	Age6+	B(000mt)
1973	20%	10253.2	10947.8	4677.8	1335.2	664.1	61.6	5.622
1974	28%	0.0	0.0	0.0	0.0	0.0	0.0	2.813
1975	27%	13223.3	7848.6	4759.3	1939.8	670.4	340.7	5.912
1976	34%	6303.8	12596.9	6726.9	2316.6	600.6	720.4	6.600
1977	25%	8336.3	3369.7	6678.9	2286.1	520.8	387.0	5.546
1978	19%	20398.5	8995.1	5934.6	5397.9	2441.4	533.0	8.272
1979	16%	6862.6	6226.6	4536.8	2209.3	1604.1	1555.7	5.575
1980	21%	8781.9	3224.5	7869.9	2438.1	1357.2	1344.7	5.386
1981	35%	22241.3	2260.9	3415.8	2392.1	557.5	218.2	3.720
1982	28%	9618.2	7750.3	3109.5	1301.1	589.3	329.1	5.178
1983	32%	25684.2	11599.1	5732.0	1143.2	593.3	345.3	8.510
1984	25%	16431.4	7743.5	3112.5	888.5	52.9	0.0	4.611
1985	26%	53270.5	11520.9	8872.3	4211.0	394.0	0.0	11.760
1986	28%	19161.6	8618.4	1948.4	642.3	216.5	0.0	4.788
1987	36%	17745.5	24635.5	1873.3	559.1	173.9	0.0	6.454
1988	26%	12656.9	28969.2	3205.2	237.7	26.5	0.0	5.903
1989	21%	9082.5	22022.5	7874.4	681.4	124.2	0.0	6.177
1990	33%	4143.3	19925.8	4208.3	1185.5	262.5	0.0	5.004
1991	49%	2058.3	8055.8	3870.3	722.1	26.5	0.0	2.808
1992	31%	12976.8	11667.0	1663.2	150.0	0.0	0.0	3.277
1993	16%	22742.5	18502.6	1894.0	367.9	0.0	0.0	4.215
1994	22%	4162.7	14601.6	1315.1	227.8	0.0	0.0	2.629
1995	41%	36320.2	13168.4	1984.8	109.9	24.2	0.0	5.270
1996	21%	4640.1	6595.1	1365.0	90.1	0.0	0.0	1.480
1997	21%	13166.7	9125.2	1010.5	79.1	0.0	0.0	2.755
1998	36%	4748.0	7988.6	725.1	238.4	0.0	0.0	1.891
1999	30%	21293.8	10837.6	1007.5	84.8	0.0	0.0	2.716
2000	62%	1978.5	10553.8	1038.9	216.2	27.1	0.0	2.395
2001	41%	65534.4	19651.2	991.0	345.7	26.4	0.0	6.743
2002	21%	10754.8	21521.5	609.5	60.9	0.0	0.0	3.893
2003	37%	35866.4	11142.0	1595.5	113.7	0.0	0.0	4.704
2004	18%	65266.9	4749.3	997.2	76.8	0.0	0.0	4.102
2005	20%	21784.7	6852.2	1074.5	54.4	0.0	0.0	3.101
2006	20%	37081.2	5964.6	3335.6	232.1	0.0	0.0	4.680
2007	26%	26012.3	3766.4	512.5	433.1	28.5	45.4	2.895
2008	18%	43819.5	8795.8	1065.7	126.5	0.0	0.0	4.513
2009a	27%	79099.4	50105.0	7161.3	210.2	0.0	0.0	15.826
2009b	NA	16273.2	11362.2	1685.5	54.9	0.0	0.0	3.626

Table A52: NEFSC spring survey indices of minimum swept area abundance for southern silver hake stock in thousands of fish and thousands of metric tons (Note that 2009a are raw Bigelow Values and 2009b are converted Bigelow values to Albatross units)

Year	CV	Age1	Age2	Age3	Age4	Age5	Age6+	B(000mt)
1973	10%	23216.7	28594.1	13686.5	4411.0	461.5	444.3	15.290
1974	19%	104382.4	8053.2	13057.8	7587.7	2534.4	1179.3	11.809
1975	19%	58454.3	17071.7	32399.7	9237.4	2545.3	262.8	18.868
1976	21%	42942.4	20578.0	13881.5	6775.9	1484.6	485.0	14.811
1977	15%	6986.5	6084.6	17959.1	9840.0	1990.1	1401.8	14.036
1978	17%	17383.0	14294.7	7623.8	11028.3	5194.0	1786.2	17.842
1979	17%	17435.4	6898.7	3638.6	1658.1	2540.0	1894.4	7.136
1980	19%	16115.3	13853.7	8564.7	2655.6	845.6	1982.2	9.117
1981	13%	15333.7	8390.5	10064.3	6951.4	3366.6	3090.1	11.434
1982	14%	4534.8	10927.0	3547.2	3527.3	3133.3	2111.3	6.569
1983	15%	9440.1	14156.3	3170.8	2046.4	844.9	1260.4	4.289
1984	21%	8799.5	21514.3	8743.2	2175.9	563.8	582.4	7.559
1985	16%	31074.2	13642.2	14057.3	5059.9	1196.9	579.4	8.800
1986	18%	12520.1	36261.6	8422.4	7110.0	1040.3	181.1	9.055
1987	25%	12185.7	51033.7	19782.4	4940.7	2512.2	175.1	11.658
1988	24%	17296.8	9247.0	21241.4	3235.1	204.0	16.8	5.564
1989	12%	22894.9	17626.4	25833.9	4946.7	240.4	68.9	7.348
1990	33%	11031.5	46469.4	21782.2	3927.5	632.4	72.2	9.685
1991	13%	10555.2	3100.6	14473.5	8034.0	1713.3	465.8	4.755
1992	20%	21388.9	4697.7	5565.6	2077.1	102.6	0.0	1.864
1993	39%	21848.8	39640.3	12190.1	2698.9	505.0	0.0	5.153
1994	22%	2224.8	22240.5	37090.5	1827.8	116.0	0.0	6.089
1995	26%	23867.3	6953.7	14572.8	4287.2	56.3	0.0	3.346
1996	1%	6805.4	44641.9	146495.8	4756.3	163.2	0.0	20.553
1997	13%	6915.1	3822.6	8567.2	1338.3	24.0	0.0	2.142
1998	29%	13695.1	6767.6	11494.4	383.8	0.0	0.0	2.305
1999	21%	41367.2	27313.8	17347.3	890.6	90.7	0.0	5.026
2000	12%	4618.2	5012.6	22022.1	851.5	79.5	0.0	3.443
2001	21%	36543.7	9513.9	16918.2	3099.2	200.3	0.0	3.840
2002	16%	6964.3	14237.4	16791.1	686.3	0.0	0.0	3.074
2003	14%	3226.7	6534.5	4954.0	1134.9	15.2	0.0	1.131
2004	24%	63875.7	11964.3	3883.6	794.6	0.0	0.0	1.547
2005	12%	8959.0	11265.3	15589.3	779.7	58.6	0.0	2.910
2006	39%	37114.2	5765.0	2969.3	414.5	28.4	0.0	1.635
2007	22%	15693.2	12443.0	4701.3	612.2	51.3	0.0	2.759
2008	28%	68912.7	26971.5	1734.5	425.8	41.4	0.0	4.185
2009a	13%	86549.1	202485.5	46310.8	1633.4	82.2	0.0	28.47
2009b	NA	11177.5	42971.2	9828.0	346.6	17.4	0.0	5.975

Table A53: Swept area abundance and biomass with 95% confidence intervals for silver hake from NEFSC winter surveys in the southern management region

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1992	30014	48.76	58.55	38.96	3066.24	3686.45	2445.80
1993	29928	137.05	182.72	91.39	7947.14	11916.37	3977.68
1994	30014	39.13	52.01	26.24	3450.01	4532.11	2367.90
1995	30014	35.74	45.25	26.23	3594.12	4395.56	2792.45
1996	30014	41.20	49.10	33.30	2811.92	3353.32	2270.30
1997	30014	71.73	89.77	53.70	3879.14	5264.59	2493.91
1998	30014	41.50	61.28	21.71	2260.44	2633.90	1886.99
1999	30014	71.04	92.95	49.13	4532.57	5779.64	3285.50
2000	30014	52.49	65.05	39.94	4512.64	5622.70	3402.58
2001	30014	222.80	289.34	156.27	4947.04	5999.59	3894.49
2002	30014	49.52	60.22	38.81	3606.03	4317.89	2894.17
2003	26984	41.11	58.14	24.07	1434.89	1887.44	982.55
2004	30014	215.98	298.19	133.77	4742.90	6318.75	3167.05
2005	29358	39.69	50.62	28.75	1053.75	1301.61	805.89
2006	30014	40.01	52.39	27.62	1467.48	1691.32	1243.40
2007	26984	79.29	152.22	6.35	2066.44	2786.97	1345.90

Table A54: Fall survey swept area abundance and biomass with 95% confidence intervals for silver hake from the Massachusetts Division of Marine Fisheries state survey in the southern management area.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1978	864	0.07	0.19	-0.05	3.68	14.89	-7.50
1979	864	0.23	0.46	-0.01	6.02	8.83	3.21
1980	864	0.19	0.42	-0.03	3.91	5.68	2.13
1981	864	0.89	1.99	-0.22	9.50	21.68	-2.67
1982	864	4.90	9.40	0.40	51.35	94.30	8.38
1983	864	0.04	0.15	-0.06	2.61	10.60	-5.39
1984	864	0.15	0.29	0.00	0.94	1.71	0.18
1985	864	1.04	2.00	0.09	3.26	5.98	0.54
1986	864	12.92	23.81	2.02	126.74	206.35	47.13
1987	864	0.01	0.02	0.00	0.52	2.13	-1.08
1988	864	0.07	0.12	0.01	0.83	1.89	-0.22
1989	864	0.37	0.61	0.13	0.67	1.24	0.11
1990	864	0.22	0.50	-0.05	1.44	3.01	-0.16
1991	864	3.15	6.35	-0.05	8.02	16.29	-0.25
1992	864	0.97	2.45	-0.51	5.84	14.35	-2.67
1993	864	1.47	3.85	-0.92	5.89	15.46	-3.71
1994	864	4.13	9.88	-1.62	38.73	111.94	-34.48
1995	864	6.06	9.59	2.54	50.75	85.90	15.61
1996	864	0.17	0.30	0.04	15.34	26.46	4.20
1997	864	0.43	0.77	0.10	0.61	1.19	0.02
1998	864	0.04	0.07	0.02	0.18	0.31	0.04
1999	864	1.15	2.28	0.02	4.56	9.23	-0.13
2000	864	0.05	0.09	0.02	2.36	4.76	-0.04
2001	864	0.02	0.04	-0.01	0.27	1.06	-0.54
2002	864	0.05	0.09	0.01	0.36	1.08	-0.34
2003	864	1.44	3.51	-0.64	4.40	10.96	-2.16
2004	864	0.12	0.21	0.02	0.25	0.45	0.04
2005	864	0.09	0.19	-0.01	1.19	2.61	-0.25
2006	864	3.95	6.79	1.11	24.64	38.75	10.54
2007	864	0.03	0.10	-0.03	0.04	0.13	-0.04
2008	864	0.02	0.04	0.00	0.34	1.08	-0.43
2009	864	0.05	0.09	0.01	0.22	0.43	0.04

Table A55: Spring survey swept area abundance and biomass with 95% confidence intervals for silver hake from the Massachusetts Division of Marine Fisheries state survey in the southern management area

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1978	864	1.21	1.70	0.73	76.74	122.02	31.45
1979	864	2.03	3.68	0.38	865.62	1653.35	77.90
1980	864	2.76	7.65	-2.14	519.65	2020.38	-981.08
1981	864	0.53	1.11	-0.05	117.60	241.73	-6.56
1982	864	1.04	1.49	0.59	63.41	182.83	-56.02
1983	864	5.26	9.34	1.17	508.33	930.60	86.06
1984	864	8.43	14.06	2.80	1641.33	2646.33	636.33
1985	864	1.54	2.29	0.78	229.06	289.87	168.25
1986	864	1.93	2.35	1.50	157.00	204.44	109.58
1987	864	19.64	34.79	4.49	2106.26	3692.45	520.10
1988	864	2.28	3.92	0.64	138.29	240.07	36.50
1989	864	3.48	4.63	2.33	470.70	633.36	308.07
1990	864	4.40	8.37	0.44	847.82	1743.52	-47.89
1991	864	1.37	5.30	-2.57	312.07	1224.88	-600.75
1992	864	7.45	15.04	-0.15	75.37	133.68	17.05
1993	864	2.84	4.83	0.84	57.64	117.33	-2.07
1994	864	1.02	1.26	0.79	89.00	116.86	61.12
1995	864	0.82	1.92	-0.28	27.34	80.44	-25.79
1996	864	0.91	1.72	0.10	39.33	125.93	-47.26
1997	864	0.36	0.60	0.12	26.42	46.45	6.40
1998	864	1.94	6.80	-2.91	202.02	794.11	-390.08
1999	864	0.95	3.41	-1.50	34.30	123.62	-55.01
2000	864	2.01	7.31	-3.28	93.18	288.39	-102.03
2001	864	0.96	1.20	0.72	23.83	58.14	-10.47
2002	864	0.92	1.10	0.74	113.31	167.85	58.74
2003	864	0.14	0.24	0.03	2.04	4.52	-0.43
2004	864	1.88	6.12	-2.37	17.41	55.89	-21.07
2005	864	0.56	1.52	-0.40	12.62	33.38	-8.13
2006	864	0.78	1.53	0.03	14.15	26.71	1.57
2007	864	6.97	21.75	-7.81	128.69	367.69	-110.30
2008	864	1.45	3.89	-1.00	20.08	55.51	-15.32
2009	864	0.37	1.11	-0.36	26.37	104.73	-51.96

Table A56: Stratified mean number and weight per tow for silver hake from Rhode Island and Connecticut state surveys in the southern management area for both fall and spring

	RI Fall	RI Fall	RI Spring	RI Spring	CT Fall	CT Fall	CT Spring	CT Spring
Year	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)
1979	3.77	0.20	3.05	0.34				
1980	0.48	0.04	13.73	0.33				
1981	4.10	0.40	1.52	0.28				
1982	1.85	0.03	0.45	0.06				
1983	0.13	0.01	11.65	0.59				
1984	10.14	0.10	8.01	1.20	0.55		7.53	
1985	9.71	0.05	3.24	0.98	0.23		1.83	
1986	29.15	0.29	5.59	0.86	1.65		1.19	
1987	1.63	0.17	3.89	0.53	0.01		2.48	
1988	55.36	0.22	0.00	0.00	0.30		2.25	
1989	0.47	0.04	2.56	0.18	0.60		4.86	
1990	0.12	0.01	2.24	0.33	0.96		5.53	
1991	0.09	0.00	2.54	0.19	0.32		3.87	
1992	0.38	0.03	0.26	0.01	0.48	0.04	2.67	0.20
1993	0.38	0.03	0.38	0.04	0.20	0.02	1.56	0.14
1994	2.28	0.04	0.27	0.03	3.34	0.28	1.73	0.40
1995	1.88	0.02	2.69	0.06	0.22	0.02	4.88	0.36
1996	0.18	0.01	2.11	0.20	0.06	0.01	1.15	0.12
1997	8.25	0.18	28.98	0.84	0.80	0.06	4.32	0.39
1998	0.02	0.00	6.48	0.27	0.07	0.01	4.64	0.48
1999	0.65	0.04	8.91	0.14	0.16	0.03	12.57	0.56
2000	2.02	0.01	4.86	0.20	0.09	0.01	2.28	0.19
2001	0.47	0.02	2.96	0.03	0.07	0.01	7.64	0.54
2002	0.21	0.00	11.19	1.08	0.07	0.01	5.92	0.52
2003	13.09	0.15	0.86	0.01	0.18	0.02	0.76	0.06
2004	2.21	0.05	31.04	0.19	0.18	0.02	2.63	0.16
2005	0.48	0.00	0.16	0.00	0.09	0.01	0.57	0.05
2006	8.05	0.08	8.67	0.43	0.64	0.08	4.75	0.33
2007	0.04	0.00	1.06	0.04	0.04	0.01	0.98	0.10
2008	0.02	0.00	140.13	1.38	0.28	0.03	19.08	1.02
2009	0.90	0.01	0.37	0.01	0.18	0.02	2.30	0.27
2010			11.84	0.15				

Table A57: NEFSC fall survey indices of minimum swept area abundance for combined north and south silver hake stocks in thousands of fish and thousand of metric tons (Note that 2009a are raw Bigelow Values and 2009b are converted Bigelow values to Albatross units)

Year	CV	Age1	Age2	Age3	Age4	Age5	Age6+	B(000mt)
1973	16%	24689.7	28013.8	11184.4	2291.5	1304.6	446.3	14.4
1974	22%	0.0	0.0	0.0	0.0	0.0	0.0	10.2
1975	22%	48902.1	73136.9	20254.6	6801.5	2456.1	1664.8	23.2
1976	25%	21762.9	46344.7	42107.1	15633.7	2656.1	3023.9	30.7
1977	23%	20230.3	14841.7	26337.4	14733.5	2648.0	906.8	19.9
1978	15%	43001.9	16788.1	10835.9	12411.0	11922.5	3214.9	21.8
1979	15%	61027.1	42079.1	8575.3	4083.1	3845.8	5010.9	18.8
1980	21%	16802.4	30499.5	34660.3	8590.3	3643.8	7956.5	20.8
1981	29%	38610.5	12482.9	15111.2	12099.8	2088.4	2812.9	13.4
1982	33%	42290.1	26005.9	9705.1	8102.6	6810.6	1841.5	18.6
1983	26%	111488.7	70942.3	8172.2	2399.7	1877.8	1165.5	27.2
1984	20%	29270.1	23428.2	7887.8	1966.4	448.9	248.0	11.8
1985	19%	138083.8	19226.9	23248.9	7096.3	604.8	51.6	29.5
1986	19%	190171.4	55436.1	8308.8	6720.0	959.0	0.0	32.7
1987	24%	24801.5	113428.3	23394.3	2889.6	1992.8	229.0	27.4
1988	19%	21038.8	41988.7	40336.4	2905.0	346.2	79.6	18.8
1989	17%	124497.6	48983.2	36674.3	3568.0	265.2	17.1	28.7
1990	27%	49467.3	136565.1	33786.9	14525.8	1892.2	0.0	38.4
1991	34%	78156.4	69446.5	25504.4	4770.6	256.7	0.0	25.3
1992	22%	91994.0	92361.6	26769.5	990.5	0.0	0.0	25.2
1993	15%	125964.2	81366.7	11762.4	2253.7	112.1	0.0	20.3
1994	17%	45536.3	93598.5	8754.6	454.0	0.0	0.0	17.3
1995	27%	210580.0	88274.8	20907.1	882.2	24.2	0.0	32.9
1996	18%	35315.9	82388.7	21196.7	1951.7	119.4	39.6	17.7
1997	19%	37963.6	48310.5	12035.5	935.1	53.9	17.8	14.9
1998	28%	441804.4	93739.4	11411.5	1650.0	45.2	86.0	42.4
1999	22%	103502.9	135068.1	4959.3	922.3	106.8	20.1	26.6
2000	37%	218259.1	102999.1	15045.8	1076.4	82.6	0.0	31.3
2001	27%	91734.6	131393.3	8402.0	1653.4	250.9	0.0	24.6
2002	17%	66131.3	86311.7	5510.6	689.6	38.3	0.0	21.0
2003	25%	171766.3	45782.5	17238.1	650.8	55.8	0.0	22.4
2004	18%	104791.9	33031.4	4758.2	467.1	36.2	0.0	11.1
2005	18%	30773.9	22331.5	5542.3	224.9	88.6	55.6	6.8
2006	30%	93421.5	10013.0	6347.4	2570.9	0.0	65.1	12.6
2007	19%	189783.8	10422.3	1330.6	933.8	472.5	45.4	16.7
2008	16%	116977.8	40937.4	2198.6	334.5	0.0	0.0	15.8
2009a	20%	428469.8	182139.1	62552.5	1142.8	1458.7	32.7	83.1
2009b	NA	87985.7	42002.8	15236.1	340.7	357.7	11.9	18.4

Table A58: NEFSC spring survey indices of minimum swept area abundance for combined silver hake stocks in thousands of fish and thousands of metric tons (Note that 2009a are raw Bigelow Values and 2009b are converted Bigelow values to Albatross units)

Year	CV	Age1	Age2	Age3	Age4	Age5	Age6+	B(000mt)
1973	14%	34633.9	54340.0	16273.4	4747.2	574.7	485.0	21.1
1974	20%	185111.2	16470.0	17106.6	8704.3	2753.3	1332.3	17.6
1975	21%	162093.5	180874.5	49514.9	12111.1	3483.3	382.5	37.1
1976	17%	68474.6	77737.3	44846.3	10369.1	2727.6	1318.2	32.8
1977	15%	19728.9	18529.6	28783.0	14208.1	2863.6	2120.8	21.8
1978	21%	27662.1	18734.6	8464.3	11477.9	5642.3	1950.8	19.6
1979	20%	37549.5	37255.5	4676.4	1946.7	2687.7	2199.1	10.8
1980	17%	25859.2	58122.1	23744.8	3720.8	1150.9	2597.6	17.7
1981	14%	39798.7	21069.0	18630.9	9756.7	3715.0	3234.5	16.0
1982	15%	28433.8	23140.4	6984.6	5020.9	4290.1	2397.6	9.6
1983	16%	32760.1	32127.6	5051.4	2592.9	1611.8	1527.0	7.6
1984	21%	17385.9	33795.3	10635.0	2579.0	671.5	715.5	9.9
1985	22%	101464.5	21010.0	18266.8	6638.4	1653.1	892.7	13.8
1986	19%	175154.3	48563.6	10018.2	8565.0	1351.6	363.4	15.4
1987	22%	18648.0	123273.0	26833.3	5901.7	2973.2	271.8	19.6
1988	20%	19253.7	12830.3	31680.9	4552.6	422.5	114.2	8.2
1989	17%	259747.4	24962.6	27333.5	8065.2	490.5	68.9	14.7
1990	26%	41491.2	66273.7	25026.0	4664.0	1046.0	114.1	13.0
1991	13%	95748.1	13344.5	17109.8	9262.0	1803.2	512.7	7.6
1992	23%	259150.4	95807.5	17697.7	5780.5	292.0	16.0	13.5
1993	32%	101859.0	89554.0	18822.9	5529.5	786.8	0.0	10.7
1994	27%	17682.7	161592.1	59874.0	4233.4	141.2	33.4	17.3
1995	22%	116415.8	120743.8	28733.5	6635.0	181.3	37.0	10.3
1996	10%	14551.9	88171.6	175652.8	7188.2	200.9	45.4	27.0
1997	13%	12206.5	17767.0	16162.5	1917.7	196.5	37.7	4.7
1998	20%	170389.3	219132.4	16417.7	1460.3	190.0	47.3	10.7
1999	19%	66091.1	150934.1	28493.2	2377.8	552.3	16.0	13.8
2000	14%	42894.1	362617.6	71415.9	6044.2	637.1	126.7	23.7
2001	17%	44914.7	271025.6	89502.4	9355.7	814.9	65.3	26.1
2002	15%	21329.5	93404.0	47351.6	4393.6	350.3	240.3	10.5
2003	16%	107360.5	166823.2	18564.3	4036.1	182.1	73.6	8.6
2004	21%	74483.6	123808.2	11646.6	3568.4	236.0	33.0	8.1
2005	14%	14087.1	32631.0	22830.6	1335.2	94.8	0.0	5.3
2006	26%	55576.8	8109.0	3600.1	1452.5	87.9	36.2	2.6
2007	20%	175913.8	24741.6	5951.2	996.3	389.8	43.7	7.5
2008	23%	92451.2	91346.3	3691.8	707.8	69.8	161.6	10.5
2009a	14%	544553.5	334189.2	112250.0	3234.4	387.2	958.9	103.7
2009b	NA	64137.5	70819.8	23821.6	686.4	82.1	203.5	11.6

Table A59: Northern silver hake arithmetic fall biomass survey, total catch and relative exploitation index

	Fall SV	Fall SV - Bmass	Northern Landings	Northern Discards	Total Catch	Relative Exploitation Index	Relative Exploitation Index
Year	arithmetic mean kg/tow	3-yr avg	000's mt	000's mt	000's mt	Catch/Fall_SV ~F	3-yr avg ~F
1955			53.36		53.36		
1956			42.15		42.15		
1957			62.75		62.75		
1958			49.90		49.90		
1959			50.61		50.61		
1960			45.54		45.54		
1961			39.69		39.69		
1962			79.00		79.00		
1963	23.10		73.92		73.92	3.20	
1964	4.34		94.46		94.46	21.77	
1965	7.06	11.50	45.28		45.28	6.41	10.46
1966	4.19	5.20	47.81		47.81	11.41	13.20
1967	2.27	4.51	33.37		33.37	14.70	10.84
1968	2.28	2.91	41.38		41.38	18.15	14.75
1969	2.41	2.32	24.06		24.06	9.98	14.28
1970	3.03	2.57	27.53		27.53	9.09	12.41
1971	2.67	2.70	36.40		36.40	13.63	10.90
1972	5.78	3.83	25.22		25.22	4.36	9.03
1973	4.12	4.19	32.09		32.09	7.79	8.60
1974	3.45	4.45	20.68		20.68	5.99	6.05
1975	8.09	5.22	39.87		39.87	4.93	6.24
1976	11.25	7.60	13.63		13.63	1.21	4.05
1977	6.72	8.69	12.46		12.46	1.85	2.66
1978	6.32	8.10	12.61		12.61	2.00	1.69
1979	6.18	6.41	3.42		3.42	0.55	1.47
1980	7.23	6.58	4.73		4.73	0.65	1.07
1981	4.52	5.98	4.42	2.64	7.05	1.56	0.92
1982	6.28	6.01	4.66	2.91	7.57	1.21	1.14
1983	8.76	6.52	5.31	2.64	7.95	0.91	1.22
1984	3.36	6.13	8.29	2.59	10.88	3.24	1.78
1985	8.28	6.80	8.30	2.56	10.86	1.31	1.82
1986	13.04	8.23	8.50	2.35	10.86	0.83	1.79
1987	9.79	10.37	5.66	2.11	7.77	0.79	0.98
1988	6.05	9.63	6.79	1.79	8.57	1.42	1.01
1989	10.53	8.79	4.65	2.32	6.96	0.66	0.96
1990	15.61	10.73	6.38	1.96	8.34	0.53	0.87
1991	10.52	12.22	6.06	1.26	7.31	0.69	0.63
1992	10.25	12.13	5.31	1.42	6.73	0.66	0.63
1993	7.50	9.42	4.36	0.69	5.05	0.67	0.67
1994	6.84	8.20	3.90	0.24	4.14	0.61	0.65
1995	12.89	9.08	2.59	0.63	3.22	0.25	0.51
1996	7.57	9.10	3.62	0.82	4.44	0.59	0.48
1997	5.66	8.71	2.80	0.24	3.05	0.54	0.46
1998	18.91	10.71	2.05	0.69	2.74	0.14	0.42
1999	11.15	11.91	3.45	0.74	4.19	0.38	0.35
2000	13.51	14.52	2.59	0.36	2.95	0.22	0.25
2001	8.33	11.00	3.39	0.48	3.87	0.46	0.35
2002	7.99	9.94	2.59	0.51	3.11	0.39	0.36
2003	8.29	8.20	1.81	0.20	2.01	0.24	0.37
2004	3.28	6.52	1.05	0.12	1.16	0.35	0.33
2005	1.72	4.43	0.83	0.06	0.89	0.52	0.37
2006	3.69	2.90	0.90	0.04	0.94	0.26	0.38
2007	6.44	3.95	1.01	0.75	1.76	0.27	0.35
2008	5.27	5.13	0.62	0.17	0.79	0.15	0.23
2009	6.89	6.20	1.04	0.19	1.23	0.18	0.20

Table A60: Southern silver hake arithmetic fall biomass survey, total catch and relative exploitation index

	Fall SV	Fall SV	Southern Landings	Southern Discards	Total Catch	Relative Exploitation Index	Relative Exploitation Index
Year	Arithmetic mean kg/tow	3-yr avg	000's mt	000's mt	000's mt	Catch/Fall_SV ~F	3-yr avg ~F
1955			13.26		13.26		
1956			14.24		14.24		
1957			16.43		16.43		
1958			12.90		12.90		
1959			16.39		16.39		
1960			8.82		8.82		
1961			12.65		12.65		
1962			17.94		17.94		
1963	4.66		89.43		89.43	19.19	
1964	4.06		147.05		147.05	36.22	
1965	5.28	4.67	294.12		294.12	55.70	37.04
1966	2.64	3.99	202.32		202.32	76.64	56.19
1967	2.44	3.45	87.38		87.38	35.81	56.05
1968	2.73	2.60	58.16		58.16	21.30	44.58
1969	1.26	2.14	74.89		74.89	59.44	38.85
1970	1.35	1.78	26.83		26.83	19.88	33.54
1971	2.21	1.61	70.51		70.51	31.90	37.07
1972	2.13	1.90	88.18		88.18	41.40	31.06
1973	1.70	2.01	102.08		102.08	60.05	44.45
1974	0.85	1.56	102.40		102.40	120.47	73.97
1975	1.79	1.45	72.16		72.16	40.32	73.61
1976	1.99	1.54	64.61		64.61	32.47	64.42
1977	1.68	1.82	57.16		57.16	34.02	35.60
1978	2.50	2.06	25.83		25.83	10.33	25.61
1979	1.68	1.95	16.40		16.40	9.76	18.04
1980	1.63	1.94	11.68		11.68	7.17	9.09
1981	1.12	1.48	13.43	3.50	16.93	15.12	10.68
1982	1.56	1.44	14.15	4.65	18.81	12.06	11.45
1983	2.57	1.75	11.86	4.81	16.67	6.49	11.22
1984	1.40	1.84	12.96	4.88	17.84	12.74	10.43
1985	3.55	2.51	12.82	3.87	16.69	4.70	7.98
1986	1.45	2.13	9.70	4.33	14.03	9.68	9.04
1987	1.95	2.32	9.55	4.25	13.80	7.08	7.15
1988	1.78	1.73	8.95	4.50	13.45	7.55	8.10
1989	1.87	1.87	13.00	6.57	19.57	10.46	8.37
1990	1.52	1.72	13.02	5.97	18.99	12.49	10.17
1991	0.85	1.41	9.74	3.08	12.82	15.08	12.68
1992	0.99	1.12	10.53	3.45	13.98	14.12	13.90
1993	1.28	1.04	12.49	5.17	17.65	13.79	14.33
1994	0.79	1.02	12.18	5.94	18.12	22.93	16.95
1995	1.59	1.22	11.99	1.40	13.39	8.42	15.05
1996	0.45	0.94	12.13	0.48	12.61	28.03	19.80
1997	0.83	0.96	12.55	0.62	13.17	15.87	17.44
1998	0.57	0.62	12.56	0.53	13.08	22.95	22.28
1999	0.82	0.74	10.42	3.55	13.97	17.03	18.62
2000	0.72	0.70	9.47	0.33	9.80	13.61	17.87
2001	2.04	1.19	8.88	0.19	9.07	4.45	11.70
2002	1.18	1.31	4.89	0.41	5.30	4.49	7.52
2003	1.42	1.55	6.28	0.60	6.89	4.85	4.60
2004	1.24	1.28	6.97	1.20	8.17	6.59	5.31
2005	0.94	1.20	6.40	1.58	7.97	8.48	6.64
2006	1.42	1.20	4.58	0.16	4.74	3.34	6.14
2007	0.87	1.08	5.07	0.15	5.21	5.99	5.94
2008	1.36	1.22	5.58	1.03	6.62	4.86	4.73
2009	1.10	1.11	6.60	0.84	7.43	6.76	5.87

Table A61. Summary of catch, NEFSC fall and spring bottom trawl survey indices, replacement ratios and relative fishing mortality rates for silver hake. Catch is based on length-based estimator. Northern and southern stocks are combined.

		NEFSC Survey		Replacement Ratio		Relative Fishing Mortality	
Year	Catch(mt)	Fall (kg/tow)	Spring (kg/tow)	Fall	Spring	Relative F Fall (mt/kg)	Relative F Spring (mt/kg)
1963	163349.2	-999	-999				
1964	241509.6	-999	-999				
1965	339396.2	-999	-999				
1966	250126.1	-999	-999				
1967	120753.6	2.37	-999			50950.9	
1968	99535.6	2.55	2.27			39033.6	43848.3
1969	98946.0	1.71	1.38			57863.2	71700.0
1970	54359.9	2.01	3.07			27044.7	17706.8
1971	106904.6	2.39	1.57			44729.9	68092.1
1972	113402.6	3.57	1.5	1.6183		31765.4	75601.7
1973	134169.2	2.65	3.86	1.0834	1.9714	50629.9	34758.8
1974	123077.9	1.87	3.23	0.7583	1.4192	65817.1	38104.6
1975	112038.5	4.26	7.1	1.7054	2.6833	26300.1	15780.1
1976	78242.5	5.63	6.01	1.9098	1.7410	13897.4	13018.7
1977	69617.0	3.66	4.01	1.0178	0.9240	19021.0	17360.9
1978	38443.1	4	3.59	1.1068	0.7414	9610.8	10708.4
1979	19813.2	3.45	1.99	0.8883	0.4156	5742.9	9956.4
1980	16413.6	3.83	3.24	0.9119	0.7137	4285.5	5065.9
1981	23985.2	2.46	2.95	0.5980	0.7829	9750.1	8130.6
1982	26375.5	3.42	1.76	0.9828	0.5577	7712.1	14986.1
1983	24628.1	5	1.39	1.4569	0.5137	4925.6	17718.1
1984	28718.5	2.17	1.82	0.5975	0.8032	13234.3	15779.4
1985	27549.9	5.41	2.53	1.6025	1.1335	5092.4	10889.3
1986	24885.4	6	2.82	1.6251	1.3493	4147.6	8824.6
1987	21569.2	5.03	3.59	1.1432	1.7393	4288.1	6008.1
1988	22020.8	3.46	1.51	0.7327	0.6214	6364.4	14583.3
1989	26530.4	5.27	2.7	1.1939	1.1002	5034.2	9826.1
1990	27327.0	7.06	2.4	1.4025	0.9125	3870.7	11386.3
1991	20131.4	4.65	1.4	0.8669	0.5376	4329.3	14379.6
1992	20707.1	4.64	2.49	0.9109	1.0733	4462.7	8316.1
1993	22703.3	3.72	1.96	0.7416	0.9333	6103.0	11583.3
1994	22257.7	3.17	3.19	0.6255	1.4566	7021.4	6977.3
1995	16618.0	6.03	1.9	1.2973	0.8304	2755.9	8746.3
1996	17055.2	3.24	4.95	0.7294	2.2623	5264.0	3445.5
1997	16216.6	2.73	0.87	0.6563	0.3002	5940.1	18639.8
1998	15822.4	7.77	1.96	2.0566	0.7615	2036.3	8072.6
1999	18155.6	4.87	2.53	1.0615	0.9829	3728.1	7176.1
2000	12752.0	5.74	4.35	1.1648	1.7813	2221.6	2931.5
2001	12940.6	4.51	4.8	0.9261	1.6371	2869.3	2696.0
2002	8403.7	3.85	1.93	0.7514	0.6651	2182.8	4354.3
2003	8890.3	4.12	1.58	0.7704	0.5074	2157.8	5626.8
2004	9332.8	2.04	1.48	0.4418	0.4872	4574.9	6306.0
2005	8885.7	1.25	0.98	0.3085	0.3465	7108.5	9067.0
2006	5686.9	2.31	0.47	0.7324	0.2182	2461.8	12099.7
2007	6979.7	3.06	1.37	1.1275	1.0637	2281.0	5094.7
2008	7403.4	2.9	1.92	1.1346	1.6327	2552.9	3855.9
2009	8666.0	3.37	2.14	1.4576	1.7203	2571.5	4049.5

Table A62. Summary of AIM results silver hake, both stocks combined, for NEFSC fall and spring bottom trawl surveys and catch estimates based on Sosebee method.

Silver Hake	***Fall Survey***	***Spring Survey***
Critical value (observed correlation between replacement ratio and relative F	-0.019413	-0.214283
Probability of observing correlation < Critical Value	0.97750	0.9200
Relative F at Replacement (mt/kg)	492.9	5651.1
90% Confidence Interval for RelF at replacement	(4.6, 647745)	(483.8, 14560.5)

Table A63.Summary results of Silver hake ASAP model runs.

Model #	1	2	3	4	5	6	7	8	9
Converge	N	Y	Y	Y	Y	Y	Y	Y	Y
Num Est Params	p*	p	p*-8	p-8	p-10	p-18	p-15	p-23	p*
Model	No Split M = 0.4	No Split M=0.15	No Split M = 0.4_Surv_Flat-top_IndexSel	No Split M = 0.15_Surv_Flat-top_Index Sel	Run 2 (3 block Fishery Selectivity)	Run 4 (3 block Fishery Selectivity)	Run5 (2 block Fishery Selectivity)	Run6 (2 Block Fishery Selectivity)	Run 2 (Apply Time and Age variant M from Run 6 to Run1)
Fishery Slectivity	5 blocks (fleet1: 73-88; 89-99; 00-09) (Fleet2: 73-99; 00-09)	5 blocks (fleet1: 73-88; 89-99; 00-09) (Fleet2: 73-99; 00-09)	5 blocks (fleet1: 73-88; 89-99; 00-09) (Fleet2: 73-99; 00-09)	5 blocks (fleet1: 73-88; 89-99; 00-09) (Fleet2: 73-99; 00-09)	3 blocks (fleet1: 73-88; 89-09) (Fleet2: 73-09)	3 blocks (fleet1: 73-88; 89-09) (Fleet2: 73-09)	2 blocks (fleet1: 73-09) (Fleet2: 73-09)	2 blocks (fleet1: 73-09) (Fleet2: 73-09)	5 blocks (fleet1: 73-88; 89-99; 00-09) (Fleet2: 73-99; 00-09)
Overall Objective Fxn	3899	4524	4083	4601	4491	4526	4532	4511	3970
Total Index	1053	1022	1248	1180	1028	1173	1032	1194	1068
Index Age Comp	846	839	786	741	832	735	822	752	815
Total Catch	506	918	627	1025	918	1015	921	1032	511
Catch Age Comp	617	783	606	768	777	762	834	742	630
q_fall	0.13	0.23	0.48	0.62	0.25	0.62	0.17	0.61	0.49
q_spr	0.13	0.23	0.42	0.48	0.24	0.48	0.18	0.47	0.41
Fleet 1 Sel	Strong Dome in the Recent Years	Strong Dome in the Recent Years	Flat Top (1973-1999), Strong Dome (2000-2009)	Flat Top (1973-1999), Moderate Dome (2000-2009)	Strong Dome in the Recent Years	Flat Top Selectivity	Srong Dome	Flat Top Selectivity	Strong Dome
Fleet2 Sel	Dome	Dome	Dome	Dome	Dome	Dome	Dome	Dome	Dome
Fleet3 Sel	NA	Exponential	NA	Exponential	Exponential	Exponential	Exponential	Exponential	NA
Fall_Surv_Sel	Strong Dome	Strong Dome	Fixed- Flat top (Estimated Age1)	Fixed- Flat top (Estimated Age1)	Strong Dome	Fixed- Flat top (Estimated Age1)	Strong Dome	Fixed- Flat top (Estimated Age1)	Strong Dome
Spr_Surv_Sel	Strong Dome	Strong Dome	Fixed- Flat top, (Estimated Age 1)	Fixed- Flat top, (Estimated Age 1)	Strong Dome	Fixed- Flat top, (Estimated Age 1)	Strong Dome	Fixed- Flat top, (Estimated Age 1)	Strong Dome
Retro_SSB (Rel. Diff)	6-13%	9-44%	49-320%	51-160%	15-72%	44-82%	11-39%	48-70%	7-13%
Retro_Rec (rel Diff)	7-90%	5-14%	19-230%	2-6%	5-16%	1-5%	7-18%	<1 - 4 %	7-90%
Retro_F (Rel Diff)	8-17%	23-53%	40-82%	36-64%	32-62%	26-41%	29-57%	35-46%	8-18%
Comments	4 year Peel. Model did not converge initially but now it is??? Unsure about the inconsistent estimation process	4 year Peel. Strong Dome . Very High SSB (Cryptic Biomass???)	4 Year Peel. Relative to model 4, better overall model fit. Better fit to the to the catch but poorer fit to the index with stronger retro. Patterns	4 Year Peel. Relative to model 2, less improvement in overall fit, but better fit to the index and catch at age comp. Less improvement to the total catch fit, better retro for Rec, Similar retro for F, and stronger retro for SSB. Less doming in the fishery and SSB estimates appears reasonable in the model	Retro2 (4yr peel). Relative to Model 2, Stronger retro for SSB and F rellative to model. Improved overall model fit, less improvement to total index fit but better fit to index age comp. Similar fit to total catch. Better fit to catch at age comp. Q's are similar and strong dome persists	Relative to Model 4, Improved fit in the overall model as well as in the index and catch. Improved Retro Patterns. No Dome in the Fishery	4 year Peel. Relative to Model 2 and 5, less improvement in overall model fit, total catch and total index , but some improvement in the index catch at age. Stromg dome, lower q's . Better retro patterns for SSB. Slightly stronger for Rec, but better retro for F relative to Model 5.	4 year Peel. Relative to model 4 and 6, Less improvement in model likelihood with the exception of slight improvement in the firt to the catch at age. Flat top selectivity. Q's are similar to model 4 and 6. Retro Pttaerns improve in Rec and SSB and slighlty improved reative to model 4.	Relative to 1, No improvement in Retro. Less Improvement in likelihood components except for index age comp.

Table A64 Silver hake estimated Fishing Mortality at Age for the Combined Areas

Year	age-1	age-2	age-3	age-4	age-5	age-6
1973	0.069	0.621	1.168	1.168	1.168	1.168
1974	0.063	0.564	1.062	1.062	1.062	1.062
1975	0.062	0.551	1.037	1.037	1.037	1.037
1976	0.044	0.393	0.739	0.739	0.739	0.739
1977	0.050	0.444	0.835	0.835	0.835	0.835
1978	0.055	0.488	0.918	0.918	0.918	0.918
1979	0.031	0.275	0.518	0.518	0.518	0.518
1980	0.030	0.266	0.500	0.500	0.500	0.500
1981	0.076	0.526	0.839	0.818	0.735	0.685
1982	0.100	0.689	1.097	1.069	0.958	0.892
1983	0.082	0.570	0.918	0.896	0.811	0.760
1984	0.080	0.569	0.927	0.908	0.829	0.782
1985	0.089	0.646	1.071	1.051	0.972	0.925
1986	0.075	0.535	0.874	0.855	0.782	0.738
1987	0.058	0.394	0.622	0.605	0.539	0.500
1988	0.063	0.429	0.677	0.659	0.587	0.544
1989	0.070	0.429	1.069	1.039	0.920	0.849
1990	0.067	0.429	1.149	1.122	1.013	0.949
1991	0.058	0.408	1.261	1.241	1.161	1.114
1992	0.057	0.395	1.202	1.182	1.102	1.055
1993	0.065	0.451	1.374	1.352	1.261	1.207
1994	0.066	0.444	1.294	1.270	1.172	1.114
1995	0.034	0.286	1.064	1.056	1.025	1.006
1996	0.040	0.360	1.438	1.431	1.406	1.392
1997	0.047	0.440	1.817	1.812	1.789	1.776
1998	0.043	0.400	1.619	1.613	1.588	1.574
1999	0.071	0.531	1.773	1.752	1.666	1.615
2000	0.034	0.330	1.394	1.390	1.378	1.370
2001	0.042	0.409	1.743	1.740	1.726	1.718
2002	0.035	0.311	1.228	1.222	1.199	1.185
2003	0.035	0.318	1.283	1.278	1.258	1.246
2004	0.039	0.323	1.195	1.186	1.150	1.129
2005	0.067	0.526	1.863	1.846	1.775	1.734
2006	0.045	0.450	1.952	1.949	1.939	1.933
2007	0.060	0.562	2.302	2.294	2.263	2.244
2008	0.041	0.364	1.434	1.427	1.398	1.381
2009	0.023	0.200	0.777	0.773	0.756	0.746

Table A65: Silver hake estimates SSB in mt and Rec in 000's of fish for the Combined Areas. Note that age-1 recruits are based o year class

Year	Rec	SSB
1973	501,582	81,836
1974	724,312	62,112
1975	512,547	66,245
1976	524,166	82,865
1977	298,756	62,461
1978	295,999	33,981
1979	412,695	35,678
1980	402,731	39,748
1981	477,966	31,930
1982	448,965	28,607
1983	469,867	27,387
1984	457,895	34,466
1985	750,780	27,876
1986	952,229	41,447
1987	533,575	48,047
1988	426,136	35,024
1989	964,751	26,931
1990	614,801	24,745
1991	597,209	16,527
1992	920,823	15,306
1993	789,319	15,793
1994	531,306	17,249
1995	719,677	15,949
1996	819,880	12,748
1997	311,817	9,728
1998	775,926	10,233
1999	691,649	10,731
2000	879,755	11,485
2001	661,829	10,873
2002	496,505	8,177
2003	839,234	8,372
2004	782,181	8,349
2005	496,877	6,515
2006	653,558	5,545
2007	1,061,500	6,684
2008	856,253	13,472
2009	742,192	23,117

Table A66 Silver hake natural mortality estimates based on predatory consumption (M2) and other sources (M1 = 0.15)

Year	age-1	age-2	age-3	age-4	age-5	age-6
1973	0.394	0.242	0.172	0.154	0.151	0.150
1974	0.417	0.250	0.174	0.155	0.151	0.150
1975	0.209	0.172	0.155	0.151	0.150	0.150
1976	1.575	0.686	0.277	0.176	0.155	0.151
1977	1.233	0.558	0.246	0.169	0.154	0.151
1978	0.594	0.317	0.190	0.158	0.152	0.150
1979	0.860	0.417	0.213	0.163	0.152	0.150
1980	1.549	0.676	0.275	0.175	0.155	0.151
1981	1.424	0.629	0.263	0.173	0.154	0.151
1982	1.119	0.515	0.236	0.167	0.153	0.151
1983	0.862	0.418	0.213	0.163	0.152	0.150
1984	1.488	0.654	0.269	0.174	0.155	0.151
1985	1.296	0.581	0.252	0.171	0.154	0.151
1986	1.053	0.490	0.230	0.166	0.153	0.151
1987	1.281	0.576	0.251	0.170	0.154	0.151
1988	0.826	0.405	0.210	0.162	0.152	0.150
1989	1.239	0.560	0.247	0.170	0.154	0.151
1990	1.563	0.682	0.276	0.175	0.155	0.151
1991	1.099	0.507	0.235	0.167	0.153	0.151
1992	1.344	0.600	0.256	0.171	0.154	0.151
1993	1.369	0.609	0.259	0.172	0.154	0.151
1994	1.086	0.502	0.233	0.167	0.153	0.151
1995	1.086	0.502	0.233	0.167	0.153	0.151
1996	2.169	0.910	0.330	0.186	0.157	0.151
1997	0.571	0.308	0.188	0.158	0.151	0.150
1998	1.082	0.501	0.233	0.167	0.153	0.151
1999	1.307	0.586	0.253	0.171	0.154	0.151
2000	1.636	0.709	0.282	0.177	0.155	0.151
2001	1.722	0.742	0.290	0.178	0.155	0.151
2002	1.484	0.652	0.269	0.174	0.155	0.151
2003	1.763	0.757	0.294	0.179	0.156	0.151
2004	2.141	0.899	0.327	0.186	0.157	0.151
2005	2.444	1.013	0.354	0.191	0.158	0.151
2006	2.328	0.970	0.344	0.189	0.157	0.151
2007	1.879	0.801	0.304	0.181	0.156	0.151
2008	1.579	0.688	0.277	0.176	0.155	0.151
2009	1.174	0.535	0.241	0.168	0.154	0.151

Table A67. Species of consistent silver hake predators. Whether abundances were estimated from recent stock assessments (SA) or swept area (SWA) from surveys are noted, as is the resolution of the diet data (all predators were presented as two year averages). *Pollock was ultimately excluded from the analyses due to an excessive degree of variability in diet composition comprised of silver hake.

Common Name	**Species Name**	**Assessment or Swept Area**	**Diet Resolution**
Spiny dogfish	*Squalusa canthias*	SWA	2yr
Little skate	*Raja ocellata*	SWA	2yr
Winter skate	*Raja erinacea*	SWA	2yr
Thorny skate	*Raja radiata*	SWA	2yr
Silver Hake	*Merluccius bilinearis*	SWA	2yr
Atlantic cod	*Gadus morhua*	SA	2yr
Pollock*	*Pollachius virens*	SA	2yr
Red hake	*Urophycis chuss*	SWA	2yr
White hake	*Urophycis tenuis*	SWA	2yr
Fourspot flounder	*Paralichthys oblongus*	SWA	2yr
Summer Flounder	*Paralichthys dentatus*	SA	2yr
Windowpane	*Scophthalmus aquosus*	SWA	2yr
Bluefish	*Pomatomuss altatrix*	SA	2yr
Goosefish	*Lophius americanus*	SA	2yr

Table A68: Age-0 proportion at length derived from the survey age-length keys to adjust consumption estimates for the ASAP model.

Length	North	South	Combined
<5	0.97	0.97	0.97
5-10	0.86	0.66	0.75
11-15	0.32	0.19	0.29
16-20	0.02	0.02	0.02
21-25	0.00	0.00	0.00
26-30	0.00	0.00	0.00
31-35	0.00	0.00	0.00
36-40	0.00	0.00	0.00
41-45	0.00	0.00	0.00

Table A69. Total Consumption and CV of silver hake for both stocks. Consumption units in 000s MT.

Year	Combined	CV
1973	25.8	NA
1974	31.9	NA
1975	4.0	NA
1976	18.7	NA
1977	8.1	0.35
1978	7.1	0.35
1979	30.3	0.35
1980	53.0	0.35
1981	67.0	0.35
1982	77.9	0.68
1983	95.8	0.63
1984	116.9	0.6
1985	142.1	0.75
1986	167.7	0.81
1987	151.6	0.42
1988	54.2	0.47
1989	51.0	0.58
1990	48.2	0.47
1991	38.3	0.48
1992	60.2	0.37
1993	88.2	0.38
1994	66.4	0.61
1995	62.6	0.37
1996	31.5	0.58
1997	12.8	0.5
1998	68.3	0.45
1999	131.3	0.69
2000	129.8	0.39
2001	107.1	0.63
2002	93.3	0.35
2003	101.6	0.35
2004	98.0	0.66
2005	65.0	0.46
2006	52.6	0.43
2007	83.8	0.43
2008	88.0	0.45
2009	71.0	0.45

Table A70 Proportion of all silver hake lengths in all predators of silver hake at size, in 5 cm size classes.

Year	<5	5-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45
1973	0.053	0.263	0.316	0.211	0.053	0	0.105	0	0
1974	0	0.067	0.467	0.2	0.067	0.2	0	0	0
1975	0.667	0.333	0	0	0	0	0	0	0
1976	0.231	0.308	0.231	0.154	0	0.077	0	0	0
1977	0.759	0.034	0	0.034	0.103	0.034	0.034	0	0
1978	0.776	0.096	0.032	0.032	0.016	0.016	0.032	0	0
1979	0.053	0.105	0.316	0.263	0.105	0.053	0.053	0.053	0
1980	0	0.071	0.143	0.214	0.143	0.214	0	0.143	0.071
1981	0.143	0	0	0.143	0.571	0.143	0	0	0
1982	0.094	0.156	0.156	0.125	0.188	0.094	0.156	0.031	0
1983	0	0.054	0.405	0.189	0.216	0.081	0.054	0	0
1984	0.216	0.081	0.054	0.135	0.297	0.162	0.027	0.027	0
1985	0.106	0.187	0.211	0.154	0.203	0.098	0.024	0.008	0.008
1986	0.055	0.097	0.29	0.255	0.166	0.103	0.028	0.007	0
1987	0.06	0.048	0.048	0.145	0.434	0.241	0.024	0	0
1988	0.143	0.446	0.286	0.012	0.042	0.036	0.024	0.006	0
1989	0.08	0.492	0.174	0.148	0.061	0.035	0.01	0	0
1990	0.227	0.241	0.124	0.149	0.188	0.057	0.007	0.007	0
1991	0.157	0.442	0.235	0.078	0.041	0.046	0	0	0
1992	0.129	0.3	0.229	0.194	0.077	0.06	0.011	0	0
1993	0.176	0.127	0.337	0.173	0.15	0.037	0	0	0
1994	0.159	0.37	0.077	0.159	0.183	0.053	0	0	0
1995	0.056	0.222	0.268	0.193	0.18	0.072	0.007	0	0.003
1996	0.09	0.244	0.167	0.141	0.256	0.103	0	0	0
1997	0.183	0.639	0.063	0.042	0.037	0.021	0.005	0	0
1998	0.106	0.229	0.402	0.162	0.067	0.022	0.006	0	0.006
1999	0.047	0.253	0.24	0.197	0.219	0.039	0.004	0	0
2000	0.246	0.192	0.069	0.277	0.177	0.038	0	0	0
2001	0.099	0.441	0.053	0.138	0.211	0.039	0.007	0.013	0
2002	0.108	0.313	0.325	0.06	0.12	0.06	0	0	0
2003	0.095	0.23	0.459	0.135	0.041	0.034	0	0.007	0
2004	0.013	0.227	0.16	0.213	0.28	0.107	0	0	0
2005	0.133	0.167	0.1	0.3	0.267	0.033	0	0	0
2006	0.115	0.462	0.115	0.038	0.192	0.038	0.038	0	0
2007	0.186	0.116	0.209	0.163	0.186	0.093	0.047	0	0
2008	0.075	0.275	0.1	0.125	0.325	0.1	0	0	0
2009	0.036	0.384	0.268	0.08	0.125	0.08	0.027	0	0

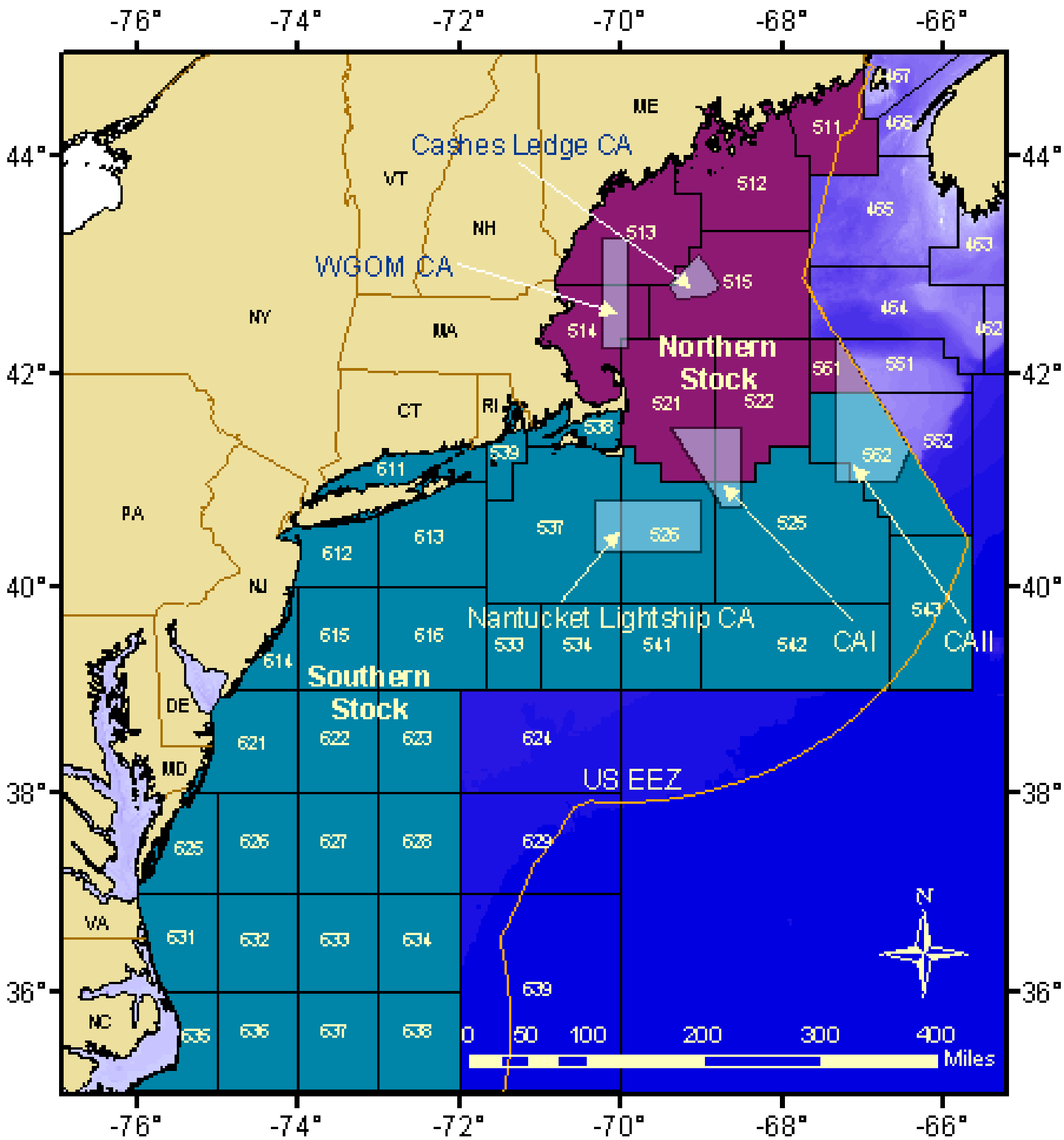

Figure A1. Commercial fishery statistical areas for northern (SA 511-515, 521, 522, 551, and 561) and southern (SA 525, 526, 533-539, 541-543, 552, 562, 611-639) silver hake in the northwest Atlantic.

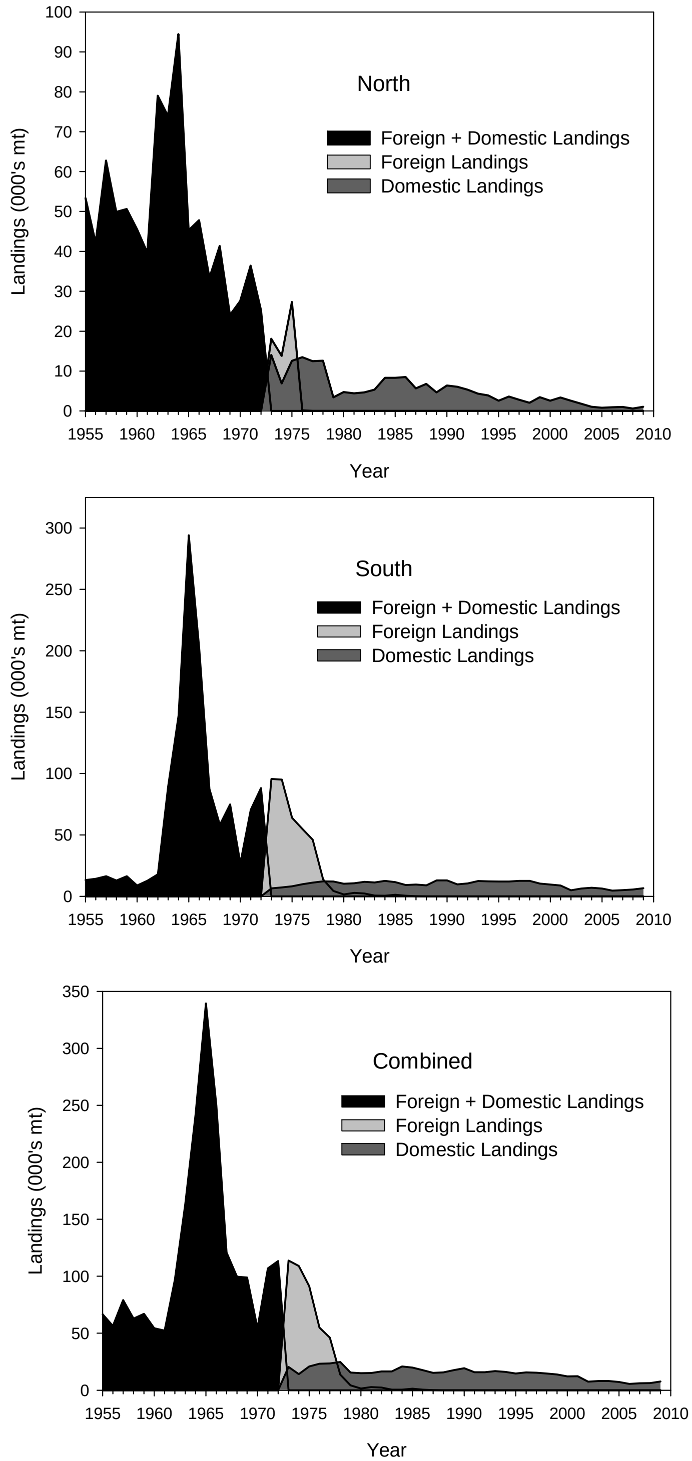

Figure A2: Silver hake catch in thousands of metric tons for the north (Top), south (middle) and combined stock areas (bottom).

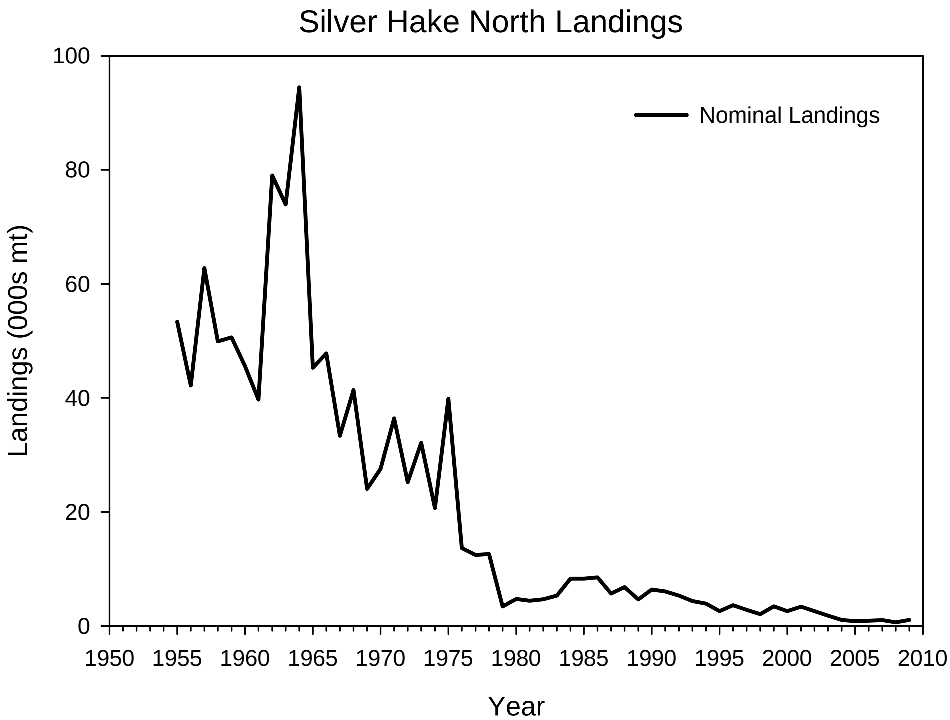

Figure A3. Nominal landings of silver hake (mt) from the northern stock.

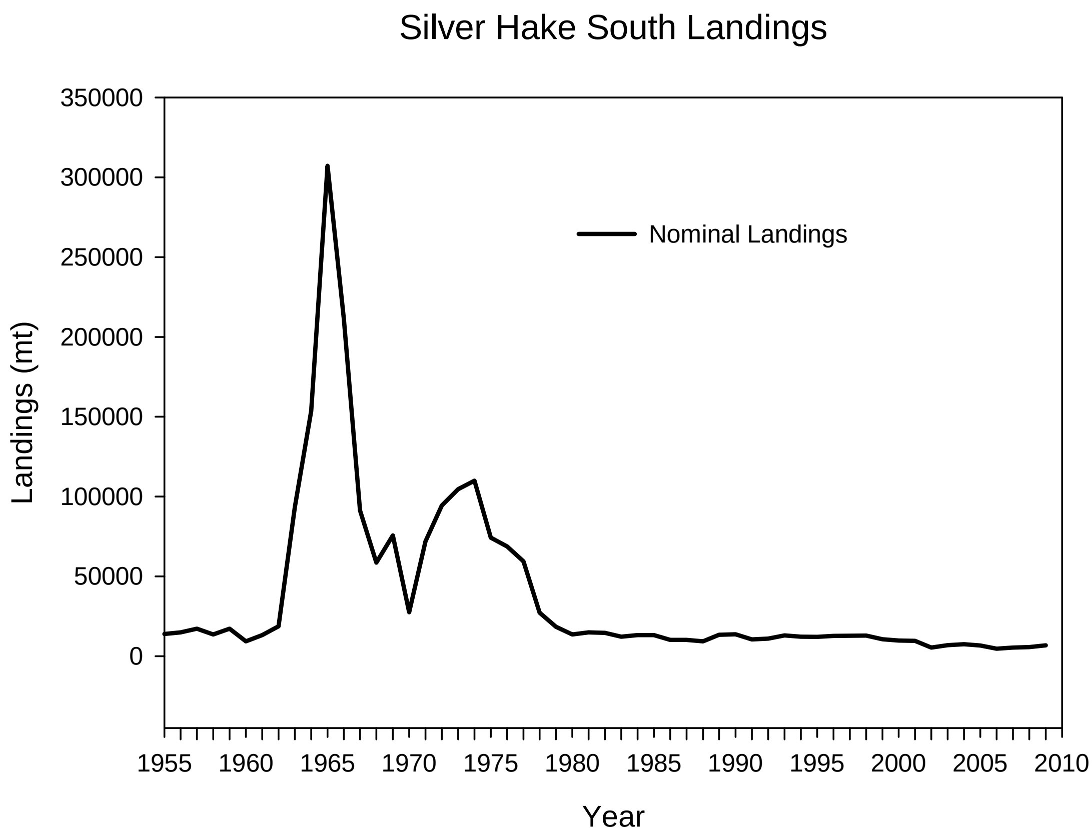

Figure A4. Comparison of nominal landings with the two model-based estimates for silver hake from the southern stock.

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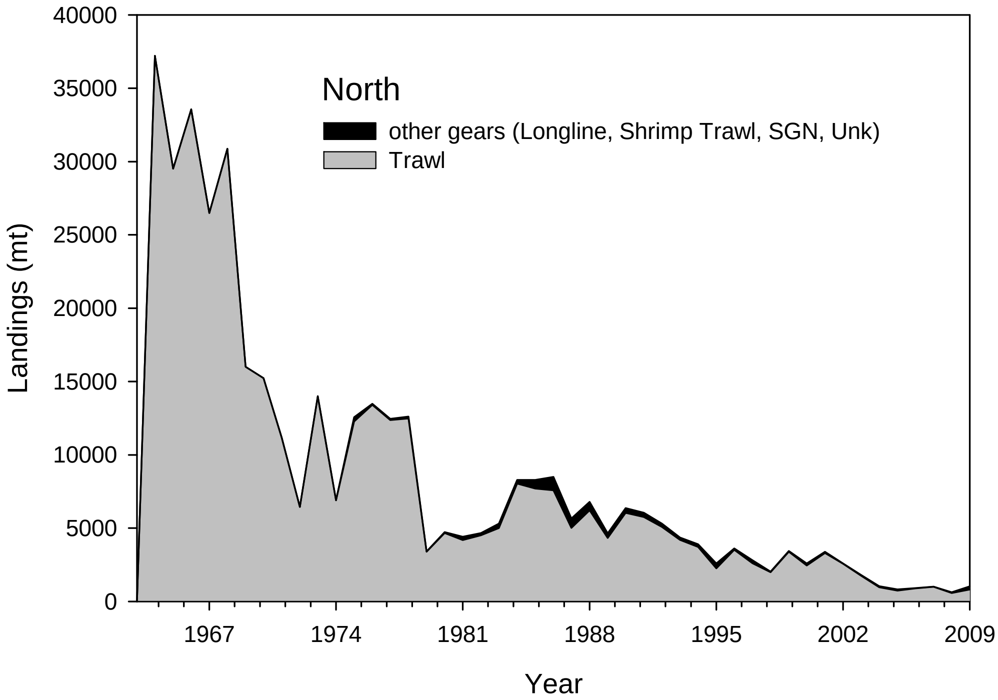


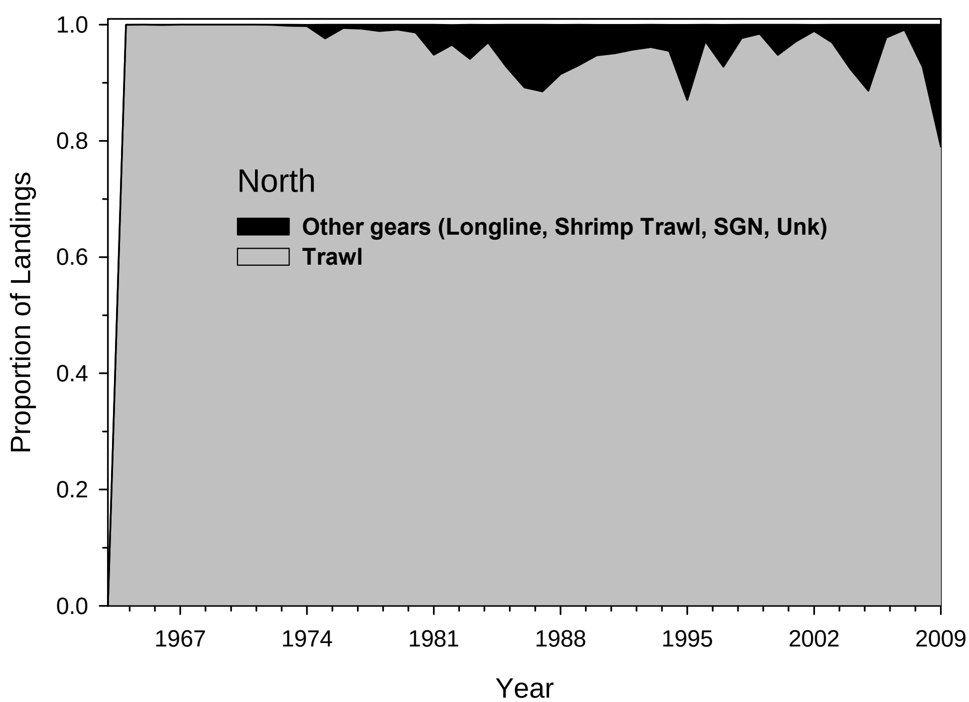
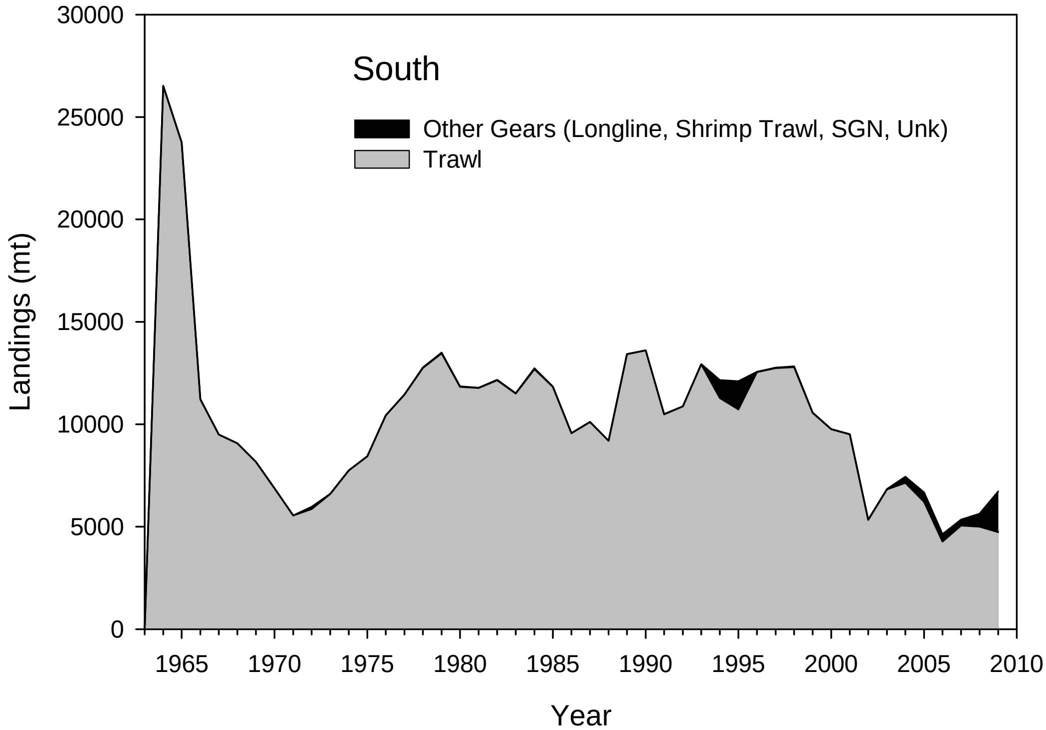


Figure A5. Landings of Silver hake (mt) by gear from the northern stock.



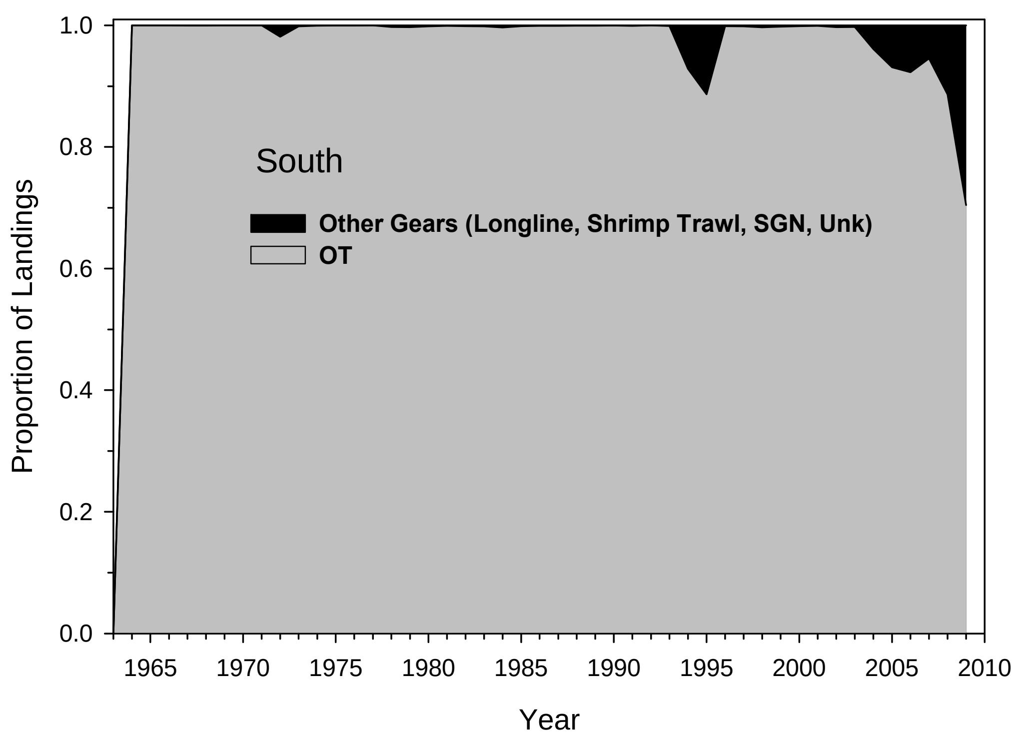


Figure A6. Landings of Silver hake (mt) by gear from the southern stock.

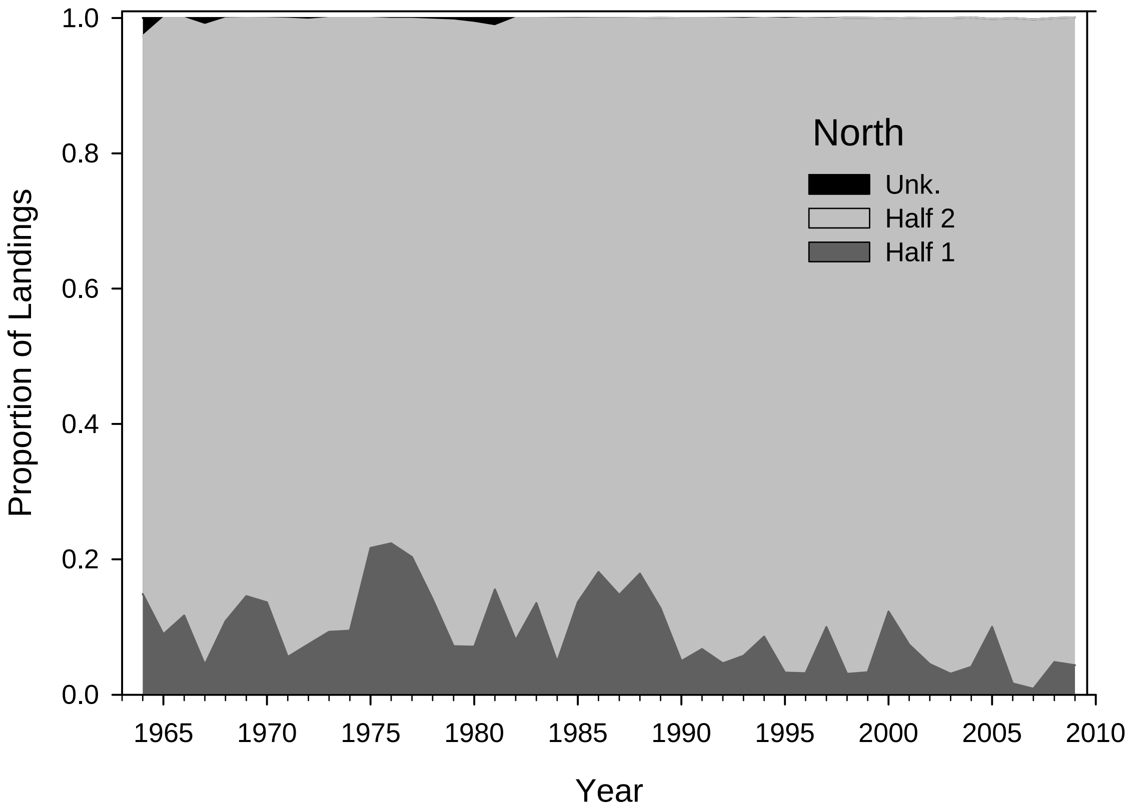


Figure A7. Landings of Silver hake by half year in the northern stock.

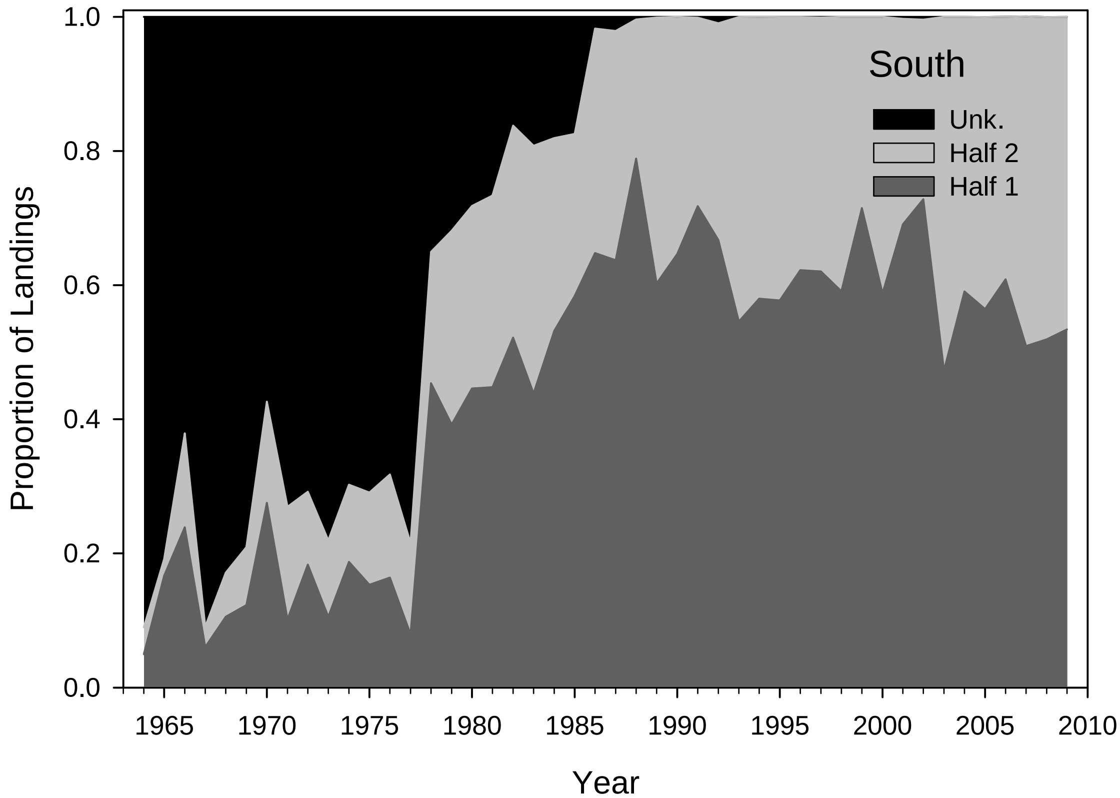
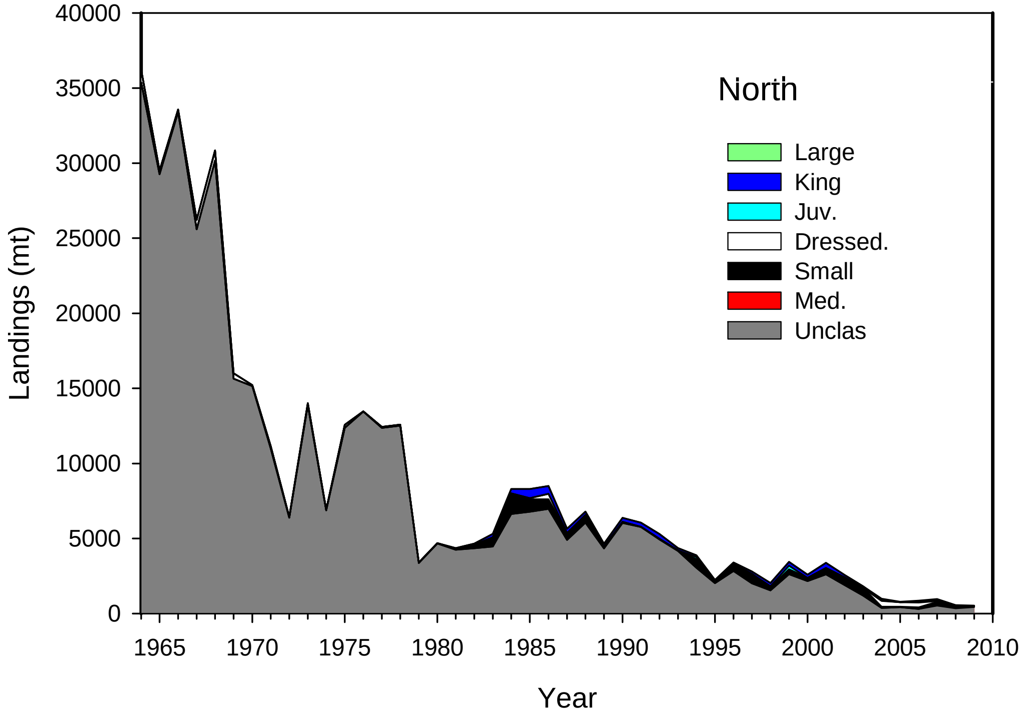


Figure A8. Landings of silver hake by half year in the southern stock.



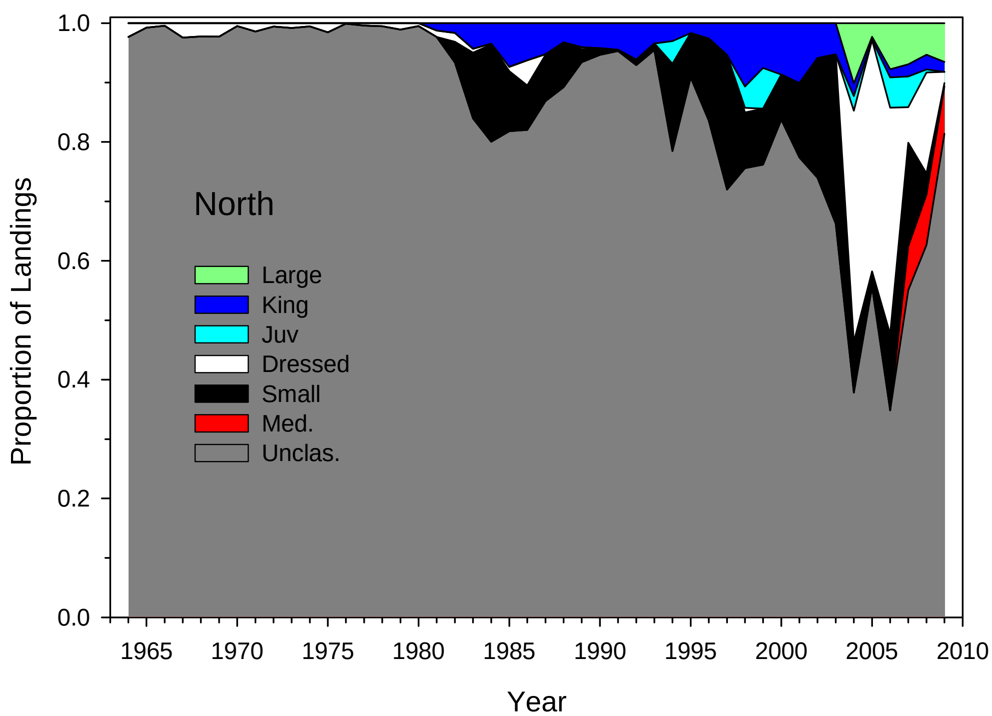
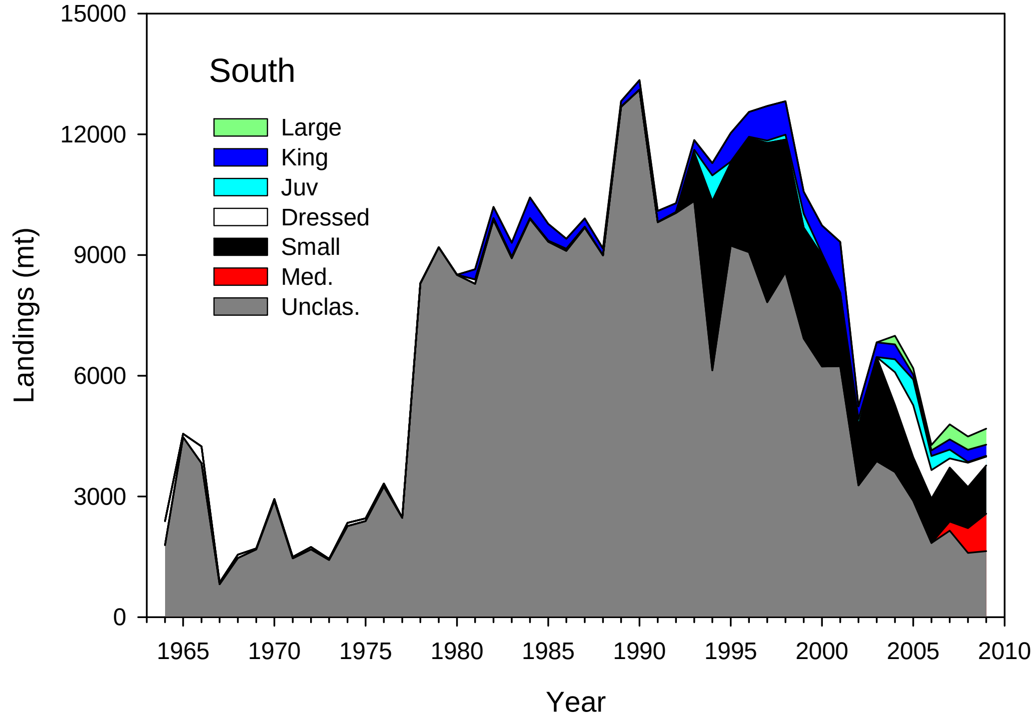


Figure A9. Landings of silver hake (mt) by market category from the northern stock.



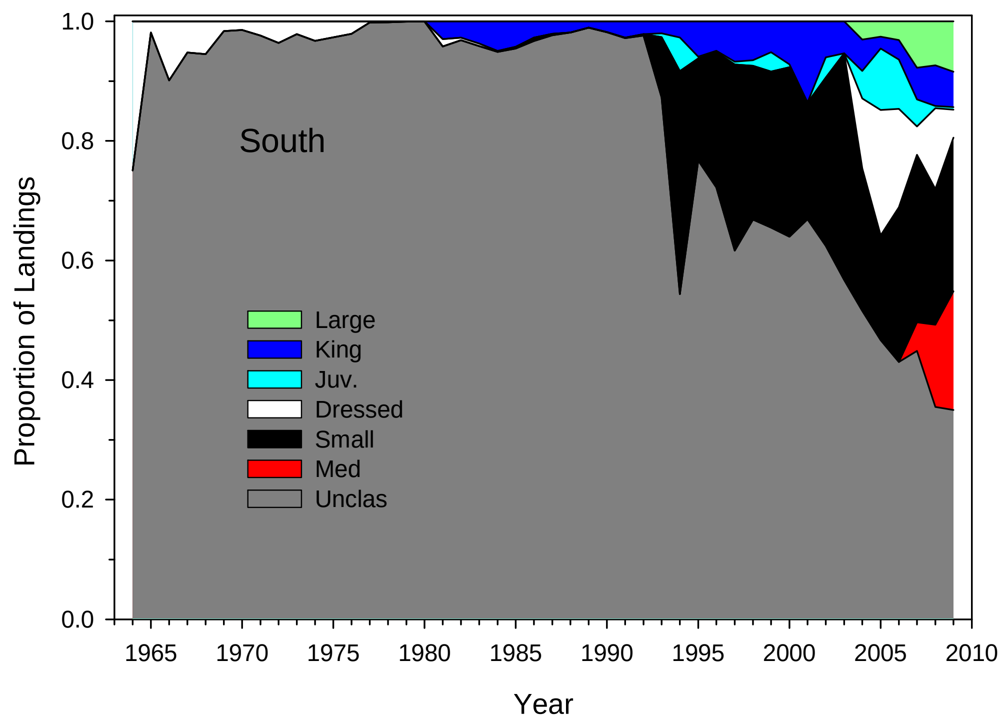


Figure A10. Landings of silver hake (mt) by market category from the southern stock.

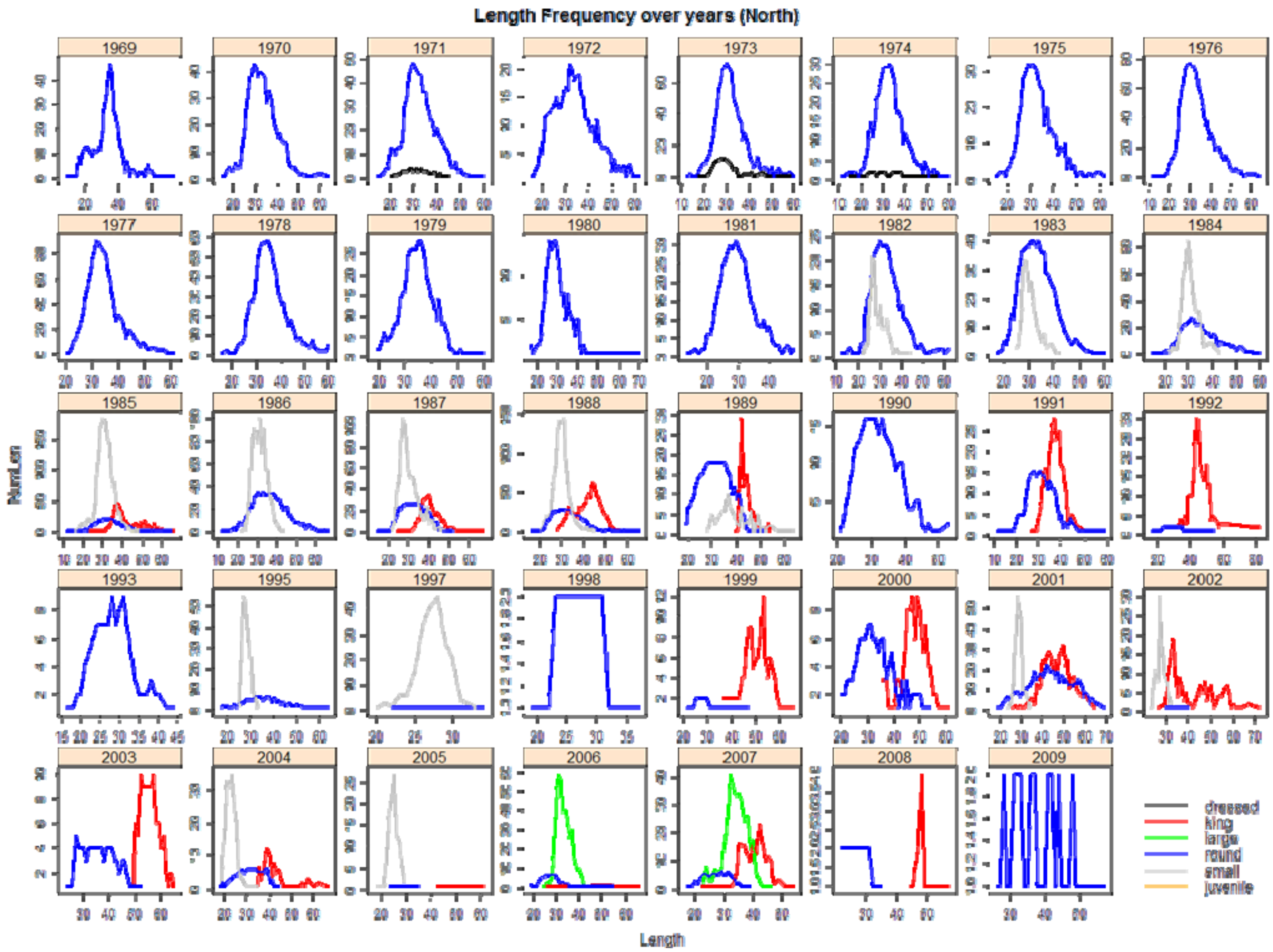


Figure A11: Silver hake length samples by market category in the northern region.

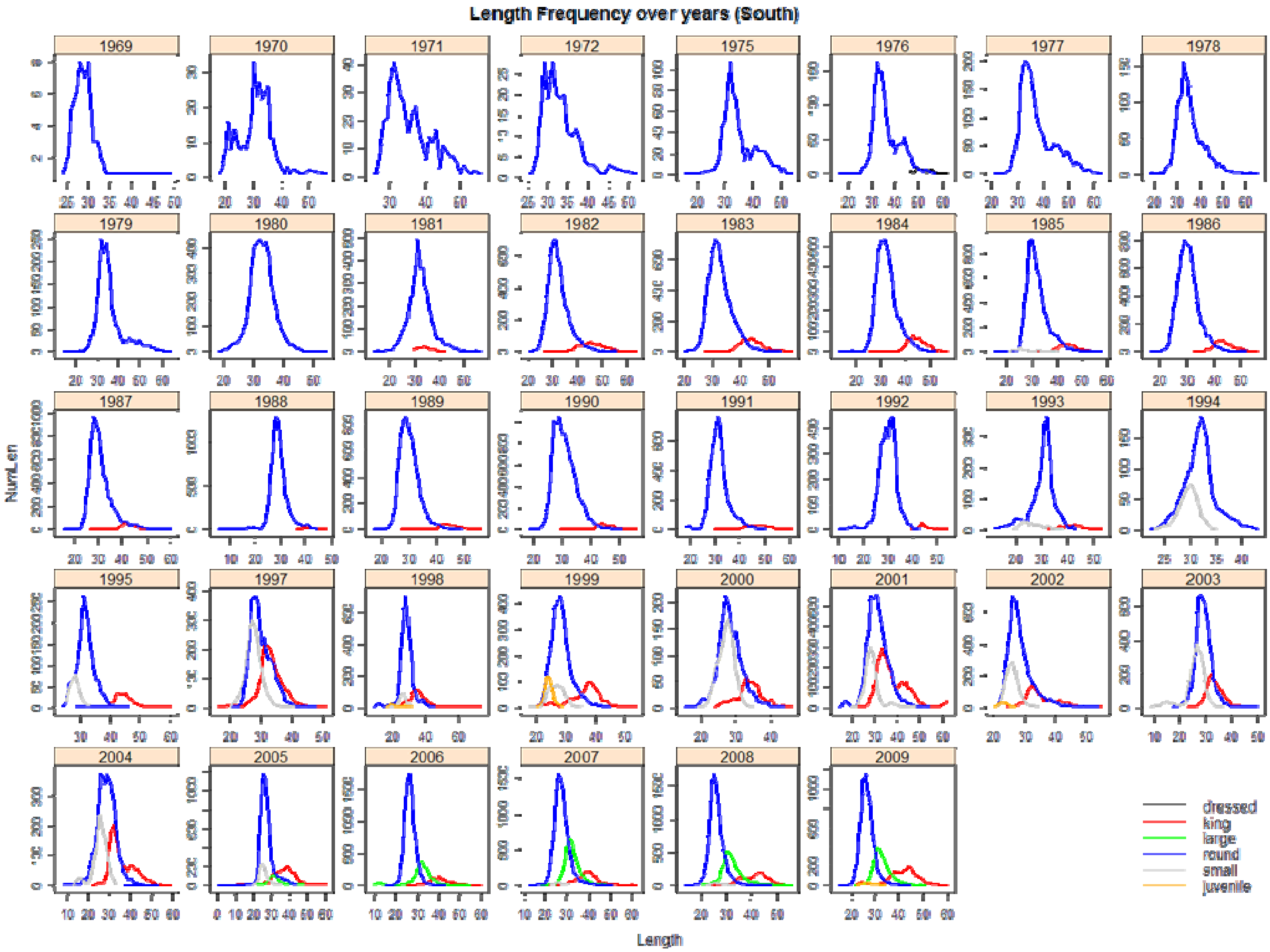


Figure A12: Silver hake length samples by market category in the southern region.

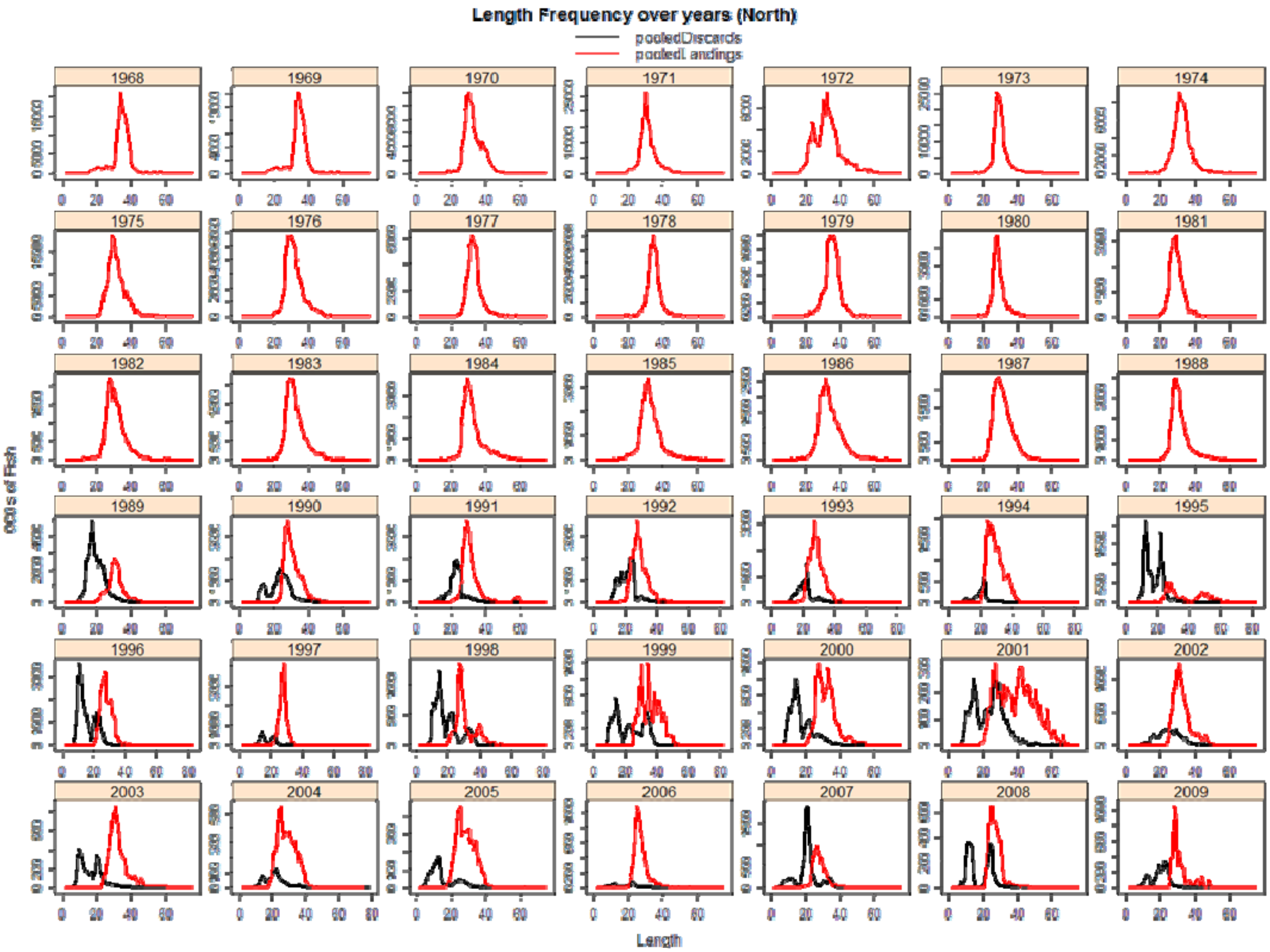


Figure A13. Silver hake length in thousands of fish frequencies from the northern region.

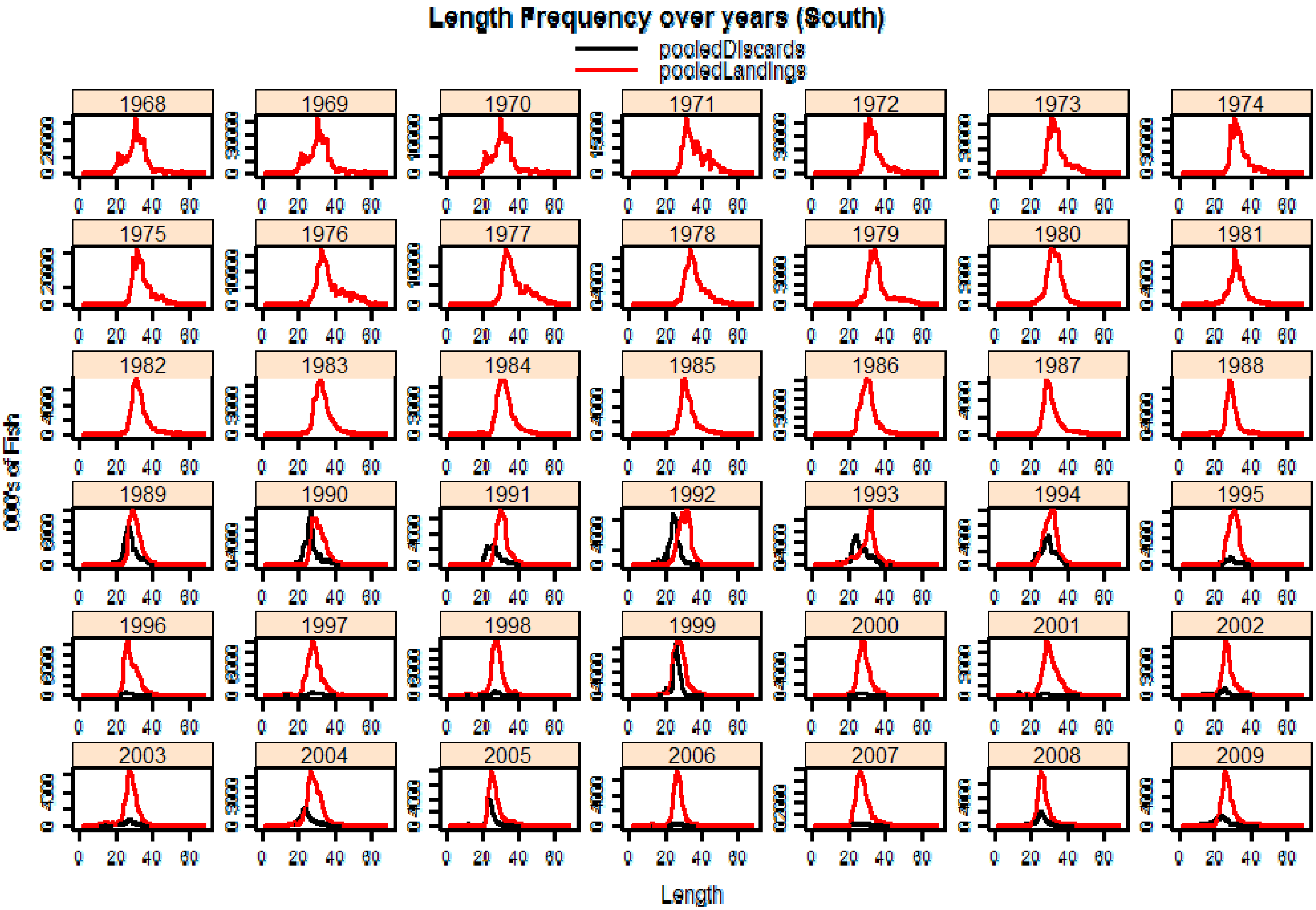
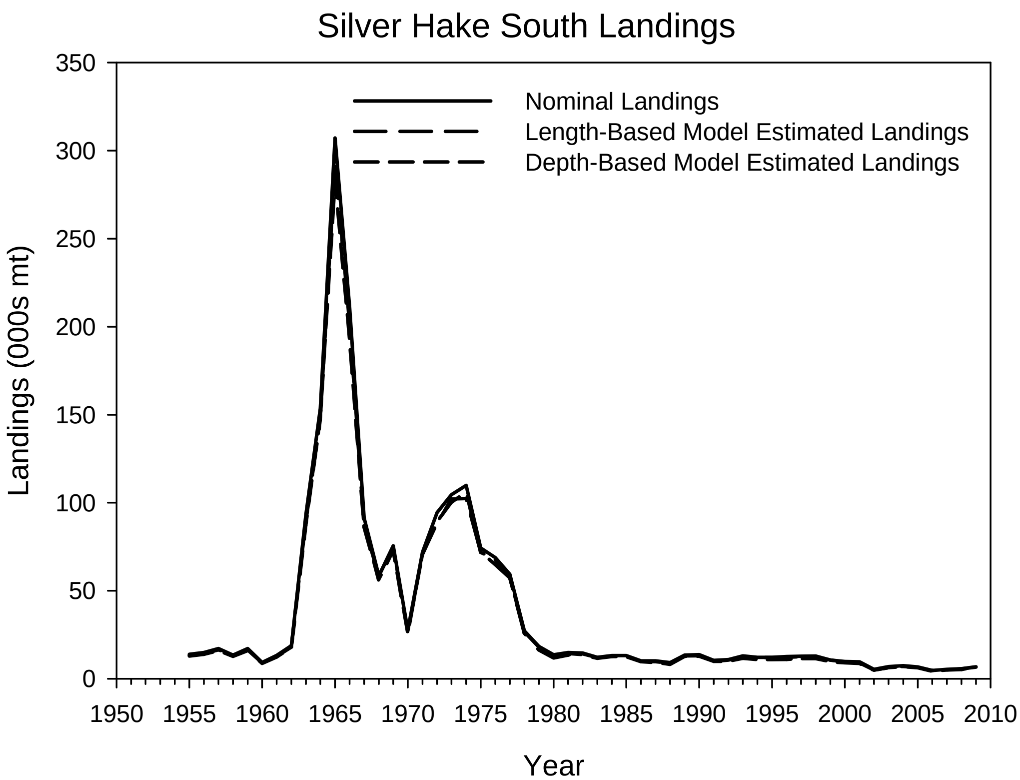


Figure A14. Silver hake length in thousands of fish frequencies from the southern region.



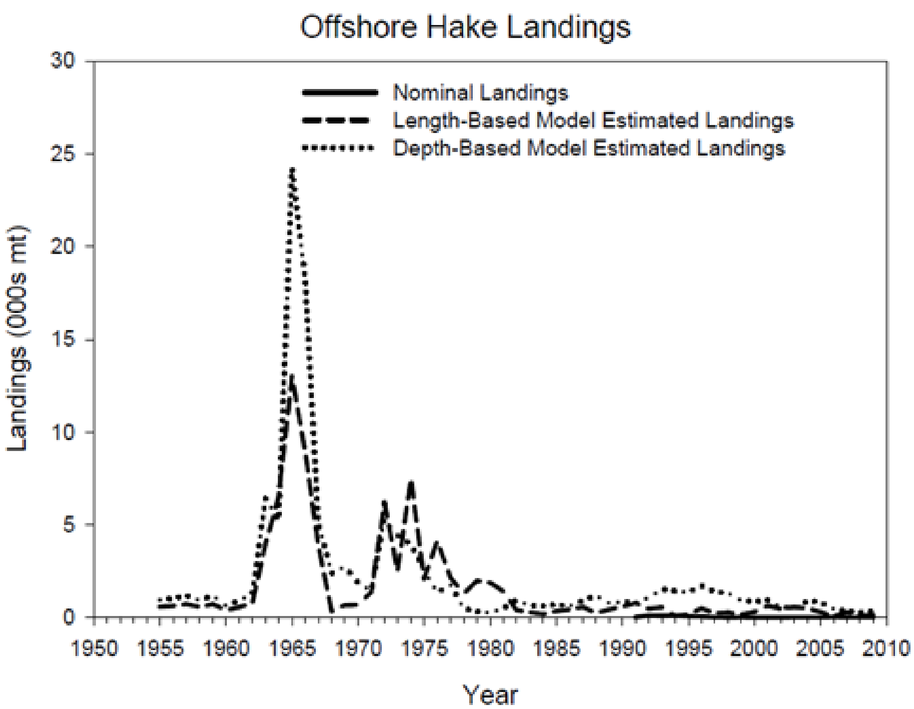


Figure A15. Comparison of nominal landings with the two model-based estimates for silver hake and offshore hake in the southern region.

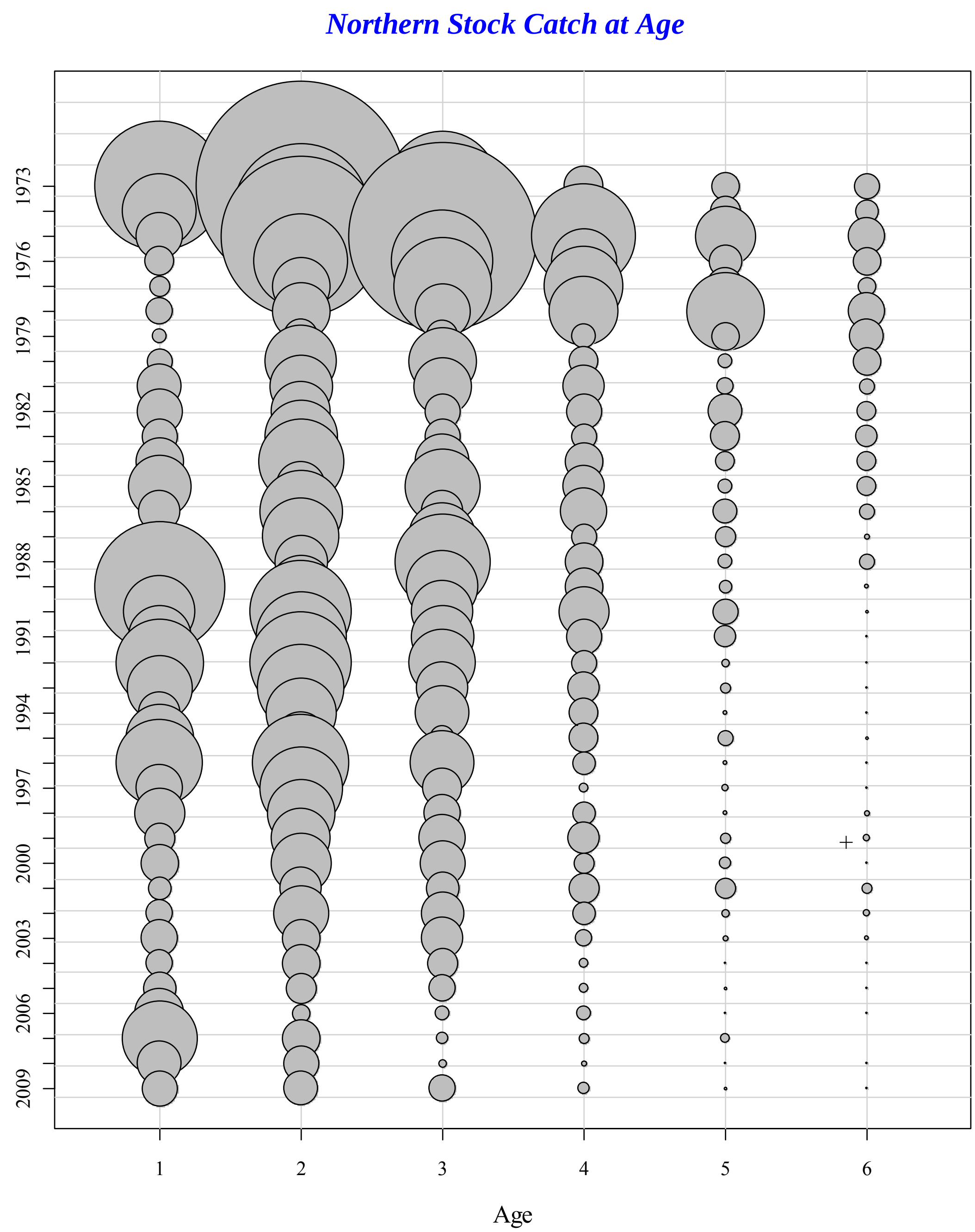


Figure A16. Catch at age of silver hake in the northern stock. (The area of the bubble is proportional to the magnitude of the catch).

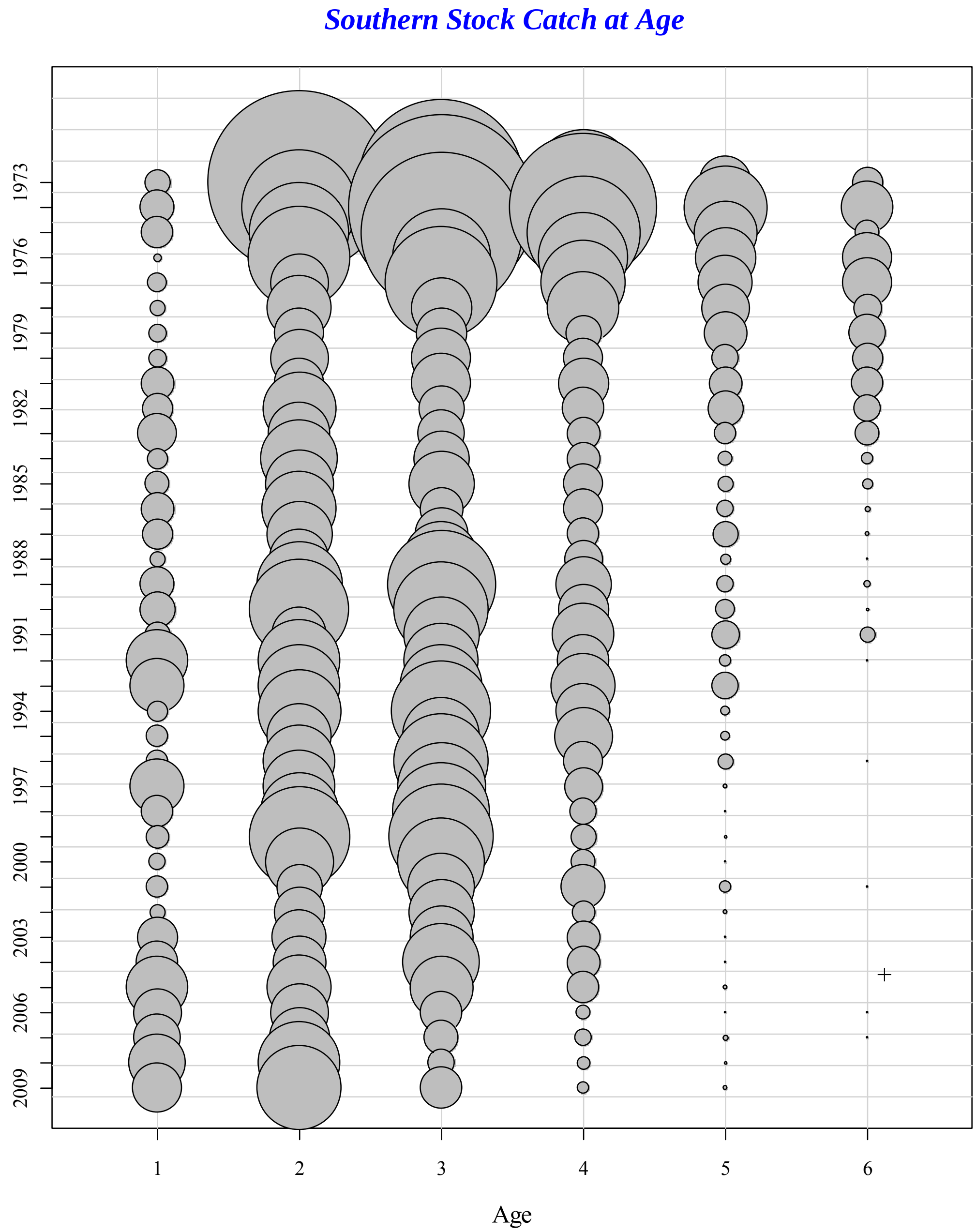


Figure A17. Catch at age of silver hake in the southern stock. (The area of the bubble is proportional to the magnitude of the catch).

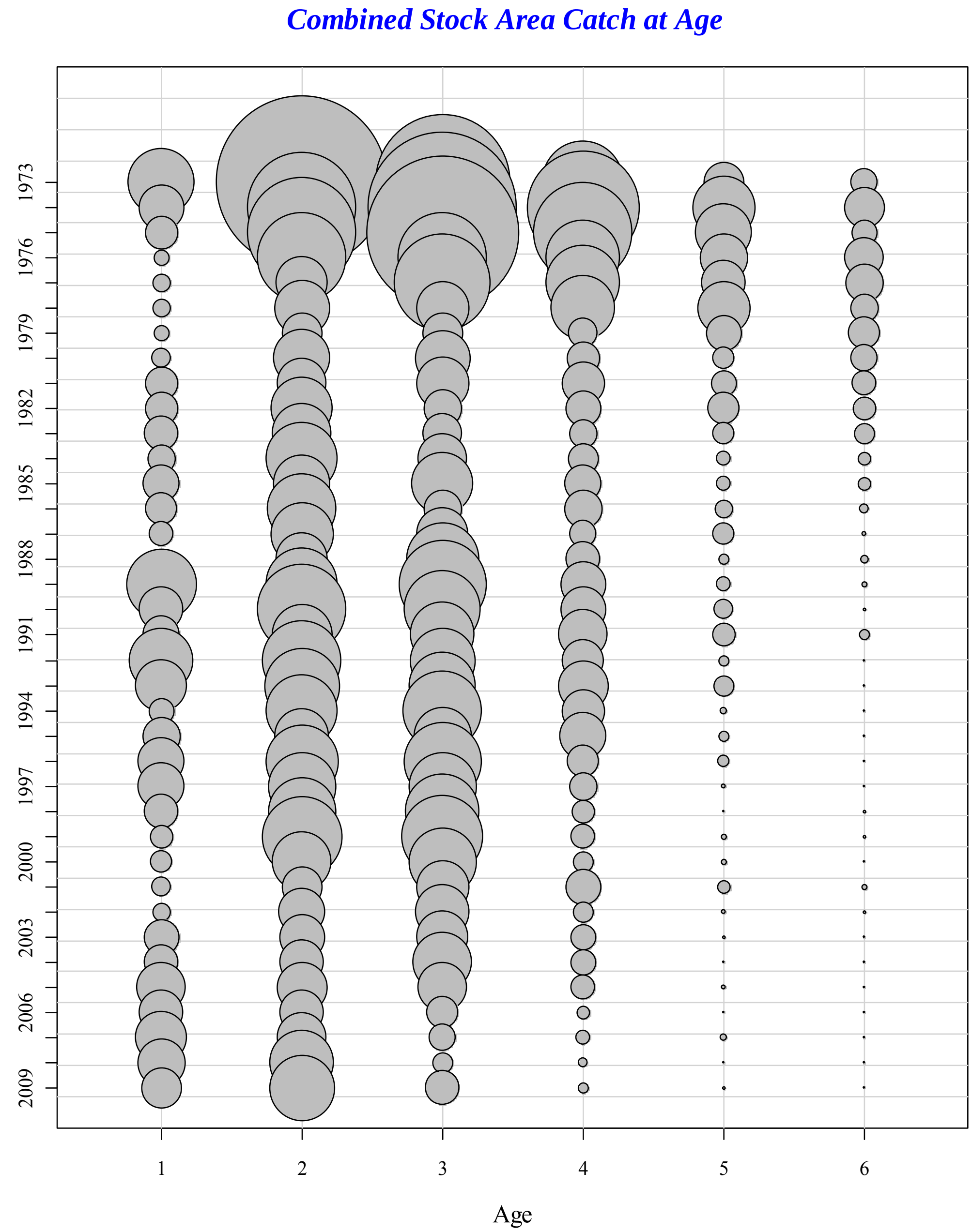


Figure A18. Catch at age of silver hake for the combined stock area. (The area of the bubble is proportional to the magnitude of the catch).

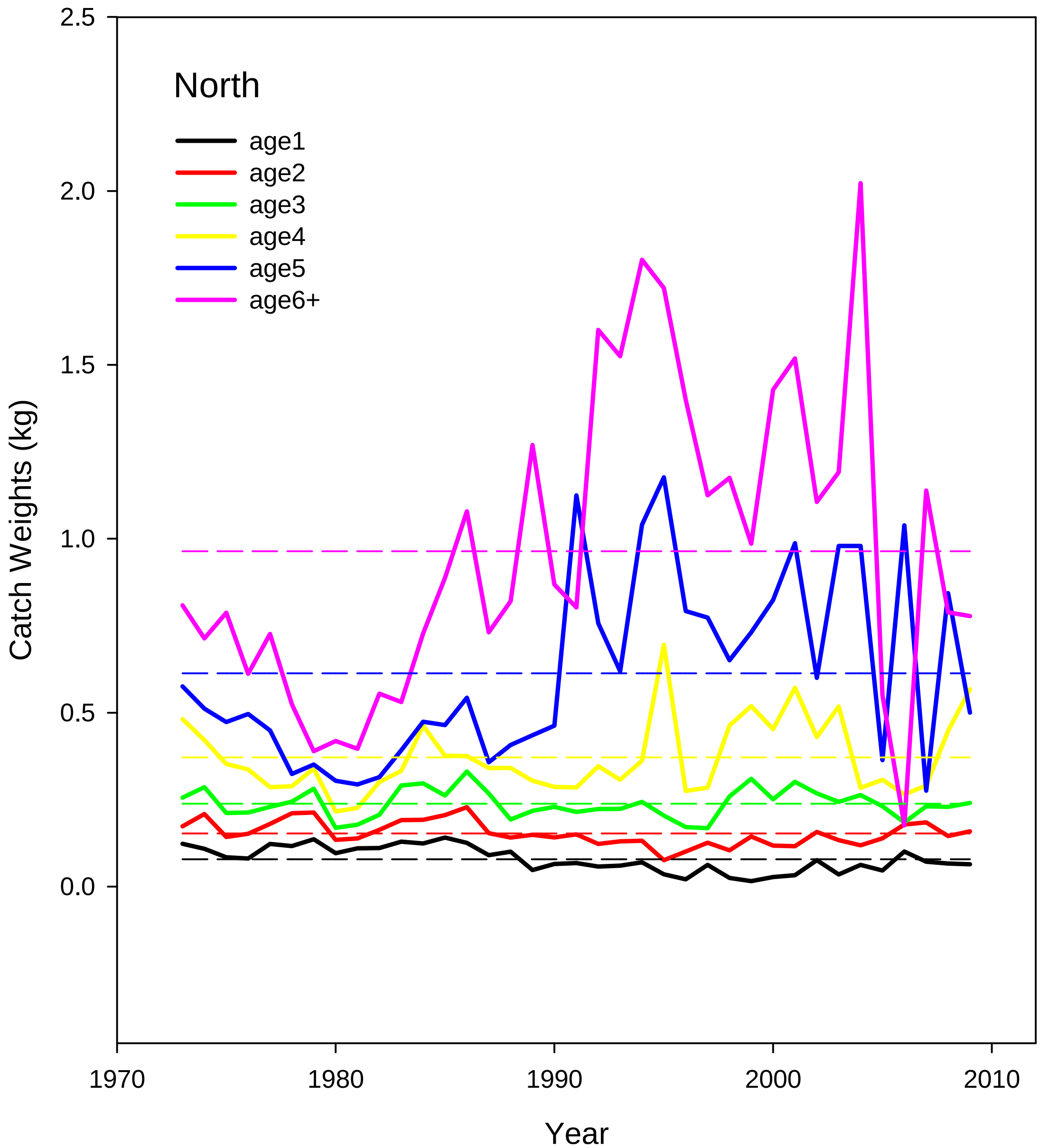


Figure A19. Trends in mean weight at age of silver hake from the northern stock. Dash lines denote the time series average.

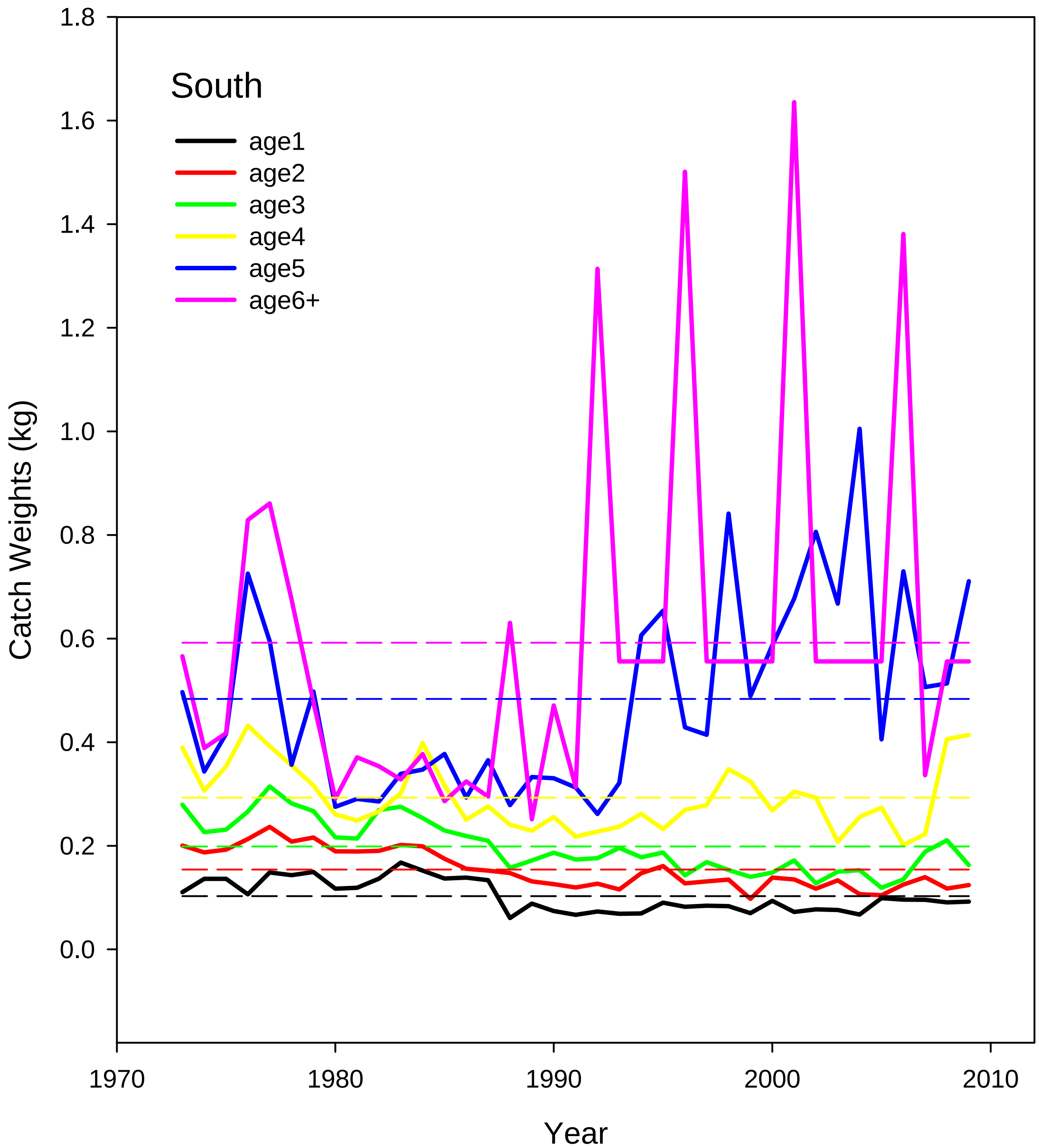


Figure A20. Trends in mean weight at age of silver hake from the southern stock. Dash lines denote the time series average.

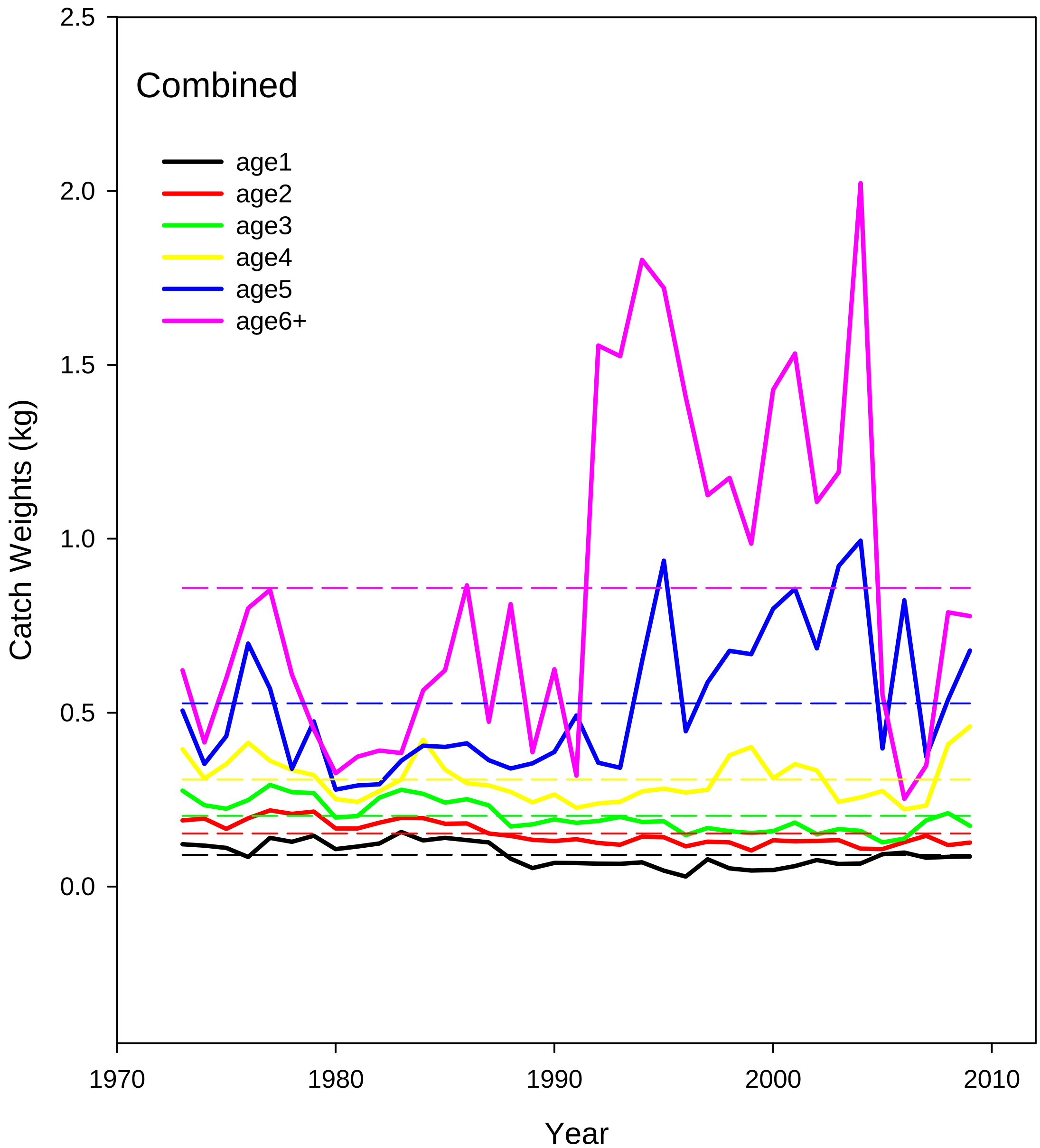


Figure A21. Trends in mean weight at age of silver hake for the combined stock areas. Dash lines denote the time series average.

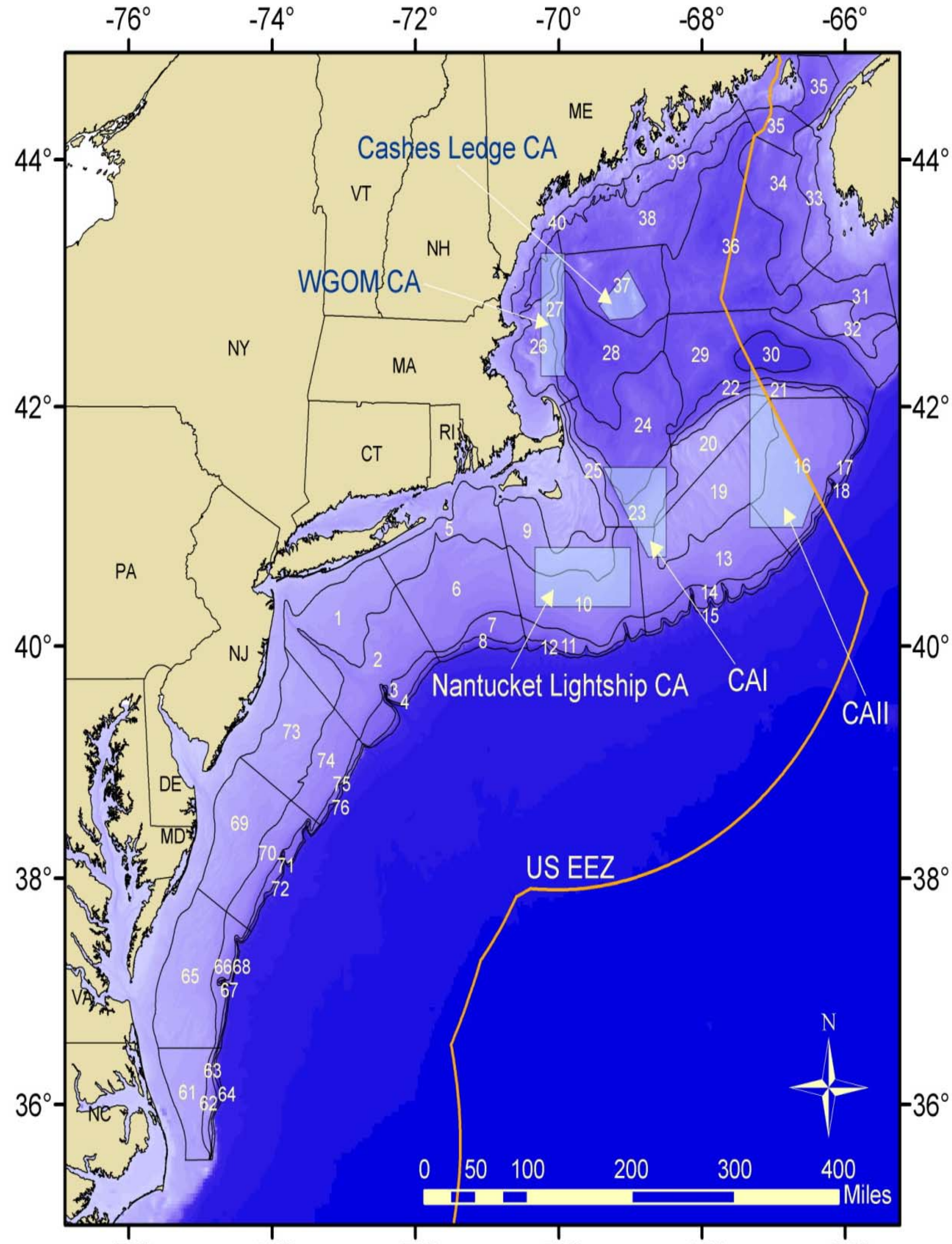


Figure A22. NEFSC bottom trawl survey strata for the northern (offshore strata 20-30 and 36-40) and southern (offshore strata 1-19 and 61-76) silver hake in the northwest Atlantic.

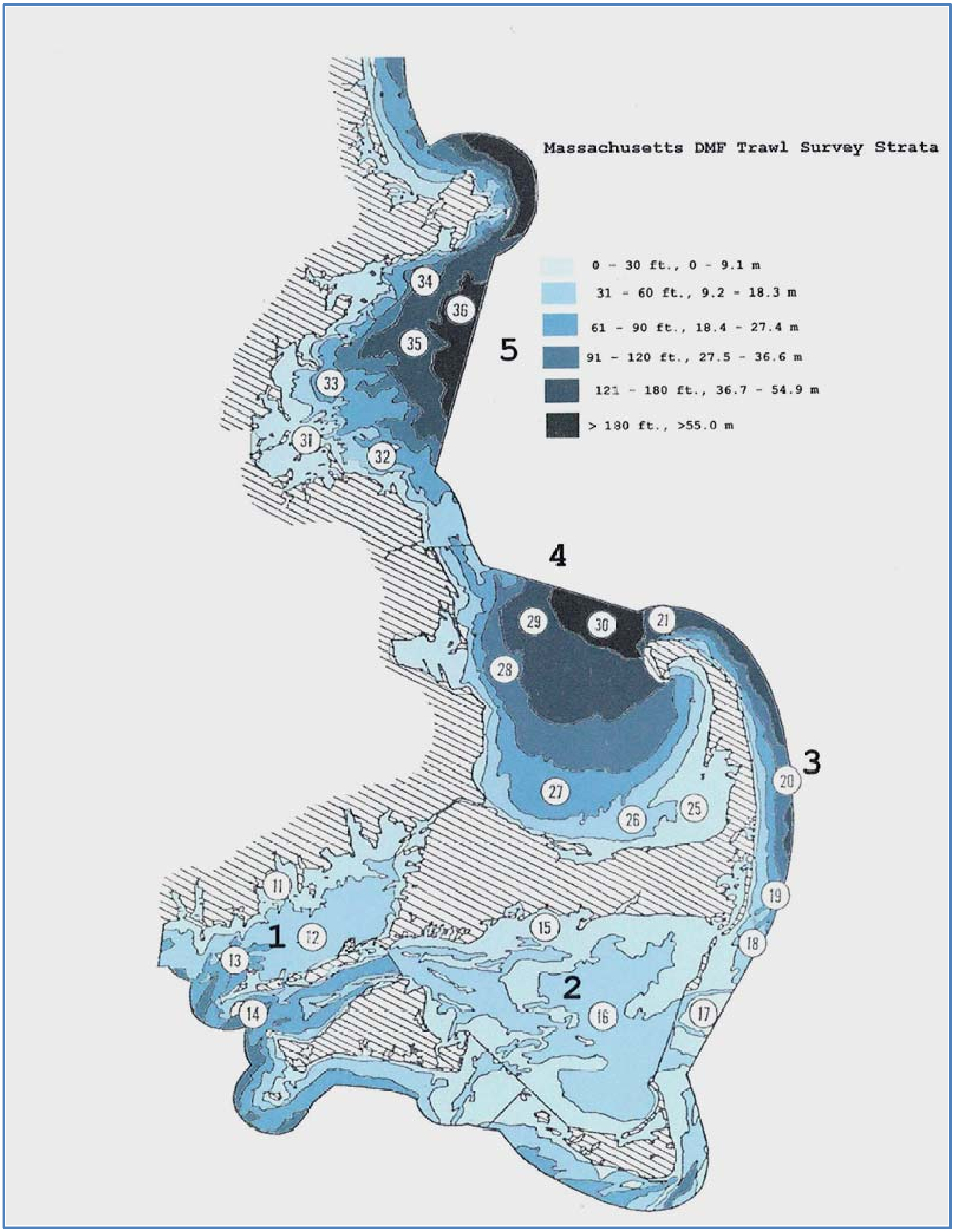
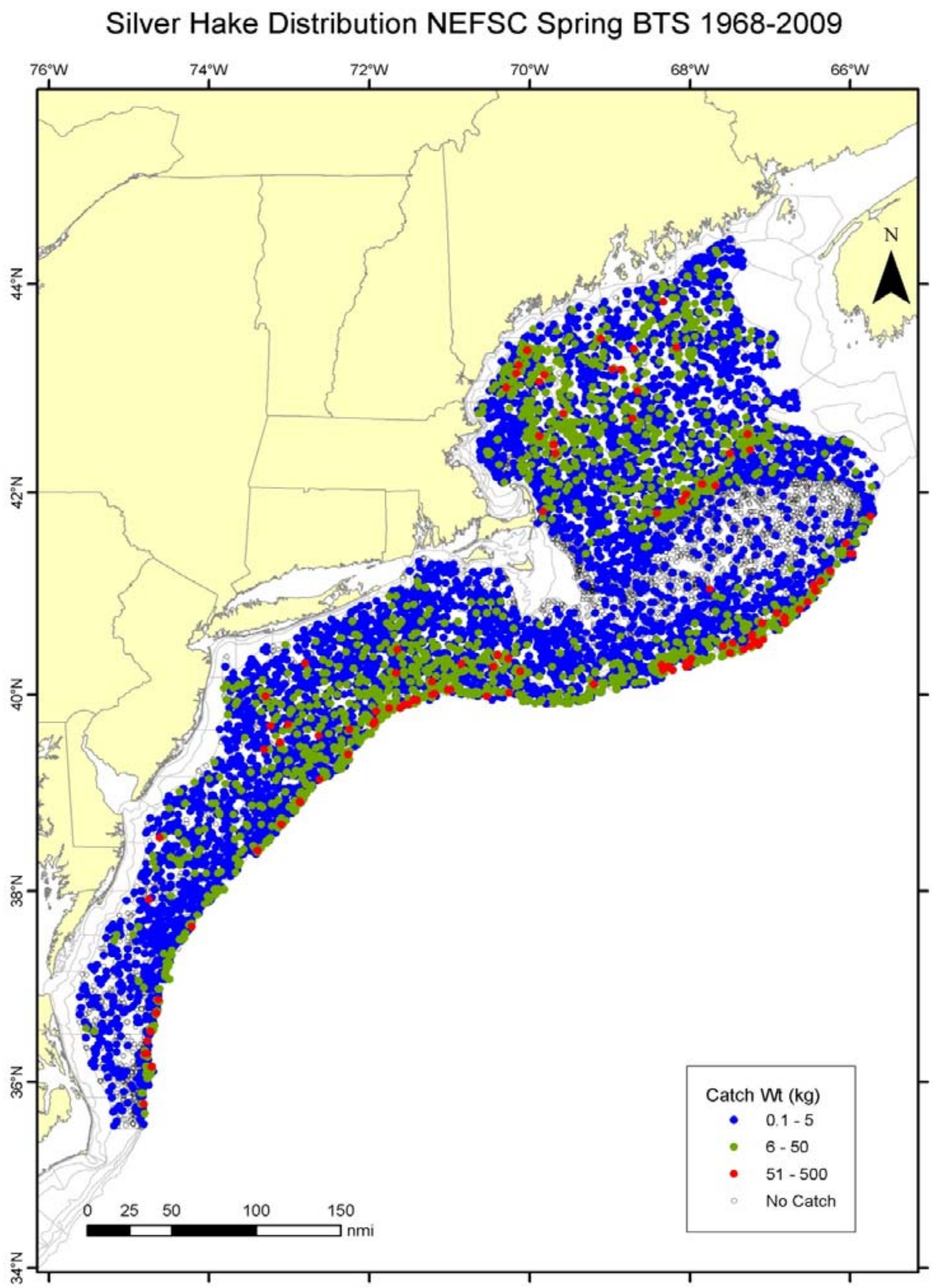


Figure A23. Massachusetts Division of Marine Fisheries (MADMF) survey strata.



A24. Spring survey distribution of silver hake from the NEFSC bottom trawl surveys, 1968-2009.

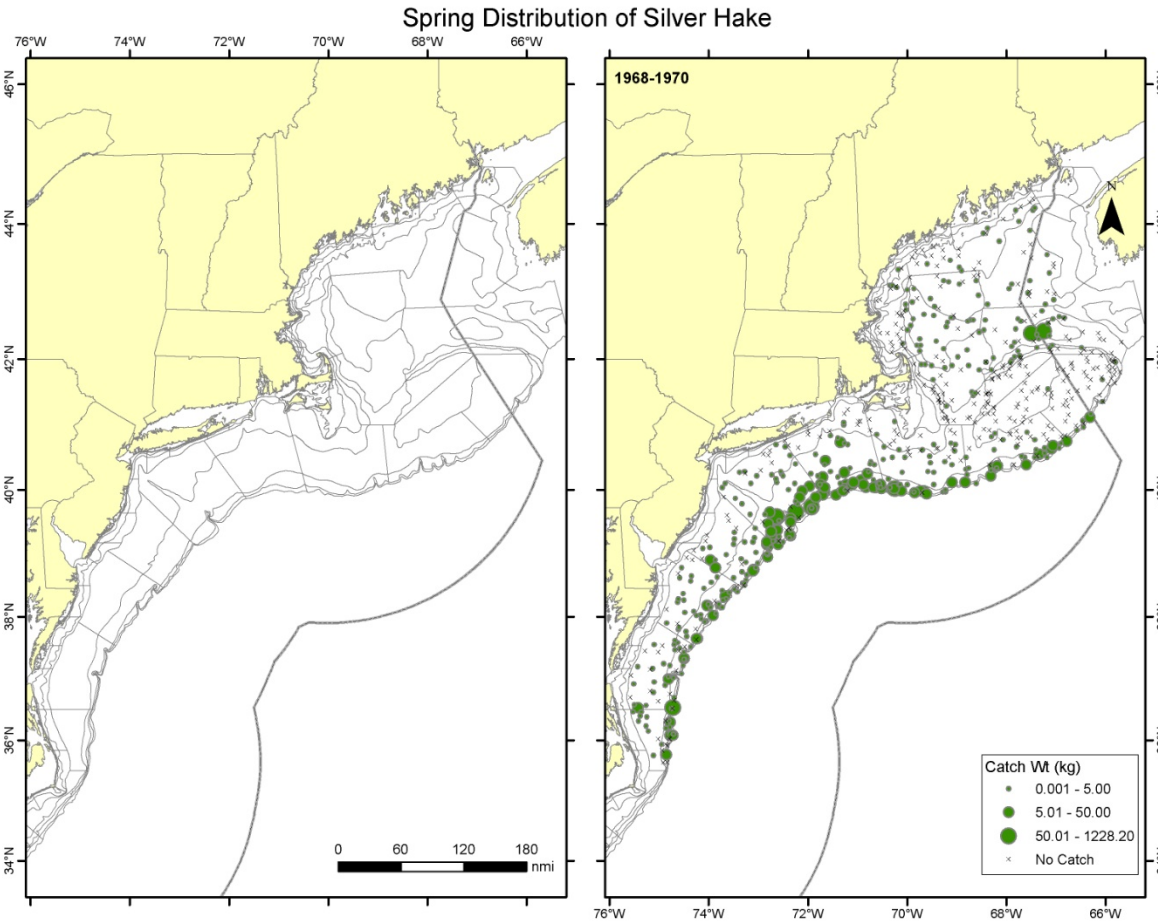


Figure A25. NEFSC distribution maps for silver hake during the spring bottom trawl surveys, 1968-1970.

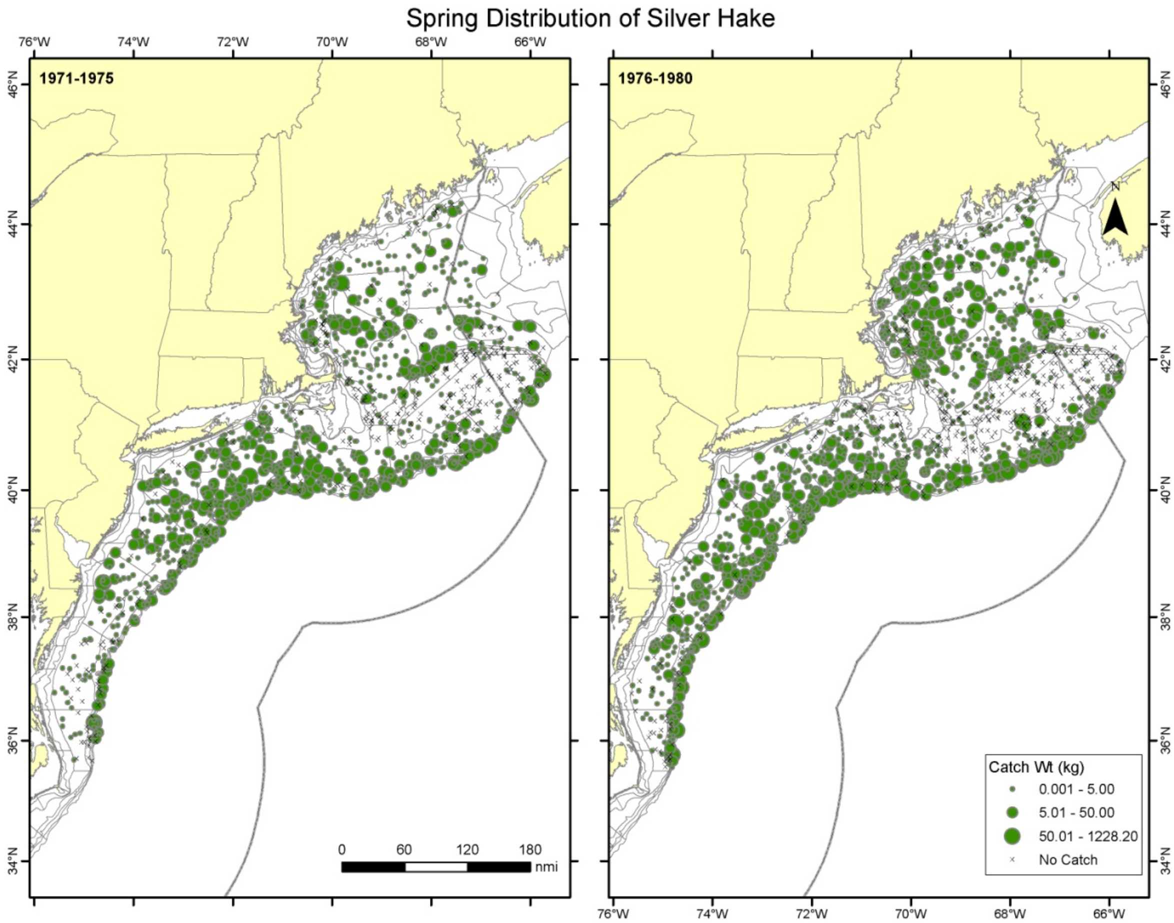


Figure A26. NEFSC distribution maps for silver hake during the spring bottom trawl surveys, 1971-1980.

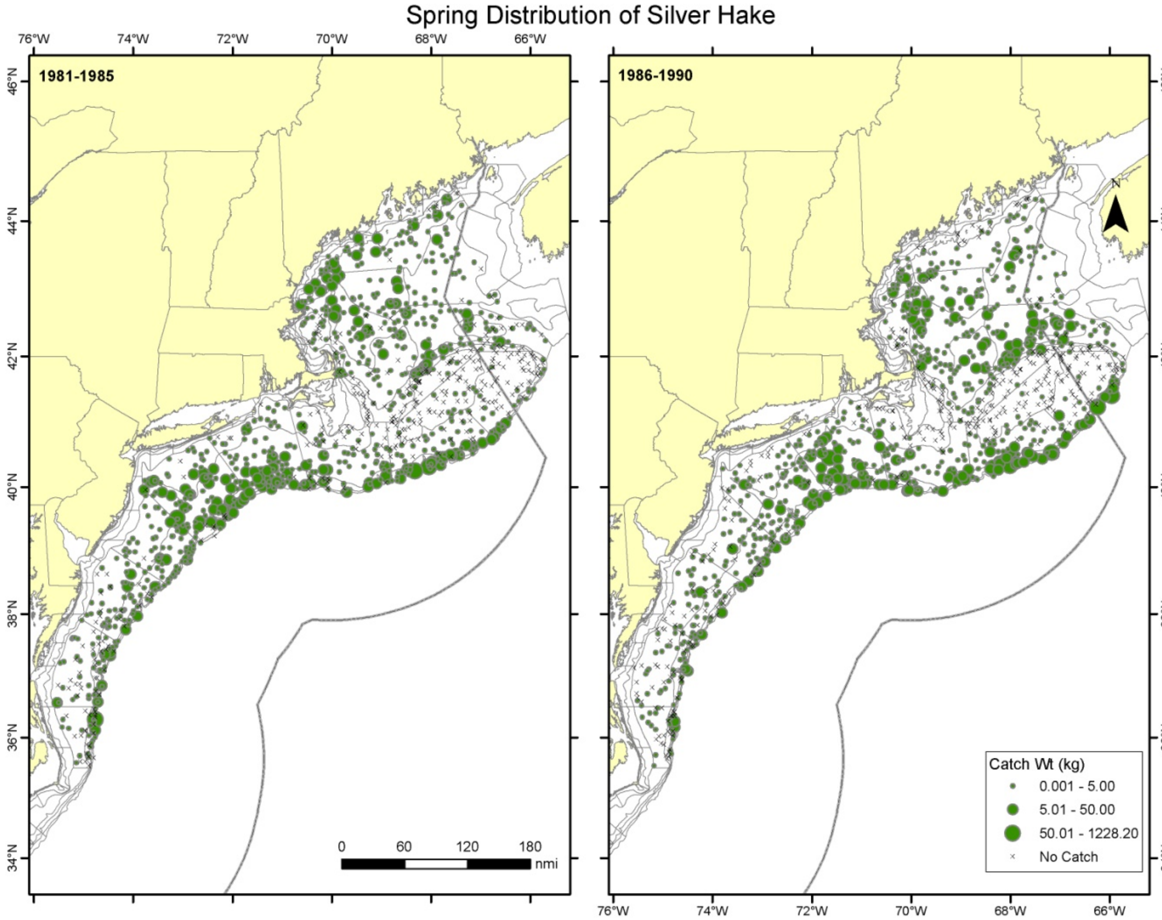


Figure A27. NEFSC distribution maps for silver hake during the spring bottom trawl surveys, 1981-1990.

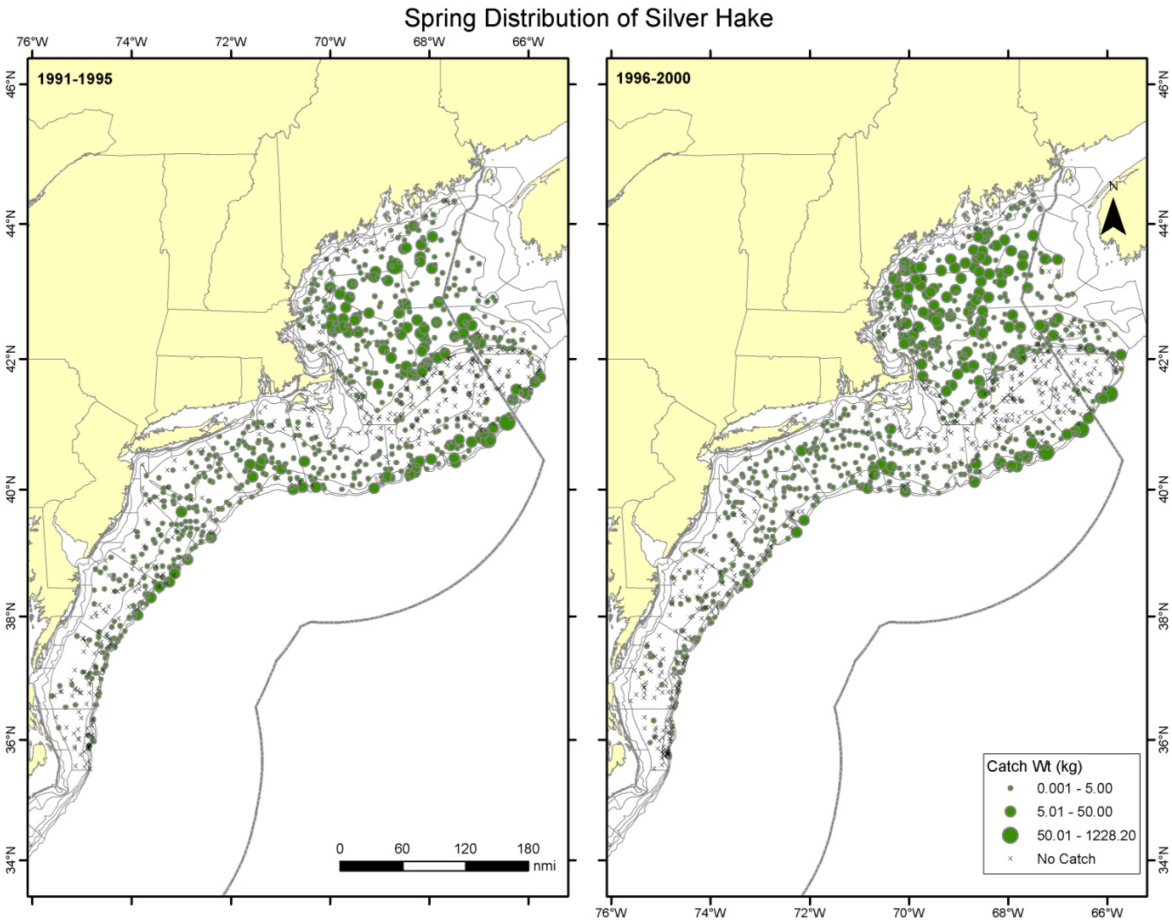


Figure A28. NEFSC distribution maps for silver hake during the spring bottom trawl surveys, 1991-2000.

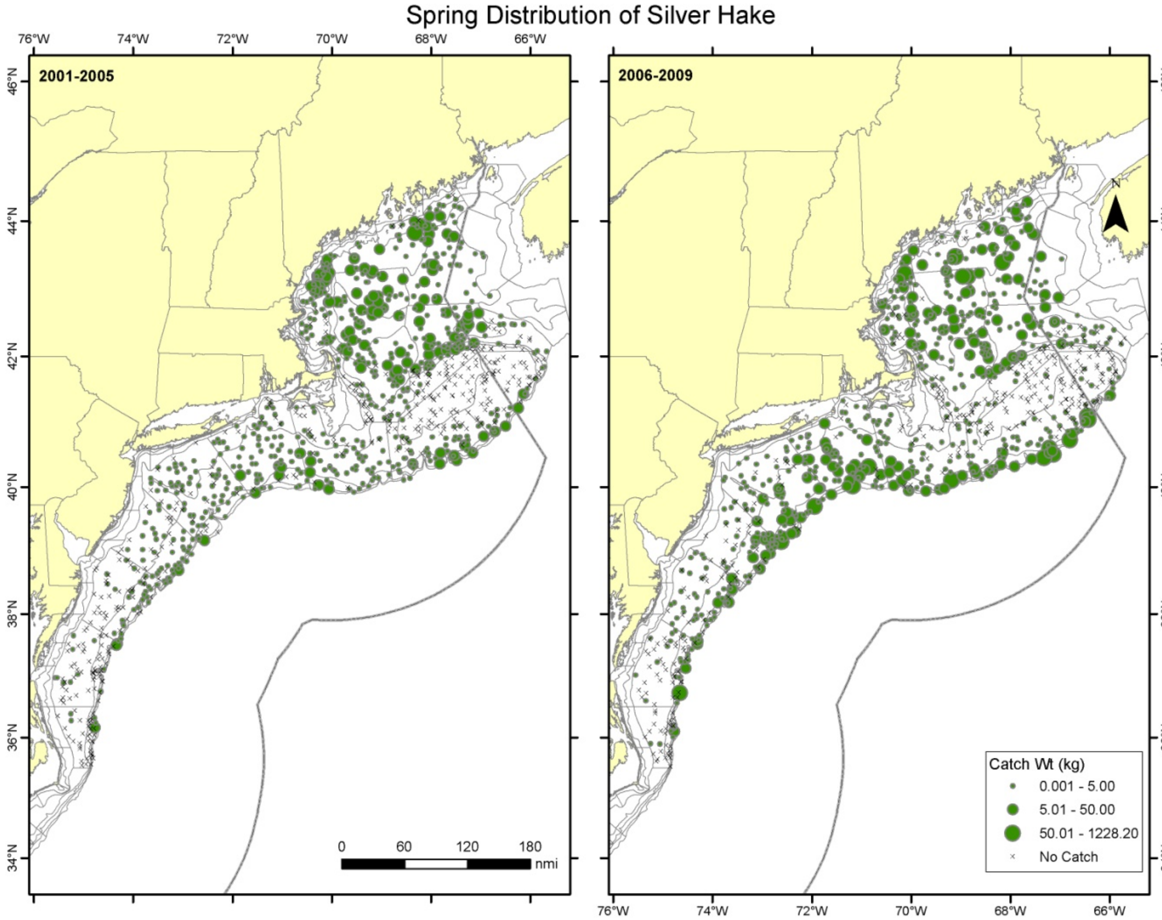


Figure A29. NEFSC distribution maps for silver hake during the spring bottom trawl surveys, 2001-2009.

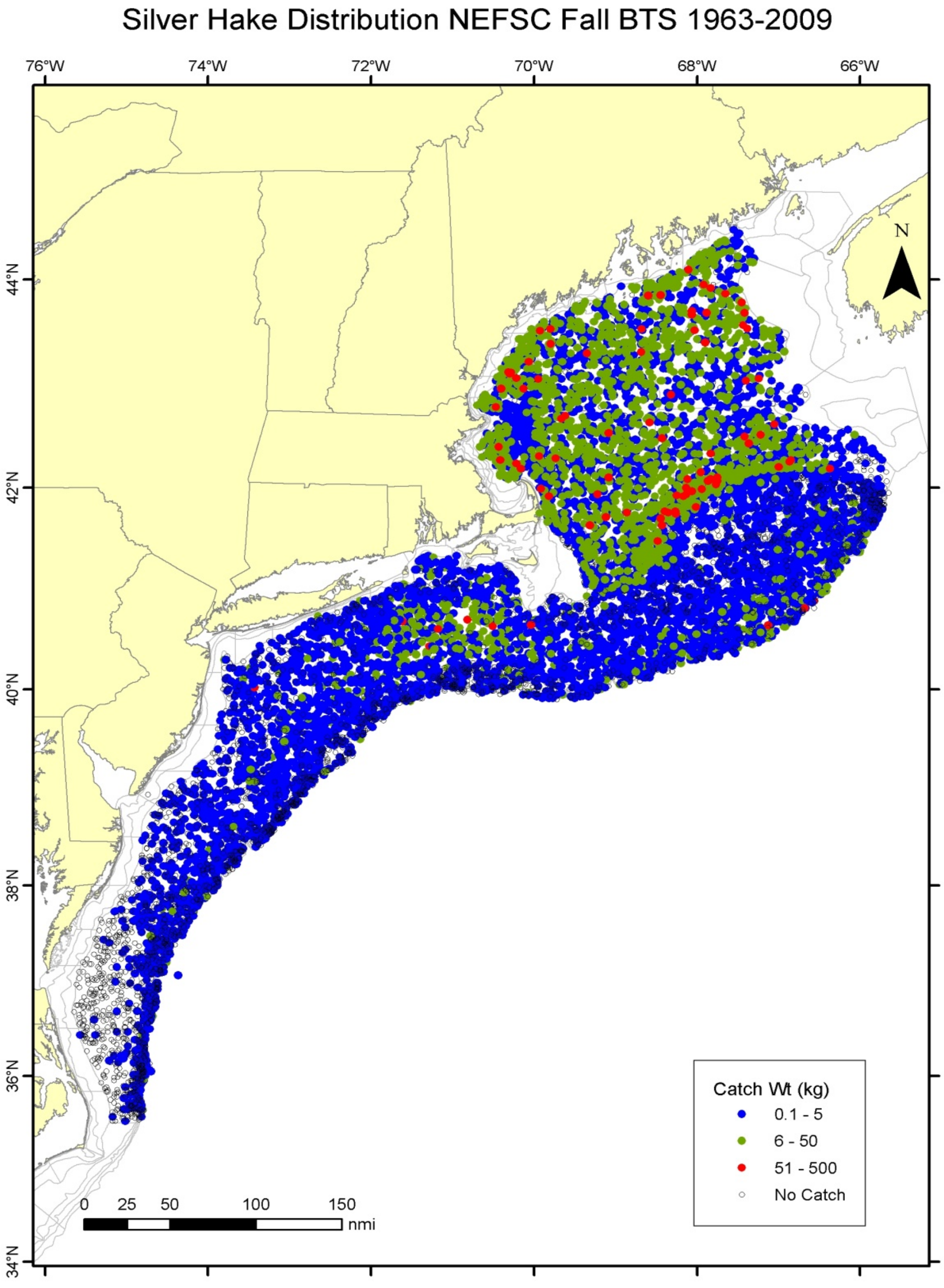


Figure A30. Fall survey distribution of silver hake from the NEFSC bottom trawl surveys, 1963-2009.

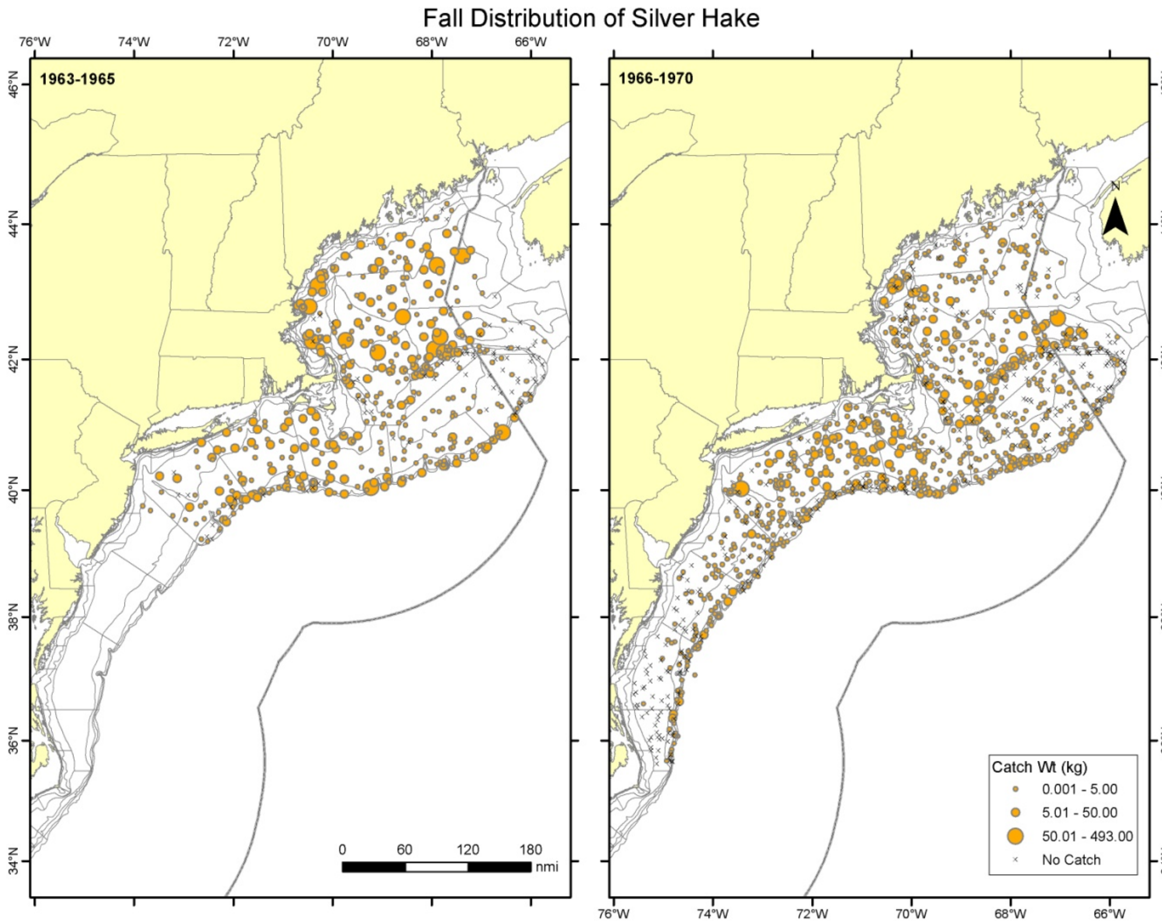


Figure A31. NEFSC distribution maps for silver hake during the fall bottom trawl surveys, 1963-1970.

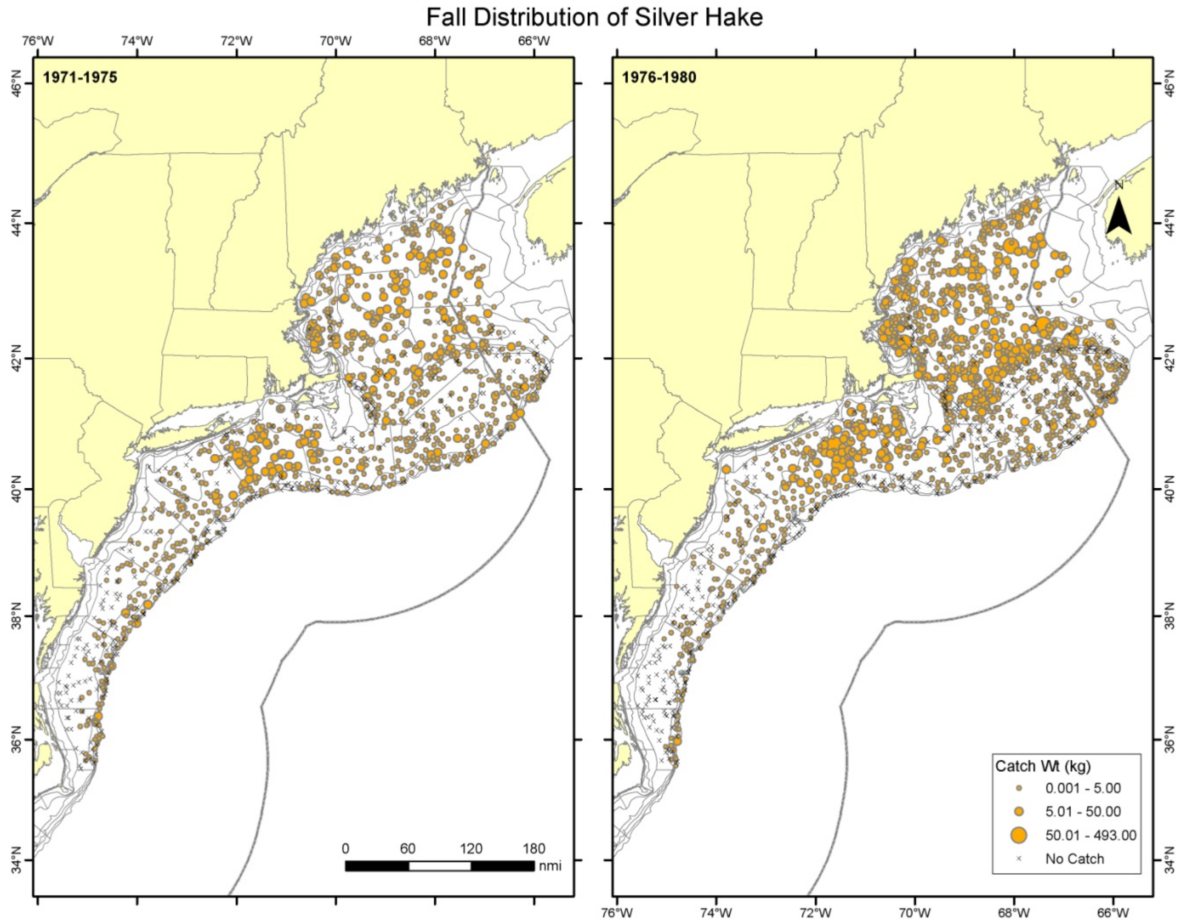


Figure A32. NEFSC distribution maps for silver hake during the fall bottom trawl surveys, 1971-1980.

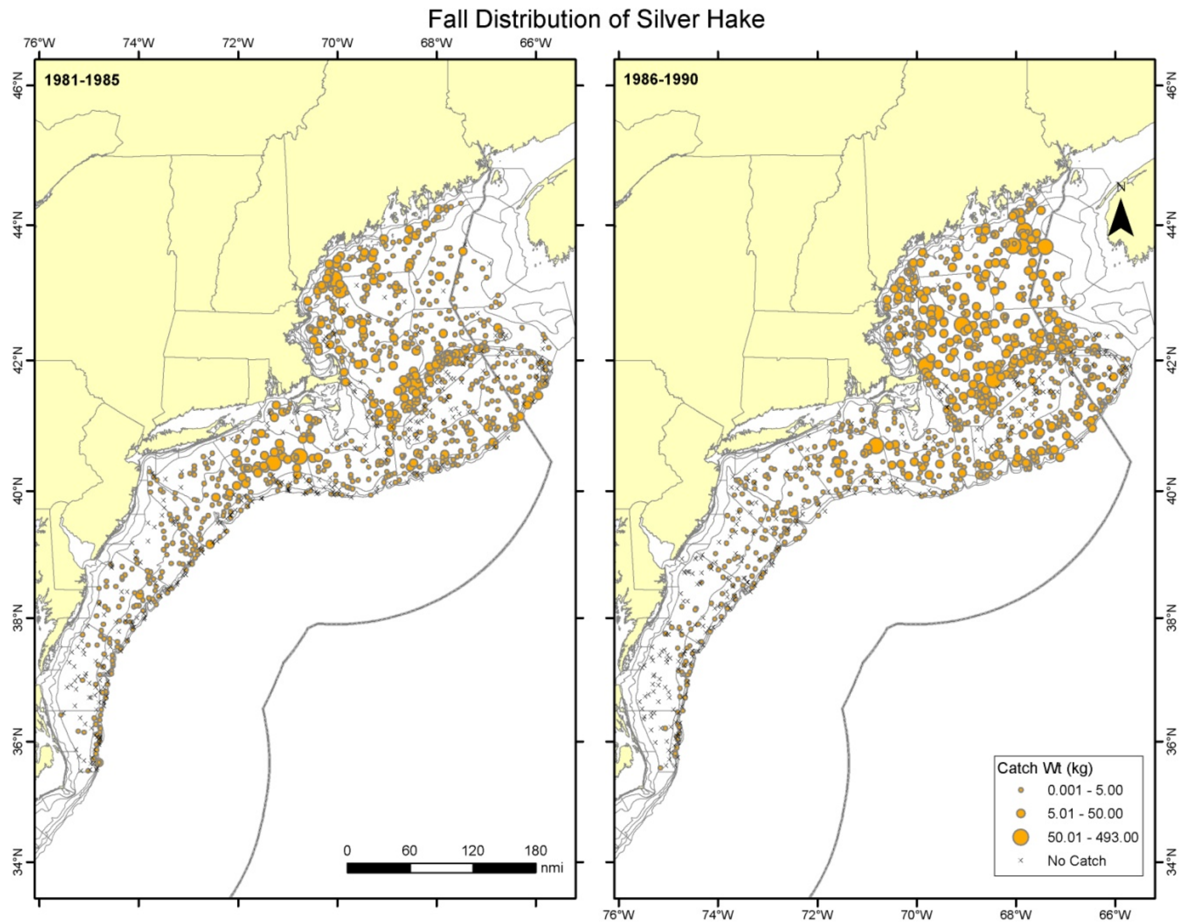


Figure A33. NEFSC distribution maps for silver hake during the fall bottom trawl surveys, 1981-1990.

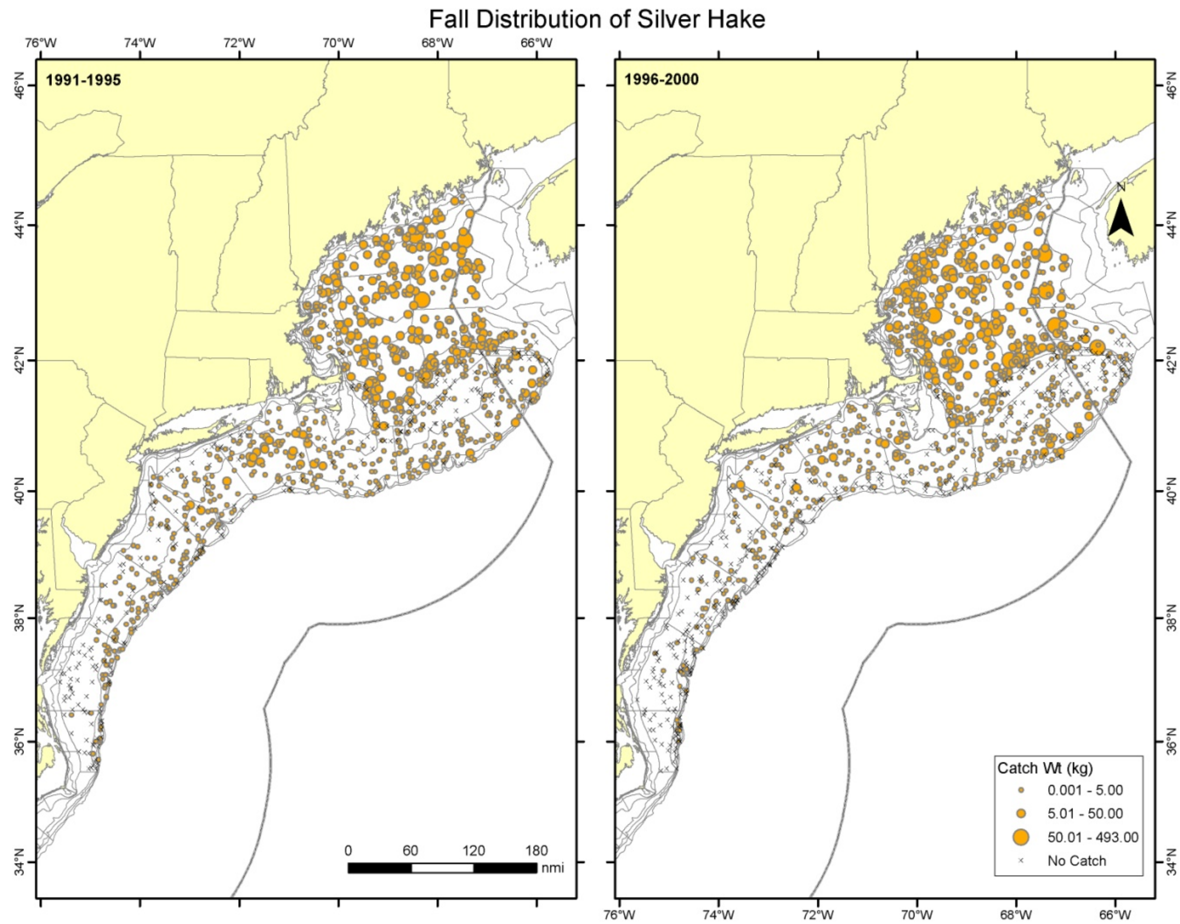


Figure A34. NEFSC distribution maps for silver hake during the fall bottom trawl surveys, 1991-2000.

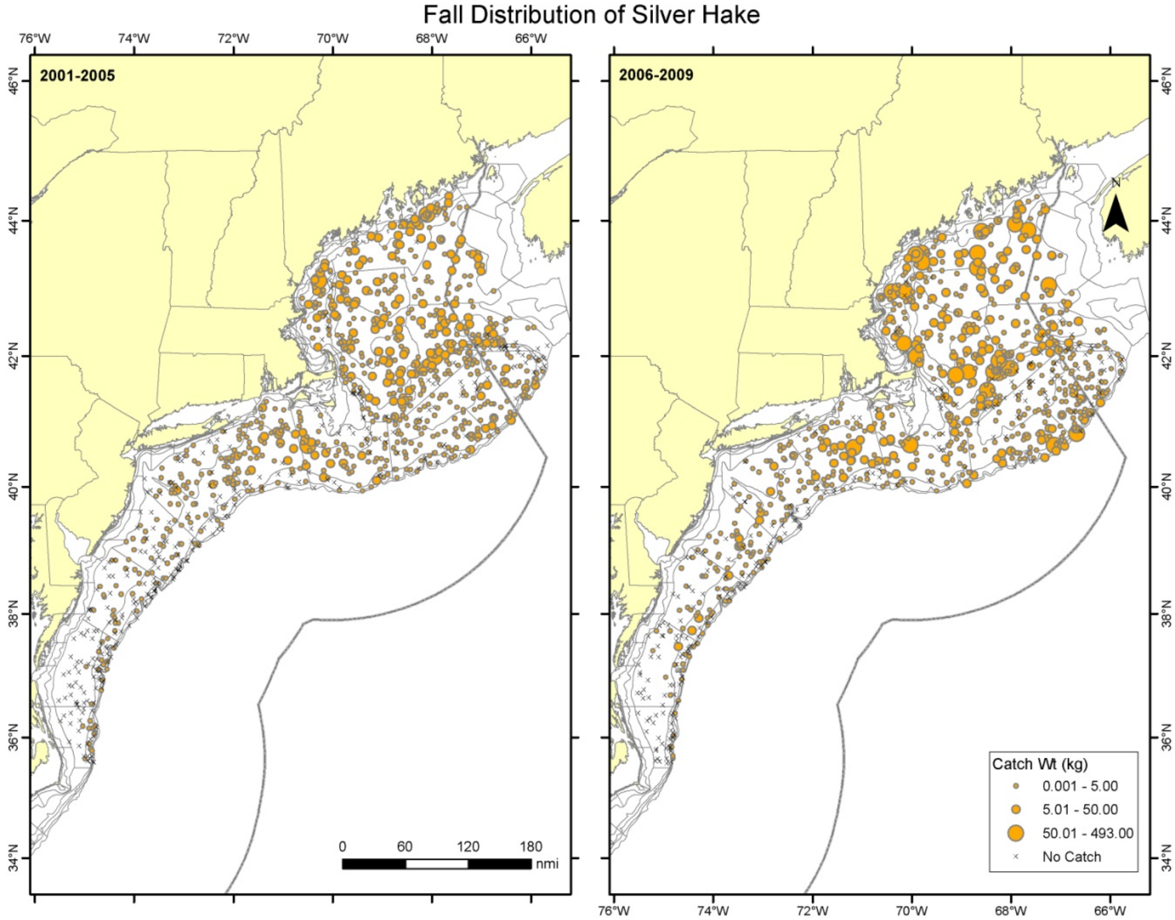


Figure A35. NEFSC distribution maps for silver hake during the fall bottom trawl surveys, 2001-2009.

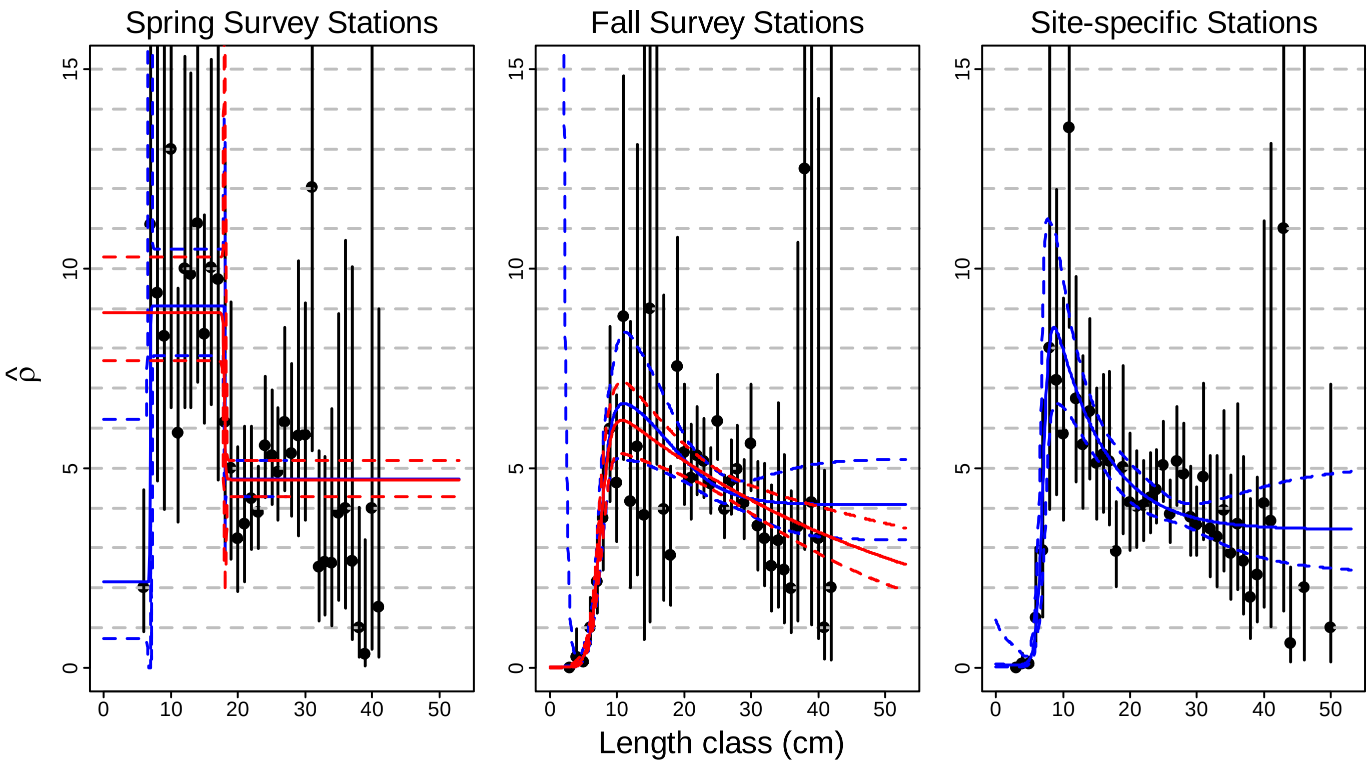
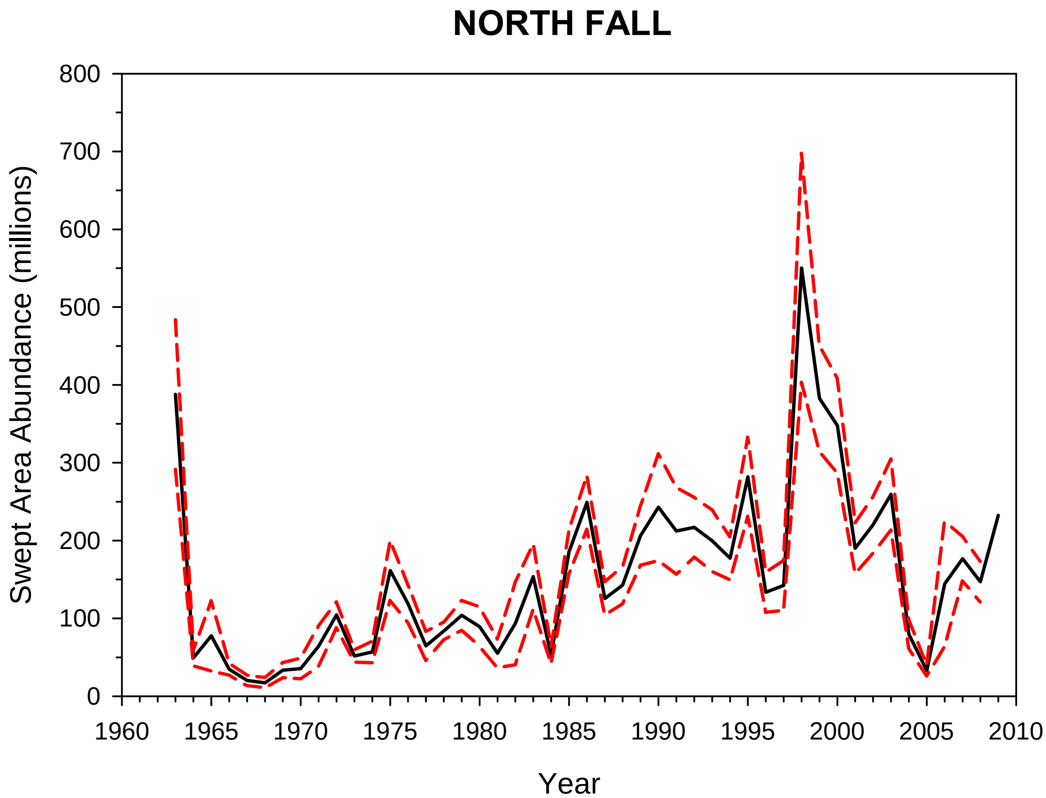


Figure A36: Beta-binomial based estimates of calibration factors and corresponding 95% confidence intervals by length class (1 cm bins) for **silver hake**. The black points and vertical bars represent results where different calibration factors are estimated for each length class. The blue lines represent results from fully parameterized double-logistic models. For the spring, the red lines represent results for a (single) logistic model whereas they represent results for a double logistic model with no minima for the ascending or descending logistic function for the fall.



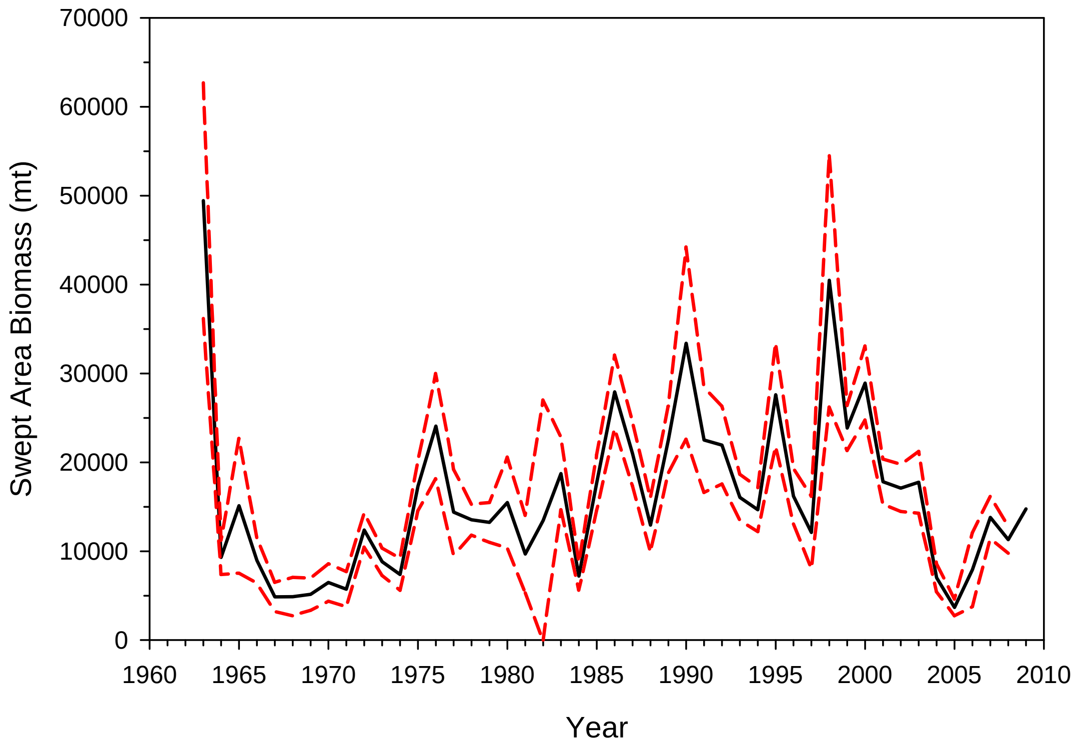


Figure A37. Trends in fall Survey abundances (top) and biomass (bottom) estimates for Silver hake in the northern stock expressed as minimum swept area estimates. Solid lines represent point estimates while the dash lines are the confidence intervals.

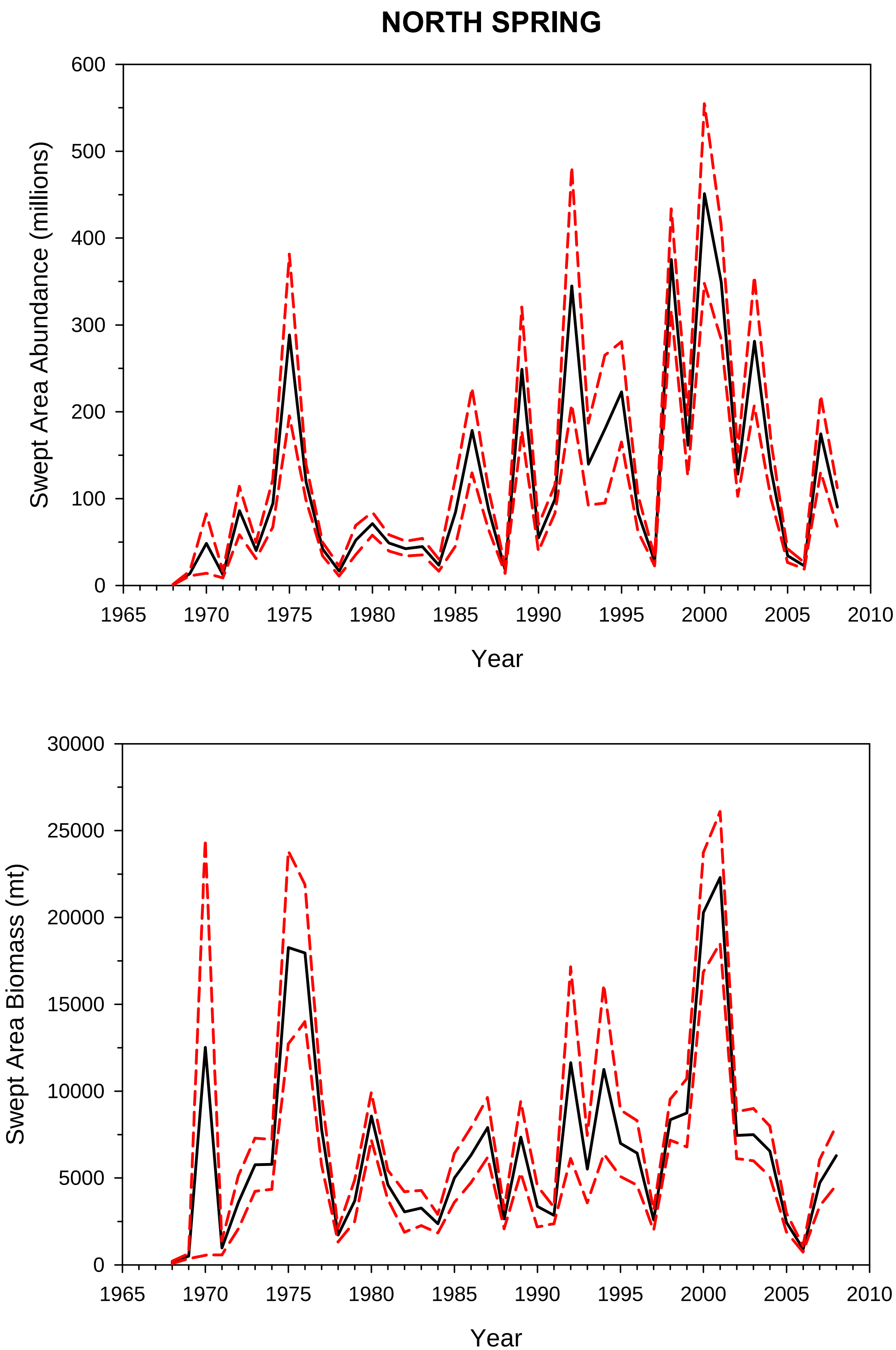


Figure A38. Swept area abundance (top) and biomass (bottom) with confidence intervals for the NEFSC spring survey in the northern management region.

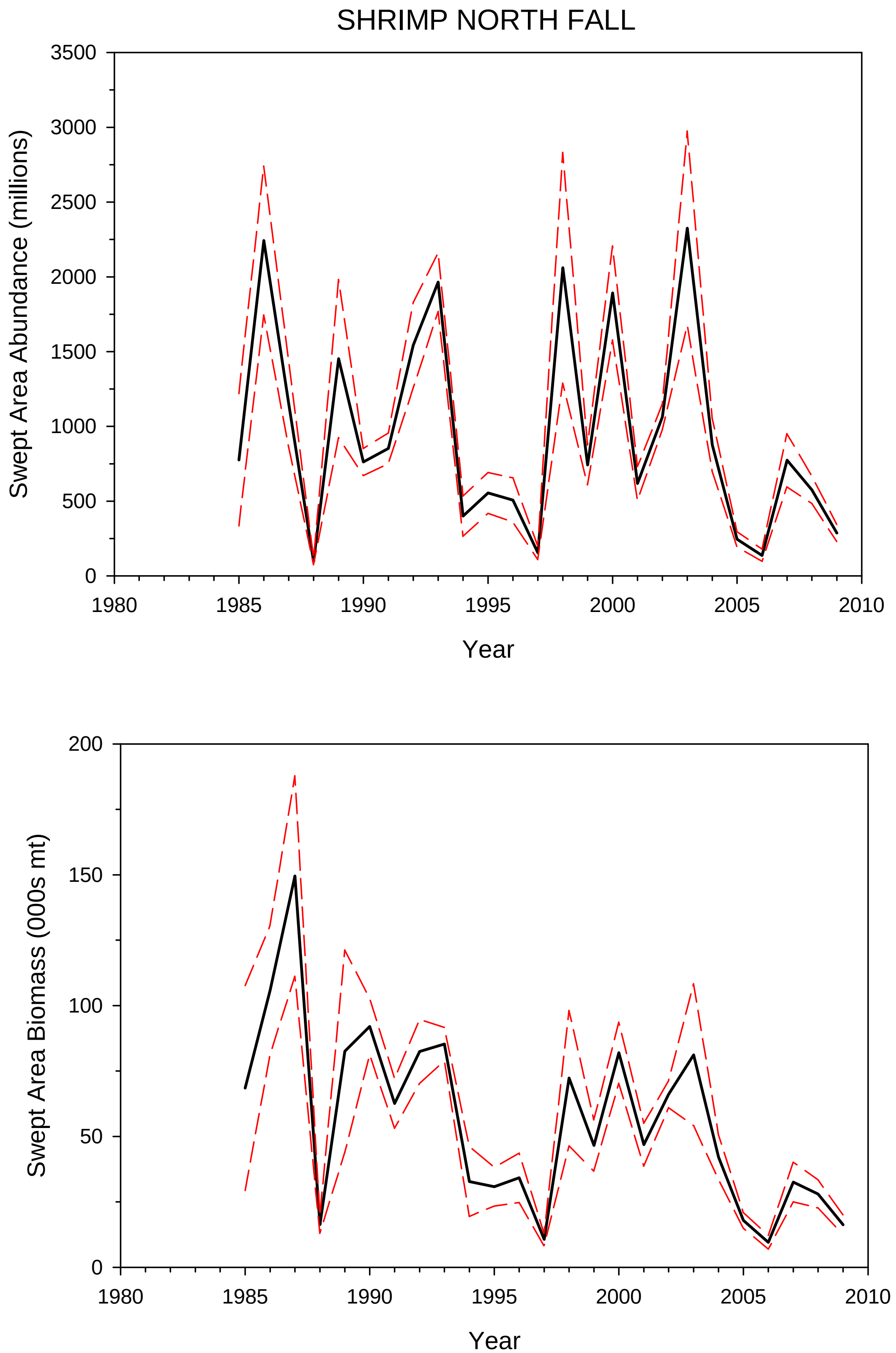
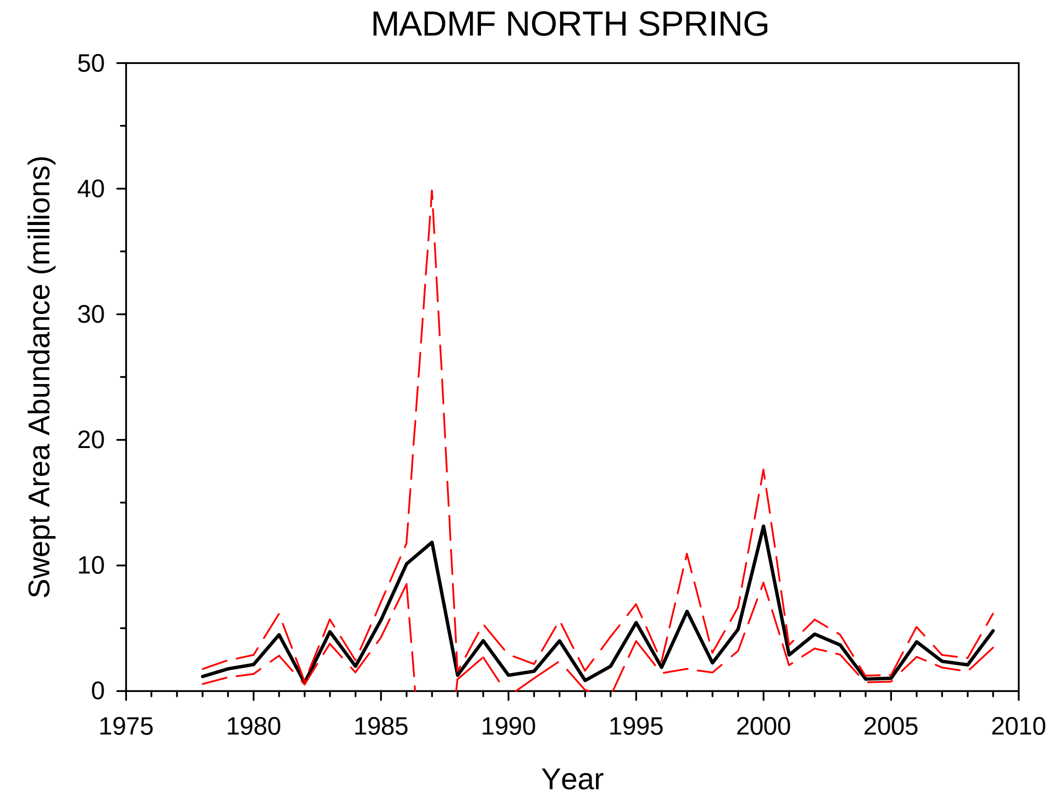


Figure A39. Swept area abundance (top) and biomass (bottom) with confidence intervals for the NEFSC shrimp survey.



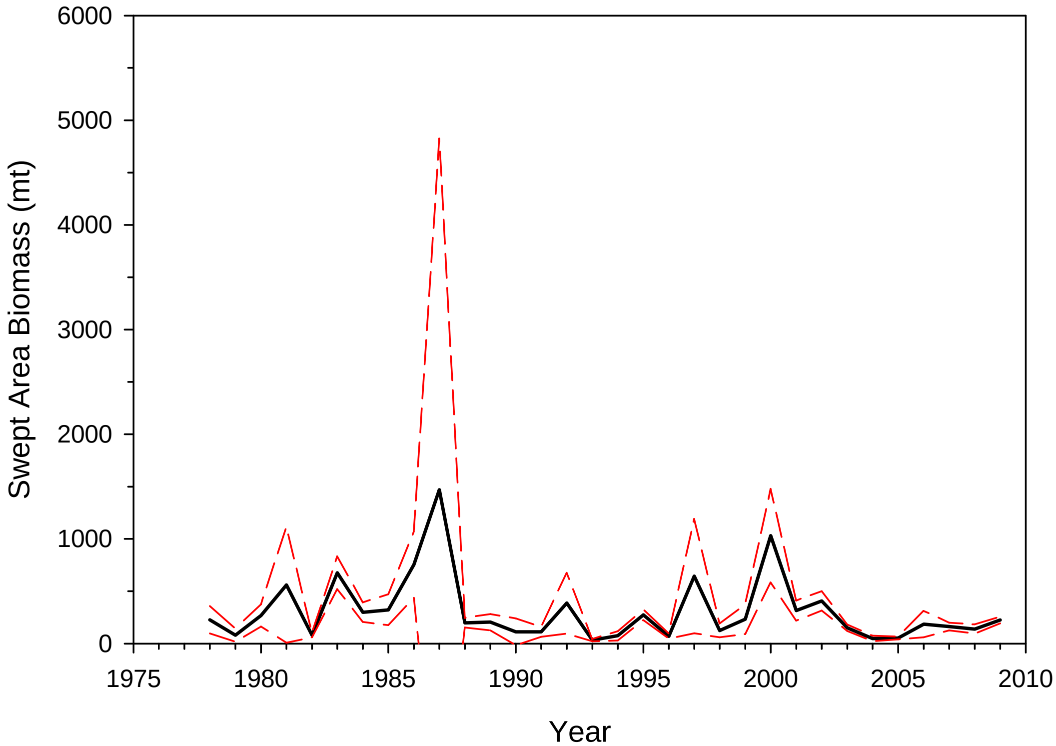
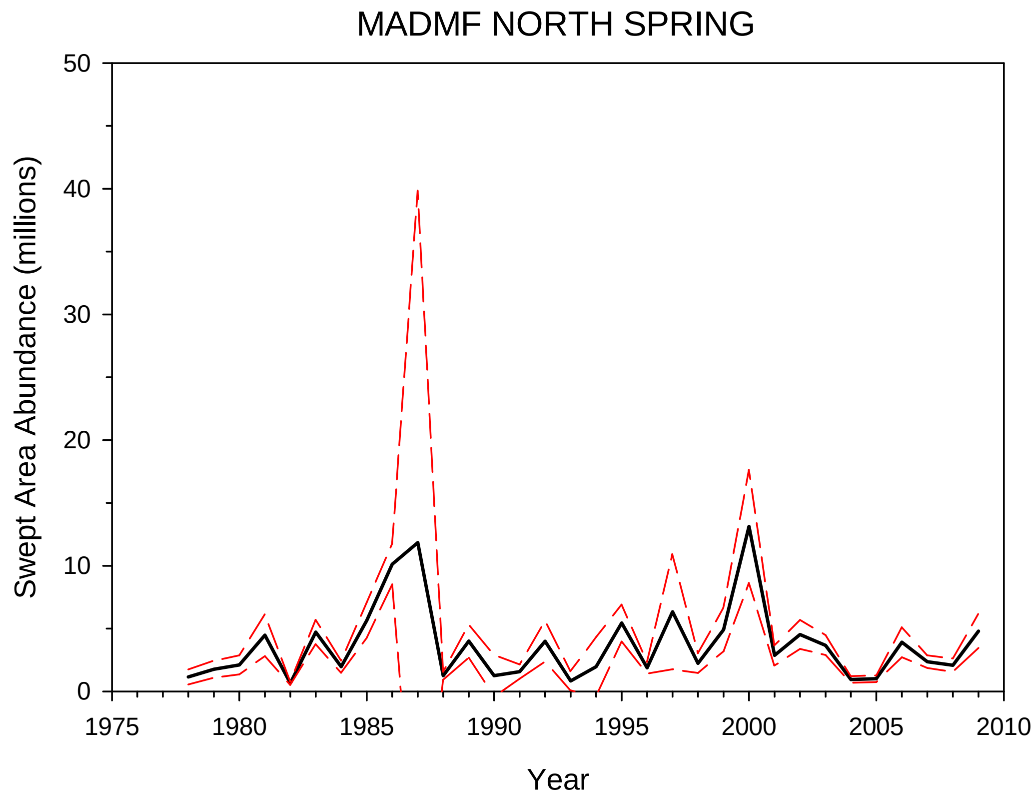
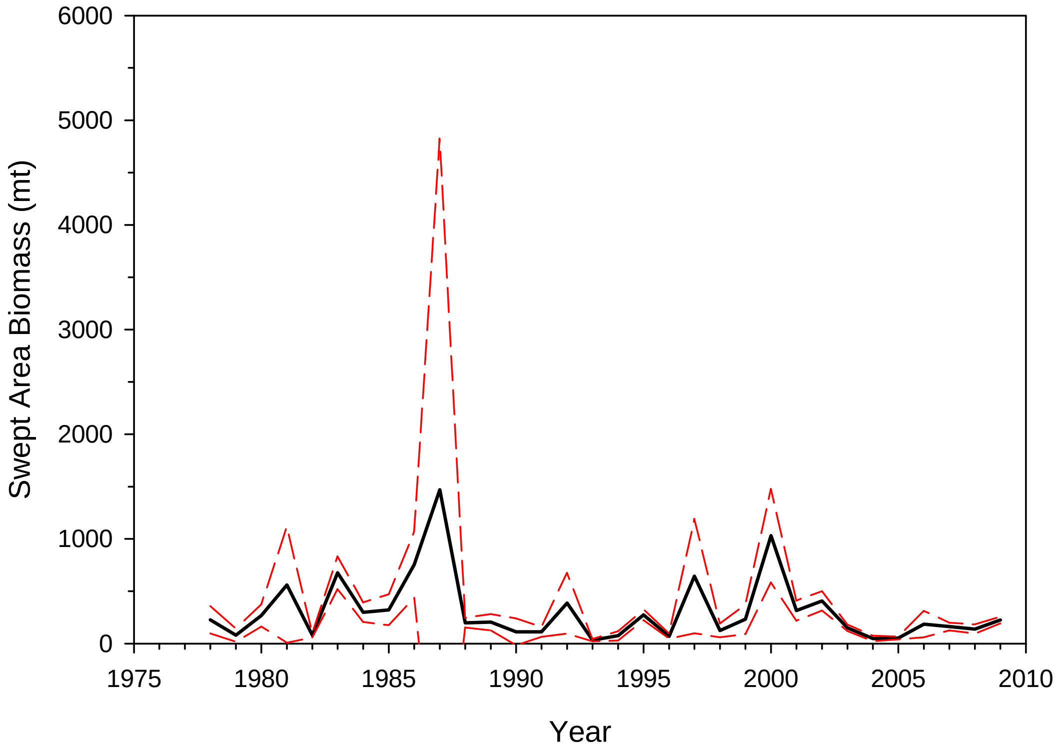
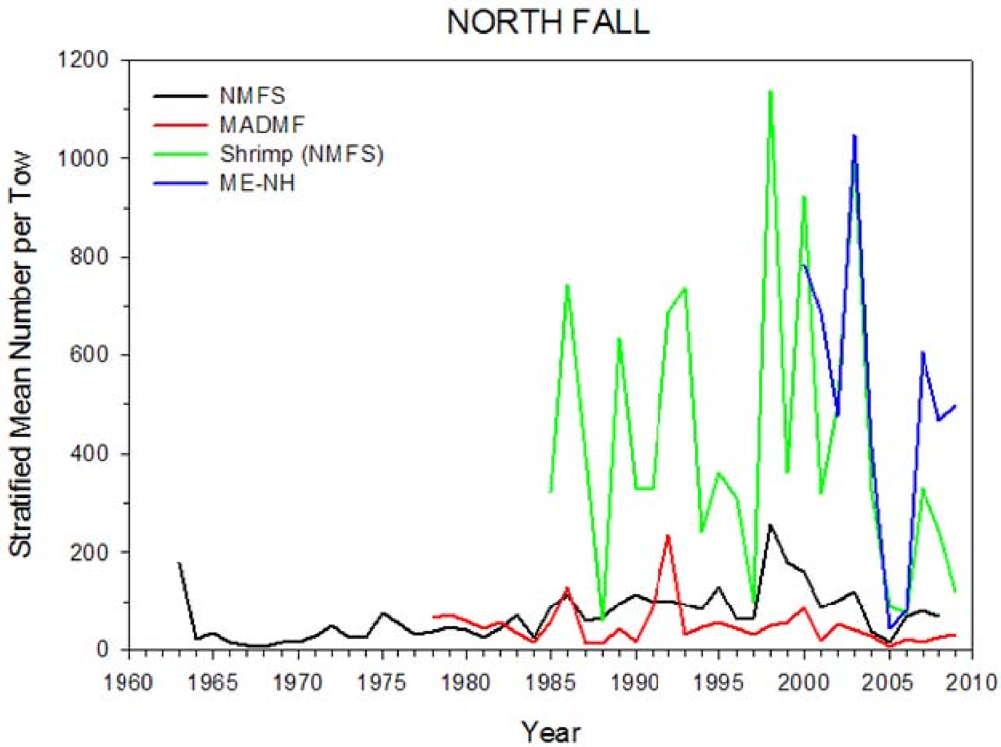


Figure A40. Swept area abundance (top) and biomass (bottom) with confidence intervals for silver hake from the Massachusetts Division of Marine Fisheries fall north survey (strata 18-36).





A41. Swept area abundance (top) and biomass (bottom) with confidence intervals for silver hake from the Massachusetts Division of Marine Fisheries spring north survey (strata 18-36).



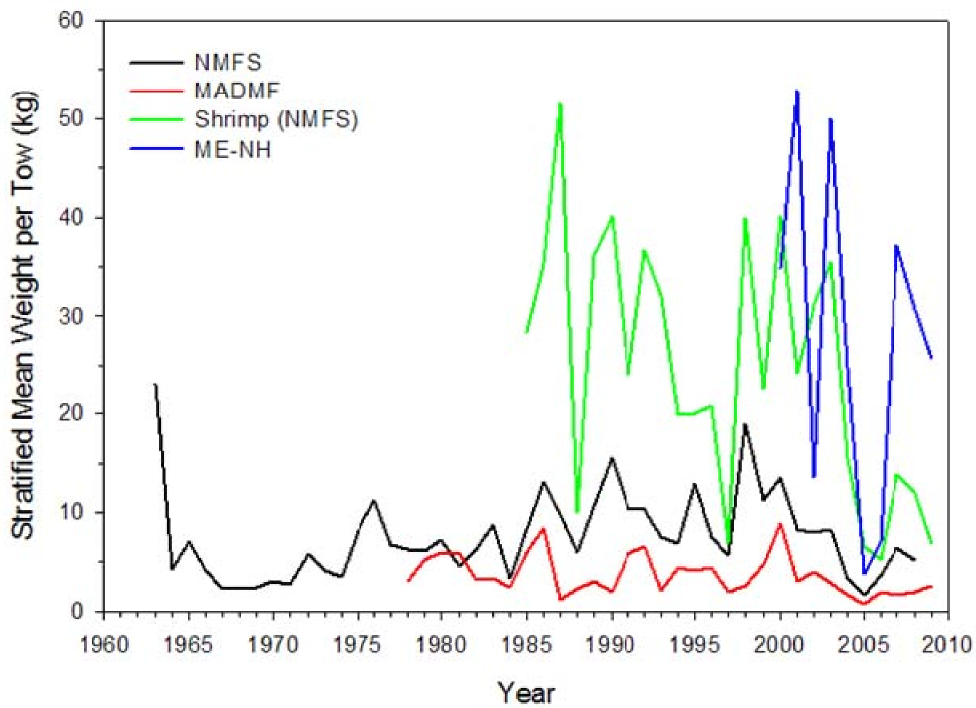


Figure A42. Survey abundances (millions of fish) and biomass (mt) for silver hake from the fall NEFSC, MADMF, and shrimp surveys.

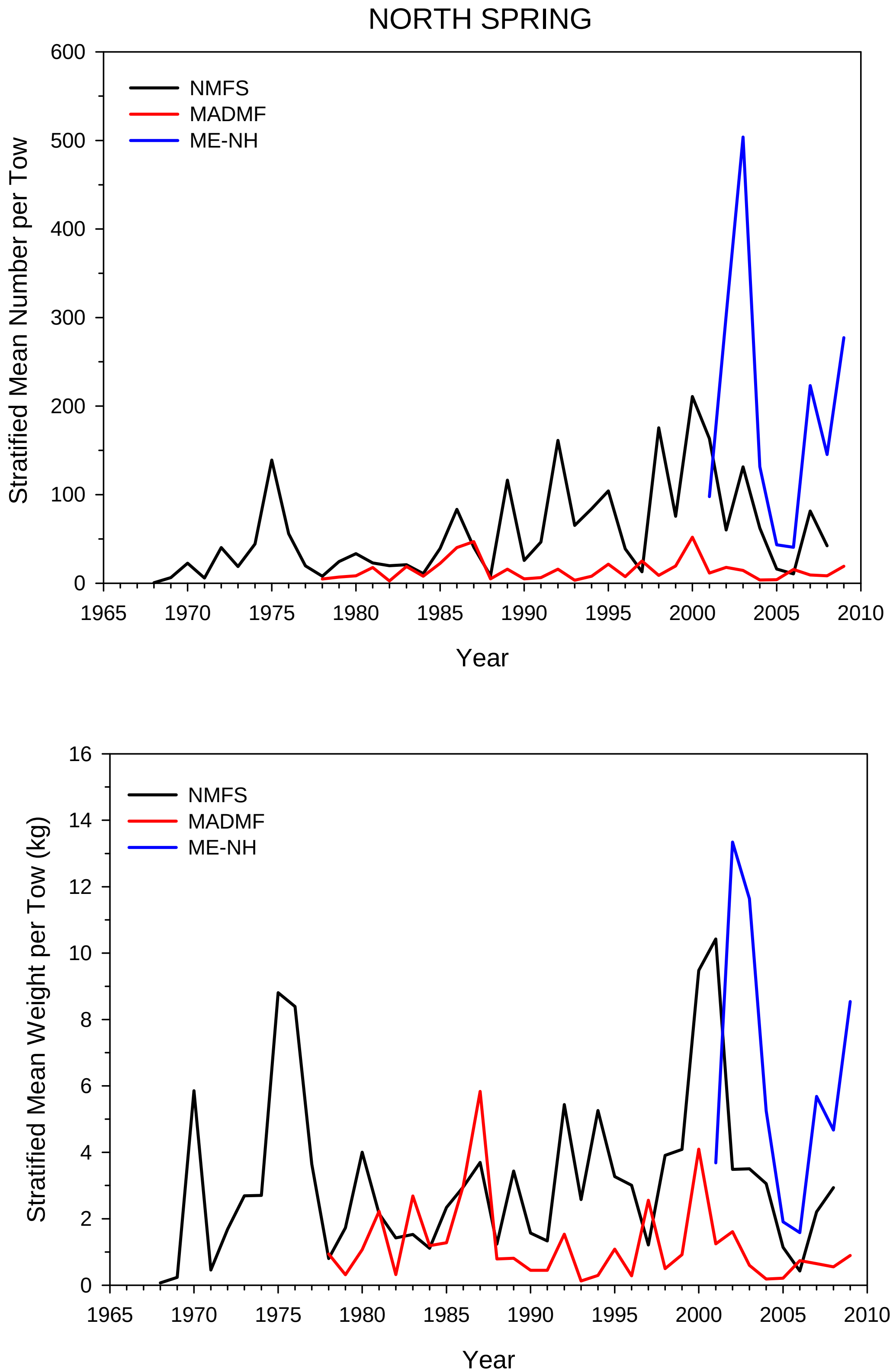


Figure A43. Survey abundances (millions of fish) and biomass (mt) for silver hake from the spring NEFSC, MADMF, and Maine-New Hampshire state surveys.

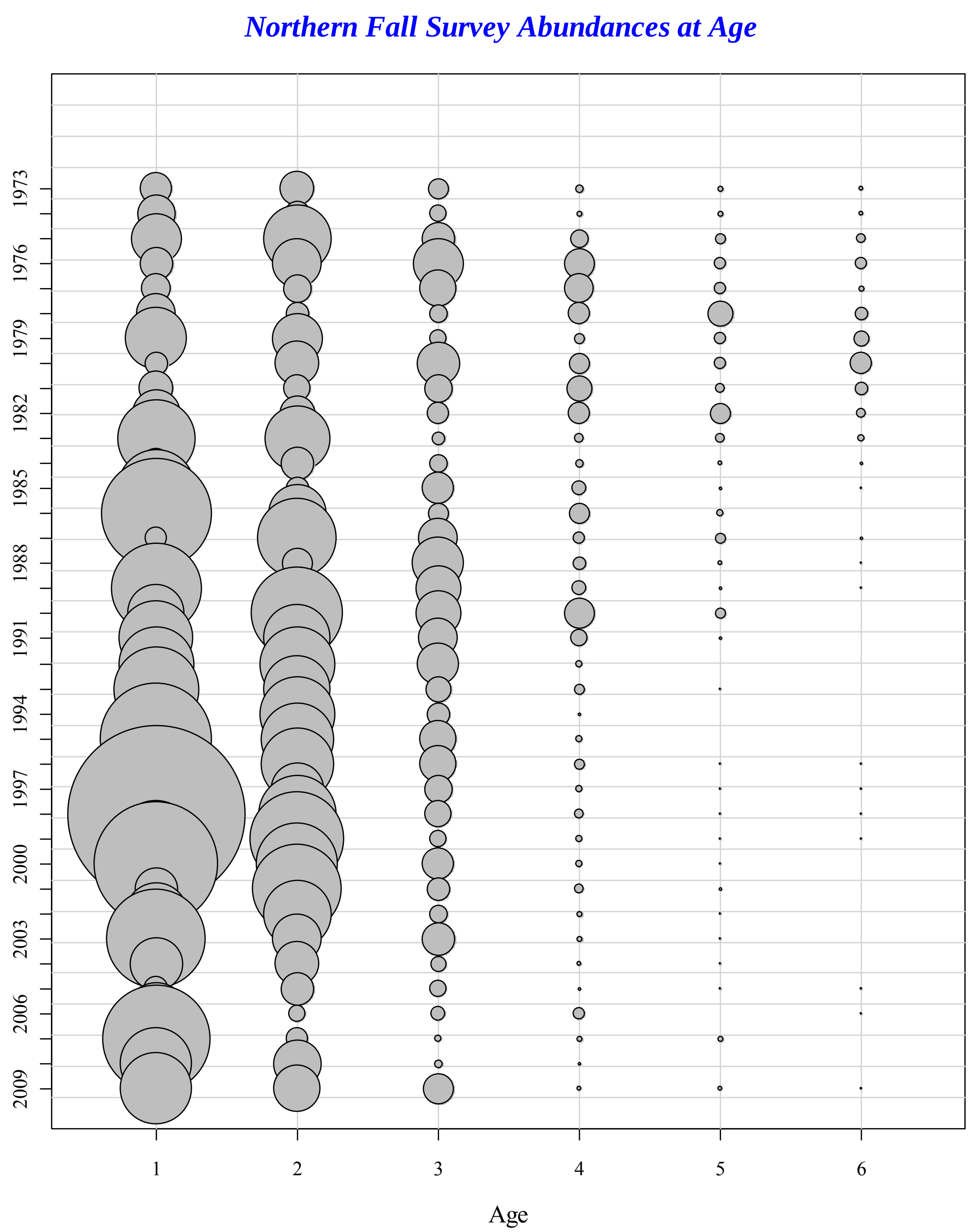


Figure A44. Silver hake age specific indices of abundance for the fall survey in the northern stock area. The area of the bubble plot is proportional to the magnitude.

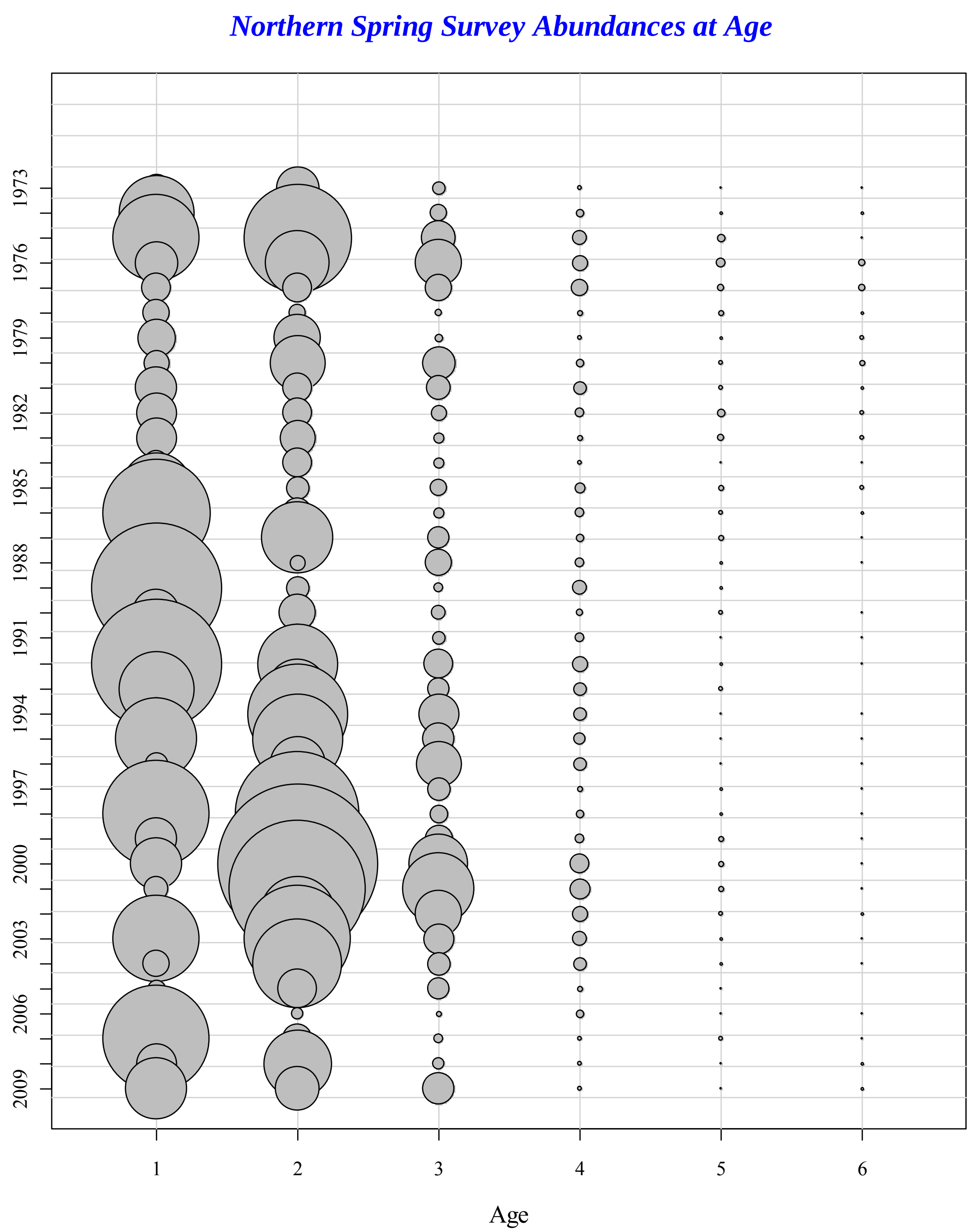
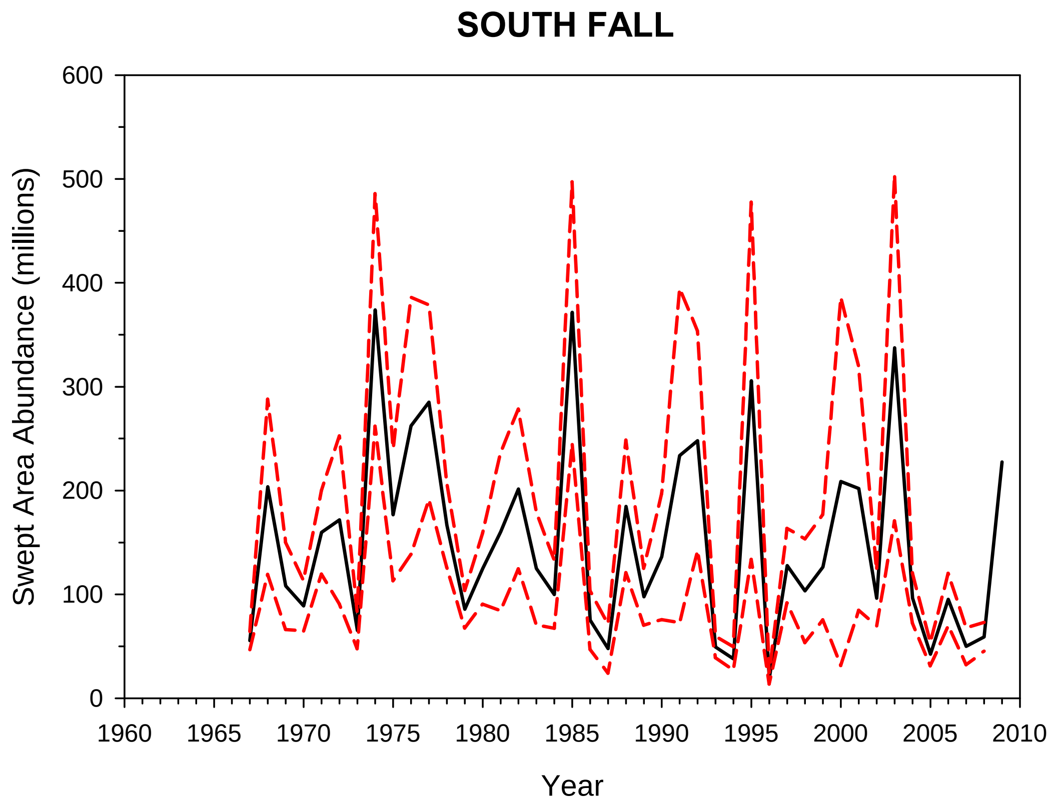


Figure A45. Silver hake age specific indices of abundance for the spring survey in the northern stock area. The area of the bubble plot is proportional to the magnitude.



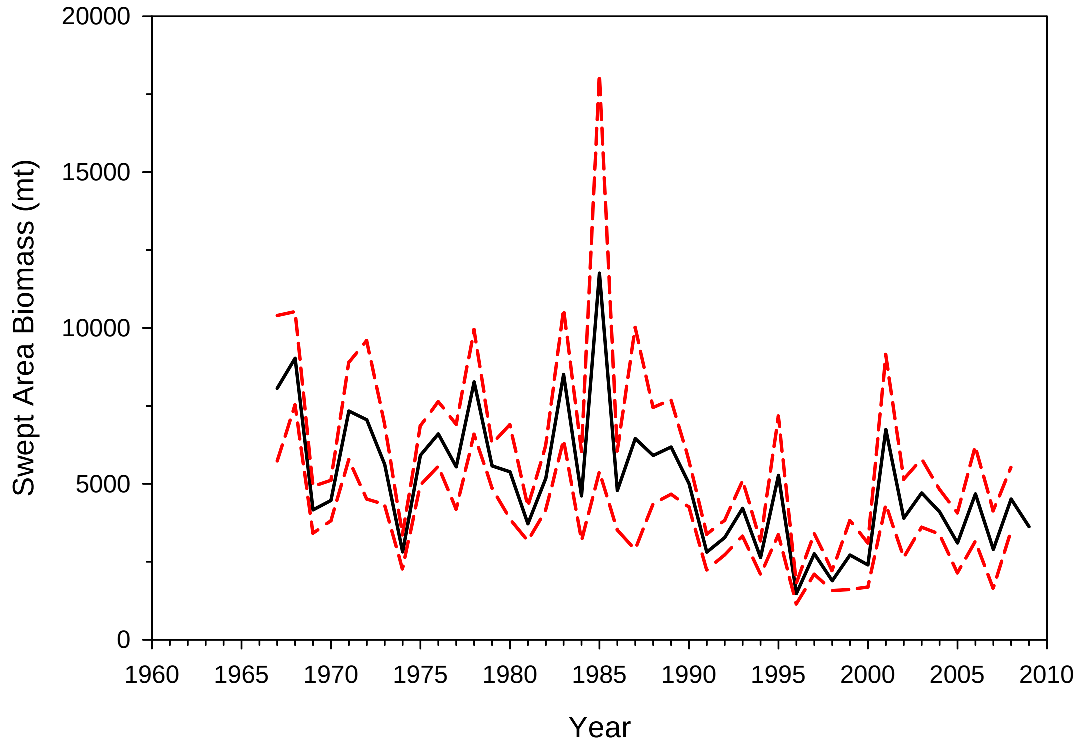


Figure A46. Swept area abundance (top) and biomass (bottom) with confidence intervals for the NEFSC fall survey in the southern management region.

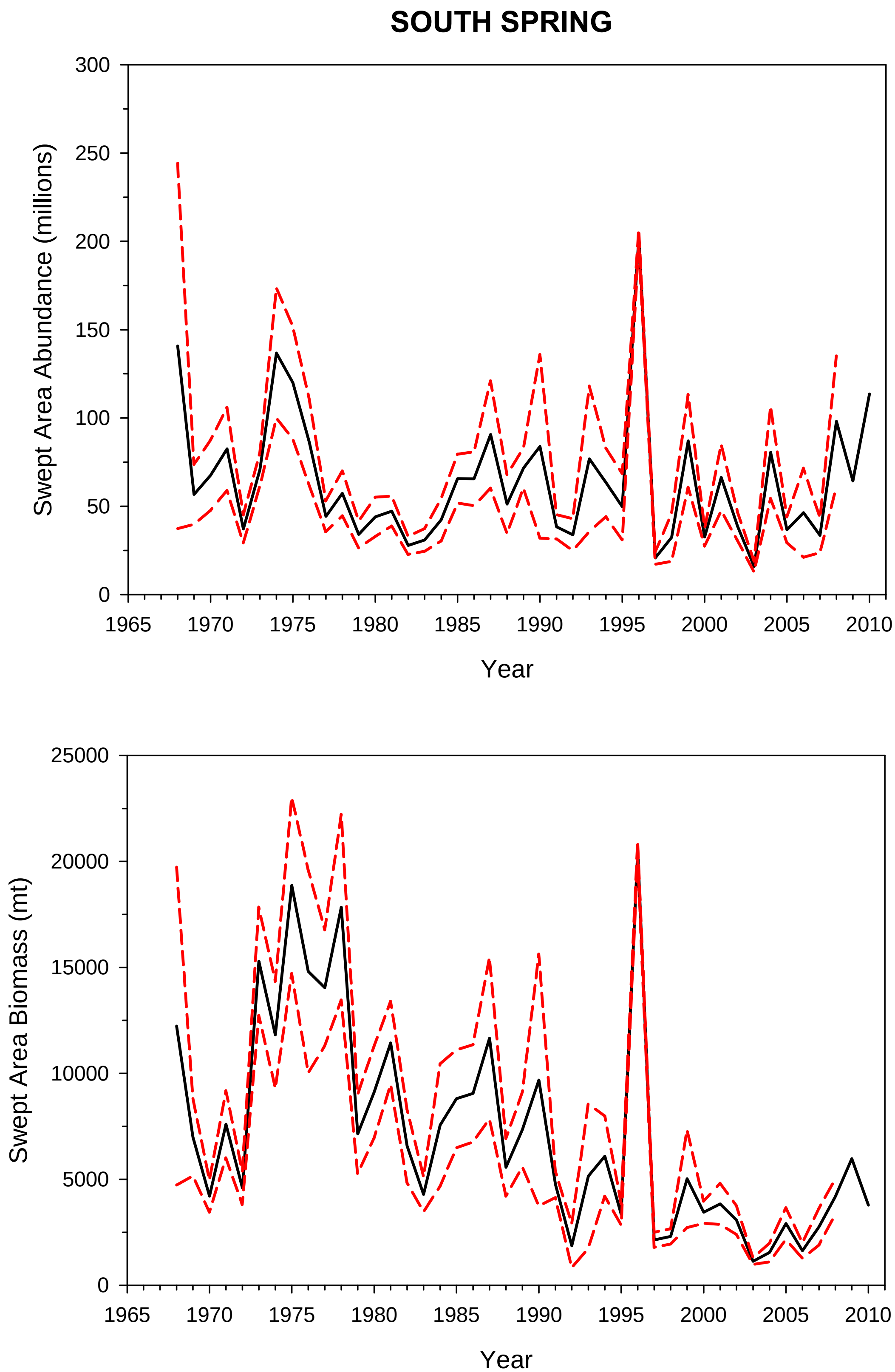


Figure A47. Swept area abundance (top) and biomass (bottom) with confidence intervals for the NEFSC spring survey in the southern management region.

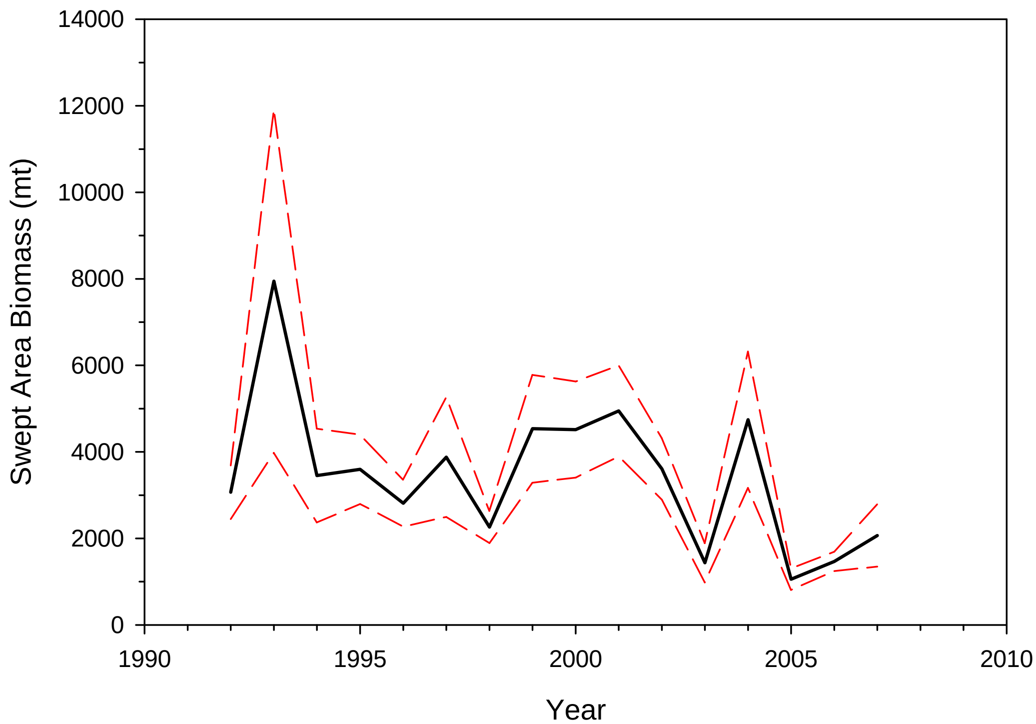


Figure A48. Swept area abundance and biomass with upper and lower confidence intervals for silver hake from the NEFSC winter survey in the southern management region.

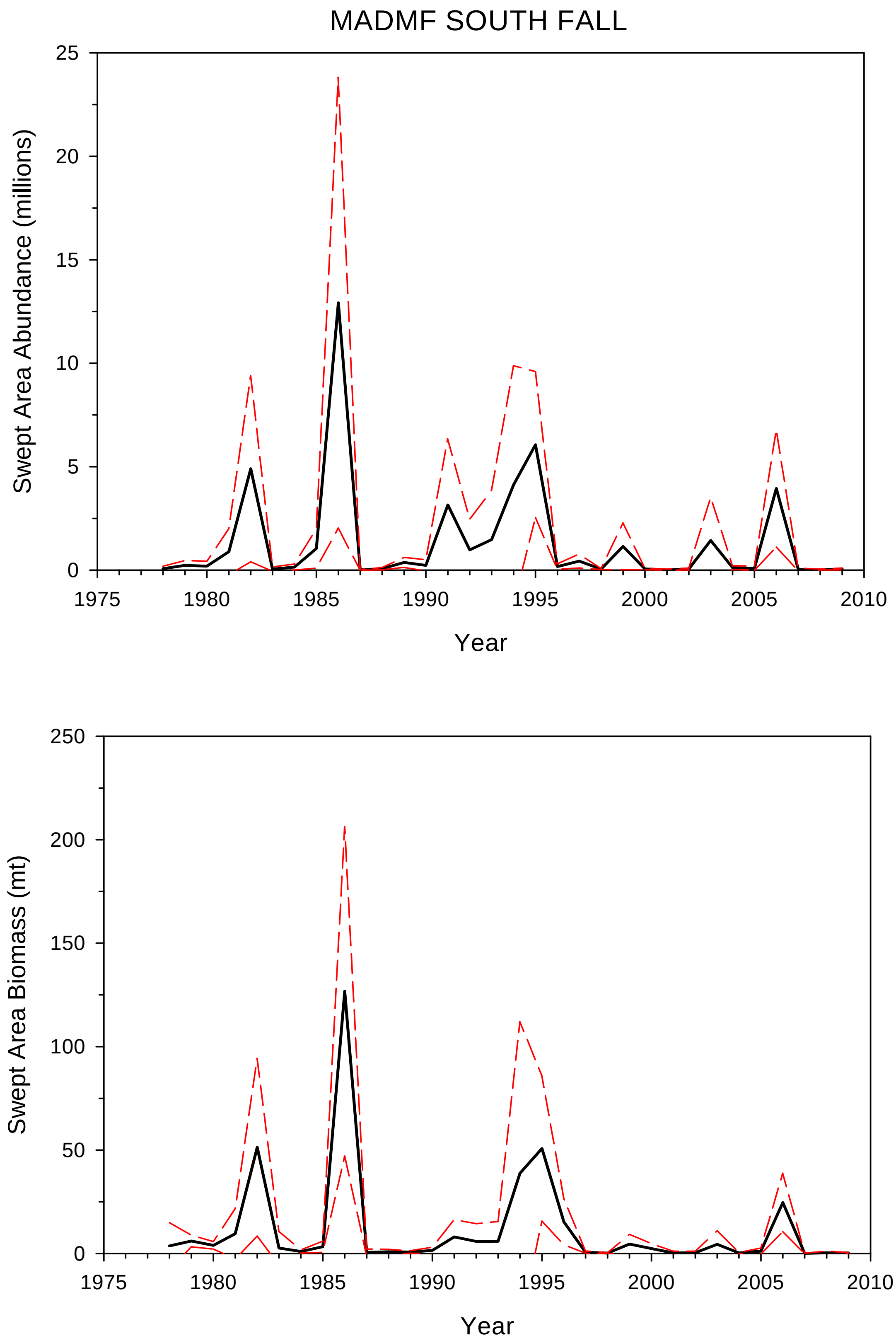


Figure A49. Swept area abundance (top) and biomass (bottom) with confidence intervals for silver hake from the Massachusetts Division of Marine Fisheries fall south survey (strata 11-17).

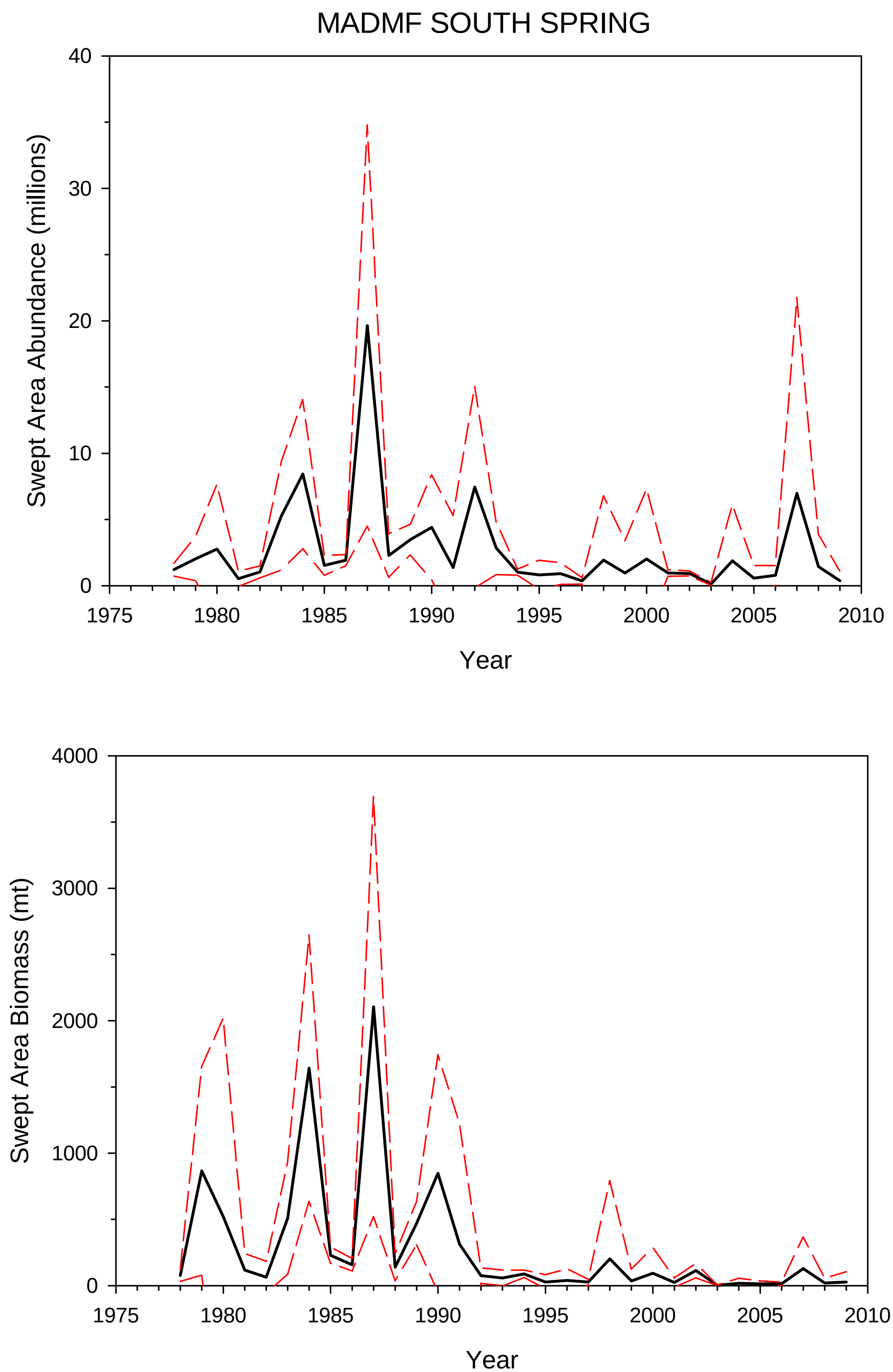


Figure A50. Swept area abundance (top) and biomass (bottom) with confidence intervals for silver hake from the Massachusetts Division of Marine Fisheries spring south survey (strata 11-17).

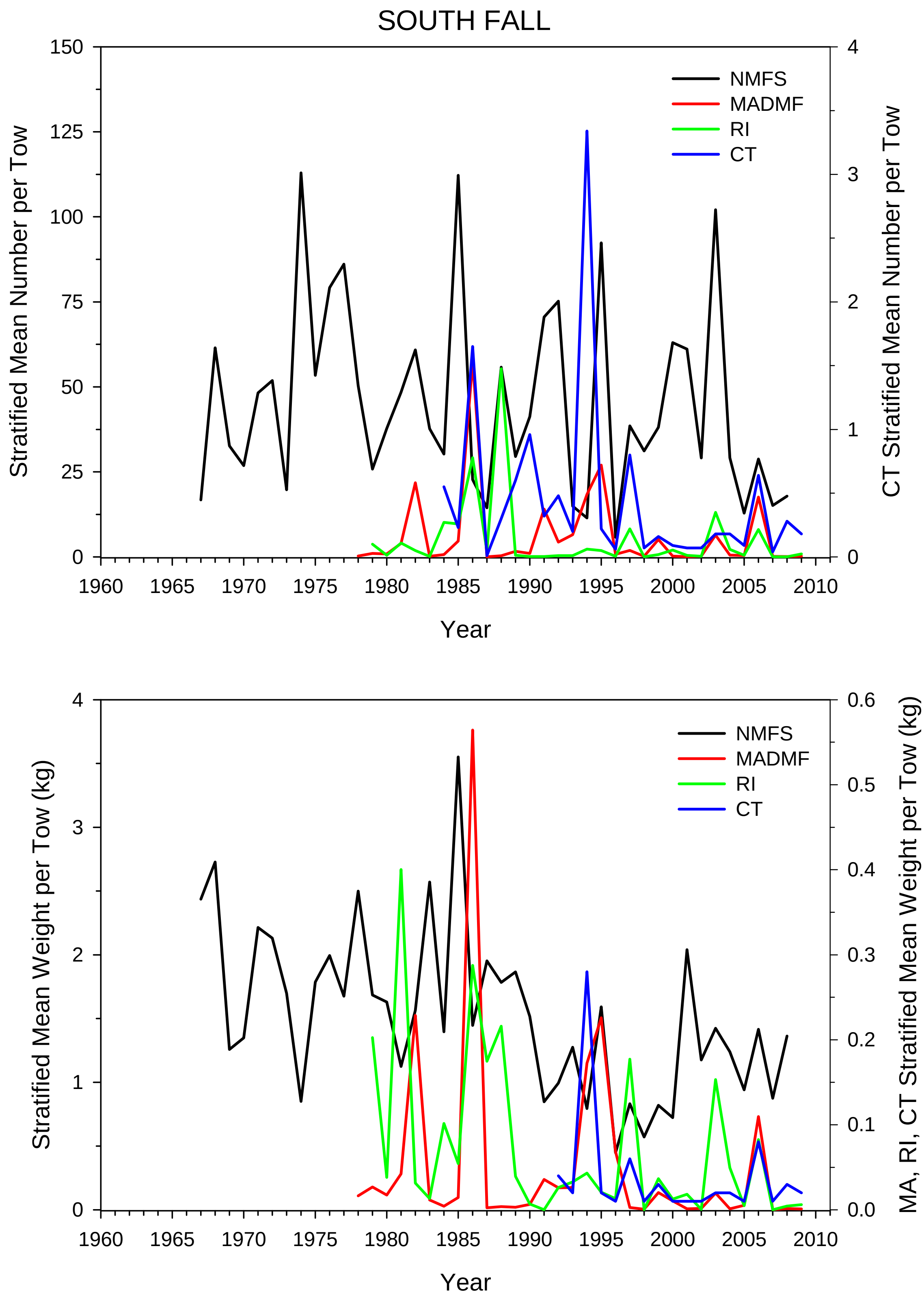
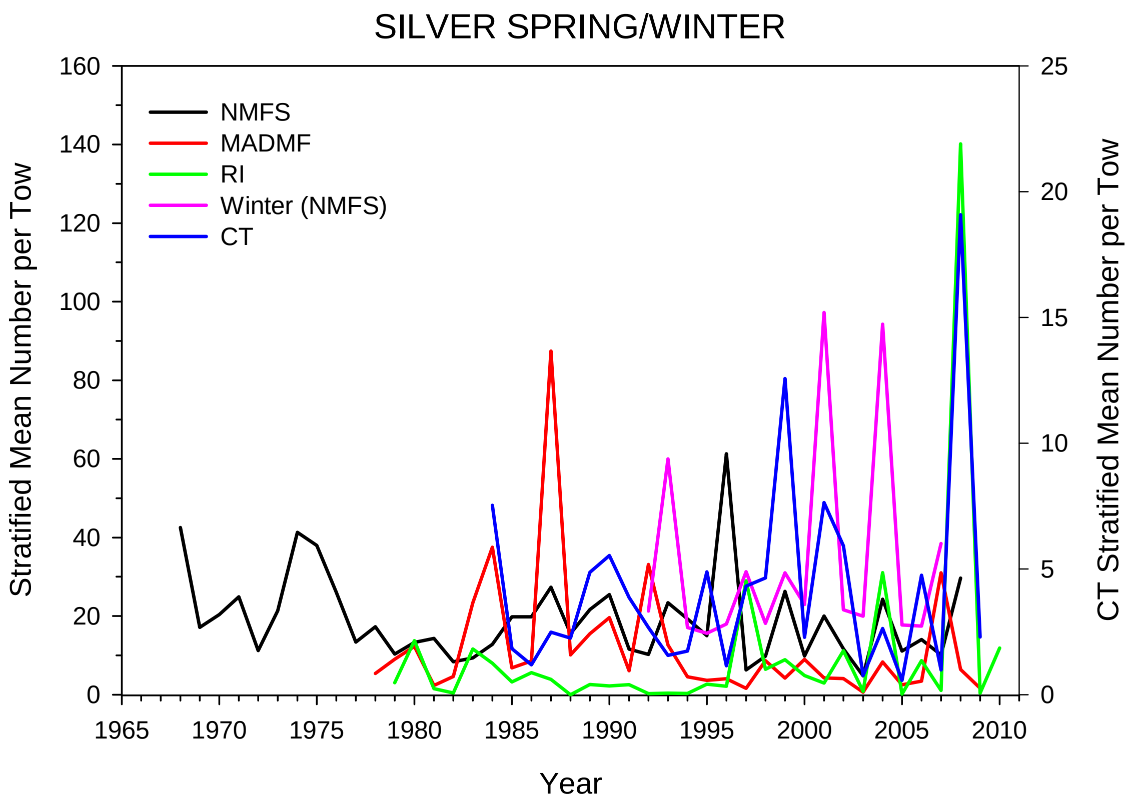


Figure A51. Stratified mean number and weight per tow (kg) for silver hake from the fall NEFSC, MADMF, Rhode Island and Connecticut state surveys.



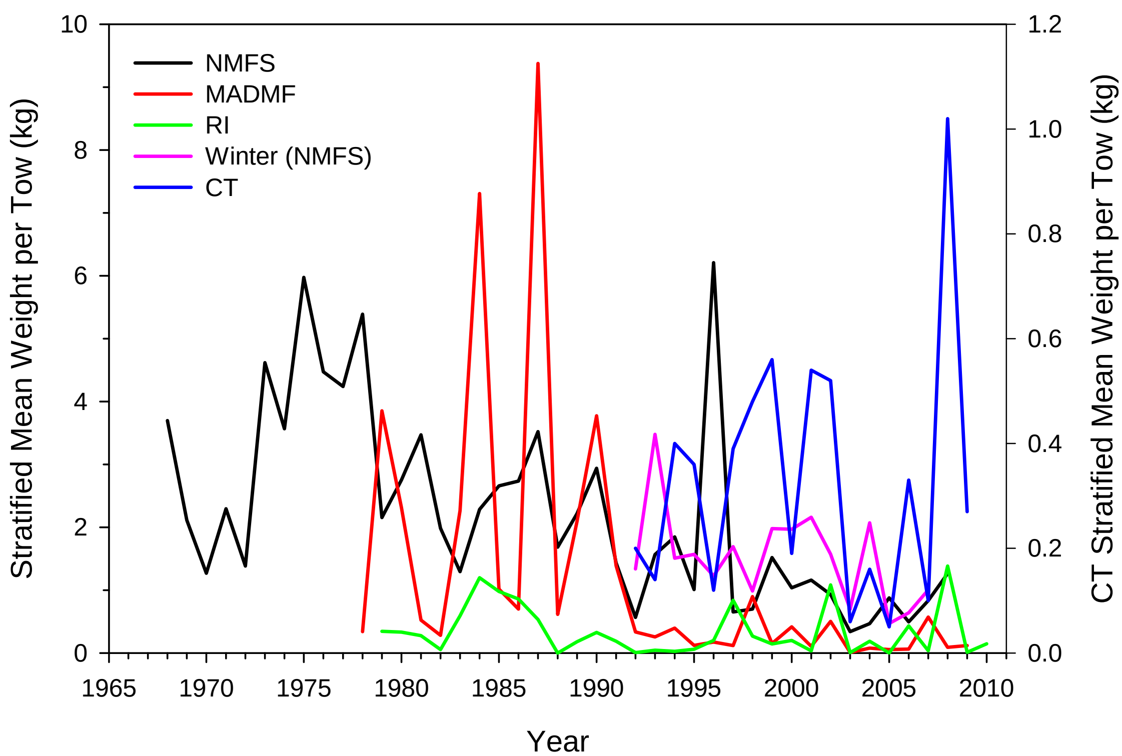


Figure A52. Stratified mean number and weight per tow (kg) for silver hake from the spring and winter NEFSC, MADMF, Rhode Island and Connecticut state surveys.

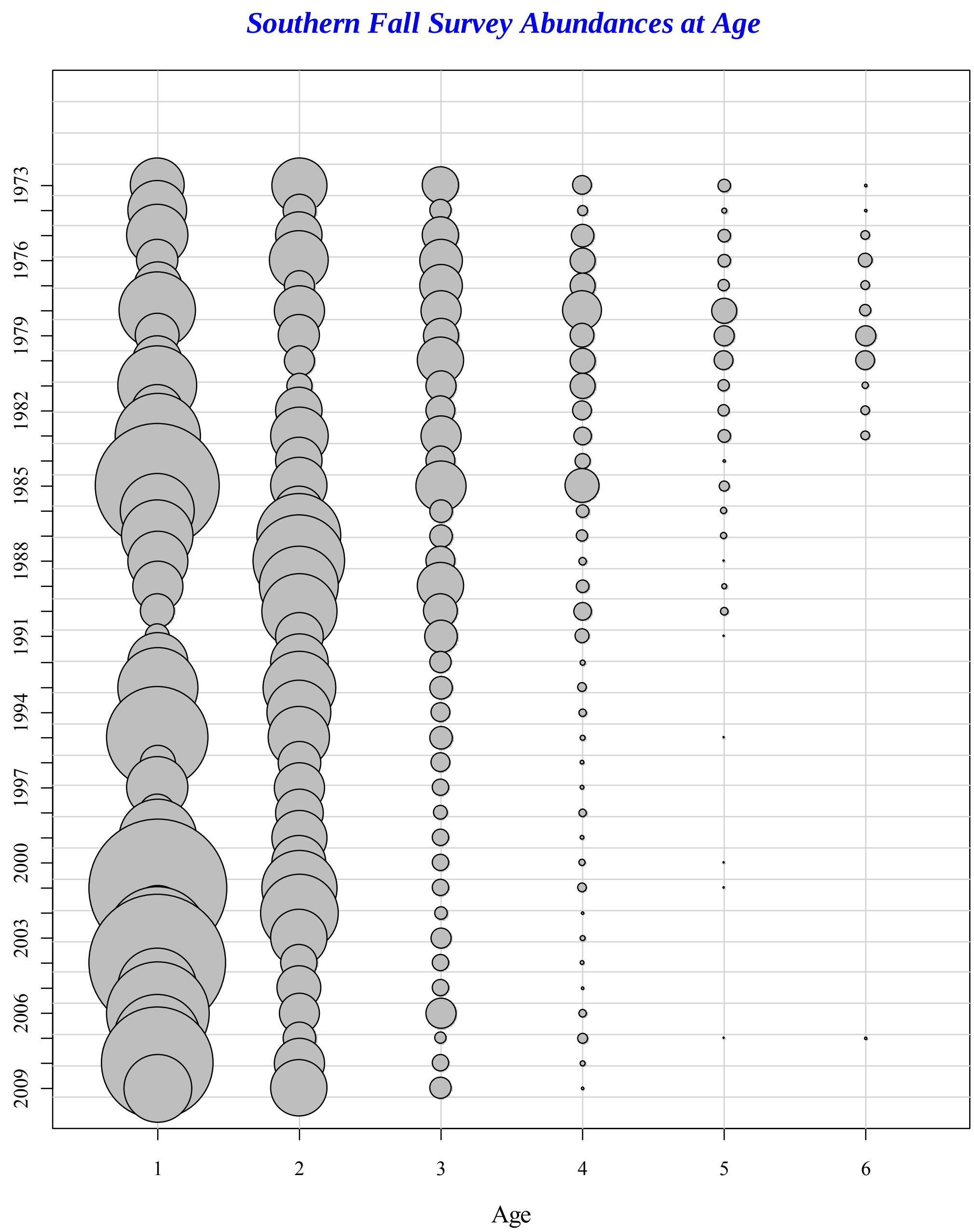


Figure A53. Silver hake age specific indices of abundance for the fall survey in the southern stock area. The area of the bubble plot is proportional to the magnitude.

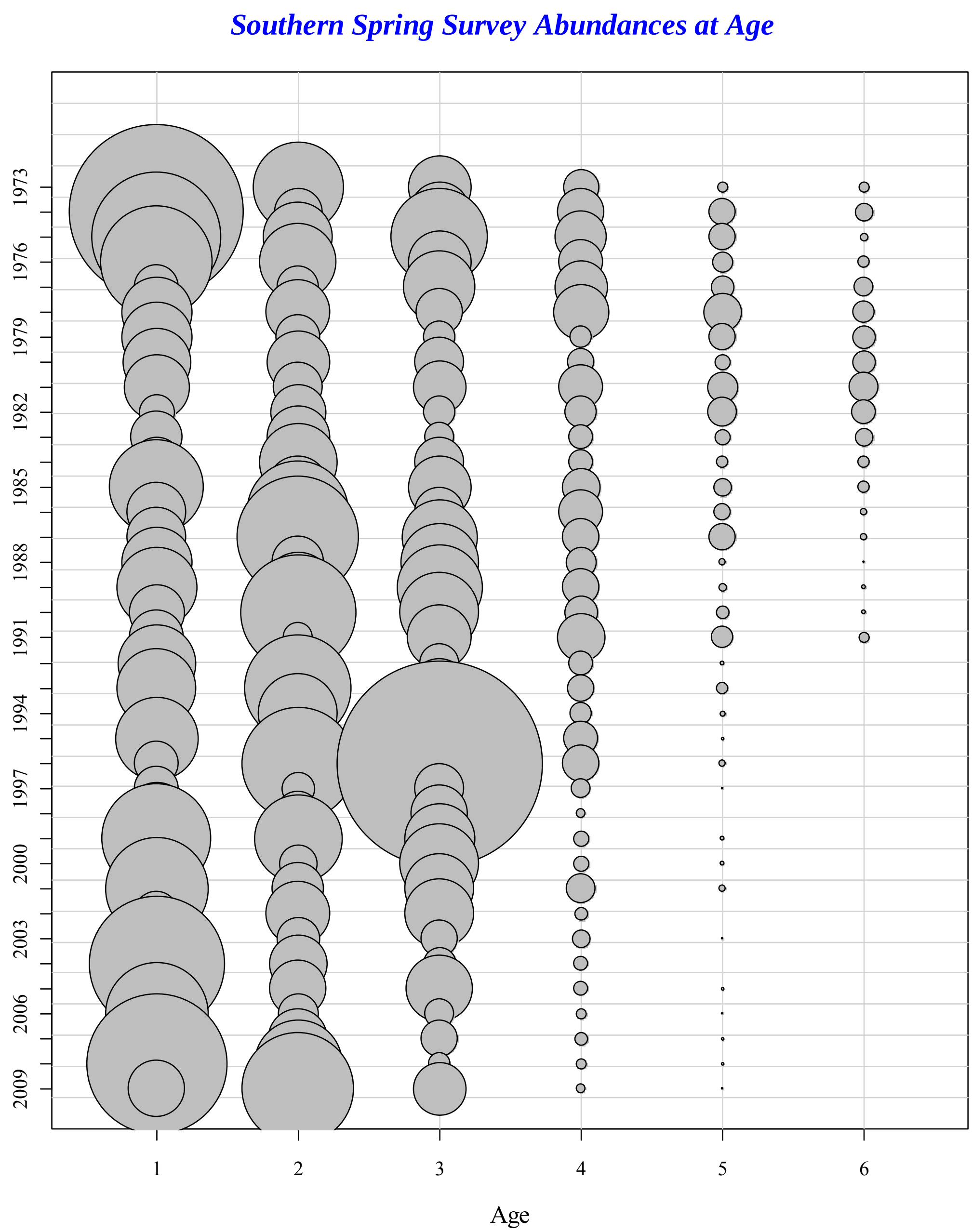


Figure A54. Silver hake age specific indices of abundance for the spring survey in the southern stock area. The area of the bubble plot is proportional to the magnitude.

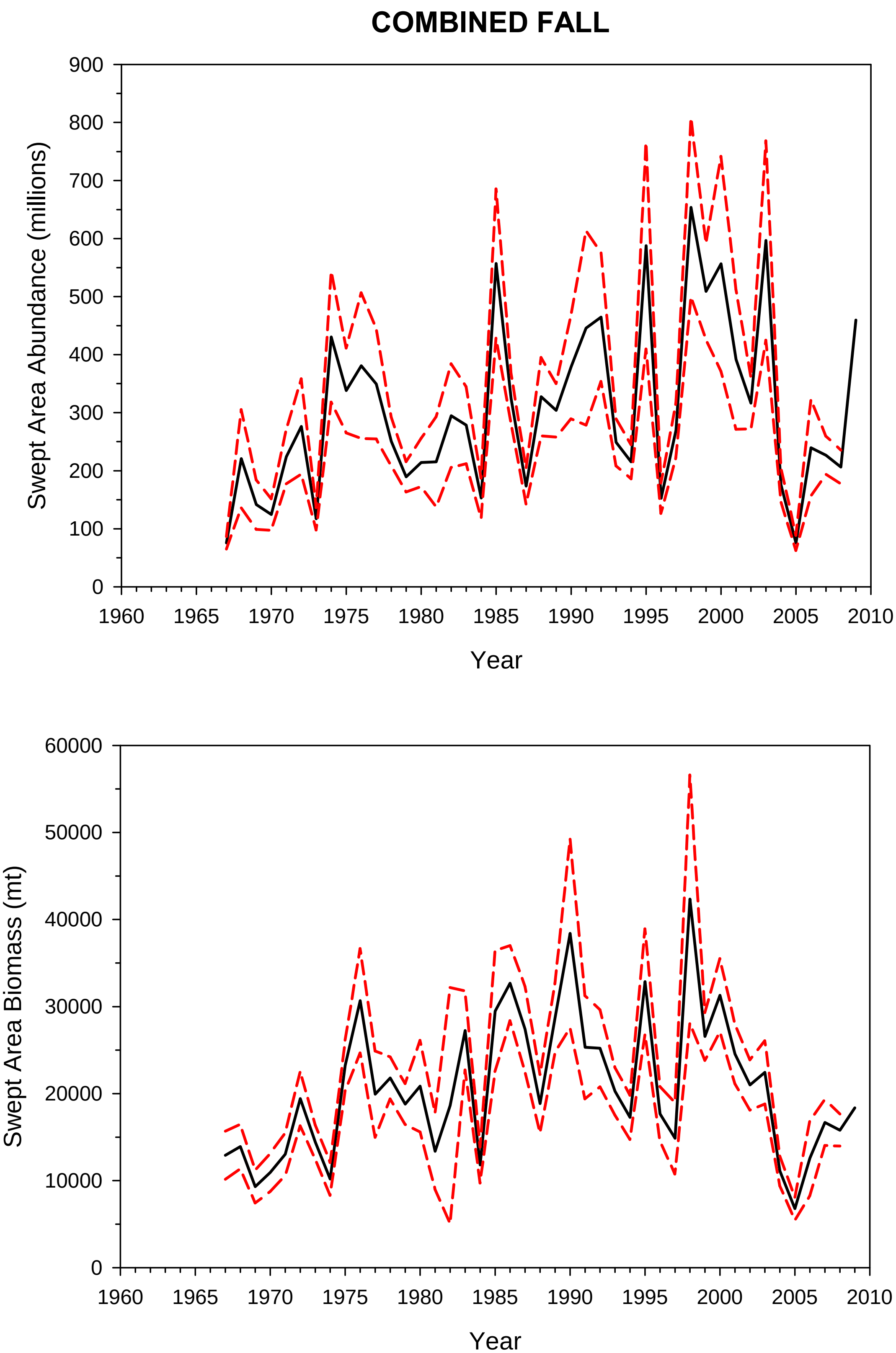
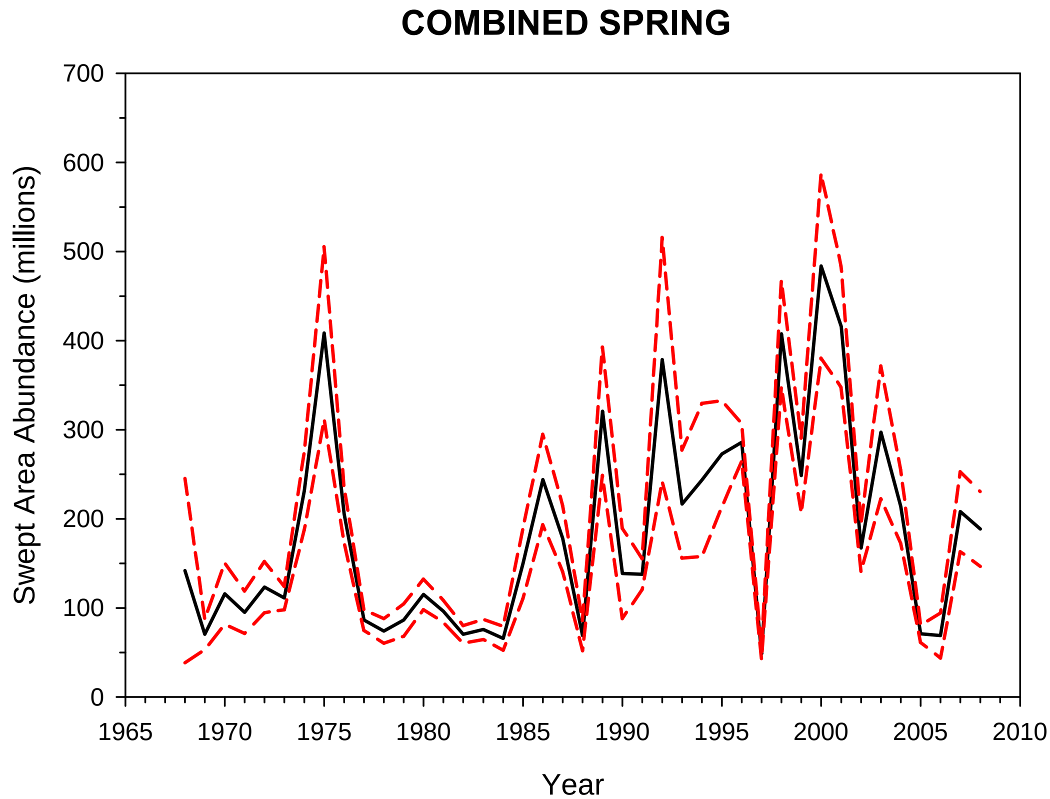


Figure A55. Swept area abundance and biomass and upper and lower confidence intervals for silver hake from the NEFSC fall bottom trawl surveys in the northern and southern management regions combined.



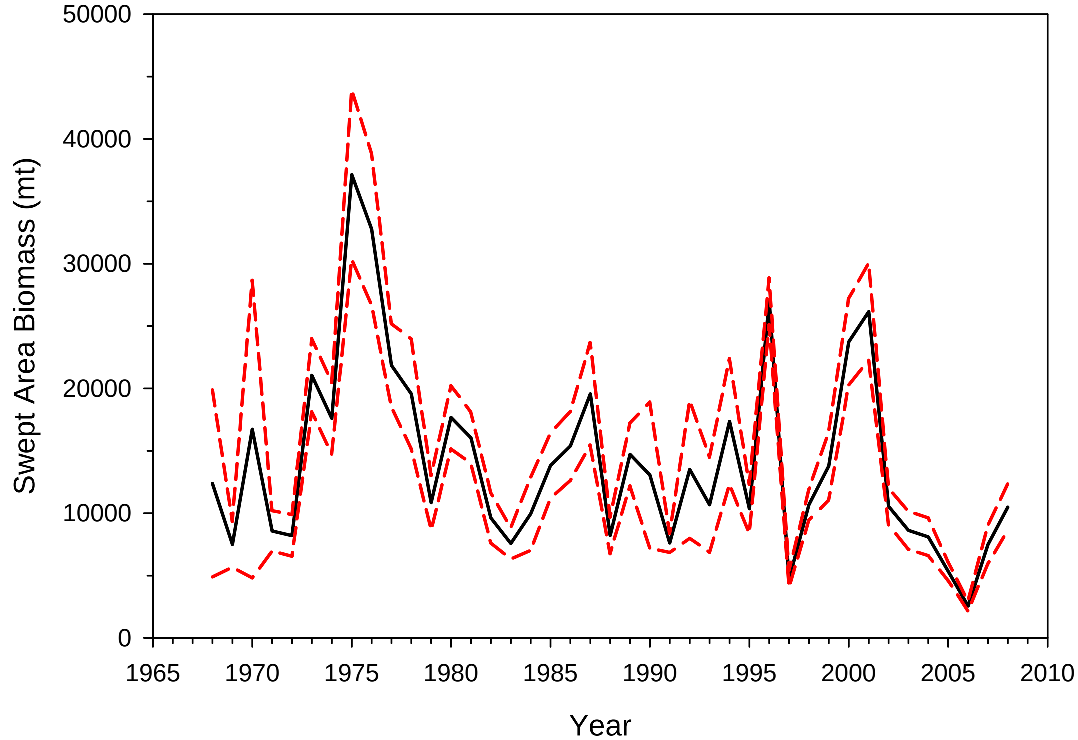


Figure A56. Swept area abundance and biomass and upper and lower confidence intervals for silver hake from the NEFSC spring bottom trawl surveys in the northern and southern management regions combined.

Combined Area Fall Survey Abundances at Age

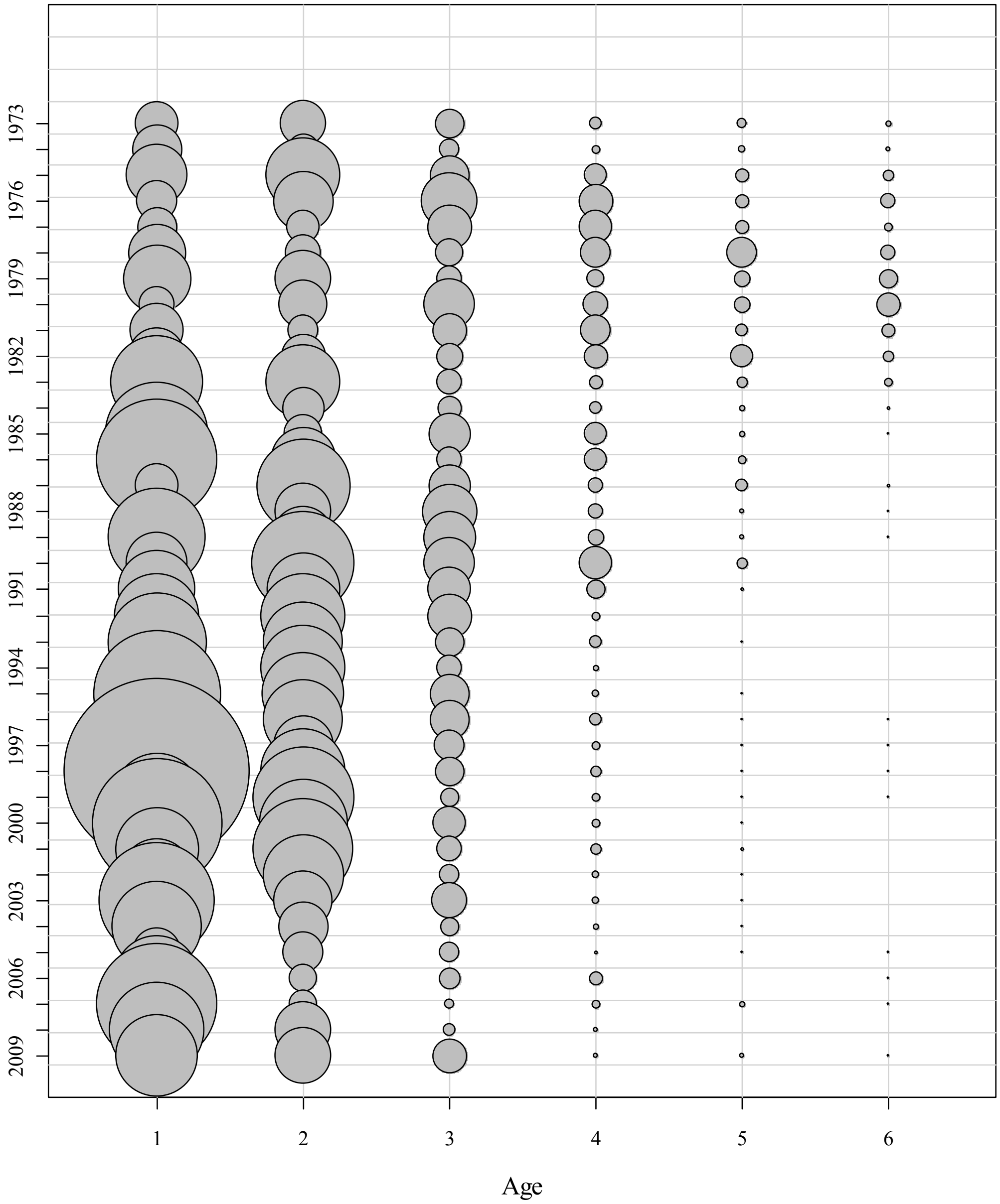


Figure A57 Silver hake age specific fall survey indices of abundance for the combined stock areas. The area of the bubble plot is proportional to the magnitude.

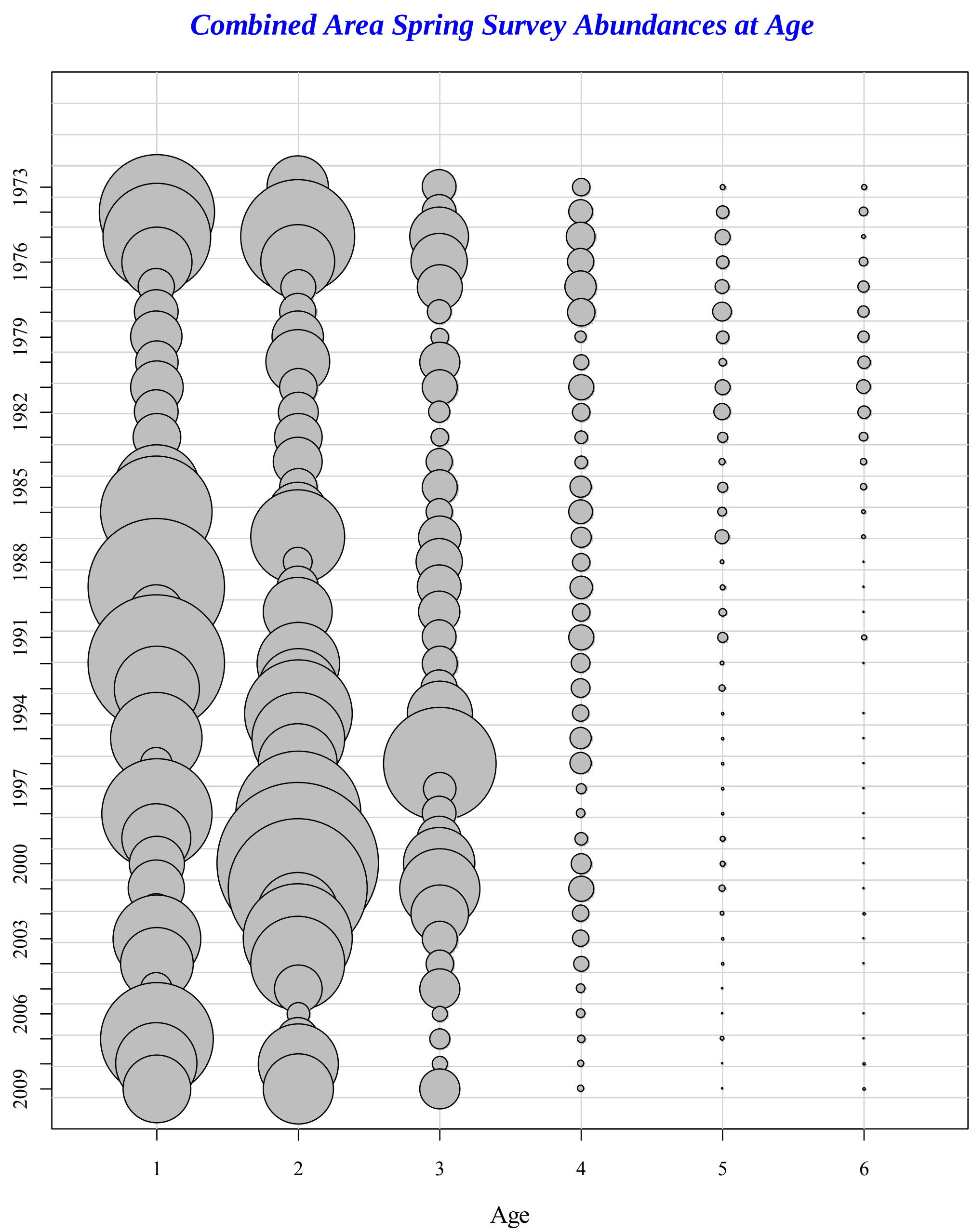


Figure A58. Silver hake age specific spring survey indices of abundance for the combined stock areas. The area of the bubble plot is proportional to the magnitude.

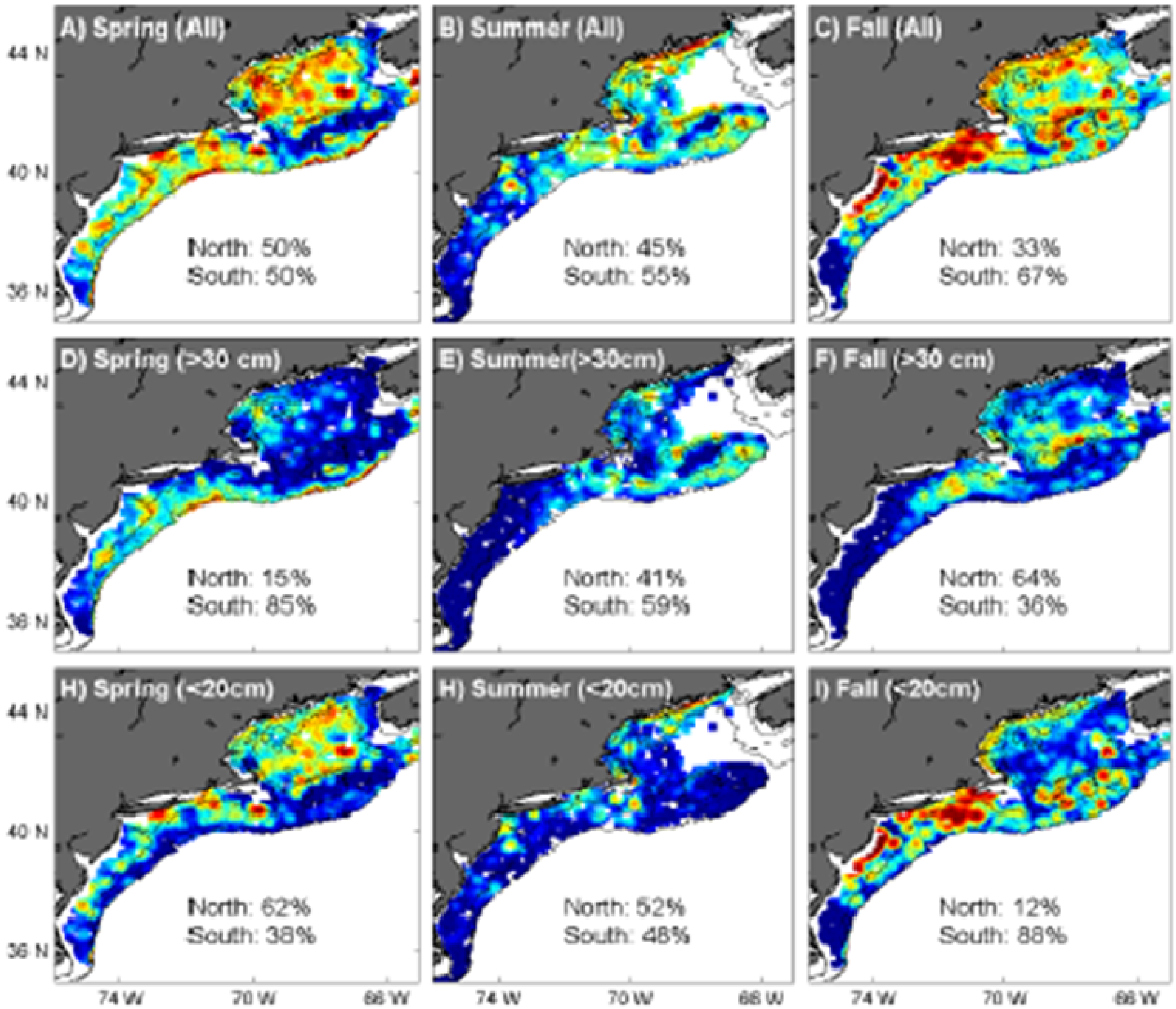
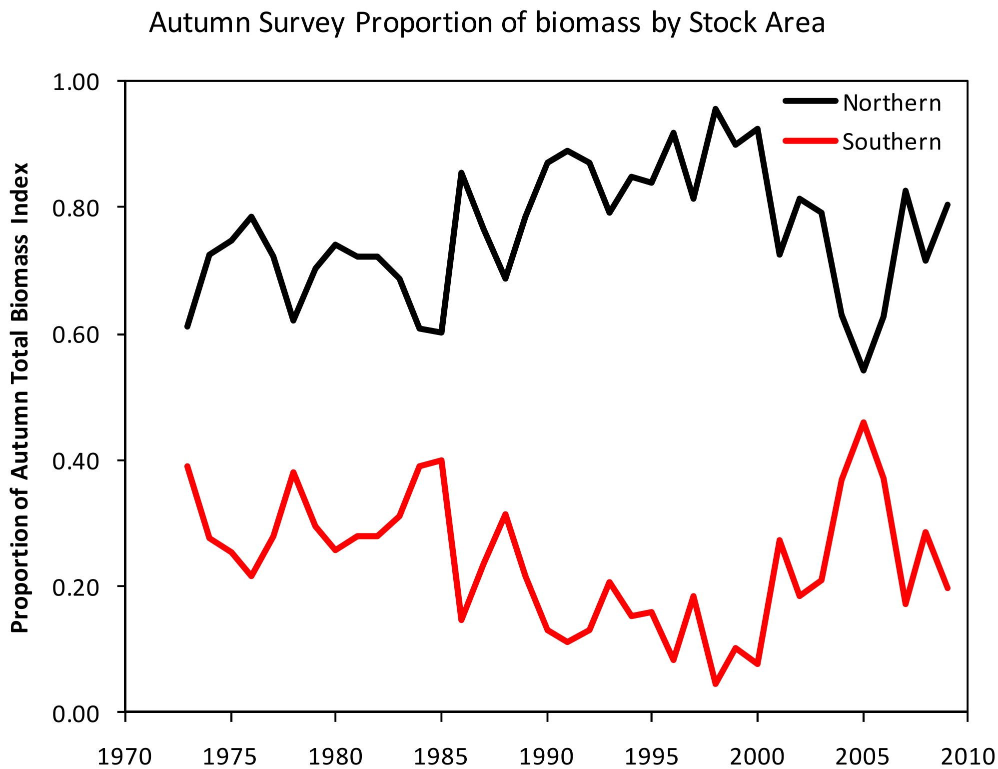


Figure A59: Distribution of silver hake during the NEFSC trawl surveys in the spring, summer and fall of 1977-1981. The summer >30 cm size class should correspond to the spawning distribution of silver hake.



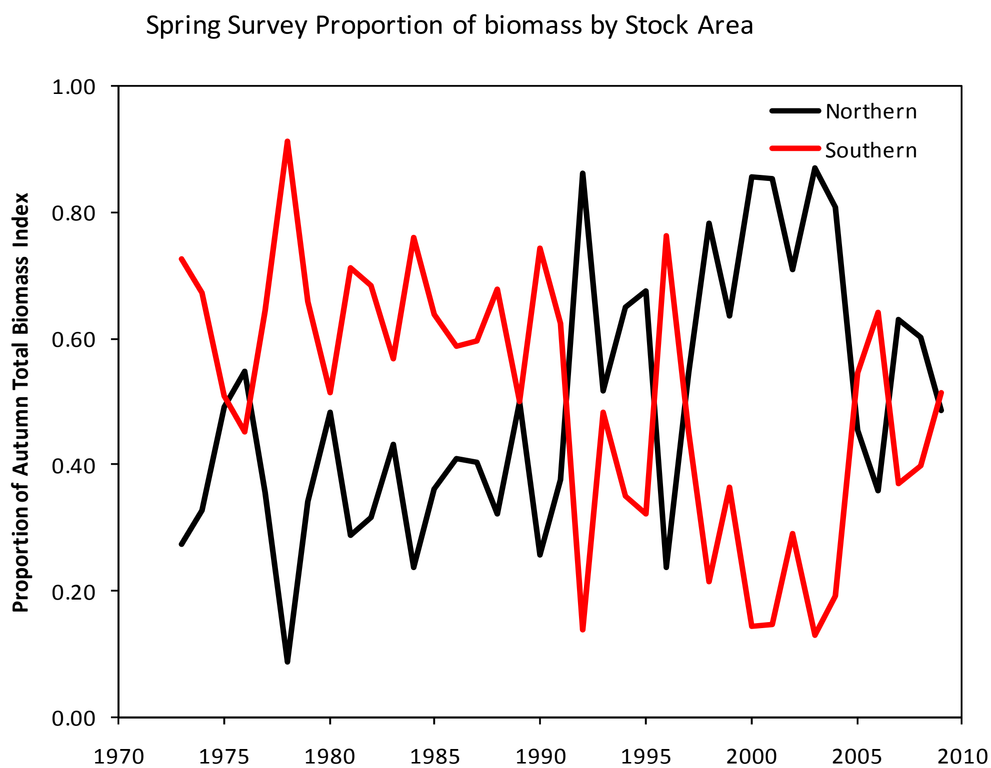


Figure A60: Autumn (top) and spring (bottom) survey distribution of silver hake by area.

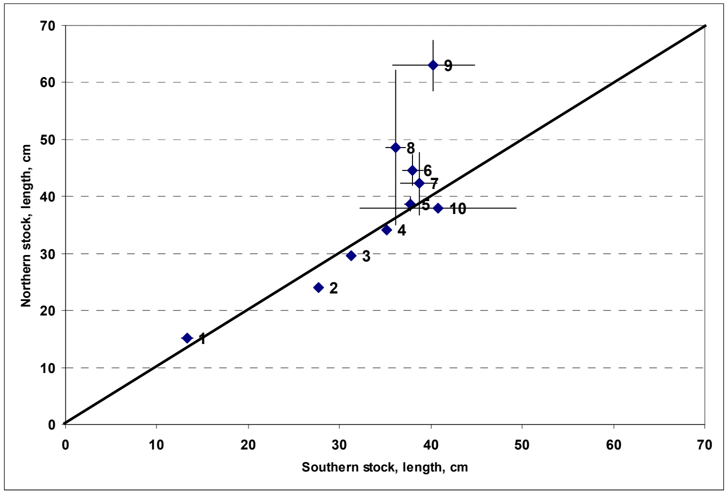
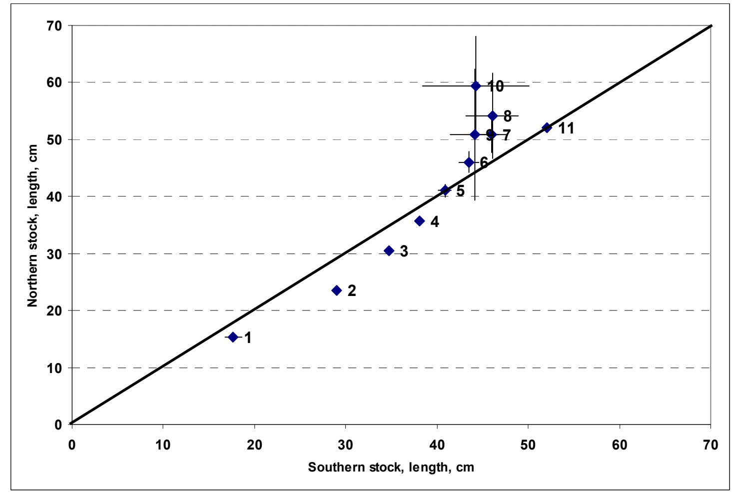
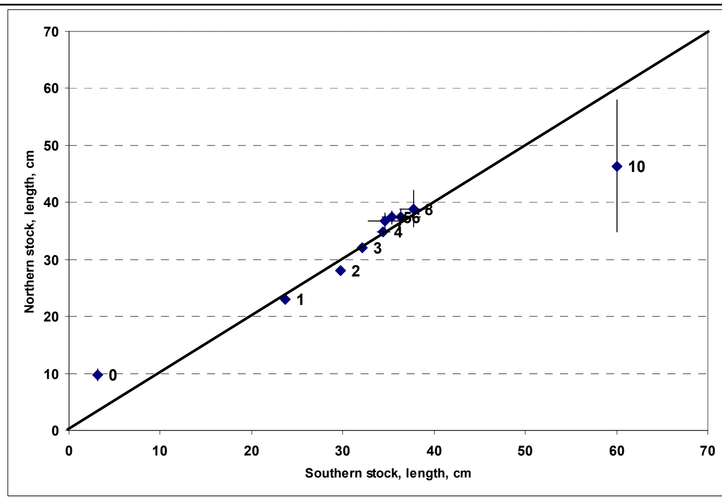
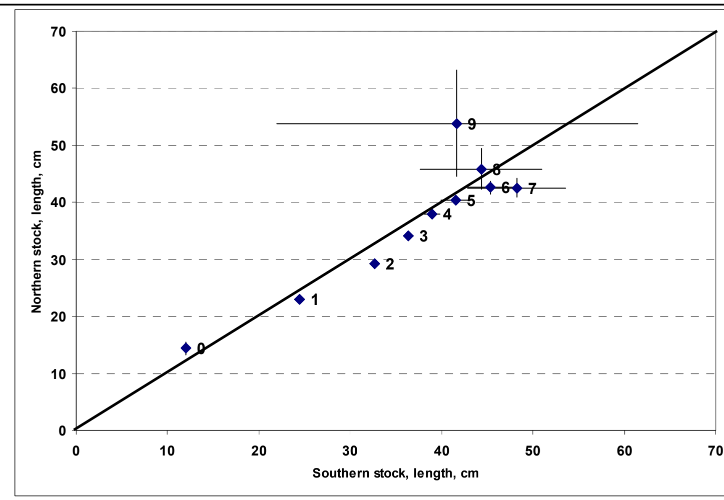
Silver hake	Males	Females
Spring		
Fall		

Figure A61. Size (cm total length) at age comparison between silver hake caught in strata 1-19, 61-76 (Southern stock) and strata 20-40 (Northern stock) for 1962-1979 cohorts.

