Northeast Fisheries Science Center Reference Document 06-09a

42nd Northeast Regional Stock Assessment Workshop (42nd SAW)

Stock Assessment Report
Part A: Silver Hake, Atlantic Mackerel, & Northern Shortfin Squid

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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Northeast Fisheries Science Center
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Assessment Report (42nd SAW/SARC)

Table of Contents (Volume A)

INTRODUCTION TO SAW-42 ASSESSMENT REPORT

The Northeast 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 Regions managers.

Starting with SAW-39 (June 2004), the process was revised in two fundamental ways. First, the Stock Assessment Review Committee (SARC) is now a smaller panel with panelists provided by the University of Miami's Independent System for Peer Review (Center of Independent Experts, CIE). Second, the SARC no longer provides management advice. Instead, Council and Commission teams (e.g., Plan Development Teams, Monitoring and Technical Committees) formulate management advice, given that an assessment has been accepted by the SARC.

Reports that are produced following the SAW/SARC-41 meeting include: An *Assessment Summary Report* - a brief summary of the assessment results in a format useful to managers; this *Assessment Report* – a detailed account of the assessments for each stock; and the SARC panelist report – a summary of the panel's recommendations as well as appendices consisting of a report 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 42nd SARC was convened in Woods Hole at the Northeast Fisheries Science Center, November 28 – December 4, 2005 to review three assessments (silver hake, Atlantic mackerel, *Illex* squid) and a multispecies predator-prey model known as MSVPA-X. The reviews were based on detailed reports produced by the SAW Northern Demersal, Coastal/Pelagic and Invertebrate Working Groups for silver hake, Atlantic mackerel, *Illex* squid assessment, and the ASMFC Multispecies Assessment Subcommittee and ASMFC Stock Assessment Committee for the MSVPA-X model.

This Introduction contains a brief summary of the SARC comments, a list of SARC panelists, meeting agenda, list of working group meetings and a list of attendees (Tables 1 – 4). Maps of the Atlantic coast of the USA are also provided (Figures 1 -3).

The SARC accepted part of the silver hake assessment. Three approaches were used in the assessment to estimate fishing mortality (F) and stock biomass. Two of these approaches were new and were designed to derive lower bounds for biomass and upper bounds for F: (1) a comparison of catches in the NEFSC survey with those in a Supplemental Finfish survey; and (2) a method based on the assumption that landings must be less than stock biomass. The third approach was the existing method which uses standard biomass and exploitation indices derived from NEFSC fall bottom trawl survey data and commercial landings. The results of the two new approaches were not accepted by the SARC because the approaches depended on key assumptions that were not well supported. Thus, the assessment was based on the existing method which was used for determining stock status. The SARC concluded that although the silver hake assessment was able to evaluate stock status, more work should be done to evaluate the appropriateness of the existing threshold criteria.

The SARC accepted the Atlantic mackerel stock assessment, and indicated that the assessment was scientifically-sound and provided a credible basis for developing management advice. It was noted that estimates of fishing mortality and biomass from the new mackerel assessment model (ASAP) model had a retrospective pattern, raising concerns about whether these quantities were estimated well. The SARC felt that a suitable description was provided regarding the transition from an earlier assessment model to the ASAP model, but that more details and documentation should have been provided in the mackerel assessment report.

The *Illex* squid assessment was not able to estimate fishing mortality rate, stock biomass, or to determine stock status. The SARC indicated that the available data on *Illex* were not adequate to estimate these quantities; nevertheless, significant advances in modeling had taken place. The SARC advocated finding a new approach for evaluating overfishing, and deemed the existing criteria inappropriate for this short-lived species.

With respect to the MSVPA-X model, the reviewers concluded that all of the Terms of Reference were met; however, they stressed that it would not be appropriate to use the present model as a basis for quantitative fishery management advice about menhaden or its predators. Rather, they felt that the MSVPA-X model was a valuable tool for understanding predator-prey dynamics and for exploring “what if” scenarios.

Due to its large size, this Assessment Report consists of two volumes. The first volume has the Working Group reports for the three stock assessments. The second volume has the MSVPA-X report. Members of the Working Groups are listed in Table 3. Sections of the Working Group reports that were not completed successfully, based on the opinion of the independent review panel (CIE), have been omitted by the SAW Chairman. The CIE report can be found at: (http://www.nefsc.noaa.gov/nefsc/saw/). In those places where text has been omitted, a note has been inserted informing the reader of this. The CIE’s decision to accept or reject assessment results was based on scientific criteria such as the quality of the input data that were available, quality of the data analysis and modeling, and whether the conclusions of the Working Group held up during the independent peer review SARC meeting. The CIE panel also considered whether the results were strong enough to serve as a basis for developing fishery management measures and advice.

Table 1. 42nd Stock Assessment Review Committee Panel.

42nd Northeast Regional Stock Assessment Workshop (SAW 42)
Stock Assessment Review Committee (SARC) Meeting

November 28 – December 4, 2005

SARC Chairman:

Dr. Andrew Payne
Centre for Environment, Fisheries and
Aquaculture Science, Lowestoft,
Suffolk NR33 0HT, UK (CIE)

SARC Panelists:

Dr. John Casey
Centre for Environment, Fisheries and
Aquaculture Science, Lowestoft,
Suffolk NR33 0HT, UK (CIE)

Dr. Vivian Haist
Consultant, 1262 Marina Way, Nanoose Bay,
British Columbia, Canada (CIE)

Dr. Yan Jiao
Department of Fisheries and Wildlife Sciences
Virginia Polytechnic Institute & State University
Blacksburg, VA, USA 24061 (CIE)

Table 2. Agenda, 42nd Stock Assessment Review Committee Meeting.

42nd Northeast Regional Stock Assessment Workshop (SAW 42)
Stock Assessment Review Committee (SARC) Meeting

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

November 28 – December 4, 2005

AGENDA

TOPIC	PRESENTER	SARC LEADER	RAPPORTEUR
Monday, 28 Nov. (1:00 – 5:00 PM)……………………………………………………			
Opening			
Welcome	**James Weinberg**, SAW Chairman		
Introduction	**Andrew Payne**, SARC Chairman		
Agenda			
Conduct of Meeting			
Silver Hake (A)	**Larry Jacobson**	**John Casey**	**Laurel Col**
SARC Discussion	**Andrew Payne**		
Tuesday, 29 Nov. (8:30 AM – 12:00)……………………………………………………			
Mackerel (B)	**William Overholtz**	**Vivian Haist**	**Chris Legault**
SARC Discussion	**Andrew Payne**		
Tuesday, 29 Nov. (1:15 – 5:00 PM)……………………………………………………			
Illex squid (C)	**Lisa Hendrickson**	**Yan Jiao**	**Rich Seagraves**
SARC Discussion	**Andrew Payne**		

Wednesday, 30 Nov. (8:30 AM – 12:00) ……………………………………………

MSVPA-X Model (D) **Matthew Cieri**
Lance Garrison TBA Patrick Kilduff

SARC Discussion **Andrew Payne**

Wednesday, 30 Nov. (1:15 PM – 5:00) ……………………………………………

Revisit Assessments and Model, as needed.

Thursday, 1 Dec. (8:30 AM –) ……………………………………………

Revisit Assessments and Model, if needed.

SARC Report writing (closed)

Friday, 2 Dec. (8:30 AM –) – 4 Dec. ………………………………………

SARC Report writing. (closed)

Table 3. 42nd Stock Assessment Workshop, list of working groups and meetings.

Assessment Group	Chair	Species	Meeting Date/Place
SAW Invertebrate Working Group	Larry Jacobson, NMFS NEFSC	***Illex* squid**	Oct. 3-4,2005 Woods Hole

L. Hendrickson, NEFSC
R. Seagraves, MAFMC
Dvora Hart, NEFSC
Teresa Johnson , Rutgers U.
Eric Powell, Rutgers U.
Glenn Goodwin, Seafreeze, Ltd.
Jim Ruhle, MAFMC, F/V Daina R
Phil Ruhle, NEFMC, F/V Sea Breeze
Lynne Purchase, Imperial College, Lond

SAW Northern Demersal, Coastal/Pelagic and Invertebrate Working Group	Ralph Mayo, NMFS NEFSC	***Illex* squid, Atlantic mackerel, Silver hake**	Oct. 24-28, 2005 Woods Hole

J. Burnett, NEFSC
S. Cadrin, NEFSC/SMAST
L. Col, NEFSC
D. Farnham, Industry Advisor
F. Gregoire, Dept. of Fisheries and Oceans, Canada
D. Hanselman,AFSC
D. Hart, NEFSC
L. Hendrickson, NEFSC
L. Jacobson, NEFSC
K. Lang, NEFSC
C. Legault, NEFSC
P. Nitschke, NEFSC
M. Ortiz, SEFSC
E. Powell, Rutgers University
P. Rago, NEFSC
M. Radlinski, U. MA (SMAST)
J. Ruhle, Industry Advisor
R. Seagraves, MAFMC
M. Terceiro, NEFSC
M.B. Tooley, ECPH
J. Weinberg, NEFSC
A. Westwood, NEFSC
S. Wigley, NEFSC
B. Overholtz, NEFSC
V. Wespestad, Industry Consultant

The MSVPA-X Multispecies Assessment Subcommittee presented its work to the ASMFC Stock Assessment Committee on September 28, 2005. Membership:

MSVPA-X Multispecies Assessment Subcommittee
Matt Cieri – Subcommittee Chair, Maine Department of Marine Resources
Lance Garrison – Garrison Environmental Analysis and Research
Robert Latour – Virginia Institute of Marine Science
Behzad Mahmoudi – Florida Fish and Wildlife Conservation Commission
Brandon Muffley – New Jersey Department of Environmental Protection
Alexei Sharov – Maryland Department of Natural Resources
Doug Vaughan – National Marine Fisheries Service, Center for Coastal Fisheries and Habitat Research

ASMFC Stock Assessment Committee members present:
John Carmichael – Committee Chair, South Atlantic Fisheries Management Council
Matt Cieri – Subcommittee Chair, Maine Department of Marine Resources
Doug Grout – New Hampshire Department of Fish and Game
Kim McKown – New York Department of Environmental Conservation
Brandon Muffley – New Jersey Department of Environmental Protection
Mike Murphy – Florida Fish and Wildlife Conservation Commission
Des Kahn – Delaware Department of Natural Resources
Alexei Sharov – Maryland Department of Natural Resources
Doug Vaughan - National Marine Fisheries Service, Center for Coastal Fisheries and Habitat Research

Table 4. 42nd SAW/SARC, List of Attendees

Hassan Moustahfid, NEFSC
Michelle Traver, NEFSC
Loretta O'Brian, NEFSC
Laurel Col, NEFSC
Teresa Johnson, Rutgers U.
Gary Shepherd, NEFSC
Stacy Rowe, NEFSC
Sandy Sutherland, NEFSC
Susan Wigley, NEFSC
Chad Demerest, NEFMC
Jeff Kaelin, WFCNC
Jim Ruhle, MAFMC
Rich Seagraves, MAFMC
Paul Nitschke, NEFSC
Mary Radlinski, SMAST
Ralph Mayo, NEFSC
Mary Beth Tooley, ECPA
Matt Cieri, ME DMR
Chris Legault, NEFSC
Lisa Hendrickson, NEFSC
Devora Hart, NEFSC
Michael Fogarty, NEFSC
Patric Kilduff, ASMFC
J. Cox, Atl. Pel. Seafood
Peter Moore, Am. Pel. Assoc, NORPEL

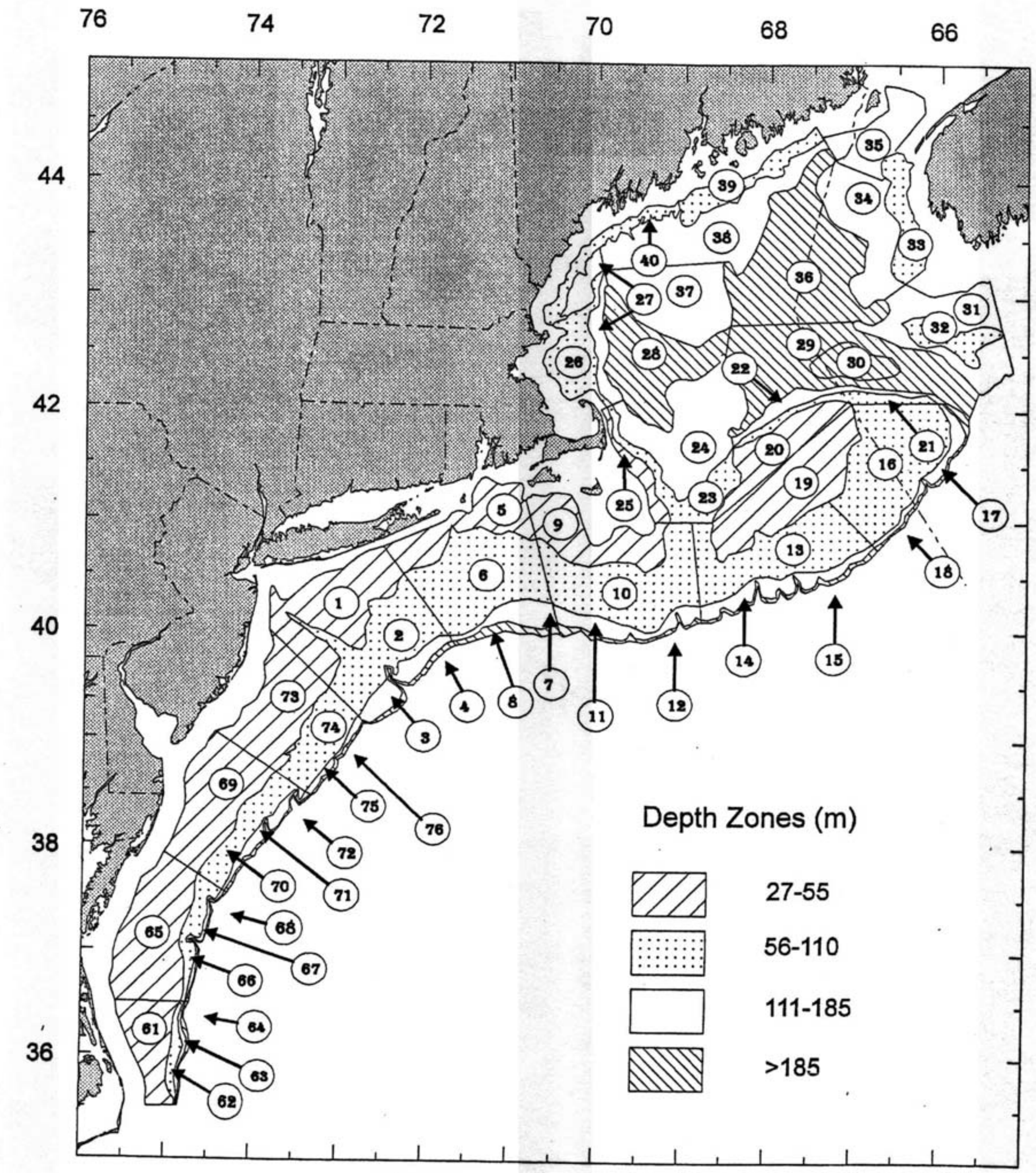

Figure 1. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

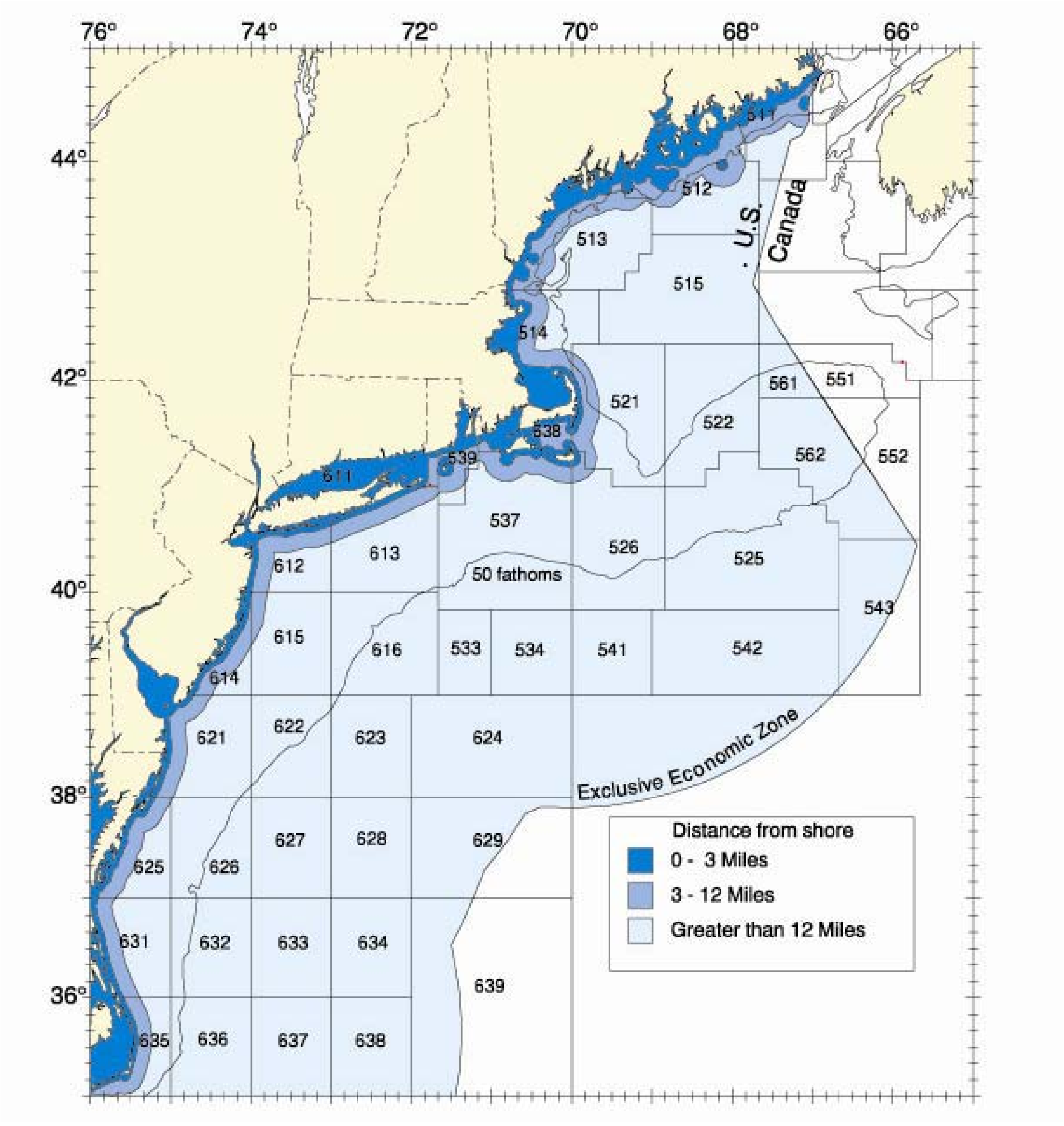

Figure 2. Statistical areas used for reporting commercial catches.

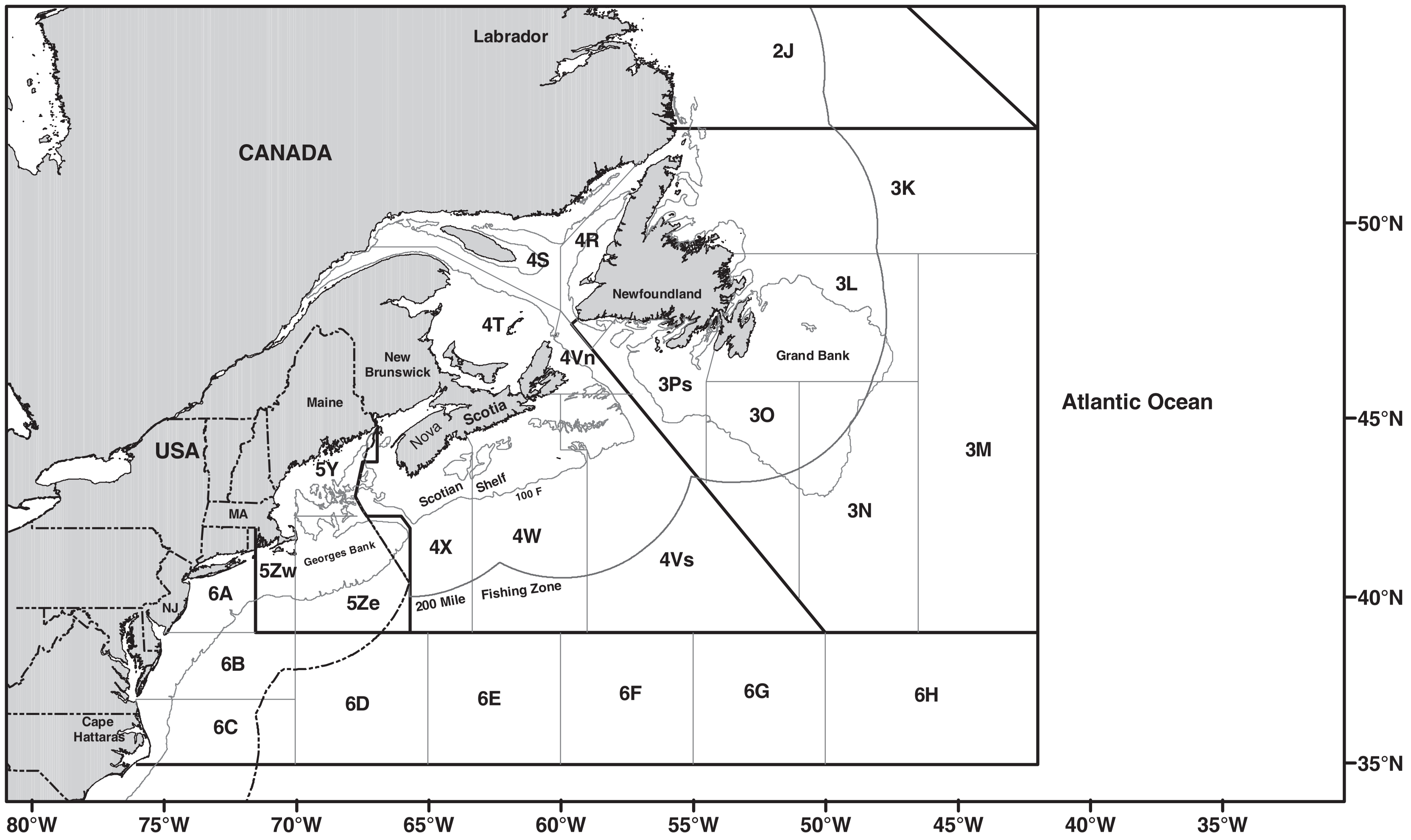

Figure 3. Catch reporting areas of the Northwest Atlantic Fisheries Organization (NAFO) for Subareas 3-6.

A. ASSESSMENT OF SILVER HAKE

EXECUTIVE SUMMARY

1) Overfishing definitions and biological reference points used in this assessment for the northern and southern stocks of silver hake are based on trends in three-year moving averages of fall survey biomass indices (delta mean kg/tow) and three-year averages of exploitation indices (landings / fall survey biomass index).

2) The biological reference points based on exploitation indices are new since the last assessment. They were developed during the interim by the New England Council's Whiting Monitoring Committee because fishing mortality estimates were not estimated for whiting in the last assessment and because it was not possible to use the original fishing mortality based reference points ($F_{0.1}$) in Amendment 12. The Whiting Monitoring Committee's proposal is a typical approach that was based on the original reference points to the extent possible. The new biological reference points were reviewed for this assessment and used because fishing mortality rates could not be estimated in this assessment either.

3) The northern stock of silver hake is not overfished and overfishing is not occurring. In particular, the three year average biomass index for 2002-2004 (6.72 kg/tow) was above the management threshold level (3.31 kg/tow) and near the target level (6.63 kg/tow). The three year average exploitation index for 2002-2004 (0.24) was below the management threshold and target level (2.57). The target and threshold reference points for defining overfishing in the northern stock are identical. The northern stock of silver hake was not overfished based on results from the last assessment (NEFSC 2001). Overfishing was not evaluated in the last assessment because fishing mortality rates were not estimated.

4) Based on current reference points, the southern stock of silver hake is not overfished and overfishing is not occurring. In particular, the three year average biomass index for 2002-2004 (1.37 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 for 2002-2004 (4.85) was below the management threshold level (34.39) and below the management target level (20.63). The southern stock of silver hake was overfished based on results from the last assessment (NEFSC 2001). Overfishing was not evaluated in the last assessment because fishing mortality rates were not estimated. The change in status is due to increases in stock biomass indices for the southern stock of silver hake.

5) The southern stock of silver hake was overfished based on results from the last assessment (NEFSC 2001). The change in status is due to increases in stock biomass indices for the southern stock of silver hake.

6) (EDITOR'S NOTE: THIS PART OF THE WORKING GROUP REPORT HAS BEEN OMITTED. IT WAS NOT ACCEPTED BY THE REVIEW PANEL.)

7) Fall survey recruitment indices show variable but generally increasing trends in the northern stock area since 1967. In the southern stock area, recruit and fishable biomass during fall surveys varied without trend.

8) Coast wide silver hake landings were less than 10 thousand mt per annually after 2002. During 2001-2004, coast wide silver hake discards averaged about 4000 mt y^{-1} (CV 17%) with at least 1,600 mt y^{-1} in the north and 2000 mt y^{-1} in the south on average during 2001-2004.

9) The most important uncertainties in management stem from clearly decreasing trends in abundance of relatively old and large individuals, despite low fishing mortality rates and relatively high biomass levels during recent years. Declines in abundance and occurrence of relatively old silver hake appear real and not due entirely to age reader errors, misidentification of offshore hake in surveys, or slower somatic growth. There is evidence of northward and offshore shifts in average location that may make relatively old and large silver hake less available to bottom trawl surveys. The possibility of increased natural mortality rates due to predation is a key area for future research.

10) Total allowable landings (TAL) for 2005 were calculated based on fall survey data through 2004 and exploitation index reference points. For the northern stock area during 2005, where the target and threshold reference points are the same, TAL < 17.3 mt. For the southern stock area during 2005 and based on the target reference point, TAL=28.3 mt. For comparison, annual landings averaged 1.71 thousand mt in the north and 6.65 thousand mt in the south during 2002-2004.

11) Stock projections were not carried out but stock biomass levels are relatively high. Fishing mortality rates are very low in the north and probably low in the south also. Recent recruitments have been roughly average. Significant declines in stock biomass due to fishing are unlikely in the short term.

1.0 TERMS OF REFERENCE:

1. Characterize the commercial and recreational catch including landings and discards.

Recreational landings of silver hake were not estimated in this assessment but are minor based on estimates in the last assessment (Brodziak et al. 2001).

Discards were estimated in this assessment.

2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.

(EDITOR'S NOTE: THIS PART OF THE WORKING GROUP REPORT HAS BEEN OMITTED. IT WAS NOT ACCEPTED BY THE REVIEW PANEL.)

3. Evaluate and either update or re-estimate biological reference points, as appropriate.

> *Reference points proposed by the New England Fishery Management Council's Whiting Monitoring Committee and used in overfishing definitions for silver hake during recent years were reviewed and used in this assessment.*

4. As needed by management, estimate a single-year or multi-year TAC and/or TAL by calendar year or fishing year, based on stock biomass and target mortality rate.

> *TAL levels were calculated based on fall survey data through 2004 and exploitation index reference points.*

5. If possible,
   a. provide short term projections (2-3 years) of biomass and fishing mortality rate, and characterize their uncertainty, under various TAC/F strategies and
   b. evaluate current and projected stock status against existing rebuilding or recovery schedules, as appropriate.

> *Based on a qualitative analysis, significant declines in stock biomass due to fishing are unlikely in the short term. It was not possible to carry out quantitative projection analyses.*

6. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in previous SARC-reviewed assessments.

> *This information is provided at the end of the stock assessment report.*

2.0 INTRODUCTION

Silver hake (*Merluccius bilinearis* or "whiting") range from Newfoundland to South Carolina and are most abundant between Nova Scotia to New Jersey (Figure A1; Collette and Klein-MacPhee 2002). Silver hake are found over a broad range of depths ranging from shallow coastal areas to the continental slope. The offshore limit of habitat of silver hake habitat on the continental slope is uncertain but the species ranges to at least 400 m depth (Collette and Klein-MacPhee 2002). Silver hake are found in midwater as well as on the bottom but the extent to which they use the water column as habitat is unknown because most of the available information comes from bottom trawl gear.

As shown below, adult silver hake (age ≥ 2 y and TL ≥ 20 cm TL) tend to be distributed further offshore and further north than younger, smaller individuals. The size and age at which the offshore and northern shift in distribution occurs are approximately the same as the size and age at sexual maturity. Distribution patterns change seasonally as the adult population moves inshore with warmer water temperatures during the spring and summer to spawn near coastal juvenile habitat areas. Depth appears more important than temperature or season in determining distribution patterns because small individuals remain in shallow coastal areas despite substantial seasonal changes in water temperatures (warm during summer-fall and cool during winter-spring). Similarly, larger individuals remain primarily in deeper water that is relatively warm during winter-spring and cool during summer-fall.

Silver hake are important as predators and prey in the food web of the northeast continental shelf ecosystem (Sissenwine and Cohen 1991). They feed mainly at night (Collette and Klein-MacPhee 2002). Small silver hake (< 20 cm TL) eat euphausids, shrimp, amphipods and decapods. Larger silver hake eat fish (including other silver hake), crustaceans and squid. The shift in diet coincides with the onset of sexual maturity and offshore/north shift in distribution and cannibalism is common.

Two stocks of silver hake are currently assumed in managing the fishery and in stock assessments for silver hake in US waters (Figure A1). The northern stock area includes northern Georges Bank and the Gulf of Maine. The southern stock area includes southern Georges Bank, southern New England, and the Mid-Atlantic Bight. The two stock areas are based on differences in morphology (Almeida 1987), otolith shape (Bolles and Begg 2000), abundance trends, fishery patterns and the apparent break in silver hake habitat at Georges Bank.

Although management and stock assessments have been based on two stocks, silver hake along the northeast coast are likely one population with incomplete mixing between northern and southern areas (Brodziak et al. 2001). Larvae are pelagic and remain in the water column where they circulate freely for 1-5 months before metamorphosing to juvenile form and presumably settling to the bottom at about 1.7-2.0 cm TL (Lock and Packer 2004). North-south movement patterns are not well understood but it is likely, based on results from this assessment, that adults move around Georges Bank seasonally and depending on environmental conditions. The northern and southern stocks of silver hake are probably best viewed as management units.

Silver hake in Canadian waters are abundant enough to support a fishery.[1] The US and Canadian stocks of silver hake are probably linked to some degree and this is an important topic for future research.

The proportion of silver hake minimum swept area biomass in the northern area has varied substantially over time from less than 40% to more than 90% with proportions in the north generally increasing until recently (Figure A2). One of the key questions regarding silver hake is whether the shifts in distribution between the northern and southern areas are due to environmental effects on distribution or relatively high mortality in the southern area (Brodziak et al. 2001).

Silver hake grow rapidly (Figure A3). Growth rates vary over time and among areas but in an inconsistent fashion (Helser 1996; Brodziak et al. 2001). Based on Brodziak et al. (2001), growth has been rapid and almost linear in silver hake during recent years based on Brodziak et al. (2001). However, scarcity of older fish makes growth curves estimated from recent data difficult to compare to growth curves estimated from historic data (Brodziak et al. 2001). Growth and maturity rates may depend on stock biomass (Helser and Brodziak 1998).

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[1] http://www.frcc.ca/2004/SF2004.pdf

Based on data from Canadian waters, growth of males and females is similar up to about 22 cm TL (Collette and Klein-MacPhee 2002), which coincides with the onset of sexual maturity (Figure A4). After sexual maturity, females grow more rapidly and to larger maximum sizes.

Survey age data for silver hake collected during 1973-2005 are from thin sectioned otoliths. Age data for earlier years are from whole otoliths and less reliable. Age reader experiments described in this assessment show that criteria used to age silver age changed during 1973-2005. Historical age estimates are one or two years higher than estimates made recently from the same otoliths. The precision of age estimates decreases for older silver hake. Age data for silver hake are currently being re-audited to remove duplicate records discovered during this assessment.

There is considerable uncertainty about the potential longevity and underlying natural mortality rates silver hake. Brodziak et al. (2001) report that maximum ages observed in NEFSC fall and spring surveys declined from 14 y (corresponding to a natural mortality rate M of about 0.3 y^{-1}, Hoenig 1983) during the mid-1970's to 6 y recently (corresponding to a natural mortality rate of about 0.8 y^{-1}, Figure A5). One of the key questions regarding the stock is whether changes in maximum ages are due to environmental effects on availability of older fish to surveys, increased mortality, age estimation errors, or mis-identification of offshore hake (*M. albidus*).

3.0 THE FISHERY

Silver hake landings (Table 1) increased substantially during the 1960s due to directed fishing for silver hake by distant water fleets operating in US waters (Figure A6). During the 1990s, total silver hake landings were relatively low in comparison to historic values. Silver hake landings declined further to less than 10 thousand mt per year after 2002 (Figure A7).

Landings were almost entirely from the northern area prior to 1964 (Table A1 and Figures A8). After 1964, silver hake landings were mostly from the southern stock area.

Recreational Fishery

Silver hake once supported a recreational fishery in the Mid-Atlantic Bight (Fritz 1960) with annual landings of around 1,000 mt (2.2 million pounds) in the southern stock area. Recreational fishery landings decreased substantially in the 1970s and 1980s and are currently very low. Recreational landings of silver hake averaged only 18,000 fish per year during 1995-1999 (Brodziak et al. 2001).

Commercial Fishery

Directed commercial fishing for silver hake began in the 1920s. The fishery evolved over time from an inshore fishery using pound and trap nets to the modern otter trawl fishery (Fritz 1960; Table A2). The bulk of silver hake landings during recent years were from the southern stock area. In the northern stock area, landings are mostly from the Cultivator shoals, Gulf of Maine and the rest of Georges Bank (Table A2 and Figure A9). In the southern stock area landings are mostly from Southern New England and the Mid-Atlantic Bight (Table A2 and Figure A9). Landings data for years after 1994 are prorated to area of catch based on Vessel Trip Report (VTR) logbook data. Area of catch is identified in records for earlier years based on interviews by port samplers.

Silver hake were landed in six commercial market categories during 1995-2004 including the category "5095 (Large round)" that was new in 2004 (Table A2). Intensity of sampling was measured as number of length measurements divided by metric tons landed (Table A3). Sampling was highest (intensity > 1.5) for the hook & line gear group, gillnet gear group, and for the 5091 (King round) market category.
Length composition data for commercial landings indicate that the fishery has taken smaller silver hake since 1997 and that recruitment to the fishery begins to occur at about 20 cm TL (Figure A10). The shift in commercial length frequencies may be due to management measures, other changes in the fishery, or a change in the silver hake population.

Age composition data for commercial landings from Brodziak et al. (2001) show declines in proportions of older silver hake. Age data are not collected from the commercial fishery but commercial age composition can be inferred based on survey age data and commercial length composition data. Commercial and survey age composition data were not updated for silver hake in this assessment. Survey age data for silver hake used to construct age-length keys are currently being audited and should be ready for use in the next assessment.

Bycatch and Discards

Sea sampling data for 1989-1999 collected by observers on fishing vessels and reviewed by Brodziak et al. (2001) showed that discarding of silver hake captured by otter trawls occurred throughout the northern and southern stock areas. Discarding of silver hake by scallop dredges occurred in both northern and southern stock areas but discarding by sink gill nets occurred primarily in the northern stock area. Discard to kept (DK) ratios by weight (weight of silver hake discarded / weight of species landed) varied through time, ranging from 0% to over 100% for the directed silver hake fishery (small mesh otter trawl, cod end mesh 3" or less) and for the non-directed fisheries (large mesh otter trawl, shrimp trawl, sink gill net, and scallop dredge). Variability in discard ratios may have been due to non-random coverage of the fleet, small sample sizes, or inherent variation in discard rates and practices.

New discard estimates for recent years (2001-2004) in this assessment were based on observer data and a ratio estimator first used for spiny dogfish (*Squalus acanthias*, NEFSC 2003). Estimates in this assessment were for recent years only because observer data coverage has increased in recent years and because recent discards were most important in evaluating the status of the silver hake resource.

The ratio estimator approach has several potential advantages including well defined statistical properties, relative simplicity and objective stratification based on landings data (i.e. it is not necessary to determine target species for tows or trips based criteria that are possibly arbitrary). However, ratio estimators are biased (see below) and the relative merits of discard estimators used in the Northeast (Rago et al. 2005) have not been fully evaluated.

Species groups and gear groups were used to tabulate and stratify observer and “landings” data (landings and hail weights in this analysis were hail weights for individual tows recorded by observers) at the trip level (Tables A4-A6). The species groups and gear groups used for silver hake were similar to the groups used for spiny dogfish (NEFSC 2003) with some modifications. All species potentially landed were assigned to a species group and all potential gear types are assigned to a gear group.

In the first step, kept (and presumably landed) weight $K_{G,S,T}$ is tabulated for each trip (T) in the observer database by species group (S) and gear group (G). Information about total silver hake discards on each trip ($D_{G,S,T}$) is retained but information about discard of other species is not. At the end of the first step, there is one record for each observed trip. The record contains total silver hake discards (which may be zero) and landings in each of the species groups. The sum of landings for all species groups equals total landings for the trip.

In the second step, the primary species group is determined based on the species group with highest landings. The secondary species group with second highest landings is used for diagnostic plots and identified as well (Rago et al. 2005). At the end of the second step, there is one record for each trip that contains the total silver hake discard, variables that identify the primary and secondary species group, a variable that identifies the gear group, and landings in the primary and secondary species groups.

The third step is to calculate DK ratios for each species group and gear group using the ratio estimator:

$$R_{G,S} = \frac{\sum_T D_{G,S,T}}{\sum K_{G,S,T}}$$

where $R_{G,S}$ is the DK ratio. The variance of the ratio estimator (Cochran 1977) is approximately:

$$Var\left(R_{G,S}\right) = \frac{Var\left(D_{G,S}\right) + R_{G,S}{}^2 Var\left(K_{G,S}\right) - 2R_{G,S}Cov\left(D_{G,S}, K_{G,S}\right)}{n\bar{K}^2_{G,S}}$$

As shown in Cochran (1977) the ratio estimator is biased with:

$$bias = -\frac{Cov(R,\overline{K})}{\overline{k}} = -\frac{\rho\sigma_R\sigma_{\overline{L}}}{\overline{k}}$$

where $\overline{K}$ is average landed weight estimated from observer data and $\overline{k}$ is the true (unknown) value. Note that the absolute value of the bias increases with the variance and correlation in R and $\overline{K}$. It is therefore advantageous, in terms of minimizing both bias and variance, to pool data and choose primary species groups and gear groups that minimize the variance in these quantities.

In the final step, total landings in weight ($L_{G,S}$, based on dealer records) is calculated for each species gear and gear group. Total discard (Λ) is:

$$\Delta = \sum_G \sum_S L_{G,S} R_{G,S}$$

Assuming that landings are measured without error, the variance is:

$$Var(\Delta) = \sum_G \sum_S L_{G,S}^2 Var\left(R_{G,S}\right)$$

For silver hake in this assessment, observer data for 2001-2004 were pooled to estimate one set of DK ratios and average annual discard estimates for 2001-2004. Pooling observer data for adjacent years, and use of relatively broad species groups and gear groups increased sample size and decreased variance. However, bias may have increases as well because of non-representative sampling and discard rates that probably varied among years, gear groups and primary species groups. The potential importance of these potential problems was not evaluated. However, the statistical (not sampling related) bias of ratio estimators is proportional to their CV (Cocharan 1977) and it seemed reasonable to pool data sufficiently to reduce CVs.

Results

Mean annual discards during 2001-2004 are presented for gear and species groups with DK ratios > 0.0001 (Table A7). During 2001-2004, silver hake discards averaged about 3,820 mt y^{-1} (CV 17%). Trips with hakes and ocean pout as the primary species group in the other/unknown and bottom trawl gear groups had the highest DK ratios. The highest level of average annual silver hake discards were for crab/shrimps in shrimp trawls, and hakes and ocean pout in bottom trawls. See Appendix A4 for diagnostic plots (NEFSC 2003) presented to reviewers but not originally included in this assessment.

Discards were not estimated separately for northern and southern stock areas but it was possible to prorate estimates approximately for the most important primary species and gear groups with discards of at least 70 mt y^{-1} based on general knowledge about the fisheries (Table A7). On this basis, discards of silver hake in the northern stock area averaged at least 1,580 mt y^{-1} and discards in the southern stock area averaged at least 1998 mt y^{-1} during 2001-2004. For comparison, silver hake landings during the same period averaged 2,142 mt y^{-1} in the north and 7,153 mt y^{-1} in the south (Table A1).

4.0 SURVEY INFORMATION

Trends in survey biomass indices for the two silver hake stocks are evaluated in a subsequent section under the heading “Biomass And Fishing Mortality”. Analyses in this section are confined to trends in recruitment and related factors. Survey recruitment trends show that recruitment to the fishery (silver hake ≥ 20 cm TL) was at least average in the north during recent years. In the south, recruitment to the fishable stock fluctuated around average levels in recent years. Despite average or better recruitment, survey trends show reductions in abundance of relatively large silver hake and reduction in mean weight of individual fish that are analogous to reductions in abundance of old fish mentioned above.

A number of analyses were carried out to measure environmental effects on silver hake catches in NEFSC surveys, by size group, age, and stock area. Results suggest an ontogenetic shift at about the size and age of sexual maturity. In particular, relatively large and old fish are found further north and in deeper water (further offshore). Survey catches are highest at night, contrary to expectations, suggesting that silver hake have a reverse diel migration pattern. Depth seems to be more important than temperature in determining the distribution of silver hake. Small/young silver hake inhabit relatively shallow waters and larger/older silver hake inhabit deeper waters year around, despite large seasonal fluctuations in bottom temperatures.

Survey data are used to track the average position of silver hake in both stock areas and to test for trends in average position over time that might explain recent reductions in abundance of larger and older silver hake. Results generally suggest a shift in the distribution of larger fish to the north and offshore over time.

North-south movements of silver hake between stock areas is likely because the center of distribution for large fish n the northern area during the spring and small fish in the southern area during the fall is close to the boundary between the two stocks. It seems unlikely that silver hake in the north and south are separate populations but, depending on management goals, differences between the two areas are clear enough to justify use of the northern and southern regions as separate management areas.

Survey age data were examined to determine if relatively old silver hake observed historically might have been mis-aged or mis-identified offshore hake. Results indicate some imprecision in age estimation and a positive bias in historical ages (age reading criteria used historically result in ages 1-2 y higher than criteria used recently). The factors do not, however, completely explain the absence of older fish during recent years.

Spatial patterns in NEFSC survey catches

Maps showing locations and size of survey catches for all inshore and offshore strata sampled since 1979 (when inshore strata were first sampled consistently during spring and fall, Figures A11-A13) show how ubiquitous and widely distributed silver hake are in all seasons. Nearshore areas at 35^{o}-38^{o} N Lat. have a relatively high proportion of zero tows during fall and winter but not during spring. In addition, the southern flank of Georges Bank north of 40^{o} N Lat. has a relatively high proportion of zero tows in winter, but not during spring or fall. Silver hake were distributed in an apparently normal fashion during the most recent NEFSC surveys (Figures A14-A16).

None of the NEFSC bottom trawl surveys appear to cover the entire range of the silver hake stocks (Figures A11-A13). Catches were relatively high in deep water during winter, spring and fall along the 100-fathom contour and eastern edge of the area surveyed. In addition, catches from coastal areas north of 38° N Lat. were relatively high during spring and fall (inshore strata were not sampled during winter).

"Traditional" and "Special" strata sets for survey data

In this assessment, "traditional" strata sets are those used in previous assessments to describe trends in silver hake stock biomass (Brodziak et al. 2001). In particular, trends in abundance and biomass of silver hake for the northern stock area are traditionally measured using NEFSC fall and spring survey data from offshore strata 01200-01300 and 01360-01400 (NEFSC 2001). Strata 01610-01760 were not sampled during 1963-1966 so the survey biomass for sampled strata during 1963-1966 was increased by 1.8% in Brodziak et al. (2001), the long-term average proportion of silver hake biomass in strata 01610-01760. In this assessment, data for 1963-1966 were usually ignored. Previous assessments did not typically use inshore survey strata for silver hake, although inshore habitats are used by young and small silver hake, because inshore strata were not sampled consistently until 1979.

Different "special" strata sets were used for survey data in this assessment for environmental and trend analyses described below. Special strata sets for each survey and season were considered carefully with the goals of: 1) using as much information over the widest range of environmental conditions as possible; 2) using as many inshore strata as possible (small silver hake are most common in relatively shallow water; and 3) avoiding spurious results due to lack of sampling in some years. The primary criterion for choosing strata was consistency of sampling (i.e., was the stratum sampled during all years?). Winter and spring survey data were available through 2005. Fall survey data were available only through 2004.

Beginning in 1979, offshore and inshore strata were sampled consistently in the northern and southern stock areas (Tables A8-A11). The winter survey is carried out in offshore strata and in the southern stock area exclusively (Table A12). Based on this information, stock-specific strata sets were derived for the fall and spring surveys beginning in 1979 and for the winter survey beginning in 1992 (Table A13). In this assessment, special strata sets are consistently sampled inshore and offshore strata starting in 1979 (fall and spring surveys) or 1992 (winter surveys).

Mean weight and recruitment trends

Using the special strata sets, mean body weight of silver hake in NEFSC spring and fall surveys and north and south stock areas combined declined steadily during 1979 to 2005 (Figure A17). There were similar trends using the traditional strata sets for individual stock areas (results not shown). Mean weights were usually highest in the northern stock area because larger fish tend to be found further north than smaller individuals. Survey length composition data show progressive reductions in abundance of large individuals (Figure A18).

Fall survey biomass indices (delta mean kg/tow) for recruit (< 20 cm TL) and fishable (≥ 20 cm TL) silver hake in the northern stock show variable but generally increasing trends in abundance since 1967 (Figures A19-A20). In the southern stock area, recruit and fishable abundance during fall surveys varied without trend (Figures A19-A20).

Based on spring survey data, recruit and fishable biomass peaked in both the north and south during 1973-1974 and then declined to relatively low levels by 1980 (Figures A19-A20). In the north, recruit and fishable biomass indices show noisy but generally increasing trends since the early 1980s. In the south, recruit biomass was low during 1982-1998 but may have increased somewhat during 1999-2005. Fishable biomass, in contrast, showed a variable but declining trend during the same period (Figures A19-A20).

Environmental effects on silver hake density and occurrence

Environmental effects on catchability of large or small silver hake may contribute to issues in interpreting survey data trends. The special set of survey strata were used in these analyses. A few tows in anomalously deep water (> 400 m), and tows with missing temperature, depth or time of day data were omitted. Analyses were carried out for the southern and northern stocks independently and combined.

Models were developed for the probability of occurrence of at least one silver hake in survey bottom trawl tows, and for numbers of silver hake caught in tows where at least one silver hake was caught. The first type of model measures probability of occurrence. The second measures density in areas where silver hake occur. Both types of models were fit to tow-by-tow data for individual length groups. Based on preliminary analyses, five cm length groups (1-5.9, 6-10.9, 11-15. 9, 16-20.9, 21-25.9 and 26+ cm) were used in modeling. Very few small silver hake (1-5.9 cm TL) were captured during the spring survey in the northern stock areas. Therefore, the smallest size group was excluded from analyses for the northern stock area and for the northern and southern stock areas combined.

Relationships between environmental variables and the probability of occurrence were evaluated using step-wise logistic regression and generalized additive models (GAMs). Relationships between environmental variables and catch in positive tows were evaluated in a similar manner using step-wise log-linear regression and GAM models. The step-wise procedure used in both cases (step.gam in Splus) minimized the AIC statistic for a set of models.

The most complicated model considered for probability of occurrence was:

```
          gam(P ~ as.factor(Y) + lo(T) + lo(D) + lo(L),
family=binomial)
```

where the dependent variable P was either one (if at least one silver hake of appropriate size was caught in the tow) or zero (if no silver hake of appropriate size were caught). The most complicated model for density in positive tows was similar:

```
            gam(log(d) ~ as.factor(Y) + lo(T) + lo(D) +
lo(L))
```

where the dependent variable was the logarithm of the number of silver hake of appropriate size taken in the tow. In both models, the independent variables were year (Y), bottom temperature (T), average depth of the tow (D) and time of day (L, decimal EST time; e.g. 23.5 for 11:30 pm). The term lo(x) is the loess locally linear scatter plot smoother fit with a span of 0.5 (Hastie and Tibshirani 1990).

Year (Y) was a categorical variable that was "forced" in each model (i.e. the step-wise procedure could not eliminate it). Other independent variables could enter the model either as a loess term, quadratic polynomial, linear term or could be omitted completely. Latitude and longitude were omitted in modeling because they were highly correlated with depth and bottom temperature and because the purpose was to understand environmental effects. Latitudinal and longitudinal patterns are explored in subsequent analyses (see below).

Results - probability of occurrence

Based on GAM model results (Table A14 and Figures A21-A25), small silver hake were most likely to be found in relatively shallow waters that tend to be relatively warm during autumn surveys and cool during spring and winter surveys. Depth and temperature distributions for positive tows confirm GAM results (Figures A26 to A28). Patterns related to depth and temperature were strongest for the southern stock probably because of the wider area sampled in the south.

Depth seemed more important than bottom temperature in predicting occurrence of silver hake because small individuals were found in relatively shallow water for both stocks during all surveys. Relationships between probability of occurrence for silver hake size and temperature differed in the winter, spring and fall surveys.

The probability of a positive tow for small silver hake was generally highest at night with the northern stock and fall survey being the notable exception (Table A14). This "reverse" diel pattern was first noted by Bowman and Bowman (1980) and is unexpected because most mesopelagic organisms migrate off bottom during the night time so that catch rates are highest during the day. Bowman and Bowman (1980) attributed low catch rates during the day to behavior of silver hake. They hypothesized that silver hake were very close to the bottom during the day and not efficiently captured by survey bottom trawls with roller gear, which might roll over them. Reverse diel migration patterns are not as strong for silver hake in winter surveys which use bottom trawls that have cables, rather than rollers, as ground gear (Tables A14-A15).

Results-catch in positive tows

GAM results for catches of silver hake in positive survey tows were generally similar to results for probability of occurrence although patterns were clearer for density with more significant loess terms in models (Table A15). In particular, density of small silver hake was highest in relatively shallow waters. The highest catches of large silver hake (> 21 cm) were at depths of at least 150 m at or near the offshore edge of the bottom trawl surveys. Bottom temperature, depth and time of day were significant in 30, 31 and 27 out of 31 total cases. All models with significant time of day effects predicted highest catch rates at night.

Temporal patterns in stock distribution

Mean depth, latitude, longitude and bottom temperature for silver hake of different sizes in the northern and southern stock areas were computed as catch weighted averages so that the latitude of a tow with a large catch received a higher weight than the latitude of a tow with a small catch (special strata set). Tows with zero catches were, in effect, omitted from the analysis because they received zero weight. Murawski (1993) and Overholtz and Friedland (2002) carried out similar analyses for latitude and longitude in a variety of species but used unweighted means. The weighted means used here should more accurately measure average position and environmental variables encountered by silver hake stocks. Linear regression analyses with year as the independent variable and mean latitude or longitude as the dependent variable were used to test for trends in location of silver hake. Both linear and loess regression lines were plotted to help visualize trends.

Results

Results (not shown) for trends in average temperature and depth supported results from the GAM model analysis because larger fish were found in deeper water that was relatively cold during fall surveys and relatively warm during spring and winter surveys. Variation in average temperature and depth was irregular and inconsistent. It did not indicate steady unidirectional trends or abrupt shifts in average depth or temperature of silver hake in any size group.

Results for trends in average location (latitude and longitude, Figures A29-A35) show that small silver hake (< 6 cm) in the northern stock area during the fall and southern stock area during the spring are located further south (lower mean latitude) than larger individuals. Larger individuals were located further offshore (at lower mean longitude) during the spring and winter surveys in the southern stock area.

Differences between location and size were clearest when the northern and southern stock areas combined (Figure A31 and A34). In particular, small silver hake tend to occur over inshore regions in the south while larger individuals are further north and offshore. As pointed out by reviewers, trends towards the north and offshore might be spurious and due to increasing abundance in the north of the northern and southern stocks are, in fact, independent populations.

Average latitude results indicate that substantial interchange of silver hake is likely between the northern and southern stock areas. The northern and southern stock areas are divided at approximately 41-42° N (Figure A1). Average locations of silver hake in the northern stock were generally close to the northern boundary of the southern stock area (Figures A29 and A32). Similarly, average locations of silver hake in the southern stock area during fall when water temperatures are warm were generally close to the southern boundary of the northern stock area (Figures A30).

Trends in mean bottom temperature over time were statistically significant (Table A16) in only two out of 40 possible cases. In particular, there were negative trends for two size groups in the fall survey with north and south stock areas combined. Trends in mean depth were statistically significant and positive in 12 out of 40 possible cases, most often for combined north and south stock areas during the fall.). Two apparently significant trends would be expected under the null hypothesis of no trends in bottom temperature using *p*-value 0.05.

Trends in latitude and longitude (Table A16 and Figures A29 to A35) indicate a general shift in the distribution of silver hake to the north and offshore. In particular, trends in mean latitude were statistically significant in 16 out of 40 cases. Trends in mean longitude were statistically significant in eight out of 40 cases (significant trends were positive in two cases and negative in eight cases). Two apparently significant trends would be expected under the null hypothesis of no trends in bottom temperature using *p*-value 0.05.

Trends in distribution may be confounded with changes in relative abundance of the north and south stocks because higher abundance in the north would result in a positive shift in mean latitude and a negative shift in mean longitude. Omitting cases with the southern and northern stocks combined, there were significant positive trends in mean latitude in ten cases and significant trends in mean longitude in six out of 30 cases (four negative trends and two positive trends, Table A16). One or two apparently significant trends would be expected under the null hypothesis of no trends in bottom temperature using *p*-value 0.05.

What happened to the old fish?

NEFSC survey age composition data for silver hake are currently being audited to remove some duplicate records. The provisional survey age data used here were corrected for obvious errors by the assessment authors and are meant only for use in this assessment.

Survey age composition data were not updated for silver hake in this assessment but age-specific abundance indices for silver hake from Brodziak et al (2001) show the declining trends in abundance of old fish despite trends for young fish that increased in recent years (Figure A36). Trends for relatively old silver hake are similar to results for relatively large fish (Figures A18-A20).

Several analyses indicate that normal variability in age reader data may exaggerate the apparent decline old silver hake in survey catches (see below). However, age data errors do not appear to be sufficient to completely explain the decline of old silver hake. As shown above, relatively abundance of relatively large silver hake have declined in abundance as well.

Accounting for changes in criteria used to age silver hake (see below), the small number of old fish observed, and age estimation errors (see below), it appears likely that the apparent decline in maximum age from 14 to 6 years represents an actual decline from perhaps 10 to 6 years (see below). Based on the provisional survey data and original age estimates (Table A17), only sixteen "old" individuals (originally aged 11-14 years) have been observed out of roughly 100,000 age estimates for silver hake taken in NEFSC fall and spring surveys during 1973-2005. Sixteen age estimation errors of at least +2 y are plausible given experimental results shown below.

It is unlikely that old silver hake observed in surveys were all or mostly offshore hake, although the two species are similar in appearance (Collette and Klein-MacPhee 2002). Plots (not shown) of length versus age for all silver hake in the NEFSC survey database indicate that lengths at age for relatively old individuals were not anomalous. Geographic distributions of silver hake ages 8+ and offshore hake overlap (Figures A11-A12 and A37-A38). However, survey staffs are aware of potential misidentification problems with silver hake and are generally alert to the possibility of misidentification in areas where both species occur. Moreover, otoliths from the two species differ in shape (Figure A39) and age readers are able to distinguish otoliths from the two species.

An environmental change that shifted large silver hake into deeper water might explain the apparent decline in abundance (Brodziak et al. 2001). Relatively old and large silver hake are most common in deep water at the limit of depths sampled in NEFSC surveys (Figure A40-A41). Trends in the mean locations of large and presumably old silver hake have been noted (see above). However, despite a range of potential candidates (Brodziak et al 2001), no environmental factor with a definitive mechanism that might cause a shift to the north or offshore has been clearly identified.

Distribution plots for relatively old silver hake may indicate a north-south seasonal migration pattern (prepared after this assessment was completed and presented to reviewers, Appendix A4). During spring surveys, silver hake ages 8+ were found south of Georges Bank. During fall surveys, in contrast, silver hake ages 8+ were almost entirely north of Georges Bank.

Age reader experiments

Three experiments were undertaken to determine the precision of current and historic age estimates for silver hake in NEFSC surveys. In the first experiment, the primary age reader who estimated ages for silver hake in the 2001-2005 surveys re-aged a sample of 99 fish originally aged 1-5 y. The sample size at ages 3 y and older was small but percent agreement declines for older silver hake (Table A18).

In the second experiment, an alternate age reader who was experienced in ageing silver hake re-aged the 99 specimens used in the first experiment. Percent agreement between readings was generally lower than in the first experiment. As in the first experiment, the sample size was small for ages 3 y and older but percent agreement appears to have declined with age (Table A19).

In the third experiment, a sample of 17 fish from fall and spring surveys during 1973-1975, 1979 and 1982 originally aged 7-14 y were re-aged by the primary reader. Although sample size was small, it appears that current criteria for ageing silver hake would result in age estimates that would be 1-2 y lower than originally (Table A20).

Relationships between age and depth

Cumulative distributions for silver hake of different ages in fall and spring surveys (all strata and tows) show older fish in deeper water with an apparent shift to deep water during fall between ages 2-3 y (Figure A42). Cumulative distributions for age and temperature show older fish in relatively warm water during the fall and relatively cool water during the spring. Patterns for old fish are similar to those described above for large fish. In particular, depth seems to be more important than temperature in determining habitat for silver hake of different size.

Supplemental “Transect” bottom trawl survey

Bottom trawl data from the Supplemental Finfish Survey Targeting Mid-Atlantic Migratory Species were used in this assessment to estimate lower bounds for catchability in NEFSC bottom trawl surveys and to better characterize the distribution of silver hake in deep water along the shelf break (Tables A21-A22). The survey is described in general terms below and in Appendix A2. See HSRL (2005) for a more complete description.

Supplemental survey data for silver hake in this assessment were collected during March of 2004-2005 following transects along the northern flank of Baltimore and Hudson canyons (transects and tow locations were the same in all years, Figure A43). Data for 2003 were not used because silver hake and offshore hake were not distinguished in survey catch records. Baltimore canyon stations included in this analysis were in NEFSC survey strata 01020-01040. Hudson canyon stations were in NEFSC survey strata 01700-01720 (Figure A1). For simplicity in this analysis, “fixed” stations along transects are treated like random samples from NEFSC survey strata. Supplemental survey data used in the analysis were from fixed stations at target depths of 73, 91, 110, 146, 183, 229 and 274 m (40, 50, 60, 80, 100, 125 and 150 fathoms) that were occupied during the daytime. Deeper stations were occupied at night and omitted from this analysis except in estimating survey length composition.

The F/V Jason and Danielle (96 ft and 1080 hp) was used in 2003-2004 Supplemental surveys and the F/V Luke & Sarah (120 ft and 1500 hp) was used during 2005. The captain, bottom trawl gear and sampling protocols were the same in all surveys.

The commercial 4 seam box net bottom trawl used in supplemental surveys was the same in each year. The wingspread averaged about 67 m and head rope height averaged about 5.5 m. In contrast, the Yankee #36 standard bottom trawl currently used in NEFSC fall and spring surveys is smaller with a wingspread of about 12 m and head rope height of about 2 m. The commercial bottom trawl has a larger liner in the cod end (6 cm vs. 1.27 cm). The sweep of the commercial net is covered with 3 inch rubber cookies. The Yankee #36 bottom trawl has a combination of 5 and 15 inch rollers. The Yankee #36 bottom trawl used in NEFSC surveys catches more small whiting (< 20 cm TL, Figure A44).

Supplemental survey tows were made at 3 knots in a direction perpendicular to the slope and transect. NEFSC survey tows were made at 3.8 knots in the direction of the next station. The amount of wire let out was constant for all tows at the same depth. Distance towed in the Supplemental survey was determined based on a depth data from a depth sensor on the trawl.

Twenty cm is a reasonable lower bound for defining the fishable stock of silver hake. Silver hake captured by the commercial bottom trawl used in Supplemental surveys are seldom < 20 cm TL (Figure A45). Small silver hake are more common in NEFSC surveys but not often encountered in the areas of interest during the spring (Figure A44). In analyses that follow, catch was in kg per tow for silver hake ≥ 20 cm TL in NEFSC surveys and total catch for Supplemental surveys. Densities of silver hake (kg/km^2) were calculated for each tow by dividing catch by area swept (Table A22).

Relationships between density and depth were generally similar for the two surveys (Figures A45-A47). Densities measured by the Supplemental Survey were substantially higher and less variable.

5.0 BIOMASS AND MORTALITY ESTIMATES

Three methods were used to characterize biomass and fishing mortality for silver hake in the northern and southern stock areas, and for the stocks combined. The first method is based on trends in biomass and exploitation indices that are calculated from landings and NEFSC fall survey data. The first method is the current standard and used by managers to specify management targets and thresholds and to define overfishing and overfished stock conditions. The second and third methods provide lower bound estimates for stock biomass and upper bound estimates for fishing mortality based on NEFSC survey, landings, discard and Supplemental survey data. The later two methods are new and have not been used previously. They are not intended to displace the standard method. Rather, they provide information about the scale (magnitude) of biomass and fishing mortality for silver hake.

Based on all three approaches, silver hake appear to be at relatively high biomass levels in both the northern and southern stock areas. Fishing mortality rates were low during recent years and much higher historically.

Trends in biomass and exploitation indices

Survey biomass trends for both the northern and southern stock areas (delta mean kg/tow for fall surveys during 1967-2004, calculated for “traditional” offshore strata) indicate that stock biomass is relatively high and near target levels used in management (Tables A22-A23 and Figures A48-A49). Relative exploitation indices (landings divided by the survey stock biomass index) indicate that fishing mortality rates are low in both stock areas and less than threshold levels used in management (Tables A22-A23 and Figures A48-A49).

A conventional age-structured stock assessment model was not used in this assessment for silver hake due to lack of time, uncertainty about stock structure, uncertainty about natural mortality stemming from trends in maximum age, ongoing audit of silver hake age data, low levels of fishing mortality during recent years (particularly in the north) which may complicate modeling, lack of a hypothesis regarding old fish to test in modeling, uncertainty about the magnitude of discards, a new stock assessment author, and the apparently misleading results from previous modeling efforts. In lieu of an age-structured stock assessment model, two approaches were used to estimate lower bounds for silver hake biomass and upper bounds for fishing mortality rates.

Bounds for fishable biomass and fishing mortality

(EDITOR’S NOTE: THIS PART OF THE WORKING GROUP REPORT HAS BEEN OMITTED. IT WAS NOT ACCEPTED BY THE REVIEW PANEL.)

Bounds based on NEFSC and Supplemental surveys

(EDITOR’S NOTE: THIS PART OF THE WORKING GROUP REPORT HAS BEEN OMITTED. IT WAS NOT ACCEPTED BY THE REVIEW PANEL.)

Bounds based on historical landings and concurrent survey data

(EDITOR’S NOTE: THIS PART OF THE WORKING GROUP REPORT HAS BEEN OMITTED. IT WAS NOT ACCEPTED BY THE REVIEW PANEL.)

A bridge between the current and last assessment

Trends in biomass and exploitation indices suggest that results from a virtual population analysis for silver hake in the previous assessment were overly pessimistic (NEFSC 2001). It appears that the virtual population analysis (VPA) used in the last assessment mistakenly interpreted trends in abundance of old silver hake as evidence of low abundance and high fishing mortality. A Bayesian surplus production model in the last assessment appears to have given more plausible results with generally increasing biomass trends for the stock as a whole.

6.0 OVERFISHING DEFINITIONS AND STATUS

Overfishing definitions and biological reference points used by managers for the northern and southern stocks of silver hake are summarized below and in NEFMC (2002).

Summary of biolgical reference points used in overfishing definitions for silver hake. The new exploitation based target for silver hake in the southern stock area is 60% of the threshold, F_{MSY} proxy level. The biomass based reference points include an adjustment made in NEFSC (2001) to accommodate recalculation of survey biomass indices.

Stock	Biomass target (B_{MSY} proxy, average delta mean kg tow for NEFSC fall survey during 1973-1982)	Biomass threshold (1/2 BMSY proxy, delta mean kg tow in NEFSC fall survey)	New exploitation index reference points (landings / biomass index)		Original fishing mortality (F) based reference points in Ammendment 12 (y^{-1})	
			Target	Threshold (F_{MSY} proxy)	Target	Threshold (F_{MSY} proxy)
North	6.63	3.31	2.57	2.57	$F < F_{0.1}$	$F_{0.1} = 0.41$
South	1.78	0.89	20.63	34.39	$F < F_{0.1}$	$F_{0.1} = 0.39$

The B_{MSY} proxies and biomass reference points used for both stocks of silver hake in this assessment and in NEFSC (2002) are based on average catch rates in the NEFSC fall survey (delta mean kg/tow) during 1973-1982, a period of relative stability in the fishery (Figure A48-A49). The biomass reference points for silver hake are compared to the most recent three-year averages of fall survey biomass (delta mean kg/tow) to determine if either stock is overfished.

The F_{MSY} proxies and associated reference points used for silver hake in this assessment and in NEFSC (2002) are based on exploitation indices (landings / fall survey delta mean kg/tow), are new since the last assessment (NEFSC 2001), and differ from the reference points in Amendment 12 of the Northeast Multispecies Fishery Management Plan. In particular, the F_{MSY} proxies and fishing mortality reference points used for silver hake in this assessment are based on exploitation indices (landings / fall survey delta mean kg/tow) during 1973-1982, a period of relative stability in the fisheries that is already used to define biomass reference points (Figure A48-A49). The new reference points for silver hake are compared to the most recent three-year averages of the exploitation rates indices (landings over delta mean kg/tow) to determine if overfishing is occurring in either stock.

The new reference points based on exploitation indices were developed since the last assessment and used annually by the New England Council's Whiting Monitoring Committee because fishing mortality rates were not estimated for whiting in the last assessment (NEFSC 2001) and because it was not possible to use the original fishing mortality based reference points ($F_{0.1}$) in Amendment 12.

The Whiting Monitoring Committee's new reference points were reviewed and used in this assessment because fishing mortality rates were not estimated. The exploitation index approach is common in northeast fisheries when fishing mortality cannot be estimated, and it was based on the original reference points to the extent possible. The exploitation based target for the southern stock is set at 60% of the F_{MSY} proxy and is more risk averse than the original approach in Amendment 12. The target and threshold reference points for defining overfishing in the northern stock are identical.

Northern stock

The northern stock of silver hake is not overfished and overfishing is not occurring (Table A22 and Figure A48). In particular, the three-year average biomass index for 2002-2004 (6.72 kg/tow) was above the management threshold level (3.31 kg/tow) and near the target level (6.63 kg/tow). The three-year average exploitation index for 2002-2004 (0.24) was below the management threshold and target level (2.57).

The northern stock of silver hake was not overfished based on results from the last assessment (NEFSC 2001). Overfishing was not evaluated in the last assessment because fishing mortality rates were not estimated.

Southern stock

Based on current reference points, the southern stock of silver hake is not overfished and overfishing is not occurring (Table A23 and Figure A49). In particular, the three year average biomass index for 2002-2004 (1.37 kg/tow) was above the management threshold level (0.89 kg/tow) and near the target level (1.78 kg/tow). The three year average exploitation index for 2002-2004 (4.85) was below the management threshold level (34.39) and below the management target level (20.63).

The southern stock of silver hake was overfished based on results from the last assessment (NEFSC 2001). Overfishing was not evaluated in the last assessment because fishing mortality rates were not estimated. The change in status is due to increases in stock biomass indices for the southern stock of silver hake.

7.0 STOCK PROJECTIONS

Stock projections were not carried out because current age structure, abundance and were not estimated biomass in absolute terms. However, stock biomass levels are relatively high and current fishing mortality rates are very low in the north and probably low in the south also. Recent recruitments have been roughly average. Uncertainties exist because old fish are still absent and the cause is unknown. Given these factors, a qualitative analysis suggests that significant declines in stock biomass due to fishing are unlikely in the short term.

8.0 TOTAL ALLOWABLE LANDINGS (TAL)

Total allowable landings (TAL) for 2005 were calculated based on fall survey data through 2004 and exploitation index reference points (Table A27). In particular, target exploitation indices (landings / three year average survey) were multiplied by the most recent three-year average survey abundance index to estimate landings at the target exploitation level. Assuming that the reference points are exact, CVs measuring uncertainty in TAL calculations are the same as the CV for the three year average survey.

For the northern stock area during 2005, where the target and threshold reference points are the same, TAL < 17.3 mt. For the southern stock area during 2005 based on the target reference point, TAL=28.3 mt. For comparison, annual landings averaged 1.71 thousand mt in the north and 6.65 thousand mt in the south during 2002-2004.

9.0 SOURCES OF UNCERTAINTY AND NEW RESEARCH RECOMMENDATIONS

The most important uncertainties stem from clearly decreasing trends in abundance of relatively old and large individuals. These reductions have occurred despite apparently normal growth patterns, low fishing mortality rates and relatively high biomass levels during recent years. The possibility of increased natural mortality rates due to predation or other ecosystem level effect is a key area for future research.

Survey data indicate that relatively large silver hake may move around Georges Bank from the southern stock area to the northern. Uncertainty about north-south movements of adult silver is important because of uncertainty about linkages between the northern and southern stock areas.

Considerable amounts of silver hake biomass may occur midwater and on the bottom at depths that are not effectively sampled by NEFSC bottom trawl surveys. Stock biomass would be better estimated if more information about use of midwater habitat information was available and if the lower depth distribution of silver hake was determined.

10.0 RESEARCH RECOMMENDATIONS FROM PREVIOUS ASSESSMENTS

1) Develop survey information that covers the offshore range of the population. *The Supplemental ("Transect") survey during 2003-2005 sampled relatively deep water along several transects.*

2) Conduct surveys of spawning aggregations on the southern flank of Georges Bank. *This research recommendation was not addressed.*

3) Investigate bathymetric demography of population. *The current assessment includes extensive analysis of relationships between location, depth, size and age based on bottom trawl survey data.*

4) 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. *The current assessment includes extensive analysis of survey data to determine trends in locations of highest silver hake density (catch*

weighted mean latitude and longitude) and to determine environmental factors that affect density of silver hake of different sizes and at different times of the year.

5) Quantify age-specific fecundity of silver hake. *This research recommendation was not addressed.*

11.0 LITERATURE CITED

Almeida, F. 1987. Stock identification of silver hake in the New England-Middle Atlantic area. N. Amer. J. Fish. Mgmt. 7: 169-186.

Bolles, K.L., and G.A. Begg. 2000. Distinction between silver hake (*Merluccius bilinearis*) stocks in U.S. waters of the Northwest Atlantic based on whole otolith morphometrics. Fish. Bull. 98: 451-462.

Bowman, R. and E. Bowman. 1980. Diurnal variation in the feeding intensity and catchability of silver hake. Can. J. Fish. Aquat. Sci. 37: 1565-1572.

Brodziak, J.K.T., E.M. Holmes, K.A. Sosebee, and R.K. Mayo. 2001. Assessment of the silver hake resource in the northwest Atlantic in 2000. NEFSC Ref. Doc. 01-03.

Cochran, W.G. 1977. Sampling techniques. John Wiley & Sons, NY.

Collette, B.B., and G. Klein-MacPhee. 2002. Bigelow and Schroeder's fishes of the Gulf of Maine. Smithsonian Institution Press, Washington, DC.

Fritz, R. 1960. A review of the Atlantic coast whiting fishery. Commer. Fish. Rev. 22: 1-11.

Hastie, T.J., and R.J. Tibshirani. 1990. Generalized additive models. Chapman and Hall, New York, NY

Helser, T.E. 1996. Growth of silver hake within the U.S. continental shelf ecosystem of the northwest Atlantic Ocean. J. Fish. Biol. 48: 1059-1073.

Helser, T., and J. Brodziak. 1998. Impacts of density-dependent growth and maturation on assessment advice to rebuild depleted U.S. silver hake stocks. Can. J. Fish. Aquat. Sci. 55: 882-892.

Hoenig, J. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82: 898-903.

HSRL (Haskin Shellfish Research Laboratory). 2005. Supplemental finfish survey targeting Mid-Atlantic Species. March 2005 Supplementary Survey Cruise Report. Haskin Shellfish Research Laboratory, Port Norris, NJ.

Lock, C.L., and D.B. Packer. 2004. Essential fish habitat source document: silver hake, *Merluccius bilinearis*, life history and habitat characteristics (2nd edition). NOAA Tech. Memo. NMFS-NE-186.

Murawski, S.A. 1993. Climate change and marine fish distributions: forecasting from historical analogy. Tran. Am. Fish. Soc. 122: 647-658.

New England Fishery Management Council (NEFMC). 2002. Final 2002 stock assessment and fishery evaluation (SAFE) report for small mesh multispecies (whiting, red hake and offshore hake).

Northeast Fisheries Science Center (NEFSC). 2001. Report of the 32nd Northeast Regional Stock Assessment Workshop (32nd SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. Northeast Fish. Sci. Cent. Ref. Doc. 01-05. 289 pp.

Northeast Fisheries Science Center (NEFSC). 2002. Longfin squid. */In/*: Report of the 34th Northeast Regional Stock Assessment Workshop (34th SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. Northeast Fish. Sci. Cent. Ref. Doc. 02-06. 346 pp.

Northeast Fisheries Science Center (NEFSC). 2003. Report of the 37th Northeast Regional Stock Assessment Workshop (37th SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. Northeast Fish. Sci. Cent. Ref. Doc. 03-16. 597 pp.

Overholtz, W. J., and K. Friedland. 2002. Recovery of the Gulf of Maine-Georges Bank Atlantic Herring (*Clupea harengus*) complex: perspectives based on bottom trawl survey data. Fish. Bull. 100: 593-608.

Rago, P.J., S.E. Wigley, M.J. Fogarty. 2005. NEFSC bycatch estimation methodology: allocation, precision and accuracy. Northeast Fisheries Science Center Ref. Doc. 05-09.

Sissenwine, M., and E. Cohen. 1991. Resource productivity and fisheries management of the Northeast shelf ecosystem, p. 107-124. *In:* Sherman, K., Alexander, L., and Gold, D. (eds.). Food chains, yields, models and management of large marine ecosystems. Westview Press, San Francisco, CA.

SILVER HAKE TABLES

Table A1. Silver hake landings (mt) by stock area during 1955-2004 for foreign and domestic fishing fleets.

Year	Northern stock area			Southern stock area			North plus south stock areas		
	Foreign	Domestic	Total	Foreign	Domestic	Total	Foreign	Domestic	Foreign + domestic
1955		53,361	53,361		13,842	13,842	0	67,203	67,203
1956		42,150	42,150		14,871	14,871	0	57,021	57,021
1957		62,750	62,750		17,153	17,153	0	79,903	79,903
1958		49,903	49,903		13,473	13,473	0	63,376	63,376
1959		50,608	50,608		17,112	17,112	0	67,720	67,720
1960		45,543	45,543		9,206	9,206	0	54,749	54,749
1961		39,688	39,688		13,209	13,209	0	52,897	52,897
1962	36,575	42,427	79,002	5,325	13,408	18,733	41,900	55,835	97,735
1963	37,525	36,399	73,924	74,023	19,359	93,382	111,548	55,758	167,306
1964	57,240	37,222	94,462	127,036	26,518	153,554	184,276	63,740	248,016
1965	15,793	29,449	45,242	283,366	23,765	307,131	299,159	53,214	352,373
1966	14,239	33,477	47,716	200,058	11,212	211,270	214,297	44,689	258,986
1967	6,882	26,489	33,371	81,749	9,500	91,249	88,631	35,989	124,620
1968	10,506	30,873	41,379	49,422	9,074	58,496	59,928	39,947	99,875
1969	8,047	15,917	23,964	67,396	8,165	75,561	75,443	24,082	99,525
1970	12,305	15,223	27,528	20,633	6,879	27,512	32,938	22,102	55,040
1971	25,243	11,158	36,401	66,344	5,546	71,890	91,587	16,704	108,291
1972	18,784	6,440	25,224	88,381	5,973	94,354	107,165	12,413	119,578
1973	18,086	13,997	32,083	97,989	6,604	104,593	116,075	20,601	136,676
1974	13,775	6,905	20,680	102,112	7,751	109,863	115,887	14,656	130,543
1975	27,308	12,566	39,874	65,812	8,441	74,253	93,120	21,007	114,127
1976	151	13,483	13,634	58,307	10,434	68,741	58,458	23,917	82,375
1977	2	12,455	12,457	47,850	11,458	59,308	47,852	23,913	71,765
1978		12,609	12,609	14,353	12,779	27,132	14,353	25,388	39,741
1979		3,415	3,415	4,877	13,498	18,375	4,877	16,913	21,790
1980		4,730	4,730	1,698	11,848	13,546	1,698	16,578	18,276
1981		4,416	4,416	3,043	11,783	14,826	3,043	16,199	19,242
1982		4,656	4,656	2,397	12,164	14,561	2,397	16,820	19,217
1983		5,310	5,310	620	11,520	12,140	620	16,830	17,450
1984		8,289	8,289	412	12,731	13,143	412	21,020	21,432
1985		8,297	8,297	1,321	11,843	13,164	1,321	20,140	21,461
1986		8,502	8,502	550	9,573	10,123	550	18,075	18,625
1987		5,658	5,658	2	10,121	10,123	2	15,779	15,781
1988		6,767	6,767		9,195	9,195	0	15,962	15,962
1989		4,646	4,646		13,169	13,169	0	17,815	17,815
1990		6,379	6,379		13,615	13,615	0	19,994	19,994
1991		6,053	6,053		10,093	10,093	0	16,146	16,146
1992		5,302	5,302		10,288	10,288	0	15,590	15,590
1993		4,360	4,360		12,912	12,912	0	17,272	17,272
1994		5,724	5,724		10,334	10,334	0	16,058	16,058
1995		3,033	3,033		11,694	11,694	0	14,727	14,727
1996		3,200	3,200		12,999	12,999	0	16,199	16,199
1997		2,591	2,591		12,994	12,994	0	15,585	15,585
1998		2,258	2,258		12,701	12,701	0	14,959	14,959
1999		4,042	4,042		9,970	9,970	0	14,012	14,012

2000	2,418	2,418	9,760	9,760	0	12,178	12,178
2001	3,446	3,446	8,694	8,694	0	12,140	12,140
2002	2,839	2,839	5,153	5,153	0	7,992	7,992
2003	1,727	1,727	6,916	6,916	0	8,643	8,643
2004	557	557	7,889	7,889	0	8,445	8,445

Table A1. (cont.)

Table A2. Proportion of total landings (mt) by market category and gear group during 1995-2004.

Market Category	Gillnets	Hook&Line	OtherGear	OtterTrawl	UnkGear	Grand Total
5090 (Round)	0.15%	0.04%	0.32%	65.84%	1.56%	67.91%
5091 (King round)	0.06%	0.00%	0.05%	6.36%	0.06%	6.54%
5092 (Small round)	0.18%	0.02%	0.04%	22.73%	0.10%	23.07%
5093 (Dressed)	0.01%	0.00%	0.95%	0.02%	0.00%	0.97%
5094 (Juvenile)	0.00%	0.00%	0.00%	1.09%	0.19%	1.28%
5095 (Large round)	0.00%	0.00%	0.09%	0.12%	0.02%	0.23%
Grand Total	0.39%	0.06%	1.45%	96.16%	1.93%	100.00%

Table A3. Sampling intensity (length measurements / mt landed) for commercial landings during 1995-2004.

		Gear Groups					
Market Category	Landings (mt)	Gillnets	Hook&Line	OtherGear	OtterTrawl	UnkGear	All
5090 (Round)	85,316	3.91	0	0.34	0.48	0	0.47
5091 (King round)	8,220	0.50	0	0	1.63	0	1.59
5092 (Small round)	28,981	0	9.26	0	0.48	0	0.48
5093 (Dressed)	1,219	0	0	0	0	0	0
5094 (Juvenile)	1,608	No landings	0	0	0.47	0	0.40
5095 (Large round)	289	No landings	0	0	0	0	0
All	125,633	1.54	2.61	0.07	0.55	0	0.54

Table A4. Names, database codes (NESPP3) and groups for species used to estimate discard for silver hake.

Species Group	Species Code (NESPP3)	Species Name	Species Group	Species Code (NESPP3)	Species Name
Monkfish	12	ANGLER	Crabs/Shrimps	711	CRAB
Squid/ButterFish	51	BUTTERFISH	Crabs/Shrimps	712	CRAB
Squid/ButterFish	801	SQUID (LOLIGO)	Crabs/Shrimps	713	CRAB
Squid/ButterFish	802	SQUID (ILLEX)	Crabs/Shrimps	714	CRAB
Squid/ButterFish	803	SQUIDS (NS)	Crabs/Shrimps	715	CRAB
Principal Grndfsh	81	COD	Crabs/Shrimps	718	CRAB
Principal Grndfsh	147	HADDOCK	Crabs/Shrimps	724	CRAB
Principal Grndfsh	153	HAKE	Crabs/Shrimps	727	LOBSTER
Principal Grndfsh	155	HAKE MIX RED & WHITE	Crabs/Shrimps	735	SHRIMP (NK)
Principal Grndfsh	240	REDFISH	Crabs/Shrimps	736	SHRIMP (PANDALID)
Principal Grndfsh	269	POLLOCK	Crabs/Shrimps	737	SHRIMP (MANTIS)
Herring/Shad/Other/Pelagics	112	HERRING	Crabs/Shrimps	738	SHRIMP (PENAEID)
Herring/Shad/Other/Pelagics	347	SHAD	Mollusks	748	QUAHOG
Flatfish	120	FLOUNDER	Mollusks	754	QUAHOG
Flatfish	122	FLOUNDER	Mollusks	764	CLAM NK
Flatfish	123	FLOUNDER	Mollusks	769	CLAM
Flatfish	124	FLOUNDER	Mollusks	775	CONCHS
Flatfish	125	FLOUNDER	Mollusks	776	WHELK
Flatfish	126	FLOUNDERS (NK)	Mollusks	777	WHELK
Flatfish	128	HOGCHOCKER	Mollusks	781	MUSSELS
Flatfish	158	HALIBUT	Mollusks	786	OCTOPUS
Flatfish	159	HALIBUT	Mollusks	799	SCALLOP
Fluke/Fourspot	121	FLOUNDER	Scallops	800	SCALLOP
Fluke/Fourspot	127	FLOUNDER	Urchins/Cumcumbers/Shellfish	805	SEA URCHINS
Hakes+OceanPout	152	HAKE	Urchins/Cumcumbers/Shellfish	806	SEA CUCUMBERS
Hakes+OceanPout	250	POUT	Urchins/Cumcumbers/Shellfish	828	STARFISH
Hakes+OceanPout	508	HAKE	Other Species	1	ALEWIFE
Hakes+OceanPout	509	HAKE	Other Species	23	BLUEFISH
Atlantic herring	167	HERRING (NK)	Other Species	24	SQUIRRELFISH
Atlantic herring	168	HERRING	Other Species	33	BONITO
Atllantic mackerel	212	MACKEREL	Other Species	87	CREVALLE
Menhaden	221	MENHADEN	Other Species	90	CROAKER
Scup/Seabass	329	SCUP	Other Species	93	CUNNER
Scup/Seabass	335	SEA BASS	Other Species	96	CUSK
Dogfishes	350	DOGFISH (NK)	Other Species	106	DRUM
Dogfishes	351	DOGFISH SMOOTH	Other Species	107	DRUM
Dogfishes	352	DOGFISH SPINY	Other Species	115	EEL
Other sharks	353	SHARK	Other Species	116	EEL
Other sharks	357	SHARK	Other Species	117	EEL
Other sharks	359	SHARK	Other Species	130	FLOUNDER
Other sharks	478	SHARK	Other Species	133	GARFISH
Other sharks	482	SHARK	Other Species	134	GIZZARD SHAD
Skates/Rays	365	SKATES	Other Species	150	HAGFISH
Skates/Rays	366	SKATE	Other Species	165	HARVEST FISH
Skates/Rays	367	SKATE	Other Species	173	SHAD
Skates/Rays	368	SKATE	Other Species	188	JOHN DORY
Skates/Rays	369	SKATE	Other Species	189	DORY
Skates/Rays	370	SKATE	Other Species	194	MACKEREL
Skates/Rays	372	SKATE	Other Species	197	WHITING
Striped Bass	418	BASS	Other Species	210	LUMPFISH
Large Pelagics	466	TUNA	Other Species	213	BLUE RUNNER
Large Pelagics	468	TUNA	Other Species	215	MACKEREL
Crabs/Shrimps	700	CRAB	Other Species	234	MULLETS
Crabs/Shrimps	710	CRAB	Other Species	235	STRIPED MULLET

Table A4 (cont.)

Species Group	Species Code (NESPP3)	Species Name
Other Species	242	ROSEFISH
Other Species	258	PIGFISH
Other Species	267	PINFISH
Other Species	268	LADYFISH
Other Species	272	POMPANO
Other Species	326	SCULPINS
Other Species	327	SEA RAVEN
Other Species	333	SEA BASS
Other Species	334	SEATROUT
Other Species	340	SEA ROBIN
Other Species	341	SEA ROBINS
Other Species	342	SEA ROBIN
Other Species	343	SEA ROBIN
Other Species	344	WEAKFISH
Other Species	345	WEAKFISH
Other Species	356	SHEEPSHEAD
Other Species	364	SKATE
Other Species	371	SMELT
Other Species	381	SPADEFISH
Other Species	384	MACKEREL
Other Species	406	SPOT
Other Species	429	PUFFER
Other Species	430	PUFFER
Other Species	438	TAUTOG
Other Species	444	TILEFISH
Other Species	446	TILEFISH
Other Species	447	TILEFISH (NK)
Other Species	456	TRIGGERFISH
Other Species	512	WOLFFISHES
Other Species	526	OTHER FISH
Other Species	660	OTHER FISH
Other Species	661	OTHER FISH
Other Species	662	OTHER FISH
Other Species	664	OTHER FISH
Other Species	667	OTHER FISH
Other Species	668	OTHER FISH
Other Species	678	OTHER FISH
Other Species	679	OTHER FISH
Other Species	681	OTHER FISH
Other Species	686	OTHER FISH
Other Species	687	OTHER FISH
Other Species	688	OTHER FISH
Other Species	733	SHRIMP ROYAL RED
Other Species	778	WHELK
Other Species	796	SCALLOPS NK
Other Species	804	MOLLUSKS NK

Table A5. Names, database codes (NEGEAR) and groups for fishing gear used to estimate discard for silver hake. “Total Hail Weight” is the total hail weight for landings by the gear group in observer data for 2001-2004 (a measure of potential importance for each gear group).

Gear Group	Gear Code (NEGEAR)	Gear Name	Total Hail Weight (mt)
Dredges	132	DREDGE, SCALLOP,SEA	8,172
Gill/set nets	100	GILL NET, FIXED OR ANCHORED,SINK, OTHER/NK SPECIES	2,999
Gill/set nets	105	GILL NET, ANCHORED-FLOATING, FISH	13
Gill/set nets	116	GILL NET, DRIFT-FLOATING, FISH	50
Hook & line	10	LONGLINE, BOTTOM	265
Shrimp trawls	58	TRAWL,OTTER,BOTTOM,SHRIMP	18
Trawls	50	TRAWL,OTTER,BOTTOM,FISH	14,823
Trawls	52	TRAWL,OTTER,BOTTOM,SCALLOP	39
Other/unknown gear	20	HANDLINE	0.21
Other/unknown gear	60	TROLL LINE, OTHER/NK SPECIES	0.01
Other/unknown gear	117	GILL NET, DRIFT-SINK, FISH	554
Other/unknown gear	120	PURSE SEINE, OTHER/NK SPECIES	217
Other/unknown gear	121	PURSE SEINE, HERRING	2,324
Other/unknown gear	170	TRAWL,OTTER,MIDWATER PAIRED	15,685
Other/unknown gear	181	POTS + TRAPS,FISH	2
Other/unknown gear	200	POT/TRAP, LOBSTER OFFSH NK	0.19
Other/unknown gear	360	SCOTTISH SEINE	25
Other/unknown gear	370	TRAWL,OTTER,MIDWATER	2,848

Table A6. Number of trips with observers during 2001-2004 used to estimate discard rates and discard for silver hake, by primary species group and gear group.

Species Group	Gear Groups								Total
	Dredges	Gill/set nets	Hook & line	Shrimp trawls	Bottom Trawls	Purse seines	Midwater trawls	Other/ unknown gear	
Atlantic herring	0	5	0	0	12	27	27	82	153
Atllantic mackerel	0	10	0	0	8	0	2	15	35
Bonito	0	3	0	0	0	0	0	1	4
Crabs/Shrimps	0	6	0	31	66	0	0	5	108
Dogfishes	0	242	2	0	16	0	0	0	260
Flatfish	0	229	0	0	722	0	0	13	964
Fluke/Fourspot	0	54	1	0	358	0	0	4	417
Hakes+OceanPout	0	2	0	0	93	0	3	6	104
Herring/Shad/Other	0	16	0	0	3	0	0	0	19
Large Pelagics	0	9	1	0	0	0	0	0	10
Menhaden	0	75	0	0	0	2	0	0	77
Mollusks	0	0	0	0	1	0	0	0	1
Monkfish	0	865	0	0	147	0	0	0	1012
Other Species	0	928	3	0	51	0	0	1	983
Principal Grndfs	0	1595	146	0	559	0	0	5	2305
Scallops	285	0	0	0	37	0	0	0	322
Scup/Seabass	0	1	0	0	67	0	0	9	77
Skates/Rays	0	218	0	0	102	0	0	0	320
Squid/ButterFish	0	5	0	0	233	0	12	0	250
Striped Bass	0	90	3	0	5	0	0	0	98
Total	285	4353	156	31	2480	29	44	141	7519

Table A7. Discard to kept (DK) ratios and mean annual discard (mt y^{-1}) for silver hake from ratio estimators, by primary species group and primary gear group, based on observer data for 2001-2004. Results are sorted in descending order by DK ratio. Primary species group and gear group combinations not shown had DK ratios < 0.00001. The CV for the DK ratio is the same as the CV for discard because landings were assumed measured without error. The "Assumed stock area" for cases with mean annual discard > 70 mt per year is the principle silver hake stock area for landings and discards based on the primary geographical location of the fishery. Landings for crabs/shrimps in shrimp trawls also include landings for crabs/shrimps in other/unknown gear.

Species Group	Gear Group	N trips	DK ratio	CV	Mean 2001 - 2004 landings (mt y^{-1})	Mean discard 2001-2004 (mt y^{-1})	Assumed stock area
Hakes+OceanPout	Other/unknown gear	6	0.24082	1.46	297	72	South
Hakes+OceanPout	Bottom trawls	93	0.12455	0.20	9,822	1,223	South
Squid/ButterFish	Bottom trawls	233	0.02423	0.24	24,673	598	South
Crabs/Shrimps	Shrimp trawls	31	0.02150	0.32	73,479	1,580	North
Dogfishes	Bottom trawls	16	0.00946	0.39	232	2.2	
Monkfish	Bottom trawls	147	0.00830	0.14	12,672	105	South
Principal Grndfsh	Other/unknown gear	5	0.00458	0.91	415	1.9	
Flatfish	Bottom trawls	722	0.00437	0.15	17,133	75	
Principal Grndfsh	Bottom trawls	559	0.00434	0.14	19,112	83	
Flatfish	Other/unknown gear	13	0.00406	0.84	651	2.6	
Atlantic herring	Bottom trawls	12	0.00371	1.04	7,678	28	
Scup/Seabass	Bottom trawls	67	0.00189	0.41	2,775	5.2	
Flatfish	Gill/set nets	229	0.00166	0.41	648	1.1	
Fluke/Fourspot	Bottom trawls	358	0.00085	0.28	5,831	5.0	
Squid/ButterFish	Midwater trawls	12	0.00080	0.90	176	0.1	
Principal Grndfsh	Gill/set nets	1595	0.00045	0.13	5,892	2.7	
Scallops	Bottom trawls	37	0.00028	0.73	14,540	4.1	
Atlantic herring	Other/unknown gear	82	0.00020	0.63	38,263	7.7	
Skates/Rays	Bottom trawls	102	0.00020	0.35	9,897	2.0	
Dogfishes	Gill/set nets	242	0.00011	0.27	1,156	0.1	
Other Species	Bottom trawls	51	0.00011	0.81	5,612	0.6	
Scallops	Dredges	285	0.00010	0.37	191,675	19.2	
Monkfish	Gill/set nets	865	0.00006	0.25	8,428	0.5	
Atlantic herring	Midwater trawls	27	0.00005	0.73	26,953	1.3	
Skates/Rays	Gill/set nets	218	0.00003	0.72	3,292	0.1	
Crabs/Shrimps	Bottom trawls	66	0.00002	0.60	1,057	0.0	
All	All	6073		0.17	482,358	3,820	na

Table A8. Number of successful random tows (SHG code <= 136) for offshore strata during fall NEFSC bottom trawl surveys during 1963-2004. Cells with zero tows are black. Strata are assigned to stock ("S" for southern and "N" for northern).

		Year of Survey																																							
Stratum	Stock	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
1010	S	5	4	4	4	9	9	7	9	8	7	8	6	8	8	7	8	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
1020	S	5	4	4	4	8	7	10	7	7	7	7	7	7	8	7	7	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
1030	S	5	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
1040	S	2	3	4	4	3	3	3	3	3	3	3	3	2	3	3	1	3	3	3	3	2	3	2	3	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1
1050	S	4	5	3	5	4	5	7	5	8	7	5	6	6	6	5	10	10	4	5	5	5	5	4	5	5	5	5	5	5	5	5	6	3	5	5	5	5	5	5	4	5	5
1060	S	7	5	5	5	9	7	11	8	11	11	8	8	9	8	7	17	16	8	8	8	8	6	8	8	8	7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1070	S	5	4	4	5	5	4	3	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1080	S	2	3	4	3	3	3	3	3	3	3	3	3	2	3	2	3	3	2	2	3	2	3	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1
1090	S	4	5	5	5	6	7	5	7	8	5	5	5	5	5	5	10	15	5	5	5	5	5	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
1100	S	4	5	5	5	6	9	8	9	11	9	8	8	9	8	9	15	16	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1110	S	2	4	4	4	5	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1120	S	■	3	4	4	4	2	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1130	S	5	5	7	6	8	8	9	7	9	9	9	9	9	9	10	18	18	9	9	8	9	9	9	9	10	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
1140	S	6	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	4	3	5	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
1150	S	1	3	3	4	3	4	3	4	3	3	3	4	3	3	3	3	2	2	2	3	2	3	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1160	S	7	7	7	7	8	8	12	8	11	12	11	12	11	10	17	30	20	20	10	10	9	10	10	10	10	10	10	16	10	10	10	13	11	10	10	10	10	10	10	10	11	10
1170	S	5	6	4	5	3	4	4	4	4	4	4	4	4	4	7	8	4	8	4	3	3	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	4
1180	S	1	2	4	3	3	3	3	3	3	3	3	3	3	3	1	5	3	3	3	1	3	3	4	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
1190	S	4	6	5	6	9	9	9	9	9	9	9	9	9	9	11	18	18	9	9	9	9	9	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
1200	N	4	5	5	5	6	6	6	6	6	6	6	6	6	5	7	14	12	6	9	6	6	6	5	5	6	6	6	6	5	5	6	6	6	6	6	6	6	6	6	6	6	6
1210	N	6	4	5	5	4	4	4	4	4	4	4	4	4	3	8	8	8	7	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4
1220	N	2	5	6	6	4	4	4	4	4	4	4	4	4	3	4	10	8	8	5	4	4	4	4	4	4	4	4	4	4	4	5	4	4	4	4	4	4	3	4	4	4	4
1230	N	3	6	6	6	6	5	5	6	5	5	5	5	5	5	10	11	14	5	4	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	6	5	5	5	5	5	5	5
1240	N	11	6	6	6	5	6	6	8	7	6	7	6	7	5	12	23	23	6	6	8	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
1250	N	2	4	3	4	4	4	4	3	4	4	4	4	4	4	7	4	11	4	2	4	4	3	4	3	3	4	3	4	3	3	2	4	3	3	4	4	4	3	4	4	4	4
1260	N	7	4	4	4	5	4	5	5	5	5	5	5	15	9	9	15	19	5	6	5	5	4	5	5	5	5	5	5	5	4	4	5	5	5	5	6	9	5	5	3	5	5
1270	N	2	4	4	4	4	4	4	4	4	4	4	4	4	4	9	7	8	4	4	4	4	4	4	4	4	4	4	4	4	5	4	3	4	4	4	5	8	4	4	4	4	4
1280	N	6	5	6	6	7	7	7	7	7	7	7	8	7	6	11	11	15	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
1290	N	15	8	7	5	8	8	8	8	8	9	8	8	8	8	8	16	23	7	8	8	9	8	5	8	8	8	8	8	8	8	8	8	9	7	8	8	7	8	8	8	8	8
1300	N	1	2	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3
1310	N	9	4	5	6	5	6	7	8	6	7	7	7	6	7	6	6	5	6	7	7	5	6	5	7	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
1320	N	6	5	5	5	4	5	5	5	5	5	6	5	5	4	5	4	4	5	5	5	5	6	5	5	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
1330	N	4	4	4	4	3	4	3	4	4	4	3	4	4	4	3	4	4	3	4	3	4	4	2	4	4	3	4	4	4	3	4	5	4	1	4	3	4	4	4	3	4	3
1340	N	5	6	5	5	5	5	5	5	6	6	5	6	7	6	4	6	6	6	6	6	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	6	5	6	6	6
1350	N	■	4	4	4	4	2	3	3	3	4	3	5	4	1	3	5	■	4	4	4	■	4	4	4	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
1351	S	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1360	S	9	8	5	6	7	9	8	9	10	9	10	10	9	8	9	9	8	8	8	9	4	8	8	8	8	7	8	8	8	8	8	8	8	8	8	11	9	7	8	8	8	8
1370	S	5	5	5	5	4	5	5	5	6	5	5	6	6	6	7	15	14	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	5	5	5	10	5	5	5	5	5
1380	S	7	6	7	5	4	4	5	6	5	5	6	5	5	5	8	19	18	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	7	5	5	8	9	5	5	4	5	4
1390	S	2	3	3	4	2	3	3	3	5	5	3	5	5	4	4	14	11	4	5	5	3	4	5	5	3	5	3	5	5	4	5	4	5	5	4	8	5	5	6	4	4	3
1400	S	3	2	4	4	4	3	3	3	2	3	3	3	3	2	3	11	10	3	2	3	3	3	3	3	3	3	3	2	3	2	3	3	3	3	3	6	3	3	3	3	2	1
1410	S	■	■	4	4	6	6	6	15	17	18	15	18	16	■	18	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
1420	S	■	■	2	2	4	4	4	6	6	6	6	6	6	■	6	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
1490	S	■	■	■	■	■	■	■	3	3	3	3	3	3	■	3	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
1610	S	■	■	■	■	5	5	3	5	3	3	4	4	5	4	5	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
1620	S	■	■	■	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	3	2	2	2
1630	S	■	■	■	■	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	■	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	1	2	2	2
1640	S	■	■	■	■	2	2	2	2	2	2	2	2	2	2	2	2	1	■	2	2	2	3	2	2	1	1	1	1	1	1	■	1	1	1	1	1	1	1	■	1	■	1
1650	S	■	■	■	■	7	10	9	9	7	7	7	8	8	10	10	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
1660	S	■	■	■	■	3	3	3	3	4	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
1670	S	■	■	■	■	3	2	2	2	3	2	2	2	2	2	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2
1680	S	■	■	■	■	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	1	2	2	■	1	1	1	1	■	1	1	1	1	1	1	1	1	1	1	1	1
1690	S	■	■	■	■	8	9	6	8	7	6	6	5	7	10	10	6	6	7	6	6	6	5	7	6	6	6	6	6	6	6	6	6	5	6	6	6	6	6	6	6	6	6
1700	S	■	■	■	■	3	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4
1710	S	■	■	■	■	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	1	2	2	2	3	1
1720	S	■	■	■	■	3	2	2	2	3	2	2	1	2	2	2	1	2	2	2	1	2	2	2	2	1	1	1	■	1	■	1	1	1	1	1	1	1	1	1	1	1	1
1730	S	■	■	■	■	7	7	5	7	5	5	6	5	5	8	8	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	5	5	5	5	5	5	5	5	5	5
1740	S	■	■	■	■	5	5	4	5	4	4	4	4	5	5	5	4	4	4	4	5	4	4	4	3	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5
1750	S	■	■	■	■	3	2	3	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1760	S	■	■	■	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1990		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	2	■	■	1

Table A9. Number of successful random tows (SHG code <= 136) for inshore strata during fall NEFSC bottom trawl surveys during 1963-2004. Cells with zero tows are black. Strata are assigned to stock ("S" for southern and "N" for northern).

