Northeast Fisheries Science Center Reference Document 02-06

34th Northeast Regional Stock Assessment Workshop (34th SAW)

Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

April 2002

Recent Issues in This Series:

01-09 **Results of a Field Collection of Biopsy Samples from Coastal Bottlenose Dolphin in the Mid-Atlantic.** By J. Nicolas, D.C. Potter, C.W. Potter, and P.E. Rosel. July 2001.

01-10 **Assessment of the Georges Bank Atlantic Cod Stock for 2001.** By L. O'Brien and N.J. Munroe. [A report of the 4th Transboundary Resources Assessment Committee Meeting.] July 2001.

01-11 **Protocol and Guide for Estimating Nucleic Acids in Larval Fish Using a Fluorescence Microplate Reader.** By E.M. Caldarone, M. Wagner, J. St. Onge-Burns, and L.J. Buckley. July 2001.

01-12 **Northeast Fisheries Science Center Publications, Reports, and Abstracts for Calendar Year 2000.** By L. Garner and J.A. Gibson. August 2001.

01-13 **Elemental Composition of Fish Otoliths: Results of a Laboratory Intercomparison Exercise.** By V.S. Zdanowicz. September 2001.

01-14 **Identification of Seasonal Area Management Zones for North Atlantic Right Whale Conservation.** By R.L. Merrick, P.J. Clapham, T.V.N. Cole, P. Gerrior, and R.M. Pace, III. October 2001.

01-15 **Bycatch Estimates of Coastal Bottlenose Dolphin (*Tursiops truncatus*) in U.S. Mid-Atlantic Gillnet Fisheries for 1996 to 2000.** By D.L. Palka and M.C. Rossman. November 2001.

01-16 **Causes of Reproductive Failure in North Atlantic Right Whales: New Avenues for Research -- Report of a Workshop Held 26-28 April 2000, Falmouth, Massachusetts.** By R.R. Reeves, R. Roland, and P.J. Clapham, editors. November 2001.

01-17 **Collected Abstracts of the Northeast Fisheries Science Center's Seventh Science Symposium, Westbrook, Connecticut, December 11-13, 2001.** By R. Mercaldo-Allen, J. Choromanski, M.S. Dixon, J.B. Hughes, D.R. Lanyon, C.A. Kuropat, C. Martin, and J.J. Ziskowski, compilers. December 2001.

01-18 **Report of the 33rd Northeast Regional Stock Assessment Workshop (33rd SAW): Stock Assessment Review Committee (SARC) Consensus Summary of Assessments.** [By Northeast Regional Stock Assessment Workshop No. 33.] December 2001.

01-19 **Report of the 33rd Northeast Regional Stock Assessment Workshop (33rd SAW): Public Review Workshop.** [By the 33rd Northeast Regional Stock Assessment Workshop.] December 2001.

01-20 **Assessment of 19 Northeast Groundfish Stocks through 2000: A Report to the New England Fishery Management Council's Multi-Species Monitoring Committee.** By Northern Demersal and Southern Demersal Working Groups, Northeast Regional Stock Assessment Workshop. December 2001.

02-01 **Workshop on the Effects of Fishing Gear on Marine Habitats off the Northeastern United States, October 23-25, 2001, Boston, Massachusetts.** By Northeast Region Essential Fish Habitat Steering Committee. February 2002.

02-02 **The 2001 Assessment of the Gulf of Maine Atlantic Cod Stock.** By R.K. Mayo, E.M. Thunberg, S.E. Wigley, and S.X. Cadrin. [A report of the 33rd Northeast Regional Stock Assessment Workshop.] March 2002.

02-03 **An Age-Structured Assessment Model for Georges Bank Winter Flounder.** By J.K.T. Brodziak. [A report of the 34th Northeast Regional Stock Assessment Workshop.] March 2002.

02-04 **Re-Evaluation of Biological Reference Points for New England Groundfish.** By Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. March 2002.

02-05 **Biological Characteristics, Population Dynamics, and Current Status of Redfish, *Sebastes fasciatus* Storer, in the Gulf of Maine - Georges Bank Region.** By R.K. Mayo, J.K.T. Brodziak, M. Thompson, J.M. Burnett, and S.X. Cadrin. [A report of the 33rd Northeast Regional Stock Assessment Workshop.] April 2002.

Northeast Fisheries Science Center Reference Document 02-06

A Report of the 34th Northeast Regional Stock Assessment Workshop

34th Northeast Regional Stock Assessment Workshop (34th SAW)

Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

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

April 2002

Northeast Fisheries Science Center Reference Documents

This series is a secondary scientific series designed to assure the long-term documentation and to enable the timely transmission of research results by Center and/or non-Center researchers, where such results bear upon the research mission of the Center (see the outside back cover for the mission statement). These documents receive internal scientific review but no technical or copy editing. The National Marine Fisheries Service does not endorse any proprietary material, process, or product mentioned in these documents.

All documents issued in this series since April 2001, and several documents issued prior to that date, have been copublished in both paper and electronic versions. To access the electronic version of a document in this series, go to *http://www.nefsc.nmfs.gov/nefsc/publications/series/crdlist.htm*. The electronic version will be available in PDF format to permit printing of a paper copy directly from the Internet. If you do not have Internet access, or if a desired document is one of the pre-April 2001 documents available only in the paper version, you can obtain a paper copy by contacting the senior Center author of the desired document. Refer to the title page of the desired document for the senior Center author's name and mailing address. If there is no Center author, or if there is corporate (*i.e.*, non-individualized) authorship, then contact the Center's Woods Hole Laboratory Library (166 Water St., Woods Hole, MA 02543-1026).

This document may be cited as:

Northeast Fisheries Science Center. 2002. 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. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

TABLE OF CONTENTS

MEETING OVERVIEW

The Stock Assessment Review Committee (SARC) meeting of the 34th Northeast Regional Stock Assessment Workshop (34th SAW) was held in the Aquarium Conference Room of the Northeast Fisheries Science Center's Woods Hole Laboratory, Woods Hole, MA during November 26-30, 2001. The SARC Chairman was Dr. Robin Cook, Aberdeen Marine Laboratory. Members of the SARC included scientists from the NEFSC, the Northeast Regional Office (NERO), the New England Fishery Management Council (NEFMC), the Mid-Atlantic Fishery Management Council (MAFMC), the University of Rhode Island, the Woods Hole Marine Biological Laboratory, Atlantic States Marine Fisheries Commission (ASMFC), and the Canadian Department of Fisheries and Oceans (Table 1). Support for Drs. Cook and Mohn was provided by the Center for Independent Experts, University of Miami. In addition, 52 other persons attended some or all of the meeting (Table 2). The meeting agenda is presented in Table 3.

Table 1. SAW-34 SARC Composition.

Chairman, **Robin Cook (FRS, Aberdeen, UK)**

NEFSC, NMFS Regional Office
Russell Brown, Jay Burnett
Loretta O'Brien, Bill Overholtz,
John Witzig

Regional Fishery Management Councils
Andrew Applegate, NEFMC
Richard Seagraves, MAFMC

Atlantic States Marine Fisheries Commission/States:
Megan Gamble, ASMFC - Gary Nelson, MA

Other experts:
Joseph DeAlteris (URI), **Roger Hanlon (MBL)**
Bob Mohn (DFO/BIO, Halifax)
Advisors:
Kathy Downey, Jack Jones,
Robert Lane, Maggie Raymond

Opening

Dr. Terrence Smith, Stock Assessment Workshop (SAW) Chairman, welcomed the meeting participants and briefly reviewed the overall SAW process. Dr. Cook reviewed the agenda and discussed the conduct of the meeting.

Table 2. List of Participants

NMFS, Northeast Fisheries Science Center

Frank Almeida
John Boreman
Jon Brodziak
Steve Cadrin
Peter Chase
David Curelli
Michael Fogarty
Wendy Gabriel
Lisa Hendrickson
Devorah Hart
Joe Idoine
Larry Jacobson
Ambrose Jearld
Chad Keith
Han-Lin Lai
Kathy Lang
Chris Legault
Jason Link
Ralph Mayo
Henry Milliken
Steve Murawski
Paul Nitschke
Paul Rago
Anne Richards
Marjorie Rossman
Fred Serchuk
Gary Shepherd
Pie Smith
Terry Smith
Katherine Sosebee
Lorraine Spenle
Sandra Sutherland
Mark Terceiro
Michelle Thompson
Jim Weinberg
Susan Wigley
Amy Wittingham

NEFMC/ASMFC/States/Industry

Sarah Babson-Pike, NERO
Steve Correira, MA
Steve Gorniak, Cornell
Phil Haring, NEFMC
Jill Jennings, Observer
Bob Johnson, MA
Jeremy King, MA
Albert Leo, Cornell
Leslie Anne McGee, NEFMC
J.J. Maguire, Industry
Garth Peterson, Congressional
David Pierce, MA
Eric Powell, Industry
John Quinlan, WHOI
Mark Simonitsch, Industry

Table 3. Agenda of the 34th Northeast regional Stock Assessment Workshop (SAW-34) Stock Assessment Review Committee (SARC) meeting.

Aquarium Conference Room
NEFSC Woods Hole Laboratory
Woods Hole, Massachusetts
November 26-30, 2001
AGENDA

TOPIC	WORKING GROUP & PRESENTER(S)	SARC LEADER	RAPPORTEUR(S)
MONDAY, 26 November(1:00 - 5:30 PM)........			
Opening			
Welcome	**Terry Smith**, **SAW Chairman**		P. Smith
Introduction	**Robin Cook, SARC Chairman**		
Agenda			
Conduct of meeting			
Georges Bank winter flounder (B)	L. Hendrickson	W. Overholtz	P. Nitschke
Informal reception (**6:00 PM**) at SWOPE Building (Marine Biological Laboratory)			
TUESDAY, 27 November (8:30 AM - 6:00 PM)........			
Goosefish (C)	R. A. Richards	R. Brown	C. Legault
WEDNESDAY, 28 November (8:30 AM - 5:00 PM)........			
Loligo (A)	L. Jacobson H. Lai J. Brodziak	B. Mohn	G. Shepherd
THURSDAY, 29 November (8:30 AM - 6:00 PM)........			
Review Advisory Reports and Sections for the SARC Report			
FRIDAY, 30 November (8:30 AM - Noon PM)........			
SARC comments, research recommendations, and 2nd drafts of Advisory Reports			
Other business		P. Smith	

The Process

The Northeast Coordinating Council, which guides the SAW process, is composed of the executives of the five partner organizations responsible for fisheries management in the Northeast Region (NMFS/Northeast Fisheries Science Center, New England Fishery Management Council, Mid-Atlantic Fishery Management Council, and the Atlantic States Marine Fisheries Commission). Working groups assemble the data for assessments, decide on methodology, and prepare documents for SARC review. The SARC members have a dual role; panelists are both reviewers of assessments and drafters of management advice. More specifically, although the SARC's primary role is peer review of the assessments tabled at the meeting, the Committee also prepares a report with advice for fishery managers contained in the *34th SAW Advisory Report*.

Assessments for SARC review were prepared at meetings listed in Table 4.

Table 4. SAW-34 Working Group meetings and participants.

Working Group and Participants	Meeting Date	Stock/Species
Southern Demersal Working Group J. Brodziak, NEFSC R. Brown, NEFSC S. Cadrin, NEFSC L. Hendrickson, NEFSC R. Mayo, NEFSC P. Nitschke, NEFSC L. O'Brien, NEFSC K. Sosebee, NEFSC M. Terceiro, NEFSC (Chair) S. Wigley, NEFSC	29-30 October, 2001	Georges Bank winter flounder
Southern Demersal Working Group A. Applegate, NEFMC K. Downey, Industry H. Franco, Indusy P. Haring, Industry P. Kavanagh, Industry C. Legault, NEFSC J. Maguire, Industry J. Mahoney, NERO N. McHugh, NEFSC H. Milliken, NEFSC A. Richards, NEFSC G. Shepherd, NEFSC T. Smith, NEFSC K. Sosebee, NEFSC M. Terceiro, NEFSC M. Vassal, Industry A. Wittingham, NEFSC S. Wigley, NEFSC	31 October and 2 November, 2001	Goosefish

Working Group and Participants	Meeting Date	Stock/Species (continued)
Invertebrate Subcommittee J. Brodziak, NEFSC S, Cadrin, NEFSC C. Glass, Manomet L. Jacobson, NEFSC (Chair) C. Keith, NEFSC H. Lai, NEFSC G. Monsen, Industry E. Powell, Industry P. Rago, NEFSC R. Seagraves, MAFMC J. Weinberg, NEFSC	26 September, 2001 5-6, November 2001	Longfinned Squid

Agenda and Reports

The SAW-34 SARC agenda (Table 3) included presentations on assessments for Georges Bank winter flounder, mnkfish, and long-finned squid.

A chart of US commercial statistical areas used to report landings in the Northwest Atlantic is presented in Figure 1. A chart showing the sampling strata used in NEFSC bottom trawl surveys is presented in Figure 2.

SARC documentation includes two reports; one containing the assessments, SARC comments, and research recommendations (this report, the SARC Consensus Summary), and another produced in a standard format which includes the status of stocks and management advice (SARC Advisory Report). The draft reports were made available at two sessions of the SAW-34 Public Review Workshop held during regularly scheduled NEFMC and MAFMC meetings (January 15, Portsmouth NH; January 30, Secaucus NJ, respectively). The documents will be published in the NEFSC Reference Document series as the *34th SARC Consensus Summary of Assessments* and the *34th SAW Public Review Workshop* Report (the latter document includes the Advisory Report), after the Public Review Workshop sessions.

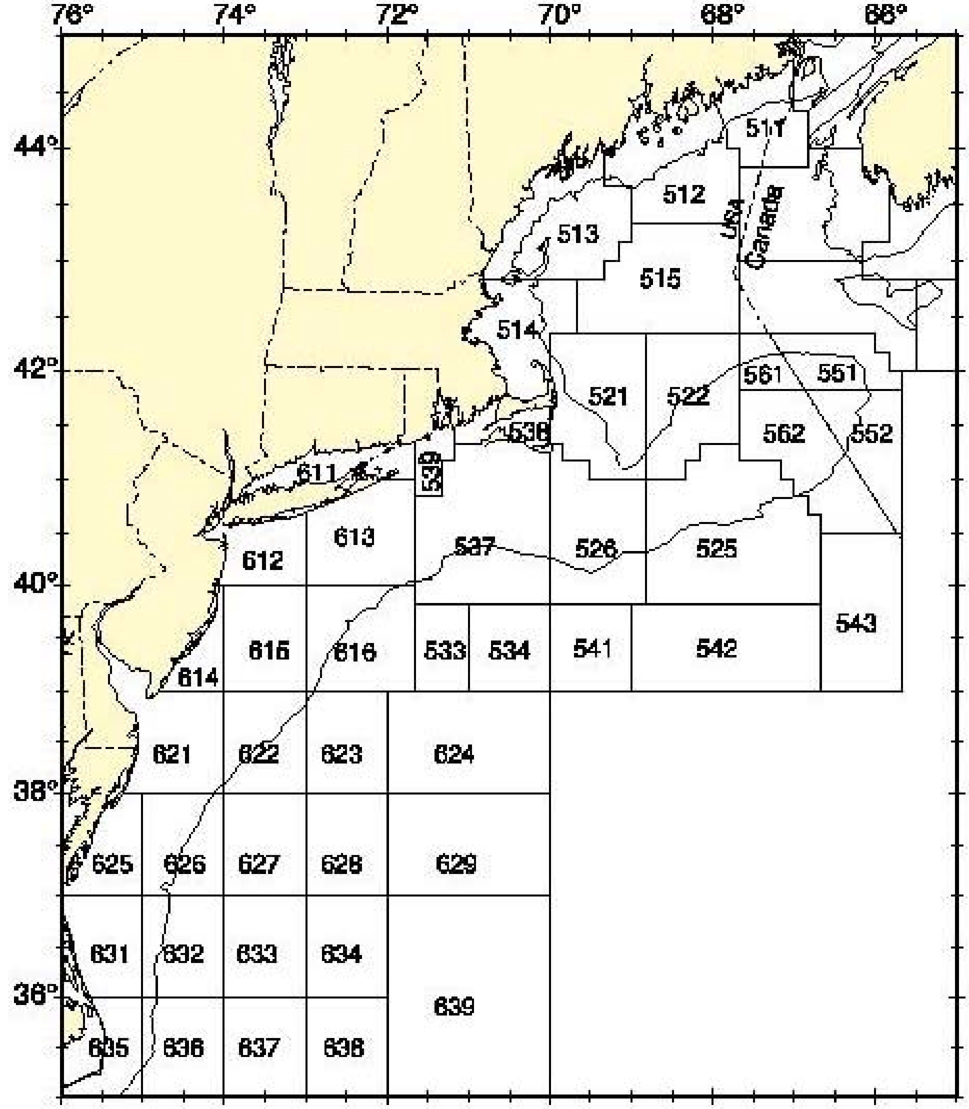


Figure 1. Statistical areas used for catch monitoring in offshore fisheries in the Northeast United States.