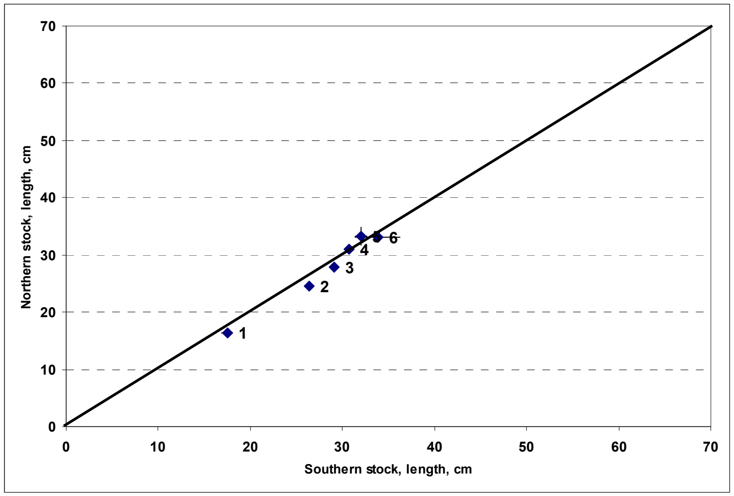
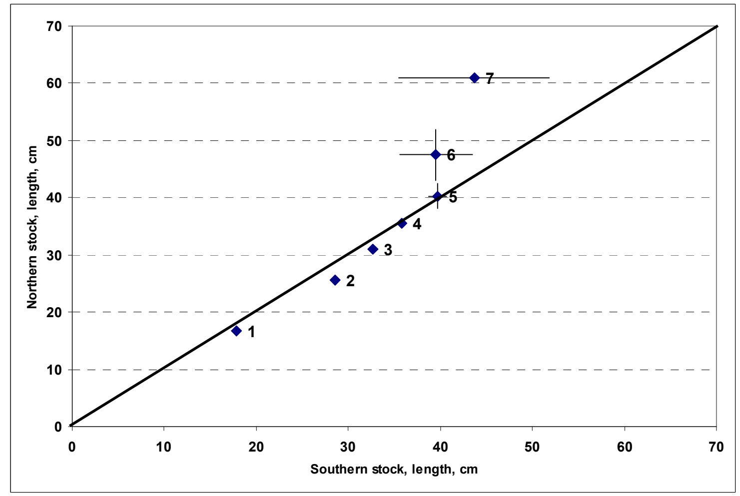
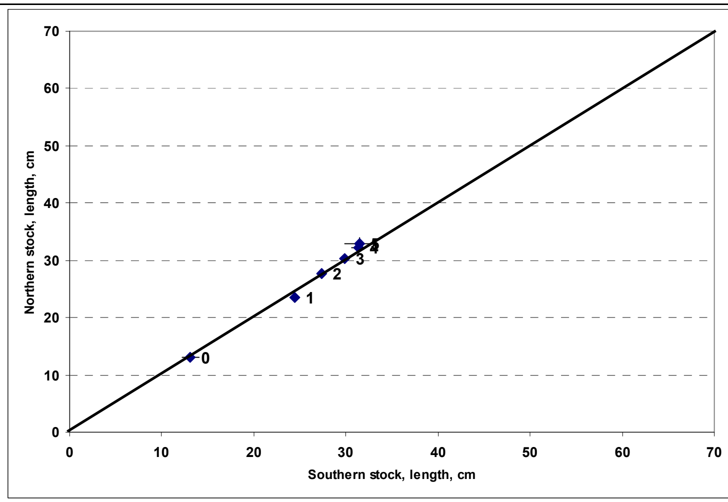
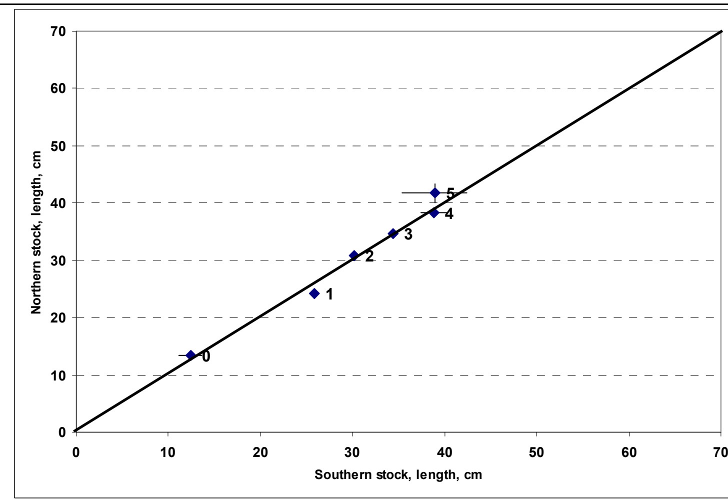
Silver hake	Males	Females
Spring		
Fall		

Figure A62. Size (cm total length) at age comparison between silver hake caught in strata 1-19, 61-76 (Southern stock) and strata 20-40 (Northern stock) for 1980-1989 cohorts.

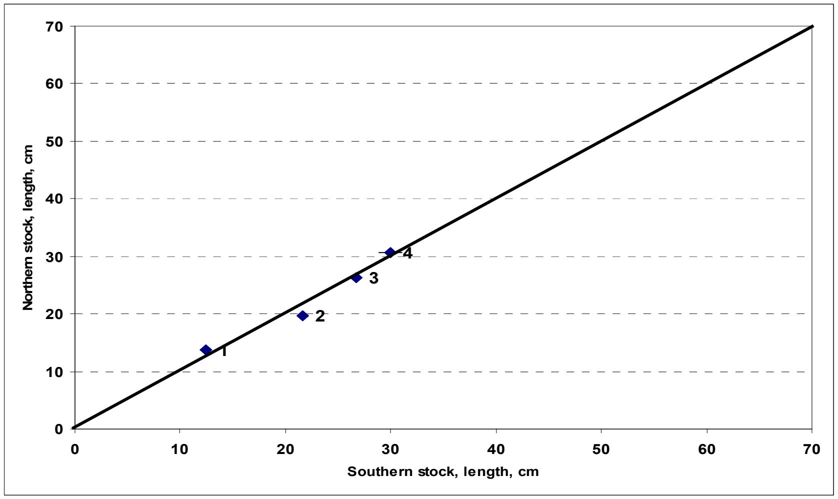
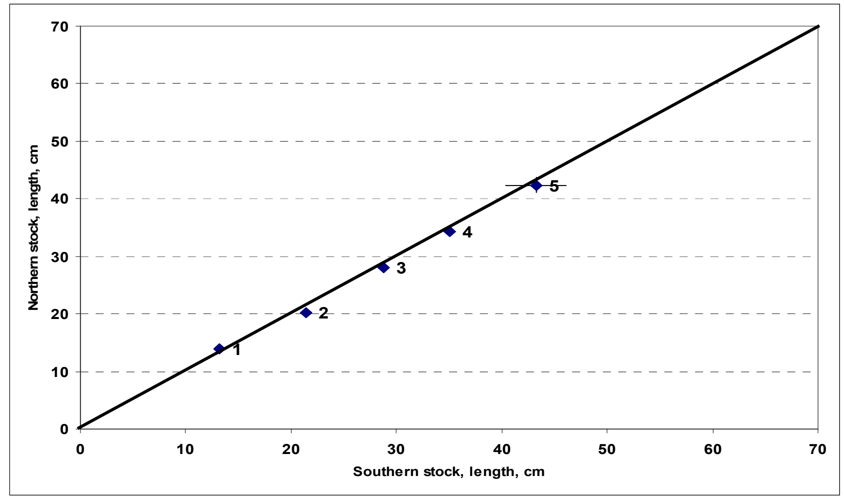
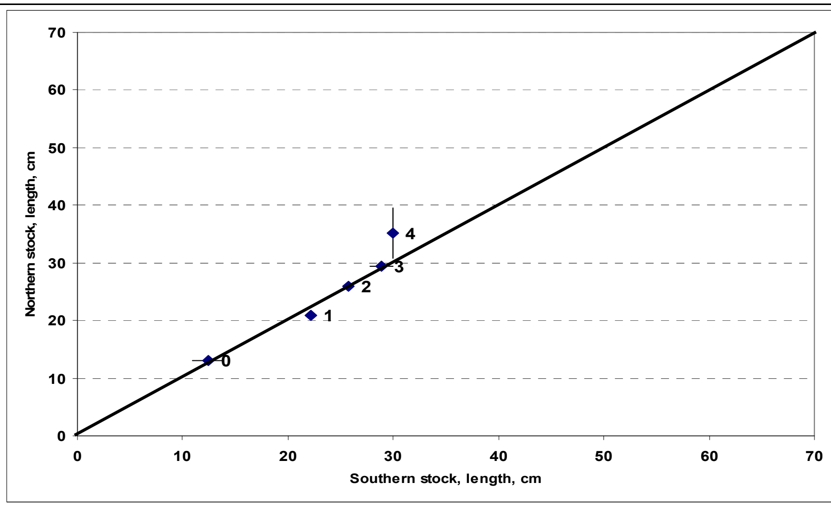
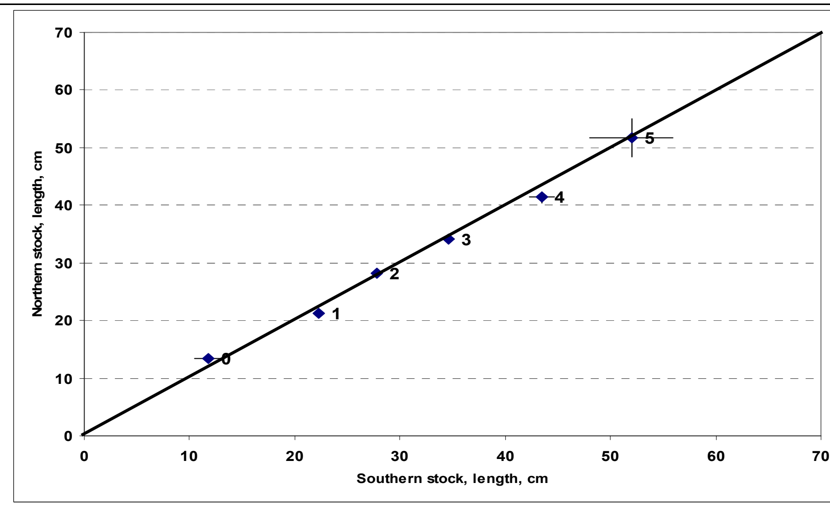
Silver hake	Males	Females
Spring		
Fall		

Figure A63. Size (cm total length) at age comparison between red hake caught in strata 1-19, 61-76 (Southern stock) and strata 20-40 (Northern stock) for 1990-1999 cohorts.

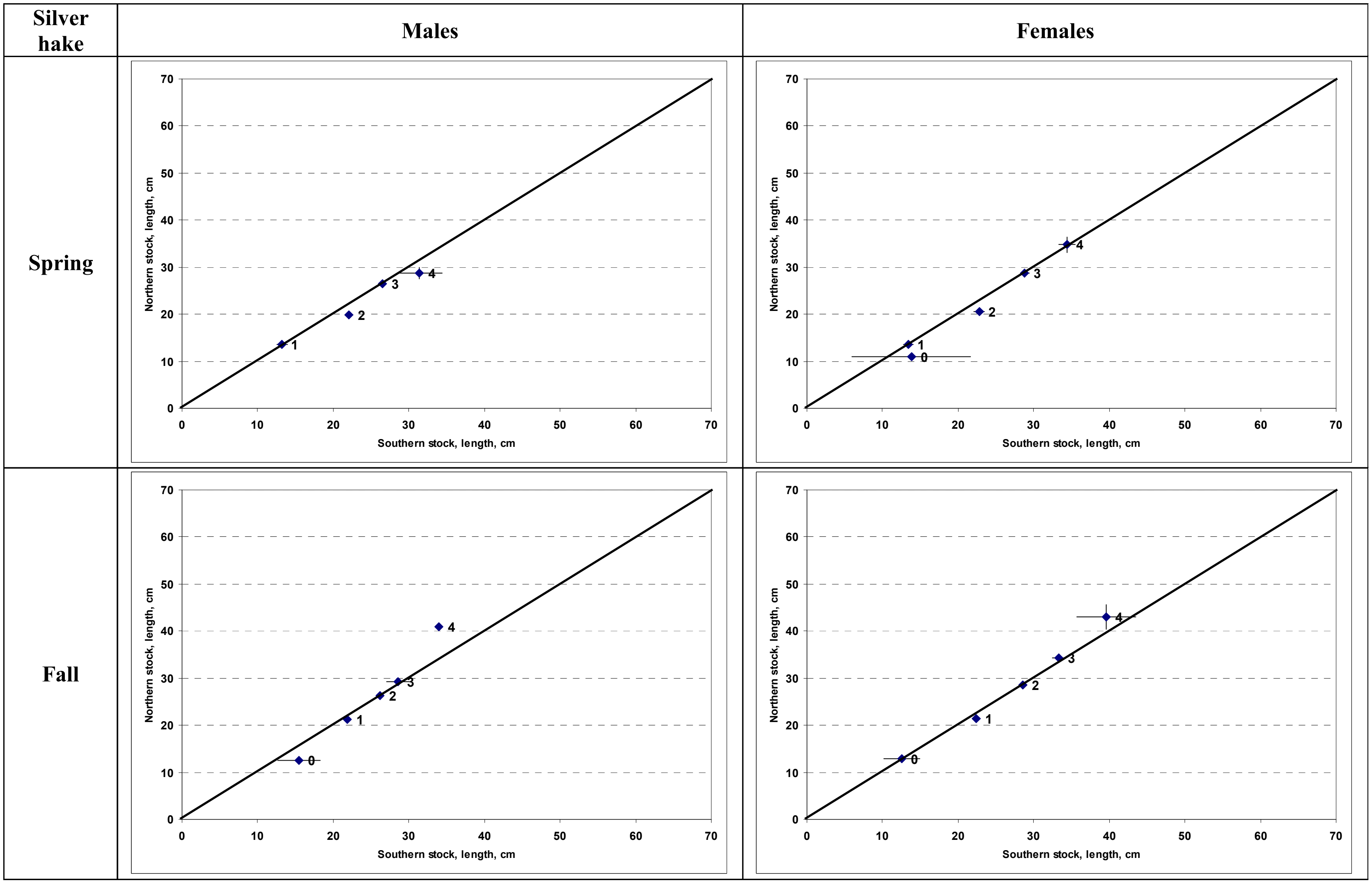


Figure A64. Size (cm total length) at age comparison between red hake caught in strata 1-19, 61-76 (Southern stock) and strata 20-40 (Northern stock) for 2000-2009 cohorts.

A50 North and South Silver Hake

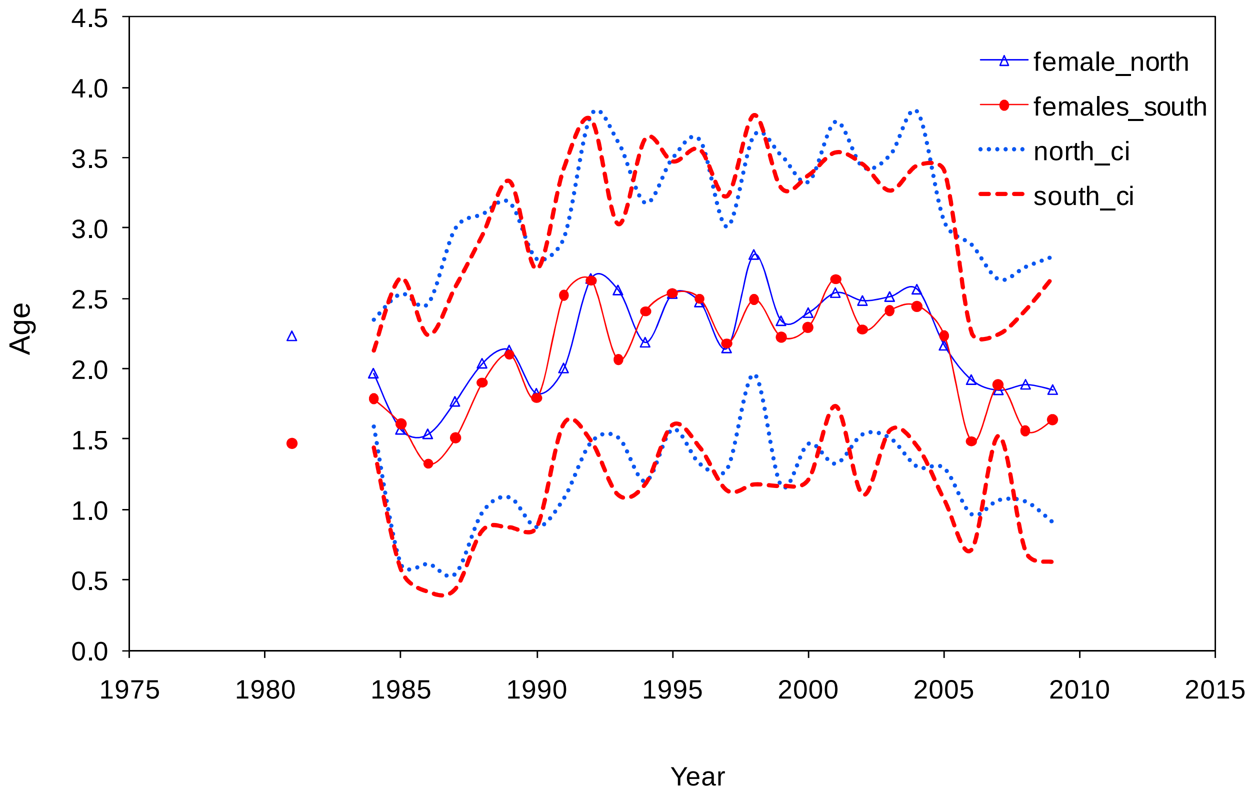
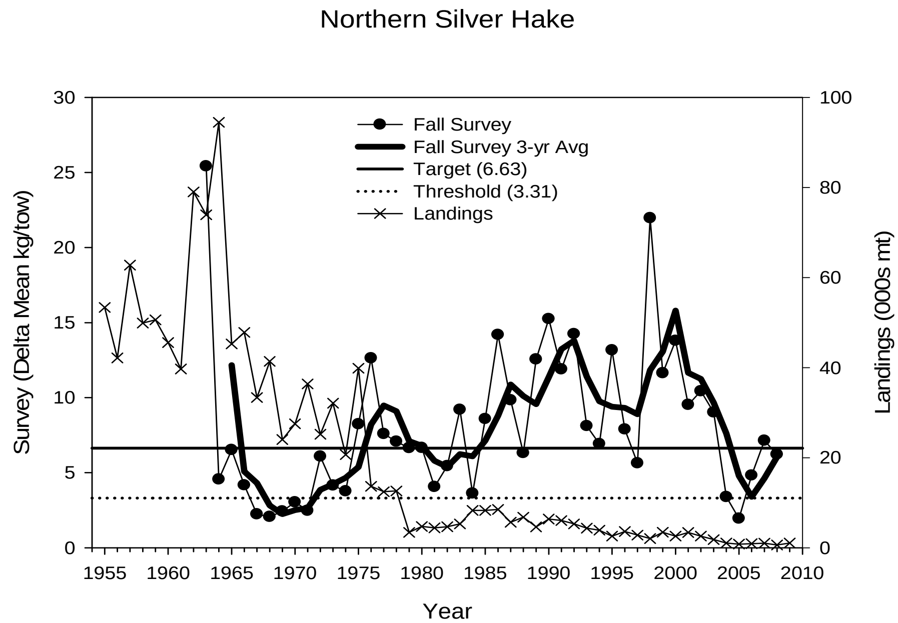


Figure A65: Time series of median size at maturity (A50) and 95% confidence interval for silver hake in the northern and southern management area



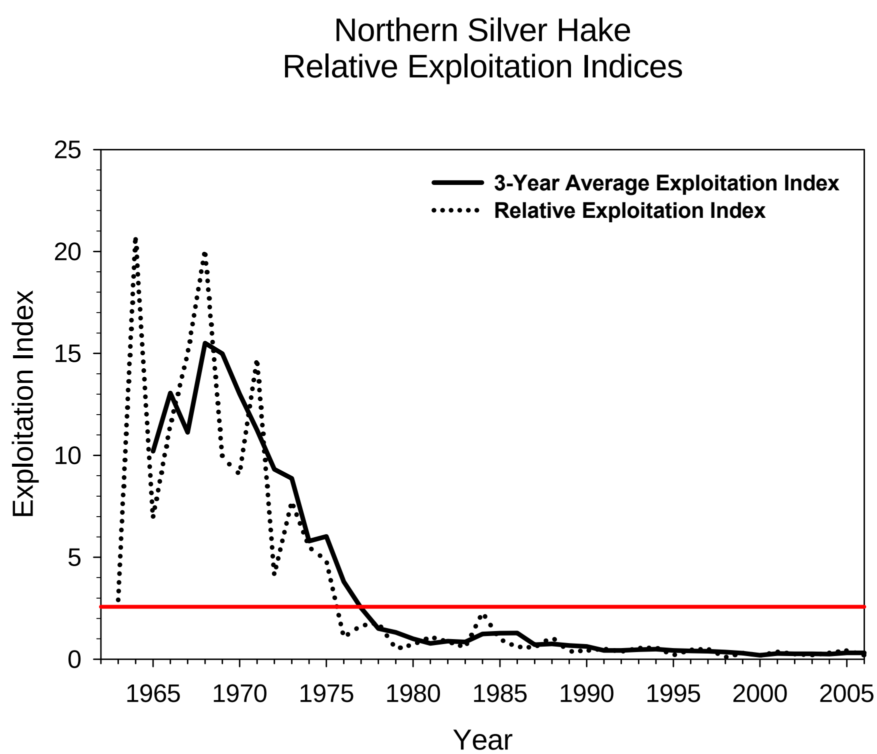
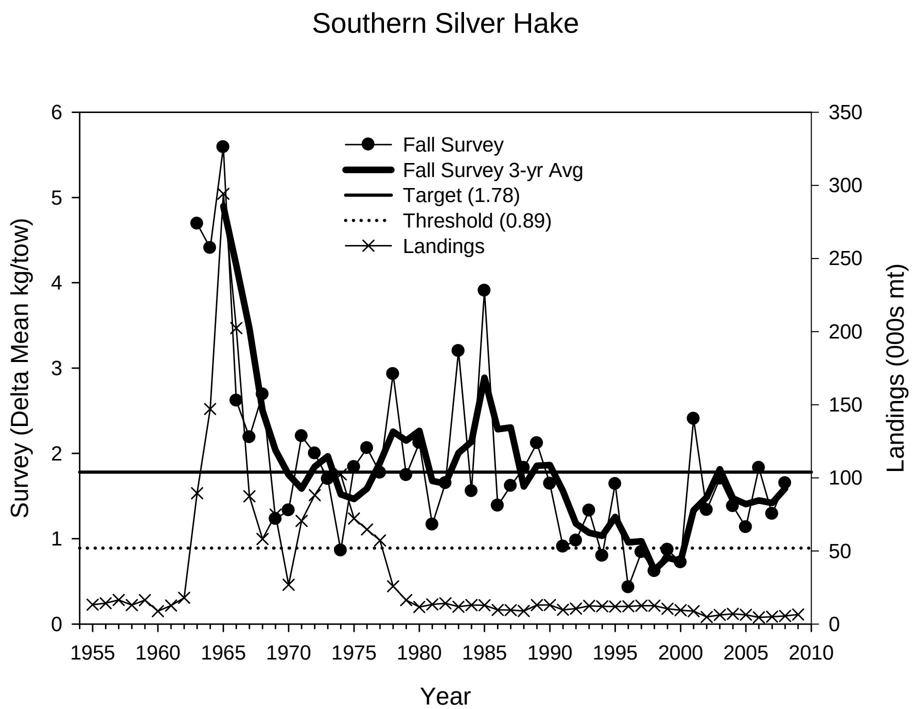


Figure A66. Abundance and exploitation indices for the northern stock of silver hake. Top: Fall abundance index (delta mean/tow) with 3 yr running average and current reference points for biomass. Bottom: landings/delta fall survey biomass (exploitation index)



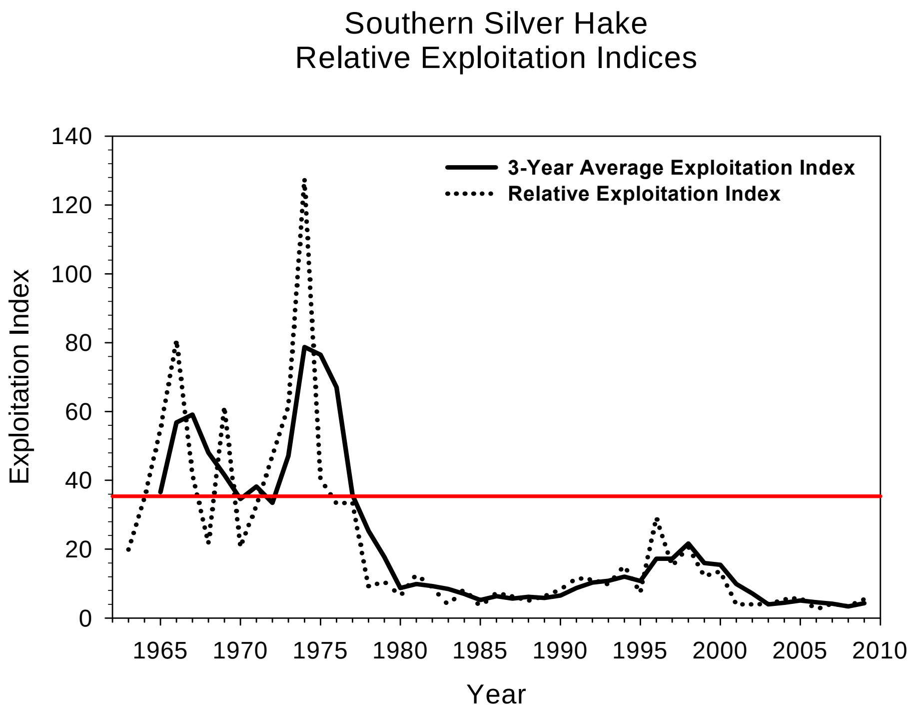
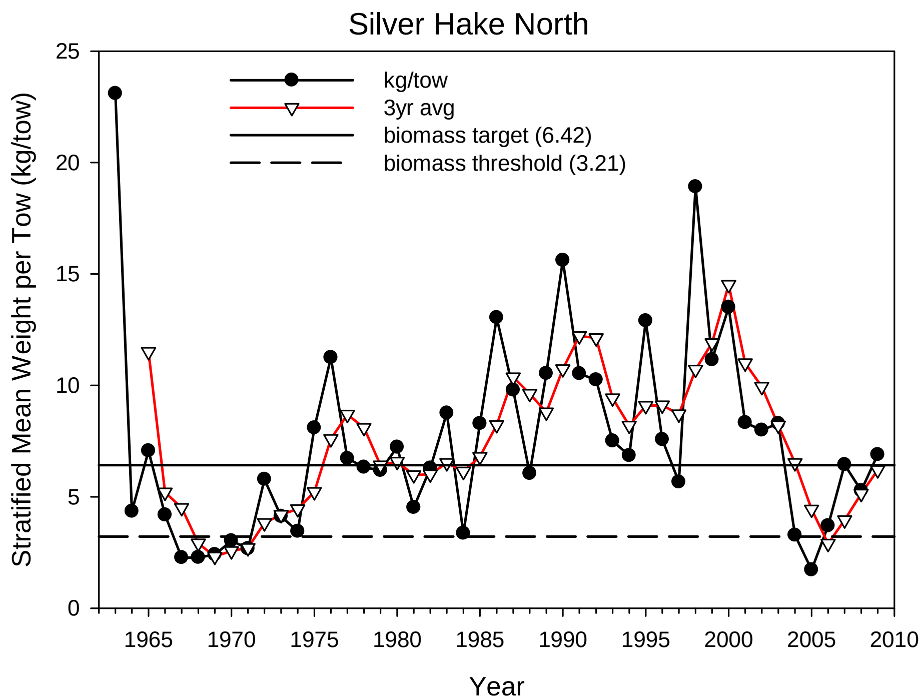


Figure A67. Abundance and exploitation indices for the southern stock of silver hake. Top: Fall abundance index (delta mean/tow) with 3 yr running average and current reference points for biomass. Bottom: landings/delta fall survey biomass (exploitation index)



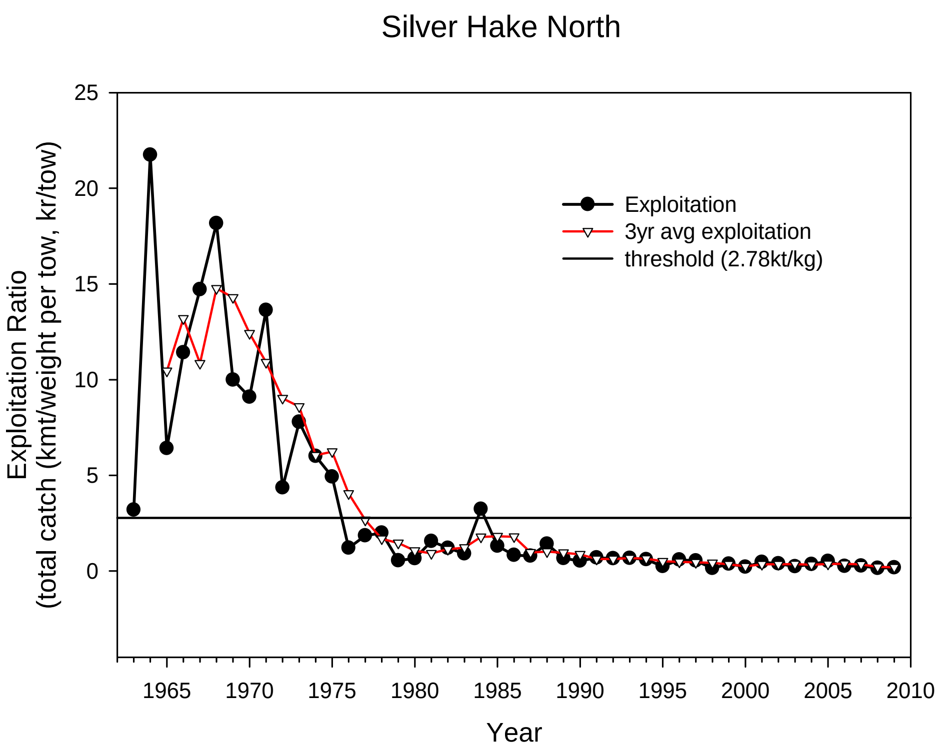
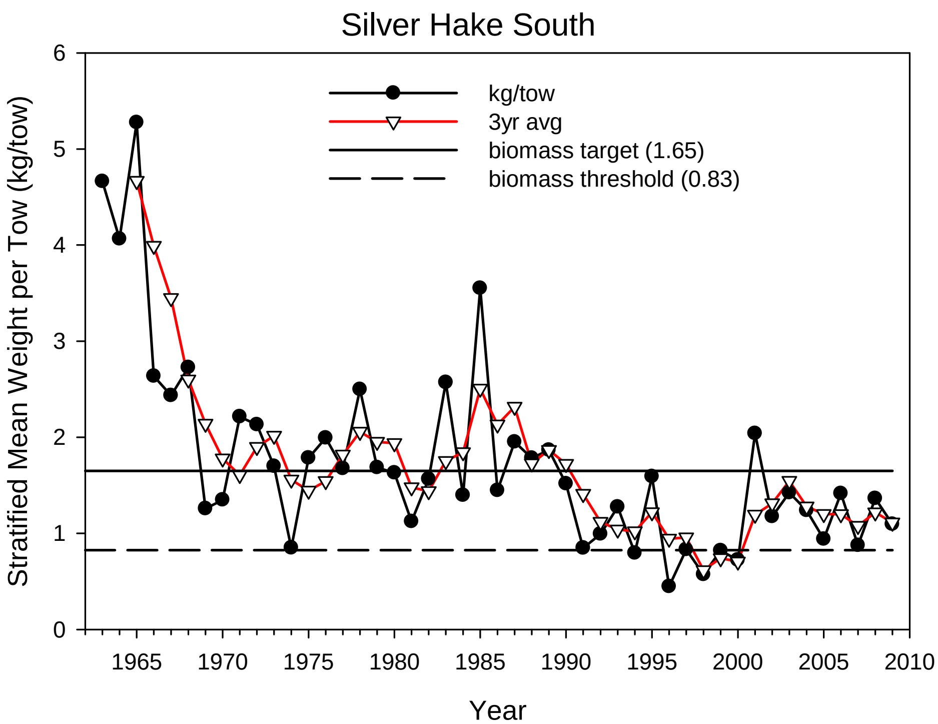


Figure A68. Abundance and exploitation indices for the northern stock of silver hake. Top: Fall abundance index (arithmetic mean/tow) with 3 yr running average and current reference points for biomass. Bottom: catch/arithmetic fall survey biomass (exploitation index)



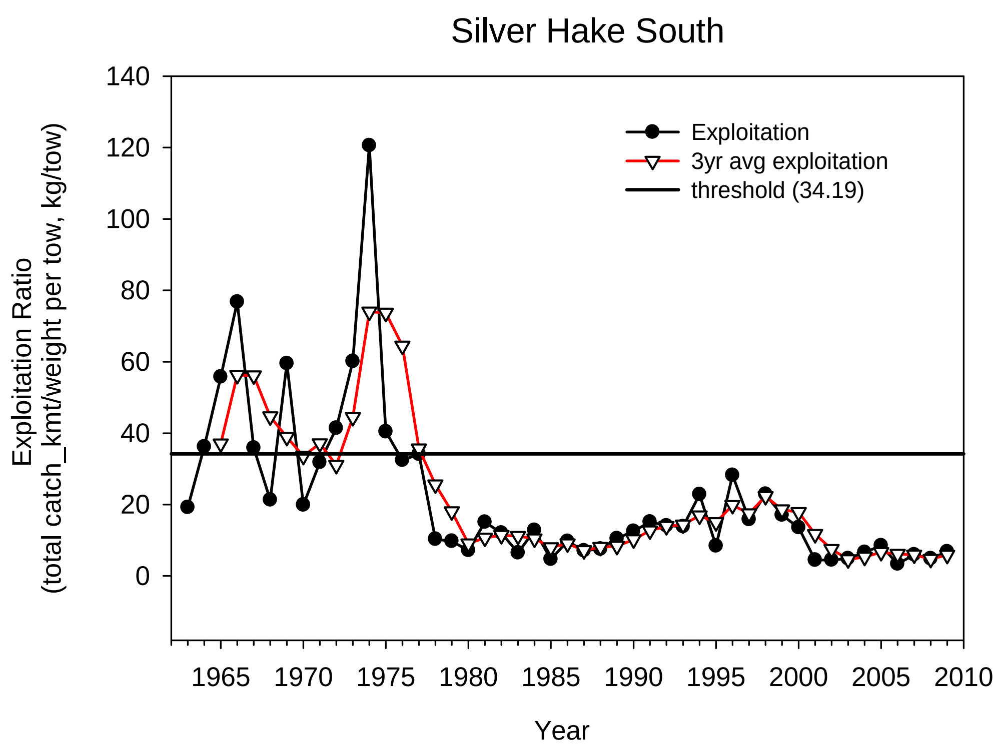


Figure A69. Abundance and exploitation indices for the southern stock of silver hake. Top: Fall abundance index (arithmetic mean/tow) with 3 yr running average and current reference points for biomass. Bottom: catch/arithmetic fall survey biomass (exploitation index)

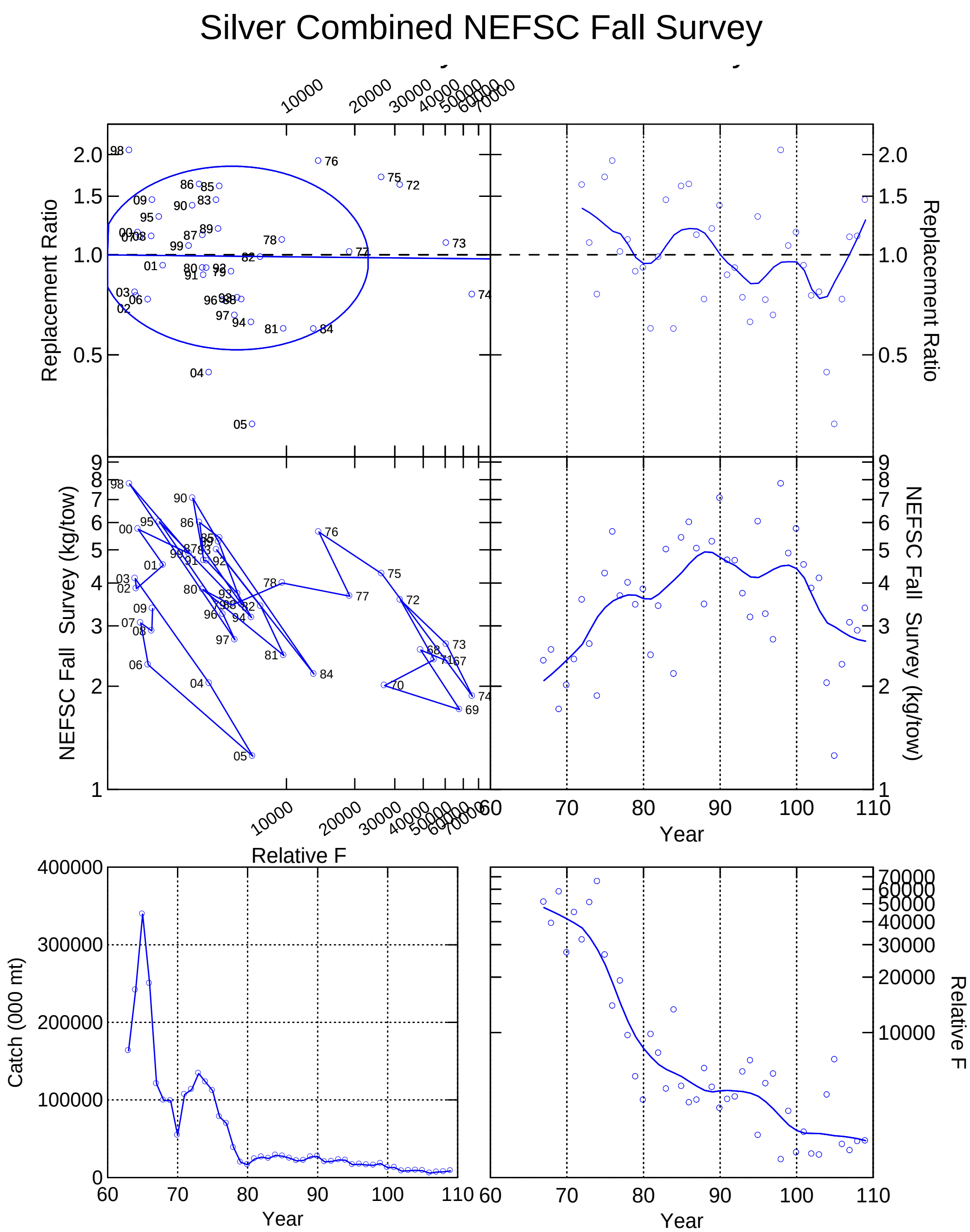


Figure. A70. Six panel plot for silver hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC Fall bottom trawl survey index and landings based on the Sosebee method. Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.

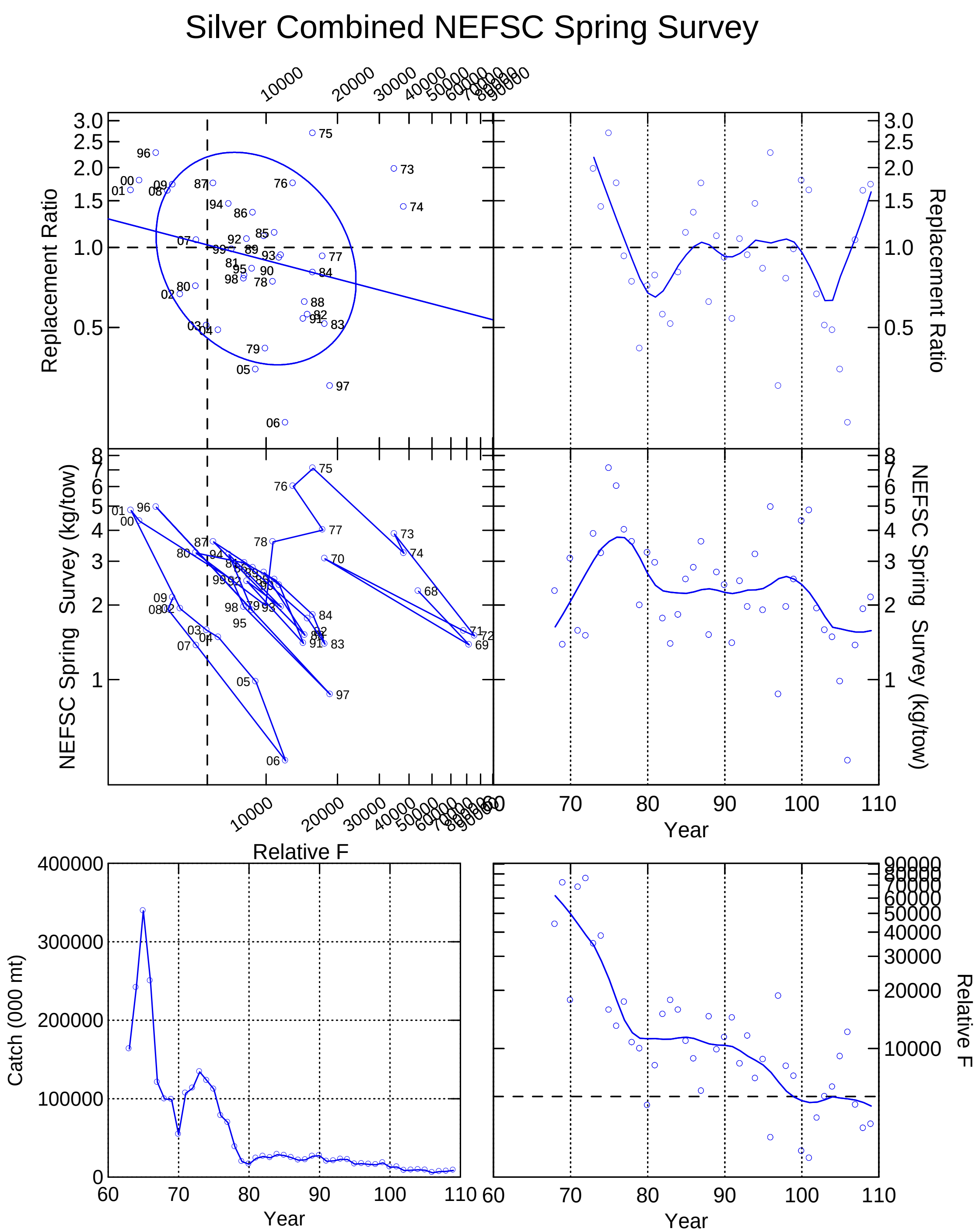
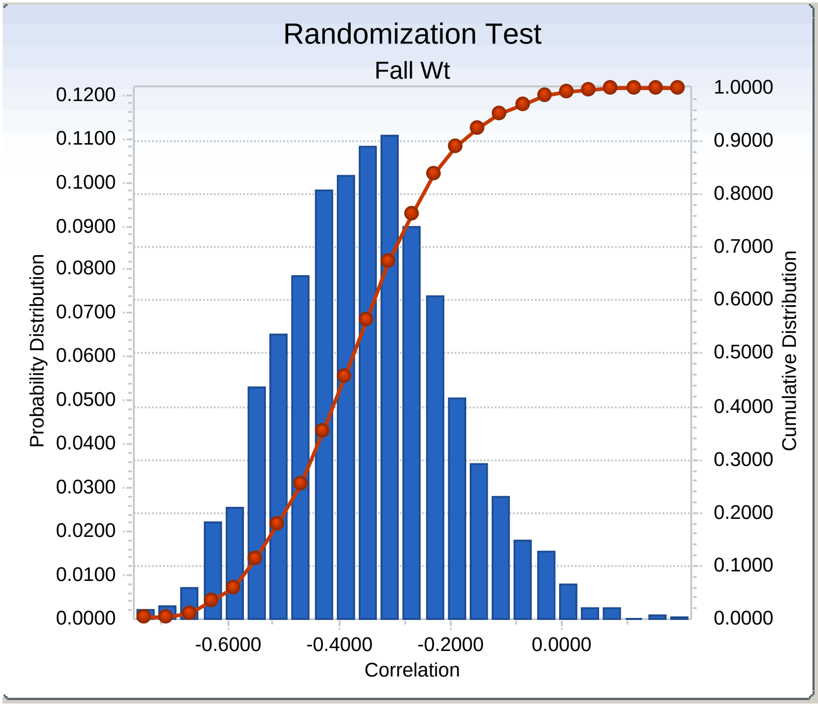


Figure. A71. Six panel plot for silver hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC spring bottom trawl survey index and landings based on the Sosebee method . Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.



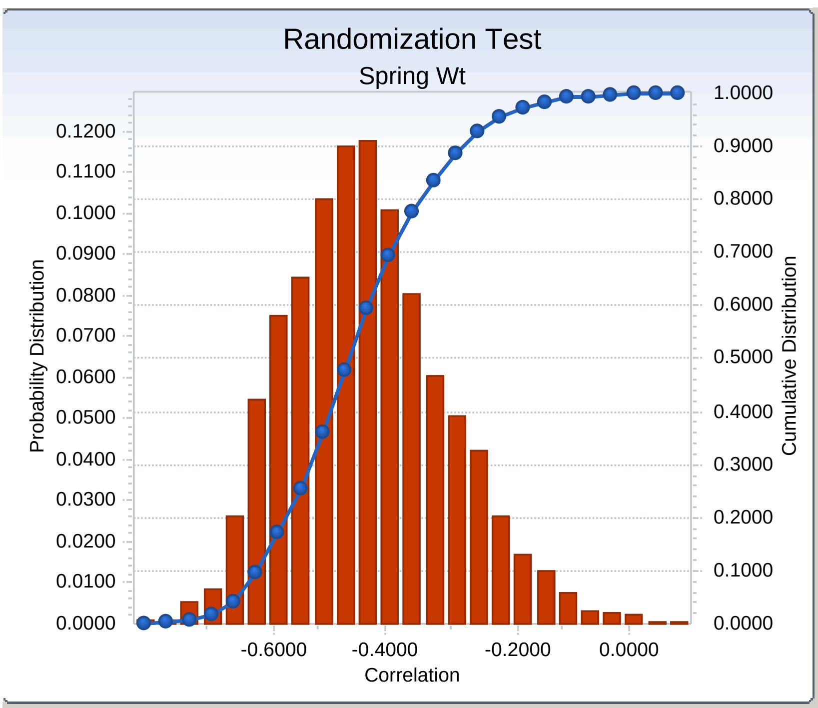


Figure A72 Randomization tests summary of sampling distribution of correlation coefficient between replacement ratio and relative F for fall(top) and spring (bottom) survey indices.

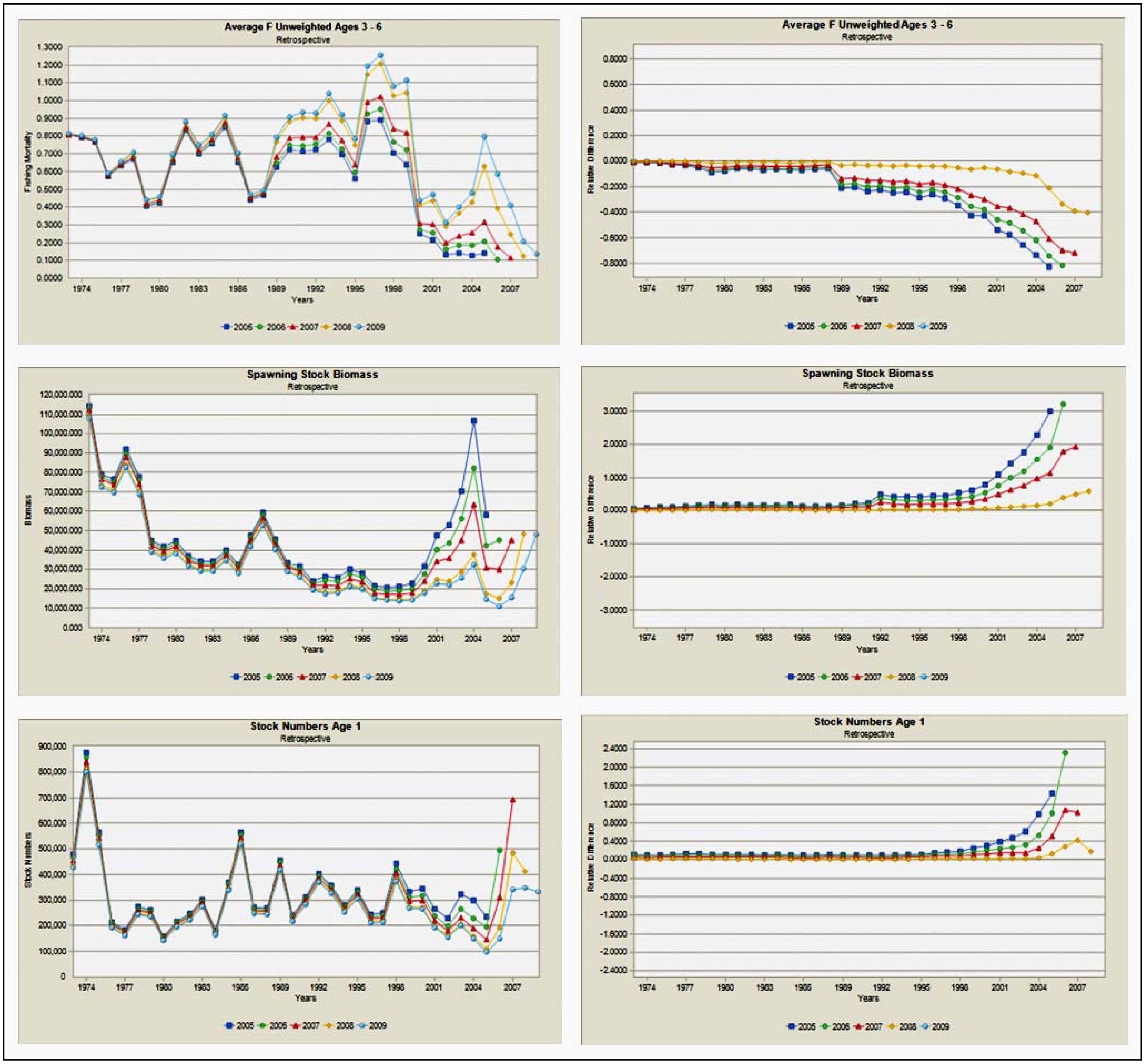


Figure A73: Age 6+ ASAP formulation (M = 0.4 model with NO consumption) - Retrospective plots of fully selected F, SSB and Recruitment.

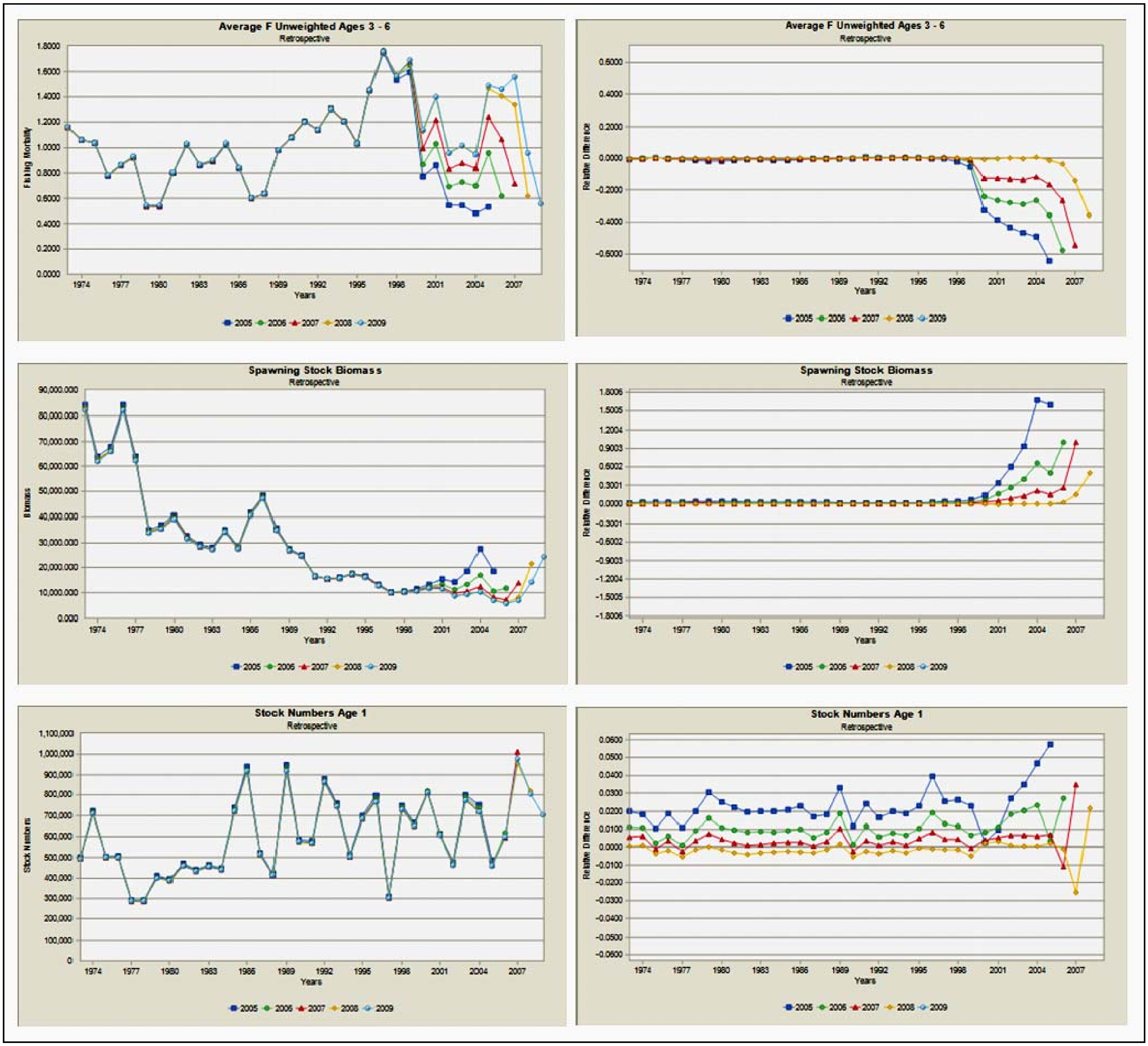


Figure A74 Age 6+ ASAP formulation (M = 0.15 model WITH consumption) - Retrospective plots of fully selected F, SSB and Recruitment.

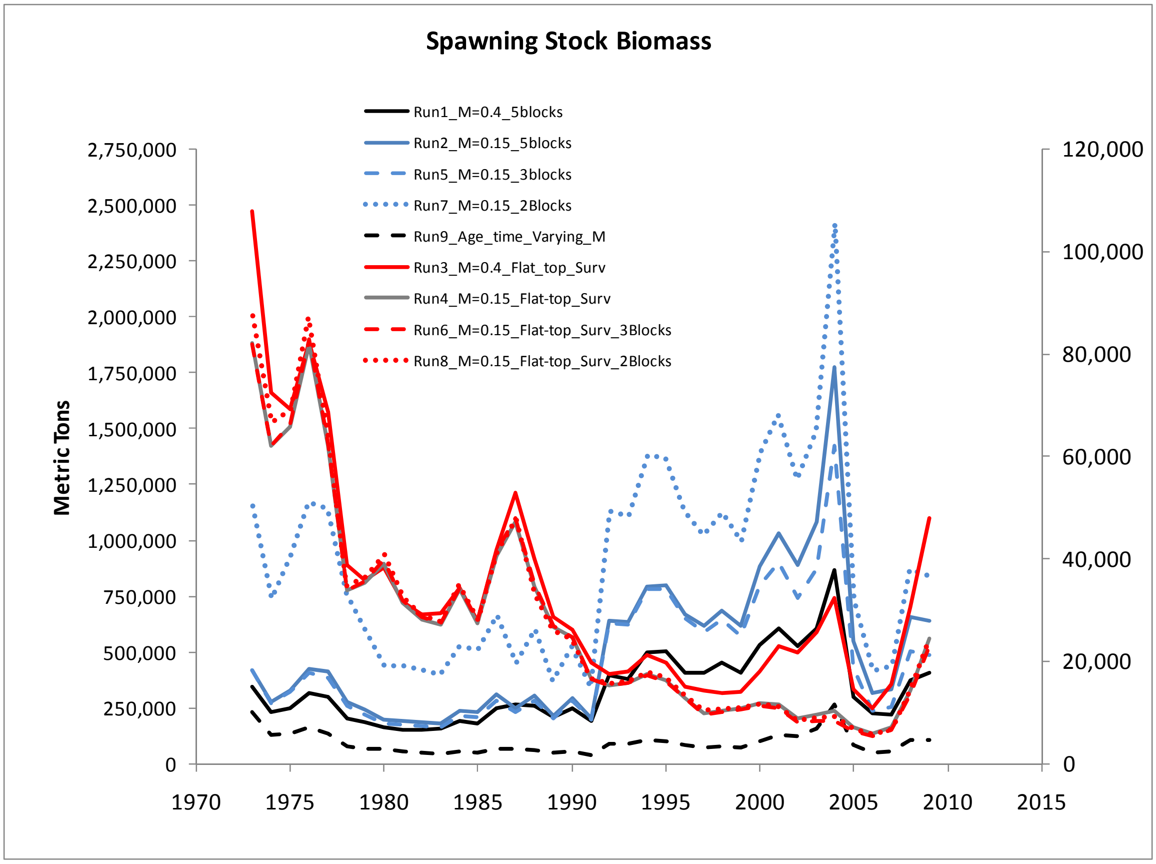


Figure A75: Silver hake SSB sensitivity analyses to the base combined ASAP model.

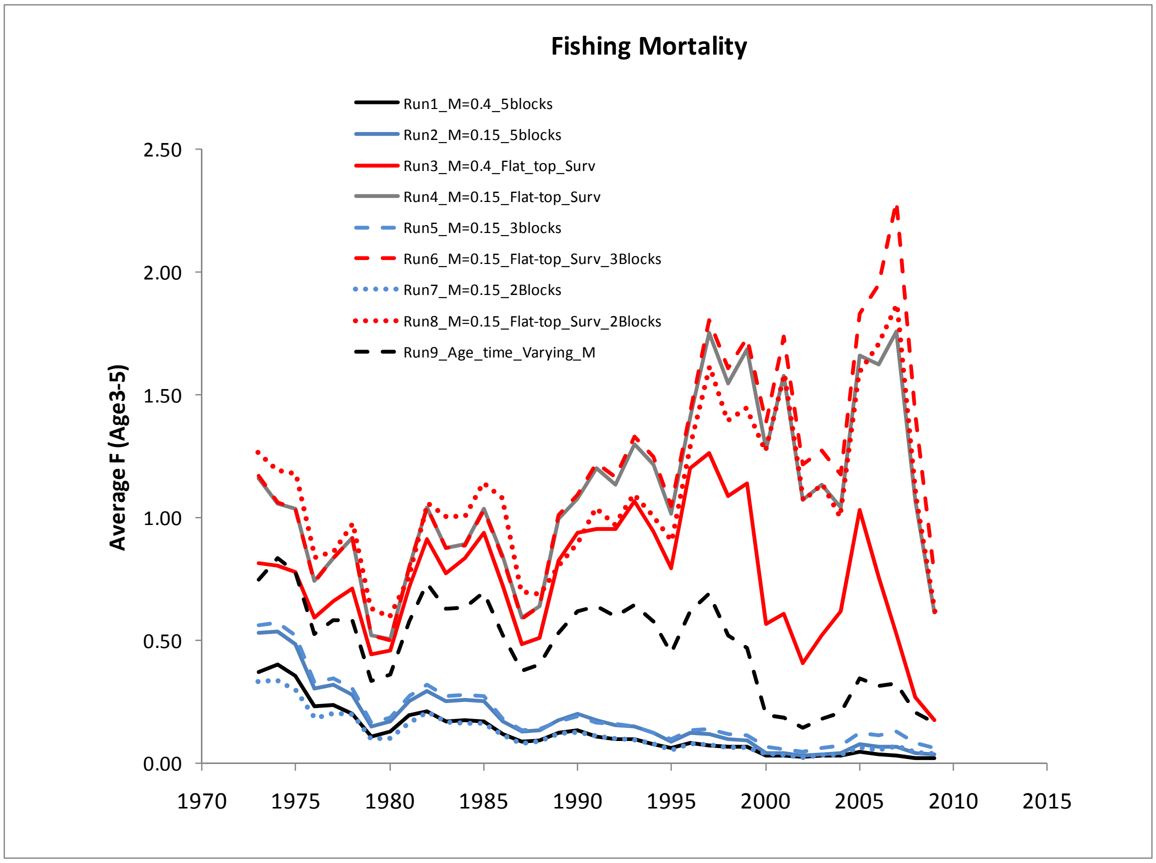


Figure A76: Silver hake SSB sensitivity analyses to the base combined ASAP model.

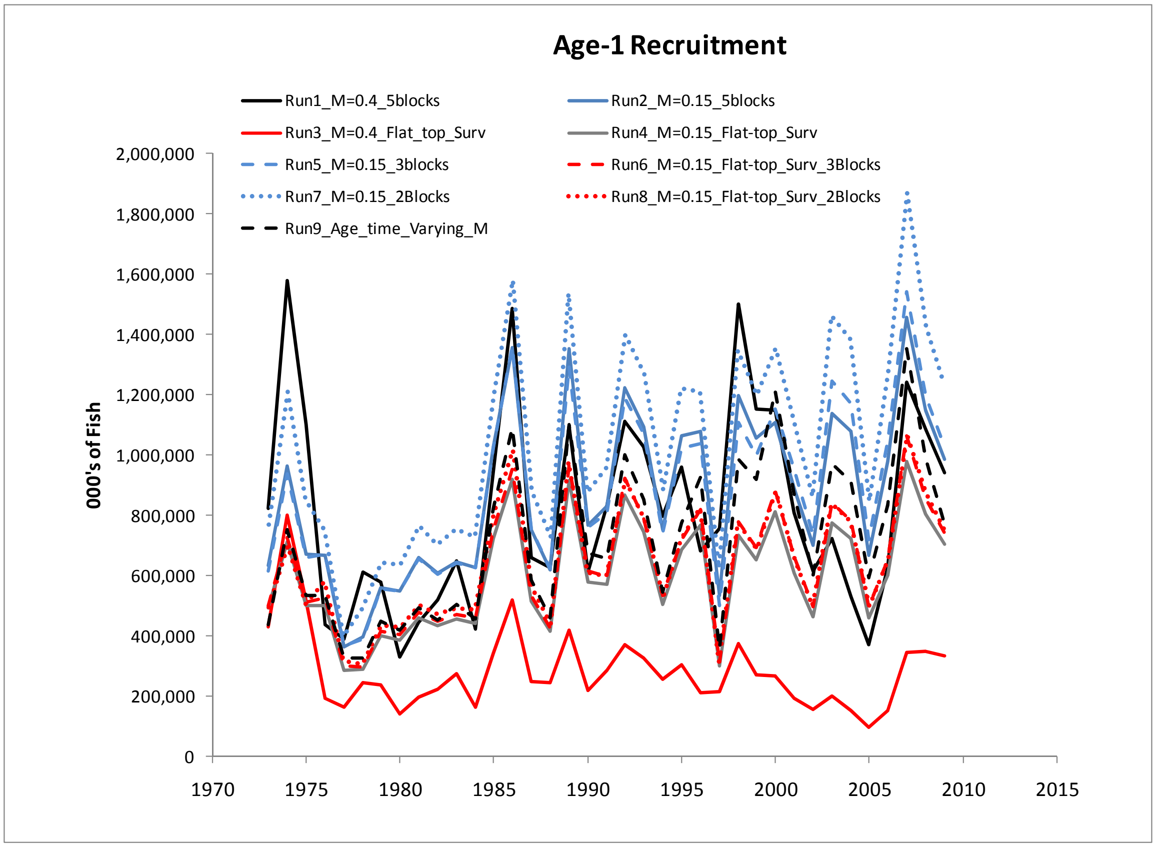


Figure A77: Silver hake SSB sensitivity analyses to the base combined ASAP model.

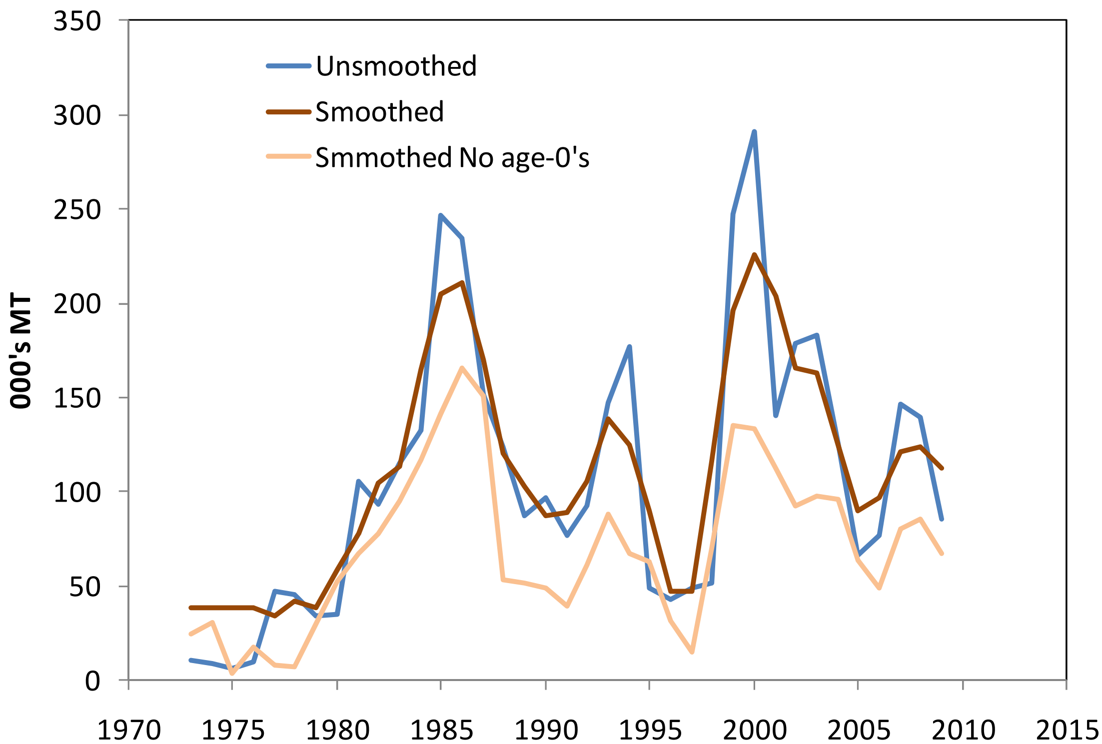


Figure A78. A comparison of silver hake consumption trends with and without the 3 year moving average including the adjustment for age-0.

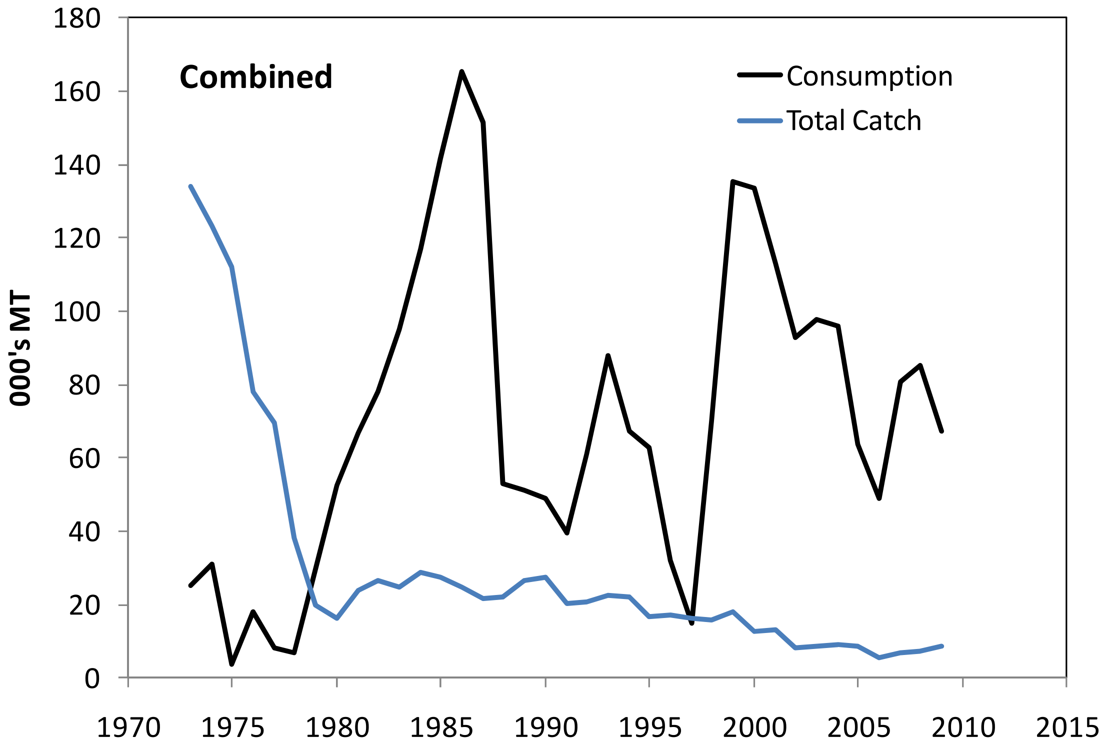
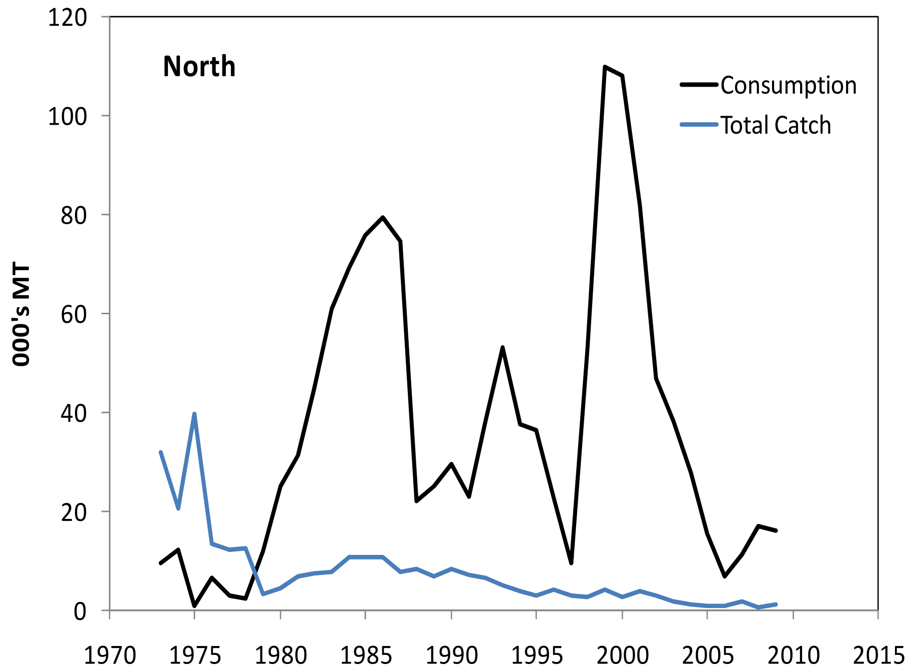


Figure A79. Estimates of total silver hake biomass removed, as that consumed by major fish predators and total catch in the fishery. A three year smoothed estimate of consumption is also shown.



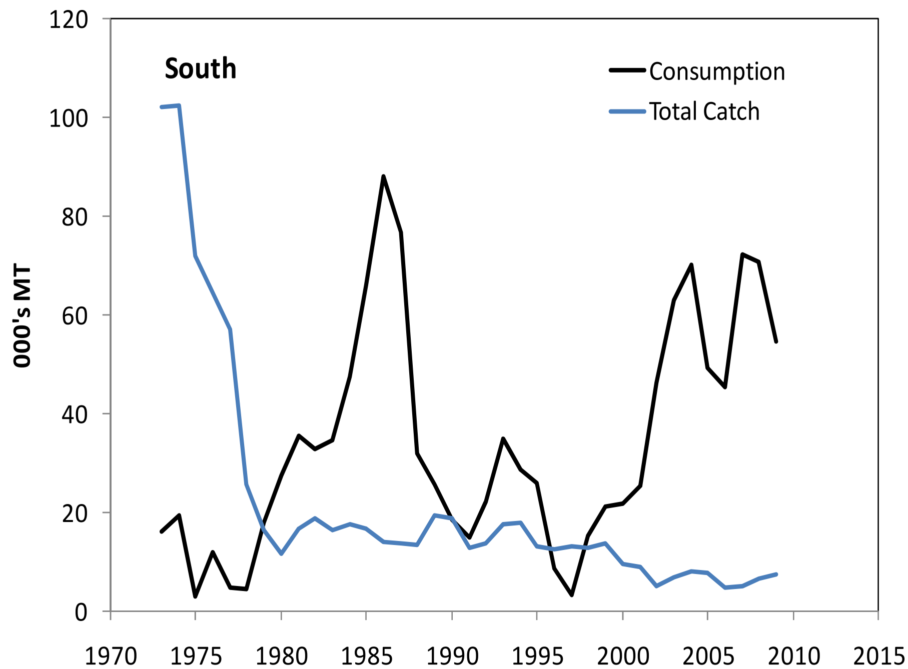


Figure A80. Estimates of total silver hake biomass removed, as that consumed by major fish predators and total catch in the fishery for the north (top) and south (bottom). A three year smoothed estimate of consumption is also shown.

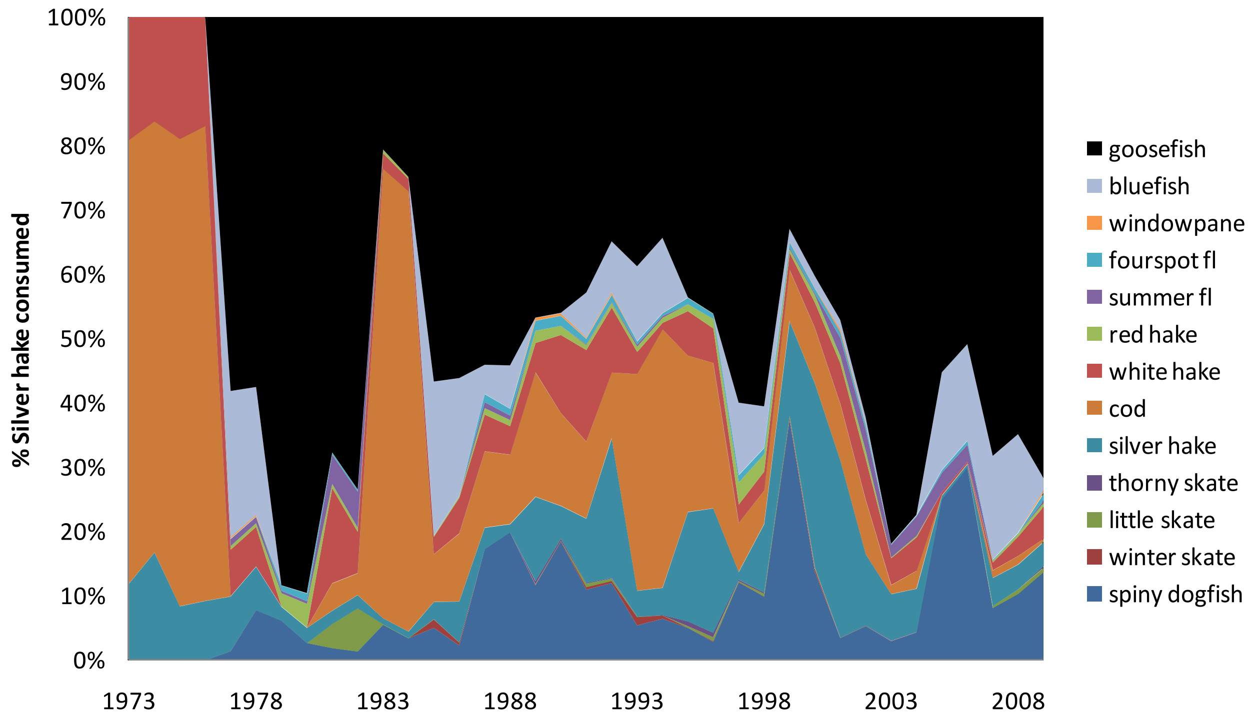
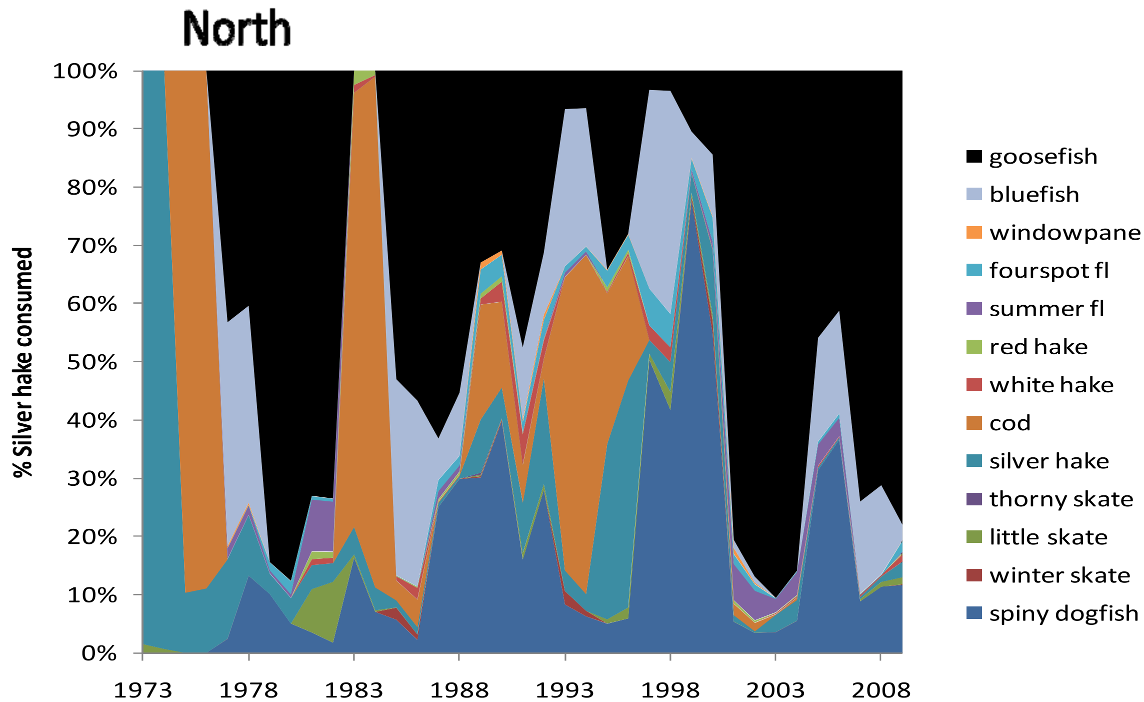


Figure A81. Consumption of silver hake by predator, for all predators, in both areas.



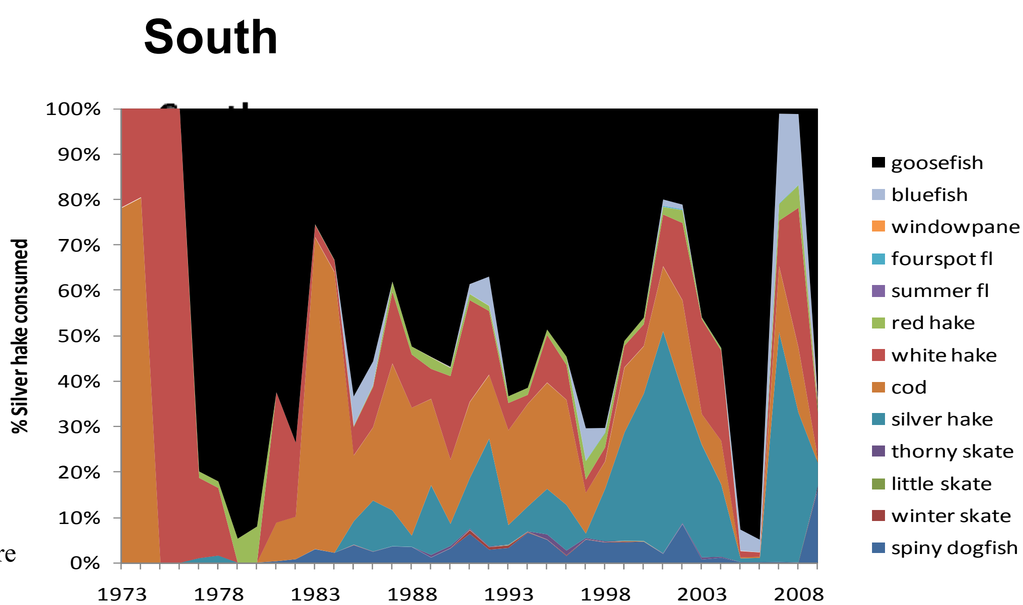


Figure A82. Consumption of silver hake by predator, for all predators, for north (top) and south (bottom)

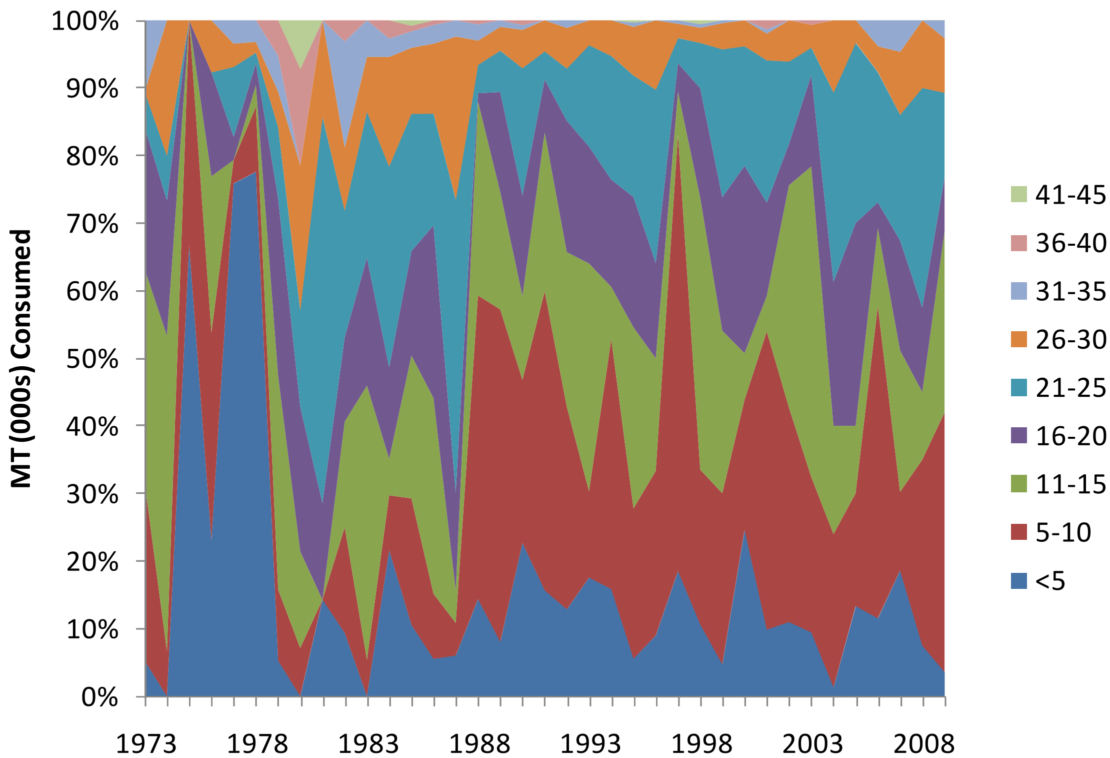


Figure A83. Proportion of total consumption by size classes of silver hake eaten by the predators in this study.

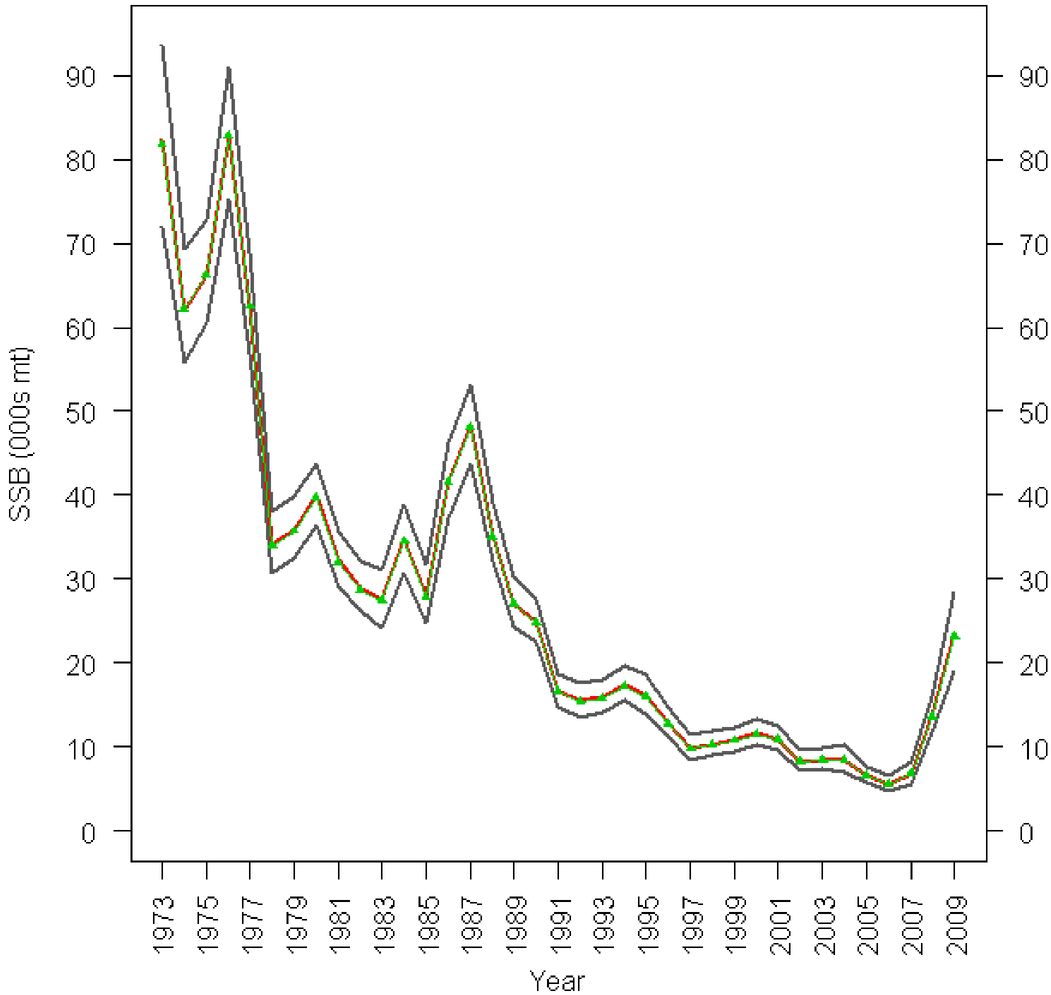


Figure A84**.** A 90% probability interval for silver hake spawning stock biomass (SSB) in thousands of mt is plotted for the entire time series. The median value is in red, while the 5th and 95th percentiles are in dark grey. The point estimate from the base model (joint posterior modes) is shown in the thin green lined with filled triangles. (ASAP base model).

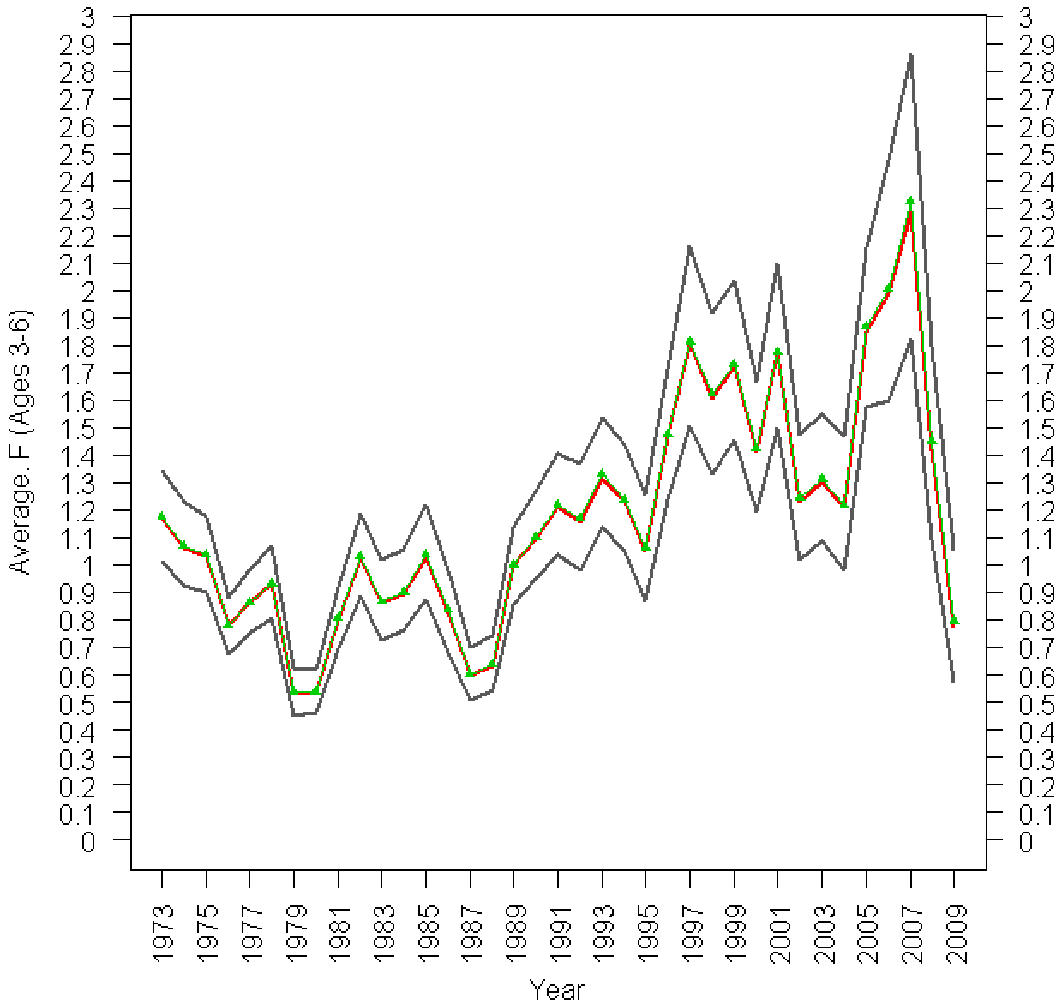
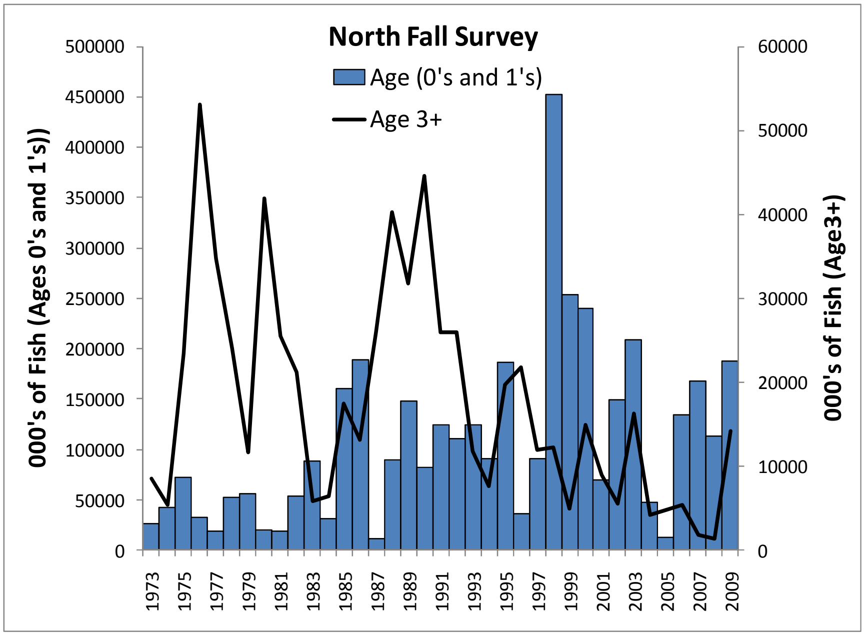


Figure A85. A 90% probability interval for the average F on ages 5-7 (F5-7) for silver hake is plotted for the entire time series. The median value is in red, while the 5th and 95th percentiles are in dark grey. The point estimate from the base model (joint posterior modes) is shown in the thin green lined with filled triangles. (ASAP base model).



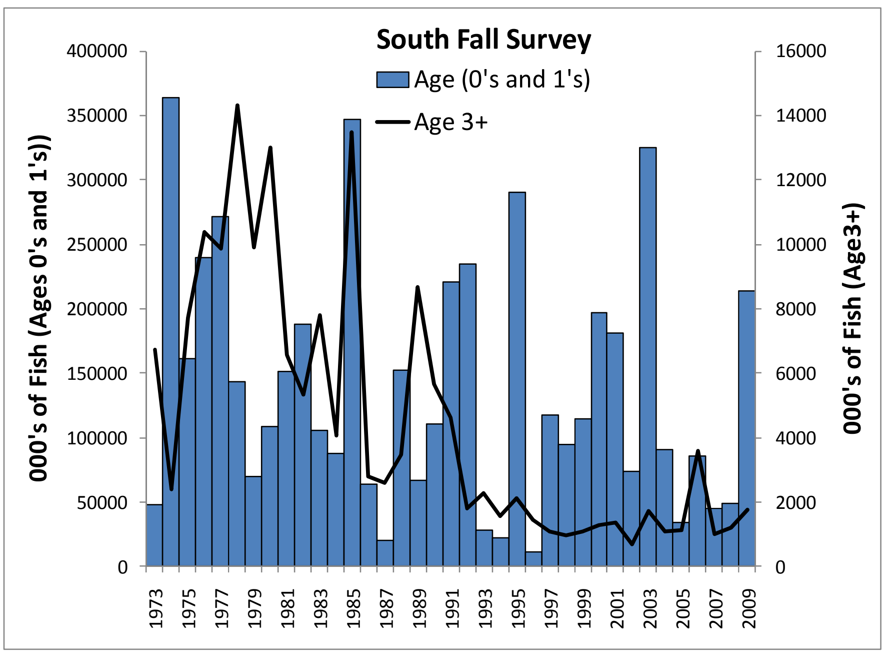


Figure A86: Recruitment (ages 0's and 1's) and adult abundances (ages 3+) derived from the NEFSC Fall bottom trawl Survey in the northern (TOP) and southern (BOTTOM) management areas

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Appendix A1

New England Fishery Management Council
Whiting Advisory Panel Meeting
SMAST – Fairhaven, MA

DRAFT Meeting Summary
August 6, 2010

Purpose of meeting: The advisory panel meeting served as an initial hake assessment meeting for stakeholders and fishermen to provide input on fishery and survey data.

Attendance: Advisors: Dan Farnham and Bill Phoel. Also in attendance were David Goethel (Oversight Committee chair), Andrew Applegate (staff) Steve Cadrin (SSC and WG chair, SMAST), Pingguo He, Klondike Jonas, Yuying Zhang, Tony Wood, and Daniel Goethel (SMAST), Loretta O'Brien, Michele Traver, Katherine Sosebee and Larry Alade (NEFSC), and Dick Allen (advisor at large).

Motions: No motions were made.

Summary

Steve Cadrin gave a presentation outlining the benchmark assessment Terms of Reference and known issues from previous assessments for the three hake species: silver, offshore, and red. He emphasized that besides simply assessing the status of the stocks with new data and models, it was important that the stock assessment produced sufficient projections for 2011-2013 to set ACLs and specifications within the planned FMP amendment for small mesh multispecies.

All five stocks (northern and southern silver hake, offshore hake, and northern and southern red hake) have existing proxy MSY reference points developed in 2002 during the last amendment, but these may be inconsistent with new estimates of MSY. Dr. Cadrin stressed the importance of making a status determination against the existing reference points as well as against any reference point recommendations that would be estimated and developed. Meeting participants also noted that another benchmark assessment may be a long way off, so that this benchmark assessment needed to identify how future update assessments should be conducted, either by the PDT or another group.

Dr. Cadrin also reviewed the calendar of related meetings, including a data meeting in early September, followed by a models/analysis meeting in late October, and the SAW review in early December.

Larry Alade, Michele Travers, and Kathy Sosebee gave an overview of the assessment data for silver, offshore, and red hakes, respectively. Data for all three species exhibited problems with mis-identification and reporting, uncertain stock structure (north and south stocks for silver and red hake), and difficult to estimate stock dynamics. Particularly for silver hake, it was noted that landings have been at relatively low levels since 1980, yet the survey biomass indices have not increased very much. The low landings may have been a result of the 5% groundfish catch limit for small mesh fisheries.

During the presentations, several issues were raised and there was some discussion of possible approaches and analyses to address these issues.

Silver hake

For silver hake, these issues included mis-reporting of species (silver and offshore hake mixed), stock structure (separate north/south stocks or combined), potential aging errors (mis-interpretation of annuli), difficulty in following strong and weak cohorts beyond age 2, and the effects of cannibalism on biological reference points and productivity. The work group was given a term of reference and had plans to develop model-based estimates of the species composition in landings and discard.

Species composition may be resolved through a variety of means. Although the dealer data is considered to be the more accurate estimate of landings volume, in this case, the vessel trip reports may be the more accurate estimate of species composition. Although sampling frequency in the observer data may be too low to estimate species composition, the VMS data may be useful because silver and offshore hake stratify by depth.

Some suggested that the dealer reports may also be subject to some underreporting, either via sales as bait or via sales to dealers in other states via truck. Some states, particularly CT, obtain these landings and make an aggregate report at the end of the year. Nonetheless, one of the advisors suggested that silver hake reported landings may be as much as 2 million pounds too low. Some discussion also occurred about industrial, or 'trash' fish, landings in the 1960s and 1970s, particularly at the Point Judith fish meal plant. Someone would investigate whether there was more information about those landings. Some fishermen thought that there might have been an increase in CPUE around 1975, when larger vessels began to fish offshore, which also may have lead to an increase in landings of offshore hake. Advisors reported that the hake fishery was market driven, controlled by what can be landed for a price, rather than what can be caught.

Some discussion also occurred about the apparent absence of larger 3+ fish in the survey data, without high landings. It was decided that the working group would inquire about growth ring validation. Fishermen reported that the larger silver hake move more seasonally than the smaller silver hake and can be found in deeper water (> 40 fathoms). Periodic or ad hoc offshore surveys, like the cooperative monkfish survey, should be investigated for presence of silver hake in deep water, the working group decided. Some wondered whether the larger fish in the southern portion of the range end up in the northern portion, but there is no tagging data suggesting that this is the case. Hake are difficult to tag due to their delicate nature and high discard mortality.

Red hake

It has been 20 years since the last red hake assessment and aging data is only available up to

1985. It was noted that there is significant over the side bait sales (supposedly reported on vessel trip reports), but that there were few red hake in the groundfish catch, suggesting low discards by vessels using large groundfish mesh. There were also industrial fish landings that included red hake, potentially recoverable data in the ICNAF data.

Although previous assessments analyzed a northern and southern stock separately, there was little evidence for such a separation. The group decided that a combined assessment would be appropriate, but that separate north/south assessments would also be needed for status determinations using the existing reference points and overfishing definitions.

Offshore hake

Besides the species composition of the commercial catch discussed in the context of silver hake, the offshore range and what proportion of the stock was sampled by the NMFS trawl survey was an issue. And like silver hake, periodic offshore surveys like the cooperative monkfish survey might be informative. The length of the derived catch series was questioned and it might be difficult to complete an analytical assessment. A catch/biomass exploitation rate might be possible, but its utility as a measure of population trend and mortality would be questionable due to noise caused by availability to the survey and to the fishery. It was suggested that the relationship between the survey index (or number of positive tows) might be related to the NAO and Gulf Stream positioning. The working group thought that this could be a productive avenue for analysis.

Depending on the amount of catch and the range of the stock relative to the commercial fishery, it seemed that offshore hake might be re-classified as an ecosystem fishery component by a new amendment. This would mean that there would be monitoring, but no overfishing definition.

Other issues; Management and amendment schedule

For both red and silver hake, discards would be estimated and hindcasted, using sea sampling data, most recently collected using standard bycatch reporting methodology (SBRM). Dr. He indicated that there were some experiments planned to estimate discard mortality, but not enough data would be available for this assessment. In the absence of more data, the group thought that 100% discard mortality was the most reasonable assumption for trawls and especially dredges. Non-catch mortality was discussed, but not having any data, it would be assumed that there was no non-catch mortality of hakes, although some is likely, particularly in scallop dredges and might occur in large mesh trawls.

Andy Applegate gave a brief summary of the amendment timeline and process going forward. He indicated that except for the structure of accountability measures, it was difficult to make much progress on the amendment until the stock assessment was completed because the assessment might change the biological reference points and stock status. He said that the January Council meeting would be the earliest that the Council could approve draft amendment alternatives, which then would be analyzed and taken to public hearing. The Council could consider final alternatives in April, but he thought that June would be much more likely. In this case, the Council would submit the final amendment in June or July, and the final rule could be published in late 2011, with an ACL that applied to the 2011 fishing year beginning in May 2011. He thought that unless the assessment changed the status, the specification cycle would be for three years, or 2011-2013.

Appendix A2-A6 Silver Hake ASAP Model Results

[SAW51 Editor's Note: The SARC-51 peer review panel concluded that no single silver hake ASAP model run provided a suitable basis for providing management advice. The silver hake ASAP model results, which are described in Appendices A2-A6, are included in this report mainly to document the ASAP modeling runs that the Hake Working Group provided to the SARC for peer review.]

A. **Appendix 2:** Combined Area Consumption ASAP model results (Also summarizes as Run 6 in Table A52). Two block selectivity in the directed fleet and assumes Flat-top selectivity in the survey.

B. **Appendix A3:** North Model ASAP results M=0.4 Base run

C. **Appendix A4:** North Model ASAP results M=0.4 assuming Flat-top selectivity in the survey

D. **Appendix A5:** North Model Consumption ASAP model results M=0.15 _Base run

E. **Appendix A6:** North Model ASAP results M=0.15. Assuming Flat-top selectivity in survey

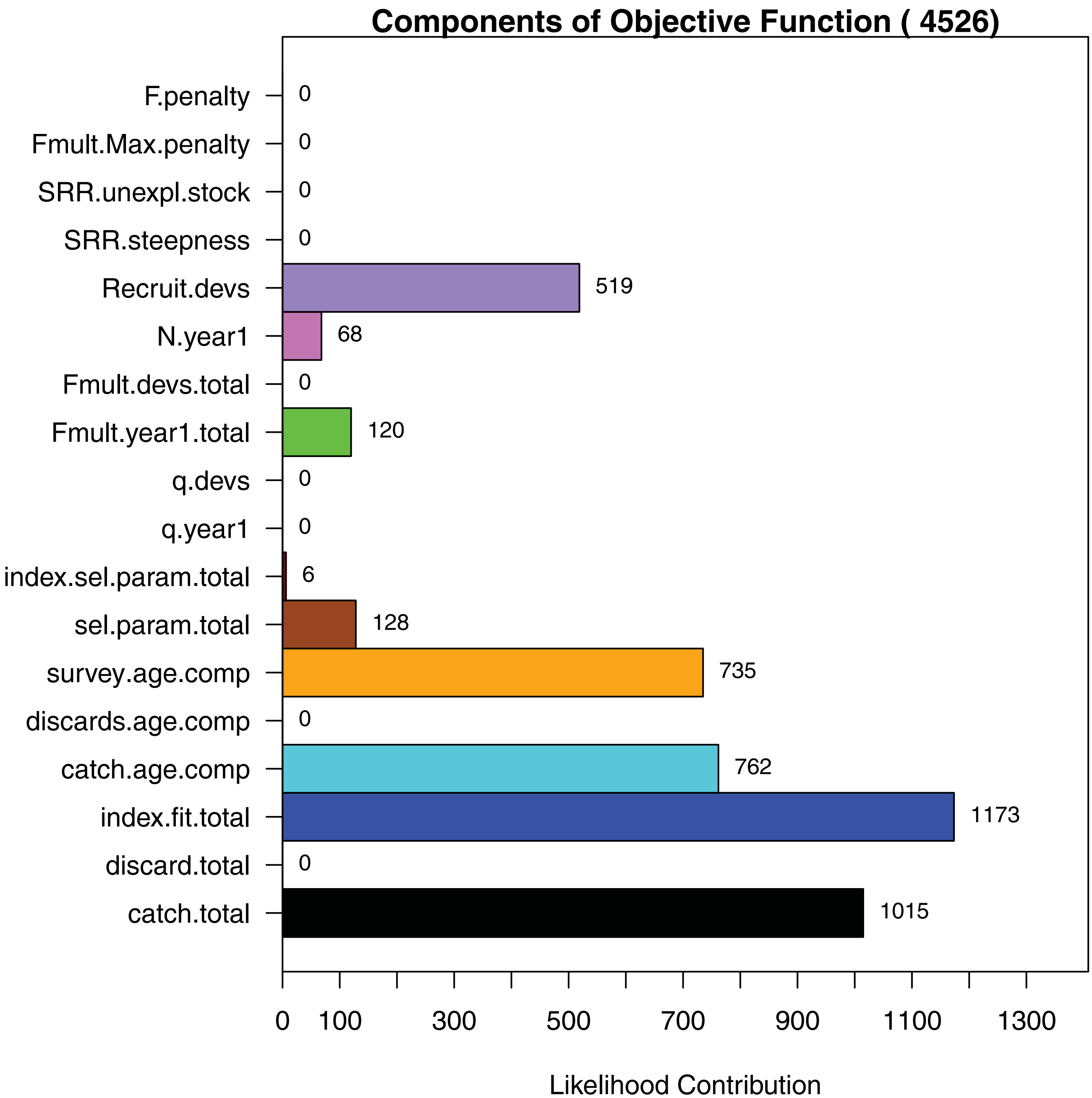
Appendix A2: Combined Area Consumption ASAP Model Results (Also summarized as Run 6 in Table A52)

Model Attributes:

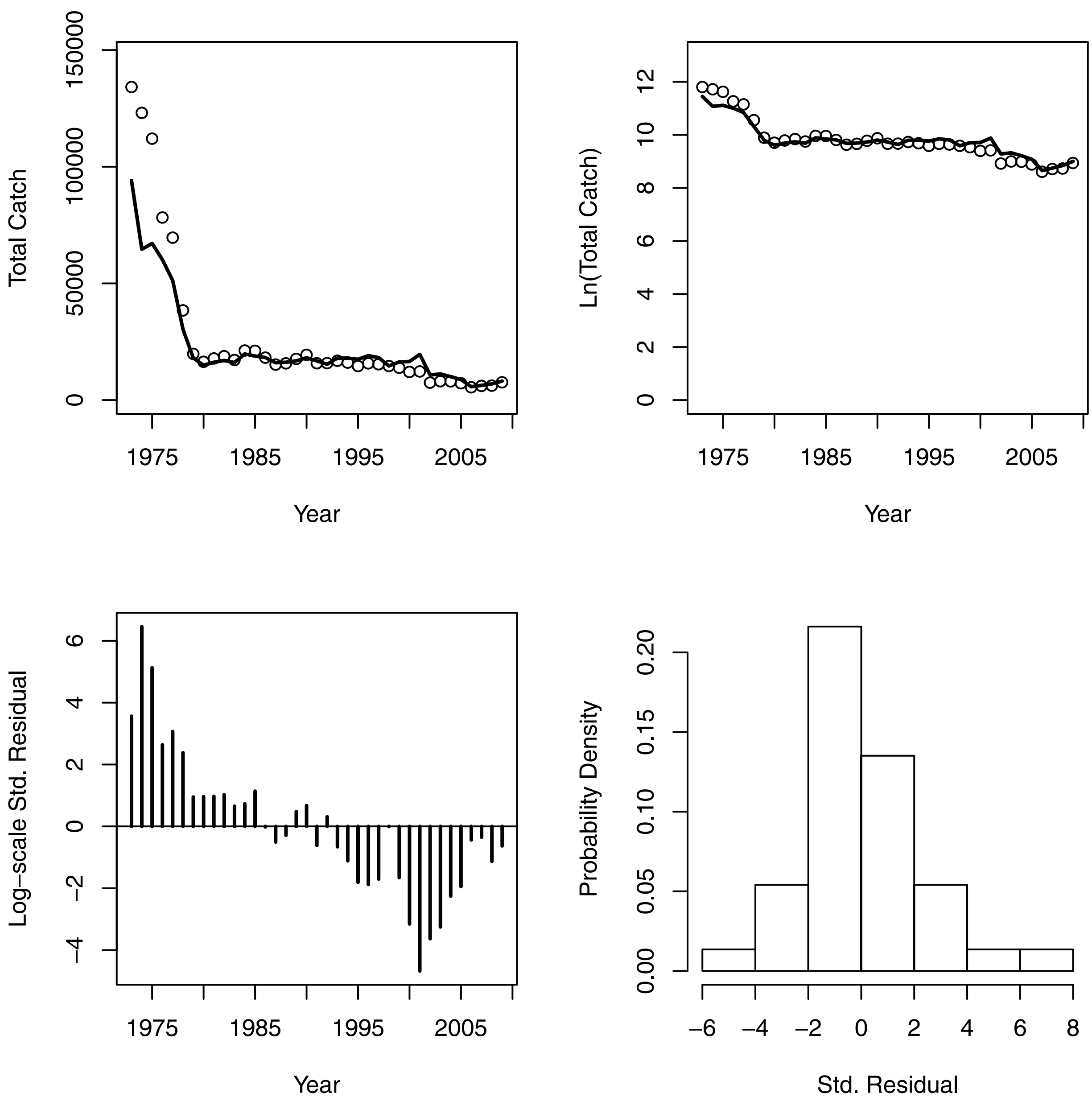
1. 3 Fleet Model
   a. Catch : 1973-2009
   b. Discards: 1981 – 2009
   c. Consumption – 1973-2009

2. Fishery Selectivity (3 Block Selectivity)
   a. Landings (2 Blocks: 1973-1988; 1989-2009)
   b. Discards (1 Block: 1981-2009)
   c. Consumption (Double Logistic Functional Form)

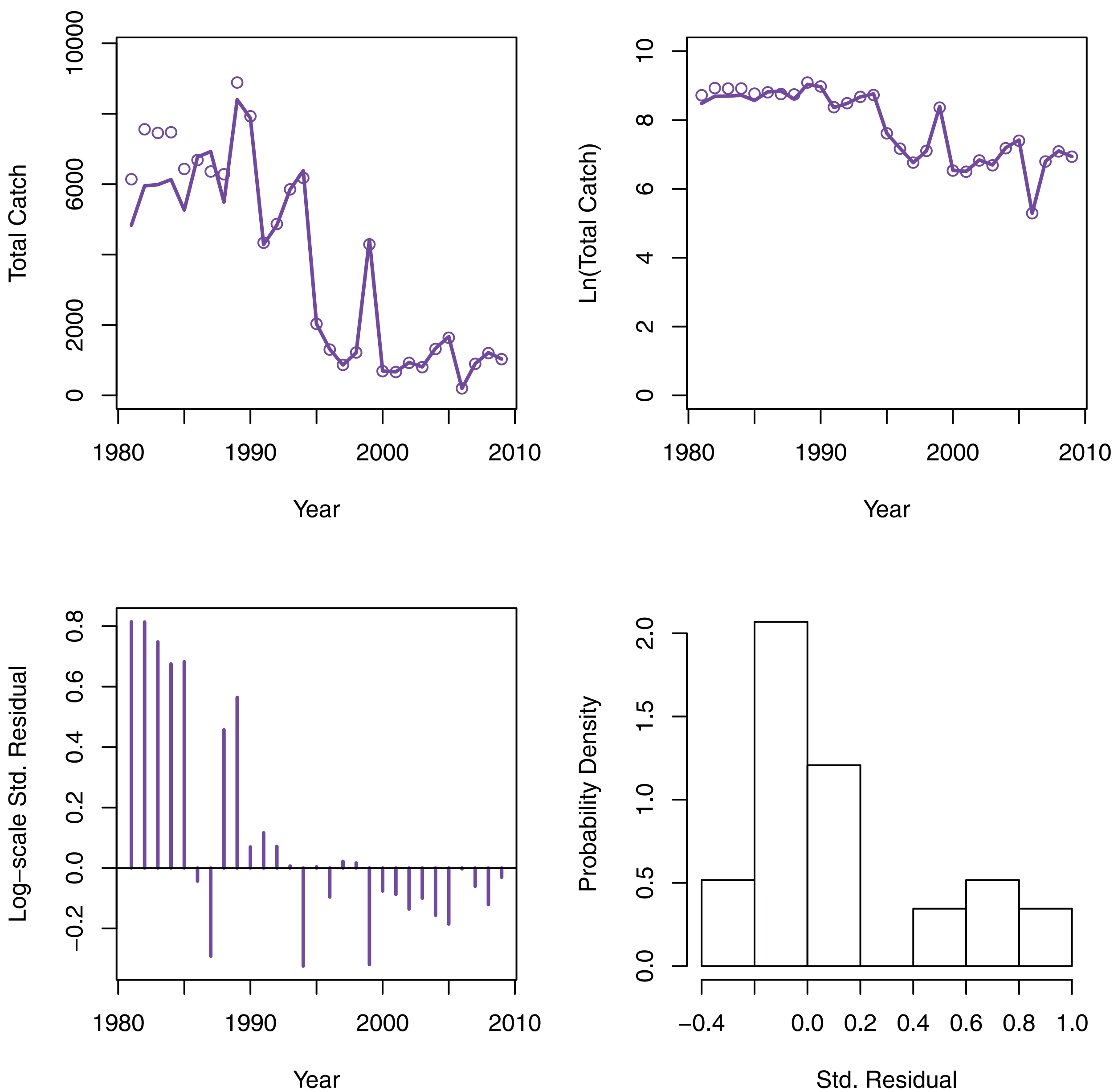
3. Survey Selectivity (Fixed 100% at age 2 – 6+) i.e. Flat-top

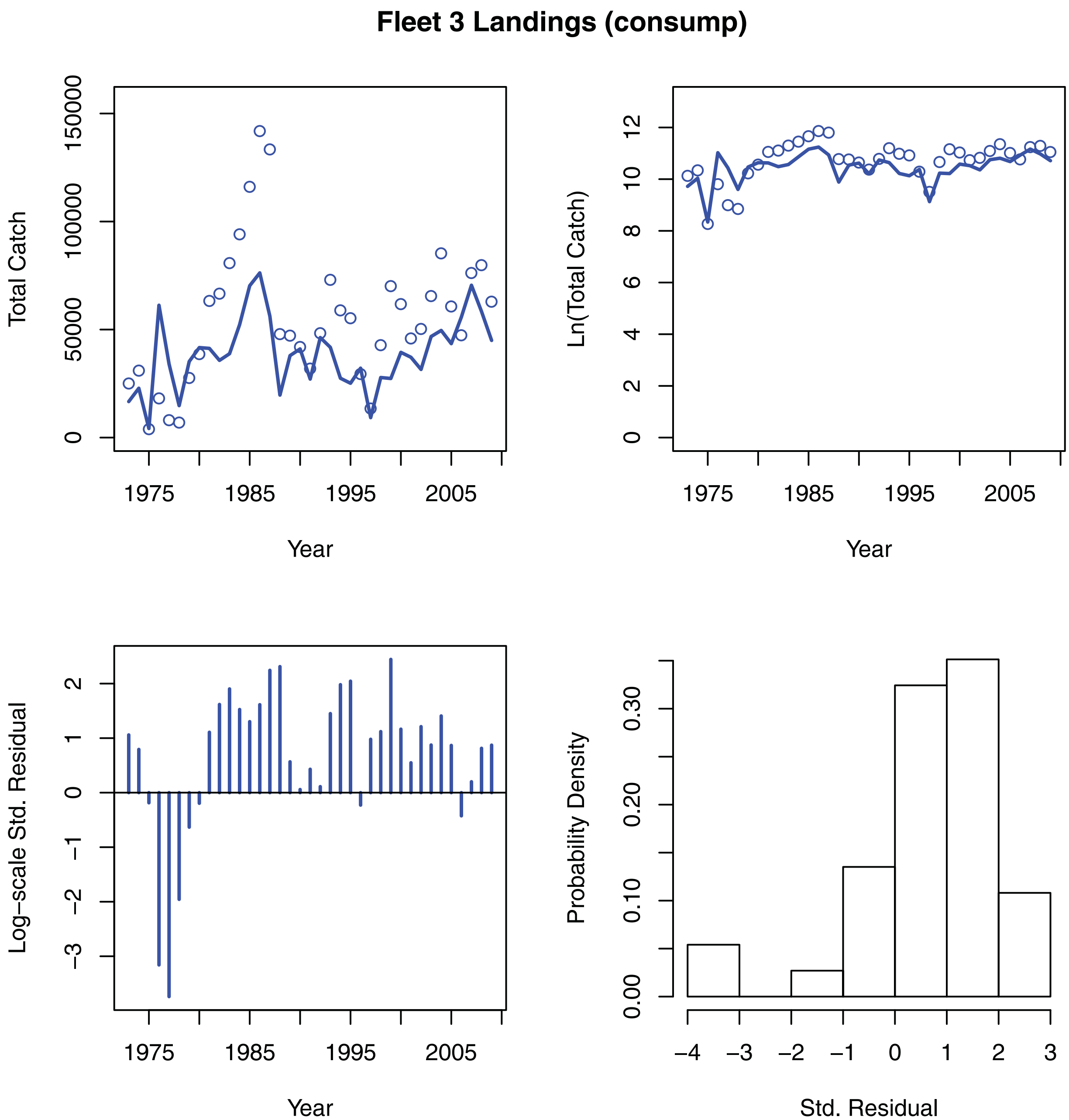

Components of Objective Function (4526)
F.penalty
Fmult.Max.penalty
SRR.unexpl.stock
SRR.steepness
Recruit.devs
N.year1
Fmult.devs.total
Fmult.year1.total
q.devs
q.year1
index.sel.param.total
sel.param.total
survey.age.comp
discards.age.comp
catch.age.comp
index.fit.total
discard.total
catch.total
0
0
0
0
519
68
0
120
0
0
6
128
735
0
762
1173
0
1015
0 100 300 500 700 900 1100 1300
Likelihood Contribution

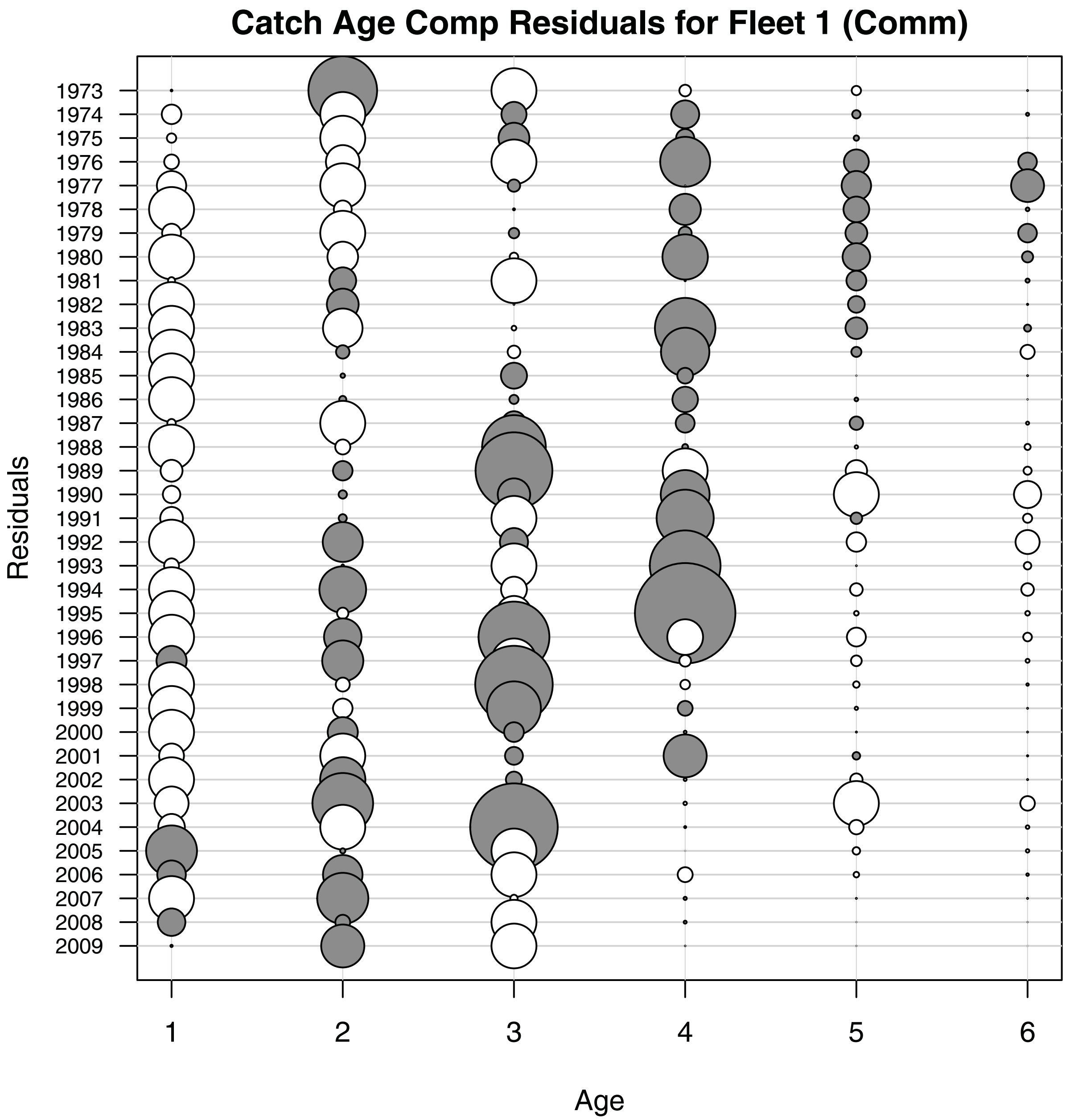
Fleet 1 Landings (Comm)

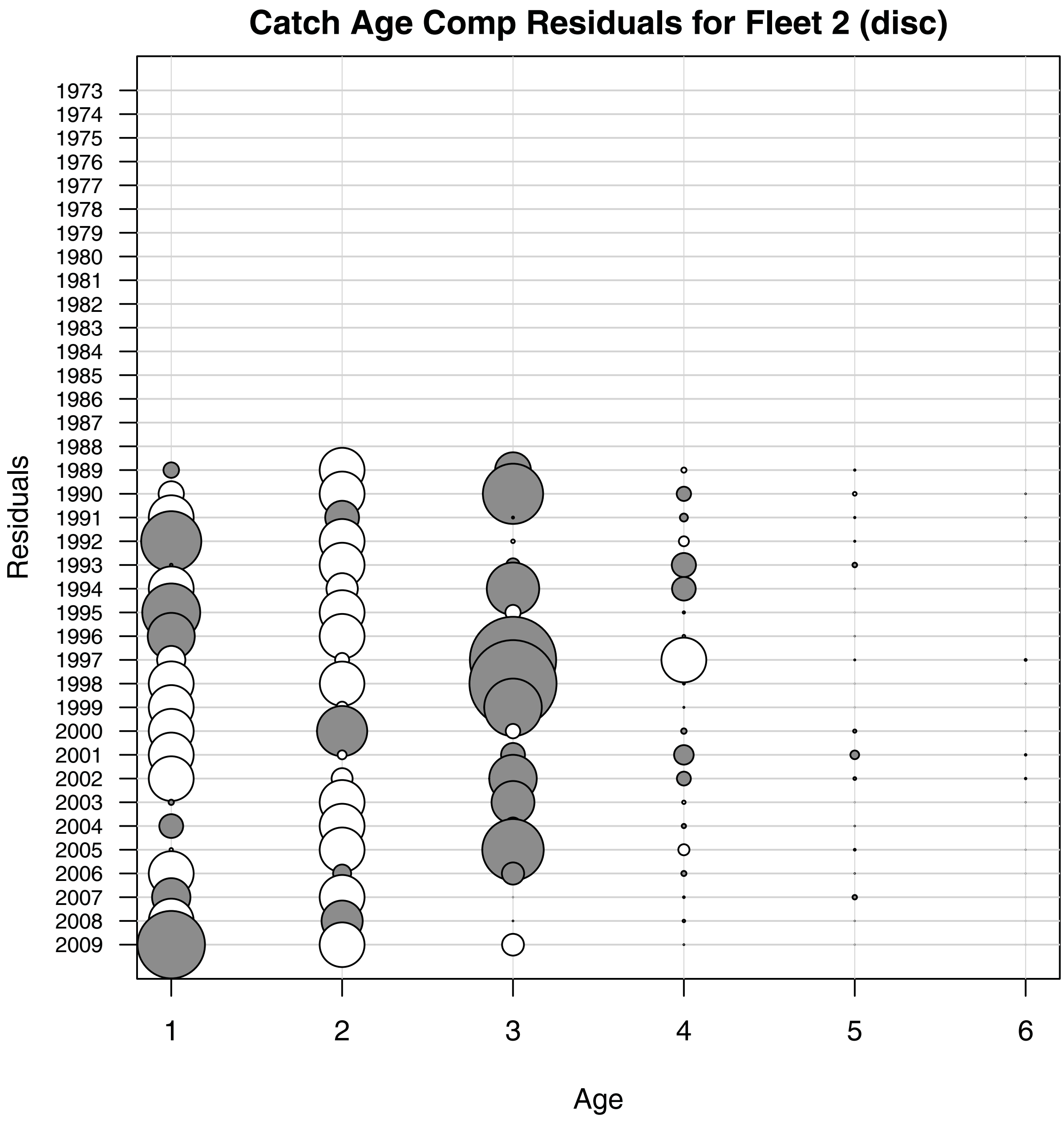


Fleet 2 Landings (disc)

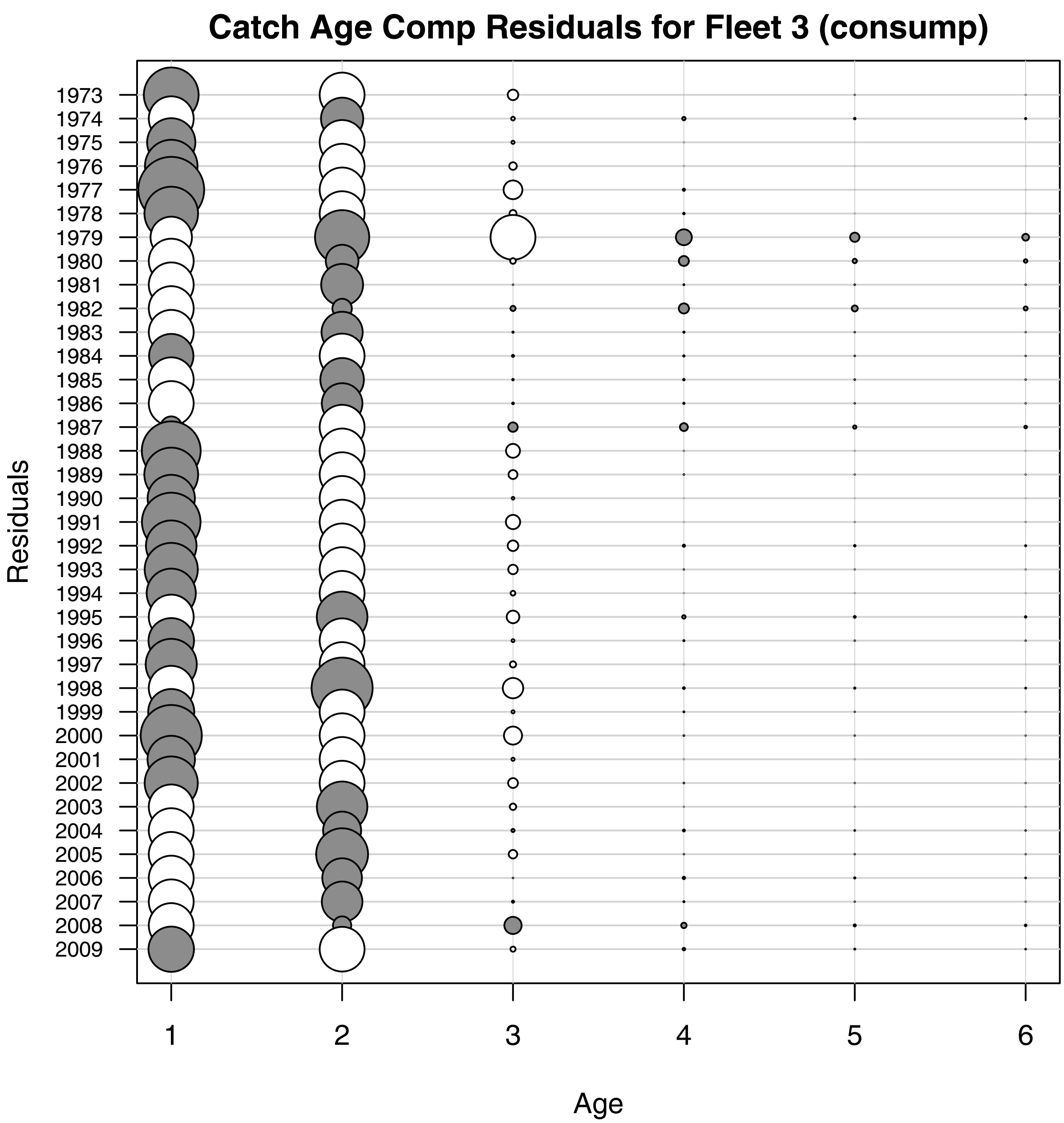


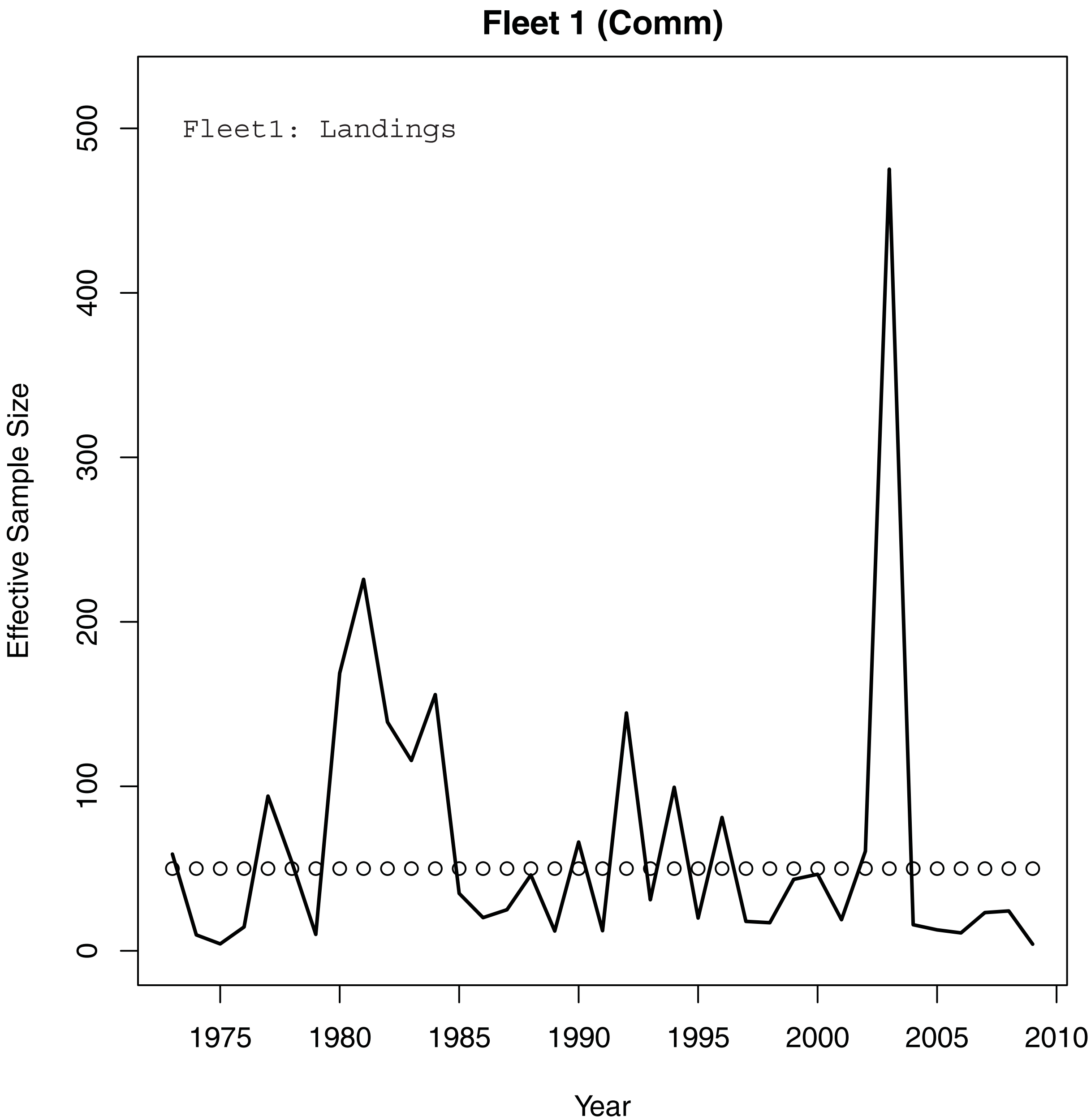

Fleet 3 Landings (consump)
Total Catch
0
50000
100000
150000
1975
1985
1995
2005
Year
Ln(Total Catch)
0
2
4
6
8
10
12
Year
Log−scale Std. Residual
−3
−2
−1
0
1
2
Year
Probability Density
0.00
0.10
0.20
0.30
−4
−3
−2
−1
0
1
2
3
Std. Residual

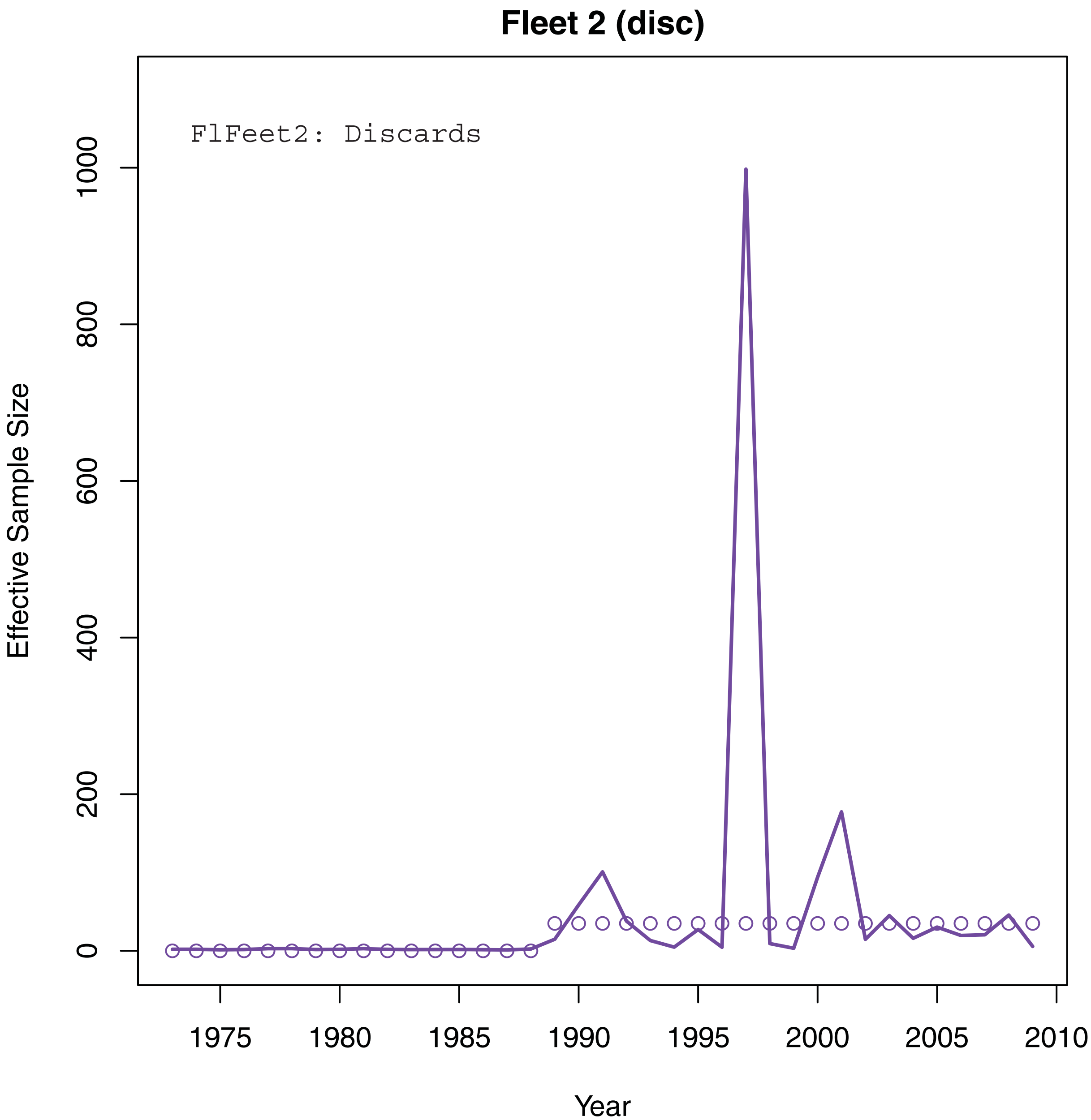

Catch Age Comp Residuals for Fleet 1 (Comm)
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age

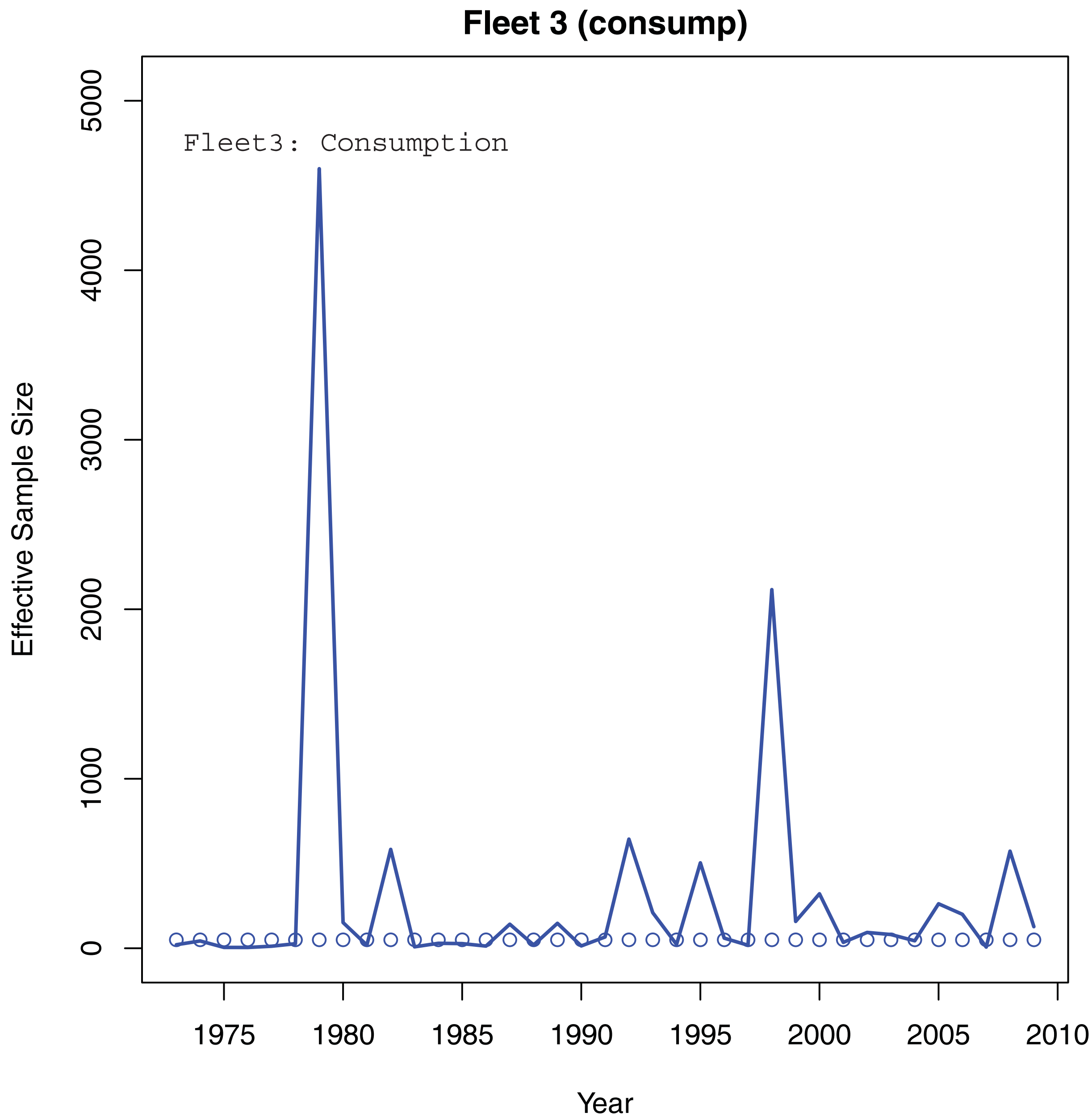


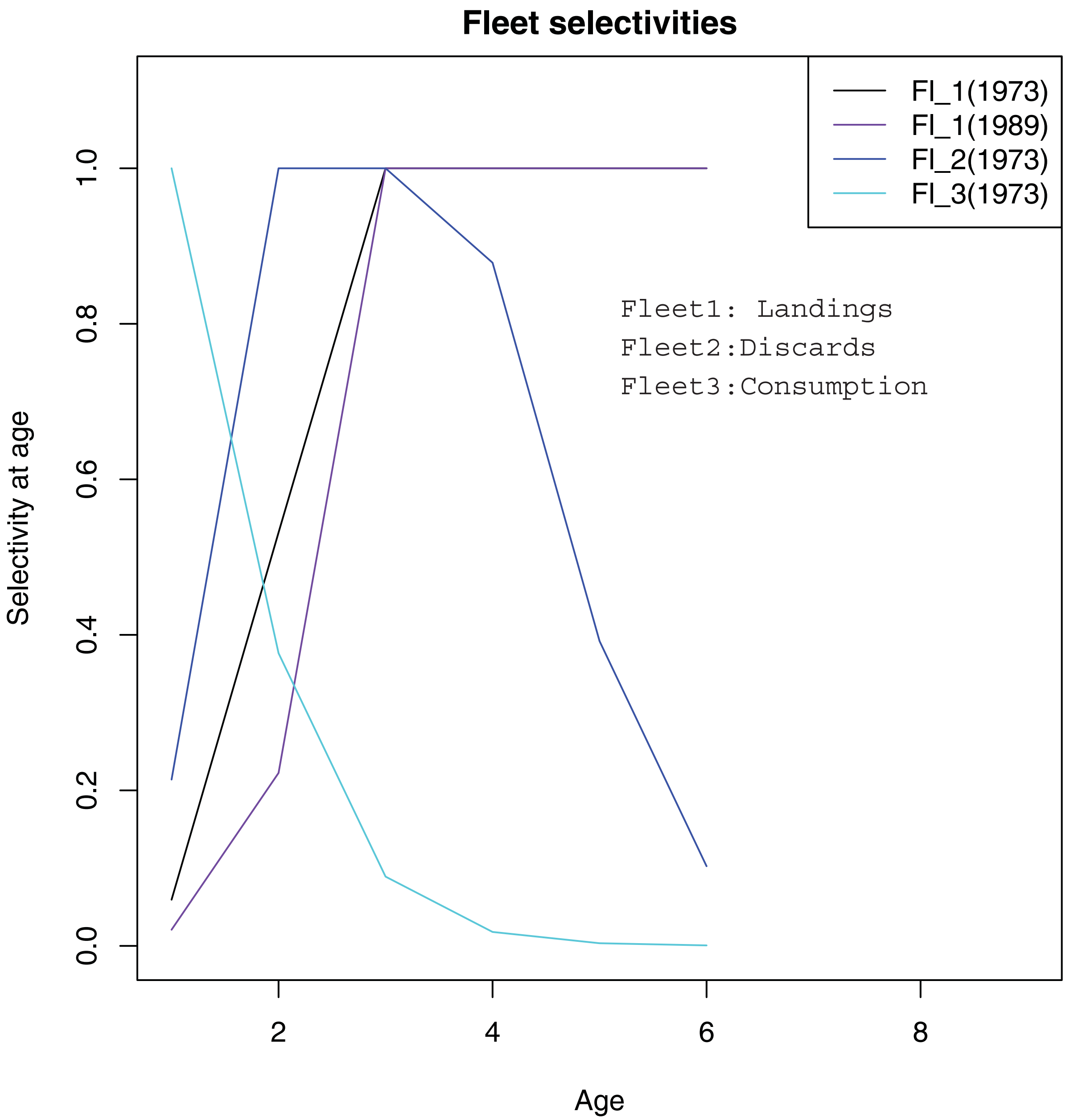
Catch Age Comp Residuals for Fleet 2 (disc)
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age


Catch Age Comp Residuals for Fleet 3 (consump)
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age

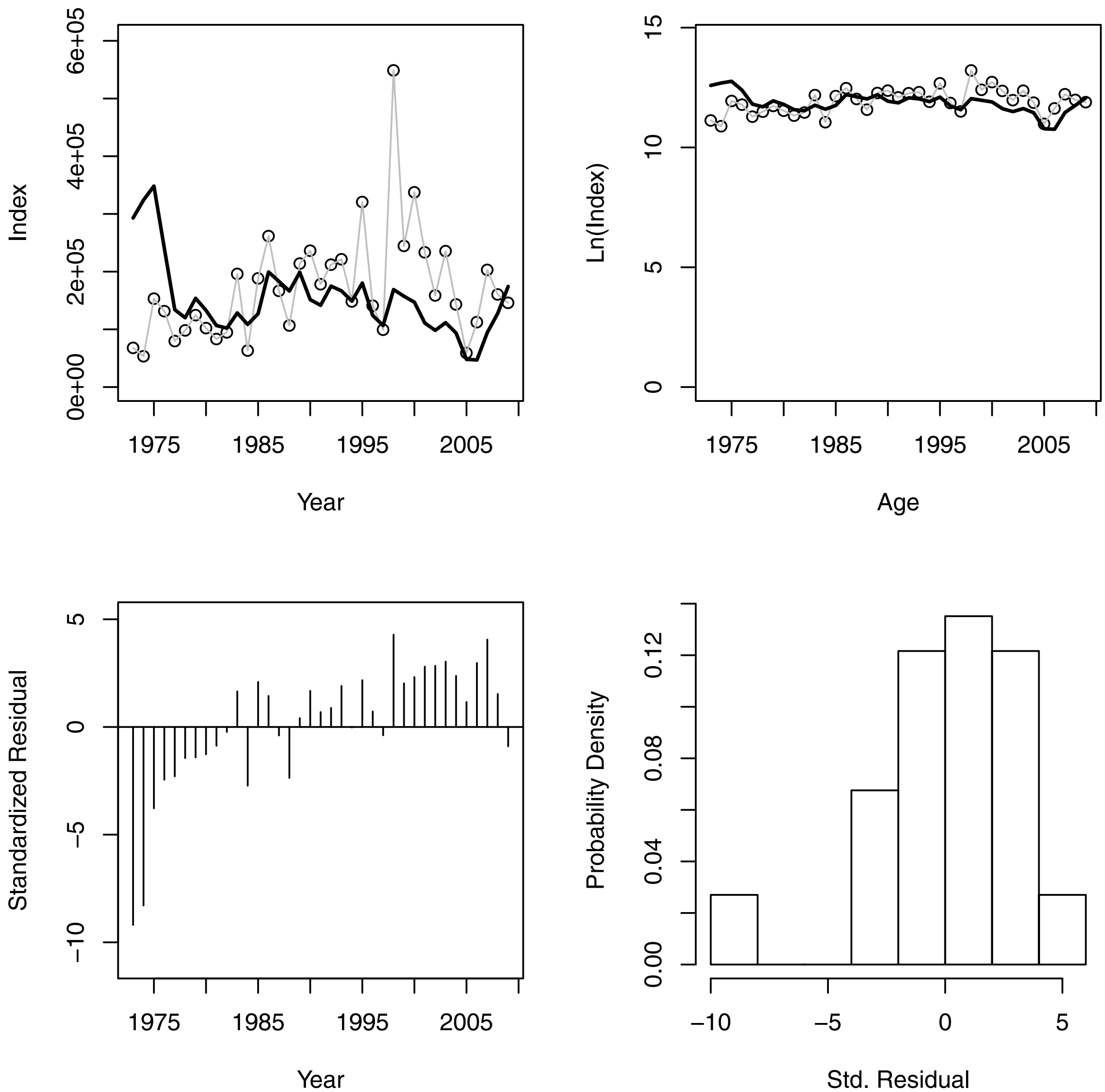

Fleet 1 (Comm)
Fleet1: Landings
Effective Sample Size
0
100
200
300
400
500
1975
1980
1985
1990
1995
2000
2005
2010
Year


Fleet 2 (disc)
FlFeet2: Discards
Effective Sample Size
0
200
400
600
800
1000
1975
1980
1985
1990
1995
2000
2005
2010
Year


Fleet 3 (consump)
Fleet3: Consumption
Effective Sample Size
0
1000
2000
3000
4000
5000
1975
1980
1985
1990
1995
2000
2005
2010
Year

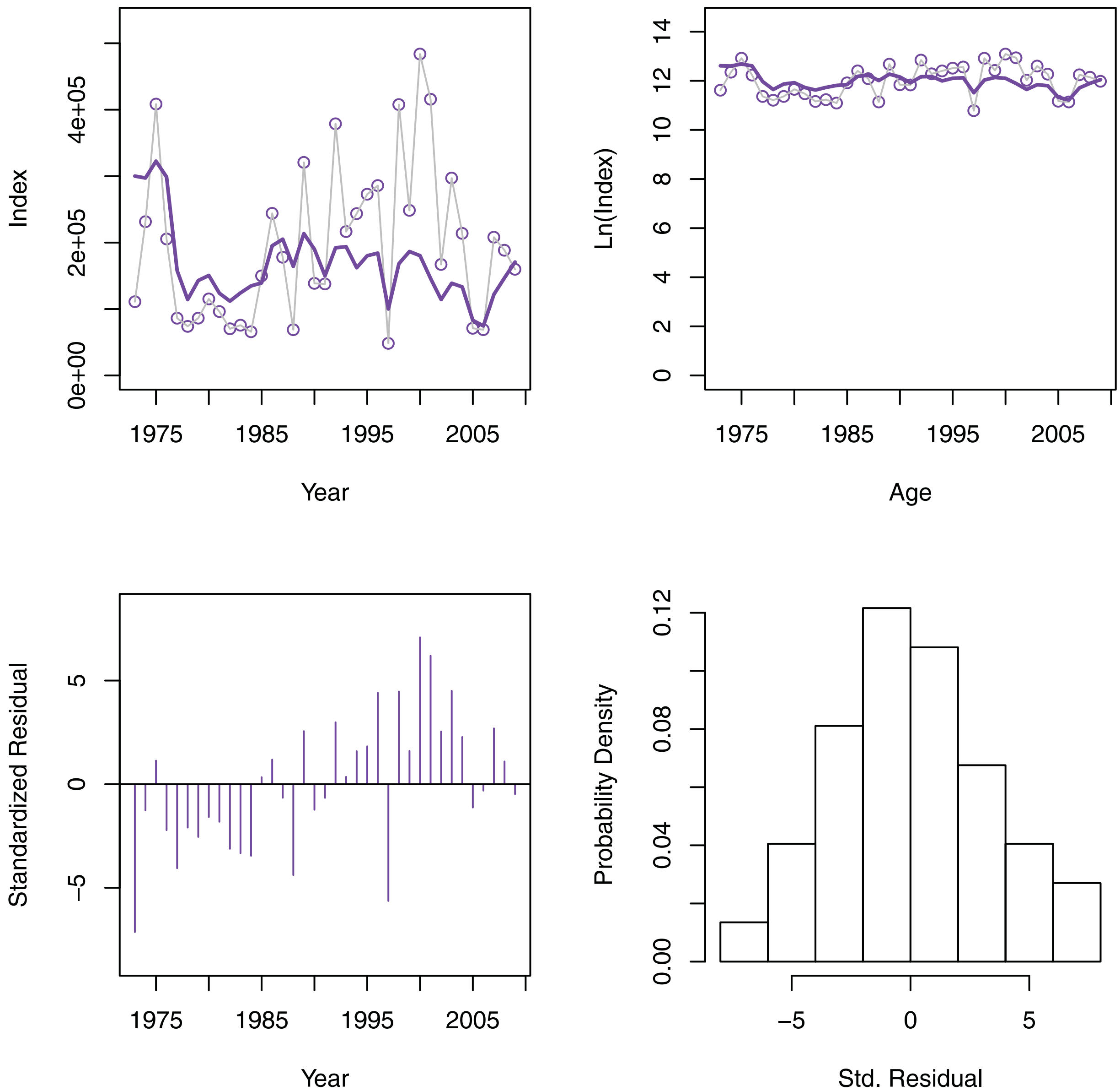

Fleet selectivities
Fl_1(1973)
Fl_1(1989)
Fl_2(1973)
Fl_3(1973)
Fleet1: Landings
Fleet2:Discards
Fleet3:Consumption
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
Age

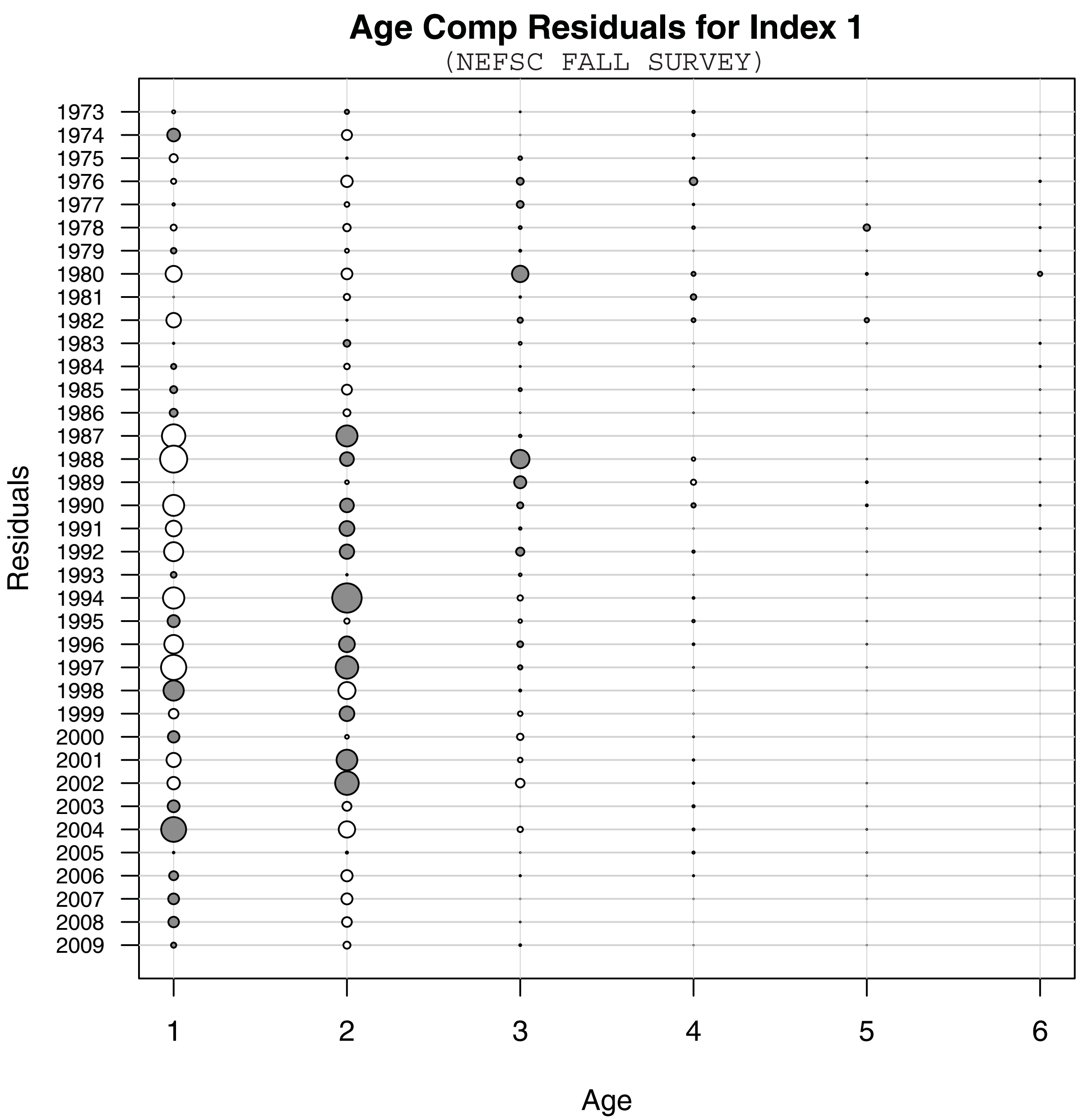
Index 1
NEFSC FALL SURVEY

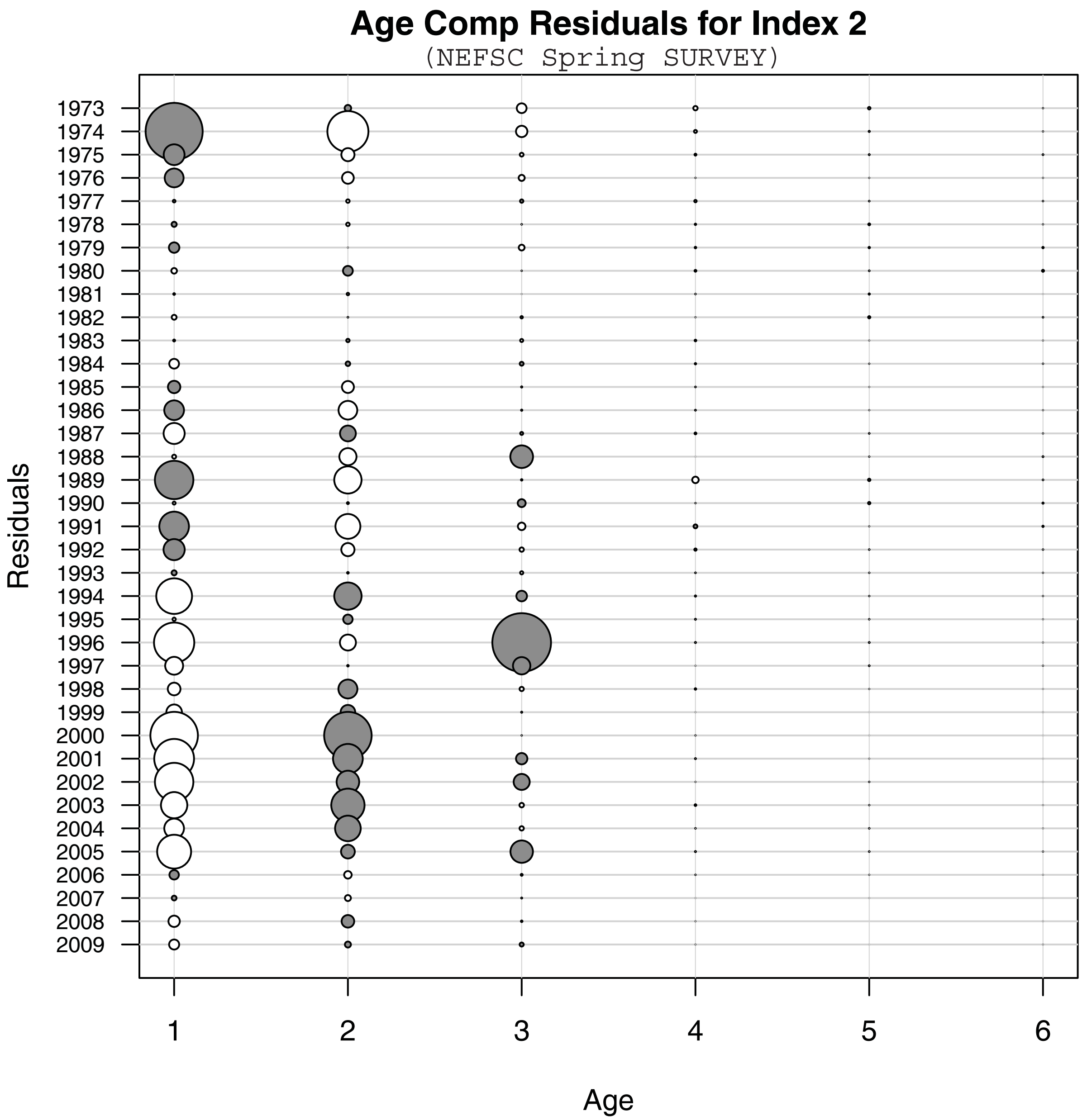


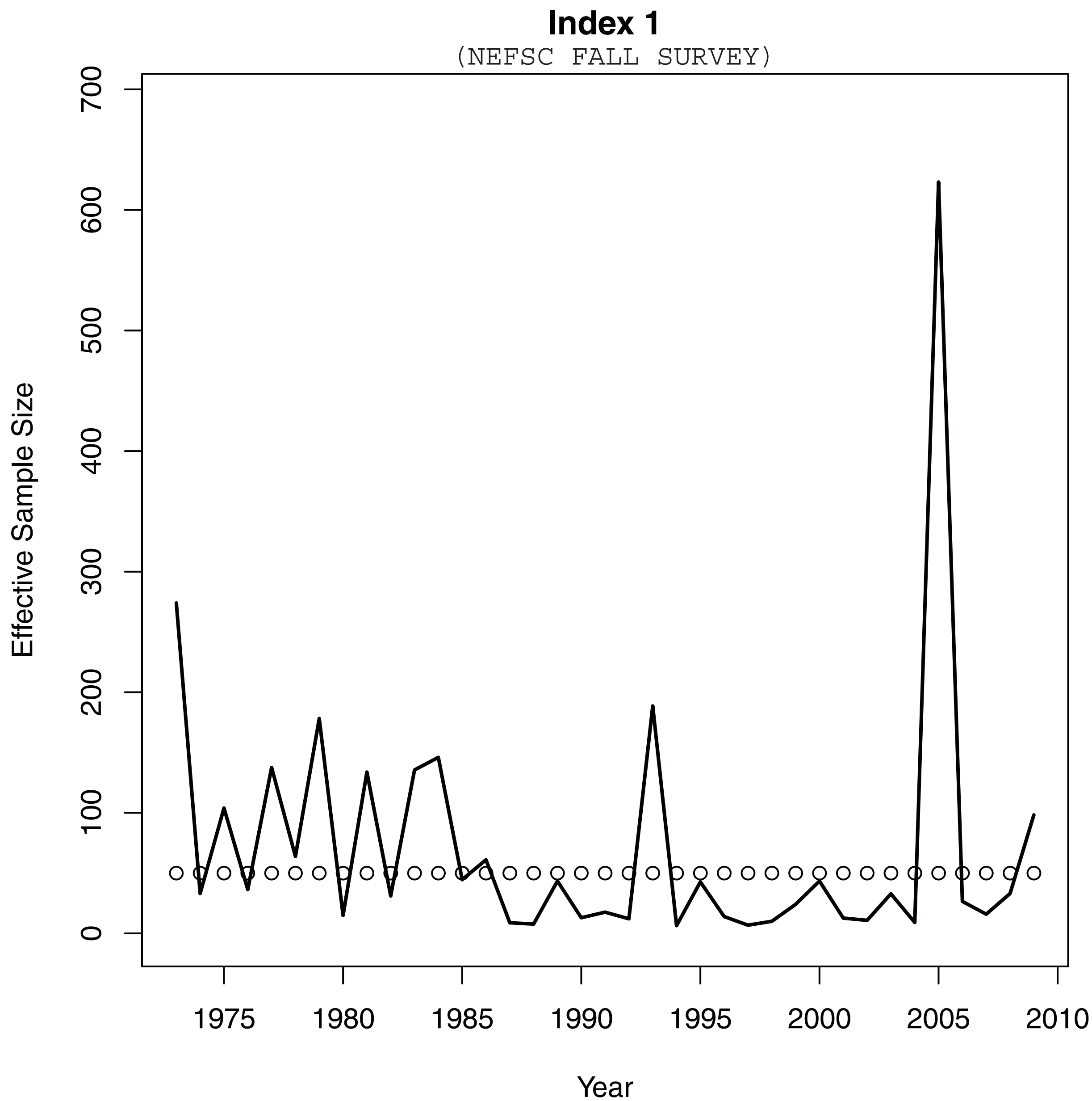
Index 2

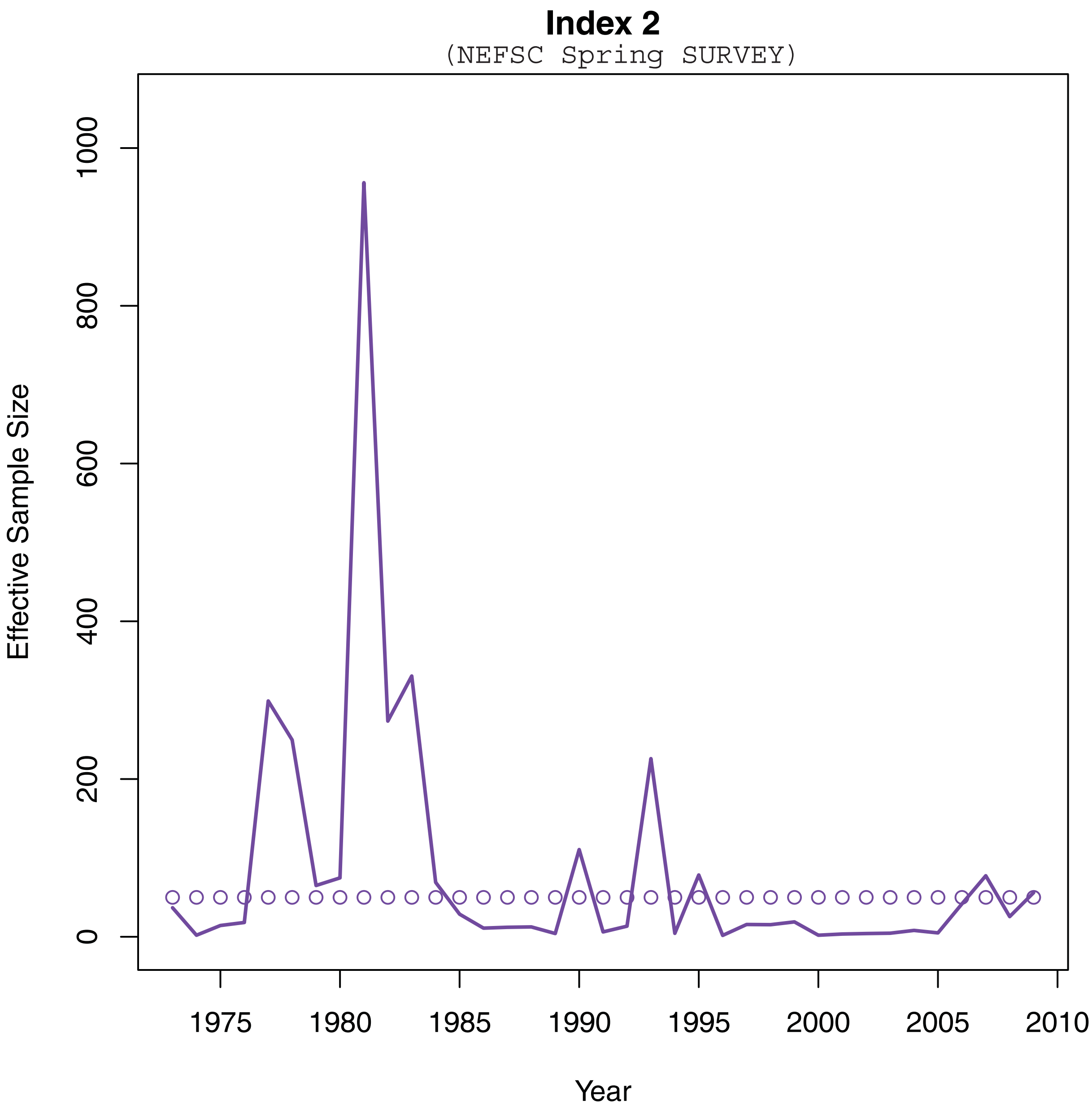
NEFSC Spring Survey

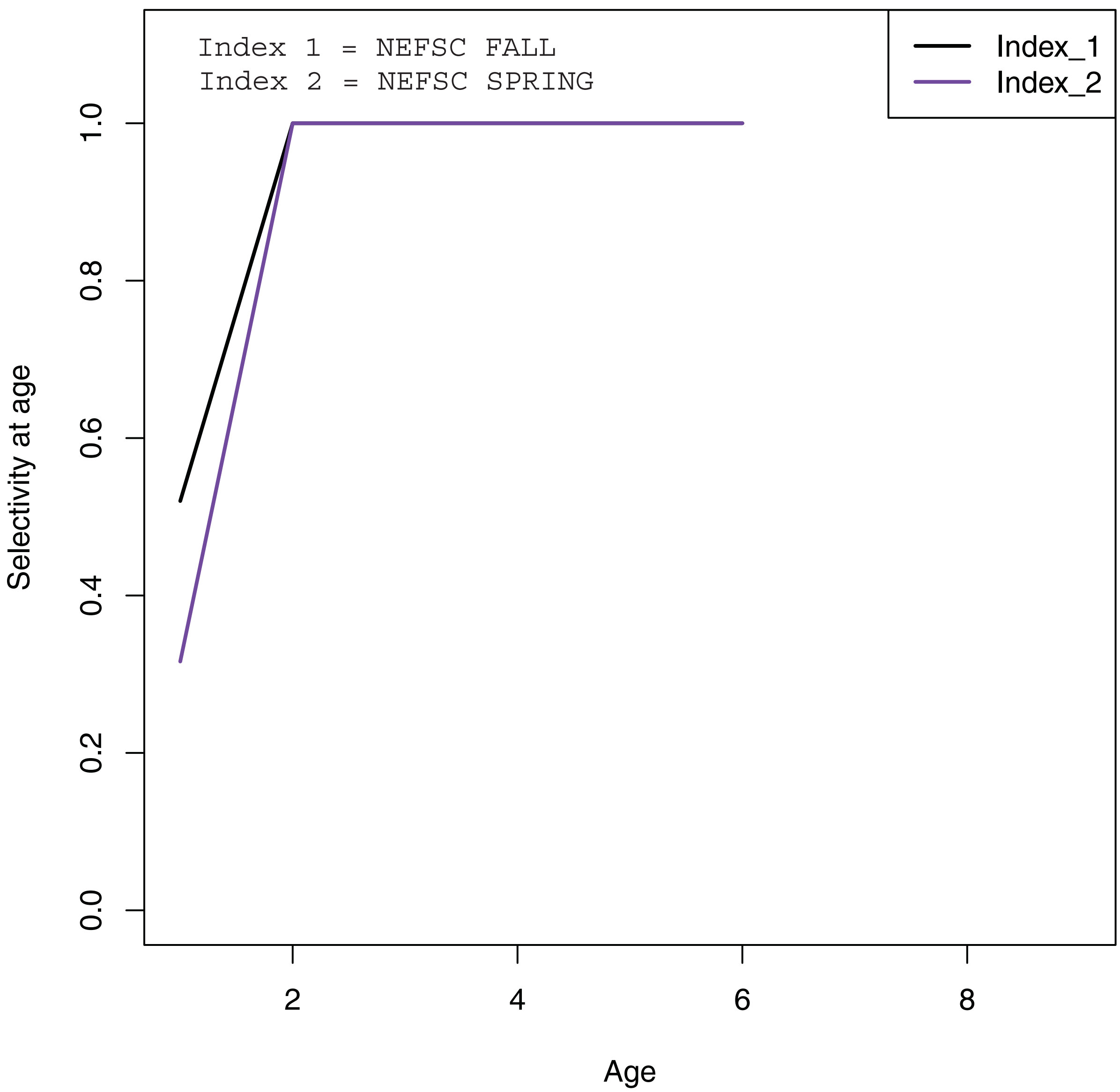


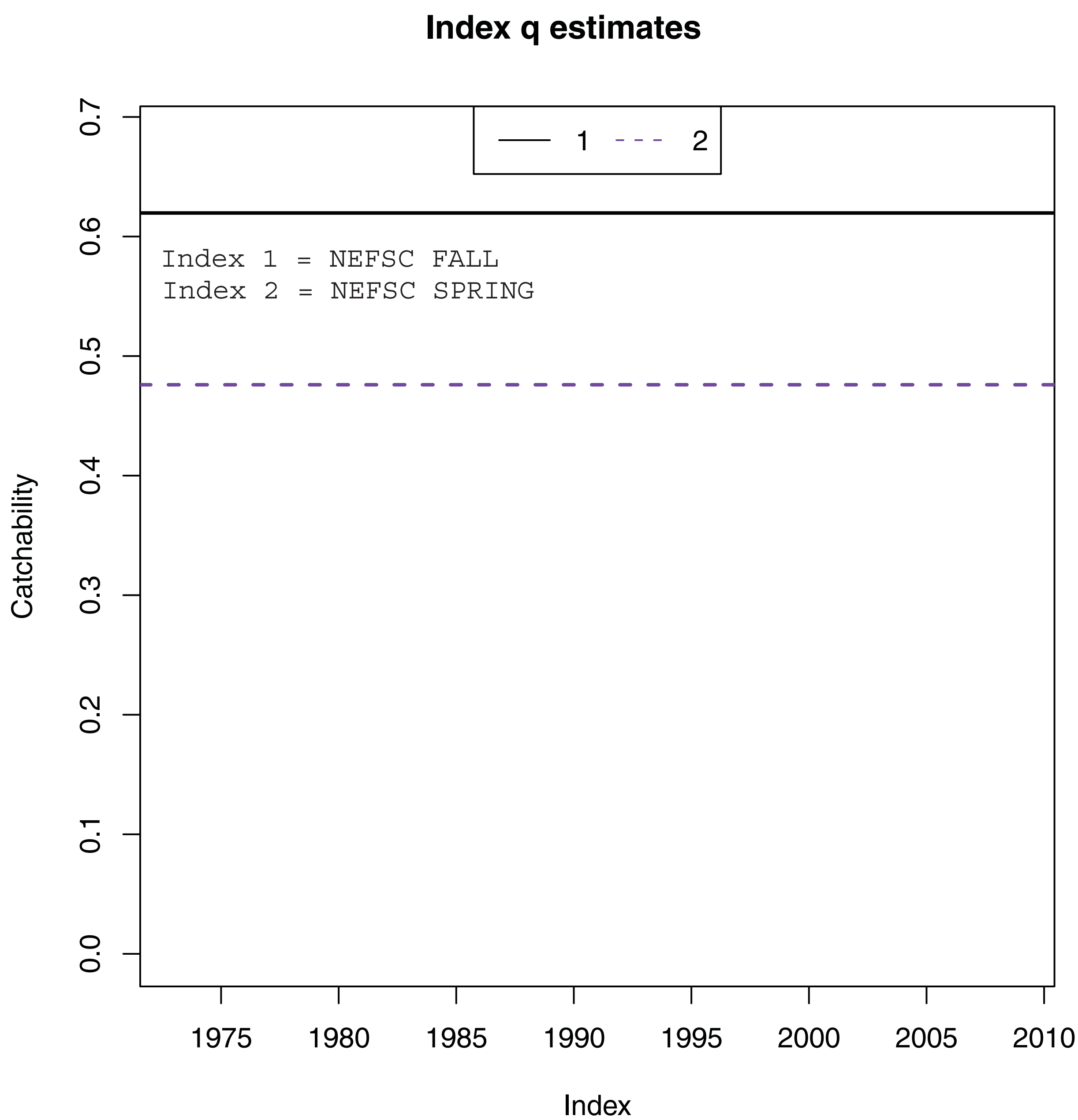

Age Comp Residuals for Index 1
(NEFSC FALL SURVEY)
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age

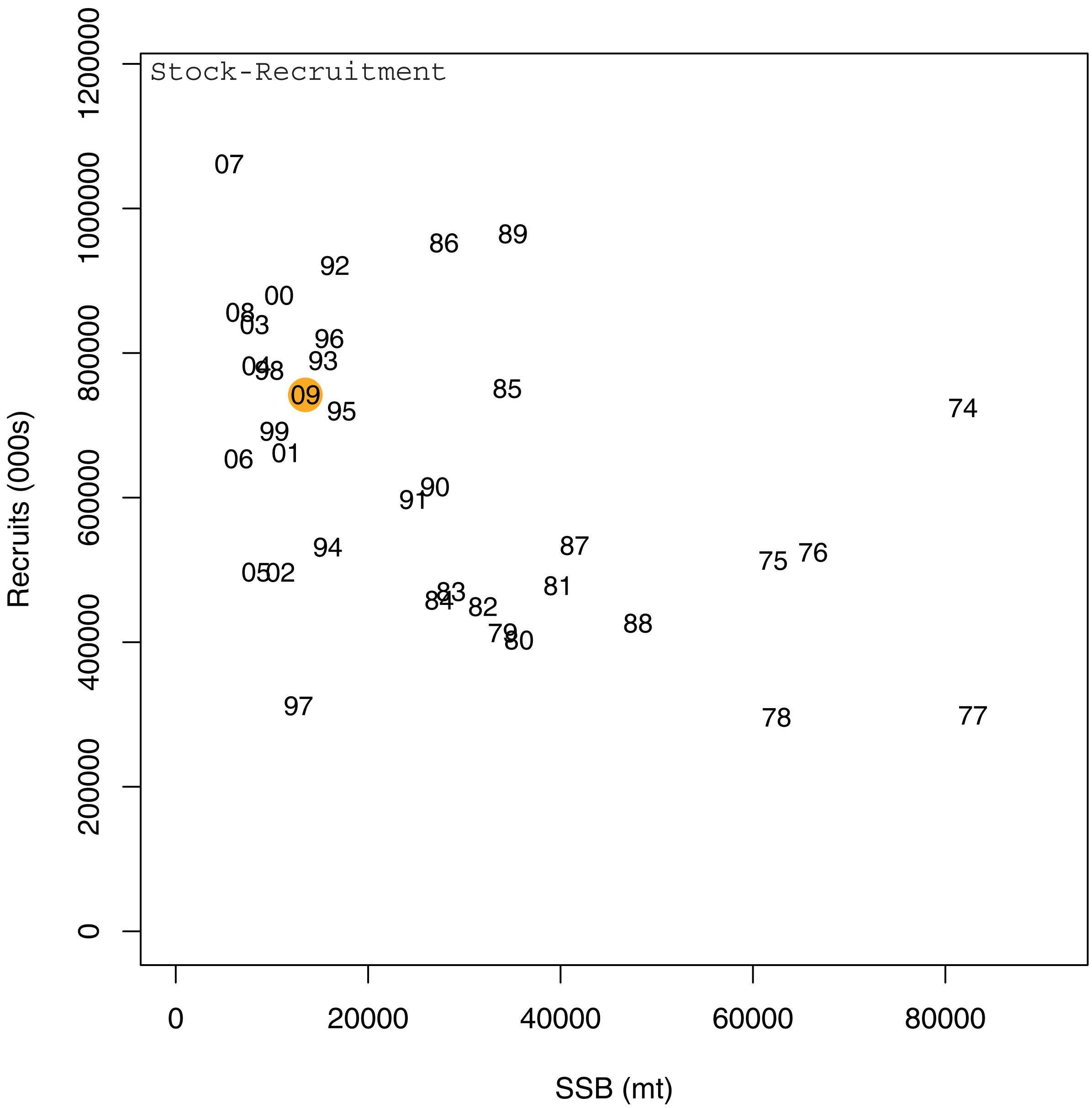

Age Comp Residuals for Index 2
(NEFSC Spring SURVEY)
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age

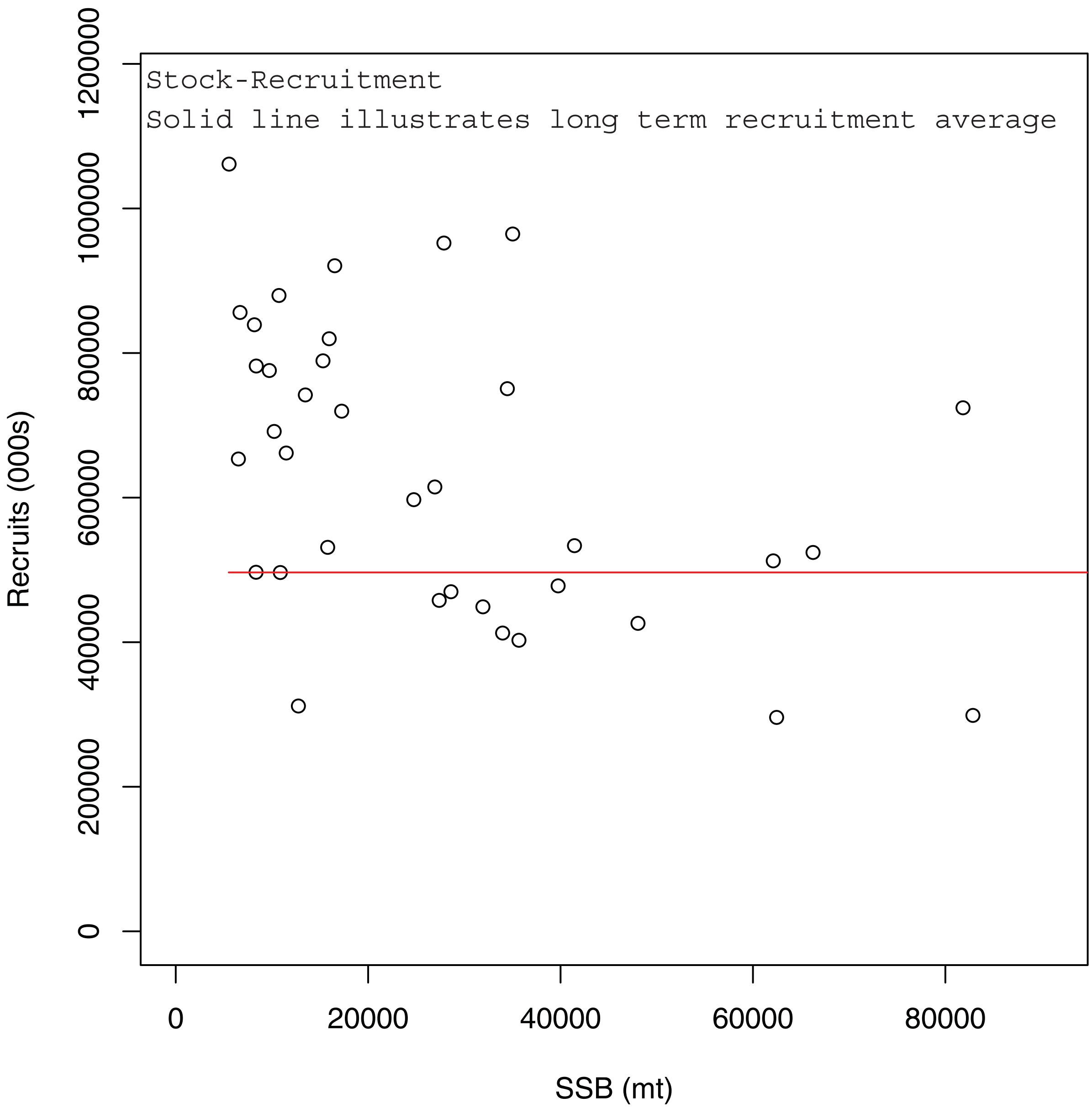

Index 1
(NEFSC FALL SURVEY)
Effective Sample Size
0
100
200
300
400
500
600
700
1975
1980
1985
1990
1995
2000
2005
2010
Year

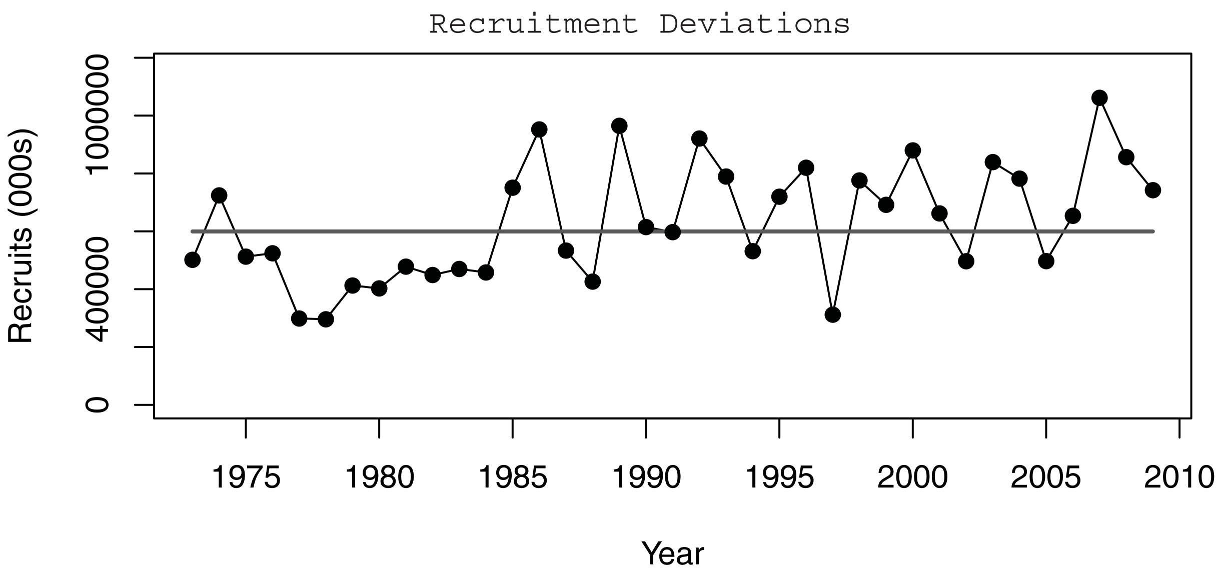

Index 2
(NEFSC Spring SURVEY)
Effective Sample Size
0
200
400
600
800
1000
1975
1980
1985
1990
1995
2000
2005
2010
Year

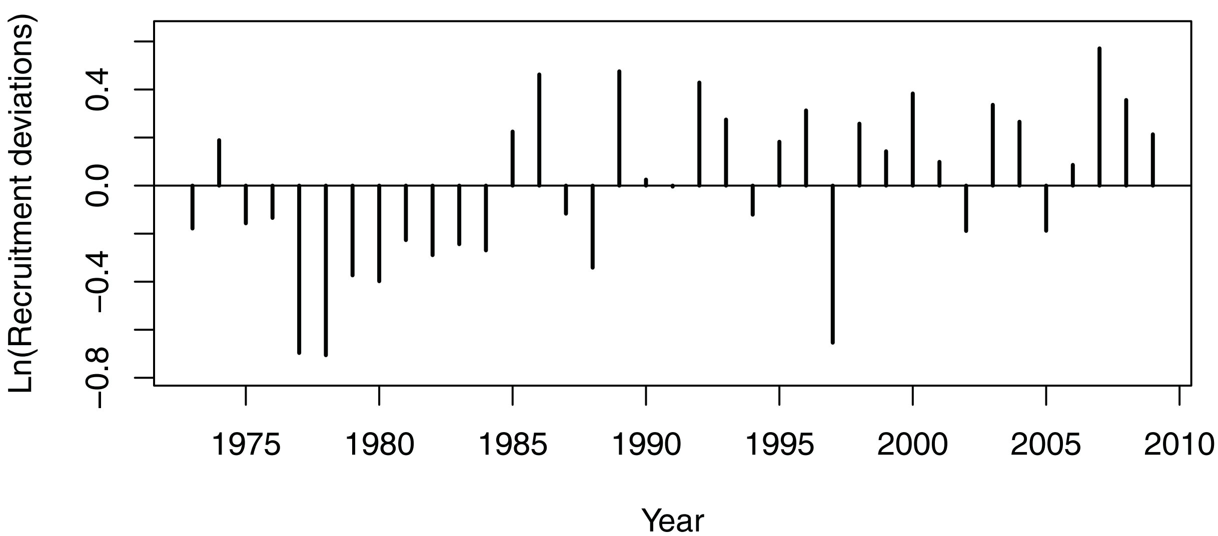

Index 1 = NEFSC FALL
Index 2 = NEFSC SPRING
Index_1
Index_2
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
Age

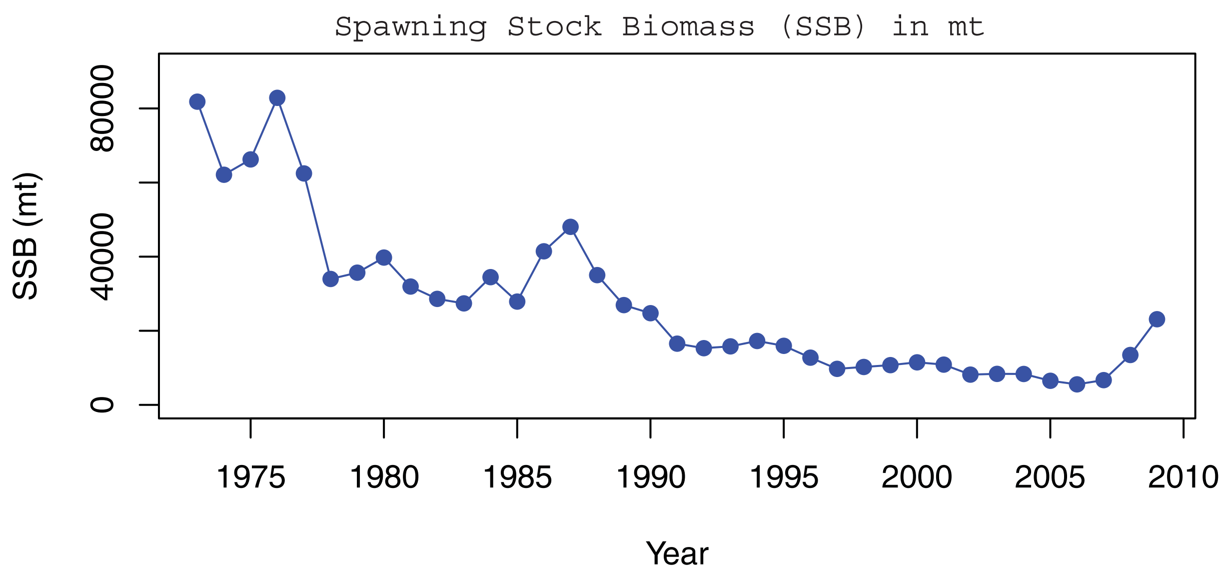

Index q estimates
1
2
Index 1 = NEFSC FALL
Index 2 = NEFSC SPRING
Catchability
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1975
1980
1985
1990
1995
2000
2005
2010
Index

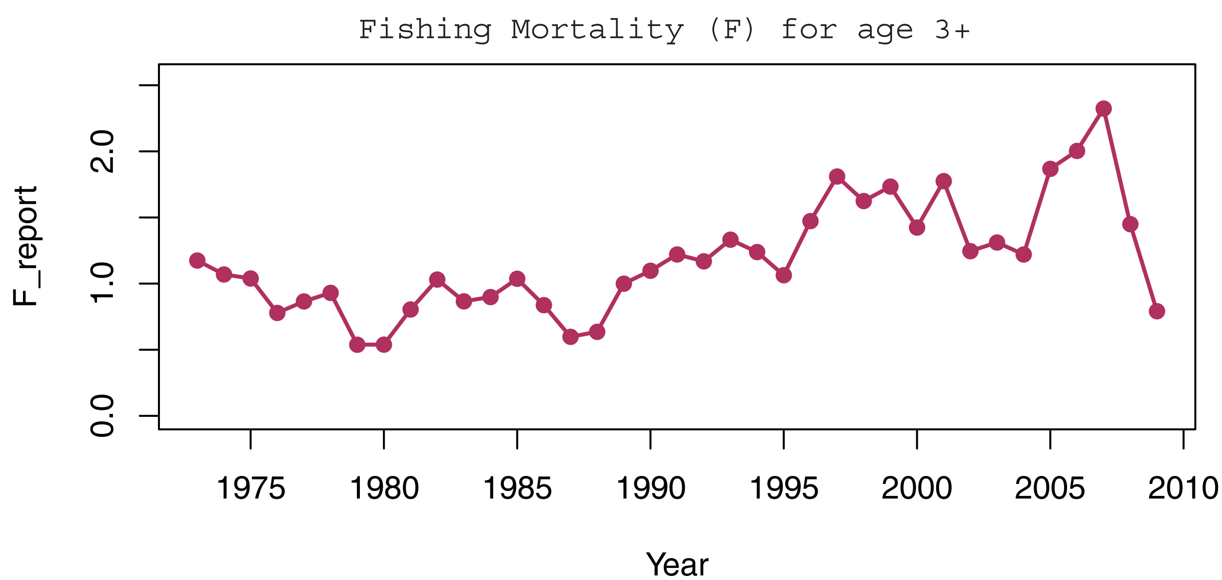

Stock-Recruitment
Recruits (000s)
SSB (mt)
0
200000
400000
600000
800000
1000000
1200000
0
20000
40000
60000
80000
07
86
89
92
00
08
03
96
04
98
93
09
85
74
95
99
01
06
91
90
94
87
75
76
05
02
83
84
82
81
88
79
80
97
78
77

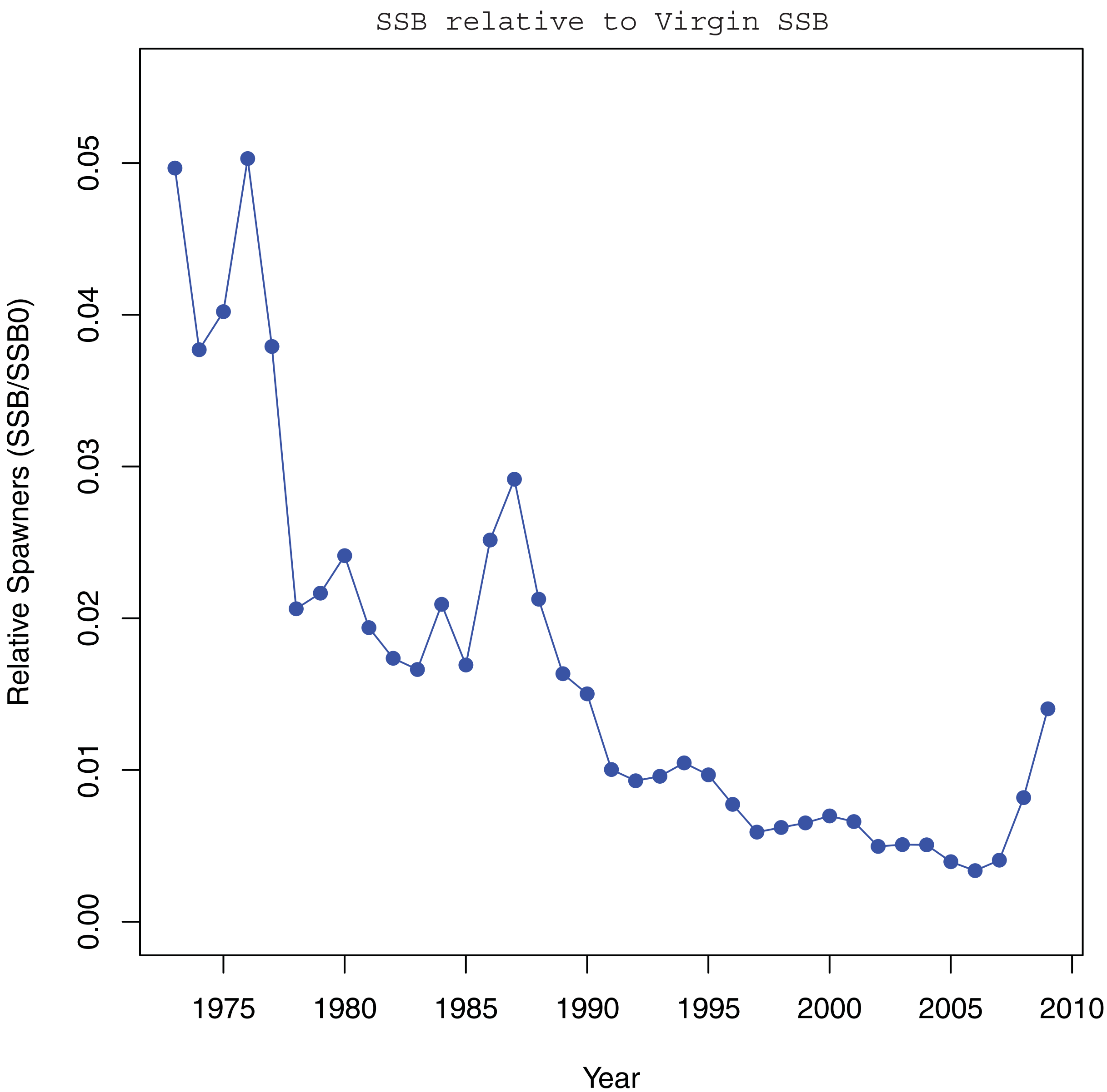

Stock-Recruitment
Solid line illustrates long term recruitment average
Recruits (000s)
0
200000
400000
600000
800000
1000000
1200000
0
20000
40000
60000
80000
SSB (mt)

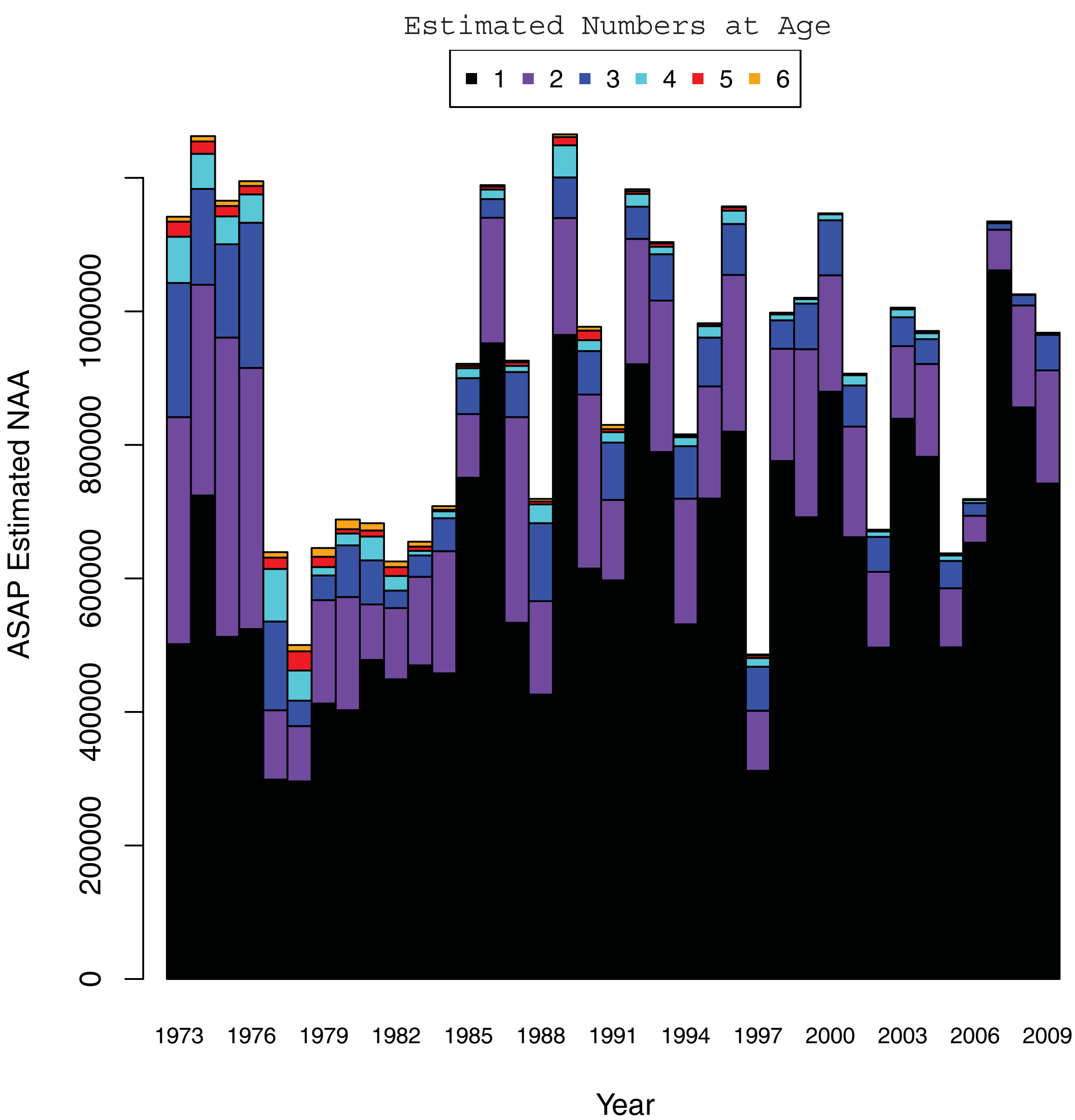

Recruitment Deviations
Recruits (000s)
0
400000
1000000
1975
1980
1985
1990
1995
2000
2005
2010
Year

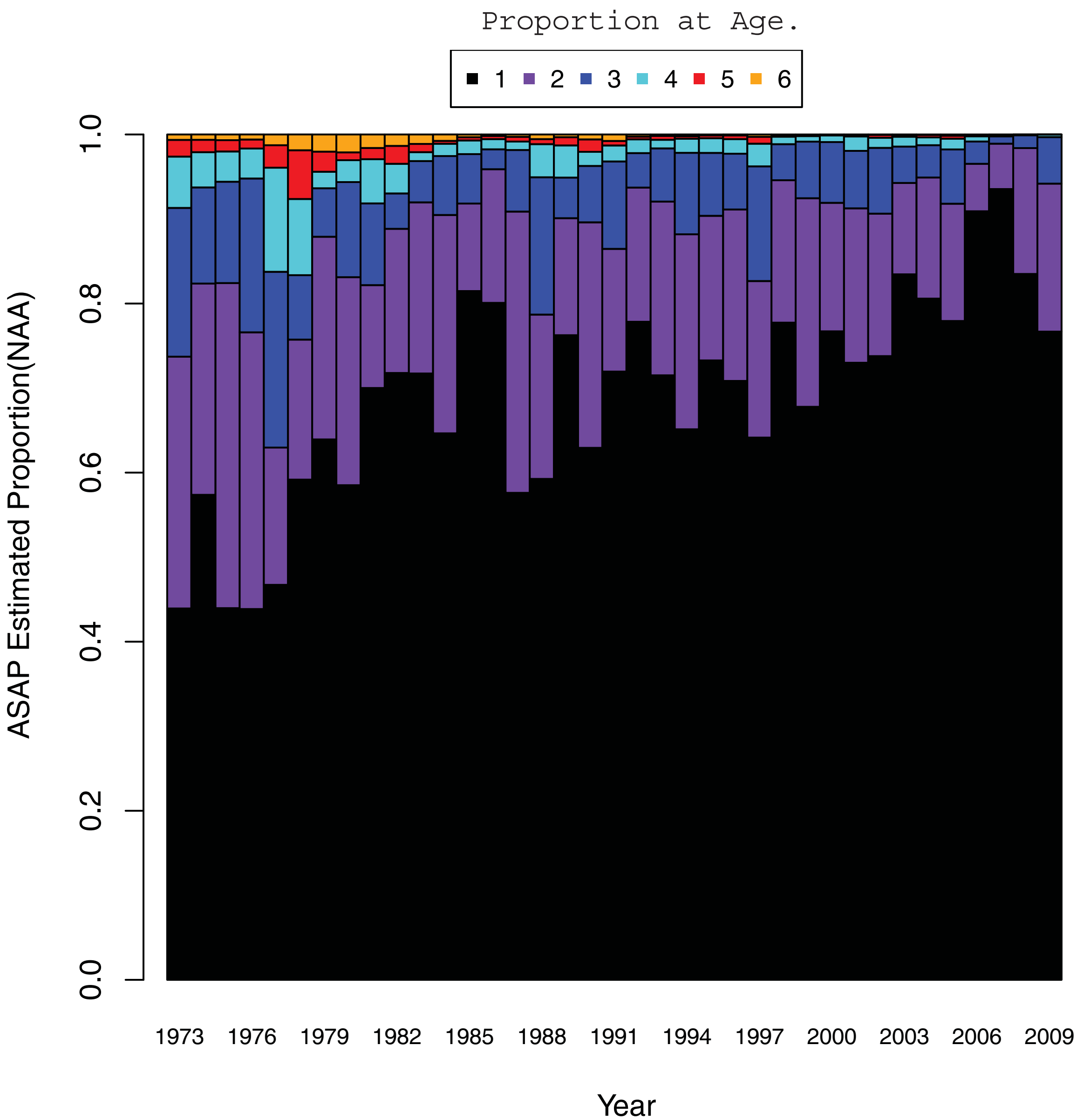

Ln(Recruitment deviations)
−0.8
−0.4
0.0
0.4
1975
1980
1985
1990
1995
2000
2005
2010
Year

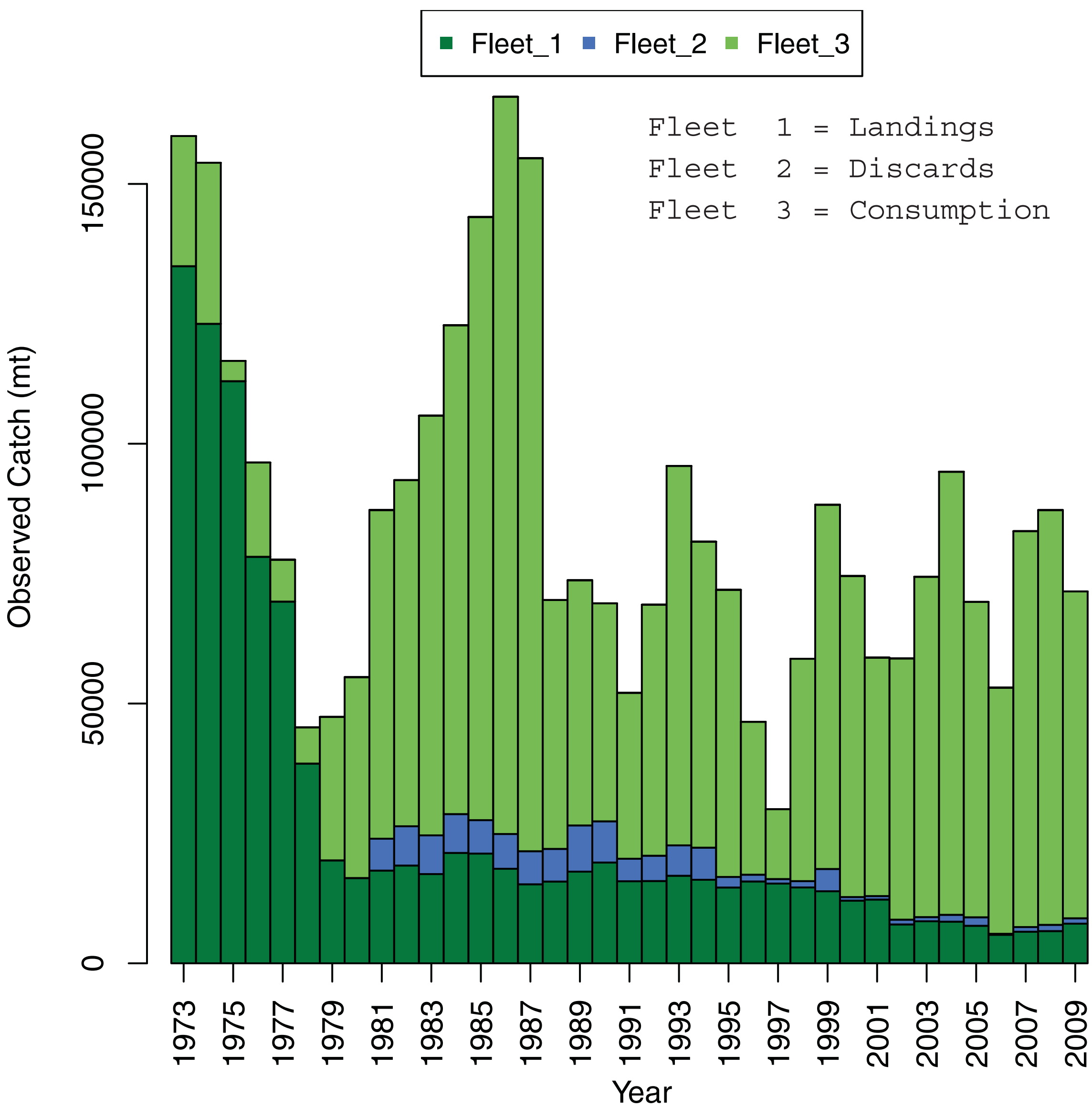

Spawning Stock Biomass (SSB) in mt
SSB (mt)
0
40000
80000
1975
1980
1985
1990
1995
2000
2005
2010
Year

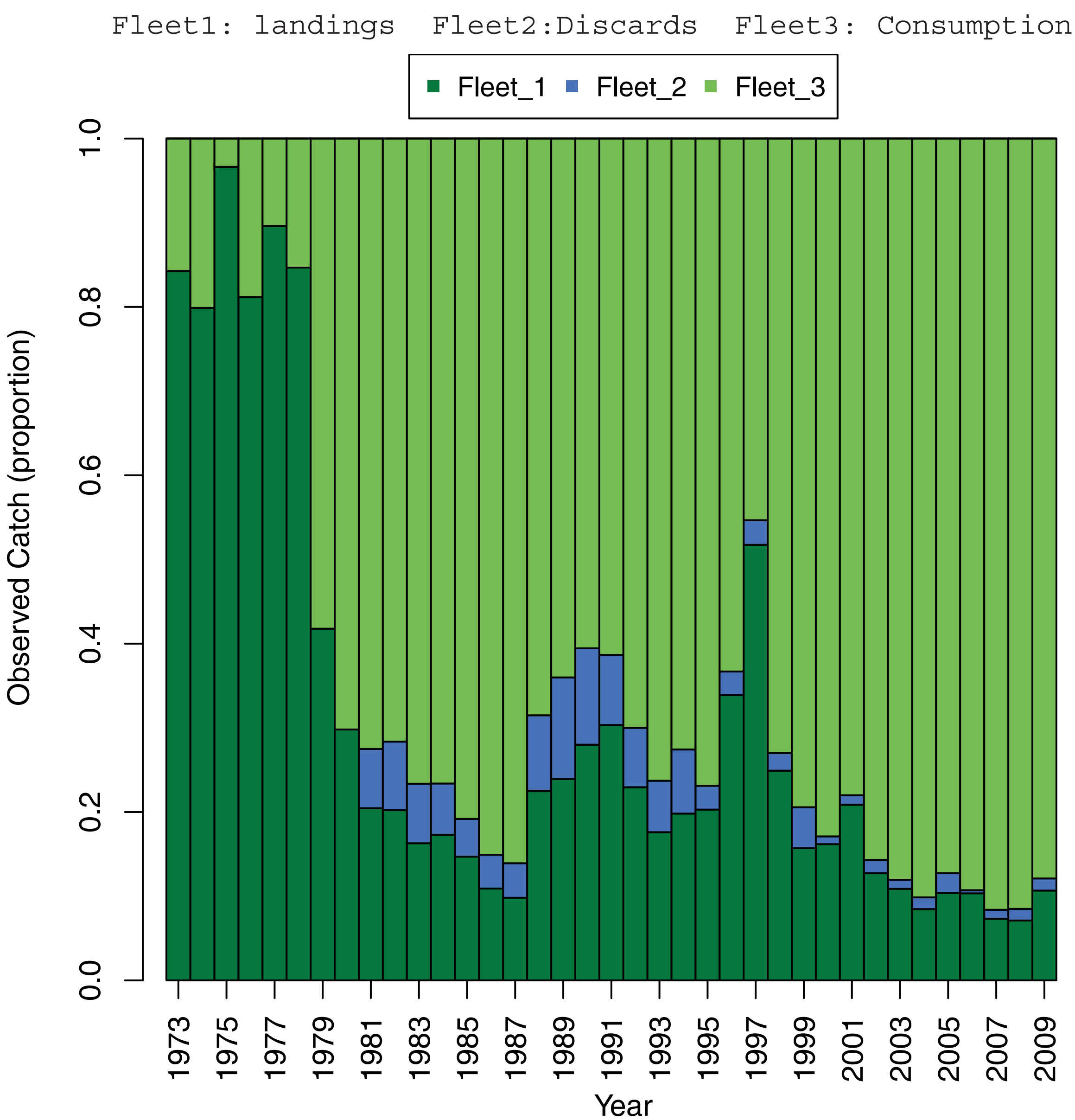

Fishing Mortality (F) for age 3+
F_report
0.0
1.0
2.0
1975
1980
1985
1990
1995
2000
2005
2010
Year

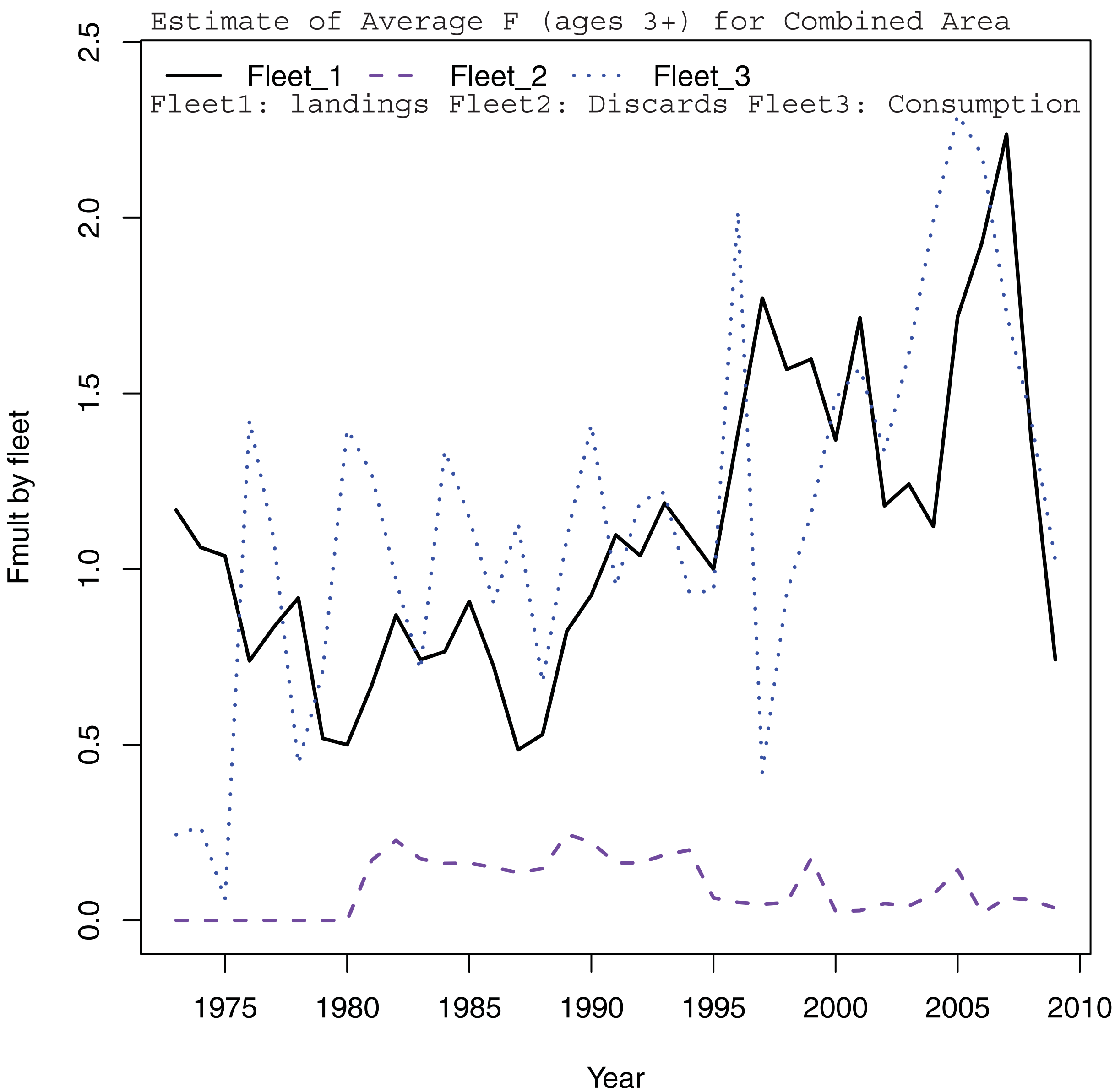

SSB relative to Virgin SSB
Relative Spawners (SSB/SSB0)
0.00
0.01
0.02
0.03
0.04
0.05
1975
1980
1985
1990
1995
2000
2005
2010
Year

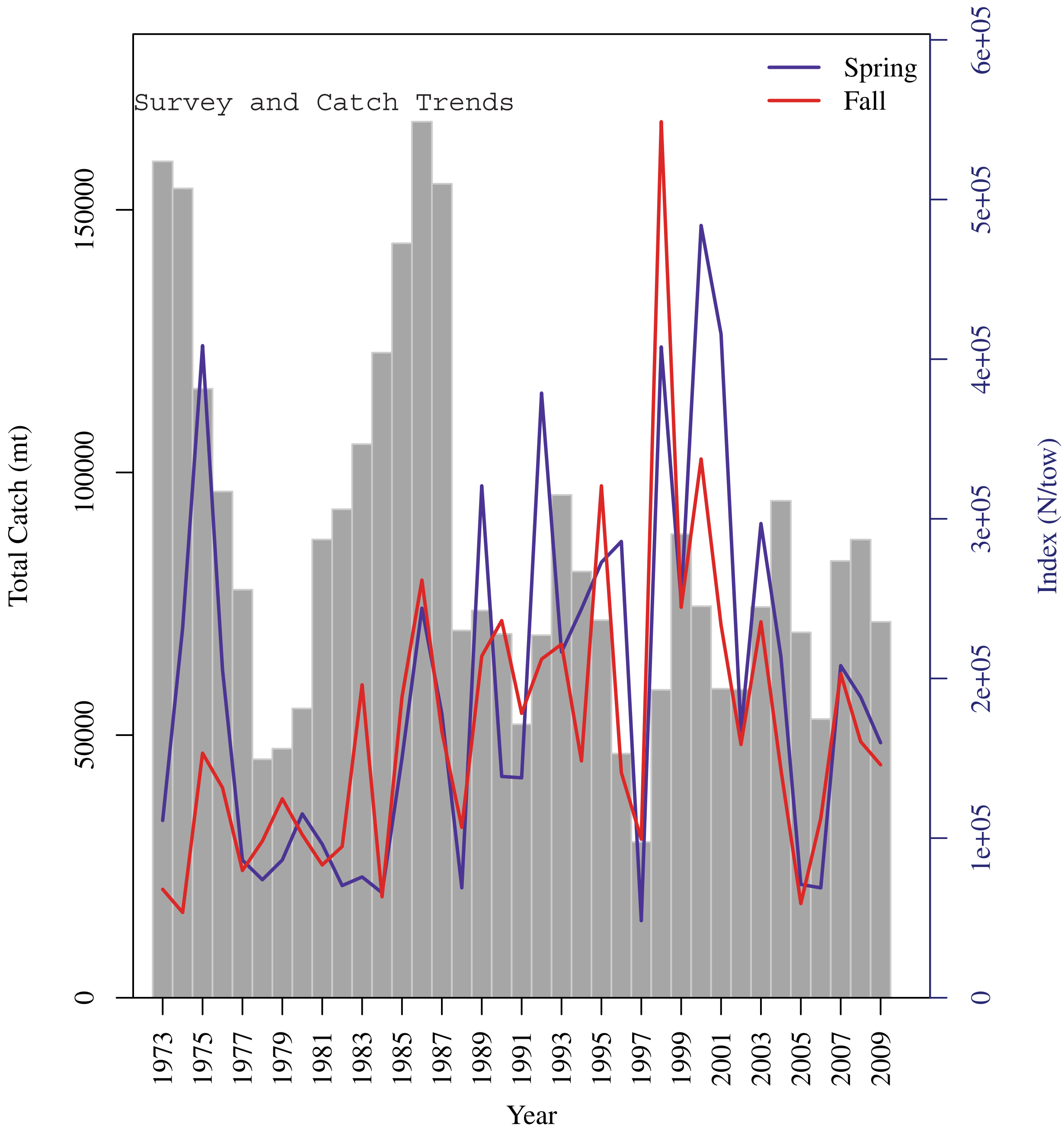

Estimated Numbers at Age
1
2
3
4
5
6
ASAP Estimated NAA
0
200000
400000
600000
800000
1000000
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

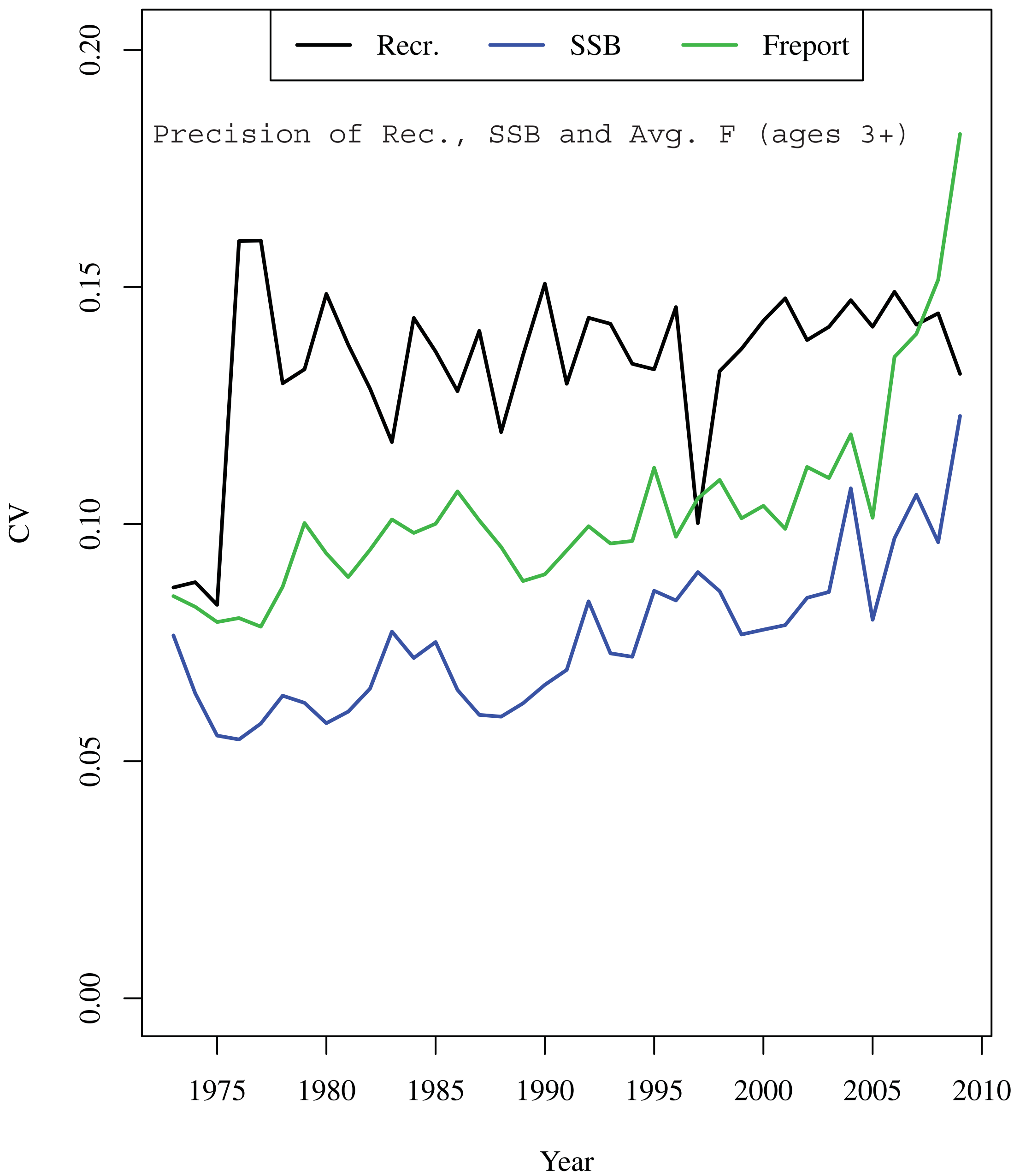

Proportion at Age.
1
2
3
4
5
6
ASAP Estimated Proportion(NAA)
0.0
0.2
0.4
0.6
0.8
1.0
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

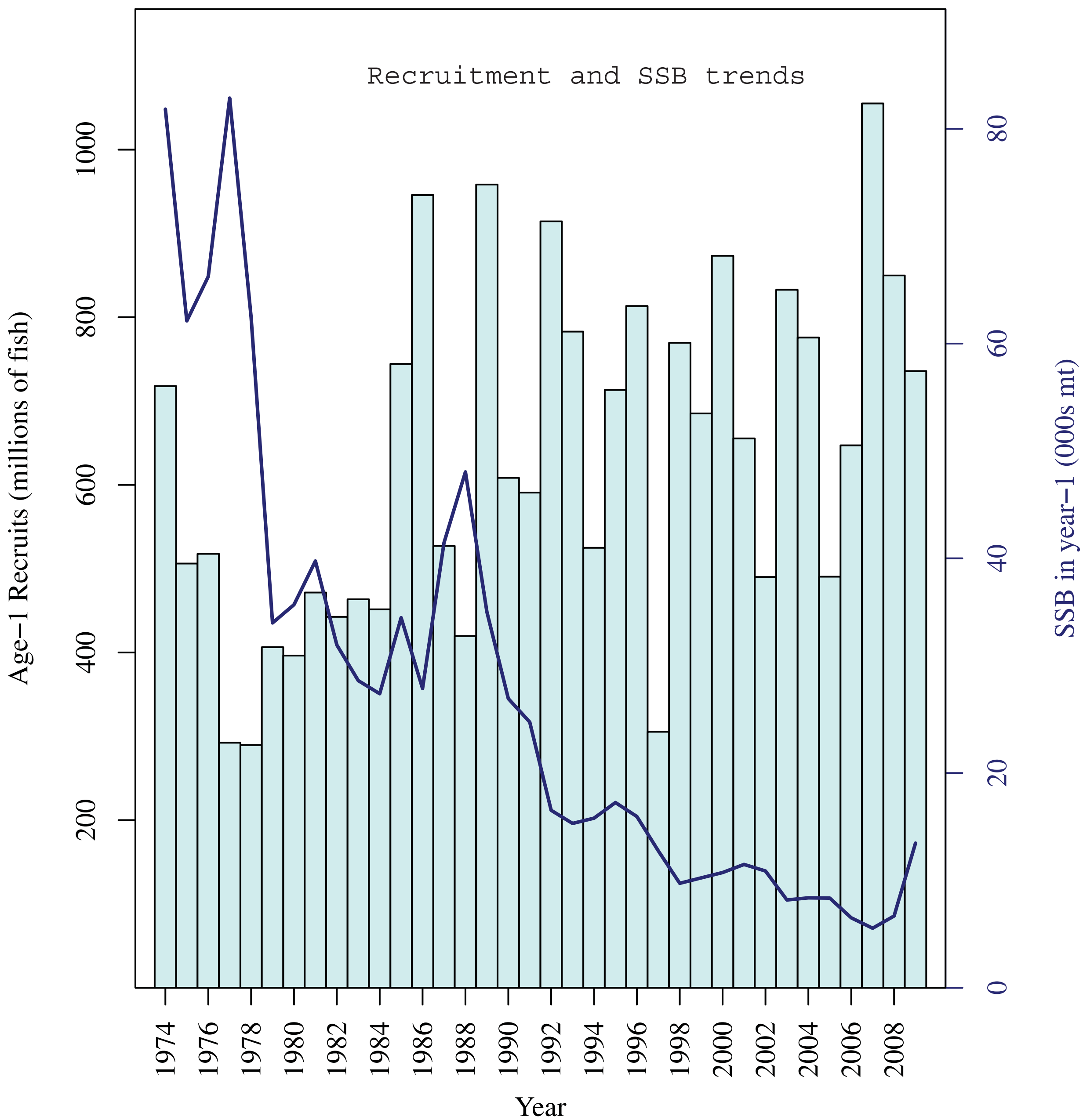

Fleet_1
Fleet_2
Fleet_3
Fleet 1 = Landings
Fleet 2 = Discards
Fleet 3 = Consumption
Observed Catch (mt)
0
50000
100000
150000
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year


Fleet1: landings Fleet2:Discards Fleet3: Consumption
Fleet_1
Fleet_2
Fleet_3
Observed Catch (proportion)
0.0
0.2
0.4
0.6
0.8
1.0
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year


Estimate of Average F (ages 3+) for Combined Area
Fleet_1
Fleet_2
Fleet_3
Fleet1: landings Fleet2: Discards Fleet3: Consumption
Fmult by fleet
0.0
0.5
1.0
1.5
2.0
2.5
1975
1980
1985
1990
1995
2000
2005
2010
Year


Survey and Catch Trends
Spring
Fall
Total Catch (mt)
Index (N/tow)
Year
0
50000
100000
150000
0
1e+05
2e+05
3e+05
4e+05
5e+05
6e+05
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009


Recr.
SSB
Freport
Precision of Rec., SSB and Avg. F (ages 3+)
CV
0.00
0.05
0.10
0.15
0.20
1975
1980
1985
1990
1995
2000
2005
2010
Year


Recruitment and SSB trends
Age−1 Recruits (millions of fish)
SSB in year−1 (000s mt)
Year

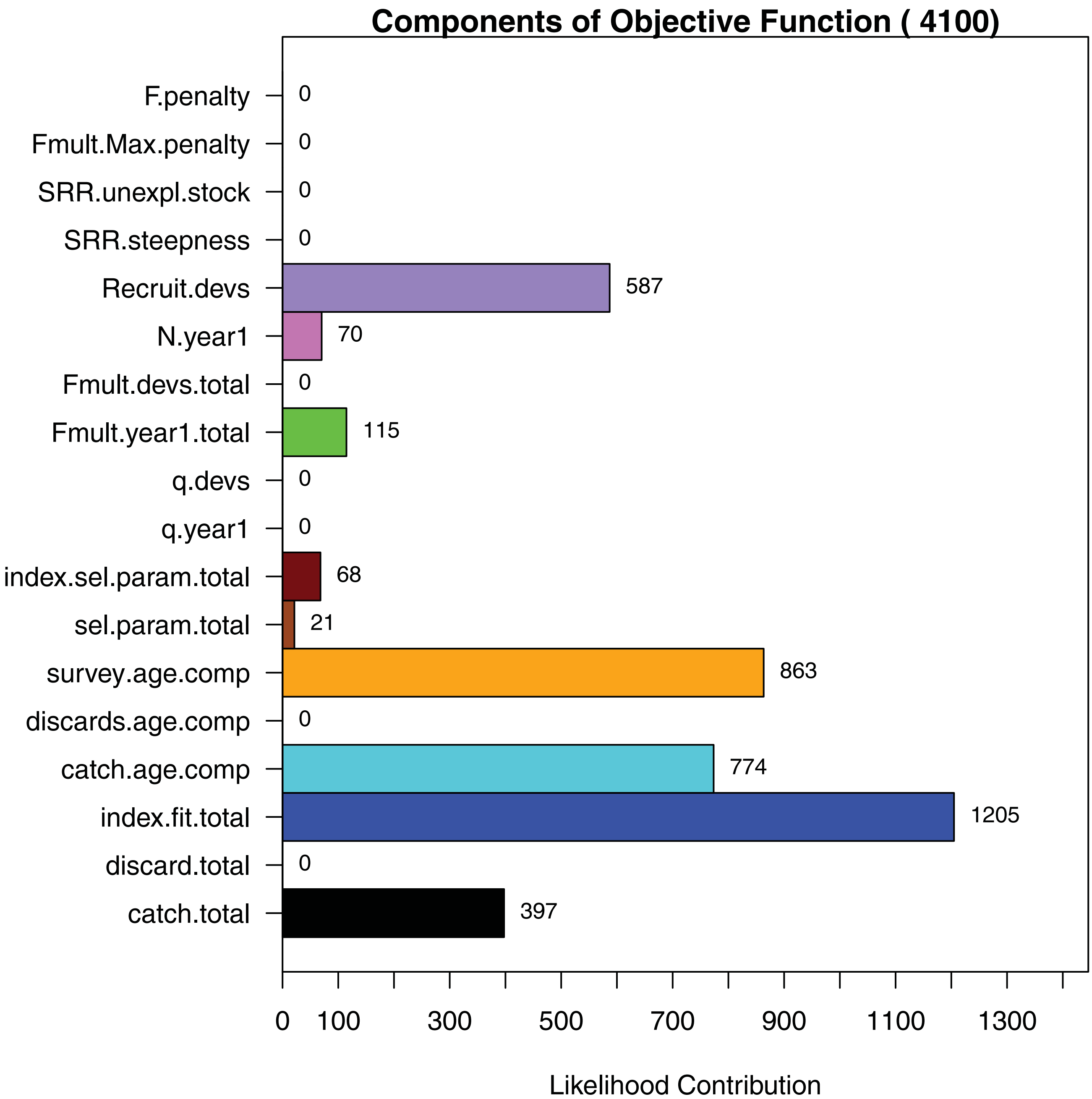
Appendix A3: North Model ASAP results M = 0.4 Base run

Model Attributes:

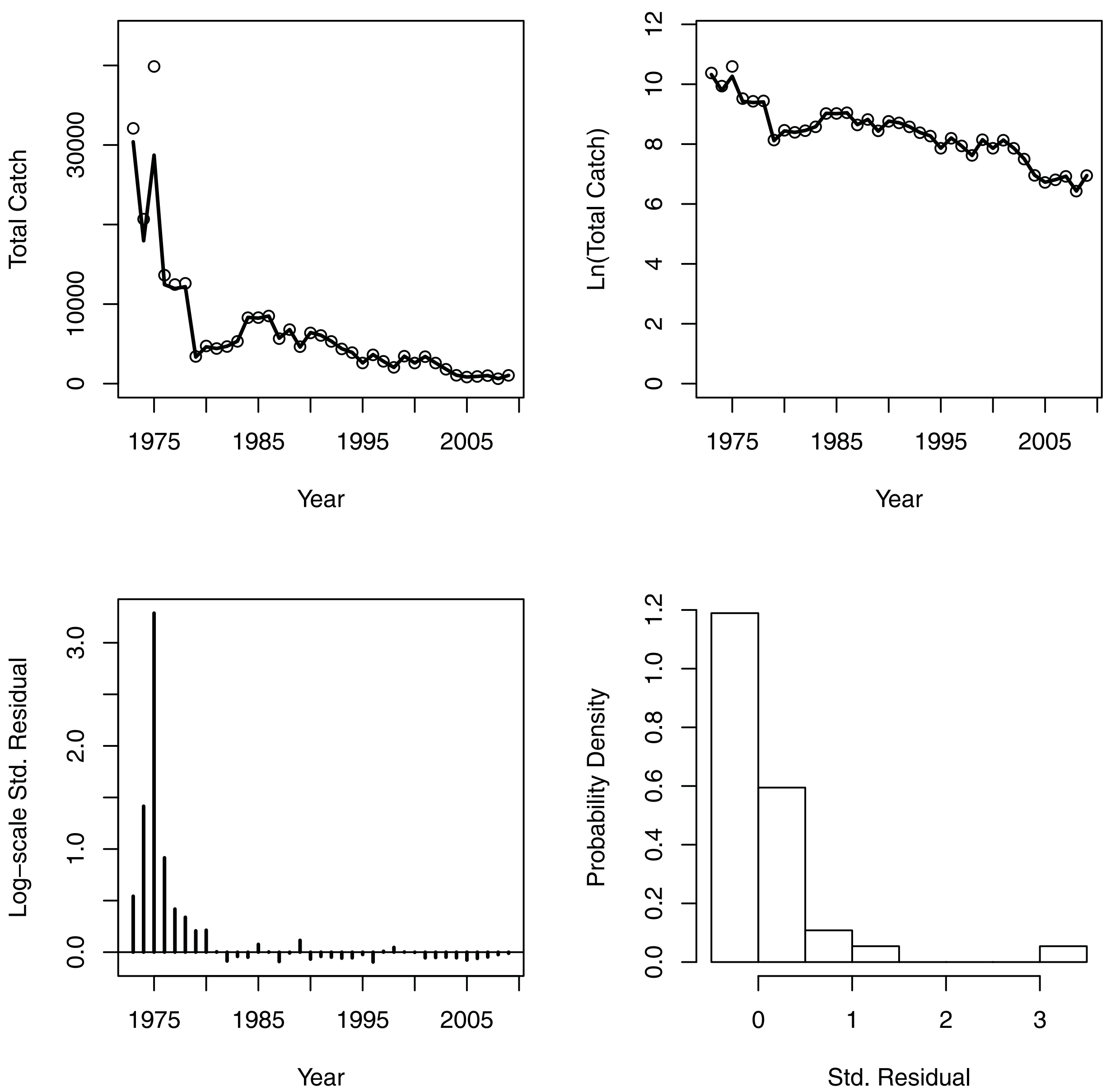
1. 3 Fleet Model
   a. Catch : 1973-2009
   b. Discards: 1981 – 2009
   c. Consumption – 1973-2009

2. Fishery Selectivity (3 Block Selectivity)
   a. Landings (1 Blocks: 1973-2009)
   b. Discards (1 Block: 1981-2009)
   c. Consumption (Double Logistic Functional Form)

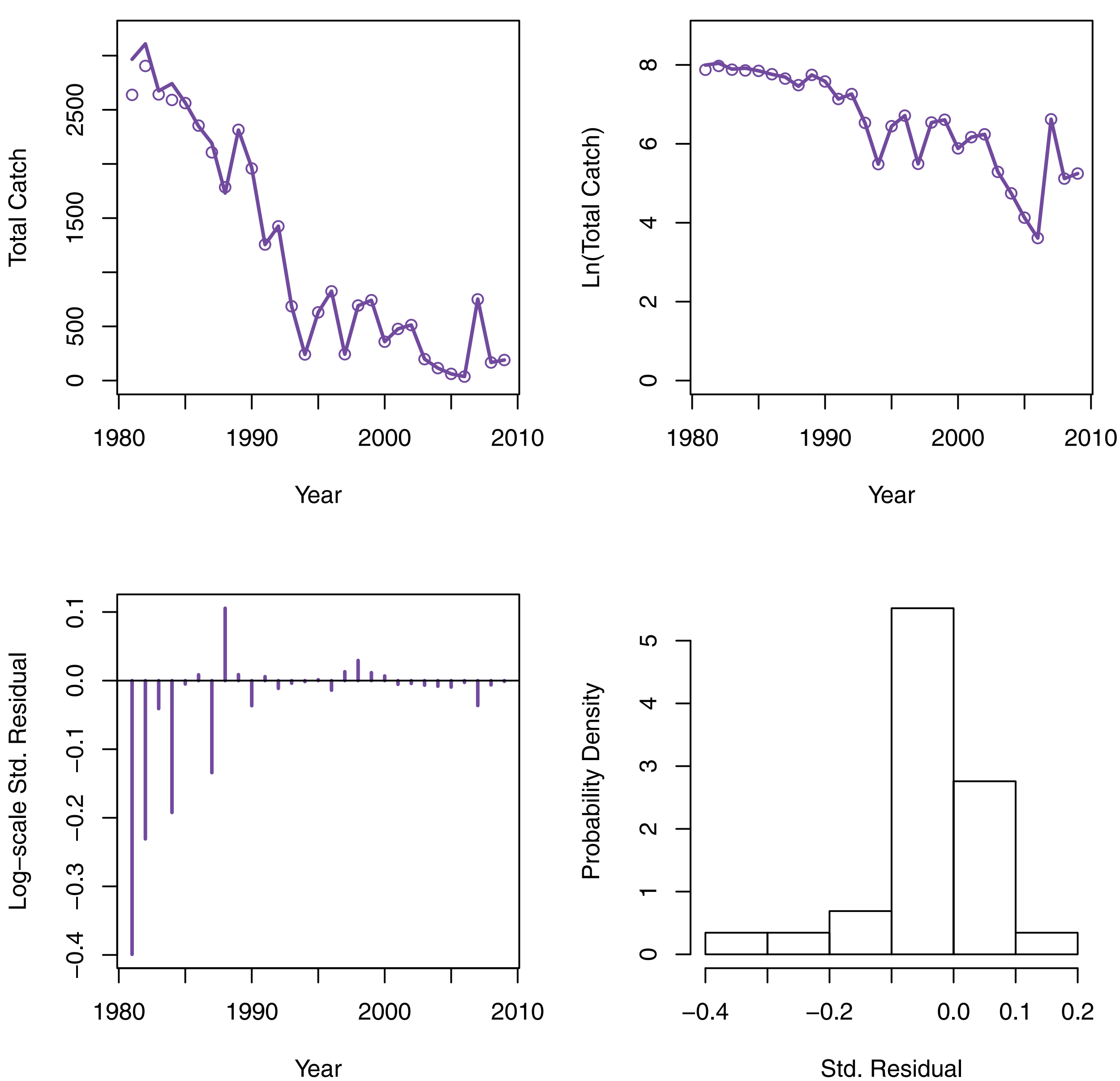
3. Survey Selectivity (Fixed 100% at age 2 and freely estimated older aged (3+)


Components of Objective Function (4100)
F.penalty
Fmult.Max.penalty
SRR.unexpl.stock
SRR.steepness
Recruit.devs
N.year1
Fmult.devs.total
Fmult.year1.total
q.devs
q.year1
index.sel.param.total
sel.param.total
survey.age.comp
discards.age.comp
catch.age.comp
index.fit.total
discard.total
catch.total
0
0
0
0
587
70
0
115
0
0
68
21
863
0
774
1205
0
397
0 100 300 500 700 900 1100 1300
Likelihood Contribution

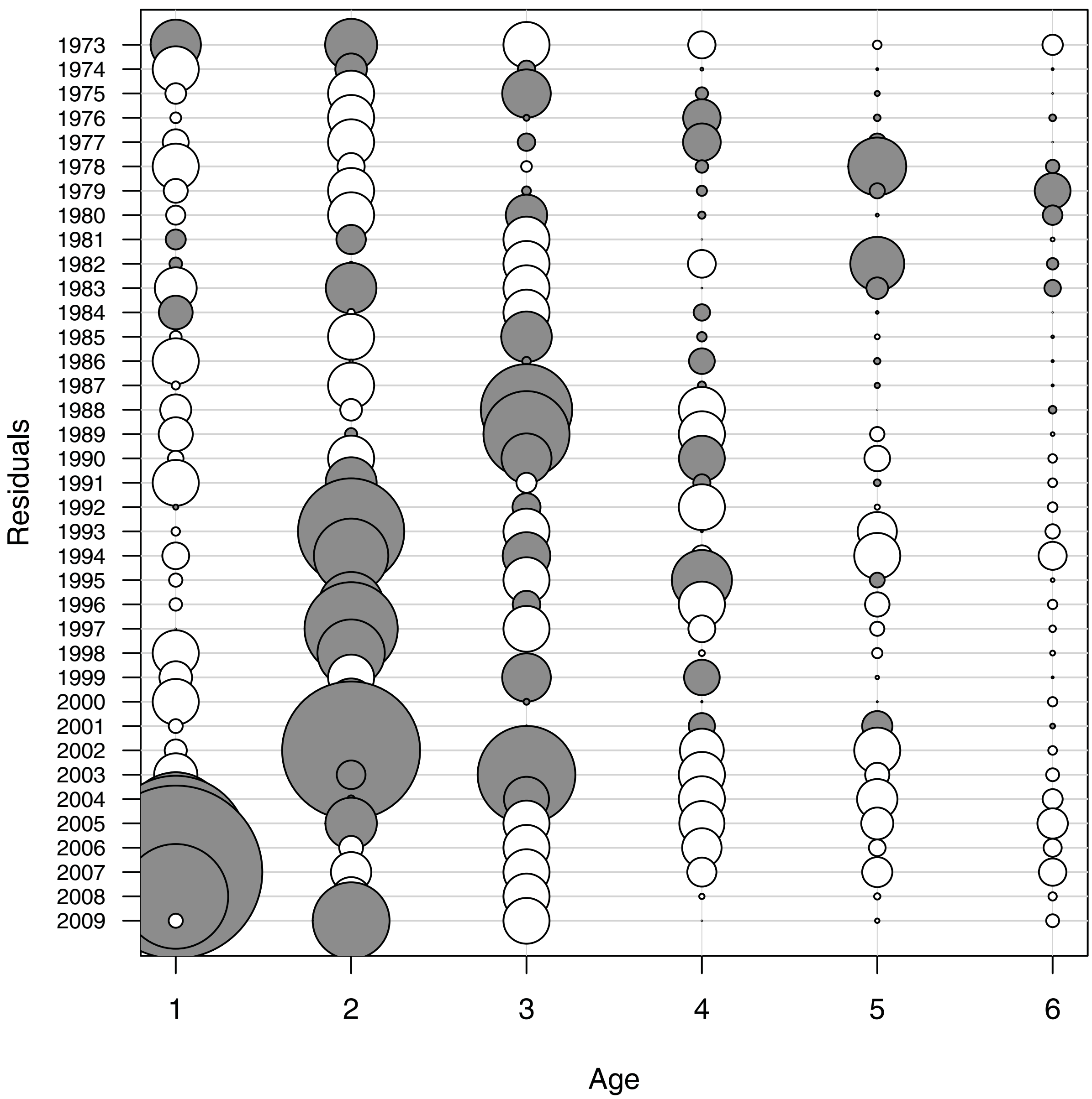
Fleet 1 Landings (Comm)

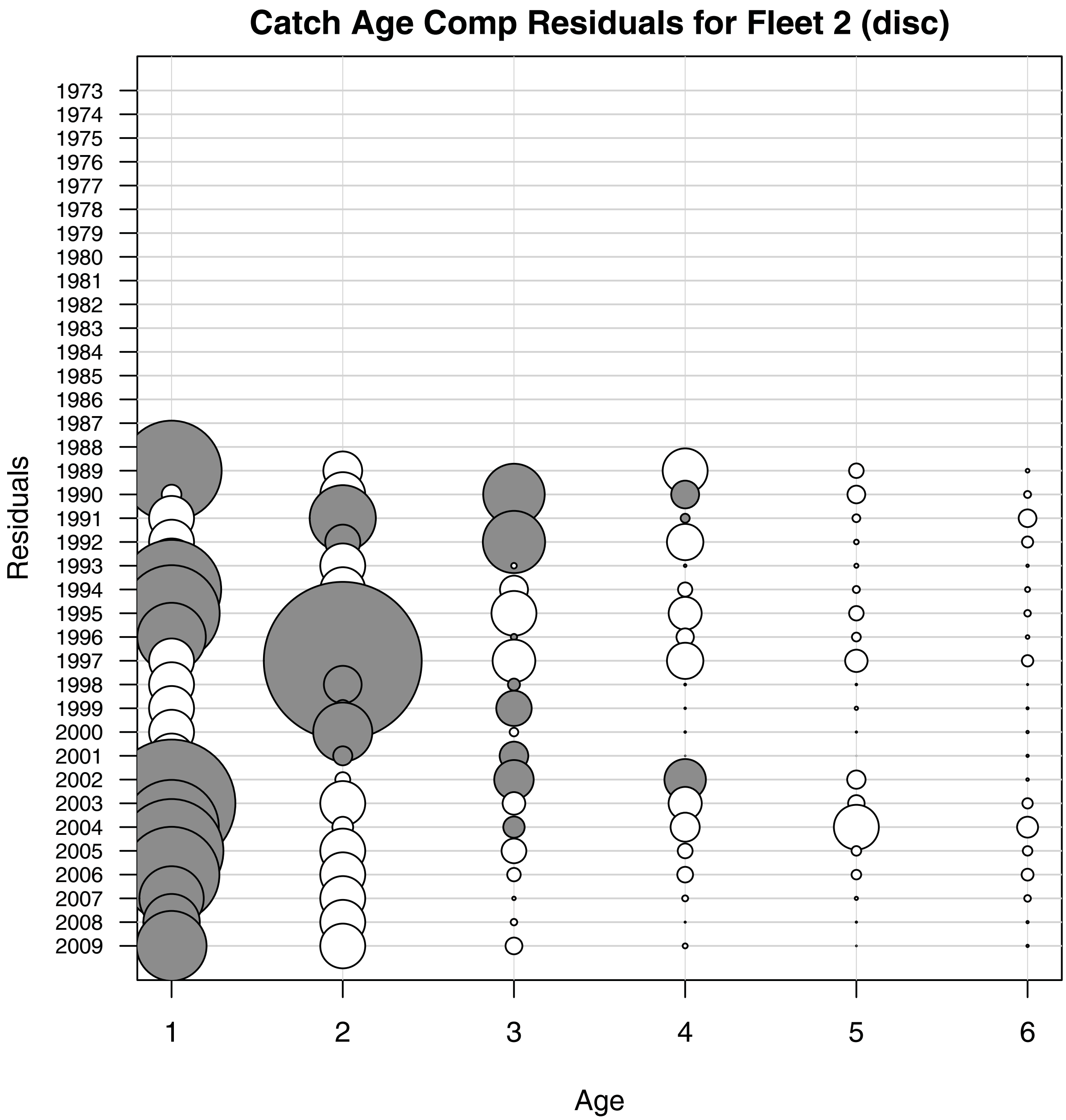


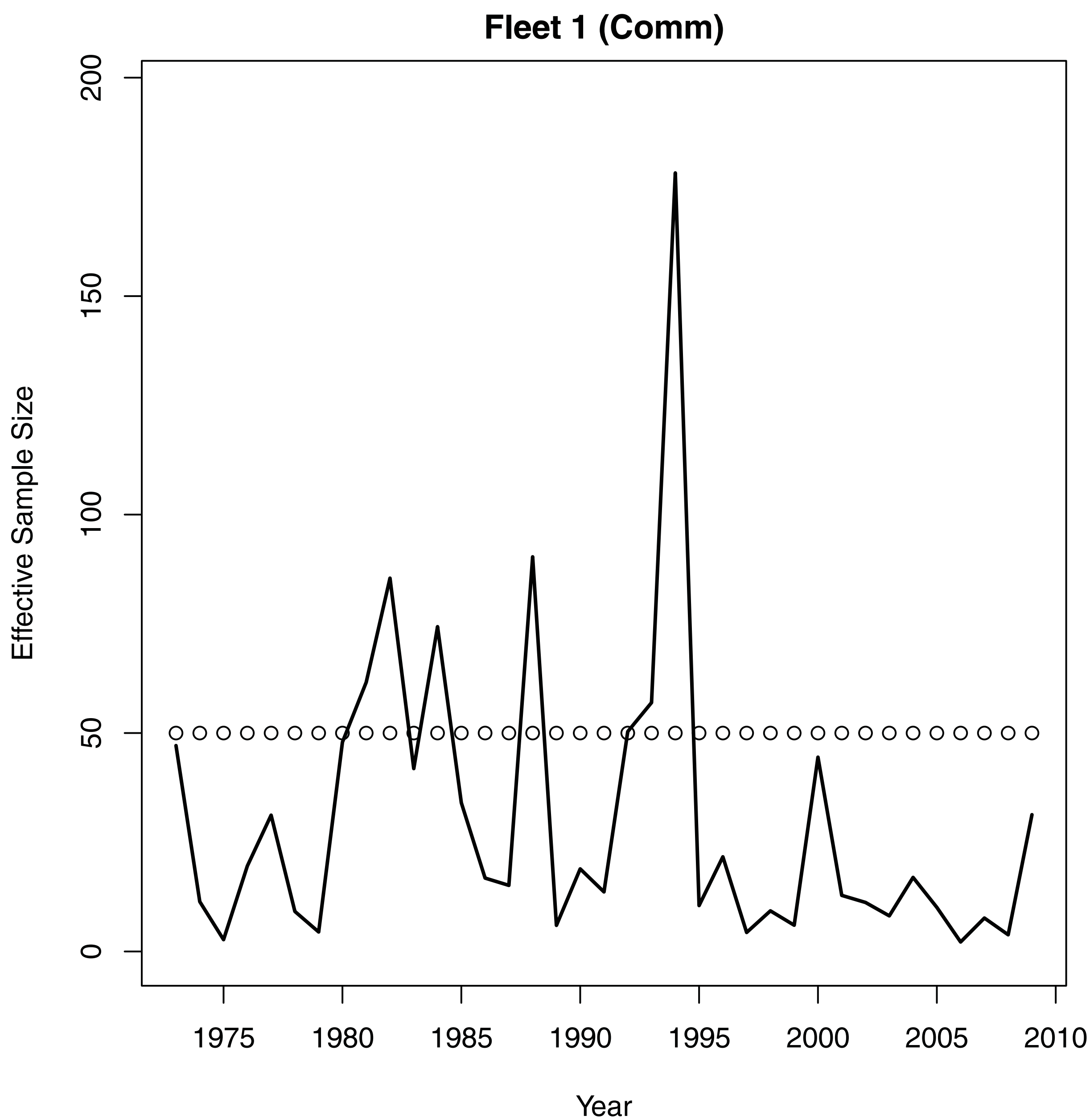
Fleet 2 Landings (disc)

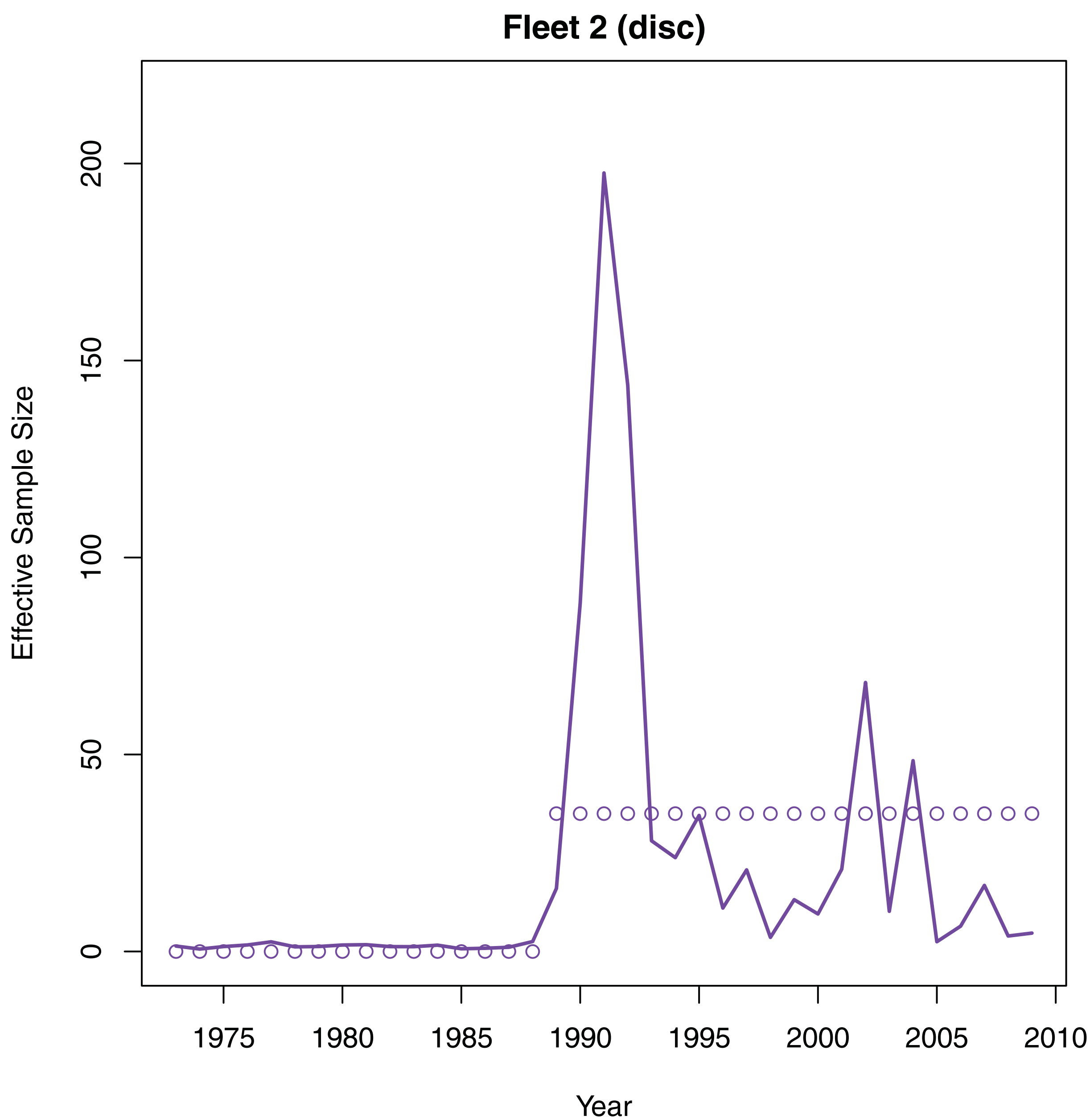


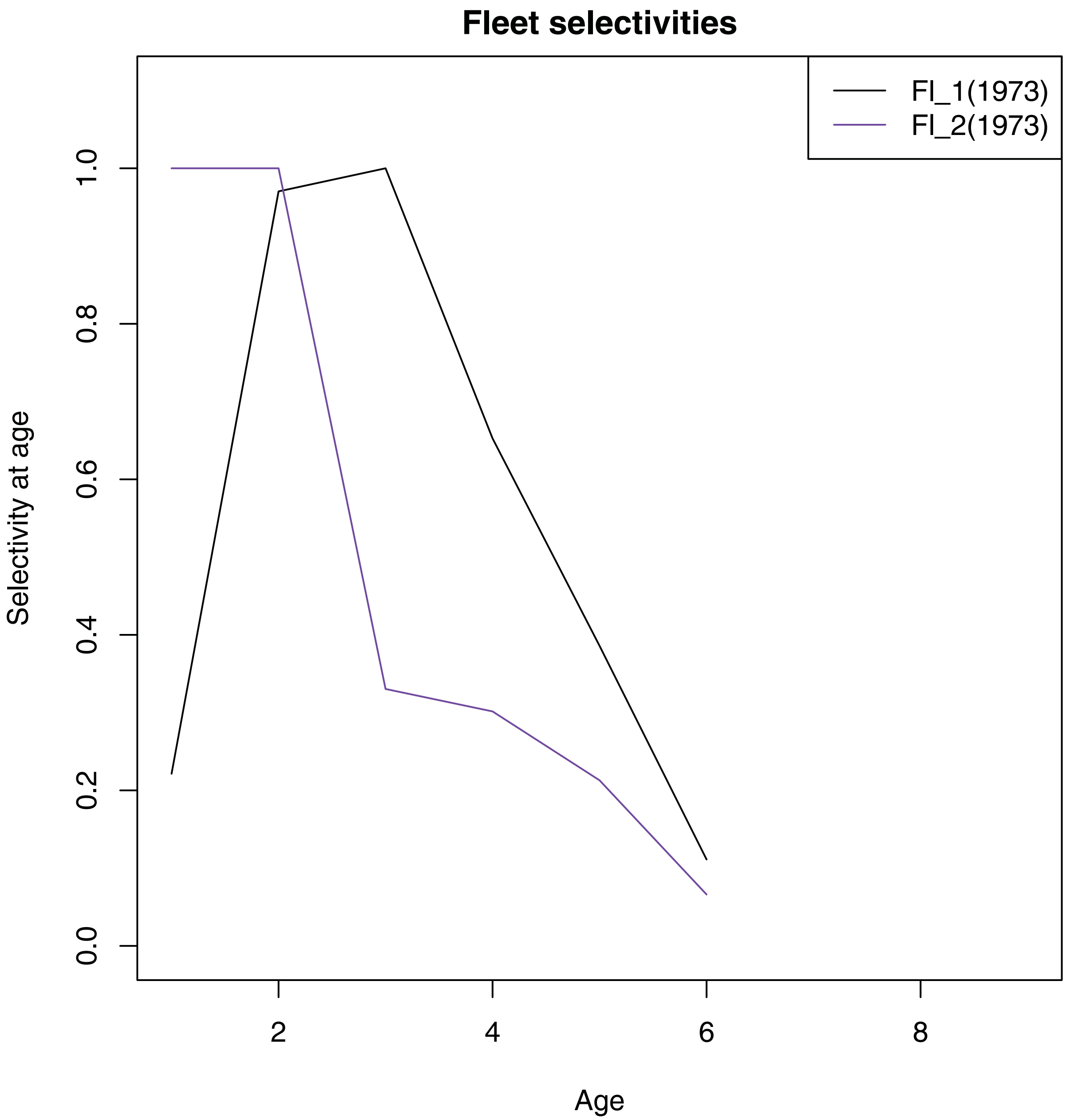
Catch Age Comp Residuals for Fleet 1 (Comm)



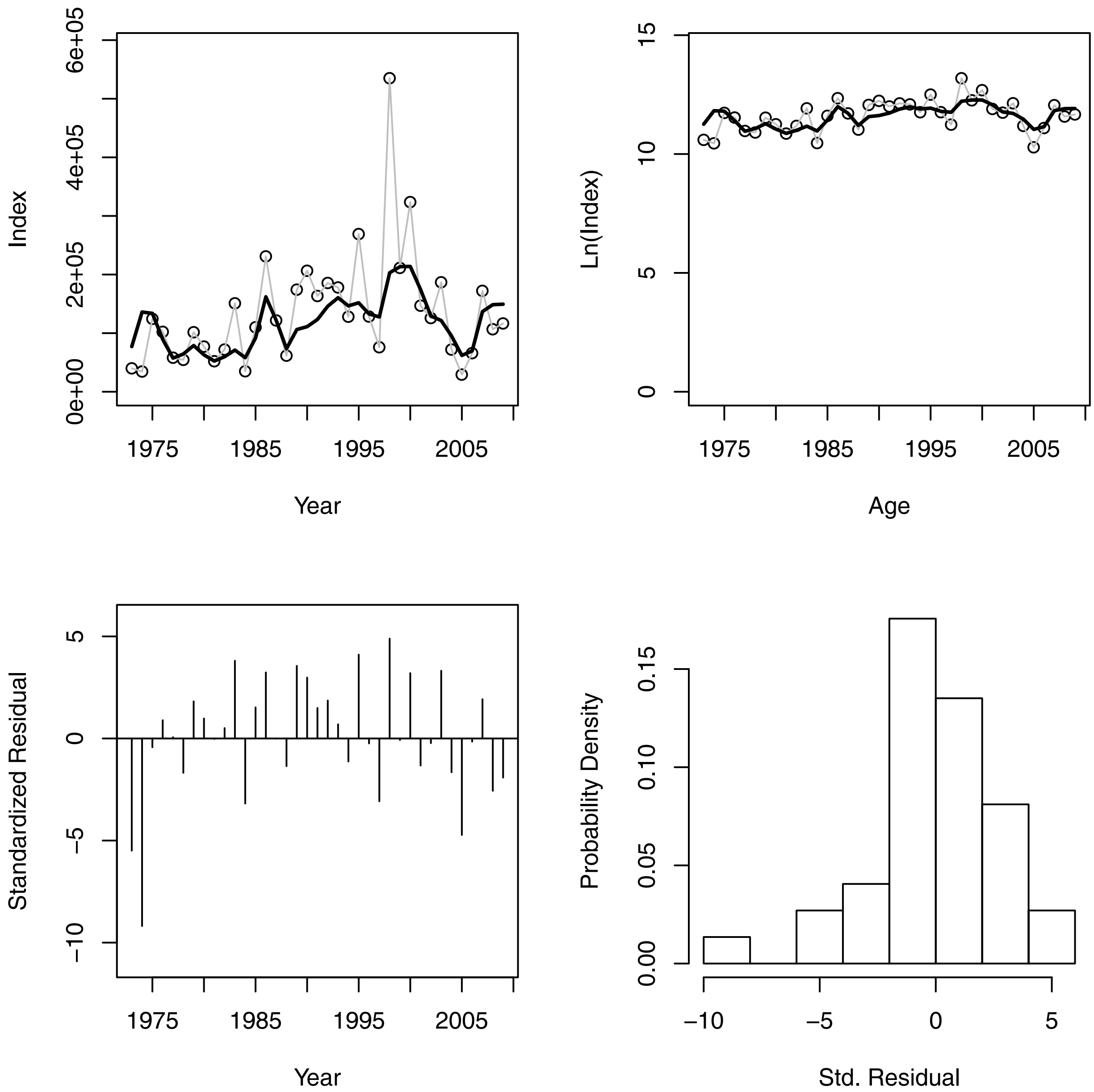

Catch Age Comp Residuals for Fleet 2 (disc)
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age


Fleet 1 (Comm)
Effective Sample Size
0
50
100
150
200
1975
1980
1985
1990
1995
2000
2005
2010
Year

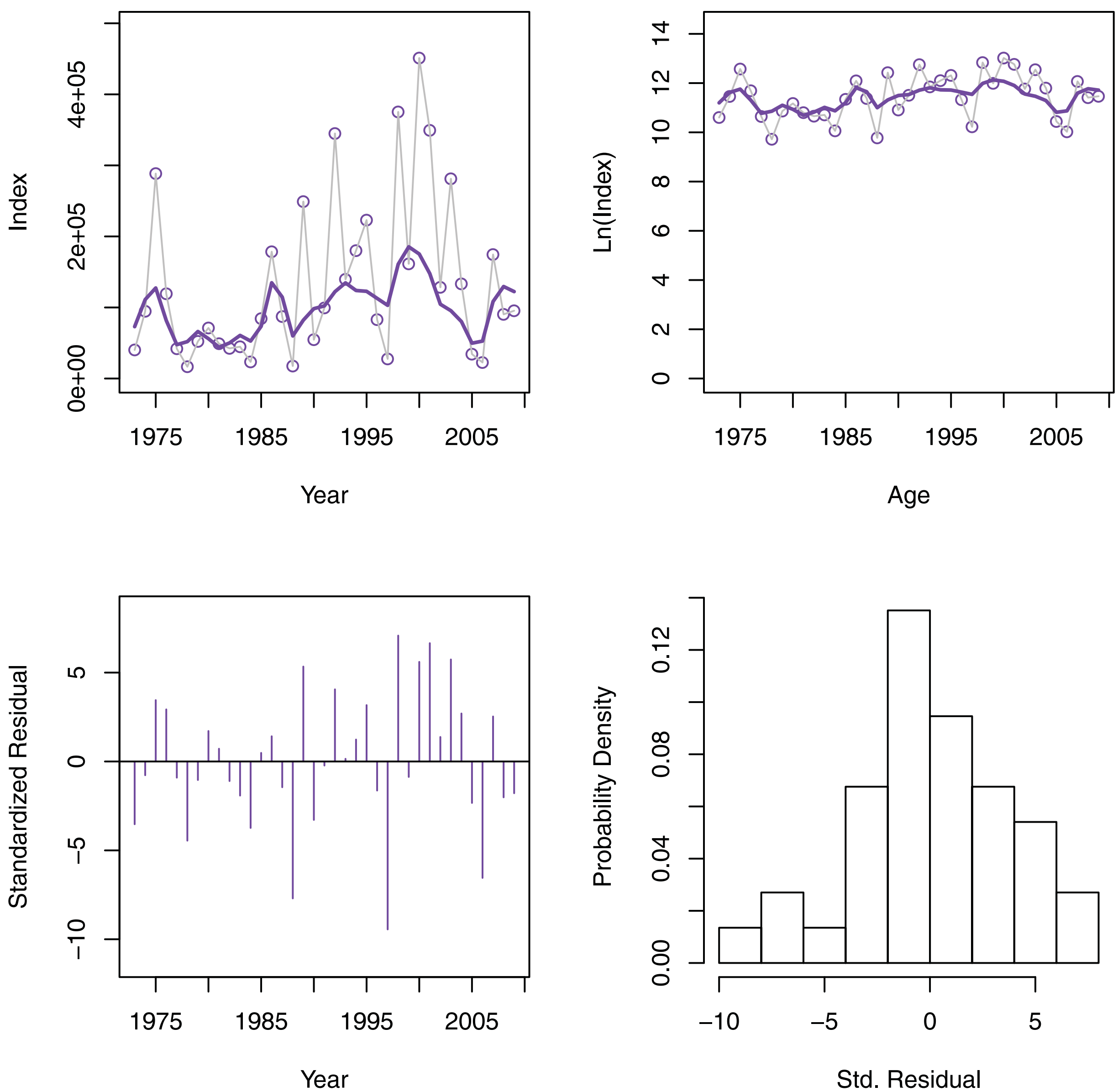

Fleet 2 (disc)
Effective Sample Size
0
50
100
150
200
1975
1980
1985
1990
1995
2000
2005
2010
Year

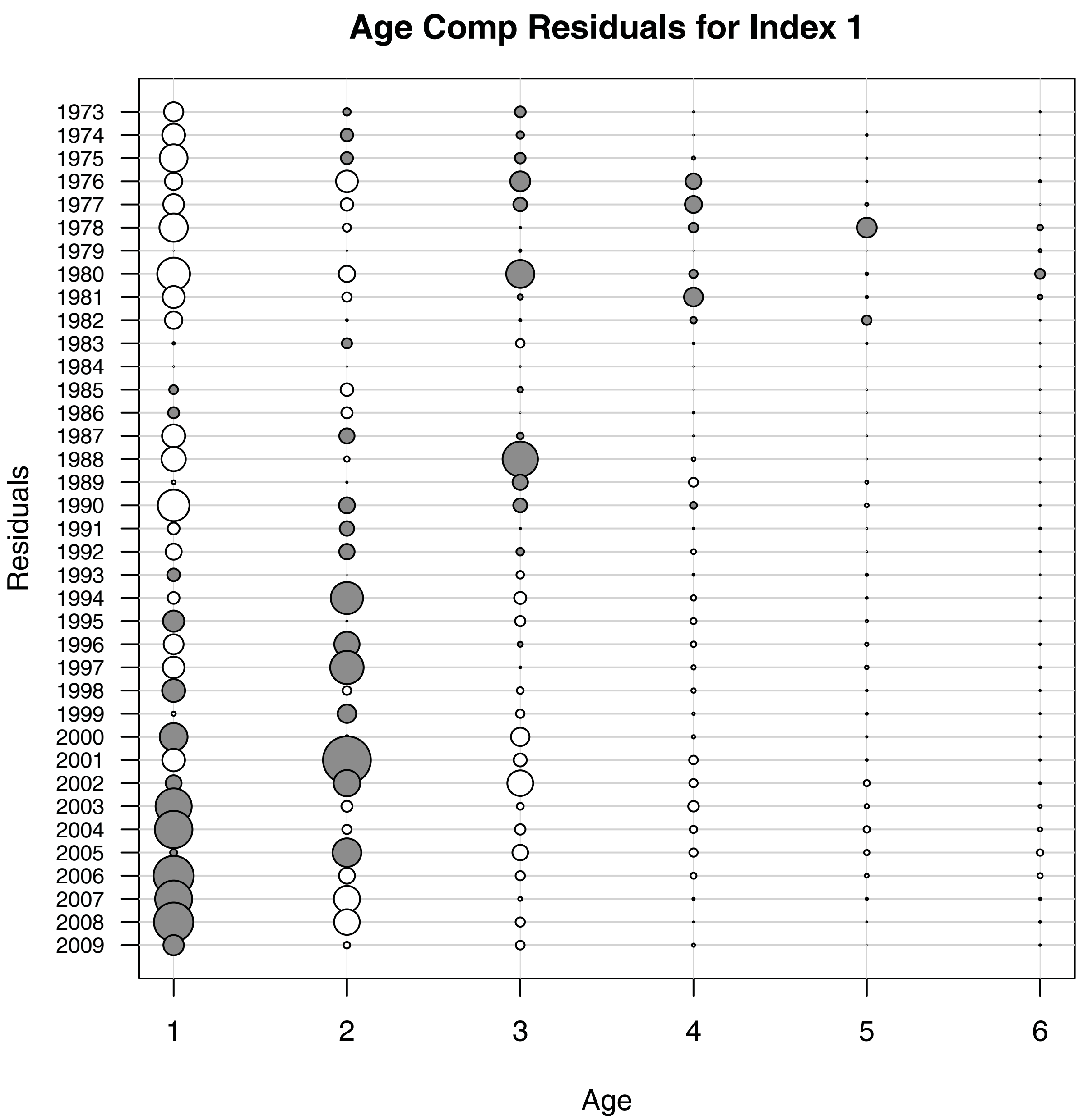

Fleet selectivities
Fl_1(1973)
Fl_2(1973)
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
Age

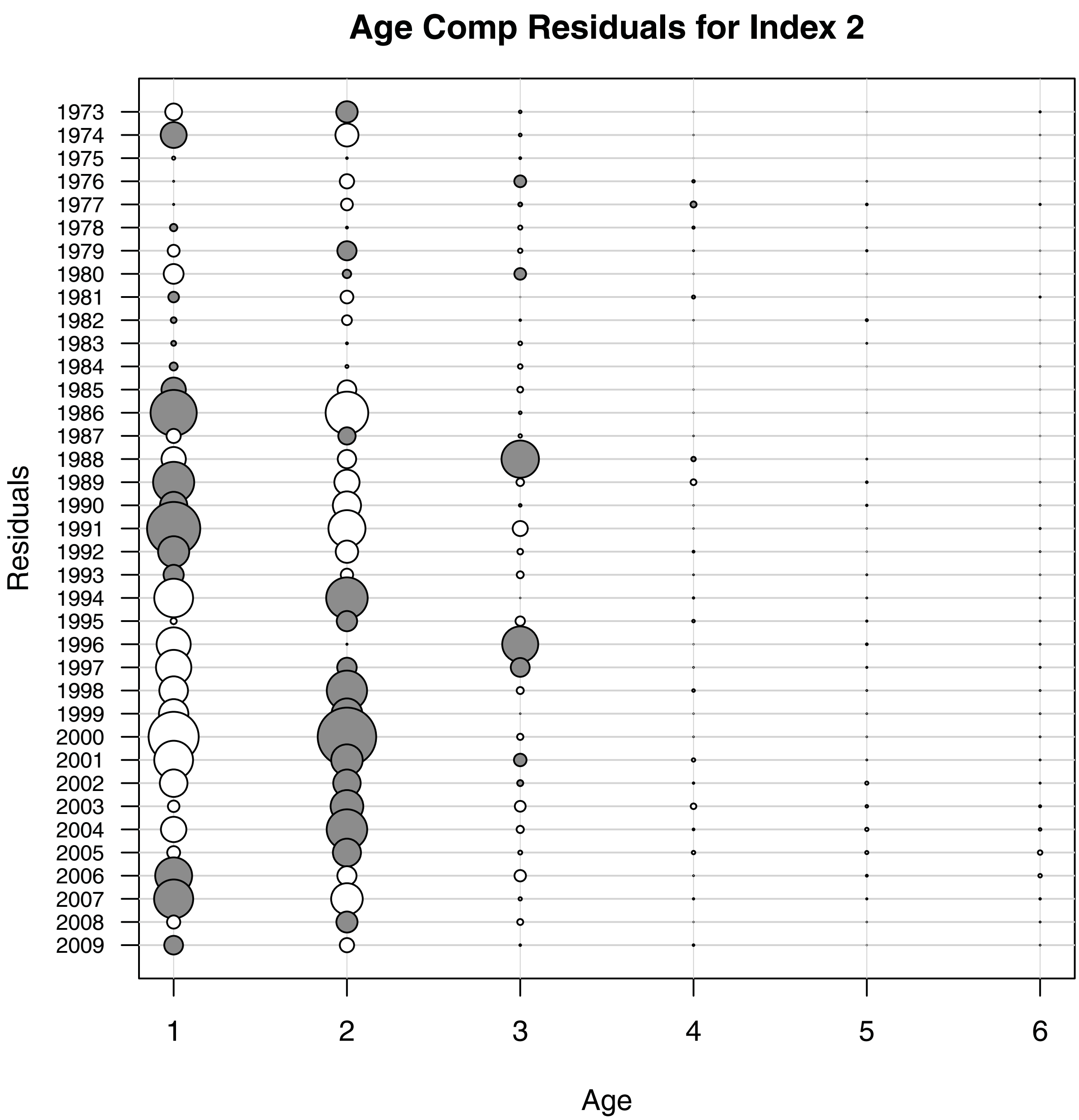
Index 1

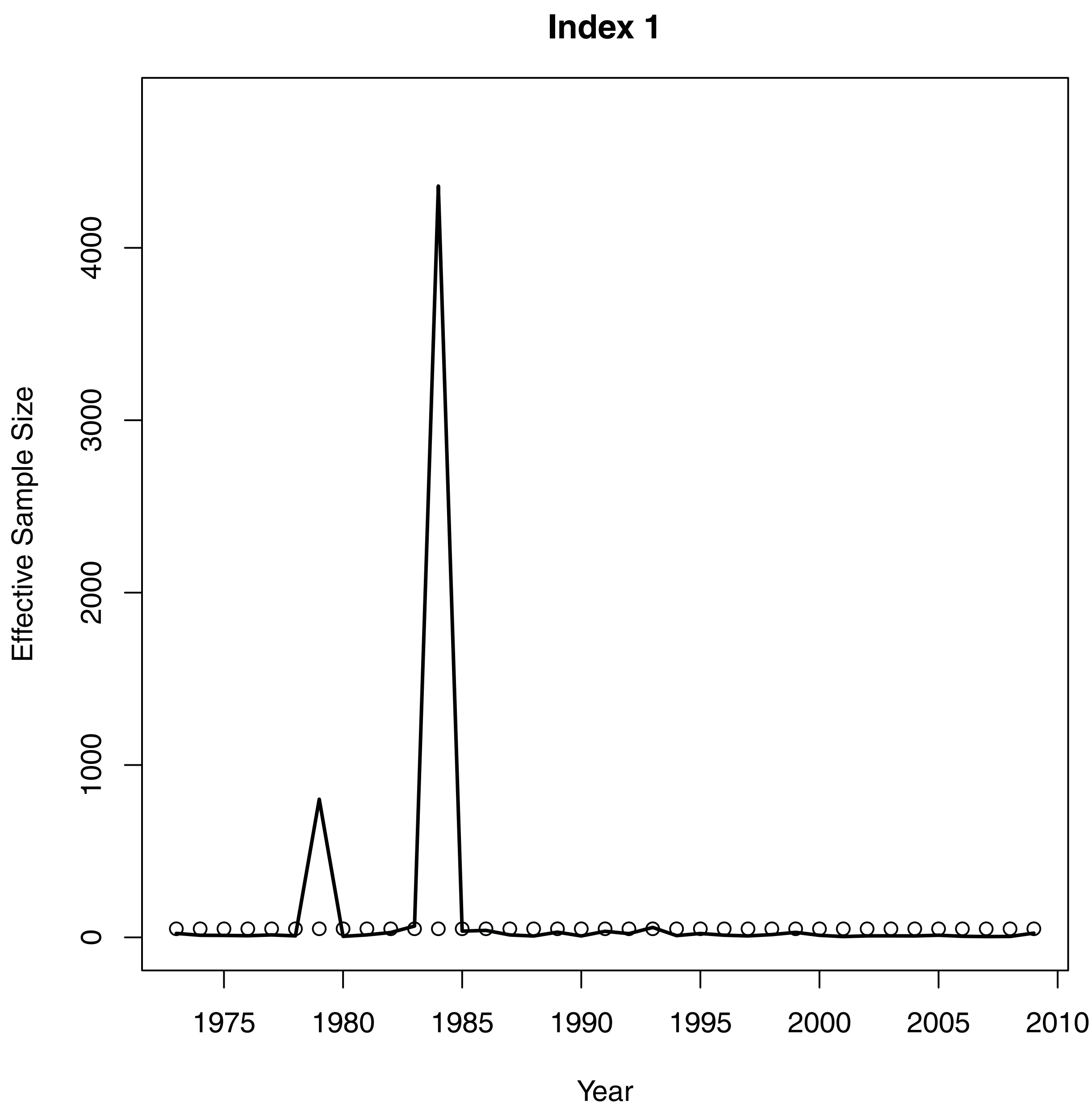

Index
0e+00
2e+05
4e+05
6e+05
1975
1985
1995
2005
Year
Ln(Index)
0
5
10
15
1975
1985
1995
2005
Age
Standardized Residual
5
0
−5
−10
1975
1985
1995
2005
Year
Probability Density
0.00
0.05
0.10
0.15
−10
−5
0
5
Std. Residual

Index 2

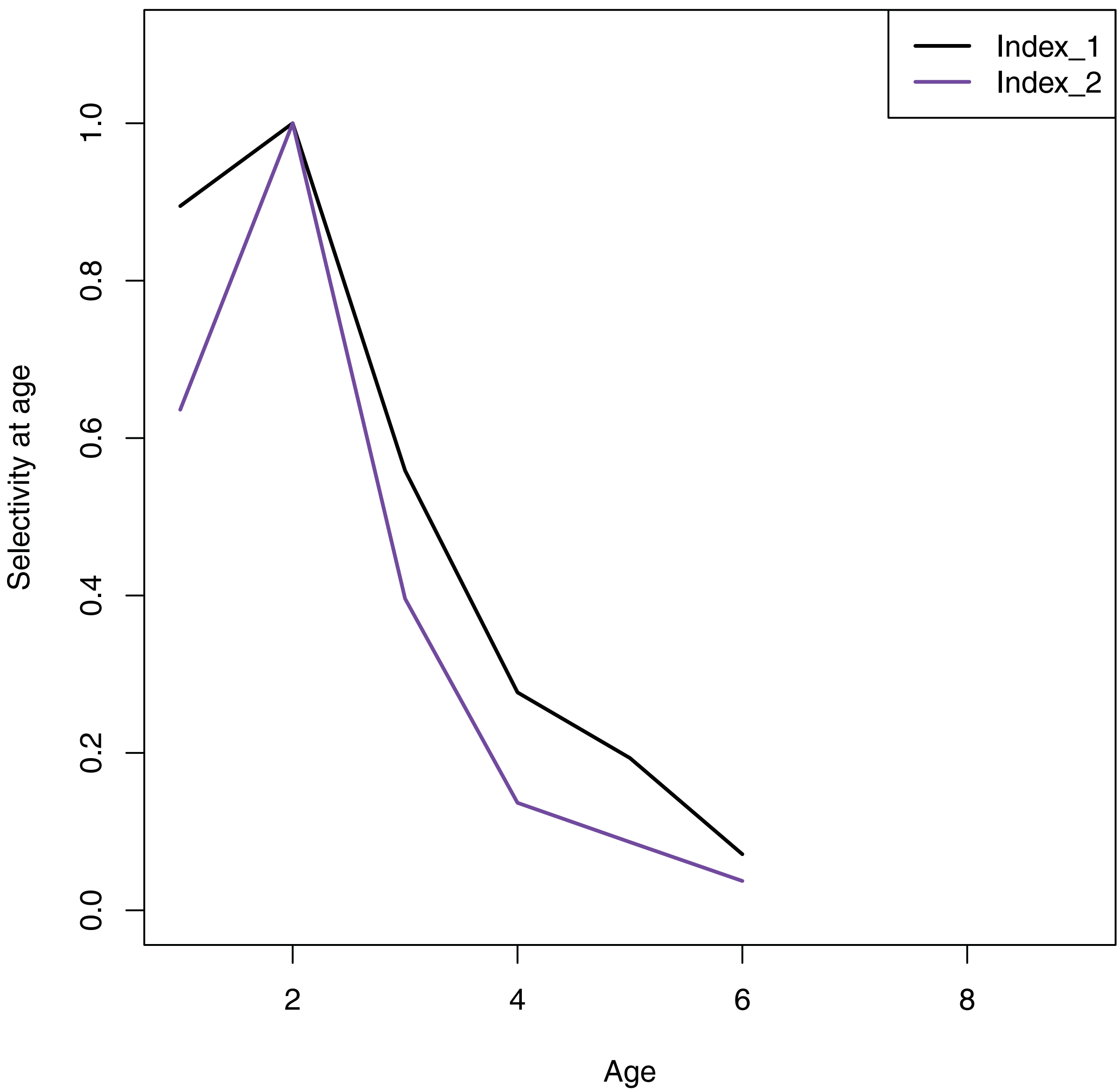

Index
0e+00
2e+05
4e+05
1975
1985
1995
2005
Year
Ln(Index)
0
2
4
6
8
10
12
14
Age
Standardized Residual
−10
−5
0
5
Year
Probability Density
0.00
0.04
0.08
0.12
−10
−5
0
5
Std. Residual

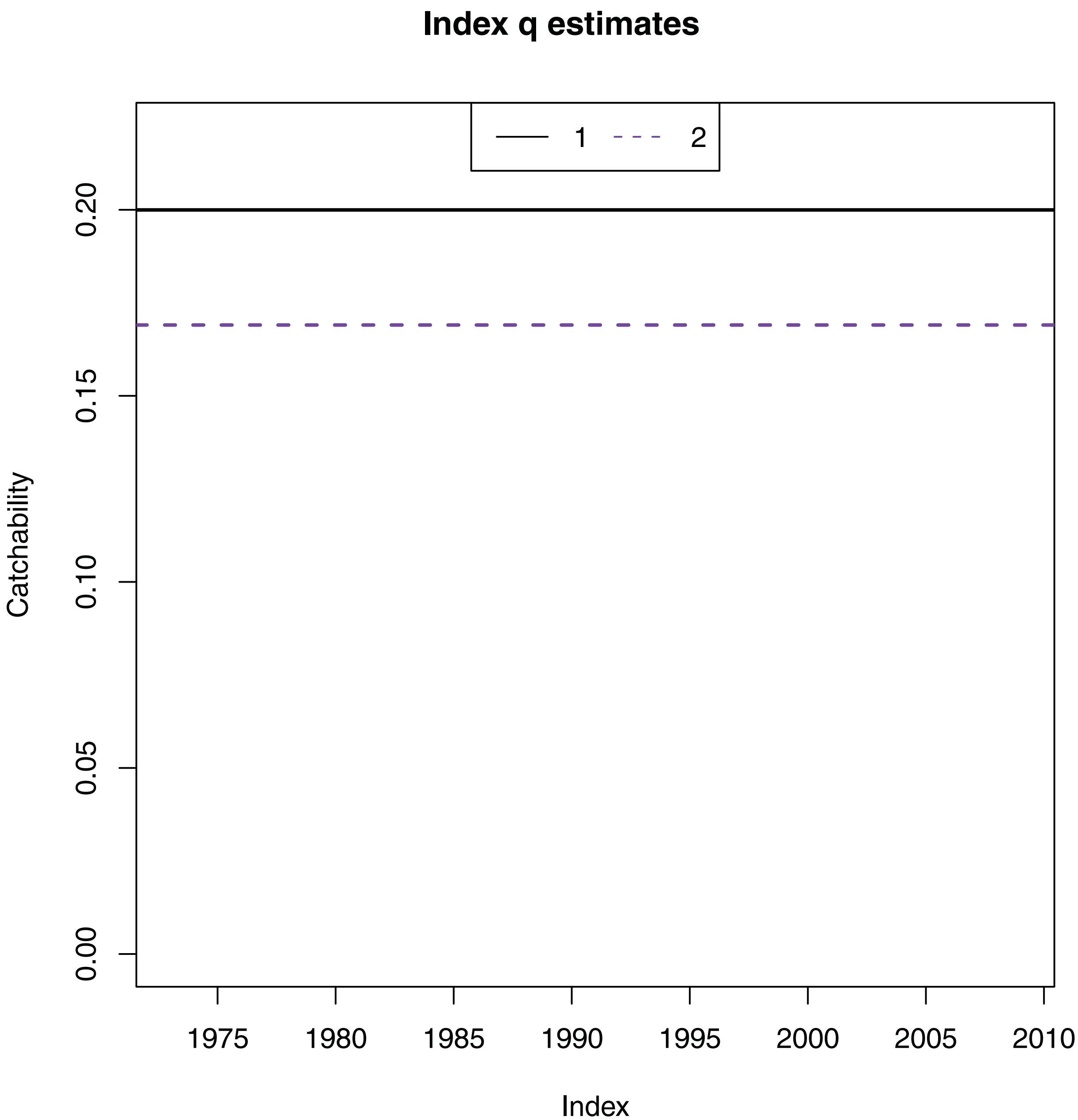

Age Comp Residuals for Index 1
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Residuals
1
2
3
4
5
6
Age

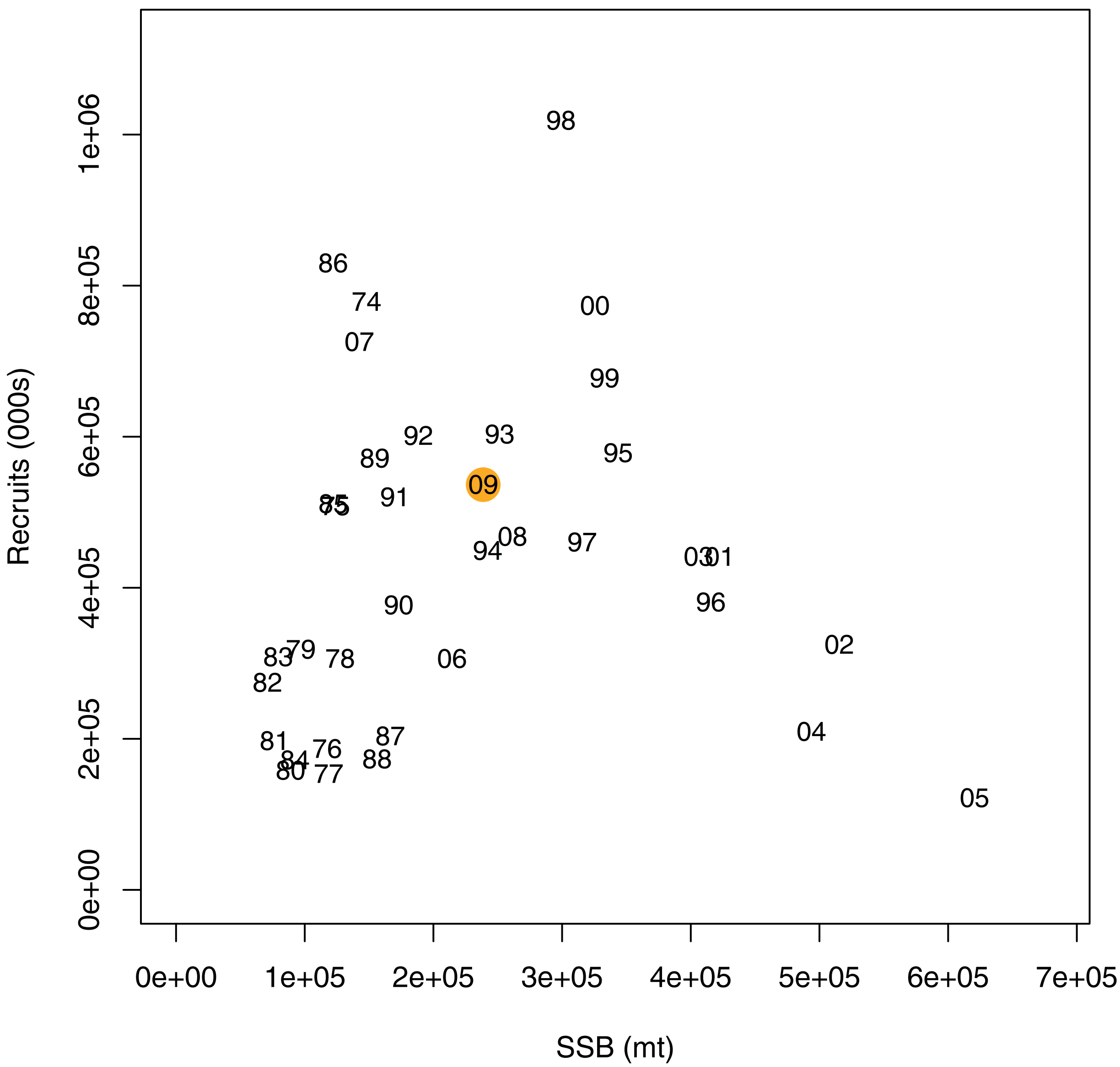

Age Comp Residuals for Index 2
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age