		Year of Survey																																									
Stratum	Stock	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04
3010	S	■	■	■	■	■	■	■	■	■	2	2	■	2	1	1	1	1	■	1	1	1	1	1	1	1	2	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3020	S	■	■	■	■	■	■	■	■	■	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
3030	S	■	■	■	■	■	■	■	■	■	2	2	■	2	1	1	1	1	1	1	■	■	■	1	1	■	■	■	1	1	1	1	■	1	1	1	1	1	1	1	1	■	1
3040	S	■	■	■	■	■	■	■	■	■	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2	2	1	3	2	2	2	2	3	2	2	2	2	2	2	2	2	3	2
3050	S	■	■	■	■	■	■	■	■	■	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3060	S	■	■	■	■	■	■	■	■	■	2	2	■	1	■	1	■	1	1	■	■	■	■	1	1	■	■	■	■	1	1	1	1	1	1	1	1	1	1	1	■	1	1
3070	S	■	■	■	■	■	■	■	■	■	2	2	1	3	3	2	3	2	2	3	2	3	3	2	2	2	1	3	3	2	2	2	2	2	2	2	2	2	2	2	3	2	2
3080	S	■	■	■	■	■	■	■	■	■	2	2	4	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3090	S	■	■	■	■	■	■	■	■	■	2	2	■	2	1	1	1	1	1	1	1	■	1	1	1	■	■	■	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3100	S	■	■	■	■	■	■	■	■	■	2	4	2	2	2	2	2	1	2	2	2	3	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3110	S	■	■	■	■	■	■	■	■	■	3	5	3	3	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3120	S	■	■	■	■	■	■	■	■	■	5	6	■	■	1	1	1	1	1	1	■	1	1	1	1	■	■	1	■	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3130	S	■	■	■	■	■	■	■	■	■	4	6	2	3	2	2	2	2	2	2	3	2	2	2	2	2	1	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3140	S	■	■	■	■	■	■	■	■	■	5	14	4	3	2	2	2	2	1	2	2	2	2	2	2	2	2	2	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3150	S	■	■	■	■	■	■	■	■	■	3	2	■	■	■	1	1	1	■	■	1	1	■	1	1	■	■	■	1	1	■	1	1	1	■	■	1	1	1	1	■	1	■
3160	S	■	■	■	■	■	■	■	■	■	3	2	2	3	3	2	2	2	2	3	2	2	3	2	2	2	2	3	2	2	3	2	2	2	2	2	2	2	2	2	2	2	3
3170	S	■	■	■	■	■	■	■	■	■	4	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2
3180	S	■	■	■	■	■	■	■	■	■	2	3	■	2	1	1	1	1	1	1	■	■	1	1	1	■	■	■	■	1	1	1	1	1	1	1	1	■	1	1	1	2	1
3190	S	■	■	■	■	■	■	■	■	■	4	3	2	3	2	2	2	2	2	2	3	2	2	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3200	S	■	■	■	■	■	■	■	■	■	3	4	4	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3210	S	■	■	■	■	■	■	■	■	■	3	2	■	2	1	■	1	1	1	1	1	1	1	1	1	■	■	1	1	1	1	1	■	1	■	■	■	■	■	1	1	■	1
3220	S	■	■	■	■	■	■	■	■	■	3	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3230	S	■	■	■	■	■	■	■	■	■	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3240	S	■	■	■	■	■	■	■	■	■	3	2	■	2	1	1	1	1	1	1	1	1	1	1	1	■	■	2	2	2	1	2	2	2	2	2	2	1	2	2	2	2	2
3250	S	■	■	■	■	■	■	■	■	■	4	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3260	S	■	■	■	■	■	■	■	■	■	3	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3270	S	■	■	■	■	■	■	■	■	■	1	2	■	2	1	1	1	1	1	1	■	■	1	1	■	■	■	1	■	1	1	1	1	1	1	■	1	1	■	■	1	1	■
3280	S	■	■	■	■	■	■	■	■	■	3	3	3	2	2	2	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2
3290	S	■	■	■	■	■	■	■	■	■	3	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3300	S	■	■	■	■	■	■	■	■	■	4	2	■	2	1	1	1	■	1	1	■	■	1	1	1	■	■	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	■
3310	S	■	■	■	■	■	■	■	■	■	3	4	3	3	2	2	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3320	S	■	■	■	■	■	■	■	■	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3330	S	■	■	■	■	■	■	■	■	■	2	1	■	2	1	1	1	1	1	1	■	1	1	1	1	■	■	1	1	1	1	1	1	1	■	1	1	1	■	1	1	1	■
3340	S	■	■	■	■	■	■	■	■	■	3	3	3	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2
3350	S	■	■	■	■	■	■	■	■	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3360	S	■	■	■	■	■	■	■	■	■	3	2	2	1	1	1	1	1	1	1	1	1	1	1	■	■	■	1	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2
3370	S	■	■	■	■	■	■	■	■	■	4	4	4	3	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3380	S	■	■	■	■	■	■	■	■	■	3	3	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3390	S	■	■	■	■	■	■	■	■	■	2	2	■	2	1	1	1	1	1	1	■	1	1	1	2	■	■	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	■
3400	S	■	■	■	■	■	■	■	■	■	3	3	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
3410	S	■	■	■	■	■	■	■	■	■	4	4	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3420	S	■	■	■	■	■	■	■	■	■	2	2	■	1	1	1	1	1	1	1	1	1	1	1	1	■	■	■	1	1	1	1	1	1	1	1	1	1	1	1	1	■	■
3430	S	■	■	■	■	■	■	■	■	■	3	2	■	4	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3440	S	■	■	■	■	■	■	■	■	■	2	4	4	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3450	S	■	■	■	■	■	■	■	■	■	1	■	■	2	■	2	2	1	2	1	2	1	2	1	2	2	1	2	2	2	2	2	2	2	2	2	3	2	2	2	1	2	2
3460	S	■	■	■	■	■	■	■	■	■	■	■	■	■	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2
3520	S	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	4	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3550	S	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	4	4	3	2	4	4	3	2	4	4	4	5	5	5	5	5	5	4	5	5	5	5	3	5	4	4
3560	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	1	■	■	■	1	■	1	1	1	■	1	1	1	1	■	1	1	1	1	1	■	■	1	■	1
3580	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	1	■	1	1	1	1	■	1	1	■	■	1	1	1	1	■	1	1	1	1	1	1	1	■	1
3590	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	1	■	1	1	1	1	1	1	1	1	1	1	1	1	1	■	1	1	1	1	1	1	1	■	1
3600	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	2	2	■	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2
3610	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	3	1	2	2	2	2	2	2	2	2	2
3630	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	2	■	■	■	■	1	■	1	■	1	■	1	1	■	■	■	■	■
3640	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	1	■	■	1	■	1	■	■	■	1	1	■	1	■	1	■	1	1	1	1	1	2	■
3650	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	1	1	1	1	■	2	1	1	1	■	1	1	1	1	1	■	1	1	1	1	2	2	■	■	■
3660	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	2	3	3	■	2	1	2	2	2	2	■	2	1	2	2	1	1	2	2	2	2	2	2	3	1	2
3890	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3900	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	2	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Table A10. Number of successful random tows (SHG code <= 136) for offshore strata during spring NEFSC bottom trawl surveys during 1968-2005. Cells with zero tows are black. Strata are assigned to stock ("S" for southern and "N" for northern).

		Year of Survey																																								
Stratum	Stock	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
1010	S						6	7	7	8	7	16	7	6	8	7	8	7	7	8	7	7	7	7	7	7	7	7	7	7	7	7	7	7	8	7	7	7	7	7	7	6	7	7
1020	S						5	7	9	7	8	14	6	8	7	7	8	7	7	7	7	7	7	5	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6	7	7
1030	S						4	3	8	3	5	6	3	3	3	3	3	2	3	3	3	3	3	3	3	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1040	S						4	3	3	3	4	3	3	3	2	3	1	3	2	1	3	3	3	2	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1050	S						4	5	5	5	5	10	4	6	5	5	7	10	17	3	5	4	4	5	5	5	6	5	5	5	4	4	5	5	4	5	5	5	5	5	5	5	5	5
1060	S						6	8	9	11	9	16	8	9	9	8	10	8	28	8	8	8	9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1070	S						4	3	4	3	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2
1080	S						3	3	3	3	3	3	3	2	3	2	4	3	3	2	3	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1090	S						4	5	5	6	5	5	4	5	5	6	5	15	18	5	5	5	5	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
1100	S						6	8	10	9	8	8	8	7	10	9	8	8	20	8	8	8	7	7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1110	S						4	3	4	3	4	3	3	3	3	3	3	3	3	3	3	3	3	4	3	3	2	2	2	2	2	2	3	2	2	2	2	2	2	3	2	2	2	2
1120	S						3	3	3	3	4	3	3	3	3	3	2	3	2	3	3	3	2	2	3	3	1	1	1	1				1	1		1	1	1	1	1	1	1	1
1130	S						7	9	9	13	9	9	8	9	9	9	9	18	8	9	9	9	9	9	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
1140	S						4	4	4	4	4	4	3	4	4	5	5	4	4	4	4	4	4	5	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
1150	S						4	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	2	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1160	S						9	14	10	20	13	10	10	10	10	9	12	20	10	10	10	10	11	10	10	10	10	10	10	10	10	10	10	9	10	10	10	10	10	10	10	10	10	10
1170	S						4	4	4	7	4	4	3	4	3	4	4	4	5	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
1180	S						3	3	3	2	3	3	3	3	2	2	3	3	2		3	2	3	2	3	3	1	1		1	1	1	1	1	1	2	1	1	1	1	1	1	1	1
1190	S						8	8	8	14	9	9	9	9	9	8	9	18	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
1200	N						6	6	5	9	6	6	6	6	6	6	6	12	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	4	6	6
1210	N						4	4	4	9	4	4	5	4	4	4	4	8	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4
1220	N						4	4	4	6	5	4	2	4	4	4	5	8	4	4	4	4	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
1230	N						6	5	5	7	5	5	5	5	6	6	6	10	5	4	5	5	5	4	5	5	4	4	5	5	4	6	4	4	4	5	5	5	5	5	5	5	5	5
1240	N						6	6	6	10	7	6	6	6	6	7	9	12	6	6	6	6	6	5	6	6	6	6	6	6	6	6	6	6	4	6	9	6	6	6	6	6	6	6
1250	N						4	4	4	4	4	4	3	4	3	3	4	7	2	4	5	3	4	2	4	4	4	2	4	3	4	3	3	3	2	3	4	4	4	4	4	3	4	3
1260	N						3	5	5	5	5	5	5	15	14	14	5	9	5	6	7	5	4	5	5	3	5	5	5	4	5	5	5	5	5	5	8	5	5	5	5	5	5	5
1270	N						4	4	4	5	4	2	4	3	3	4	5	8	4	4	4	4	4	4	4	3	4	4	4	4	4	4	5	4	4	4	6	4	4	4	4	4	4	5
1280	N						7	7	7	7	7	7	6	7	8	9	8	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	6	7	7	7	11	7	7	7	7	7	7	7
1290	N						8	8	9	8	9	7	5	6	8	8	10	8	8	8	8	8	8	7	8	8	9	8	8	8	8	8	8	8	8	8	9	8	7	8	8	8	8	8
1300	N						3	3	3	3	3	4	2	3	3	3	4	3	3	2	3	3	3	3	3	3	3	2	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
1310	N						6	7	11	10	7	7	6	7	7	7	8	6	7	5	6	7	5	6	4	6																		
1320	N						5	5	5	7	5	4	4	5	5	5	5	5	5	4	3	3	5	3	5	5																		
1330	N						4	2	5	4	4	4	4		4	4	5	4	4	3	4	3	3	3	3	4	3		4	3		3	3	4	2	4	4		3	4	3	4	3	4
1340	N						5	5	6	7	6	5	5	6	4	6	8	6	6	5	5	6	6	6	6	5	6	6	6	6	3	6	6	6	4	6	6	6	6	6	6	6	6	6
1350	N						3	3	4	2	4	5	4		2	4	5	4	2	2	4	3	1	3	3																			
1351	S																									2	2	2	2	2		2	2	2	2	2	2		2	2	2	2	3	2
1360	S						8	8	8	9	9	8	8	7	9	9	10	8	8	7	8	8	7	6	8	8	8	8	8	8	8	8	8	8	8	8	11	8	8	8	8	8	8	8
1370	S						5	5	5	5	5	4	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	5	8	5	5	5	5	5	5	5
1380	S						6	5	5	6	6	5	5	5	7	7	10	9	5	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	7	5	5	5	5	5	4	5
1390	S						2	2	3	5	5	4	5		4	5	5	9	3	4	3	5	4	3	5	2	5	5	5	3	4	3	5	5	4	5	7	5	5	4	5	4	3	3
1400	S						2	3	3	4	2	2	2	2	3	3	4	6	2	3	3	3	3	3	2	3	3	3	2	3	3	3	3	3	3	3	5	2	3	3	5	3	3	2
1410	S						6	6	8	15	17	16	13		14		19																											
1420	S						4	4	4	6	6	6	6		6		6																											
1490	S									3	3	3	3		3		3																											
1610	S						3	3	3	4	4	3	1		5	5	4	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	3
1620	S						2	2	2	2	2	2	1		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	3	2
1630	S						2	2	2	2	2	2	1		2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	1	2	1	2
1640	S						2	2	2	2	2	2	1		2	1	2	1	2	3	2	1	2	2	2	2	1	1	1	1			1	1	2	1	1	1	1	1	2	1	1	1
1650	S						8	8	6	8	8	7	3	1	9	9	7	6	7	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	8	7	7	7	7	7	7	6	7	7
1660	S						4	3	4	3	3	3	3	3	3	3	4	4	3	3	3	3	3	4	4	3	3	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	3
1670	S						2	2	1	2	2	2	1	2	2	2	2	2	2	1	2	2	2	1	1	2	2	2	2	2	2	2	2	1	3	2	2	2	2	2	2	2	2	2
1680	S						2	2	2	2	2	2	1	2	2	2	2	1	2	2	2	2	2	2	2	2	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1690	S						7	7	7	6	7	6	5	4	9	10	7	6	6	6	6	6	6	7	6	6	6	6	6	6	6	6	6	6	7	6	6	6	6	6	6	5	6	6
1700	S						4	4	5	4	4	4	4	4	4	4	4	6	4	4	4	4	4	4	4	4	4	2	2	4	4	4	4	4	5	4	4	4	4	4	4	4	4	4
1710	S						3	2	3	2	2	2	2	2	3	2	2	2	2	3	2	2	2	2	2	2	3	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
1720	S						3	2	2	2	2	1	2	2	2	2	2	3	2	1	2	2	2	2	2	2		1	1	1	1	1	1	1	2		1	1	1	1	1	1	1	1
1730	S						6	5	6	6	6	9	5	6	7	8	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	5	5	5	5	5	5	4	5	5
1740	S						4	4	5	5	4	6	4	4	5	5	4	5	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4
1750	S						3	2	3	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2
1760	S						3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1
1990																																												1

Table A11. Number of successful random tows (SHG code <= 136) for inshore strata during spring NEFSC bottom trawl surveys during 1973-2005. Cells with zero tows are black. Strata are assigned to stock ("S" for southern and "N" for northern).

		Year of Survey																																										
Stratum	Stock	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05
3010	S	■	■	■	■	■	■	■	■	■	■	2	2	■	1	1	1	■	2	1	1	1	1	1	1	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3020	S	■	■	■	■	■	■	■	■	■	■	2	2	1	1	2	1	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3030	S	■	■	■	■	■	■	■	■	■	■	2	2	1	1	■	1	1	2	1	■	2	1	■	■	■	■	■	■	■	1	1	1	1	■	1	1	1	■	1	■	1	1	1
3040	S	■	■	■	■	■	■	■	■	■	■	2	2	■	2	2	2	2	4	2	3	2	1	3	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3050	S	■	■	■	■	■	■	■	■	■	■	2	2	■	2	3	2	2	4	2	2	1	3	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3060	S	■	■	■	■	■	■	■	■	■	■	2	■	1	1	■	1	■	■	1	■	1	■	■	1	■	■	■	■	1	1	■	1	1	1	1	1	1	1	1	1	1	■	1
3070	S	■	■	■	■	■	■	■	■	■	■	2	4	1	2	2	2	3	3	2	3	2	3	3	1	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	3	2	2	2
3080	S	■	■	■	■	■	■	■	■	■	■	2	2	3	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3090	S	■	■	■	■	■	■	■	■	■	■	3	2	■	1	■	1	1	1	1	1	1	1	1	1	1	■	■	■	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3100	S	■	■	■	■	■	■	■	■	■	■	3	3	3	2	2	3	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2
3110	S	■	■	■	■	■	■	■	■	■	■	3	9	4	2	2	3	2	1	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3120	S	■	■	■	■	■	■	■	■	■	■	5	1	1	1	1	1	1	1	1	1	■	■	■	■	■	■	■	■	1	■	1	1	1	■	1	1	1	1	1	1	1	1	1
3130	S	■	■	■	■	■	■	■	■	■	■	9	4	1	2	2	1	1	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3140	S	■	■	■	■	■	■	■	■	■	■	23	6	3	2	2	1	2	2	2	2	2	3	3	3	2	2	2	2	2	2	2	2	2	3	2	2	1	2	2	2	2	2	2
3150	S	■	■	■	■	■	■	■	■	■	■	3	2	1	1	■	■	1	1	1	1	1	1	■	■	■	■	■	■	■	1	1	1	1	■	■	1	1	■	1	1	■	1	1
3160	S	■	■	■	■	■	■	■	■	■	■	3	3	1	2	3	2	2	2	2	1	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2
3170	S	■	■	■	■	■	■	■	■	■	■	4	4	6	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3180	S	■	■	■	■	■	■	■	■	■	■	3	2	2	1	1	■	1	1	1	1	1	1	■	1	■	■	■	■	1	1	1	1	1	1	1	1	1	■	1	1	1	■	1
3190	S	■	■	■	■	■	■	■	■	■	■	4	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3200	S	■	■	■	■	■	■	■	■	■	■	6	3	4	3	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3210	S	■	■	■	■	■	■	■	■	■	■	3	■	■	1	1	■	1	■	1	1	1	1	1	1	■	■	■	■	1	1	1	1	1	1	1	1	■	1	■	1	1	1	1
3220	S	■	■	■	■	■	■	■	■	■	■	2	2	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3230	S	■	■	■	■	■	■	■	■	■	■	2	2	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3240	S	■	■	■	■	■	■	■	■	■	■	2	2	■	■	1	1	1	■	1	1	1	1	1	1	■	■	■	■	2	1	2	2	2	1	2	2	2	2	2	2	1	2	2
3250	S	■	■	■	■	■	■	■	■	■	■	3	3	■	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3260	S	■	■	■	■	■	■	■	■	■	■	2	2	■	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3270	S	■	■	■	■	■	■	■	■	■	■	3	2	■	1	1	1	1	1	■	1	1	1	■	1	■	■	■	■	1	1	■	1	1	■	1	1	■	1	1	1	1	1	1
3280	S	■	■	■	■	■	■	■	■	■	■	4	2	■	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	3	2	2	3	2	2	3	2	2	2	2	2	2
3290	S	■	■	■	■	■	■	■	■	■	■	4	2	■	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3300	S	■	■	■	■	■	■	■	■	■	■	3	2	■	1	1	■	1	■	1	1	1	1	■	1	■	■	■	■	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1
3310	S	■	■	■	■	■	■	■	■	■	■	6	2	■	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3320	S	■	■	■	■	■	■	■	■	■	■	3	2	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2
3330	S	■	■	■	■	■	■	■	■	■	■	3	2	■	1	1	■	1	1	1	1	1	1	■	1	■	■	■	■	1	1	1	1	1	2	1	1	1	1	■	1	1	1	1
3340	S	■	■	■	■	■	■	■	■	■	■	4	2	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	3	2	2	2	2
3350	S	■	■	■	■	■	■	■	■	■	■	2	2	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3360	S	■	■	■	■	■	■	■	■	■	■	2	2	■	1	1	1	1	1	1	1	1	■	■	1	■	■	■	■	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3370	S	■	■	■	■	■	■	■	■	■	■	5	2	■	2	2	3	2	2	2	2	2	2	4	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3380	S	■	■	■	■	■	■	■	■	■	■	4	2	■	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3390	S	■	■	■	■	■	■	■	■	■	■	3	2	■	1	1	■	1	1	1	1	1	1	■	1	■	■	■	■	1	1	1	■	1	1	1	1	1	1	1	1	1	1	1
3400	S	■	■	■	■	■	■	■	■	■	■	4	3	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	3	2	2	2	2	2	2	2	2	2
3410	S	■	■	■	■	■	■	■	■	■	■	7	4	■	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3420	S	■	■	■	■	■	■	■	■	■	■	2	2	■	1	1	1	1	1	1	1	1	1	■	1	■	■	■	■	1	1	1	■	1	1	1	1	1	1	1	1	1	1	1
3430	S	■	■	■	■	■	■	■	■	■	■	3	2	■	2	2	2	2	2	2	2	2	2	5	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3440	S	■	■	■	■	■	■	■	■	■	■	5	2	■	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2
3450	S	■	■	■	■	■	■	■	■	■	■	2	■	■	■	■	2	4	4	2	2	2	1	1	2	2	■	2	2	2	2	2	2	1	2	2	2	2	2	2	1	2	2	2
3460	S	■	■	■	■	■	■	■	■	■	■	■	7	■	2	■	2	3	4	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	1	2	2	2
3520	S	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	4	4	3	4	4	4	3	5	4	5	5	5	5	1	4	5	4	4	5	5	5	5	5	5	5	5	4
3550	S	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	1	1	■	■	1	■	1	■	1	1	1	1	■	■	■	■	1	■	1	1	■	1
3560	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	1	1	1	1	1	1	1	■	■	■	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1
3580	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	1	1	1	1	1	1	1	1	1	■	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1
3590	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	2	2	2	2	2	2	2	2	2	■	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2
3600	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	2	2	2	2	2	2	2	2	2	2	■	1	2	1	2	2	2	2	2	3	2	1	2	2	2	2	2
3610	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	■	1	1	■	■	■	■	■	■	1	1	1	1	■	1	1	■	1	1	■	1	1	1	1
3630	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	1	1	2	1	■	■	■	1	1	■	■	■	■	■	1	1	1	1	2	1	1	2	■	1	1	1
3640	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	1	1	1	1	2	1	1	1	■	■	1	■	1	1	1	1	1	1	1	■	1	1	■	1	1
3650	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	1	3	1	■	2	2	2	2	2	2	■	2	1	2	3	1	2	1	2	2	2	1	2	2	3	2	2
3660	N	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Table A12. Number of successful random tows (SHG code <= 136) for offshore strata covered by winter NEFSC bottom trawl surveys during 1992-2005. Cells with zero tows are black. Strata are assigned to stock ("S" for southern and "N" for northern). Inshore strata and the northern stock area are not sampled in the winter survey.

		Year of Survey													
STRATUM	Stock	92	93	94	95	96	97	98	99	00	01	02	03	04	05
1010	S	9	8	6	8	8	7	8	8	8	8	8	4	6	5
1020	S	7	7	5	7	8	7	7	7	8	8	8	4	7	5
1030	S	3	2	2	2	3	2	3	3	4	4	4	2	4	3
1040	S	■	■	■	1	■	1	■	1	1	2	2	2	1	1
1050	S	7	4	3	5	5	5	4	5	5	7	7	4	4	3
1060	S	9	9	5	9	10	9	9	8	10	12	11	5	11	7
1070	S	2	3	1	2	2	2	3	3	4	4	4	2	4	3
1080	S	■	■	■	1	■	1	1	1	■	2	2	1	2	1
1090	S	5	3	4	5	4	6	5	5	3	7	5	3	5	4
1100	S	6	8	8	8	10	8	8	9	7	12	12	6	10	7
1110	S	2	2	2	2	3	2	3	3	4	4	4	2	4	3
1120	S	■	■	■	■	■	1	1	1	■	2	2	2	1	1
1130	S	7	9	7	9	7	9	9	9	4	9	8	■	4	2
1140	S	1	3	2	3	4	3	4	4	2	4	4	■	4	■
1150	S	■	■	■	■	■	1	1	1	■	2	■	■	1	■
1160	S	5	■	1	9	2	5	10	8	■	6	■	■	■	■
1170	S	■	■	■	1	2	1	3	3	■	2	■	■	■	■
1180	S	■	■	■	■	■	■	■	■	■	1	■	■	■	■
1190	S	5	■	4	5	■	■	■	4	■	■	■	■	■	■
1610	S	4	5	3	4	4	4	4	4	5	6	7	7	7	6
1620	S	1	2	1	2	2	2	2	2	3	2	5	3	3	1
1630	S	1	■	2	1	2	2	3	3	3	2	3	3	4	2
1640	S	■	■	■	■	■	■	1	1	1	2	■	2	1	■
1650	S	7	9	5	8	9	8	9	9	10	12	12	10	10	8
1660	S	2	3	1	4	4	3	3	3	4	4	4	3	4	3
1670	S	2	1	2	2	3	3	3	3	4	4	4	4	4	3
1680	S	■	■	■	■	■	■	1	1	1	2	2	2	2	1
1690	S	8	10	5	8	9	8	8	8	9	9	9	6	6	7
1700	S	4	5	4	4	5	4	4	4	5	5	5	4	5	4
1710	S	2	2	1	2	3	2	3	3	4	4	4	4	4	3
1720	S	■	■	■	■	■	1	1	1	1	3	1	2	2	2
1730	S	5	6	3	5	6	5	5	5	3	5	5	3	4	4
1740	S	4	5	4	4	5	4	4	4	5	5	5	3	5	5
1750	S	2	2	1	2	3	2	3	3	4	5	5	4	4	3
1760	S	■	1	■	■	■	1	1	1	1	1	1	2	2	2

Table A13. Strata for silver hake survey data used for environmental and trend analyses. Offshore and inshore bottom trawl survey strata in the table were consistently sampled (at least one during each year) in the fall survey during 1979-2004, spring survey during 1979-2005 and winter survey during 1992-2005, by stock area for silver hake. The winter survey does not sample inshore strata or the northern stock area.

Survey	Stock	Offshore	Inshore	N offshore	N inshore	N total
Winter	Southern	1010-1030, 1050-1070, 1090-1110, 1610-1620, 1650-1670, 1690-1710, 1730-1750	NA	20	NA	20
Spring	Northern	1020-1300,1340	None	12	0	12
Spring	Southern	1010-1110, 1130-1170, 1190, 1360-1400	3020, 3040-3050, 3070-3080, 3100-3110, 3130-3140, 3160-3170, 3190-3200, 3220-3230, 3250-3260, 3280-3290, 3310-3320, 3340-3350, 3370-3380, 3400-3410, 3430-3440, 3460, 3520	17	31	48
Fall	Northern	1200-1300,1330-1340, 1360-1400	3610	18	1	19
Fall	Southern	1010-1190, 1610-1620, 1650-1670, 1690-1710, 0173-0176	3020, 3040-3050, 3070-3080, 3100-3110, 3130-3140, 3160-3170, 3190-3200, 3220-3230, 3250-3260, 3280-3290, 3310-3320, 3340-3350, 3370-3380, 3400-3410, 3430-3460, 3550	31	32	63

Table A14. Final generalized additive models (GAMs) for probability of occurrence of silver hake in winter, spring and fall surveys. Final models were selected by a step-wise procedure based on the AIC statistic. Variables included in final models were either loess, quadratic or linear terms. Blank cells indicate variables that were not statistically significant based on AIC. Temperatures, depths and time at highest probability of a positive tow (PPT) were identified subjectively by looking at fitted lines in logit-scale partial residual plots. Time at highest PPT is labeled "noon" for predicted curves that were concave down and "midnight" for curves that were concave up.

Survey	Stock	Lengths	Length Group Label in Plots	Bottom Temperature (*T*)	Depth (*D*)	Time of Day (*L*)	Temperature range highest PPT (°C)	Depth range highest PPT (m)	Time at highest PPT
Fall	Northern	1.0 - 5.9	2.5	loess	loess	quadratic	> 15	< 150	noon
		6.0 - 10.9	7.5	loess		quadratic	> 15		noon
		11.0 - 15.9	12.5	quadratic		loess	8		noon
		16.0 - 20.9	17.5	quadratic	loess		8	< 150	
		21.0 - 25.9	22.5	loess	loess		11	190	
		26+	27.5	loess	loess		< 15	> 200	
	Southern	1.0 - 5.9	2.5	loess	loess	loess	10 -17	< 150	midnight
		6.0 - 10.9	7.5	loess	loess	loess	> 15	< 150	midnight
		11.0 - 15.9	12.5	loess	loess	loess	> 15	not clear	not clear
		16.0 - 20.9	17.5	quadratic	loess	linear	10	< 150	not clear
		21.0 - 25.9	22.5	loess	loess	loess	< 15	< 150	not clear
		26+	27.5	quadratic	loess		14	> 90	not clear
	Both	1.0 - 5.9	2.5	loess	loess	loess	15	< 100	midnight
		6.0 - 10.9	7.5	loess	loess	loess	> 15	< 100	midnight
		11.0 - 15.9	12.5	loess	loess	quadratic	< 10	> 100	noon
		16.0 - 20.9	17.5	loess	quadratic		< 10	150	
		21.0 - 25.9	22.5	loess	loess	loess	< 10	200	not clear
		26+	27.5	loess	loess		< 15	> 100	not clear
Spring	Northern	1.0 - 5.9	2.5	NA	NA	NA	NA	NA	NA
		6.0 - 10.9	7.5		loess	loess		100 - 250	midnight
		11.0 - 15.9	12.5	loess	loess	loess	< 9	200	midnight
		16.0 - 20.9	17.5	quadratic	loess	quadratic	6	200	midnight
		21.0 - 25.9	22.5	loess	quadratic		< 10	250	
		26+	27.5	quadratic	quadratic		< 6	300	
	Southern	1.0 - 5.9	2.5		loess	loess		< 200	midnight
		6.0 - 10.9	7.5	quadratic	loess	loess	9	< 100	midnight
		11.0 - 15.9	12.5		loess	quadratic		< 100	midnight
		16.0 - 20.9	17.5	loess	loess	loess	6	< 250	midnight
		21.0 - 25.9	22.5	loess	loess		7	> 100	
		26+	27.5	quadratic	loess		not clear	not clear	
	Both	1.0 - 5.9	2.5	NA	NA	NA	NA	NA	NA
		6.0 - 10.9	7.5	quadratic	loess	loess	< 6	not clear	midnight
		11.0 - 15.9	12.5	loess	loess	loess	< 6	220	midnight
		16.0 - 20.9	17.5	loess	loess	quadratic	5	200	midnight
		21.0 - 25.9	22.5	quadratic	loess	loess	8	> 100	not clear
		26+	27.5	loess	loess	loess	> 8	>80	not clear
Winter	Southern	1.0 - 5.9	2.5	loess	loess	quadratic	> 8	< 150	midnight
		6.0 - 10.9	7.5	loess	quadratic		< 8	150	
		11.0 - 15.9	12.5	loess	loess		< 8	> 150	
		16.0 - 20.9	17.5	loess	loess		5	> 100	
		21.0 - 25.9	22.5	loess	loess		6	> 100	
		26+	27.5	loess	loess		7	> 75	

Table A15. Final generalized additive models (GAMs) for catches of silver hake in winter, spring and fall survey tows where at least one silver hake was taken. Final models were selected by a step-wise procedure based on the AIC statistic. Variables included in final models were either loess, quadratic or linear terms. Blank cells indicate variables that were not statistically significant based on AIC. Temperatures, depths and time at highest density were identified subjectively by looking at fitted lines in log-scale partial residual plots. Time at highest density is labeled "noon" for predicted curves that were concave down and "midnight" for curves that were concave up.

Survey	Stock	Lengths	Length Group Label in Plots	Bottom Temperature (*T*)	Depth (*D*)	Time of Day (*L*)	Temperature range highest PPT (°C)	Depth range highest PPT (m)	Time at highest PPT
Fall	Northern	1.0 - 5.9	2.5	loess	loess	loess	10 - 17	< 100	midnight
		6.0 - 10.9	7.5	loess	loess	loess	10 - 17	< 100	midnight?
		11.0 - 15.9	12.5	quadratic	quadratic		12	100 - 200	
		16.0 - 20.9	17.5	loess	loess		10	100	
		21.0 - 25.9	22.5	loess	loess	loess	8	125 - 225	midnight
		26+	27.5	loess	loess	loess	8	200	midnight
	Southern	1.0 - 5.9	2.5	loess	loess	loess	10 - 16	< 100	midnight
		6.0 - 10.9	7.5	loess	loess	loess	10 - 18	< 100	midnight
		11.0 - 15.9	12.5	quadratic	quadratic		12	100 - 200	
		16.0 - 20.9	17.5	loess	loess		8 - 10	100 - 150	
		21.0 - 25.9	22.5	loess	loess	loess	9	150 - 250	midnight
		26+	27.5	loess	loess	loess	< 10	200	midnight
	Both	1.0 - 5.9	2.5	loess	loess	loess	8 - 17	< 100	midnight
		6.0 - 10.9	7.5	loess	loess	loess	10 - 17	< 100	midnight?
		11.0 - 15.9	12.5	quadratic	quadratic		12	125	
		16.0 - 20.9	17.5	loess	loess		7 - 10	100	
		21.0 - 25.9	22.5	loess	loess	loess	9	150 - 220	midnight
		26+	27.5	loess	loess	loess	< 10	> 200	midnight
Spring	Northern	1.0 - 5.9	2.5	NA	NA	NA	NA	NA	NA
		6.0 - 10.9	7.5	loess	loess	loess	< 8	< 100	midnight
		11.0 - 15.9	12.5	loess	loess	quadratic	< 8	200 - 250	midnight
		16.0 - 20.9	17.5	loess	loess	quadratic	8	> 150	midnight
		21.0 - 25.9	22.5	loess	loess		< 12	> 150	
		26+	27.5	loess	loess	quadratic	12	> 250	midnight
	Southern	1.0 - 5.9	2.5	NA	NA	NA	NA	NA	NA
		6.0 - 10.9	7.5	loess	loess	loess	< 10	< 100	midnight
		11.0 - 15.9	12.5	loess	loess	quadratic	< 10	200 - 250	midnight
		16.0 - 20.9	17.5	loess	loess	quadratic	6 - 8	> 150	midnight
		21.0 - 25.9	22.5	loess	loess		< 12	> 150	
		26+	27.5	loess	loess	quadratic	> 9	> 250	midnight
	Both	1.0 - 5.9	2.5	NA	NA	NA	NA	NA	NA
		6.0 - 10.9	7.5	loess	loess	loess	< 10	< 100	midnight
		11.0 - 15.9	12.5	loess	loess	quadratic	< 10	200 - 250	midnight
		16.0 - 20.9	17.5	loess	loess	quadratic	6 - 9	> 150	midnight
		21.0 - 25.9	22.5	loess	loess		< 12	> 150	
		26+	27.5	loess	loess	quadratic	> 9	> 250	midnight
Winter	Southern	1.0 - 5.9	2.5		linear	quadratic		< 100	midnight
		6.0 - 10.9	7.5	loess	loess	quadratic	< 6	< 100	midnight
		11.0 - 15.9	12.5	loess	loess	loess	< 6	70	not clear
		16.0 - 20.9	17.5	linear	quadratic		< 6	150 - 200	
		21.0 - 25.9	22.5	loess	loess		6- 8	> 150	
		26+	27.5	loess	loess		8	> 150	

Table A16. Direction and statistical significance of estimated trends (linear regression models) in abundance weighted mean bottom temperatures, depths, latitudes and longitudes for silver hake taken during fall (1979-2004), spring (1978-2005) and winter (1992-2005) bottom trawl surveys. Symbols are "+" for increasing trends and "-" for decreasing trends. Variables with statistically significant regressions on time are identified by single ("*" for 0.1≥ p-values > 0.05) or double ("**" for 0.05 ≥ p-value) asterisks.

Lengths	Length Group Label in Plots	Fall			Spring			Winter
		North	South	Both	North	South	Both	South
				Mean Bottom Temperature				
1.0 - 5.9	2.5				NA		NA	
6.0 - 10.9	7.5							
11.0 - 15.9	12.5			- * *				
16.0 - 20.9	17.5							
21.0 - 25.9	22.5							
26+	27.5			- *				
				Mean Depth				
1.0 - 5.9	2.5							
6.0 - 10.9	7.5	+ *		+ * *				
11.0 - 15.9	12.5			+ *		+ *		
16.0 - 20.9	17.5	+ *						
21.0 - 25.9	22.5	+ *		+ *		+ * *		+ *
26+	27.5			+ * *			+ * *	+ *
				Mean Latitude				
1.0 - 5.9	2.5		+ *	+ *			NA	+ * *
6.0 - 10.9	7.5	+ *		+ * *				
11.0 - 15.9	12.5	+ *		+ * *		+ * *		
16.0 - 20.9	17.5				+ * *	+ *	+ *	
21.0 - 25.9	22.5		+ * *					
26+	27.5		+ * *	+ * *		+ * *	+ * *	
				Mean Longitude				
1.0 - 5.9	2.5				NA		NA	- * *
6.0 - 10.9	7.5			- *				
11.0 - 15.9	12.5				+ * *			
16.0 - 20.9	17.5				+ *			
21.0 - 25.9	22.5		- * *	- *				
26+	27.5		- * *	- *		- * *	- * *	

Table A17. Number of relatively old individual fish in provisional survey age data for silver hake, by season and year. Duplicate records were removed manually.

Count of AGE		AGE							
Season	year	8	9	10	11	12	13	14	Grand Total
Fall	1973			3	2		1		6
	1975	2	1	1					4
	1976	1		1					2
	1977	3	2	1					6
	1978	14		1					15
	1979	6	4			1			11
	1980	21	3	2	1				27
	1981	23	2	1					26
	1982	6	3						9
	1983	1	2						3
	1984		1						1
	1985	1							1
	1989					1			1
Fall Total		78	18	10	3	2	1		112
Spring	1973	1	2	1		1		1	6
	1974	1	5		1			1	8
	1975		1						1
	1976	11	2	1					14
	1977	10	3	1					14
	1978	12		3	1			1	17
	1979	4	1						5
	1980	22	7	4		1			34
	1981	33	21		1				55
	1982	6	7	5		2			20
	1983	1	2	4					7
	1985	1	1						2
	1986	2							2
	1987	1	2						3
Spring Total		105	54	19	3	4		3	188
Grand Total		183	72	29	6	6	1	3	300

Table A18. Age reader precision experiment using 99 silver hake ototliths collected during the NEFSC spring 2004 bottom trawl survey. The sample of otoliths were aged a second time by the original technician without knowledge of the original ages.

Production Age	N	N agreed	% Agreement	Mean Age	SD
0					
1	9	9	100%	1.00	0.00
2	41	38	93%	2.07	0.26
3	23	21	91%	3.09	0.29
4	23	20	87%	3.96	0.37
5	3	3	100%	5.00	0.00
Total	99	91	92%		

Second age->

First age	0	1	2	3	4	5
0						
1		9				
2			38	3		
3				21	2	
4				2	20	1
5						3
					Total	99

Table A19. Age reader precision experiment using 99 silver hake ototliths collected during the NEFSC spring 2004 bottom trawl survey. The sample of otoliths were aged a second technician without knowledge of the ages estimated by the original technician.

Secondary reader reages a sample from 200402 cruise.

Production Age	N	N agreed	% Agreement	Mean Age	SD
0					
1	9	8	89%	1.11	0.33
2	41	39	95%	2.00	0.22
3	23	21	91%	2.95	0.21
4	23	7	30%	3.38	0.58
5	3	1	33%	5.67	0.58
Total	99	76	77%		

Second age ->

First age	0	1	2	3	4	5	6
0							
1		8	1				
2		1	39	1			
3			1	21			
4				16	7	1	
						1	2
5							
						Total	99

Table A20. Otoliths from a sample of 15 fish taken in NEFSC surveys during 1973-1982 and originally estimated to be at least age 7 y by several technicians were reaged by the current technician. New ages were all from sectioned otoliths. In some cases, original ages were from "baked" otoliths. All of the original age estimates were made prior to 1983.

ID	Cruise	Station	Length	Preparation for original age	Original age	Preparation for new age	New age
1	73-3	112	46	Section	7	Section	6
2	73-3	112	59	Section	7	Section	6
3	73-3	197	54	Section	10	Section	9
4	73-8	179	51	Section	10	Section	9
5	73-8	196	50	Section	10	Section	10
6	74-4	64	53	Section	9	Section	7
7	74-4	98	59	Section	9	Section	7
8	74-4	223	60	Section	9	Section	7
9	74-4	226	61	Section	14	Section	12
10	75-12	275	50	Baked	8	Section	5
11	75-12	321	63	Baked	6	Section	5
12	75-12	321	61	Baked	8	Section	6
13	79-12	616	68	Section	12	Section	11
14	82-02	348	64	Section	12	Section	11
15	82-02	420	66	Section	12	Section	9

Count of Cruise	New age									
Original age	5	6	7	9	10	11	12	13	14	Grand Total
5										
6	1									1
7		2								2
8	1	1								2
9			3							3
10				2	1					3
12				1		2				3
13										0
14							1			1
Grand Total	2	3	3	3	1	2	1	0	0	15

Table A21. Number of tows, mean catch per tow and mean densities of silver hake by stratum and transect canyon area for the NEFSC spring and Supplemental surveys during March, 2004-2005.

				NEFSC Survey (averages for all tows)						Supplemental Survey (averages for all tows)						
Year	Season	Canyon Area	NEFSC Stratum	N Random Stations	Bottom Temp. (^{o}C)	Depth (m)	Catch (kg)	Swept Area (km^2)	Density (kg/km^2)	N Fixed Stations	Bottom Temp. (^{o}C)	Depth (m)	Catch (kg)	Swept Area (km^2)	Density (kg/km^2)	Ratio NEFSC / Supplemental Density
2004	Spring	Hudson	1020	7	3.5	69	0.274	0.041	6.7	3	5.5	89	202.4	0.269	739.7	0.0090
2005	Spring	Hudson	1020	7	8.0	79	0.764	0.041	18.6	2	8.7	81	109.1	0.145	770.3	0.0242
2004	Spring	Hudson	1030	2	7.7	16	2.268	0.041	55.3	1	10.7	144	691.6	0.293	2358.1	0.0235
2005	Spring	Hudson	1030	2	10.6	81	0.286	0.041	7.0	2	11.5	127	141.0	0.130	1074.2	0.0065
2004	Spring	Hudson	1040	1	11.3	216	0.553	0.041	13.5	3	10.6	224	394.2	0.294	1366.5	0.0099
2005	Spring	Hudson	1040	1	6.5	289	26.142	0.041	637.8	3	10.6	227	1283.2	0.130	10078.4	0.0633
2004	Spring	Baltimore	1700	4	6.7	73	0.057	0.041	1.4	3	2.3	91	18.5	0.246	77.1	0.0181
2005	Spring	Baltimore	1700	4	7.8	67	0.112	0.041	2.7	2	9.9	82	35.0	0.144	238.2	0.0114
2004	Spring	Baltimore	1710	4	6.7	73	0.057	0.041	1.4	2	5.7	162	36.6	0.270	132.0	0.0106
2005	Spring	Baltimore	1710	4	7.8	67	0.112	0.041	2.7	3	10.9	149	143.7	0.149	950.7	0.0029
2004	Spring	Baltimore	1720	1	5.8	375	0.000	0.041	0.0	2	10.1	244	257.1	0.265	968.1	0.0000
2005	Spring	Baltimore	1720	1	6.8	355	1.042	0.041	25.4	2	8.3	256	2000.1	0.142	13932.3	0.0018
													Average Hudson Canyon			0.0227
													Median Hudson Canyon			0.0167
				38						28			Average Baltimore Canyon			0.0075
													Median Baltimore Canyon			0.0067
													Average 2004			0.0118
													Median 2004			0.0102
													Average 2005			0.0184
													Median 2005			0.0090

Table A22. NEFSC fall survey biomass index (delta mean kg/tow, all size groups), landings data, and exploitation index (landings / survey biomass index) for silver hake in the nothern stock area. Survey data are for traditional NEFSC survey strata that have been consistently occupied since 1964. Three year averages show trends and are used in overfishing definitions.

Year	Fall Survey (delta mean kg/tow, all sizes)	CV	3-Year Average	Landings (L_t, 1000 mt)	Landings / Survey (all sizes)	3-Year Average
1964	4.42	0.20		94.46	21.40	
1965	6.48	0.28		45.24	6.99	
1966	4.12	0.19	5.00	47.72	11.57	13.32
1967	2.16	0.27	4.25	33.37	15.46	11.34
1968	2.05	0.27	2.78	41.38	20.20	15.75
1969	2.64	0.22	2.28	23.96	9.09	14.92
1970	3.03	0.26	2.57	27.53	9.07	12.79
1971	2.47	0.20	2.71	36.40	14.76	10.98
1972	6.09	0.16	3.86	25.22	4.15	9.33
1973	4.15	0.14	4.23	32.08	7.73	8.88
1974	3.76	0.28	4.67	20.68	5.49	5.79
1975	8.23	0.14	5.38	39.87	4.84	6.02
1976	12.63	0.22	8.21	13.63	1.08	3.81
1977	7.59	0.33	9.49	12.46	1.64	2.52
1978	7.07	0.14	9.10	12.61	1.78	1.50
1979	6.65	0.15	7.11	3.42	0.51	1.31
1980	6.66	0.18	6.79	4.73	0.71	1.00
1981	4.06	0.25	5.79	4.42	1.09	0.77
1982	5.45	0.56	5.39	4.66	0.85	0.88
1983	9.21	0.21	6.24	5.31	0.58	0.84
1984	3.62	0.22	6.09	8.29	2.29	1.24
1985	8.58	0.16	7.14	8.30	0.97	1.28
1986	14.19	0.16	8.80	8.50	0.60	1.28
1987	9.84	0.14	10.87	5.66	0.58	0.71
1988	6.31	0.20	10.11	6.77	1.07	0.75
1989	12.55	0.26	9.57	4.65	0.37	0.67
1990	15.25	0.25	11.37	6.38	0.42	0.62
1991	11.89	0.29	13.23	6.05	0.51	0.43
1992	14.25	0.38	13.79	5.30	0.37	0.43
1993	8.12	0.19	11.42	4.36	0.54	0.47
1994	6.93	0.14	9.76	5.72	0.83	0.58
1995	13.16	0.15	9.40	3.03	0.23	0.53
1996	7.89	0.16	9.32	3.20	0.41	0.49
1997	5.64	0.20	8.90	2.59	0.46	0.37
1998	21.97	0.31	11.83	2.26	0.10	0.32
1999	11.64	0.10	13.08	4.04	0.35	0.30
2000	13.79	0.13	15.80	2.42	0.18	0.21
2001	9.53	0.20	11.65	3.45	0.36	0.29
2002	8.00	0.11	10.44	2.84	0.35	0.30
2003	8.77	0.18	8.77	1.73	0.20	0.30
2004	3.40	0.22	6.72	0.56	0.16	0.24

Table A23. NEFSC fall survey biomass index (delta mean kg/tow, all size groups), landings data, and exploitation index (landings / survey biomass index) for silver hake in the southern stock area. Survey data are for traditional NEFSC survey strata that have been consistently occupied since 1964. Three year averages show trends and are used in overfishing definitions.

Year	Fall Survey (delta mean kg/tow, all sizes)	CV	3-Year Average	Landings (L_t, 1000 mt)	Landings / Survey (all sizes)	3-Year Average
1967	2.19	0.14	2.19	91.25	41.74	41.74
1968	2.69	0.13	2.44	58.50	21.72	31.73
1969	1.26	0.14	2.05	75.56	60.16	41.21
1970	1.33	0.13	1.76	27.51	20.65	34.18
1971	2.21	0.16	1.60	71.89	32.53	37.78
1972	2.00	0.22	1.85	94.35	47.18	33.45
1973	1.70	0.18	1.97	104.59	61.56	47.09
1974	0.86	0.21	1.52	109.86	127.45	78.73
1975	1.84	0.16	1.47	74.25	40.35	76.46
1976	2.06	0.14	1.59	68.74	33.34	67.05
1977	1.77	0.24	1.89	59.31	33.45	35.71
1978	2.93	0.24	2.26	27.13	9.26	25.35
1979	1.74	0.12	2.15	18.38	10.55	17.75
1980	2.12	0.35	2.26	13.55	6.38	8.73
1981	1.17	0.14	1.68	14.83	12.72	9.88
1982	1.65	0.20	1.65	14.56	8.82	9.31
1983	3.20	0.35	2.01	12.14	3.79	8.44
1984	1.56	0.30	2.14	13.14	8.44	7.02
1985	3.91	0.49	2.89	13.16	3.37	5.20
1986	1.39	0.17	2.28	10.12	7.29	6.37
1987	1.62	0.24	2.30	10.12	6.25	5.64
1988	1.83	0.23	1.61	9.20	5.02	6.19
1989	2.12	0.26	1.86	13.17	6.21	5.83
1990	1.65	0.17	1.87	13.62	8.28	6.50
1991	0.91	0.22	1.56	10.09	11.13	8.54
1992	0.98	0.14	1.18	10.29	10.52	9.97
1993	1.33	0.19	1.07	12.91	9.72	10.45
1994	0.80	0.16	1.04	10.33	12.93	11.06
1995	1.64	0.34	1.26	11.69	7.13	9.92
1996	0.43	0.16	0.96	13.00	30.16	16.74
1997	0.84	0.19	0.97	12.99	15.43	17.57
1998	0.62	0.18	0.63	12.70	20.49	22.03
1999	0.87	0.40	0.78	9.97	11.46	15.79
2000	0.72	0.22	0.74	9.76	13.50	15.15
2001	2.23	0.28	1.27	8.69	3.90	9.62
2002	1.18	0.22	1.38	5.15	4.35	7.25
2003	1.56	0.22	1.66	6.92	4.44	4.23
2004	1.37	0.21	1.37	7.89	5.76	4.85

Table A24. Lower bound estimates for silver hake (southern stock) fishable biomass and upper bound estimates for fishing mortality based on relative efficiency of NEFSC and Supplemental survey bottom trawls and NEFSC fall survey data.

(EDITOR'S NOTE: THIS PART OF THE WORKING GROUP REPORT HAS BEEN OMITTED. IT WAS NOT ACCEPTED BY THE REVIEW PANEL.)

Table A25. Lower bounds for fishable biomass and upper bounds for fishing mortality in the northern silver hake during 1964-2004 based on historical landings and fall survey data.

(EDITOR'S NOTE: THIS PART OF THE WORKING GROUP REPORT HAS BEEN OMITTED. IT WAS NOT ACCEPTED BY THE REVIEW PANEL.)

Table A26. Lower bounds for fishable biomass and upper bounds for fishing mortality in the southern silver hake during 1964-2004 based on historical landings and fall survey data.

(EDITOR'S NOTE: THIS TABLE FROM THE WORKING GROUP REPORT HAS BEEN OMITTED. IT WAS NOT ACCEPTED BY THE REVIEW PANEL.)

Table A27. Total allowable landings (TAL, thousand mt) for silver hake during 2005 based on exploitation index (landings / fall survey biomass index) reference points and average fall survey biomass index during 2002-2004. For comparison, landings averaged 1.71 thousand mt in the north and 6.65 thousand mt in the south during 2002-2004. The CV is for the 2002-2004 mean biomass index and measures uncertainty in the TAL calculation assuming that the reference points are exact.

Stock Area	Exploitation Index Reference Points		2002-2004 Mean Biomass Index	TAL (1000 mt)	CV
	Type	Value			
Northern	Both	2.57	6.72	17.27	0.10
Southern	Target	20.63	1.37	28.26	0.13
Southern	Threshold	34.39		47.11	0.13

SILVER HAKE FIGURES

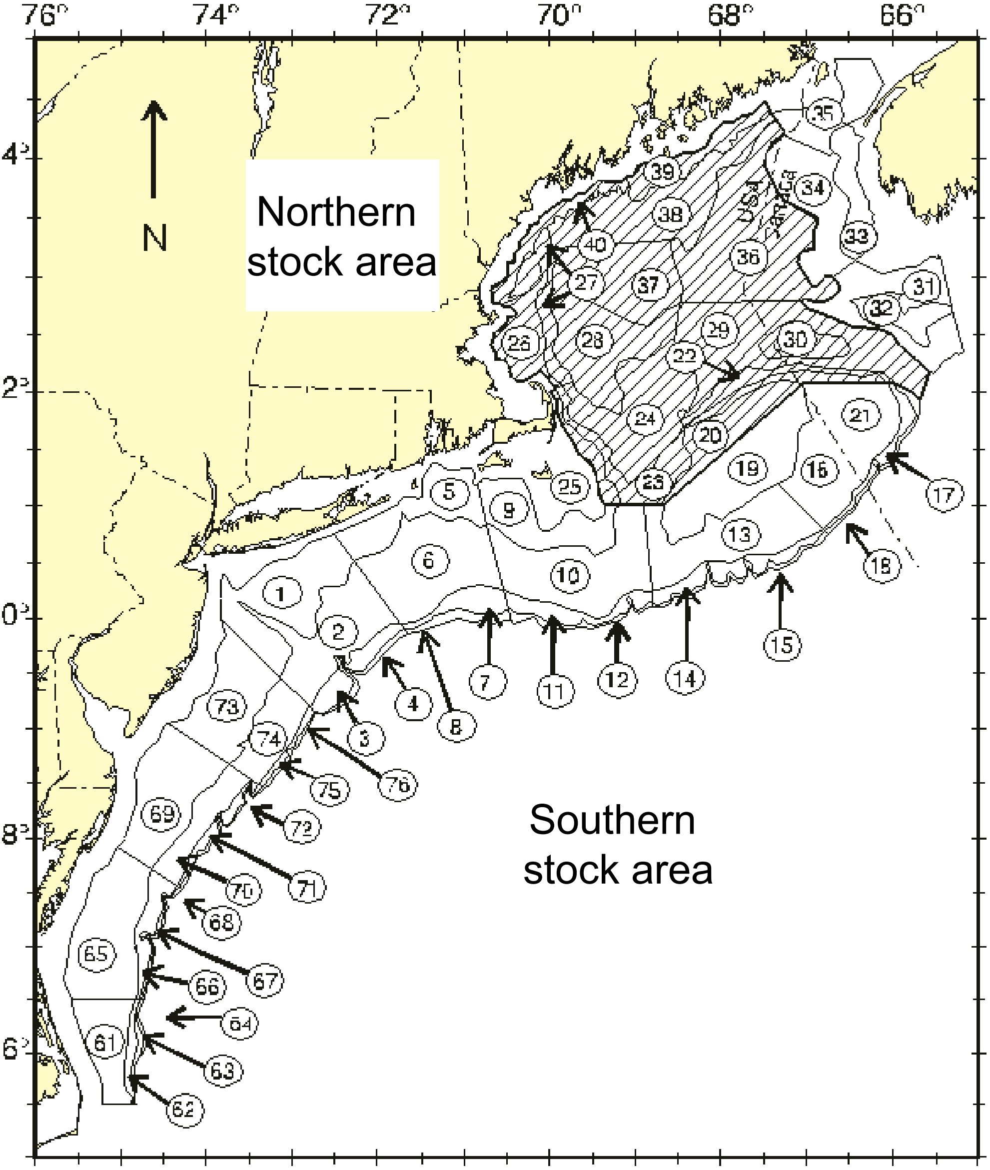


Figure A1. Silver hake stock areas in US waters with NEFSC offshore survey strata. The straum labeled “73” is, for example, stratum 01730. Numerous inshore survey strata, where silver hake also occur, are not shown. The northern stock area is shown by diagonal lines.

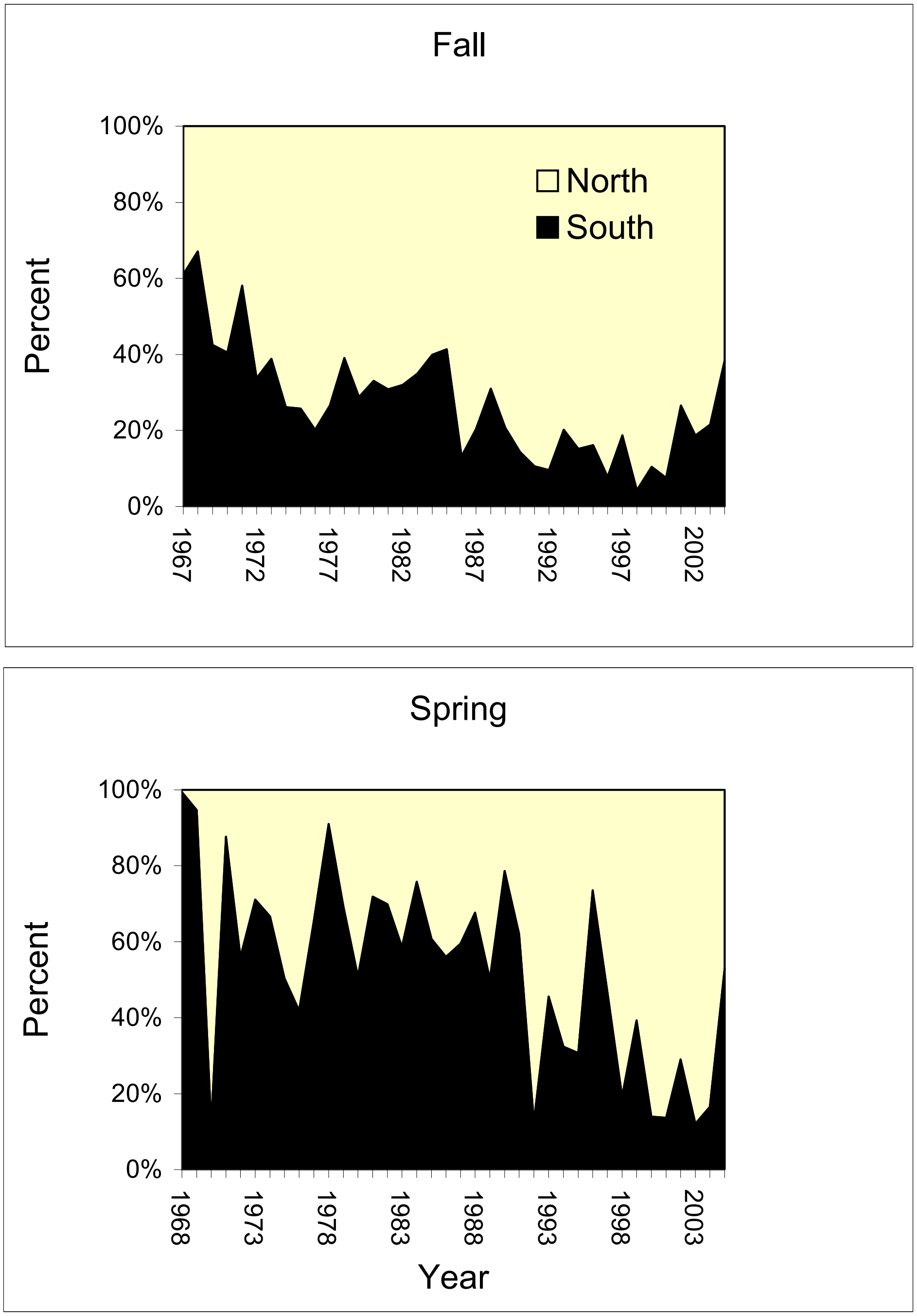


Figure A2. Percent of minimum swept area biomass in the northern and southern stock areas based on NEFSC fall surveys during 1967-2004 and NEFSC spring surveys during 1968-2005. Traditional (consistently occupied offshore strata) were used for survey data.

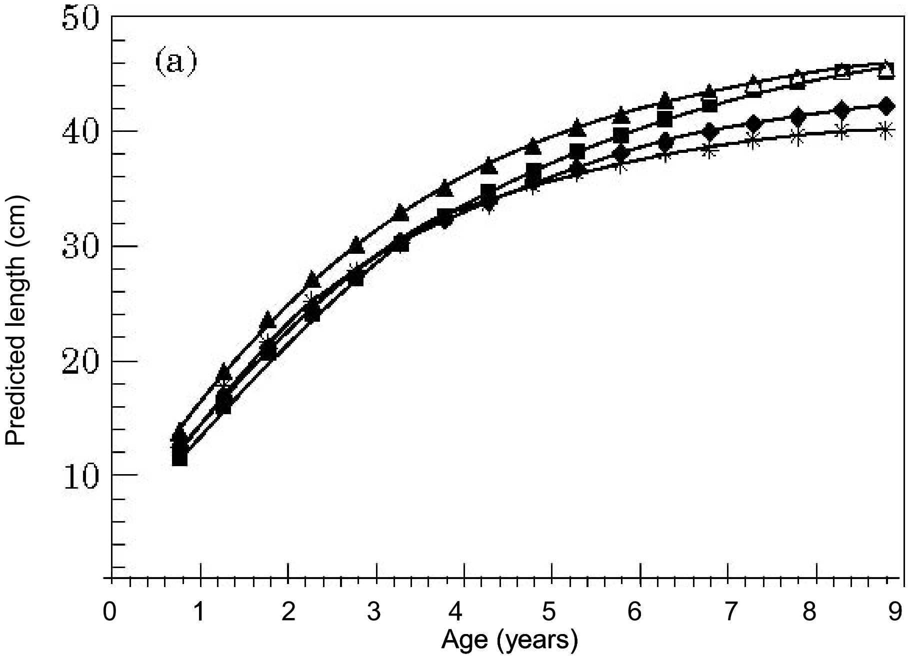


Figure A3. "Typical" growth curves for silver hake from NEFSC fall surveys along the northeast coast between the Gulf of Maine and Mid-Atlantic during 1975-1980 (from Helser 1996).

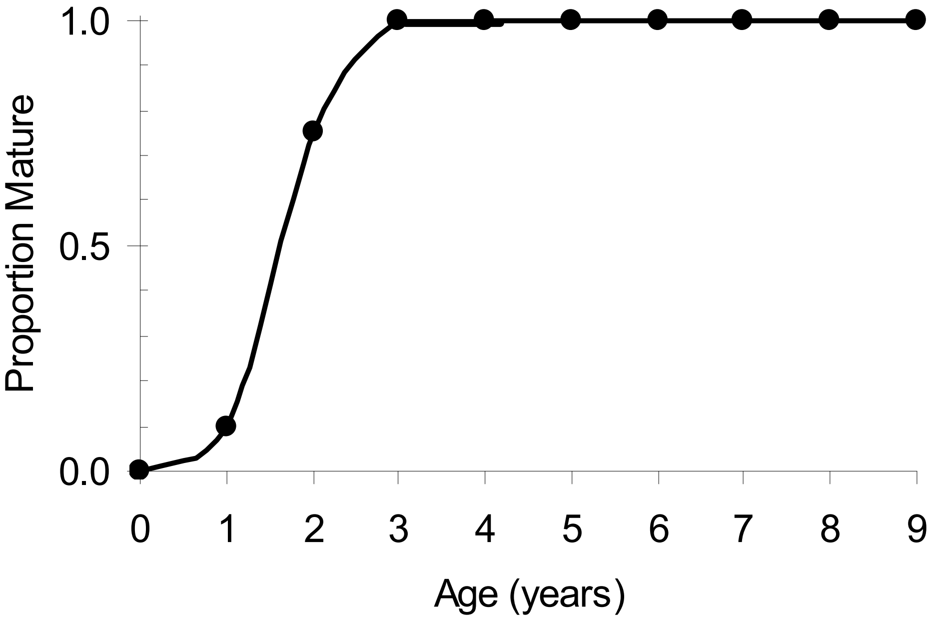


Figure A4. Maturity at age for silver hake from Brodziak et al. (2001).

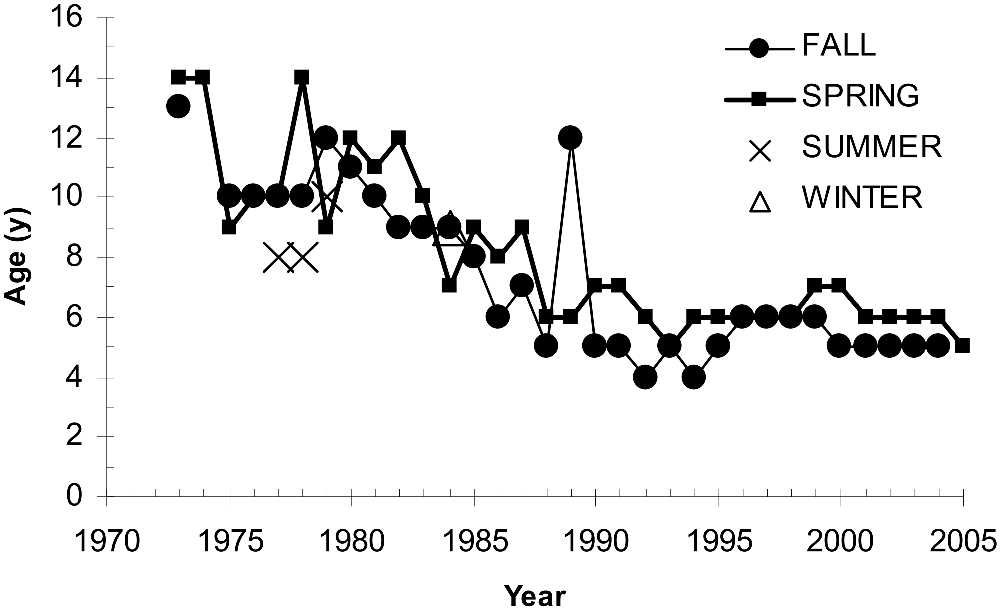


Figure A5. Maximum observed ages by year in NEFSC fall, spring, summer, and winter bottom trawl surveys. Silver hake in summer and winter surveys are not routinely aged. Silver hake age data are currently being audited and are preliminary.

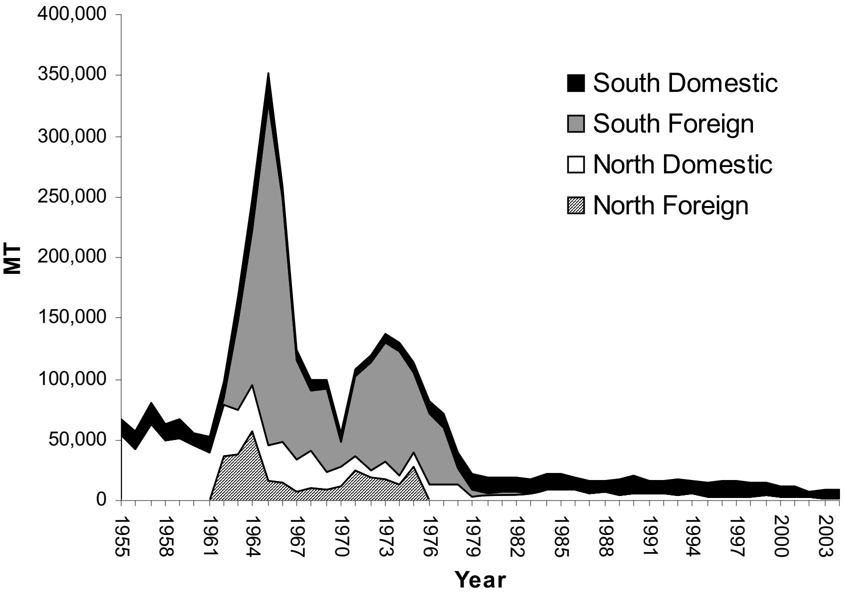


Figure A6. Silver hake landings (mt) by stock area during 1955-2004 for foreign and domestic fishing fleets.

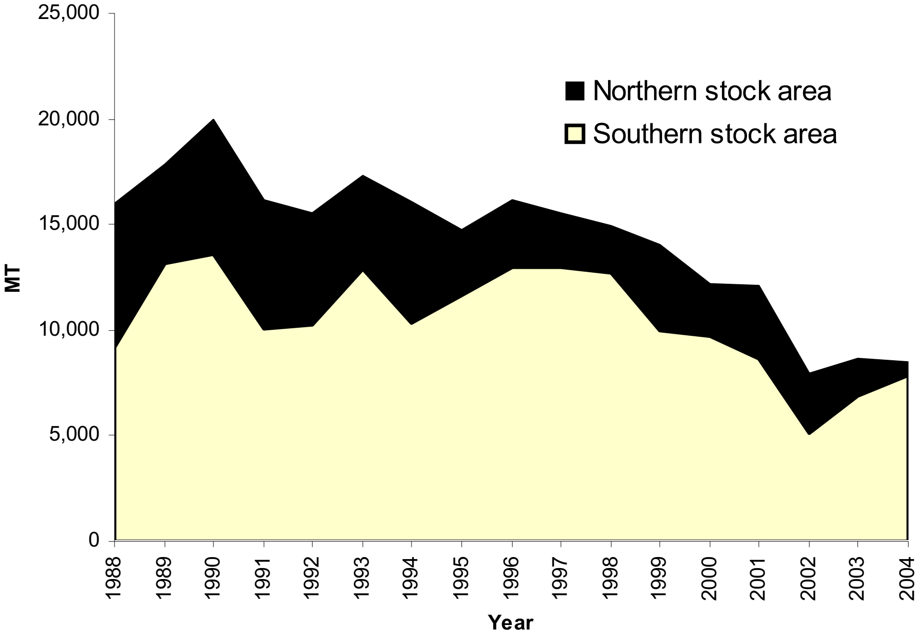


Figure A7. Silver hake landings (mt) in the US domestic fishery by stock area during 1988-2004.

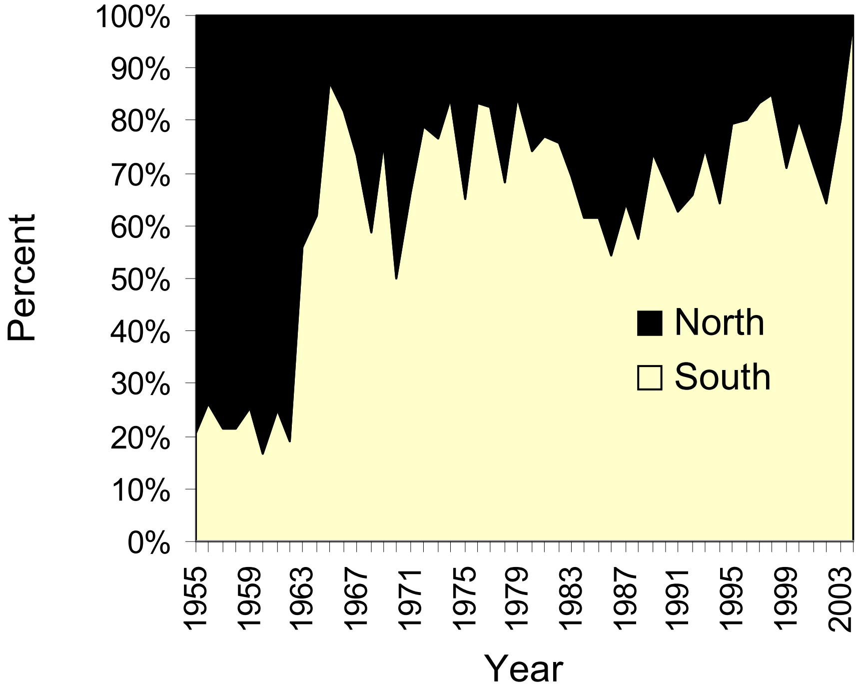


Figure A8. Percent of total silver hake landings (domestic + foreign) from the northern and southern stock areas during 1955-2004.

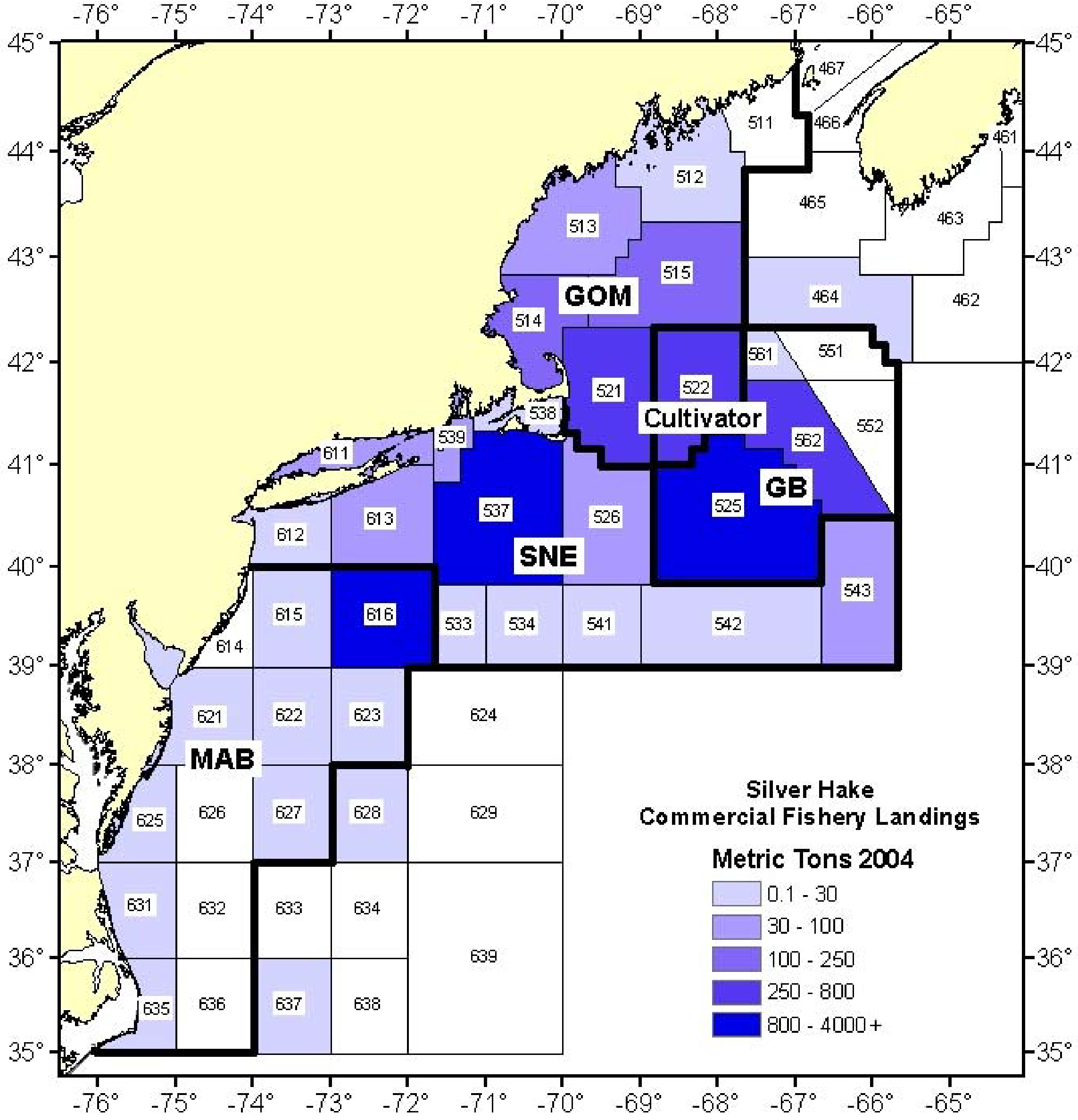


Figure A9. Landings by statistical area (identified by 3-digit numbers) and region during 2004, which was a typical year. Regions are the Gulf of Maine (GOM), Cultivator Shoals, Georges Bank (GB), Southern New England (SNE), and the Mid-Atlantic Bight (MAB).

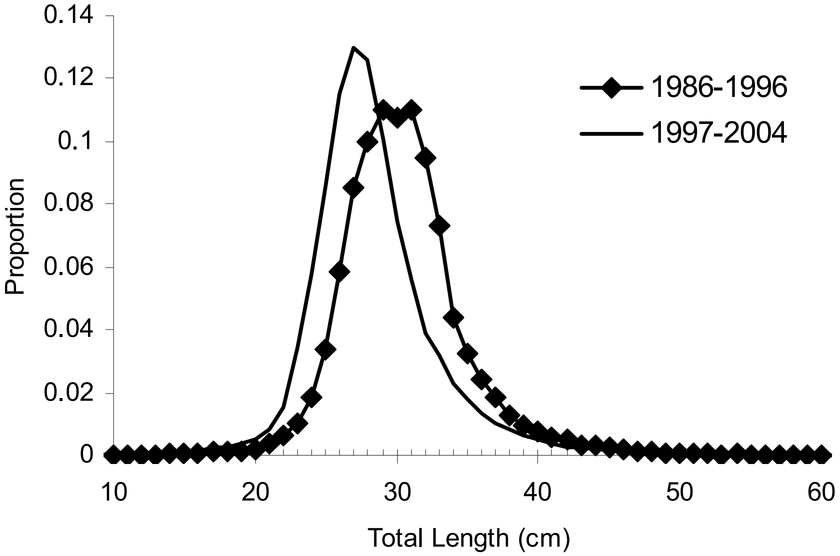


Figure A10. Commercial length composition data for silver hake during 1986-1996 and 1997-2004.

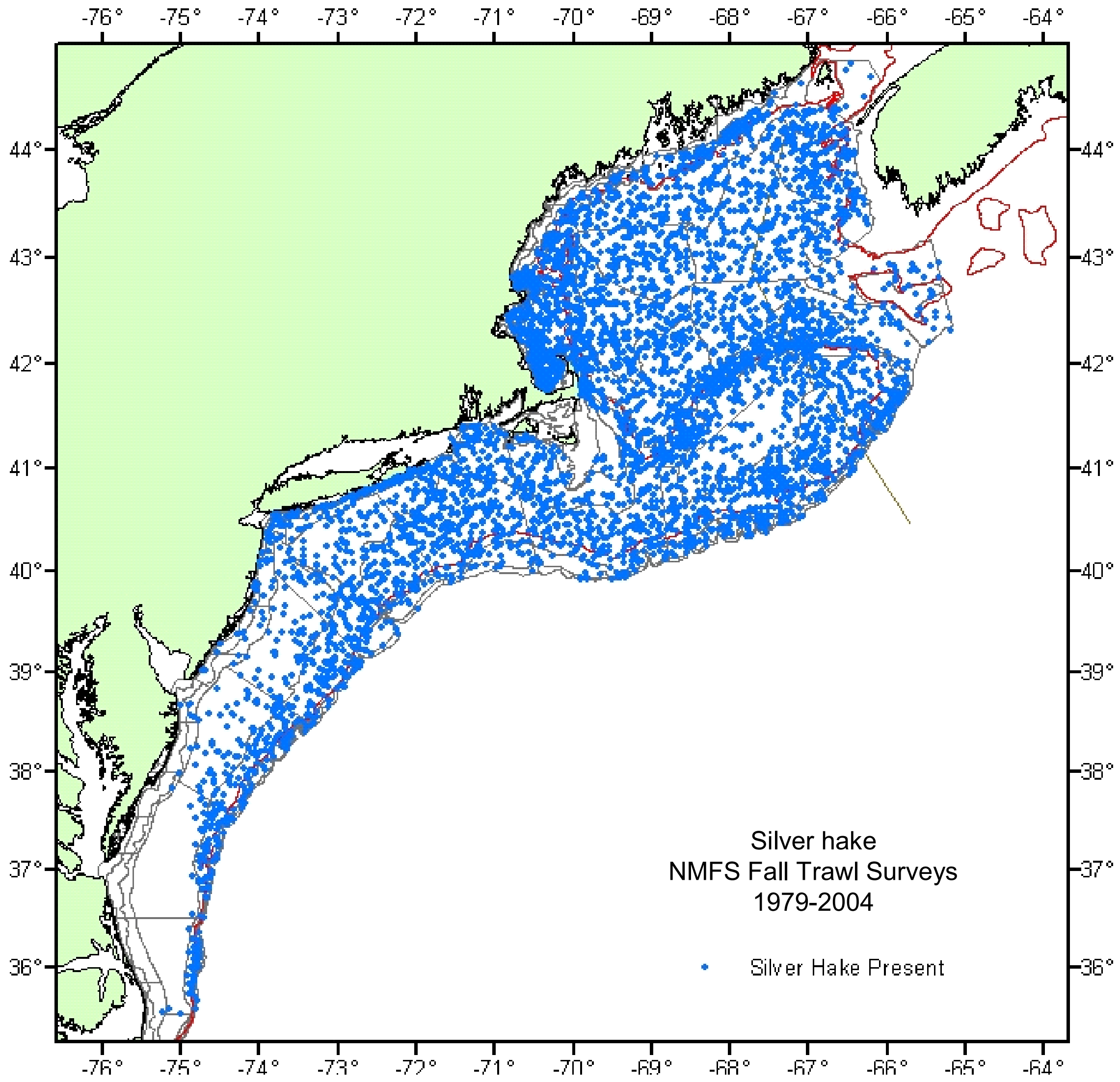


Figure A11. Locations of NEFSC fall bottom trawl survey tows that caught at least one silver hake during 1979-2004, based on all inshore and offshore strata that were sampled.

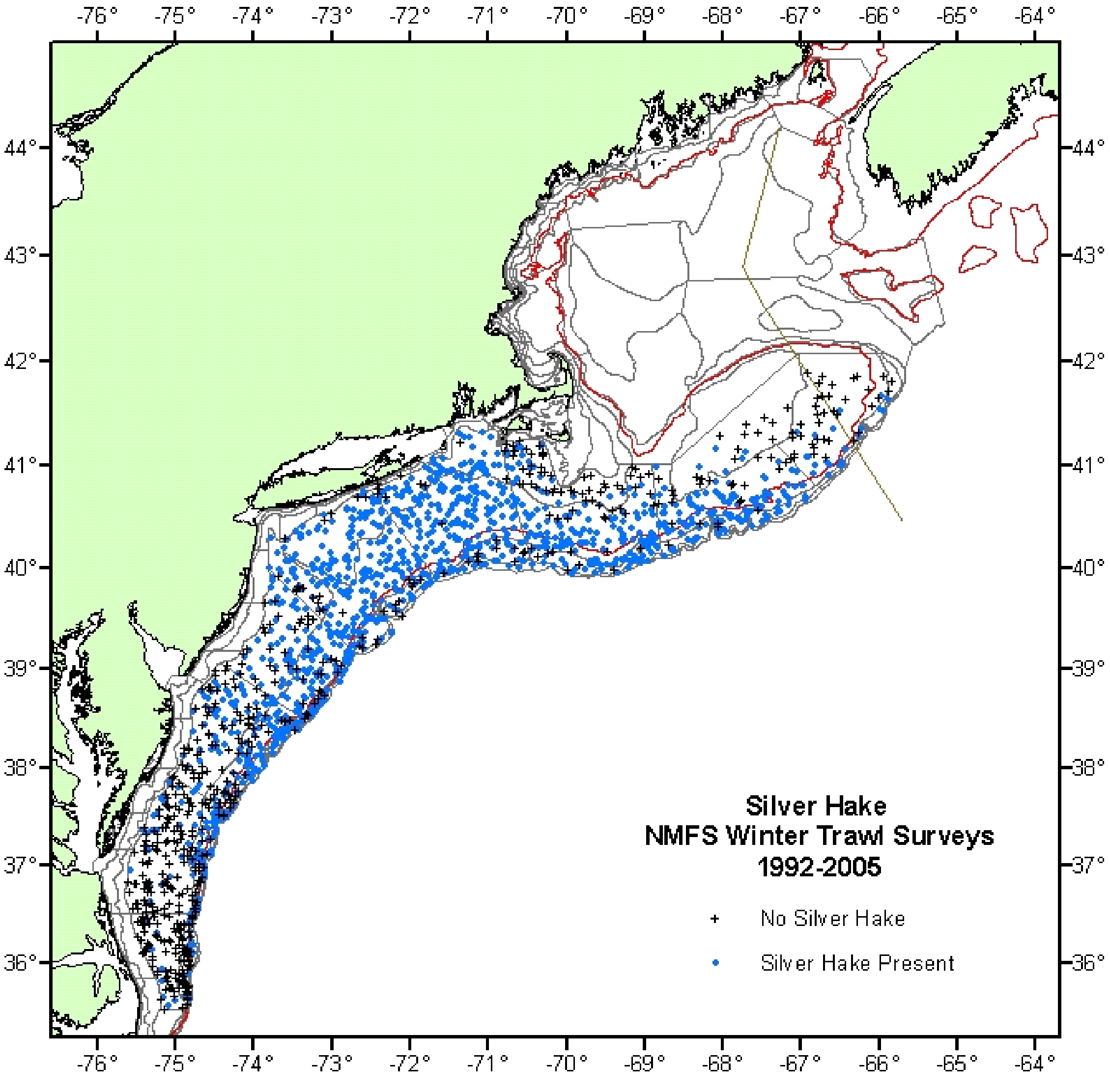


Figure A12. Locations of NEFSC winter bottom trawl survey tows with and without silver hake during 1992-2002, based on all offshore strata that were sampled. The winter survey does not cover strata above southern Georges Bank or inshore strata.

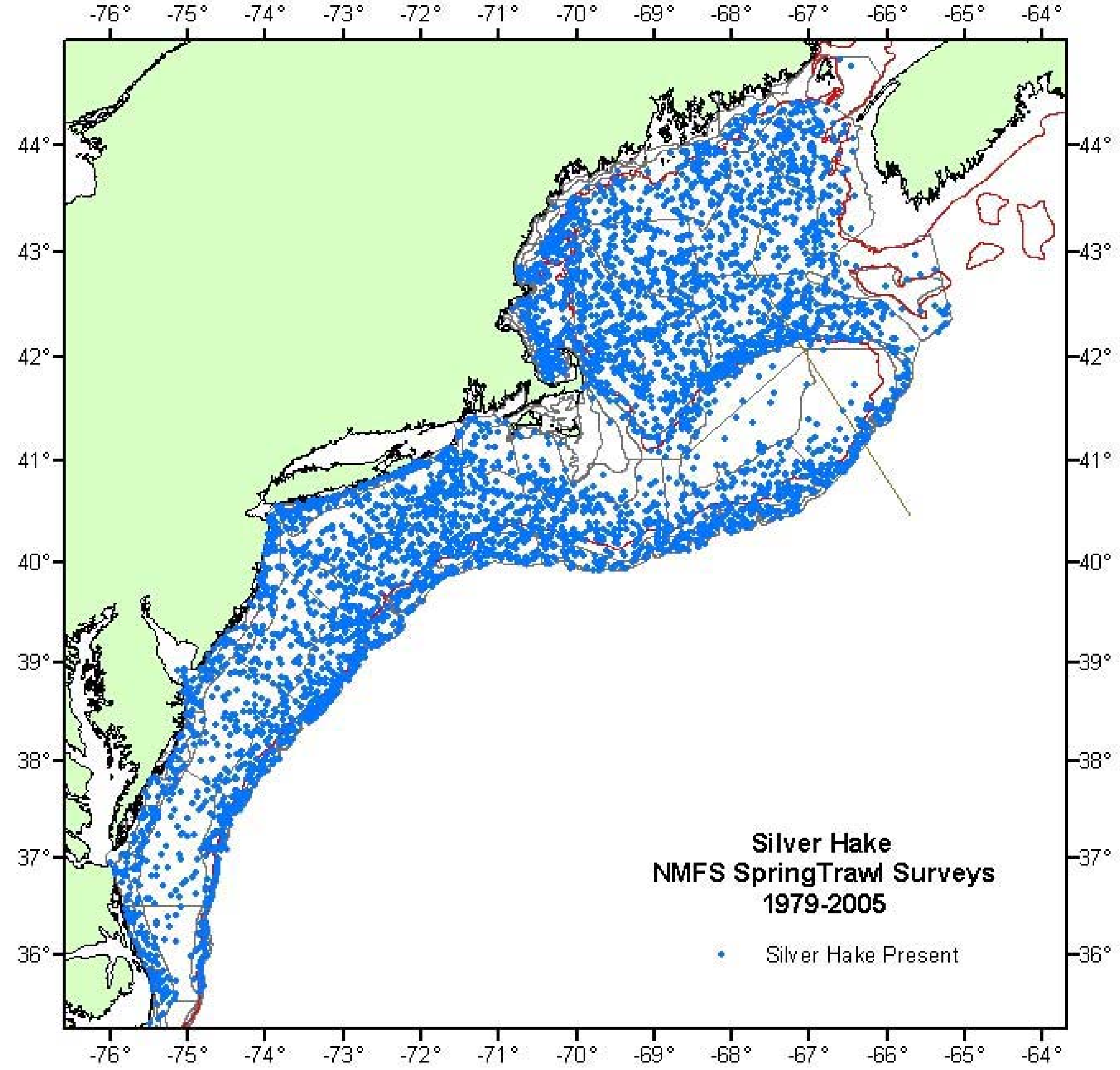


Figure A13. Locations of NEFSC spring bottom trawl survey tows that caught at least one silver hake during 1979-2004, based on all inshore and offshore strata that were sampled.

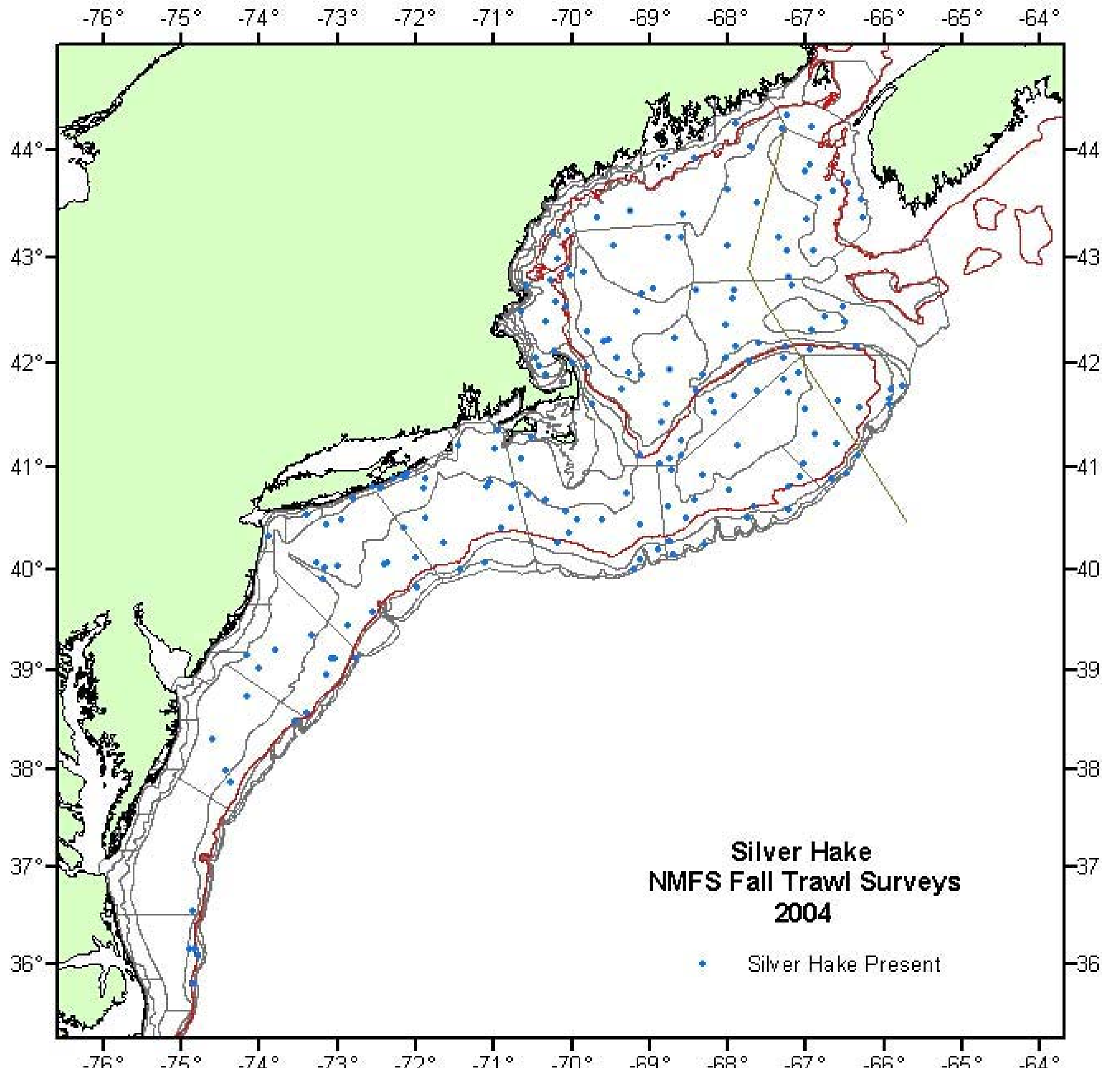


Figure A14. Locations of NEFSC fall bottom trawl survey tows that caught at least one silver hake during 2004, based on all inshore and offshore strata that were sampled.

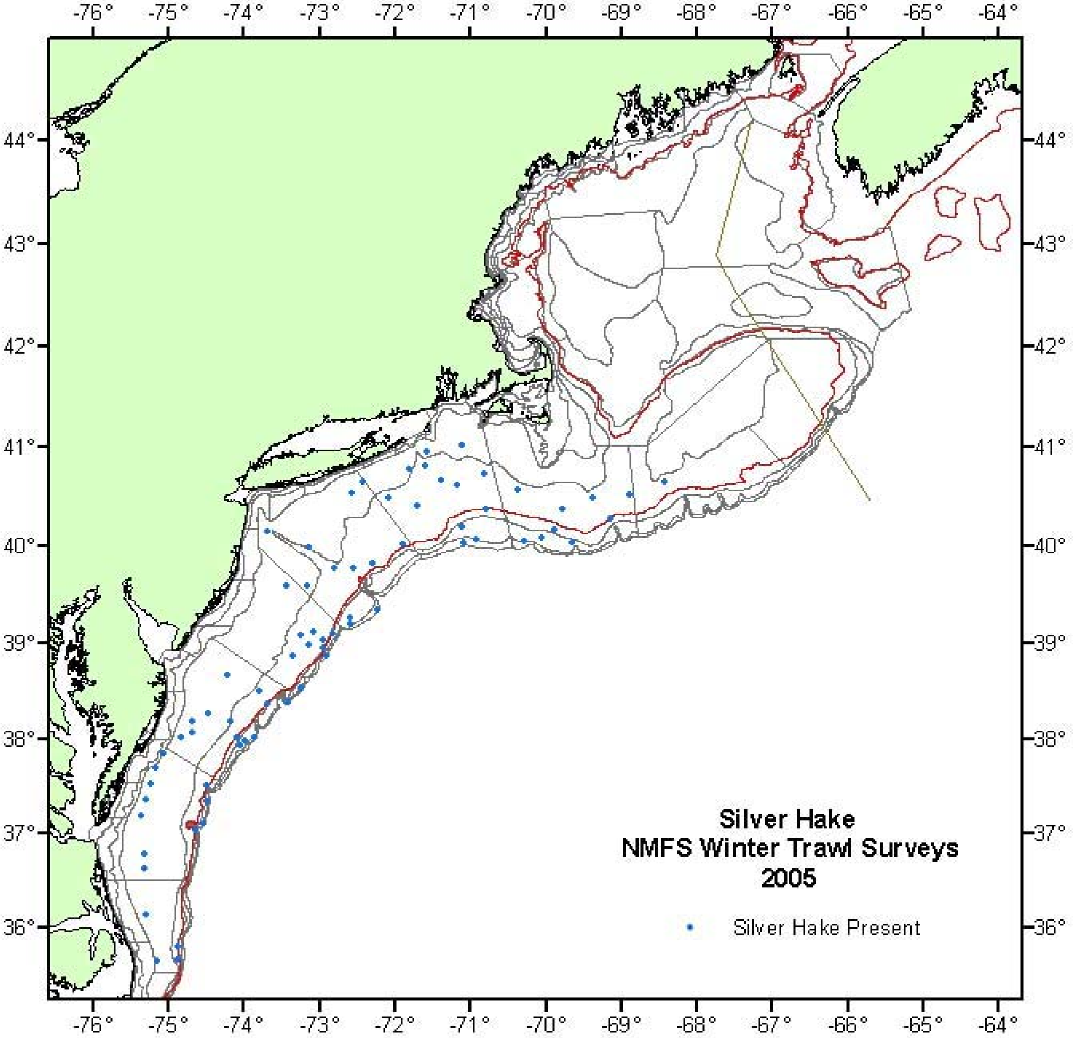


Figure A15. Locations of NEFSC winter bottom trawl survey tows that caught at least one silver hake during 2005, based on all offshore strata that were sampled. The winter survey does not cover strata above southern Georges Bank or inshore strata.

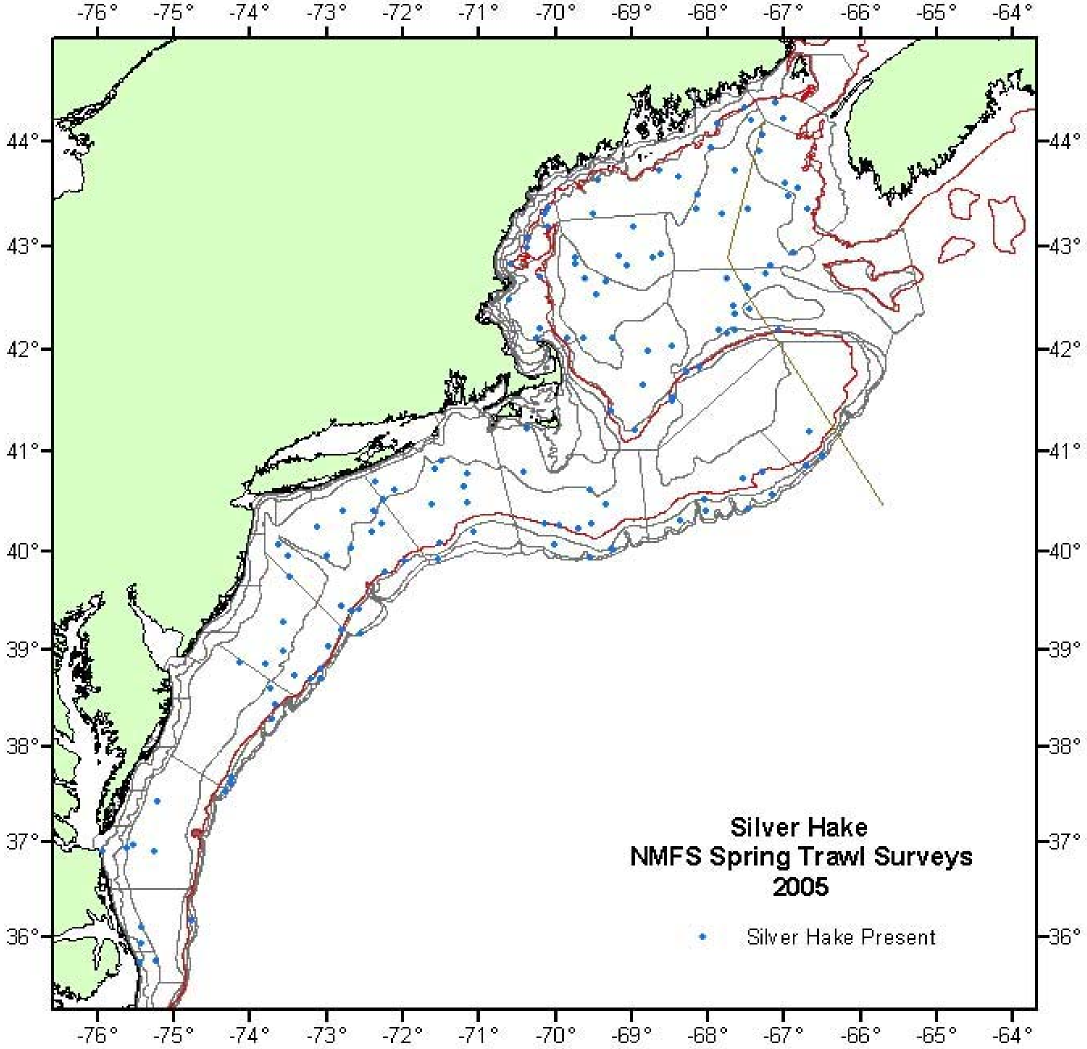


Figure A16. Locations of NEFSC spring bottom trawl survey tows that caught at least one silver hake during 1979-2004, based on all inshore and offshore strata that were sampled.

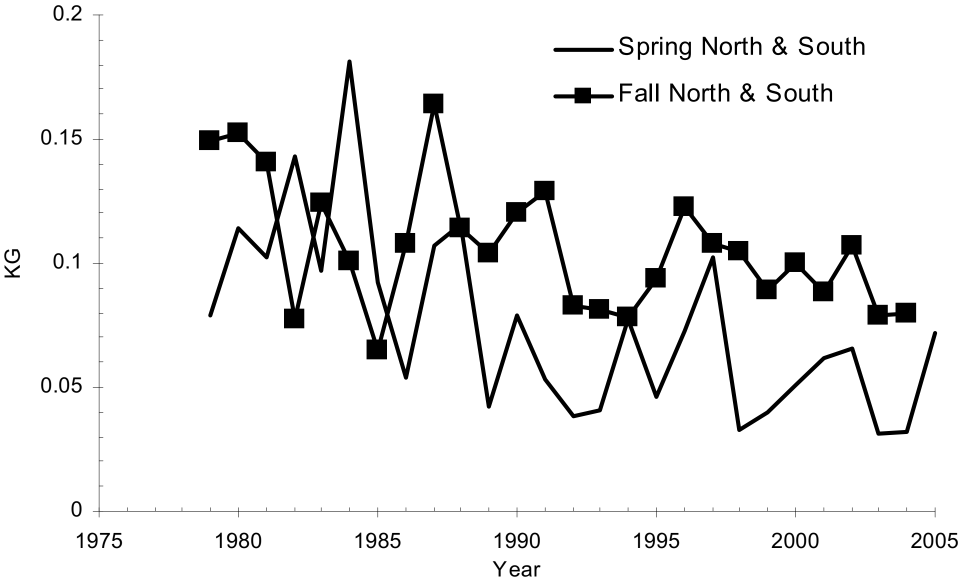


Figure A17. Trends in mean body weight for silver hake in NEFSC surveys during 1979-2005 (special strata set, north and south stock areas combined).

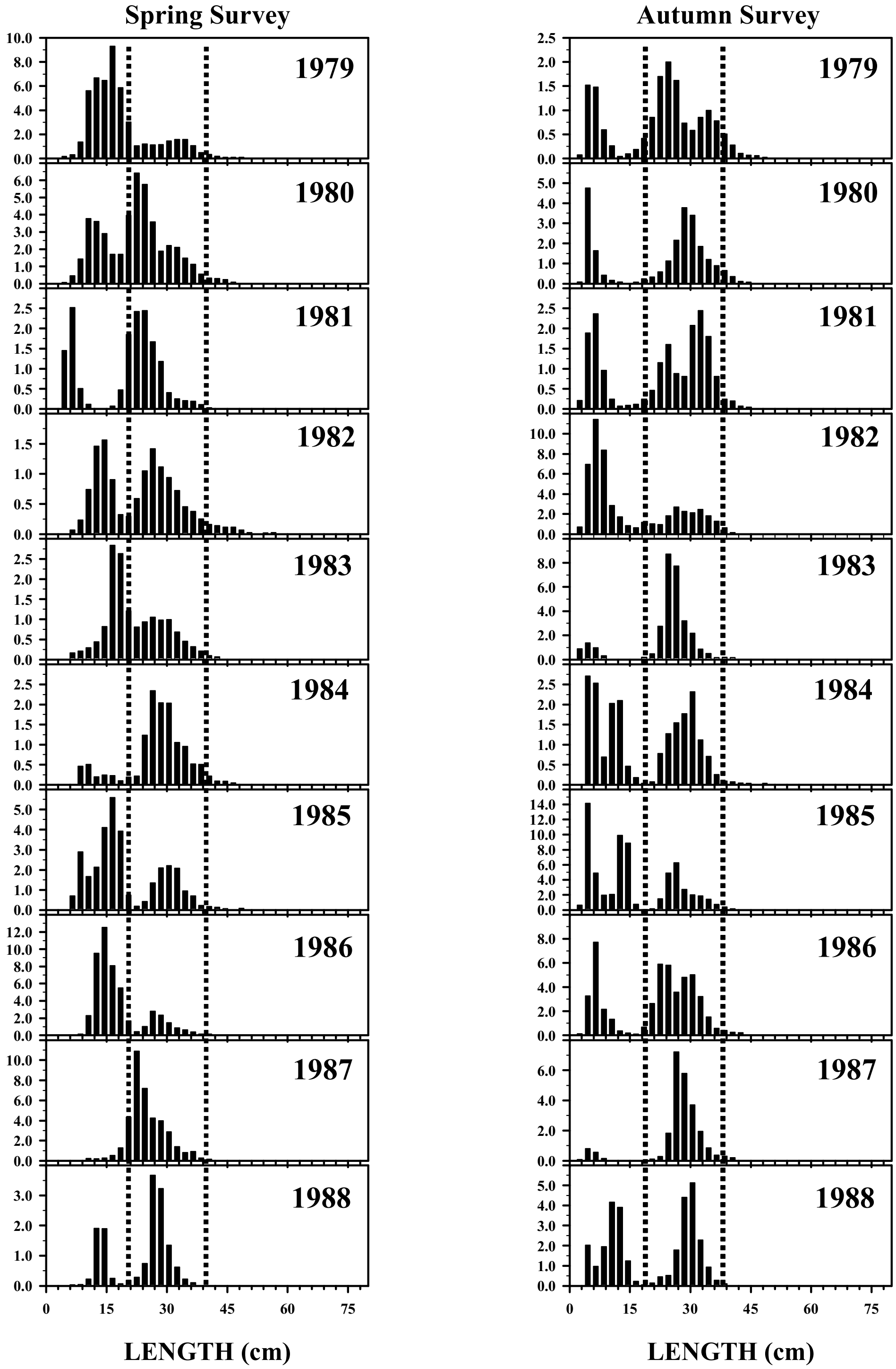


Figure A18. Silver hake length composition from the NEFSC spring and autumn bottom trawl surveys in the combined inshore and offshore regions, 1979-1988 (special strata set). Vertical lines are at approximately 20 cm and 40 cm TL.

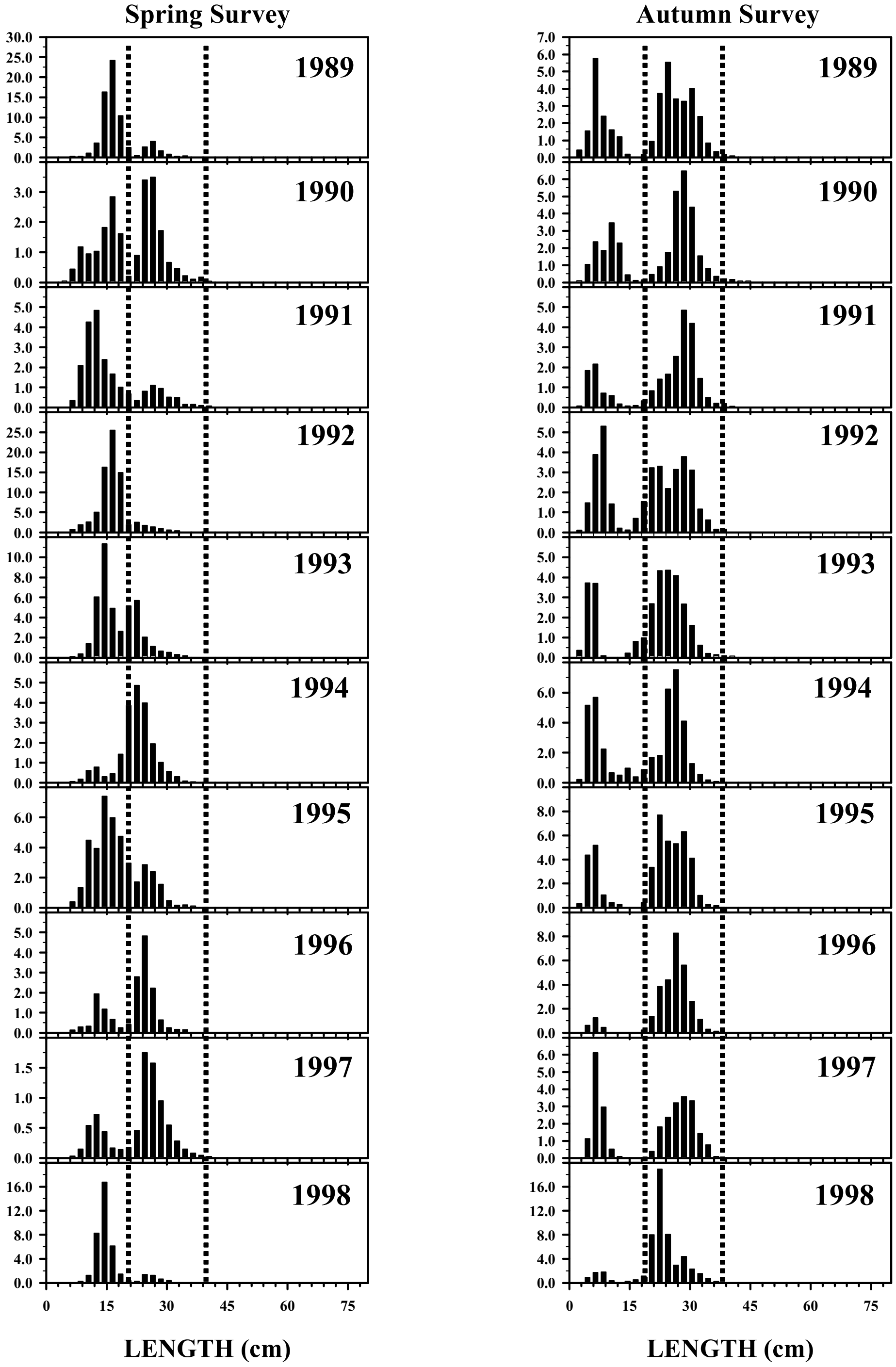


Figure A18. (cont.)