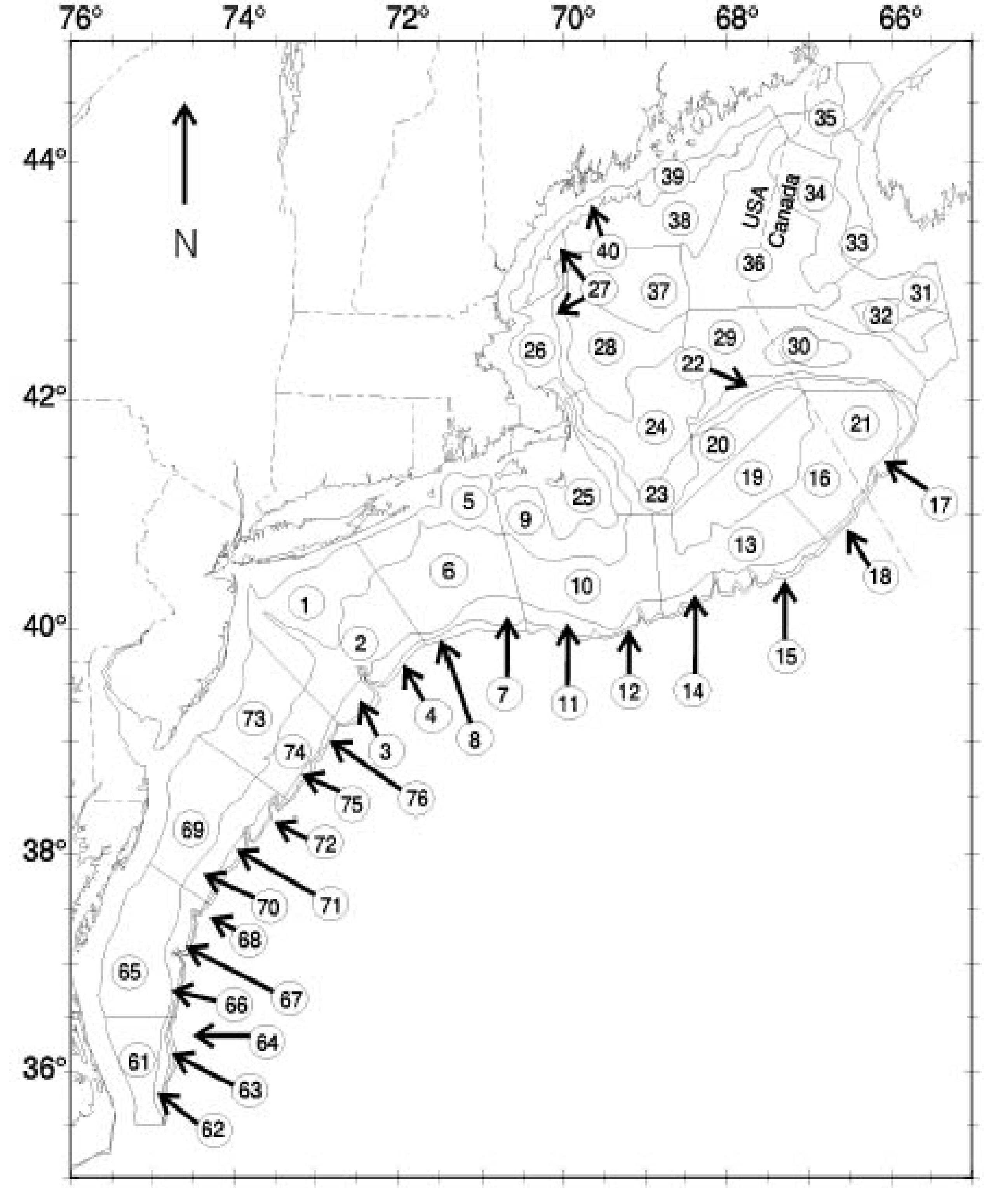


Figure 2. Offshore sampling strata used in NEFSC bottom trawl surveys.

A. LONGFIN SQUID

TERMS OF REFERENCE

1. Update fishery dependent (including discards) and fishery independent data for longfin squid.

2. Provide estimates of fishing mortality and stock biomass and characterize stock status in 2000, in absolute or relative terms, and characterize uncertainties as appropriate.

3. Update estimates of biological reference points and uncertainties, as appropriate.

EXECUTIVE SUMMARY

1) The inshore longfin squid (*Loligo pealeii*) is distributed from the Caribbean to Newfoundland, depending on season and oceanographic conditions. The stock area for this assessment is defined as wherever longfin squid are found between the northern edge of Georges Bank and Cape Hatteras. More precisely, the northern and southern boundaries of the stock are defined by survey strata used in this assessment to calculate abundance indices based on Northeast Fisheries Science Center (NEFSC) autumn bottom trawl survey data. This stock definition includes the main range of commercial exploitation. The stock area assumed in previous assessments was similar, but did not include northern Georges Bank.

2) Longfin squid are short-lived (less than 11 months) and grow rapidly. Males grow faster and reach larger size. Spawning occurs year round. Substantial new information about life history and biology is available, particularly in the areas of age and growth, geographic distribution and reproductive biology. Much of the new information is used in this assessment.

3) In the northeast, longfin squid move offshore and probably south during late autumn and then inshore and probably north during the spring and early summer.

4) The peak length body size of longfin squid in landings is 12-15 cm dorsal mantle length (DML) but appreciable amounts are landed out to about 30 cm DML.

5) Abundance information used in this assessment include bottom trawl survey data for NEFSC autumn surveys during 1967-2001, NEFSC spring surveys during 1968-2001, NEFSC winter surveys during 1992-2001, and Massachusetts inshore spring surveys data during 1978-2001. Standardized commercial landings per unit effort (LPUE) for winter and summer fisheries during 1983-1993 are also used. None of the bottom trawl surveys cover the entire range of the stock although coverage is best during the NEFSC autumn survey.

6) Longfin squid generally move towards the bottom during the day. Survey data used in this assessment are adjusted to daytime equivalents based on estimated diel correction factors.

7) All surveys indicate relatively low longfin squid biomass during the mid- to late 1990's, increases to moderate or high levels by 2000 with modest declines in all but the autumn survey during 2000-2001. The autumn survey increased to near record levels during 2000-2001.

8) Trends in the autumn survey are generally most reliable for longfin squid because the autumn survey has the highest catch rates, lowest CV's, and best overlap between survey strata and squid distribution.

9) This is the first assessment for longfin squid where NEFSC autumn survey data were available for use in an assessment during the same year. NEFSC survey data were available more rapidly due to improvements in data recording and auditing at sea.

10) It is likely that environmental factors affect longfin squid catchability and catch rates in all of the bottom trawl surveys available. This hypothesis is a major topic of investigation in this assessment.

11) Bottom trawl survey data indicate increased recruitment of longfin squid since 1998.

12) Length based virtual population analysis (LVPA) for longfin squid in the winter and summer fisheries gave trends in relative biomass and fishing mortality that were similar to trend estimates by other methods. In particular, LVPA biomass estimates for longfin squid declined in the late 1990's then increased to intermediate recent levels. LVPA *F* estimates increased in the late 1990's and appear to have declined recently.

13) Feasible bounds and distributions measuring prior uncertainty for the NEFSC autumn trawl survey catchability coefficient are important parts of this assessment. Factors affecting uncertainty in catchability are the size of the effective area occupied by the squid stock, the average distance of a standard survey tow, the effective width of the survey bottom trawl, and the efficiency of the trawl for longfin squid above the ground swept by the trawl.

14) Scaled catch-survey fishing mortality estimates for longfin squid based on autumn trawl survey data were high in 1998 but declined to below average levels during 1999-2000. Trends in unscaled fishing mortality rates based on spring and winter survey data also indicate that fishing mortality rates for longfin squid declined during 1999-2001.

15) The new surplus production-modeling program (PDQ) used in this assessment has greater flexibility, and more options for characterizing uncertainty than programs used previously for longfin squid. Population dynamics calculations can be based on a conventional logistic surplus production model or a "simple" production model that does not assume a carrying capacity. In addition to survey measurement errors, PDQ accommodates process errors (natural variability) in surplus production rates and survey catchability.

16) Biomass trend data from length based virtual population analysis (LVPA) for longfin squid during winter and summer fisheries were used experimentally as abundance indices in PDQ. LVPA biomass trends are an almost independent source of information based on port sampling, growth, and longevity data that are not otherwise included in PDQ. In addition, LVPA data for longfin squid may be less affected by changes in oceanographic conditions that appear to affect catchability of longfin squid in bottom trawl surveys.

17) The most important characteristic of LVPA trend data in production modeling for longfin squid is relative stability from year to year. In the PDQ model, the stability of

LVPA information tends to counteract interannual variability in bottom trawl survey data in a way that makes estimates of biomass and B_{MSY} higher and more feasible.

18) A new hypothesis explains problems with infeasible low biomass estimates that have plagued production model estimates in stock assessments for longfin squid over the last decade. Based on experience with LVPA data and likelihood profile analysis, problems stem from the high year to year variability in bottom trawl survey data. Relatively high values in NEFSC autumn bottom trawl survey data for longfin squid in one time step, for example, tend to be followed by low values in the next time step and so on. In order to fit bottom trawl survey data, production rates have to change rapidly. To accomplish this, traditional production models (with surplus production always positive) estimate low biomass and carrying capacity for longfin squid so that moderate increases or decreases in biomass are followed by substantial decreases or increases in production rates. It is likely that high variability in bottom trawl survey data stems from oceanographic features that affect catchability.

19) Estimated production rates ρ_t for longfin squid in preliminary runs of the simple PDQ model that does not estimate carrying capacity were autocorrelated with production rates higher or lower than average for periods of 1-5 years. Some environmental variable, acting over periods of years, appears to effect either surplus production in the longfin squid stock or catchability of longfin squid in bottom trawl surveys.

20) Process errors in bottom trawl survey catchability for longfin squid, estimated in the basecase PDQ model run, were correlated across surveys and autocorrelated within surveys. Environmental variables affecting catchability or surplus production appear to act consistently on all surveys carried out within periods of 1-5 years. This suggests it may be possible to model catchability or production process errors for longfin squid in a more simple and parsimonious fashion based on variation in water temperatures or some other environmental variable.

21) Traditional per recruit models were run with updated estimates of natural mortality, growth, fishery selectivity, and maturity at age. Reference point *F*'s estimated in this assessment were lower than estimates in the last assessment.

22) It is unlikely that the overfishing is occurring in the longfin squid fishery based on a number of reference points and stock status measures.

23) It is unlikely that the longfin squid stock is overfished based on a number of reference points and stock status measures.

INTRODUCTION

The inshore longfin squid (*Loligo pealeii*) is a short lived (maximum observed age less than 11 months, Brodziak and Macy 1996, Macy and Brodziak 2001) squid distributed between the Caribbean in the south (Cohen 1976) and, depending on environmental conditions and season, as far north as Newfoundland (Dawe et al. 1990). In most years, however, they are not abundant in the Gulf of Maine and Canadian waters. South of Cape Hatteras, the geographic distribution of longfin squid overlaps with the distribution of the morphologically similar species *L. plei* (Cohen 1976). The distribution of longfin squid in the water column depends on time of day and, in most seasons, densities are highest on the bottom in the daytime (Hatfield and Cadrin in press).

The stock in this assessment is distributed at all depths were longfin squid are found between the northern edge of Georges Bank and Cape Hatteras. The northern and southern boundaries of the stock are defined more precisely by survey strata used in this assessment to calculate abundance indices based on Northeast Fisheries Science Center (NEFSC) autumn bottom trawl survey data. This stock definition includes the main range of commercial exploitation. The stock definition in all fut the previous assessments was similar, but did not include northern Georges Bank (NEFSC 1986, Cadrin and Hatfield 1999).

Relationships between the population dynamics of inshore-offshore, and northern-southern components of the longfin squid stock in this assessment are complex and not well understood. Longfin squid have complicated seasonal and annual distribution patterns (Brodziak and Macy 2001, Hatfield and Cadrin in press). Depending on season and water temperatures, they are distributed from relatively shallow near shore areas, across the continental shelf and on the upper continental slope with the largest individuals in relatively deep water (Cadrin and Hatfield in press).

In the northeast, longfin squid move offshore and probably south during late autumn, to over-winter in warmer waters along the continental shelf and possibly deeper water (Cadrin and Hatfield 1999, Brodziak and Macy 2001, Hatfield and Cadrin in press). They move inshore during the spring and early summer. Migratory patterns in deep water on the continental slope, and along the continental shelf are less well understood but probably occur.

Considerable progress has been made in characterizing average growth, maturity and other biological parameters for the longfin squid stock but the problem is a difficult one. Uncertainty is understandable and probably unavoidable because sampling is often opportunistic, the distribution of longfin squid is dynamic, schools are patchy and the stock is distributed nonrandomly with respect to size across a large area at unknown local densities.

Longfin squid grow rapidly and are sexually dimorphic with males growing faster and to larger size than females. Males may grow larger than 40 cm dorsal mantle length (DML). The largest individuals recorded in Northeast Fisheries Science Center (NEFSC) survey databases were larger than 50 cm DML. Longfin squid from the “summer hatch” (June-October) grow more rapidly than individuals from the “winter hatch” (November-May). Growth is highly variable among individuals (Brodziak and Macy 1996) and samples (Macy and Brodziak 2001). Variation among samples may be due to different sampling locations, environmental conditions in different years, seasonal effects, different hatch dates, or all of these factors (Macy and Brodziak 2001).

Female longfin squid reach 50% sexual maturity at about 21 cm DML and males reach 50% sexual maturity at about 20 cm DML (Hatfield and Cadrin, in press). Reproductive biology in longfin squid is complex (Maxwell and Hanlon 2000). Spawning occurs year round. Macy and Brodziak (2001) suggest that two spawning peaks are evident in samples from the northeast, one inshore during August-September and one elsewhere with a peak in November-December. Hatfield and Cadrin (in press) hypothesize that the majority of squid taken north of Cape Hatteras during the summer are spawned south of Cape Hatteras during the winter.

DATA

In this assessment, the "winter" quarter is January-March, "spring" is April-June, "summer" is July-September, and "autumn" is October-December. Following Cadrin and Hatfield (1999), the "summer fishery" is during the second and third quarters and the "winter fishery" is during the fourth and first quarters. In this assessment, for example, the 1998 winter fishery occurred during October 1998-April 1999. The last assessment used a different naming convention with, for example, the 1998 fishery during October 1997-April 1998. Following Macy and Brodziak (2001), the "winter hatch" for longfin squid includes individuals hatched during November-April and the "summer hatch" includes individuals hatched during May-October. All survey data are in units of either weight (kg) or numbers per standard survey tow. All survey data are adjusted to daytime equivalents using diel correction factors in Hatfield and Cadrin (in press, see below for details).

Landings

Landings data for longfin squid (Tables A1-A2 and Figure A1) during 1963-1997, with corrections for unspecified squid landings, are from Cadrin and Hatfield (1999). New landings data for 1998-2000 were from the National Marine Fisheries Service (NMFS), Northeast Region (NER) commercial fishery detail species (CFDETS) database with adjustments for unspecified squid described below. Landings data for longfin squid during January-June 2001 (without corrections for unspecified squid) were from the Interactive Voice Response (IVR) database used by NER to monitor landings of quota-managed species. IVR data probably underestimated actual landings during January-June 2001, but were the best data available. Landings data (without corrections for unspecified squid) for the second half of 2001 were assumed equal to quarterly quota allocations used to manage the longfin squid fishery (i.e. 2,941 mt total during July-September and 5,416 mt total during November-December).

Unspecified squid landings were less than 22-65 mt per year during 1998-2000 and were prorated into longfin squid and northern shortfin squid *(Illex illecebrosus)* portions based on ratios of squid landings that were identified to species during each month and year:

$$R_{m,y} = \frac{L_{Longfin,m,y}}{L_{Shortfin,m,y} + L_{Longfin,m,y}}$$

where, for example, $L_{\mathrm{Longfin,m,y}}$ was longfin squid landings during month m of year y and $R_{m,y}$ was the ratio used to prorate unspecified squid landings.

According to Cadrin and Hatfield (1999), there is substantial uncertainty in estimates of foreign landings and historical domestic landings. Accuracy of landings estimates is better beginning in 1987 due to better reporting of landings by species and prohibitions on foreign fishing (Cadrin and Hatfield 1999). There was no observer coverage of foreign fleets before 1978, and observer coverage was low in the early 1980s (Cadrin and Hatfield 1999). The relative proportion of total landings from unspecified squid landings was substantial in some years (e.g., 20% in 1983), but has been generally low since 1985 (<5%; with the exception of 1996, when 10% of total landings estimates were from unspecified records). Some landings of L. plei may be included in longfin squid catches south of Cape Hatteras, because landings are categorized to genus, not species.

Port sample length composition data (Figure A2) show that the peak length of longfin squid in landings is about 12-15 cm DML. Appreciable amounts of longfin squid are landed out to about 30 cm DML.

Discarded catch

Discarded longfin squid are generally small (<10 cm DML; Figure A3) and difficult to market. Cadrin and Hatfield (1999) concluded that discard of longfin squid is currently minor but indicated that precise estimates of discard are difficult to obtain and that discard rates likely vary by fishery, season, time of day, location and target species. In addition to reviewing published reports, Cadrin and Hatfield (1999) used data from 915 otter trawl trips in the National Marine Fisheries Service (NMFS) observer database to calculate ratios of the weight of longfin squid discarded divided by the weight of all species landed during 1989-1998. The ratios ranged 1%-14% and averaged 6%. Mesh size regulations changed in 1996 when minimum mesh sizes increased. Changes in regulations since 1997 may have reduced discard rates for longfin squid to levels below 6% of total landings.

In this assessment, observer data were used to estimate discard rates for longfin squid during trips directed at key target species during 1997-2000 (while net size regulations were unchanged). Observers determined target species for each tow by asking the captain on the vessel after the tow was completed. Target species include longfin squid because small squid may be discarded following tows that target longfin squid.