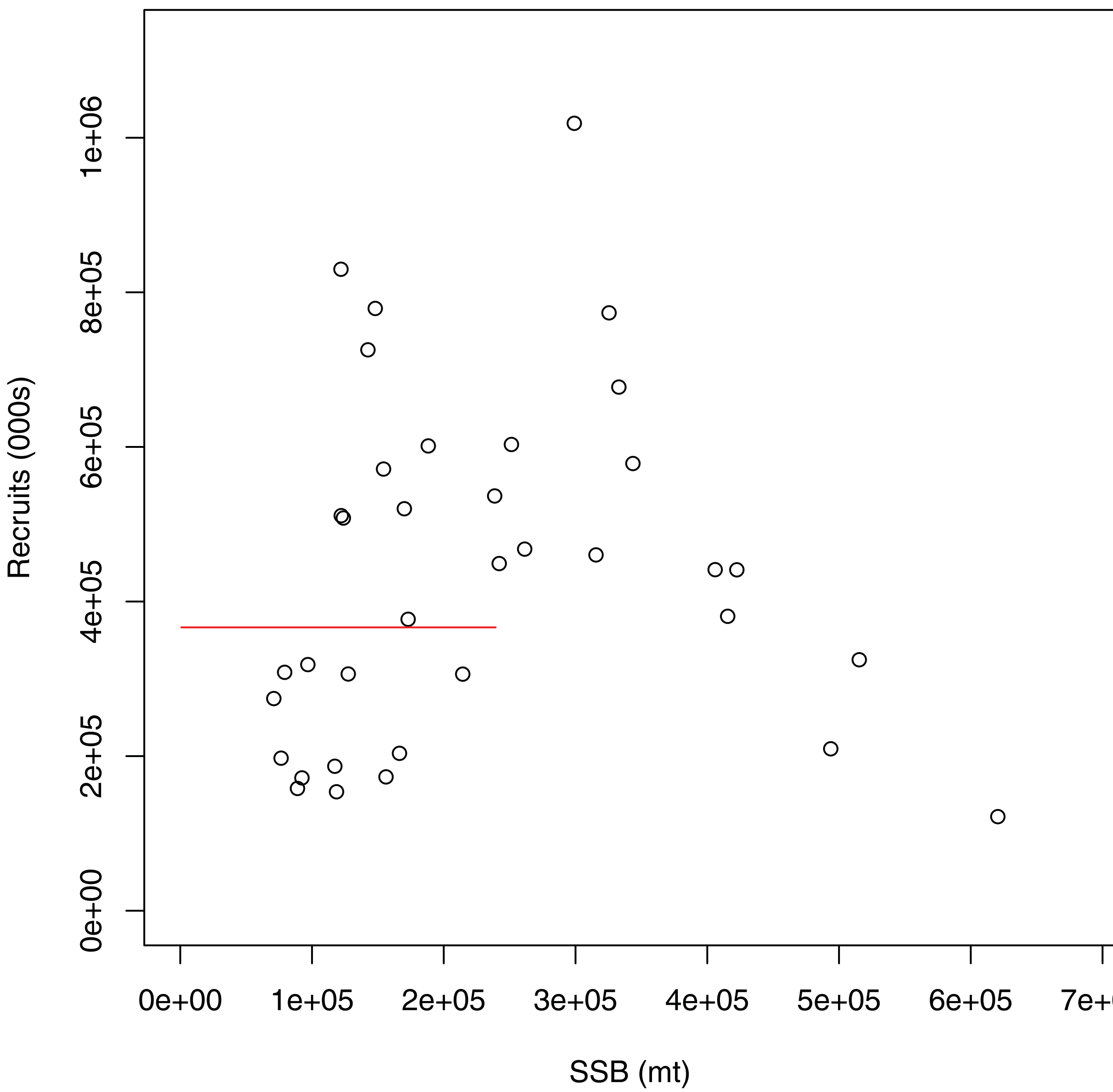

Index 1
Effective Sample Size
0
1000
2000
3000
4000
Year
1975
1980
1985
1990
1995
2000
2005
2010

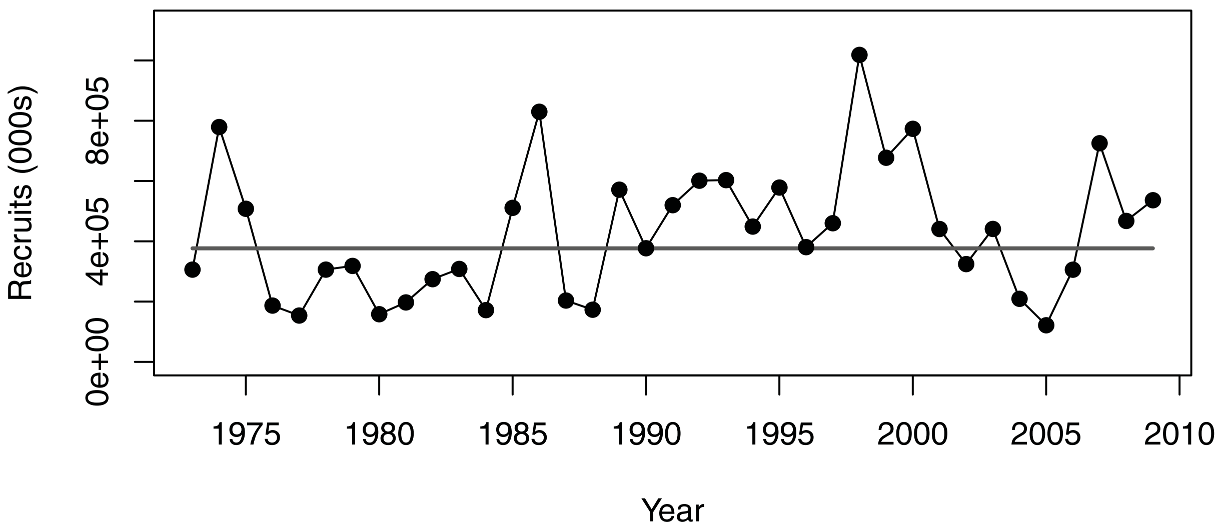

Index 2
Effective Sample Size
0
200
400
600
1975
1980
1985
1990
1995
2000
2005
2010
Year


Index_1
Index_2
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
Age

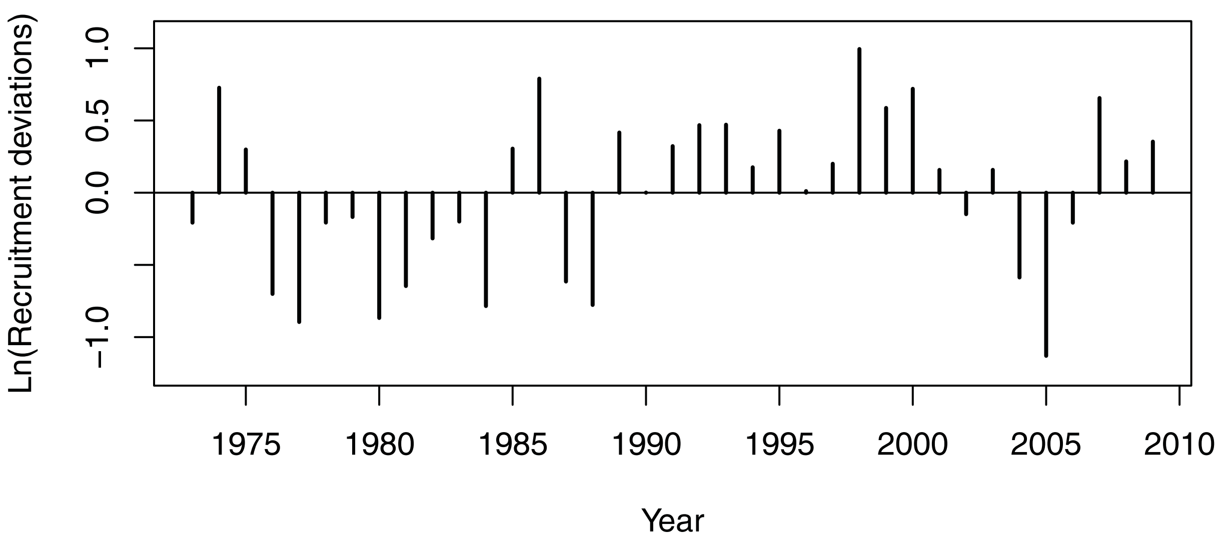

Index q estimates
1
2
Catchability
0.00
0.05
0.10
0.15
0.20
1975
1980
1985
1990
1995
2000
2005
2010
Index


Recruits (000s)
SSB (mt)
0e+00
2e+05
4e+05
6e+05
8e+05
1e+06
0e+00
1e+05
2e+05
3e+05
4e+05
5e+05
6e+05
7e+05
98
86
74
00
07
99
92
93
89
95
09
75
91
08
94
97
03
01
96
90
02
83
79
78
06
82
87
04
81
76
84
88
80
77
05

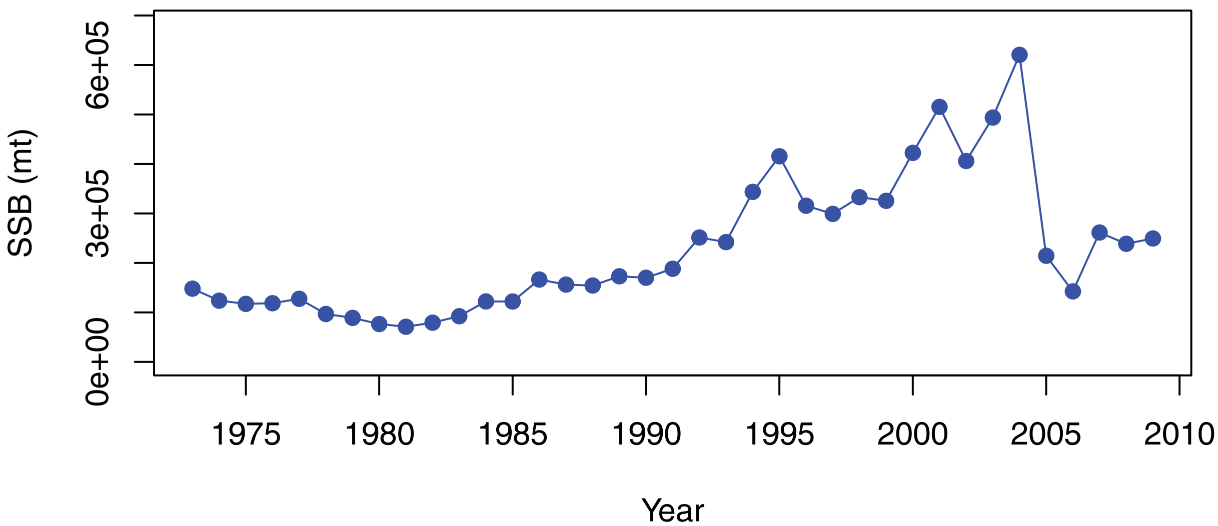

Recruits (000s)
0e+00
2e+05
4e+05
6e+05
8e+05
1e+06
0e+00
1e+05
2e+05
3e+05
4e+05
5e+05
6e+05
7e+05
SSB (mt)



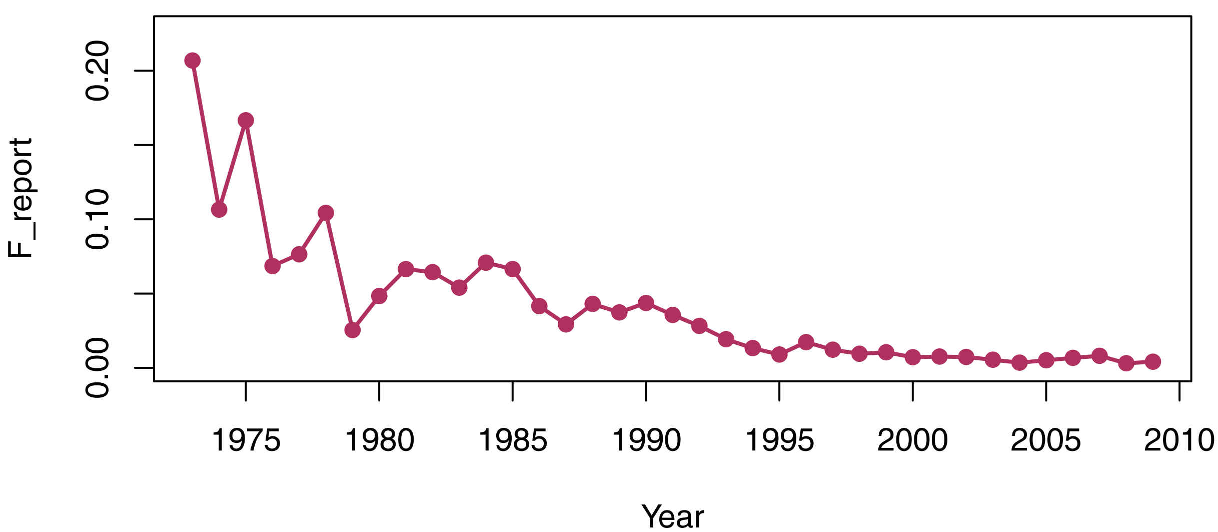
Recruits (000s)
0e+00
4e+05
8e+05
1975
1980
1985
1990
1995
2000
2005
2010
Year



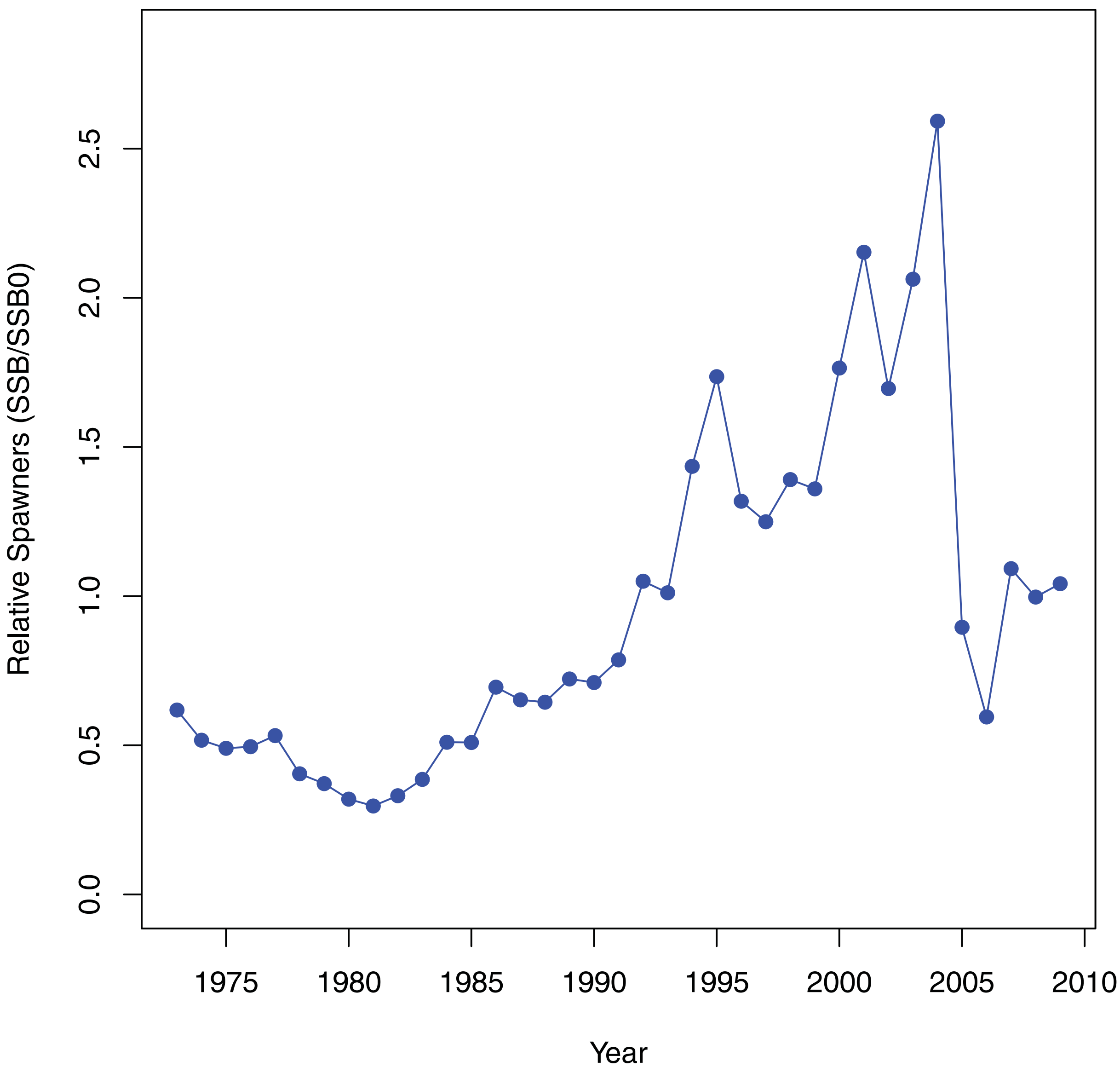
Ln(Recruitment deviations)
−1.0
0.0
0.5
1.0
1975
1980
1985
1990
1995
2000
2005
2010
Year

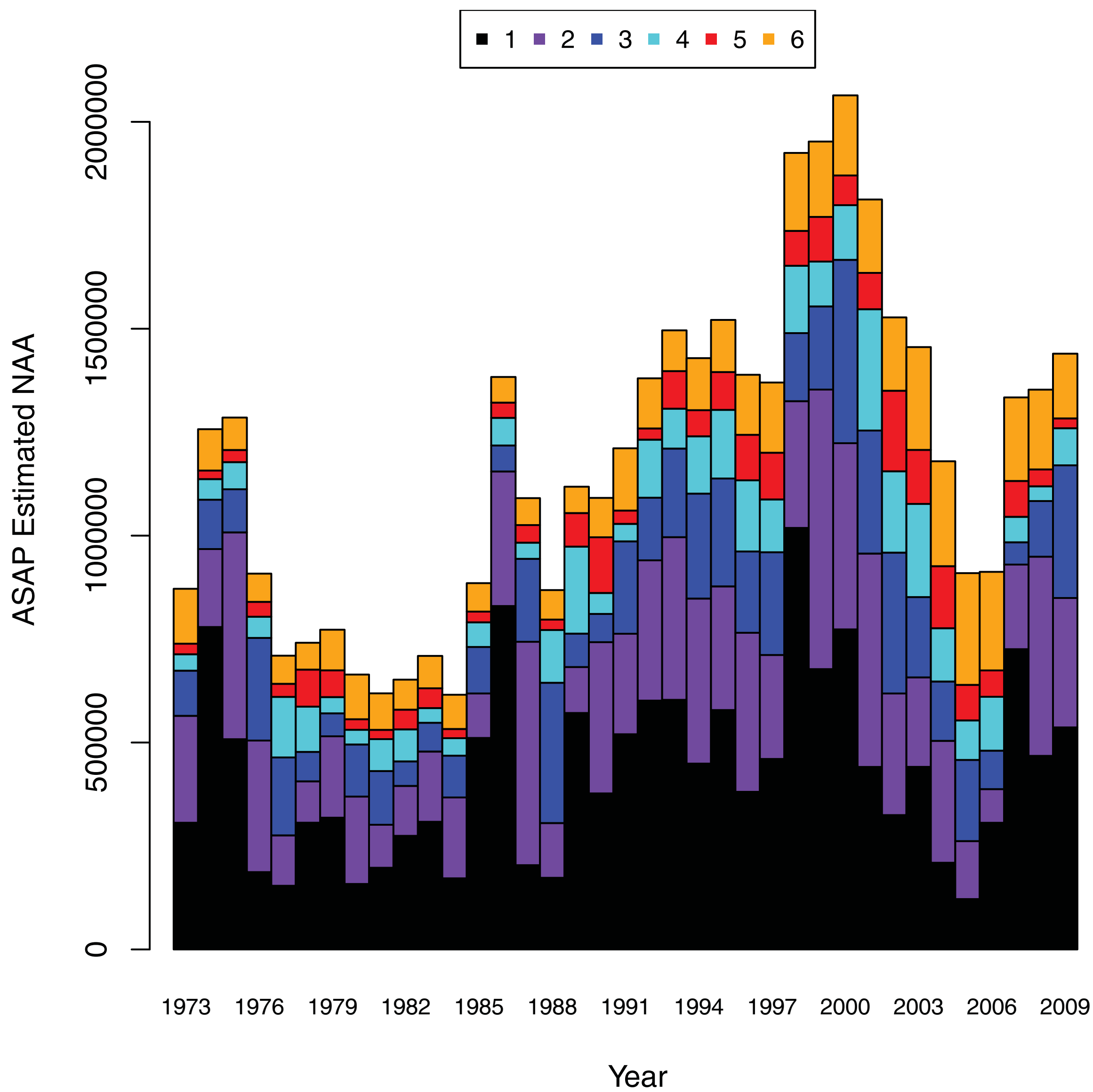


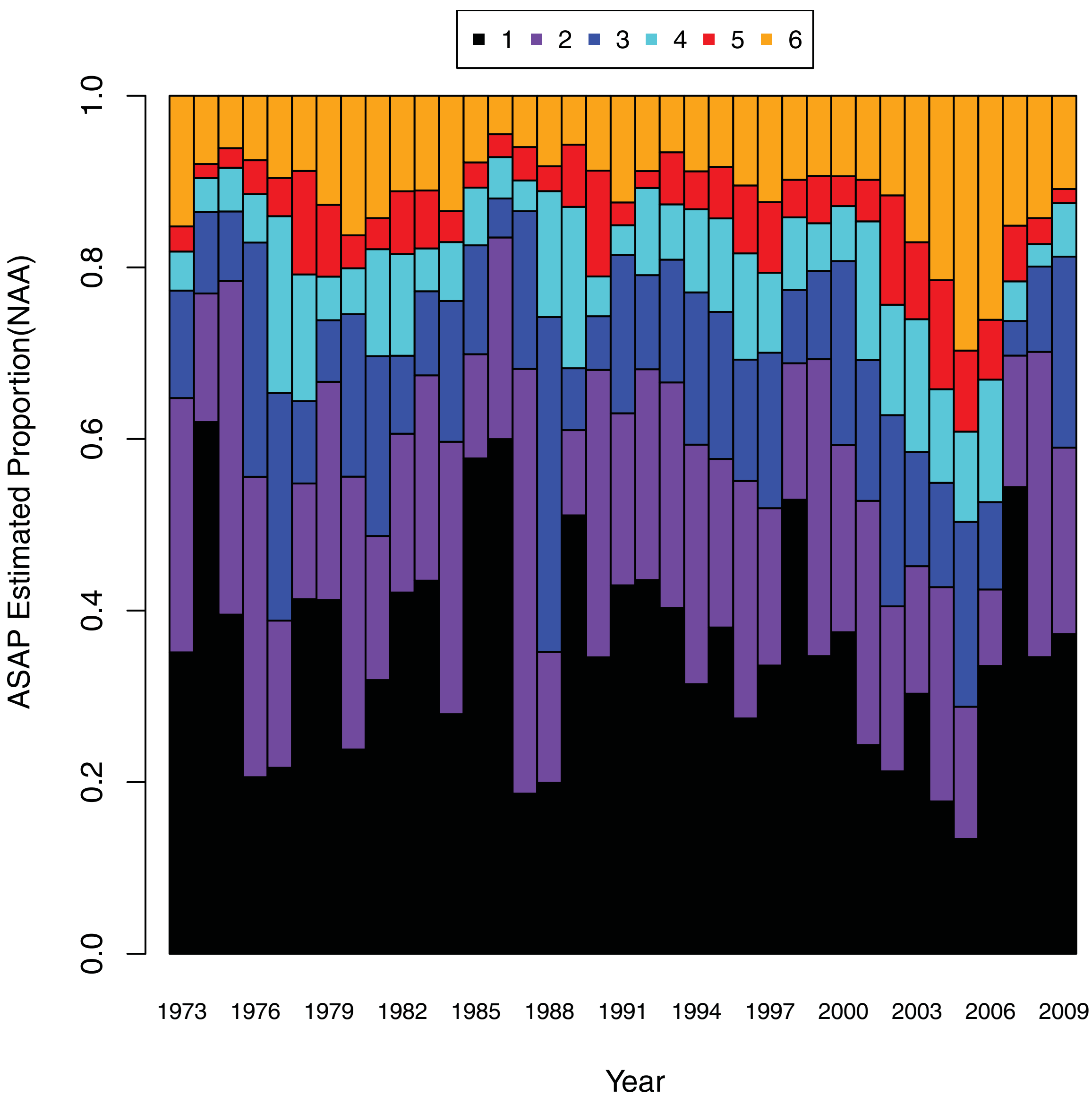
SSB (mt)
0e+00
3e+05
6e+05
1975
1980
1985
1990
1995
2000
2005
2010
Year



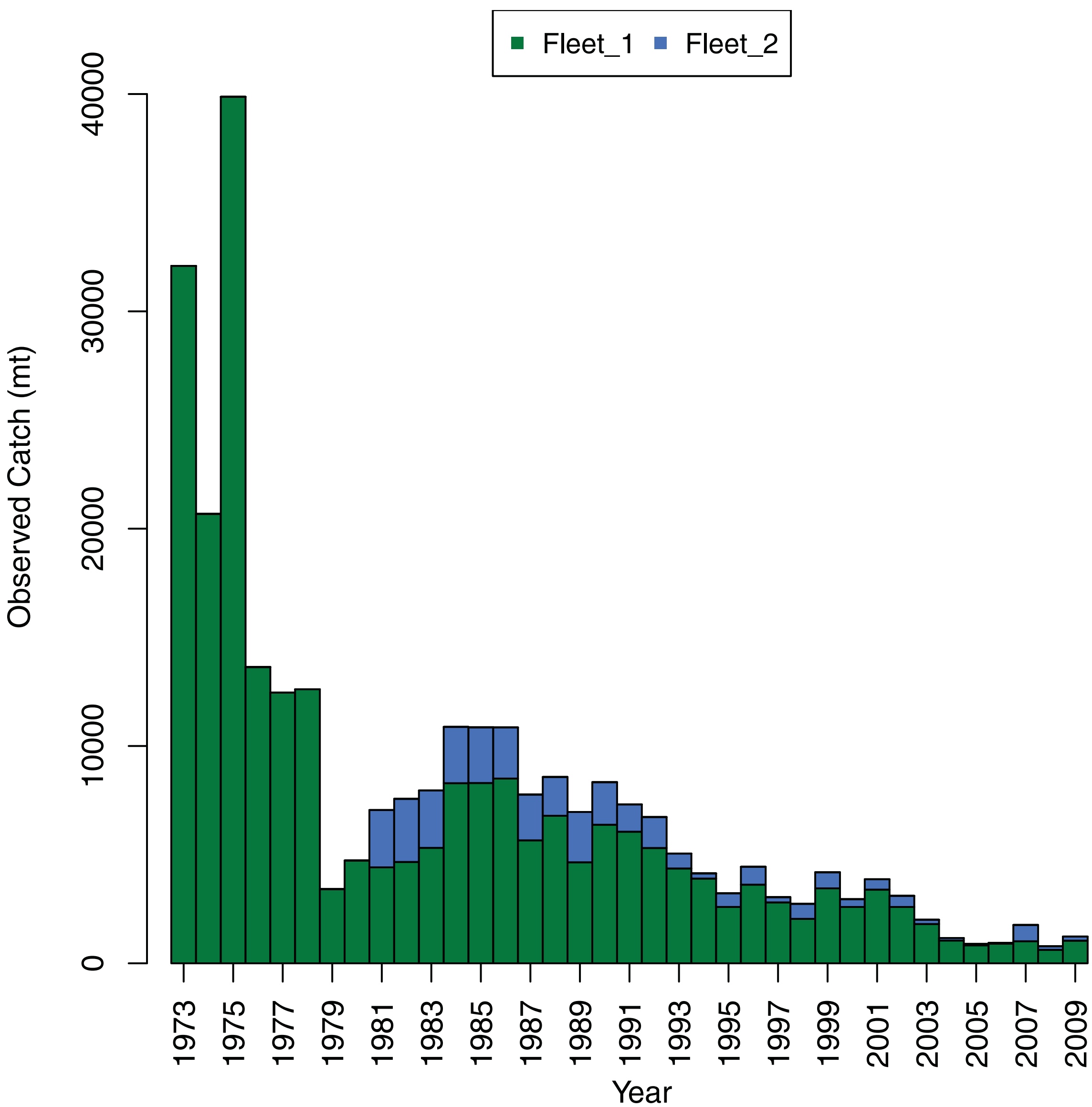
F_report
0.00
0.10
0.20
1975
1980
1985
1990
1995
2000
2005
2010
Year

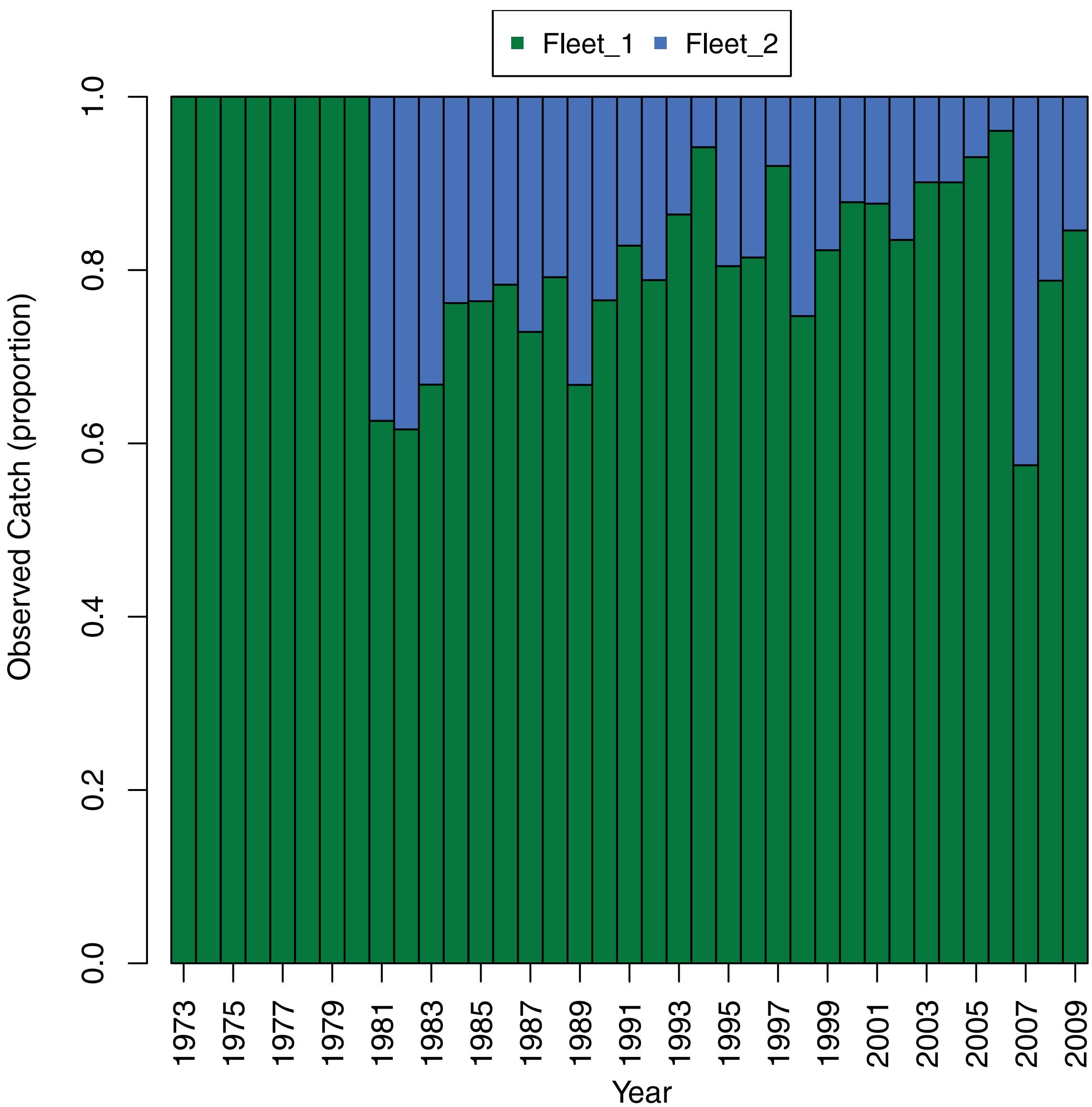

Relative Spawners (SSB/SSB0)
0.0
0.5
1.0
1.5
2.0
2.5
1975
1980
1985
1990
1995
2000
2005
2010
Year

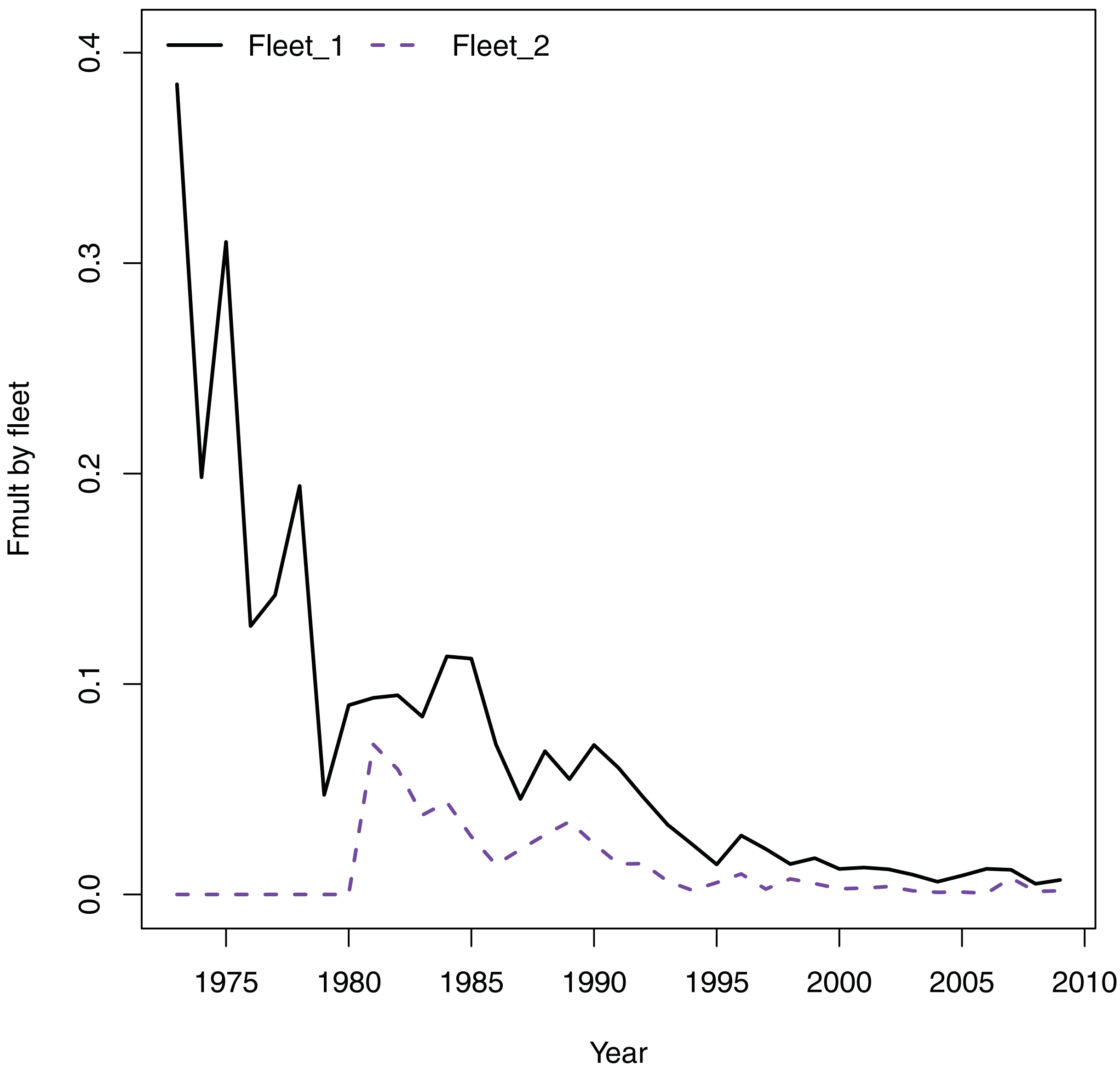

1 2 3 4 5 6
ASAP Estimated NAA
0
500000
1000000
1500000
2000000
1973 1976 1979 1982 1985 1988 1991 1994 1997 2000 2003 2006 2009
Year

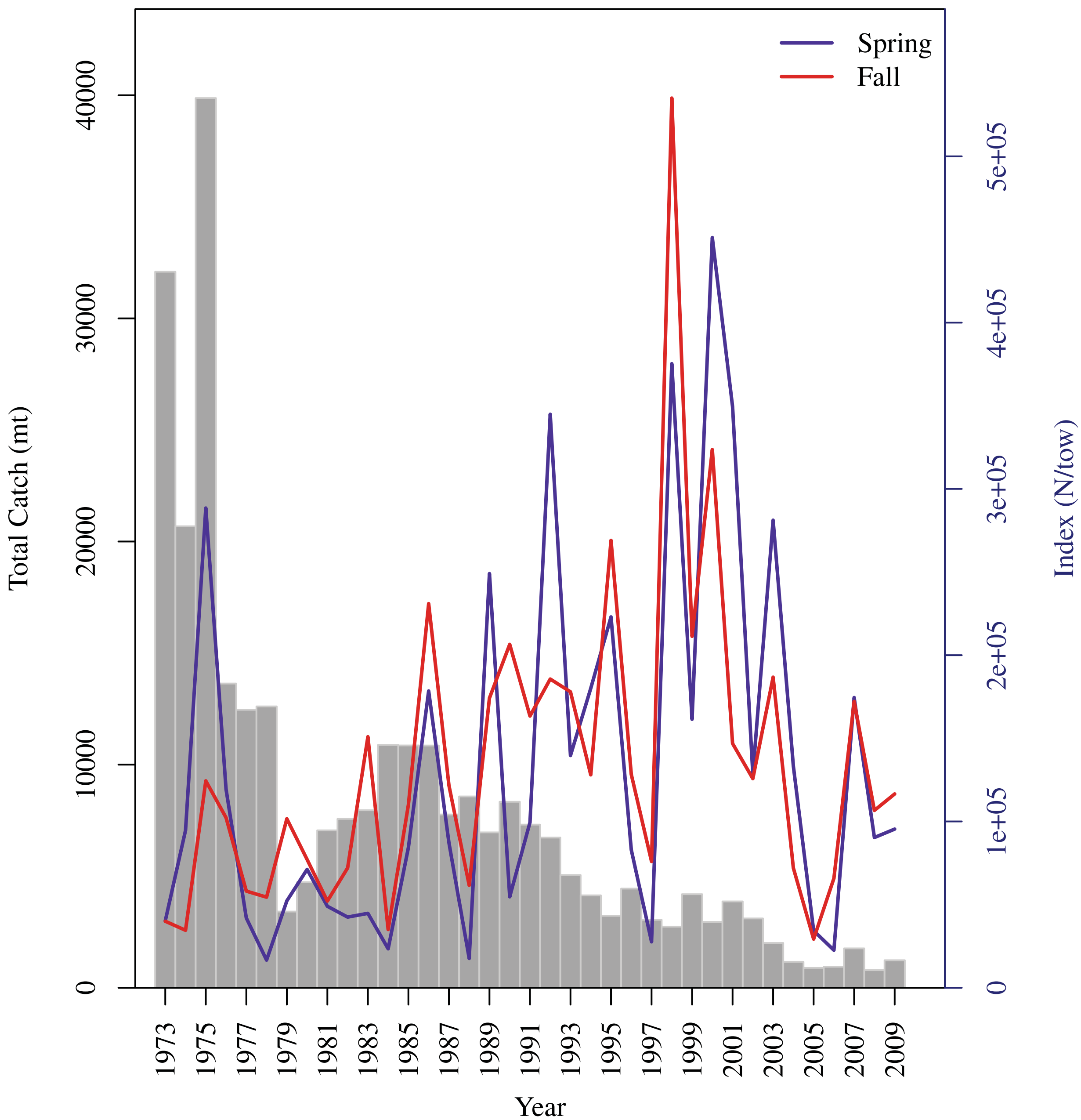


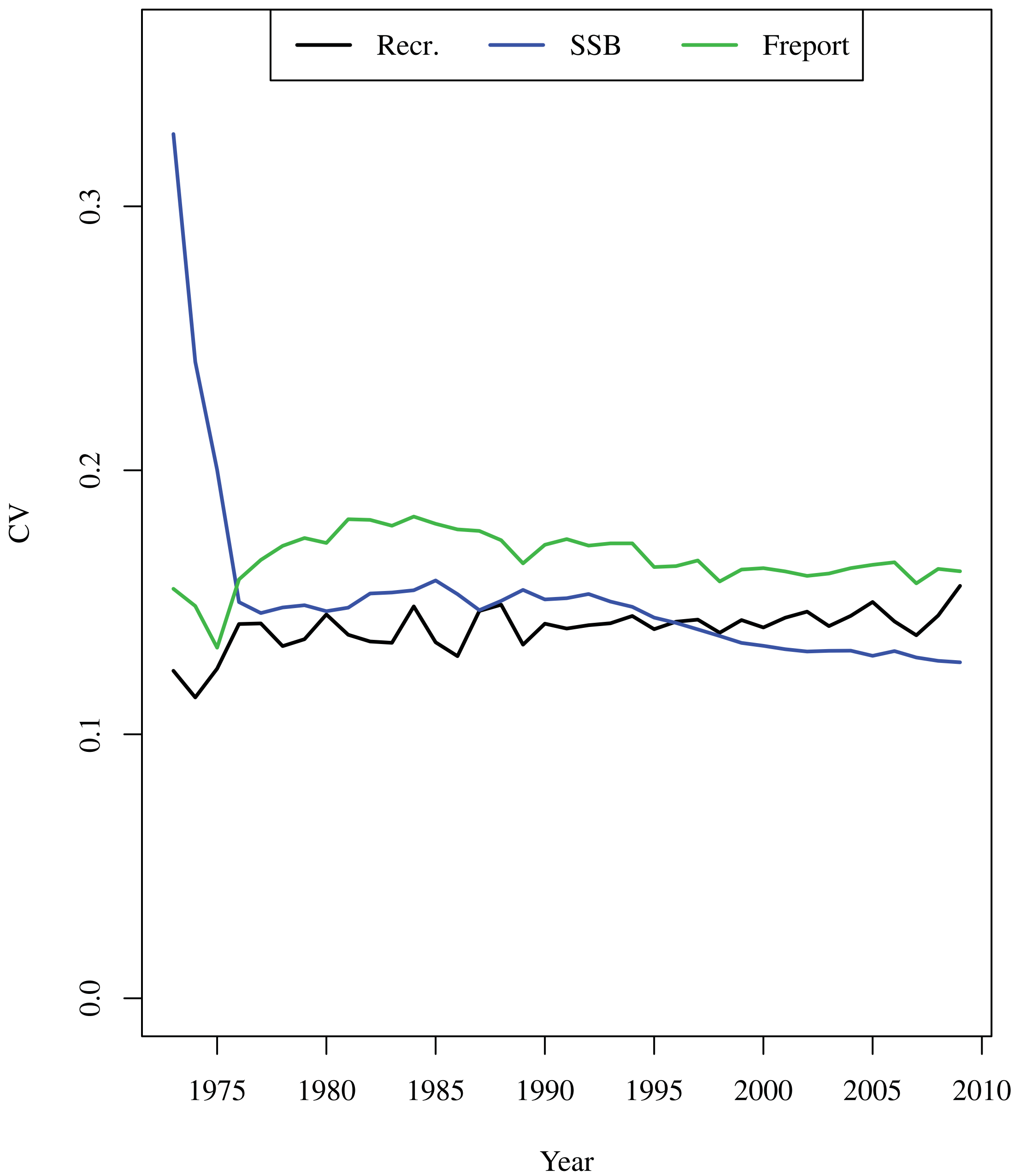
1 2 3 4 5 6
ASAP Estimated Proportion(NAA)
0.0
0.2
0.4
0.6
0.8
1.0
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

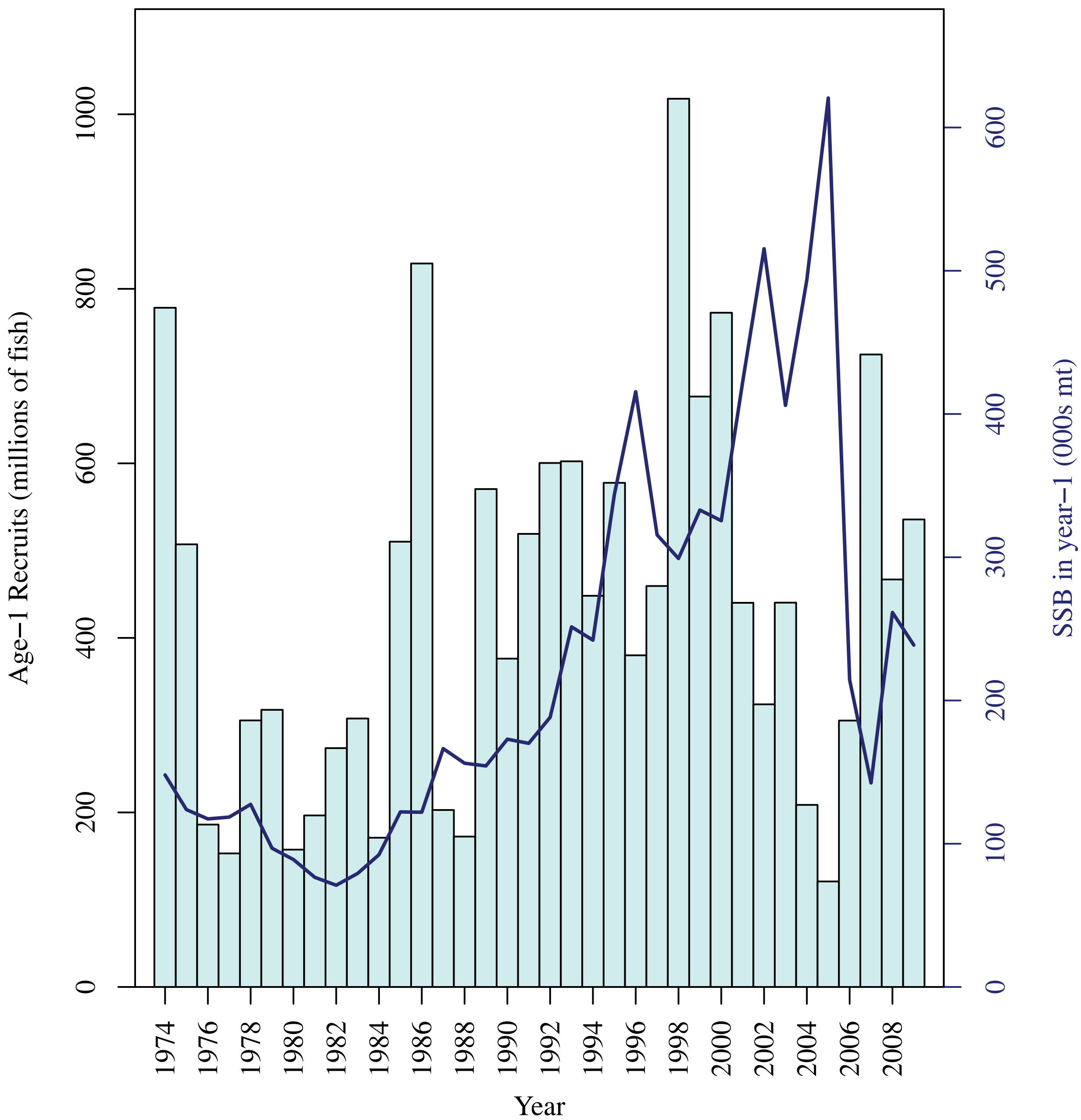

Fleet_1
Fleet_2
Observed Catch (mt)
0
10000
20000
30000
40000
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year


Fleet_1
Fleet_2
Observed Catch (proportion)
0.0
0.2
0.4
0.6
0.8
1.0
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year


Fleet_1
Fleet_2
Fmult by fleet
0.0
0.1
0.2
0.3
0.4
1975
1980
1985
1990
1995
2000
2005
2010
Year


Spring
Fall
Total Catch (mt)
Index (N/tow)
Year


Recr.
SSB
Freport
CV
0.0
0.1
0.2
0.3
1975
1980
1985
1990
1995
2000
2005
2010
Year


Age−1 Recruits (millions of fish)
SSB in year−1 (000s mt)
Year
0
200
400
600
800
1000
100
300
500
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008

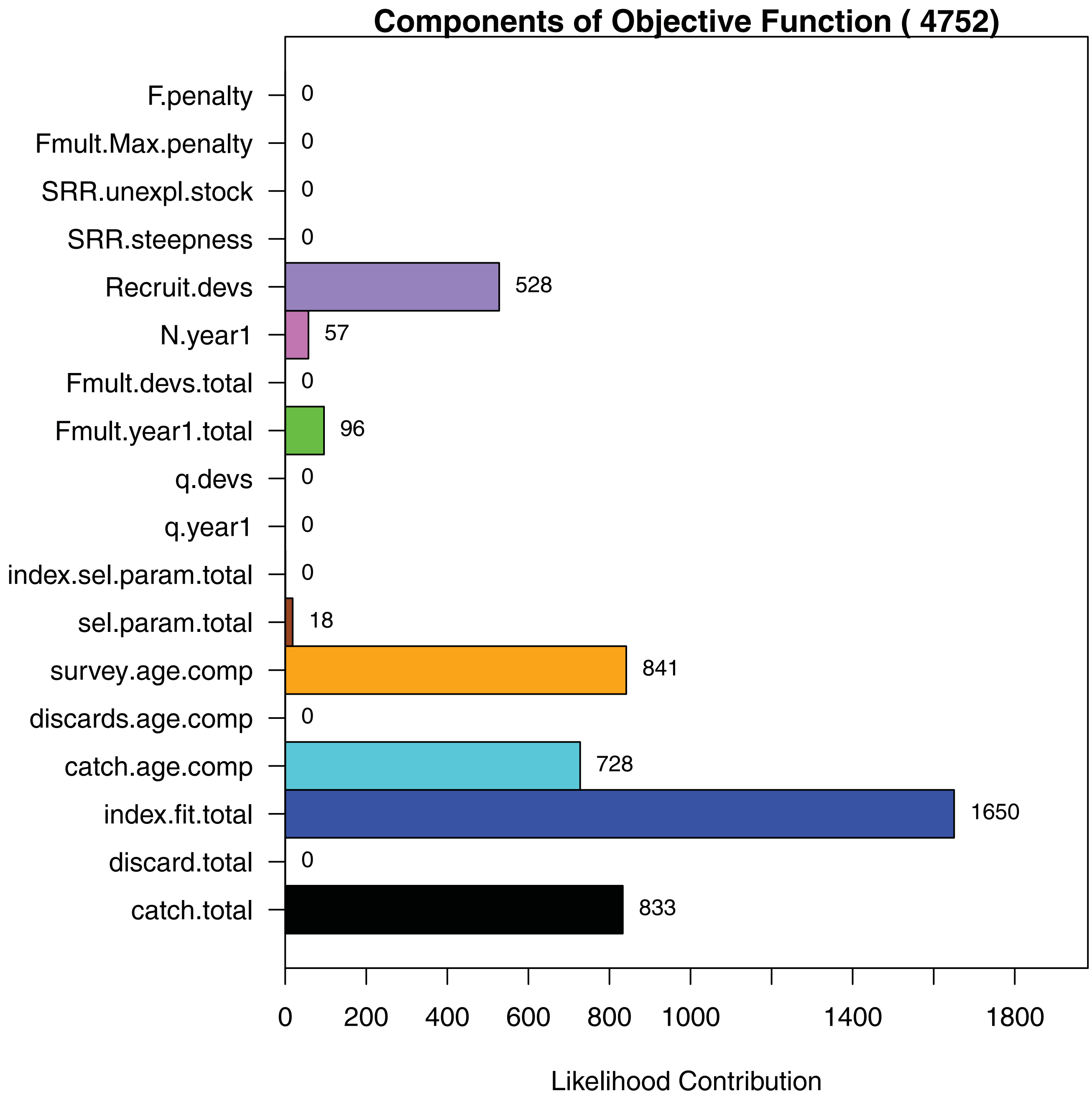
Appendix A4: North Model ASAP results M = 0.4 assuming Flat-top Selectivity in the Survey

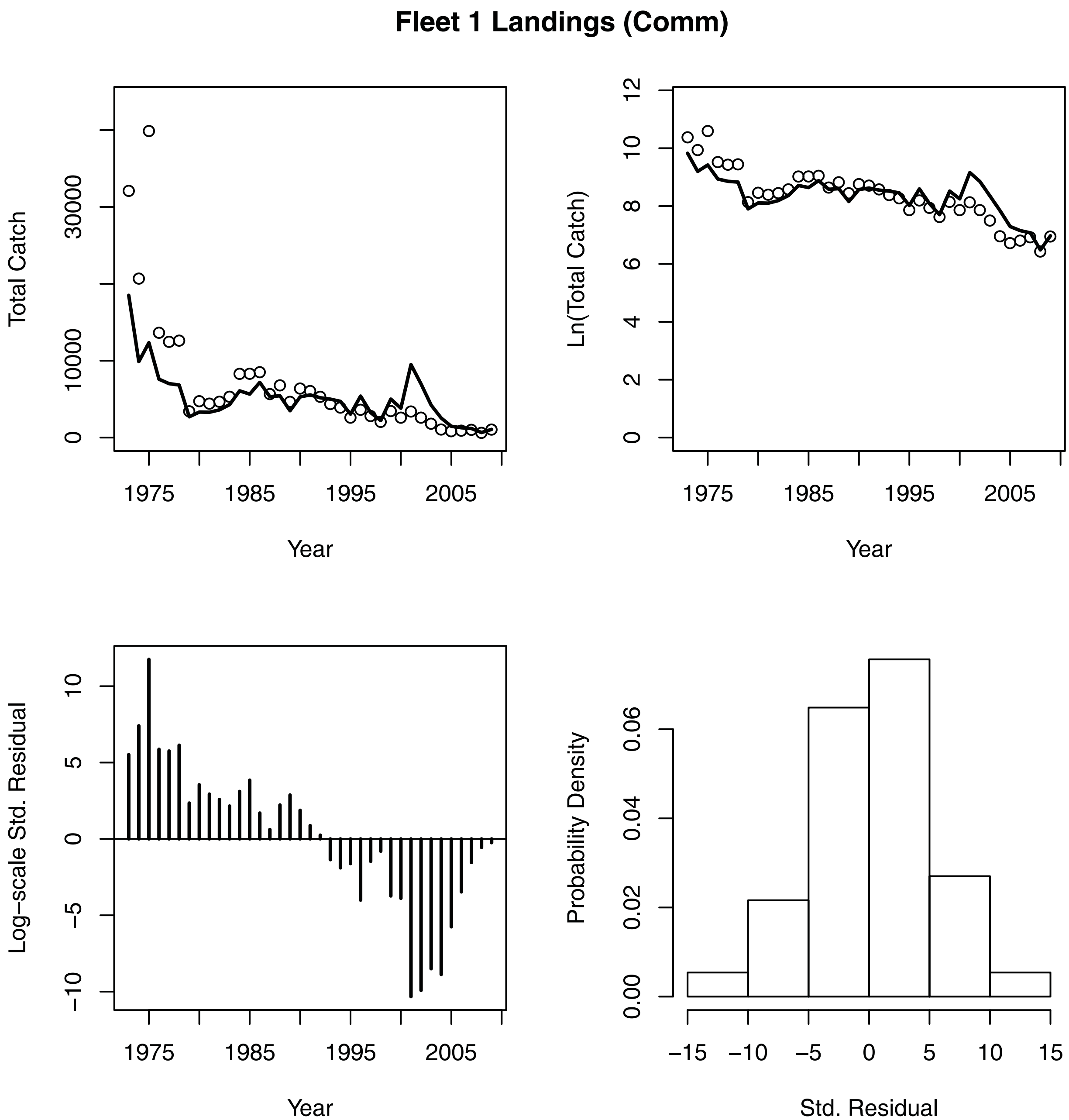
Model Attributes:

1. 3 Fleet Model
    a. Catch : 1973-2009
    b. Discards: 1981 – 2009
    c. Consumption – 1973-2009

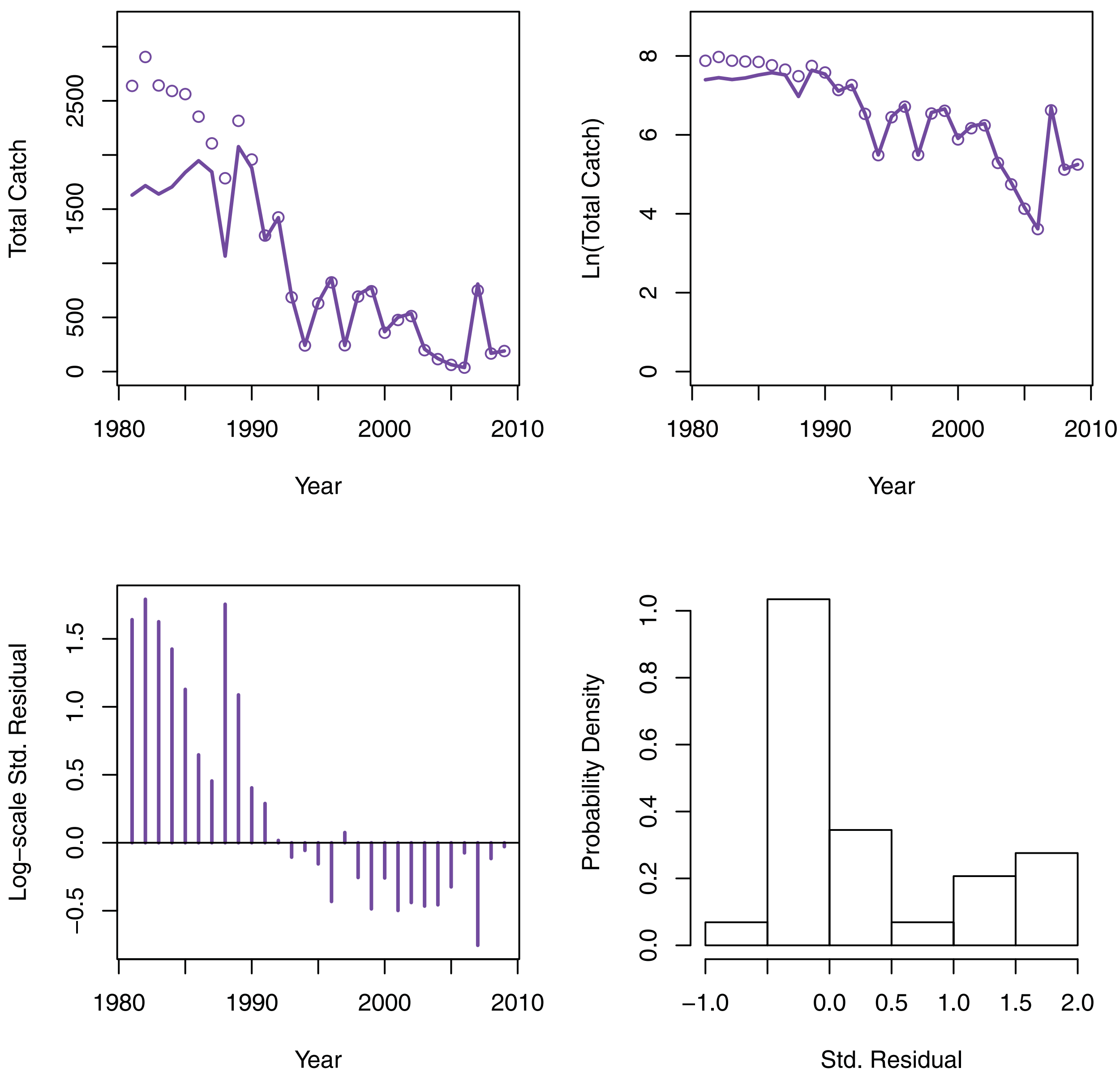
2. Fishery Selectivity (3 Block Selectivity)
    a. Landings (1 Blocks: 1973-2009)
    b. Discards (1 Block: 1981-2009)
    c. Consumption (Double Logistic Functional Form)

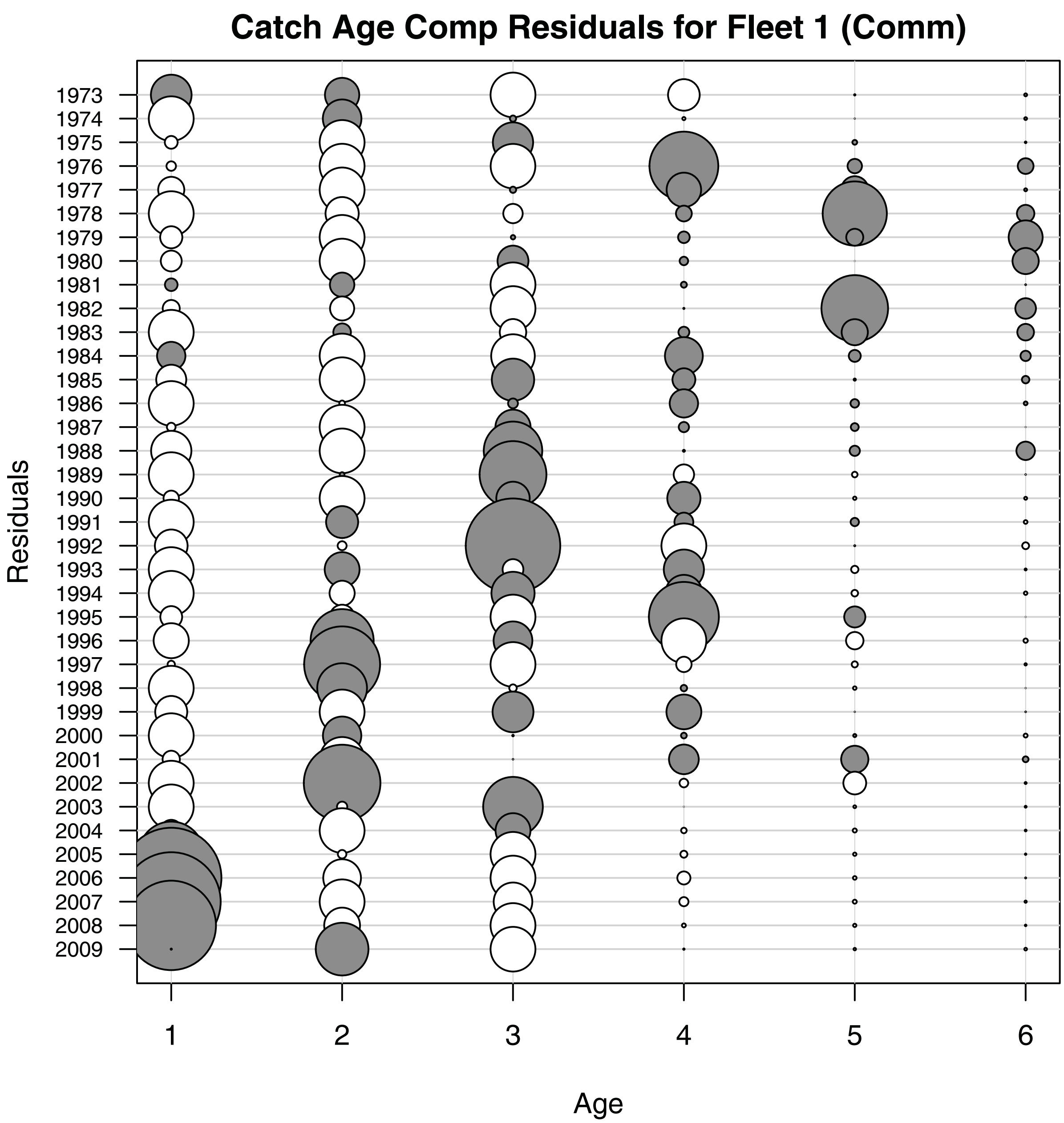
3. Survey Selectivity (Fixed 100% at age 2-6+)

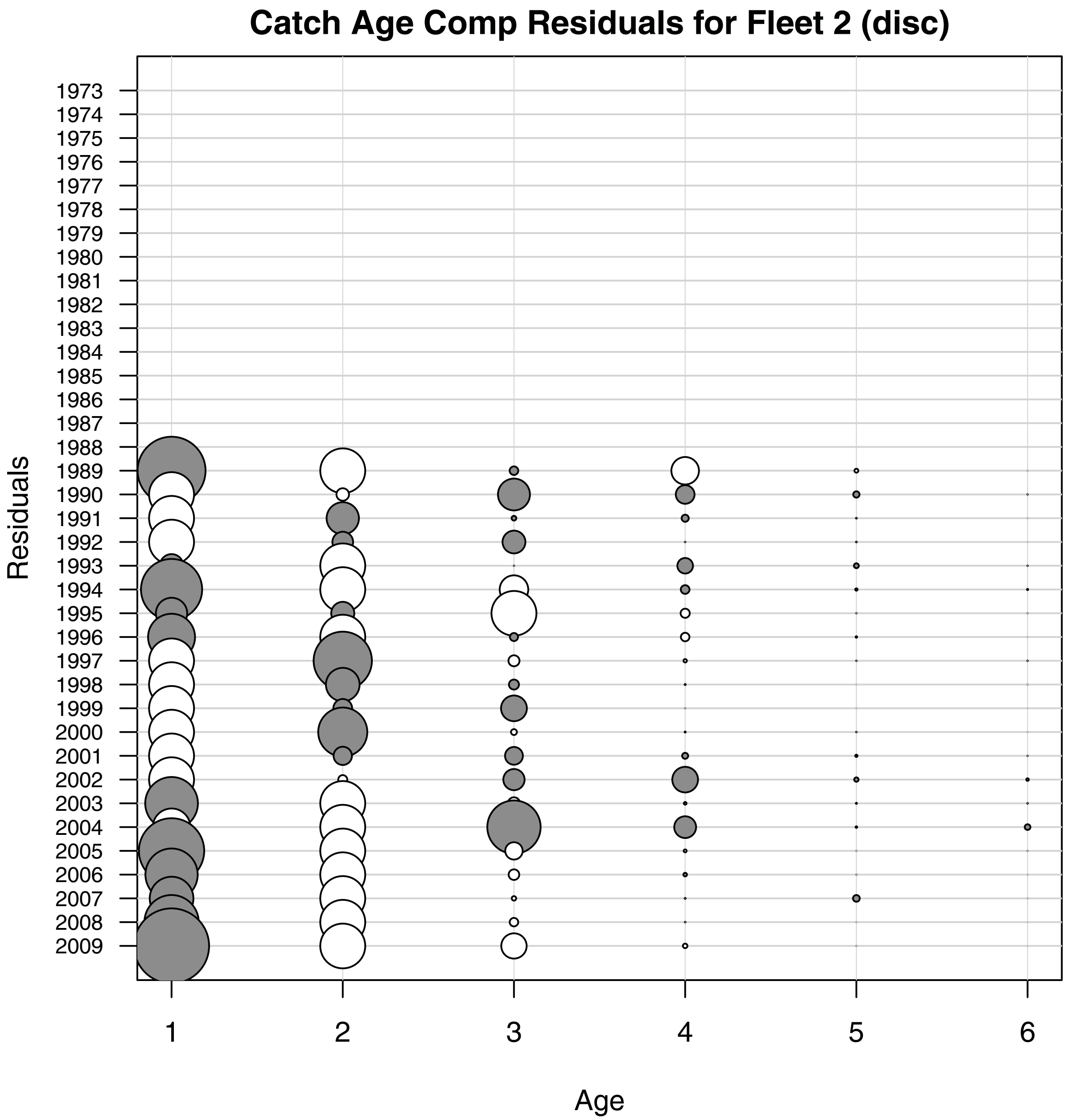

Components of Objective Function (4752)
F.penalty
Fmult.Max.penalty
SRR.unexpl.stock
SRR.steepness
Recruit.devs
N.year1
Fmult.devs.total
Fmult.year1.total
q.devs
q.year1
index.sel.param.total
sel.param.total
survey.age.comp
discards.age.comp
catch.age.comp
index.fit.total
discard.total
catch.total
0
0
0
0
528
57
0
96
0
0
0
18
841
0
728
1650
0
833
0
200
400
600
800
1000
1400
1800
Likelihood Contribution

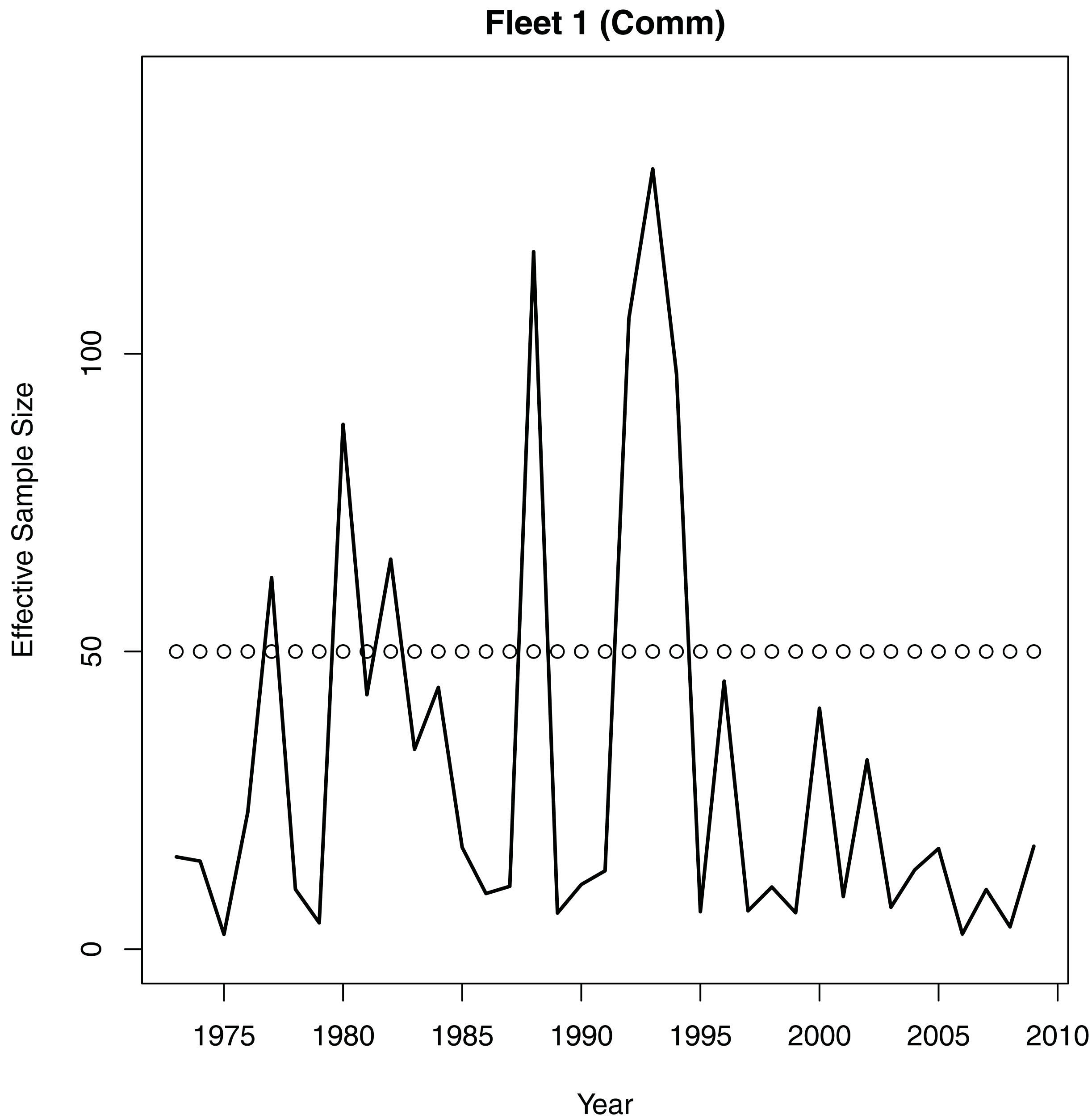

Fleet 1 Landings (Comm)
Total Catch
0
10000
30000
1975
1985
1995
2005
Year
Ln(Total Catch)
0
2
4
6
8
10
12
Log−scale Std. Residual
−10
−5
0
5
10
Probability Density
0.00
0.02
0.04
0.06
−15
−10
−5
0
5
10
15
Std. Residual

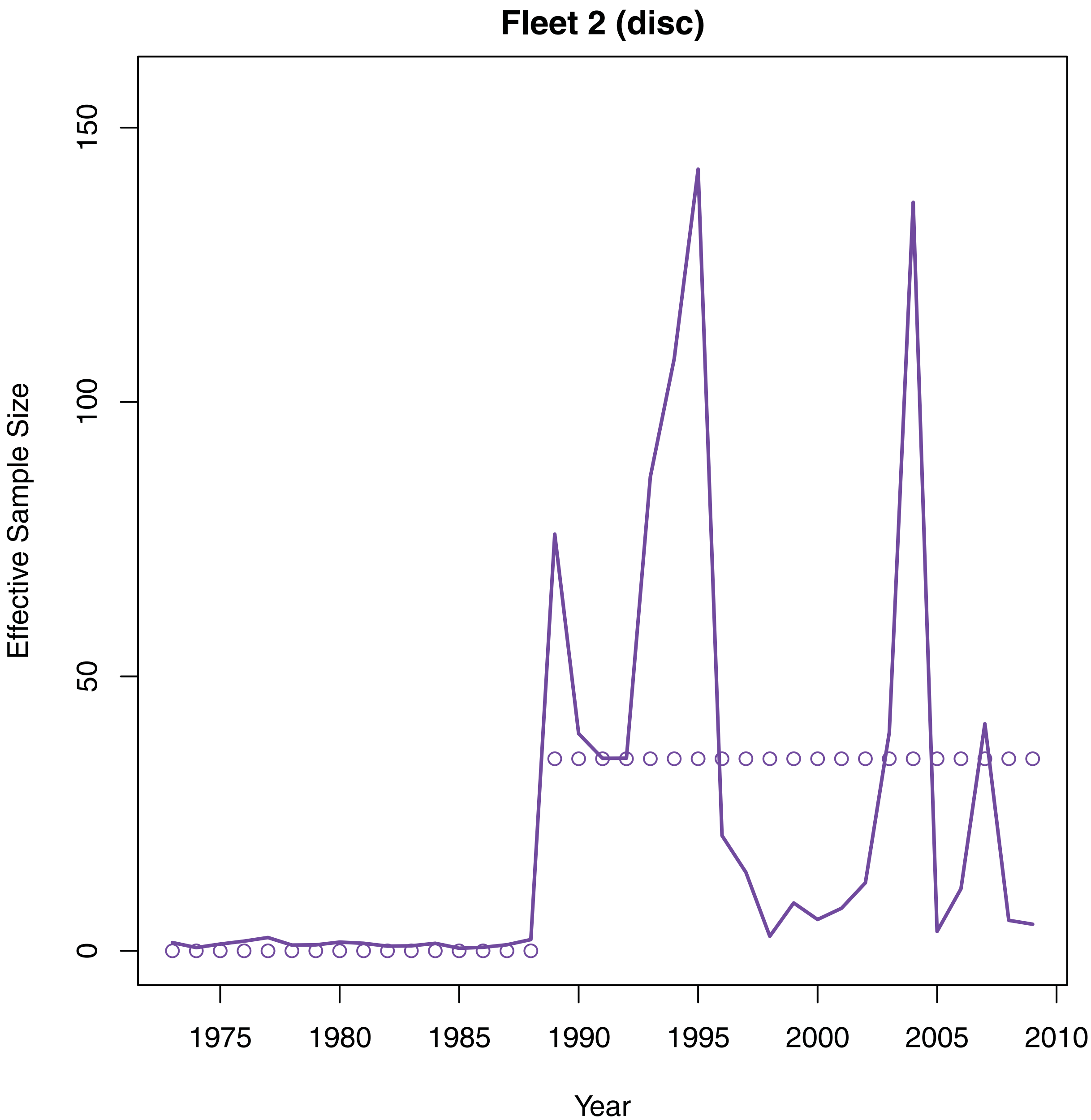
Fleet 2 Landings (disc)

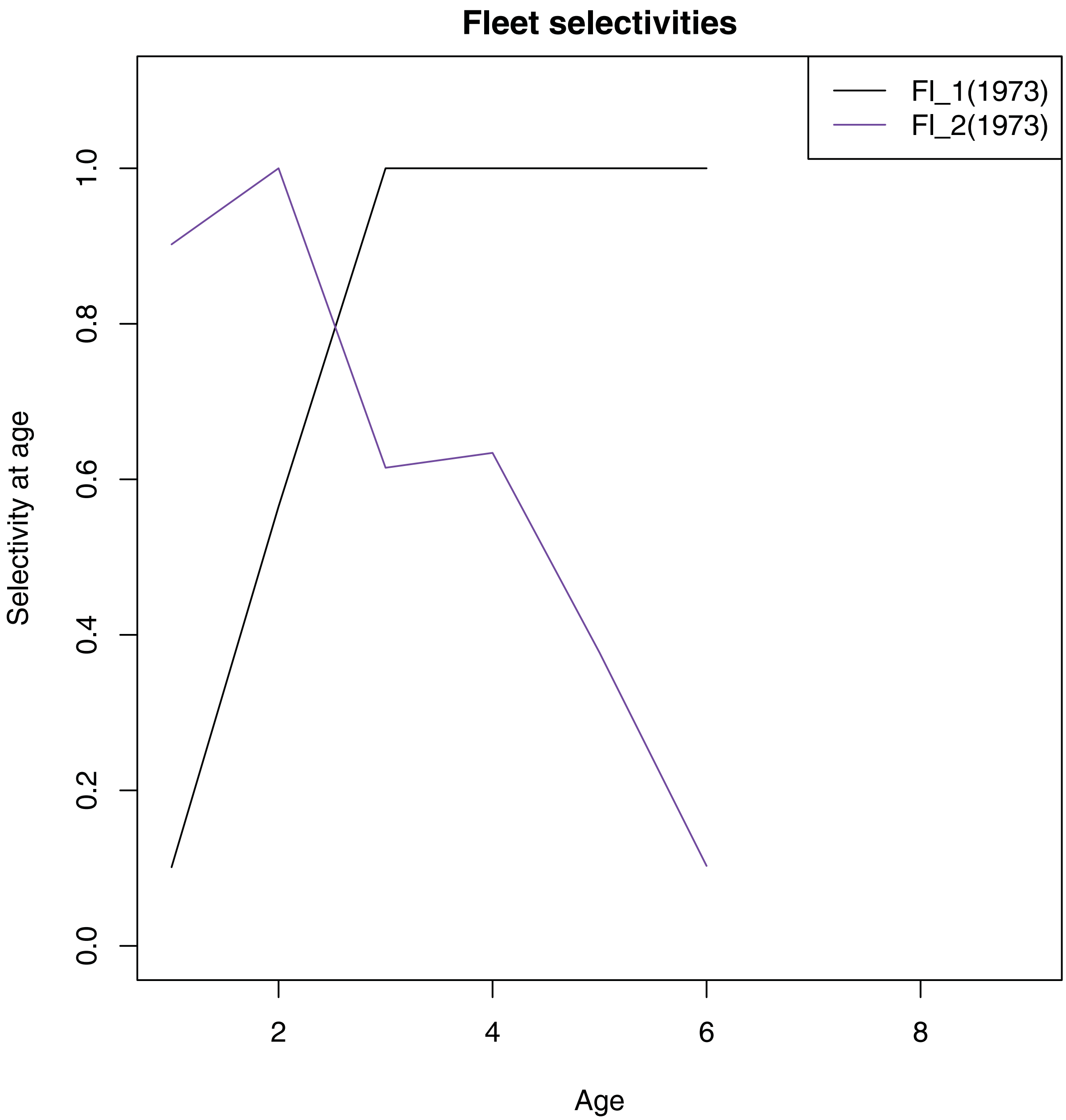


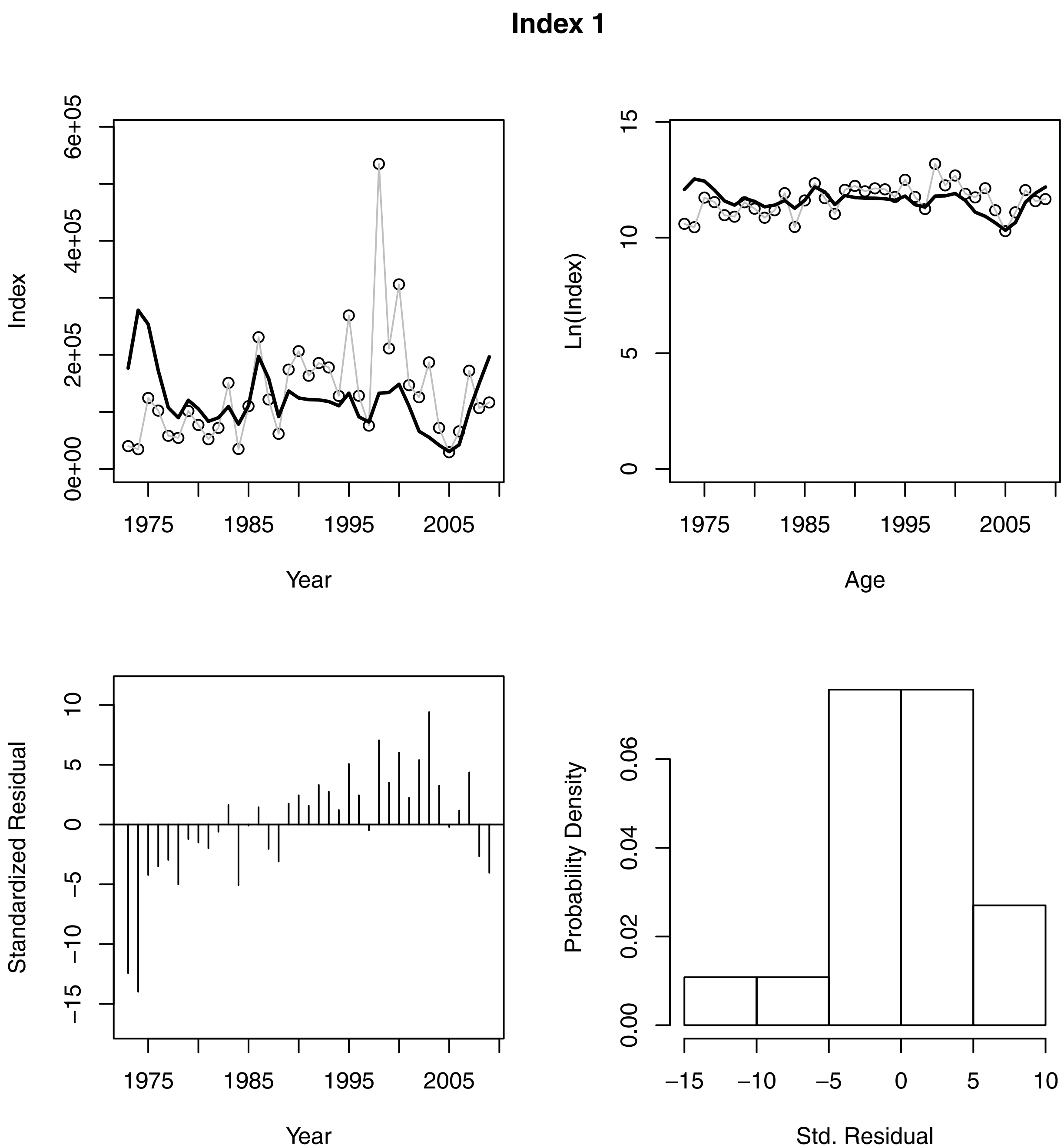

Catch Age Comp Residuals for Fleet 1 (Comm)
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age


Catch Age Comp Residuals for Fleet 2 (disc)
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Residuals
1
2
3
4
5
6
Age

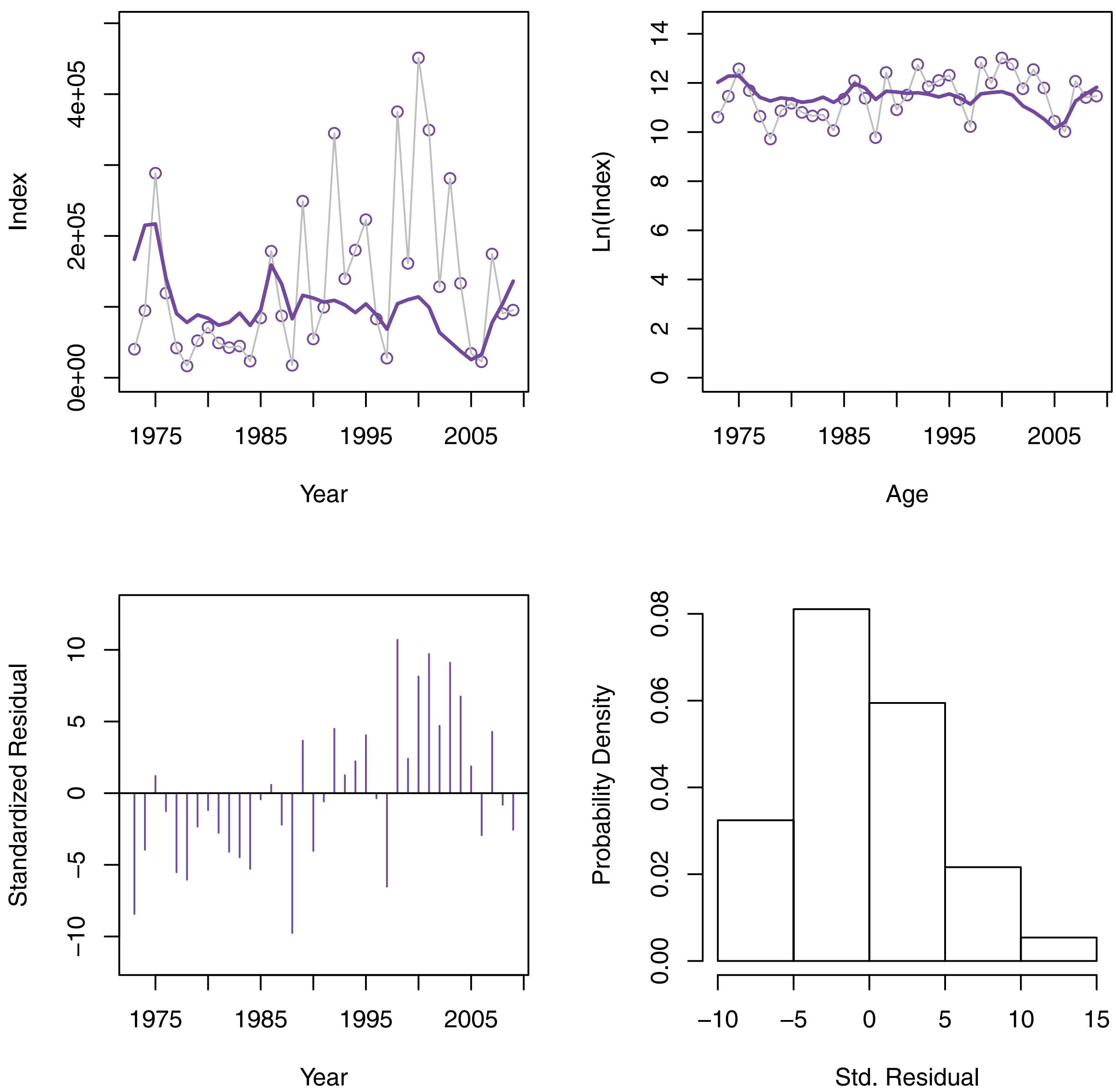

Fleet 1 (Comm)
Effective Sample Size
0
50
100
1975
1980
1985
1990
1995
2000
2005
2010
Year

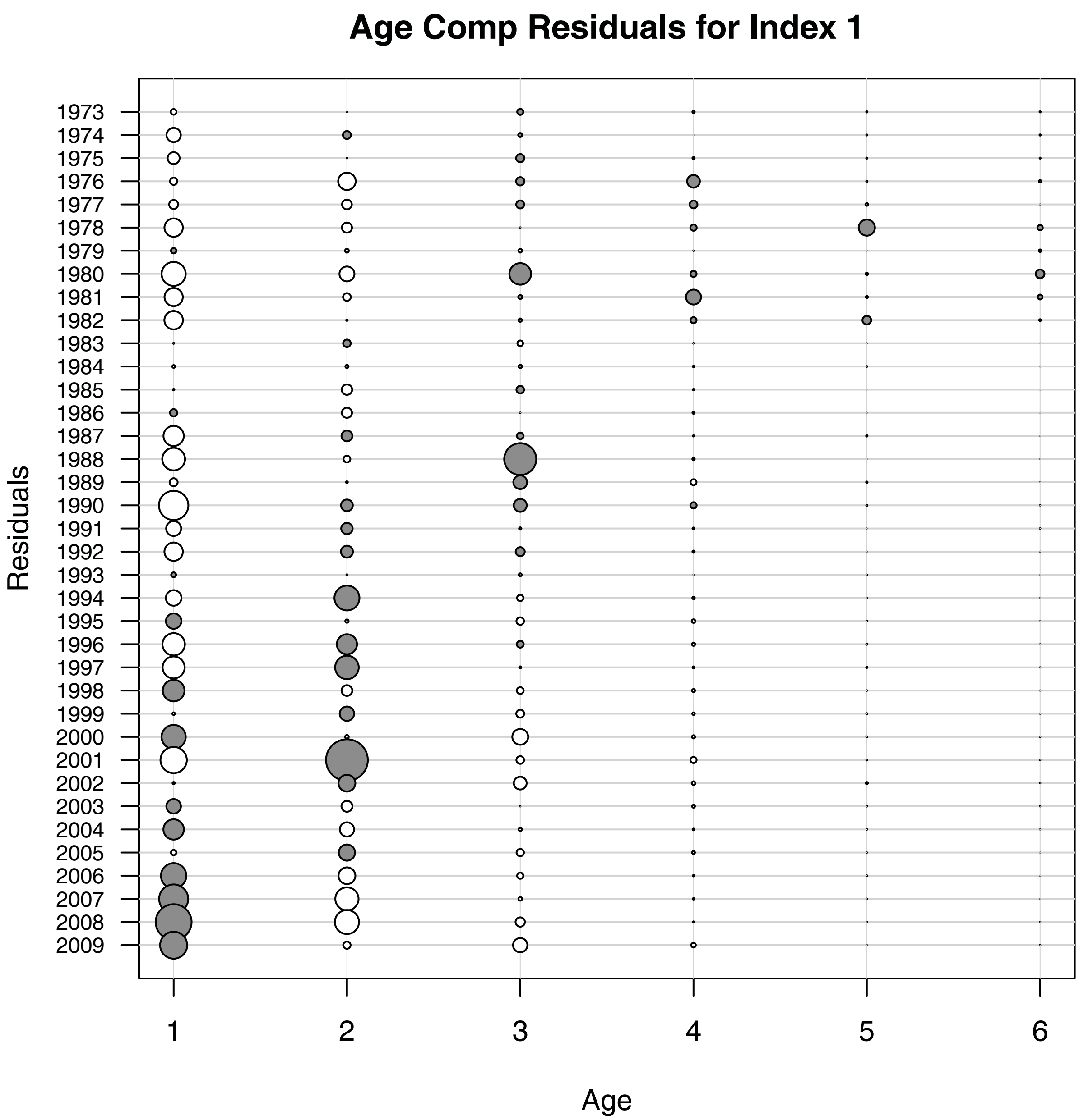

Fleet 2 (disc)
Effective Sample Size
0
50
100
150
1975
1980
1985
1990
1995
2000
2005
2010
Year

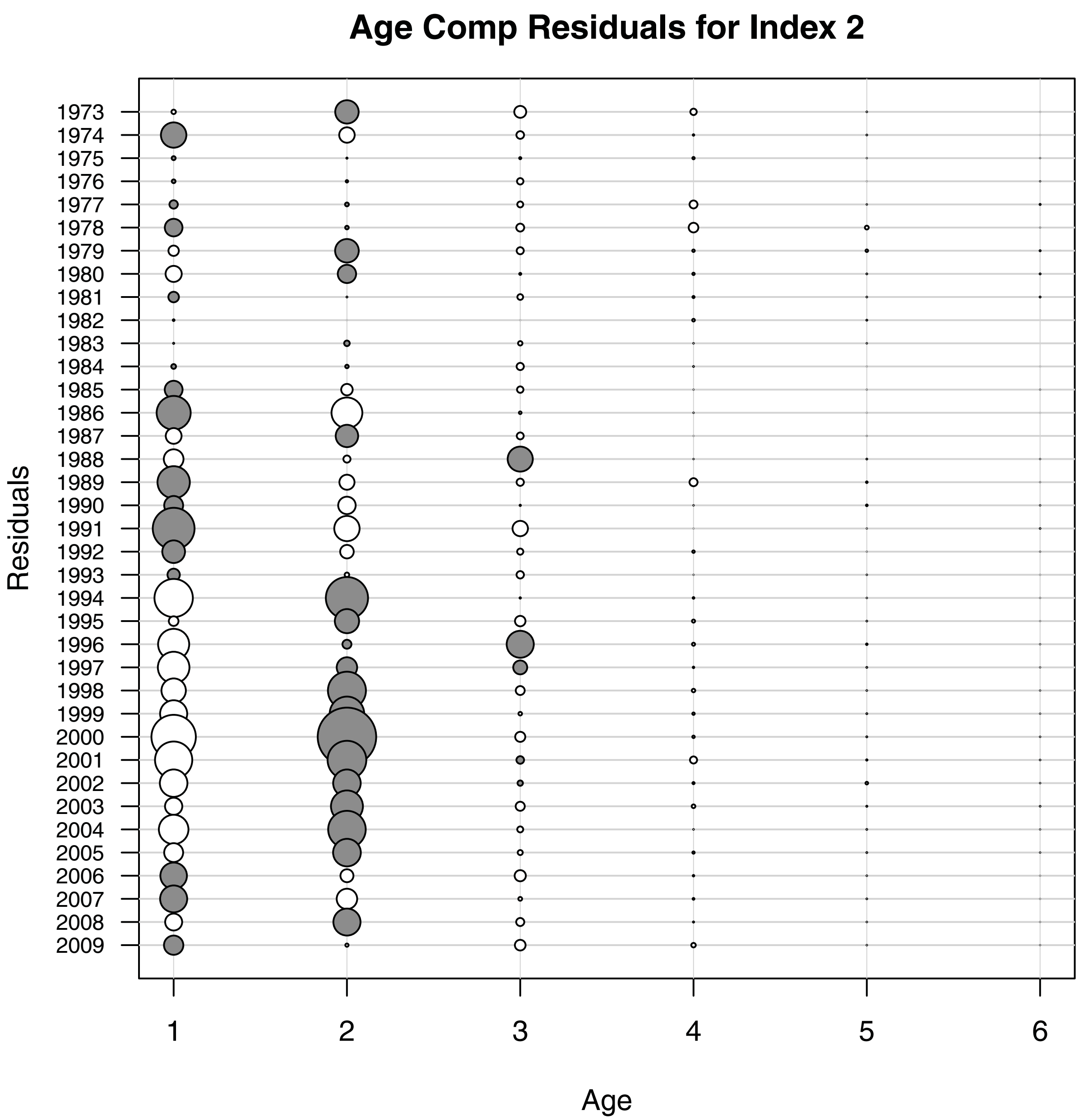

Fleet selectivities
Fl_1(1973)
Fl_2(1973)
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
Age

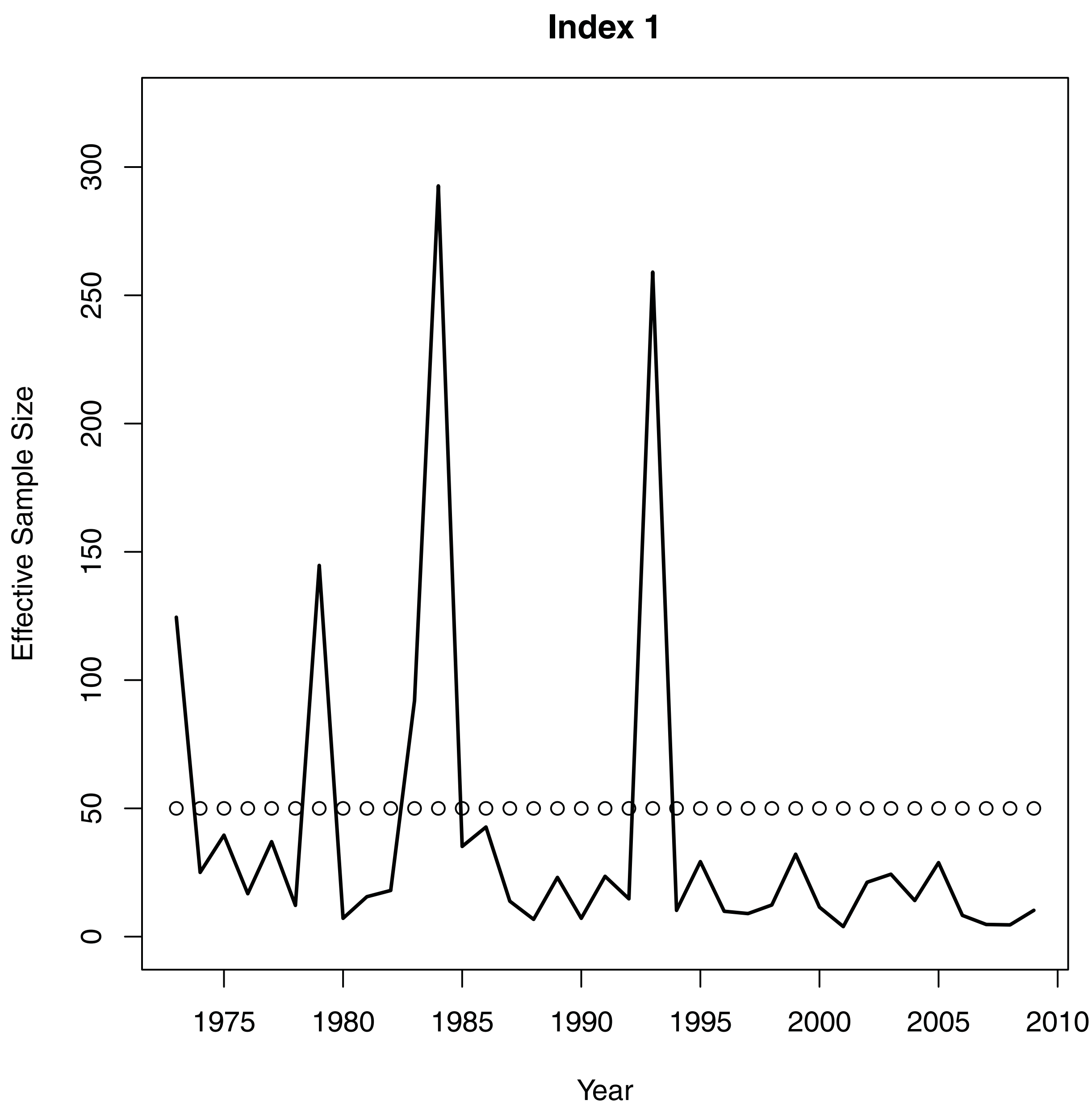

Index 1
Index
0e+00
2e+05
4e+05
6e+05
1975
1985
1995
2005
Year
Ln(Index)
0
5
10
15
Age
Standardized Residual
−15
−10
−5
0
5
10
Probability Density
0.00
0.02
0.04
0.06
−15
−10
−5
0
5
10
Std. Residual

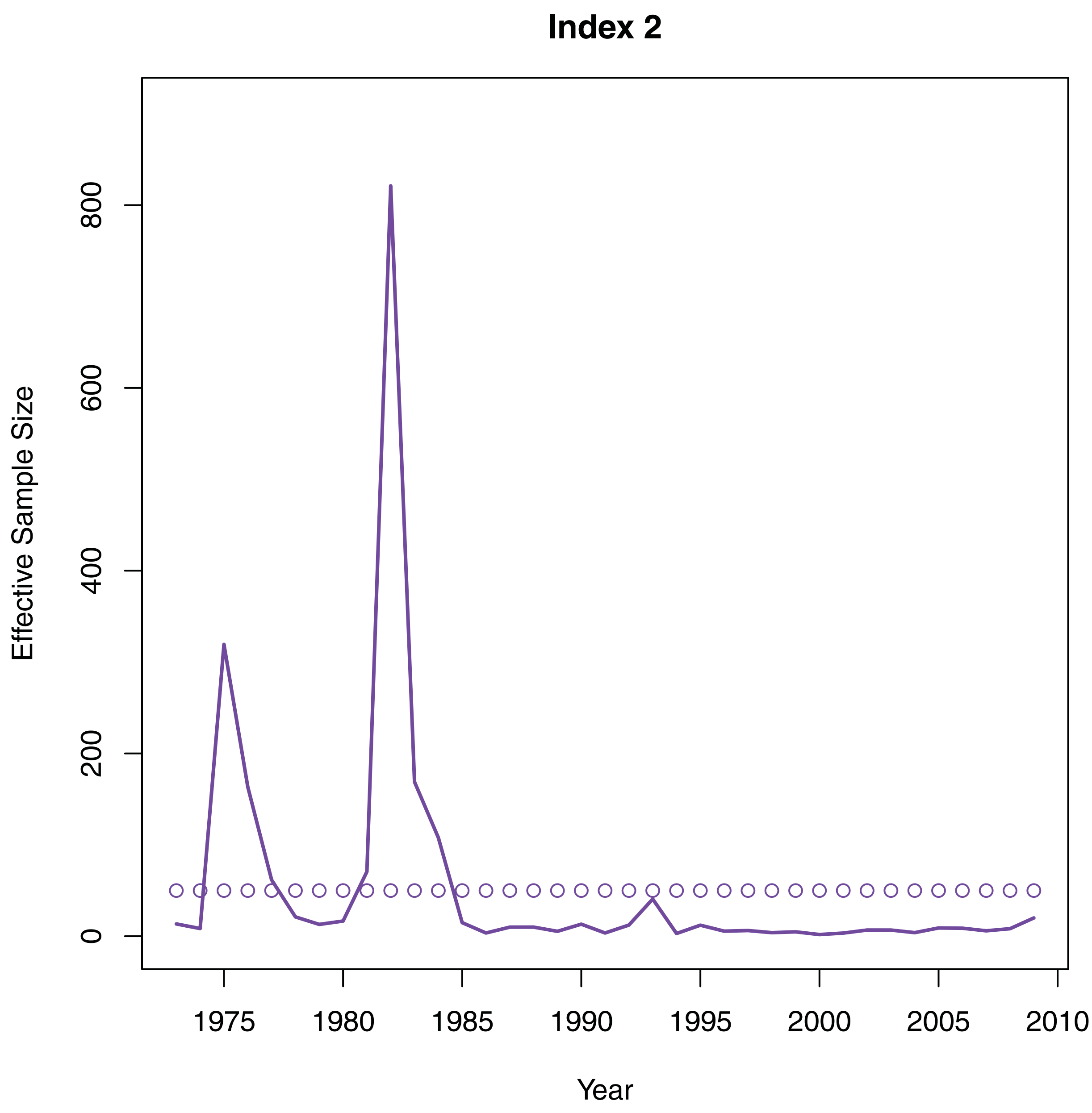
Index 2

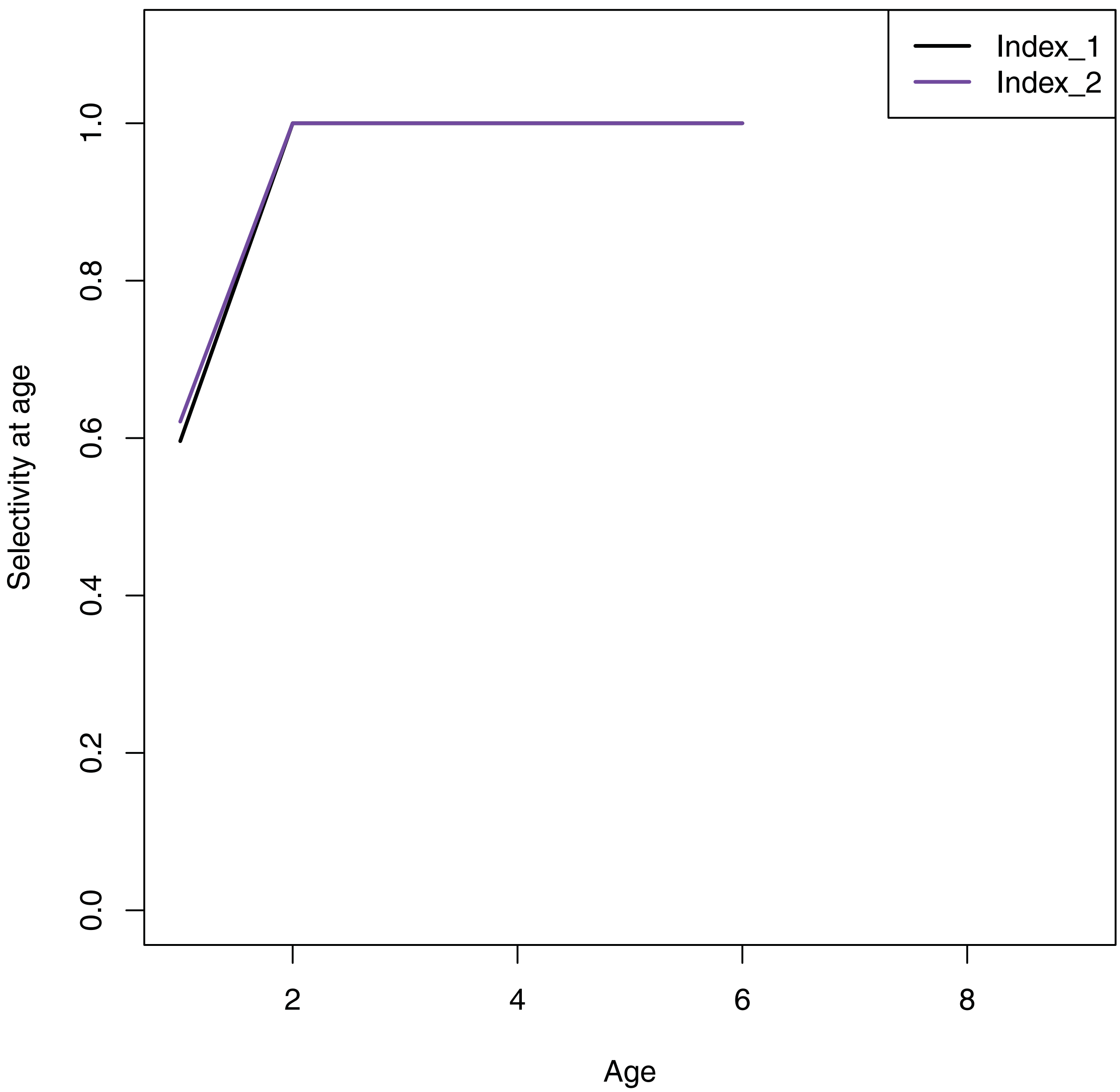

Index
0e+00
2e+05
4e+05
1975
1985
1995
2005
Year
Ln(Index)
0
2
4
6
8
10
12
14
Age
Standardized Residual
−10
−5
0
5
10
Year
Probability Density
0.00
0.02
0.04
0.06
0.08
−10
−5
0
5
10
15
Std. Residual

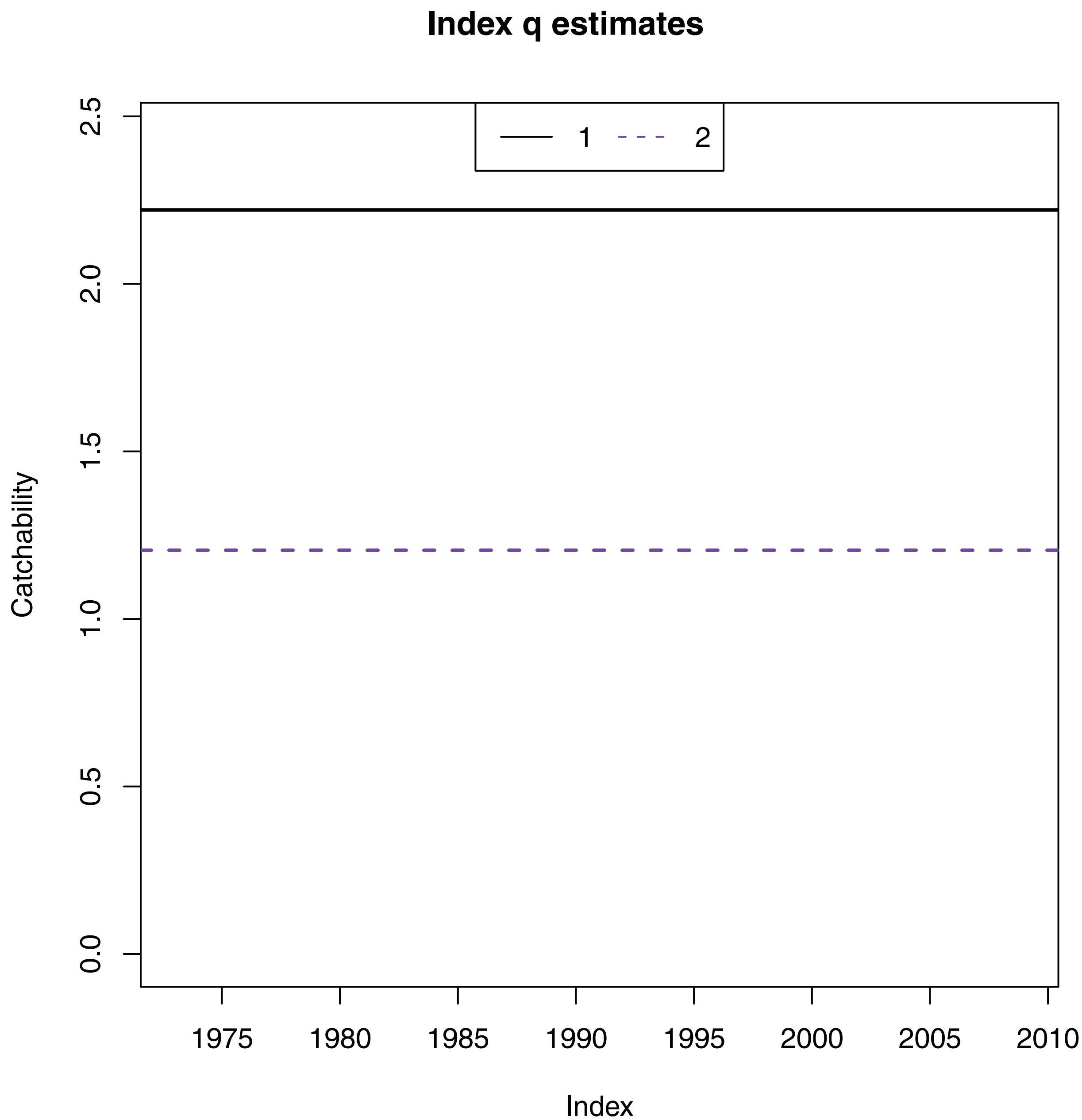

Age Comp Residuals for Index 1
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age

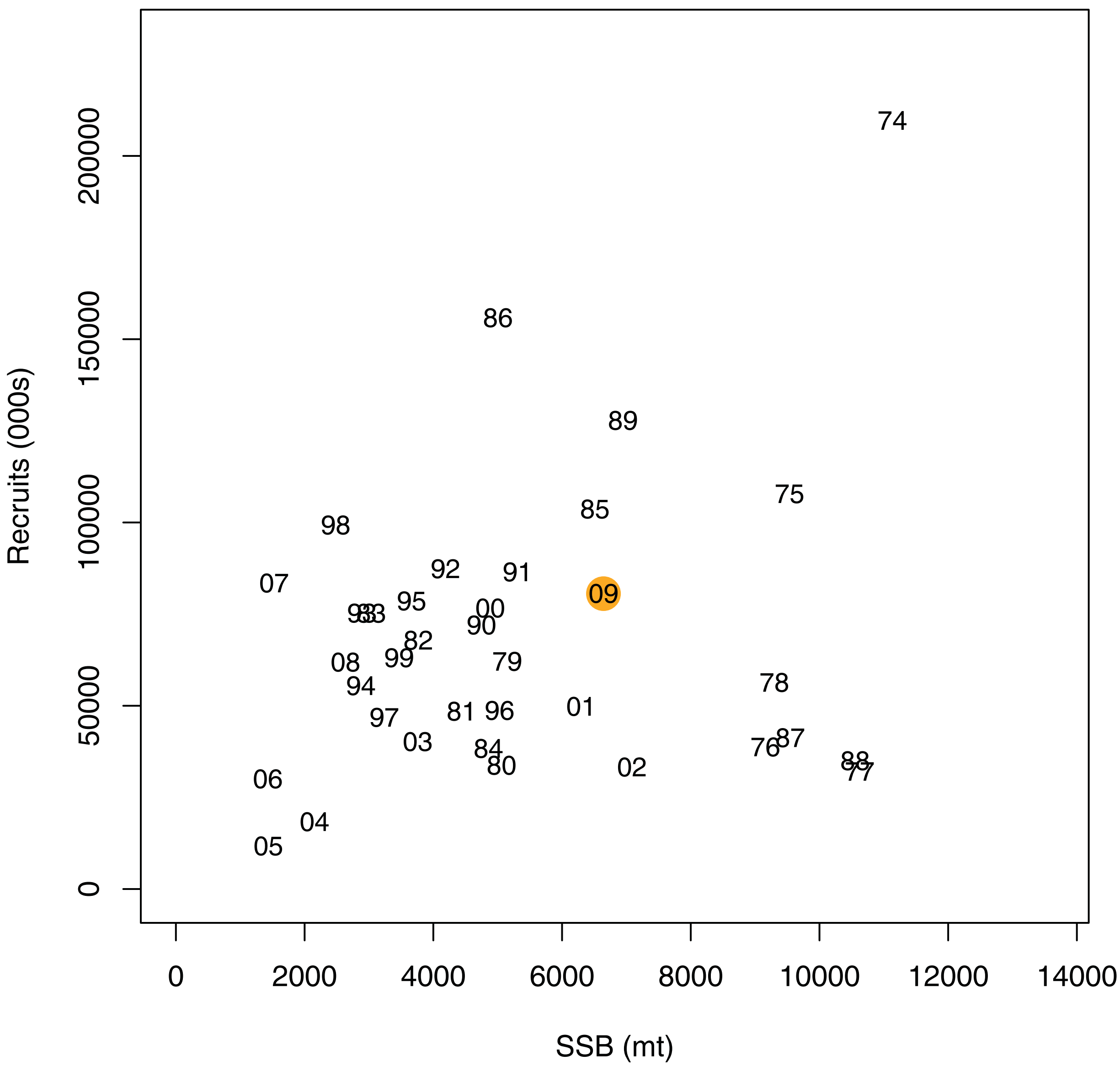

Age Comp Residuals for Index 2
Residuals
Age
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6

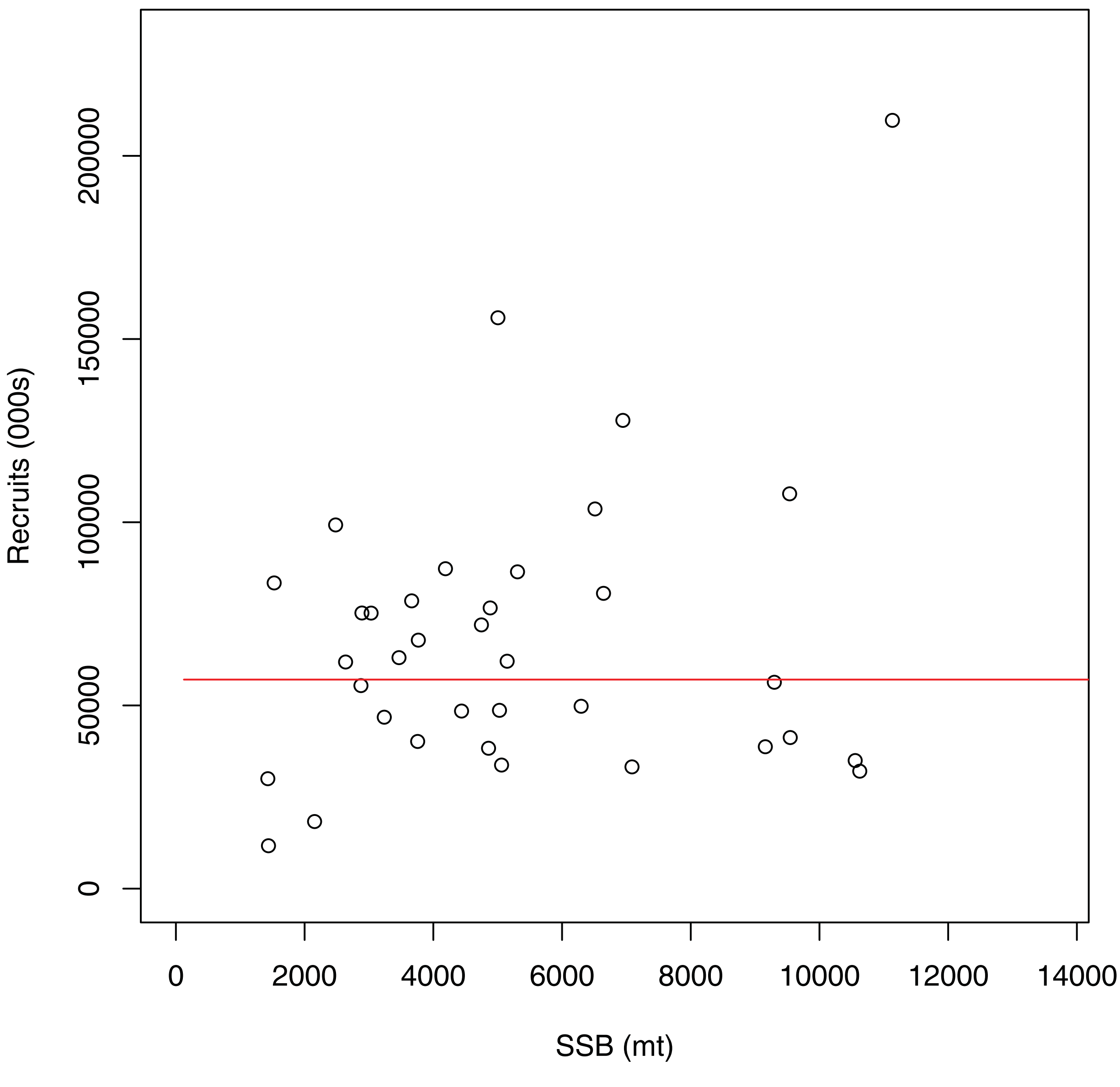

Index 1
Effective Sample Size
Year
0
50
100
150
200
250
300
1975
1980
1985
1990
1995
2000
2005
2010

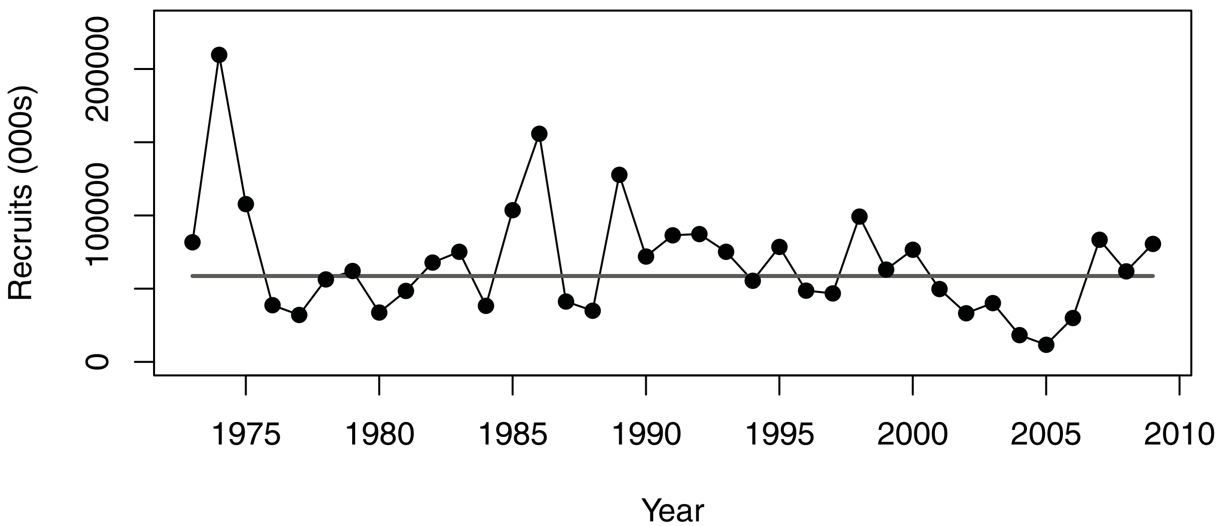

Index 2
Effective Sample Size
0
200
400
600
800
1975
1980
1985
1990
1995
2000
2005
2010
Year

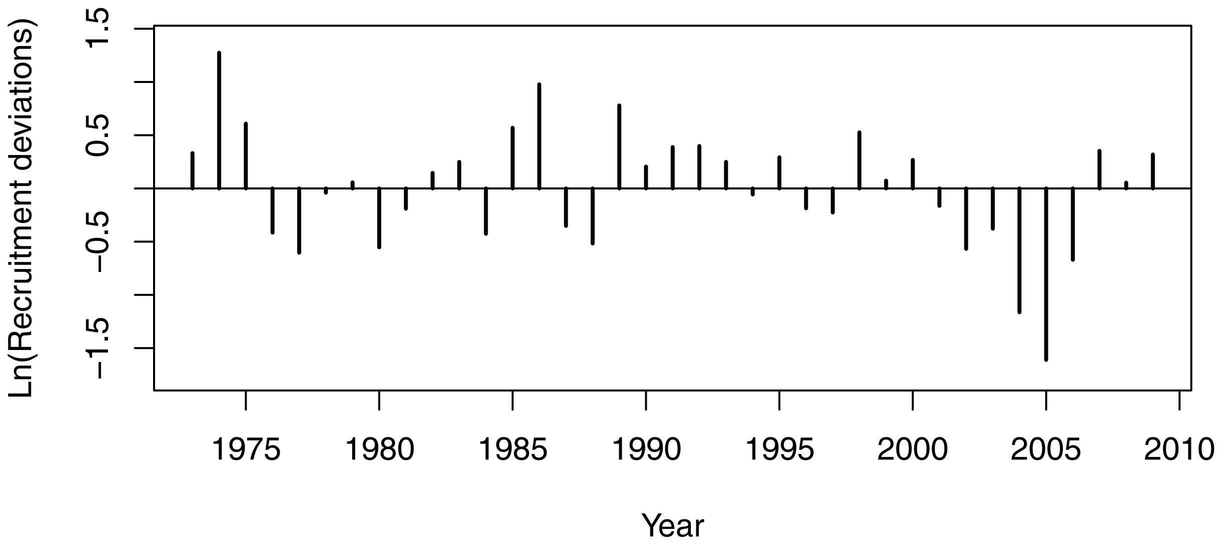

Index_1
Index_2
1.0
0.8
0.6
0.4
0.2
0.0
Selectivity at age
2
4
6
8
Age

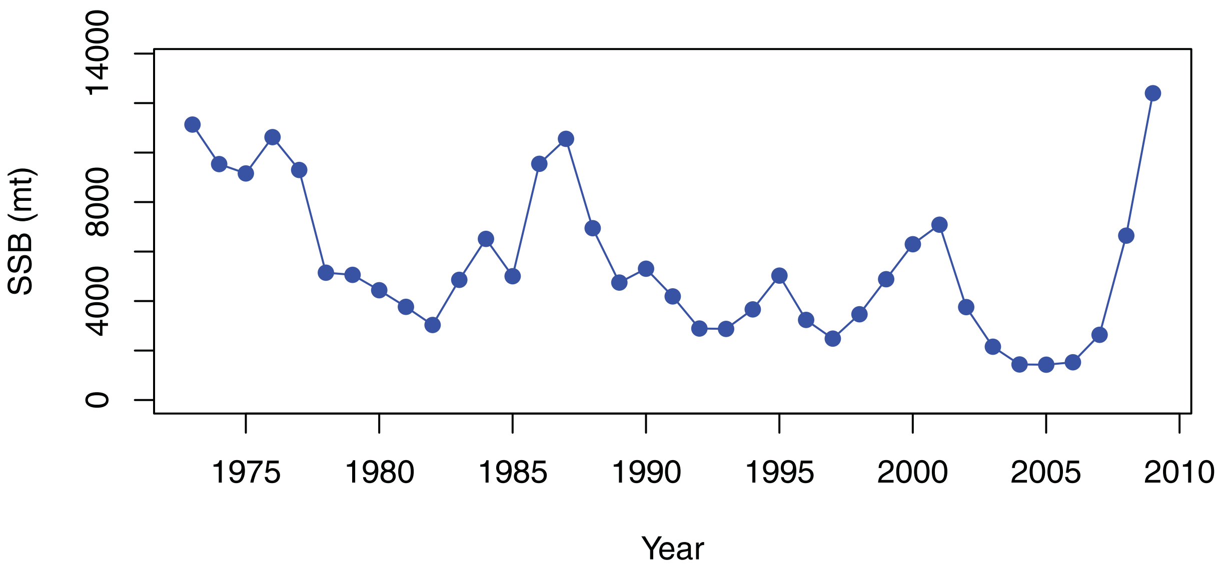

Index q estimates
Catchability
Index
1
2
0.0
0.5
1.0
1.5
2.0
2.5
1975
1980
1985
1990
1995
2000
2005
2010


Recruits (000s)
0
50000
100000
150000
200000
SSB (mt)
0
2000
4000
6000
8000
10000
12000
14000
74
86
89
75
85
98
92
91
07
09
95
00
93
83
90
82
08
99
79
94
78
01
81
96
97
87
76
03
84
88
77
80
02
06
04
05

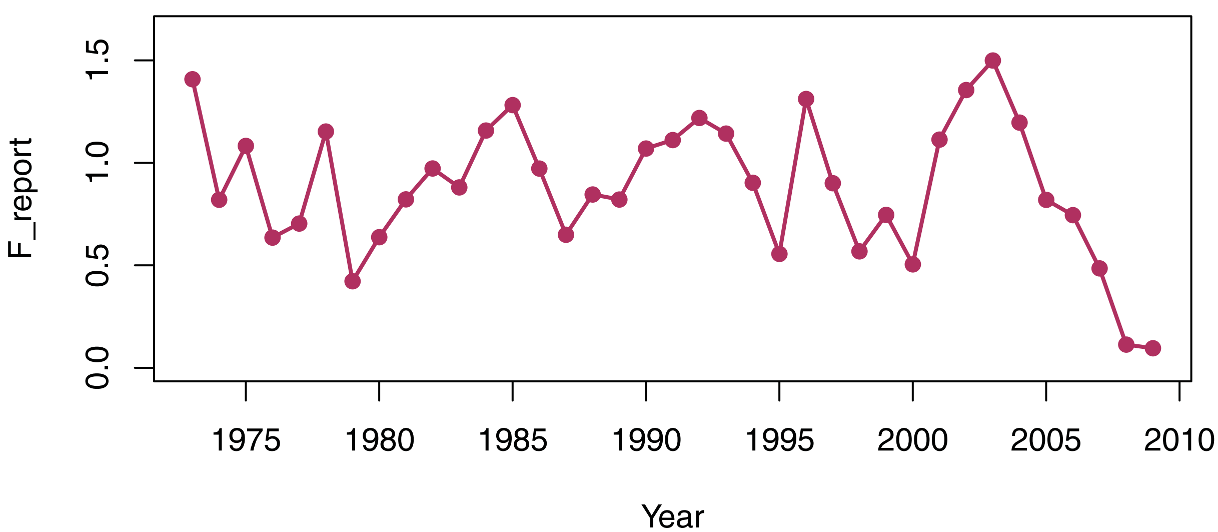

Recruits (000s)
0
50000
100000
150000
200000
0
2000
4000
6000
8000
10000
12000
14000
SSB (mt)


Recruits (000s)
0
100000
200000
1975
1980
1985
1990
1995
2000
2005
2010
Year

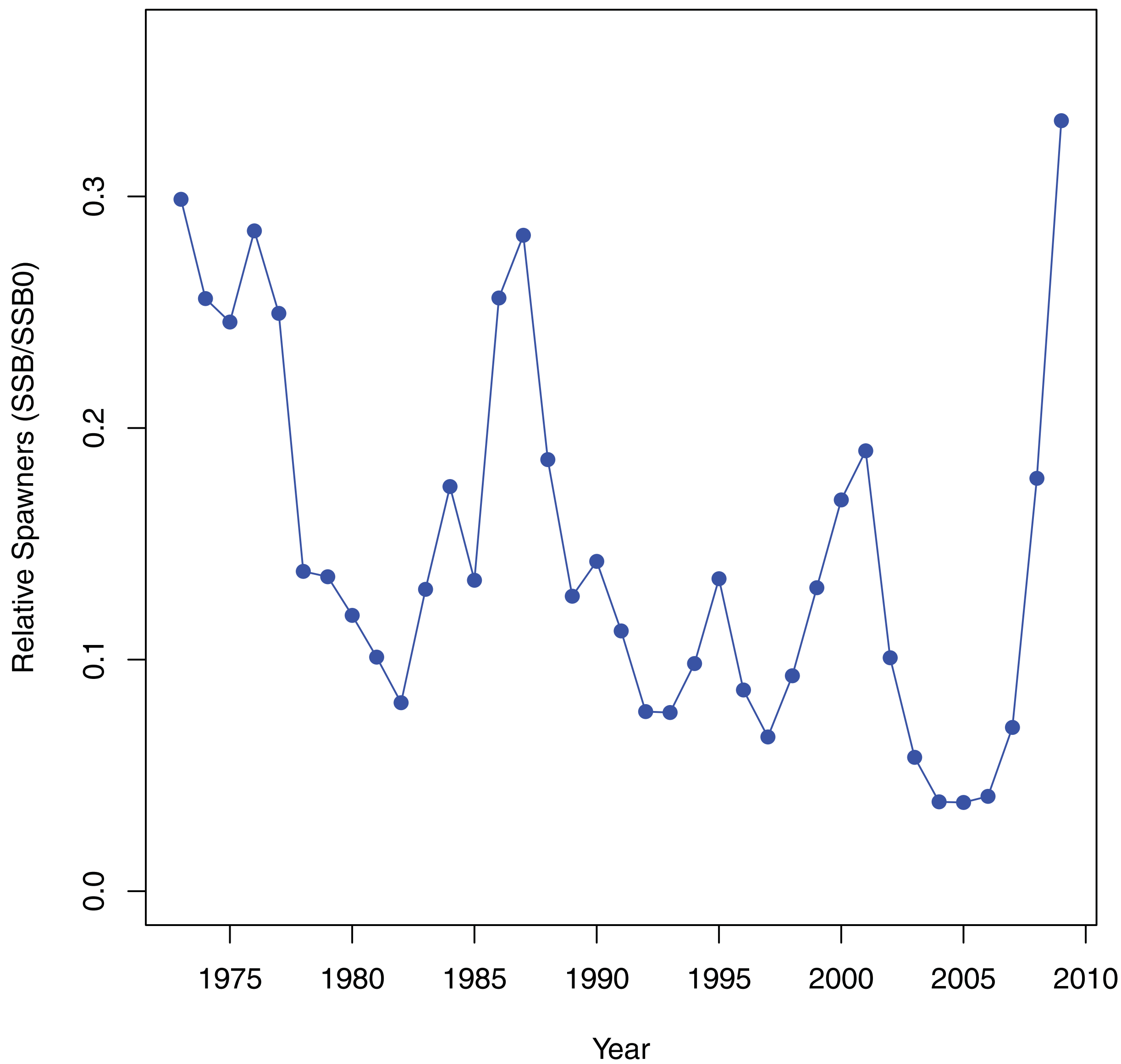

Ln(Recruitment deviations)
−1.5
−0.5
0.5
1.5
1975
1980
1985
1990
1995
2000
2005
2010
Year

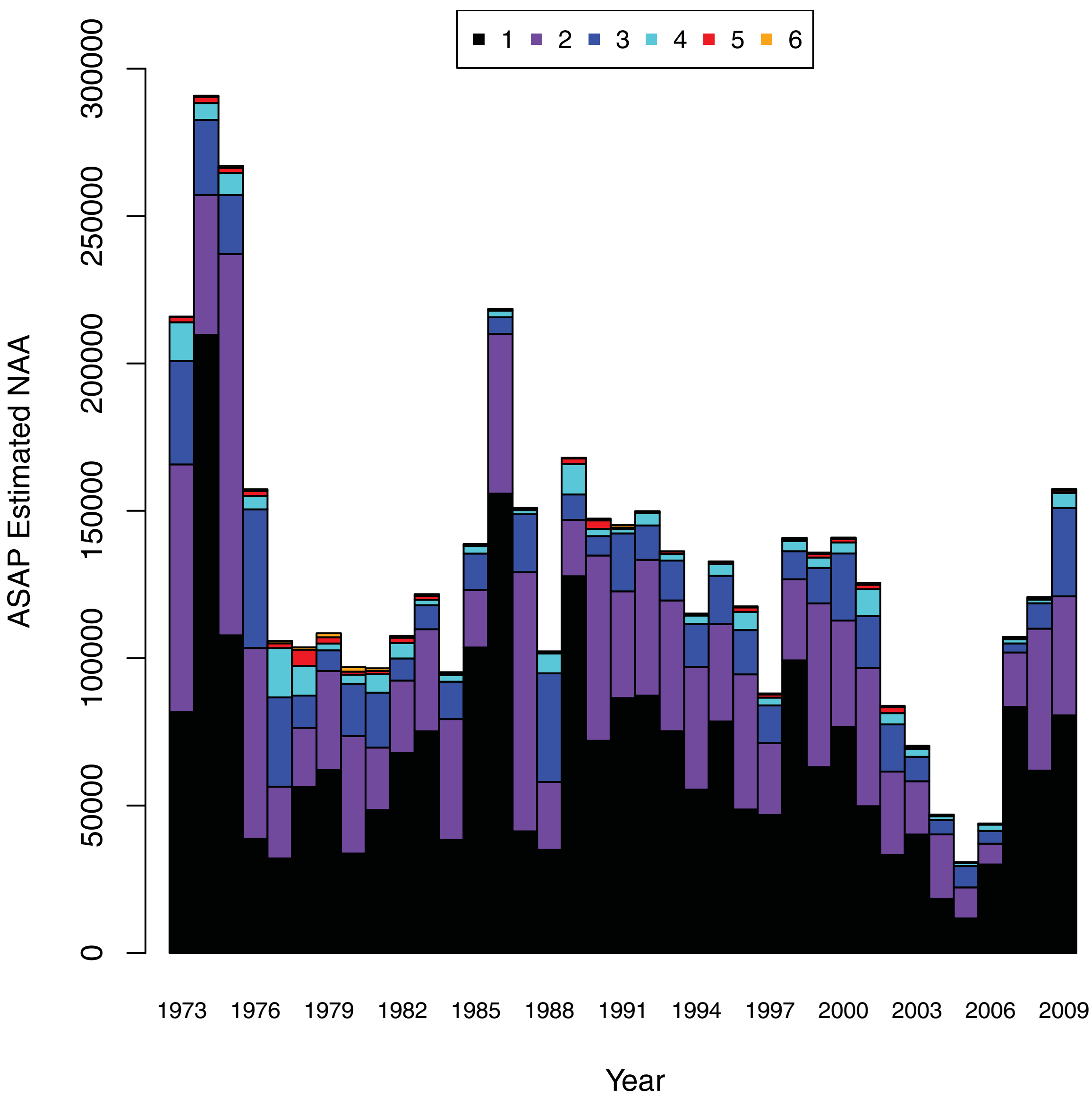


SSB (mt)
0
4000
8000
14000
1975
1980
1985
1990
1995
2000
2005
2010
Year

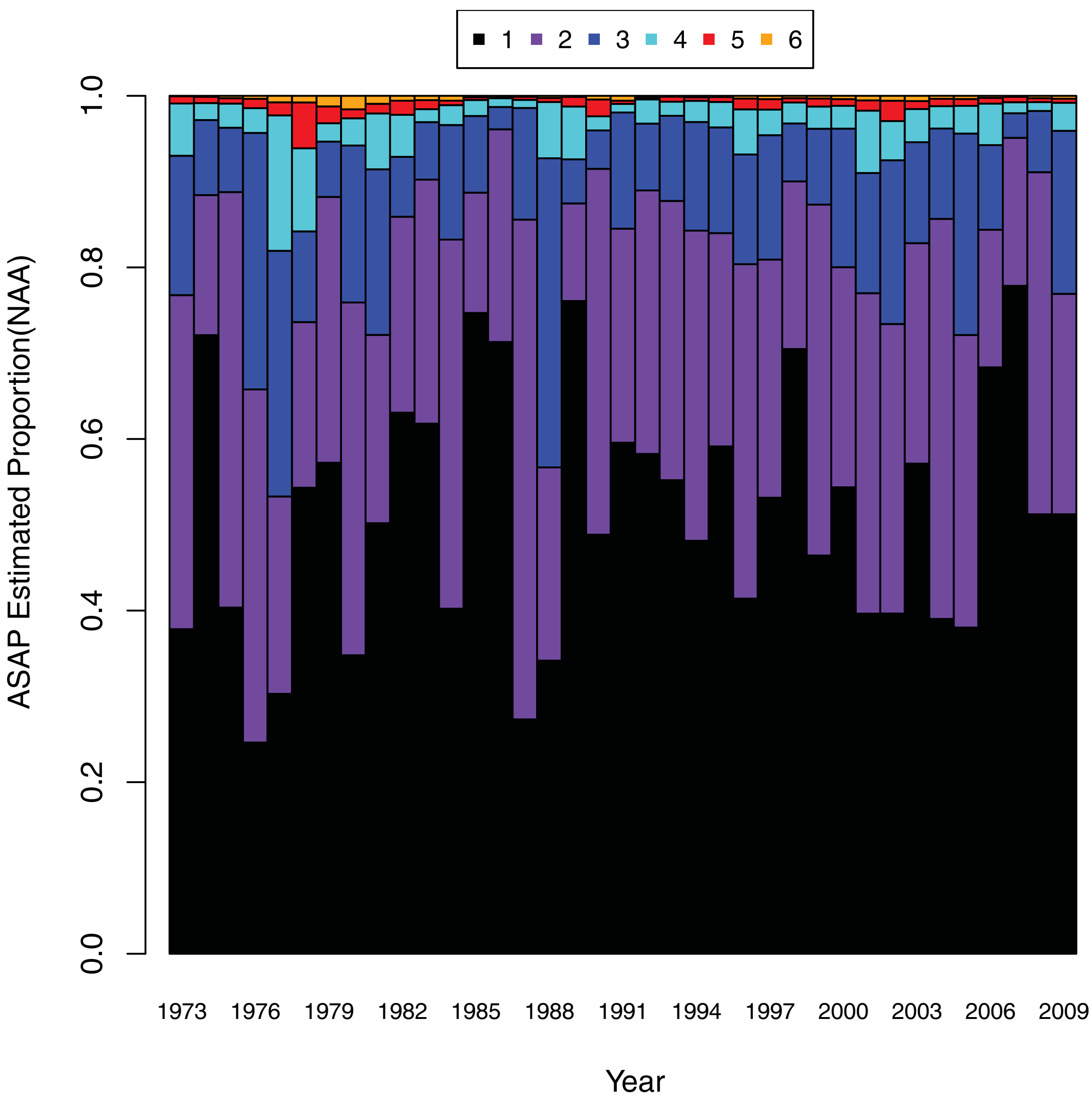


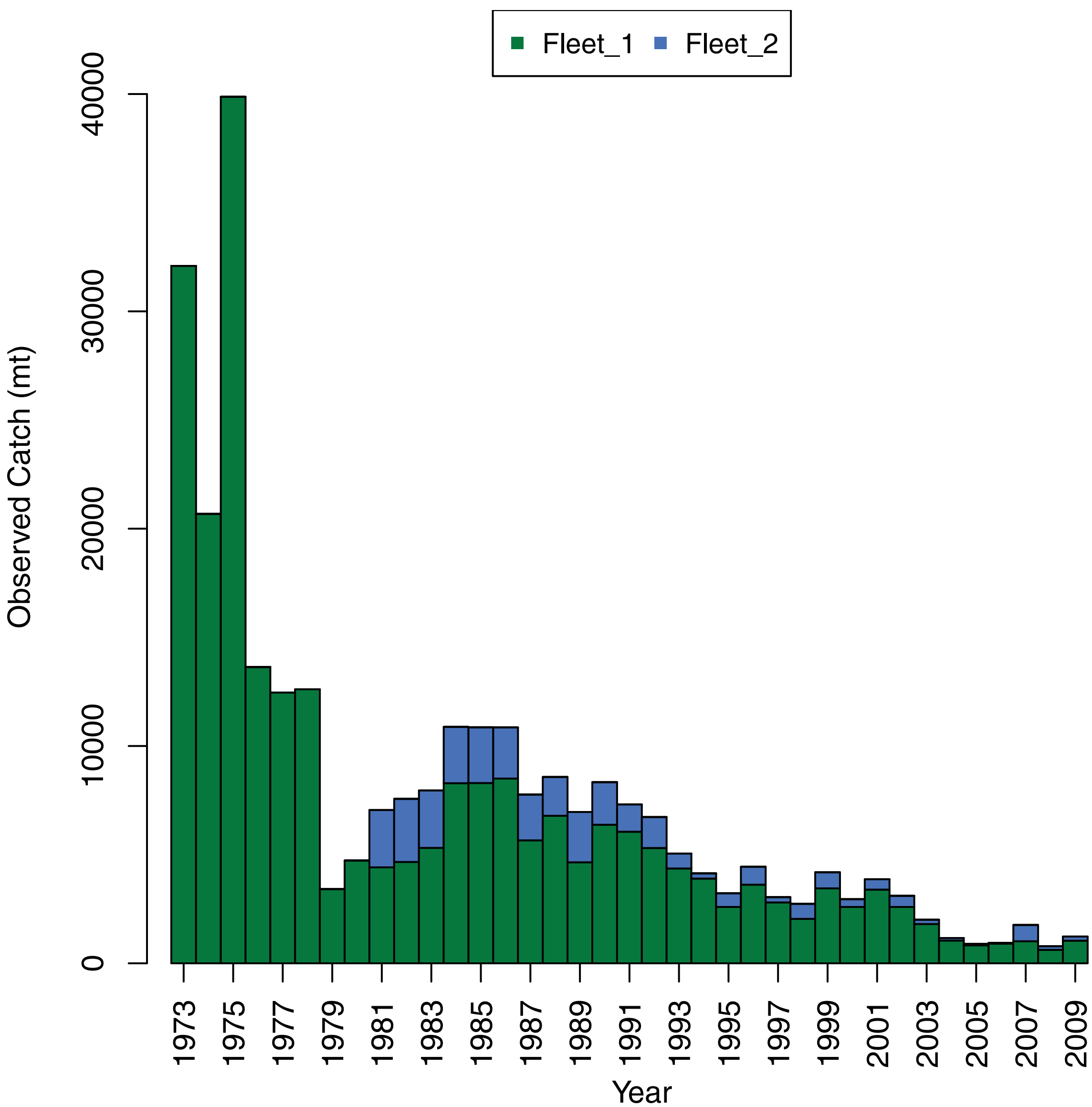
F_report
0.0
0.5
1.0
1.5
1975
1980
1985
1990
1995
2000
2005
2010
Year


Relative Spawners (SSB/SSB0)
0.0
0.1
0.2
0.3
1975
1980
1985
1990
1995
2000
2005
2010
Year

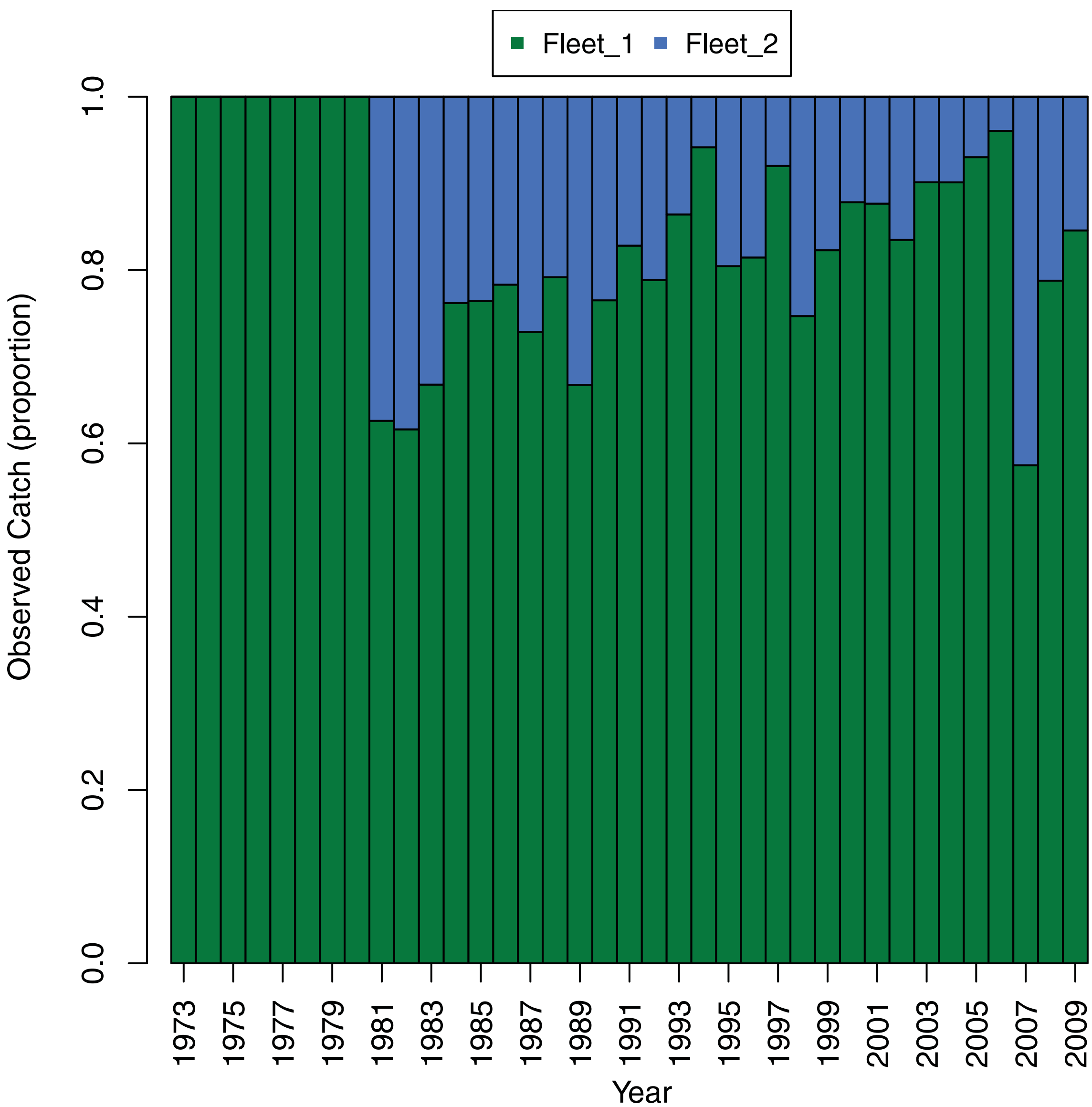


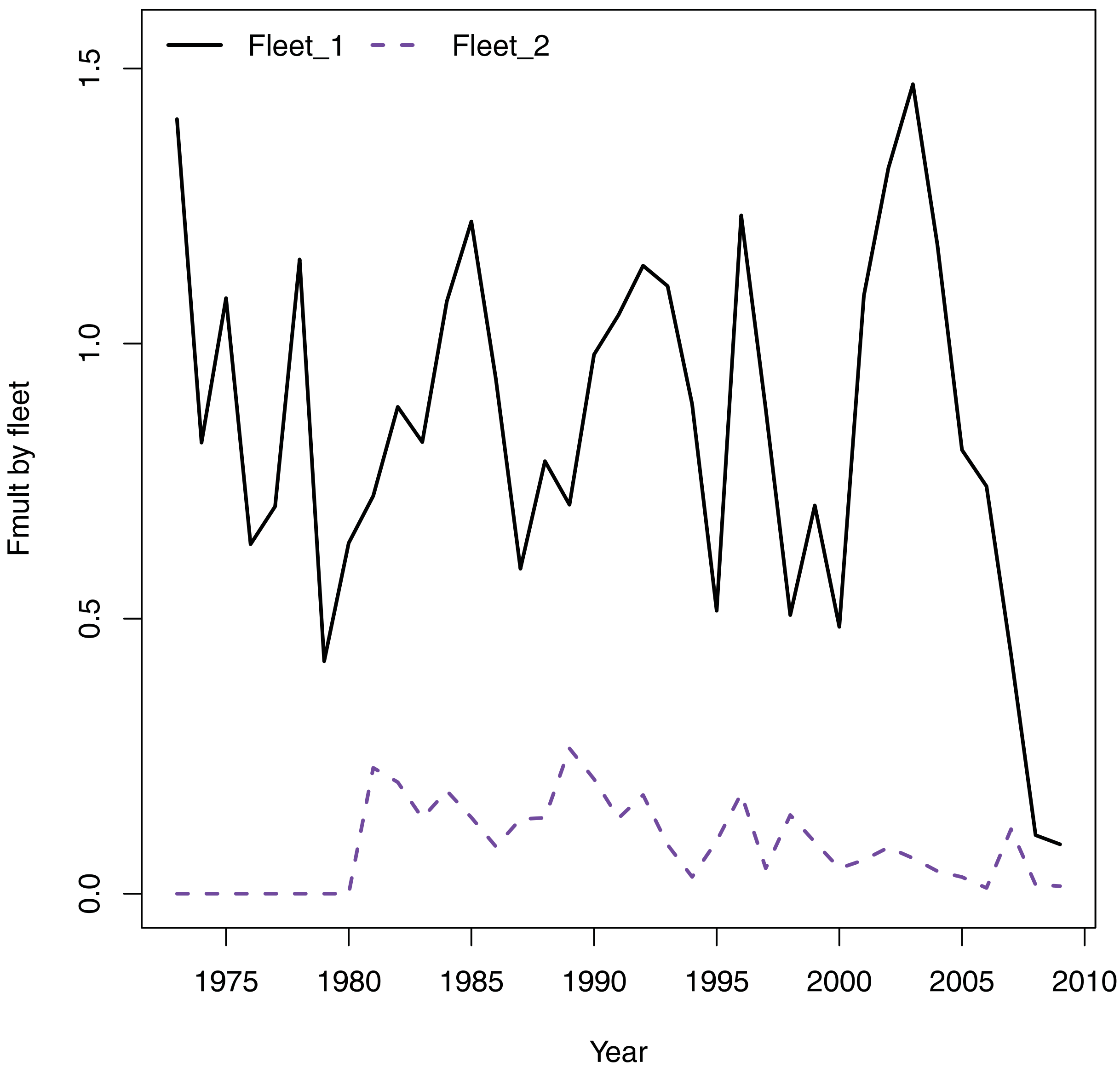
1 2 3 4 5 6
ASAP Estimated NAA
0
50000
100000
150000
200000
250000
300000
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

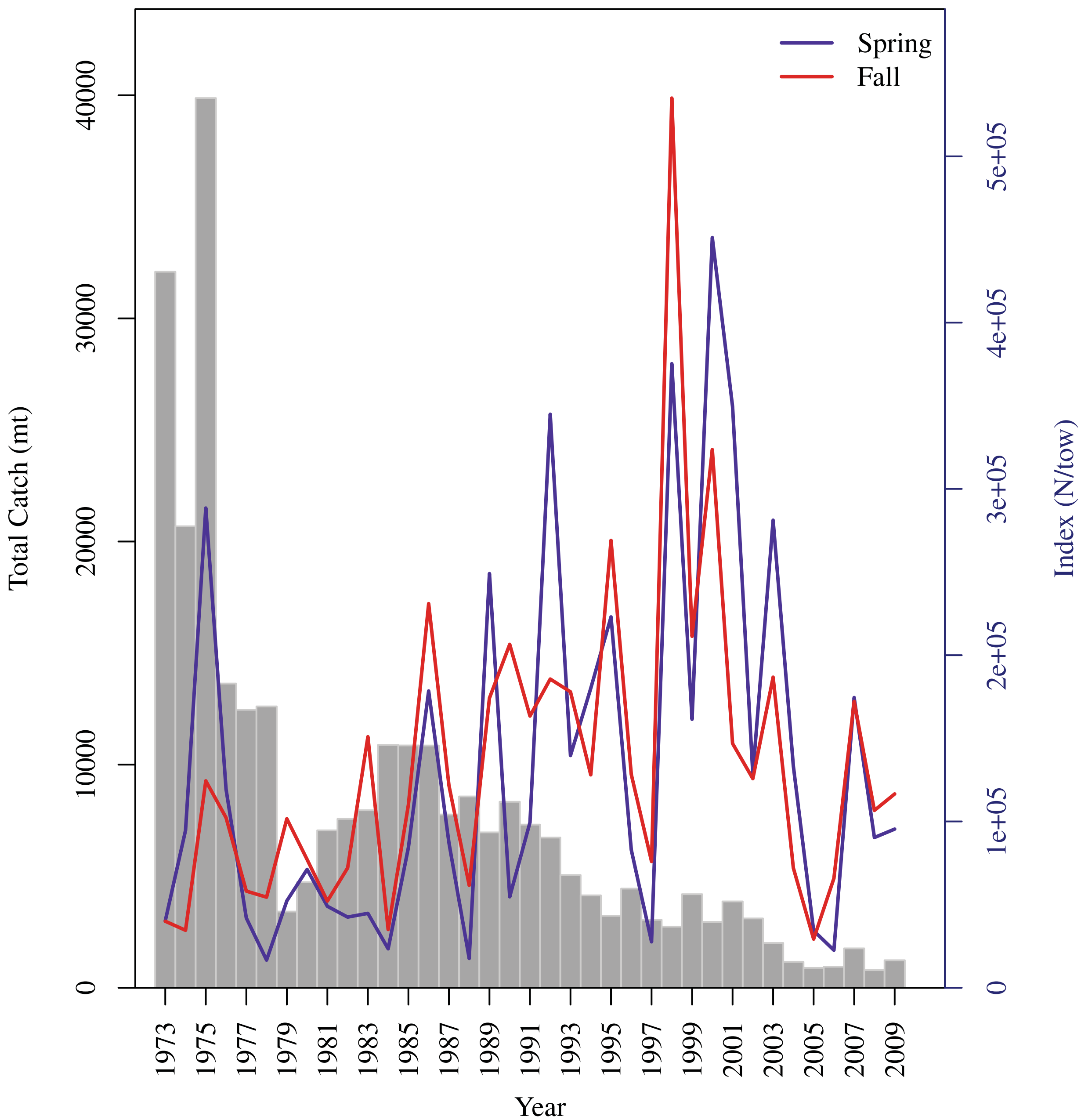

1
2
3
4
5
6
ASAP Estimated Proportion(NAA)
0.0
0.2
0.4
0.6
0.8
1.0
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

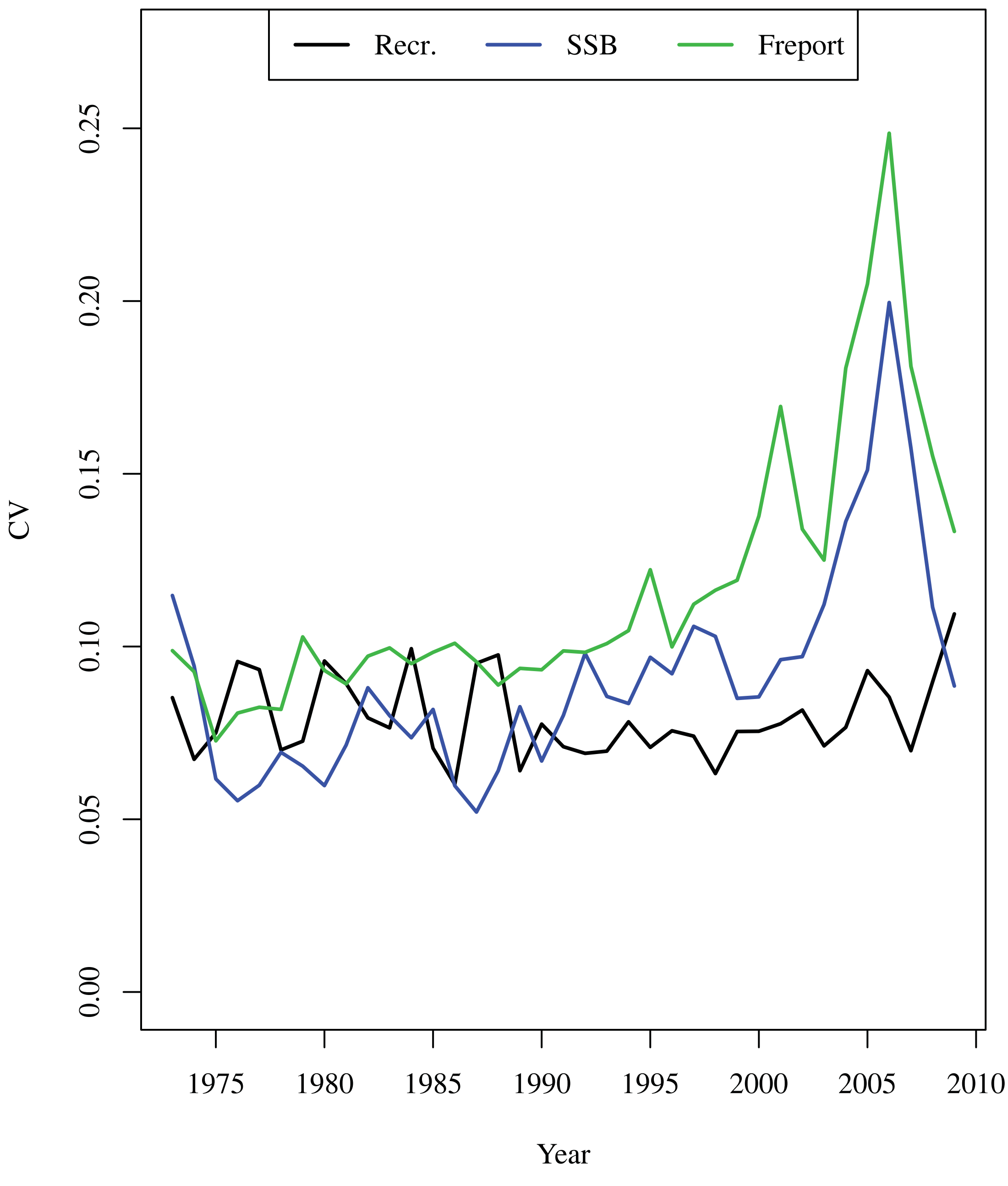


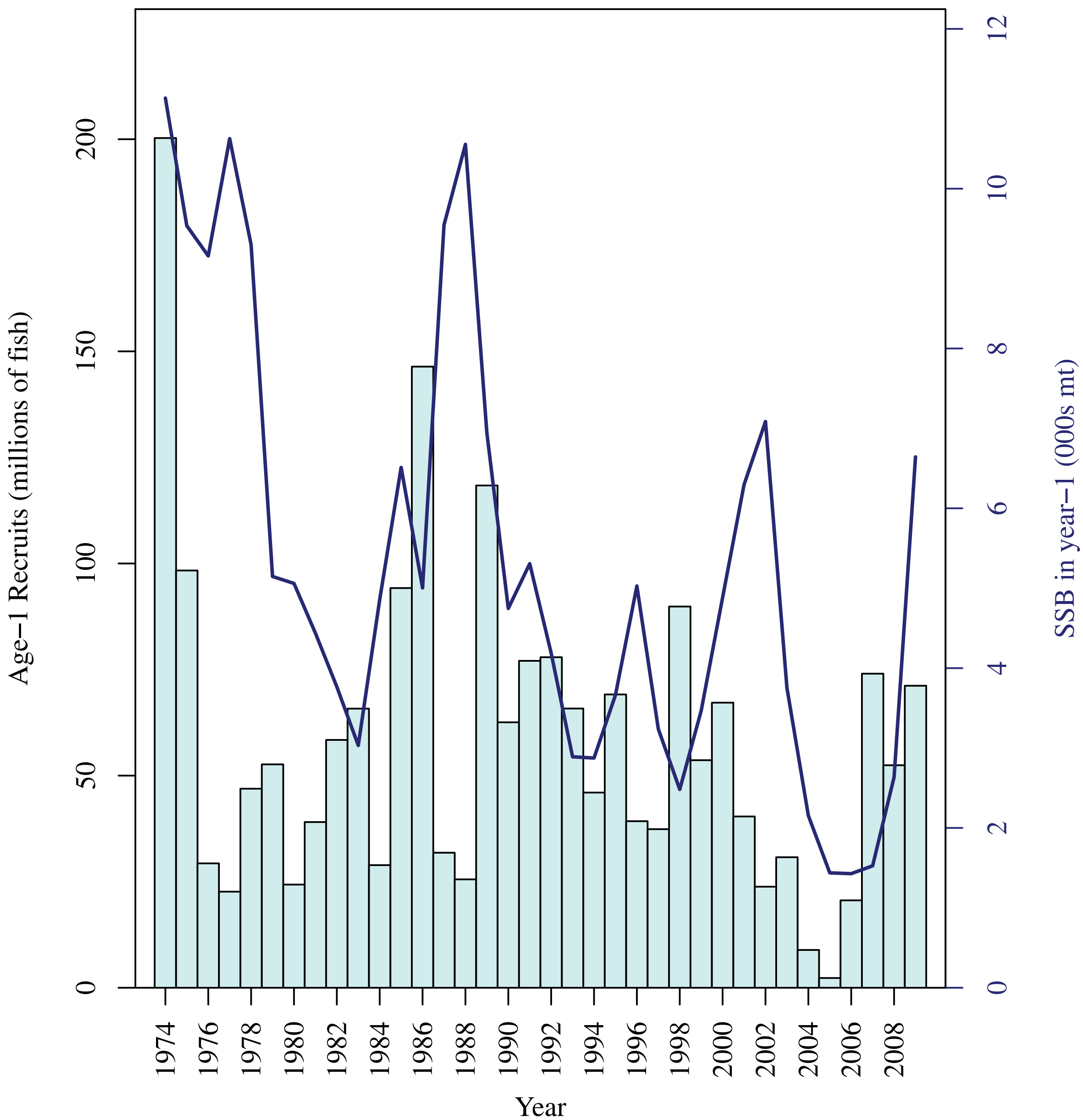
Fleet_1
Fleet_2
Observed Catch (mt)
0
10000
20000
30000
40000
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year


Fleet_1
Fleet_2
Observed Catch (proportion)
0.0
0.2
0.4
0.6
0.8
1.0
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year


Fleet_1
Fleet_2
1.5
1.0
0.5
0.0
Fmult by fleet
1975
1980
1985
1990
1995
2000
2005
2010
Year


Spring
Fall
Total Catch (mt)
Index (N/tow)
Year
0
10000
20000
30000
40000
0
1e+05
2e+05
3e+05
4e+05
5e+05
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009


Recr.
SSB
Freport
0.00
0.05
0.10
0.15
0.20
0.25
CV
1975
1980
1985
1990
1995
2000
2005
2010
Year


Age−1 Recruits (millions of fish)
SSB in year−1 (000s mt)
Year
0
50
100
150
200
0
2
4
6
8
10
12
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008

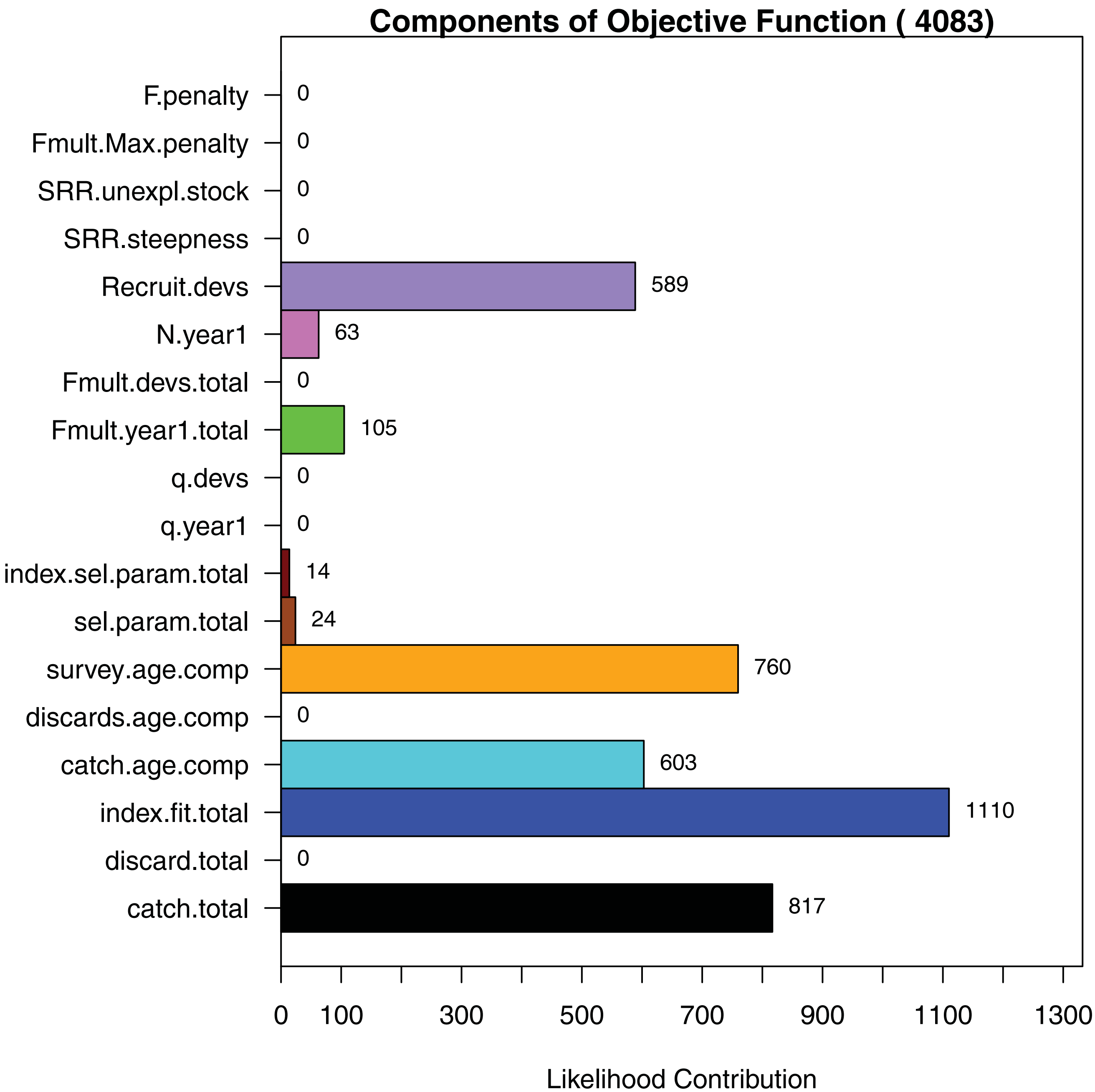
Appendix A5: North Model Consumption ASAP results M = 0.15_Base run

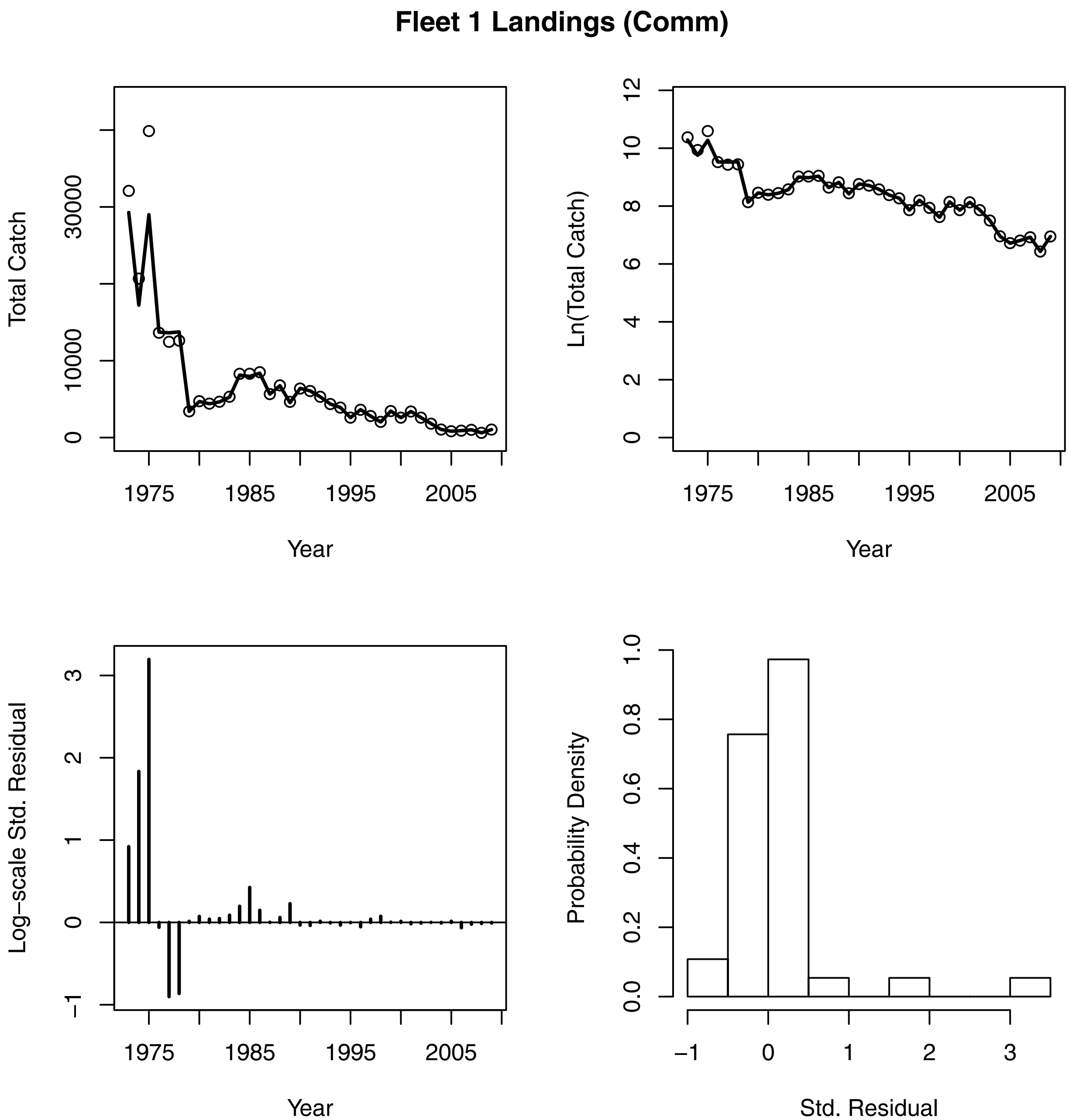
Model Attributes:

1. 3 Fleet Model
    a. Catch : 1973-2009
    b. Discards: 1981 – 2009
    c. Consumption – 1973-2009

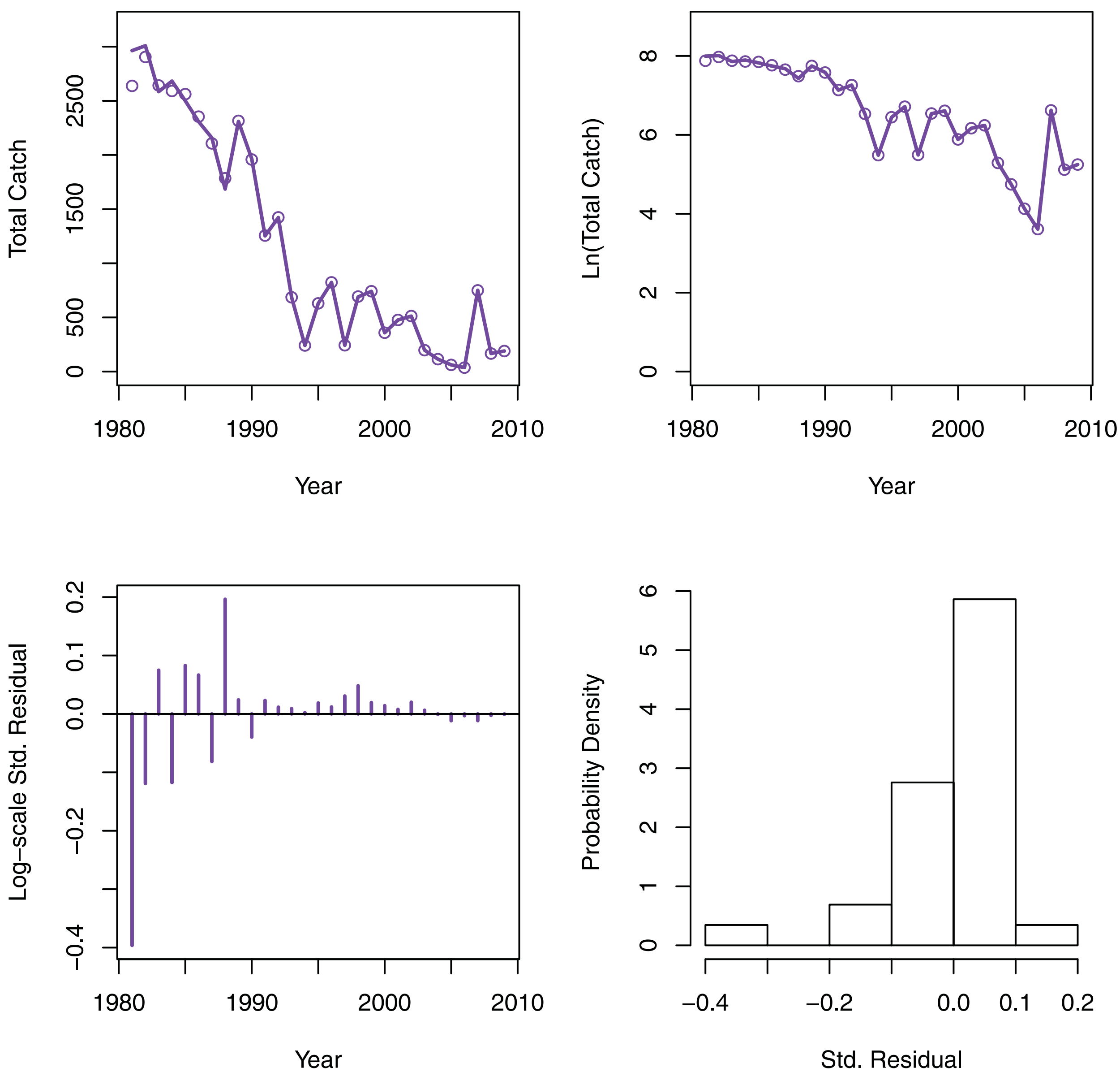
2. Fishery Selectivity (3 Block Selectivity)
    a. Landings (1 Blocks: 1973-2009)
    b. Discards (1 Block: 1981-2009)
    c. Consumption (Double Logistic Functional Form)

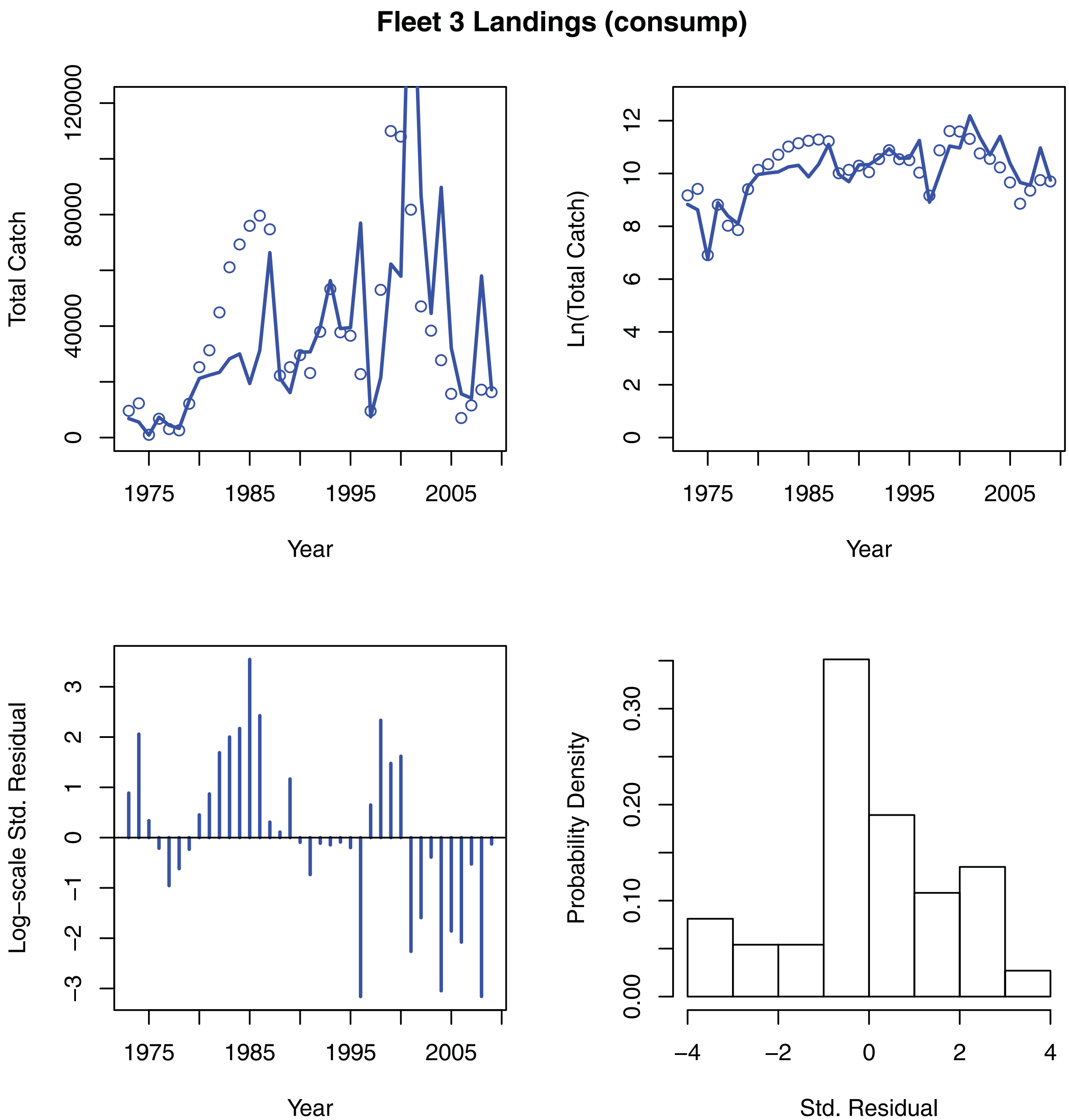
3. Survey Selectivity (Fixed 100% at age 2 and freely estimating older ages (3+)

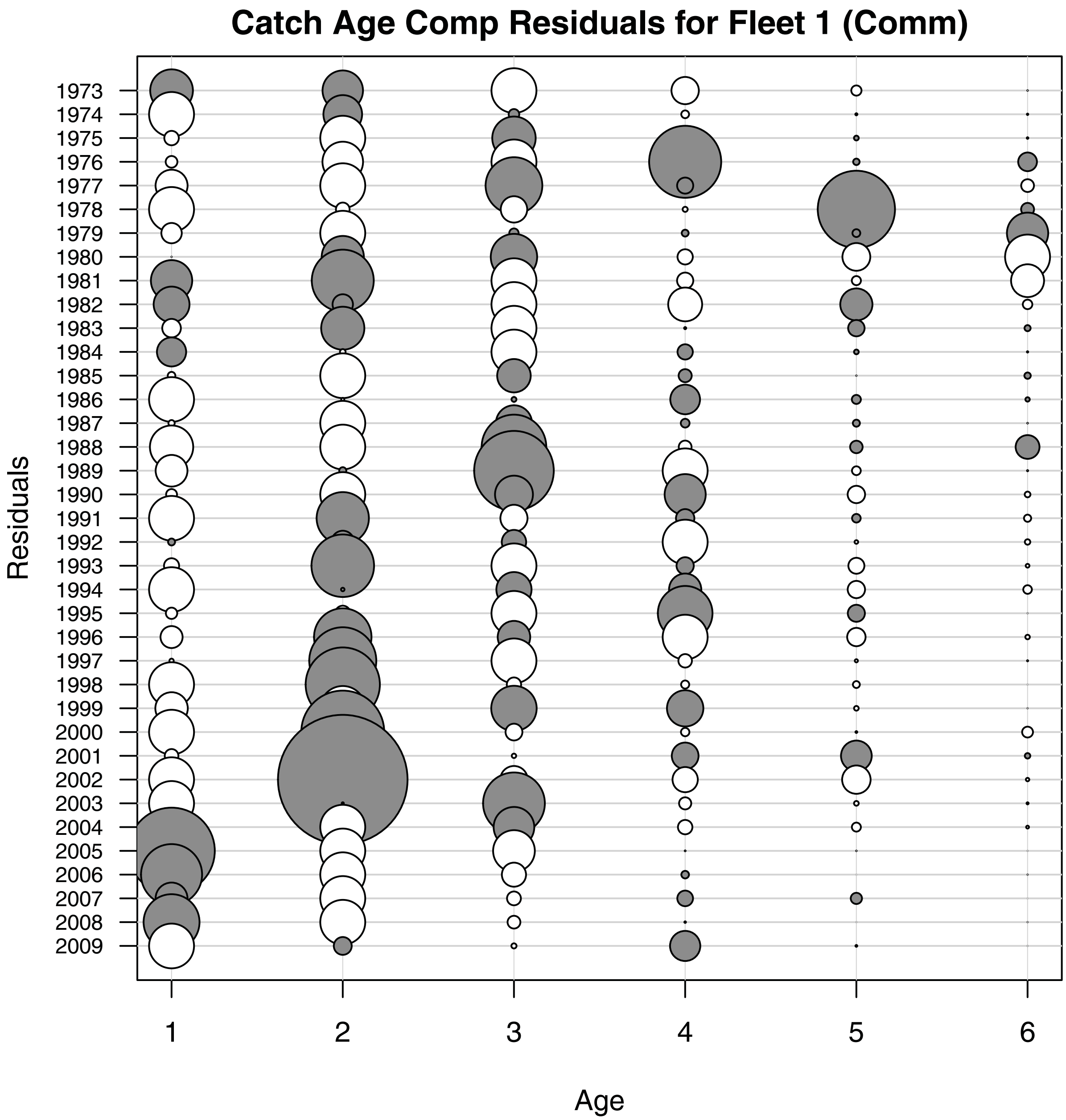

Components of Objective Function (4083)
F.penalty
Fmult.Max.penalty
SRR.unexpl.stock
SRR.steepness
Recruit.devs
N.year1
Fmult.devs.total
Fmult.year1.total
q.devs
q.year1
index.sel.param.total
sel.param.total
survey.age.comp
discards.age.comp
catch.age.comp
index.fit.total
discard.total
catch.total
0
0
0
0
589
63
0
105
0
0
14
24
760
0
603
1110
0
817
0
100
300
500
700
900
1100
1300
Likelihood Contribution

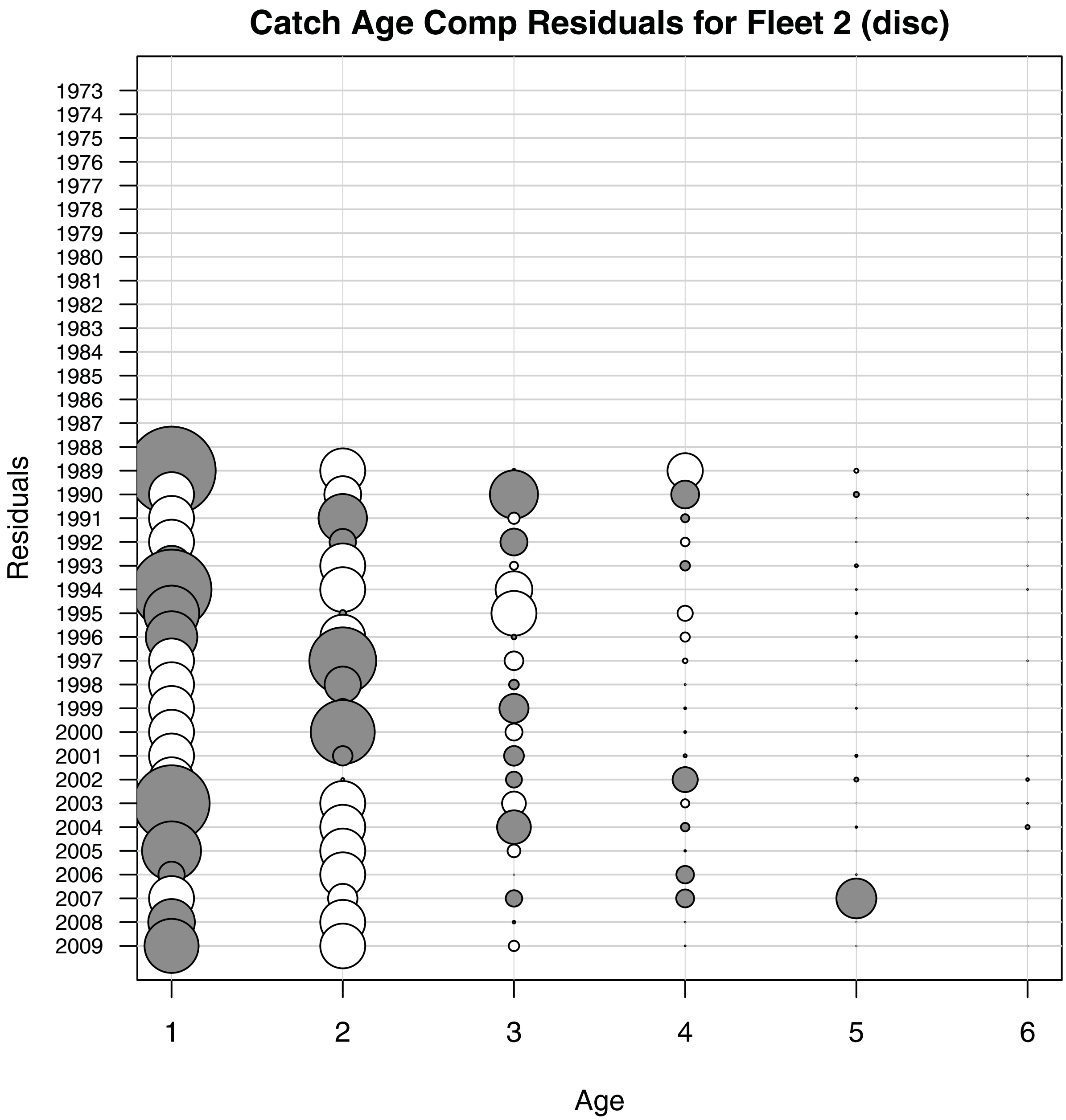

Fleet 1 Landings (Comm)
Total Catch
0
10000
30000
1975
1985
1995
2005
Year
Ln(Total Catch)
0
2
4
6
8
10
12
Log−scale Std. Residual
−1
0
1
2
3
Probability Density
0.0
0.2
0.4
0.6
0.8
1.0
−1
0
1
2
3
Std. Residual

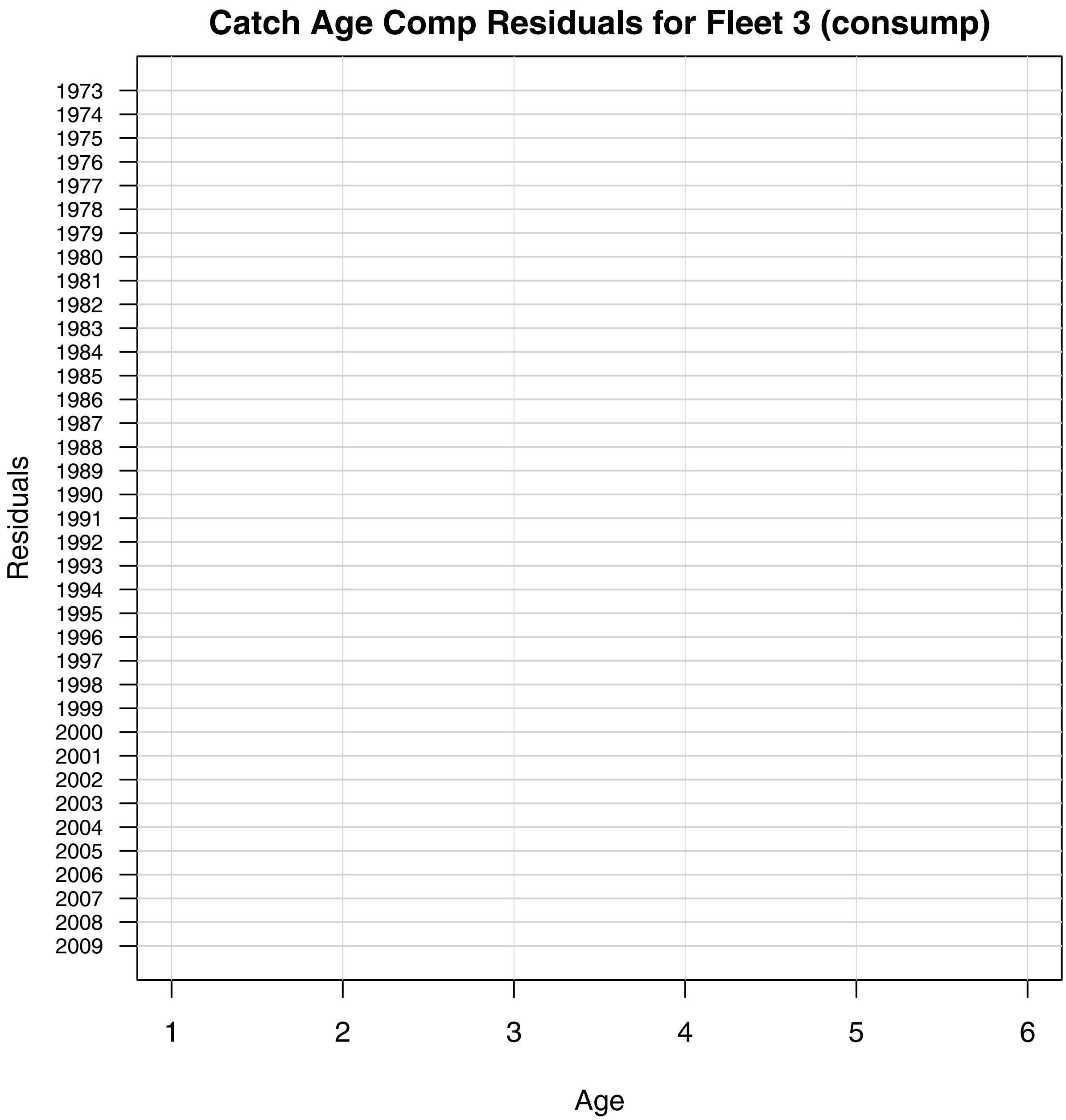
Fleet 2 Landings (disc)

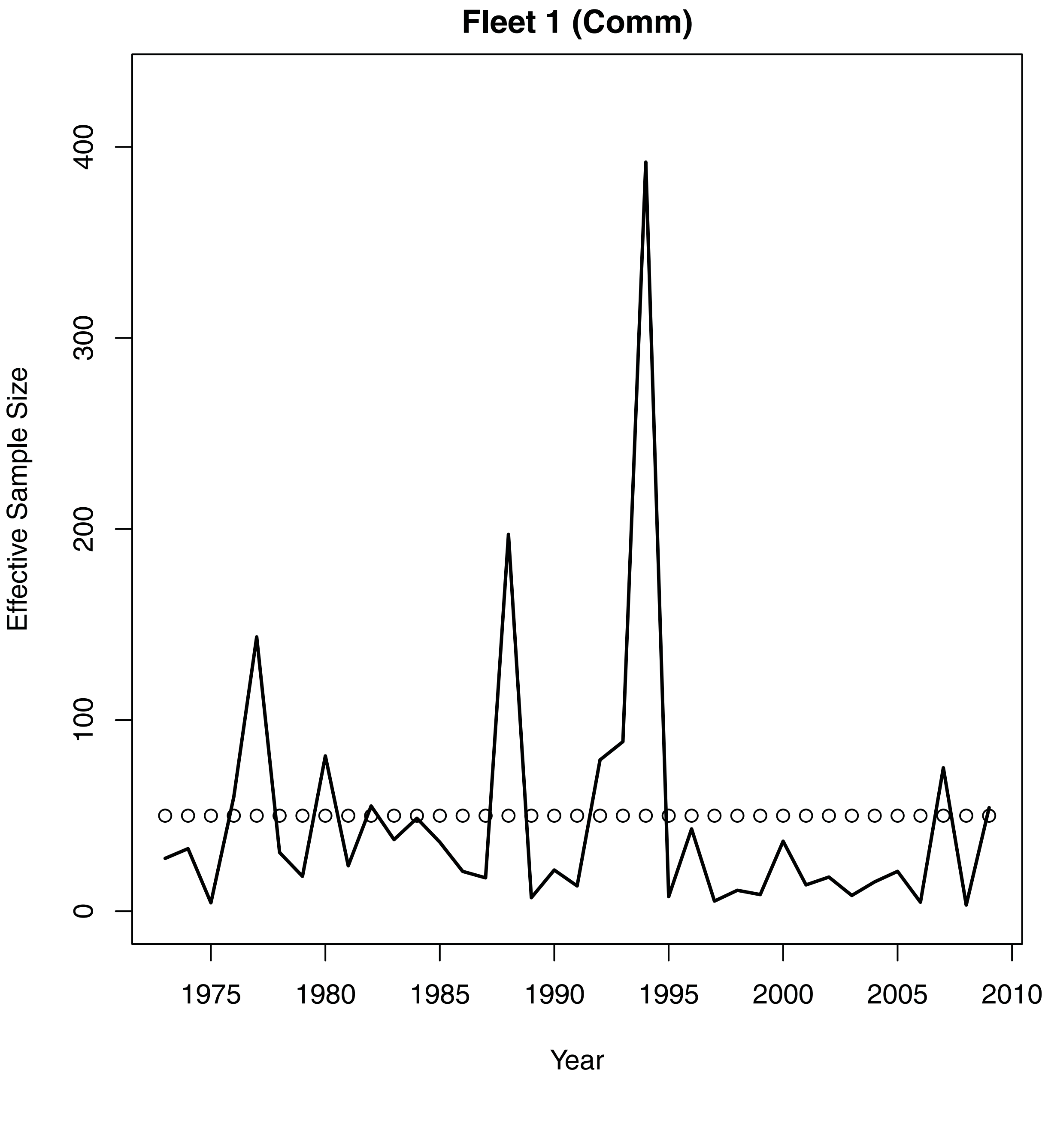


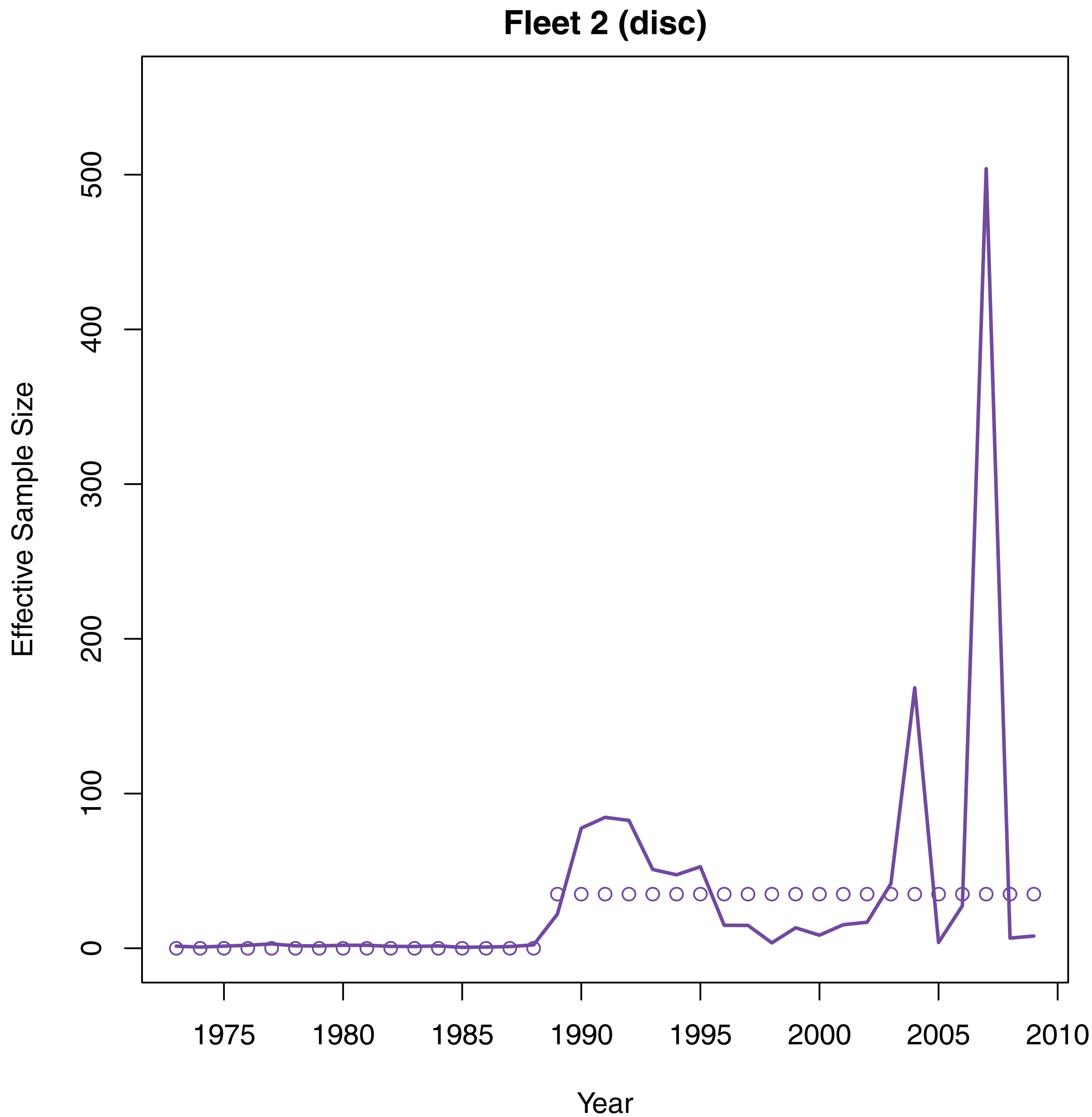

Fleet 3 Landings (consump)
Total Catch
0
40000
80000
120000
1975
1985
1995
2005
Year
Ln(Total Catch)
0
2
4
6
8
10
12
Log−scale Std. Residual
−3
−2
−1
0
1
2
3
Probability Density
0.00
0.10
0.20
0.30
−4
−2
0
2
4
Std. Residual

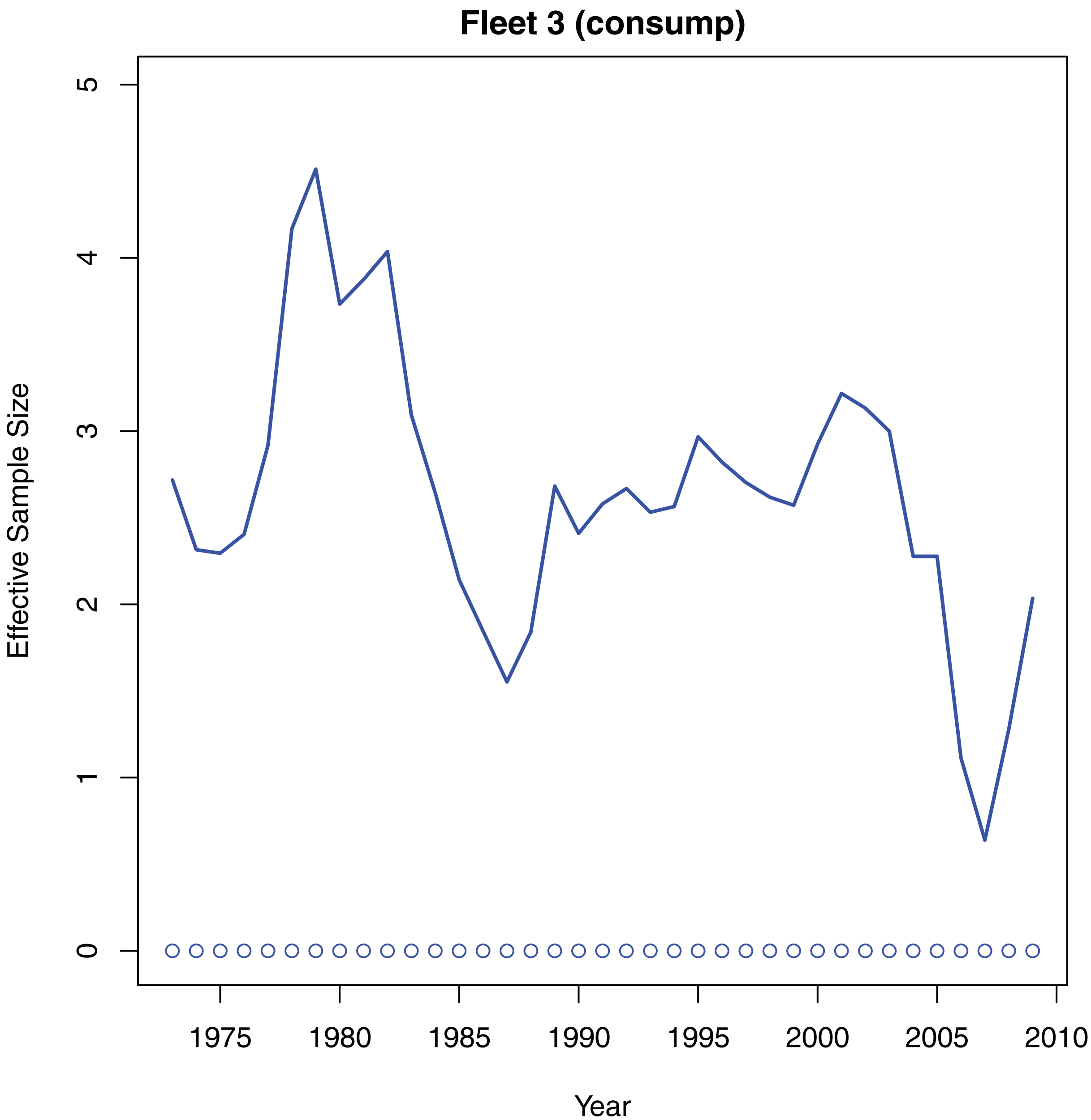

Catch Age Comp Residuals for Fleet 1 (Comm)
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age

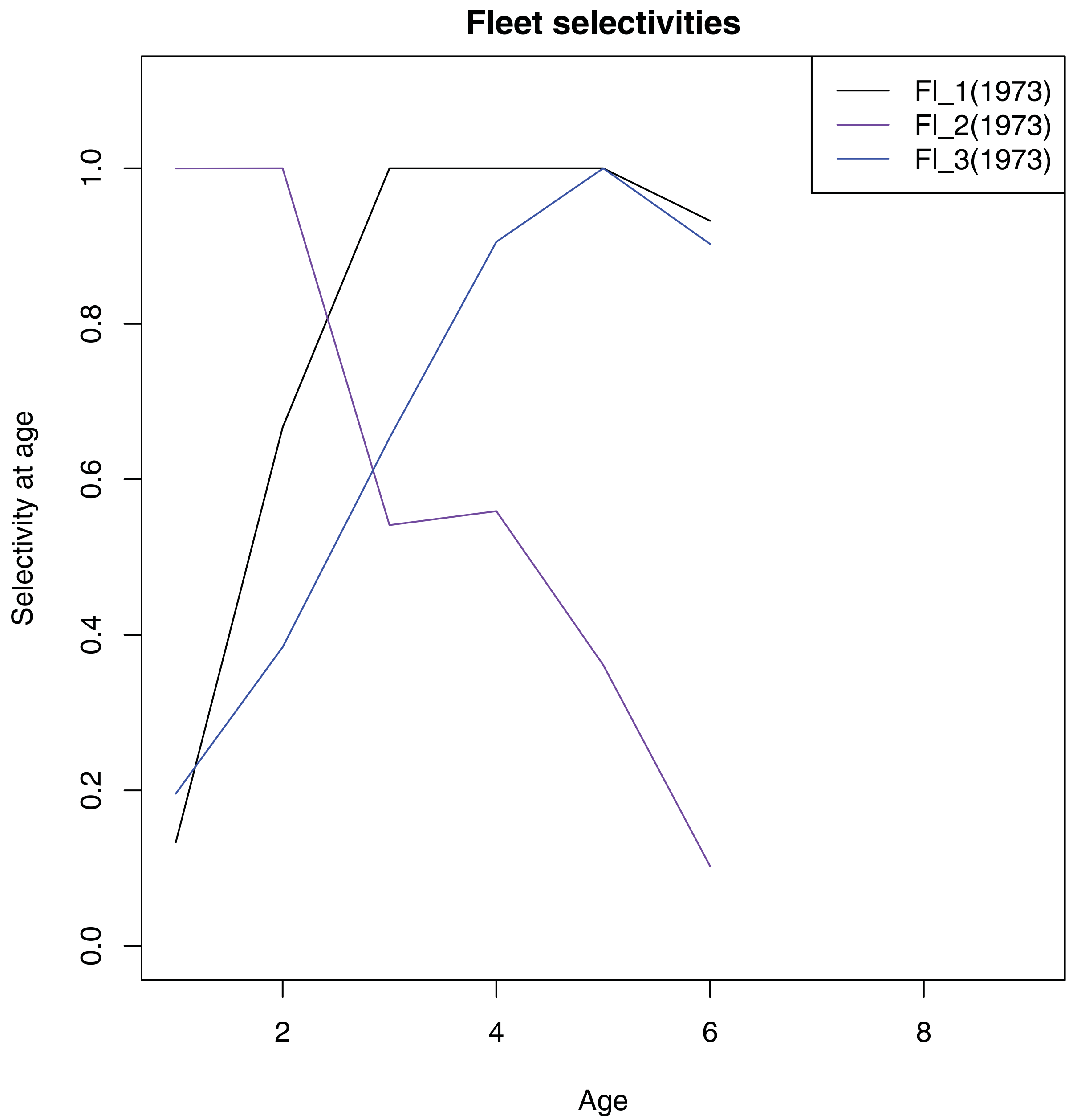

Catch Age Comp Residuals for Fleet 2 (disc)
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age


Catch Age Comp Residuals for Fleet 3 (consump)
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age


Fleet 1 (Comm)
Effective Sample Size
0
100
200
300
400
1975
1980
1985
1990
1995
2000
2005
2010
Year

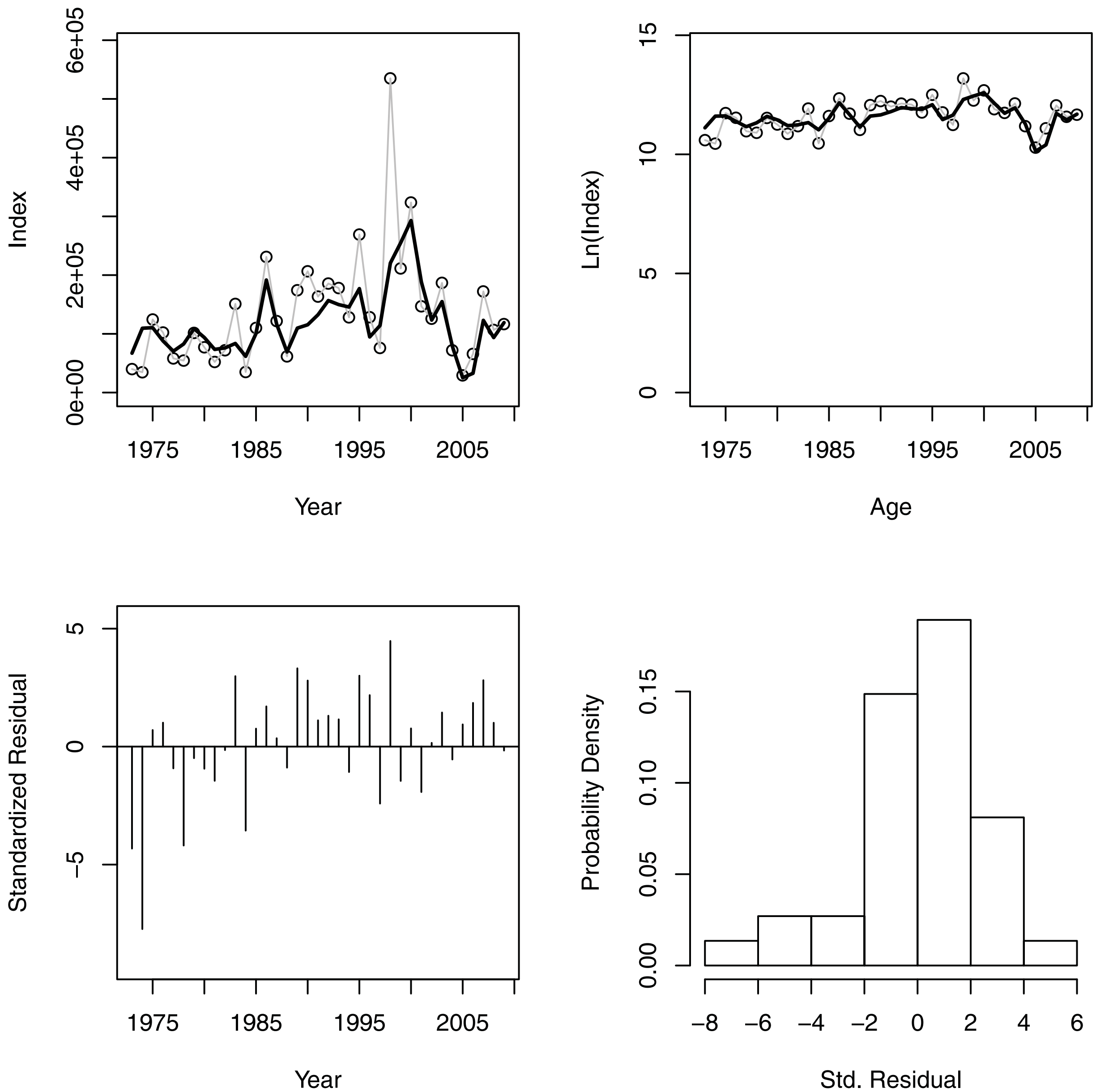

Fleet 2 (disc)
Effective Sample Size
0
100
200
300
400
500
1975
1980
1985
1990
1995
2000
2005
2010
Year

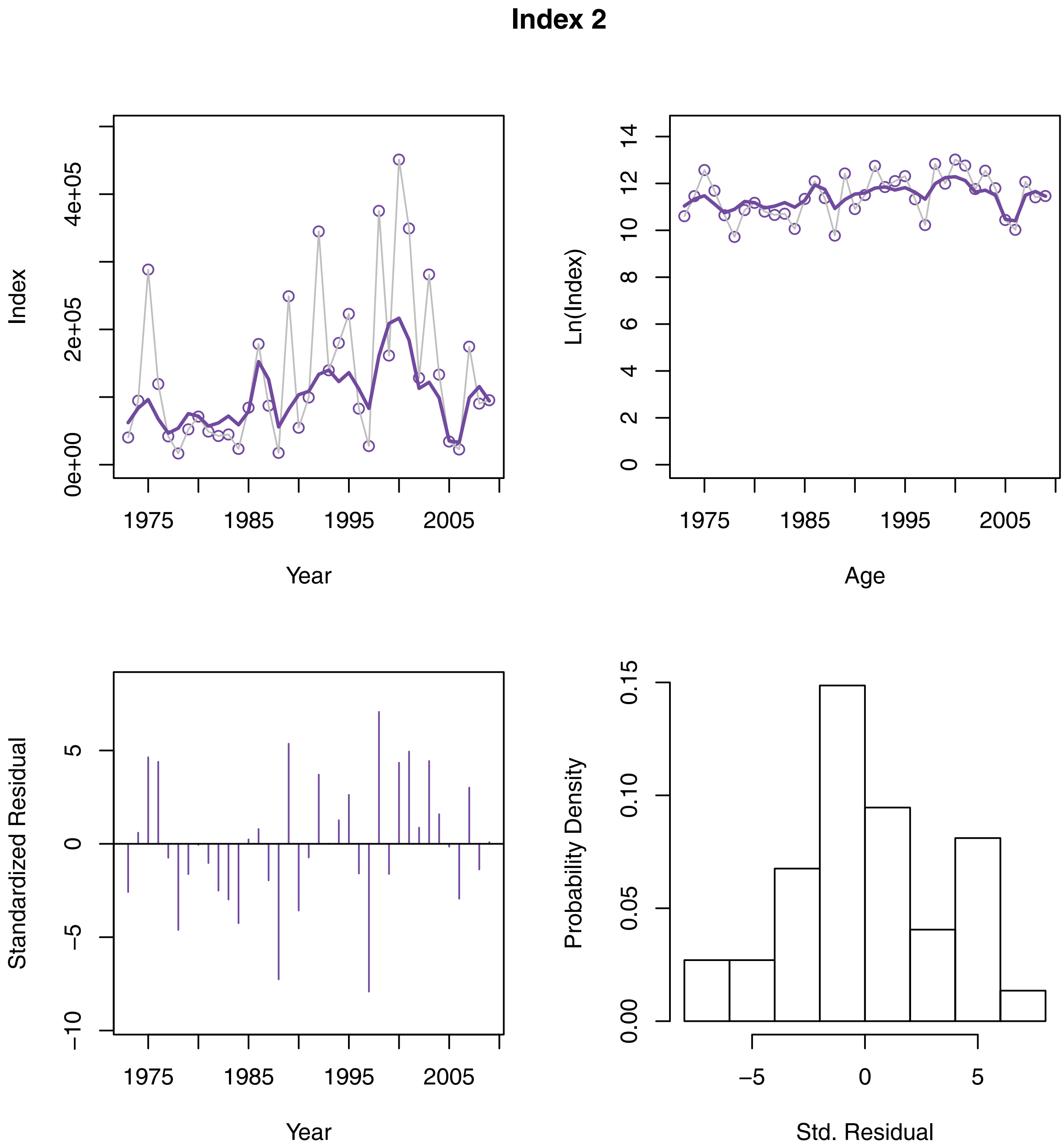

Fleet 3 (consump)
Effective Sample Size
Year
0
1
2
3
4
5
1975
1980
1985
1990
1995
2000
2005
2010

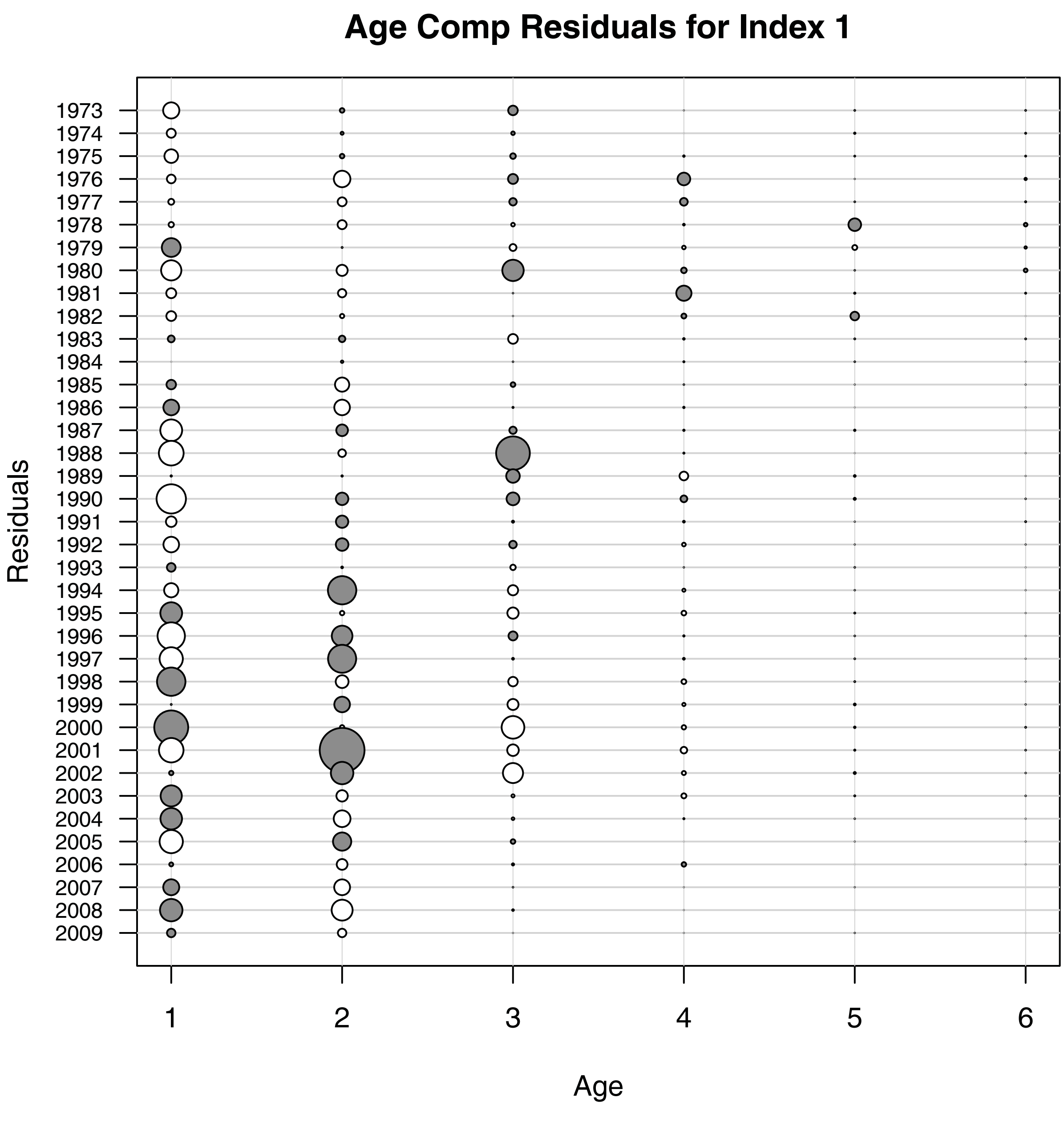


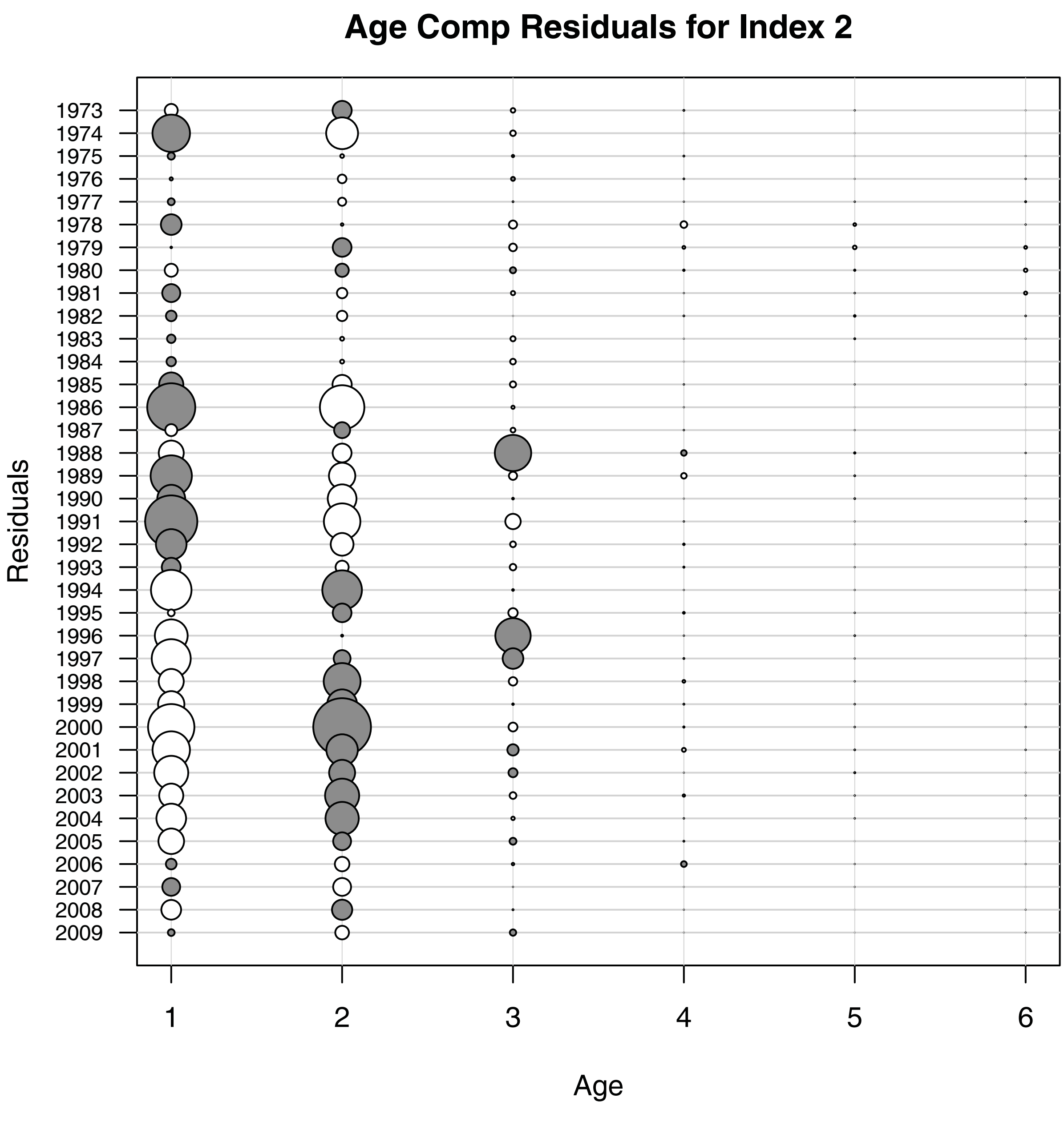
Fleet selectivities
Fl_1(1973)
Fl_2(1973)
Fl_3(1973)
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
Age

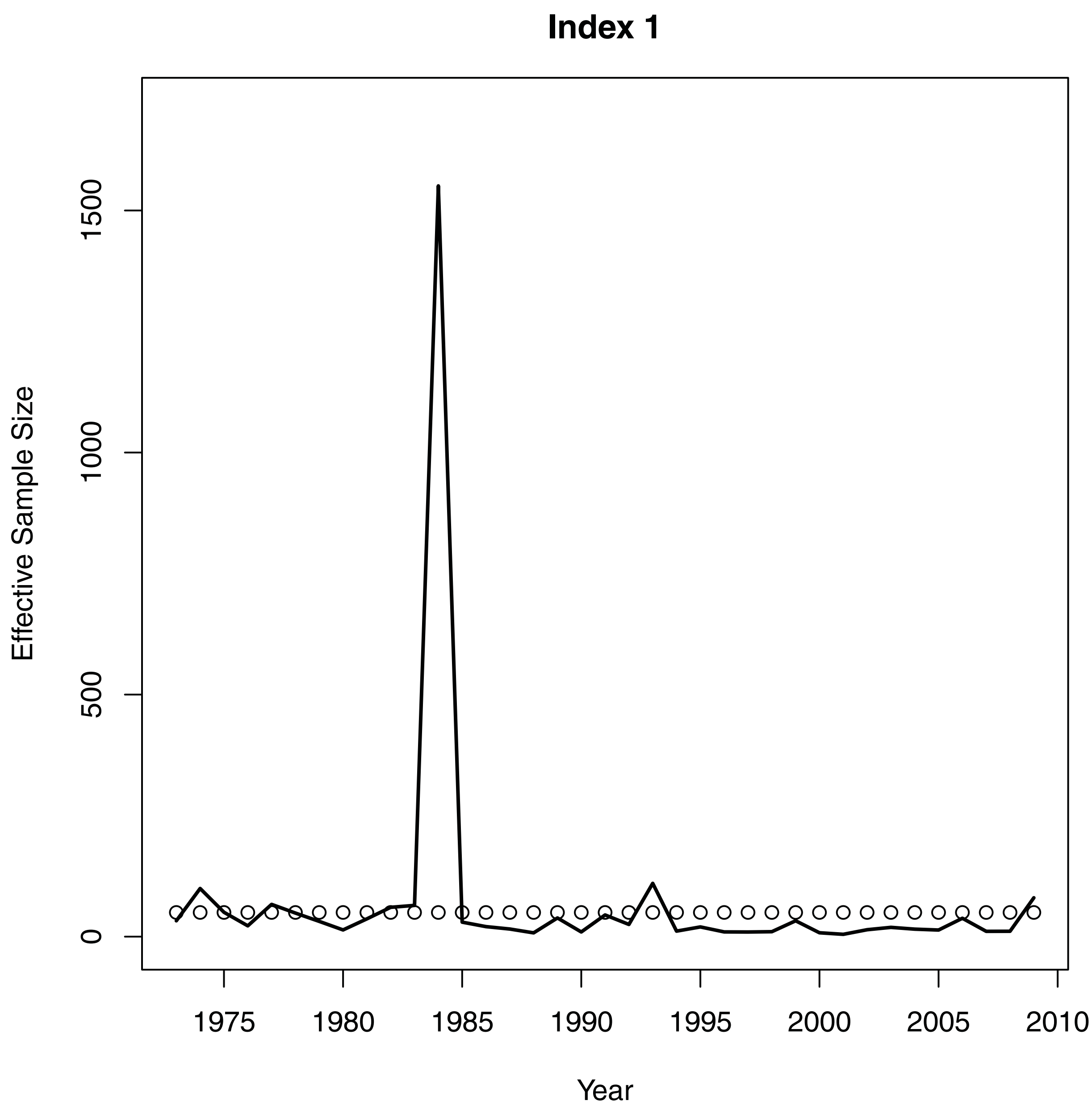
Index 1

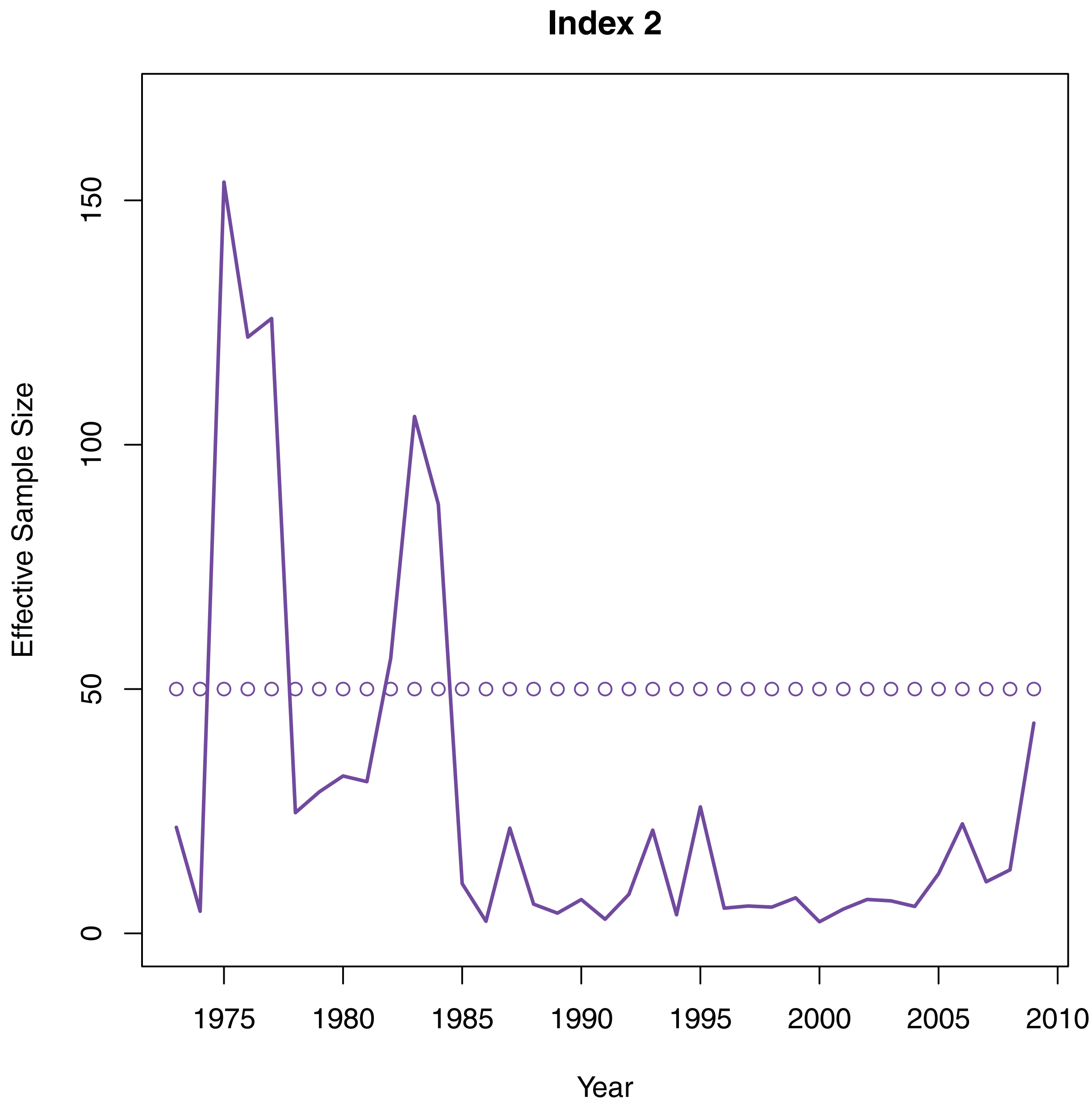

Index
0e+00
2e+05
4e+05
6e+05
1975
1985
1995
2005
Year
Ln(Index)
0
5
10
15
Age
Standardized Residual
−5
Probability Density
0.00
0.05
0.10
0.15
−8
−6
−4
−2
2
4
6
Std. Residual

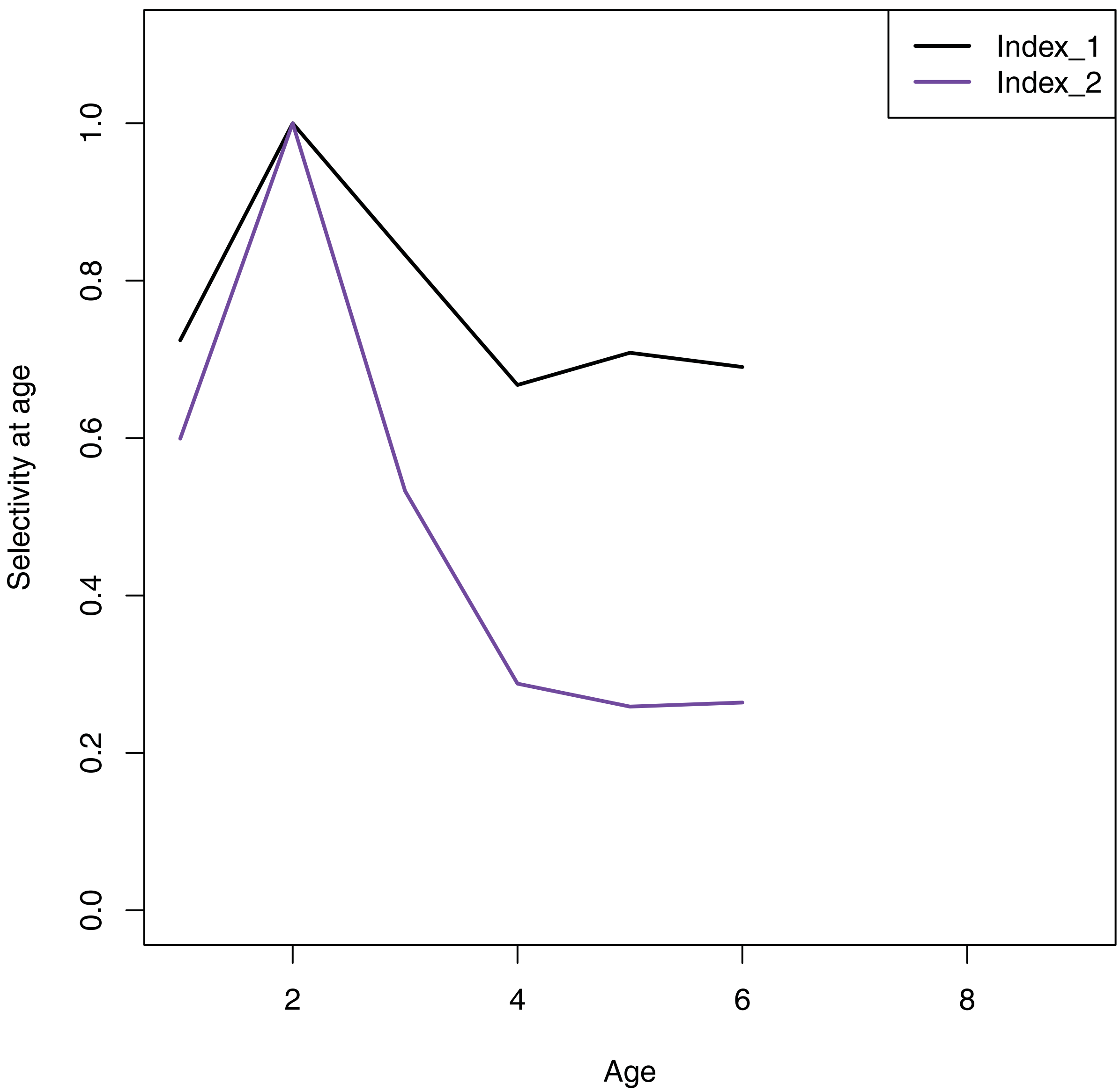

Index 2
Index
0e+00
2e+05
4e+05
1975
1985
1995
2005
Year
Ln(Index)
0
2
4
6
8
10
12
14
Age
Standardized Residual
−10
−5
0
5
Probability Density
0.00
0.05
0.10
0.15
−5
Std. Residual

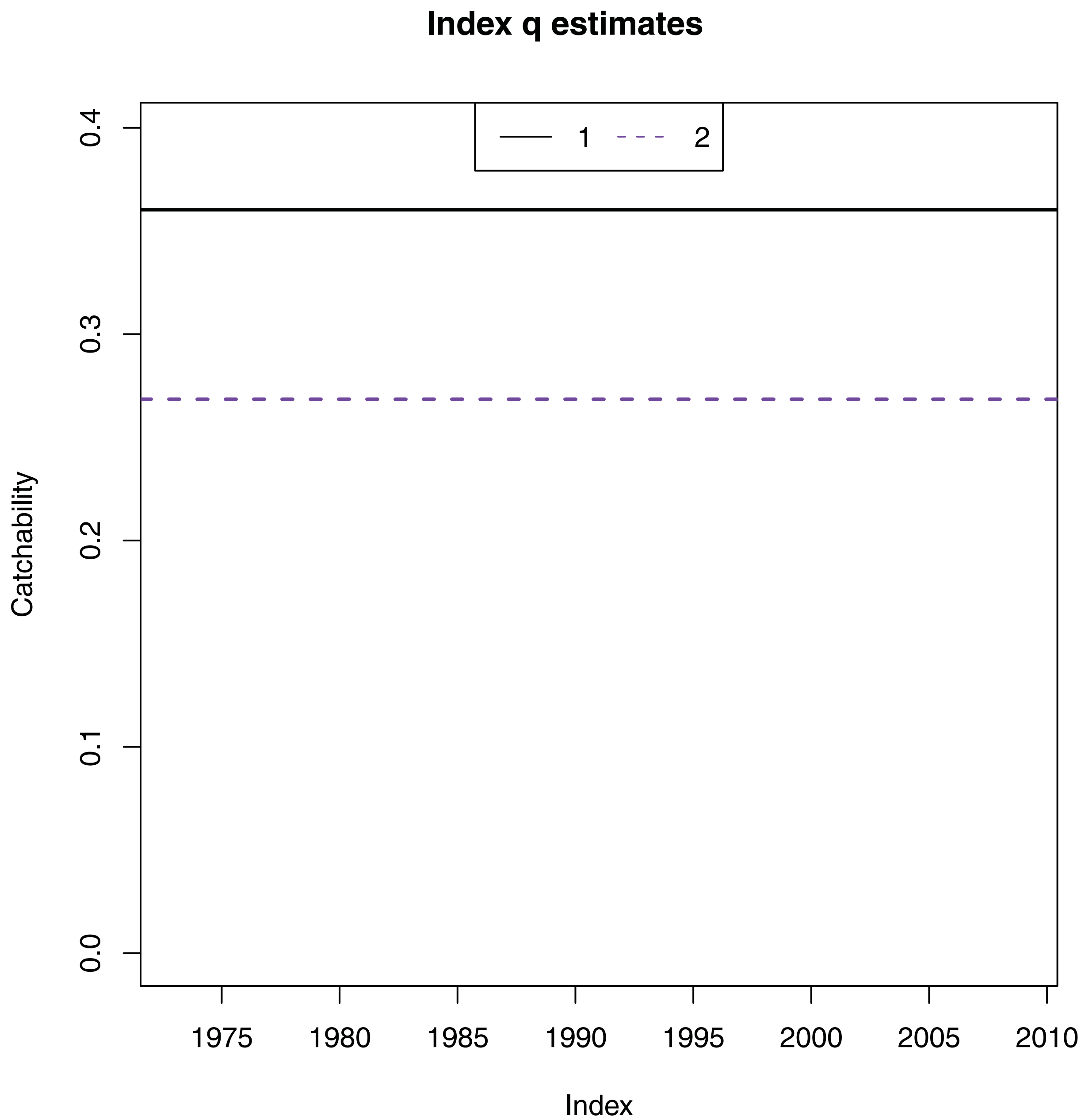

Age Comp Residuals for Index 1
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age

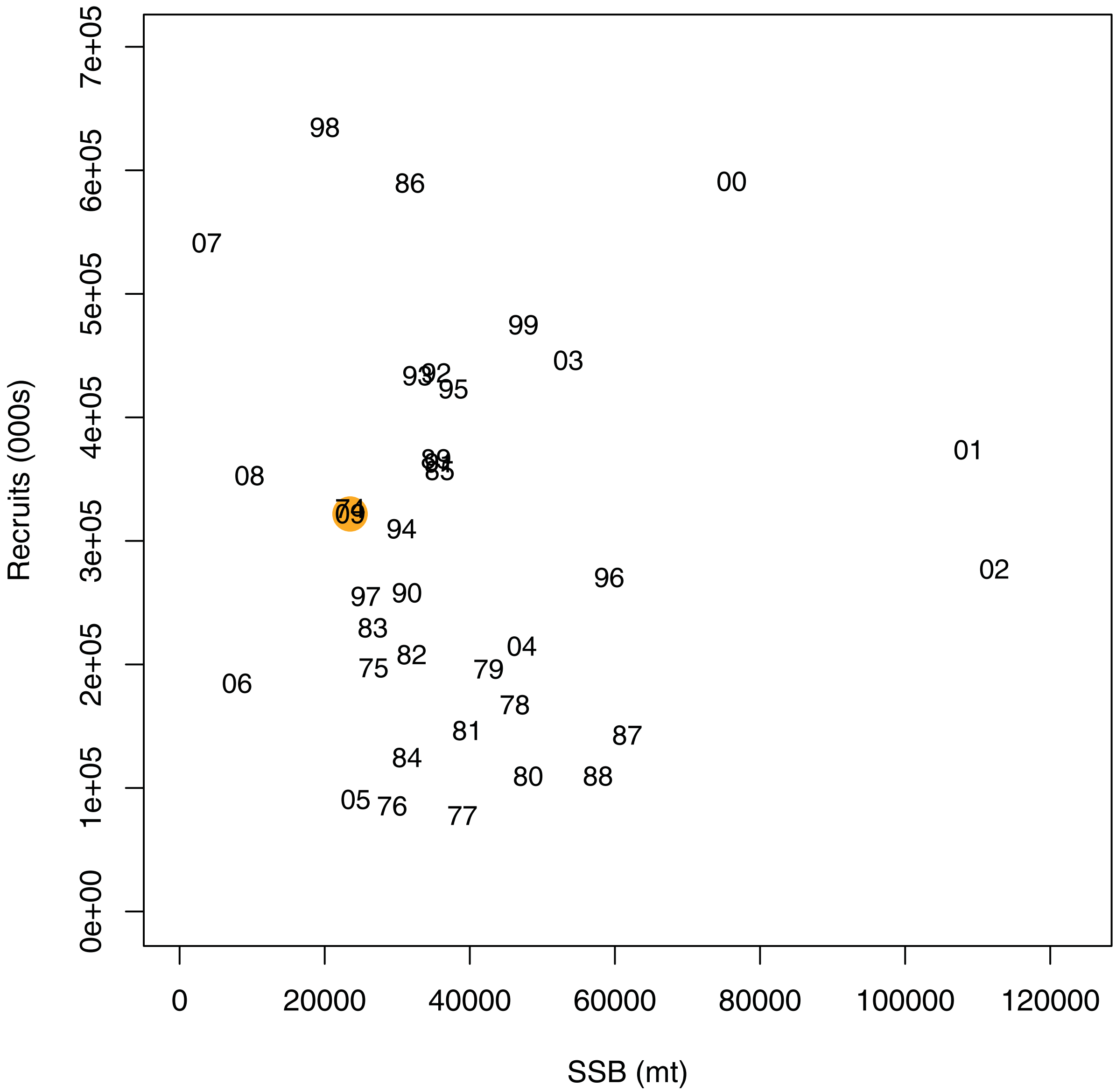

Age Comp Residuals for Index 2
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age


Index 1
Effective Sample Size
0
500
1000
1500
1975
1980
1985
1990
1995
2000
2005
2010
Year

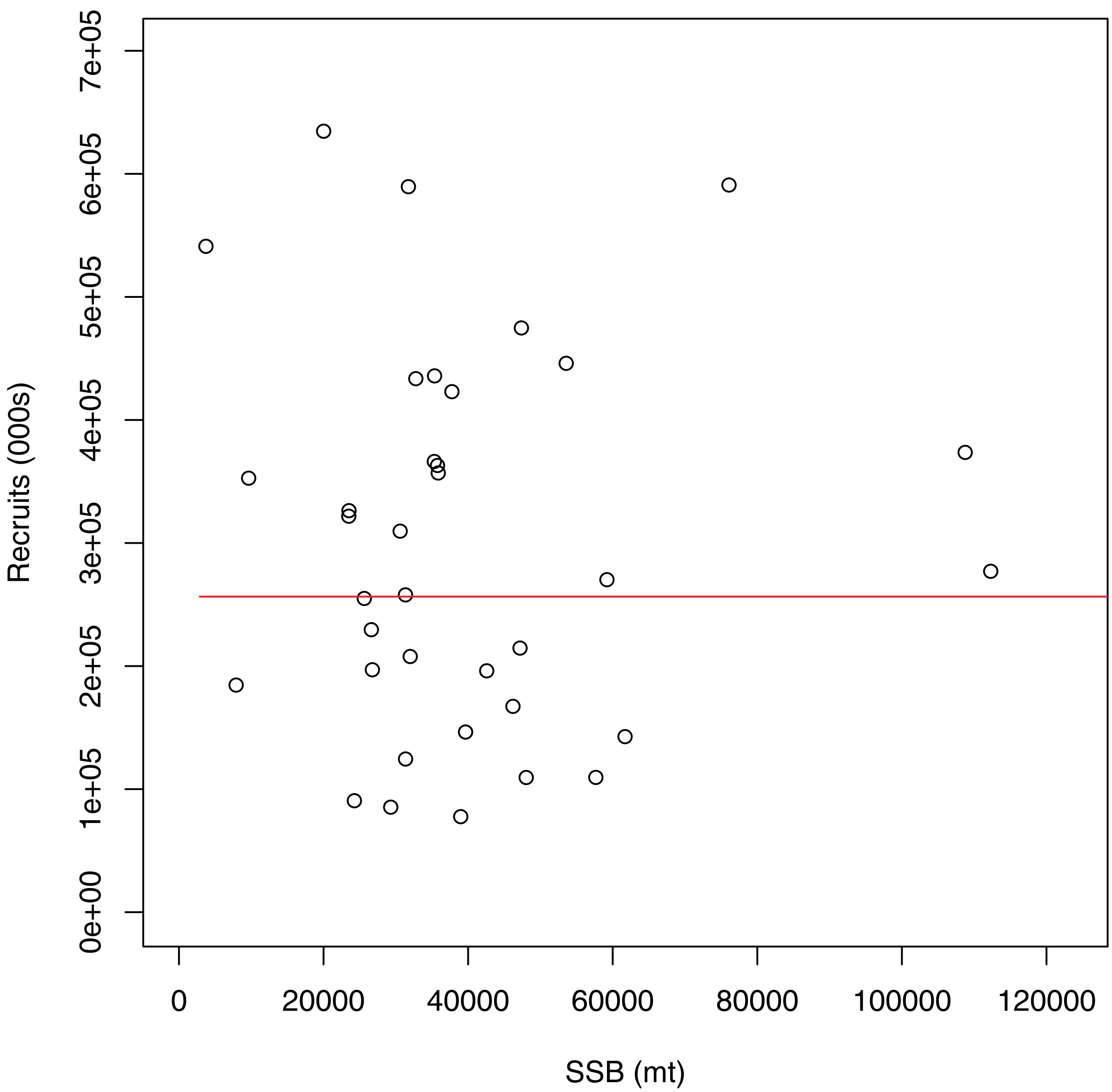

Index 2
Effective Sample Size
0
50
100
150
1975
1980
1985
1990
1995
2000
2005
2010
Year

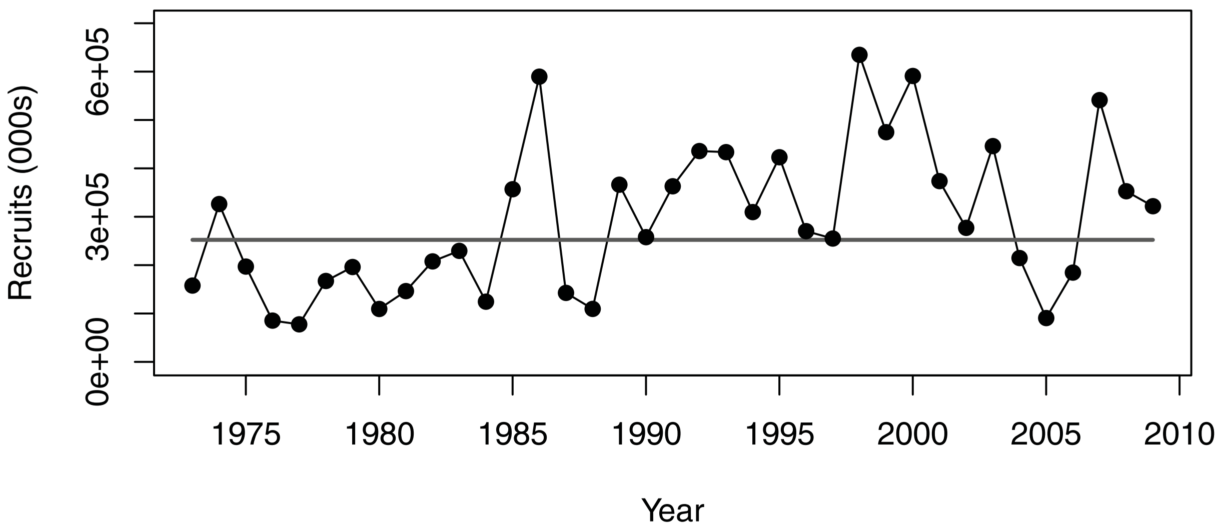

Index_1
Index_2
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
Age

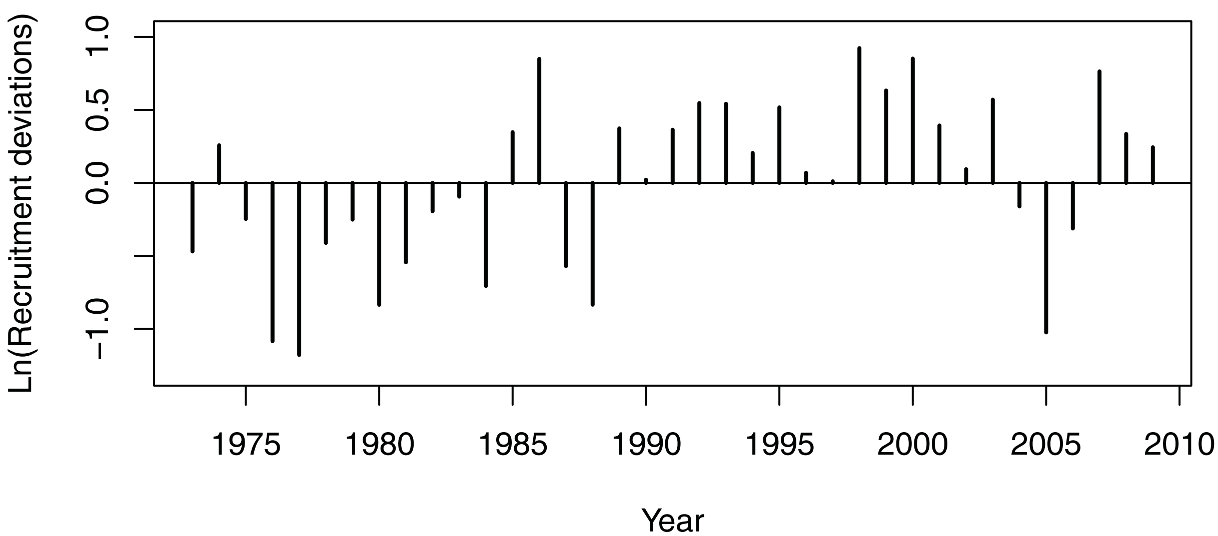

Index q estimates
1
2
Catchability
0.0
0.1
0.2
0.3
0.4
1975
1980
1985
1990
1995
2000
2005
2010
Index

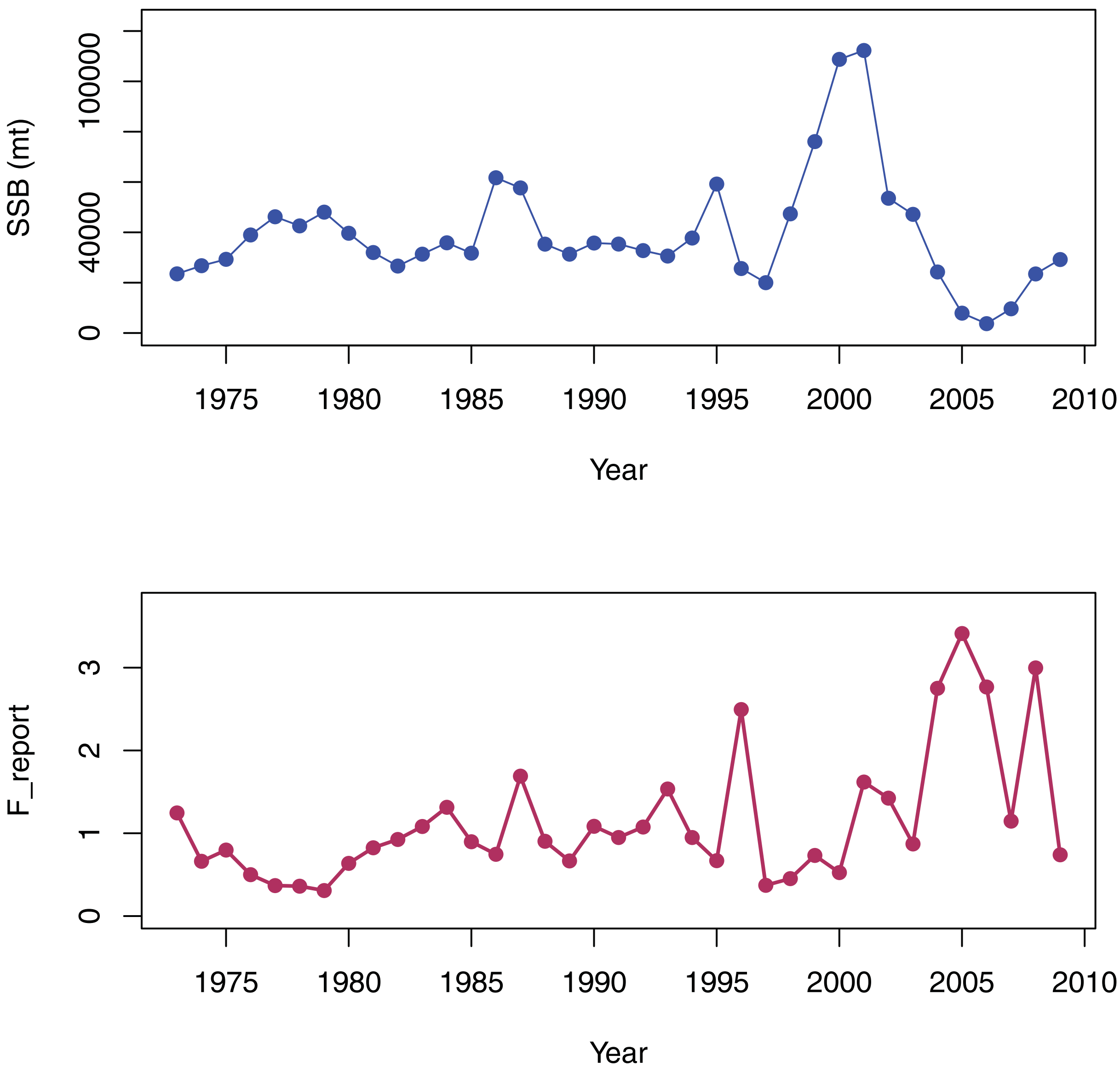


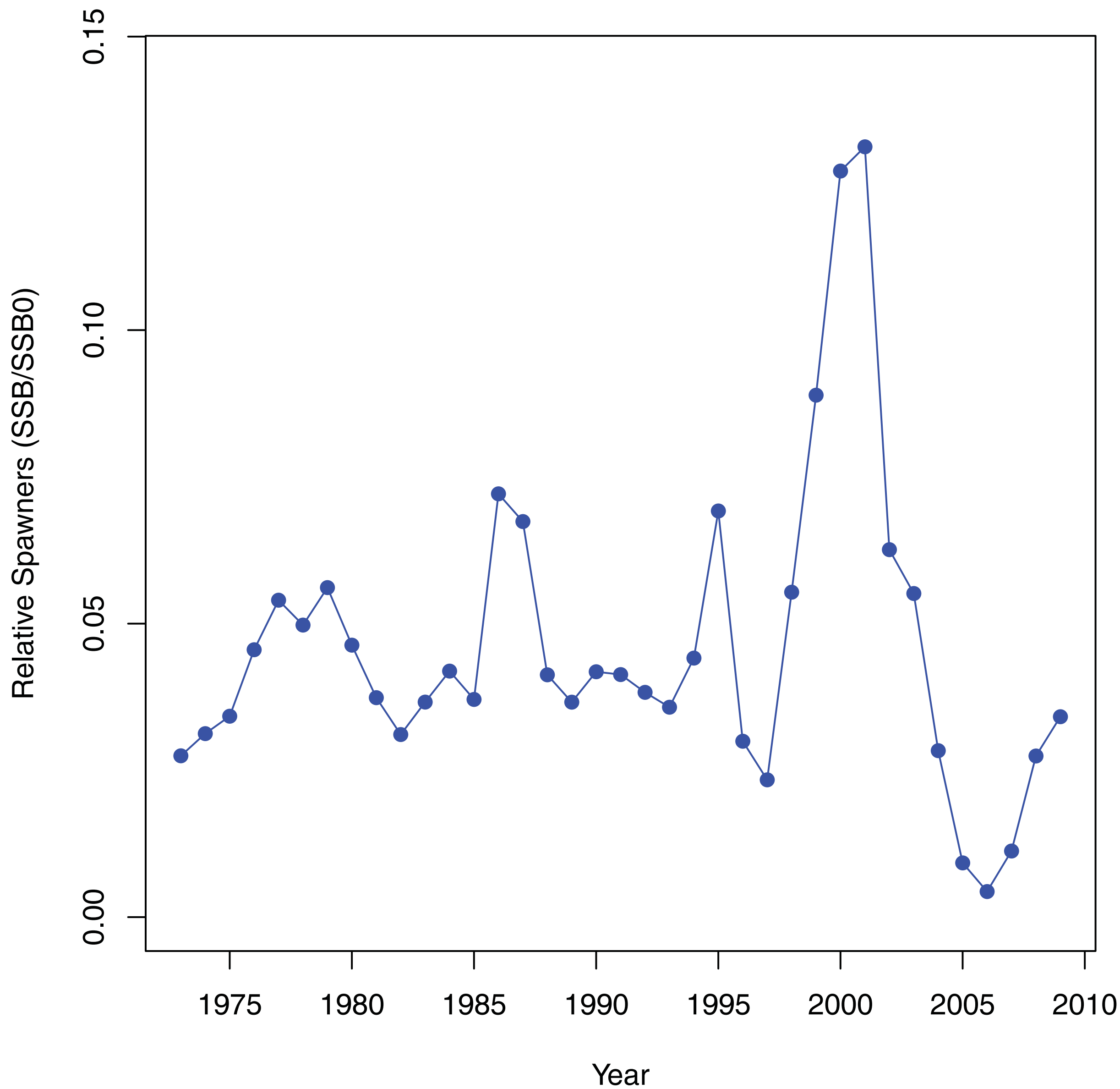
Recruits (000s)
0e+00
1e+05
2e+05
3e+05
4e+05
5e+05
6e+05
7e+05
0
20000
40000
60000
80000
100000
120000
SSB (mt)
98
86
00
07
99
03
93
92
95
01
08
94
96
02
97
90
83
04
82
75
79
06
78
81
87
84
80
88
05
76
77

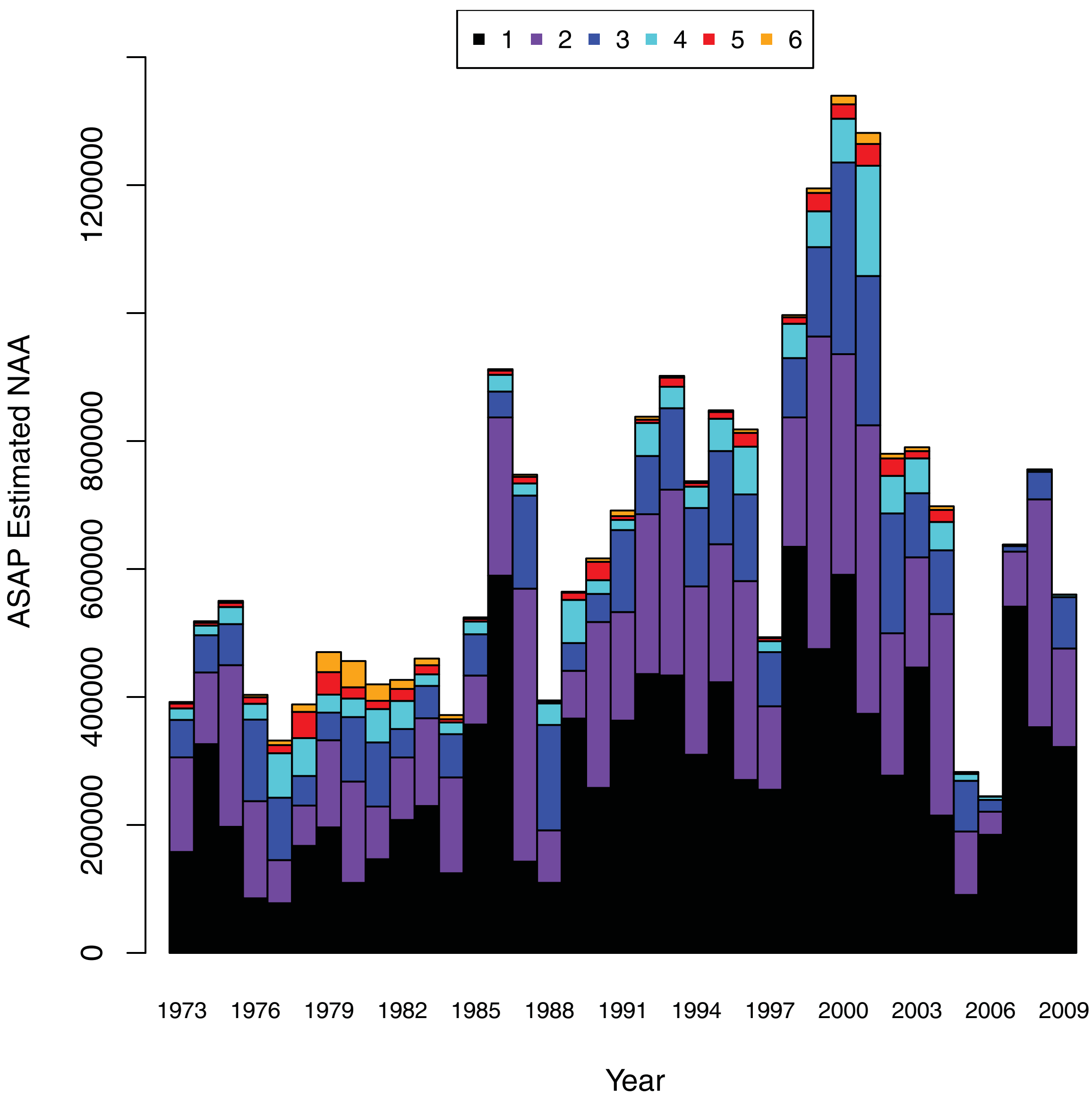

Recruits (000s)
0e+00
1e+05
2e+05
3e+05
4e+05
5e+05
6e+05
7e+05
0
20000
40000
60000
80000
100000
120000
SSB (mt)

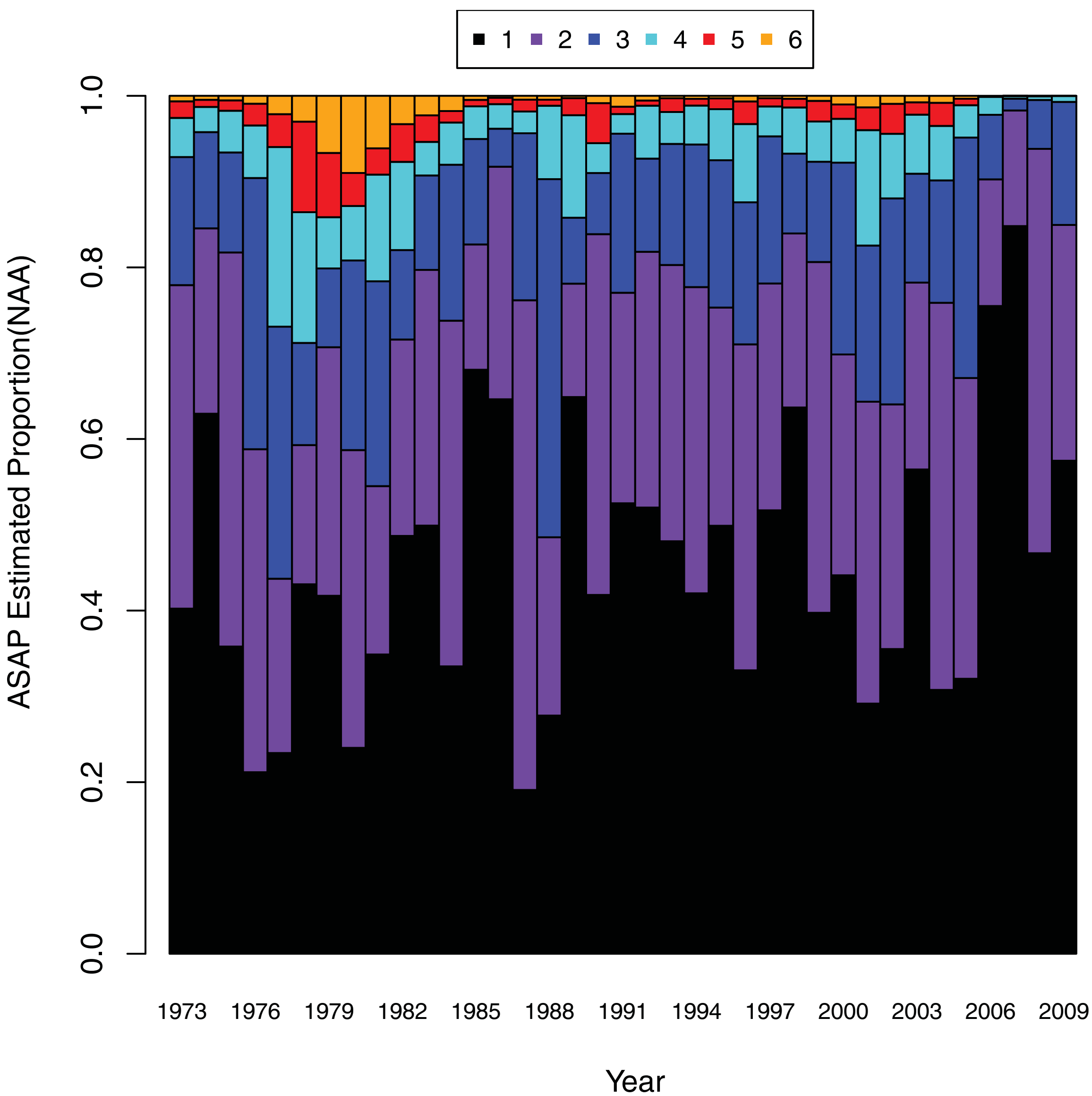

Recruits (000s)
0e+00
3e+05
6e+05
1975
1980
1985
1990
1995
2000
2005
2010
Year

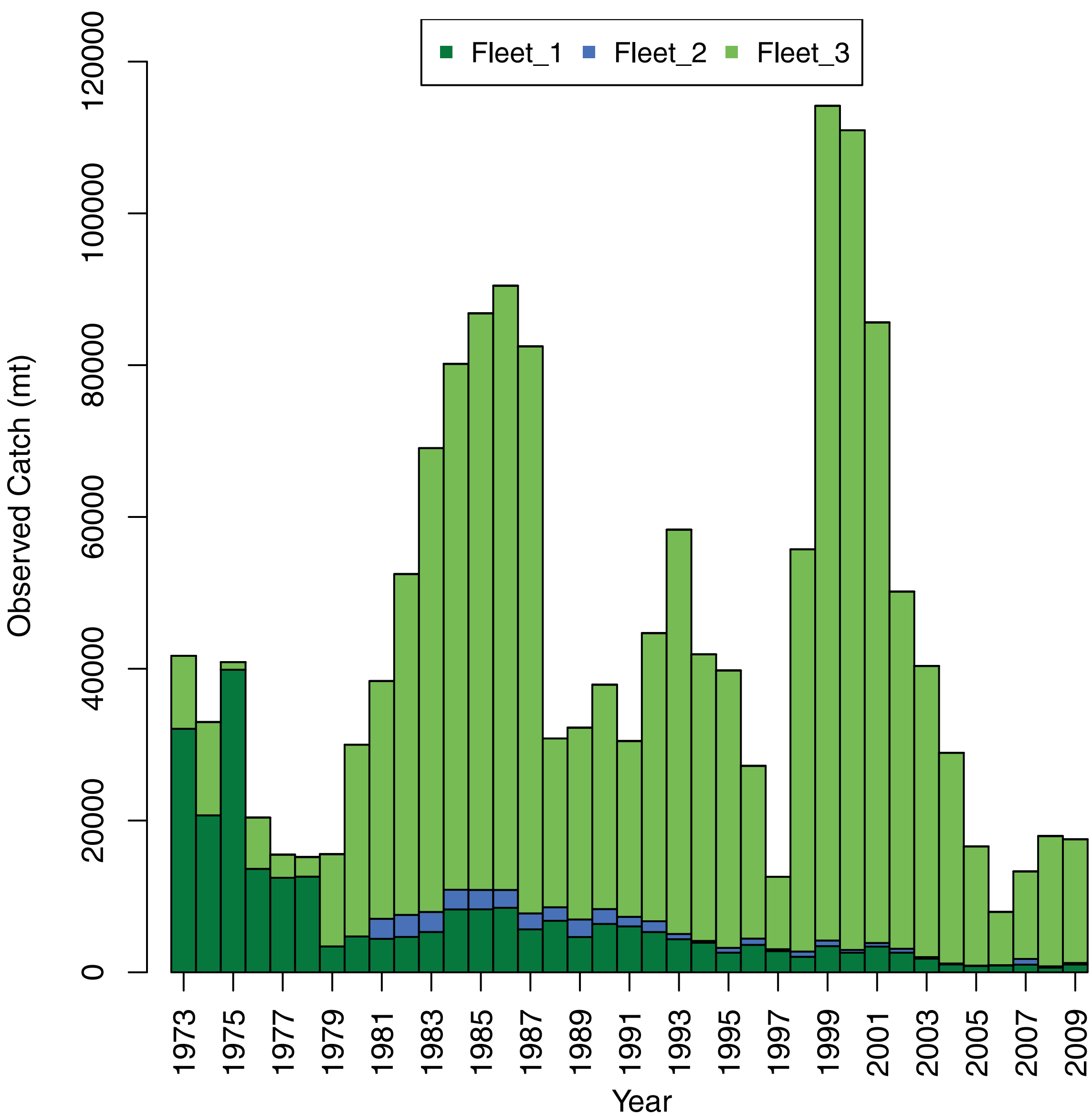

Ln(Recruitment deviations)
−1.0
0.0
0.5
1.0
1975
1980
1985
1990
1995
2000
2005
2010
Year

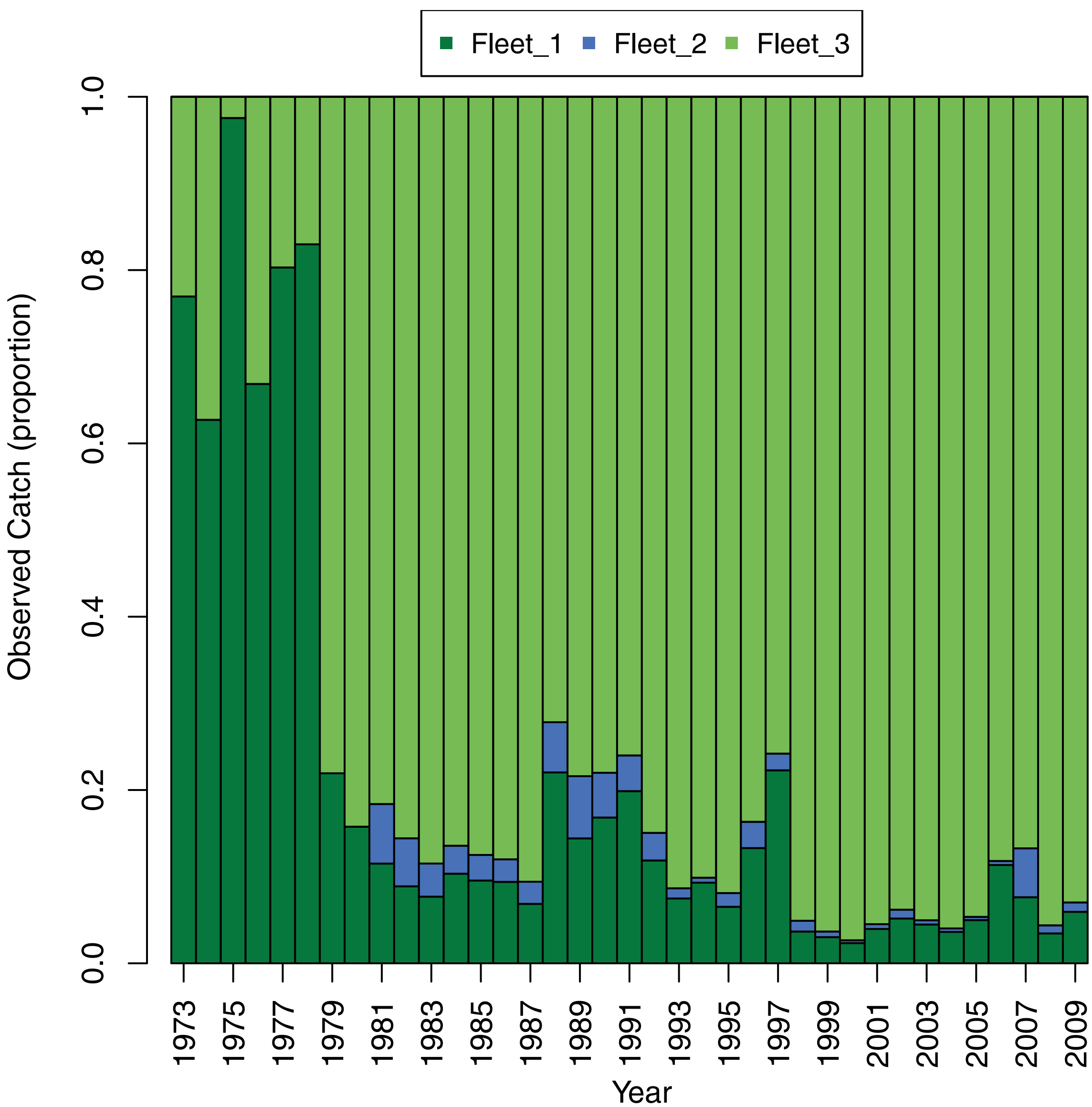

SSB (mt)
0
40000
100000
1975
1980
1985
1990
1995
2000
2005
2010
Year
F_report
0
1
2
3
1975
1980
1985
1990
1995
2000
2005
2010
Year

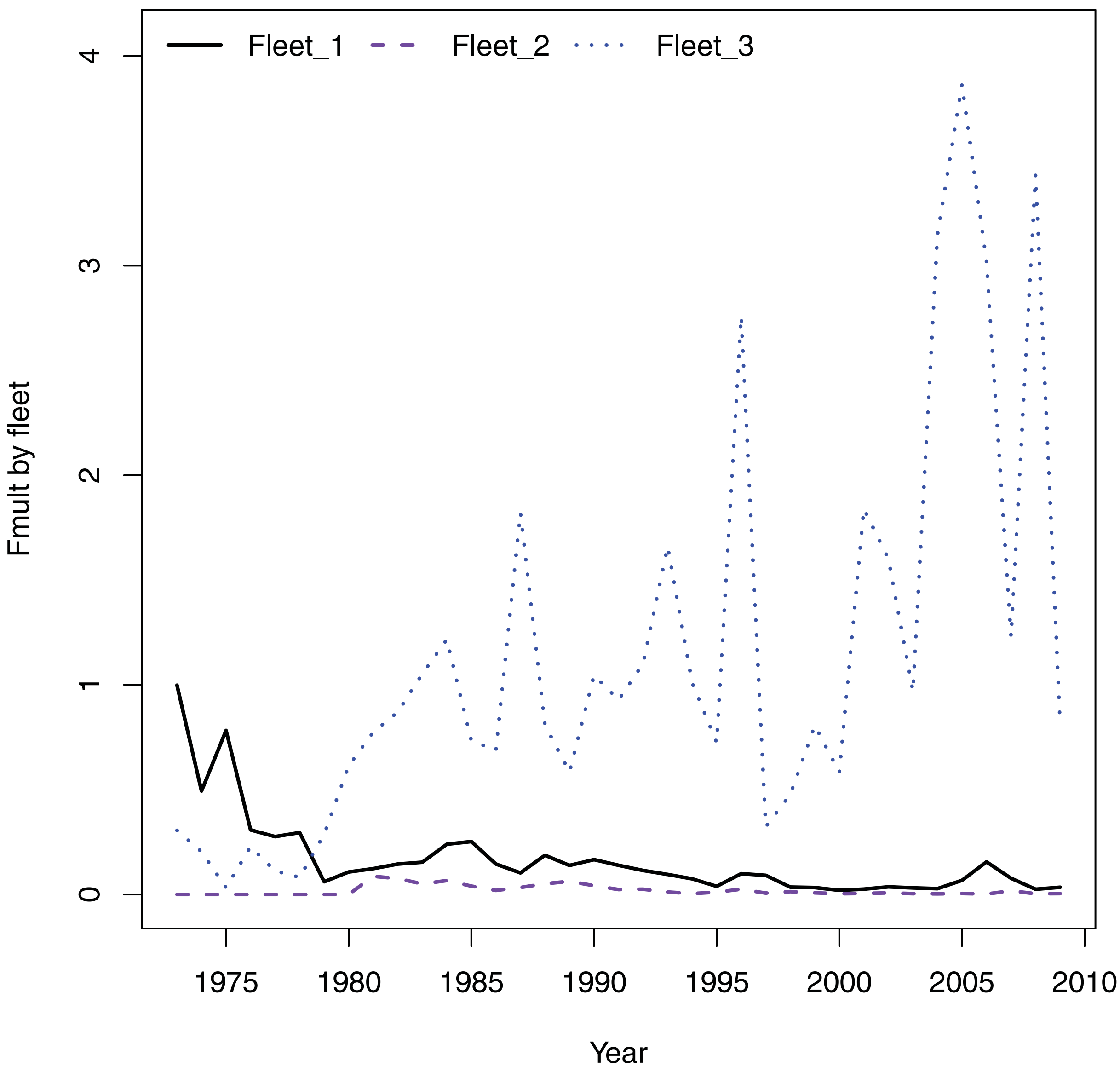

0.15
0.10
0.05
0.00
Relative Spawners (SSB/SSB0)
1975
1980
1985
1990
1995
2000
2005
2010
Year

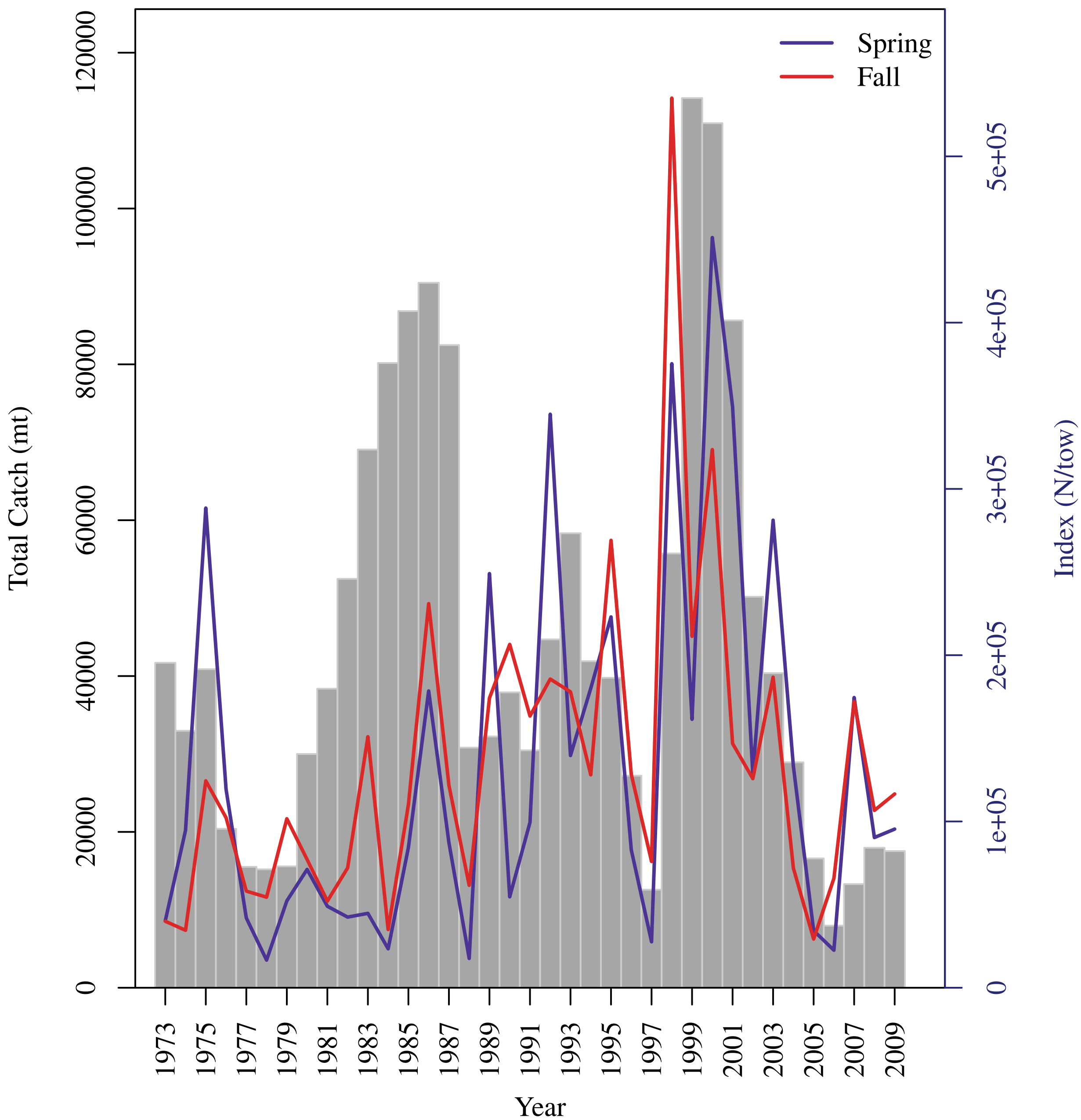

1
2
3
4
5
6
ASAP Estimated NAA
0
200000
400000
600000
800000
1200000
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

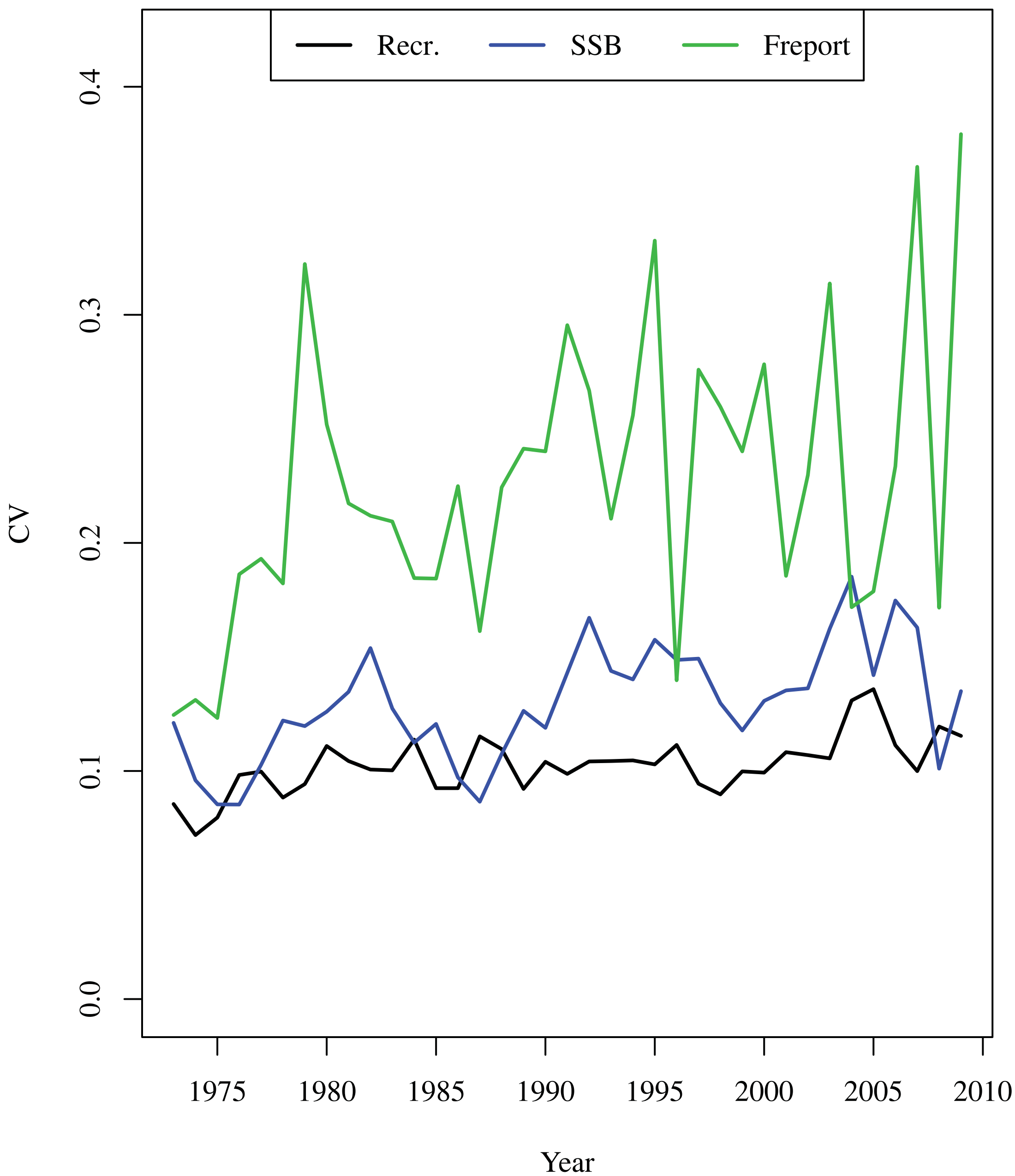

1 2 3 4 5 6
ASAP Estimated Proportion(NAA)
0.0
0.2
0.4
0.6
0.8
1.0
1973 1976 1979 1982 1985 1988 1991 1994 1997 2000 2003 2006 2009
Year


Fleet_1
Fleet_2
Fleet_3
Observed Catch (mt)
0
20000
40000
60000
80000
100000
120000
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year

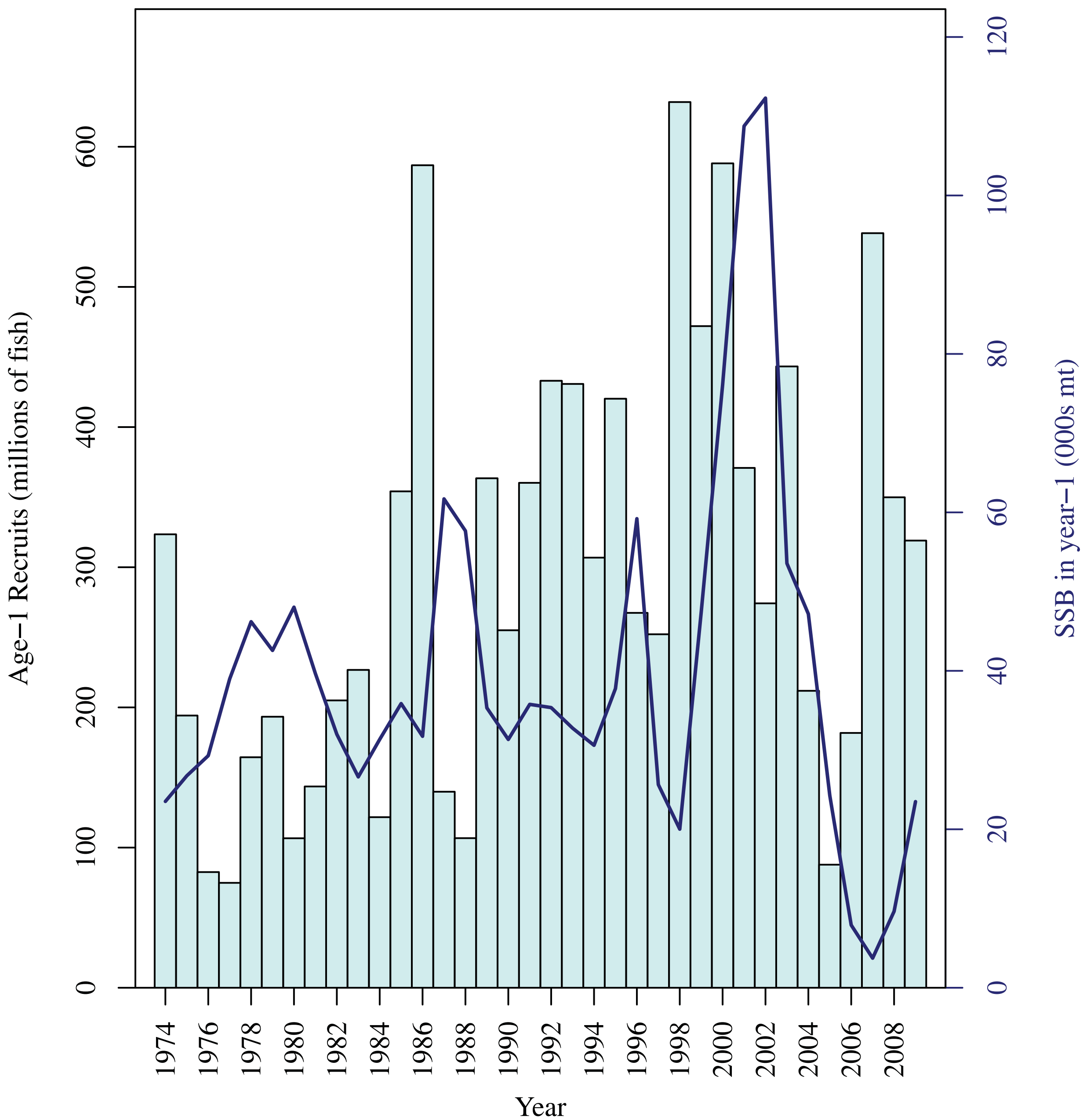

Fleet_1
Fleet_2
Fleet_3
Observed Catch (proportion)
0.0
0.2
0.4
0.6
0.8
1.0
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year


Fleet_1
Fleet_2
Fleet_3
0
1
2
3
4
Fmult by fleet
1975
1980
1985
1990
1995
2000
2005
2010
Year


Spring
Fall
Total Catch (mt)
Index (N/tow)
Year
0
20000
40000
60000
80000
100000
120000
1e+05
2e+05
3e+05
4e+05
5e+05
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009



Recr.
SSB
Freport
CV
0.0
0.1
0.2
0.3
0.4
1975
1980
1985
1990
1995
2000
2005
2010
Year


Age−1 Recruits (millions of fish)
SSB in year−1 (000s mt)
Year
0
100
200
300
400
500
600
0
20
40
60
80
100
120
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008

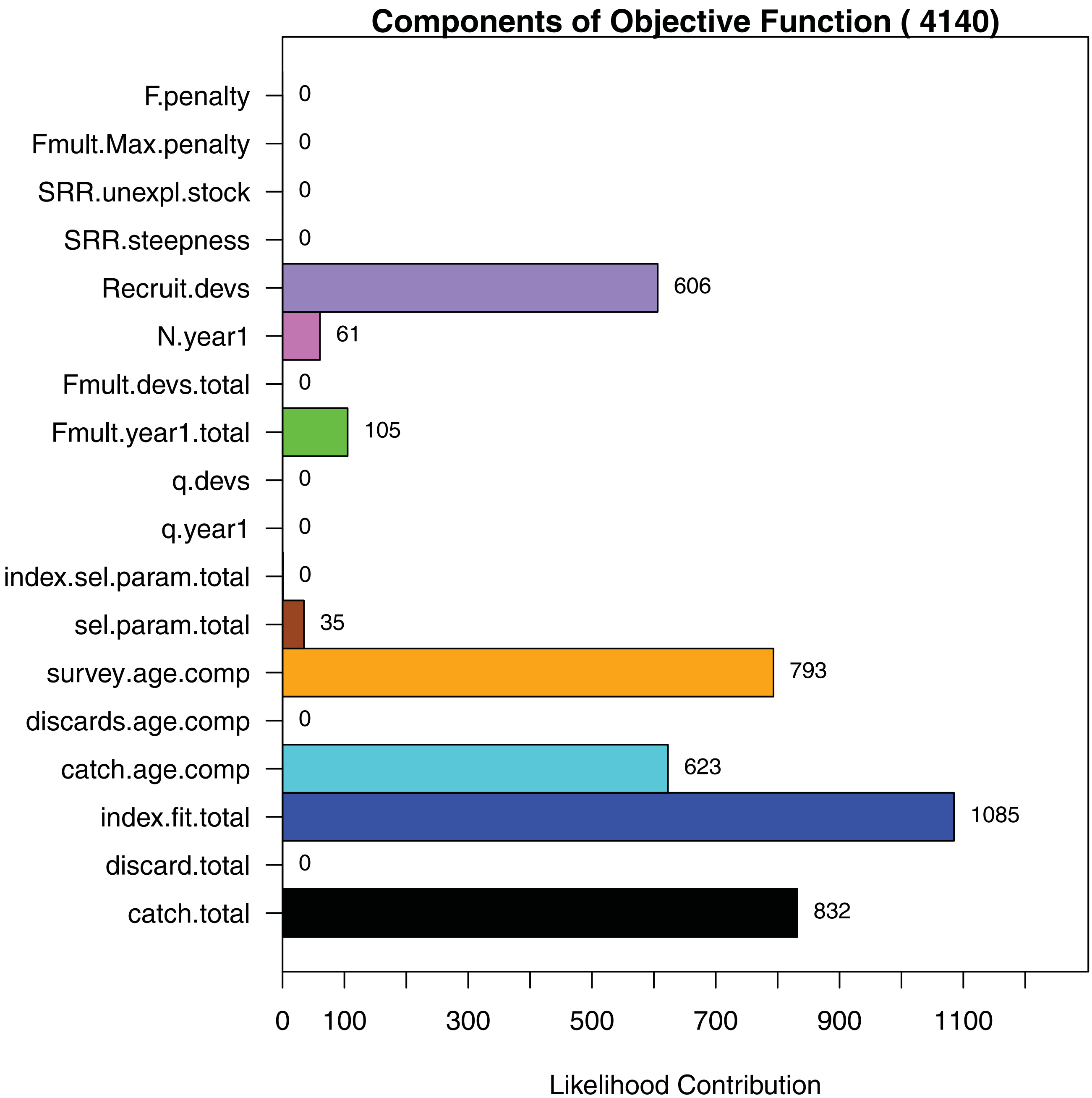
Appendix A6: North Model Consumption ASAP results M = 0.15_Assuming Flat-top Selectivity in the Survey

Model Attributes:

1. 3 Fleet Model
    a. Catch : 1973-2009
    b. Discards: 1981 – 2009
    c. Consumption – 1973-2009