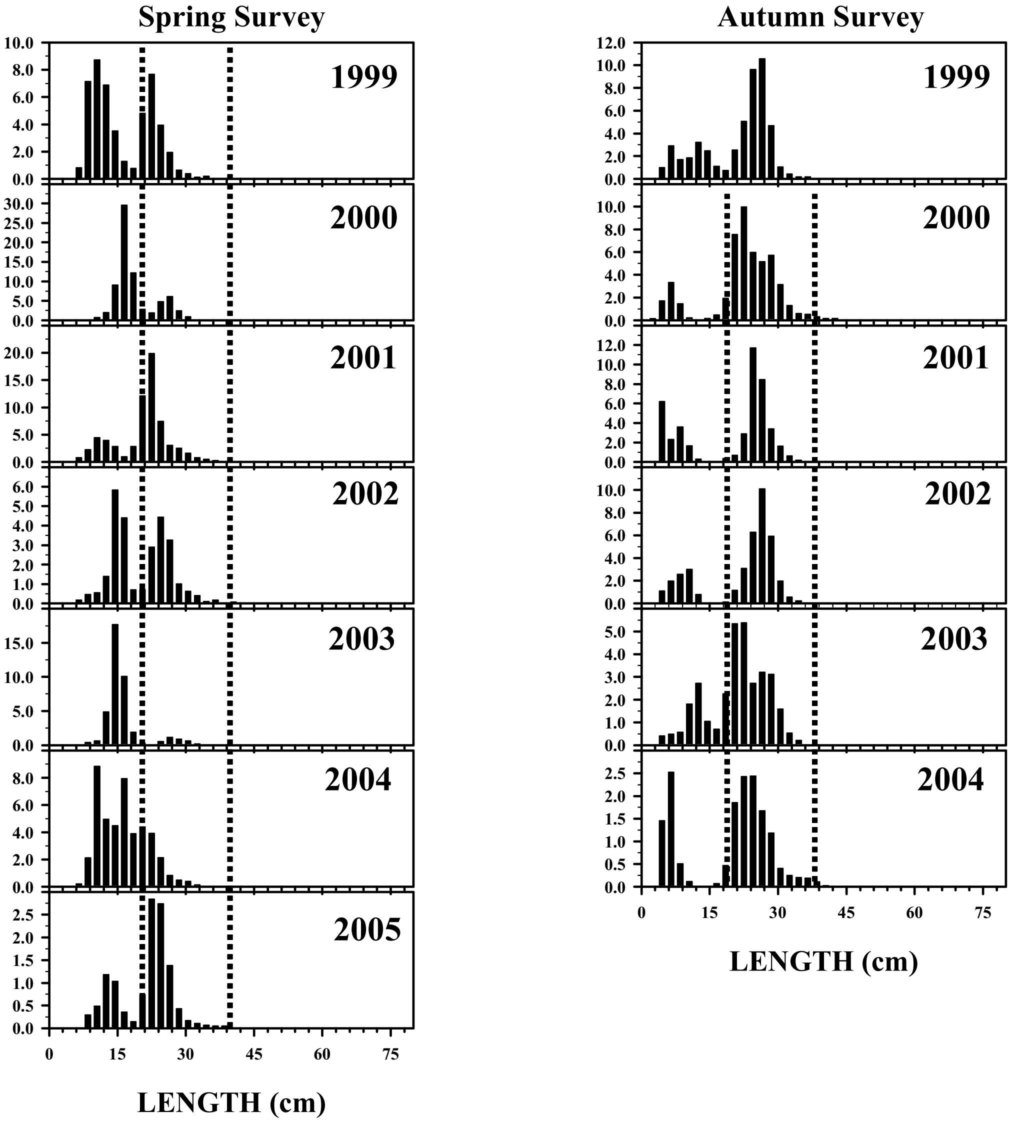


Figure A18. (cont.)

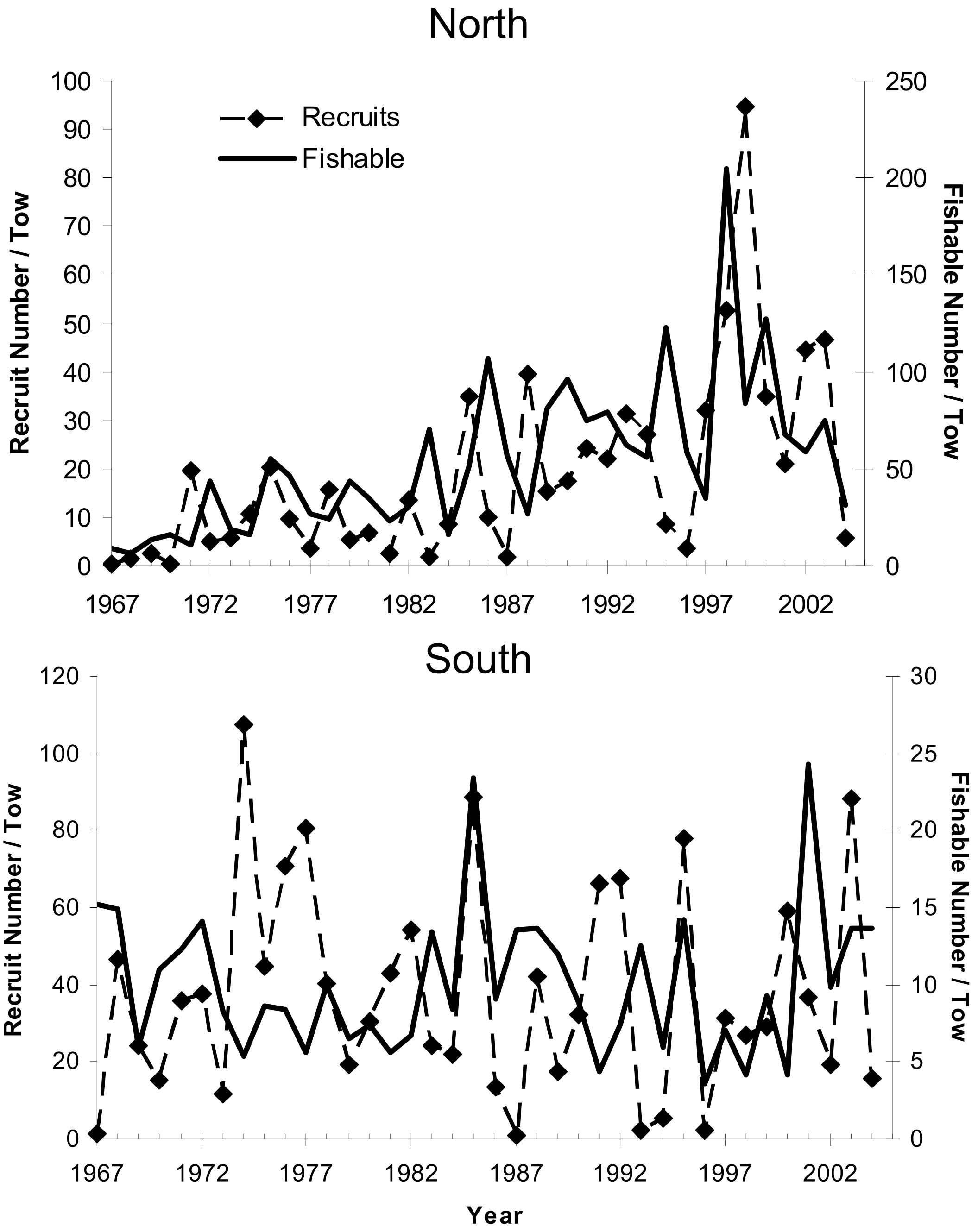


Figure A19. Trends in abundance for recruit (< 20 cm TL) and fishable (= 20 cm TL) silver hake in NEFSC fall surveys.

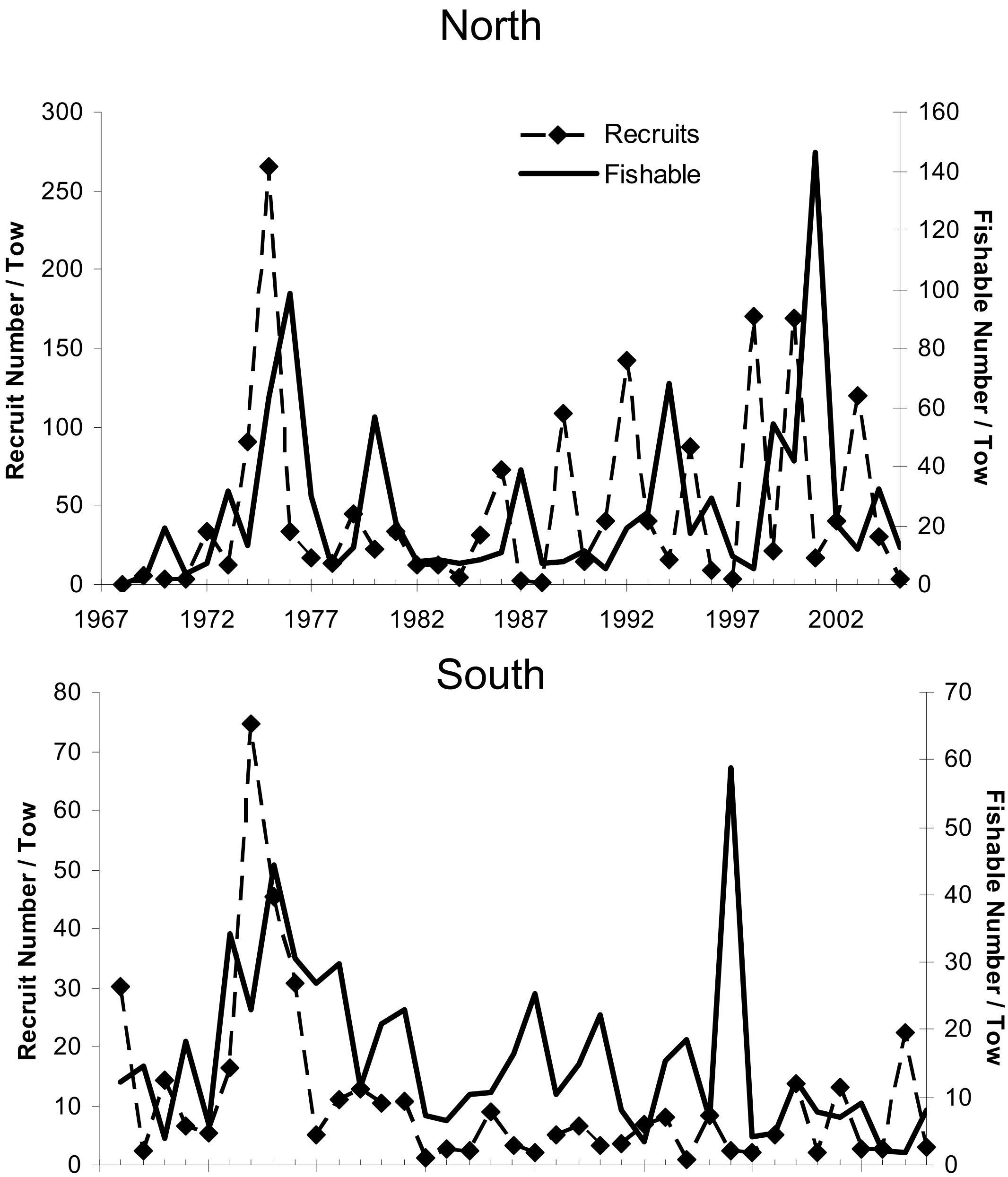


Figure A20. Trends in abundance for recruit (< 20 cm TL) and fishable (= 20 cm TL) silver hake in NEFSC spring surveys.

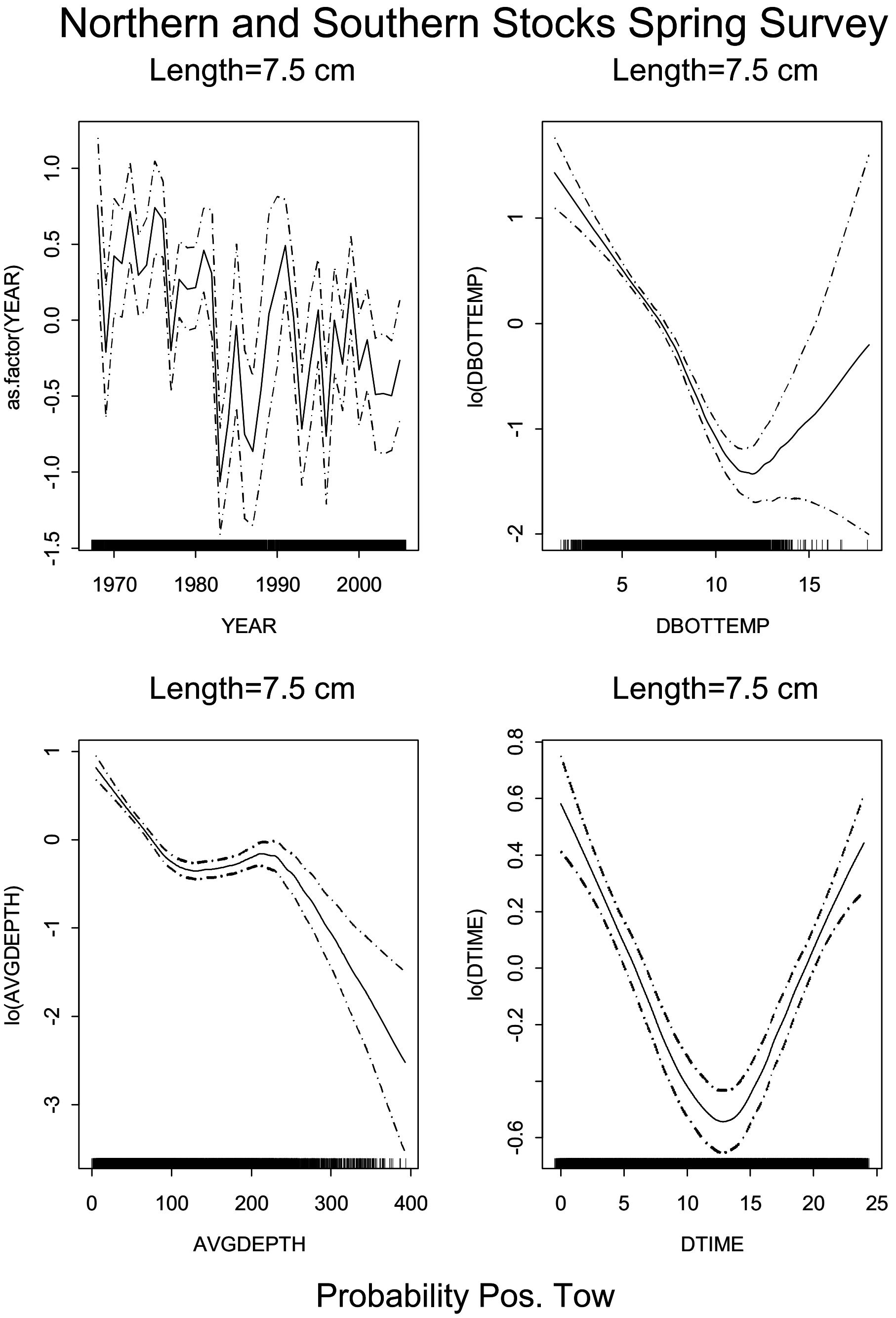


Figure A21. GAM results (partial residual plots for the probability of a positive tow) for silver hake 5-9.9 cm TL in the NEFSC spring survey during 1979-2005 (north and south stock areas combined). The y-axis gives standardized logit-scale residuals. Trends are shown for all terms that were statistically significant based on the AIC criteria.

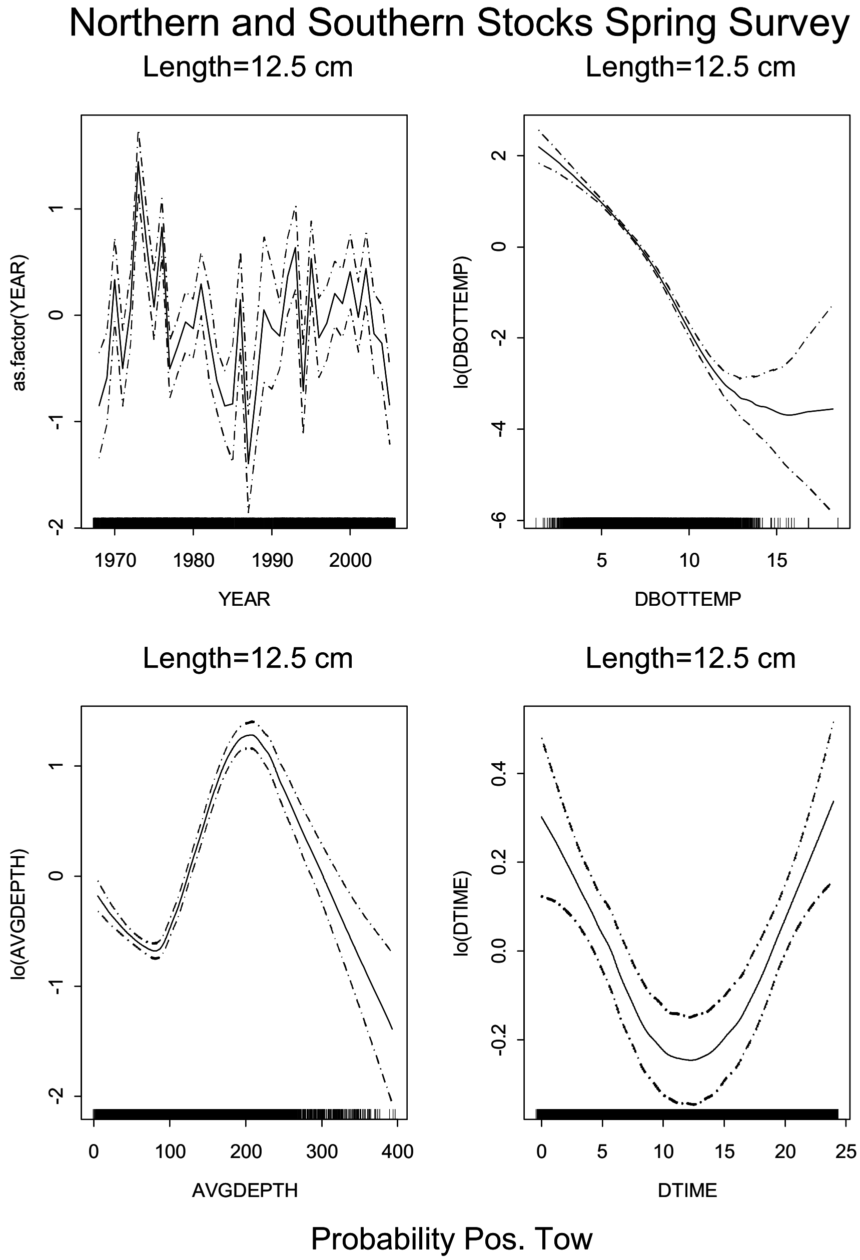


Figure A22. GAM results (partial residual plots for the probability of a positive tow) for silver hake 10-14.9 cm TL in the NEFSC spring survey during 1979-2005 (north and south stock areas combined). The y-axis gives standardized logit-scale residuals. Trends are shown for all terms that were statistically significant based on the AIC criteria.

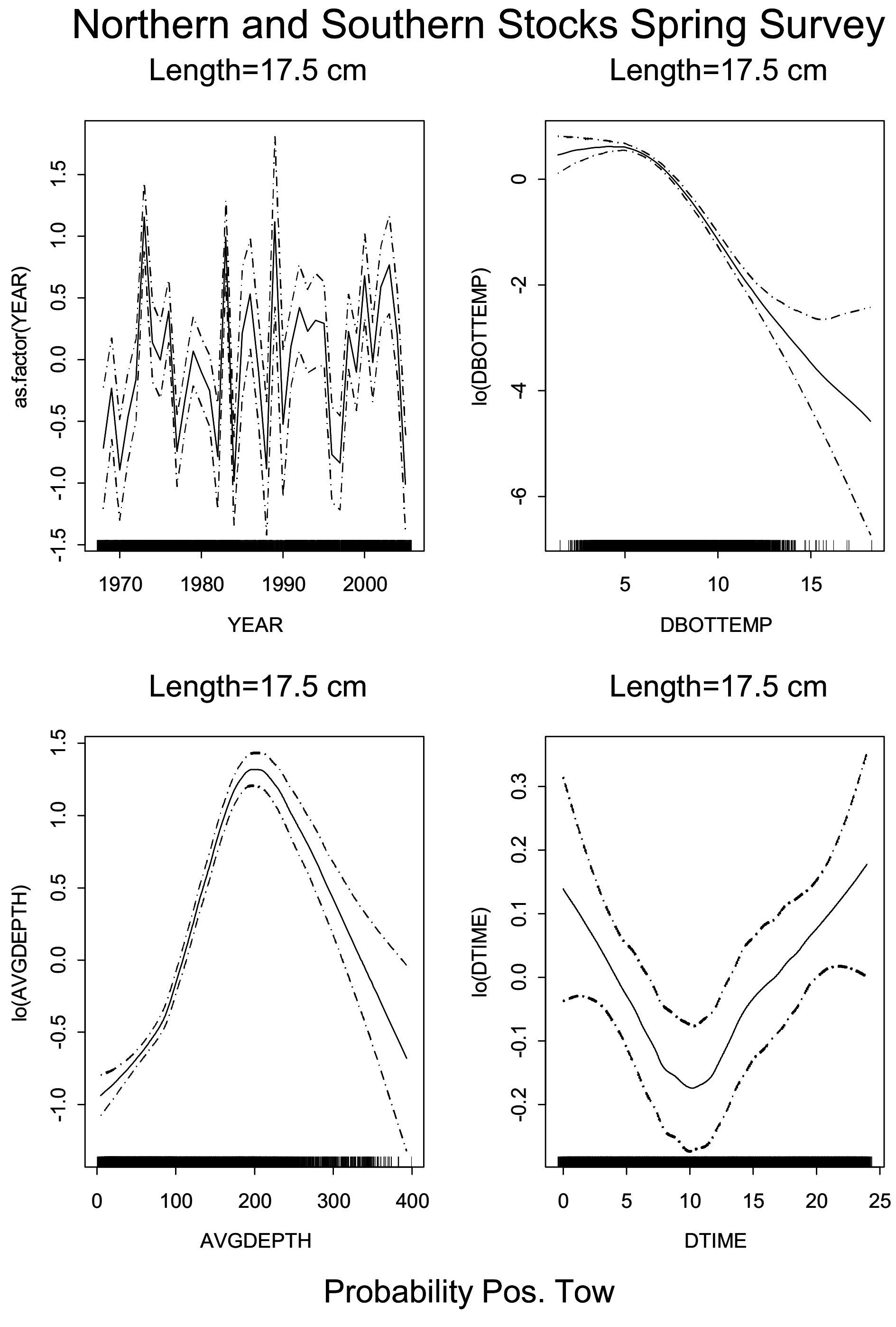


Figure A23. GAM results (partial residual plots for the probability of a positive tow) for silver hake 15-19.9 cm TL in the NEFSC spring survey during 1979-2005 (north and south stock areas combined). The y-axis gives standardized logit-scale residuals. Trends are shown for all terms that were statistically significant based on the AIC criteria.

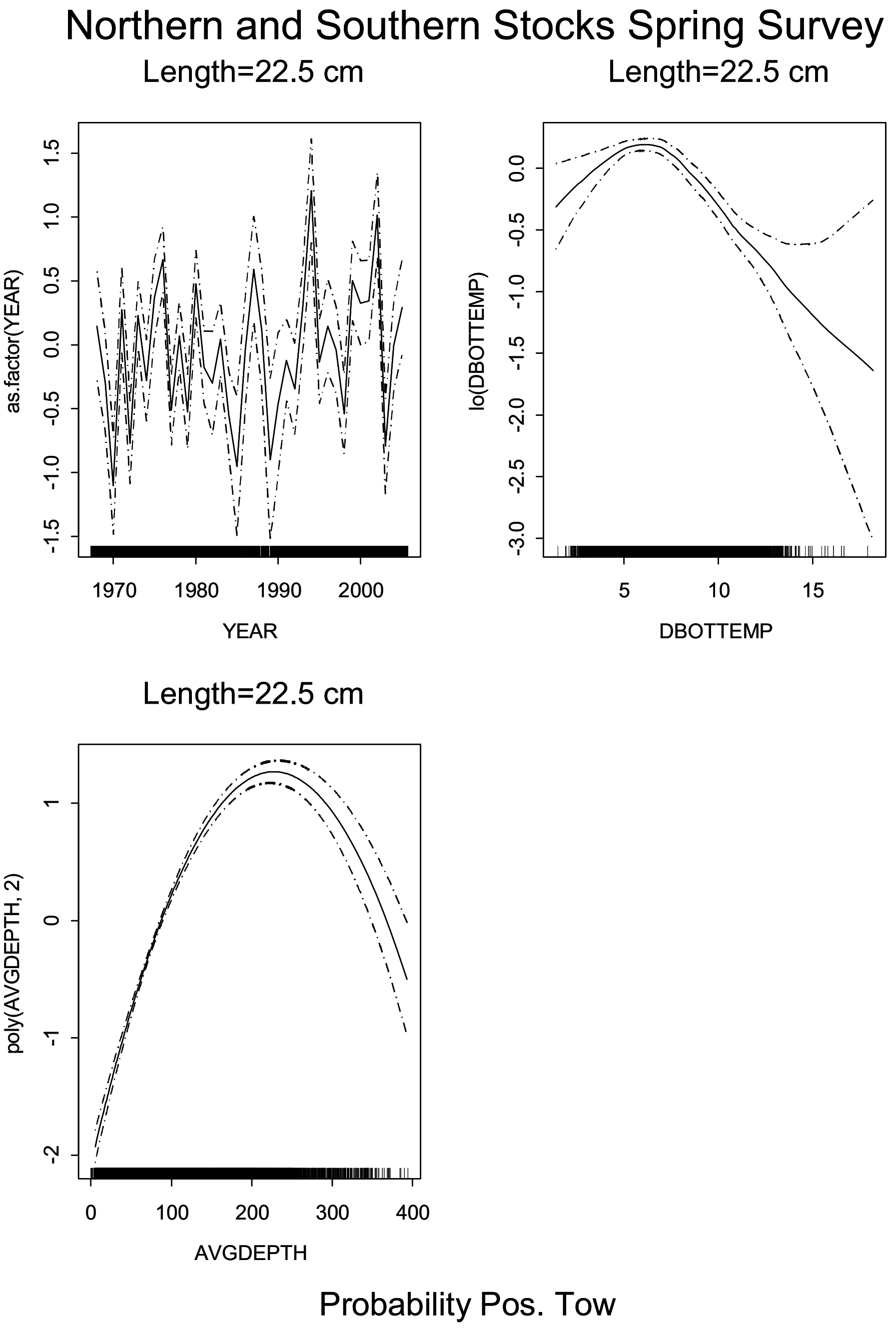


Figure A24. GAM results (partial residual plots for the probability of a positive tow) for silver hake 20-24.9 cm TL in the NEFSC spring survey during 1979-2005 (north and south stock areas combined). The y-axis gives standardized logit-scale residuals. Trends are shown for all terms that were statistically significant based on the AIC criteria.

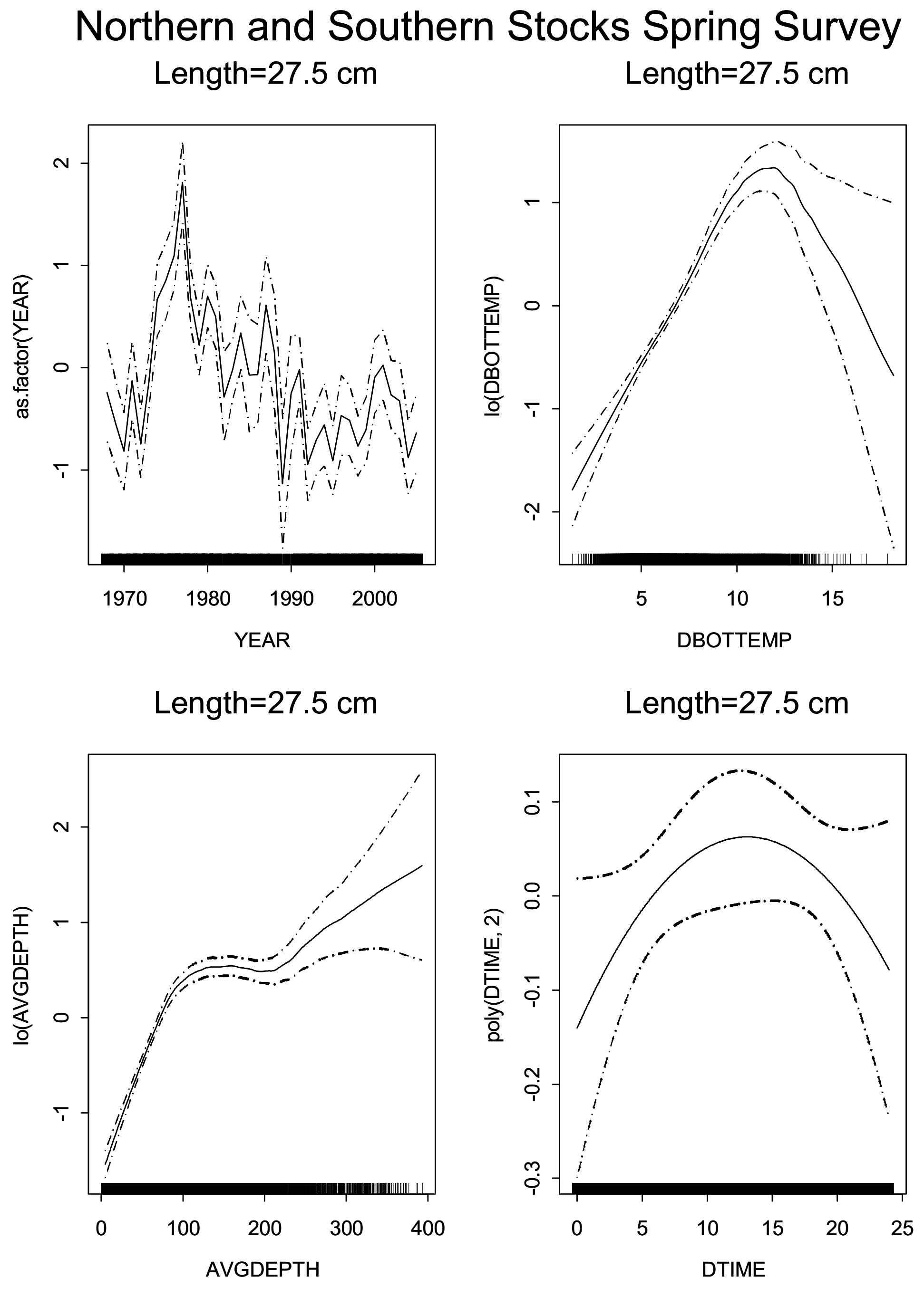


Figure A25. GAM results (partial residual plots for the probability of a positive tow) for silver hake 25+ cm TL in the NEFSC spring survey during 1979-2005 (north and south stock areas combined). The y-axis gives standardized logit-scale residuals. Trends are shown for all terms that were statistically significant based on the AIC criteria.

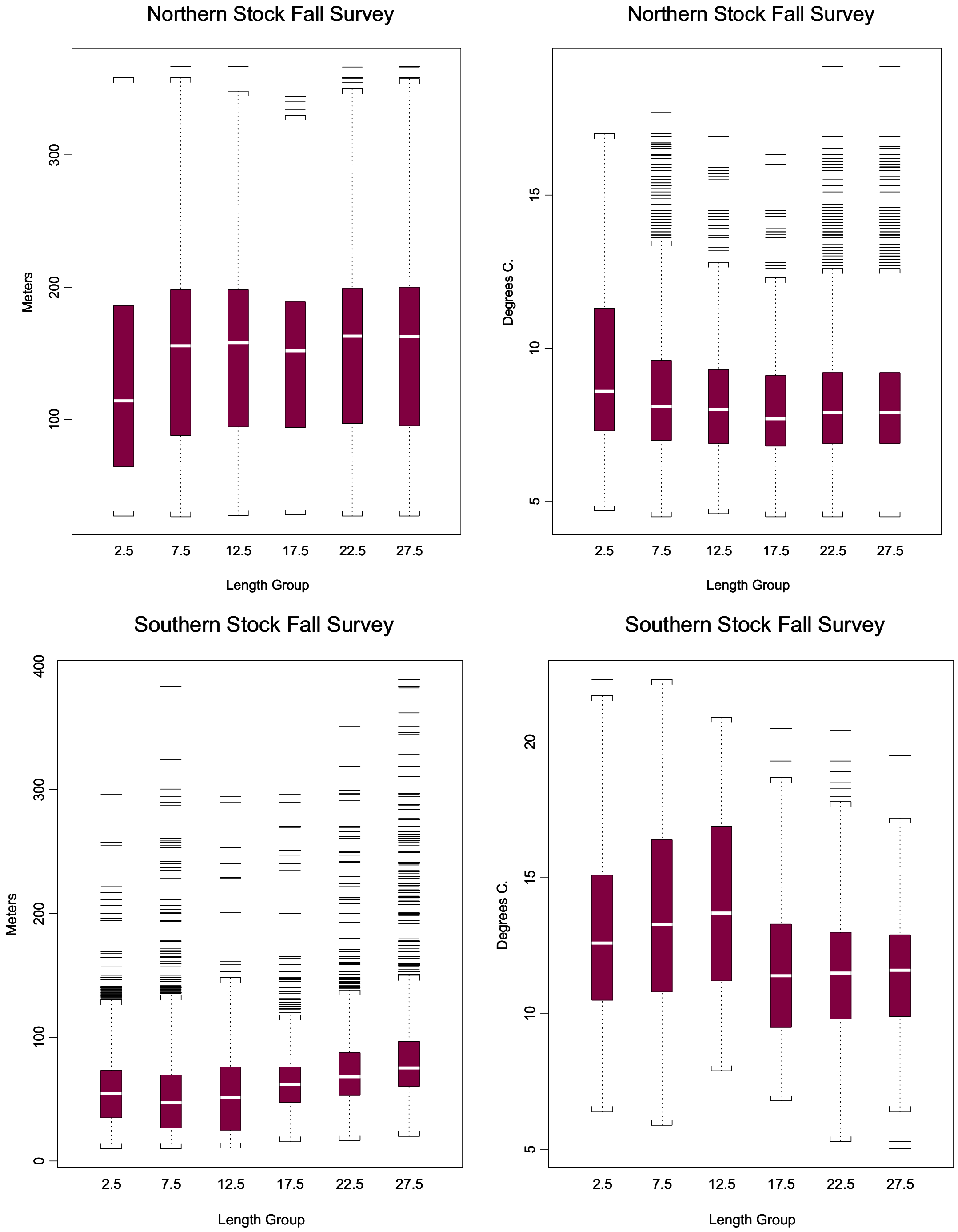


Figure A26. Distributions of depths and bottom temperatures by size and stock for tows that took silver hake in NEFSC fall bottom trawl surveys.

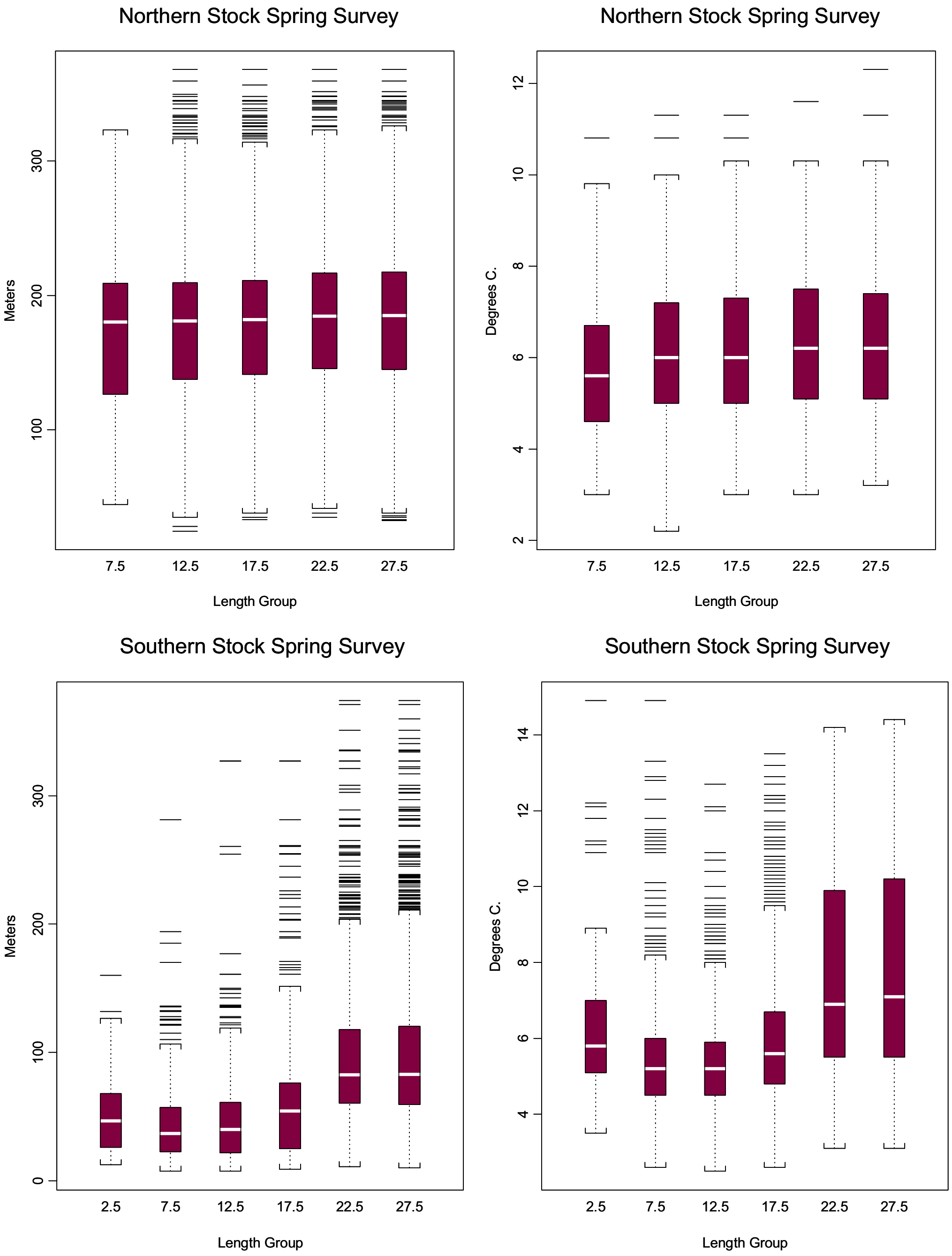


Figure A27. Distributions of depths and bottom temperatures by size and stock for tows that took silver hake in NEFSC spring bottom trawl surveys.

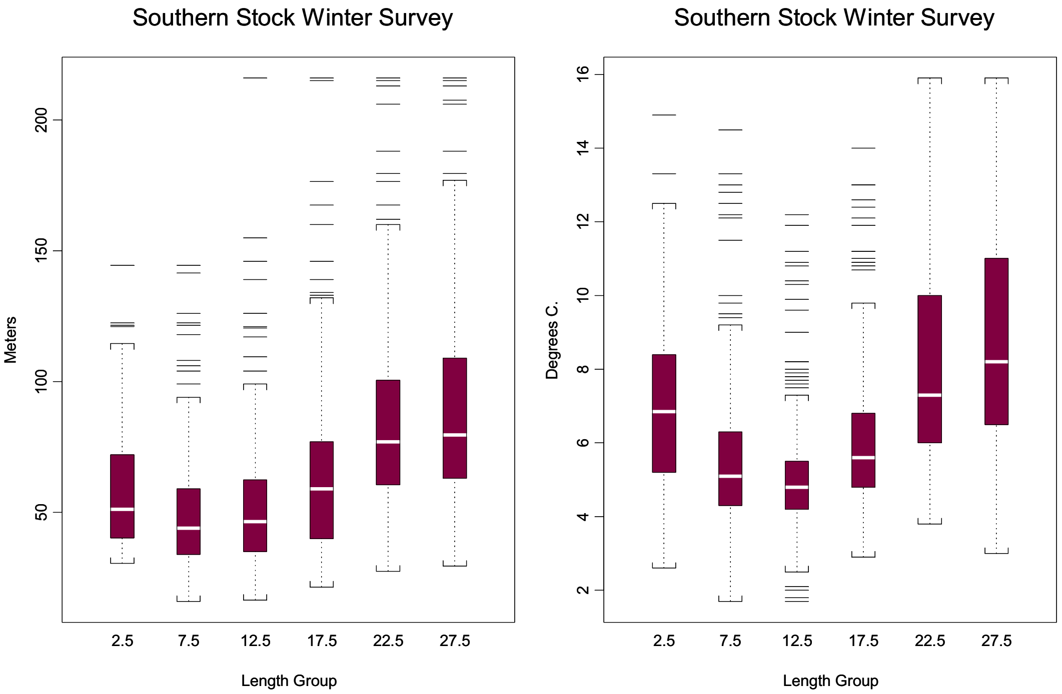


Figure A28. Distributions of depths and bottom temperatures by size and stock for tows that took silver hake in NEFSC winter bottom trawl surveys.

Figure A29. Average position (latitude in left panel and longitude in right) for silver hake in fall bottom trawl surveys in the northern stock area, by size group. Averages are for tows, weighted by catch of the appropriate size group.

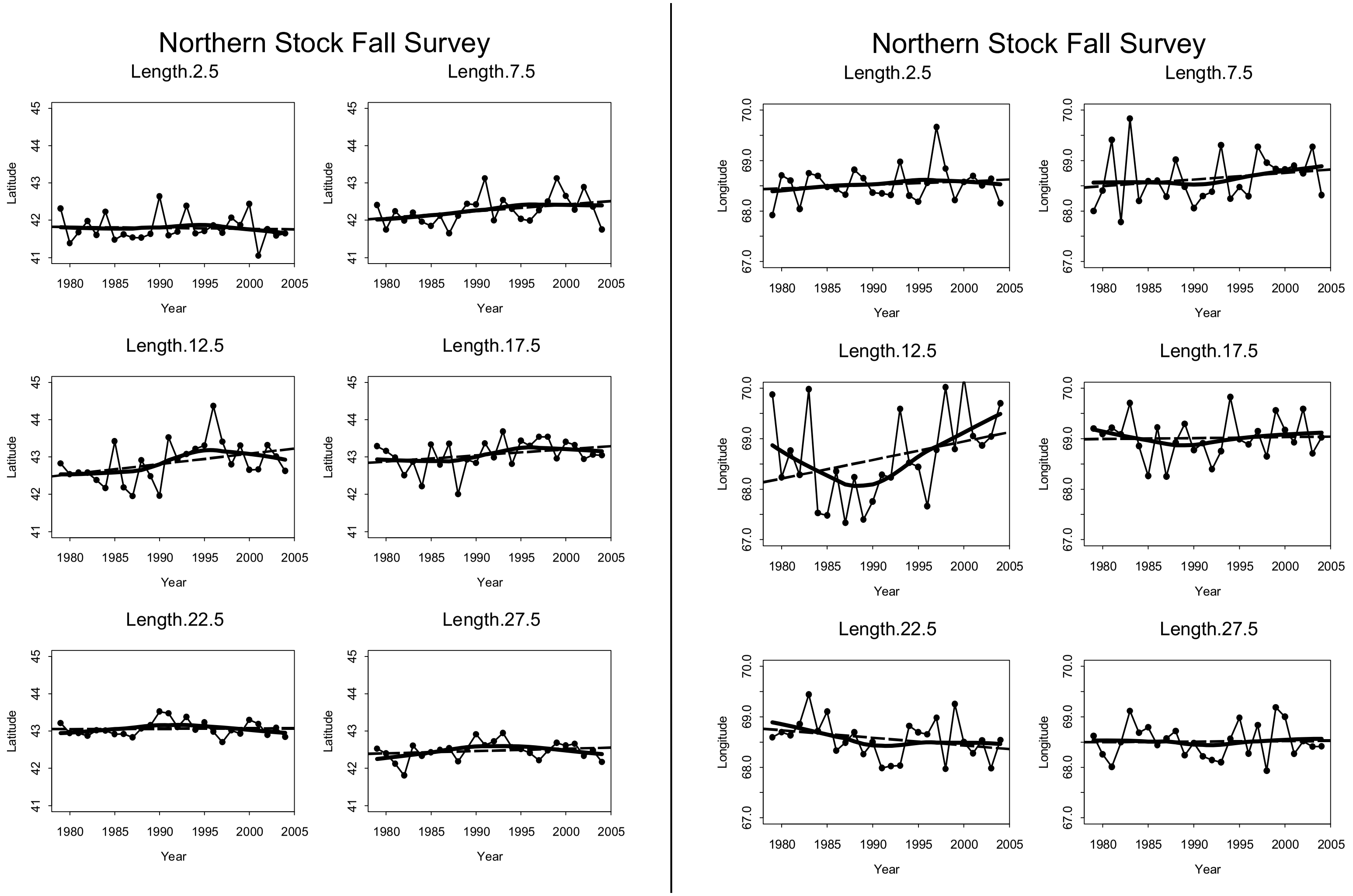


Figure A30. Average position (latitude in left panel and longitude in right) for silver hake in fall bottom trawl surveys in the southern stock area, by size group. Averages are for tows, weighted by catch of the appropriate size group.

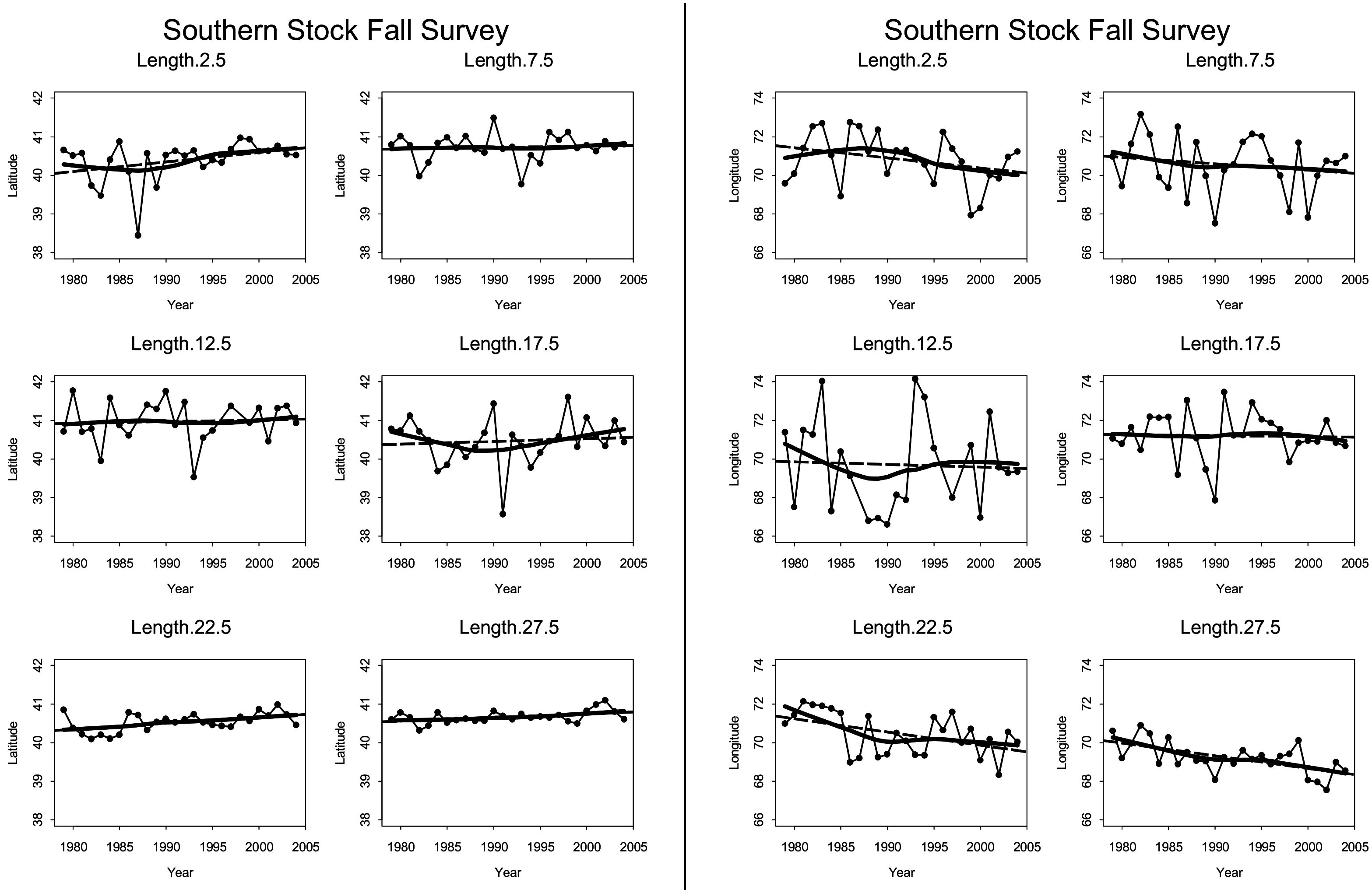


Figure A31. Average position (latitude in left panel and longitude in right) for silver hake in fall bottom trawl surveys in the combined northern and southern stock areas, by size group. Averages are for tows, weighted by catch of the appropriate size group.

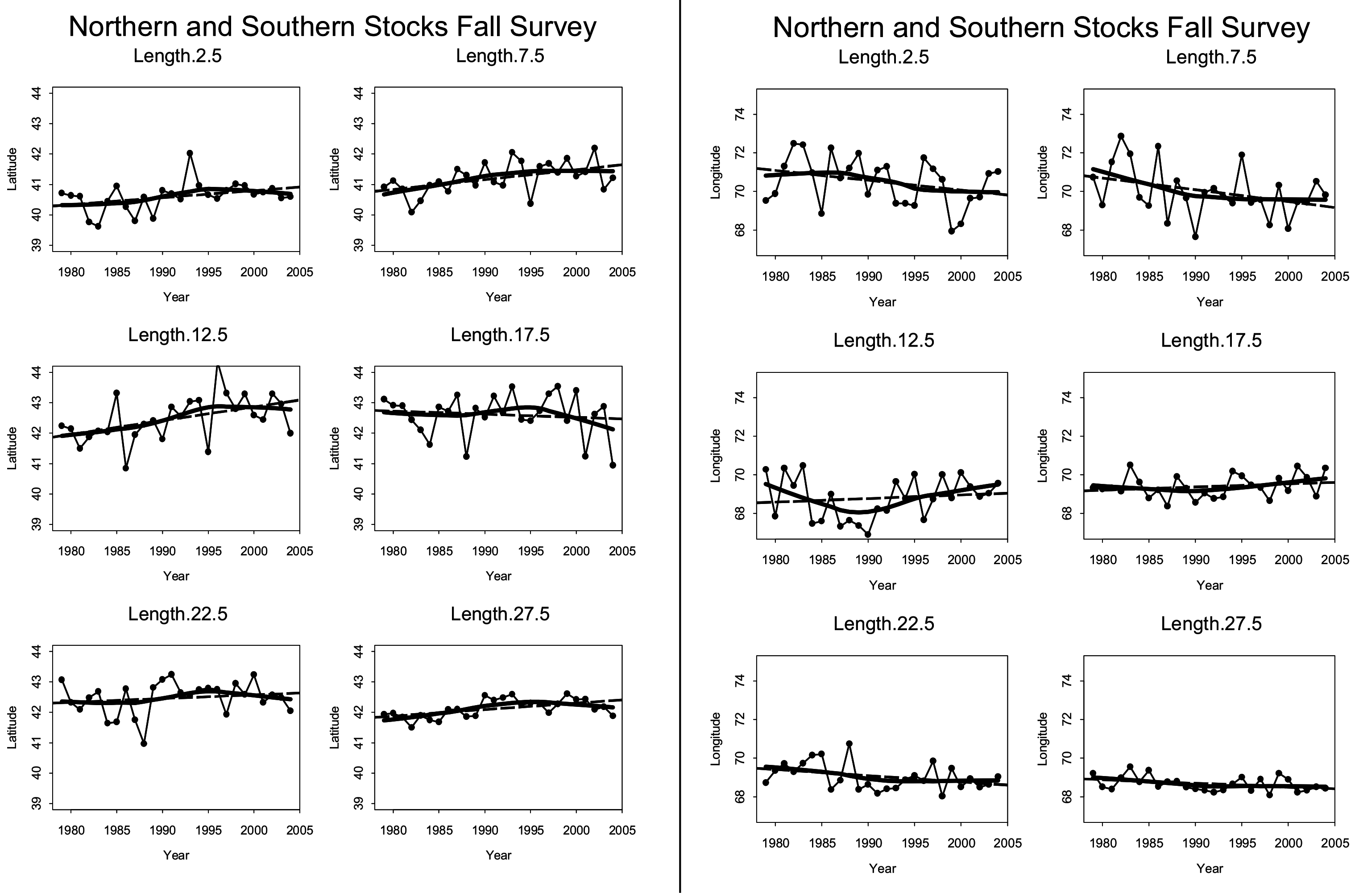


Figure A32. Average position (latitude in left panel and longitude in right) for silver hake in spring bottom trawl surveys in the northern stock area, by size group. Averages are for tows, weighted by catch of the appropriate size group.

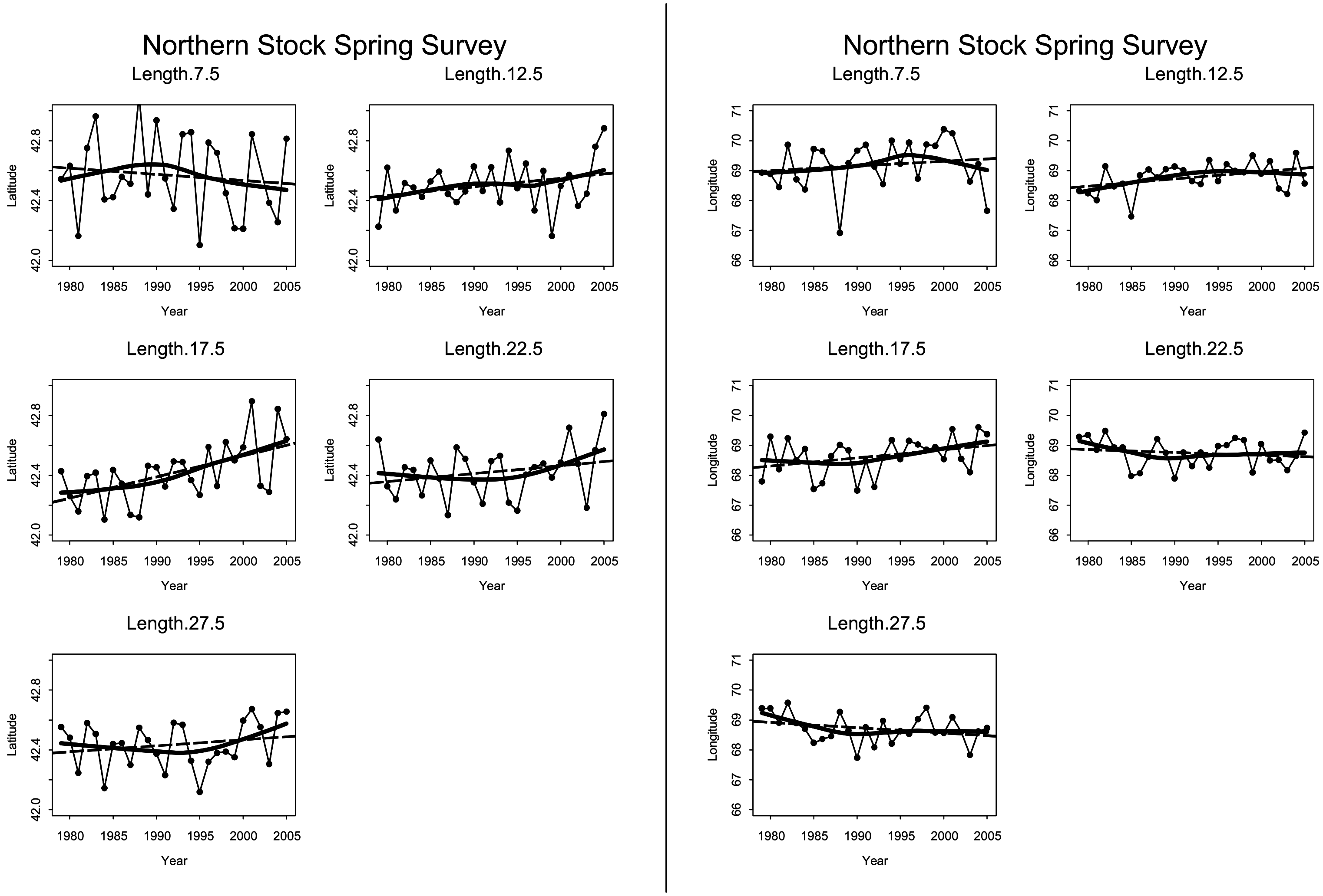


Figure A33. Average position (latitude in left panel and longitude in right) for silver hake in spring bottom trawl surveys in the southern stock area, by size group. Averages are for tows, weighted by catch of the appropriate size group.

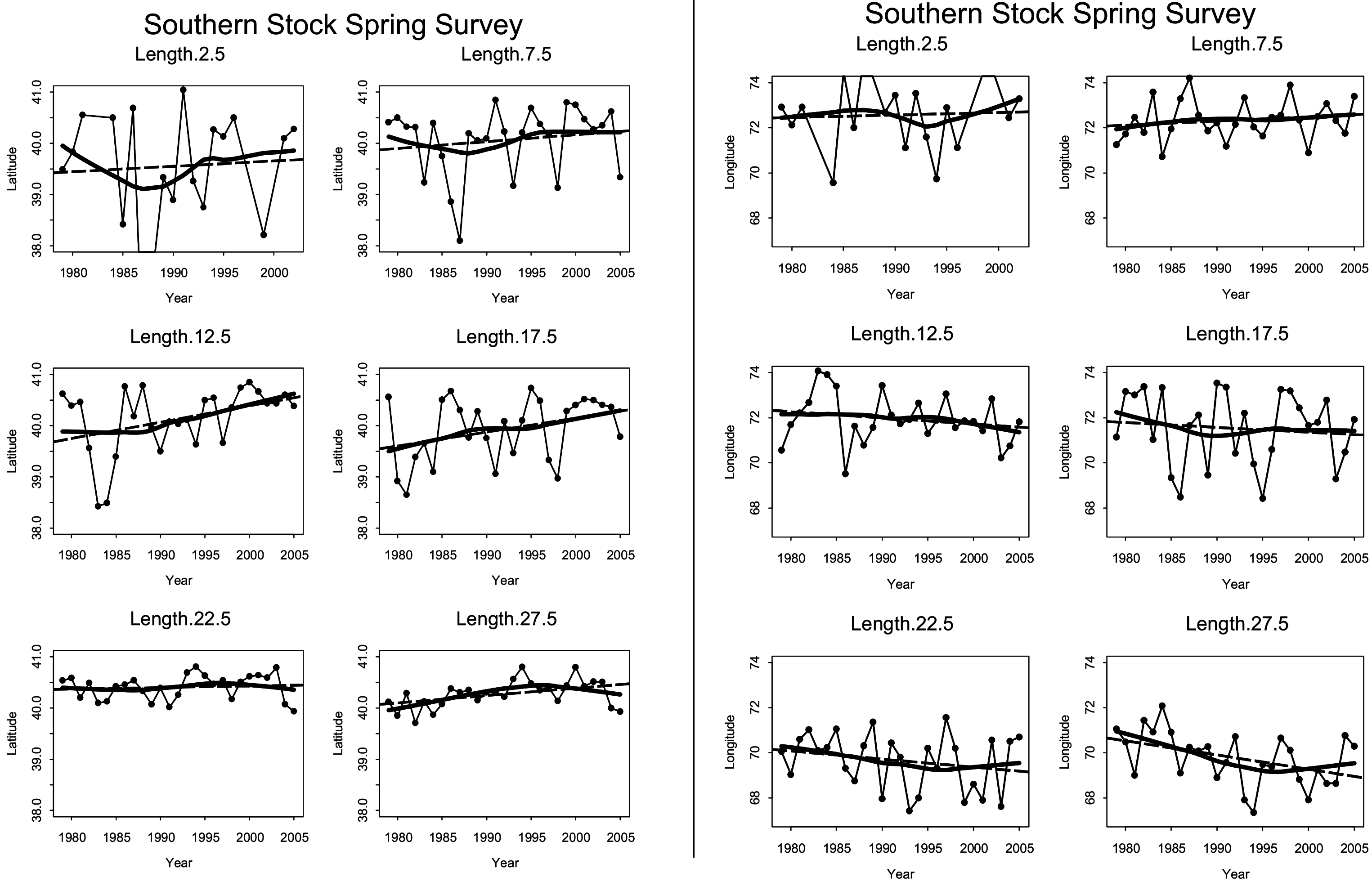


Figure A34. Average position (latitude in left panel and longitude in right) for silver hake in spring bottom trawl surveys in the combined northern and southern stock areas, by size group. Averages are for tows, weighted by catch of the appropriate size group.

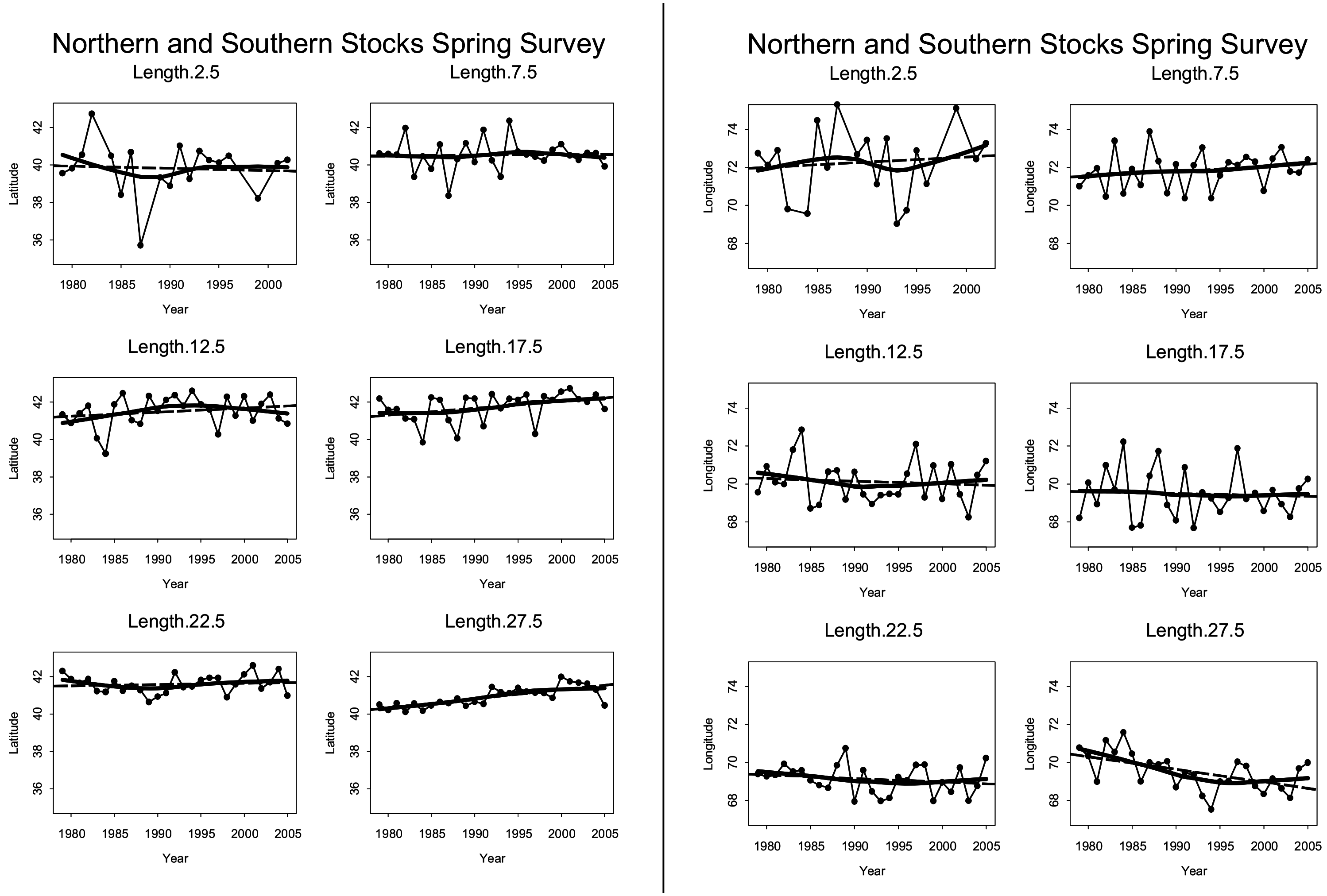
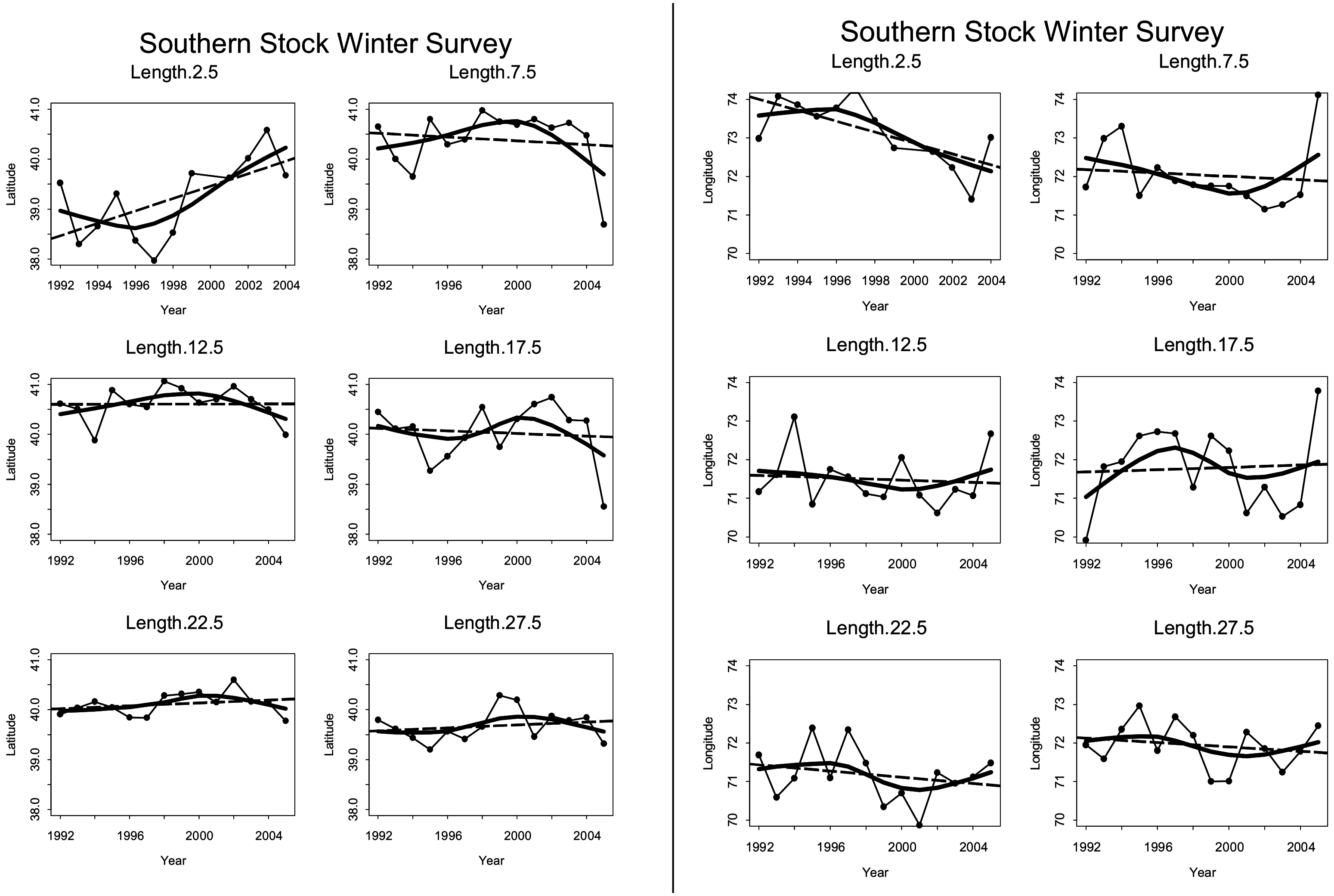


Figure A35. Average position (latitude in left panel and longitude in right) for silver hake in winter bottom trawl surveys in the southern stock area, by size group. Averages are for tows, weighted by catch of the appropriate size group.



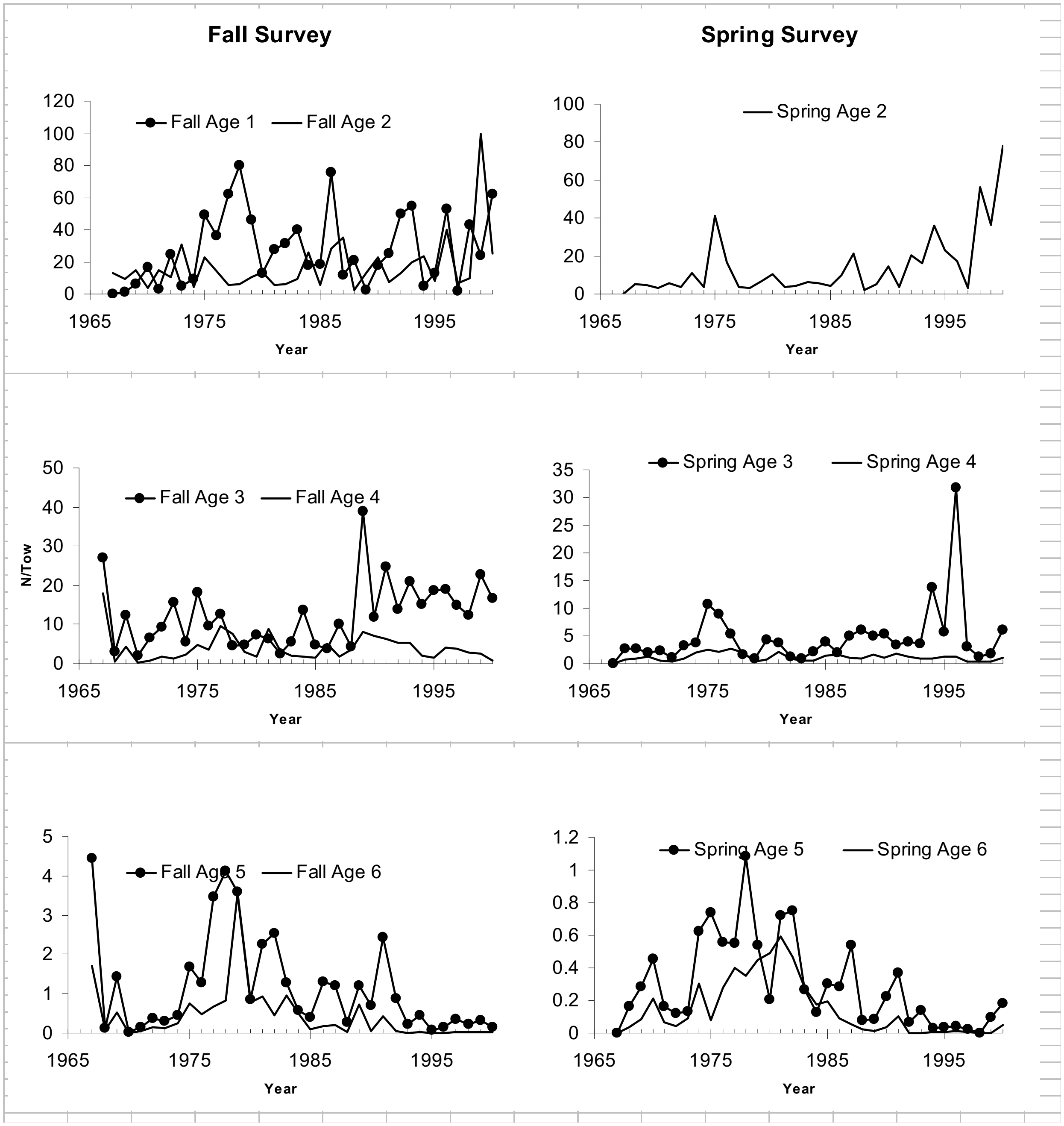


Figure A36. Relative abundance data from Brodziak et al. (2001) for silver hake ages 1-6+ in NEFSC fall and spring surveys. Data for years prior to 1973 were calculated using average age-length keys for spring and fall surveys during 1973-1975.

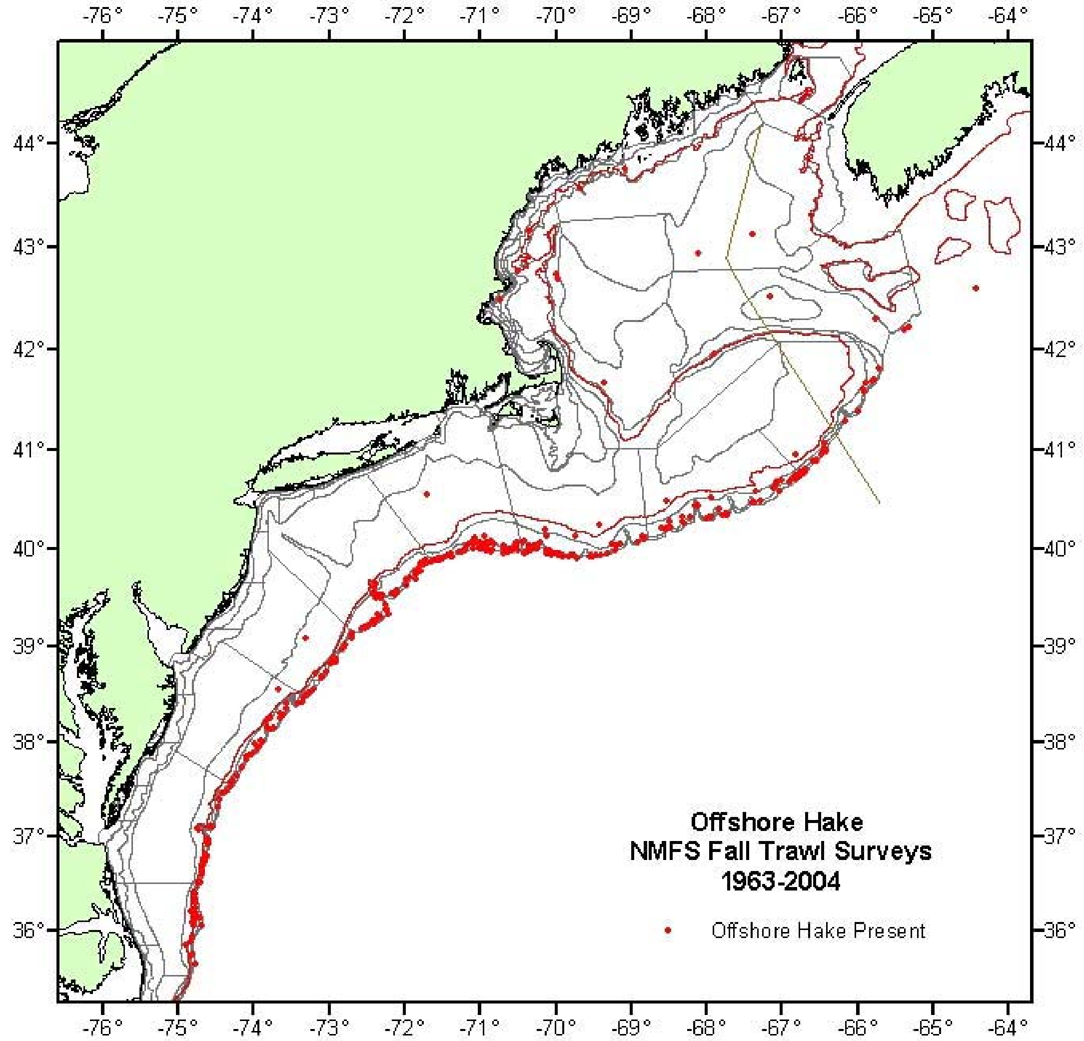


Figure A37. Locations of NEFSC fall bottom trawl survey tows that caught at least one offshore hake during 1963-2004, based all strata that were sampled.

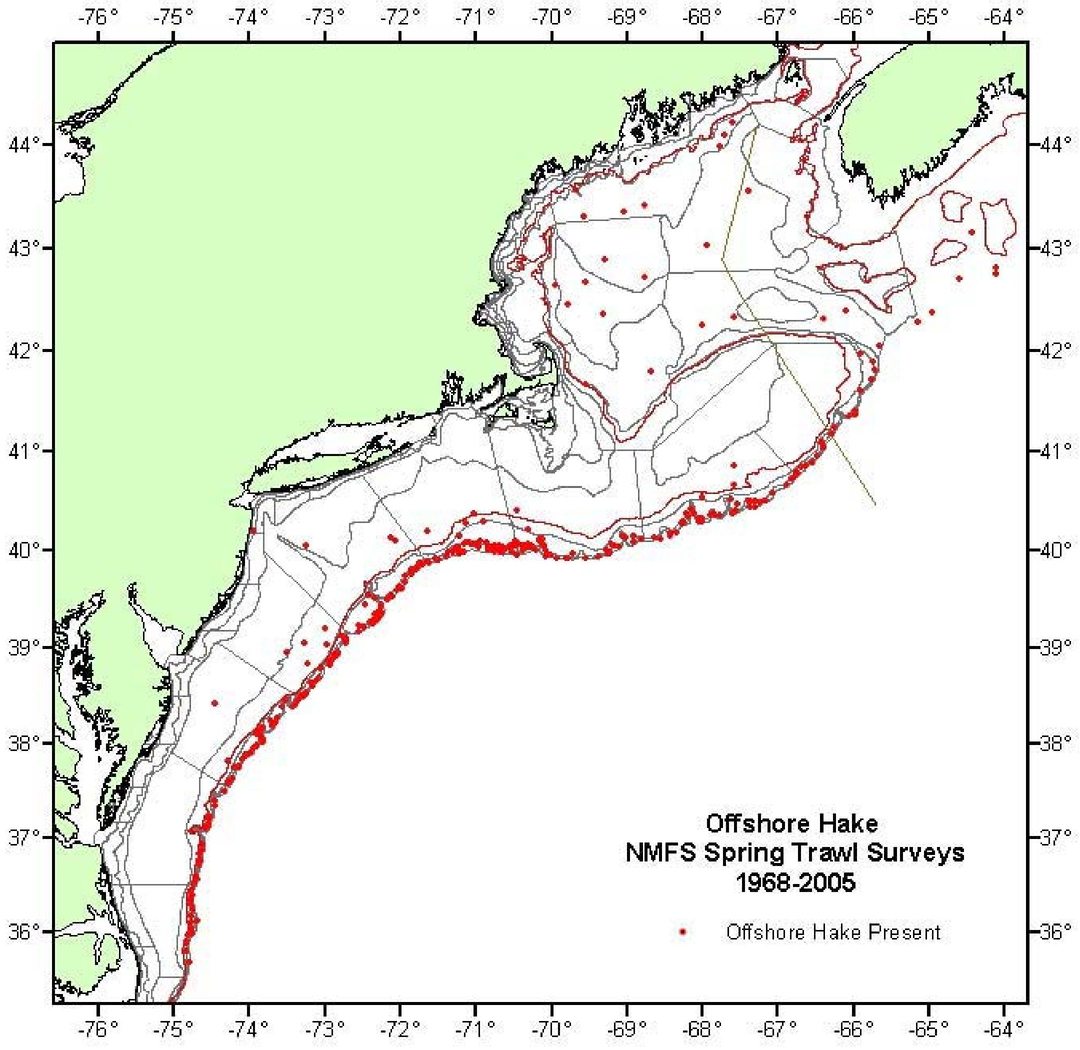


Figure A38. Locations of NEFSC spring bottom trawl survey tows that caught at least one offshore hake during 1963-2004, based all strata that were sampled.

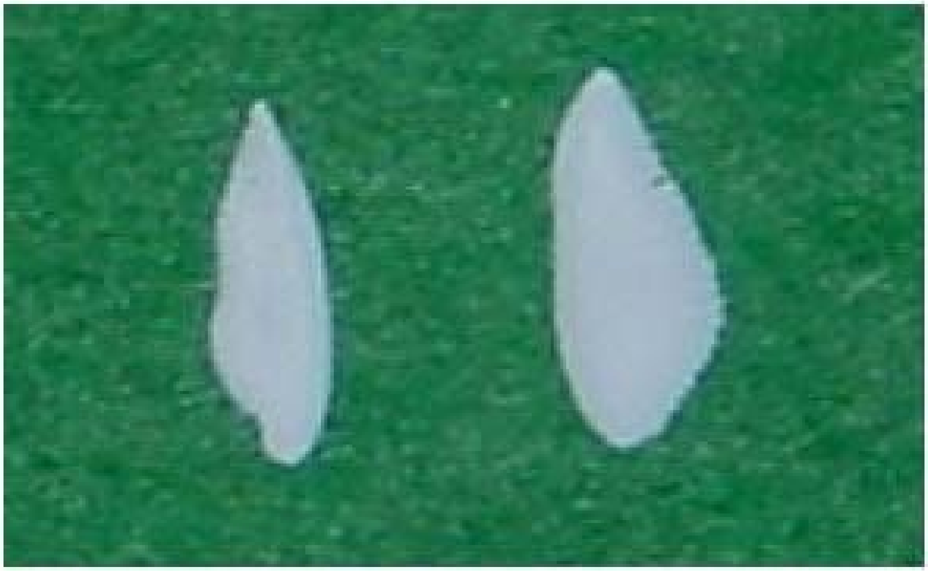


Figure A39. Otoliths from a silver hake (left) and an offshore hake (right). Both specimens were 35 cm TL.

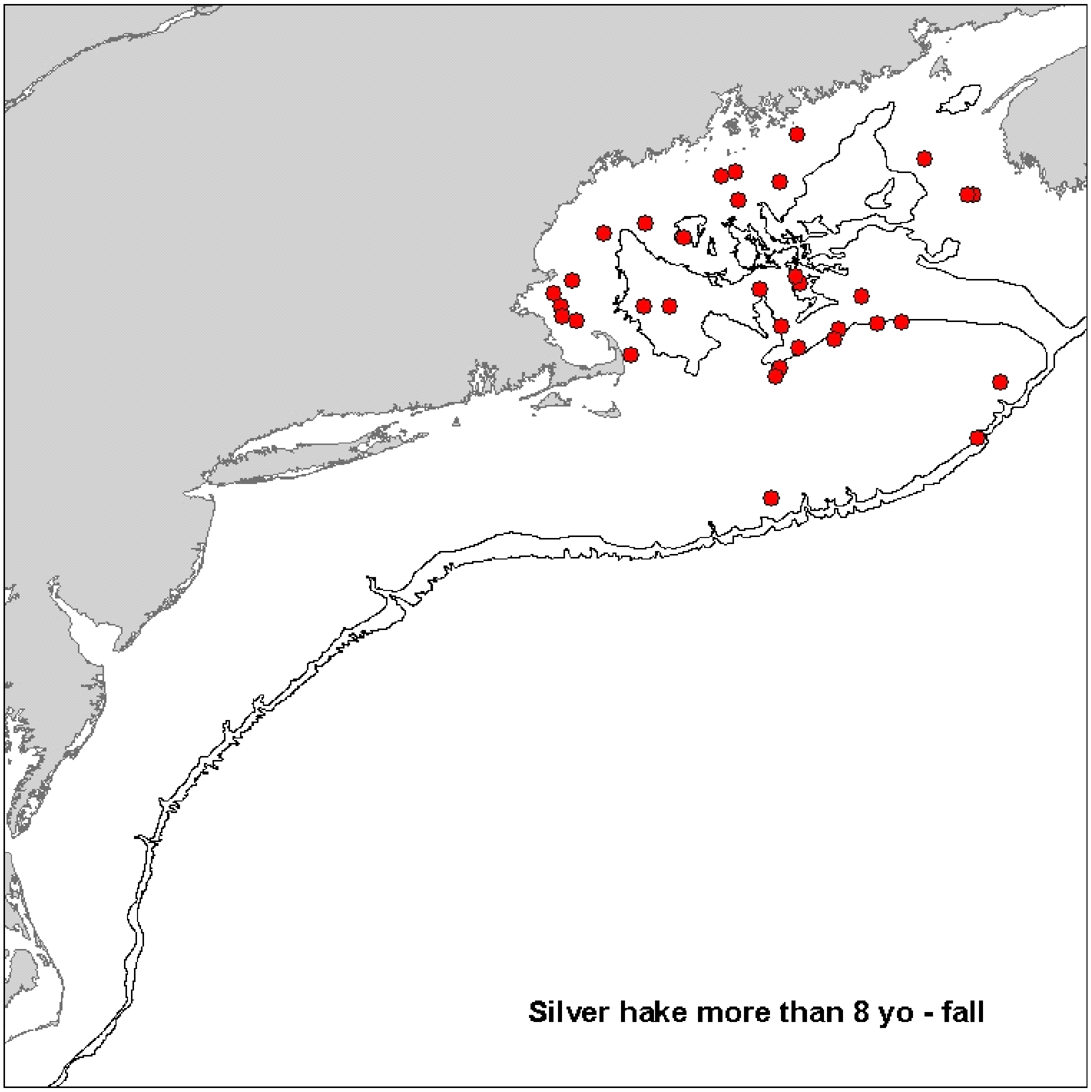


Figure A40. Catch locations for silver hake 8+ y captured during NEFSC fall surveys since 1973.

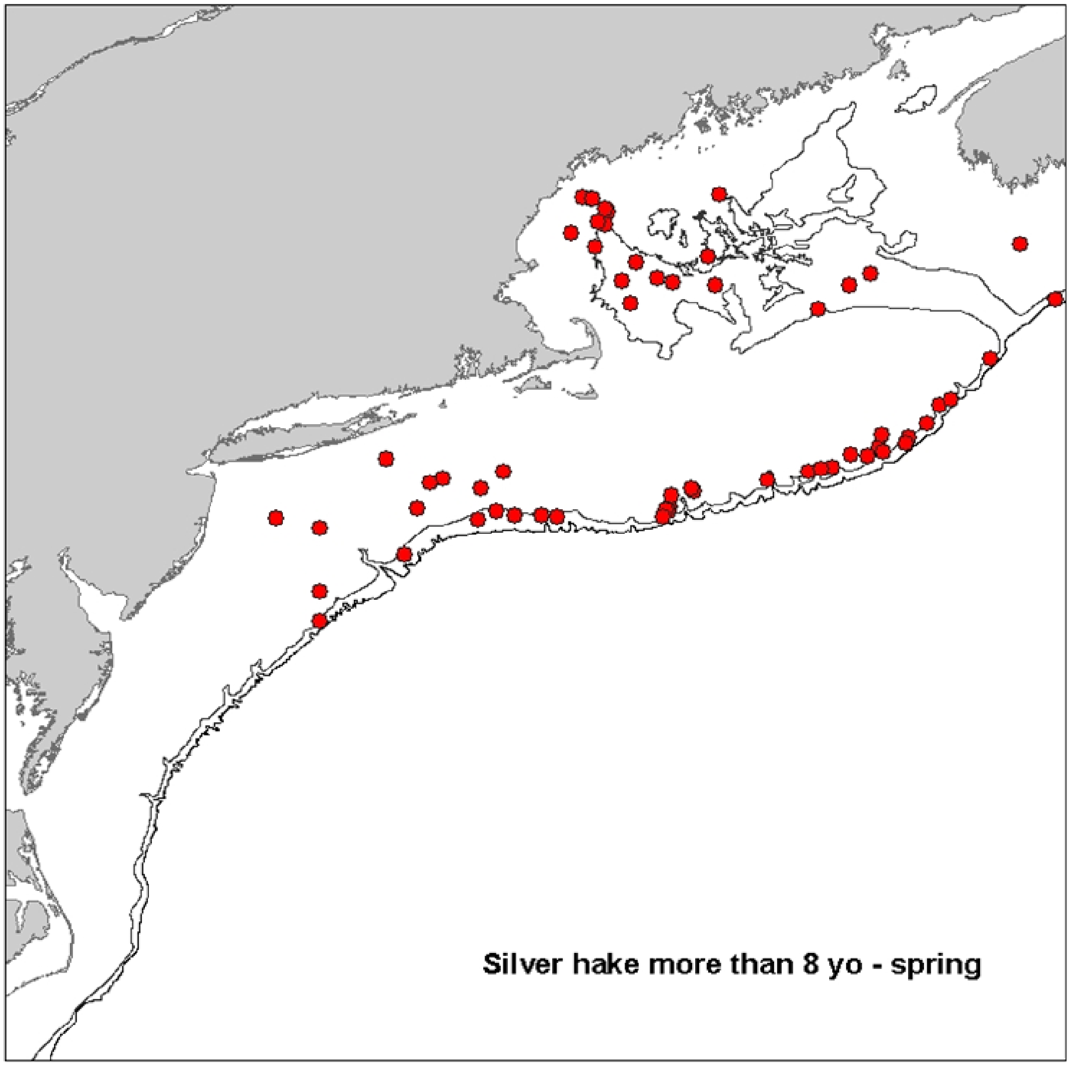


Figure A41. Catch locations for silver hake 8+ y captured during NEFSC spring surveys since 1973.

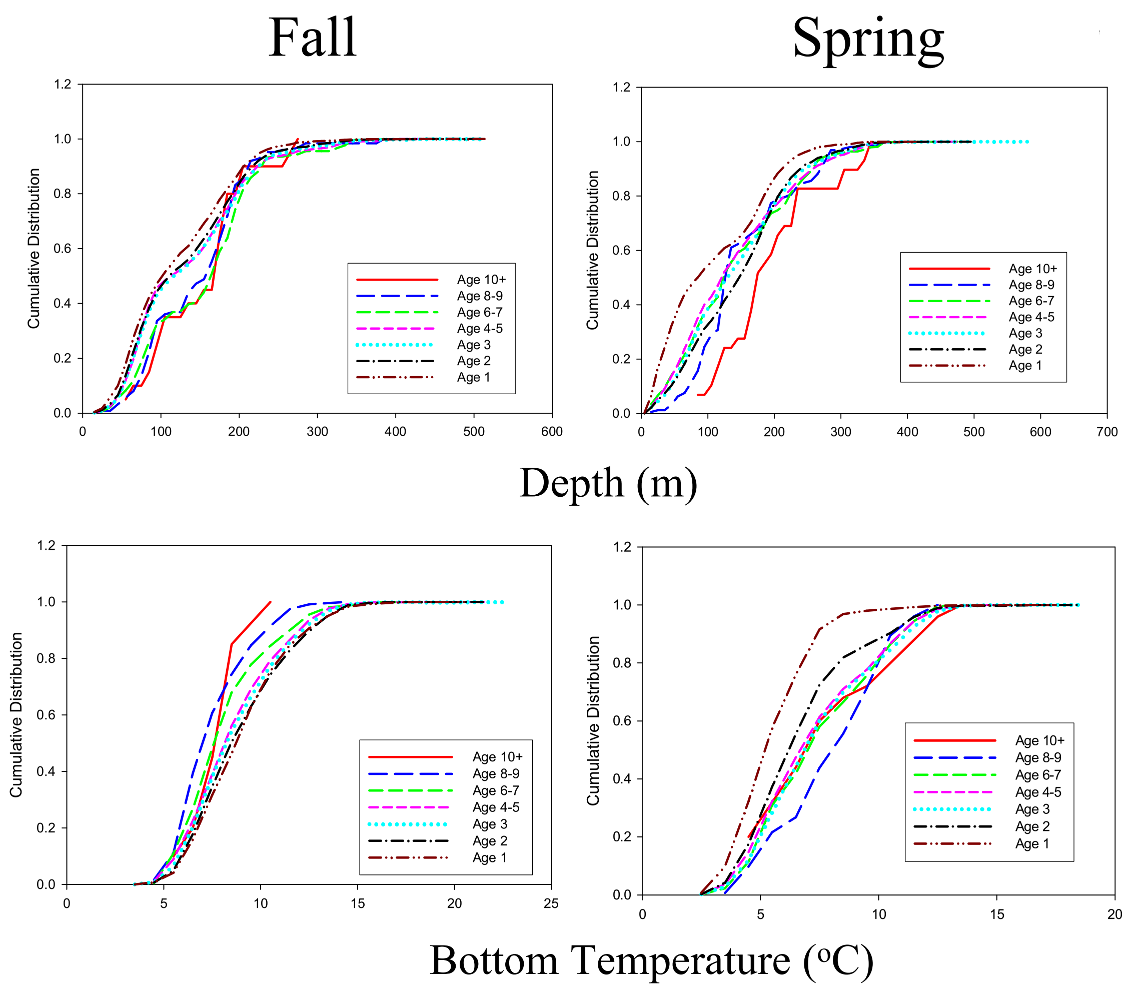


Figure A42. Cumulative depth and bottom temperature distributions for silver hake ages 1-10+ in NEFSC fall and spring bottom trawl surveys.

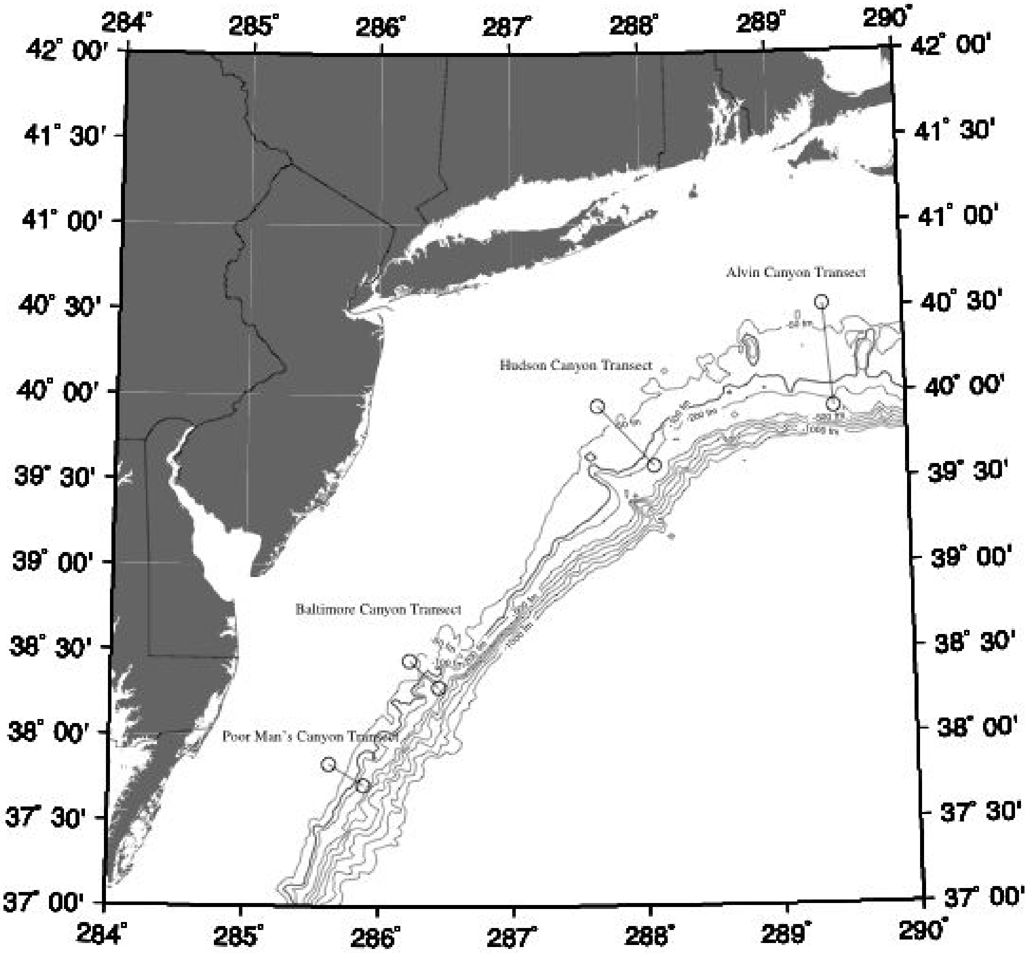


Figure A43. Location of transects for Supplemental Survey sampling. Data from the Baltimore and Hudson canyon transects at depths ≤ 274 m (150 fathoms) were used for silver hake.

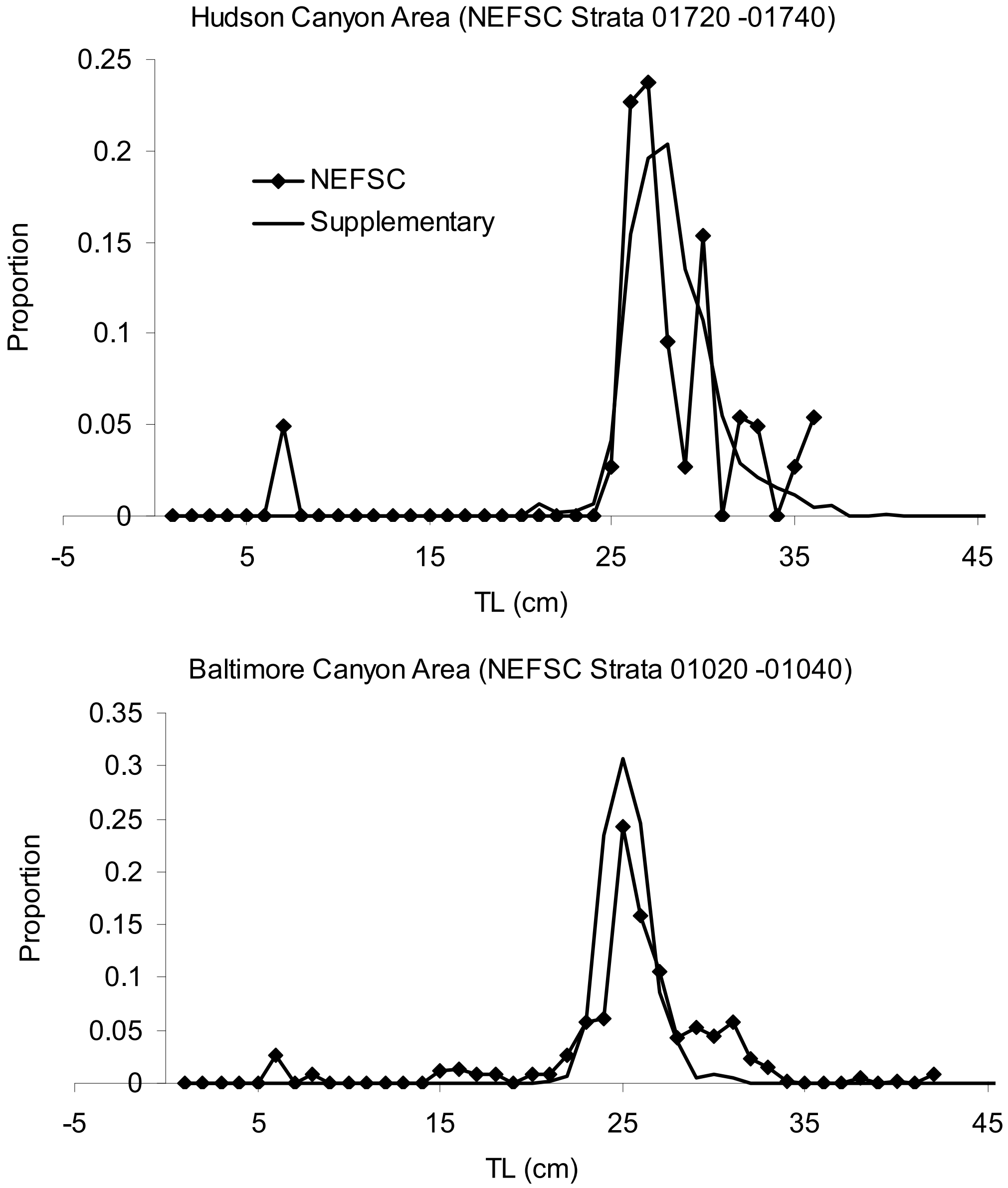


Figure A44. Length composition data for NEFSC and Supplemental surveys during 2004-2005 in the Hudson and Baltimore canyon areas. Data are for 12 tows in each area for the Supplemental survey (both fixed and adaptive stations during day or night were used). NEFSC data are for 14 tows in the Baltimore canyon area and 20 tows in the Hudson canyon area.

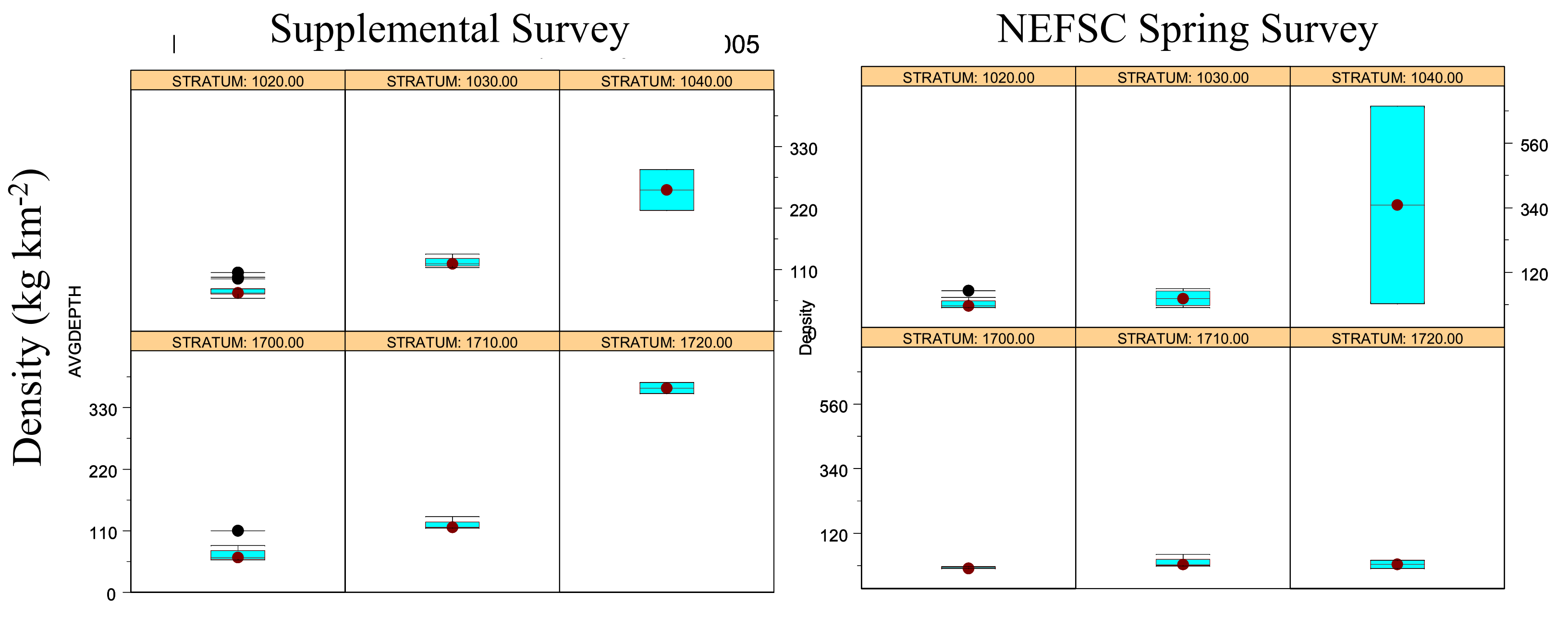


Figure A45. Densities of silver hake measured by the Supplemental and NEFSC spring bottom trawl surveys during March, 2004-2005. Y-axis are the same in all panels.