Discard estimates were calculated as the product of average landings during 1997-2000 and discard rates from observer data for 1997-2001 (Table A3). The data were collected by NMFS observers on commercial fishing boats during 1997 to mid-2000, and by Rutgers University personnel aboard five commercial boats during13 trips targeting black sea bass and scup during January-February 2001 as described by Powell et al. (2001). In most cases, the number of trips and tows was small and possibly non-representative so that the estimated discard rates, like Cadrin and Hatfield's (1999), are imprecise and possibly biased.

All available discard information was used to estimate discard rates for each target species. Butterfish are typically taken in tows directed at other species. Tows with butterfish as target species may also have been identified as trips for other target species. Our calculations may therefore overestimate the discard rate for longfin squid in directed butterfish trips, to the extent that multiple target species were identified for the same tow. No observer data was available for trips targeting Atlantic herring so discard rates for Atlantic mackerel were used instead.

Results indicate that total longfin squid discards during fishing for key target species averaged about 600 mt per year during 1997-2000. By comparison, longfin squid landings averaged about 18,000 mt per year so that the ratio of discards of longfin squid to longfin squid landings was about 0.03. The bulk of average longfin squid discards (about 500 mt per year) were from tows and trips targeting longfin squid. Of course, longfin squid are taken in tows targeting many species, including target species not in this analysis. It seem reasonable, therefore, that the estimated 3% discard rate for key target species is less than Cadrin and Hatfield's (1999) estimate for the entire bottom trawl fishery.

Landings per unit of commercial fishing effort (LPUE)

Landings per unit commercial fishing effort (LPUE) data from NEFSC (1996, Table A4 and Figure A4) were for the domestic squid fishery during the winter (October-March) of 1983-1993 and the summer (April-September) of 1981-1993. Standardized LPUE was computed as the ratio of landings and standardized fishing effort for otter trawl trips that caught at least 10% longfin squid by weight. Effort was standardized using a general linear model (GLM) with years, seasons (summer or winter), catch areas and vessel ton-classes as explanatory factors. The original effort data were collected by port agent interviews. Standard LPUE data time series were not updated because of changes in data collection procedures starting in 1994 and associated problems in measuring fishing effort and catch location for longfin squid.

Bottom trawl survey data

Bottom trawl survey data for longfin squid used in this assessment were from: a) NEFSC autumn surveys during 1967-2001 (offshore strata 1-23, 25 and 61-76, Figure A5, 2001 data preliminary); b) NEFSC spring surveys during 1968-2001 (same strata as autumn survey, Figure A5); c) NEFSC winter surveys during 1992-2001 (offshore strata 1-17, 61-76, Figure A5); and c) Massachusetts inshore spring surveys data during 1978-2001 (Massachusetts bottom trawl survey strata 11-20, Figure A6). Strata sets used with bottom trawl survey data for longfin squid in this assessment were the same as in Cadrin and Hatfield (1999) and previous assessments. The traditional set for NEFSC strata for longfin squid consists of all consistently occupied offshore strata between Georges Bank and Cape Hatteras. However, longfin squid catch rates are relatively high during the autumn survey in many inshore strata along the Mid-Atlantic Bight (Figure A7). Strata sets used for longfin squid should be revaluated prior to the next assessment.

This assessment marks the first time NEFSC autumn survey data were available for an autumn assessment during the same year. Quicker availability of data is due to new procedures for electronic data entry and at-sea data auditing. Use of recent survey data is an important advantage in assessments for longfin squid, which are short-lived and highly dynamic.

Survey data used in this stock assessment for longfin squid are either mean numbers of "pre-recruit" squid $\leq$ 8.9 cm DML per standard tow (number/tow), or total catch weight (all sizes) per standard tow (KG/tow). The former is a measure of relative recruitment strength. The latter is a measure of total stock biomass and was computed by converting lengths (in 1 cm increments) to weights and multiplying the estimated weights by numbers per tow in the same length group.

NEFSC surveys

NEFSC surveys follow a stratified random design with stations allocated in rough proportion to stratum area. Standard tows in NEFSC surveys are 30 minutes in duration at a speed of 3.8 knots. The type of trawl door used in NEFSC spring and autumn surveys was changed in 1985 (NEFSC 1992) from the original "BMV" door to a newer polyvalent door (Tables A5-A6).

Autumn NEFSC survey data have been collected since 1964 (longfin squid identified starting in 1967) using a single type of trawl and the NOAA research vessels Albatross IV and Delaware II. The timing of the autumn survey changed during the late 1960's and early 1970's (Table A5) along with average water temperatures at tow stations (Table A9). Spring NEFSC survey data have been collected since 1968 with longfin squid identified starting in the first year. Two types of bottom trawls and both NOAA research vessels have been used in the spring survey (Table A6). In particular, the "high-rise" Yankee No. 41 trawl was used during 1974-1981 while the standard Yankee No. 36 trawl was used in 1968-1974, 1981 and subsequent years. The winter survey has been conducted with a single type of trawl and both NOAA research vessels (Table A7).

Survey data collected with polyvalent and BMV doors, by the NOAA research vessels Albatross IV and Delaware II, the No. 36 and No. 41 Yankee bottom trawls are used in this assessment without adjustment because catch rates in paired gear experiments did not differ significantly for longfin squid (NEFSC 1992, Sissenwine and Bowman 1978). There are no obvious discontinuities in average survey catch rates that correspond to changes in doors, vessels or bottom trawls. The autumn NEFSC bottom trawl survey time series was not adjusted for changes in survey timing (or associated changes in bottom temperatures). However, this issue was addressed indirectly in catchability process error models (see below).

Massachusetts inshore survey

The Massachusetts inshore spring bottom trawl survey has been conducted in state waters since 1978 from the borders of New Hampshire to Rhode Island (including Cape Cod Bay and Nantucket sound) (Table A8). Sampling is based on a stratified random design involving five geographic regions and depth zones. Standard survey tows are 20 minutes at 2.5 knots using a ¾ North Atlantic type two seam ('whiting') otter trawl (11.9 m head rope, 15.5 m footrope), rigged with a 19.2 m chain sweep and 7.6 cm rubber discs, 18.3 m bottom legs of 9.5 mm chain, 19.2 m wire top legs, 1.8 x 1.0 m 147 kg wooden trawl doors, and a 6.4 mm mesh cod end liner. Data for longfin squid data used in this assessment are from Massachusetts survey strata 11-20 (Figure A6).

Survey coverage

As pointed out in Cadrin and Hatfield (1999), the autumn NEFSC survey is carried out while longfin squid are distributed across the continental shelf at the northern end of their seasonal migration (Figure A7). In contrast, the spring and winter NEFSC surveys (Figures A8-A9) are carried out while longfin squid are along the shelf-edge and in water deeper than sampled by NEFSC surveys. The Massachusetts spring survey is carried out in inshore waters (within 3 miles of shore) exclusively (Figure A10). Although sampling and stock distribution overlap to the greatest degree during the autumn NEFSC survey, longfin squid are common along both the shallow (western) and deep (eastern) boundaries of the autumn survey and along the deep southeastern boundaries of the spring and winter surveys. Thus, none of the bottom trawls surveys cover the entire range of the longfin squid resource but overlap between the stock and the autumn survey is relatively high.

Adjustments for diel catchability differences

Longfin squid catch rates in bottom trawl surveys depend on time of day and season because longfin squid move towards the bottom during daylight hours and up into the water column during night, to a degree that depends on size of squid and season. Hatfield and Cadrin's (in press) diel correction factors (see below) were used to adjust all bottom trawl survey data used in this assessment for longfin squid to daytime equivalent (maximum) values. Adjustment factors for the Massachusetts spring survey were not available so corrections factors for the NEFSC spring survey were used for Massachusetts spring data. CV's for the adjusted and unadjusted series were assumed the same because variances were not available for the diel correction factors.

Diel connection factors for longfin squid (Hatfield and Cadrin, in press).

Time of Day	**≤80 mm DML**	**> 80 mm DML**
NEFSC autumn survey		
Night (8 PM-4 AM)	0.0873	0.3420
Dawn/Dusk (4 AM-8 AM or 4 PM-PM)	0.4654	0.8325
Day (8 AM-4 PM)	1.0000	1.0000
NEFSC spring survey		
Night	0.5102	0.7205
Dawn/Dusk	0.7872	0.9157
Day	1.0000	1.0000
NEFS winter survey		
Night	0.6519	1.3051
Dawn/Dusk	0.8098	1.1451
Day	1.0000	1.0000

Survey data computations

Mean total weight (all size classes) per standard tow (computed from numbers caught in 1 cm length groups and length-weight relationships[2]) and pre-recruit abundance (mean number of longfin squid ≤ 8.9 cm DML per standard tow), along with coefficients of variation (CV=standard error/mean), were computed for each survey and year using standard formulas (Tables A9-A12). Not all strata were sampled in all years during NEFSC surveys. Weights used in computing survey averages were adjusted in calculations to accommodate missing strata. CV's for NEFSC survey data underestimate the true variance in NEFSC survey data because some small strata are sampled only once. Variances for stratum means with only one station could not be calculated and were assumed to be zero. Mean surface and bottom temperatures were calculated as the simple average of temperatures recorded at each tow location used for longfin squid.

Survey results

Trends in weight per tow were generally similar except during 2001 (the most recent year). All of the surveys suggest relatively low squid biomass levels during the mid- to late 1990's and increases to moderate or high levels by 2000 with declines in all but the autumn survey during 2000-2001 (Tables A9-A12 and Figures A11-A14). The autumn survey during 2001 was at a near record level. Overall, catch rates for longfin squid were highest and CV's were lowest in the autumn survey. In contrast, the NEFSC spring survey had the lowest kg per tow values and the highest CV's.

Water temperatures may affect catchability of longfin squid i bottom trawl surveys (Hatfield and Cadrin, in press). Mean bottom temperatures increases in the NEFSC autumn survey after 1981 but bottom temperatures for the autumn survey, along with surface and bottom temperatures for other surveys, fluctuated without trend (Tables A9-A12 and Figures A15-A16). The trend in bottom temperature in the NEFSC autumn survey was likely due to changes in survey timing. Since the early 1960's, the average date of autumn bottom trawl tows has decreased by about six weeks (Table A5 and Figure A17). The timing of other surveys has varied but without trend (Tables A6-A8 and Figure A17).

The NEFSC autumn bottom trawl survey index was at a near record level in 2001 while other surveys showed some decline during 2000-2001 and longfin squid in the Massachusetts spring survey were quite low. However, trends in the autumn survey are generally most reliable for longfin squid because it has the highest catch rates, lowest CV's, and best overlap between survey strata and squid distribution. Other bottom trawl surveys for longfin squid have lower catch rates, higher CV's and low overlap between survey strata and squid distribution. Autumn survey data for longfin squid are the most recent information available. As discussed, it is likely that environmental factors affect longfin squid catchability and catch rates in all of the bottom trawl surveys available.

Trends in pre-recruit abundance were consistent among surveys. All surveys indicate a steady general increase in recruitment since the early 1990's (Tables A9-A12, Figure A18). Based on NEFSC and Massachusetts bottom trawl survey data, recent longfin squid recruitment has been at high to record high levels (Massachusetts

---

[2] $W=0.249118\ L^{2.18390}$ for NEFSC surveys; $W=0.250206\ L^{2.14418}$ for Massachusetts surveys, DML in cm and W in grams.

survey data for longfin squid were low during 2001) but trends in the Massachusetts survey are highly variable.

Length composition data for NEFSC offshore surveys (Figure A19) show that smaller longfin squid are taken offshore during the autumn survey. The highest proportions of large squid are taken offshore in the winter survey. The widest range of lengths is taken in the Massachusetts inshore survey (Figure A19) where length distributions are bimodal. Bimodal length distributions in the Massachusetts survey are likely due to small mature males and large mature females on spawning grounds during May (Figure A19).

ASSESSMENT CALCULATIONS

In this assessment, longfin squid biomass is measured in units of mt. Body weights for individual squid are in units of kg whole wet weight. All instantaneous mortality rates are for quarterly time steps, although length based virtual population and reference point calculations used monthly time steps. Divide quarterly rates by three to get monthly values and multiply quarterly rates by four to get annual values. Use care in comparing results from this assessment to results in Cadrin and Hatfield (1999) who present mortality rates in both quarterly and monthly time steps.

Length-based virtual population analysis

Length-based virtual population analyses (LVPA, Jones 1974, 1981, 1986) were carried out for longfin squid in the winter and the summer fisheries of each year (Cadrin and Hatfield 1999). In this assessment, the 1991 "winter" fishery, for example, took place during the six-month period October 1990 to March 1991. Similarly, the 1991 "summer" fishery took place during the six-month period April 1991 to September 1991. Cadrin and Hatfield (1999) used a different naming convention. Two cm length groups were used in LVPA calculations for longfin squid (Table A13).

Growth and Δt_L values

The amount of time that longfin squid spend in each 2 cm size class (Δt_L, Table A13) is a key parameter in LVPA (Cadrin and Hatfield 1999). For this assessment, Δt_L values were calculated based on unpublished exponential growth curves fit by J. Brodziak (NEFSC, Woods Hole) to all of the length-age data available for longfin squid. Data used in fitting growth curves for this assessment include all observations used in Brodziak and Macy (1996) and Macy and Brodziak (2001). Curves were for males and females combined and with "summer hatch" dates (November-April, N=517, ages 1.6-9.2 months) and "winter hatch" dates (May-October, N=314, ages 2.6-9.7 months).

Based on the new curves, summer hatch squid appear to grow more rapidly and to larger sizes than winter hatch date squid (Figure A20). The new Δt_L values for winter hatch dates changed substantially (Figure A21) but there was little change in Δt_L values for summer hatch squid. Like Cadrin and Hatfield (1999), we used separate sets of Δt_L values for summer hatch and winter hatch squid, based on hatch date-specific growth curves for males and females combined.

Natural mortality rate

Cadrin and Hatfield (1999) assumed that the natural mortality rate for summer hatch and winter hatch longfin squid in LVPA calculations was M_L=0.3 month^{-1} (0.9 quarter^{1}). Longfin squid larger than 50 cm DML are unusual and 50 cm is a reasonable practical estimate of maximum size. The new growth curves (Figure A20) suggest that summer hatch squid reach 50 cm DML before age 10 months and that winter hatch squid reach 50 cm at about age 12 months. Using age at 50 cm DML as an estimate of maximum age, Gabriel et al's (1989) "3/M rule" suggests $M=3/9=0.33$ month^{-1} or $M= 1.00$ quarter^{-1} for summer hatch longfin squid and $M=3/12=0.25$ month^{-1} or $M= 0.75$ quarter^{1} for winter hatch date squid. These estimates of natural mortality were used in LVPA calculations for length groups (L) up to 27-28.9 cm. For the last length group (29-30.9 cm), the assumed natural mortality rate was doubled to further reduce survival at large sizes. Assumptions about natural mortality rates affected the scale but not trends in biomass and F estimates. The assumption of higher mortality in the last length group made selectivity curves more asymptotic in shape, but had little effect on trends in biomass or F estimates.

LVPA calculations

Length-based virtual population analysis estimates the length composition, abundance and biomass of a theoretical equilibrium population based on catch at length data and a number of simplifying assumptions (i.e. constant recruitment and constant mortality over time). As in traditional virtual population analysis (VPA), LVPA calculations for longfin squid were carried out "backwards" in time, from the largest length group towards the smallest.

Abundance in the largest length group in LVPA calculations for longfin squid (N_{29}) was calculated as

$$N_{29} = \frac{C_{29} Z_{29}}{F_{29}\left(1 - e^{-Z_{29}\Delta t_{29}}\right)}$$

where C_L was catch in length group L (length groups identified by the lower bound, e.g. "29" for 29-31.9 cm), F_L was the instantaneous fishing mortality rate (see below), and the total instantaneous mortality rate $Z_L=F_L+M_L$. Calculations did not include a plus group (the few squid surviving to grow larger than 30.9 cm were ignored).

The terminal fishing mortality rate F_{29} was chosen using an ad-hoc scheme that combined the method used in Cadrin and Hatfield (1999) with a smoothing penalty. Trends in biomass and fishing mortality rates were not sensitive to choice of terminal F but estimated selectivity patterns were more domed using the method in Cadrin and Hatfield (1999).

Fishing mortality rates for smaller size classes were calculated "exactly" by solving for F_t (Sims 1982) in the "backward" catch equation:

$$C_L = \frac{F_L\left(1 - e^{-Z_L \Delta t_L}\right) N_{L+2} e^{Z_{L=2}\Delta t_{L+2}}}{Z_L}$$

Abundance of squid in smaller sizes classes was calculated as

$$N_L = N_{L+2} e^{Z_{L+2}}$$

Biomass of squid in each size class (B_L) was calculated as

$$B_L = N_L W_L$$

where mean weights were calculated based on a length-weight relationship ($W_L=0.2566\ L^{2.1518}$, with L the middle of the length group).

LVPA catch data

Catch at length of longfin squid in the winter and summer fisheries during 1987-2000 was estimated for each length group using quarterly length data from port samples as described by Cadrin and Hatfield (1999). Port sample length data were collected during every quarter after 1987, but sampling was not carried out during every month when landings occurred. In addition, some market categories were not sampled during some quarters (market categories are based on size: super small, small, medium, large, extra large, and unclassified). Quarterly landings for market categories with no port samples or length data were pooled with adjacent categories for calculation of catch at length (i.e., extra large were pooled with large; extra small were pooled with small; medium were pooled with unclassified, etc). When port samples and length composition data were not available for adjacent categories, landings were pooled with landings of unclassified squid. Mean individual body weight was estimated from length composition data for each pooled market category using the length weight relationship used in LVPA calculations (see above). Catch at length was computed for each pooled market category by multiplying proportions at each length (from port samples) by the ratio of total landings and mean individual weight. Total catch at length for each quarter was computed by summing catch at length for all pooled market categories.