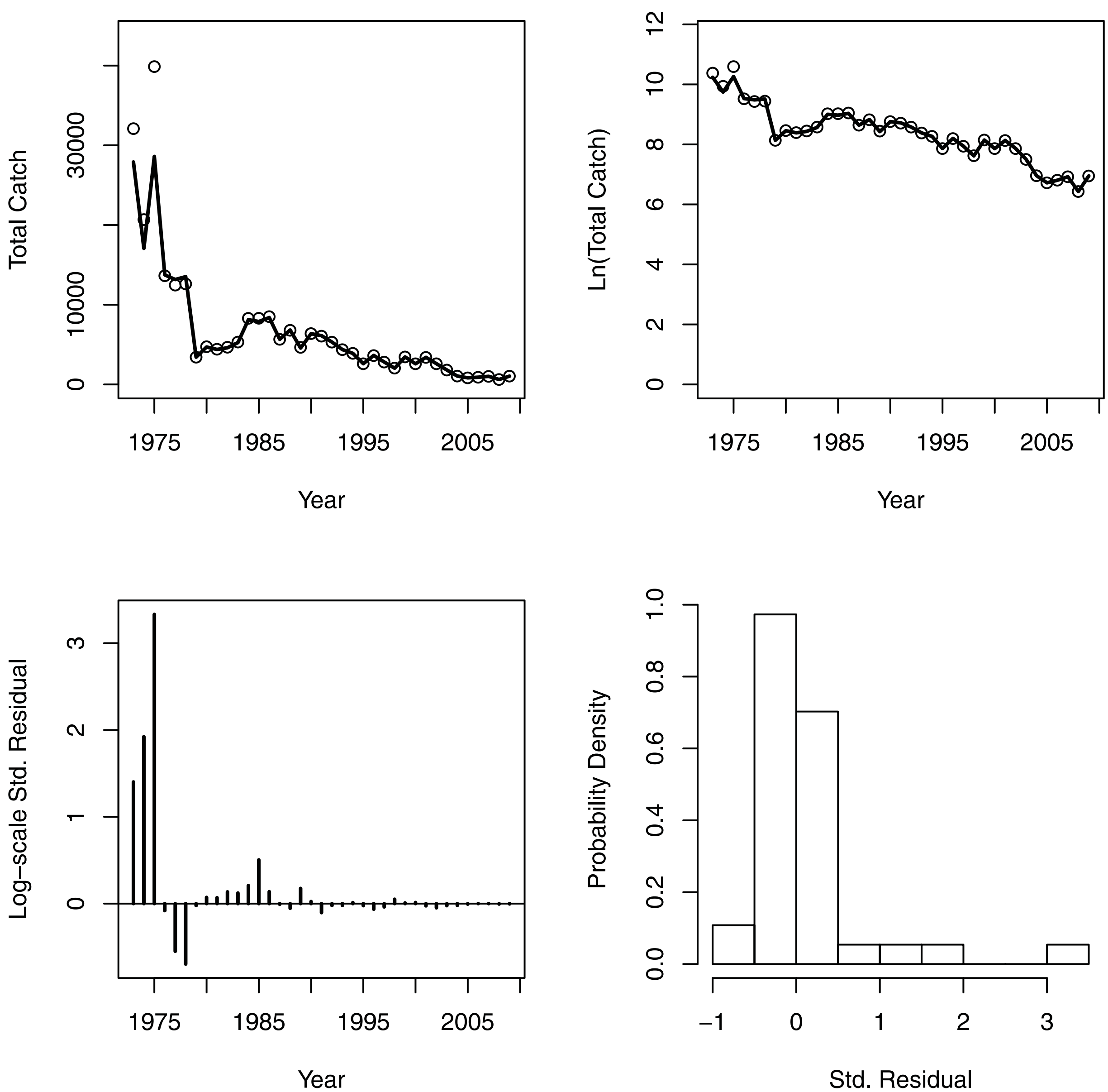
2. Fishery Selectivity (3 Block Selectivity)
    a. Landings (1 Blocks: 1973-2009)
    b. Discards (1 Block: 1981-2009)
    c. Consumption (Double Logistic Functional Form)

3. Survey Selectivity (Fixed 100% at age 2-6)

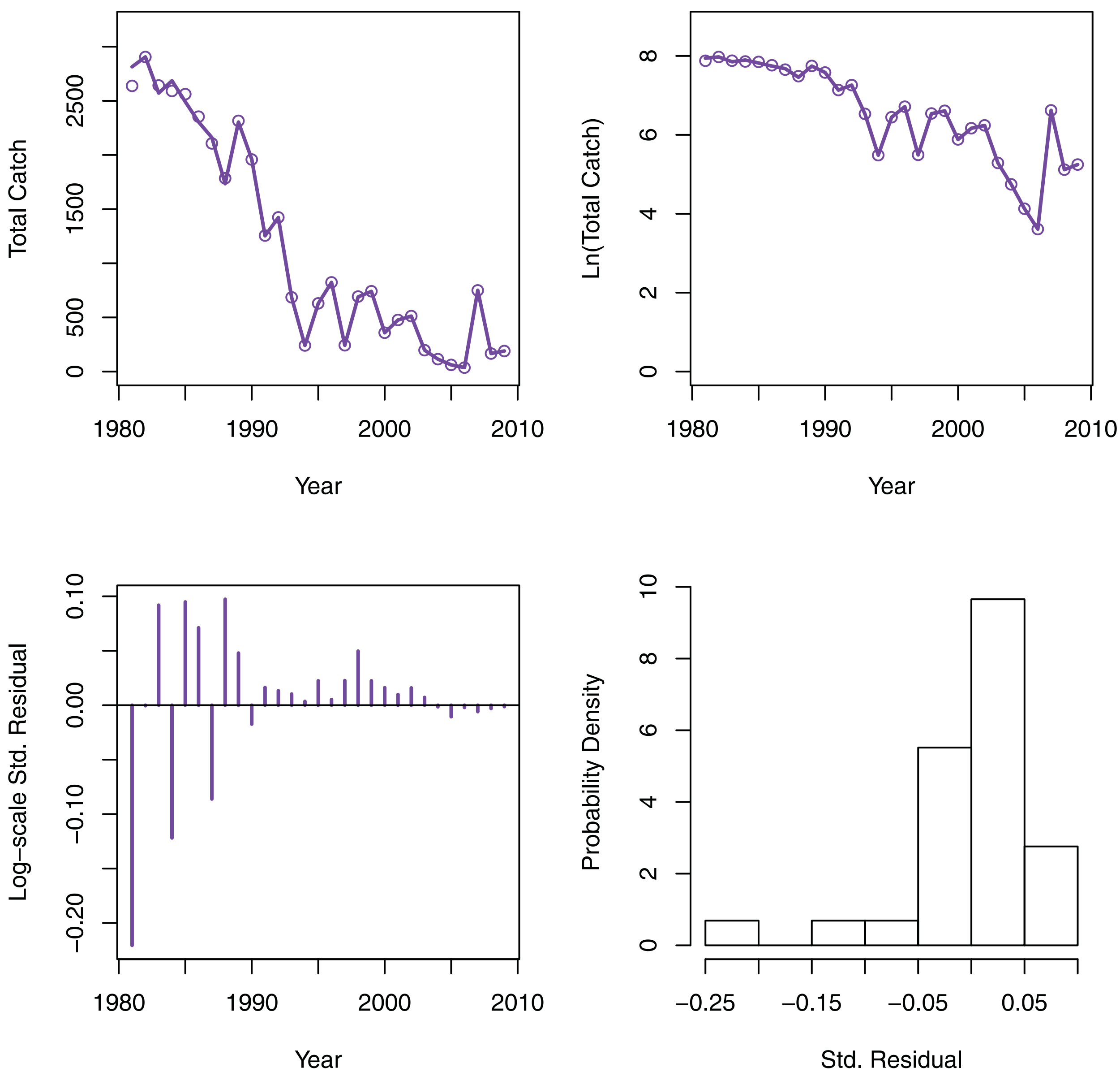


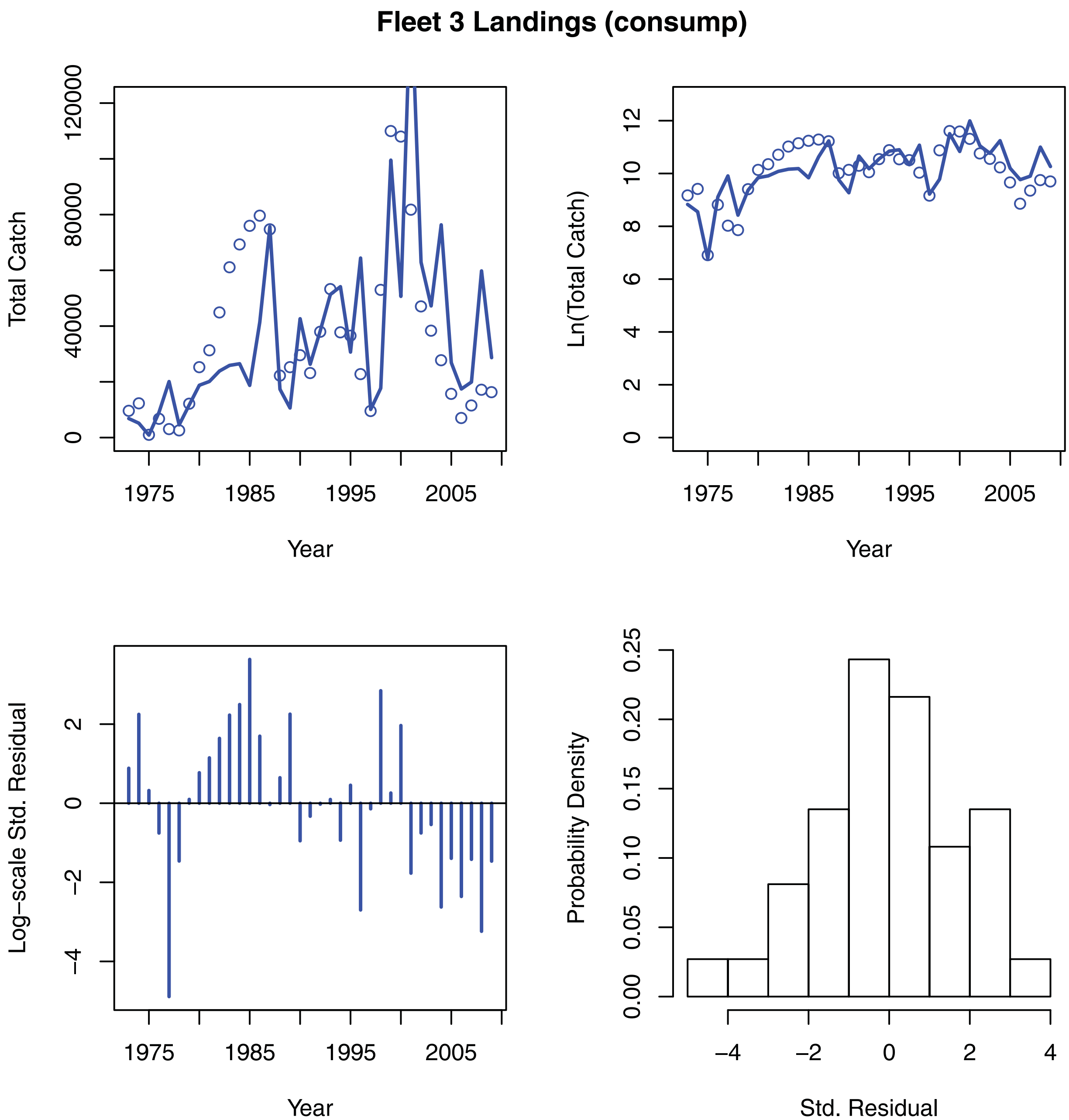
Components of Objective Function (4140)
F.penalty
Fmult.Max.penalty
SRR.unexpl.stock
SRR.steepness
Recruit.devs
N.year1
Fmult.devs.total
Fmult.year1.total
q.devs
q.year1
index.sel.param.total
sel.param.total
survey.age.comp
discards.age.comp
catch.age.comp
index.fit.total
discard.total
catch.total
0
0
0
0
606
61
0
105
0
0
0
35
793
0
623
1085
0
832
0
100
300
500
700
900
1100
Likelihood Contribution

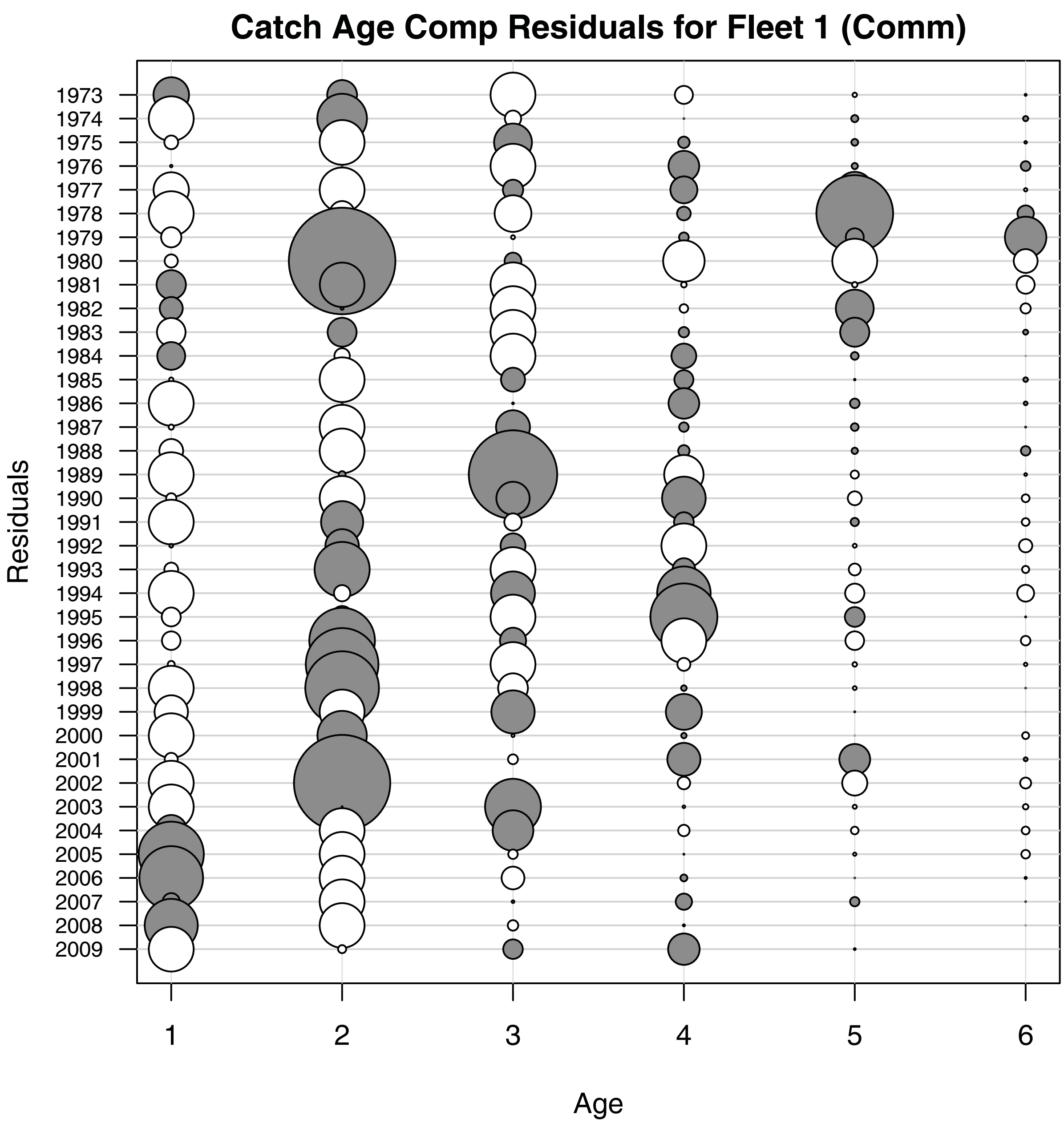
Fleet 1 Landings (Comm)

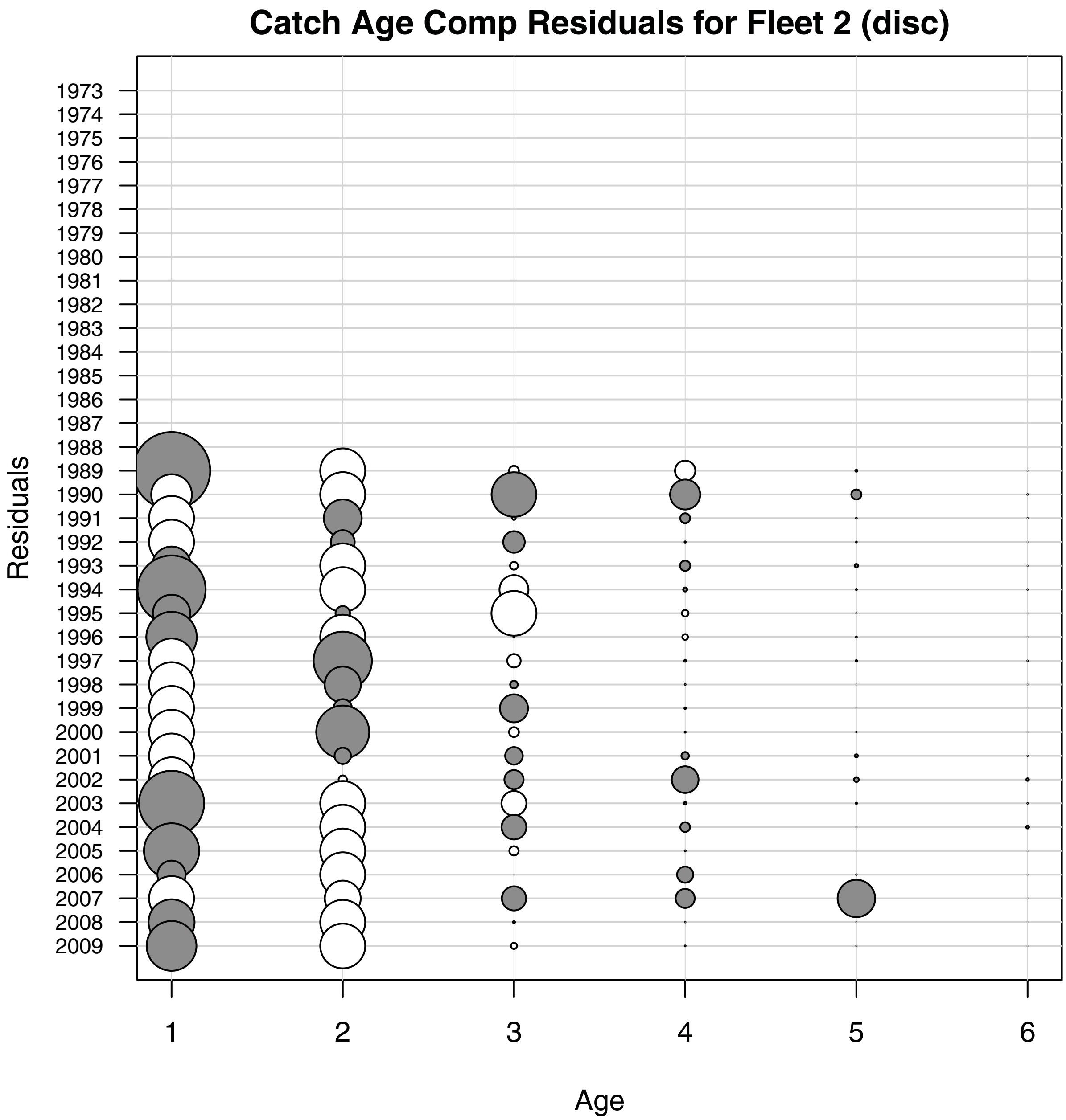


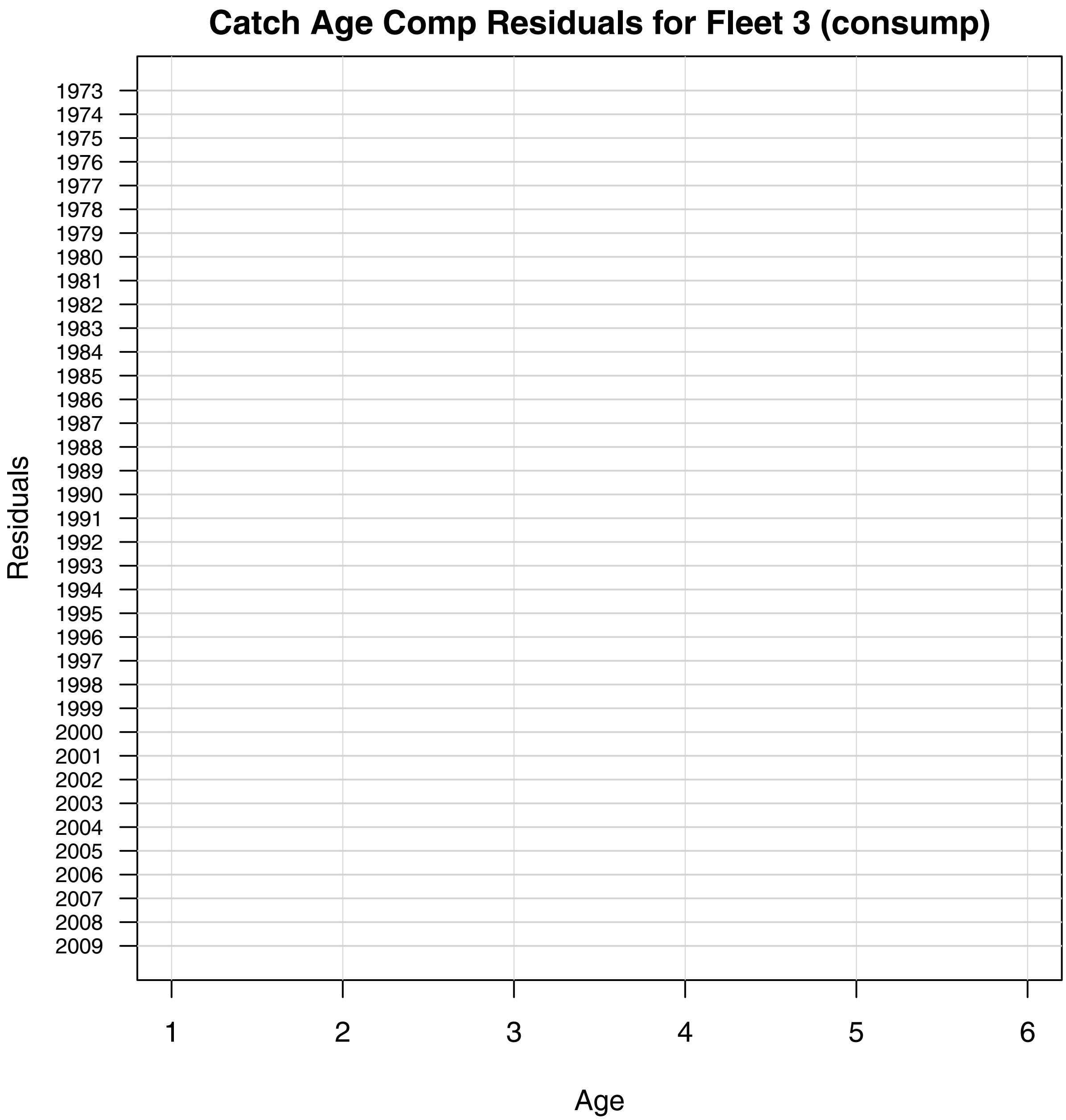
Fleet 2 Landings (disc)

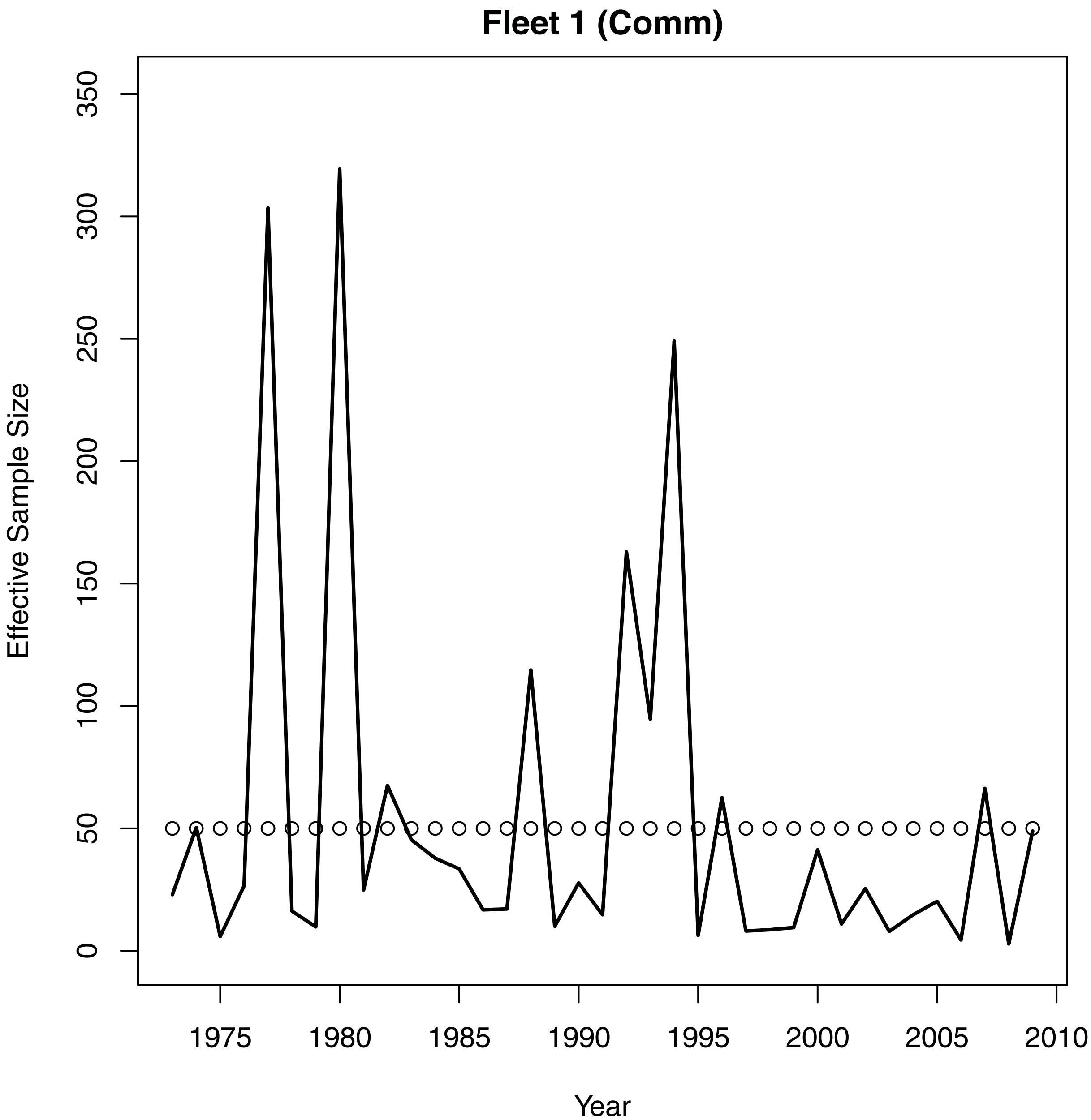


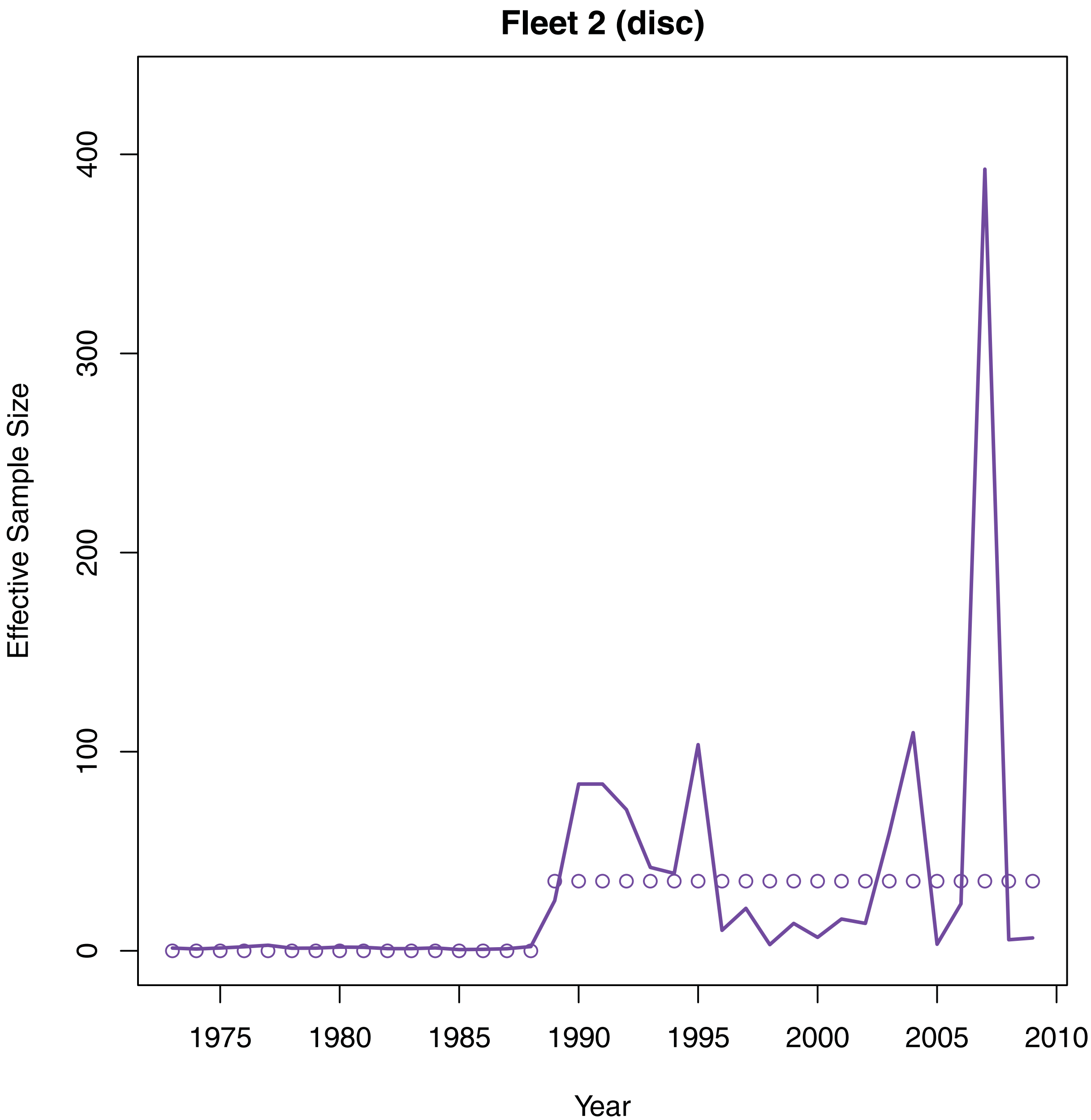

Fleet 3 Landings (consump)
Total Catch
0
40000
80000
120000
1975
1985
1995
2005
Year
Ln(Total Catch)
0
2
4
6
8
10
12
Log−scale Std. Residual
−4
−2
0
2
Probability Density
0.00
0.05
0.10
0.15
0.20
0.25
−4
−2
0
2
4
Std. Residual

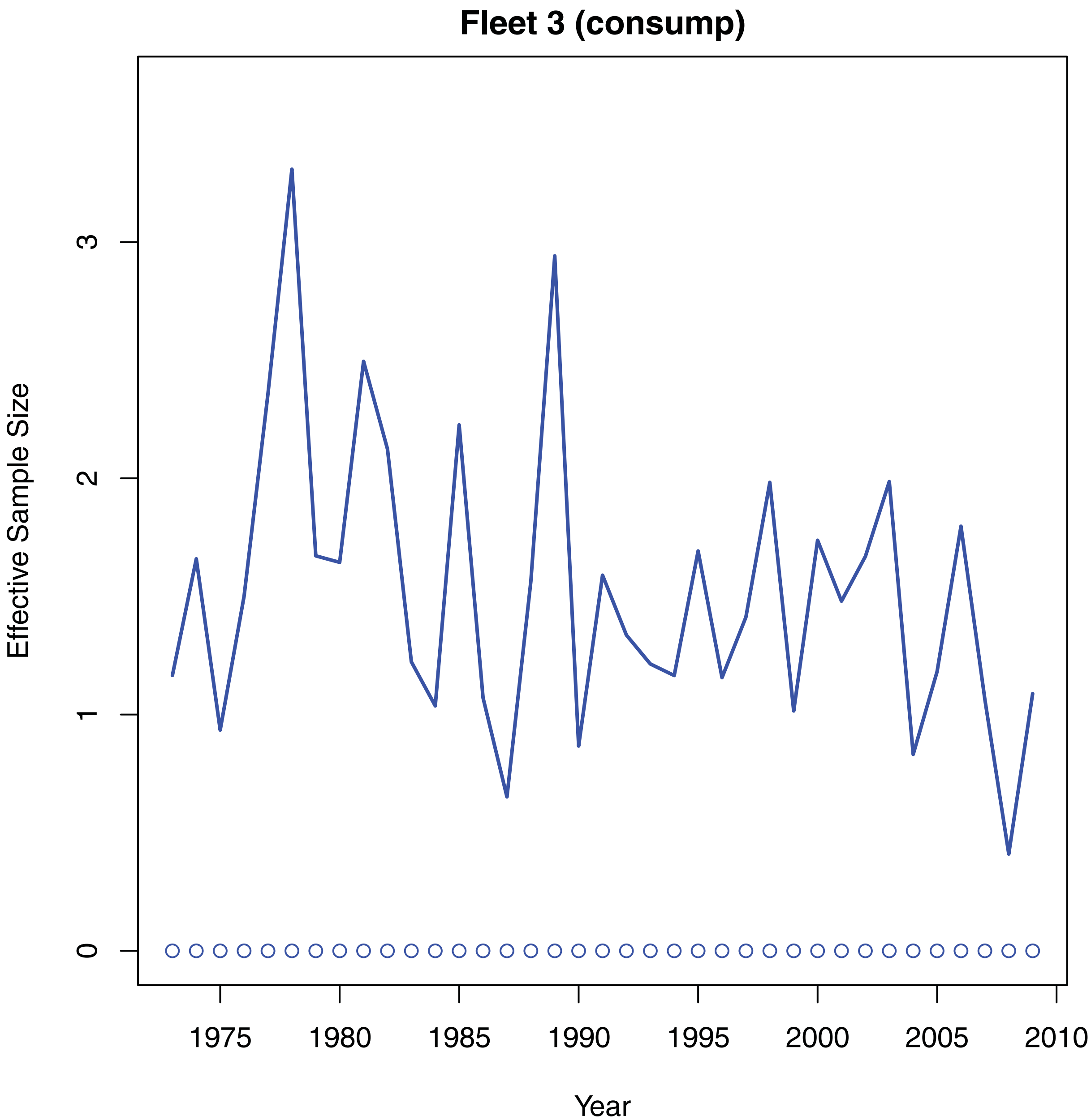

Catch Age Comp Residuals for Fleet 1 (Comm)
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age

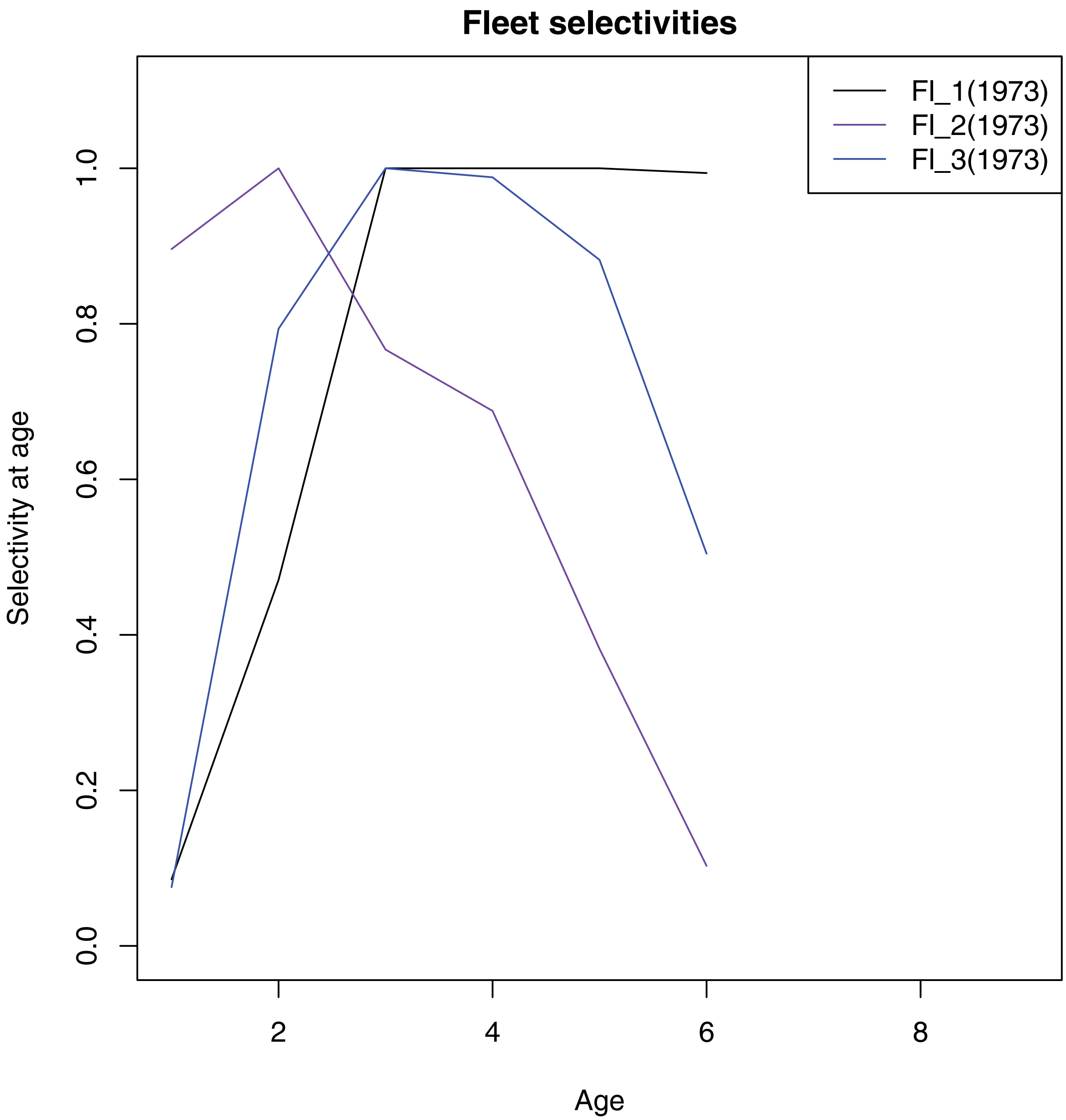

Catch Age Comp Residuals for Fleet 2 (disc)
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Residuals
1
2
3
4
5
6
Age


Catch Age Comp Residuals for Fleet 3 (consump)
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age

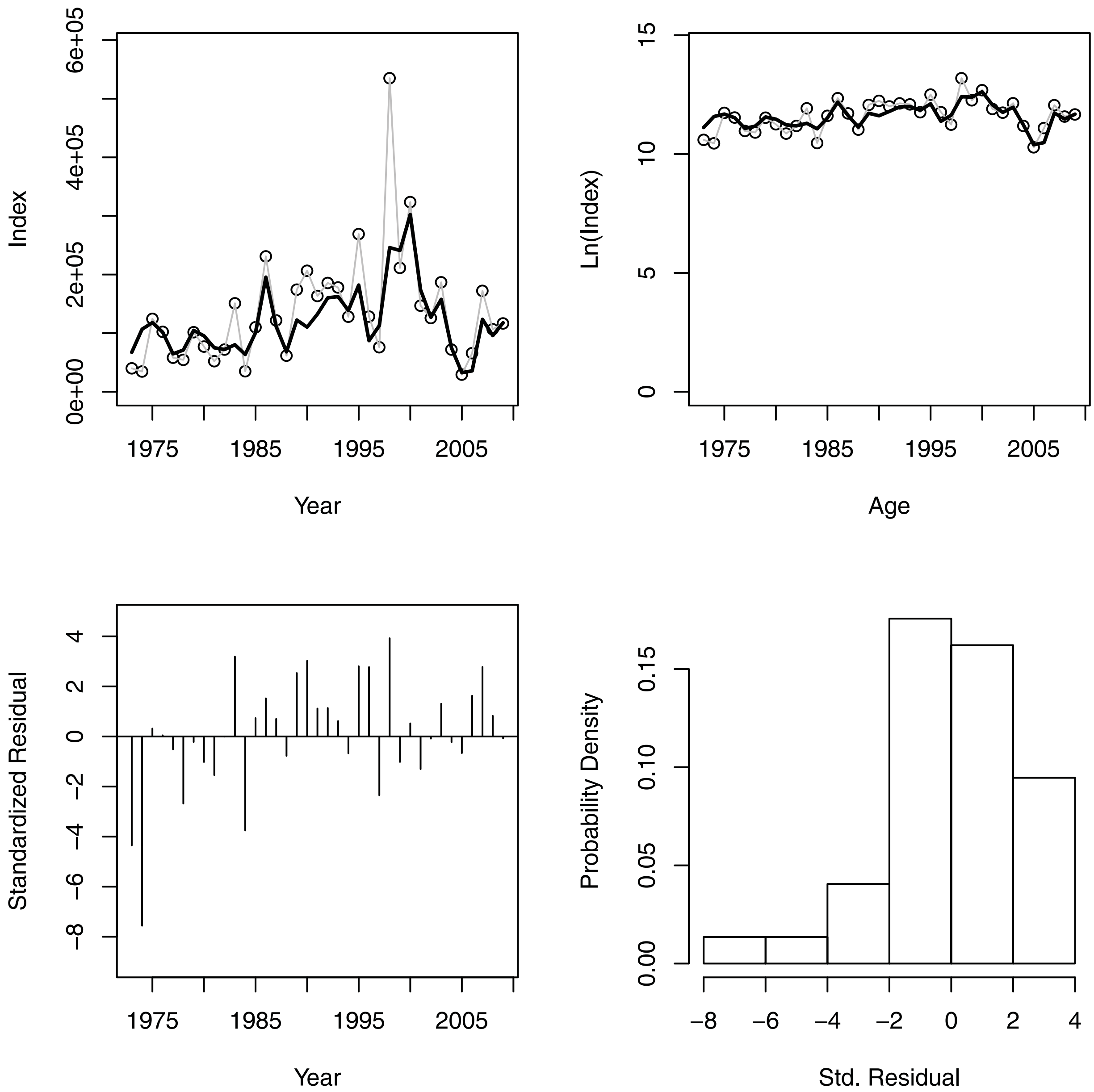

Fleet 1 (Comm)
Effective Sample Size
0
50
100
150
200
250
300
350
1975
1980
1985
1990
1995
2000
2005
2010
Year


Fleet 2 (disc)
Effective Sample Size
0
100
200
300
400
1975
1980
1985
1990
1995
2000
2005
2010
Year

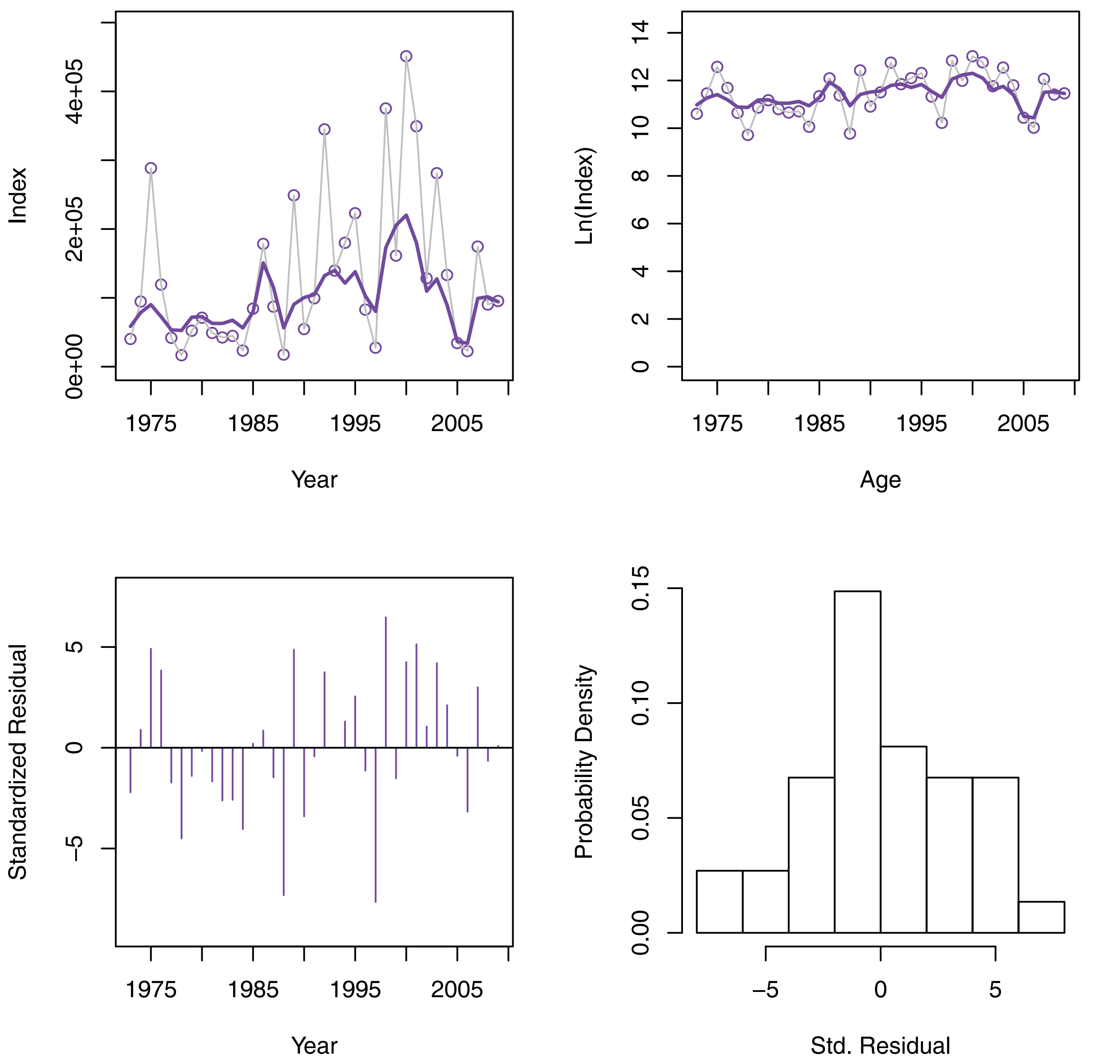

Fleet 3 (consump)
Effective Sample Size
0
1
2
3
1975
1980
1985
1990
1995
2000
2005
2010
Year

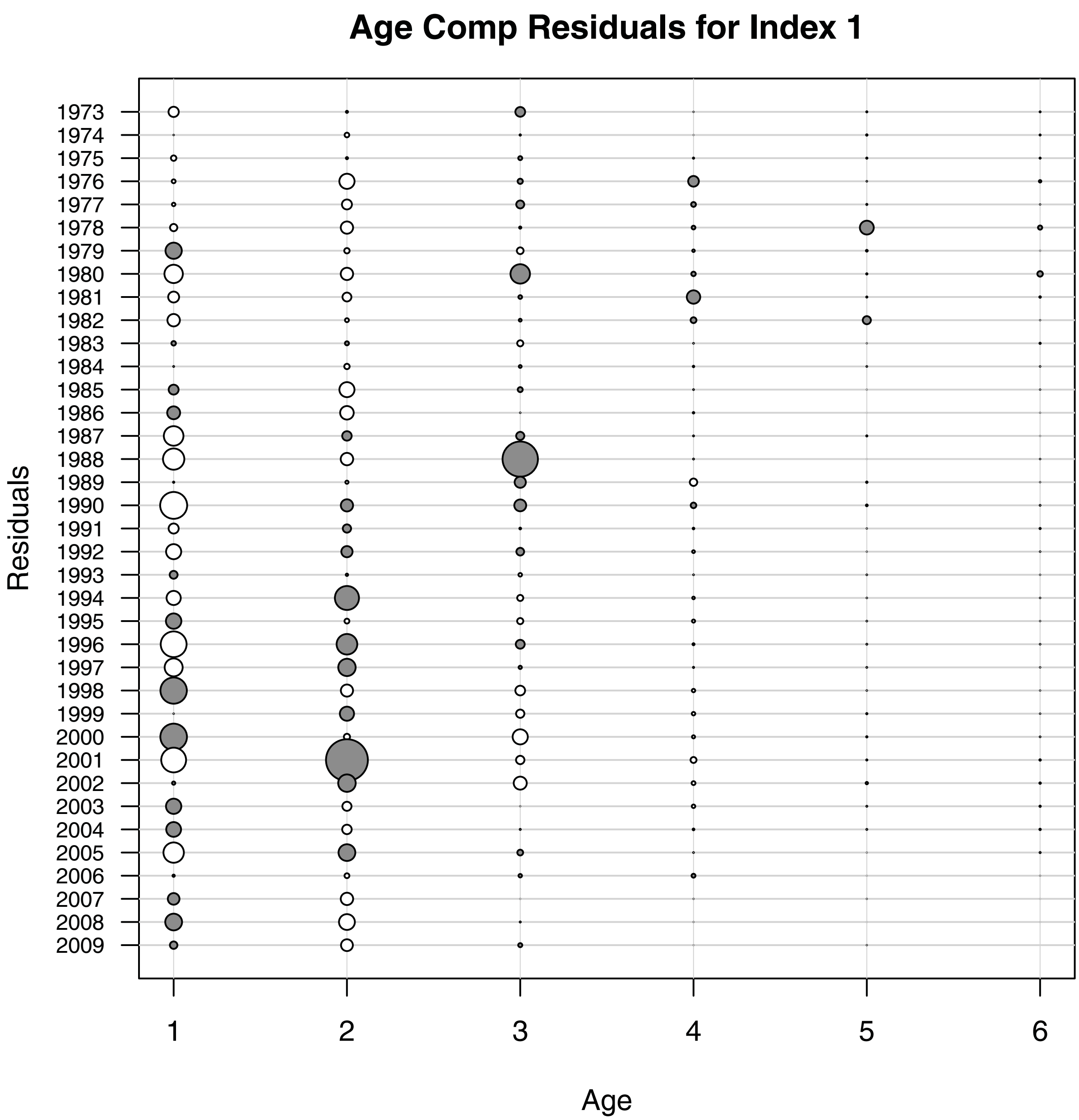

Fleet selectivities
Fl_1(1973)
Fl_2(1973)
Fl_3(1973)
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
Age

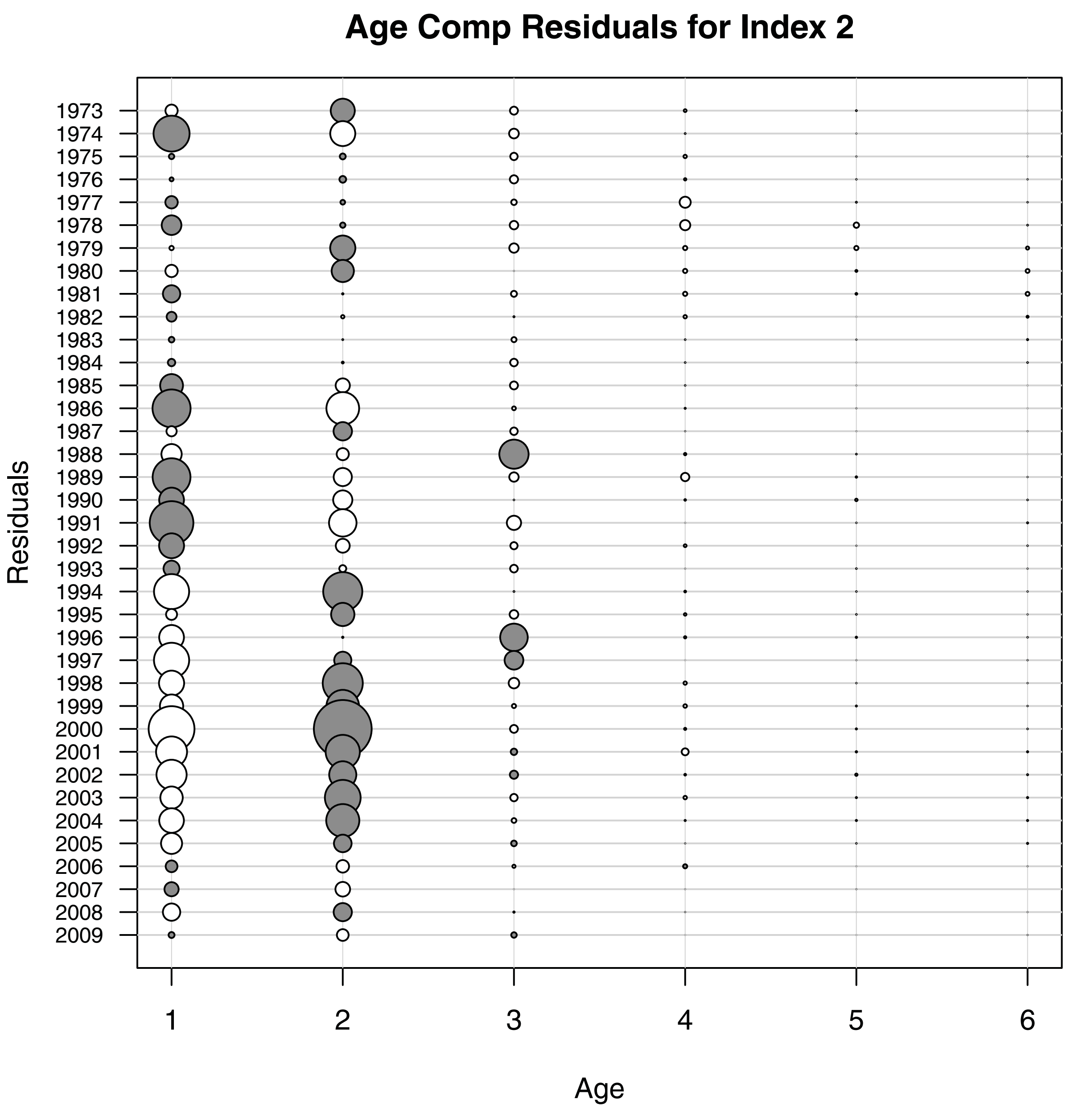
Index 1

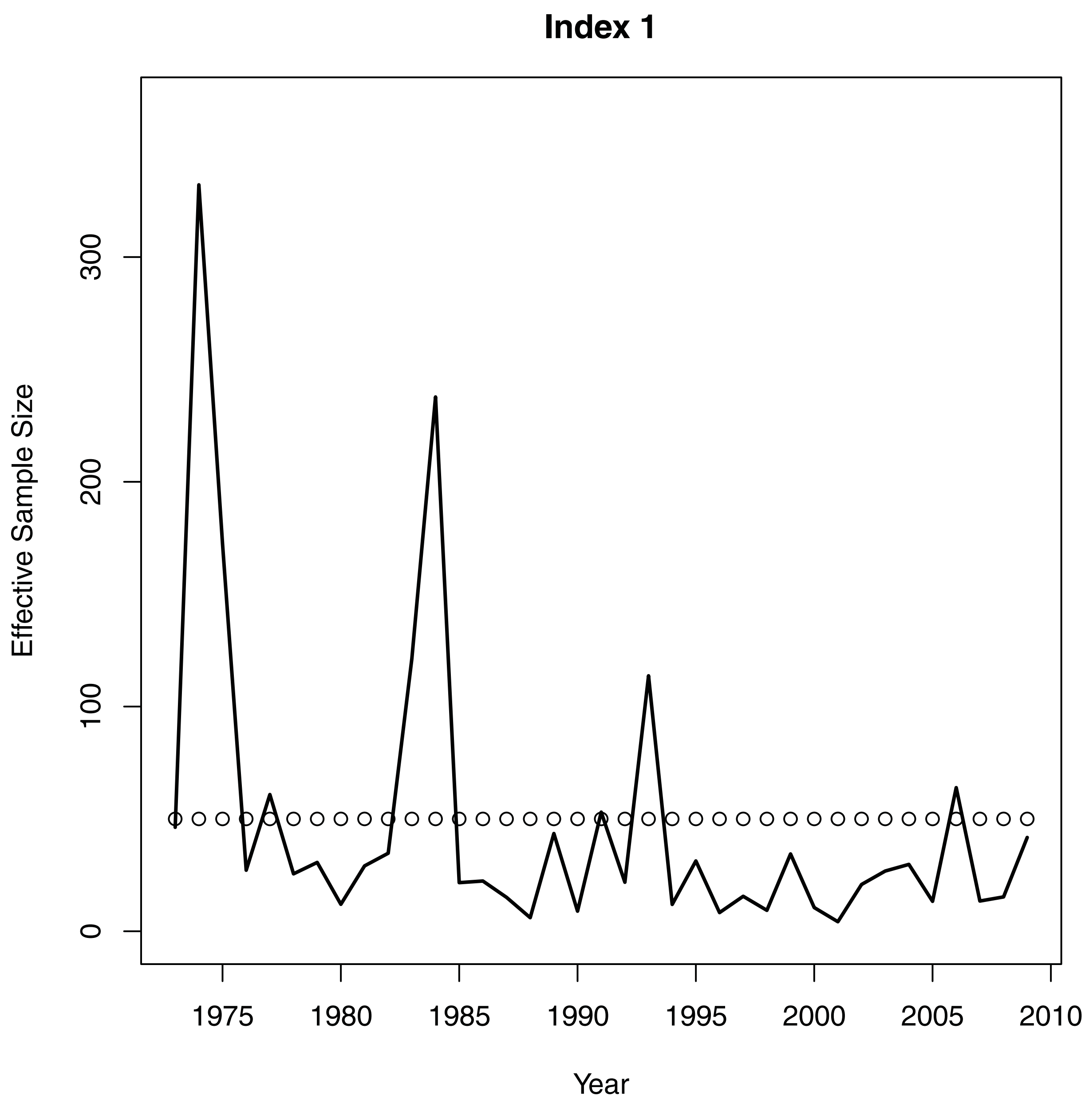

Index
0e+00
2e+05
4e+05
6e+05
1975
1985
1995
2005
Year
Ln(Index)
0
5
10
15
Age
Standardized Residual
4
2
0
−2
−4
−6
−8
Probability Density
0.00
0.05
0.10
0.15
−8
−6
−4
−2
0
2
4
Std. Residual

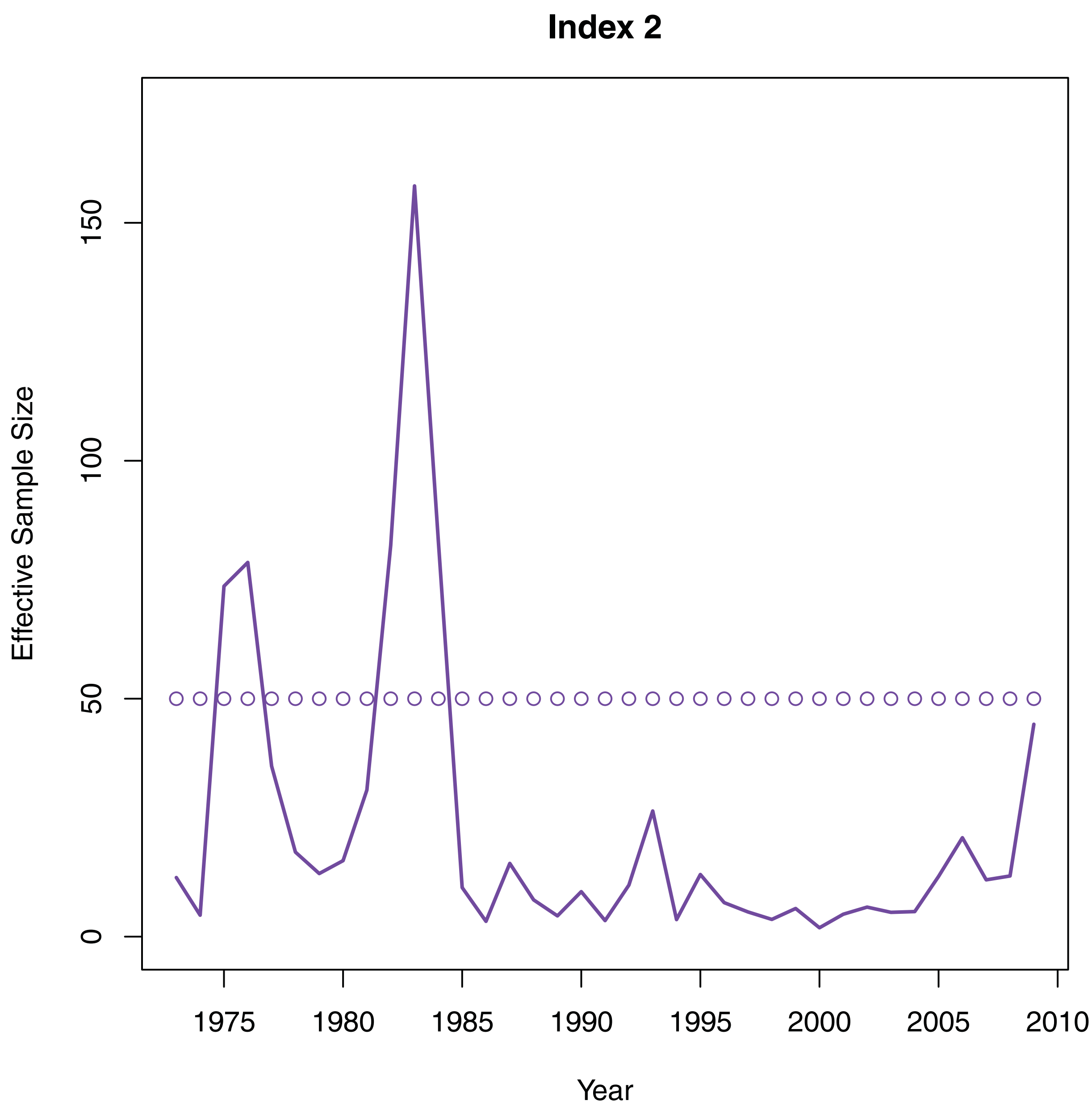
Index 2

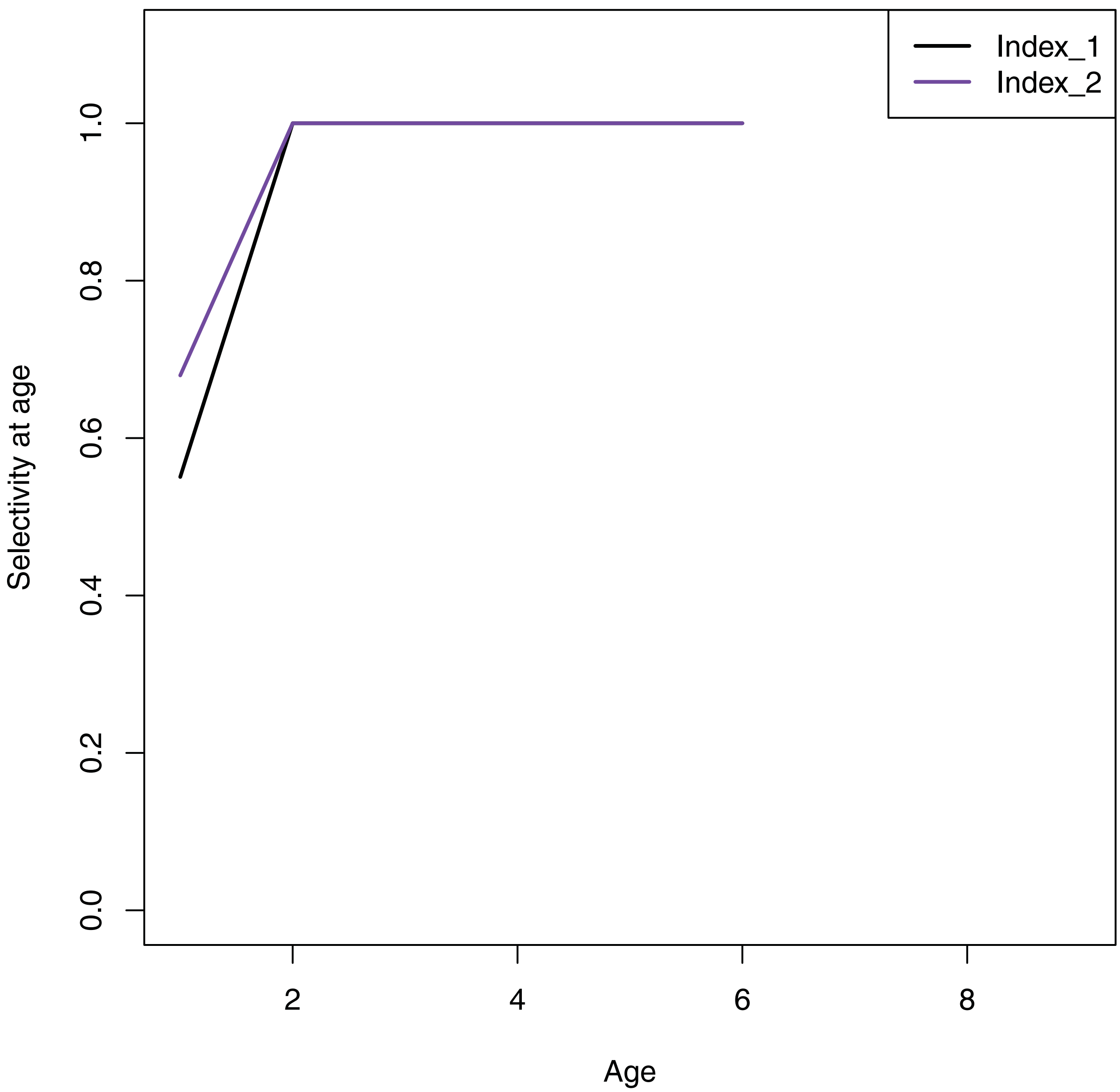

Index
0e+00
2e+05
4e+05
1975
1985
1995
2005
Year
Ln(Index)
0
2
4
6
8
10
12
14
Age
Standardized Residual
−5
0
5
Year
Probability Density
0.00
0.05
0.10
0.15
−5
0
5
Std. Residual

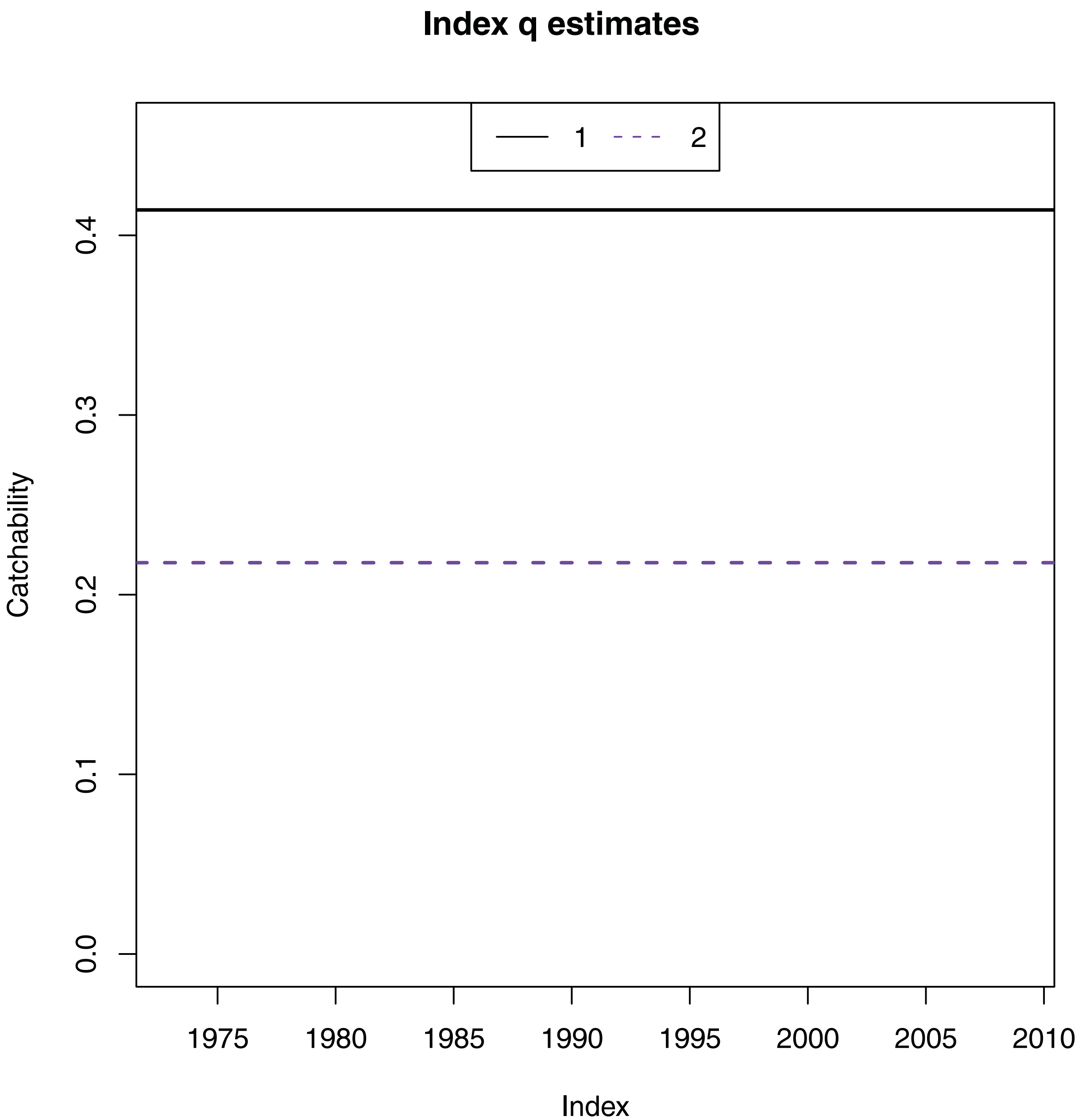

Age Comp Residuals for Index 1
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age

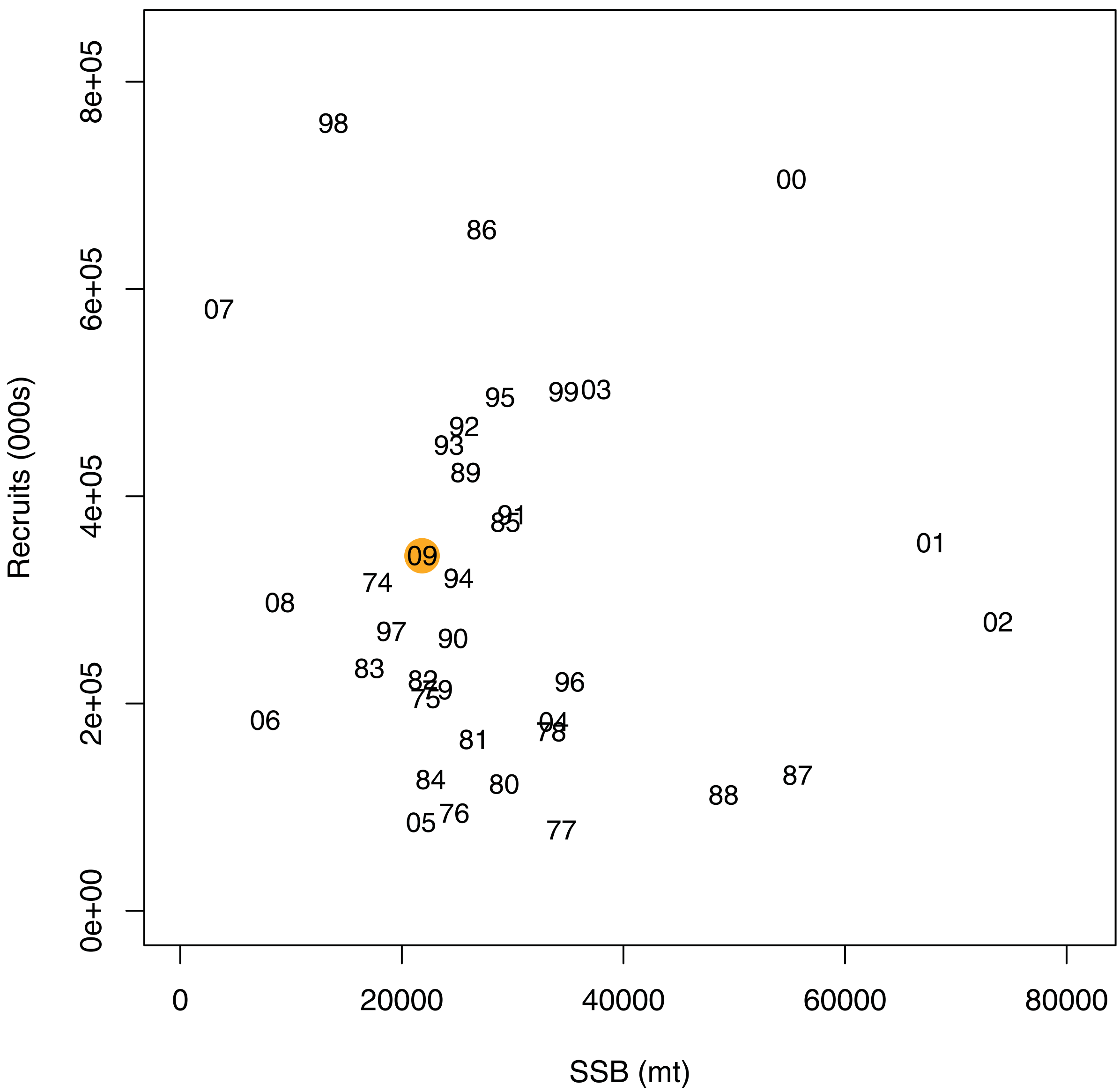

Age Comp Residuals for Index 2
Residuals
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
1
2
3
4
5
6
Age


Index 1
Effective Sample Size
0
100
200
300
1975
1980
1985
1990
1995
2000
2005
2010
Year

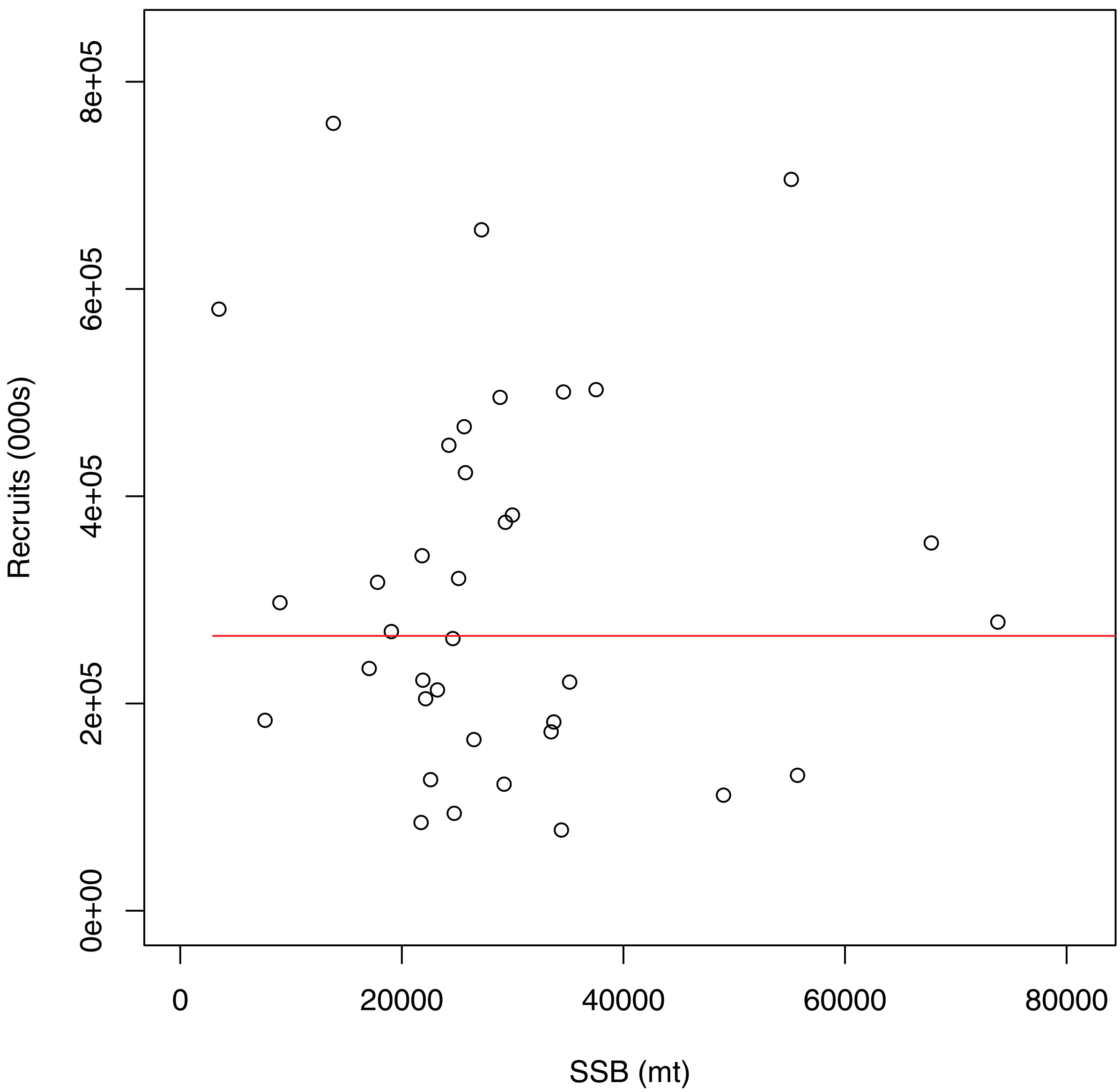

Index 2
Effective Sample Size
0
50
100
150
1975
1980
1985
1990
1995
2000
2005
2010
Year


Index_1
Index_2
Selectivity at age
0.0
0.2
0.4
0.6
0.8
1.0
2
4
6
8
Age

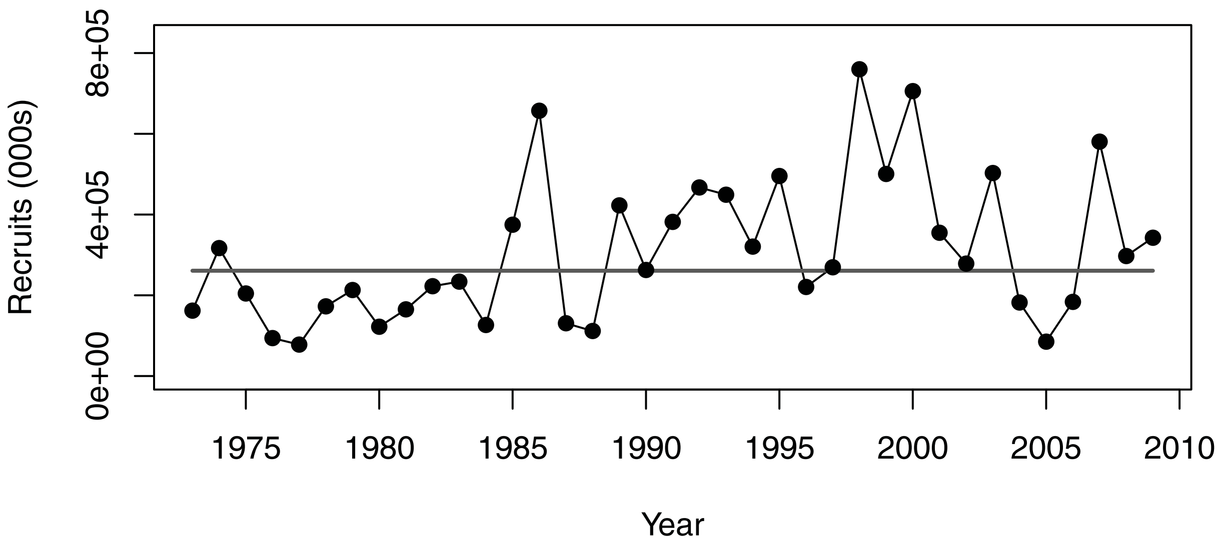

Index q estimates
1
2
Catchability
0.0
0.1
0.2
0.3
0.4
1975
1980
1985
1990
1995
2000
2005
2010
Index

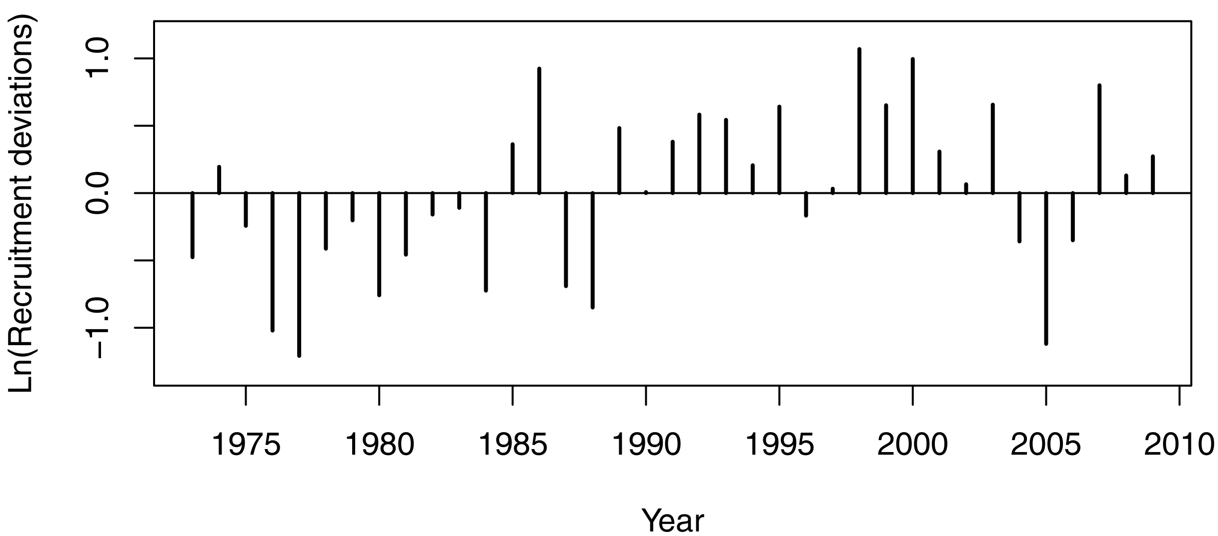


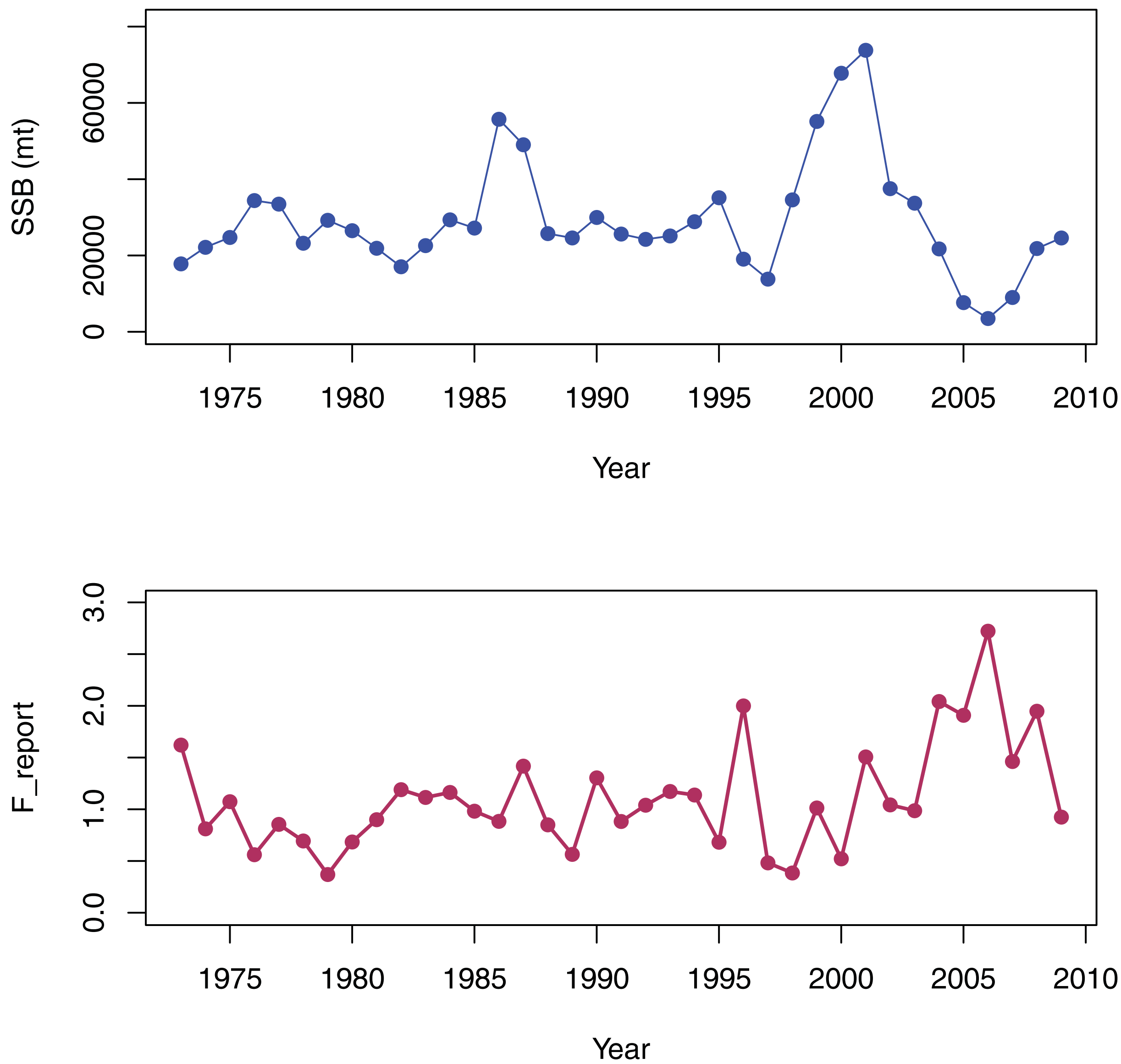
Recruits (000s)
0e+00
2e+05
4e+05
6e+05
8e+05
0
20000
40000
60000
80000
SSB (mt)
98
00
86
07
95
99
03
92
93
89
91
85
01
09
74
94
08
02
97
90
83
82
79
75
96
06
04
78
81
87
84
80
88
05
76
77

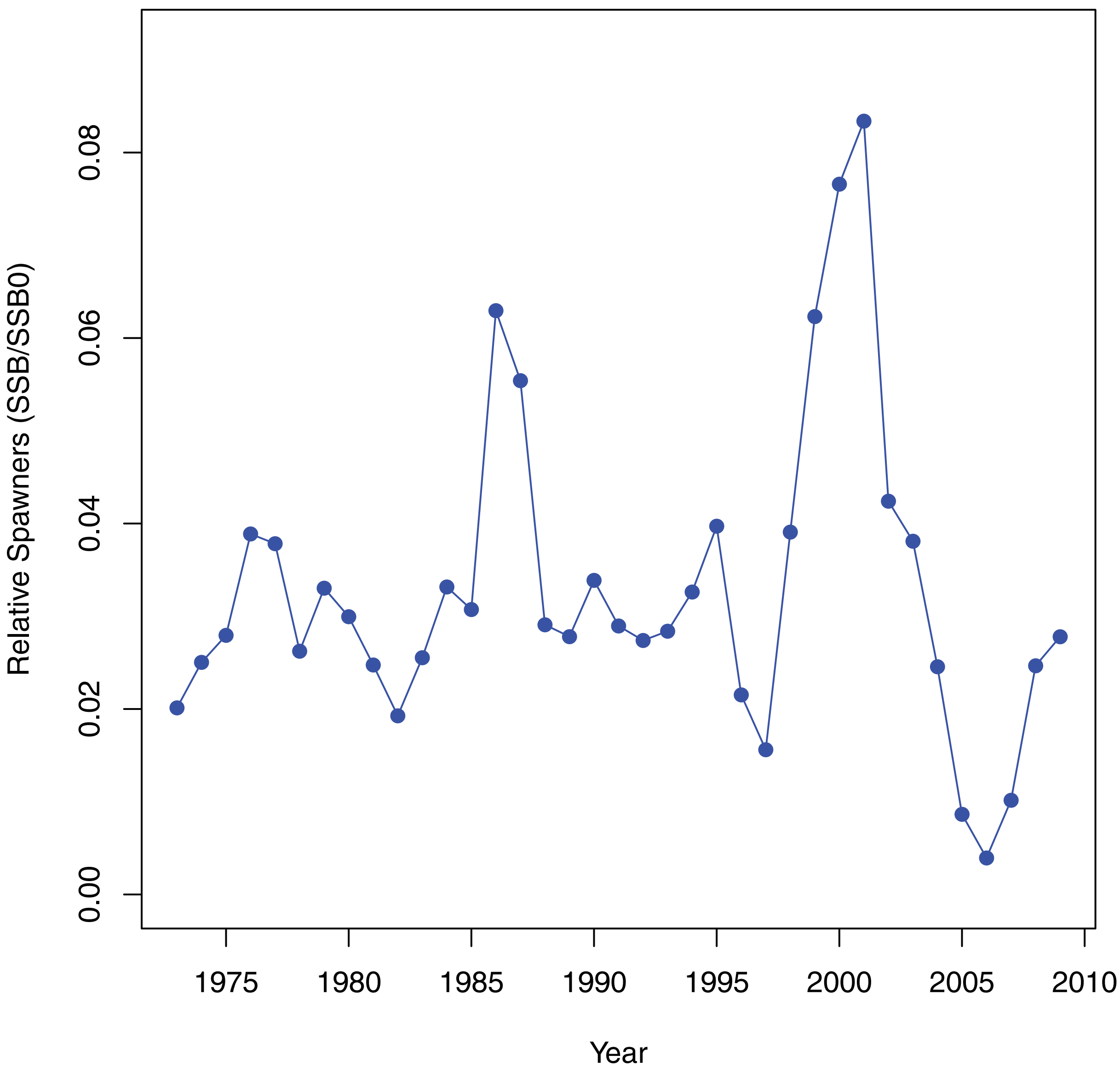


8e+05
6e+05
4e+05
2e+05
0e+00
Recruits (000s)
0
20000
40000
60000
80000
SSB (mt)

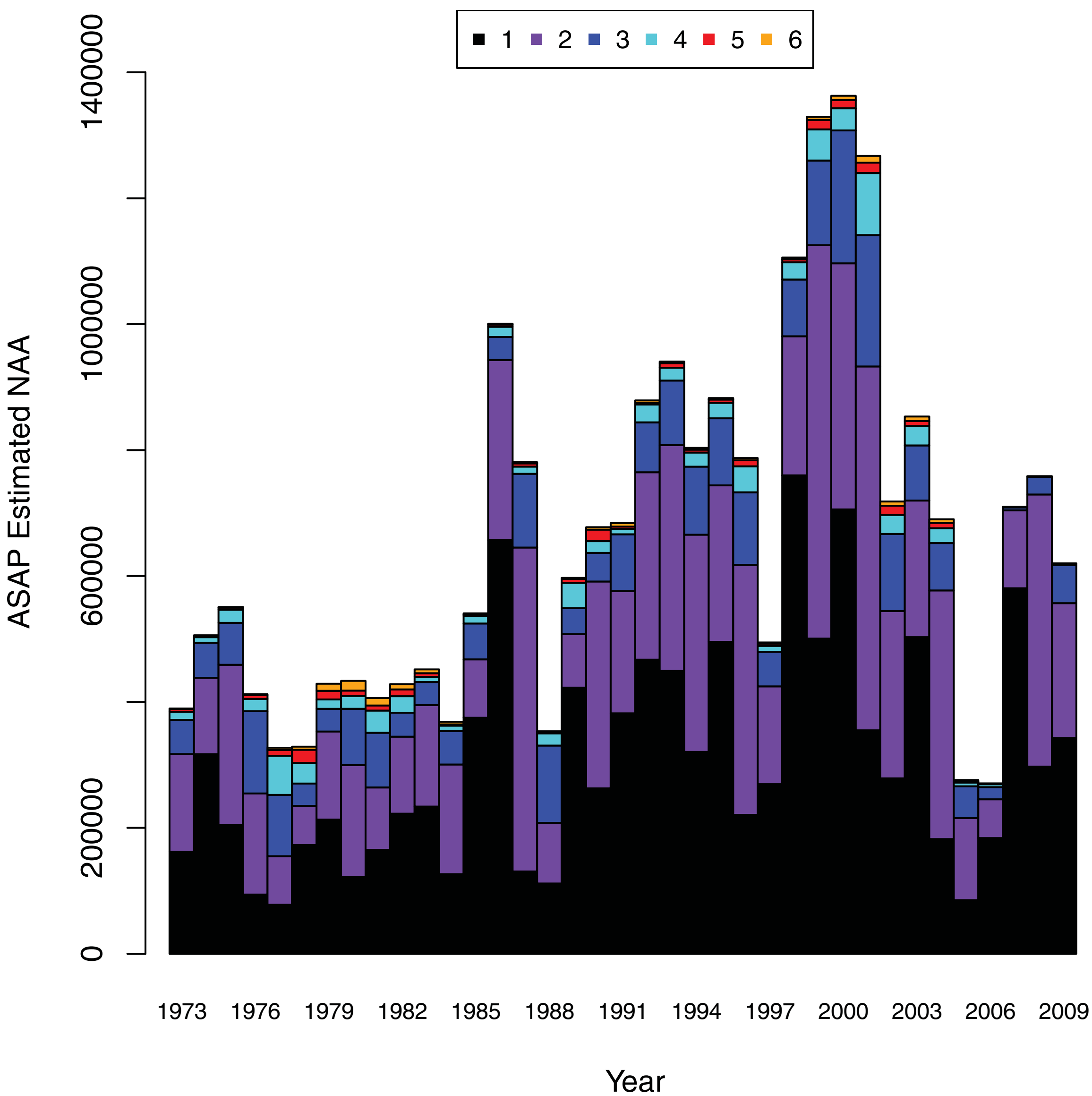

Recruits (000s)
0e+00
4e+05
8e+05
1975
1980
1985
1990
1995
2000
2005
2010
Year

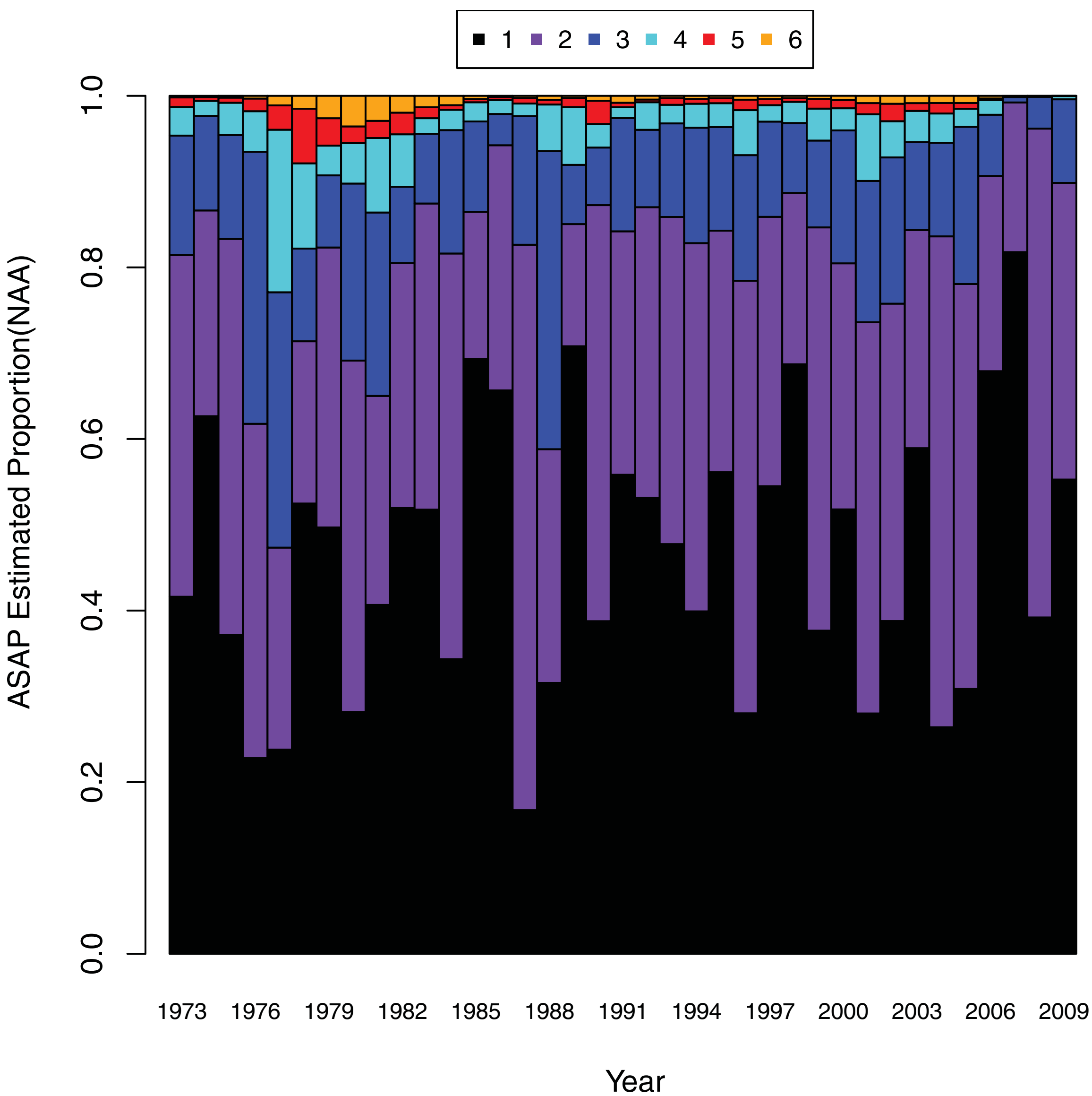

Ln(Recruitment deviations)
−1.0
0.0
1.0
1975
1980
1985
1990
1995
2000
2005
2010
Year

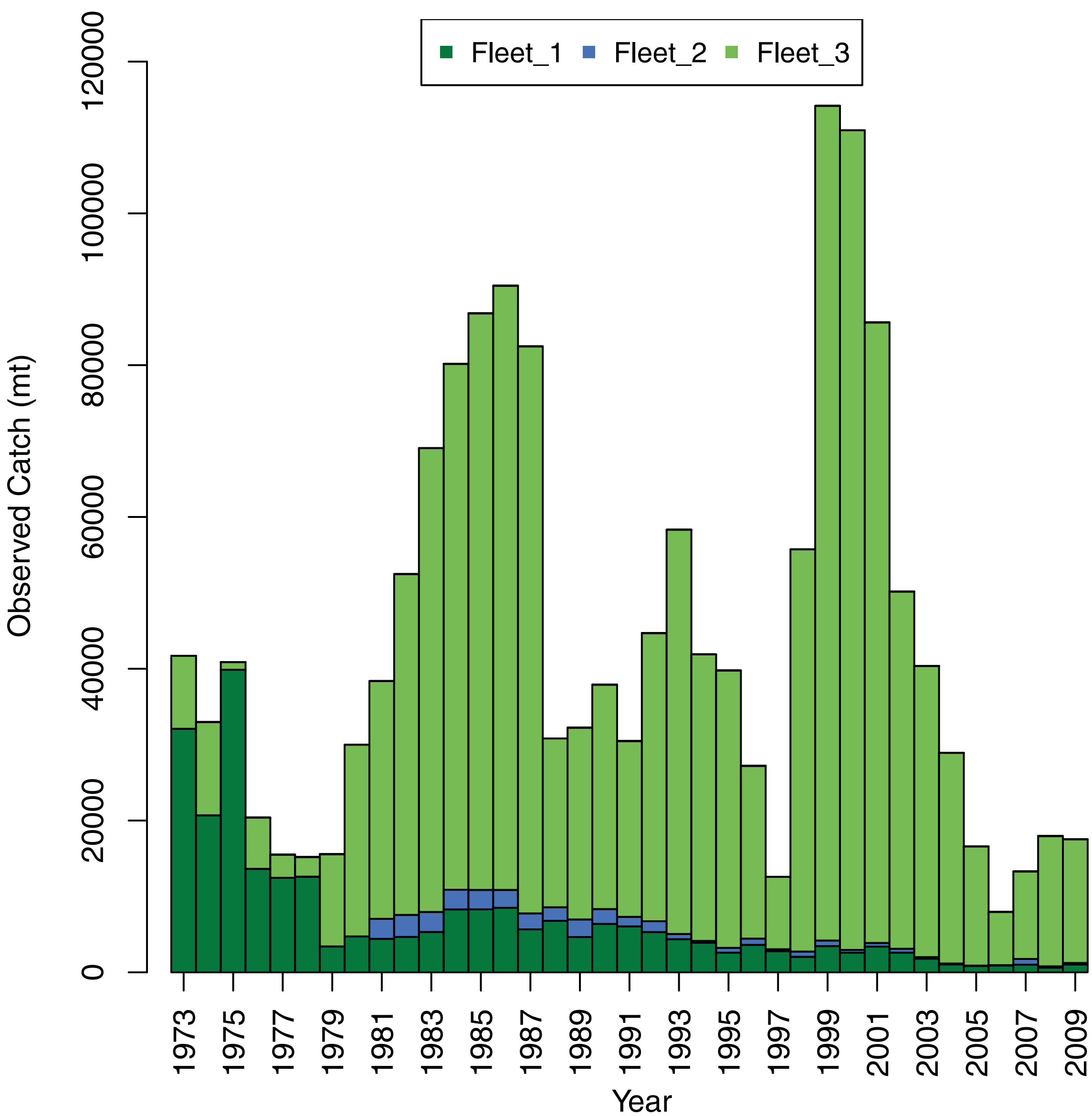

SSB (mt)
0
20000
60000
1975
1980
1985
1990
1995
2000
2005
2010
Year
F_report
0.0
1.0
2.0
3.0
1975
1980
1985
1990
1995
2000
2005
2010
Year

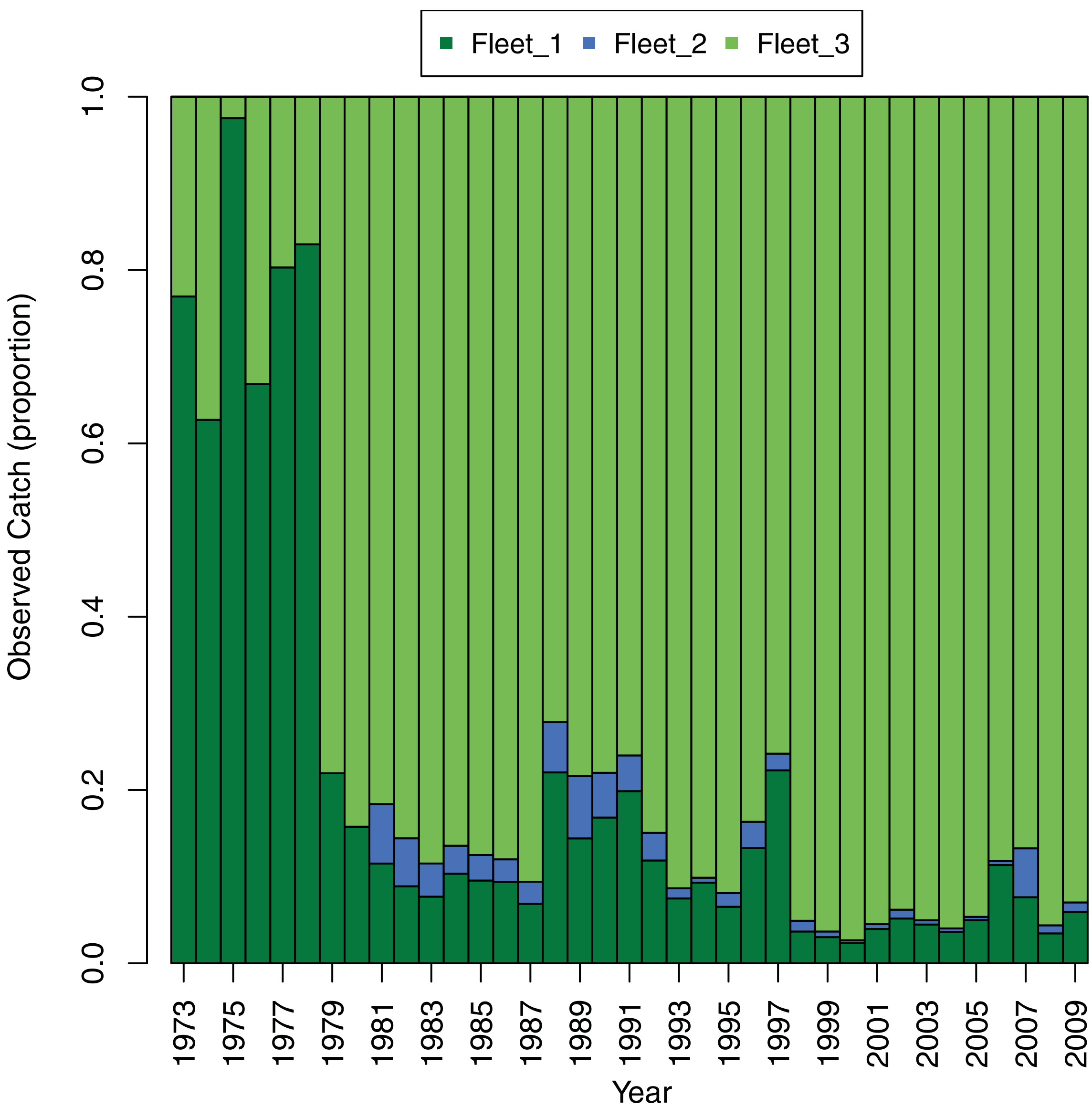


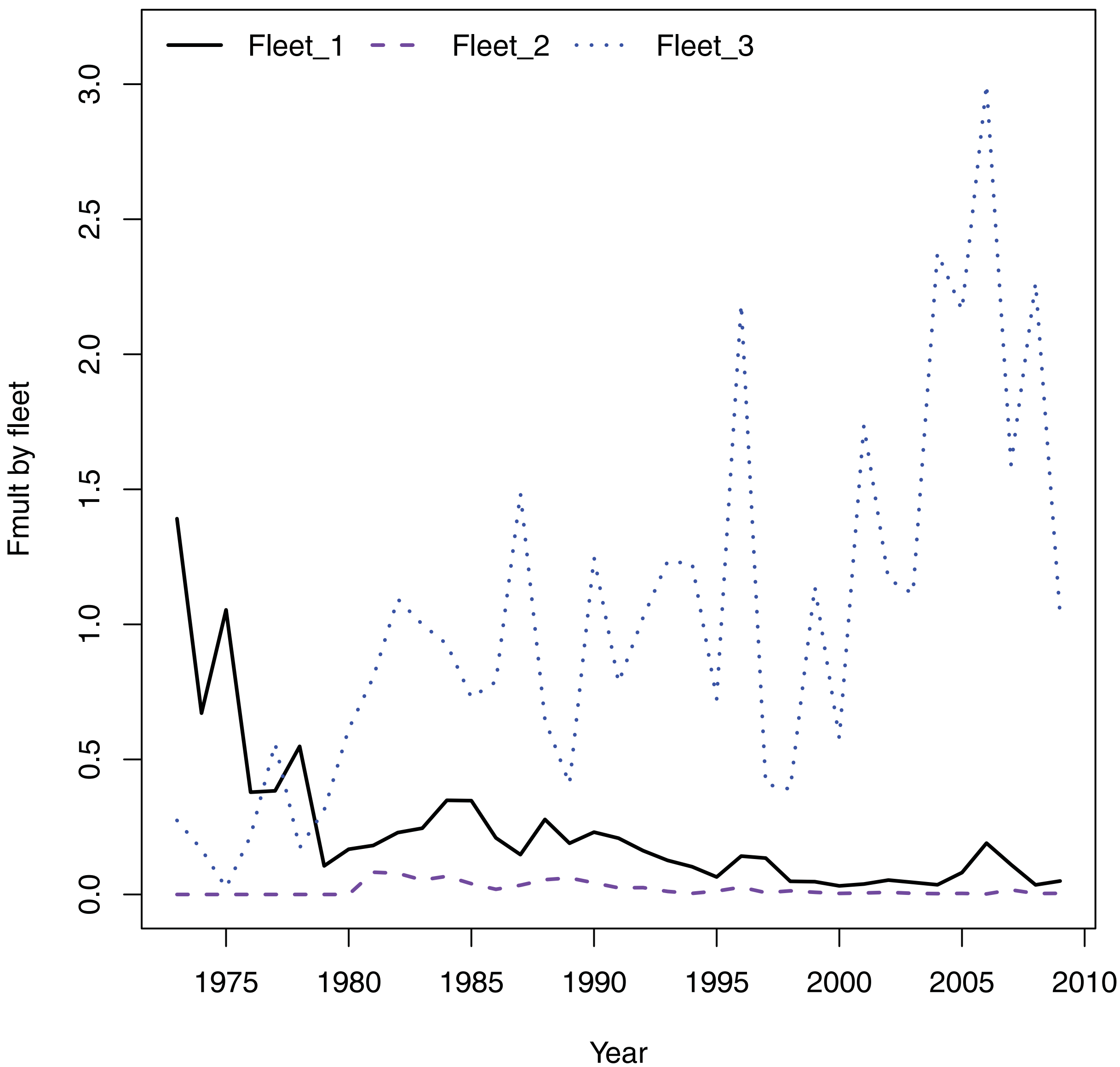
Relative Spawners (SSB/SSB0)
0.00
0.02
0.04
0.06
0.08
1975
1980
1985
1990
1995
2000
2005
2010
Year

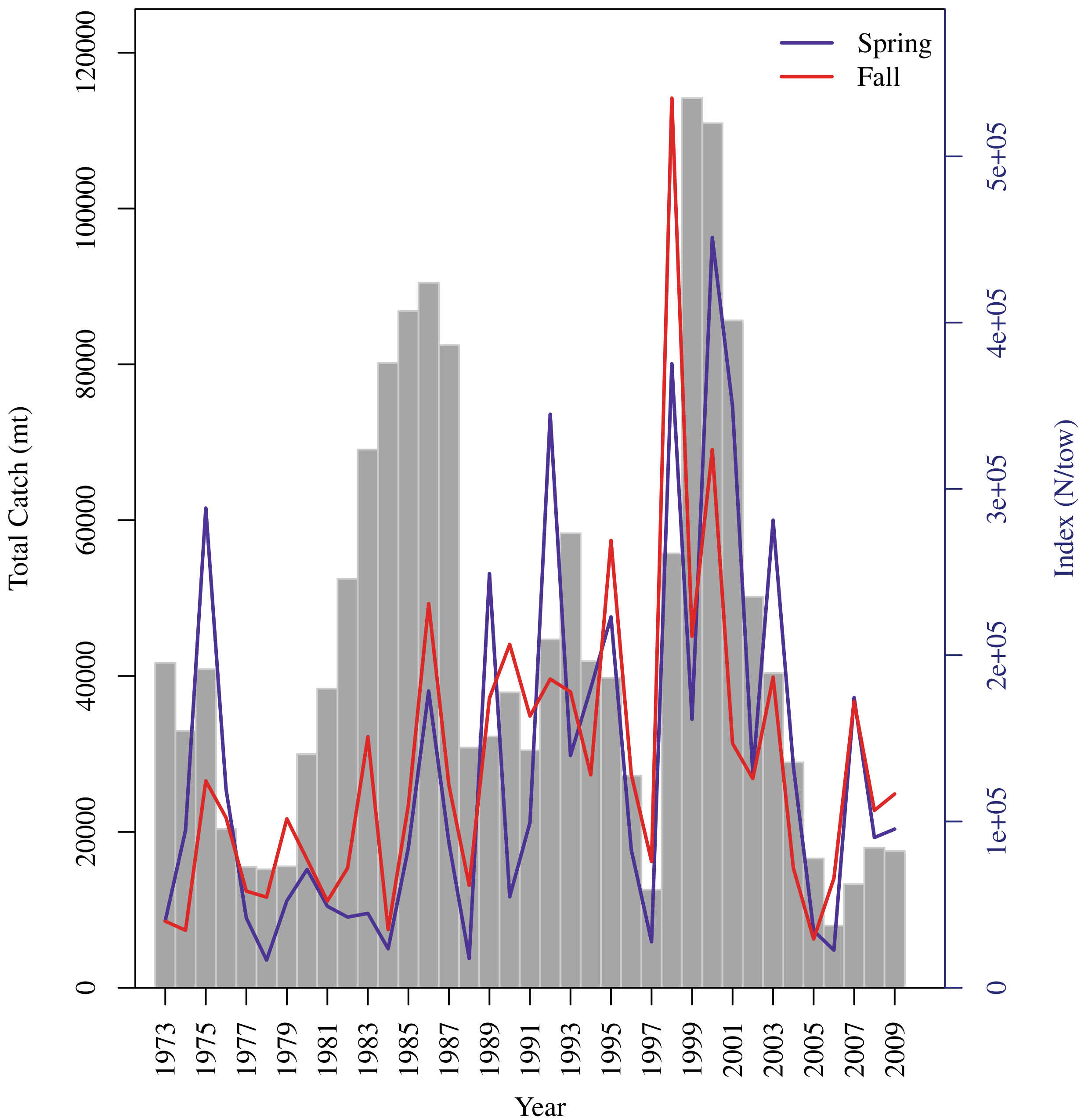

1
2
3
4
5
6
ASAP Estimated NAA
0
200000
600000
1000000
1400000
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

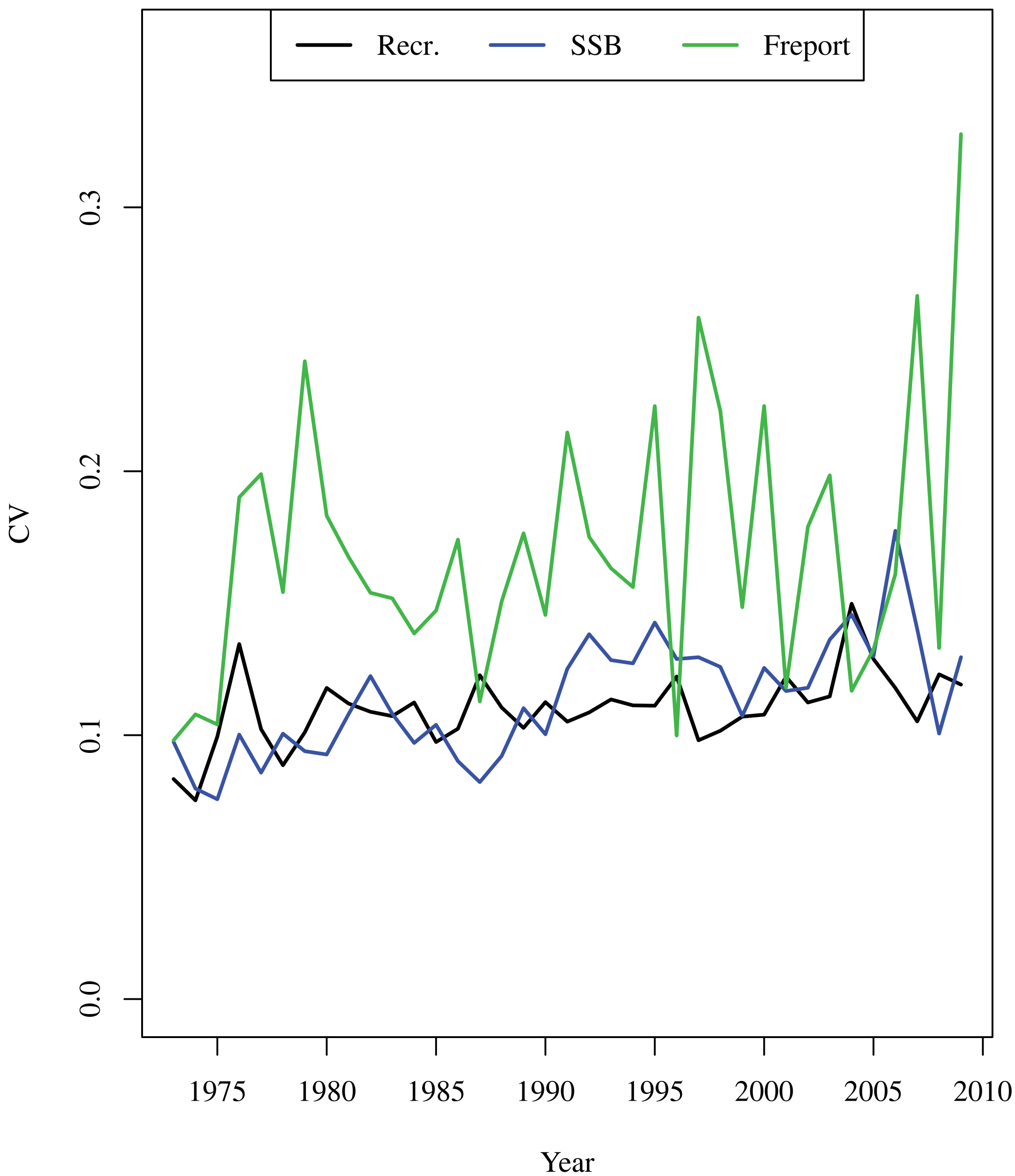

1
2
3
4
5
6
ASAP Estimated Proportion(NAA)
0.0
0.2
0.4
0.6
0.8
1.0
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year

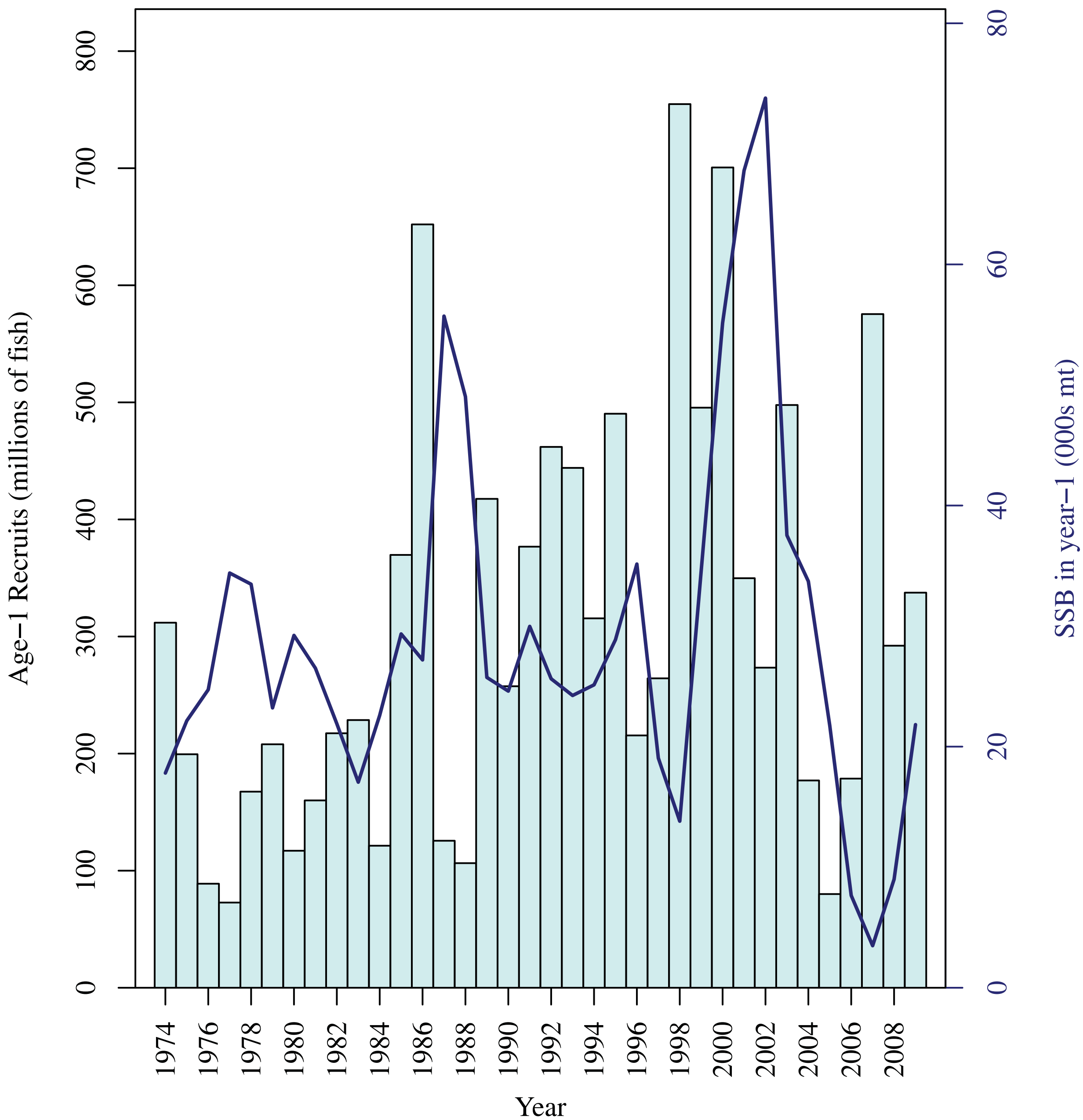

Fleet_1
Fleet_2
Fleet_3
Observed Catch (mt)
0
20000
40000
60000
80000
100000
120000
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year


Fleet_1
Fleet_2
Fleet_3
Observed Catch (proportion)
0.0
0.2
0.4
0.6
0.8
1.0
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
Year


Fleet_1
Fleet_2
Fleet_3
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Fmult by fleet
1975
1980
1985
1990
1995
2000
2005
2010
Year


Spring
Fall
Total Catch (mt)
Index (N/tow)
Year
0
20000
40000
60000
80000
100000
120000
0
1e+05
2e+05
3e+05
4e+05
5e+05
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009


Recr.
SSB
Freport
CV
0.0
0.1
0.2
0.3
1975
1980
1985
1990
1995
2000
2005
2010
Year


Age−1 Recruits (millions of fish)
0
100
200
300
400
500
600
700
800
SSB in year−1 (000s mt)
0
20
40
60
80
Year
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008

B. *Loligo pealeii* STOCK ASSESSMENT FOR 2010

Executive Summary

Term of Reference 1: Landings data are presented for 1963-2010 but the 2010 landings are preliminary and incomplete. Landings of squid (*Loligo pealeii* and *Illex illecebrosus*) during 1928-196 were taken inshore and ranged from 500 to 2,000 mt. Total landings were dominated by offshore distant water fleets during 1967-1984, averaging 20,130 mt with a peak of 37,613 mt in 1973. After 1986, fishing by distant water fleets was prohibited and landings from the U.S. fleets, dominated by those from the winter offshore fishery, averaged 16,610 mt during 1987-2009 with a peak of 23,738 mt in 1989. There is substantial uncertainty in the landings data prior to 1987, due to a lack of observer coverage of distant water fleets prior to 1978 and reporting of unspecified squid catches.

Overall, annual discards were low, averaging 3.4% of the landings during 1989-2009. However, precision of the estimates was also low. Annual CVs averaged 0.53 during this same period. During 1988-1995, catches were generally at or above the 1987-2008 median (17,328 mt), but have generally been below the median since in-season quotas were implemented, in 2000. After 2005, catches declined and reached the lowest level since 1968 in 2009 (9,560 mt).

Annual trends in nominal LPUE (mt/day fished) were correlated for the January-June and July-December fisheries during 1996-2009. However, the trends are difficult to interpret because of one or more fishery closures during each year since 2000 and the lack of a clear understanding of what the LPUE values actually represent given the complex population dynamics of the species.

Term of Reference 2: *Characterize the survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, age-length data, etc.). Describe the uncertainty in these sources of data.*

NEFSC fall and spring bottom trawl survey data are used in this assessment to compute q-adjusted biomass estimates for two of the primary seasonal cohorts. The average lifespan of a seasonal *Loligo* cohort is about six months and the spring and fall surveys occur about six months apart. *Loligo* caught in the spring surveys (March) were hatched about six months prior, during the previous fall, and *Loligo* caught in the fall (September) surveys were hatched during the previous spring.

Swept-area biomass estimates from inshore fall NEAMAP surveys were used to account for biomass in inshore areas (≤ 18 m) which are no longer able to be sampled by the new research survey vessel starting in 2009. Only daytime survey tows are used in the assessment because *Loligo* are most available to bottom trawls during the daytime. The higher catch rates resulting from daytime tows were used in the swept-area biomass calculations and reduced the variance of the stratified mean survey indices during most years. CVs were on the order of 10-25%, indicating reasonable levels of precision.

As is typical for most squid species, abundance and biomass indices for *Loligo* were highly variable, particularly for NEFSC fall surveys, making it difficult to discern trends. The large differences in the biomass estimates for the seasonal cohorts caught in the spring and fall surveys are a major source of uncertainty. The spring biomass levels are only about one fifth of the fall biomass levels. Fall and spring survey indices from the same, but not adjacent, years are correlated. However, it is not known whether these "year" effects reflect true seasonal cohort dynamics for *Loligo*, which have a cohort lifespan of about 6 months, or if they are due to environmental effects on availability to the survey gear.

Term of Reference 3: *Estimate annual fishing mortality, recruitment and stock biomass for the time series, and characterize the uncertainty of those estimates (consider Loligo TOR-4). Include a historical retrospective analysis to allow a comparison with previous assessment results.*

A simple survey-based approach, similar to one of the methods used in the previous assessment, was used to estimate biomass and exploitation indices. The method is based on a composite q-prior for survey catchability which incorporates uncertainty and bounds on all of the key factors that affect *Loligo* catchability. Uncertainties in *q*-priors have been substantially reduced since the last assessment by an in-depth review of existing and new information and the results of paired-tow catchability experiments using the survey vessels, SRV *Albatross IV* and SRV *H. B. Bigelow*. For "best estimates", we used the median *q*-prior catchability value because the chance of being either too low or too high is 50% (the median is risk-neutral). One of the most important aspects of the *q*-prior is the upper bound for survey catchability, which corresponds to the upper bound for fishery exploitation and the minimum bound for biomass.

Annual measures of biomass were derived by averaging the annual biomass estimates for the NEFSC fall and spring surveys after adjustment using the median *q*-prior for catchability. Annual biomass fluctuated widely about the median of 76,329 mt during 1976-2009 and ranged between 25,806 mt and 175,894 mt. Annual exploitation indices were computed as the annual catch divided by the annual biomass. However, the rapid growth rates, high cohort turnover rates and short lifespan of *Loligo* make the exploitation indices difficult to interpret. During 1993-1998, annual exploitation indices were generally at or above the 1987-2008 median (0.237), averaging 0.273, and generally at or below the median during 1999-2008, averaging 0.18.

Seasonal *Loligo* cohorts have different growth rates and the assessment results suggest that cohorts caught in the spring and fall surveys appear to have very different levels of productivity and biomass. Exploitation indices for the January-June fishery (median = 0.315) are much higher on the lesser productive, spring survey cohort than the exploitation indices for the July-December fishery (median = 0.064) on the more productive fall survey cohort.

Comparison of results from the current assessment with results from historical assessments is difficult because of the lack of temporal overlap between assessments and changes to the data and methods used to estimate stock status. The majority of assessments relied on relative trends in survey data. The stock is now considered lightly exploited but overfishing was determined to be occurring in 2 out of 4 historical assessments. The stock has never been considered overfished, although it was close to its biomass threshold at the time in two cases. In contrast, the current assessment concludes that the stock was not overfished and that overfishing was probably not occurring in 2009.

Term of Reference 4: *Summarize what is known about consumptive removals of Loligo by predators and explore how this could influence estimates of natural mortality (M).*

On an annual basis, *Loligo* catches appears minor relative to preliminary minimum consumption estimates for a subset of fish predators (i.e. without adjusting abundance for some predators to account for survey catchability and excluding consumption by birds, large pelagic fish and marine mammals). Thus, the consumption data for *Loligo* provide a frame of reference for judging the potential importance of fishery removals.

Minimum consumption is generally higher on the fall survey cohort than on the spring survey cohort. Seasonal estimates of minimum consumption are a substantial fraction of the estimated biomass, particularly during the spring.

This assessment did not require any assumptions about M. However, natural mortality rates for non-spawning *Loligo* are known to be high based on their short 6-8 month lifespan, and because the species is semelparous, natural mortality rates after spawning are even higher. Based on the results from two models that have been used to estimate M for other squid species, preliminary estimates of non-spawning and spawning mortality are 0.11 and 0.19-0.48 per week, respectively. It is doubtful that consumption data would substantially change or improve these estimates of *M*.

Term of Reference 5: *State the existing stock status definitions for the terms "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and $F_{MSY;}$ and estimates of their uncertainty). Comment on the scientific adequacy of existing BRPs and for the "new" (i.e., updated, redefined, or alternative) BRPs.*

The current overfishing definition states that overfishing is occurring when the exploitation index falls below the 75th percentile of the quarterly exploitation indices during 1987-2000. However, there is no sound scientific basis for using this F_{MSY} proxy because the *Loligo* stock is lightly exploited. Under these conditions, any percentile of the exploitation time series is unsuitable as an estimate of or proxy for F_{MSY}.

Conventional approaches for deriving BRPs are based on finfish population dynamics and are inappropriate for *Loligo*. In particular, there is no theory linking *M* and F_{MSY} for short lived squid species like *Loligo* and per-recruit reference points can only be approximated (a). In addition, there is no theory linking F_{SPR} per-recruit reference points to F_{MSY} for species like *Loligo*. Finally, there is too little contrast in the catch or survey data to provide information that could be used to estimate F_{MSY} in a modern dynamical model.

There are no existing biomass-based reference points. The current assessment recommends a new threshold B_{MSY} proxy of 21, 203 mt and a biomass target of 42, 405 mt. B_{MSY} is estimated as $B_{MSY} \approx 0.5\frac{\breve{b}}{0.9}$ where $\breve{b}$ is the 1976-2008 median annual biomass (76,329 mt). Annual biomass is defined as the average the annual biomass estimates for the NEFSC fall and spring surveys after adjustment using the median q-prior for catchability. The median biomass is assumed to represent 90% of carrying capacity because the stock is lightly fished. If the underlying surplus production curve is symmetrical, B_{MSY} occurs at 50% of the carrying capacity. Annual biomass estimates exceed annual carrying capacity in multiple years, which is to be expected for a species with highly variable seasonal population dynamics which are linked to variability in environmental conditions. It is not necessary for *b* to be in biomass units because unscaled survey data would give the same results.

Term of Reference 6: *Evaluate stock status with respect to the existing BRPs, as well as with respect to the "new" BRPs (from Loligo TOR 5).*

There are no existing biomass reference points for the stock, and as a result, overfished status cannot be determined. Based on the current fishing mortality reference point threshold, overfishing was not occurring because the 2009 exploitation index (estimated using the method from SARC 34, Oct-Dec. catch over *q*-adjusted fall survey swept-area biomass) was 0.063 compared to the Fthreshold (i.e., 75th percentile of the exploitation indices during 1987-2009) which is 0.277). However, the current F reference point is inappropriate for the lightly exploited *Loligo* stock. In addition, the new exploitation indices used in the current assessment are not comparable to the existing fishing mortality reference points because of differences in computation methods and input data.

Based on the new recommended biomass reference point threshold from SAW/SARC-51, the stock was not overfished during 2009. The two-year average of catchability-adjusted spring and fall survey biomass levels during 2008-2009 was 54,442 mt (80% CI = 38,452-71,783 mt) and is higher than the proposed threshold Bmsy proxy of 21,203 mt. The overfishing status during 2009 is unknown because new fishing mortality reference points could not be recommended in the current assessment due to the lack of evidence that fishing impacted annual biomass levels during 1975-2009. The 2009 exploitation index of 0.176 (catch in 2009 divided by the average of the spring and fall survey biomass during 2008-2009; 80% CI = 0.124-0.232) was slightly below the 1987-2008 median of 0.237.

Term of Reference 7: *Develop approaches for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs), and comment on the ability to perform projections for this stock.*

Possible approaches

Use the omnibus amendment approach. The Council is developing an omnibus amendment that provides the SSC with a general procedure for setting ABC levels. The omnibus approach ranks stocks into four tiers, depending on the information about the stock and reference points provided in the assessment. The omnibus approach is flexible and may well be a sufficient basis for specifying ABC levels for the *Loligo* fishery.

Consider the differences in seasonal cohort productivity and biomass. *Loligo* biomass and productivity appear to be substantially lower for the cohort caught in the spring survey than for the cohort caught in the fall survey. Lower spring biomass may be due to a variety of factors, including differences in available habitat, migration patterns, seasonal reproduction, differences in growth rates, and/or consumption removals. Within-year relative abundance indices from the spring and fall surveys are correlated and exploitation indices for the January-June fishery (median = 0.315) are much higher on the less-productive, spring survey cohort than those for the

July-December fishery (median = 0.064) on the more-productive fall survey cohort.

ABC by analogy to consumption estimates for key predators. *Loligo* are prey for a wide range of marine fish, diving birds, and marine mammals. Natural mortality rates for non-spawning *Loligo* range from 0.058 to 0.110 per week (3.0 to 5.7 per year) due, presumably, to predation. The ecological importance of *Loligo* as prey for a wide range of species could be considered in specifying ABC levels.

Consumption estimates for six (cod, bluefish, goosefish, pollock, summer flounder and weakfish) of the 15 *Loligo* finfish predators included in this assessment are based on predator stock biomass estimates from peer-reviewed assessment reports that include estimates of survey catchability. The consumption estimates for these six species may be plausible estimates of consumption. Considering consumption by humans and fish predators, specifying ABC levels for *Loligo* based on consumption estimates for important predators may be a practical approach to ecosystem-based management. Consumption is generally higher during the fall than spring and seasonal differences could be considered as well.

Term of Reference 8: *Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.*

Substantial progress was achieved for many of the research recommendations in the last assessment and a number of additional topics were identified. Please see the relevant portions of the text.

Terms of Reference

1. Characterize the commercial catch including landings, effort, LPUE and discards. Describe the uncertainty in these sources of data.

2. Characterize the survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, age-length data, etc.). Describe the uncertainty in these sources of data.

3. Estimate annual fishing mortality, recruitment and stock biomass for the time series, and characterize the uncertainty of those estimates (consider *Loligo* TOR 4). Include a historical retrospective analysis to allow a comparison with previous assessment results.

4. Summarize what is known about consumptive removals of *Loligo* by predators and explore how this could influence estimates of natural mortality (M).

5. State the existing stock status definitions for the terms "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and $F_{MSY;}$ and estimates of their uncertainty). Comment on the scientific adequacy of existing BRPs and for the "new" (i.e., updated, redefined, or alternative) BRPs.

6. Evaluate stock status with respect to the existing BRPs, as well as with respect to the "new" BRPs (from *Loligo* TOR 5).

7. Develop approaches for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs), and comment on the ability to perform projections for this stock.

8. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

Introduction

Range, distribution and life history

Longfin inshore squid (*Loligo pealeii*) are distributed primarily in continental shelf waters located between Newfoundland and the Gulf of Venezuela (Cohen 1976; Dawe *et al.* 1990). In the northwest Atlantic Ocean, longfin squid are most abundant in the waters between Georges Bank and Cape Hatteras, NC where the species is commercially exploited. The stock area extends from the Gulf of Maine to southern Florida. However, the southern limit of the species' distribution in US waters is unknown due to an overlap in geographic distribution with the congener, *Loligo pleii*, which cannot be visually distinguished from *L. pealeii* using gross morphology (Cohen 1976). A recent genetics study indicates that the population inhabiting the waters between Cape Cod Bay, MA and Cape Hatteras, NC is a single stock (Shaw *et al.* 2010). Distribution varies seasonally. North of Cape Hatteras, squid migrate offshore during late autumn to overwinter in warmer waters along the shelf edge and slope, and then return inshore during the spring where they remain until late autumn (Jacobson 2005).

The life history characteristics of short-lived, semelparous cephalopod species, like *Loligo pealeii*, present some unique challenges to stock assessment and most of the traditional approaches that have been used for finfish species have not been successfully applied to squid stocks (Boyle and Rodhouse 2005). *Loligo pealeii* serves as a key prey species for a variety of marine mammals, diving birds, and finfish species (Clarke 1996; Overholtz *et al*. 2000; Jacobson 2005). Consequently, natural mortality rates are very high, especially after spawning. The species is migrates long distances during its short lifespan; inshore during spring and offshore during late fall. Recruitment occurs throughout the year with seasonal peaks in overlapping "microcohorts" which have rapid and different growth rates (Brodziak and Macy 1996; Macy and Brodziak 2001). As a result, seasonally stable biomass estimates may mask substantial population turnover (Guerra *et al*. 2010). Recruitment of *L. pealeii* is largely driven by environmental factors (Dawe *et al.* 2007). For most squid species, temperature plays a large role in migrations and distribution, growth, and spawning (Boyle and Rodhouse 2005). For *Loligo pealeii*, individuals hatched in warmer waters during the summer grow more rapidly than those hatched in winter and males grow faster and attain larger sizes than females (Brodziak and Macy 1996).

A schematic of the life history of *Loligo pealeii*, in relation to the timing of the directed fisheries and NEFSC surveys is shown in Figure B1. Recruitment occurs year-round with seasonal peaks in cohorts. The average lifespan of a *Loligo pealeii* cohort is about six months. Individuals hatched inshore during the summer are taken in the winter offshore fishery and those hatched in the winter are taken in the inshore summer fishery (Macy and Brodziak 2001). Age data indicate that NEFSC spring surveys (March-April) capture *Loligo* that were hatched during the previous six months, in the fall, and *Loligo* caught in the NEFSC fall surveys (September-October) were hatched during the previous spring. *Loligo peaeleii* attaches its egg masses to the substrate and fixed objects (MAFMC 2009). Fishing and spawning mortality occur concurrently during late spring through fall, when spawning *Loligo* and an unknown proportion of their egg masses are taken inshore, in bottom trawl fisheries (Hatfield and Cadrin 2002) and in weirs (MAFMC 2009). The locations of spawning sites at other times of the year are unknown.

Management background

During 1974-1977, the *Loligo pealeii* stock was managed by the Northwest Atlantic Fisheries Organization (formerly ICNAF) and was subject to annual TACs (Lange and Sissenwine 1980). Historically, the distant water fleets fishing for *Loligo* were subject to a minimum codend mesh size (60 mm inside stretched mesh), fishing in defined offshore fishing areas during the fall and winter (Kolator and Long 1980). Since 1978, the stock has been managed by the Mid-Atlantic Fishery Management Council (MAFMC) under the Atlantic Mackerel, Squid, and Butterfish Fishery Management Plan (MSB FMP). Distant water fleets have been prohibited from fishing for *Loligo pealeii* in US waters since 1987. Since 1996, the primary stock management measures have included: a total allowable catch (TAC); mandatory reporting of *Loligo* landings purchased by federally-permitted dealers; and mandatory submittal of Vessel Trip Reports (VTRs) by fishermen who possess federal *Loligo*/butterfish moratorium and incidental catch permits (Table B1). A minimum codend mesh size requirement of 48 mm (1 7/8 in., inside stretched mesh) and a strengthener minimum mesh size of 114 mm (4.5 in.) were also implemented in 1996.

Since 2000, the *Loligo* fishery has been subject to in-season quotas which were trimester-based during 2000 and 2007-2010 and quarterly-based during 2001-2006. When the in-season quotas are attained, trip limits of < 2,500 lbs go into effect. Since 2000, *Loligo* fishery closures have occurred when 90% of each trimester or quarterly quota was landed or when 95% of the annual quota was landed. Closures have occurred at least once per year under this management system (Table B2). The annual quota has only been exceeded once, during 2000, when the quota of 15,000 mt was exceeded by 16.5%. Currently, the annual quota is allocated as: 43% in Trimester 1, 17% in Trimester 2, and 40% in Trimester 3. Currently, there are also roll-overs of quota underages (Trimester 1 toTrimesters 2 and 3; Trimester 2 to Trimester 3) and overages (Trimesters 1 and 2 to Trimester 3).

Term of Reference 1: *Characterize the commercial catch including landings, effort, LPUE and discards. Describe the uncertainty in these sources of data.*

The stock boundary includes all Statistical Areas located within the Northeast Region of the Northwest Atlantic Ocean (Figure B2). Commercial landings data are available for 1963-2009 (Table B3, Figure B3). The 2010 landings data are presented as well, but are preliminary and incomplete (i.e, retrieved from the landings database on October 27, 2010).

Several caveats are important in interpreting landings data. The two major species of squid landed in US east coast waters (i.e., *Illex illecebrosus* and *Loligo pealeii*) were not recorded by species until 1979. Landings during 1963-1978 for each species were estimated by proration (Lange and Sissenwine 1980). Since 1979, a portion of the U.S. squid landings have been reported as unspecified squid species (i.e., *Illex illecebrosus* and *Loligo pealeii*). Unspecified squid landings for 1982-1995 were prorated by month and two-digit Statistical Area by Cadrin and Hatfield (1999) and these landings are included in the current assessment. Unspecified squid landings reported from 1996 onward have been much lower (0- 161 mt per year), and since a majority of the prorated landings of unspecified squid are *L. pealeii* landings, all unspecified squid landings were combined with the *L. pealeii* landings for 1996-2009.

Several different methods have been used to collect the landings, fishing location and effort data. During 1963 through April of 1994, U.S. commercial landings, effort, fishing area, and other fishery-related data were collected and entered into Northeast Region Commercial Fisheries Database (CFDBS) by NMFS port agents, who entered landings data from all dealer purchase receipts and interviewed a subset of captains to obtain information about fishing location and effort (Burns *et al*. 1983). Since then, landings data have been self-reported electronically by dealers who have a federal permit to purchase *Loligo*, but such reporting was not mandatory until 1996. Beginning in May of 1994, fishing location (Statistical Area) and effort data, plus estimated catch, were self-reported by fishermen on logbooks (i.e., Vessel Trip Reports or VTRs) and are entered into the Vessel Trip Report Database. However, submittal of VTRs was not mandatory for fishermen who hold *Loligo* fishing permits until 1996. In order to integrate data from the VTR Database with data from the CFDBS, an "allocation" database was created using a trip-based allocation scheme (Wigley *et al*. 2008). Landings data are assumed known and originate from the CFDBS. The allocation determines the area fished and effort information reported on the VTR data and joins this information with the landings data from each trip as reported in the CFDBS. Two levels (A and B) represent vessel-oriented data and two levels (C and D) represent fleet-oriented data. Level A comprises audited VTR trips that have not been grouped and for which a one-to-one match exists between the VTR and CFDBS fields which define a trip (i.e., year, month, day and permit). Level B comprises VTR trips from Level A that have been pooled by vessel permit, gear group, main species group, and month. Level C comprises VTR trips from Level A that have been pooled by ton class, port group, gear group, main species group, and calendar quarter. Level D comprises VTR trips from Level A that have been grouped by port group. If a CFDBS trip has a corresponding one-to-one match with a VTR trip, then the area fished and the effort information, if present, is transferred directly onto the CFDBS trip record. "A" level trips correspond to pre-1994 trips for which similar information was obtained from a vessel captain via a port agent interview.

Landings

The U.S. squid fishery began in the late 1800s as a source of bait, and from 1928 to 1967, annual squid landings (including *Illex illecebrosus* landings) from Maine to North Carolina ranged from 500 to 2,000 mt (Lange 1980). During 1964 through the mid-1980s, landings of *L. pealeii* by distant water fleets occurred in offshore waters and landings by the U.S. fishery occurred when *Loligo* were available inshore during spring and summer (Lange *et al*. 1984). Total landings increased rapidly during 1967-1973 with the development of a directed fishery by distant water fleets in offshore waters, from 1,677 mt in 1967 to a peak of 37,613 mt in 1973, but then declined to 10,646 mt in 1978 (Figure B3, Table B3). Total landings were dominated by landings from the foreign fleets during 1967-1984, ranging between 76% and 98% of the total landings during most years and averaging 20,130 mt.

During 1978-1982, bottom trawlers engaged in directed fisheries for *Illex* and *Loligo* in U.S. waters were required to fish with a minimum codend mesh size of 60 mm (with specific chafing gear requirements) and were restricted to fishing seaward of the 183 m isobath and during late fall through winter (ICNAF 1978). Fishing by distant water fleets was phased out by 1987 due to the development of an offshore U.S. fishery for *L. pealeii*. There is substantial uncertainty in the landings data prior to 1987, due to the lack of observer coverage of distant water fleets prior to 1978 and low coverage thereafter, and because unspecified squid landings were as high as 20% during some years (Cadrin and Hatfield 1999).

The domestic fishery currently occurs primarily in Southern New England and Mid-Atlantic waters, but some fishing also occurs along the southern edge of Georges Bank. Spatial patterns in fishing effort reflect seasonal *Loligo* migration patterns whereby effort is generally directed offshore during October-March and inshore during April-September (Figure B4). The fishery is dominated by small-mesh otter trawlers, modal codend mesh size = 50 mm inside stretched mesh (Hendrickson 2011), but near-shore pound net and weir fisheries also occur during spring and summer. During 1963-1982, the domestic fishery occurred primarily in inshore waters during spring and summer. Offshore fishing by U.S. vessels began in 1983. During 1987-1999, total landings averaged 18,453 mt with a peak of 23,738 mt in 1989 (Table B3).

Since the implementation of in-season quotas, in 2000, landings have been lower (averaging 14,214 mt) and have declined from 16,720 mt in 2005 to 9,307 mt in 2009. Although preliminary and incomplete, the 2010 landings through mid-October are very low (5,256 mt). Despite a general decline in landings during 1994-2009, the annual ex-vessel price (average dollars per lb in 1990 dollars) of *L. pealeii* increased during 1990-1998 (from $0.43/lb to $0.83/lb), then decreased to $0.60/lb in 2000, but remained remained fairly stable thereafter (Figure B5). Since 1996, annual TACs have ranged between 15,000 mt and 25,000 mt and were only exceeded in 2000, when the annual TAC of 15,000 mt was exceeded by 16.9% (Table B3).

Changes in the monthly distribution of landings occurred during 1987-2009, particularly during the first half of the year. Since 1989, most of the landings have been taken in the offshore winter fishery, during Quarters 1 and 4 (Cadrin and Hatfield 1999). Between 1987-1995 and 1996-1999 (mandatory reporting of squid landings began in 1996), landings increased by 9% during Quarter 1 and decreased by 9% during Quarter 2, but remained similar during Quarters 3 and 4 (Figure B6).

Since 2000, the seasonal distribution of landings has been affected by in-season quotas (i.e., quotas were trimester-based in 2000 and during 2007-2009 and quarterly-based during 2001-2006) which have led to one or more fishery closures per year. Landings increased during January from 10% during 1996-1999 to 13% during 2000-2009. Landings during Quarter 2 increased from 16% during 1996-1999- to 18% during 2000-2009 (Figure B6). During 2007-2009, landings during Trimesters 1-3 represented 43%, 26% and 32% of the total landings, respectively.

During 1994-2009, most of the *Loligo* landings were from Rhode Island ports which accounted for 40-50% of the total during 1994-2002 and 55-60% of the total during 2003-2009 (Figure B7). The second and third highest percentages of the annual landings since 1994 were from New York (15-34%) and New Jersey ports. The proportion of total landings in New Jersey ports declined from 31% in 1994, to 9% in 2004 then increased to 17% in 2009. Massachusetts and Connecticut ports accounted for < 10% of landings since 1994.

Landings size composition

The size composition of the landings was estimated from samples collected at the principal ports where *Loligo* are landed. The numbers of samples and landings length composition for 1987-1995 was taken from Cadrin and Hatfield (1999) and the landings length composition for 1996-2009 was updated for the current assessment. Annual sampling intensity was low during 1987-1996, ranging between 48 and 94 trips per year, with no sampling of trips during some months (Table B4). After 1996, sampling intensity increased and ranged between 131 and 214 trips per year with sampling during every month.

Most *L. pealeii* landings during 1987-1996 were landed as "Unclassified" rather than by market category (i.e., Large, Medium, Small and Super Small). After 1996, sampling occurred by market category and the numbers of length samples also increased (Table B5). During 1996-2009, there was a large amount of size overlap between the different market categories (Figure B8). Most samples were from the Unclassified size category, which includes all sizes except for a portion of squid in the Large size category.

Landings at length were estimated using monthly, quarterly and half-year time bins, depending on sample availability by month and market category. Numbers of *Loligo* length samples, by month and market category, are presented in Table B6. Unclassified sizes were prorated. Sampled length compositions were expanded to the landings using predicted sample weights (Lange and Johnson 1981). A small proportion (< 0.05) of squid between 5 and 8 cm dorsal mantle length (DML) are partially recruited to the fishery, but most pre-recruits are > 8 cm DML. Squid were fully recruited to the fishery at 12 cm DML during 1987-2009 (Figure B9). Length compositions of the landings were similar for 1996-1999, a period of annual quota management, and 2000-2009, a period of in-season quota management, but a greater proportion of squid larger than 18 cm DML were landed during 1987-1995 (Figure B9).

Discards

Kept and discarded portions of the catches, along with length composition data for both portions, have been collected onboard fishing vessels by the Northeast Fishery Observer Program (NEFOP) since 1989. Discards for the most recent *Loligo* assessment (NEFSC 2002a) were assumed to be 6% of the landings, based on an analysis conducted by (Cadrin and Hatfield (1999). Cadrin and Hatfield (1999) computed an average ratio of discarded to kept *Loligo* of 6% based on observed tows from all otter trawl trips (N=915 trips) which landed *L. pealeii* during 1989-1998 . Quarterly discard to kept ratios for these trips were scaled up to the quarterly landings then summed across quarters to obtain annual discard estimates. The total amount of discards from trips with no *Loligo* landings (i.e., trips where all *Loligo* catches were discarded) was minor (10 mt for 207 trips).

For the subject assessment, the combined ratio method (Wigley *et al.* 2007), which has become the standard discard estimation methodology for the Northeast Fisheries Science Center stock assessments, was used to estimate *Loligo* discards (mt) and their precision (CV) during 1989-2009. The combined ratio method is based on a ratio estimate pooled over all strata and trips within a fleet. For each trip, a combined discard to catch (d/k) ratio estimator (Cochran 1977) was computed using NEFOP data, where d = discard weight of *Loligo* and k = kept weight of all species. These discard ratios were then expanded by the total weight of all species landed during a trip (using landings from the dealer database) to estimate total discard weight.

Strata included in the discard analysis included: gear type, bottom trawl codend mesh size, and fishing region. The majority of *Loligo* discards occur in trawl fisheries Cadrin and Hatfield 1999). Therefore, bottom trawls, midwater trawls and scallop trawls/dredges were included in the current discard analysis. Fishing trips that occurred within in Statistical Areas ≥ 600 and < 600 were defined as the Mid-Atlantic and New England regions, respectively. Bottom trawl codend mesh sizes categories included: large mesh (codend mesh sizes ≥ 5.5 in.), medium mesh (codend mesh sizes of 2.5-5.49 in.), and small mesh (codend mesh sizes < 2.5 in.). Discards were estimated by quarter and cells with fewer than two trips were imputed using the respective annual estimate for each stratum. Discards that occurred during years where no trips were sampled for a particular fleet were estimated by interpolation and are noted as such in the discard summary tables.

The largest source of *Loligo* discards during 1989-2009 was from bottom trawl fisheries (≥ 95% during most years), primarily the small-mesh bottom trawl fisheries, which accounted for 60-98% of the total annual discards during 2001-2009 (Table B7). Most of the small-mesh discards occurred in the Mid-Atlantic region (Table B8). During 2000-2003, when seasonal *Loligo* quotas were frequently attained and a trip limit of 2,500 lbs was in place, regulatory discarding of *Loligo* occurred in the directed fishery (MAFMC 2009).

Loligo discard estimates were highly variable inter-annually, ranging between 54 mt and 2,140 mt and averaging 534 mt during 1989-2009 (Table B7). However, the 95% confidence intervals of the annual estimates were very wide (Figure B10). Overall, annual discards were low in relation to landings, averaging 3.4% of the landings during 1989-2009. Annual CVs averaged 0.53 during this same period (Table B7). Annual CVs for the small-mesh fleets were lower during 2004-2009 (0.26-0.77), concurrent with increased sampling of small-mesh bottom trawl trips in the Mid-Atlantic region. However, the annual numbers of Mid-Atlantic small-mesh trips that were sampled during 2004-2009 (57-145 trips per year) were very low compared to the numbers of trips for medium and large-mesh fleets (Table B8, Figure B11). In addition to low sampling coverage, the high variability in discard ratios for this schooling species also probably affected the precision of the discard estimates.

Size composition of the discards

During 1989-2009, the numbers of NEFOP observer trips sampled for length compositions of the catches for directed *Loligo* trips (i.e., tows where the captain specified *Loligo peaelii* as the target species) was fairly high for the kept portion of the catch, particularly from 2004 onward, but the numbers of trips sampled for discards was quite low during most years (Table B9). The low sampling intensity of the discards may have been attributable to a low incidence of discarding, but this possibility was not examined.

Since 2000, *Loligo* trip limits have been in effect for the directed fishery during portions of each year. Therefore, discard size compositions were compared for 1994-1999, 2001-2006 and 2000 and 2007-2009. The discard reason indicated by the captain for most tows was lack of a market for small individuals and this is evident in the discard size composition data. The modal size of the discards was 5 cm DML during 1994-1999, and was 8 cm DML from 2000 onward (Figure B12). Discards were generally small squid (≤ 10 cm DML), but a greater percentage of squid larger than 10 cm were discarded during 2001-2006, a period when the fishery was closed multiple times per year during 2002, 2005 and 2006 (Table B2). The size compositions of the kept portions of the catches during 2000-2009 were similar to the size composition of the landings during the same time period (Figure B9), with a modal size of about 12 cm DML (Figure B12).

Catches

Total catches during the period of dominance by the distant water fleets (1967-1984) averaged 20,814 mt with a peak of 38,892 mt in 1973 (Figure B13; Table B10). During the period of dominance by the domestic fishery, (1987-2009), catches averaged 17,181 mt with a peak of 24,566 mt in 1994. Catches for 1989-2009 include quantitative estimates of discards. However, since most of the catch consists of landings, and landings are substantially uncertain prior to 1987 (Cadrin and Hatfield 1999), this assessment focuses on catches during 1987-2009. During 1988-1995, catches were generally at or above the 1987-2008 median (17,328 mt), but have generally been below the median since in-season quotas were implemented in 2000. After 2005, catches declined to the lowest level since 1968 in 2009 (9,560 mt).

Nominal LPUE

As described above in paragraph two of this Term of Reference, reporting of *Loligo* landings purchased by federally permitted dealers and *Loligo* catches by federally permitted fishermen did not become mandatory until 1996. Therefore, a nominal LPUE time series was derived from *Loligo* fishery data for 1996-2009. Since 2000, when in-season quotas were implemented, the regulatory definition of a directed *Loligo* trip has been a trip for which ≥ 2,500 lbs of *Loligo* was landed. Trips with ≥ 2,500 lbs of *Loligo* comprised 90% of the cumulative *Loligo* landings during 1996-1999 and 2000-2009 (Figure B14A), which equates to trips where *Loligo* comprised > 30% of the landed trip weight (i.e., the 40% bin in Figure B14B). During 1996-2009, most of the annual *Loligo* landings were taken in trips lasting 2-7 days (Figure B15). During 1996-2009, a fairly high percentage of the annual *Loligo* landings in the CFDBS, 60-75%, matched on a one-to-one basis with VTR trips (i.e., "A" level trips) and could be used to compute nominal LPUE (Figure B16). Nominal LPUE was calculated for the January-June fishery and the July-December fishery based on the regulatory definition of a directed *Loligo* trip.

During the period of quarterly landings quotas, 2001-2006, nominal effort (days fished) was higher during January and February, than when either annual or trimester quotas were in place (Figure B17). Since implementation of trimester-based quotas, in 2007, nominal effort during January-May has been greatly reduced, but annual effort has remained highest during January-March. Nominal effort in both the January-June and July-December fisheries were much lower during 2000-2009, than during 1996-1999, primarily due to fishery closures when the in-season quotas were attained (Table B11, Figure B18A).

In summary, the July-December fishery shows an increasing trend in nominal LPUE during 1996-2004, followed by a decrease through 2009 (Figure B18A). The nominal LPUE trend is similar for the January-June fishery, but the trend is delayed by one year. LPUE trends for the two fisheries are correlated ($r = 0.48$). However, these trends are difficult to interpret because of one or more fishery closures during each year since 2000 and the lack of a clear understanding of what the LPUE values actually represent given the complex population dynamics of the species and the fact that effort has not been standardized.

Term of Reference 2: *Characterize the survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, age-length data, etc.). Describe the uncertainty in these sources of data.*

Seasonal distribution patterns

The NEFSC conducts annual bottom trawl surveys, using a stratified random design (Azarovitz 1981), during the fall (generally during September-October) and spring (generally during March-April) between the Gulf of Maine and Cape Hatteras, North Carolina (Figure B19). Inshore strata (8-27 m) and offshore strata (27-366 m) have been most consistently sampled by the SRVs *Albatross IV* and *Delaware II* since 1975.

The distribution of *Loligo* during the spring and fall surveys depends on the timing of the survey in relation to the annual offshore and southerly migration of *Loligo* in the fall and the inshore and northerly migration of the species in the spring. In general, the species is distributed offshore during October-March and inshore during April-September. During fall surveys, *Loligo* are widely distributed across most of the shelf (Figure B20). Squid ≤ 8 cm DML (fishery pre-recruits) prefer shallow depths of < 55 m (catches were highest at bottom temperatures > 16°C) and squid larger than 8 cm DML (recruits) prefer deeper waters of 111-366 m where bottom temperatures are 11-16°C (Brodziak and Hendrickson 1999). During spring surveys, *Loligo* are distributed primarily in warmer offshore waters near the edge of the shelf (Figure B20) where bottom temperatures are ≥ 8°C (Summers 1969). A portion of the stock is also distributed south of Cape Hatteras, North Carolina during both survey periods. However, the amount is unknown because the strata south of Cape Hatteras are not consistently sampled during every survey and the species' range overlaps with the congener, *Loligo pleii*, which cannot be readily distinguished from *L. pealeii* at sea on the basis of gross morphology (Cohen 1976). Thus, it is unknown which of the two *Loligo* species is represented in the catches shown south of Cape Hatteras (Figure B20).

Survey relative abundance and biomass indices

Indices of relative abundance (stratified mean number per tow) and biomass (stratified mean kg per tow) were derived for fishery pre-recruits (≤ 8 cm DML) and recruits (> 8 cm DML), as well as all sizes combined, for NEFSC spring and fall bottom trawl surveys. Important improvements to the indices used in this assessment include:

1) Expanding the set of survey strata to include most of the surveyed area where *Loligo* occur. The previous assessment included only offshore habitat (strata 1-23, 25 and 61-76) and this assessment includes important inshore and offshore habitat (inshore strata 2-46, 58-61, and 65-66 plus offshore strata 1-23, 25-26, and 61-76).
2) Derivation of relative abundance and biomass estimates for both of the primary *Loligo* cohorts caught in the NEFSC fall (1975-2009) and spring surveys (1976-2010). An average of the annual spring and fall survey biomass is used as the main survey time series instead of using only the fall survey.
3) Use of an adjustment factor to account for the survey door change that occurred in 1985 (i.e., pre-1985 kg per tow x 1.24 ; no adjustment for number per tow (Byrne and Forrester (1991a)).
4) Use of SRV *Delaware II* catchability adjustment factors for both surveys to obtain *Albatross IV* equivalents (i.e., *DE II* number per tow x 0.83 and weight per tow x 0.85 (Byrne and Forrester 1991b)).
5) Use of "daytime" tows instead of using all tows with night and dawn/dusk converted to daytime equivalents using diel catchability factors estimated using a GLM
6) Addition of swept-area biomass estimates from the fall NEAMAP surveys to account for biomass in inshore areas (≤ 18 m) which are no longer able to be sampled by the new research vessel (SRV *H. B. Bigelow*) beginning in 2009.
7) Use of "daytime" calibration coefficients, as of 2009, to convert SRV *H. B. Bigelow* catches (for numbers of recruits, pre-recruits, and all sizes combined) to *AL IV* equivalents

Definition of *Loligo* habitat

The strata set used to derive relative abundance and biomass indices from the NEFSC spring and fall surveys has been expanded to include important inshore habitat (inshore strata 2-46, 58-61, and 65-66, shown in pink) as well as the offshore habitat included in the previous assessment (offshore strata 1-23, 25-26, and 61-76, shown in blue, Figure B21). Since 2009, when the SRV *H. B. Bigelow* replaced the SRV *Albatross IV*, the two shallowest series of inshore strata (8-18 m depths) are no longer sampled due to the deeper draft of the Bigelow. Since these inshore strata constitute important *Loligo* habitat during the fall, the swept-area biomass estimate from the 2009 NEAMAP survey was added to the 2009 biomass estimate from the NEFSC fall survey to compute total stock biomass. The estimation method and results are described below in the section for Term of Reference 3.

Diel effects on bottom trawl catches of *Loligo*

Catches of *Loligo* in bottom trawls tend to be higher during the daytime because of diel migration patterns. *Loligo* are on or near the bottom during the day and feeding higher in the water column at night (Sissenwine and Bowman 1978). Diel effects on survey catches of *Loligo* are size-dependent (Brodziak and Hendrickson 1999). The swept-area based methods used in this assessment are most accurate when the survey data are for daytime tows only because they provide estimates as close as possible to actual stock biomass.

In the most recent stock assessment (NEFSC 2002a), tows during dawn/dusk and nighttime were adjusted to daytime equivalents based on adjustment factors, for pre-recruit and recruit squid, from GLM models fit to log transformed catches for positive tows. The primary disadvantages of the approach used in the last assessment are: 1) diel effects on the probability of a positive tow are ignored; 2) bias in adjustment factors due to log transforming survey catches is ignored; 3) additional model and estimation uncertainty is generated; and 4) model and estimation uncertainty are not included in the variance estimates for survey mean numbers and weight per tow.

In this assessment, only survey data from daytime tows are used. The major benefits are that stratified mean numbers and weight per tow provide more accurate measures of stock biomass (in effect, the capture efficiency of the survey gear is increased) and estimates have similar or lower CVs (equivalent or increased precision). Other benefits of using only daytime tows are: 1) zero tows are included in calculations so that diel effects on the probability of a positive tow are handled automatically; 2) additional and complex modeling to estimate adjustment factors and their variance is not required; 3) standard variance formulas for stratified means are unbiased estimates of sampling variability in mean numbers and weight per tow; 4) differences in diel adjustments for individual sizes are accommodated automatically; and 5) the approach is very simple and easy to implement in standard software used to calculate stratified random mean number and weight per tow indices.

The major potential disadvantages are that sample size (i.e., number of tows) is reduced and strata sampled exclusively during the night are omitted. Both of these disadvantages are exacerbated if the number of tows per stratum is often small. Another disadvantage is that criteria for defining the daytime period are required in deciding which tows to use and which tows to omit from calculations. In this assessment, GAM models and a grid-search procedure were used to find objective criteria for defining daytime tows based on the solar zenith (see Appendix B2). Solar zenith is the angle of the sun at the time of a survey tow relative to a line drawn normal to the earth at the geographic location of a tow and is the primary factor controlling irradiance at the ocean surface and at depth. Solar zenith is more useful than time of day in modeling because illumination depends on latitude, longitude, Julian date and year (which are all used in calculation of the solar zenith). Although there is a clear general relationship between solar zenith and time of day (Figure B22), tows carried out at the same time but at different geographic locations may have substantially different solar zenith and illumination levels that might affect survey catchability.

The results of the grid-search procedure (Appendix B2) show that a wide range of criteria work for defining cut points for daytime tows and that it is only important to avoid using tows conducted at night. An objective method was used to select the solar zenith cut points, performance scores based on an approximate mean squared error (MSE) approach. Based on this method, daytime fall survey data used in this assessment include tows with solar zenith values of 43-80° and daytime spring survey data include tows with solar zenith values of 29-84°. In general, daytime tows for these fall and spring survey solar zenith angles were conducted during approximately 6:30 AM-4:30 PM and 6:30 AM-5:30 PM, respectively (Figure B22). The relationships between *Loligo* catch rates (number per tow) and solar zenith angle for the spring and fall survey time series included in the assessment are shown in Figure B23.

Some strata, particularly small strata with few tows, may be lost using daytime tows only. The practical significance of this loss is modest because the lost strata tend to be small. Maps of station locations indicate that daytime tows cover the entire survey area and that large portions of the survey area are not ignored using daytime tows (Figure B24). There is a general pattern with respect to cruise timing and cruise track from year to year, but sampling stations are randomly selected within strata and delays occur due to special sampling and weather conditions so that the locations of day- and nighttime tows vary from survey to survey. As mentioned above, trends based solely on daytime data are similar to trends based on both day and night data. The trends are robust because catch rates are very low for *Loligo* during the nighttime. In effect, nighttime tows contribute little additional information about trends in relative abundance of *Loligo*. The major effect of nighttime tows is to reduce mean numbers and weight per tow by approximately n_d/n_{24}, where n_d is the number of daytime tows and n_{24} is the total number of tows.

Another explanation for the robustness of survey trends to the use of daytime only catches is theoretical. NEFSC bottom trawl surveys are based on numerous small strata and the survey may be over-stratified for a species like *Loligo*. In the context of an over-stratified survey area, the use of daytime only tows approximates an unbiased two-stage sampling design. The first stage is a random determination (with probability of sampling = n_d/n_{24}) of whether or not a stratum is sampled. The second stage is random selection of tow locations within a sampled stratum. A stratum may be missed entirely if daytime only data are used. However, the effect of the missed stratum is minimized because strata with similar densities of *Loligo* were likely sampled during the daytime and used to estimate mean numbers and weight per tow.

For *Loligo*, the potential loss of precision due to reduced sample size is more than counterbalanced by reducing the variability in survey catches. Differences in catch rates between day and night are substantial (e.g., 11.5 times higher during the day than at night, for catches of squid ≤ 8 cm DML in NEFSC fall surveys, Table B12) and diel sources of variance are removed when only daytime tows are used. Relative abundance indices computed for the daytime tows used in the assessment versus all tows were compared for pre-recruits and recruits during the 1975-2008 fall surveys and the 1976-2008 spring surveys. The results indicate similar annual trends between the sets of indices computed using all tows versus daytime tows for both size categories and time series (Figures B25-B28). In addition, the CVs of indices computed from daytime tows were reduced for pre-recruits and recruits during 65% and 50% of the years, respectively, in the fall survey time series (Table B13) and during 70% and 67%, respectively, of the years in the spring survey time series (Table B14).

The magnitude of the effect of solar zenith on *Loligo* relative abundance indices (i.e., the percent difference computed using daytime tows versus all tows) was greater during the fall surveys than during the spring surveys and and affected pre-recruits and recruits differently by season. The average increase in daytime relative abundance indices for pre-recruits and recruits from the fall surveys was 87% and 172%, respectively (Table B13), and was 56% and 25% for the spring surveys, respectively (Table B14).

Similar to trends in relative abundance indices, trends in the percentage of tows with *Loligo* catch were also similar between daytime tows and all tows during spring and fall surveys (Figure B29). The magnitude of the effect of solar zenith on the percentage of tows with *Loligo* catch was also greater for fall survey tows (i.e., averages of 77% for all tows versus 84% for day tows) than for spring survey tows (i.e., averages of 31% for all tows versus 33% for day tows; Figure B29).

Survey length composition

Loligo length compositions computed using all tows were similar to those computed using "daytime" tows for the fall surveys conducted during 1975-2008 and the spring surveys conducted during 1976-2008 (Figure B30). Squid were fully-recruited to the gear used in the fall and spring surveys at 3 and 4 cm DML, respectively.

The 2009 length compositions of the *Bigelow* catches were slightly different depending on whether they were computed using all tows or "daytime" tows (Figure B30). For the 2009 fall survey, the "daytime" tows included a smaller proportion of squid larger than 7 cm DML than the length composition of all tows, but the opposite was true for the "daytime" tows in the spring survey. Squid were fully recruited to the Bigelow's net at 5 cm DML. However, more years of data are needed to confirm the 2009 trends.

Conversion factors for the new SRV *H. B. Bigelow*

The vessels and gear types used to conduct the fall and spring bottom trawl surveys are shown in Tables B15 and B16, respectively. In addition to the gear and vessel conversion factors described earlier in this section, gear/vessel calibration coefficients were also applied to *Loligo* catches by the SRV *H. B. Bigelow,* beginning in 2009, when the SRV *Albatross IV* was decommissioned and the SRV *H.BH. Bigelow* was used to conduct the spring and fall bottom trawl surveys. Calibration coefficients were computed from paired tow studies using daytime tows conducted during the spring and fall of 2008. The paired tow studies are described in Miller *et al*. (2007) and Miller *et al*. (2010). and the methods used to compute the *Bigelow* calibration coefficients for *Loligo* catches are described in Appendix B3. The calibration coefficients (ρ) that were applied to catch numbers of pre-recruits, recruits and all sizes combined, and their CVs, are included in Table B17.

Trends

As is typical for squid species (Boyle and Rodhouse 2005), indices for both surveys show a high degree of inter-annual variability, particularly for the fall survey, which makes any trends difficult to discern. Although the spring survey indices are much lower than the fall survey indices, trends are more evident in the spring time series (Figure B31). Relative biomass indices were generally above the median level during 1979-1992, 1999-2002 and 2005-2008, but were generally at or slightly below the median during 1993-1998, 2003-2004 and 2009-2010. During 1976-2009, correlations between spring and fall relative abundance indices were fairly high (r =

0.53, $p < 0.01$), but correlations between relative biomass indices were much lower ($r = 0.32$, $p < 0.05$).

Fall relative abundance and biomass indices were more precisely estimated (median CVs were 13% and 12%, respectively, Table B18) than the spring indices (median CVs were 18% and 15%, respectively, Table B19). Overall, both surveys were dominated by pre-recruits (≤ 8 cm DML) and relative abundance of recruits was higher prior to 1987 than after (Figure B31). Trends in pre-recruit and recruit relative abundance indices were significantly correlated for the spring surveys ($r = 0.58$, $p < 0.01$) but not for the fall surveys ($r = 0.20$, $p = 0.19$; Figure B32).

Term of Reference 3: *Estimate annual fishing mortality, recruitment and stock biomass for the time series, and characterize the uncertainty of those estimates (consider Loligo TOR-4). Include a historical retrospective analysis to allow a comparison with previous assessment results.*

Data and methodological differences between current and prior assessment

Previous assessment

This section explains the data and methodological differences between the current and prior assessment and documents the effects of each change on key assessment results. The previous assessment (NEFSC 2002a) included a variety of stock assessmentmethods including length-based VPA (LVPA), *q*-adjusted fall survey swept-area biomass (i.e., based on a composite prior distribution for survey catchability), exploitation indices (i.e., Oct-Dec. catch over *q*-adjusted fall survey swept-area biomass), a complicated surplus production model ("PDQ") tailored to *Loligo*, and traditional age-based per-recruit calculations.

The previous assessment's conclusion that the stock was "unlikely to be overfished" during 2000 was based on a comparison of a fall survey biomass estimate in 2000 (= 34,000 mt, assuming q = 0.45 from the PDQ model) with the Bmsy threshold which existed at thae time (1/2 Bmsy = 40,000 mt) and a variety of other information. The conclusion that "it is unlikely that overfishing was occurring", was based on a comparison of fishing mortality estimates from the PDQ model with a new quarterly estimate for Fmax.

However, the SARC reviewers concluded that the existing biomass reference points were inappropriate and that new biomass reference points could not be estimated (NEFSC 2002b). The SARC reviewers also concluded that "overfishing was not occurring" based on a comparison of the 2000 exploitation index (Oct-Dec landings plus 6% assumed discards/fall survey biomass) with a new quarterly Fmsy proxy (= 0.31 per quarter or 1.24 per year). The new Fmsy proxy represents the 75th percentile of the 1987-2000 exploitation indices. The mean exploitation index during 1987-2000 was selected as the Ftarget (= 0.24 per quarter or 0.96 per year). These fishing mortality references points were implemented in 2009 (MAFMC 2009).
The existing threshold reference point calculations involved an assumed value of *Loligo* catchability (q) in the fall survey that was estimated in the PDQ production model (even though assumptions about q would have no effect on status determination results which are based on

trends in catch and survey data). The key source of information about survey catchability in the PDQ model was the *q*-prior used in fitting it because the survey and catch data were not informative for *Loligo*. Thus, the most important and useful parts of the previous assessment were the catch and fall survey data, with the *q*-prior providing bounds on possible biomass and exploitation levels and information about scale.

In view of this history, the current assessment is based on the most promising of the approaches from the previous assessment and includes a number of improvements. In particular, the current assessment uses updated and improved *q*-priors, additional and improved survey data, landings, and improved discard estimates to bound biomass and exploitation estimates. The *q*–prior provides bounds and a set of plausible estimates of biomass and exploitation rates but does not affect status determination measures, which are based on relative trends.

A number of changes were made in the current assessment to *q*-prior calculations, survey data, and catch data. The changes in *q*-prior calculations include:

- Updated estimates for bounds on mean tow distance and effective net width and use of the expanded survey strata area as the stock area, in place of bounds on stock area.
- Updated estimates for bounds on capture efficiency.
- Use of the median *q*-prior value in place of an estimate from the PDQ model.

Changes to survey and catch data included:

- Expanding the set of survey strata used to derive stratified mean number and weight per tow indices. The previous assessment included only offshore habitat (strata 1-23, 25 and 61-76) and this assessment includes important inshore and offshore habitat (inshore strata 2-46, 58-61, and 65-66 plus offshore strata 1-23, 25-26, and 61-76).
- Derivation of biomass estimates for both of the two primary *Loligo* cohorts caught in the NEFSC fall (1975-2009) and spring surveys (1976-2010)
- Use of standard door conversion factors for both survey time series (i.e., pre-1985 kg per tow x 1.24, no adjustment for number per tow), where appropriate.
- Use of standard SRV *Delaware II* catchability adjustment factors for both survey time series (i.e., *DE II* number per tow x 0.83 and weight per tow x 0.85), where appropriate.
- Addition of the fall 2009 biomass estimate from the NEAMAP survey to account for *Loligo* biomass at depths <= 18 m because these inshore strata can no longer be sampled by the SRV *H.B. Bigelow*
- Use of only daytime survey tows instead of using all survey tows with diel correction factors for night and dawn/dusk.
- Use of average annual survey mean weight per tow as the main survey time series instead of fall survey data only (i.e. average of spring and fall biomass estimates in year *t*).

- Use of annual catches in place of fall (October-December) catches and with improved estimates of discards.

A historical retrospective analysis was conducted to allow a comparison of the current assessment results with those from the previous assessment (NEFSC 2002a; NEFSS 2002b). The effects of the changes noted above on *q*-prior calculations and mean catch, biomass indices and biomass estimates during 1987-2000 (the time period of overlap between assessments), along with an exploitation measure (mean annual catch/mean annual q-adjusted survey biomass), indicate that the most important assessment differences were the new bounds for capture efficiency and the calculation of survey biomass as the annual mean of the spring and fall survey biomass estimates (Table B20).

Biomass estimation

A comparison of biomass estimates from a surplus production model used in a previous assessment to minimum swept-area biomass estimates (assuming 100% efficiency or the capture of 100% of the squid in the water column above the ground swept by the net) resulted in implausibly high estimates of q, or survey bottom trawl catchability and implausibly low biomass estimates (Cadrin and Hatfield 1999). Biomass is estimated as B=I/q where I is the survey biomass index, in kg per tow, and tends to be too low when q is too large. This problem seems to pervade all previous modeling approaches.

In the current assessment, upper and lower bounds on factors which affect the daytime survey bottom trawl catchability of *Loligo* by the SRV *Albatross*, in both the spring and fall surveys, were used to compute upper and lower bounds on *q*. Based on non-informative uniform prior distributions for uncertainty in each underlying factor, we characterized uncertainty about survey catchability by means of a composite prior distribution, which includes uncertainty in all of the underlying factors.

The hypothetical relationship between survey biomass indices (I_y = stratified mean biomass per tow computed from all survey tows in year *y*) and the true *Loligo* biomass in year *y* is:

$$I_y = qB_y$$

where *q* is a survey-specific catchability coefficient. The catchability coefficient is:

$$q = \frac{aeu}{A}$$

where u=10^6 converts from kg to thousands of mt, *a* is the area swept during one standard tow ((in km^2), *e* is the capture efficiency of the survey bottom trawl (the trawl captures the proportion *e* of *Loligo* in the water column above the ground swept by the trawl) and *A* is the area of the stock. Capture efficiency must be larger than zero if the survey takes at least one individual and, by definition, must be smaller than or equal to one ($0< e \leq 1$). Area swept (*a*) is equal to the product of average effective tow distance for the survey (*d*, assumed constant over time) and average effective width (*w*) of the area swept by the survey gear such that:

$$q = \frac{dweu}{A}$$

Upper and lower bounds for each of the key factors (*d, w*, *e*, and *A*) affecting the daytime catchability of *Loligo* in the NEFSC fall and spring bottom trawl surveys, during 1975-2010, are shown in Table B21. The bounds included in the previous assessment, for NEFSC fall surveys, are also shown. For 2009 onward, differences between the *Albatross* and *Bigelow* with respect to *d*, *w*, and *e* are accounted for in the *Bigelow* to *Albatross* conversion coefficients (Table B17) that were applied to the relative biomass indices from the *Bigelow*.

Bounds for effective tow distance (d)

Variance in the length of individual tows probably contributes little uncertainty to estimates of average tow distance because the tow distance used in the calculations is based on a relatively large sample size (see the following paragraph). However, the mean value is uncertain due to questions about when the survey trawl starts and stops fishing for *Loligo* during daytime tows. Actual tow distance is not likely the same as the nominal tow distance because of lags between winch lock and net touchdown and between winch re-engage and net lift-off (which may vary with station depth) and changes in sea state and tides. All of these factors may affect when the net starts and stops fishing.

The nominal tow distance in the 1975-2008 surveys is 3.42 km based on a target tow duration and speed of 30 minutes at 3.5 knots. However, one study where actual measurements of mean tow distance were measured using Doppler distance indicated that the modal tow distance was 2.96 km during the 1975 and 1976 surveys (Overholtz and Lewis 1978). We also computed the GPS tow distance for the 2007 fall and the 2008 spring surveys. We examined plots of speed over ground, tow duration, temperature, wingspread, and doorspread to determine the times when net touchdown and liftoff occurred for a range of survey station depths (N= 445 tows). GPS tow distance was then computed for the time period between net touchdown and lift-off. We found that tow distance was not dependent on station depth (Figure B33) because depth-related changes in the delay between winch lock and net touchdown was offset by changes in the delay between winch re-engage and net lift-off. Although individual tow distances were variable, the mean for both surveys combined (3.57 km, 95% CI = ±0.01 km) was not. Based on these two estimation methods, we used 2.96 km and 3.57 km as the lower and upper bounds on effective tow distance, respectively.

Bounds for effective width swept by the survey gear (w)

The mean of the SRV *Albatross* wingspread measurements for the Yankee 36 bottom trawl, during the 2006-2008 spring and fall surveys (N = 1,985 tows) was used as the lower bound for effective width of the area swept by the survey gear (0.01069 km, 95% CI = ±0.000201). The mean of the *Albatross* doorspread measurements (N = 1,992 tows), during the same time period, was used as the upper bound for effective width of the area swept by the survey gear (0.02192 km, 95% CI = ±0.000743). The lower bound accommodates the hypothesis that no horizontal herding of *Loligo* occurs during daytime fishing and the upper bound accommodates the alternate hypothesis that such herding does occur (i.e., 100% of the squid between the wings and doors are herded into the mouth of the trawl are captured and don't escape). Uncertainty about squid which avoid capture by swimming out beyond the area swept by the doors and wings are included in the bounds for effective width of the survey gear.

Bounds for survey bottom trawl capture efficiency (e)

Uncertainty due to squid avoiding capture because they are initially located above the headrope ("school slicing") or because they eventually move up and over the headrope is included in uncertainty about capture efficiency *e*. Escapement beneath the footrope and through the trawl meshes following capture is also included in the uncertainty about capture efficiency. The average headrope height of the Yankee 36 trawl (1.95 m, 95% CI = ±0.17) is low in relation to commercial *Loligo* bottom trawls. This mean is based on 21 tows conducted by the *Albatross* with 1-3 three sensor measurements per tow. Headrope height ranged between 1.7 and 2.1 m. However, given that the survey bottom trawl is towed at a similar or faster speed (3.2-3.8 knots) than that used in the *Loligo* fishery,3.0-3.2 knots, (Hendrickson 2005) and because survey data include only daytime tows (when *Loligo* are closest to the bottom), escapement over the net may be minimized.

If the bottom trawl used on the SRV *Albatross* failed to catch one individual, then the efficiency (*e*) of the trawl would be zero. However, *Loligo* are caught at relatively high rates and within the survey strata used in the assessment. In addition, the use of only the survey catches of *Loligo* from daytime tows effectively increase efficiency because both the percentages of tows with *Loligo* catch and the amounts of *Loligo* catch per tow are greater for daytime tows (Figures B25-B29). The lower bound for *e* accommodates the hypothesis that the gear has low efficiency due, for example, to squid initially distributed above the trawl and/or squid that escape capture by moving up and over the headrope. Escapement through the trawl meshes following capture is another possibility. The upper bound for *e* accommodates the alternate hypothesis that the Yankee 36 bottom trawl is very efficient for *Loligo* during the daytime.

In order to estimate a lower bound for *e* during the daytime, we used behavioral information gleaned from daytime video footage of *Loligo* in front of the sweep and within various types of bottom trawls. In general, squid behaved similarly to the capture behavior reported by Glass *et al*. (1999) for *Loligo* in bottom trawls used in the directed fishery. Video camera recordings of bottom trawl capture behavior indicate that *L. pealeii* tires shortly after encountering the net. Individuals swim for approximately three minutes at a towing speed of 3 knots then rise upward in the net, turn toward the codend, cease swimming and allow the net to overtake them (Glass *et*. al. 1999). We observed schools of squid located on and near the seabed, in front of the sweep, to use alternating jet population and finning to swim forward in the direction of the tow and upward within the net mouth. This same behavior appeared to result in capture, even for raised footrope trawls (footrope at 1-1.5 m above the seabed and rigged with tickler chains), whereby schools of squid tended to use burst speed to quickly jet off the bottom and above the sweep where they were quickly overtaken by the net. Given this rising behavior, it is highly unlikely that escapement occurs beneath the footrope. In addition, squid schools were never observed turning perpendicular to the meshes in the mouth and attempting to escape. Although these behaviors suggest little likelihood of escapement once captured, there is no video footage to determine whether escapement over the headrope occurs. The rapid towing speed of the NEFSC survey trawl and the presence of a square in the Yankee 36 net (webbing that overhangs the area in front of the sweep) probably minimize escapement over the headrope. However, the rapid rising behavior of *Loligo* near the net mouth combined with the lack of information about the height of schools suggests that these low-opening survey nets may only be slicing off the lower portion of schools. Taking all of this information into consideration, we set the lower bound on *e* at 0.20.

The upper bound on capture efficiency for *Loligo* taken in surveys conducted by the *Albatross* was based on calibration factors (ρ) derived experimentally and used to convert *Loligo* catches by the *Bigelow* to *Albatross* catch equivalents. Capture efficiency for *Loligo* is higher for the *Bigelow* than for the *Albatross* due to differences in net design and other factors. For these calculations, the maximum possible capture efficiency of the *Bigelow* was assumed to be 0.95. Although this assumed efficiency of the *Bigelow* is somewhat arbitrary, it is intended to be an upper bound and a number of factors indicate that the bottom trawl towed by the *Bigelow* is likely to have high efficiency, particularly during the daytime. The wingspread and doorspread of the *Bigelow* are wider, and the headrope height is higher than for the Yankee 36 and Yankee 41 trawls. The Polyice net used on the Bigelow is a modified version of one type of commercial *Loligo* trawl. Based on sensor measurements from 357 tows conducted during the 2009 fall survey, the mean wingspread of the Bigelow Polyice net (12.76 m, 95% CI = ±0.21 m) is 19.4% wider than the mean wingspread of the Yankee 36 net (10.69 m, 95% CI = ±0.20) and the mean doorspread of the Polyice net (33.02 m, 95% CI = ±0.49, N=361 tows) is 50.6% wider than the mean doorpsread of the Yankee 36 (21.92 m, 95% CI = ±0.74). The mean headrope height of the Polyice net (= 3.69 m, 95% CI = ±0.09, N=360 tows) is 89.2% higher than the mean headrope height of the Yankee 36 net (1.95 m, 95% CI = ±0.17).

Assuming the maximum capture efficiency of the *Bigelow* is 0.95, maximum capture efficiency of the *Albatross* (e_{max}) could be no larger than 0.95/ρ, where ρ is the calibration factor for converting *Bigelow* catches to *Albatross* equivalents adjusted for wingspread swept-area differences. Thus, the upper bound on *e* was computed as:

$$e_{max} = \frac{0.95\ a_{Bigelow}}{\rho\ a_{Albatross}} = 0.393$$

Where ρ is the calibration factor for the fall survey (= 1.51 for all sizes combined using daytime tows), 0.95 is an upper bound for capture efficiency on the *Bigelow*, and $a_{Bigelow}$ = 0.0382 km^2 and $a_{Albatross}$ = 0.0239 km^2 are the areas swept by the bottom trawls used by the two vessels. The upper bound for the NEFSC spring survey was nearly identical so, for the sake of simplicity, only e_{max} for fall was used in the assessment.

Definition of the stock *area (A)*

Instead of setting upper and lower bounds on the stock area, *A*, we assumed that the *Loligo* strata set used in the assessment (total area = 166,007 km^2) represents the stock area. The expanded strat set is much larger than the strata set used in the previous assessment and includes the primary *Loligo* habitat within the surveyed area. As noted in Term of Reference 2, the expanded strata includes the offshore strata used in the previous assessment (1-23, 24-26, and 61-76) plus a set of inshore strata (2-46, 58-61 and 65-66) because GIS maps (see Figures B20 and B21) indicate that these strata constitute important *Loligo* habitat, primarily during the fall.

In order to determine the importance of the inshore habitat which can no longer be sampled by the *Bigelow* (strata ≤ 18 m deep), we conducted several analyses. The annual percentages of *Loligo* relative abundance and biomass originating from these strata were determined for daytime tows conducted during NEFSC spring (1976-2008) and fall surveys (1975-2008). The results indicate that this habitat is more important during the fall surveys than during the spring surveys. During the fall, 0.1-3% of the relative biomass and 0.1-4% of the relative abundance occurred in strata ≤ 18 m deep (Figure B34). However these percentages are probably underestimated because only 50% or less of the total area of these inshore strata was sampled in the daytime during the fall surveys in most years (Figure B35). During the spring surveys, strata ≤ 18 m deep only accounted for a substantial percentage of the relative abundance (4.3%) and biomass (7.2%) during 1985 and 2002, respectively (Figure B34).

In order to account for *Loligo* biomass in the survey strata ≤ 18 m deep, we computed swept area estimates of biomass from the 2009 fall NEAMAP (Northeast Area Assessment and Monitoring Program) survey, which now surveys these inshore strata, and added this amount to the 2009 *q*-adjusted biomass estimate from the NEFSC fall survey. The NEAMAP survey has been conducted during the fall (late Sept.-mid-Oct., which is similar to the timing of the fall NEFSC survey) and during spring (late April-mid-May, which is later than the NEFSC spring survey) since the fall of 2007 (Bonzek *et al*. 2009). Approximately 150 stations are sampled at depths ranging between 6.1 and 18.3 m in waters located between Cape Hatteras, NC and the eastern end of Montauk, NY. Fourteen of the stations are located in Block Island Sound and Rhode Island Sound at depths ranging between 18.3 m and 36.6 m (Figure B36). The total area of all strata is 15,191 km^2, but a slightly smaller area was sampled during the fall of 2007 and spring of 2008 (Table B22).

There have been no calibration studies conducted between the *Bigelow* and the NEAMAP survey vessel (the F/V *Darana R*) but the towing protocols are the same (20 minutes at 3 knots) and the nets are similar barring some minor differences.Other differences include a 3-inch cookie sweep on the *Darana R* (versus a rockhopper sweep on the *Bigelow*) and different types of doors.

Biomass estimates were computed for *Loligo* by multiplying the geometric mean weight per tow (C. Bonzek, pers. comm.), for all NEAMAP strata, by the area swept by the trawl (0.025 km^2); the latter which is based on mean wingspread and tow distance (Bonzek *et al*. 2009). For the short time series available, the *Loligo* minimum biomass estimates from the fall NEAMAP surveys were fairly low, and ranged between 1,720 mt and 3,482 mt (CV range of 3.5-4.5%) during 2007-2009 (Table B22). However, the estimates were not adjusted for catchability of the NEAMAP survey gear and are probably biased low. The CVs for these biomass estimates were low, ranging between 3.5% and 4.5%. Biomass estimates from the spring NEAMAP surveys were more variable and lower than the fall estimates, ranging between 389 mt and 1,420 mt during 2008-2010 and the estimates were less precise (.CV range of 5.4-9.3%). The spring estimates were likely lower and more variable because the NEAMAP survey occurs at a time when the species is migrating into the survey area. An attempt was also made to compare the fall biomass estimates from the NEAMAP surveys, during 2007-2008, with biomass estimates for a set of overlapping strata sampled during NEFSC surveys, by the *Albatross*, during a similar time period.. However, the resulting estimates were not reliable because the numbers of "daytime" tows conducted by the *Albatross* in these inshore strata were too few (Table B22).

Several additional analyses were conducted in order to address the question of whether substantial amounts of *Loligo* exist outside the NEFSC survey strata, in particular at depths greater than the limit of the surveys (> 366 m), during the time periods in which the NEFSC spring and fall surveys are conducted. The methods utilized and the results of these analyses are included in Appendix B4. One set of analyses used catch-per-tow data from the *Loligo* fishery and NEFSC spring and fall surveys to characterize daytime catch rates of *Loligo* as a function of depth. Results for spring indicated declining fishery catch rates at depths beyond 175 m, although data for deep water tows were limited. Results for all *Loligo* size groups caught in NEFSC spring and fall surveys indicated that the predicted daytime catches declined to low values with increasing depth.

A third analysis involved an examination of *Loligo* catch rates in seasonal depth transect surveys that were conducted at depths greater than the limit of NEFSC surveys, by Rutgers University, during 2003-2007. The surveys utilized a standardized towing protocol (tow distance of 2 nautical miles at a speed of 3 knots) and a commercial *Loligo* bottom trawl. Catch rates of *Loligo pealeii* (kg per tow) in these surveys also show declines with increasing depth, similar to the analysis of catch rates with depth for daytime tows from NEFSC surveys. During some years, daytime catch rates declined to very low levels at stations with depths shallower than 366 m (e.g., < 274 m). Catch rates of *Loligo* were also very low at depths greater than 366 m during January, March and November. However, this result may be an artifact of nighttime sampling at depths > 274 m. In conclusion, the results from all three analyses suggest that high densities of *Loligo* at depths greater than those included in this assessment are unlikely.

Bounds for q

The lower bounds or q_{min} values were 0.038 for 1975-2008 and 0.041 for 2009-2010 (Table B21) for catchability in the NEFSC fall and spring bottom trawl surveys and were calculated from the minimum values for *d, w* and *e* in the numerator, and the value for stock area, *A*, in the denominator:

$$q_{\min} = \frac{u\, d_{\min} w_{\min} e_{\min}}{A}$$

Similarly, the upper bounds or q_{max} values were 0.185 for 1975-2008 and 0.197 for 2009-2010 (Table B21) were calculated using the maximum values for *d, w* and *e* in the numerator and the value for stock area, *A*, in the denominator:

$$q_{\max} = \frac{u\, d_{\max} w_{\max} e_{\max}}{A}$$

Statistical distributions to characterize uncertainty

We characterized uncertainty in effective tow distance, effective trawl width *w*, and trawl efficiency *e* with uniform distributions that had upper and lower bounds described above. This means, for example, that any value of *w* between the upper and lower bound seemed equally probable, *a priori*. Uniform distributions for these parameters are "non-informative" prior distributions that don't require knowing or guessing the most likely single value or most probable values (Gelman *et al*. 1995).

Uncertainties about *d, w* and *e* were independent in our analysis because of the definitions for each term. Therefore, the bounds for each term were statistically independent (uncertainty and bounds for efficiency *e* did not depend, for example, on bounds and uncertainty about effective width *w* of the net). Moreover, we tried to choose bounds for each factor in an independent manner so that, for example, the lower bound on effective net width was independent of the upper bound on effective net width.

Given independence, the statistical distribution for uncertainty in *q* can be evaluated by simulation. The first step is to draw random numbers *d'*, *w'*, and *e'* from uniform probability distributions (where, for example, *d'* is drawn from the uniform distribution with upper and lower bounds for effective tow distance, *d*). The second step is to calculate simulated catchability values as $q'=(d'w'e'u)/A$. Recall that *A*, the stock area, is a constant.

We characterized the distribution of the uncertainty in *q* using five million simulated *q'* values (Figure B37). Minimum, maximum and quantiles (Q25, Q50 and Q75) of the two simulated distributions, for 1975-2009 and 2009-2010, are presented in Table B23. Both distributions were similar in shape and were slightly skewed to the left. The distribution ranges were narrow, 0.038-0.185 for 1975-2008 and 0.041-0.197 for 2009-2010, with modes at 0.082 and 0.087 for the two time periods, respectively. The median *q*-priors (Q50 = 0.092 for 1975-2009 and 0.098 for 2009-2010) were located slightly to the right of the distribution modes. In comparison, the q-prior in the previous assessment had bounds between 0.20 and 0.56, was strongly skewed to the right, and had a broad mode between 0.05 and 0.22 (Figure A25 from NEFSC 2002a).

Biomass trends

Biomass estimates derived using the minimum, maximum, Q25, Q50, and Q75 values from the *q*-prior distributions are shown in Figure B38. The lowest feasible biomass estimates are more important than the highest feasible biomass estimates when determining stock status because they amount to “worst-case scenarios”. The lowest feasible biomass estimates (derived using the minimum *q*-priors) ranged between 15,070 mt and 164,182 mt (median = 62,028 mt) for the fall surveys and ranged between 4,036 mt and 40,646 mt for the spring surveys (median = 13,386 mt; Figure B38). The biomass estimates used in the assessment were derived using the median *q*-priors because they have an equal probability of either under- or overestimating biomass.

The spring and fall NEFSC surveys track different seasonal cohorts which appear to have very different levels of productivity. The spring biomass levels are only about one fifth of the fall biomass levels (Table B24, Figure B39). During 1976-2008, biomass estimates (derived using the median q-priors) ranged between 30,304 and 330,148 mt (median = 124,730 mt) during the fall and between 8,116 mt and 81,734 mt during the spring (median = 27,578 mt).

Federal fishery regulations require that stock status be reported for the terminal “year” of the assessment data series. Therefore, in order to annualize the biomass estimates for this sub-annual species, annual averages of the fall and spring survey biomass estimates were computed for 1976-2009. As is characteristic for squid species (Boyle and Rodhouse 2005), annual biomass fluctuated widely about the median of 76,329 mt during 1976-2009 and ranged between 25,806 mt and 175,894 mt (Figure B40, Table B25). Consequently, trends were difficult to discern, with the exception of an increase in biomass from 25,806 mt in 1996 to the time series high of 175,894 mt in 2000. Biomass generally declined thereafter to about 50% of the median in 2009 (39,792 mt). However, given the high inter-annual variability in biomass estimates, a two-year moving average of stock biomass (i.e., mean biomass during 2008-2009) is recommended for the 2009 stock status determination.

Exploitation indices

Exploitation indices, which are considered to be correlated with fishing mortality on a relative basis, were used in the previous assessment and are also used in this assessment. The spring and fall biomass estimates represent mean biomass estimates for the seasonal cohorts that are available to the January-June and July-December fisheries, respectively. Exploitation indices for the two fisheries were computed for 1987-2009 as January-June catch/March biomass and July-December catch/September biomass. Annual exploitation indices were also computed as the annual catch divided by the annual average of NEFSC spring and fall survey biomass estimates.

Exploitation indices were calculated as catch/ biomass of all size groups of squid, including pre-recruit sizes (≤ 8 cm DML) which are not immediately selected by the fishery. Pre-recruit sizes were included in the calculations to partially account for the high turnover rates and the fact that these squid will be large enough to be selected by the fishery shortly after the survey. Likewise, given the semelparous life history of the species, most of the recruits that enter each six-month fishery period will have died by the end of each period.

The maximum feasible exploitation indices are more important than the minimum exploitation indices when determining stock status, because they amount to worst-case scenarios. During 1987-2009, the maximum feasible exploitation indices, computed using the biomass estimates derived with the maximum *q*-prior, ranged between 0.32 and 0.05 (median = 0.132) for the July-December fisheries and ranged between 0.317 and 2.535 for the January-June fisheries (median = 0.634; Figure B41).

The exploitation indices used in the assessment were derived using the biomass estimates for the median *q*-priors. During 1987-2009, catches in the January-June fishery were 1.4 times higher than the July-December catches on average (Table B24). Exploitation indices for the January-June fishery (range = 0.158-1.261; median = 0.315) are much higher on the lesser productive, spring survey cohort than those for the July-December fishery (range = 0.02-0.16; median = 0.064) on the more productive fall survey cohort (Figure B42, Table B24).

During 1993-1998, annual exploitation indices were generally at or above the 1987-2008 median (0.237), averaging 0.273, and generally at or below the median during 1999-2008, averaging 0.18 (Figure B43, Table B25). The 2009 annual exploitation index was 0.176. This 2009 value was computed as the catch in 2009 / mean of the 2008-2009 fall and spring survey biomass estimates. Given the inter-annual variability in biomass estimates, a two-year moving average of stock biomass is recommended for the 2009 stock status determination.

Historical retrospective analysis

Comparison of results from this assessment with results from historical assessments (NEFSC

1994; 1996; 1999; 2002a) is difficult because of the lack of temporal overlap between assessments (particularly between NEFSC 2002a and the current assessment), and changes to the data and models used to estimate stock status. However, comparisons (Table B26) reflect the difficulties encountered using both index-based approaches (NEFSC 1994) and surplus production models (NEFSC 1996; 1999; 2002a) for *Loligo*. The majority of assessments relied on relative trends in survey data (NEFSC 1994, 2002a and the current assessment). The stock is now considered lightly exploited but overfishing was determined to be occurring in 2 out of 4 historical assessments. The stock has never been considered overfished, although it was close to its biomass threshold at the time in two cases (NEFSC 1996; 1999).

Term of Reference 4: *Summarize what is known about consumptive removals of Loligo by predators and explore how this could influence estimates of natural mortality (M).*

Natural Mortality

Spawning (Msp) and non-spawning (Mns) natural mortality rates were estimated for *Loligo pealeii* using the methods of Hendrickson and Hart (2006) and Caddy (1996), respectively. The methods and results are presented in Appendix B5. Preliminary natural mortality estimates were very high, 0.11 per week for Mns and 0.19-0.48 per for Msp, similar to estimates for another northwest Atlantic squid species (Hendrickson and Hart 2006). Natural mortality estimates from the current assessment are compared with those used in previous assessments in Table B27. Previous *Loligo* assessments used traditional natural mortality estimation approaches which apply to iteroperous finfish species. Estimates from the current assessment are considered more realistic because the estimation method accounts for the semelparous life history of the species and the fact that natural mortality increases with age for spawners. However, additional maturity-at-age data are needed to determine the range of M estimates for the various seasonal cohorts.

Preliminary minimum consumption estimates of *Loligo pealeii*

Natural mortality attributable solely to predation was not estimated for *Loligo*, but preliminary minimum consumption estimates during spring and fall were used for comparison with seasonal fishery removals. Size compositions of the *Loligo* prey consumed were also compared to the size compositions of the *Loligo* caught during NEFSC spring and fall surveys and in the fishery. Preliminary estimates of the seasonal consumption of each of the two primary *Loligo* cohorts were computed using food habits data collected during the 1977-2009 NEFSC spring and fall surveys. The spring and fall estimates were summed to derive an annual estimate. Details of the methodology used to compute the consumption estimates, effective sample sizes, and results from the analysis are presented in Appendix B6.

The consumption estimates are preliminary and represent minimums because they do not include consumption by all predators, such as: marine mammals, seals, large pelagic fish species, and birds. In addition, ecosystem and predator dynamics in relation to the complex life history and high turnover rates of squid populations are poorly understood. Minimum consumption estimates were highly variable inter-annually, but were 0.8 to 11 times higher than annual catches during 1977-2009 (Figure B44).

During 1977-1984 and 1999-2010, minimum consumption was much higher during the fall than during the spring (Figure B45). Minimum seasonal consumption estimates, particularly during the spring, are a substantial fraction of the stock biomass (Figure B39). This may imply that the stock is very productive or that the biomass estimates (computed using the median *q* values) are too low, particularly during the spring. Fortunately, the status of the stock with respect to biomass thresholds is trend-based and would not be affected by an underestimation of *Loligo* biomass. Furthermore, higher levels of consumption would reinforce the assessment conclusion that catch is low relative to consumption and that the *Loligo* stock is lightly exploited.

Term of Reference 5: *State the existing stock status definitions for the terms "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and $F_{MSY;}$ and estimates of their uncertainty). Comment on the scientific adequacy of existing BRPs and for the "new" (i.e., updated, redefined, or alternative) BRPs.*

Existing Biological Reference Points

There are no existing biomass reference points for the *Loligo* stock because the previous Bmsy proxy was deemed inappropriate at SARC 34 and a revised estimate was not provided (NEFSC 2002b). Proxies for Ftarget and Fthreshold were promulgated in Amendment 9 (MAFMC 2009) based on the recommendations from the SARC 34 reviewers that are reflected in the the SAW 34 Advisory Report (NEFSC 2002a). The existing Fmsy proxy is 1.24 per year and is based on the 75th percentile of the quarterly exploitation indices (0.31 per quarter) during 1987-2000. The annual F_{target} is 0.96 and represents the quarterly mean of the exploitation indices during the same time period. The exploitation indices were computed in SARC 34 using a different methodology and different data that those used during the current assessment (refer to Term of Reference 3). In addition, the exploitation indices are ad-hoc because the fall survey data were scaled up by a catchability coefficient estimated in an independent model. The estimates from the independent model were based on survey data and, primarily, on a composite q-prior that is now obsolete because of improvements made in the current assessment.

Proposed **Biological Reference Points**

A new threshold Bmsy proxy of 21, 203 mt and a biomass target of 42, 405 mt are proposed (Table B28). The median of the average of the catchability-adjusted spring and fall survey biomass levels during 1976-2008 is 76,329 mt. The stock appears to be lightly exploited and assuming that biomass is at 90% of the stock's carrying capacity (*K*), a new Bmsy target of 50% of *K* (0.50*(76,329/0.90) = 42,405 mt) is recommended. Based on logistic production models, an appropriate biomass threshold for a short-lived species like *Loligo* is 50% of Bmsy (= 21,203 mt). Annual biomass estimates exceed annual carrying capacity in multiple years, which is to be expected for a species with highly variable seasonal population dynamics which are linked to variability in environmental conditions.

A new Fmsy proxy could not be recommended due to the lack of evidence that fishing has impacted stock biomass since 1975. Conventional approaches based on finfish population dynamics are inappropriate. In particular, there is no theory linking *M* and F_{MSY} for short lived organisms like *Loligo* and per-recruit reference points can be calculated only approximately

(NEFSC 2002a). There is also no theory linking F_{SPR} per recruit reference points to F_{MSY} for species like *Loligo*. Finally, there is too little contrast in either the fishery catch or survey data to provide information that could be used to estimate F_{MSY} in a modern dynamical model.

Term of Reference 6: *Evaluate stock status with respect to the existing BRPs, as well as with respect to the "new" BRPs (from Loligo TOR 5).*

Stock status

There are no existing biomass-based reference points for the stock, and as a result, overfished status cannot be determined. Based on the current fishing mortality reference points, overfishing was not occurring because the 2009 exploitation index (estimated using the method from SARC 34, Oct-Dec. catch over *q*-adjusted fall survey swept-area biomass) was 0.063 compared to the Fthreshold (i.e., 75th percentile of the exploitation indices during 1987-2009) which is 0.277). However, the current fishing mortality reference points are inappropriate for the lightly exploited *Loligo* stock. The stock appears to be lightly exploited because annual catches were low relative to annual estimates of minimum consumption by a subset of fish predators and there was no evidence of fishing effects on annual survey biomass estimates (i.e., annual averages of the spring and fall biomass estimates) during 1975-2009.

The new exploitation indices used in the current assessment are not comparable to the existing fishing mortality reference points because of differences in computation methods and input data. In the previous assessment, exploitation indices were computed for Quarter 1 as the landings during October-December, plus 6% discards, divided by a *q*-adjusted fall survey biomass estimate. The existing F reference points assume that exploitation is constant during the other three quarters the year. The fall survey catchability *q* (= 0.45) for *Loligo* in the NEFSC fall surveys was estimated from a production model based largely on the obsolete composite prior for fall survey catchability in the previous assessment. The relative biomass indices were computed using all survey tows adjusted to daytime equivalents (i.e., diel conversion factors for night and dawn/dusk). In addition, the fall survey biomass estimates did not include important inshore *Loligo* habitat and biomass estimates for the other primary seasonal cohort (i.e., spring survey biomass estimates) were not used in the assessment. In the current assessment, exploitation indices were computed as the annual catch divided by the mean of the annual spring and fall survey biomass estimates, the latter which were derived using a different survey strata set, only daytime tows, vessel and door correction factors, and the median values of the updated composite *q*-priors.

Based on the proposed biomass reference point threshold from the current assessment, the stock was not overfished during 2009. The two-year average of catchability-adjusted spring and fall survey biomass levels during 2008-2009 was 54,442 mt (80% CI = 38,452-71,783 mt) and is higher than the proposed threshold Bmsy proxy of 21,203 mt (Figure B46, Table B28). The overfishing status during 2009 is unknown because new fishing mortality reference points could not be recommended in the current assessment due to the lack of evidence that fishing impacted annual biomass levels during 1975-2009. The 2009 exploitation index of 0.176 (catch in 2009 divided by the average of the spring and fall survey biomass during 2008-2009; 80% CI = 0.124-0.232) was slightly below the 1987-2008 median of 0.237 (Figure B47, Table B28).

Term of Reference 7: *Develop approaches for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs), and comment on the ability to perform projections for this stock.*

Stock size projections

Stock size projections were not possible for this semelparous, sub-annual species due to the lack of an assessment model and because like most squid stocks, the short sub-annual lifespan and semelparous life history of this species result in rapid changes in stock size in response to environmental conditions (Hendrickson and Showell 2010; Dawe *et al.* 2007; Boyle and Rodhouse 2005).

Potential approaches for computing ABCs

TOR 7 does not include the specification of ABC levels for *Loligo* nor characterization of the various risks involved in fishery management, but rather involves recommending approaches for computing candidate ABCs. ABC refers to a level of "catch" that is "acceptable" given the "biological" characteristics of the stock. Adequate escapement of spawners is needed for this semelparous squid stock to ensure sufficient recruitment in the subsequent year. The magnitude of escapement could be affected by increased exploitation.

The following "Omnibus" approach to setting ABC levels is currently under consideration. It is described as follows. "Allowable biological catch is a level of a stock or stock complex's annual catch that accounts for the scientific uncertainty in the estimate of [overfishing limit] OFL and any other scientific uncertainty…" (Federal Register, vol. 74, no. 11, January 16, 2009). The MAFMC's Scientific and Statistical Committee (SSC) is responsible for adjusting OFL levels of catch downward, based on available information about the stock, fishery and uncertainty. The Council is already developing an omnibus amendment that provides the SSC with a general procedure for setting ABC levels. The omnibus approach ranks stocks into four tiers, depending on the information about the stock and reference points provided in the assessment. The omnibus approach is flexible and may well be a sufficient basis for specifying ABC levels for the *Loligo* fishery. The alternative ideas provided in this assessment should not be construed as an indication that the omnibus approach is inadequate.

The ecological importance of *Loligo* as prey for a wide range of species could be considered in specifying ABC levels. *Loligo* are prey for a wide range of non-demersal fish, birds, and marine mammals. Ignoring additional mortality at spawning, mortality rates (mostly natural mortality) for non-spawning *Loligo* range from 0.058 to 0.11 per week (3.0 to 5.7 per year) due, presumably, to predation.

Potential approaches to computing ABCs include:

1) *Seasonal ABC levels*. When setting the annual ABC, consideration of the differences in seasonal cohort productivity and biomass may be prudent. *Loligo* biomass and productivity appear to be substantially lower for the cohort caught in the spring survey than for the cohort caught in the fall survey. Lower spring biomass may be due to a variety of factors, including differences in available habitat, migration patterns, reproduction, growth rates, and/or consumption removals. Relative abundance indices from the spring and fall surveys are correlated and exploitation indices for the January-June fishery (median = 0.315) are much higher on the less-productive, spring survey cohort than those for the July-December fishery (median = 0.064) on the more-productive fall survey cohort.

2) *ABC by analogy to consumption estimates for key predators*. Consumption estimates for six (cod, bluefish, goosefish, pollock, summer flounder and weakfish) of the 15 *Loligo* finfish predators included in this assessment are based on predator stock biomass estimates from peer-reviewed assessment reports that include estimates of survey catchability. The consumption estimates for these six species are plausible estimates of consumption for the six species. Considering consumption by humans and fish predators, specifying ABC levels for *Loligo* based on consumption estimates, based on stock assessment abundance data, for important predators may be a practical approach to ecosystem-based management. Consumption is generally higher during the fall and seasonal differences could be considered as well.

3)

Term of Reference 8: *Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.*

Prior research recommendations from SARC34

1) Based on results from the SARC 34 assessment, it appears that traditional per-recruit reference points like F_{MAX} may be poor proxies for F_{MSY} in longfin squid because they do not permit a sufficient level of spawning escapement. There appears to be no satisfactory biomass based reference points for longfin squid at this time. Fishing mortality and biomass reference points for use as targets and thresholds are an important area for research.

   A new Bmsy reference point was estimated in the current assessment, but an Fmsy BRP or a proxy thereof requires further research due to the complex life history of this species and the lack of theory linking F_{SPR} per-recruit reference points to F_{MSY} for species like Loligo .

2) It is important to carry out further research on standardizing and modeling survey data for longfin squid. A preliminary GAM (general additive model) analysis of survey data should serve as a good starting point in developing standardization approaches that adjust for diel and other factors affecting catchability. PDQ model results show that survey

catchability processes errors follow similar trends in different surveys and are autocorrelated within surveys. Survey catchabilities probably vary in response to water temperatures. These circumstances suggest that survey catchability processes errors might be modeled robustly and parsimoniously as a simple function of water temperatures in the PDQ model.

A new GAM was developed and used in the current assessment to define cut points for defining daytime survey tows, based on solar zenith angle, depth, temperature, and other factors, which were used to derive biomass estimates.

3) Growth information, particularly for older longfin squid, is still uncertain. Additional age and growth studies are required to better estimate average growth patterns and to discern seasonal patterns. The latter are potentially important in more realistic, seasonally explicit population and reference point models like the preliminary, multi-cohort reference point model.

   More statolith-based age data are needed, by season, for the fishery and NEFSC surveys to accomplish this task. Variable selectivities of the existing age data sets make this task difficult to accomplish.

4) The potential for fuller use of catch data prior to 1987 from foreign fishing should be investigated for longfin squid. Current assessment approaches use seasonal time steps but historical catch data are currently available only by calendar year. The working group should consult historical NAFO reports and determine if monthly or quarterly catches can be estimated. Alternatively, the PDQ model could be modified to use annual time steps prior to 1987 and quarterly time steps later. Another approach would be to use an annual surplus production model including years before and after 1987.

   The use of production models to assess squid stocks is not recommended by the ICES Working Group on Cephalopod Fisheries and Life History given their unique life history characteristics, which include the lack of a strong relationship between current and future stock size estimates and the fact that natural mortality is difficult to estimate and varies with age (Anonymous 2001).

5) Results from this assessment demonstrate that retrospective analyses are a useful part of an assessment involving surplus production models because they provide an estimate of the stability of model estimates. However, retrospective patterns for estimates in production models may have a different meaning and origin than in traditional age structured models. This is a topic for analysis by the Methods Working Group.

   This research recommendation is now moot because a production model is no longer used in the assessment.

6) Available logbook data are not adequate to measure fishing effort after 1993, or to prorate landings and effort data by area. It is not currently possible to measure commercial catch rates after 1993, to track trends in fishing effort, or to investigate

relationships between catches and abundance in near shore, offshore, northern and southern areas. The spatial resolution, coverage and accuracy of commercial catch data for longfin squid should be improved.

Logbook data for 1996-2009 were used in the current assessment to compute nominal fishing effort and LPUE indices.

7) Information about the population biology of longfin squid has improved in recent years but relationships between seasonal migrations, environmental conditions and temporal and spatial variability in sex ratios, maturity and growth rates are still not clear. It may be useful to carryout additional studies that collect sex and maturity data from longfin squid taken during NEFSC surveys.

This task was not completed.

New research recommendations for SARC51

1) Use a mass balance approach to determine if the large apparent differences between the spring and fall biomass estimates are plausible, and what they imply about seasonal patterns in growth, recruitment and mortality.
2) Investigate the use of assessment models with short time steps (i.e., weekly) that incorporate data which allow for cohort-based estimates of biomass and exploitation (e.g., depletion models). Especially consider methods that track changes in fishing mortality.
3) Biomass estimates from NEAMAP inshore survey strata that were previously sampled by NEFSC survey vessels (depths ≤ 18 m between Cape Hatteras and Long Island) were computed for this assessment. Develop additional approaches to estimating *Loligo* biomass in unsampled areas, in particular regions south of Cape Hatteras.
4) Refine consumption estimates for *Loligo*. Where possible, use stock assessment biomass estimates for predator biomass. If a stock assessment-based biomass estimate is not available, it may be advisable to assume a range of survey catchability values in calculating predator swept-area biomass. Estimate consumption by predators (including birds and marine mammals) not well sampled by bottom trawls. Consider smoothing consumption rate estimates to eliminate sampling errors.
5) Develop methods for describing trends in relative fishing mortality for *Loligo*. Conventional approaches developed for fish do not account for recruitment to fishable sizes during fishing or to very high mortality and somatic growth rates.
6) Develop new F_{MSY} proxy or threshold reference point approaches for *Loligo* because conventional approaches developed for finfish with relatively low mortality and slow growth rates are not applicable. Refine B_{MSY} proxies for *Loligo* as well.
7) Maturation-mortality results were encouraging but the data sets used in modeling were not ideal. Collect more age, sex and maturity data for each seasonal cohort and use it in

the model. Also, estimate age-reader error for *Loligo* because this information is important in estimating maturity-mortality model parameters.

8) Refine, carry out sensitivity analyses and document gnomonic natural mortality estimates for *Loligo*.
9) Refine the upper and lower bounds for factors (efficiency, tow distance, tow width, and stock area) that affect survey catchability, particularly for the new survey vessel, and evaluate whether uniform distributions are the best choice for representing uncertainty in these factors.
10) Analyze the costs and benefits of specifying ABC levels based on predator consumption estimates.
11) Develop approaches to smoothing survey biomass estimates that take into account the short lifespan of *Loligo* and differences between spring and fall surveys.

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B. *Loligo*-Tables

Table B1. History summary of the Atlantic Mackerel, Squid and Butterfish Fishery Management Plan.

Year	Document	Management Action
1978-1980	Original FMPs (3) and individual amendments	Established and continued management of Atlantic mackerel, squid, and butterfish fisheries
1983	Merged FMP	Consolidated management of Atlantic mackerel, squid, and butterfish fisheries under a single FMP
1984	Amendment 1	Implemented squid OY adjustment mechanism
		Revised Atlantic mackerel mortality rate
1986	Amendment 2	Equated fishing year with calendar year
		Revised squid bycatch TALFF allowances
		Implemented framework adjustment process
		Converted expiration of fishing permits from indefinite to annual
1991	Amendment 3	Established overfishing definitions for all four species
1991	Amendment 4	Limited the activity of directed foreign fishing and joint venture transfers to foreign vessels
		Allowed for specification of OY for Atlantic mackerel for up to three years
1996	Amendment 5	Adjusted *Loligo* MSY; established 1 7/8" minimum mesh size
		Eliminated directed foreign fisheries for *Loligo*, *Illex*, and butterfish
		Instituted a dealer and vessel reporting system; Instituted operator permitting
		Implemented a limited access system for *Loligo*, *Illex* and butterfish
		Expanded management unit to include all Atlantic mackerel, *Loligo*, *Illex*, and butterfish under U.S. jurisdiction.
1997	Amendment 6	Established directed fishery closure at 95% of DAH for *Loligo*, *Illex* and butterfish with post-closure trip limits for each species
		Established a mechanism for seasonal management of the *Illex* fishery to improve the yield-per recruit
		Revised the overfishing definitions for *Loligo*, *Illex* and butterfish
1997	Amendment 7	Established consistency among FMPs in the NE region of the U.S. relative to vessel permitting, replacement and upgrade criteria
1998	Amendment 8	Brought the FMP into compliance with new and revised National Standards and other required provisions of the Sustainable Fisheries Act.
		Added a framework adjustment procedure.
2001	Framework 1	Established research set-asides (RSAs).

Table B1 (cont.)		
Year	**Document**	**Management Action**
2002	Framework 2	Established that previous year specifications apply when specifications for the management unit are not published prior to the start of the fishing year (excluding TALFF specifications)
		Extended the *Illex* moratorium for one year; Established *Illex* seasonal exemption from *Loligo* minimum mesh;
		Specified the *Loligo* control rule; Allowed *Loligo* specs to be set for up to 3 years
2003	Framework 3	Extended the moratorium on entry to the *Illex* fishery for an additional year
2004	Framework 4	Extended the moratorium on entry to the *Illex* fishery for an additional 5 years
2009	Amendment 9	Extended the moratorium on entry into the *Illex* fishery, without a sunset provision
		Adopted biological reference points for *Loligo* recommended by the stock assessment review committee (SARC).
		Designated EFH for *Loligo* eggs based on available information
		Prohibited bottom trawling by MSB-permitted vessels in Lydonia and Oceanographer Canyons
		Authorized specifications to be set for all four MSB species for up to 3 years
2010	Amendment 10	Implemented a butterfish rebuilding program. (cap to begin in 2011)
		Increased the *Loligo* minimum mesh in Trimesters 1 and 3.
		Implemented a 72-hour trip notification requirement for the *Loligo* fishery (2011).

[1]In 2000, a 2,500-pound trip limit was implemented during fishery closures.
[2]During 2000 and 2007-2009, the *Loligo* DAH was divided up into trimesters. Quarterly quotas were implemented during 2001-2006. The fishery closes during each seasonal time period when the threshold of the seasonal quota allocation is reached.

Table B2. *Loligo* fishery closure dates (prohibition on *Loligo* landings ≥ 2,500 lbs per trip), during 2000-2009, when in-season quotas were in effect. Quotas were trimester-based during 2000 and 2007-2009 and quarterly during 2001-2006.

Year	**Quota period I**	**Quota period II**	**Quota period III**	**Quota period IV**
2000	Mar 25 – Apr 30	Jul 1- Aug 31	Sep 7 – Oct 6, Oct 26 - Dec 31	
2001		May 29 – Jun 30		
2002		May 28 – Jun 30	Aug 16 – Sep 30	Nov 2 - Dec 11 Dec 24 – Dec 31
2003	Mar 25 - Mar 31			
2004	Mar 5 - Mar 31			
2005	Feb 20 - Mar 31	Apr 25 - Jun 30		Dec 18 - Dec 31
2006	Feb 13 - Mar 31	Apr 21 - Apr 27 May 23 - Jun 30	Sep 2 - Sep 30	
2007	Apr 13 - Apr 30			
2008		July 17 - Aug 31		
2009		Aug 6 - Aug 31		

Table B3. *Loligo pealeii* landings during 1963-2010 and Total Allowable Catches (TACs) during 1974-2010. The 2010 landings are preliminary and incomplete.

Year	U.S.	Foreign	Total	Annual TAC	% Foreign
1963	1,294	0	1,294		0.0%
1964	576	2	578		0.3%
1965	709	99	808		12.3%
1966	722	226	948		22.6%
1967	547	1,130	1,677		67.4%
1968	1,084	2,327	3,411		68.2%
1969	899	8,643	9,542		90.6%
1970	653	16,732	17,385		96.2%
1971	727	17,442	18,169		96.0%
1972	725	29,009	29,734		97.6%
1973	1,105	36,508	37,613		97.1%
1974	2,274	32,576	34,850	71,000	93.5%
1975	1,621	32,180	33,801	71,000	95.2%
1976	3,602	21,682	25,284	44,000	85.8%
1977	1,088	15,586	16,674	44,000	93.5%
1978	1,476	9,355	10,831	44,000	87.9%
1979	4,252	13,068	17,320	44,000	75.5%
1980	3,996	19,750	23,746	44,000	83.2%
1981	2,316	20,212	22,528	44,000	89.7%
1982	2,848	15,805	18,653	44,000	84.7%
1983	10,867	11,720	22,587	44,000	51.9%
1984	7,689	11,031	18,720	44,000	58.9%
1985	6,899	6,549	13,448	44,000	48.7%
1986	11,525	4,598	16,123	44,000	28.5%
1987	10,367	2	10,369	44,000	<0.1%
1988	18,593	3	18,596	44,000	<0.1%
1989	23,733	5	23,738	44,000	<0.1%
1990	15,399	0	15,399	44,000	
1991	20,299	0	20,299	44,000	
1992	19,018	0	19,018	44,000	
1993	23,020	0	23,020	44,000	
1994	23,480	0	23,480	44,000	
1995	18,880	0	18,880	36,000	
1996	12,503	0	12,503	25,000	
1997	16,270	0	16,270	21,000	

Table B3. (cont.)

Year	U.S.	Foreign	Total	Annual TAC	% Foreign
1998	19,145	0	19,145	21,000	
1999	19,173	0	19,173	21,000	
2000	17,540	0	17,540	15,000	
2001	14,345	0	14,345	17,000	
2002	16,868	0	16,868	17,000	
2003	11,941	0	11,941	17,000	
2004	15,629	0	15,629	17,000	
2005	16,978	0	16,978	17,000	
2006	15,920	0	15,920	17,000	
2007	12,342	0	12,342	17,000	
2008	11,418	0	11,418	17,000	
2009	9,306	0	9,306	19,000	
2010	5,256	0	5,256	19,000	

[1] Landings during 1963-1978 were not reported by species, but are proration-based estimates by Lange and Sissenwine (1980)
[2] Landings during 1979-2010 are from the NEFSC Commercial Fisheries Database
[3] Domestic landings during 1982-1991 include Joint-Venture landings
[4] Domestic landings include unclassified squid which were pro-rated by month and 2-digit Statistical Area (1982-1995) or additive (since 1996)
[5] The source of the landings data for 1963-1995 is NEFSC CRD 02-06.
[6] Since May of 2004, landings have been reported electronically by dealers
[7] Landings during 2010 are preliminary and incomplete
[8] TACs for 1974 and 1975 are for *Illex* and *Loligo* combined

Table B4. Numbers of trips sampled, by month, for landings length composition during 1987-2009.

	Month												
Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1987	1	3	7	4	5	11	1	2	3	1	5	5	48
1988	1	3	5	5	15	7	6	3	1	3	3	2	54
1989	4	2	11	2	17	10	5	2	8	10	7	4	82
1990	6	7	11	5	16	11	3	5	6	13	8	3	94
1991	3	5	9	8	11	4	1	5	6	5	7	9	73
1992	8	3	8	8	7	3	6	6	3	6	10	3	71
1993	4	4	10	4	3	5	2	4	1	9	5	2	53
1994	4	2	7	0	1	6	3	3	7	7	4	2	46
1995	4	5	6	3	5	0	3	3	0	3	0	2	34
1996	1	2	16	1	3	3	5	4	0	11	13	13	72
1997	10	12	16	12	12	8	7	9	4	15	6	1	112
1998	7	18	24	15	2	3	3	9	3	13	18	16	131
1999	18	14	13	31	11	15	36	25	12	12	14	13	214
2000	18	17	15	1	10	28	10	7	2	6	5	7	126
2001	7	16	17	21	10	9	16	9	6	22	24	6	163
2002	25	13	18	21	6	5	20	16	1	22	3	5	155
2003	9	20	16	10	9	2	6	14	7	14	20	4	131
2004	7	21	13	10	15	10	14	8	1	17	10	19	145
2005	20	25	15	21	21	4	4	7	4	21	36	14	192
2006	38	9	22	34	14	6	14	18	3	27	32	10	227
2007	16	10	25	20	4	6	30	25	4	38	9	6	193
2008	23	24	3	19	13	7	32	2	4	37	6	4	174
2009	12	16	18	18	16	4	29	7	4	21	9	10	164

Table B5. Numbers of *Loligo* sampled for landings length composition, by market category, during 1987-2009.

Year	Unclassified	Lg	Sm	Med	SS	Total
1987	2,449	49				2,498
1988	3,153					3,153
1989	4,455					4,455
1990	4,903	152				5,055
1991	3,626	252				3,878
1992	3,852	50				3,902
1993	2,718	151				2,869
1994	3,462	316				3,778
1995	2,370	1,100				3,470
1996	5,071	1,183				6,254
1997	8,850	1,765	1,136	100	200	12,051
1998	9,650	2,944	451	195	888	14,128
1999	12,659	7,210	1,258	956	1,701	23,784
2000	8,381	3,904	118	161	430	12,994
2001	9,884	4,538	8,080	2,033	1,807	26,342
2002	6,638	5,632	18,598	7,373	8,680	46,921
2003	7,457	1,740	8,210	2,381	12,638	32,426
2004	11,090	3,322	699		1,983	17,094
2005	12,966	4,867	3,738	1,051	10,392	33,014
2006	14,123	8,664	1,614	109	2,138	26,648
2007	14,145	5,282	603	269	548	20,847
2008	12,020	5,649	200	100		17,969
2009	9,605	6,197	305	400		16,507

Table B6. Number of *Loligo* length samples from the landings, by market category and month, during 1996-2009.

		Month												
Year	Market category	1	2	3	4	5	6	7	8	9	10	11	12	Total
1996	8010	1	2	12	1	3	2	5	3		8	12	8	57
	8011			4			1		1		3	1	5	15
Total		1	2	16	1	3	3	5	4		11	13	13	72
1997	8010	10	9	10	7	12	8	5	7	1	12	5	1	87
	8011		3	5	2			2	2	2	1	1		18
	8012			1	1					1	1			4
	8013				1									1
	8014				1						1			2
Total		10	12	16	12	12	8	7	9	4	15	6	1	112
1998	8010	4	12	19	10	2	3	2	7	3	7	14	11	94
	8011	3	5	5	5			1	2		3	2	3	29
	8012		1								1		1	3
	8013										1	1		2
	8014										1	1	1	3
Total		7	18	24	15	2	3	3	9	3	13	18	16	131
1999	8010	12	8	4	17	7	12	14	17	7	9	10	3	120
	8011	4	2	5	12	4	3	19	7	5	3	4	4	72
	8012	1	2	1	1			1					2	8
	8013	1		2				2	1				2	8
	8014		2	1	1								2	6
Total		18	14	13	31	11	15	36	25	12	12	14	13	214
2000	8010	9	15	12	1	9	12	8	3	1	4	3	5	82
	8011	6	2	3		1	14	2	4	1	2	2	2	39
	8012	1												1
	8013	1												1
	8014	1					2							3
Total		18	17	15	1	10	28	10	7	2	6	5	7	126
2001	8010	6	9	11	11	8	5	13	6	5	14	5	2	95
	8011	1	6	6	9	2	4	3	3	1	5	5		45
	8012										1	7	2	10
	8013		1		1						1	6	2	11
	8014										1	1		2
Total		7	16	17	21	10	9	16	9	6	22	24	6	163
2002	8010	8	7	5	11	2	1	5	5		10	2	5	61
	8011	7	2	6	4	1	2	6	7		5			40
	8012	4	2	3	2	1	1	3	3	1	3	1		24
	8013	4	2	3	2	1	1	3			3			19
	8014	2		1	2	1		3	1		1			11
Total		25	13	18	21	6	5	20	16	1	22	3	5	155
2003	8010	3	10	9	4	5	2	6	13	4	4	11	4	75
	8011	1	4	2	1	1			1		5	3		18
	8012	2	2	2	2	1				1	1	2		13
	8013	1	2	1	1	1				1	2	2		11
	8014	2	2	2	2	1				1	2	2		14
Total		9	20	16	10	9	2	6	14	7	14	20	4	131

Table B6 (cont.)		Month												
Year	Market category	1	2	3	4	5	6	7	8	9	10	11	12	Total
2004	8010	6	14	9	3	11	8	12	7	1	15	10	13	109
	8011	1	7	4	7	4	2	2	1		2		2	32
	8012												2	2
	8014												2	2
Total		7	21	13	10	15	10	14	8	1	17	10	19	145
2005	8010	10	14	11	11	16	3	3	6	4	8	21	10	117
	8011	3	5	4	10	4	1	1	1		5	9	4	47
	8012	2	2								3	1		8
	8013	2	1			1					2	2		8
	8014	3	3								3	3		12
Total		20	25	15	21	21	4	4	7	4	21	36	14	192
2006	8010	22	7	15	19	9	5	13	12		14	15	6	137
	8011	11	2	7	15	5	1	1	6	3	13	17	4	85
	8012	2												2
	8013	1												1
	8014	2												2
Total		38	9	22	34	14	6	14	18	3	27	32	10	227
2007	8010	12	7	14	12	3	5	18	18	4	32	7	5	137
	8011	4	3	8	8	1	1	12	7		6	2		52
	8012			1										1
	8013			1									1	2
	8014			1										1
Total		16	10	25	20	4	6	30	25	4	38	9	6	193
2008	8010	19	22	3	11	10	5	16	1	1	21	5	2	116
	8011	4	2		7	3	2	16	1	3	14	1	2	55
	8012				1						1			2
	8013										1			1
Total		23	24	3	19	13	7	32	2	4	37	6	4	174
2009	8010	6	11	14	8	11	4	12	5	2	10	5	7	95
	8011	5	5	4	9	5		17	2	2	9	3	1	62
	8012	1			1								1	3
	8013										2	1	1	4
Total		12	16	18	18	16	4	29	7	4	21	9	10	164

Table B7. *Loligo* discard estimates (mt) and CVs, by fleet, and number of observer trips per year during 1989-2009.

	***Loligo* Discards (mt)**								
	Bottom trawls by codend mesh size								
	>= 5.5 in.	**2.5-5.49 in.**	**<= 2.49 in.**	**Total**	**MW trawls**	**Scallop dredges/trawls**	**Grand Total**	**CV**	**Total N obs. trips**
1989	134	479	183	796	2.11	8.79	806	0.22	178
1990	285	164	698	1,147	2.11	8.79	1,158	0.59	139
1991	98	155	254	506	28.94	8.79	544	0.78	269
1992	113	353	303	770	0.01	10.26	780	0.64	213
1993	8	149	195	352	0.02	15.02	367	0.02	110
1994	284	703	85	1,072	0.29	14.19	1,086	0.49	119
1995	28	39	1,121	1,187	2.11	19.46	1,209	0.29	288
1996	6	264	19	288	2.11	2.67	293	0.90	224
1997	3	89	99	191	2.11	10.34	204	1.14	130
1998	5	45	161	211	2.11	18.15	232	0.87	82
1999	12	27	2,099	2,139	0.06	1.24	2,140	0.64	124
2000	113	6	12	131	2.11	3.51	137	0.28	452
2001	4	3	40	47	2.11	5.04	54	0.43	380
2002	3	3	348	354	2.11	16.61	373	0.64	450
2003	18	3	134	156	2.11	10.94	169	0.79	690
2004	7	3	266	277	0.04	6.58	283	0.30	1,431
2005	4	7	682	692	0.02	3.62	696	0.25	2,343
2006	20	50	119	189	0.00	10.47	199	0.52	1,180
2007	10	3	112	125	0.08	5.23	130	0.42	1,463
2008	17	5	81	103	0.05	2.63	106	0.59	1,799
2009	73	3	175	251	0.07	2.25	254	0.40	2,075
Average 1989-2009	59	122	342	523	2	9	534	0.53	673

Table B8. Number of NEFOP observer trips, *Loligo* discard estimates (mt) and CVs, by fleet and region, during 1989-2009.

Bottom trawls with codend mesh size ≥ 5.5 in.

	MA			NE			Total		
YEAR	N Obs trips	Discards (mt)	CV	N Obs trips	Discards (mt)	CV	N Obs trips	Discards (mt)	CV
1989	1	66.9	0.72	56	66.9	0.72	57	133.8	0.72
1990	0	142.7	0.43	54	142.7	0.43	54	285.4	0.43
1991	4	64.0	2.41	78	34.0	0.38	82	98.0	1.58
1992	14	8.8	1.36	68	104.6	1.09	82	113.4	1.01
1993	7	3.8	1.98	31	4.1	1.50	38	7.8	1.23
1994	13	13.8	0.86	27	269.7	0.57	40	283.5	0.54
1995	52	9.1	0.75	67	18.7	0.53	119	27.8	0.43
1996	16	1.4	3.68	39	4.5	4.75	55	5.8	3.75
1997	5	**2.7**	0.63	24	0.2	0.63	29	2.9	0.63
1998	13	4.1	0.90	11	1.2	0.44	24	5.3	0.69
1999	5	3.1	1.09	32	9.3	0.25	37	12.4	0.33
2000	27	105.0	0.33	99	8.3	0.37	126	113.3	0.31
2001	44	0.1	0.97	156	3.7	0.40	200	3.7	0.40
2002	37	0.1	0.45	214	2.8	0.30	251	2.8	0.30
2003	11	16.1	0.89	386	2.4	0.57	397	18.5	0.78
2004	91	5.6	0.40	527	1.7	0.37	618	7.3	0.32
2005	87	1.1	0.62	1346	2.4	0.26	1,433	3.5	0.27
2006	62	4.5	0.88	613	15.1	0.16	675	19.6	0.68
2007	160	4.8	0.41	619	4.9	0.30	779	9.7	0.25
2008	127	7.6	0.89	750	9.1	0.26	877	16.6	0.43
2009	164	68.7	0.40	868	4.1	0.31	1,032	72.7	0.38

Table B8 (cont.)

	Bottom trawls with codend mesh size 2.5-5.49 in.								
	MA			NE			Total		
YEAR	**N Obs trips**	**Discards (mt)**	**CV**	**N Obs trips**	**Discards (mt)**	**CV**	**N Obs trips**	**Discards (mt)**	**CV**
1989	23	282.49	0.41	68	196.12	0.32	91	479	0.28
1990	36	120.91	0.51	30	42.71	1.30	66	164	0.51
1991	47	95.44	0.50	67	59.30	0.33	114	155	0.33
1992	26	215.61	0.48	33	137.85	0.60	59	353	0.38
1993	7	123.03	0.67	17	26.20	0.64	24	149	0.56
1994	8	23.63	0.80	9	679.64	0.69	17	703	0.67
1995	21	31.33	1.37	4	7.27	0.75	25	39	1.12
1996	28	24.86	0.61	8	239.27	1.08	36	264	0.98
1997	15	5.43	1.26	9	83.97	1.01	24	89	0.95
1998	5	0.46	1.10	1	**44.78**	1.10	6	45	1.10
1999	10	1.87	0.93	9	**25.19**	0.93	19	27	0.93
2000	16	0.45	1.58	12	5.60	1.39	28	6	1.29
2001	19	0.03	6.68	14	3.46	0.76	33	3	0.75
2002	19	2.84	0.35	44	0.45	0.57	63	3	0.31
2003	54	0.67	0.65	45	2.27	0.56	99	3	0.46
2004	158	2.75	0.34	120	0.72	0.87	278	3	0.32
2005	111	5.42	0.37	199	1.39	0.49	310	7	0.31
2006	59	49.40	0.71	46	0.38	2.04	105	50	0.70
2007	157	2.28	0.43	42	0.90	0.81	199	3	0.39
2008	95	5.03	0.48	25	0.09	1.57	120	5	0.47
2009	142	1.93	0.37	75	1.16	0.52	217	3	0.30

Table B8 (cont.)

	Bottom trawls with codend mesh size ≤ 2.49 in.								
	MA			NE			Total		
YEAR	N Obs trips	Discards (mt)	CV	N Obs trips	Discards (mt)	CV	N Obs trips	Discards (mt)	CV
1989	11	125	0.56	19	58	0.62	30	183	0.43
1990	12	581	0.98	7	117	0.95	19	698	0.83
1991	33	171	2.24	31	82	0.46	64	254	1.52
1992	21	295	1.57	24	8	2.02	45	303	1.53
1993	1	**182**		4	**12**		5	195	0.00
1994	3	70	2.47	1	**15**		4	85	2.47
1995	42	1104	0.32	36	17	0.89	78	1,121	0.31
1996	51	15	0.56	42	4	1.32	93	19	0.52
1997	36	92	2.25	12	7	5.53	48	99	2.13
1998	22	54	1.27	4	106	1.37	26	161	1.00
1999	24	124	0.65	10	1975	0.69	34	2,099	0.65
2000	20	7	0.68	5	5	2.65	25	12	1.14
2001	36	23	0.52	4	17	1.08	40	40	0.55
2002	14	328	0.73	21	20	0.56	35	348	0.68
2003	18	50	0.93	27	84	1.45	45	134	0.97
2004	96	207	0.40	49	59	0.26	145	266	0.32
2005	63	559	0.29	54	123	0.55	117	682	0.26
2006	89	88	1.11	38	32	0.29	127	119	0.51
2007	64	45	0.98	36	66	0.45	100	112	0.48
2008	57	27	1.37	37	54	0.92	94	81	0.77
2009	145	160	0.62	146	16	0.53	291	175	0.56

[1] Values shown in bold were interpolated either because there were fewer than 2 trips per year or all trips occurred in one quarter

Table B9. Numbers of *Loligo* length measurements used to characterize the kept and discarded portions of the catches and
numbers of trips sampled by NEFOP observers during 1994-2009.

	N *Loligo* sampled		N trips sampled	
Year	Kept	Discarded	Kept	Discarded
1994	3,162	224	3	2
1995	5,398	2,958	36	14
1996	5,310	1,138	22	7
1997	10,803	884	29	5
1998	8,030	0	18	0
1999	18,463	2,442	34	9
2000	8,898	1,163	25	5
2001	15,126	1,579	31	10
2002	9,278	1,075	31	4
2003	3,060	108	18	1
2004	20,653	1,082	81	9
2005	17,082	1,127	71	9
2006	9,715	637	51	9
2007	3,407	628	28	7
2008	5,875	309	36	5
2009	12,810	1,432	88	17

Table B10. *Loligo pealeii* landings (mt), during 1963-2010, and discards (mt) and catches (mt) during 1963-2009.

Year	Landings (mt) U.S.	Foreign	Total	Discards (mt)	Catch (mt)
1963	1,294	0	1,294	44	1,338
1964	576	2	578	20	598
1965	709	99	808	27	835
1966	722	226	948	32	980
1967	547	1,130	1,677	57	1,734
1968	1,084	2,327	3,411	116	3,527
1969	899	8,643	9,542	324	9,866
1970	653	16,732	17,385	591	17,976
1971	727	17,442	18,169	618	18,787
1972	725	29,009	29,734	1,011	30,745
1973	1,105	36,508	37,613	1,279	38,892
1974	2,274	32,576	34,850	1,185	36,035
1975	1,621	32,180	33,801	1,149	34,950
1976	3,602	21,682	25,284	860	26,144
1977	1,088	15,586	16,674	567	17,241
1978	1,476	9,355	10,831	368	11,199
1979	4,252	13,068	17,320	589	17,909
1980	3,996	19,750	23,746	807	24,553
1981	2,316	20,212	22,528	766	23,294
1982	2,848	15,805	18,653	634	19,287
1983	10,867	11,720	22,587	768	23,355
1984	7,689	11,031	18,720	636	19,356
1985	6,899	6,549	13,448	457	13,905
1986	11,525	4,598	16,123	548	16,671
1987	10,367	2	10,369	353	10,722
1988	18,593	3	18,596	632	19,228
1989	23,733	5	23,738	806	24,544
1990	15,399	0	15,399	1,158	16,557
1991	20,299	0	20,299	544	20,843
1992	19,018	0	19,018	780	19,798
1993	23,020	0	23,020	367	23,387
1994	23,480	0	23,480	1,086	24,566
1995	18,880	0	18,880	1,207	20,087
1996	12,503	0	12,503	293	12,796
1997	16,270	0	16,270	204	16,474
1998	19,145	0	19,145	232	19,377
1999	19,173	0	19,173	2,140	21,313
2000	17,540	0	17,540	135	17,674
2001	14,345	0	14,345	54	14,399
2002	16,868	0	16,868	373	17,241
2003	11,941	0	11,941	167	12,107
2004	15,738	0	15,738	283	16,022
2005	16,720	0	16,720	696	17,416
2006	15,920	0	15,920	1,138	17,058
2007	12,342	0	12,342	130	12,472
2008	11,418	0	11,418	106	11,524
2009	9,307	0	9,307	254	9,560
2010	5,256	0	5,256		

[1] Landings during 1963-1978 were not reported by species, but are proration-based estimates by Lange and Sissenwine (1980)

[2] Landings during 1979-2010 are from the NEFSC Commercial Fisheries Database

[3] Domestic landings during 1982-1991 include Joint-Venture landings

[4] Domestic landings include unclassified squid which were pro-rated by month and 2-digit Statistical Area (1982-1995) or additive (1996-2008)

[5] Since May of 2004, landings have been reported electronically by dealers

[6] Landings during 2010 are preliminary and incomplete

Table B11. Nominal effort (days fished), landings (mt), and nominal LPUE (mt/day fished) for bottom trawl trips with *Loligo* landings ≥ 2,500 lbs during January-June and July-December, 1996-2009.

	Jan-June fishery			July-Dec fishery		
Year	Days fished	Landings (mt)	Nominal LPUE (mt/day fished)	Days fished	Landings (mt)	Nominal LPUE (mt/day fished)
1996	1064	5162	4.85	373	866	2.32
1997	800	2936	3.67	1322	6016	4.55
1998	1277	7466	5.85	999	3364	3.37
1999	1141	4265	3.74	1350	5729	4.24
2000	1045	5516	5.28	521	4117	7.91
2001	642	3620	5.64	775	4394	5.67
2002	872	4433	5.08	796	4890	6.14
2003	727	3892	5.35	585	3848	6.57
2004	828	5889	7.11	458	3719	8.12
2005	715	6320	8.84	430	2761	6.43
2006	832	5459	6.56	870	4717	5.42
2007	690	4633	6.71	427	3018	7.06
2008	692	3971	5.74	777	3715	4.78
2009	582	2647	4.55	626	2712	4.33

Table B12. Relative catch rates during the day, versus night and dawn/dusk, for *Loligo* pre-recruits (≤ 8 cm DML) and recruits (> 8 cm DML), during NEFSC fall and spring surveys. For example, the relative catch rate of fall nighttime catches of pre-recruits, on average, is 11.5 times higher than for daytime tows. These diel conversion factors, estimated from a GLM, were used in the previous assessment.

NEFSC survey	Time period	≤ 8 cm DML	> 8 cm DML
Fall[1]	Night (8PM-4AM)	11.5	2.9
	Dawn/Dusk (4-7:59AM and 4-7:59PM)	2.2	1.2
	Day (8AM-3:59PM)	1.0	1.0
Spring[2]	Night (8PM-4AM)	2.0	0.8
	Dawn/Dusk (4-7:59AM and 4-7:59PM)	1.2	0.9
	Day (8AM-3:59PM)	1.0	1.0

[1] Source: Brodziak and Hendrickson (1999)

[2] Source: Hatfield and Cadrin (2002)

Table B13. Comparison of *Loligo* relative abundance indices, pre-recruits (≤ 8 cm DML) and recruits (> 8 cm DML), for all times of day versus daytime only (solar zenith = 43-80°) during 1975-2008 NEFSC fall surveys.

	Pre-recruits (≤ 8 cm DML)					Recruits (> 8 cm DML)				
	Mean number per tow		CV		CV difference	Mean number per tow		CV		CV difference
Year	All	Day	All	Day	All-Day	All	Day	All	Day	All-Day
1975	415	902	22	15	6	85	103	16	14	2
1976	304	562	15	13	2	102	144	22	19	3
1977	259	404	13	17	-4	71	101	19	23	-4
1978	101	193	15	21	-6	41	72	16	12	4
1979	149	297	14	13	1	30	69	13	14	-1
1980	297	432	14	16	-1	67	115	13	10	3
1981	137	269	16	14	1	51	119	14	8	6
1982	226	427	22	14	7	49	91	17	21	-4
1983	281	595	15	19	-4	112	192	15	24	-9
1984	154	407	22	7	15	135	196	17	21	-4
1985	240	482	18	20	-1	105	201	14	12	2
1986	295	554	17	16	1	77	146	14	8	6
1987	38	72	14	10	4	25	30	16	7	9
1988	397	565	13	16	-3	82	105	13	19	-6
1989	230	490	14	21	-7	116	312	22	40	-19
1990	216	364	16	14	2	74	109	11	16	-5
1991	177	245	11	16	-5	95	126	14	11	3
1992	698	1919	28	27	1	36	56	13	18	-4
1993	102	117	31	39	-8	52	62	8	11	-3
1994	308	564	12	11	1	155	314	15	15	-1
1995	142	269	21	18	2	45	53	15	13	1
1996	155	253	22	19	3	30	42	20	32	-12
1997	259	436	16	22	-7	67	105	21	20	1
1998	153	310	16	15	1	43	62	14	12	2
1999	572	1139	14	11	2	96	150	10	11	-1
2000	529	643	15	17	-2	128	372	19	6	12
2001	268	318	20	13	7	69	102	13	10	3
2002	642	1659	26	4	22	129	236	13	5	9
2003	332	730	27	11	16	56	175	24	13	11
2004	468	968	24	15	9	43	66	15	12	3
2005	185	389	19	13	5	74	127	16	27	-11
2006	820	1572	27	11	16	92	155	11	14	-3
2007	562	988	17	18	-1	71	110	19	24	-5
2008	308	530	18	17	1	57	112	17	23	-6
% years with reduction in CV					65					50

[1] Pre-1985 data multiplied by door conversion factors (nos.= 0, wt.= 1.24) and data from R/V *DE II* tows multiplied by vessel conversion factors (nos.= 0.83, wt. = 0.85) during 1975-2008.

Table B14. Comparison of *Loligo* relative abundance indices, pre-recruits (≤ 8 cm DML) and recruits (> 8 cm DML), for all times of day versus daytime only (solar zenith = 29-84^{0}) during 1976-2008 NEFSC spring surveys.

	Pre-recruits (≤ 8 cm DML)					Recruits (> 8 cm DML)				
	Mean number per tow		CV		CV difference	Mean number per tow		CV		CV difference
Year	All	Day	All	Day	All-Day	All	Day	All	Day	All-Day
1976	116	185	19	18	1	34	54	14	12	2
1977	7	11	24	20	4	7	9	46	51	-4
1978	31	27	44	22	22	11	18	34	6	29
1979	68	128	38	17	22	13	19	18	8	10
1980	28	71	44	27	18	11	20	20	9	11
1981	20	25	30	32	-3	14	16	31	32	-1
1982	34	70	37	5	32	16	25	19	12	7
1983	15	20	24	9	15	25	24	31	50	-20
1984	45	71	34	37	-3	20	37	37	11	26
1985	54	65	25	16	9	19	29	27	7	19
1986	59	70	31	39	-8	24	23	15	11	4
1987	11	13	14	16	-2	16	19	23	32	-9
1988	81	164	37	26	11	30	31	13	14	-1
1989	66	112	43	39	4	44	53	20	9	11
1990	75	124	27	22	6	24	19	25	23	3
1991	93	179	30	23	8	36	45	16	12	4
1992	59	118	36	6	30	17	25	23	4	20
1993	26	36	40	47	-7	17	16	23	18	5
1994	15	18	19	18	2	7	7	15	12	3
1995	38	70	18	28	-10	17	21	12	17	-5
1996	17	33	30	18	12	5	9	32	33	-1
1997	57	85	42	40	2	22	38	35	12	23
1998	38	38	17	13	4	13	10	25	36	-12
1999	160	282	25	26	-1	25	36	15	18	-3
2000	81	68	30	13	17	26	24	19	9	10
2001	80	127	28	27	1	14	19	13	16	-3
2002	251	336	10	10	-1	34	41	13	12	1
2003	25	33	50	60	-10	9	9	18	16	2
2004	31	46	25	9	16	9	9	25	7	18
2005	63	152	45	11	34	17	18	21	26	-5
2006	115	134	15	16	-1	44	39	20	19	1
2007	112	181	19	17	2	30	45	24	18	6
2008	121	191	30	16	14	8	8	14	12	2
% years with reduction in CV					70					67

[1] Pre-1985 data multiplied by door conversion factors (nos.= 0, wt.= 1.24) and data from R/V *DE II* tows multiplied by vessel conversion factors (nos.= 0.83, wt. = 0.85) during 1976-2008.

Table B15. Summary of NEFSC fall bottom trawl surveys during 1975-2009. Mean Julian date and N stations pertain to stations sampled in the *Loligo* strata set during the daytime (solar zenith 43-80°) and area sampled also pertains to the *Loligo* strata set. The 1975-2008 strata set includes offshore strata 1-23, 25-26, and 61-76 plus inshore strata 2-46, 58-61, and 65-66. The 2009 strata set is the same but without strata ≤ 18 m.

Year	Mean Julian Date	Trawl Type	Research Vessels	Trawl Doors	N stations sampled during "day"	Area Sampled (km^2)
1975	294	Yankee 36	Albatross IV, Delaware II	BMV	103	129,866
1976	290	Yankee 36	Albatross IV	BMV	104	149,547
1977	287	Yankee 36	Delaware II	BMV	100	135,989
1978	280	Yankee 36	Delaware II	BMV	114	147,102
1979	286	Yankee 36	Albatross IV, Delaware II	BMV	113	133,578
1980	284	Yankee 36	Delaware II	BMV	90	112,233
1981	283	Yankee 36	Albatross IV, Delaware II	BMV	95	137,539
1982	279	Yankee 36	Albatross IV	BMV	85	130,312
1983	279	Yankee 36	Albatross IV	BMV	95	140,527
1984	273	Yankee 36	Albatross IV	BMV	78	124,255
1985	284	Yankee 36	Albatross IV, Delaware II	Polyvalent	97	144,498
1986	277	Yankee 36	Albatross IV, Delaware II	Polyvalent	89	134,459
1987	272	Yankee 36	Albatross IV	Polyvalent	77	131,479
1988	275	Yankee 36	Albatross IV, Delaware II	Polyvalent	77	130,412
1989	274	Yankee 36	Delaware II	Polyvalent	84	126,526
1990	270	Yankee 36	Delaware II	Polyvalent	86	133,821
1991	267	Yankee 36	Delaware II	Polyvalent	85	135,999
1992	273	Yankee 36	Albatross IV	Polyvalent	87	135,323
1993	266	Yankee 36	Delaware II	Polyvalent	89	140,040
1994	271	Yankee 36	Albatross IV	Polyvalent	82	129,541
1995	265	Yankee 36	Albatross IV	Polyvalent	84	130,998
1996	270	Yankee 36	Albatross IV	Polyvalent	87	120,678
1997	270	Yankee 36	Albatross IV	Polyvalent	89	143,730
1998	279	Yankee 36	Albatross IV	Polyvalent	80	126,066
1999	280	Yankee 36	Albatross IV	Polyvalent	84	128,374
2000	266	Yankee 36	Albatross IV	Polyvalent	89	123,360
2001	265	Yankee 36	Albatross IV	Polyvalent	81	127,421
2002	269	Yankee 36	Albatross IV	Polyvalent	82	136,020
2003	271	Yankee 36	Albatross IV	Polyvalent	79	119,981
2004	273	Yankee 36	Albatross IV	Polyvalent	83	139,319
2005	274	Yankee 36	Albatross IV	Polyvalent	82	135,258
2006	267	Yankee 36	Albatross IV	Polyvalent	87	130,690
2007	274	Yankee 36	Albatross IV	Polyvalent	87	129,174
2008	270	Yankee 36	Albatross IV	Polyvalent	88	134,559
2009	281	400x12 cm 4-seam	Henry H. Bigelow	Polyice Oval	84	132,271

Table B16. Summary of NEFSC spring bottom trawl surveys during 1976-2010. Mean Julian date and N stations pertain to stations sampled in the *Loligo* strata set during the daytime (solar zenith 29-84°) and area sampled also pertains to the *Loligo* strata set. The 1976-2008 strata set includes offshore strata 1-23, 25-26, and 61-76 plus inshore strata 2-46, 58-61, and 65-66. The 2009-2010 strata set is the same but without strata ≤ 18 m.

Year	Mean Julian Date	Trawl Type	Research Vessels	Type Trawl Doors	N stations sampled during "day"	Area Sampled (km^2)
1976	82	Yankee No. 41	Albatross IV, Delaware II	BMV	127	152,785
1977	98	Yankee No. 41	Albatross IV, Delaware II	BMV	133	155,008
1978	97	Yankee No. 41	Albatross IV	BMV	118	150,652
1979	102	Yankee No. 41	Albatross IV, Delaware II	BMV	152	154,099
1980	101	Yankee No. 41	Albatross IV, Delaware II	BMV	155	132,610
1981	102	Yankee No. 41	Delaware II	BMV	119	145,476
1982	97	Yankee No. 36	Delaware II	BMV	125	151,022
1983	90	Yankee No. 36	Albatross IV	BMV	118	152,223
1984	82	Yankee No. 36	Albatross IV	BMV	125	152,123
1985	76	Yankee No. 36	Albatross IV	Polyvalent	111	138,500
1986	85	Yankee No. 36	Albatross IV	Polyvalent	115	131,513
1987	98	Yankee No. 36	Albatross IV, Delaware II	Polyvalent	113	147,277
1988	79	Yankee No. 36	Albatross IV	Polyvalent	110	136,887
1989	72	Yankee No. 36	Delaware II	Polyvalent	92	145,984
1990	81	Yankee No. 36	Delaware II	Polyvalent	102	145,510
1991	81	Yankee No. 36	Delaware II	Polyvalent	102	145,994
1992	80	Yankee No. 36	Albatross IV	Polyvalent	104	145,123
1993	88	Yankee No. 36	Albatross IV	Polyvalent	115	133,560
1994	82	Yankee No. 36	Delaware II	Polyvalent	104	143,466
1995	89	Yankee No. 36	Albatross IV	Polyvalent	107	136,256
1996	89	Yankee No. 36	Albatross IV	Polyvalent	121	146,477
1997	80	Yankee No. 36	Albatross IV	Polyvalent	111	144,649
1998	78	Yankee No. 36	Albatross IV	Polyvalent	107	136,706
1999	85	Yankee No. 36	Albatross IV	Polyvalent	113	133,807
2000	91	Yankee No. 36	Albatross IV	Polyvalent	112	151,396
2001	83	Yankee No. 36	Albatross IV	Polyvalent	117	141,676
2002	85	Yankee No. 36	Albatross IV	Polyvalent	109	128,964
2003	85	Yankee No. 36	Delaware II	Polyvalent	113	151,132
2004	82	Yankee No. 36	Albatross IV	Polyvalent	108	148,371
2005	81	Yankee No. 36	Albatross IV	Polyvalent	110	132,370
2006	81	Yankee No. 36	Albatross IV	Polyvalent	109	150,912
2007	82	Yankee No. 36	Albatross IV	Polyvalent	125	142,564
2008	87	Yankee No. 36	Albatross IV	Polyvalent	125	146,772
2009	88	400x12 cm 4-seam	Henry H. Bigelow	Polyice Oval	140	149,016
2010	82	400x12 cm 4-seam	Henry H. Bigelow	Polyice Oval	123	147,431

Table B17. Coefficients (rho) used to convert SRV *H. B. Bigelow* catches of *Loligo pealeii* to SRV *Albatross IV* equivalents for the fall 2009 and spring 2009-2010 NEFSC bottom trawl surveys.

	Spring Surveys			Fall Surveys		
Size range (DML)	rho	SE	CV	rho	SE	CV
≤ 8 cm	1.29	0.204	16	1.26	0.088	7
> 8 cm	2.11	0.325	15	1.70	0.090	5
All sizes combined	1.53	0.171	11	1.51	0.064	4

Table B18. Stratified mean numbers and weight (kg) per tow for *Loligo pealeii* pre-recruits (≤ 8 cm DML) and recruits (> 8 cm) caught in NEFSC fall surveys during 1975-2009. The 1975-2008 survey strata set includes offshore strata 1-23, 25-26, and 61-76 plus inshore strata 2-46, 58-61, and 65-66. The 2009 strata set is the same except strata ≤ 18 m were not included because they are too shallow to be sampled by the new survey vessel, the FRV *Henry B. Bigelow.*

	Number per tow						Kg per tow	
Year	Pre-recruits	CV	Recruits	CV	All sizes	CV	All sizes	CV
1975	902	15	103	14	1,004	14	14.4	11
1976	562	13	144	19	707	12	18.8	15
1977	404	17	101	23	505	14	11.5	18
1978	193	21	72	12	265	16	7.6	11
1979	297	13	69	14	366	12	8.2	12
1980	432	16	115	10	547	13	14.2	8
1981	269	14	119	8	388	10	12.5	6
1982	427	14	91	21	518	13	12.4	15
1983	595	19	192	24	787	14	23.7	20
1984	407	7	196	21	603	9	20.8	17
1985	482	20	201	12	683	15	19.6	11
1986	554	16	146	8	700	13	14.8	4
1987	72	10	30	7	101	8	2.8	9
1988	565	16	105	19	670	14	9.3	13
1989	490	21	312	40	803	25	21.5	34
1990	364	14	109	16	474	12	10.4	14
1991	245	16	126	11	371	12	11.5	10
1992	1,919	27	56	18	1,975	27	10.4	20
1993	117	39	62	11	179	26	4.9	10
1994	564	11	314	15	878	11	27.5	15
1995	269	18	53	13	322	15	5.8	8
1996	253	19	42	32	295	18	3.8	20
1997	436	22	105	20	541	21	10.3	22
1998	310	15	62	12	372	14	5.3	14
1999	1,139	11	150	11	1,289	10	15.4	10
2000	643	17	372	6	1,014	12	30.4	7
2001	318	13	102	10	421	11	8.5	8
2002	1,659	4	236	5	1,895	4	23.4	5
2003	730	11	175	13	904	8	14.0	11
2004	968	15	66	12	1,034	14	8.6	10
2005	389	13	127	27	515	14	9.9	20
2006	1,572	11	155	14	1,727	10	22.9	6
2007	988	18	110	24	1,097	17	10.1	18
2008	530	17	112	23	642	18	11.3	25
2009	437	8	49	18	419	8	6.4	12
Median 1976-2008	436	16	112	14	603	13	11	12

[1] Pre-1985 indices were multiplied by door conversion factors (nos.= 0, wt.= 1.24) and data from R/V *DE II* tows multiplied by vessel conversion factors (nos.= 0.83, wt. = 0.85) during 1975-2008.
[2] Only daytime tows (solar zenith of 43-80 degrees) were used to compute the above indices
[3] Bigelow conversion factors of 1.26 for pre-recruits, 1.70 for recruits, and 1.51 for all sizes were applied to the 2009 number and weight indices

Table B19. Stratified mean numbers and weight (kg) per tow for *Loligo pealeii* pre-recruits (≤ 8 cm DML) and recruits (> 8 cm) caught in NEFSC spring surveys during 1976-2010. The 1976-2008 survey strata set includes offshore strata 1-23, 25-26, and 61-76 plus inshore strata 2-46, 58-61, and 65-66. The 2009-2010 strata set is the same except strata ≤ 18 m were not included because they are too shallow to be sampled by the new survey vessel, the FRV *Henry B. Bigelow*.

	Number per tow						Kg per tow	
Year	Pre-recruits	CV	Recruits	CV	All sizes	CV	All sizes	CV
1976	185	18	54	12	239	15	7.5	11
1977	11	20	9	51	20	30	1.0	41
1978	27	22	18	6	45	15	2.2	9
1979	128	17	19	8	147	15	3.2	8
1980	71	27	20	9	91	22	3.2	12
1981	25	32	16	32	40	29	2.0	26
1982	70	5	25	12	95	6	2.9	12
1983	20	9	24	50	44	29	2.2	46
1984	71	37	37	11	107	28	4.5	15
1985	65	16	29	7	94	12	2.9	6
1986	70	39	23	11	93	31	2.5	17
1987	13	16	19	32	32	21	2.1	27
1988	164	26	31	14	195	23	4.0	16
1989	112	39	53	9	165	28	4.8	12
1990	124	22	19	23	143	19	2.8	15
1991	179	23	45	12	223	18	4.3	9
1992	118	6	25	4	143	5	3.6	4
1993	36	47	16	18	52	35	1.6	25
1994	18	18	7	12	25	15	0.7	13
1995	70	28	21	17	91	25	2.2	22
1996	33	18	9	33	42	17	0.9	28
1997	85	40	38	12	122	28	2.7	13
1998	38	13	10	36	48	16	0.9	30
1999	282	26	36	18	318	24	4.1	16
2000	68	13	24	9	92	10	2.0	10
2001	127	27	19	16	145	25	2.5	17
2002	336	10	41	12	376	10	5.0	12
2003	33	60	9	16	42	47	0.9	21
2004	46	9	9	7	55	8	0.8	5
2005	152	11	18	26	170	12	1.8	21
2006	134	16	39	19	173	13	3.2	14
2007	181	17	45	18	226	14	3.7	15
2008	191	16	8	12	199	15	1.4	8
2009	38	22	10	26	46	22	1.1	22
2010	38	25	7	19	42	22	0.8	17
Median 1976-2008	71	18	21	12	95	18	3	15

[1] Pre-1985 indices were multiplied by door conversion factors (nos.= 0, wt.= 1.24) and data from R/V *DE II* tows multiplied by vessel conversion factors (nos.= 0.83, wt. = 0.85) during 1976-2008.
[2] Only daytime tows (solar zenith of 29-84 degrees) were used to compute the above indices
[3] Bigelow conversion factors of 1.29 for pre-recruits, 2.11 for recruits, and 1.53 for all sizes were applied to the 2009-2010 number and weight indices

Table B20. Comparison of the previous and current assessments for *Loligo*, with a stepwise demonstration of effects on mean catch and mean survey kg/tow and mean survey biomass, in NEFSC surveys, during 1987-2000 (the time period of overlap). Effects on a simple average exploitation index (mean catch/mean survey biomass) are also shown. Note that the mean catch/mean survey biomass is a ratio of averages, not the average of annual exploitation indices. Values in the table are meant to show effects of changes in data, methodology and assumptions and should not be used for management purposes. Boxes indicating parameter changes are shaded.

Step	Notes and explanation	*q*-prior			*q* used	Estimates for 1987-2000			
		Lower bound	Median	Upper bound		Mean catch (000s mt/year)	Mean survey kg/tow	Mean survey biomass (*q* x kg/tow, 000s mt)	Mean catch / mean survey biomass
Previous assessment	Note: a *q*-prior was calculated in the last assessment and used in the PDQ model but not used directly for status determination.	0.022	0.187	0.556	0.450	19.436	11.1	24.59	0.790
1	Update all factors in *q*-prior except capture efficiency	**0.019**	**0.154**	**0.423**	0.450	19.436	11.1	24.59	0.790
2	Update capture efficiency in *q*-prior	**0.038**	**0.092**	**0.185**	0.450	19.436	11.1	24.59	0.790
3	Use median *q* from *q*-prior distribution	0.038	0.092	0.185	**0.092**	19.436	11.1	**120.17**	**0.162**
4	Fall survey data for expanded strata set; vessel correction factors for SRVs *Albatross IV* and *Delaware II*; daytime tows only	0.038	0.092	0.185	0.092	19.436	**12.1**	**131.31**	**0.148**
5	Average fall and spring survey data	0.038	0.092	0.185	0.092	19.436	7.4	**79.96**	**0.243**
Current assessment	Improved discard information	0.038	0.092	0.185	0.092	**19.098**	7.4	79.96	**0.239**

Table B21. Bounds for factors affecting catchability of *Loligo* in NEFSC fall and spring bottom trawl surveys, during 1975-2010, for the current assessment and the previous assessment. Survey biomass indices for the previous assessment were adjusted to daytime equivalents based on diel correction factors from a GLM. Indices for the current assessment were computed using "daytime" tows (solar zenith angle = 43-80^{0} for fall surveys and 29-84^{0} for spring surveys) to account for diel catchability effects.

	Previous assessment (SARC 34)			**Current assessment (SARC 51)**		
Factor	**Lower Bound**	**Upper Bound**	**Basis**	**Lower Bound**	**Upper Bound**	**Basis**
Tow distance (d)	5% < nominal d = 3.34 km	10% > nominal d = 3.87 km	Based on information from clam and scallop studies; Nominal d = 3.52 km	Mean of SRV*Albatross IV* (*AL*) doppler tow distance for 30 min. at 3.2 kts = 2.96 km	Mean of *AL* GPS tow distance for 30 min. at 3.8 kts = 3.57 km	Lower bound is mode of AL doppler distance (LRD 78-08) Upper bound is mean of *AL* GPS distances between net touchdown and liftoff based on plots of speed over ground, tow duration, and wingspread and doorspread for 2007 fall and 2008 spring surveys
Effective survey trawl width (w)	Mean wing spread = 0.01164 km	Mean door spread = 0.02380 km	Based on *AL* wingspread and doorspread sensor measurements	Yankee 36 mean wingspread = 0.01069 km	Yankee 36 mean doorspread = 0.02192 km	*AL* mean wingspread and doorspread measurements for the Yankee 36 trawl during 2006-2008 fall and spring surveys
Survey bottom trawl efficiency (e)	0.1	0.9	$0 < e \leq 1$ based on arbitrary guestimates	0.20	0.39 (CV=4%)	Lower bound based on videos of daytime *Loligo* behavior in front of sweep and in trawl; upper bound based on wingspread area swept ratio of *Bigelow* to *AL* (= 0.625) x 1/rho x *Bigelow* max e rho = 1.51 and *Bigelow* max e = 0.95
Effective stock area (A)	5% > *Loligo* strata set = 146,324 km^2	30% > *Loligo* strata set = 181,163 km^2	Fall surveys (offshore strata 1-25, 61-76)	Expanded *Loligo* strata set 1975-2008 = 166,007 km^2 2009-2010 *Bigelow* strata set = 155,896 km^2		1975-2008 fall and spring surveys (inshore strata 2-46, 58-61, 65-66 and offshore strata 1-23,25-26, 61-76) 2009-2010 *Bigelow* strata set is same, but without strata ≤ 18 m
Weight units (u)	100,000	100,000	Survey data in kg/tow, biomass in 1000 MT	100,000	100,000	Survey data in kg/tow, biomass in 1000 MT
Survey daytime catchability (q)	q_{min} = 0.02149	q_{max} = 0.5569	$q_{min}=[d_{min} w_{min} e_{min}]/A_{max}$ $q_{max}=[d_{max} w_{max} e_{max}]/A_{min}$	q_{min} 1975-2009 = 0.038 q_{min} 2009-2010 = 0.041	q_{max} 1975-2008 = 0.185 q_{max} 2009-2010 = 0.197	$q_{min}=[d_{min} w_{min} e_{min}]/A$ $q_{max}=[d_{max} w_{max} e_{max}]/A$

Table B22. Minimum biomass estimates of *Loligo* for inshore strata (≤ 18 m) no longer sampled during NEFSC surveys as of 2009, but sampled during the NEAMAP spring and fall surveys (2007-2010). NEFSC fall survey biomass estimates were based on day tows which occurred during 6:30 AM-4:30 PM (2007-2008). Area swept by the trawl during NEAMAP surveys is 0.025 km^2 and is 0.038 km^2 during NEFSC surveys based on mean wingspread and tow distance measurements for the *Albatross IV*. Inestimable CVs were a result of too few daytime *Albatross IV* tows in strata ≤ 18 m deep. Therefore, the 2007 and 2008 minimum biomass estimates for the NEFSC fall surveys are not reliable.

		NEAMAP				NEFSC			
Season	Year	Area sampled (km^2)	N tows	Min. biomass (mt)	CV	Area sampled (km^2)	N tows	Min. biomass (mt)	CV
fall	2007	14,666	150	2,951	3.9	2,909	12	7,071	inestimable
fall	2008	15,191	150	1,720	4.5	5,388	16	1,076	inestimable
fall	2009	15,191	160	3,482	3.5				
spring	2008	14,666	150	1,420	5.4				
spring	2009	15,191	160	966	5.6				
spring	2010	15,191	160	389	9.3				

[1] NEAMAP standardized tows are 20 min. tow at 3.0 kts with sampling between sunrise and sunset

[2] NEFSC standardized tows for *AL IV* are 30 min. at 3.8 kts with sampling round-the-clock, but include only daytime tows (6:30-4:30 PM)

Table B23. Minimum, maximum and quantiles (Q25, Q50 and Q75) for the composite *q*-priors for *Loligo* catches in NEFSC spring and fall surveys, 1975-2010. The median values were used in the assessment.

Survey years	Minimum	Q25	Q50	Q75	Maximum
1975-2008	0.038	0.075	0.092	0.113	0.185
2009-2010	0.041	0.080	0.098	0.121	0.197

Table B24. Biomass estimates (000s mt) for the spring survey *Loligo* cohort (1976-2009) in relation to exploitation indices for the Jan-June fishery (1987-2009) and biomass estimates for the fall survey cohort in relation to exploitation indices for the July-Dec fishery. Spring and fall biomass estimates are for March-April and September-October, respectively.

Year	Spring biomass (000s mt)	Jan-June catch (000s mt)	Exploitation Indices Jan-June fishery (Jan-June catch/Spring biomass)	Fall biomass (000s mt)	July-Dec catch (000s mt)	Exploitation Indices July-Dec fishery (July-Dec catch/Fall biomass)
1976	81.734			204.483		
1977	10.842			124.730		
1978	23.709			82.372		
1979	34.657			89.006		
1980	34.948			154.830		
1981	21.293			135.505		
1982	31.449			135.185		
1983	23.719			257.470		
1984	48.822			226.068		
1985	31.270			212.810		
1986	27.578			160.412		
1987	22.304	6.990	0.313	30.304	3.716	0.123
1988	43.315	11.352	0.262	101.390	7.841	0.077
1989	52.510	16.629	0.317	233.315	7.106	0.030
1990	29.904	8.529	0.285	112.536	7.406	0.066
1991	46.615	9.044	0.194	125.268	10.881	0.087
1992	39.402	10.692	0.271	113.255	8.260	0.073
1993	17.875	17.582	0.984	52.983	8.379	0.158
1994	8.116	7.224	0.890	298.443	16.411	0.055
1995	23.652	9.780	0.414	62.885	9.774	0.155
1996	10.133	10.196	1.006	41.480	2.508	0.060
1997	29.379	6.247	0.213	112.203	10.064	0.090
1998	10.229	12.897	1.261	57.658	6.411	0.111
1999	44.192	8.927	0.202	167.873	12.296	0.073
2000	21.639	10.010	0.463	330.148	7.600	0.023
2001	26.917	6.468	0.240	92.460	7.821	0.085
2002	54.622	8.619	0.158	253.946	8.458	0.033
2003	9.393	5.926	0.631	151.733	6.175	0.041
2004	8.976	9.300	1.036	93.264	5.779	0.062
2005	19.843	12.272	0.618	107.945	5.405	0.050
2006	34.397	9.820	0.285	249.422	7.225	0.029
2007	40.325	7.731	0.192	109.552	4.741	0.043
2008	15.486	5.814	0.375	122.699	5.691	0.046
2009	10.795	4.648	0.431	68.788	4.912	0.071
Median						
1976-2008	27.578			124.730		
1987-2008		9.172	0.315		7.503	0.064

Table B25. Annualized biomass estimates (000s mt), during 1976-2009, and annualized exploitation indices, during 1987-2009, for *Loligo pleaeii*. Annualized biomass estimates are the means of the annual estimates from the NEFSC spring and fall surveys. The two-year moving averages were only used for the 2009 stock status determination.

Year	Annual biomass (000s mt)	Two-year moving average of biomass (000s mt)	Annual catch (000s mt)	Annual exploitation index: Catch/biomass (000s mt)	Annual exploitation index: Catch/2yr moving avg. of biomass (000s mt)
1976	143.108				
1977	67.786	105.447			
1978	53.041	60.413			
1979	61.832	57.436			
1980	94.889	78.360			
1981	78.399	86.644			
1982	83.317	80.858			
1983	140.594	111.956			
1984	137.445	139.020			
1985	122.040	129.743			
1986	93.995	108.018			
1987	26.304	60.150	10.722	0.408	0.178
1988	72.353	49.328	19.228	0.266	0.390
1989	142.912	107.633	24.544	0.172	0.228
1990	71.220	107.066	16.557	0.232	0.155
1991	85.942	78.581	20.843	0.243	0.265
1992	76.329	81.135	19.798	0.259	0.244
1993	35.429	55.879	23.387	0.660	0.419
1994	153.280	94.354	24.566	0.160	0.260
1995	43.269	98.274	20.087	0.464	0.204
1996	25.806	34.538	12.796	0.496	0.370
1997	70.791	48.299	16.474	0.233	0.341
1998	33.944	52.367	19.377	0.571	0.370
1999	106.032	69.988	21.313	0.201	0.305
2000	175.894	140.963	17.674	0.100	0.125
2001	59.688	117.791	14.399	0.241	0.122
2002	154.284	106.986	17.241	0.112	0.161
2003	80.563	117.423	12.107	0.150	0.103
2004	51.120	65.841	16.022	0.313	0.243
2005	63.894	57.507	17.416	0.273	0.303
2006	141.909	102.902	17.058	0.120	0.166
2007	74.939	108.424	12.472	0.166	0.115
2008	69.092	72.015	11.524	0.167	0.160
2009	39.792	54.442	9.560	0.240	0.176
Median					
1976-2008	76.329	83.890			
1987-2008			17.328	0.237	0.236

Table B26. Historical retrospective analysis covering the current and previous four assessments. Start year and end year are for the survey data used in making status determinations. The primary approach or model for status determination is identified for each assessment but a variety of auxiliary data or calculations were usually considered as well.

SARC/ SAW	Citation	Start year	End year	Primary approach for status determination	Type of F threshold	Fishing mortality status	Over-fishing?	Type biomass reference points	Biomass status	Over-fished?
17	NEFSC (1994)	1967	1994	Relative fall suurvey trends for prerecruits	Three-year average of prerecruits from the NEFSC fall survey falls below the first quartile of the time series	3-year moving average for 1992 (mean for 1991-1993)/first quartile of same = 412 / 123=3.3	No	Overfishing and overfished stock conditions not distinguished. Only overfishing status was evaluated.		
21	NEFSC (1996)	1987	1999 for biomass, 1998 for F	Shaeffer surplus production model (semester time steps but *K* and *r* are constant) using spring and fall survey data	F / Fmsy (threshold value is 1)	F / Fmsy=1.7 (average of estimates for 4 qtrs in 1998)	Yes	January biomass / Bmsy in January 1999 (threshold is 0.5)	0.57	No
29	NEFSC (1999)	1987	1999 for biomass, 1998 for F	Shaeffer surplus production model (quarterly time steps but *K* and *r* are constant) using spring and fall survey data, and two season CPUE indices	F / Fmsy (threshold value is 1)	F/Fmsy=1.7 on January 1, 1999	Yes	B/Bmsy during spring 2009 (threshold value is 0.5)	0.57	No
34	NEFSC (2002)	1967	2001	Fall survey and exploitation index trends. Survey data were scaled by a catchability parameter estimated from the PDQ model, but status determination would be the same without scaling.	F proxy/ Fmsy (threshold value is 1)	F proxy / Fmsy proxy=0.2 / 0.31 (F proxy is the mean of quarterly estimates in 2000	No	No satisfactory reference point available	NA	NA
51	In prep.	1976	2009	Average spring & fall survey biomass and exploitation index. Survey data were scaled by the median catchability of a prior, but status determination would be the same without scaling.	No satisfactory reference point available	Not model based, uses a wide range of data and judgement	Probably not	Mean biomass during 2008-2009 / Bmsy	1.28	No

Table B27. Summary of weekly natural mortality rate estimates for *Loligo* spp. (published and new estimates for *Loligo pealeii* from this assessment). The estimate M=0.069 for lifetime natural mortality (juvenile through spawner) used for the SARC 21 assessment (NEFSC 1996) and Cadrin and Hatfield (1999) is the average of the three estimates from Brodziak (1998) which are shown in the table below. Non-spawning estimates (Mns) are for juvenile through pre-spawning stages. Spawning estimates (Msp) are for actively spawning squid. Estimates in the first row (labeled NEFSC 2002) are from the last assessment.

Source	Lifestages/cohort assumptions	Winter-hatched cohort (per week)		Summer-hatched cohort (per week)		Details
		Non-spawning (M_{ns})	Spawning (M_{sp})	Non-spawning (M_{ns})	Spawning (M_{sp})	
NEFSC (2002) Previous assessment	Juvenile through spawner, by cohort	0.076		0.058		Observed maximum size; 3/M rule; assumed to double at maturity
Brodziak (1998)	Juvenile through spawner, both cohorts	0.078				Hoenig's (1983) method assuming maximum age 296 days
		0.060				Rosenberg's (1990) estimate for *Illex argentinus*
		0.069				Peterson and Wroblewski (1984) , bioenergetics
Macewicz (2004) for California market squid (*Loligo opalescens*)	Spawners, cohort not specified		3.15 *			Reproductive biology assuming maximum life of spawners = 8 days; implies an average spawning lifespan of 1.67 days
Gnomonic method for Mns ; Maturation-natural mortality model for Msp (this assessment)	Separate estimates for non-spawning and spawning stages, winter-hatched cohort only	0.110	0.19-0.48 *			The gnomonic estimate M_{ns} = 0.11 is for lifestages up to maturity; estimates for M_{sp} from maturity-mortaltity model assume gnomonic estimate of M_{ns}=0.11
Min **	Non-spawning	0.058				Excludes M_{sp} estimates
Average **		0.075				
Max **		0.110				

* Includes some fishing mortality

** Non-spawning natural mortality estimated from all sources listed in the above table

Table B28. Current and proposed biological reference points for the *Loligo pealeii* stock and the 2009 exploitation index and biomass estimate used to determine stock status.

Biomass Reference Points				Fishing Mortality Reference Points		
	Current	Proposed	**Mean 2008-2009 Biomass (mt)[3]**	Current	Proposed	**2009 Exploitation Index[4]**
Target	Bmsy[1]	Bmsy proxy = 42,405 mt (50% of carrying capacity)[2]		Mean quarterly exploitation rate during 1987-2000 = 0.96/yr	None	
Threshold	50% of Bmsy	50% of Bmsy proxy = 21,203 mt	54,442 mt 80% CI (38,452-71,783)	FMSY proxy = 75th percentile of exploitation rates during 1987-2000 = 1.24/yr	None	0.176

1 Amendment 9 to the SMB FMP states that the previous biomass reference points were rejected at SARC34 and new ones were not proposed
2 Based on averages of the annual NEFSC spring and fall swept-area biomass estimates, at the median *q*-prior level, and assumes that the stock is lightly exploited and that the median biomass during 1976-2008 (76,329 mt) represents 90% of carrying capacity (*K*), so *K* = 84,810 mt
3 Based on annual mean of the NEFSC 2008-2009 spring and fall survey swept area biomass estimates

4 Computed as the 2009 catch / mean of 2008-2009 spring and fall survey swept area biomass estimates

B. *Loligo*-Figures

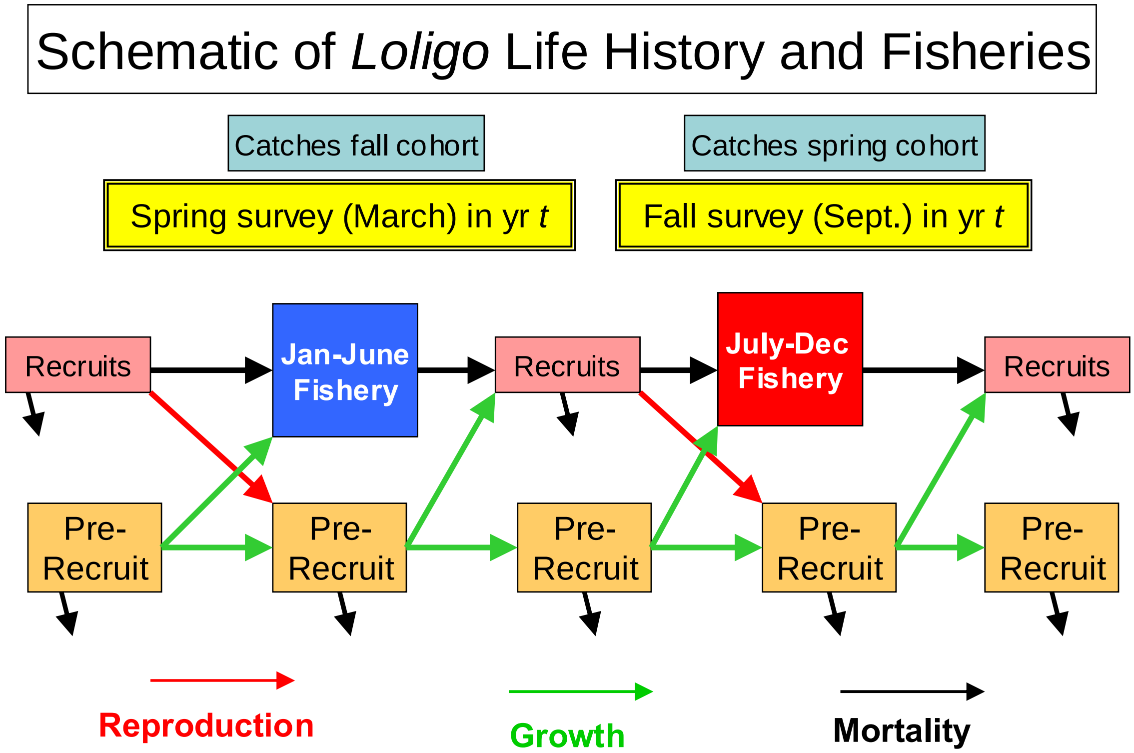


Figure B1. Schematic of *Loligo pealeii* life history in relation to NEFSC spring and fall surveys and the January-June and July-December *Loligo* fisheries. Fishery pre-recruits are ≤ 8 cm DML and recruits are > 8 cm DML.

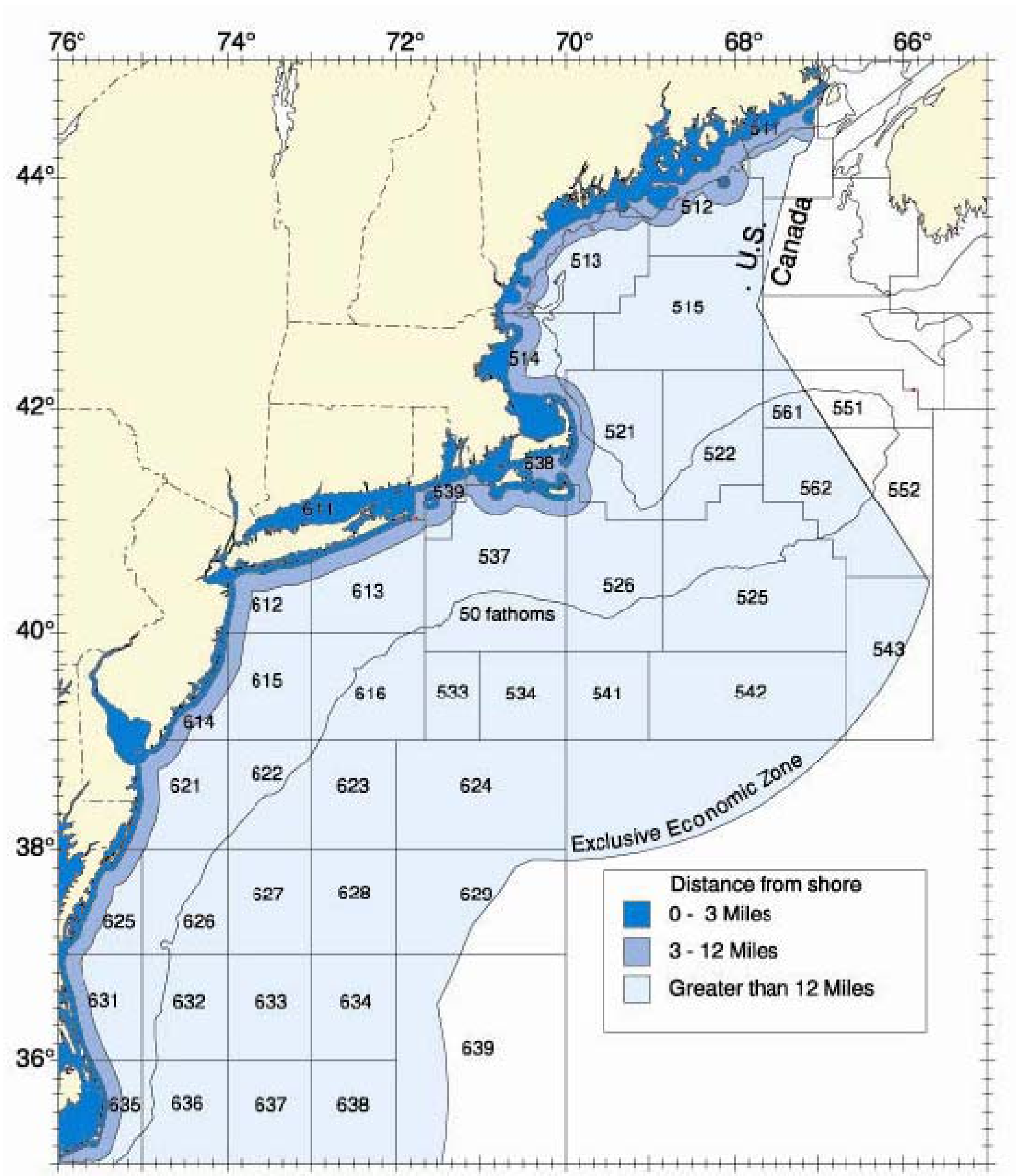


Figure B2. Statistical Areas used for reporting fishery data in the Northeast region of the U.S. and Federal (Exclusive Economic Zone) and state (0-3 miles) jurisdictional limits.

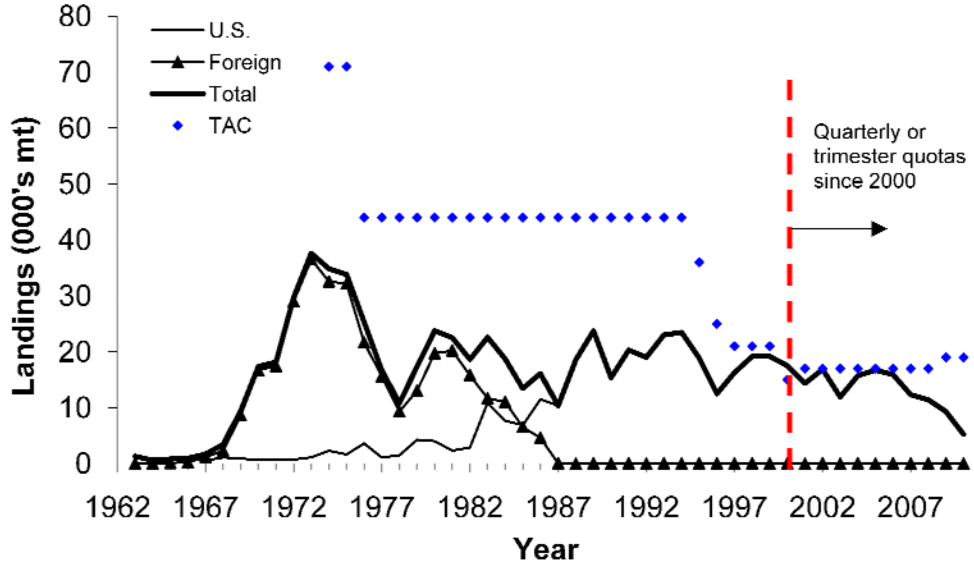


Figure B3. U.S. foreign, and total *Loligo pealeii* landings during 1963-2010 and TACs during1974-2010. The 2010 landings are preliminary and incomplete.

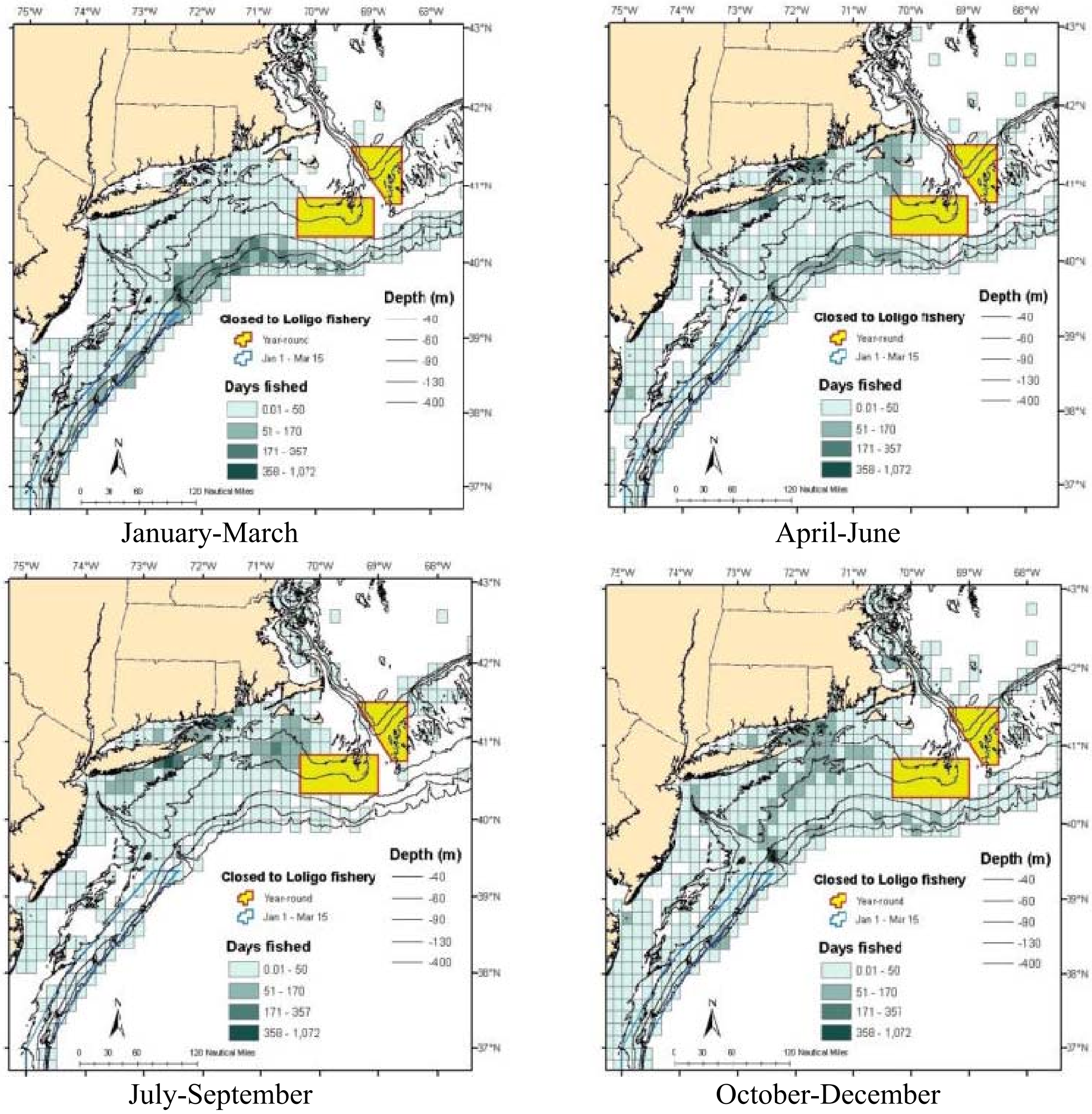


Figure B4. Spatial distribution of *Loligo* fishing effort (days fished) during the winter (Jan.-March and Oct.-Dec.) offshore fishery and the summer (April-Sept.) inshore fishery during 1997-2004.

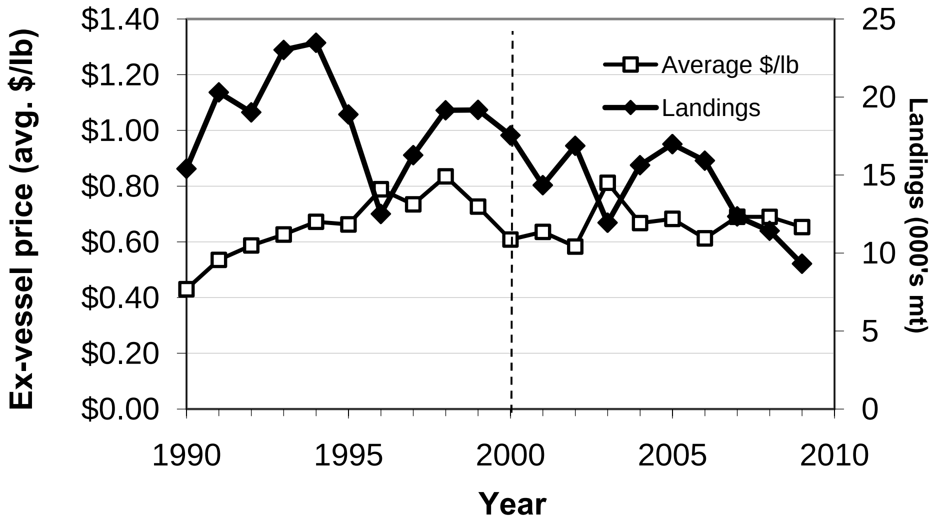


Figure B5. Annual ex-vessel price (avg. $ per lb in 1990 dollars) of *L. pealeii*, in relation to landings, during 1990-2009.

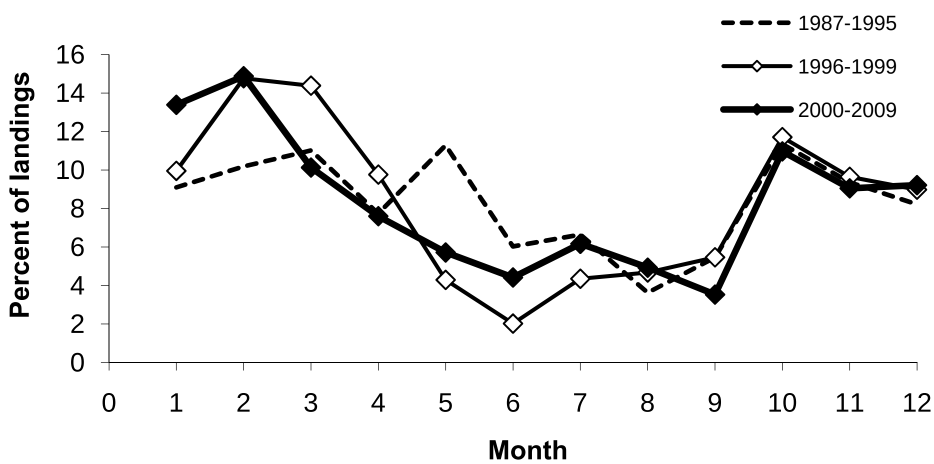


Figure B6. Trends in *Loligo* landings, percent by month, during 1987-1995, 1996-1999, and 2000-2009.