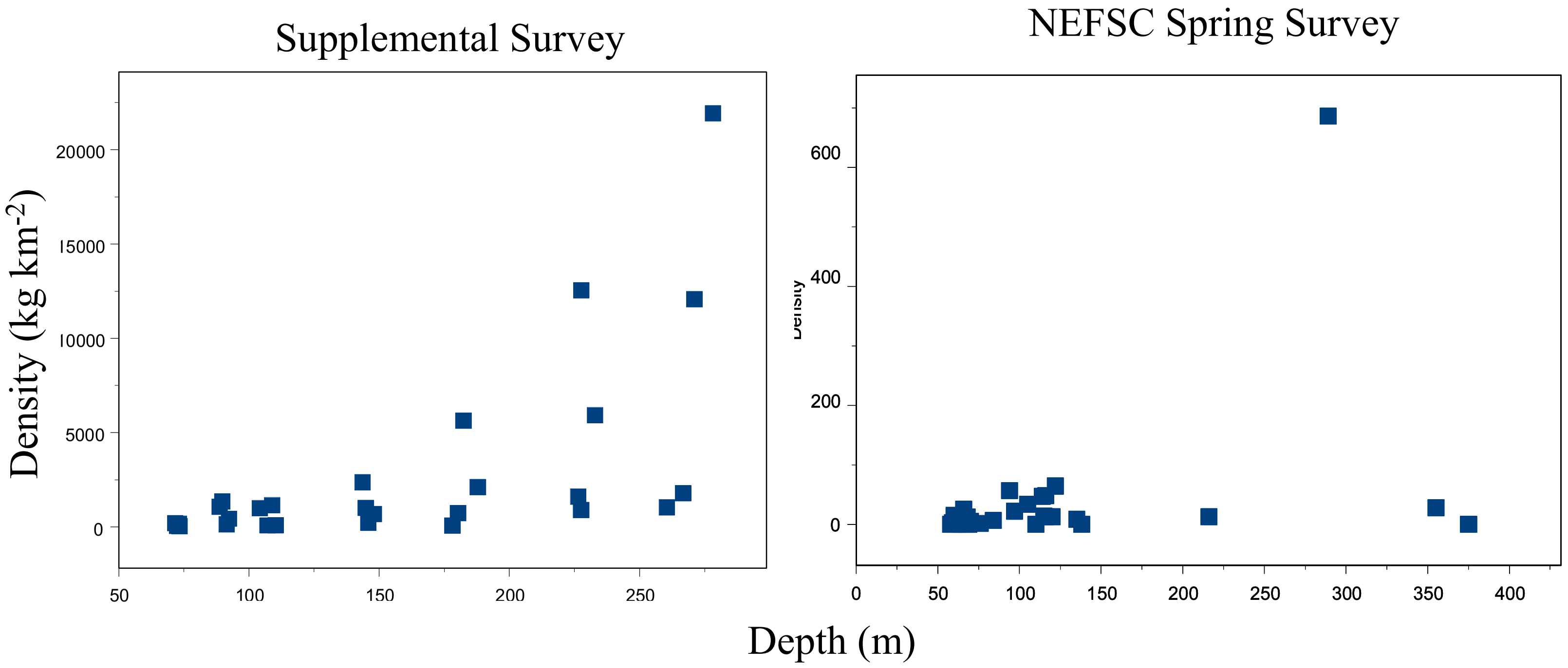


Figure A46. Densities of silver hake measured by the Supplemental and NEFSC spring bottom trawl surveys during March, 2004-2005.

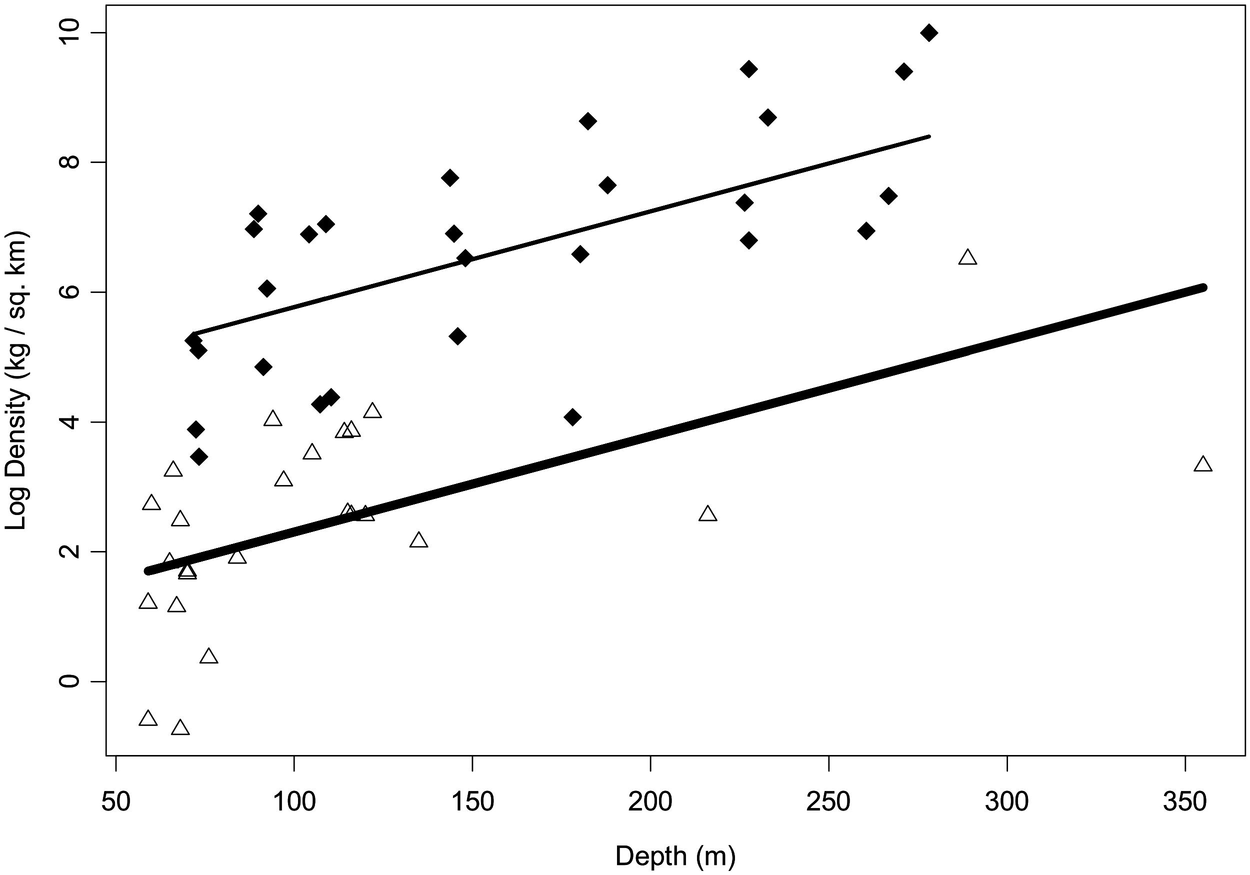
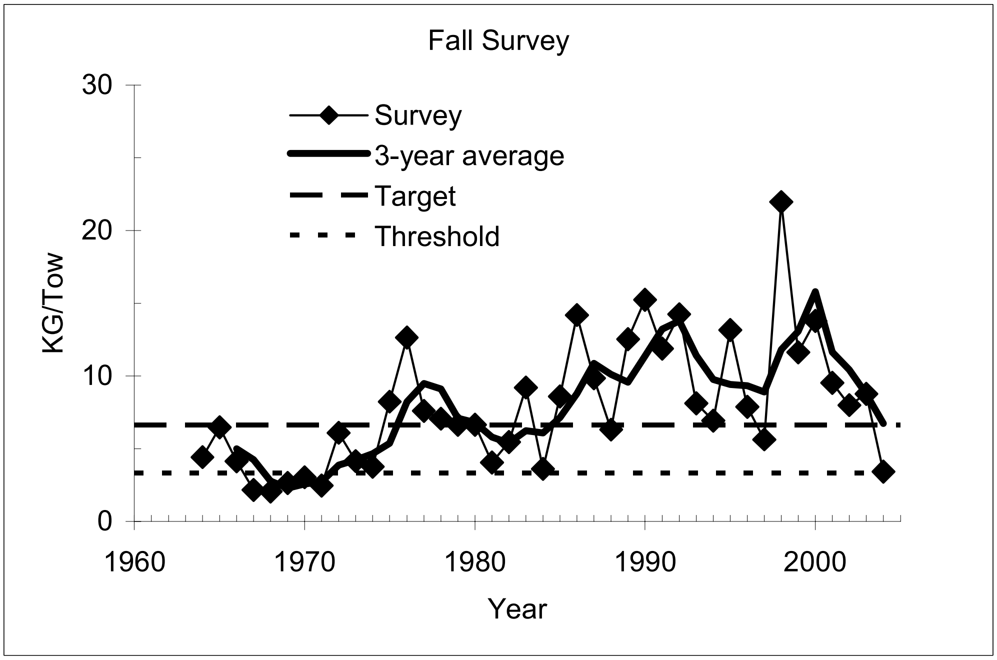


Figure A47. Densities of silver hake measured by the Supplemental (solid diamonds) and NEFSC (open triangles) spring bottom trawl surveys during March, 2004-2005. Lines from the best analysis of covariance model are also shown.



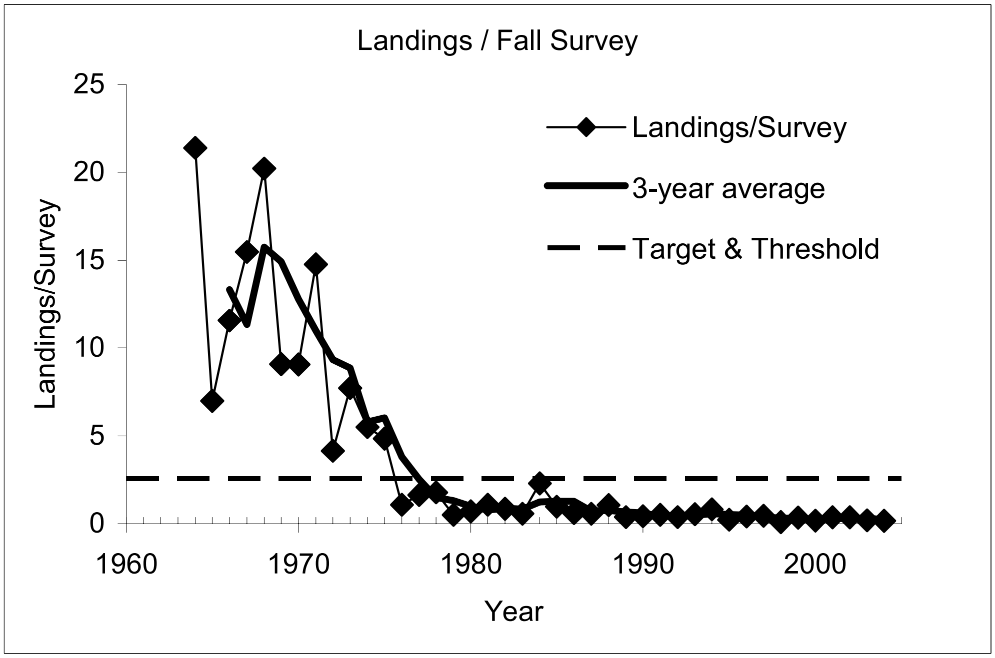
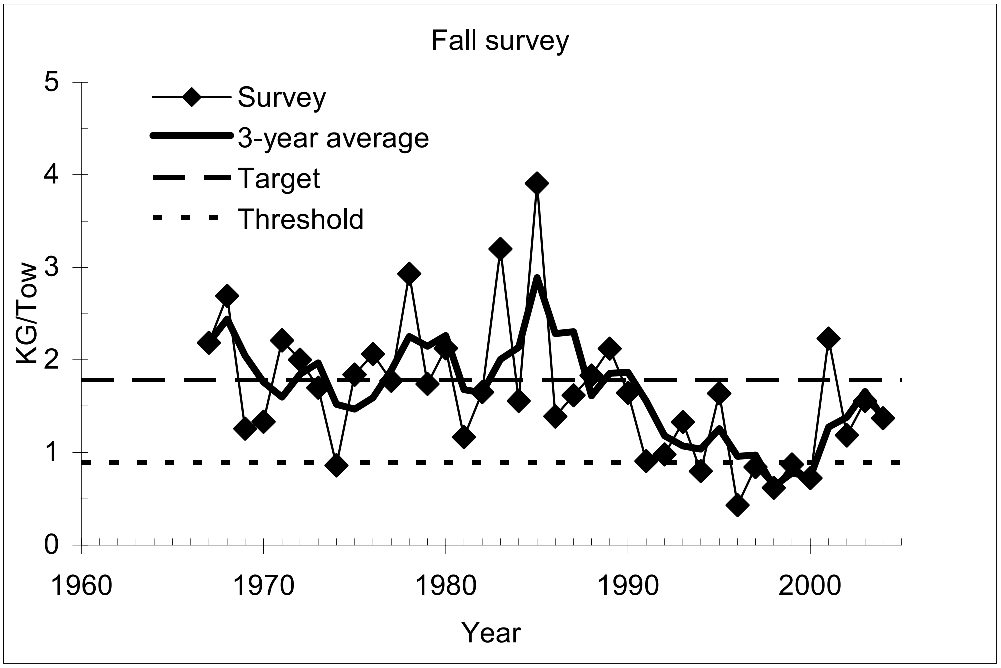


Figure A48. Abundance and exploitation indices for the northern stock of silver hake. Top: fall survey abundance index (delta mean kg/tow, based on consistently occupied offshore strata starting in 1964) with 3-year running average and current reference points for biomass. Bottom: landings/survey (exploitation index) and current reference points.



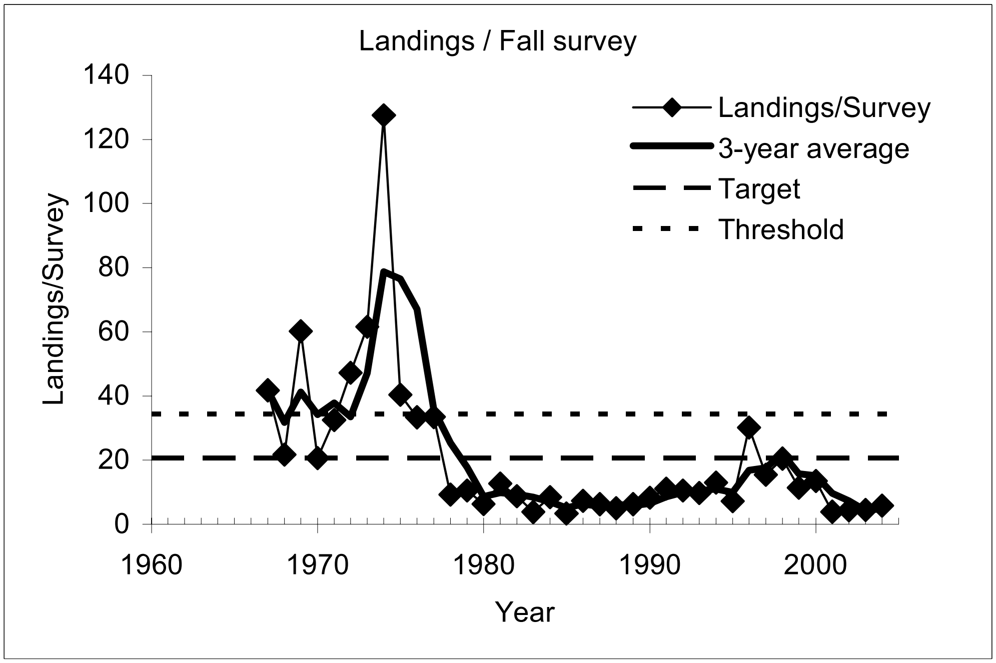


Figure A49. Abundance and exploitation indices for the southern stock of silver hake. Top: fall survey abundance index (delta mean kg/tow, based on consistently occupied offshore strata starting in 1967) with 3-year running average and current reference points for biomass. Bottom: landings/survey (exploitation index) and current reference points.

Figure A50. Lower bounds for fishable biomass and upper bounds for fishing mortality in the northern stock of silver hake during 1964-2004 based on historical landings and fall survey data.

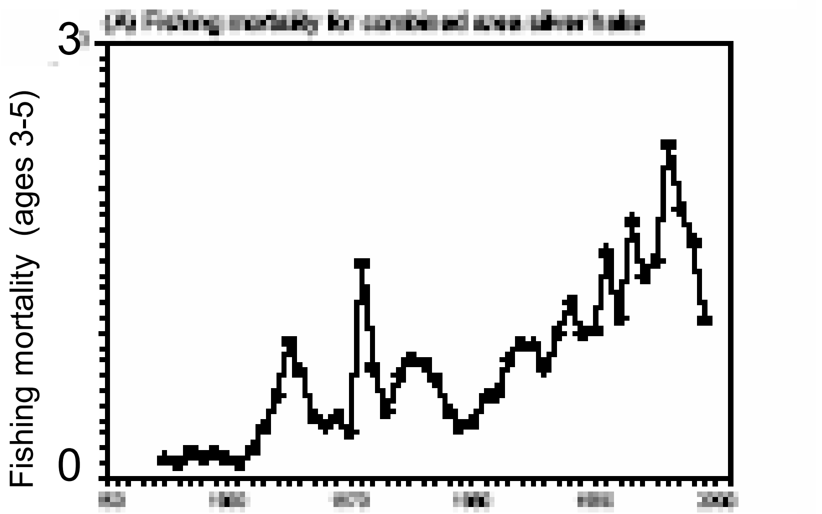
(EDITOR'S NOTE: THIS FIGURE FROM THE WORKING GROUP REPORT HAS BEEN OMITTED. IT WAS NOT ACCEPTED BY THE REVIEW PANEL.)

Figure A51. Lower bounds for fishable biomass and upper bounds for fishing mortality in the northern stock of silver hake during 1964-2004 based on historical landings and fall survey data.

(EDITOR'S NOTE: THIS FIGURE FROM THE WORKING GROUP REPORT HAS BEEN OMITTED. IT WAS NOT ACCEPTED BY THE REVIEW PANEL.)

Estimated fishing mortality and spawning biomass for combined area silver hake from best fit ADAPT model.

(A) Fishing mortality for combined area silver hake



(B) Spawning biomass for combined area silver hake

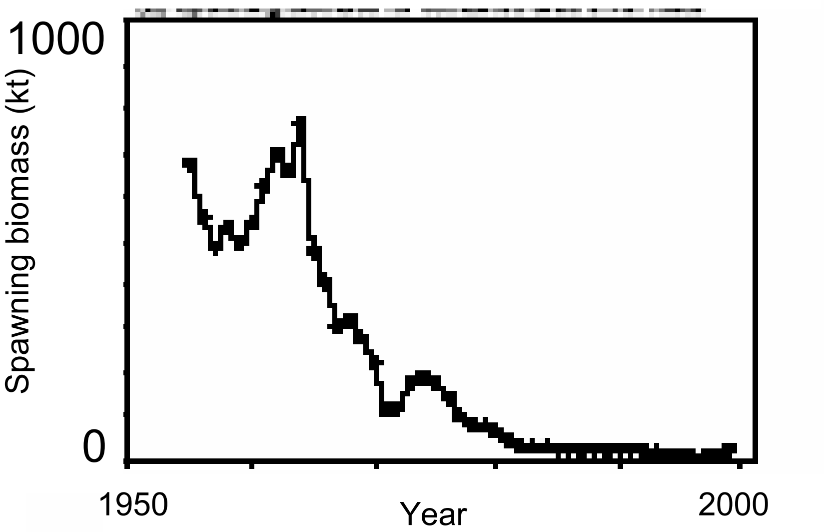


Figure 52. Fishing mortality and spawning biomass estimates for silver hake (northern and southern stock area) from the age structured stock assessment mode in NEFSC (2001).

APPENDIX A1: Stock assessment team members and persons who contributed to the silver hake assessment. "NMFS/NEFSC" stands for the National Marine Fisheries Service / Northeast Fisheries Science Center in Woods Hole, MA.

Name	Organization
F. Almeida	NMFS/NEFSC
J. Brodziak	NMFS/NEFSC
J. Burnett	NMFS/NEFSC
T. Chute	NMFS/NEFSC
L. Col	NMFS/NEFSC
P. Jones	NMFS/NEFSC
L. Jacobson (lead)	NMFS/NEFSC
S. King	Rutgers University (Haskins Shellfish Research Laboratory)
K. Lang	NMFS/NEFSC
J. Link	NMFS/NEFSC
P. Rago	NMFS/NEFSC
K. Sosebee	NMFS/NEFSC
M. Traver	NMFS/NEFSC
S. Wigley	NMFS/NEFSC

APPENDIX A2: Supplemental "Transect" Survey. General information regarding silver hake in the Supplemental "Transect" Survey carried out cooperatively by Industry and the Haskin Shellfish Research Laboratory in Bivalve, NJ. Some calculations (e.g. for "swath areas") were not discussed by the Joint Working Group or used in the assessment for silver hake.

Summary of results for whiting from the Supplemental Finfish Survey Targeting Mid-Atlantic Migratory Species: March 2003 – May 2005

Sarah King
Haskin Shellfish Research Laboratory
Rutgers University
Port Norris, NJ

To date, nine Supplemental Finfish Surveys have been completed. Surveys took place on the F/V Jason & Danielle during the weeks of March 8-12, 2003, May 25-31, 2003, January 24-February 2, 2004, March 4-17, 2004, and May 19-23, 2004. During the weeks of November 15-21, 2004, January 10-22, March 13-23, and May 4-10, 2005 the survey was conducted on the F/V Luke & Sarah. Two transects located near Hudson and Baltimore Canyon were sampled during every survey effort. A transect near Poor Man's Canyon was sampled during March of 2004 and 2005 and in March of 2005, a transect was sampled near Alvin Canyon (Figure 1). The survey gear, including net, sweep and doors were transferred from the original survey vessel and have remained constant throughout the survey. In November 2004, two new codends were built by the same company and to the same specifications as those used during previous surveys.

To obtain a relative index of silver hake, *Merluccius bilinearis*, from the Supplemental Finfish Surveys Targeting Mid-Atlantic Migratory Species, all calculations have been adjusted to swath area. Swath area measures the relative importance of each sampled depth according to its contribution to total distance along the transect line set perpendicular to the depth contour. Figure 2 shows an example of how the distance along the transect line was allocated to each tow for the calculation of swath area. The calculation projects the swept area of the tow had the net been towed continuously down slope along the transect line, from the shallowest to deepest station, for the distance allocated to each sample depth. This distance is established by the midpoints between perpendiculars dropped to the transect line from the midpoints of each tow (Figure 2).

During the March 2003 survey, silver and offshore hake were not separated and thus, the March 2003 data were excluded from this synopsis. Since the Poor Man's and Alvin Canyon transects were not sampled during every survey effort, data from these transects were also excluded.

Cross-Shelf Biomass By Transect and Survey

The highest overall cross-shelf projected biomasses were observed during March of 2005 along the Hudson and Baltimore Canyon transects. The survey consistently caught, in biomass and abundance, more whiting along Hudson Canyon transect than Baltimore Canyon transect (Tables 1 & 2 and Figure 3).

Swath Projected Biomass By Depth

In order to understand how whiting are distributed both spatially and temporally, the data are broken down by transect, by survey, and by depth. A comparison of depth changes for the 20th, 50th, and 80th percentiles of cumulative catch on each transect is plotted in Figure 4. The 50th percentile, for example, is the depth where the cumulative catch curve reached 50% of the total catch and the 20th and 80th percentiles are confidence interval bands, where cumulative catch reached 20% and 80% of the total catch. Observations show that silver hake are widely distributed across the shelf but are caught most frequently at depths ranging from 80 to 350 m on the Hudson and Baltimore Canyon transects. Whiting are caught as deep as 457 m, the deepest station, though catches tend to be smaller and less frequent at these depths (Table 3 and Figure 4). It is likely that the survey misses a small percentage of the inshore portion of the stock during some surveys. Instances include all of the surveys, but most notably May 2003 (Baltimore), May 2004 (Hudson and Baltimore) (Table 3). Also noteworthy, is the fact that the whiting catches occurred in deeper water more frequently in 2005 than in 2003 and 2004, and it is likely that the survey also misses a small percentage of the offshore portion of the stock.

Silver hake appear to make seasonal inshore/offshore migrations and the population tends to be situated further offshore on the Baltimore Canyon transect than the Hudson Canyon transect (Figure 4). Generally, silver hake are narrowly distributed inshore during the spring surveys (May 2003, 2004, 2005) and migrate further offshore, spreading out over the shelf, during the winter months (March and November 2004 and January 2005). Along the Hudson and Baltimore Canyon transects during the May 2003 and 2004 surveys, silver hake tended to be most abundant at depths ranging 80-130 m. They spread out over the shelf and move into deeper water during the winter surveys. For example, 60% of the whiting caught along the Hudson Canyon transect occurred at depths of 90-180 m during March 2004, and 210-325 m, in January 2005. Along Baltimore Canyon transect, 60% of the whiting caught occurred at depths ranging from 110-260 m, in March 2004 and 270-360 m, in January 2005 (Figure 4).

Cross Shelf Numbers Per Size Class By Transect and Survey

The size of silver hake caught ranged from 19-52 cm during the March 2004 and 2005 supplemental surveys (Table 4 and Figure 5). More than 95% of the whiting measured during the March surveys ranged from 21-34 cm.

Length-Weight Relationship By Transect and Survey

The von Bertalanffy equation for isometric growth is: $W = a\sum L^b$, where W=weight, L=length, b=3, and a is a constant. The length-weight relationships observed for whiting are consistent with this equation and the growth exponent, b, ranged from 3.23-3.30, and R^2 values fell between 68-85% (Figure 6).

Median Size Class Per Depth By Transect and Survey

The 50th percentile size class was determined for each depth sampled for tows with 20 or more measured individuals (Table 5). Within a given survey, the median size of whiting does not appear to vary with depth. In a given survey, the median size of whiting caught on the Baltimore Canyon transect is, on average, 1-2 cm larger than whiting captured on Hudson Canyon transect (Table 5 and Figure 7).

Table 1 (APPENDIX A2). Swath area whiting catch (kg) per tow summed across all tows per transect. This is a theoretical number caught if the net had been towed continuously down slope from the shallowest to the deepest station along each transect.

	Hudson Canyon Transect	**Baltimore Canyon Transect**
May 2003	240,209.7	17,214.3
January 2004	966,929.5	96,870.9
March 2004	3,057,810.4	256,876.6
May 2004	1,184,289.6	187,153.3
November 2004	5,218,371.8	799,376.9
January 2005	3,041,186.9	499,071.9
March 2005	9,445,397.0	1,130,256.1
May 2005	5,215,401.3	625,998.6

Table 2 (APPENDIX A2). Swath area projected total abundance of measured whiting across all tows for each survey. The multiplication of these numbers and the percentages in Table 4, provide the reader with the project number of whiting per size class (March 2004 and 2005, only).

	Hudson Canyon Transect	**Baltimore Canyon Transect**
May 2003	1,171,783.4	76,713.8
January 2004	68,783,310.9	815,642.1
March 2004	646,675,951.2	12,803,011.3
May 2004	24,839,510.8	1,111,541.7
November 2004	4,176,326,937.9	1,211,781,610.3
January 2005	3,332,306,046.2	235,738,849.4
March 2005	14,076,324,593.3	894,659,210.2
May 2005	1,663,613,791.5	41,528,449.4

Table 3 (APPENDIX A2). Percentage of total whiting catch (kg) at each depth. Dashes represent stations that were not sampled. For each transect, the depth with highest percentage of whiting caught per transect is highlighted. H=Hudson Canyon transect, B=Baltimore Canyon transect.

Target Depth (m)	**Mar-04**		**Mar-05**	
	H	**B**	**H**	**B**
73.15	3.38	2.00	1.47	0.32
82.30	-	-	-	5.96
91.44	26.14	13.73	12.08	5.30
100.58	1.28	-	1.09	2.56
109.73	9.23	11.15	3.42	2.63
128.02	10.75	-	2.22	-
146.30	17.88	24.47	2.64	18.64
164.59	8.94	3.00	-	-
182.88	3.61	0.66	11.75	10.98
204.83	-	6.10	8.29	-
228.60	7.51	4.45	14.62	16.59
250.55	2.01	11.11	14.22	3.23
274.32	9.15	19.67	12.68	25.48
320.04	-	2.35	13.93	5.80
365.76	0.12	1.30	0.69	2.33
387.71	-	-	-	-
411.48	0.00	0.02	0.88	0.19
457.20	0.00	-	0.02	-

Table 4 (APPENDIX A2). Cumulative size-frequency distribution of whiting across all tows, reported as a percentage of total abundance. For each transect, the size with highest percentage of whiting caught per survey is highlighted. H=Hudson Canyon transect, B=Baltimore Canyon transect.

Length	**Mar-04**		**Mar-05**	
(cm)	**H**	**B**	**H**	**B**
18	0	0	0	0
19	0	0.001	0	0
20	0	0	0.32	0
21	0.03	0.77	3.30	0.12
22	0.64	0.41	17.47	0.90
23	1.59	0.15	29.53	4.82
24	7.62	0.76	22.59	21.85
25	15.55	3.28	14.55	30.54
26	18.76	15.52	5.82	26.77
27	14.83	19.71	4.15	7.57
28	15.41	22.51	0.85	5.02
29	8.16	13.32	0.41	0.75
30	8.29	11.52	0.15	0.85
31	3.89	3.95	0.03	0.74
32	1.09	2.42	0.02	0.01
33	1.68	2.29	0.01	0.01
34	0.80	1.20	0.13	0.0004
35	0.60	1.18	0.003	0.003
36	0.48	0.33	0.01	0.01
37	0.15	0.56	0.02	0.01
38	0.32	0.03	0.45	0.02
39	0	0.07	0.0003	0
40	0.10	0.03	0	0.001
41	0.002	0	0	0
42	0	0	0.01	0
43	0.002	0	0.17	0
44	0	0	0.01	0
45	0	0.01	0.001	0
46	0	0	0	0
47	0	0	0	0
48	0	0	0	0
49	0	0	0	0
50	0	0	0	0
51	0	0	0	0
52	0	0	0.001	0
53	0	0	0	0

Table 5 (APPENDIX A2). Dashes represent tows where less than 20 whiting were measured or station was not sampled.

Target Depth (m)	**Mar-04**		**Mar-05**	
	H	**B**	**H**	**B**
73.15	26.7	28.1	24.9	26.1
82.30	-	-	-	24.9
91.44	27.0	28.9	25.0	25.3
100.58	26.9	-	25.1	24.8
109.73	26.3	-	25.2	25.0
128.02	-	-	26.8	-
146.30	27.1	28.1	23.9	24.2
164.59	25.6	28.6	-	-
182.88	25.5	-	22.5	24.1
204.83	-	27.2	23.0	-
228.60	25.6	26.5	22.6	24.4
250.55	25.0	27.7	23.3	24.4
274.32	27.8	27.3	23.1	24.8
320.04	-	28.8	23.5	24.9
365.76	-	27.9	25.6	25.0
387.71	-	-	-	-
411.48	-	-	24.5	24.8
457.20	-	-	-	-
Overall	**26.4**	**27.4**	**23.0**	**24.7**

Figure 1 (APPENDIX A2). Location of transects sampled during Supplemental Survey cruises.

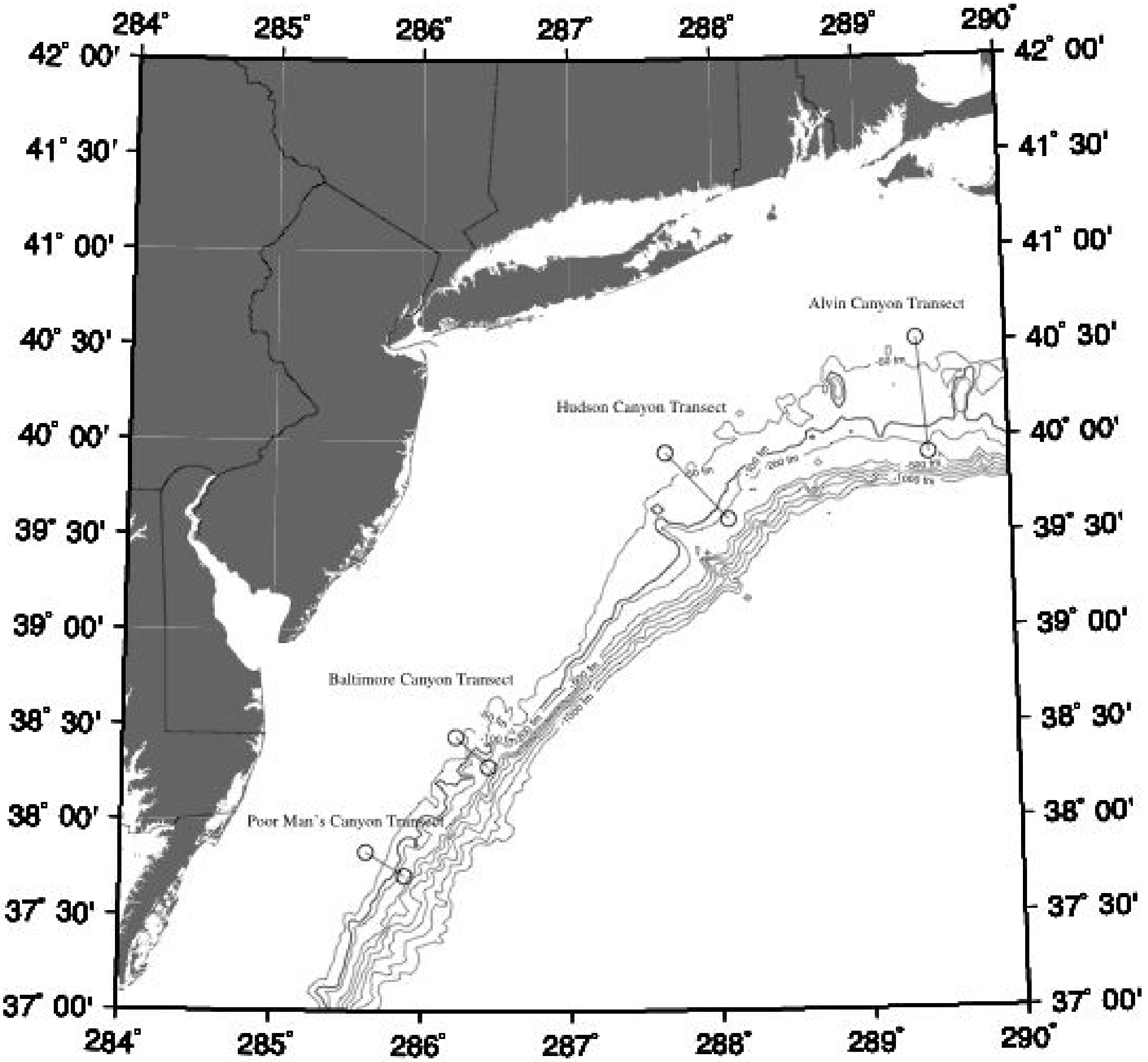


Figure 2 (APPENDIX A2). Swath distance for tows 1, 2, and 3, taken near a transect, showing the distance allotted to each tow had it actually been taken along the transect line.

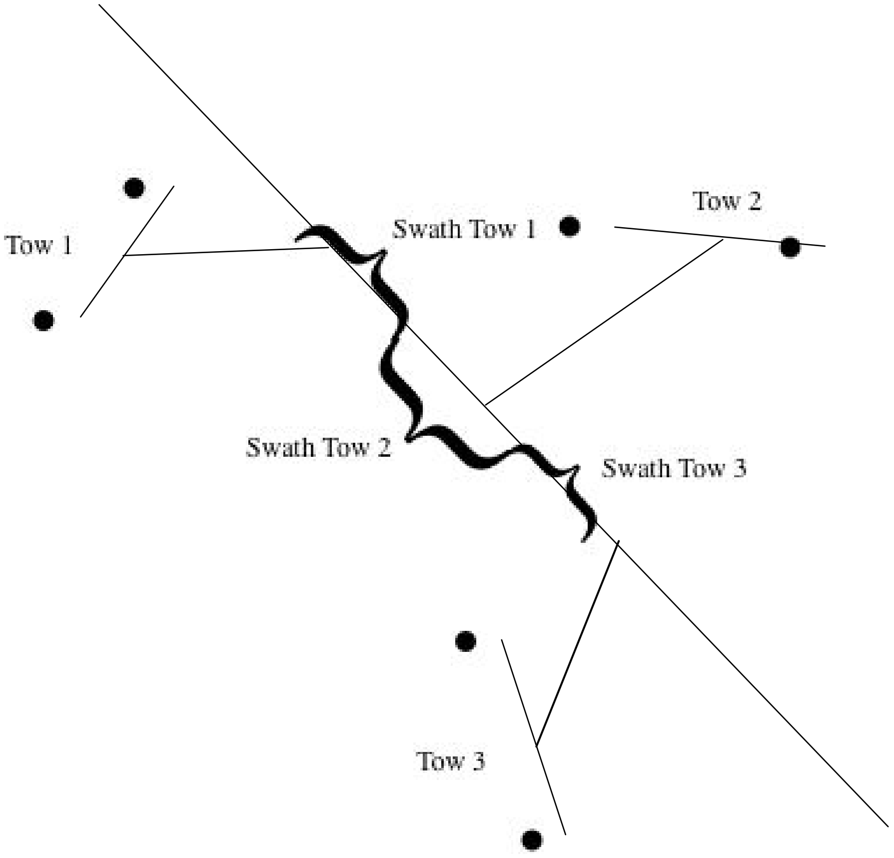


Figure 3 (APPENDIX A2). Projected biomass and abundance of whiting along each transect for each survey. In order to display all of the data on the same figure, there is an axis break in projected biomass. Logarithmic axis scaling was necessary in order to plot the projected abundances from all of the surveys on one figure.

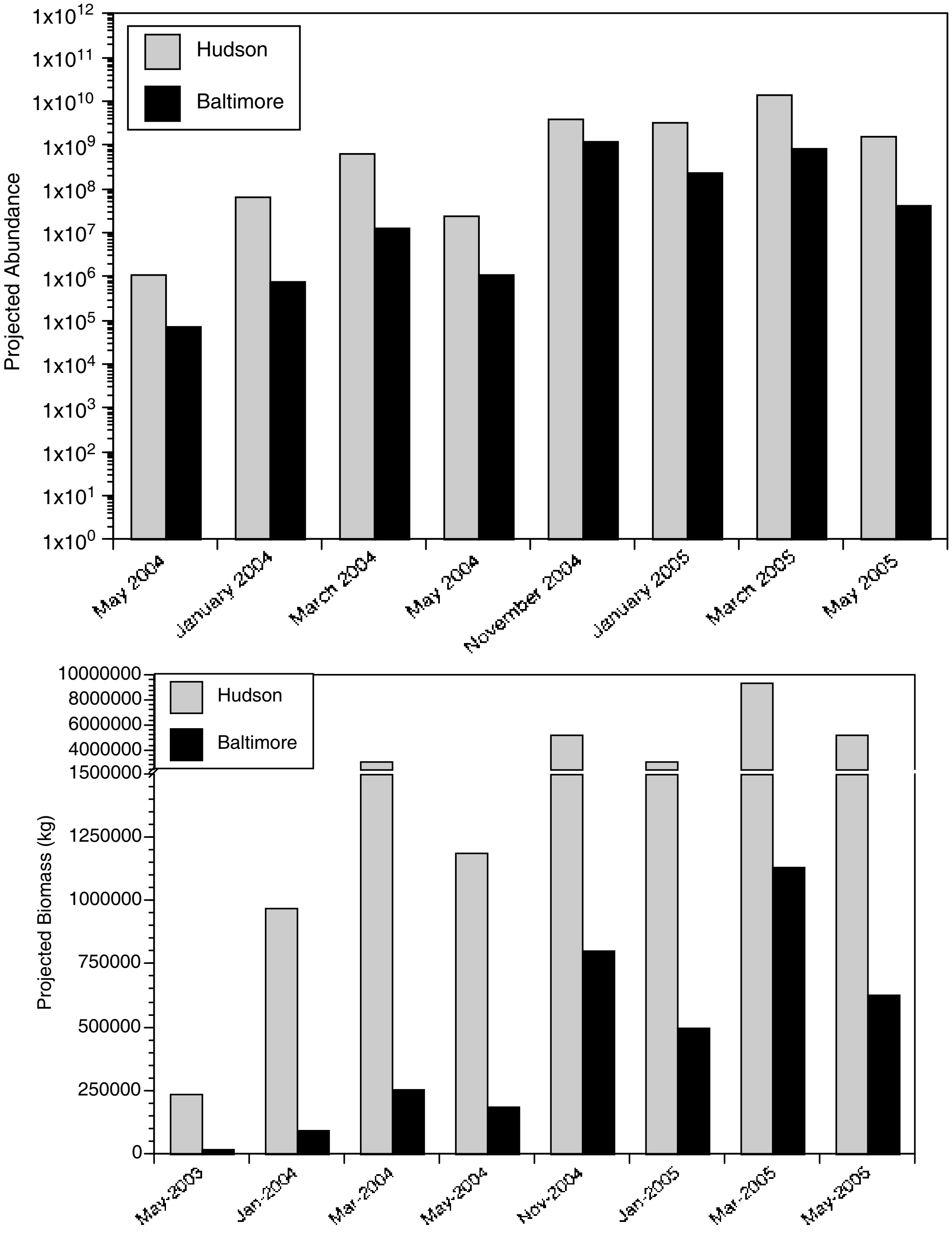


Figure 4 (APPENDIX A2). Comparison of changes in depth for the 20th, 50th, and 80th percentiles of cumulative catch during all surveys completed through May 2005. To calculate the percentiles, swath area catch (Table 2) was cumulated from the shallowest to the deepest station on each transect. The 20th percentile, for example, is the depth where the cumulative catch curve reached 20% of the total catch.

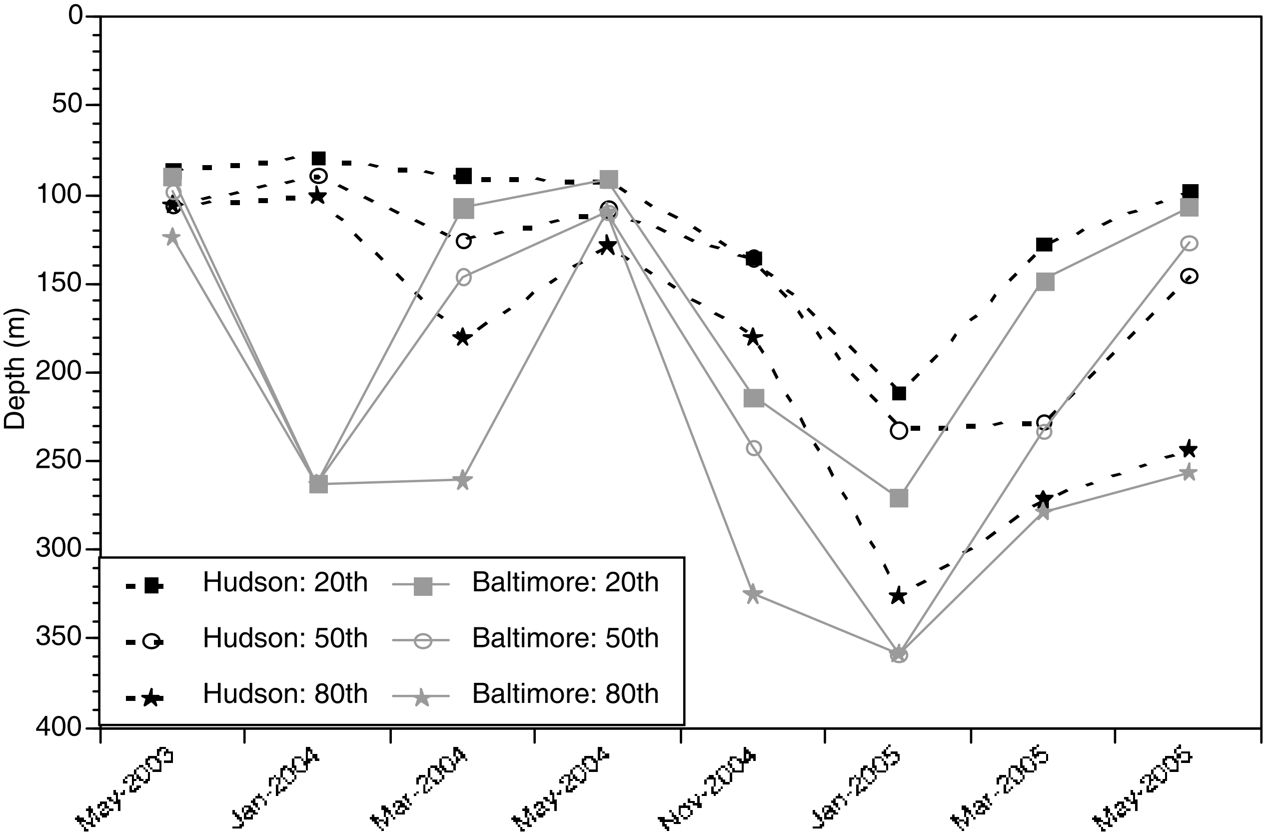


Figure 5 (APPENDIX A2). Projected number of whiting per size class across all tows for the March 2004 and 2005 surveys. Tow size frequencies were corrected to the number caught per km^2 swept area. Tows were then normalized to swath distance along the transect and the abundances were summed across all tows for each transect. Logarithmic axis scaling was necessary in order to plot data from all surveys on one figure. Note: zeros were not plotted.

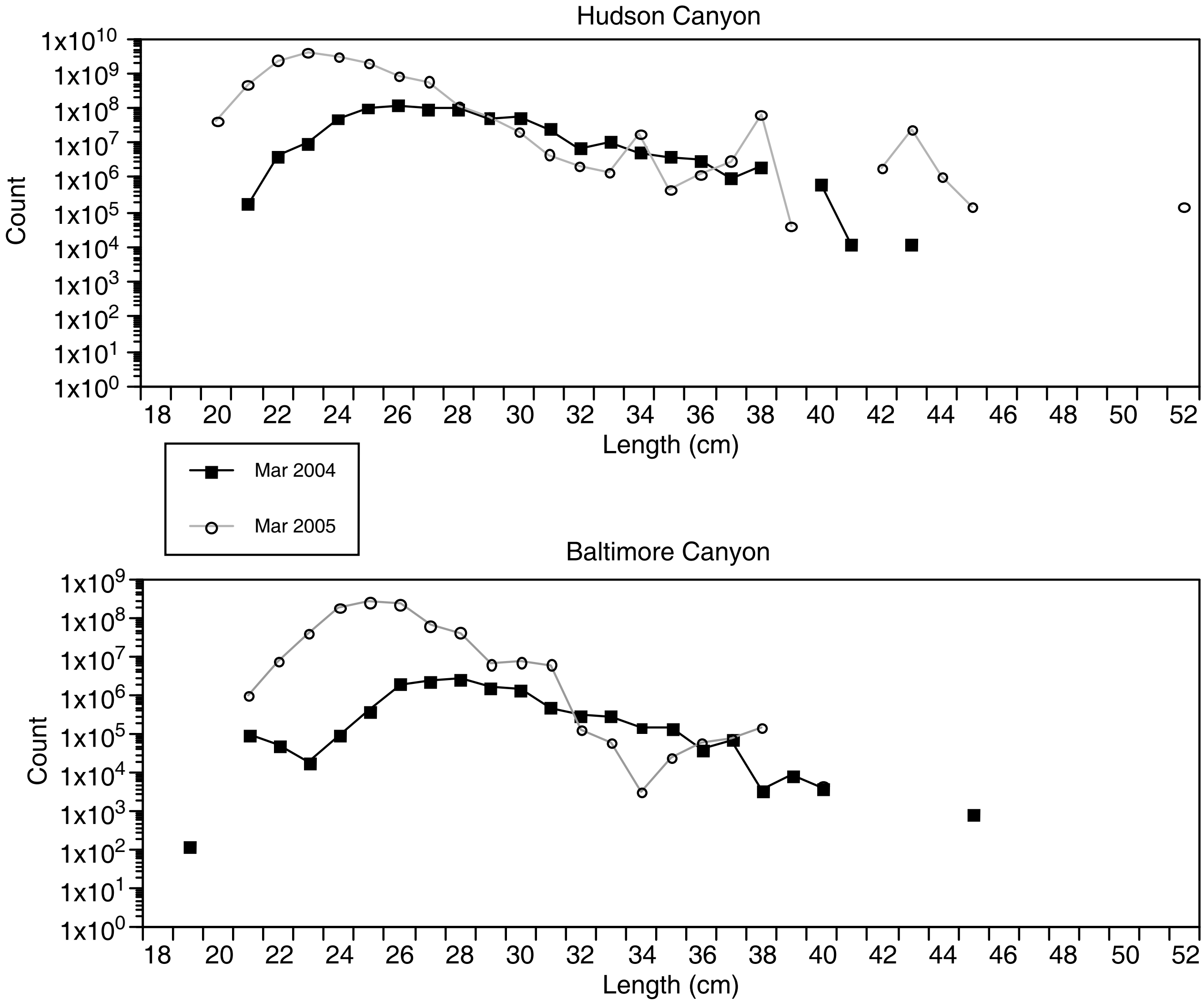


Figure 6 (APPENDIX A2). Relationship between length and weight for silver hake measured in March 2004 and 2005. f(x)=weight, x=length.

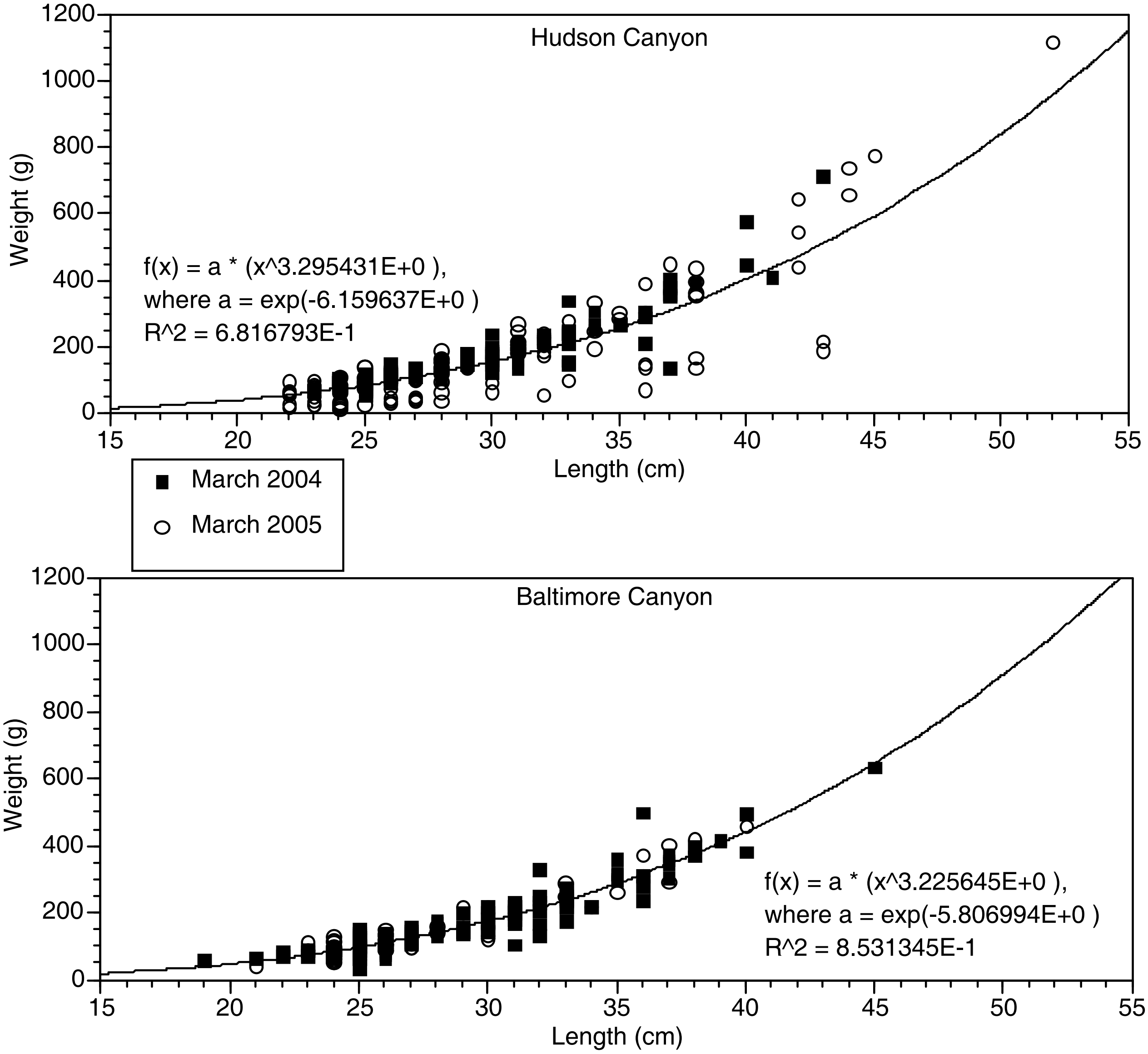
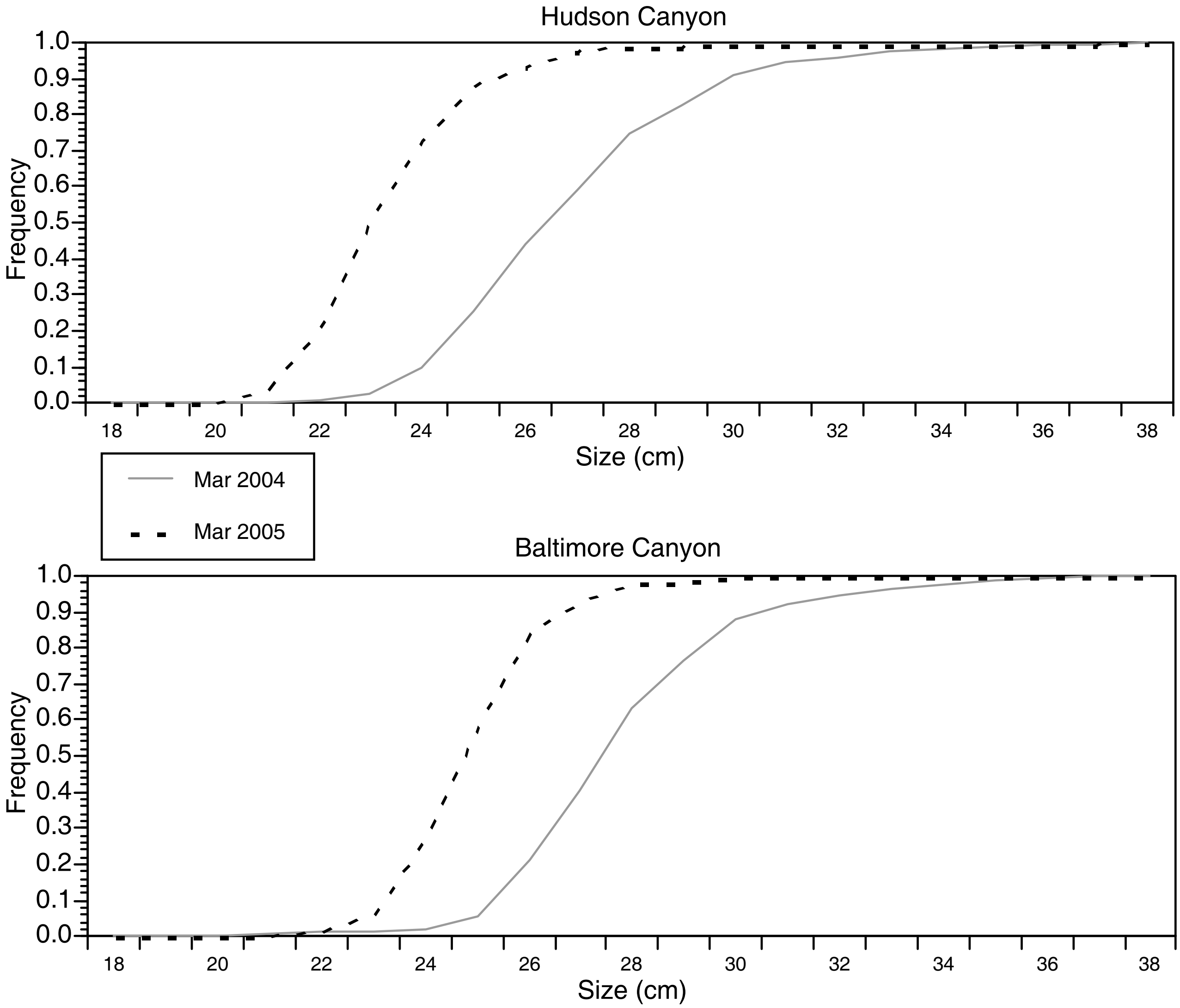


Figure 7 (APPENDIX A2). Cumulative size frequency for whiting from the March 2004 and 2005 surveys.



APPENDIX A3: Chairman and Rapporteur's Report from Working Group Meeting.

Silver Hake WG Meeting, Oct. 24-28, 2005.

Truncation of Older Fish

A concern was raised that the relatively high spawning stock biomass and low fishing mortality estimates for silver hake are inconsistent with the recent truncation of older, larger fish in the commercial and NMFS survey data. The Working Group also noted that the change in total mortality needed to account for the observed decline in age structure seems unrealistic. The intense fishing effort by foreign fleets during the 1960s and 1970s may have caused such a decline in age structure, but it was noted that recently the age structure does not show expansion despite decades of lower fishing effort. It was observed that the truncation of the older silver hake started in the mid 1980s when survey doors changed, and it was recommended that gear comparisons be reexamined by length.

Ageing error was discussed as one possibility for the recent lack of older silver hake, since sectioning methods and age readers have changed. Attempts to re-age old fish from archived otoliths show that new ages average one to two years younger than original ageing. However, these slight biases do not seem to explain the age truncation seen in the survey, and the older fish in the earlier part of the survey time series also correspond to larger fish than are currently being observed.

The Working Group also discussed the possibility that the older fish in the historical NMFS data could have been miss-identified as offshore hake. In the NMFS spring survey, the distributions of older silver hake roughly corresponded to offshore hake distributions. However, it is not likely that the aged fish are mis-identified since the otoliths are distinct between the two species, and no mis-identified otoliths have been found in recent years. The older fish also seem to fall on the same age-length growth curve as the young silver hake, indicating that they are most likely not offshore hake, although growth curves for offshore hake were not examined. The commercial sample data are not aged. The commercial catch is not sorted by species and may include offshore hake, especially from the area along the shelf edge where offshore hake are often found.

The decrease of large silver hake in commercial landings was discussed by the Working Group, and it was noted that the closure of areas for lobster pot fisheries could be affecting catch composition since large fish were historically caught in these areas. The recent decrease in silver hake landings can be attributed to catch limits implemented in 2001.

Stock Structure

A question was raised about whether the northern and southern silver hake stocks are in fact distinct. The two stocks are within close proximity to each other, and it is thought that some exchange exists between the two areas. However, there is currently no new evidence to refute the current stock structure assumed in management.

The Working Group noted that silver hake recruitment seemed strong in both stocks. Concern was expressed that estimates of fishable biomass of silver hake in the NMFS surveys is far less in the southern stock than in the northern stock. Several potential explanations were discussed including greater fishing efforts in the south, less thorough coverage of silver hake habitat by NMFS surveys in the south, especially in deep waters, and possible exchange between the Scotian Shelf and the northern stock.

Survey and Commercial Data Uncertainty

Concern was expressed that the catchability of silver hake in the NMFS survey could be variable since silver hake are known to come off the bottom during the day. The point was also made that the decreased catchability during the day could be a net avoidance issue, since the species is a visual feeder. However, the NMFS survey design assumes that strata are sampled randomly during day and night, and catchability is not biased over the time series.

Commercial discard estimates were calculated on a trip basis, but the Working Group discussed examining changing target species between tows. Due to variability between years, small sample sizes, and the belief that target species during a trip would not frequently change, discards were estimated on a trip basis. A recommendation was made to also include catches that are entirely discarded, as well as some fisheries with low discard rates but large landings such as large mesh groundfish. Despite the low discard ratio of silver hake in the groundfish fishery, these discard estimates should be included due to the substantial catch volume.

Depth was found to be a more significant predictor of large silver hake distribution than temperature, and concern was expressed that the NMFS survey does not thoroughly cover deeper habitat. The Working Group noted that interactions should be tested between temperature and depth in GAM models.

Population Density Estimation

The Working Group discussed possible issues for using supplemental survey data to calibrate NMFS survey data. These issues include uncertainty of area swept, diel migration of fish, tow duration, and availability of tow-specific sensor data. These concerns merit further research. The analysis would benefit from controlled side-by-side tows involving both vessels. Estimates were only applied in the southern region where the surveys overlapped.

Three methods were presented to calculate an expansion factor of silver hake density between NMFS and supplemental surveys, and the viability of each method was discussed. Small sample sizes were a concern for all of these models. The first method estimated a median density by year and strata in order to obtain a ratio of relative fishing power, but was inefficient in utilizing the available data. The second method was to use a conventional ratio estimator. The bootstrap estimates of precision for this method show substantial bias due to small sample size. A third regression method using density by tow was performed in order to use the survey data most efficiently and account for depth and other effects. The regression method had the narrowest confidence intervals, and was agreed to be the best model using the supplemental survey data.

Finally, a catch-survey ratio method was applied to both stock areas. This method gives a reasonable minimum biomass estimate since the catch in the years of greatest fishing effort cannot exceed the total biomass. Concerns were expressed that the bootstrap results from this method do not reflect all of the uncertainty since a constant catchability is assumed, and a minimum estimate of biomass is not comparable between years. Do to the difficulty in comparing this assessment to previous years and the potential to ignore missing older fish, it was recommended that future assessments be based on model-based assessments.

Research Recommendations:

- A study be conducted to verify silver hake species identification with port agents, and to take additional age samples of larger commercial silver hake.

-The presence of silver hake in stratum 99 of NMFS surveys as well as in special deepwater surveys needs to be examined in order to determine if the NMFS survey is missing silver hake in deeper waters, and if additional tows in existing NMFS deep water stations would be beneficial. All available surveys that cover depths in excess of NMFS surveys should be examined for the distribution of silver hake.

-Acoustics data could be examined to augment silver hake distributions.

-Review effects of gear changes in NMFS survey on catchability of silver hake by size.

-Devise a method to cast the current survey based reference points into a form that is compatible with abundance indices derived from the new vessel.

-A study needs to be conducted to determine the extent of movement along the coast, especially around Georges Bank.

-The next assessment be based on an age-structure model, and reference points be derived from model results.

Sources of Uncertainty:

-There is uncertainty in the aging precision of silver hake from NMFS surveys due to changes in sectioning methods and age readers.

-Offshore hake could be incorrectly identified as silver hake, especially in commercial data.

-Gear changes in NMFS survey could affect catchability of silver hake over time.

-There is uncertainty as to whether silver hake is appropriately divided into two stocks.
-The NMFS surveys may have reduced catchability and coverage in deep water, and may not capture a good representation of the larger silver hake.

APPENDIX A4: Supporting information. Information in this appendix was presented and discussed during the SARC review meeting but not presented in the original assessment document. In most cases, the information was not presented in the original document because it was requested by the reviewers or prepared during discussions. This information was not discussed to the Working Group that prepared the assessment.

Figure 1 (APPENDIX A4) . Silver hake discards and landings (hail weights) for all trips (all gear and primary species groups) with observers during 2001-2004.

```
 Plot of Discard*TargetGrpMT.  Legend: A = 1 obs, B = 2 obs, etc.

Discard |
 7.4180 +    A
        |
        |
        |                                Correlations:
 5.5635 +      A                          Pearson = 0.03 (ns)
        |                                 Spearman =  0.26 (p < 0.0001)
        |   AB                            Kendall Tau = 0.20 (p < 0.0001)
        |   A
 3.7090 +   A
        |
        |  BAB
        |  ADBA
 1.8545 +  DA
        |  BCB       A
        |  DDCB A         A
        |  ZSFD  A
 0.0000 +  ZZZZZZXUNIGGMHGFHEBDFDAAA C BADBD  ABA AAA  AA       A  A   A    B
        ---+----------+----------+----------+----------+----------+----------+--
           0         100        200        300        400        500        600

                                       TargetGrpMT
```

Figure 2 (APPENDIX A4). Same as previous figure except that trips with zero discards are omitted and both axes are log scale.

```
 Plot of LnDiscard*LnGroupMT.  Legend: A = 1 obs, B = 2 obs, etc.

              Correlations:
LnDiscard |    Pearson = 0.37 (p < 0.0001)
        5 +    Spearman =  0.39 (p < 0.0001)
          |    Kendall Tau = 0.27 (p < 0.0001)
          |
          |                                               A  C   A
          |                              A  AA A   AB   CAACBAB
        0 +                              A   AA  A CAAAACAAC BC A A   A A
          |                          A   B A ABAAGBDCBCAEBDDEABC   A
          |                             AACBAEABBAAABDCCIEGGGBB  A  A A    A
          |                    A   AAAC  AEFBCDACBFAGDKFKIDRID B A          A
          | A               A    BEBGCHAFJFGDCC DFJFLHHIQJGHFGD CBC    C    CA
       -5 +                   ACACFAHMKHJGIFGGFBGGCEGFHHMGEFAEF BBBAA   A AAA
          |               A AAACCJGFPJMNLMGAFGEDBGFCHBGDBFEDBECCEDB E  A  A
          |             AB AACBHCJGHURQNMNFKJHEDF DDGCDCCCBCCAABACFBAAA A
          |         A  A   CBBDCDGJCMPXSQGKJMHDCB DBFCCCACBCFCBCEDCAC A   A A A
          |        A   A    A  A AC AADCA CAB  B A     CA  A A   A    A   A  A
      -10 +                      AA  A   A  A        A AA     A    A  A
          |
          --+----------+----------+----------+----------+----------+----------+-
           -6         -4         -2          0          2          4          6

                                         LnGroupMT
```

Figure 3 (APPENDIX A4). *Top*: Silver hake discards and landings (hail weights) for the Trawls gear group and all primary species groups based on trips with observers during 2001-2004. *Bottom*: Same as top but records with zero discard are omitted and both axes are log scale.

```
------------------------------- GearGroup=Trawls -------------------------------

        Plot of Discard*TargetGrpMT.  Legend: A = 1 obs, B = 2 obs, etc.
Discard
 7.3881 +      A
        |
 6.3326 +
        |
 5.2772 +          A
        |    A B
 4.2217 +   A
        |    A
 3.1663 +       A
        |   ABA
 2.1109 +  ABABBA
        |  BB BAA             A
 1.0554 +  CBBA A A  A
        |  NRHHCD
 0.0000 +  ZZZZZUKECFB  BB A      A  AA             A   A A           AAA  B
        ---+----------+----------+----------+----------+----------+----------+--
           0         50         100        150        200        250        300

                                       TargetGrpMT

        Plot of Discard*TargetGrpMT.  Legend: A = 1 obs, B = 2 obs, etc.
          (NOTE: 50 obs hidden.  1429 obs out of range.)
 Discard |
         |
   10000 +
    1000 +
     100 +
      10 +                                            A
       1 +                               AA BB BGBAKCIFEAB A
     0.1 +                            ACABFCHFIIHNOZPZKE  A
    0.01 +             A           DALJOIPSPLHNWUZZZRZKEBB   A AC
   0.001 +                     BAADLMQZZUZKNRJLFRLQNMGLFAA
  0.0001 +                  B B  CDCEKHNMHBCFCCBDCGAAFB        A
         |                          AA A         AAA   A  A
         ---+-------+-------+-------+-------+-------+-------+-------+-------+--
         0.0001   0.001   0.01     0.1      1      10      100    1000    10000
```

Figure 4 (APPENDIX A4). *Top*: Silver hake discards and landings (hail weights) for the Squid and Butterfish primary species group and all gear groups based on trips with observers during 2001-2004. *Bottom*: Same as top but records with zero discard are omitted and both axes are log scale.

```
------------------------- TargetGrpID=Squid/ButterFish -------------------------

        Plot of Discard*TargetGrpMT.  Legend: A = 1 obs, B = 2 obs, etc.
Discard
 7.3881 +      A
        |
 6.3326 +
        |
 5.2772 +          A
        |    A B
 4.2217 +
        |    A
 3.1663 +       A
        |    B
 2.1109 +   BAABA
        |  AB BAA             A
 1.0554 +  AAA  A A  A
        |  CCAECD
 0.0000 +  ZUQHGGJDDDB   B A A    A  A                                 AA  B
        ---+----------+----------+----------+----------+----------+----------+--
           0         50        100        150        200        250        300

                                       TargetGrpMT
```

```
        Plot of Discard*TargetGrpMT.  Legend: A = 1 obs, B = 2 obs, etc.
Discard
   1000 +
        |
    100 +
        |
     10 +                                          A
        |                                   A  ABBACAB A
      1 +                               B A C A B CABBA A A
        |                                 CAAB  A DCAC
    0.1 +                            B   A     A  B  A   A
        |                               A  B BB BA  A  A    A
   0.01 +                     A AB A  A  AA B   AAA    A       BB
        |                       AA   A    A         BA A
  0.001 +                   A     A B AC          A ABA
        |             A         B AA   A          A A B
 0.0001 +          A            AA   B
        -+---------+---------+---------+---------+---------+---------+---------+
       0.00      0.01      0.10      1.00      10.00    100.00  1000.00 10000.00

                                       TargetGrpMT
```

Figure 5 (APPENDIX A4). *Top*: Silver hake discards and landings (hail weights) for the Hakes and Ocean Pout primary species group and Trawls gear group based on trips with observers during 2001-2004. *Bottom*: Same as top but records with zero discard are omitted and both axes are log scale.

```
----------------- TargetGrpID=Hakes+OceanPout GearGroup=Trawls -----------------

        Plot of Discard*TargetGrpMT.  Legend: A = 1 obs, B = 2 obs, etc.

      4 +                                  A
        |
        |
Discard |
        |               A                                                      A
        |
        |                                                                  A
      2 +  A
        |     A
        |
        |                                  A
        |  A  A
        |  AAA    AA  AB  A A  A           A                                 A
        | A A CBA AAA  A    A B     A      A  A                      A
      0 +DLCCFADBAC  A  AAA        AAB    A A    A         A          A
        -+---------+---------+---------+---------+---------+---------+---------+
         0         2         4         6         8        10        12        14

                                       TargetGrpMT

        Plot of Discard*TargetGrpMT.  Legend: A = 1 obs, B = 2 obs, etc.
Discard
   1000 +
        |
    100 +
        |
     10 +
        |                                   A  A  B
      1 +                           B  B    AA A
        |                       A   B AACACBBBAAA B
    0.1 +                           BAADAA   BAA
        |                   A        B  A        AA
   0.01 +                             A
        |                   A    CB           A
  0.001 +                       A
        |
 0.0001 +
        -+---------+---------+---------+---------+---------+---------+---------+
       0.00      0.01      0.10      1.00      10.00    100.00  1000.00 10000.00

                                       TargetGrpMT
```

Figure 6 (APPENDIX A4). *Top*: Silver hake discards and landings (hail weights) for the Squid and Butterfish primary species group and Trawld gear group based on trips with observers during 2001-2004. *Bottom*: Same as top but records with zero discard are omitted and both axes are log scale.

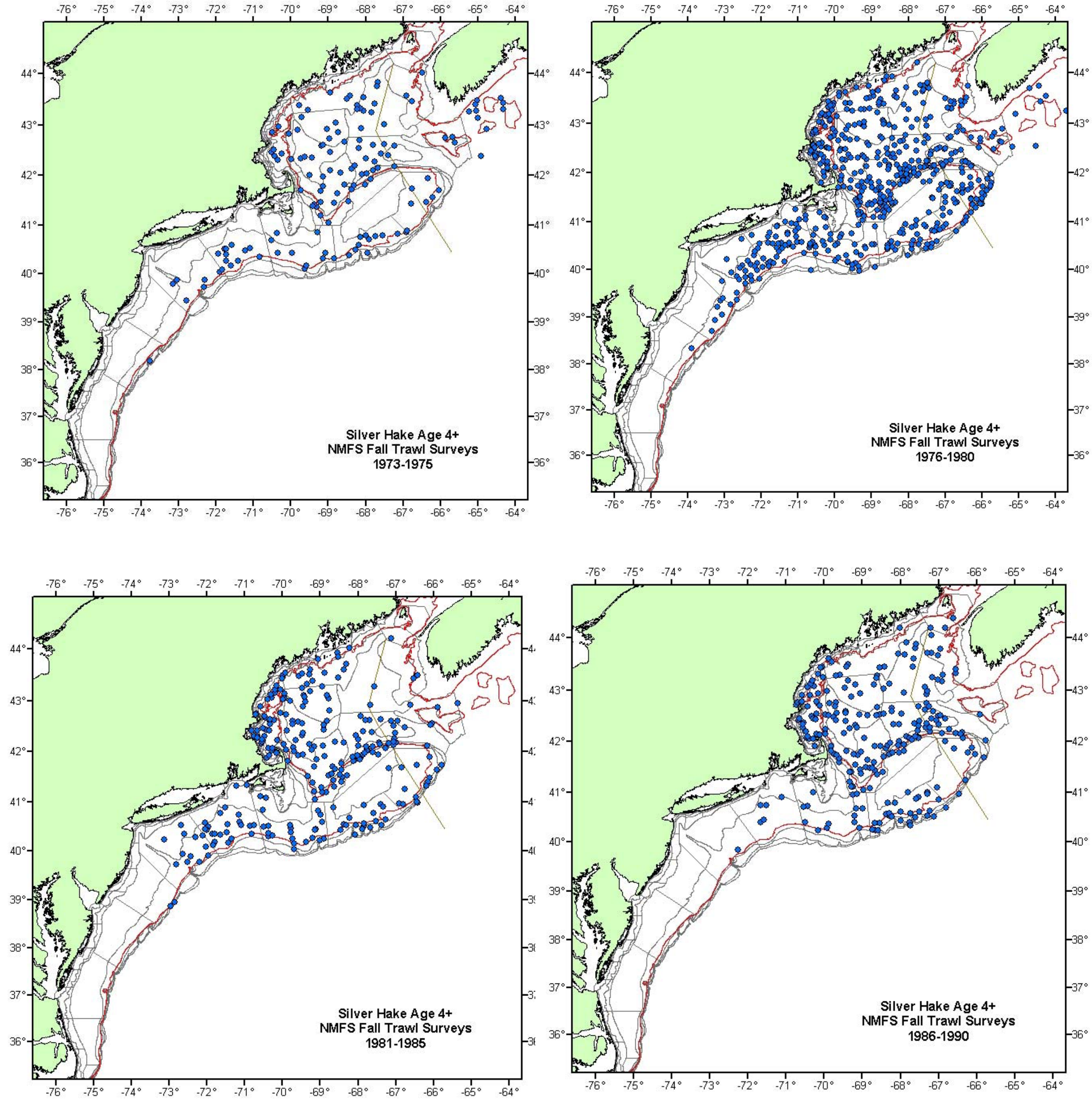
```
---------------- TargetGrpID=Squid/ButterFish GearGroup=Trawls -----------------

        Plot of Discard*TargetGrpMT.  Legend: A = 1 obs, B = 2 obs, etc.
Discard
 7.3881 +      A
        |
 6.3326 +
        |
 5.2772 +          A
        |    A B
 4.2217 +
        |    A
 3.1663 +       A
        |    B
 2.1109 +   BAABA
        |  AB BAA              A
 1.0554 +  AAA  A A  A
        |  CCAECD
 0.0000 +  ZUNHGFIBCDB   B        A  A                                 AA  B
        ---+----------+----------+----------+----------+----------+----------+--
           0         50         100        150        200        250        300

                                       TargetGrpMT
```

```
Plot of Discard*TargetGrpMT.  Legend: A = 1 obs, B = 2 obs, etc.
Discard
   1000 +
        |
    100 +
        |
     10 +                                          A
        |                                   A  ABBACAB A
      1 +                               B A C A B CABBA A A
        |                                 BAAB  A DCAC
    0.1 +                            B   A     A  B  A   A
        |                               A  B BB B   A  A    A
   0.01 +                     A AB A  A  AA B   AAA    A       BB
        |                       AA   A    A         BA A
  0.001 +                   A     A B AC           A AB
        |             A         B AA   A           A A
 0.0001 +          A            AA   B
        -+---------+---------+---------+---------+---------+---------+---------+
       0.00      0.01      0.10      1.00      10.00    100.00  1000.00 10000.00

                                       TargetGrpMT
```

Figure 7 (APPENDIX A4). *Top*: Silver hake discards and landings (hail weights) for the Hakes and Ocean Pout primary species group and Other/unknown gear group based on trips with observers during 2001-2004. *Bottom*: Same as top but records with zero discard are omitted and both axes are log scale.

```
----------- TargetGrpID=Hakes+OceanPout GearGroup=Other/unknown gear -----------

        Plot of Discard*TargetGrpMT.  Legend: A = 1 obs, B = 2 obs, etc.

     Discard |
           3 +
             |
             |             A
             |
           2 +
             |
             |
             |
           1 +
             |
             |
             |
           0 +  A     A     A   A      A       A      A            A
             |
             ---+-------------+-------------+-------------+-------------+--
                0             1             2             3             4

                                       TargetGrpMT

        Plot of Discard*TargetGrpMT.  Legend: A = 1 obs, B = 2 obs, etc.
Discard
   1000 +
        |
    100 +
        |
     10 +
        |                             A
      1 +
        |
    0.1 +
        |
   0.01 +                               A
        |                                 AA
  0.001 +
        |
 0.0001 +
        -+---------+---------+---------+---------+---------+---------+---------+
       0.00      0.01      0.10      1.00      10.00    100.00  1000.00 10000.00

                                       TargetGrpMT
```

Figure 8 (APPENDIX A4). Location of tows with silver hake ages 4+ for NEFSC fall bottom trawl surveys during 1979-2004. The plots show the successive reduction in abundance of silver hake ages 4+ in the southern area over time. The last panel shows the location of all tows with silver hake of all ages during all years and, in comparison to other panels, shows the tendency for relatively young (ages 1-3) silver hake to use southern and nearshore habitats.



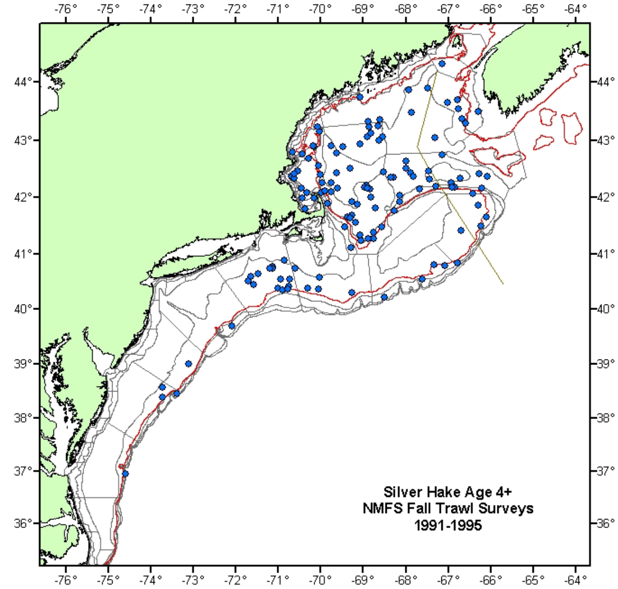
Silver Hake Age 4+
NMFS Fall Trawl Surveys
1973-1975

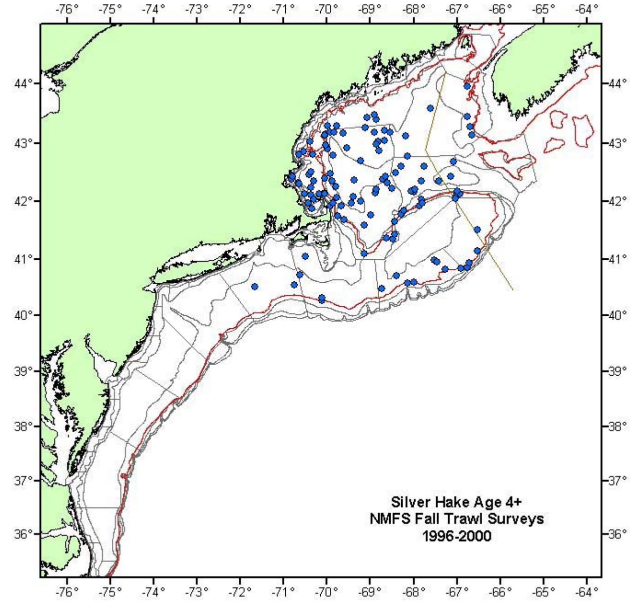
Silver Hake Age 4+
NMFS Fall Trawl Surveys
1976-1980

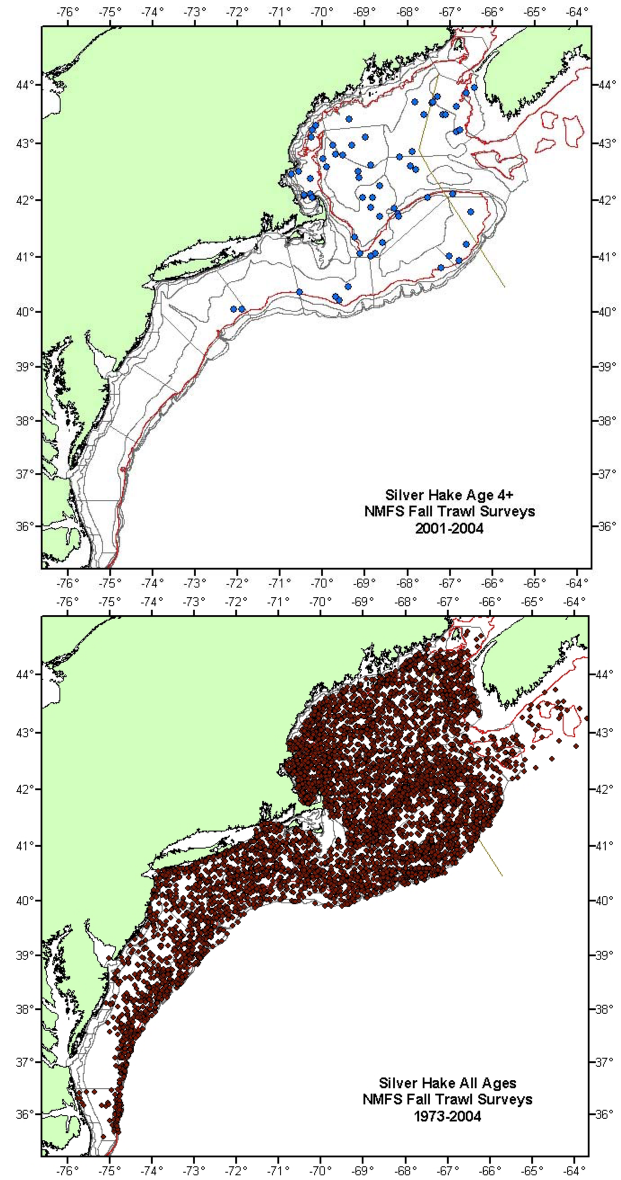
Silver Hake Age 4+
NMFS Fall Trawl Surveys
1981-1985

Silver Hake Age 4+
NMFS Fall Trawl Surveys
1986-1990

Appendix 5 Figure 8 (cont.)







Appendix 5 Figure 8 (cont.)

Figure 9 (APPENDIX A4). Location of random NEFSC spring bottom trawl survey tows (blue dots) and fixed Supplemental (Transect) bottom trawl survey tows (red dots) in the Hudson Canyon area during 2004-2005 that were used to estimate relative fishing power. Red lines show the 50, 100 and 200 m depth contours. Dark lines show NEFSC bottom trawl survey strata.

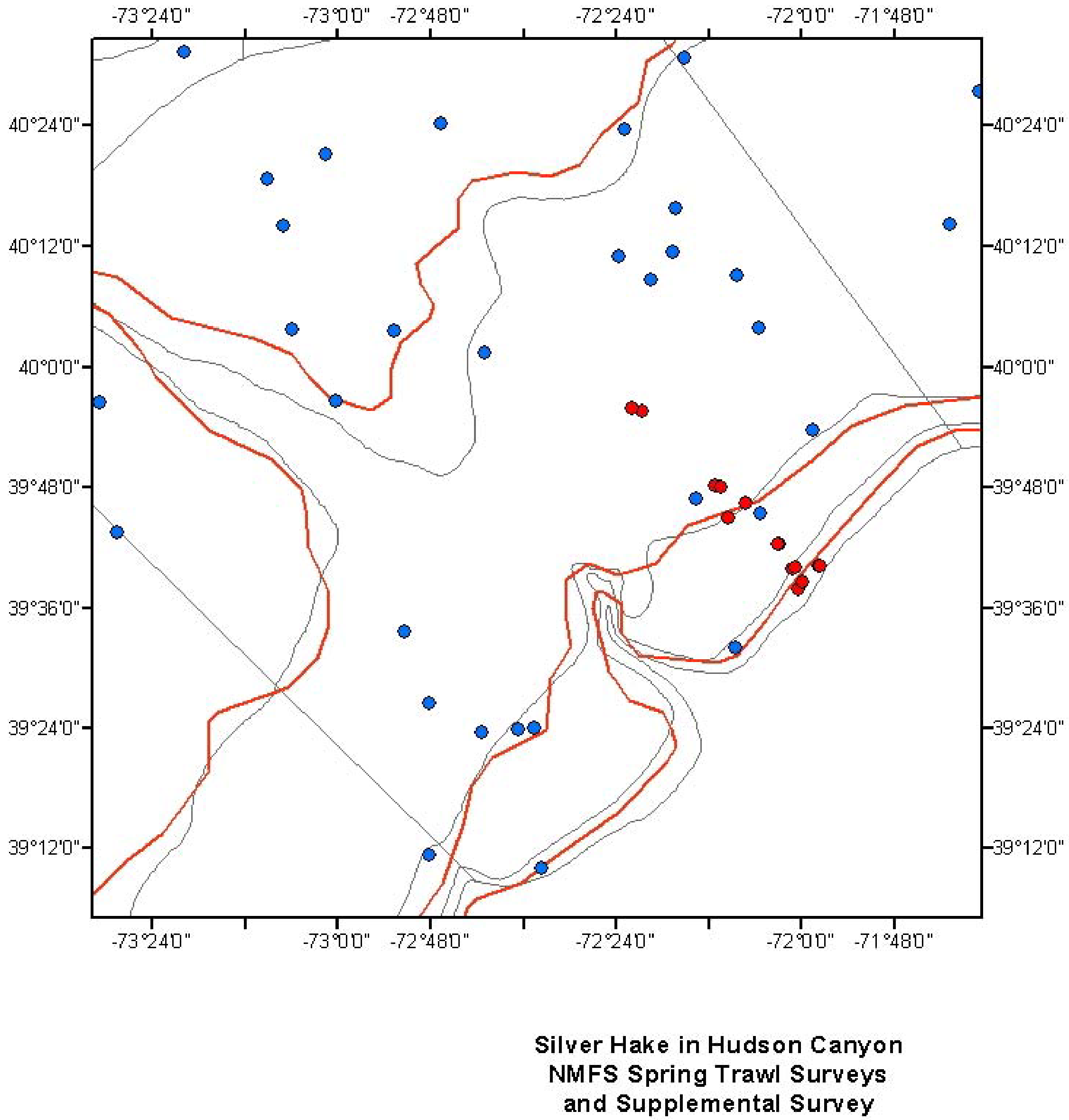
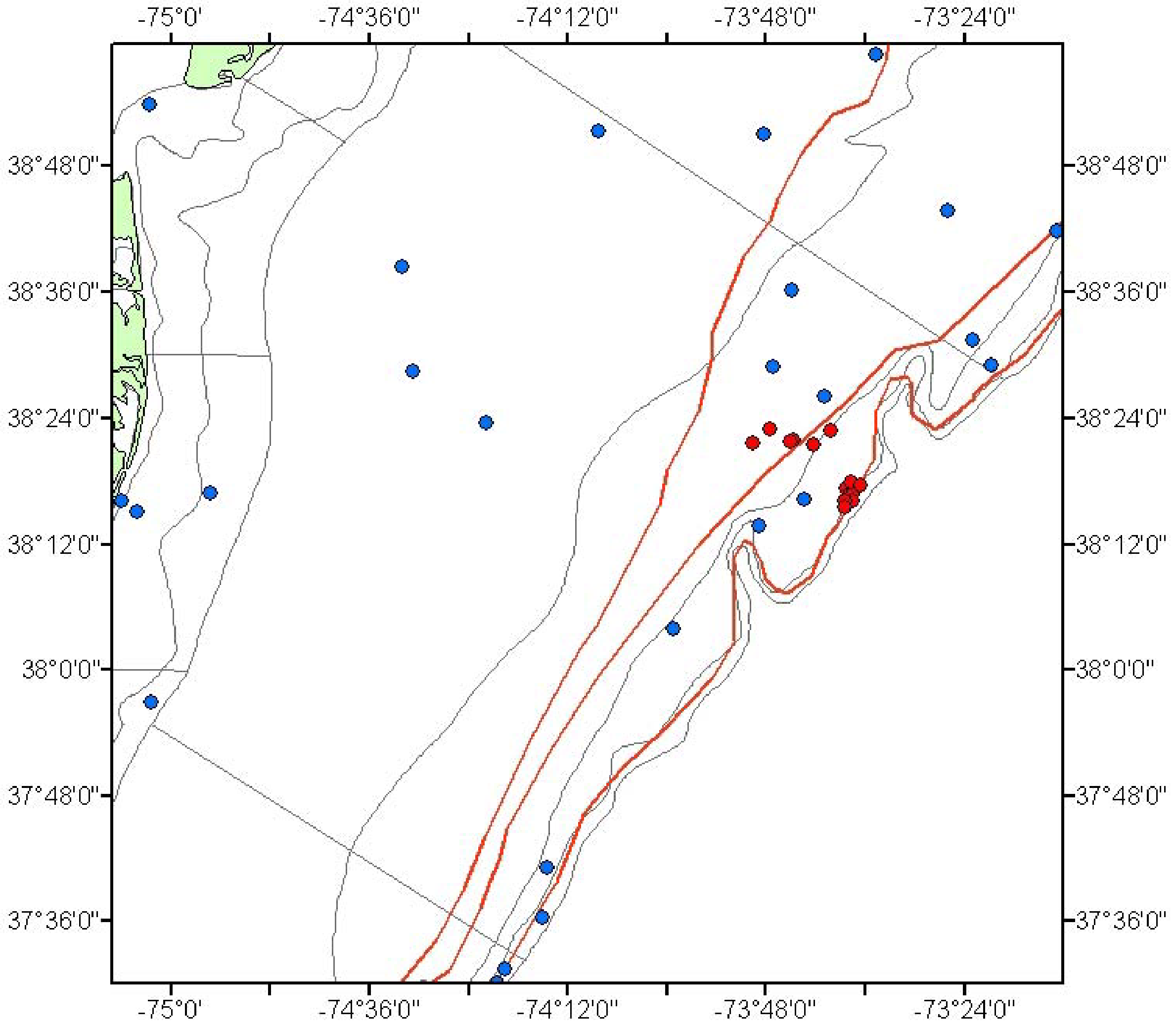
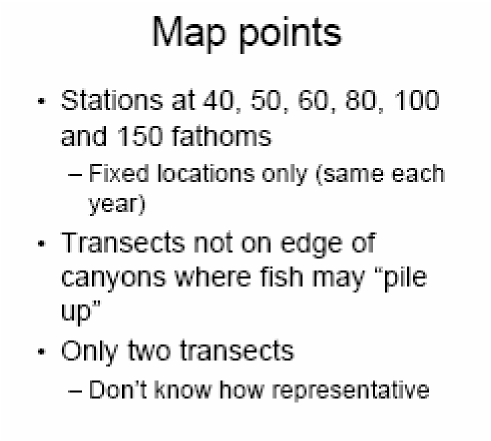


Figure 10 (APPENDIX A4). Location of random NEFSC spring bottom trawl survey tows (blue dots) and fixed Supplemental (Transect) bottom trawl survey tows (red dots) in the Baltimore Canyon area during 2004-2005 that were used to estimate relative fishing power. Red lines show the 50, 100 and 200 m depth contours. Dark lines show NEFSC bottom trawl survey strata.



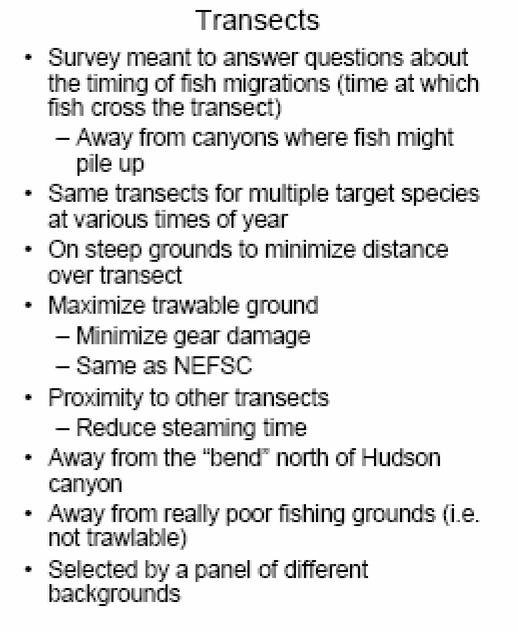
Silver Hake in Baltimore Canyon
NMFS Spring Trawl Surveys
and Supplemental Survey

Figure 11 (APPENDIX A4). Text slides with information about Supplemental survey transects and stations that were requested by reviewers.



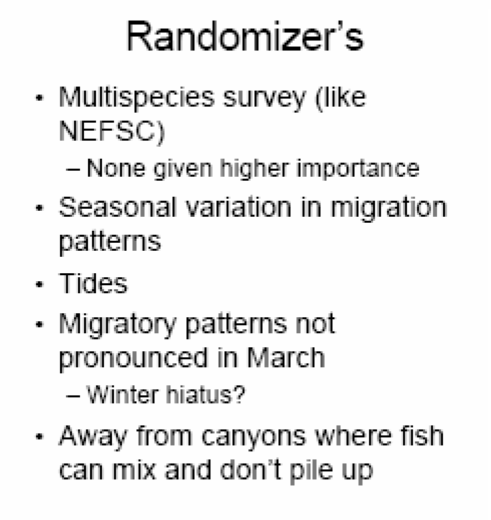
Map points

- Stations at 40, 50, 60, 80, 100 and 150 fathoms
  - Fixed locations only (same each year)
- Transects not on edge of canyons where fish may “pile up”
- Only two transects
  - Don’t know how representative



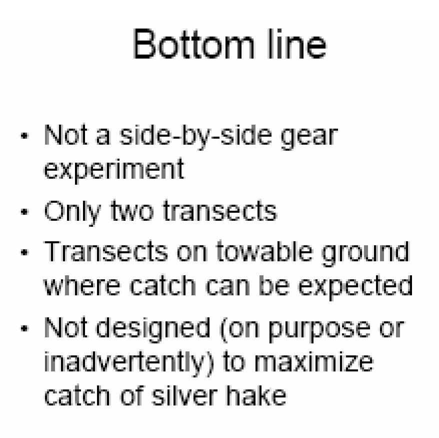
Transects

- Survey meant to answer questions about the timing of fish migrations (time at which fish cross the transect)
  - Away from canyons where fish might pile up
- Same transects for multiple target species at various times of year
- On steep grounds to minimize distance over transect
- Maximize trawable ground
  - Minimize gear damage
  - Same as NEFSC
- Proximity to other transects
  - Reduce steaming time
- Away from the “bend” north of Hudson canyon
- Away from really poor fishing grounds (i.e. not trawlable)
- Selected by a panel of different backgrounds



Randomizer’s

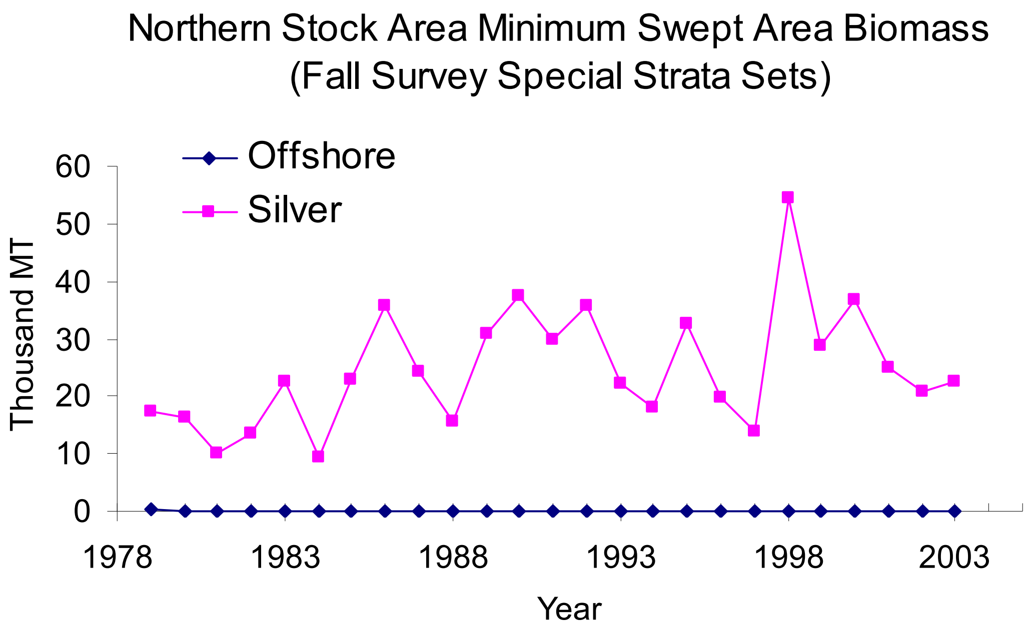
- Multispecies survey (like NEFSC)
  - None given higher importance
- Seasonal variation in migration patterns
- Tides
- Migratory patterns not pronounced in March
  - Winter hiatus?
- Away from canyons where fish can mix and don’t pile up

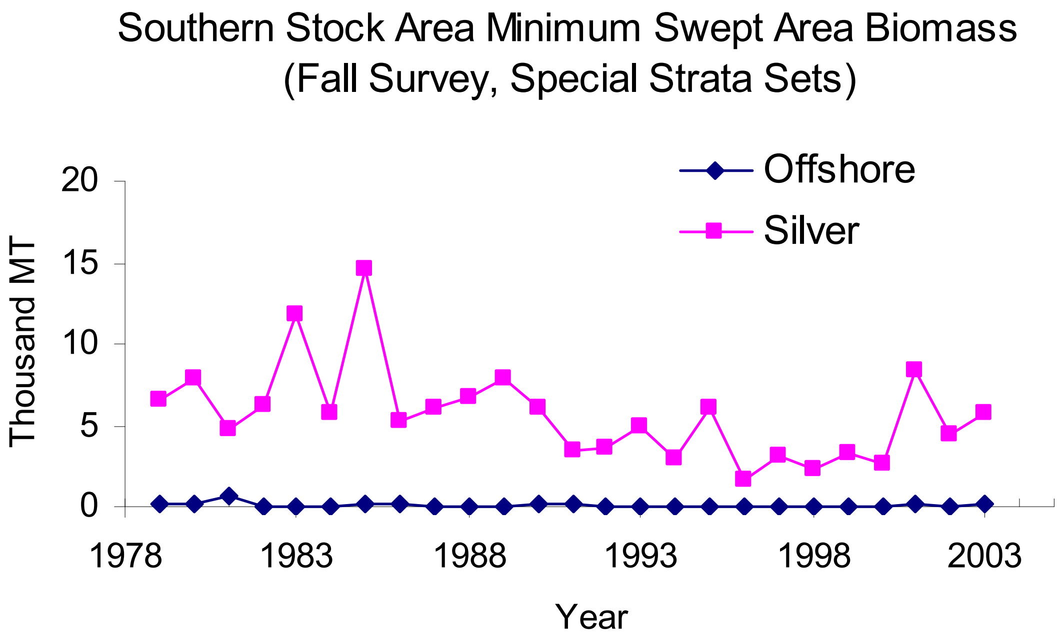


Bottom line

- Not a side-by-side gear experiment
- Only two transects
- Transects on towable ground where catch can be expected
- Not designed (on purpose or inadvertently) to maximize catch of silver hake

Figure 12 (APPENDIX A4). Minimum swept-area biomass (mt) for silver hake and offshore hake in the northern and southern stock areas based on NEFSC fall survey data and the special survey strata set.





B. ATLANTIC MACKEREL STOCK ASSESSEMENT

TERMS OF REFERENCE

1. Characterize the commercial and recreational catch including landings and discards.
2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.
3. Evaluate and either update or re-estimate biological reference points, as appropriate.
4. As needed by management, estimate a single-year or multi-year TAC and/or TAL by calendar year or fishing year, based on stock biomass and target mortality rate.
5. If possible,
    a. provide short term projections (2-3 years) of biomass and fishing mortality rate, and characterize their uncertainty, under various TAC/F strategies and
    b. evaluate current and projected stock status against existing rebuilding or recovery schedules, as appropriate.
6. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in previous SARC-reviewed assessments

EXECUTIVE SUMMARY

(TOR 1) Atlantic mackerel were heavily exploited by distant water fleets during the 1970's. Total landings in NAFO subareas 2-6 averaged 350,000 mt during 1970-1976, but this level was not sustainable (Figure B1). Annual landings decreased to less than 50,000 mt during 1978-1984. Landings in Canada remained relatively constant at an average of 24,000 mt during 1968-2000. Landings in the US EEZ increased during 1985-1991 to an average of 76,000m t, with the advent of a JV fishery in the Mid-Atlantic region. More recently landings by both the USA and Canada have increased as world demand has improved. Commercial landings in the U.S. increased from a low of 5,646m t in 2000 to 53,724 mt in 2004, while landings in Canada increased form 13,383 mt in 2000 to 51,444 mt in 2004. Recreational landings of mackerel in the USA averaged 1,344 mt during 1990-2000, but decreased from 1,538m t in 2001 to only 467 mt in 2004.

The northwest Atlantic mackerel stock is not overfished and overfishing is not occurring relative to the new reference points from this assessment. (TOR 2) Fishing mortality has remained low for the last decade, but increased slightly from 0.02 in 2002 to 0.05 in 2004. The confidence interval (± 2 SD) for F in 2004 ranged from 0.035 to 0.063, but retrospective analysis shows that

F has sometimes been underestimated in recent years. The overfishing reference point, Fmsy, was re-estimated at Fmsy=0.16 (previously Fmsy=0.45).

(TOR 2) Spawning stock biomass increased steadily over the last several decades from a low of 663,000 t in 1976 to 2.3 million mt in 2004. The confidence interval on SSB (± 2 SD) ranged from 1.49 to 3.14 million mt in 2004; however, retrospective analysis showed that SSB has sometimes been overestimated in recent years. The biomass reference point was re-estimated in this assessment at SSBmsy= 644,000 mt (previously SSBmsy=890,000 mt).

(TOR 3) Fishing mortality based biological reference points (BRP's) were re-estimated during SARC 42. Fishing mortality reference points are $F_{0.1} = 0.25$ and $F_{40\%} = 0.24$. Reference points from model estimated B-H parameters are MSY = 89,000 mt, SSBmsy = 644,000 mt, and Fmsy = 0.16. Surplus production in the mackerel stock was available sporadically during 1962-2004. Periods of positive SP occurred before the ICNAF fishery in the late 1960s, during the early 1980s, and more recently in the late 1990s through 2003. The average SP available during 1962-2003 was 148,000 mt; this can serve as a proxy upper bound on MSY for the current assessment. Stock-recruitment BRP's were estimated prior to SARC 30 using a bootstrap method as Fmsy=0.45, F target=0.25, MSY=326,000 mt, and SSBmsy=887,000 mt (NEFMC 1998), these should be replaced with the more current values

(TOR 4, 5)Deterministic projections for 2006-2008 were conducted by inputting an estimated catch of 95,000 mt in 2005 and a target fishing mortality of 0.12 (MAFMC 1998, Ftarget=0.75 x Fmsy) in 2006-2008. If 95,000 mt are landed in 2005, SSB in 2006 will increase to 2.6 million mt. If the Ftarget F=0.12 is attained in 2006-2008, SSB will decline to 2.3 million mt in 2007 and to 2.0 million mt in 2008. Landings during 2006-2008 would be 273,000 mt, 239,000 mt, and 212,000 mt, respectively. These landings are the result of an unusually large year-class (1999) present in 2005, and will not be sustainable in the long term. It is expected that these projected landings will decline to MSY (89,000 mt) in the future when a more average recruitment condition exists in the stock.