LVPA results

LVPA results are affected by many factors and assumptions (Lai and Gallucci 1988). LVPA results for longfin squid may give useful information about trends in biomass and mortality based on fishery length composition data, but should not be used by managers as direct estimates of stock biomass or fishing mortality.

LVPA results were summarized in terms of the estimated total biomass of squid (all length groups, in relative terms to show trends only, Figure A22) and biomass weighted average *F* (in relative units to show trends only, Figure A23) for squid 13+ cm (13 cm is approximately the peak length taken in the commercial fishery). LVPA biomass and fishing mortality estimates for winter 2001 were affected by incomplete landings data for 2001 and are not presented. Length-based fishery selectivity was characterized for each fishery (Figure A24) by averaging F_L values across all years, and dividing by the largest average value.

Trends in biomass estimates from LVPA (Figure A22) were similar to trends in survey data and estimates from other models (see below). LVPA results indicate that biomass declined in the late 1990's then increased to intermediate current levels. Trends in biomass-weighted average *F* (Figure A23) from LVPA were also similar to trends in *F* estimates from other models (see below). LVPA biomass weighted average F estimates increased in the late 1990's and appear to have declined recently.

Fishery selectivity results from LVPA analyses (Figure A24) were almost asymptotic and indicate that fishing mortality rates for longfin squid generally increase with length. In contrast, fishery selectivity results in Cadrin and Hatfield (1999) from LVPA were more domed, indicating that fishing mortality rates for longfin squid decrease at the largest sizes. Sensitivity analyses (not shown) showed that differences in fishery selectivity results were due mostly to the scheme chosen to set F_L for the largest size groups and higher assumed M_L values for the largest length group. A single smooth average selectivity curve

$$s_L = e^{\eta_L} / \left(1 + e^{\eta_L}\right)$$

with

$$\eta_L = 0.343\ \overline{L} - 6.08$$

($\overline{L}$ the midpoint of the 2 cm length intervals) fit by least squares adequately describes the selectivity curves for both winter and summer fisheries (Figure A24).

Bounds for Q in assessment models for longfin squid

Recent modeling efforts using surplus production models (NEFSC 1996, Cadrin and Hatfield 1999) estimated implausibly low biomass levels. As pointed out by Cadrin and Hatfield (1999), problems are evident in comparing biomass estimates from the model to minimum swept area biomass estimates which are computed from survey data under the assumption that survey bottom trawls are 100% percent efficient and capture 100% of the squid in the water column above the ground swept by the net. As shown below, this problem means that stock assessment models used recently for longfin squid tended to estimate implausibly high estimates of survey bottom trawl catchability (Q). Biomass is estimated as $B=I/Q$ were I is survey KG/tow and tends to be too low when Q is too large.

This assessment considers factors that determine survey bottom trawl efficiency for longfin squid individually, and upper and lower bounds for each. Using the bounds for each factor, upper and lower bounds for catchability in the NEFSC autumn bottom trawl survey are computed. Moreover, based on non-informative prior distributions for uncertainty in each underlying factor, we characterize uncertainty about survey catchability by means of a prior distribution. Our approach could be extended easily to accommodate informative prior distributions and may be useful for other species.

NEFSC autumn survey adjusted for diel catchability affects (Table A9 and Figure A11) are used exclusively in analysis of survey catchability because the geographic distribution of the autumn survey overlaps with the distribution of longfin squid to the greatest degree (Figures A7-A10). The autumn survey is highly variable from year to year for longfin squid but, based on survey CV's (Tables A9-A12 and Figures A11-A14), is most precise for longfin squid. The adjusted autumn bottom trawl survey for longfin squid series measures biomass per tow during the day when longfin squid are closest to the bottom and the efficiency of bottom trawl survey gear is highest. Other surveys were not used because uncertainties were too large to be readily characterized.

Factors affecting autumn survey catchability

The hypothetical relationship between survey data (I_y, e.g. mean biomass per tow) and longfin squid biomass is:

$$I_y = QB_y$$

where Q is the survey-specific catchability coefficient (here assumed constant over years). The catchability coefficient is:

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

where $u=10^6$ changes weight from units for stock biomass (thousand mt in this assessment) to units of weight for survey data (kg), a is the area swept during one standard tow (all distances in km and all areas in km^2), e is the efficiency of the survey bottom trawl (the net captures the proportion e of the squid in the water column above the ground swept by the net) and A is the "effective" area of the stock.[3] Survey bottom trawl efficiency must be larger than zero if the survey takes at least one longfin squid and, by definition, must be smaller than or equal to one ($0 < e \leq 1$). Breaking area swept (a) into the product of average "effective" tow distance for the survey (d, assumed constant over time) and effective width (w) of the survey bottom trawl[4] for longfin squid gives:

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

Uncertainties about effective stock area A, effective width of the survey bottom trawl w, effective tow distance d, and about the efficiency of the survey bottom trawl e for longfin squid under daytime conditions are substantial and the focus of this analysis.

Bounds for each of the key factors (d, w, e, and A) affecting catchability of longfin squid in the autumn NEFSC bottom trawl survey (Table A14) are explained below. Bounds are subjective but were based on common sense and available information. We made an effort to honest about uncertainties, and to include the whole range of potential values for each parameter, because there was neither modeling advantage nor technical justification for understating uncertainty.

Bounds for effective tow distance (d)

Variance in the length of individual tows probably contributes little uncertainty to estimates of average tow distance because tow distance used in calculations is a mean for all the tows in a survey, the number of tows is large (average 150, Table A9), and tow times are controlled carefully during the survey. However, the mean value is uncertain due to questions about when the survey trawl starts and stops fishing effectively for longfin squid during daytime tows. The nominal tow distance in the autumn survey is d=3.52 km/tow, based on a 0.5 hr standard tow time at 3.8 knots (7.04 km/hr).

Data measuring time on bottom were collected for 17 tows using inclinometers (bottom sensors) during the 1999 spring NEFSC bottom trawl survey (H. Milliken, NEFSC, Woods Hole, pers. comm.). Time on bottom ranged from 27.5-31.9 minutes with a median of 31.7 minutes and an average of 30.7 minutes and a standard error of 0.31

---

[3] The effective area A is a hypothetical area larger than the area covered by the survey but smaller than the geographic distribution of the stock, where the density of squid (measured in units of squid biomass per standard tow) is equivalent to density in the area surveyed. Mathematically, S =139,357 km^2 $\leq A \leq$ the total area of the stock. This abstraction is useful because the stock is distributed over a very large area that includes substantial grounds with low densities of squid, and because uncertainty about A is easier to characterize than uncertainty about the area of the stock (see below).

[4] The effective width of the survey bottom trawl w is a hypothetical measurement. For longfin squid, it is larger than the width of the wings and smaller than the width of the doors (see below). Mathematically, $w_{wings} \leq w \leq \mathrm{w}_{\mathrm{doors}}$. The notion of effective width is useful because w_{wings} and $\mathrm{w}_{\mathrm{doors}}$ are upper and lower bounds for uncertainty about the effective width of the survey bottom trawl for squid

minutes. Tow distance depends on depth for the NEFSC survey clam dredge (Weinberg et al., in press, based on analysis of bottom contact sensor measurements). The same relationship likely exists for survey bottom trawl tows. However, tows in the bottom trawl survey are allocated in relatively constant numbers to depth strata, so uncertainty in tow distance due to variance in tow depth may be unimportant for longfin squid in the autumn bottom trawl survey.

Sensor data used for surfclam, ocean quahog and sea scallop shows that effective mean tow distances in NEFSC surveys using clam and scallop dredges may be different than the nominal value (NEFSC 2000a, NEFSC 2000b, NEFSC 2001). This is the most important area of uncertainty for longfin squid in the autumn bottom trawl survey as well. Squid are distributed near the bottom during the day but individuals off bottom may be taken before the survey trawl is on the bottom and the winches are locked or as the net is retrieved, so that effective tow distance may be greater than the nominal value. As described above, effective tow distance increases with depth for the NEFSC clam survey dredge and this may occur in bottom trawl surveys as well. It is also possible, but probably unlikely, that the survey bottom trawl does not begin to fish effectively until after the winches are locked so that tow distances are less than the nominal value.

In this analysis, the lower bound for effective tow distance d_{min}=0.95 x 3.52 = 3.34 km was 5% smaller than the normal tow distance. This assumption accommodates the hypothesis that the survey bottom trawl does not fish effectively until after the trawl contacts the bottom. The upper bound for effective tow distance d_{max}=1.1 x 3.52 = 3.87 km/tow in this analysis was 10% larger than the nominal tow distance. This accommodates the alternate hypothesis that the survey bottom trawl fishes a distance effectively greater than the nominal distance because squid are taken before the winches are locked, as the net is retrieved, or due to depth effects. The upper bound is farther from the nominal value (the uncertainty interval is asymmetric) because many factors seem likely to increase the effective tow distance.

<u>Bounds for effective trawl width (w)</u>

The lower bound for effective width of the survey bottom trawl (w_{min}, Table A14) in this analysis was 11.6 m (CV=1%), based on 51 door spread measurements (mean of three sensor measurements per tow, H. Milliken, NEFSC, Woods Hole, pers. comm.) that ranged from 9.67-13.0 m (median=11.7, CV 6%). Door spread measurements were for the NEFSC standard bottom trawl fished from the NOAA Research Vessel Albatross IV during the 2000 NEFSC bottom trawl survey (data provided by H. Milliken, NEFSC, Woods Hole, MA). The lower bound accommodates the hypothesis that no herding of longfin squid occurs during fishing by the NEFSC survey bottom trawl during daytime (herding means that squid originally beyond the sides of the wings of the net, move towards the mouth of the trawl and are captured). Uncertainty due to squid initially above the head rope is included in uncertainty about survey bottom trawl efficiency *e* (see below).

Squid in the path of the net may escape by moving up above, or out beyond the wings so that the effective width of the net could actually be less than the width of the wings. Average head rope height in 21 tows (mean of 1-3 three sensor measurements per tow, a subset of the tows used for door- and wingspread measurements) averaged 1.95 m

(CV 1%) and ranged from 1.7-2.1 m (median=1.93, CV 5%). However, the survey bottom trawl is towed rapidly (3.8 knots, roughly twice the speed of commercial bottom trawls) and survey data are adjusted to daytime equivalents when longfin squid are closest to the bottom so that escapement may be minimized. A bycatch reduction experiment (Glass et al. 1999) in Nantucket Sound and Vineyard Sound during May-June 1997-1999 aboard commercial vessels did not find substantial escapement of longfin squid with commercial small mesh bottom trawls towed in daytime.[5] Commercial bottom trawls in the study were relatively large and towed at about one-half or two-thirds the speeds used in the NEFSC autumn survey. The upper bound for effective width of the survey bottom trawl in this analysis is the mean w_{max}= 23.8 m (CV 1%, Table A14) of door spread measurements (mean of three sensor measurements per tow) for the same 51 tows (H. Milliken, NEFSC, Woods Hole, pers. comm.). Tow door spreads ranged from 19.5-27.0 m (median 24.3 m, CV=9%). The upper bound accommodates the alternate hypothesis that 100% of longfin squid between the wings and doors are herded into the mouth of the NEFSC survey bottom trawl and captured.

Bounds for effective stock area (A)

During the NEFSC autumn survey, longfin squid densities are relatively high (Figure A11) and squid are found throughout the area covered by the survey (Figure A7). Densities are high during the autumn survey because water temperatures are still relatively warm, squid are on the continental shelf and likely near the northern end of their seasonal migration pattern. Autumn survey catches are high around the border of strata used in tabulation of survey data for longfin squid, indicating that the survey does not cover the whole area of the stock. However, survey data (Figure A7) and Dawe et al. (1990) indicate longfin squid abundance is low north of Georges Bank in, in both US and Canadian waters.

Longfin squid are found south of Cape Hatteras during the autumn but the stock in this assessment is defined to be in the range of commercial exploitation from southern Georges Bank to Cape Hatteras. Squid south of Cape Hatteras during the autumn survey (when the stock is likely at the northern end of its seasonal distribution) are therefore irrelevant. Hatfield and Cadrin (in press) suggest that spawning south of Cape Hatteras during the winter and spring is important to fisheries north of Cape Hatteras, but the autumn survey would measure abundance of biomass and squid spawned south of Cape Hatteras when (and if) they recruit to the stock in northern waters.

Abundance of longfin squid outside the range of the autumn survey in shallow water near

---

[5] According to Glass et al. (1997), "the behavior of *Loligo* squid towards trawl gear is very similar to that adopted by many fish species. That is, they react to the approaching ground-gear of the net by turning and swimming at the same speed as the net in the direction of the tow. . . While being herded in the mouth of the net, squid tend to move to the edges of the net close to the wing-ends and side panels and gradually rise up to a position close to the top of the net…On tiring, *Loligo* were also observed to rise upwards and turn so that the mantle faces directly towards the codend of the net. The squid cease to swim and allow the net to overtake them. The overall effect of these behavior patterns results in squid being distributed in the upper and upper-lateral parts of the net during herding and falling back through the main body of the net."

shore and deep water offshore is an important uncertainty. Depth increases rapidly offshore of the continental shelf and autumn survey strata for squid. It seems unlikely that high densities extend over very broad areas in deep water.

Considering all factors, bounds used in this assessment for the effective stock area of longfin squid (A) were 5% and 30% larger than the area of all survey strata (S, Table A14) used for autumn bottom trawl survey data for this assessment:

$$A_{\min} = S(1+\delta_{\min})$$

and

$$A_{\max} = S(1+\delta_{\max})$$

with $\delta_{\min} = 5\%$

and $\delta_{\max} = 30\%$

accommodates the hypothesis that there are only small additional areas during the autumn where average effective biomass densities of squid are as high as in the area surveyed. A_{max} accommodates the alternative hypothesis that longfin squid are distributed during the autumn over large areas outside the area surveyed, where average biomass densities are relatively high.

Bounds for survey bottom trawl efficiency (e)

If the autumn survey bottom trawl failed to catch a single longfin squid, then the efficiency of the trawl would be zero ($e = \phi$). However, longfin squid are caught at relatively high rates and in the majority of autumn survey tows in the survey strata used in this assessment. In addition, autumn survey data for longfin squid are adjusted for diel catchability patterns to daytime equivalents, which effectively increases Q. If the autumn survey bottom trawl caught all of the squid in the water column above the zone of effective net with (w), then its efficiency would be 100% (i.e. e=1.0).

Bounds used for the efficiency of NEFSC autumn bottom trawl survey tows for longfin squid during the daytime (e) were taken to be 0.1 and 0.9 (Table A14). The lower bound for e accommodates the hypothesis that the gear has low efficiency due, for example, to squid distributed above the trawl squid or squid that escape by moving into the water column above the head rope of the net. The upper bound for e accommodates the alternate hypothesis that the NEFSC autumn bottom trawl is very efficient for longfin squid during the daytime.

Bounds for Q_{Fall}=dwe/A

The lower bound, ${}^{min}Q_{Fall}$=0.02149 (Table A14), for catchability in the autumn NEFSC bottom trawl survey was calculated from the minimum values for d, w and e in the numerator, and maximum value for stock area A in the denominator:

$${}^{\min}Q_{Fall} = \frac{u\, d_{\min}\, w_{\min}\, e_{\min}}{A_{\max}}$$

Similarly, the upper bound ${}^{max}Q_{Fall}$=0.5669 (Table A14) was calculated using the maximum values for d, w and e in the numerator, and the minimum value for A in the denominator:

$${}^{\max}Q_{Fall} = \frac{u\, d_{\max} w_{\max} e_{\max}}{A_{\min}}$$

Statistical distributions for uncertainty

We characterized uncertainty in effective stock area *A*, effective tow distance, effective trawl width *w*, and trawl efficiency *e* with uniform distributions that had upper and lower bounds described above. This means, for example, that any value of *A* between the upper and lower bound seemed equally probable, *a priori*. Uniform distributions for these parameters are "non-informative" prior distributions that don't require knowing or guessing the most likely single value or most probable values (Gelman et al. 1995). Moreover, uniform distributions accurately characterized our uncertainties about factors affecting autumn survey catchability for longfin squid.

Uncertainties about *A*, *d,* *w* and *e* were independent in our analysis because of the definitions for each term and independently chosen bounds (uncertainty and bounds for efficiency *e* did not depend, for example, on bounds and uncertainty about effective width *w* of the net). Given independence, the statistical distribution for uncertainty in *Q* can be evaluated to any level of precision by simulation. The first step is to draw random numbers *d'*, *w'*, *e'* and *A'* from uniform probability distributions (where, for example, *A'* is drawn from the uniform distribution with upper and lower bounds for effective stock area *A*). The second step is to calculate simulated catchability values as $Q'=d'w'e'u/A'$.