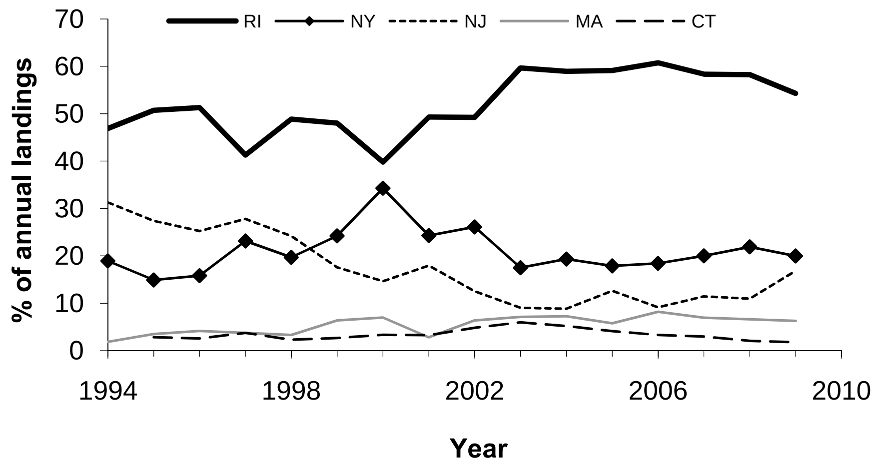


Figure B7. *Loligo* landings by state during 1994-2009.

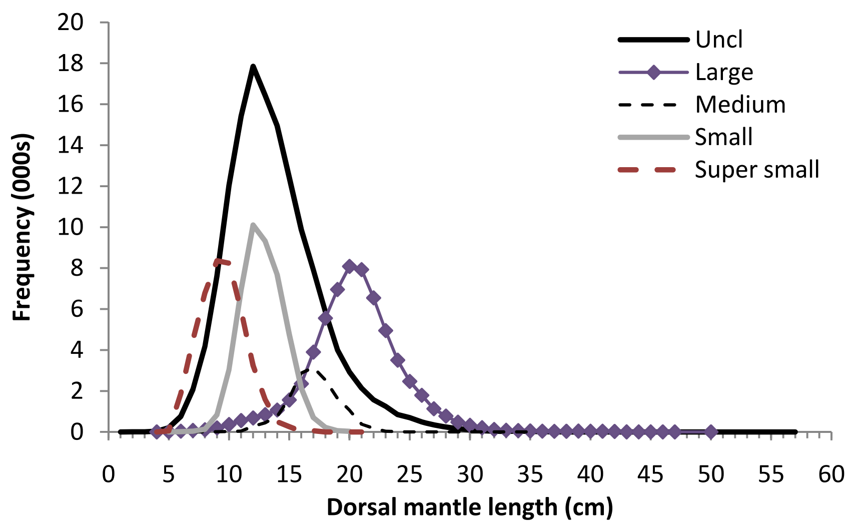


Figure B8. Length composition of the landings samples, during 1996-2009, by market category.

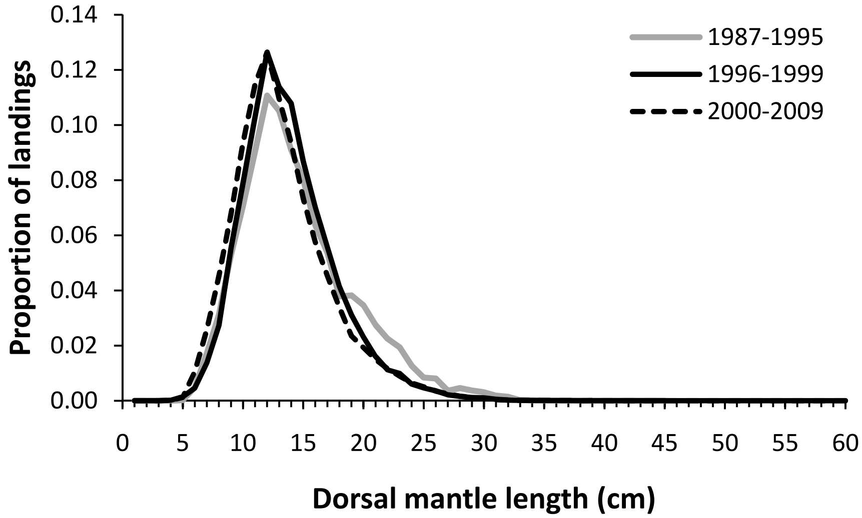


Figure B9. Length compositions of the *Loligo* landings during 1987-1995, 1996-1999, and 2000-2009.

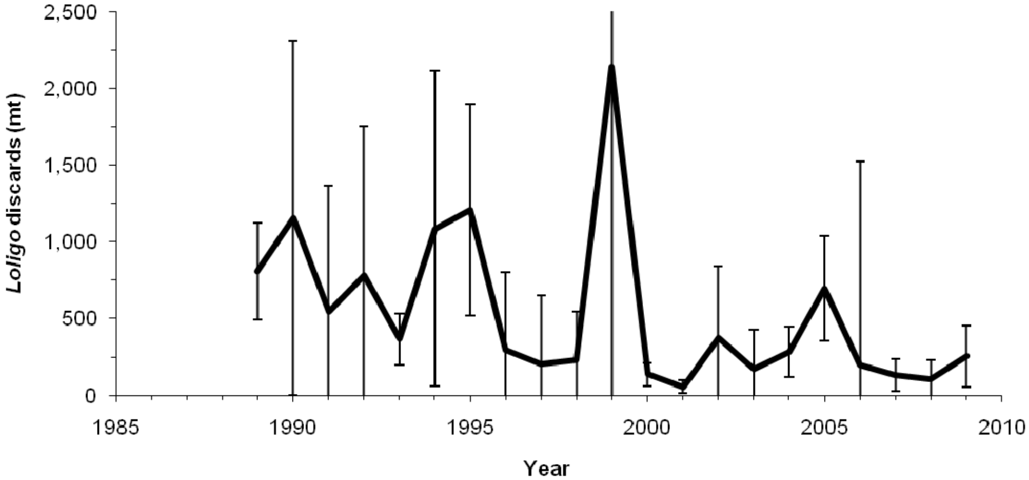


Figure B10. Discards of *Loligo pealeii* during 1989-2009 and 95% confidence intervals.

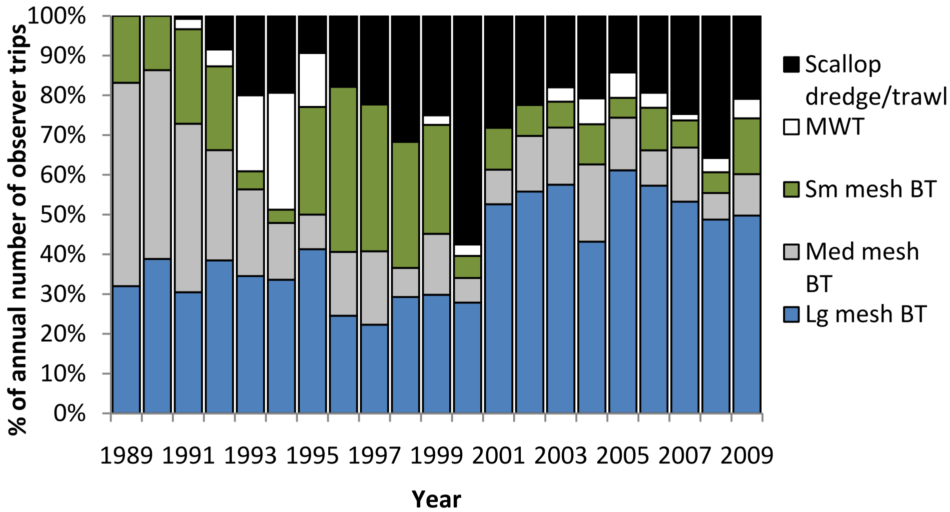


Figure B11. Percentage of annual numbers of fishery observer trips, by fleet, that were used to compute *Loligo* discards.

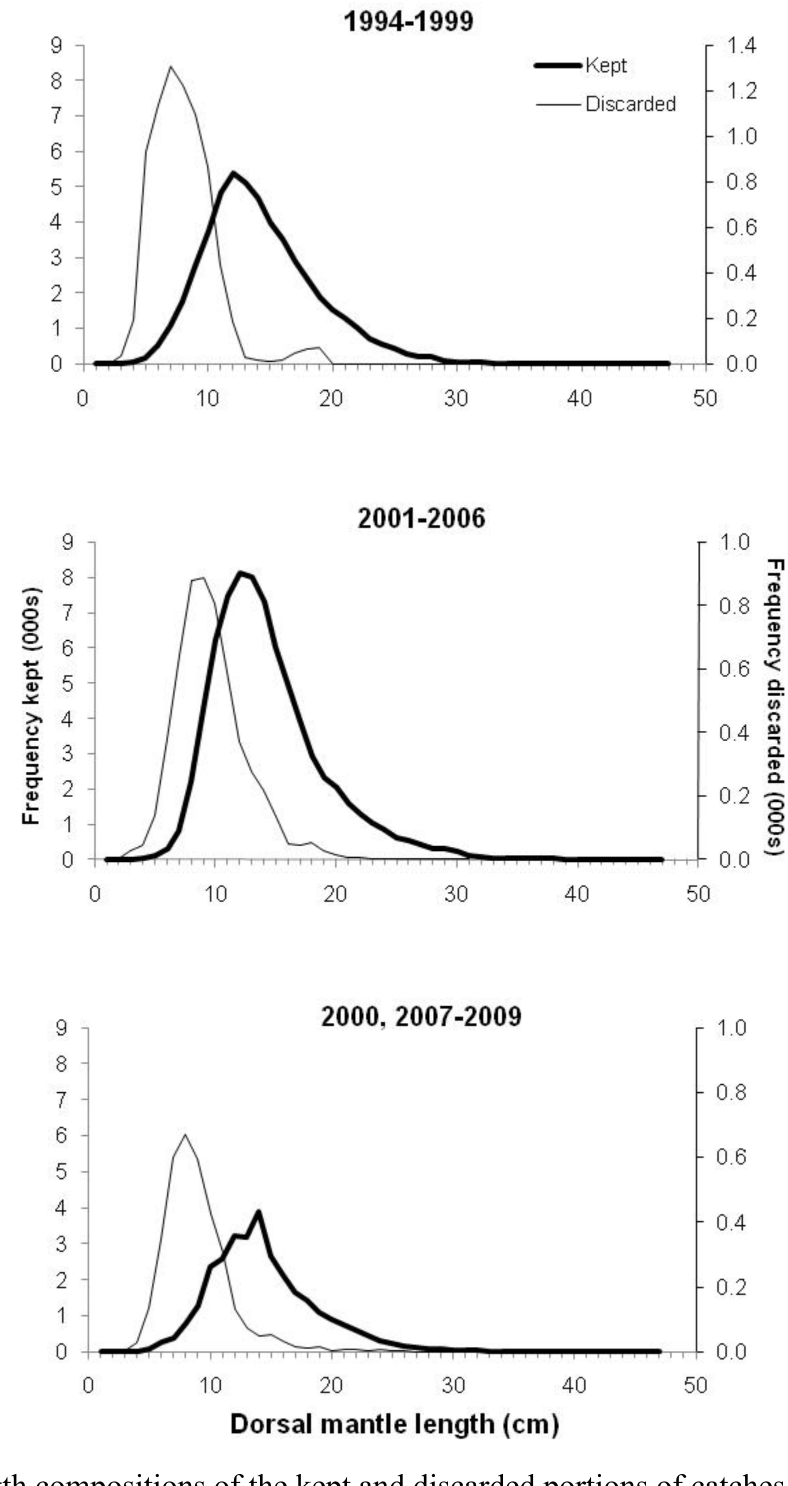


Figure B12. Length compositions of the kept and discarded portions of catches on trips where *Loligo* were discarded during 1994-1999, 2001-2006 and 2000 and 2007-2009. Since 2000, trip limits have been in effect during portions of each year.

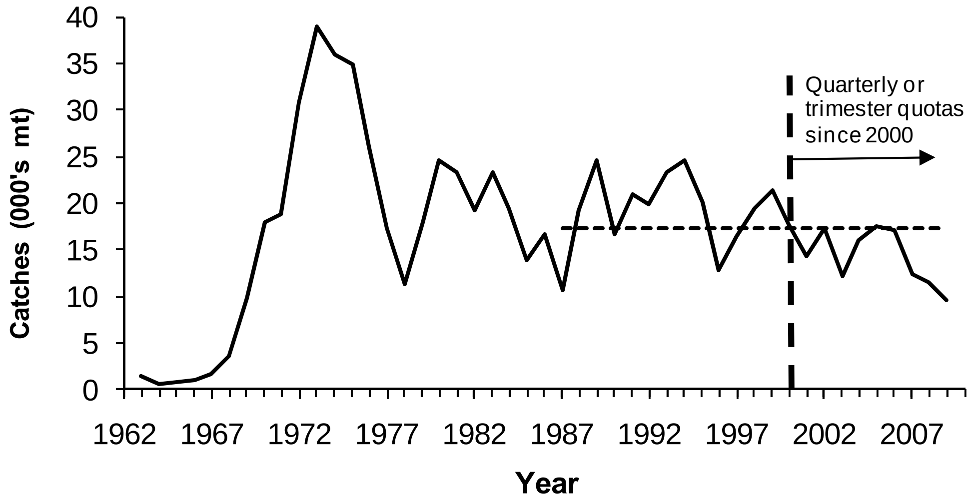
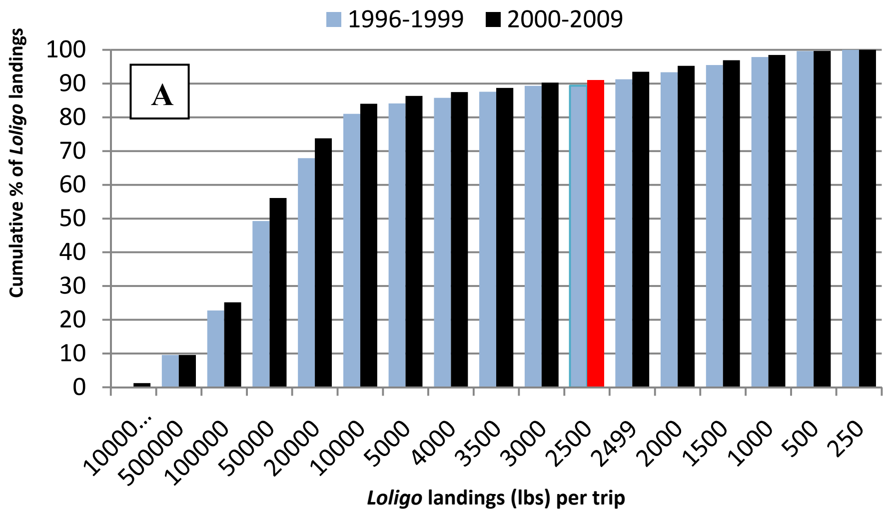


Figure B13. Catches (000s mt) of *Loligo pealeii* during 1963-2009 and the 1987-2008 median.



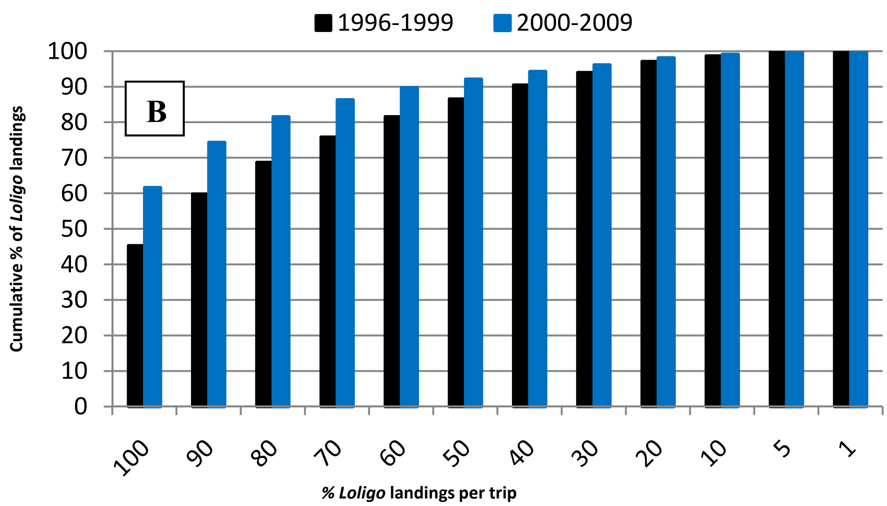


Figure B14. *Loligo* landings (lbs) per trip (A) and *Loligo* landings as a percentage of the total trip weight (B) as cumulative percentages of the *Loligo* landings during a period of annual quotas (1996-1999) versus a period of in-season quotas (2000-2009).

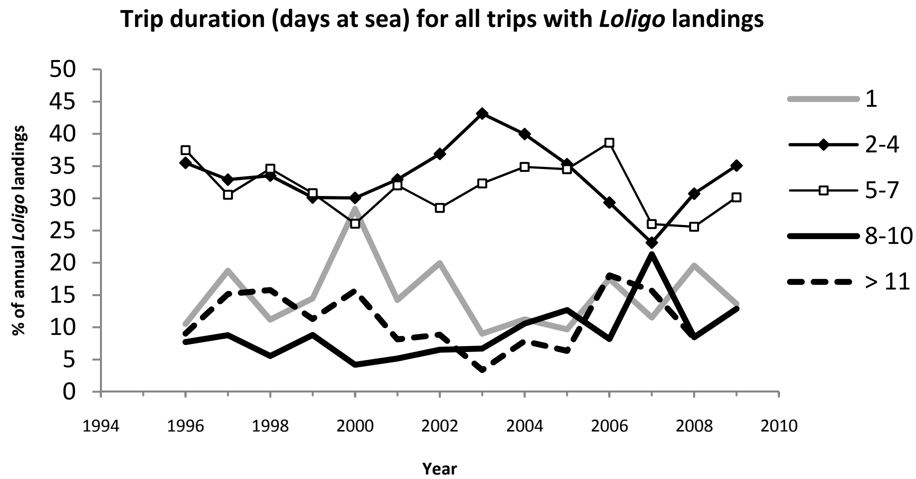
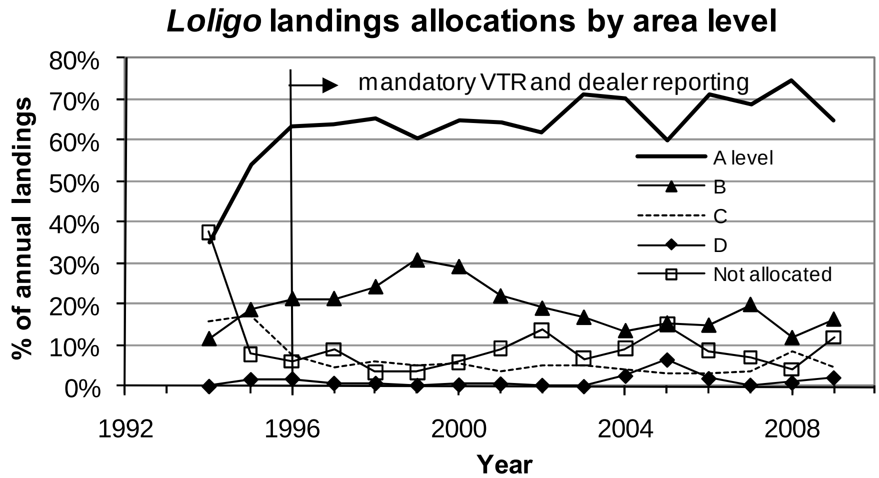


Figure B15. Percent of annual *Loligo* landings, during 1996-2009, by trip duration (days at sea).



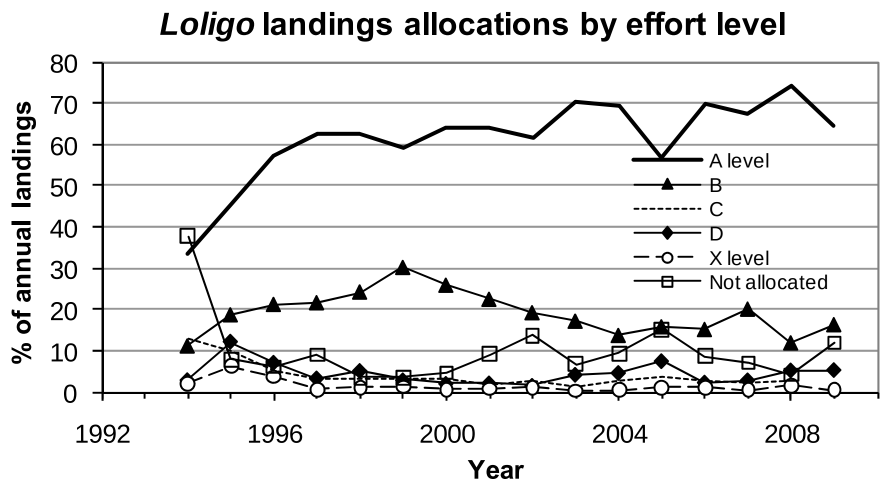


Figure B16. Percentage of annual *Loligo* landings allocated by fishing area level (A) and effort allocation level (B) during 1994-2009. The "A level" trips, which represent a one-to-one match between a trip in the Dealer Database and the Vessel Trip Report Database, were used to computed nominal LPUE for the directed fishery.

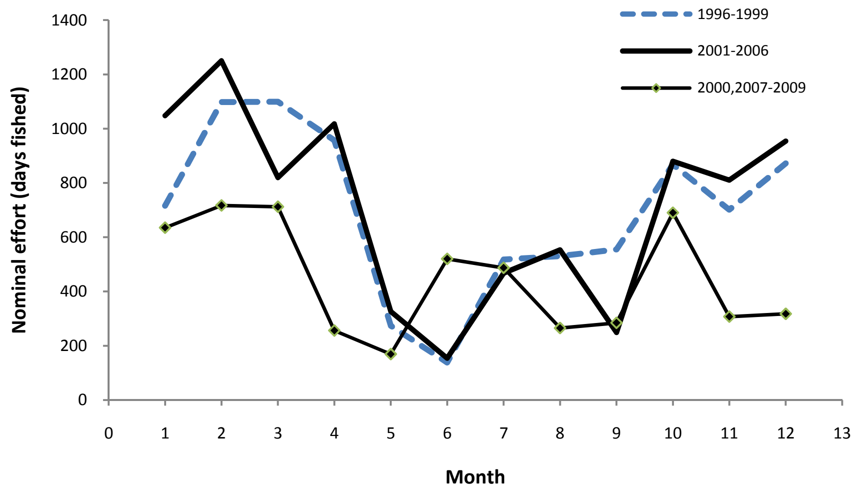
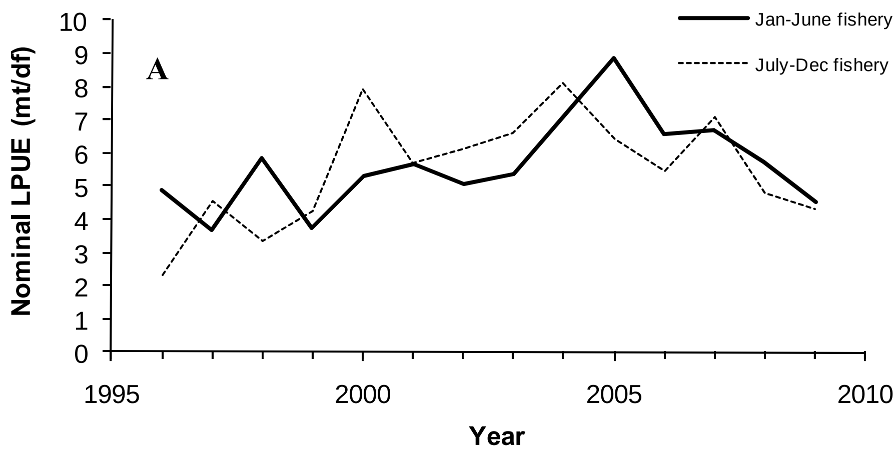


Figure B17. Monthly nominal effort (days fished) in the *Loligo* fishery during 1996-2009.



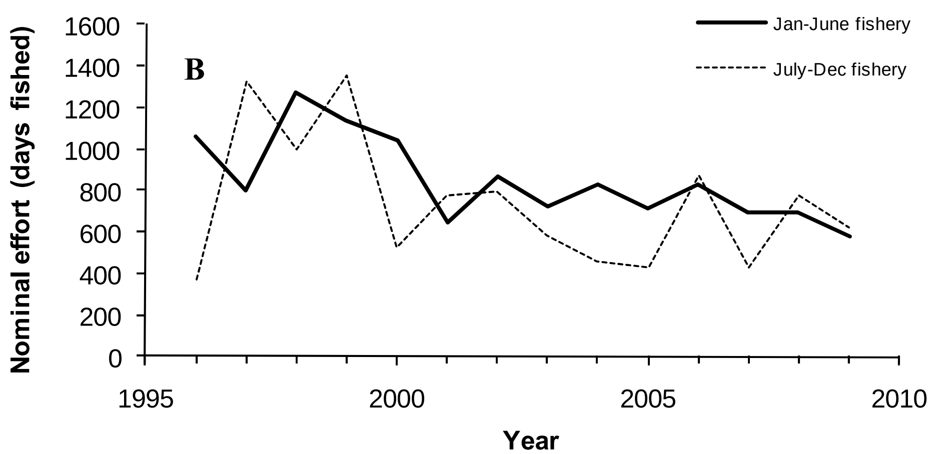


Figure B18. Nominal landings per unit of effort (mt/day fished) (A) and nominal effort (B) in the January-June fishery versus the July-December fishery.

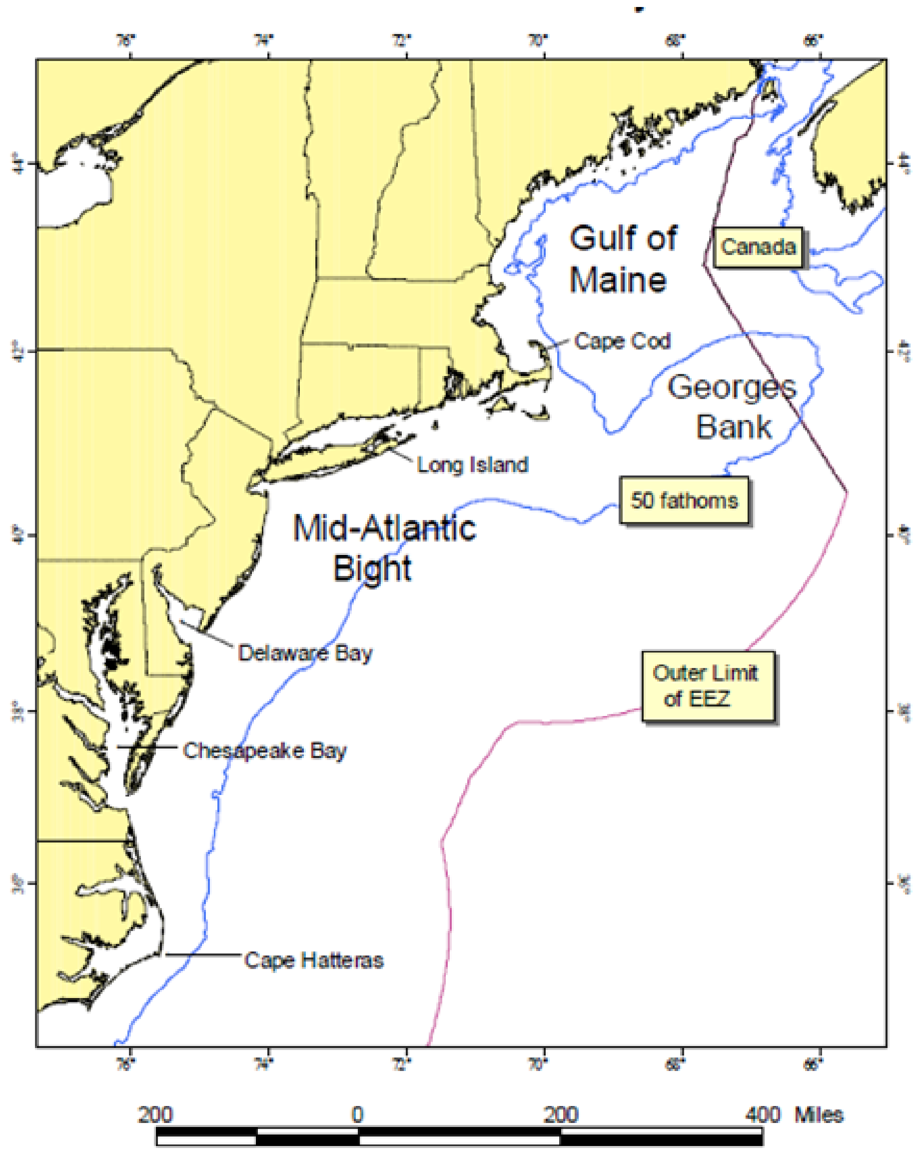


Figure B19. Map of the region covered by the Northeast Fisheries Science Center bottom trawl surveys; the Gulf of Maine to Cape Hatteras, North Carolina.

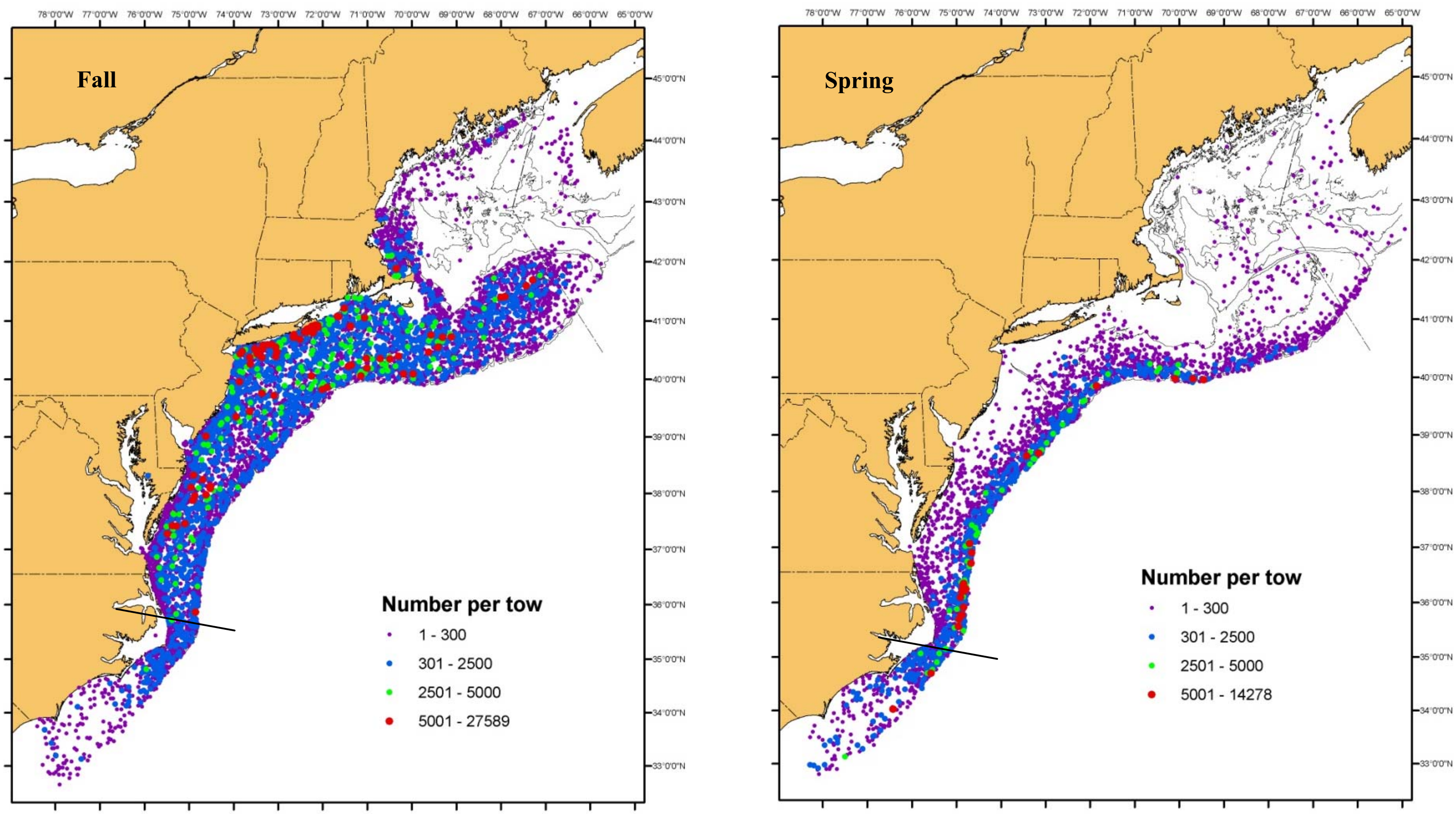


Figure B20. Distribution of *Loligo pealeii* during NEFSC fall (1975-2008) and spring (1976-2008) bottom trawl surveys. Survey strata located south of the solid black line (Cape Hatteras, NC) were not regularly sampled and these squid represent an unknown mix of *Loligo pealeii* and *Loligo pleii.* The 60, 100,200 and 400 m isobaths are also shown.

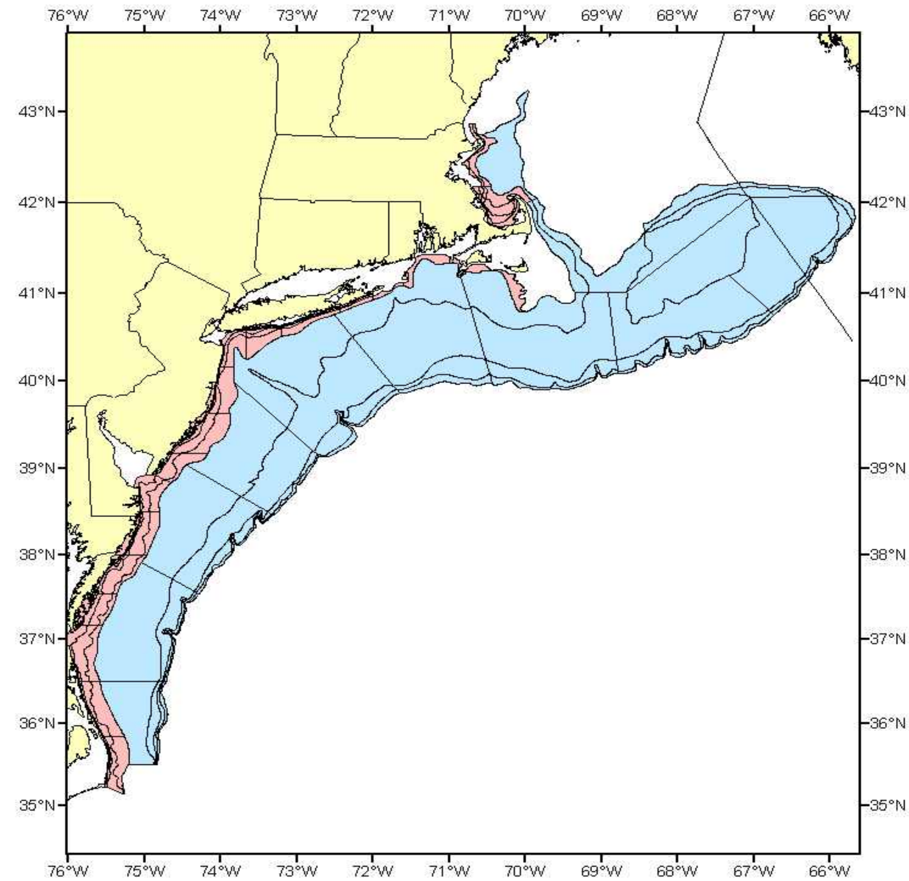


Figure B21. NEFSC survey depth strata used to derive relative abundance and biomass estimates. Inshore strata, including depths 8-27 m, are shaded pink and offshore strata, including depths 27-366 m, are shaded blue.

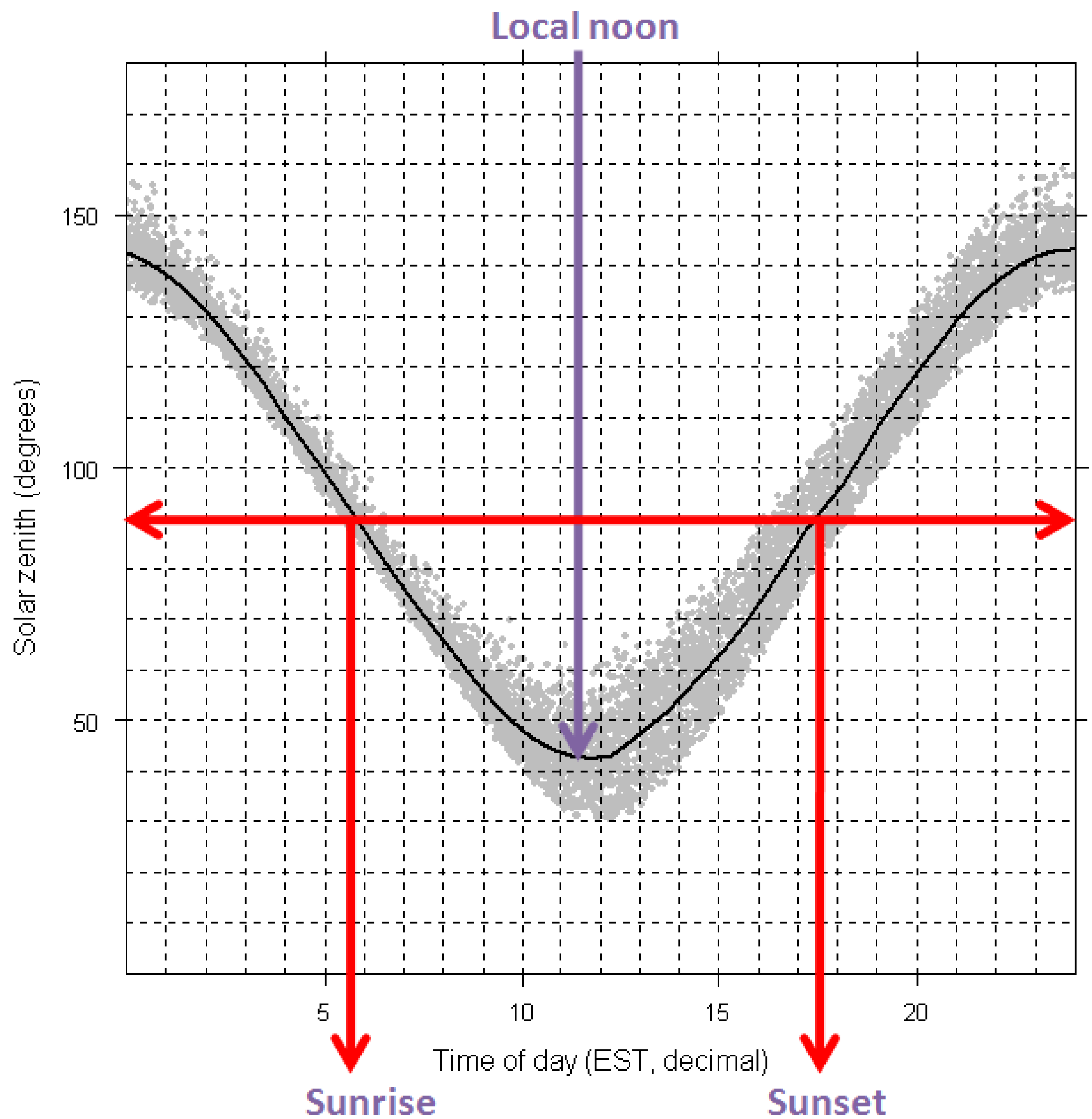


Figure B22. The relationship between solar zenith and time of day in NEFSC fall surveys, 1975-2008. The sun rises and sets at a solar zenith of 90.83° when the disk of the sun first appears or disappears along the horizon. At local noon, the sun is at its apogee and the solar zenith is at its minimum value.

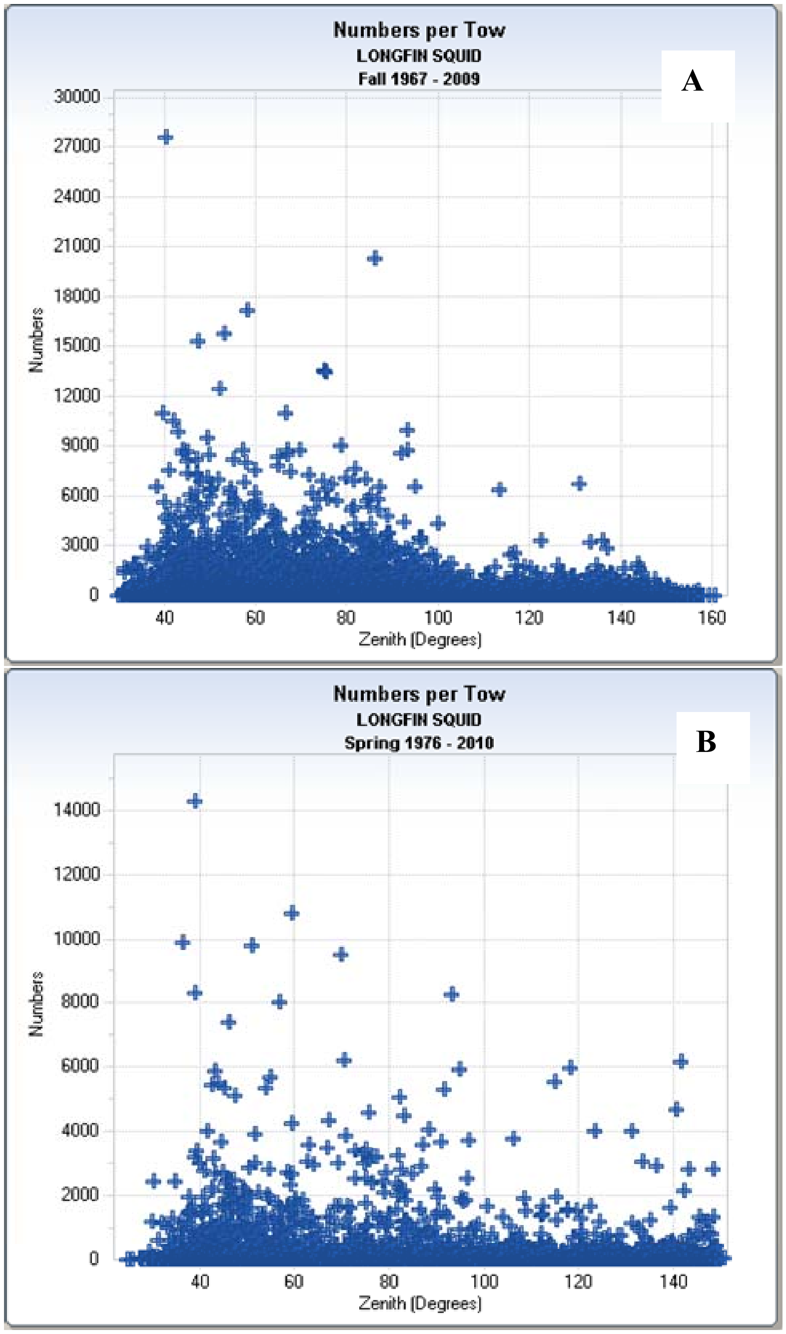


Figure B23. *Loligo* catch rates, number per tow, in relation to solar zenith angle (degrees) during NEFC bottom trawl surveys conducted during fall, 1975-2009 (A), and spring, 1976-2010 (B).

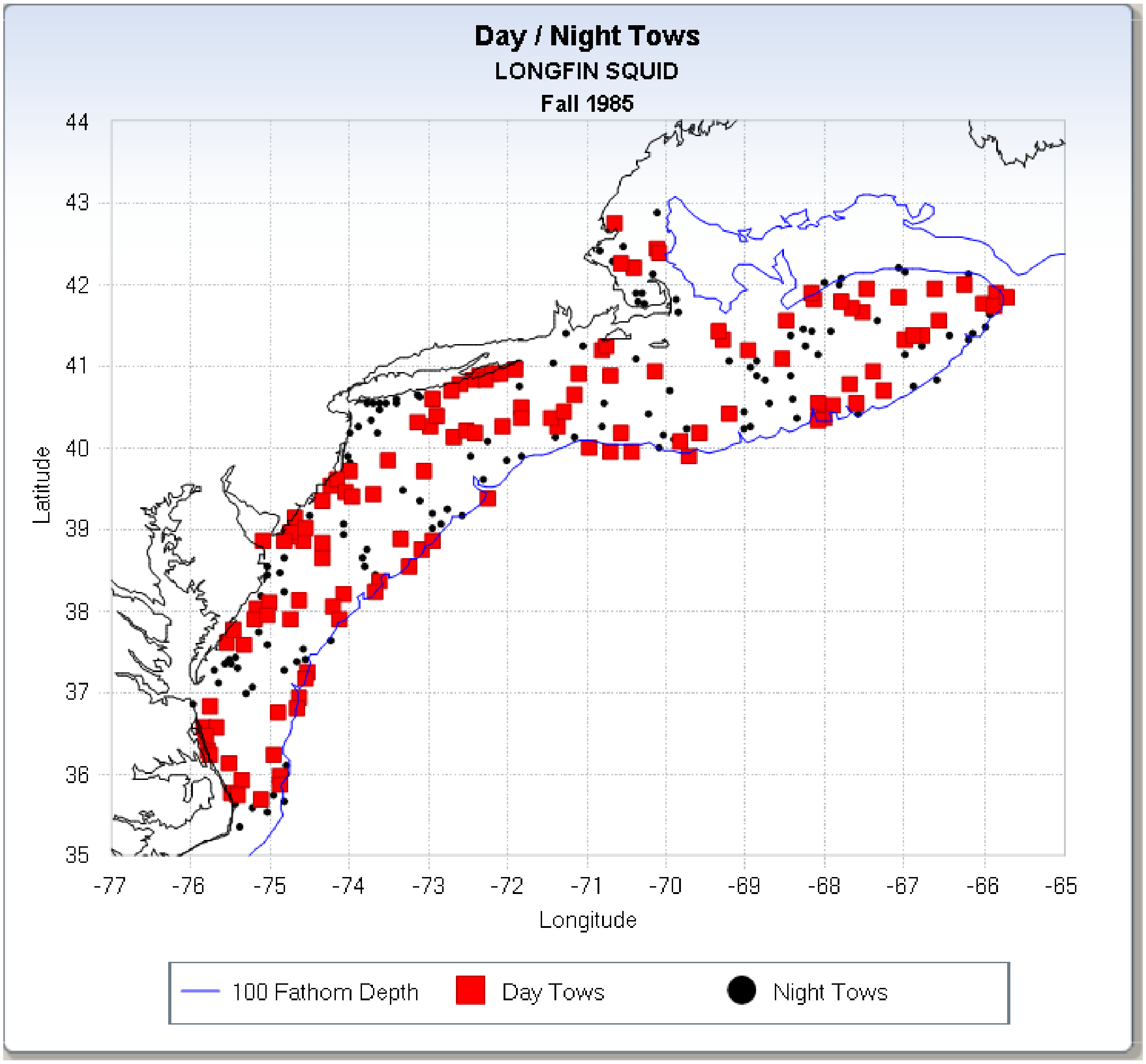


Figure B24. Location of day- and nighttime tows, for the *Loligo pealeii* strata set, during the fall 1985 survey. The year shown was chosen at random.

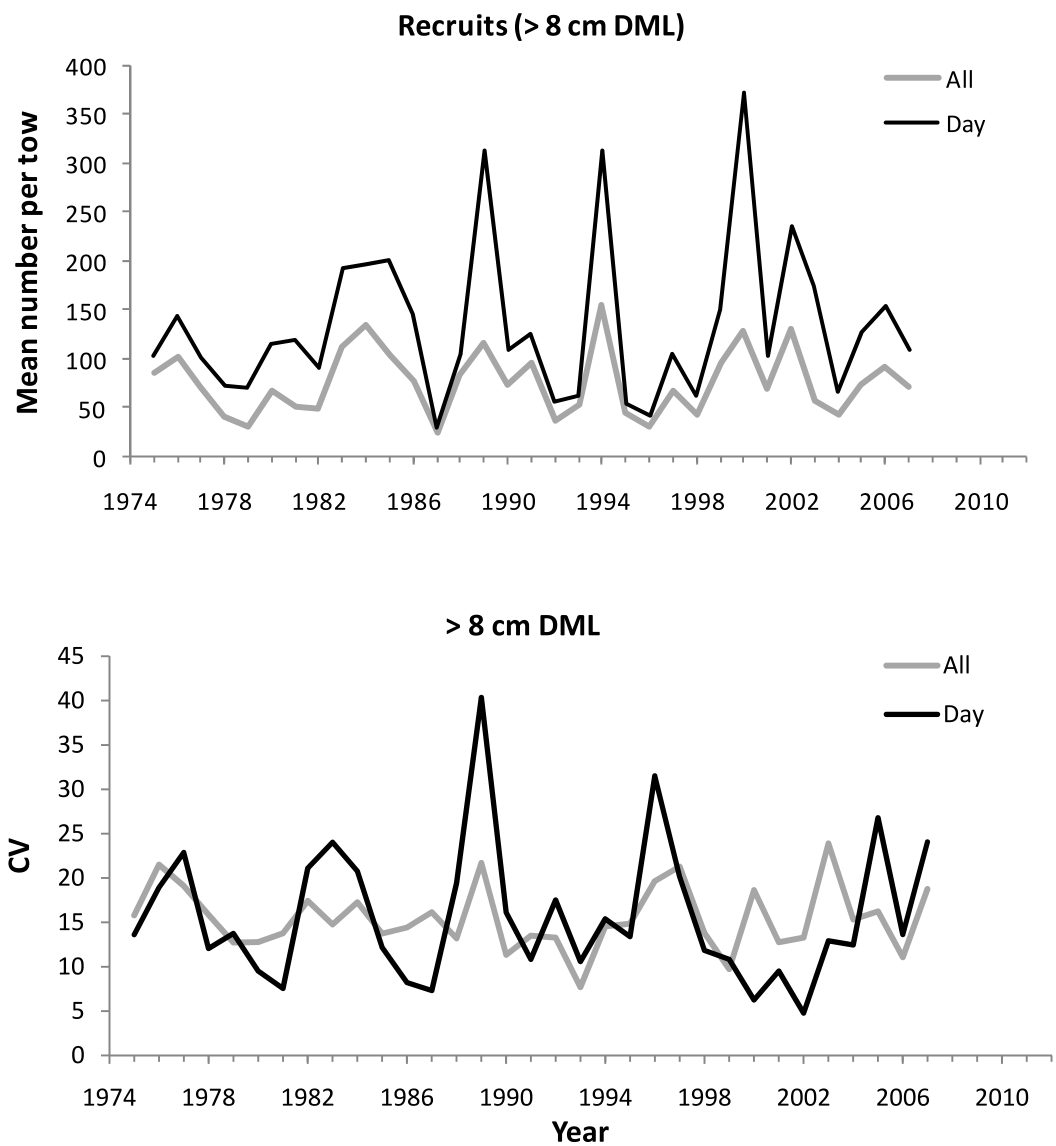
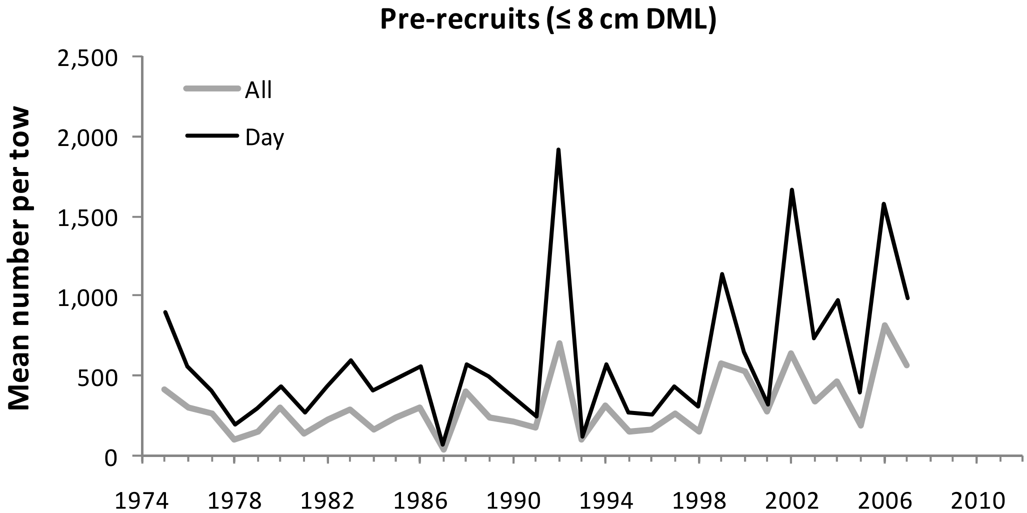


Figure B25. Comparison of *Loligo pealeii* relative abundance indices and CVs for recruits (> 8 cm DML) based on day tows (solar zenith 43-80□) versus all tows from NEFSC fall bottom trawl surveys, 1975-2008.



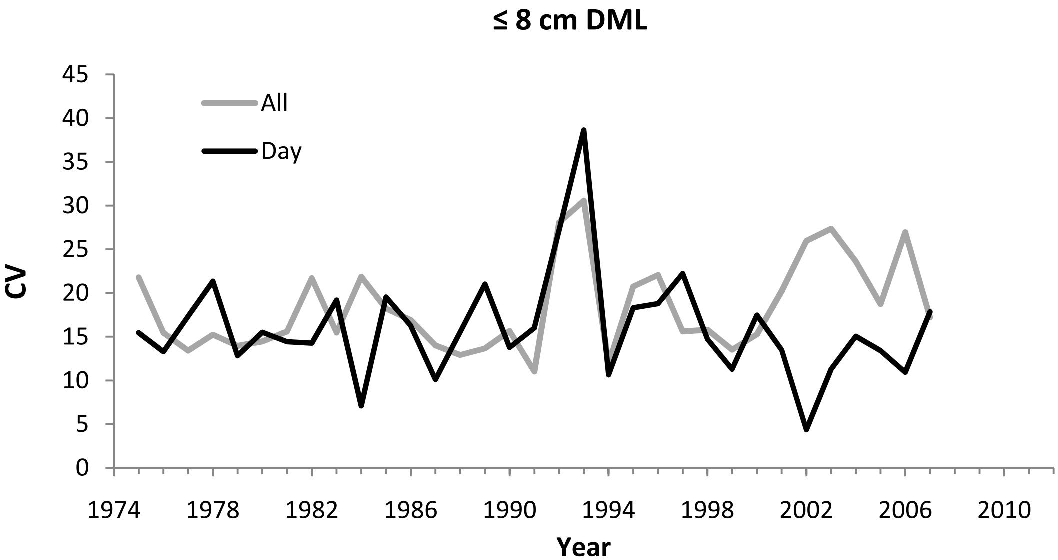


Figure B26. Comparison of *Loligo pealeii* relative abundance indices and CVs for pre-recruits (≤ 8 cm DML) based on day tows (solar zenith 43-80□) versus all tows from NEFSC fall bottom trawl surveys, 1975-2008.

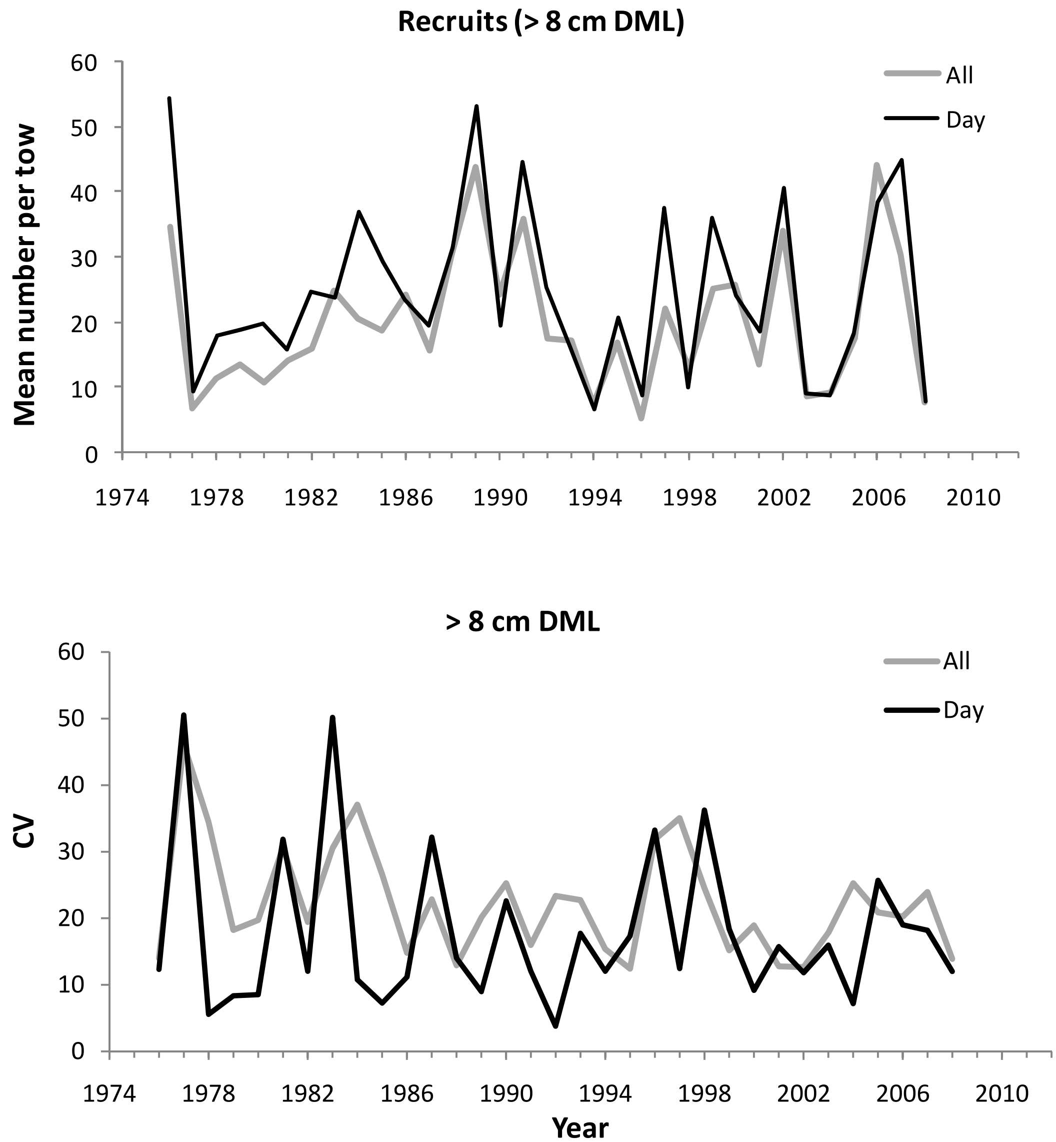
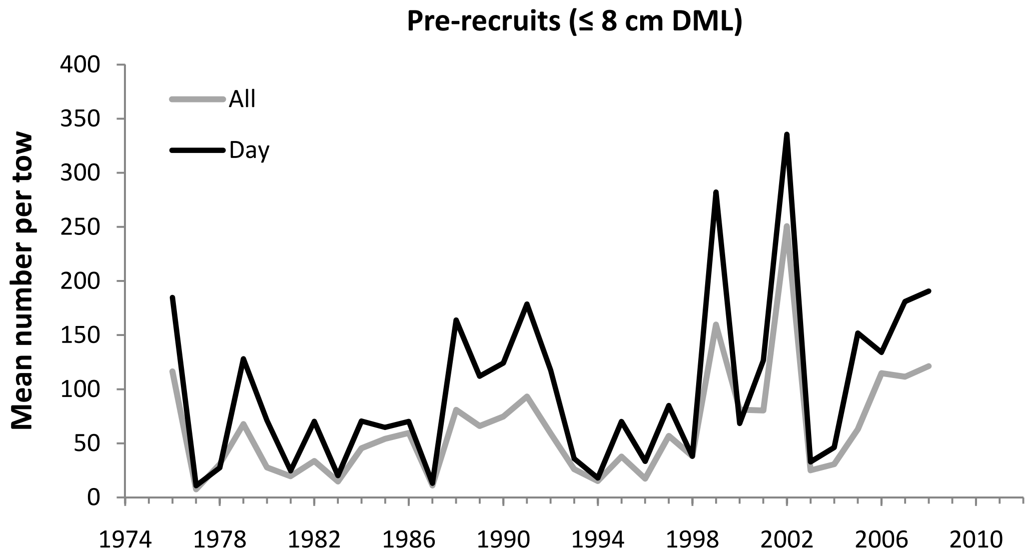


Figure B27. Comparison of *Loligo pealeii* relative abundance indices and CVs for recruits (> 8 cm DML) based on day tows (solar zenith 29-84□) versus all tows from NEFSC spring bottom trawl surveys, 1976-2008.



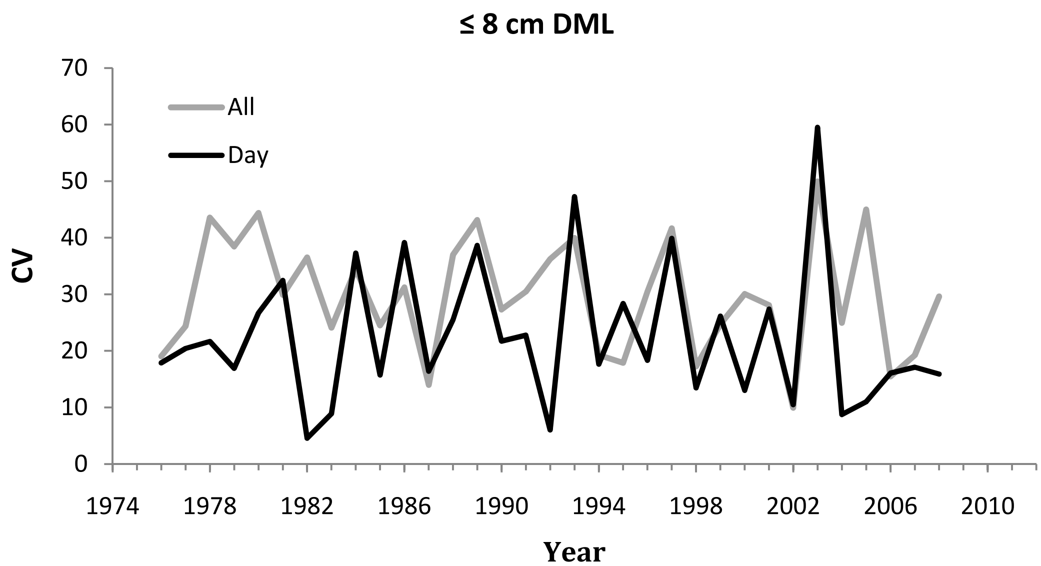


Figure B28. Comparison of *Loligo pealeii* relative abundance indices and CVs for pre-recruits (≤ 8 cm DML) based on day tows (solar zenith 29-84□) versus all tows from NEFSC spring bottom trawl surveys, 1976-2008.

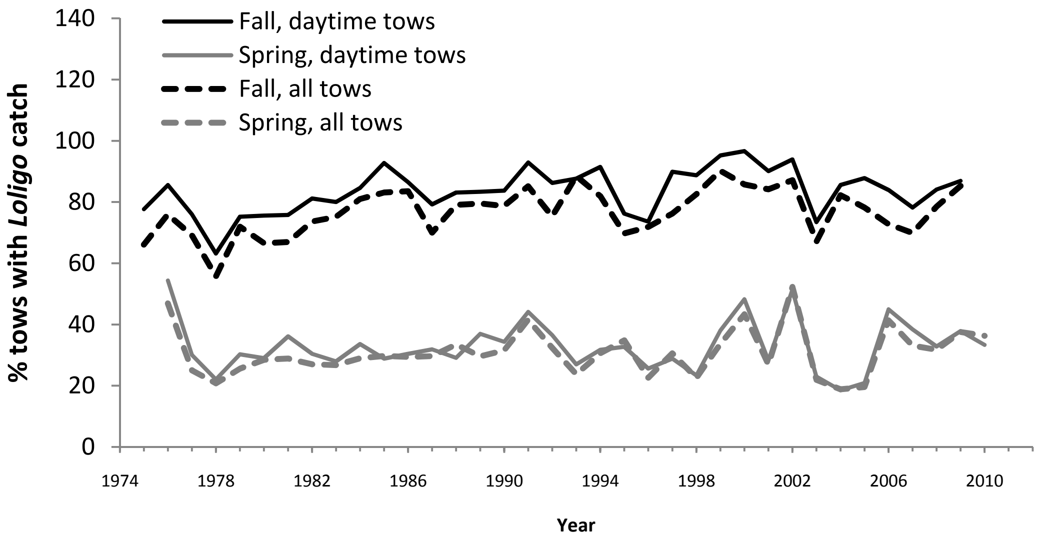
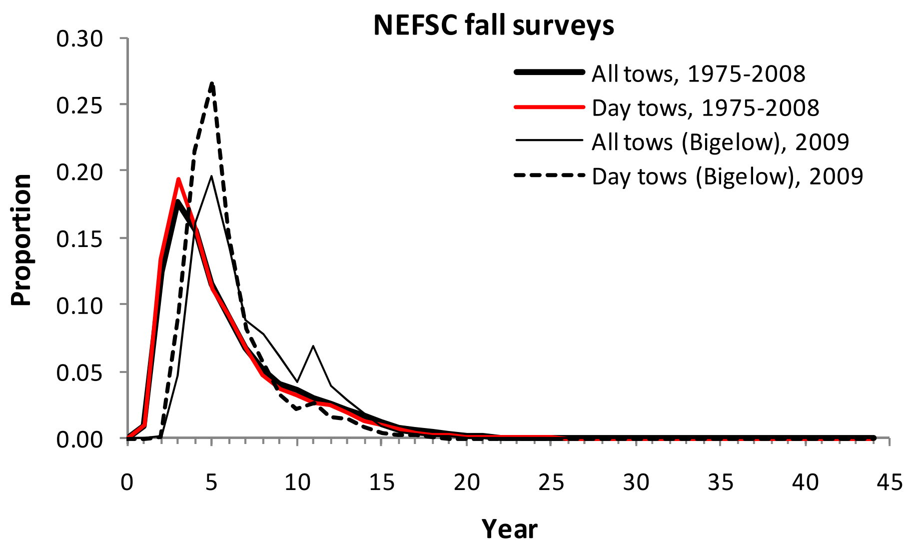


Figure B29. Percentages of “daytime” tows versus all tows with *Loligo pealeii* catch in NEFSC spring (1976-2010) and fall (1975-2009) bottom trawl surveys. Solar zenith angles of 29-84 and 43-80 were used to define daytime tows for the spring and fall surveys, respectively.



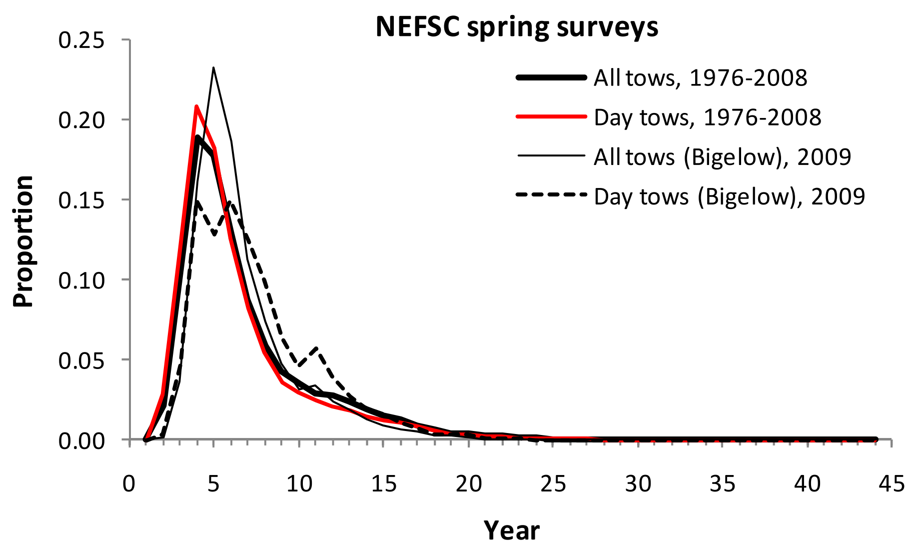


Figure B30. *Loligo* length compositions for NEFSC fall and spring surveys, based on all tows versus "daytime" tows (fall and spring "daytime" tows are for solar zenith angles of 43-80° and 29-84°, respectively).

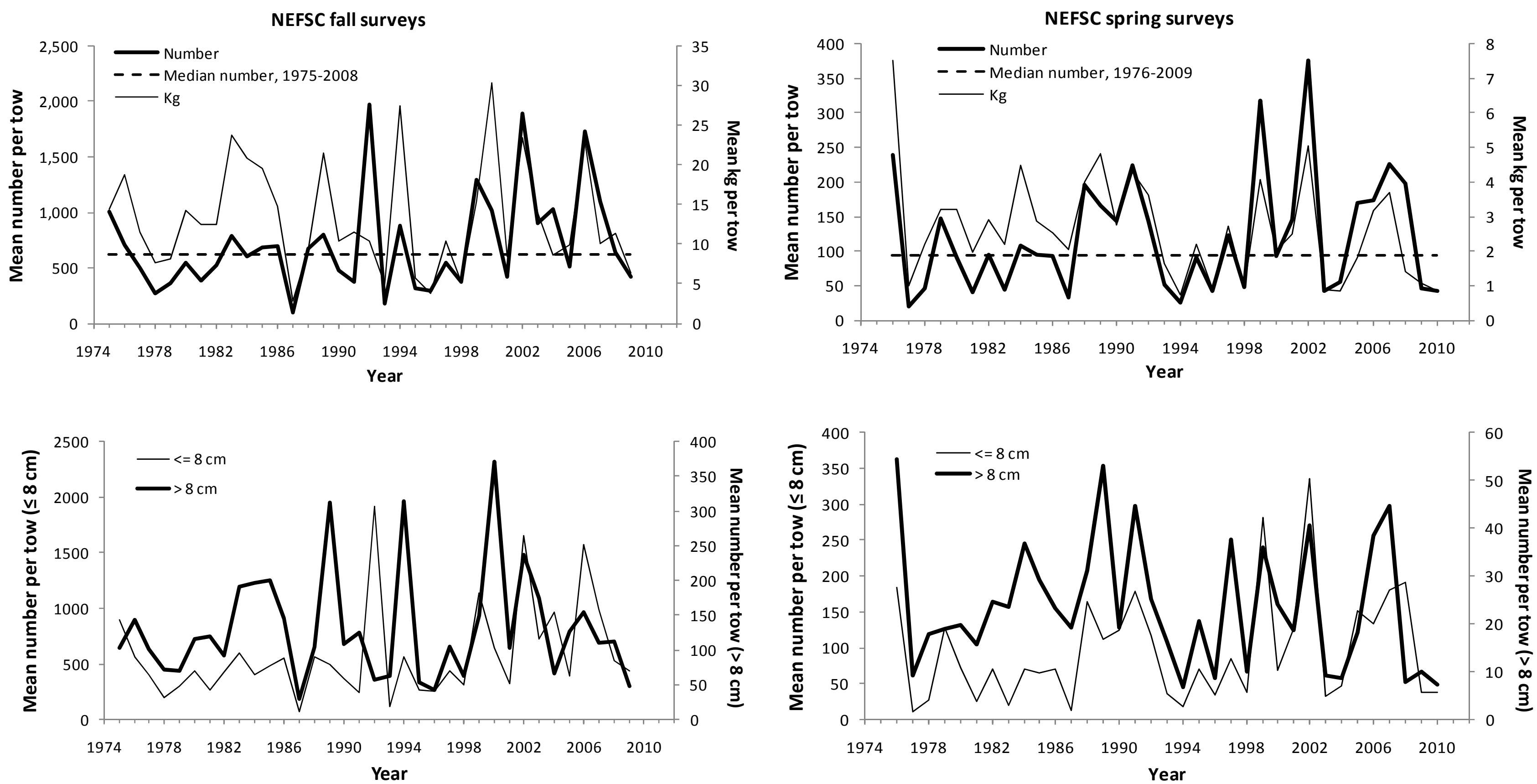
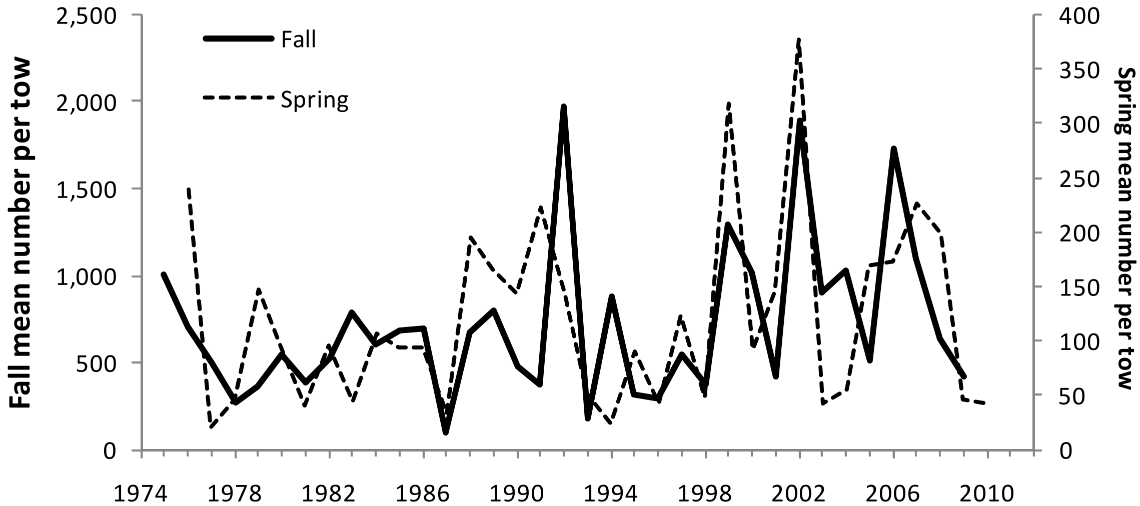


Figure B31. *Loligo pealeii* relative abundance and biomass indices (stratified mean number and kg per tow) and relative abundance indices for pre-recruits (≤ 8 cm DML) and recruits (> 8 cm DML) from NEFSC fall (1975-2009) and spring (1976-2010) bottom trawl surveys.



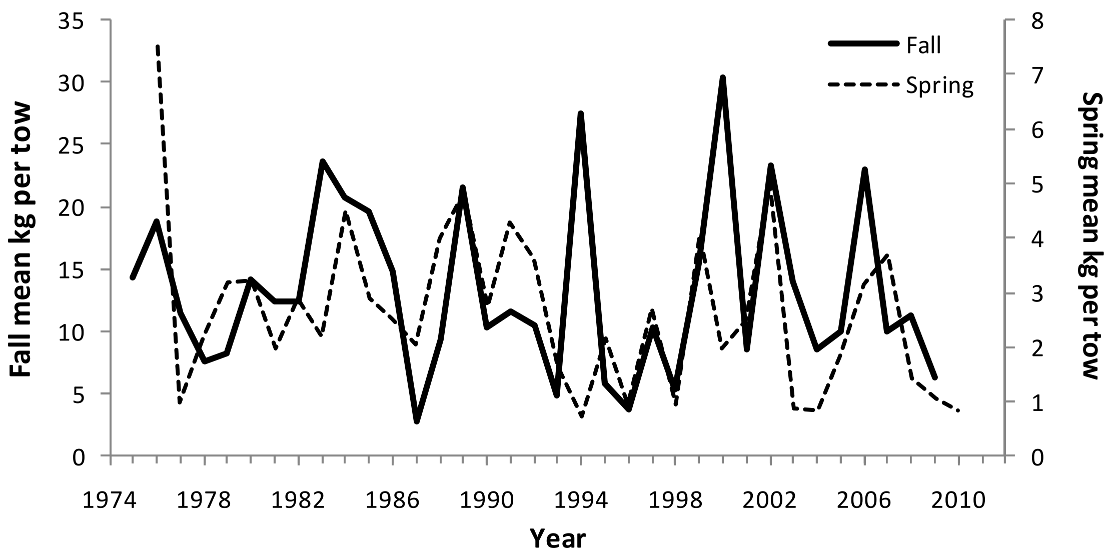


Figure B32. Trends in *Loligo* relative abundance and biomass indices for NEFSC spring (1976-2010) and fall (1975-2009) bottom trawl surveys.

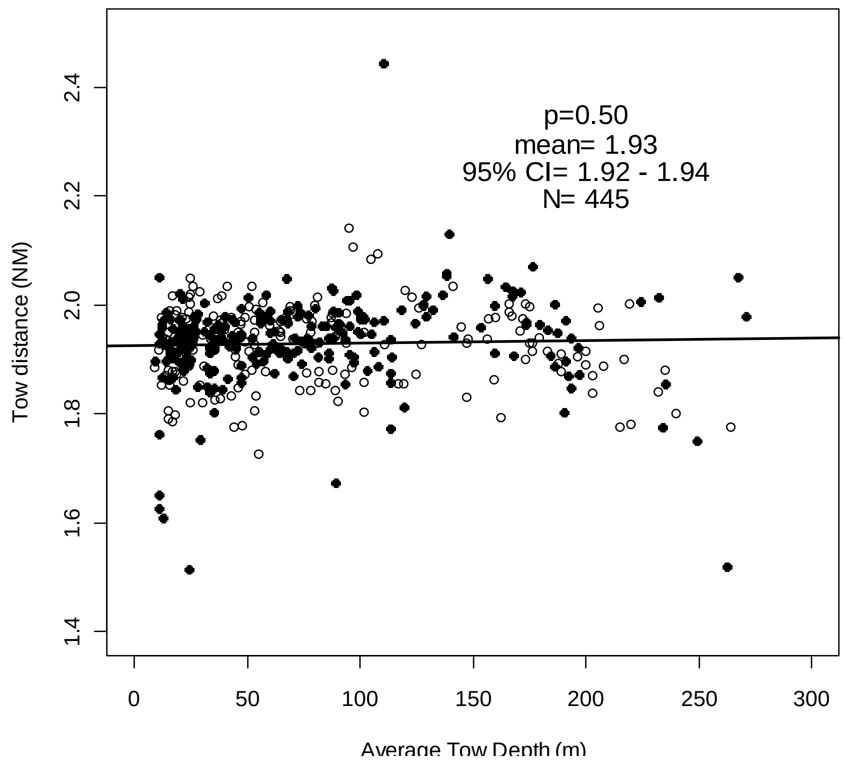


Figure B33. Tow distance (nautical miles) in relation to average station depth based on data from the 2008 spring (open circles) and 2007 fall bottom trawl surveys (solid circles).

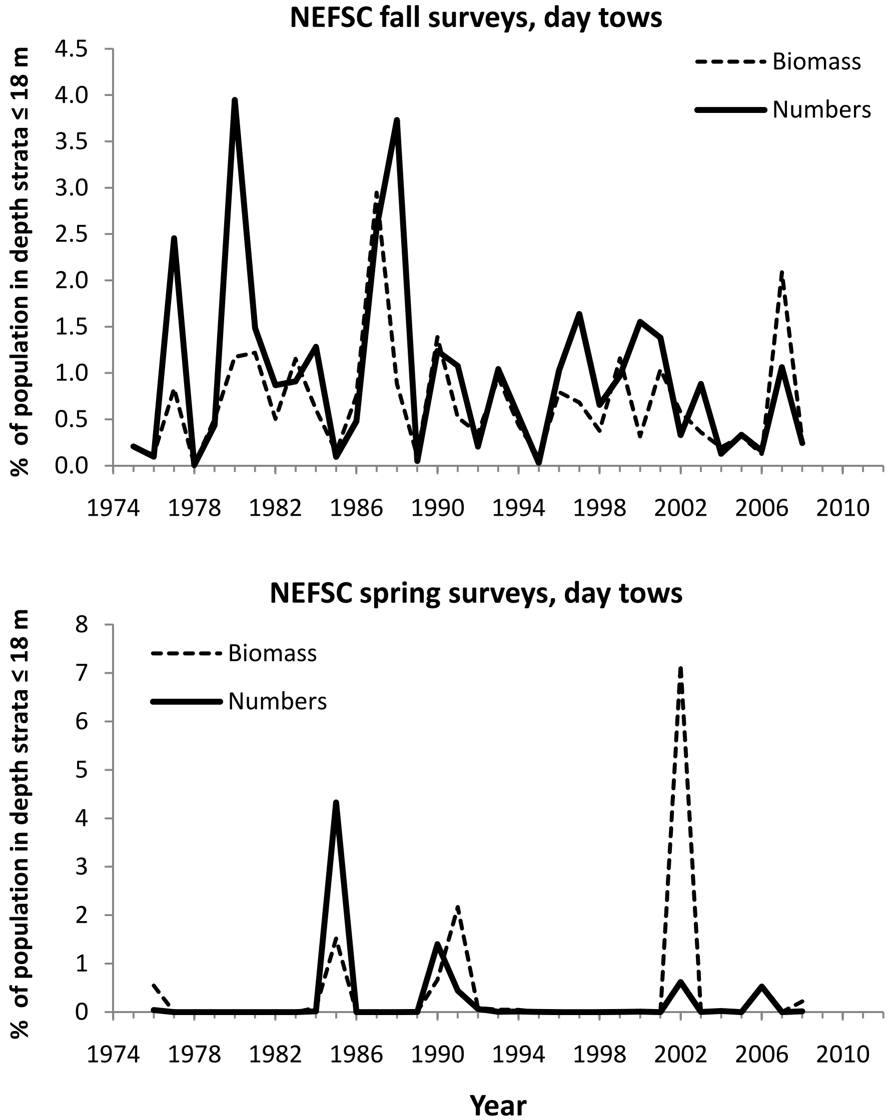


Figure B34. Percentages of the *Loligo pealeii* stratified mean number and kg per tow indices, based on "day" tows conducted during NEFSC spring and fall bottom trawl surveys, in NEFSC survey strata that can no longer be sampled as of 2009.

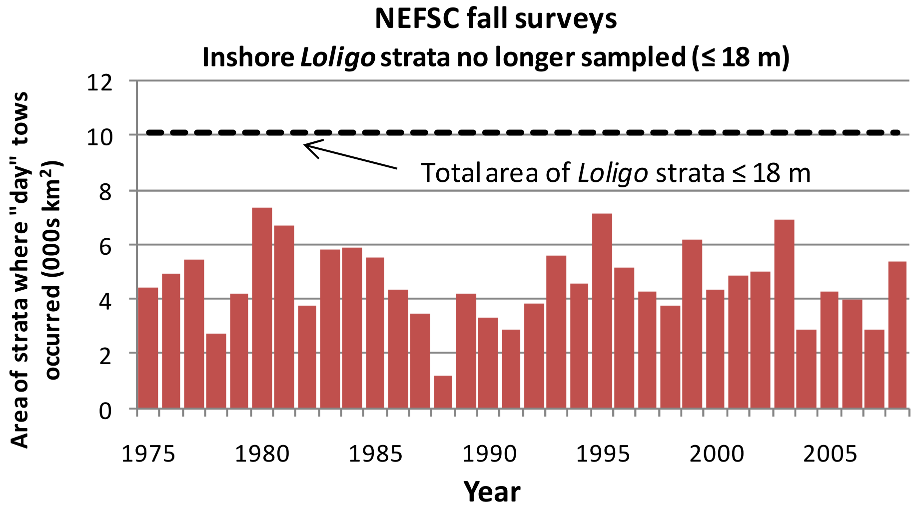


Figure B35. Areas (000s km^2) where daytime tows occurred during NEFSC fall surveys (1975-2008), in the inshore *Loligo* strata (≤ 18 m) which are no longer sampled. The dashed line indicates the total area (10,111 km^2) of these inshore strata.

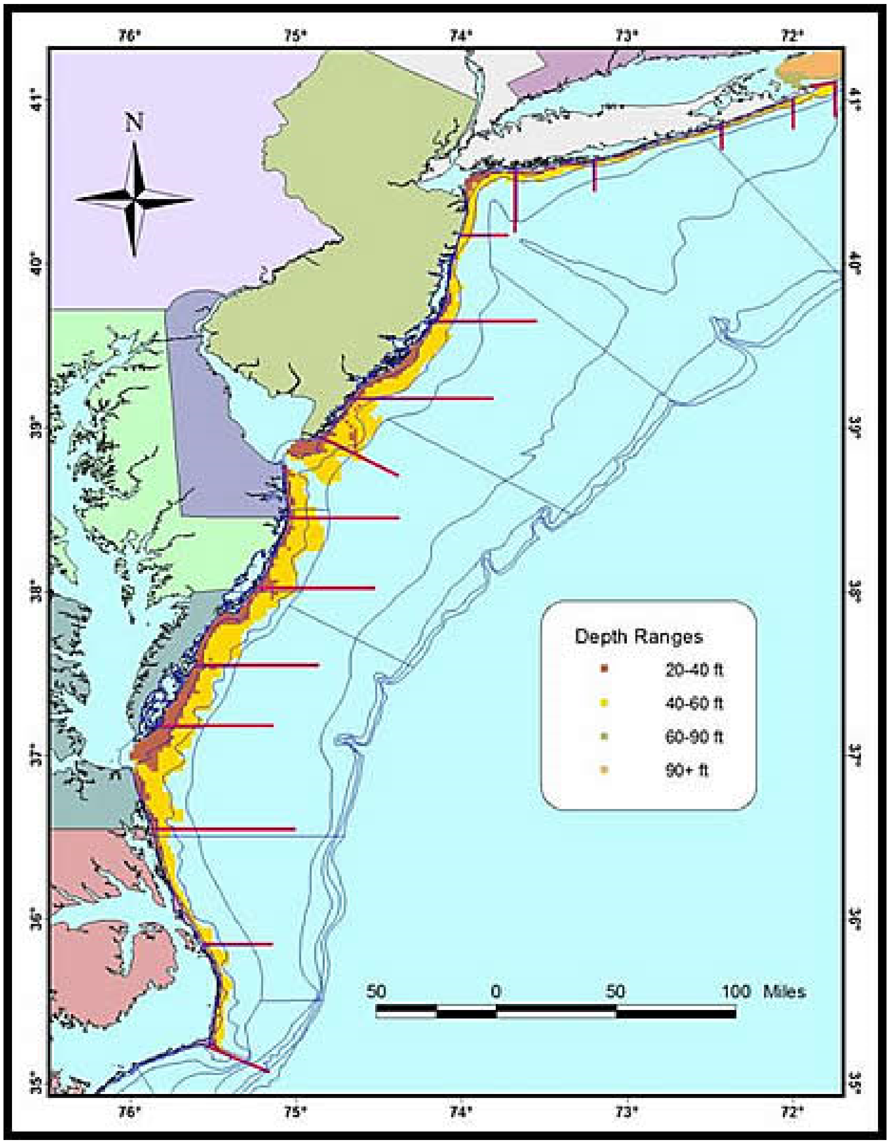


Figure B36. Locations of the NEAMAP bottom trawl survey strata (the two shallowest strata sets shaded red and yellow and ranging in depth from 6.1-18.3 m), between Long Island, NY and Cape Hatteras, NC, in relation to the NEFSC bottom trawl survey strata (polygons outlined in blue).

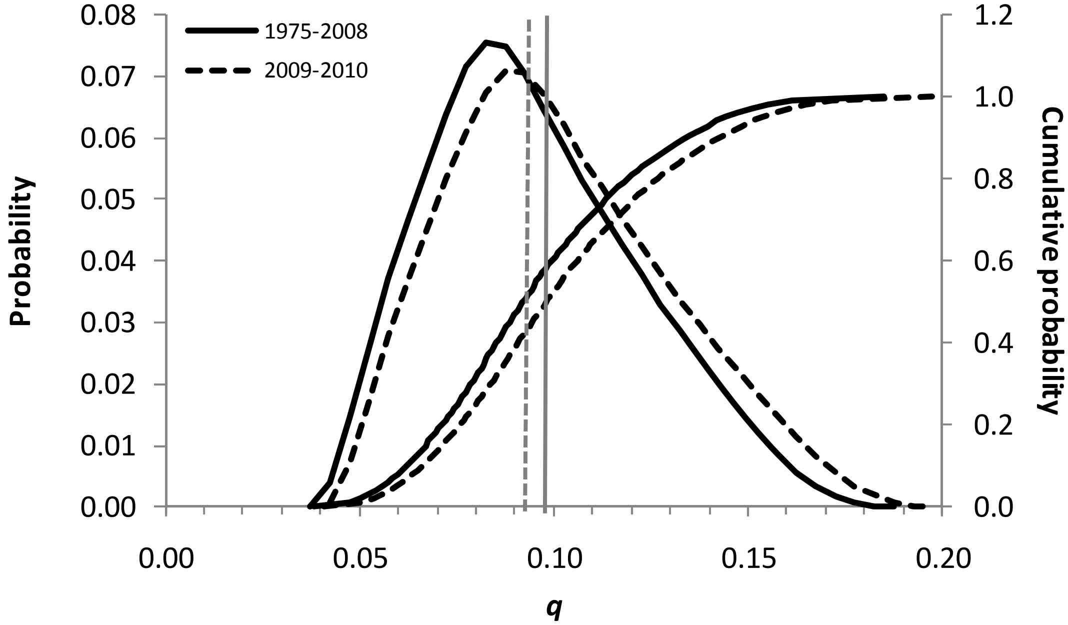
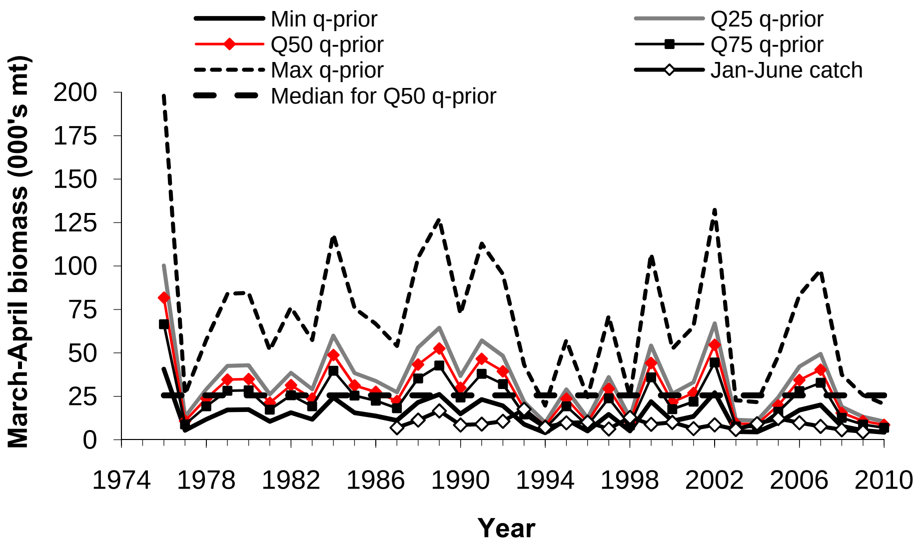


Figure B37. Uncertainty in catchability (q) priors for *Loligo pealeii* in NEFSC spring and fall surveys and median q-priors (0.092 for 1975-2009 and 0.098 for 2009-2010) used to compute biomass estimates.



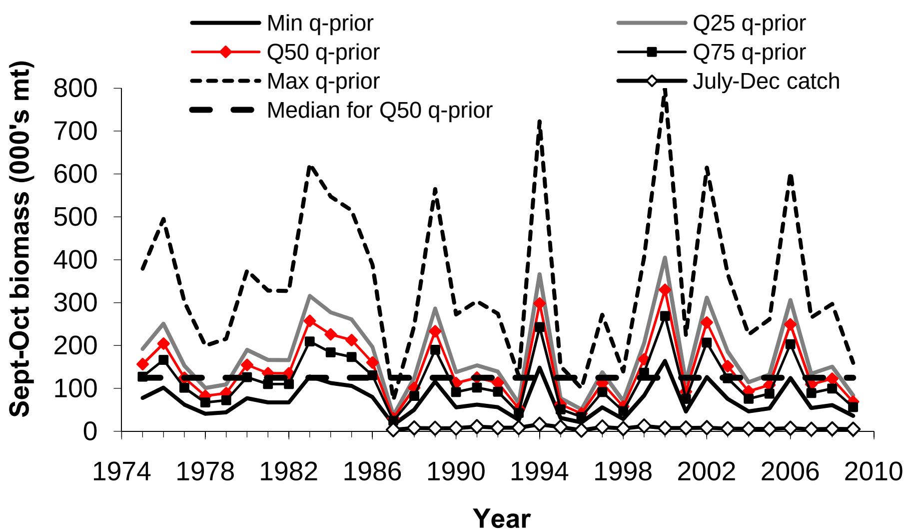


Figure B38. *Loligo* biomass estimates, derived using the minimum, maximum, 25th, 50th and 75th percentiles of the *q*-prior distributions (Q25,50 and 75), for cohorts caught in the NEFSC spring (1976-2010, top) and fall (1975-2009, bottom) bottom trawl surveys.

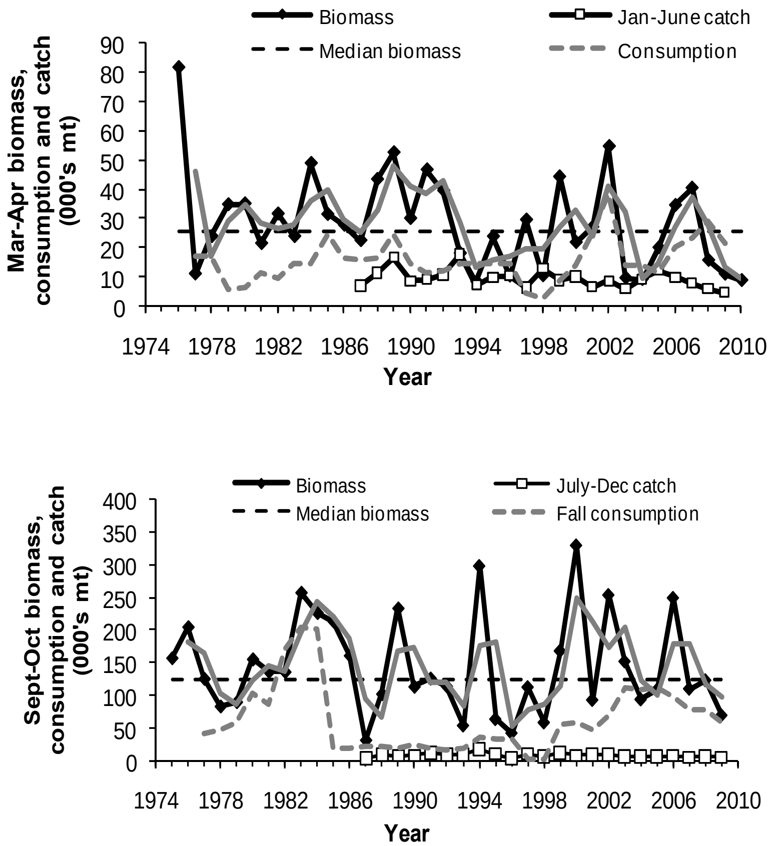


Figure B39. Estimates of *Loligo pealeii* biomass (derived using the median q-priors) for seasonal cohorts caught in the NEFSC spring (top) and fall surveys (bottom) in relation to their respective seasonal consumption estimates and fishery catches. The grey lines represent the two-year moving averages of the biomass estimates.

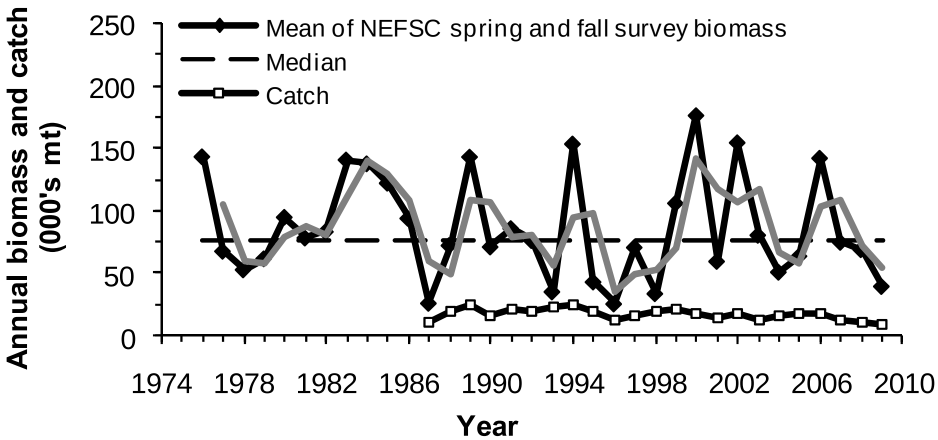
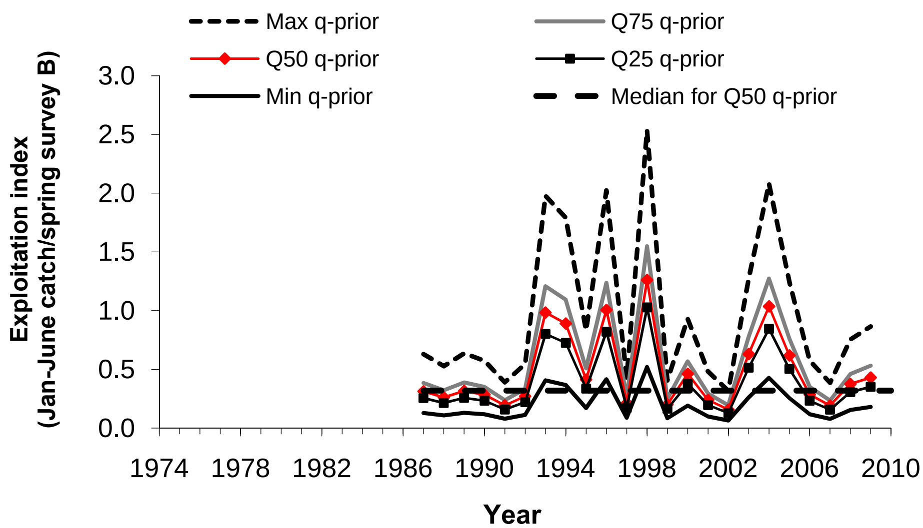


Figure B40. Annualized estimates (annual averages of NEFSC spring and fall survey biomass) of *Loligo* biomass in relation to annual catches. The grey line is the two-year moving average of the biomass estimates.



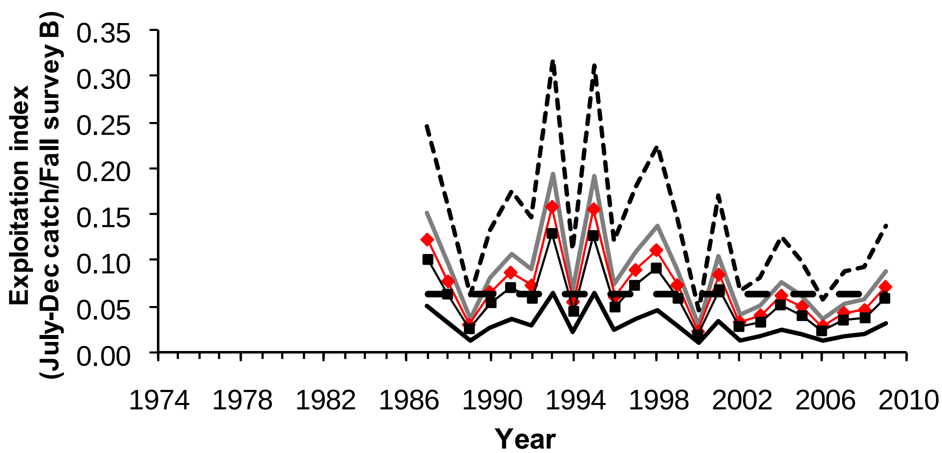


Figure B41. *Loligo* exploitation indices, derived using the minimum, maximum, 25th, 50th and 75th percentiles of the *q*-prior distributions (Q25,50 and 75), for the January-June fishery (January-June catch/March survey biomass, top) and the July-December fishery (July-December catch/September survey biomass, bottom), 1987-2009.

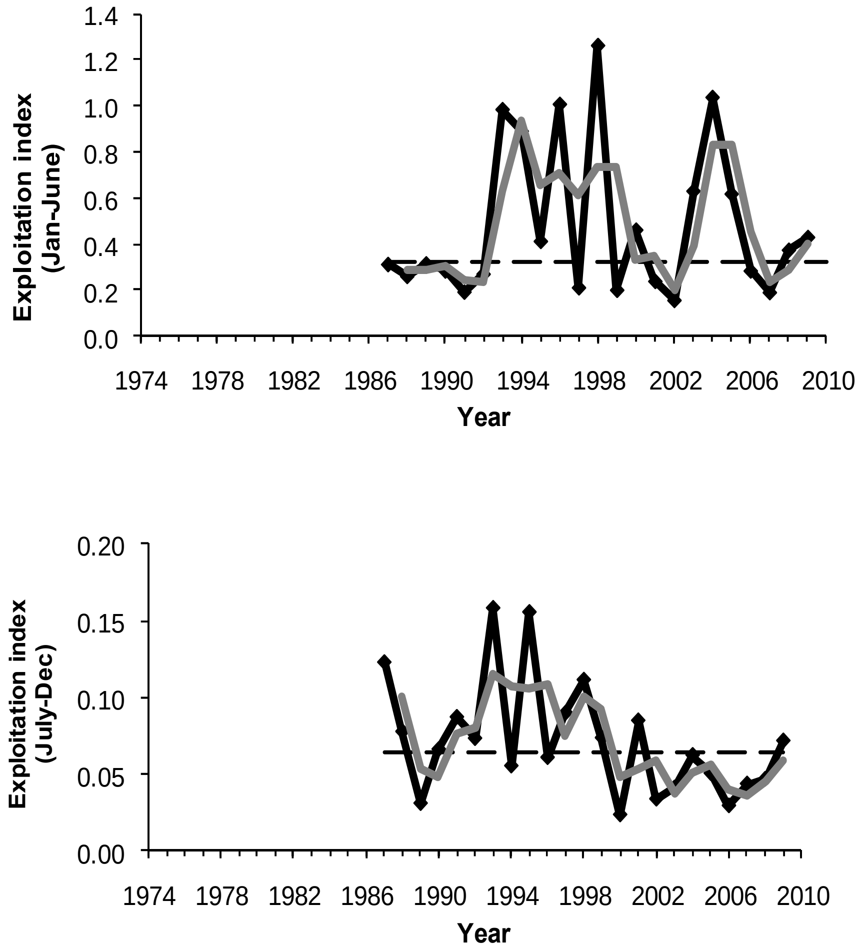


Figure B42. Exploitation indices for the January-June fishery (top) and the July-December fishery (bottom) in relation their medians during 1987-2008. The grey lines represent the two-year moving averages.

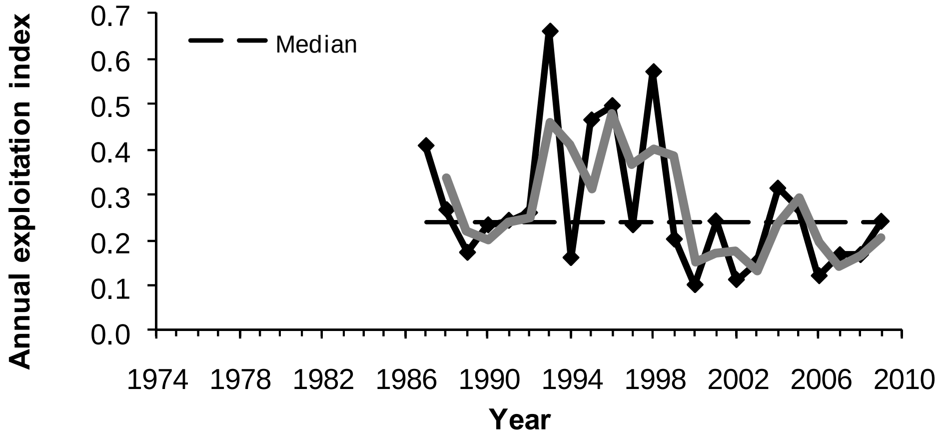


Figure B43. Annual exploitation indices for *Loligo* (annual catch/ annual mean of NEFSC spring and fall survey biomass). The grey lines represent the two-year moving averages.

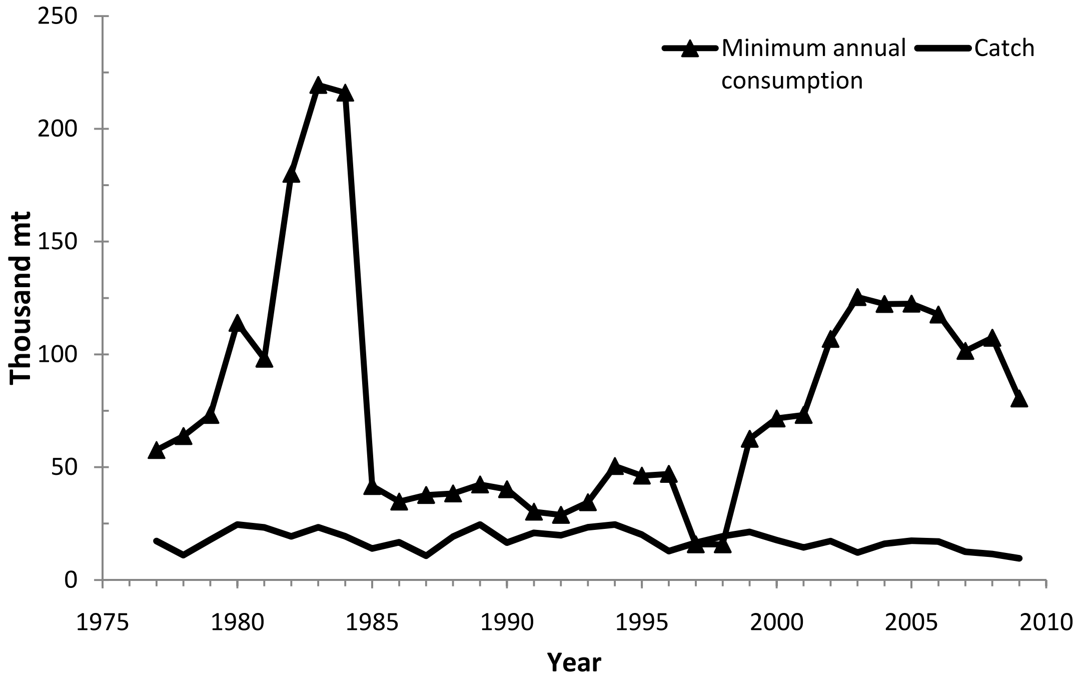


Figure B44. Annual estimates of minimum consumption and catches of Loligo pealeii during 1977-2009.

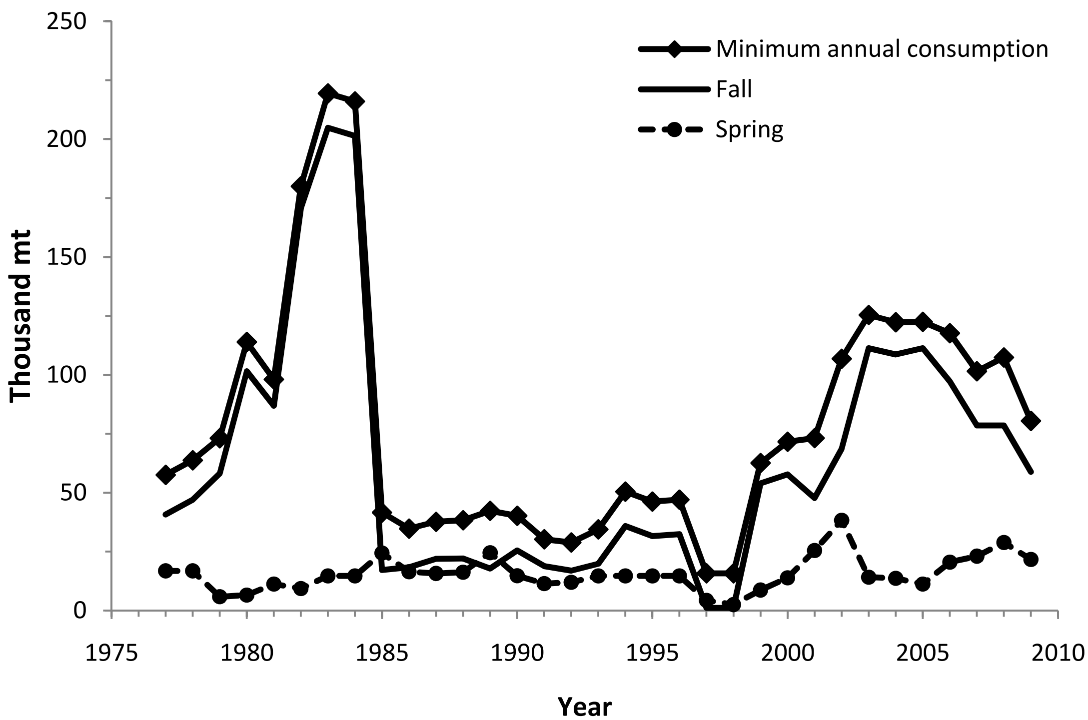


Figure B45. Minimum seasonal and annual estimates of *Loligo* consumption.

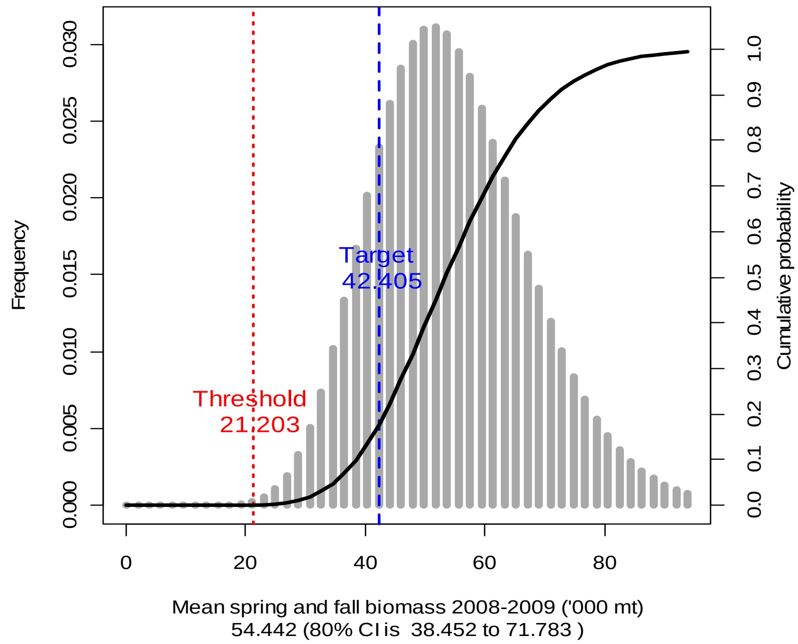


Figure B46. *Loligo* biomass estimate (000s mt), spring and fall survey average for 2008-2009, shown as a probability distribution. Also shown are proposed biomass reference points.

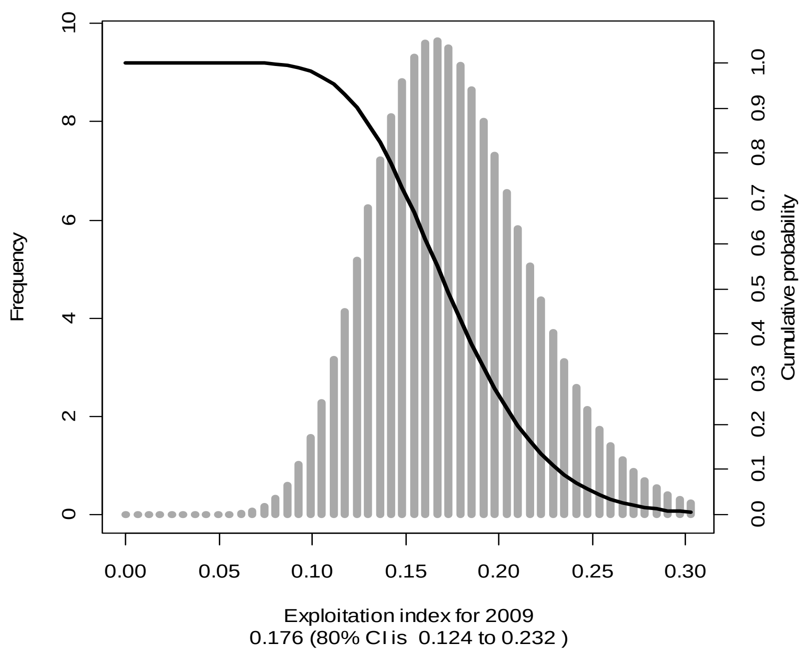


Figure B47. *Loligo* exploitation index for 2009 (2009 catch / mean of 2008-2009 spring and fall survey biomass) shown as a probability distribution.

Appendix B1: Invertebrate Subcommittee meetings for the SAW/SARC-51 assessment of *Loligo.*

The Invertebrate Subcommittee met on September 28-29 and on October 18-20 at the Northeast Fisheries Science Center in Woods Hole, MA to work on the SAW/SARC-51 stock assessment for *Loligo pealeii*. Members attended in person and by Webex/conference call. The Subcommittee met again briefly by WebEx/conference call on the morning of October 25 to complete its work. The following persons attended one or more of the meetings.

- Lisa Hendrickson, Northeast Fisheries Science Center (NEFSC), Assessment Lead
- Larry Jacobson, NEFSC, Subcommittee Chair
- Toni Chute, NEFSC, Rapporteur
- Dan Hennen, NEFSC, Rapporteur
- Aja Peters-Mason, NERO (SMB Plan Manager)
- Chris Legault, NEFSC
- DJ Kowalske, NEFSC, Cooperative Research
- Fred Serchuk, NEFSC
- Greg DiDomenico (Industry Advisor)
- Jason Didden (MAFMC,SMB staff person)
- Jason Link, NEFSC
- Jeff Kaelin (Lunds Fisheries, Cape May, NJ)
- Jeff Reichle (Lunds Fisheries, Cape May, NJ)
- Jon Knight (Superior Trawl, Pt. Judith, RI)
- Lars Axelsson (F/V Flicka, Cape May, NJ)
- Mark Terciero, NEFSC
- Paul Rago, NEFSC
- Sam Martin (Atlantic Cape Fisheries, Cape May, NJ)
- Tim Miller, NEFSC
- Vidar Westpestad (Industry consultant)

Appendix B2: Assessment of the effects of solar zenith angle and other environmental factors on the diel catchability of *Loligo* in bottom trawls

Solar zenith at the time and geographic location of each tow was used in place of the more conventional time of day in estimating diel effects on *Loligo* catchability in bottom trawls. Solar zenith is the angle between a line drawn between the center of the sun and the observer and a line drawn directly overhead at the location of the observer (Meeus, 1998). Solar zenith is the primary determinant of the amount of irradiance (watts m^{-2}) at the surface of the ocean where the observer is located (Frouin *et al.*, 1989). Solar zenith is more useful than time of day in modeling because irradiance varies by latitude, longitude, Julian date and year (which are all used in calculation of the solar zenith). Although there is a clear general relationship between solar zenith and time of day (Figure 1), tows carried out at the same time but at different geographic locations may have substantially different irradiance levels that might affect survey catchability to different extents.

GAM models were fit to fall and spring survey data from the same strata and years used elsewhere in the assessment, and used to confirm diel catchability patterns as functions of squid size, season and other variable. Based on preliminary analyses, the maximum likelihood GAM models fit using the *R* statistical language were:

$$Y = f[s(L,Z) + s(L,D) + s(T) + region + year] + \varepsilon$$

where *Y* is the dependent variable for one size group in one tow, *f()* is the link function (see below), and ε is a statistical error. The continuous variables are *L* (DML in 1 cm increments), *Z* (solar zenith at the time and location of tow, degrees), *D* (tow depth, m), and *T* (bottom temperature, ^{o}C). The categorical predictor variables are region (Gulf of Maine, Georges Bank, Southern New England, Mid-Atlantic Bight, and Chesapeake Bay to Cape Hatteras) and year. One *s(x)* and two dimensional *s(x,y)* nonlinear spline functions were used to model the continuous predictor variables. The two dimensional splines allow interaction between size and soar zenith or between size and depth. The degree of nonlinearity in the spline functions were chosen using by minimizing of an AIC-type statistic (Wood, 2006).

Modeling mimicked delta-distribution methods in which the probability of a positive survey tow (catch > 1 squid) was estimated in presence-absence models and the catch in positive tows was estimated separately in catch number models. In presence absence modeling, the dependent variable was *Y*=0 or 1 (if at least one squid was taken in the tow), *f( )* was the logit link function, likelihood was calculated assuming errors were from a binomial distribution, and data for all size groups in each tow were included. In catch numbers models, the dependent variable was the survey catch, *f( )* was the log link function was used, likelihood was calculated assuming that the errors were from a negative binomial distribution with estimated shape and scale parameters, and only data for positive tows and size groups were used. Spring and fall survey data were modeled separately. The linear and nonlinear terms in all of the models were statistically significant.

Predicted values from the models showed clear diel effects on the probability of a positive tow and catches in positive tows. Diel effects were size and season dependent (Figures 2-5).

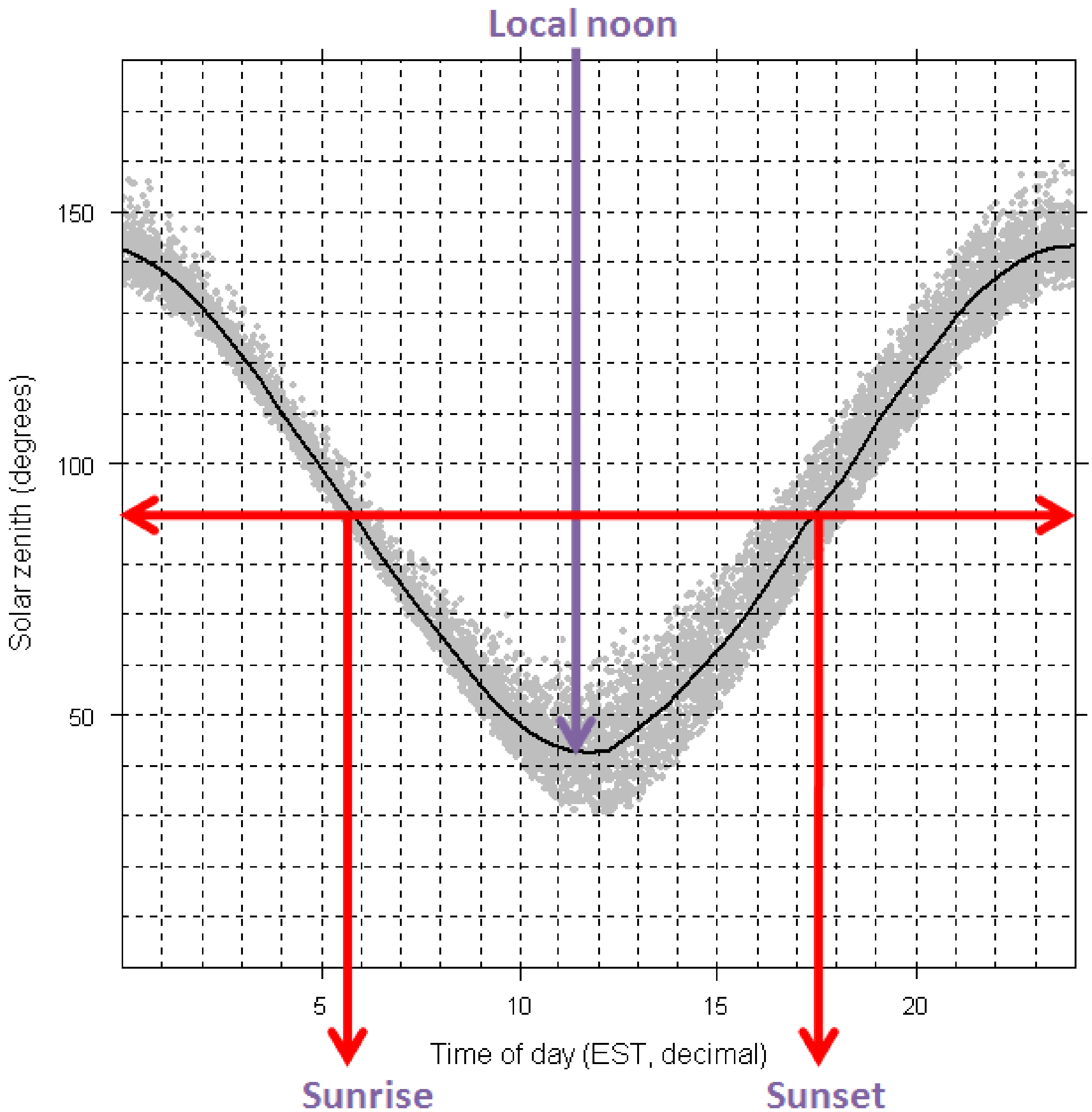
Objective criteria for defining daytime tows

All preliminary choices of solar zenith cutoffs to define daytime tows resulted in higher mean survey abundance and biomass levels and similar or smaller CVs. However, there was uncertainty about whether to include data collected around noon and data collected around dawn/dusk. Criteria for defining daytime tows were therefore defined objectively using performance scores based on an approximate mean squared error (MSE) approach. In particular, if the bias in a measurement is *b* and the variance of the measurements is σ^2, then MSE=$b^2 + \sigma^2$. We chose criteria with minimum values of the MSE in order to reduce bias (due to night time tows) and variance of mean numbers and weight per tow. This analysis was not based on GAM or any other model results. Rather, annual mean numbers and weight per tow were calculated from survey data for a wide range of possible criteria. Spring and fall surveys were analyzed separately.

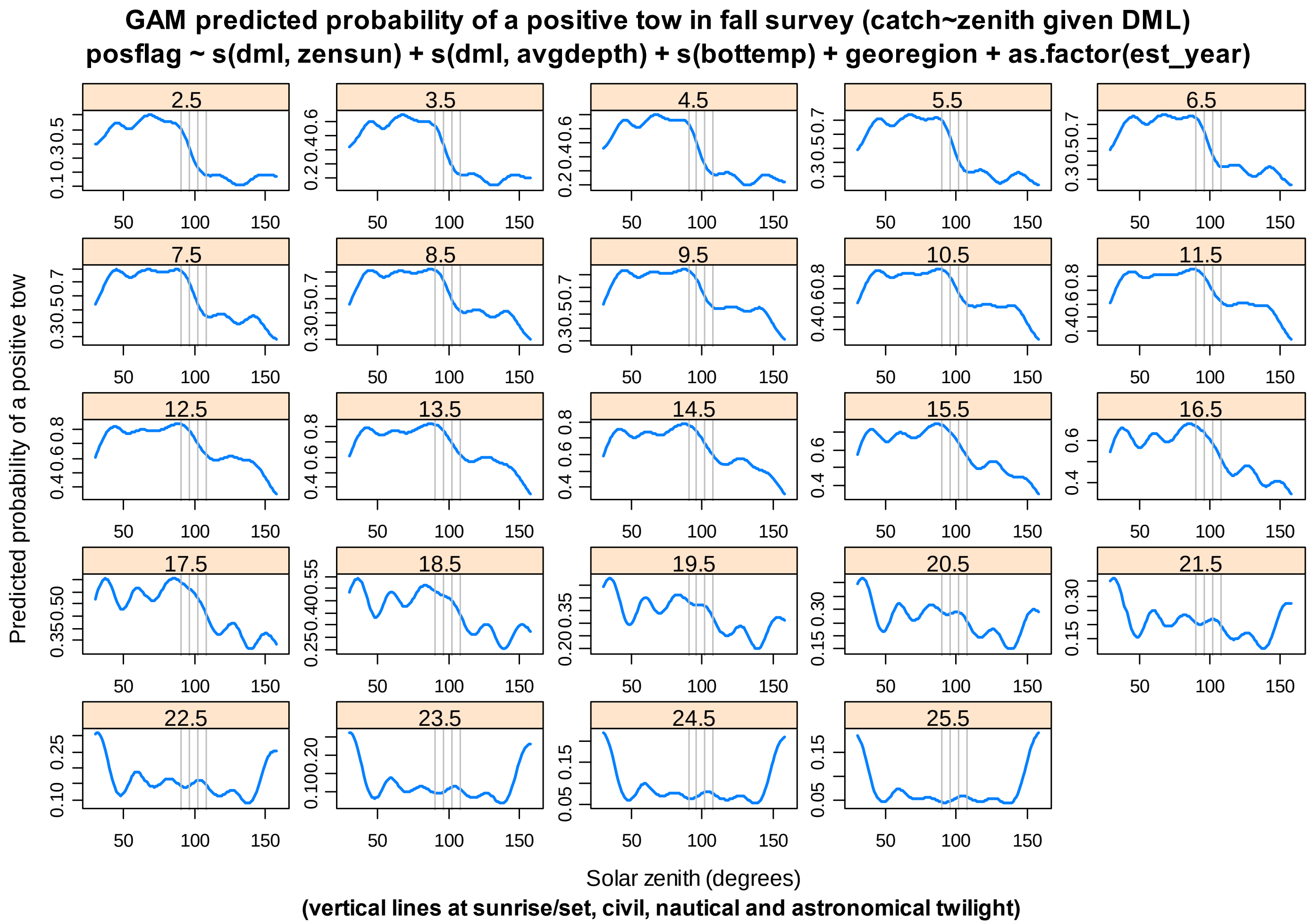
The score used to choose solar zenith criteria was:

$$\mathrm{X}^{\mathrm{n}}_{\mathrm{test}} = [\overline{\mathrm{cv}}_{\mathrm{test}} - (\bar{\mathrm{n}}_{\mathrm{test}} - \bar{\mathrm{n}}_{24})^2] + \left[\frac{\overline{\mathrm{cv}}_{\mathrm{test}}}{\overline{\mathrm{cv}}_{24}} - \frac{\bar{\mathrm{n}}_{\mathrm{test}}}{\bar{\mathrm{n}}_{24}}\right]$$

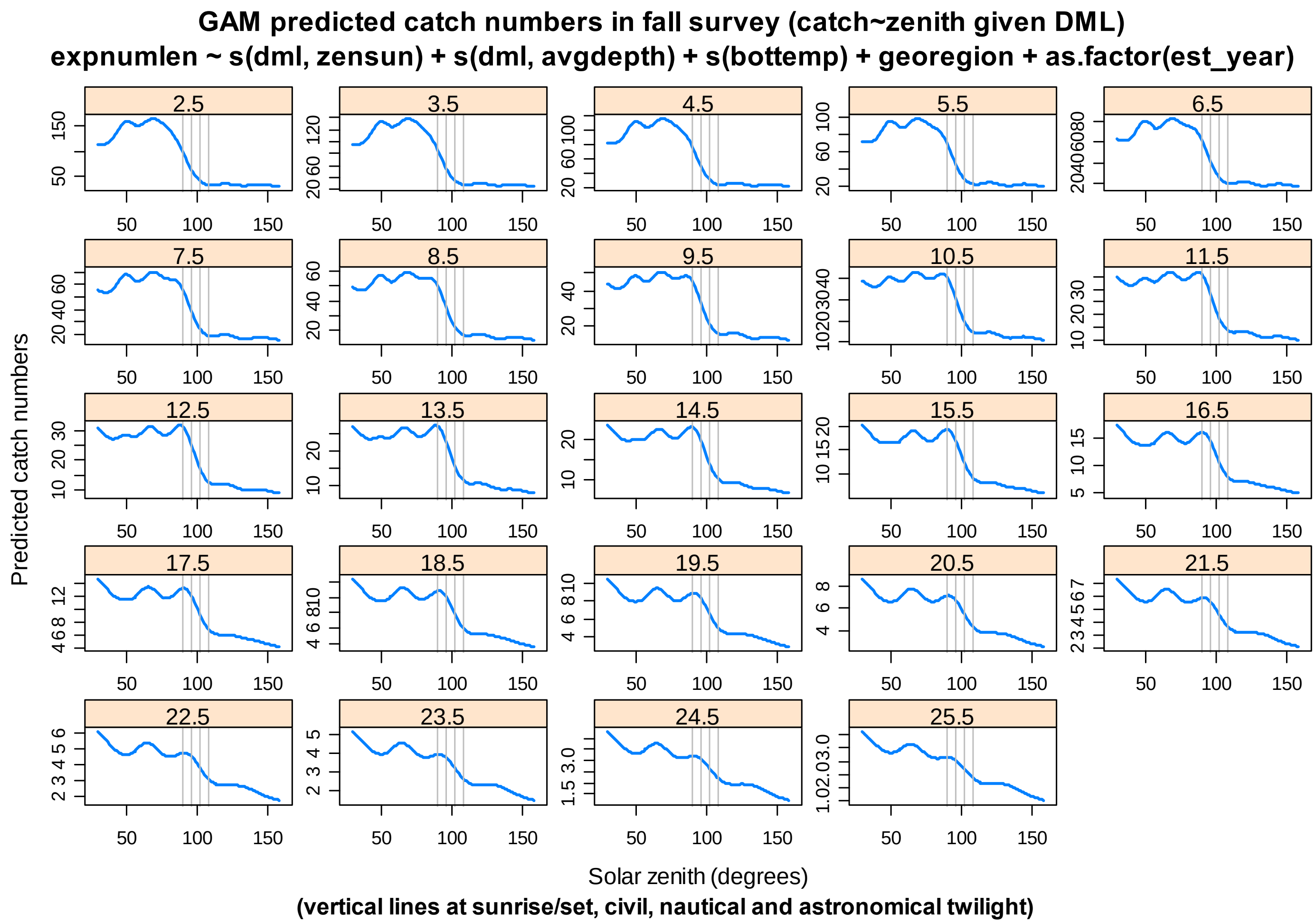
where $\mathrm{X}^{\mathrm{n}}_{\mathrm{test}}$ was the score for mean numbers per tow and a particular set of minimum and maximum values for solar zenith (Z_1 and Z_2, one possible set of criteria for defining daytime tows), $\bar{\mathrm{n}}_{\mathrm{test}}$ and $\bar{\mathrm{n}}_{24}$ were the average (over all years) of the annual stratified random mean numbers per tow for the test criteria and using all tows (day and night), $\overline{\mathrm{cv}}_{\mathrm{test}}$ and $\overline{\mathrm{cv}}_{24}$ were the average (over all years) CVs of the annual stratified mean numbers per tow. The terms $(\bar{\mathrm{n}}_{\mathrm{test}} -$ n24 and ntestn24 are approximate absolute and relative measures of the reduction in bias using the test criteria relative to using all tows. The terms $\overline{\mathrm{cv}}_{\mathrm{test}}$ and $\frac{\overline{\mathrm{cv}}_{\mathrm{test}}}{\overline{\mathrm{cv}}_{24}}$ are approximate absolute and relative measures of variance. A similar score $\mathrm{X}^{\mathrm{b}}_{\mathrm{test}}$ was calculated for mean weight per tow. The combined score $\mathrm{X}_{\mathrm{test}} = \mathrm{X}^{\mathrm{n}}_{\mathrm{test}} + \mathrm{X}^{\mathrm{b}}_{\mathrm{test}}$ was calculated Z_1= 30 to 45° and Z_2 = 75 to 90° in steps of one degree. The combined score surfaces were very bumpy with a wide range of criteria giving similar performance but inclusion of nighttime tows resulted in poor performance. The resulting grid of calculated values was smoothed using a two dimensional loess regression surface and contoured for graphical analysis. The "best" choice for the criteria Z_1 and Z_2 was the combination with the lowest combined score. The criteria chosen for the fall survey was Z_1 =43° and Z_2 =80° (Figure 6). The criteria chosen for the spring survey was Z_1 =29° and Z_2 =84° (Figure 7). Thus, daytime fall survey data used in this assessment are for tows with solar zenith values of 43-80° and daytime spring survey data are for tows with solar zenith values of 29-84°.



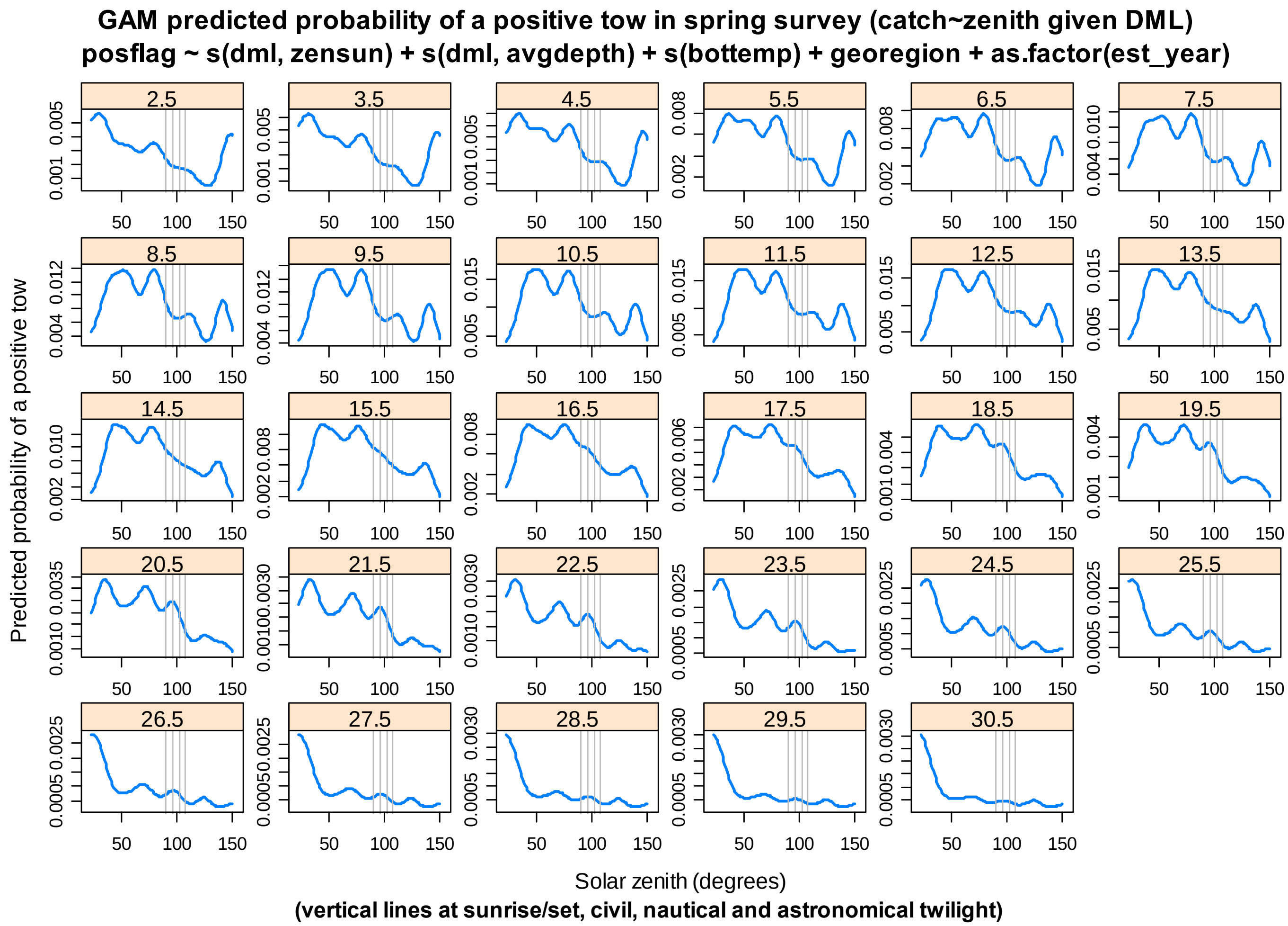
Appendix B2 Figure B1. The relationship between solar zenith and time of day (EST) in fall surveys, 1975-2008. Relationships during the spring survey are similar. The sun rises and sets at a solar zenith of 90.83° when the sun first appears or disappears along the horizon. At local noon, the sun is at its apogee and the solar zenith is at its minimum value.



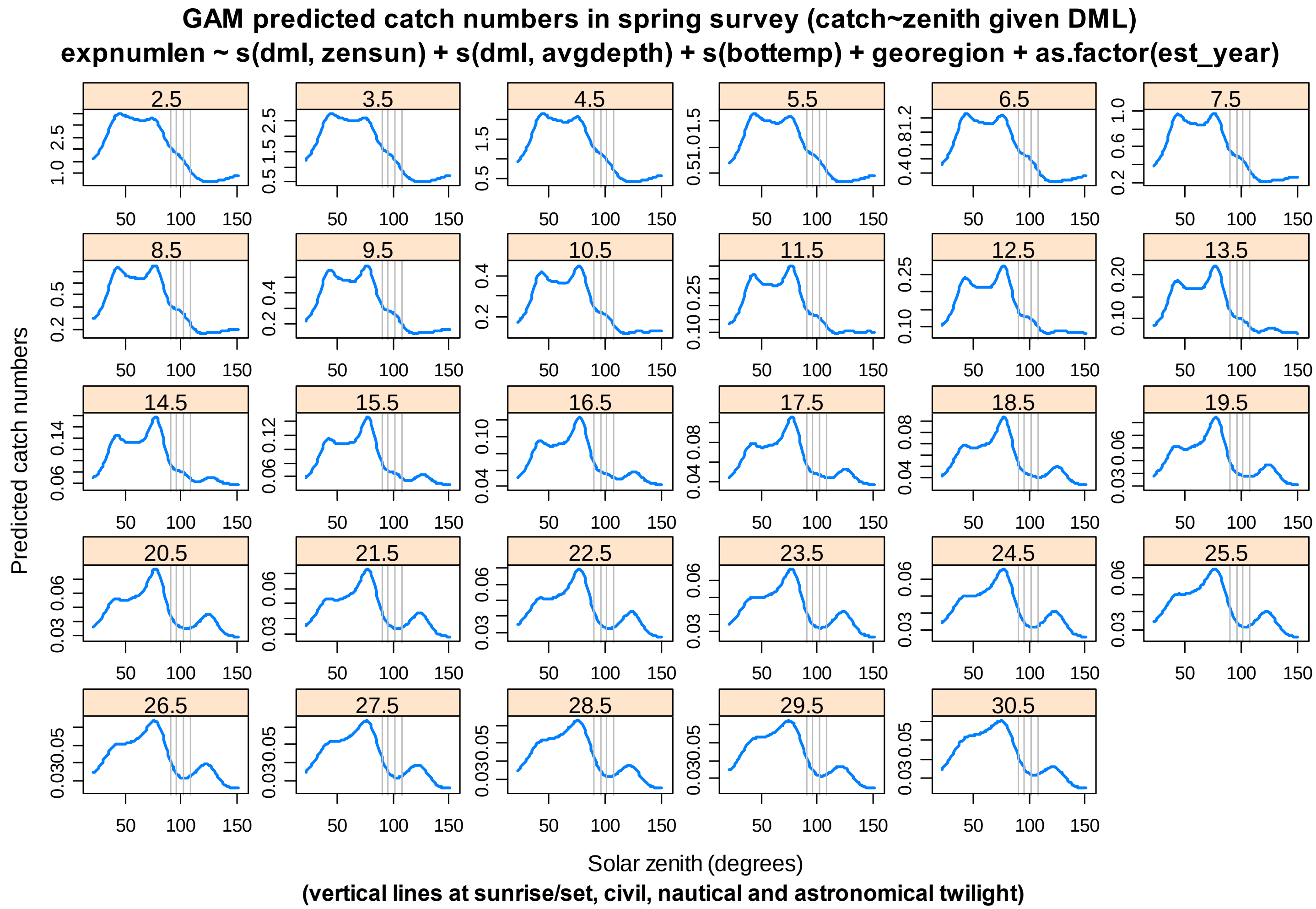
Appendix B2 Figure2. Predicted probability of a positive tow from a GAM model fit to fall survey data for an arbitrary location and date. The labels at the top of each frame are dorsal mantle length groups in cm (e.g. 19.5 means 19-19.9 cm DML).



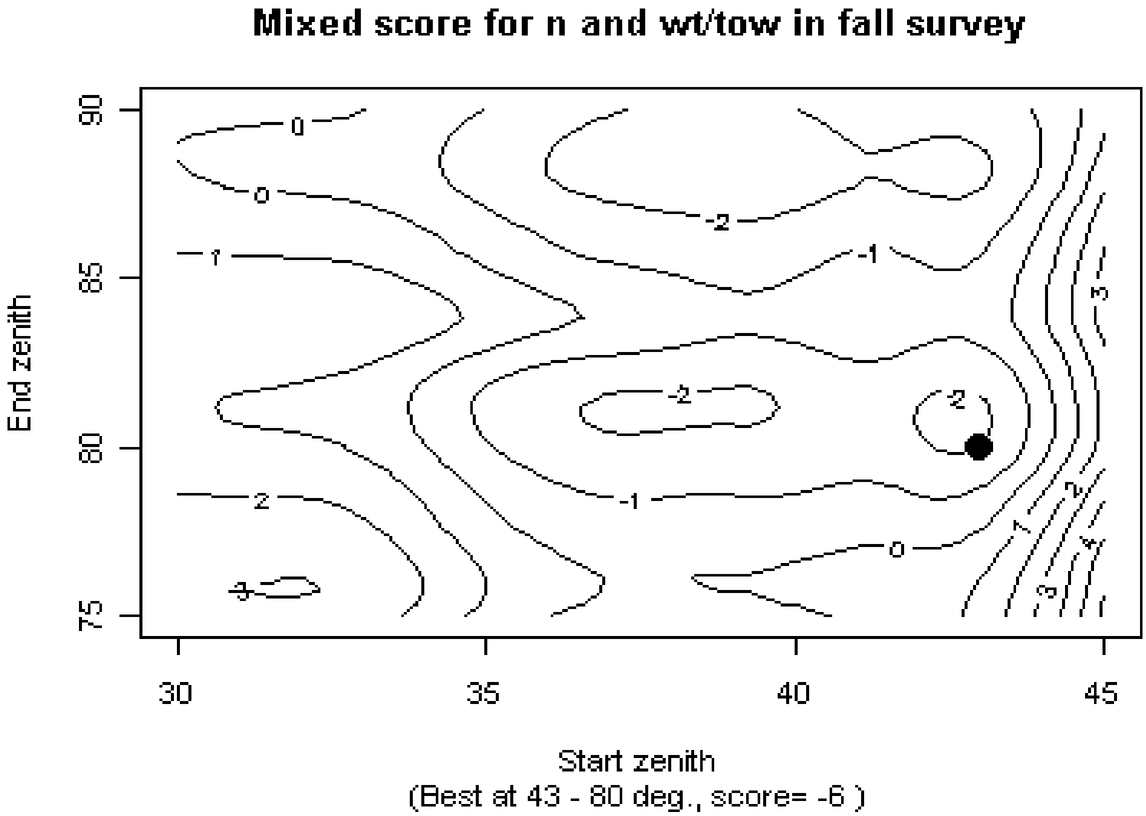
Appendix B2 Figure 3. Predicted catch in positive tows from a GAM model fit to fall survey data for an arbitrary location and date. The labels at the top of each frame are dorsal mantle length groups in cm (e.g. 19.5 means 19-19.9 cm DML).



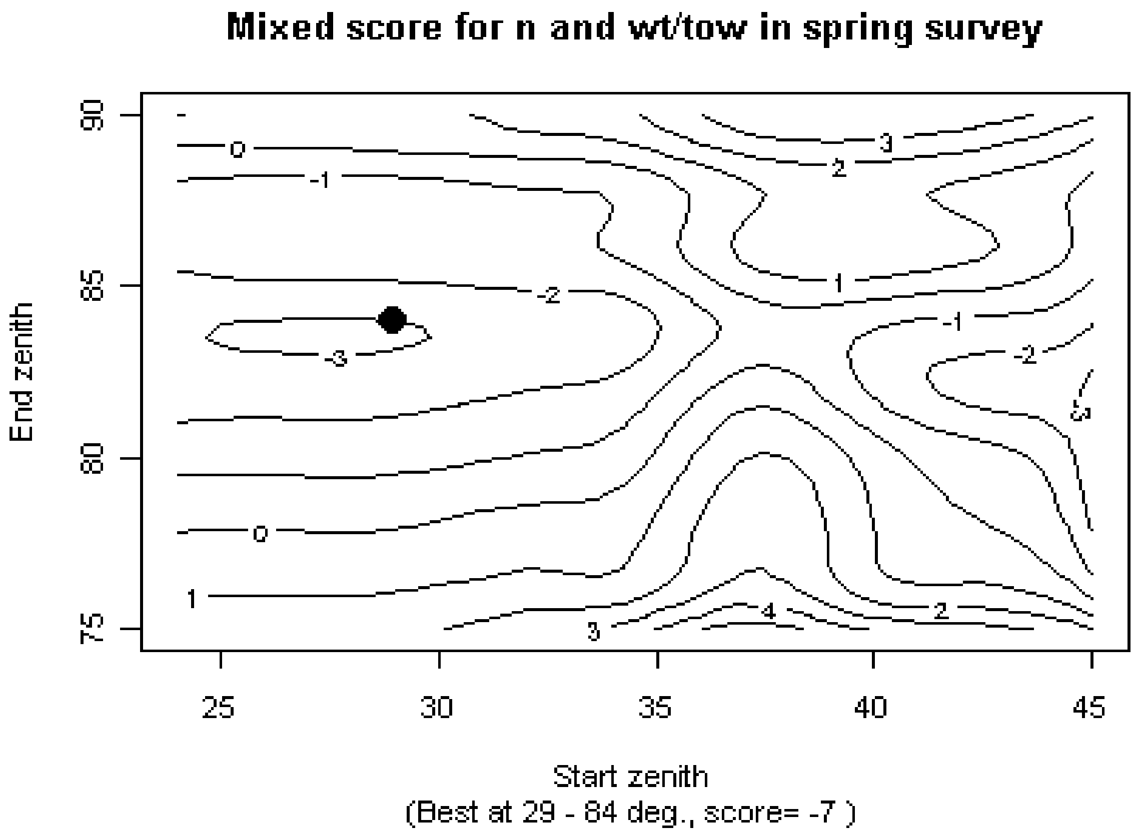
Appendix B2 Figure 4. Predicted probability of a positive tow from a GAM model fit to spring survey data for an arbitrary location and date. The labels at the top of each frame are dorsal mantle length groups in cm (e.g. 19.5 means 19-19.9 cm DML).



Appendix B2 Figure 5. Predicted catch in positive tows from a GAM model fit to spring survey data for an arbitrary location and date. The labels at the top of each frame are dorsal mantle length groups in cm (e.g. 19.5 means 19-19.9 cm DML).



Appendix B2 Figure 6. Contours showing lowess smoothed overall scores for solar zenith criteria used to choose daytime cutoff points for fall survey tows.



Appendix B2 Figure 7. Contours showing loess smoothed overall scores for solar zenith criteria used to choose daytime cutoff points for spring survey tows.

Appendix B3: Calculation of SRV *H. B. Bigelow* calibration coefficients for *Loligo pealeii*

In 2009 the *FRV Henry B. Bigelow* replaced the *R/V Albatross IV* as the primary vessel for conducting spring and fall annual bottom trawl surveys for the Northeast Fisheries Science Center (NEFSC). There are many differences in the vessel operation, gear, and towing procedures between the new and old research platforms (NEFSC Vessel Calibration Working Group 2007). To merge information collected in 2009 onward with that collected previously, we need to be able to transform indices (perhaps at size and age) of abundance from the *FRV Henry B. Bigelow* into those that would have been observed had the *R/V Albatross IV* still been in service. The general method for merging information from these two time series is to calibrate the new information to that of the old. Specifically we need to predict the relative abundance that would have been observed by the *Albatross IV* ($\hat{R}_A$) using the relative abundance from the *Henry B. Bigelow* (R_B) and a "calibration factor" (ρ),

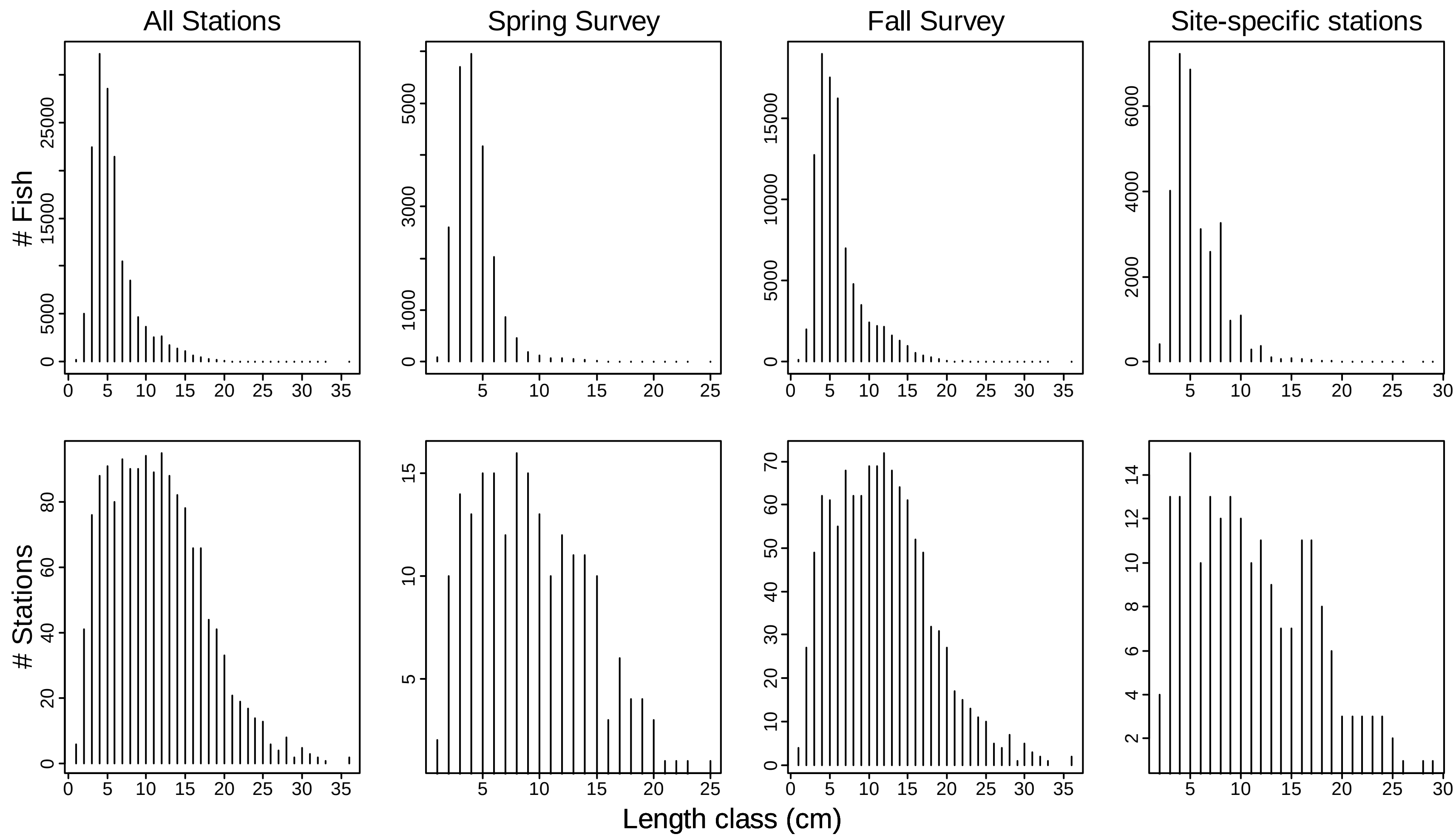
$$\hat{R}_A = \rho R_B \,. \qquad (2)$$

To provide information from which to estimate calibration factors for a broad range of species, 636 paired tows were conducted with the two vessels during 2008. Paired tows occurred at many stations in both the spring and fall surveys. Paired tows were also conducted during the summer and fall at non-random stations to improve the number of non-zero observations for some species. Protocols for the paired tows are described in NEFSC Vessel Calibration Working Group (2007).

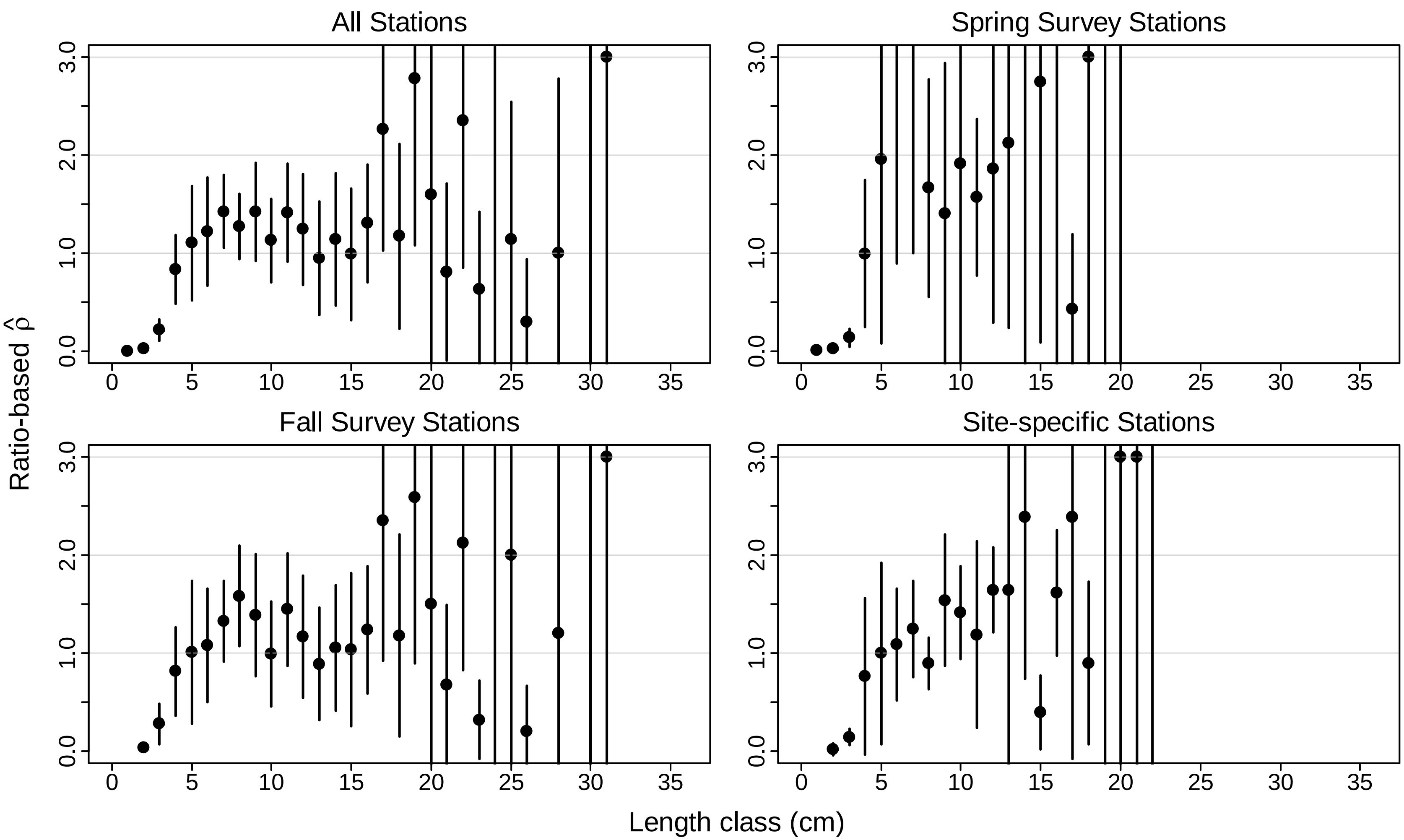
The methodology for estimating the calibration factors was proposed by the NEFSC and reviewed by a panel of independent scientists in 2009. The reviewers considered calibration factors that could potentially be specific to either the spring or fall survey (Miller *et al.* 2010). They recommended using a calibration factor estimator based on a beta-binomial model for the data collected at each station for most species, but also recommended using a ratio-type estimator under certain circumstances and not attempting to estimate calibration factors for species that were not well sampled.

Since the review, it has become apparent that accounting for size of individuals can be necessary for many species. When there are different selectivity patterns for the two vessels, the fraction of available fish of a given size taken by the two gears is different. Therefore, the ratio of the mean catches by the two vessels will change with size. Under these circumstances, the estimated calibration factor that ignores size reflects an average ratio weighted across sizes where the weights of each size class are at least in part related to the number of individuals at that size and the number of stations where individuals at that size were caught. Applying calibration factors that ignore size effects to surveys conducted in subsequent years when the size composition is unchanged should not produce biased predictions (eq. 1). However, when the size composition changes, the frequency of individuals and number of stations where individuals are observed at each size changes and the implicit weighting across size classes used to obtain the estimated calibration factor will not apply to the new data. Consequently, the predicted numbers per tow that would have been caught by the *Albatross IV* will be biased.

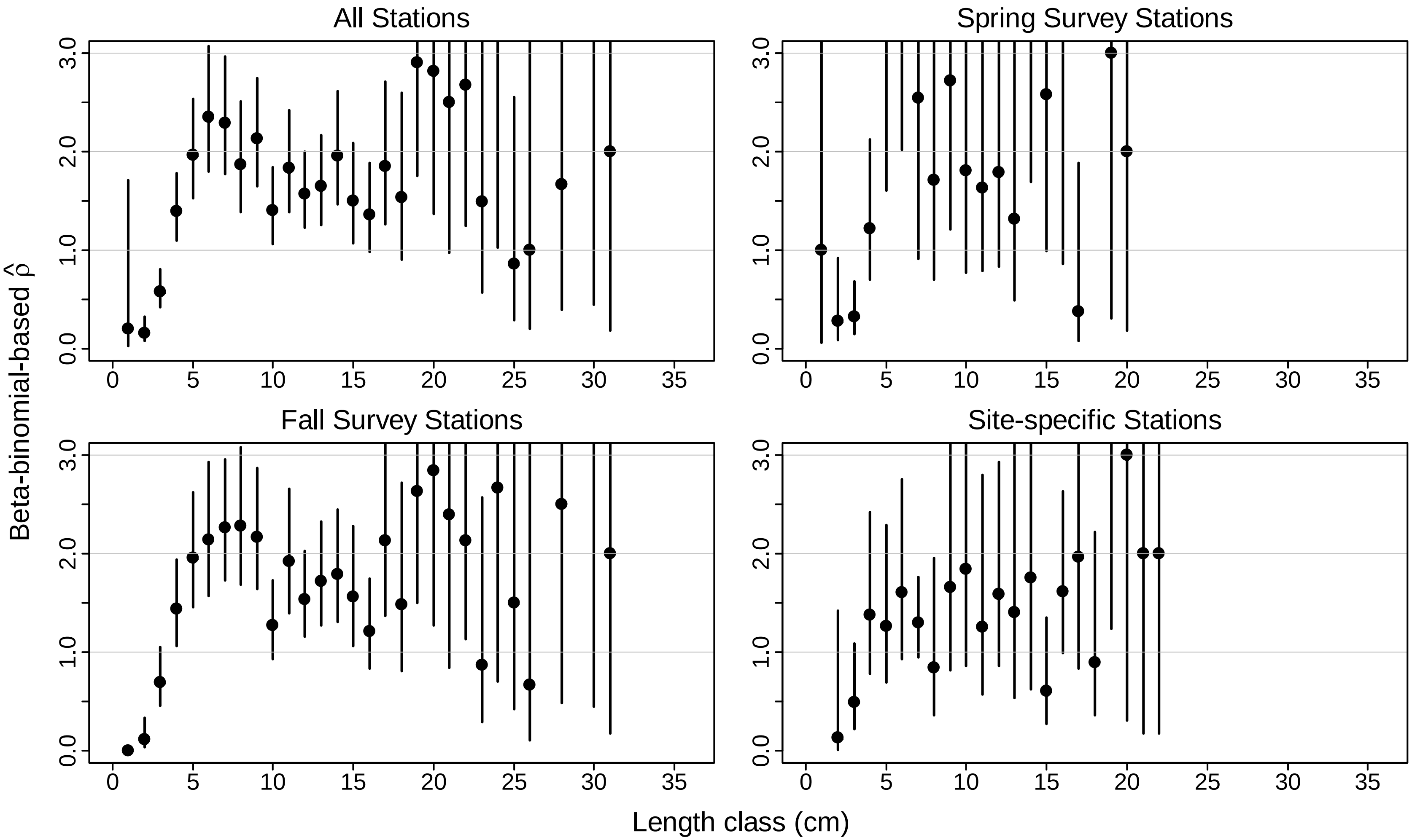
For *Loligo*, there are two primary seasonal cohorts observed each year in the NEFSC bottom trawl surveys and their abundances fluctuate substantially from year to year. Also, the assessment defines two size classes: pre-recruits (≤ 8 cm DML) and recruits (> 8 cm DML). The effects of inter-annual changes in size composition are negligible within each of the pre-recruit and recruit size classes. Therefore, we used a simple size-based calibration model that provided estimates of calibration factors that differ seasonally and are constant within each of the two size classes. Because only tows conducted during the daylight hours (between 0630 and 1630 during the fall and between 0630 and 1730 in the spring) were used in calculating abundance indices, we used the subset of paired tows from the calibration experiment that occurred during the same periods to fit models and estimate the *Loligo* calibration factors.



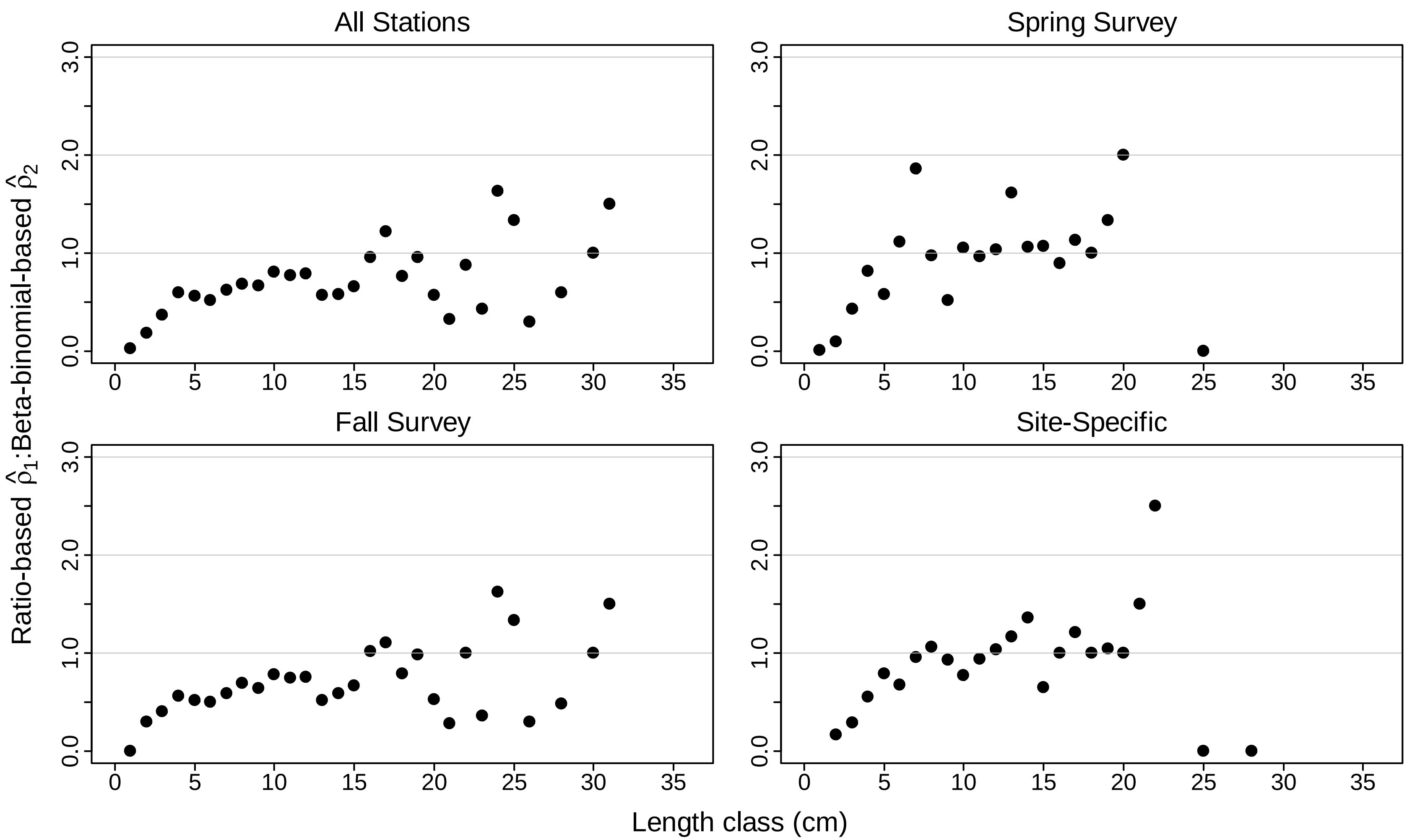
Appendix B3 Figure 1. Numbers of fish and number of stations where some fish were caught by length class for *Loligo* data from Spring and Fall survey stations, site-specific stations and all stations combined.



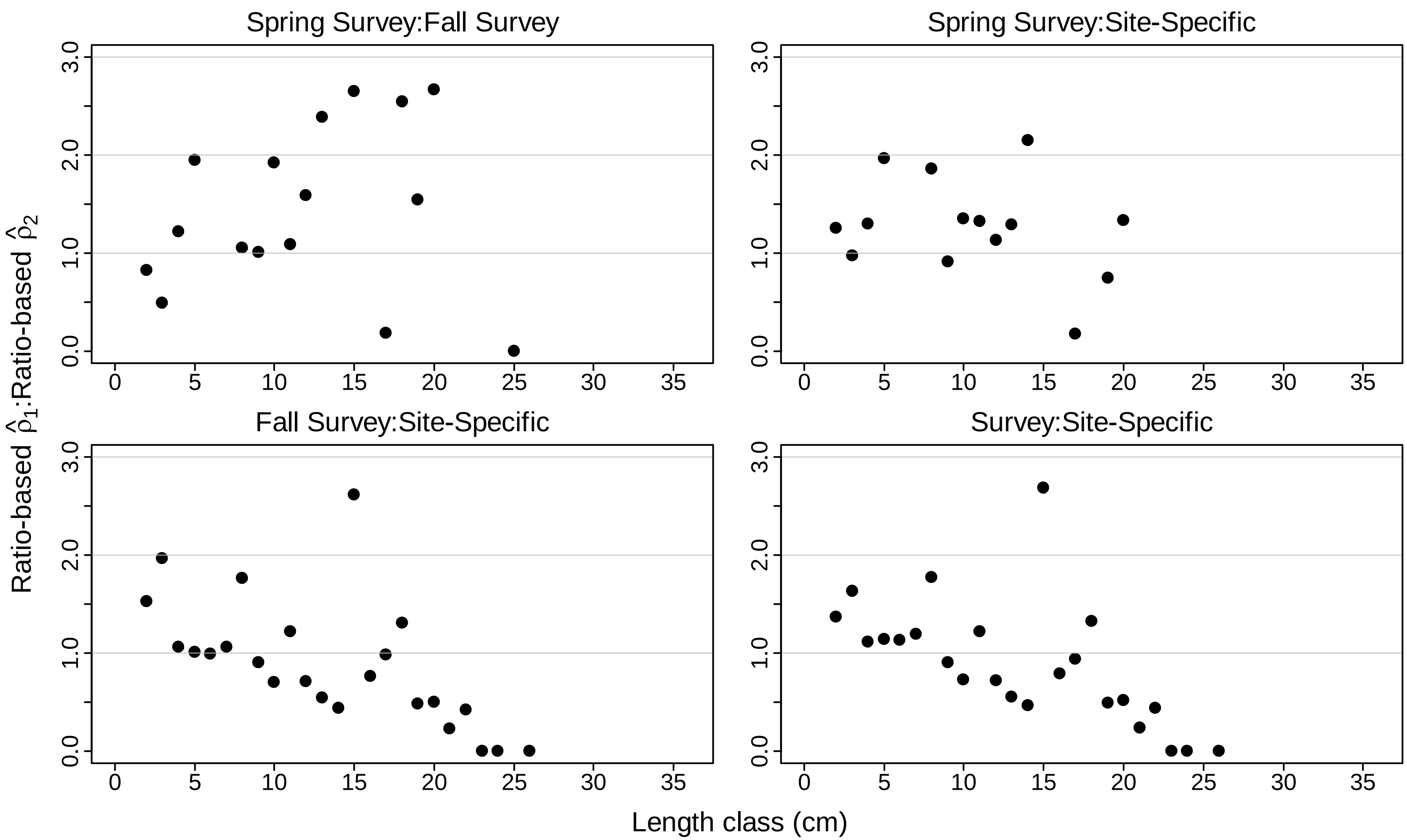
Appendix B3 Figure 2. Calibration factor estimates for *Loligo* catches from the Bigelow and Albatross IV by length bin in different sets of stations based on ratios of mean catches. Lengths are binned in 1 cm intervals.



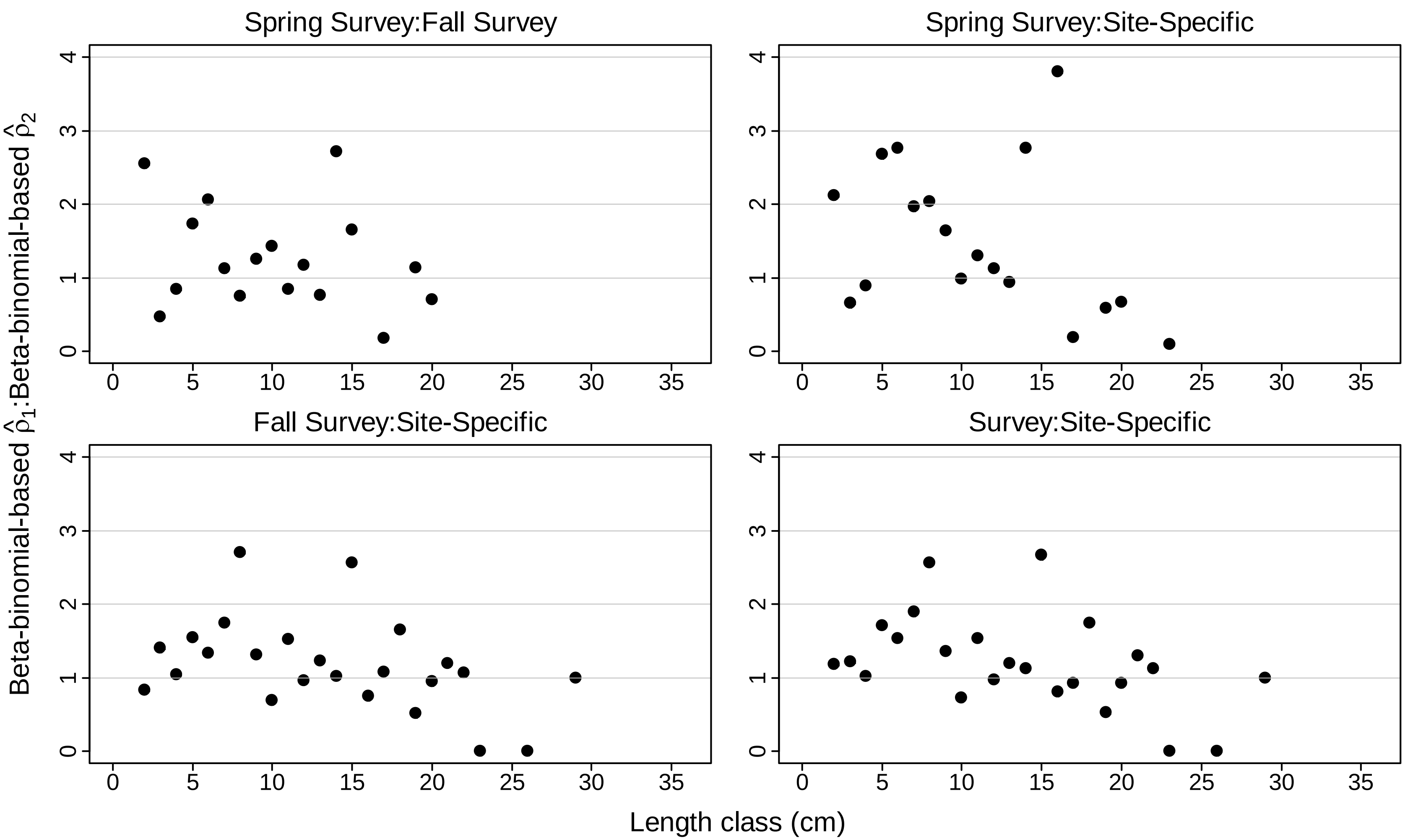
Appendix B3 Figure 3. Calibration factor estimates for *Loligo* catches from the Bigelow and Albatross IV by length bin in different sets of stations based on a beta-binomial model. Lengths are binned in 1 cm intervals.



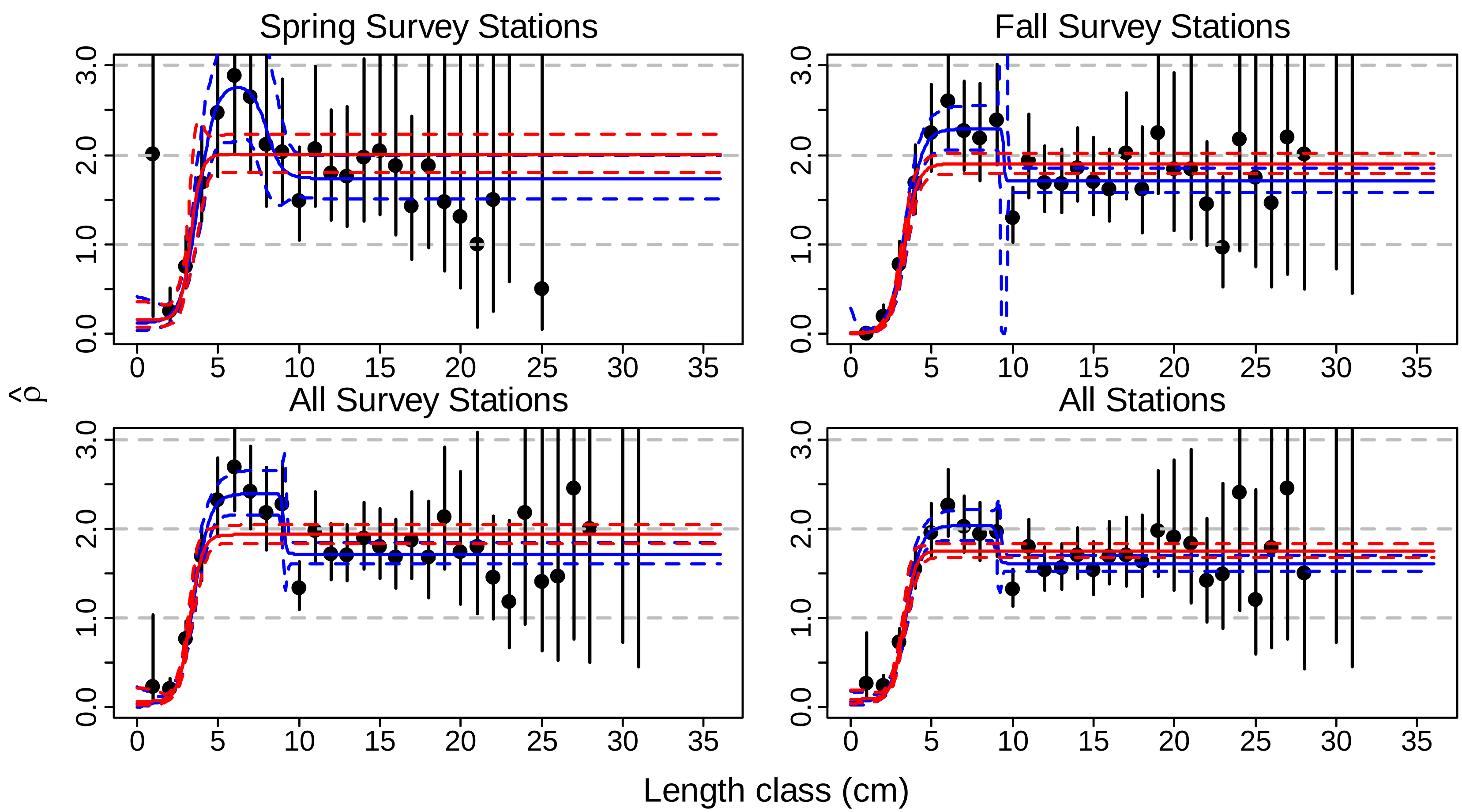
Appendix B3 Figure 4. Ratios of ratio-based to beta-binomial based calibration factors, by length bin, for *Loligo* catches from the Bigelow and Albatross IV in different sets of data. Lengths are binned in 1 cm intervals.



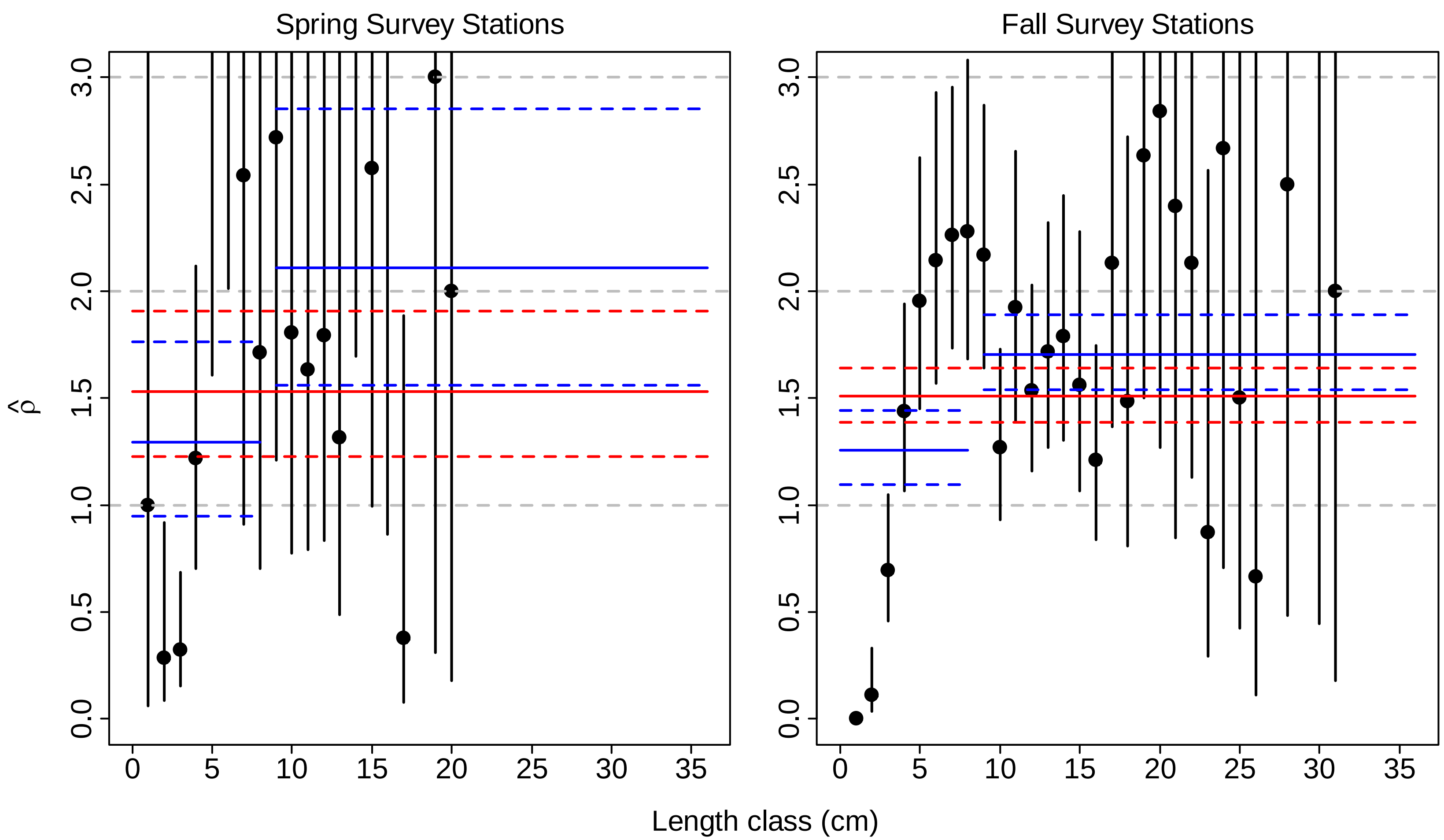
Appendix B3 Figure 5. Ratios of calibration factor estimates for *Loligo* catches from the Bigelow and Albatross IV by length bin in different sets of data based on ratios of mean catches. Lengths are binned in 1 cm intervals.



Appendix B3 Figure 6. Ratios of calibration factor estimates for *Loligo* catches from the Bigelow and Albatross IV by length bin in different sets of data based on a beta-binomial model. Lengths are binned in 1 cm intervals.



Appendix B3 Figure 7. Calibration factors for *Loligo* at length based on a logistic (red) or double-logistic (blue) functional form fit to data from spring, fall, and all survey stations, and all stations combined.



Appendix B3 Figure 8. Calibration factors for pre-recruit (≤ 8 cm DML) and recruit (> 8cm DML) *Loligo* for stations sampled during daytime hours.

Appendix B3 Table 1. AIC values for models fit to *Loligo* length data.

Model	# parameters	-LL	AIC_c	Δ (AIC_c)	AIC_c Weights
Constant	2	10804.69	21613.37	539.7736	0.0000
Survey, S-S, constant	4	10790.77	21589.55	515.9484	0.0000
S,F,S-S, constant model	6	10787.28	21586.58	512.9762	0.0000
Logistic model	5	10562.58	21135.17	61.5728	0.0000
Survey, S-S logistic	10	10538.09	21096.22	22.6256	0.0000
S, F, S-S, logistic	15	10529.00	21088.10	14.5053	0.0006
Double logistic model	8	10551.54	21119.11	45.5072	0.0000
Survey, S-S, double-logistic model	16	10522.42	21076.96	3.3617	0.1569
S,F,S-S, double-logistic model	24	10512.67	21073.60	0.0000	0.8425

The constant model that ignores length is

$$\rho(l) = e^{\gamma}$$

and the logistic model is

$$\rho(l) = e^{\gamma} + \frac{e^{\alpha}}{1 + e^{-(\beta_0 + \beta_1 l)}}$$

which allows the lowest calibration factors to asymptote at a value greater than zero and the difference between the lowest and greatest values to be different than 1.

The double-logistic model is

$$\rho(l) = e^{\alpha}\left(e^{\gamma_1} + \frac{1 - e^{\gamma_1}}{1 + e^{-(\beta_0 + e^{\beta_1} l)}}\right)\left(e^{\gamma_2} + \frac{1 - e^{\gamma_2}}{1 + e^{(\beta_2 + e^{\beta_3} l)}}\right)$$

which allows the lowest calibration factors to asymptote at a value greater than zero at both small and large size classes and the difference between the lowest and greatest values to be greater than 1. In all models, the exponentiation of various parameters avoids boundary conditions during estimation. The parameters may differ for data obtained at spring or fall survey stations or the site-specific stations.

Letting the full set of calibration factor parameters be θ (which depends on the above models used), the beta-binomial likelihood we maximized is

$$L(\theta, \phi) = \prod_{i=1}^{S} \prod_{j=1}^{M} \frac{\text{Beta}\left(a_j + N_{Bij}, b_j + N_{Aij}\right)}{\text{Beta}\left(a_j, b_j\right)} \binom{N_{Aij} + N_{Bij}}{N_{Bij}}$$

where $\text{Beta}()$ is the beta function, and N_{Aij} and N_{Bij} are the numbers caught at station i in length class j by the Albatross IV and Bigelow, respectively. The likelihood is parameterized with parameters a and b which are functions of the calibration factor and dispersion parameter ϕ,

$$a_j = \rho\left(l_j \mid \theta\right)\phi$$

and

$$b_j = \phi / (1 + \rho(l_j \mid \theta)).$$

Appendix B4. *Loligo* habitat outside the range of the survey strata set used in the assessment

The following analyses were conducted to determine the likelihood that substantial amounts of *Loligo pealeii* exist outside the range of the NEFSC bottom trawl survey strata used in the assessment during the survey time periods.

Density-depth relationships for *Loligo*

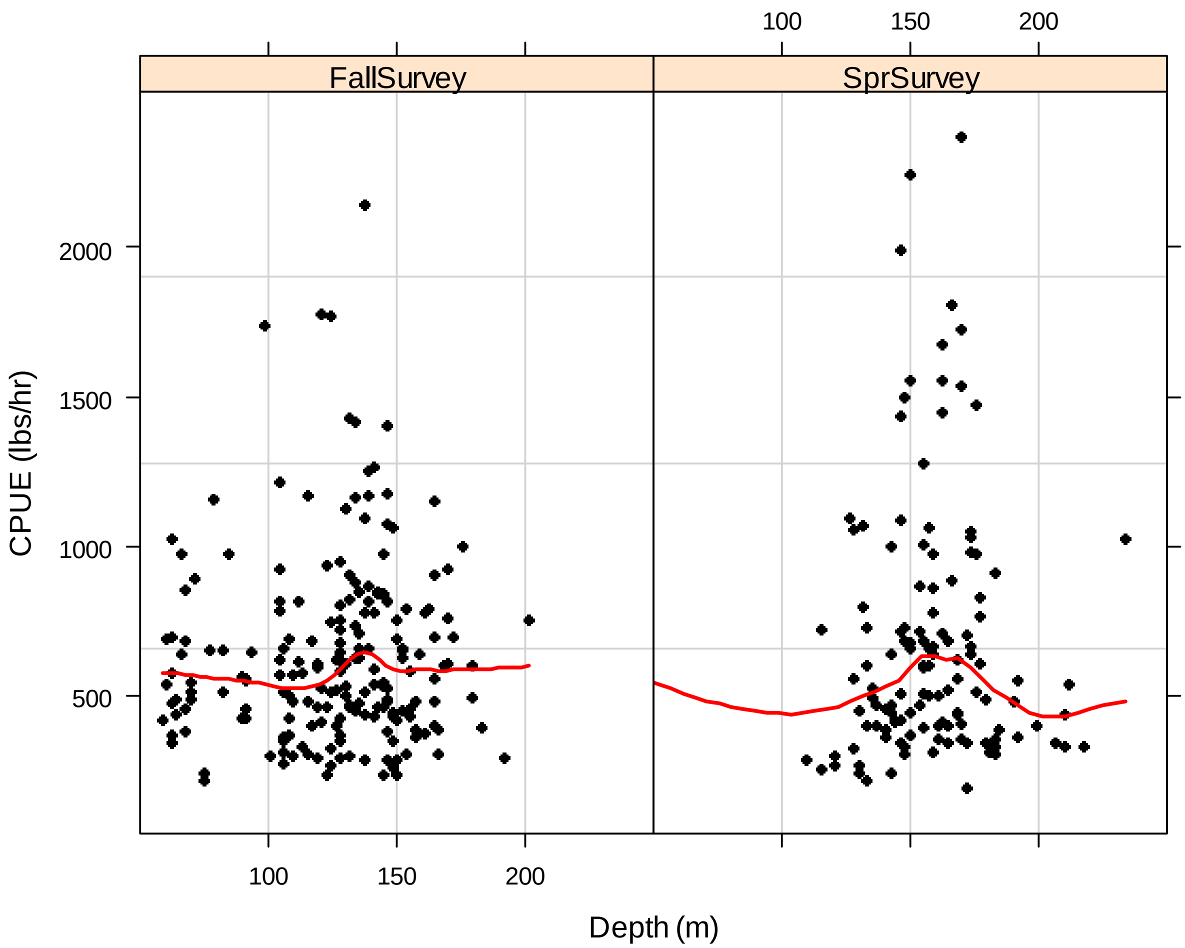
One set of analyses used catch-per tow data from the *Loligo* fishery and NEFSC spring and fall surveys to characterize daytime catch rates of *Loligo* as a function of depth. The analyses included only daytime tows based on the solar zenith criteria described in Appendix B2.

Commercial data were subset for spring (March-April, the time period of the spring survey) and fall (September-October-November, the time period of the fall survey). The data set included bottom trawl tows conducted during 1996-2009, with *Loligo* catches ≥ 2500 lbs, and with *Loligo* identified as the target species. The data for each tow included the time and location at the beginning and end of each haul, in addition to *Loligo* catch. The following variables were computed for each tow: tow duration (hours), CPUE (lbs hour^{-1}), and time, location and solar zenith for the middle of the tow. Tows were excluded if the solar zenith at the middle of the tow failed to meet the criteria for daytime tows. Categorization of daytime commercial tows was more difficult than for survey tows because commercial tows ranged from 1.2 to 6.8 hours in duration, often beginning in the day and ending at night or vice-versa. The commercial data used in the analysis were from 200 daytime tows in the fall and 129 daytime tows in the spring. CPUE was plotted against depth and smoothed with a loess regression line to identify trends. Results for fall were equivocal because there were no tows at depths beyond about 200 m. Results for spring indicated declining CPUE at depths beyond 175 meters (Figure 1), although data for deep water tows were limited.

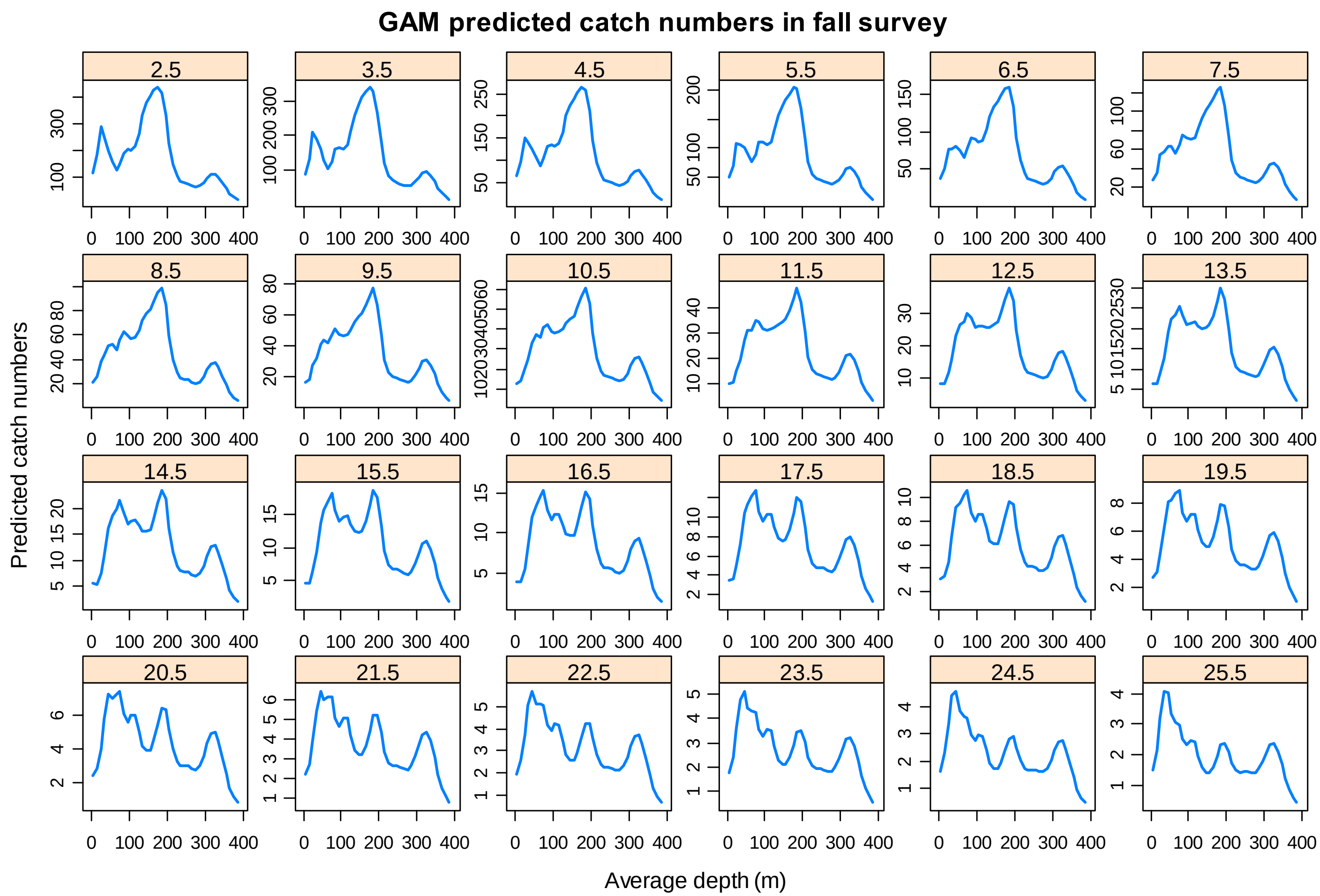
Survey catches at depth were predicted for *Loligo* of different sizes using the GAM models that were also used to characterize diel patterns in survey catches. As described in Appendix B2, the GAM models predicted survey catches in positive tows (tows catching at least one individual). The predictor variables included *Loligo* length (DML, in 1 cm increments), solar zenith, depth, temperature, region and year as well as interactions between size and solar zenith and size and depth. Spring and fall survey data were modeled separately.

Results for all size groups indicated that the predicted daytime catches declined to low values with increasing depth during fall and spring surveys (Figures 2-3). These trends suggest that high densities of *Loligo* at depths greater than those included in this assessment are unlikely.

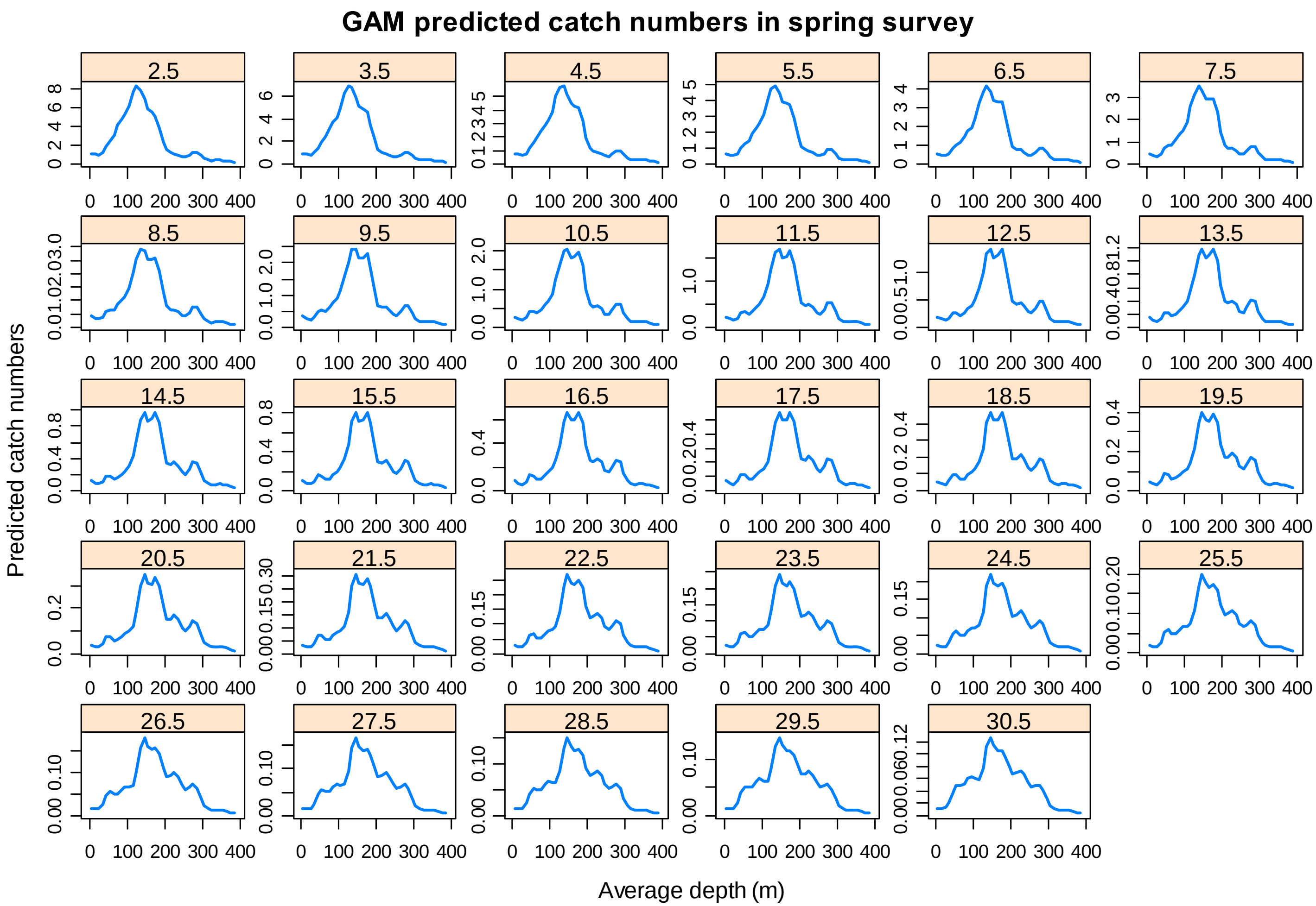
A third analysis used information from seasonal bottom trawl surveys that were conducted at depths greater than the limit of NEFSC surveys (366 m), by Rutgers University, during 2003-2007. Stations along transects located parallel to Baltimore and Hudson Canyons were sampled using a commercial *Loligo* bottom trawl. However, stations located at depths greater than 274 m were sampled at night. Catch rates of *Loligo pealeii* (kg per tow) in these surveys also show declines with increasing depth, similar to the analysis of catch rates with depth for daytime tows from NEFSC surveys. During some years, catch rates decline to very low levels at depths < 274 m which were sampled during the day (i.e., Hudson Canyon March 2003 and Nov. 2004 and 2007, Figure 4). Catch rates of *Loligo* were very low at depths greater than 366 m during January, March and November, but this result may be an artifact of nighttime sampling.



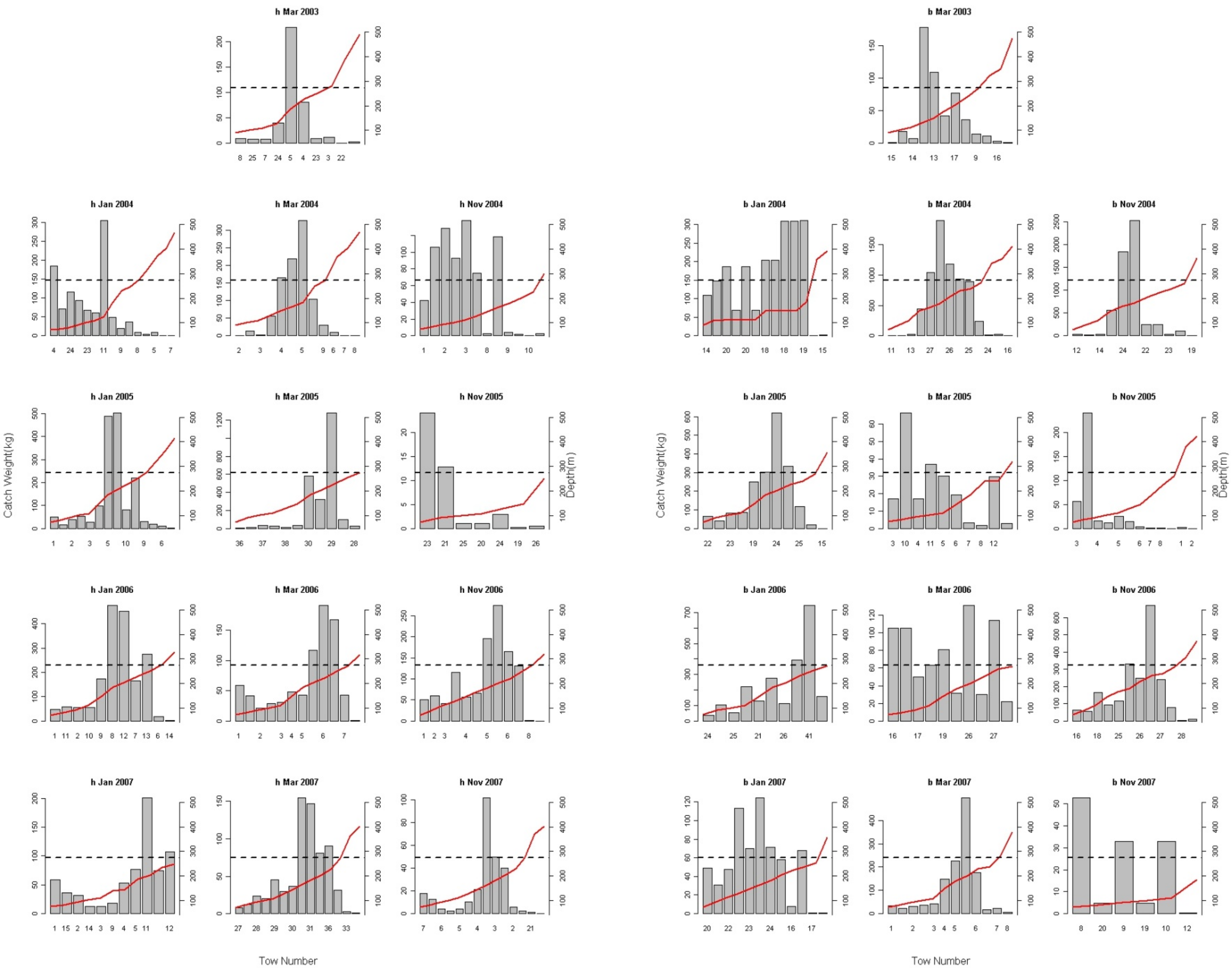
Appendix B4 Figure 1. CPUE for commercial tows targeting *Loligo* during the daytime vs. depth of tow, based on NEFOP observer data. The red line was fit by loess regression and is meant to show underlying trends.



Appendix B4 Figure 2. Predicted catch numbers in positive tows for NEFSC fall bottom trawl surveys as a function of depth from, GAM modeling. The label at the top of each panel is squid size (DML, in 1 cm intervals).



Appendix B4 Figure 3. Predicted catch numbers in positive tows for NEFSC spring bottom trawl surveys as a function of depth, from GAM modeling. The label at the top of each panel is squid size (DML, in 1 cm intervals).



Appendix B4 Figure 4. Relationship between *Loligo pealeii* catch rates (kg per tow) and depth based on seasonal bottom trawl transect surveys conducted by Rutgers University during 2003-2007. The red lines indicate station depths (m) and the black dashed line indicates the depth (274 m) beyond which stations were sampled at night. The titles indicate the transect identifier (b = Baltimore Canyon and h =Hudson Canyon.

Appendix B5. Estimation of natural mortality

Hendrickson and Hart (2006) developed an age-based cohort model for estimating the spawning mortality of semelparous cephalopods (a “maturation-natural mortality model”). The model was designed to estimate spawning and non-spawning natural mortality rates and maturity parameters based on maturity and age samples for another semelparous squid species, *Illex illecebrosus*. The model was used for *Loligo* for the first time in this assessment. The approach appears promising for estimation of maturity and mortality parameters but model estimates in this assessment should be regarded as preliminary due to data limitations and other uncertainties. Mortality and maturity rates in this analysis are weekly rates, unless stated otherwise.

Natural mortality rates for semelparous, short-lived squid species like *Loligo* tend to be very high (Hendrickson and Hart 2006). However, this is not unusual since *Loligo* serve as prey for many marine species and natural mortality rates increase at the time of spawning. The traditional approach to estimating maturity-at-age is misleading for squid species like *Loligo* because mature individuals are underrepresented in samples due to increased mortality rates after spawning. Similarly, age composition data are difficult to interpret because maturation rates (and total mortality) increase with age. Thus, in principle, a simple catch curve (log-transformed abundance vs. age) should be nonlinear (concave) and it is necessary to account for maturity and mortality rates in the same model.

Materials and methods

The data for the model are assumed to consist of a random sample from the cohort or population over a range of ages, including spawning ages and ages completely recruited to the sampling gear. Age and maturity were recorded for each individual in the sample.

Two data sets were available and only results for females are reported here. The first (N=128 with 37 mature females) was collected during NEFSC and Connecticut (Long Island Sound) spring bottom trawl surveys in March (mostly) and May, respectively, during 1996-1998. The second set (N=68 with 51 mature females) was collected in March and May (mostly), during 1991-1993, in the offshore *Loligo* fishery and the Massachusetts weir fishery, respectively.. It was necessary to combine sampling locations and years because data were limited.

Ignoring gender, the maturity-mortality model assumes that maturation rates R_a are a quadratic function of age a:

$$R_a = r_0 + r_1 a + r_2 a^2$$

where r_0, r_1 and r_2 are potentially estimable maturation parameters. In this assessment, the statistical significance of each of the maturation parameters is evaluated with the goal of omitting imprecise parameters and simplifying the model.Population dynamics are based on the differential equations:

$$\frac{dN}{dt} = -(M_{ns} + R)N$$

and

$$\frac{dS}{dt} = RN - (M_{ns} + M_{sp})S$$

where N is the number of immature individuals, S is the number of spawners, M_{ns} is the non-spawning (immature) mortality rate, M_{sp} is the spawning (mature) mortality rate, and the mortality parameters (M_{ns} and M_{sp}) are potentially estimable. Hendrickson and Hart (2006) give exact solutions for these differential equations.

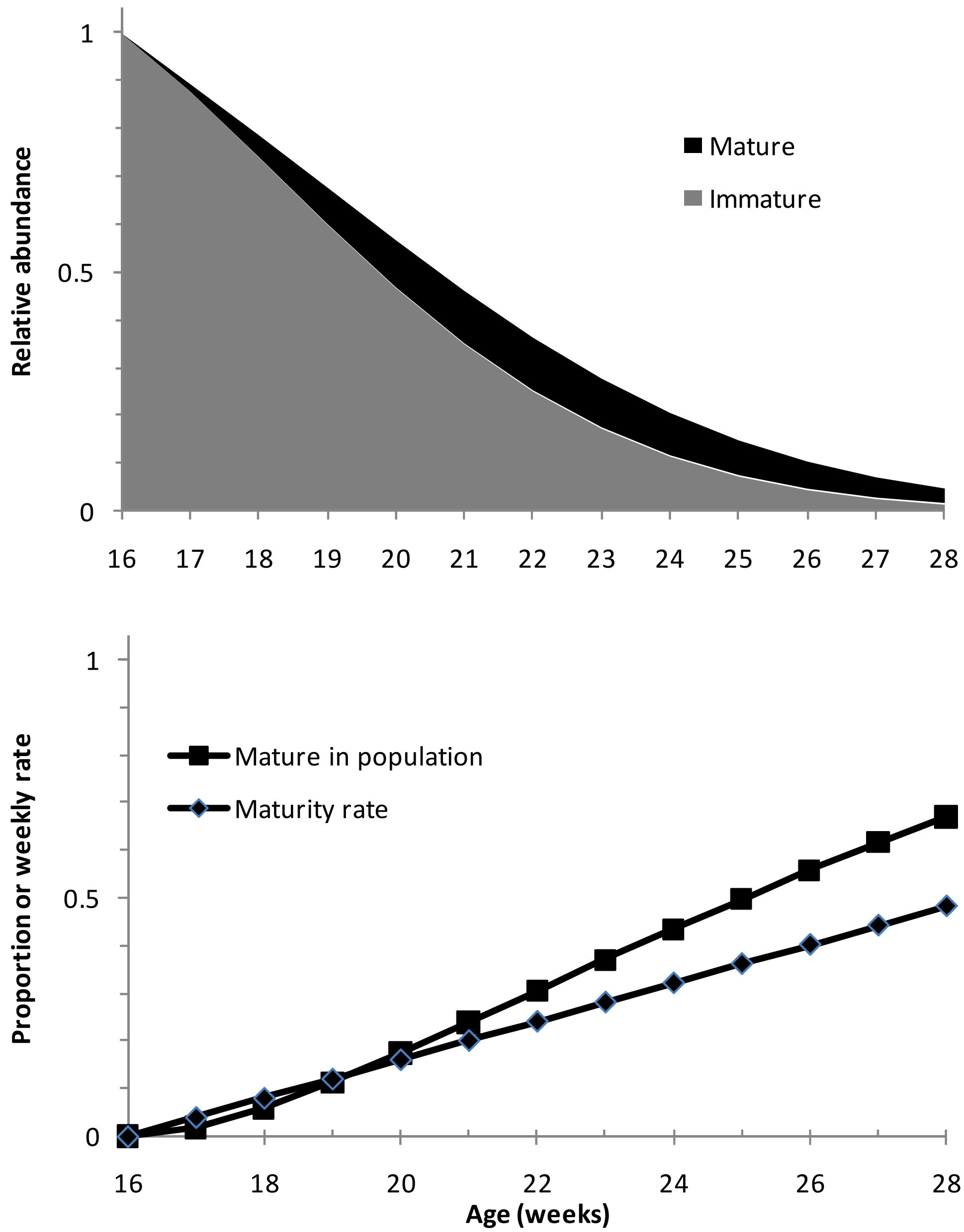
The maximum likelihood objective function used in fitting the model assumes that the age composition data (for fully recruited ages only) are multinomial with predicted age composition for mature and immature *Loligo* from the model (i.e., predicted age composition proportional to N_a+S_a), conditioned on the sample size. The objective function assumes that the observed proportions of mature individuals in each age group are independent binomials with sample size equal to the number of maturity samples in each age group, and predicted values from the model [i.e. predicted values = S_a / (N_a+S_a)]. There are five potentially estimable parameters (r_0, r_1, r_2, M_{ns}, M_{sp}). The parameters r_0, M_{ns} and M_{sp} were estimated as log transformed parameters and therefore constrained to be positive. The remaining maturity parameters were estimated directly so that estimates might be either positive or negative.

Hendrickson and Hart (2006) used data from a special age reader experiment to quantify aging precision. The predicted values from the model were smeared to account for ageing imprecision, before comparison to the data. Maturity parameter estimates for *Illex illecebrosus* were sensitive to assumptions about ageing imprecision, but natural mortality parameters were not. Ageing precision was not included for *Loligo* due to lack of experimental data.

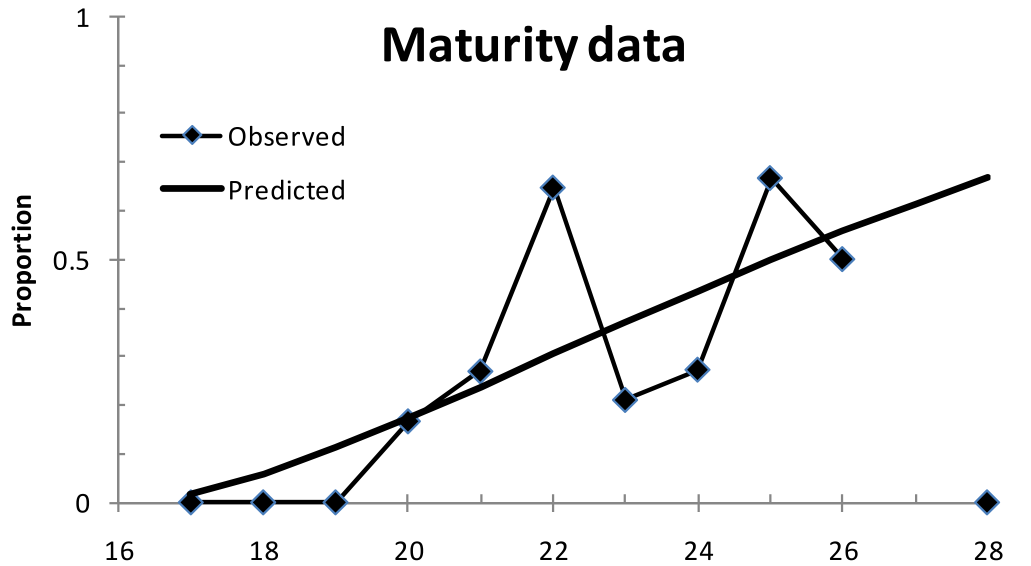
Results

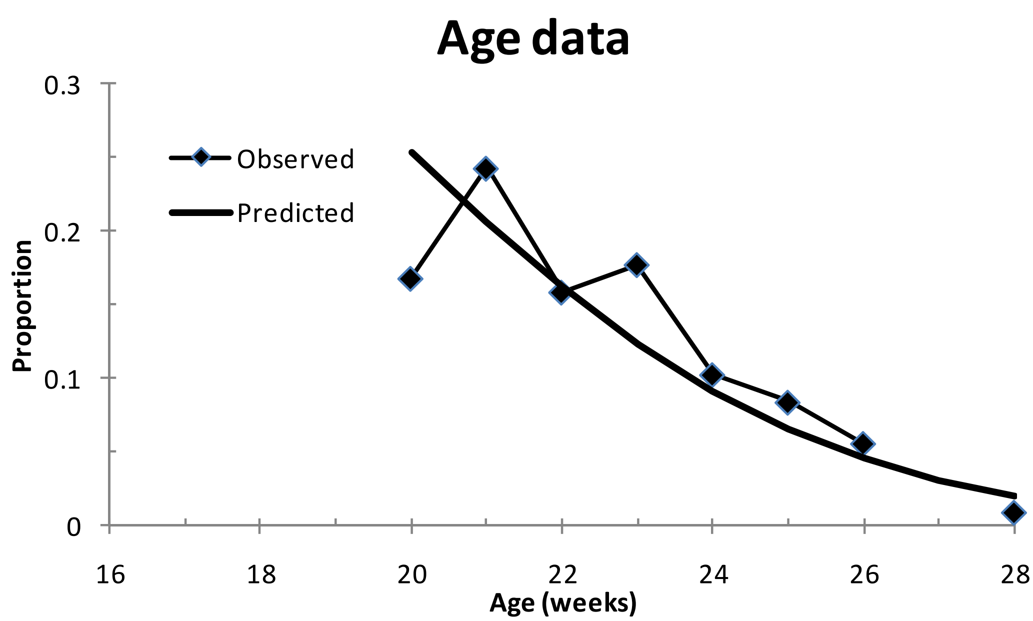
As in Hendrickson and Hart (2006), preliminary model runs indicated that it was not possible to estimate both M_{ns} and M_{sp} simultaneously. Following Hendrickson and Hart, M_{ns} was estimated using Caddy's (1996) gnomonic approach (= 0.11) and assumed in the model while fitting other parameters. As suggested by Hendrickson and Hart's (2006) results, only one (r_1 for data set 1) or two (r_0 and r_1 for data set 1) maturity parameters were statistically significant. Other maturity parameters were "turned off" and did not affect model estimates.

The best models for each data set (after fixing M_{ns} = 0.11 and omitting unnecessary maturity parameters), gave estimated maturation rates ≤ 0.8 at all ages (Appendix B5 Figure 1). However, the shapes of the estimated relationships between age and maturity rates were different for the two data sets. M_{sp} estimates ranged 0.19 (CV 0.40) to 0.48 (CV 0.11). There were no trends in the residual plots (Appendix B5 Figure 2).



Appendix B5 Figure 1. Biological estimates for *Loligo* from the best maturation-natural mortality model fit to data set 1. Estimates for data set 2 were generally similar although the maturity rate for data set 2 declined with age.





Appendix B5 Figure 2. Example residual plots for *Loligo* from the best maturation-mortality model fit to data set 1. Goodness of fit to data set 2 was generally similar.

Appendix B6: Estimates of minimum consumption of *Loligo pealeii*

Food habits were evaluated for 15 fish predators that consume *Loligo pealeii* consistently and commonly occur in NEFSC spring and fall bottom trawl surveys. The amount of food eaten, the type of food eaten and estimates of predator abundance were used to compute per capita consumption (*Loligo* consumed per predator) and total consumption of *Loligo*.

Loligo consumption estimates in this paper are minimum estimates and may represent a small fraction of total consumption because predation by other *Loligo*, birds, marine mammals and large pelagic fish area was not included. Predation by predators outside the survey area was not included either. Moreover, swept-area biomass estimates for many of predators were based on bottom trawl survey data without adjustments for survey bottom trawl catchability, resulting in underestimates of predator abundance and consumption. Finally, formulas used to compute per capita consumption probably produce conservative (biased low) estimates.

Results suggest that minimum consumption estimates for 15 fish predators in the survey area is relatively large in comparison to catches in most years (Figure 1). Consumption appears highest during fall when *Loligo* are most abundant and are widely distributed across the continental shelf and when predators which migrate south of the survey area during the spring surveys (e.g., bluefish and weakfish) are within the survey area.

Methods

Every predator that contained *Loligo* was identified in the NEFSC Food Habits Database. From that original list, a subset of key predators (Table 1) was according to several "rules of thumb". In particular, the selected predators had *Loligo*: 1) amounting to more than 1% of prey composition during at least one five year block; as prey in more than 10 tows for each two year block; and in at least 10 stomachs for each three year block (Tables 2 and 3).

Food habits data collection is a routine part of NEFSC spring and fall bottom trawl surveys (Azarovitz 1981; NEFC 1988). Annual consumption for each predator species was estimated on a seasonal basis (January-June ="spring" and July-December = "fall") using data from spring and fall bottom trawl surveys during 1977-2009. Although food habits sampling was quantitative beginning in 1973, not all *Loligo* predators were sampled prior to 1977 (Link and Almeida (2000)). Consumption was calculated separately based on two size groups (≤ 20 cm and > 20 cm) for large predators. Total consumption for a predator was estimated as the sum of the estimates for each size group. Annual consumption was computed as the sum of estimates for spring and fall.

Methods were similar to previously described methods for estimating consumption using an evacuation rate model (Durbin *et al.* 1983; Ursin *et al.* 1985; Pennington 1985; Overholtz *et al.* 1991, 1999, 2000, 2008; Tsou & Collie 2001a, 2001b; Link & Garrison 2002; Link *et al.* 2006, 2008, 2009; Methratta & Link 2006; Link & Soseebe 2008; Overholtz & Link 2007, 2009; Tyrrell *et al.* 2007, 2008; Link and Idoine 2009, Moustahfid *et al.* 2009; NEFSC 2006, 2007a, 2007b, 2008, 2010a, 2010b). The main input data are: mean stomach contents (S_i) for each *Loligo* predator *i*; diet composition (D_i, proportion of total stomach contents consisting of *Loligo*), and bottom temperature records T from the bottom trawl surveys (Taylor *et al.* 2005). Units for stomach estimates are in grams.

As noted above, the gastric evacuation rate method was used to calculate per capita consumption (Eggers 1977, Elliott and Persson 1978). The two main parameters were fixed at α =0.004 and β =0.115, based on previous studies and sensitivity analyses (NEFSC 2007a, 2007b). However, α was set at 0.002 for elasmobranch predators to reflect relatively high metabolic costs in sharks and rays. As in most other studies, an additional parameter γ was set to one and had no effect on consumption estimates (Gerking 1994).

Per capita consumption rates C_{it} were calculated:

$$C_{it} = 24 \cdot E_{it} \cdot \overline{S_{it}}^{\gamma}$$

where 24 is the number of hours in a day and the evacuation rate E_{it} is:

$$E_{it} = \alpha e^{\beta T}$$

where *t* is a subscript for time period (season and year). Due to lack of data and to limit variability in the results, stomach contents data for some predators were averaged in blocks of two or three years (Table 1).

Estimated daily per capita consumption rates were scaled up to seasonal per capita consumption estimates for each *Loligo* predator. This was done by multiplying per capita consumption by the diet composition D_{ij} for *Loligo,* and then by the number of days in each half year. The seasonal per capita estimates were summed to estimate annual per capita consumption. Annual per capita consumption was multiplied by the abundance of each predator to estimate the minimum amount of *Loligo* consumed on an annual basis.

Abundance estimates from stock assessments were available for six of the fifteen predators (Table 1). A crude estimate of the survey catchability parameter was derived by comparison of simple swept-area and stock assessment abundance estimates. The catchability parameter was used to scale minimum swept area estimates for the six predators to estimates of total abundance. Predator species without stock assessments used minimum swept area abundances without adjustment for catchability.

We used a simple and crude approach to approximate variance in *Loligo* consumption estimates (Link and Almeida 2000). Previous studies indicate that the largest source of variance is associated with the estimates of abundance. We therefore took the largest CV (with slight modifications) for abundance of each predator as a variance measure for total consumption These CVs ranged from 0.1 to 1.0 and were mostly in the range 0.35-0.50.

Length compositions of *Loligo* prey present in predator stomachs were plotted for each predator and season and compared to *Loligo* size composition data from the surveys and fishery data. These comparisons show the extent to which surveys, the fishery and predators sample the same size groups.

Results

The consumption estimates from this analysis are considered preliminary because further research is needed regarding the multiple sources of uncertainty noted below and because ecosystem and predator dynamics in relation to the complex life history and high turnover rates of squid populations are poorly understood. Minimum estimates of consumption for *Loligo* were 16,000-219,000 mt per year during 1977-2009 (Figure 1 and Table 4). During most years, consumption was higher during the fall than during the spring (Figure 2).

Most of the *Loligo* consumed were <10 cm DML (Figures 3 and 4) although some predators (summer flounder and goosefish) consumed larger individuals. In general, *Loligo* size compositions from stomachs samples were similar to survey size compositions indicating that predators may "sample" the *Loligo* stock in a representative manner. The fishery targets *Loligo* > 8 cm DML (annual modal size = 12 cm), which are larger than the bulk of *Loligo* prey found in predator stomachs.

Ignoring the differences in length composition that reduce the comparability of fishery and consumption data, minimum estimates of annual consumption removals were larger (often substantially) than annual catches (Figures 1 and 5). The exception was 1997 to 1998, when minimum consumption and catch were about equal.

Sources of Uncertainty

1. Stock assessment estimates of abundance were not available for all predators resulting in underestimation of *Loligo* consumption.
2. The assumed value α =0.004 is in the range used in other studies, but may be too low resulting in underestimation of consumption.
3. The distribution of *Loligo pleii* overlaps with *L. pealeii* near Cape Hatteras and the two species cannot be distinguished between using gross morphology. Therefore, the amount of *Loligo pealeii* consumption may be overestimated in geographic range where the two species overlap.
4. Some fish predators that did not consistently consume *Loligo* (e.g. some of the skates) were not included in the analysis resulting in underestimation of consumption.
5. Consumption of *Loligo* by seabirds, squids and marine mammals and cannibalism by other *Loligo* was not included resulting in underestimation of consumption.
6. Squid beaks are not enumerated in food habits sampling and *Loligo* probably digest rapidly. Thus per-capita consumption estimates may be biased low.
7. The analysis assumed complete spatial-temporal overlap of predators and *Loligo*.

Appendix B6 Table 1. *Loligo* predators included in minimum consumption estimates. Abundance information was from either from minimum swept area calculations (SWA) or from stock assessments (SA). The temporal resolution of the data (annual, 2 yr, or 3 yr) indicates the number of years used to average stomach contents and diet composition data.

Common name	Scientific name	Source of abundance estimates	Time blocks
Pollock	*Pollachius virens*	SA	2 yr
Bluefish	*Pomatomus saltatrix*	SA	2 yr
Weakfish	*Cynoscion regalis*	SA	2 yr
Summer Flounder	*Paralichthys dentatus*	SA	3 yr
Goosefish	*Lophius americanus*	SA	3 yr
Atlantic cod	*Gadus morhua*	SA	Annual
Red hake	*Urophycis chuss*	SWA	2 yr
Spotted hake	*Urophycis regia*	SWA	2 yr
Smooth dogfish	*Mustelus canis*	SWA	3 yr
Fourspot flounder	*Paralichthys oblongus*	SWA	3 yr
Spiny dogfish	*Squalus acanthias*	SWA	Annual
Little skate	*Raja ocellata*	SWA	Annual
Winter skate	*Raja erinacea*	SWA	Annual
Silver Hake	*Merluccius bilinearis*	SWA	Annual
White hake	*Urophycis tenuis*	SWA	Annual

Appendix B6 Table 2. Numbers of tows in which *Loligo* was detected during spring survey food habits sampling. Figures are given starting in 1975, instead of 1977 when consumption estimates begin, because data were averaged in three year blocks for some species.

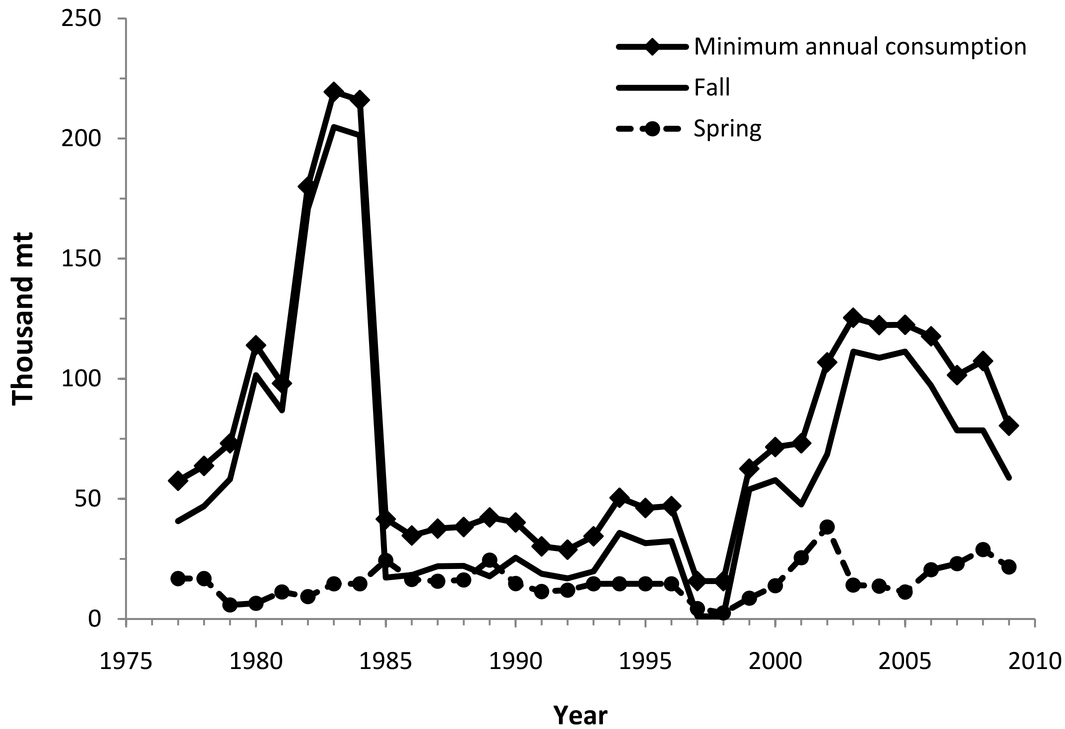
Year	COD	BLUEFISH	FOURSPOT FLOUNDER	GOOSEFISH	LITTLE SKATE	POLLOCK	RED HAKE	SILVER HAKE	SMOOTH DOGFISH	SPINY DOGFISH	SPOTTED HAKE	SUMMER FLOUNDER	WEAKFISH	WHITE HAKE	WINDOWPANE	WINTER SKATE
1975	2	0	1	0	7	1	2	14	0	0	1	0	0	0	0	0
1976	40	0	7	0	26	33	18	37	0	0	11	0	0	11	0	0
1977	22	0	5	31	15	8	39	36	3	50	0	9	0	3	16	11
1978	15	0	3	26	18	6	35	42	7	44	0	6	1	5	21	11
1979	17	2	4	21	7	2	30	27	7	50	0	23	3	5	28	22
1980	22	3	5	29	3	11	18	25	9	37	0	14	3	3	20	14
1981	47	0	1	13	2	7	5	45	20	111	0	2	0	13	11	0
1982	70	2	3	40	10	24	23	65	12	102	5	21	3	35	10	16
1983	24	2	6	31	10	22	59	35	6	115	3	16	0	47	6	5
1984	3	0	1	11	6	36	60	0	7	114	0	1	0	28	2	5
1985	115	3	12	17	27	38	50	150	8	115	1	18	6	33	23	29
1986	82	7	31	30	52	28	51	148	6	137	15	48	3	57	36	40
1987	85	0	30	23	77	17	51	115	2	134	6	24	0	44	35	57
1988	83	1	20	17	50	15	43	90	1	109	1	21	0	44	1	57
1989	106	0	37	24	120	27	67	138	3	139	29	19	3	43	87	92
1990	91	1	1	16	97	24	48	103	5	147	9	12	4	36	37	79
1991	100	1	41	55	149	52	61	146	8	167	30	43	7	53	42	100
1992	72	4	55	38	130	29	70	133	7	149	23	50	10	53	79	94
1993	89	6	70	43	160	37	92	149	10	150	37	49	12	52	84	103
1994	81	1	56	45	141	29	85	144	8	145	45	58	9	62	90	98
1995	70	0	75	60	143	33	105	158	8	177	50	45	13	57	75	82
1996	72	6	62	40	153	20	90	121	13	165	41	61	1	50	87	114
1997	82	4	73	26	127	40	85	142	7	178	60	61	2	35	59	68
1998	74	3	71	76	184	50	134	185	12	195	73	72	7	62	114	97
1999	68	5	83	80	155	40	117	181	14	185	83	78	4	53	96	88
2000	82	7	73	71	170	43	101	156	12	171	67	80	17	56	97	101
2001	66	3	80	81	146	32	103	162	11	150	63	71	6	51	64	68
2002	90	8	85	75	146	39	109	184	27	210	87	85	22	56	79	71
2003	69	5	67	56	163	31	111	134	12	160	70	73	3	47	81	101
2004	81	2	59	50	138	33	98	151	9	143	60	72	1	49	70	104
2005	73	5	63	58	129	31	88	130	13	141	59	64	6	49	69	71
2006	69	10	79	44	132	37	130	177	15	200	82	78	9	56	76	90
2007	79	5	84	49	148	34	122	153	12	183	89	75	7	50	77	101
2008	67	5	63	40	120	42	114	164	15	180	85	75	12	54	74	89
2009	91	3	117	131	209	30	200	272	19	198	113	118	1	103	120	187
Total	2299	104	1523	1447	3370	981	2614	4112	328	4651	1298	1542	175	1455	1866	2265

Appendix B6 Table 3. Numbers of tows in which *Loligo* was detected during fall survey food habits sampling. Figures are given starting in 1975, instead of 1977 when consumption estimates begin, because data were averaged in three year blocks for some species.

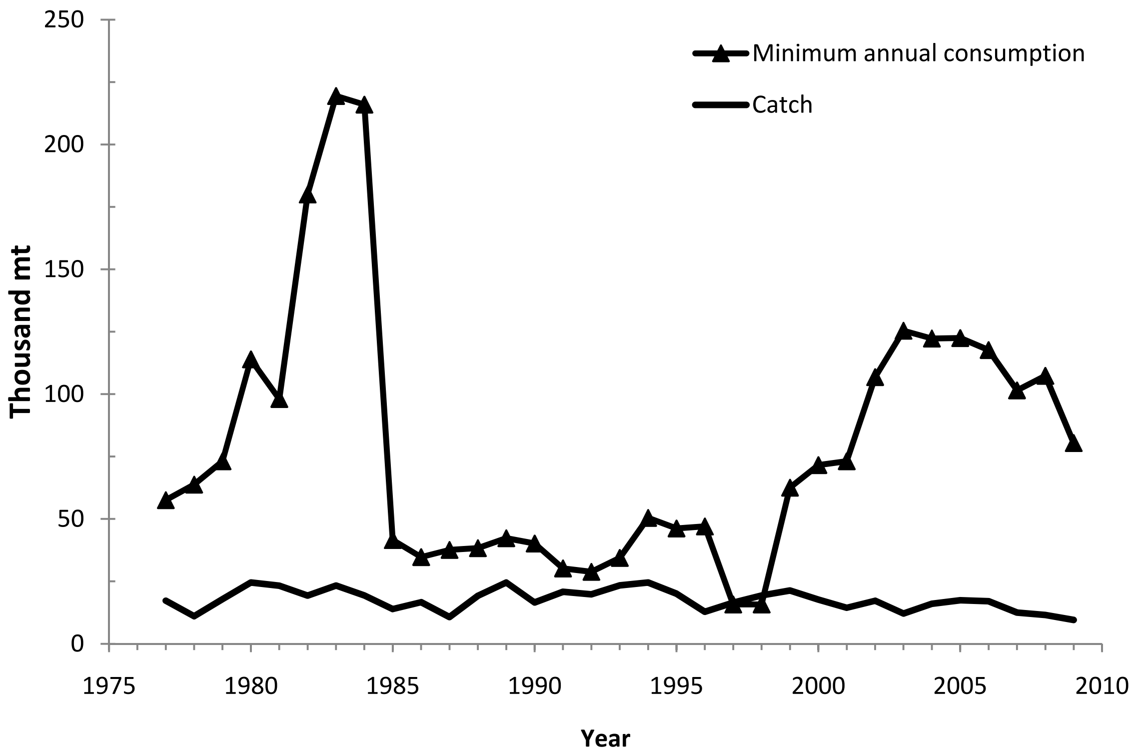
Year	COD	BLUEFISH	FOURSPOT FLOUNDER	GOOSEFISH	LITTLE SKATE	POLLOCK	RED HAKE	SILVER HAKE	SMOOTH DOGFISH	SPINY DOGFISH	SPOTTED HAKE	SUMMER FLOUNDER	WEAKFISH	WHITE HAKE	WINDOWPANE	WINTER SKATE
1975	34	0	3	0	17	18	7	41	0	0	6	0	0	14	0	0
1976	30	0	9	0	17	13	16	43	0	0	12	0	0	11	0	0
1977	0	1	0	32	11	1	31	34	10	34	0	9	0	3	12	11
1978	4	19	4	50	14	0	28	26	21	35	0	17	11	2	8	11
1979	2	40	7	44	3	1	31	19	32	36	2	49	13	1	33	9
1980	1	15	0	29	1	0	18	7	4	17	0	14	4	0	9	13
1981	26	27	4	14	2	5	6	24	11	38	3	19	2	12	3	1
1982	0	20	5	32	1	21	54	10	15	64	7	10	9	45	6	5
1983	0	7	0	24	0	24	47	2	12	97	0	1	0	60	0	3
1984	23	24	11	17	9	19	61	26	16	72	1	4	5	58	6	25
1985	45	42	18	24	16	26	55	115	25	78	17	40	25	50	11	6
1986	63	32	18	13	30	12	39	112	25	65	8	15	15	73	15	21
1987	43	47	30	24	24	14	36	99	25	46	43	31	8	53	28	20
1988	55	23	40	17	14	23	52	115	26	63	47	29	4	52	0	26
1989	60	60	51	24	60	19	73	132	40	63	55	40	38	68	38	41
1990	55	46	76	21	74	22	76	160	43	94	53	53	23	96	50	45
1991	55	43	63	65	95	30	75	153	42	87	63	63	21	121	62	62
1992	54	54	96	47	106	25	70	177	45	97	85	72	36	86	75	59
1993	49	48	93	66	111	24	98	186	45	82	72	65	24	88	78	62
1994	0	3	90	10	122	18	101	173	39	89	75	6	34	80	79	65
1995	51	4	82	65	116	23	102	147	52	90	77	77	60	69	80	84
1996	66	54	95	60	108	26	99	146	51	123	89	70	44	59	82	67
1997	55	53	68	52	85	30	92	138	45	124	58	81	25	71	65	56
1998	81	54	99	55	125	34	132	182	56	156	95	94	37	88	86	86
1999	64	69	92	69	126	36	104	147	57	137	81	107	62	80	79	73
2000	49	59	91	72	114	42	101	134	47	105	72	96	51	66	72	60
2001	56	61	85	81	110	54	101	163	61	116	103	94	41	60	70	70
2002	42	64	91	84	120	27	90	129	62	119	84	94	50	54	64	60
2003	52	65	99	75	120	39	118	166	82	111	131	92	66	60	97	57
2004	49	57	66	59	76	38	83	156	60	96	69	97	38	75	56	47
2005	51	58	99	64	105	41	115	136	63	126	97	79	44	60	79	68
2006	62	86	95	63	114	25	108	180	80	166	104	93	65	72	84	71
2007	54	61	99	46	103	23	111	155	61	119	70	96	43	79	71	67
2008	55	69	95	45	106	27	112	178	60	131	97	96	59	81	77	64
2009	45	50	152	136	134	14	150	206	49	129	141	97	21	96	71	58
Total	1431	1415	2026	1579	2389	794	2592	4017	1362	3005	1917	1900	978	2043	2905	1473

Appendix B6 Table 4. Minimum annual consumption estimates (000s mt) and CVs for *Loligo*.

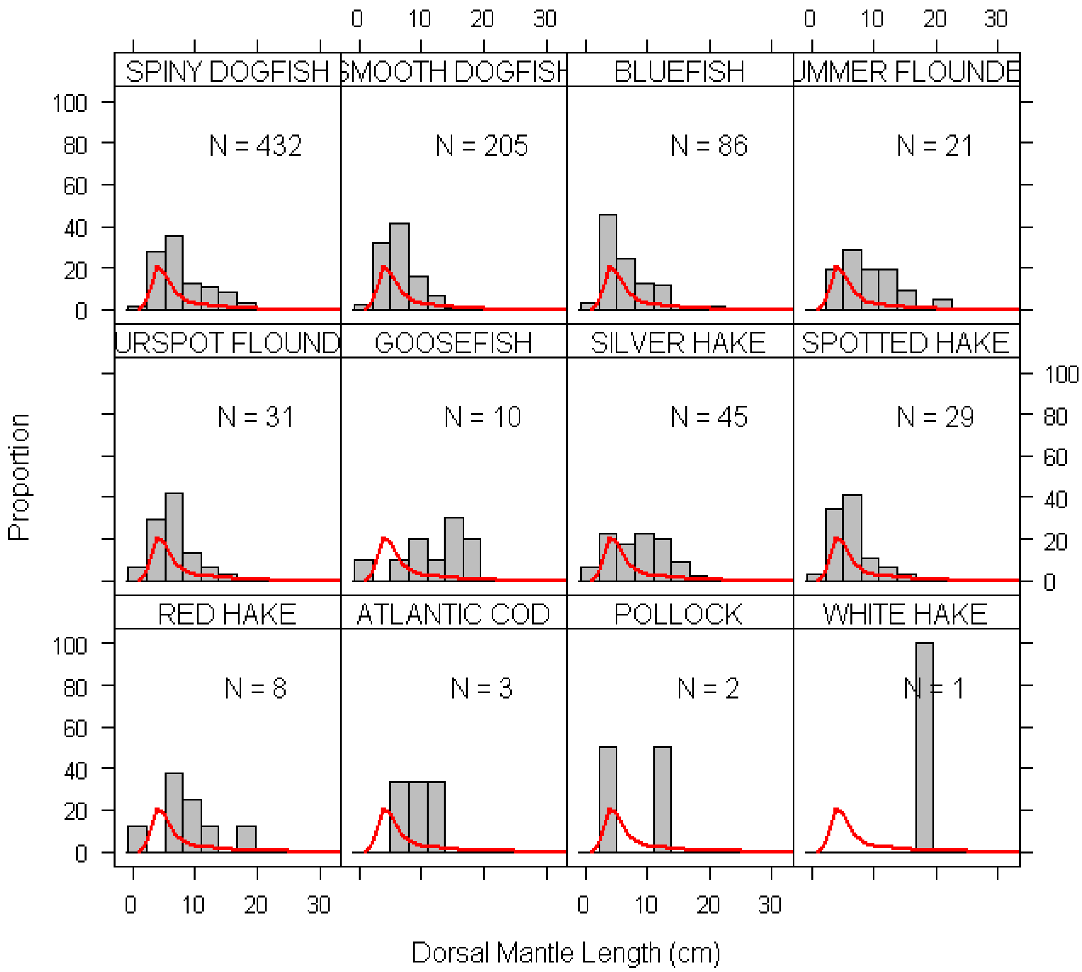
Year	Mimimum consumption (1000 mt)	CV
1977	57.5	0.35
1978	63.7	0.35
1979	73.1	0.35
1980	113.9	0.35
1981	98.1	0.35
1982	180.0	0.68
1983	219.4	0.63
1984	216.0	0.60
1985	41.6	0.75
1986	34.7	0.81
1987	37.6	0.42
1988	38.3	0.47
1989	42.3	0.58
1990	40.2	0.47
1991	30.2	0.48
1992	28.9	0.37
1993	34.4	0.38
1994	50.4	0.61
1995	46.2	0.37
1996	47.0	0.58
1997	15.8	0.50
1998	15.8	0.45
1999	62.6	0.69
2000	71.6	0.39
2001	73.1	0.63
2002	106.8	0.35
2003	125.4	0.35
2004	122.3	0.66
2005	122.5	0.46
2006	117.7	0.43
2007	101.5	0.43
2008	107.4	0.45
2009	80.5	0.45



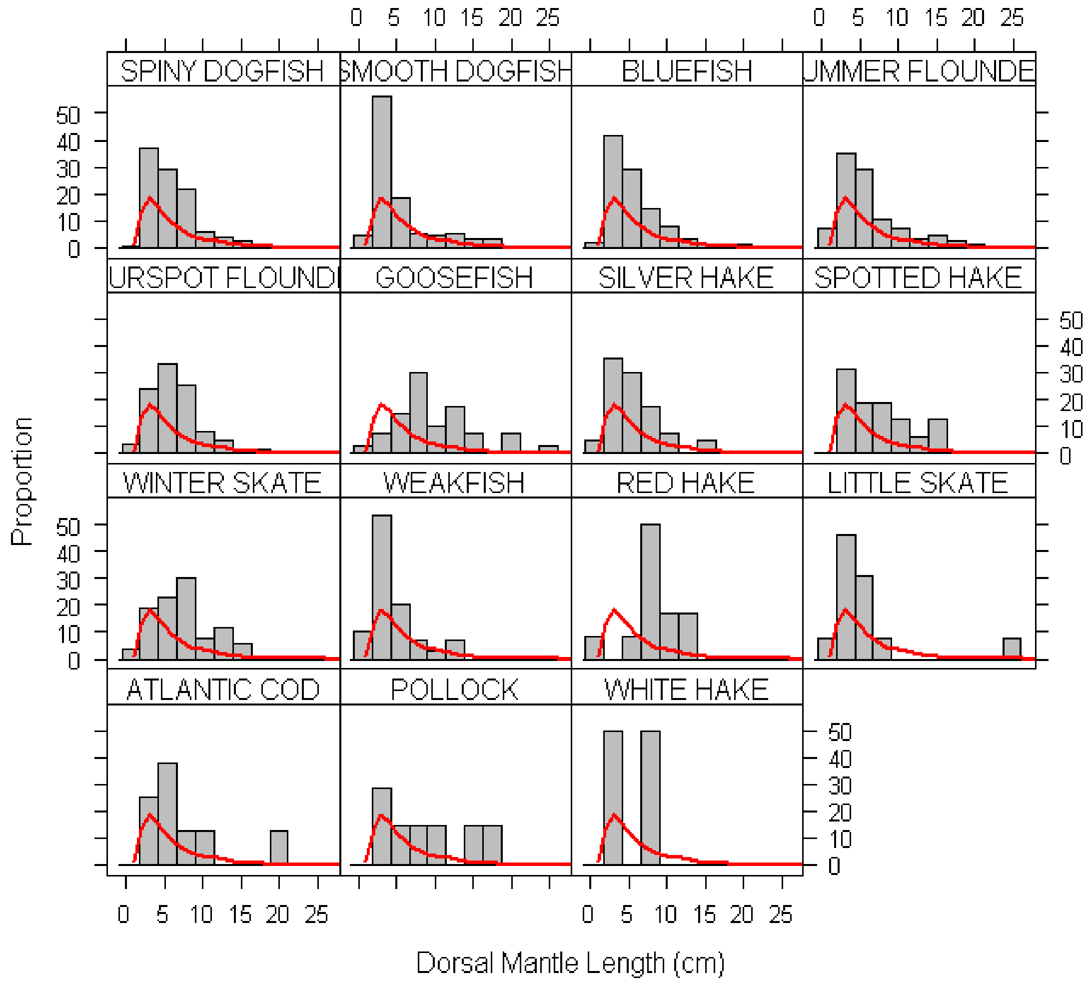
Appendix B6 Figure 1. Minimum seasonal and annual estimates of consumption for *Loligo*.



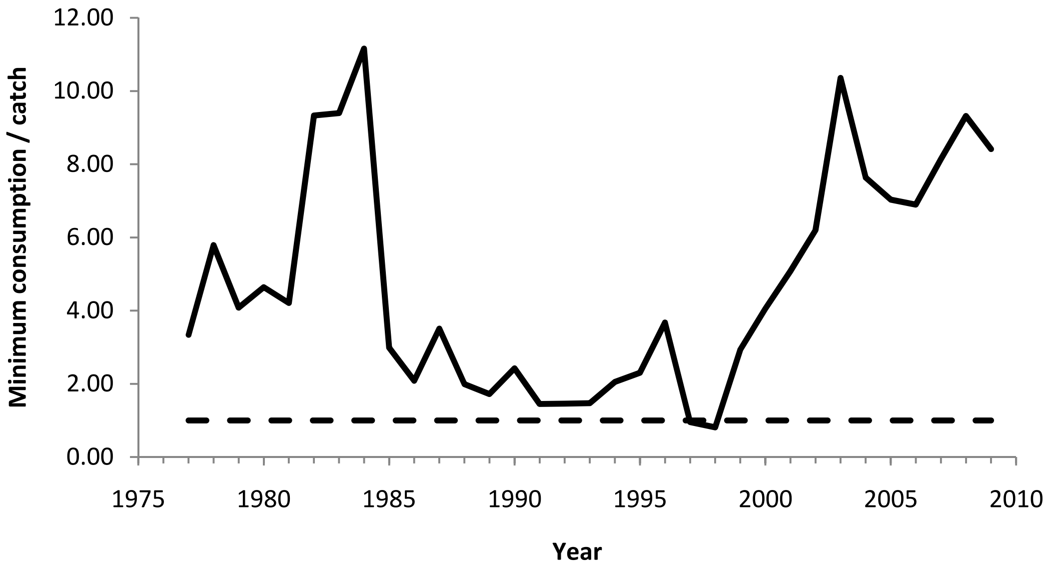
Appendix B6 Figure 2. Annual estimates of minimum consumption and catch for *Loligo*.



Appendix B6 Figure 3. Size frequency of *Loligo* eaten by the predators sampled during spring surveys. The red line shows the average survey length composition during 1975-2009. Numbers in each panel are the number of *Loligo* measured.



Appendix B6 Figure 4. Size frequency of *Loligo* eaten by the predators sampled during fall surveys. The red line shows the average survey length composition during 1975-2009. Numbers in each panel are the number of *Loligo* measured.



Appendix B6 Figure 5. Minimum annual consumption estimates divided by annual catch for *Loligo*. The horizontal line is drawn at one (minimum consumption / catch =1).

C. RED HAKE STOCK ASSESSMENT FOR 2010

Executive Summary

Red hake, *Urophycis chuss*, is a demersal gadoid species distributed from the Gulf of St. Lawrence to North Carolina, and is most abundant from the western Gulf of Maine through Southern New England waters (Bigelow and Schroeder 1953). Red hake are separated into northern and southern stocks for management purposes. The northern stock is defined as the Gulf of Maine to Northern Georges Bank region, while the southern stock is defined as the Southern Georges Bank to Mid-Atlantic Bight region.

Nominal red hake commercial landings in the northern stock peaked at 15,000 mt in 1972 and 1973, followed by a sharp decline in 1977 corresponding to the departure of the distant water fleets. Landings then averaged 1000 mt from 1977-1994, but declined to average only 100 mt through 2009. In the southern stock, nominal landings peaked at over 100,000 mt in 1965 with a secondary peak of over 60,000 in 1972. Landings then averaged 2000 mt from 1977-1994, but declined to average 900 mt through 2009. Discards from the northern stock averaged 1300 mt in the early 1980s, declined to about 250 mt from 1995-2000 and have averaged 100 mt through 2009. Discards from the southern stock averaged 4000 mt in the 1980s, declined to about 1000 mt from 1995-2000 and have averaged 700 mt through 2009. Recreational landings were much more significant in the south with catch averaging 300 mt compared to less than 3 mt in the north through the time series.

Catch data are a major source of uncertainty for this stock assessment, because of potentially mixed reported landings with white hake and uncertain identification to species by observers. Therefore, a length-based model was developed to estimate the proportion of red hake caught from the total hake catch (red and white hake combined). The model estimates for the north were generally lower than the nominal and the large peak in landings in the 1970s is eliminated. The landings for the south were also lower but the trend was similar. The Hakes Working Group was not comfortable with the complete change in trend in the north, so nominal catch was used in the assessment.

For the northern stock, total biomass indices were derived for two time series. The fall survey shows an increase from 1970 through 2002 followed by a decline through 2005. The spring survey increases from 1970 through 1980, but declines through 1990, increases again through 2002 and then is consistent with the fall survey.For the southern stock, the spring survey increases from 1970 through 1980, but declines through 2005, with a slight increase through 2009.

Total consumptive removals by all consistent red hake predators, using swept area abundance estimates of the predators, were consistently around 5 thousand mt per year during the late 1970s to late 1990s; more recently these removals have averaged approximately 10 thousand mt in the 2000s. These minimum estimates of red hake consumed by the consistent fish predators in this study were compared to total catch. Catch and minimum swept area estimates of consumption were approximately equal for much of the time series, with landings a little higher earlier in the

time series (1970s), but with consumption the dominant source of removals more recently averaging more than five times higher than catch.

For the northern stock, exploitation indices were derived for two time series. The fall survey shows very high exploitation in the 1960s and early 1970s, followed by a drop to low values from 1977 through the rest of the time series. This coincides with the departure of the distant water fleet. The second time series for exploitation was derived using the spring survey and shows a similar trend.

There is only one time series for the southern stock and it is based on the spring survey. The same peak is evident in the 1960s-1970s followed by a decline. However, exploitation increased from the late 1970s through 2005, with a slight decline in 2002. Exploitation has declined since 2005.

Although some statistical catch at age models (SCALE and SS3) were attempted, the diagnostics were not adequate for stock status determination or fishery management. Therefore the assessment is based on An Index Method (AIM) analyses for the northern and southern stocks which use the catch and spring survey data from 1980-2009 and is the basis for proposed biological reference points.

Based on current biological reference points in the existing FMP, the northern stock of red hake is not overfished and overfishing is not occurring. The three year delta mean biomass index, based on NEFSC fall bottom trawl survey data for 2007-2009 (2.87 kg/tow), was above the management threshold level (1.6 kg/tow) and slightly below the target (3.1 kg/tow). The three year average exploitation index (landings divided by biomass index) for 2007-2009 (0.03) was below both the target (0.39) and the threshold (0.65).

Based on current biological reference points in the existing FMP, the southern stock of red hake is not overfished and overfishing is unknown. The three year delta individual mean weight index, based on NEFSC fall bottom trawl survey data for 2007-2009 (0.10 kg/individual), is below the management threshold (0.12 kg/individual) but the three year average recruitment index (5.95 num/tow) is above the threshold value (4.72 num/tow).

Based on new recommended biological reference points from SAW/SARC-51, the **northern** stock of red hake is not overfished and overfishing is not occurring. The three year arithmetic mean biomass index, based on NEFSC spring bottom trawl survey data in Albatross units for 2008-2010 (2.42 kg/tow), was above the proposed management threshold (1.27 kg/tow) and close to the target (2.53 kg/tow). The exploitation index (catch divided by biomass index) for 2007-2009 (0.103 kt/kg) was below the threshold (0.163 kt/kg).

Based on new recommended biological reference points from SAW/SARC-51, the **southern** stock of red hake is not overfished and overfishing is not occurring. The three year arithmetic mean biomass index, based on NEFSC spring bottom trawl survey data in Albatross units for 2008-2010 (0.95 kg/tow), was above the proposed management threshold (0.51 kg/tow) and slightly below the target (1.02 kg/tow). The exploitation index (catch divided by biomass index) for 2007-2009 (1.150 kt/kg) was below the threshold (3.038 kt/kg).

Stochastic projections were not performed for this assessment. However, applying the Relative F reference points to the three-year average biomass index allows catches of 394 mt in the north and 2897 mt in the south.

Terms of Reference

For each stock or combined,

1. Estimate catch from all sources including landings, discards, and effort. Characterize the uncertainty in these sources of data, and estimate LPUE. Analyze and correct for any species mis-identification in these data.
2. Present the survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, etc.). Characterize the uncertainty in these sources of data.
3. Evaluate the validity of the current stock definition, and determine whether this should be changed. Take into account what is known about migration among stock areas.
4. Estimate measures of annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and characterize their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results.
5. State the existing stock status definitions for the terms "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; estimates or proxies for BMSY, BTHRESHOLD, and FMSY; and estimates of their uncertainty). If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.
6. Evaluate stock status (overfished and overfishing) with respect to the existing BRPs, as well as with respect to the "new" BRPs (from Red hake TOR 5).
7. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).
    a. Provide numerical short-term projections (3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).
    b. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.
    c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.

8. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

Hake Working Group (HWG) Meetings

Three meetings were held in preparation of the 2010 red hake assessment

1. Hake fishermen's/stakeholder's meeting – August 6, 2010 – UMASS School of Marine Science and Technology (SMAST), Fairhaven, MA. Participants include fishermen Dan Farnham and Bill Phoel. Also in attendance were David Goethel (Oversight Committee chair), Andrew Applegate (staff) Steve Cadrin (SSC and WG chair, SMAST), Pingguo He, Klondike Jonas, Yuying Zhang, Tony Wood, and Daniel Goethel (SMAST), Loretta O'Brien, Michele Traver, Katherine Sosebee and Larry Alade (NEFSC), and Dick Allen (advisor at large). A summary of the discussions is in Appendix A1.

2. Data Meeting – September 7-10, 2010, NEFSC Woods Hole MA. Participants included Steve Cadrin (WG Chair), Assessment leads (Larry Alade, Kathy Sosebee , Michele Traver), Rapporteurs (Jessica Blaylock and Julie Nieland), Mark Showell (DFO), Andy Applegate (NEFMC Staff), NEFSC (Loretta O'Brien, Mark Terceiro, Chris Legault, Tim Miller, Dave Richardson, Ayeisha Brinson, Jiashen Tang, Janet Nye, Mike Palmer, Paul Rago, Josef Idoine, Jon Hare), Moira Kelly (NERO), SMAST(Tony Wood, Yuying Zhang, Saang-Yoon Hyun)

3. Model Meeting – October 25-29, 2010, NEFSC, Woods Hole, MA. Participants included Steve Cadrin (WG chair), Assessment leads ((Larry Alade, Kathy Sosebee , Michele Traver), Rapporteurs (Jessica Blaylock and Julie Nieland), Mark Showell (DFO), Andy Applegate (NEFMC Staff), Dan Farnham (Fisherman and Industry Advisor), (Loretta O'Brien, Paul Nitschke, Mark Terceiro, Jay Burnett, Chris Legault, Tim Miller, Jon Deroba, Rich McBride, Jim Weinberg, Paul Rago, Josef Idoine, Jon Hare, Janet Nye, Dave Richardson, Laurel Col, Jason Link), SMAST(Tony Wood, Yuying Zhang, Dan Goethel). The groups met by correspondence after the meetings, including a WebEx meeting on November 5, 2010 to report updates on silver hake analyses, provide guidance on reference points and discuss plans for report development.

This Working Group (WG) report includes products from all three meetings and contributions from all participants.

Fishery Regulations

The following outlines the current small mesh multispecies regulations (based on the small mesh exemption program) for the New England whiting fishery to provide context for interpreting the fishery and model results.
1. 1994 & 2000 - Exempted fisheries allows vessels to fish for specific species such as whiting or northern shrimp in designated areas using mesh sizes smaller than the minimum mesh size allowed (Gulf of Maine, Georges Bank, Southern New England, Mid-Atlantic : 6.5-inch square or diamond) under the Regulated Mesh Area (RMA) regulations.

2. Permits

a. Open access Category K Multispecies

b. Limited Access Category A-F (non Days-at-Sea fishing)

3. No Size Limits

4. 500 lbs at sea transfer limit.

5. 2003 - Possession limits vary by exemption area

a. 3,500 lbs if mesh < 2.5 inches (63.5mm)

b. 7,500 lbs if mesh <=3.0 inches (76.2mm)

c. 30,000 lbs if mesh > 3.0 inches (76.2mm)

d. No Red Hake possession limit

Introduction

Red hake, *Urophycis chuss*, is a demersal gadoid species distributed from the Gulf of St. Lawrence to North Carolina, and is most abundant from the western Gulf of Maine through Southern New England waters. Red hake are separated into northern and southern stocks for management purposes. The northern stock is defined as the Gulf of Maine to Northern Georges Bank region, while the southern stock is defined as the Southern Georges Bank to Mid-Atlantic Bight region (Figure C1). Both red hake stocks were last assessed in the fall of 1990.

Red hake migrate seasonally, preferring temperatures between 5 and 12° C (41-54° F) (Grosslein and Azarovitz 1982). During the spring and summer months, red hake move into shallower waters to spawn, and during the winter months move offshore to deep waters in the Gulf of Maine and the edge of the continental shelf along Southern New England and Georges Bank. Spawning occurs from May through November, with primary spawning grounds on the southwest part of Georges Bank and in the Southern New England area off Montauk Point, Long Island (Colton and Temple 1961).

Red hake do not grow as large as white hake, and normally reach a maximum size of 50 cm (20 in.) and 2 kg (4.4 lbs.) (Musick 1967). However, females are generally larger than males of the same age, and reach a maximum length of 63 cm (25 in.) and a weight of 3.6 kg (7.9 lbs.) (Collette and Klein-MacPhee eds. 2002). Although they generally do not live longer than 8 years, red hake have been recorded up to 14 years old. In the northern stock, the age at 50% maturity is 1.4 years for males and 1.8 years for females, and the size at 50% maturity is 22 cm (8.7 in.) for males and 27 cm (10.6 in.) for females (O'Brien et al. 1993). In the southern red hake stock, the age at 50% maturity is 1.8 years for males and 1.7 years for females, and the size at 50% maturity is 24 cm (9.5 in.) for males and 25 cm (9.8 in.) for females (O'Brien et al. 1993).

Red hake prefer soft sand or muddy bottom, and feed primarily on crustaceans such as euphausiids, decapods, and rock crabs as well as fish such as haddock, silver hake, sea robins, sand lance, mackerel and small red hake (Bowman et al. 2000). Primary predators of red hake include spiny dogfish, cod, goosefish, and silver hake (Rountree 1999). As juveniles, red hake seek shelter from predators in scallop beds, and are commonly found in the mantle cavities of (or underneath) sea scallops. In the fall, red hake likely leave the safety of the scallop beds due to their increasing size and to seek warmer temperatures in offshore waters (Steiner et al. 1982).

TOR1. Estimate catch from all sources including landings, discards, and effort. Characterize the uncertainty in these sources of data, and estimate LPUE. Analyze and correct for any species mis-identification in these data.

Commercial Fishery Landings

Following the arrival of distant-water fleets in the early 1960s, nominal commercial landings from both stocks combined peaked at 113,500 mt in 1966 (Table C1, Figure C2). Nominal landings then declined sharply to 12,500 mt in 1970, increased to 76,200 mt in 1972, and then declined steadily with increased restrictions on distant-water fishing effort. Prior to implementation of the Magnuson Fisheries Conservation and Management Act (MFCMA) in 1977, distant-water fleets accounted for approximately 80-90% of the nominal landings from both stocks. Between 1977 and 1986, landings generally declined due to restrictions placed on distant water fleets, and foreign landings ceased in 1987 (Table C1, Figure C3). Red hake landings continued to decline afterwards, and averaged only 1,400 mt per year during 1996-2000. Nominal red hake landings then declined further to average 770 mt between 2001 and 2009. Red hake are often sold as bait over the side. These landings are not reported in the dealer database, but are supposed to be reported on Vessel Trip Reports (VTR). All the landings tables include whatever landings are reported in the totals. Due to some confidentiality issues, they are not reported separately.

The northern red hake stock had significantly lower commercial landings than the southern stock through the mid-1970s (Table C1, Figure C2). In 1973, total commercial landings peaked at 15,288 mt but have since declined progressively. After 1976, landings declined considerably due to the withdrawal of the distant water fleet. Commercial landings declined to less than 100 mt in 2005 and have remained low (Table C1, Figure C3).

During 1962 to 1976, landings from the southern red hake stock were much higher than those from the northern stock (Table 1, Figure C2). However, southern red hake landings decreased sharply after 1966 and also after 1976 due to restrictions on distant water fleets. The southern stock landings continued to decrease, and reached a record low of 356 mt in 2005 before increasing to 575 mt in 2009 (Table C1, Figure C3).

Commercial landings in the northern stock generally came from Massachusetts with smaller amounts landed in Maine and Rhode Island (Table C2). The primary states in which red hake were landed in the southern stock are Rhode Island, New Jersey, and New York (Table C3). Massachusetts was a historically important port, with some of the industrial fleet landings probably landed there.

Otter trawls in both regions accounted for the majority of the commercial landings of red hake, although the assumption was made that both the industrial fishery and the bait fishery are from otter trawl (Tables C4-C5). This assumption is likely valid since otter trawls were the main reported gear type throughout the history of the fishery.

Commercial landings from the northern stock are taken primarily in the summer months, mainly June through October (Table C6) although in the last five years, significant landings have only occurred in July, August and September. Commercial landings from the southern stock occur more evenly during the year (Table C7).

Species and Length Composition of Landings

Identification of hakes is uncertain in the commercial landings. An alternative method to estimate landings by species (red/white) was developed. Landings by region, half year, and, in the case of white hake, market category (Tables C8-C10) were converted to length composition. Market categories of white hake were aggregated as they were done in the white hake assessment (NEFSC 2001, 2008). The port samples by half year, region, and market were used (Tables C11-C13). In general, there were marginally adequate numbers of fish measured for red hake in the south and white hake in the north (Tables C14-C15). Pooling over years by species within a region was required to get an adequate number of fish, particularly for red hake in the north and white hake in the south (Table C16-C17). The length-weight equations by season from Wigley et al 2003 were applied to the samples and used to estimate the landings numbers at length for each market category.

Length compositions for each species for the two regions (GOM-NGBK Offshore strata 20-30, 36-40; SGBK-MA – Offshore strata 1-19, 61-76) were estimated for the spring and fall surveys. The species length-weight equations were then applied to determine weight-at-length by species. The proportions at length by species for both number and weight were applied to the commercial landings-at-length to estimate landings-at-length by species. The lengths had to be grouped into intervals to avoid zero cells in the survey. All fish greater than 70 cm were set to be white hake. Landings from 1964-2009 were hind-cast using the average proportion of red hake by region over the entire time series.

The landings that result from this method are very different than the nominal landings in the north (Table C18, Figure C4) but fairly similar for the southern landings (Table C18, Figure C5). The HWG decided that the hind-cast landings were too uncertain and that the increase seen in the northern stock disappears (and becomes white hake during that time). Therefore, nominal landings will be used for the assessment.

The length compositions from the raw length samples and the length-based model estimates show different patterns for the northern stock (Figures C6-C7). The raw data (only showing years which had red hake length samples) are noisy with some years having fairly small fish (i.e. 1992 and 2007). When the data are pooled to estimate the length compositions and split using survey proportions, trends of these small fish are evident from 1992-1996 and 2006-2009. In the southern stock, the length compositions are fairly similar (Figures C8-C9).

Commercial Fishery Discards

Discard estimates were calculated in this assessment. The ratio-estimator used in this assessment is based on the methodology described in Rago et al. (2005) and updated in Wigley et al 2007. It relies on a d/k ratio where the kept component is defined as the total landings of all species within a "fishery". A fishery is defined as a homogeneous group of vessels with respect to gear type (longline, otter trawl, shrimp trawl, sink gill net, and scallop dredge), quarter, and area fished (GOM-NGBK, SGBK-MA), and for otter trawls, mesh size (<= 5.49", > = 5.5 "). All trips were included if they occurred within this stratification regardless of whether or not they caught hakes.

The discard ratio for hakes in stratum h is the sum of discard weight over all trips divided by sum of kept weights over all trips:

$$\hat{R}_h = \frac{\sum_{i=1}^{n_h} d_{ih}}{\sum_{i=1}^{n_h} k_{ih}} \qquad (1)$$

where d_{ih} is the discards for hakes within trip i in stratum h and k_{ih} is the kept component of the catch for all species. R_h is the discard rate in stratum h. The stratum weighted discard to kept ratio is obtained by weighted sum of discard ratios over all strata:

$$\hat{R} = \sum_{h=1}^{H} \left(\frac{N_h}{\sum_{h=1}^{H} N_h} \right) \hat{R}_h \qquad (2)$$

The total discard within a strata is simply the product of the estimate discard ratio R and the total landings for the fishery defined as stratum h, i.e., $D_h=R_hK_h$.

Cells with < three trips were imputed using annual averages by gear type and region. To hind-cast the discards to 1981 (the first year in which there was no industrial fishery), discards/total landings by half year for the first three years (1989-1991 for otter trawl, sink gill net, and shrimp trawl; 1992-1994 for longline and scallop dredge) were averaged and the rate applied to the total landings from the dealer database. For the otter trawl fisheries, the mesh sizes were combined for the hind-cast.

The main sources of red hake discards in the north were the two small-mesh trawl fisheries, including the shrimp trawl fishery, at least until the early 1990s, with the implementation of the Nordmore grate in that fishery (Table C19). The small-mesh trawl fishery in the south is also the largest contributor to discards of red hake, with large-mesh trawl and scallop dredge catching some significant amounts (Table C20). Discards from the longline and sink gill net fisheries were minimal in both regions.

Discards from the northern stock averaged 1300 mt in the early 1980s, declined to about 250 mt from 1995-2000 and have averaged 100 mt through 2009 (Figure C10). Discards from the southern stock averaged 4000 mt in the 1980s, declined to about 1000 mt from 1995-2000 and have averaged 700 mt through 2009 (Figure C11).

Species and Length Composition of Discards

The same problem with species identification that exists in the landings is found in the Fisheries Observer Program data. The same length-based method used for commercial landings was used to split discards. Discards were estimated for white hake using the same method as for red hake (Tables C21-C22). Enough length samples were available for large and small mesh otter trawls in both regions and sink gill net and shrimp trawl in the north (Tables C23-26). Pooling over years was still required to get an adequate number of fish (Tables C27-30). To hind-cast the species proportions back to 1981, the average proportion of red hake for the time series was used and applied to the total red and white hake discards. This method resulted in slightly different discard estimates for the north (Table C31, Figure C10) and almost imperceptible differences in the south (Table C31, Figure C11). To be consistent with landings, the nominal discards were used for the assessment. The length compositions from the nominal discards and the length-based model estimates show very little difference in either stock (Figures C12-C15).

Recreational Catch

USA recreational landings of red hake were estimated by stock using data provided by NOAA MRFSS from 1981-2009 (Table C32). Landings prior to 1981 were hind-cast for the north using an average proportion of the total landings. The southern stock had estimates previously derived (NEFC 1990) and these were used directly. Recreational landings were much more significant in the south with catch averaging 300 mt compared to less than 3 mt in the north through the time series (Figure C16). The number of length samples taken in the recreational fishery is sparse for the northern stock, so the southern stock length frequencies were used for both stocks (Figure C17).

Commercial Fishing Effort and LPUE

There are currently no estimates of CPUE or effort for this species. Given the uncertainties given above with species identification and the major changes in management noted in the introduction, CPUE is not likely to be a good indicator of stock status. In particular, the fishery in the north has been limited in areas they can fish with small mesh. These are not necessarily areas for good red hake fishing. Over time, the fishery has also changed from one dominated by a distant water fleet that took substantial quantities of everything to a much smaller by-catch fishery that may be driven more by prices of silver hake and regulation than abundance.

TOR 2. Present the survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, etc.). Characterize the uncertainty in these sources of data.

Data Source: The primary sources of biological information for red hake are based on the annual fishery independent surveys conducted by the Northeast Fisheries Science Center (NEFSC). The surveys were conducted using a random stratified sampling design which allocates samples relative to the size of the strata, defined by depth. The surveys extend from the Gulf of Maine to Cape Hatteras, in offshore waters at depths 27-365 meters, and have been conducted in the fall since 1963 and in the spring since 1968. The winter bottom trawl survey began in 1992 and was specifically designed for flatfish, however, the deeper survey strata were not sampled until 1998 (Figure C18). The winter trawl survey does not cover the Georges Bank area because the survey was designed specifically for flatfish in the southern region. Details on the stratified random survey design and biological sampling methodology may be found in Grosslein (1969), Azarovitz (1981) and Sosebee and Cadrin (2006). Other surveys used in the analysis of silver hake are NEFSC shrimp survey (1985-2009), Massachusetts Division of Marine Fisheries (1978-2009) fall and spring surveys and Rhode Island (1979-2010), Connecticut (1984-2009), and Maine-New Hampshire (2000-2009) state surveys.

The NEFSC spring and fall survey estimates were calculated for northern, southern and combined management regions. The NEFSC strata used for the northern area are offshore strata 20-30 and 36-40. The NEFSC strata used for the southern management area are: offshore strata 1-19 and 61-76. The combined strata set is: offshore 1-30, 36-40, and 61-76.The strata set for the shrimp survey is shrimp strata 1-12. The strata set for the winter surveys is: offshore strata 1-3, 5-7, 9-11, 13-14, 61-63, 65-67, 69-71, and 73-75. Massachusetts Division of Marine Fisheries data was separated into northern and southern areas. The northern strata used were MADMF 18-36 and the southern strata used were 11-17 (Figure C19).

Minimum swept area abundance and biomass were calculated by using swept area conversions of 0.0112 for the NEFSC fall and spring surveys, 0.004 for NEFSC shrimp survey, 0.0131 for the NEFSC winter survey, and 0.003846208 for Massachusetts Division of Marine Fisheries (MADMF) fall and spring surveys. Swept area estimates were not calculated for the other state surveys

Transform: NEFSC spring and fall survey estimates were computed using both delta transformation and arithmetic means for numbers and weight. The Whiting Plan Development Team (PDT) has used the delta mean for assessing stock status. The delta transformation uses only the positive tows for log transformation:

$$\hat{M}_{\delta} = \begin{cases} \frac{m}{n} e^{\bar{y}} \psi_m\left(\frac{1}{2}s_y^2\right) & m > 1, \\ \frac{1}{n} x_1 & m = 1, \\ 0 & m = 0 \end{cases}$$

m = number of non-zero tows
n = total number of tows

$$\hat{V}_{\delta} = \begin{cases} \frac{m}{n} e^{2\bar{y}} \left[\psi(2s_y^2) - \frac{m-1}{n-1} \psi_m\left(\frac{m-2}{m-1} s_y^2\right) \right] & m > 1, \\ \frac{1}{n} x_1^2 & m = 1, \\ 0 & m = 0 \end{cases}$$

Examination of the differences between the delta and arithmetic means revealed that use of the delta transformation did not reduce the variability of the survey and may have increased the variability between years (Figure C20). If a survey has a high variance, the back-transformation may be biased high. The delta transformation was also more sensitive to the handling of missing weights. Prior to 2001, the data for weights were recorded to the nearest 0.1 kg and if a tow contained only a single small fish, the weight was entered into the data as zero. Since the delta transform uses the positive tow, how this is handled has an impact on the result. There are three options: taking out the zeros, leaving in the zeros, and filling in zeros using a length-weight equation. Since these options did not affect the arithmetic as much as the delta mean, the decision was made to use the arithmetic and length-weight options for any new analyses (Figure C21).

Calibration: In 2009 the *NOAA SHIP Henry B. Bigelow* replaced the *R/V Albatross IV* as the primary vessel for conducting spring and fall annual bottom trawl surveys for the Northeast Fisheries Science Center (NEFSC). There are many differences in the vessel operation, gear, and towing procedures between the new and old research platforms (NEFSC Vessel Calibration Working Group 2007). To merge survey information collected in 2009 onward with that collected previously, we need to be able to transform indices (perhaps at size and age) of abundance from the *Henry B. Bigelow* into those that would have been observed had the *Albatross IV* still been in service. The general method for merging information from these two time series is to calibrate the new information to that of the old (Pelletier 1998). Specifically we need to predict the relative abundance that would have been observed by the *Albatross IV* ($\hat{R}_A$) using the relative abundance from the *Henry B. Bigelow* (R_B) and a "calibration factor" (ρ),

$$\hat{R}_A = \rho R_B . \qquad (3)$$

To provide information from which to estimate calibration factors for a broad range of species, 636 paired tows were conducted with the two vessels during 2008. Paired tows occurred at many stations in both the spring and fall surveys. Paired tows were also conducted during the summer and fall at non-random stations to improve the number of non-zero observations for some species. Protocols for the paired tows are described in NEFSC Vessel Calibration Working Group (2007).

The methodology for estimating the calibration factors was proposed by the NEFSC and reviewed by a panel of independent scientists in 2009. The reviewers considered calibration factors that could potentially be specific to either the spring or fall survey (Miller et al. 2010). They recommended using a calibration factor estimator based on a beta-binomial model for the data collected at each station for most species, but also recommended using a ratio-type estimator under certain circumstances and not attempting to estimate calibration factors for species that were not well sampled.
Since the review, it has become apparent that accounting for size of individuals can be necessary for many species. When there are different selectivity patterns for the two vessels, the fraction of available fish of a given size taken by the two gears is different. Therefore, the ratio of the mean catches by the two vessels will change with size. Under these circumstances, the estimated calibration factor that ignores size reflects an average ratio weighted across sizes where the weights of each size class are at least in part related to the number of individuals at that size and the number of stations where individuals at that size were caught. Applying calibration factors that ignore size effects to surveys conducted in subsequent years when the size composition is unchanged should not produce biased predictions (eq. 1). However, when the size composition changes, the frequency of individuals and number of stations where individuals are observed at each size changes and the implicit weighting across size classes used to obtain the estimated calibration factor will not apply to the new data. Consequently, the predicted numbers per tow that would have been caught by the *Albatross IV* will be biased.

For red hake, we fit a suite of beta-binomial models that made different assumptions on the relationship of the calibration factor to length. The models ranged from those that were constant with respect to length to logistic and double-logistic functions of length. For red hake, the working group decided to use a season-specific double-logistic model relating the calibration factor to length due to it providing the best fit to the data with respect to AIC_c (Table C33-34, Figure C22). Note that the minima for both logistic components in the fall were assumed equal to 0 (e^{-100}) due to poorly estimated variance of model coefficients in the fully parameterized model. To estimate weight pre tow for the 2009 and 2010 surveys, the length-weight equations by season from Wigley et al 2003 were applied to the length frequencies.

Survey Data Results: Distribution maps for red hake show that there are higher concentrations of red hake by catch weight (kg) during the NEFSC spring surveys than the NEFSC fall surveys. There were less red hake caught in the middle of Georges Bank in the spring than the fall. They tended to be more in the Gulf of Maine and along the shelf, than in the middle of the bank. The maps are broken into 5-year blocks, by season, for the duration of the time series (Figures C23-C34).

<u>North</u>
The fall survey biomass steadily increased during the 1970s, spiked in 2000 at its highest of 12,118 metric tons and then decreased until 2005, where the stock declined to 2,486 metric tons. Biomass has increased the past few years and is currently at 5,086 metric tons in 2009, a 24% increase from 2008 (Table C35, Figure C35).

The spring survey biomass was variable during the 1970s, with many peaks and valleys. There was a large spike in 1981, where it increased to 13,594 metric tons. In 1982, the biomass index dropped sharply to 4,551 metric tons, a decline of 67%. The stock was quite low in 1990, and then increased until 2002, where the stock was at 9,543 metric tons and then considerably declined until 2006, with 1,952 metric tons. Since then, the minimum swept area biomass has increased again to 4,326 metric tons, a 122% increase over 2006 (Table C36, Figure C36).

The shrimp survey swept area biomass was quite low during the early part of the time series. The lowest point was in 1994, at 3,262 metric tons. Biomass continued to slowly increase, until it spiked in 2002 with an all time high of 64,925 metric tons. Then biomass declined by 74% to 17,194 metric tons in 2003. The 2009 estimate is currently at 13,164 metric tons (Table C37, Figure C37).

The lowest biomass estimate from the MADMF fall surveys was in 1987, where there were only 447 metric tons caught. Then biomass increased through the 1990s, where it hit a maximum value in 2000 of 3,842 metric tons. A decline occurred between 2002 and 2008, although 2009 increased by 83% over 2008 (Table C38, Figure C38).

The MADMF spring surveys have extremely low biomass estimates. There were two spikes early in the time series, in 1979 and 1981, with catches of 3,888 metric tons and 5,129 metric tons, respectively. The biomass declined considerably in 1982 and stayed low until a small bump in 2000 with 1,414 metric tons. The survey biomass then declined to its lowest value in 2004 of 75 metric tons. It increased by 226% in 2009, to 245 metric tons (Table C39, Figure C39).

The trends for all the fall surveys are in general agreement showing an increase through 2000, a decline through 2005 and an increase over the last few years (NH data in Table C40, Figure C40). The spring surveys also show a general agreement with higher values in the 1980s, declining through 1995, increasing through 2002, and followed by a decline until the last couple of years (NH data in Table C40, Figure C41).

South

The fall survey swept area biomass was higher during the 1970s and 1980s than any other part of the time series. Biomass peaked at 20,002 metric tons in 1983 before dropping drastically by 80% to 3,905 metric tons in 1984. The stock has continued to decline until 2005. Biomass has increased slightly and is currently at 3,368 metric tons (Table C41, Figure C42).

Similar to the fall survey, the spring survey swept area biomass was higher during the 1970s and early part of the 1980s. After 1981, when the biomass was 15,201 metric tons, it declined to reach a low value of 511 metric tons. Biomass continued to increase to 3,460 metric tons in 2010, a 577% increase since 2004 (Table C42, Figure C43).

The winter survey has a very short time series, 1992-2007. The swept area biomass was high during the early part of the time series, with 18,483 metric tons in 1993. The survey biomass then declined, hitting its lowest value in 2003 at only 159 metric tons. The biomass varied until the winter survey was discontinued in 2007 (Table C43, Figure C44).

The MADMF fall survey in the southern region has much smaller biomass than in the northern region. The survey was variable at best with many peaks and valleys throughout the time series. In 2004, the survey was at its lowest point with 0.22 metric tons of swept area biomass. In 2009, there was an increase of 645% to 1.64 metric tons than in 2004 (Table C44, Figure C45).

The MADMF spring survey has larger swept area biomass than the MADMF fall survey. The early part of the time series has greater values than the latter. The highest biomass was estimated in 1987 with 894 metric tons, where 2003 was the lowest, at 0.36 metric tons. In 2009, the swept area biomass was 6.92 metric tons (Table C45, Figure C46).

The trends for all the fall surveys are much noisier than in the northern area (RI and CT data in Table C46, Figure C47). The spring surveys also show great deal of noise (RI and CT data in Table C46, Figure C48).

<u>Combined</u>
The fall survey swept area biomass, combining both the northern and southern management areas, had a steep decline to 4,467 metric tons in 1974 from 17,737 metric tons in 1972. Then the biomass increased substantially to 28,807 metric tons in 1983. After a considerable drop in 1986, the biomass estimates were stable throughout the rest of the time series. The biomass in 2009 was 8,454 metric tons (Table C47, Figure C49).

In the spring survey, biomass peaked at 30,831 metric tons and 28,794 metric tons in 1978 and 1981, respectively. Biomass then declined until 1998, when biomass increased slightly. There was a 75% decline from 11,337 metric tons in 2002 to 2,812 metric tons in 2003. The stock increased since then and was 9,022 metric tons in 2009 (Table C48, Figure C50).

Length Composition

The length compositions from the fall survey show a large proportion of very small fish in the northern stock (Figure C51). There has also been a truncation of size of fish with very few fish caught that are greater than 40 cm. The spring survey length composition has many fewer small fish (except for 1974) but shows the same size truncation (Figure C52).

In the south, the young-of-the-year are very dominant in the length composition, but the size truncation is less noticeable, possibly since there may have already been truncation before the time series started (Figure C53). However, the spring survey shows some truncation occurring in the late 1980s and early 1990s, with fewer fish greater than 35 cm caught in the survey (Figure C54). The winter survey shows more young fish than the spring, possibly because the survey used a cookie sweep and was able to capture small fish and, more importantly, the scallops that they inhabit (Figure C55).

Estimates of Consumption of Red Hake

Every predator that contained red hake was identified from the NEFSC FHDBS. From that original list, a subset of predators (Table C49) was examined to elucidate which predators consistently ate red hake, determined by “rules of thumb” that include having a diet composition of >1% for any five year block, and with >5 tows for each two year block and > 10 stomachs for each three year block.

Annual consumption estimates were calculated on a seasonal basis (two 6 month periods) based on spring and fall bottom trawl surveys and for each predator species. Although the food habits data collections started quantitatively in 1973, not all species of red hake predators were sampled during the full extent of this sampling program, thus the time series used here begins in 1977 (Link and Almeida 2000). This sampling program was a part of the NEFSC bottom trawl survey program (Azarovitz 1981; NEFC 1988). There are various ways to integrate seasonally, but the simple sum of the two seasonal estimates was used in this analysis. The analyses were done for various size classes of predators, and then were integrated across all predator size classes to come up with a total consumption of red hake for each predator.

This approach followed previously established and described methods for estimating consumption, using an evacuation rate model methodology. For further details, see Durbin et al. (1983), Ursin et al. (1985), Pennington (1985), Overholtz et al. (1991, 1999, 2000, 2008), Tsou & Collie (2001a, 2001b), Link & Garrison (2002), Link et al. (2006, 2008, 2009), Methratta & Link (2006), Link & Sosebee (2008), Overholtz & Link (2007, 2009), Tyrrell et al. (2007, 2008), Link and Idoine (2009), Moustahfid et al. (2009a, 2009b), and NEFSC (e.g., 2006, 2007a, 2007b, 2008, 2010a, 2010b). The main data inputs are mean stomach contents (S_i) for each red hake predator i, diet composition (D_{ij}) where the subscript j refers to red hake as a prey item, and T is the bottom temperature taken from the bottom trawl surveys (Taylor et al. 2005). Units for stomach estimates are in g.

As noted, to estimate per capita consumption, the gastric evacuation rate method was used (Eggers 1977, Elliott and Persson 1978). There has been copious experience in this region using these models (see references listed above). The two main parameters, α and β, were set to 0.004 and 0.115 respectively based upon prior studies and sensitivity analyses (NEFSC 2007a, 2007b). The exception is that α was set to 0.002 for elasmobranch predators consistent with and to reflect their slightly lower metabolism than teleost fishes.

Using the evacuation rate model to calculate consumption requires two variables and two parameters. The per capita consumption rate, C_{it} is calculated as:

$$C_{it} = 24 \cdot E_{it} \cdot \overline{S_{it}}^{\gamma}$$

where 24 is the number of hours in a day and the evacuation rate E_{it} is:

$$E_{it} = \alpha e^{\beta T} \qquad ;$$

and is formulated such that estimates of mean stomach contents (S_{it}) and ambient temperature (T; here used as bottom temperature from the NEFSC bottom trawl surveys for either season (Taylor & Bascuñán 2000, Taylor et al. 2005)) are the only data required. This was done for each predator i (size and species) for each time period t (season and year). The parameters α and β are set as values chosen noted above. The parameter γ is a shape function is almost always set to 1 (Gerking 1994).

Once daily per capita consumption rates were estimated for each red hake predator, those estimates were then scaled up to a seasonal estimate. This was done by multiplying the number days in each half year, which were then multiplied by the diet composition D_{ij} that was red hake, to estimate the seasonal per capita consumption of red hake. That is, once per capita consumption rates were estimated for each red hake predator in a temporal period (t), those estimates were then scaled up to a seasonal estimate (C'_{it} = C_{fall} or C_{spr}) by multiplying the number days in each half year:

$$C'_{it} = C_{it} \cdot 182.5$$

These were then multiplied by the diet composition D_{ijt} that was red hake, to estimate the seasonal per capita consumption of this fish C_{ijt}:

$$C_{ijt} = C'_{it} \cdot D_{ijt}$$

These were then summed to provide an annual estimate, C'_{ij}:

$$C'_{ij} = C_{ij,fall} + C_{ij,spring}$$

Once these were summed to provide an annual estimate (or the following could be seasonally and the summed), they were then scaled by the total stock abundance of each predator to estimate the amount of red hake removed by any of the predators included in the study. Swept area estimates of abundance from bottom trawl survey estimates were used for all predators (Table C49). These consumption estimates were then scaled by the total stock abundance to estimate a total amount of red hake (j) removed by any predator i, C_{ij}:

$$C_{ij} = C'_{ij} \cdot N_i \qquad ,$$

where N_i is the estimate of abundance for each predator for each year. These C_{ij} were then summed across all i predators to obtain an estimate a total amount of red hake removed by these red hake predators, C_j:

$$C_j = \sum_i C_{ij} \qquad .$$

Total consumptive removals by all consistent red hake predators, using swept area abundance estimates of the predators, were consistently around 5 thousand mt per year during the late 1970s to late 1990s; more recently these removals averaged approximately 10 thousand mt in the 2000s (Figure C56). For more explicit presentation of the step-by-step data series used to derive the consumptive removal results, please contact the working group, as has been done for similar prior assessments (e.g., NEFSC 2007a, 2007b).

These minimum estimates of red hake consumed by the consistent fish predators in this study were compared to total catch (Figure C56). Catch and minimum swept area estimates of consumption were approximately equal for much of the time series, with landings a little higher earlier in the time series (1970s), but with consumption the dominant source of removal more recently averaging more than five times than catch (Figure C57).

Estimates of predatory removal of red hake via consumption are likely conservative given nature of these consumption estimates. These consumption estimates should be useful to inform both the scaling of biomass estimates and the magnitude of mortalities for red hake. The estimates of consumption also imply that there has been a change in natural mortality over time. This is likely to be important in any model attempts.

There were enough red hake measured in the stomachs of the predators to pool over the entire time series (n=612). In the future, it may be useful to break into time periods. More than half of the fish measured are between 3 and 8 cm with the mode at 4 cm (Figure C58).

TOR 3. Evaluate the validity of the current stock definition, and determine whether this should be changed. Take into account what is known about migration among stock areas.

Two subpopulations of red hake are assumed to exist within the U.S. EEZ based largely by analogy with silver hake (NEFC 1986). No morphometric or genetic analyses of the population structure have been conducted. The northern red hake stock inhabits Gulf of Maine - Northern Georges Bank waters, and the southern red hake stock inhabits Southern Georges Bank - Middle Atlantic Bight waters (Figure C1). These boundaries were established at SAW 2.

Distribution

While it is likely that the northern and the southern stocks mix on Georges Bank, the degree of mixing and movement among the management areas are unknown. NEFSC trawl surveys indicate a generally continuous distribution of silver hake from the Gulf of Maine to the southern New England/Mid-Atlantic Bight (Figures C23 and C24). However, the relative density of red hake has varied through time between the northern and southern management areas. Population density as measured by the NEFSC fall bottom trawl survey increased in northern area during the mid-1980's and then declined in the 2000's (Figure C35). In contrast southern area showed stability through 1982 with a drop in 1983 and a progressive decline through 2004. Since 2004, there has been a slight increase (Figure C42). The spring trends indicate a stable biomass through 1987 followed by a decline through 1995 (Figure C36). Biomass increased through 2000 followed by a decline. The southern trends in the spring are similar to that of the fall survey (Figure C43). The proportion of the total biomass in each area has changed from 80% in the 1960s to 60-80% in the north in the last decade (Figure C59). This could indicate movement, differential mortality, or both.

Growth and Maturity

In addition to morphology, genetics, and recruitment trends, growth is often a factor in deciding whether to assess adjacent populations as separate stocks or as one combined stock. Comparisons of growth parameters k and L_∞ (Roomian and Jamili 2011, for example) and growth plots (Brooks and Ortiz 2004, for example) may be confounded by the covariance between these two parameters when simultaneously fitted to size at age data. Similar data can be fit equally well with Von Bertalanffy growth parameters having a low k and high L_∞, and vice versa, unless there are sufficient age samples for old fish. Comparison of plots with associated age data to demonstrate variance around the fitted curves can also lead to subjective mis-interpretation (e.g. determination that growth is not different when in fact it is).

A plot of mean size at age with confidence intervals, one population along the abscissa and one along the ordinate is an alternative and possibly more informative way of comparing growth characteristics between two populations. Similarities in size at age will appear along a slope=1, while differences in growth are readily identifiable as horizontal or vertical deviations from the slope=1 line and the confidence intervals show whether that deviation is significantly different from the other population. Distance between successive ages represents the annual growth increment, which of course declines with age as the fish size approaches L_∞. Another advantage of this approach is that it can be readily applied to cohorts and grouped by time frame, examining the growth of fish that have experienced similar environmental characteristics and food availability.

Age determination of red hake by reading otoliths is described in Penttila and Dery 1988, Chapter 9. Dery's otolith analysis concluded that red hake otoliths in the northern stock area were considerably more difficult to interpret than those from red hake captured in the southern stock area, due to "numerous and sometimes prominent checks", factors that "blur the [sic] distinction between annular zones".

The analysis also indicates that otoliths from red hake captured in the northwestern and eastern part of the Bay of Fundy (Gulf of Maine) varied from the otolith morphology for red hake captured elsewhere and had intermediate characteristics with white hake, suggesting the possible existence of hybridization in that area.

Red hake from the spring and fall surveys have been aged from 1970 to 1985. Before 1975 (1957-1974 cohorts), age 1 to 3 red hake appear to have the same growth rates in the northern and southern stock areas. Then age 4+, growth appears to slow in the southern area and continue to a higher L_∞ in the northern stock area (Figure C60a, Figure C61a). Age 4 to 10 red hake are always larger in the north than in the south.

This general pattern of large, old red hake in the northern stock area persists for the 1975-1985 cohorts (Figure C60b, Figure C61b)). Size at age is also relatively consistent between the two cohort time series.

There are also slight differences in size at maturity between stocks although the differences are in one direction for males and the opposite for females (Figure C62).

Although the large, older fish in the northern stock area would argue for separate population modeling and stock dynamics, there appears to be considerable uncertainty in the interpretation of red hake ages in the northern stock area, due to the aforementioned otolith anomalies, potential hybridization with white hake, and possible differential exploitation patterns between the two areas. It is equivocal whether not there are two stocks, one stock or more. There is not enough information to come to a definitive conclusion.

TOR 4. Estimate measures of annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and characterize their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results.

Historical Retrospective

The last assessments for these stocks were conducted in 1990 and at the time both stocks were considered to be “under-exploited”.

In this assessment, three models were attempted. They were An Index Method (AIM), Stock Synthesis (SS3) and Statistical Catch-at-Length (SCALE). While all three had problems, AIM was considered to be most useful for guidance on reference points and stock status. The other models needed more time to be developed properly.

AIM model

The AIM model is a simple approach for examining the relationship between survey data and catch in data poor stock assessments. AIM is designed to address the question of whether a given rate of fishing mortality is likely to increase or decrease the population size. Survey data are used to define a relative rate of increase and the ratio of catch to survey indices provides a measure of relative fishing mortality. Theoretically the model can identify a stable point about which the stock will neither increase nor decrease in response to a fixed harvest rate. The model assumes that the resource dynamics are approximately linear with relatively minor influence of density dependent effects or variable environmental or ecological factors. Such conditions often typify stocks that have been historically harvested at high fishing rates and are therefore at low population sizes. AIM is both an analytic and graphing approach. The analytical methods can be used to define relative Fs for replacement and the graphical methods can be used to identify transient conditions that are relevant to implementation of any model. The details of the methodology are described below.

- ✓ Population biomass at time t can be written as a linear combination of historical population biomasses
- ✓ Recruitment is proportional to population biomass
- ✓ Fishing mortality is proportional to catch divided by an index of population size (relative F).
- ✓ The rate of change in population biomass is a monotonically decreasing function of relative F.
- ✓ Smoothing methods can be used to identify underlying trends.
- ✓ Randomization methods can be used to develop sampling distributions of test statistics
- ✓ Graphical methods can help identify linkages among variables

Relative F is defined as the ratio of catch to an index of population abundance. A three-year centered average of the abundance index is chosen as the measure of average stock size.

$$relF_{j,s,t} = \left(\frac{C_{s,t}}{\frac{I_{j,s,t-1} + I_{j,s,t} + I_{j,s,t+1}}{3}} \right) \qquad (1)$$

Where $relF_{j,s,t}$ = relative F for relative index j for stock s at time t
$C_{s,t}$ = catch or landings of stock s at time t (in units of weight)
$I_{j,s,t}$= Index of abundance j for stock s at time t expressed in terms of average weight per tow

The population size at any given time can be viewed as a weighted sum of previous recruitment events. For a population with a maximum age of A years, the population in year t consists of the recruits from year t-1, t-2, …t-A. At high levels of total mortality, the contributions from the earliest recruitments, say t-k-1 to t-A will diminish in importance such that the population can be viewed as the sum of recruitments from t-1 to t-k years.

Using the linearity assumption defined above, we can employ basic life history theory to write abundance at time t as a function of the biomasses in previous time periods. The number of recruits at time t (R_t) is assumed to be proportional to the biomass at time t (B_t). More formally,

$$R_t = S_o \, Egg \, B_t \qquad (2)$$

where **Egg** is the number of eggs produced per unit of biomass, and $\mathbf{S_o}$ is the survival rate between the egg and recruit stages. Survival for recruited age groups at age a and time t ($S_{a,t}$) is defined as

$$S_{a,t} = e^{-F_{a,t} - M_{a,t}} \qquad (3)$$

where F and M refer to the instantaneous rates of fishing and natural mortality, respectively. We also need to consider the weight at age a and time t ($W_{a,t}$) and the average longevity (A) of the species.

Using these standard concepts we now write the biomass at time t as a linear combination of the A previous years. Without loss of generality, we can drop the subscripts on the survival terms and assume that average weight at age is invariant with respect to time. Further, set the product S_o Egg equal to the coefficient α. The biomass at time t can now be written as

$$B_t = R_{t-1} S^1 W_1 + R_{t-2} S^2 W_2 + R_{t-3} S^3 W_3 + .. + . R_{t-(A-1)} S^{A-1} W_{A-1} + R_{t-A} S^A W_A \quad (4)$$

Substituting Eq. (2) into Eq. (4) leads to

$$B_t = \alpha \, B_{t-1} S^1 W_1 + \alpha \, B_{t-2} S^2 W_2 + \alpha \, B_{t-3} S^3 W_3 + .. + .\alpha \, B_{t-(A-1)} S^{A-1} W_{A-1} + \alpha \, B_{t-A} S^A W_A \, (5)$$

If the population is replacing itself, then the left hand side of Eq. 5 will equal the right hand side. The replacement ratio can then be defined as

$$\Psi_t = \frac{B_t}{\alpha B_{t-1} S^1 W_1 + \alpha B_{t-2} S^2 W_2 + \alpha B_{t-3} S^3 W_3 + .. + .alphaB_{t-(A-1)} S^{A-1} W_{A-1} + \alpha B_{t-A} S^A W_A} \quad (6)$$

Substituting observed values of abundance indices into Eq 6 leads to

$$\Psi_t = \frac{\frac{I_t}{q}}{\alpha \frac{I_{t-1}}{q} S^1 W_1 + \alpha \frac{I_{t-2}}{q} S^2 W_2 + \alpha \frac{I_{t-3}}{q} S^3 W_3 + .. + \alpha \frac{I_{t-(A-1)}}{q} S^{A-1} W_{A-1} + \alpha \frac{I_{t-A}}{q} S^A W_A} \quad (7)$$

By noting that the q's cancel out, and letting $\varphi_j = \alpha\ S^j W_j$, Eq. 6 simplifies to

$$\Psi_t = \frac{I_t}{\sum_{j=1}^{A} \phi_j \quad I_{t-j}} \qquad (8)$$

All of the I_t and φ_j are positive, and at equilibrium $I_t = I_{t+1}$ and $I_t = \sum \varphi_j I_{t-j}$ both hold. Therefore $\sum \varphi_j = 1$. When the population is not at equilibrium the parameter Ψ becomes a measure of the non equilibrium state of the population and a measure of whether the population is increasing or decreasing relative to prevailing fishery and ecosystem conditions.