1.0 INTRODUCTION

Atlantic mackerel (*Scomber scombrus*) are distributed from North Carolina to the Gulf of St Lawrence, and on occasion as far north as Labrador (Bigelow and Schroeder 2002). Mackerel are a fast moving, schooling species that undergo extensive seasonal migrations. The northern and southern components generally over-winter on the continental shelf off the Mid-Atlantic bight and begin their spring migration in April. The southern component spawns along the Southern New England corridor and disperses throughout the Gulf of Maine-Georges Bank region during summer (Sette 1950; Morse et al. 1987; O'Brien et al. 1993). It is believed that the northern component crosses Georges Bank during April-May reaches the Scotian shelf in late May or early June and moves into the Gulf of St Lawrence during late June and early July to spawn in the Magdalen shallows region (Sette 1950; Gregoire et al. 2003; DFO 2004; Gregoire 2005). Post spawning fish disperse into the Gulf as far east as Newfoundland. This schooling species often attains ages greater than 10; ages up to 14 are not uncommon. Mackerel begin to mature at age 2, and are generally fully mature at age 3. (Bigelow and Schroeder 2002; Gregoire et al. 2003). They exhibit a planktivorous diet, feeding mainly on zooplankton, chaetognaths, euphasids; and larval fish (Bigelow and Schroeder 2002). Mackerel are preyed upon by a large number of medium-sized predatory fishes such as cod, white hake, and spiny dogfish; marine mammals such as pilot whales, white-sided dolphins, and common dolphins; seabirds such as greater shearwaters and northern gannets; and large pelagic fish such as swordfish and blue shark, throughout their range.

The Mid Atlantic Fishery Management Council manages mackerel as part of the Atlantic mackerel, Squid, and Butterfish (MSB) Fishery Management Plan. The current overfishing definition is based on an MSY of 326,000 mt, a Bmsy of 890,000 mt, and a limit fishing rate of Fmsy = 0.45 (MAFMC 1998; NEFMC 1998). Overfishing for this species is defined as occurring when Fmsy is exceeded, and the overfishing limit is Fmsy = 0.45 when the SSB is greater than 890,000 mt. An MSY of 326,000 mt represents the current estimate of long-term potential catch for the stock and was revised in Amendment 8 of the FMP. The F target is defined as the tenth percentile of Fmsy and is set at F=0.25. If SSB is less than 890,000, F target decreases linearly from 0.25 at 890,000 mt to zero at 450,000 mt. The biomass target for this stock is defined as Bmsy and the minimum biomass threshold is defined as ½ Bmsy. There have been a series of amendments to the MSB Fishery Management Plan; the most recent amendment (Amendment 9) does not propose any changes for the mackerel OFD.

The most recent assessment for this stock was completed in 1999 (SARC 30) (NEFSC 2000). Although no quantitative assessment was accepted, conclusions were that the stock was at a high level of biomass, F was low, and that catches were well below the MSY of 326,000 mt.

2.0 THE FISHERY

Commercial Landings

Commercial mackerel landings by the United States averaged 2,368 mt from 1960-1983, peaked at 31,261 mt in 1990, and declined to 4,666 mt in 1993 (Table B1; Figure B1). USA landings increased to 16,137 mt in 1996, declined to 5,646 mt in 2000 and steadily increased to 53,724 mt in 2004. Recreational landings in the USA have generally declined during 1979-2004. Landings averaged 2,945 mt during 1979-1988 and declined to a low of 344 mt in 1992 (Table B1: Figure B1). Landings in the US sport fishery peaked at 1,735 mt in 1997, declining slightly thereafter, but remaining relatively steady until declining to 724 mt in 2003 and 467 mt in 2004. Landings by Canada averaged 6,891 mt during 1960-1967, and 23,882 during 1968-2000 (Table B1; Figure B1). Canadian landings increased steadily from 23,868 mt in 2001 to 51,444 mt in 2004. For details of Canadian landings see Gregoire et al. (2003), DFO (2004), and Gregoire (2005) available online at www.dfo-mpo.gc.ca/csas. Landings by foreign countries, primarily during the ICNAF era, averaged 143,532 mt during 1961-1977, and 18,315 mt during 1978-1991 (Table B1; Figure B1). Foreign countries were excluded from fishing in the US EEZ after 1991.

Sampling Intensity

Commercial length frequencies used to characterize USA landings were obtained from port samples obtained in the Northeast Region. The mackerel fishery is strongly seasonal, with most of the landings occurring during the first 5 months of the calendar year and any remaining landings during November and December. Because of stable growth patterns, length samples were aggregated over the first and second half of each year. Most of the landings occurred during the first half of the year in all years from 1998-2004, but in some landings occurred in the second half of the year during 2001-2004 (Table B2). Sample size for commercial length compositions ranged from 907 in 2000 to 4,297 in 1999 for the first half of each year (Table B2). Sample size for length data for the commercial fishery in the second half of 2001-2004 ranged from 116 in 2001 to 322 in 2003. Landings at age for the second half of 2001-2004 were estimated with length data from the 4th quarters of each year (Table B2). A length-weight relationship was used to estimate sample weight and expansion factors for commercial samples from 1998-2004. Length-weight parameters used in the last assessment (a=0.0059, b=3.154) were used for the estimation of commercial catch at length.

Recreational length samples obtained from the MRFSS data base were used to characterize the landings of this species by sport fisherman. Sample numbers and lengths were judged to be adequate enough to estimate recreational catch at length. Recreational length samples were available for each year during 1998-2004 and ranged from 483-1,347 fish measured (Table B2). The same length-weight equation was used to estimate sample parameters and expansion factors for the recreational landings data.

Age length data used for estimating commercial and recreational catch at age were obtained from commercial port samples, sea sampling, and NEFSC Spring and Winter bottom trawl surveys. Combined age-length keys from these sources were used to age commercial and recreational landings from the first half of 1998-2004 (Table B2). . Sample size for the first part of the year during 1998-2004 ranged from 719-1901 (Table B2). Generally only fall survey ages in small numbers were available to age the second half of each year during 2001-2004, samples sizes ranged from 71-121. Catch-at-age for Canada was developed using similar procedures, although many more length samples were available. For details of Canadian commercial length and age sampling see Gregoire et al. (2003), DFO (2004), and Gregoire (2005) available online at www.dfo-mpo.gc.ca/csas.

Catch-at-Age

USA commercial and recreational catch at age for 1962-1997 were taken from the previous assessment (NEFSC 2000). Catch at age for the USA during 1998-2004 were estimated from the length and age composition and landings data previously cited (Table B3). Canadian catch at age data for 1998-2004 were obtained from DFO Canada (Gregoire et al. 2003) and are included in Table (B3). Canadian catch-at-age data for 1990-1993 were updated based on a revision in Canadian landings for 1990-1993. For details of Canadian catch-at-age see Gregoire et al. 2003), DFO (2004), and Gregoire (2005) available online at www.dfo-mpo.gc.ca/csas.

Commercial Mean Weights

Commercial mean weights used in the current assessment were obtained from the previous assessment for 1962-1997 and were estimated for 1998-2004. The length weight relationship used to estimate sample weights (a=0.0059, b=3.154) was used to calculate the mean weights at age for the USA commercial fishery for 1998-2004. Mean weights for the commercial fishery during 1998-2004 were calculated as weighted means of the USA and Canadian fishery catch-at-age and mean weights-at-age (Table B4).

3.0 RESEARCH SURVEY ABUNDANCE INDICES FOR TREND

Research survey abundance indices are available from winter and spring NEFSC bottom trawl surveys for assessing the status of the mackerel resource. Survey indices are available from NMFS surveys for the winter 1992-2005 and spring 1968-2005. The autumn survey series from 1963-2004 was investigated for use as a tuning index, but very few mackerel are taken in this survey and an unknown proportion, perhaps large, is distributed in Canadian waters, and is unavailable to the USA survey.

Standard and ln transformed spring survey indices were updated for 1998-2005. Standard indices in weight and number per tow continued to show improving trends for the stock during 1989-2005 (Table B5; Figure B2). The biomass index generally increased from 1989-1996, declined slightly in 1997-1998, and increased from 1999-2004. Mean number per tow indices followed nearly the same trends, increasing over the early 1990s, decreasing in 1997-1998, and increasing again from 1999-2004. The index reached 116 in 2001, the highest value in the 43 year series (Table B5; Figure B2).

Spring indices for 1998-2004 were recomputed to produce aggregated ln retransformed catch per tow indices. The standard number per tow index increased by an order of magnitude from the 1980s to the 1990s and increased further from 1998-2004. The index was high and relatively stable throughout the 1990s, except for 1997 and increased in 2000 and 2001 (Table B5; Figure B4). The highest value in the series was obtained in 2001 (59.106). Number per tow indices at age (ln retransformed) were updated for 1998-2005. Indices at age were generally higher, with a few exceptions, for ages 1-6 during 1997-2004 than for all other years in the 1968-2005 time-series (Table B6).

The winter bottom trawl survey began in 1992 and was included as an index for this stock in the previous assessment. The standard biomass and abundance indices for mackerel are generally high, but variable (Table B7). The biomass index ranged from 0.25-32.05 kg/tow during 1992-2005 (Table B7; Figure B4). Number per tow ranged from 1.16 to 245.58 during this same period. Some of the variation in survey indices may be attributed to the more inconsistent coverage of survey strata during the winter survey. Number per tow at age indices (ln retransformed) were produced for the winter survey, including ages 1-10+ (Table B8). Indices in this survey have also increased in recent years (Table B8).

Growth

Trends in average weight from the spring survey were examined to see if there were any changes during 1968-2005. With the exception of the period after the ICNAF fishery in the 1970s, average weights have fluctuated between 100-200 grams, but there appears to be a slight overall decline from 1985 onward (Figure B6). Average weight-at-age from the USA and Canadian fishery were also examined for trends (Figure B7). The same increase in weight occurred following the ICNAF era, but mean weights have been relatively constant since then and very similar to weights in the 1960s through the mid-1970s (Figure B7).

Predation Mortality

Evidence suggests that natural mortality rates for this species may be more variable than the current constant value (M=0.2) used in assessments. Overholtz et al. (2000) studied consumption of pelagic fishes and squids in the Northeast shelf ecosystem and found that the pelagic fish community in the region is heavily consumed by predatory fishes in the region. This study suggested that mackerel were important in the diets of predatory fish in the region during 1973-1997. Consumption by predatory fish as a group was certainly important during this time (Figure B8). Spiny dogfish are an important consumer of mackerel, removing significant quantities of this prey species during 1979-1997 (Figure B9).

Mackerel Distribution

The positions of mackerel survey catches during 2002-2005 from the NEFSC spring survey were plotted to observe if any changes in distribution had taken place over that time period. Mackerel were widely distributed over the Mid-Atlantic-Georges Bank region during 2002 (Figure B10). During 2003, mackerel were further to the south and distributed about midway along the Mid-Atlantic continental shelf (Figure B11). In 2004, the mackerel distribution was further to the south and further offshore than in 2003 (Figure B12). Mackerel survey catches were much further to the south and more offshore in 2005 than during the three previous years (Figure B13).

4.0 VPA CALIBRATION AND DIAGNOSTICS

Catch-at-age and mean weight data for 1962-2004 and bottom trawl survey data for winter 1992-2004 and spring 1968-2004 (ages 1-10+), were used in a VPA calibration to update the previous assessment (NEFSC 2000). Results from this run suggest that current spawning stock biomass is rebuilding, but much below levels observed in the early 1970s (Figure 1 App1). Fishing mortality increased steadily from 1980 through 2002, reaching very high values of 0.7 in 1999 and over 1.0 in 2002 (Figure 2 App1). Trends in the observed vs./ predicted series for the spring survey show patterning with a block of negative residuals prior to 1984 and positive residuals thereafter (Figure 3 App1). Observed-predicted trends from the winter survey are mixed, but the fit is reasonable (Figure 4 App1). Since there was a prominent retrospective pattern in the previous assessment, a new analysis was completed. There is still a prominent retrospective pattern for spawning stock biomass in the current VPA with successive years from 2002-2004 showing major declines in SSB when compared to the previous year (Figure 5 App1). Fishing mortality also had a pattern indicating that F was underestimated during 2002-2004 (Figure 6 App1).

Since the retransformed winter trawl series in relatively flat (Figure B5) and residual patterns for the spring survey from the previous run were poor, the next VPA run utilized only the spring survey time-series. The spring series is the longest time-series available and has long been considered the best available index for monitoring trends in this stock. Scaling was a problem with this model run, spawning stock biomass increased to very high values, exceeding 40 million mt during 2000-2004 (Figure 7 App1). The pattern in fishing mortality was much different than in the first run, with higher mortality rates in the 1970s and much lower F's from the 1980s onward (Figure 8 App1). Model fit improved greatly in this model formulation (Figure 9 App1). However, because of the many problems encountered in the VPA formulations, another more flexible modeling approach (ASAP), that can be used to address issues such as fishery selectivity, biomass scaling, and recruitment estimation, was utilized.

5.0 ASAP FORWARD PROJECTION DESCRIPTION

ASAP is an age structured forward projection model with flexibility to address fishery selectivity, stock-recruitment, and constraints on virgin biomass, steepness, scale and other factors. The analysis for Atlantic mackerel starts in 1962 and projects forward through 2004. Total biomass, spawning stock biomass, recruitment, fishing mortality, and surplus production are estimated in the model.

Growth

The same mean weight data from the VPA (1962-2004 ages 1-10+) were used in ASAP model runs.

Maturity

Maturity was assumed to be 0.2 at age 2 and 1.0 at age 3 and older for mackerel.

Natural Mortality

Natural mortality was assumed to be 0.2 as in previous assessments.

Partial Recruitment

Partial recruitment was assumed to be 0.2 at age 1, 0.6 at age 2 and 1.0 for age 3 and older. These data were based on the old VPA run (NEFSC 2000), the new VPA run and results in the recent USA fishery.

Recruitment

A Beverton-Holt stock-recruitment model was used to model recruitment with the alpha and beta parameters estimated internally in the model. In ASAP runs 1 and 2 the SR relationship was assumed to be fit without any error, while in run 3 and the base case run the relationship was fit with error (lamda=1).

Surplus Production

Surplus production for the mackerel stock was estimated by using parameters from the B-H model fit. Stock recruitment parameters were estimated internally and used to calculate management parameters such as MSY and Fmsy. In addition output from the model was used to a fit a Fox model (Fox 1975) and a Schaefer model (Schaefer 1954).

Landings

The total catch-at-age for the USA and Canada model were included in the ASAP formulations (Figure B3). For details of Canadian CAA see Gregoire et al. (2003), DFO (2004), and Gregoire (2005) available online at www.dfo-mpo.gc.ca/csas.

Research Surveys for Trend

The spring survey (1968-2004 ages 1-10+, and 1-7+) was used to tune the mackerel ASAP model.

6.0 ASAP INITIAL MODEL TRIALS AND RESULTS

A series of ASAP model runs were conducted to address various aspects of model scale and goodness of fit. The first model run repeated the last formulation used in the VPA, a run that utilized only the spring survey. Results from this trial showed an improvement in scale for spawning stock biomass when compared to the VPA (Figure 10 App1). The historic period during 1962-1977 was very similar in magnitude to the VPA, but the spawning stock increased steadily thereafter to over 6.5 million mt in 2003 (Figure 10 App1). The pattern in fishing mortality showed a large increase in the mid 1970s followed by very low rates thereafter (Figure 11 App1). However, a comparison of the observed vs. predicted survey series indicated that this model run produced estimated values that were functionally a smoothed series through the survey index values (Figure 12 App1). This occurred because the SR relationship was fit without error, resulting in a smooth trend in predicted survey values. Overall, this model run resulted in a large improvement in scaling when compared to the similar VPA run, but diagnostics (residuals) were very poor. To further address issues of scale and poor model fit, another ASAP model run was completed.

It is hypothesised that another important issue related to the spring time series is a change in catchability due to a conversion to polyvalent doors that occurred in 1985. After 1984, survey catches of mackerel on average increased dramatically when compared to values prior to the door change (Table B5; Figure B2). The GARM and trawl warp investigation in 2002 suggested that the current door configuration for the 36-Yankee trawl results in an overspread condition for the net (S. Murawski, pers. comm.. 2002). This means that now the net is always open both high and wide. Evidence suggests that historically the 36-Yankee survey gear probably did not operate in this fashion because water hauls were common and the net probably functioned in a more compressed state (Pers. Comm. NEFSC Survey Group, *various years)*. Results from door comparison work that was completed on a variety of species, were not available for mackerel, because the design was oriented toward groundfish and few mackerel were available during the experiment (Byrne and Forrester 1991). Coefficients for Atlantic herring from this same gear study were not significant, but these experiments were not designed to estimate the effects of door changes on herring. Extensive work on herring in subsequent studies confirmed that the door change was an important factor in explaining survey catchability changes in the spring survey for this species (Overholtz et al. 2004). Therefore, the spring survey was split in 1985 to address the survey catchability issue for mackerel. The two separate series were used to tune the mackerel ASAP model in this model run.

Results from the ASAP model utilizing the split spring time-series showed an improvement in scale, but a continued smoothing of survey predicted values. Again, the smoothing resulted from the assumption of no error in the SR relationship. Spawning stock biomass increased steadily from the late 1970s to 4 million mt in 2003 (Figure 13 App1). Fishing mortality was high in the 1970s, increased in the late 1980s and early 1990s, and slightly increased in recent years (Figure 14 App1). Patterns in the observed vs. predicted spring survey series were apparent in the pre-1985 and post 1985 periods, as the ASAP model smoothed the predicted values (Figure 15; 16 App1).

As a further approach for addressing the problem of scale and patterns in residuals, some of the features of the ASAP model that are useful for addressing issues of scale directly were used. A stock-recruitment function (Beverton-Holt) was fit with a low emphasis coefficient (lambda = 1) to attempt to improve these factors. Results suggest that biomass decreased substantially and the pattern in the residuals improved greatly. Spawning biomass in the 1970s peaked at over 1.5 million mt, declined, and then increased steadily from the late 1970s onward to a maximum of 2.7 million mt in 2003 (Figure 17 App1). Fishing mortality increased slightly in the 1970s over previous runs, but remained relatively low from 1980-2004 (Figure 18 App1). Patterns in the survey residuals improved greatly, with observed and predicted series tracking nicely for both the pre 1985 and post 1985 series, and with little patterning in both series (Figures 19; 20 App1). Results for the various likelihood components in the trial, base case, and sensitivity runs are presented in Table (B11).

7.0 BASE CASE MODEL

The base case model for mackerel used a CAA that was further aggregated to 7+. The recent lack of older aged fish in the spring survey (Table B6) is probably related to availability of these larger faster swimming fish to the survey gear. The Yankee-36 trawl has always had a tendency to under-sample large mackerel over the years, but for some unknown reason survey catches in the most recent years have been low or zero (Table B6). One explanation is that large mackerel have moved further offshore or south during recent cold winters. The average temperature in the spring survey during 2002-2004 was much below the average from the preceding decade (Figure B14). The commercial fishery in recent years has also caught few larger fish, but this may be explainable since the fishery has been narrowly focused in inshore areas off Rhode Island and New Jersey and apparently large fish have not been available in those areas (Figure B15). Commercial vessels have done little searching in offshore areas that are far removed from inshore fishing grounds that are close to ports. Therefore, to further address issues of scale and goodness-of-fit caused by low survey and commercial landings of older fish, the CAA was aggregated at 7+. Preliminary model runs with a delay-difference biomass model (Schnute 1985) (biomass, age 2 and 3+) also indicated that aggregating over older age groups might be a useful approach. Emphasis coefficients for the base case model are listed in Table (B9). The working group decided that this was the best model formulation currently available for determining the status of the mackerel stock. Several additional sensitivity runs were examined by the WG and results are presented in subsequent pages. Results for the accepted base case run are as follows.

Total Biomass

Total biomass reached 1.9 million mt in 1969 and declined to just over 0.7 million mt in 1977 (Figure B16). Total biomass increased steadily to 1.4 million mt in 1999 and then increased rapidly to 2.9 million mt in 2004 (Figure B16). Total biomass ranged between 2.3 and 2.9 million mt during 2000-2004, averaging 2.5 million mt.

Spawning Biomass

Spawning biomass peaked in 1972 at 1.7 million mt, declined until 1976, and began to increase thereafter (Figure B17). During 1978-2000 spawning biomass increased steadily to 1.3 million mt in 2000. SSB continued to increase and then stabilized at 2.3 million mt in 2003-2004 (Figure B17). Spawning biomass ranged between 1.3 and 2.3 million mt in 2000-2004 and averaged 2.0 million mt.

Fishing Mortality

Fishing mortality was relatively high during 1969-1975, peaking at 0.54 in 1975 (Figure B18). Fishing rates dropped dramatically to a low of 0.05 in 1978 followed by a very low and stable period during 1979-1986. Fishing mortality reached a small peak in 1988 of 0.09, coincident with the joint venture (JV) fishery that operated for several years, and then declined to a low of 0.02 in 2000 (Figure B18). The average fishing rate during 2001-2004 was 0.04 and F in 2004 was 0.05.

Stock-Recruitment, Recruitment

Recruitment has been highly variable for the mackerel stock over a range of spawning biomass between about 0.3-2.3 million mt (Figure B19). Recruitment ranged between 0.1-5.8 billion fish during 1962-2004 and averaged 1.1 billion fish (Figure B20). There have been three large year classes during that period, the 1967, 1982, and 1999 year-classes (Figure B20). Recruitment from the 2002 and 2003 year-class appears promising, but is difficult to quantify at this time. The recent average recruitment during 2001-2004 was 1.6 billion fish and recruitment in 2004 was estimated at 2.8 billion.

Surplus Production

Biological reference points were estimated with a Fox model (Fox 1975), Schaefer model (Schaefer 1954) and from an internal B-H stock-recruitment relationship. Reference points from the B-H parameters were MSY = 89,000 t, SSBmsy = 644,000 t, and Fmsy = 0.16. Surplus production (SP) in the mackerel stock was available sporadically during the 1962-2004 time-period (Figure B21). Periods of SP occurred before the ICNAF fishery in the late 1960s, during the early 1980s, and more recently in the late 1990s through 2003 (Figure B21). Results from the Schaefer and Fox models were not used because the surplus production (SP) data surfaces for both model was flat over a wide range of SSB, resulting in very high estimates of K and Bmsy. Only the results from the B-H model were deemed to be useful by the committee. The average SP for this stock during 1962-2003 was 148,000 mt; this value can serve as a proxy upper bound on MSY for the current assessment.

Precision of ASAP Estimates

The relative precision of the estimates for spawning stock biomass and fishing mortality were calculated using the Hessian matrix from the ASAP model fitting procedure. This approach produces a mean and standard deviation for every parameter in the model (Table B12). Results indicate that estimates for both SSB and F are moderately precise. The estimated mean SSB was 2.32 million mt, ranging from 1.49-3.14 million mt, for a two standard deviation interval. The average estimate of F was 0.05, ranging from 0.035-0.063, again for a 2 SD interval. Results from an MCMC run of the ASAP model indicated that these 2SD intervals are comparable to a 95% CI.

Model Diagnostics

Plots of observed-predicted series for the spring NEFSC survey used to tune the ASAP model for trend were produced as a diagnostic measure of goodness of fit. Plots of observed vs. predicted data series (log scale) are shown in Figures (B22; B23) for the base case model. Survey observed and predicted series for the pre 1985 and post 1985 period track nicely with few indications of patterning. The committee examined all the available ASAP diagnostics such as age and year specific observed vs. predicted CAA, indices at age, effective sample size, stock-recruitment plot, and population by year, and concluded that these were also reasonable.

Retrospective Analysis

A retrospective analysis was conducted to observe if there are any patterned trends in SSB and recruitment of the ASAP base model. Results for SSB indicate a moderate pattern for 2001-2003 and larger difference for 2004 (Figure B24). There also appeared to be a change in trend for 2004. For recruitment there appears to be some consistent patterning for years prior to 1999. For the large 1999 year-class the pattern is not consistent among years, but estimates are highly variable across years (2000-2004) (Figure B25).

Projections

Natural mortality was set at M=0.2 for the projections. Partial recruitment to the fishery was set at 0.2 for age 1, 0.6 for age 2, and 1.0 for age 3 and older. Maturity was held constant a 0.2 at age 2 and 1.0 at age 3 and older. Mean weights used in the projections were held constant, the values used were for 2004 (Table B4).

Deterministic projections for 2006-2008 were conducted by inputting an estimated catch of 95,000 mt (209 million lbs) in 2005, a target fishing mortality of 0.12 (MAFMC 1998, Ftarget=0.75 x Fmsy) in 2006-2008, and annual recruitment values based on the S/R curve that was estimated from data. If 95,000 mt (209 million lbs) are landed in 2005, SSB in 2006 will increase to 2,640,210 mt (5.8 billion lbs) (Table B13). If the Ftarget F=0.12 is attained in 2006-2008, SSB will decline to 2,304,020 mt (5.1 billion lbs) in 2007 and to 2,043,440 mt (4.5 billion lbs) in 2008. Landings during 2006-2008 would be 273,290 mt (603 million lbs), 238,790 mt (527 million lbs), and 211,990 mt (467 million lbs), respectively (Table B13). These landings are the result of an unusually large year-class (1999) present in 2005, and will not be sustainable in the long term. It is expected that these projected landings will decline to MSY (89,000 mt (196 million lbs)) levels in the future when a more average recruitment condition exists in the stock.

8.0 SENSITIVITY ANALYSIS

An additional trial run was conducted to address the retrospective problem that occurred in the base run. It was assumed that there is still a great deal of variability in the model fit caused by the lack of older fish in the CAA and survey. Even aggregating the CAA and survey to 7+ did not appear to alleviate this problem fully. We therefore decided to allow the model to estimate selectivity during 1995-2004 in the fishery to see if this impacted the results. Emphasis coefficients for this model are listed in Table (B10). This approach changed and improved the retrospective pattern in SSB and recruitment. The retrospective for SSB appears to have been minimized as all the trajectories are consistent and there is no apparent pattern (Figure 1 App2). The retrospective pattern for recruitment also appears to be lessoned, but there is still some sequential patterning for year-classes prior to 1999 and a clear pattern for the 1999 year-class (Figure 2 App2).

The working group also wanted to see an ASAP model run that included the NEFSC winter bottom trawl survey to compare the results to the VPA. SSB in this model run showed the familiar peak in biomass in the early 1970s, but this was followed by a steep decline in SSB to a low of 99,000 mt in 2004 Figure 3 App2). This steep decline in SSB was the result of a very sharp increase in fishing mortality during the late 1990s and 2000-2004 (Figure 4 App2). The observed vs. predicted series for the winter (Figure 5 App2), and spring 1 (Figure 6 App2) were reasonable, but the pattern for the spring2 series deteriorated, with a series of negative residuals from 1990-2003 (Figure 7 App2). Adding the winter series to the ASAP model obviously caused the model fit to deteriorate seriously, producing infeasible trends in SSB and fishing mortality.

The final sensitivity run requested by the committee was a model that allowed selectivity to be estimated for the entire time-series from 1962-2004. This run was accomplished by using the same parameter setup as for the base case, but designating two separate time-blocks, one from 1962-1994 and the other from 1995-2004, and letting the model estimate fishery selectivity. In this run, SSB increased to over 1.6 million mt in 1972, declined sharply, and then steadily increased to about 1.4 million mt in 2004 (Figure 8 App2). As in several of the previous runs, fishing mortality peaked in the 1970s, declined, and remained low during the 1980s-2004. However, in this run F was much more asymptotic during the early years and then more dome shaped during the late 1990s, through 2004 (Figure 9 App2). The observed vs. predicted series for this model show that goodness of fit was reasonable with both the spring1 and spring2 series showing little patterning (Figure 10; 11 App2). The fishery selectivity for this model was asymptotic for the early years of the time-series and showed a moderate dome thereafter (Figure 12 App2).

9.0 SARC-30 RESEARCH RECOMMENDATIONS (TOR 6)

a. Explore logbook data for information on catch rates and geographic distribution.

No analysis was completed on this recommendation. Previous analyses have suggested that catch rates from the mackerel are an unreliable index of abundance because electronics are used to actively search for this species. Frequent technological improvements in winches, nets, doors, and other equipment also make it very difficult to compare fishery dependent catch rates among years. The fishery also tends to be aggregated in isolated small areas, piggybacked on the success of other vessels during the season. The recent and current fishery in the USA takes place along the inshore areas of New Jersey and Rhode Island depending on the location of mackerel on the continental shelf during winter. This factor means that very little information on the distribution of mackerel can probably be obtained from fishery dependent data.

b. Explore Canadian trawl survey indices for use in VPA calibrations.

Several additional trawl survey indices and egg indices were explored as tuning indices, but currently they do not appear useful in resolving assessment issues with this stock (Pers. comm. F. Gregoire DFO 2005)

c. Explore the feasibility of acoustic surveys for monitoring stock size.

Several attempts have been made to use acoustics to survey mackerel during recent winter cruises on the RV Delaware II. To date there has been little success, but this does not preclude the use of acoustics on this species, especially with the RV Bigelow in future.

d. Examine estimates of Z calculated from research vessel survey data with respect to their usefulness in estimating natural mortality.

No progress was made on this recommendation during the interim period.

10.0 RESEARCH RECOMMENDATIONS

- Currently there are historical age data that are only in hard copy form. These data should be put into an electronic database to allow examination of alternative methods, such as non-transformed indices.

- The current approach of transforming the survey indices should be expanded to include an exploratory analysis of geometric mean or other distributions instead of retransformed mean.

- Examine NEFSC Spring survey since 1999 to see what may have caused large increases in catch/tow.

- Explore use of environmental covariates to help explain recruitment deviations from the stock recruitment relationship.

- Consider the use of environmental variables to adjust the NEFSC Winter and Canadian surveys for changes in availability and consider their use as tuning indices in modeling.

- Increase sampling of commercial landings and survey catches to better characterize age and length composition.

- Conduct simulation exercises to determine the sample sizes required to detect old fish with high probability in commercial samples assuming they are present.

- Explore discard estimation, especially for years when large year classes are first entering the fishery.

- Pilot survey to explore for old fish to test hypothesis regarding dome in commercial fishery selectivity.

11.0 LITERATURE CITED

Bigelow, H.B., and W.C. Schroeder. 2002. Fishes of the Gulf of Maine. Edited by B.C. Collette and G. Klein-MacPhee. Third edition. Smithsonian Institution Press, Washington D.C.

Byrne, C.J., and J.R.S. Forrester. 1991. Relative fishing power of two types of trawl doors. NEFSC SAW/12. 7pp.

DFO. 2004. Atlantic mackerel of the Northwest Atlantic in 2003. Department of Fisheries and Oceans, Canada. Stock Staus Report 2004/018. 12 pp.

Fox, W.W. 1975. Fitting the generalized stock production model by least squares and equilibrium approximation. US Fish Bulletin. 73:23-37.

Gregoire , F., C. Levesque, J. Guerin, L. Hudon, and J. Lavers. 2003. Atlantic mackerel (Scomber scombrus L.) fishery and biology in NAFO Subarea 3 and 4 in 2002. DFO Canada Sci. Advis. Sec. Res. Doc. 2003/085. 36p.

Grégoire, F. 2005. Update (September 2005) of the Atlantic mackerel (*Scomber scombrus* L.) landings in NAFO Subareas 3 and 4 in 2004. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/057. 17pp.

MAFMC. 1998. Amendment 8 to the Atlantic mackerel, squid, and butterfish fishery management plan. Mid-Atlantic Fishery management Council. October 1998. 351 p.

Morse, W.W., M.P. Fahay, and W.G. Smith. 1987. MARMAP surveys of the continental shelf from Cape Hatteras, North Carolina, to Cape Sable, Nova Scotia (1977-1984). Atlas No. 2. Annual distribution patterns of fish larvae. NOAA Tech. Memo. NMFS-F/NEC-47, 215 pp.

NEFMC 1998. Evaluation of existing overfishing definitions and recommendations for new overfishing definitions to comply with the Sustainable Fisheries Act. Overfishing Definition Review Panel. 179 p.

Northeast Fisheries Science Center (NEFSC). 2000. Atlantic Mackerel. 30th Northeast Regional Stock Assessment Workshop (30th SAW). Consensus summary of assessments. Northeast Fisheries Science Center Reference Document 00-03:273-310.

O'Brien, L, J. Burnett, and R.K. Mayo. 1993. Maturation of nineteen species of finfish off the northeast coast of the United States, 1985-1990. NOAA, NMFS, Tech. Rep. 113. 66p.

Overholtz, W.J., J.S. Link, and L.E. Suslowicz. 2000. Consumption of important pelagic fish and squid by predatory fish in the northeastern USA shelf ecosystem with some fishery comparisons. Ices Journal of Marine Science. 57:1147-1159.

Overholtz, W.J., L.D. Jacobson, G.D. Melvin, M. Cieri, M. Power, D. Libby, and K. Clark. 2004. Stock assessment of the Gulf of Maine- Georges Bank Atlantic herring complex. Northeast Fisheries Science Center Reference Document 04-06. 290 p.

Schnute, J. 1985. A general theory for analysis of catch and effort data. Can. J. Fish. Aquat. Sci. 42: 414-429.

Schaefer, M.B. 1954. Some aspects of the dynamics of populations important in the management of commercial fisheries. Bulletin Inter-Tropical Tuna Commission. 1:27-56.

MACKEREL TABLES.

Table B1. Commercial and Recreational landings (mt) of Atlantic mackerel for the USA, Canada, and other countries from NAFO SA 2-6 during 1960-2004

1 Landings by Canadian vessels (Commercial) or foreign countries (Foreign) in Canadian waters (SA 2-4)

2 Landings by USA vessels (Commercial), recreational sources (Recreational), or foreign countries (Foreign) in USA waters (SA5-6).

	Canada		USA			
Year	**Commercial[1]**	**Foreign[1]**	**Commercial[2]**	**Recreational[2]**	**Foreign[2]**	**Total**
1960	5888	0	1396	2478	0	9762
1961	5458	11	1361	-	11	6841
1962	6901	64	938	-	175	8078
1963	6363	99	1320	-	1299	9081
1964	10786	174	1644	-	801	13405
1965	11185	405	1998	4292	2945	20825
1966	11577	1244	2724	-	7951	23496
1967	11181	62	3891	-	19047	34181
1968	11134	9720	3929	-	65747	90530
1969	13257	5379	4364	-	114189	137189
1970	15710	5296	4049	16039	210864	251958
1971	14942	9554	2406	-	355892	382794
1972	16254	6107	2006	-	391464	415831
1973	21619	16984	1336	-	396759	436698
1974	16701	27954	1042	-	321837	367534
1975	13544	22718	1974	5190	271719	315145
1976	15746	17319	2712	-	223275	259052
1977	20362	2913	1377	-	56067	80719
1978	25429	470	1605	-	841	28345
1979	30244	368	1990	3588	440	36630
1980	22136	161	2683	2364	566	27910
1981	19294	61	2941	3233	5361	30890
1982	16380	3	3330	666	6647	27026
1983	19797	9	3805	3022	5955	32588
1984	17320	913	5954	2457	15045	41689
1985	29855	1051	6632	2986	32409	72933
1986	30325	772	9637	3856	26507	71097
1987	27488	71	12310	4025	36564	80458
1988	24060	956	12309	3251	42858	83434
1989	20795	347	14556	1862	36823	74383
1990	19190	3854	31261	1908	30678	86891
1991	24914	1281	26961	2439	15714	71309
1992	24307	2417	11775	344	0	38843
1993	26158	591	4666	540	0	31955
1994	20564	49	8877	1705	0	31195
1995	17650	0	8479	1249	0	27378
1996	20364	0	16137	1416	0	37917
1997	21309	0	15400	1735	0	38444
1998	19334	0	14415	670	0	34419
1999	16561	0	12026	1335	0	29922
2000	13383	0	5646	1448	0	20477
2001	23868	0	12336	1538	0	37742
2002	34402	0	26452	1286	0	62140
2003	44475	0	34292	724	0	79491
2004	51444	0	53724	467	0	105635
2005	0	0	41234	0	0	41234

Table B2. USA sampling of Atlantic mackerel commercial and recreational landings during 1998-2004.

	Commercial Lengths		**Ages-All Sources**		**Recreational Lengths**
Year	**Jan-June**	**July-Dec**	**Jan-June**	**July-Dec**	
1998	1956		1901		615
1999	4297		920		979
2000	907		625		723
2001	2910	116	1333	91	778
2002	2264	197	1207	118	483
2003	2465	322	1061	121	606
2004	938	163	719	71	1347

Table B3. Atlantic mackerel catch-at-age (millions) for NAFO SA 2-6 during 1962-2004

Year	1	2	3	4	5	6	7	8	9	10+	Total
1962	16.1	2.8	15.2	3.8	1.2	1.6	1.4	0.8	0.4	0.4	43.7
1963	1.1	4.2	1.3	26.3	6.0	0.3	0.2	0.2	0.2	0.2	40.0
1964	12.9	7.0	4.1	4.0	19.4	4.1	3.9	0.7	0.8	0.2	57.1
1965	9.0	3.6	2.9	4.0	5.2	19.5	4.2	4.0	0.7	0.0	53.1
1966	24.0	11.5	5.3	2.6	4.7	7.9	21.8	0.5	0.2	0.0	78.5
1967	0.8	26.7	19.8	3.5	3.3	5.1	6.1	32.3	0.3	0.0	97.9
1968	141.4	61.5	59.3	38.1	14.3	6.6	0.7	1.0	6.1	0.1	329.1
1969	7.1	262.1	160.7	65.8	5.7	3.0	2.0	3.1	2.2	8.3	520.0
1970	193.5	54.5	522.1	162.9	27.6	7.0	5.3	9.9	10.0	6.6	999.4
1971	74.6	294.2	127.4	558.9	203.5	34.6	8.9	3.6	4.3	15.3	1325.3
1972	22.1	85.7	256.2	182.6	390.4	87.3	24.0	4.2	8.2	9.4	1070.1
1973	161.8	283.2	285.1	233.6	192.4	197.2	31.2	11.0	4.1	5.4	1405.0
1974	95.9	242.2	264.4	101.5	114.3	111.8	108.3	25.7	6.4	3.3	1073.8
1975	373.7	431.4	113.7	100.8	58.6	67.8	51.9	50.5	12.5	3.3	1264.2
1976	12.5	353.5	272.5	85.7	52.4	27.3	40.5	34.6	22.6	14.8	916.4
1977	2.0	27.0	101.0	54.0	12.0	9.9	5.6	6.3	3.8	4.2	225.8
1978	0.1	0.2	4.7	17.4	13.3	8.4	4.7	2.2	4.5	7.3	62.8
1979	0.4	0.6	1.3	7.1	18.6	13.1	6.2	2.6	2.2	6.5	58.6
1980	1.2	10.9	1.0	1.0	6.9	13.8	4.7	2.0	1.0	5.2	47.7
1981	16.1	7.1	9.2	1.4	2.0	6.1	11.7	4.9	2.5	3.5	64.5
1982	3.7	11.8	2.7	9.1	1.2	1.9	3.4	8.4	2.9	5.1	50.2
1983	2.2	15.3	6.5	1.9	7.0	0.7	1.2	5.5	10.2	6.5	57.0
1984	0.5	40.4	27.2	3.2	1.2	4.6	0.6	0.7	3.4	14.0	95.8
1985	3.4	1.9	135.7	33.4	2.7	0.8	3.2	0.3	0.5	11.4	193.3
1986	1.1	10.4	6.5	91.7	22.1	1.7	0.5	3.1	0.2	5.6	142.9
1987	9.7	14.2	13.3	7.5	106.9	17.5	2.6	0.4	2.1	3.8	178.0
1988	1.5	13.0	10.3	10.1	11.5	107.4	22.5	2.6	1.2	5.7	185.8
1989	1.9	14.0	11.0	7.4	6.8	2.3	85.7	4.3	0.8	1.7	135.9
1990	1.7	19.9	30.4	7.9	6.4	4.3	0.8	54.1	2.6	1.2	129.4
1991	1.4	12.6	55.2	23.9	6.1	3.9	3.3	1.0	27.3	1.2	136.0
1992	0.7	6.5	5.0	24.9	14.9	2.0	1.4	1.2	1.3	16.1	74.0
1993	1.1	8.8	10.9	6.1	16.4	8.9	1.9	0.8	1.1	8.4	64.5
1994	1.9	1.6	12.0	13.8	5.3	19.4	6.7	1.1	0.3	4.0	66.1
1995	11.9	20.7	2.7	9.5	8.2	3.2	10.3	3.2	0.3	0.9	71.0
1996	3.0	26.5	24.1	1.9	12.6	9.8	2.5	10.2	2.3	1.5	94.5
1997	6.9	22.0	23.4	11.1	1.1	8.5	6.8	2.8	7.2	1.9	91.6
1998	2.2	29.8	19.1	16.6	8.7	1.2	5.9	4.1	1.0	2.4	91.0
1999	1.7	6.5	23.3	14.1	9.2	4.8	1.4	2.9	2.0	1.3	67.2
2000	26.0	9.3	6.0	10.3	4.4	3.3	0.7	0.1	0.2	0.4	60.6
2001	8.6	74.9	23.3	7.3	9.6	2.3	2.1	0.7	0.2	0.3	129.4
2002	9.9	12.4	120.0	14.2	5.3	9.7	3.1	0.8	0.2	0.1	175.7
2003	9.6	23.5	26.4	121.8	14.0	5.0	4.9	0.3	0.0	0.0	205.5
2004	35.1	74.0	22.0	24.9	120.1	9.0	2.8	0.9	0.2	0.0	288.8

Table B4. Mean weight-at-age (USA and Canada, kg) for Atlantic mackerel during 1962-2004.

Year	1	2	3	4	5	6	7	8	9	10+
1962	0.130	0.208	0.289	0.365	0.433	0.491	0.541	0.581	0.614	0.657
1963	0.120	0.192	0.264	0.334	0.395	0.448	0.492	0.529	0.559	0.593
1964	0.116	0.188	0.262	0.332	0.395	0.450	0.495	0.533	0.564	0.588
1965	0.123	0.200	0.278	0.352	0.419	0.477	0.525	0.565	0.598	0.595
1966	0.128	0.209	0.294	0.374	0.447	0.509	0.562	0.605	0.641	0.595
1967	0.123	0.202	0.283	0.360	0.428	0.489	0.540	0.581	0.615	0.595
1968	0.148	0.241	0.335	0.425	0.506	0.576	0.634	0.683	0.722	0.753
1969	0.131	0.214	0.300	0.382	0.456	0.520	0.574	0.618	0.654	0.683
1970	0.107	0.179	0.253	0.324	0.389	0.444	0.491	0.530	0.562	0.596
1971	0.110	0.181	0.256	0.327	0.391	0.446	0.494	0.532	0.564	0.599
1972	0.123	0.210	0.300	0.386	0.464	0.533	0.590	0.638	0.677	0.723
1973	0.113	0.189	0.269	0.345	0.414	0.473	0.524	0.565	0.600	0.635
1974	0.111	0.190	0.273	0.352	0.425	0.487	0.541	0.585	0.621	0.655
1975	0.104	0.176	0.252	0.326	0.393	0.451	0.500	0.540	0.573	0.606
1976	0.097	0.168	0.244	0.316	0.382	0.440	0.489	0.530	0.563	0.592
1977	0.114	0.198	0.288	0.375	0.454	0.524	0.582	0.631	0.671	0.707
1978	0.192	0.285	0.425	0.463	0.509	0.582	0.625	0.659	0.673	0.713
1979	0.190	0.272	0.531	0.567	0.579	0.603	0.652	0.714	0.752	0.803
1980	0.146	0.376	0.548	0.609	0.617	0.635	0.672	0.705	0.781	0.777
1981	0.114	0.315	0.523	0.577	0.643	0.660	0.674	0.707	0.723	0.768
1982	0.152	0.340	0.541	0.606	0.666	0.743	0.737	0.722	0.719	0.775
1983	0.098	0.257	0.479	0.593	0.628	0.659	0.712	0.709	0.705	0.730
1984	0.098	0.162	0.338	0.525	0.625	0.657	0.696	0.715	0.705	0.716
1985	0.111	0.260	0.277	0.416	0.558	0.644	0.677	0.665	0.737	0.715
1986	0.079	0.234	0.349	0.366	0.452	0.581	0.640	0.729	0.777	0.740
1987	0.107	0.210	0.316	0.404	0.411	0.505	0.502	0.706	0.747	0.744
1988	0.100	0.222	0.343	0.408	0.453	0.484	0.584	0.694	0.755	0.770
1989	0.100	0.231	0.375	0.414	0.474	0.509	0.529	0.631	0.753	0.813
1990	0.138	0.224	0.336	0.449	0.487	0.527	0.609	0.570	0.644	0.742
1991	0.187	0.293	0.399	0.462	0.543	0.596	0.616	0.688	0.686	0.768
1992	0.163	0.270	0.378	0.420	0.477	0.522	0.579	0.639	0.642	0.655
1993	0.185	0.270	0.351	0.435	0.477	0.534	0.595	0.644	0.682	0.693
1994	0.158	0.232	0.318	0.399	0.492	0.520	0.587	0.629	0.705	0.665
1995	0.187	0.261	0.343	0.417	0.469	0.544	0.554	0.617	0.704	0.768
1996	0.218	0.254	0.354	0.481	0.482	0.552	0.596	0.644	0.692	0.684
1997	0.199	0.301	0.382	0.451	0.547	0.532	0.571	0.609	0.658	0.685
1998	0.149	0.250	0.373	0.482	0.535	0.560	0.592	0.604	0.656	0.682
1999	0.167	0.266	0.393	0.459	0.529	0.581	0.611	0.618	0.681	0.685
2000	0.200	0.231	0.322	0.443	0.530	0.585	0.614	0.674	0.693	0.678
2001	0.137	0.263	0.359	0.402	0.507	0.580	0.649	0.628	0.663	0.677
2002	0.138	0.220	0.344	0.430	0.471	0.563	0.599	0.645	0.707	0.677
2003	0.129	0.229	0.308	0.435	0.517	0.573	0.635	0.641	0.839	0.677
2004	0.179	0.226	0.342	0.387	0.480	0.501	0.607	0.698	0.572	0.677

Table B5. Stratified mean weight and number per tow (standard) of Atlantic Mackerel from the NEFSC spring bottom trawl survey during 1968-2005.

Year	Kg	Number
1968	5.609	70.869
1969	0.055	0.484
1970	2.2	9.356
1971	3.145	12.668
1972	1.542	8.49
1973	6.746	20.973
1974	0.656	2.241
1975	0.242	3.54
1976	0.254	1.8
1977	0.081	0.287
1978	0.345	0.97
1979	0.089	0.172
1980	0.202	0.559
1981	2.47	5.872
1982	0.854	5.167
1983	0.135	0.884
1984	2.611	16.228
1985	2.232	8.242
1986	1.264	4.178
1987	7.492	35.231
1988	4.133	16.792
1989	1.1	12.273
1990	1.548	10.748
1991	5.604	23.265
1992	4.705	24.275
1993	5.583	26.089
1994	5.987	38.638
1995	5.1	24.387
1996	11.101	40.887
1997	2.494	22.054
1998	3.378	25.11
1999	7.109	50.617
2000	6.934	70.357
2001	15.726	116.454
2002	7.65	35.201
2003	11.082	60.488
2004	8.088	110.683
2005	4.276	32.322

Table B6. Atlantic mackerel number per tow (ln retransformed) at age from the NEFSC Spring bottom trawl survey during 1968-2005

Year	1	2	3	4	5	6	7	8	9	10+
1968	12.9400	0.4150	0.1894	0.0523	0.0164	0.0000	0.0000	0.0000	0.0000	0.0000
1969	0.0297	0.1418	0.0167	0.0058	0.0003	0.0007	0.0005	0.0009	0.0004	0.0004
1970	0.2795	0.1845	1.3910	0.6115	0.1812	0.0617	0.0549	0.0877	0.0827	0.0473
1971	0.3282	0.9409	0.4383	1.1250	0.3929	0.0621	0.0141	0.0073	0.0062	0.0083
1972	0.8719	0.3077	0.5929	0.2261	0.3254	0.0583	0.0112	0.0011	0.0018	0.0004
1973	0.3514	0.3398	0.1758	0.2338	0.1262	0.2846	0.1821	0.1524	0.0460	0.1022
1974	0.3478	0.1796	0.2358	0.0478	0.0985	0.0599	0.2084	0.0912	0.0590	0.0232
1975	0.6544	0.2298	0.0409	0.0226	0.0064	0.0073	0.0043	0.0039	0.0034	0.0000
1976	0.0959	0.3871	0.0710	0.0135	0.0024	0.0006	0.0028	0.0004	0.0019	0.0006
1977	0.0095	0.0472	0.0850	0.0453	0.0154	0.0052	0.0028	0.0070	0.0038	0.0139
1978	0.0502	0.1097	0.1032	0.1943	0.0958	0.0284	0.0110	0.0027	0.0148	0.0177
1979	0.0105	0.0037	0.0072	0.0126	0.0495	0.0144	0.0103	0.0057	0.0057	0.0482
1980	0.0234	0.1877	0.0066	0.0048	0.0233	0.0489	0.0110	0.0107	0.0070	0.0284
1981	0.3355	0.1371	0.4294	0.0476	0.0463	0.1613	0.4041	0.2302	0.1385	0.4021
1982	0.4323	0.1950	0.0215	0.0979	0.0182	0.0102	0.0245	0.0965	0.0440	0.0836
1983	0.2357	0.2873	0.0222	0.0016	0.0036	0.0006	0.0002	0.0014	0.0022	0.0020
1984	0.2598	1.8014	0.6055	0.0415	0.0050	0.0432	0.0036	0.0025	0.0161	0.0837
1985	0.3382	0.0846	1.8513	0.2348	0.0277	0.0107	0.0469	0.0032	0.0097	0.1864
1986	0.1301	0.4497	0.0778	0.5908	0.1177	0.0080	0.0014	0.0196	0.0004	0.0474
1987	1.4842	1.7945	0.8742	0.3719	2.9450	0.4967	0.1427	0.0156	0.1383	0.2560
1988	0.6336	0.4577	0.3666	0.3357	0.3748	1.7688	0.4428	0.0513	0.0478	0.2232
1989	1.5826	1.6407	0.0707	0.2841	0.0087	0.0108	0.0666	0.0086	0.0050	0.0182
1990	1.3003	1.3849	0.5010	0.0157	0.0129	0.0059	0.0004	0.0762	0.0094	0.0157
1991	1.6697	0.8891	1.4843	0.5374	0.2400	0.1144	0.0578	0.0000	0.2685	0.0027
1992	2.6984	2.3787	0.5585	1.0531	0.6272	0.1155	0.1321	0.0312	0.0449	0.2983
1993	0.9331	2.2477	0.9019	0.6031	0.9864	0.4515	0.1389	0.0915	0.2184	0.6286
1994	4.1386	1.7436	2.1139	0.8699	0.2534	0.5039	0.1133	0.0512	0.0105	0.2267
1995	3.1701	3.4871	0.5893	1.1824	0.7122	0.2848	0.7191	0.2258	0.0451	0.1351
1996	4.0058	3.2257	1.3258	0.1481	0.6175	0.4196	0.1927	0.2800	0.1456	0.1220
1997	3.0378	1.1619	0.4485	0.2247	0.0254	0.1244	0.1149	0.0452	0.0702	0.0159
1998	5.6955	3.1199	0.6787	0.2863	0.1211	0.0171	0.0867	0.0633	0.0179	0.0240
1999	5.0097	4.1347	2.9205	0.9221	0.4061	0.1784	0.0498	0.0819	0.0389	0.0191
2000	14.8080	2.4561	1.1156	0.7272	0.2514	0.1189	0.0500	0.0000	0.0194	0.0239
2001	12.4610	26.5960	1.7581	0.3622	0.2115	0.0375	0.0114	0.0093	0.0042	0.0012
2002	1.2662	2.9770	5.7418	0.4438	0.1229	0.0493	0.0192	0.0014	0.0000	0.0000
2003	9.1159	8.3906	2.9148	3.2997	0.4028	0.1207	0.0555	0.0000	0.0000	0.0000
2004	21.9190	3.0060	0.3165	0.1166	0.1516	0.0121	0.0010	0.0000	0.0000	0.0000
2005	1.7745	3.7293	0.9319	0.1697	0.1354	0.3667	0.0258	0.0050	0.0000	0.0000

Table B7. Weight and number per tow (standard) number per tow from the NEFSC winter bottom trawl survey during 1992-2005.

Year	Kg	Number
1992	14.813	47.694
1993	4.265	17.263
1994	0.254	1.161
1995	27.125	74.658
1996	6.828	40.034
1997	3.139	20.792
1998	4.123	18.332
1999	1.675	13.254
2000	1.342	4.676
2001	4.238	25.285
2002	5.528	25.609
2003	24.262	103.576
2004	5.042	59.469
2005	32.047	245.577

Table B8. Number of Atlantic mackerel per tow at age (retransformed) from the NEFSC Winter bottom trawls survey during 1992-2005.

Year	1	2	3	4	5	6	7	8	9	10+
1992	3.0523	1.4908	0.5367	1.6471	1.2904	0.3196	0.4615	0.1702	0.3949	2.1468
1993	0.7766	3.4136	0.9937	0.3717	0.9014	0.6192	0.1061	0.1033	0.249	0.3242
1994	0.3244	0.1053	0.2362	0.1387	0.0284	0.066	0.0116	0.0043	0	0.0043
1995	1.6475	4.0829	0.12502	2.0966	1.693	0.9592	2.0291	0.9036	0.2251	0.5583
1996	3.6854	2.4076	0.9712	0.1034	0.5132	0.3334	0.1294	0.2284	0.0864	0.0235
1997	2.1225	2.0327	1.5196	0.6153	0.0429	0.2684	0.2356	0.1026	0.1556	0.0283
1998	1.7823	2.8163	0.8565	0.6274	0.3459	0.076	0.1595	0.2664	0.0381	0.1187
1999	1.2908	0.6953	0.8	0.2662	0.1451	0.0802	0.0253	0.0498	0.0147	0.0164
2000	0.3437	0.8842	0.5921	0.4236	0.1798	0.0954	0.0365	0	0.01	0.0377
2001	2.0193	2.9817	0.5373	0.2485	0.3259	0.0922	0.0507	0.0282	0.011	0.0012
2002	1.871	0.7383	0.0269	0.412	0.1711	0.169	0.0633	0.009	0	0.0005
2003	15.955	4.4698	2.0118	2.4065	0.5303	0.3372	0.2546	0.0452	0	0
2004	11.334	2.1515	0.2461	0.2624	0.6209	0.0871	0.0102	0.001	0.001	0
2005	34.691	38.056	3.822	0.5594	0.4275	1.0818	0.0235	0.0122	0	0

Table B9. Likelihood components and emphasis coefficients in ASAP base case model run

Likelihood Component	**Lambda**
Landings	1000
SR relationship	1
Spring survey	6.74
Recruitment CV	0.5
CAA	50

Table B10. Likelihood components and emphasis coefficients in ASAP model run to address retrospective patterning

Likelihood Component	**Lambda**
Landings	1000
SR relationship	10
Fishery Selectivity	10
Spring survey	6.74
Recruitment CV	0.5, and 0.01 in 2000&2004
CAA	50

Table B11. Likelihood results for various model components for preliminary, base case, and sensitivity runs of the ASAP model.

ASAP model runs					**Sensitivity model runs**		
	spring only	**spring split**	**spring split**	**Base**	**winter &**	**retro**	**est selectivity**
			SR on	**Case**	**spring**	**fix 95-04**	**62-94, 95-04**
obj_fun	4327.18	3943.78	2499.00	1580.08	3241.43	1692.53	1540.11
Catch_Fleet_Total	3.17	2.57	1.03	0.50	6.78	0.60	0.99
CAA_proportions	1048.16	998.27	317.64	254.81	310.93	350.87	211.44
Index_Fit_Total	3275.85	2942.94	2075.09	1221.98	2777.30	1253.53	1219.76
Winter					597.87		
Spring no split	3275.85						
Spring1 split		1657.48	1150.56	653.71	1199.72	685.56	655.31
Spring2 split		1285.46	924.53	568.27	979.71	567.97	564.46

Table B12. Parameter file from ASAP base case model run with parameter name, parameter estimate (value), and standard deviation (std)

index	name	value	std
1	log_Fmult_year1	-3.15E+00	1.41E-01
2	log_Fmult_devs	1.20E-01	3.91E-02
3	log_Fmult_devs	2.65E-01	3.82E-02
4	log_Fmult_devs	8.42E-02	3.65E-02
5	log_Fmult_devs	1.59E-01	4.05E-02
6	log_Fmult_devs	1.67E-01	4.96E-02
7	log_Fmult_devs	1.59E-01	5.49E-02
8	log_Fmult_devs	8.20E-02	4.64E-02
9	log_Fmult_devs	4.10E-01	3.68E-02
10	log_Fmult_devs	4.85E-01	3.43E-02
11	log_Fmult_devs	6.78E-02	3.40E-02
12	log_Fmult_devs	4.07E-01	3.50E-02
13	log_Fmult_devs	5.72E-02	3.61E-02
14	log_Fmult_devs	6.77E-02	3.88E-02
15	log_Fmult_devs	-8.90E-02	4.21E-02
16	log_Fmult_devs	-1.29E+00	3.86E-02
17	log_Fmult_devs	-1.00E+00	3.45E-02
18	log_Fmult_devs	2.05E-02	3.33E-02
19	log_Fmult_devs	-2.58E-01	3.48E-02
20	log_Fmult_devs	1.34E-01	3.57E-02
21	log_Fmult_devs	-1.11E-01	3.60E-02
22	log_Fmult_devs	-6.07E-02	4.09E-02
23	log_Fmult_devs	-5.93E-02	4.00E-02
24	log_Fmult_devs	4.25E-01	3.90E-02
25	log_Fmult_devs	-1.07E-01	3.33E-02
26	log_Fmult_devs	3.52E-01	3.35E-02
27	log_Fmult_devs	3.09E-01	3.46E-02
28	log_Fmult_devs	-2.14E-01	3.61E-02
29	log_Fmult_devs	-1.89E-01	3.68E-02
30	log_Fmult_devs	-7.82E-02	3.65E-02
31	log_Fmult_devs	-6.40E-01	3.39E-02
32	log_Fmult_devs	-6.99E-02	3.56E-02
33	log_Fmult_devs	7.39E-02	3.38E-02
34	log_Fmult_devs	-1.02E-01	3.42E-02
35	log_Fmult_devs	3.07E-01	3.45E-02
36	log_Fmult_devs	-3.79E-02	3.51E-02
37	log_Fmult_devs	-6.95E-02	3.43E-02
38	log_Fmult_devs	-2.51E-01	3.53E-02
39	log_Fmult_devs	-5.82E-01	3.76E-02
40	log_Fmult_devs	4.95E-01	4.11E-02
41	log_Fmult_devs	2.29E-01	3.75E-02
42	log_Fmult_devs	2.29E-01	3.37E-02
43	log_Fmult_devs	2.60E-01	3.74E-02
44	log_recruit_devs	-9.64E-01	1.80E-01
45	log_recruit_devs	-8.62E-01	2.50E-01
46	log_recruit_devs	-7.25E-01	2.20E-01

47	log_recruit_devs	-1.94E-01	2.02E-01
48	log_recruit_devs	7.81E-01	1.84E-01
49	log_recruit_devs	1.33E+00	1.67E-01
50	log_recruit_devs	2.40E+00	1.38E-01
51	log_recruit_devs	7.20E-01	1.23E-01
52	log_recruit_devs	1.00E+00	1.33E-01
53	log_recruit_devs	-3.52E-02	1.56E-01
54	log_recruit_devs	2.89E-01	1.55E-01
55	log_recruit_devs	2.63E-01	1.58E-01
56	log_recruit_devs	8.22E-01	1.25E-01
57	log_recruit_devs	1.07E+00	9.80E-02
58	log_recruit_devs	-2.53E-01	1.19E-01
59	log_recruit_devs	-1.37E+00	1.39E-01
60	log_recruit_devs	-1.79E+00	1.45E-01
61	log_recruit_devs	-3.42E-01	1.17E-01
62	log_recruit_devs	-1.58E+00	1.37E-01
63	log_recruit_devs	-5.04E-01	1.25E-01
64	log_recruit_devs	5.84E-01	1.07E-01
65	log_recruit_devs	1.59E+00	8.67E-02
66	log_recruit_devs	-9.97E-01	1.37E-01
67	log_recruit_devs	-1.29E+00	1.38E-01
68	log_recruit_devs	-1.05E+00	1.38E-01
69	log_recruit_devs	-1.06E+00	1.36E-01
70	log_recruit_devs	4.07E-02	1.11E-01
71	log_recruit_devs	5.02E-01	9.94E-02
72	log_recruit_devs	-3.56E-01	1.17E-01
73	log_recruit_devs	5.24E-03	1.07E-01
74	log_recruit_devs	-6.88E-02	1.12E-01
75	log_recruit_devs	-1.26E+00	1.33E-01
76	log_recruit_devs	-1.44E-01	1.11E-01
77	log_recruit_devs	-1.80E-02	1.08E-01
78	log_recruit_devs	-1.72E-01	1.13E-01
79	log_recruit_devs	1.68E-01	1.11E-01
80	log_recruit_devs	-2.11E-01	1.22E-01
81	log_recruit_devs	3.51E-03	1.27E-01
82	log_recruit_devs	1.82E+00	1.12E-01
83	log_recruit_devs	2.72E-01	1.49E-01
84	log_recruit_devs	-1.13E-01	1.82E-01
85	log_recruit_devs	6.28E-01	2.03E-01
86	log_recruit_devs	1.08E+00	2.47E-01
87	log_N_year1_devs	-7.55E-01	2.74E-01
88	log_N_year1_devs	9.70E-01	1.78E-01
89	log_N_year1_devs	-2.89E-01	2.77E-01
90	log_N_year1_devs	-1.79E+00	7.31E-01
91	log_N_year1_devs	-1.39E+00	6.93E-01
92	log_N_year1_devs	-2.28E+00	4.77E-01
93	log_q_year1	-8.40E+00	1.06E-01
94	log_q_year1	-7.12E+00	1.05E-01
95	log_q_year1	-7.12E+00	1.06E-01
96	log_q_year1	-6.90E+00	1.11E-01

97	log_q_year1	-6.40E+00	1.17E-01
98	log_q_year1	-5.99E+00	1.26E-01
99	log_q_year1	-6.96E+00	1.46E-01
100	log_q_year1	-7.28E+00	1.66E-01
101	log_q_year1	-6.92E+00	1.65E-01
102	log_q_year1	-6.59E+00	1.65E-01
103	log_q_year1	-6.34E+00	1.67E-01
104	log_q_year1	-6.42E+00	1.69E-01
105	log_q_year1	-6.25E+00	1.70E-01
106	log_q_year1	-7.33E+00	1.73E-01
107	log_SRR_virgin	7.38E+00	1.43E-01
108	SRR_steepness	5.07E-01	1.09E-01
109	SSB	2.98E+02	4.09E+01
110	SSB	3.02E+02	4.11E+01
111	SSB	3.16E+02	4.26E+01
112	SSB	3.36E+02	4.46E+01
113	SSB	3.70E+02	4.55E+01
114	SSB	4.45E+02	4.55E+01
115	SSB	8.31E+02	6.16E+01
116	SSB	1.36E+03	6.49E+01
117	SSB	1.60E+03	6.67E+01
118	SSB	1.65E+03	6.52E+01
119	SSB	1.70E+03	7.37E+01
120	SSB	1.23E+03	5.92E+01
121	SSB	9.38E+02	5.33E+01
122	SSB	7.23E+02	4.37E+01
123	SSB	6.63E+02	4.49E+01
124	SSB	6.77E+02	6.12E+01
125	SSB	7.82E+02	7.51E+01
126	SSB	8.03E+02	7.80E+01
127	SSB	7.98E+02	7.70E+01
128	SSB	7.74E+02	7.46E+01
129	SSB	7.79E+02	7.46E+01
130	SSB	8.59E+02	8.11E+01
131	SSB	1.09E+03	1.05E+02
132	SSB	1.36E+03	1.37E+02
133	SSB	1.30E+03	1.39E+02
134	SSB	1.15E+03	1.29E+02
135	SSB	1.07E+03	1.29E+02
136	SSB	9.62E+02	1.26E+02
137	SSB	1.03E+03	1.42E+02
138	SSB	1.25E+03	1.79E+02
139	SSB	1.27E+03	1.91E+02
140	SSB	1.16E+03	1.77E+02
141	SSB	1.08E+03	1.68E+02
142	SSB	1.06E+03	1.66E+02
143	SSB	1.14E+03	1.82E+02
144	SSB	1.17E+03	1.90E+02
145	SSB	1.19E+03	1.97E+02
146	SSB	1.26E+03	2.11E+02

147	SSB	1.33E+03	2.22E+02
148	SSB	1.85E+03	3.10E+02
149	SSB	2.27E+03	3.89E+02
150	SSB	2.35E+03	4.12E+02
151	SSB	2.32E+03	4.13E+02
152	recruits	3.32E+02	5.86E+01
153	recruits	1.78E+02	3.74E+01
154	recruits	2.06E+02	3.68E+01
155	recruits	3.60E+02	5.47E+01
156	recruits	9.91E+02	1.21E+02
157	recruits	1.81E+03	1.91E+02
158	recruits	5.85E+03	3.47E+02
159	recruits	1.46E+03	1.61E+02
160	recruits	2.27E+03	2.14E+02
161	recruits	8.40E+02	1.04E+02
162	recruits	1.17E+03	1.33E+02
163	recruits	1.15E+03	1.28E+02
164	recruits	1.85E+03	1.68E+02
165	recruits	2.16E+03	1.88E+02
166	recruits	5.22E+02	6.44E+01
167	recruits	1.65E+02	2.35E+01
168	recruits	1.09E+02	1.63E+01
169	recruits	4.93E+02	6.42E+01
170	recruits	1.44E+02	2.18E+01
171	recruits	4.23E+02	6.15E+01
172	recruits	1.24E+03	1.65E+02
173	recruits	3.41E+03	4.01E+02
174	recruits	2.65E+02	4.54E+01
175	recruits	2.16E+02	3.89E+01
176	recruits	2.91E+02	5.12E+01
177	recruits	2.85E+02	5.02E+01
178	recruits	8.28E+02	1.31E+02
179	recruits	1.28E+03	1.99E+02
180	recruits	5.25E+02	9.06E+01
181	recruits	7.71E+02	1.31E+02
182	recruits	7.60E+02	1.31E+02
183	recruits	2.31E+02	4.30E+01
184	recruits	6.91E+02	1.21E+02
185	recruits	7.66E+02	1.35E+02
186	recruits	6.52E+02	1.18E+02
187	recruits	9.38E+02	1.69E+02
188	recruits	6.48E+02	1.21E+02
189	recruits	8.07E+02	1.52E+02
190	recruits	5.04E+03	9.36E+02
191	recruits	1.09E+03	2.22E+02
192	recruits	8.04E+02	1.79E+02
193	recruits	1.76E+03	4.21E+02
194	recruits	2.79E+03	7.92E+02
195	plus_group	5.63E+01	2.63E+01
196	plus_group	6.81E+01	2.34E+01

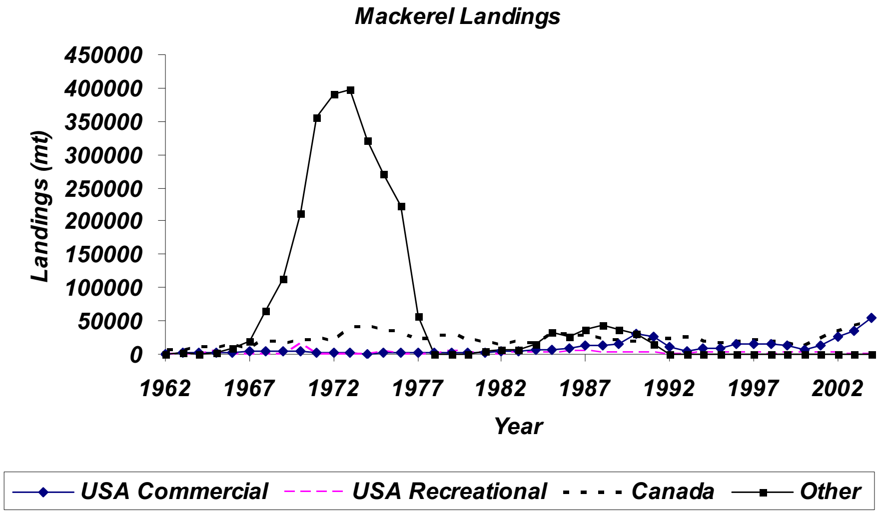
197	plus_group	6.84E+01	1.99E+01
198	plus_group	1.17E+02	2.47E+01
199	plus_group	3.01E+02	5.05E+01
200	plus_group	2.63E+02	4.57E+01
201	plus_group	2.67E+02	4.63E+01
202	plus_group	2.31E+02	3.96E+01
203	plus_group	2.07E+02	3.27E+01
204	plus_group	2.03E+02	2.85E+01
205	plus_group	2.61E+02	3.23E+01
206	plus_group	3.57E+02	3.94E+01
207	plus_group	6.35E+02	6.48E+01
208	plus_group	3.94E+02	4.97E+01
209	plus_group	2.78E+02	4.15E+01
210	plus_group	1.66E+02	2.93E+01
211	plus_group	1.66E+02	2.88E+01
212	plus_group	1.99E+02	3.13E+01
213	plus_group	3.31E+02	4.38E+01
214	plus_group	5.92E+02	6.80E+01
215	plus_group	5.73E+02	6.48E+01
216	plus_group	4.90E+02	5.57E+01
217	plus_group	4.13E+02	4.72E+01
218	plus_group	4.49E+02	5.01E+01
219	plus_group	3.84E+02	4.33E+01
220	plus_group	4.02E+02	4.59E+01
221	plus_group	6.02E+02	7.45E+01
222	plus_group	1.21E+03	1.65E+02
223	plus_group	9.78E+02	1.42E+02
224	plus_group	7.98E+02	1.23E+02
225	plus_group	6.79E+02	1.10E+02
226	plus_group	6.02E+02	9.93E+01
227	plus_group	6.74E+02	1.12E+02
228	plus_group	8.51E+02	1.42E+02
229	plus_group	8.12E+02	1.37E+02
230	plus_group	8.39E+02	1.45E+02
231	plus_group	8.58E+02	1.51E+02
232	plus_group	7.38E+02	1.33E+02
233	plus_group	7.66E+02	1.39E+02
234	plus_group	8.19E+02	1.49E+02
235	plus_group	8.27E+02	1.51E+02
236	plus_group	9.06E+02	1.67E+02
237	plus_group	8.85E+02	1.65E+02
238	MSY	8.95E+01	0.00E+00
239	SSB_ratio	7.79E+00	1.58E+00
240	proj_SSB_ratio	6.85E+00	0.00E+00
241	SSmsy_ratio	3.61E+00	6.42E-01
242	Fmsy_ratio	3.08E-01	0.00E+00
243	MSYp	8.95E+01	0.00E+00

Table B13. Projection for SSB (000 mt) and landings (000 mt) during 2006-2008 for the northwest Atlantic stock of mackerel.

Year	SSB	F	Land
2005	2450.68	0.04	95.00
2006	2640.21	0.12	273.29
2007	2304.02	0.12	238.79
2008	2043.44	0.12	211.99

MACKEREL FIGURES

A.



B.

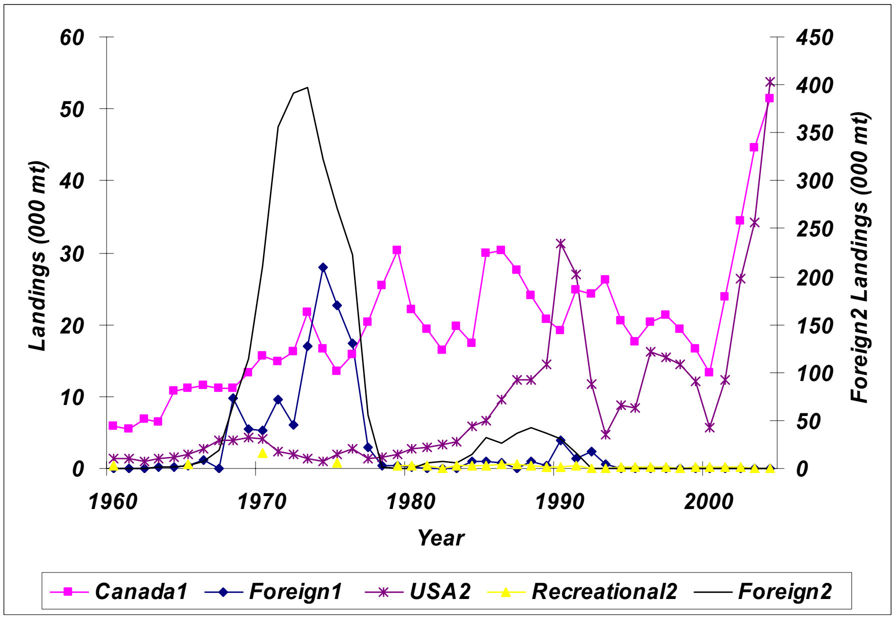


Figure B1. **A.** Landings of Atlantic mackerel in NAFO SA 2-6 during 1962-2004 by USA commercial, USA recreational, Canada, and other countries. **B.** Landings by Canadian vessels (Canada1) or foreign countries (Foreign1) in Canadian waters (SA 2-4). Landings by USA vessels (USA2), recreational sources (Recreational2), or foreign countries (Foreign2) in USA waters (SA5-6).

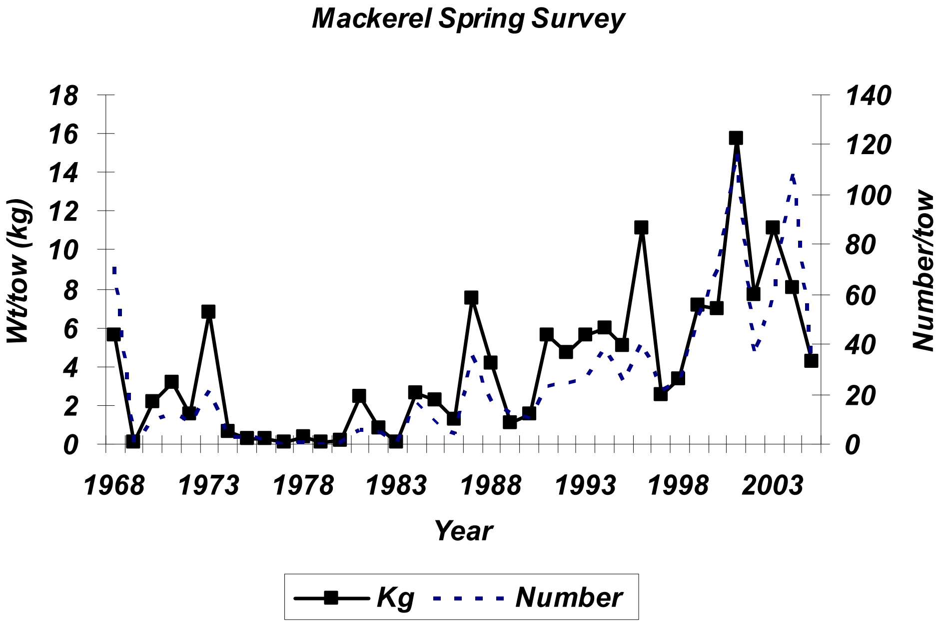


Figure B2. Mackerel Spring bottom trawl survey indices in wt/tow and number/tow during 1968-2005.

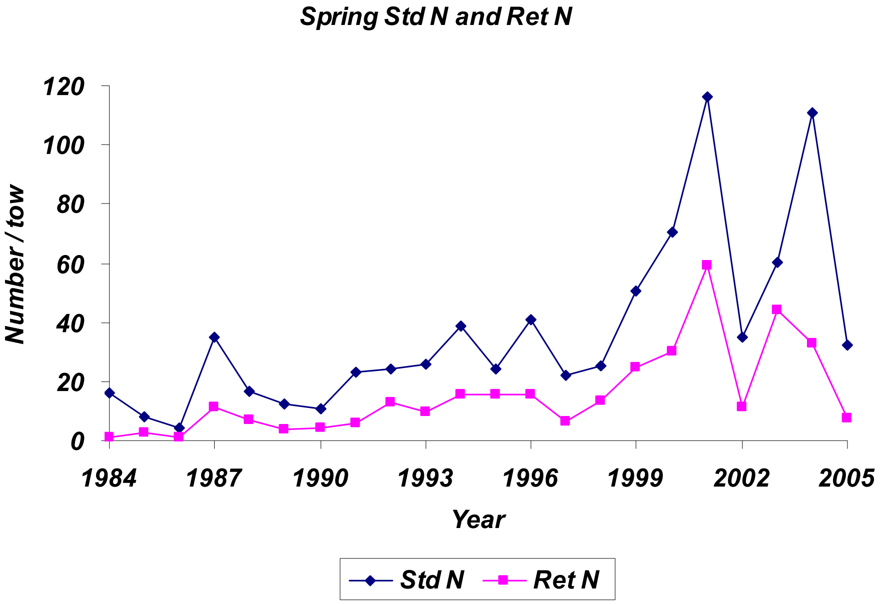


Figure B3. Mackerel Spring bottom trawl survey indices number/tow (standard-std and log retransformed-ret) during 1984-2005.

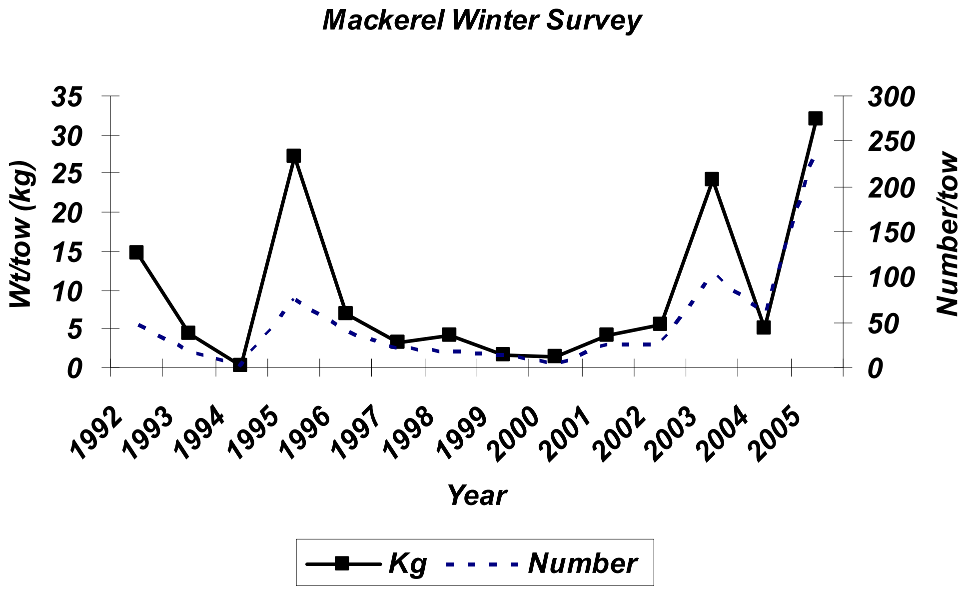


Figure B4. Mackerel winter bottom trawl survey indices in wt/tow and number/tow during 1992-2005.

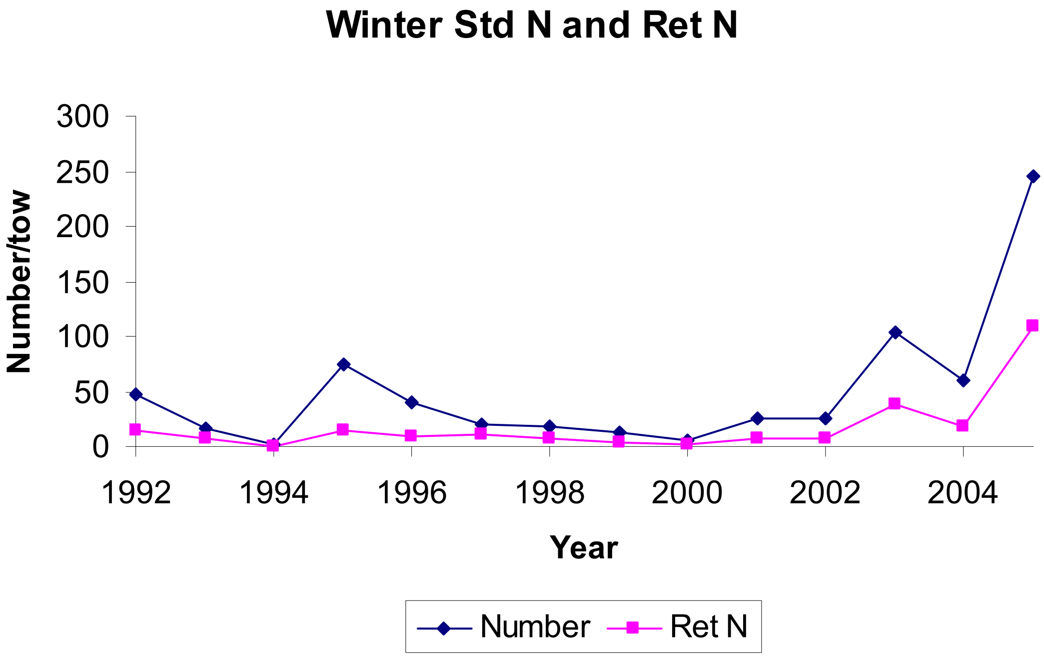


Figure B5. Mackerel winter survey indices in number/tow (standard-std and log retransformed-ret) during 1992-2005.

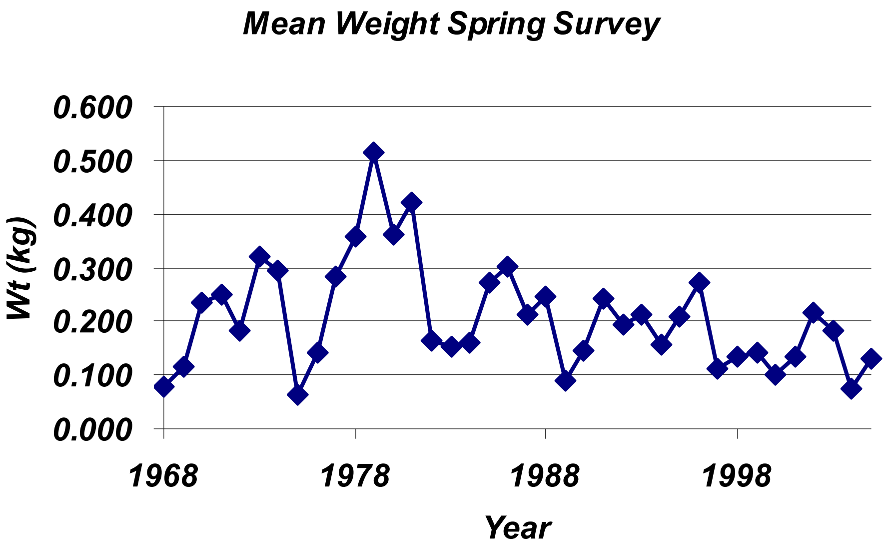


Figure B6. Average weight (kg) of Atlantic mackerel from NEFSC spring surveys during 1968-2005.

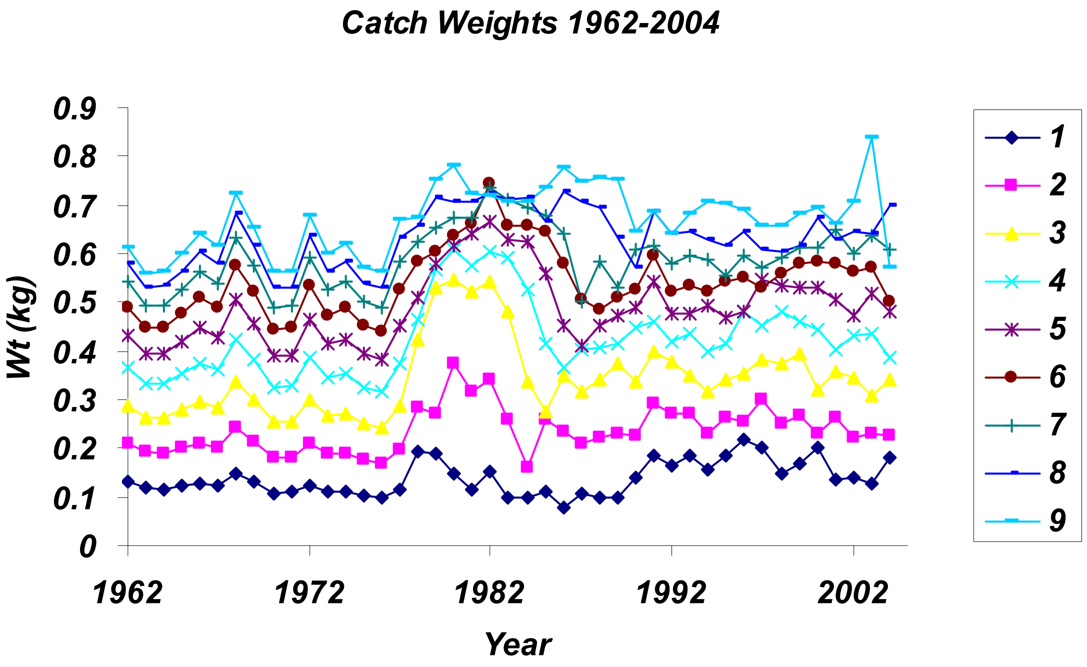


Figure B7. Landed weight (kg) of Atlantic mackerel from USA and Canadian fisheries in NAFO SA 2-6 during 1962-2004.

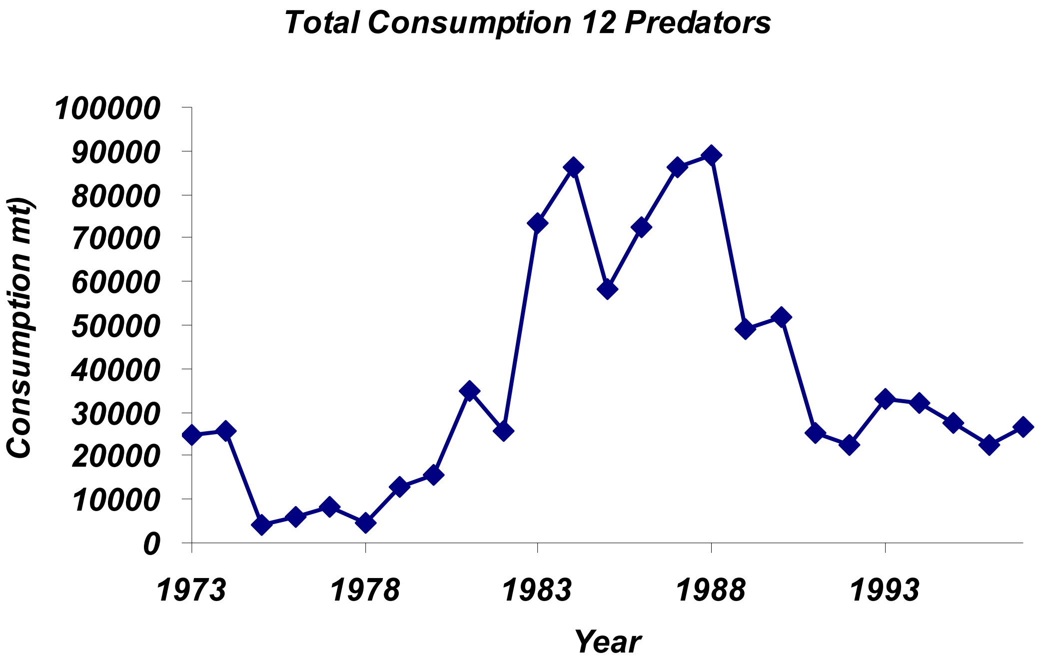


Figure B8. Consumption of Atlantic mackerel by 12 picivorous fish in the Mid-Atlantic-gulf of Maine region during 1973-1997.

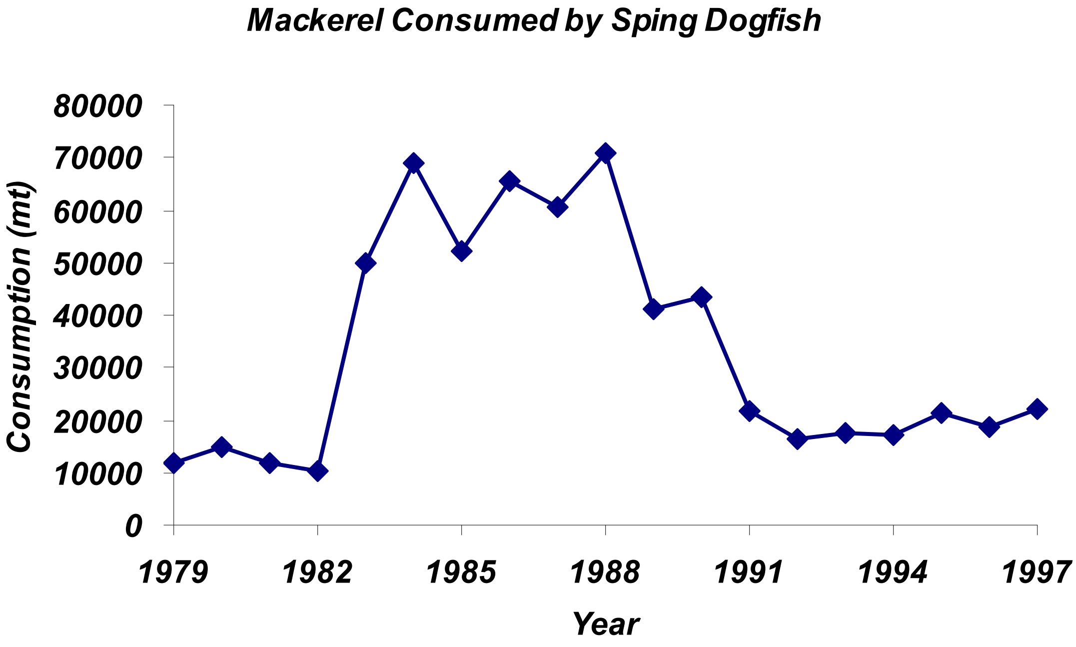


Figure B9. Consumption of Atlantic mackerel by spiny dogfish in the Mid-Atlantic-Gulf of Maine region during 1979-1997.

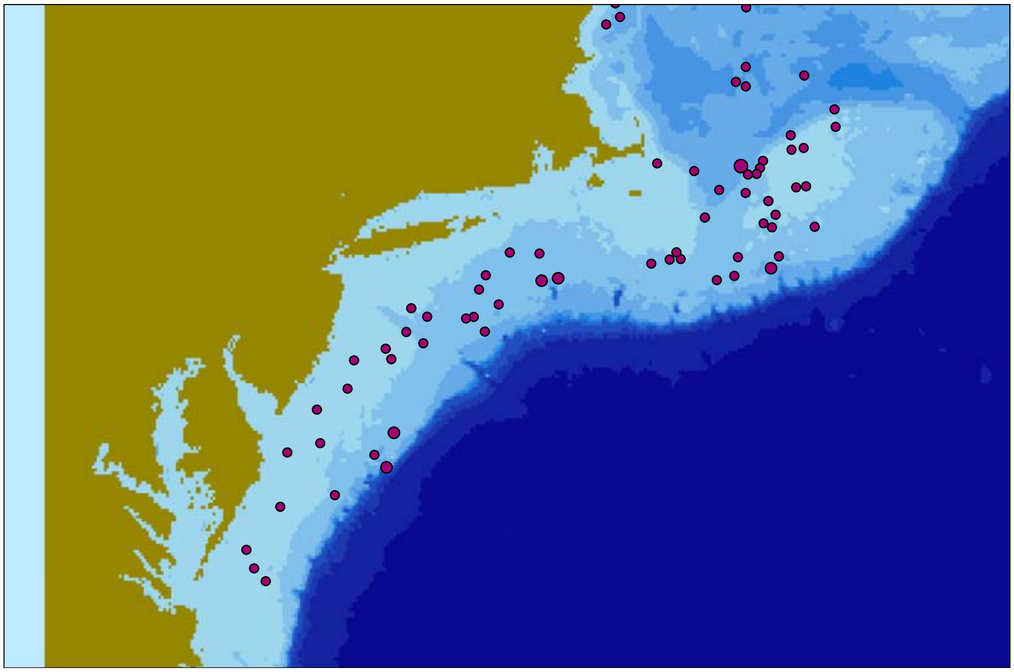


Figure B10. Distribution of mackerel during the spring NEFSC bottom trawl survey in 2002.

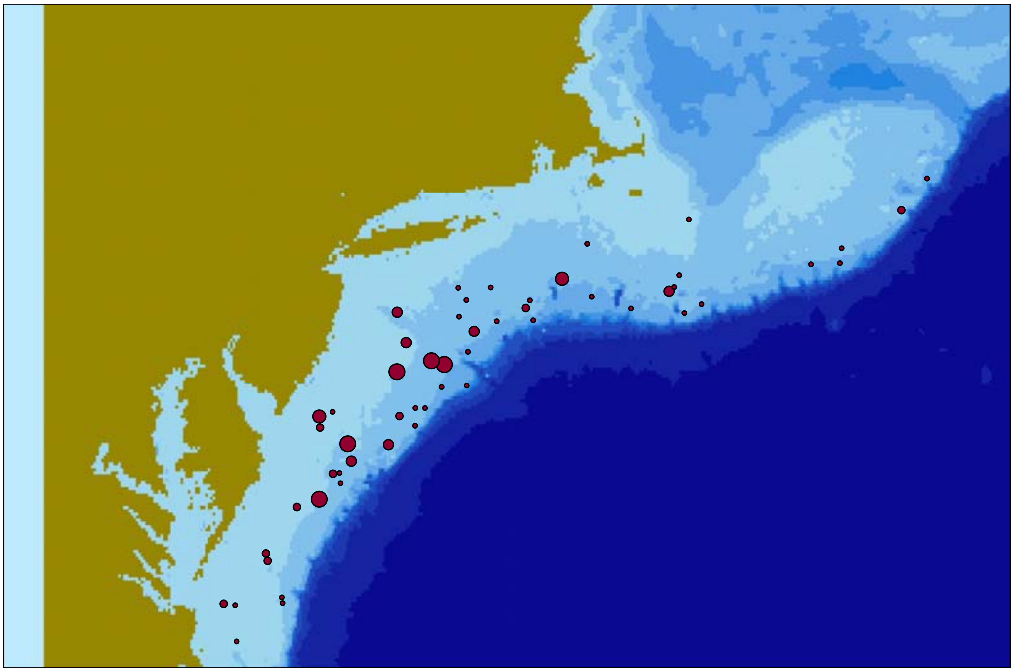


Figure B11. Distribution of mackerel during the spring NEFSC bottom trawl survey in 2003.

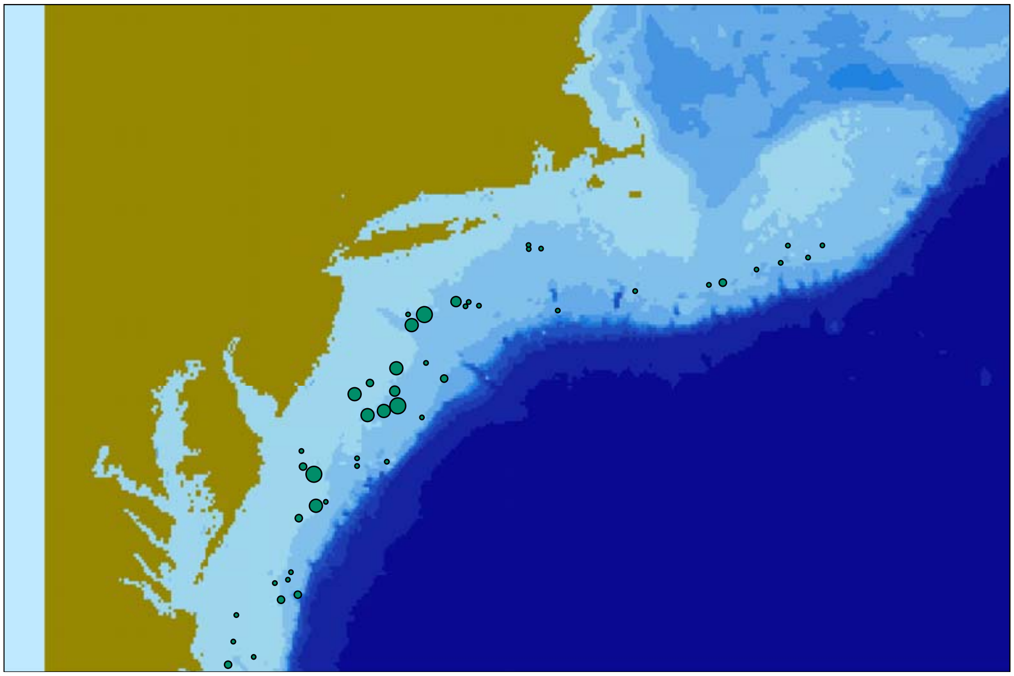


Figure B12. Distribution of mackerel during the spring NEFSC bottom trawl survey in 2004

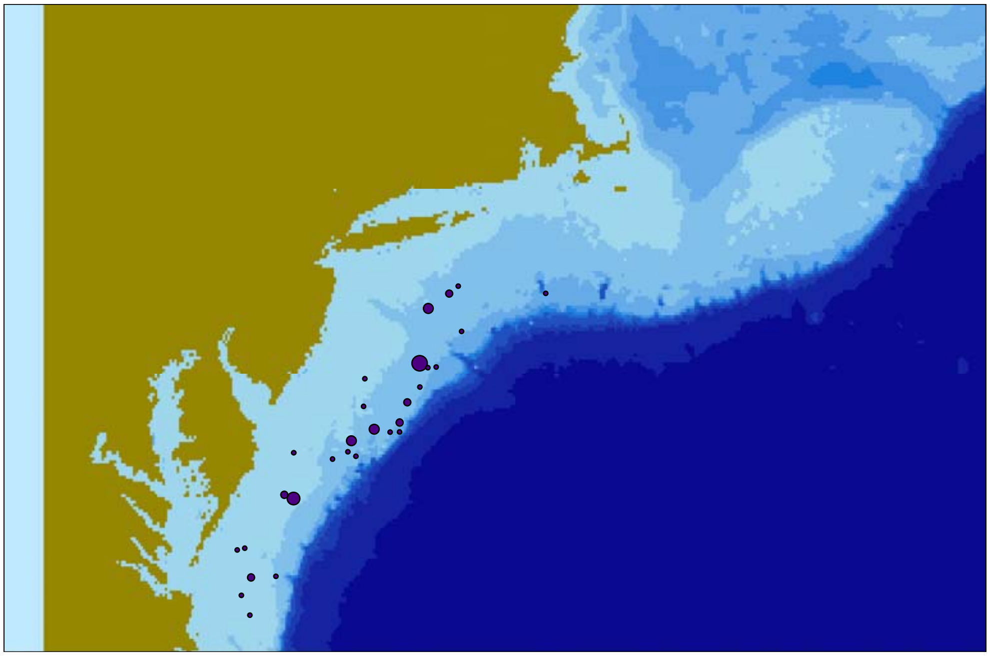


Figure B13. Distribution of mackerel during the spring NEFSC bottom trawl survey in 2005.

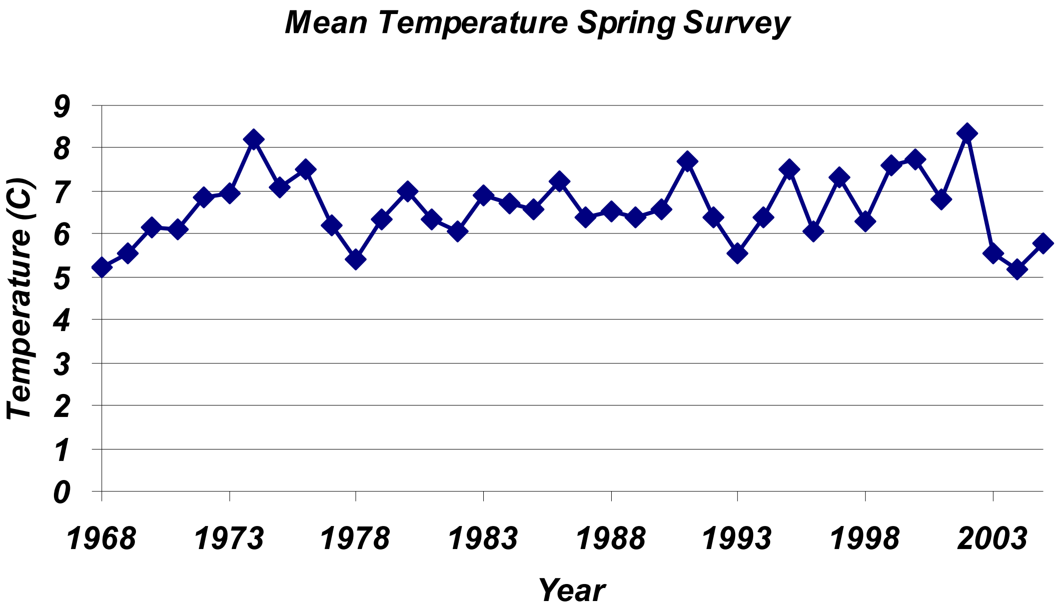


Figure B14. Average temperature from the NEFSC spring survey during 1968-2005.

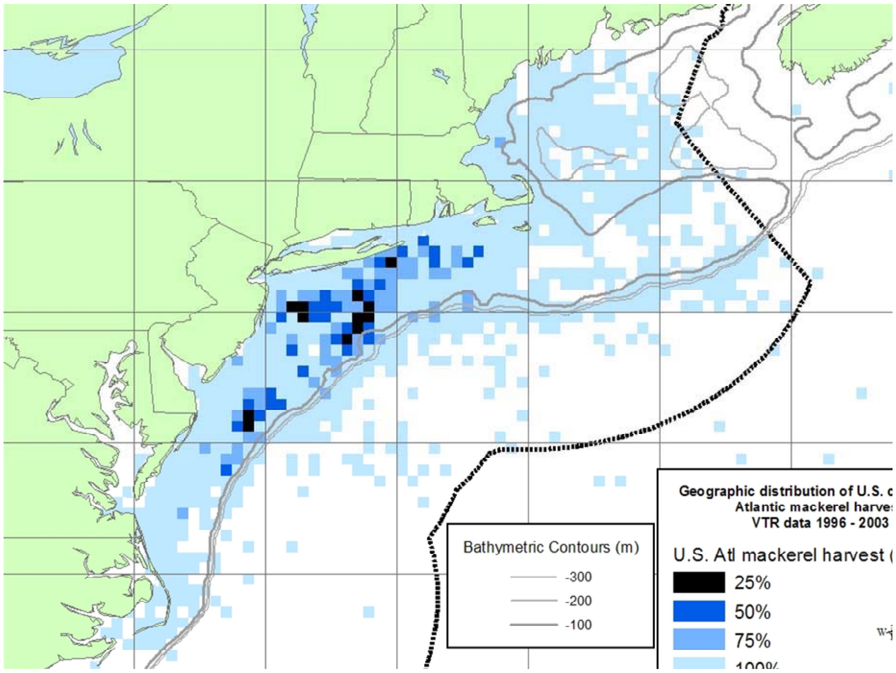


Figure B15. Map of fishing activity for mackerel during 1996-2003.