We characterized the distribution of our uncertainty about *Q* using 100,000 simulated *Q'* values (Figure A25). The mean of the simulated distribution was 0.20 (CV 52%) with values ranging from 0.023-0.55. The distribution had a broad flat peak with a "modal range" of high and almost equally probable *Q'* values ranging from 0.05-0.22. The 2.5%, 5%, 50%, 95% and 97.5% percentiles were at Q'=0.044, 0.052, 0.19, 0.38, 0.41. Thus, (0.044, 0.41) and (0.052, 0.38) are non-parametric 90% and 95% uncertainty intervals for Q_{Fall}. The modal range (0.023-0.22) of simulations contained roughly 60% of the total probability mass of the distribution for Q'_{Fall} values. This means that 0.05-0.22 is the narrowest uncertainty interval with 60% coverage for Q_{Fall}.

The broad mode in simulated Q_{Fall} values at intermediate values may seem surprising given that the simulation was based on uniform distributions with no mode. However, large values of simulated Q_{Fall} near the maximum can only occur when *d'*, *w'*, and *e'* are large and *A'* is small. Similarly, small values of simulated Q_{Fall} near the minimum can only occur when *d'*, *w'* and *e'* are small and *A'* is large. These combinations of events occur infrequently in the simulations and reflect the fact that large and small values of Q_{Fall} seem unlikely in nature, if uncertainty about *d*, *w*, *e* and *A* is accurately characterized by uniform distributions. Another, more statistical approach to understanding the mode in simulated Q_{Fall} values involves the central limit theorem. Ignoring weight units and taking logs gives $\ln(Q_{Fall})=\ln(d)+\ln(\mathrm{w})+\ln(e)+\ln(1/A)$. Thus, $\ln(Q_{Fall})$ is a random number that is the sum of four independent random variables. By the central limit theorem, the distribution of $\ln(Q_{Fall})$ will tend towards a normal distribution with a single mode. If the distribution of $\ln(Q_{Fall})$ has a mode, then the distribution of Q_{Fall} will also, although the distribution of Q_{Fall} may be more skewed.

In addition to characterizing the distribution of uncertainty in Q_{Fall} values by simulation, we used the method of moments to find parameters for a beta distribution that approximated the distribution of simulated values.[6] The beta distribution had parameters $\alpha = 1.624$, and $\beta = 3.293$, $k_{Mode} = 0.135$ (the middle of the mode in simulated Q_{Fall} values, see above), the same upper and lower bounds as simulated Q_{Fall}, and the same mean and variance as the simulated distribution of Q_{Fall} values.

The beta distribution approximated uncertainty in Q values reasonably well. The peak of the beta distribution (based on 100,000 values from a random number distribution with the parameters given) was sharper at the peak than the original simulated distribution but the cumulative distributions were almost identical (Figure A25). Percentiles for 2.5%, 5%, 50%, 95% and 97.5% of cumulative probability in the beta distribution were at $Q_{Fall} = 0.043$, 0.054, 0.18, 0.38 and 0.42 and generally similar to percentiles of the simulated Q_{Fall} values.

Scaled catch-survey model

Using catch and survey data, longfin squid stock biomass ($B_{Fall,t}$) was estimated as

$$\hat{B}_{Fall,t} = \frac{I_{Fall,t}}{Q_{Fall}}$$

where $I_{Fall,t}$ is an autumn bottom trawl survey datum for longfin squid (adjusted to daytime units). Autumn fishing mortality rates for longfin squid were estimated as

$$\hat{F}_{Fall,t} = \frac{C_{Fall,t}}{\hat{B}_{Fall,t}}$$

where $C_{Fall,t}$ is autumn catch (landings plus 6% discard after 1987).

In catch-survey biomass and fishing mortality calculations, Q_{Fall} was 0.050, 0.22 (the upper or lower bounds of the "most likely" simulated values) or 0.547 (the highest feasible bound for Q_{Fall} to get the lowest feasible biomass and the highest feasible fishing mortality estimates). The mean simulated Q_{Fall} was not used for scaled catch-survey calculations because the distribution of simulated Q_{Fall} values is skewed and the mean has relatively low probability (Figure A25). However, the mean at $Q'_{\text{Autumn}} = 0.20$ and upper bound of the most likely range at $Q'_{\text{Autumn}} = 0.22$ were close and can be used interchangeably.

Relative exploitation rates for other surveys

Crude estimates of unscaled relative fishing mortality rates were calculated using quarterly catch data and unadjusted NEFSC spring and winter bottom trawl survey data. Absolute estimates of biomass, F and variances were not estimated because there was no information about catchability or its uncertainty for the spring and winter bottom trawl surveys. Winter and spring survey data for 2001 were available and used, with preliminary landings data for 2001, to calculate relative trends in F through the spring of 2001. Thus, relative trends give the

---

[6] If k follows a beta distribution with $k_{Min}<k<k_{Max}$ and parameters $(\alpha>0,\beta>0)$, then $\kappa=(k-k_{Min})/(k_{Max}-k_{Min})$ is a standardized beta variate. The expected value (mean) of the standardized beta distribution is $Exp(\kappa)=\alpha/(\alpha+\beta)$, the variance is $Var(\kappa)=\alpha\beta/[(\alpha+\beta)^2(\alpha+\beta+1)]$, and the mode is at $\kappa_{Mode} =(\alpha-1)/(\alpha+\beta-2)$. It follows that $Exp(k)= Exp(\kappa)(\alpha+\beta)+\alpha$, $Var(k)=Var(\kappa)(\alpha+\beta)^2$, and $k_{Mode}=\kappa_{Mode}(\alpha+\beta)+\alpha$.

most current catch-survey based information available for longfin squid during 2001.

Catch-survey results

Average autumn biomass estimates for longfin squid during 1967-2001 from scaled catch-survey calculations ranged from 14-90 (average 51) thousand mt at one end of the most likely interval for Q_{Fall} values (Table A15; Figure A26). At the other end of the most likely interval, biomass estimates ranged from 63-396 (average 226) thousand mt. The lowest feasible biomass estimates ranged from 6-36 (average 21) thousand mt. The scaled autumn catch-survey biomass estimate in 2001 based on autumn survey data was at nearly a record high. However, other surveys declined during 2000-2001 to moderate levels (Figures A12-A14).

Fishing mortality estimates for longfin squid during 1967-2000 ranged from 0.01-0.04 (average 0.03) quarter^{-1} at the low end of the most likely interval, and ranged from 0.05-0.20 quarter^{-1} (average 0.12) quarter^{-1} at the other end of the interval (Table A15; Figure A27). The maximum feasible fishing mortality estimates ranged from 0.11-0.49 (average 0.30) quarter^{-1}. Fishing mortality estimates were at maximum levels in 1998 but declined to below average levels during 1999-2000. Unscaled relative fishing mortality rates based on spring and winter survey (Table A16 and Figure A28) indicate that fishing mortality rates for squid declined during 1999-2001.

Production modeling

A new surplus production modeling program called PDQ (Pretty Darn Quick) was developed using AD Model Builder (ADMB, Otter Software, Ltd.) tools and libraries and used for longfin squid (source code and program files available from L. Jacobson, NEFSC, Woods Hole, MA). PDQ is an alternative to the ASPIC program (Prager 1994). Advantages of PDQ include faster parameter estimation, greater flexibility including many options for modeling production and catchability process errors, more options for characterizing uncertainty, and population dynamics calculations based on either of two types of surplus production models. The first type of surplus production model is the conventional Schaefer logistic surplus production model (Prager 1994). The second type is a production model that does not assume the existence or require estimation of carrying capacity. Either model can be fit assuming “measurement errors only”, as in ASPIC (see Polacheck and Punt 1993), or with “process errors” in surplus production rates or survey catchability. In PDQ, it is not necessary to assume catches are known with out error.

Carrying capacity is difficult to estimate for many stocks in the northeast that have been heavily fished and at low biomass for many decades because little data are available for periods of relatively high stock biomass NEFSC (2001b). In such cases, and in estimating biomass and fishing mortality rates, it may be advantageous to avoid numerical and statistical problems by using a production model that does not involve an inestimable carrying capacity parameter.

Catch data in the PDQ model are landings plus discard, based on user supplied discard rates for each landings observation:

$$C_t = L_t \left(1 + D_t\right),$$

if $D_t \geq 0$ and

$$C_t = L_t + abs\,(D_t)$$

if D_t <0 and where C_t is catch in weight for time step t in the model and L_t is landings data. If the discard datum D_t ≥0, PDQ treats it as a discard rate (computed as the ratio of weight discarded and weight landed). If the discard datum D_t <0, PDQ treats the absolute value $abs(D_t)$ as discards in weight. This approach is flexible because discards in different time steps in the same model run can be specified as either discard rates or discard weights and discard information can be utilized in whatever form available.

Logistic surplus production population dynamics

Using notation in Prager (1994), the logistic surplus production model calculates the rate of surplus production *dBt/dt* as a function of stock biomass B_t:

$$\frac{dB_t}{dt} = r_t B_t - \frac{r_t}{K} B_t^2$$

where r_t is a parameter (potentially time varying) measuring the maximum instantaneous ("intrinsic") rate of increase for population biomass, and K is the equilibrium unfished biomass. With fishing, the rate of increase is

$$\frac{dB_t}{dt} = (r_t - F_t) B_t - \frac{r_t}{K} B_t^2$$

where F_t is the instantaneous rate of fishing mortality. All instantaneous rates in production model calculations for longfin squid were quarterly values, although PDQ will use any user specified time step.

For simplicity, Prager (1994) defined $\alpha_t = r_t - F_t$ and $\beta_t = r/K$ so that:

$$\frac{dB_t}{dt} = \alpha B_t - \beta B_t^2$$

If F_t is constant during time step t, the equation for dB_t/dt can be integrated and solved to obtain:

$$B_{t+1} = \frac{\alpha_t B_t e^{\alpha_t}}{\alpha_t + \beta B_t \left(e^{\alpha_t} - 1\right)}$$

when $\alpha_t \neq 0$. If $\alpha_t = 0$, then

$$B_{t+1} = \frac{B_t}{1 + \beta B_t}$$

We use B'_{t+1} for the special case where F_t is zero and $\alpha_t = r_t$. Maximum surplus production in year t, defined as the increment to biomass during one time step with no fishing (Jacobson et al. 2001) during time period t, is $P_t = B'_{t+1} - B_t$.

As described in Prager (1994), predicted catch c_t in the fishery is calculated as

$$c_t = \frac{F_t}{\beta} \ln\left[1 - \frac{\beta B_t \left(1 - e^{\alpha_t}\right)}{\alpha_t}\right]$$

when $\alpha_t = 0$. If $\alpha_t \neq 0$ then

$$c_t = \frac{F_t}{\beta} \ln\left(1 + \beta B_t\right)$$

Population dynamics parameters in PDQ with n time steps and logistic population dynamics include: r_t (one value if r_t is assumed constant, n values otherwise), F_t (one value if F_t is assumed constant, n values in most cases), B_f (biomass at the beginning of the first time step), and K. All naturally positive parameters in PDQ (e.g. r_t, F_t and B_f) are estimated as log transformed values.

Fishing mortality rates F_t are estimated as formal parameters in PDQ. Although not done for longfin squid in this assessment, an important advantage in this approach is that catches can be estimated if catch data include measurement errors. Conventional iterative approaches with catches assumed accurate (e.g. Sims 1982) are not applicable in production modeling because the realized instantaneous surplus production rates

$$r_t\,(1 - \frac{B_t}{K})$$

are not constant within a time step. In PDQ, fishing mortality rates were parameterized:

$$F_t = e^{\phi + \nu_t}$$

where ϕ is the log scale geometric mean fishing mortality rate parameter and the ν_t are time period specific deviations that average and sum to zero. Typically, the log-scale geometric mean fishing mortality for longfin squid ϕ was estimated with all ν_t=0 (i.e. $F_t=e^{\phi}$ constant at the geometric mean level) in a preliminary phase of parameter estimation. In a latter phase, once mean fishing mortality ϕ had been estimated to a "good" starting value, the geometric mean and deviation parameters ν_t for fishing mortality rates were estimated together.

Simple production population dynamics (without K)

Let ρ be the instantaneous surplus production rate during time step t and let $z_t=\rho\ \ F_t$ with the rates ρ and F_t defined as positive numbers. If no fishing occurs $F_t=c_t=0$, then

$$B'_{t+1} = B_t e^{\rho_t}$$

Maximum surplus production is

$$P_t = B'_{t+1} - B_t$$

If fishing occurs and $z_t \neq 0$, then

$$B_{t+1} = B_t e^{z_t}$$

and

$$c_{t+1} = -\frac{F_t}{z_t}\left(1 - e^{z_t}\right)B_t$$

If the rates of surplus production and fishing mortality rates exactly balance, then z_t=0 and:

$$B_{t+1} = B_t$$

with

$$c_t = F_t B_t$$

Process errors and variability in r_t

PDQ models with r_t or ρ_t values that vary are "process error" models because they include natural variability in a biological parameter. As described in Hilborn and Walters (1992) and Jacobson and Cadrin (in press), there is a natural continuum with "all measurement error" models (such as ASPIC and PDQ with constant r_t or ρ_t) at one extreme and "all process error" models on the other. All measurement error models assume that all variability in data is due to measurement error. All process error models assume that all variability in data is due to variability in underlying biological parameters. All measurement error approaches tend to be biased but in the context of simple surplus production models fit to catch and fishing effort data (Polacheck and Punt 1993), relatively robust. All process error models are more realistic and complex, and capable of representing relatively complex biological hypotheses and data patterns. The approach in PDQ allows the user to use a model configuration anywhere in the continuum between all measurement error and all process error approaches.

Production process errors in PDQ may be random and independent (no autocorrelation) or may follow a random walk that changes relatively slowly (autocorrelated), depending on goodness of fit calculations (see below). For process errors in the logistic model

$$r_t = e^{\eta + \varepsilon_t}$$

where η is the log scale geometric mean production parameter and the ε_t are time period specific deviations from the geometric mean that average zero. If process errors are excluded from the model configuration, then the r_t are constant because $\varepsilon_t = 0$ and $r_t = e^{\eta}$ for all t. Similarly, with simple surplus production dynamics (no carrying capacity)

$$\rho_t = e^{\eta + \varepsilon_t}$$

For longfin squid, the log-scale geometric mean production rate η was typically estimated with all $\varepsilon_t = 0$ (i.e. $r_t = e^{\phi}$ constant) in a preliminary phase of parameter estimation. In a latter phase, the geometric mean and time-specific parameters ε_t were estimated together. Process errors in survey catchabilities (see below) and process error in production rates should probably not be used in PDQ at the same time because effects of changes in catchability and changes in productivity may be confounded.

Abundance data

Expected values for abundance data are calculated as

$$\hat{I}_{w,t} = \hat{Q}_w \hat{B}_t$$

where $\hat{I}_{w,t}$ is the predicted value for survey datum of kind w in time step t (KG/tow for longfin squid), Q_w is a catchability coefficient for survey w, and B_t is estimated biomass. If the relationship between biomass and the abundance data is nonlinear, then

$$\hat{I}_{w,t} = \hat{Q}_w \hat{B}_t^{\hat{\Theta}_k}$$

where the exponent $\hat{\Theta}_w = e^{\hat{\theta}_w} > 0$. Parameters estimated in PDQ for abundance data include one catchability parameter Q_k for each index and one exponent parameter Θ_k for each nonlinear index.

Although catchability parameters can be estimated as formal model parameters, they are calculated in PDQ via an equivalent closed form maximum likelihood estimator that assumes lognormal survey measurement errors (NEFSC 2000b)

$$\hat{Q}_w = \exp\left\{ \frac{\sum_{t=1}^{N_w} \ln\left(I_{w,t} / \sigma_{w,t}^2 \right)}{\sum_{j=1}^{Nw} 1 / \sigma_{w,t}^2} \right\}$$

where $I_{w,t}$ is an observed survey datum (Tables A9-A12) and N_w is the number of survey observations. The log-scale variance (due to measurement errors) σ_w^2 was calculated from the arithmetic-scale sampling-based CV (Tables A9-A12) using a formula in Jacobson et al. (1994):

$$\sigma_{k,t}^2 = \ln\left(1 + CV_{k,t}^2\right)$$

<u>Process errors in bottom trawl survey catchabilities</u>

Variability in catchabilities for abundance data is another type of process error that can be modeled in PDQ. Survey catchability coefficients for longfin squid in the NEFSC autumn bottom trawl survey may change from year to year due, for example, to changing oceanographic features that control the distribution of the stock and availability of squid to the survey. With process errors in catchability coefficients

$$\hat{I}_{w,t} = \hat{Q}_w e^{\chi_{w,t}} \hat{B}_t$$

where the survey- and year- specific process error terms $\chi_{w,t}$ are deviation parameters, and Q_w is the geometric mean catchability. In PDQ calculations, it is convenient to calculate

$$\hat{B}_{w,t}^a = \hat{B}_t e^{\chi_{w,t}}$$

where

$\hat{B}_{w,t}^a$ is the adjusted biomass in year t for survey w. Then, Q_w can be calculated using the closed form maximum likelihood expression given above.

<u>Goodness of fit for each component</u>

Goodness of fit for observed C_t and predicted c_t catch data was calculated as

$$L_C = 0.5\sum_{t=1}^{n}\left(\frac{c_t - C_t}{\sigma_t}\right)^2$$

where L_C is the kernel of the negative log-likelihood for the normal distribution with variances known.[7] The user supplies the assumed standard deviation for catch σ. For longfin squid in this assessment, $\sigma = 0.2$ but the standard deviation is not relevant for longfin squid in this assessment because a high weight was placed on goodness of fit for the catch data (see below) so that observed and predicted catches matched almost exactly. In effect, catch data for longfin squid were modeled as though measured without error (a common and relatively robust approach, Methot 1990).