It would be desirable to express the parameters of φ_j weighting terms as function of the underlying parameters. Analyses of other stocks with more detailed information, such as Georges Bank haddock, have suggested that setting the φ_j to 1/A is a reasonable approximation. Equations 2 to 8 are a long way of justifying that the ratio of current stock size to a moving average of the previous A years of stock size can be used as a measure of population growth rate. This ratio embeds some life history theory into the basis for the ratio and simultaneously provides a way of damping the variations in abundance owing to measurement error. A ratio defined as I_t/I_{t-1} has been found, as expected to be much more noisy measure of population change.

Further details on the AIM methodology may be found in Working Group (2002) and the NOAA Fisheries Toolbox 3.1 (2010a) software package http://nft.nefsc.noaa.gov/AIM.html. The relationship between $\mathbf{\Psi_t}$ and $\mathbf{relF_t}$ can be expressed as

$$\ln(\Psi_t) = a + b \ln(relF_t) \quad (9)$$

The usual tests of statistical significance do not apply for the model described in Eq. 9. The relation between $\mathbf{\Psi_t}$ and $\mathbf{relF_t}$ is of the general form of Y/X vs X where X and Y are random variables. The expected correlation between Y/X and X is less than zero and is the basis for the oft stated criticism of spurious correlation. To test for spurious correlation we developed a sampling distribution of the correlation statistic using a randomization test. The randomization test is based on the null hypothesis that the catch and survey time series represent a random ordering of observations with no underlying association. The randomization test was developed as follows:

1. Create a random time series of length **T** of $\mathbf{C_{r,t}}$ from the set $\{\mathbf{C_t}\}$ and $\mathbf{I_{r,t}}$ from the set $\{\mathbf{I_t}\}$ by sampling with replacement.
2. Compute a random time series of relative F ($\mathbf{relF_{r,t}}$) and replacement ratios ($\mathbf{\Psi_{r,t}}$)
3. Compute the r-th correlation coefficient, say $\boldsymbol{\rho_r}$ between ln($\mathbf{relF_{r,t}}$) and ln($\mathbf{\Psi_{r,t}}$).
4. Repeat steps 1 to 3 K times.
5. Compare the observed correlation coefficient $\mathbf{r_{obs}}$ with the sorted set of $\boldsymbol{\rho_r}$
6. The approximate significance level of the observed correlation coefficient $\mathbf{r_{obs}}$ is the fraction of values of $\boldsymbol{\rho_r}$ less than $\mathbf{r_{obs}}$

It should be emphasized that relF is not necessarily an adequate proxy for Fmsy, since this parameter only estimates the average mortality rate at which the stock was capable of replacing itself. Thus, while relF defined as average replacement fishing mortality is a necessary condition for an F_{msy} proxy, it is not sufficient, since the stock could theoretically be brought to the stable point under an infinite array of biomass states. The relF at replacement does however provide some guidance on the contemporary rate of harvesting and its potential impact on future stock abundance.

AIM was applied to northern and southern stocks of red hake using 1963-2009 catches which include commercial landings and discards described as “Raw C2”. An alternative catch series from 1980 to 2009, which includes recreational catch, described as “Catch 3” was also applied to both northern and southern red hake. Results of these analyses are described separately in subsequent sections. Each section consists of two tables and three graphs. For all applications Relative F was defined as the ratio of catch to a centered 3-year average of survey abundance (Eq. 1) and the replacement ratio was defined as a 5-year moving average of previous stock sizes (Eq. 8). The relationship between catch, survey, relative F and the replacement ratio for the fall and spring survey indices are depicted for each scenario. Although none of the randomization tests resulted in significant statistical relationship between the replacement ratio and relative F, The HWG decided that the results of the shorter series were considered “best” for purposes of reference point proxies and stock status. This was instead of any more subjective look at the survey and catch data.

Application of AIM to Red Hake, Northern Stock, catch series “Raw C2”

AIM was applied to northern red hake using catches derived from the method denoted as “Raw C2”, and the NEFSC fall and spring bottom trawl survey indices (Table C50). Randomization tests for the fall and spring surveys revealed no significant statistical relationship between the replacement ratio and relative F (Table C51). In fact the randomization test suggested a low probability of obtaining test statistics greater than those observed. Relative F at replacement was poorly specified for both the fall (Figure C63) and spring surveys (Figure C64). The 90% confidence intervals for both surveys (Table C51, Figure C65) were very wide suggesting no information about the relationship between population growth rate and relative F. The six panel plots for the fall and spring surveys (Figures C63 and C64, respectively) suggest that despite a continuously decreasing relative F neither the replacement ratio nor the surveys have any consistent trends. The relationship between the relative F and survey indices suggests that the surveys appear to be changing over time. The large pulse in landings during the early 1970s followed by relatively low catches resulted in about a 3 fold increase in stock size by the early 1980s but the absence of population response in the following three decades since then suggests that factors other than fishing mortality may be responsible.

Application of AIM to Red Hake, Southern Stock, catch series "Raw C2"

AIM was applied to southern red hake using catches derived from the method denoted as "Raw C2", and the NEFSC fall and spring bottom trawl survey indices (Table C52). Randomization tests for the fall and spring surveys revealed no significant statistical relationship between the replacement ratio and relative F (Table C53).

Trends in relative F for the fall (Figure C66) and spring (Figure C67) surveys are remarkably similar owing to similar trends in survey abundance. Abundance indices in both fall and spring surveys show increases since 2000 but remain well below rates observed before 1980. Estimated relative F at replacement for both fall and spring surveys is about 2,200 mt/kg/tow. Bootstrap estimates suggested about a 3-fold range of estimates in the 90% confidence interval (Figure C68)

Relative F at replacement was poorly specified for both the fall (Figure C66) and spring surveys (Figure C67). The 90% confidence intervals for both surveys (Table C53, Figure C68) were very wide suggesting relatively little information about the relationship between population growth rate and relative F. The relationship between the relative F and survey indices suggests that the functional relationship appears to be changing over time. The large pulse in landings during the late 1960s and early 1970s, followed by relatively low catches, was matched with consistently low survey indices. The phase plane plot of survey indices and relative F (left middle panel Figures C66-C67) suggests three separate stanzas wherein the survey declined by similar ranges while the relative F varied by progressively smaller ranges (1967-1976, 1977-1994, 1995-2009). Such changes in the southern stock suggest that factors other than fishing mortality may be responsible for the declines in abundance.

Application of AIM to Red Hake, Northern Stock, catch series "Catch3 short"

In the preceding sections analyses of the relationship between the replacement ratio and relative F suggested nonstationarity. More specifically, the rate of increase in stock size with respect to relative F appeared to be decreasing over time. The reduced duration of the time series for catch was designed to address the potential changes in natural mortality suggested by the consumption estimates. The working group considered another catch estimate, denoted as "Catch 3" for the period 1980-2009 for both the Northern and Southern stocks of red hake.

For northern red hake the continuous declines in landings and relatively small range of change in survey abundance resulted in a steady decline in relative F in the fall survey (Table C54, Figure C69). The replacement ratio varied about 1.0 until 2000 when it fell to low levels before rising sharply in 2009. A similar response was observed in the spring survey (Figure C70). The estimated relative Fs at replacement were nearly identical (162 and 163.1 mt/kg or 0.162 and 0.163 kt/kg; Table C55) but the spring survey estimate had a slightly smaller confidence interval. Bootstrap estimates of relF at replacement had some extreme values (Figure C71). Randomization tests suggest that the probability of observing correlations less than the observed value were 26 to 38% (Table C55).

Application of AIM to Red Hake, Southern Stock, catch series "Catch3 short"

The truncated catch time series was also considered for the southern stock of red hake (Tables C56-C57, Figures C72-C74). Catch estimates for the southern red hake stock consist of two stanzas of landings of about 5000 mt before 1994 and roughly half as much annually since then (Table C56, Figures C72-C73). Both the fall and spring surveys declined consistently during the high catch stanza and have recently increased since the early 2000s. The increase in replacement ratio since 2000 was preceded by near halving of relative F in the late 1990s from its peak value (Figures C72-C73).

The phase plane plots of survey and relative F again suggest similar population responses to exploitation but differing slopes before and after 1994. Fall and spring relative fishing mortalities at replacement are similar, 2300 vs 3038 mt/kg (2.300 vs 3.038 kt/kg; Table C57). The relative F at replacement for the fall and spring surveys have overlapping confidence intervals but randomization tests suggest that the degree of association between relative F and the replacement ratio is not significant.

AIM Model Choice

Although none of the randomization tests resulted in significant statistical relationship between the replacement ratio and relative F, the HWG decided that the results of the shorter series were considered "best" for purposes of reference point proxies and stock status. This was instead of any more subjective look at the survey and catch data at least until an analytical assessment can be developed in the future.

[SAW51 Editor's Note: The red hake SCALE and SS3 model description and results, which are described below, are included in the report mainly to document the modeling that the Red Hake Working Group provided to the SARC-51 for peer review. The results from these two models were not accepted as a basis for providing management advice.]

Stock Synthesis Model (SS3)

A forward-projecting statistical catch-at age model (Stock Synthesis 3 version 3.11c, NOAA Fisheries Toolbox (NFT) 3.1 (2010c)) was attempted to be used to estimate fishing mortality rates and stock sizes for the northern stock, southern stock and combined areas. The first attempts at modeling used the length-based model estimated catches and fit stock-recruitment relationships using both Ricker and Beverton-Holt. The results were promising, but the stock-recruitment relationships caused some problems including some negative SSBmsy estimates). After the HWG decided to use the nominal catch in the models, there were no improvements to the fits of any of the models with stock-recruitment relationships. Therefore, the SR alternative to not fit a SR relationship was used for the remainder of the models.

Other issues involved fits to the length compositions (Figure C75), particularly the fall survey in which the small fish are under-estimated in the model. The HWG decided that this may be due to a peculiarity of red hake. The survey may be catching more small fish before they settle and inhabit scallop shells. This may result in an unusual selectivity pattern not available in any current model. So the Age-0 fish were removed from the fall survey and used as a recruitment index as well as the Age-1 spring survey data.

Another length fitting problem was initially thought to be a major model problem (Figure C76). In all the model runs, there is a knife-edge increase at 55 cm. On further inspection, it was due to the binning of length data above 55 cm. The length bins above 5 cm were single cm intervals until 55 cm at which time a 5 cm and then a 10 cm bin was used. After this was changed to cm intervals through 80 cm, the fits were better, although in recent years there is some problem with the model estimating more large fish than in any of the data (Figure C77).

One of the final model runs used four fleets of catch data (landings, discards, recreational catch and consumption) and four survey indices (spring, fall, spring recruitment and fall recruitment). The fits to the survey data were not very good and showed some patterning in the residuals (Figure C78). The main problem was in the fit to the length composition of the consumption data. The single length composition did not fit the model predicted length composition (Figure C79). Several tweaks were attempted to solve this, including changing the size at age 1, moving the time of consumption from mid-year to the beginning of the year, and removing consumption to be replaced with an age-varying natural mortality. None of these options were successful and most of the variations did not converge. Therefore, no SS3 models were accepted at this time, although the HWG thought that it was worthwhile to pursue for the next assessment.

Statistical Catch-at-Length Model (SCALE)

<u>Introduction</u>

Incomplete or lack of age-specific catch and survey indices often limits the application of a full age-structured assessment (e.g. Virtual Population Analysis and many forward projecting age-structured models). Stock assessments will often rely on the simpler size/age aggregated models (e.g. surplus production models) when age-specific information is lacking. However the simpler size/age aggregated models may not utilize all of the available information for a stock assessment. Knowledge of a species growth and lifespan, along with total catch data, size composition of the removals, recruitment indices and indices on numbers and size composition of the large fish in a survey can provide insights on population status using a simple model framework.

The Statistical Catch At LEngth (SCALE,NOAA Fisheries Toolbox (NFT) 3.1 (2010b)) model, is a forward projecting age-structured model tuned with total catch (mt), catch at length or proportional catch at length, recruitment at a specified age (usually estimated from first length mode in the survey), survey indices of abundance of the larger/older fish (usually adult fish) and the survey length frequency distributions. The SCALE model was developed in the AD model builder framework. The model parameter estimates are fishing mortality and recruitment in each year, fishing mortality to produce the initial population (Fstart), logistic selectivity parameters for each year or blocks of years and Qs for each survey index.

The SCALE model was developed as an age-structured model that does NOT rely on age-specific information on a yearly basis. The model is designed to fit length information, abundance indices, and recruitment at age which can be estimated by using survey length slicing. However the model does require an accurate representation of the average overall growth of the population which is input to the model as mean lengths at age. Growth can be modeled as sex-specific growth and natural mortality or growth and natural mortality can be model with the sexes combined. The SCALE model will allow for missing data.

Model Configuration

The SCALE model assumes growth follows the mean input length at age with predetermined input error in length at age. Therefore a growth model or estimates of the average mean length at age is essential for reliable results. The model assumes static growth and therefore population mean length/weight at age are assumed constant over time.

The SCALE model estimates logistic parameters for a flattop selectivity curve at length in each time block specified by the user for the calculation of population and catch age-length matrices or the user can input fixed logistic selectivity parameters. Presently the SCALE model cannot account for the dome shaped selectivity pattern.

The SCALE model computes an initial age-length population matrix in year one of the model as follows. First the estimated populations numbers at age starting with age-1 recruitment get normally distributed at one cm length intervals using the mean length at age with the assumed standard deviation. Next the initial population numbers at age are calculated from the previous age at length abundance using the survival equation. An estimated fishing mortality (Fstart) is also used to produce the initial population. This F can be thought of as the average fishing mortality that occurred before the first year in the model. Now the process repeats itself with the total of the estimated abundance at age getting redistributed according to the mean length at age and standard deviation in the next age (age+1).

This two step process is used to incorporate the effects of length specific selectivities and fishing mortality. The initial population length and age distribution is constructed by assuming population equilibrium with an initial value of F, called F_{start}. Length specific mortality is estimated as a two step process in which the population is first decremented for the length specific effects of mortality as follows:

$$N^{*}_{a,len,y_1} = N_{a-1,len,y_1} e^{-\left(PR_{len}F_{start}+M\right)}$$

In the second step, the total population of survivors is then redistributed over the lengths at age *a* by assuming that the proportions of numbers at length at age *a* follow a normal distribution with a mean length derived from the input growth curve (mean lengths at age).

$$N_{a,len,y_1} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^*_{a,len,y_1}$$

where

$$\pi_{len,a} = \Phi\left(len + 1 \mid \mu_a, \sigma_a^2\right) - \Phi\left(len \mid \mu_a, \sigma_a^2\right)$$

where

$$\mu_a = L_\infty\left(1 - e^{-K(a-t_0)}\right)$$

Mean lengths at age can be calculated from a von Bertalanffy model from a prior study as shown in the equation above or mean lengths at age can be calculated directly from an age-length key. Variation in length at age a = σ_s^2 can often be approximated empirically from the growth study used for the estimation of mean lengths at age. If large differences in growth exist between the sexes then growth can be input as sex-specific growth with sex-specific natural mortality. However catch and survey data are still fitted with sexes combined.

This SCALE model formulation does not explicitly track the dynamics of length groups across age because the consequences of differential survival at length at age a do not alter the mean length of fish at age a+1. However, it does more realistically account for the variations in age-specific partial recruitment patterns by incorporating the expected distribution of lengths at age.

In the next step the population numbers at age and length for years after the calculation of the initial population use the previous age and year for the estimate of abundance. Here the calculations are done on a cohort basis. Like in the previous initial population survival equation the partial recruitment is estimated on a length vector.

$$N^*_{a,len,y} = N_{a-1,len,y-1} e^{-\left(PR_{len} F_{y-1} + M\right)}$$

second stage

$$N_{a,len,y} = \pi_{len,a} \sum_{len=0}^{L_\infty} N^*_{a,len,y}$$

Constant M is assumed along with an estimated length-weight relationship to convert estimated catch in numbers to catch in weight. The standard Baranov=s catch equation is used to remove the catch from the population in estimating fishing mortality.

$$C_{y,a,len} = \frac{N_{y,a,len} \, F_y \, PR_{len}\left(1 - e^{-\left(F_y PR_{len} + M\right)}\right)}{(F_y \quad PR_{len}) + M}$$

Catch is converted to yield by assuming a time invariant average weight at length.

$$Y_{y,a,len} = C_{y,a,len} W_{len}$$

The SCALE model results in the calculation of population and catch age-length matrices for the starting population and then for each year thereafter. The model is programmed to estimate recruitment in year 1 and estimate variation in recruitment relative to recruitment in year 1 for each year thereafter. Estimated recruitment in year one can be thought of as the estimated average long term recruitment in the population since it produces the initial population. The residual sum of squares of the variation in recruitment $\sum(\text{Vrec})^2$ is then used as a component of the total objective function. The weight on the recruitment variation component of the objective function (Vrec) can be used to penalize the model for estimating large changes in recruitment relative to estimated recruitment in year one.

The model requires an age-1 recruitment index for tuning or the user can assume relatively constant recruitment over time by using a high weight on Vrec. Usually there is little overlap in ages at length for fish that are one and/or two years of age in a survey of abundance. The first mode in a survey can generally index age-1 recruitment using length slicing. In addition numbers and the length frequency of the larger fish (adult fish) in a survey where overlap in ages at a particular length occurs can be used for tuning population abundance. The model tunes to the catch and survey length frequency data using a multinomial distribution. The user specifies the minimum size (cm) for the model to fit. Different minimum sizes can be fit for the catch and survey data length frequencies.

The number of parameters estimated is equal to the number of years in estimating F and recruitment plus one for the F to produce the initial population (Fstart), logistic selectivity parameters for each year or blocks of years, and for each survey Q. The total likelihood function to be minimized is made up of likelihood components comprised of fits to the catch, catch length frequencies, the recruitment variation penalty, each recruitment index, each adult index, and adult survey length frequencies:

$$\mathrm{L_{catch}} = \sum_{years}\left(l\,\mathrm{n}(Y_{\mathrm{obs,y}}+1) - \ln\left(\sum_{a}\sum_{len}\mathrm{Y_{pred,len,a,y}}+1\right)\right)^2$$

$$L_{catch\_lf} = -N_{eff}\sum_{y}\left(\sum_{inlen}^{L_\infty}\left(\left(C_{y,len}+1\right)\ln\left(1+\sum_{a}C_{pred,y,a,len}\right)-\ln\left(C_{y,len}+1\right)\right)\right)$$

$$\mathrm{L_{vrec}} = \sum_{y=2}^{Nyears}\left(Vrec_y\right)^2 = \sum_{y=2}^{Nyears}\left(R_1 - R_y\right)^2$$

$$\sum L_{rec} = \sum_{i=1}^{Nrec}\left[\sum_{y}^{Nyears}\left(\ln\left(I_{rec_i,inage_i,y}\right)-\ln\left(\sum_{len}^{L_\infty} N_{y,inage_i,len} * q_{rec\,i}\right)\right)^2\right]$$

$$\sum L_{adult} = \sum_{i=1}^{Nadult}\left[\sum_{y}^{Nyears}\left(\ln\left(I_{adult_i,inlen+_i,y}\right)-\left(\sum_{a}\sum_{inlen_i}^{L_\infty}\ln\left(N_{pred,y,a,len} * q_{adult\,i}\right)\right)\right)^2\right]$$

$$\sum L_{lf} = \sum_{i=1}^{Nlf}\left[-N_{eff}\sum_{y}\left(\sum_{inlen_i}^{L_\infty}\left(\left(I_{lf_i,y,len}+1\right)\ln\left(1+\sum_{a}N_{pred,y,a,len}\right)-\ln\left(I_{lf_i,y,len}+1\right)\right)\right)\right]$$

In equation L_{catch_lf} calculations of the sum of length are made from the user input specified catch length to the maximum length for fitting the catch. Input user specified fits are indicated with the prefix "in" in the equations. LF indicates fits to length frequencies. In equation L_{rec} the input specified recruitment age and in L_{adult} and L_{lf} the input survey specified lengths up to the maximum length are used in the calculation.

$$Obj\ \ fcn = \sum_{i=1}^{N}\lambda_i L_i$$

Lambdas represent the weights to be set by the user for each likelihood component in the total objective function.

Application to red hake

Various model formulations were attempted for the northern stock, southern stock and combined stocks. These included different natural mortalities, the alternative catch series, and different time series. All models had issues with the absence of older ages (sizes) at the end of the time series and lack of fit to the catch at the beginning of the time series. The model run done starting the time series in 1980, but the model does not fit to the declining trend in catch. The model also had a very strong retrospective pattern (Figures C80a-c). Since consumption cannot be added to SCALE as it is configured, it will no longer be considered as a potential candidate model for this red hake assessment.

5. ***State the existing stock status definitions for the terms "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; estimates or proxies for BMSY, BTHRESHOLD, and FMSY; and estimates of their uncertainty). If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.***

The overfishing definitions are taken from NEFMC (2000, 2003) and are as follows:

The northern stock of red hake is overfished when the three-year moving average of stock biomass, derived from the fall survey, is below **1.6 kg/tow**. *If an analytical assessment is available for northern red hake, then the three-year moving average will be replaced with the terminal year biomass estimate and compared with the biomass reference points.*

Overfishing occurs when the ratio between catch and survey biomass exceeds ***0.65****, the proxy for FMSY. When biomass is less than 3.1 kg/tow (the biomass target), the stock is overfished when fishing mortality is above a rate that declines linearly to zero when biomass equals the minimum biomass threshold (1.6 kg/tow).*

In 1998 the Overfishing Definition Review Panel (Applegate et al. 1998) concluded that MSY and F reference points could not be determined for southern red hake because the time series of landings and survey biomass indices did not include a period of stable landings at high biomass levels. The Panel noted that discarding could be significant, especially in the scallop and trawl fisheries. Habitat destruction was also thought to be prohibiting stock recovery since juveniles rely on intact scallop beds for shelter. However, in recent years the scallop stock has been recovering, but red hake biomass indices have not increased.

The southern stock of red hake is in an overfished condition when the three-year moving average weight per individual in the fall survey falls below the 25th percentile of the average weight per individual from the fall survey time series 1963-1997 (0.12) ***AND*** *when the three-year moving average of the abundance of immature fish less than 25 cm falls below the median value of the 1963-1997 fall survey abundance of fish less than 25 cm (4.72).*

In previous SAFE Reports, the Whiting Monitoring Committee (WMC) noted problems associated with the overfishing definition for southern red hake. Although the current definition is intended to identify overfished (i.e. low biomass) stock conditions, it is a better indication of overfishing (high exploitation rate) conditions. The WMC recommends that the overfishing definition for the southern stock of red hake be revisited after a benchmark stock assessment is completed.

The Hake Working Group examined both the fall and spring surveys and decided that the spring had more consistency in the AIM results (smaller confidence intervals for the relative F). The Hake Working Group also agreed with the WMC about the problems associated with the existing biomass reference point for the southern stock of red hake. Therefore the HWG proposes new BRPs (in kg/tow in Albatross units) for both northern and southern red hake stocks as follows:

> *Red hake is overfished when the three-year moving average of the spring survey weight per tow (i.e., the biomass threshold) is less than one half of the BMSY proxy, where the BMSY proxy is defined as the average observed from 1980 – 2010. The current estimates of Bthreshold for the northern and southern stocks are 1.27 kg/tow and 0.51 kg/tow, respectively.*
>
> *Overfishing occurs when the ratio between catch and survey biomass exceeds 0.163 kt/kg and 3.038 kt/kg, respectively, derived from AIM analyses from 1980-2009.*

Applying the BMSY proxy to the replacement F allows for an MSY of 412 mt and 3086 mt for the northern and southern stocks, respectively.

The biomass reference points could be considerably different depending on the time series used to develop the average. For instance, if the entire time series was used, the B*MSY proxy* would be 2.43 kg/tow for the north and 1.61 for the south. If a shorter time series was chosen, for example 1990-2010, the two reference points would be 2.17 and 0.58, respectively. Other stocks have used the entire time series, but instead of the average, used the 75th percentile of the series (NEFSC 2007b). This would also change the reference points to 3.22 and 2.25 kg/tow, respectively. The Working Group chose the intermediate to reflect the potential increase in natural mortality suggested by the consumption estimates.

The 80% confidence intervals around the Freplacement for the north are from 0.062-0.240 kt/kg/tow (Figure C71) and for the south are 2.240 -3.700 kt/kg/tow (Figure C74).

6. Evaluate stock status (overfished and overfishing) with respect to the existing BRPs, as well as with respect to the "new" BRPs (from Red hake TOR 5).

Based on current biological reference points in the existing FMP, the northern stock of red hake is not overfished and overfishing is not occurring. The three year delta mean biomass index (Figure C81), based on NEFSC fall bottom trawl survey data for 2007-2009 (2.87 kg/tow), was above the management threshold level (1.6 kg/tow) and slightly below the target (3.1 kg/tow). The three year average exploitation index (landings divided by biomass index, Figure C82) for 2007-2009 (0.03) was below both the target (0.39) and the threshold (0.65).

Based on current biological reference points in the existing FMP, the southern stock of red hake is not overfished and overfishing is unknown. The three year delta individual mean weight index (Figure C83), based on NEFSC fall bottom trawl survey data for 2007-2009 (0.10 kg/individual), is below the management threshold (0.12 kg/individual) but the three year average recruitment index (5.95 num/tow) is above the threshold value (4.72 num/tow).

Based on new recommended biological reference points from SARC 51, the northern stock of red hake is not overfished and overfishing is not occurring. The three year arithmetic mean biomass index (Figure C84), based on NEFSC spring bottom trawl survey data in Albatross units for 2008-2010 (2.42 kg/tow), was above the proposed management threshold (1.27 kg/tow) and slightly below the target (2.53 kg/tow). The exploitation index (catch divided by biomass index, Figure C85) for 2007-2009 (0.103 kt/kg) was below the threshold (0.163 kt/kg).

Based on new recommended biological reference points from SARC 51, the southern stock of red hake is not overfished and overfishing is not occurring. The three year arithmetic mean biomass index (Figure C86), based on NEFSC spring bottom trawl survey data in Albatross units for 2008-2010 (0.95 kg/tow), was above the proposed management threshold (0.51 kg/tow) and slightly below the target (1.02 kg/tow). The exploitation index (catch divided by biomass index, Figure C87) for 2007-2009 (1.150 kt/kg) was below the threshold (3.038 kt/kg).

7. Develop and apply analytical approaches and data that can be used for conducting single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).
a. Provide numerical short-term projections (3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment (e.g., terminal year abundance, variability in recruitment).
b. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.
c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.

Stochastic projections were not performed for this assessment. However, applying the Relative F reference points to the three-year average biomass index allows catches of 394 mt in the north and 2897 mt in the south.

8. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

SAW 1 - 1985

1. Updated VPA based on new stock boundaries will be undertaken
   Attempted several analytical models with no success.

2. A re-analysis of growth rate

This assessment estimated growth parameters for the "new" stock definitions as well as smaller regions.

3. Predator/prey considerations for red hake are important
   This assessment estimated consumption of red hake by the major predators.

4. CPUE indices need to be re-calculated given new stock boundaries
   CPUE is no longer considered a valid abundance index for this species due to the management changes that have occurred in the last twenty-five years.

New Research Recommendations

- Studies to estimate discard mortality should be conducted.
- Develop explicit process and criteria for the application of length-based (vs. constant) calibration coefficients (other than purely statistical criteria such as AIC, etc.). It may be useful, if enough data exist, to attempt a cross validation with a subset of data.
- Information on consumption by more predators (including mammals, highly migratory species (HMS)) needs to be included.
- Diel (day/night) variation in consumption of hakes.
- Validation of the ageing method for red hake via tagging, radiocarbon, or tetracyclin research.
- More comprehensive analysis of red hake stock structure based on DNA (expanded genetic analysis).
- Perform a stock reduction analysis
- Continue developing an analytical assessment with Stock Synthesis or ASAP as more age data are available.
- Continue ageing the available samples.

Sources of Uncertainty

8. Catch data are uncertain given the identification issues between red and white hake, as well as possible hybridization between the two species.
9. Stock structure is not known and has been assumed by analogy with silver hake.
10. Growth estimates are from a time of assumed high mortality and should be revisited when data become available.
11. Natural mortality is unknown.
12. Consumption
    a. Minimum swept area estimates for some predator abundance does not account for q for all predators; these are likely lower estimates of predator abundance and thus these consumption estimates should be viewed as conservative estimates. Although stock assessment estimates of abundance were used for some predators, using a full range of abundance estimates from stock assessments for more predators would also likely increase the estimates noted here.
    b. Is the α too low compared to literature? These too may be somewhat conservative, but are within the range of those generally reported. Again, these should be viewed as conservative estimates.

c. Some fish predators that did not consistently eat red hake (e.g. some of the skates, other gadids) were not included in the analysis.
d. Also, these estimates did not include a wide range of other (non-fish) predators known to consume red hake (e.g., seabirds, squids, marine mammals), nor did they include red hake cannibalism, which is suspected to be significant. Collectively this relatively limited set of predators thus may result in these being fairly conservative estimates of overall predatory removals of red hake.
e. Spatio-temporal overlap considerations between predators and red hake were assumed. This work was done for both red hake stocks combined and could be reevaluated for both stocks separately.

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C. Red Hake-Tables

Table C1. Nominal commercial landings of red hake (mt) from the northern stock from 1960-2009. US landings from 1994-2009 include landings reported as bait on Vessel Trip Reports.

	Northern Stock			Southern Stock			Combined Stock		
Year	US	DWF	Total	US	DWF	Total	US	DWF	Total
1960	3,792		3,792	4,286		4,286	8,078		8,078
1961	3,276		3,276	8,105		8,105	11,381		11,381
1962	1,911		1,911	11,865		11,865	13,776		13,776
1963	1,225	2,056	3,281	29,712	2,189	31,901	30,937	4,245	35,182
1964	288	1,121	1,409	32,622	10,751	43,373	32,910	11,872	44,782
1965	200	2,573	2,773	25,246	67,744	92,990	25,446	70,317	95,763
1966	885	4,690	5,575	3,985	103,937	107,922	4,870	108,627	113,497
1967	577	1,286	1,863	6,764	52,019	58,783	7,341	53,305	60,646
1968	552	2,075	2,627	7,001	11,137	18,138	7,553	13,212	20,765
1969	146	1,875	2,021	5,539	47,389	52,928	5,685	49,264	54,949
1970	261	771	1,032	4,679	6,775	11,454	4,940	7,546	12,486
1971	377	4,428	4,805	3,227	31,907	35,134	3,604	36,335	39,939
1972	538	14,488	15,026	1,995	59,199	61,194	2,533	73,687	76,220
1973	362	14,926	15,288	3,603	47,759	51,362	3,965	62,685	66,650
1974	891	6,332	7,223	2,183	24,460	26,643	3,074	30,792	33,866
1975	450	8,251	8,701	2,065	17,911	19,976	2,515	26,162	28,677
1976	653	5,684	6,337	3,905	18,560	22,465	4,558	24,244	28,802
1977	889	2	891	2,522	4,540	7,062	3,411	4,542	7,953
1978	1,223		1,223	3,327	2,136	5,463	4,550	2,136	6,686
1979	1,523		1,523	6,624	968	7,592	8,147	968	9,115
1980	1,029		1,029	3,927	155	4,082	4,956	155	5,111
1981	1,246		1,246	2,124	196	2,320	3,370	196	3,566
1982	1,210		1,210	2,993	177	3,170	4,203	177	4,380
1983	895		895	1,334	107	1,441	2,229	107	2,336
1984	1,059		1,059	1,214	57	1,271	2,273	57	2,330
1985	992		992	827	76	903	1,819	76	1,895
1986	1,457		1,457	644	50	694	2,101	50	2,151
1987	1,013		1,013	943		943	1,956		1,956
1988	862		862	871		871	1,733		1,733
1989	776		776	931		931	1,707		1,707
1990	826		826	798		798	1,624		1,624
1991	743		743	925		925	1,668		1,668
1992	918		918	1,245		1,245	2,163		2,163
1993	768		768	924		924	1,693		1,693
1994	727		727	983		983	1,710		1,710
1995	186		186	1,428		1,428	1,613		1,613
1996	409		409	700		700	1,109		1,109
1997	338		338	999		999	1,337		1,337
1998	187		187	1,154		1,154	1,342		1,342
1999	220		220	1,351		1,351	1,571		1,571
2000	197		197	1,417		1,417	1,614		1,614
2001	222		222	1,469		1,469	1,691		1,691
2002	275		275	663		663	938		938
2003	210		210	623		623	832		832
2004	103		103	588		588	691		691
2005	96		96	356		356	452		452
2006	96		96	375		375	471		471
2007	69		69	470		470	539		539
2008	52		52	580		580	632		632
2009	85		85	575		575	659		659

Table C2. US landings of red hake (mt) from the northern region by state. Unknown state landings include landings reported as bait on Vessel Trip Reports as well as industrial fishery landings.

Year	CT	ME	MD	MA	NH	NJ	NY	RI	Unknown	Total
1964				144					144	288
1965		<1		200						200
1966				371					514	885
1967		<1		118					459	577
1968				92					460	552
1969				134					12	146
1970				261					<1	261
1971		12		363					2	377
1972				538						538
1973		39		323						362
1974		17		469				<1	405	891
1975		1		448				1		450
1976		3		650				<1		653
1977		25		864				1		889
1978		18		1205				<1	<1	1,223
1979		12		1509				1	1	1,523
1980		26		1000				1	2	1,029
1981		83		1162	1			1		1,246
1982		70		1073	61	6		1		1,210
1983		56		839	<1			<1		895
1984		47		1011	1			<1		1,059
1985		77		909	<1			5		992
1986		190		1265	<1			2		1,457
1987		132		877	1			4		1,013
1988		34		763	7	<1		58		862
1989		20		675	1			79		776
1990		5	<1	719	<1			100		826
1991		4		712	<1			27		743
1992		13		818	22			65		918
1993		<1		686	21			62		768
1994		37		631	30			16	13	727
1995	7	<1	<1	122	14		2	1	40	186
1996	5			360			<1	13	31	409
1997	5	<1		309	<1	1	2	6	15	338
1998	6	<1		136			21	10	14	187
1999	23	<1		162		<1	12	7	16	220
2000	13	<1		151		<1		8	25	197
2001	22	<1		154	<1		10	15	21	222
2002	20	<1		197	<1		5	22	31	275
2003	3	<1		141	<1		7	34	25	210
2004	21			50	<1		1	2	29	103
2005	16			47	<1		1	<1	32	96
2006	12			55	<1		2	6	21	96
2007	<1	<1	<1	31			1	3	33	69
2008	<1	<1		9		<1	<1	<1	43	52
2009	1	<1		10	<1		<1	<1	74	85

Table C3. US landings of red hake (mt) from the southern region by state. Unknown state landings include landings reported as bait on Vessel Trip Reports as well as industrial fishery landings.

Year	CT	DE	ME	MD	MA	NH	NJ	NY	NC	RI	VA	Unknown	Total
1964					1160					67		31395	32,622
1965					880					119		24247	25,246
1966					39					77		3869	3,985
1967										40		6724	6,764
1968										155		6846	7,001
1969					<1					266		5273	5,539
1970										330		4349	4,679
1971					2					142		3083	3,227
1972					<1					216		1779	1,995
1973					<1					182		3421	3,603
1974					<1					193		1990	2,183
1975					<1					411		1654	2,065
1976					1					594		3310	3,905
1977					5					243		2274	2,522
1978					3		592			130		2602	3,327
1979					7		958			247		5412	6,624
1980					<1		787			317		2823	3,927
1981					5		732			184		1203	2,124
1982				12	2		427			378	7	2166	2,993
1983				15	1		439			587	16	276	1,334
1984				24	1		403			617	26	143	1,214
1985				8	1		276			418	9	115	827
1986				3	2		225	61		350	3		644
1987				8	1		171	210		548	5		943
1988				13	1		233	180		440	4		871
1989	11			21	1		319	239		337	4		931
1990	12	<1		12	2		332	96		338	6		798
1991	52	<1		5	2		274	147		441	3		925
1992	134	1		5	2		195	319		588	1		1,245
1993	149	2		5	1		234	199		333	2		924
1994	92	1		4	4		225	235		415	2	5	983
1995	418	1	<1	3	1	<1	186	272		539	1	7	1,428
1996	100		<1	2	14		61	196		324	1	2	700
1997	169			4	4		104	275	<1	430	1	12	999
1998	114			2	8		111	373	<1	544	2		1,154
1999	141			3	22		112	428	<1	641	<1	4	1,351
2000	159			<1	29		153	398	<1	676	<1	2	1,417
2001	129		1	12	15		145	451	<1	688	<1	28	1,469
2002	132	<1		<1	15	<1	61	186	<1	244	1	24	663
2003	186			<1	54		14	119	<1	249	<1	1	623
2004	169	<1		<1	77		18	98	<1	210	1	15	588
2005	156			<1	18		21	47		102	<1	12	356
2006	108	<1		1	47		19	19		174	<1	6	375
2007	121	<1		1	43		53	46		170	<1	36	470
2008	64	<1		1	30		47	73		273	2	89	580
2009	87	<1		1	45		81	74		175		113	575

Table C4. US landings of red hake (mt) from the northern region by gear. Landings reported as bait on Vessel Trip Reports and industrial fishery landings are assumed to be otter trawl.

Year	LL	OTF	OTS	SGN	OTH	Total
1964	<1	288			<1	288
1965	<1	199			<1	200
1966	<1	885				885
1967	<1	577			<1	577
1968	<1	552			<1	552
1969	1	145			<1	146
1970	1	260				261
1971	1	376				377
1972	1	538				538
1973	1	339		23	<1	362
1974	<1	890		1		891
1975	8	397	36	6	3	450
1976	41	589	4	19	1	653
1977	24	824	15	26	<1	889
1978	28	1190		4	1	1,223
1979	<1	1516	4	2	<1	1,523
1980	1	1021	1	4	1	1,029
1981	5	1140	6	95	1	1,246
1982	<1	1148	21	39	1	1,210
1983	1	866	22	4	2	895
1984	<1	1038	17	2	1	1,059
1985	3	920	44	24	<1	992
1986	<1	1174	269	5	9	1,457
1987	1	815	171	4	22	1,013
1988	1	793	46	5	16	862
1989	2	690	47	34	2	776
1990	2	720	76	22	4	826
1991	5	642	64	30	3	743
1992	4	861	22	25	6	918
1993	3	729	<1	5	32	768
1994	2	690	1	8	26	727
1995	1	171		2	12	186
1996	2	404	1	1	1	409
1997	3	323	1	2	9	338
1998	1	184		1	1	187
1999	<1	215		4	1	220
2000	<1	191		2	4	197
2001	<1	208		2	12	222
2002	<1	273		2	<1	275
2003	<1	206		1	3	210
2004	<1	100		<1	3	103
2005	<1	95		<1	1	96
2006		96		<1	<1	96
2007		69		<1	<1	69
2008	<1	52		<1	<1	52
2009		85		<1	<1	85

Table C5. US landings of red hake (mt) from the southern region by gear. Landings reported as bait on Vessel Trip Reports and industrial fishery landings are assumed to be otter trawl.

Year	LL	OTF	SGN	OTH	Total
1964		32622			32,622
1965		25246			25,246
1966		3985			3,985
1967		6764			6,764
1968		7001			7,001
1969		5539		<1	5,539
1970		4679		<1	4,679
1971		3227			3,227
1972		1983	<1	12	1,995
1973		3603			3,603
1974	<1	2183		<1	2,183
1975		2065		<1	2,065
1976		3903	<1	2	3,905
1977		2520		2	2,522
1978		3269		58	3,327
1979		6526	<1	98	6,624
1980	<1	3885	<1	42	3,927
1981		2076	<1	48	2,124
1982		2928	<1	64	2,993
1983		1265	4	65	1,334
1984		1102	1	111	1,214
1985		772	2	53	827
1986	<1	601	<1	44	644
1987	<1	889	<1	54	943
1988	<1	800	<1	70	871
1989		838	1	92	931
1990	<1	741	1	56	798
1991	<1	868	3	54	925
1992	15	1185	1	44	1,245
1993	<1	849	2	73	924
1994	<1	853	3	127	983
1995	<1	992	1	435	1,428
1996	<1	693	1	6	700
1997	<1	984	1	14	999
1998	1	1141	1	11	1,154
1999	1	1337	<1	13	1,351
2000	<1	1399	3	15	1,417
2001	1	1443	10	15	1,469
2002	<1	654	1	8	663
2003	<1	620	<1	2	623
2004	<1	576	2	10	588
2005	<1	349	<1	6	356
2006	<1	369	<1	6	375
2007		460	<1	10	470
2008	2	567	3	8	580
2009		550	<1	25	575

Table C6. US landings of red hake (mt) from the northern region by month. Landings reported as bait on Vessel Trip Reports and industrial fishery landings are included as unknown month.

Year	Unk	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1964	144	1	2	1	1	<1	6	9	17	34	48	25	2	288
1965		2	1	3	1	31	2	8	19	18	39	61	15	200
1966	514	2	2	3	3	1	4	67	93	56	54	73	13	885
1967	459	2	1	3	<1	1	23	11	9	3	24	21	21	577
1968	460	1	1	1	<1		4	5	1	5	28	42	4	552
1969	12	1	<1	1	<1	1	1	4	4	22	58	32	12	146
1970	<1	2	4	11	28	7	10	25	22	53	55	39	5	261
1971	2	4	4	8	4	6	18	32	54	75	86	61	23	377
1972		7	4	3	7	2	23	82	97	85	125	71	31	538
1973		8	3	4	12	4	10	41	56	41	81	59	45	362
1974	405	22	9	8	34	16	23	65	84	85	79	40	22	891
1975		17	6	8	19	26	43	86	51	77	58	43	16	450
1976		7	15	6	14	25	73	125	99	105	91	58	36	653
1977		20	17	42	28	48	74	154	124	105	137	79	63	889
1978	<1	17	17	19	29	33	99	255	248	211	165	90	40	1,223
1979	1	27	8	16	30	78	191	403	271	205	169	87	37	1,523
1980	2	10	7	7	15	41	133	218	176	184	130	73	32	1,029
1981		44	24	25	25	59	143	182	233	195	212	80	25	1,246
1982		29	20	14	26	44	110	175	179	193	263	100	59	1,210
1983		24	10	10	15	35	153	169	145	134	122	57	21	895
1984		20	8	4	5	18	106	199	219	185	176	79	40	1,059
1985		14	4	12	11	41	74	169	173	205	166	70	52	992
1986		18	72	65	47	75	134	146	172	156	179	217	176	1,457
1987		22	12	29	47	92	120	126	137	133	94	109	92	1,013
1988		16	7	27	14	33	61	148	160	115	145	97	38	862
1989		7	2	8	14	29	147	108	141	110	127	58	23	776
1990		18	9	6	18	23	60	170	198	97	133	49	42	826
1991		28	10	8	14	18	39	156	122	72	154	90	30	743
1992		16	8	4	2	56	66	148	144	122	175	146	31	918
1993		20	<1	<1	1	63	59	120	150	114	145	70	25	768
1994	13	5	<1	<1	16	13	39	143	155	132	127	62	23	727
1995	40	<1	1	<1	1	1	1	30	58	33	19	2	1	186
1996	31	<1	<1	<1	<1	14	89	36	79	64	81	11	2	409
1997	15	1	<1	1.3	2	12	5	27	48	53	142	28	3	338
1998	14	<1	<1	<1	6	<1	2	21	41	34	55	10	2	187
1999	16	<1	<1	<1	<1	1	4	35	44	64	47	7	4	220
2000	25	5	3	6.8	1	<1	7	24	35	26	54	8	2	197
2001	21	4	2	2.1	4	2	5	35	25	34	50	33	5	222
2002	31	2	4	<1	<1	1	3	36	43	67	64	17	5	275
2003	25	2	<1	<1	<1	1	2	40	52	42	26	15	5	210
2004	29	1	1	0.9	<1	1	<1	4	12	35	15	3	<1	103
2005	32	<1	<1	<1		<1		13	45	4	1	1	<1	96
2006	21		1	<1	<1		<1	12	41	19	1	<1	<1	96
2007	33	<1		1	<1	<1	<1	6	15	4	7	1	<1	69
2008	43	<1	<1	<1	<1	<1	<1	<1	3	1	1	2	1	52
2009	74		<1	<1		<1	<1	5	3	2	<1	1	<1	85

Table C7. US landings of red hake (mt) from the southern region by month. Landings reported as bait on Vessel Trip Reports and industrial fishery landings are included as unknown month.

Year	Unk	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1964	31395	<1	2	<1	114	899	173	6	3	1	4	8	16	32,622
1965	24247	2	2	11	50	724	102	43	24	2	14	23	3	25,246
1966	3869	1	8	9	8	2	45	8	6	5	2	5	16	3,985
1967	6724	1	<1	2	3	<1	2	2	6	<1	8	8	7	6,764
1968	6846	2	1	3	<1	5	14	15	34	14	14	31	22	7,001
1969	5273	<1	2	7	19	23	44	48	26	10	11	39	38	5,539
1970	4349	11	4	8	14	22	77	61	35	20	9	26	42	4,679
1971	3083	2	1	8	8	9	23	21	18	2	4	4	43	3,227
1972	1779	24	5	2	2	12	22	26	25	22	<1	24	54	1,995
1973	3421	47	7	6	6	13	23	9	17	2	2	16	33	3,603
1974	1990	24	12	24	44	30	12	3	1	<1	<1	11	33	2,183
1975	1654	41	12	4	14	50	17	21	2	4	13	43	189	2,065
1976	3310	110	15	25	85	34	12	8	10	14	19	152	111	3,905
1977	2274	21	1	7	4	24	18	12	21	17	8	42	73	2,522
1978	2602	92	14	50	142	180	54	29	24	13	14	54	60	3,327
1979	5412	167	162	60	272	164	86	33	21	23	47	80	96	6,624
1980	2823	150	70	52	174	147	104	36	20	25	52	116	158	3,927
1981	1203	45	7	18	196	165	48	26	24	15	35	105	237	2,124
1982	2166	74	32	61	137	124	41	24	34	38	30	78	154	2,993
1983	276	231	42	61	99	227	86	35	54	38	19	28	139	1,334
1984	143	134	47	128	117	182	129	42	61	47	46	46	92	1,214
1985	115	90	17	38	113	170	83	35	29	27	32	9	69	827
1986		56	37	55	120	131	77	37	19	14	18	16	66	644
1987		71	86	107	80	170	122	70	54	38	8	35	101	943
1988		100	51	86	172	145	73	24	9	10	14	47	141	871
1989		62	48	26	109	141	99	58	20	30	34	42	108	931
1990		40	21	45	221	177	43	45	32	38	47	20	41	798
1991		64	44	43	168	143	56	19	53	71	28	86	94	925
1992		142	125	99	170	241	52	29	61	72	47	24	47	1,245
1993		74	80	67	75	76	108	37	40	49	40	49	77	924
1994	5	64	86	98	152	126	82	29	34	44	77	46	49	983
1995	7	87	112	97	137	108	117	113	97	152	106	165	128	1,428
1996	2	66	50	55	84	83	50	71	28	30	44	69	66	700
1997	12	121	87	125	112	94	127	77	40	66	43	27	70	999
1998		102	109	84	86	79	153	122	42	141	84	73	80	1,154
1999	4	119	146	131	88	206	123	74	91	75	106	76	111	1,351
2000	2	79	158	120	120	150	187	69	123	165	113	61	68	1,417
2001	28	123	139	218	163	234	175	124	87	42	51	38	46	1,469
2002	24	54	56	60	52	54	99	62	36	55	31	38	42	663
2003	1	56	51	60	53	61	52	40	16	52	60	61	60	623
2004	15	36	49	54	59	74	38	52	72	42	39	39	19	588
2005	12	41	27	32	47	27	39	33	20	29	15	17	18	356
2006	6	18	24	37	37	40	38	54	40	15	24	15	27	375
2007	36	23	25	30	27	49	32	61	50	54	26	23	32	470
2008	89	29	34	29	26	46	59	43	50	47	65	22	38	580
2009	113	44	22	39	42	44	88	31	27	46	36	19	25	575

Table C8. Nominal landings of red hake (mt) by region and half year. Landings reported as bait on Vessel Trip Reports and industrial fishery landings are included as unknown half.

	Northern Stock				Southern Stock			
Year	1	2	Unknown	Total	1	2	Unknown	Total
1964	11	134	144	288	1188	39	31395	32,622
1965	39	161		200	890	109	24247	25,246
1966	15	356	514	885	74	42	3869	3,985
1967	28	90	459	577	9	31	6724	6,764
1968	7	86	460	552	25	130	6846	7,001
1969	3	131	12	146	96	171	5273	5,539
1970	61	200	<1	261	137	194	4349	4,679
1971	44	331	2	377	52	92	3083	3,227
1972	47	491		538	66	150	1779	1,995
1973	40	323		362	102	80	3421	3,603
1974	112	374	405	891	145	48	1990	2,183
1975	118	331		450	139	272	1654	2,065
1976	140	514		653	281	314	3310	3,905
1977	227	662		889	75	173	2274	2,522
1978	214	1009	<1	1,223	531	193	2602	3,327
1979	349	1173	1	1,523	912	300	5412	6,624
1980	213	813	2	1,029	697	408	2823	3,927
1981	320	926		1,246	478	443	1203	2,124
1982	243	967		1,210	469	358	2166	2,993
1983	247	648		895	746	312	276	1,334
1984	161	897		1,059	736	334	143	1,214
1985	157	835		992	511	201	115	827
1986	412	1045		1,457	475	169		644
1987	323	690		1,013	637	306		943
1988	158	704		862	626	245		871
1989	208	567		776	484	292		931
1990	134	689		826	547	224		798
1991	118	624		743	518	350		925
1992	152	766		918	830	280		1,245
1993	143	625		768	480	293		924
1994	73	641	13	727	607	279	5	983
1995	4	143	40	186	658	762	7	1,428
1996	104	274	31	409	390	309	2	700
1997	21	301	15	338	666	321	12	999
1998	8	164	14	187	612	542		1,154
1999	5	200	16	220	814	532	4	1,351
2000	22	150	25	197	816	600	2	1,417
2001	20	183	21	222	1052	388	28	1,469
2002	11	232	31	275	375	264	24	663
2003	5	180	25	210	333	290	1	623
2004	3	70	29	103	310	263	15	588
2005	<1	64	32	96	213	132	12	356
2006	1	73	21	96	194	175	6	375
2007	2	33	33	69	186	247	36	470
2008	<1	9	43	52	223	266	89	580
2009	<1	10	74	85	278	184	113	575

Table C9. Nominal landings of white hake (mt) by market and half year for the northern region.

	Unclassified			Small			Large		
Year	1	2	Total	1	2	Total	1	2	Total
1985	794	2009	2803	418	705	1123	633	1751	2385
1986	873	1690	2563	359	312	672	651	1245	1896
1987	517	985	1502	448	1449	1897	473	1312	1785
1988	155	557	712	812	1657	2469	449	1013	1462
1989	206	870	1076	453	944	1397	645	1364	2010
1990	187	744	931	733	1796	2529	446	911	1358
1991	366	824	1190	692	2324	3016	337	861	1199
1992	246	1367	1612	1193	3690	4883	499	1063	1562
1993	493	1372	1865	1229	2205	3434	564	1193	1757
1994	370	663	1033	566	971	1537	554	951	1505
1995	285	732	1017	383	1157	1540	504	952	1456
1996	214	484	698	333	921	1253	505	694	1199
1997	39	46	85	269	764	1033	289	772	1061
1998	38	37	76	183	590	773	442	945	1387
1999	11	34	46	296	568	864	734	881	1614
2000	10	21	31	421	642	1062	775	1036	1811
2001	9	64	73	453	857	1310	895	1119	2014
2002	10	20	30	662	470	1132	810	1205	2015
2003	4	33	37	288	362	650	1887	1801	3688
2004	57	174	231	211	374	584	1469	1134	2603
2005	388	231	619	201	339	540	792	662	1454
2006	231	108	339	140	178	319	483	519	1003
2007	134	90	224	97	217	314	416	532	949
2008	41	24	65	119	295	414	294	501	794
2009	41	24	65	201	368	569	463	552	1015

Table C10. Nominal landings of white hake (mt) by market and half year for the southern region.

	Unclassified			Small			Large		
Year	1	2	Total	1	2	Total	1	2	Total
1985	40	6	46	15	5	20	36	7	43
1986	34	10	43	9	2	11	44	8	52
1987	43	14	58	12	14	26	24	4	28
1988	51	15	65	26	13	39	17	7	24
1989	19	2	21	11	10	21	13	9	22
1990	22	15	36	35	13	49	19	5	24
1991	46	32	78	72	12	84	30	10	40
1992	95	23	118	162	16	179	83	7	90
1993	65	36	102	162	42	204	86	18	104
1994	174	45	219	106	57	163	133	142	275
1995	74	40	113	76	16	92	92	14	106
1996	48	23	71	25	2	28	31	2	33
1997	22	5	28	8	4	12	2	1	4
1998	13	11	25	35	10	45	29	33	61
1999	13	7	20	25	8	33	38	6	44
2000	18	10	28	23	7	31	15	6	21
2001	23	5	28	15	15	30	15	11	27
2002	7	2	9	36	8	44	24	11	35
2003	4	1	5	12	4	16	30	8	37
2004	1	15	16	19	6	25	41	11	52
2005	26	8	35	5	5	10	10	3	12
2006	9	5	14	9	6	14	5	7	12
2007	1	1	2	19	3	22	13	4	18
2008	11	2	14	9	14	23	5	9	14
2009	6	3	8	12	9	20	14	5	18

Table C11. Summary of number of red hake measured by port samplers by region and half.

	North			South		
Year	1	2	Total	1	2	Total
1975					206	206
1976					103	103
1977				159		159
1979					94	94
1980				318		318
1981		101	101			
1982		431	431			
1983	125	1232	1357	182		182
1984	209	546	755	982	200	1182
1985	43	914	957	1139	599	1738
1986	335	1227	1562	948	320	1268
1987		967	967	786	213	999
1988	666	1172	1838	612	100	712
1989	111	410	521	201	309	510
1990	242	607	849	518	275	793
1991	826	214	1040	701	299	1000
1992		111	111	400	404	804
1993		95	95	303	100	403
1994				419	356	775
1995				1067	62	1129
1996					193	193
1997				1730	246	1976
1998		138	138	904	309	1213
1999		47	47	748	795	1543
2000				250	388	638
2001		99	99	1010	720	1730
2002				432	406	838
2003		345	345	1068	509	1577
2004		370	370	755	1195	1950
2005				1030	1208	2238
2006		93	93	1255	1146	2401
2007		37	37	2819	1758	4577
2008			957	2560	2183	4743
2009			1562	1139	599	1738

Table C12. Summary of number of white hake measured by port samplers by market category and half in the northern region.

	Uncl			Small			Large		
Year	1	2	Total	1	2	Total	1	2	Total
1985	101	397	498	356	640	996	509	790	1299
1986	215	398	613	686	668	1354	332	221	553
1987	245	237	482	443	998	1441	111	754	865
1988	100	41	141	1414	823	2237	233	299	532
1989	100	106	206	185	511	696		410	410
1990		101	101	613	749	1362	214	306	520
1991	207	94	301	674	1118	1792	474	728	1202
1992	97	237	334	1177	1423	2600	94	622	716
1993	214	293	507	1097	616	1713	361	851	1212
1994	236	697	933	397	1063	1460	303	667	970
1995	100		100	191	535	726	221	103	324
1996	199	546	745	101	976	1077	202	1210	1412
1997		58	58	1634	2455	4089	1166	1574	2740
1998		118	118	500	886	1386	897	1226	2123
1999				213	640	853	831	425	1256
2000				1172	1146	2318	229	336	565
2001				881	887	1768	784	1457	2241
2002				1171	1746	2917	1055	761	1816
2003				1637	1500	3137	1945	3285	5230
2004				988	978	1966	3536	1646	5182
2005	28	61	89	1203	1760	2963	1849	1711	3560
2006				1467	1936	3403	1922	1748	3670
2007				1524	1759	3283	1469	1489	2958
2008				1226	1857	3083	1698	1467	3165
2009				981	1691	2672	1248	1920	3168

Table C13. Summary of number of white hake measured by port samplers by market category and half in the southern region.

	Uncl			Small			Large		
Year	1	2	Total	1	2	Total	1	2	Total
1985									
1986									
1987	113		113						
1988				100		100			
1989									
1990				104		104			
1991				151		151			
1992				52	55	107	100		100
1993				50		50	100		100
1994									
1995									
1996									
1997									
1998				100		100			
1999					107	107		104	104
2000									
2001									
2002							85		85
2003				92	96	188			
2004				96		96			
2005	111		111	61		61	106		106
2006									
2007	201		201						
2008				142		142	5		5
2009					101	101	28		28

Table C14. Sampling intensity (mt/100 lengths) of red hake by region and half.

	North		South	
Year	1	2	1	2
1975				132
1976				304
1977			47	
1978				
1979				320
1980			219	
1981		917		
1982		224		
1983	198	53	410	
1984	77	164	75	167
1985	364	91	45	34
1986	123	85	50	53
1987		71	81	144
1988	24	60	102	245
1989	187	138	241	95
1990	55	114	106	82
1991	14	292	74	117
1992		690	207	69
1993		658	158	293
1994			145	78
1995			62	1228
1996				160
1997			38	131
1998		119	68	175
1999		425	109	67
2000			326	155
2001		184	104	54
2002			87	65
2003		52	31	57
2004		19	41	22
2005			21	11
2006		79	15	15
2007		91	7	14
2008			9	12
2009			24	31

Table C15. Sampling Intensity (mt/100 lengths) of white hake by market category and half in the northern region.

	Uncl		Small		Large	
Year	1	2	1	2	1	2
1985	786	506	118	110	124	222
1986	406	425	52	47	196	563
1987	211	416	101	145	426	174
1988	155	1358	57	201	193	339
1989	206	820	245	185		333
1990		737	120	240	209	298
1991	177	877	103	208	71	118
1992	253	577	101	259	531	171
1993	230	468	112	358	156	140
1994	157	95	143	91	183	143
1995	285		201	216	228	925
1996	108	89	329	94	250	57
1997		80	16	31	25	49
1998		32	37	67	49	77
1999			139	89	88	207
2000			36	56	338	308
2001			51	97	114	77
2002			57	27	77	158
2003			18	24	97	55
2004			21	38	42	69
2005	1387	378	17	19	43	39
2006			10	9	25	30
2007			6	12	28	36
2008			10	16	17	34
2009			20	22	37	29

Table C16. Pooling of red hake port length samples to estimate length and species composition of the commercial landings by region and half.

	North			South	
	Half 1	Half 2		Half 1	Half 2
1985					
1986					
1987					
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
2002					
2003					
2004					
2005					
2006					
2007					
2008					
2009					

Table C17. Pooling of white hake port length samples to estimate length and species composition of the commercial landings by region, market category and half.

	North							South					
	Uncl		Small		Large			Uncl		Small		Large	
	Half 1	Half 2	Half 1	Half 2	Half 1	Half 2		Half 1	Half 2	Half 1	Half 2	Half 1	Half 2
1985													
1986													
1987													
1988													
1989													
1990													
1991													
1992													
1993													
1994													
1995													
1996													
1997													
1998													
1999													
2000													
2001													
2002													
2003													
2004													
2005													
2006													
2007													
2008													
2009													

Table C18. Comparison of nominal landings (mt) with the length-based model-estimated landings (mt) by stock.

	Northern Stock		Southern Stock	
Year	Nominal	Length-Based Model Estimate	Nominal	Length-Based Model Estimate
1960	3792		4286	
1961	3276		8105	
1962	1911		11865	
1963	3281		31901	
1964	1409	272	43373	30087
1965	2773	338	92990	64462
1966	5575	442	107922	74815
1967	1863	191	58783	40755
1968	2627	237	18138	12612
1969	2021	206	52928	36725
1970	1032	172	11454	8003
1971	4805	452	35134	24428
1972	15026	1111	61194	42484
1973	15288	1133	51362	35652
1974	7223	674	26643	18496
1975	8701	701	19976	13861
1976	6337	575	22465	15584
1977	891	274	7062	4914
1978	1223	291	5463	3809
1979	1523	269	7592	5273
1980	1029	264	4082	2854
1981	1246	437	2320	1668
1982	1210	454	3170	2253
1983	895	449	1441	1052
1984	1059	478	1271	959
1985	992	827	903	739
1986	1457	557	694	502
1987	1013	452	943	755
1988	862	598	871	656
1989	776	486	931	637
1990	826	601	798	480
1991	743	321	925	593
1992	918	456	1245	684
1993	768	302	924	865
1994	727	391	983	924
1995	186	296	1428	1381
1996	409	183	700	654
1997	338	179	999	827
1998	187	118	1154	1075
1999	220	141	1351	1084
2000	197	105	1417	1413
2001	222	195	1469	1381
2002	275	240	663	592
2003	210	149	623	537
2004	103	40	588	278
2005	96	23	356	298
2006	96	67	375	338
2007	69	40	470	357
2008	52	7	580	489
2009	85	37	575	431

Table C19. Red hake discards (mt) from the northern region by gear and half. The discards from 1981-1988 (1991 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

	Longline			Large Mesh Otter Trawl			Small Mesh Otter Trawl			Sink Gill Net			Scallop Dredge			Shrimp Trawl		
	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total
1981	3.1	1.8	4.8	269.8	921.1	1190.9	Na			2.1	4.0	6.1	6.9	8.1	15.0	107.2	0.5	107.7
1982	2.8	1.5	4.3	265.9	1026.5	1292.4	Na			0.9	3.6	4.5	4.1	6.2	10.4	135.4	12.9	148.3
1983	4.0	1.7	5.8	293.1	865.3	1158.4	Na			1.0	3.0	3.9	3.5	4.9	8.4	137.1	39.5	176.7
1984	2.7	0.3	3.1	244.8	795.7	1040.5	Na			0.9	3.9	4.8	2.0	2.9	4.9	178.9	95.1	274.0
1985	2.5	0.8	3.4	211.5	671.4	882.9	Na			1.0	3.3	4.3	1.4	2.8	4.2	249.7	125.5	375.2
1986	3.6	1.1	4.7	181.8	538.3	720.2	Na			1.2	3.5	4.7	2.6	3.0	5.6	304.7	148.7	453.4
1987	6.3	3.3	9.6	154.7	483.8	638.5	Na			1.1	3.6	4.6	3.1	5.8	8.9	308.6	82.2	390.9
1988	6.7	4.2	10.8	144.7	461.3	606.0	Na			1.2	3.6	4.8	3.9	7.4	11.3	182.4	81.6	264.0
1989	6.2	3.3	9.5	301.2	94.2	395.3	4.2	687.9	692.0	2.5	4.9	7.4	4.4	8.5	12.9	259.4	70.5	329.9
1990	4.9	3.3	8.2	30.8	112.0	142.8	10.2	101.6	111.8	1.1	3.6	4.7	3.3	9.7	13.0	194.0	120.5	314.5
1991	31.2	17.9	49.2	7.7	214.8	222.5	17.8	309.4	327.2	0.7	3.2	3.9	1.2	1.6	2.8	168.6	44.0	212.5
1992	0.4	0.2	0.6	54.9	93.0	147.9	69.4	417.5	486.9	0.5	0.4	0.9	0.2	2.2	2.4	77.1	10.5	87.6
1993	0	0	0	17.6	3.1	20.7	5.1	27.5	32.6	0.4	0.4	0.8	9.2	15.4	24.5	4.4	0.2	4.6
1994	0	0	0	8.9	0	8.9	3.0	49.8	52.8	0.1	3.7	3.8	1.6	2.1	3.7	3.0	4.5	7.5
1995	3.6	4.5	8.1	2.5	13.0	15.5	3.2	22.9	26.1	0.9	0.7	1.6	0.3	0.8	1.0	3.8	6.9	10.7
1996	3.3	3.5	6.9	11.8	0	11.8	25.1	498.9	524.0	0.8	2.9	3.7	0.1	3.7	3.8	74.8	31.0	105.8
1997	3.5	3.6	7.1	3.7	8.5	12.2	0.5	3.6	4.0	0.8	0.2	1.1	0.2	5.5	5.7	84.8	10.2	95.0
1998	2.7	4.1	6.8	5.5	2.5	8.0	7.5	87.4	94.8	0.4	1.1	1.5	0	0	0	17.7	1.0	18.7
1999	2.7	3.6	6.3	6.7	304.7	311.4	6.6	128.4	135.1	0.6	2.3	2.8	1.7	1.9	3.7	8.1	0.2	8.2
2000	1.6	3.8	5.4	0	27.0	27.0	0.1	0.4	0.4	2.1	1.6	3.7	2.2	4.1	6.2	11.9	0.2	12.1
2001	2.2	2.6	4.9	40.0	7.6	47.6	0.2	65.2	65.4	7.6	4.2	11.8	2.7	2.1	4.8	0.7		0.7
2002	0.8	0.5	1.3	4.1	31.1	35.2	0	53.7	53.7	0.5	2.7	3.2	3.1	4.1	7.2	0.2		0.2
2003	0	0	0	10.0	18.5	28.5	0.0	27.8	27.8	0.9	1.3	2.3	0	28.6	28.6	0.4		0.4
2004	0.0	1.7	1.7	10.4	15.9	26.3	0	25.6	25.6	0.9	1.0	1.8	0.8	0.4	1.2	0.8	0.0	0.8
2005	0.5	2.4	2.9	5.3	30.8	36.1	0.2	10.8	10.9	0.1	0.4	0.5	0.2	6.6	6.8	0.2	0.0	0.2
2006	0.2	1.3	1.5	3.4	38.4	41.8	0.0	124.6	124.6	0.4	8.4	8.9	0.6	0.6	1.1	0.1	3.3	3.3
2007	0	0.9	0.9	6.6	14.8	21.3	4.6	72.7	77.3	0.0	0.1	0.1	2.3	18.1	20.4	5.9	1.4	7.4
2008	0.0	2.2	2.2	5.6	28.6	34.2	2.1	16.4	18.5	2.4	0.2	2.6	0.2	0.4	0.6	0.8	0.5	1.3
2009	0.2	0.4	0.6	7.8	37.3	45.2	5.6	39.4	45.0	0.2	0.8	1.0	0.3	1.7	2.0	0.3	0.9	1.2

Table C20. Red hake discards (mt) from the southern region by gear and half. The discards from 1981-1988 (1991 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

	Longline			Large Mesh Otter Trawl			Small Mesh Otter Trawl			Sink Gill Net			Scallop Dredge		
	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total
1981	0.4	1.0	1.4	1592.0	1113.4	2705.4	Na			0	0.003	0.003	3.4	4.6	8.0
1982	0.3	0.5	0.8	1806.3	1959.1	3765.3	Na			0	0.003	0.003	4.4	5.3	9.7
1983	0.2	0.5	0.7	1958.6	1918.1	3876.7	Na			0	0.005	0.005	5.8	5.6	11.4
1984	0.2	0.3	0.5	2132.9	1764.5	3897.4	Na			0	0.008	0.008	6.9	5.3	12.2
1985	0.1	0.5	0.7	1741.8	1214.9	2956.7	Na			0	0.004	0.004	6.0	5.1	11.1
1986	0.1	0.5	0.6	1724.9	1650.1	3375.1	Na			0	0.007	0.007	6.0	6.9	12.9
1987	0.2	0.6	0.8	1787.8	1503.9	3291.7	Na			0	0.008	0.008	10.7	9.9	20.6
1988	0.1	0.1	0.2	2002.2	1439.3	3441.5	Na			0	0.008	0.008	11.0	9.1	20.0
1989	0.07	0.15	0.21	39.4	19.5	58.9	1875.0	3047.6	4922.6	0	0	0	15.0	8.8	23.8
1990	0.05	0.21	0.26	1112.1	226.0	1338.1	1717.4	1634.8	3352.2	0	0	0	18.8	38.3	57.0
1991	0.83	0.47	1.30	380.9	65.2	446.1	1439.0	704.8	2143.8	0	0	0	13.6	7.2	20.8
1992	0	1.96	1.96	595.9	172.9	768.9	3542.2	2009.1	5551.4	0.033	0.144	0.177	14.7	5.9	20.6
1993	0	0	0	53.5	0.5	54.1	2089.5	3146.7	5236.3	0.064	0.111	0.175	7.1	10.0	17.2
1994	0	0	0	38.5	1.1	39.6	1187.7	442.1	1629.9	0	0.012	0.012	7.2	43.1	50.3
1995	0	0	0	38.7	1.7	40.5	718.3	542.6	1260.8	0.007	0	0.007	19.5	8.0	27.5
1996	1.06	0.75	1.82	4.8	8.1	12.9	325.6	20.6	346.2	0	0	0	8.2	10.5	18.7
1997	1.21	1.04	2.25	0.4	290.9	291.3	2062.4	0.2	2062.6	0.056	0	0.056	43.1	23.2	66.3
1998	1.17	0.80	1.97	0.3	0	0.3	199.6	534.1	733.7	0.015	0	0.015	2.7	1.5	4.3
1999	0.90	0.42	1.31	0	0	0	985.9	4.9	990.8	0.148	0	0.148	24.1	43.9	68.0
2000	0.60	0.52	1.11	11.2	1.5	12.8	108.6	9.7	118.3	0.032	0	0.032	77.9	39.7	117.6
2001	0.84	0.84	1.68	0.0	0	0.0	76.6	22.4	99.0	0.076	0	0.076	17.3	19.6	36.9
2002	0	0	0	0.6	0.8	1.4	6.5	292.7	299.2	0.148	0	0.148	3.0	23.2	26.2
2003	0	0	0	10.3	37.8	48.1	272.0	14.9	286.9	0	0	0	1.6	8.4	10.0
2004	0.01	0.01	0.01	22.2	91.4	113.6	213.3	259.5	472.8	0	0	0	12.0	17.3	29.4
2005	0.03	0.01	0.04	56.0	75.0	131.0	232.1	581.7	813.9	0	0	0	7.0	55.3	62.3
2006	0.01	0.08	0.09	43.6	56.4	99.9	378.6	95.3	473.9	0	0	0	27.4	72.5	99.9
2007	3.20	4.35	7.55	85.5	45.8	131.3	1188.7	196.6	1385.3	0	0	0	9.3	12.0	21.3
2008	3.78	3.64	7.42	96.6	16.7	113.3	488.4	150.3	638.7	0	0	0	17.4	37.0	54.4
2009	2.76	4.77	7.53	105.0	36.8	141.7	110.1	548.2	658.4	0	0	0	33.6	27.7	61.3

Table C21. White hake discards (mt) from the northern region by gear and half. The discards from 1981-1988 (1991 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

	Longline			Large Mesh Otter Trawl			Small Mesh Otter Trawl			Sink Gill Net			Scallop Dredge			Shrimp Trawl		
	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total
1981	1.2	0.8	2.0	106.0	537.6	643.6	Na			18.6	65.6	84.2	8.9	127.1	136.0	6.9	0.1	7.0
1982	1.1	0.6	1.8	104.5	599.2	703.6	Na			8.1	59.1	67.2	5.3	98.2	103.5	8.7	3.7	12.4
1983	1.6	0.8	2.4	115.2	505.0	620.1	Na			8.6	49.1	57.7	4.5	77.0	81.5	8.8	11.3	20.2
1984	1.1	0.1	1.3	96.2	464.4	560.6	Na			8.2	64.6	72.8	2.6	46.2	48.8	11.5	27.3	38.8
1985	1.0	0.4	1.3	84.1	418.2	502.2	Na			8.8	55.3	64.1	1.8	44.3	46.1	16.1	36.0	52.1
1986	1.4	0.5	1.9	73.5	328.4	401.9	Na			10.8	57.9	68.7	3.4	47.5	50.9	19.6	42.7	62.3
1987	2.5	1.4	4.0	61.8	292.1	353.9	Na			9.7	58.8	68.5	4.0	91.3	95.3	19.9	23.6	43.5
1988	2.6	1.8	4.4	57.6	278.1	335.7	Na			10.8	59.9	70.8	5.0	116.3	121.3	11.8	23.4	35.2
1989	2.48	1.45	3.93	70.7	288.8	359.4	49.94	86.52	136.46	11.6	22.3	33.9	5.61	133.97	139.58	9.78	17.42	27.20
1990	1.98	1.43	3.40	16.1	79.8	95.9	1.04	268.18	269.22	8.5	124.3	132.8	2.02	144.98	147.00	8.65	3.73	12.39
1991	1.22	0.70	1.93	6.5	132.3	138.8	1.82	31.57	33.38	18.3	46.4	64.7	7.85	10.07	17.91	21.63	46.26	67.89
1992	11.49	7.25	18.74	42.7	219.8	262.5	33.59	0	33.59	34.4	94.2	128.5	3.92	11.86	15.78	71.90	1.01	72.91
1993	0	0	0	28.8	62.8	91.5	14.52	276.75	291.27	62.8	167.4	230.2	1.93	278.97	280.90	3.37	0.54	3.91
1994	0	0	0	14.9	0	14.9	3.93	64.31	68.24	1.7	19.0	20.7	0.99	1.31	2.29	5.43	6.02	11.45
1995	4.23	5.28	9.52	27.3	88.0	115.2	0.74	5.01	5.76	2.0	43.3	45.3	0.50	1.50	2.00	12.34	1.00	13.34
1996	3.89	4.13	8.02	17.4	0.5	18.0	1.22	8.24	9.46	7.1	73.2	80.3	0.04	2.83	2.87	15.69	1.64	17.33
1997	4.12	4.24	8.36	3.6	13.8	17.4	4.10	31.67	35.76	17.0	23.0	40.0	0.03	0.65	0.68	2.31	0.28	2.58
1998	3.13	4.84	7.97	25.5	21.5	47.0	0.24	2.80	3.04	2.2	2.3	4.5	22.47	24.89	47.36	5.46	0.30	5.75
1999	3.22	4.17	7.38	3.8	106.2	110.0	0	0	0	8.9	4.6	13.6	1.16	1.38	2.53	2.48	0.06	2.54
2000	1.82	4.49	6.31	40.6	73.1	113.7	0.25	1.34	1.59	5.8	8.9	14.7	1.43	2.66	4.08	3.65	0.06	3.71
2001	2.62	3.10	5.72	55.2	139.0	194.2	2.68	0	2.68	1.3	47.0	48.2	0.69	0.53	1.22	0		0
2002	1.27	0.82	2.09	49.1	51.5	100.7	0	0.17	0.17	1.4	2.7	4.1	0.31	0.41	0.72	0.06		0.06
2003	0	0	0	30.4	26.5	56.9	0.02	0	0.02	7.3	8.0	15.2	0.09	0.46	0.55	0.21		0.21
2004	0	2.02	2.02	6.7	31.5	38.2	0.00	0.85	0.85	1.2	10.0	11.2	0.00	0.00	0.01	0.33	0.01	0.34
2005	0.11	3.08	3.19	5.4	14.9	20.3	0.06	0.49	0.56	2.6	13.1	15.7	0	0.77	0.77	0.40	0.02	0.42
2006	0.05	2.51	2.55	7.0	15.7	22.7	0.01	0.09	0.11	1.8	12.5	14.3	0.13	0.19	0.32	1.00	0	1.00
2007	0	0.77	0.77	3.9	5.6	9.5	0.03	0.48	0.51	2.5	2.1	4.6	0.25	0.13	0.38	3.54	0.85	4.39
2008	0.03	3.13	3.16	2.6	8.3	10.9	0.09	0.73	0.82	3.3	8.8	12.1	0.04	0.13	0.17	3.29	0.82	4.11
2009	0.04	0.26	0.30	8.0	13.7	21.6	0.17	1.21	1.39	2.4	4.9	7.3	0	0.86	0.86	2.54	1.83	4.38

Table C22. White hake discards (mt) from the southern region by gear and half. The discards from 1981-1988 (1991 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

	Longline			Large Mesh Otter Trawl			Small Mesh Otter Trawl			Sink Gill Net			Scallop Dredge		
	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total
1981	0.4	1.0	1.4	1592.0	1113.4	2705.4	Na			0	0.003	0.003	3.4	4.6	8.0
1982	0.3	0.5	0.8	1806.3	1959.1	3765.3	Na			0	0.003	0.003	4.4	5.3	9.7
1983	0.2	0.5	0.7	1958.6	1918.1	3876.7	Na			0	0.005	0.005	5.8	5.6	11.4
1984	0.2	0.3	0.5	2132.9	1764.5	3897.4	Na			0	0.008	0.008	6.9	5.3	12.2
1985	0.1	0.5	0.7	1741.8	1214.9	2956.7	Na			0	0.004	0.004	6.0	5.1	11.1
1986	0.1	0.5	0.6	1724.9	1650.1	3375.1	Na			0	0.007	0.007	6.0	6.9	12.9
1987	0.2	0.6	0.8	1787.8	1503.9	3291.7	Na			0	0.008	0.008	10.7	9.9	20.6
1988	0.1	0.1	0.2	2002.2	1439.3	3441.5	Na			0	0.008	0.008	11.0	9.1	20.0
1989	0	0	0	6.4	9.0	15.3	10.8	142.9	153.8	0	0	0	9.8	111.4	121.3
1990	0	0	0	238.3	40.7	279.0	185.1	12.9	198.0	0	0	0	10.3	188.9	199.3
1991	0	0	0	0.7	1.0	1.7	7.0	87.4	94.3	0	0	0	8.0	4.3	12.3
1992	0	0	0	4.0	0	4.0	247.5	9.7	257.2	0	0	0	6.9	4.8	11.7
1993	0	0	0	20.2	0	20.2	2.4	0	2.4	0.128	0.037	0.165	8.2	284.6	292.7
1994	0	0	0	165.4	10.6	176.0	78.9	99.3	178.1	0.085	0.004	0.088	0.8	1.8	2.7
1995	0	0	0	24.5	0.1	24.6	2.8	0	2.8	0	0	0	68.3	62.5	130.8
1996	0.134	0.095	0.229	1.8	0.1	1.9	6.5	0.4	6.9	0	0	0	0.0	1.2	1.2
1997	0.153	0.131	0.284	23.7	27.0	50.7	18.4	0	18.4	0.195	0.266	0.461	0.3	1.9	2.2
1998	0.148	0.101	0.249	0	0	0	0	0	0	0	0	0	0.4	43.7	44.0
1999	0.113	0.053	0.166	0	7.6	7.6	0.3	576.8	577.1	0	0	0	0	7.7	7.7
2000	0.076	0.065	0.141	1.6	0.7	2.3	32.0	1.4	33.4	1.622	0	1.622	25.8	15.2	41.0
2001	0.106	0.106	0.212	0	0	0	0.2	0	0.2	0	0	0	3.5	1.4	4.9
2002	0	0	0	0	0.4	0.4	0	1.9	1.9	0	0	0	1.0	3.0	4.0
2003	0	0	0	0.2	1.6	1.8	0	378.3	378.3	0.538	0	0.538	0.3	1.5	1.7
2004	0.025	0.021	0.047	2.6	25.1	27.7	35.1	9.3	44.4	0.605	0	0.605	0.9	4.9	5.9
2005	0	0.051	0.051	2.1	3.6	5.7	5.1	86.8	92.0	0.918	0	0.918	0.5	2.5	3.0
2006	0	0.608	0.608	4.8	12.0	16.8	6.0	0.2	6.2	0.112	0	0.112	0.3	3.0	3.3
2007	0	0	0	10.3	5.0	15.3	2.9	0.0	2.9	1.196	0	1.196	0.7	1.9	2.6
2008	0	0	0	5.0	5.3	10.4	117.4	30.9	148.3	0	0	0	5.4	7.0	12.4
2009	0	0	0	8.0	0.4	8.3	0.2	14.7	14.9	0	0	0	7.0	2.2	9.2

Table C23. Number of discarded red hake sampled from the FOP in the northern region by gear type.

	Large Mesh				Small Mesh				Sink Gill Net				Scallop Dredge				Shrimp Trawl			
	Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2	
	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len
1989	4	557	4	167	2	273	6	627	-	-	1	1	-	-	-	-	11	1815	-	-
1990	-	-	1	44	-	-	4	711	-	-	-	-	-	-	-	-	2	160	-	-
1991	-	-	1	1	-	-	6	429	1	2	6	7	-	-	-	-	-	-	-	-
1992	2	72	-	-	2	535	4	463	2	4	1	1	-	-	-	-	7	39	2	152
1993	-	-	-	-	2	650	-	-	-	-	1	1	-	-	-	-	1	2		
1994	-	-	-	-	-	-	-	-	1	1	1	2	-	-	1	27	1	1	3	116
1995	-	-	1	22	-	-	1	3	-	-	-	-	-	-	-	-	12	136	1	3
1996	-	-	-	-	-	-	10	750	2	2	2	4	-	-	-	-	7	151	1	32
1997	-	-	1	61	-	-	-	-	-	-	-	-	-	-	-	-	6	104	-	-
1998	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	2	152	-	-	1	43	1	2	3	5	-	-	1	7	-	-	-	-
2000	-	-	1	4	-	-	-	-	3	22	1	1	-	-	-	-	-	-	-	-
2001	1	1	-	-	-	-	-	-	1	3	2	4	-	-	-	-	-	-	-	-
2002	-	-	7	136	-	-	9	198	2	2	2	6	-	-	1	1	-	-	-	-
2003	12	89	10	261	-	-	3	116	9	12	4	7	-	-	1	103	2	7	-	-
2004	4	37	20	210	-	-	9	316	9	12	21	40	-	-	1	1	3	48	-	-
2005	23	126	19	86	2	5	8	63	1	1	6	10	-	-	2	2	1	1	-	-
2006	12	105	6	65	-	-	3	274	-	-	2	2	-	-	4	17	1	1	-	-
2007	13	175	6	25	-	-	3	1079	-	-	-	-	-	-	1	2	2	30	-	-
2008	2	2	26	183	-	-	-	-	1	1	1	2	2	3	1	16	1	16	-	-
2009	7	27	10	210	-	-	2	85	1	1	2	3	-	-	-	-			-	-

Table C24. Number of discarded red hake sampled from the FOP in the southern region by gear type.

	Large Mesh				Small Mesh				Scallop Dredge			
	Half 1		Half 2		Half 1		Half 2		Half 1		Half 2	
	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len
1989	1	9	1	10	5	460	-	-	-	-	-	-
1990	-	-	-	-	4	383	-	-	-	-	-	-
1991	-	-	-	-	1	45	3	193	-	-	-	-
1992	-	-	-	-	9	1583	1	73	-	-	-	-
1993	-	-	-	-	-	-	1	110	1	4	-	-
1994	-	-	-	-	1	29	3	27	-	-	2	24
1995	2	13	1	3	2	89	1	14	1	2	-	-
1996	-	-	-	-	-	-	1	11	-	-	2	7
1997	-	-	1	482	4	203	3	3	1	184	1	7
1998	-	-	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	3	67	1	1	2	29
2000	-	-	-	-	1	87	1	2	4	202	2	3
2001	-	-	-	-	-	-	-	-	-	-	-	-
2002	-	-	-	-	-	-	1	92	-	-	2	114
2003	-	-	-	-	1	107	-	-	2	3	2	104
2004	4	255	13	690	3	152	12	832	2	28	9	185
2005	15	365	14	498	13	525	14	1219	-	-	6	217
2006	10	40	4	279	9	353	10	502	-	-	3	4
2007	4	135	12	114	8	630	4	45	-	-	4	20
2008	7	29	5	42	6	290	3	47	5	51	7	53
2009	4	71	4	27	2	2	17	922	7	31	2	14

Table C25. Number of discarded white hake sampled from the FOP in the northern region by gear type.

	Large Mesh				Small Mesh				Sink Gill Net				Scallop Dredge				Shrimp Trawl			
	Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2	
	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len
1989	3	217	7	709	1	472	6	583	0	0	1	2	-	-	-	-	-	-	-	-
1990	2	8	1	9	-	-	4	303	0	0	1	32	-	-	-	-	-	-	-	-
1991	-	-	1	43	-	-	-	-	1	135	7	30	-	-	-	-	-	-	-	-
1992	-	-	1	86	-	-	-	-	0	0	4	4	-	-	-	-	6	17	3	58
1993	2	29	1	14	-	-	1	30	1	1	10	13	-	-	-	-	17	282	-	-
1994	4	26	-	-	-	-	-	-	0	0	2	4	-	-	1	1	30	517	4	256
1995	10	146	5	163	-	-	3	106	1	1	7	30	-	-	1	7	37	958	-	-
1996	5	56	-	-	2	145	8	309	2	12	2	3	-	-	-	-	9	325	2	15
1997	2	6	5	47	-	-	-	-	0	0	2	4			-	-	4	25	-	-
1998	2	11	1	2	-	-	-	-	0	0	1	1	1	5	-	-	0	0	-	-
1999	-	-	4	31	-	-	-	-	0	0	3	20			-	-	0	0	-	-
2000	3	12	-	-	-	-	2	10	2	9	0	0			-	-	0	0	-	-
2001	-	-	-	-	3	42	-	-	1	4	2	2			-	-	0	0	-	-
2002	-	-	9	126	-	-	2	14	0	0	1	2			-	-	0	0	-	-
2003	8	23	11	172	1	1	-	-	3	7	12	52			-	-	1	1	-	-
2004	13	125	30	392	2	4	5	92	4	6	19	69			-	-	0	0	-	-
2005	43	454	45	660	3	4	4	12	2	3	16	35			-	-	5	28	-	-
2006	21	280	20	346	-	-	-	-	1	1	3	4			-	-	4	131	-	-
2007	18	163	29	209	-	-	1	3	2	7	1	5	1	1	-	-	3	43	-	-
2008	14	118	50	465	-	-	1	5	1	3	4	6	2	3	-	-	2	31	1	25
2009	22	99	23	214	-	-	2	12	2	2	2	3	-	-	-	-	1	13	1	1

Table C26. Number of discarded white hake sampled from the FOP in the southern region by gear type.

	Large Mesh				Small Mesh				Sink Gill Net				Scallop Dredge			
	Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2	
	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len
1989	-	-	-	-	-	-	3	115	-	-	-	-	-	-	-	-
1990	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-
1993	-	-	-	-	-	-	0	0	-	-	-	-	1	1	-	-
1994	-	-	-	-	-	-	1	2	-	-	-	-	1	1	2	2
1995	-	-	-	-	-	-	0	0	-	-	-	-	2	51	1	66
1996	-	-	-	-	-	-	1	26	-	-	-	-	-	-	1	1
1997	2	33	2	17	1	29	-	-	-	-	-	-	-	-	0	0
1998	0	0	0	0	0	0	-	-	-	-	-	-	-	-	3	41
1999	0	0	2	11	0	0	-	-	-	-	-	-	-	-	3	32
2000	0	0	0	0	2	107	-	-	-	-	-	-	-	-	0	0
2001	0	0	0	0	0	0	-	-	-	-	-	-	-	-	0	0
2002	0	0	2	3	0	0	-	-	-	-	-	-	-	-	0	0
2003	1	1	1	24	0	0	-	-	-	-	-	-	-	-	0	0
2004	6	65	8	215	3	89	-	-	-	-	-	-	-	-	6	212
2005	9	40	14	114	6	87	-	-	-	-	-	-	-	-	4	60
2006	12	220	5	69	2	19	-	-	-	-	-	-	-	-	1	4
2007	4	46	4	10	2	39	-	-	-	-	-	-	-	-	1	15
2008	5	9	4	32	3	6	-	-	-	-	-	-	-	-	4	42
2009	1	1	1	3	1	1	-	-	-	-	-	-	1	1	1	1

Table C27. Pooling of red hake observer length samples to estimate length and species composition of the commercial discards by gear from the north.

	Red North		Red North		Red North		Red North	
	Large Mesh		Small Mesh		Shrimp Trawl		Sink Gill Net	
	Half1	Half2	Half1	Half2	Half1	Half2	Half1	Half2
1989								
1990								
1991								
1992								
1993								
1994								
1995								
1996								
1997								
1998								
1999								
2000								
2001								
2002								
2003								
2004								
2005								
2006								
2007								
2008								
2009								

Table C28. Pooling of red hake observer length samples to estimate length and species composition of the commercial discards by gear from the south.

	Red South			Red South	
	Large Mesh			Small Mesh	
	Half1	Half2		Half1	Half2
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
2002					
2003					
2004					
2005					
2006					
2007					
2008					
2009					

Table C29. Pooling of white hake observer length samples to estimate length and species composition of the commercial discards by gear from the north.

	White North			White North			White North			White North	
	Large Mesh			Small Mesh			Shrimp Trawl			Sink Gill Net	
	Half1	Half2		Half1	Half2		Half1	Half2		Half1	Half2
1989											
1990											
1991											
1992											
1993											
1994											
1995											
1996											
1997											
1998											
1999											
2000											
2001											
2002											
2003											
2004											
2005											
2006											
2007											
2008											
2009											

Table C30. Pooling of white hake observer length samples to estimate length and species composition of the commercial discards by gear from the south.

	White South			White South	
	Large Mesh			Small Mesh	
	Half1	Half2		Half1	Half2
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
2002					
2003					
2004					
2005					
2006					
2007					
2008					
2009					

Table C31. Comparison of nominal discards (mt) with the length-based model-estimated discards (mt) by stock.

	Northern Stock		Southern Stock	
Year	Nominal	Length-Based Model Estimate	Nominal	Length-Based Model Estimate
1981	1324	1230	2715	2680
1982	1460	1315	3776	3709
1983	1353	1195	3889	3824
1984	1327	1148	3910	3844
1985	1270	1084	2968	2938
1986	1189	993	3389	3362
1987	1052	906	3313	3325
1988	897	820	3462	3462
1989	1447	1308	5006	4737
1990	595	647	4748	4441
1991	818	531	2612	2334
1992	726	639	6343	5887
1993	83	380	5308	5509
1994	77	115	1720	1818
1995	63	109	1329	1386
1996	656	602	380	377
1997	125	141	2422	2251
1998	130	184	740	629
1999	468	381	1060	1483
2000	55	110	250	299
2001	135	239	138	136
2002	101	116	327	333
2003	88	90	345	650
2004	57	42	616	546
2005	57	37	1007	1077
2006	181	134	674	677
2007	127	112	1545	1532
2008	59	49	814	896
2009	95	74	869	862

Table C32. Estimates of nominal recreational catch (mt) by stock.

Year	North	South
1960	13.82	317
1961	11.94	612
1962	6.97	892
1963	4.47	770
1964	1.05	848
1965	0.73	634
1966	3.23	94
1967	2.10	165
1968	2.01	575
1969	0.53	489
1970	0.95	410
1971	1.37	287
1972	1.96	177
1973	1.32	317
1974	3.25	191
1975	1.64	52
1976	2.38	645
1977	3.24	750
1978	4.46	971
1979	5.55	245
1980	3.75	144
1981	30.89	176
1982	2.94	29
1983	0.03	135
1984	1.36	548
1985	0.00	29
1986	0.47	205
1987	0.25	472
1988	4.10	251
1989	0.48	436
1990	4.10	514
1991	1.60	285
1992	0.67	194
1993	0.97	89
1994	1.70	69
1995	1.01	45
1996	5.37	19
1997	0.83	173
1998	0.01	53
1999	0.06	53
2000	0.06	44
2001	0.48	24
2002	0.28	10
2003	0.13	18
2004	0.02	10
2005	0.02	55
2006	0.05	53
2007	0.21	20
2008	0.22	74
2009	0.43	100

Table C33. Minimized negative log-likelihood, number of model parameters, AIC_c measures for beta-binomial models with the specified relationship of the calibration factor to length fit to **red hake** catch data from the 2008 *Albatross IV*/*Henry B. Bigelow* calibration experiment.

Model	Model	-LL	# parameters	AIC_c	Δ (AIC_c)	AIC_c Weights
1	Constant	4791.267	2	9586.536	303.482	0
2	Survey, S-S, constant	4787.159	4	9582.327	299.2727	0
3	S,F,S-S, constant model	4781.916	6	9575.853	292.7986	0
4	All stations, logistic model	4670.32	5	9350.655	67.6003	0
5	Survey, S-S logistic	4658.74	10	9337.532	54.4778	0
6	S, F, S-S, logistic	NA	NA	NA	NA	NA
7	All stations, double logistic model[1]	4649.882	6	9311.784	28.7294	0
8	Survey, S-S, double-logistic model[2]	4638.766	14	9305.632	22.5777	0
9	S,F,S-S, double-logistic model[3]	4619.406	22	9283.054	0	1

1 Minima for both ascending and descending logistic components were assumed equal to 0 (exp(-100)) to allow variance estimation.
2 Minima for both ascending and descending logistic components were assumed equal to 0 (exp(-100)) for the survey data to allow variance estimation.
3 Minima for both ascending and descending logistic components were assumed equal to 0 (exp(-100)) for the fall data to allow variance estimation.

Table C34. Resulting length-based calibration factors for red hake by season.

Length	Spring	Fall
1	2.855	0.001
2	2.855	0.003
3	2.855	0.011
4	2.855	0.036
5	2.854	0.115
6	2.853	0.357
7	2.853	0.977
8	2.888	2.065
9	3.225	3.114
10	5.457	3.679
11	12.282	3.892
12	12.930	3.960
13	7.305	3.979
14	4.455	3.983
15	3.532	3.982
16	3.263	3.978
17	3.186	3.974
18	3.164	3.967
19	3.158	3.960
20	3.157	3.950
21	3.156	3.938
22	3.156	3.923
23	3.156	3.905
24	3.156	3.883
25	3.156	3.855
26	3.156	3.821
27	3.156	3.780
28	3.156	3.730
29	3.156	3.669
30	3.156	3.596
31	3.156	3.510
32	3.156	3.407
33	3.156	3.288
34	3.156	3.150
35	3.156	2.994
36	3.156	2.820
37	3.156	2.630
38	3.156	2.426
39	3.156	2.212
40	3.156	1.993
41	3.156	1.775
42	3.156	1.561
43	3.156	1.358
44	3.156	1.169
45	3.156	0.996
46	3.156	0.841
47	3.156	0.704
48	3.156	0.586
49	3.156	0.484
50	3.156	0.398

Table C35. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC fall bottom trawl surveys in the northern management region (strata 20-30, 36-40). Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1963	23966	24.57	30.67	18.46	10371.71	14147.00	6596.43
1964	23966	7.98	11.72	4.25	2811.73	3566.44	2057.01
1965	23966	5.84	8.43	3.25	2603.09	3735.70	1470.27
1966	23966	5.01	6.63	3.39	1976.34	2658.73	1293.74
1967	23966	2.93	4.66	1.20	1045.30	1552.01	538.59
1968	23966	2.13	3.22	1.03	548.65	791.52	305.57
1969	23966	9.24	13.43	5.06	1433.47	2098.31	768.41
1970	23966	9.95	14.45	5.46	1284.32	1733.26	835.39
1971	23966	13.96	22.86	5.06	2851.10	3505.24	2196.95
1972	23966	20.63	27.14	14.11	4998.41	6708.55	3288.48
1973	23966	15.64	23.03	8.26	3342.62	4711.89	1973.34
1974	23966	6.33	8.27	4.38	1444.81	1824.41	1065.20
1975	23966	17.59	22.54	12.63	3771.65	4629.08	2914.44
1976	23966	15.52	20.10	10.94	3631.92	4639.99	2623.64
1977	23966	28.56	33.93	23.18	7458.99	8774.34	6143.43
1978	23966	30.76	38.95	22.58	6543.36	8118.70	4968.02
1979	23966	14.58	18.09	11.08	3900.89	4833.21	2968.57
1980	23966	36.25	48.66	23.84	8042.09	10563.87	5520.53
1981	23966	38.41	66.71	10.10	6007.33	7245.86	4768.81
1982	23966	16.29	23.40	9.18	3575.21	5269.10	1881.12
1983	23966	22.91	27.67	18.14	8804.72	10655.03	6954.42
1984	23966	22.43	28.66	16.20	7578.61	9535.90	5621.52
1985	23966	39.02	48.32	29.73	10130.34	11882.86	8377.61
1986	23966	18.44	21.70	15.17	6077.73	7146.58	5009.11
1987	23966	18.46	24.31	12.61	4818.88	5971.17	3666.58
1988	23966	14.55	18.01	11.10	5443.71	6764.40	4122.79
1989	23966	60.03	90.17	29.89	9995.75	13533.09	6458.62
1990	23966	30.94	45.93	15.96	7104.64	9402.16	4807.32
1991	23966	28.60	46.18	11.01	5473.02	7860.85	3085.19
1992	23966	22.94	31.72	14.16	4898.48	6147.07	3649.89
1993	23966	25.67	43.32	8.01	4259.96	6810.62	1709.29
1994	23966	47.05	66.45	27.65	7904.07	11461.53	4346.62
1995	23966	53.99	69.48	38.50	7009.84	8223.76	5795.92
1996	23966	28.11	33.41	22.81	5421.02	6421.82	4420.23
1997	23966	27.49	32.66	22.32	6242.07	7512.91	4971.45
1998	23966	45.62	55.49	35.75	10361.44	12258.82	8464.06
1999	23966	35.87	42.56	29.17	7107.20	8417.63	5796.56
2000	23966	53.05	65.01	41.09	12117.81	14917.34	9318.49
2001	23966	46.89	58.90	34.87	10453.24	12160.18	8746.52
2002	23966	52.29	61.25	43.33	11498.97	13983.95	9013.78
2003	23966	33.54	39.47	27.61	7593.58	9003.30	6183.87
2004	23966	20.66	24.97	16.36	3328.06	4099.26	2557.09
2005	23966	25.62	36.01	15.23	2485.62	3040.69	1930.76
2006	23966	51.31	67.74	34.89	4679.36	5775.16	3583.34
2007	23966	39.66	53.38	25.93	5184.15	6394.86	3973.65
2008	23966	27.35	33.18	21.51	4087.49	5000.55	3174.43
2009	23966	26.67			5085.50		

Table C36. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC spring bottom trawl surveys in the northern management region (strata 20-30, 36-40). Estimates for 2009 and 2010 were converted to Albatross units using the calibration factors at length in Table C34.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1968	23966	5.17	6.64	3.69	2434.90	3200.74	1669.27
1969	23966	5.09	6.95	3.23	1367.99	2024.27	711.92
1970	23966	3.12	4.13	2.11	1157.22	1629.26	684.96
1971	23966	5.92	7.97	3.88	1386.60	1888.18	885.03
1972	23966	15.25	20.48	10.02	3338.98	4202.18	2475.56
1973	23966	34.98	57.00	12.95	9225.63	13956.99	4494.27
1974	23966	21.01	28.03	14.00	5201.91	6682.23	3721.36
1975	23236	29.87	34.75	24.98	8824.49	10584.21	7064.57
1976	23966	30.23	35.52	24.95	7213.55	9164.86	5262.25
1977	23966	20.52	24.55	16.48	5682.94	7075.11	4290.77
1978	23966	18.63	22.23	15.03	5501.05	6534.16	4468.16
1979	23966	19.27	26.97	11.58	4366.73	5981.66	2752.02
1980	23966	30.87	40.52	21.23	8308.71	10350.74	6266.68
1981	23966	57.82	89.12	26.52	13594.07	19459.11	7729.25
1982	23966	18.30	24.88	11.71	4551.40	5832.94	3270.08
1983	23966	28.09	39.79	16.39	7913.92	11193.62	4634.43
1984	23966	20.50	24.77	16.22	6381.16	7696.30	5065.81
1985	23966	21.88	26.41	17.36	8373.34	10285.05	6461.40
1986	23966	21.76	25.96	17.57	6974.75	8556.93	5392.56
1987	23966	25.01	29.52	20.49	6293.21	7447.65	5139.00
1988	23966	15.64	19.89	11.38	4271.51	5320.67	3222.14
1989	23966	17.11	21.16	13.07	3533.49	4439.27	2627.91
1990	23966	13.24	16.33	10.14	2848.32	3386.05	2310.37
1991	23966	16.97	22.84	11.10	3469.29	4665.45	2272.92
1992	23966	20.17	25.61	14.74	5351.91	7026.96	3677.07
1993	23966	27.31	34.07	20.55	6042.43	7244.79	4840.06
1994	23966	17.31	21.52	13.09	3403.17	4252.04	2554.52
1995	23966	17.98	21.31	14.66	4221.87	5043.56	3400.18
1996	23966	21.15	26.40	15.90	3834.77	4689.63	2979.70
1997	23966	23.51	29.35	17.67	3875.00	4670.16	3079.84
1998	23966	25.68	29.48	21.88	5389.78	6150.70	4628.65
1999	23966	24.37	29.36	19.39	4969.31	6098.28	3840.55
2000	23966	34.27	39.81	28.73	6818.33	7989.24	5647.42
2001	23966	40.77	48.94	32.59	7659.06	8941.89	6376.03
2002	23966	47.06	53.34	40.78	9542.75	10587.41	8498.09
2003	23966	12.35	14.18	10.53	2131.26	2464.22	1798.31
2004	23966	21.05	27.70	14.41	3791.55	4807.96	2775.13
2005	23966	13.64	16.78	10.51	2347.81	2779.41	1916.42
2006	23966	13.50	15.84	11.16	1952.16	2229.91	1674.20
2007	23966	34.04	43.97	24.11	4399.90	5586.86	3212.94
2008	23966	48.92	58.54	39.30	7464.55	9179.19	5750.13
2009	23966	24.18			3740.11		
2010	23966	26.82			4326.30		

Table C37. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC shrimp trawl surveys (strata -12).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1985	9675	35.44	49.81	21.07	10948.96	14769.13	7129.02
1986	12022	32.38	42.23	22.53	11030.49	14657.52	7403.75
1987	11595	67.48	77.05	57.91	18964.78	21544.38	16385.47
1988	6574	24.32	29.15	19.49	8548.50	10208.11	6888.73
1989	9167	33.32	36.84	29.81	7563.46	8300.03	6826.89
1990	9167	31.60	38.40	24.81	10288.81	13032.95	7544.67
1991	10401	65.96	94.78	37.15	16716.75	22794.31	10639.44
1992	8983	37.89	48.26	27.51	10817.33	13639.11	7995.54
1993	10629	41.20	50.45	31.94	13543.74	16983.81	10103.66
1994	6574	12.27	15.06	9.48	3261.53	3887.86	2635.35
1995	6147	30.89	35.60	26.17	4824.63	5546.13	4102.97
1996	6574	78.94	95.44	62.45	10073.18	11794.41	8351.94
1997	6147	44.64	51.67	37.61	8796.36	10312.51	7280.20
1998	7241	32.15	43.13	21.17	6906.65	9766.84	4046.63
1999	8195	57.68	73.67	41.69	9216.30	10608.22	7824.18
2000	8195	104.36	134.79	73.93	18844.61	22430.33	15258.89
2001	7749	120.34	137.57	103.11	22746.41	25921.95	19571.07
2002	8500	271.96	435.27	108.64	64924.91	107687.35	22162.48
2003	9167	70.30	81.75	58.85	17193.85	20037.46	14350.25
2004	10788	88.93	103.62	74.23	17285.61	20197.83	14373.12
2005	10788	43.79	51.34	36.24	8889.31	10395.05	7383.58
2006	7241	51.81	58.55	45.06	8560.49	9769.01	7352.15
2007	9370	84.43	98.02	70.84	9015.58	10069.00	7962.39
2008	9370	93.14	111.49	74.79	14413.17	16642.06	12184.05
2009	9370	76.77	85.81	67.73	13164.38	14861.99	11466.77

Table C38. Swept area abundance and biomass and upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries fall north survey (strata 18-36).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1978	948	4.25	4.99	3.50	1427.07	1635.40	1218.78
1979	969	5.64	7.50	3.78	1292.13	1584.58	999.66
1980	969	8.28	15.39	1.17	1638.04	2626.21	649.90
1981	969	12.42	15.87	8.97	2369.36	2823.30	1915.45
1982	969	7.56	9.06	6.05	1569.36	1925.80	1212.95
1983	969	11.94	18.38	5.50	2789.64	4424.86	1154.45
1984	969	3.89	4.78	3.01	1219.57	1518.30	920.85
1985	948	10.38	15.88	4.88	2494.86	3267.44	1722.28
1986	969	8.13	9.48	6.77	1650.91	1979.39	1322.44
1987	933	2.66	3.28	2.04	446.75	554.14	339.39
1988	933	3.89	5.68	2.09	862.92	1168.10	557.71
1989	875	3.94	5.32	2.55	757.29	1178.32	336.26
1990	969	4.48	5.67	3.28	1309.44	1640.06	978.82
1991	914	10.64	12.16	9.12	1660.65	1795.32	1525.98
1992	969	8.13	9.98	6.28	926.22	1117.84	734.60
1993	969	4.30	5.56	3.05	733.24	982.22	484.27
1994	969	4.73	5.84	3.61	1083.86	1364.34	803.40
1995	969	13.23	16.26	10.21	1486.15	1884.23	1088.06
1996	969	11.03	12.87	9.18	1927.19	2423.78	1430.62
1997	969	4.74	5.54	3.94	912.01	1031.10	792.89
1998	969	8.77	10.76	6.78	1282.00	1804.87	759.11
1999	969	21.98	36.00	7.95	2307.39	2780.98	1833.80
2000	969	21.95	28.03	15.87	3841.93	4891.75	2792.11
2001	969	7.42	10.99	3.84	1313.92	1658.77	969.07
2002	969	12.07	21.60	2.54	2021.49	3597.25	445.73
2003	969	7.19	11.66	2.72	940.88	2074.02	-192.25
2004	969	4.48	5.78	3.18	644.10	750.72	537.51
2005	969	4.44	5.23	3.65	617.92	735.20	500.67
2006	969	5.50	7.54	3.46	562.52	725.05	400.02
2007	948	3.01	3.92	2.09	484.03	586.89	381.18
2008	969	5.13	6.27	3.98	673.20	851.04	495.36
2009	948	10.87	13.07	8.68	1232.85	1557.19	908.51

Table C39. Swept area abundance and biomass and upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries spring north survey (strata 18-36).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1978	930	0.82	0.90	0.73	87.00	112.02	62.00
1979	969	10.69	41.33	-19.95	3887.58	15468.92	-7693.76
1980	969	4.56	6.58	2.54	964.61	1264.49	664.71
1981	969	12.70	37.99	-12.60	5128.72	18529.83	-8272.38
1982	969	2.04	4.82	-0.74	712.27	1847.95	-423.43
1983	969	3.83	4.40	3.26	928.16	1199.55	656.80
1984	969	2.38	3.04	1.72	444.49	587.26	301.72
1985	969	5.10	6.94	3.25	877.82	1349.65	405.97
1986	969	8.20	11.56	4.84	1270.11	1811.98	728.22
1987	969	2.44	3.08	1.80	582.48	950.83	214.10
1988	969	1.77	2.33	1.21	284.81	359.64	210.01
1989	969	3.61	4.54	2.67	454.01	588.80	319.20
1990	969	1.58	2.34	0.82	362.76	479.69	245.84
1991	969	3.42	6.94	-0.10	332.86	444.26	221.45
1992	969	3.85	5.47	2.22	335.81	440.23	231.35
1993	969	0.74	0.92	0.56	107.32	152.07	62.58
1994	969	2.24	4.02	0.45	277.28	390.53	164.04
1995	969	4.06	5.08	3.05	246.19	298.82	193.54
1996	969	3.80	6.93	0.67	150.48	203.54	97.42
1997	969	6.18	7.53	4.84	832.25	1065.59	598.90
1998	969	3.53	5.19	1.87	719.96	1124.85	315.07
1999	969	4.61	6.68	2.53	721.42	1145.15	297.71
2000	969	7.14	8.86	5.41	1414.04	1904.64	923.42
2001	969	4.15	6.59	1.70	888.71	1929.66	-152.25
2002	969	3.34	4.65	2.03	635.43	783.09	487.75
2003	969	1.12	1.36	0.88	142.12	188.40	95.81
2004	969	0.86	1.10	0.62	75.08	96.26	53.89
2005	969	4.96	7.61	2.31	149.57	210.77	88.38
2006	969	5.18	6.95	3.40	347.14	457.11	237.17
2007	969	1.17	1.62	0.72	133.40	215.83	50.97
2008	969	0.98	1.29	0.66	180.94	263.35	98.53
2009	969	3.16	4.92	1.39	244.66	358.43	130.88

Table C40. Stratified mean number and weight per tow (kg) for red hake from the fall and spring Maine-New Hampshire state surveys, 2000-2009.

	MENH Fall	MENH Fall	MENH Spring	MENH Spring
Year	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)
2000	25.78	2.70		
2001	31.33	4.34	5.30	0.22
2002	17.92	2.51	9.08	1.00
2003	29.38	5.43	9.45	0.78
2004	15.30	2.91	3.21	0.31
2005	13.41	1.37	6.74	0.71
2006	11.18	1.37	2.56	0.10
2007	25.86	3.35	9.70	0.46
2008	35.07	4.16	11.82	0.57
2009	30.43	3.41	23.89	0.78

Table C41. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC fall bottom trawl surveys in the southern management region (strata 1-19, 61-76). Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1967	37081	26.06	36.15	15.98	5601.55	7555.92	3647.51
1968	37081	49.14	62.91	35.37	10172.78	13136.94	7208.28
1969	37081	58.22	75.34	41.10	11761.30	15180.03	8342.56
1970	37081	50.23	60.59	39.88	7471.49	8940.16	6002.49
1971	37081	57.72	70.61	44.83	8502.47	10424.73	6579.89
1972	37081	84.47	112.47	56.47	12739.31	16307.69	9170.59
1973	37081	63.56	88.28	38.84	7785.35	10573.38	4997.33
1974	37081	73.00	92.27	53.73	3022.43	4394.76	1650.10
1975	37081	112.16	142.02	82.30	16169.96	20158.49	12181.11
1976	37081	66.05	82.64	49.45	11047.16	13842.14	8252.18
1977	37081	42.09	53.86	30.33	8319.72	10941.54	5697.56
1978	37081	38.82	47.96	29.68	6219.68	7779.73	4659.62
1979	37081	56.00	67.10	44.90	7879.71	9766.21	5993.55
1980	37021	80.00	100.65	59.36	10359.93	13498.78	7220.75
1981	37081	61.95	76.52	47.38	7676.10	9955.92	5396.28
1982	37081	51.83	68.60	35.06	10247.93	13423.98	7071.88
1983	37081	97.56	134.36	60.77	20001.56	27804.79	12198.32
1984	36995	25.21	38.27	12.15	3904.95	6048.02	1762.22
1985	37081	134.25	200.35	68.14	6582.54	9071.60	4093.81
1986	37081	24.73	39.22	10.23	3171.75	5036.73	1306.77
1987	37029	18.05	25.93	10.16	2511.36	3399.06	1623.66
1988	37081	26.58	42.51	10.65	2549.65	4063.68	1035.62
1989	37081	31.46	47.09	15.84	3908.73	5739.28	2077.86
1990	36976	33.54	51.72	15.36	4017.51	5958.75	2075.94
1991	37081	38.12	59.42	16.82	5324.43	8306.81	2342.06
1992	36924	14.59	18.97	10.21	2075.33	2756.77	1393.88
1993	37021	32.90	42.13	23.67	2986.14	4111.64	1860.64
1994	37081	33.81	54.63	13.00	2658.24	4003.09	1313.73
1995	37081	30.91	44.75	17.07	1537.87	2120.24	955.83
1996	37081	10.93	15.56	6.30	1305.78	1885.83	726.06
1997	37081	13.39	22.15	4.64	1980.19	3753.79	206.93
1998	37081	13.13	16.54	9.71	1655.73	2258.96	1052.50
1999	37081	59.12	106.03	12.21	1787.17	3196.91	377.43
2000	37081	8.70	11.60	5.81	1576.94	2400.00	753.54
2001	37021	37.18	56.03	18.34	1822.62	2399.75	1245.49
2002	37081	28.33	35.91	20.76	1990.79	2480.79	1500.46
2003	37021	22.49	28.80	16.17	1833.20	2463.22	1202.85
2004	37081	21.69	26.56	16.82	1326.64	1628.25	1025.02
2005	36916	34.51	48.16	20.87	2089.71	2948.34	1231.08
2006	37029	33.26	45.18	21.33	2704.44	4703.67	705.53
2007	37081	46.75	63.43	30.08	1821.94	2532.76	1111.11
2008	37081	22.36	31.37	13.35	2408.61	3332.99	1484.23
2009	37081	30.33			3368.29		

Table C42. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC spring bottom trawl surveys in the southern management region (strata 1-19, 61-76). Estimates for 2009 and 2010 were converted to Albatross units using the calibration factors at length in Table C34.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1968	37081	20.66	28.71	12.62	4255.38	5837.28	2673.80
1969	37081	18.89	23.77	14.01	3582.95	4552.35	2613.55
1970	37081	31.48	37.24	25.72	5704.85	6855.02	4554.67
1971	37081	80.99	114.98	47.01	11549.41	15652.82	7446.33
1972	37081	59.23	87.88	30.57	11885.12	17216.18	6553.74
1973	37081	70.98	87.06	54.90	13218.05	16203.07	10232.70
1974	37081	46.87	58.56	35.17	9395.07	11808.31	6982.15
1975	35374	42.63	63.22	22.04	10039.58	14482.81	5596.04
1976	37081	78.15	136.55	19.75	17592.95	33299.40	1886.16
1977	37081	39.93	48.93	30.94	7616.17	9202.71	6029.64
1978	37081	110.37	151.64	69.09	25319.70	32988.18	17651.55
1979	37081	28.72	40.72	16.72	5011.56	6798.40	3224.39
1980	37081	48.96	60.50	37.41	7878.72	10112.85	5644.59
1981	36909	91.24	127.92	54.56	15200.58	20687.49	9713.66
1982	37081	58.50	80.31	36.69	11065.04	16856.63	5273.45
1983	37081	40.04	53.42	26.67	7306.28	9845.34	4767.23
1984	37081	24.32	38.39	10.25	4406.02	7141.40	1670.30
1985	37081	23.49	31.18	15.79	4609.63	6232.26	2986.68
1986	37081	37.45	53.45	21.46	5740.60	8417.06	3064.15
1987	37081	14.65	21.47	7.84	2905.23	4190.82	1619.31
1988	36976	20.14	27.48	12.81	3320.91	4619.03	2022.79
1989	37081	12.98	16.97	8.98	1613.35	2213.27	1013.11
1990	36909	15.85	21.15	10.55	2329.55	3095.08	1563.69
1991	37081	15.75	20.86	10.64	2022.24	2693.67	1351.14
1992	36845	10.64	15.28	6.00	1529.07	2395.25	662.88
1993	36845	10.91	13.22	8.60	1393.20	1846.20	940.53
1994	36905	19.58	30.66	8.50	2223.20	3280.92	1165.14
1995	37081	10.89	14.31	7.46	1707.05	2250.68	1163.09
1996	37081	11.31	19.19	3.43	1499.46	2899.93	98.99
1997	36800	25.60	46.86	4.34	3814.39	6946.99	681.46
1998	37021	6.08	7.09	5.08	706.04	845.86	566.55
1999	37081	10.71	14.49	6.92	1505.42	2082.16	928.68
2000	37081	11.41	14.52	8.30	1400.14	1958.34	841.94
2001	37081	13.38	16.86	9.89	2125.20	2758.89	1491.85
2002	37081	12.25	18.38	6.11	1794.46	2797.30	791.61
2003	37081	6.18	8.15	4.21	680.70	874.71	486.69
2004	37081	5.74	8.66	2.83	511.19	818.43	203.95
2005	37081	9.65	12.01	7.29	1245.19	1587.53	902.86
2006	37021	10.92	13.85	7.98	1256.07	1712.88	799.59
2007	37081	25.33	33.99	16.68	2838.68	3710.75	1966.29
2008	37081	13.73	19.38	8.07	1567.33	2233.80	900.54
2009	36995	29.84			4433.65		
2010	37081	26.45			3459.51		

Table C43. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC winter flatfish surveys in the southern management region (strata 1-3, 5-7, 9-11, 13-14, 61-63, 65-67, 69-71, 73-75).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1992	30014	107.45	174.39	40.51	15311.03	26314.03	4307.81
1993	29928	126.71	196.99	56.44	18482.71	29030.39	7935.03
1994	30014	73.83	123.70	23.95	6571.00	10607.77	2534.46
1995	30014	17.00	28.11	5.89	1711.94	2676.74	746.91
1996	30014	5.90	7.71	4.10	768.91	1061.95	475.87
1997	30014	23.91	35.89	11.94	2674.91	4014.54	1335.28
1998	30014	13.92	17.22	10.61	1399.43	1903.25	895.61
1999	30014	35.79	58.39	13.19	5108.57	8330.83	1886.07
2000	30014	45.65	58.99	32.31	4298.88	6195.49	2402.04
2001	30014	31.22	41.37	21.07	3999.65	5543.20	2456.34
2002	30014	15.43	22.01	8.85	1278.69	1834.29	723.09
2003	26984	7.46	11.97	2.94	159.23	237.91	80.54
2004	30014	57.02	96.82	17.23	5327.60	9446.16	1208.81
2005	29358	7.65	9.52	5.79	315.54	425.35	205.95
2006	30014	20.56	25.70	15.41	1490.39	2164.44	816.33
2007	26984	5.44	7.06	3.83	263.66	360.89	166.44

Table C44. Swept area abundance and biomass and upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries fall south survey (strat 11-17).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1978	864	0.08	0.10	0.06	13.46	20.06	6.83
1979	864	0.13	0.25	0.01	6.54	17.86	-4.76
1980	864	0.02	0.03	0.00	2.36	4.94	-0.20
1981	864	0.05	0.06	0.04	2.34	6.33	-1.66
1982	864	0.23	0.37	0.08	26.10	41.76	10.47
1983	864	0.01	0.02	-0.01	0.52	2.11	-1.08
1984	864	0.04	0.15	-0.07	5.66	22.42	-11.10
1985	864	0.03	0.06	0.01	0.09	0.18	0.02
1986	864	0.44	0.86	0.01	14.40	27.77	1.01
1987	864	0.04	0.06	0.01	0.81	1.62	0.02
1988	864	0.02			2.88		
1989	864	0.12	0.33	-0.08	14.71	45.24	-15.79
1990	864	0.20	0.42	-0.02	1.57	3.14	0.00
1991	864	0.29	0.53	0.05	2.34	3.84	0.83
1992	864	0.01	0.02	0.00	0.58	2.16	-0.99
1993	864	0.20	0.51	-0.11	1.42	3.53	-0.72
1994	864	0.12	0.33	-0.08	7.97	31.07	-15.10
1995	864	1.03	1.66	0.40	9.39	13.14	5.64
1996	864	0.04	0.07	0.02	7.10	12.87	1.33
1997	864	0.05	0.10	0.00	2.02	4.13	-0.09
1998	864	0.04	0.07	0.02	0.34	0.70	0.00
1999	864	1.38	2.69	0.07	13.59	22.49	4.69
2000	864	0.03			2.63	10.54	-5.26
2001	864	0.00	0.01	-0.01	0.27	1.06	-0.54
2002	864	0.21	0.44	-0.03	0.61	1.17	0.02
2003	864	0.13	0.24	0.02	0.29	0.56	0.02
2004	864	0.12	0.21	0.04	0.22	0.43	0.02
2005	864	0.32	0.69	-0.04	1.03	2.43	-0.38
2006	864	0.94	1.69	0.20	2.25	3.80	0.70
2007	864	0.19	0.36	0.01	1.06	2.00	0.11
2008	864	0.24	0.52	-0.03	7.64	30.84	-15.57
2009	864	0.17	0.34	0.01	1.64	2.94	0.34

Table C45. Swept area abundance and biomass and upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries spring south survey (strata 11-17).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1978	864	0.11	0.18	0.04	5.10	9.82	0.38
1979	864	6.22	11.71	0.73	2093.08	3843.67	342.50
1980	864	0.86	1.47	0.24	230.34	506.33	-45.67
1981	864	1.63	2.90	0.35	565.30	1054.65	75.97
1982	864	1.52	3.77	-0.74	696.33	1913.68	-521.02
1983	864	2.84	5.63	0.05	592.08	1209.58	-25.43
1984	864	2.12	4.11	0.12	420.52	794.07	46.97
1985	864	0.57	0.97	0.17	71.41	133.01	9.84
1986	864	0.64	0.74	0.53	76.06	111.08	41.06
1987	864	5.08	7.08	3.08	893.83	1423.59	364.07
1988	864	0.15	0.29	0.00	18.67	35.85	1.51
1989	864	2.14	3.17	1.11	581.54	924.67	238.38
1990	864	2.60	4.82	0.37	753.09	1514.12	-7.91
1991	864	0.01	0.02	0.00	1.17	2.67	-0.36
1992	864	1.18	1.77	0.58	262.08	509.97	14.17
1993	864	0.29	0.44	0.14	35.58	46.63	24.53
1994	864	4.33	7.92	0.74	757.18	1316.64	197.70
1995	864	1.86	5.92	-2.20	86.19	320.65	-148.26
1996	864	0.34	0.60	0.09	29.97	61.06	-1.12
1997	864	1.72	2.76	0.69	230.68	364.54	96.82
1998	864	0.28	0.87	-0.30	28.35	111.46	-54.74
1999	864	0.59	2.15	-0.98	100.68	381.75	-180.41
2000	864	0.71	1.94	-0.52	210.33	579.11	-158.46
2001	864	0.25	0.69	-0.20	40.70	160.66	-79.23
2002	864	0.40	1.47	-0.66	124.34	497.21	-248.54
2003	864	0.04	0.09	-0.02	0.36	1.08	-0.34
2004	864	0.20	0.38	0.03	1.06	2.04	0.09
2005	864	1.40	1.76	1.04	42.16	98.91	-14.60
2006	864	0.11	0.15	0.06	3.35	5.30	1.42
2007	864	0.35	0.61	0.08	36.08	67.75	4.40
2008	864	0.14	0.24	0.05	1.80	4.31	-0.74
2009	864	0.72	1.03	0.41	6.92	20.80	-6.94

Table C46. Stratified mean number and weight (kg) per tow for red hake from Rhode Island and Connecticut state surveys in the southern management area for both fall and spring.

	RI Fall	RI Fall	RI Spring	RI Spring	CT Fall	CT Fall	CT Spring	CT Spring
Year	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Stratified Mean Number/Tow	Stratified Mean Weight/Tow (Kg)
1979	2.91	0.22	5.72	0.55				
1980	0.71	0.09	8.75	0.48				
1981	2.60	0.24	1.43	0.24				
1982	1.84	0.15	1.37	0.07				
1983	0.61	0.09	8.00	1.14				
1984	3.00	0.43	14.26	2.84	0.74		15.04	
1985	3.16	0.22	2.67	0.15	0.33		3.02	
1986	12.47	0.75	19.25	1.37	1.00		4.67	
1987	2.24	0.26	34.34	1.77	0.37		3.84	
1988	1.93	0.40	9.42	1.06	0.75		3.64	
1989	2.91	0.34	12.57	0.87	1.14		13.12	
1990	0.36	0.03	2.12	0.19	0.44		4.75	
1991	0.00	0.00	9.30	0.63	0.33		4.35	
1992	0.32	0.04	0.17	0.00	0.39	0.11	4.83	0.78
1993	0.54	0.05	0.83	0.01	1.81	0.34	6.00	0.85
1994	0.56	0.07	0.39	0.04	0.59	0.19	0.89	0.14
1995	0.20	0.02	7.39	0.11	0.20	0.04	4.12	0.66
1996	0.58	0.10	2.01	0.13	1.62	0.48	1.49	0.21
1997	3.35	0.23	16.87	1.79	0.89	0.18	1.41	0.33
1998	0.15	0.02	2.39	0.25	0.53	0.10	6.28	0.94
1999	0.26	0.02	4.15	0.26	0.29	0.06	7.21	1.05
2000	0.46	0.06	5.87	0.40	1.20	0.32	4.01	0.59
2001	0.31	0.03	0.82	0.18	0.41	0.07	2.64	0.45
2002	0.10	0.01	1.04	0.27	0.15	0.02	5.11	0.96
2003	1.45	0.19	4.20	0.04	0.73	0.19	1.18	0.13
2004	1.33	0.09	2.04	0.08	0.76	0.14	1.37	0.20
2005	2.84	0.20	1.51	0.01	0.45	0.10	1.06	0.22
2006	0.49	0.03	1.51	0.10	0.33	0.06	1.30	0.25
2007	0.14	0.01	0.60	0.02	0.54	0.12	3.85	0.67
2008	0.33	0.03	1.01	0.01	0.41	0.09	3.37	0.61
2009	0.63	0.07	0.43	0.02	0.90	0.13	1.48	0.23
2010			1.03	0.02				

Table C47. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC fall bottom trawl surveys in the northern and southern management regions combined (strata 1-30, 36-40, 61-76). Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1967	61047	29.00	39.18	18.81	6647.04	8648.51	4645.57
1968	61047	51.27	65.07	37.47	10721.38	13692.52	7750.24
1969	61047	67.46	84.94	49.98	13194.87	16659.84	9729.37
1970	61047	60.19	71.33	49.04	8755.88	10278.79	7232.98
1971	61047	71.68	86.86	56.50	11353.65	13375.29	9332.02
1972	61047	105.10	133.74	76.46	17737.42	21625.90	13849.49
1973	61047	79.20	104.73	53.67	11128.00	14159.09	8096.36
1974	61047	79.32	98.67	59.97	4467.33	5882.31	3052.35
1975	61047	129.75	159.92	99.57	19941.66	24006.73	15876.58
1976	61047	81.57	98.70	64.44	14679.08	17627.87	11730.29
1977	61047	70.65	83.41	57.88	15778.47	18667.30	12889.64
1978	61047	69.59	81.72	57.45	12763.18	14942.89	10582.93
1979	61047	70.58	82.17	58.99	11780.98	13856.58	9704.84
1980	60987	116.25	139.67	92.83	18401.74	22294.02	14510.01
1981	61047	100.36	130.20	70.51	13683.25	16244.50	11122.55
1982	61047	68.12	85.98	50.27	13822.79	17331.90	10314.22
1983	61047	120.47	157.50	83.44	28806.55	36780.27	20832.29
1984	60961	47.64	61.86	33.42	11483.53	14312.23	8655.37
1985	61047	173.27	239.86	106.68	16712.71	19717.64	13708.32
1986	61047	43.16	57.94	28.38	9249.71	11359.65	7139.77
1987	60995	36.51	45.89	27.12	7330.29	8736.44	5924.14
1988	61047	41.13	57.30	24.96	7993.34	9917.96	6068.73
1989	61047	91.49	123.91	59.07	13904.54	17744.51	10064.58
1990	60942	64.48	86.81	42.15	11121.92	14013.40	8230.98
1991	61047	66.72	92.93	40.50	10797.14	14428.89	7165.94
1992	60890	37.53	47.01	28.04	6973.54	8371.83	5575.78
1993	60987	58.57	77.64	39.50	7246.02	9938.70	4553.33
1994	61047	80.86	108.07	53.66	10562.77	14247.39	6877.60
1995	61047	84.90	104.96	64.83	8547.67	9883.07	7212.81
1996	61047	39.04	45.92	32.16	6727.16	7864.16	5589.62
1997	61047	40.88	50.73	31.04	8222.27	10322.39	6122.69
1998	61047	58.75	69.07	48.42	12016.99	13987.39	10047.14
1999	61047	94.99	142.25	47.72	8894.33	10539.33	7249.33
2000	61047	61.75	73.99	49.51	13694.70	16591.70	10797.69
2001	60987	84.07	105.60	62.55	12275.81	14064.04	10487.59
2002	61047	80.63	92.14	69.11	13489.75	16000.85	10978.10
2003	60987	56.03	64.53	47.53	9426.85	10949.34	7903.81
2004	61047	42.35	48.75	35.96	4654.83	5471.34	3838.33
2005	60882	60.14	76.76	43.52	4575.39	5582.66	3568.66
2006	60995	84.57	104.27	64.87	7383.66	9593.64	5174.23
2007	61047	86.41	107.40	65.42	7006.23	8383.61	5628.32
2008	61047	49.71	60.13	39.29	6496.05	7751.88	5240.23
2009	61047	57.00			8453.82		

Table C48. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC spring bottom trawl surveys in the northern and southern management regions combined (strata 1-30, 36-40, 61-76). Estimates for 2009 and 2010 were converted to Albatross units using the calibration factors at length in Table C34.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1968	61047	25.83	33.98	17.68	6690.64	8420.13	4960.61
1969	61047	23.98	29.15	18.82	4950.80	6104.15	3798.00
1970	61047	34.60	40.44	28.76	6861.79	8087.09	5636.49
1971	61047	86.92	120.95	52.89	12935.97	17062.64	8809.85
1972	61047	74.48	103.49	45.47	15223.60	20610.99	9836.74
1973	61047	105.95	130.04	81.87	22443.49	27805.27	17081.71
1974	61047	67.88	81.29	54.46	14597.32	17390.22	11803.87
1975	58610	72.49	93.49	51.50	18864.05	23568.55	14159.02
1976	61047	108.38	166.94	49.83	24806.34	40570.64	9042.04
1977	61047	60.45	70.20	50.70	13298.98	15376.76	11221.20
1978	61047	128.99	170.40	87.59	30821.10	38546.82	23094.84
1979	61047	47.99	62.01	33.98	9378.35	11723.75	7032.94
1980	61047	79.83	94.57	65.09	16187.27	19172.57	13202.50
1981	60875	149.06	194.77	103.35	28794.42	36579.35	21010.03
1982	61047	76.80	99.39	54.21	15616.59	21514.71	9717.92
1983	61047	68.13	85.31	50.96	15220.33	19203.10	11237.01
1984	61047	44.82	59.38	30.25	10786.79	13766.10	7808.02
1985	61047	45.37	54.14	36.60	12982.84	15427.45	10538.24
1986	61047	59.22	75.66	42.77	12715.22	15755.58	9674.86
1987	61047	39.66	47.70	31.62	9198.47	10889.26	7507.69
1988	60942	35.78	44.14	27.42	7592.18	9227.82	5956.54
1989	61047	30.09	35.52	24.66	5147.03	6184.28	4109.23
1990	60875	29.08	35.10	23.07	5177.64	6093.48	4261.79
1991	61047	32.72	40.18	25.26	5491.50	6820.91	4162.10
1992	60811	30.82	37.79	23.84	6880.87	8726.38	5035.91
1993	60811	38.22	45.29	31.15	7435.77	8706.29	6165.26
1994	60871	36.89	48.57	25.21	5626.22	6945.82	4306.62
1995	61047	28.87	33.51	24.22	5928.64	6891.77	4965.52
1996	61047	32.46	40.93	23.99	5333.98	6780.58	3887.39
1997	60766	49.11	70.55	27.68	7689.07	10857.04	4521.64
1998	60987	31.76	35.67	27.86	6095.98	6867.57	5323.84
1999	61047	35.08	41.22	28.93	6474.80	7724.08	5225.51
2000	61047	45.68	51.93	39.44	8218.45	9479.18	6957.72
2001	61047	54.14	62.91	45.38	9784.42	11197.22	8371.61
2002	61047	59.31	67.83	50.78	11337.30	12747.92	9926.13
2003	61047	18.53	20.99	16.08	2811.98	3179.89	2444.06
2004	61047	26.80	33.74	19.85	4302.72	5342.70	3262.74
2005	61047	23.29	27.06	19.52	3593.05	4125.03	3061.62
2006	60987	24.42	28.11	20.72	3208.35	3735.45	2681.25
2007	61047	59.37	71.52	47.22	7238.43	8591.82	5885.04
2008	61047	62.65	73.58	51.72	9031.69	10840.20	7223.17
2009	60961	54.02			8173.75		
2010	61047	62.67			9022.02		

Table C49. Species of consistent red hake predators. Whether abundances where estimated from recent stock assessments (SA) or swept area (SWA) from surveys are noted, as is the resolution of the diet data (annual, 2 yr, or 3 yr).

Common Name	Species Name	Assessment or Swept Area	Diet Resolution
Spiny dogfish	*Squalus acanthias*	SWA	Annual
Little skate	*Raja ocellata*	SWA	Annual
Winter skate	*Raja erinacea*	SWA	3 yr
Thorny skate	*Raja radiata*	SWA	2 yr
Silver Hake	*Merluccius bilinearis*	SWA	Annual
Atlantic cod	*Gadus morhua*	SWA	Annual
White hake	*Urophycis tenuis*	SWA	Annual
Fourspot flounder	*Paralichthys oblongus*	SWA	3 yr
Summer Flounder	*Paralichthys dentatus*	SWA	3 yr
Windowpane	*Scophthalmus aquosus*	SWA	3 yr
Sea raven	*Hemitripterous americanus*	SWA	3 yr
Goosefish	*Lophius americanus*	SWA	3 yr

Table C50. Summary of catch, NEFSC fall and spring bottom trawl survey indices, replacement ratios and relative fishing mortality rates for red hake, northern stock. Catch is based on method "Raw C2". Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

		NEFSC Survey		Replacement Ratio		Relative Fishing Mortality	
Year	Catch(mt)	Fall (kg/tow)	Spring (kg/tow)	Fall	Spring	Relative F Fall (mt/kg)	Relative F Spring (mt/kg)
1963	3281.0	4.85	-999			676.5	
1964	1409.0	1.31	-999			1075.6	
1965	2773.0	1.22	-999			2273.0	
1966	5575.0	0.92	-999			6059.8	
1967	1863.0	0.49	-999			3802.0	
1968	2627.0	0.26	1.14	0.1479		10103.8	2304.4
1969	2021.0	0.67	0.64	0.7976		3016.4	3157.8
1970	1032.0	0.6	0.54	0.8427		1720.0	1911.1
1971	4805.0	1.33	0.65	2.2619		3612.8	7392.3
1972	15026.0	2.34	1.56	3.4925		6421.4	9632.1
1973	15288.0	1.56	4.31	1.5000	4.7572	9800.0	3547.1
1974	7223.0	0.68	2.43	0.5231	1.5779	10622.1	2972.4
1975	8701.0	1.76	4.25	1.3518	2.2392	4943.8	2047.3
1976	6337.0	1.7	3.37	1.1082	1.2765	3727.6	1880.4
1977	891.0	3.49	2.66	2.1704	0.8354	255.3	335.0
1978	1223.0	3.06	2.57	1.6649	0.7550	399.7	475.9
1979	1523.0	1.82	2.04	0.8513	0.6675	836.8	746.6
1980	1029.0	3.76	3.88	1.5892	1.3029	273.7	265.2
1981	2570.5	2.81	6.35	1.0159	2.1866	914.8	404.8
1982	2669.9	1.67	2.13	0.5589	0.6086	1598.7	1253.5
1983	2248.1	4.11	3.7	1.5663	1.0902	547.0	607.6
1984	2386.3	3.54	2.98	1.2491	0.8232	674.1	800.8
1985	2262.4	4.73	3.91	1.4884	1.0268	478.3	578.6
1986	2645.9	2.84	3.26	0.8422	0.8547	931.6	811.6
1987	2065.7	2.25	2.94	0.6661	0.9199	918.1	702.6
1988	1758.7	2.54	2	0.7270	0.5956	692.4	879.4
1989	2223.0	4.67	1.65	1.4686	0.5467	476.0	1347.3
1990	1420.6	3.32	1.33	0.9748	0.4833	427.9	1068.2
1991	1561.4	2.56	1.62	0.8195	0.7245	609.9	963.8
1992	1643.9	2.29	2.5	0.7464	1.3103	717.9	657.6
1993	851.6	1.99	2.82	0.6469	1.5495	428.0	302.0
1994	804.2	3.69	1.59	1.2441	0.8014	217.9	505.8
1995	248.9	3.28	1.97	1.1841	0.9990	75.9	126.3
1996	1064.8	2.53	1.79	0.9160	0.8524	420.9	594.8
1997	463.0	2.92	1.81	1.0595	0.8482	158.6	255.8
1998	316.9	4.84	2.52	1.6794	1.2625	65.5	125.8
1999	687.1	3.32	2.32	0.9618	1.1983	207.0	296.2
2000	251.7	5.66	3.19	1.6755	1.5322	44.5	78.9
2001	357.2	4.89	3.58	1.2688	1.5391	73.0	99.8
2002	375.7	5.37	4.46	1.2413	1.6617	70.0	84.2
2003	297.1	3.55	1	0.7371	0.3111	83.7	297.1
2004	160.0	1.56	1.77	0.3423	0.6082	102.6	90.4
2005	153.2	1.16	1.1	0.2758	0.3929	132.1	139.3
2006	276.8	2.19	0.91	0.6624	0.3820	126.4	304.2
2007	196.6	2.42	2.06	0.8749	1.1147	81.2	95.4
2008	111.6	1.91	3.49	0.8778	2.5512	58.4	32.0
2009	180.0	12.46	1.75	6.7424	0.9378	14.4	102.8

Table C51. Summary of AIM results for northern red hake for NEFSC fall and spring bottom trawl surveys and catch estimation method “raw C2” for 1963-2009.

Red Hake, North, RawC2	***Fall Survey***	***Spring Survey***
Critical value (observed correlation between replacement ratio and relative F	-0.208518	0.006928
Probability of observing correlation < Critical Value	0.9775	0.996
Relative F at Replacement (mt/kg)	607.85	7973.31
90% Confidence Interval for RelF at replacement	(14.29,37701)	(0.066,11261)

Table C52. Summary of catch, NEFSC fall and spring bottom trawl survey indices , replacement ratios and relative fishing mortality rates for red hake, southern stock. Catch is based on method "Raw C2". Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

		NEFSC Survey		Replacement Ratio		Relative Fishing Mortality	
Year	Catch(mt)	Fall (kg/tow)	Spring (kg/tow)	Fall	Spring	Relative F Fall (mt/kg)	Relative F Spring (mt/kg)
1963	31901.0	-999	-999				
1964	43373.0	-999	-999				
1965	92990.0	-999	-999				
1966	107922.0	-999	-999				
1967	58783.0	1.69	-999			34782.8	
1968	18138.0	3.07	1.29			5908.1	14060.5
1969	52928.0	3.55	1.08			14909.3	49007.4
1970	11454.0	2.26	1.72			5068.1	6659.3
1971	35134.0	2.57	3.49			13670.8	10067.0
1972	61194.0	3.85	3.59	1.4650		15894.5	17045.7
1973	51362.0	2.35	3.99	0.7680	1.7860	21856.2	12872.7
1974	26643.0	0.91	2.84	0.3121	1.0238	29278.0	9381.3
1975	19976.0	4.88	3.18	2.0436	1.0173	4093.4	6281.8
1976	22465.0	3.34	5.31	1.1470	1.5535	6726.0	4230.7
1977	7062.0	2.51	2.3	0.8187	0.6081	2813.5	3070.4
1978	5463.0	1.88	7.65	0.6719	2.1708	2905.9	714.1
1979	7592.0	2.38	1.51	0.8802	0.3548	3189.9	5027.8
1980	4082.0	3.13	2.38	1.0440	0.5965	1304.2	1715.1
1981	5034.8	2.32	4.61	0.8761	1.2037	2170.2	1092.1
1982	6945.9	3.1	3.34	1.2684	0.9051	2240.6	2079.6
1983	5329.8	6.04	2.21	2.3575	0.5670	882.4	2411.7
1984	5181.2	1.18	1.33	0.3477	0.4733	4390.8	3895.6
1985	3871.4	1.99	1.39	0.6309	0.5011	1945.4	2785.2
1986	4082.6	0.96	1.73	0.3281	0.6716	4252.7	2359.9
1987	4256.3	0.76	0.88	0.2864	0.4400	5600.4	4836.7
1988	4332.6	0.77	1.01	0.3522	0.6698	5626.7	4289.7
1989	5936.9	1.18	0.49	1.0424	0.3864	5031.3	12116.1
1990	5545.9	1.22	0.71	1.0777	0.6455	4545.9	7811.2
1991	3536.8	1.61	0.61	1.6462	0.6328	2196.8	5798.0
1992	7588.0	0.63	0.46	0.5686	0.6216	12044.5	16495.8
1993	6231.8	0.9	0.42	0.8318	0.6402	6924.2	14837.7
1994	2702.8	0.8	0.67	0.7220	1.2454	3378.5	4034.1
1995	2756.5	0.46	0.52	0.4457	0.9059	5992.3	5300.9
1996	1079.5	0.39	0.45	0.4432	0.8396	2768.0	2399.0
1997	3421.5	0.6	1.16	0.9434	2.3016	5702.4	2949.5
1998	1894.8	0.5	0.21	0.7937	0.3261	3789.6	9022.8
1999	2411.6	0.54	0.45	0.9818	0.7475	4466.0	5359.2
2000	1667.2	0.48	0.42	0.9639	0.7527	3473.3	3969.5
2001	1606.3	0.55	0.64	1.0956	1.1896	2920.5	2509.8
2002	990.0	0.6	0.54	1.1236	0.9375	1650.0	1833.3
2003	967.9	0.55	0.21	1.0300	0.4646	1759.8	4609.0
2004	1203.9	0.4	0.15	0.7353	0.3319	3009.7	8025.8
2005	1363.5	0.63	0.38	1.2209	0.9694	2164.3	3588.1
2006	1049.2	0.82	0.38	1.5018	0.9896	1279.5	2760.9
2007	2015.0	0.55	0.86	0.9167	2.5904	3663.6	2343.0
2008	1393.5	0.73	0.47	1.2373	1.1869	1908.9	2964.8
2009	1443.5	1.02	1.34	1.6294	2.9911	1415.2	1077.2

Table C53. Summary of AIM results for southern red hake for NEFSC fall and spring bottom trawl surveys and catch estimation method “raw C2” for 1963-2009.

Red Hake, South, RawC2	***Fall Survey***	***Spring Survey***
Critical value (observed correlation between replacement ratio and relative F	-0.461619	-0.45839
Probability of observing correlation < Critical Value	0.4755	0.745
Relative F at Replacement (mt/kg)	2201.7	2304.1
90% Confidence Interval for RelF at replacement	1027.9,3251.9	(1087.4, 3128.7)

Table C54. Summary of catch, NEFSC fall and spring bottom trawl survey indices, replacement ratios and relative fishing mortality rates for red hake, northern stock. Catch is based on method "Raw C3", 1980-2009. Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

		NEFSC Survey		Replacement Ratio		Relative Fishing Mortality	
Year	Catch(mt)	Fall (kg/tow)	Spring (kg/tow)	Fall	Spring	Relative F Fall (mt/kg)	Relative F Spring (mt/kg)
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975							
1976							
1977							
1978							
1979							
1980	1032.8	3.76	3.88			274.7	266.2
1981	2601.4	2.81	6.35			925.8	409.7
1982	2672.8	1.67	2.13			1600.5	1254.8
1983	2248.2	4.11	3.7			547.0	607.6
1984	2387.7	3.54	2.98			674.5	801.2
1985	2262.4	4.73	3.91	1.4884	1.0268	478.3	578.6
1986	2646.4	2.84	3.26	0.8422	0.8547	931.8	811.8
1987	2065.9	2.25	2.94	0.6661	0.9199	918.2	702.7
1988	1762.8	2.54	2	0.7270	0.5956	694.0	881.4
1989	2223.5	4.67	1.65	1.4686	0.5467	476.1	1347.6
1990	1424.8	3.32	1.33	0.9748	0.4833	429.1	1071.2
1991	1563.0	2.56	1.62	0.8195	0.7245	610.6	964.8
1992	1644.6	2.29	2.5	0.7464	1.3103	718.2	657.8
1993	852.6	1.99	2.82	0.6469	1.5495	428.4	302.3
1994	805.9	3.69	1.59	1.2441	0.8014	218.4	506.9
1995	249.9	3.28	1.97	1.1841	0.9990	76.2	126.9
1996	1070.1	2.53	1.79	0.9160	0.8524	423.0	597.8
1997	463.8	2.92	1.81	1.0595	0.8482	158.8	256.2
1998	317.0	4.84	2.52	1.6794	1.2625	65.5	125.8
1999	687.2	3.32	2.32	0.9618	1.1983	207.0	296.2
2000	251.8	5.66	3.19	1.6755	1.5322	44.5	78.9
2001	357.7	4.89	3.58	1.2688	1.5391	73.1	99.9
2002	376.0	5.37	4.46	1.2413	1.6617	70.0	84.3
2003	297.2	3.55	1	0.7371	0.3111	83.7	297.2
2004	160.1	1.56	1.77	0.3423	0.6082	102.6	90.4
2005	153.3	1.16	1.1	0.2758	0.3929	132.1	139.3
2006	276.9	2.19	0.91	0.6624	0.3820	126.4	304.3
2007	196.8	2.42	2.06	0.8749	1.1147	81.3	95.5
2008	111.8	1.91	3.49	0.8778	2.5512	58.5	32.0
2009	180.4	12.46	1.75	6.7424	0.9378	14.5	103.1

Table C55. Summary of AIM results for northern red hake for NEFSC fall and spring bottom trawl surveys and catch estimation method “Catch 3” for 1980-2009.

Red Hake, North, Catch3 short	***Fall Survey***	***Spring Survey***
Critical value (observed correlation between replacement ratio and relative F	-0.424471	-0.474634
Probability of observing correlation < Critical Value	0.379	0.2595
Relative F at Replacement (mt/kg)	162	163.1
90% Confidence Interval for RelF at replacement	(51.9, 407.0)	(42.9,260.3)

Table C56. Summary of catch, NEFSC fall and spring bottom trawl survey indices , replacement ratios and relative fishing mortality rates for red hake, southern stock. Catch is based on method "Raw C3", 1980-2009. Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

		NEFSC Survey		Replacement Ratio		Relative Fishing Mortality	
Year	Catch(mt)	Fall (kg/tow)	Spring (kg/tow)	Fall	Spring	Relative F Fall (mt/kg)	Relative F Spring (mt/kg)
1963							
1964							
1965							
1966							
1967							
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975							
1976							
1977							
1978							
1979							
1980	4226.0	3.13	2.38			1350.2	1775.6
1981	5210.7	2.32	4.61			2246.0	1130.3
1982	6975.3	3.1	3.34			2250.1	2088.4
1983	5464.8	6.04	2.21			904.8	2472.7
1984	5729.5	1.18	1.33			4855.5	4307.9
1985	3900.8	1.99	1.39	0.6309	0.5011	1960.2	2806.3
1986	4288.1	0.96	1.73	0.3281	0.6716	4466.7	2478.6
1987	4728.4	0.76	0.88	0.2864	0.4400	6221.6	5373.2
1988	4583.5	0.77	1.01	0.3522	0.6698	5952.6	4538.1
1989	6372.4	1.18	0.49	1.0424	0.3864	5400.3	13004.9
1990	6059.9	1.22	0.71	1.0777	0.6455	4967.2	8535.1
1991	3821.5	1.61	0.61	1.6462	0.6328	2373.6	6264.8
1992	7782.3	0.63	0.46	0.5686	0.6216	12352.9	16918.1
1993	6321.2	0.9	0.42	0.8318	0.6402	7023.5	15050.4
1994	2771.7	0.8	0.67	0.7220	1.2454	3464.7	4136.9
1995	2801.4	0.46	0.52	0.4457	0.9059	6090.0	5387.3
1996	1098.8	0.39	0.45	0.4432	0.8396	2817.4	2441.8
1997	3594.9	0.6	1.16	0.9434	2.3016	5991.5	3099.0
1998	1947.6	0.5	0.21	0.7937	0.3261	3895.1	9274.0
1999	2464.6	0.54	0.45	0.9818	0.7475	4564.0	5476.8
2000	1711.6	0.48	0.42	0.9639	0.7527	3565.8	4075.1
2001	1630.2	0.55	0.64	1.0956	1.1896	2964.1	2547.2
2002	1000.3	0.6	0.54	1.1236	0.9375	1667.2	1852.4
2003	985.7	0.55	0.21	1.0300	0.4646	1792.1	4693.6
2004	1214.4	0.4	0.15	0.7353	0.3319	3035.9	8095.7
2005	1418.5	0.63	0.38	1.2209	0.9694	2251.6	3732.9
2006	1102.7	0.82	0.38	1.5018	0.9896	1344.7	2901.7
2007	2034.6	0.55	0.86	0.9167	2.5904	3699.3	2365.8
2008	1467.1	0.73	0.47	1.2373	1.1869	2009.8	3121.6
2009	1543.4	1.02	1.34	1.6294	2.9911	1513.1	1151.8

Table C57. Summary of AIM results for southern red hake for NEFSC fall and spring bottom trawl surveys and catch estimation method "Catch 3" for 1980-2009.

Red Hake, South, Catch3 short	***Fall Survey***	***Spring Survey***
Critical value (observed correlation between replacement ratio and relative F	-0.565693	-0.665111
Probability of observing correlation < Critical Value	0.7015	0.6485
Relative F at Replacement (mt/kg)	2306.9	3038.2
90% Confidence Interval for RelF at replacement	(1313.8, 2982.0)	(2134.8, 3730.9)

C. Red Hake - Figures

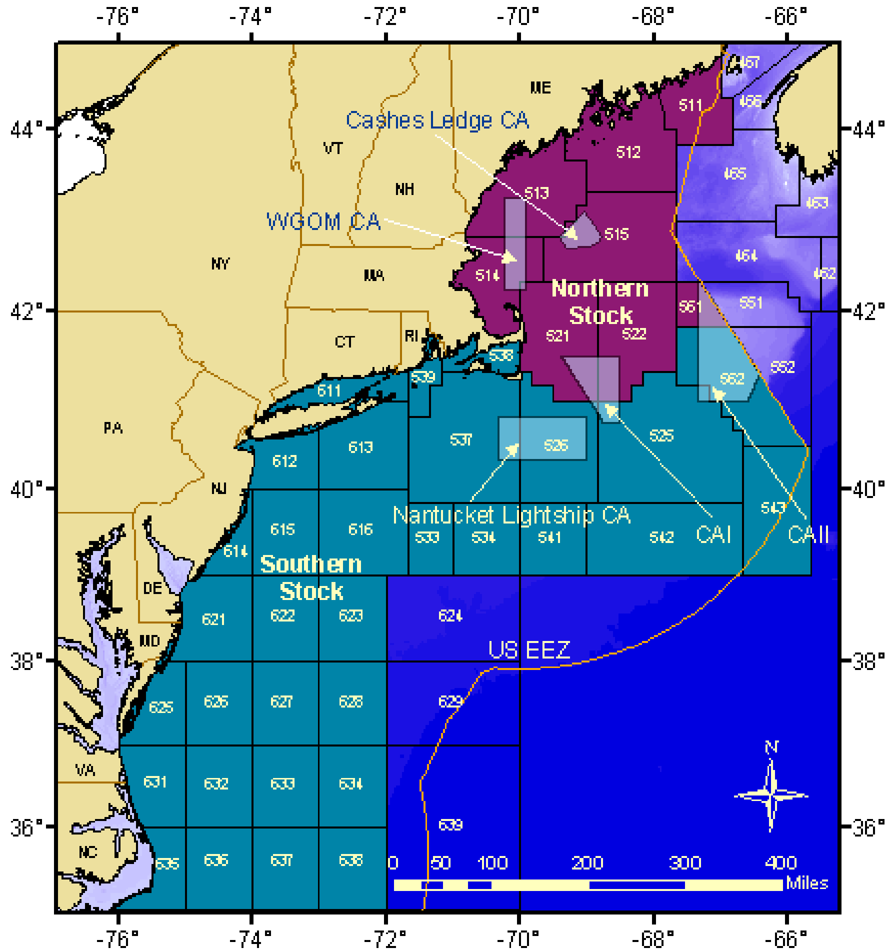


Figure C1. Statistical areas used to define the northern and southern red hake stocks.

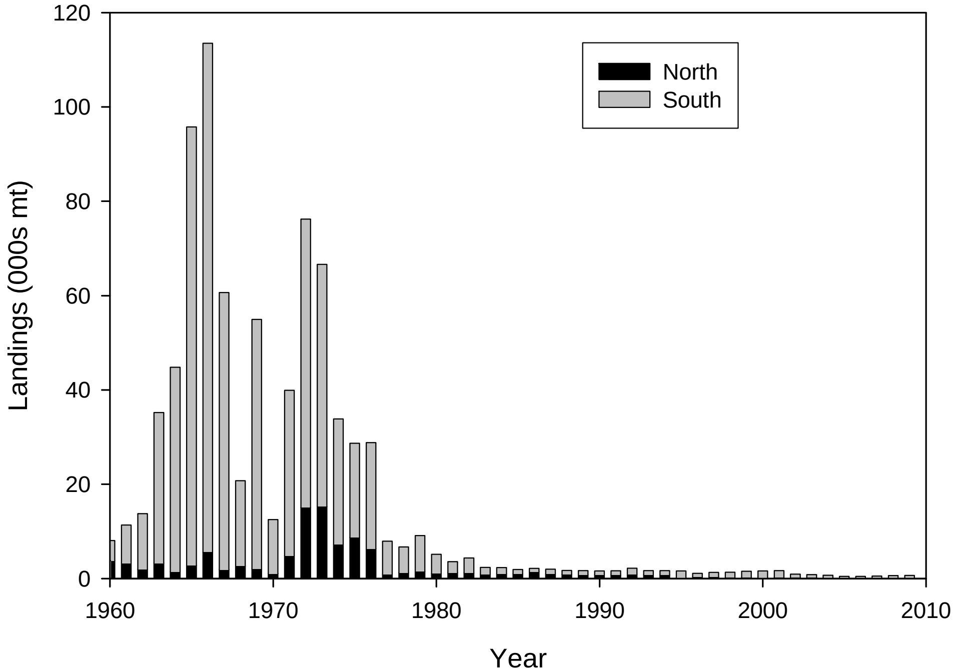


Figure C2. Nominal commercial landings (000s mt) by stock area for red hake, 1960-2009.

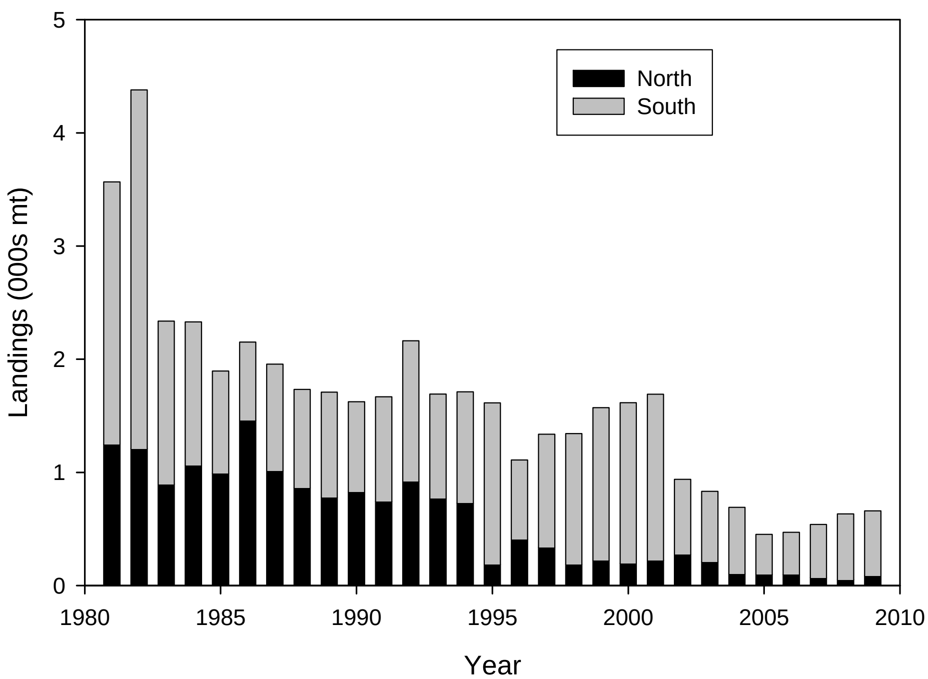


Figure C3. Nominal commercial landings (000s mt) by stock area for red hake, 1981-2009.

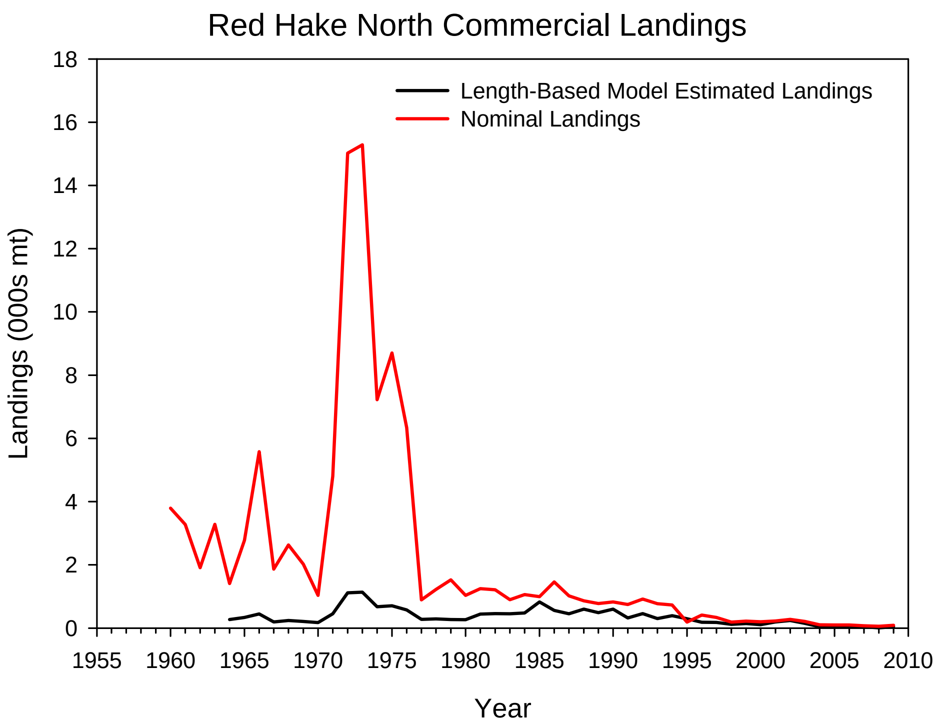


Figure C4. Comparison of nominal landings (000s mt) of red hake with length-based model estimated landings from the northern stock.

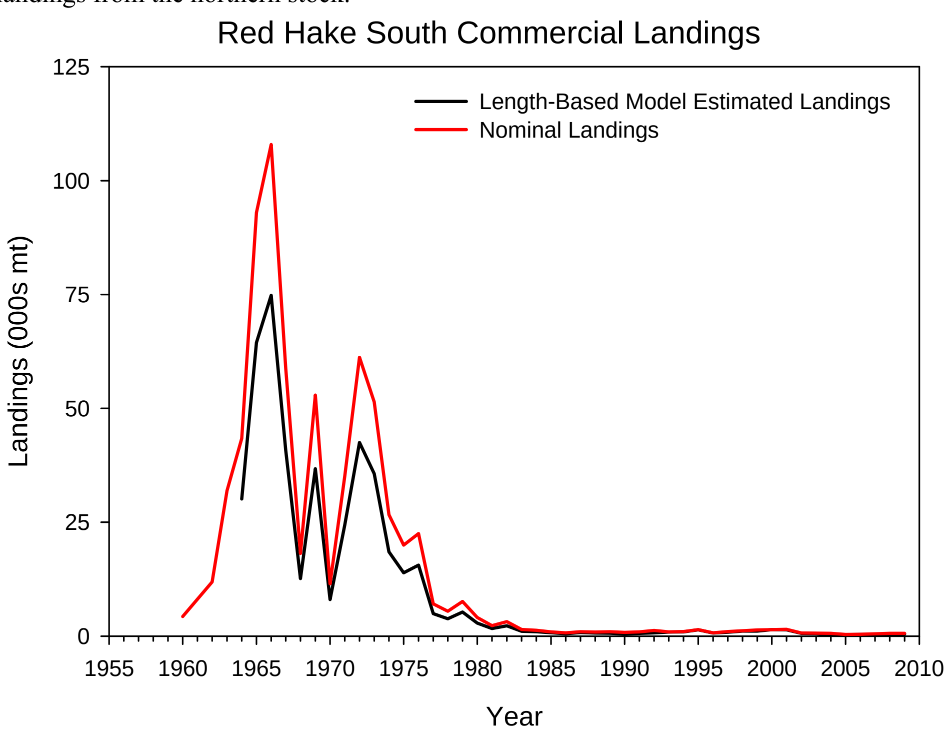
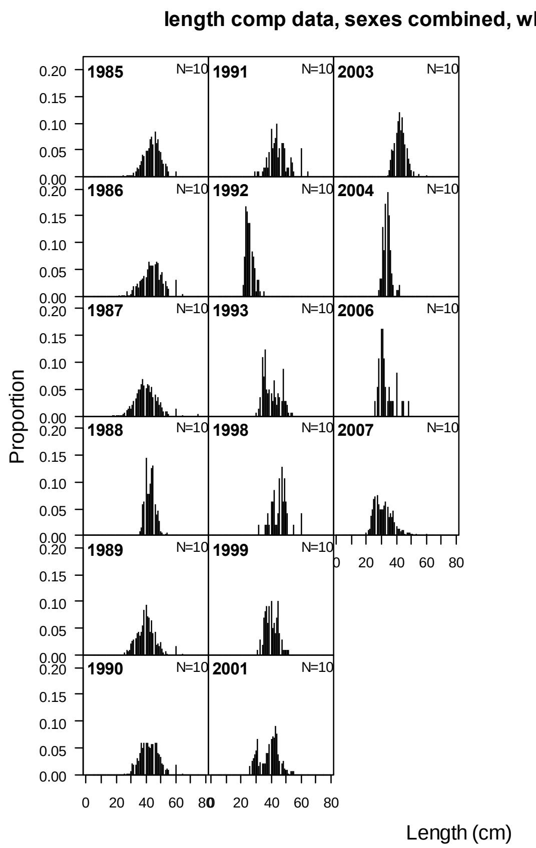


Figure C5. Comparison of nominal landings (000s mt) of red hake with length-based model estimated landings from the southern stock.



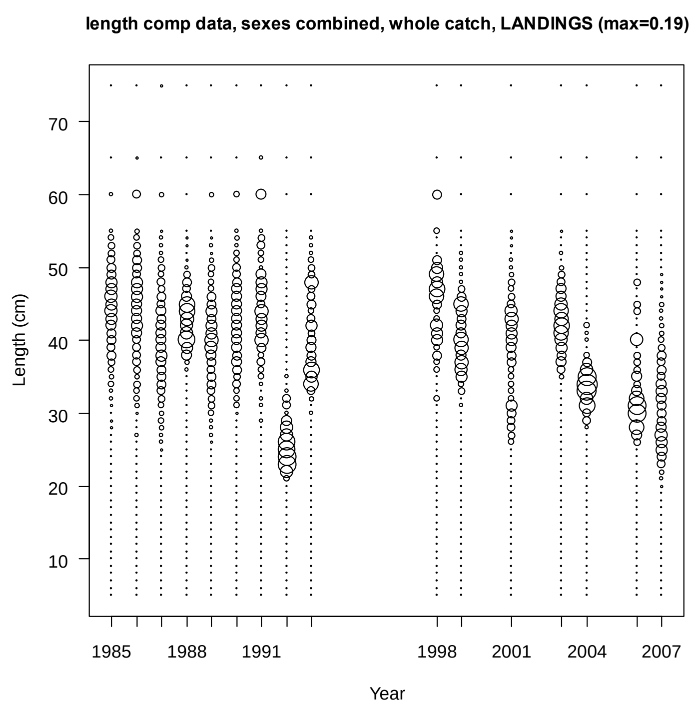
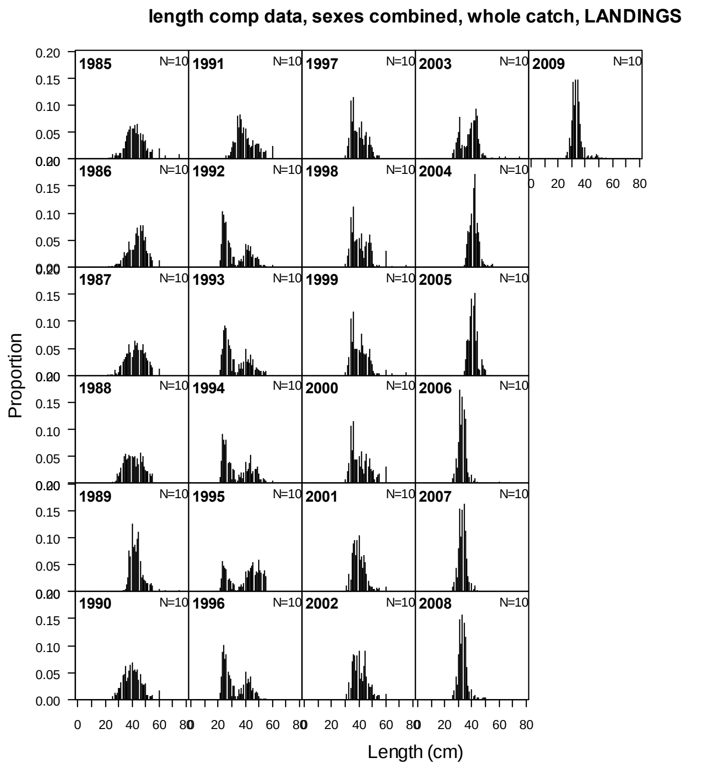


Figure C6. Length composition of nominal commercial landings from the northern stock.



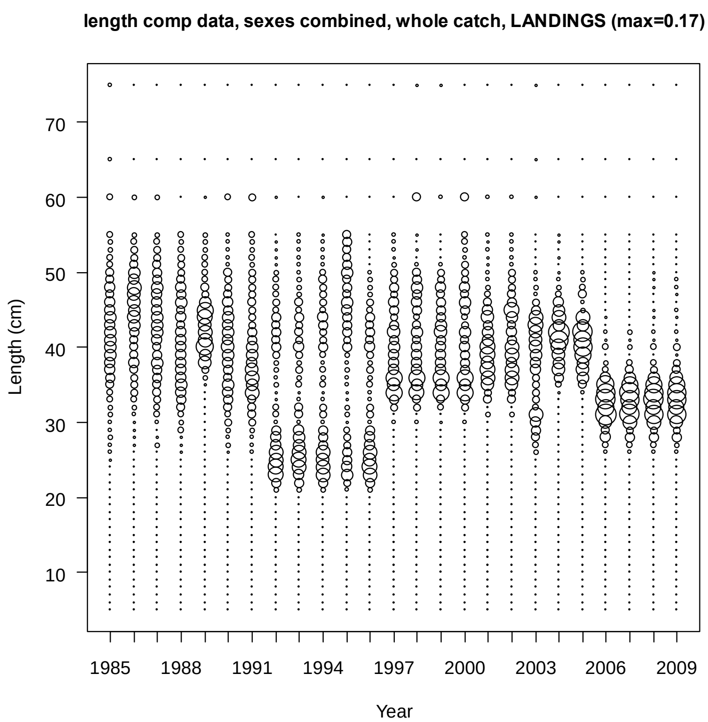


Figure C7. Length composition of length-based model estimated commercial landings from the northern stock.

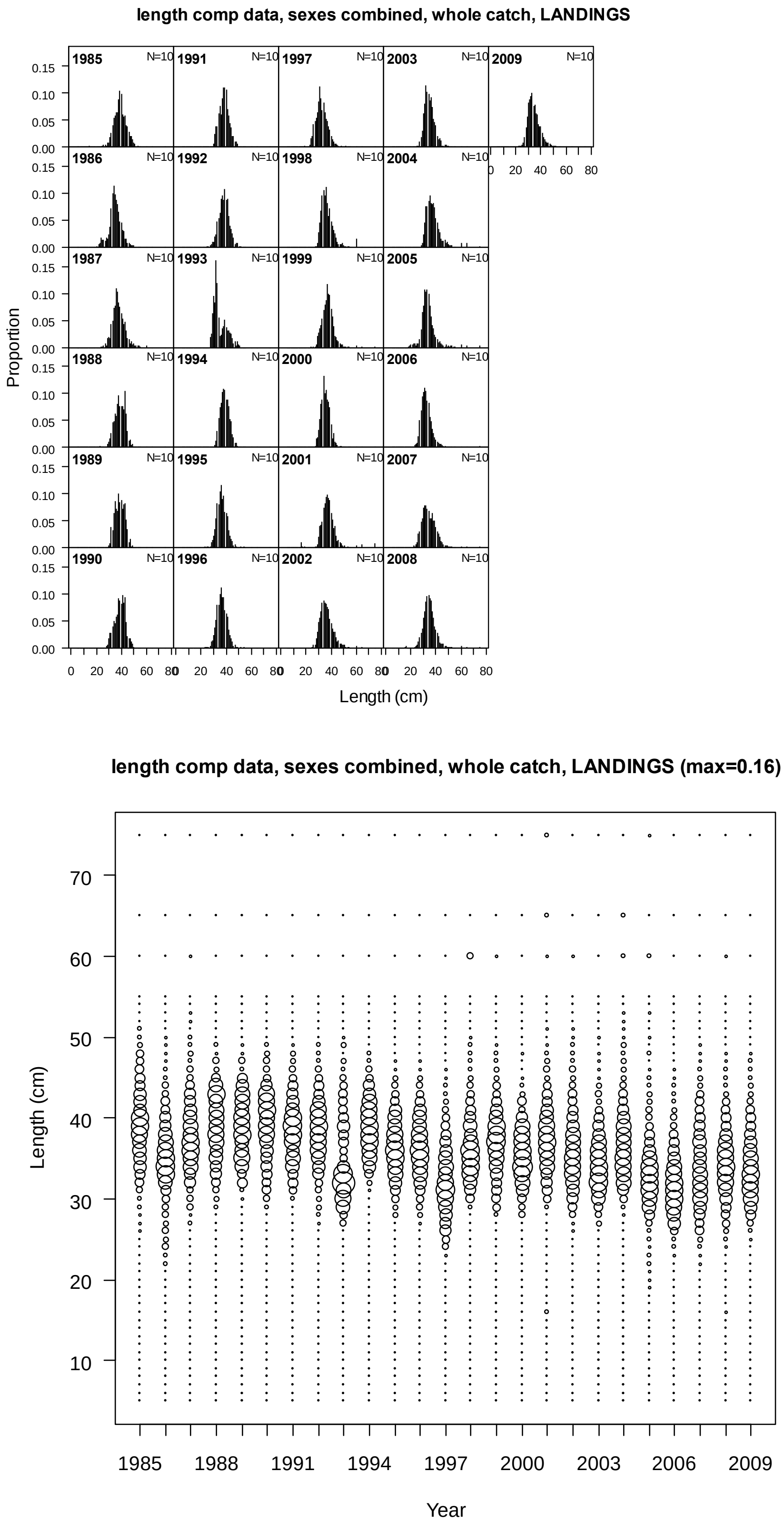
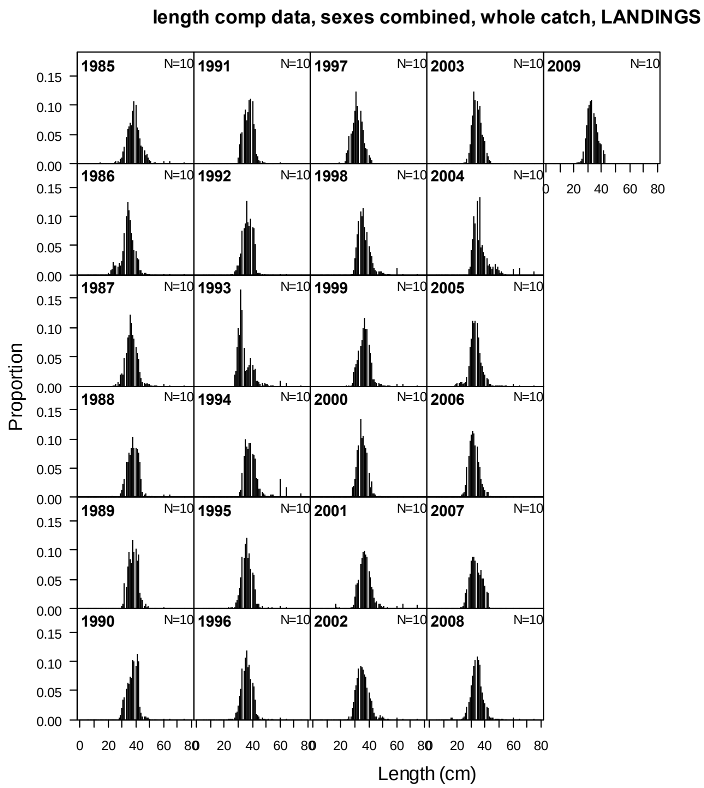


Figure C8. Length composition (proportion) of nominal commercial landings from the southern stock.



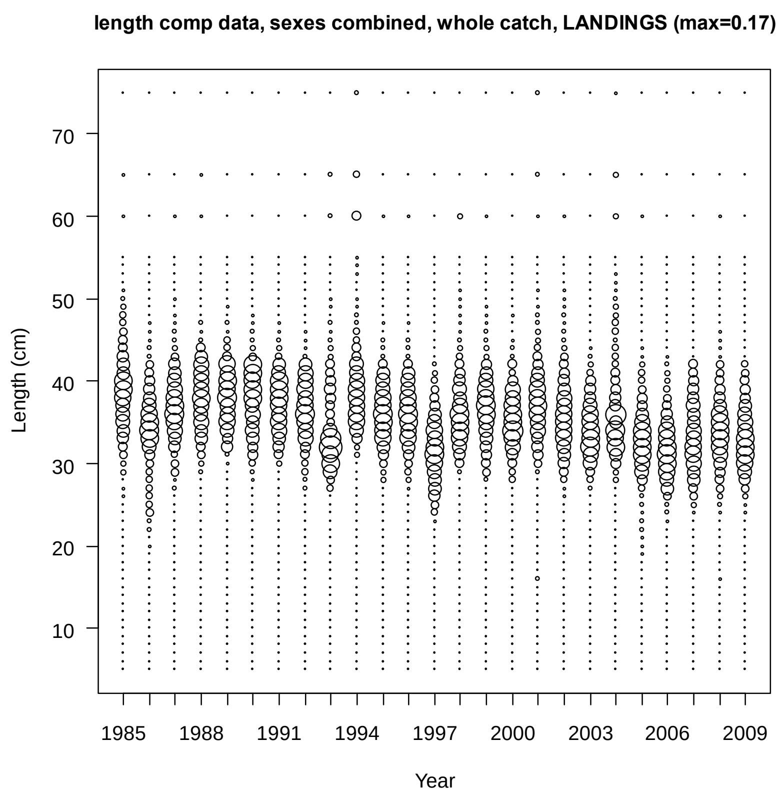


Figure C9. Length composition of length-based model estimated commercial landings from the northern stock.

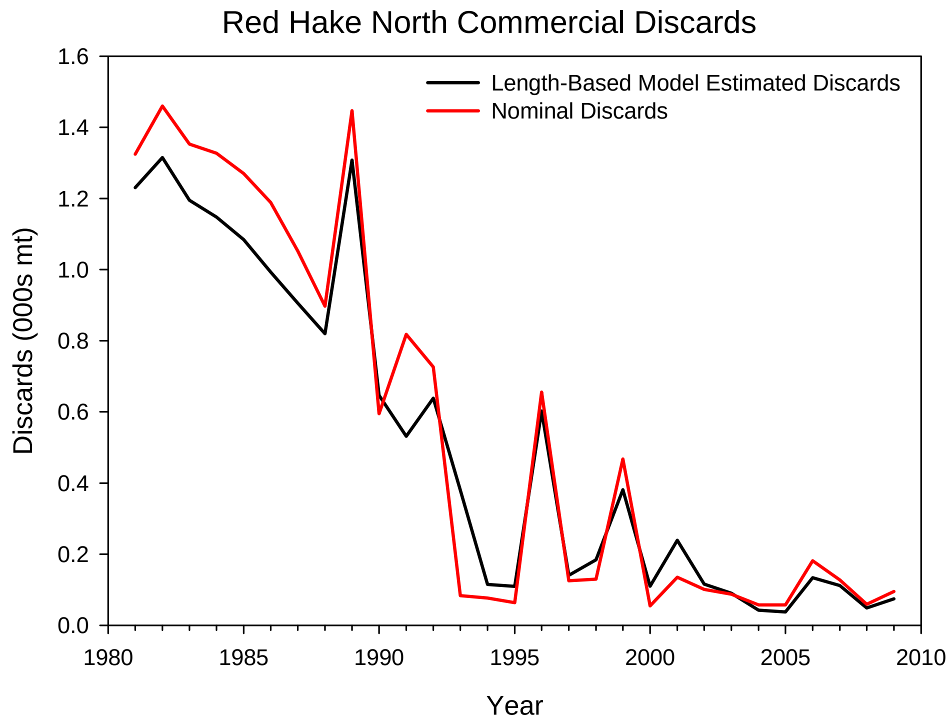


Figure C10. Comparison of nominal discards (000s mt) of red hake with length-based model estimated landings from the northern stock.

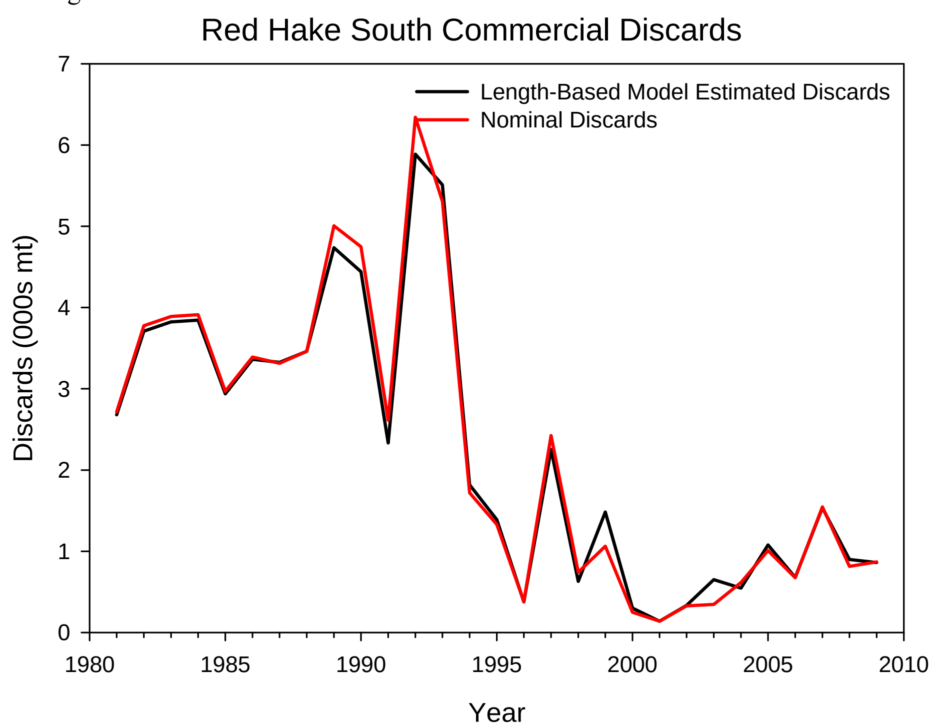
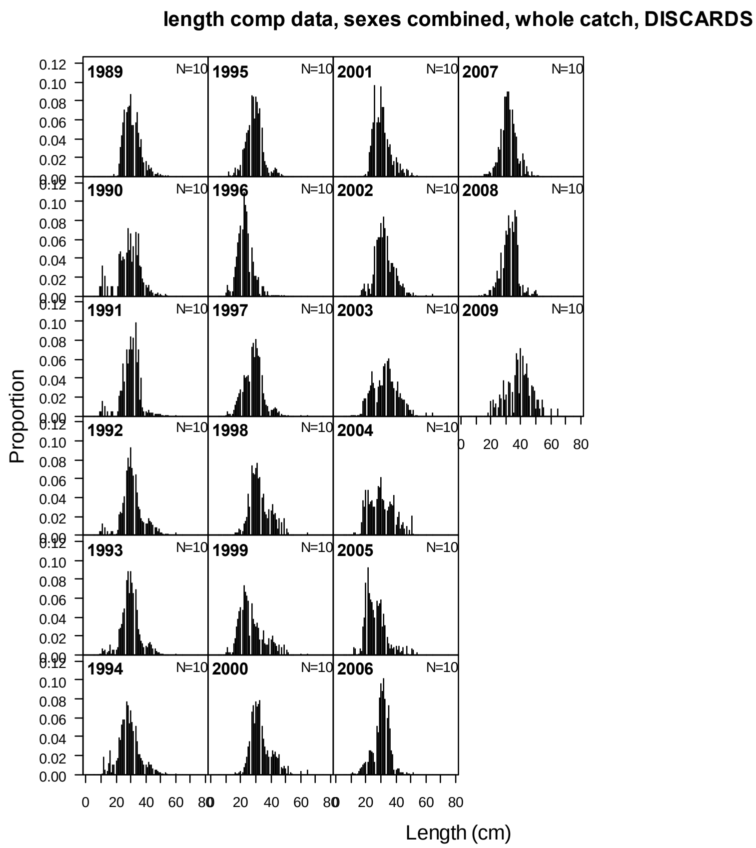


Figure C11. Comparison of nominal discards (000s mt) of red hake with length-based model estimated landings from the southern stock.



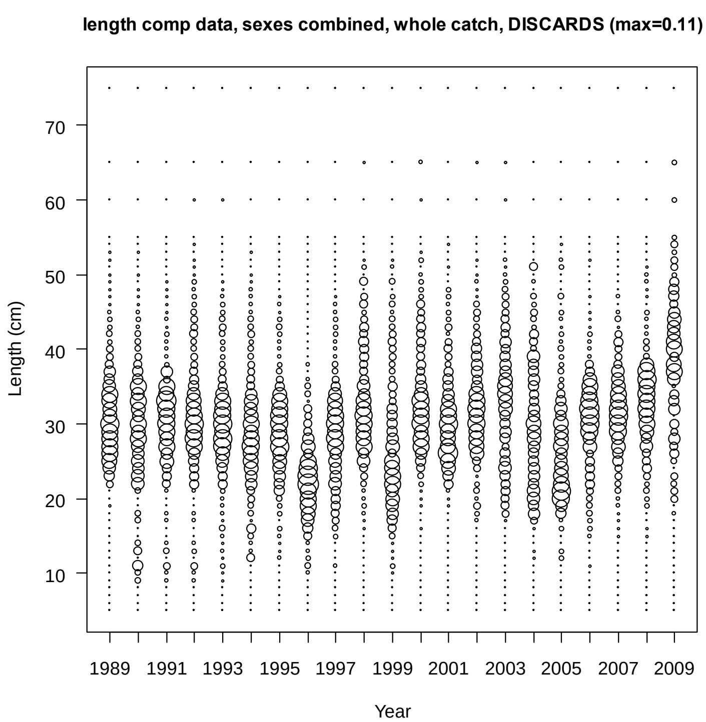
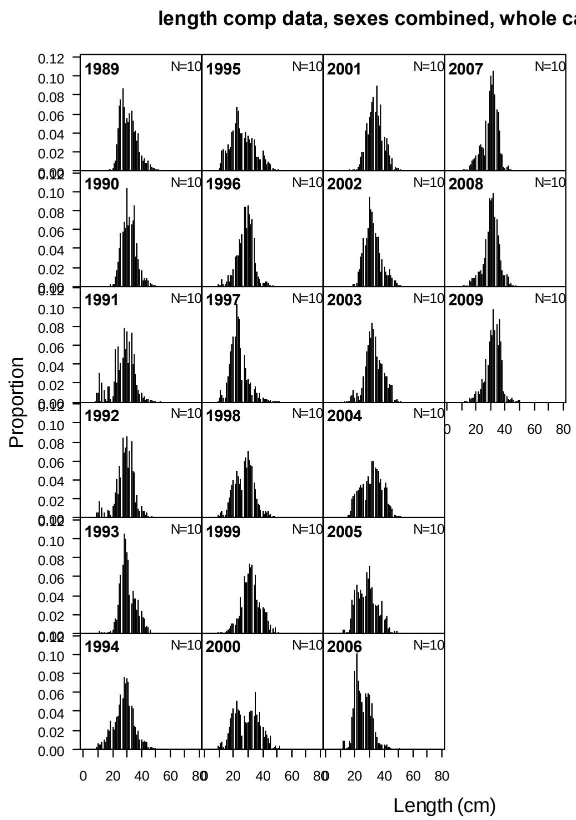


Figure C12. Length composition of nominal red hake commercial discards from the northern stock.



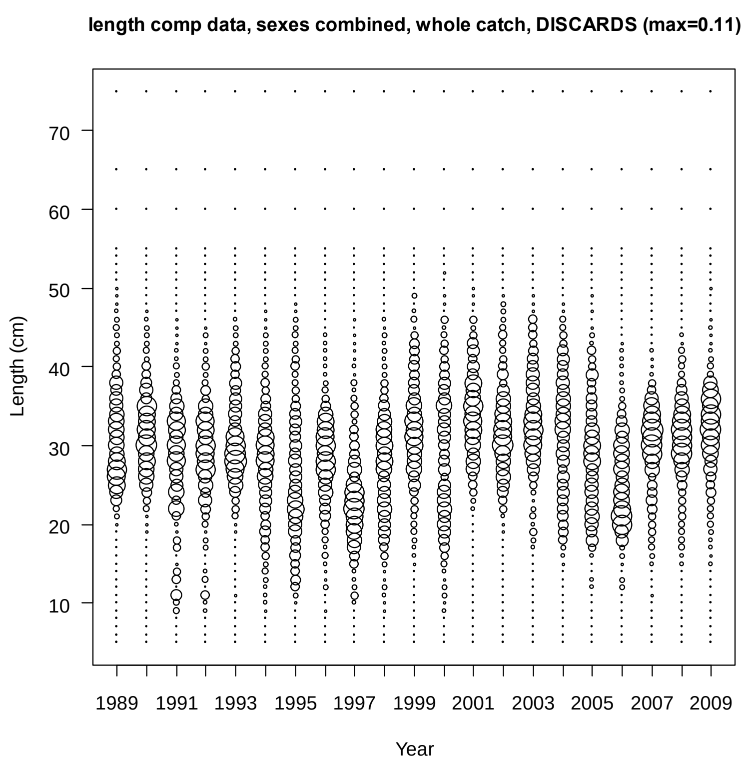
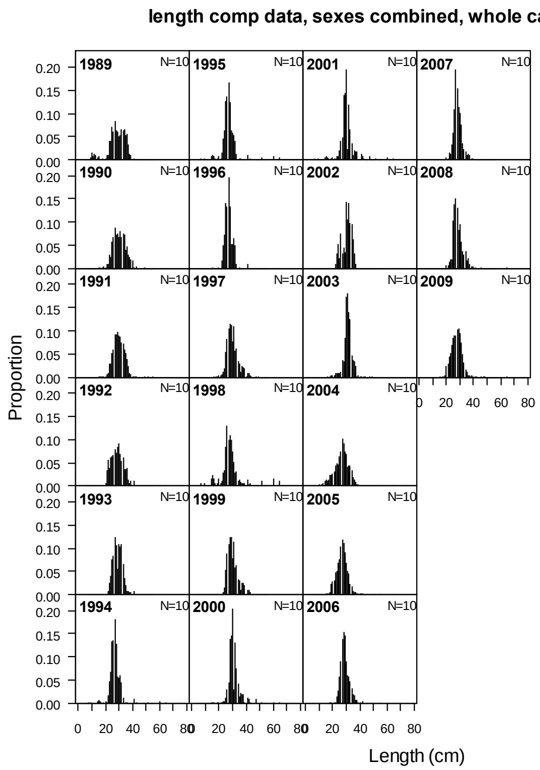


Figure C13. Length composition of length-based model estimated commercial discards from the northern stock.



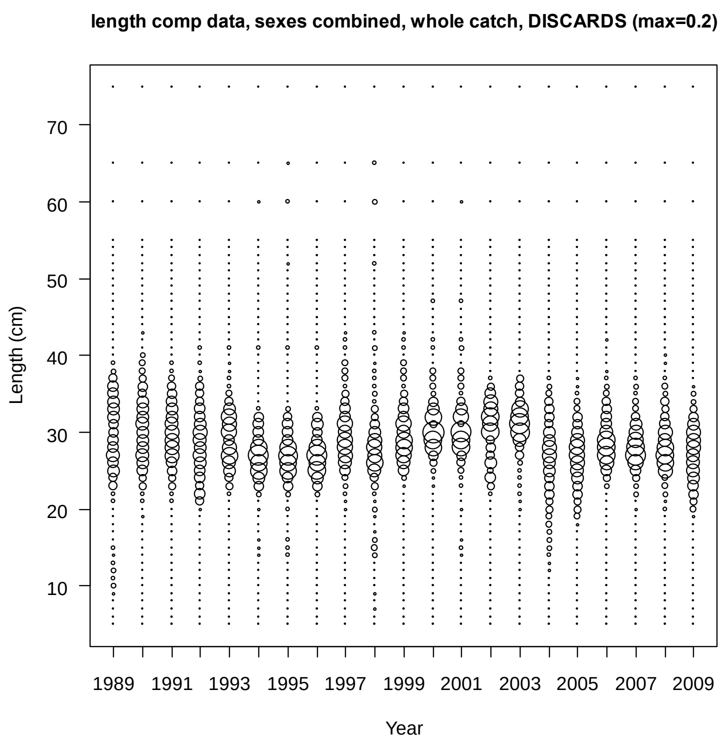
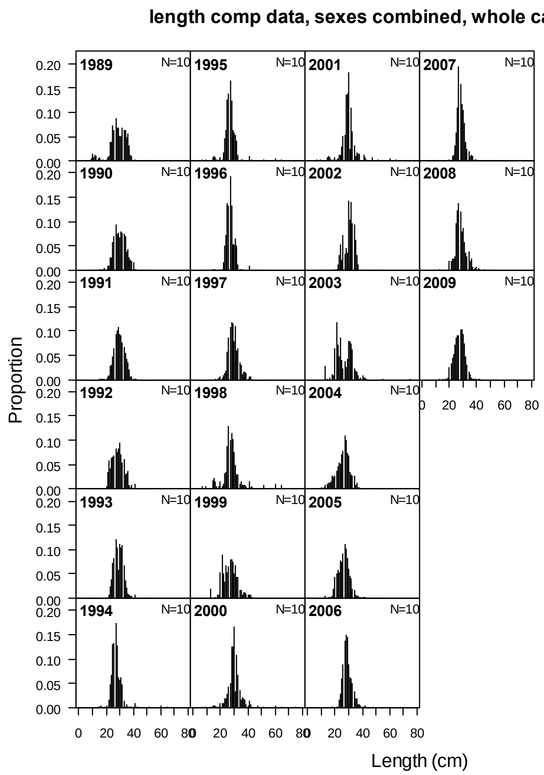


Figure C14. Length composition of nominal red hake commercial discards from the southern stock.



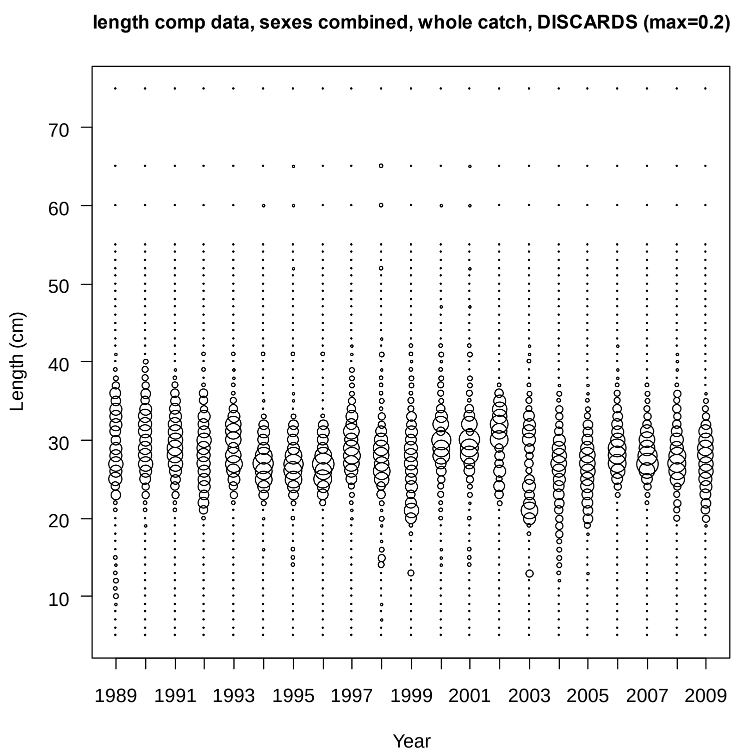


Figure C15. Length composition of length-based model estimated commercial discards from the southern stock.

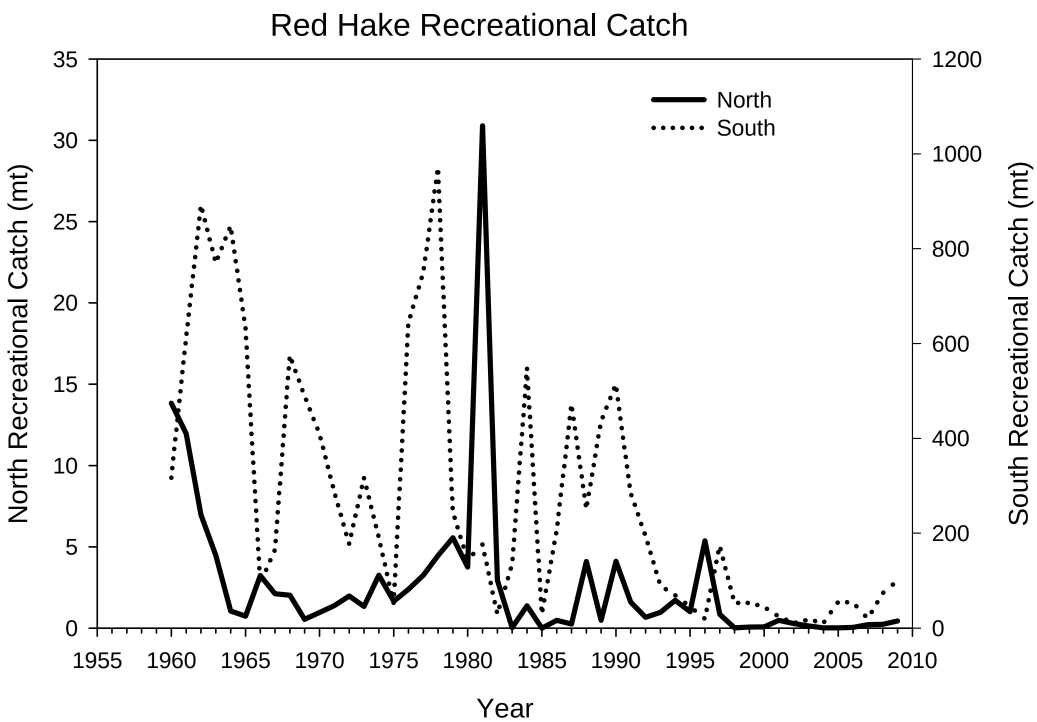
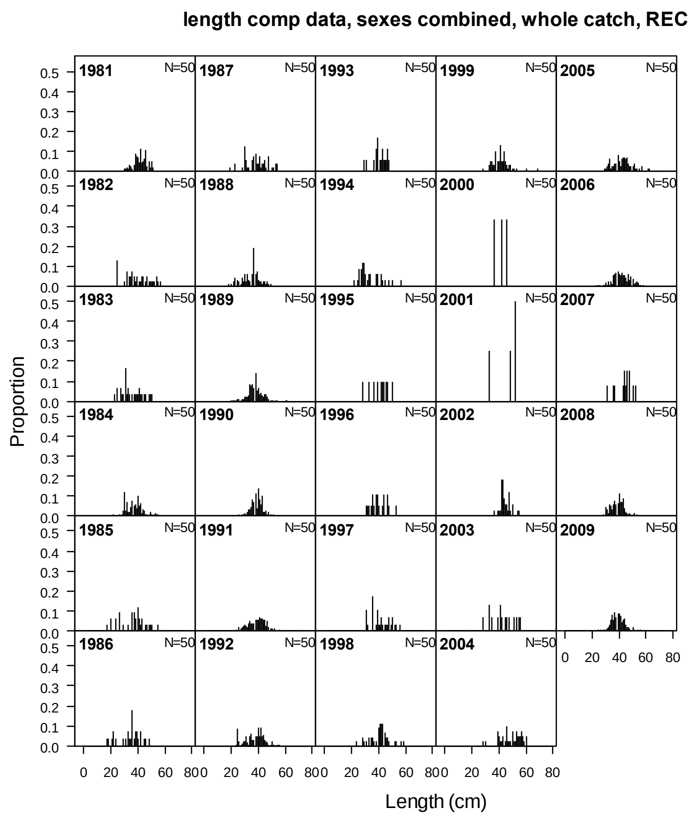


Figure C16. Recreational catch (mt) of red hake by stock. Note the southern stock is plotted against the right-hand axis.



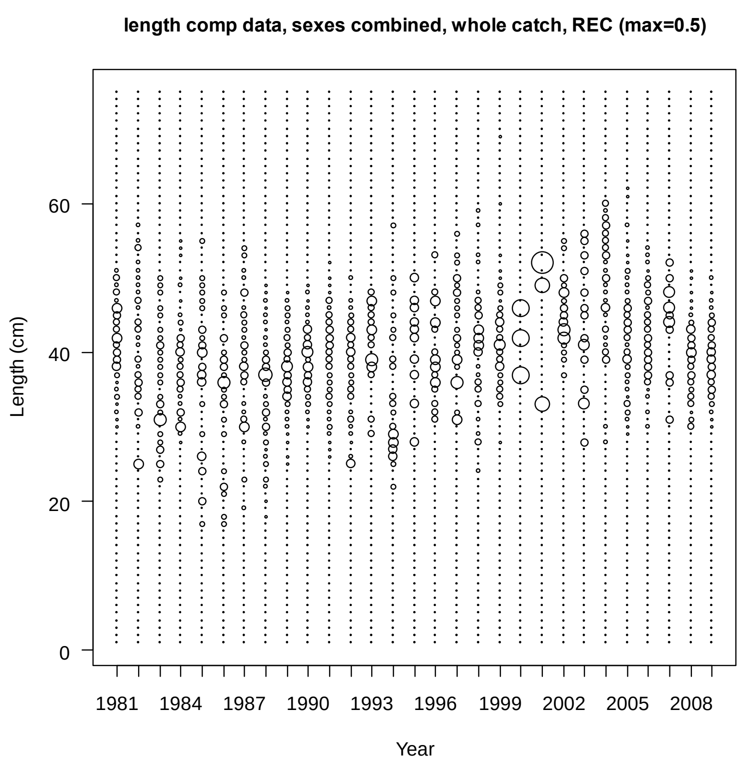


Figure C17. Length composition of recreational catch from the combined stock (mostly southern).

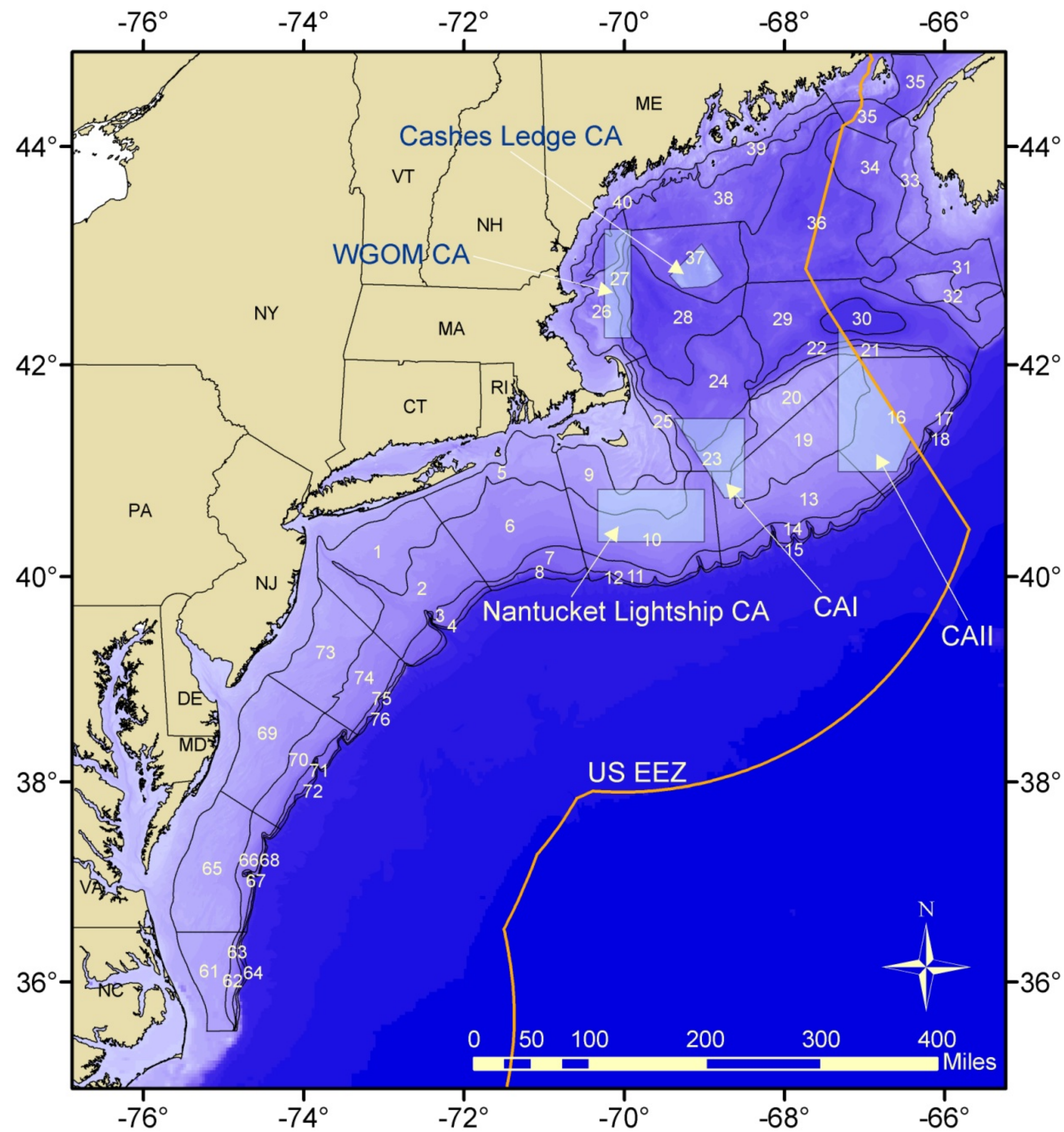


Figure C18. NEFSC survey strata.

Region	Stratum	Area(nm²)
1. Buzzards Bay Vineyard Sd & coastal water south of Marthas Vineyard	11	102
	12	160
	13	88
	14	16
2. Nantucket Sound	15	190
	16	212
3. East of Cape Cod Race Point to Muskeget Island	17	85
	18	88
	19	39
	20	24
	21	40
4. Cape Cod Bay	25	47
	26	87
	27	94
	28	93
	29	103
	30	32
5. Massachusetts Bay north to N.H. border	31	41
	32	49
	33	78
	34	38
	35	174
	36	33

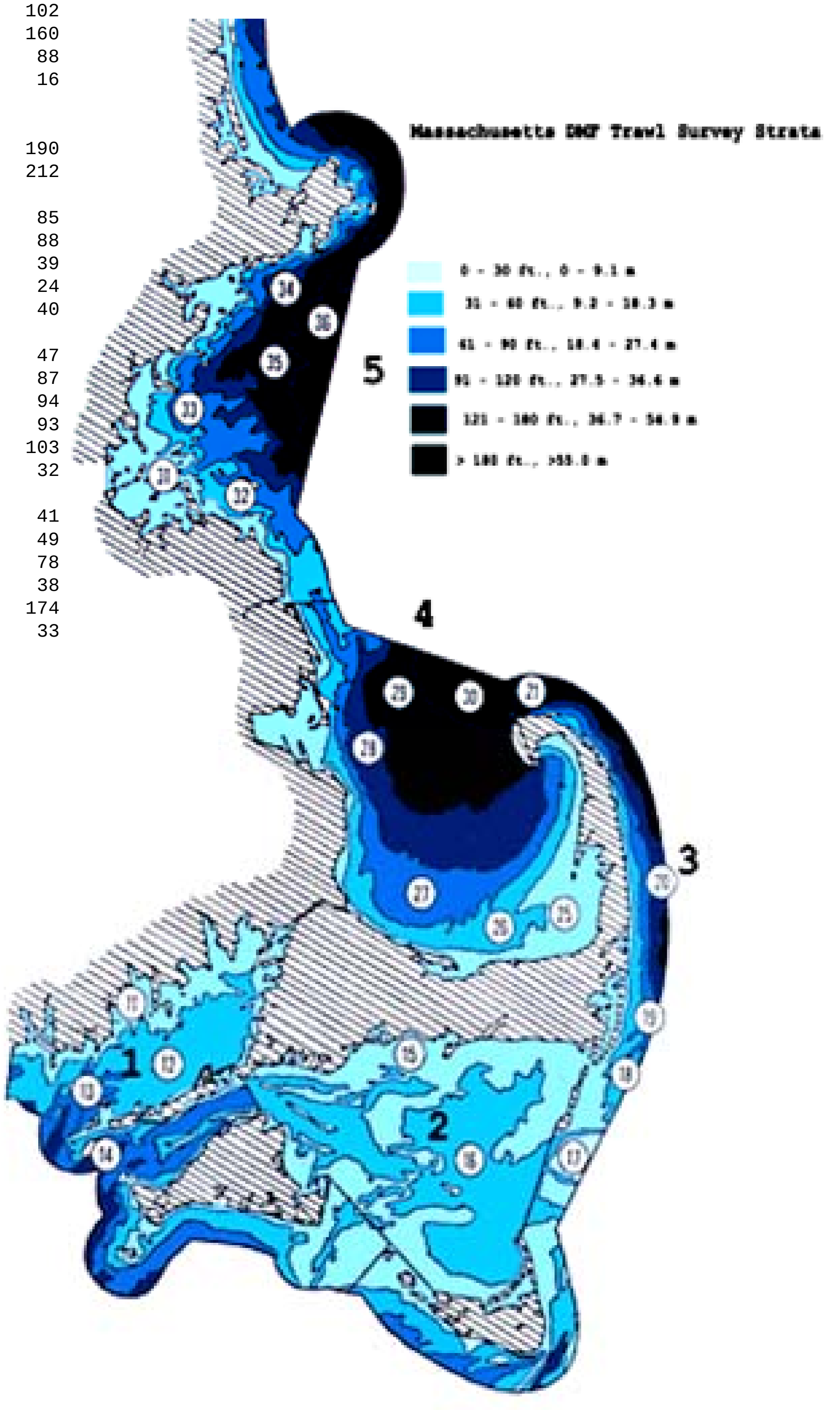


Figure C19. MADMF survey strata.

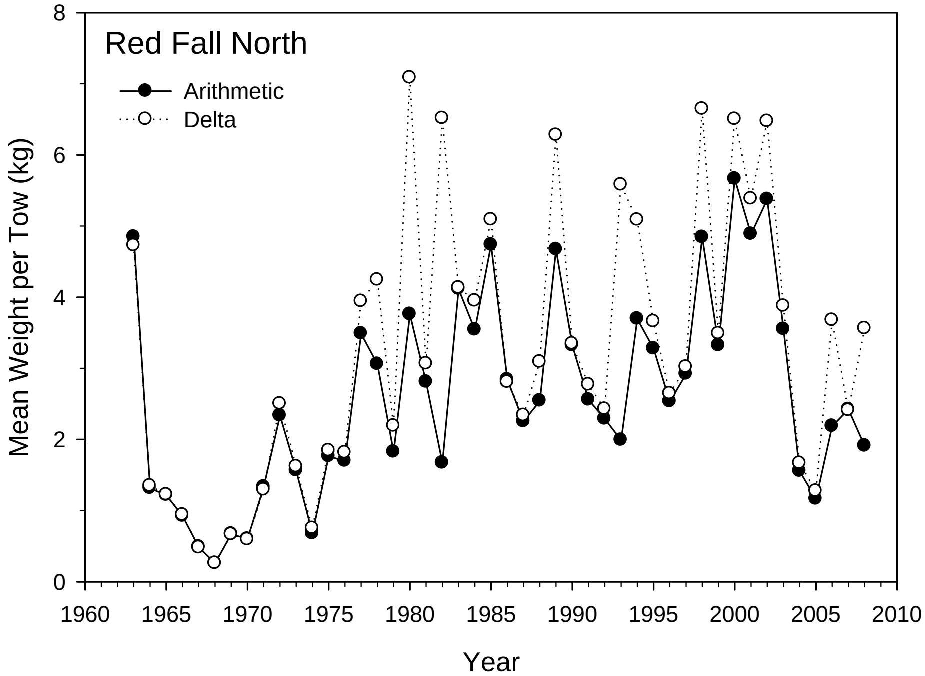
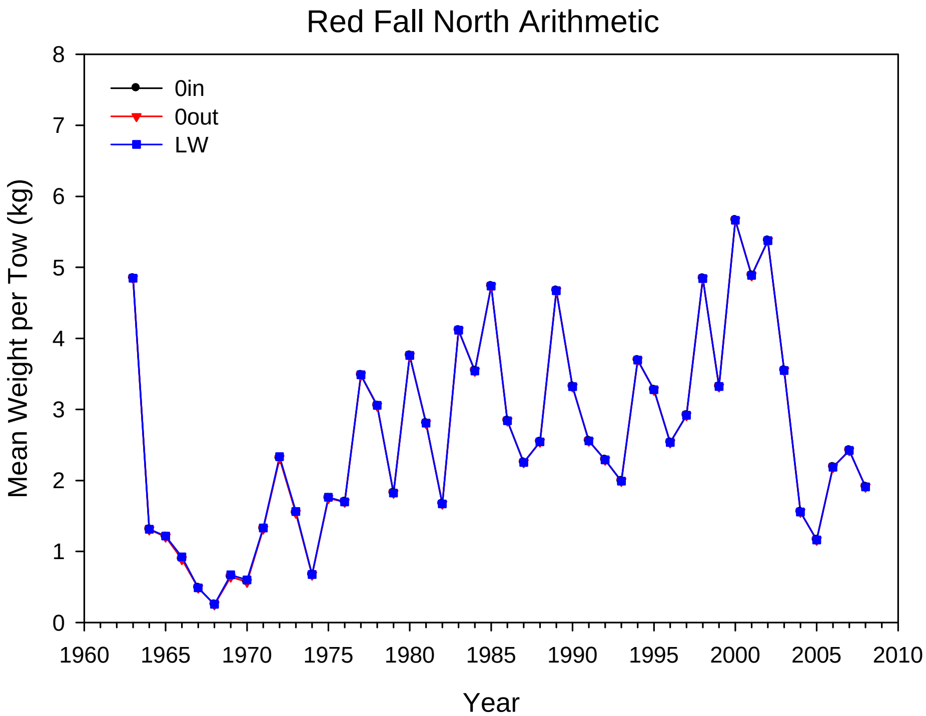


Figure C20.Comparison of the arithmetic and delta transformed mean weight per tow from the fall survey.



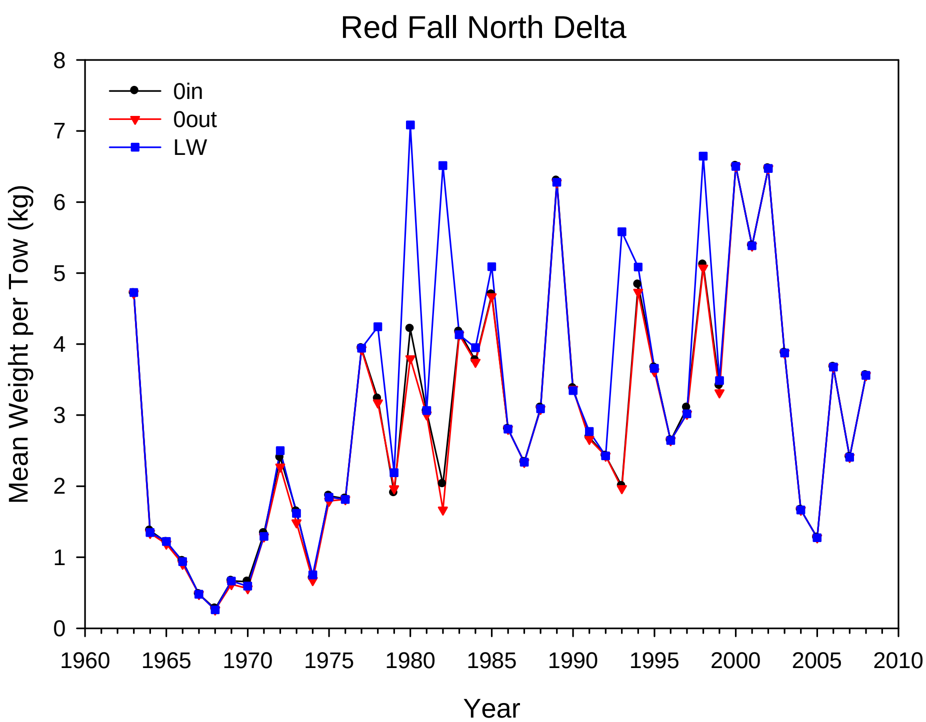


Figure C21. Comparison of the arithmetic and delta transformed mean weight per tow from the fall survey with three methods of handling missing weight data.

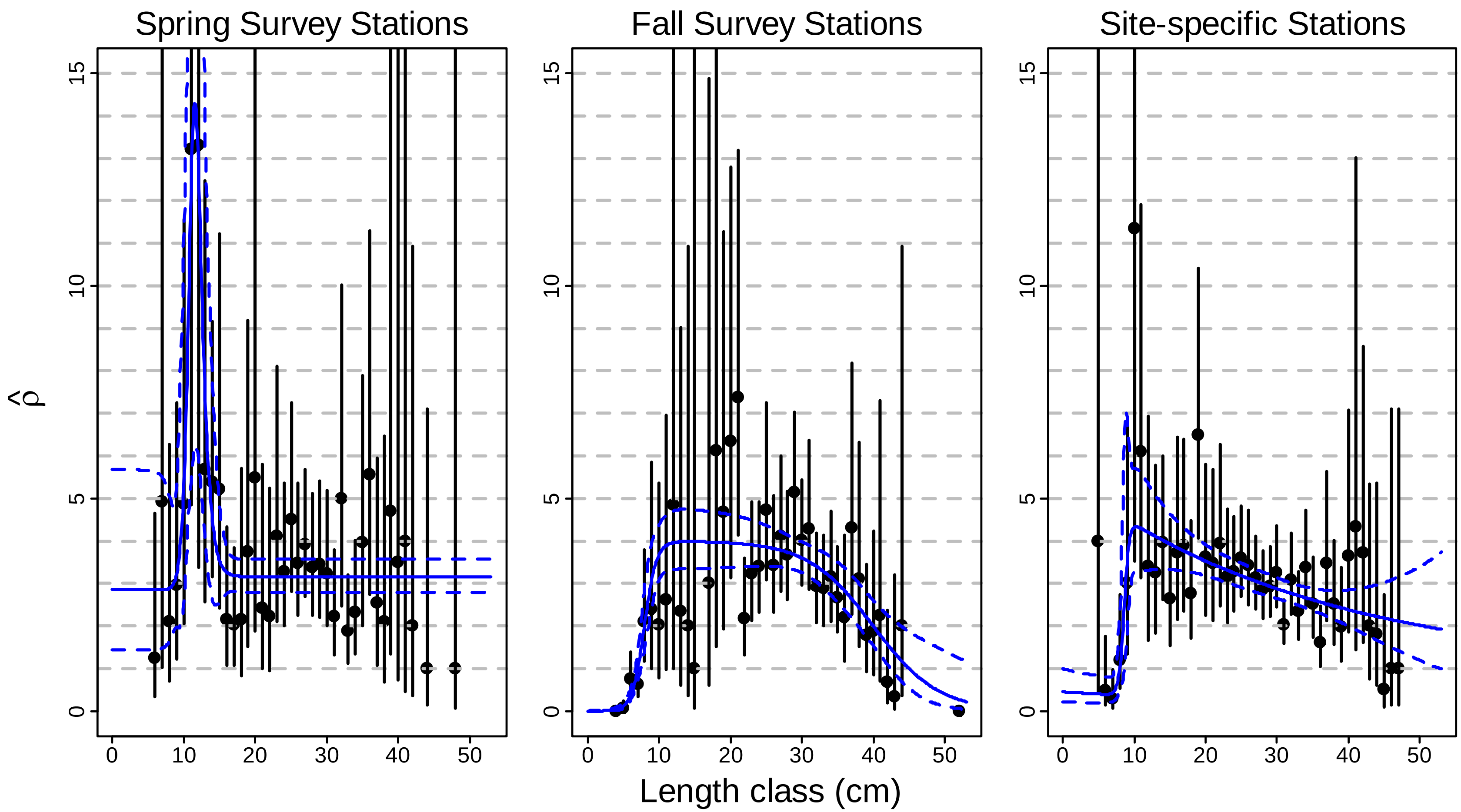


Figure C22. Beta-binomial based estimates of calibration factors and corresponding 95% confidence intervals by length class (1 cm bins) for **red hake**. The black points and vertical bars represent results where different calibration factors are estimated for each length class. The blue lines represent results from double-logistic models. For the fall, the double logistic model has with no minima (assumed equal to 0) for the ascending or descending logistic function.

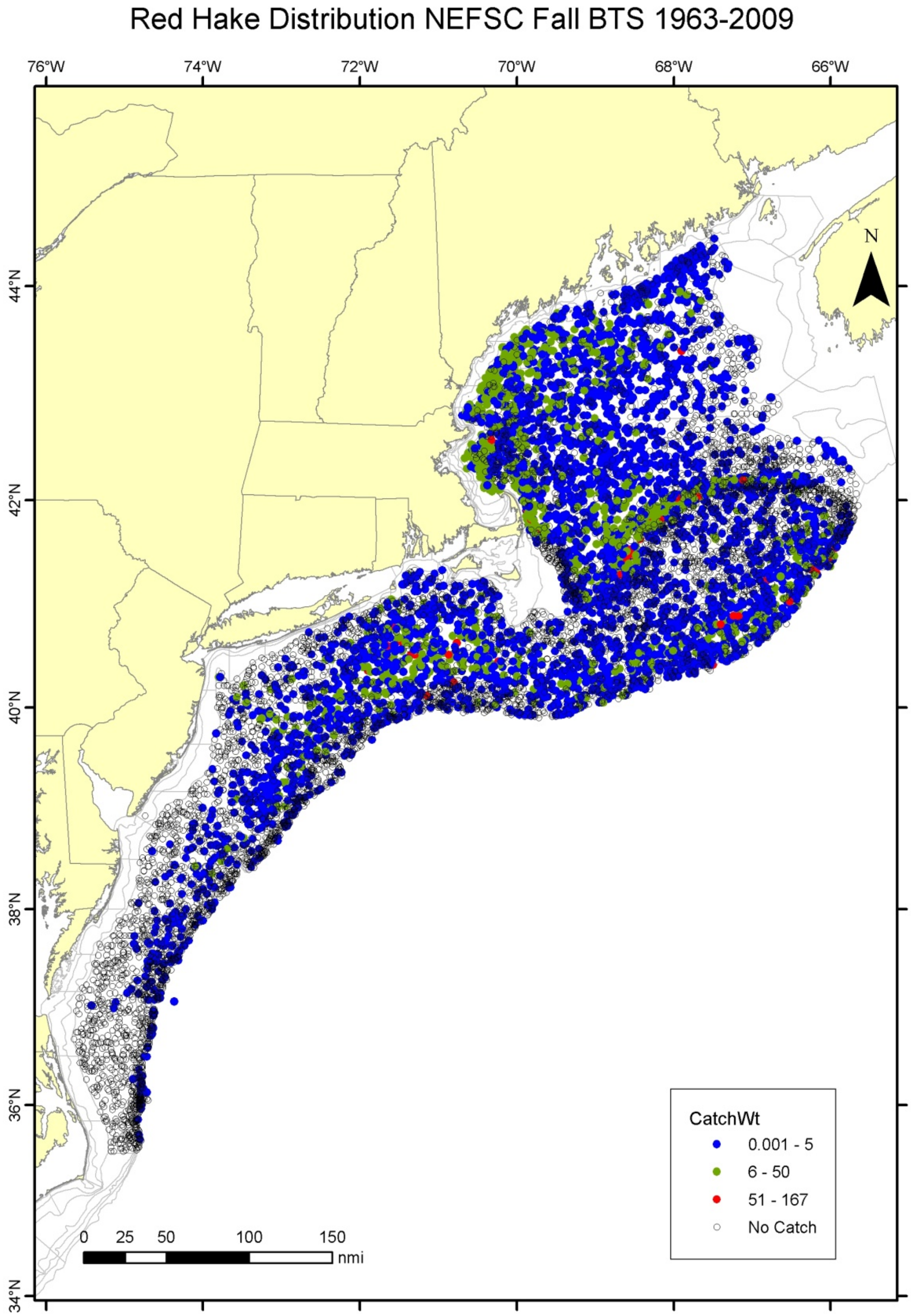


Figure C23. NEFSC distribution maps for red hake during the fall bottom trawl surveys, 1963-2009.

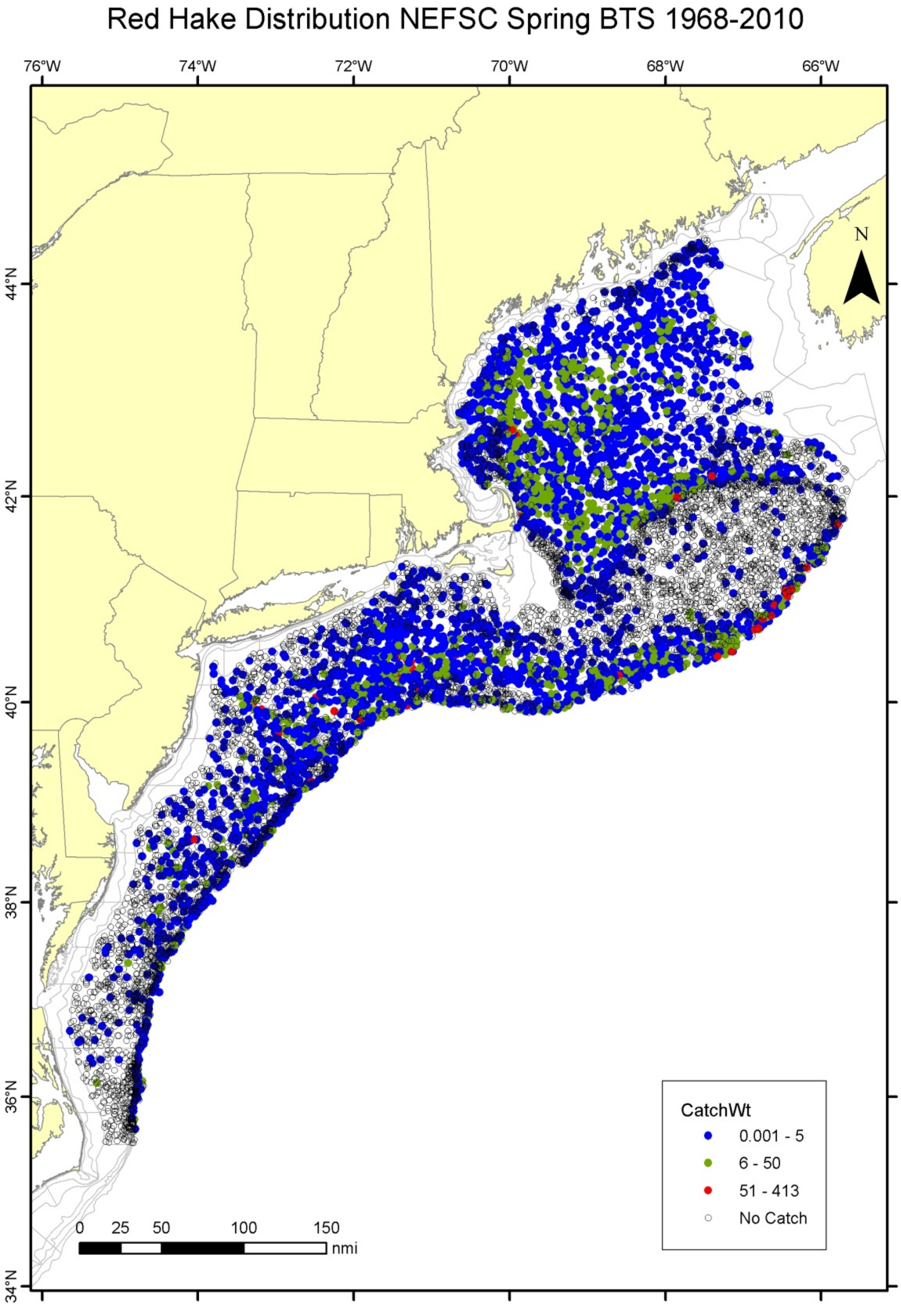


Figure C24. NEFSC distribution maps for red hake during the spring bottom trawl surveys, 1968-2010.

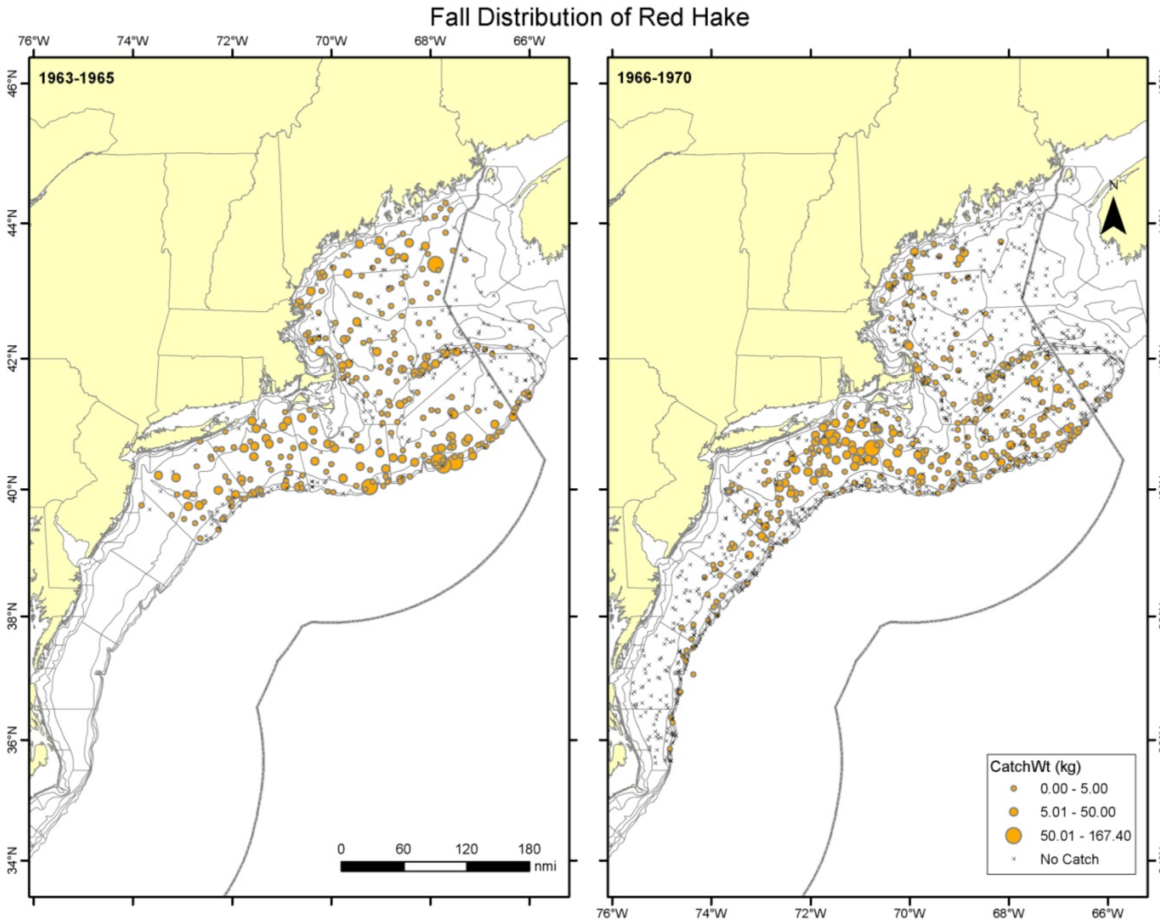


Figure C25. NEFSC distribution maps for red hake during the fall bottom trawl surveys, 1963-1970.

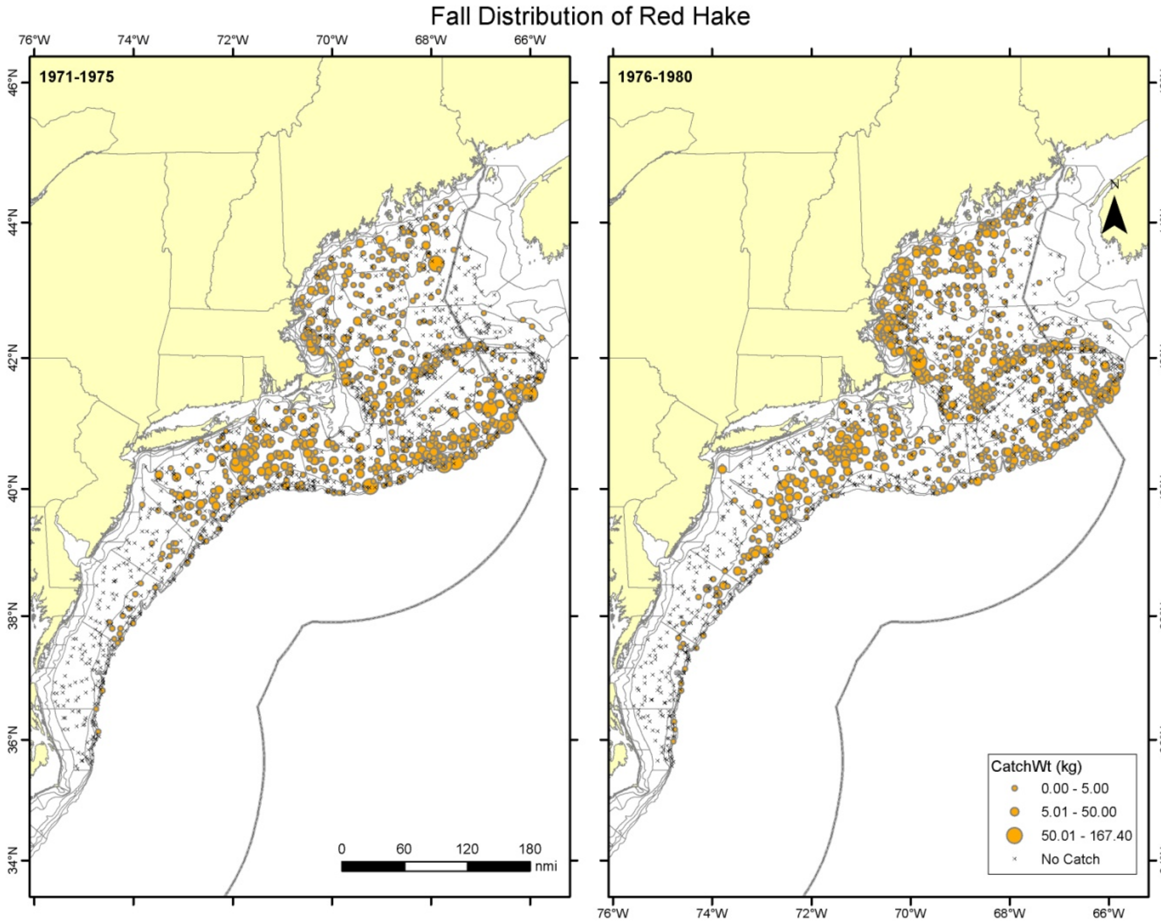


Figure C26. NEFSC distribution maps for red hake during the fall bottom trawl surveys, 1971-1980.

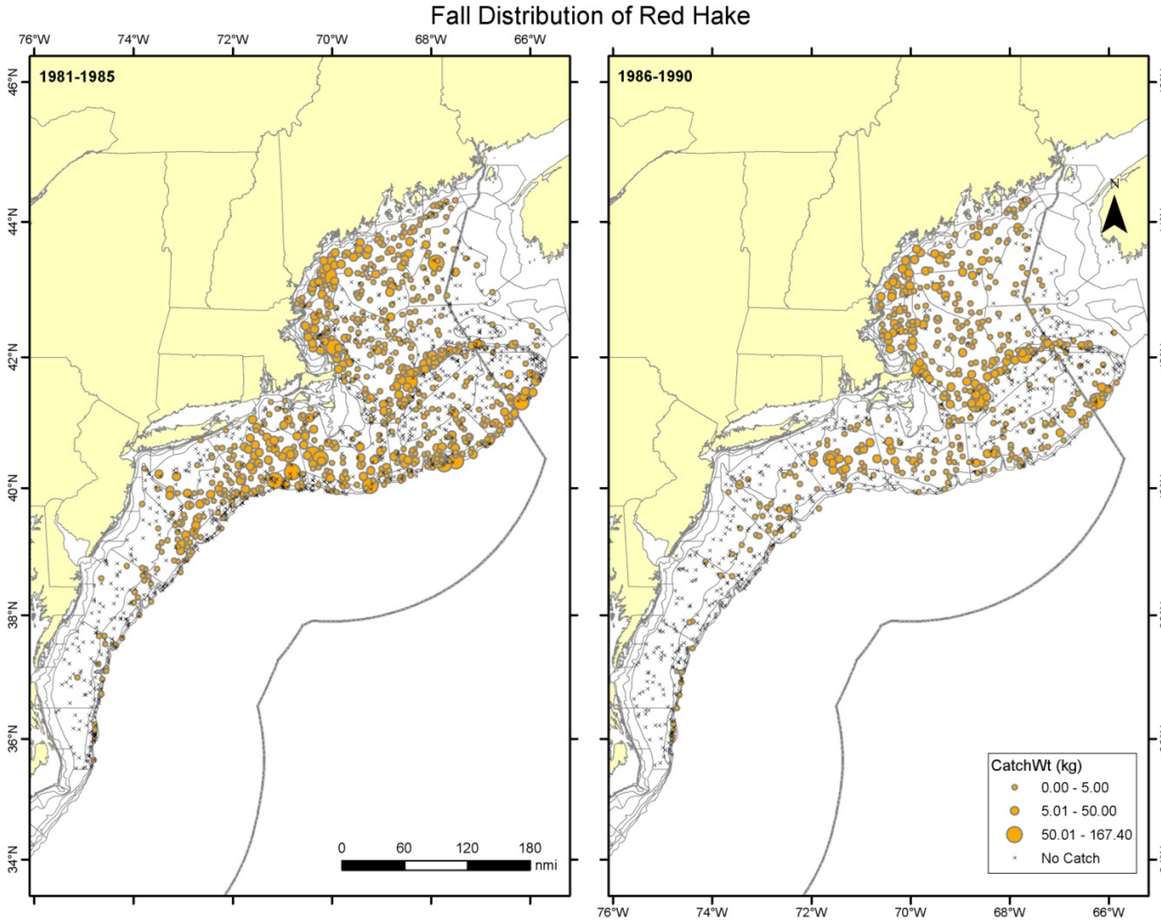


Figure C27. NEFSC distribution maps for red hake during the fall bottom trawl surveys, 1981-1990.

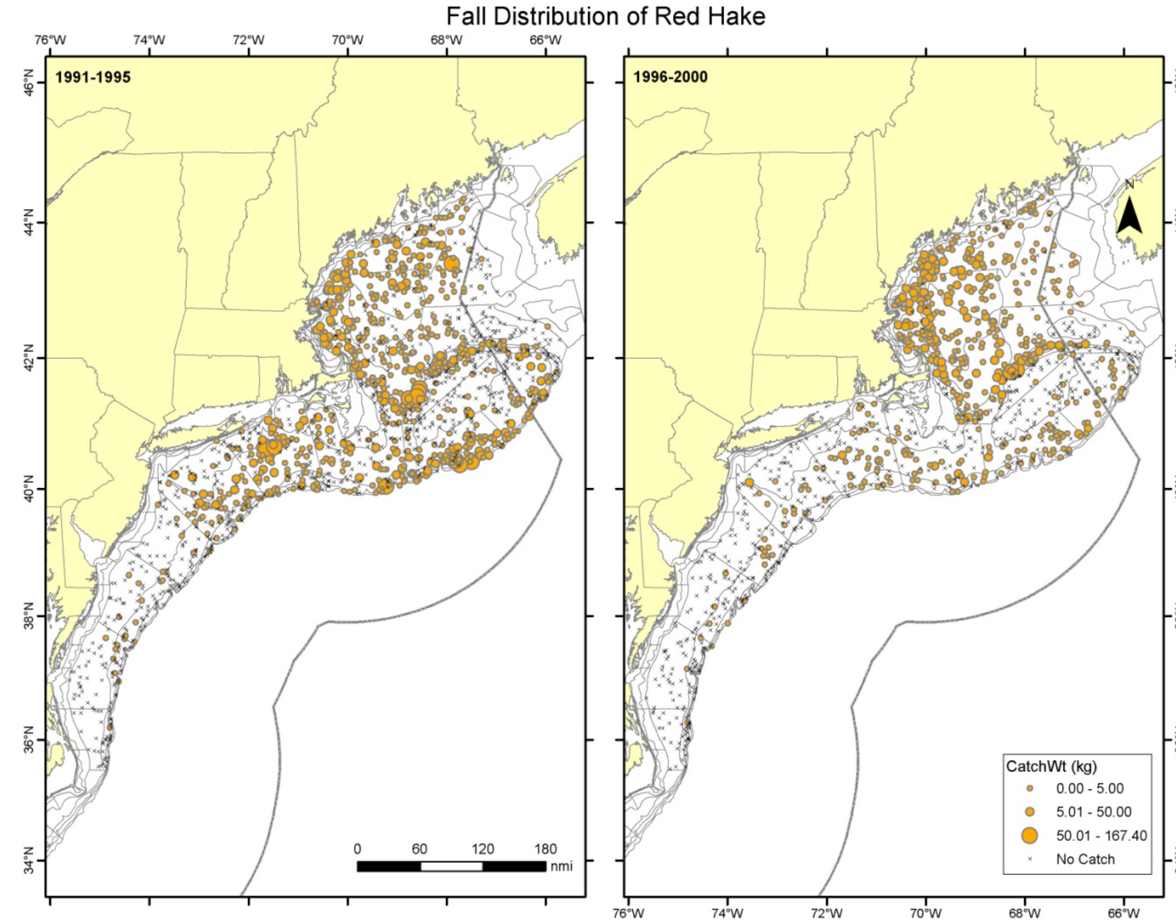


Figure C28. NEFSC distribution maps for red hake during the fall bottom trawl surveys, 1991-2000.

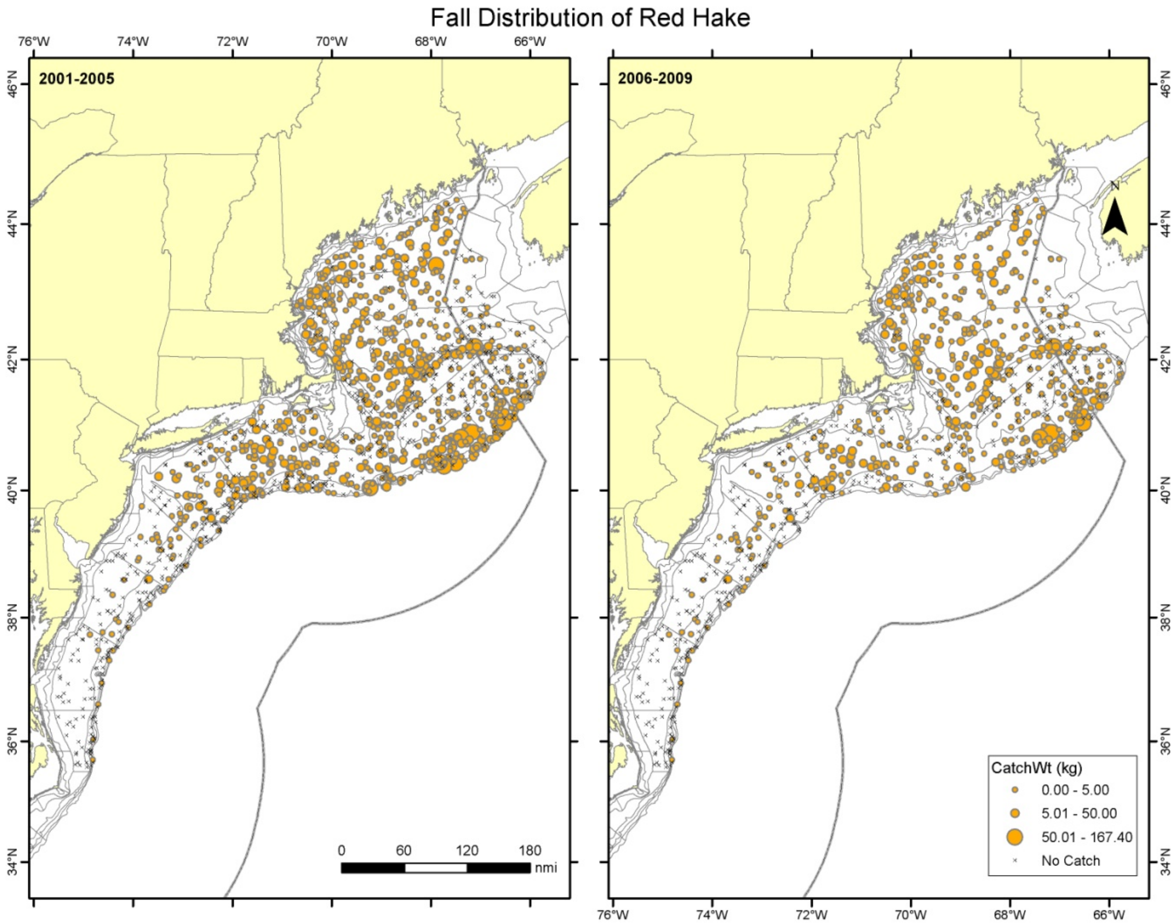


Figure C29. NEFSC distribution maps for red hake during the fall bottom trawl surveys, 2001-2009.

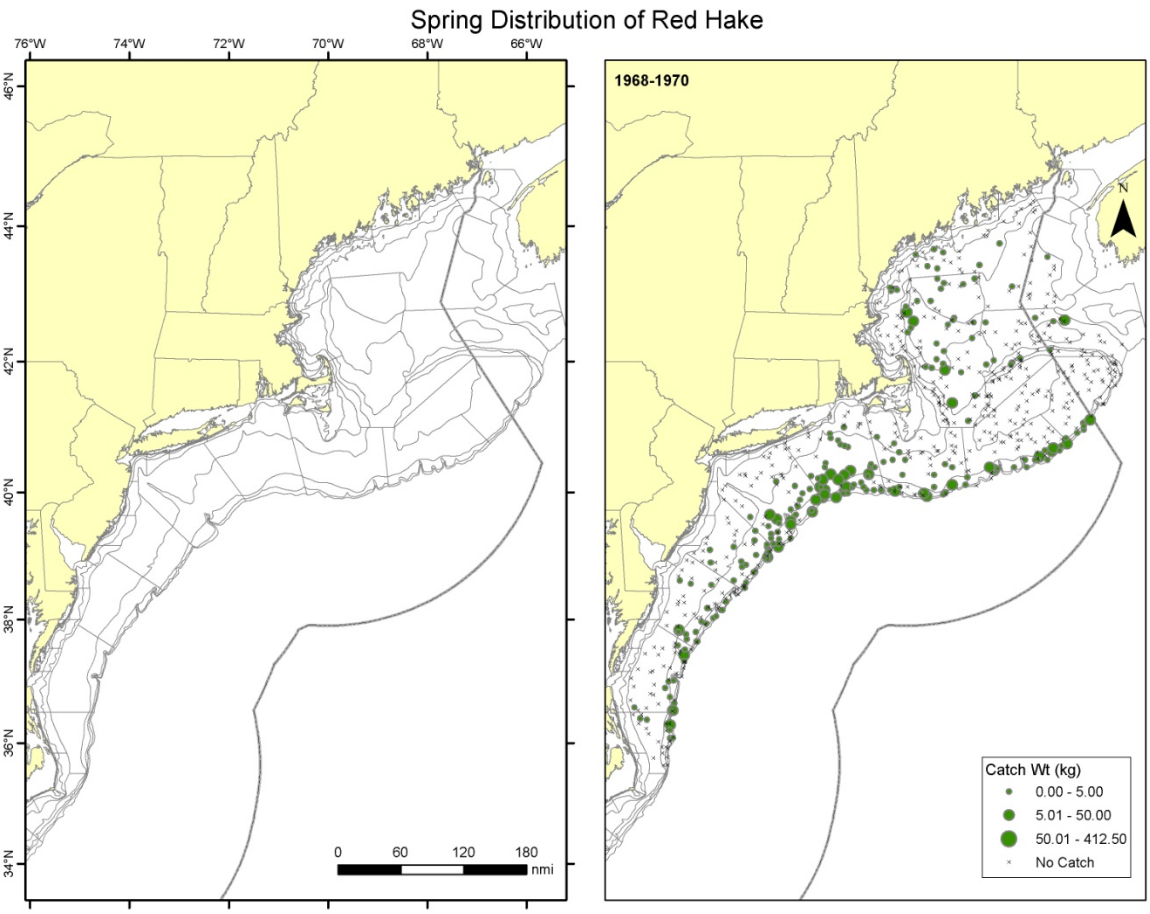


Figure C30. NEFSC distribution maps for red hake during the spring bottom trawl surveys, 1968-1970.

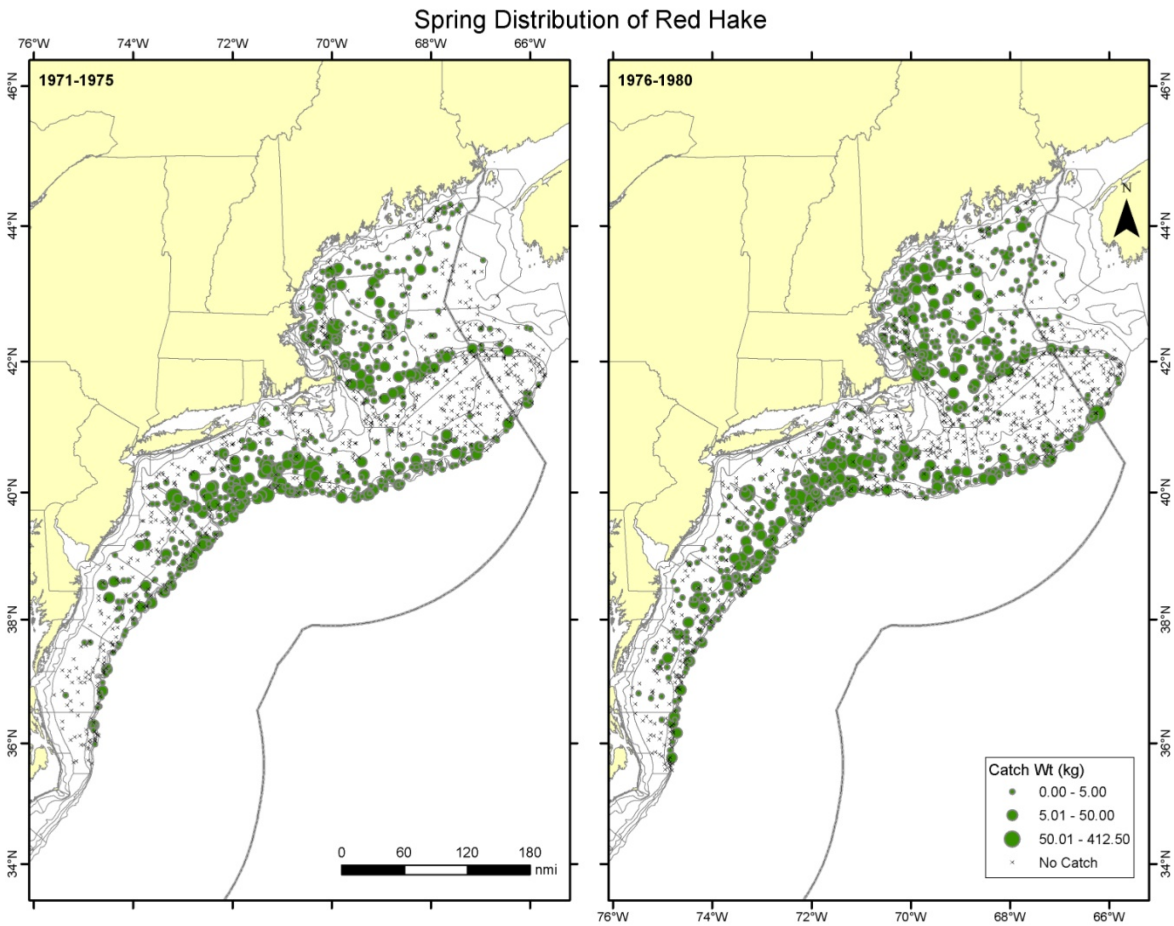


Figure C31. NEFSC distribution maps for red hake during the spring bottom trawl surveys, 1971-1980.

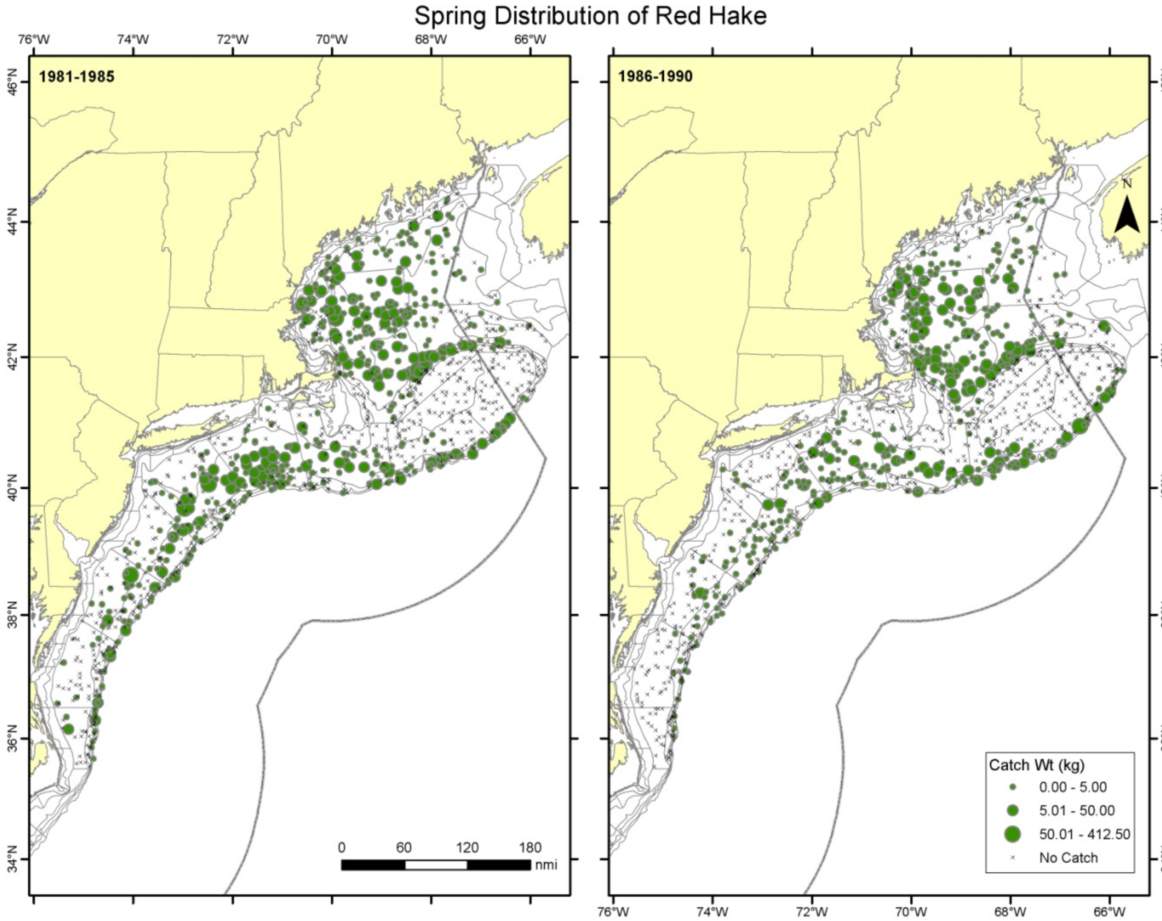


Figure C32. NEFSC distribution maps for red hake during the spring bottom trawl surveys, 1981-1990.

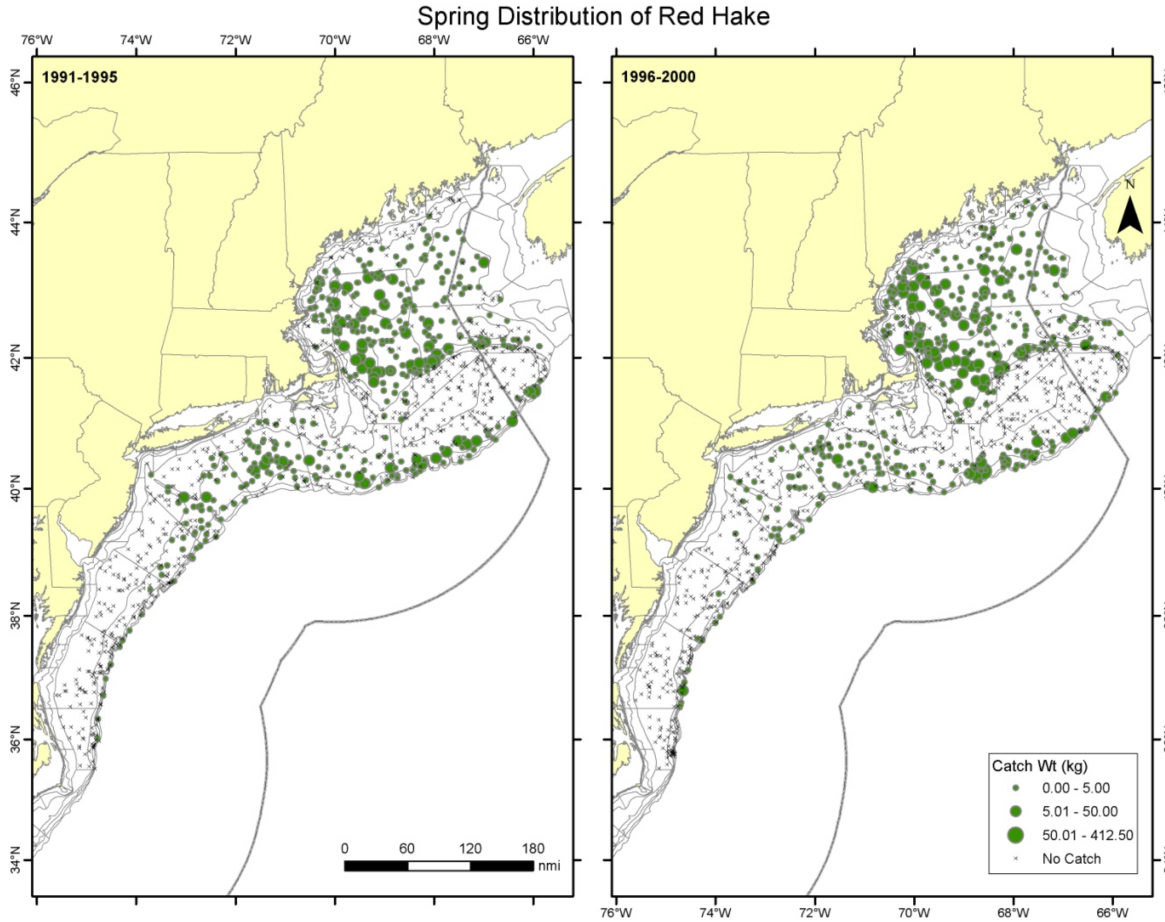


Figure C33. NEFSC distribution maps for red hake during the spring bottom trawl surveys, 1991-2000.

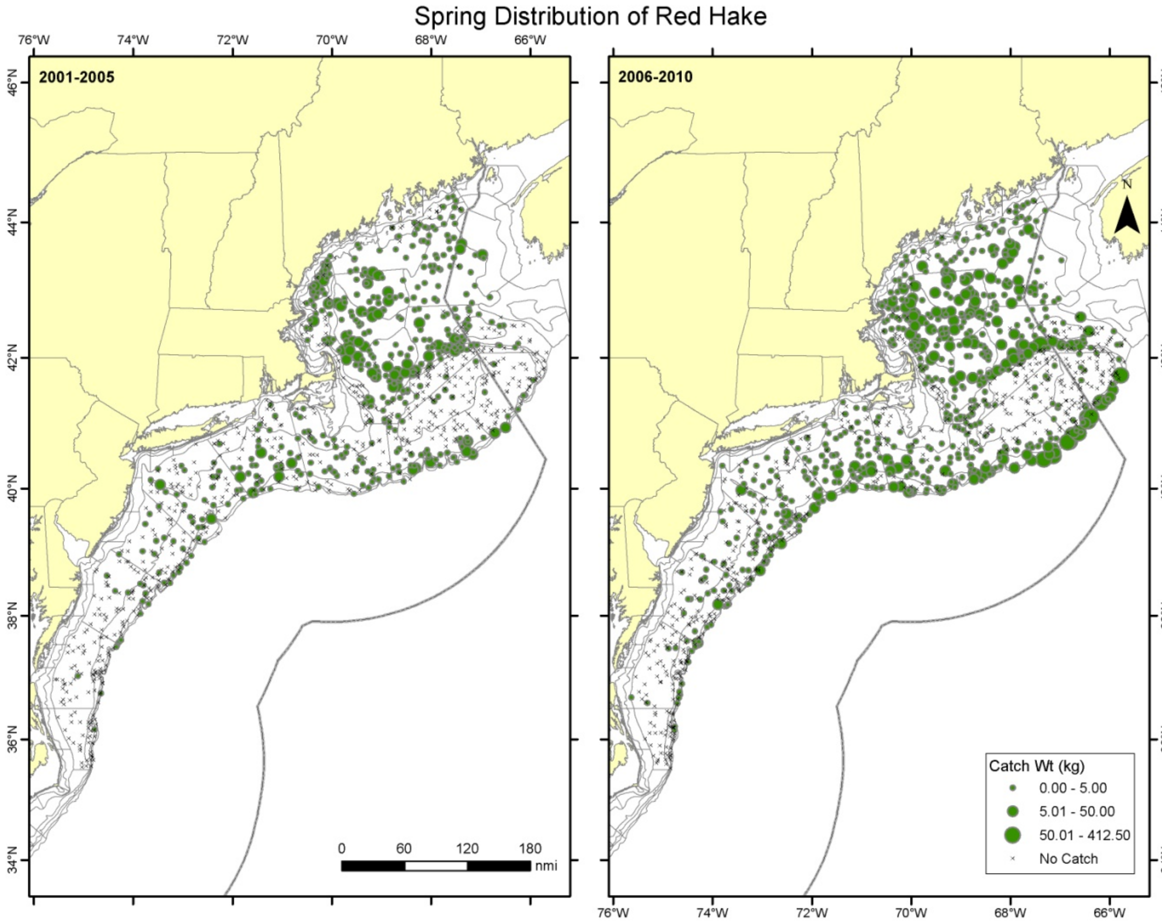
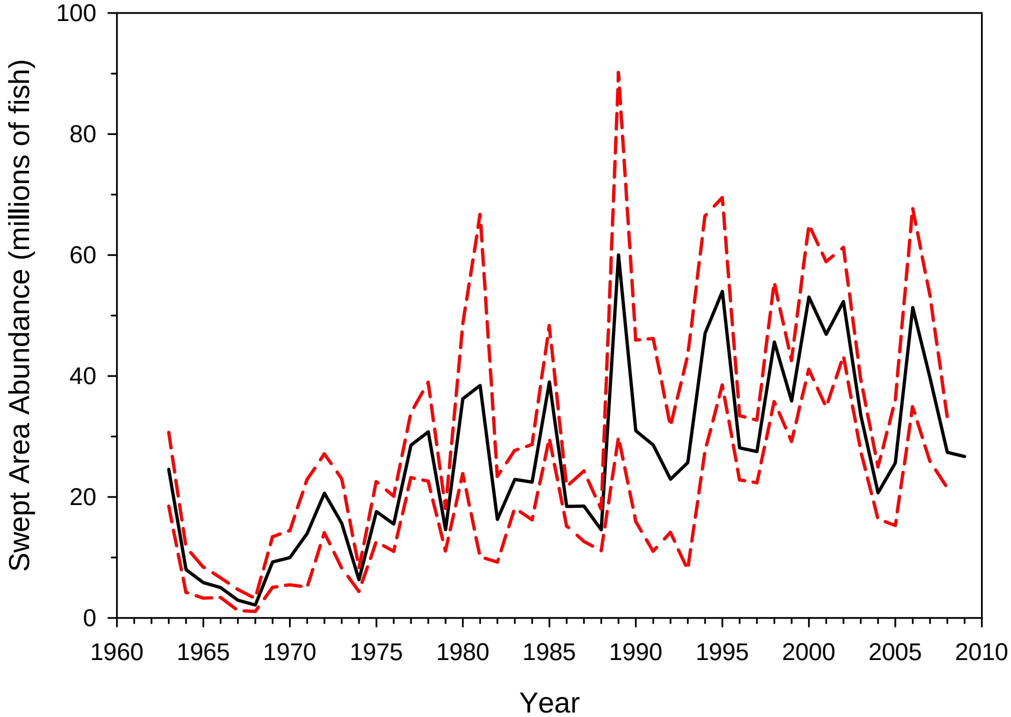


Figure C34. NEFSC distribution maps for red hake during the spring bottom trawl surveys, 2001-2010.

NORTH FALL



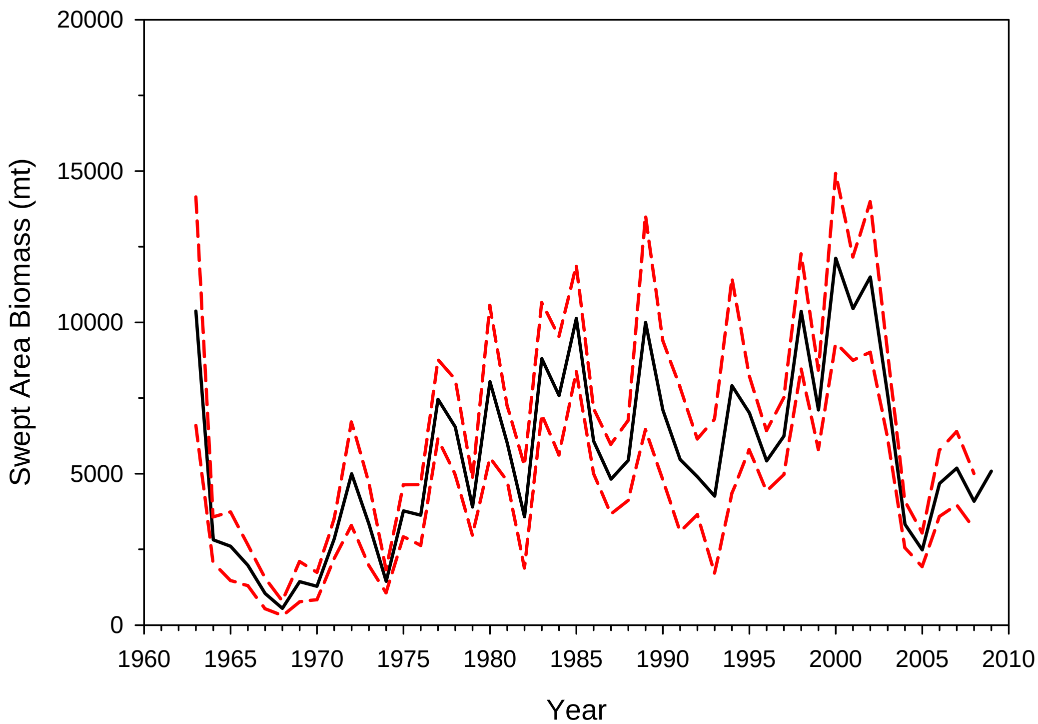


Figure C35. Swept area abundance (top) and biomass (bottom) with confidence intervals for the NEFSC fall survey in the northern management region. Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.

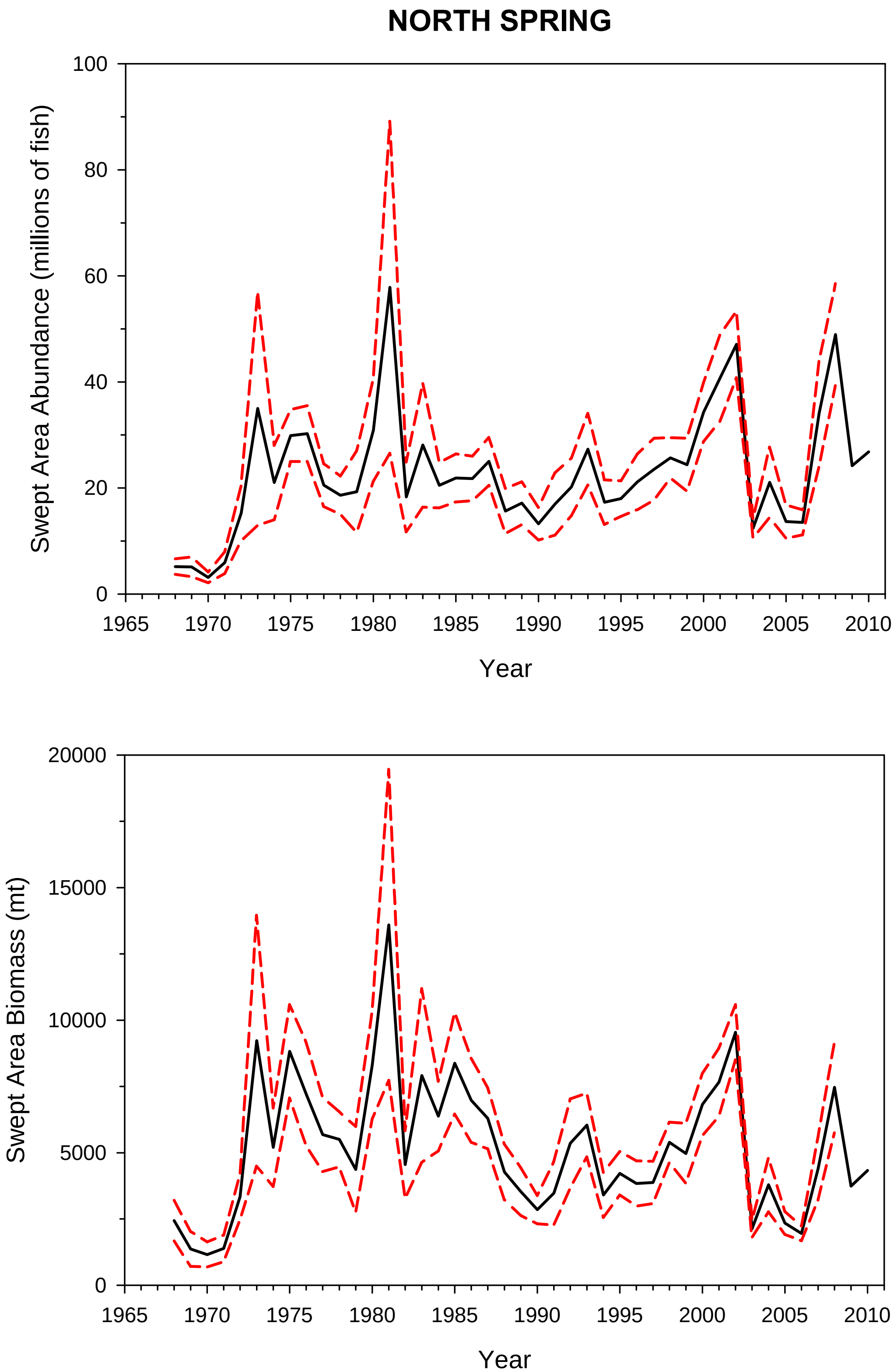


Figure C36. Swept area abundance (top) and biomass (bottom) with confidence intervals for the NEFSC spring survey in the northern management region. Estimates for 2009 and 2010 were converted to Albatross units using the calibration factors at length in Table C34.

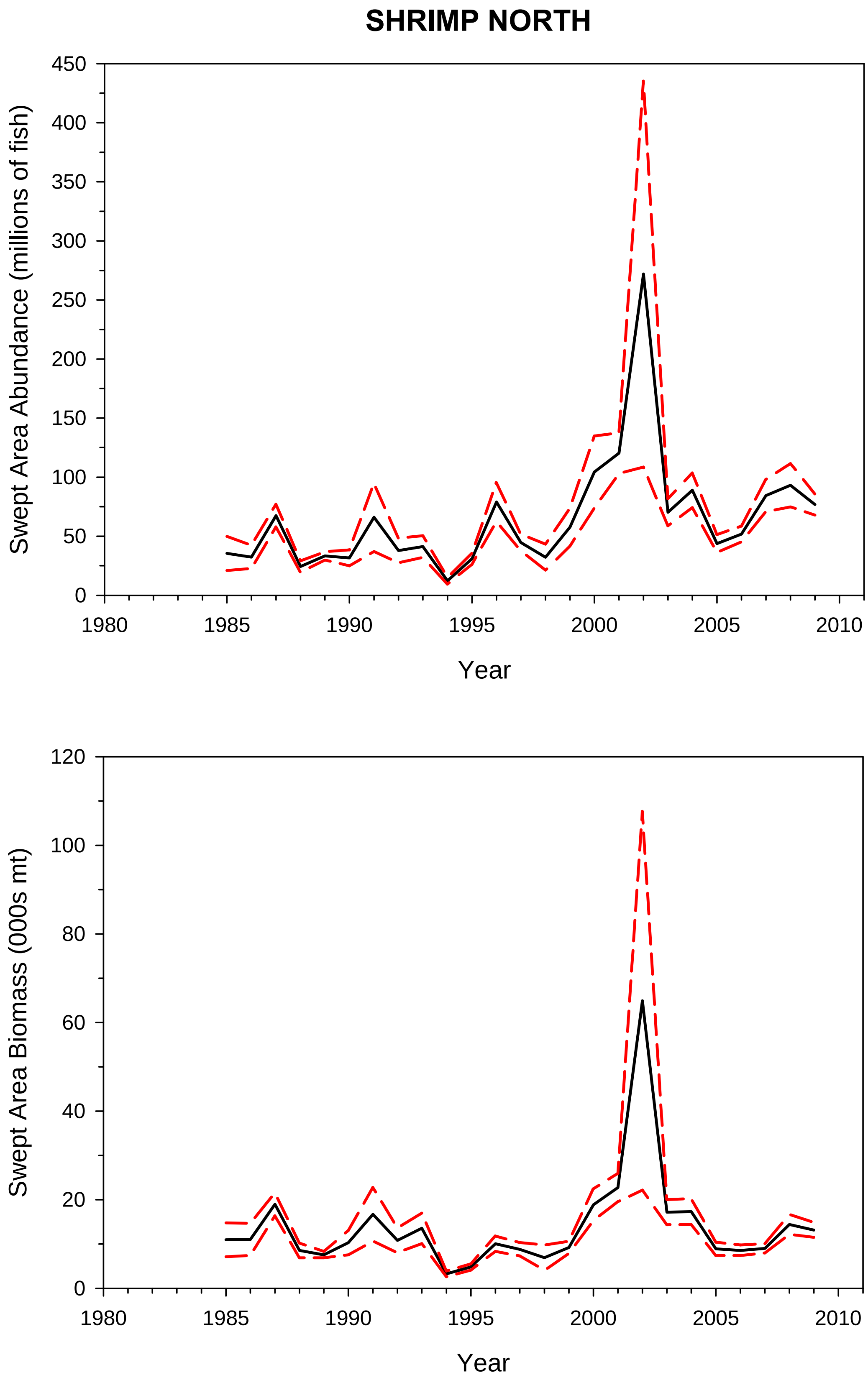


Figure C37. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from the NEFSC shrimp trawl surveys (strata 1-12).

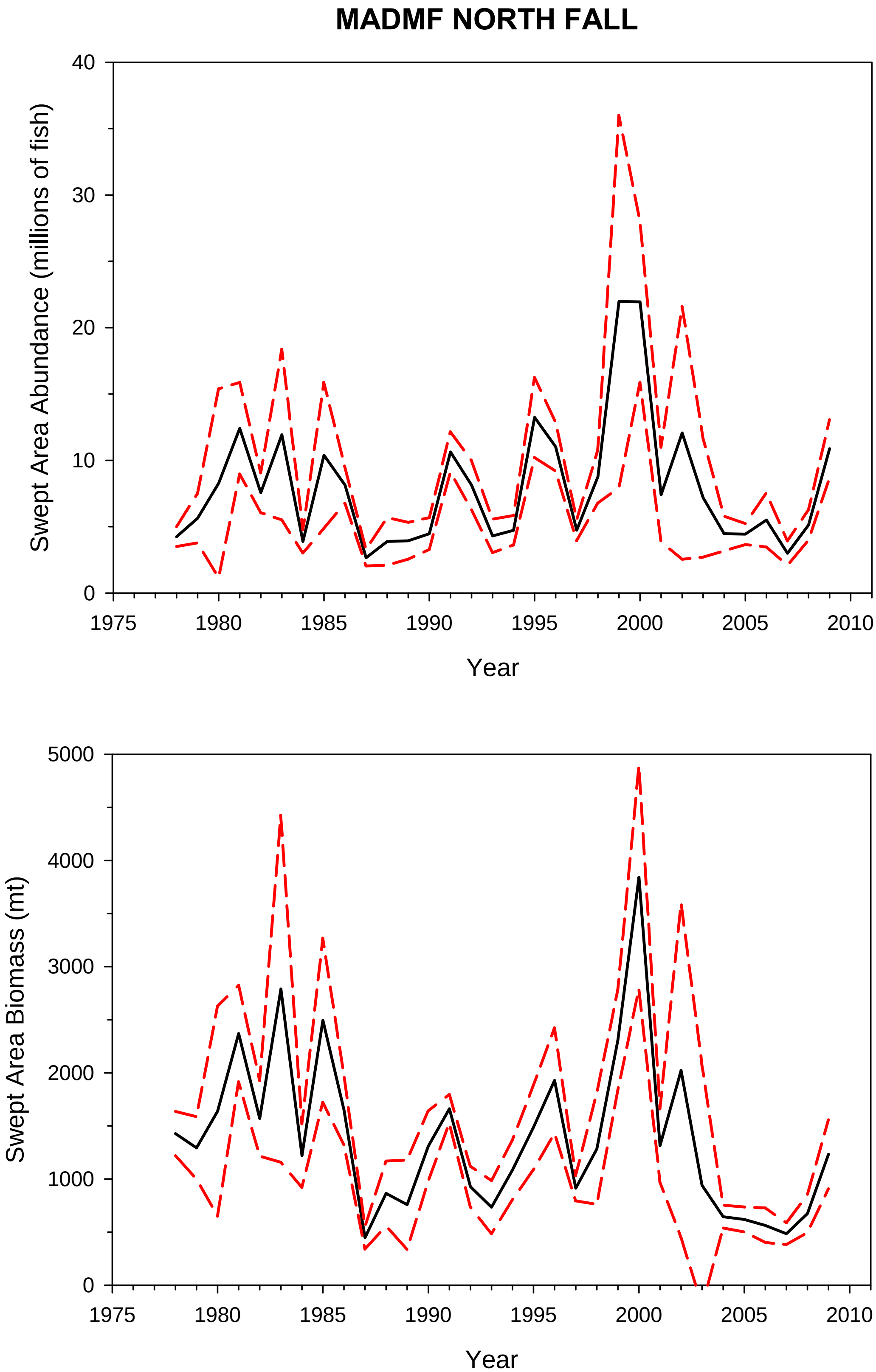
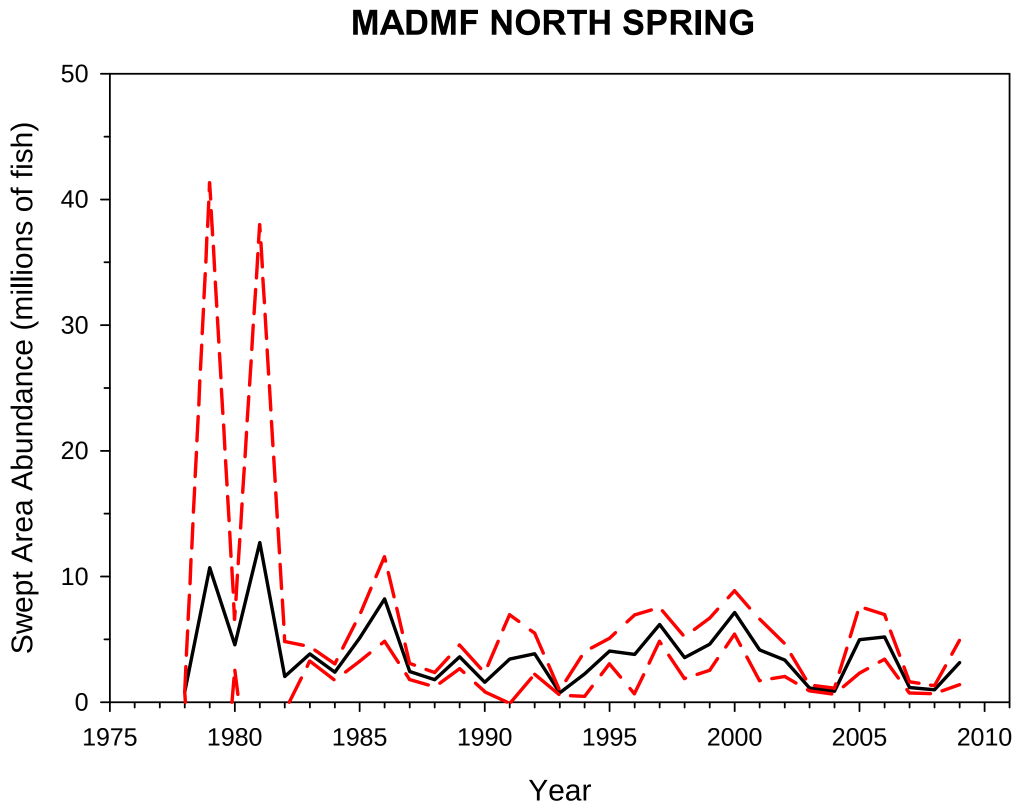


Figure C38. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries fall north survey (strata 18-36).



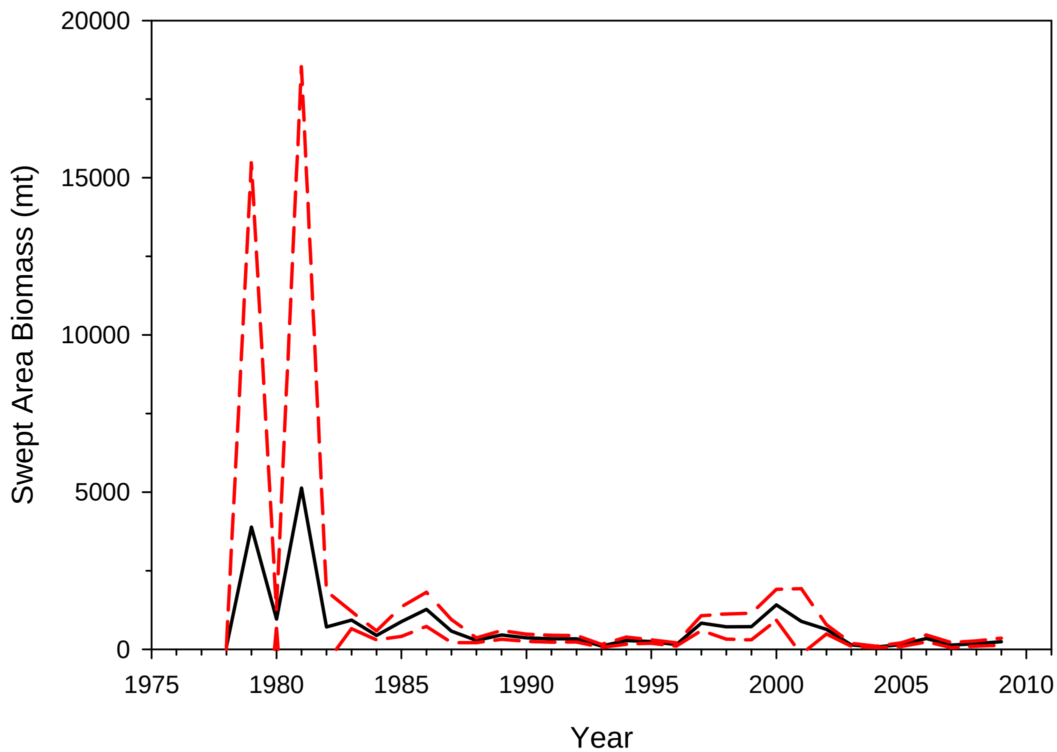
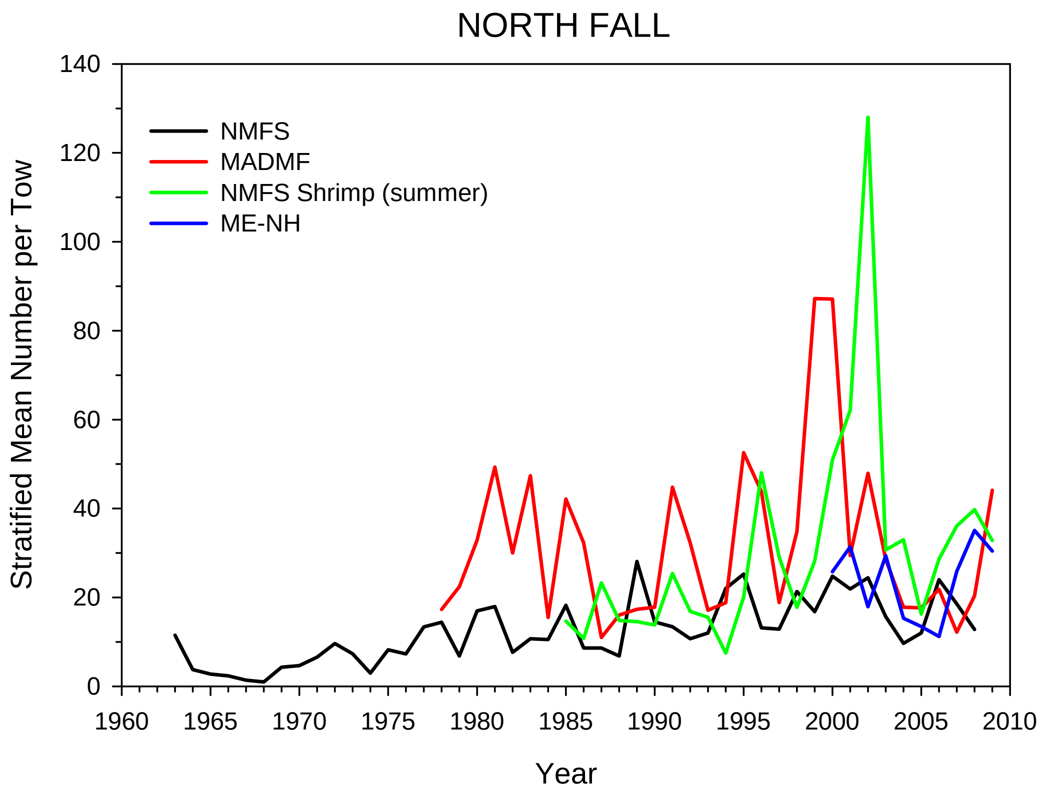


Figure C39. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries spring north survey (strata 18-36).

NORTH FALL



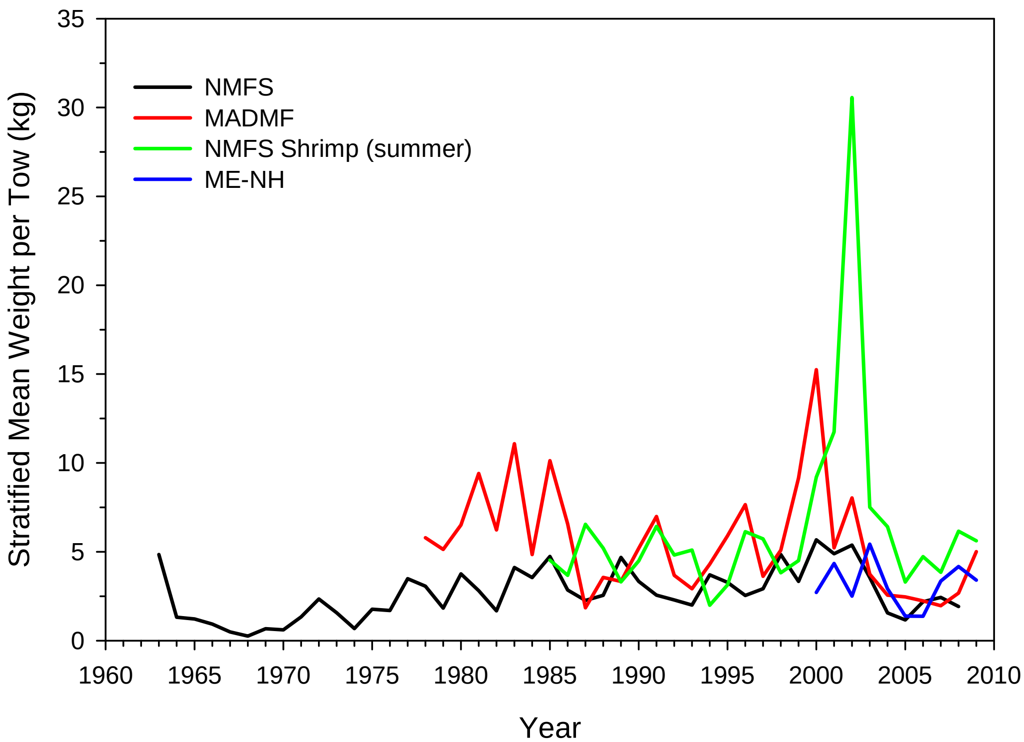
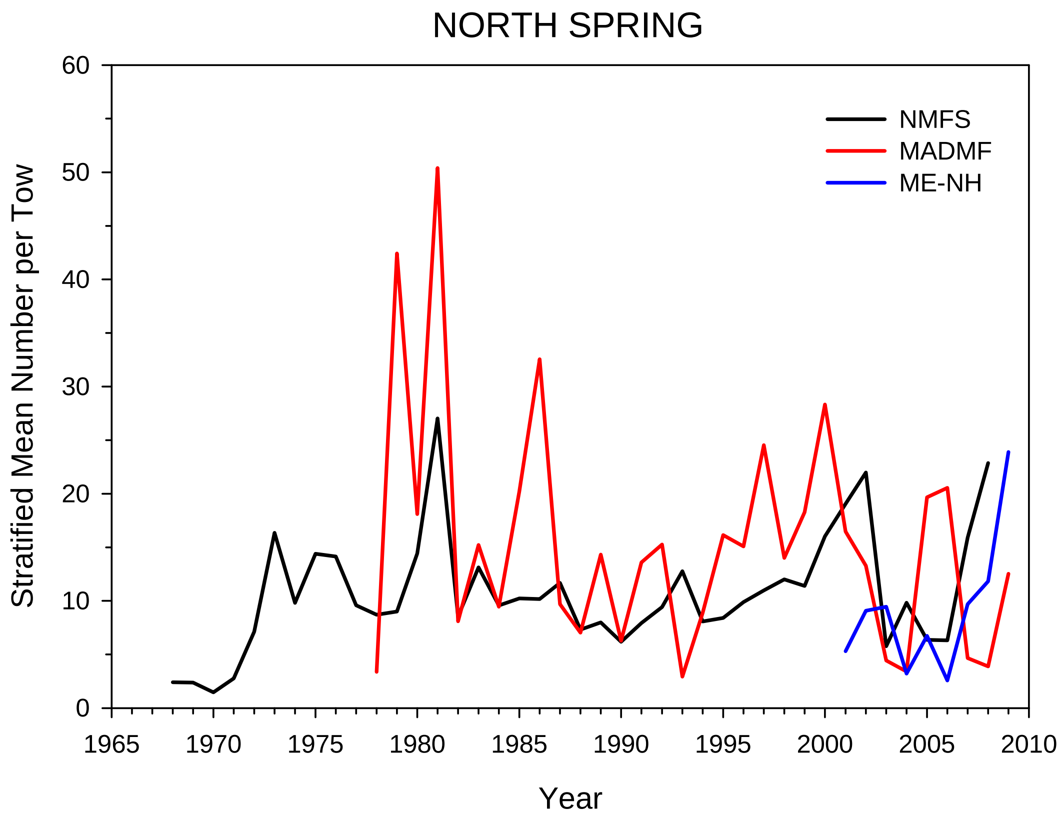


Figure C40. Stratified mean number and weight per tow (kg) for red hake from the all the fall north surveys: NEFSC, MADMF, shrimp and Maine-New Hampshire state surveys.



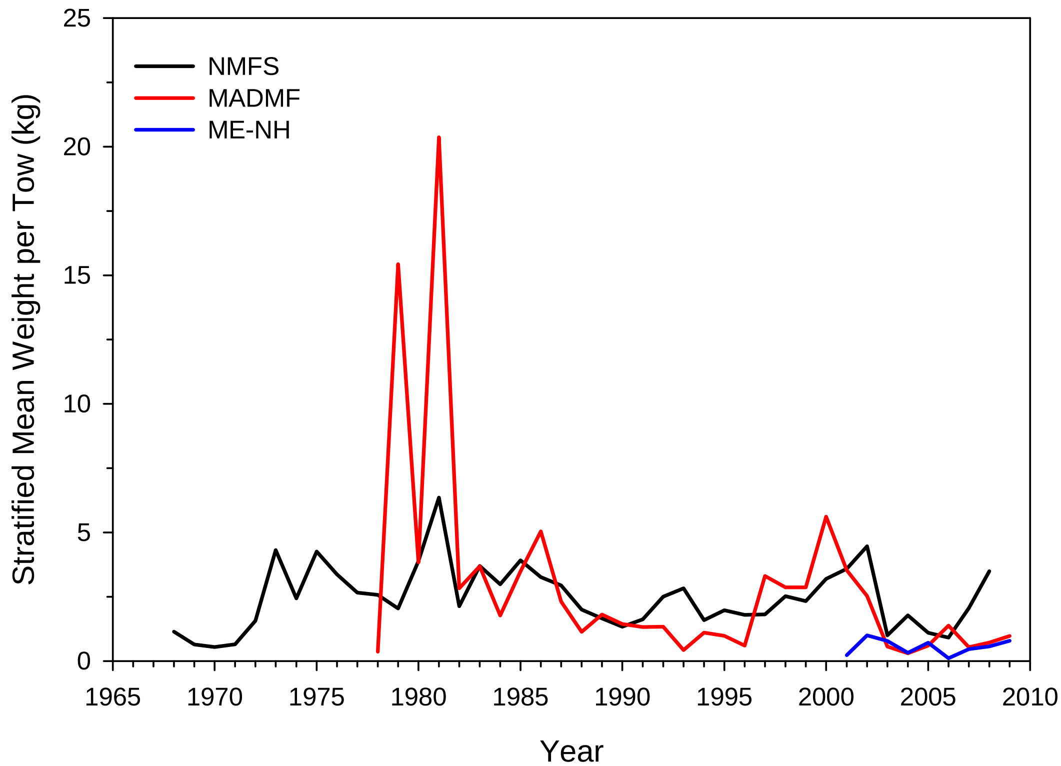


Figure C41. Stratified mean number and weight per tow (kg) for red hake from the all the spring north surveys: NEFSC, MADMF, and Maine-New Hampshire state surveys.