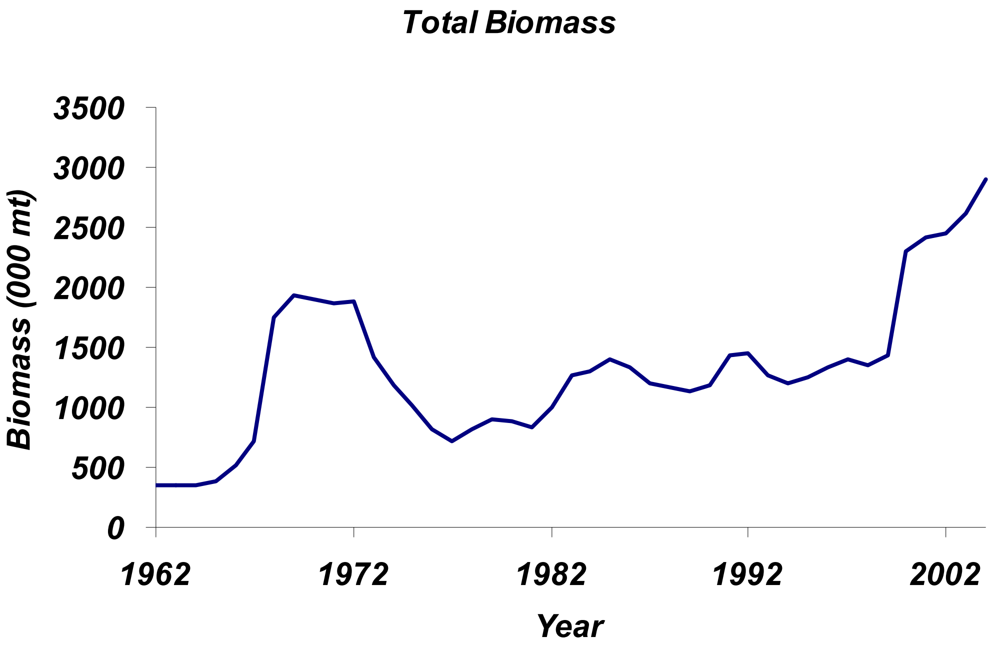


Figure B 16. Total biomass for Atlantic mackerel during 1962-2004 from the ASAP base model run.

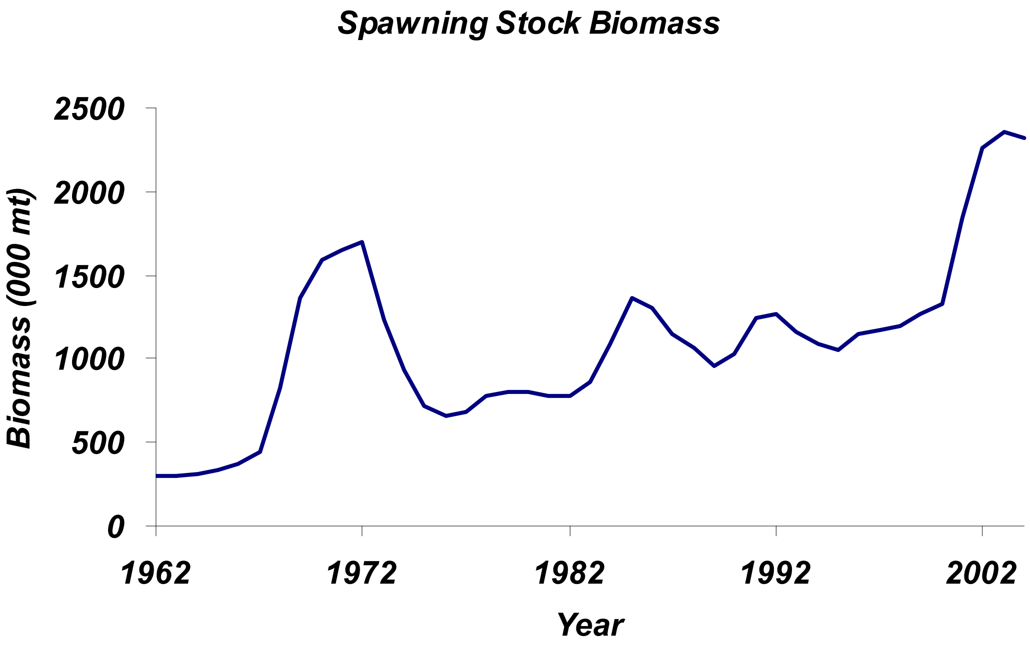


Figure B17. Spawning stock biomass for Atlantic mackerel during 1962-2004 from the ASAP base model run.

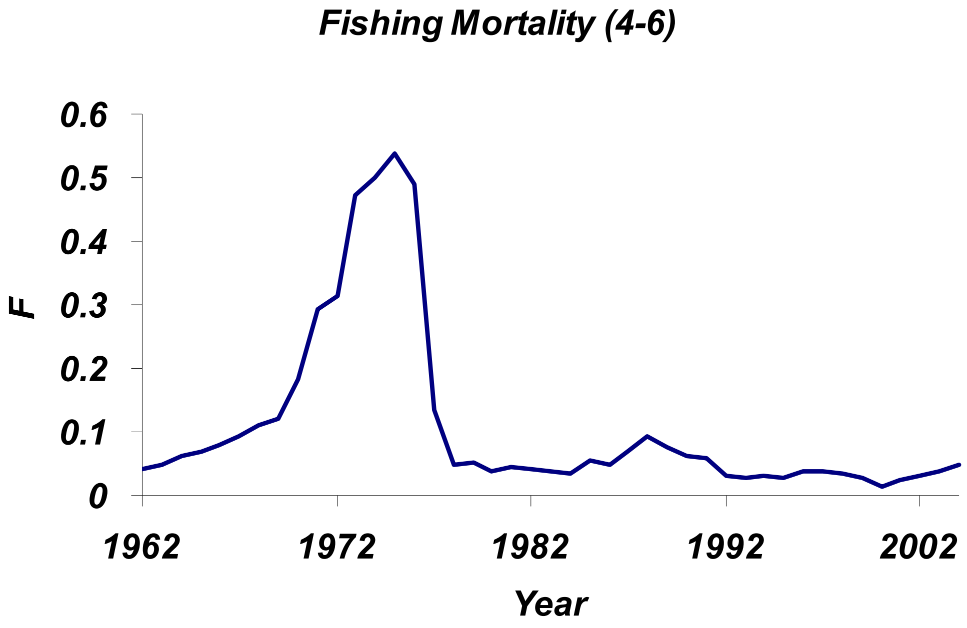


Figure B18. Fishing mortality for Atlantic mackerel during 1962-2004 from the ASAP base model run.

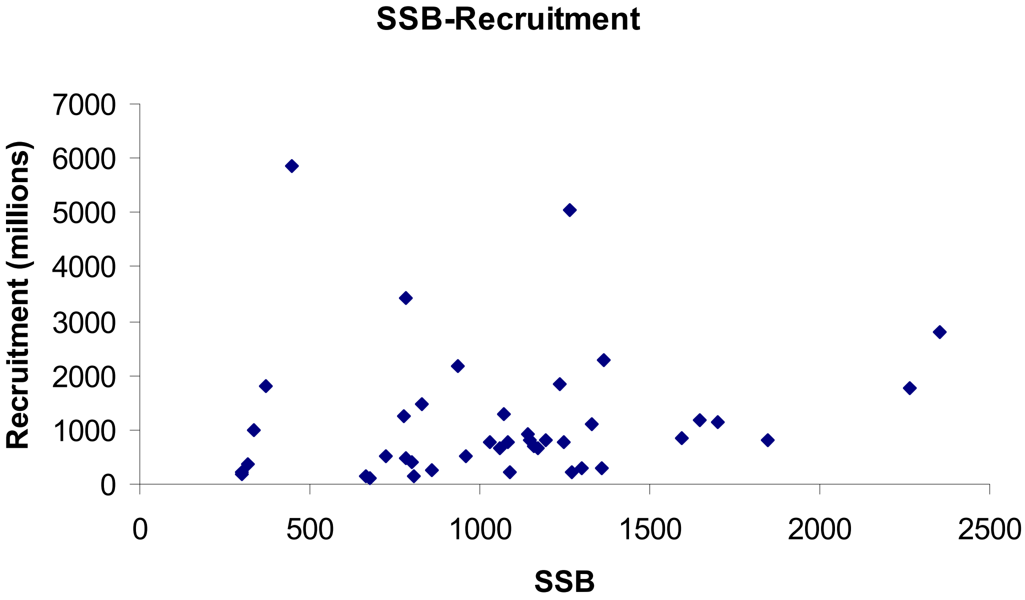


Figure B19. Stock recruitment for Atlantic mackerel during 1962-2004 from the ASAP base model run

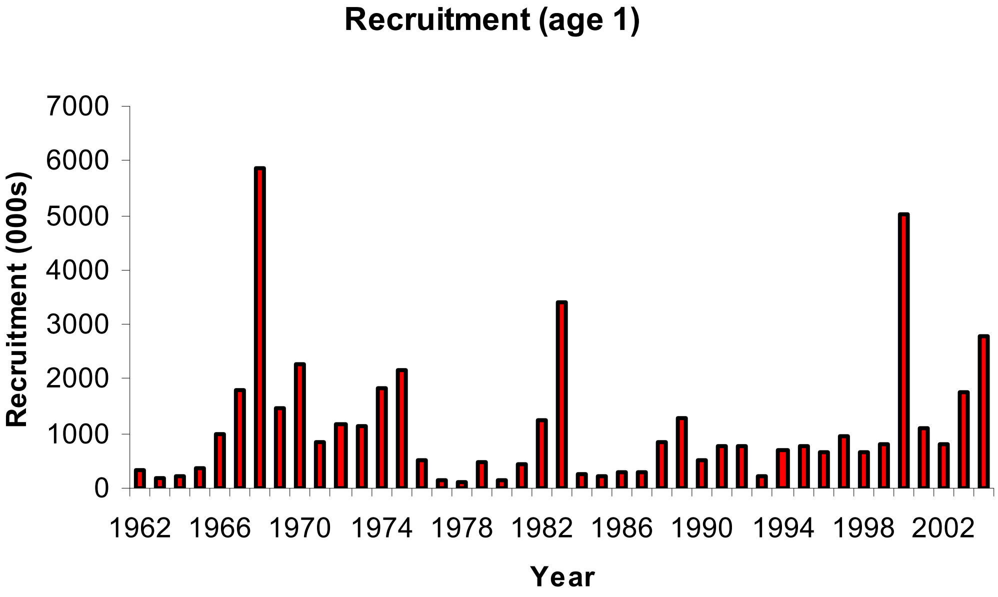


Figure B20. Recruitment (age 1) for Atlantic mackerel during 1962-2004 from the ASAP base model run.

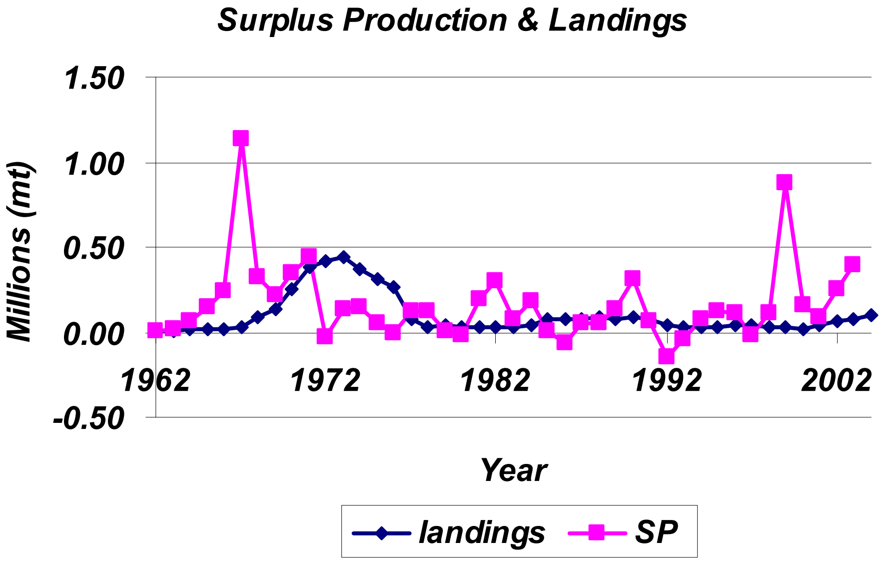


Figure B21. Surplus production and landings of Atlantic mackerel during 1962-2004 from the ASAP base model run.

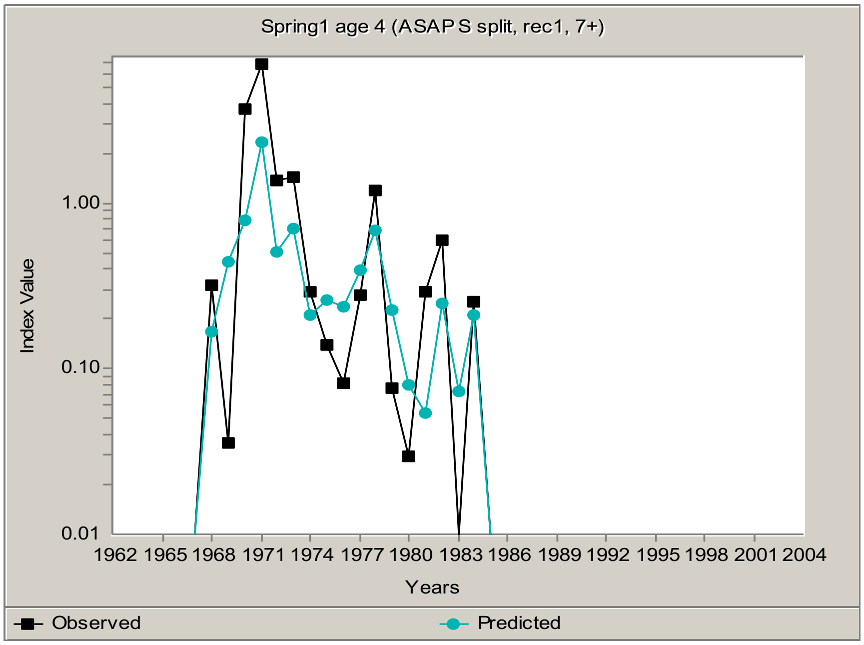


Figure B22. Spring survey observed vs. predicted series (1968-1984, age 4) for the base case ASAP model with the spring survey split in 1985, B-H SR model (lambda = 1), and ages aggregated to 7+.

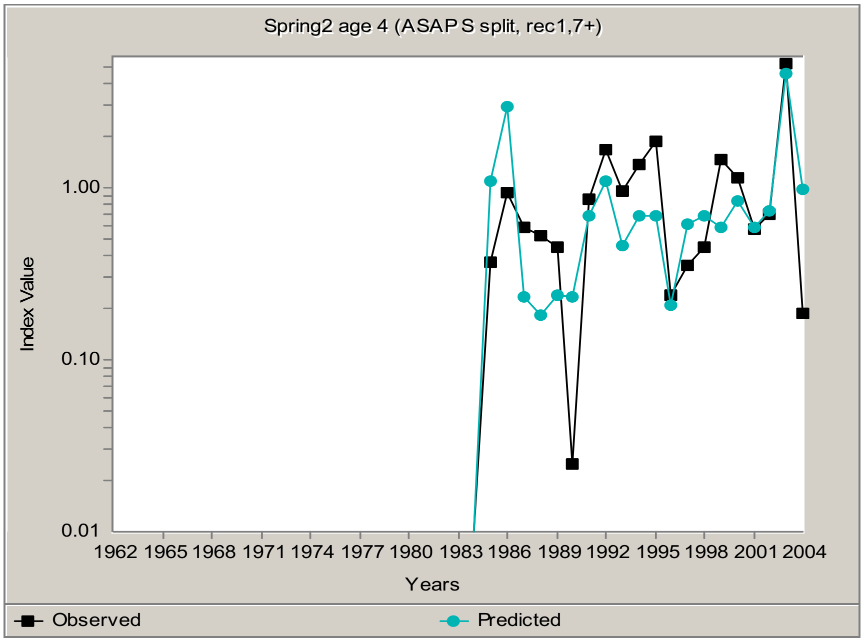


Figure B23. Spring survey observed vs predicted series (1985-2004, age 4) for the base case ASAP model with the spring survey split in 1985, B-H SR model (lambda = 1), and ages aggregated to 7+.

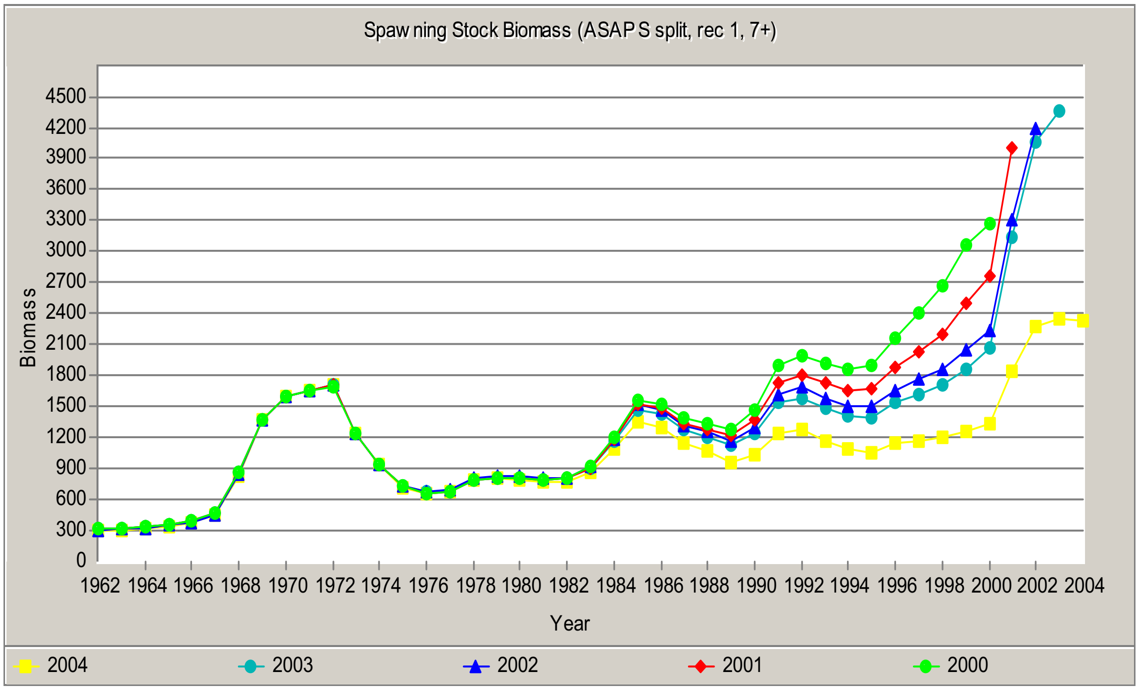


Figure B24. Retrospective pattern for SSB for the base case ASAP model with the spring survey split in 1985, B-H SR model (lambda = 1), and ages aggregated to 7+.

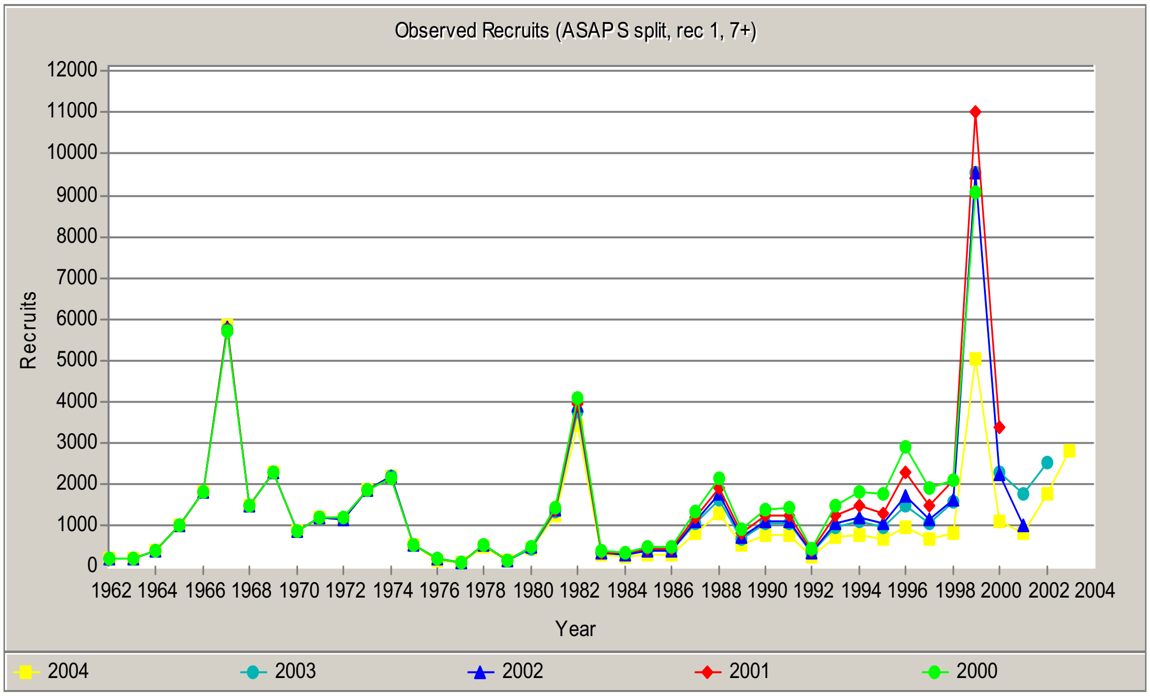


Figure B25. Retrospective pattern for recruitment for the base case ASAP model with the spring survey split in 1985, B-H SR model (lambda = 1), and ages aggregated to 7+.

APPENDIX B1: Trial runs for the VPA and ASAP models.

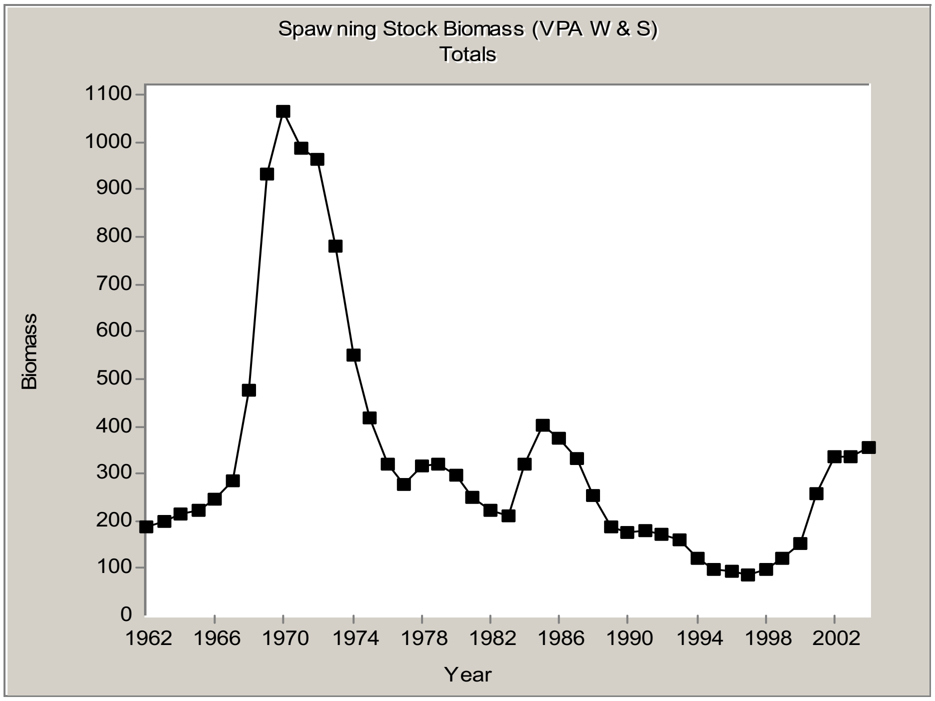


Figure 1 (APPENDIX B1). Spawning stock biomass for a VPA trial run with the winter and spring survey indices.

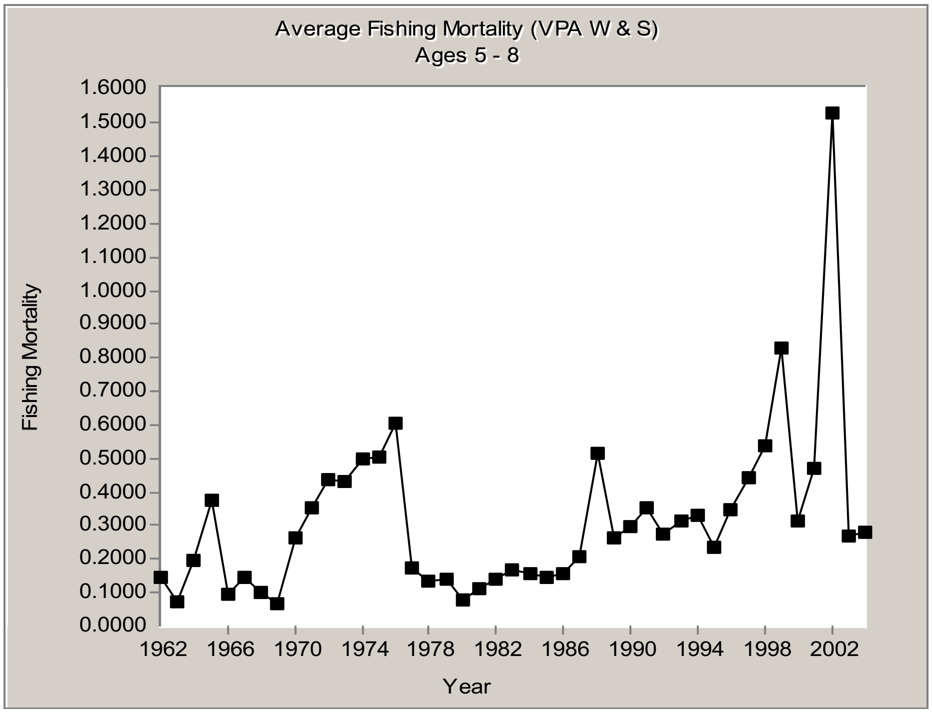


Figure 2 (APPENDIX B1). Fishing mortality for a VPA trial run with the winter and spring indices.

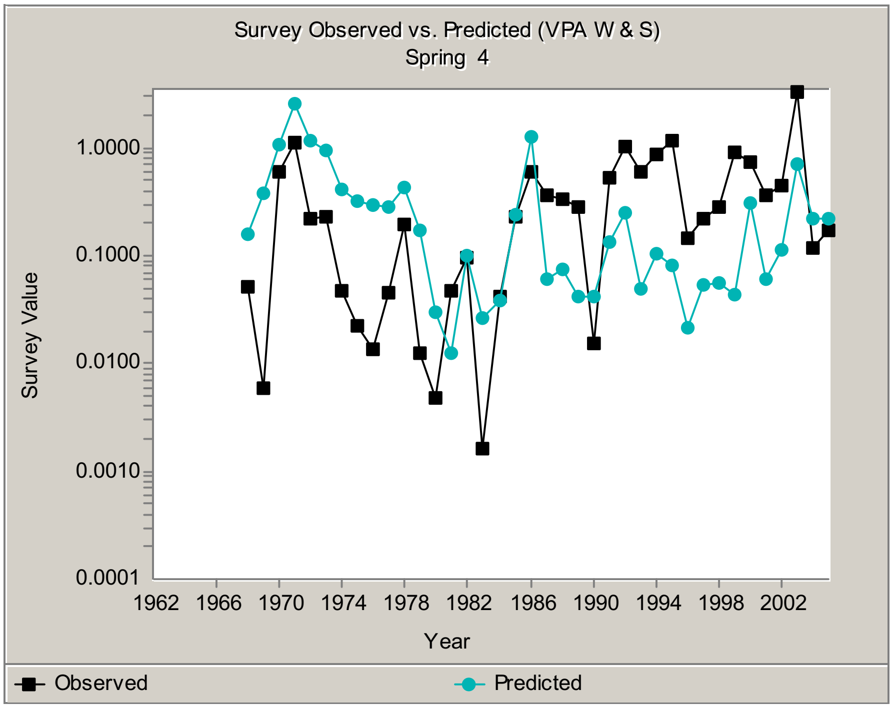


Figure 3 (APPENDIX B1). Spring survey observed vs. predicted series (age 4) for a VPA trial run with the winter and spring survey indices.

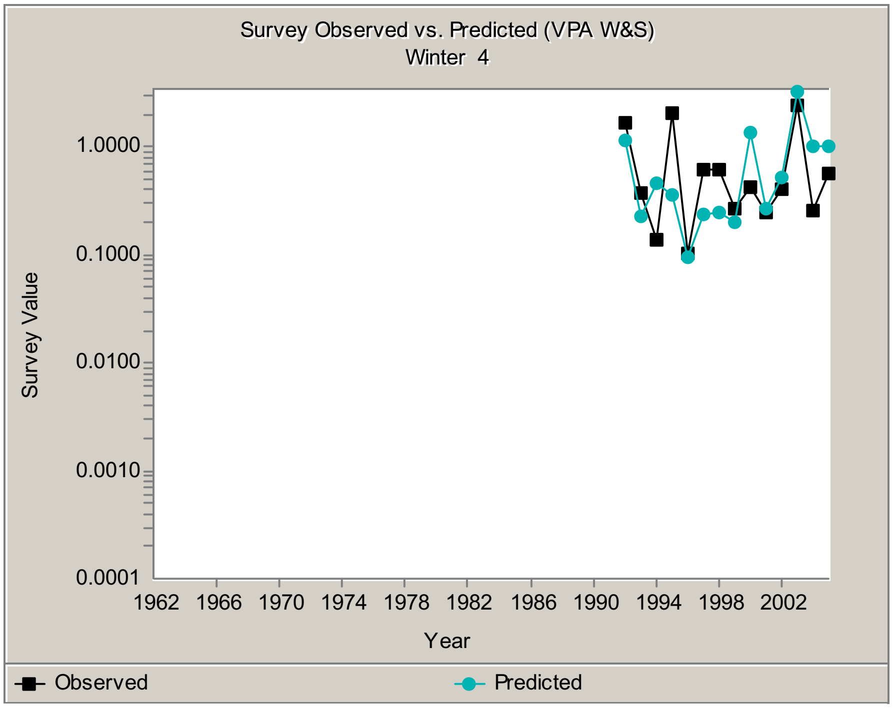


Figure 4 (APPENDIX B1). Winter survey observed vs. predicted series (age 4) for a VPA trial run with the winter and spring survey indices.

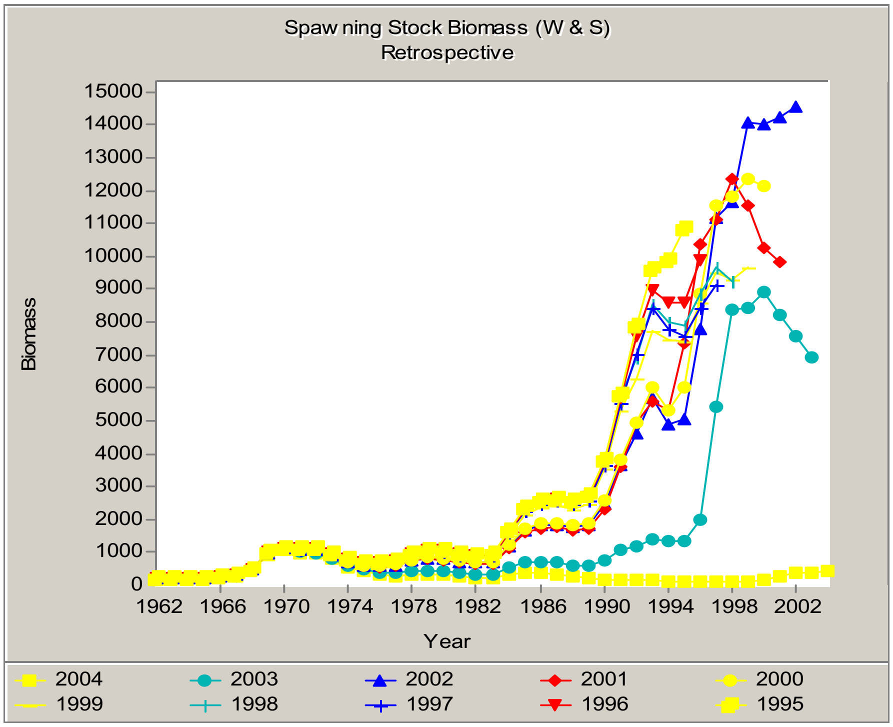


Figure 5 (APPENDIX B1). Retrospective pattern for SSB for a VPA trial run with the winter and spring survey indices.

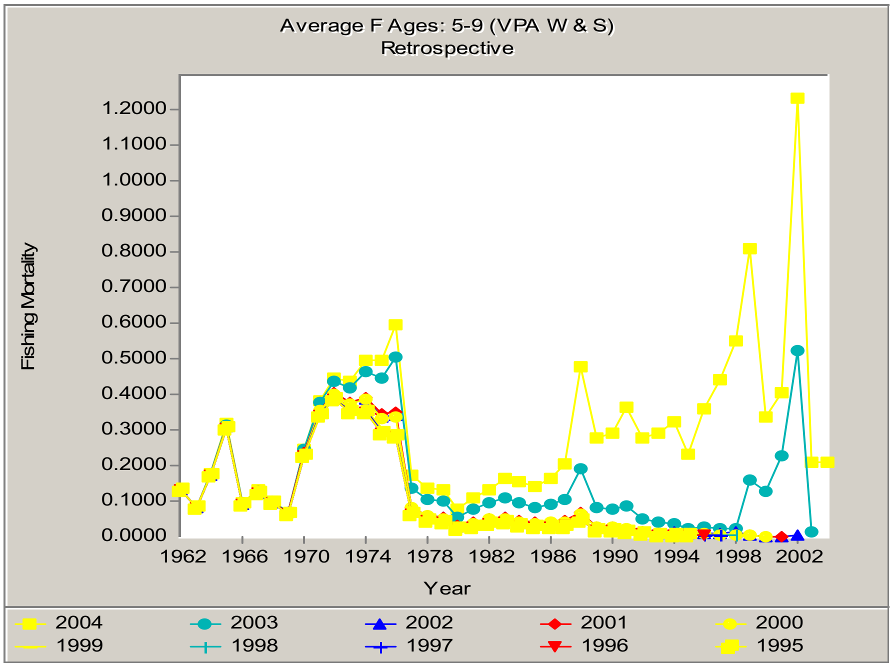


Figure 6 (APPENDIX B1). Retrospective pattern for SSB for a VPA trial run with the winter and spring survey indices.

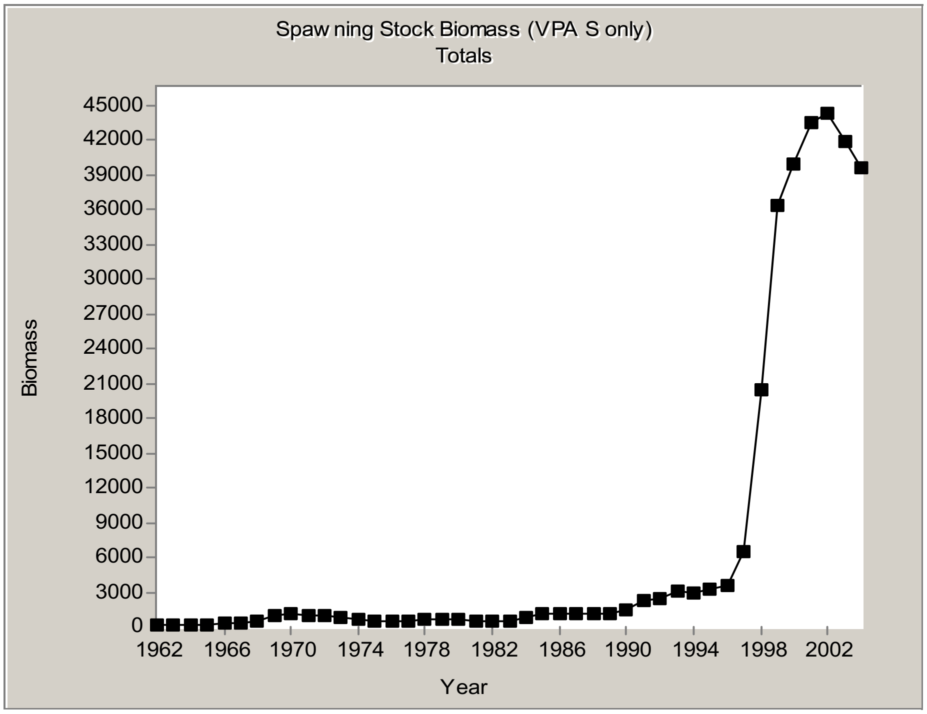


Figure 7 (APPENDIX B1). Spawning stock biomass for a VPA trial run with the spring survey indices.

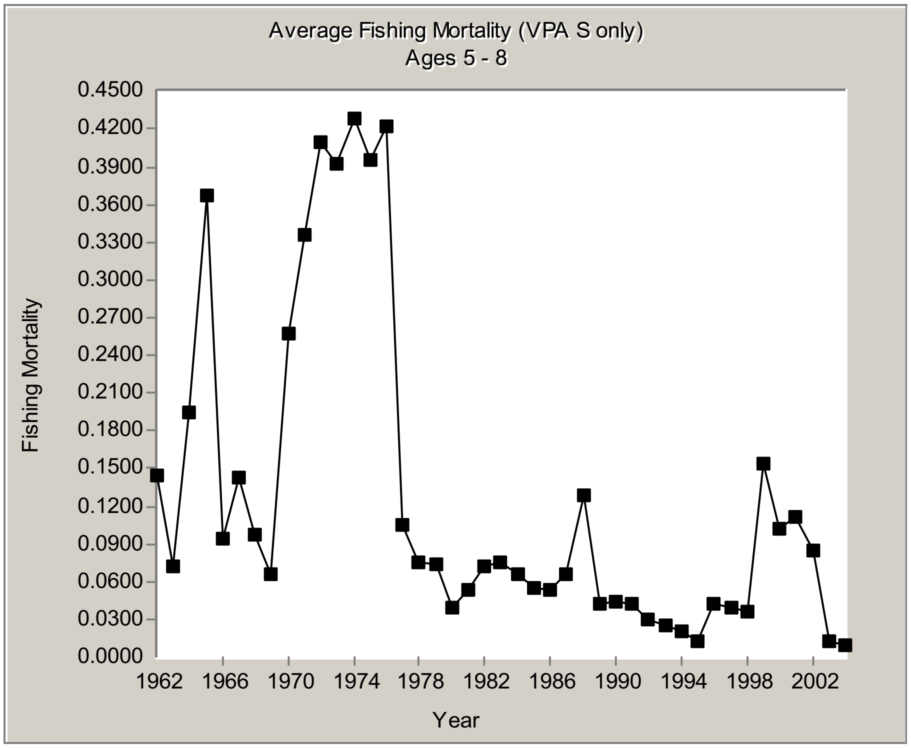


Figure 8 (APPENDIX B1). Fishing mortality for a VPA trial run with the spring survey indices.

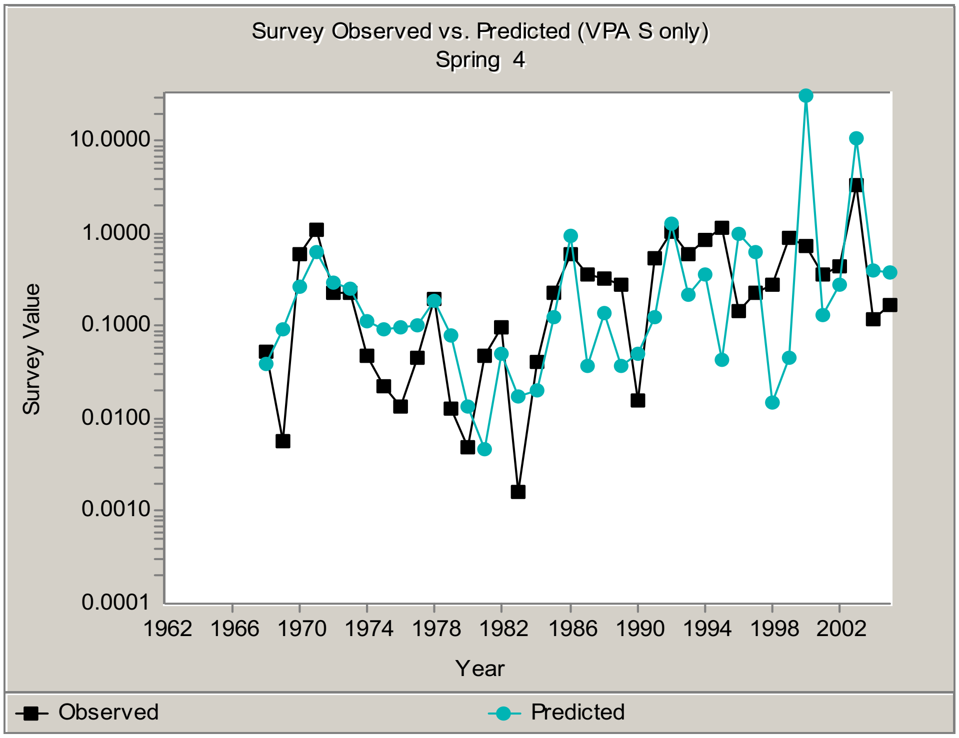


Figure 9 (APPENDIX B1). Spring survey observed vs. predicted series (1968-2004, age 4) for a VPA trial run with the spring survey indices.

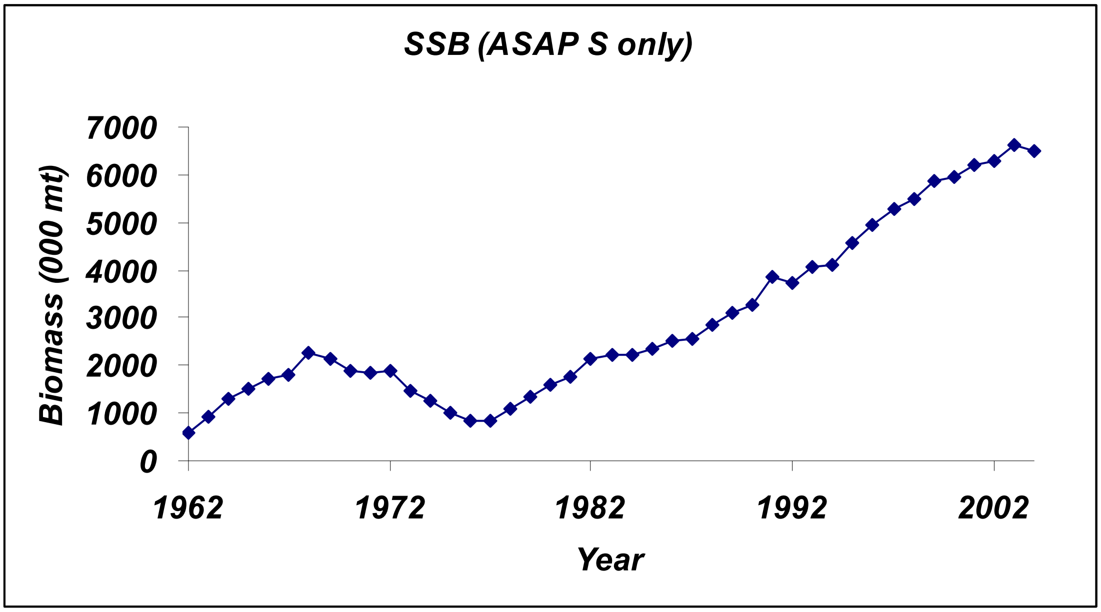


Figure 10 (APPENDIX B1). Spawning stock biomass for an ASAP trial run with the spring survey only.

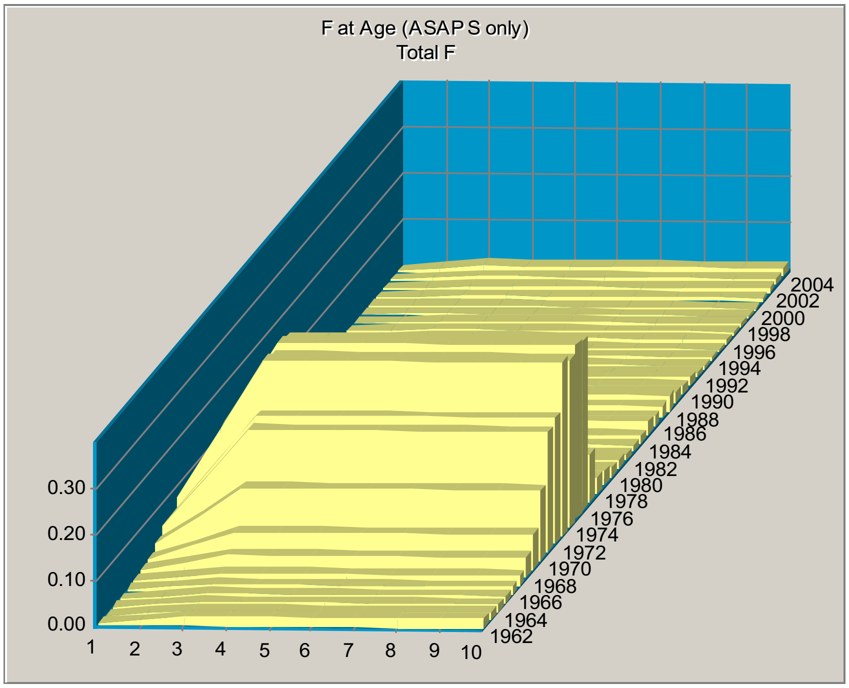


Figure 11 (APPENDIX B1). Fishing mortality by age and year for an ASAP trial run with the spring survey only.

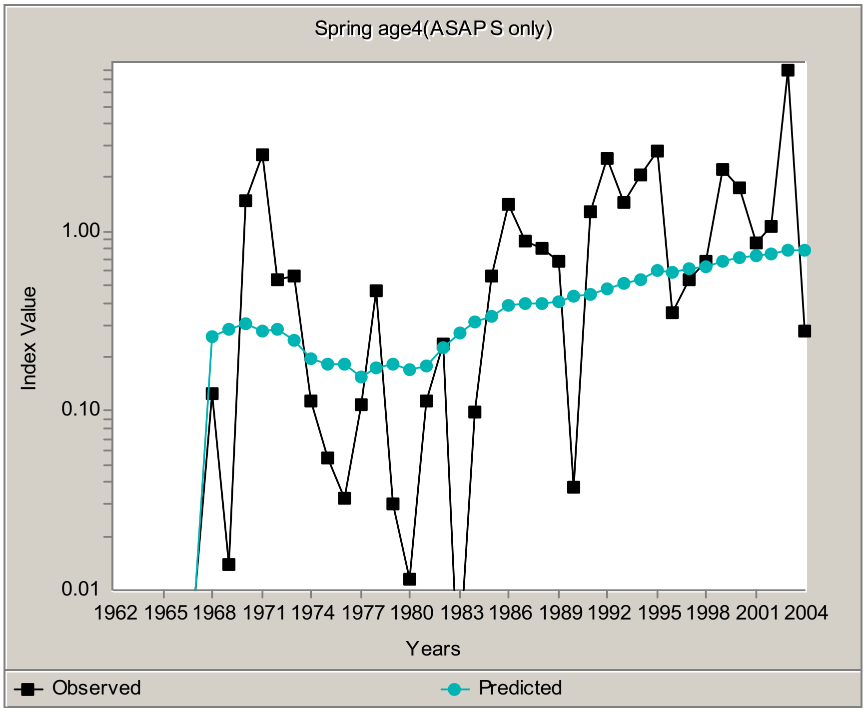


Figure 12 (APPENDIX B1). Spring survey observed vs. predicted series (1968-2004, age 4) for an ASAP trial run with the spring survey only.

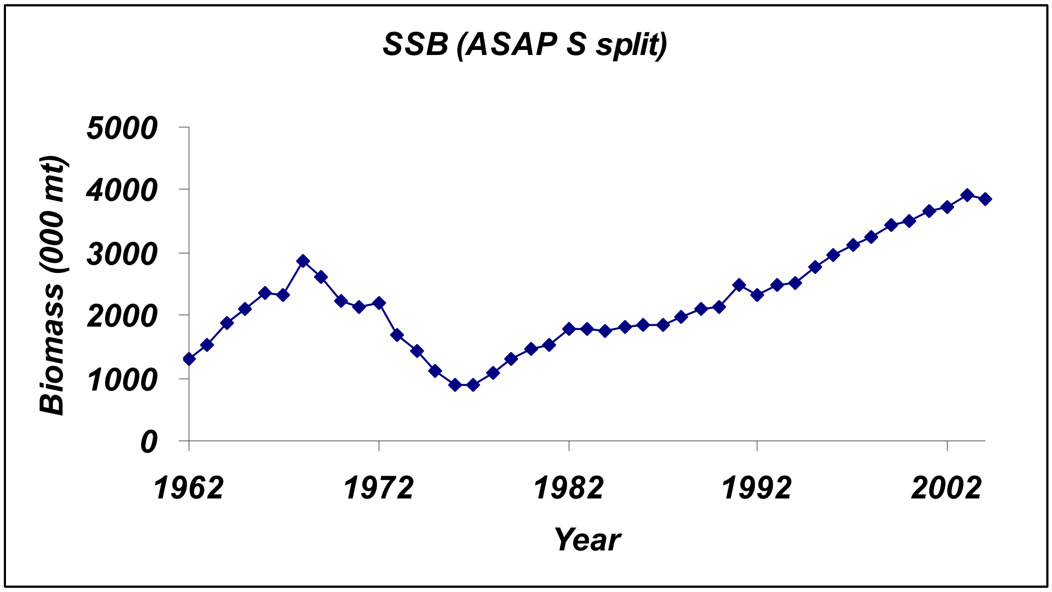


Figure 13 (APPENDIX B1). Spawning stock biomass for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series.

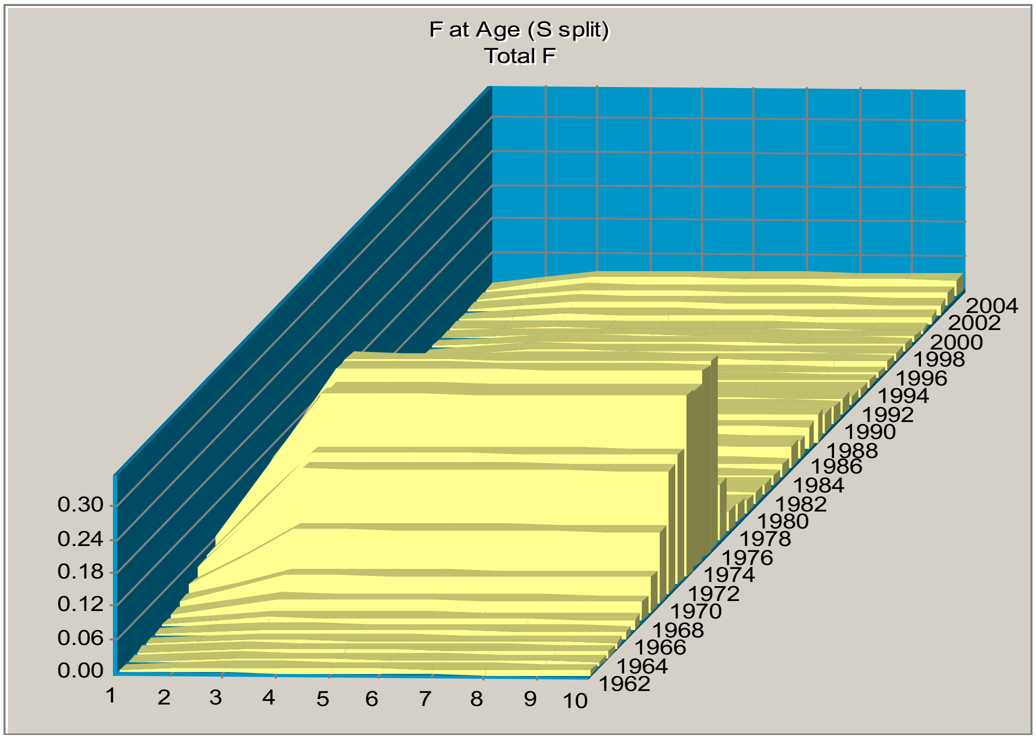


Figure 14 (APPENDIX B1). Fishing mortality by age and year for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series.

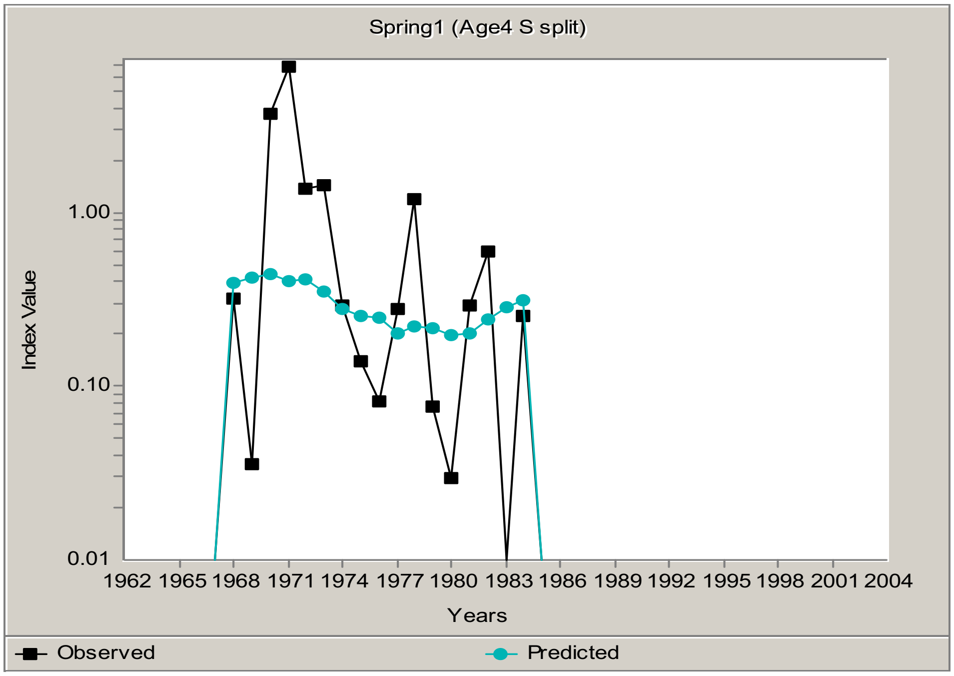


Figure 15 (APPENDIX B1). Spring survey observed vs. predicted series (1968-1984, age 4) for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series.

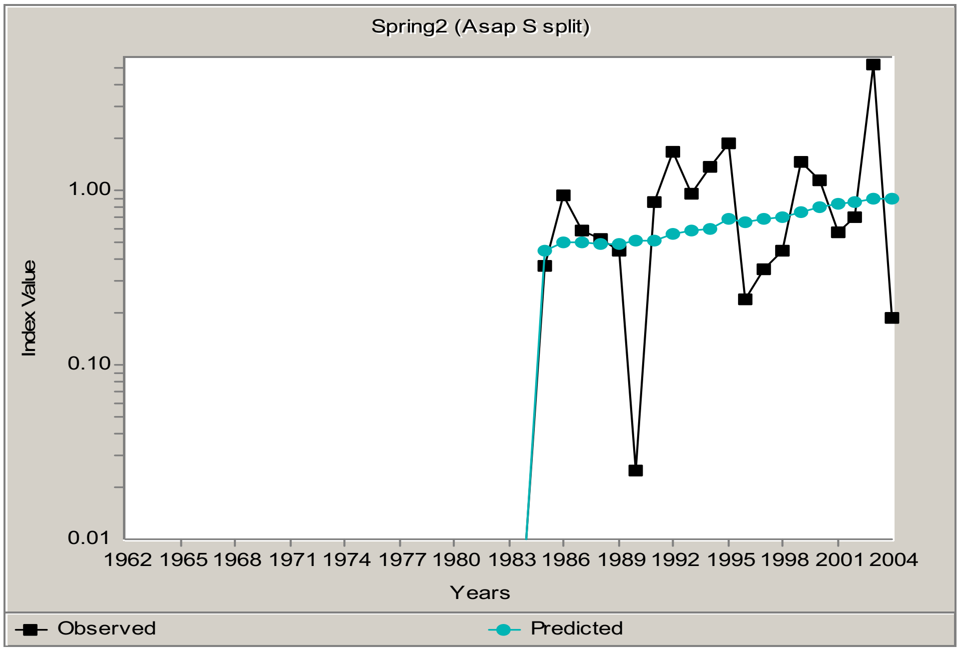


Figure 16 (APPENDIX B1). Spring survey observed vs. predicted series (1985-2004, age 4) for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series.

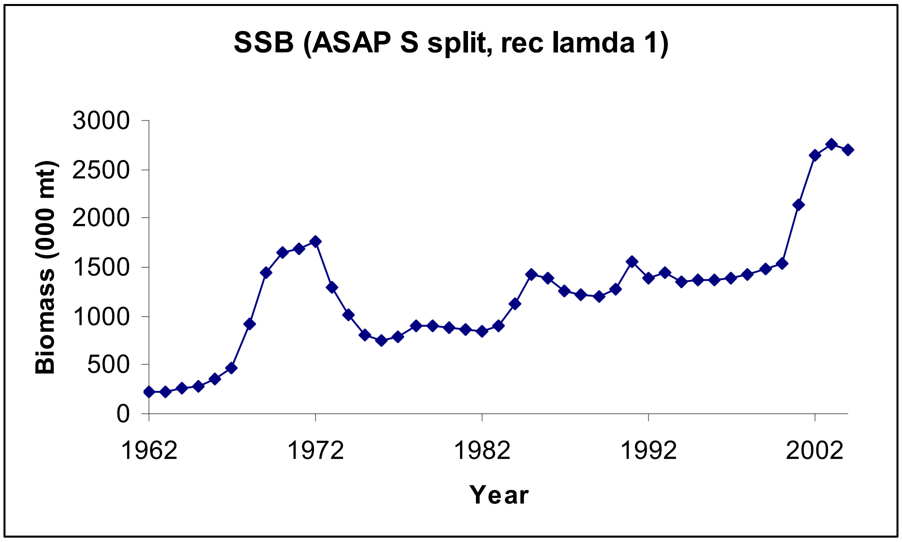


Figure 17 (APPENDIX B1). Spawning stock biomass for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series and a B-H SR relationship with lambda = 1.

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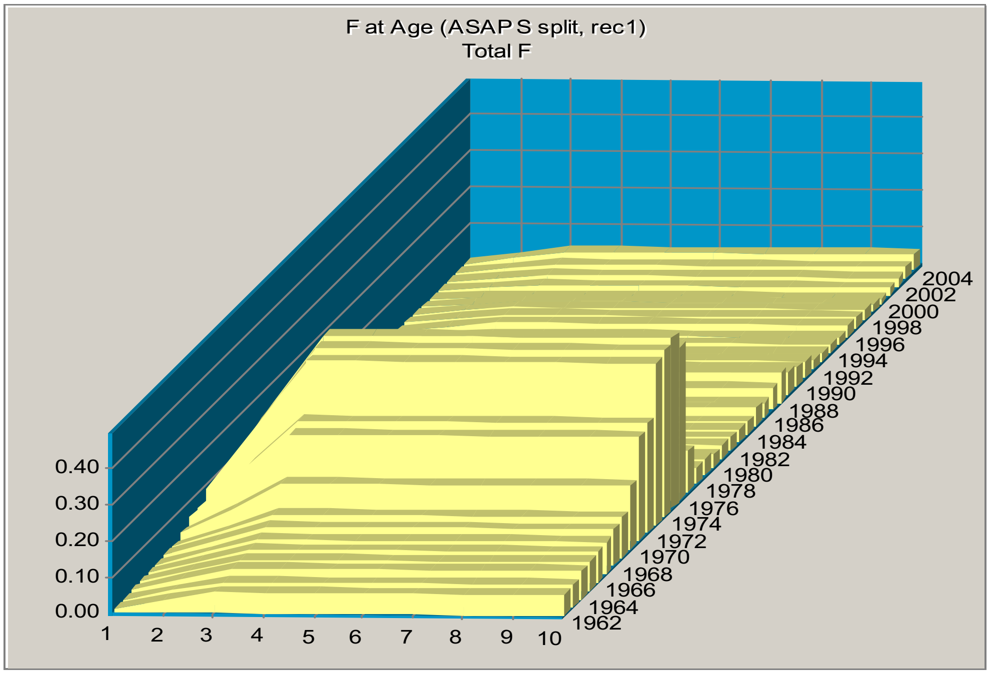

Figure 18 (APPENDIX B1). Fishing mortality for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series and a B-H SR relationship with lambda = 1.

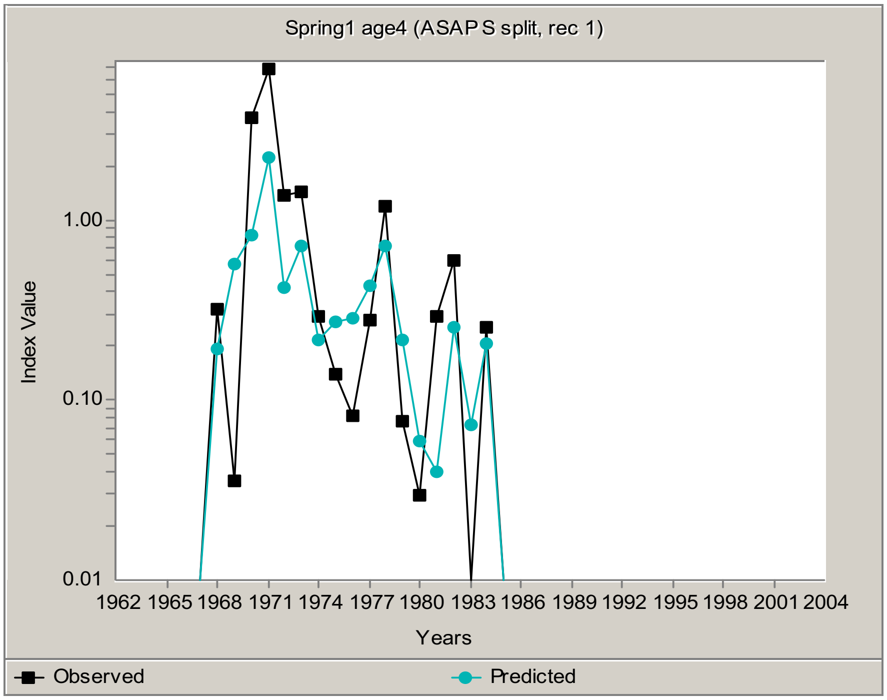

Figure 19 (APPENDIX B1). Spring survey observed vs. predicted series (1968-1984, age 4) for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series and a B-H SR relationship with lambda = 1.

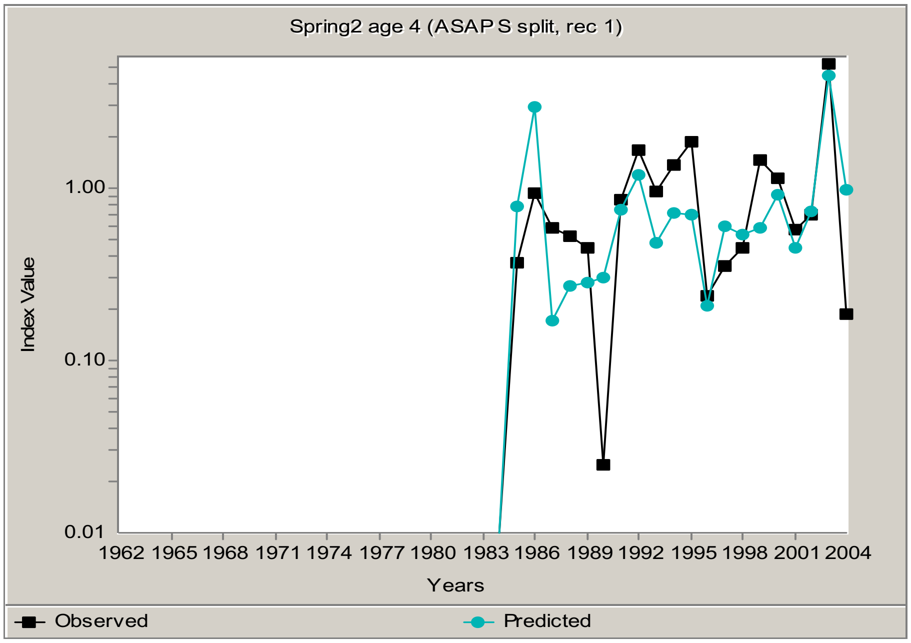

Figure 20 (APPENDIX B1). Spring survey observed vs. predicted series (1985-2004, age 4) for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series and a B-H SR relationship with lambda = 1.

Appendix B2. Sensitivity Runs for Atlantic mackerel stock assessment.

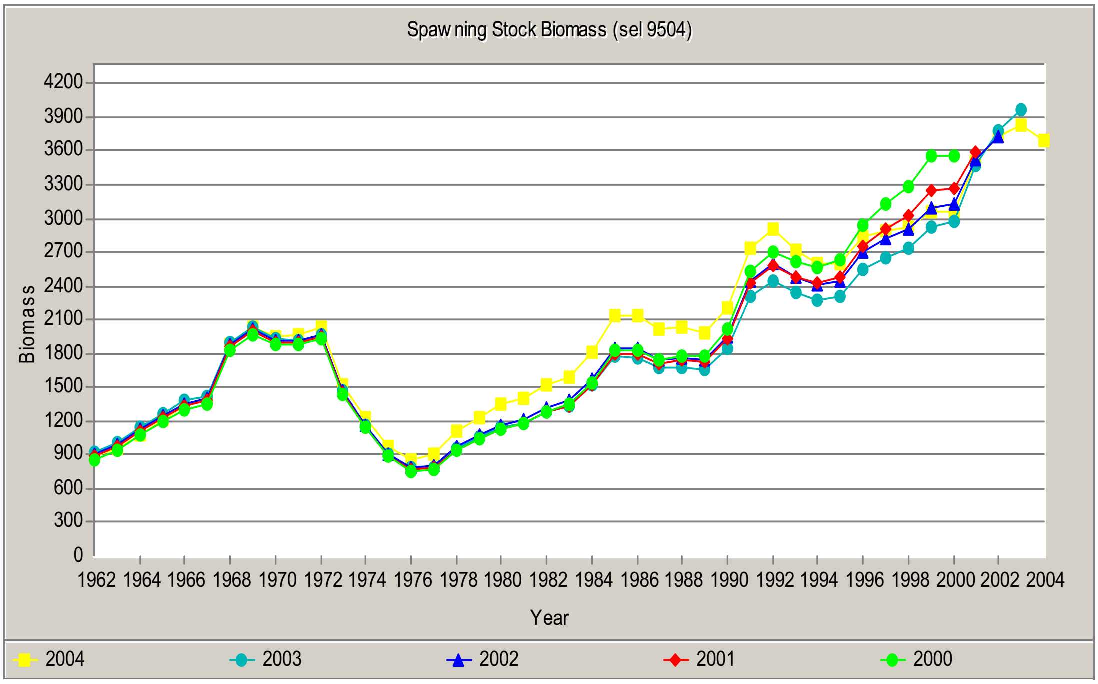

Figure 1 (APPENDIX B2). Retrospective pattern for SSB for the ASAP model with the spring survey split in 1985, B-H SR model (lambda = 1), ages aggregated to 7+, and estimated fishery selectivity during 1995-2004.

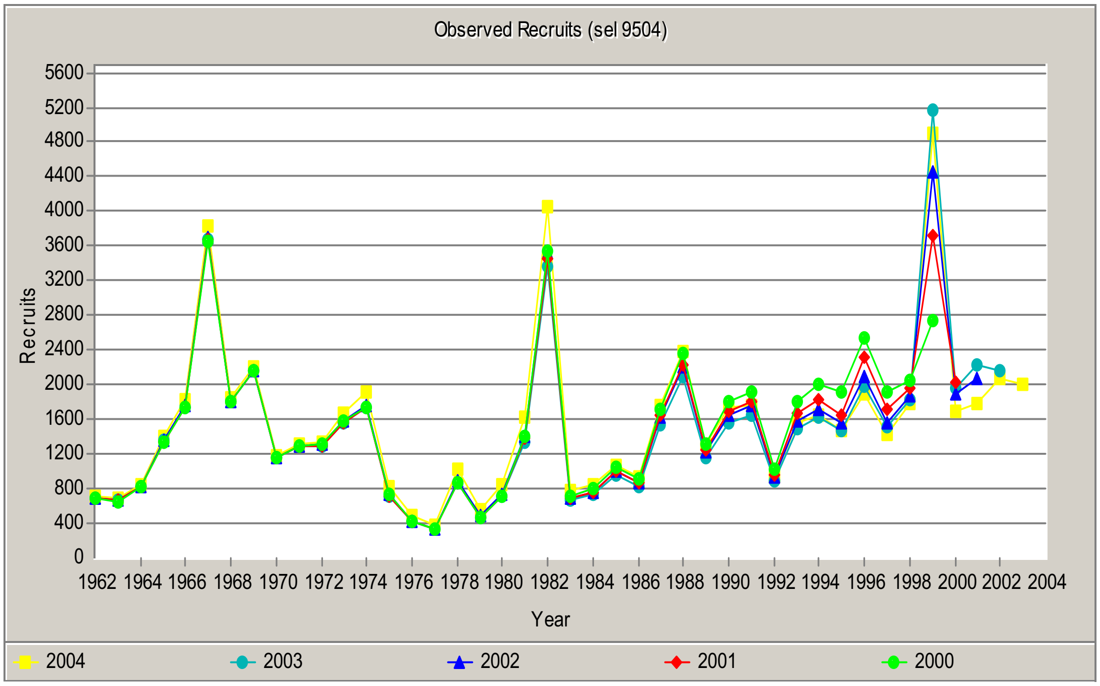

Figure 2 (APPENDIX B2). Retrospective pattern for recruitment for the ASAP model with the spring survey split in 1985, B-H SR model (lambda = 1), ages aggregated to 7+, and estimated fishery selectivity during 1995-2004.

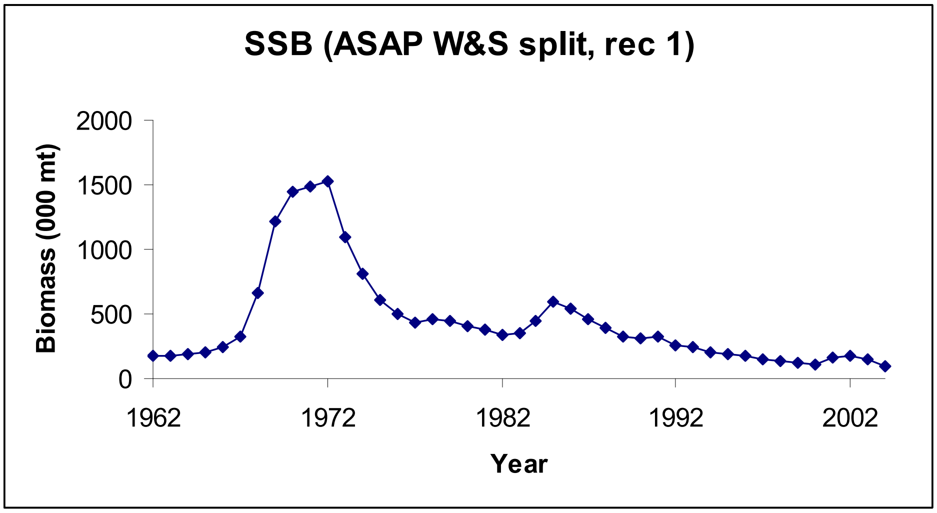

Figure 3 (APPENDIX B2). Sensitivity run to assess the effect of adding the NEFSC winter survey to the ASAP model, impact on spawning stock biomass.

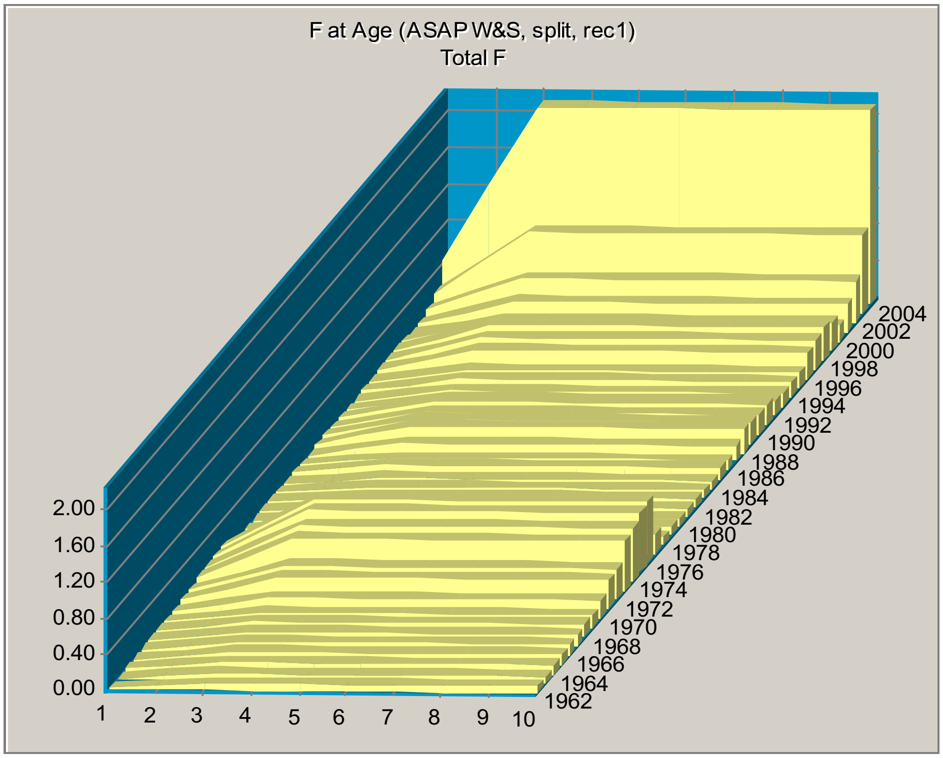

Figure 4 (APPENDIX B2). Sensitivity run to assess the effect of adding the NEFSC winter survey to the ASAP model, impact on fishing mortality.

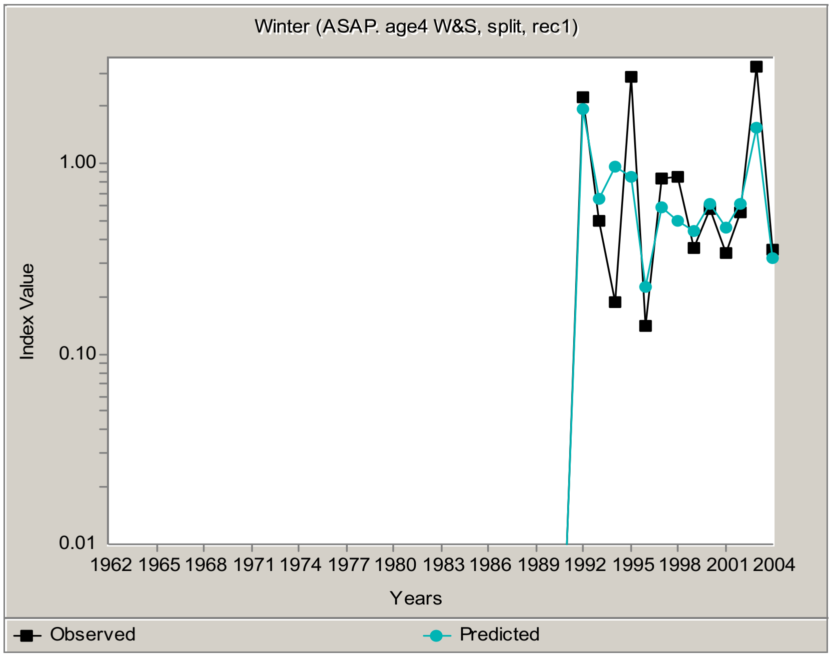

Figure 5 (APPENDIX B2). Sensitivity run to assess the effect of adding the NEFSC winter survey to the ASAP model, impact on winter survey observed vs. predicted series.

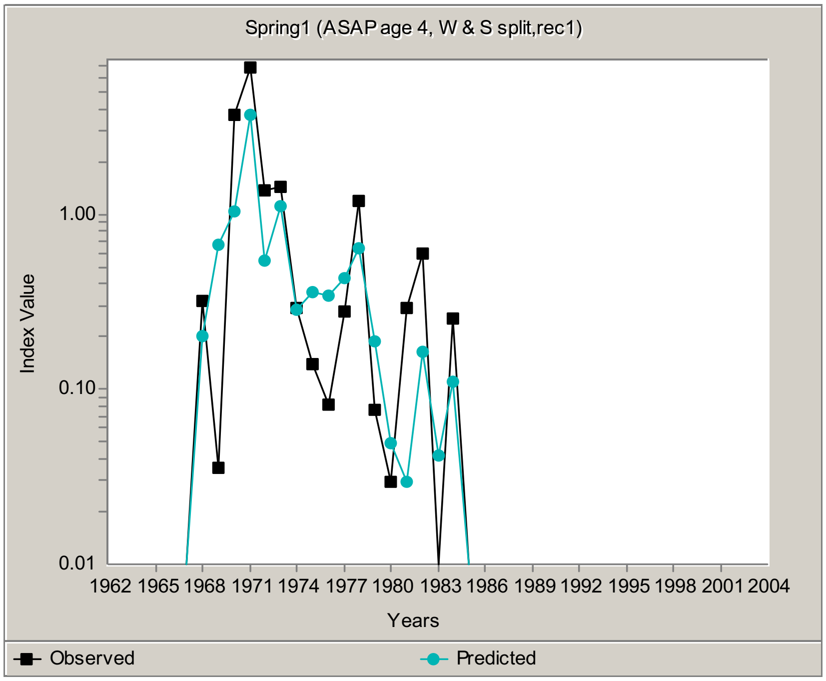

Figure 6 (APPENDIX B2). Sensitivity run to assess the effect of adding the NEFSC winter survey to the ASAP model, impact on spring1 survey observed vs. predicted series.

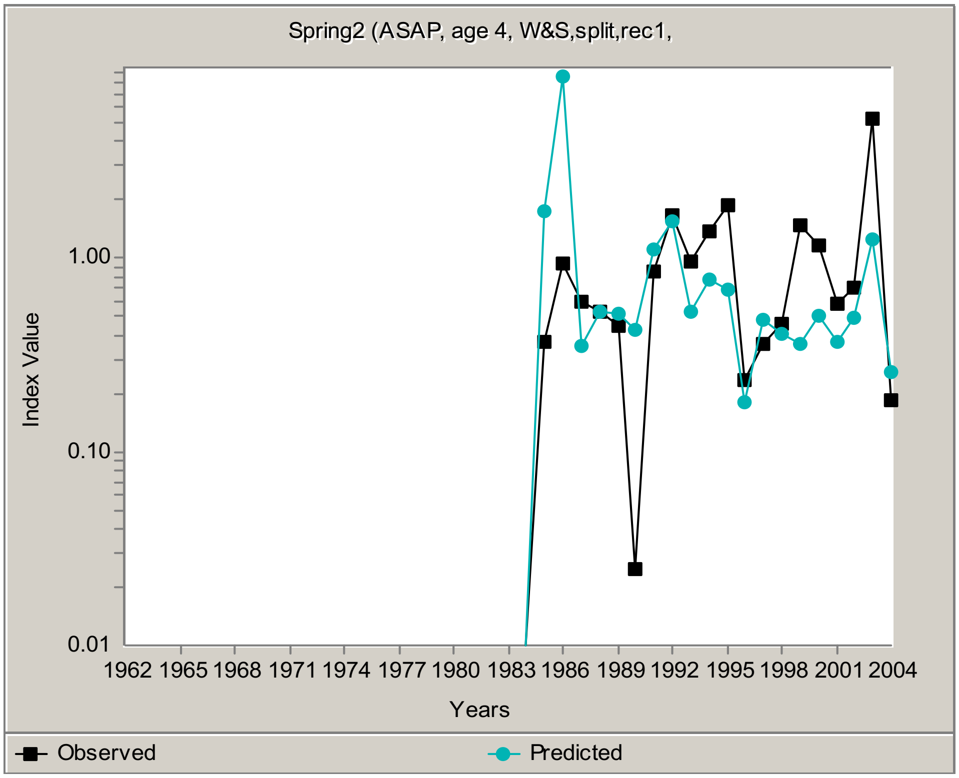

Figure 7 (APPENDIX B2). Sensitivity run to assess the effect of adding the NEFSC winter survey to the ASAP model, impact on spring2 survey observed vs. predicted series.

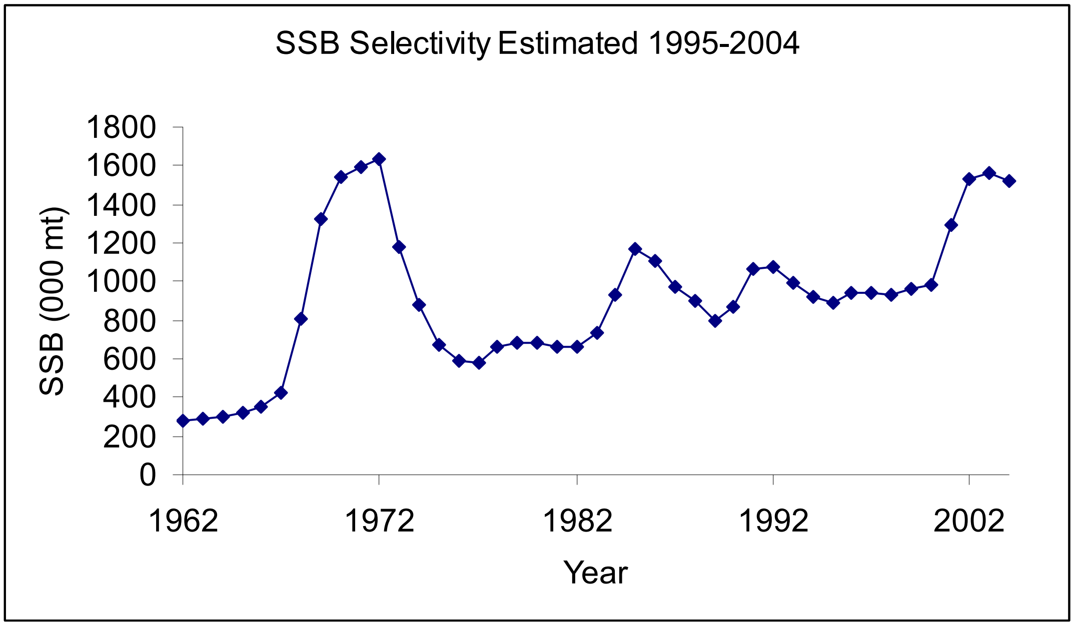

Figure 8 (APPENDIX B2). Results for SSB from a sensitivity run to assess the effect of estimating fishery selectivity during 1962-1994 and 1995-2004 in the ASAP model.

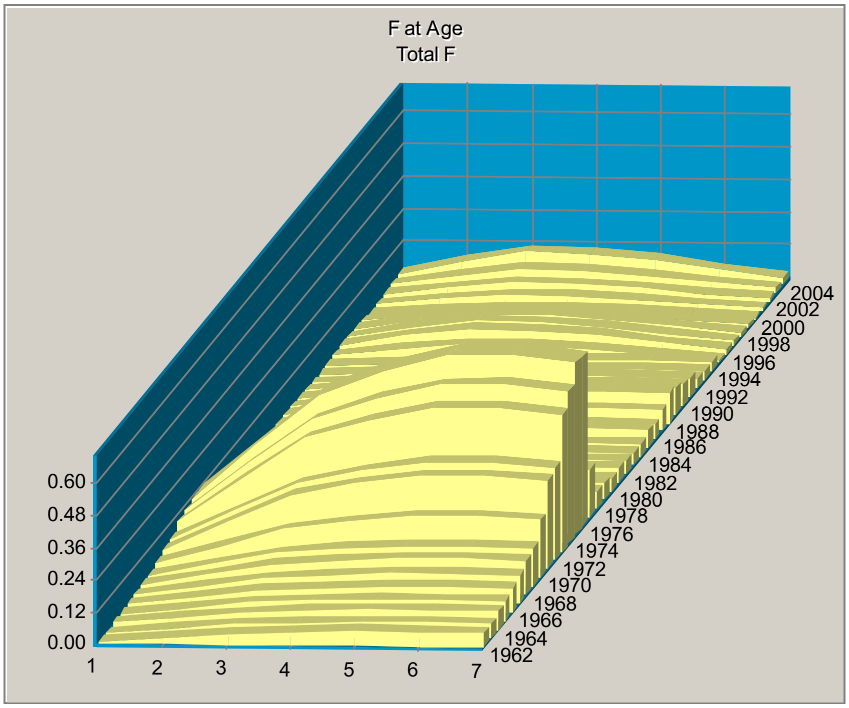

Figure 9 (APPENDIX B2).Results for fishing mortality from a sensitivity run to assess the effect of estimating fishery selectivity during 1962-1994 and 1995-2004 in the ASAP model.

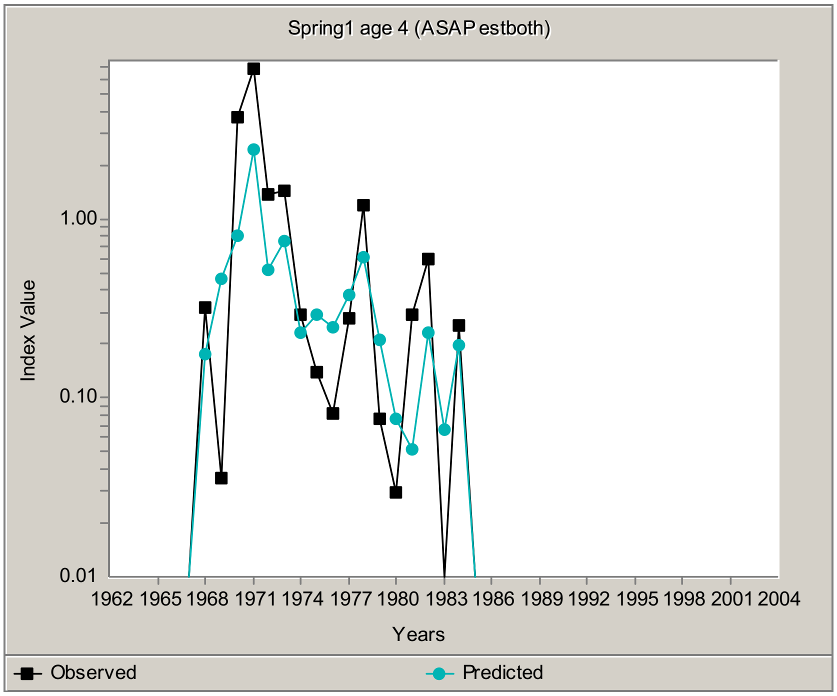

Figure 10 (APPENDIX B2). Sensitivity run to assess the effect of estimating fishery selectivity during 1962-1994 and 1995-2004 in the ASAP model on spring1 survey observed vs. predicted series.

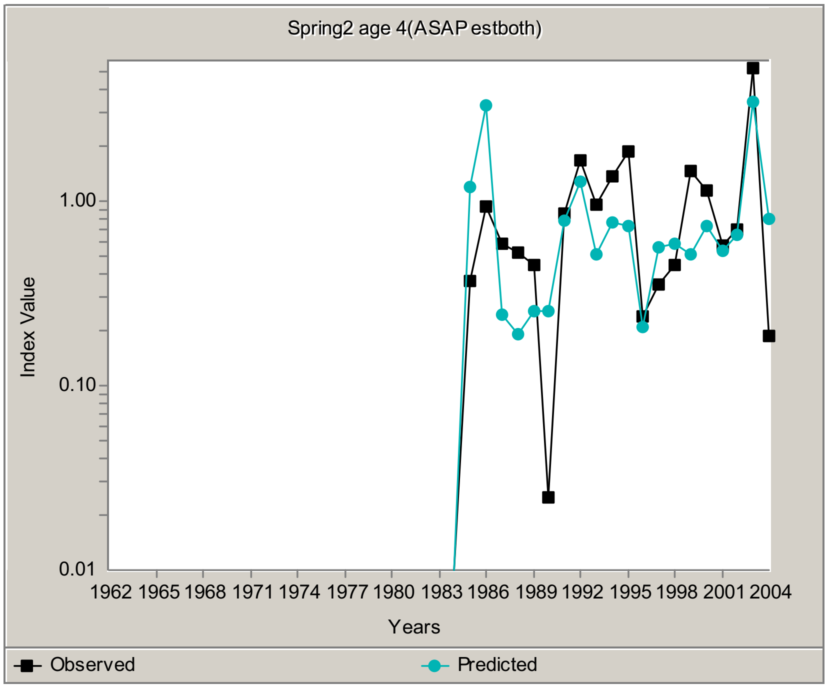

Figure 11 (APPENDIX B2). Sensitivity run to assess the effect of estimating fishery selectivity during 1962-1994 and 1995-2004 in the ASAP model on spring2 survey observed vs. predicted series.

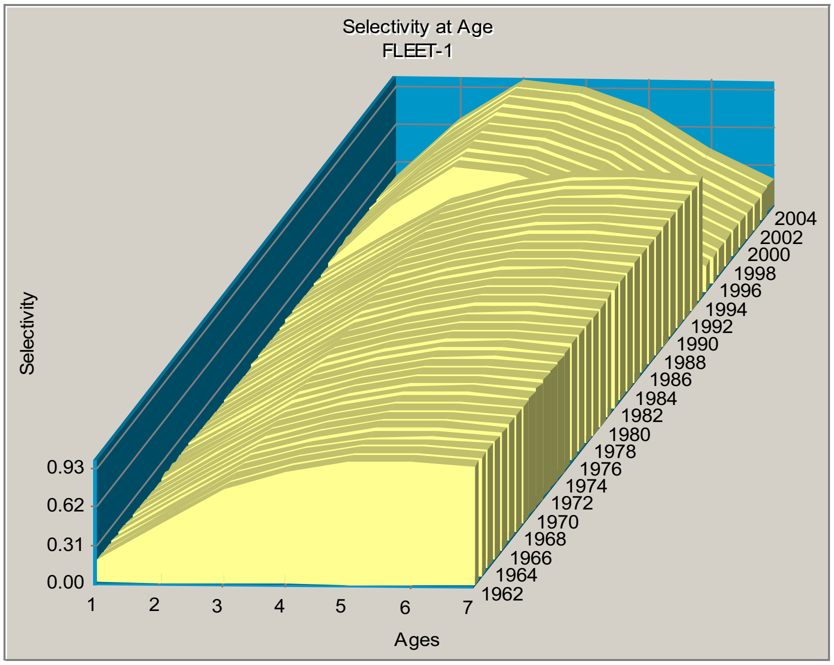

Figure 12 (APPENDIX B2). Sensitivity run to assess the effect of estimating fishery selectivity during 1962-1994 and 1995-2004 in the ASAP model on fishery selectivity.

APPENDIX B3: Rapporteur's Report from Mackerel Working Group Meeting

Concerns were raised regarding the lack of correspondence between the total landings from VTR and weighout data for 2004. Although some Atlantic mackerel may be going to bait markets without passing through dealers, industry representatives think 85-90% of landings pass through dealers, accounting for the vast bulk of landings. In Canada it is known that there is underreporting of catch going to the bait market, but they cannot quantify the magnitude, although it is not expected to be a major portion of the catch. There are no discard estimates but these catches are thought to be minor based on the gear required to catch mackerel in most years. However, as large year classes enter the fishery discarding of small fish may be an issue. The Working Group agreed that current catch estimates are reasonable.

The Working Group noted that although commercial landings increased in 2004 the number of length and age samples collected decreased. The 2004 sampling was inadequate and sampling should increase in future years to ensure the estimated catch at age is representative of the actual landings.

The relative lack of old fish in both the commercial catch and the surveys caused concern. Several possible explanations were discussed. The most likely explanations for the commercial catch was either a shift in location of the fishery to more inshore waters where older fish are less available, a shift in the location of fish due to environmental conditions, or insufficient sampling of the catch to detect the old fish amongst the more numerous younger fish. It was noted that the surveys have never caught large numbers of old mackerel but it could not be easily explained why the old fish are not currently seen by the survey if they are present in the area. The alternative explanation of a high fishing mortality rate does not agree with the recent low catches compared to historical catches. The Canadian fishery is targeting the large 1999 year class, which could explain the lack of old fish in that portion of the landings.

Retransformation of the spring index was discussed in detail. The technical procedure was described but an apparent inconsistency between the regular scale and retransformed data caused concern, specifically the change in direction from 2003 to 2004 between the regular and retransformed plots. It was explained that single large tows can lead to this apparent inconsistency. Since the retransformed data is then split into age groups, and the age samples from the early part of the time series are not available electronically, it is currently not possible to compute untransformed indices for the entire time series.

The Canadians have observed large changes in migration paths, timing of arrival and departure, distribution, etc. in recent years. This has made Canadian surveys difficult to use because their surveys are not measuring changes in abundance but rather changes in availability. They are continuing to explore development of indices, but the indices are not ready yet.

The Working Group agreed that since it is not possible currently to quantify the impact of consumption by predators on the natural mortality rate, the use of constant M in modeling is justified.

The Working Group agreed that the VPA models did not provide reasonable estimates for this stock and so was not used as a tool for classifying current stock status. The added structure in the

ASAP model allowed development of a Base Case analysis and a number of sensitivity runs to evaluate current stock status. The Base Case ASAP run has good fits to the indices and catch at age data, but exhibits a retrospective pattern. The Working Group concluded that it was preferable to keep this model even though it has a retrospective pattern because the approach that reduced the retrospective pattern, allowing a dome in recent years for the commercial fishery, could not be sufficiently justified. The Working Group agreed that without strong evidence for a domed pattern in recent years, the default of an asymptotic pattern for all years was most appropriate for this stock. The uncertainty in the recent SSB estimates was relatively high and encompassed most sensitivity runs.

C. ASSESSMENT OF NORTHERN SHORTFIN SQUID ON THE EASTERN USA SHELF DURING 2003 and 2004

A Report of the
SARC 42 Assessment Working Group
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, MA 02543

EXECUTIVE SUMMARY

The northern shortfin squid, *Illex illecebosus*, inhabits the continental shelf and slope waters of the Northwest Atlantic Ocean between Iceland and the east coast of Florida and constitutes a unit stock throughout its range. The species is highly migratory, growth is rapid and the lifespan is short, up to 215 days for individuals inhabiting the USA shelf. *I. illecebrosus* is semelparous and females spawn and die within several days of mating. Thus, natural mortality increases with age for the age range where spawning occurs. Fishing mortality and spawning mortality occur simultaneously. Stock structure is complicated by the overlap of seasonal cohorts. Age data indicate that spawning occurs throughout the year and that the first several months of the US fishery are supported by the winter cohort. The onset and duration of the fisheries occur in relation to annual migration patterns on and off the continental shelf which appear to be highly influenced by environmental conditions. On the USA shelf, a bottom trawl fishery generally occurs during June through October. Since its inception in 1987, the domestic fishery has taken a majority of the total annual landings. In recent years, there has been no fishery on the Scotian Shelf and landings from the Newfoundland jig fishery have been very low. There are no stock-wide research surveys and it is unknown whether NEFSC research bottom trawl surveys track *Illex* abundance or its availability on the shelf because these surveys cover only a portion of the *Illex* habitat and they occur during migration periods.

The northern stock component, extending from Newfoundland to the Scotian Shelf, is assessed annually and managed by the Northwest Atlantic Fisheries Organization (NAFO) based on a total allowable catch (TAC). The southern stock component, extending from the Gulf of Maine to the east coast of Florida, is managed by the Mid-Atlantic Fisheries Management Council (MAFMC) based on an annual TAC. According to the regulations, closure of the directed fishery occurs when 95% of the quota has been landed then a trip limit of 4.5 mt (10,000 lbs) takes effect. The stock was last assessed in 2003, at SAW 37, and updated fishery and survey data for 1999-2002. At SAW 37, it was not possible to evaluate stock status because there were no reliable estimates of stock biomass or fishing mortality rates. However, based on qualitative information, it was determined that overfishing was not likely to have occurred during 1999-2002. Stock status with respect to biomass was unknown.

The current assessment focuses on the southern stock component, particularly during 2003 and 2004, but survey indices and landings from the northern stock component are also presented. This is a data-poor stock, and because there are no reliable research survey indices for *Illex* inhabiting the U.S. Shelf, the assessment relies on fisheries data, in particular, catch per unit

effort (CPUE) indices and biological data collected during prior cooperative research projects. Due to its short lifespan and the short fishing season, *Illex* was assessed using an in-season (weekly) model. Estimates of natural mortality were included in the in-season model and in a weekly per-recruit model. Although the Working Groups felt the model formulations were sound, it was decided that the use of the results from the three models was premature, mainly due to a lack of seasonal age, growth and maturity data which greatly affect the model results. Due to the lack of adequate data regarding fishing mortality rates and absolute biomass, stock status could not be determined for 2003 or 2004.

TERMS OF REFERENCE

The following Terms of Reference were addressed and are summarized below:

1.) *Characterize the commercial and recreational catch including landings and discards.*

There is no recreational fishery for *Illex*. Landings and discards from the USA fishery were updated for 2003 and 2004. Landings from the fisheries involving the northern stock component (Scotian Shelf and Newfoundland) were also updated for 2003 and 2004. Refer to Section 3.0.

2.) *Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates.*

A revised version of the SARC 37 in-season assessment model was run using data for 2003 and 2004. However, the model estimates of fishing mortality and stock size were not reliable because new data on seasonal growth rates and maturity are required for the model. Refer to Section 7.0.

3.) *Evaluate and either update or re-estimate biological reference points as appropriate.*

A revised version of the SARC 37 maturation-natural mortality model was presented but the results were not considered reliable because new data on seasonal growth rates and maturity are required for the model. Because the preliminary natural mortality estimates are a data input to the per-recruit models that were used to estimate biological reference points, the reference point estimates from the per-recruit models were also considered preliminary. In addition, seasonal changes in growth rates are likely for this species and this will affect the reference point estimates. Therefore, seasonal growth rate data are required to test the sensitivity of the per-recruit models to growth rates. Refer to Section 6.0.

4.) *Where appropriate, estimate a TAC and/or TAL based on stock status and target fishing mortality rate for the year following the terminal assessment year.*

5.) *If possible,*

   a. *provide short term projections (2-3 years) of stock status under various TAC/F strategies and*

   b. *evaluate current and projected stock status against existing rebuilding or recovery schedules, as appropriate.*

Illex is a sub-annual species so assessments should be based on data from the current year. However, stock assessments are prepared for the previous year because data for the current year are unavailable at the time of the assessment and/or the current year's fishery is ongoing at the time of the SARC. Consideration of the timing of the *Illex* assessment and the collection of in-season assessment data are needed to remedy these issues.

6.) *Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in previous SARC-reviewed assessments*.

The accomplishment of many of the previous SARC research recommendations, as a result of external grant funds obtained by the lead assessment scientist and cooperative research projects, has resulted in an increased understanding of the complex life history of this species and has allowed the development and testing of new models which appear promising. This information has been documented in several journal and report publications. Refer to Section 9.0 for the status of the SARC 37 research recommendations.

1.0 INTRODUCTION

An initial review of the *Illex illecebrosus* assessment was conducted on October 3, 2005 at a meeting of the Invertebrate Working Group held at the Northeast Fisheries Science Center in Woods Hole, Massachusetts. Lynne Purchase, a squid assessment scientist from the Renewable Resources Assessment Group (RRAG), at Imperial College in London, attended the meeting as an external reviewer. Ms. Purchase's comments are presented in Appendix C1. The assessment was revised according to the recommendations made at the October 3 meeting and was reviewed again at a second Working Group meeting held during October 24-28 in Woods Hole, MA. The comments from second Working Group meeting are included in Appendix C2. The follows persons attended the second meeting:

Name	Organization
Jay Burnett	NMFS/NEFSC
Ralph Mayo	NMFS/NEFSC
Larry Jacobsen	NMFS/NEFSC
Chris Legault	NMFS/NEFSC
Susan Wigley	NMFS/NEFSC
Laurel Col	NMFS/NEFSC
Jim Weinberg	NMFS/NEFSC
Mark Terceiro	NMFS/NEFSC
Azure Westwood	NMFS/NEFSC
Dan Farnham	Industry Advisor
Kathy Lang	NMFS/NEFSC
Paul Rago	NMFS/NEFSC
Bill Overholtz	NMFS/NEFSC
Vidar Wespestad	Industry Consultant
Jim Ruhle	Industry Advisor
Dvora Hart	NMFS/NEFSC
Mauricio Ortiz	NMFS/SEFSC

Dana Hanselman	NMFS/AFSC
Eric Powell	Rutgers University
Francois Gregoire	DFO, Canada
Lisa Hendrickson	NMFS/NEFSC
Rich Seagraves	MAFMC
Marybeth Tooley	ECPH
Paul Nitschke	NMFS/NEFSC
Steve Cadrin	NMFS/NEFSC/SMAST
Mary Radlinski	SMAST

The *Illex illecebrosus* stock was last assessed in 2003 at the 37th Stock Assessment Workshop (SAW) (NEFSC 2003). The assessment included updates of fisheries and research survey data for 1999 through 2002. An in-season (weekly) assessment model that incorporated recruitment, landings and effort data, mean body weights from the fishery, and natural mortality rates computed from a maturation-natural mortality model were used to estimate initial stock size and fishing mortality rates in the U.S. fishing area during 1999 but the model was considered preliminary because additional testing was required (NEFSC 2003). The SARC 37 assessment also included a weekly yield-per-recruit (YPR) and egg-per-recruit (EPR) analysis which was also considered premature. With respect to stock status, SARC 37 concluded that it was not possible to evaluate the current stock status because there are no reliable estimates of absolute stock biomass or fishing mortality rate.

The current assessment pertains to the southern stock component (US EEZ, from the Gulf of Maine to Cape Hatteras, NC), but also summarizes landings and research survey data from the northern stock component (Newfoundland and the Scotian Shelf). Fisheries data and research survey biomass and abundance indices were updated to include 2003 and 2004. *Illex illecebrosus* is a semelparous species and an age-based maturation-natural mortality model that estimates spawning mortality rates was presented during the last assessment. The model has been reformulated, changing from a discrete time step to a continuous process. Output from the reformulated model, including the probability of spawning at age and spawning mortality rate estimates, are incorporated in yield-per-recruit and egg-per-recruit analyses along with fishery selectivity estimates and catch mean weights, during 1999-2002, to estimate biological reference points. Results from the reformulated maturation-natural mortality model and the per-recruit models are taken from a journal publication (Hendrickson and Hart 2006) prepared by the *Illex* assessment scientists. The in-season stock assessment model that was considered preliminary during the last assessment was further developed and tested using simulation analyses. Simulation analysis results are presented herein.

2.0 BACKGROUND

The northern shortfin squid, *Illex illecebosus*, inhabits the continental shelf and slope waters of the Northwest Atlantic Ocean between Iceland and the east coast of Florida and is assumed to constitute a unit stock throughout its range (Dawe and Hendrickson 1998). The northern stock component, extending from Newfoundland to the Scotian Shelf, is assessed annually and managed by the Northwest Atlantic Fisheries Organization (NAFO) based on a total allowable catch (TAC). The southern stock component, extending from the Gulf of Maine to the east coast of Florida, is managed by the Mid-Atlantic Fisheries Management Council (MAFMC) based on an annual TAC.

The life history and habitat requirements of *I. illecebrosus* are summarized in Hendrickson and Holmes (2004). The northern shortfin squid is a highly-migratory ommastrephid that lives for up to one year (Dawe et al. 1985; Dawe and Beck 1997; O'Dor and Dawe 1998; Hendrickson 2004). Temporal and spatial distribution patterns are highly variable at the northern limit of this species' range (Newfoundland) and are associated with environmental factors (Dawe et al. 1998). Recruitment dynamics are complex and have not been fully elucidated for the U.S. EEZ component of the stock, so reliable predictions of annual recruitment levels are not currently possible. Stock structure is complex and, in Newfoundland waters, is complicated by overlapping seasonal cohorts that migrate through the fishing grounds (Dawe and Beck 1997). Mean size at maturity varies between northern and southern geographic regions in some years (Coelho and O'Dor 1993). However, it is not known whether these differences are due to inherent population structure. O'Dor and Coelho (1993) speculated that changes in the seasonal spawning patterns could have played a role in the collapse of the Canadian fishery during the early 1980's.

The *Illex* stock is fished on the continental shelf from Newfoundland, Canada to Cape Hatteras, North Carolina. However, there are no stock-wide indices of relative abundance or biomass. The NEFSC bottom trawl surveys do not cover the entire habitat range of the species and it is unknown whether the survey indices measure relative abundance or availability to the survey gear. In addition, CPUE data for the US fishery is of coarse temporal and spatial resolution and age and growth information for the U.S. stock component is limited to data from a single pre-fishery survey (Hendrickson 2004). As a result, research recommendations in previous assessments have emphasized the need for improved stock assessment data, particularly given the short lifespan and short fishing season (4-5 months on average for the US fishery).

Since 1997, the NEFSC has conducted multiple cooperative research projects with the *Illex* fishing industry that have increased our knowledge about the age, growth and life history of *Illex* in US waters (Hendrickson 2004) and that have improved the spatial and temporal resolution of fisheries catch, effort and biological data in real-time via electronic logbook reporting (Hendrickson et al. 2003). The products of these research projects have been used extensively in new assessment models that take into account the semelparous life history of *I. illecebrosus*.