Goodness of fit for observed and predicted survey data was calculated assuming lognormal measurement errors:

$$L_{Survey,w} = 0.5\sum_{t=1}^{Nw}\left[\frac{\ln\left(I_{w,t} / \hat{I}_{w,t}\right)}{\sigma_{w,t}}\right]^2$$

Goodness of fit for autumn survey catchability estimates was calculated based on a beta probability prior distribution. The first step was to calculate standard beta deviates

$$\hat{q} = \frac{\hat{Q} - {}^{Min}Q_{Fall}}{{}^{Max}Q_{Fall} - {}^{Min}Q_{Fall}}$$

---

[7] The kernel of a negative log-likelihood L contains all components important in calculation of simple and partial derivatives $dL/d\theta_i$ and $dL/d\theta_i d\theta_j$ of the complete log-likelihood with respect to parameters in the model.

where ${}^{Min}Q_{Fall}$ and ${}^{Max}Q_{Fall}$ (Table A14). For $0<\hat{q}<1$, the standardized beta probability density function is

$$p(\kappa)=\frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)}\hat{q}^{\alpha-1}(1-\hat{q})^{\beta-1}$$

where $\Gamma()$ is the gamma function, $\alpha>0$ and $\beta>0$. Log transforming the probability density function, changing sign, and eliminating constants to obtain the kernel of the negative log-likelihood gives

$$L_k = (1-\alpha)\ln(\hat{q}) + (1-\beta)\ln(1-\hat{q})$$

In the beta distribution, the probability of

$\hat{Q}_{Fall} \leq Q_{Min}$ ($\hat{q}\leq 0$)

or

$\hat{Q}_{Fall} \geq Q_{Max}$ ($\hat{q}\geq 1$)

is zero and the negative log-likelihood is undefined. A goodness of fit penalty was used to prevent infeasible estimates and numerical problems when trial parameter values went out of bounds during parameter estimation:

$$\begin{aligned}
&\mathit{If}\ \left(\hat{Q}_{Fall} \leq Q_{Min}\right)\\
&\quad \mathit{then}\ L_k = 1000\left(\hat{Q}_{Fall} - Q_{Miin}\right)^2\\
&\mathit{else\ if}\ \left(\hat{Q}_{Fall} \geq Q_{Max}\right)\\
&\quad \mathit{then}\ L_k = 1000\left(\hat{Q}_{Fall} - Q_{Max}\right)^2
\end{aligned}$$

Goodness of fit for production process errors was computed assuming that process errors were either random or followed a random walk process. In the case of random process errors

$$L_r = 0.5\sum_{t=1}^{N}\left(\frac{\varepsilon_t}{\omega}\right)^2$$

where ω was a standard deviation for the independent log scale production process errors ε_t. In PDQ, the user specifies an assumed arithmetic scale CV for production process errors and the log scale standard deviation is calculated

$$\omega=\sqrt{\ln\left(CV^2+1\right)}.$$

In the case of process errors that follow a random walk

$$L_r = 0.5\sum_{t=2}^{N}\left(\frac{\varepsilon_t - \varepsilon_{t-1}}{\omega}\right)^2$$

where ω was a standard deviation for the autocorrelated log scale production process errors ε_t (also calculated from a user specified CV).

Goodness of fit for catchability process errors was computed assuming they were either random or followed a random walk process. In the case of random process errors

$$L_{Q_w} = 0.5\sum_{t=1}^{N_w}\left(\frac{\chi_{w,t}}{\xi}\right)^2$$

where ξ was a standard deviation from a user specified CV for the independent log scale process errors $\chi_{w,t}$. In the case of process errors that follow a random walk

$$L_{Q_w} = 0.5 \sum_{t=2}^{N_w} \left(\frac{\chi_{w,t} - \chi_{w,t-1}}{\xi} \right)^2$$

where ξ was a standard deviation from a user specified CV for the autocorrelated log scale production process errors $\chi_{w,t}$.

Forward simulation models such as PDQ may explore low biomass scenarios during parameter estimation that involve implausibly high exploitation rates. To prevent possible numerical problems and to avoid implausible solutions, another penalty strategy was used

$$If \left(\frac{C_t}{\hat{B}_t} \geq \tau \right) then\ L_{C/B} = 0.5 \left(\frac{C_t}{\hat{B}_t} - \tau \right)^2$$

For longfin squid, the threshold $\tau = 0.9$.

Objective function

The objective function in PDQ for longfin squid was a weighted sum of the log-likelihood kernels for each component:

$$\Xi = \lambda_C L_C + \sum_{k=1}^{N_{Surveys}} \left(\lambda_{Survey,k} L_{Survey,k} \right) + \sum_{j=1}^{N_{Surveys}} \left(\lambda_{Q_J} L_{Q_J} \right) + \lambda_k L_k + \lambda_r L_r + \lambda_{C/B} L_{C/B}$$

The weighting factors (λ) for longfin squid were generally one except during sensitivity analysis. The exceptions in the PDQ model for longfin squid were weighting factors λ=1000 for catch data and the penalty for low C_t/B_t levels. A large weighting factor (λ_C=1000) was used for catch data in the PDQ model so that the observed and estimated longfin squid catches would be almost equal (catches were assumed known without error).

Variance and confidence interval calculations

Variances, covariances and uncertainty intervals for parameters in the PDQ model for longfin squid can be estimated by:

1) Inverting the Hessian matrix to obtain asymptotic variance and covariance estimates and calculating confidence interval bounds as ±1.96σ;

2) Likelihood profiles;

3) Bootstrapping survey and catch data (see below); and

4) Integrating the posterior distribution for parameters using Markov Chain Monte Carlo (MCMC) techniques (Gelman et al. 1995).

Variances, covariances and confidence intervals for derived variables (e.g. biomass estimates) were obtained by the same methods except that asymptotic variances and covariances were by the delta method based on asymptotic variances for parameters (Seber 1982).

Software for calculation of asymptotic and delta method variances, likelihood profiles and MCMC is supplied with ADMB. Bootstrapping was carried out by extracting predicted values ($I_{w,t}$) for active ($\sigma_{w,t}$>0) survey data and standardized residuals from a basecase PDQ model run:

$$r_{w,t} = \frac{\ln \left(\hat{I}_{w,t} \big/ \hat{I}_{w,t} \right)}{\sigma_{w,t}}$$

After fitted values and residuals were saved to a file, bootstrap calculations were carried out by a FORTRAN program that constructed data files and ran the PDQ model once for each bootstrap iteration.

For each bootstrap iteration and each active survey datum, the FORTRAN program constructed generated the simulated survey datum as:

$$I_{w,t}^{j} = \hat{I}_{w,t} \exp\left(r_{w,t}^{j} \sigma_{w,t}\right)$$

for the j^{th} bootstrap iteration and with the bootstrap residuals $r_{w,t}^{J}$ drawn randomly with replacement from the pool of original standardized survey residuals $r_{w,t}$. It is possible to include catch data in bootstrap calculations and this is a topic for future research.

PDQ model configuration for longfin squid

Model runs for longfin squid covered the period with quarterly landings data during 1987-2001 Table A2). Catch data were increased by 6% to account for discards based on the average discard rate during 1989-1998 in Cadrin and Hatfield (1999). Biomass estimates were for January 1, 1987 to January 1, 2002 but were not reliable for time steps after the first quarter of 2001 due to preliminary catches for 2001.

Some exploratory runs were conducted for 1963-2001. Annual landings data are available beginning in 1963 (Table A1) but data for years prior to 1987 may be less reliable (Cadrin and Hatfield 1999). For runs including years prior to 1987, hypothetical quarterly catches were calculated for 1963-1986 by dividing the historical annual catch into four equal portions. Actual quarterly catches were used for later years. This is a topic for future research.

All available abundance information was used in the model for longfin squid including bottom trawl survey data through 2001 from NEFSC autumn, winter and spring surveys, and the Massachusetts inshore spring survey. Standardized LPUE for summer and winter fisheries during 1982-1993 was included assuming CV's =20%. Preliminary runs with LPUE treated as a nonlinear index had exponent parameter estimates that were near zero and not statistically significant. LPUE was therefore modeled as a linear index of longfin squid biomass trends. Finally, as an experimental approach, we used trends in LVPA biomass estimates for longfin squid as an index of stock biomass in PDQ.

LVPA biomass "data"

LVPA biomass trends were used experimentally in PDQ because

1) Trends in LVPA biomass and fishing mortality estimates were similar to trends in survey data and relative catch-survey fishing mortality estimates. This suggests that commercial catch at length data based on port samples contain substantial information about dynamics of longfin squid (see also Cadrin and Hatfield 1999).

2) Port sampling data are expensive to collect. Substantial energy was involved in programming and carrying out LVPA calculations (Cadrin and Hatfield 1999). Catch at length data are not usually used in surplus production modeling although there are few technical barriers (Jacobson and Cadrin, in press). It would be advantageous,

therefore, to use port sample data (and LVPA calculations) to the fullest extent.

3) LVPA biomass estimates for longfin squid were based almost completely on data not otherwise used in PDQ so that "double-dipping" (using the same data twice) was not a problem. Data used for LVPA but not otherwise used in PDQ include length composition information from port samples, new growth curves and a notion of the natural mortality rate and lifespan. Both LVPA and PDQ use total landings to estimate biomass but, in casting LVPA biomass estimates as measures of relative trend in the PDQ model, double dipping is reduced to the extent possible.

4) LVPA data are less variable over time than bottom trawl survey data and may be less affected by oceanographic features that likely affect catchability of longfin squid in bottom trawl surveys.

LVPA biomass estimates for winter and summer longfin squid fisheries were used as separate measures of biomass trends in PDQ because they were based on different growth curves and because winter and summer calculations were not linked in the LVPA model. One series might be biased or affected by imprecise growth estimates. The "seesaw" summer-winter pattern in LVPA biomass estimates (Figure A22) may be due to imprecise estimates of seasonal growth rates. For comparison, we combined the LVPA summer and winter results into a single index as well. In model runs, likelihood weights (λ) were one for the both the separate summer and autumn LVPA series while the likelihood weight for the combined summer and winter series was set to a nil values so that LVPA trend data were never used twice for parameter estimation in the same PDQ model run.

Cadrin and Hatfield (1999) used Monte Carlo simulations to estimate a CV of 5% for LVPA biomass estimates but noted that the CV was underestimated because variance in total catch, port sampling, natural mortality and growth was not included in the simulations. In PDQ, we assumed a CV of 35% for LVPA biomass trend estimates. LVPA biomass information for the winter 2001 fishery was not used because catch data for the first quarter of 2001 may be incomplete and underestimated catches would affect LVPA trends.

Status variables

Surplus production models calculate biomass at the beginning of the next time step *after* the last time step in the model without resorting to projection. This means, for example, that a model with catch and abundance data for 20 time steps can be used to estimate biomass at the beginning of the 21st time step without projection. In most cases for longfin squid, PDQ was run in quarterly time steps from the first quarter of 1987 to the last quarter of 2001. Thus, the model produced abundance estimates current to January 1, 2002 and fishing mortality estimates through the fourth quarter of 2001

Estimates of average biomass and average fishing mortality during 2000 were used for comparison to reference points. Thus, status variable estimates from PDQ runs for longfin squid were comparable to scaled catch-survey biomass and fishing mortality estimates.

Gauging goodness of fit - how much is enough?

In a hypothetical "perfect" PDQ model for longfin squid, the variance of residuals for model fit to abundance data would equal the variance of the survey index due to measurement errors in collecting the survey data. In dealing with imperfect real models, we expect the variance of residuals to be larger than the variance for measurement errors in the abundance data because the model should not fit the data more precisely than the data were originally measured. We used a variant of this "rule of thumb" in specifying process error parameters in the PDQ model for longfin squid ("models with catchability process errors", see below). In particular, we configured the PDQ model so that the goodness of fit CV for residuals in each survey was be larger than the average data CV for each observation used in fitting the model (Tables A9-12). Goodness of fit CV's were computed as

$$\mathrm{CV}=\sqrt{e^{\tau^{2}}+1}$$

where τ^2 was the mean squared residual for log scale residuals from a particular abundance index and model run.

Pseudo-ASPIC runs

The first step was to run PDQ in an ASPIC-like mode with quarterly times steps, logistic dynamics (carrying capacity K estimated), all abundance information included, no constraints on Q_{FALL} and process errors turned off. Results were similar to those in Cadrin and Hatfield (1999) because the model estimated implausibly low biomass levels (with Q_{Fall} larger than the largest feasible value) and B_{MSY} and K levels that, depending on the run, were either implausibly high or low. Fit to abundance indices was "too good" because average CV's for abundance data were usually larger than goodness of fit CV's.

Additional model runs used simple surplus production calculations (no carrying capacity) in PDQ with other factors as in the pseudo-ASPIC runs. Results were generally similar to results from the pseudo-ASPIC run.

Problems in the pseudo-ASPIC and other preliminary runs suggest that bounds to constrain Q_{Fall} for the NEFSC autumn bottom trawl survey may be required and that capacity, K, may not be estimable for longfin squid. Problems estimating K could stem from limitations in the available data or inapplicability of the logistic surplus production model (NEFSC 2001).

Likelihood profile calculations with the simple model

The next step was a likelihood profile analysis with the simple model (no carrying capacity) for a series of runs covering the entire feasible range of autumn survey catchability and longfin squid biomass values. The purpose of the likelihood profile analysis was to determine how different kinds of data affected model estimates and to understand modeling problems. Results (not shown) indicated that, with the exception of LVPA biomass trend data, abundance indices generally fit best at high autumn catchability/low biomass values. LVPA biomass trend data, in contrast, fit best at low autumn catchability/high biomass values. These results and additional sensitivity analyses (not shown) suggest that the most important characteristic of LVPA trend was their relative stability from year to year. In preliminary PDQ model runs, the stability of LVPA trend data tended to counteract interannual variability in bottom trawl survey data. In effect, the LVPA data stabilized model results and increased biomass estimates by preventing a close fit to the highly variable survey data.

The trouble with production models for longfin squid-a hypothesis

Likelihood profile analysis and experience in this assessment with LVPA data suggest an explanation for problems with infeasible low biomass and carrying capacity estimates that have plagued production models in stock assessments for longfin squid over the last decade. Problems appear to stem from the high year to year variability in bottom trawl survey data. Relatively high values in NEFSC autumn bottom trawl survey data for longfin squid in one time step, for example, are often followed by low values in the next time step and vice versa. In order to fit bottom trawl survey data, production rates have to change rapidly. To accomplish this, production models estimate low biomass and carrying capacity for longfin squid so that moderate increases or decreases in biomass are followed by substantial decreases or increases in production rates. In other words, conventional production models for longfin squid tend to estimate production rates that turn “on” and “off” as trawl survey and biomass estimates become smaller and larger.

Conventional surplus production models assume that production is always larger than zero. This characteristic likely exacerbates problems with low biomass estimates for longfin squid. Even with estimated production as small as possible (i.e. near zero), biomass in a production model can decline only due to catch. In order to achieve relatively large decreases in biomass, the observed catch must be relatively large in comparison to biomass. Thus, substantial declines in biomass (indicated by survey data for longfin squid) are achieved in production models by estimating biomass estimates that are relatively small (i.e., slightly larger than catches).

It seems likely that some of the variability in bottom trawl survey data for longfin squid stems from survey catchability process errors caused by variation in environmental conditions. It is possible that longfin squid biomass is low relative to catches, but not as low as the infeasible estimates from conventional production models. Based on likelihood profile results, experience with LVPA data and the considerations described above, it appears that relatively complex process error models may be required to interpret survey data in production modeling for longfin squid.

Two process error approaches were used for longfin squid. The first assumed process errors in surplus production rates. This approach is parsimonious (one process error parameter per time step) but indirect because process errors in surplus production rates and process errors in survey catchabilities during the same time step might be confounded in the estimated parameters. The second approach assumed process errors in survey catchabilities over time only. This is a more realistic but relatively complex approach. If separate process errors affect each survey, for example, then the number of parameters estimated is potentially as large as the number of survey observations.

Simple model with independent production process errors

We used the simple model without carrying capacity to explore production process error models. The simple surplus production model was run assuming independent production process errors with CV=0.1 (a modest level of variability). Fit to survey data was better than with the simple production model and no production process errors. Goodness of fit CV's were closer to average sampling CV's (see below). Autumn survey catchability was near its upper bound.

Estimated production rates, ρ_t, from the simple model with independent surplus production process errors were strongly autocorrelated with production rates higher or lower than average for periods of 1-5 years. Log scale production process errors ε_t had a lag 1 autocorrelation of 0.88 and the CV for variability in log scale production process errors ε_t was about 3%. This suggests that some environmental variable, acting over periods of years, effects either production or catchability in a variety of surveys during different seasons.

Models with catchability process errors

To parameterize catchability process errors for longfin squid we ran the simple version (no carrying capacity) of PDQ repeatedly with production process errors turned off and independent catchability process errors turned on for all surveys, while increasing the assumed CV for the variance of log scale catchability process errors ξ. In each subsequent run, the assumed CV's for catchability process errors were adjusted manually until the goodness of fit CV's for all abundance indices were larger, but within 0.1, of the average measurement CV. The final assumed CV's for catchability process errors in the basecase model run ranged from zero (for LPUE indices) to 0.35 for the Massachusetts spring bottom trawl survey (Table A17). Likelihood profile analysis (Table A18) showed that two abundance indices fit best at the higher boundary for feasible Q_{Fall} values, one fit best at the lower boundary, and three fit best at intermediate values.