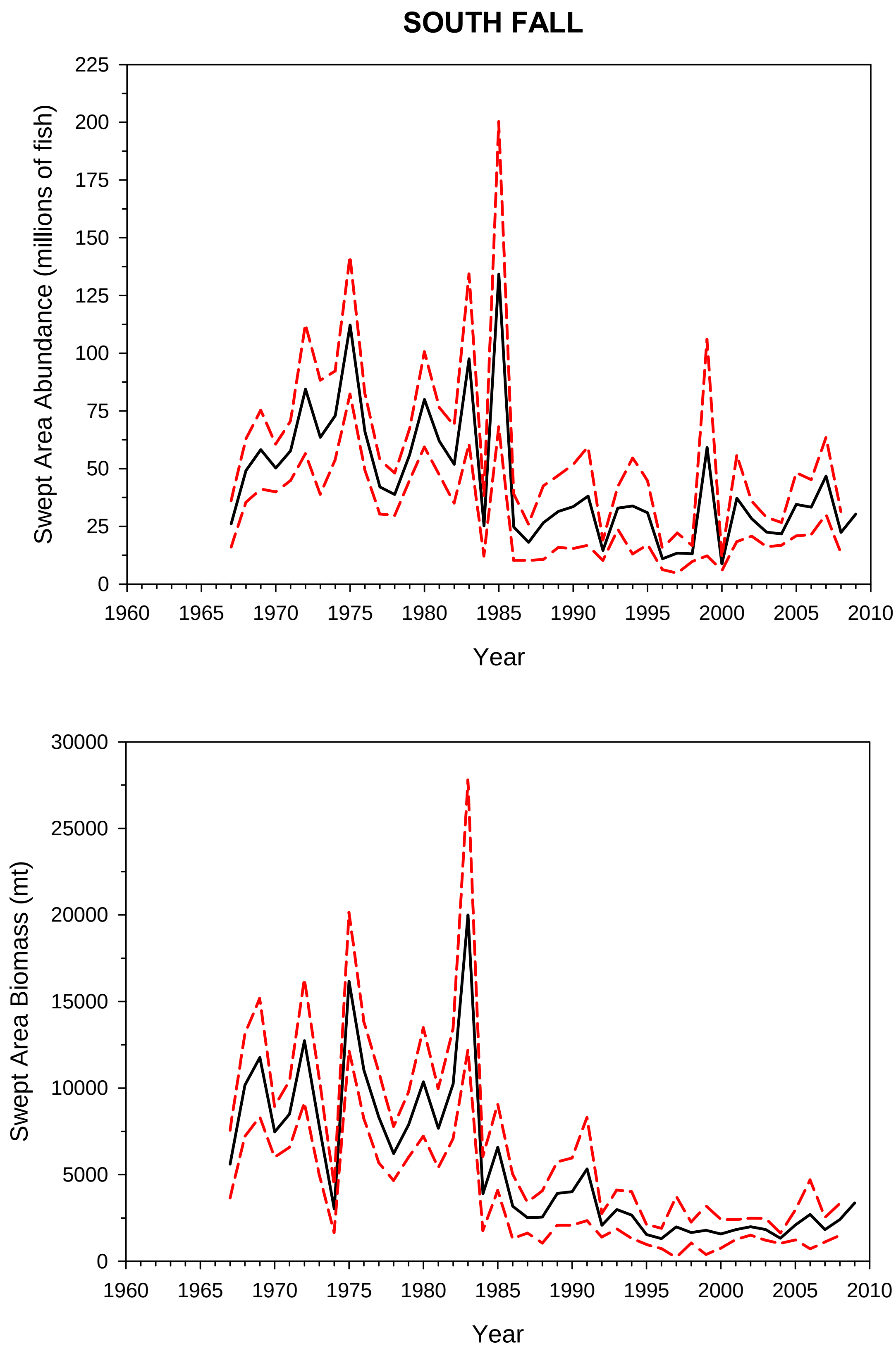
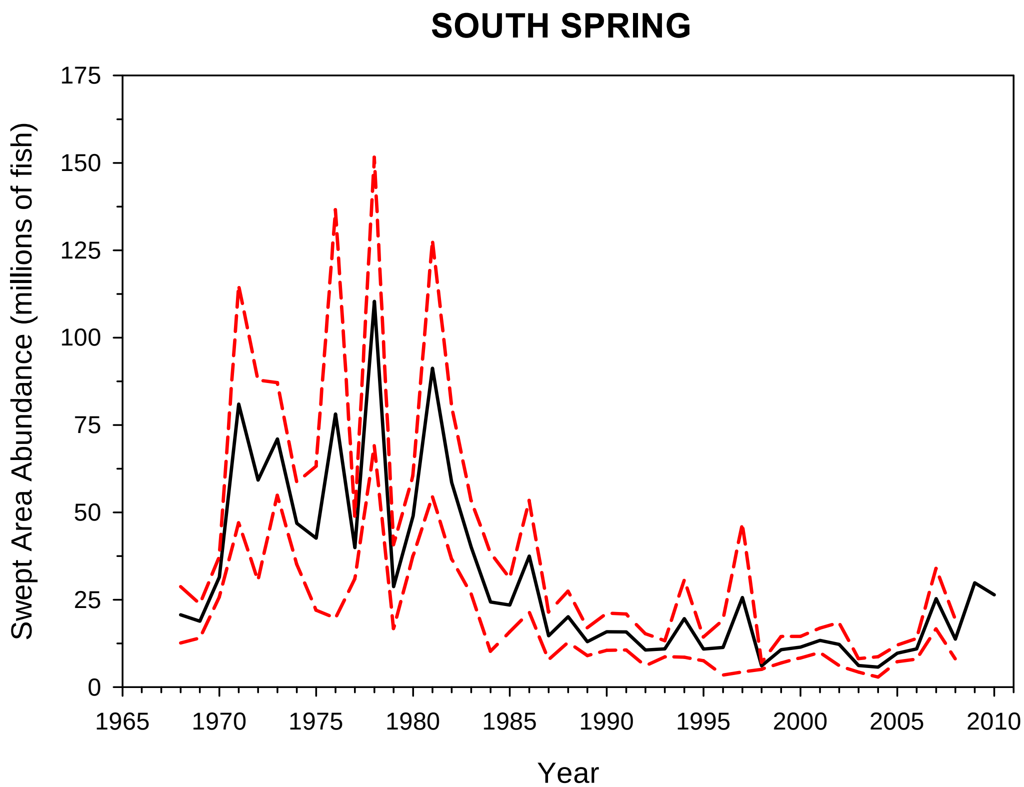


Figure C42. Swept area abundance (top) and biomass (bottom) with confidence intervals for the NEFSC fall survey in the southern management region. Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.



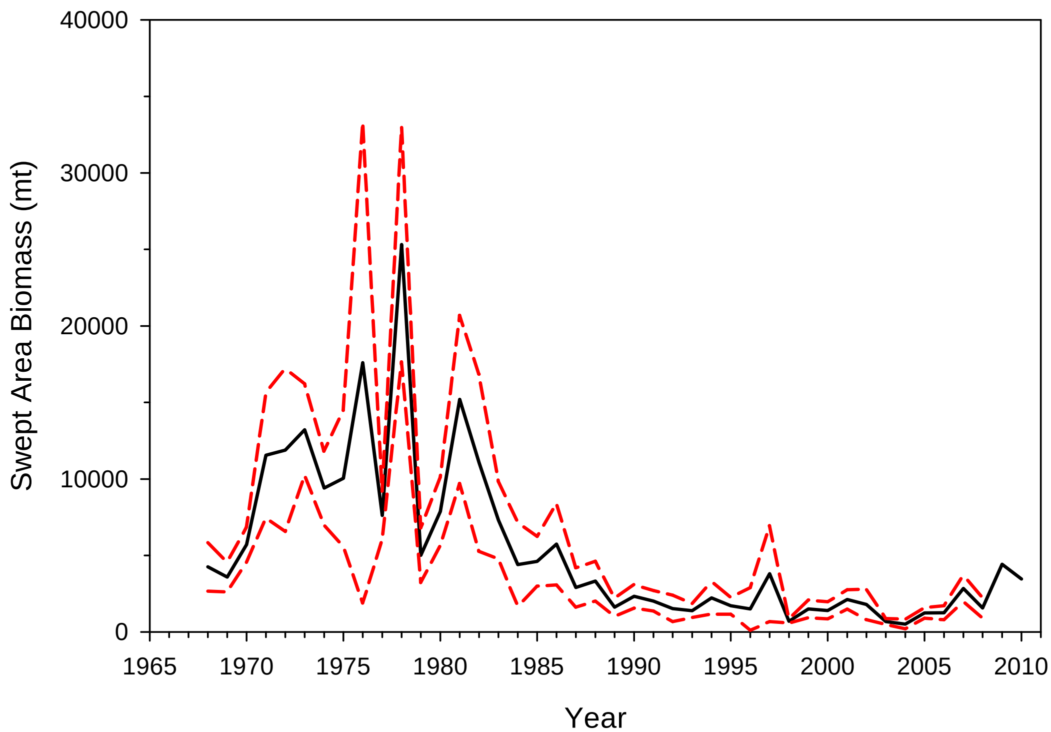


Figure C43. Swept area abundance (top) and biomass (bottom) with confidence intervals for the NEFSC spring survey in the southern management region. Estimates for 2009 and 2010 were converted to Albatross units using the calibration factors at length in Table C34.

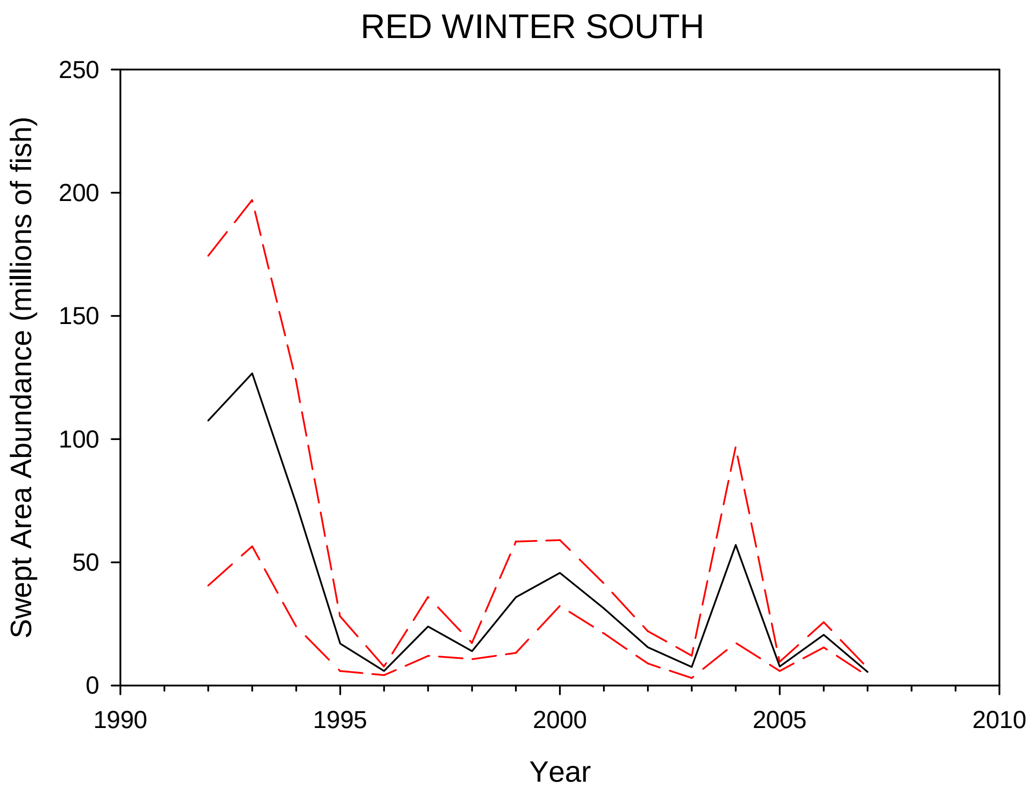
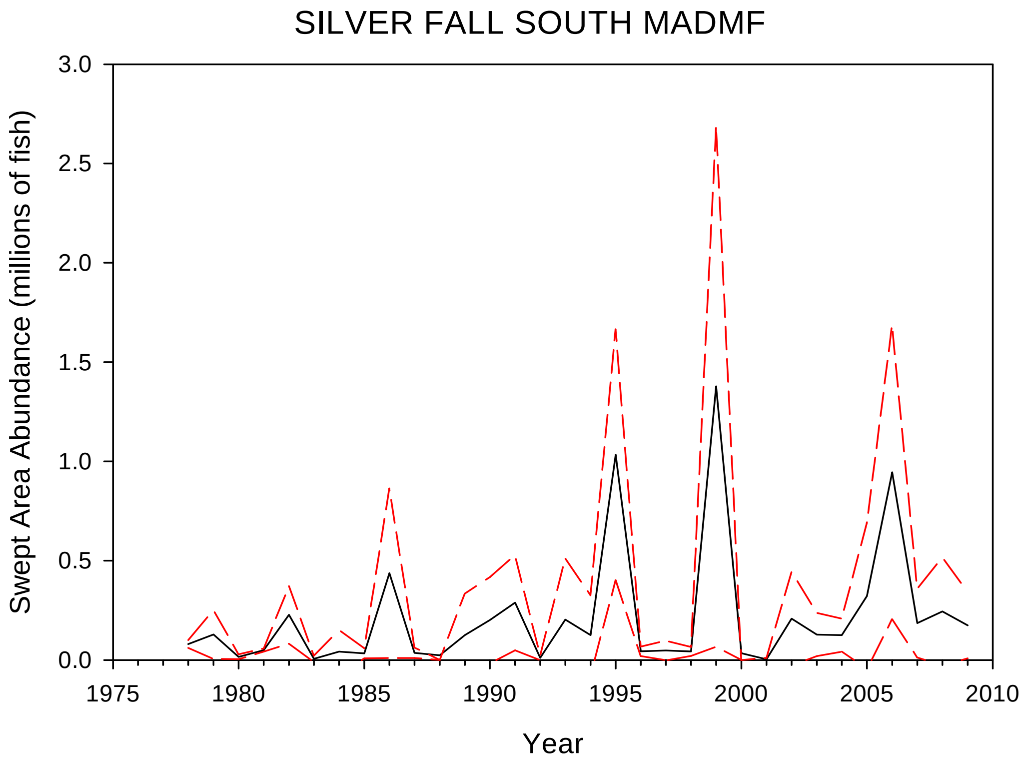


Figure C44. Swept area abundance and biomass and upper and lower confidence intervals for red hake from the NEFSC winter flatfish surveys in the southern management region (strata 1-3, 5-7, 9-11, 13-14, 61-63, 65-67, 69-71, 73-75).



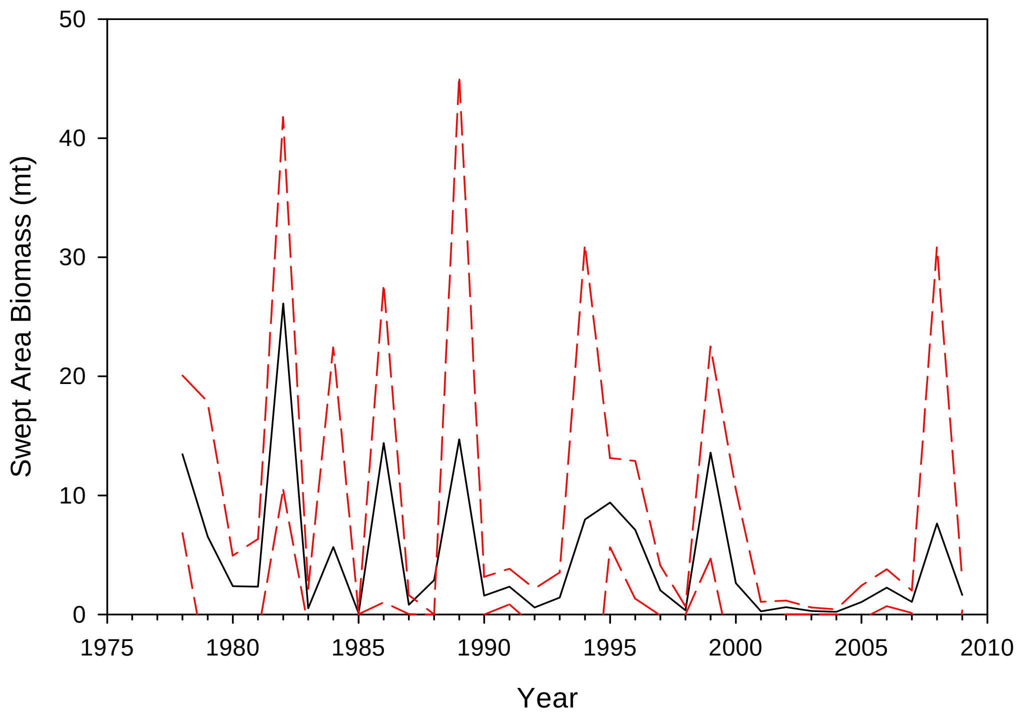
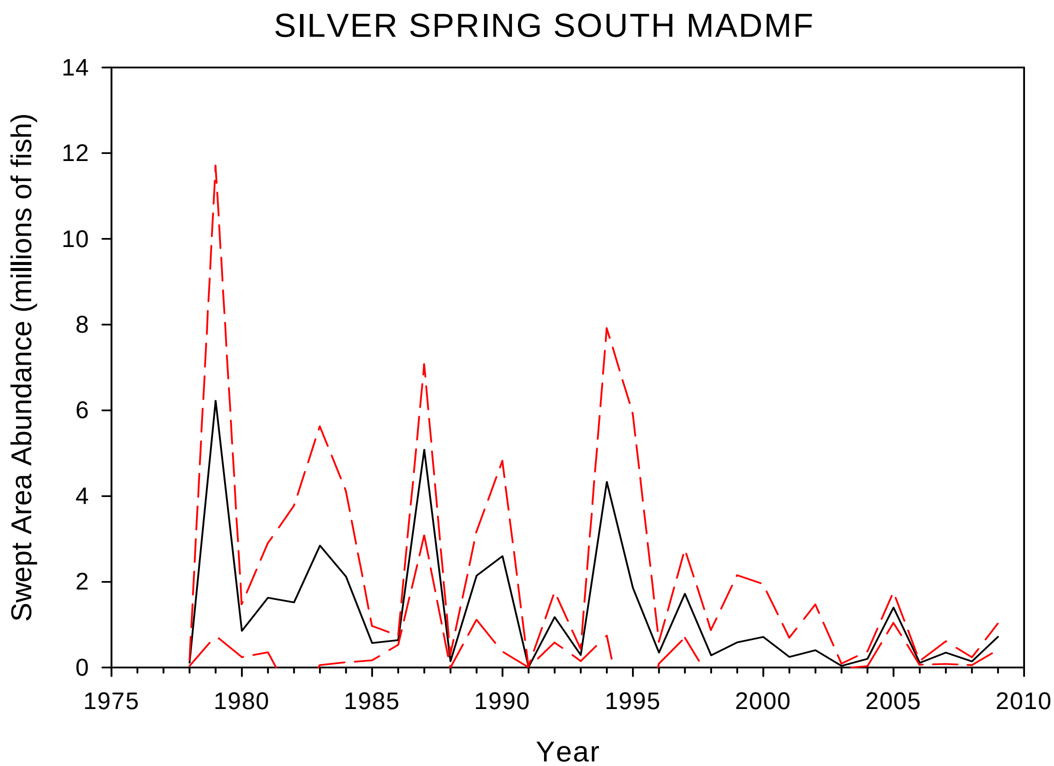


Figure C45. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries fall south survey (strata 11-17).



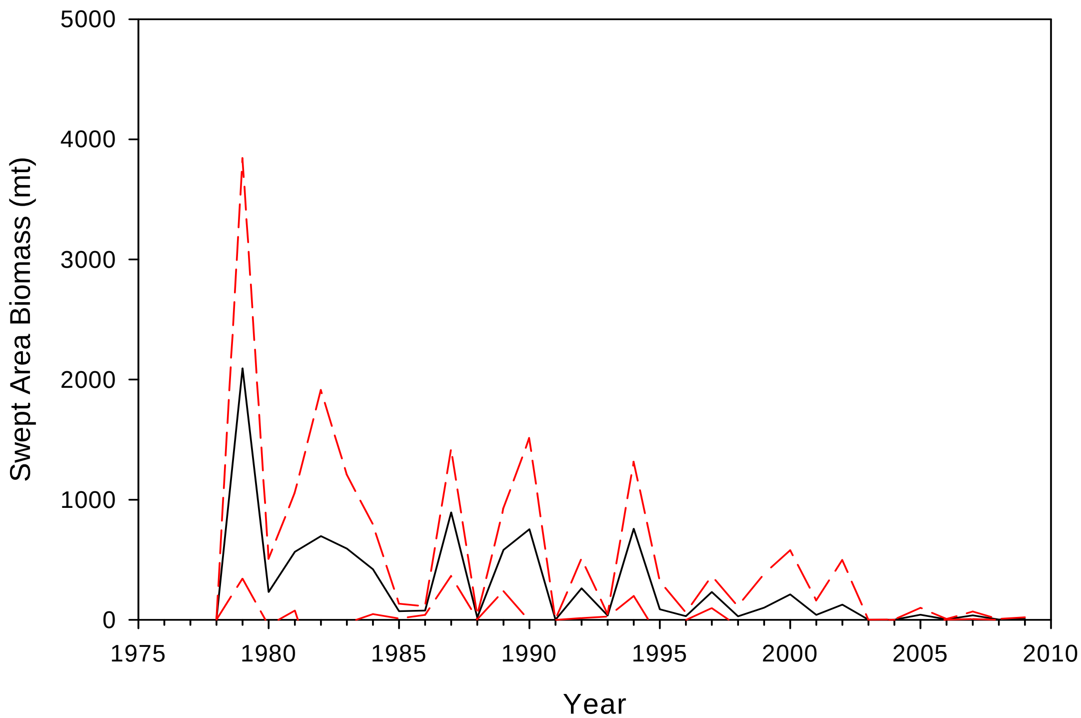


Figure C46. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from Massachusetts Division of Marine Fisheries spring south survey (strata 11-17).

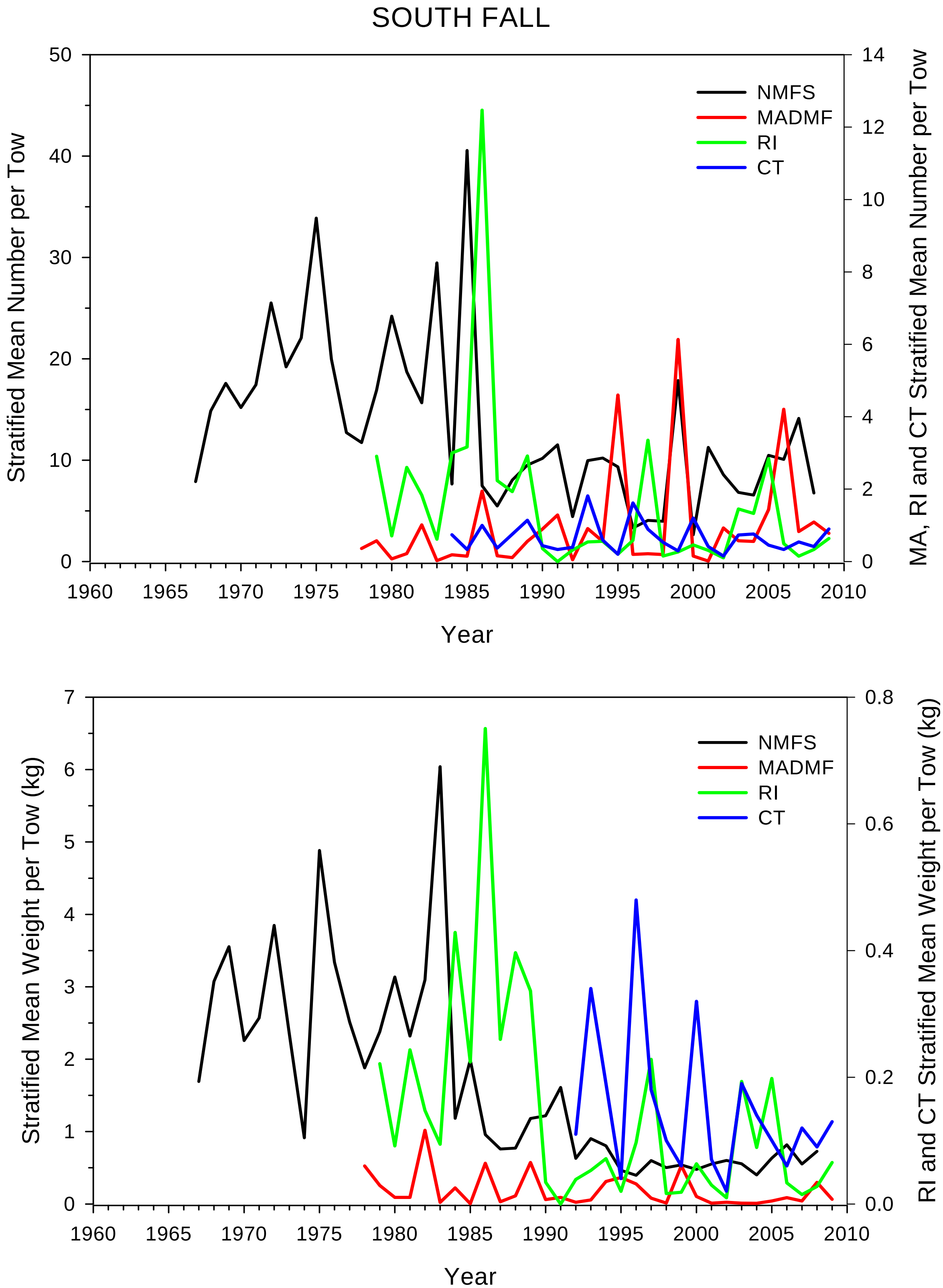
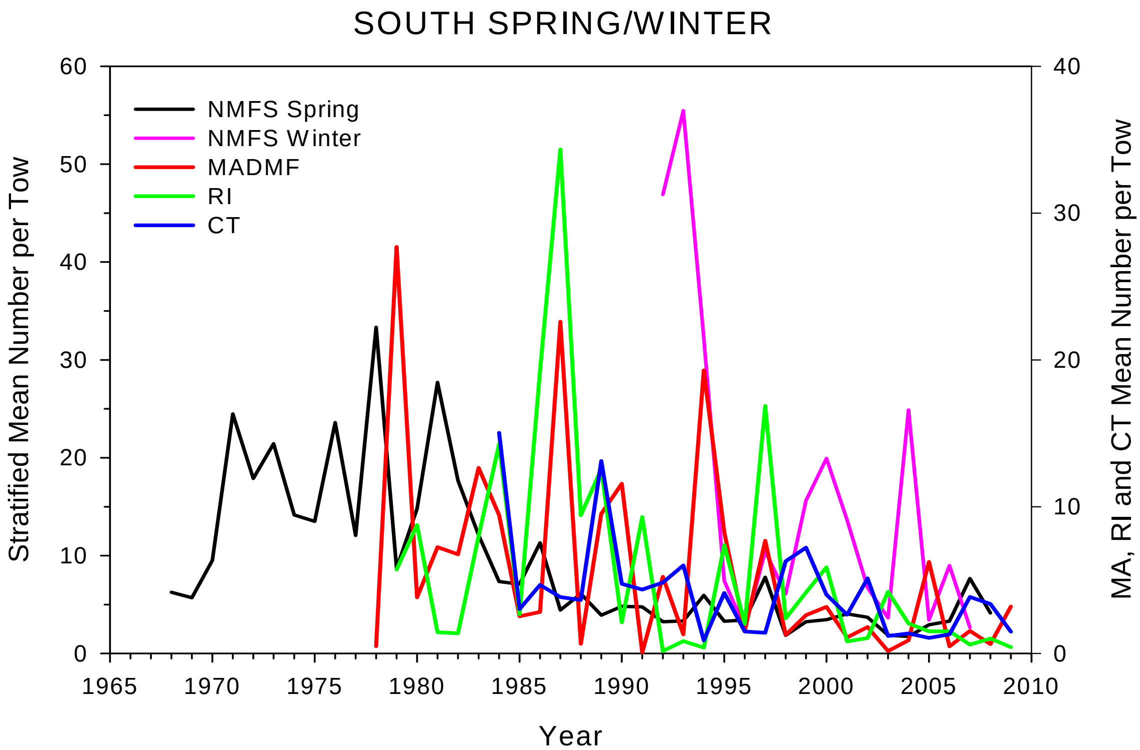


Figure C47. Stratified mean number and weight (kg) per tow for red hake from all the fall surveys in the southern management area: NEFSC, MADMF, RI and CT.



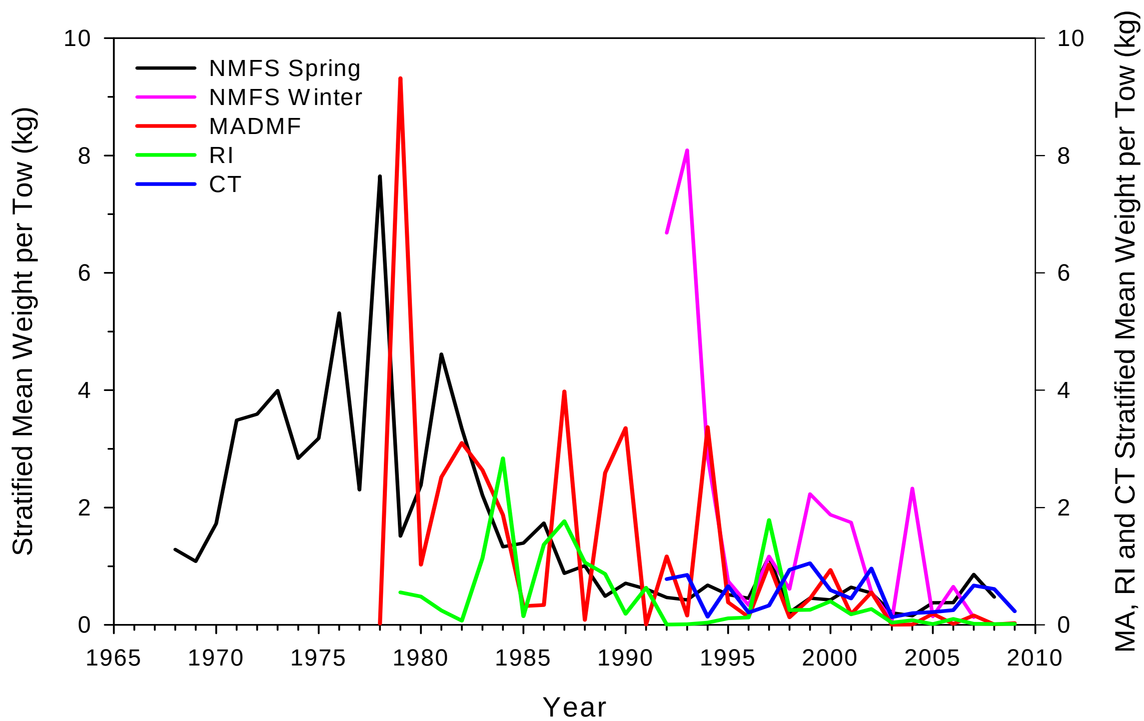


Figure C48. Stratified mean number and weight (kg) per tow for red hake from all the spring surveys in the southern management area: NEFSC, MADMF, RI and CT.

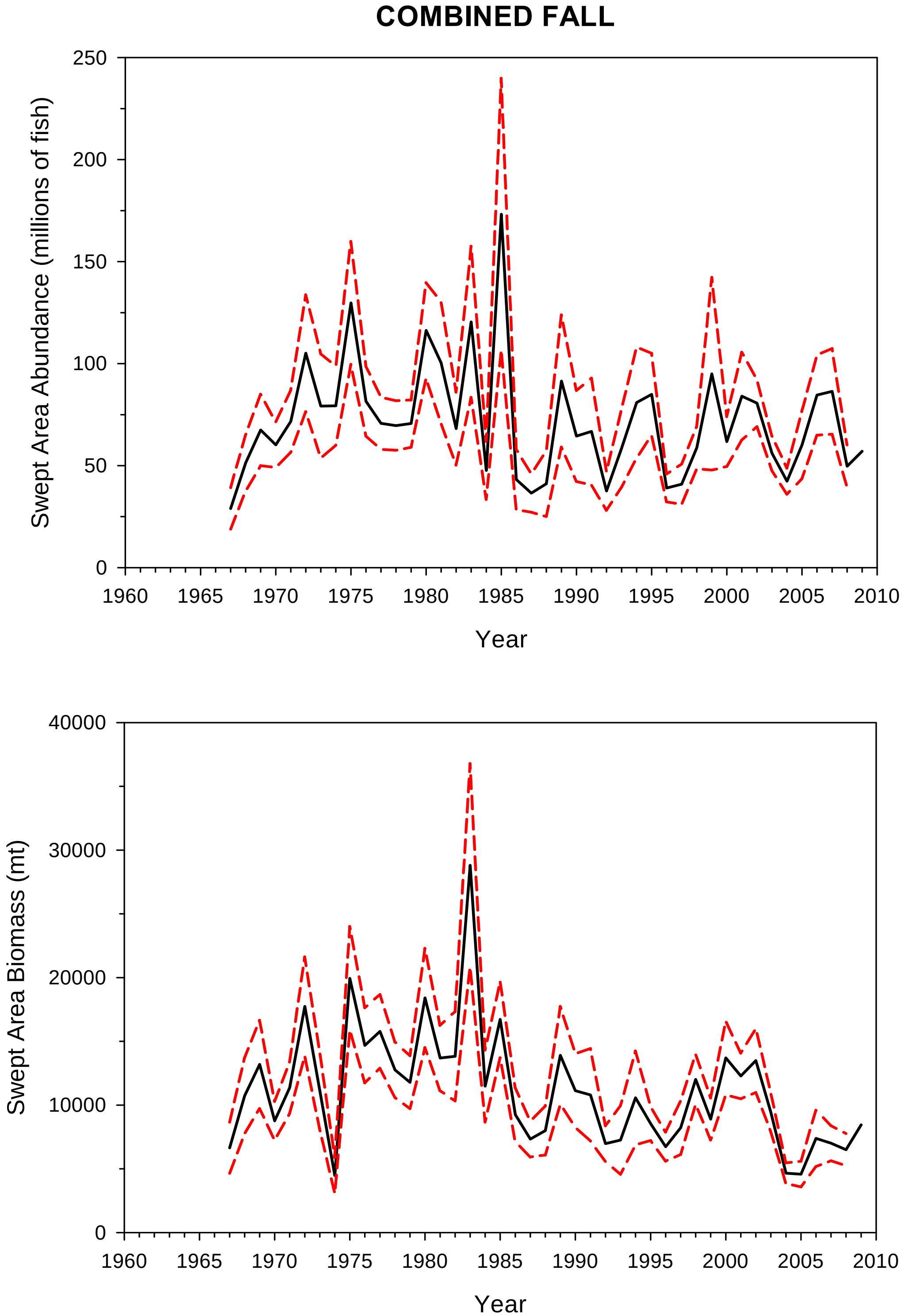
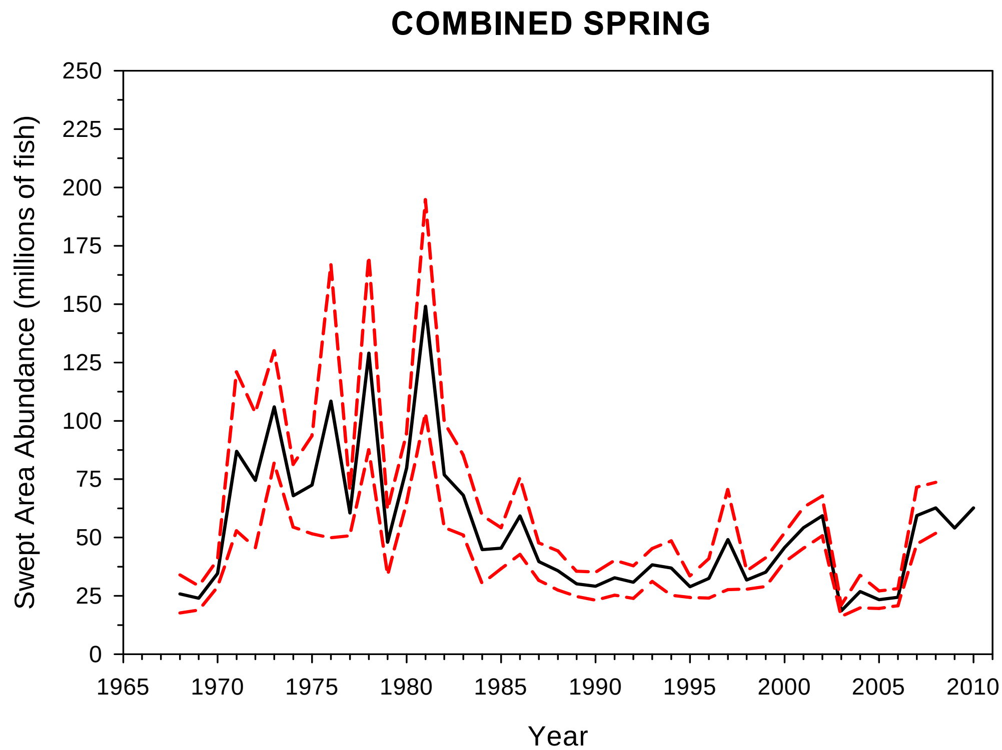


Figure C49. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from the NEFSC fall bottom trawl surveys in the northern and southern management regions combined (strata 1-30, 36-40, 61-76). Estimates for 2009 were converted to Albatross units using the calibration factors at length in Table C34.



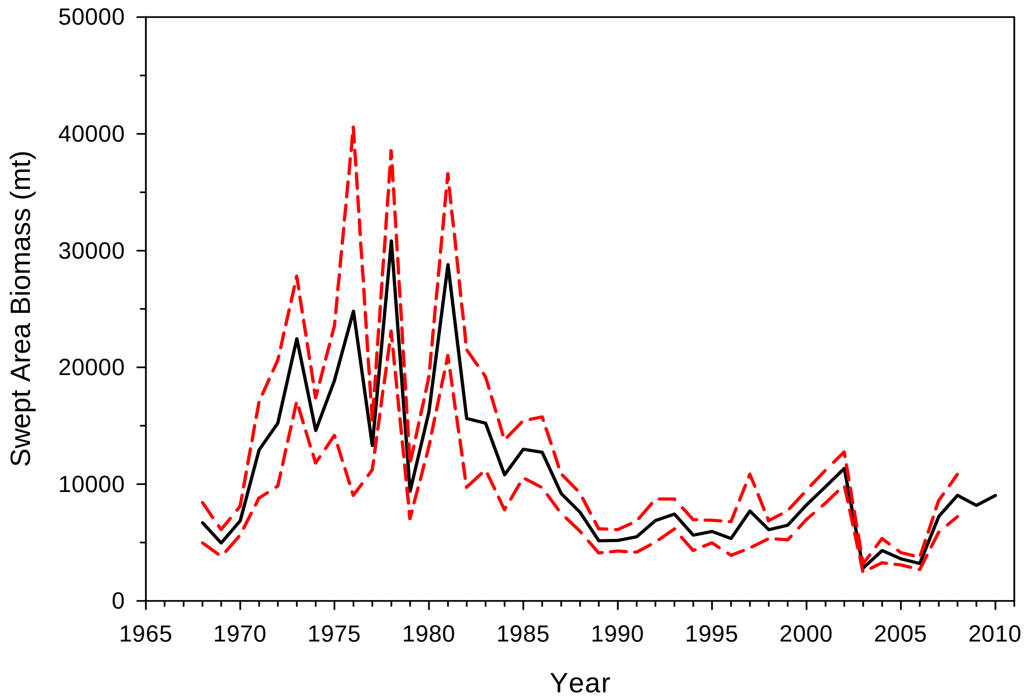
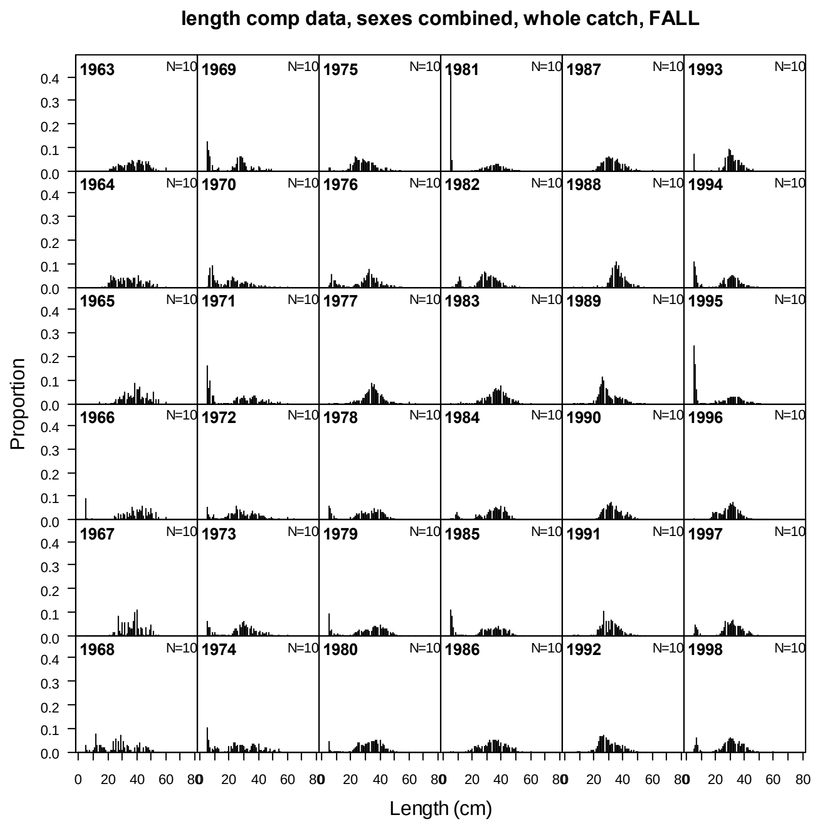


Figure C50. Swept area abundance (top) and biomass (bottom) with upper and lower confidence intervals for red hake from the NEFSC spring bottom trawl surveys in the northern and southern management regions combined (strata 1-30, 36-40, 61-76). Estimates for 2009 and 2010 were converted to Albatross units using the calibration factors at length in Table C34.



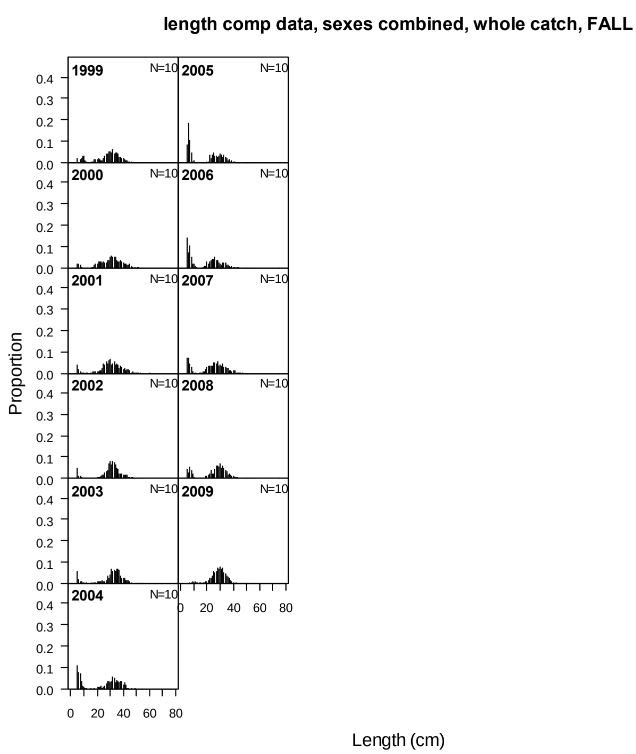


Figure C51. Length composition of red hake from the fall survey for the northern stock.

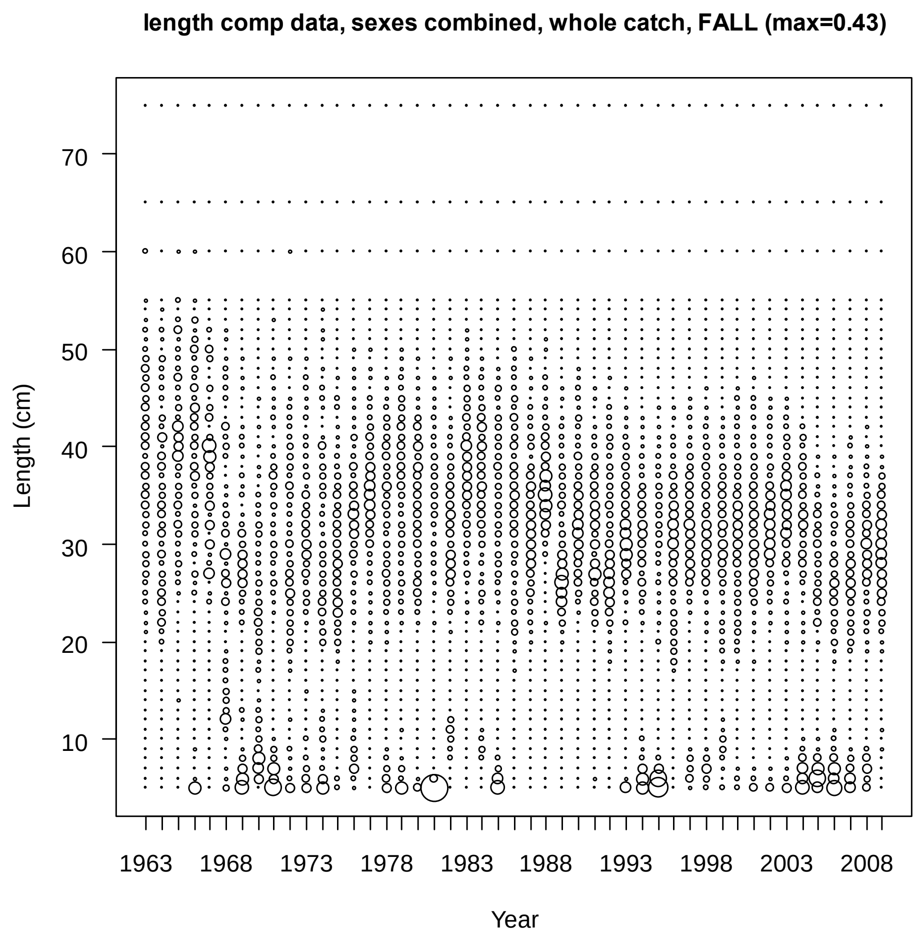
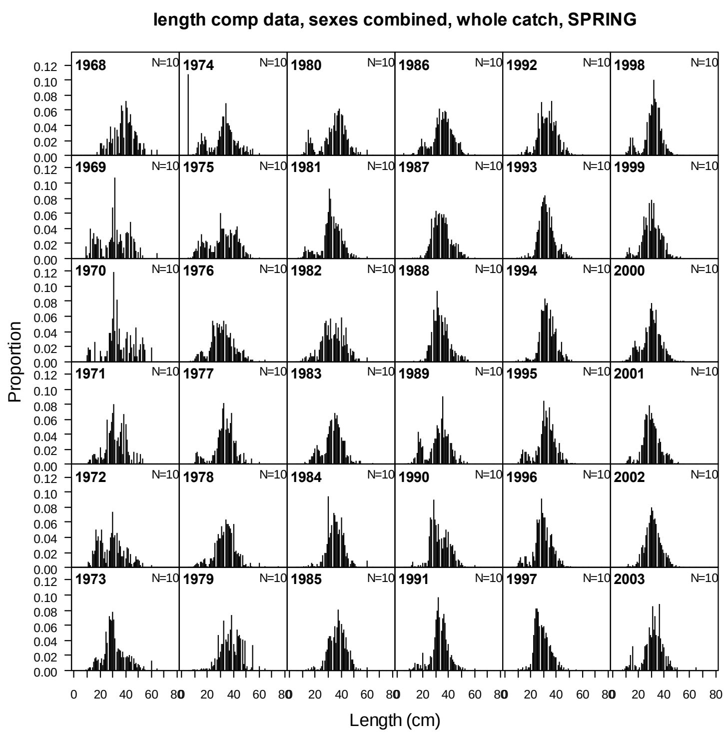


Figure C51 cont. Length composition of red hake from the fall survey for the northern stock.



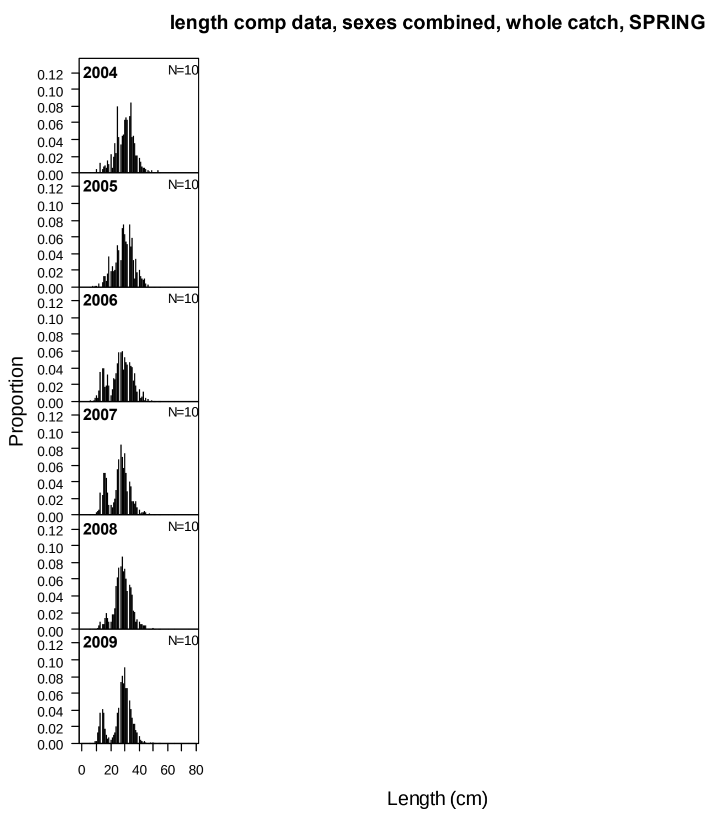


Figure C52. Length composition of red hake from the spring survey for the northern stock.

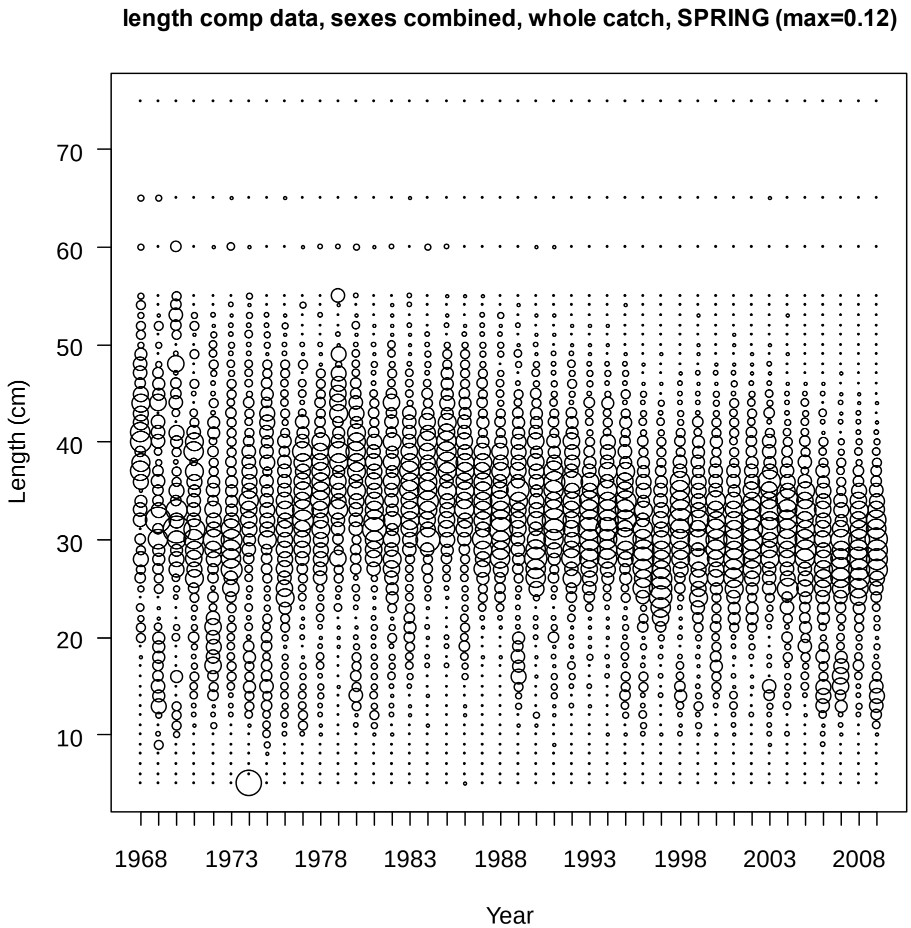
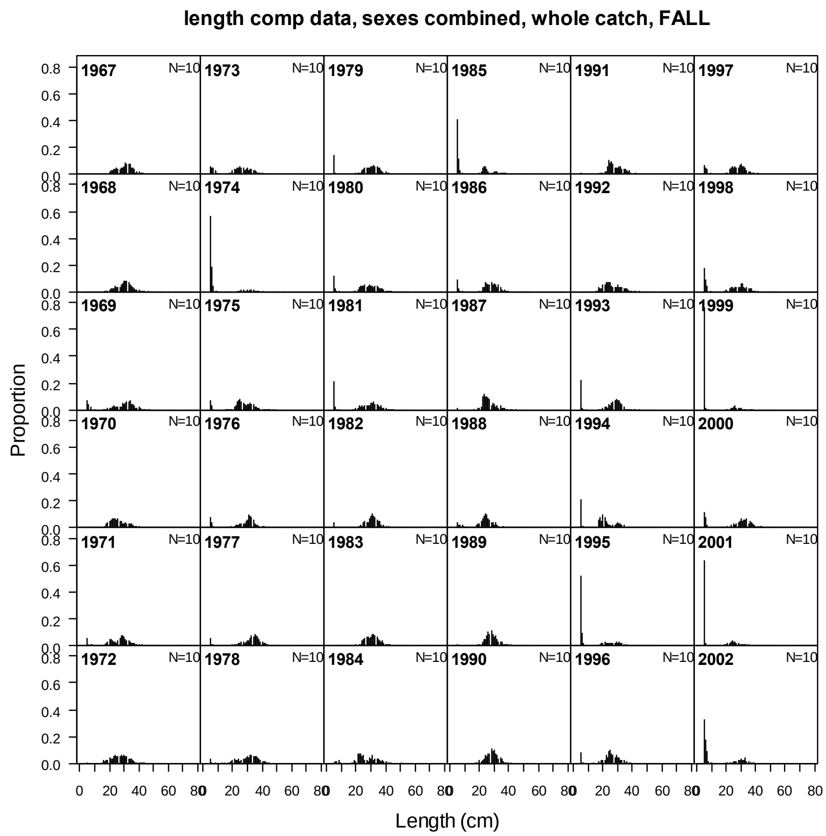


Figure C52 cont. Length composition of red hake from the spring survey for the northern stock.



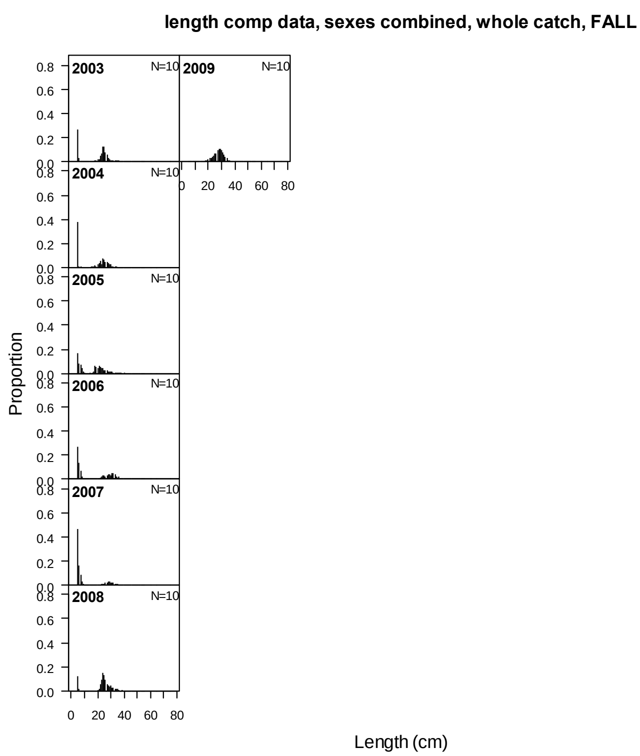


Figure C53. Length composition of red hake from the fall survey for the southern stock.

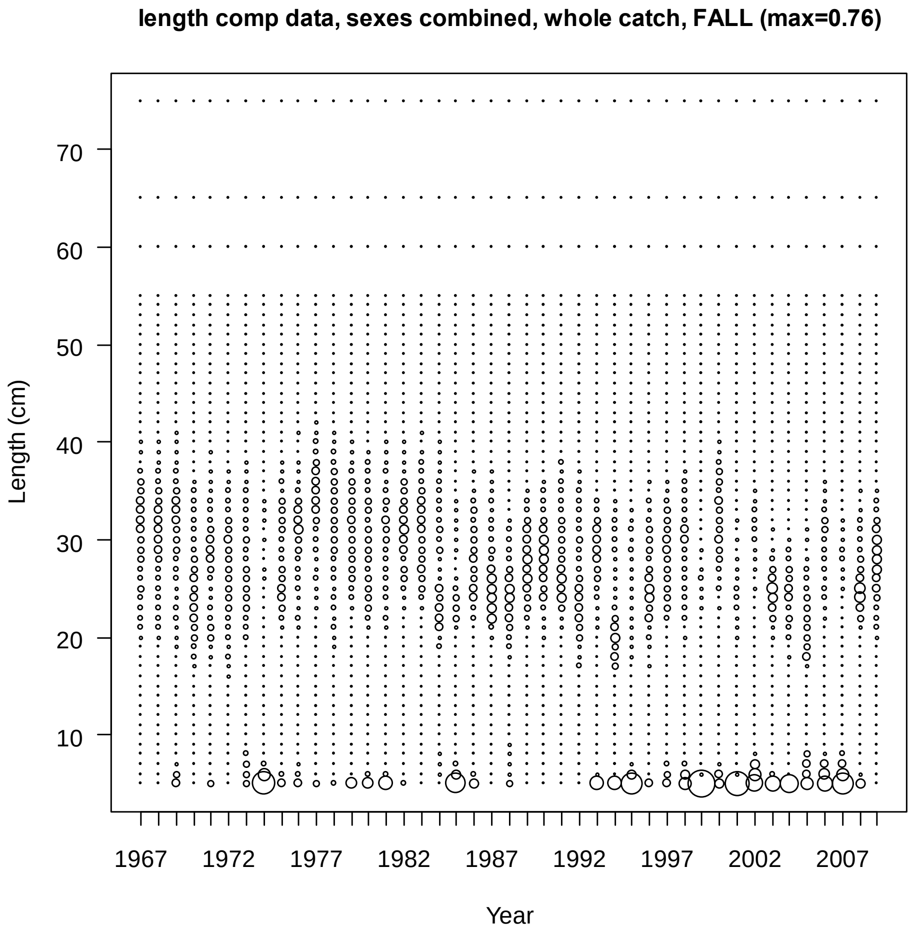
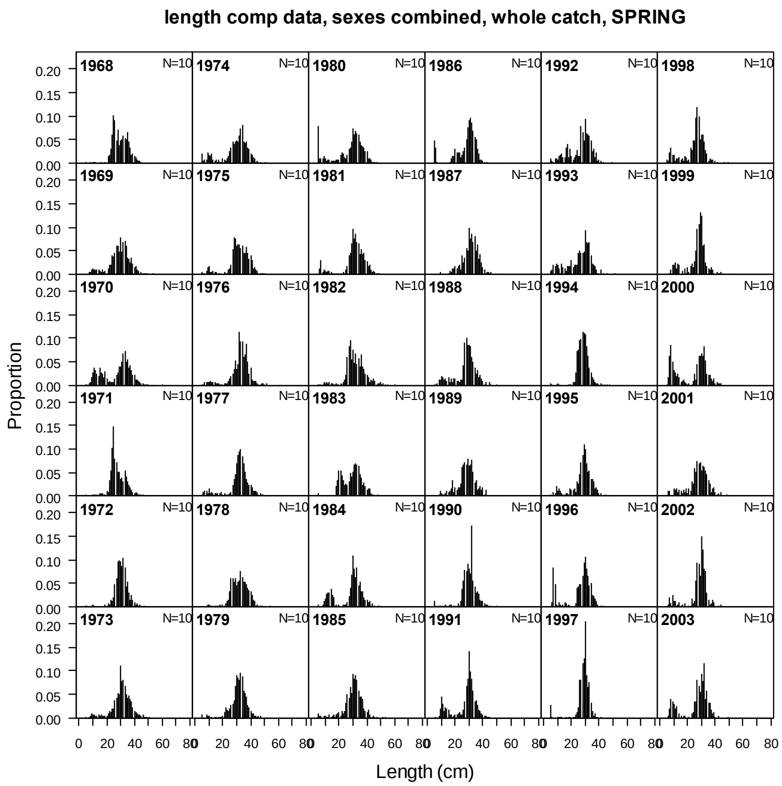


Figure C53 cont. Length composition of red hake from the fall survey for the southern stock.



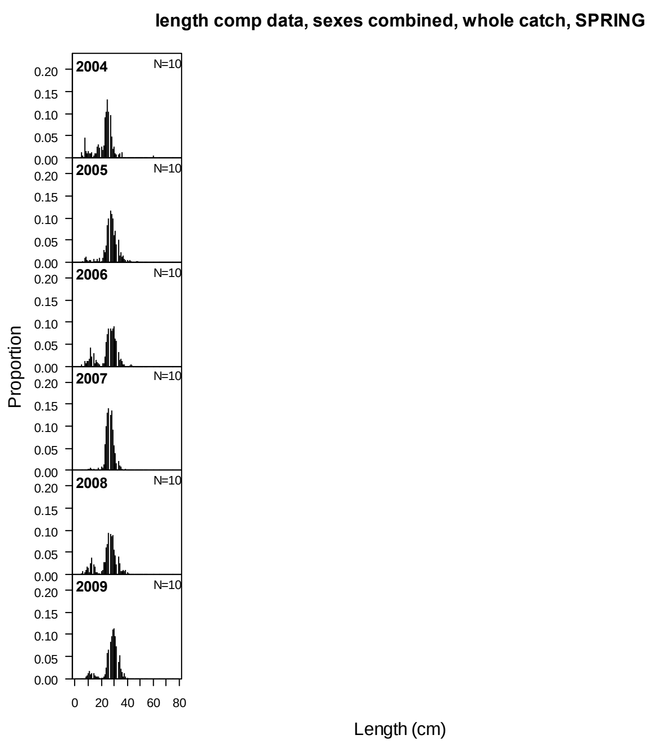


Figure C54. Length composition of red hake from the spring survey for the southern stock.

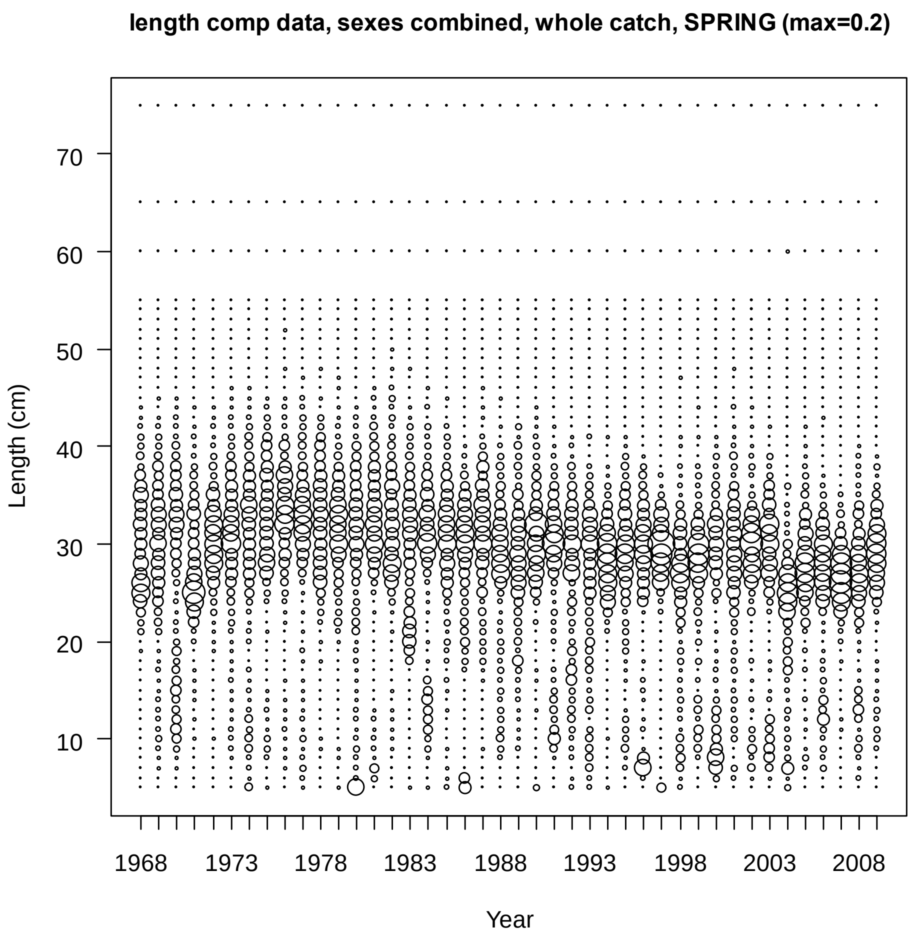
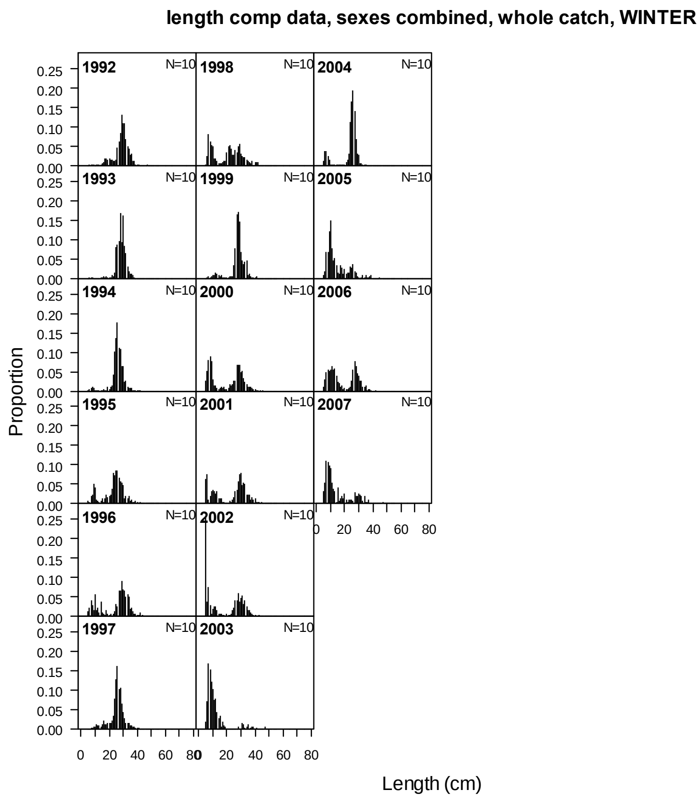


Figure C54 cont. Length composition of red hake from the spring survey for the southern stock.



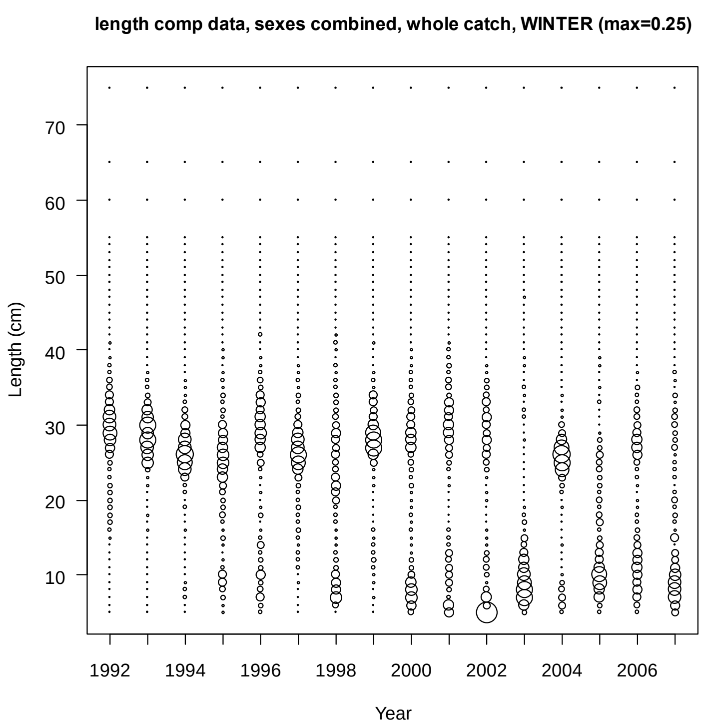


Figure C55. Length composition of red hake from the winter survey for the southern stock.

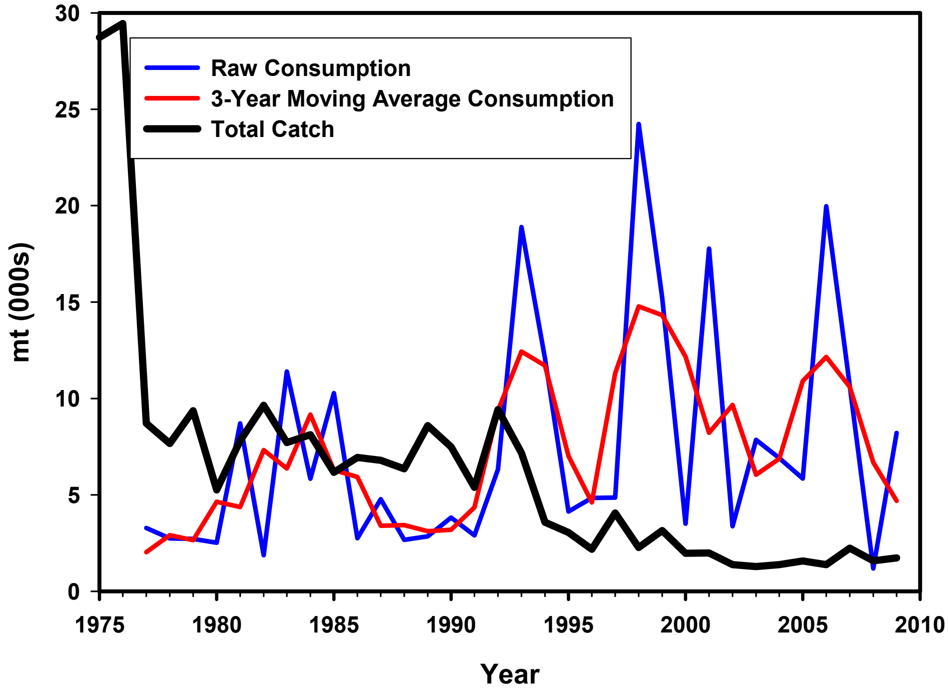


Figure C56. Minimal estimates of total red hake biomass removed by consumption by major fish predators compared to total catch.

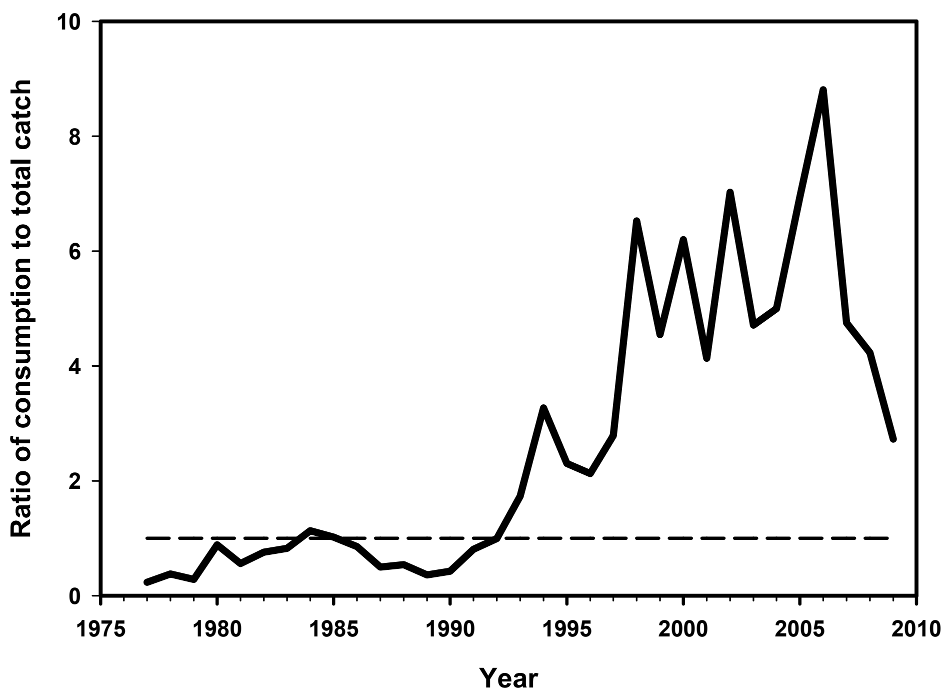
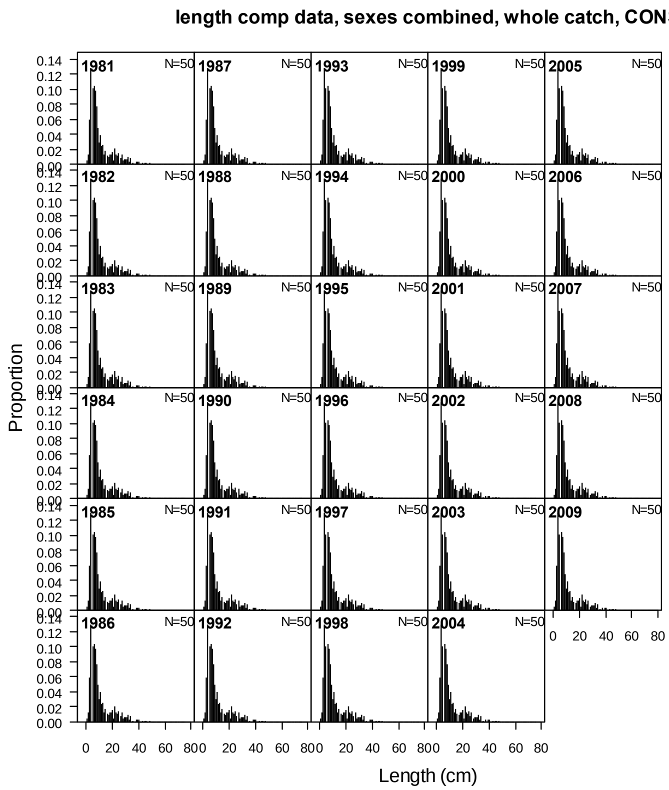


Figure C57. Ratio of consumption to total catch of red hake over the time series. The constant line represents a ratio of unity.



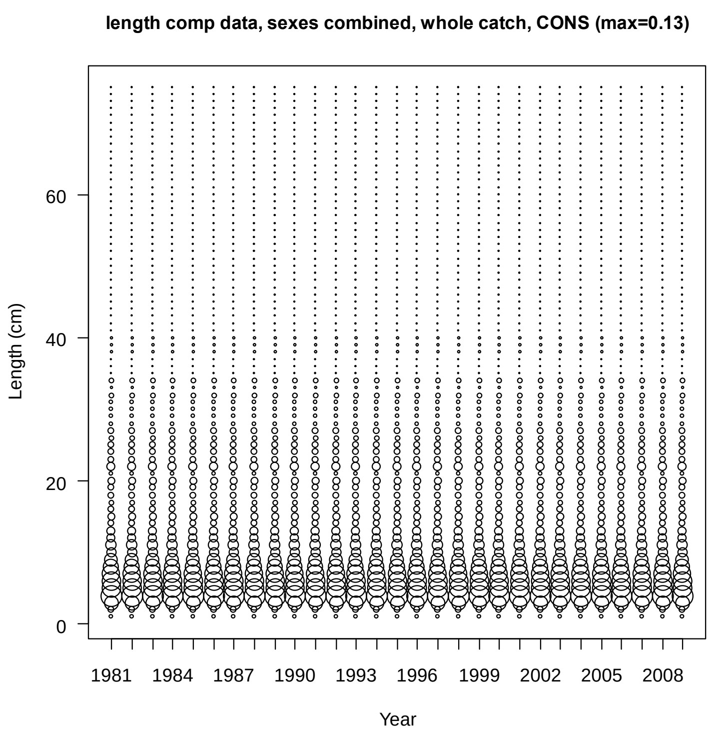
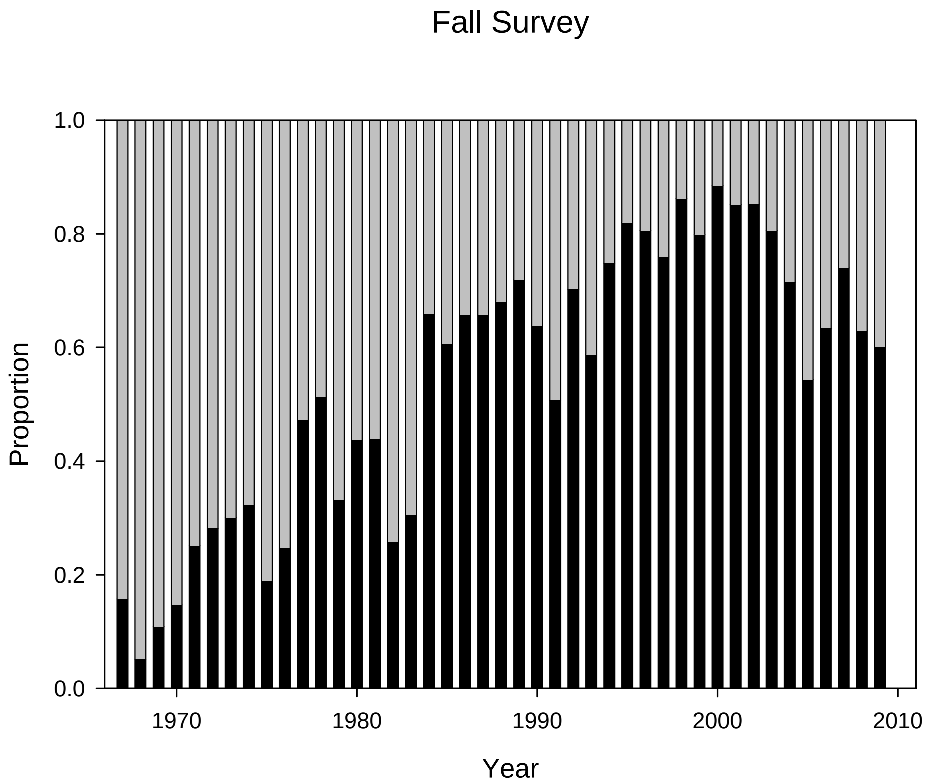


Figure C58. Length composition of red hake consumed by major predators from the NEFSC surveys for the northern and southern stocks combined.



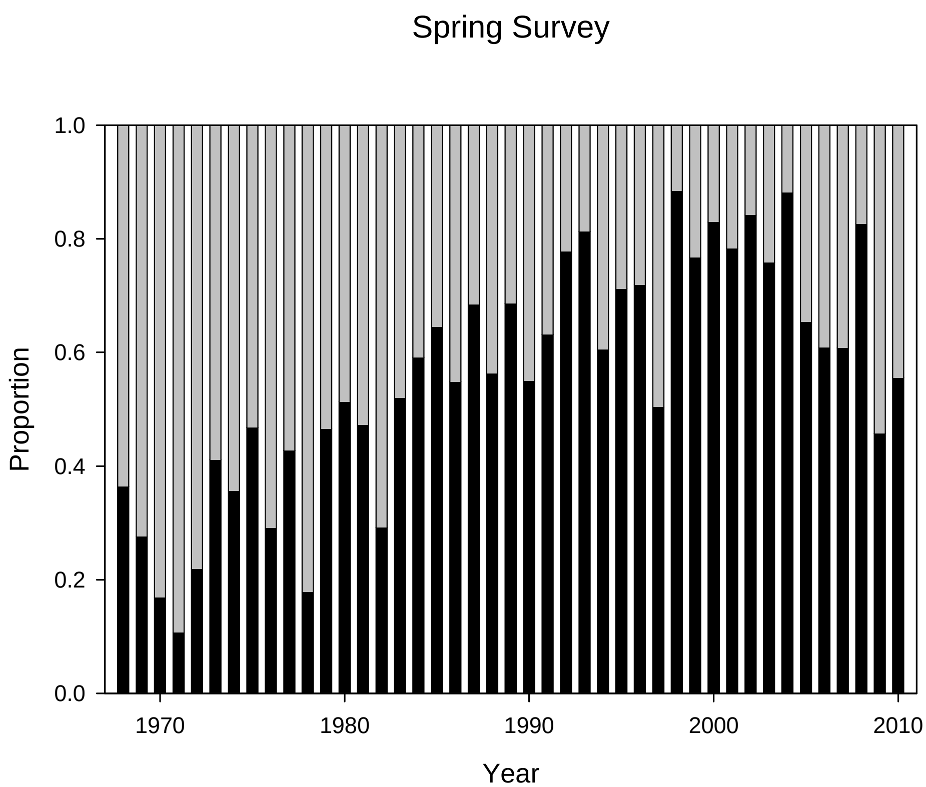
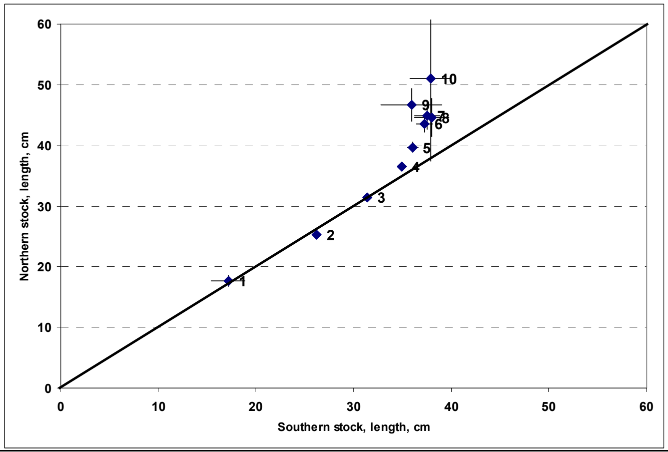
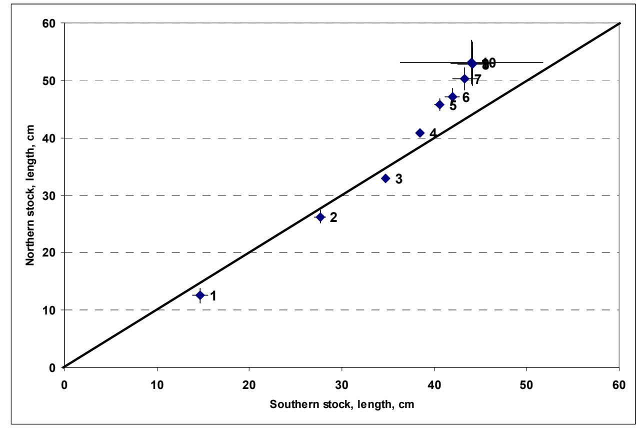


Figure C59. Proportion of swept area biomass found in the northern area (black) and the southern area (gray bars).

<table>
<tr><th>Red hake</th><th>Males</th><th>Females</th></tr>
<tr><td>Spring</td><td>
</td><td>
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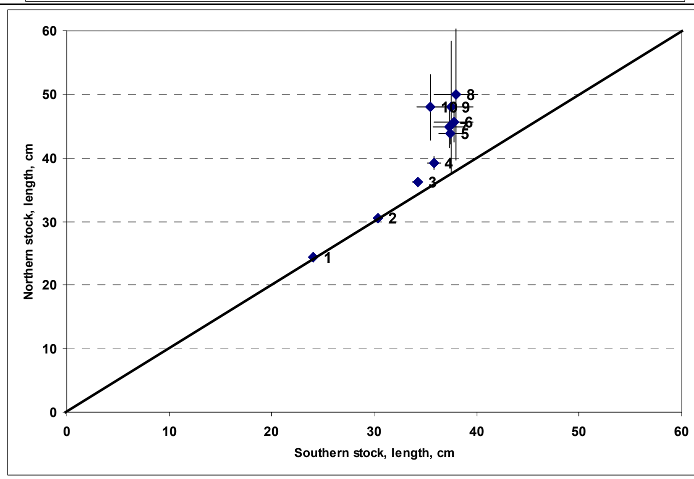
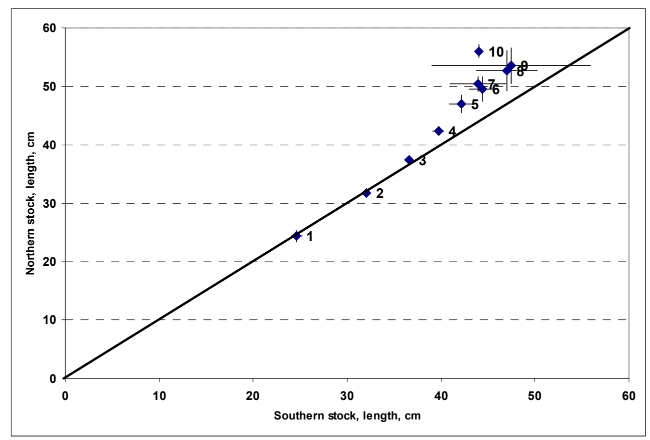
<tr><td>Fall</td><td>
</td><td>
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Figure C60a. Size (cm total length) at age comparison between red hake caught in strata 1-19, 61-76 (Southern stock) and strata 20-40 (Northern stock) for 1957-1974 cohorts.

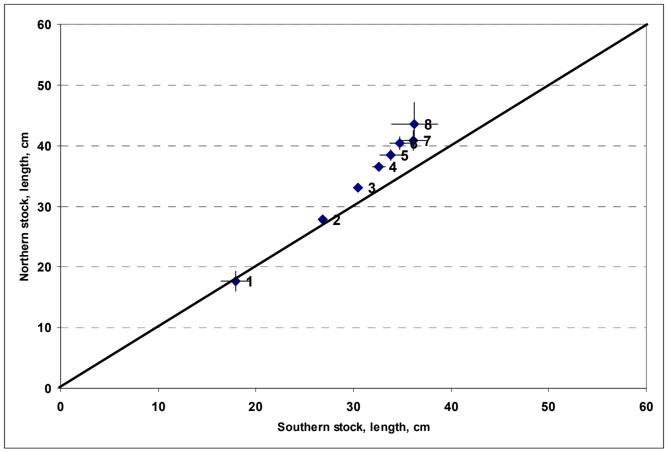
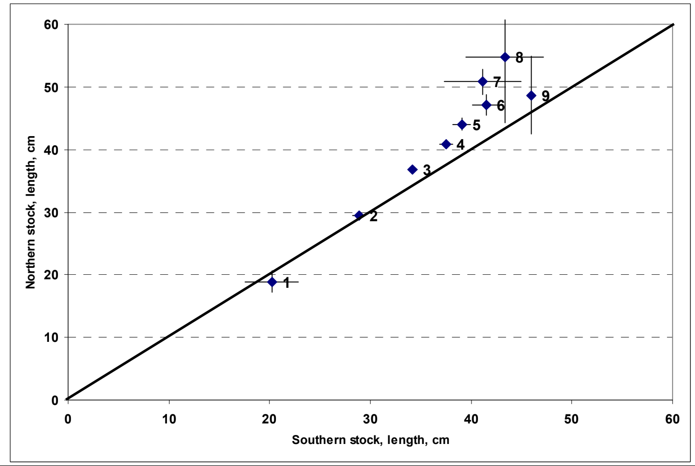
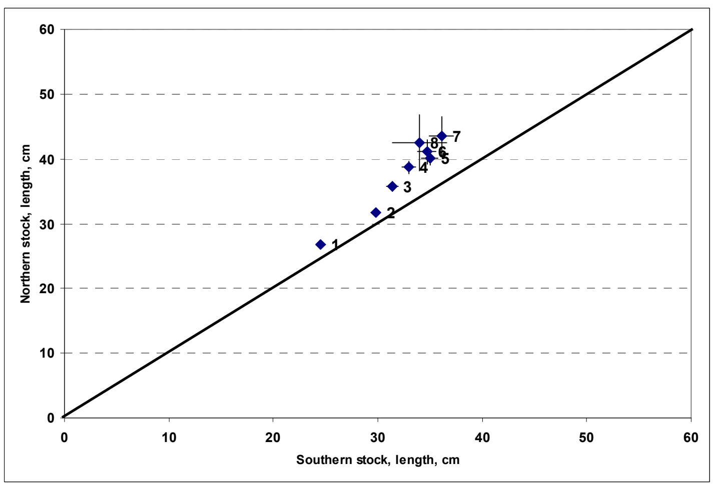
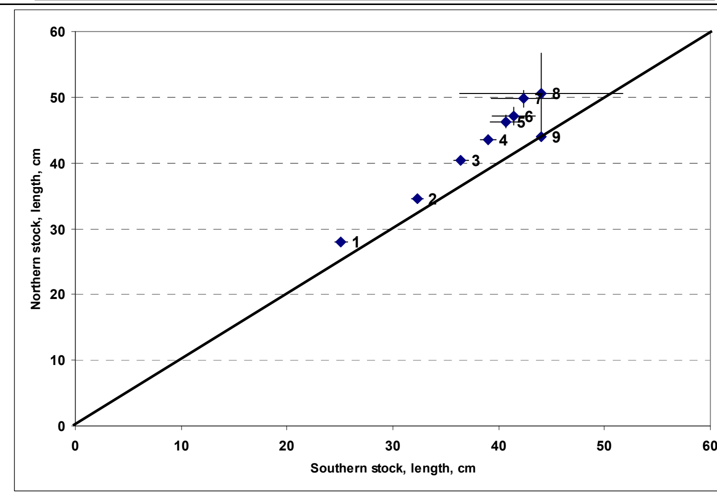
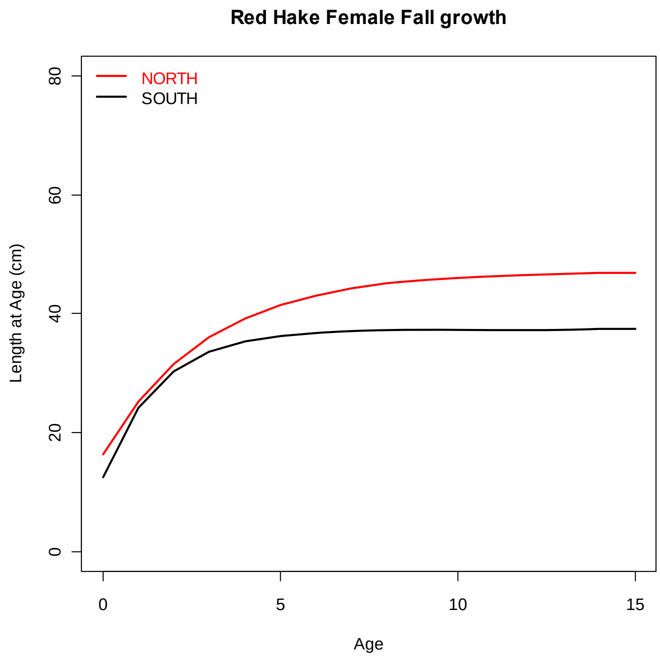
Red hake	Males	Females
Spring		
Fall		

Figure C60b. Size (cm total length) at age comparison between red hake caught in strata 1-19, 61-76 (Southern stock) and strata 20-40 (Northern stock) for 1975-1985 cohorts.



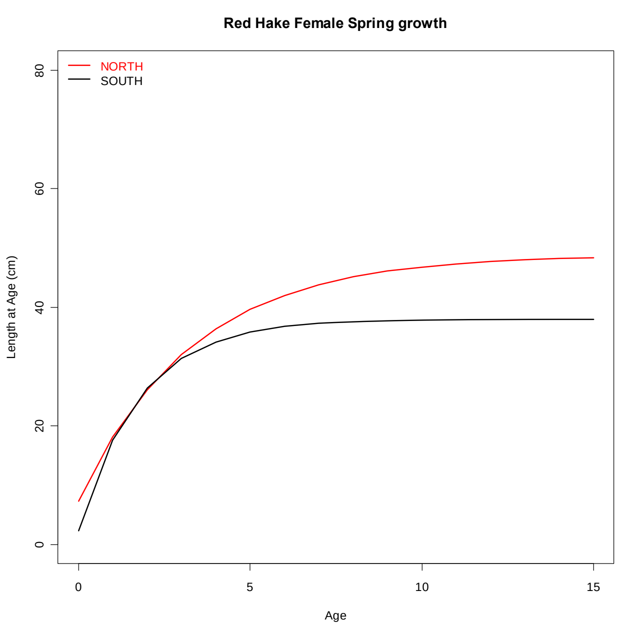
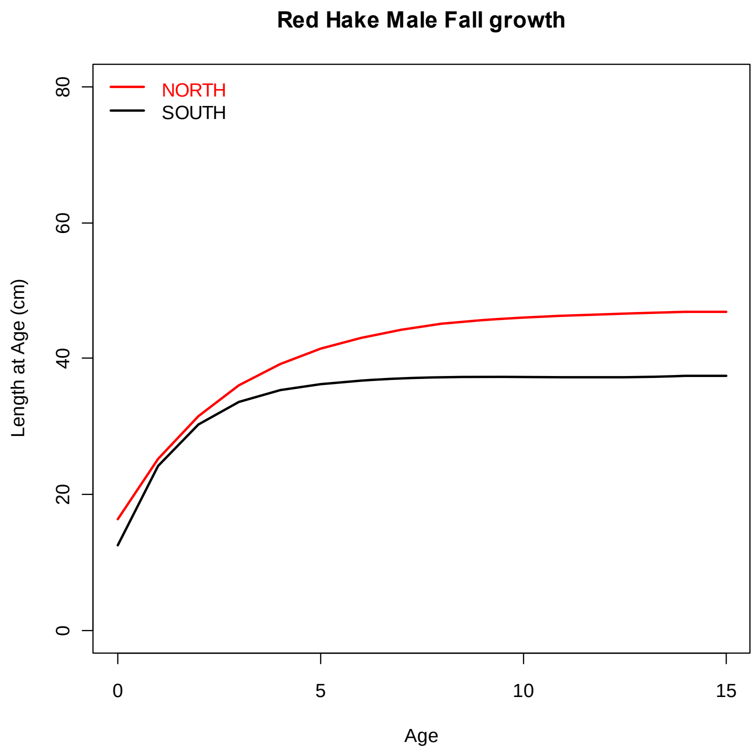


Figure C61a. Growth curves for female red hake by stock area.



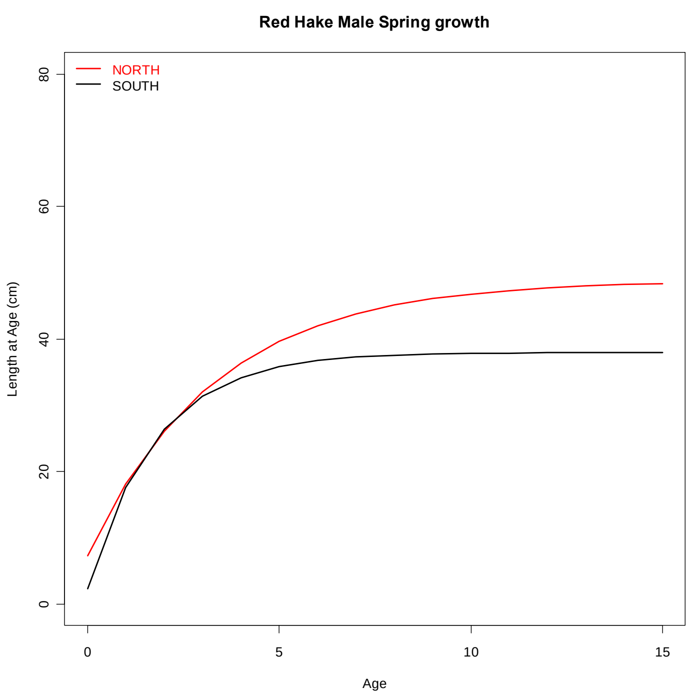
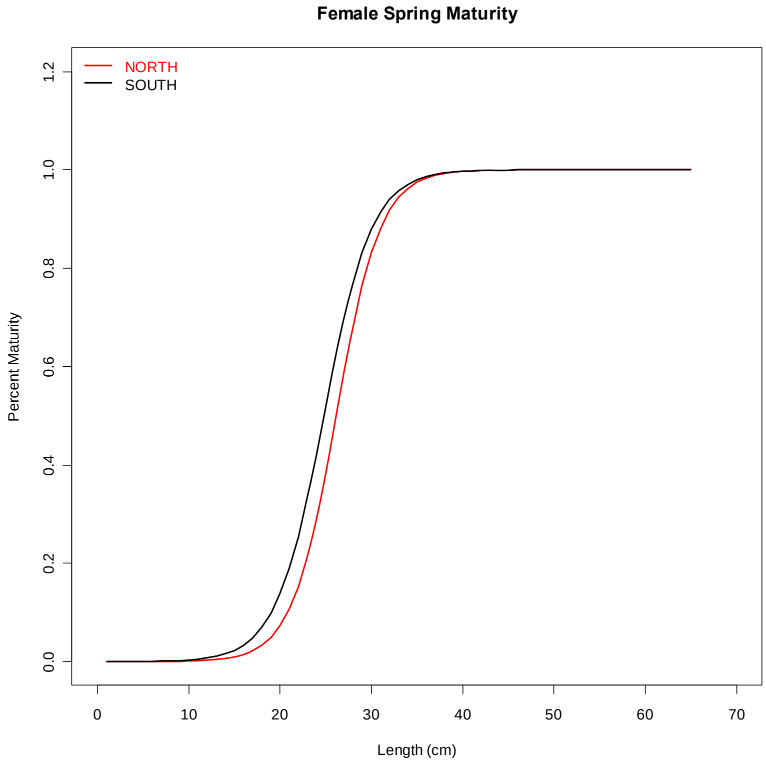


Figure C61a. Growth curves for male red hake by stock area.



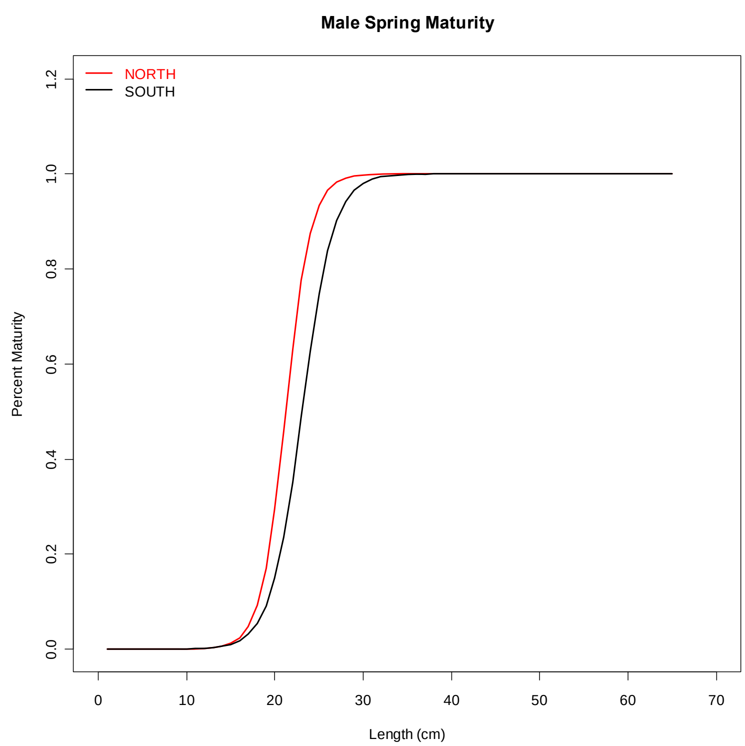


Figure C62. Maturity ogives for red hake by stock and sex.

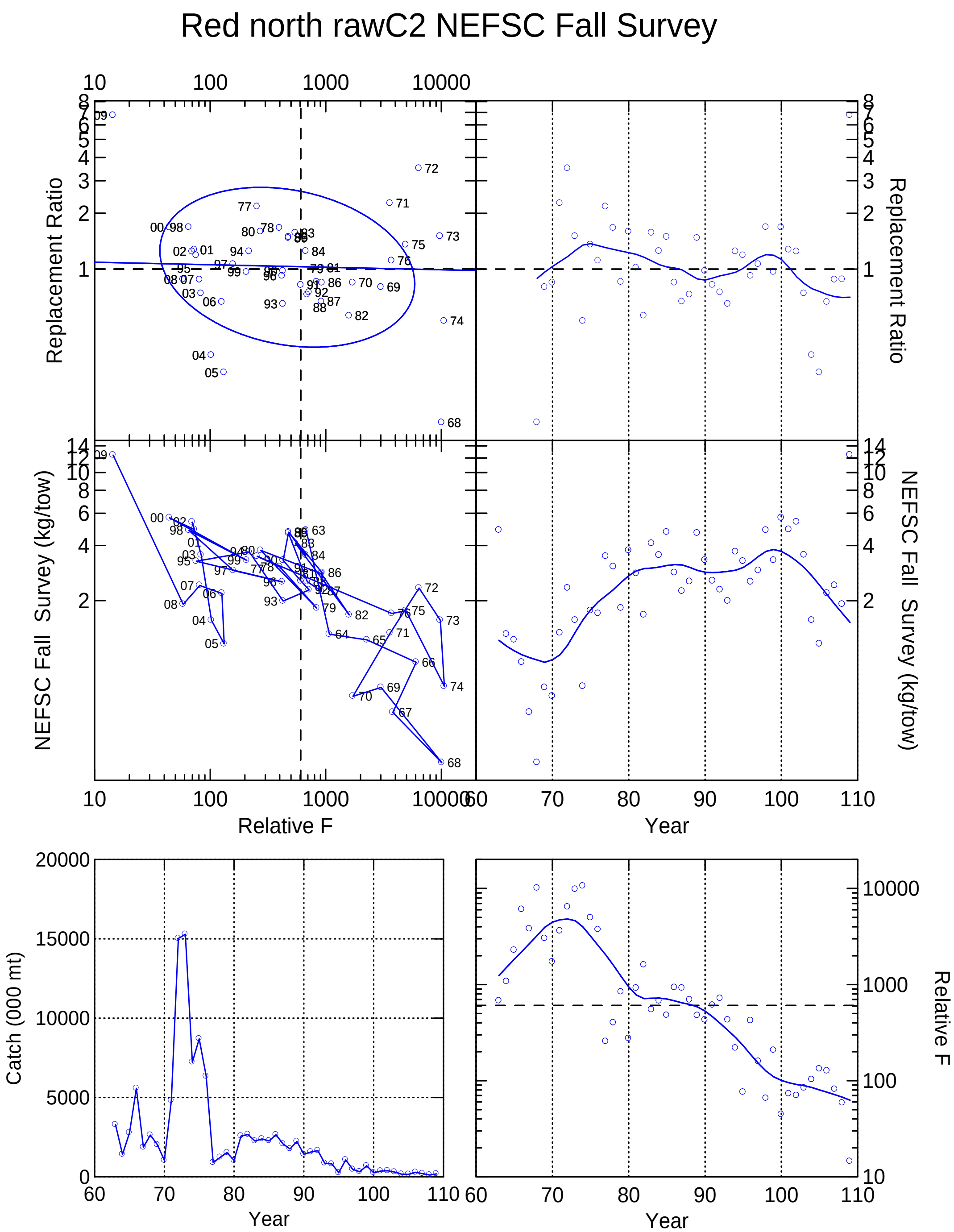


Figure C63. Six panel plot for northern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC fall survey index and landings based on catch method "raw C2". Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.

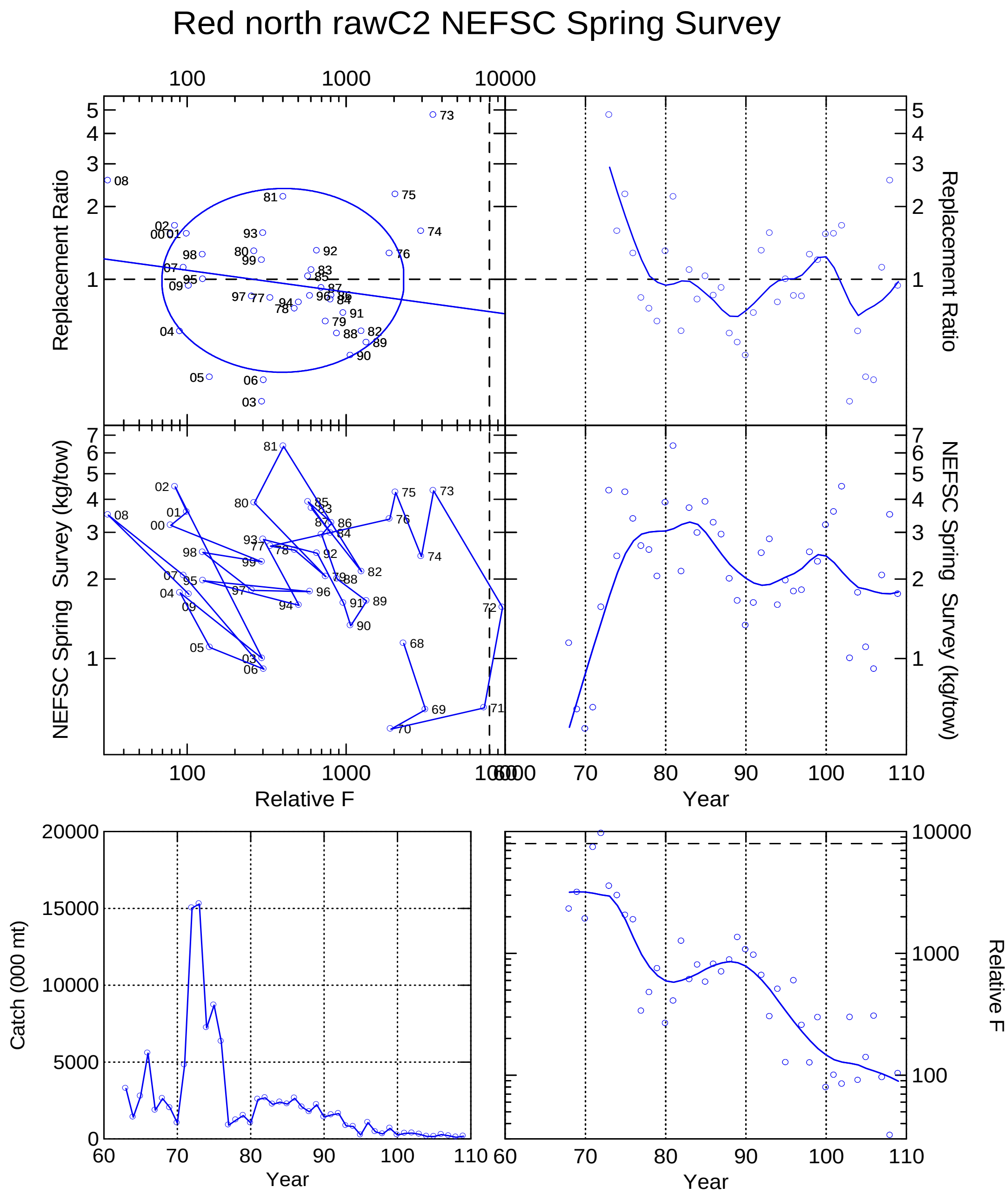
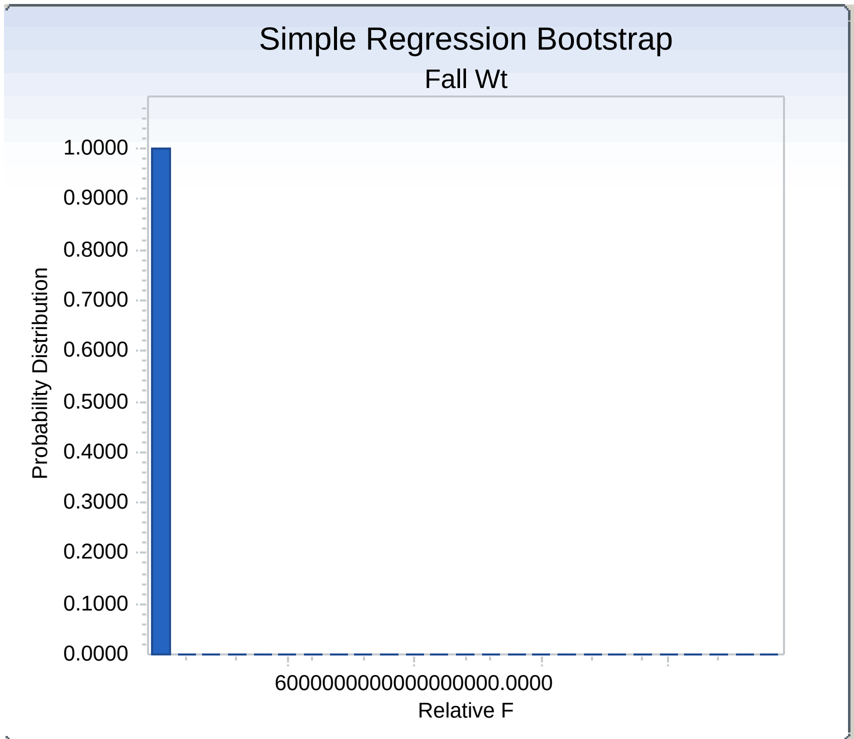


Figure C64. Six panel plot for northern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC spring survey index and landings based on catch method "raw C2". Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.



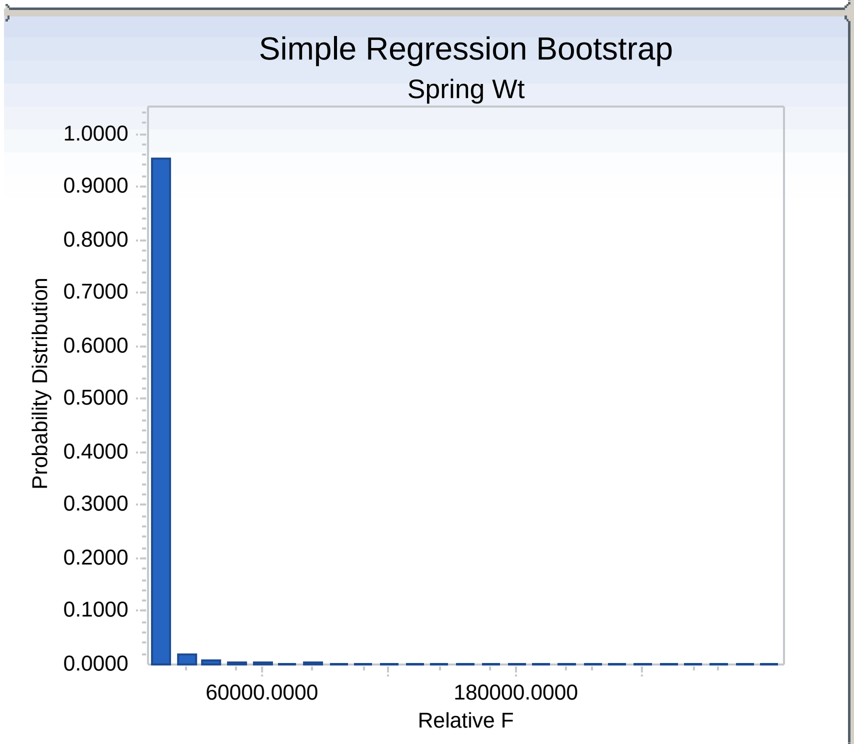


Figure C65.Randomization tests summary of sampling distribution of correlation coefficient between replacement ratio and relative F for fall (top) and spring (bottom) survey indices for northern red hake, using catch estimation method “raw C2”, 1963-2009.

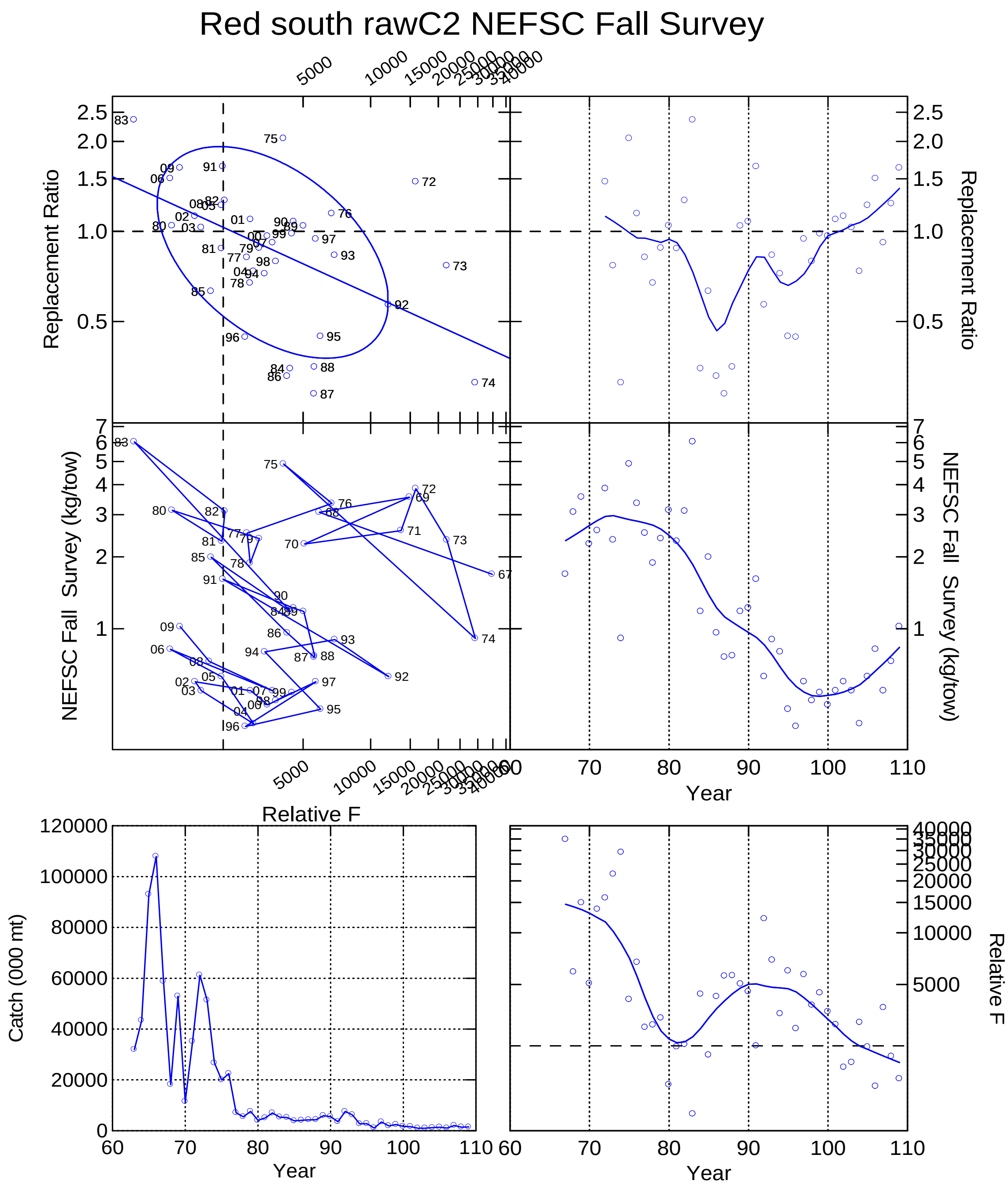


Figure C66. Six panel plot for southern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC fall survey index and landings based on catch method "raw C2". Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.

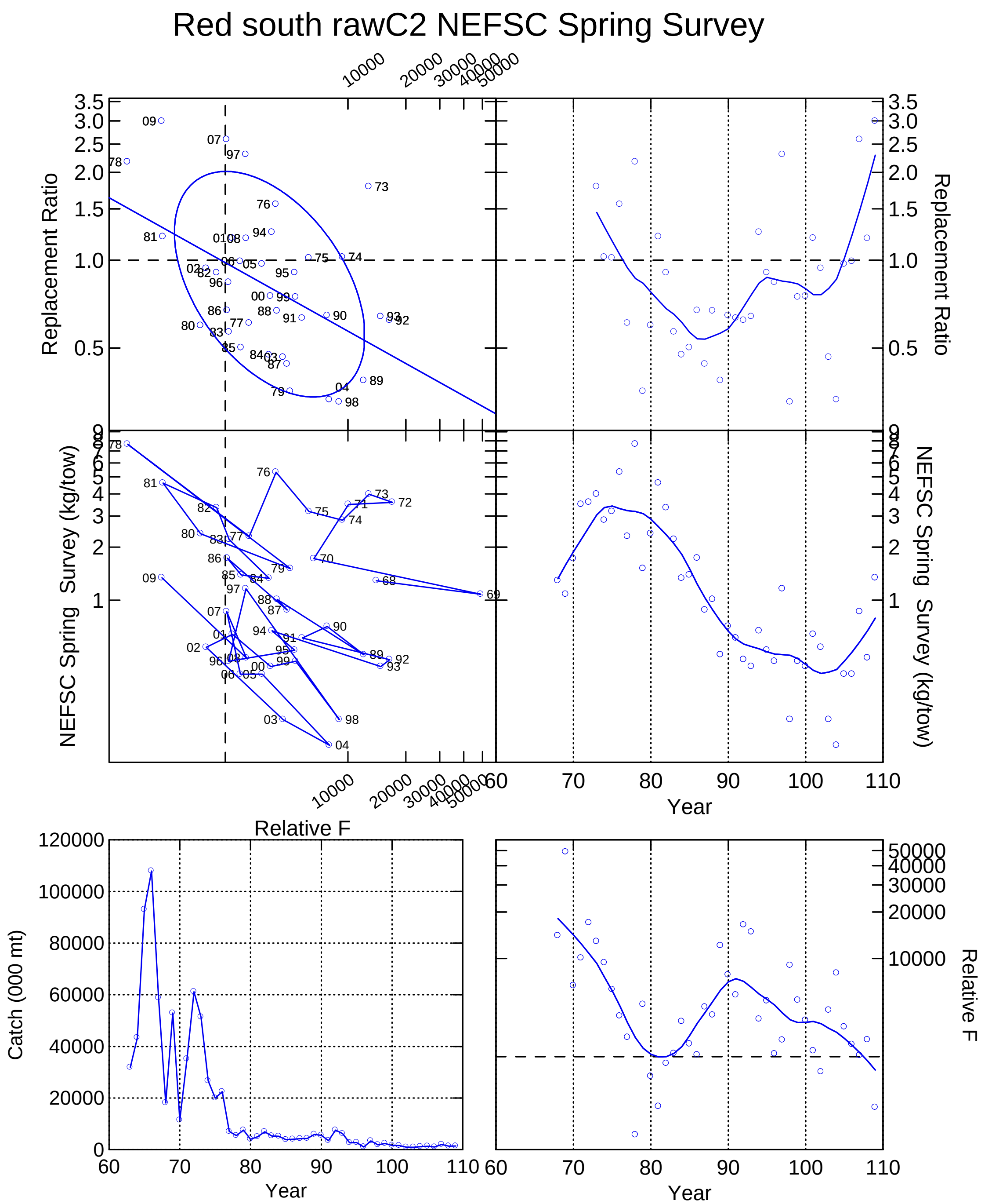
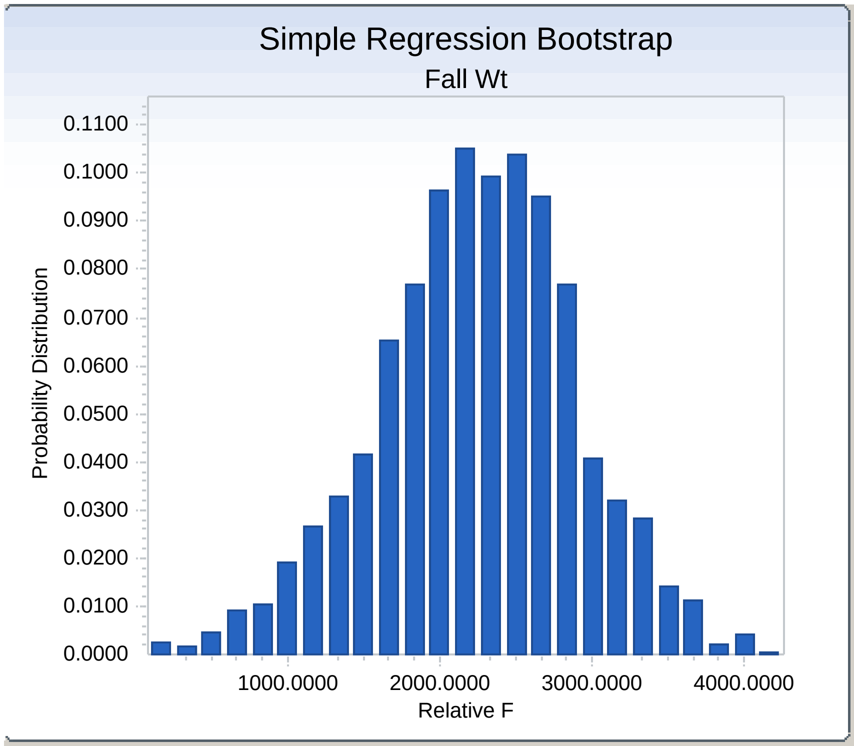


Figure C67. Six panel plot for southern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC spring survey index and landings based on catch method "raw C2". Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.



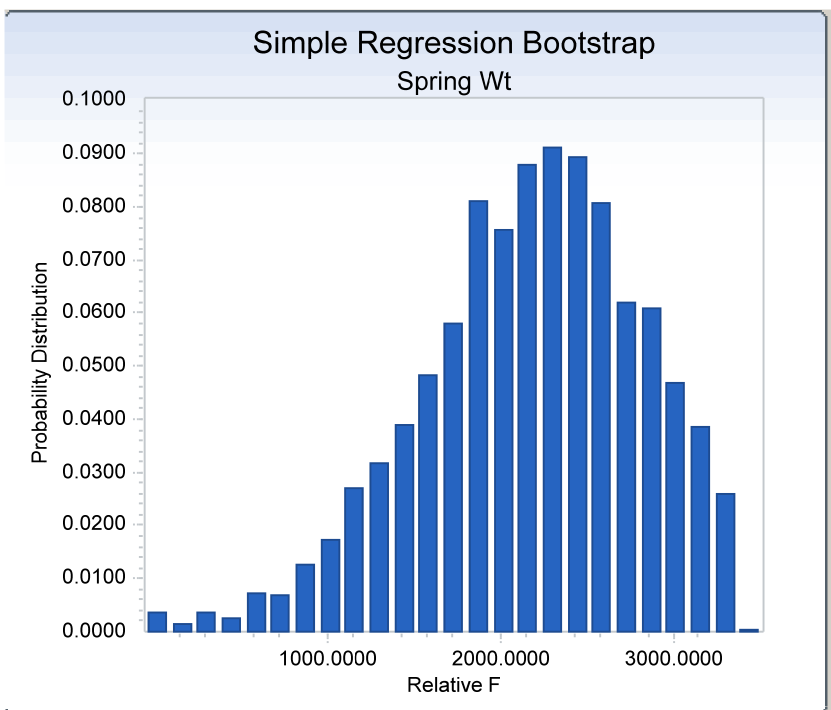


Figure C68. Randomization tests summary of sampling distribution of correlation coefficient between replacement ratio and relative F for fall (top) and spring (bottom) survey indices for southern red hake, using catch estimation method “raw C2”, 1963-2009.

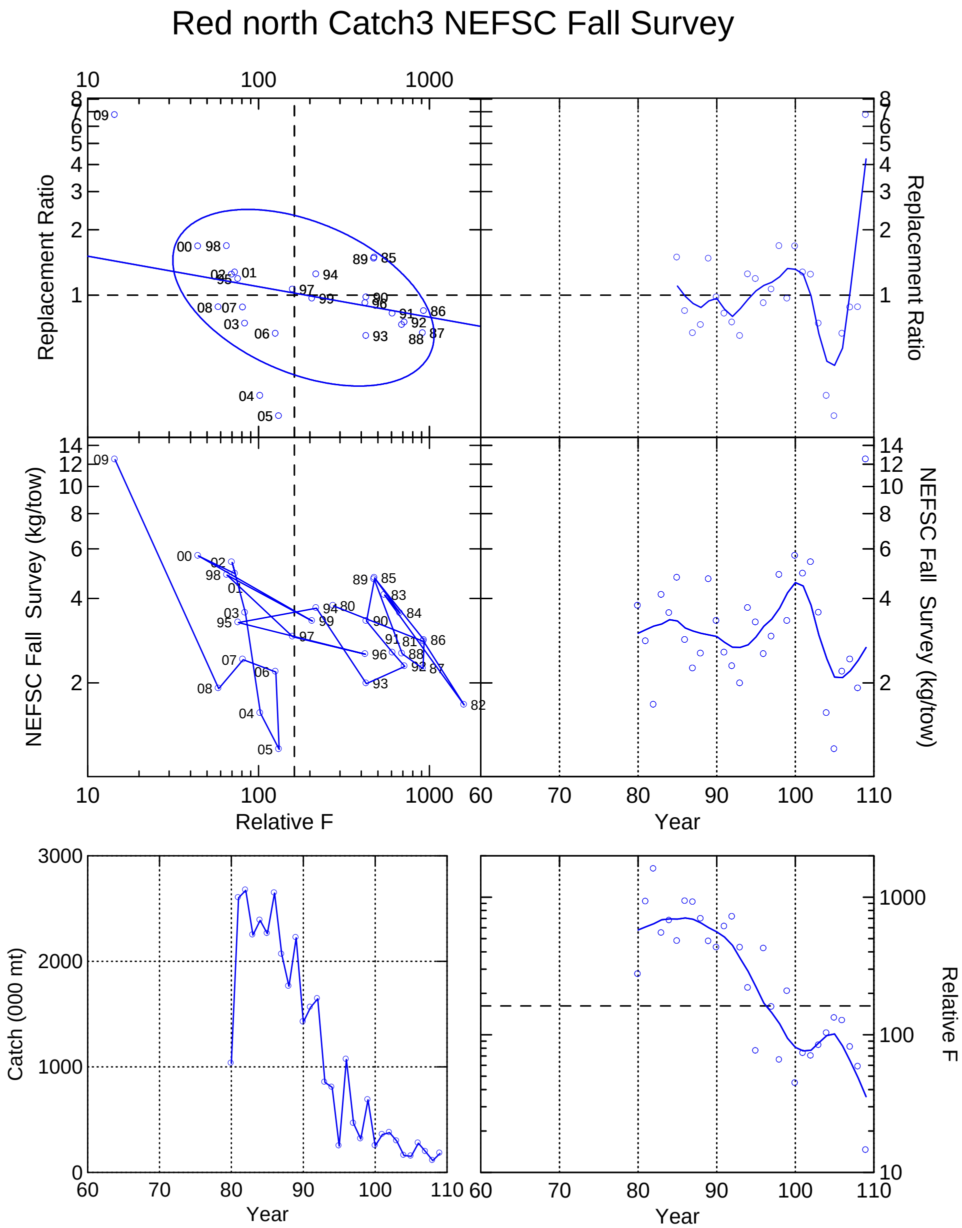


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Figure C69. Six panel plot for northern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC fall survey index and landings based on catch method "Catch 3", 1980-2009. Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.

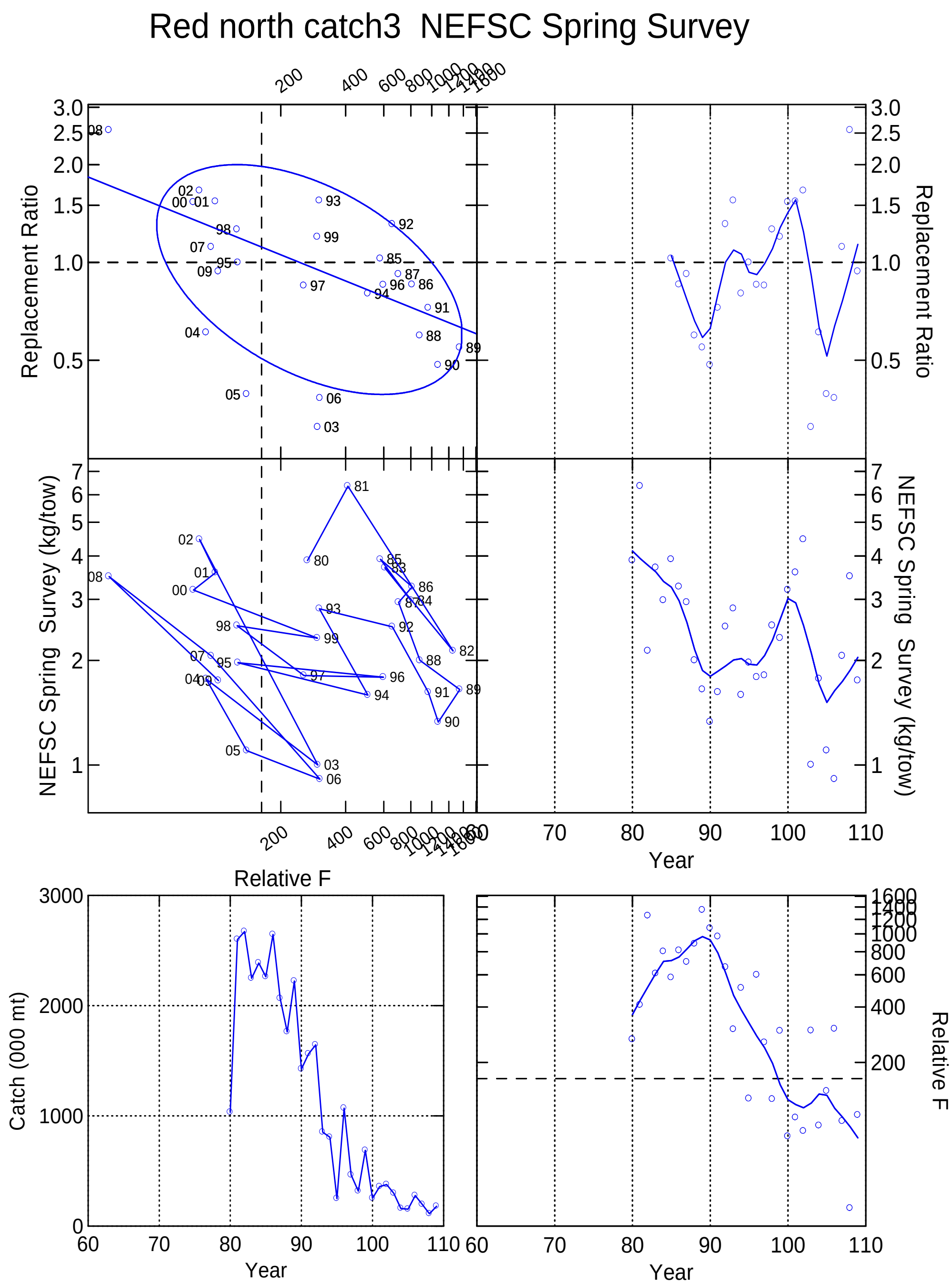
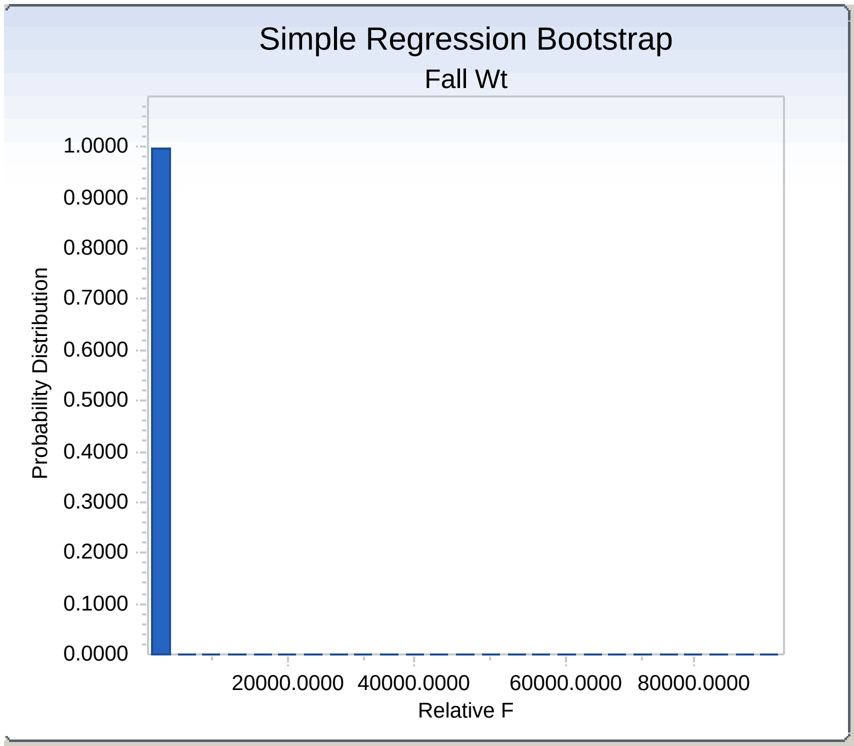


Figure C70. Six panel plot for northern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC springl survey index and landings based on catch method "Catch 3", 1980-2009. Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.



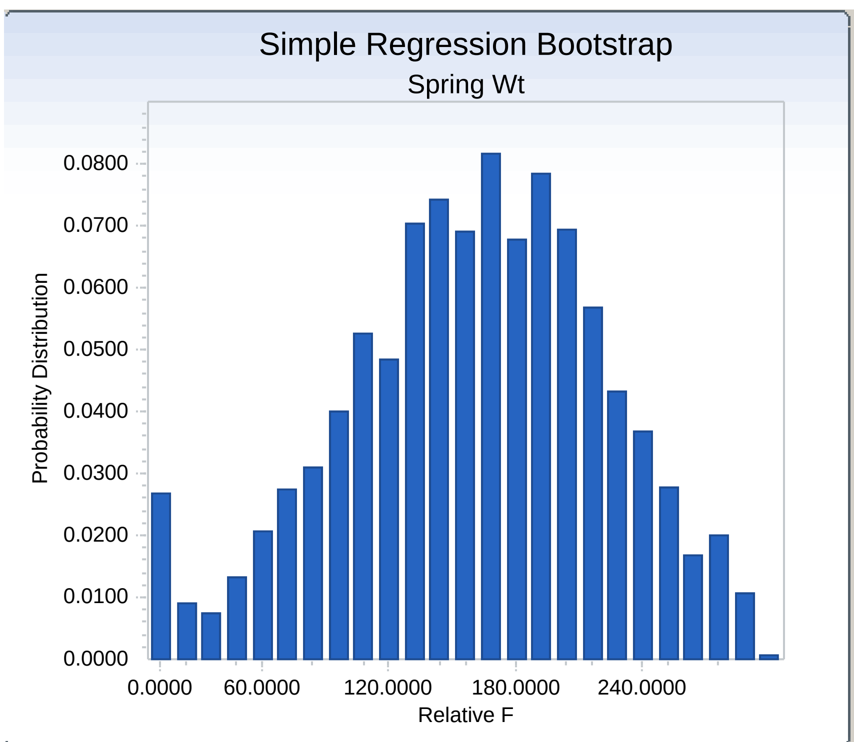


Figure C71. Randomization tests summary of sampling distribution of correlation coefficient between replacement ratio and relative F for fall (top) and spring (bottom) survey indices for northern red hake, using catch estimation method “Catch 3”, 1980-2009.

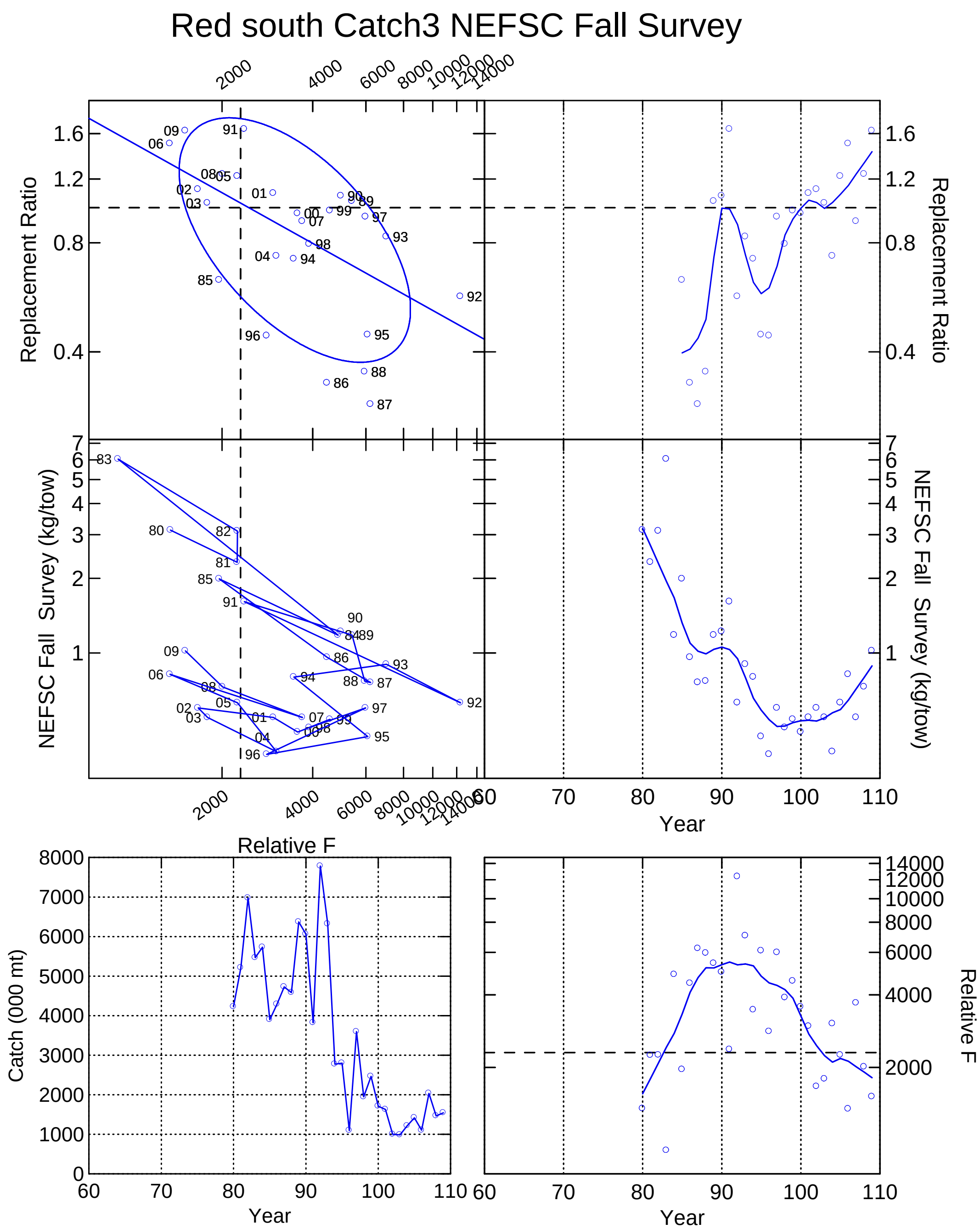


Figure C72. Six panel plot for southern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC fall survey index and landings based on catch method "Catch 3", 1980-2009. Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.

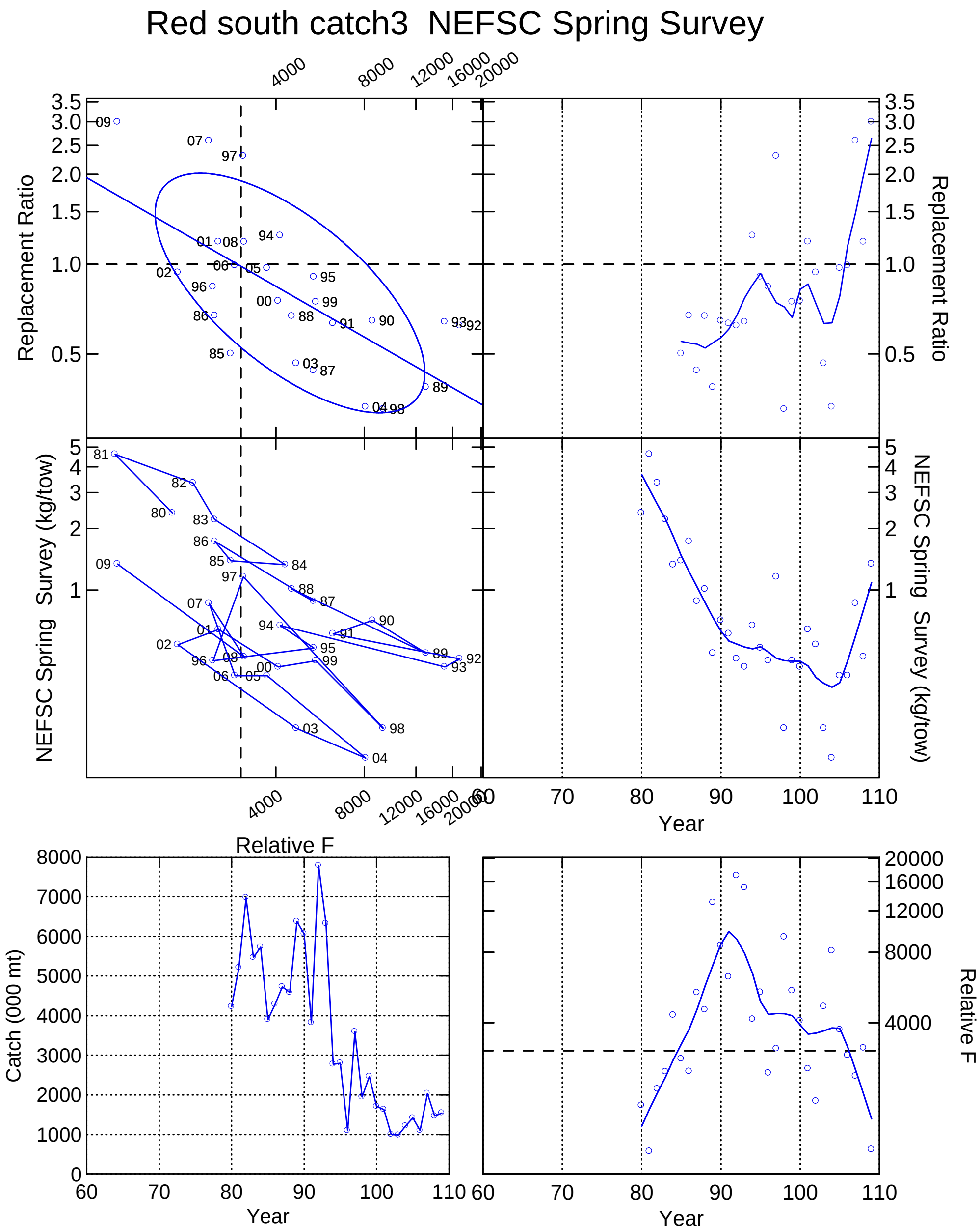
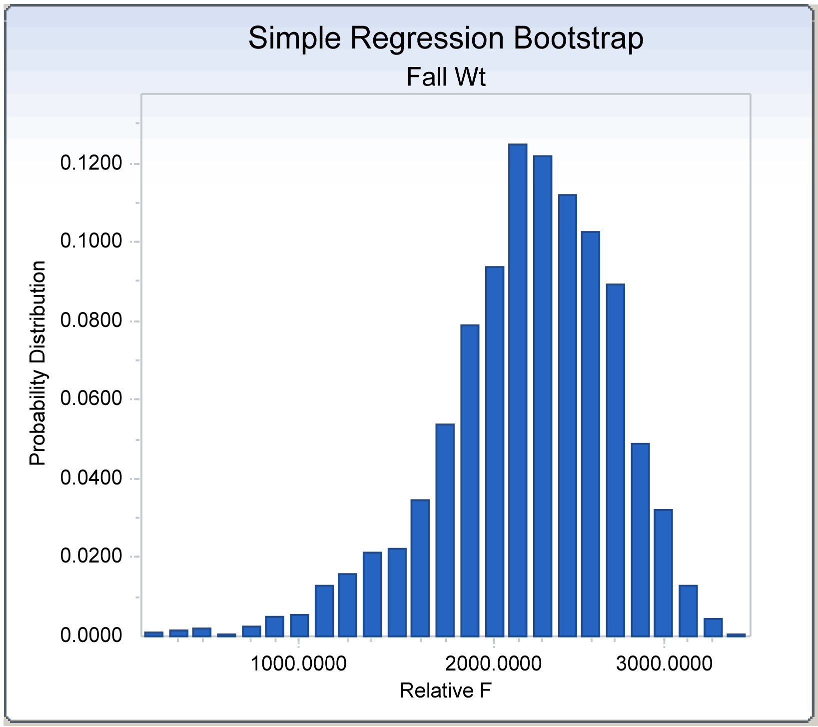


Figure C73. Six panel plot for southern red hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC spring survey index and landings based on catch method “Catch 3”, 1980-2009. Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.



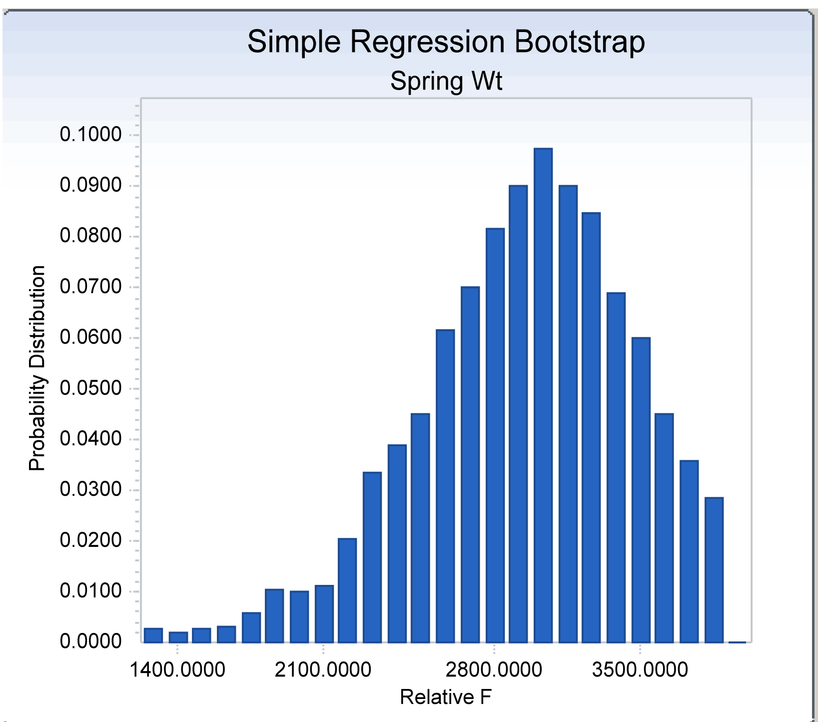


Figure C74. Randomization tests summary of sampling distribution of correlation coefficient between replacement ratio and relative F for fall (top) and spring (bottom) survey indices for southern red hake, using catch estimation method "Catch 3", 1980-2009.

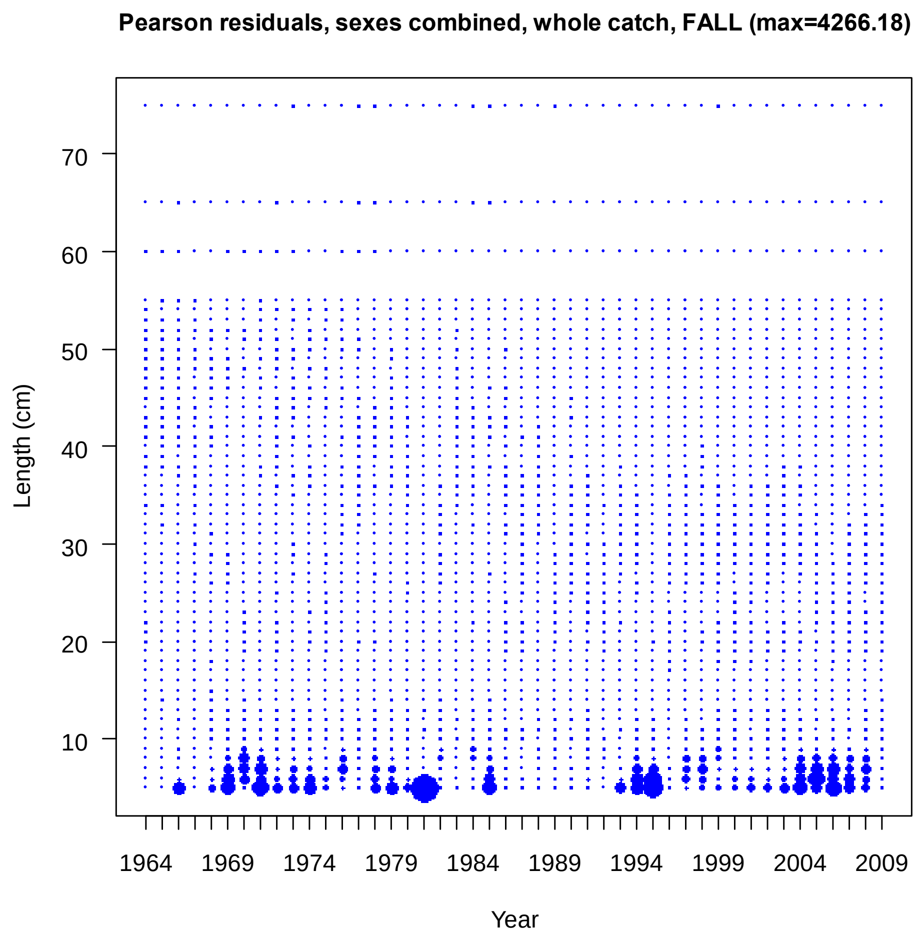


Figure C75. Residuals from SS3 run with the entire length composition for the fall survey.

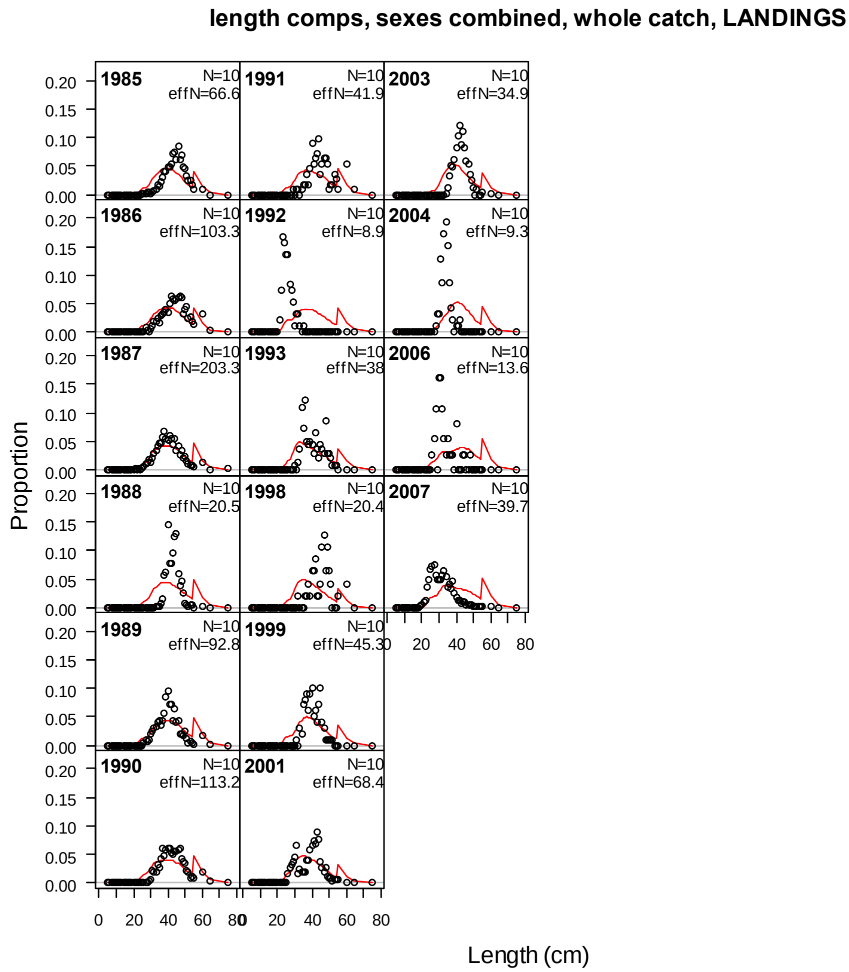


Figure C76. Fits to the length composition of the commercial landings with data pooled above 55 cm.

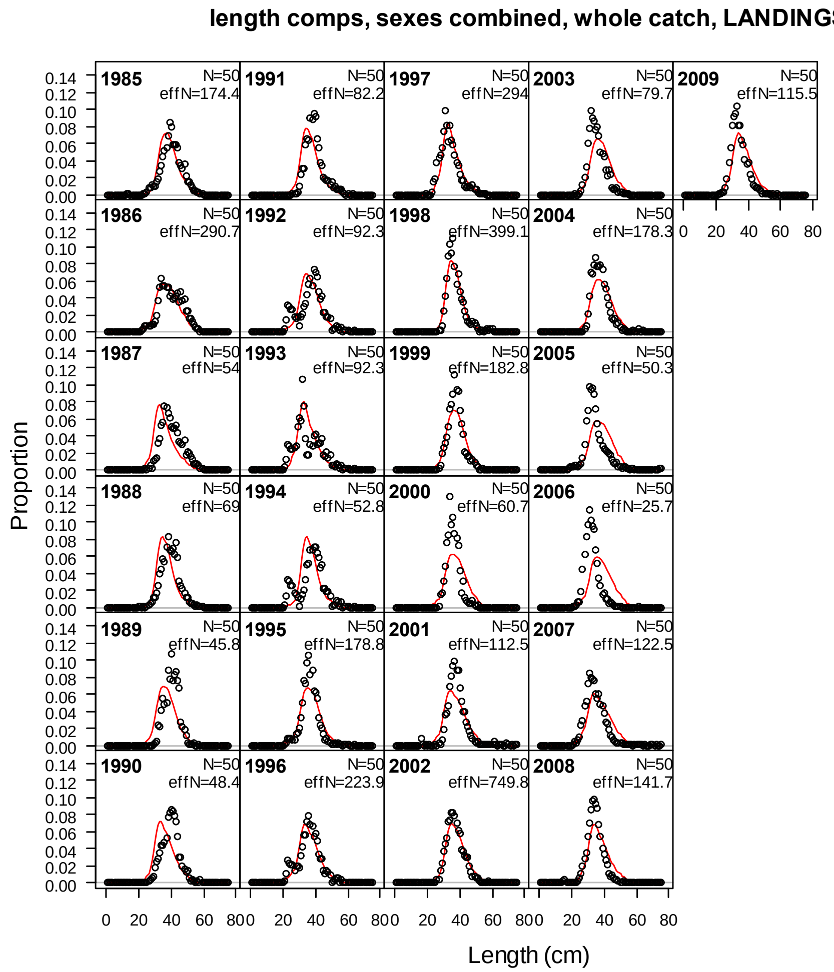


Figure C77. Fits to the length composition of the commercial landings data unpooled.

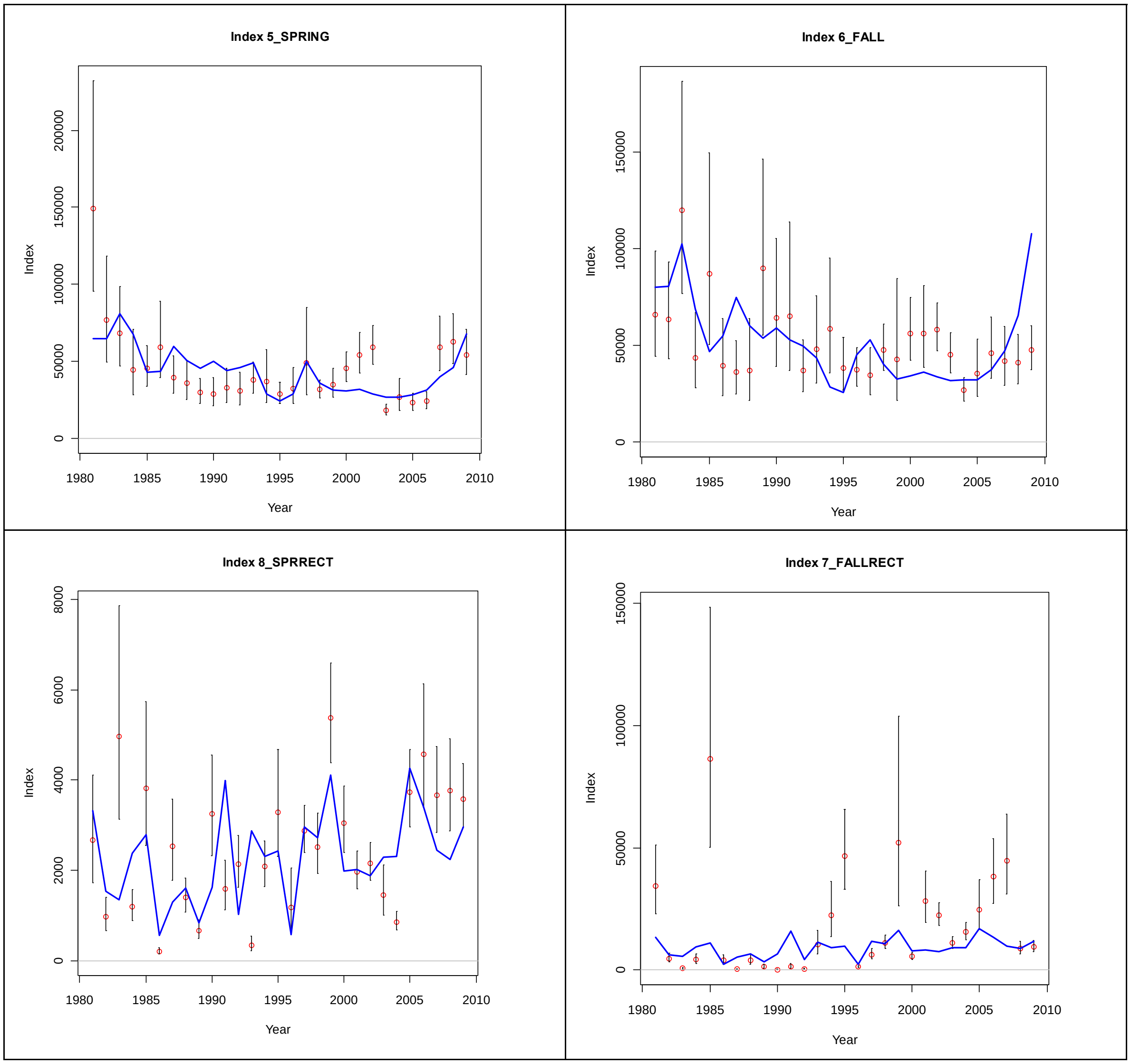


Figure C78. Fits to the survey indices from a final model run.

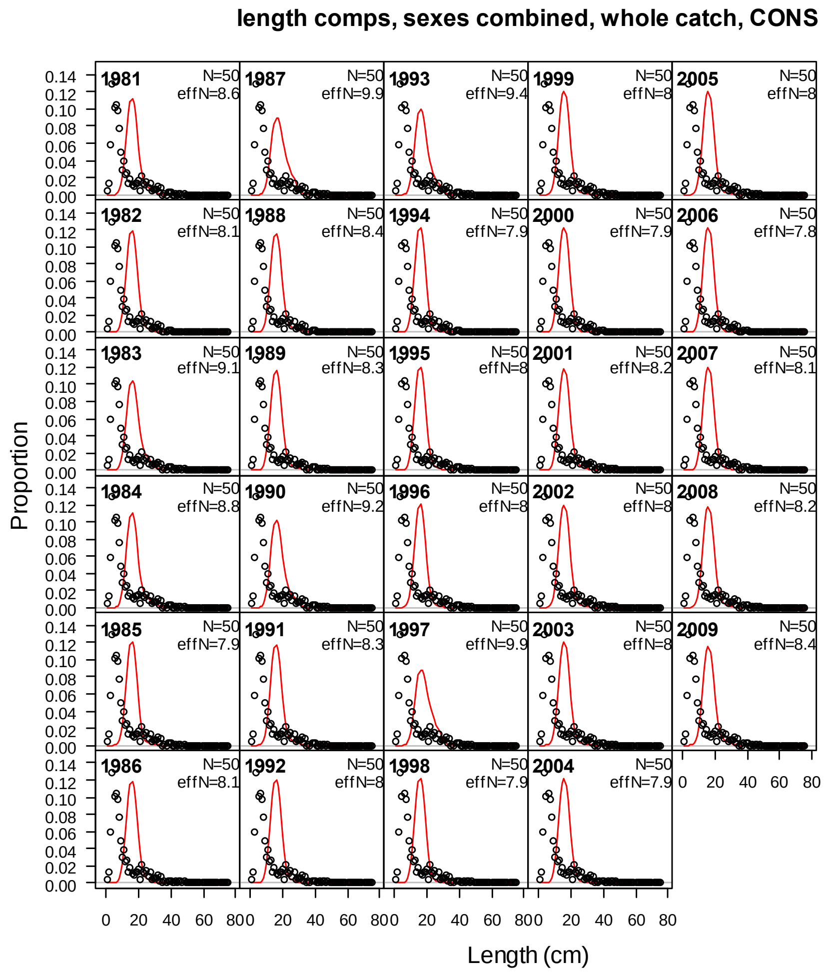
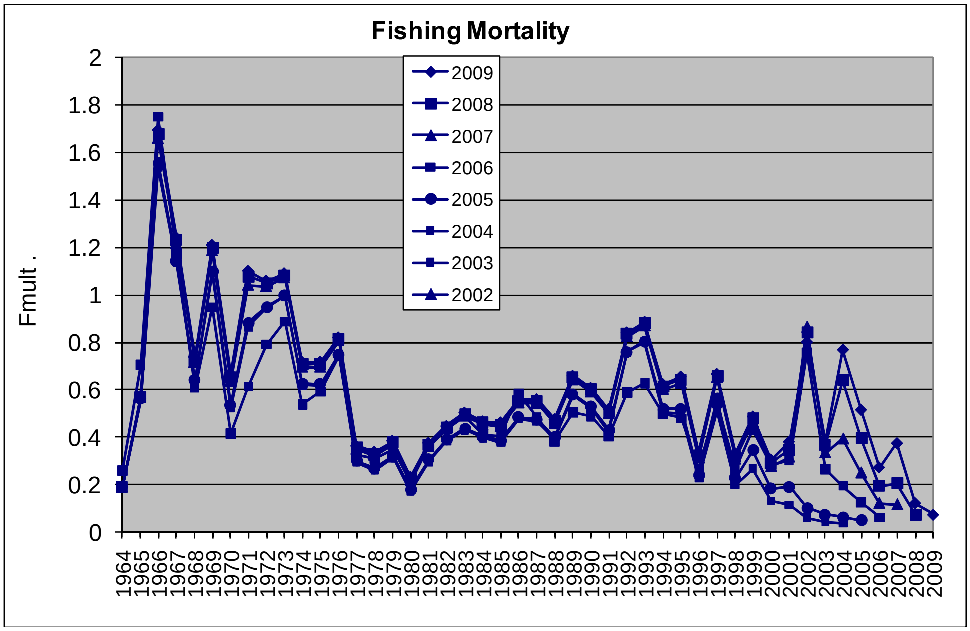


Figure C79. Fits to the length composition of the consumption.



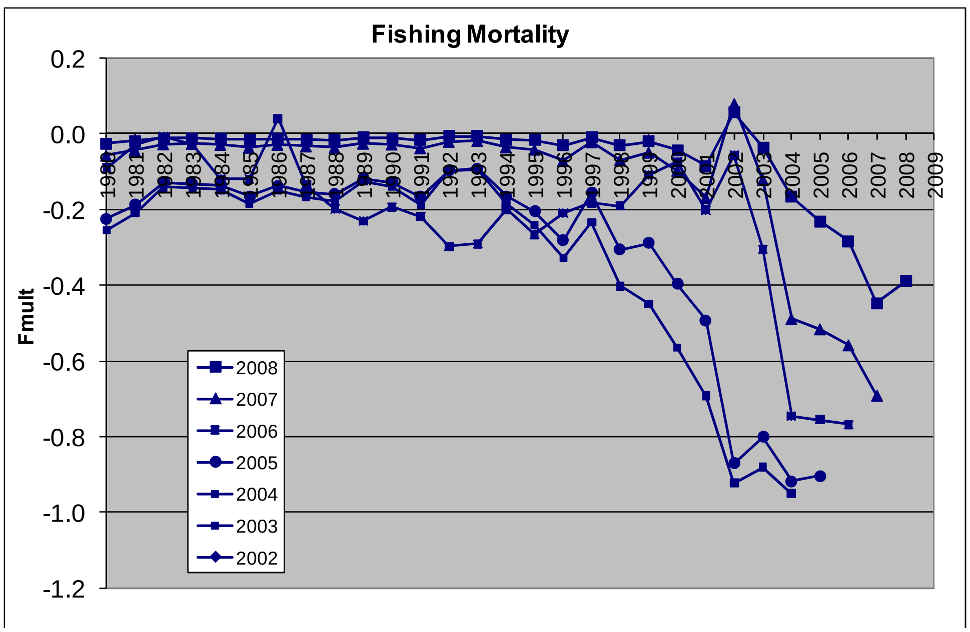
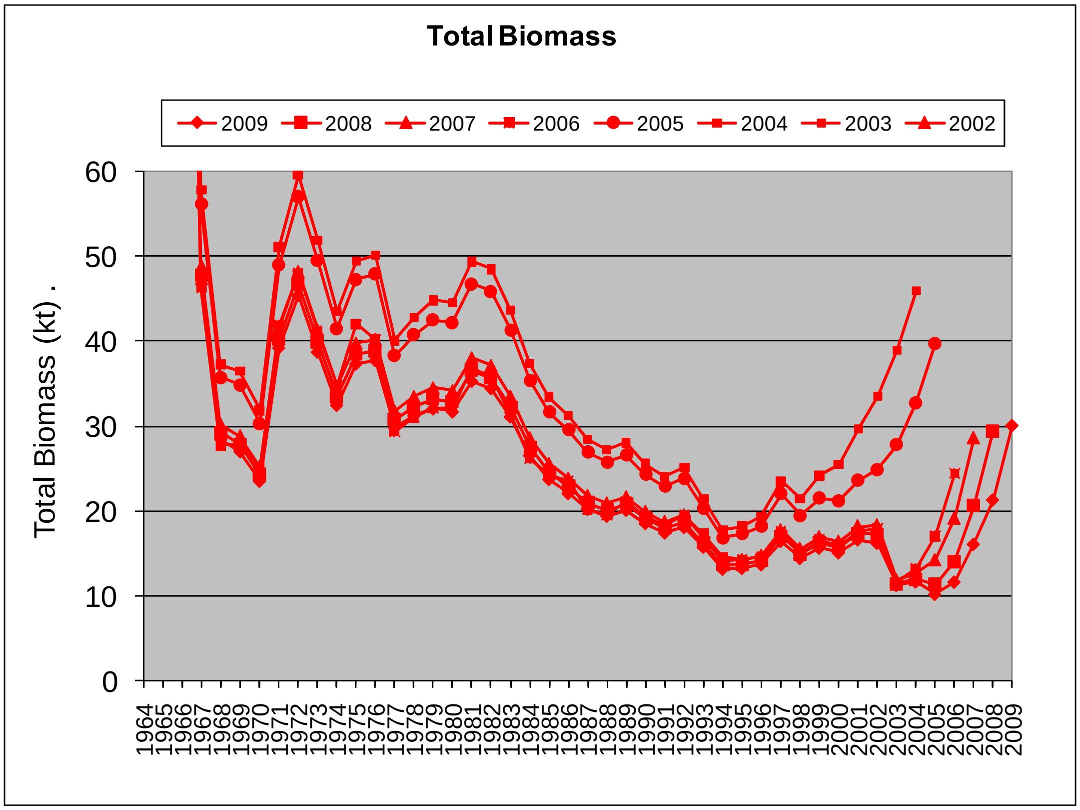


Figure C80a. Fishing mortality retrospective pattern of final SCALE model run.



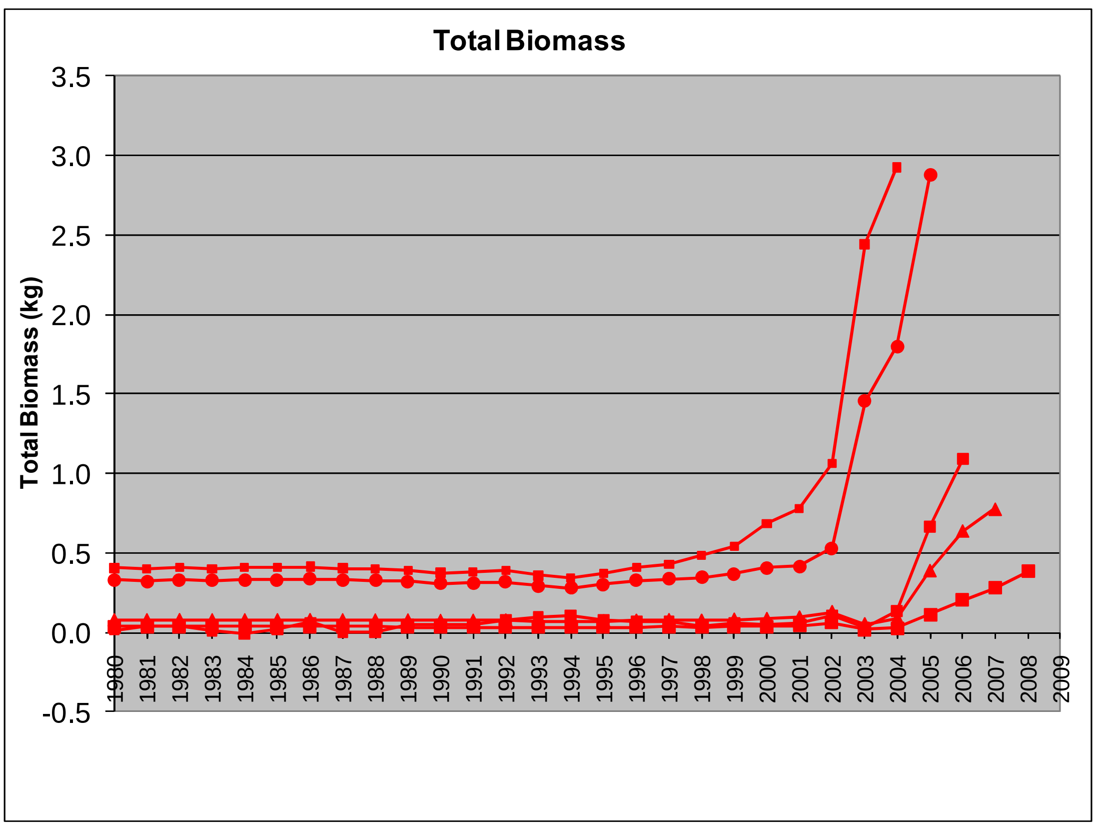
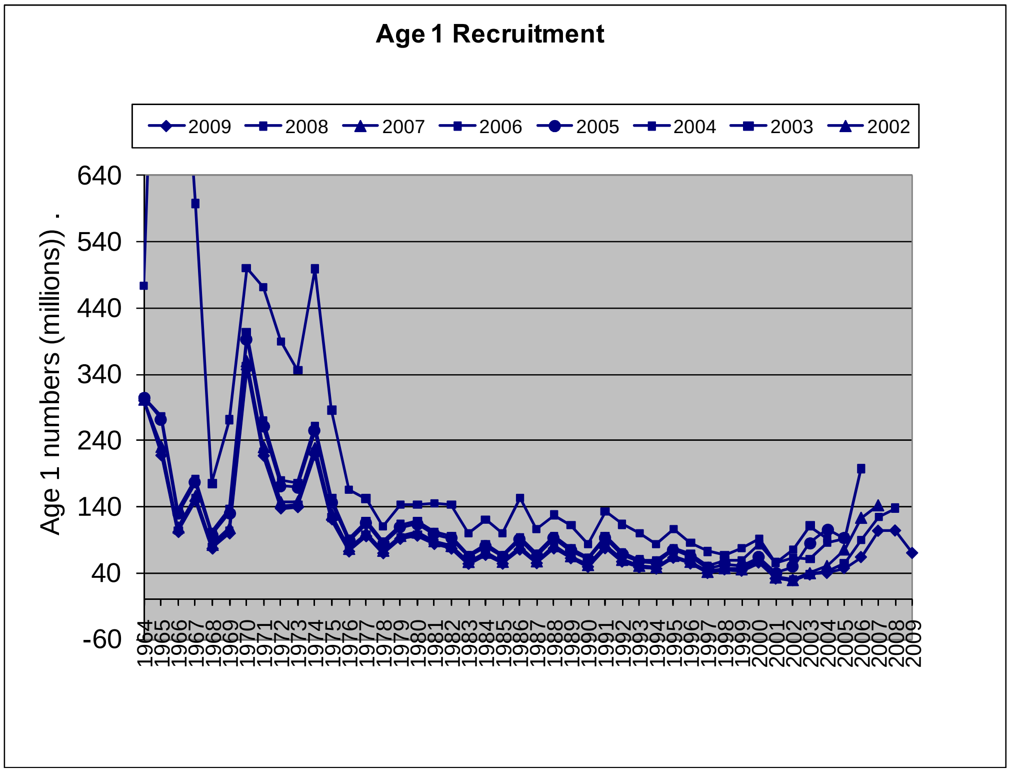


Figure C80b. Total biomass retrospective pattern of final SCALE model run.



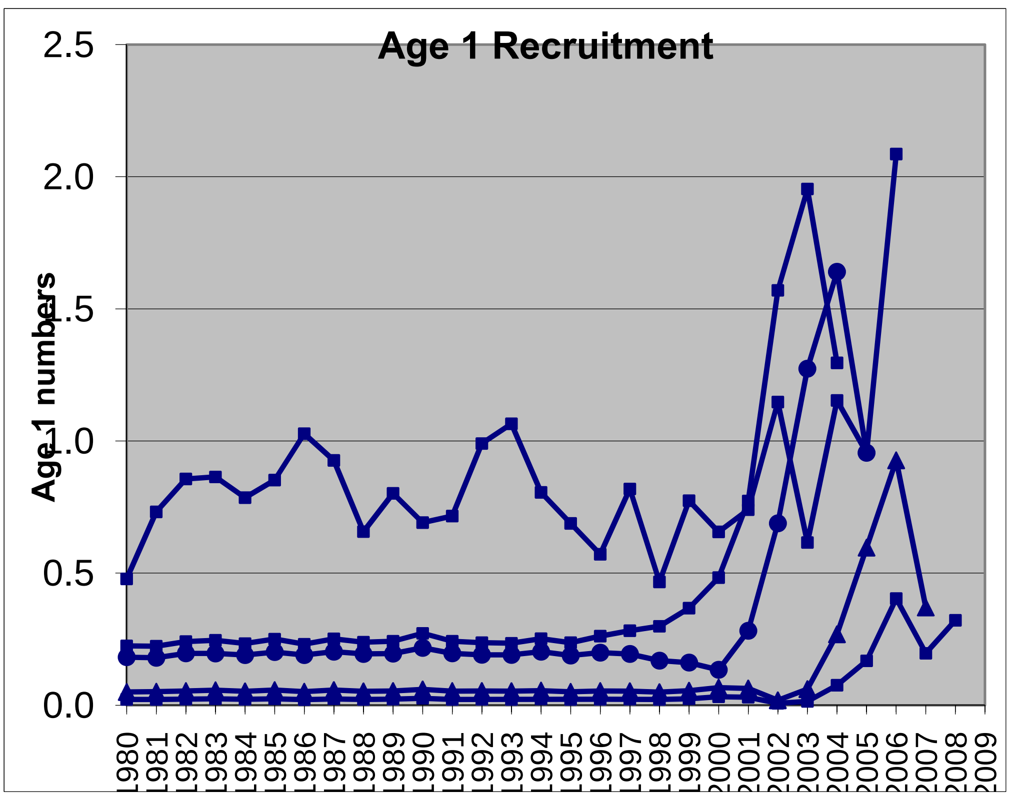


Figure C80c. Recruitment retrospective pattern of final SCALE model run.

Northern Red Hake (delta)

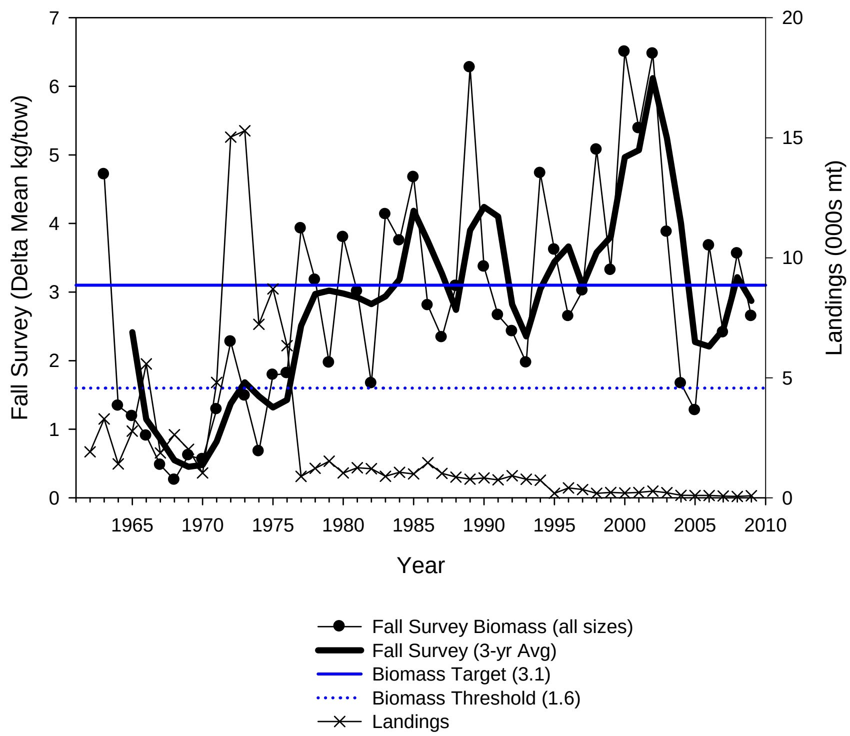


Figure C81. Fall survey biomass (delta transformation) and current BRPs (as opposed to "proposed" BRPs) for the northern stock of red hake.

Northern Red Hake (delta)

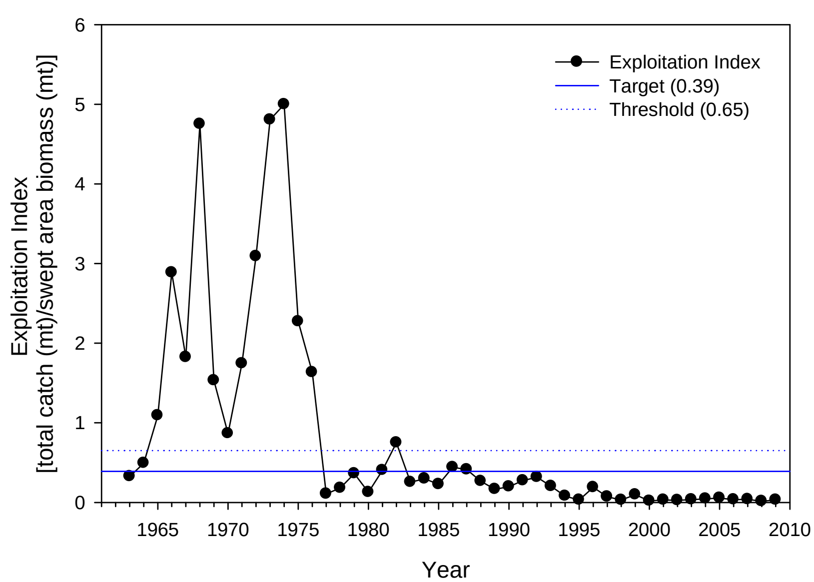


Figure C82. Exploitation Indices (delta transformation of fall survey) and current BRPs BRPs (as opposed to "proposed" BRPs) for the northern stock of red hake.

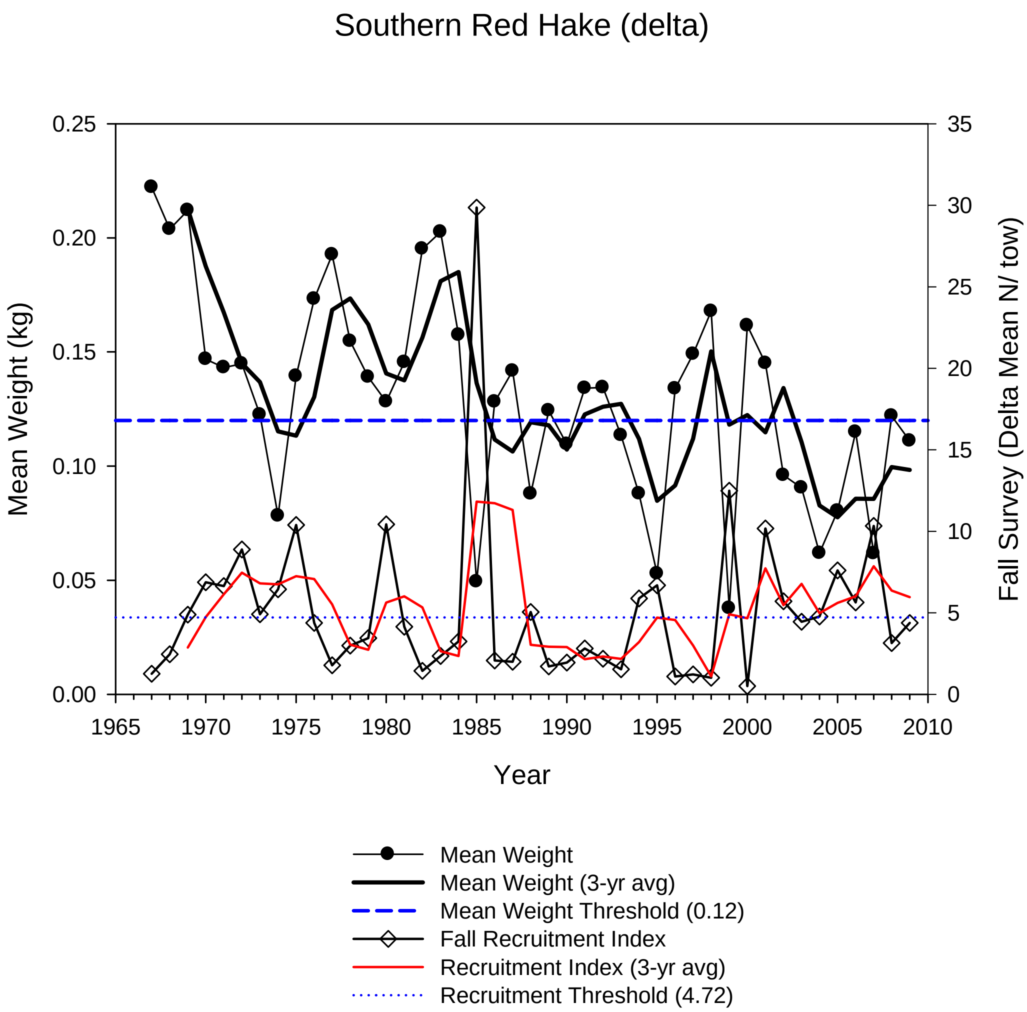


Figure C83. Mean individual weight (kg)/tow and recruitment index (Number of fish <25cm) from the NEFSC fall survey for the southern stock of red hake. Also shown are current BRP thresholds.

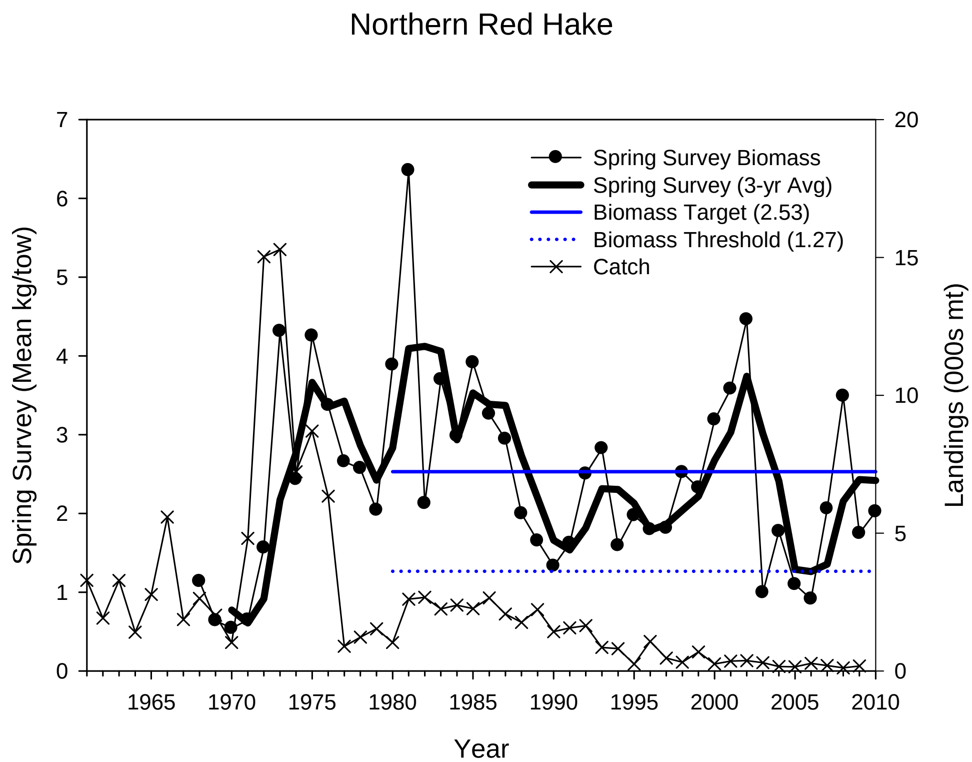


Figure C84. Spring survey biomass and newly proposed BRPs for the northern stock of red hake.

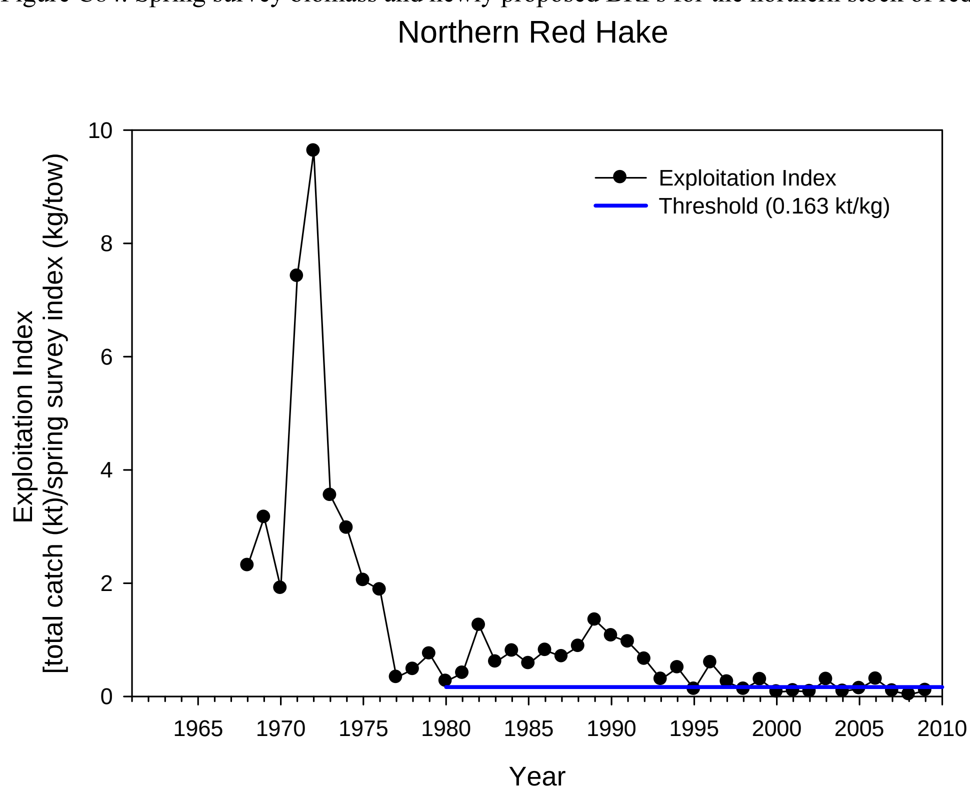


Figure C85. Exploitation indices (spring survey) and newly proposed overfishing threshold for the northern stock of red hake.

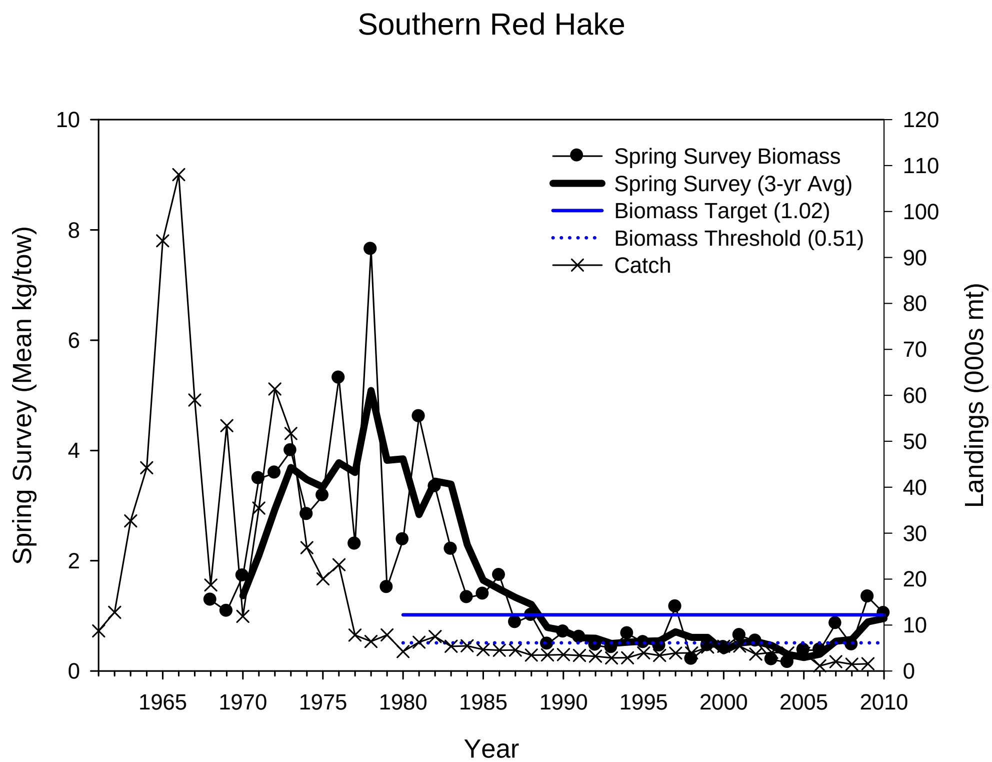
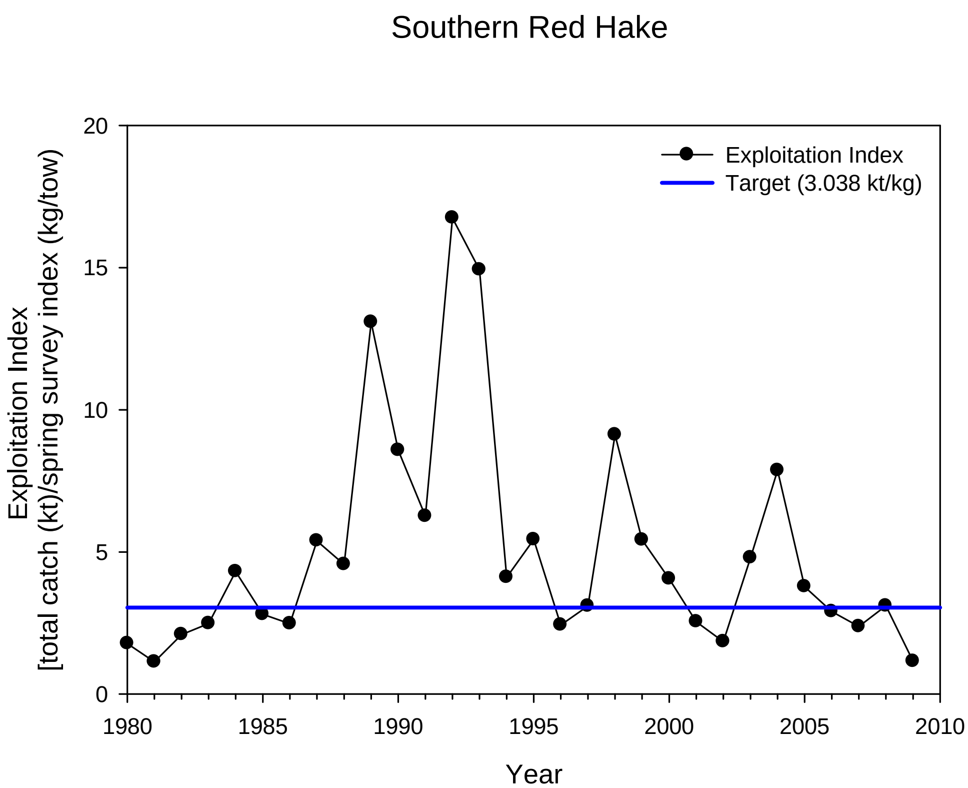


Figure C86. Spring survey biomass and newly proposed BRPs for the southern stock of red hake.



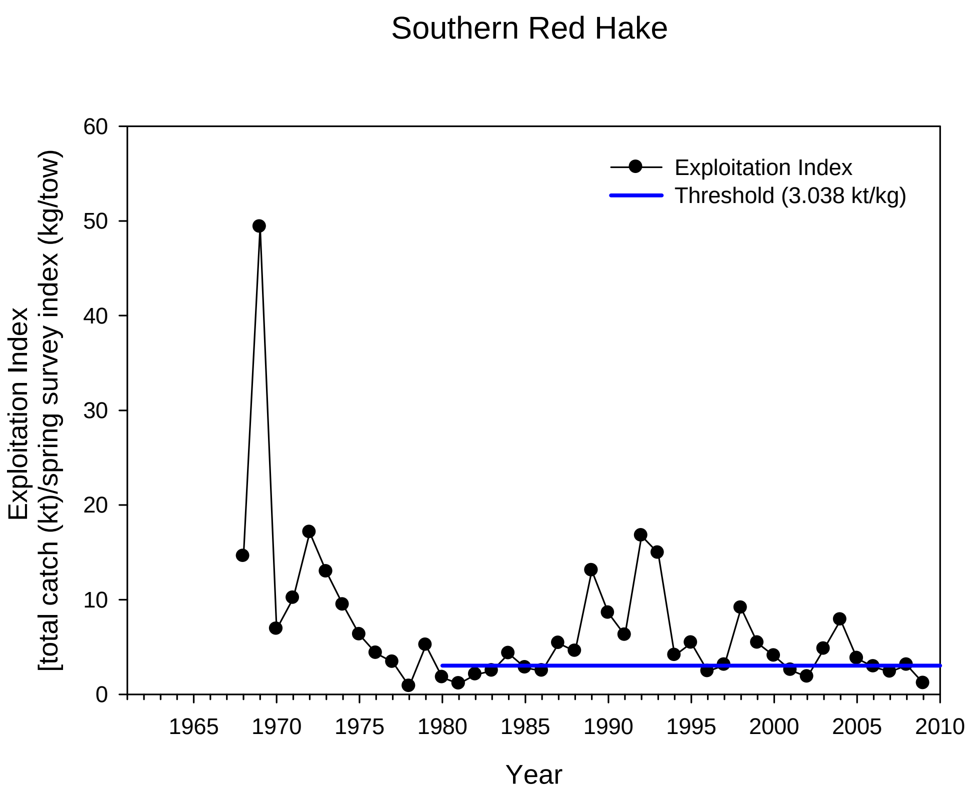


Figure C87. Exploitation indices (spring survey) and newly proposed overfishing threshold for the southern stock of red hake.

D. OFFSHORE HAKE STOCK ASSESSMENT FOR 2010

[SAW-51 Editor's Note: The SARC-51 Review Panel concluded that sufficient information is not available to determine offshore hake stock status with confidence, because fishery data are insufficient and one cannot assume that survey data reflect stock trends. The Panel concluded that it is not possible at this time to provide a reliable definition for overfished and overfishing for this stock. SEINE and AIM modeling is included in this report to show what the Working Group provided to the SARC-51 for peer review.]

Terms of Reference

1. Use models to estimate the commercial catch. Describe the uncertainty in these sources of data.
2. Characterize the survey data that are being used in the assessment (e.g., regional indices of abundance, recruitment, age-length data, etc.). Describe the uncertainty in these sources of data.
3. Estimate measures of annual fishing mortality, recruitment and stock biomass for the time series, and characterize the uncertainty of those estimates.
4. State the current definitions for overfished and overfishing. Then update or redefine biological reference points (BRPs; estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and F_{MSY}; and estimates of their uncertainty). Comment on the scientific adequacy of existing and redefined BRPs.
5. Evaluate stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from Offshore hake TOR 4).
6. If a model can be developed, conduct single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).
    1. Provide numerical short-term projections (3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment.
    2. Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.
    3. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.
7. Propose new research recommendations.

Executive Summary

Offshore hake (*Merluccius albidus*) is a data-poor stock and very little is known about its biology and life history. They are commonly distributed from southern Georges Bank through the Mid-Atlantic Bight, at depths of 160-550 meters and temperatures ranging between 11-13°C.

They are known to co-occur with silver hake (*Merluccius bilineris*) in the outer continental slopes of the Atlantic Ocean and are easily confused with silver hake because of their strong morphological resemblances.

The primary sources of biological information for offshore hake are based on the annual fishery independent surveys conducted by the Northeast Fisheries Science Center (NEFSC). The NEFSC have conducted both spring and fall bottom trawl surveys off the US continental shelf annually since 1963. The surveys extend from the Gulf of Maine to Cape Hatteras, in offshore waters at depths 27-365 meters, and have been conducted in the fall since 1963 and in the spring since 1968. The winter bottom trawl survey began in 1992 and was specifically designed for flatfish, however, the deeper survey strata were not sampled until 1998. The winter trawl survey does not cover the Georges Bank area because the survey was designed specifically for flatfish in the southern region.

Survey catches are highly variable but the trends in the spring and fall are similar. The higher catchability in the winter survey can be explained by the net configuration (i.e smaller cookies) specifically designed to target flatfish.

Offshore hake are located primarily on the continental shelf and presumably beyond the NEFSC survey area. Offshore hake tend to be concentrated in the southern Georges Bank region in the fall, whereas in the spring, they are found further south in the Mid-Atlantic Bight. They also appear to be more abundant during the winter months at temperatures ranging between 11-13 °C and in deeper waters.

Offshore hake appear to be sexually dimorphic with females slightly larger than males. Females mature at a larger length than males, similar to other gadoid species (O'Brien et al 1993). Length at 50% maturity (L_{50}) also differed significantly between sexes with females maturing at larger sizes (28cm) relative to males (23cm). More fish are found in the developing stage in April than in the other months sampled. There is also more frequency in resting stage in the fall than in the spring, which would also indicate that spawning occurs in the late spring and summer months (Traver et al., in review). We do not have a summer survey to verify these results.

Offshore hake is a trawl based fishery and primarily a bycatch fishery for silver hake, with 95% being caught by otter trawl. They are being caught in deep waters, where they are potentially being mixed with and reported as silver hake. Landings data are a major source of uncertainty for this stock, due to mixed reported landings with silver hake and landings were not reported until 1991. Even those that are reported may not be correctly identified (Garcia-Vazquez et al., 2009), therefore fishing mortality rates remain unknown. Two models were used to estimate the proportion of offshore hake landed as silver hake, a length-based and a depth-based model. The two models give similar estimates that are both much higher than the nominal landings. The data used in the assessment include survey indices from the NEFSC fall survey, landings estimated using two models, and discards estimated using a single model. The length-based model used the catch-at-length for silver hake and used the proportion of offshore hake at length from the survey to apportion catch. The depth-based model used VMS data and depth-based logistic functions from the survey to apportion landings. Two assessment models were attempted, An Index Method (AIM) and Survival Estimation in Non-Equilibrium Situations Model (SEINE). Neither model was considered adequate for management.

The survey data may not be a good index of abundance, and the values may be driven more by environmental changes or fish migrations. The survey likely does not cover the entire stock area and therefore, the survey estimates could potentially be under-representing the population. It also appears that the fishery as estimated by either the length-based model or the depth-based model has not had an impact on the stock. The mortality estimates from the SEINE model are in direct contrast to the catch data. Developing ACLs will be challenging given that the landings are not separated to a great extent. Garcia-Vazquez et al (2009) found 12% of hake sold in Spain as silver hake were actually offshore hake. No alternative reference points are recommended and the existing BRPs should also not be accepted.

Hake Working Group Meetings

Three meetings were held in preparation of the 2010 silver hake assessment.

1. Hake fishermen's/stakeholder's meeting – August 6, 2010 – UMASS School of Marine Science and Technology (SMAST), Fairhaven, MA. Participants include fishermen Dan Farnham and Bill Phoel. Also in attendance were David Goethel (Oversight Committee chair), Andrew Applegate (staff) Steve Cadrin (SSC and WG chair, SMAST), Pingguo He, Klondike Jonas, Yuying Zhang, Tony Wood, and Daniel Goethel (SMAST), Loretta O'Brien, Michele Traver, Kathy Sosebee and Larry Alade (NEFSC), and Dick Allen (advisor at large).

2. Data Meeting – September 7-10, 2010, NEFSC Woods Hole MA. Participants included Steve Cadrin (WG Chair), Assessment leads (Larry Alade, Kathy Sosebee , Michele Traver), Rapporteurs (Jessica Blaylock and Julie Nieland), Mark Showell (DFO), Andy Applegate (NEFMC Staff), NEFSC (Loretta O'Brien, Mark Terceiro, Chris Legault, Tim Miller, Dave Richardson, Ayeisha Brinson, Jiashen Tang, Janet Nye, Mike Palmer, Paul Rago, Josef Idoine, Jon Hare), Moira Kelly (NERO), SMAST (Tony Wood, Yuying Zhang, Saang-Yoon Hyun).

3. Model Meeting – October 25-29, 2010, NEFSC, Woods Hole, MA. Participants included Steve Cadrin (WG chair), Assessment leads (Larry Alade, Kathy Sosebee , Michele Traver), Rapporteurs (Jessica Blaylock and Julie Nieland), Mark Showell (DFO), Andy Applegate (NEFMC Staff), Dan Farnham (Fisherman and Industry Advisor), (Loretta O'Brien, Paul Nitschke, Mark Terceiro, Jay Burnett, Chris Legault, Tim Miller, Jon Deroba, Rich McBride, Jim Weinberg, Paul Rago, Josef Idoine, Jon Hare, Janet Nye, Dave Richardson, Laurel Col, Jason Link), SMAST (Tony Wood, Yuying Zhang, Dan Goethel). The groups met by correspondence after the meetings, including a WebEx meeting on November 5, 2010 to report updates on silver hake analyses, provide guidance on reference points and discuss plans for report development.

This Working Group (WG) report includes products from all three meetings and contributions from all participants.

Fishery Regulations

The following outlines the current small mesh multispecies regulations (based on the small mesh exemption program) for the New England whiting fishery to provide context for interpreting the fishery and model results.

1. 1994 & 2000 - Exempted fisheries allows vessels to fish for specific species such as whiting or northern shrimp in designated areas using mesh sizes smaller than the minimum mesh size allowed (Gulf of Maine, Georges Bank, Southern New England, Mid-Atlantic : 6.5-inch square or diamond) under the Regulated Mesh Area (RMA) regulations .

2. Permits
a. Open access Category K Multispecies
b. Limited Access Category A-F (non Days-at-Sea fishing)

3. No Size Limits

4. 500 lbs at sea transfer limit.

5. 2003 - Possession limits vary by exemption area
a. 3,500 lbs if mesh < 2.5 inches (63.5mm)
b. 7,500 lbs if mesh <=3.0 inches (76.2mm)
c. 30,000 lbs if mesh > 3.0 inches (76.2mm)
d. No Red Hake possession limit

Introduction
Offshore hake, *Merluccius albidus* belongs to one of the twelve hake species of the genus *Merluccius*, inhabiting the northern and southern hemisphere of the world's oceans (Pitcher and Alheit 1995; Helser 1996). Like other species of the *Merluccius* genus, they are considered to be a 'true hake' species and are morphologically distinct from other gadoid-like hakes (e.g., red and white hake, Helser 1996). Offshore hake are known to be distributed off the continental slope of the northwest Atlantic to the Caribbean and the Gulf of Mexico (Chang et al 1999) (Figures D1-4). They are commonly located off southern Georges Bank through the Mid-Atlantic Bight at depths ranging from 160-550 meters (Bigelow and Schroeder 1953, Klein-MacPhee 2002). Offshore hake and silver hake (*M. bilinearis*) are sympatric species, and they co-exist over a considerable range of the continental slope, but are often separated by depth preferences (Helser 1996). The most distinguishing morphological characteristics between these species are the number of gill rakers and lateral line scales (Chang et al 1999). Due to the similar morphological features and spatial areas where they co-exist, they have been commonly misidentified for many years. The fishing industry did not separate the commercial landings of the two species until 1991, but the extent to which they are still landed as a single species is unknown (Helser 1996).

Offshore hake is currently included in the New England Fishery Management Council's (NEFMC) small mesh multi-species fishery management plan. Unfortunately, very little is known about the biology and population dynamics of offshore hake. They have never been formally assessed before.

Biology
Spawning usually occurs between April and July in the New England area, at depths ranging from 330-550 meters (Cohen et al. 1990). The maximum observed length from all areas is 40cm for males and 70cm for females (Chang et. al. 1999). Maximum observed size in samples from the Northwest Atlantic was approximately 43cm for males and 56cm for females, and fish greater 40cm consist mainly of females, suggesting that they are sexually dimorphic (Traver et al. in review). Length at 50% maturity (L_{50}) also differed significantly between sexes with females maturing at larger sizes (28cm) relative to males (23cm) (Traver et al. in review).

TOR 1. Use models to estimate the commercial catch. Describe the uncertainty in these sources of data.

Nominal commercial landings of offshore hake did not occur until 1991 (Figure D5, Table D1). Offshore hake commercial landings peaked at 120 mt in the early 1990s, then declined sharply to less than 5mt in 2001, the lowest in the time series (Figure D5). Landings have since increased slightly and average around 15 mt. Nominal landings of offshore hake occur in the silver hake northern area even though offshore hake are not found in these areas.

In the north, Massachusetts is the primary state that has nominal offshore hake landings while New Jersey and Rhode Island account for most of the southern area landings (Tables D2-D3). Otter trawl is the dominant fishing gear for offshore hake, accounting for 95% of the total nominal landings in both regions (Tables D4-D5). Other gears such as gillnet or hook and line were very minimal, contributing less than 1% in offshore hake catches.

Nominal landings of offshore hake occur sporadically in the north over time (Table D6). The landings are spread somewhat evenly among months in the south (Table D7-D8). Offshore hake are landed in an unclassified or dressed market category (has been combined in Table D9). King offshore hake are large component of the southern stock landings accounting for more than 50% of the total (Table D9).

There are currently no estimates of CPUE or effort for this species. Given the uncertainties given below with species identification and the major changes in management noted in the introduction, CPUE is not likely to be a good indicator of stock status.

It is thought that landings of offshore hake are likely under-reported or mis-reported and landed as silver hake as well as reported in areas that are not likely. There is no price differential so there is no real incentive to separate the two species when they are landed. Landings from the northern area are assumed to be silver hake. In order to estimate landings of offshore hake from the landings of silver hake from the southern region (Table D10-D13), two alternative methods were developed.

The first method used the port length samples of both species directly. Length samples of silver and offshore hake were combined by stock (Tables D14-D16). In examining the silver hake length samples by market category, it appeared that most of the market categories were similar in length composition to the round category (Figures D6-9). Therefore, only three market categories were used for stratification: round, king, and large. Even with the reduction of market categories, pooling over years was required to get an adequate number of fish (Table D17). The length-weight equations for silver hake by season from Wigley et al. 2003 were applied to the samples and used to estimate the landings numbers at length for each market category.

For the southern stock, length compositions for each species were estimated for the spring and fall surveys from 1968-2009. The species-specific length-weight equations were then applied to determine weight-at-length by species. The proportions at length by species for both number and weight were applied to the commercial landings-at-length to estimate landings-at-length by species. The lengths had to be grouped into intervals to avoid zero cells in the survey. To hind-cast the species proportions back to 1955, the average proportion of offshore hake for the time series was used and applied to the total silver hake landings.

The second method relates survey catch composition to Vessel Monitoring System (VMS) derived commercial landings from 2004-2009 using survey depth as an explanatory factor to develop a model that predicts the hake species landings composition. Offshore and silver hake composition (R_{23}) in the trawl survey tows were modeled as a two parameter logistic function of average depth. Only survey tows with silver hake, offshore hake or both were fitted and mean depth was the dependent variable.

$$R_{23} = \frac{e^{a+b*depth}}{1+e^{a+b*depth}}$$

For each stratum group, survey (winter, spring, and fall), and sets of time series, the catch and depth data were fitted by a non-linear least squares, weighted by the number of positive tows in a stratum, using the Marquardt method (Marquardt 1963) to aide convergence. Data were weighted by the number of positive tows in a stratum group. R^2 and Wald 95% confidence intervals (Cook and Weisberg 1990) were calculated for parameters a, b, D50, and the range to evaluate goodness of fit. Fitting the data with a two parameter logistic non-linear regression using maximum likelihood estimation and iteratively reweighted least squares approaches was attempted, but did not improve the results.

The parameter estimates for 1985-2009 were applied to the depth association with the VMS-derived commercial landings at depth (Applegate 2010). The model ratio of offshore to silver hake were assigned to landings from each group depth zone, survey season, and survey stratum group and summed for the calendar year (Applegate 2010). The final landings from this method were greater than 90% of the total landings reported by dealers in 2004-2009.

Estimates of offshore hake landings ranged between 290 – 893 mt and 5 – 12% of total hake landings (Table D18). These estimates are considerably higher than those reported by either dealers or by fishermen on Vessel Trip Reports (VTR).

Given that VMS data for 2004 – 2009 were deemed acceptable for direct estimation of silver and offshore hake landings composition, landings prior to 2004 (1955 – 2003) were hindcasted to generate longer time series of removal for assessments and for developing biological reference points. Although the hindcast procedure allowed the distribution of catch to vary between statistical areas, the distribution of catch within these intermediate depth statistical areas was assumed to be constant, equal to the average depth distribution observed by VMS during 2004-2009. Details of the hindcasting methodology can be found in Applegate (2010).

Hindcast and model based estimates of offshore hake landings were an order of magnitude greater than that reported by dealers. Landings rose from 951 mt in 1955 (7.0% of the total) to 24,189 mt in 1965 (8% of the total). Offshore hake as a proportion of total hake landings ranged from 2% in 1971, 1976, 1978-1980 to 13% in 1988 and 1996 (Tables D18a-b).

Relative to the length-based approach, the results from the depth-based method for allocating silver hake catches were very similar (<1 – 14% relative difference). Conversely, offshore hake estimates showed substantial differences between both methods. However, these differences are more noticeable on a relative scale because offshore hake consists of a small fraction of the total hake catches (Figure D10).

For assessment purposes, the Working group felt that the length-based estimator was more suitable because of the shorter period in hindcasting analyses. The group also felt that the small differences between the methods for silver hake estimates are likely not to influence assessment model results.

The resulting offshore hake landings for the two methods are given in Tables D18a-b and Figures D11-12. On average, the two methods gave slightly different results, with the length-based model averaging 7% silver hake while the depth-based method averaged 4% silver hake.

Commercial Fishery Discards

Discard estimates were calculated in this assessment. The ratio-estimator used in this assessment is based on the methodology described in Rago et al. (2005) and updated in Wigley et al. 2007. It relies on a d/k ratio where the kept component is defined as the total landings of all species within a "fishery". A fishery is defined as a homogeneous group of vessels with respect to gear type (longline, otter trawl, shrimp trawl, sink gill net, and scallop dredge), quarter, and area fished (GOM-NGBK, SGBK-MA), and for otter trawls, mesh size (<= 5.49", > = 5.5 "). All trips were included if they occurred within this stratification regardless of whether or not they caught hakes.

The discard ratio for hakes in stratum h is the sum of discard weight over all trips divided by sum of kept weights over all trips:

$$\hat{R}_h = \frac{\sum_{i=1}^{n_h} d_{ih}}{\sum_{i=1}^{n_h} k_{ih}} \qquad (1)$$

where d_{ih} is the discards for hakes within trip i in stratum h and k_{ih} is the kept component of the catch for all species. R_h is the discard rate in stratum h. The stratum weighted discard to kept ratio is obtained by weighted sum of discard ratios over all strata:

$$\hat{R} = \sum_{h=1}^{H} \left(\frac{N_h}{\sum_{h=1}^{H} N_h} \right) \hat{R}_h \qquad (2)$$

The total discard within a strata is simply the product of the estimate discard ratio R and the total landings for the fishery defined as stratum h, i.e., $D_h=R_hK_h$. Cells with < three trips were imputed using annual averages by gear type and region. To hind-cast the discards to 1981 (the first year in which there was no industrial fishery), discards/total landings by half year for the first three years (1989-1991 for otter trawl, sink gill net, and shrimp trawl; 1992-1994 for longline and scallop dredge) were averaged and the rate applied to the total landings from the dealer database. For the otter trawl fisheries, the mesh sizes were combined for the hind-cast.

Discards from the longline and sink gill net fishery were minimal for silver and offshore hake in both stock areas (Table D19-D22). Discards from the otter trawl fisheries have been significant and variable for silver hake.

The same problem with species identification that exists in the landings is found in the FOP data. There are discards of offshore hake estimated for the north. The geographical distribution of offshore hake is limited to the southern stock of silver hake and therefore, any discards from the northern stock (Tables D19) are considered to be silver hake. In order to estimate discards of offshore hake from the southern region, only one of the alternative methods was employed.

The observer discard length samples of silver and offshore hake were combined by stock (Tables D23-D26). Enough length samples were available for large and small mesh otter trawls in both regions and sink gill net and shrimp trawl in the north. Pooling over years was still required to get an adequate number of fish (Table D27-D28). The length-weight equations by season from Wigley et al 2003 were applied to the samples and used to estimate the landings numbers at length for each market category. The discards-at-length were raised to the total discards including all the gear types to account for as much of the removals as possible.

For the southern stock, length compositions for each species were estimated for the spring and fall surveys from 1968-2009. The species length-weight equations were then applied to determine weight-at-length by species. The proportions at length by species for both number and weight were applied to the commercial discards-at-length to estimate discards-at-length by species. The lengths had to be grouped into intervals to avoid zero cells in the survey. To hind-cast the species proportions back to 1981, the average proportion of offshore hake for the time series was used and applied to the total silver hake discards (Table D29).

TOR 2. Characterize the survey data being used in the assessment (e.g., regional indices of abundance, recruitment, age-length data, etc.). Describe uncertainty in these sources of data.

Data Source: The primary sources of biological information for offshore hake are based on the annual fishery independent surveys conducted by the Northeast Fisheries Science Center (NEFSC). The surveys were conducted using a random stratified sampling design which allocates samples relative to the size of the strata, defined by depth. The NEFSC have conducted both spring and fall bottom trawl surveys off the US continental shelf annually since 1963. The surveys extend from the Gulf of Maine to Cape Hatteras, in offshore waters at depths 27-365 meters, and have been conducted in the fall since 1963 and in the spring since 1968. The winter bottom trawl survey began in 1992 and was specifically designed for flatfish, however, the deeper survey strata were not sampled until 1998 (Figure D1). The winter trawl survey does not cover the Georges Bank area because the survey was designed specifically for flatfish in the southern region. Details on the stratified random survey design and biological sampling methodology may be found in Grosslein (1969), Azarovitz (1981) and Sosebee and Cadrin (2006).

Survey analysis suggests that offshore hake are distributed within the narrow band of the outer continental shelf from southern Georges Bank to the Mid-Atlantic region (strata 3-4, 7-8, 11-12, 14-15, 17-18, 63-64, 67-68, 71-72, and 75-76). There are seasonal differences in the patterns of distribution with concentrations shifting south of Georges Bank in the winter months and extending to the southern flank of Georges Bank and further south in the spring (Figures D2-4).

Transform: Survey estimates were computed using both delta transformation and arithmetic means for numbers and weight. The Whiting Plan Development Team (PDT) has used the delta mean for assessing stock status. The delta transformation uses only the positive tows for log transformation:

$$\hat{M}_\delta = \begin{cases} \dfrac{m}{n} e^{\bar{y}} \psi_m\left(\dfrac{1}{2}s_y^2\right) & m > 1, \\ \dfrac{1}{n}x_1 & m = 1, \\ 0 & m = 0 \end{cases}$$

$m =$ number of non - zero tows

$n =$ total number of tows

$$\hat{V}_\delta = \begin{cases} \dfrac{m}{n} e^{2\bar{y}} \left[\psi(2s_y^2) - \dfrac{m-1}{n-1}\psi_m\left(\dfrac{m-2}{m-1}s_y^2\right)\right] & m > 1, \\ \dfrac{1}{n}x_1^2 & m = 1, \\ 0 & m = 0 \end{cases}$$

Examination of the differences between the delta and arithmetic means revealed that use of the delta transformation did not reduce the variability of the survey (Figure D13). If a survey has a high variance, the back-transformation may be biased high (see Silver Hake Assessment). The delta transformation was also more sensitive to the handling of missing weights. Prior to 2001, the data for weights were recorded to the nearest 0.1 kg and if a tow contained only a single small fish, the weight was entered into the data as zero. Since the delta transform uses the positive tow, how this is handled has an impact on the result. There are three options: taking out the zeros, leaving in the zeros, and filling in zeros using a length-weight equation. Since these options did not affect the arithmetic as much as the delta mean, the decision was made to use the arithmetic and length-weight options for any new analyses (Figure D14).

Calibration: In 2009 the *NOAA SHIP Henry B. Bigelow* replaced the *R/V Albatross IV* as the primary vessel for conducting spring and fall annual bottom trawl surveys for the Northeast Fisheries Science Center (NEFSC). There are many differences in the vessel operation, gear, and towing procedures between the new and old research platforms (NEFSC Vessel Calibration Working Group 2007). To merge survey information collected in 2009 onward with that collected previously, we need to be able to transform indices (perhaps at size and age) of abundance from the *Henry B. Bigelow* into those that would have been observed had the *Albatross IV* still been in service. The general method for merging information from these two time series is to calibrate the new information to that of the old (Pelletier 1998). Specifically we need to predict the relative abundance that would have been observed by the *Albatross IV* ($\hat{R}_A$) using the relative abundance from the *Henry B. Bigelow* (R_B) and a "calibration factor" (ρ),

$$\hat{R}_A = \rho R_B . \qquad (4)$$

To provide information from which to estimate calibration factors for a broad range of species, 636 paired tows were conducted with the two vessels during 2008. Paired tows occurred at many stations in both the spring and fall surveys. Paired tows were also conducted during the summer and fall at non-random stations to improve the number of non-zero observations for some species. Protocols for the paired tows are described in NEFSC Vessel Calibration Working Group (2007).

The methodology for estimating the calibration factors was proposed by the NEFSC and reviewed by a panel of independent scientists in 2009. The reviewers considered calibration factors that could potentially be specific to either the spring or fall survey (Miller et al. 2010). They recommended using a calibration factor estimator based on a beta-binomial model for the data collected at each station for most species, but also recommended using a ratio-type estimator under certain circumstances and not attempting to estimate calibration factors for species that were not well sampled. In the case of offshore hake, the Working Group decided that using silver hake calibration factors as a proxy was better than not using any calibration factors.

Since the review, it has become apparent that accounting for size of individuals can be necessary for many species. When there are different selectivity patterns for the two vessels, the fraction of available fish of a given size taken by the two gears is different. Therefore, the ratio of the mean catches by the two vessels will change with size. Under these circumstances, the estimated calibration factor that ignores size reflects an average ratio weighted across sizes where the weights of each size class are at least in part related to the number of individuals at that size and the number of stations where individuals at that size were caught. Applying calibration factors that ignore size effects to surveys conducted in subsequent years when the size composition is unchanged should not produce biased predictions (eq. 1). However, when the size composition changes, the frequency of individuals and number of stations where individuals are observed at each size changes and the implicit weighting across size classes used to obtain the estimated calibration factor will not apply to the new data. Consequently, the predicted numbers per tow that would have been caught by the *Albatross IV* will be biased.

Calibration coefficients for silver hake were used because an insufficient number of offshore hake were captured during calibration studies to derive a coefficient for offshore hake. For silver hake, a suite of beta-binomial models were fit that made different assumptions on the relationship of the calibration factor to length. The models ranged from those that were constant with respect to length to logistic and double-logistic functions of length. A season-specific model was chosen based on AIC_c for silver hake by the working group where a logistic functional form for the spring and a double-logistic form for the fall provided the best fit (Table D30, Figure D15). Refer to the silver hake chapter of this NEFSC CRD for more details.

Survey Data Results: Swept Area abundance and biomass were calculated by using swept area conversions of 0.0112 for the NEFSC fall and spring surveys and 0.0131 for the NEFSC winter survey. A three-year moving average was calculated for the arithmetic means and swept area abundance and biomass for the fall and spring surveys in order to smooth out the variability of the surveys (Tables 31-32).

The fall survey stayed rather stable with similar trends to the spring survey in the late 1970s and early 1980s. The highest swept area biomass was in 1981, with 577 metric tons. It sharply declined to 17 metric tons in 1982. It stayed fairly low until 2001 and 2003, where the biomass was over 100 metric tons. 2009 has a 28% increase over 2008, with 56 metric tons (Table D34, Figure D17).

The spring survey was low in the early part of the time series and increased steadily to a record high in 1980 at 1,886 metric tons. Like the fall survey, the spring survey then had a sharp decline to 336 metric tons. It has continued to decline, with its lowest value in 2006 at 10 metric tons. It has since increased from 2006 to 30 metric tons (Table D36, Figure D19).

The winter survey abundance and biomass have varied substantially over the entire time series (1998-2007) with no trend (Table D38, Figure D21). Survey catches are highly variable but the trends in the spring and fall are similar. The higher catchability in the winter survey can be explained by the net configuration (i.e. smaller cookies) specifically designed to target flatfish.

Age Data: Growth parameters were calculated from the survey data using the Von Bertalanffy growth equation:

$$L(t) = L\infty * (1 - exp(-k * t - t0))$$

There are 55 ages that were aged by the NEFSC that were used in this analysis. The lengths range from 13cm to 45cm, with ages 1-5. The ages are considered preliminary since there is no published ageing study in the Northwest Atlantic and were based on the same ageing criteria for silver hake. The growth equation with an L_∞ value set to 70cm resulted in a k value of 0.174.

Length Data: Survey length distributions for offshore hake in the spring and the fall do not show any clear modes and were difficult to interpret due to very low sample sizes. However, the general trend indicates that majority of the catches range between 20-40 cm in the fall and spring with very few fish greater than 40 cm. Despite, the higher sampling in the winter survey, the trends in the length distribution remain similar to the fall and spring (Table D39, Figures D22-24). To improve sampling intensity and trends in the length distribution, a three year moving average was calculated for the fall and the spring surveys and there were still no clear trends in the length distributions (Figures D25-26).

TOR 3. Estimate measures of annual fishing mortality, recruitment and stock biomass for the time series, and characterize the uncertainty of those estimates.

Application of Survival Estimation in Non-Equilibrium Situations (SEINE) to Offshore hake

SEINE Method

Gedamke and Hoenig (2006) developed a method to estimate mortality from mean length data in nonequilibrium situations, now called Survival Estimation in Non-Equilibrium Situations Model (SEINE, available at http://nft.nefsc.noaa.gov/). It is an extension of the Beverton-Holt length-based mortality estimator that assumes constant recruitment throughout the time series and mortality at fixed levels for certain periods within the time series. The approach allows for the transitory changes in mean length to be modeled as a function of mortality rate changes. After an increase in mortality, mean length will gradually decrease due to larger animals being less prevalent in the population. After a decrease in mortality, mean length will increase slowly due to growth of the fish in the population. The rates of change in both cases depend on the von Bertalanffy growth parameters and the magnitude of change in the mortality rates. Since the method requires only a series of mean length above a user defined minimum size and the von Bertalanffy growth parameters, it can be applied in many data poor situations. Gedamke and Hoenig (2006) demonstrated the utility of this approach using both simulated data and an application to data for goosefish caught in the NEFSC fall groundfish survey.

The SEINE model requires the growth parameters, L_∞ and k. It also requires mean lengths and sample size (Table D40). Since there are no accepted growth parameters for offshore hake, we used an average of Southern Georges Bank and Southern New England silver hake growth parameters (L_∞ = 43.91 and k = 0.33) for Lcritical values of 20cm as a base model. We varied the Lcritical values to 17cm and 23cm. The three mortality cut points (17cm, 20cm, and 23cm) were chosen because it is synonymous with fishable biomass.

Sensitivity analyses were run for the fall survey only, as the working group thought one season would be sufficient and it had the best likelihood value compared to the spring. Winter has too short of a time series. The model was run with higher and lower growth parameters at the different cut points. Silver hake growth parameters for the Southern Georges Bank (L_∞ = 43.78 and k = 0.28) and Southern New England (L_∞ = 44.04 and k = 0.37) alone were used. Using the preliminary offshore hake ages, von Bertalanffy growth parameters (L_∞ = 70 and k = 0.174) were estimated, and used in the SEINE model as part of the sensitivity analyses (Tables D41-42, Figure D27).

We set L_∞ to 70cm, as it corresponded with the largest offshore hake seen in both the NEFSC and Canadian DFO surveys. When it wasn't set, Solver gave an L_∞ result of 274cm, which is completely infeasible. The model results showed that using the offshore hake estimated growth parameters at 20cm were the best fit. They had the lowest AIC and likelihood values and realistic z values of all the runs completed.

The model includes an assumption of flat-topped selectivity. The working group felt that there is no correspondence between the mortality rate and the catch (Figures D28-34). For example, in the 1970s, when landings increased substantially, total mortality apparently decreased. Subsequently, when catch declined, mortality increased. Therefore, the results from SEINE are not a reliable basis for management.

Application of An Index Method (AIM) Model to Offshore Hake

AIM Method

The AIM model is a simple approach for examining the relationship between survey data and catch in data poor stock assessments. AIM is designed to address the question of whether a given rate of fishing mortality is likely to increase or decrease the population size. Survey data are used to define a relative rate of increase and the ratio of catch to survey indices provides a measure of relative fishing mortality. Theoretically the model can identify a stable point about which the stock will neither increase nor decrease in response to a fixed harvest rate. The model assumes that the resource dynamics are approximately linear with relatively minor influence of density dependent effects or variable environmental or ecological factors. Such conditions often typify stocks that have been historically harvested at high fishing rates and are therefore at low population sizes. AIM is both an analytic and graphing approach. The analytical methods can be used to define relative Fs for replacement and the graphical methods can be used to identify transient conditions that are relevant to implementation of any model. The details of the methodology are described below.

- ✓ Population biomass at time t can be written as a linear combination of historical population biomasses
- ✓ Recruitment is proportional to population biomass
- ✓ Fishing mortality is proportional to catch divided by an index of population size (relative F).
- ✓ The rate of change in population biomass is a monotonically decreasing function of relative F.
- ✓ Smoothing methods can be used to identify underlying trends.
- ✓ Randomization methods can be used to develop sampling distributions of test statistics
- ✓ Graphical methods can help identify linkages among variables

Relative F is defined as the ratio of catch to an index of population abundance. A three-year centered average of the abundance index is chosen as the measure of average stock size.

$$relF_{j,s,t} = \left(\frac{C_{s,t}}{\frac{I_{j,s,t-1} + I_{j,s,t} + I_{j,s,t+1}}{3}} \right) \qquad (1)$$

Where $relF_{j,s,t}$ = relative F for relative index j for stock s at time t
$C_{s,t}$ = catch or landings of stock s at time t (in units of weight)
$I_{j,s,t}$= Index of abundance j for stock s at time t expressed in terms of average weight per tow

The population size at any given time can be viewed as a weighted sum of previous recruitment events. For a population with a maximum age of A years, the population in year t consists of the recruits from year t-1, t-2, …t-A. At high levels of total mortality, the contributions from the earliest recruitments, say t-k-1 to t-A will diminish in importance such that the population can be viewed as the sum of recruitments from t-1 to t-k years.

Using the linearity assumption defined above, we can employ basic life history theory to write abundance at time t as a function of the biomasses in previous time periods. The number of recruits at time t (R_t) is assumed to be proportional to the biomass at time t (B_t). More formally,

$$R_t = S_o \, Egg \, B_t \qquad (2)$$

where **Egg** is the number of eggs produced per unit of biomass, and $\mathbf{S_o}$ is the survival rate between the egg and recruit stages. Survival for recruited age groups at age a and time t ($S_{a,t}$) is defined as

$$S_{a,t} = e^{-F_{a,t} - M_{a,t}} \qquad (3)$$

where F and M refer to the instantaneous rates of fishing and natural mortality, respectively. We also need to consider the weight at age a and time t ($W_{a,t}$) and the average longevity (A) of the species

Using these standard concepts we now write the biomass at time t as a linear combination of the A previous years. Without loss of generality, we can drop the subscripts on the survival terms and assume that average weight at age is invariant with respect to time. Further, set the product S_o Egg equal to the coefficient α. The biomass at time t can now be written as

$$B_t = R_{t-1} S^1 W_1 + R_{t-2} S^2 W_2 + R_{t-3} S^3 W_3 + .. + . R_{t-(A-1)} S^{A-1} W_{A-1} + R_{t-A} S^A W_A \quad (4)$$

Substituting Eq. (2) into Eq. (4) leads to

$$B_t = \alpha\, B_{t-1} S^1 W_1 + \alpha\, B_{t-2} S^2 W_2 + \alpha\, B_{t-3} S^3 W_3 + .. + .\alpha\, B_{t-(A-1)} S^{A-1} W_{A-1} + \alpha\, B_{t-A} S^A W_A \quad (5)$$

If the population is replacing itself, then the left hand side of Eq. 5 will equal the right hand side. The replacement ratio can then be defined as

$$\Psi_t = \frac{B_t}{\alpha\, B_{t-1} S^1 W_1 + \alpha\, B_{t-2} S^2 W_2 + \alpha\, B_{t-3} S^3 W_3 + .. + .alphaB_{t-(A-1)} S^{A-1} W_{A-1} + \alpha\, B_{t-A} S^A W_A} \quad (6)$$

Substituting observed values of abundance indices into Eq 6 leads to

$$\Psi_t = \frac{\frac{I_t}{q}}{\alpha \frac{I_{t-1}}{q} S^1 W_1 + \alpha \frac{I_{t-2}}{q} S^2 W_2 + \alpha \frac{I_{t-3}}{q} S^3 W_3 + .. + \alpha \frac{I_{t-(A-1)}}{q} S^{A-1} W_{A-1} + \alpha \frac{I_{t-A}}{q} S^A W_A} \quad (7)$$

By noting that the q's cancel out, and letting $\varphi_j = \alpha\, S^j W_j$, Eq. 6 simplifies to

$$\Psi_t = \frac{I_t}{\sum_{j=1}^{A} \phi_j \quad I_{t-j}} \qquad (8)$$

All of the I_t and φ_j are positive, and at equilibrium $I_t = I_{t+1}$ and $I_t = \sum \varphi_j I_{t-j}$ both hold . Therefore $\sum \varphi_j = 1$. When the population is not at equilibrium the parameter Ψ becomes a measure of the non equilibrium state of the population and a measure of whether the population is increasing or decreasing relative to prevailing fishery and ecosystem conditions.

It would be desirable to express the parameters of φ_j weighting terms as function of the underlying parameters. Analyses of other stocks with more detailed information, such as Georges Bank haddock, has suggested that setting the φ_j to 1/A is a reasonable approximation. Equations 2 to 8 are a long way of justifying that the ratio of current stock size to a moving average of the previous A years of stock size can be used as a measure of population growth rate. This ratio embeds some life history theory into the basis for the ratio and simultaneously provides a way of damping the variations in abundance owing to measurement error. A ratio defined as I_t/I_{t-1} has been found, as expected to be much more noisy measure of population change.

Further details on the AIM methodology may be found in Working Group (2002) and the NOAA

Fisheries Toolbox (NFT) 3.1 (2010a) software package http://nft.nefsc.noaa.gov/AIM.html. The relationship between $\mathbf{\Psi_t}$ and $\mathbf{relF_t}$ can be expressed as

$$\ln(\Psi_t) = a + b\ln(relF_t) \quad (9)$$

The usual tests of statistical significance do not apply for the model described in Eq. 9. The relation between $\mathbf{\Psi_t}$ and $\mathbf{relF_t}$ is of the general form of Y/X vs X where X and Y are random variables. The expected correlation between Y/X and X is less than zero and is the basis for the oft stated criticism of spurious correlation. To test for spurious correlation we developed a sampling distribution of the correlation statistic using a randomization test. The randomization test is based on the null hypothesis that the catch and survey time series represent a random ordering of observations with no underlying association. The randomization test was developed as follows:

1. Create a random time series of length **T** of $\mathbf{C_{r,t}}$ from the set $\{\mathbf{C_t}\}$ and $\mathbf{I_{r,t}}$ from the set $\{\mathbf{I_t}\}$ by sampling with replacement.

2. Compute a random time series of relative F ($\mathbf{relF_{r,t}}$) and replacement ratios ($\mathbf{\Psi_{r,t}}$)
3. Compute the r-th correlation coefficient, say $\boldsymbol{\rho_r}$ between ln($\mathbf{relF_{r,t}}$) and ln($\mathbf{\Psi_{r,t}}$).
4. Repeat steps 1 to 3 K times.
5. Compare the observed correlation coefficient $\mathbf{r_{obs}}$ with the sorted set of $\boldsymbol{\rho_r}$
6. The approximate significance level of the observed correlation coefficient $\mathbf{r_{obs}}$ is the fraction of values of $\boldsymbol{\rho_r}$ less than $\mathbf{r_{obs}}$

It should be emphasized that relF is not necessarily an adequate proxy for Fmsy, since this parameter only estimates the average mortality rate at which the stock was capable of replacing itself. Thus, while relF defined as average replacement fishing mortality is a necessary condition for an F_{msy} proxy, it is not sufficient, since the stock could theoretically be brought to the stable point under an infinite array of biomass states. The relF at replacement does however provide some guidance on the contemporary rate of harvesting and its potential impact on future stock abundance.

Application of AIM to Offshore Hake

AIM was applied to offshore hake using catches derived from the method of Sosebee, and the NEFSC fall and spring bottom trawl survey indices (Table D43). Relative F was defined as the ratio of catch to a centered 3-year average of survey abundance (Eq. 1) and the replacement ratio was defined as a 5-year moving average of previous stock sizes (Eq. 8). The relationship between catch, survey, relative F and the replacement ratio for the fall and spring survey indices are depicted in Figs. D35 and D36, respectively. Neither of the randomization tests resulted in significant statistical relationship between the replacement ratio and relative F (Table D44).

Bootstrap estimation of the relative F at replacement were imprecise (Table D44, Figure D37) and may not be appropriate measures of Fmsy proxies. Graphical results suggest some underlying causes for the absence of a strong statistical relationship. Relative F has been declining continuously for the fall index (Figure D35). For the spring (Figure D36) survey indices relative F declined through the mid 1980 rebounded for a decade and then declined again from the late 1990s onward. Fall and spring survey trends suggest high abundance before 1980 but much lower values (about one order of magnitude) since then. Replacement ratios for offshore hake in the fall survey have been generally below one since 1980 (Figure D35). The spring survey is slightly different with a brief excursion above 1.0 in the late 1990s followed by a general decline since 2001. Catch rates for offshore hake in both surveys is generally low, perhaps reflecting low abundance, low gear efficiency or both factors. Low gear efficiency can make the detection of trends difficult.

The relationship between survey abundance and relative F suggest a temporal trend wherein reductions in relative F do not necessarily induce similar increases in relative abundance (Figure D35 and D36--left middle panel). At a minimum these stanzas suggest major changes in the population abundance indices and exploitation rates. It is not possible from these data alone to identify causal factors but it does suggest that more advanced modeling if possible, will need to account for these changes in apparent productivity and/or natural mortality.

Survey exploitation indices were calculated using the swept area biomass for the fall, spring, and winter surveys, using the length-based total catch (Table D45, Figures 38-40). It was also calculated using the length-based landings, but the Working group decided that the catch was more accurate due to it being total removals (Table D45, Figures 41-43).

TOR 4. State the existing definitions for overfished and overfishing. Then update or redefine biological reference points (BRPs; estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, and $F_{MSY;}$ and estimates of their uncertainty). Comment on the scientific adequacy of existing and redefined BRPs.

Existing BRPs

The current overfishing definition is that:

> offshore hake is in an overfished condition when the three year moving average weight per individual in the fall survey falls below the 25th percentile of the average weight per individual from the fall survey time series 1963-1997 (0.236) **AND** when the three year moving average of the abundance of immature fish less than 30 cm falls below the median value of the 1963-1997 fall survey abundance of fish less than 30 cm (0.33) (NEFMC 2003).

In previous SAFE Reports, the WMC noted problems associated with this overfishing definition. Although the current definition is intended to identify overfished (i.e. low biomass) stock conditions, it is a better indication of overfishing (high exploitation rate). The WMC recommended that the overfishing definition for offshore hake be revisited.

The Hake Working Group noted that the survey data may not be a good index of abundance but may be driven more by the environment. Therefore, the existing BRPs should not be accepted, and no alternative reference points are recommended by SAW/SARC51.

TOR 5. Evaluate stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from Offshore hake TOR 4).

Based on current biological reference points, offshore hake (Figure D44,Table 46) is not overfished and overfishing is unknown. The three year delta individual mean weight index (Figure D44, Table 46), based on NEFSC fall bottom trawl survey data for 2007-2009 (0.16 kg/individual), is below the management threshold (0.24 kg/individual) but the three year average recruitment index (0.89 num/tow) is above the threshold value (0.33 num/tow).

Based on the SAW/SARC51 review, stock status is unknown.

TOR 6. If a model can be developed, conduct single and multi-year stock projections and for computing candidate ABCs (Acceptable Biological Catch; see Appendix to the TORs).

a. ***Provide numerical short-term projections (3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. In carrying out projections, consider a range of assumptions about the most important uncertainties in the assessment***
b. ***Comment on which projections seem most realistic, taking into consideration uncertainties in the assessment.***
c. ***Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC.***

No model could be developed. Therefore, this term of reference could not be completed.

TOR 7. Propose new research recommendations.

- Studies to estimate discard mortality should be conducted.
- As an alternative to using silver hake calibration coefficients, it may be better to explore depth-based survey calibration coefficients.
- Develop explicit process and criteria for the application of length-based (vs. constant) calibration coefficients (other than purely statistical criteria such as AIC, etc.). It may be useful, if enough data exist, to attempt a cross validation with a subset of data.
- Investigate silver and offshore hake data in deepwater surveys (e.g., monkfish survey).
- Information on consumption by more predators (including mammals, highly migratory species (HMS)) needs to be included.
- Examine diel (day/night) variation in consumption of hakes.
- Identify offshore hake otoliths found in predators' stomachs.
- Validation of the ageing method for offshore hake via tagging, radiocarbon, or tetracyclin research needs to be conducted.
- The extent of the stock covered by the NEFSC needs to be examined.
- Perform a stock reduction analysis.

Sources of Uncertainty

- It appears that the fishery as estimated by either the length-based model or the depth-based model has not had an impact on the stock. The mortality estimates from the SEINE model are in direct contrast to the catch data. Developing ACLs will also be challenging given that the landings are not separated to a great extent. Garcia-Vazquez et al (2009) found 12% of hake sold in Spain as silver hake were actually offshore hake.
- Given that the distribution of offshore hake in the NEFSC survey is very close to the edge of the survey range, the survey index may be more driven by environmental factors than abundance. The survey likely does not cover the entire stock area and therefore, the survey estimates could potentially be under-representing the dynamics of the population.

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D. Offshore Hake-Tables

Table D1. Landings (mt) of offshore hake by region.

Year	North	South
1991		30.246
1992		118.663
1993		98.076
1994		115.069
1995		71.094
1996		66.849
1997		22.333
1998	0.018	5.268
1999	5.257	6.545
2000		3.729
2001	0.338	1.781
2002	0.139	6.281
2003	0.159	10.202
2004	0.207	23.199
2005	1.389	12.135
2006	0.110	36.916
2007	0.051	11.581
2008	0.001	21.070
2009	3.567	16.707

Table D2. Landings (mt) of offshore hake from the northern region by state.

Year	ME	MA	NH	NY	RI	Total
1998					0.018	0.018
1999		5.257				5.257
2001		0.338				0.338
2002		0.139				0.139
2003		0.159				0.159
2004		0.195	0.011			0.207
2005	0.311	1.060			0.018	1.389
2006				0.110		0.110
2007				0.051		0.051
2008					0.001	0.001
2009		3.567				3.567

Table D3. Landings (mt) of offshore hake from the southern region by state.

Year	CT	MD	MA	NJ	NY	RI	VA	Total
1991				30.246				30.246
1992				36.625		82.039		118.663
1993				98.076				98.076
1994				85.887		29.182		115.069
1995	25.261		0.035	23.205	0.027	22.565		71.094
1996				34.833	0.033	31.983		66.849
1997				10.915		11.418		22.333
1998						5.268		5.268
1999						6.545		6.545
2000						3.729		3.729
2001						1.781		1.781
2002					0.027	6.254		6.281
2003			9.185	0.030		0.986		10.202
2004			5.537		12.064	5.523	0.029	23.199
2005		0.015	7.058		0.954	4.109		12.135
2006		0.015			35.126	1.774		36.916
2007		0.091	1.263	0.211	9.856	0.160		11.581
2008	0.412	0.029		0.008	20.077	0.544		21.070
2009			0.097	0.122	15.346	1.142		16.707

Table D4. Landings (mt) of offshore hake from the northern region by gear.

Year	LL	OTF	SGN	OTH	Total
1998		0.018			0.018
1999		5.257			5.257
2001		0.338			0.338
2002		0.035	0.105		0.139
2003		0.159			0.159
2004	0.156		0.049	0.002	0.207
2005	0.012	0.979	0.398		1.389
2006		0.109			0.110
2007		0.051			0.051
2008		0.001			0.001
2009		3.567			3.567

Table D5. Landings (mt) of offshore hake from the southern region by gear.

Year	LL	OTF	SGN	OTH	Total
1991		30.246			30.246
1992		118.663			118.663
1993		98.076			98.076
1994		115.069			115.069
1995	0.029	45.769		25.297	71.094
1996		66.849			66.849
1997		22.333			22.333
1998		5.268			5.268
1999		6.545			6.545
2000		3.729			3.729
2001		1.781			1.781
2002		6.281			6.281
2003		10.202			10.202
2004		22.852	0.064	0.283	23.199
2005		4.243		7.893	12.135
2006		35.846	0.108	0.961	36.916
2007	0.211	11.161		0.210	11.581
2008		20.085		0.985	21.070
2009	0.122	15.445	0.002	1.138	16.707

Table D6. Landings (mt) of offshore hake from the northern region by month.

Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1998							0.018						0.018
1999									3.569	1.687			5.257
2001									0.034			0.304	0.338
2002			0.098			0.003	0.035		0.005				0.139
2003							0.159						0.159
2004							0.029		0.018	0.047		0.114	0.207
2005	0.027				0.018	0.004		0.337	0.265	0.739			1.389
2006									0.110				0.110
2007										0.051			0.051
2008			0.001										0.001
2009		1.393	1.066	0.349	0.032	0.379	0.011	0.014	0.005	0.304	0.016		3.567

Table D7. Landings (mt) of offshore hake from the southern region by month.

Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1991						25.778	4.468						30.246
1992				62.859	18.760	0.419	25.850	6.645	4.130				118.663
1993						47.850	23.428	12.980	9.446	4.067	0.306		98.076
1994			1.778	1.437	21.918	52.785	24.538	2.403	6.432	0.091	2.779	0.909	115.069
1995	8.773	1.361	14.232	1.568	15.483	23.245	1.189	0.876	0.987	1.431	1.427	0.524	71.094
1996				2.191	5.312	0.515	17.234	19.287	12.725	3.648	5.191	0.747	66.849
1997	0.446	0.881	1.030	1.148	1.775	1.112	2.392	10.946	2.539	0.042		0.023	22.333
1998	0.075	1.581	2.220	0.109	0.063	0.868	0.007					0.345	5.268
1999	0.229	0.085	1.276	0.276	1.470	3.178						0.032	6.545
2000	0.011	1.216		0.307	2.195								3.729
2001		0.297	1.371	0.113									1.781
2002	0.027				5.408		0.846						6.281
2003		0.015	8.087					0.060	0.443			1.597	10.202
2004	0.449	0.472	0.486	0.068	4.675	1.058	2.535	8.433	2.001	0.386	1.738	0.897	23.199
2005	0.231	0.433	3.834	0.500	0.015		0.064		6.831	0.227			12.135
2006	0.567	0.727	2.004	1.584	7.456	9.480	1.134	0.110	4.441	8.309	0.388	0.716	36.916
2007	0.132	0.024	1.191	1.540	3.103	1.882	0.219	0.428	0.344	0.899	0.844	0.976	11.581
2008	2.886	2.144	2.857	0.590	3.026	0.549	0.399	2.156	1.617	3.183	0.366	1.296	21.070
2009	0.478	0.604	5.022	1.320	1.034	0.988	1.134	0.329	1.394	2.676	0.907	0.820	16.707

Table D8. Nominal landings (mt) of offshore hake by region and half year.

	North			South		
	Half 1	Half 2	Total	Half 1	Half 2	Total
1991				25.778	4.468	30.246
1992				82.038	36.625	118.663
1993				47.850	50.226	98.076
1994				77.918	37.151	115.069
1995				64.661	6.434	71.094
1996				8.017	58.832	66.849
1997				6.391	15.942	22.333
1998		0.018	0.018	4.916	0.352	5.268
1999		5.257	5.257	6.513	0.032	6.545
2000				3.729		3.729
2001		0.338	0.338	1.781		1.781
2002	0.101	0.039	0.140	5.435	0.846	6.281
2003		0.159	0.159	8.102	2.100	10.202
2004		0.207	0.207	7.209	15.991	23.200
2005	0.049	1.340	1.389	5.013	7.122	12.136
2006		0.110	0.110	21.817	15.099	36.916
2007		0.051	0.051	7.871	3.710	11.582
2008	0.001		0.001	12.053	9.017	21.070
2009	3.218	0.349	3.567	9.447	7.260	16.707

Table D9. Landings (mt) of offshore hake by market category by region.

	Half 1		Half 2		Half 1		Half 2	
	Uncl	King	Uncl	King	Uncl	King	Uncl	King
1991						21.548	4.230	3.697
1992						82.038		30.264
1993						47.850		44.795
1994						66.300	11.617	32.551
1995						60.440	4.221	5.495
1996						7.141	0.876	49.400
1997						5.994	0.398	14.911
1998			0.018		0.018	3.901	1.015	0.304
1999			5.257		5.257	5.815	0.699	0.027
2000			0.000			3.677	0.052	
2001			0.338		0.338	1.755	0.026	
2002	0.101		0.039		0.140	5.408	0.027	0.846
2003			0.159		0.159	8.026	0.076	1.929
2004			0.195	0.012	0.207	5.843	1.366	12.056
2005	0.049		1.212	0.128	1.389	0.911	4.102	6.895
2006			0.110		0.110	16.461	5.355	13.461
2007			0.051		0.051	7.474	0.398	3.637
2008		0.001			0.001	9.227	2.826	6.579
2009	1.524	1.694	0.349		3.567	7.510	1.936	6.875

Table D10. Nominal landings (mt) of silver hake by stock from 1955-2009.

	Northern Stock			Southern Stock			Combined Stock		
Year	US	DWF	Total	US	DWF	Total	US	DWF	Total
1955	53,361		53,361	13,842		13,842	67,203		67,203
1956	42,150		42,150	14,871		14,871	57,021		57,021
1957	62,750		62,750	17,153		17,153	79,903		79,903
1958	49,903		49,903	13,473		13,473	63,376		63,376
1959	50,608		50,608	17,112		17,112	67,720		67,720
1960	45,543		45,543	9,206		9,206	54,749		54,749
1961	39,688		39,688	13,209		13,209	52,897		52,897
1962	42,427	36,575	79,002	13,408	5,325	18,733	55,835	41,900	97,735
1963	36,399	37,525	73,924	19,359	74,023	93,382	55,758	111,548	167,306
1964	37,222	57,240	94,462	26,518	127,036	153,554	63,740	184,276	248,016
1965	29,486	15,793	45,279	23,765	283,366	307,131	53,251	299,159	352,410
1966	33,569	14,239	47,808	11,212	200,058	211,270	44,781	214,297	259,078
1967	26,489	6,882	33,371	9,500	81,749	91,249	35,989	88,631	124,620
1968	30,873	10,506	41,379	9,074	49,422	58,496	39,947	59,928	99,875
1969	16,008	8,047	24,055	8,165	67,396	75,561	24,173	75,443	99,616
1970	15,223	12,305	27,528	6,879	20,633	27,512	22,102	32,938	55,040
1971	11,158	25,243	36,401	5,546	66,344	71,890	16,704	91,587	108,291
1972	6,440	18,784	25,224	5,973	88,381	94,354	12,413	107,165	119,578
1973	14,005	18,086	32,091	6,604	97,989	104,593	20,609	116,075	136,684
1974	6,907	13,775	20,682	7,751	102,112	109,863	14,658	115,887	130,545
1975	12,566	27,308	39,874	8,441	65,812	74,253	21,007	93,120	114,127
1976	13,483	151	13,634	10,434	58,307	68,741	23,917	58,458	82,375
1977	12,455	2	12,457	11,458	47,850	59,308	23,913	47,852	71,765
1978	12,609		12,609	12,779	14,353	27,132	25,388	14,353	39,741
1979	3,415		3,415	13,498	4,877	18,375	16,913	4,877	21,790
1980	4,730		4,730	11,848	1,698	13,546	16,578	1,698	18,276
1981	4,416		4,416	11,783	3,043	14,826	16,199	3,043	19,242
1982	4,664		4,664	12,164	2,397	14,561	16,828	2,397	19,225
1983	5,312		5,312	11,520	620	12,140	16,832	620	17,452
1984	8,289		8,289	12,731	412	13,143	21,020	412	21,432
1985	8,297		8,297	11,843	1,321	13,164	20,140	1,321	21,461
1986	8,502		8,502	9,573	550	10,123	18,075	550	18,625
1987	5,658		5,658	10,121	2	10,123	15,779	2	15,781
1988	6,789		6,789	9,195		9,195	15,984		15,984
1989	4,648		4,648	13,428		13,428	18,076		18,076
1990	6,377		6,377	13,610		13,610	19,987		19,987
1991	6,055		6,055	10,492		10,492	16,547		16,547
1992	5,306		5,306	10,873		10,873	16,179		16,179
1993	4,364		4,364	12,942		12,942	17,306		17,306
1994	3,899		3,899	12,159		12,159	16,058		16,058
1995	2,594		2,594	12,102		12,102	14,696		14,696
1996	3,619		3,619	12,561		12,561	16,180		16,180
1997	2,802		2,802	12,763		12,763	15,565		15,565
1998	2,045		2,045	12,828		12,828	14,873		14,873
1999	3,444		3,444	10,577		10,577	14,021		14,021
2000	2,592		2,592	9,769		9,769	12,361		12,361
2001	3,391		3,391	9,517		9,517	12,908		12,908
2002	2,593		2,593	5,344		5,344	7,937		7,937
2003	1,808		1,808	6,835		6,835	8,643		8,643
2004	1,049		1,049	7,436		7,436	8,485		8,485
2005	827		827	6,670		6,670	7,497		7,497
2006	903		903	4,629		4,629	5,532		5,532
2007	1,014		1,014	5,345		5,345	6,359		6,359
2008	620		620	5,638		5,638	6,258		6,258
2009	1,038		1,038	6,720		6,720	7,755		7,758

Table D11. Nominal landings (mt) of silver hake by region and half year.

	North				South			
Year	1	2	Unknown	Total	1	2	Unknown	Total
1964	5532	30689	1000	37,222	1318	1067	24,133	26,518
1965	2635	26876		29,512	3960	597	19,208	23,765
1966	3928	29641		33,569	2681	1570	6,961	11,212
1967	1180	25045	265	26,489	575	288	8,637	9,500
1968	3356	27502	15	30,873	958	597	7,519	9,074
1969	2332	13677		16,008	1004	706	6,455	8,165
1970	2075	13145	3	15,223	1895	1037	3,947	6,879
1971	624	10526	8	11,158	564	932	4,050	5,546
1972	480	5946	14	6,440	1096	647	4,230	5,973
1973	1305	12700		14,005	697	753	5,154	6,604
1974	652	6255		6,907	1452	893	5,406	7,751
1975	2724	9843		12,566	1294	1159	5,988	8,441
1976	3019	10449	15	13,483	1711	1606	7,117	10,434
1977	2531	9909	15	12,455	912	1560	8,986	11,458
1978	1781	10801	27	12,609	5800	2501	4,478	12,779
1979	245	3158	12	3,415	5297	3898	4,303	13,498
1980	335	4361	34	4,730	5283	3225	3,340	11,848
1981	688	3675	53	4,416	5279	3366	3,138	11,783
1982	376	4288		4,664	6347	3845	1,972	12,164
1983	719	4593		5,312	5053	4255	2,212	11,520
1984	402	7886	1	8,289	6769	3661	2,301	12,731
1985	1133	7159	5	8,297	6914	2862	2,067	11,843
1986	1543	6957	2	8,502	6203	3205	165	9,573
1987	835	4822	1	5,658	6449	3459	213	10,121
1988	1215	5574		6,789	7252	1908	35	9,195
1989	594	4055		4,648	8091	5326	11	13,428
1990	317	6061		6,377	8799	4811		13,610
1991	408	5647		6,055	7530	2951	11	10,492
1992	246	5058	2	5,306	7256	3513	104	10,873
1993	251	4110	3	4,364	7065	5874	3	12,942
1994	335	3564		3,899	7052	5107		12,159
1995	85	2507	2	2,594	6988	5110	4	12,102
1996	114	3505		3,619	7815	4744	2	12,561
1997	280	2520	1	2,802	7919	4834	10	12,763
1998	63	1983		2,045	7581	5246	1	12,828
1999	114	3331		3,444	7562	3015		10,577
2000	319	2272		2,592	5741	4029		9,769
2001	251	3141		3,391	6574	2916	27	9,517
2002	117	2476		2,593	3892	1431	22	5,345
2003	56	1752		1,808	3232	3604		6,835
2004	43	1007		1,049	4391	3045		7,436
2005	83	743		827	3764	2906		6,671
2006	15	888		903	2818	1812		4,629
2007	9	1003		1,014	2718	2625		5,338
2008	30	590		620	2927	2710		5,638
2009	45	994		1,038	3589	3132		6,720

Table D12. Landings (mt) of silver hake by market category from the northern region.

	Half 1							Half 2						
Year	Round	Med	Small	Dressed	Juv	King	Large	Round	Med	Small	Dressed	Juv	King	Large
1964	5350			183				30023			666			
1965	2633			2				26626			225			
1966	3916			11				29510			131			
1967	1179			1				24410			634			
1968	3300			55				26867			634			
1969	2331			<1				13314			362			
1970	2052			23				13095			50			
1971	581			43				10415			113			
1972	471			8				5917			29			
1973	1292			13				12600			99			
1974	648			4				6222			33			
1975	2691			28				9678			168			
1976	3010			8				10447			3			
1977	2530			<1				9847			49			
1978	1779			1				10739			62			
1979	241			4				3125			33			
1980	333			4				4341			19			
1981	667			20		1		3591			28		53	
1982	366			6		3		3986		163	63		74	
1983	414		241	18		46		4047		348	16		183	
1984	199		121	2		81		6436		1234	10		206	
1985	788		232	<1		113		5995		606	61		496	
1986	1147		280	2		114		5826		360	355		418	
1987	680		118	1		35		4234		323	6		260	
1988	1027		167	1		19		5030		344	<1		201	
1989	520		51	<1		22		3818		51	16		166	
1990	258		53	<1		6		5776		17	1		263	
1991	394		5	<1		7		5373		9	<1		263	
1992	236		8			3		4692		40			323	
1993	250		1			1		3913		47			148	
1994	275		49		6	4		2774		521		143	113	
1995	73		5	<1		1		1954		162			36	
1996	84		27			1		2755		442			87	
1997	191		87			2		1825		548			148	
1998	54		3			6		1489		188	16	73	212	
1999	79		35			5		2545		289		236	255	
2000	279		8	<1		31		1890		189			193	
2001	206		5			39		2405		416			302	
2002	94		15			5		1801		501			146	
2003	20		34			2		1177		481			93	
2004	13		8	21		1	<1	359		76	362	24	20	100
2005	71		<1	1		<1	1	363		20	303	<1	4	17
2006	10		1	<1	3	<1	<1	291		110	329	41	12	67
2007	9		<1	1		<1	<1	525	72	169	57	50	20	67
2008	17	<1	2	3	<1	1	3	337	48	18	93	3	13	27
2009	1	<1	<1	4		<1	<1	436	43	3	6		9	35

Table D13. Landings (mt) of silver hake by market category from the southern region.

	Half 1							Half 2						
Year	Round	Med	Small	Dressed	Juv	King	Large	Round	Med	Small	Dressed	Juv	King	Large
1964	1243			76				548			519			
1965	3934			26				540			59			
1966	2449			223				1374			196			
1967	557			17				259			28			
1968	909			48				560			37			
1969	980			24				701			4			
1970	1864			32				1028			10			
1971	536			29				925			7			
1972	1037			59				644			4			
1973	676			20				743			11			
1974	1388			63				879			13			
1975	1265			28				1121			38			
1976	1674			38				1574			32			
1977	907			5				1561			<1			
1978	5791			8				2496			5			
1979	5294			3				3897			1			
1980	5282			<1				3225			1			
1981	5028			107		145		3253			1		112	
1982	6153			35		160		3718		<1	8		120	
1983	4928			3		122		3994			36		225	
1984	6491		1	12		265		3407		1	1		252	
1985	6662			19		232		2667		10	<1		185	
1986	6005		50	<1		147		3094		1			110	
1987	6291		22			137		3387		<1			72	
1988	7135		<1			117		1853		1	<1		54	
1989	7922		<1			61		4763			4		71	
1990	8564			4		110		4542		1	<1		127	
1991	7168		3	2		154		2643		4	<1		121	
1992	6856		12	<1		155		3187		14	<1		65	
1993	6897		<1			124		3447		1197	1	75	114	
1994	3606		2533	1	361	229		2529		1672	<1	277	75	
1995	5142		1375	<1	33	385		4091		680	<1		328	
1996	5999		1474	<1	2	335		3070		1369	1	23	283	
1997	4620		2583		61	606		3210		1369	<1		251	
1998	5411		1542		75	552		3159		1756		45	282	
1999	4817		1989		338	418		2108		767		4	128	
2000	3793		1571	2	44	299		2438		1187		<1	403	
2001	4335		1214		6	908		1905		602			355	
2002	2355		1059	<1	178	228		916		413			88	
2003	1917		1064			248		1959		1524			118	
2004	2403	<1	1101	406	54	206	63	1203		566	410	267	162	150
2005	1587		640	746	293	85	109	1303		443	551	344	38	49
2006	1103		701	445	209	86	92	739	<1	405	260	143	53	43
2007	1153	128	582		163	128	218	996	101	759	228	53	126	153
2008	864	240	652	318	14	127	198	731	378	367	288	3	179	132
2009	955	592	472	144		160	228	684	338	730	75	20	117	166

Table D14. Summary of number of offshore hake measured by port samplers by market category, half and region.

	North	South		
	Round	Round		King
Year	Half 1	Half 1	Half 2	Half 1
1993			103	
1994				
1997		135		
2003				31
2004				337
2005	1			
2006		29		

Table D15. Summary of number of silver hake measured by port samplers by market category and half in the northern region.

	Round		Small		Dressed		King		Large	
Year	1	2	1	2	1	2	1	2	1	2
1969	202	2135								
1970	218	1838								
1971	243	2481				218				
1972		1221								
1973	320	3572			614					
1974	191	1409			84					
1975	799	855								
1976	1789	2126								
1977	878	3795								
1978	1217	1808								
1979	103	1362								
1980		775								
1981	98	1577								
1982		2007		117						
1983	210	3003		200						
1984	433	1829		519						
1985	221	1946	515	1130			125	338		
1986	974	3183	290	586						
1987	367	2717		839				324		
1988	691	2400	300	728			201	519		
1989	763	1146	106					100		
1990	466	1467								
1991	634	1232					114	129		
1992	215							262		
1993		886								
1995	348	344	202							
1997		207		209						
1998		514								
1999	100	45						113		
2000	269	407						102		
2001	1255	800	218				263	217		
2002	103		98				76	106		
2003	19	426						95		
2004	134	488		201				93		
2005		100		100				4		
2006	110	521						9	108	293
2007		547						189		344
2008		200						12		
2009	87	100								

Table D16. Summary of number of silver hake measured by port samplers by market category and half in the southern region.

	Round		Small		Dressed		Juv		King		Large	
Year	1	2	1	2	1	2	1	2	1	2	1	2
1969	50											
1970	316											
1971	98	311										
1972	216											
1975		793										
1976	200	1268			61							
1977	1418	685										
1978	1039	378										
1979	882	1321										
1980	2128	1995										
1981	1270	2570								154		
1982	3159	2699							472	190		
1983	4246	2067							256	541		
1984	3302	1716							323	306		
1985	5048	2025		110					344	186		
1986	3565	3118							201	468		
1987	5004	2539							167	182		
1988	4778	2922							87			
1989	3643	2594							167	104		
1990	5147	4069							201	100		
1991	3004	2397							95	198		
1992	2610	1023							96			
1993	1414	900		212					41	100		
1994	1003		303									
1995	1489		308						236			
1997	2535	236	1396	317					1475	157		
1998	2877	1585	411	32			104		781	410		
1999	2563	603	102	536			413		526	396		
2000	919	542	526	410					223	182		
2001	3598	2131	1178	555					2201	1021		
2002	3243	1274	1139	221			121		958	98		
2003	3088	1536	981	1309					713	618		
2004	1888	2129	1177	319					515	1163		
2005	2646	4512	539	517					1980	526		696
2006	5634	3341							632	461	1503	1256
2007	7499	3575		102					1209	614	1833	2585
2008	5432	3828	109						997	964	2376	1331
2009	4013	2890					100		1498	683	1339	1340

Table D17. Pooling of silver/offshore hake port length samples to estimate length and species composition of the commercial landings by region and market category.

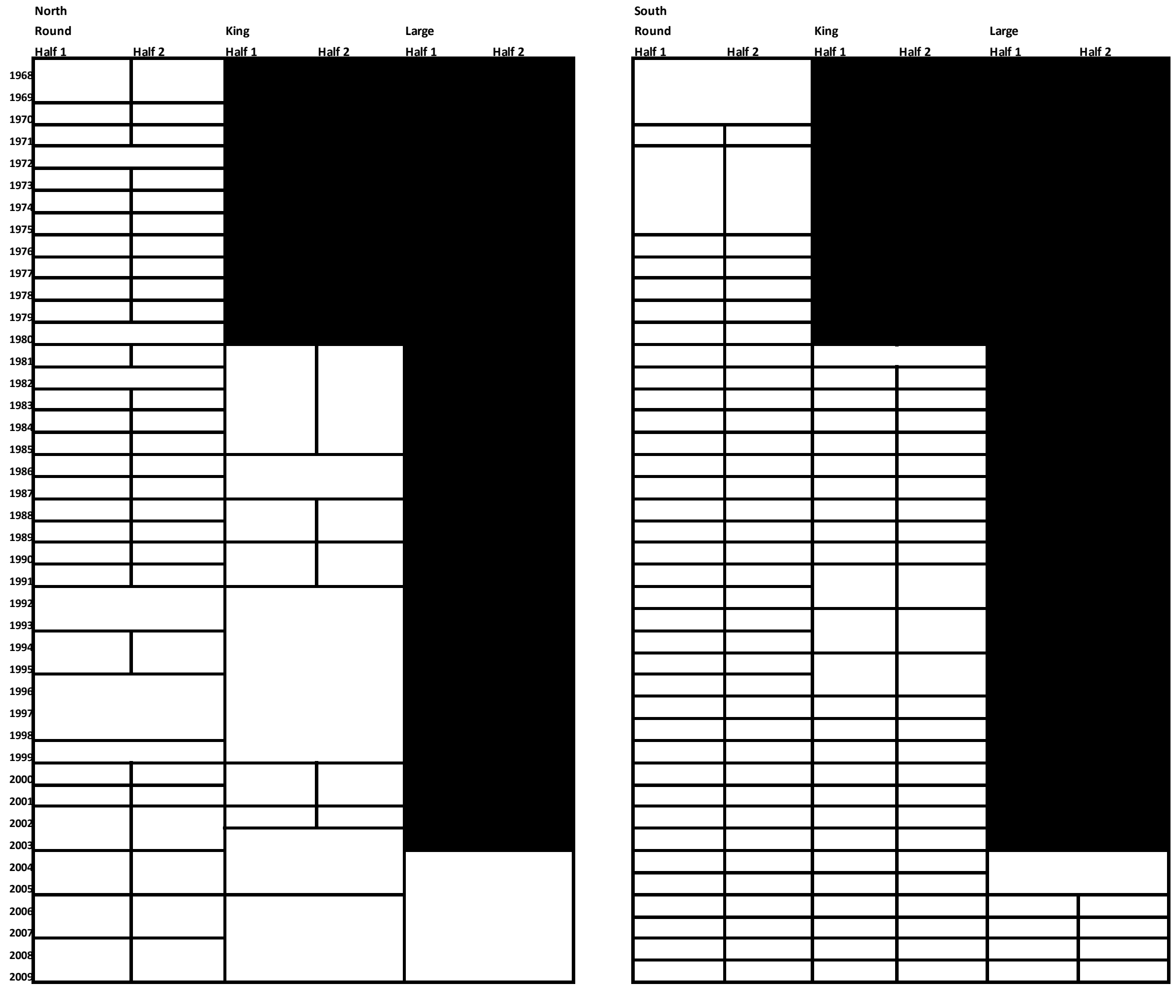


Table D18a. Comparison of estimated and reported offshore and silver hake landings (mt), 2004-2009. Red values reflect revised from the original working paper. Differences are less than 1%.

	Model based estimate			Dealer reported landings			VTR hail weights			
	Offshore hake	Silver hake	Percent offshore	Offshore hake	Silver hake	Percent offshore	Reporting vessels	Offshore hake	Silver hake	Percent offshore
2004	894	6,566	12.00%	18	6,096	0.30%	371	169	6,124	2.70%
2005	819	5,865	12.20%	9	5,886	0.10%	321	213	6,439	3.20%
2006	459	4,207	9.80%	35	3,973	0.90%	405	121	4,170	2.80%
2007	350	5,006	6.50%	11	4,316	0.30%	384	180	4,677	3.70%
2008	290	5,376	5.10%	19	4,127	0.50%	370	194	4,544	4.10%
2009	331	6,406	4.90%	13	4,328	0.30%	382	139	5,363	2.50%

Table D18b. Comparison of alternative methods of landings (mt) estimation for offshore hake.

Year	Nominal	Length-Based	Depth-Based
1955		586.5	951.0
1956		630.1	1021.7
1957		726.8	1178.5
1958		570.9	925.7
1959		725.1	1175.7
1960		390.1	632.5
1961		559.7	907.5
1962		793.8	1287.1
1963		3956.8	6415.9
1964		6506.4	5242.2
1965		13013.8	24189.3
1966		8951.9	18269.9
1967		3866.4	5085.6
1968		339.4	2375.8
1969		670.3	2743.9
1970		680.2	1870.4
1971		1383.7	1431.0
1972		6175.7	5306.5
1973		2514.8	4416.7
1974		7467.5	3958.6
1975		2088.7	2546.9
1976		4132.8	1345.7
1977		2148.1	1757.7
1978		1298.0	477.1
1979		1976.9	323.3
1980		1862.4	251.3
1981		1397.3	509.8
1982		409.2	927.1
1983		279.9	641.4
1984		188.3	612.1
1985		344.4	696.3
1986		425.8	622.8
1987		570.6	903.6
1988		245.2	1178.5
1989		433.2	771.9
1990		590.2	826.5
1991	30.246	783.3	792.2
1992	118.663	460.4	1079.0
1993	98.076	553.1	1523.1
1994	115.069	92.6	1423.1
1995	71.094	181.5	1362.6
1996	66.849	494.0	1703.1
1997	22.333	237.4	1372.0
1998	5.268	275.0	1334.7
1999	6.545	167.3	916.6
2000	3.729	302.2	855.6
2001	1.781	634.7	934.0
2002	6.281	462.8	577.6
2003	10.202	564.6	481.9
2004	23.200	494.3	893.8
2005	12.136	288.1	818.5
2006	36.916	81.7	459.3
2007	11.582	289.5	349.7
2008	21.070	83.9	290.2
2009	16.707	142.2	330.9

Table D19. Offshore hake discards (mt) from the northern region by gear and half. The hind-cast discards for offshore hake are zero.

	Large Mesh Otter Trawl				Small Mesh Otter Trawl				Sink Gill Net				Scallop Dredge		
	1	2	Total		1	2	Total		1	2	Total		1	2	Total
1989	0	0	0		0	0	0		0	0	0		0	0	0
1990	0	0	0		0	0	0		0	0	0		0	0	0
1991	0	0	0		0	0	0		0	0	0		0	0	0
1992	0	0	0		0	0	0		0	0	0		0	0	0
1993	0	0	0		0	0	0		0	0.023	0.023		0	0	0
1994	0	0	0		0	0	0		0	0	0		0	0	0
1995	0	0	0		0	0	0		0	0	0		0	0	0
1996	0	0	0		0	0	0		0	0	0		0	0	0
1997	0	0	0		0	0	0		0	0	0		0	0	0
1998	0	0	0		0	0	0		0	0	0		0	0	0
1999	0	0	0		0	0	0		0	0	0		0	0	0
2000	0	6.544	6.544		0	0	0		0	0	0		0	0	0
2001	0	0.065	0.065		0	0	0		0	0	0		0	0	0
2002	0.428	0.028	0.457		0	0	0		0.272	0	0.272		0.016	0.021	0.038
2003	0.028	0	0.028		0	0	0		0	0.085	0.085		0	0.339	0.339
2004	2.169	0.023	2.192		0	0	0		0	0	0		0	0	0
2005	0.168	0.025	0.192		0	0	0		0	0.032	0.032		0	0	0
2006	0	0.520	0.520		0	0	0		0	0	0		0	0	0
2007	0.089	0.630	0.719		0	0	0		0	0.004	0.004		0	0.027	0.027
2008	0.079	0.007	0.086		0	0	0		0	0	0		0	0	0
2009	0.915	4.311	5.226		0.013	0.089	0.102		0	0	0		0	0	0

Table D20. Offshore hake discards (mt) from the southern region by gear and half. The hind-cast discards for offshore hake are zero.

	Large Mesh Otter Trawl				Small Mesh Otter Trawl				Sink Gill Net				Scallop Dredge		
	1	2	Total		1	2	Total		1	2	Total		1	2	Total
1989	0	0	0		0	0	0		0	0	0		0	0	0
1990	0	0	0		0	0	0		0	0	0		0	0	0
1991	0	0	0		0	0	0		0	0	0		0	0	0
1992	0	0	0		0	0	0		0	0	0		0	0	0
1993	0	0	0		0	0	0		0	0	0		0	0	0
1994	0	0	0		0	0	0		0	0	0		0	0	0
1995	0	0	0		0	0	0		0	0	0		0.064	0.001	0.064
1996	0	0	0		0	0	0		0	0	0		0	0	0
1997	0	0	0		0.019	1.810	1.828		0.028	0	0.028		1.028	0.435	1.463
1998	0	0	0		170.494	0	170.494		0	0	0		3.386	0	3.386
1999	0	0	0		0	1.168	1.168		0	0	0		0	0.571	0.571
2000	0	0.619	0.619		0.183	0.239	0.422		0	0	0		0	0.056	0.056
2001	0	0.065	0.065		0	9.685	9.685		0	0	0		0	0	0
2002	0	0	0		143.674	0	143.674		0	0	0		0	2.563	2.563
2003	0	0	0		0	0	0		0	0	0		2.183	0.015	2.199
2004	0.036	0.030	0.066		2.131	0.909	3.040		0	0	0		1.618	0.219	1.837
2005	0	0	0		0	6.384	6.384		0	0	0		0	0	0
2006	0	0.416	0.416		0	4.109	4.109		0	0	0		0	0.012	0.012
2007	0.510	0.685	1.195		19.386	0	19.386		0	0	0		0	0.036	0.036
2008	0.926	0.176	1.102		0.006	0	0.006		0	0	0		0.001	0.035	0.035
2009	0.440	4.941	5.381		0.025	20.262	20.287		0.050	0	0.050		0	0	0

Table D21. Silver hake discards (mt) from the northern region by gear and half. The discards from 1981-1988 (91 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

	Longline			Large Mesh Otter Trawl			Small Mesh Otter Trawl			Sink Gill Net			Scallop Dredge			Shrimp Trawl		
	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total	1	2	Total
1981	0	0	0	417.9	1898.6	2316.4	Na			13.4	53.2	66.6	2.7	28.4	31.1	223.4	0.6	224.0
1982	0	0	0	411.8	2116.1	2527.9	Na			5.9	47.9	53.7	1.6	21.9	23.6	282.0	17.7	299.7
1983	0	0	0	453.9	1783.5	2237.4	Na			6.2	39.8	46.0	1.4	17.2	18.6	285.6	54.1	339.7
1984	0	0	0	379.2	1640.3	2019.4	Na			5.9	52.4	58.3	0.8	10.3	11.1	372.6	130.1	502.7
1985	0	0	0	331.3	1476.8	1808.2	Na			6.4	44.8	51.2	0.6	9.9	10.5	520.1	171.7	691.8
1986	0	0	0	289.6	1159.9	1449.5	Na			7.8	46.9	54.7	1.0	10.6	11.6	634.7	203.5	838.1
1987	0	0	0	243.7	1031.4	1275.1	Na			7.0	47.7	54.6	1.2	20.4	21.6	642.8	112.5	755.4
1988	0	0	0	227.0	982.0	1209.0	Na			7.8	48.6	56.4	1.5	26.0	27.5	379.9	111.7	491.6
1989	0	0	0	56.2	241.6	297.8	183.2	1005.1	1188.3	17.9	34.5	52.4	1.7	29.9	31.6	612.7	159.0	771.7
1990	0	0	0	271.4	415.8	687.2	18.8	611.2	630.0	6.2	81.8	88.0	0.6	31.9	32.5	420.0	130.9	551.0
1991	0	0	0	19.4	372.9	392.3	28.0	486.5	514.5	3.6	40.1	43.8	2.7	3.5	6.2	262.6	31.6	294.2
1992	0	0	0	99.8	271.9	371.8	28.1	555.0	583.0	5.1	37.4	42.4	0.0	5.2	5.2	378.4	48.7	427.1
1993	0	0	0	94.7	165.3	260.1	9.7	179.2	189.0	5.2	55.2	60.4	1.5	58.5	60.0	62.2	108.4	170.6
1994	0	0	0	29.0	15.6	44.7	3.8	63.0	66.8	2.8	41.0	43.8	0.6	0.5	1.1	25.5	58.3	83.8
1995	0.008	0.010	0.019	56.5	64.2	120.7	2.7	17.6	20.2	5.6	23.5	29.1	1.9	5.7	7.6	216.7	239.5	456.1
1996	0.008	0.008	0.016	55.7	9.3	65.1	1.2	19.5	20.7	3.6	52.9	56.5	0.0	2.1	2.1	576.3	105.0	681.3
1997	0.008	0.008	0.017	28.1	28.8	56.8	1.8	14.3	16.1	14.1	13.3	27.4	0.5	6.9	7.4	126.4	15.1	141.5
1998	0.006	0.010	0.016	116.8	21.5	138.3	23.0	269.3	292.3	4.6	4.4	9.0	19.2	17.3	36.6	206.2	11.2	217.4
1999	0.006	0.008	0.015	26.9	143.1	170.0	20.4	395.6	415.9	8.9	9.3	18.2	8.9	10.6	19.5	93.6	2.2	95.8
2000	0.004	0.009	0.013	102.2	83.3	185.5	0.1	0.7	0.9	9.3	15.1	24.4	1.4	2.7	4.1	137.8	2.3	140.1
2001	0.005	0.006	0.011	182.7	221.2	404.0	3.5	14.3	17.7	3.7	8.9	12.6	1.8	1.4	3.2	39.4		39.4
2002	0	0	0	291.6	95.8	387.4	0	103.0	103.0	3.5	5.7	9.2	1.7	2.2	3.9	9.7		9.7
2003	0	0	0	40.5	34.7	75.2	0.3	90.3	90.6	7.3	2.9	10.2	0	4.4	4.4	22.0		22.0
2004	0	0	0	22.1	44.5	66.5	0.1	29.6	29.6	1.2	1.8	2.9	0.1	0.0	0.1	13.4	0.6	13.9
2005	0	0.019	0.019	5.2	35.4	40.6	0.2	9.1	9.3	0.1	0.9	1.0	0.0	0.6	0.6	10.3	0.5	10.7
2006	0	0	0	3.7	17.3	21.1	0	4.9	5.0	0.7	0.4	1.1	0	1.1	1.1	2.5	7.3	9.8
2007	0.002	0	0.002	4.1	14.9	18.9	42.3	669.7	712.0	0.8	0.6	1.5	0.2	1.9	2.1	11.7	2.8	14.5
2008	0	0.002	0.002	12.6	32.2	44.8	8.1	63.6	71.7	1.4	4.7	6.2	0.2	0.1	0.3	35.1	9.0	44.1
2009	0	0	0	13.9	54.5	68.4	11.9	83.7	95.6	2.0	4.3	6.4	0.1	2.7	2.8	14.6	28.3	42.9

Table D22. Silver hake discards (mt) from the southern region by gear and half. The discards from 1981-1988 (91 for scallop dredge and longline) are hind-cast using the first three years of available data. The otter trawl discards are hind-cast combining mesh-sizes.

	Longline				Large Mesh Otter Trawl				Small Mesh Otter Trawl				Sink Gill Net				Scallop Dredge		
	1	2	Total		1	2	Total		1	2	Total		1	2	Total		1	2	Total
1981	0	0	0		2332.4	1176.2	3508.5		Na				0.0	0.1	0.1		6.1	87.9	94.0
1982	0	0	0		2646.2	2069.8	4716.0		Na				0.0	0.1	0.1		3.6	67.9	71.6
1983	0	0	0		2869.3	2026.3	4895.7		Na				0.0	0.1	0.1		3.1	53.3	56.4
1984	0	0	0		3124.7	1864.3	4989.1		Na				0.0	0.2	0.2		1.8	31.9	33.7
1985	0	0	0		2580.7	1369.7	3950.3		Na				0.0	0.1	0.1		1.2	30.7	31.9
1986	0	0	0		2598.7	1822.2	4420.9		Na				0.0	0.2	0.2		2.3	32.9	35.2
1987	0	0	0		2664.5	1643.3	4307.8		Na				0.0	0.2	0.2		2.7	63.2	65.9
1988	0	0	0		2971.7	1570.4	4542.1		Na				0.0	0.2	0.2		3.4	80.5	83.9
1989	0	0	0		31.1	81.0	112.1		5295.8	1085.1	6380.9		0	0	0		12.5	136.8	149.3
1990	0	0	0		2342.0	420.7	2762.6		1211.4	1961.3	3172.7		0	0	0		20.5	237.5	258.0
1991	0	0	0		201.0	993.0	1194.0		539.8	1480.5	2020.3		0	0.1	0.1		12.8	6.8	19.6
1992	0	0	0		443.9	211.2	655.1		244.7	2559.4	2804.1		0.6	2.7	3.3		9.8	7.4	17.2
1993	0	0	0		250.5	15.7	266.2		3144.5	1475.9	4620.4		1.4	3.4	4.8		6.9	346.2	353.1
1994	0	0	0		549.7	11.0	560.7		3067.1	2335.5	5402.7		0.4	0.3	0.7		15.0	12.4	27.4
1995	0	0	0		136.9	5.8	142.7		83.1	1087.9	1171.0		0.2	0.3	0.4		64.5	60.5	125.0
1996	0.058	0.041	0.099		9.2	10.4	19.6		386.0	52.6	438.6		0.2	0	0.2		19.7	12.7	32.4
1997	0.066	0.057	0.123		26.7	341.4	368.2		220.7	0.1	220.8		1.7	0.4	2.1		33.6	14.5	48.1
1998	0.064	0.044	0.108		2.0	0	2.0		322.0	14.2	336.2		0.3	0.2	0.5		2.5	12.5	15.0
1999	0.049	0.023	0.072		0	18.9	18.9		3461.8	29.5	3491.4		0.9	0	0.9		22.1	18.5	40.6
2000	0.033	0.028	0.061		7.4	1.9	9.4		29.7	161.2	190.9		7.6	0	7.6		80.2	44.7	124.9
2001	0.046	0.046	0.092		2.9	0.3	3.2		25.3	152.0	177.4		0	0	0		6.1	5.7	11.8
2002	0	0	0		5.9	1.3	7.2		160.5	96.8	257.3		0.4	0	0.4		11.4	3.6	14.9
2003	0	0	0		3.8	11.0	14.8		137.2	515.7	652.9		1.2	0.0	1.3		1.7	5.2	7.0
2004	0	0	0		25.2	63.9	89.1		380.4	760.5	1141.0		0.4	0	0.4		4.5	9.0	13.5
2005	0	0	0		19.5	31.2	50.7		825.6	685.9	1511.5		0.1	0.2	0.2		3.4	8.4	11.8
2006	0.045	0.028	0.073		8.9	15.7	24.5		95.7	28.0	123.7		0.0	0	0.0		1.0	11.2	12.2
2007	0.140	0.190	0.331		8.0	13.5	21.5		47.5	53.8	101.3		0	0	0		5.3	3.5	8.8
2008	0.165	0.160	0.325		12.6	12.1	24.7		713.7	299.3	1013.1		0.0	0	0.0		3.7	3.5	7.2
2009	0.121	0.209	0.330		33.2	24.9	58.2		185.9	562.2	748.1		0.1	0.0	0.1		14.5	6.3	20.8

Table D23. Number of discarded offshore hake sampled in all gears from the FOP in the northern region.

	Large Mesh Trawl			Sink Gill Net			
	Half 2			Half 1		Half 2	
Year	ntrips	numlen		ntrips	numlen	ntrips	numlen
2002				1	19		
2004	1	1					
2005	2	3				1	1
2006	1	9					
2009	1	1					

Table D24. Number of discarded offshore hake sampled in all gears from the FOP in the southern region.

	Large Mesh Trawl		Small Mesh Trawl				Scallop Dredge	
	Half 1		Half 1		Half 2		Half 1	
Year	ntrips	numlen	ntrips	numlen	ntrips	numlen	ntrips	numlen
1997					1	7		
2001	1	1						
2002								
2004					1	8	1	3
2007								
2009			1	1	1	1		

Table D25. Number of discarded silver hake sampled from the FOP in the northern region by gear type.

	Large Mesh				Small Mesh				Sink Gill Net				Scallop Dredge				Shrimp Trawl			
	Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2		Half 1		Half 2	
	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len	trips	len
1989	2	213	10	779	3	1543	23	6445	-	-	-	-	-	-	-	-	16	3590	4	546
1990	-	-	5	362	1	84	7	1130	1	4	-	-	-	-	-	-	8	1221	-	-
1991	1	31	1	150	-	-	27	8063	2	5	4	10	-	-	-	-	8	1055	-	-
1992	1	1	-	-	1	100	19	3888	4	24	5	22	-	-	-	-	-	-	-	-
1993	2	222	1	70	-	-	2	371	2	19	2	7	-	-	-	-	13	2383	2	224
1994	-	-	1	11	-	-	-	-	-	-	6	63	-	-	1	1	9	446	2	459
1995	3	32	1	48	-	-	1	81	1	1	-	-	-	-	-	-	4	404	5	728
1996	1	1	-	-	-	-	4	343	1	3	3	31	-	-	-	-	9	470	1	149
1997	1	1	2	66	1	20	-	-	-	-	-	-	-	-	1	1	9	739	-	-
1998	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
1999	-	-	-	-	-	-	9	218	1	2	6	85	-	-	-	-	-	-	-	-
2000	-	-	-	-	-	-	-	-	6	60	2	22	-	-	-	-	-	-	-	-
2001	-	-	1	14	-	-	-	-	2	2	2	3	-	-	-	-	-	-	-	-
2002	-	-	11	265	-	-	9	542	3	4	3	7	-	-	-	-	-	-	-	-
2003	13	565	13	255	-	-	5	241	11	229	12	39	-	-	1	113	5	372	-	-
2004	4	9	23	749	1	5	9	325	6	12	22	65	-	-	-	-	3	284	-	-
2005	13	105	17	259	2	5	9	97	1	1	10	66	-	-	1	2	2	66	-	-
2006	9	69	5	30	-	-	4	1028	1	1	1	1	-	-	-	-	-	-	-	-
2007	9	127	15	195	-	-	2	733	3	14	3	4	-	-	-	-	4	444	-	-
2008	5	155	16	255	-	-	1	144	6	7	6	62	1	3	-	-	6	206	-	-
2009	7	34	16	260	-	-	3	180	3	15	1	1	-	-	-	-	-	-	-	-

Table D26. Number of discarded silver hake sampled from the FOP in the southern region by gear type.

	Large Mesh					Small Mesh					Sink Gill Net					Scallop Dredge			
	Half 1		Half 2			Half 1		Half 2			Half 1		Half 2			Half 1		Half 2	
Year	trips	len	trips	len		trips	len	trips	len		trips	len	trips	len		trips	len	trips	len
1989	2	40	1	150		12	2265	10	1659		-	-	-	-		-	-	-	-
1990	2	399	-	-		8	2090	2	95		-	-	-	-		-	-	-	-
1991	-	-	2	29		5	657	7	860		-	-	-	-		-	-	-	-
1992	-	-	-	-		1	20	5	459		1	1	-	-		-	-	-	-
1993	1	127	-	-		-	-	-	-		1	12	-	-		1	2	-	-
1994	2	49	-	-		1	20	5	239		-	-	-	-		2	5	2	6
1995	1	3	1	11		2	73	-	-		-	-	1	3		4	50	-	-
1996	-	-	-	-		4	290	8	494		2	2	-	-		2	31	3	17
1997	-	-	1	216		7	371	1	2		7	69	1	4		2	112	1	1
1998	-	-	-	-		3	656	-	-		-	-	-	-		-	-	-	-
1999	-	-	-	-		2	309	4	97		-	-	-	-		1	2	-	-
2000	-	-	1	19		1	198	3	88		-	-	-	-		3	456	1	1
2001	-	-	-	-		2	160	3	13		-	-	-	-		-	-	-	-
2002	-	-	-	-		3	139	-	-		-	-	-	-		-	-	-	-
2003	-	-	2	2		3	76	3	40		1	2	-	-		2	3	4	140
2004	6	150	16	359		6	293	24	2007		2	4	-	-		1	17	15	224
2005	9	118	12	471		15	1191	11	1346		-	-	-	-		-	-	5	53
2006	7	48	4	24		10	762	15	764		-	-	-	-		-	-	1	1
2007	3	13	7	106		7	130	14	479		-	-	-	-		4	13	2	10
2008	6	38	10	110		6	580	12	626		-	-	-	-		4	31	7	36
2009	2	19	1	1		10	832	30	1998		1	1	-	-		12	91	6	37

Table D27. Pooling of silver/offshore hake observer length samples to estimate length and species composition of the commercial discards by gear from the north.

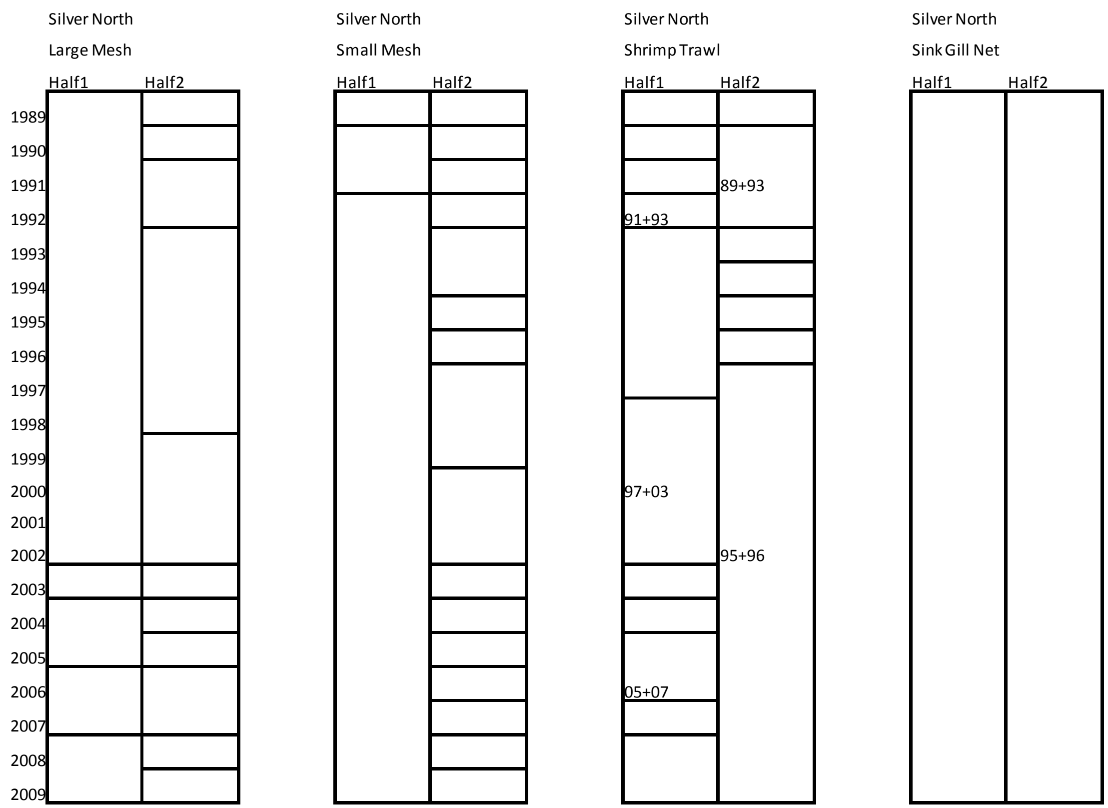


Table D28. Pooling of silver/offshore hake observer length samples to estimate length and species composition of the commercial discards by gear from the south.

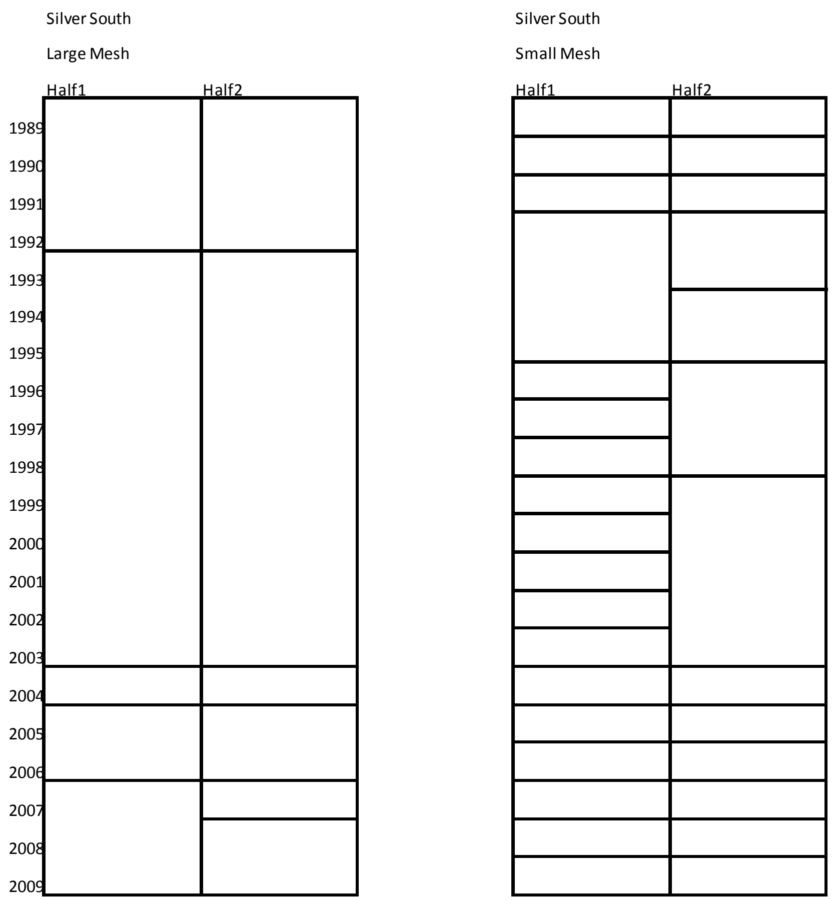


Table D29. Comparison of alternative methods of discard estimation for offshore hake.

Year	Nominal Discards (mt)	Length-Based Estimates (mt)
1981	0	100.3
1982	0	133.2
1983	0	137.8
1984	0	139.8
1985	0	110.8
1986	0	124.0
1987	0	121.7
1988	0	128.7
1989	0	69.6
1990	0	221.0
1991	0	152.7
1992	0	33.7
1993	0	78.1
1994	0	55.2
1995	0.1	37.3
1996	0	12.2
1997	3.3	18.7
1998	173.9	1.7
1999	1.7	5.1
2000	1.1	5.4
2001	10.0	14.5
2002	146.2	16.4
2003	2.2	74.7
2004	4.9	46.2
2005	6.4	5.0
2006	4.5	3.7
2007	20.6	6.8
2008	1.1	13.1
2009	25.7	14.2

Table D30. Negative log-likelihood, number of model parameters, AIC_c measures for beta-binomial models with the specified relationship of the calibration factor to length fit to **silver hake** catch data from the 2008 *Albatross IV/Henry B. Bigelow* calibration experiment.

Model	Model	-LL	# parameters	AIC_c	$\Delta(AIC_c)$	AIC_c Weights
1	All stations, constant (no length effect)	9341.745	2	18687.49	494.4465	0
2	Survey, S-S, constant	9322.744	4	18653.49	460.4489	0
3	S,F,S-S, constant model	9305.244	6	18622.5	429.4549	0
4	All stations, logistic model	9186.488	5	18382.99	189.9405	0
5	Survey, S-S logistic	9163.663	10	18347.36	154.3148	0
6	S, F, S-S, logistic	9146.738	15	18323.55	130.5072	0
7	All stations, double logistic model	9115.248	8	18246.52	53.4731	0
8	Survey, S-S, double-logistic model	9089.773	16	18211.63	18.5858	1.00E-04
9	S,F,S-S, double-logistic model	9073.961	24	18196.11	3.0675	0.1774
10	Spring logistic model	9076.506	21	18195.16	2.1138	NA
11	No minimum of ascending logistic for Fall	9073.981	23	18194.14	1.0926	NA
12	No minima for ascending or descending logistic for Fall	9074.917	22	18194	0.9499	NA
13	Spring logistic, no minima for ascending or descending logistic for Fall	9076.527	19	18193.05	0	0.8225

Table D31. The 3-year moving average of the stratified mean number per tow, stratified mean weight per tow (kg), swept area abundance (millions of fish), and swept area biomass (kg) of offshore hake for the NEFSC fall survey.