Commercial fisheries for *I. illecebrosus* occur from Newfoundland to Cape Hatteras, North Carolina. The bottom trawl fishery operating within the U.S. EEZ (Northwest Atlantic Fisheries Organization Subareas 5 and 6) is managed by the Mid-Atlantic Fishery Management Council (MAFMC) and fisheries operating within Northwest Atlantic Fisheries Organization (NAFO) Subareas 2, 3 and 4 are managed by NAFO (Fig. C1). During 1980-1998, the annual total allowable catch (TAC) established by NAFO for Subareas 2-4 was 150,000 mt (NAFO 1995). The NAFO TAC was reduced to 75,000 mt in 1999 (NAFO 2000) and has been 34,000 mt since 2000 (Hendrickson et al. 2005). Annual levels of allowable biological catch (ABC) and domestic annual harvest (DAH) in the U.S. EEZ are determined in accordance with the Atlantic Mackerel, Squid and Butterfish Fishery Management Plan (SMB FMP) and are based on the best available information about the current status of the stock. During 1991-1995, the optimum yield (OY), ABC and DAH were 30,000 mt (MAFMC 1994). The DAH was reduced to 21,000 mt in 1996 (MAFMC 1995a) and 19,000 mt during the 1997-1999 fishing seasons (MAFMC 1996a; 1997a;

1998a). The DAH has been 24,000 mt since 2000 and was set at 24,000 for 2006 (MAFMC 2000; 2001; 2002).

Amendment 5 of the SMB FMP was enacted (MAFMC 1995b; 1996b) in recognition that the domestic resource was approaching full utilization and that expansion of the U.S. fleet might lead to overcapitalization. Amendment 5 established a permit moratorium to limit entry into the directed fishery, required mandatory logbook and dealer reporting as of January 1, 1997, and established a 5,000-pound trip limit for incidental catches of *Illex* by non-moratorium vessels. Amendment 6 (MAFMC 1996c) provided a mechanism for in-season closures of the *Illex* fishery, and established an overfishing definition of $F_{20\%}$ and procedures for the specification of annual quotas based on $F_{50\%.}$ Amendment 7 (MAFMC 1998b) was enacted to achieve consistency between FMP's with regards to Limited Access Federal permits. Based on the requirements of the Sustainable Fisheries Act (SFA), Amendment 8 (MAFMC 1998c) established MSY-based biological reference points. Threshold and target fishing mortality rates were specified as F_{MSY} and 75% of F_{MSY}, respectively. In addition, a biomass target and minimum biomass threshold were specified as B_{MSY} and 50% of B_{MSY}, respectively. Amendment 8 also defined the essential habitat of *Illex* in the U.S. EEZ and established a framework adjustment process for specific management measures. Amendment 9 is still in draft form, and with respect to *Illex*, could extend the moratorium on entry to the commercial fishery, allow for specification of management measures covering multiple years, require electronic daily reporting, modify the exemption from the *Loligo* minimum mesh size requirement for vessels in the *Illex* fishery, implement closures to reduce gear impact on habitat, and modify the *Loligo* possession imit by *Illex* fishery vessels during *Loligo* fishery closures..

3.0 LANDINGS AND DISCARDS

Landings

A bottom trawl fishery for *I. illecebrosus* occurs on the USA shelf (NAFO Subareas 5+6) and an artisanal jig fishery occurs in inshore Newfoundland waters (NAFO Subarea 3). Historically, a bottom trawl fishery also occurred on the Scotian Shelf in NAFO Subarea 4 (Hendrickson et al. 2005). The timing and duration of the fisheries are determined primarily by the migration of the species through the fishing grounds on the continental shelf. The inshore migration into Subarea 3 generally occurs during July, approximately three months later than it occurs on the continental shelf in Subareas 4, 5 and 6. This delay in the arrival of squid on the fishing grounds is presumably a result of the position of the Gulf Stream, the hypothesized transport mechanism for paralarvae hatched during the winter (Trites 1983), being located further from shore in this northern region. An unusually early inshore arrival of squid occurred in Subarea 3 during June of 1987, when 78% of the landings for that year were taken. *Illex* remains on the shelf longer in Subarea 3 so the fishing season often extends into November after landings reach a peak in September (NEFSC 1999). Since 1992, the U.S. fishery and the Subarea 4 fishery have generally occurred during June through October with a peak in July (NEFSC 1999). Historically, foreign trawlers involved in the silver hake and argentine fishery in Subarea 4 also targeted *Illex* if it became available before the July closure of the silver hake fishing season (Mark Showell, pers. comm. 1999). However, the mixed fishery for silver hake, argentine and *Illex* has not operated in Subarea 4 since 2000 (Hendrickson et al. 2004).

Illex landings (mt) during 1963-2005 are presented for the southern stock component inhabiting the US EEZ (NAFO Subareas 5+6) as well as the northern stock component (NAFO Subareas 3+4, Table C1, Fig. C2). US EEZ landings are partitioned into foreign and domestic components and the total allowable catches (TACs) for Subareas 3+4 and Subareas 5+6 are also presented. During 1963-1976, U.S. EEZ landings of squid by distant water fleets (foreign landings) were not consistently reported by species. In addition, domestic landings of squid were not recorded by species in the commercial fisheries dealer database until 1979. As a result, U.S. EEZ landings during 1963-1978 were derived from prorations based on the temporal and spatial landings patterns of *Illex illecebrosus* and *Loligo pealeii*, by country, from fisheries observer data (Lange and Sissenwine 1980). U.S. EEZ landings for 1979-2005 were obtained from the Weighout Database, which consists of fish purchases by dealers, and also include landings from joint ventures that occurred during 1982-1990 between U.S. and foreign fishing vessels. Dealer reporting of *Illex* purchases has been mandatory since January 1, 1997. Since April of 2004, dealers have been required to enter their fish purchases electronically in the Weighout Database these data are considered preliminary. Landings from NAFO Subareas 3+4, during 1963-2004, were obtained from Hendrickson et al. (2005).

Total *Illex* landings have varied considerably since 1963 and have consisted of three distinct levels of magnitude (Fig. C2A). A period of high landings, which occurred during 1976-1981 when distant water fleets were active in all NAFO fishing areas, was bracketed by periods of substantially lower landings. During 1963-1967, total landings were low, averaging 7,354 mt, and were primarily from the Subarea 3 inshore jig fishery. During 1968-1974, total landings averaged 13,470 mt and were predominately from distant water fleets that had begun fishing in Subareas 5+6. However, this trend was reversed during 1976-1981, when landings were predominately from Subareas 3+4. During this time, total landings averaged 100,300 mt, and in 1979, reached the highest level on record (179,333 mt). Thereafter, landings from Subareas 3+4 declined rapidly from 162,092 mt in 1979 to 426 mt in 1983. However, landings from Subareas 5+6 remained stable and did not exceed 25,000 mt, in part, due to effort limitations placed on the distant water fleets. Since its inception in 1987, landings from the domestic bottom trawl fishery have comprised a majority of the total landings. The exception occurred in 1997, when landings from Subareas 3+4 (15,485 mt) exceeded U.S. EEZ landings (13,629 mt) and were at their highest level since 1982. Landings from Subareas 3+4 declined to 57 mt in 2001, and then gradually increased to 2,034 mt in 2004. Since 2000, landings from Subareas 3+4 have primarily been from the Newfoundland jig fishery (Hendrickson et al. 2004).

U.S. EEZ landings have been characterized by two distinct periods (Fig. C2B). During 1968-1982, U.S. EEZ landings were predominately taken by distant water fleets, and in 1976, reached a peak of 24,936 mt. U.S. EEZ landings subsequently declined to 1,958 mt in 1988 (Fig. C2B) when foreign participation in the U.S. *Illex* fishery became prohibited in order to foster development of a domestic fishery. During 1998-1994, landings from the domestic fishery increased from 1,958 mt to 18,350 mt, then reached a peak of 23,597 mt in 1998. This 1998 peak led to a closure of the fishery because the quota (19,000 mt) was reached. During 1999-2002, U.S. landings declined and reached their lowest level in 2002 (2,750 mt) since the 1987 inception of the domestic fishery. U.S. landings increased to 6, 389 mt in 2003 then reached their highest level on record in 2004 (26, 087 mt) which resulted in a closure of the fishery because the quota (24,000 mt) was reached. A preliminary estimate of the U.S. landings for 2005 is 11,429 mt.

A majority (≥ 98%) of the annual landings from the U.S. EEZ are taken with bottom trawls (Table C2). Domestic fishing effort is greatly influenced by the global market demand for squid and is limited by onshore and at-sea freezer storage capacity as well as the availability of *Illex* to the bottom trawl fishery. The Vessel Trip Report (VTR) database and NEFSC Sea Sampling database indicate that the U.S. EEZ *Illex* fishery occurs primarily at depths between 128 and 366 m. Gear limitations prevent fishing in waters deeper than 457 m (Glenn Goodwin, pers. comm. 1999).

Since January 1, 1997, *Illex* moratorium permit holders have been required to report catch, effort and fishing location data to NMFS on Vessel Trip Reports from which the data are entered into the Vessel Trip Report (VTR) Database. Landings recorded in the Weighout Database are considered more accurate than the kept fraction of the catch reported on the VTRs because the latter represent estimates made by vessel captains. However, the fishing effort and location data required to compute landings per unit of effort (LPUE) are only recorded in the VTR Database and there is no single field that directly links trips from the WO Database with those from the VTR Database. Therefore, in order to avoid the use of prorated landings to compute weekly LPUE, weekly trends in landings were compared between the VTR and Weighout Databases to determine whether the VTR landings could be used to compute LPUE.

Trends in weekly *Illex* landings and the duration of the fishing season vary by year. During 1999-2004, trends in weekly *Illex* landings were similar for the VTR and WO Databases. During 1999-2002, the fishery began during weeks 23 or 24 and lasted for a period of 16 to 21 weeks (Fig. C3). During 2003, weekly landings varied without trend, which is characteristic of years with low fishing effort, such as 2001 and 2002 (NEFSC 2003), and the duration of the fishing season was longer than normal (23 weeks). The variability in weekly landings trends is partly attributable to the coarse temporal resolution of the WO and VTR Databases, which necessitates assigning week of the year by the date landed instead of the tow date. Tow-based data associated with real-time fisheries data reporting show less variability (NEFSC 2003; Hendrickson et al. 2003). Some of the variability in the weekly landings trends for both databases is attributable to the coarse resolution of the landings data (trip-based rather than tow-based) which requires trips to be assigned to weeks based on the date landed rather than the date caught. During the Working Group meeting, the weekly landings figure for 2004 suggested that *Illex* landings reported in the VTR Database underestimated the landings in the WO Database. This discrepancy was subsequently re-examined and Figure C3 has been revised to reflect the updated WO data for 2004, which now indicates similar trends in magnitude between weekly landings from the two databases. This data revision does not impact any other assessment computations. The WO and VTR Databases indicate that the weekly landings during 2004 were more than double the weekly landings obtained during 1999-2003. Weekly landings during 2004 show an increasing trend followed by a decreasing trend, with an inflection point at week 35. Landings increased rapidly between weeks 20 and 24, and then stabilized at about 1,600 mt per week through week 32. Thereafter, landings increased further and reached a peak of 2,730 mt in week 35. The fishery was closed after week 38 because the quota was taken, but landings declined prior to this time, between weeks 35 and 38.

Discards

Two sources of data are available for estimating *Illex* discards, data from the NEFSC Observer Program Database and the VTR Database. Although reporting of discards is required on VTRs, reporting of *Illex* discards is inconsistent. Therefore, *Illex* discards were quantified, by month, based on data from fishing trips monitored at sea by NEFSC fishery observers.

In addition to the *Illex* fishery, which is characterized by 34.9-60.3 mm diamond mesh codends, other fisheries likely to incur *Illex* bycatch are those that utilize bottom trawls of similarly small mesh and that occur during May-November, when *Illex* is present on the U.S. continental shelf. The offshore *Loligo* fishery meets both criteria and catch data from observed trips from the NEFSC Observer Program database indicate that a majority of the *Illex* bycatch, during 1995-2004, occurred in the offshore *Loligo* fishery.

Illex discards (mt) in the *Illex* and *Loligo* fisheries were estimated, by month and year, from catch data collected during trips sampled by observers from the NEFSC Sea Sampling Program during 1995-2004. The *Illex* fishery was defined as bottom trawl trips that occurred during May-October in which *Illex* landings comprised ≥ 25% of the total trip weight. The *Loligo* fishery was defined as bottom trawl trips that occurred during November-April in which *Loligo* landings comprised ≥ 25% of the total trip weight. Annual estimates of *Illex* discards in the *Illex* fishery were computed by multiplying the annual discard ratio (annual *Illex* discards/annual *Illex* kept, mt) by the annual *Illex* landings. Annual estimates of *Illex* discards in the *Loligo* fishery were computed by multiplying the annual discard ratio (annual *Illex* discards/annual *Loligo* kept, mt) by the annual *Illex* landings. Annual estimates for each of the two fisheries were summed to obtain the total amount of annual discards.

The annual sampling intensity of trips observed in the *Illex* fishery was low during 1995-2003, ranging between 2 and 15 trips (Table C3). There were no *Illex* trips sampled during 2001 or 2002. During 2004, 33 trips were sampled and most trips occurred during July and August, the peak of the fishing season. Temporal discarding patterns during 1995-2004 could not be discerned because the number of trips sampled by month was not representative of the seasonal landings pattern. The amount of *Illex* discarded by the *Illex* fishery during 1995-2004 ranged between 29 mt and 344 mt per year (Table C3).

The annual sampling intensity of trips observed in the *Loligo* fishery during 1995-2003 was also low, ranging between 3 and 18 trips (Table C4). During 2004, 54 trips were sampled primarily in the offshore, winter fishery. During 1995-2004, monthly sampling coverage was inconsistent during the year-round fishing season, so monthly discarding trends could not be discerned. During January of 2001, Gear Restriction Areas (GRAs) were established to reduce scup bycatch. The Southern GRA is closed to small-mesh (< 4.5 inch codend mesh) fisheries during January through March 15. NEFSC spring survey data indicate that *Illex* migration onto the U.S. continental shelf generally begins in March, during the latter part of the closure period. However, observer data were inadequate to evaluate whether this closure area also aided in the reduction of *Illex* discarding by the *Loligo* fishery. The amount of *Illex* discarded by the *Loligo* fishery during 1995-2004 ranged between 1 mt and 1,222 mt per year and was highest in 2004.

In summary, *Illex* discard estimates are imprecise but the overall level of discards in recent years was likely low in comparison to the *Illex* landings. Most of the *Illex* discards occur in the winter offshore *Loligo* fishery (Table C5). During 1995-2004, the combined *Illex* discards from both squid fisheries ranged between 53 mt and 1,556 mt and comprised 0.5-6.0% of the annual *Illex* landings by the U.S. fishery (Table C5). *Illex* discarding in both squid fisheries was higher during 1998 and 2004, when *Illex* abundance was higher. However, a quantitative comparison of discarding between years and months is difficult due to low sampling intensity, by month and year, in both fisheries.

Mean Body Size

For the northern stock component, trends in annual average body size are associated with annual trends in *Illex* relative abundance (Hendrickson et al. 2004). In-season changes in *Illex* body size reflect the combined effects of growth, mortality (from fishing and natural mortality), and emigration and immigration from the fishing grounds. Therefore, annual and in-season trends in *Illex* mantle length (cm) and body weight (g) were assessed for *Illex* samples obtained from the landings by squid processors and NMFS port samplers during 1994-2004. With the exception of 1996, *Illex* landed during 1999-2003 were smaller than in other years during 1994-2004. Median mantle lengths were highest during 1994 and 2004 and were lowest in 1996 (Fig. C4). Median body weight was highest during 1994 and lowest in 2001 (Fig. C4). Median mantle length and body weight during 2003 were similar to those from 2002. The median weight of squid in 2004 was the highest since 1998 and the median mantle length in 2004 was as high as in 1994. Median mantle length and body weight were significantly lower in 2001 than for most years during 1994-2004. Interannual trends in squid size are likely attributable to environmental conditions, particularly if they persist across multiple years, but size trends may also reflect fishing in different geographic areas. A review of bottom water temperature anomalies in the Mid-Atlantic Bight indicated that bottom temperatures near the shelf edge were warmer than average during large portions of the year in 1999-2002 (Jossi and Benway 2003) when *Illex* mean body size was small and catches were low.

The Lowess-smoothed trend line of a composite of the average body weights of squid landed during 1994-1998 indicated a steady increase in average size from 50-175 g during weeks 20 through 34, but the trend for smaller squid that were landed during 1999-2002 indicated an increase in body size that was more gradual, from 70 to 110g between weeks 22 through 30 (NEFSC 2003). Thereafter, average body size was generally stable. The attainment of an asymptotic average size may be partially driven by the recruitment of smaller squid, but most likely reflects the emigration of larger squid. In autumn, the density of large squid increases with depth and is highest in the deepest strata (186-366 m) during this offshore migration period (Brodziak and Hendrickson 1999). Maximum average size in the fishery during 1999-2002 occurred one month earlier, at week 30, than during 1994-1998 and was only 60% (110 g) of the 1994-1998 value (NEFSC 2003). In comparison, weekly increases in mean mantle length occurred more rapidly in 2004 than in 2003 (Fig. C5) and the weekly trends in mean body weight during 2003 resemble those from 1999-2002 while the 2004 trends are more similar to the trends observed for 1994-1998. During 2004, *Illex* mean body weights increased from 100 to 200 g between weeks 21 and 34 then declined thereafter (Fig. C6). The decline in mean body weight after week 34 may be due to recruitment, the annual offshore migration, or both factors.

4.0 RELATIVE ABUNDANCE AND BIOMASS INDICES

Research Surveys

Although there are no stock-wide indices of abundance or biomass for the *Illex* stock, several seasonal research surveys provide some information about local abundance trends on the USA

Shelf and the Scotian Shelf. The NEFSC spring bottom trawl survey occurs in March, prior to the USA fishery, but captures low densities of squid at few stations in comparison to the autumn survey because the spring survey occurs at a time when *Illex* are migrating onto the continental shelf (Hendrickson 2004). *Illex* are caught at 5-10% of the offshore stations sampled during spring surveys and at 30-80% of the offshore stations during autumn surveys (Fig. C7). The NEFSC autumn survey occurs when *Illex* are migrating off the shelf. The autumn survey indices can be considered as an index of spawner escapement because the survey occurs near the end of the fishing season. A portion of the *Illex* stock resides outside the range of the NEFSC surveys. The outer shelf and continental slope are important *Illex* habitats (Lange 1981) that are not intensively sampled during NEFSC bottom trawl surveys. In addition, the survey bottom trawl gear is not likely to sample pelagic species efficiently. Therefore, survey indices may represent the on-shelf availability of *Illex* rather than a measure of relative abundance or biomass. A Canadian bottom trawl survey occurs on the Scotian Shelf (NAFO Divisions 4VWX) during July. Since the Scotian Shelf survey occurs near the start of the directed fisheries, it can be considered as a pre-fishery relative abundance index for the area surveyed.

NEFSC survey procedures and details of the stratified random sampling design are provided in Azarovitz (1981). Standard survey tows in offshore strata 1-40 and 61-76 (Fig. C8) were used to compute relative abundance and biomass indices which were adjusted for differences in research vessel effects. A vessel conversion coefficient of 0.81 was applied to the *Delaware II* stratified mean weight per tow values, prior to computing the autumn survey indices, to standardize *Delaware II* catches to the *Albatross IV* catches (Hendrickson et al. 1996). Indices of relative abundance (stratified mean number per tow) and biomass (stratified mean weight per tow, in kg) from NEFSC autumn bottom trawl surveys, conducted during 1967-2004 are presented in Figure C9 and Table C6. Indices from NEFSC spring surveys, conducted during March, were also computed for the same strata set used to derive the autumn survey indices. Relative abundance and biomass indices from the Canadian bottom trawl survey, conducted on the Scotian Shelf (NAFO Division 4VWX) during July, are presented with the autumn survey indices for comparative purposes. All survey strata were used in the computations and the indices could not be standardized for gear and vessel changes that occurred in 1982, 1983 and 2004 due a lack of data from comparative fishing experiments (Hendrickson et al 2005).

As might be expected for a sub-annual species with environmental effects on availability and recruitment, all of the survey indices show a large degree of interannual variability. Autumn survey indices suggest that *Illex* relative abundance on the U.S. shelf was high during 1976-1981 and during 1987-1990 (Fig. C9). Autumn survey abundance indices were at or below the 1982-2003 average during 1991-1997. Abundance indices increased in 1998, but then declined to the second lowest level on record in 1999 (Table C6), following the high level of landings taken in 1998 (Table C1). During 1999-2002, abundance indices increased gradually during a period of low fishing effort (NEFSC 2003). Relative abundance reached the highest level on record in 2003 (28 squid per tow), then declined to below the 1982-2003 average in 2004, coincident with the highest landings on record for the U.S. stock component.

NEFSC spring survey indices are more variable than those from the autumn survey due to variability in the timing of *Illex* migrations onto the shelf in the spring. However, a notable trend is the spike in abundance and biomass indices that occurred during 1997 and 1998. Although this spike coincided with a 1998 spike in domestic landings, a similar spike in the spring abundance index did not occur in 2004, the year of the highest U.S. landings on record (Fig. C10A, Table C1). The 2005 spring survey index was very low and similar to the 2003 level.

The Canadian Scotian Shelf survey indices do not appear to track either the spring or autumn surveys of the USA Shelf. Similar to the NEFSC autumn survey indices, the Canadian survey indices also showed a peak in abundance and biomass during 1976, but not for an extended period of time (Figs. C10B and C10C). Based on an extended period of low *Illex* biomass in the July Scotian Shelf surveys and smaller than average body size (Fig. C11A), since 1982, the SA 3+4 component of the stock has been characterized as being in a low productivity regime (Hendrickson et al. 2005). The average body size of *Illex* caught in the NEFSC autumn surveys has also been much lower since 1982 and was below the 1982-2003 average during 2000-2004 (Fig. C11B). Average body size in the NEFSC spring survey was at or below the 1982-2003 average during 1995-2004 (Fig. C11C). These long-term observed difference in mean weights may be due to differing contributions of seasonal cohorts or differing growth conditions during these periods.

The migration of *Illex* squid into northern fishing areas off Newfoundland is affected by oceanographic conditions (Rowell et al. 1985; Dawe and Warren 1992; Dawe et. al. 1998). The autumn distribution of *Illex* on the U.S. shelf is also affected by water temperature conditions and bottom temperatures ranging from 9-13°C are preferred (Brodziak and Hendrickson 1999). The Mid-Atlantic Bight serves as important *Illex* habitat during spring through autumn (Hendrickson and Holmes 2004). Areal average surface and bottom temperature anomalies indicate that spring and autumn water temperatures in the Mid-Atlantic Bight have generally been warmer during 1982-2003 than during the reference period of 1977-1987 (Fig. C12) (Holzwarth and Mountain 1990; Holzwarth-Davis and Taylor 1992, 1993 and 1994; Taylor and Almgren 1996a and 1996b; Taylor and Kalidas 1997; Taylor and Bascunan 1998, 1999, 2000 and 2001; Taylor et. al. 2002). *Illex* relative abundance and biomass indices from the autumn surveys and spring average body weights, for 1982-2002, are significantly negatively correlated with bottom water temperature anomalies from the autumn surveys (NEFSC 2003). However, interpretation of these results is complicated because spring and autumn bottom water temperature anomalies are correlated so additional research on this topic is needed.

Depth transect surveys were conducted seasonally during 2003-2005 by Rutgers University with funding from the Research Set-aside Program of the Mid-Atlantic Fishery Management Council (MAFMC). Survey data were available for January (2004 and 2005), March (2003-2005), May (2003 and 2004) and November (2004). However, only the May data are relevant to the *Illex* stock because *Illex* does not consistently inhabit the U.S. Shelf during the other survey months (Black *et al.* 1987; Hendrickson 2004). *Illex* catch rates were examined from the May bottom trawl surveys, conducted along two transects located near Hudson and Baltimore Canyons, to determine what proportion of the survey catches occurred at depths beyond the limit of the majority of the NEFSC autumn survey stations (about 185 m). However, the data could not be used to evaluate *Illex* abundance by depth because declines in catch rates coincided with the depth beyond which sampling occurred at night (274 m), when *Illex* is distributed in the upper layer of the water column and not available to bottom trawl gear (Brodziak and Hendrickson 1999).

Fishery Catch per Unit of Effort Indices

The in-season pattern of CPUE reflects the balance of recruitment, fishing and natural mortality, and emigration from the fishing area (Caddy 1991). In Caddy's formulation, the boundaries between these processes are sharp and are assumed to induce point changes in the slope of log CPUE versus time. Implementation of an in-season depletion model would require an ability to detect such point changes in the CPUE trends. However, a declining trend in weekly LPUE data from the U.S. *Illex* fishery is not detectable in some years (NEFSC 1999). In order to better understand LPUE trends, spatial changes in fishing patterns were evaluated and the effects of various factors on the standardization of fishing effort were assessed. Since *Illex* discards for the U.S. fishery are low in comparison to *Illex* landings (refer to the above section on discards), LPUE is considered to be representative of CPUE.

Fishing Effort

Fishing effort in the *Illex* illecebrosus fishery is affected by catch values determined largely by the global squid market, particularly the Falklands squid fisheries, and the abundance of *Illex* on the U.S. Shelf. The *Illex* fishery is a volume-based fishery and effort patterns vary for the two fleet sectors involved in the directed fishery, refrigerated seawater system trawlers (RSW vessels) and freezer trawlers (FT vessels). The RSW vessels tend to be of smaller size than the freezer trawlers and store their catches in chilled seawater. Both factors result in shorter trips, generally less than four days, than those made by FT vessels (up to 14 days) which are larger and freeze their catches at sea. The home ports for FT vessels are North Kingston and Point Judith, Rhode Island and Cape May, New Jersey. Effort patterns for the RSW fleet are primarily determined by the travel distance between a shoreside processing facility and the offshore fishing grounds. The home port for most of the RSW vessels is Cape May, New Jersey, where there is a major *Illex* processing facility, but other home ports include Wanchese, North Carolina, Hampton Roads, Virginia and several Rhode Island ports (MAFMC 1998c).

The fleet size is small, generally less than 30 vessels, but the number of vessels participating in the fishery is highly variable from year-to-year. During 1999 and 2004, participation in the fishery was high (27-28 vessels) and during 2000-2003 participation was much lower (10-14 vessels, Fig. C13A). During 1999-2003, most of the annual landings (> 75%) were from freezer trawlers. However, in 2004, the proportion of annual landings for each fleet sector was nearly equal (Fig. C13B). This was primarily a result of an increased number of short duration trips (355 trips lasting 1.8 days on average) conducted by RSW vessels (Table C7, Fig. C13C).

Total nominal effort for both fleet sectors combined was twice as high in 2004 as in 2003, despite a shorter fishing season (five fewer weeks), and may have been higher if the fishery was not closed on September 21 (Table C7). In-season trends in weekly effort were different for the two fleet sectors during 2003 and 2004. During 2003, only three freezer trawlers fished for *Illex*, so the number of FT trips was fairly constant throughout the fishing season (Fig. C14A). The weekly trend in the number of days fished by FT vessels varied without trend in 2003 and was very erratic due to the duration (8.2 days on average) and timing of the trips which tend to start and end on the same day of the week (Fig. C14B). During 2004, twelve FT fished and the number of trips gradually increased throughout the fishing season until the fishery was closed (Fig. C14C). The number of days fished by FTs in 2004 increased between weeks 20-30 then varied without trend until the fishery closure (Fig. C14D). In contrast, weekly trends in the number of RSW trips was similar to weekly trends in the number of days fished, for 2003 and 2004, due to the short trip durations (1.8-2.8 days). During both years, a definite trend of increasing effort, which peaked at week 35, was followed by a decline. In 2003, a second rise and fall pattern was observed between weeks 37 the end of the RSW fishery (week 44). It was suggested at the Working Group meeting, that the decline in RSW effort (trips and days fished) which occurred three weeks prior to the fishery closure, during week 35, was a result of a unimplemented plan for an early-season closure of the Cap May processing facility.

A geographic information system (GIS) was used to examine the spatial distribution of effort in the *Illex* fishery, by quarter-degree square (QDSQ), during 2003 and 2004. The spatial distribution of fishing effort also varied by fleet sector. During 2003, freezer trawler effort was concentrated in several QDSQs, while RSW effort occurred across a broader area. In 2003, there was little spatial overlap between the most heavily fished QDSQs by the two fleet sectors (Fig. C15). For QDSQs that were consistently fished in 2003, the monthly effort pattern showed a rise and fall trend (Fig. C16). In contrast to 2003, fishing effort by both fleet sectors was concentrated off Cape May, New Jersey in 2004 (Fig. C17). Effort that occurred further south was primarily attributable to RSW vessels. In 2004, there was a high degree of spatial overlap between the most heavily-fished QDSQs of both fleet sectors. Within the three QDSQs with the highest effort concentrations, a monthly rise and fall pattern of effort is observed for the RSW vessels. FT effort was more constant throughout the season in QDSQs 38731 and 38733 (Fig. C18).

Trends in LPUE

As discussed in the Landings section, trends in weekly landings from the Weighout database closely matched those from the VTR database for 2003 and 2004. As a result, nominal LPUE was computed as the sum of the weekly effort (days fished) from the VTR Database divided by the sum of the weekly landings (mt) from the VTR Database. Weekly trends in nominal LPUE for RSW vessels showed a clear rise and fall pattern during 2003 and 2004, but weekly catch rates of FT vessels did not (Fig. C19). During 2003 (a year of low FT effort), FT catch rates showed several rise and fall periods with a peak during week 31, while RSW catch rates gradually increased during weeks 24-38, then declined thereafter. During 2004, RSW vessels began fishing one week earlier than FT vessels. RSW catch rates increased rapidly during weeks 20-23, then gradually increased between weeks 24 and 34. After week 34, but prior to closure of the fishery (week 38), there was a decline in RSW catch rates which occurred one week prior to the decline in the number of RSW trips and days fished (Fig. C14). FT catch rates reached a peak during the first few weeks of the fishery (week 22) then remained fairly constant during weeks 23-34. After week 34, FT catch rates also declined. However, it cannot be assumed that the decline in catch rates after week 34 were due to declining *Illex* abundance because of the confounding of reduced fishing effort during this time as a result of the proposed processing facility closure.

Spatial trends in nominal LPUE, for the entire *Illex* fleet, were very different between 2003 and 2004. High catch rates occurred across a larger area in 2004 than in 2003 and this may suggest much higher *Illex* abundance in 2004 (Fig. C20). Fairly high catch rates also occurred neat the shelf edge located off southern New England. During 2003, monthly catch rates were highest in July and were consistently high in southern areas (35º 30´ to 37º N), and (Fig. C21). During 2004, monthly catch rates were consistently high near the shelf edge off Cape May, and the area of high catch rates increased in size during July and August (Fig. C22). Fishing in the southern New England area occurred in August. A sequential rise and fall pattern in the combined catch rates of all vessels occurred in three different QDSQs during the 2003 fishing season, but it is unclear whether this represented localized depletion (Fig. C23A). During 2004, weekly trends in catch rates were similar for three FTs fishing in two different QDSQs (Fig. C24B) and the catch rates of several RSW vessels and a FT fishing within the same QDSQ all showed similar trends (Fig. C24C). These trends suggest that depletion may be possible within QDSQs during periods of high effort by both fleet sectors.

Standardization of the effort used to compute LPUE was conducted in order to determine whether this would improve the ability to detect a declining trend in weekly catch rates. A three-factor, main effects General Linear Model (GLM) was applied to log-transformed LPUE data (mt per day fished) for 2003 and 2004. LPUE was computed using the VTR landings for 2003. The WO landings were used to compute LPUE for 2004 because weekly landings data presented during the Working Group meeting suggested underreporting of VTR landings for 2004. For 2004, the VTR and WO data were matched by hull number, month and day (using the date sold field) and the VTR landings were replaced with the WO landings. This matched data set accounted for 72% of the WO landings. The trips that did not match were prorated to week of the year and QDSQ based on the ratios of the matched trips. The proration accounted for an additional 16% of the WO landings. The remainder of the trips could not be used because they had missing effort values, QDSQs, or both. As in previous assessments, directed trips used in the GLM were defined as otter trawl trips that occurred during May through November and that landed at least 25%, by weight, of *Illex*. Factors included in the GLM included: week of the year, quarter-degree, and either vessel type (RSW or freezer trawler) or hull number. Final model runs included the factors: vessel type, quarter-degree square and week of the year (Table C8 and C9). A summary of the various GLM runs is presented in Table C10. For the final 2004 models run, all three model effects were highly significant ($p < 0.0001$), but the influence of spatial effects (quarter-degree square) on LPUE was not significant in 2003. Weekly standardized fishing effort was highly variable in 2003 (Fig. C24A) and standardized LPUE did not show a rise and fall trend. Standardized effort for 2004 indicated an increasing trend which reached a peak in week 35 then declined (Fig. C24B). Nominal LPUE showed a similar trend (Fig. C25A), but the trend was removed when LPUE was computed using standardized effort (Fig. C25B).

5.0 ESTIMATION OF NATURAL MORTALITY

Maturation-Natural Mortality Model

(EDITOR'S NOTE: THIS PART OF THE WORKING GROUP REPORT REFERS TO APPENDIX C3 WHICH HAS BEEN OMITTED. REFER TO HENDRICKSON AND HART [2006], FOR MODEL RESULTS).

Based on a review of the model results, the Working Group decided that the estimates of natural mortality were preliminary. They acknowledged that the model formulation was sound and appropriate given the semelparous life history of the species, but that natural mortality estimates may vary during the fishing season because growth rates increase seasonally for squid from the northern stock component (Dawe and Beck 1997). The Working Group recommended that new data on growth and maturity be obtained for inclusion in future model runs.

6.0 BIOLOGICAL REFERENCE POINTS

The Amendment 8 control rule states that when the stock biomass exceeds B_{MSY}, the overfishing threshold is F_{MSY}, and target F is 75% of F_{MSY}. Below B_{MSY}, target F decreases linearly and is set to zero when stock size is at the biomass threshold of ½B_{MSY}. Amendment 8 specifies B_{MSY} as 39,300 mt and F_{MSY} as 1.22 per year.

Reference points that minimize the risk of recruitment overfishing, by ensuring that escapement exceeds a threshold minimum spawning stock biomass or number of eggs per recruit, have been considered to be the most appropriate for annual squid stocks that exhibit highly variable trends in interannual recruitment (Beddington et al. 1990). The current MSY-based biological reference points were based on a biomass dynamics model which estimated MSY at 24, 274 mt (NEFSC 1996). However, bootstrap analyses indicated poor precision of *r*, *q* and *K* estimates and the model assumption of constant natural mortality rate is invalid for *I. illecebrosus*. Given these considerations, %MSP-based proxies for MSY-based reference points are recommended. Further, the source of the reference point proxies should be derived from a model that accounts for the semelparous life history of *Illex*.

Yield-per-recruit and egg-per-recruit models

A semelparous life history model was derived to estimate yield-per-recruit (YPR) and the number of eggs-per-recruit (EPR) for a cohort of female squid as a function of fishing mortality (Hendrickson and Hart 2006). Consistent with the maturation-mortality model, the YPR and EPR models track females in two bins: the number of immature females, N_t, and the number of mature females, S_t. At each weekly time step, immature individuals have four possible fates: (1) death due to either non-spawning natural mortality, M_{NS}, (e.g., from predation, which is assumed to occur at a constant rate) or (2) death due to fishing mortality (calculated as $F_t = F\theta_t$, where θ_t is the fishery selectivity of the individuals of age t weeks); (3) survival to the next week either as an immature individual; or (4) survive and mature at rate P_t.

Biological reference point estimates derived from the egg-per-recruit and yield-per-recruit models were presented. However, the potential reference point proxies estimated using the EPR model were considered preliminary by the SARC 42 Working Group because they included estimates of natural mortality that were considered preliminary. In addition, seasonal changes in growth rates are likely for this species and this will affect the reference point estimates (Figure C26). Therefore, seasonal growth rate data are required to test the sensitivity of the per-recruit models to growth rates.

(EDITOR'S NOTE: THIS PART OF THE WORKING GROUP REPORT REFERS TO APPENDIX C4 WHICH HAS BEEN OMITTED) (see Hendrickson and Hart 2006).

7.0 STOCK SIZE AND FISHING MORTALITY RATES

In-season Assessment Model

The short life cycles, rapid growth rates, highly variable population abundance, high natural mortality rates and semelparous breeding strategies of most cephalopod species render many of the traditional annual-based approaches to stock assessment inappropriate (Caddy 1983). This is certainly the case for the *I. illecebrosus* stock, for which biomass dynamics models provide very imprecise estimates of stock size and fishing mortality rates (NEFSC 1996; Hendrickson et. al. 1996) which is likely attributable to the fact that cephalopod population dynamics do not conform to the underlying model assumptions (Pierce and Guerra 1994). Assessment of the *Illex* stock is hindered by the lack of research survey biomass and abundance indices for the USA stock component and the stock as a whole. Annual-based modeling approaches are inappropriate for a species with a lifespan of less than one year.

Within-season depletion models have been found to offer the most promise for assessing ommastrephid and loliginid squid stocks (Anon. 1999; Pierce and Guerra 1994) and have been used since 1987 to assess the Falkland Islands stocks of *Illex argentinus* and *Loligo gahi* (Rosenberg et. al. 1990; Agnew et al. 1998). Depletion estimation requires data consisting of: total catch, mean body weights, an abundance index (e.g., CPUE), a recruitment index proportional to the number of recruits, and an estimate of natural mortality. In addition, these data must be of appropriate temporal and spatial resolution, tow-based, and available throughout the fishing season.

During the previous *Illex* assessment at SARC 37 (NEFSC 2003), the in-season assessment model developed for SARC 29 (NEFSC 1999) was revised to include a recruitment index and an objective function. The model, which estimates weekly fishing mortality rates and initial stock size, was run using tow-based catch, effort and fishing location data instead of VTR data. During the current assessment, the SARC 37 model was further revised to allow for the possibility of fitting one of the maturity ogive parameters, α, together with F_{TOT} and N_0.

Both Working Groups felt that the SARC 42 model formulation (Appendix C5) was sound but that the model results should not be used to update fishing mortality and stock size estimates because:

1. A major model uncertainty is the use of a May growth curve which underestimates growth later in the fishing season. Despite scaling up the asymptotic length by using a percentile of the observed lengths from the fishery data, empirical length-at-age data must be collected and analyzed to determine seasonal changes in growth rate

2. The method of computing the weekly recruitment indices requires further investigation

3. Sensitivity analyses for various values of initial stock size, using 1999 and 2003 data, indicated that a broad range of N_0 and F_{TOT} values were plausible, suggesting a flat estimation surface. The Working Group felt that additional simulation testing would be beneficial in understanding how varying the model parameters affect the model results.

8.0 CONCLUSIONS

Abundance and biomass indices

Seasonal bottom trawl surveys of the USA shelf do not cover the geographic distribution of the USA stock component. *Illex* inhabit areas outside the range of the USA surveys based on data from other research surveys and fisheries data. The USA autumn survey may serve as an index of spawner escapement but for a cohort other than that which is fished at the start of the *Illex* fishing season. Furthermore, it is unknown whether autumn survey trends are due to low abundance, low availability or both. The relative abundance index for the US autumn survey was the highest on record in 2003 and very low in 2004 following the highest landings on record. Further research is needed to determine the association between fishery catch rates and *Illex* abundance.

Fishery Characteristics

Body size is likely related to productivity. *Illex* landed during 2004 were larger in size than those landed during most years since 1994. The number of vessels and trips that occurred in 2004 were much higher than any year since 2000 and landings reached a record high of 26,087 mt, which exceeded the quota and resulted in an early closure of the fishery. Landings and effort in 2003 were much lower than in 2004 and body size (an indicator of productivity) was also smaller, similar to the trends for 1999-2002. Preliminary U.S. fishery landings for 2005 are 11, 429 mt.

Estimation of fishing mortality and stock size

The in-season model estimates of fishing mortality and stock size were not considered reliable because new data on seasonal growth rates and maturity are required for the model. Use of the May growth curve underestimates growth later in the season.

Stock status

Stock status cannot be determined because adequate data are not available to estimate fishing mortality rates and absolute stock size.

9.0 RESEARCH RECOMMENDATIONS PAST AND PRESENT

The status of research recommendations from the previous *Illex* assessment, conducted at SARC 37, is presented in Table C11. Based on reviews of the current assessment, it was concluded at both Subcommittee meetings that the most important research recommendation involves the collection and analysis of seasonal age and maturity. Without these data, assessment of the stock using the models contained herein will not be possible. In order of priority, specific research recommendations from the current assessment are as follows:

1. All of the models presented require additional data collection. Maturity and age data should be collected throughout the fishing season to evaluate the effects of differential growth and maturity within seasons and between years. Emphasis should be placed on the

collection of weekly data. The in-season model would be improved with tow-based catch, effort and fishing location data, particularly if collected electronically in real-time.

2. Re-estimate M_{ns} and M_{sp} for females from each seasonal cohort and determine whether M_{ns} and M_{sp} estimates for males are similar to those of females.

3. Re-estimate biological reference points for each seasonal cohort by incorporating seasonal information regarding growth, selectivity, and natural mortality.

4. The in-season assessment model results show a high sensitivity to parameters such as growth and recruitment, so additional simulation analyses are needed to determine the range of possible responses by the model. The simulation analyses should reflect the actual reality of the fishery and data input/output (such as fishery length frequencies for estimating partial recruitment). Length data rather than age data should be utilized in the simulation model so that the simulation formulation is identical to that used in the in-season model.

5. Further exploration of relationships between oceanographic conditions and abundance and body size of squid on the US Shelf is needed to determine whether a pre-season predictor variable for abundance or stock productivity can be found.

6. It is important to know what fraction of the stock inhabits waters deeper than 185 m, particularly during May and in the fall. Seasonal transect surveys are conducted by Rutgers University with Mid-Atlantic research funds in order to monitor the seasonal depth distribution of Mid-Atlantic species. Although *Illex* is not a “target” species, abundance and length frequency data are collected. However *Illex* abundance by depth could not be determined from these surveys because diel migration patterns were confounded with the sampling protocol. Therefore, it would be useful to conduct some adaptive or fixed stations for determining *Illex* abundance and length composition, during daylight hours, at depths beyond 185 m during May and in the fall.

7. A pre-fishery, stratified random survey would be useful to estimate initial stock size.

8. Evaluate the utility of relative abundance and biomass indices from the NEFSC winter survey.

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11.0 REFERENCES

Agnew, D.J., J.R. Beddington, R. Baranowski, S. des Clers, and C.P. Nolan. 1998. Approaches to assessing stocks of *Loligo gahi* around the Falkland Islands. Fish. Res. 35: 155-169.

Anonymous. 1999. Report of the working group on cephalopod fisheries and life history. ICES CM 1999/G:4.

Applegate, A, S. Cadrin, J. Hoenig, C. Moore, S. Murawski and E. Pikitch. 1998. Evaluation of existing overfishing definitions and recommendations for new overfishing definitions to comply with the Sustainable Fisheries Act. Final Report. 179 p.

ASMFC [Atlantic States Marine Fisheries Commission]. 1994. Assessment report for Gulf of Maine northern shrimp, 1994.

Azarovitz, T.R. 1981. A brief historical review of the Woods Hole Laboratory trawl survey time series. In: Doubleday, W.G. and Rivard, D. (Eds.) Bottom trawl surveys. *Canadian Special Publication of Fisheries and Aquatic Sciences* 58, p. 62-67.

Basson, M., J.R. Beddington, J.A. Crombie, S.J. Holden, L.V. Purchase and G.A. Tingely. 1996. Assessment and management techniques for migratory annual squid stocks: the *Illex argentinus* fishery in the southwest Atlantic as an example. Fish. Res., 28:3-27.

Beddington, J.R., A.A. Rosenberg., J.A. Crombie and G.P. Kirkwood. 1990. Stock assessment and the provision of management advice for the short fin squid fishery in Falkland Island waters. Fish. Res., 8:351-365.

Black, G.A.P., T.W. Rowell, and E.G. Dawe. 1987. Atlas of the biology and distribution of the squids *Illex illecebrosus* and *Loligo pealei* in the Northwest Atlantic. Can. Spec. Publ. Fish. Aquat. Sci. 100: 62 p.

Brodziak, J. and L.C. Hendrickson. 1999. An analysis of environmental effects on survey catches of squids, *Loligo pealei* and *Illex illecebrosus,* in the Northwest Atlantic. Fish. Bull. 97:9-24.

Caddy, J. F. 1983. The cephalopods: factors relevant to their population dynamics and to the assessment and management of stocks. In J. F. Caddy, Ed. Advances in assessment of world cephalopod resources, p. 416-452. FAO Fish. Tech. Pap. No. 231. Rome.

Caddy, J. F. 1991. Daily rings on squid statoliths: an opportunity to test standard population models? *In*: Jereb, P.S., S. Ragonese, and S. von Boletzky. (Eds.) *Squid age determination using statoliths*. Proceedings of the International Workshop held in the Istituto di Tecnologia della Pesca e del Pescato (ITPP-CNR), Mazara del Vallo, Italy, 9-14 October, 1989. N.T.R.-I.T.P.P. Special Publication No. 1, pp. 53-66.

Coelho M.L. and R.K. O'Dor. 1993. Maturation, spawning patterns and mean size at maturity in the short-finned squid *Illex illecebrosus*. p. 81-91. *In:* Okutani T., O'Dor R.K. and

Kubodera T. (eds.) *Recent Advances in Cephalopod Fisheries Biology*. Takai University Press, Tokyo, XV + 752 p.

Dawe, E.G. 2003. Personal communication. Department of Fisheries and Oceans. St. John's, Newfoundland.

Dawe, E.G. and W. Warren. 1992. Recruitment of short-finned squid in the Northwest Atlantic Ocean and some environmental relationships. J. Ceph. Biol. 2(2): 1-21.

Dawe, E.G., and P.C. Beck. 1997. Population structure, growth and sexual maturation of short-finned squid (*Illex illecebrosus*) at Newfoundland. Can. J. Fish. Aquat. Sci., 54: 137-146.

Dawe, E.G., and L. C. Hendrickson. 1998. A review of the biology, population dynamics, and exploitation of short-finned squid in the Northwest Atlantic Ocean in relation to the assessment and management of the resource. NAFO SCR. Doc. 98/59, Ser. No. N3051.

Dawe, E.G., R.K. O'Dor, P.H. Odense, and G.V. Hurley. 1985. Validation and application of an ageing technique for short-finned squid (*Illex illecebrosus*). J. Northw. Atl. Fish. Sci. 6:107-116.

Dawe, E.G., E.B. Colburne and K.F. Drinkwater. 1998. Environmental regulation on short-finned squid recruitment to Canadian fishing areas. NAFO SCR Doc. 98/54, Ser. N3045.

Durward, R.D., T. Amaratunga and R.K. O'Dor. 1979. Maturation index and fecundity for female squid, *Illex illecebrosus* (LeSueur, 1821). ICNAF Res. Bull. 14: 67-72.

Forsythe, J.W. and W.F. van Heukelem. 1987. Growth. *In*: P. R. Boyle (Ed.) *Cephalopod Life Cycles, Vol. II.* Acad. Press Inc. (London) Ltd. pp 135-156.

Goodwin, Glenn. 1999. Personal Communication. Captain of F/V *Relentless*. Davisville, RI.

Hendrickson, L.C. 2004. Population biology of northern shortfin squid (*Illex illecebrosus*) in the northwest Atlantic Ocean and initial documentation of a spawning site in the Mid-Atlantic Bight (USA). ICES J. Mar. Sci. 61: 252-266.

Hendrickson, L.C. and D. R. Hart. 2006. An age-based cohort model for estimating the spawning mortality of semelparous cephalopods with an application to per-recruit calculations for the northern shortfin squid, *Illex illecebrosus.* Fish. Res. 78: 4-13.

Hendrickson, L. C. and E. M. Holmes. 2004. Essential fish habitat source document: northern shortfin squid, *Illex illecebrosus*, life history and habitat characteristics, Second Edition. NOAA Tech. Memo. NMFS-NE-191. 36 p.

Hendrickson, L.C., J. Brodziak, M. Basson, and P. Rago. 1996. Stock assessment of northern shortfin squid, *Illex illecebrosus*, in the Northwest Atlantic during 1993. Northeast Fish. Sci. Cent. Ref. Doc. 96-05g; 63 p.

Hendrickson, L.C., E.G. Dawe and M.A. Showell. 2004. Assessment of northern shortfin squid (*Illex illecebrosus*) in Subareas 3+4 for 2003. NAFO SCR Doc. 04/38. Ser. No. N4989. 18 p.

Hendrickson, L.C., E.G. Dawe and M.A. Showell. 2005. Interim monitoring report for the assessment of northern shortfin squid (*Illex illecebrosus*) in Subareas 3+4 during 2004. NAFO SCR Doc. 05/45. Ser. No. N5131. 9 p.

Hendrickson, L.C., D.A. Hiltz, H.M. McBride, B.M. North and J.E. Palmer. 2003. Implementation of electronic logbook reporting in a squid bottom trawl study fleet during 2002. Northeast Fish. Sci. Cent. Ref. Doc. 03-07; 30 p.

Holzwarth, T.J. and D. Mountain. 1990. Surface and Bottom Temperature Distributions from the Northeast Fisheries Center Spring and Fall Bottom Trawl Survey Program, 1963-1987. Northeast Fish. Sci. Cent. Ref. Doc. 90-03.

Holzwarth-Davis, T.J. and M. Taylor. 1992. Description of the 1991 Oceanographic Conditions on the Northeast Continental Shelf. Northeast Fish. Sci. Cent. Ref. Doc.92-08.

Holzwarth-Davis, T.J. and M. Taylor. 1993. Description of the 1992 Oceanographic Conditions on the Northeast Continental Shelf. Northeast Fish. Sci. Cent. Ref. Doc.93-25.

Holzwarth-Davis, T.J. and M. Taylor. 1994. Description of the 1993 Oceanographic Conditions on the Northeast Continental Shelf. Northeast Fish. Sci. Cent. Ref. Doc. 94-11.

Hurley, G.V., P. Odense, R.K. O'Dor and E.G. Dawe. 1985. Strontium labelling for verifying daily growth increments in the statoliths of the short-finned squid (*Illex illecebrosus*). Can. J. Fish. Aquat. Sci. 42:380-383.

Jossi, J.W. and R. L. Benway. 2003. Variability of temperature and salinity in the Middle Atlantic Bight and Gulf of Maine based on data collected as part of the MARMAP Ships of Opportunity Program, 1978-2001. NOAA Tech. Memo. NMFS-NE-172.

Laptikhovsky, V. V. and C. M. Nigmatullin. 1993. Egg size, fecundity and spawning in females of the genus *Illex* (Cephaloppoda: Ommastrephidae). ICES J. Mar Sci. 50:393-403.

Lange, A. M. T. 1981. Yield-per-recruit analyses for squid*, Loligo pealei* and *Illex illecebrosus*, from the Northwest Atlantic. J. Shell. Res. 1(1): 197-207.

Lange, A.M.T., and M.P. Sissenwine. 1980. Biological considerations relevant to the management of squid *Loligo pealei* and *Illex illecebrosus* of theNorthwest Atlantic. Mar. Fish. Rev. 42(7-8):23-38.

Lange, A.M.T., M.C. Ingham and C.A. Price. 1984. Distribution of maturing *Illex illecebrosus* relative to the shelf-slope front of the northeastern United States. NAFO SCR Doc. 84/IX/109, Ser. No. N906. 18 p.

Mercer, M.C. 1973. Sexual maturity and sex ratios of the ommastrephid squid *Illex illecebrosus* (LeSueur) at Newfoundland (Subarea 3). ICNAF Res. Doc. 73/71, Ser. No. 3024. 14 p.

Mid-Atlantic Fishery Management Council. 1994. Optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing for Atlantic Mackerel, *Loligo*, *Illex*, and Butterfish for 1995.

Mid-Atlantic Fishery Management Council. 1995a. Optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing for Atlantic Mackerel, *Loligo*, *Illex*, and Butterfish for 1996.

Mid-Atlantic Fishery Management Council. 1995b. Amendment 5 to the Fishery Management Plan and the Final Environmental Impact Statement for the Atlantic Mackerel, Squid and Butterfish Fisheries. 168 p.

Mid-Atlantic Fishery Management Council. 1996a. Optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing for Atlantic Mackerel, *Loligo*, *Illex*, and Butterfish for 1997.

Mid-Atlantic Fishery Management Council. 1996b. Resubmitted portion of Amendment 5 to the Fishery Management Plan for the Atlantic Mackerel, Squid and Butterfish Fisheries. 38 p.

Mid-Atlantic Fishery Management Council. 1996c. Amendment 6 to the Fishery Management Plan for the Atlantic Mackerel, Squid and Butterfish Fisheries. 17 p. + Appendices.

Mid-Atlantic Fishery Management Council. 1997a. Optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing for Atlantic Mackerel, *Loligo*, *Illex*, and Butterfish for 1998.

Mid-Atlantic Fishery Management Council. 1998a. Optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing for Atlantic Mackerel, *Loligo*, *Illex*, and Butterfish for 1999.

Mid-Atlantic Fishery Management Council. 1998b. Amendment 7 to the Fishery Management Plan for the Atlantic Mackerel, Squid and Butterfish Fisheries. 33 p. + Appendices.

Mid-Atlantic Fishery Management Council. 1998c. Amendment 8 to the Fishery Management Plan for the Atlantic Mackerel, Squid and Butterfish Fisheries. 351 p. + Appendices.

Mid-Atlantic Fishery Management Council. 2000. Optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing for Atlantic Mackerel, *Loligo*, *Illex*, and Butterfish for 2001.

Mid-Atlantic Fishery Management Council. 2001. Optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing for Atlantic Mackerel, Squid and Butterfish for 2002.

Mid-Atlantic Fishery Management Council. 2002. Optimum yield, domestic annual harvest, domestic annual processing, joint venture processing, and total allowable level of foreign fishing for Atlantic Mackerel, Squid and Butterfish for 2003.

NAFO [Northwest Atlantic Fisheries Organization] 1980. Canadian proposal for international regulation of the fisheries for squid (*Illex*) in Subareas 3 and 4 of the Convention Area. NAFO Fisheries Commission Document 80/III/4, Ser. No. N085.

NAFO [Northwest Atlantic Fisheries Organization]. 1995. Scientific Council Reports, 1994. pp. 116-117.

NAFO [Northwest Atlantic Fisheries Organization]. 1999. Scientific Council Reports, 1998. 257 p.

NAFO [Northwest Atlantic Fisheries Organization]. 2000. Scientific Council Reports, 1999. 303 p.

NEFC. 1990. Report of the Spring 1990 NEFC Stock Assessment Workshop (Tenth SAW). NOAA\NMFS\NEFC: Woods Hole, MA. NEFC [Northeast Fisheries Center] Ref. Doc. 90-07.

Northeast Fisheries Science Center (NEFSC). 1991. Report of the Twelfth Northeast Regional Stock Assessment Workshop, Spring, 1991. NOAA\NMFS\NEFC: Woods Hole, MA. NEFSC Ref. Doc. 91-03.

Northeast Fisheries Science Center (NEFSC). 1992. Report of the Fourteenth Northeast Regional Stock Assessment Workshop: Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NOAA\NMFS\NEFC: Woods Hole, MA. NEFSC Ref. Doc. 92-07. 140 p.

Northeast Fisheries Science Center (NEFSC). 1994. Report of the Seventeenth Northeast Regional Stock Assessment Workshop: Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NOAA/NMFS/NEFSC: Woods Hole, MA. NEFSC Ref. Doc. 94-06. 124 p.

Northeast Fisheries Science Center (NEFSC). 1996. Report of the 21st Northeast Regional Stock Assessment Workshop (21st SAW): Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NEFSC Ref. Doc. 96-05d. 200 p.

Northeast Fisheries Science Center (NEFSC). 1999. Report of the 29th Northeast Regional Stock Assessment Workshop (29th SAW): Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NEFSC Ref. Doc. 99-14. 347 p.

Northeast Fisheries Science Center (NEFSC). 2003. Report of the 37th Northeast Regional Stock Assessment Workshop (37th SAW): Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NEFSC Ref. Doc. 03-16. 597 p.

O'Dor R.K. and Coelho M.L. 1993. Big squid, big currents and big fisheries. p. 385-396. *In:* Okutani T., O'Dor R.K. & Kubodera T. (Eds.) *Recent Advances in Cephalopod Fisheries Biology*. Takai University Press, Tokyo, XV + 752 p.

O'Dor, R.K. and E.G. Dawe. 1998. Chapter 4. *Illex illecebrosus. In:* P.G. Rodhouse, E.G. Dawe, and R.K. O'Dor (Eds.). Squid recruitment dynamics: the genus *Illex* as a model, the commercial *Illex* species and influences of variability. FAO Fish. Tech. Paper 376.

Pierce, G.J. & Guerra, A., 1994. Stock assessment methods used for cephalopod fisheries. Fish. Res. 21: 255-285.

Prager, M. 1994. A suite of extensions to a non-equilibrium surplus-production model. Fish. Bull. 92:374-389.

Rivard, D., L. C. Hendrickson and F. M. Serchuk. 1998. Yield estimates for short-finned squid (*Illex illecebrosus*) in SA 3-4 from research vessel survey relative biomass indices. NAFO SCR Doc. 98/75.

Rosenberg, A.A., Kirkwood, G.P., Crombie, J. and Beddington, J.R. 1990. The assessment of stocks of annual squid species. Fish. Res. 8:335-350.

Showell, M. 1999. Personal communication. Department of Fisheries and Oceans. Bedford Institute of Oceanography. Halifax, NS.

Rowell T.W., Trites R.W. and Dawe E.G. 1985. Distribution of short-finned squid larvae and juveniles in relation to the Gulf Stream Frontal Zone between Florida and Cape Hatteras. NAFO Sci. Coun. Studies 9: 77-92.

Taylor, M.H. and D.W. Almgren. 1996a. Description of the 1994 Oceanographic Conditions on the Northeast Continental Shelf. Northeast Fish. Sci. Cent. Ref. Doc. 96-07.

Taylor, M.H. and D.W. Almgren. 1996b. Description of the 1995 Oceanographic Conditions on the Northeast Continental Shelf. Northeast Fish. Sci. Cent. Ref. Doc. 96-11.

Taylor, M.H. and M.E. Kiladis. 1997. Description of the 1996 Oceanographic Conditions on the Northeast Continental Shelf. Northeast Fish. Sci. Cent. Ref. Doc. 97-16.

Taylor, M.H. and C. Bascunan. 1998. Description of the 1997 Oceanographic Conditions on the Northeast Continental Shelf. Northeast Fish. Sci. Cent. Ref. Doc. 98-01.

Taylor, M.H. and C. Bascunan. 1999. Description of the 1998 Oceanographic Conditions on the Northeast Continental Shelf. Northeast Fish. Sci. Cent. Ref. Doc. 99-01.

Taylor, M.H. and C. Bascunan. 2000. Description of the 1999 Oceanographic Conditions on the Northeast Continental Shelf. Northeast Fish. Sci. Cent. Ref. Doc. 00-01.

Taylor, M.H and C. Bascunan. 2001. Description of the 2000 Oceanographic Conditions on the Northeast Continental Shelf. Northeast Fish. Sci. Cent. Ref. Doc. 01-01.

Taylor, M.H., C. Bascunan and J.P. Manning. 2002. Description of the 2001 Oceanographic Conditions on the Northeast Continental Shelf. Northeast Fish. Sci. Cent. Ref. Doc. 02-08.

Trites R.W. 1983. Physical oceanographic features and processes relevant to *Illex illecebrosus* spawning in the western North Atlantic and subsequent larval distribution, NAFO Sci. Studies 6:39-55.

ILLEX TABLES:

Table C1. *Illex illecebrosus* landings (mt) in NAFO Subareas 5+6 (U.S. EEZ) and Subareas 3 and 4 during 1963-2005 [1,2,3,4,5,6] and total allowable catches (TACs).

	Cape Hatteras to the Gulf of Maine (Subareas 5+6)			Subareas (3+4)	All Subareas (3-6)	TAC (000's mt)		
						3+4	5+6	
Year	Domestic (mt)	Foreign (mt)	Total (mt)	Total (mt)	Total (mt)			Percent US Landings
1963	810		810	2,222	3,032			
1964	358	2	360	10,777	11,137			
1965	444	78	522	8,264	8,786			
1966	452	118	570	5,218	5,788			
1967	707	288	995	7,033	8,028			
1968	678	2,593	3,271	56	3,327			
1969	562	975	1,537	86	1,623			
1970	408	2,418	2,826	1,385	4,211			
1971	455	6,159	6,614	8,906	15,520			
1972	472	17,169	17,641	1,868	19,509			
1973	530	18,625	19,155	9,877	29,032			
1974	148	20,480	20,628	437	21,065		71	98
1975	107	17,819	17,926	17,696	35,622	25	71	50
1976	229	24,707	24,936	41,767	66,703	25	30	37
1977	1,024	23,771	24,795	83,480	108,275	25	35	23
1978	385	17,207	17,592	94,064	111,656	100	30	16
1979	1,493	15,748	17,241	162,092	179,333	120	30	10
1980	299	17,529	17,828	69,606	87,434	150	30	20
1981	615	14,956	15,571	32,862	48,433	150	30	32
1982	5,871	12,762	18,633	12,908	31,541	150	30	59
1983	9,775	1,809	11,584	426	12,010	150	30	96
1984	9,343	576	9,919	715	10,634	150	30	93
1985	5,033	1,082	6,115	673	6,788	150	30	90
1986	6,493	977	7,470	111	7,581	150	30	99
1987	10,102	0	10,102	562	10,664	150	30	95
1988	1,958	0	1,958	811	2,769	150	30	71
1989	6,801	0	6,801	5,971	12,772	150	30	53
1990	11,670	0	11,670	10,975	22,645	150	30	52
1991	11,908	0	11,908	2,913	14,821	150	30	80
1992	17,827	0	17,827	1,578	19,405	150	30	92
1993	18,012	0	18,012	2,686	20,698	150	30	87
1994	18,350	0	18,350	5,951	24,301	150	30	76
1995	14,058	0	14,058	1,055	15,113	150	30	93
1996	16,969	0	16,969	8,742	25,711	150	21	66
1997	13,629	0	13,629	15,614	29,243	150	19	47
1998	23,597	0	23,597	1,902	25,499	150	19	93
1999	7,388	0	7,388	305	7,693	75	19	96
2000	9,011	0	9,011	366	9,377	34	24	96
2001	4,009	0	4,009	57	4,066	34	24	99
2002	2,750	0	2,750	258	3,008	34	24	91

Table C1. cont.

	Cape Hatteras to the Gulf of Maine (Subareas 5+6)			Subareas (3+4)	All Subareas (3-6)	TAC (mt)		
Year	Domestic (mt)	Foreign (mt)	Total (mt)	Total (mt)	Total (mt)	3+4	5+6	Percent US Landings
2003	6,389	0	6,389	1,128	7,517	34	24	85
2004	26,087	0	26,087	2,034	28,121	34	24	93
2005	11,429	0	11,429	Not available	11,429	34	24	
Averages								
1976-1981	674	18,986	19,661	80,645	100,306			
1982-1987	7,770	2,868	10,637	2,566	13,203			
1988-1993	11,363	0	11,363	4,156	15,518			
1994-1999	15,665	0	15,665	5,595	21,260			
2000-2003	5,540	0	5,540	452	5,992			

[1] Landings during 1963-1978 were not reported by species, but are proration-based estimates by Lange and Sissenwine (1980)

[2] Landings during 1979-2003 are from the NEFSC Weighout Database

[3] Domestic landings during 1982-1991 include Joint-Venture landings

[4] Includes landings from Subarea 2

[5] Landings during 2004 are preliminary for all Subareas; USA landings were reported electronically by dealers during April 2004-2005

[6] Landings for 2005 include preliminary dealer reports as of 11/2/2005

Table C2. Landings (mt) of *Illex illecebrosus* recorded in the Weighout Database, by gear type, during 1998-2004.

Year	Bottom Trawl	Other[1] and Unknown	Midwater Pair Trawl	Total	Percent Bottom Trawl
1998	23,567.6	0.5		23,568	100.00
1999	7,387.4	1.2		7,389	99.98
2000	9,011.2	0.1		9,011	100.00
2001	4,008.6	0.0		4,009	100.00
2002	2,724.4	0.0	25.1	2,750	99.09
2003	6,364.4	0.1	26.9	6,391	99.58
2004	25,483.1	546.6		26,030	97.90

[1] As of April 2004, gear type data were reported by dealers

Table C3. Estimates of kept weight (mt), discarded weight (mt) and discard ratios (discard/kept weight) of *Illex illecebrosus* sampled in the *Illex* fishery, by observers from the NEFSC Observer Program, during 1995-2004. *Illex* trips were defined as trips where *Illex* landings were ≥ 25%, by weight, of the total trip landings. Total discard estimates are the product of discard ratios and total *Illex* andings, for *Illex* trips in the Weighout database, for all months sampled.

	May	**June**	**July**	**Aug**	**Sept**	**Oct**	**Total**
1995							
Trips	0	0	0	0	1	1	2
Total Kept (mt)					0.902	0.113	1.015
Total Discards (mt)					0.007	0.023	0.030
Ratio discard/kept					0.008	0.204	0.030
Total Landings (mt)					1,263.819	905.822	2,169.641
Total Discards (mt)					9.808	184.371	64.127
1996							
Trips	0	4	3	6	1	1	15
Total Kept (mt)		112.696	236.297	182.447	136.617	166.106	834.163
Total Discards (mt)		0.769	3.499	0.045	0.163	0.000	4.476
Ratio discard/kept		0.007	0.015	0.000	0.001	0.000	0.005
Total Landings (mt)		3,817.659	2,736.593	3,787.278	2,455.642	2,436.032	15,233.204
Total Discards (mt)		26.050	40.522	0.936	2.930	0.000	81.741
1997							
Trips	0	0	7	3	0	0	10
Total Kept (mt)			773.388	343.904			1,117.292
Total Discards (mt)			1.941	5.286			7.227
Ratio discard/kept			0.003	0.015			0.006
Total Landings (mt)			5,077.722	3,600.592			8,678.314
Total Discards (mt)			12.744	55.343			56.134

Table C3. cont.

	May	June	July	Aug	Sept	Oct	Total
1998							
Trips	0	0	2	2	0	0	4
Total Kept (mt)			106.141	48.761			154.902
Total Discards (mt)			1.656	0.000			1.656
Ratio discard/kept			0.016	0.000			0.011
Total Landings (mt)			7,526.991	6,501.153			14,028.144
Total Discards (mt)			117.435	0.000			149.970
1999							
Trips	0	0	1	2	1	0	4
Total Kept (mt)			26.218	50.723	14.011		90.952
Total Discards (mt)			0.000	0.907	0.068		0.975
Ratio discard/kept			0.000	0.018	0.005		0.011
Total Landings (mt)			2,249.614	2,550.402	596.029		5,396.045
Total Discards (mt)			0.000	45.605	2.893		57.845
2000							
Trips	0	2	4	7	0	0	13
Total Kept (mt)		85.820	135.459	182.796			404.075
Total Discards (mt)		0.000	0.680	1.198			1.878
Ratio discard/kept		0.000	0.005	0.007			0.005
Total Landings (mt)		1,409.981	2,753.821	2,122.142			6,285.944
Total Discards (mt)		0.000	13.824	13.908			29.215
2001							
Trips	0	0	0	0	0	0	0

Table C3. cont.

	May	June	July	Aug	Sept	Oct	Total
2002							
Trips	0	0	0	0	0	0	0
2003							
Trips	0	1	5	2	1	1	10
Total Kept (mt)		1.950	667.788	294.246	8.393	276.739	1,249.116
Total Discards (mt)		0	2.330	0	00.006	0.232	2.568
Ratio discard/kept		0	0.0003	0	0.001	0.001	0.002
Total Landings (mt)		1,108.513	1,196.377	1,123.499	526.248	1,931.618	5,886.256
Total Discards (mt)		0	4.174	0	0.376	1.619	6.170
2004							
Trips	1	3	12	9	7	1	33
Total Kept (mt)	24.948	89.132	327.945	378.682	342.689	0.102	1,163.498
Total Discards (mt)	0	0.907	12.774	0	2.287	0.519	16.487
Ratio discard/kept	0	0.01	0.039	0	0.007	5.088	0.014
Total Landings (mt)	1,527.714	5,646.571	6,664.912	8,184.790	3,987.020	0	26,011.007
Total Discards (mt)	0	57.459	259.609	0	26.608	0	343.676

Table C4. Estimates of kept weight (mt), discarded weight (mt) and discard ratios (discard/kept weight) of *Illex illecebrosus* sampled in the *Loligo* fishery, by observers from the NEFSC Observer Program, during 1995-2004. *Loligo* trips were defined as trips where *Loligo* landings were ≥ 25%, by weight, of the total trip landings. Estimates of total discards are based the product of discard ratios and reported *Loligo* landings, by month, for *Loligo* trips in the Weighout database.

	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**Total**
1995							
Trips	0	1	1	1	0	0	3
Total Kept (mt)		1.195	0.513	2.971			4.679
Total Discard (mt)		0.000	0.000	0.002			0.002
Ratio discard/kept		0.000	0.000	0.001			0.000
Total Landings (mt)		537.991	981.273	1,407.113			2,926.377
Total Discards (mt)		0.000	0.000	0.947			1.251
1996							
Trips	1	1	1	2	1	0	6
Total Kept (mt)	3.009	0.335	0.760	11.952	10.972		27.028
Total Discard (mt)	1.100	0.000	0.000	0.068	0.069		1.237
Ratio discard/kept	0.366	0.000	0.000	0.006	0.006		0.046
Total Landings (mt)	347.441	306.178	2,077.435	1,933.899	1,462.509		6,127.462
Total Discards (mt)	127.014	0.000	0.000	11.003	9.197		280.438
1997							
Trips	0	0	1	2	1	1	5
Total Kept (mt)			2.220	23.071	8.137	12.084	45.512
Total Discard (mt)			0.318	0.206	0.278	0.687	1.489
Ratio discard/kept			0.143	0.009	0.034	0.057	0.033
Total Landings (mt)			602.383	1,192.511	752.883	735.620	3,283.397
Total Discards (mt)			86.287	10.648	25.722	41.821	107.422

Table C4. cont.

	Nov	Dec	Jan	Feb	Mar	Apr	Total
1998							
Trips	2	0	3	3	7	3	18
Total Kept (mt)	3.629		21.514	25.045	100.520	25.540	176.248
Total Discard (mt)	0.003		0.372	0.078	0.976	3.395	4.824
Ratio discard/kept	0.001		0.017	0.003	0.010	0.133	0.027
Total Landings (mt)	1,442.321		1,202.271	3,697.553	3,720.621	1,009.754	11,072.520
Total Discards (mt)	1.192		20.789	11.516	36.125	134.225	303.061
1999							
Trips	2	3	0	0	4	5	14
Total Kept (mt)	40.183	14.411			31.508	37.670	123.772
Total Discard (mt)	0.032	0.155			2.015	2.376	4.578
Ratio discard/kept	0.001	0.011			0.064	0.063	0.037
Total Landings (mt)	1,783.164	1,286.115			1,197.348	1,343.383	5,610.010
Total Discards (mt)	1.420	13.833			76.573	84.733	207.499
2000							
Trips	1	0	4	5	5	0	15
Total Kept (mt)	0.429		14.527	63.171	53.083		131.210
Total Discard (mt)	0.000		0.005	0.492	0.530		1.027
Ratio discard/kept	0.000		0.000	0.008	0.010		0.008
Total Landings (mt)	292.562		1,232.910	2,182.140	1,769.293		5,476.905
Total Discards (mt)	0.000		0.424	16.995	17.665		42.869

Table C4. cont.

	Nov	Dec	Jan	Feb	Mar	Apr	Total
2001							
Trips	2	1	1	4	5	1	14
Total Kept (mt)	21.32	11.05	2.864	29.828	61.793	23.918	150.773
Total Discard (mt)	0.227	0	0.906	1.789	0.402	0.228	3.552
Ratio discard/kept	0.011	0.000	0.316	0.060	0.007	0.010	0.024
Total Landings (mt)	1,908.420	1,691.437	519.057	850.685	1,557.575	979.096	7,506.270
Total Discards (mt)	20.319	0.000	164.199	51.022	10.133	9.333	176.837
2002							
Trips	0	0	1	3	0	3	7
Total Kept (mt)			20.117	24.937		15.183	60.237
Total Discard (mt)			0.15	1.026		0	1.176
Ratio discard/kept			0.007	0.041		0	0.020
Total Landings (mt)			1,272.791	1,338.373		111.488	2,722.652
Total Discards (mt)			9.490	55.066		0	53.154
2003							
Trips	4	2	0	0	0	2	8
Total Kept (mt)	9.734				18.673	13.290	41.697
Total Discard (mt)	0.412				0.027	2.702	3.141
Ratio discard/kept	0.042				0.001	0.203	0.075
Total Landings (mt)	348.863				2,050.161	1,602.186	4,001.210
Total Discards (mt)	14.766				2.964	325.742	343.472
2004							
Trips	10	21	3	15	0	5	54
Total Kept (mt)	7.188	207.010	12.416	156.471		265.424	648.509
Total Discard (mt)	2.750	3.050	2.693	23.371		12.537	44.401
Ratio discard/kept	0.383	0.015	0.217	0.149		0.047	0.068
Total Landings (mt)	1,651.820	2,585.834	979.853	1,355.578		2,892.108	9,465.194
Total Discards (mt)	631.957	38.099	212.528	202.473		136.605	1,221.662

Table C5. Summary of *Illex* discards (mt), by year and fishery, estimated from data collected by observers from the NEFSC Observer Program during 1995-2004.

	Percentage of landings sampled for *Illex* discards										
	Illex Fishery		*Loligo* Fishery		***Illex* Discards (mt)**						
Year	*Illex* Landings (May-Oct, mt)	%	*Loligo* Landings (Nov-April, mt)	%	*Illex* Fishery	%	*Loligo* Fishery	%	Total	**Total *Illex* Landings (mt)**	***Illex* Discards (% of *Illex* landings)**
1995	13,494	0.01%	6,702	0.07%	64	98	1	2	65	14,058	0.5%
1996	15,563	5.36%	7,070	0.38%	82	23	280	77	362	16,969	2.1%
1997	12,709	8.79%	6,484	0.69%	56	34	107	66	163	13,629	1.2%
1998	23,091	0.67%	12,755	1.38%	150	33	303	67	453	23,597	1.9%
1999	7,115	1.28%	7,811	1.59%	58	22	207	78	265	7,388	3.6%
2000	8,901	4.54%	5,810	2.25%	29	40	43	60	72	9,011	0.8%
2001	3,452	0.00%	7,506	2.01%	No data		177		177	4,009	4.4%
2002	2,342	0.00%	6,107	0.98%	No data		53		53	2,750	2.0%
2003	5,887	21.22%	8,804	0.47%	6	2	344	98	350	6,389	5.5%
2004	26,011	4.47%	10,350	6.27%	344	22	1,222	78	1,566	26,087	6.0%

Table C6. Standardized, stratified mean catch per tow (delta-transformed) in numbers/tow, and kg/tow of *Illex illecebrosus,* pre-recruits (≤ 10 cm) and recruits (≥ 11 cm), caught during autumn research bottom trawl surveys in offshore strata 1-40 and 61-76 from Cape Hatteras to the Gulf of Maine during 1967-2004.

Year	All sizes (no./tow)	CV (%)	All sizes (kg/tow)	CV (%)	Individual Mean Weight (g)	Pre-recruits (no./tow)	Recruits (no./tow)
1967	1.57	17	0.242	17	147	0.04	1.53
1968	1.64	21	0.307	17	186	0.10	1.54
1969	0.59	23	0.073	26	121	0.09	0.50
1970	2.26	21	0.268	15	110	0.85	1.41
1971	1.68	12	0.337	14	206	0.20	1.48
1972	2.19	25	0.292	15	123	0.48	1.71
1973	1.47	24	0.353	25	242	0.04	1.43
1974	2.82	40	0.392	30	145	1.20	1.62
1975	8.74	36	1.417	18	143	3.98	4.76
1976	20.55	16	7.018	19	317	0.42	20.13
1977	12.62	18	3.740	18	299	0.72	11.90
1978	19.25	21	4.529	26	219	3.29	15.96
1979	19.42	11	6.053	11	305	1.31	18.11
1980	13.81	15	3.285	18	238	0.43	13.38
1981	27.10	32	9.340	40	327	0.22	26.88
1982	3.94	15	0.602	13	155	0.71	3.23
1983	1.73	14	0.233	13	134	0.16	1.57
1984	4.54	17	0.519	19	113	0.32	4.22
1985	2.38	17	0.355	18	147	0.19	2.19
1986	2.10	15	0.257	17	119	0.26	1.84
1987	15.83	31	1.527	29	92	0.84	14.99
1988	23.22	25	2.997	24	121	0.41	22.81
1989	22.43	45	3.307	57	118	1.05	21.38
1990	16.61	12	2.401	13	141	0.61	16.00
1991	5.21	17	0.691	18	129	0.22	4.99
1992	8.24	15	0.804	16	98	1.79	6.45
1993	10.42	19	1.595	20	159	0.15	10.27
1994	6.83	24	0.860	25	128	0.22	6.61
1995	8.01	30	0.700	39	84	0.82	7.19
1996	10.76	22	0.926	19	87	0.60	10.16
1997	5.83	24	0.521	17	89	0.74	5.09
1998	14.60	51	1.400	50	94	1.18	13.42
1999	1.39	16	0.192	17	136	0.15	1.24
2000	7.41	28	0.706	22	94	0.95	6.46
2001	4.49	27	0.323	23	72	0.46	4.03
2002	6.36	20	0.444	19	70	1.01	5.35
2003	28.46	61	1.946	67	69	3.12	25.34
2004	5.06	24	0.412	22	82	1.09	3.97
Average							
1967-1981	9.05	22	2.510	21	209	0.89	8.16
1982-2003	9.58	25	1.06	25	111	0.73	8.86
1967-2003	9.36	24	1.65	23	151	0.79	8.57
1999-2003	9.62	30	0.72	29	88	1.14	8.48

Table C7. Summary of data from Vessel Trip Reports submitted by fishermen participating in the *Illex illecebrosus* fishery during 2003 and 2004. FT represents freezer trawlers and RSW represents refrigerated seawater system trawlers.

	2003			2004		
	FT	RSW	Total	FT	RSW	Total
N vessels	3	11	14	12	16	28
N trips	32	80	112	92	355	447
Average trip duration (days absent from port)	8.2	2.8	4.4	6.5	1.8	2.8
Average nominal effort (days fished) per trip	2.1	0.8	1.2	1.1	0.5	0.6
Average landings (mt)	152	17	55	122	34	52
Average nominal LPUE (mt/df)	71	22	48	111	76	89
Total fishery landings (mt)	4,859	1,337	6,195	12,174	11,198	23,372
Proportion of total annual landings	0.78	0.22		0.52	0.48	
Total nominal effort (days fished)	69	61	130	101	161	262
Proportion of total annual effort	0.53	0.47		0.39	0.61	
Duration of fishing season (weeks) [1]			23			18
Timing of fishing season			weeks 24-46			weeks 21-38

[1] Fishery closed on 9/21/2004 because quota of 24,000 mt was landed

Table C8. Results of a General Linear Model with log-transformed landings per unit effort from the 2003 U.S. *Illex illecebrosus* fishery as the dependent variable and week of year, vessel type (freezer or RSW trawler), and quarter-degree square fishing area as class effects in the model.

Source	DF	Sum of Squares	Mean Square	F	Pr > F
Model	28	64.92159721	2.31862847	3.35	< 0.0001
Error	50	34.60964687	0.69219294		
Corrected Total	78	99.53124408			
R-Square	CV	Root MSE	ln (lpuemt) Mean		
0.652274	25.36757	0.831981	3.279705		
Source	DF	Type I SS	Mean Square	F	Pr > F
wkofyr	21	43.71807976	2.08181332	3.01	0.0007
vessel type	1	16.85165507	16.85165507	24.35	<.0001
quarter-degree square	6	4.35186239	0.7253104	1.05	0.4062
Source	DF	Type III SS	Mean Square	F	Pr > F
wkofyr	21	28.38454289	1.3516449	1.95	0.0271
vessel type	1	16.32903841	16.32903841	23.59	<.0001
quarter-degree square	6	4.35186239	0.7253104	1.05	0.4062
Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		2.892167156	0.65598996	4.41	<.0001
wkofyr	23	-0.83677222	1.09519873	-0.76	0.4484
	26	0.025684254	0.85545884	0.03	0.9762
	27	-0.556877471	0.80031553	-0.70	0.4898
	28	0.727561846	0.7656278	0.95	0.3465
	29	-1.057333371	0.80031553	-1.32	0.1925
	30	0.050102596	0.8073132	0.06	0.9508
	31	0.820210337	0.87588503	0.94	0.3535
	32	0.174250298	0.79740912	0.22	0.8279
	33	-0.810892382	0.71768494	-1.13	0.2639
	34	0.326811416	0.85266844	0.38	0.7031
	35	0.473101326	0.74953597	0.63	0.5308
	36	-0.192868857	0.72695638	-0.27	0.7919
	37	-0.448380259	0.89406911	-0.50	0.6182
	38	0.773904369	0.74364221	1.04	0.3030
	39	0.74920603	0.74830111	1.00	0.3215
	40	0.564620776	0.71213424	0.79	0.4316

	41	0.303483041	0.73487454	0.41	0.6814
	42	-0.252719536	0.7925821	-0.32	0.7512
	44	0.06387861	1.03822267	0.06	0.9512
	45	-0.87454083	1.03822267	-0.84	0.4036
	46	-2.196469961	1.09814748	-2.00	0.0509
	924	0			
vessel type	freezer	1.38042707	0.28421484	4.86	<.0001
	90	0			
quarter-degree square	35744	-0.251695345	0.48585275	-0.52	0.6067
	36744	-0.051855303	0.39807988	-0.13	0.8969
	37741	-0.554991953	0.47689578	-1.16	0.2500
	38731	-0.248242504	0.44571473	-0.56	0.5800
	38732	-0.361044568	0.33103193	-1.09	0.2806
	38734	0.673924219	0.51879469	1.30	0.1999
	936742	0			

Table C9. Results of a General Linear Model with log-transformed landings per unit effort from the 2004 U.S. *Illex illecebrosus* fishery as the dependent variable and week of year, vessel type (freezer or RSW trawler), and quarter-degree square fishing area as class effects in the model.

Source	DF	Sum of Squares	Mean Square	F	Pr > F
Model	30	31	56.7928322	1.8320268	< 0.0001
Error	340	368	167.8628528	0.4561491	
Corrected Total	370	399	224.655685		

R-Square	Coeff Var	Root MSE	lnlpuemt Mean
0.252799	15.43396	0.675388	4.375987

Source	DF	Type I SS	Mean Square	F	Pr > F
wkofyr	19	24.77420331	1.30390544	2.86	<.0001
vessel type	1	12.40259859	12.40259859	27.19	<.0001
quarter-degree square	11	19.61603029	1.78327548	3.91	<.0001

Source	DF	Type III SS	Mean Square	F	Pr > F
wkofyr	19	30.60929990	1.61101578	3.53	<.0001
vessel type	1	17.81584700	17.81584700	39.06	<.0001
quarter-degree square	11	19.61603029	1.78327548	3.91	<.0001

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		4.260992	0.232047	18.36	<.0001
wkofyr	20	0.280698	0.508075	0.55	0.581
	21	-0.395540	0.243112	-1.63	0.1046
	22	0.482445	0.254427	1.9	0.0587
	23	0.346848	0.238090	1.46	0.146
	25	-0.244626	0.211317	-1.16	0.2478
	26	0.016649	0.207027	0.08	0.9359
	27	-0.015857	0.217309	-0.07	0.9419
	28	0.340708	0.203401	1.68	0.0948
	29	-0.161689	0.210484	-0.77	0.4429
	30	-0.000075	0.220173	0.00	0.9997
	31	0.157004	0.238182	0.66	0.5102
	32	0.141091	0.228924	0.62	0.5381
	33	0.320713	0.206790	1.55	0.1218
	34	0.688085	0.215205	3.20	0.0015
	35	0.551480	0.199831	2.76	0.0061
	36	0.023374	0.213164	0.11	0.9127
	37	0.188770	0.240686	0.78	0.4334

	38	0.070158	0.236524	0.30	0.7669
	39	-0.971570	0.454831	-2.14	0.0333
	924	0			
vessel type	freezer	0.634100	0.101463	6.25	<.0001
	90	0			
quarter-degree square	37734	0.037820	0.372147	0.10	0.9191
	37741	-0.098423	0.277586	-0.35	0.7231
	37742	-0.804485	0.276812	-2.91	0.0039
	37743	0.216598	0.298521	0.73	0.4686
	38724	0.101493	0.210326	0.48	0.6297
	38731	-0.298963	0.183363	-1.63	0.1039
	38732	-0.077336	0.173498	-0.45	0.6561
	38733	-0.031082	0.188733	-0.16	0.8693
	39693	0.858187	0.701742	1.22	0.2222
	39721	-1.453390	0.236918	-6.13	<.0001
	39722	-0.806836	0.381026	-2.12	0.0349
	999999	0			

Table C10. Probability values (α = 0.05) from General Linear Models used to standardize catch rates in the *Illex illecebrosus* fishery during 2003 and 2004. Vessel types were characterized as freezer trawler (FT) or refrigerated seawater system (RSW) trawler.

Effect	**2003**		**2004**					
					RSW		FT	
Week of year	**0.0271**	0.1230	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0025**
Quarter-degree square	0.4062	0.9807	**0.0001**	0.0737	0.0588	**0.0177**	0.7251	**0.0001**
Vessel type	**0.0001**		**0.0001**					
Hull Number		**0.0008**		**0.0001**	**0.0001**		**0.0001**	
Model	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
R^2	0.65	0.75	0.25	0.67	0.65	0.20	0.72	0.28
df	28	38	31	52	45	25	47	24

Table C11. Status of research recommendations from the previous *Illex* stock assessment (SARC 37).

Research Recommendation	Status
Continue model development, with the objective of producing sound statistical models for stock assessment purposes	All three models presented at SARC 37 were improved upon and tested further. These models require seasonal age and maturity data before further model testing can be done.
Consider the development of "operating models" which can be used to test the effectiveness of alternative management strategies	This research recommendation cannot be accomplished until a reliable stock assessment model is available.
Evaluate the relationship between growth rates and sea temperature to define possible changes in stock productivity associated with environmental conditions.	Not completed. Requires a funding source for the collection and analysis of growth rate data.
Define biological indicators of low or high productivity regimes.	In progress. There is a relationship between *Illex* body size, autumn survey relative abundance indices, and bottom temperature anomalies on the US Shelf. However, further investigation of these relationships is needed.
Evaluate seasonal and latitudinal clines in growth rates.	Not completed. Requires a funding source for the collection and analysis of growth rate data.
Evaluate and design cooperative research programs with commercial vessels for sampling of size, weight and possible age of *Illex* during the fishing season	Completed. Length and weight data from the fishery are collected by the *Illex* processors/dealers and sent to the NEFSC for use in the assessments.
Continue with cooperative ventures for pre-season survey to obtain possible indices of upcoming stock abundance and productivity.	A pre-season *Illex* survey was conducted using commercial vessels in 2000 with funds from an external grant and these data were used in the assessments (SARC 37 and current). External funding is needed to conduct a second *Illex* pre-season survey to assess the inter-annual variability of the data.
Evaluate catch rates by vessel by using VTR and Weighout databases to improve procedures for standardization of nominal LPUE.	Completed during the current assessment.

ILLEX FIGURES

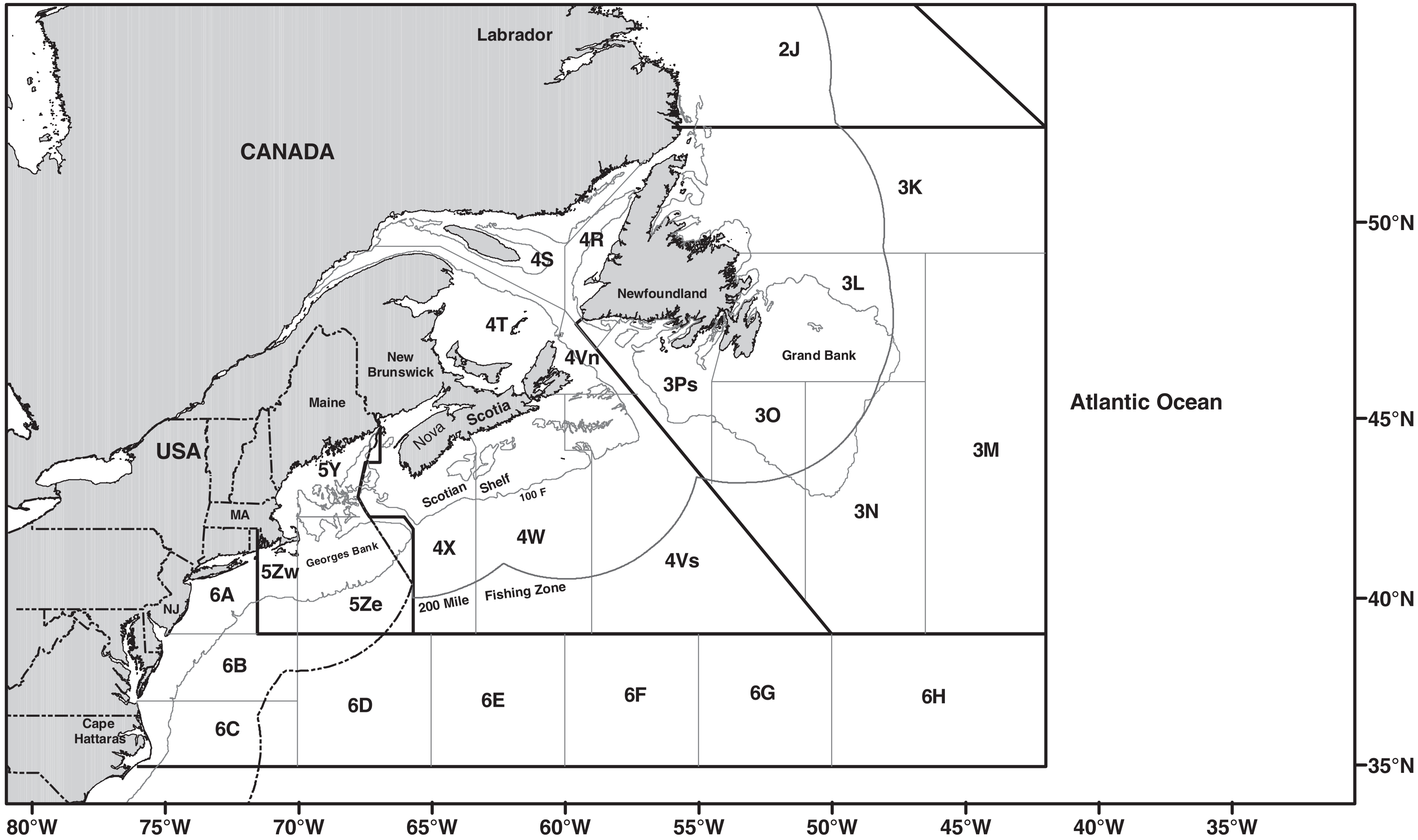

Figure C1. Catch reporting areas of the Northwest Atlantic Fisheries Organization (NAFO) for Subareas 3-6.

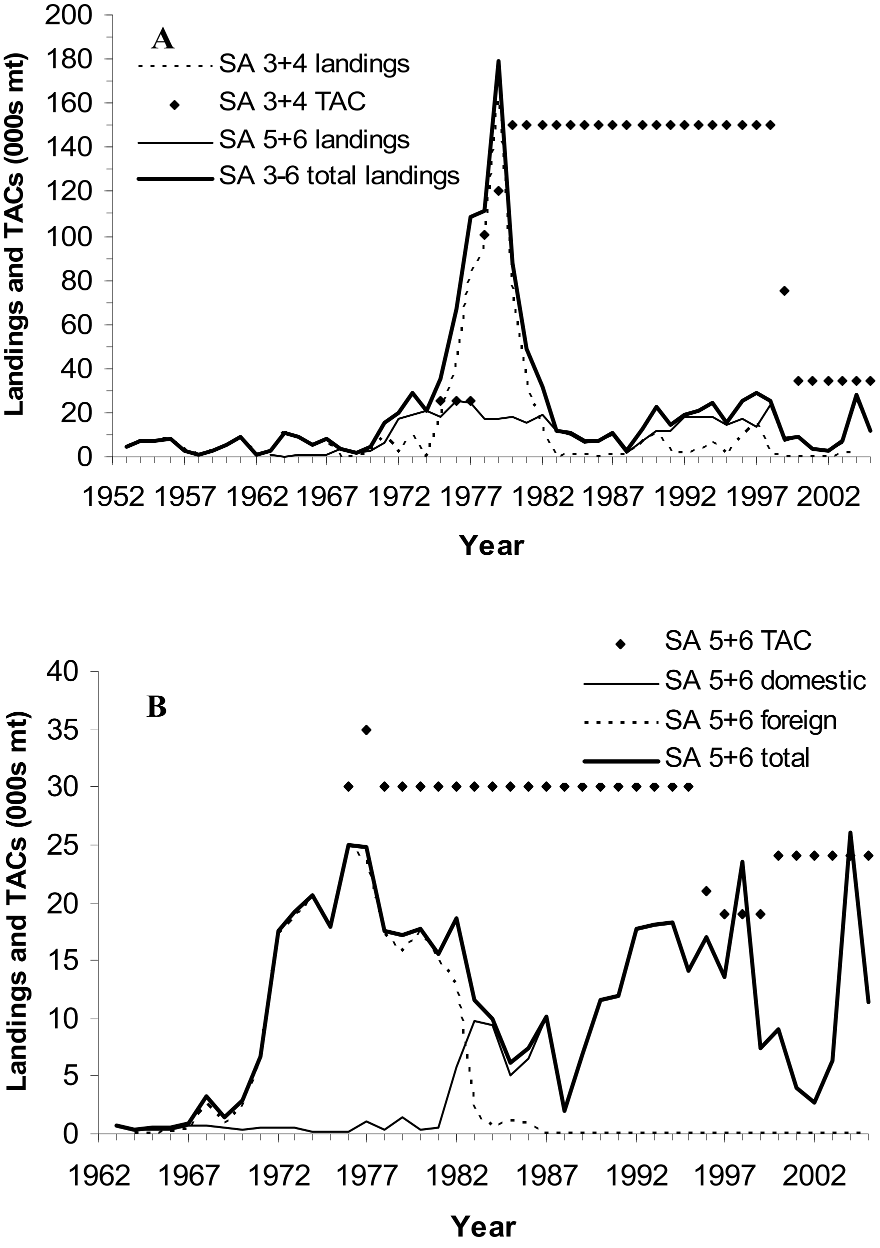

Figure C2. Total landings of *Illex illecebrosus* in (A) NAFO Subareas 3-6 and (B) in the US EEZ (NAFO Subareas 5+6), with respect to annual TACs, during 1963-2005.

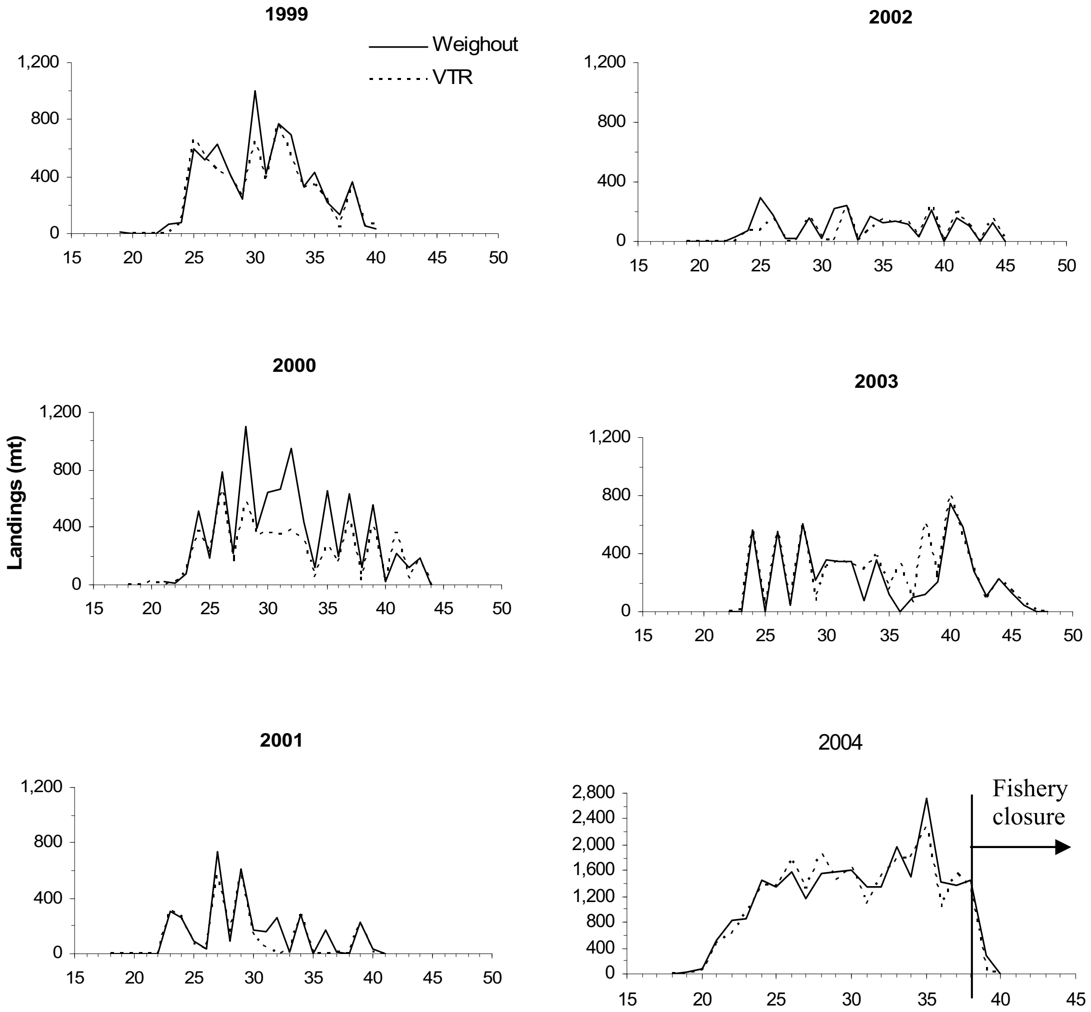

Figure C3. Trends in weekly *Illex illecebrosus* landings from the Weighout database versus the Vessel Trip Report database during 1999-2004.

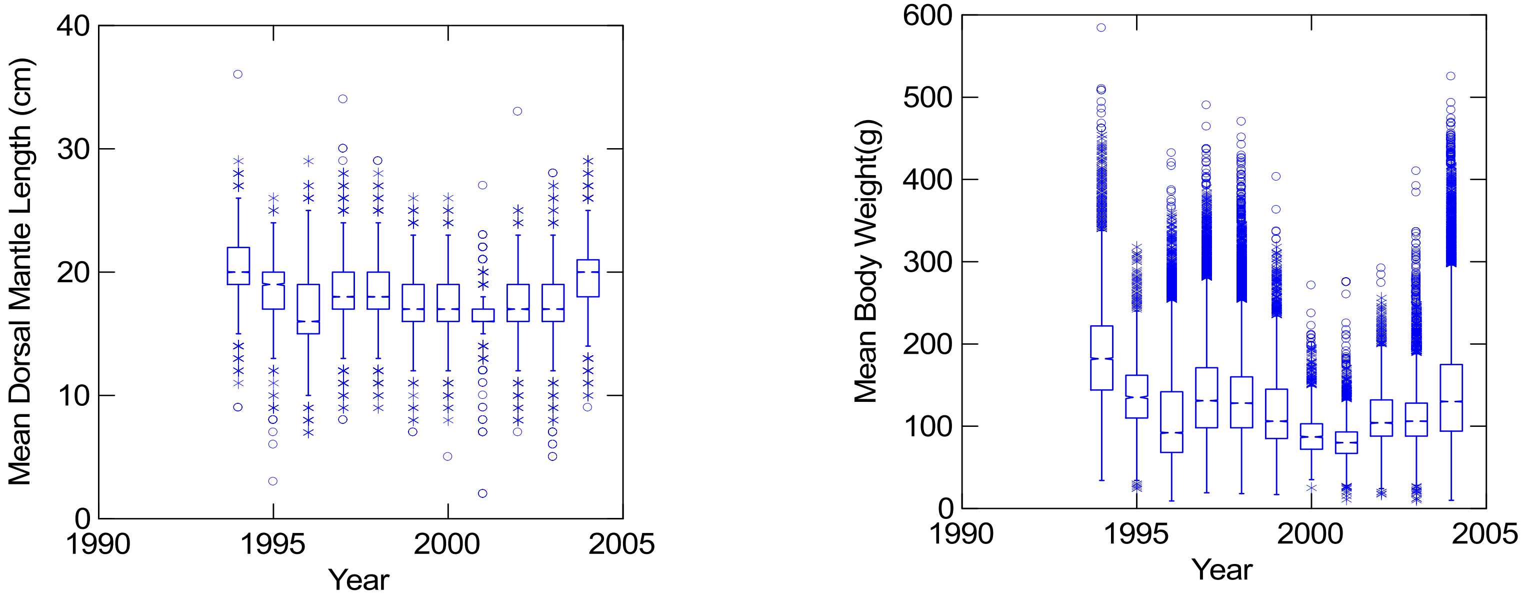

Figure C4. Annual trends in the dorsal mantle length (cm) and body weight (g) of *Illex illecebrosus* landed during 1994-2004. The boxes represent the boundaries of the interquartile range and the notch within the box represents the median.

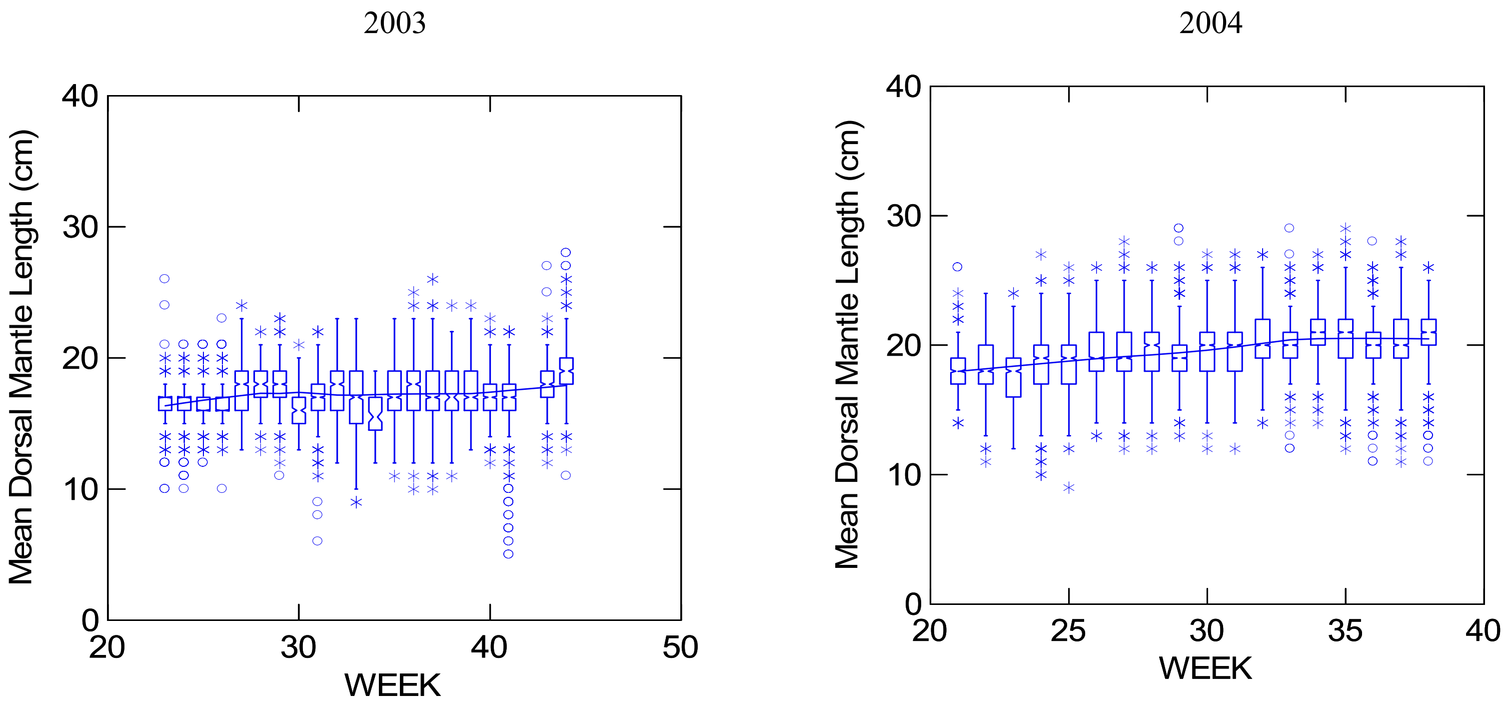

Figure C5. Weekly trends in the dorsal mantle length (cm) of *Illex illecebrosus* landings during 2003 and 2004. The solid line represents a loess smooth of the observed values with a tension factor of 0.5.