The final PDQ model with catchability process errors, which was adopted by the Stock Assessment Review Committee (SARC) at the 34th Stock Assessment Workshop (SAW) as a basecase model, converged to feasible estimates of Q_{Fall} and biomass with no additional constraints (Table A18, Figures A29-A30). The model fit abundance data reasonably well although there was serial correlation in residuals for several abundance indices (Figure A31-A38). There was substantial variation in estimated catchability for the NEFSC autumn and Massachusetts spring bottom trawl surveys (Figure A39). Catchability process errors appear random for all abundance indices except the Massachusetts spring survey, where catchability decreased after 1990 and remained low (Figure A39).

To facilitate comparison of temporal variability in catchability, estimated catchabilities were rescaled and plotted as log scale anomalies (i.e. take logs, subtract mean log scale value and divide by the log scale standard deviation assumed in fitting the model). Results indicate that catchability process errors were strongly correlated (Figure A40). An attempt to estimate carrying capacity for longfin squid by fitting a logistic surplus production model with similar catchability process error assumptions gave unfeasible results with implausibly high estimates of carrying capacity.

Preliminary retrospective analyses with the basecase model showed that terminal biomass estimates for longfin squid from the PDQ model with catchability process errors were unstable, particularly when the terminal time step in the model was summer (probably because no abundance index data are collected during the summer). The same preliminary analysis showed that average estimates for the year prior to the terminal year (e.g. average biomass or fishing mortality for 2000 from a model including data for 2001) were more stable and probably useful for status determination purposes. Model stability and retrospective patterns are important topics for future research.

Managers are advised to ignore PDQ biomass estimates for 2001, the most recent year. According to the best-fit catchability process error model, estimated longfin squid biomass reached a record high of about 50,000 mt at the end of 2001 and beginning of 2002 (Table A19 and Figure A29). Record high biomass estimates in 2001 were driven primarily by the NEFSC autumn bottom trawl survey (Figure A11) which was at a near record level in 2000, while other abundance indices were at more moderate levels (Figures A12-A14 and A22). Terminal year estimates are the least precise in most stock assessment models because estimates for the last year are not constrained by data in subsequent years. As described above, the catchability process error version of the PDQ model suffered from instability in the terminal year.

Bootstrap and asymptotic delta method CV's for biomass and F estimates were similar for 1987-1998 (Table A19). However, asymptotic and bootstrap CV's began to diverge after 1998. By 1990, bootstrap CV's were substantially larger. The relatively large bootstrap CV's were due to very low biomass estimates and high *F* estimates for recent years in some bootstrap runs.

The estimated instantaneous surplus production rate was 0.24 quarter^{-1} and estimated longfin squid biomass in 2000 averaged 24 thousand mt. During 2000, estimated average fishing mortality and catch were 0.2 quarter^{-1} and 4.8 thousand mt quarter^{-1}. Average catch was less than average surplus production (6.3 thousand mt quarter^{-1}) during the same period.

Bootstrap confidence intervals (500 iterations for average biomass of *Loligo* during 2001 and average fishing mortality during 2000 were substantially wider than likelihood profile confidence intervals (see below). In contrast, the bootstrap confidence interval for the instantaneous production rate ρ was narrower.

<u>Traditional per recruit calculations</u>

Yield and spawning biomass per recruit calculations were carried out by age-structured simulation in monthly time steps (Thompson and Bell 1934, input data in Table A20 and Figure A41). Calculations used squid ages 1-12 months for winter hatch squid in the summer fishery and ages 1-10 for summer hatch squid in the winter fishery. The last age group was not a plus group (the few survivors to ages older than the last were ignored). Fishing mortality rates are given both as traditional fully recruited fishing mortality rates and as the corresponding biomass weighted average fishing mortality rates. The latter are more comparable to results from biomass dynamic models like PDQ (NEFSC 2001).

	Likelihood Profile 95% Lower Bound	Likelihood Profile 95% Upper Bound	Bootstrap 95% Lower Bound	Bootstrap 95% Upper Bound
Production rate ρ	0.16	0.30	0.16	0.28
Average 2000 F (per quarter)	0.12	0.26	0.12	0.41
Average 2001 B	23.75	52.00	7.9	59.6

Maximum ages for per recruit modeling were chosen based on the predicted age at 50 cm DML (see LVPA, above). To mimic assumptions used in LVPA that natural mortality was higher at sizes above 30 cm DML (see above), the natural mortality rate for winter hatch squid was M=0.75 quarter^{-1} for ages 1-10 months and M=1.5^{-1} quarter (doubled) for ages 11-12. Similarly, the natural mortality rate for summer hatch squid was M=1.00 quarter^{-1} for ages 1-8 months and M=2.00 quarter^{-1} for ages 9-10. In the context of per recruit modeling, these assumptions about natural mortality mean that natural mortality increases at about the time 100% of squid become sexually mature.

Fishery selectivity at age was calculated by converting the length based selectivity curve fit to LVPA results (Figure A24) to age, using inverted growth curves used to calculate $\underline{\Delta t_L}$ values for LVPA. Maturity at age was calculated as

$$s_L = e^{\eta_L} / \left(1 + e^{\eta_L}\right)$$

where

$$\eta_L = 0.303 \quad L - 6.20$$

(Table A13) based on Hatfield and Cadrin's (in press) report that females were 25%, 50% and 75% mature at 16.6, 20.7 and 23.8 cm DML respectively. Weight at age in the summer fishery (winter hatch dates) and selectivity estimates used for per recruit modeling in this assessment were substantially different that those used by Cadrin and Hatfield (1999, compare Figures A41-A42 in this report). Changes to data, and selectivity estimates in particular, caused substantial changes in F estimates for per recruit reference points (see below).

F's for per recruit based biological reference points (Table A21, Figure A43-A44, and see below), particularly those based on yield, were lower than in Cadrin and Hatfield (1999). Spawning biomass per recruit calculations for Loligo squid appear less sensitive to uncertainty about growth, natural mortality, maturity and fishery selectivity than yield per recruit calculations. Reference points expressed as biomass weighted mean F's were smaller than the equivalent and corresponding fully recruited F's (Table A21 and Figures A43-A44). The relationship between biomass weighted and fully recruited F's for longfin squid was nonlinear with fully recruited values much higher than biomass weighted values (Figure A45).

Cohort	Source	Fully Recruited F_{MAX} (quarter^{-1})	Biomass Weighted F_{MAX} (quarter^{-1})	Fully Recruited $F_{0.1}$ (quarter^{-1})	Biomass Weighted $F_{0.1}$ (quarter^{-1})	Fully Recruited $F_{50\%}$ (quarter^{-1})	Biomass Weighted $F_{50\%}$ (quarter^{-1})
Winter hatch / Summer fishery	This assessment	1.4	0.77	0.94	0.58	0.69	0.45
Winter hatch / Summer fishery	Cadrin and Hatfield (1999)	2.6	Not available	1.5	Not available	0.82	Not available
Summer hatch / Winter fishery	This assessment	1.6	1.1	1.1	0.82	0.82	0.64
Summer hatch / Winter fishery	Cadrin and Hatfield (1999)	5.0	Not available	2.4	Not available	1.3	Not available

Yield maximizing reference points like F_{MAX} and $F_{0.1}$ should be viewed with caution for longfin squid and probably not used for management purposes. Technical problems stem from their sensitivity to input parameters, short lifespan and lack of age structure (dependence of future recruitment and stock biomass on current standing stock), uncertainties about growth, uncertainties about spatial variability and seasonal variability in biological parameters.

OVERFISHING DETERMINATION

It is unlikely that the overfishing is occurring in the longfin squid fishery. The largest feasible scaled catch-survey *F* estimates for 2000-2001 ranged from 0.11-0.17 quarter^{-1} (Table A15 and Figure A27). *F* estimates from the PDQ surplus production model for 2000-2001 ranged from 0.12-0.31 quarter^{-1} (Table A19 and Figure A30). Thus, all recent *F* estimates are less than the biomass weighed F_{MAX} values for longfin squid (0.77-1.1 quarter^{-1}). LVPA results (Figures A23), and unscaled catch-survey biomass estimates for winter and spring surveys (Table 16 and Figure A28) generally indicate that fishing mortality rates for longfin squid declined to relatively low levels during 2000 and 2001.

It is unlikely that the longfin squid stock is overfished. Survey data (with the exception of the Massachusetts inshore spring survey, Tables A9-12 and Figures A11-A14), LVPA results (Figure A22), scaled catch-survey biomass estimates (Table A15 and Figure A26), and PDQ model estimates (Figure A29) all indicate that longfin squid biomass was moderate to high during 2000 and 2001. The smallest feasible catch-survey biomass estimate for 2001 was 34,000 mt (Table A15), which is less than the best available estimate of $B_{MSY}/2$ (40,000 MT, NEFSC 1999). However, the probability of the lowest feasible biomass level is small for longfin squid.

SARC COMMENTS

The SARC review of the *Loligo* assessment focused on the results on a new surplus production model (PDQ model) presented by the working group. The recommended model run indicated a significant increase in biomass since 1998. The model results were driven by the increased biomass indices in the NEFSC autumn survey since 1999. The SARC questioned the trend given some conflicting patterns in other indices, such as the Massachusetts spring inshore survey. However, the higher precision of the autumn survey weighted the results toward that biomass trend.

Concerns about the model configuration were discussed. The PDQ model did not account for density dependent factors. Without estimation of a K parameter, the biomass estimate is not constrained but estimation of K confounds the estimation of other parameters. The results from this model changed the conclusions about the stock status since the previous assessment. The SARC requested a list of the changes in population models since the last assessment and the resulting differences in biomass and F estimates. The SARC also requested some additional analyses to evaluate the influence of catch estimates in 2001. It was suggested that the model outputs be limited to catch through 2000. A retrospective analysis was also requested to examine how robust the model estimates were to terminal catch inputs for the last five years.

The SARC concluded that the stock was not subjected to overfishing. However, the absolute values of F_{MSY} and B_{MSY} were not estimated in the model. The reference points in the current plan were based on F_{MAX} as a proxy for F_{MSY}. The SARC did not endorse a new estimate of F_{MSY} to replace the current estimate of F_{MAX}, but suggested a new threshold value.

In addition to the assessment results presented by the SAW Invertebrate Working Group, the SARC examined a new approach to analysis of the survey indices. A general additive model (GAM) was developed to account for the influence of factors such as time of day and area differences in the calculation of a survey index. This approach would adjust for influential factors prior to use in a model as opposed to an inclusive modeling approach adopted in the PDQ model. The GAM adjustments produced much different conclusions about the trend in the NEFSC autumn survey. The results suggested the biomass trend has been relatively stable over the past several decades and the changes in the indices are due to environmental effects. The SARC provided several suggestions for future GAM work, such as an increase in the number of size groups and standardization of the weeks the survey is conducted. The SARC noted the relative stability of the indices despite changes in landings and the possibility that it is the result of tremendous flexibility in life history patterns of *Loligo*.

Finally, the SARC examined some additional work on development of new estimates of F_{MAX} using model inputs specific to monthly cohorts. The SARC recommended an update in *Loligo* weight at age information. Growth differences between monthly cohorts had a noticeable effect on the monthly yield per recruit estimates. The SARC noted that the model provided some useful insight into the dynamics of *Loligo* but it was not appropriate for management use until the relative recruitment strength of each monthly cohort can be incorporated.

The SARC reviewed analyses of retrospective patterns of terminal year estimates of fishing mortality and biomass from the PDQ model. Model results suggested wide variation in the terminal year values but some stability in the penultimate year values for both F and B. It was recommended that the SARC focus on the biomass and F values for 2000 as measures of stock status. It was asserted that the biomass values generated by the model had greater utility than previous estimates because the constraints on the catchability coefficients ensured feasible upper and lower bounds.

Members of the SARC asked for comparison with results of GAM analyses and noted that these results provided a similar pattern of smoothing. Apparent convergence of these results suggested that the resource had been stable for years but that it was difficult to identify the absolute level of biomass. As a result, the SARC proposed and considered issues related to a heuristic assessment of the resource. Biomass appears to be stable given current annual harvest levels, but currently available information is insufficient to determine either the absolute level of biomass or the desired level with respect to long-term sustainability.

The SARC noted that this heuristic perspective on the status of the stock represented a marked change from previous assessments and that it would be necessary to build a bridge between this and earlier analyses.

RESEARCH RECOMMENDATIONS

1. Based on this assessment, it appears that traditional per-recruit reference points like F_{MAX} may be poor proxies for F_{MSY} in *L. pealeii* because they may not permit a sufficient level of escapement. There appears to be no satisfactory biomass based reference points for *L. pealeii* at this time. Fishing mortality and biomass reference points for use as targets and thresholds are an important area for research.

2. It is important to carry out further research on standardizing and modeling survey data for *L. pealeii*. A preliminary GAM model analysis of survey data should serve as a good starting point in developing standardization approaches that adjust for diel and other factors affecting catchability. PDQ model results show that survey catchability processes errors follow similar trends in different surveys and are auto-correlated within surveys. Survey catchabilities probably vary in response to water temperatures. These circumstances suggest that survey catchability processes errors might be modeled robustly and parsimoniously as a simple function of water temperatures in the PDQ model.

3. Growth information, particularly for older *L. pealeii*, is still uncertain. Additional age and growth studies are required to better estimate average growth patterns and to discern seasonal patterns. The latter are potentially important in more realistic, seasonally explicit population and reference point models like the preliminary multi-cohort reference point model.

4. The potential for fuller use of catch data prior to 1987 from foreign fishing

should be investigated for *L. pealeii*. Current assessment approaches use seasonal time steps but historical catch data are currently available only by calendar year. The working group should consult historical NAFO reports and determine if monthly or quarterly catches can be estimated. Alternatively, the PDQ model could be modified to use annual time steps prior to 1987 and quarterly time steps later. Another approach would be to use an annual surplus production model including years before and after 1987.

5. Results from this assessment demonstrate that retrospective analyses are a useful part of an assessment involving surplus production models because they provide an estimate of the stability of model estimates. However, retrospective patterns for estimates in production models may have a different meaning and origin than in traditional age structured models. This is a topic for analysis by the Methods Working Group.
6. Available logbook data are not adequate to measure fishing effort after 1993, or to prorate landings and effort data by area. It is not currently possible to measure commercial catch rates after 1993, to track trends in fishing effort, or to investigate relationships between catches and abundance in near shore, offshore, northern and southern areas. The spatial resolution, coverage and accuracy of commercial catch data for *L. pealeii* should be improved.
7. Information about the population biology of *L. pealeii* has improved in recent years but relationships between seasonal migrations, environmental conditions and temporal and spatial variability in sex ratios, maturity and growth rates are still not clear. It may be useful to carryout additional studies that collect sex and maturity data from *L. pealeii* taken during NEFSC surveys.

ACKNOWLEDGMENTS

J. Brodziak, S. Cadrin, L. Jacobson, C. Keith, H. Lai, P. Rago, J. Weinberg (Northeast Fisheries Science Center, Woods Hole, MA), C. Glass (Manomet Bird Observatory), G. Monsen (SeaFreeze Ltd.), E. Powell (Rutgers University), and R. Seagreaves (Mid-Atlantic Fishery Management Council) were members of the Invertebrate Subcommittee who made important contributions to this assessment. H. Milliken (NEFSC, National Marine Fisheries Service, Woods Hole, MA) provided advice, reports and data used to estimate efficiency of the bottom trawl used in NEFSC autumn surveys. K. Sosebee (NEFSC, National Marine Fisheries Service, Woods Hole, MA) provided the Massachusetts inshore survey strata map. L. Hendrickson (NEFSC, National Marine Fisheries Service, Woods Hole, MA) made useful suggestions concerning fishery data. J. Link (NEFSC, National Marine Fisheries Service, Woods Hole, MA) provided environmental and predator data. G. Gaipo (NERO, Gloucester, MA) provided IVR landings data for longfin squid during 2001. G. Shepherd (Northeast Fisheries Science Center, Woods Hole, MA) served as rapporteur for longfin squid at the Stock Assessment Review Meeting.

REFERENCES

Brodziak, J.K.T., and W.K. Macy, III. 1996. Growth of long-finned squid, *Loligo pealeii*, in the northwest Atlantic. Fishery Bulletin 94: 212-236.

Cadrin, S.X, and E.M.C. Hatfield. 1999. Stock assessment of longfin squid inshore squid, *Loligo pealeii*. NEFSC Ref. Doc. 99-12.

Cohen, A.C. 1976. The systematics and distribution of longfin squid (*Cephalopoda*, *Myopsida*) in the western North Atlantic, with descriptions of two new species. Malacologia 15: 299-367.

Dawe, E.G., J.C. Shears, N.E. Balch, and R.K. O'Dor. 1990. Occurrence, size, and sexual maturity of long-finned squid (*Loligo pealeii*) at Nova Scotia and Newfoundland, Canada. Can. J. Fish. Aquat. Sci. 47: 1830-1835.

Gabriel, WL, M.P. Sissenwine, and W.J. Overholtz. 1989. Analysis of spawning stock biomass per recruit: an example for Georges Bank haddock. N. Am. J. Fish. Mgmt. 9: 383-391.

Gelman, A., J.B. Carlin, H.S. Stern, and D.B. Rubin. 1995. Bayesian data analysis. Chapman and Hall/CRC. New York.

Glass, C., B. Sarno, H.A. Carr, H. Milliken and G. Morris. 1999. Bycatch reduction in Massachusetts inshore squid (*Loligo*) fishery. *In*: Final report. Bycatch reduction project. Vol. 1, chapter 2. Saltonstall Kennedy Program Project Report.