Year	Stratified Mean Number per Tow	Stratified Mean Weight per Tow (kg)	Swept Area Abundance (millions)	Swept Area Biomass (mt)
1967				
1968				
1969	0.52	0.15	0.21	59.76
1970	0.58	0.15	0.24	60.02
1971	0.48	0.10	0.19	41.94
1972	1.33	0.29	0.54	117.68
1973	1.29	0.29	0.53	116.74
1974	1.54	0.34	0.63	138.24
1975	0.80	0.20	0.33	80.79
1976	1.15	0.37	0.47	149.72
1977	1.22	0.41	0.50	167.91
1978	1.64	0.50	0.67	204.73
1979	1.39	0.37	0.57	153.00
1980	1.26	0.36	0.51	148.75
1981	1.34	0.66	0.55	267.61
1982	1.15	0.59	0.47	241.92
1983	1.09	0.53	0.45	216.53
1984	0.40	0.09	0.16	38.45
1985	0.76	0.24	0.31	98.51
1986	0.86	0.28	0.35	114.87
1987	0.97	0.31	0.39	126.13
1988	0.62	0.19	0.25	77.40
1989	0.54	0.17	0.22	70.06
1990	1.04	0.24	0.42	96.59
1991	1.13	0.24	0.45	98.23
1992	1.03	0.23	0.41	90.58
1993	0.42	0.13	0.17	52.74
1994	0.29	0.09	0.12	35.96
1995	0.35	0.09	0.14	35.48
1996	0.35	0.09	0.14	35.98
1997	0.42	0.12	0.17	49.17
1998	0.41	0.10	0.17	41.81
1999	0.37	0.07	0.15	30.47
2000	0.34	0.05	0.14	21.46
2001	1.00	0.18	0.41	74.04
2002	1.25	0.24	0.51	98.14
2003	1.74	0.41	0.70	164.87
2004	1.00	0.27	0.41	108.43
2005	0.73	0.21	0.30	85.08
2006	0.48	0.08	0.19	31.59
2007	0.91	0.16	0.37	64.22
2008	1.05	0.18	0.43	74.66

Table D32. The 3-year moving average of the stratified mean number per tow, stratified mean weight per tow (kg), swept area abundance (millions of fish), and swept area biomass (kg) of offshore hake for the NEFSC spring survey.

Year	Stratified Mean Number per Tow	Stratified Mean Weight per Tow (kg)	Swept Area Abundance (millions)	Swept Area Biomass (mt)
1967				
1968				
1969				
1970	0.33	0.15	0.13	62.21
1971	0.40	0.18	0.16	74.96
1972	0.67	0.30	0.28	121.19
1973	1.40	0.47	0.57	193.93
1974	2.12	0.78	0.87	317.51
1975	2.45	0.84	1.00	340.85
1976	3.01	0.88	1.22	358.84
1977	3.15	0.77	1.28	310.76
1978	3.11	1.01	1.27	413.92
1979	3.91	1.27	1.60	520.99
1980	6.12	2.57	2.50	1053.01
1981	6.67	2.40	2.71	976.59
1982	4.92	2.01	2.00	816.40
1983	2.04	0.58	0.82	232.95
1984	0.99	0.34	0.40	139.95
1985	0.90	0.33	0.37	133.32
1986	0.90	0.36	0.37	149.19
1987	1.14	0.50	0.47	202.66
1988	0.78	0.37	0.32	151.99
1989	0.63	0.32	0.26	129.27
1990	0.42	0.21	0.17	84.70
1991	0.99	0.36	0.40	148.19
1992	1.04	0.35	0.42	140.42
1993	1.00	0.31	0.40	122.67
1994	0.39	0.12	0.15	44.88
1995	0.25	0.05	0.10	18.75
1996	0.21	0.04	0.08	16.10
1997	0.24	0.05	0.10	20.03
1998	0.18	0.06	0.07	23.67
1999	0.14	0.05	0.06	20.85
2000	0.18	0.07	0.07	29.94
2001	0.37	0.10	0.15	41.07
2002	0.88	0.20	0.36	82.92
2003	1.04	0.24	0.43	98.02
2004	1.03	0.24	0.42	97.46
2005	0.52	0.14	0.21	58.13
2006	0.29	0.07	0.12	29.21
2007	0.53	0.10	0.22	39.39
2008	0.62	0.10	0.25	42.21

Year	Stratified Mean Number/Tow	Upper CI Mean Number/Tow	Lower CI Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Upper CI Mean Weight/Tow (Kg)	Lower CI Mean Weight/Tow (Kg)	Average Individual Weight (Kg)	Stratified Mean Temp. (C)	Stratified Mean Depth (M)
1967	0.36	0.49	0.24	0.11	0.20	0.01	0.30	10.02	156.14
1968	0.63	0.99	0.26	0.19	0.30	0.09	0.31	10.79	176.57
1969	0.58	0.91	0.26	0.14	0.24	0.03	0.23	10.51	172.51
1970	0.52	0.92	0.13	0.11	0.19	0.03	0.21	10.51	168.30
1971	0.32	0.54	0.10	0.06	0.10	0.02	0.19	11.49	170.69
1972	3.14	5.49	0.79	0.69	0.96	0.42	0.22	11.34	174.24
1973	0.42	0.66	0.18	0.10	0.16	0.05	0.25	12.11	168.10
1974	1.06	1.91	0.21	0.22	0.33	0.11	0.21	11.61	182.36
1975	0.93	1.25	0.60	0.27	0.35	0.19	0.29	11.28	171.13
1976	1.46	2.05	0.87	0.61	0.91	0.31	0.42	11.49	170.26
1977	1.28	2.04	0.52	0.35	0.53	0.17	0.28	11.92	169.88
1978	2.18	3.35	1.02	0.54	0.87	0.21	0.25	10.71	166.92
1979	0.71	1.17	0.25	0.23	0.36	0.10	0.32	12.01	161.71
1980	0.88	1.61	0.16	0.33	0.61	0.04	0.37	11.54	163.90
1981	2.44	3.06	1.81	1.41	2.28	0.54	0.58	9.88	178.81
1982	0.13	0.26	0.00	0.04	0.08	0.01	0.32	11.05	171.40
1983	0.70	0.98	0.42	0.14	0.18	0.10	0.19	10.91	163.17
1984	0.36	0.48	0.24	0.11	0.15	0.06	0.30	11.84	176.85
1985	1.22	2.57	-0.14	0.48	1.05	-0.09	0.40	6.80	163.89
1986	1.00	1.49	0.51	0.26	0.39	0.12	0.26	7.61	175.11
1987	0.68	0.89	0.47	0.19	********	********	0.28	5.79	176.25
1988	0.19	0.19	0.19	0.12	0.12	0.12	0.65	7.91	167.11
1989	0.76	0.76	0.76	0.20	0.20	0.20	0.27	3.75	161.57
1990	2.15	2.33	1.97	0.39	0.41	0.37	0.18	4.96	174.66
1991	0.47	0.47	0.47	0.14	0.14	0.14	0.29	11.19	158.24
1992	0.46	0.52	0.39	0.15	********	********	0.33	11.91	161.25
1993	0.32	0.50	0.15	0.11	********	********	0.33	11.66	169.89
1994	0.09	0.09	0.09	0.01	0.01	0.01	0.15	11.65	164.73
1995	0.64	0.83	0.44	0.14	0.18	0.10	0.22	12.05	158.05
1996	0.33	0.53	0.12	0.11	0.17	0.05	0.33	9.52	160.96
1997	0.29	0.29	0.29	0.11	0.11	0.11	0.38	11.82	168.27
1998	0.62	0.96	0.27	0.09	********	********	0.14	10.61	156.06
1999	0.19	0.19	0.19	0.03	0.03	0.03	0.13	12.72	162.74
2000	0.21	0.30	0.12	0.04	0.07	0.02	0.21	12.00	154.15
2001	2.61	**********	**********	0.48	0.52	0.44	0.18	11.09	159.32
2002	0.92	0.92	0.92	0.20	0.20	0.20	0.22	11.26	174.43
2003	1.68	1.78	1.59	0.54	**********	********	0.32	11.32	179.30
2004	0.40	0.43	0.36	0.06	0.07	0.05	0.15	10.81	169.33
2005	0.12	0.12	0.12	0.03	0.03	0.03	0.27	11.54	157.59
2006	0.91	2.13	-0.31	0.14	0.27	0.02	0.16	11.75	164.60
2007	1.69	1.75	1.63	0.30	**********	********	0.18	10.05	164.87
2008	0.55	0.78	0.33	0.11	0.17	0.04	0.19	10.54	164.32
2009	1.53			0.14				11.92	167.17

Table D33. Stratified mean number and weight per tow upper and lower confidence intervals, mean individual weight, mean temperature, and mean depth for offshore hake from the NEFSC fall bottom trawl surveys (strata 3-4, 7-8, 11-12, 14-15, 17-18, 63-64, 67-68, 71-72, 75-76). Values from 2009 were converted to Albatross units.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1967	4583	0.15	0.20	0.10	44.40	83.84	4.95
1968	4583	0.26	0.41	0.11	79.55	123.99	35.11
1969	4583	0.24	0.37	0.10	55.32	98.70	11.91
1970	4583	0.21	0.38	0.05	45.18	76.36	13.95
1971	4583	0.13	0.22	0.04	25.33	42.76	7.86
1972	4583	1.29	2.25	0.32	282.55	394.26	170.88
1973	4583	0.17	0.27	0.07	42.35	64.82	19.85
1974	4583	0.43	0.78	0.09	89.82	134.46	45.13
1975	4583	0.38	0.51	0.24	110.20	143.46	76.97
1976	4583	0.60	0.84	0.36	249.16	371.51	126.81
1977	4583	0.52	0.84	0.21	144.36	218.06	70.67
1978	4583	0.89	1.37	0.42	220.68	355.96	85.40
1979	4583	0.29	0.48	0.10	93.95	147.76	40.10
1980	4523	0.36	0.65	0.06	131.61	245.57	17.61
1981	4583	1.00	1.25	0.74	577.25	932.11	222.44
1982	4583	0.05	0.11	0.00	16.90	30.81	2.99
1983	4583	0.29	0.40	0.17	55.45	72.02	38.87
1984	4497	0.14	0.19	0.10	43.00	60.67	25.38
1985	4583	0.50	1.05	-0.06	197.07	429.04	-34.95
1986	4583	0.41	0.61	0.21	104.55	159.50	49.55
1987	4531	0.27	0.36	0.19	76.78	********	********
1988	4583	0.08	0.08	0.08	50.86	50.86	50.86
1989	4583	0.31	0.31	0.31	82.53	82.53	82.53
1990	4478	0.86	0.93	0.79	156.37	163.25	149.53
1991	4583	0.19	0.19	0.19	55.77	55.77	55.77
1992	4426	0.18	0.21	0.16	59.59	********	********
1993	4523	0.13	0.20	0.06	42.85	********	********
1994	4583	0.04	0.04	0.04	5.44	5.44	5.44
1995	4583	0.26	0.34	0.18	58.15	73.70	42.60
1996	4583	0.13	0.22	0.05	44.36	69.89	18.82
1997	4583	0.12	0.12	0.12	45.01	45.01	45.01
1998	4583	0.25	0.39	0.11	36.05	********	********
1999	4583	0.08	0.08	0.08	10.35	10.35	10.35
2000	4583	0.08	0.12	0.05	17.96	28.97	6.92
2001	4523	1.06	********	********	193.80	211.73	175.83
2002	4583	0.38	0.38	0.38	82.66	82.66	82.66
2003	4523	0.68	0.72	0.64	218.15	********	********
2004	4583	0.16	0.18	0.15	24.47	28.15	20.79
2005	4418	0.05	0.05	0.05	12.62	12.62	12.62
2006	4531	0.37	0.86	-0.12	57.69	108.18	7.24
2007	4583	0.69	0.72	0.67	122.35	********	********
2008	4583	0.23	0.32	0.13	43.95	69.56	18.29
2009	4583	0.63			56.11		

Table D34. Swept area abundance and biomass and upper and lower confidence intervals for offshore hake from the NEFSC fall bottom trawl surveys (strata 3-4, 7-8, 11-12, 14-15, 17-18, 63-64, 67-68, 71-72, 75-76). Values from 2009 were converted to Albatross units.

Year	Stratified Mean Number/Tow	Upper CI Mean Number/Tow	Lower CI Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Upper CI Mean Weight/Tow (Kg)	Lower CI Mean Weight/Tow (Kg)	Average Individual Weight (Kg)	Stratified Mean Temp. (C)	Stratified Mean Depth (M)
1968	0.15	0.28	0.02	0.06	0.11	0.01	0.42	9.49	165.47
1969	0.17	0.35	-0.02	0.11	0.22	0.01	0.69	10.40	176.23
1970	0.66	1.10	0.22	0.28	0.44	0.12	0.42	10.87	171.62
1971	0.37	0.82	-0.08	0.16	0.35	-0.04	0.42	10.05	175.33
1972	0.99	1.32	0.67	0.45	0.57	0.34	0.46	10.95	176.25
1973	2.83	3.96	1.69	0.81	1.23	0.40	0.29	11.11	160.33
1974	2.53	3.11	1.95	1.06	1.42	0.70	0.42	11.33	170.11
1975	2.00	2.46	1.54	0.65	0.79	0.50	0.32	9.76	163.80
1976	4.50	6.73	2.27	0.94	1.23	0.66	0.21	11.02	172.08
1977	2.95	4.23	1.67	0.71	0.92	0.50	0.24	9.66	172.70
1978	1.88	2.91	0.85	1.38	2.06	0.70	0.73	7.95	161.57
1979	6.90	10.54	3.26	1.73	2.49	0.97	0.25	10.75	153.45
1980	9.58	15.07	4.08	4.61	8.00	1.22	0.48	10.74	164.49
1981	3.55	5.53	1.57	0.85	1.65	0.05	0.24	10.18	155.33
1982	1.65	2.27	1.02	0.55	0.79	0.32	0.34	5.91	166.43
1983	0.93	1.56	0.31	0.33	0.55	0.12	0.36	10.98	175.39
1984	0.39	0.65	0.12	0.14	0.26	0.02	0.36	10.47	163.45
1985	1.38	2.74	0.03	0.51	0.93	0.08	0.37	9.41	163.70
1986	0.93	1.49	0.37	0.45	0.76	0.14	0.48	7.92	177.24
1987	1.12	1.66	0.59	0.53	0.90	0.16	0.47	10.44	172.50
1988	0.27	0.27	0.27	0.14	0.14	0.14	0.50	10.08	179.51
1989	0.49	0.49	0.49	0.28	0.28	0.28	0.58	7.10	167.67
1990	0.50	0.50	0.50	0.21	0.21	0.21	0.42	9.12	168.65
1991	1.97	4.06	-0.12	0.60	1.12	0.08	0.30	11.26	166.32
1992	0.66	0.71	0.61	0.24	********	********	0.36	11.19	163.58
1993	0.36	0.36	0.36	0.08	0.08	0.08	0.21	10.33	157.48
1994	0.14	0.23	0.05	0.03	0.06	0.00	0.22	11.78	157.77
1995	0.24	0.42	0.06	0.03	0.06	0.01	0.14	12.41	164.97
1996	0.24	0.52	-0.04	0.05	0.12	-0.01	0.22	10.38	165.57
1997	0.24	0.34	0.15	0.06	0.08	0.04	0.26	11.11	148.75
1998	0.05	0.05	0.05	0.06	0.06	0.06	1.20	8.12	158.28
1999	0.13	0.22	0.04	0.03	********	********	0.26	11.44	160.65
2000	0.35	0.77	-0.07	0.13	0.23	0.02	0.36	11.85	154.41
2001	0.63	0.66	0.60	0.14	0.14	0.14	0.22	11.11	154.97
2002	1.67	2.02	1.33	0.34	********	********	0.20	11.96	170.39
2003	0.81	0.81	0.81	0.24	0.24	0.24	0.29	8.69	161.19
2004	0.60	0.60	0.60	0.14	0.14	0.14	0.23	8.52	173.98
2005	0.15	0.15	0.15	0.05	0.05	0.05	0.35	9.45	170.79
2006	0.11	0.11	0.11	0.02	0.02	0.02	0.22	11.53	160.94
2007	1.32	1.66	0.98	0.21	0.25	0.18	0.16	9.56	171.19
2008	0.42	0.42	0.42	0.07	0.07	0.07	0.17	10.71	163.60
2009	0.42			0.08				11.26	168.78
2010	0.70			0.07					153.66

Table D35. Stratified mean number and weight per tow upper and lower confidence intervals, mean individual weight, mean temperature, and mean depth for offshore hake from the NEFSC spring bottom trawl surveys (strata 3-4, 7-8, 11-12, 14-15, 17-18, 63-64, 67-68, 71-72, 75-76). Values from 2009 and 2010 were converted to Albatross units.

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1968	4583	0.06	0.11	0.01	25.45	45.54	5.36
1969	4583	0.07	0.14	-0.01	47.02	88.02	5.97
1970	4583	0.27	0.45	0.09	114.17	179.76	48.61
1971	4583	0.15	0.33	-0.03	63.71	142.60	-15.18
1972	4583	0.41	0.54	0.27	185.69	232.38	139.00
1973	4583	1.16	1.62	0.69	332.39	502.58	162.21
1974	4583	1.04	1.27	0.80	434.44	582.90	285.99
1975	4437	0.79	0.98	0.61	255.72	313.88	197.60
1976	4583	1.84	2.75	0.93	386.36	504.13	268.60
1977	4583	1.21	1.73	0.68	290.20	377.32	203.13
1978	4583	0.77	1.19	0.35	565.18	844.58	285.74
1979	4583	2.82	4.31	1.33	707.58	1018.74	396.43
1980	4583	3.92	6.16	1.67	1886.27	3272.02	500.57
1981	4411	1.40	2.18	0.62	335.91	651.06	20.76
1982	4583	0.67	0.93	0.42	227.02	322.24	131.80
1983	4583	0.38	0.64	0.13	135.94	224.16	47.71
1984	4583	0.16	0.27	0.05	56.88	107.33	6.42
1985	4583	0.57	1.12	0.01	207.14	380.59	33.68
1986	4583	0.38	0.61	0.15	183.57	311.36	55.77
1987	4583	0.46	0.68	0.24	217.28	367.05	67.48
1988	4478	0.11	0.11	0.11	55.14	55.14	55.14
1989	4583	0.20	0.20	0.20	115.39	115.39	115.39
1990	4411	0.20	0.20	0.20	83.57	83.57	83.57
1991	4583	0.81	1.66	-0.05	245.60	459.24	31.92
1992	4347	0.25	0.27	0.24	92.10	********	********
1993	4347	0.14	0.14	0.14	30.31	30.31	30.31
1994	4407	0.06	0.09	0.02	12.24	23.25	1.26
1995	4583	0.10	0.17	0.02	13.71	24.76	2.66
1996	4583	0.10	0.21	-0.01	22.34	48.24	-3.60
1997	4302	0.09	0.13	0.06	24.05	31.38	16.67
1998	4523	0.02	0.02	0.02	24.63	24.63	24.63
1999	4583	0.05	0.09	0.02	13.87	********	********
2000	4583	0.14	0.31	-0.03	51.31	94.03	8.59
2001	4583	0.26	0.27	0.25	58.02	58.47	57.57
2002	4583	0.68	0.83	0.54	139.41	********	********
2003	4583	0.33	0.33	0.33	96.61	96.61	96.61
2004	4583	0.25	0.25	0.25	56.35	56.35	56.35
2005	4583	0.06	0.06	0.06	21.44	21.44	21.44
2006	4523	0.04	0.04	0.04	9.85	9.85	9.85
2007	4583	0.54	0.68	0.40	86.87	100.38	73.37
2008	4583	0.17	0.17	0.17	29.91	29.91	29.91
2009	4497	0.169			34.120		
2010	4583	0.287			30.146		

Table D36. Swept area abundance and biomass and upper and lower confidence intervals for offshore hake from the NEFSC spring bottom trawl surveys (strata 3-4, 7-8, 11-12, 14-15, 17-18, 63-64, 67-68, 71-72, 75-76). Values from 2009 and 2010 were converted to Albatross units.

Year	Stratified Mean Number/Tow	Upper CI Mean Number/Tow	Lower CI Mean Number/Tow	Stratified Mean Weight/Tow (Kg)	Upper CI Mean Weight/Tow (Kg)	Lower CI Mean Weight/Tow (Kg)	Average Individual Weight (Kg)	Stratified Mean Temp. (C)	Stratified Mean Depth (M)
1998	4.81	5.45	4.16	0.44	0.49	0.40	0.09	9.26	155.76
1999	3.01	3.01	3.01	0.51	0.51	0.51	0.17	12.77	154.76
2000	3.73	3.78	3.69	0.50	0.50	0.49	0.13	11.63	142.45
2001	15.74	22.80	8.68	2.99	4.12	1.86	0.19	11.45	166.84
2002	7.17	15.53	-1.18	1.67	4.53	-1.19	0.23	12.42	161.12
2003	8.78	15.18	2.39	1.87	3.29	0.46	0.21	9.35	167.52
2004	8.89	16.06	1.72	1.77	3.76	-0.21	0.20	9.37	167.41
2005	19.68	23.46	15.89	2.76	3.18	2.35	0.14	10.66	169.88
2006	3.84	6.49	1.19	0.73	1.28	0.18	0.19	12.17	163.54
2007	17.32	29.42	5.22	2.47	4.27	0.68	0.14	10.60	165.44

Table D37. Stratified mean number and weight per tow upper and lower confidence intervals, mean individual weight, mean temperature, and mean depth for offshore hake from the NEFSC winter flatfish surveys (strata 3-4, 7-8, 11-12, 63-64, 67-68, 71-72, 75-76).

Year	Swept Area (nm)	Swept Area Abundance (millions)	Swept Area Upper CI	Swept Area Lower CI	Swept Area Biomass (mt)	Swept Area Upper CI	Swept Area Lower CI
1998	2977	1.28	1.45	1.11	117.70	130.35	105.05
1999	3165	0.85	0.85	0.85	145.14	145.14	145.14
2000	2759	0.92	0.93	0.91	122.41	123.91	120.88
2001	3165	4.45	6.44	2.45	845.17	1165.57	524.74
2002	3105	1.99	4.30	-0.33	462.34	1254.48	-329.82
2003	3165	2.48	4.29	0.67	529.52	930.48	128.58
2004	3165	2.51	4.54	0.49	501.03	1062.65	-60.59
2005	3105	5.46	6.50	4.41	766.44	881.71	651.19
2006	3165	1.08	1.83	0.34	206.40	361.71	51.09
2007	3165	4.89	8.31	1.47	698.96	1205.98	191.91

Table D38. Swept area abundance and biomass and upper and lower confidence intervals for offshore hake from the NEFSC winter flatfish surveys (strata 3-4, 7-8, 11-12, 63-64, 67-68, 71-72, 75-76).

year	fall n	spring n	winter n	3yr fall n	3yr spring n
1967	24				
1968	71	13			
1969	47	11		47	
1970	39	50		52	25
1971	27	27		38	29
1972	226	81		97	53
1973	33	360		95	156
1974	76	175		112	205
1975	90	112		66	216
1976	118	448		95	245
1977	101	272		103	277
1978	164	144		128	288
1979	48	475		104	297
1980	58	545		90	388
1981	153	171		86	397
1982	16	149		76	288
1983	70	77		80	132
1984	24	26		37	84
1985	65	56		53	53
1986	95	70		61	51
1987	20	103		60	76
1988	7	6		41	60
1989	31	17		19	42
1990	78	14		39	12
1991	14	47		41	26
1992	12	16		35	26
1993	7	11		11	25
1994	4	7		8	11
1995	34	12		15	10
1996	12	14		17	11
1997	8	8		18	11
1998	18	1	123	13	8
1999	7	5	56	11	5
2000	14	7	164	13	4
2001	85	22	824	35	11
2002	35	60	220	45	30
2003	54	24	448	58	35
2004	20	25	379	36	36
2005	10	5	435	28	18
2006	29	4	260	20	11
2007	55	90	1086	31	33
2008	22	20		35	38
2009	700	188			

Table D39. Sample sizes for offshore hake survey length frequencies and 3-year moving average length frequencies.

Year	Fall Mean 20cm	Spring Mean 20cm	Winter Mean 20cm	Fall Sample Size	Spring Sample Size	Winter Sample Size
1967	31.56			9		
1968	31.67	32.89		11	5	
1969	30.58	41.46		9	4	
1970	28.04	37.14		8	9	
1971	31.46	39.12		10	8	
1972	29.76	37.50		21	19	
1973	30.09	31.63		11	11	
1974	30.10	36.44		15	19	
1975	31.37	33.65		15	22	
1976	37.47	29.98		14	15	
1977	33.32	32.39		17	14	
1978	33.03	44.63		11	10	
1979	34.22	32.86		8	10	
1980	36.89	38.16		8	15	
1981	36.65	34.23		17	7	
1982	32.21	36.48		4	18	
1983	27.72	34.59		10	12	
1984	34.48	35.69		11	10	
1985	36.23	35.80		7	10	
1986	33.20	38.45		11	12	
1987	30.27	37.49		7	13	
1988	40.12	38.43		5	3	
1989	31.29	40.35		7	4	
1990	29.29	36.10		7	3	
1991	33.60	33.28		6	5	
1992	36.24	33.91		5	5	
1993	36.09	30.61		4	4	
1994	22.53	30.57		3	4	
1995	29.50	26.96		5	4	
1996	34.65	31.25		6	4	
1997	35.35	31.67		3	5	
1998	25.72	51.00	24.51	4	1	5
1999	27.25	34.97	28.90	2	2	4
2000	30.33	36.71	26.21	3	4	4
2001	27.72	31.25	28.99	7	8	21
2002	30.52	29.47	30.40	6	7	12
2003	32.99	32.63	30.54	7	5	11
2004	28.74	32.32	29.06	5	6	11
2005	32.40	34.21	26.29	1	4	10
2006	26.68	31.97	30.99	7	2	12
2007	28.38	28.23	27.05	8	13	15
2008	29.17	28.79		9	4	
2009	24.92	31.00		17	19	
2010		25.54			10	

Table D40. Mean lengths and sample sizes for fall, spring and winter surveys, as used for input into the SEINE model (base runs). Values from 2009 and 2010 were converted to Albatross units.

Year	Fall Mean 17cm	Fall Mean 23cm	Fall Sample Size
1967	31.56	31.56	9
1968	31.38	31.78	11
1969	30.16	31.21	9
1970	27.80	32.31	8
1971	30.33	31.81	10
1972	29.03	31.81	21
1973	29.75	31.33	11
1974	29.36	32.89	15
1975	30.96	32.24	15
1976	36.93	37.74	14
1977	32.86	34.09	17
1978	30.46	35.96	11
1979	33.91	34.70	8
1980	33.58	37.22	8
1981	36.46	37.11	17
1982	32.21	33.33	4
1983	27.72	27.93	10
1984	34.48	34.48	11
1985	36.23	36.23	7
1986	32.78	33.49	11
1987	30.27	30.27	7
1988	40.12	40.12	5
1989	31.29	32.33	7
1990	28.36	30.93	7
1991	33.60	33.60	6
1992	36.24	36.24	5
1993	36.09	36.09	4
1994	22.53	23.73	3
1995	29.50	30.12	5
1996	34.65	34.65	6
1997	35.35	35.35	3
1998	25.72	27.45	4
1999	27.25	30.37	2
2000	30.33	30.87	3
2001	27.45	29.07	7
2002	30.52	30.52	6
2003	32.99	33.09	7
2004	26.56	29.70	5
2005	32.40	32.40	1
2006	26.68	27.62	7
2007	28.38	28.86	8
2008	29.17	29.55	9
2009	23.72	26.26	17

Table D41. Mean lengths and sample sizes for fall sensitivity analyses as used for input into the SEINE model.

		Growth Parameters						
Run#	Model	L_{inf}	K	L_{crit}	Cut Point	AIC	Liklihood	Comments
1	Fall BASE	43.91	0.33	20	1	327.81	159.91	silver hake average of SNE/SGB
1	Fall BASE	43.91	0.33	20	2	312.68	150.34	silver hake average of SNE/SGB
1	Fall BASE	43.91	0.33	20	3	311.35	147.68	silver hake average of SNE/SGB
2	Spring BASE	43.91	0.33	20	1	321.29	156.65	silver hake average of SNE/SGB
3	Winter BASE	43.91	0.33	20	1	70.75	31.38	silver hake average of SNE/SGB
4	Fall SENSITIVITY	43.78	0.28	20	1	315.57	153.79	silver hake SGB
4	Fall SENSITIVITY	43.78	0.28	20	2	312.98	150.49	silver hake SGB
4	Fall SENSITIVITY	43.78	0.28	20	3	311.29	147.64	silver hake SGB
5	Fall SENSITIVITY	43.78	0.28	23	1	304.08	148.04	silver hake SGB
5	Fall SENSITIVITY	43.78	0.28	23	2	303.33	145.66	silver hake SGB
5	Fall SENSITIVITY	43.78	0.28	23	3	299.51	141.76	silver hake SGB
6	Fall SENSITIVITY	43.78	0.28	17	1	315.04	153.59	silver hake SGB
7	Fall SENSITIVITY	44.04	0.37	20	1	315.57	153.78	silver hake SNE
7	Fall SENSITIVITY	44.04	0.37	20	2	312.43	150.22	silver hake SNE
8	Fall SENSITIVITY	44.04	0.37	23	1	304.09	148.05	silver hake SNE
8	Fall SENSITIVITY	44.04	0.37	23	2	303.11	145.56	silver hake SNE
8	Fall SENSITIVITY	44.04	0.37	23	3	300.39	142.19	silver hake SNE
9	Fall SENSITIVITY	44.04	0.37	17	1	317.29	154.64	silver hake SNE
9	Fall SENSITIVITY	44.04	0.37	17	2	315.07	151.53	silver hake SNE
9	Fall SENSITIVITY	44.04	0.37	17	3	313.35	148.68	silver hake SNE
10	Fall SENSITIVITY	70	0.174	20	1	289.41	140.70	offshore hake VB
10	Fall SENSITIVITY	70	0.174	20	2	280.79	134.39	offshore hake VB
10	Fall SENSITIVITY	70	0.174	20	3	274.62	129.31	offshore hake VB
10	Fall SENSITIVITY	70	0.174	20	4	255.13	117.57	offshore hake VB
11	Fall SENSITIVITY	70	0.174	23	1	304.01	148.01	offshore hake VB (z was over 1)
12	Fall SENSITIVITY	70	0.174	17	1	317.33	154.67	offshore hake VB
13	Fall SENSITIVITY	70	0.174	17	2	314.24	151.12	offshore hake VB (z was over 1 for 3-cut)

Table D42. SEINE base model results and sensitivity analyses for offshore hake. The highlighted values are the lowest AIC values calculated from the SEINE model runs and sensitivity analyses.

Table D43. Summary of catch, NEFSC fall and spring bottom trawl survey indices, replacement ratios and relative fishing mortality rates for offshore hake. Catch is based on method of Sosebee. Survey values from 2009 were converted to Albatross units.

		NEFSC Survey		Replacement Ratio		Relative Fishing Mortality	
Year	Catch(mt)	Fall (kg/tow)	Spring (kg/tow)	Fall	Spring	Relative F Fall (mt/kg)	Relative F Spring (mt/kg)
1963	3956.8	-999	-999				
1964	6506.4	-999	-999				
1965	13013.8	-999	-999				
1966	8951.9	-999	-999				
1967	3866.4	0.11	-999			35149.2	
1968	339.4	0.19	0.06			1786.1	5655.9
1969	670.3	0.14	0.11			4787.5	6093.2
1970	680.2	0.11	0.28			6183.9	2429.4
1971	1383.7	0.06	0.16			23061.6	8648.1
1972	6175.7	0.69	0.45	5.6557		8950.3	13723.8
1973	2514.8	0.1	0.81	0.4202	3.8208	25148.3	3104.7
1974	7467.5	0.22	1.06	1.0000	2.9282	33943.0	7044.8
1975	2088.7	0.27	0.65	1.1441	1.1775	7736.0	3213.4
1976	4132.8	0.61	0.94	2.2761	1.5016	6775.0	4396.6
1977	2148.1	0.35	0.71	0.9259	0.9079	6137.4	3025.5
1978	1298.0	0.54	1.38	1.7419	1.6547	2403.6	940.6
1979	1976.9	0.23	1.73	0.5779	1.8249	8595.2	1142.7
1980	1862.4	0.33	4.61	0.8250	4.2606	5643.7	404.0
1981	1497.6	1.41	0.85	3.4223	0.4536	1062.1	1761.9
1982	542.4	0.04	0.55	0.0699	0.2963	13560.8	986.2
1983	417.7	0.14	0.33	0.2745	0.1809	2983.7	1265.8
1984	328.1	0.11	0.14	0.2558	0.0867	2982.3	2343.2
1985	455.2	0.48	0.51	1.1823	0.3935	948.3	892.5
1986	549.8	0.26	0.45	0.5963	0.9454	2114.7	1221.8
1987	692.4	0.19	0.53	0.9223	1.3384	3644.0	1306.3
1988	373.9	0.12	0.14	0.5085	0.3571	3116.0	2670.9
1989	502.8	0.2	0.28	0.8621	0.7910	2514.0	1795.7
1990	811.2	0.39	0.21	1.5600	0.5497	2080.0	3862.8
1991	936.0	0.14	0.6	0.6034	1.8634	6685.8	1560.0
1992	494.1	0.15	0.24	0.7212	0.6818	3294.2	2058.9
1993	631.1	0.11	0.08	0.5500	0.2721	5737.6	7889.3
1994	147.8	0.01	0.03	0.0505	0.1064	14783.1	4927.7
1995	218.7	0.14	0.03	0.8750	0.1293	1562.4	7291.4
1996	506.2	0.11	0.05	1.0000	0.2551	4601.9	10124.2
1997	256.1	0.11	0.06	1.0577	0.6977	2328.2	4268.3
1998	276.8	0.09	0.06	0.9375	1.2000	3075.2	4612.8
1999	172.5	0.03	0.03	0.3261	0.6522	5748.8	5748.8
2000	307.6	0.04	0.13	0.4167	2.8261	7689.7	2366.1
2001	649.1	0.48	0.14	6.3158	2.1212	1352.3	4636.6
2002	479.2	0.2	0.34	1.3333	4.0476	2395.9	1409.4
2003	639.2	0.54	0.24	3.2143	1.7143	1183.8	2663.5
2004	540.4	0.06	0.14	0.2326	0.7955	9007.1	3860.2
2005	293.1	0.03	0.05	0.1136	0.2525	9768.9	5861.4
2006	85.4	0.14	0.02	0.5344	0.1099	609.9	4269.6
2007	296.3	0.3	0.21	1.5464	1.3291	987.6	1410.9
2008	97.0	0.11	0.07	0.5140	0.5303	881.4	1385.1
2009	156.4	0.14	0.08	1.0938	0.8671	1117.4	1840.9

Table D44. Summary of AIM results offshore hake, both stocks combined, for NEFSC fall and spring bottom trawl surveys and catch estimates based on Sosebee method.

Offshore Hake	***Fall Survey***	***Spring Survey***
Critical value (observed correlation between replacement ratio and relative F	-0.428349	-0.315118
Probability of observing correlation < Critical Value	0.903500	0.999500
Relative F at Replacement (mt/kg)	1963.39	1307.17
90% Confidence Interval for RelF at replacement	(660, 3347)	(125, 2177)

Year	Fall Swept Area Biomass (mt)	Spring Swept Area Biomass (mt)	Winter Swept Area Biomass (mt)	Length based Total Catch (mt)	Fall Exploitation Ratio (catch, mt)	Spring Exploitation Ratio (catch, mt)	Winter Exploitation Ratio (catch, mt)	Length based Landings (mt)	Fall Exploitation Ratio (landings, mt)	Spring Exploitation Ratio (landings, mt)	Winter Exploitation Ratio (landings, mt)
1967	44.40			3866.41	87.09			3866.41	87.09		
1968	79.55	25.45		339.35	4.27	13.33		339.35	4.27	13.33	
1969	55.32	47.02		670.25	12.12	14.26		670.25	12.12	14.26	
1970	45.18	114.17		680.23	15.06	5.96		680.23	15.06	5.96	
1971	25.33	63.71		1383.69	54.63	21.72		1383.69	54.63	21.72	
1972	282.55	185.69		6175.73	21.86	33.26		6175.73	21.86	33.26	
1973	42.35	332.39		2514.83	59.38	7.57		2514.83	59.38	7.57	
1974	89.82	434.44		7467.47	83.14	17.19		7467.47	83.14	17.19	
1975	110.20	255.72		2088.73	18.95	8.17		2088.73	18.95	8.17	
1976	249.16	386.36		4132.77	16.59	10.70		4132.77	16.59	10.70	
1977	144.36	290.20		2148.09	14.88	7.40		2148.09	14.88	7.40	
1978	220.68	565.18		1297.97	5.88	2.30		1297.97	5.88	2.30	
1979	93.95	707.58		1976.90	21.04	2.79		1976.90	21.04	2.79	
1980	131.61	1886.27		1862.43	14.15	0.99		1862.43	14.15	0.99	
1981	577.25	335.91		1497.57	2.59	4.46		1397.32	2.42	4.16	
1982	16.90	227.02		542.43	32.10	2.39		409.20	24.21	1.80	
1983	55.45	135.94		417.72	7.53	3.07		279.91	5.05	2.06	
1984	43.00	56.88		328.05	7.63	5.77		188.27	4.38	3.31	
1985	197.07	207.14		455.19	2.31	2.20		344.36	1.75	1.66	
1986	104.55	183.57		549.82	5.26	3.00		425.81	4.07	2.32	
1987	76.78	217.28		692.36	9.02	3.19		570.64	7.43	2.63	
1988	50.86	55.14		373.92	7.35	6.78		245.19	4.82	4.45	
1989	82.53	115.39		502.80	6.09	4.36		433.20	5.25	3.75	
1990	156.37	83.57		811.19	5.19	9.71		590.21	3.77	7.06	
1991	55.77	245.60		936.01	16.78	3.81		783.28	14.04	3.19	
1992	59.59	92.10		494.13	8.29	5.37		460.41	7.73	5.00	
1993	42.85	30.31		631.14	14.73	20.82		553.06	12.91	18.25	
1994	5.44	12.24		147.83	27.16	12.08		92.61	17.02	7.57	
1995	58.15	13.71		218.74	3.76	15.96		181.48	3.12	13.24	
1996	44.36	22.34		506.21	11.41	22.66		493.99	11.14	22.11	
1997	45.01	24.05		256.10	5.69	10.65		237.45	5.28	9.88	
1998	36.05	24.63	117.70	276.77	7.68	11.24	2.35	275.04	7.63	11.16	2.34
1999	10.35	13.87	145.14	172.46	16.66	12.43	1.19	167.34	16.16	12.06	1.15
2000	17.96	51.31	122.41	307.59	17.12	5.99	2.51	302.16	16.82	5.89	2.47
2001	193.80	58.02	845.17	649.13	3.35	11.19	0.77	634.65	3.27	10.94	0.75
2002	82.66	139.41	462.34	479.18	5.80	3.44	1.04	462.79	5.60	3.32	1.00
2003	218.15	96.61	529.52	639.25	2.93	6.62	1.21	564.58	2.59	5.84	1.07
2004	24.47	56.35	501.03	540.43	22.09	9.59	1.08	494.27	20.20	8.77	0.99
2005	12.62	21.44	766.44	293.07	23.22	13.67	0.38	288.07	22.82	13.43	0.38
2006	57.69	9.85	206.40	85.39	1.48	8.67	0.41	81.71	1.42	8.29	0.40
2007	122.35	86.87	698.96	296.29	2.42	3.41	0.42	289.47	2.37	3.33	0.41
2008	43.95	29.91		96.96	2.21	3.24		83.89	1.91	2.80	
2009	56.108	34.120		156.44	2.79	4.58		142.24	2.54	4.17	
2010		30.146									

Table D45. Exploitation ratios for total catch (total catch/swept area biomass) and landings (landings/swept area biomass) for offshore hake during fall, spring and winter surveys. Note: These data were considered for determining stock status, but the SARC51 panel concluded that status could not be determined from available data.

Table D46. NEFSC fall bottom trawl survey data (delta mean). Note: These data were considered for determining stock status, but the SARC51 panel concluded that status could not be determined from available data.

Year	Individual Mean Weight	3-yr Average Individual Mean Weight	Recruitment Index (< 30 cm)	3-Year Average Recruitment Index (< 30 cm)
1967	0.720		0.017	
1968	0.318		0.304	
1969	0.250	0.429	0.323	0.215
1970	0.260	0.276	0.164	0.264
1971	0.196	0.235	0.095	0.194
1972	0.221	0.226	1.522	0.594
1973	0.263	0.227	0.183	0.600
1974	0.202	0.229	0.599	0.768
1975	0.290	0.252	0.399	0.394
1976	0.420	0.304	0.302	0.433
1977	0.273	0.328	0.410	0.370
1978	0.309	0.334	0.646	0.453
1979	0.324	0.302	0.081	0.379
1980	0.369	0.334	0.317	0.348
1981	0.582	0.425	0.483	0.294
1982	0.319	0.423	0.031	0.277
1983	0.194	0.365	0.526	0.347
1984	0.317	0.277	0.044	0.200
1985	0.391	0.301	0.271	0.280
1986	0.262	0.323	0.507	0.274
1987	0.280	0.311	0.373	0.384
1988	0.646	0.396	0.049	0.310
1989	0.265	0.397	0.292	0.238
1990	0.182	0.364	1.285	0.542
1991	0.291	0.246	0.054	0.544
1992	0.330	0.268	0.064	0.468
1993	0.327	0.316	0.051	0.056
1994	0.152	0.270	0.088	0.067
1995	0.224	0.234	0.350	0.163
1996	0.333	0.236	0.009	0.149
1997	0.377	0.311	0.077	0.145
1998	0.143	0.284	0.559	0.215
1999	0.132	0.217	0.130	0.255
2000	0.212	0.163	0.057	0.249
2001	0.184	0.176	1.855	0.681
2002	0.220	0.205	0.358	0.756
2003	0.321	0.242	0.554	0.922
2004	0.151	0.231	0.268	0.393
2005	0.272	0.248	0.012	0.278
2006	0.156	0.193	0.713	0.331
2007	0.177	0.202	1.076	0.600
2008	0.195	0.176	0.216	0.669
2009	0.095	0.156	1.380	0.891

D.Offshore Hake-Figures

Figure D1. NEFSC survey strata map.

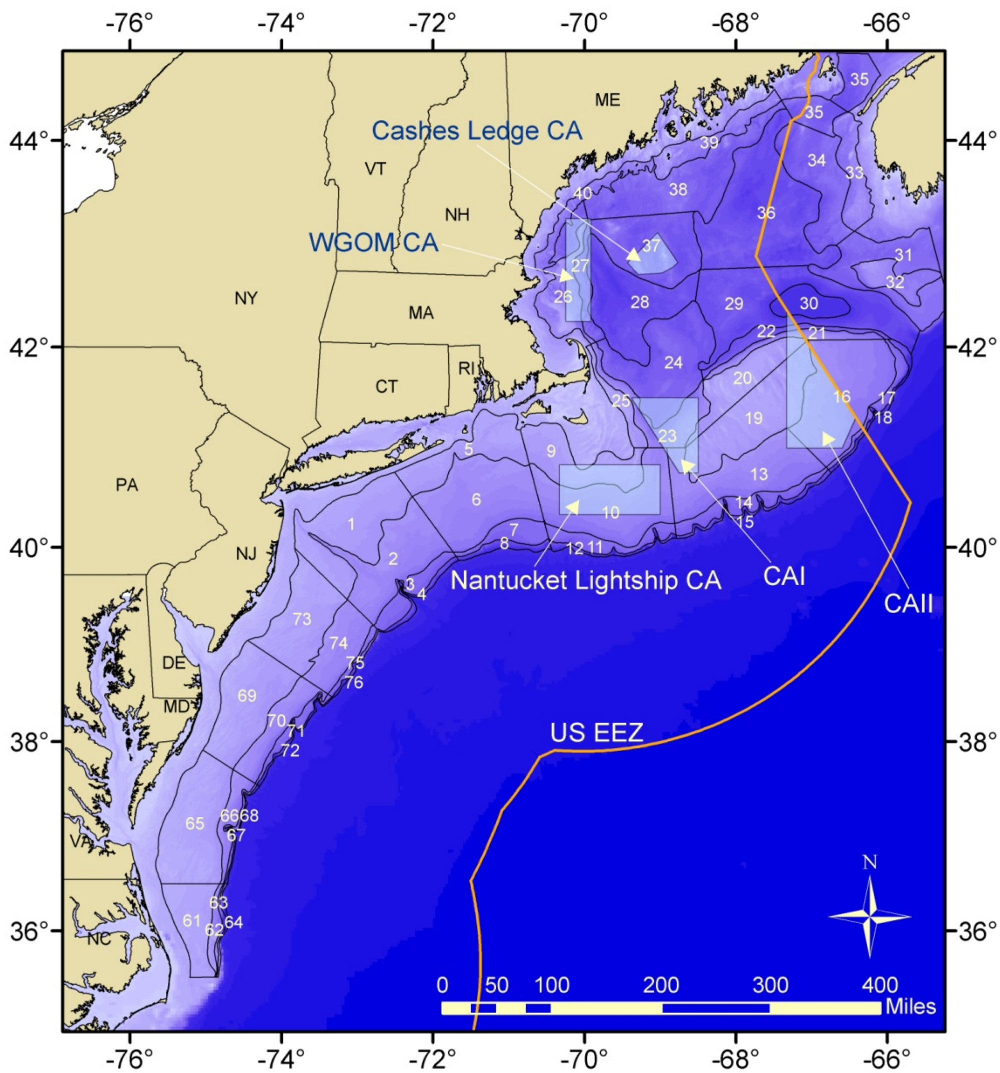


Figure D2. Distribution of offshore hake from the NEFSC fall survey (catch weight per tow, kg), 1967-2009.

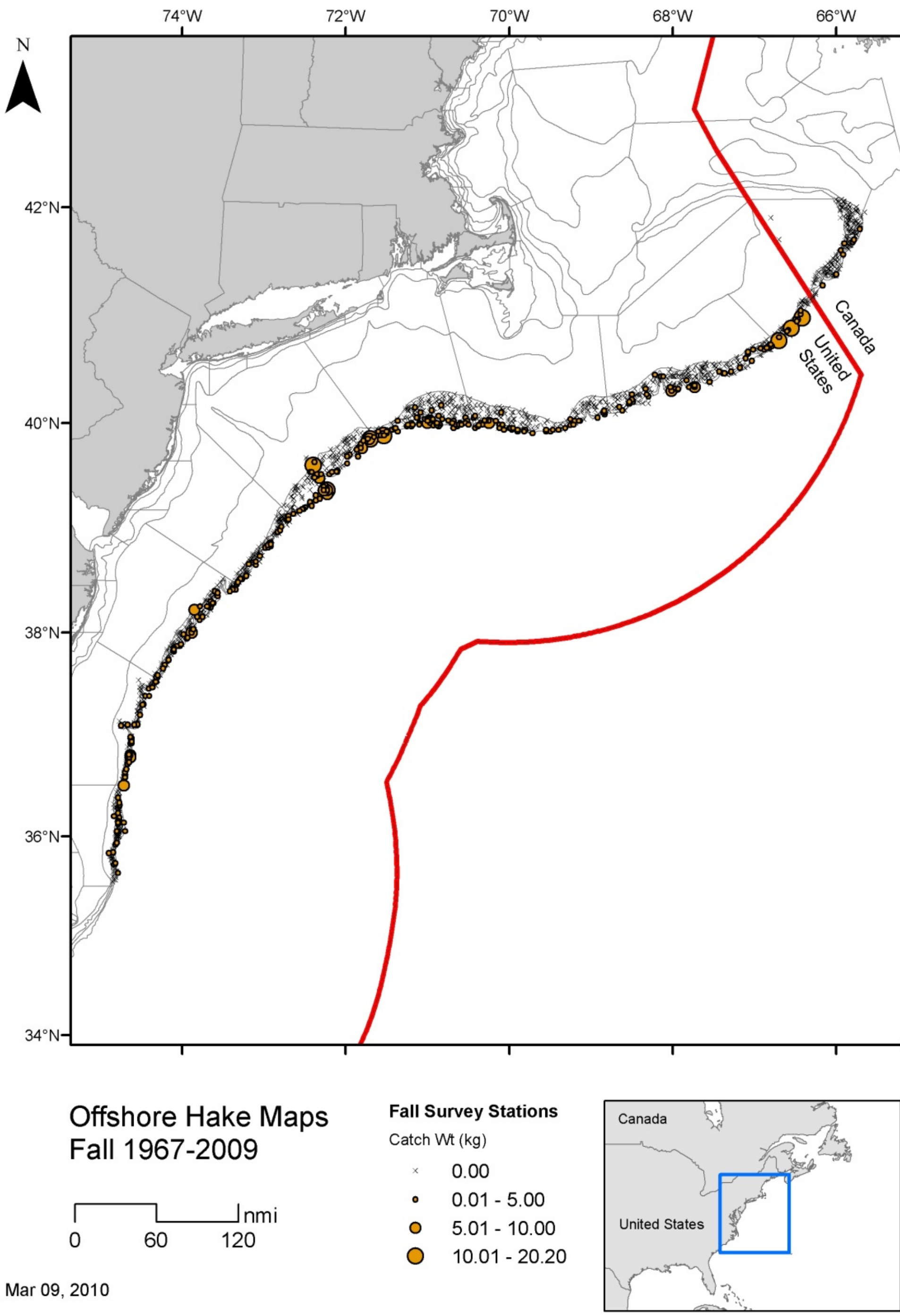
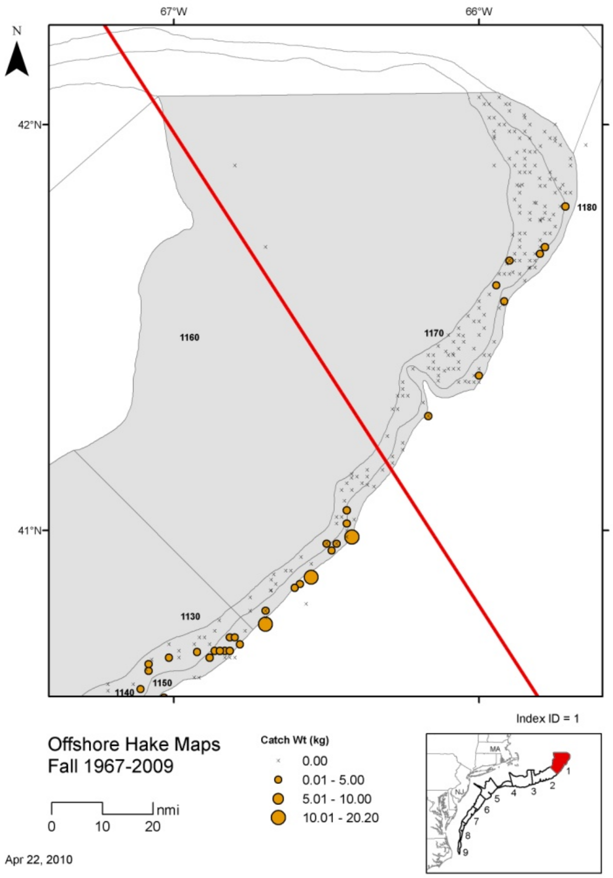


Figure D2a. NEFSC fall survey distribution (catch weight per tow, kg) of offshore hake, 1967-2009, broken up by stratum areas for easier viewing.



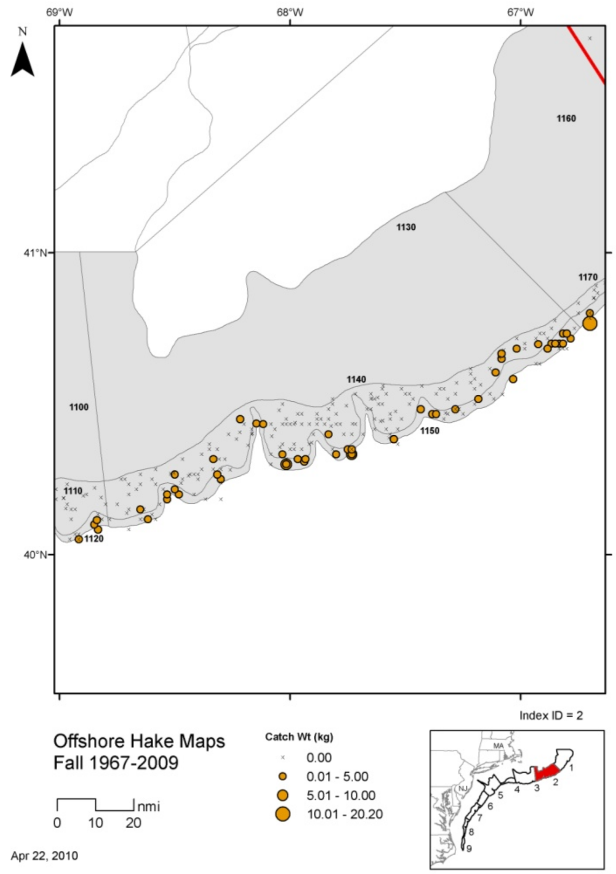
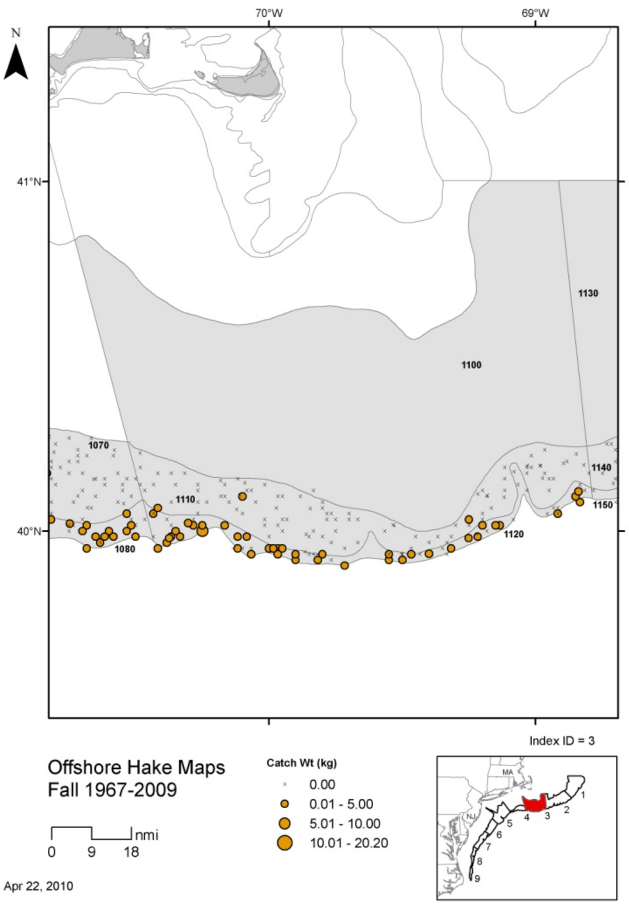


Figure D2b. NEFSC fall survey distribution (catch weight per tow, kg) of offshore hake, 1967-2009, broken up by stratum areas for easier viewing.



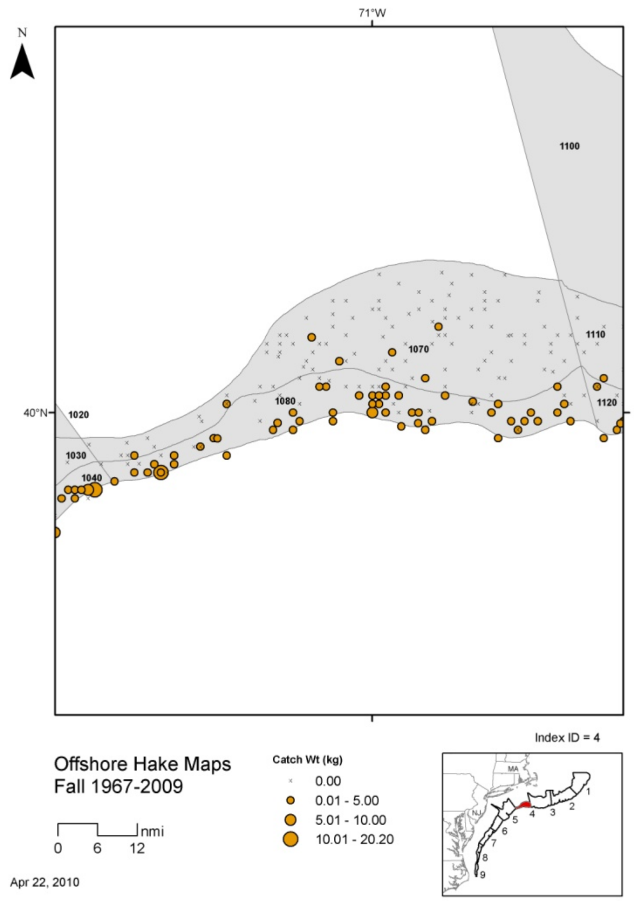
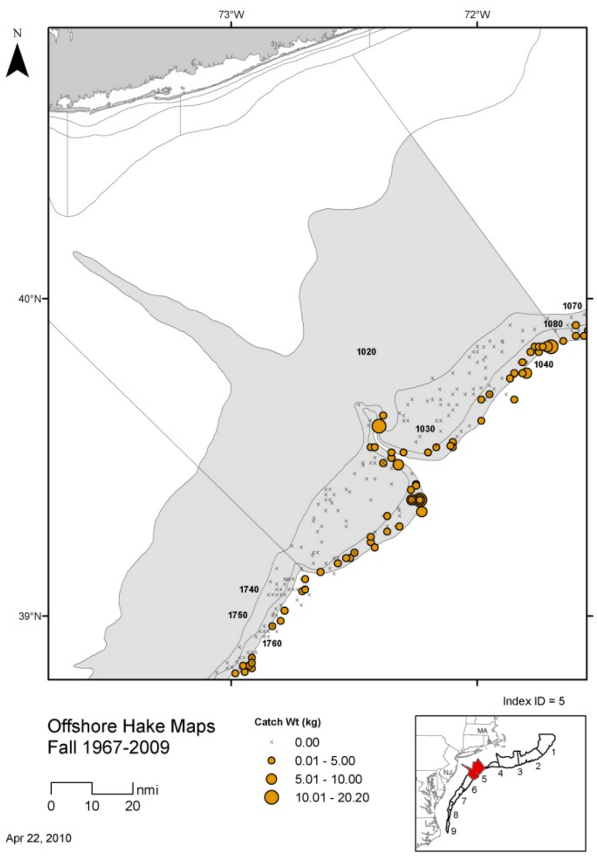


Figure D2c. NEFSC fall survey distribution (catch weight per tow, kg) of offshore hake, 1967-2009, broken up by stratum areas for easier viewing.



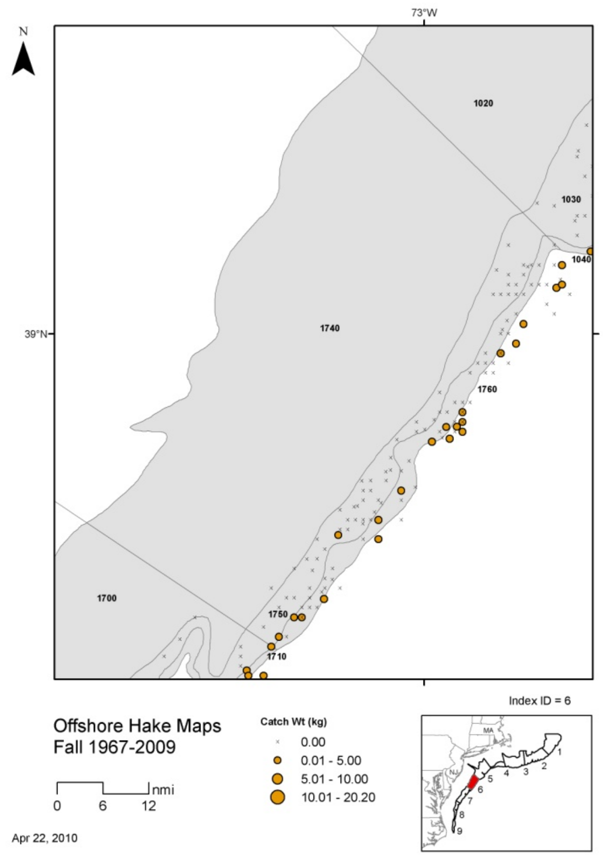
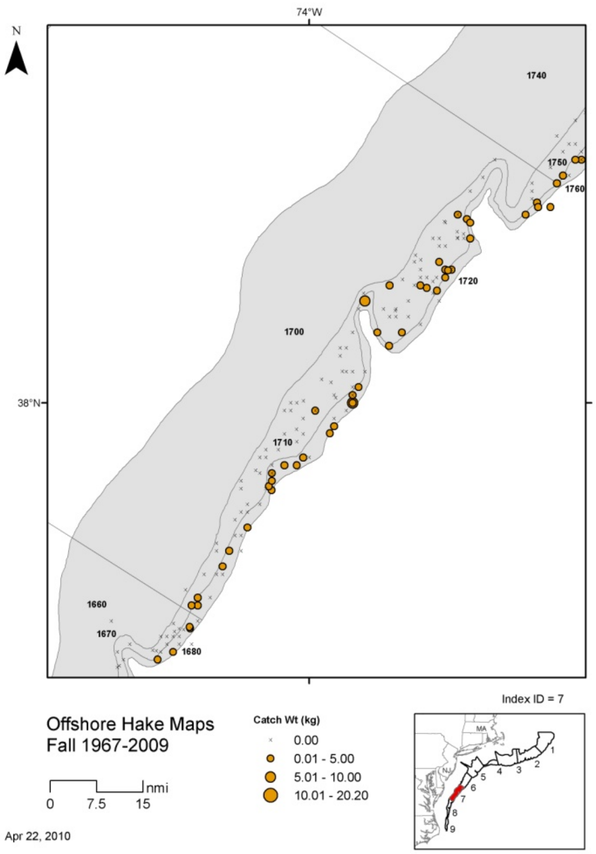


Figure D2d. NEFSC fall survey distribution (catch weight per tow, kg) of offshore hake, 1967-2009, broken up by stratum areas for easier viewing.



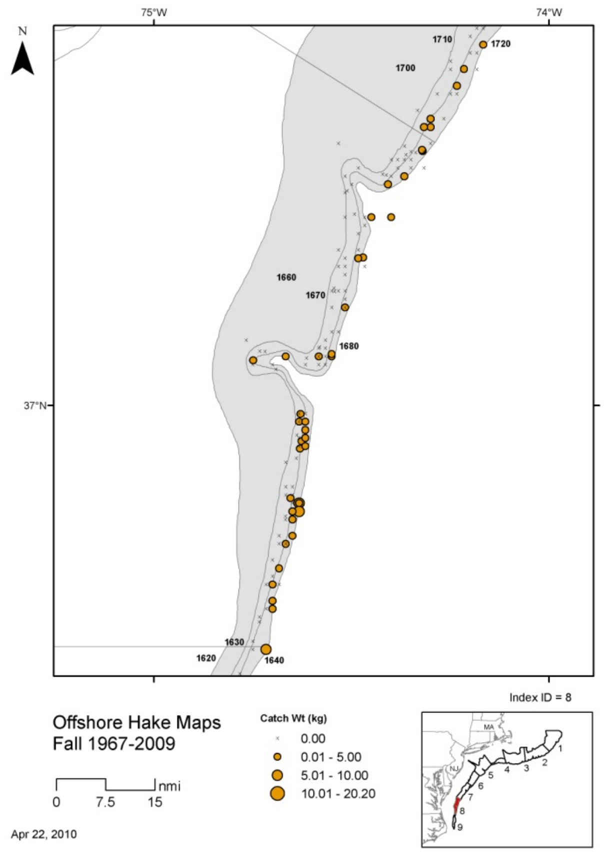


Figure D2e. NEFSC fall survey distribution (catch weight per tow, kg) of offshore hake, 1967-2009, broken up by stratum areas for easier viewing.

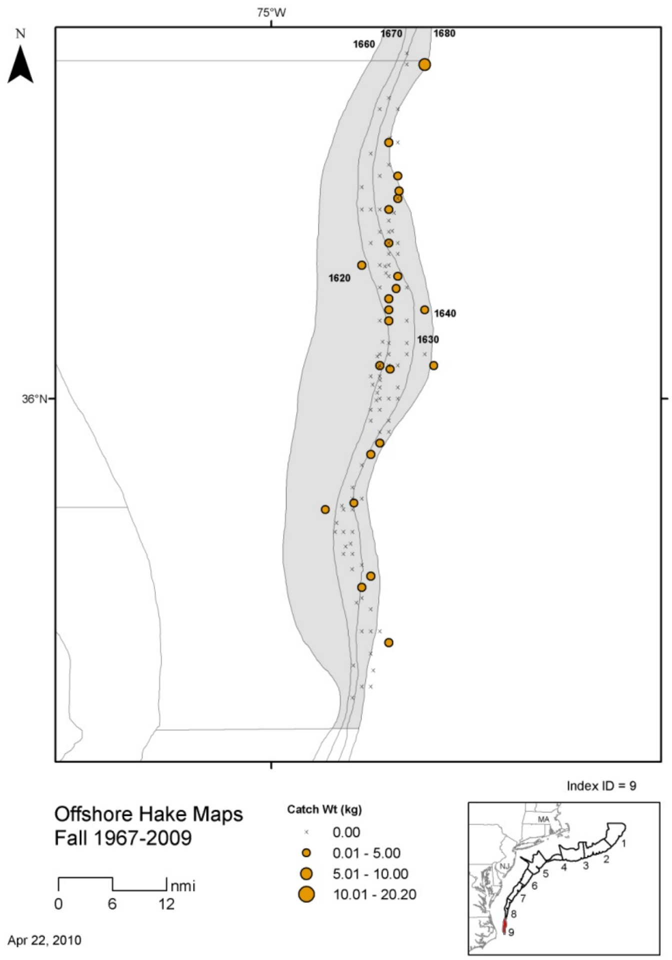


Figure D3. Distribution of offshore hake from the NEFSC spring survey (catch weight per tow, kg), 1968-2009.

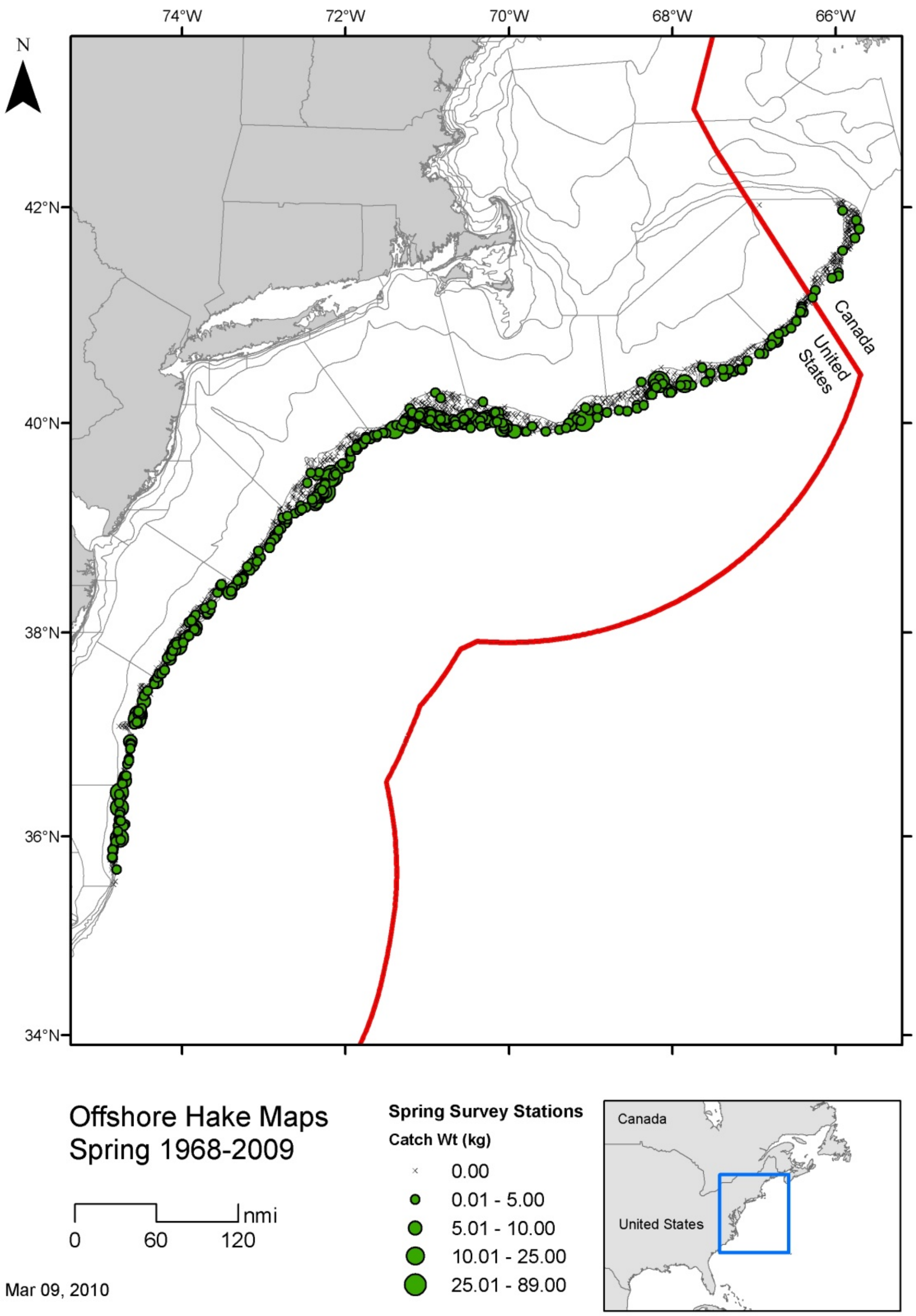
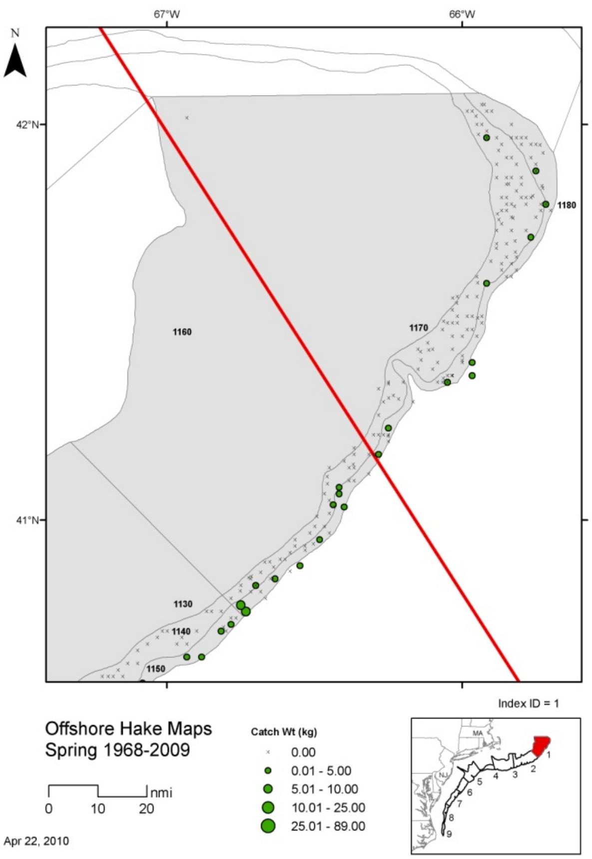


Figure D3a. NEFSC spring survey distribution (catch weight per tow, kg) of offshore hake, 1968-2009, broken up by stratum areas for easier viewing.



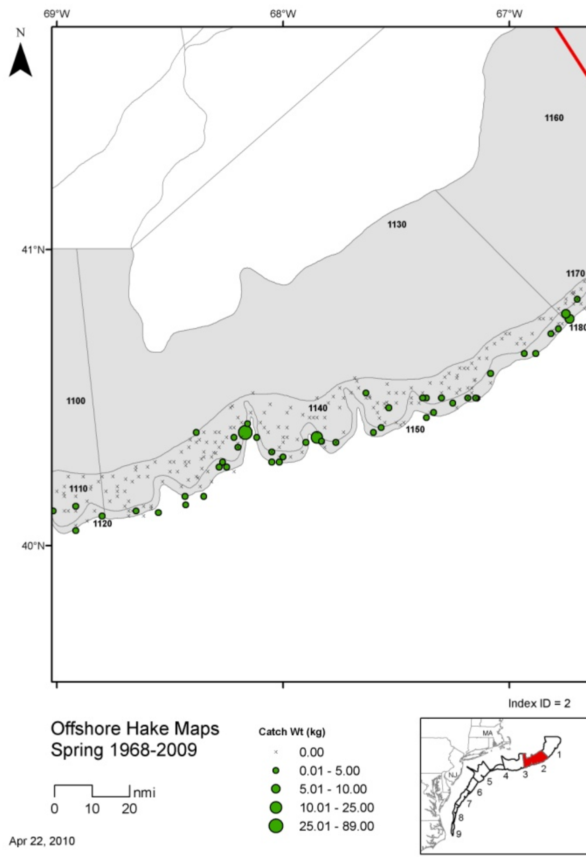
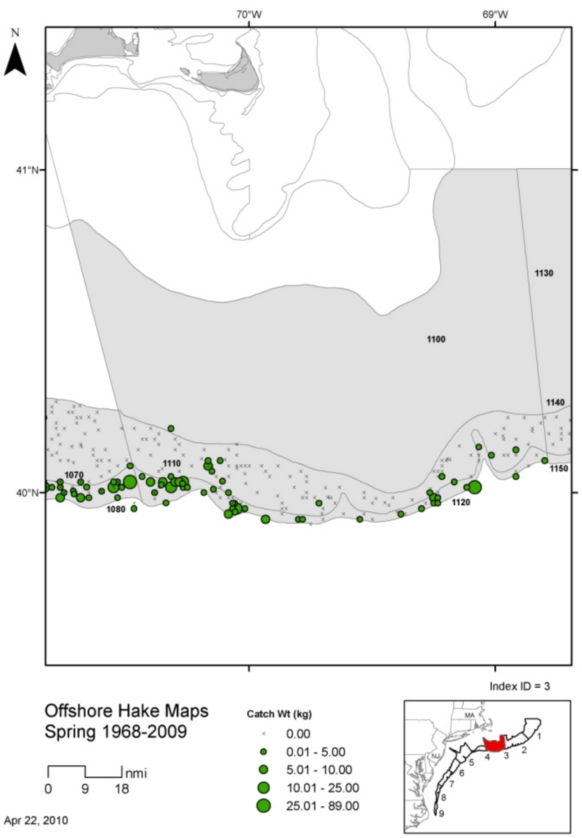


Figure D3b. NEFSC spring survey distribution (catch weight per tow, kg) of offshore hake, 1968-2009, broken up by stratum areas for easier viewing.



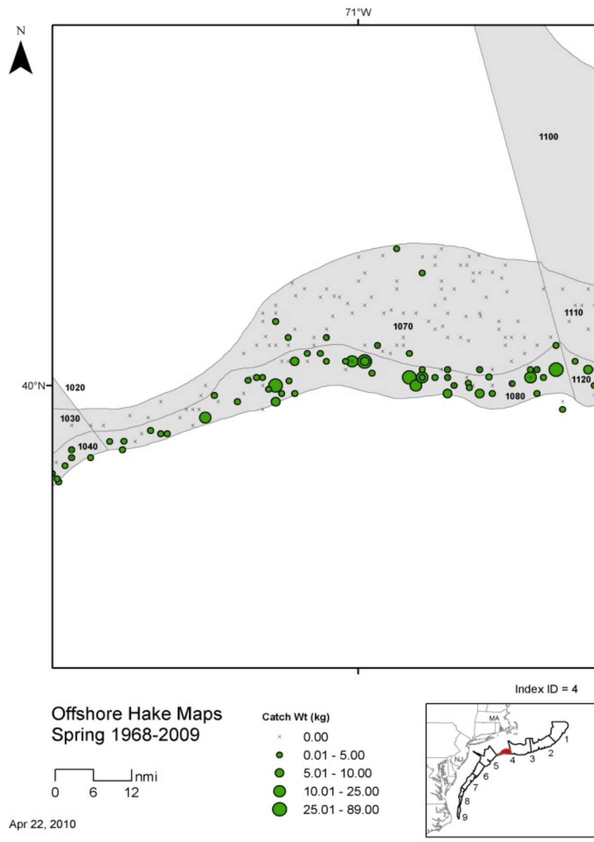
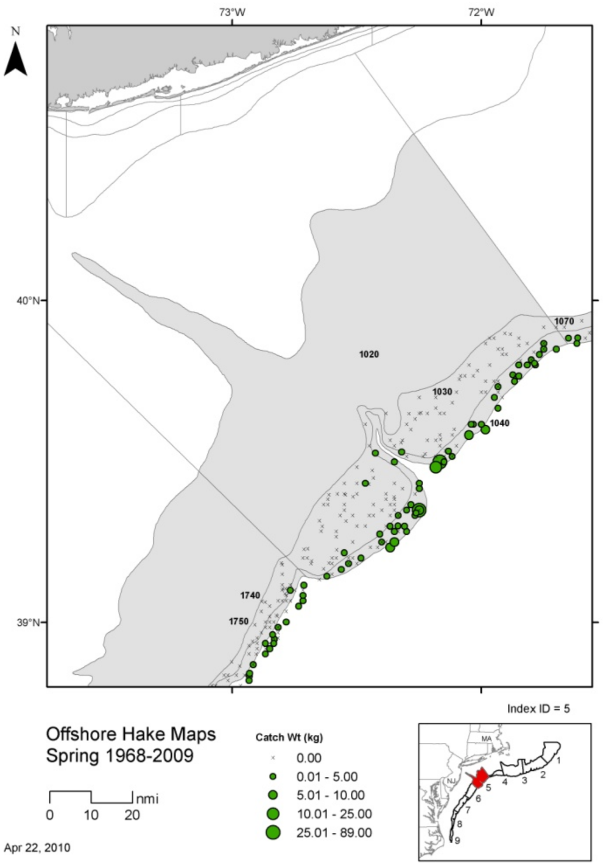


Figure D3c. NEFSC spring survey distribution (catch weight per tow, kg) of offshore hake, 1968-2009, broken up by stratum areas for easier viewing.



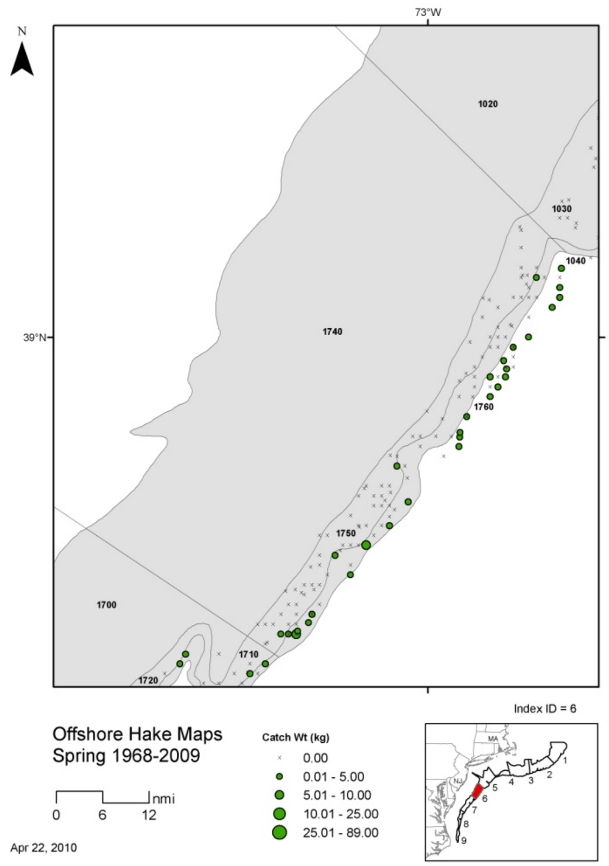


Figure D3d. NEFSC spring survey distribution (catch weight per tow, kg) of offshore hake, 1968-2009, broken up by stratum areas for easier viewing.

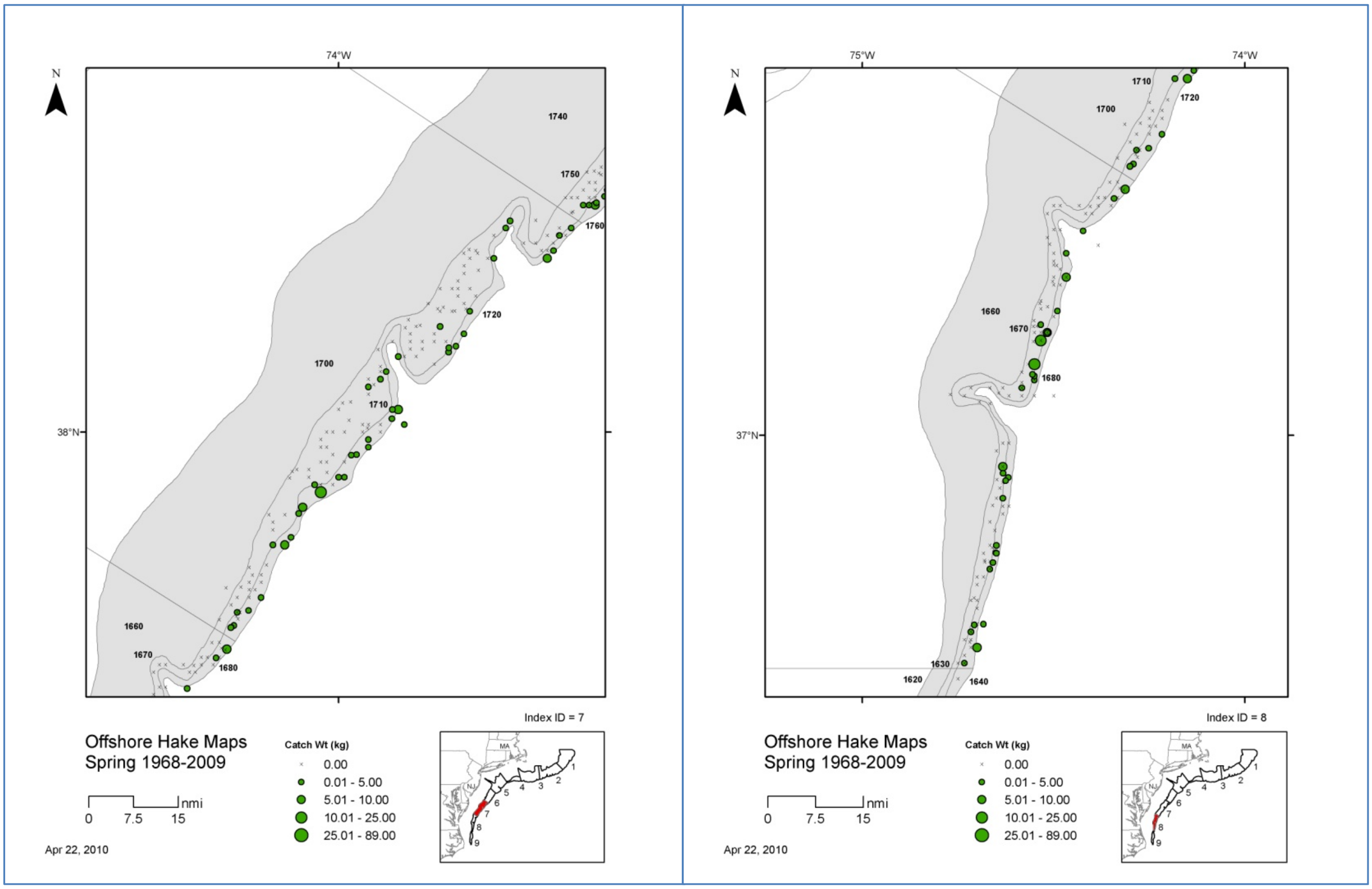


Figure D3e. NEFSC spring survey distribution (catch weight per tow, kg) of offshore hake, 1968-2009, broken up by stratum areas for easier viewing.

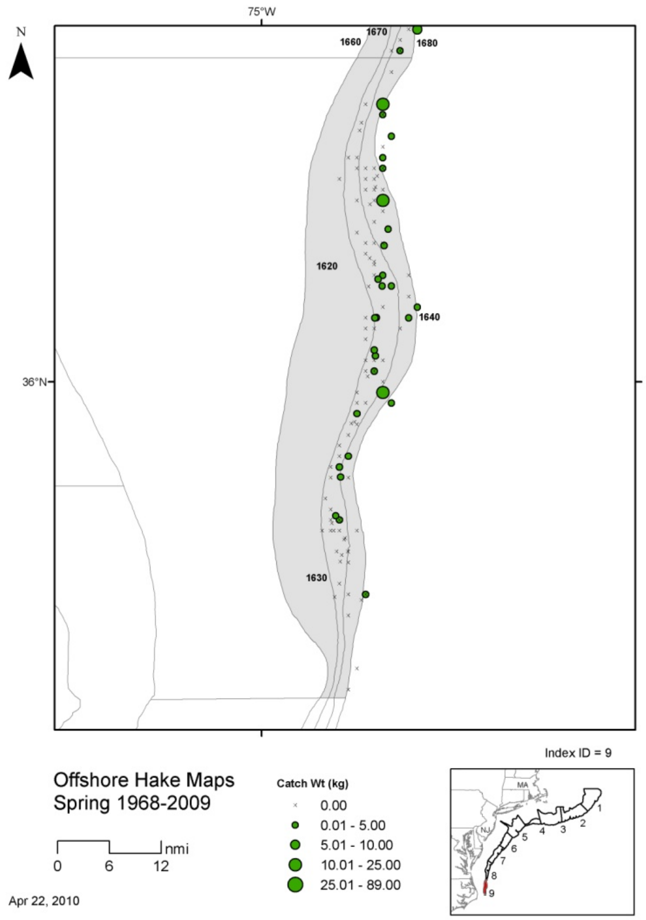


Figure D4. Distribution of offshore hake from the NEFSC winter survey (catch weight per tow, kg), 1998-2007.

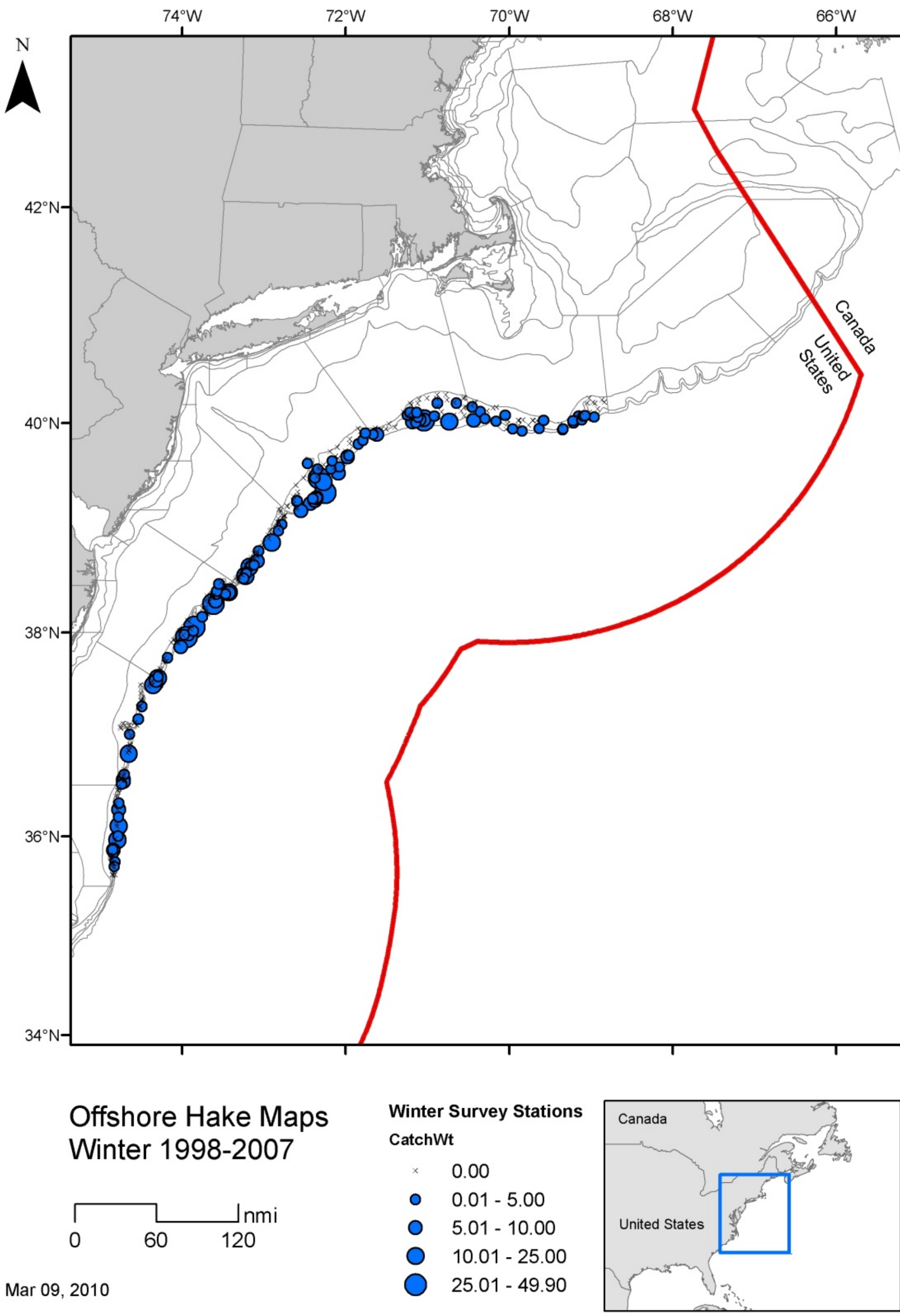


Figure D4a. NEFSC winter survey distribution (catch weight per tow, kg) of offshore hake, 1998-2007, broken up by stratum areas for easier viewing.

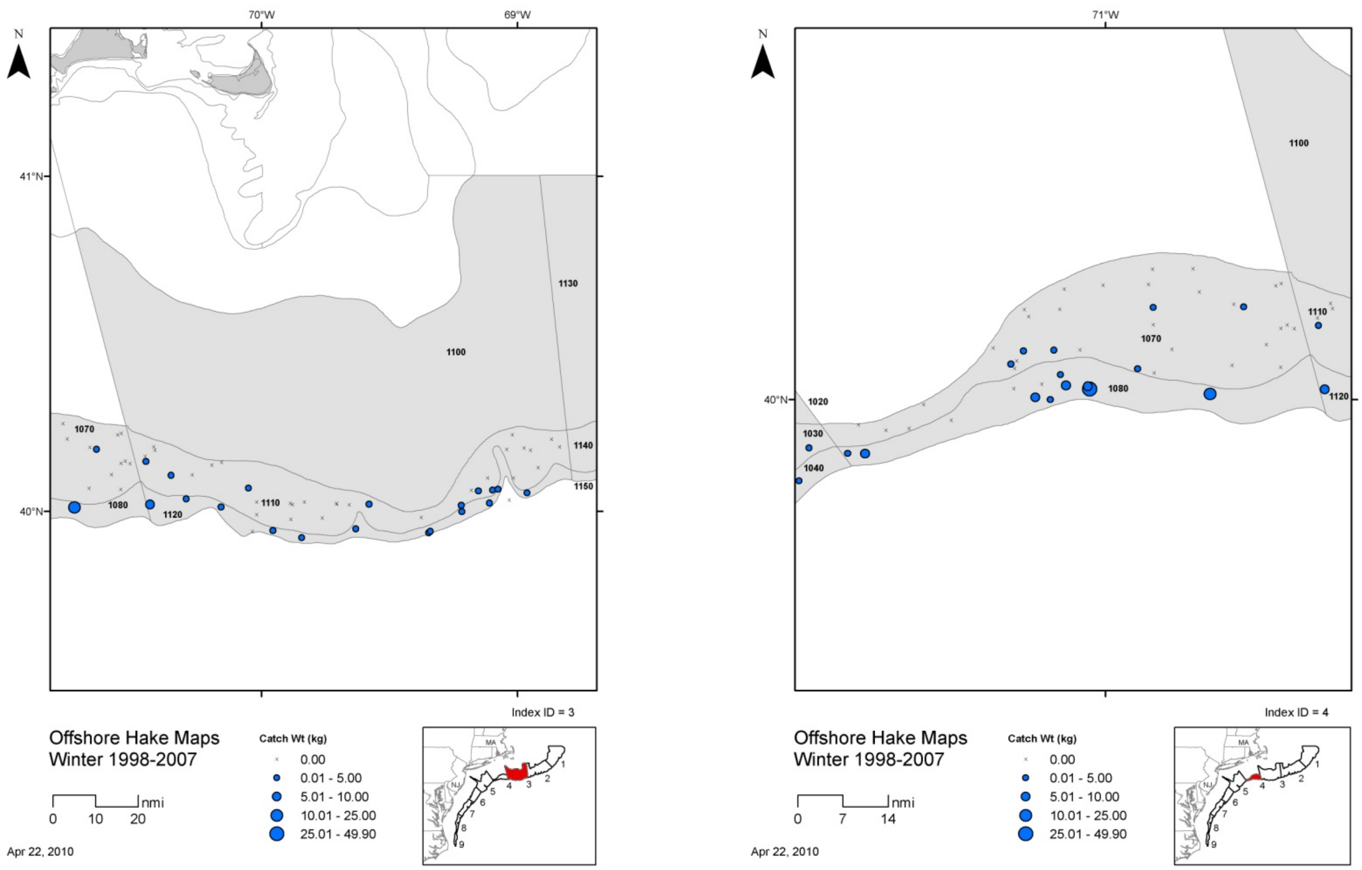
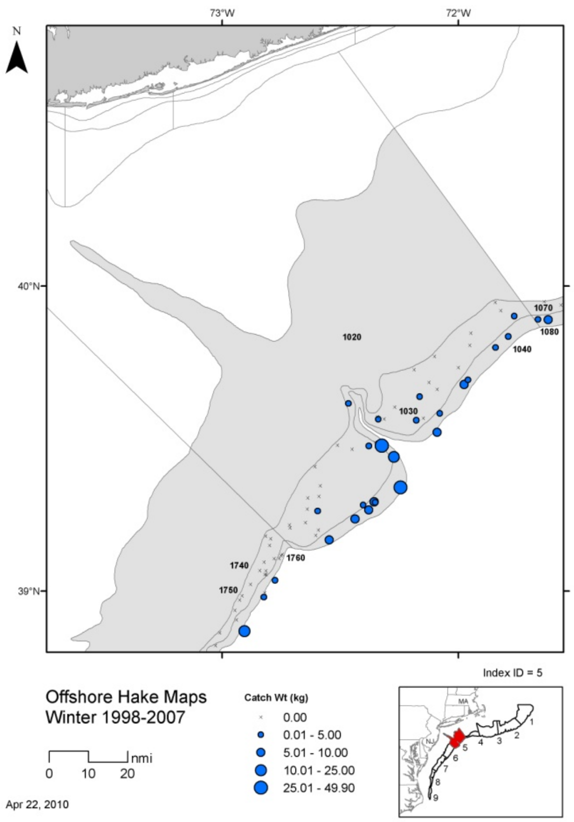


Figure D4b. NEFSC winter survey distribution (catch weight per tow, kg) of offshore hake, 1998-2007, broken up by stratum areas for easier viewing.



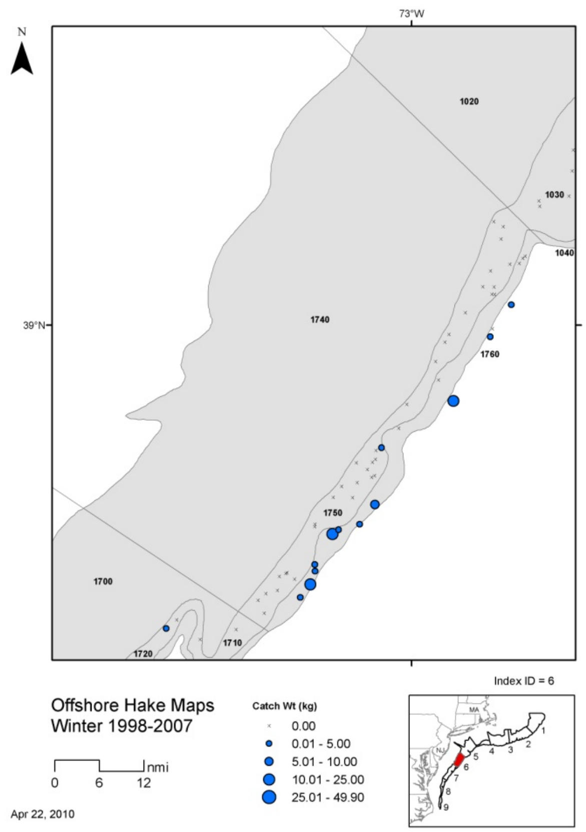
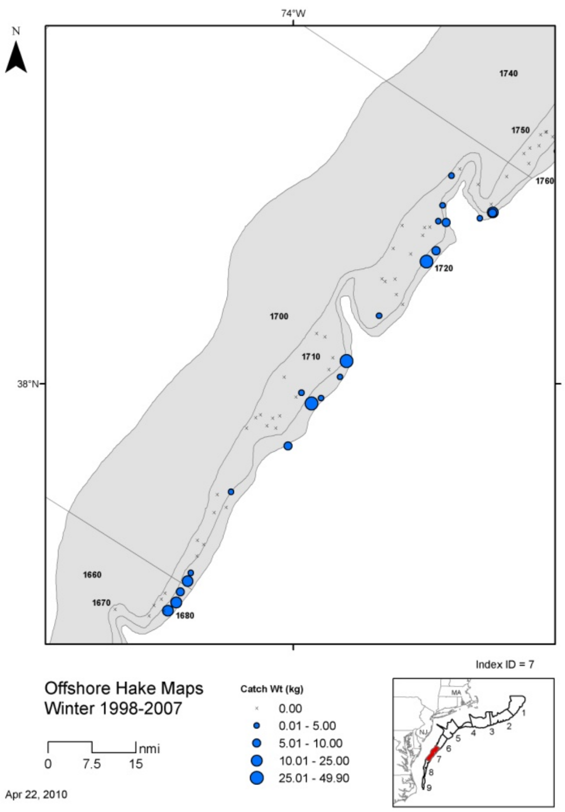


Figure D4c. NEFSC winter survey distribution (catch weight per tow, kg) of offshore hake, 1998-2007, broken up by stratum areas for easier viewing.



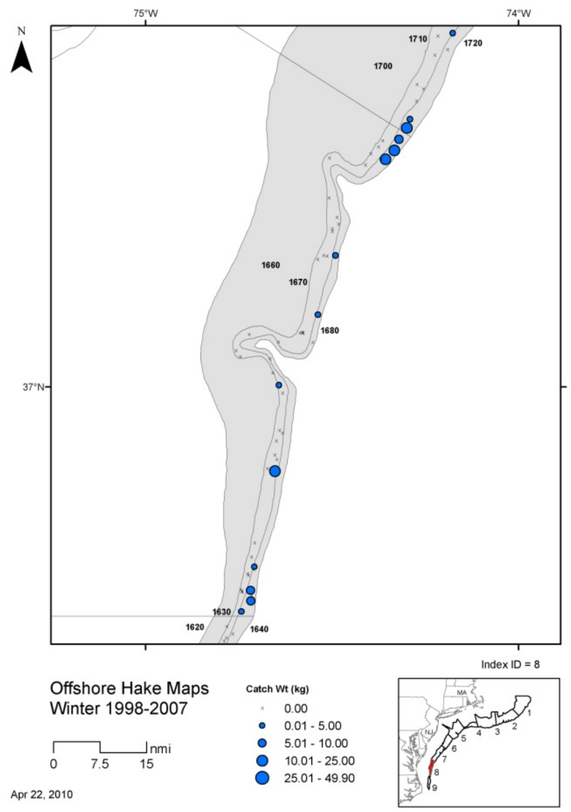
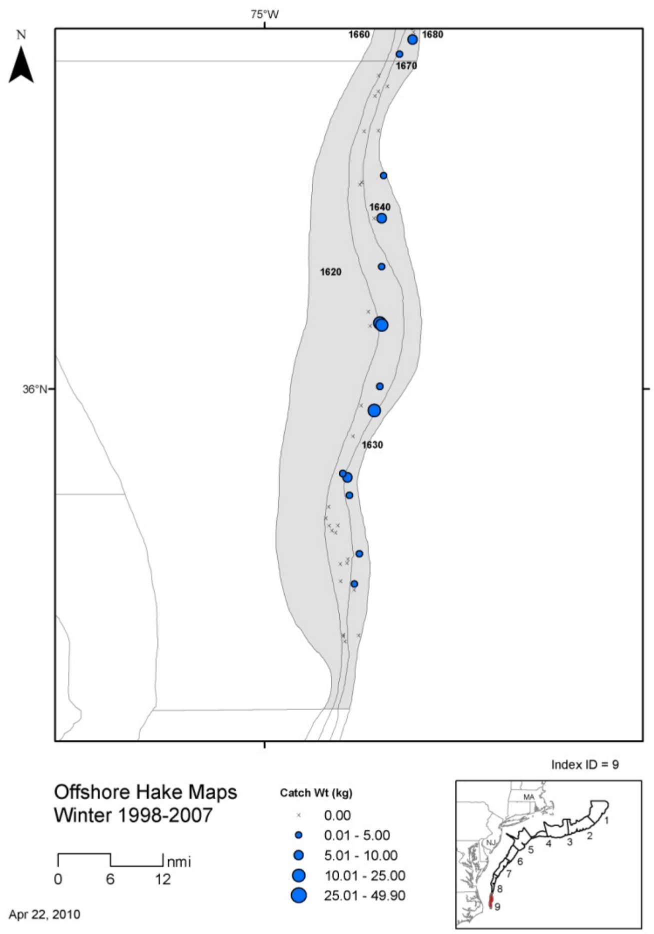


Figure D4d. NEFSC winter survey distribution (catch weight per tow, kg) of offshore hake, 1998-2007, broken up by stratum areas for easier viewing.



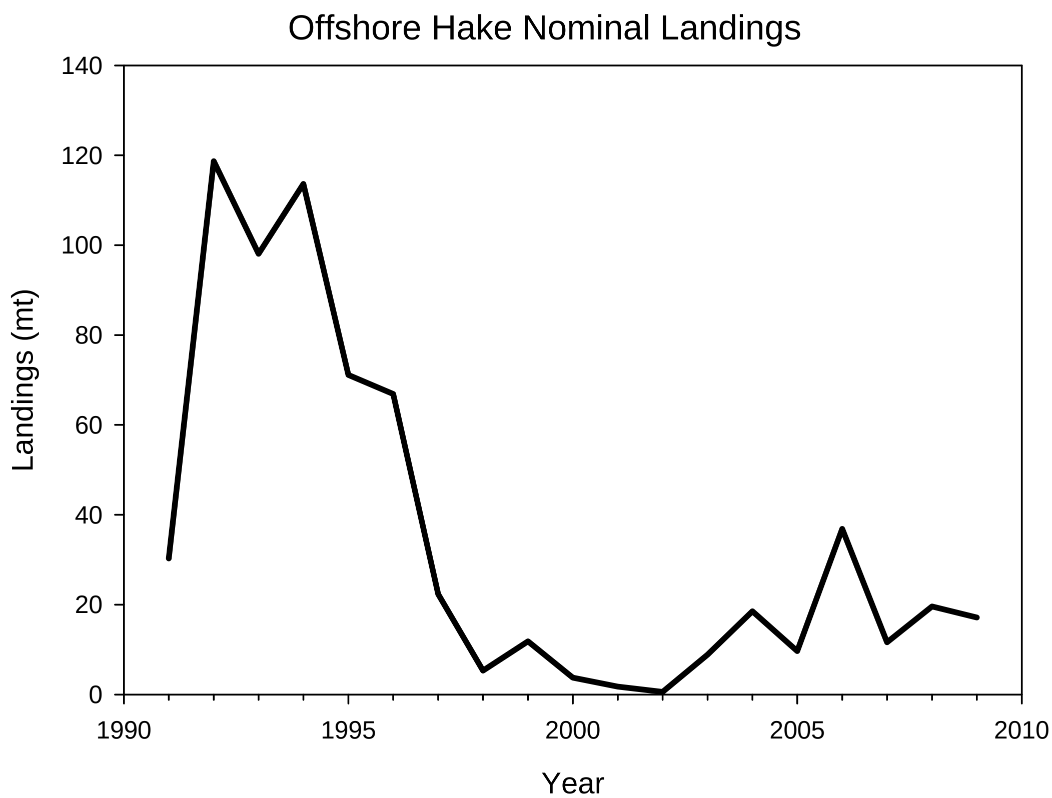


Figure D5. Nominal landings (mt) of offshore hake.

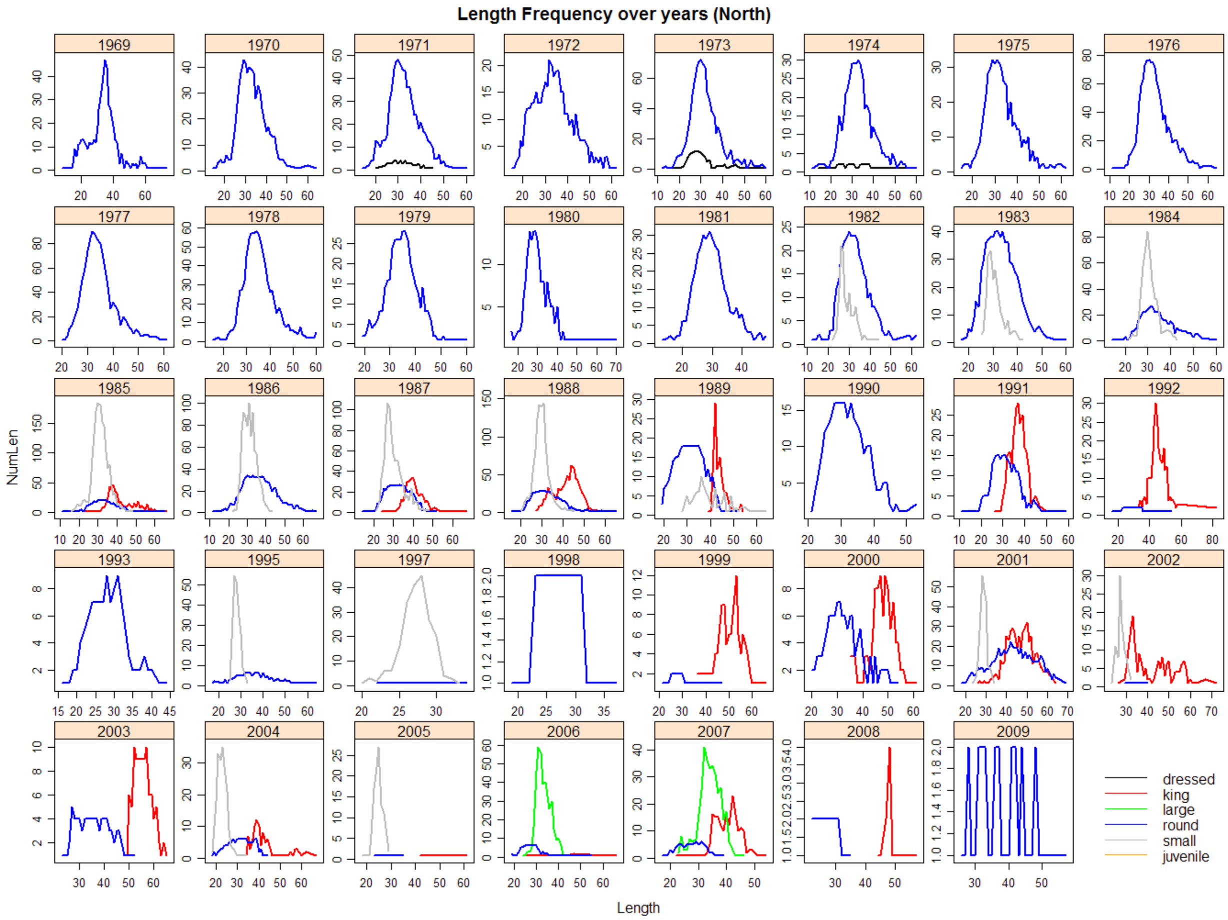


Figure D6. Length frequencies for silver hake for the northern region, before pooling, by all market categories.

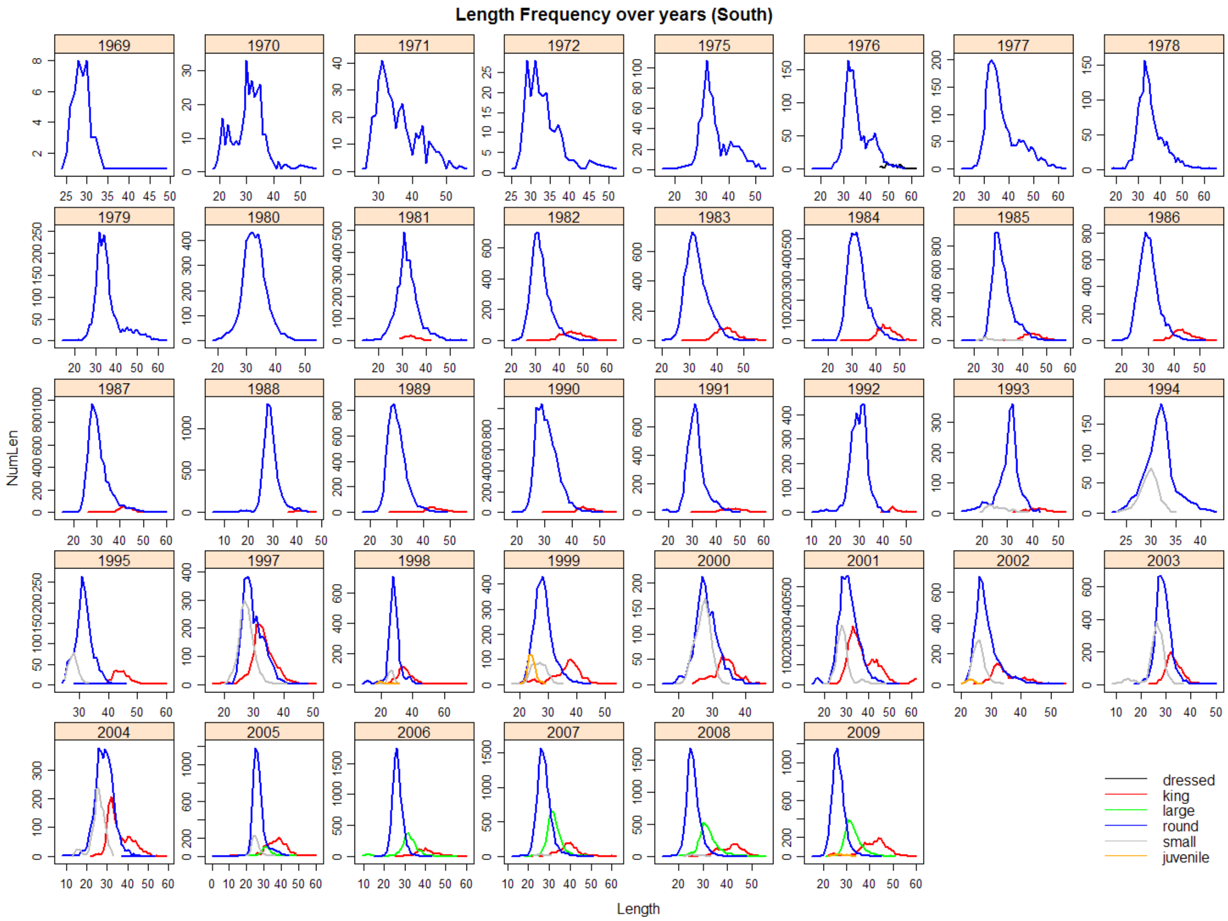


Figure D7. Length frequencies for silver hake for the southern region, before pooling, by all market categories.

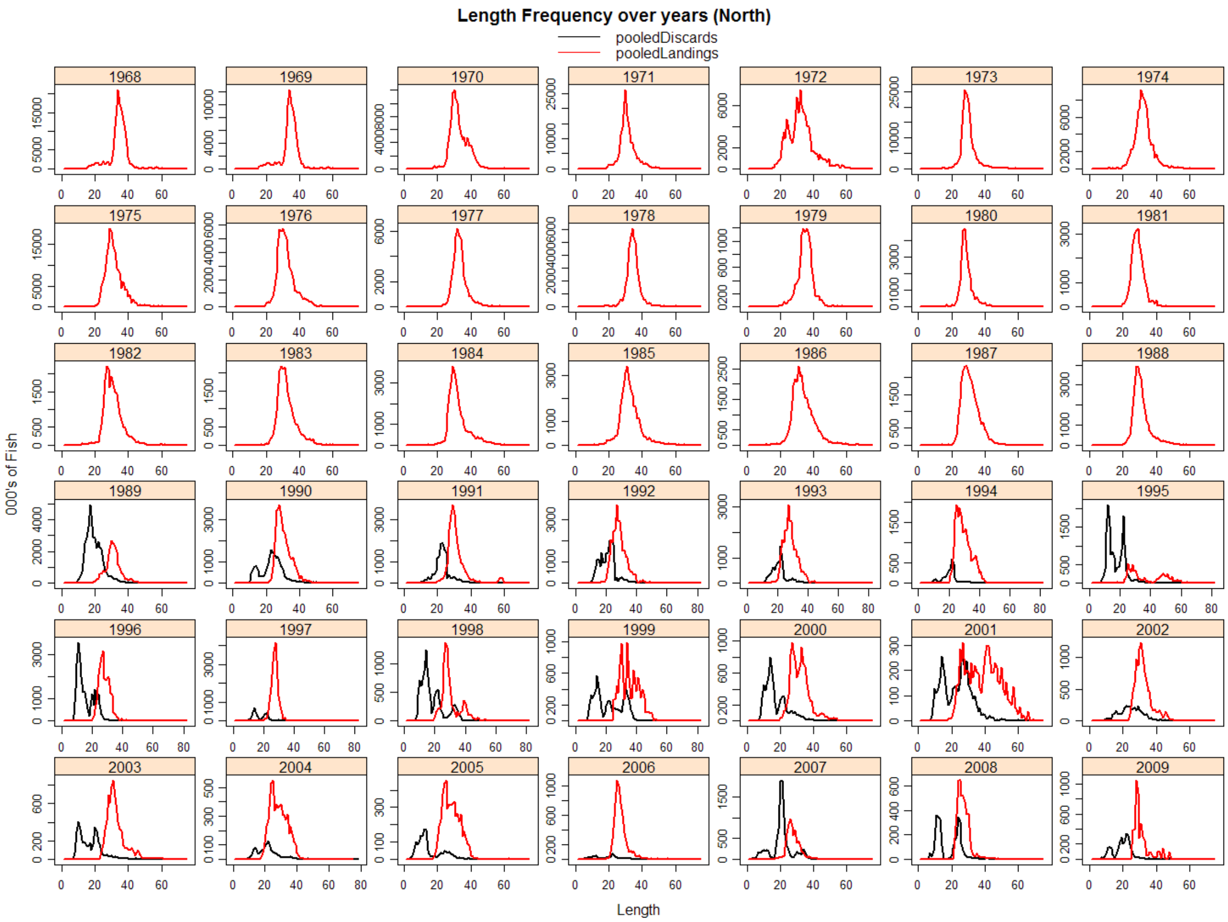


Figure D8. Length frequencies for silver hake for the northern region, landings and discards.

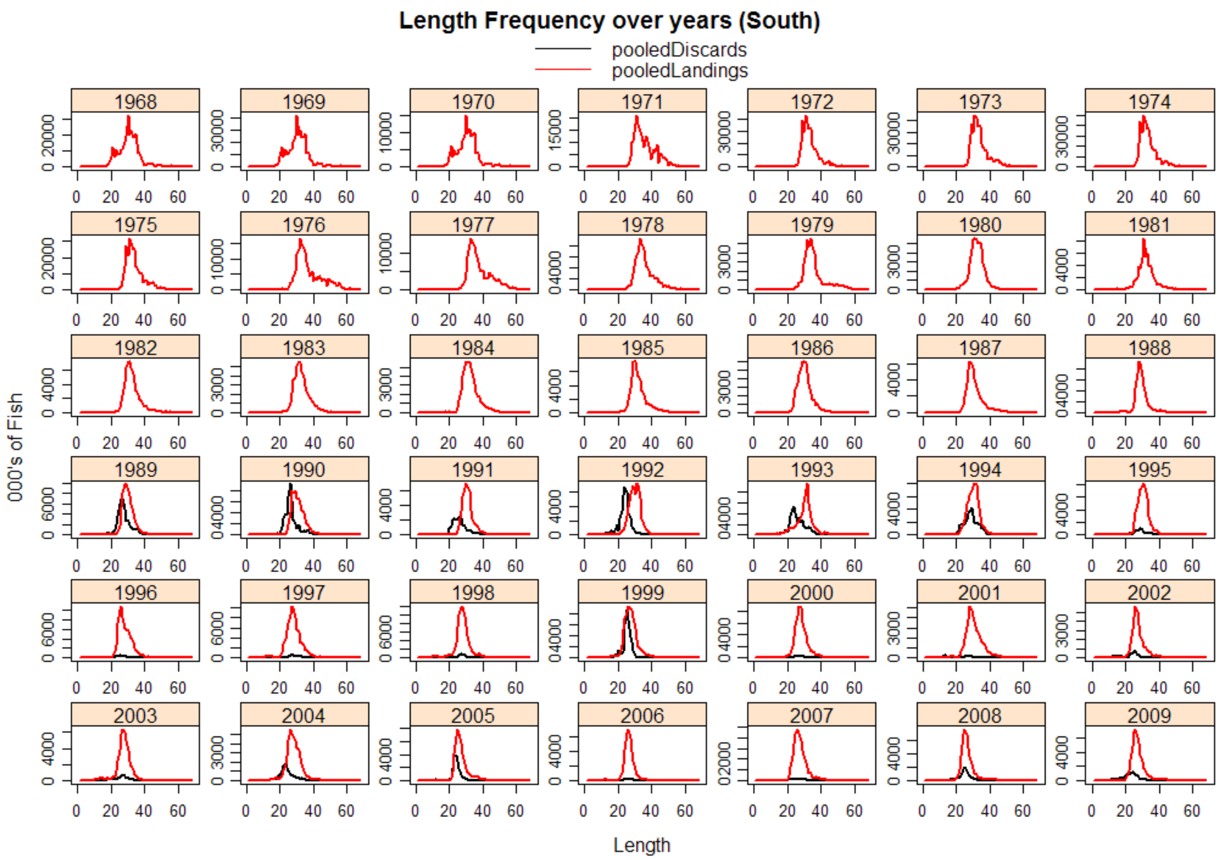


Figure D9. Length frequencies for silver hake for the southern region, landings and discards.

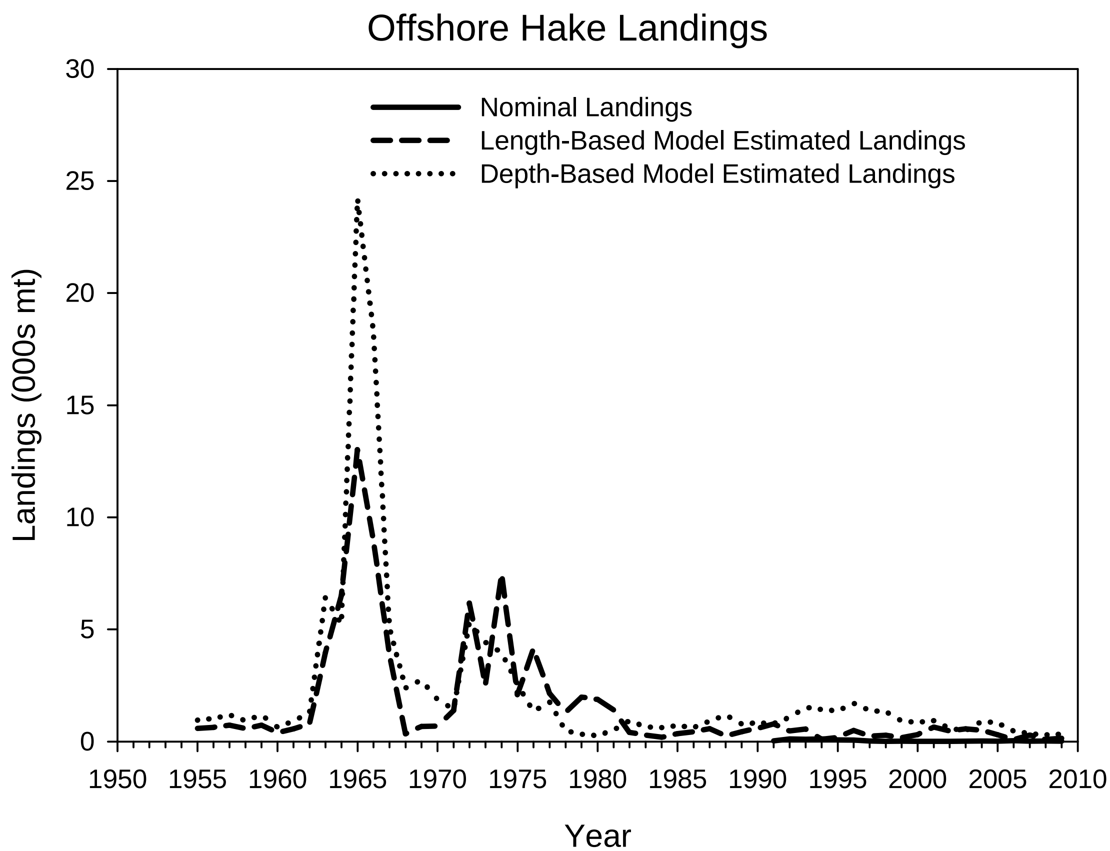
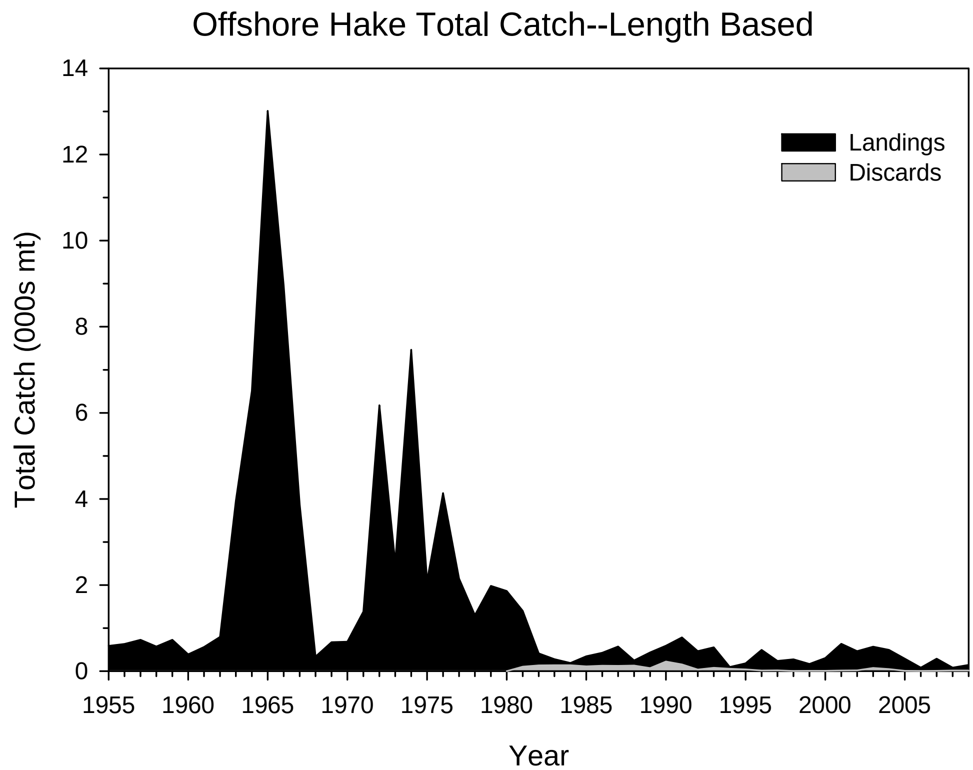


Figure D10. Comparison of nominal landings with the two model-based estimates for offshore hake from the southern stock.

Figure D11. Length-based total catch landings and discards for offshore hake, 1955-2009.



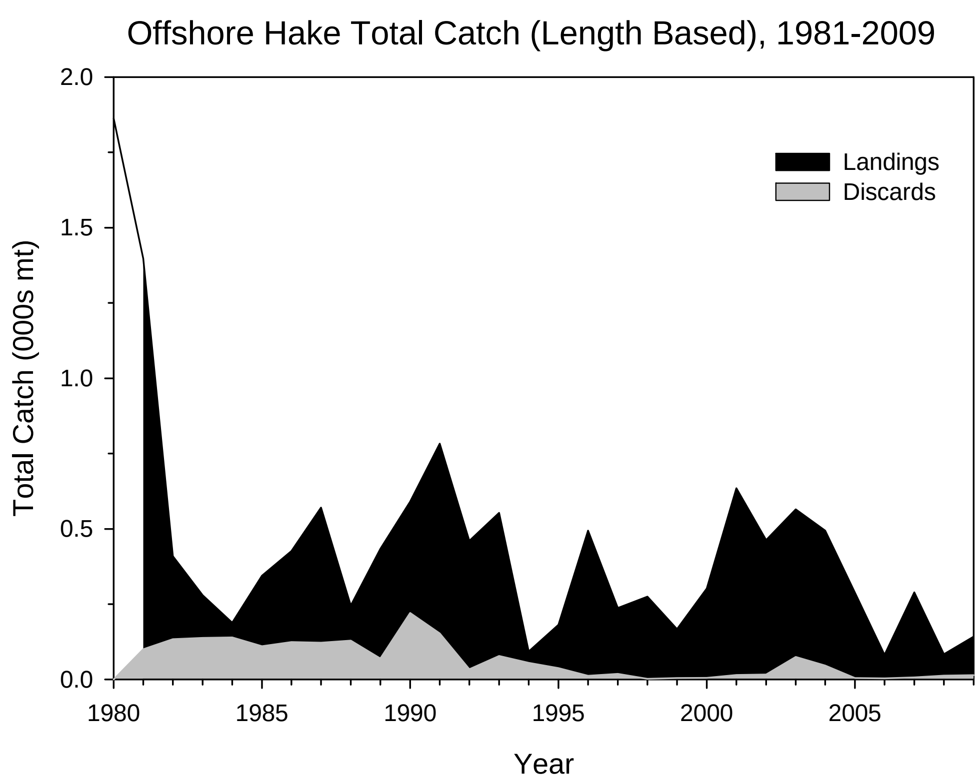
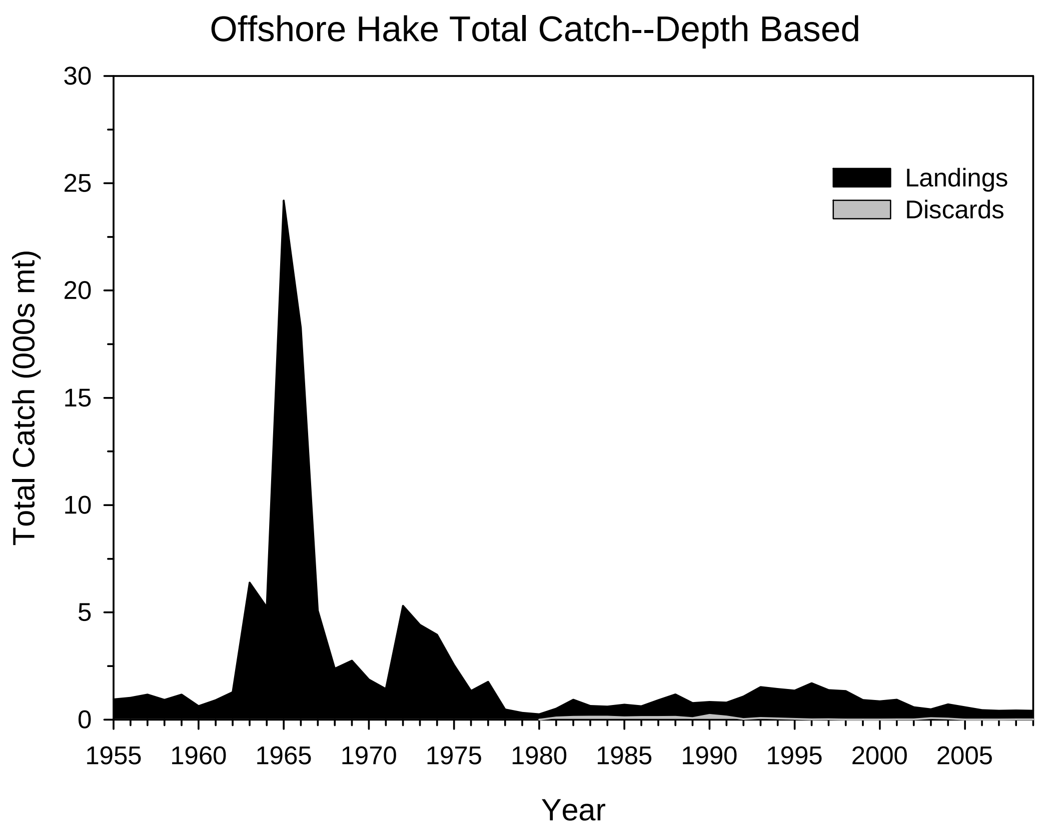


Figure D12. Depth-based total catch landings and discards for offshore hake, 1955-2009.



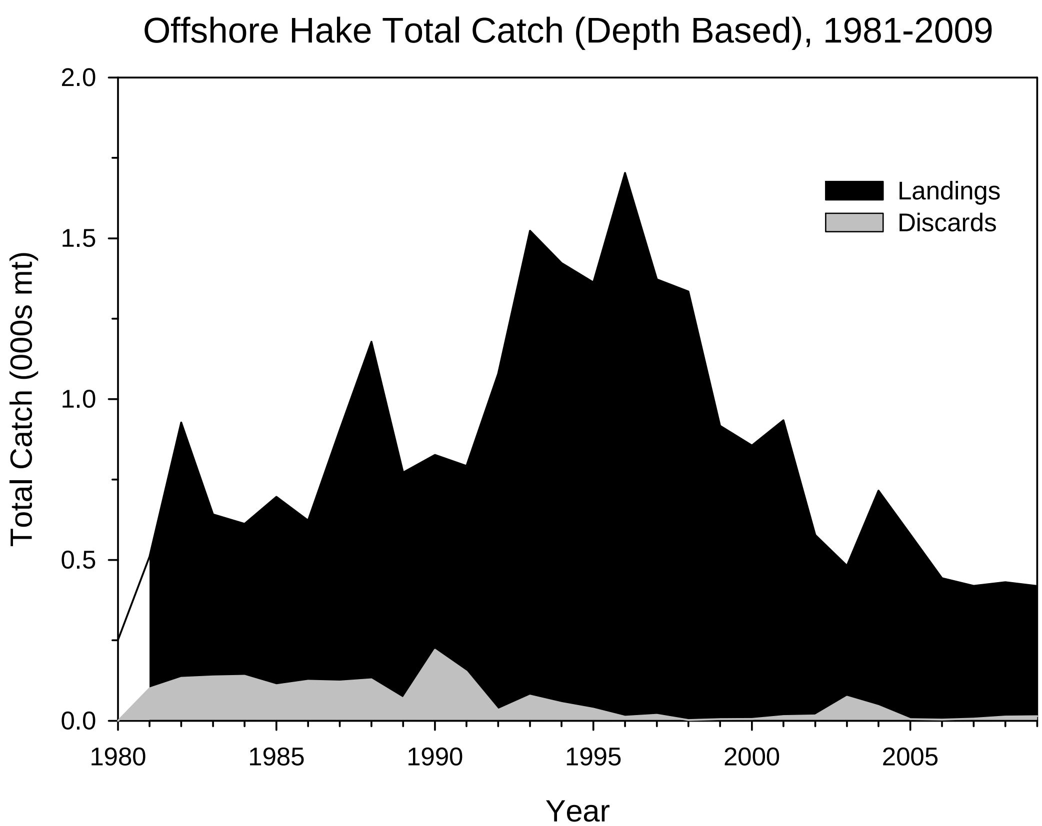


Figure D13.Comparison of the arithmetic and delta transformed mean weight per tow from the fall survey.

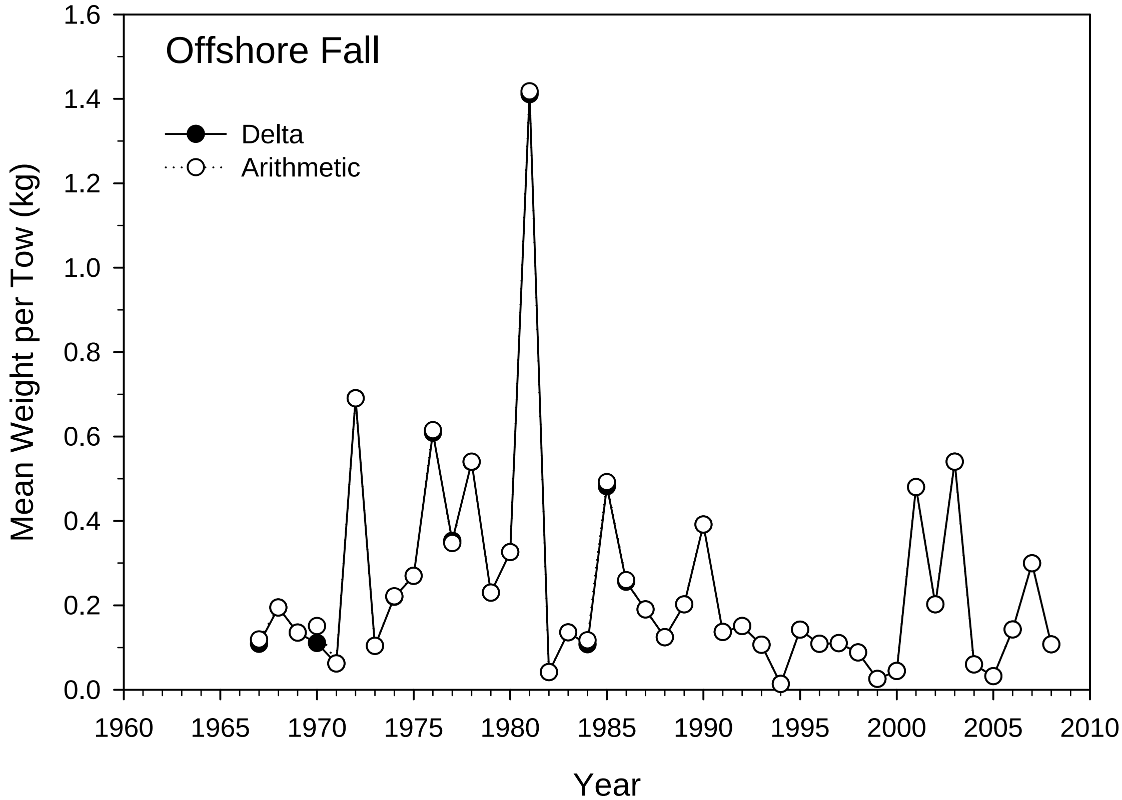
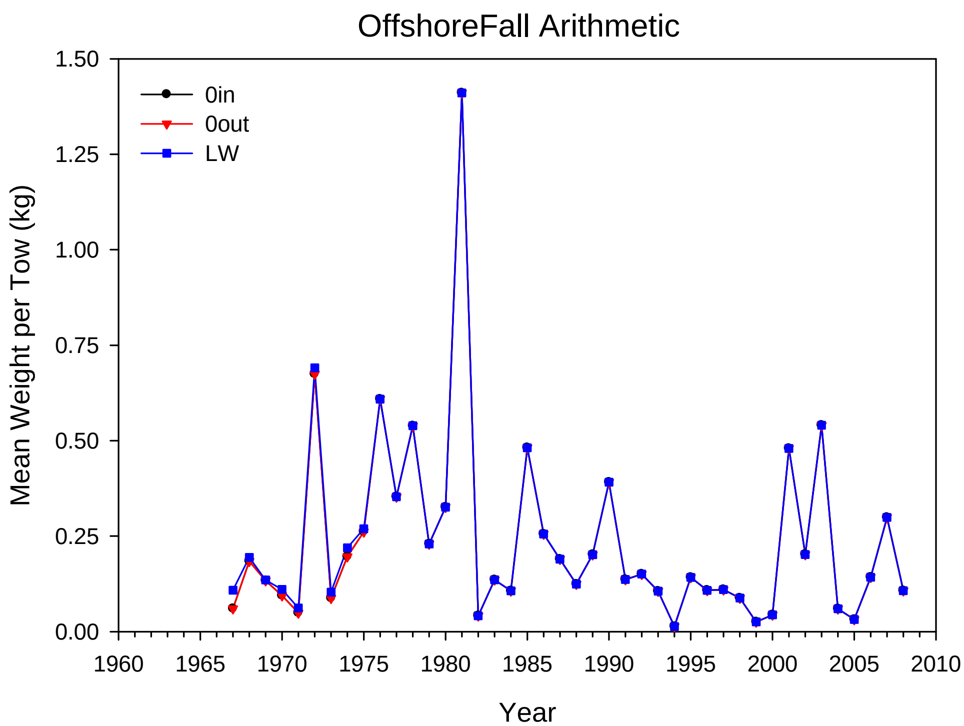
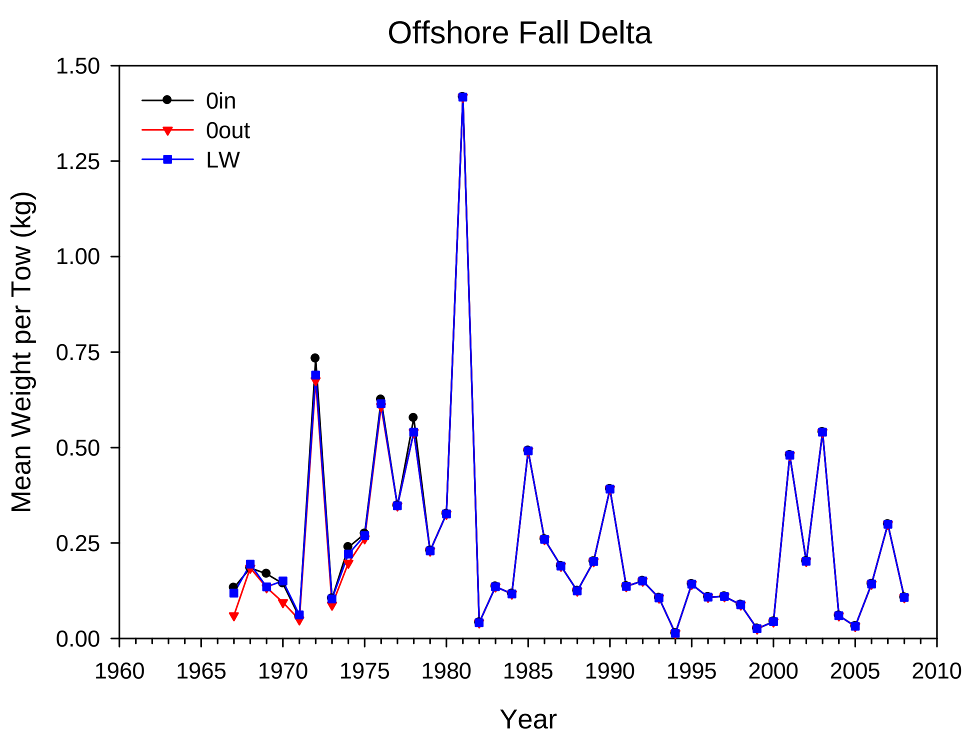


Figure D14. Comparison of the arithmetic and delta transformed mean weight per tow from the fall survey with three methods of handling missing weight data.





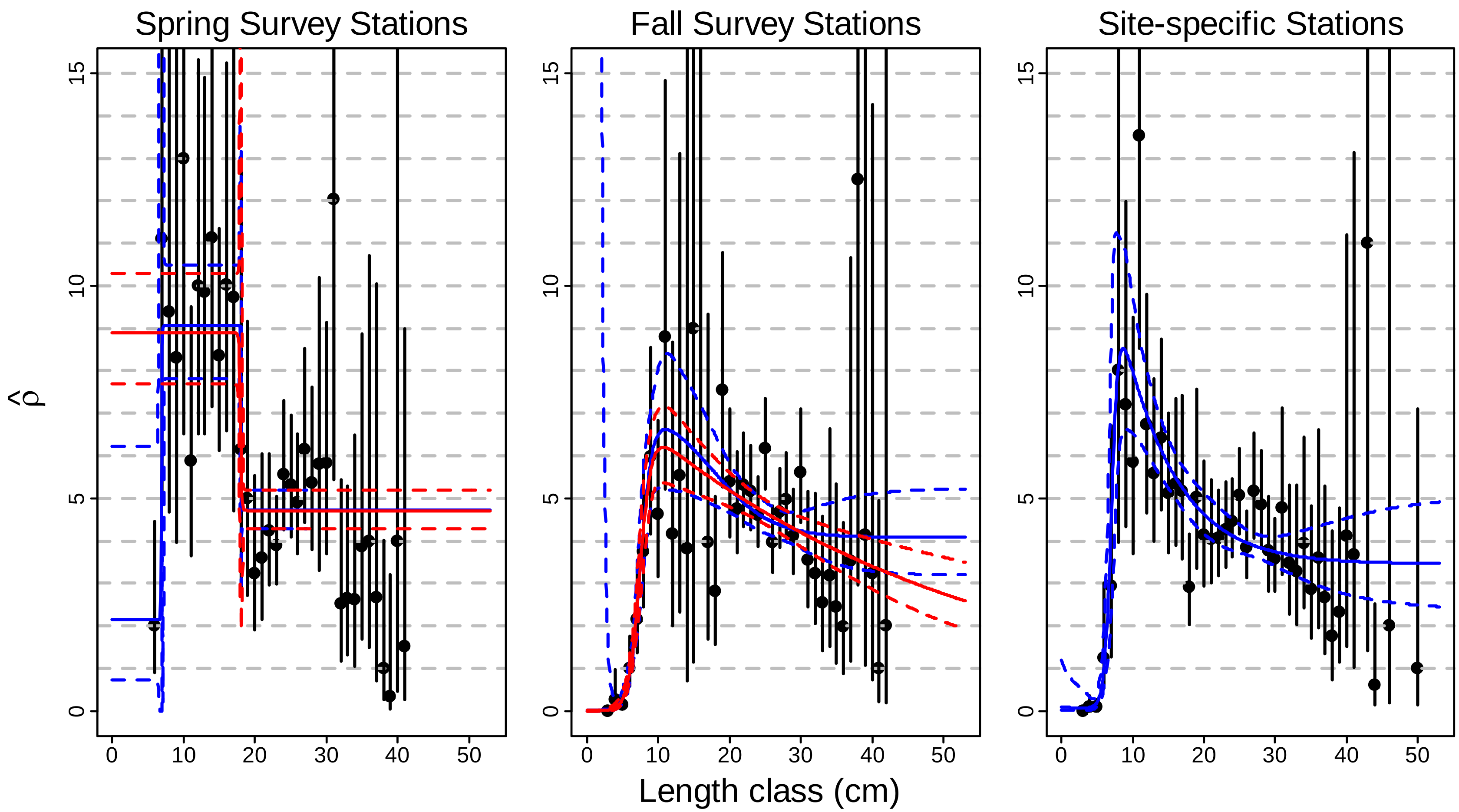


Figure D15. Beta-binomial based estimates of calibration factors and corresponding 95% confidence intervals by length class (1 cm bins) for **silver hake**. The black points and vertical bars represent results where different calibration factors are estimated for each length class. The blue lines represent results from fully parameterized double-logistic models. For the spring, the red lines represent results for a (single) logistic model whereas they represent results for a double logistic model with no minima for the ascending or descending logistic function for the fall.

Figure D16. Stratified mean number (top) and weight (kg) per tow of offshore hake for the NEFSC fall surveys, 1967-2009.

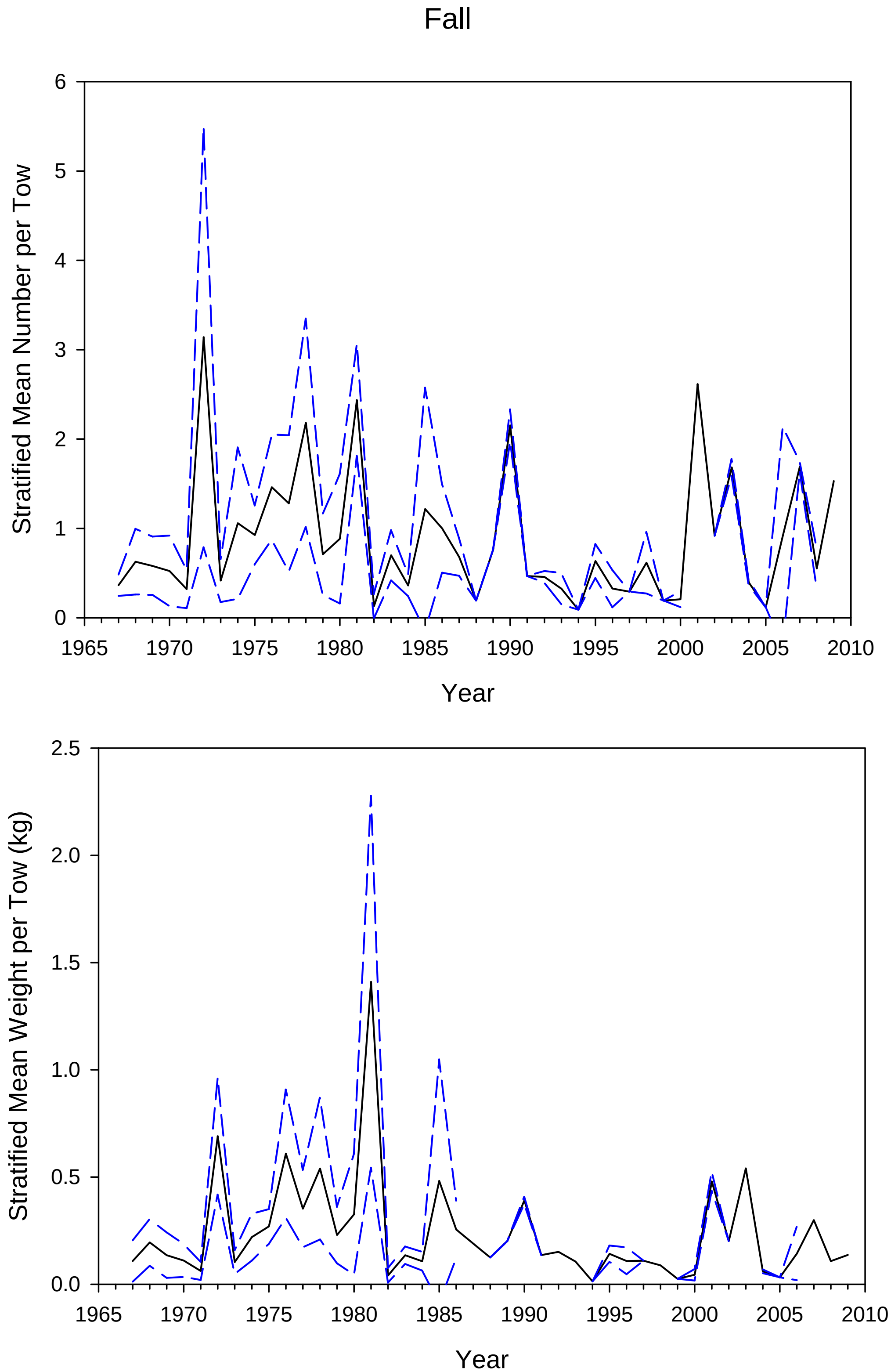


Figure D17. Swept area abundance (millions, top) and biomass (kg, bottom) of offshore hake for the NEFSC fall surveys, 1967-2009.

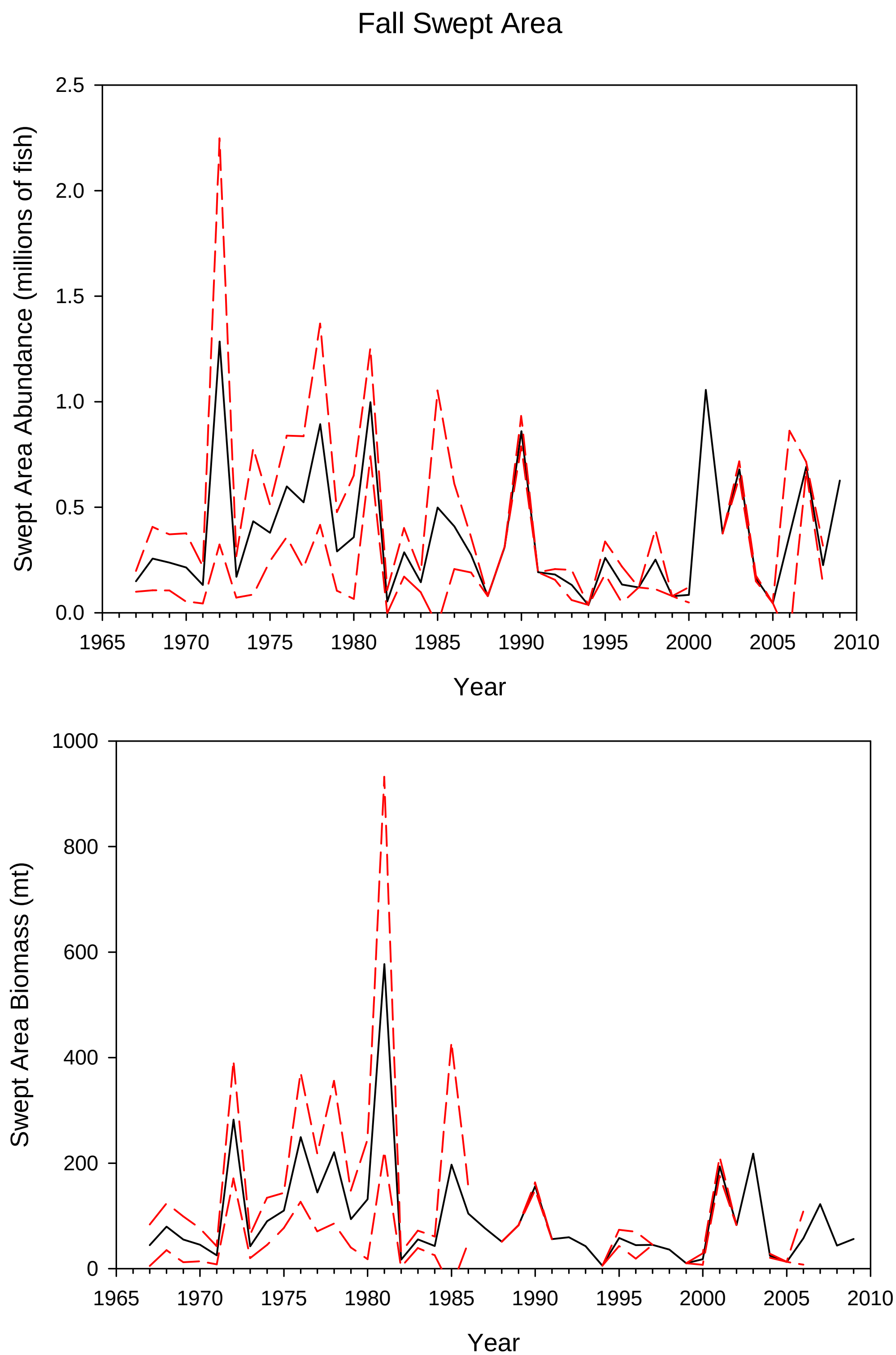
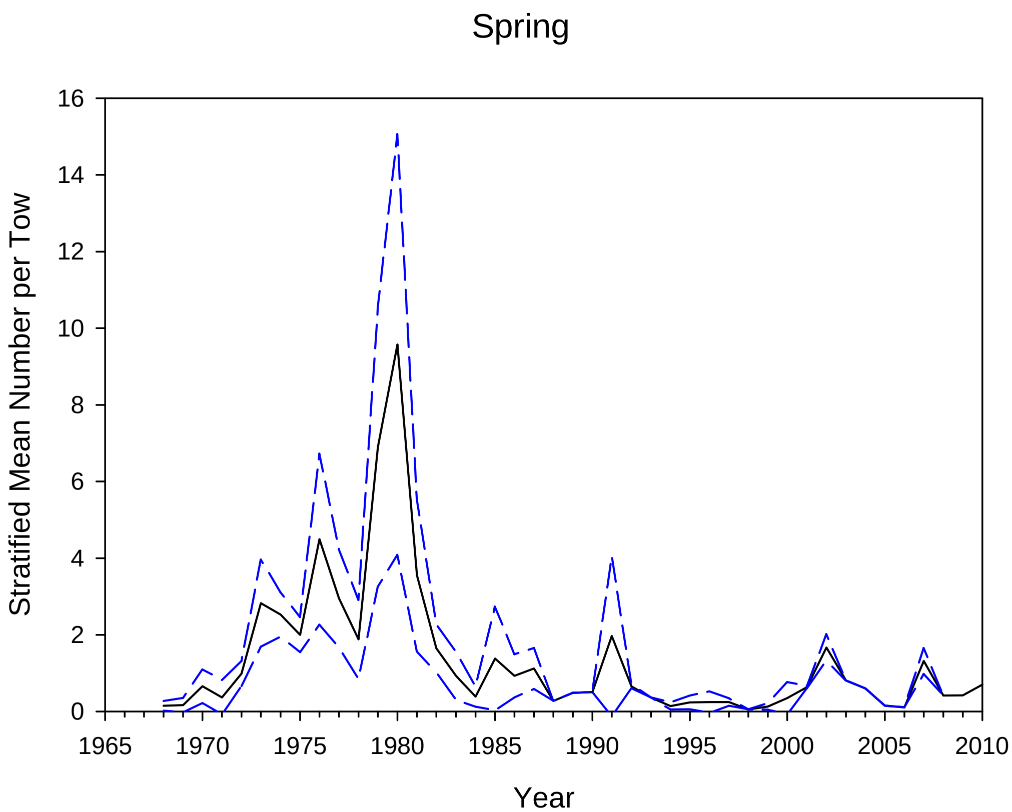


Figure D18. Stratified mean number (top) and weight (kg) per tow of offshore hake for the NEFSC spring surveys, 1968-2010.



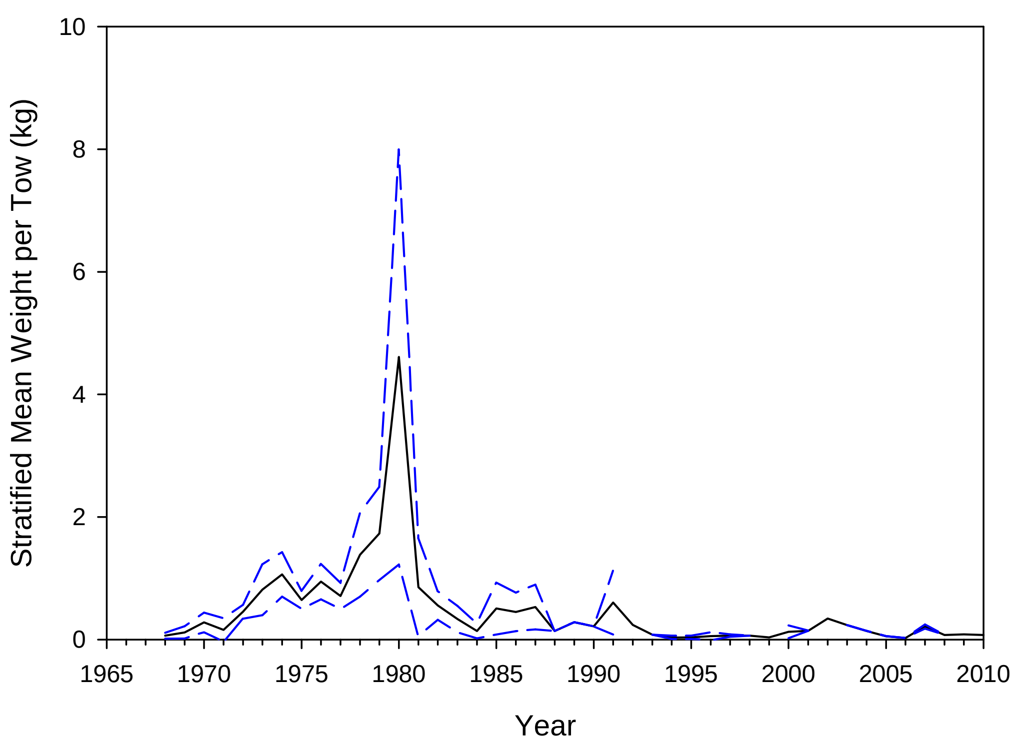


Figure D19. Swept area abundance (millions, top) and biomass (kg, bottom) of offshore hake for the NEFSC spring surveys, 1968-2010.

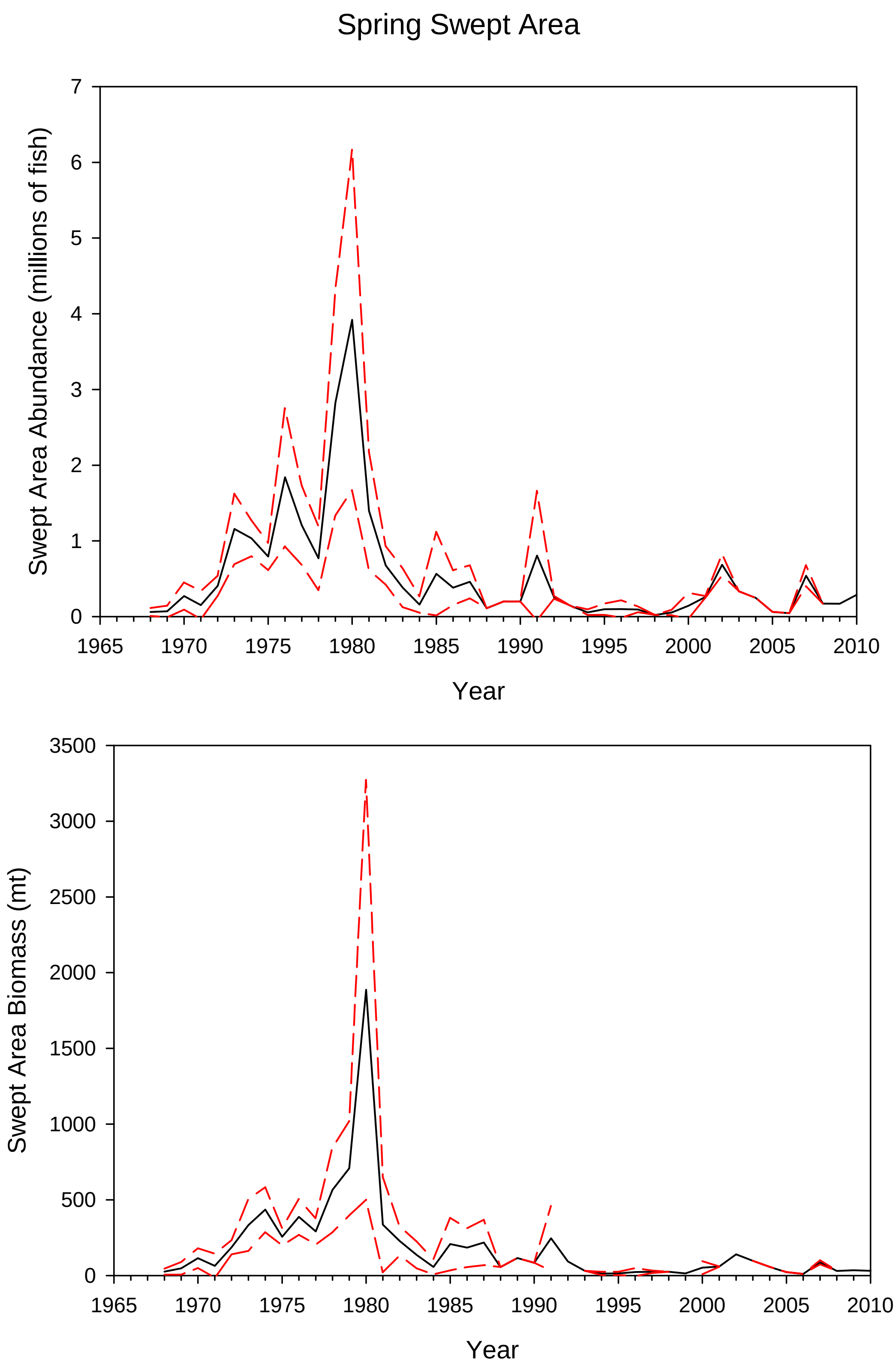
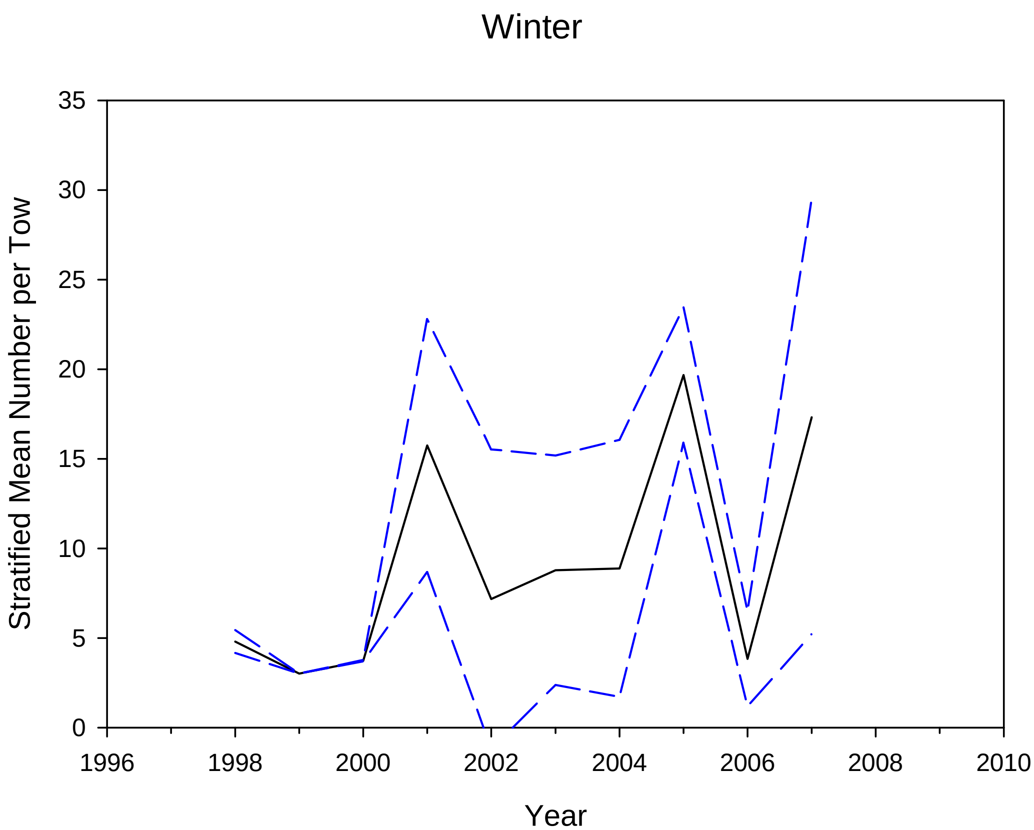


Figure D20. Stratified mean number (top) and weight (kg) per tow of offshore hake for the NEFSC winter surveys, 1998-2007.



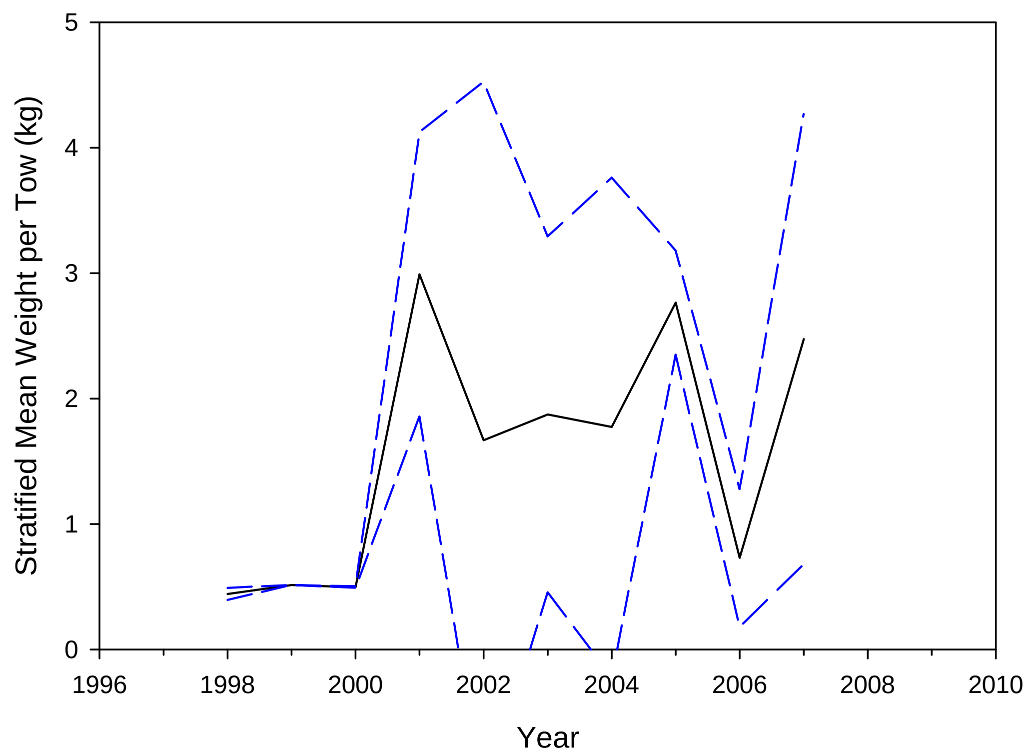
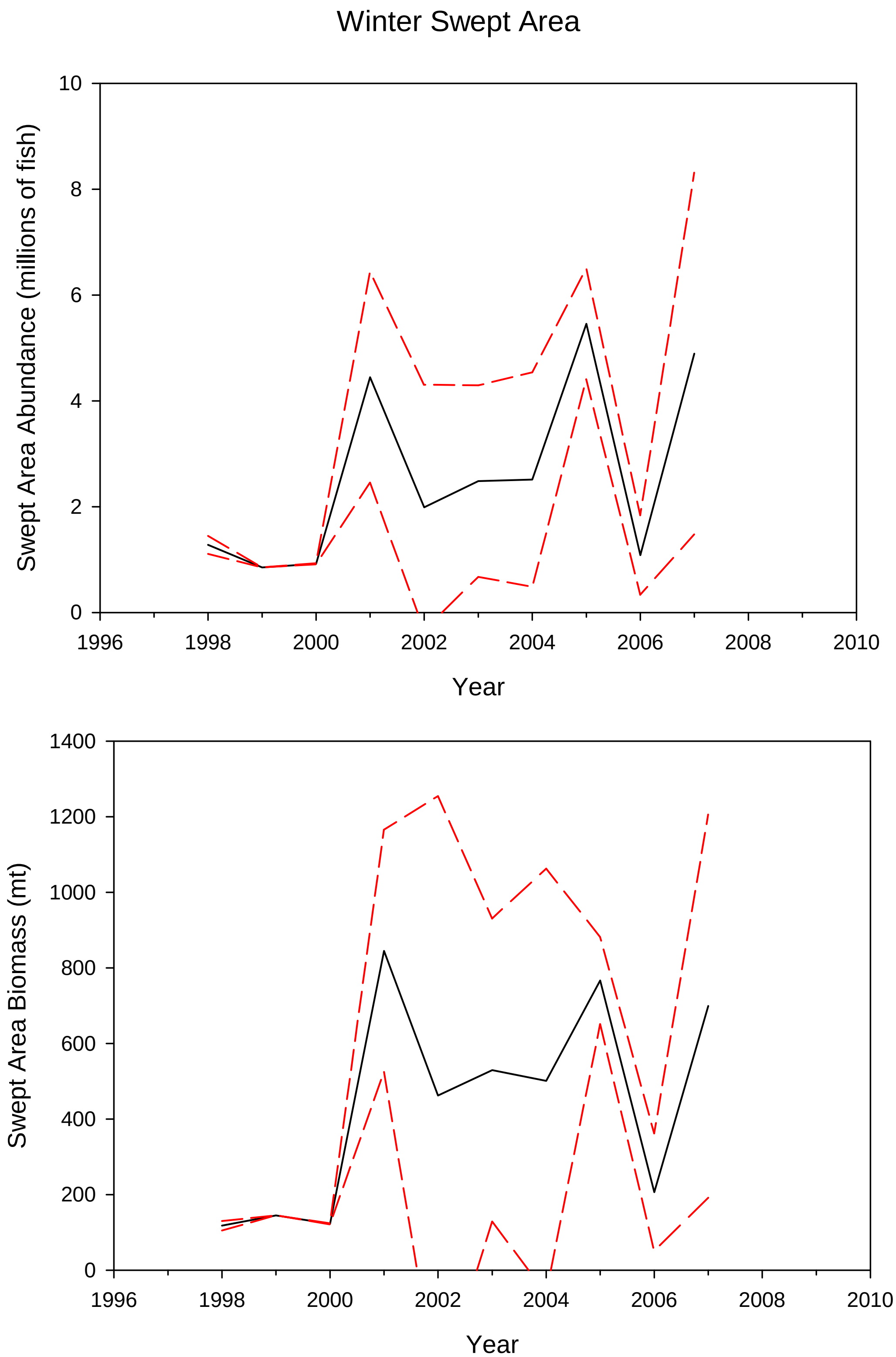


Figure D21. Swept area abundance (millions, top) and biomass (kg, bottom) of offshore hake for the NEFSC winter surveys, 1998-2007.



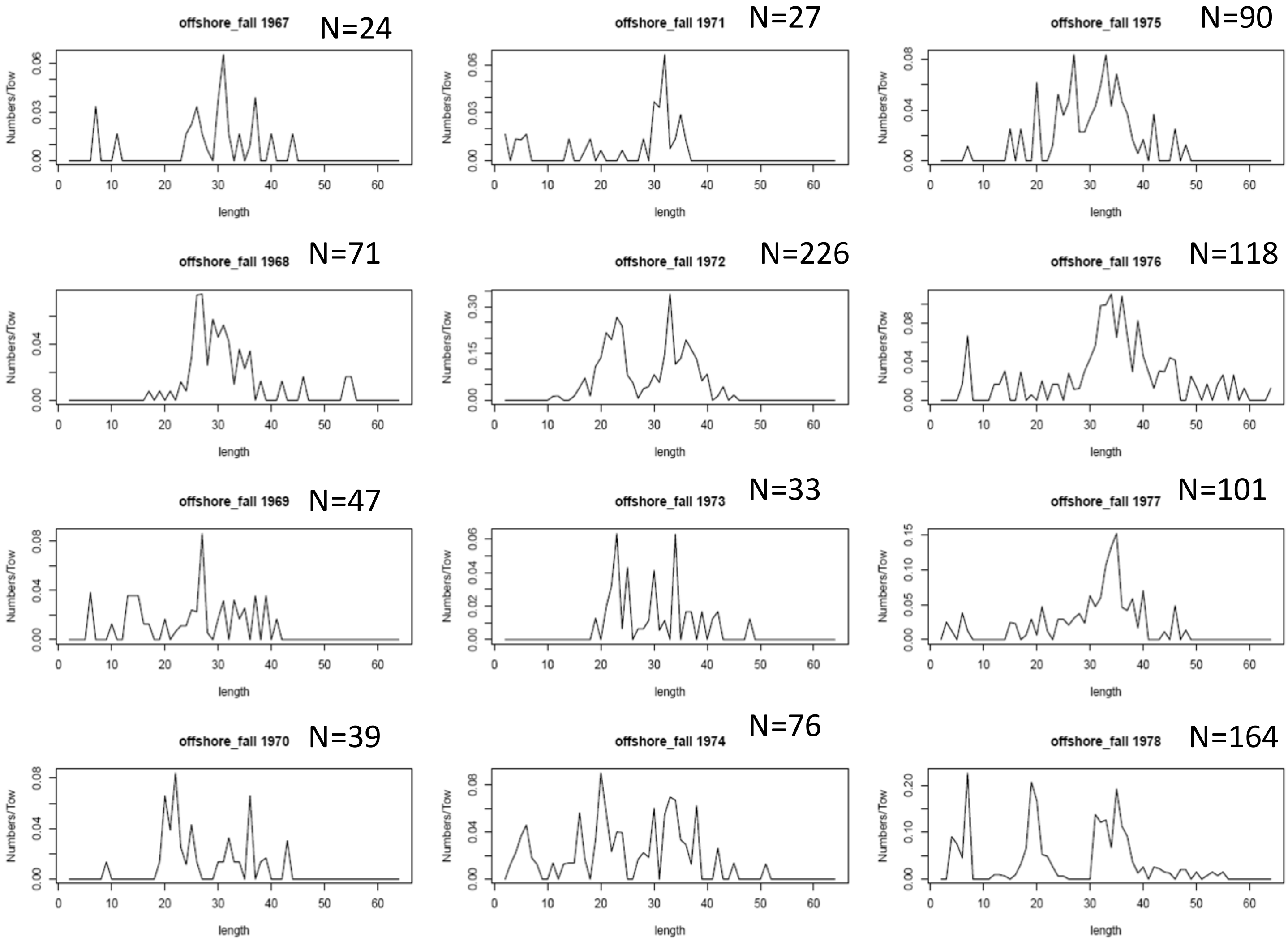


Figure D22a. Length composition (stratified mean number per tow) of offshore hake for the fall survey, 1967-2009.

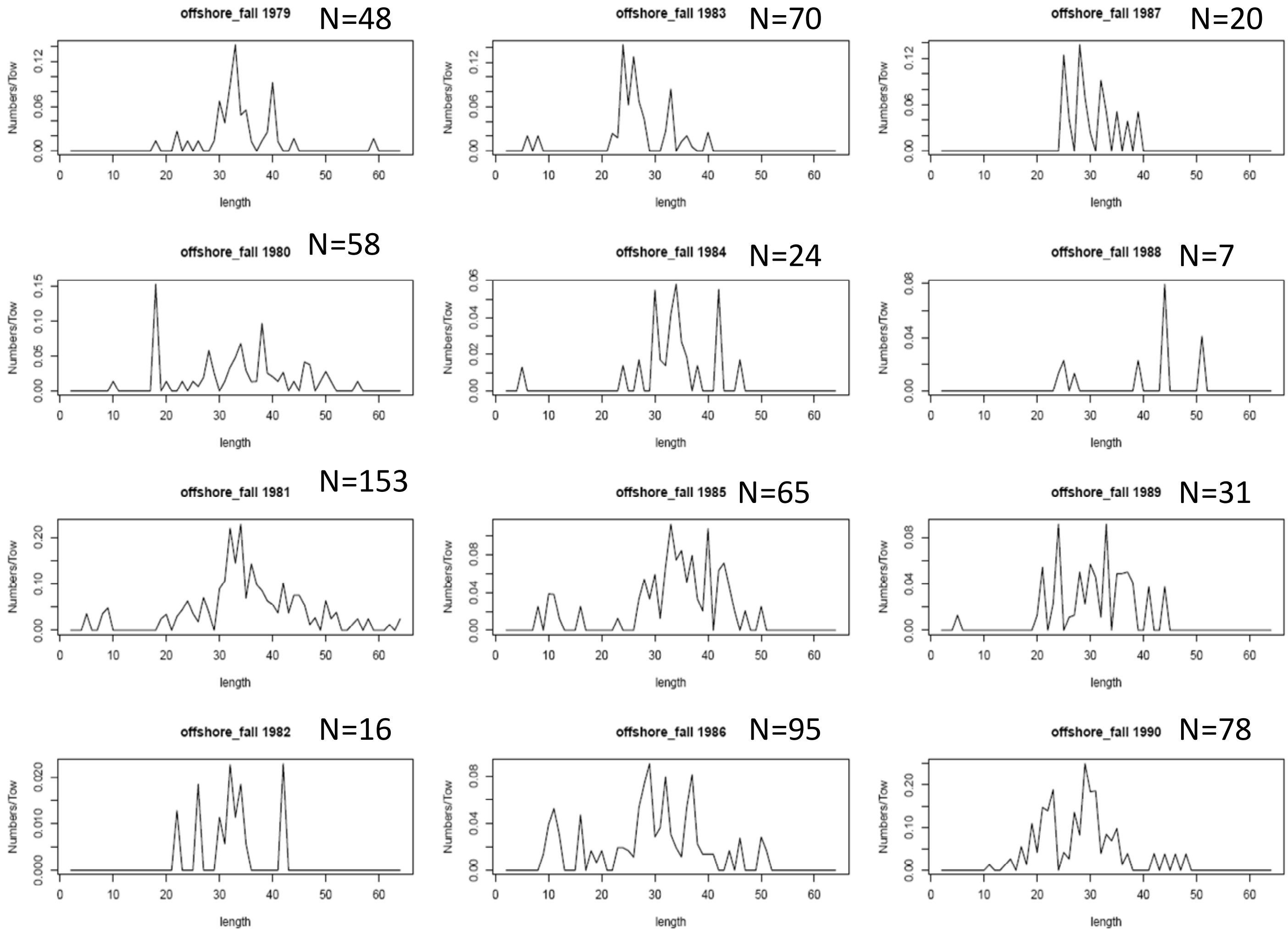


Figure D22b. Length composition (stratified mean number per tow) of offshore hake for the fall survey, 1967-2009.

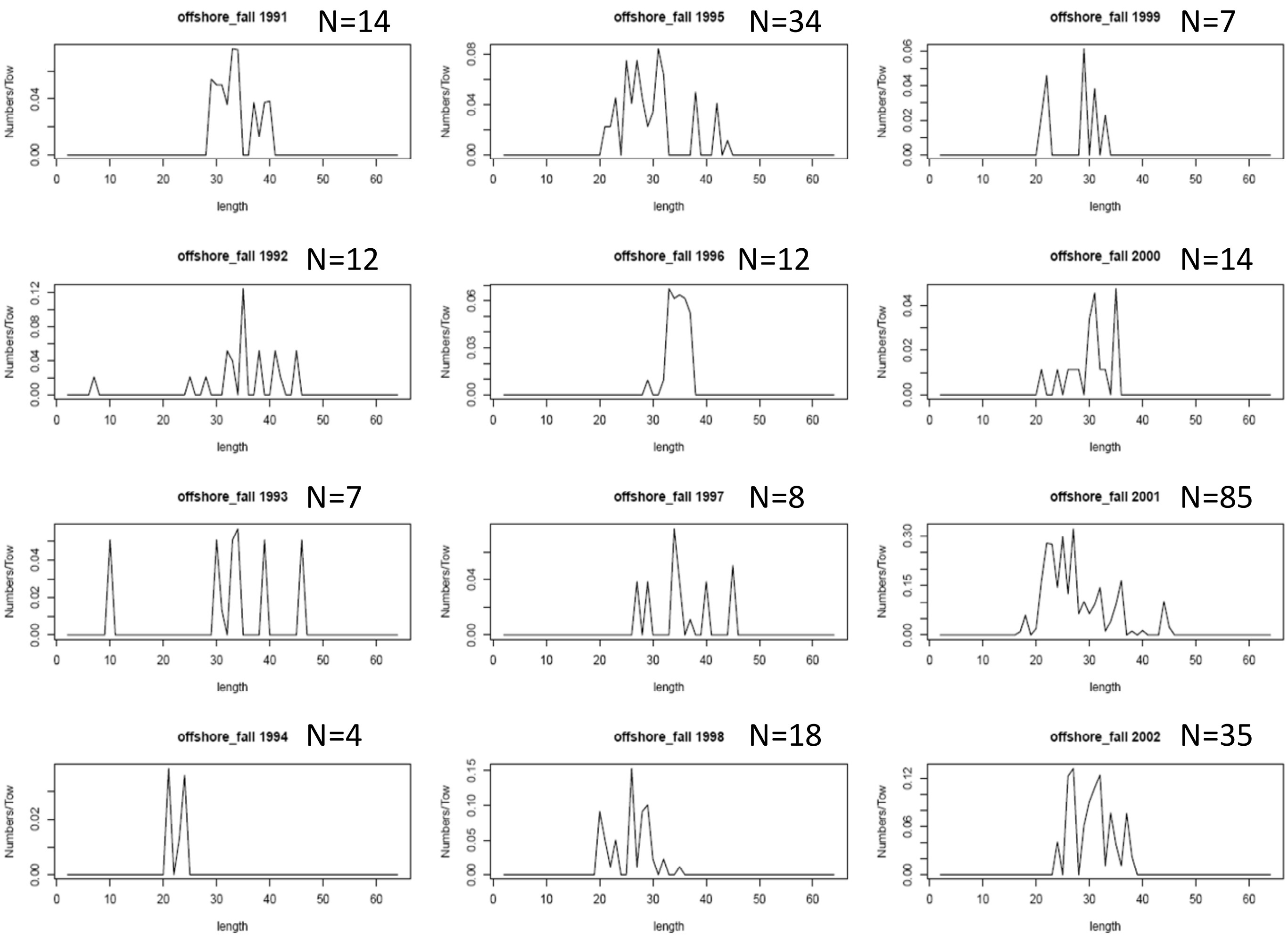


Figure D22c. Length composition (stratified mean number per tow) of offshore hake for the fall survey, 1967-2009.

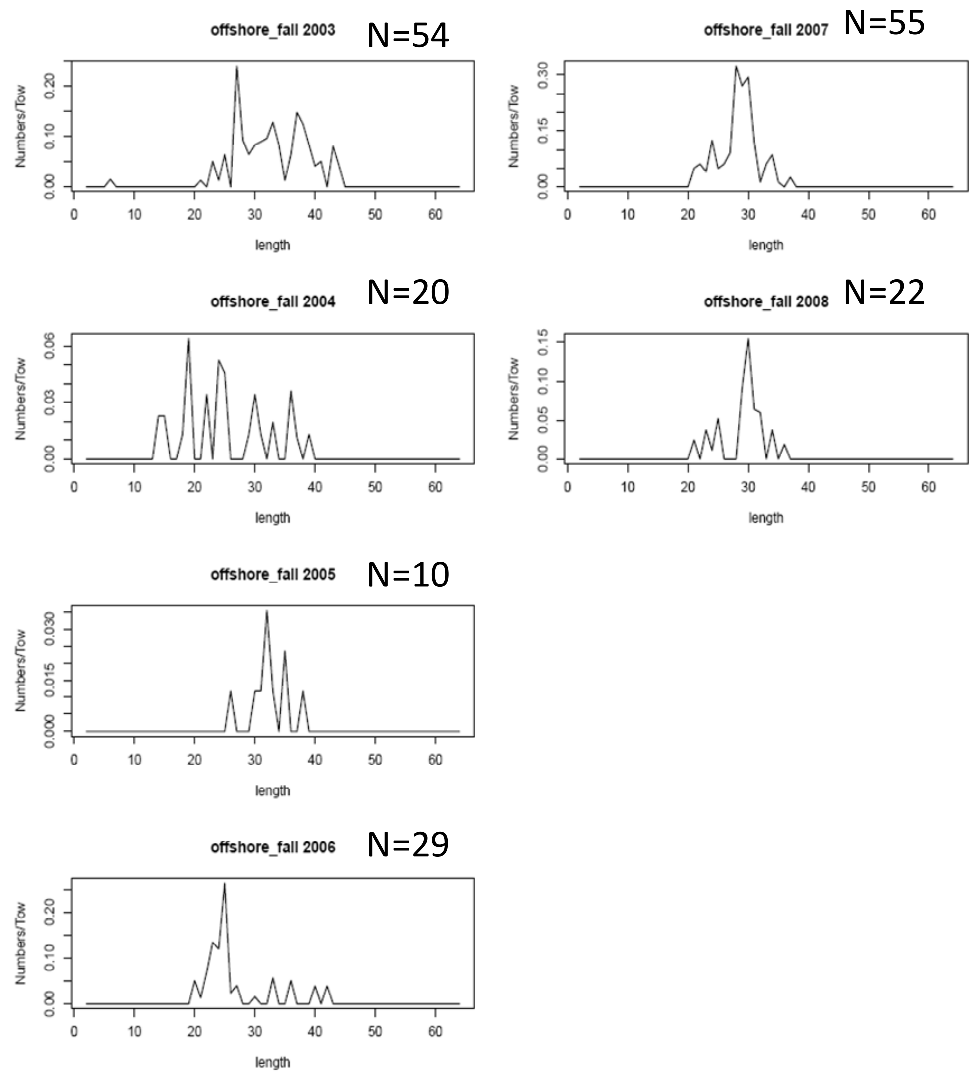


Figure D22d. Length composition (stratified mean number per tow) of offshore hake for the fall survey, 1967-2009.

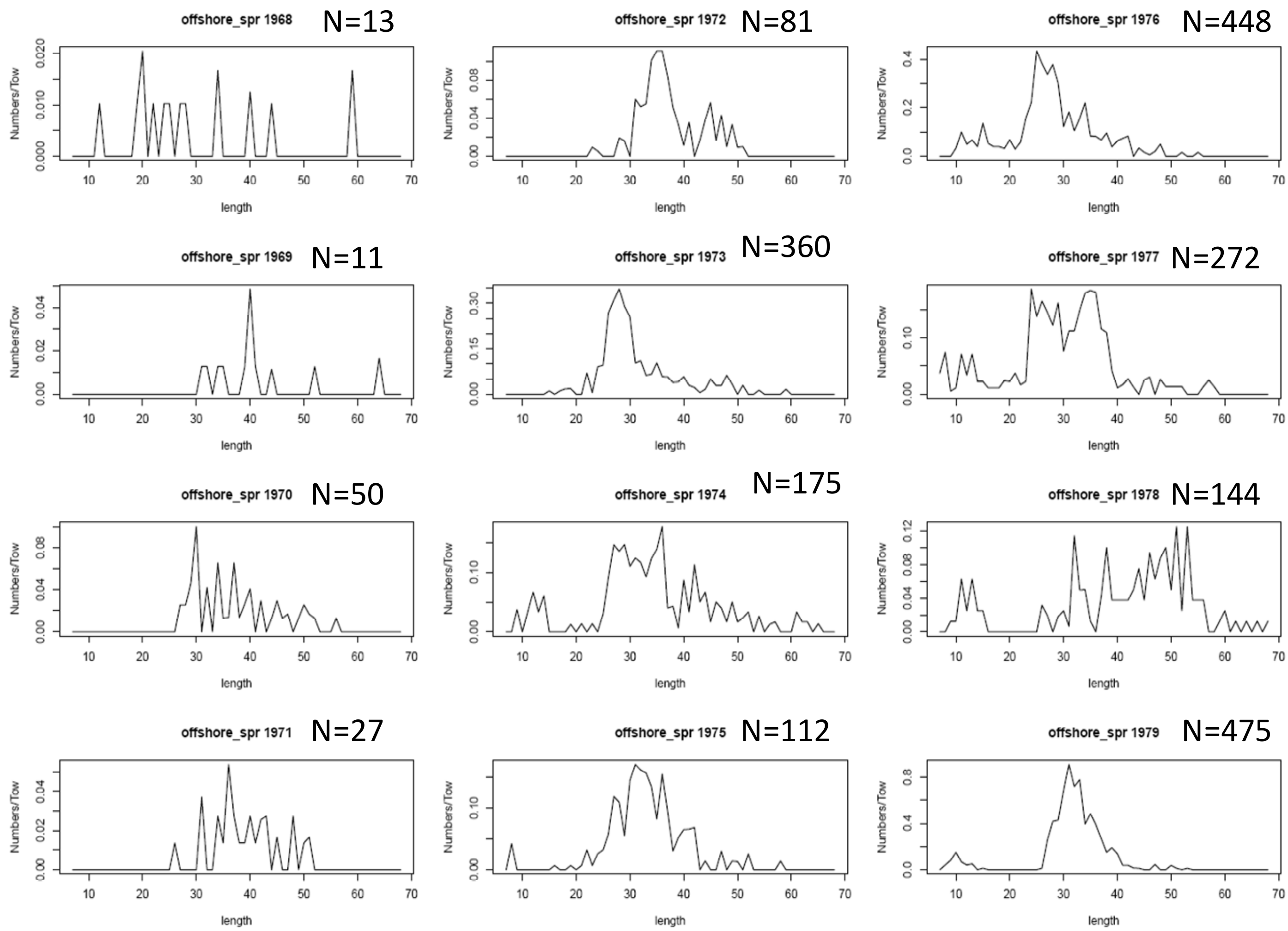


Figure D23a. Length composition (stratified mean number per tow) of offshore hake for the spring survey, 1968-2009.

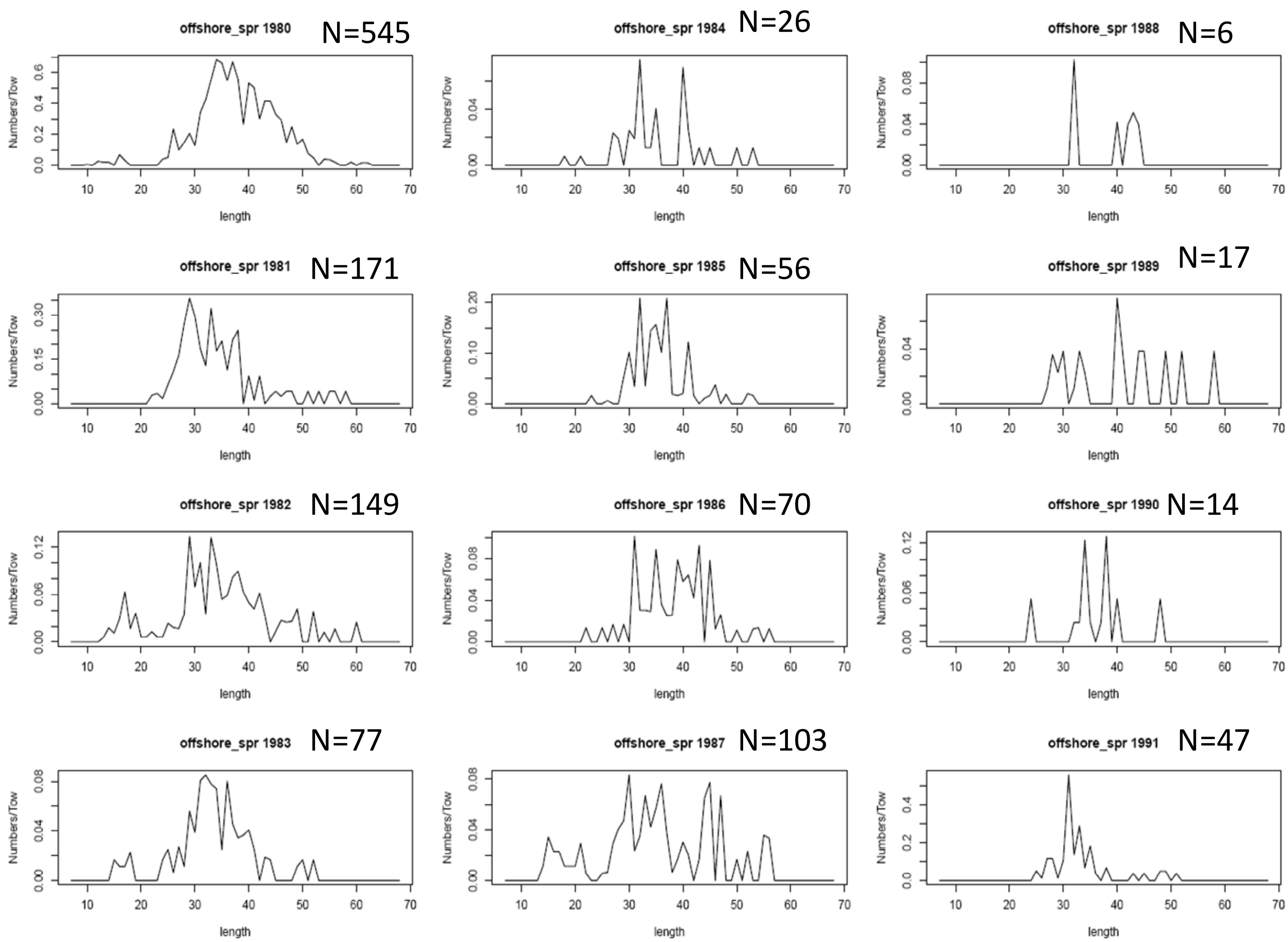


Figure D23b. Length composition (stratified mean number per tow) of offshore hake for the spring survey, 1968-2009.

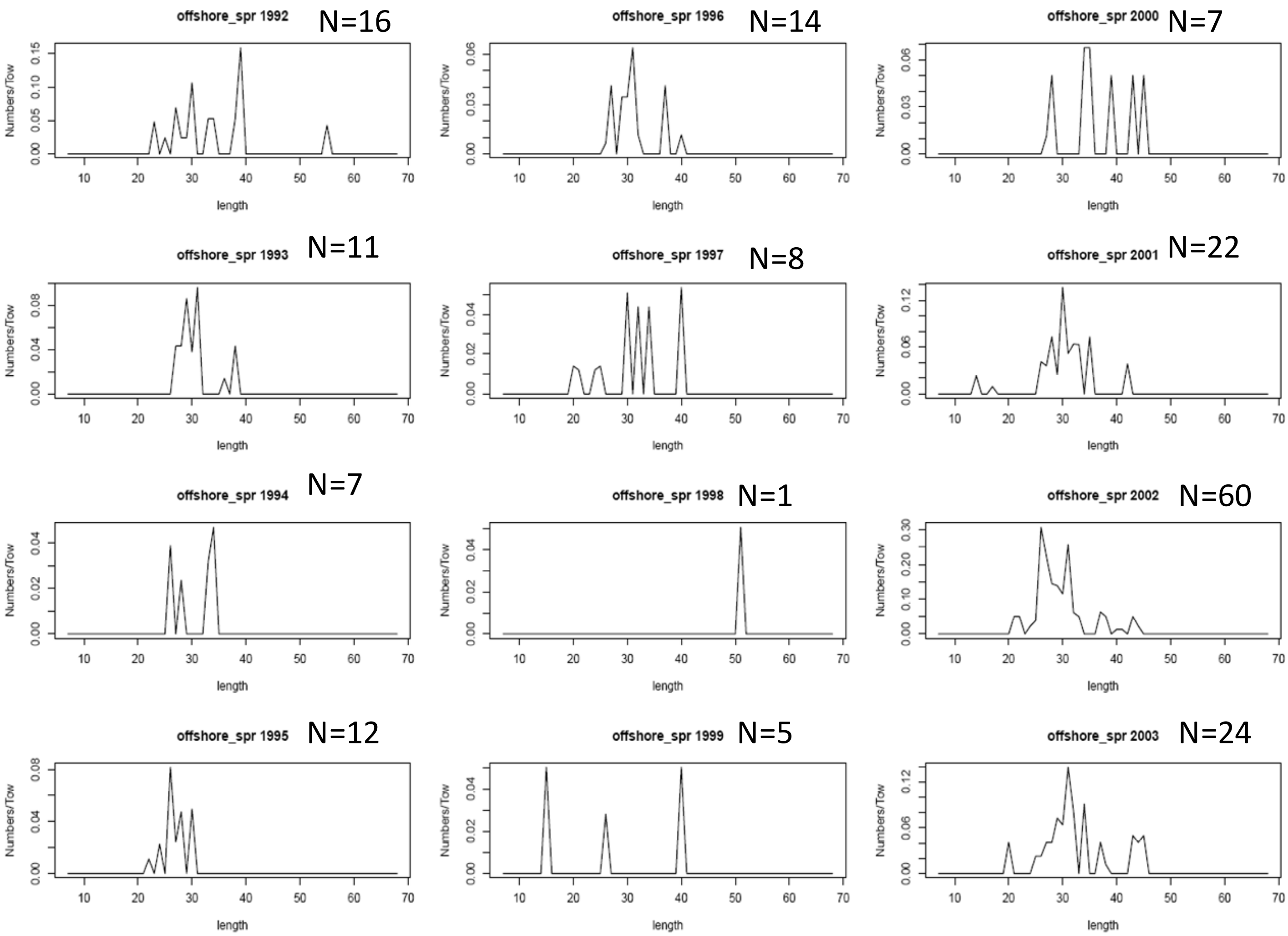


Figure D23c. Length composition (stratified mean number per tow) of offshore hake for the spring survey, 1968-2009.

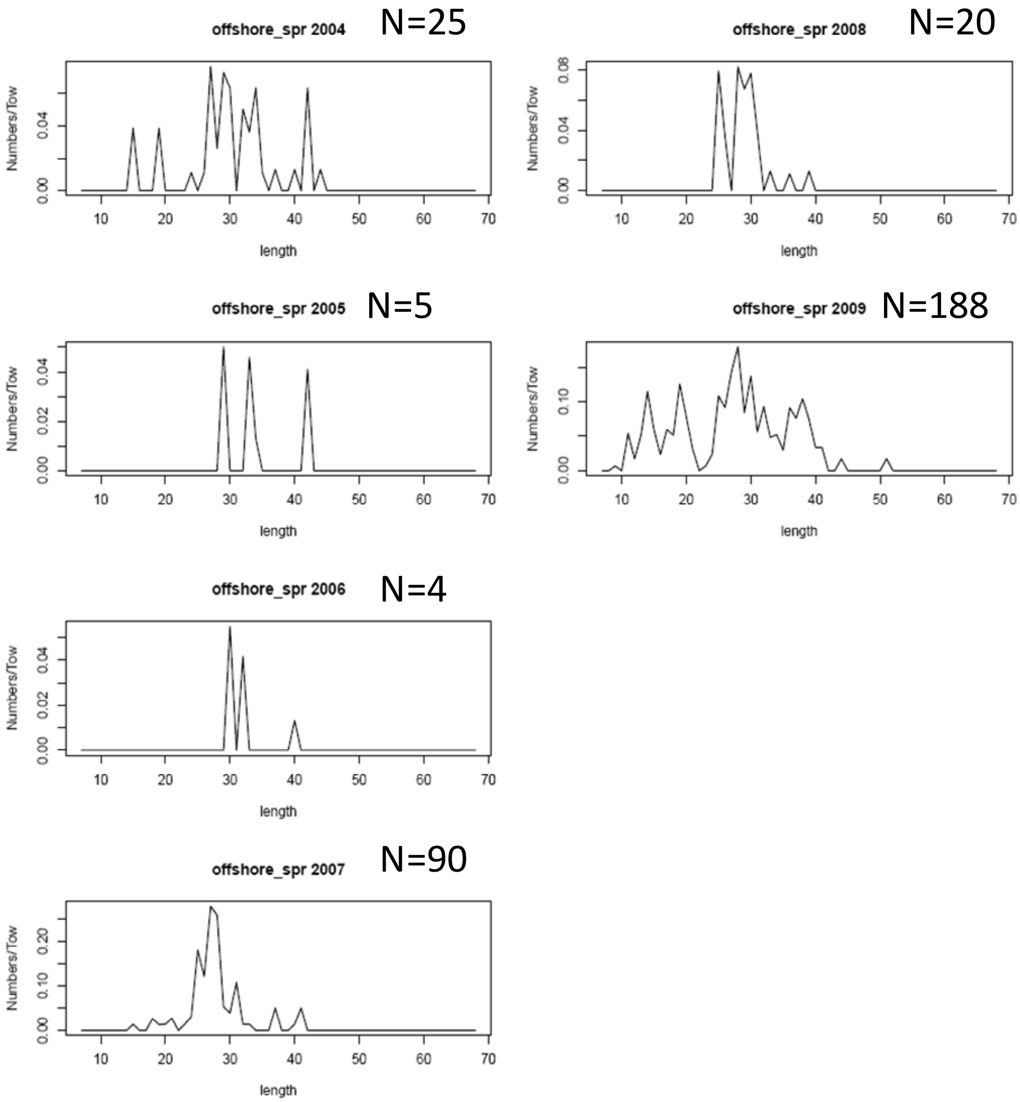


Figure D23d. Length composition (stratified mean number per tow) of offshore hake for the spring survey, 1968-2009.

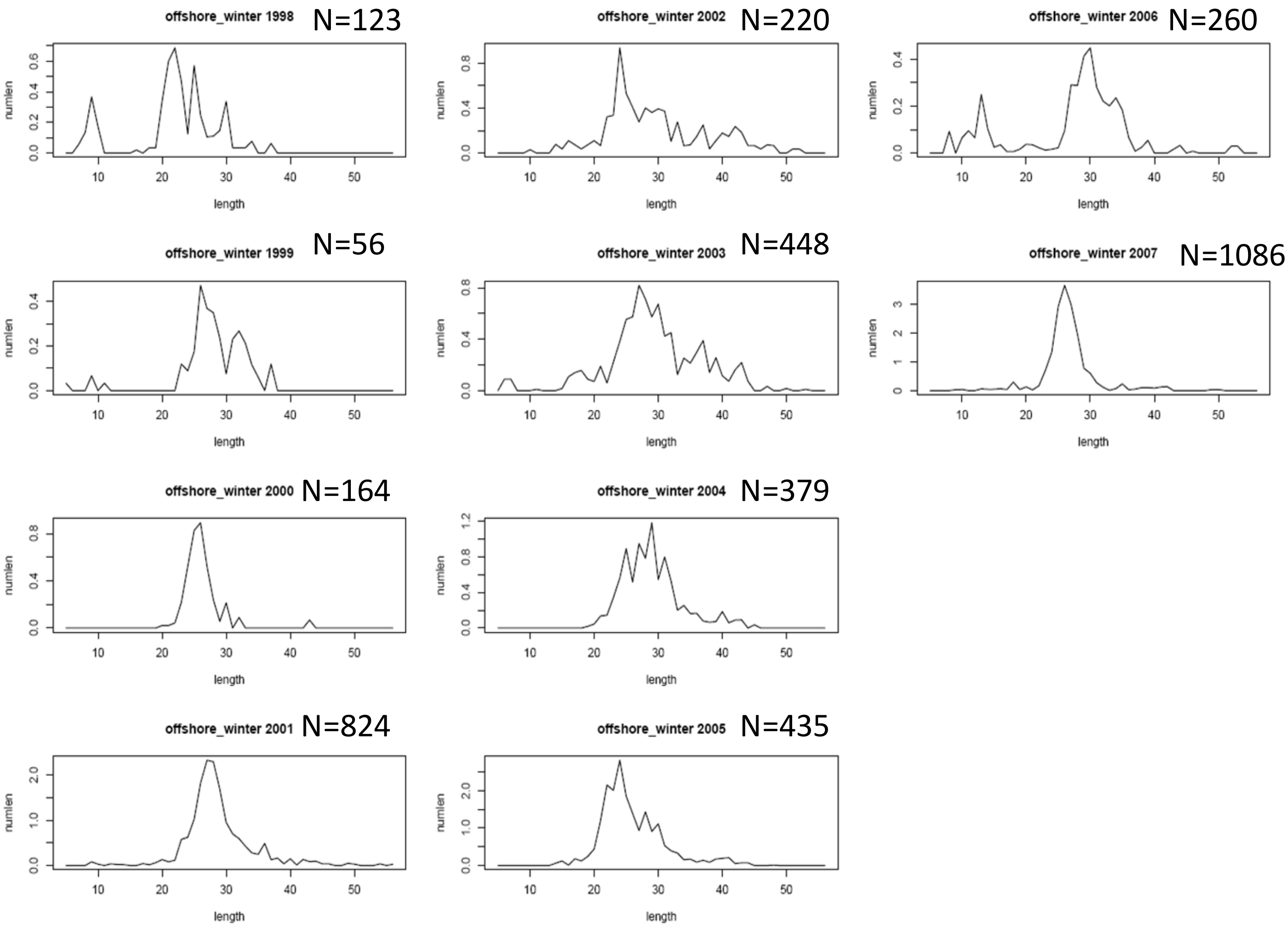


Figure D24. Length composition (stratified mean number per tow) of offshore hake for the winter survey, 1998-2007.

Figure D25a. Three-year moving average length composition (stratified mean number per tow) of offshore hake for the fall survey, 1969-2008.

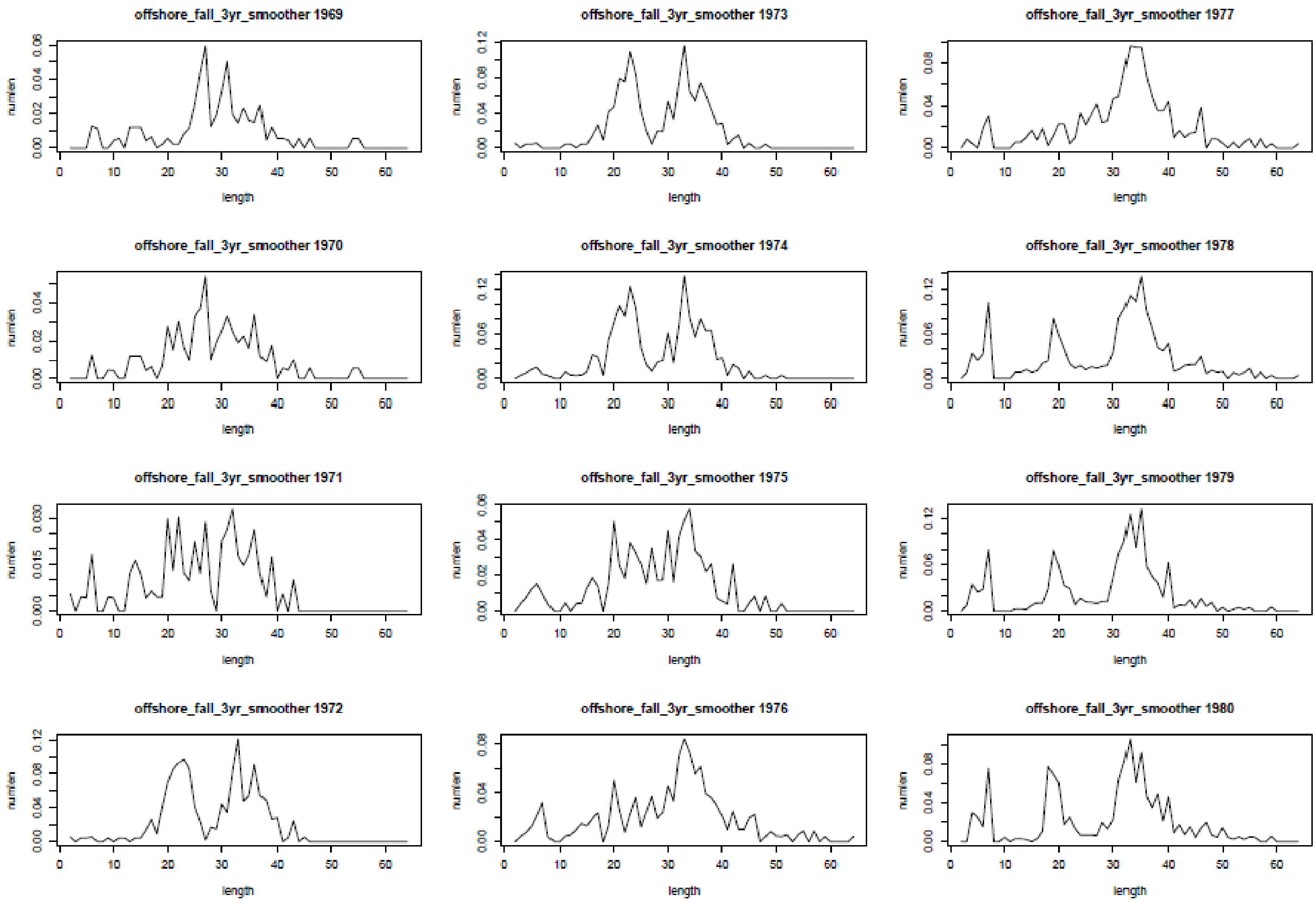


Figure D25b. Three-year moving average length composition (stratified mean number per tow) of offshore hake for the fall survey, 1969-2008.

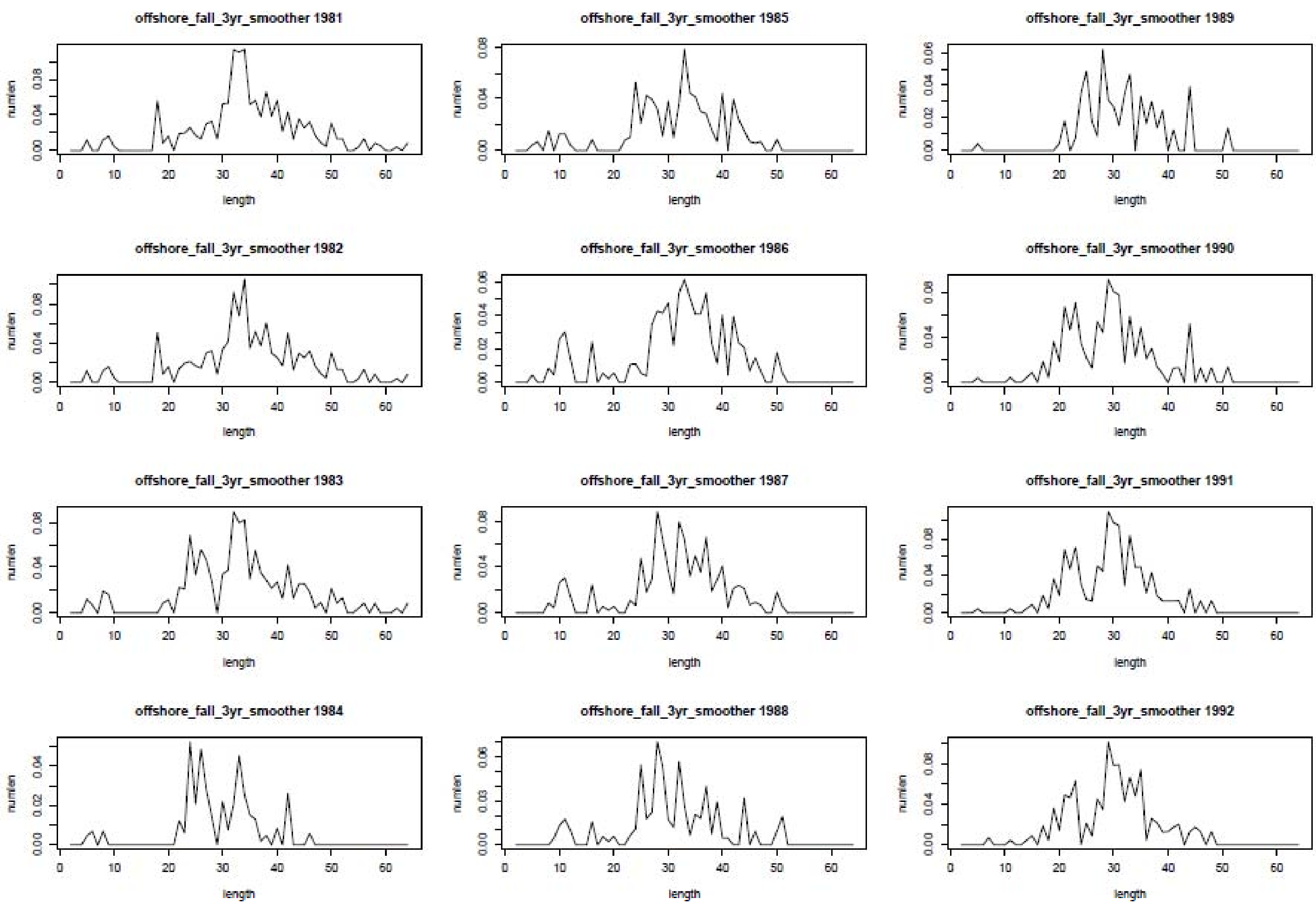


Figure D25c. Three-year moving average length composition (stratified mean number per tow) of offshore hake for the fall survey, 1969-2008.

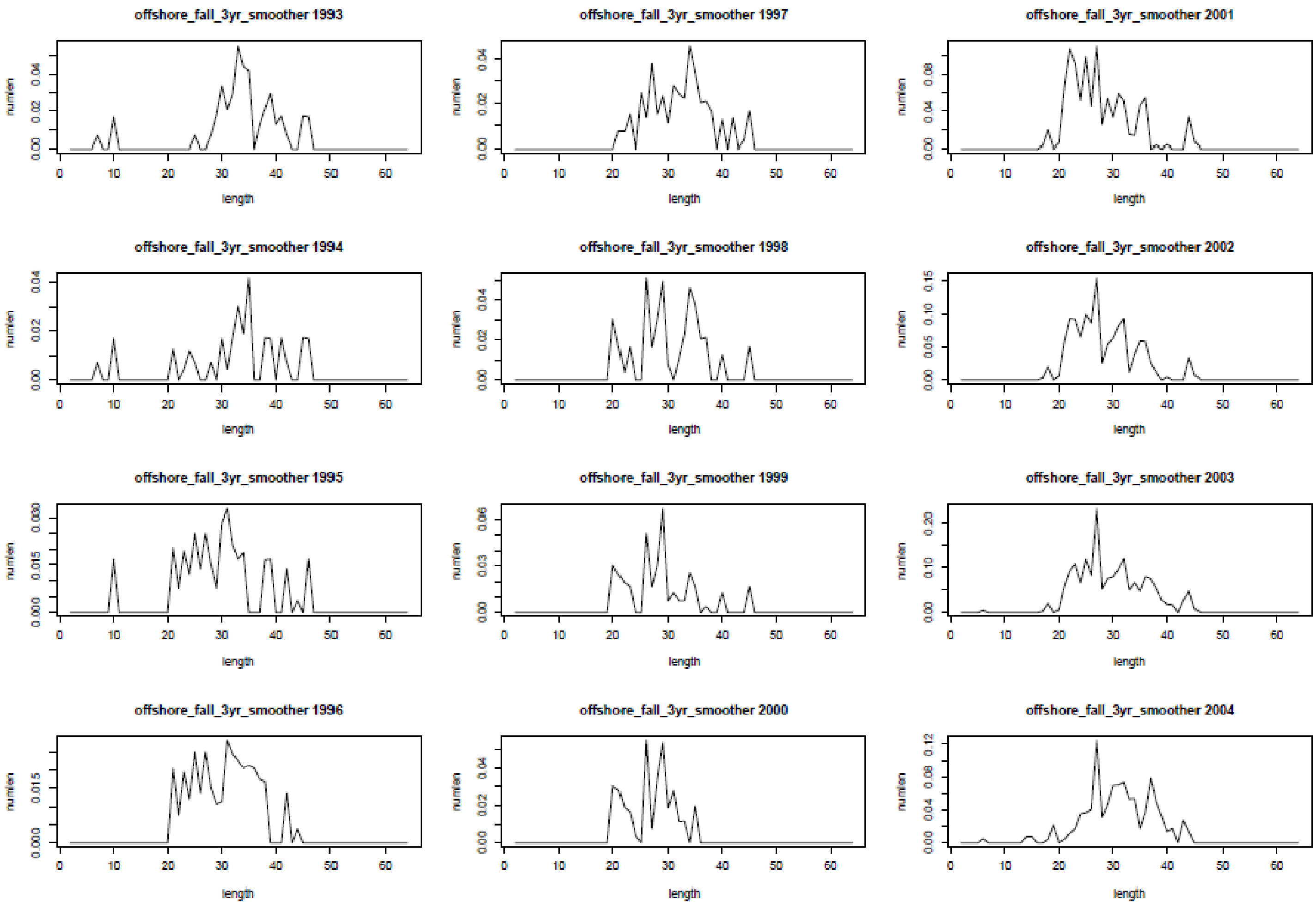
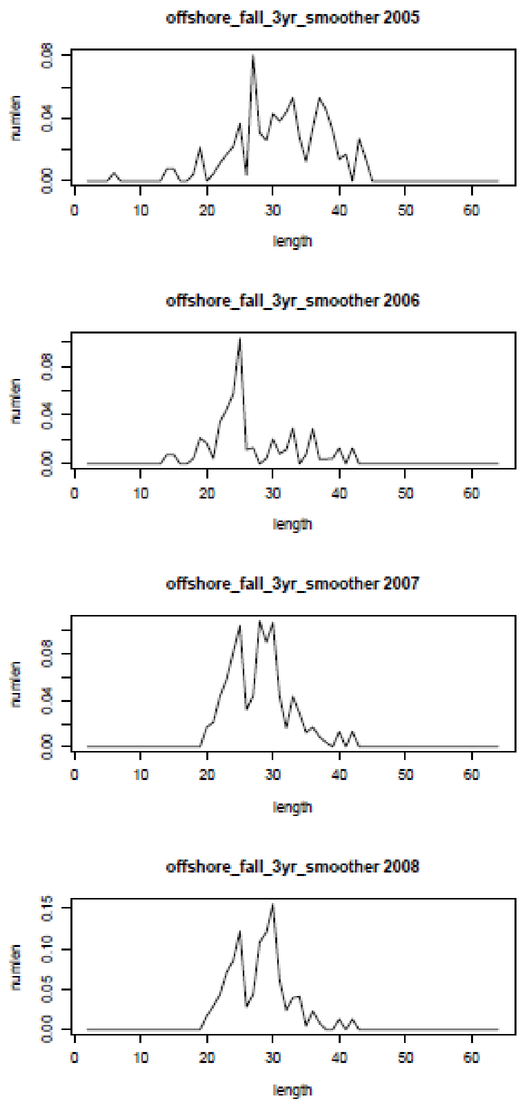


Figure D25d. Three-year moving average length composition (stratified mean number per tow) of offshore hake for the fall survey, 1969-2008.



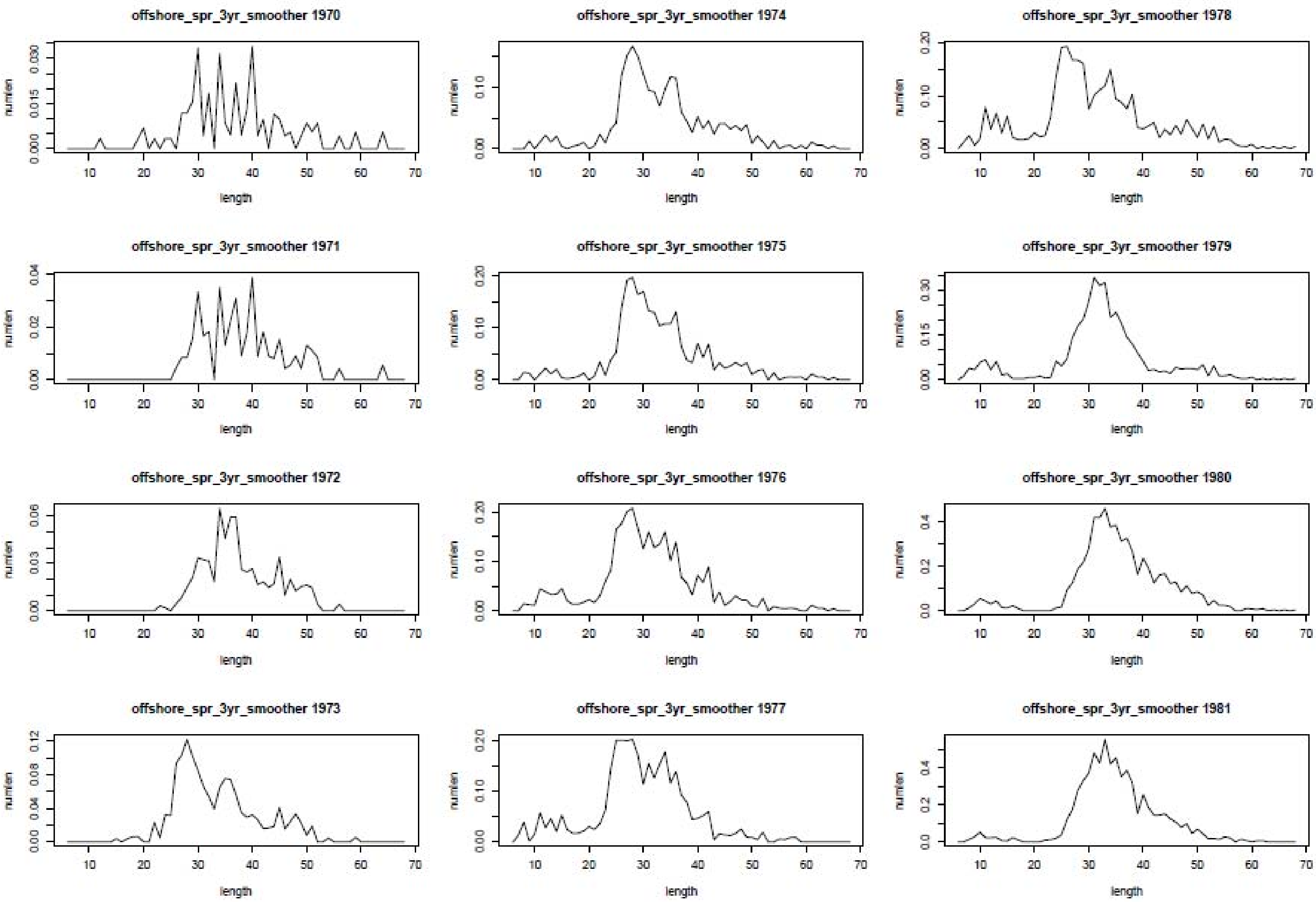


Figure D26a. Three-year moving average length composition (stratified mean number per tow) of offshore hake for the spring survey, 1970-2008.

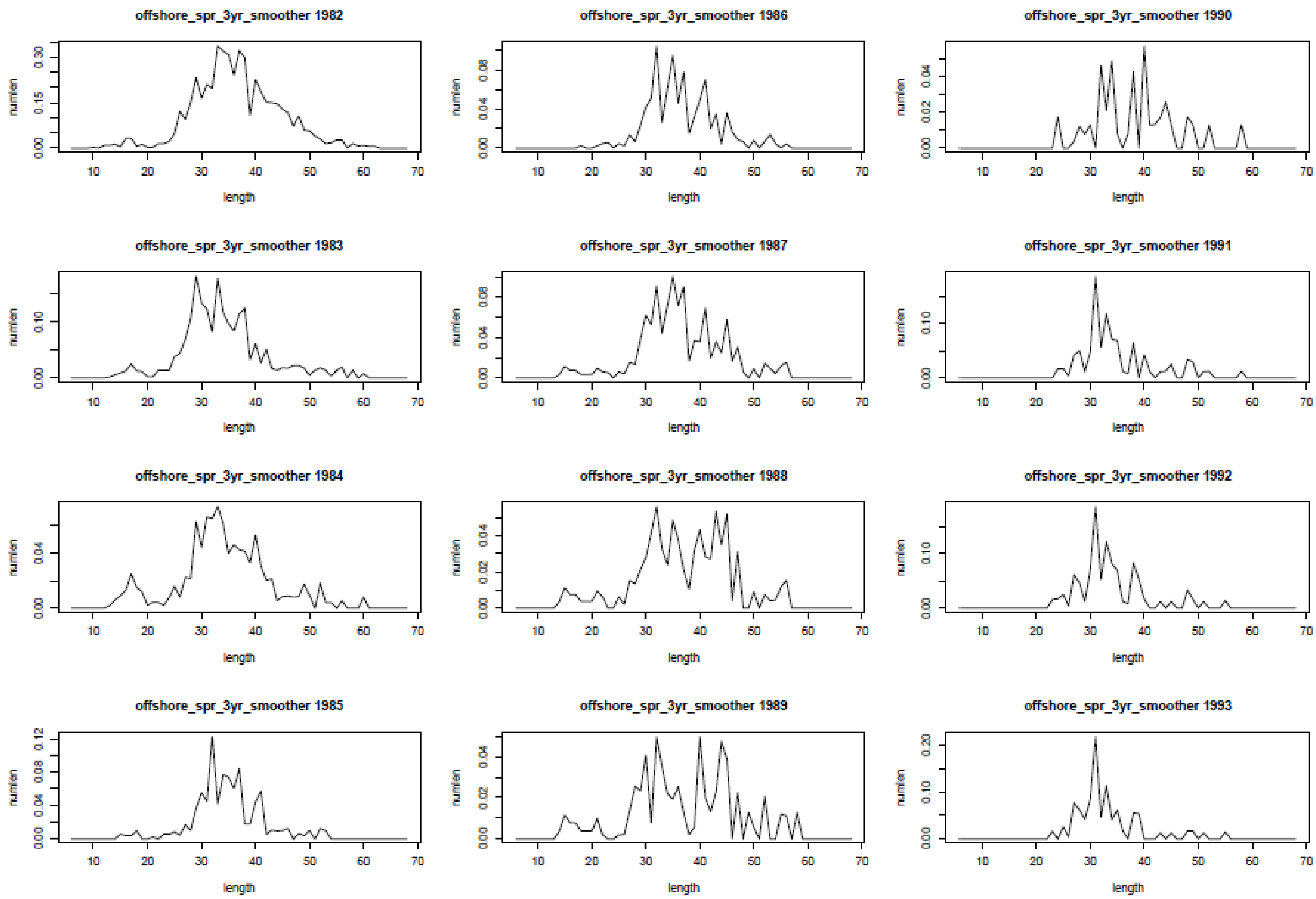


Figure D26b. Three-year moving average length composition (stratified mean number per tow) of offshore hake for the spring survey, 1970-2008.

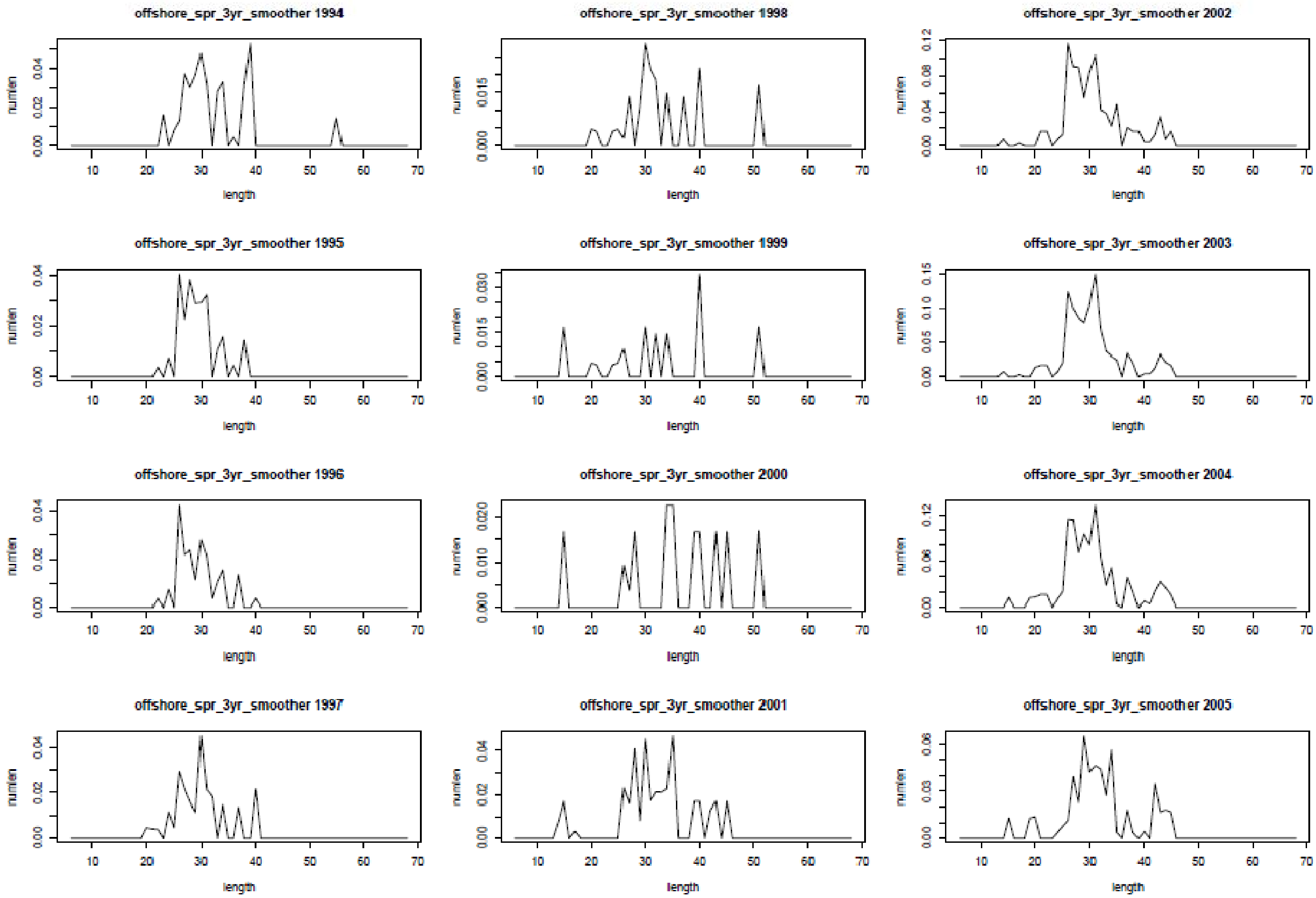


Figure D26c. Three-year moving average length composition (stratified mean number per tow) of offshore hake for the spring survey, 1970-2008.

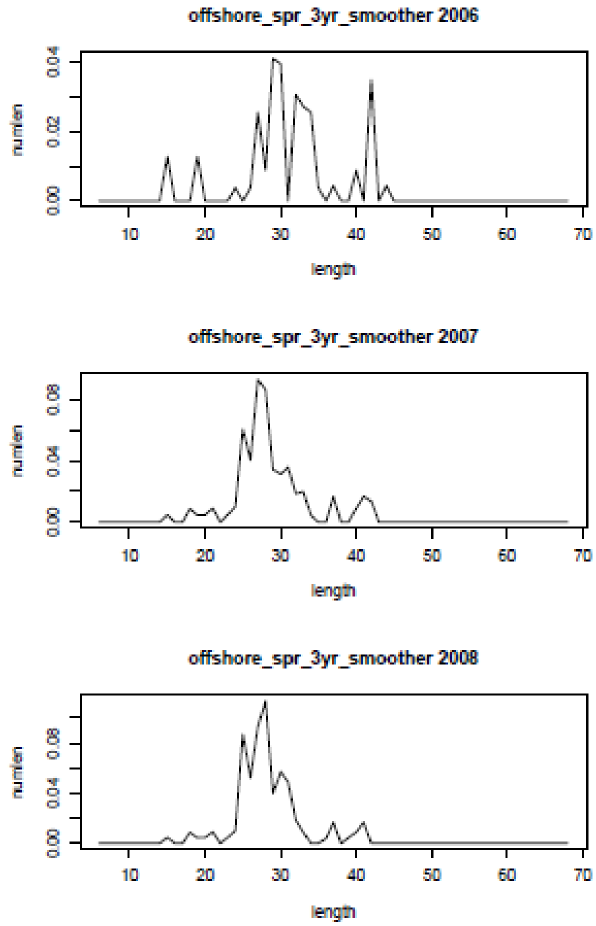


Figure D26d. Three-year moving average length composition (stratified mean number per tow) of offshore hake for the spring survey, 1970-2008.

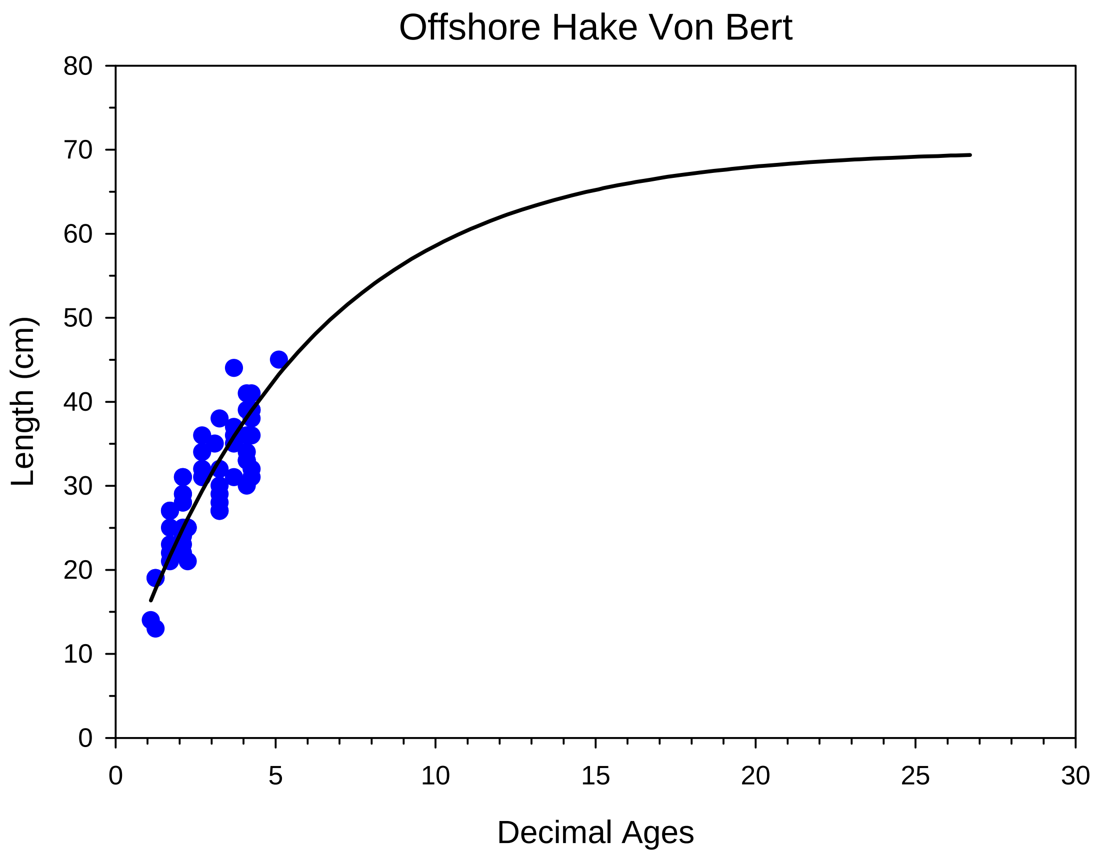


Figure D27. Von Bertalanffy estimates for offshore hake, using the NEFSC preliminary ages.

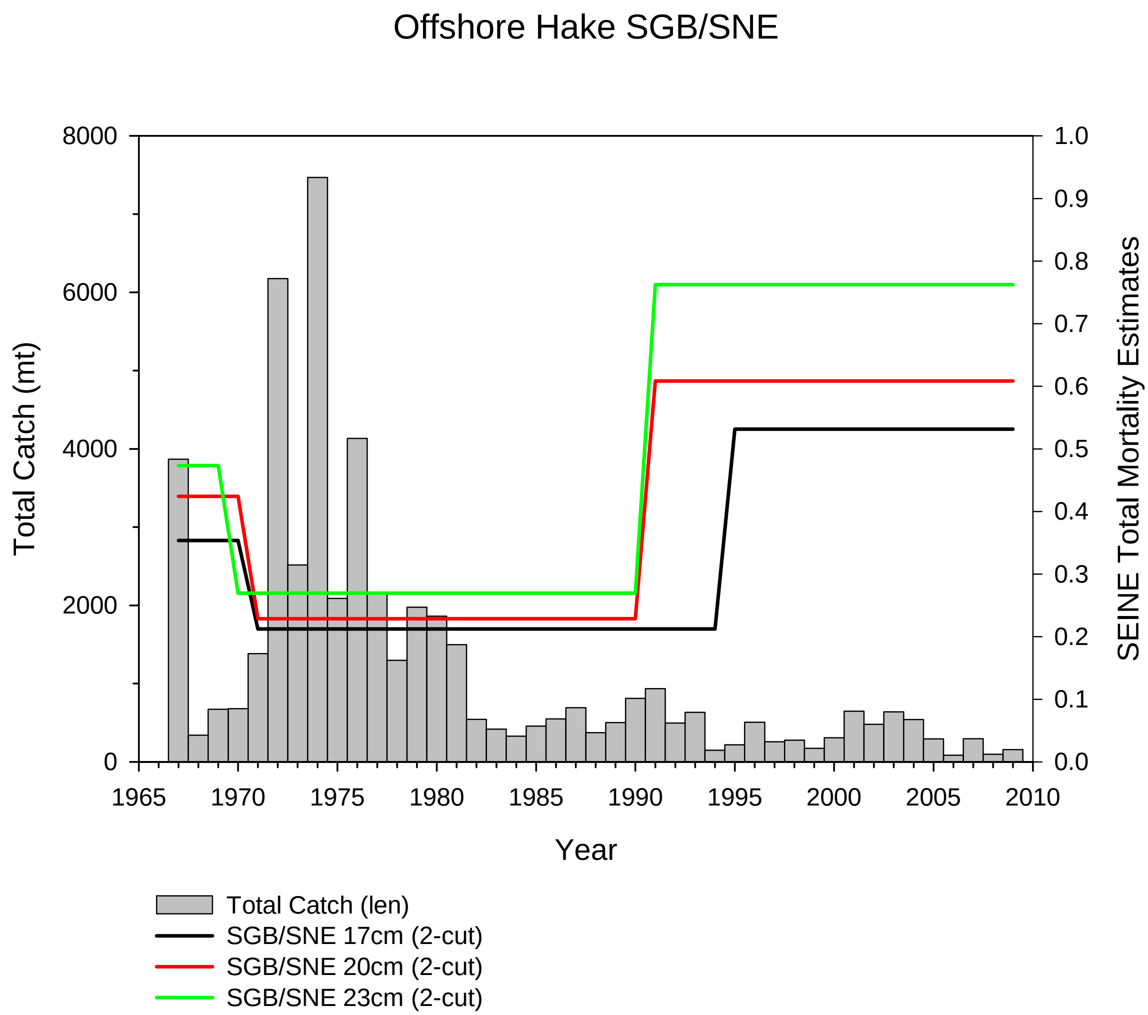


Figure D28. Offshore hake SEINE model results using silver hake average of Southern Georges Bank and Southern New England growth parameters, laid over total catch (metric tons). Lines indicate mortality estimates.

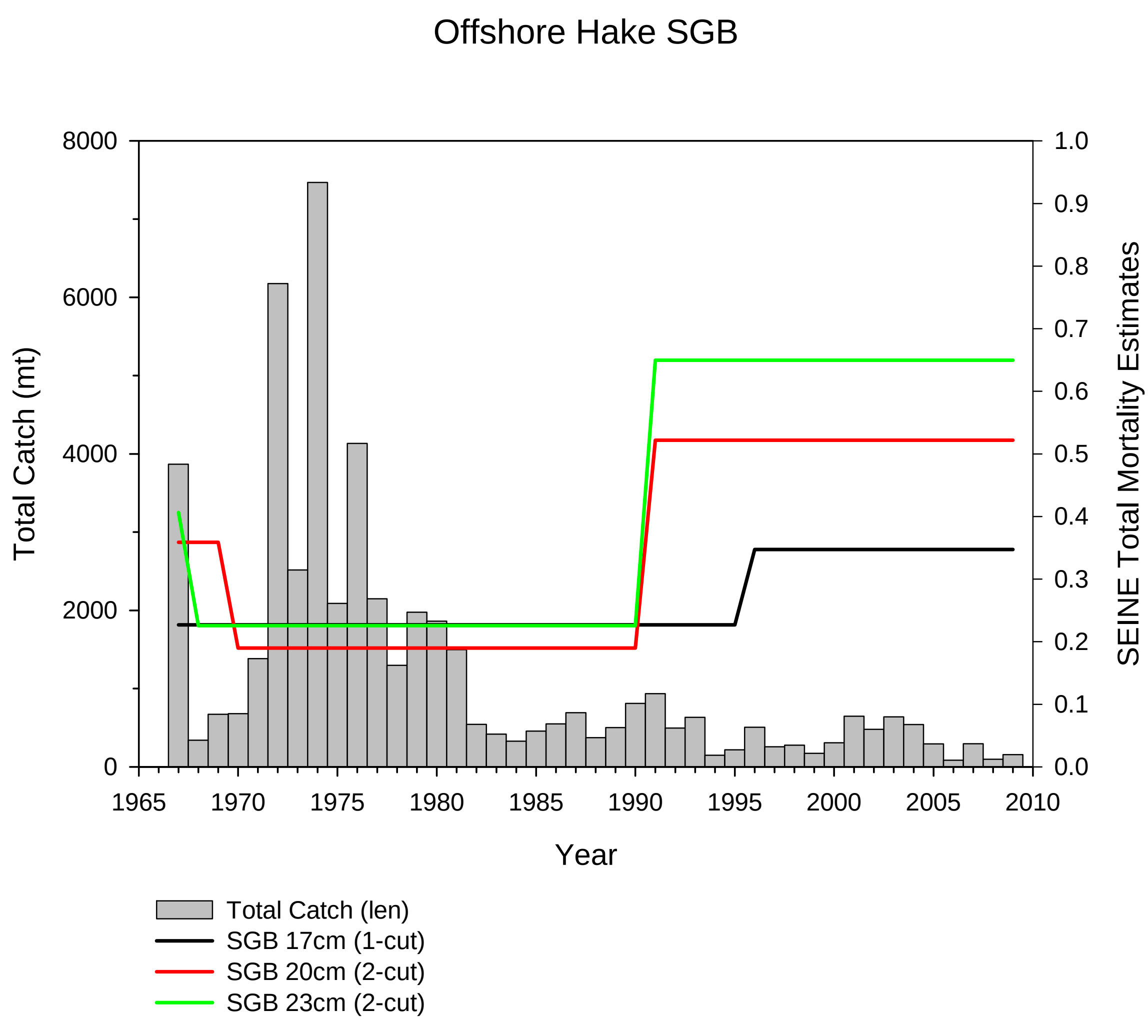


Figure D29. Offshore hake SEINE model results using silver hake Southern Georges Bank growth parameters, laid over total catch (metric tons). Lines indicate mortality estimates.

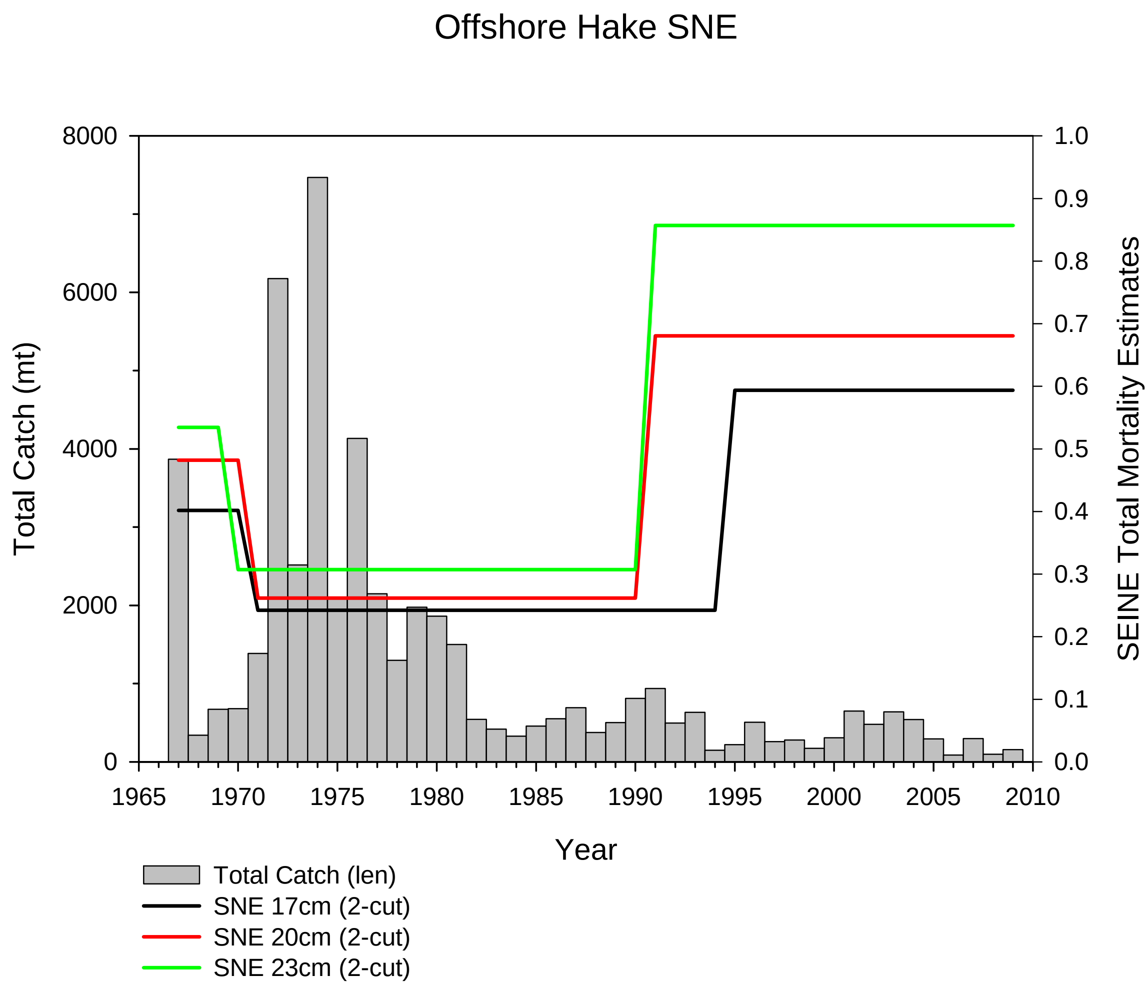


Figure D30. Offshore hake SEINE model results using silver hake Southern New England growth parameters, laid over total catch (metric tons). Lines indicate mortality estimates.

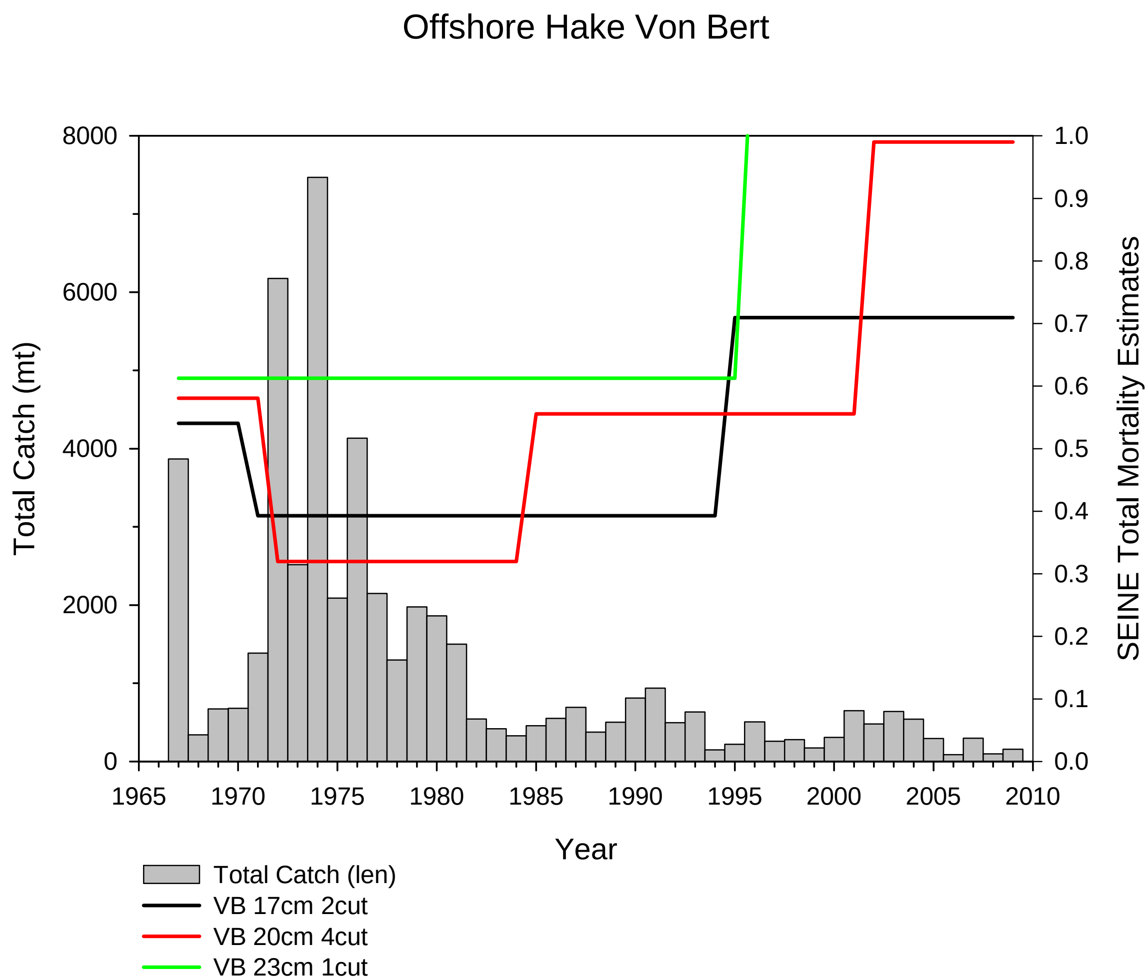


Figure D31. SEINE model results using the estimated von Bertalanffy growth parameters for offshore hake, laid over total catch (metric tons). Lines indicate mortality estimates.

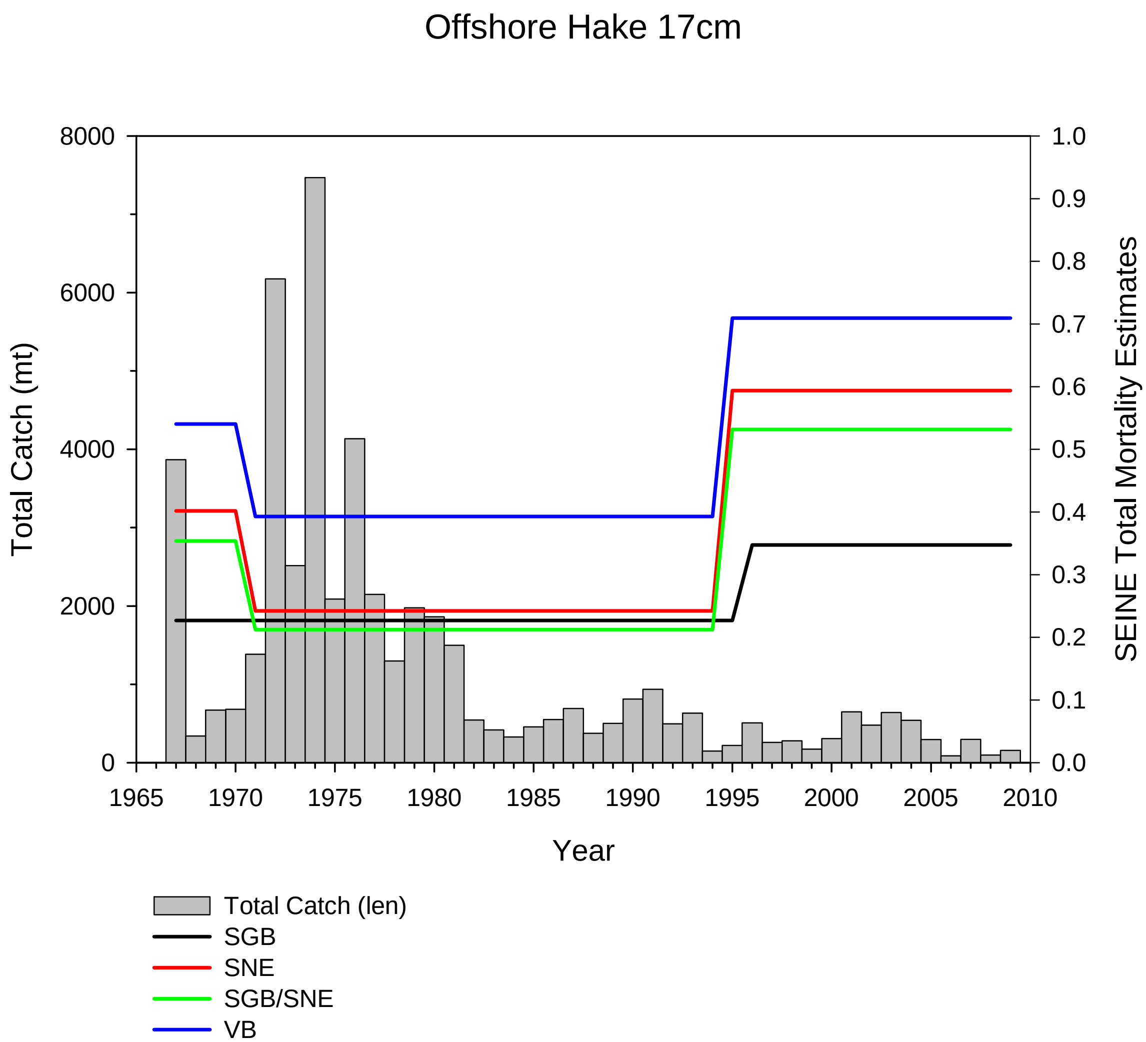


Figure D32. Offshore hake SEINE model results for the 17cm mortality cut, laid over total catch (metric tons). Lines indicate mortality estimates.

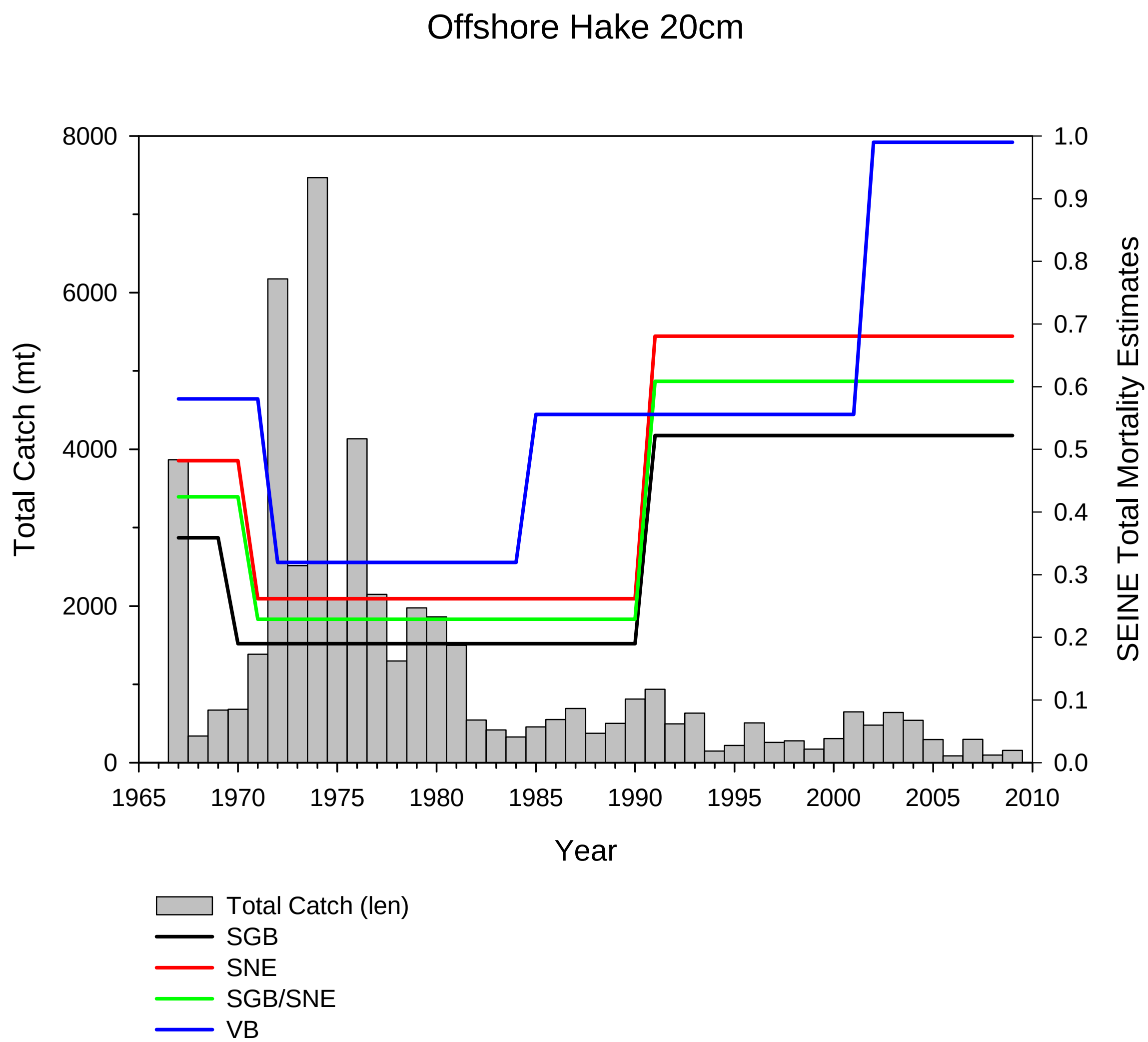


Figure D33. Offshore hake SEINE model results for the 20cm mortality cut, laid over total catch (metric tons). Lines indicate mortality estimates.

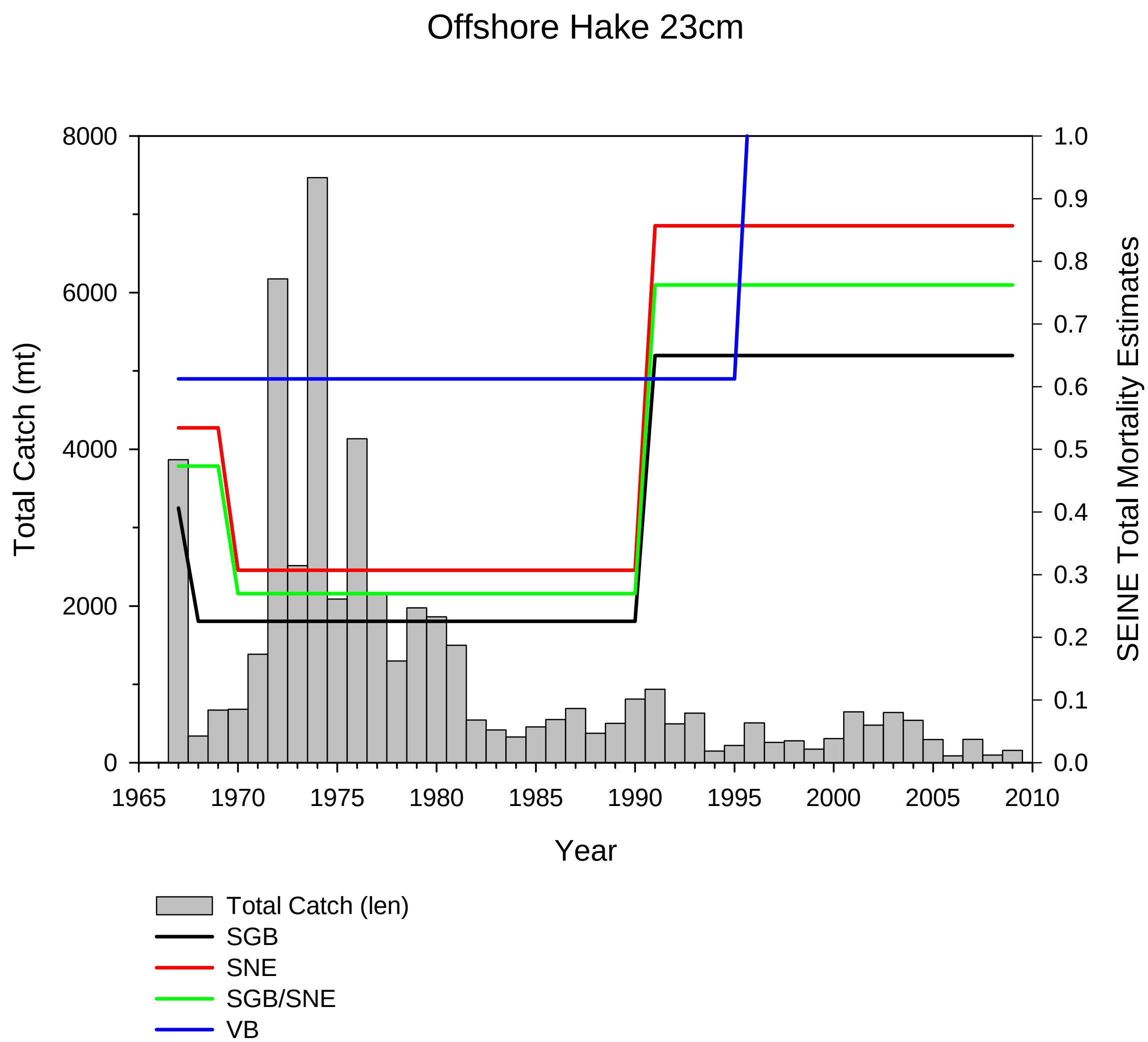


Figure D34. Offshore hake SEINE model results for the 23cm mortality cut, laid over total catch (metric tons). Lines indicate mortality estimates.

Figure D35. Six panel plot for offshore hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC Fall bottom trawl survey index and landings based on the Sosebee method. Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.

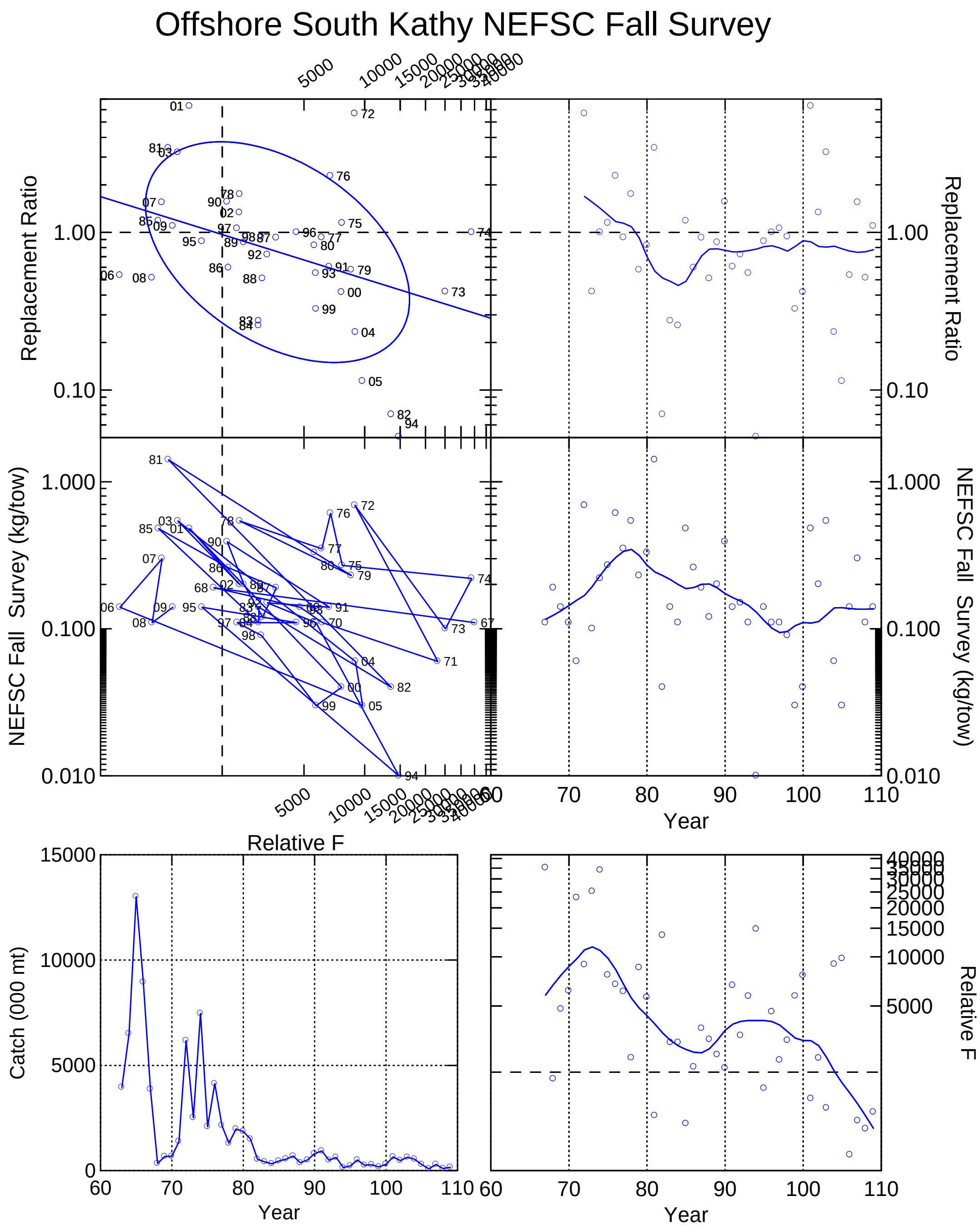


Figure D36. Six panel plot for offshore hake depicting trends in relative biomass, landings, relative fishing mortality and replacement ratios for the NEFSC spring bottom trawl survey index and landings based on the Sosebee method . Horizontal dashed lines (---) represent replacement ratios in the top two panels and the replacement F in the lower right panel. Smooth lines represent Lowess smooths (tension =0.3). The confidence ellipse in the top left panel has a nominal probability level of 0.68. The regression line in the top left panel is a robust regression using bisquare downweighting of residuals.

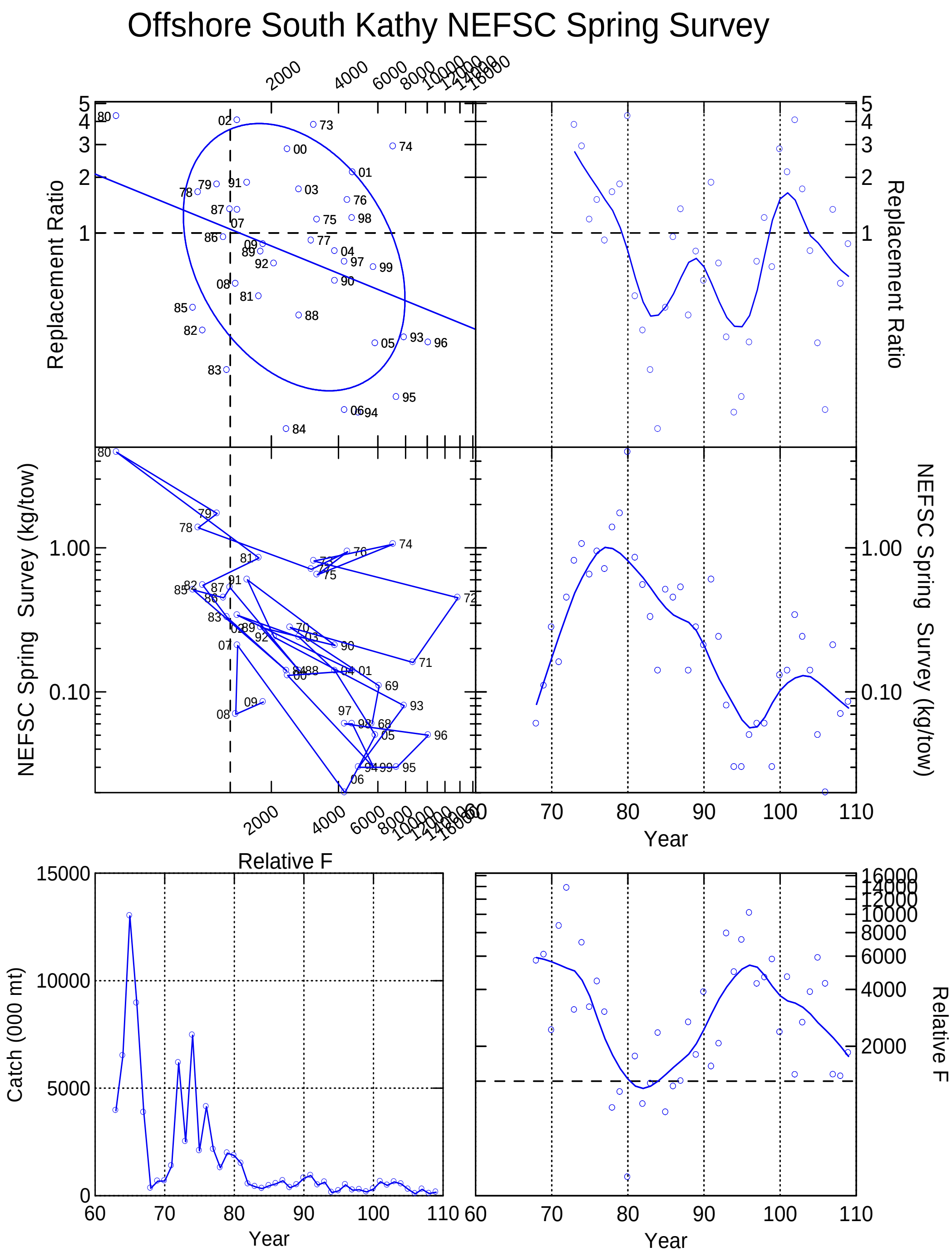
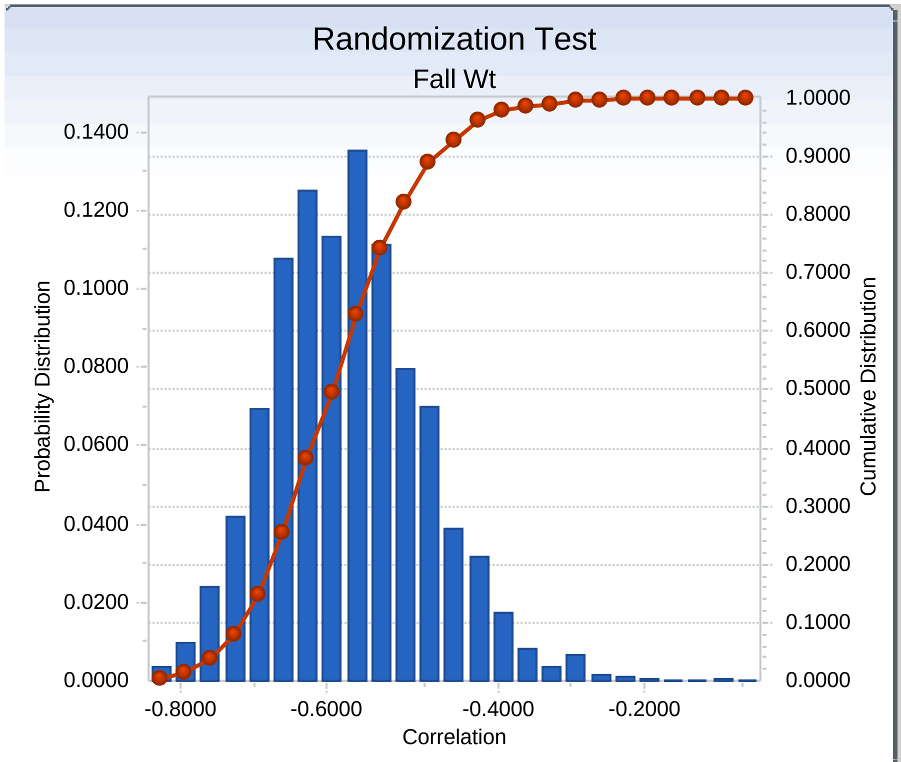


Figure D37. Randomization tests summary of sampling distribution of correlation coefficient between replacement ratio and relative F for fall (top) and spring (bottom) survey indices.



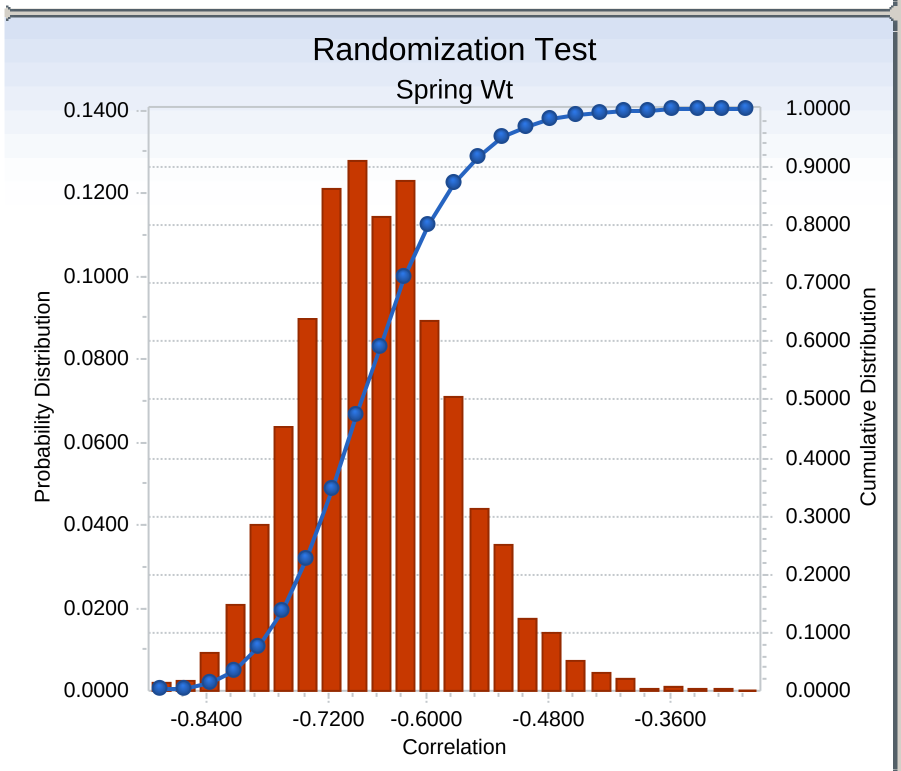


Figure D38. Exploitation ratios for total catch (total catch/swept area biomass) for offshore hake during fall surveys.

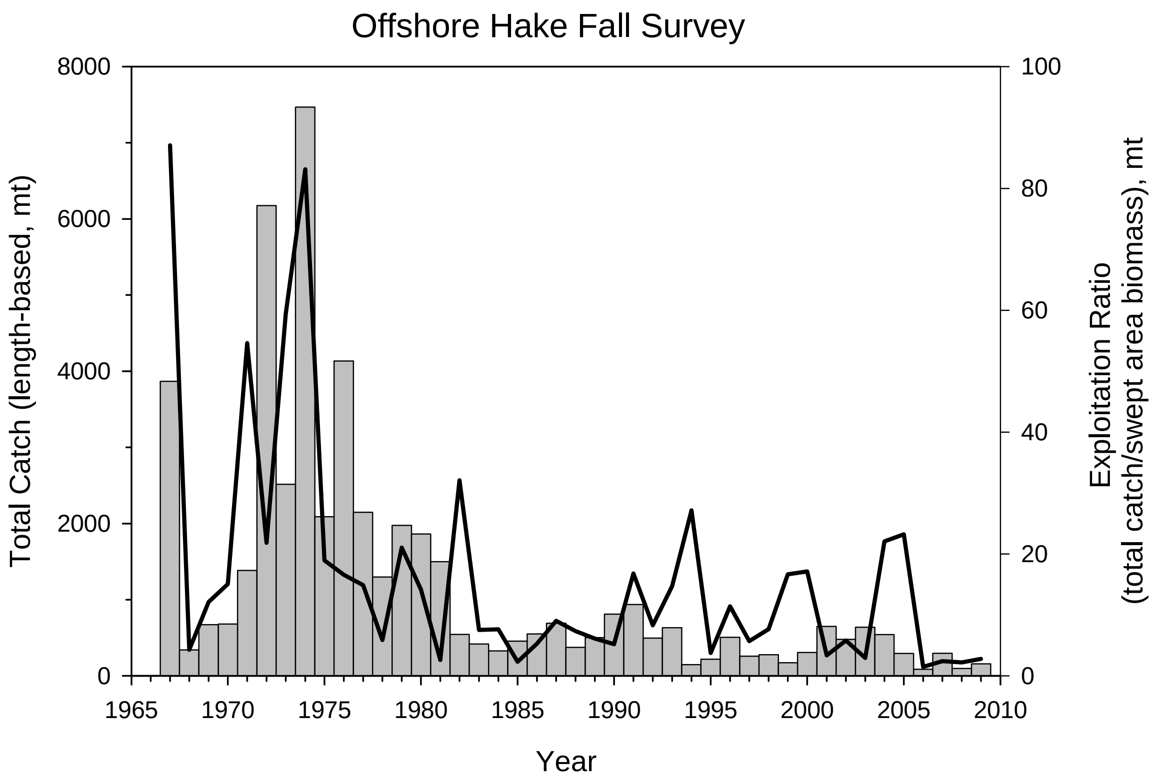


Figure D39. Exploitation ratios for total catch (total catch/swept area biomass) for offshore hake during spring surveys.

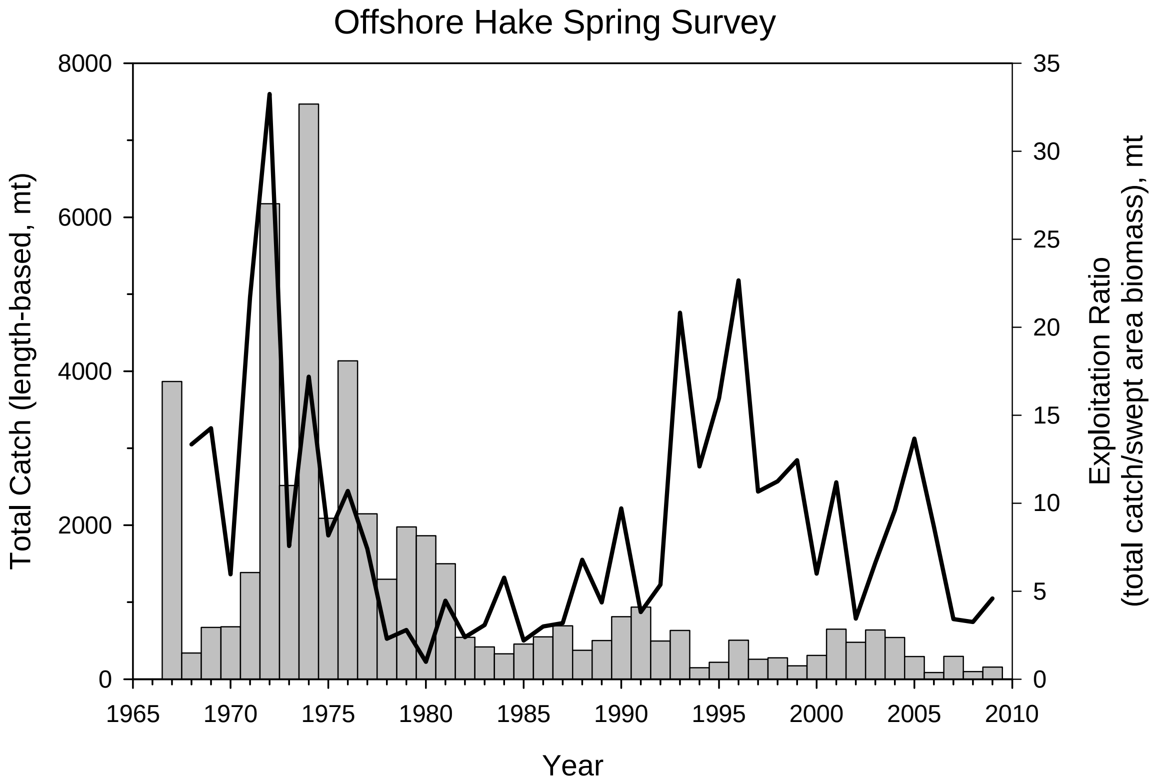


Figure D40. Exploitation ratios for total catch (total catch/swept area biomass) for offshore hake during winter surveys.

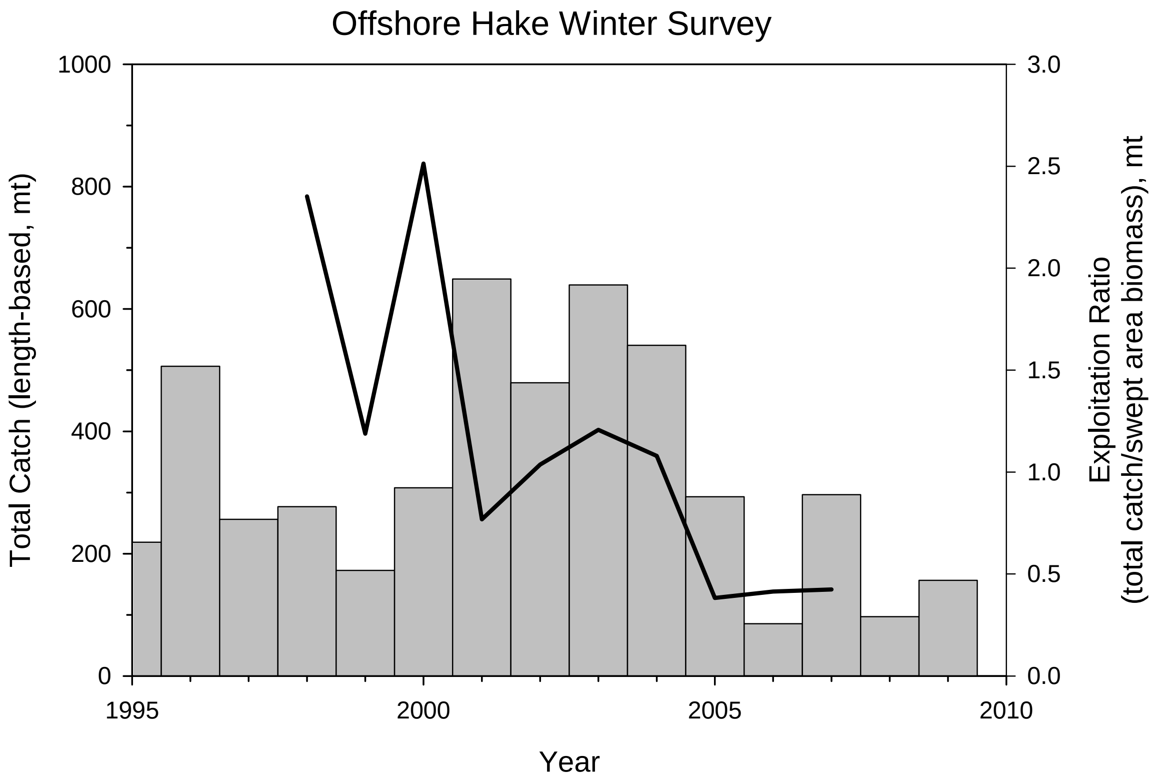


Figure D41. Exploitation ratios for landings (landings/swept area biomass) for offshore hake during fall surveys.

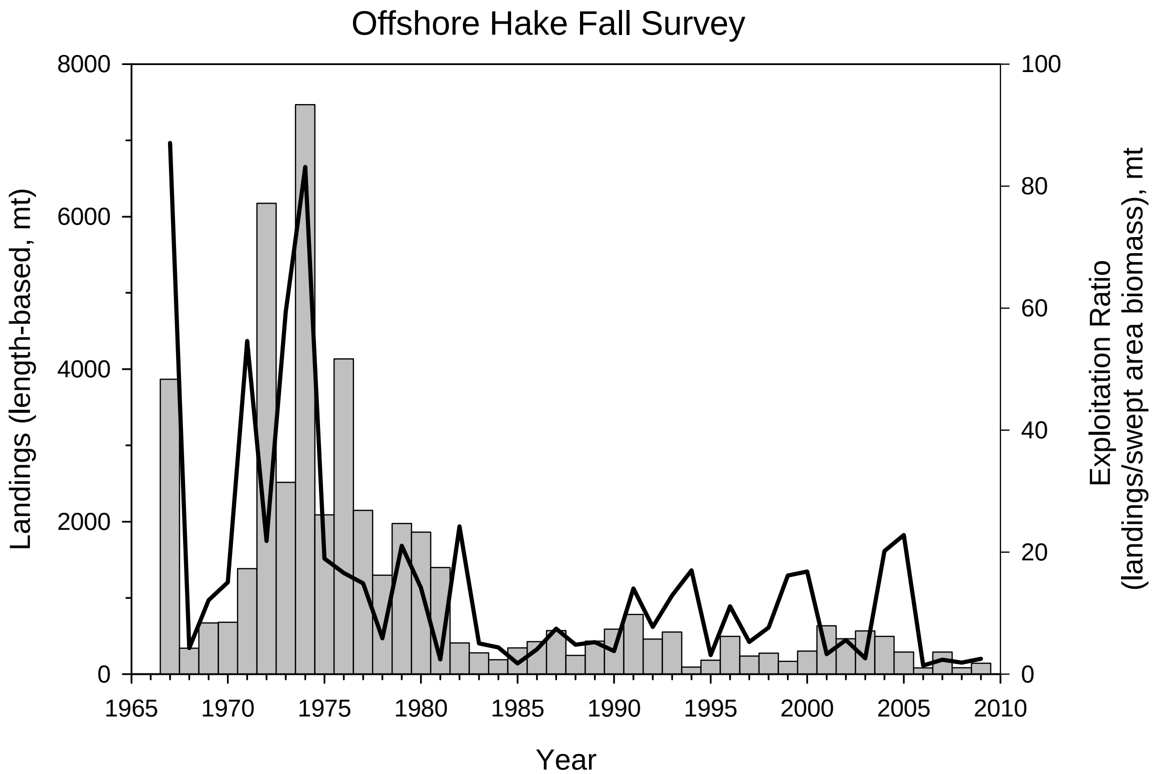


Figure D42. Exploitation ratios for landings (landings/swept area biomass) for offshore hake during spring surveys.

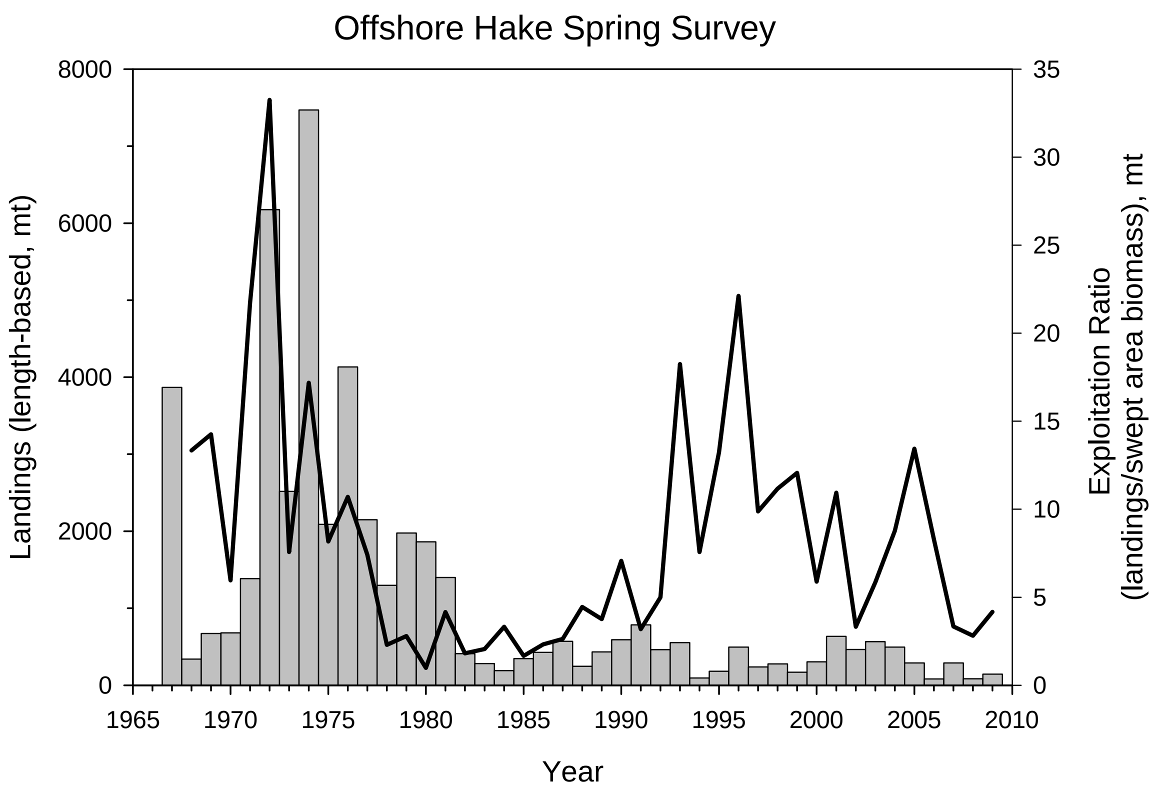
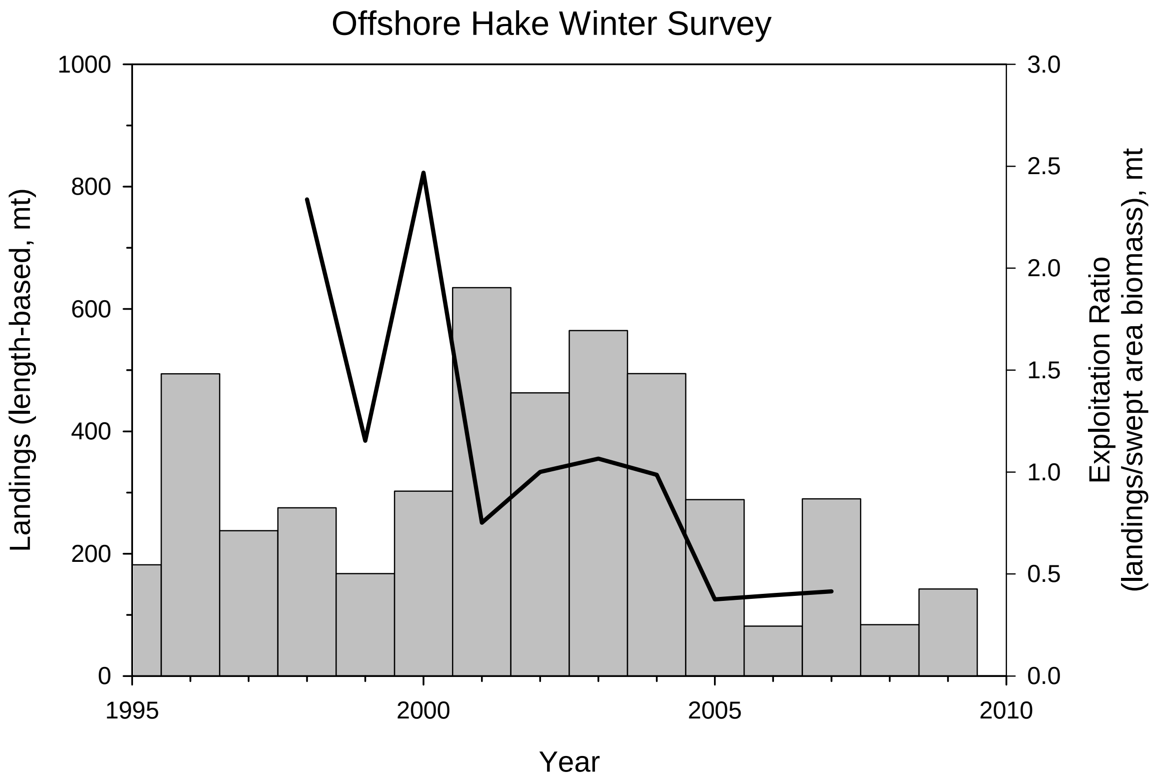


Figure D43. Exploitation ratios for landings (landings/swept area biomass) for offshore hake during winter surveys.



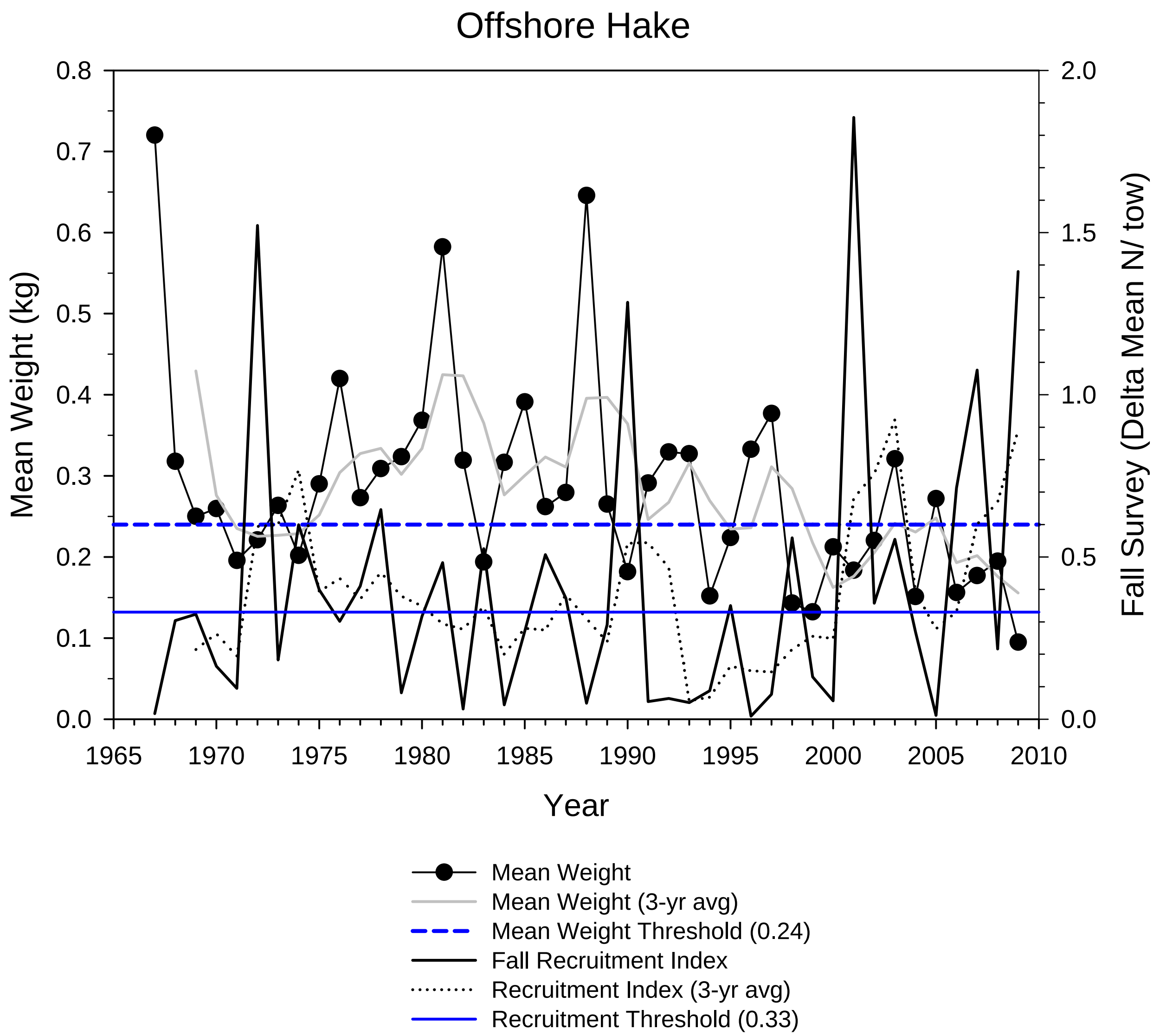


Figure D44. Comparison of current stock status indicators to existing biological reference points for offshore hake.

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Style

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The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "conducting ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources and to generate social and economic opportunities and benefits from their use." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Currently, there are three such media:

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