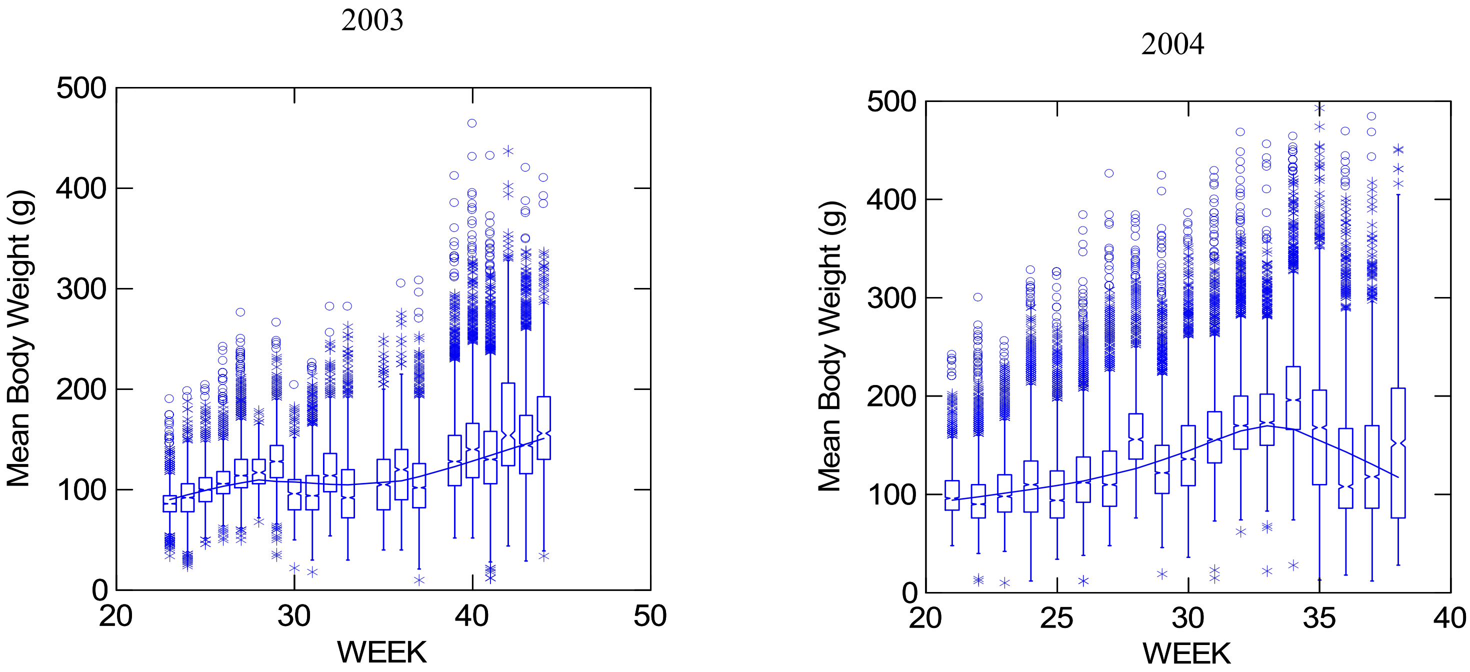

Figure C6. Weekly trends in the body weight (g) of *Illex illecebrosus* landings during 2003 and 2004. The solid line represents a loess smooth of the observed values with a tension factor of 0.5.

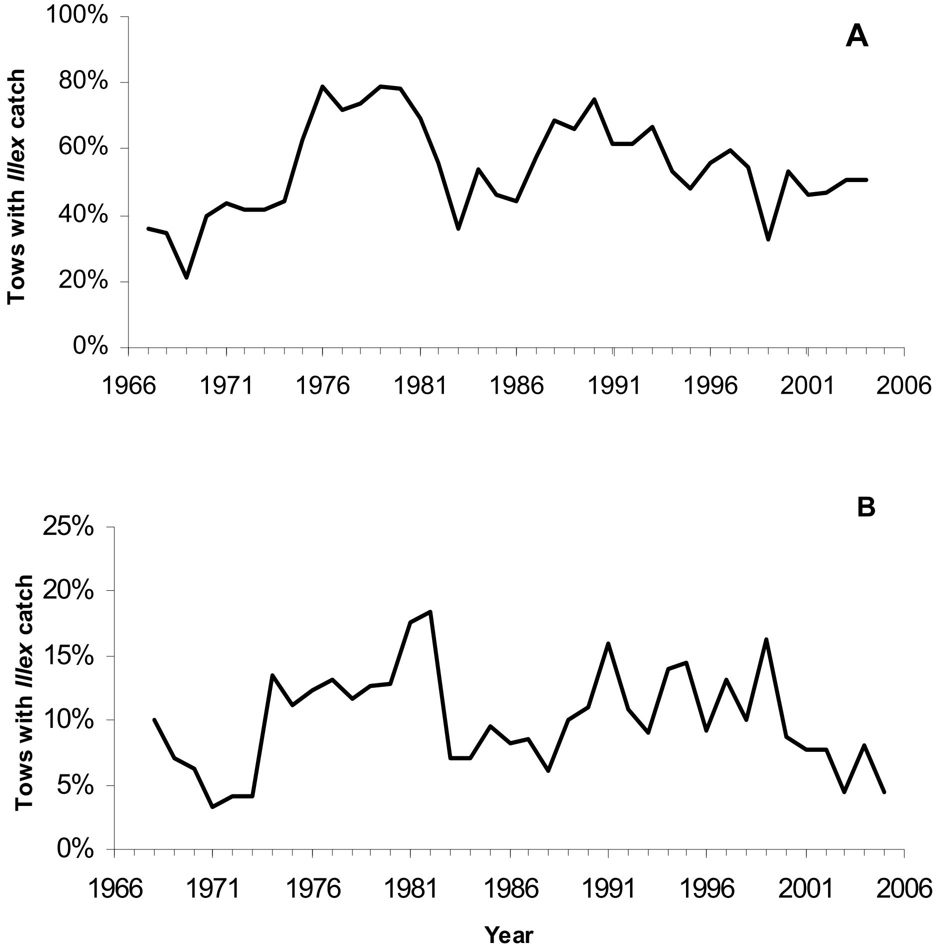

Figure C7. Annual trends in the percentage of tows with *Illex* catch, in offshore strata sampled during the (A) NEFSC autumn (1967-2004) and (B) spring (1968-2005) research bottom trawl surveys.

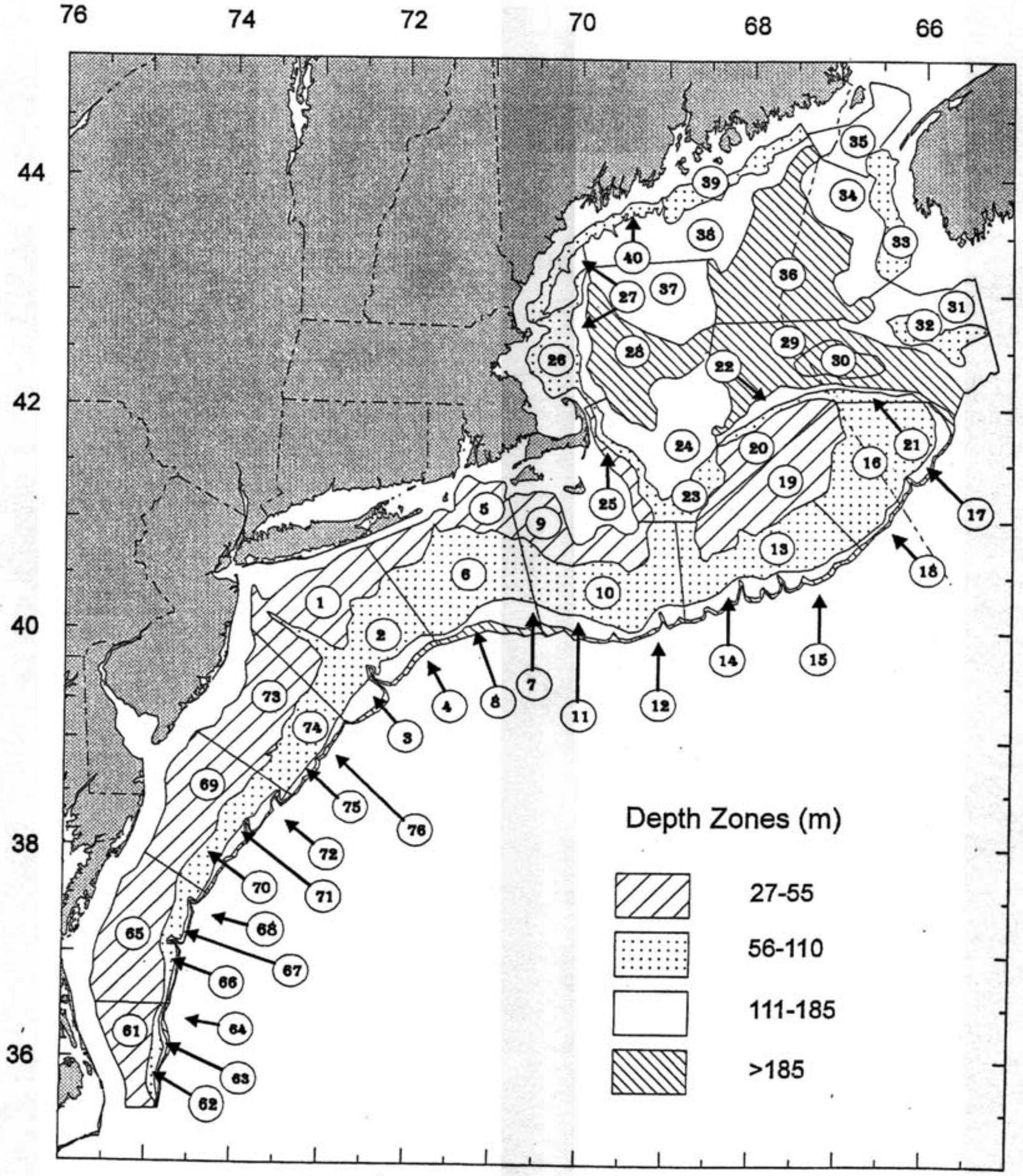

Figure C8. Offshore depth strata sampled during Northeast Fisheries Science Center bottom trawl research surveys.

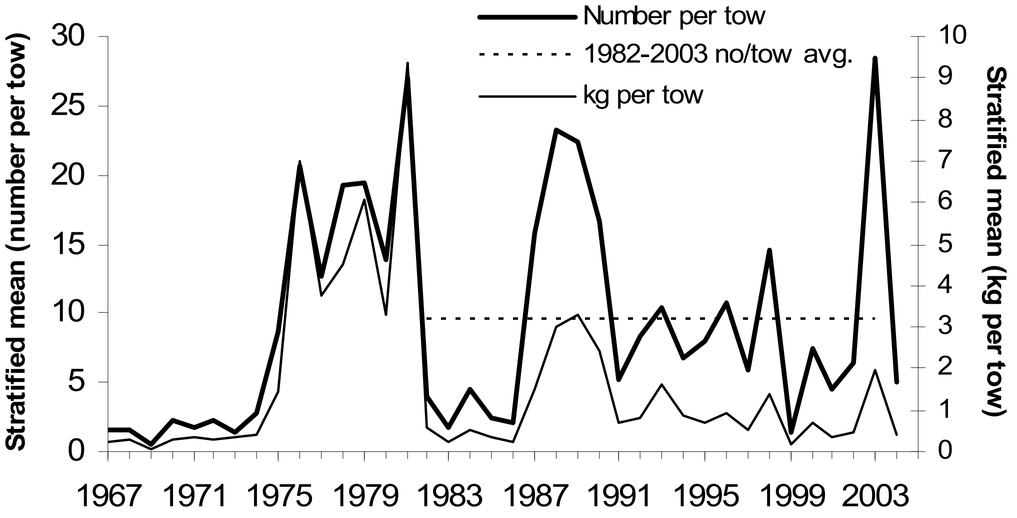

Figure C9. Trends in *Illex illecebrosus* relative abundance (stratified mean number tow) and biomass (stratified mean kg per tow) indices based on data from NEFSC autumn bottom trawl surveys conducted on the USA shelf during 1967-2004.

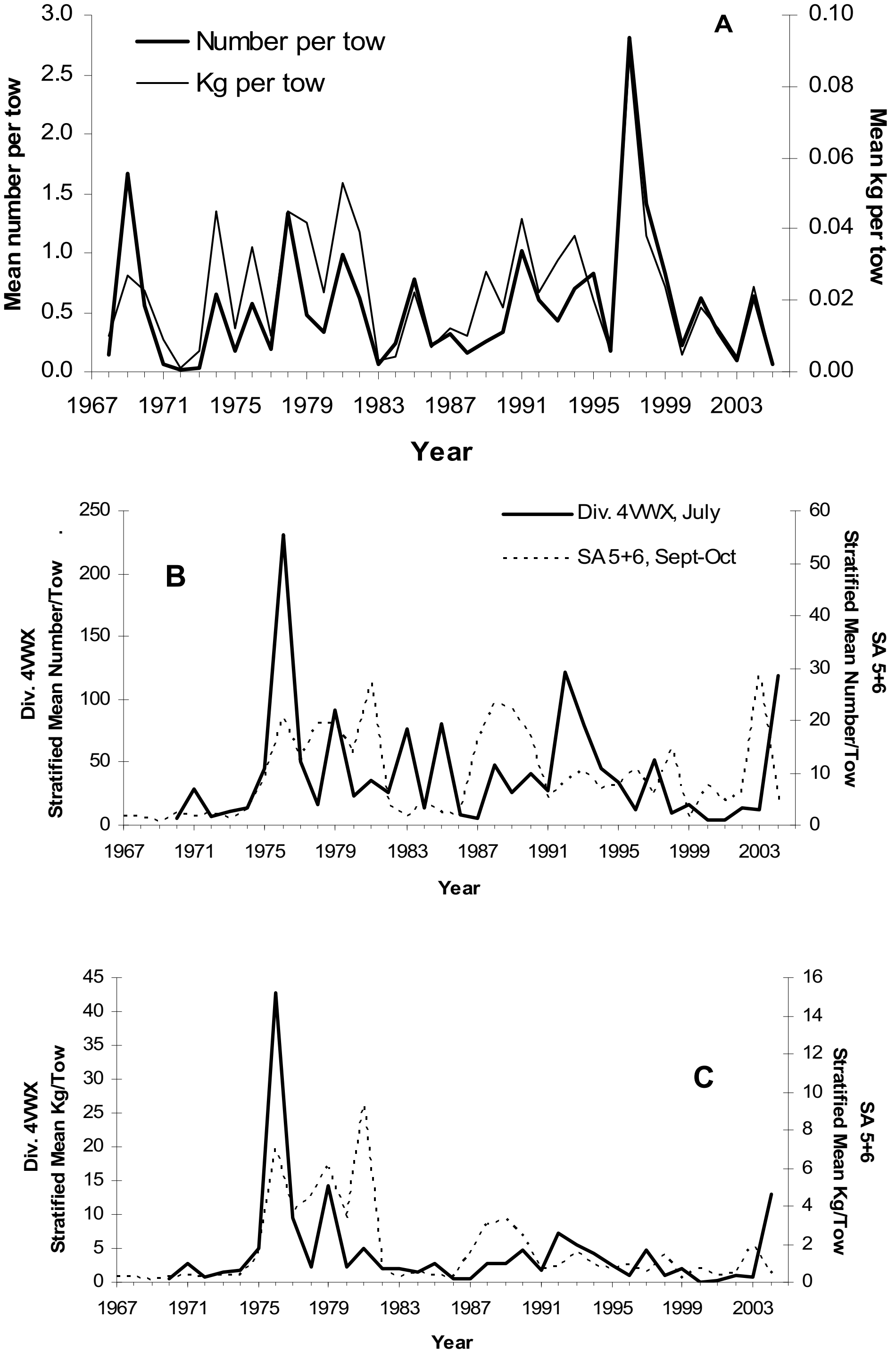

Figure C10. Trends in *Illex illecebrosus* relative abundance (stratified mean number per tow) and biomass (stratified mean kg per tow) based on bottom trawl surveys of (A) the USA shelf during March and (B and C) the USA shelf in September/October and the Scotian Shelf in July. Scotian Shelf survey indices could not be standardized for gear and vessel changes that occurred in 1982, 1983 and 2004.

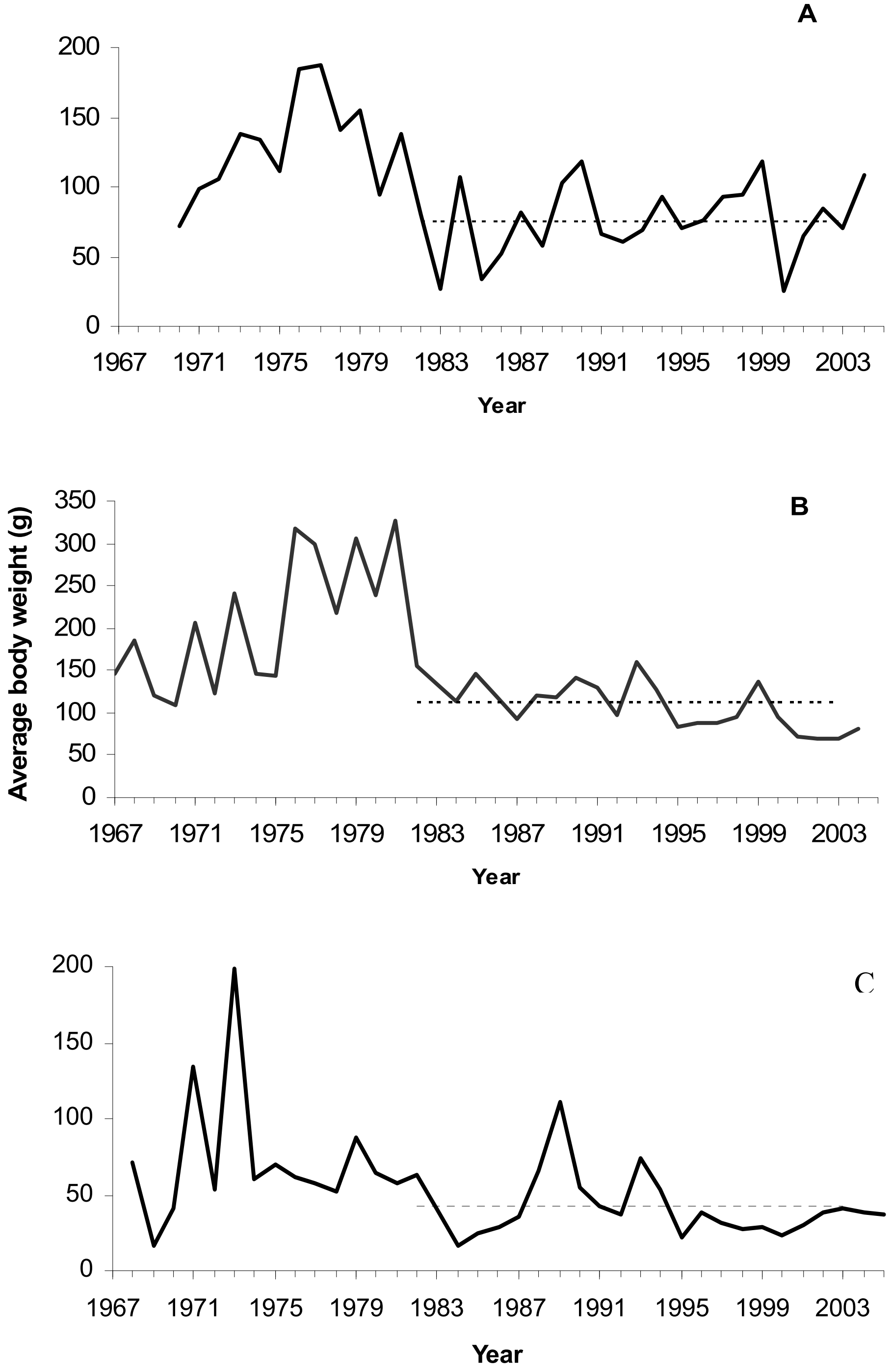

Figure C11. Trends in average body weight (g) of *Illex illecebrosus* caught during (A) Canadian research bottom trawl surveys conducted in July on the Scotian Shelf (1970-2004) and NEFSC (B) autumn (1967-2004) and (C) spring (1968-2005) research bottom trawl surveys of the U. S Shelf. The dashed line represents the 1982-2003 average body weight.

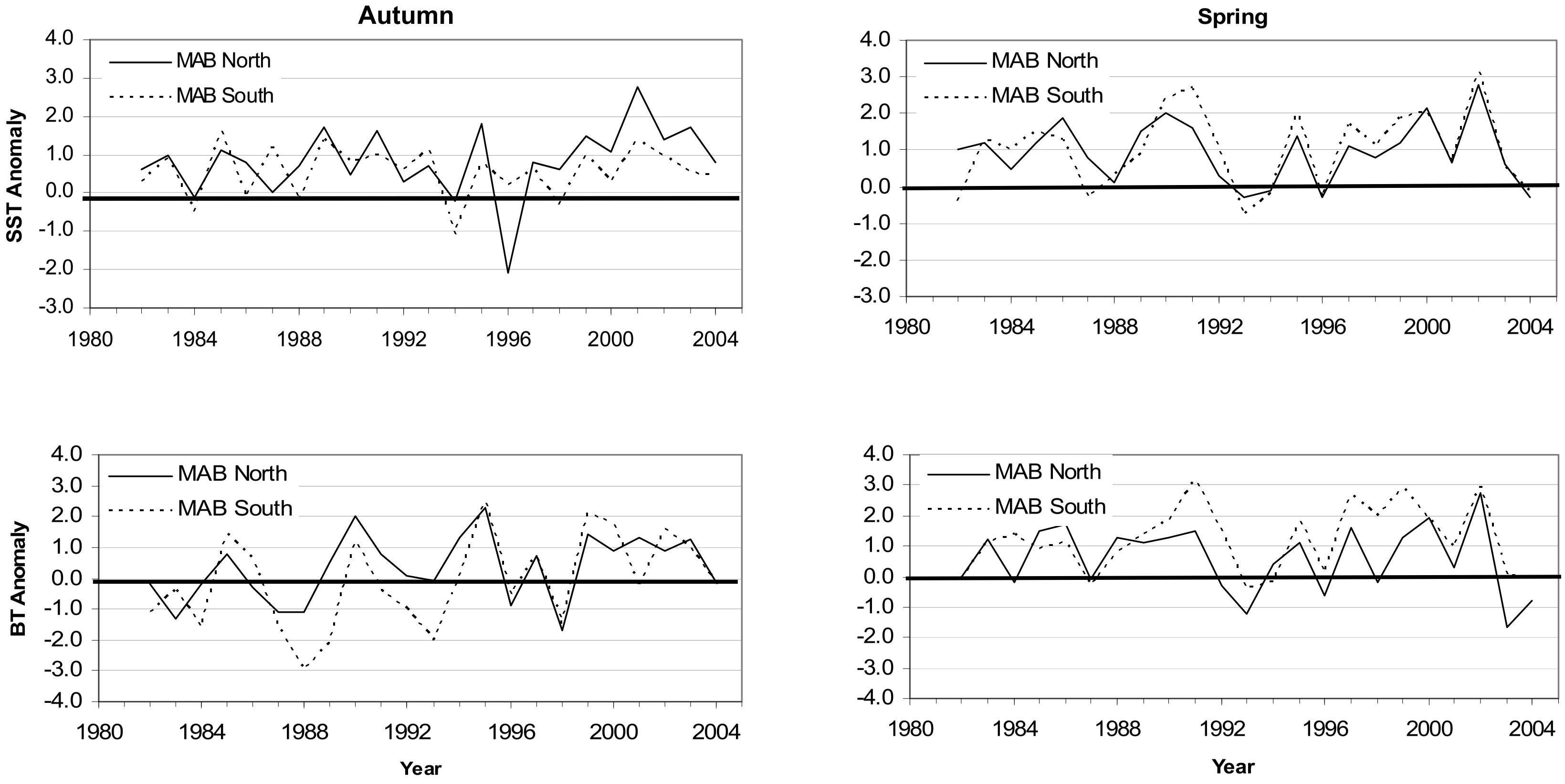

Figure C12. Sea surface temperature and bottom temperature anomalies in the Mid-Atlantic Bight, north versus south, during NEFSC autumn and spring research bottom trawl surveys, 1982-2004. The reference period is 1977-1987.

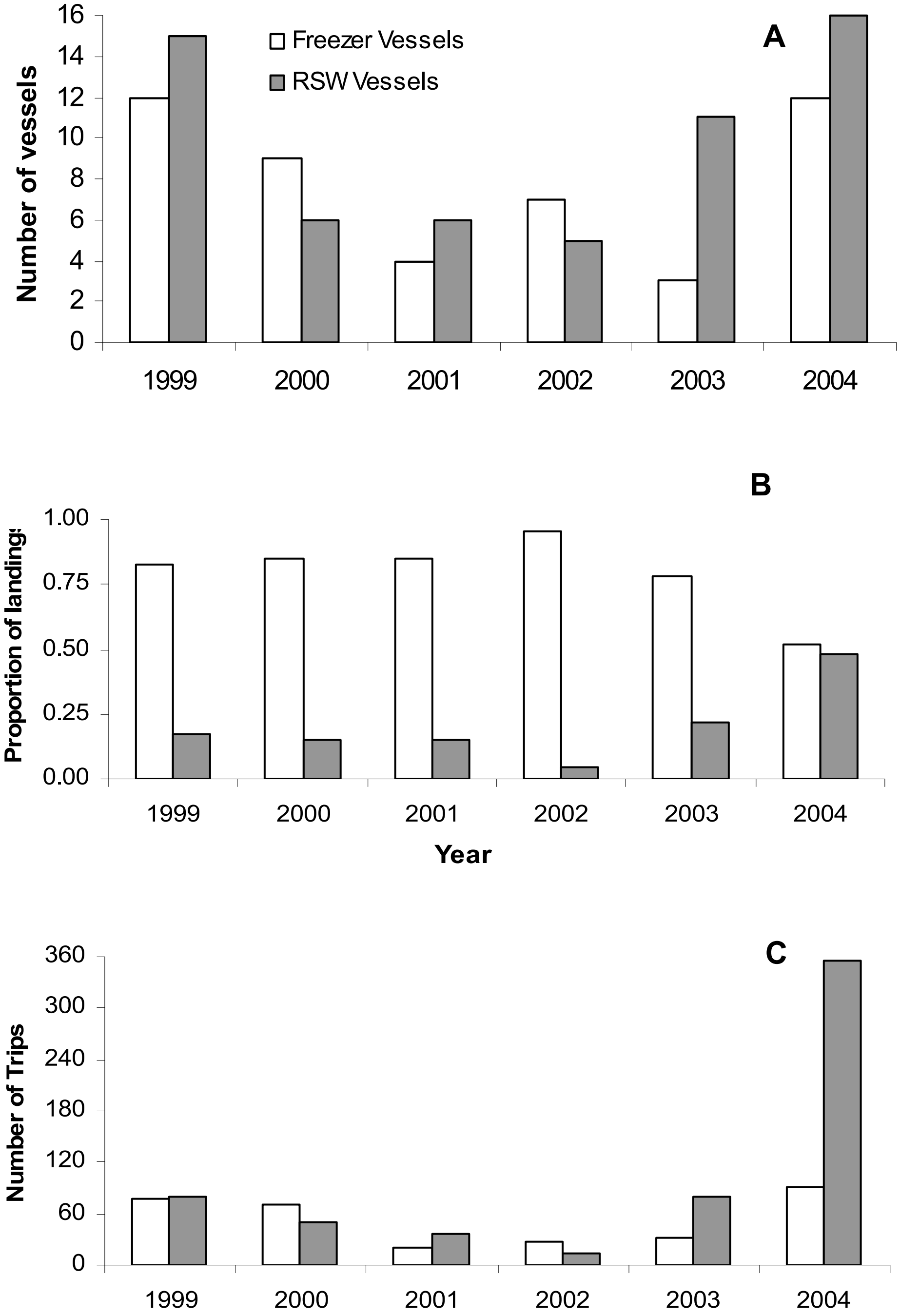

Figure C13. Number of (A) vessels, (B) proportion of annual landings and (C) number of trips, by fleet sector, in the directed fishery during 1999-2004.

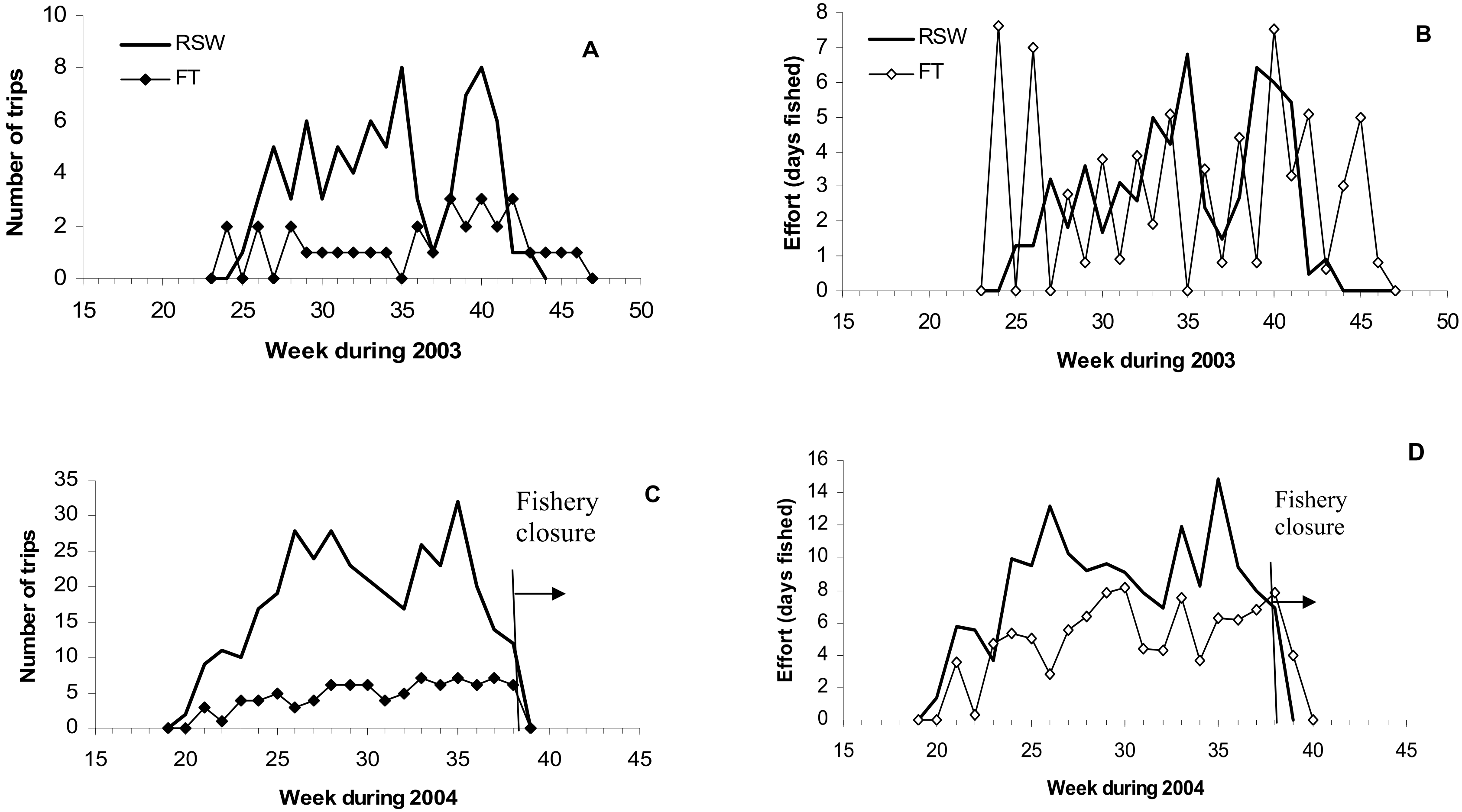

Figure C14. Number of fishing trips and nominal effort (days fished) for freezer trawlers (FT) and refrigerated seawater system (RSW) trawlers, by week, during 2003 (A and B) and 2004 (C and D).

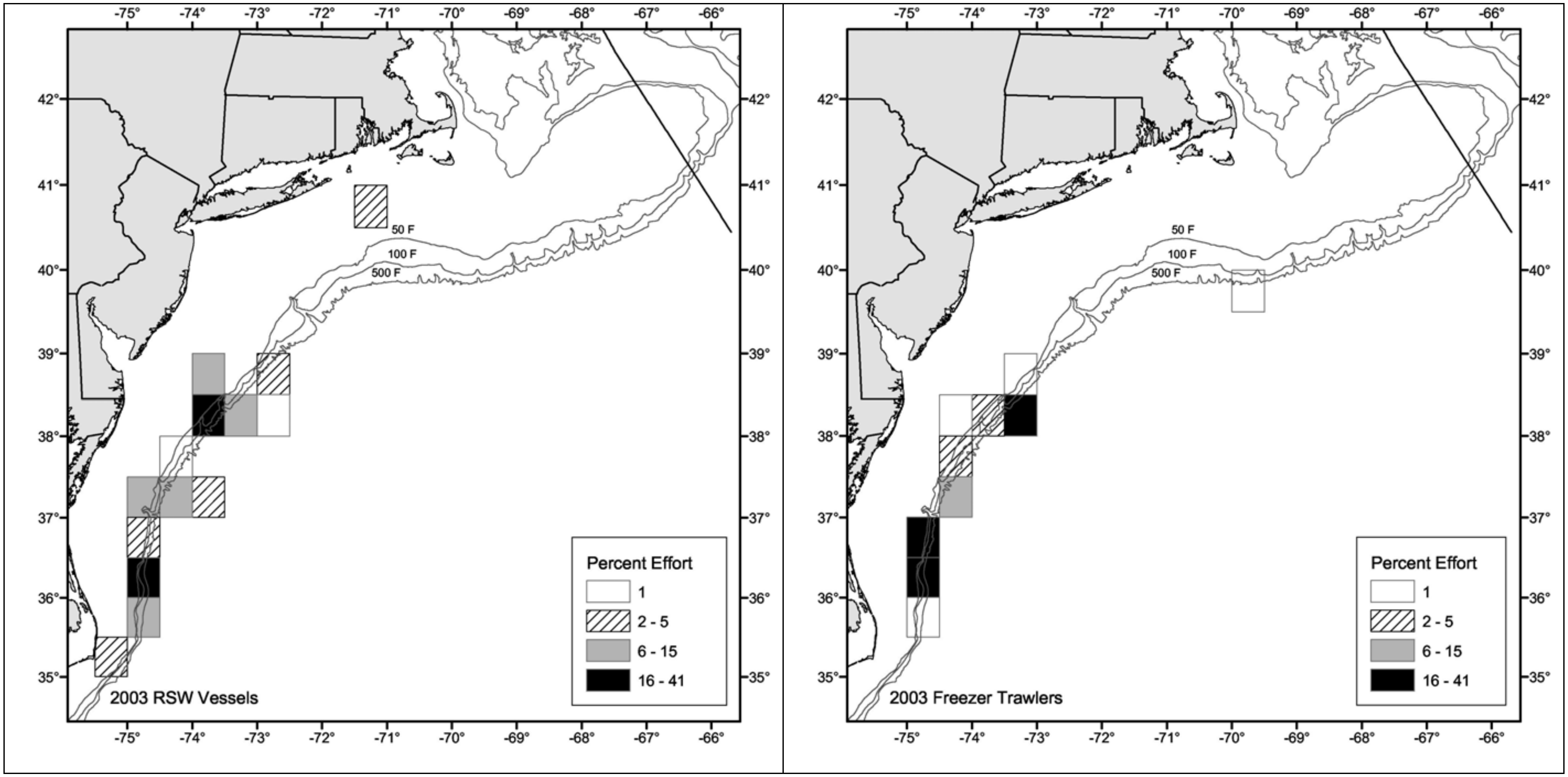

Figure C15. Percentage of nominal annual effort, by quarter-degree square, for refrigerated seawater system (RSW) trawlers and freezer trawlers participating in the *Illex illecebrosus* fishery during 2003.

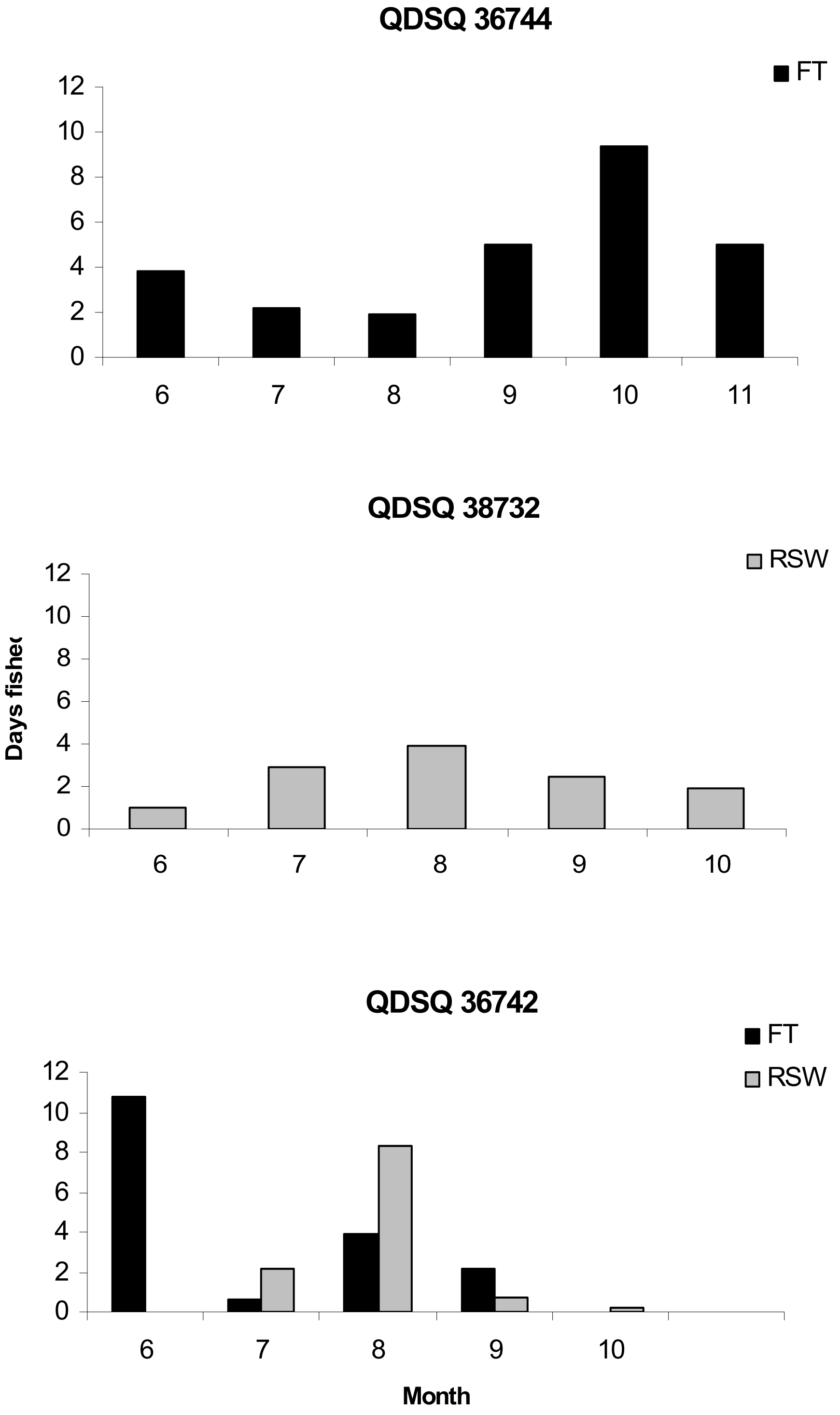

Figure C16. Effort (days fished), by fleet sector and month, in quarter-degree squares that were consistently fished during the 2003 *Illex* fishery. FT represents freezer trawlers and RSW represents refrigerated seawater system trawlers.

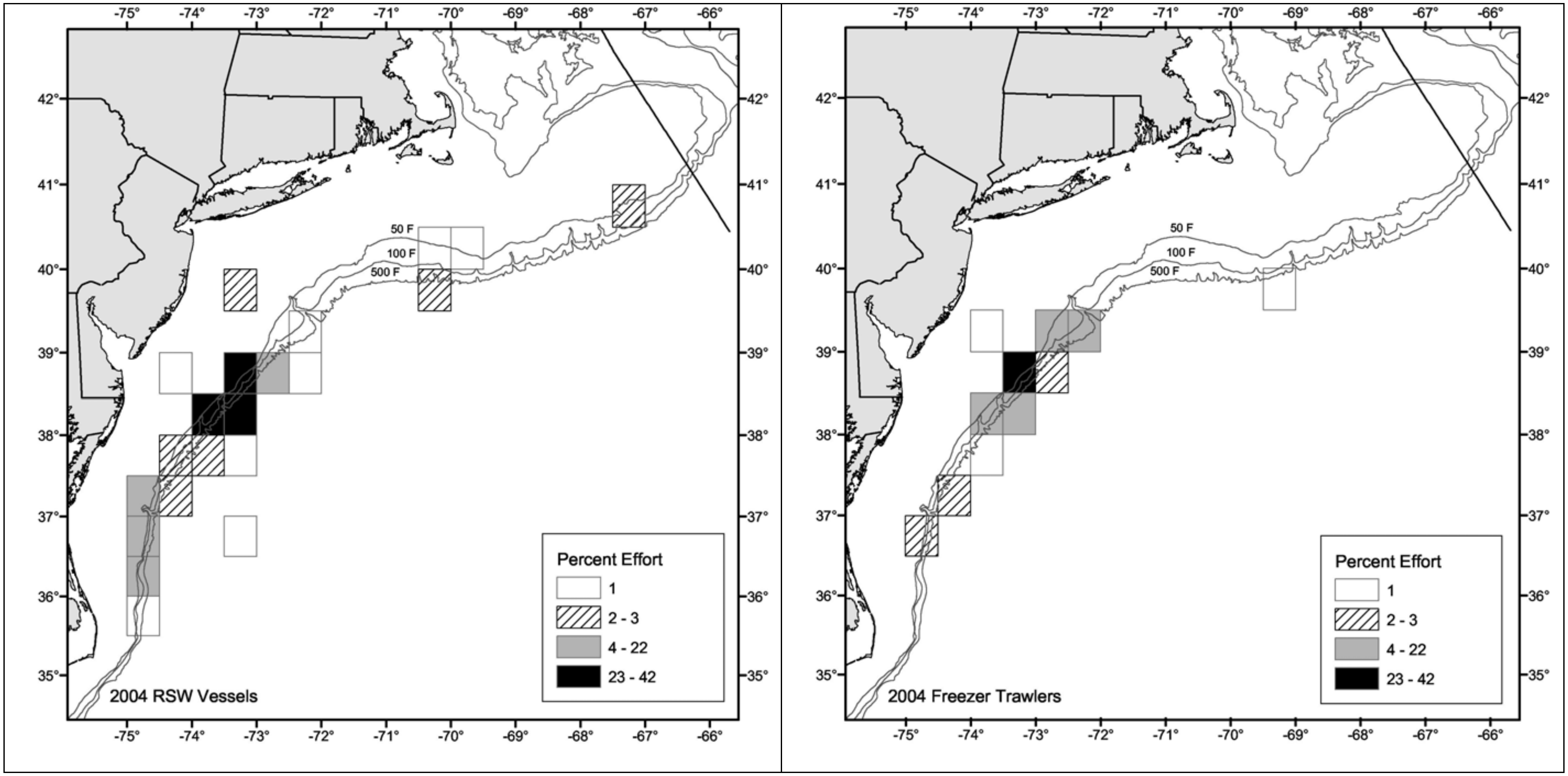

Figure C17. Percentage of nominal annual effort, by quarter-degree square, for refrigerated seawater system (RSW) trawlers and freezer trawlers participating in the *Illex illecebrosus* fishery during 2004.

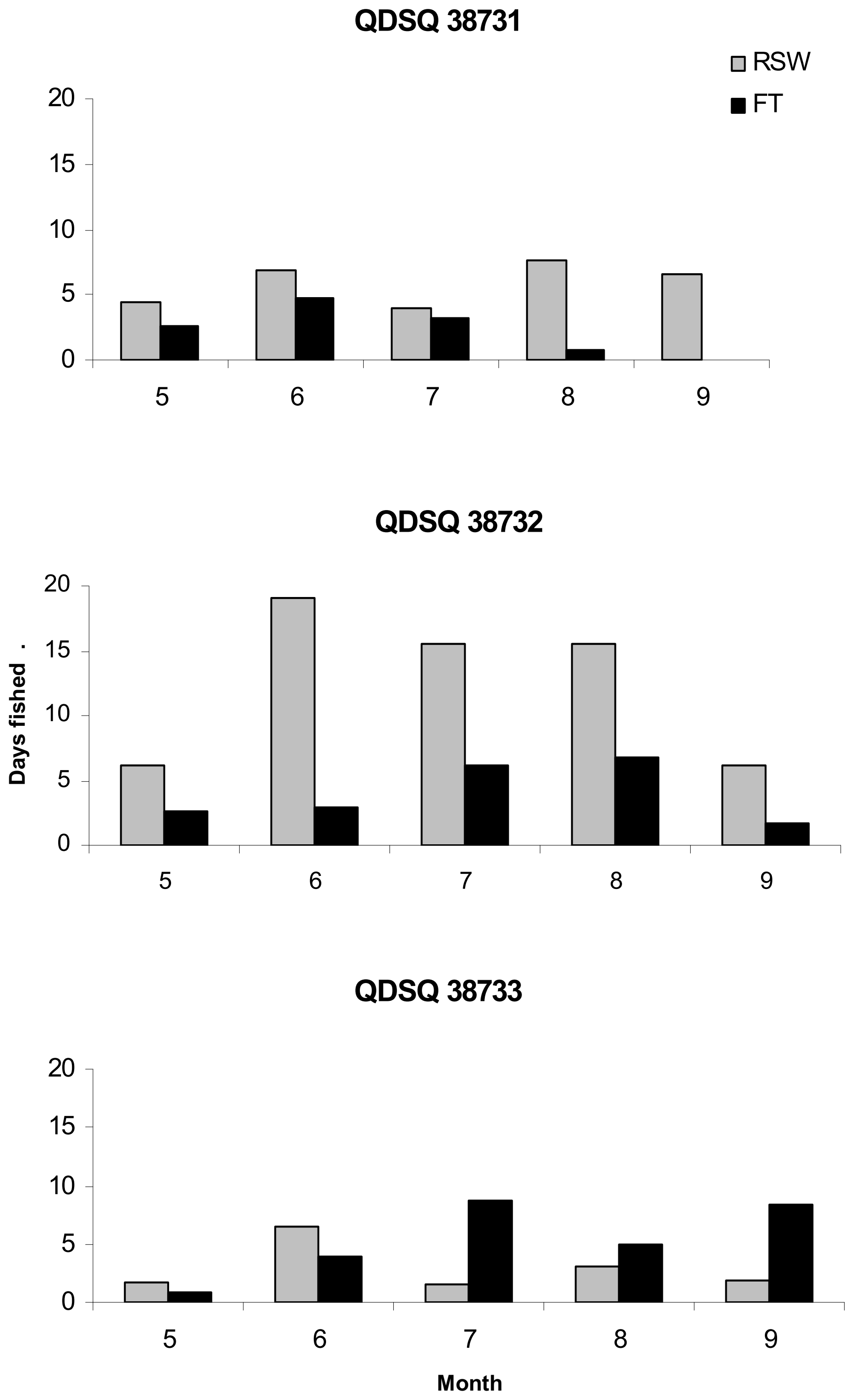

Figure C18. Effort (days fished), by fleet sector and month, in quarter-degree squares that were consistently fished during the 2004 *Illex* fishery. FT represents freezer trawlers and RSW represents refrigerated seawater system trawlers.

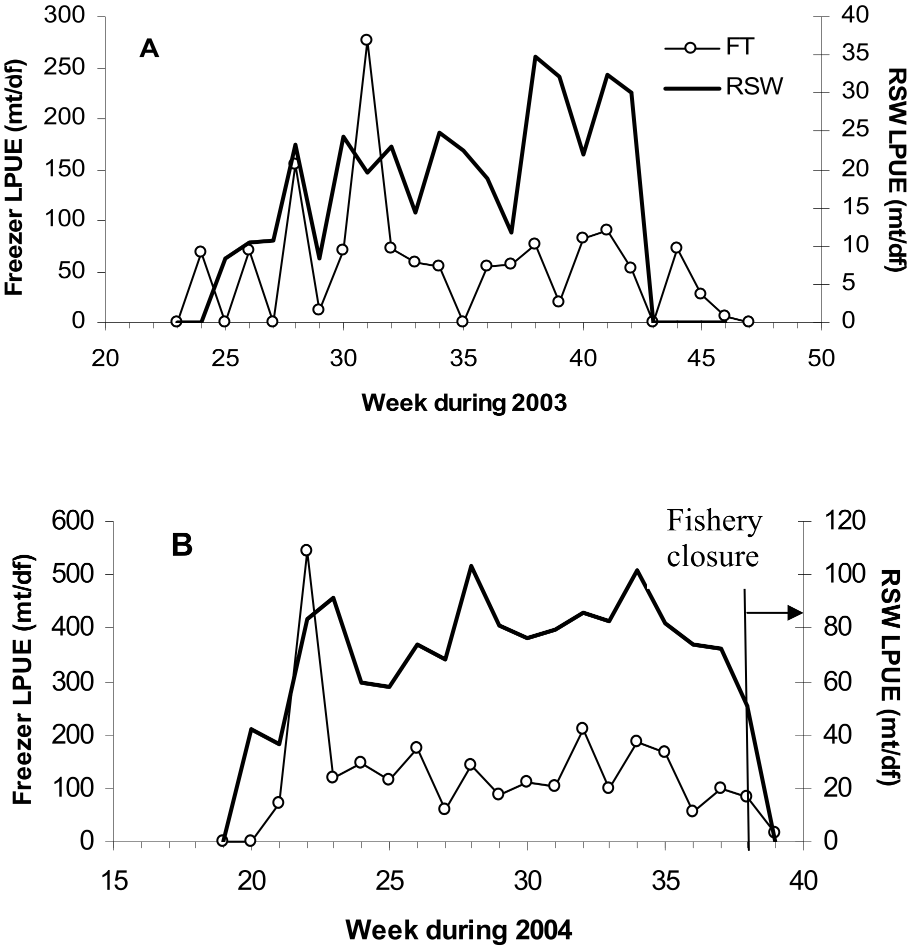

Figure C19. Weekly trends in nominal landings per unit effort (mt/day fished), by fleet sector, in the *Illex illecebrosus* fishery during (A) 2003 and (B) 2004. FT represents freezer trawlers and RSW represents refrigerated seawater system trawlers.

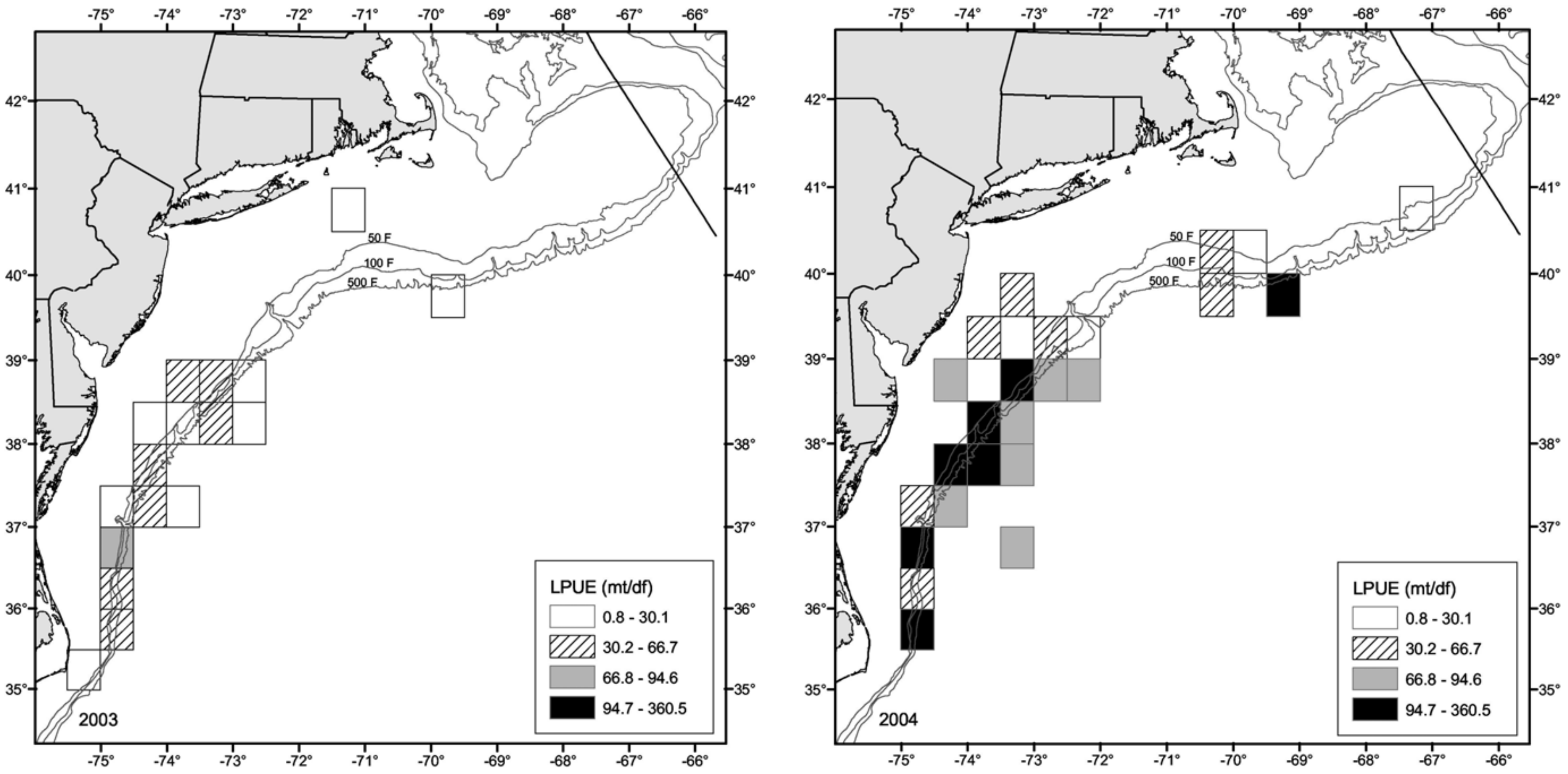

Figure C20. Nominal landings per unit of effort (mt/day fished), by quarter-degree square, for bottom trawlers participating in the *Illex illecebrosus* fishery during 2003 and 2004.

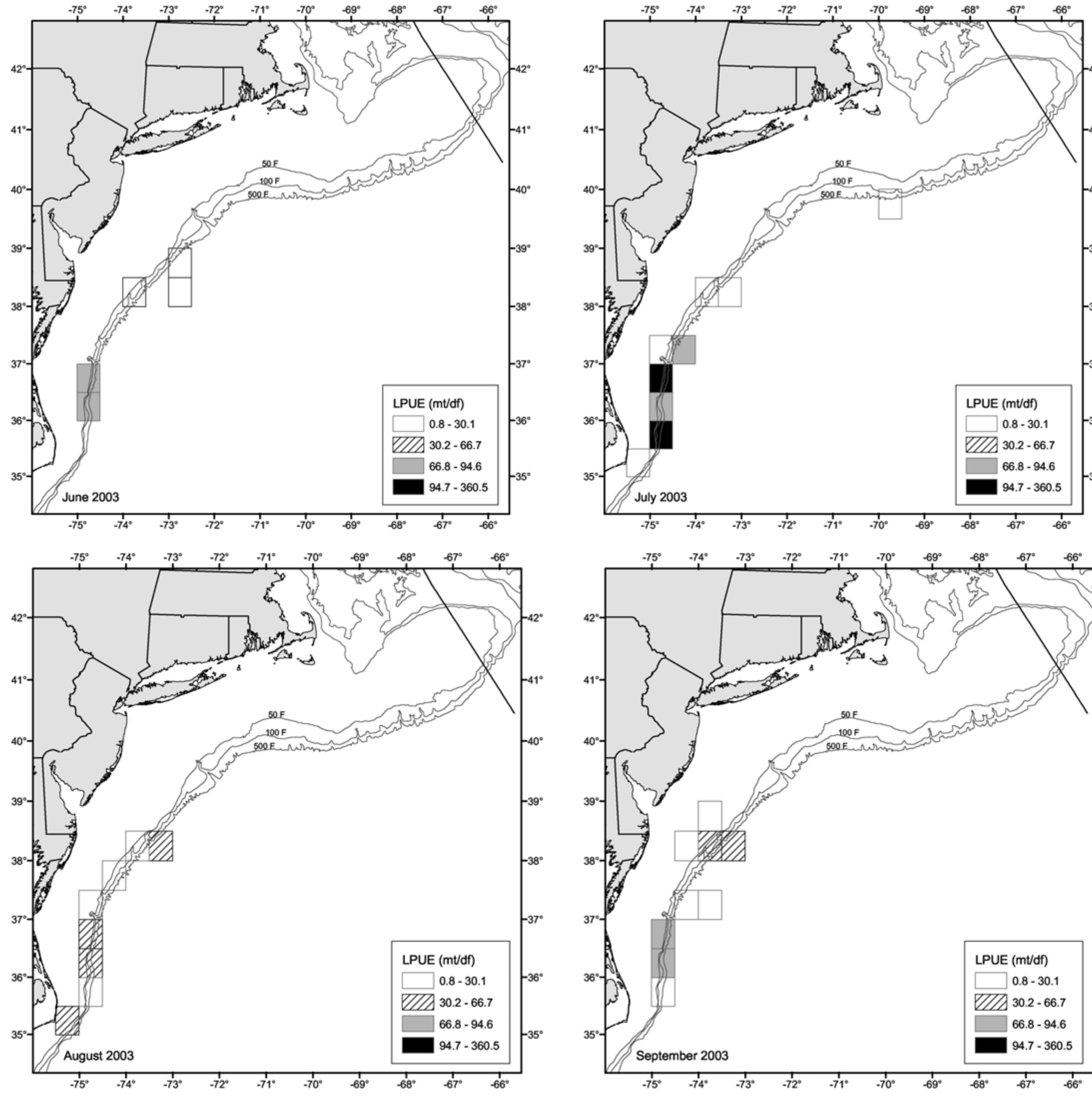

Figure C21. Monthly distribution of nominal landings per unit of effort (mt/days fished), by quarter-degree square, for bottom trawlers participating in the *Illex illecebrosus* fishery during June-October, 2003.

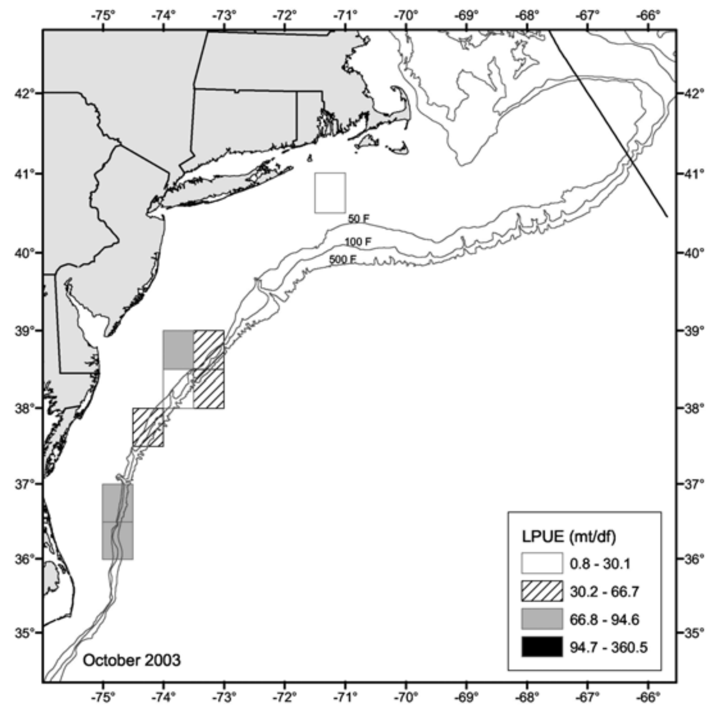

Figure C21. continued

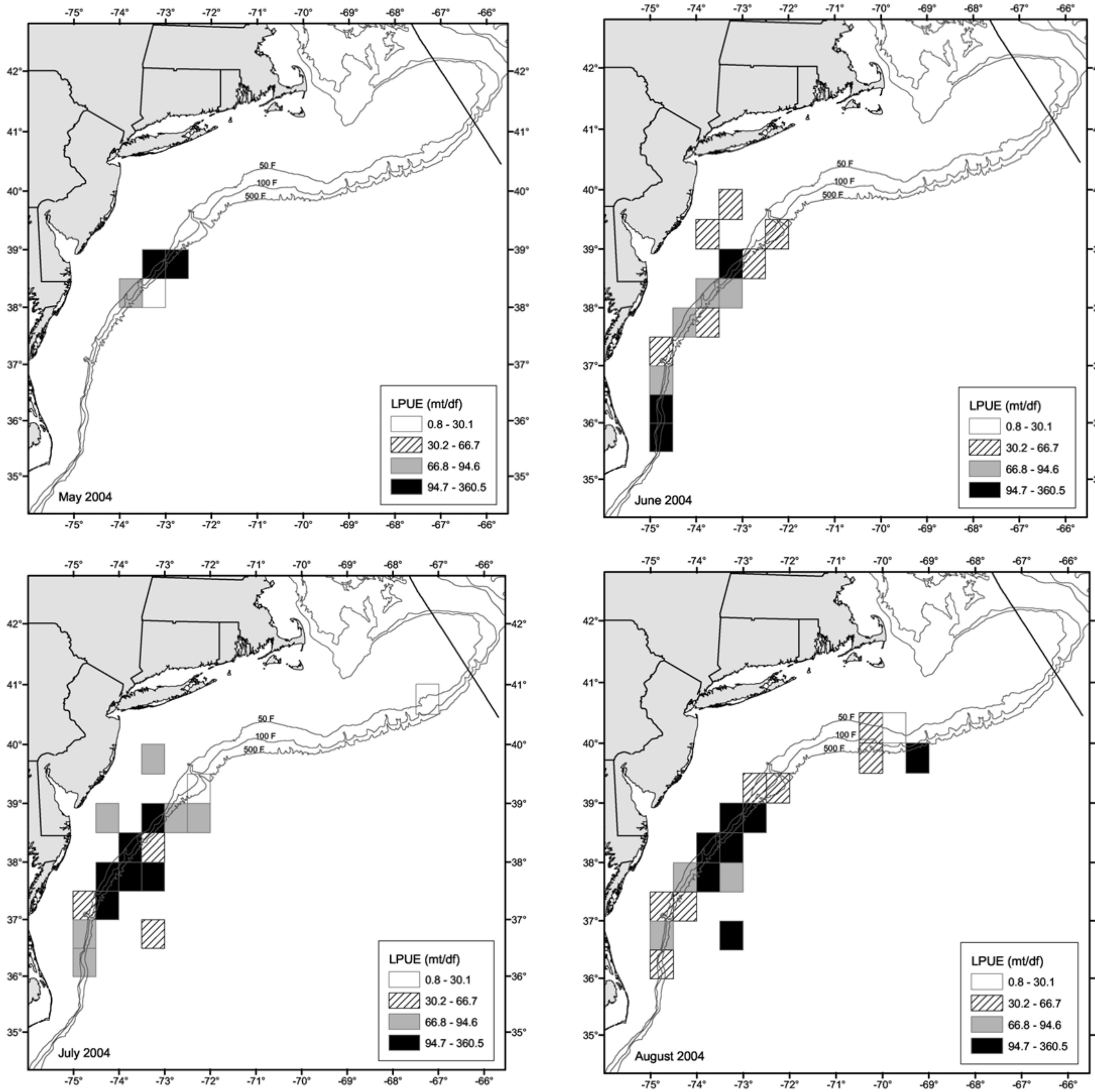

Figure C22. Monthly distribution of nominal landings per unit of effort (mt/days fished), by quarter-degree square, for bottom trawlers participating in the *Illex illecebrosus* fishery during May-September, 2004.

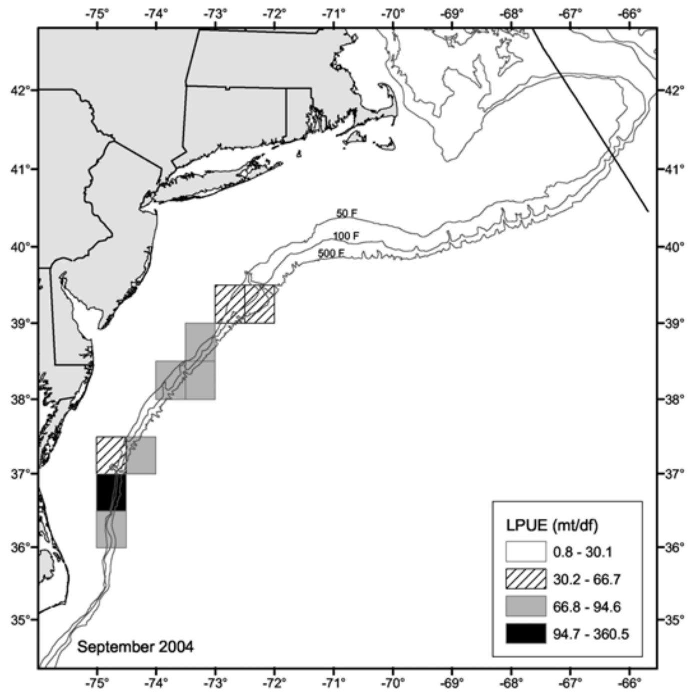

Figure C22. continued

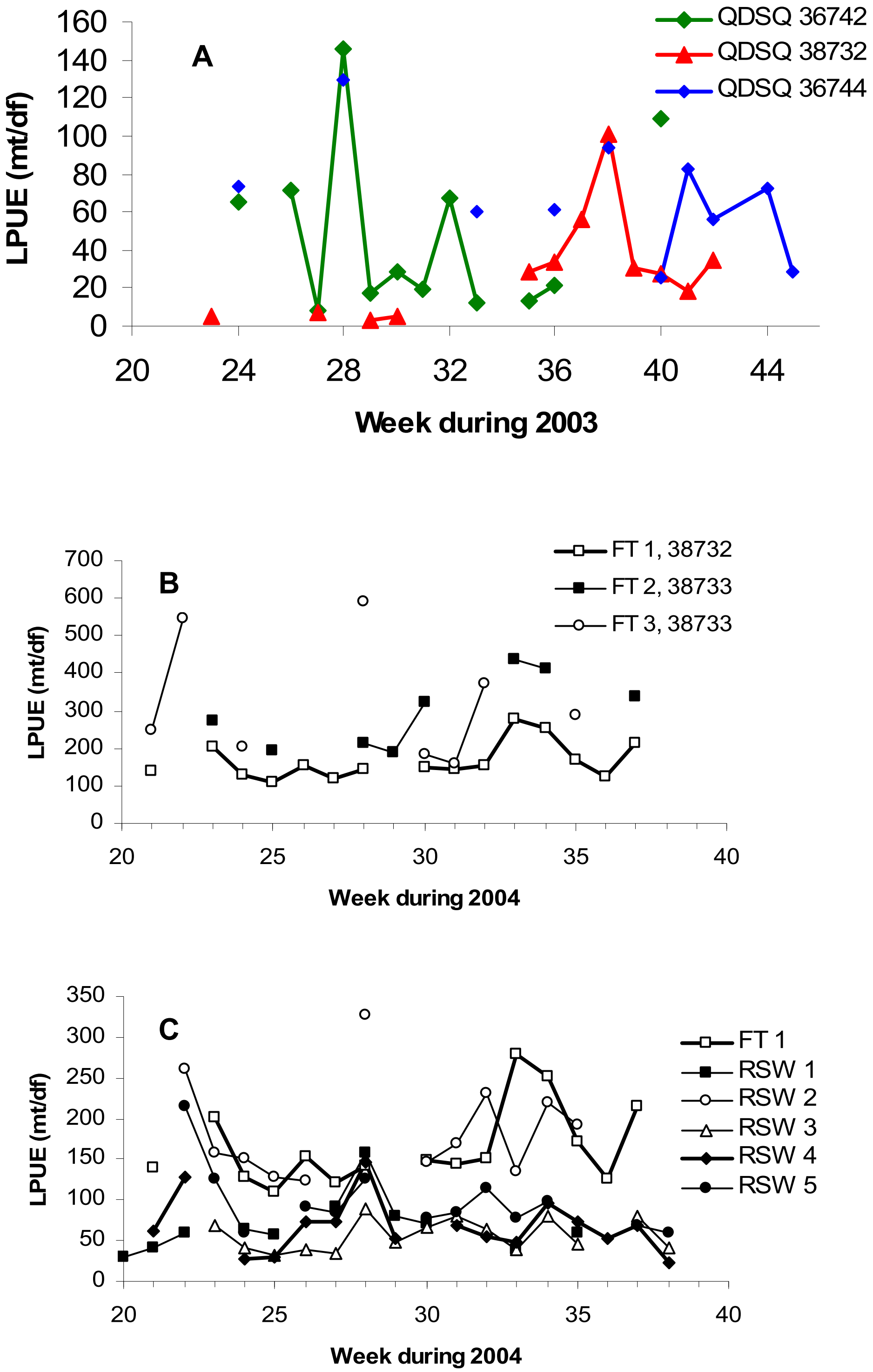

Figure C23. Example of (A) a sequential rise and fall pattern indicated by nominal LPUE for three quarter-degree squares fished by the *Illex* fleet during 2003 and examples of weekly fishing patterns (B) for freezer trawlers quarter-degree squares 38733 and 38732, and (C) for freezer trawlers versus RSW boats in square 38733 during 2004.

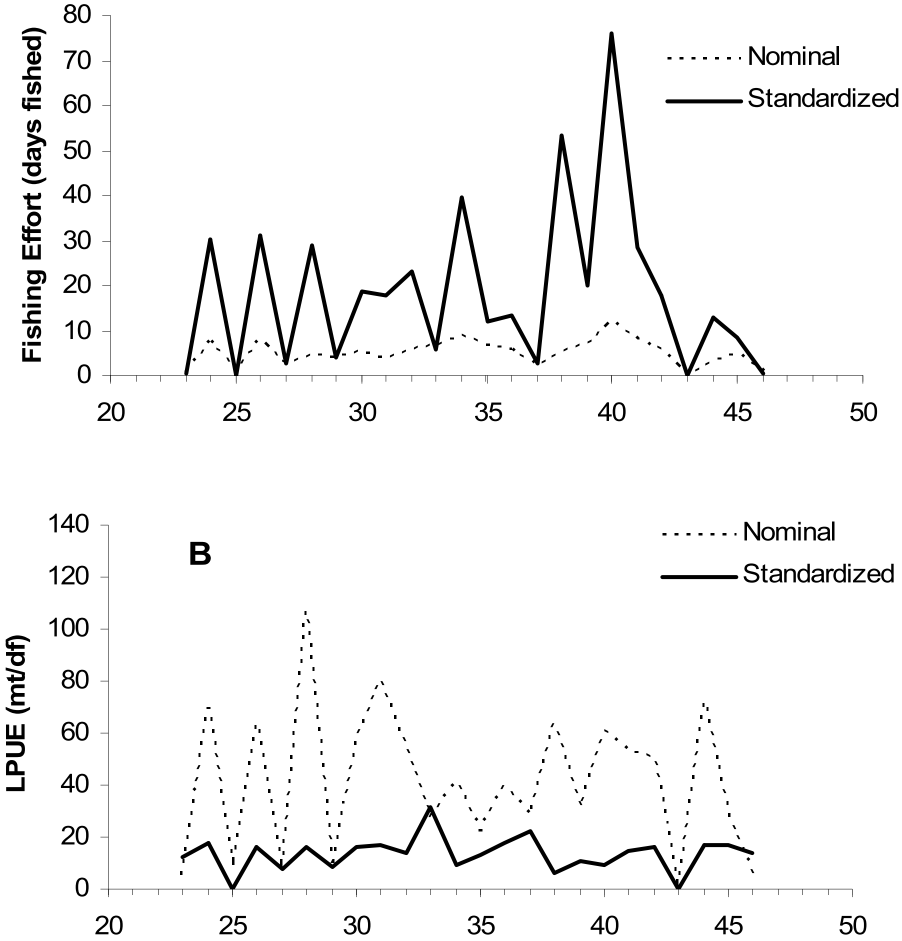

Figure C24. Weekly trends in nominal and standardized (A) fishing effort (df) based on Vessel Trip Report data and (B) LPUE (mt/df) computed from landings and effort data from the VTR Database for 2003.

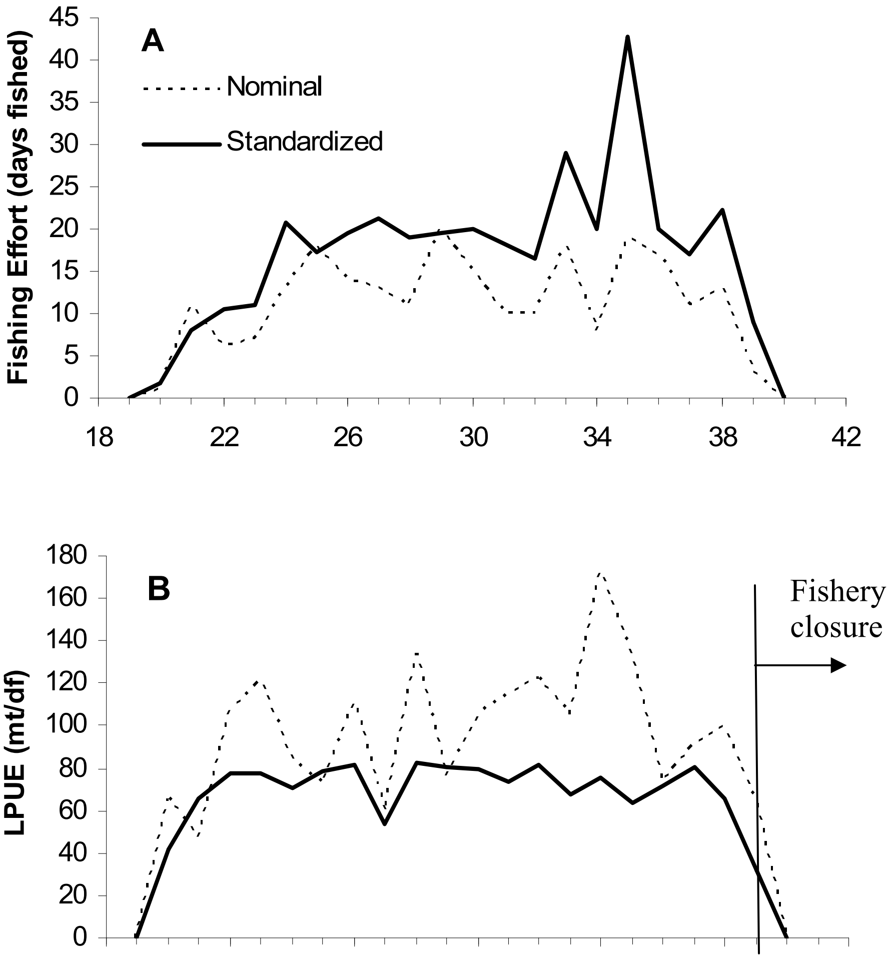

Figure C25. Weekly trends in nominal and standardized (A) fishing effort (df) based on Vessel Trip Report data and (B) LPUE (mt/df) computed from prorated landings from the Weighout Database and effort data from the VTR Database for 2004.

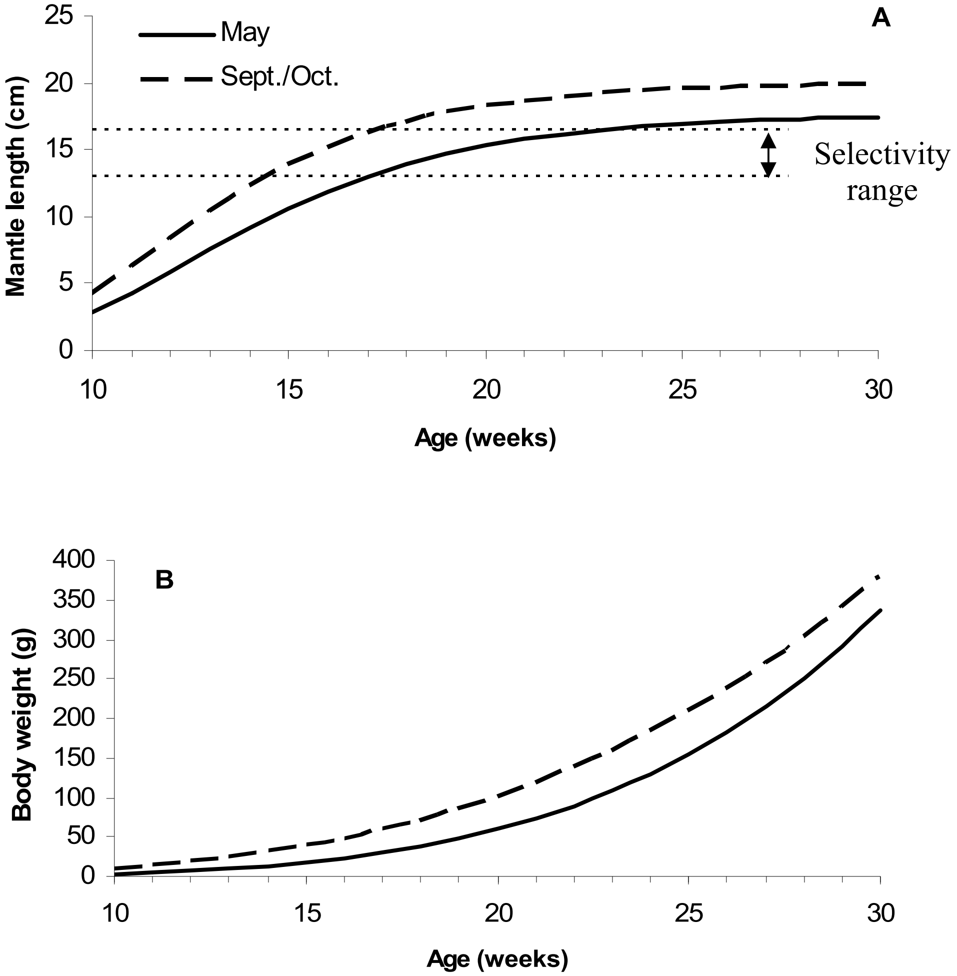

Figure C26 Growth rates of female *Illex illecebrosus* in May versus September/October, during 2000, in terms of (A) length and (B) body weight. The selectivity range shown represents the length range encompassing partial to full selectivity by the fishery and was derived by converting *Illex* lengths from the directed fishery, during 1999-2002, to ages using a weight-at-age relationship from a May 2000 *Illex* survey (Hendrickson 2004).

APPENDIX C1: Comments from external reviewer, Lynne Purchase (Renewable Resources Assessment Group, Imperial College London, England), 10/3/05 Working Group meeting

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General Comments

The purpose of this workshop was to review data and methodology available for an assessment the *Illex illecebrosus* stock in advance of the future SARC 42 meeting. This document records my observations as an outside observer on the conduct, conclusions drawn and recommendations for future work made from this working group in order to finalise the assessment and supporting data at the next subcommittee stage. Whilst noting that the data from this fishery does not lend itself to the 'standard' squid assessment methodologies, what emerged from presentation and discussion between scientists and representatives of the industry at the working group meeting was a comprehensive, coherent and rigorous synthesis of both commercial and research data in order to summarise and report on current understanding of stock status within a precautionary approach to the fishery.

Specific comments - data characteristics of fishery

Stock distribution, its range, and environmental factors affecting both were clearly defined and presented. The performance pattern within the fishery is a result of the timing and extent of the feeding migration into shelf waters and subsequent spawning migration off the shelf into deeper waters. (A spawning site for the stock was found during the May 2000 survey on the continental shelf.)

The position of the US EEZ stock (NAFO subareas 5 and 6) as a component of a larger management unit encompassing NAFO subareas 3 to 6 was apparent from landings statistics summarised over the history of the fishery since 1963. It was noted that a closure had occurred in the 2004 fishery since the TAC (24,000mt) was reached and that in order to ensure continued sustainability of the stock, adequate spawner escapement from all fishery areas is required.

Length and weight of samples from landings appear to indicate and increasing trend since 2000 when it was noted that animals were smaller and weighed less than in earlier years. It would be beneficial to obtain corresponding information on maturity from these samples in order to ascertain the presence of more than one cohort in the fishery since it is known that recruitment occurs in most months. This could be facilitated either by the training of observers and/or provision of frozen samples to NEFSC for analysis.

Specific comments - assessment models

Assessment of this stock in the context of estimation of absolute stock biomass or fishing mortality rate has not been possible; this is because the DeLury depletion-'no recruitment' type model has proven inappropriate, given observed trends in LPUE within the data from the fisheries. The autumn bottom trawl surveys do not cover the entire habitat range for the stock and so survey indices are not representative, although they do indicate a relative index of spawner escapement. Accordingly, per-recruit models and supporting analyses have and continue to be developed in order to provide biological reference points in order to minimise recruitment overfishing and to ensure sufficient escapement. Key to this development are egg- and yield-per-recruit models in which non-spawning and spawning natural mortality is accounted for explicitly.

This represents a new approach compared to the assumption of constant natural mortality for animals of all ages adopted in most other cephalopod assessments in which fishing takes place on a spawning population. Whilst the 'trigger' for onset of spawning maturity remains largely unknown, this approach reflects the observation that within semelparous species, such as *Illex*, it is the older individuals that are most likely to become mature, to spawn and then die. Far from being constant, it is much more the case that natural mortality increases over the range of ages at which spawning occurs.

The age-based cohort model developed for estimating spawning mortality (maturation-mortality model) and application of these mortalities within per-recruit models (which are highly sensitive to assumptions about natural mortality) for *Illex illecobrosus* was presented comprehensively with detailed supporting analysis.

Whilst it was noted that this model has also been peer reviewed prior to publication, in the context of testing its overall robustness and general applicability, it is worth underlining the caveat that this model has been developed on the basis of age and maturity data from one survey (May, 2000). Analyses from other squid fisheries indicate that there is often significant intra- and interannual variation in growth and maturation rates. As indicated in the course of the workgroup meeting, the effect of this on the model needs further study and, in this context, it may be worth seeking out data
(*ie.,.*biological data in which age has been recorded in addition to the more usual sex, maturity, length and weight) from other, similar cephalopod fisheries. This would extend testing of this model in a cost-effective and timely manner.

The estimates of non- and spawning mortalities have been used within the 'in-season' model developed to estimate initial abundance and total fishing mortality from real-time data. Again, it appears that the use of growth and age data from the May survey is a major source of uncertainty in this method. It was noted that current simulation analyses of this 'in-season' stock assessment model should be extended to assess its performance and to highlight the need for any additional data.

A better understanding of trends in 'in-season' LPUE are important if LPUE is to be used in future monitoring of the fishery as an indicator of abundance of squid within a given fishing area. It was noted that GLM analysis undertaken to standardise effort data within the model required further development and investigation; problematic in this case was the differing behaviour of the two vessel types in terms of trip duration and attributing landings to specific dates; it is possible that repeating this analysis on a time-scale of two- rather than one week periods as main effects may improve the standardisation process in terms of smoothing the data. It is worth noting that effort data may not be smooth over time.

APPENDIX C2: Comments from SARC 42 Working Group meeting 2 (October 24-28, 2005)

The Working Group (WG) reviewed a comparison of the weekly *Illex* landings from the Dealer Weighout database versus the Vessel Trip Report (VTR) database for 1999-2004. During all years except 2004, the weekly landings reported in the VTR database were of similar magnitude. The WG discussed the discrepancy between the weekly landings reported in the two databases for 2004 and noted that one possible reason for the discrepancy is the increase in effort by RSW boats in 2004 in comparison to 2003. Reporting of the kept fraction of the catch by RSW captains is likely to be less accurate, because unlike freezer boats, catches are not boxed and weighed at sea. However, it was unknown whether underreporting in 2004 was greater for RSW vessels than freezer trawlers and the number of vessels from both fleet sectors increased between 2003 and 2004.

The WG noted that fewer vessels were involved in the 2003 fishery and suggested a comparison of VTR landings by vessel during 2003 and 2004 to determine whether underreporting in 2004 was due in part to a change in behavior of captains who reported accurately in 2003 or due to the addition of RSW vessels with poorer reporting accuracy.

The WG noted the possibility that part of the 2004 end-of-season decline in the number of trips after week 34 was due to a temporary shut down at one of the main *Illex* processing plants, Lund’s Fisheries, for maintenance.

The WG discussed the trends in the percentage of survey tows in which *Illex* was caught with respect to whether increases in relative abundance were associated with increases in dispersion indices. The WG noted the importance of distinguishing between changes in geographic distribution that may affect the number of positive tows and changes in abundance that would also influence the number of positive tows particularly given that the NEFSC surveys only cover a portion of *Illex* habitat.

The WG noted that R^2 value from the General Linear Models (GLM) were relatively high in comparison to GLM runs for groundfish fleets. It was suggested that a histogram or other plot of the catch rate data would be useful to judge how well the *Illex* fishery data conform to the GLM model assumption of log-normality.

The WG noted that some of the weekly and bi-weekly variability in nominal landings per unit effort (LPUE) was due to the duration of freezer trawler trips which tend to be of one to two weeks in duration with trip departure and return days that consistently occur on similar days of the week (e.g., Monday and Saturday). A suggestion was made to evaluate the use of a running average of LPUE to minimize the week-to-week noise, especially in 2003, when the catch was dominated by freezer trawlers who employ this fishing strategy.

The Working Group was concerned that the underreporting of landings in the 2004 VTR reports affect might affect the LPUE estimates for 2004 and suggested the use of the ‘week’ coefficients from the GLM to back-calculate standardized model effort.

Several models were improved and carried forward from the last assessment. These models showed improvement over the last assessment but issues of data availability and model formulation still remain. The WG agreed that continued development of the models presented is important because the approaches being used appear to be valid for this semelparous species.

The WG expressed concern about the representativeness of the maturity ogive given that it was derived from data collected in May and therefore may not describe maturity trends throughout the course of the entire fishing season The WG recommended collecting in-season age and maturity data to assess how changes in growth, maturity and recruitment t influence model output.

The WG noted that the in-season assessment model has a basic assumption that maturity is age-dependent and that selectivity is length-dependent and expressed concern about whether the age- and length-based assumptions were compatible.

The WG noted that selectivity is complicated, particularly during the latter part of the fishing season due to emigration of large females to spawn, recruitment, cannibalism, and possible increases in growth rates. This might result in a dome-shaped selectivity curve at that time. The WG noted that the late-season decline in squid size/weight has a number of competing explanations that may influence the model differentially depending on, for example, the relative importance of off-shelf migration versus spawning mortality.

The WG discussed the possibility that the in-season model may not be formulated correctly for recruitment during the fishing season and suggested that alternative methods of quantifying recruitment be examined. For example, the model could be allowed to estimate recruitment by subtracting M plus F from the initial stock size and assuming that F equals zero.

APPENDIX C3: Maturation-Natural Mortality Model

See Hendrickson and Hart (*2006*).

APPENDIX C4: Per-recruit Models

See Hendrickson and Hart (*2006*).

APPENDIX C5: In-season Assessment Model

In-season assessment model formulation and input data

An in-season stock assessment model that was reviewed at SARC 37 was deemed preliminary and subject to further testing. Additional testing of a revised version of the SARC 37 model was conducted during the current assessment using input data for 2003 and 2004 in addition to output data from simulation analyses. The model revision involved a change to the objective function as described below.

The model was designed to estimate weekly stock size and fishing mortality rates of the *Illex* population (in numbers) on the U.S. shelf according to the equation:

$$N_{t+1} = N_t \exp(-Z) + r_t \exp(-M_{NS}),$$

where N_t is the population numbers in week t, Z is total mortality, r_t is recruitment to the exploitable size classes in week t, and M_{NS} is natural mortality due to causes other than spawning (e.g., predation). The predicted catch $\hat{C}_t$ (in numbers) in week t was calculated using the catch equation:

$$\hat{C}_{t+1} = N_t F_t\ [1\text{-}\exp(-Z)]/Z$$

The weekly fishing mortality rate, F_t, was calculated as:

$$F_t = qS_tE_t$$

where S_t represents the proportion of N_t that is selected by the fishery, E_t is the estimated effort in week t, and q is a constant. Weekly effort (days fished) was computed as the sum of the product of the average tow duration and the number of tows conducted per trip based on data reported by fishermen in the Vessel Trip Report database. Effort was assumed to be proportional to fishing mortality and was standardized according to the methods described in the above section on fishery LPUE. The aggregated length composition from the landings was used in the calculations presented above.

Individual squid lengths were used for the following purposes:

(a) to calculate the selectivity function S_t (Fig. C5.1) via the equation:

$$S_t = \frac{\sum_L s_L n_{L,t}}{\sum_L n_{L,t}}$$

where s_L is the estimated selectivity of the length group L, and $n_{L,t}$ is the number of squid of length group L in week t;

(b) to estimate recruitment, which was done by applying the May 2000 growth rate for combined sexes (Hendrickson 2004) to the numbers of 13-cm squid observed in the landings (the smallest size retained by the fishery) to estimate one week of growth for these individuals. Thereafter, these lengths were divided by the proportion selected by the fishing gear.

(c) and to estimate natural mortality, where the number, $n_{a,t}$, at each age group a and week t was back-calculated from the length composition using the May 2000 growth rate for combined sexes (Hendrickson 2004). Total natural mortality, m_a (both spawning and non-spawning mortality), for each age group (in weeks) was estimated from the maturation-natural mortality model. Total natural mortality was computed as:

$$M_t = \frac{\sum_a m_a n_{a,t}}{\sum_a n_{a,t}}$$

The Gompertz growth curve used in the calculation of equations (b) and (c) above was computed from data collected during a pre-fishery *Illex* survey conducted in May 2000. However, since *Illex* grow larger as the season progresses, the asymptotic size of the May growth curve was exceeded. Nearly all of the squid caught during the last few weeks of the season consisted of lengths that exceeded the estimated maximum length observed in May. In order to address the seasonal growth issue, the maximum (asymptotic) mantle length, *a*, from the May growth curve was adjusted upward each week and estimated as the 95th percentile of the length-frequency distribution of the weekly landings.

The model estimates the initial abundance, N_0, and total fishing mortality, F_{TOT}. F_{TOT} is the sum of the weekly fishing mortality rates of fully-recruited squid for the entire fishing season and was computed as:

$$F_{TOT} = \sum_t qE_t$$

The SARC 37 version of the model estimated the values of these two quantities by minimizing a chi-square statistic:

$$\chi^2 = \sum_t (C_t - \hat{C}_t)^2 / \hat{C}_t$$

subject to the constraint

$$\sum_t C_t = \sum_t \hat{C}_t$$

where C_t is the observed catch in week t.

The revised version of the model allows for the possibility of fitting one of the maturity ogive parameters, α, together with F_{TOT} and N_0. Because there may be prior information regarding these parameters (in particular, α), and because there may be insufficient information to freely fit all three parameters simultaneously, penalty terms were added to allow for deviations from the originally estimated values, so that the new objective function is:

$$\sum_t (C_t - \hat{C}_t)^2 / \hat{C}_t + k_1(N_0 - \hat{N}_0)^2 + k_2(F_0 - \hat{F}_0)^2 + k_3(\alpha - \hat{\alpha})^2 + k_4[\sum_t C_t - \sum_t \hat{C}_t]^2$$

where N_0, F_0, and α are the prior estimates of these parameters, with posterior estimates denoted by circumflexes, and the k_i terms are weightings reflective of the confidence in these values.

In-season model results

Model runs using the 2003 data indicated that the results were sensitive to varying the initial guesses of N_0 and F_{TOT}. The results also indicated that a broad range of N_0 and F_{TOT} values were plausible because the χ^2 statistic was relatively flat over large portions of parameter space. Thus, there is considerable model uncertainty regarding the exact values of these parameters. The model fits were poor for both 2003 and 2004 and are not presented herein.

Simulation model formulation and input data

A simulation model was developed to output simulated data sets to test and calibrate the in-season assessment model. The simulation model works similarly to the per-recruit model that takes into account maturity and spawning mortality, but the simulation model also includes a term for recruitment and is a discrete (weekly) model structured by age and maturity status.

The dynamics of non-mature squid [$N_t(a)$] and mature squid [$S_t(a)$] at week t and age a (in weeks) is (excluding the plus age group):

$$N_{t+1}(a+1) = N_t(a)\exp(-M_{ns}-F_t(a)-R(a)) + r_t$$

$$S_{t+1}(a+1) = S_t(a)\exp(-M_{ns}-M_{sp}-F_t(a))$$
$$+ N_t(a)R(a)[(1-\exp(-M_{ns}-F_n-R(a)))/(M_{ns}+F+R(a))][(1-\exp(-M_{ns} - M_{sp}))/(M_{sp}+M_{ns})]$$

where r_t is recruitment in week t, F_t(a) is fishing mortality in week t on the age a squid, and M_{ns} and M_{sp} are the non-spawning and spawning natural mortality rates, and R is the maturation rate. For the plus group (age a_p),

$$N_{t+1}(a_p) = N_t(a_{p-1}) \exp(-M_{ns}-F_t(a_{p-1})-R(a_{p-1}))+ N_t(a_p)\exp(-M_{ns}-F_t(a_p)-R(a_p)) + r_t$$

$$S_{t+1}(a_p) = S_t(a_p)\exp(-M_{ns}-M_{sp}-F_t(a_p) + S_t(a_{p-1})\exp(-M_{ns}-M_{sp}-F_t(\mathrm{a}_{p-1})$$
$$+ N_t(a_p)R(a_p)[(1-\exp(-M_{ns}-F_t(a_p)-R(a_p))/(M_{ns}+F(a_p)+R(a_p))][(1-\exp(-M_{ns} - M_{sp}))/(M_{sp}+M_{ns})] +$$
$$N_t(a_{p-1})R(a_{p-1})[(1-\exp(-M_{ns}- F_t(a_{p-1})-R(a_{p-1}))/(M_{ns}+F(\mathrm{a}_{p-1})+R(\mathrm{a}_{p-1}))][(1-\exp(-M_{ns} - M_{sp})/(M_{sp}+M_{ns})]$$

Non-spawning and spawning natural mortality parameters were taken from the maturity-natural mortality model (Hendrickson and Hart, 2006) and set to $M_{ns} = 0.06$ and $M_{sp} = 0.55$ for all model runs. Fishing mortality varies by age and the same selectivity-at-age ogive used in the per-recruit models was applied in the simulation models. Landings (in numbers) C_t were calculated from the catch equation:

$$C_t\,(a) = \Sigma_a\,\{N_t(a)F_t(a)[1-\exp(-M_{ns}-F_t(a)]/\,[M_{ns}+F_t(a)] +$$
$$S_t(a)F_t(a)[1-\exp(-M_{ns}- M_{sp} -\underline{F}_t(a))]/\,[M_{ns} + M_{sp}+F_t(a)]\}$$

Catches in numbers were converted to weights using a weight-at-age relationship, for combined sexes, from the May 2000 *Illex* survey (Hendrickson 2004):

$$W(a) = \varepsilon a^{\phi},\ 1.12\mathrm{x}10^{-6},\ \phi = 3.6.$$

Simulation model runs were conducted for a fishing season of 19 weeks at various levels of constant fishing mortality, various trends in fishing mortality (increasing, decreasing, and increasing then decreasing), various levels of recruitment, and with observation noise for all variables set to 10%. With the exception of model runs 10 and 11, recruitment was assumed to be constant except for a pulse of recruits which assumed to be twice as large in weeks 7-9 as during other weeks. The outputs from the simulation model were input into the in-season assessment model to evaluate the ability of the in-season model to recover the fishing mortality and N_0 estimates from the simulations.

Simulation model results

In most cases, the in-season model was able to find excellent fits to the data. As often is the case with forward-projecting models, the estimated values of F_{TOT} and N_0 were often estimated with some error, though the product of these two quantities was typically estimated close to the simulated values (Table C5.1). Allowing the in-season model to estimate the maturity parameter with a Bayesian penalty function did not consistently improve the estimates, possibly because the model was already achieving a good fit to the simulated data. Adding noise to the simulated data only mildly worsened the ability of the in-season model to recover the original parameter estimates.

It can be concluded that if the biological and fishing processes are being modeled correctly, the in-season model can usually estimate total fishing mortality and initial abundance to within 50%, and the product of these two quantities is more accurately estimated than either of them individually.

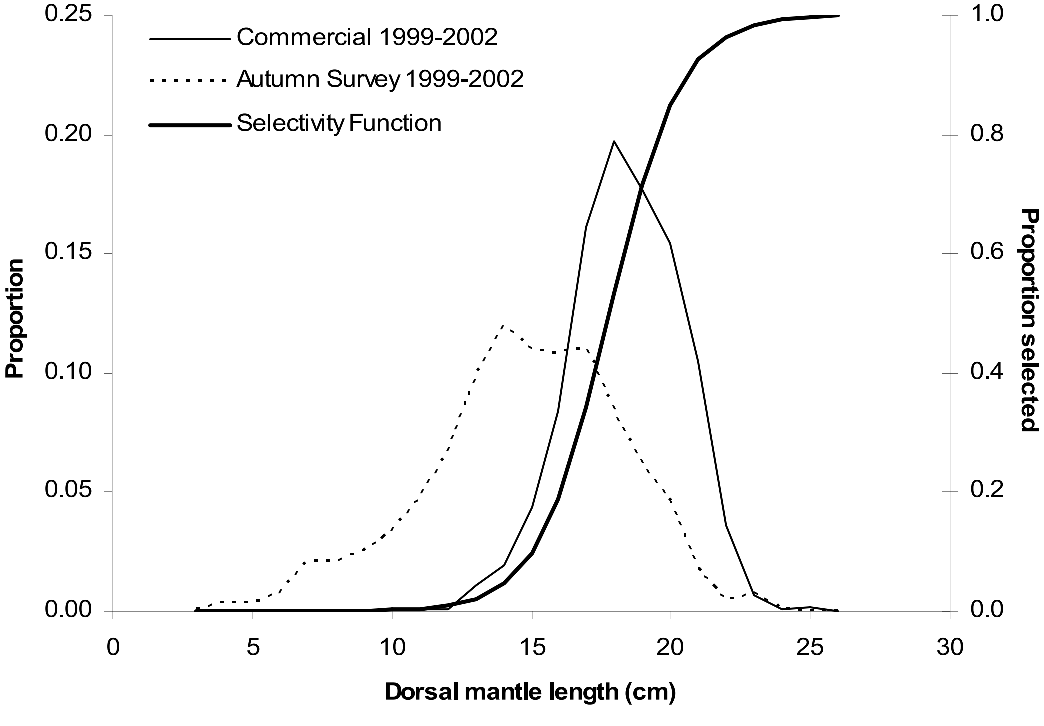

Figure C5.1. Composite length compositions, for 1999-2002, of *Illex illecebrosus* from the NEFSC autumn bottom trawl surveys (strata 1-12 and 61-76) and directed fishery landings.

Length samples from the two sources were subset to include data from similar time periods and geographic areas during each year to derive the selectivity curve shown.

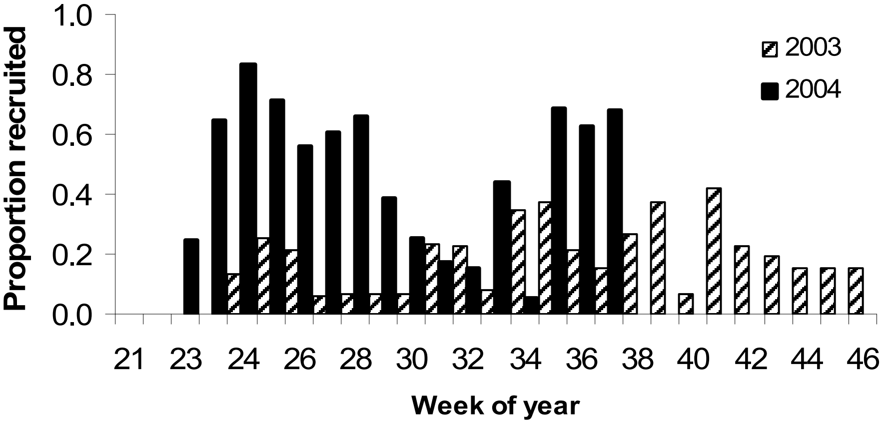

Figure C5.2. Proportion of *Illex illecebrosus* recruitment, by week, during 2003 and 2004.

Table C5.1. Results of simulation model runs under various input scenarios that included maturity ogive parameters of $\alpha = -7.93$ and $\beta = 0.0435$ (Hendrickson, 2004). F_{TOT} is the fishing mortality rate for fully-recruited squid over the entire fishing season.

Model Run	Scenario	Alpha Maturity Parameter	Penalty		Estimated			% Error		
				F_{TOT}	F_{TOT}	N_0	χ^2	F	N_0	$F*N_0$
1	Constant F	Baseline		0.95	2.53	95,428	45	166.3	61.8	1.7
	N0 = 250 mill.	alpha = -7.95	10	0.95	2.58	93,510	45	171.6	62.6	1.6
2	Constant F	Baseline		1.9	2.49	192,393	89	31.1	23.0	0.9
	N0 = 250 mill.	alpha = -8.056	10	1.9	2.88	166,668	88	51.6	33.3	1.1
3	Constant F	Baseline		3.8	4.33	219,018	178	13.9	12.4	0.2
	N0 = 250 mill.	alpha = -8.03	10	3.8	4.62	205,320	178	21.6	17.9	0.1
4	Constant F	Baseline		5.7	5.52	254,412	262	3.2	1.8	1.4
	N0 = 250 mill.	alpha = -8.09	10	5.7	5.97	235,641	261	4.7	5.7	1.3
5	Constant F	Baseline		11.4	7.92	290,473	402	30.5	16.2	19.3
	N0 = 250 mill.	alpha = -8.67	10	11.4	8.67	256,606	399	23.9	2.6	21.9
6	Constant F	Baseline-Run1		3.8	5.54	166,142	70512	45.8	33.5	3.1
	with noise	Baseline-Run2		3.8	4.59	279,201	121739	20.8	11.7	34.9
	N0 = 250 mill.	Baseline-Run3		3.8	2.71	346,602	63375	28.7	38.6	1.1
		Mean		3.8	4.28	263,982	85209	31.8	28.0	13.0
7	Two-way ramp	Baseline		5.7	5.40	244,486	649	5.3	2.2	7.4
	N0 = 250 mill.	alpha = -6.99	10	5.7	2.22	685,485	357	61.1	174.2	6.8
8	Ramp up	Baseline		5.7	5.17	213,293	502	9.3	14.7	22.6
	N0 = 250 mill.	alpha = -7.25	10	5.7	2.90	451,533	164	49.1	80.6	8.1
9	Ramp down	Baseline		5.7	5.43	285,165	294	4.7	14.1	8.7
	N0 = 250 mill.	alpha = -7.84	10	5.7	5.17	297,526	290	9.3	19.0	7.9
10	Constant F	Baseline		5.7	7.05	190,362	347	23.7	23.9	5.8
	Low recruits	alpha = -8.89	10	5.7	8.99	150,206	304	57.7	39.9	5.2
11	Constant F	Baseline		5.7	4.55	448,721	3093	20.2	79.5	43.3
	High recruits	alpha = -10.55	10	5.7	7.86	252,476	2607	37.9	1.0	39.3