Hatfield, E.M.C, and S.X. Cadrin. In press. Geographic and temporal patterns in *Loligo pealeii* size and maturity off the northeastern United States. Fish. Bull.

Hilborn, R. and Walters, C.J. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Routledge, Chapman & Hall, Inc., NY. 570p.

Jacobson, L.D., N.C.H. Lo, and J.T. Barnes. 1994. A biomass based assessment model for northern anchovy *Engraulis mordax*. Fish. Bull. U.S. 92: 711-724.

Jacobson, L.D., J.A.A. De Oliveira, M. Barange, M.A. Cisneros-Mata, R. Felix-Uraga, J.R. Hunter, J.Y. Kim, Y. Matsuura, M. Niquen, C. Porteiro, B. Rothschild, R.P. Sanchez, R. Serra, A. Uriarte, and T. Wada. 2001. Surplus production, variability and climate change in the great sardine and anchovy fisheries. Can. J. Fish. Aquat. Sci. 58: 1891-1903.

Jones, R. 1974. Assessing the long term effects of changes in fishing effort and mesh size from length composition data. ICES C.M. F:33.

Jones, R. 1981. The use of length composition data in fish stock assessments (with notes on VPA and cohort analysis). FAO Fish. Circ. No. 734.

Jones, R. 1986. Length composition analysis, the importance of choosing the correct input growth parameters. ICES C.M. G:4.

Lai, H.L. and V.F. Gallucci. 1988. Effects of parameter variability on length-cohort analysis. J. Cons. Int. Explor. Mer. 45: 82-92.

Macy, W.K., III, and J.K.T. Brodziak. 2001. Seasonal maturity and size at age of

Loligo pealeii in waters of southern New England. ICES J. Mar. Sci. 58.

Maxwell, M.R., and R.T. Hanlon. 2000. Female reproductive output in the squid *Loligo pealeii*: multiple egg clutches and implications for a spawning strategy. Mar. Ecol. Prog. Ser. 199: 159-170.

Methot, R. D. 1990. Synthesis model: an adaptive framework for analysis of diverse stock assessment data. International North Pacific Fisheries Commission Bulletin 50:259-277.

NEFSC. 1992. Report of the fourteenth Northeast Regional Stock Assessment Workshop (14th SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. Northeast Fisheries Science Center Ref. Doc. 92-07.

NEFSC (Northeast Fisheries Science Center). 1996. 21st Northeast Regional Stock Assessment Workshop (21st SAW). Northeast Fisheries Science Center Ref. Doc. 96-05 (Section D).

NEFSC (Northeast Fisheries Science Center). 1999. 29th Northeast Regional Stock Assessment Workshop (29th SAW). Woods Hole, MA: NOAA/NMFS/NEFSC. NEFSC Ref. Doc. 99-14.

NEFSC (Northeast Fisheries Science Center). 2002. 34th Northeast Regional Stock Assessment Workshop (34th SAW). Woods Hole, MA: NOAA/NMFS/NEFSC. NEFSC Ref. Doc. 02-xx.

Polacheck, T., R. Hilborn, and A. E. Punt. 1993. Fitting surplus-production models: comparing methods and measuring uncertainty. Canadian Journal of Fisheries and Aquatic Sciences 50:2597-2607.

Powell, E.N., E.A. Bochenek, S.E. Banta, and A.J. Bonner. 2001. Scup bycatch in the small-mesh fisheries of the mid-Atlantic. Unpubl. Report. Haskin Shellfish Research Laboratory, Port Norris, NJ.

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

Seber, G.A.F. 1973. The estimation of animal abundance. Hafner Press, NY.

Sims, S.E. 1982. Algorithms for solving the catch equation forward and backward in time. Can. J. Fish. Aquat. Sci. 39: 197-202.

Sissenwine, M.P., and E.W. Bowman. 1978. An analysis of some factors affecting the catchability of fish by bottom trawls. ICNAF Res. Bull. 13: 81-87.

Thompson, W. F. and F. H. Bell. 1934. Effect of changes in intensity upon total yield and yield per unit of gear. Report of the International Fisheries Commission 8:7-49.

Weinberg, J.R., P. Rago, W. Wakefield, and C. Keith. In press. Estimation of tow distance and spatial heterogeneity using data from inclinometer sensors: an example using a clam survey dredge. Fish. Res.

Table A1. Longfin squid landings during 1963-2001 (thousand mt). U.S. landings through 2000 include prorated unspecified squid landings. Landings for January-April 2001 are preliminary and possibly incomplete. Landings for July-December 2001 are preliminary and assumed equal to quarterly quota allocations.

Year	U.S.	Foreign	Total
1963	1.294	0.000	1.294
1964	0.576	0.002	0.578
1965	0.709	0.099	0.808
1966	0.772	0.226	0.998
1967	0.547	1.130	1.677
1968	1.084	2.327	3.411
1969	0.899	8.643	9.542
1970	0.653	16.732	17.385
1971	0.727	17.442	18.169
1972	0.725	29.009	29.734
1973	1.105	36.508	37.613
1974	2.274	32.576	34.850
1975	1.621	32.180	33.801
1976	3.602	21.682	25.284
1977	1.088	15.586	16.674
1978	1.291	9.355	10.646
1979	4.252	13.068	17.320
1980	3.996	19.750	23.746
1981	2.316	20.212	22.528
1982	2.848	15.805	18.653
1983	10.867	11.720	22.587
1984	7.689	11.031	18.720
1985	6.899	6.549	13.448
1986	11.525	4.598	16.123
1987	10.367	0.002	10.369
1988	18.593	0.003	18.596
1989	23.733	0.005	23.738
1990	15.399	0.000	15.399
1991	20.299	0.000	20.299
1992	19.018	0.000	19.018
1993	23.020	0.000	23.020
1994	23.480	0.000	23.480
1995	18.880	0.000	18.880
1996	12.026	0.000	12.026
1997	16.308	0.000	16.308
1998	19.151	0.000	19.151
1999	19.386	0.000	19.386
2000	17.034	0.000	17.034
2001	14.603	0.000	14.603

Table A2. Longfin squid landings data (thousand mt) by quarter during 1987-2001. Data for January-June 2001are preliminary and probably incomplete. Data for July-December 2001 are preliminary and assumed equal to quarterly quota allocations. Landings for 1987-2000 include prorated unspecified squid landings.

Year	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Nov	Total
1987	2.505	4.265	1.815	1.782	10.367
1988	3.404	7.589	3.451	4.149	18.593
1989	9.838	6.919	1.164	5.812	23.733
1990	4.538	3.847	2.933	4.081	15.399
1991	2.877	6.297	3.443	7.682	20.299
1992	7.211	3.531	2.061	6.214	19.018
1993	11.438	4.736	1.725	5.121	23.020
1994	4.762	2.285	6.603	9.830	23.480
1995	5.815	3.820	3.933	5.312	18.880
1996	5.201	4.648	1.019	1.158	12.026
1997	3.347	2.961	2.753	7.248	16.308
1998	10.692	2.128	1.128	5.204	19.151
1999	4.927	3.152	5.001	6.307	19.387
2000	6.408	3.345	3.884	3.397	17.034
2001	3.817	2.429	2.941	5.416	14.603
Average % 1987-2000	32%	23%	16%	29%	100%

Table A3. Discard rate (weight longfin squid discarded / weight target species landed) and discard estimates (mt) for longfin squid in trips targeting key species during 1997-2000. Landings data for Loligo includes prorated unspecified squid. Landings data for herring includes "Herring NK" (herring species not known). No adjustments were made to landings data for any other species. Landings data from the commercial fisheries database (CFDETS1994-CFDETS2000). Discard rate estimates from NMFS observer data during 1997 to mid-2000 and Rutgers University personnel aboard 13 trips targeting black seabass and scup. All available discard data were used.

Year	**Black Seabass**	**Butterfish**	**Herring**	**Loligo**	**Mackerel**	**Scup**	**Silver hake**	**Totals**
Landings								
1997	1,203	2,798	97,055	16,308	9,539	1,659	15,534	144,097
1998	1,184	1,967	82,597	19,151	11,599	1,179	14,691	132,368
1999	1,337	2,112	79,652	19,386	8,774	1,056	13,443	125,760
2000	1,213	1,435	75,605	17,034	4,475	742	12,145	112,649
Average Landings	1,234	2,078	83,727	17,970	8,597	1,159	13,953	128,719
Observer Trips	5	3	0	111	15	18	32	184
Observer Tows	16	21	0	1,115	97	78	147	1,474
Discard Rate	0	0.0095	0.0004	0.0277	0.0004	0.0125	0.0018	0.0046
Average Discards (MT)	0	20	34	498	4	14	25	596

Table A4. Standard landings per unit fishing effort (LPUE, mt /days fished) for longfin squid in the domestic squid fishery from NEFSC (1996). "Winter" is October-March (e.g. "1982" means October 1982-March 1983). Summer is April-September (e.g. "1982" means April-September 1982).

Year	Winter	Summer
1982	3.66	3.82
1983	6.17	7.18
1984	4.61	5.09
1985	2.18	4.62
1986	3.99	4.38
1987	4.63	4.27
1988	8.45	4.95
1989	6.13	3.54
1990	4.64	3.63
1991	7.96	4.38
1992	8.52	2.90
1993		2.59

Table A5. Summary of NEFSC autumn bottom trawl survey data for longfin squid. The autumn survey started in 1964 but longfin squid were first identified in 1967. "Mean date (Julian)" is for tows in strata used for longfin squid. In a non-leap year, the earliest mean Julian date (264) corresponds to September 21 and the latest mean Julian date (303) corresponds to October 30. The NEFSC standard Yankee No. 36 bottom trawl (www.nefsc.nmfs.gov/esb/survey%20gear.htm.) was used in all years.

Year	Mean Date (Julian)	Original Cruise Code	Cruise Code Assigned	Research Vessels	Type Trawl Doors
1967	303	721	6721	Albatross IV	BMV
1968	293	817	6817	Albatross IV	BMV
1969	291	911	6911	Albatross IV	BMV
1970	277	706	7006	Albatross IV, Delaware II	BMV
1971	285	716	7106	Albatross IV	BMV
1972	284	728	7208	Albatross IV	BMV
1973	281	738	7308	Albatross IV	BMV
1974	277	748	7411	Albatross IV	BMV
1975	294	758	7512	Albatross IV, Delaware II	BMV
1976	289	767	7609	Albatross IV	BMV
1977	283	778	7712	Delaware II	BMV
1978	284	789	7806	Delaware II	BMV
1979	287	799	7910	Albatross IV, Delaware II	BMV
1980	283	809	8007	Delaware II	BMV
1981	280	816	8106	Albatross IV, Delaware II	BMV
1982	278	NA	8206	Albatross IV	BMV
1983	276	NA	8306	Albatross IV	BMV
1984	274	NA	8405	Albatross IV	BMV
1985	283	NA	8508	Albatross IV, Delaware II	Polyvalent
1986	275	NA	8606	Albatross IV, Delaware II	Polyvalent
1987	269	NA	8705	Albatross IV	Polyvalent
1988	270	NA	8803	Albatross IV, Delaware II	Polyvalent
1989	271	NA	8904	Delaware II	Polyvalent
1990	267	NA	9004	Delaware II	Polyvalent
1991	267	NA	9105	Delaware II	Polyvalent
1992	270	NA	9206	Albatross IV	Polyvalent
1993	266	NA	9306	Delaware II	Polyvalent
1994	270	NA	9406	Albatross IV	Polyvalent
1995	266	NA	9507	Albatross IV	Polyvalent
1996	266	NA	9604	Albatross IV	Polyvalent
1997	267	NA	9706	Albatross IV	Polyvalent
1998	278	NA	9804	Albatross IV	Polyvalent
1999	280	NA	9908	Albatross IV	Polyvalent
2000	264	NA	2005	Albatross IV	Polyvalent
2001	264	NA	200109	Albatross IV	Polyvalent

Table A6. Summary of NEFSC spring bottom trawl survey data for longfin squid. "Mean date (Julian)" is for tows in strata used for longfin squid. In a non-leap year, the earliest mean Julian date (69) is 10 March and the latest mean Julian date (109) is 19 April. The standard Yankee No. 36 and No. 41 bottom trawsl are described in http://www.nefsc.nmfs.gov/esb/survey%20gear.htm.

Year	Mean Date (Julian)	Original Inshore Cruise Code	Original Offshore Cruise Code	Cruise Code Assigned	Research Vessels	Type Survey Trawl	Type Trawl Doors
1968	76	NA	NA	6803	Albatross IV	Yankee No. 36	BMV
1969	76	NA	NA	6902	Albatross IV	Yankee No. 36	BMV
1970	109	NA	NA	7003	Albatross IV	Yankee No. 36	BMV
1971	87	NA	NA	7101	Albatross IV	Yankee No. 36	BMV
1972	81	NA	NA	7202	Albatross IV	Yankee No. 36	BMV
1973	89	NA	NA	7303	Albatross IV, Delaware II	Yankee No. 36	BMV
1974	83	274	744	7404	Albatross IV	Yankee No. 41	BMV
1975	78	753	NA	7503	Albatross IV	Yankee No. 41	BMV
1976	77	450	762	7602	Albatross IV, Delaware II	Yankee No. 41	BMV
1977	95	467	771	7702	Albatross IV, Delaware II	Yankee No. 41	BMV
1978	89	782	783	7804	Albatross IV	Yankee No. 41	BMV
1979	102	792	793	7904	Albatross IV, Delaware II	Yankee No. 41	BMV
1980	98	801	802	8002	Albatross IV, Delaware II	Yankee No. 41, Yankee No. 36	BMV
1981	101	811	812	8102	Delaware II	Yankee No. 41, Yankee No. 36	BMV
1982	91	NA	NA	8202	Delaware II	Yankee No. 36	BMV
1983	85	NA	NA	8303	Albatross IV	Yankee No. 36	BMV
1984	79	NA	NA	8402	Albatross IV	Yankee No. 36	BMV
1985	72	NA	NA	8502	Albatross IV	Yankee No. 36	Polyvalent
1986	80	NA	NA	8603	Albatross IV	Yankee No. 36	Polyvalent
1987	97	NA	NA	8702	Albatross IV, Delaware II	Yankee No. 36	Polyvalent
1988	77	NA	NA	8801	Albatross IV	Yankee No. 36	Polyvalent
1989	69	NA	NA	8901	Delaware II	Yankee No. 36	Polyvalent
1990	74	NA	NA	9002	Delaware II	Yankee No. 36	Polyvalent
1991	74	NA	NA	9102	Delaware II	Yankee No. 36	Polyvalent
1992	72	NA	NA	9202	Albatross IV	Yankee No. 36	Polyvalent
1993	83	NA	NA	9302	Albatross IV	Yankee No. 36	Polyvalent
1994	77	NA	NA	9402	Delaware II	Yankee No. 36	Polyvalent
1995	85	NA	NA	9503	Albatross IV	Yankee No. 36	Polyvalent
1996	84	NA	NA	9602	Albatross IV	Yankee No. 36	Polyvalent
1997	74	NA	NA	9702	Albatross IV	Yankee No. 36	Polyvalent
1998	70	NA	NA	9802	Albatross IV	Yankee No. 36	Polyvalent
1999	75	NA	NA	9902	Albatross IV	Yankee No. 36	Polyvalent
2000	88	NA	NA	2002	Albatross IV	Yankee No. 36	Polyvalent
2001	76	NA	NA	200102	Albatross IV	Yankee No. 36	Polyvalent

Table A7. Summary of NEFSC winter bottom trawl survey data for longfin squid. Longfin squid were identified in all years. "Mean date (Julian)" is for tows in strata used for longfin squid. In a non-leap year, the earliest mean Julian date (38) is 7 February and the latest mean Julian date (49) is 18 February. The standard 60-80 bottom trawl used in winter surveys is described in ttp://www.nefsc.nmfs.gov/esb/adobe/flat_net.pdf.

Year	Mean Date (Julian)	Cruise Code	Research Vessels
1992	49	9202	Albatross IV
1993	44	9302	Albatross IV
1994	38	9402	Delaware II
1995	48	9503	Albatross IV
1996	44	9602	Albatross IV
1997	43	9702	Albatross IV
1998	44	9802	Albatross IV
1999	40	9902	Albatross IV
2000	49	2002	Albatross IV
2001	39	2101	Albatross IV

Table A8. Summary of Massachusetts spring bottom trawl survey data for longfin squid. Longfin squid were identified in all years. "Mean date (Julian)" is for tows in strata used for longfin squid. In a non-leap year, the earliest mean Julian date (132) is 11 May and the latest mean Julian date (147) is 26 May. The standard 60-80 bottom trawl used in winter surveys is described in the text.

Year	Mean Date (Julian)	Cruise Code	Research Vessels
1978	147	921	Francis Elizabeth
1979	134	923	Francis Elizabeth
1980	139	925	Francis Elizabeth
1981	136	927	Francis Elizabeth
1982	135	8291	Gloria Michelle
1983	139	8391	Gloria Michelle
1984	137	8491	Gloria Michelle
1985	136	8591	Gloria Michelle
1986	135	8691	Gloria Michelle
1987	132	8791	Gloria Michelle
1988	141	8891	Gloria Michelle
1989	137	8991	Gloria Michelle
1990	138	9091	Gloria Michelle
1991	136	9191	Gloria Michelle
1992	134	9291	Gloria Michelle
1993	134	9391	Gloria Michelle
1994	139	9491	Gloria Michelle
1995	139	9591	Gloria Michelle
1996	137	9691	Gloria Michelle
1997	135	9791	Gloria Michelle
1998	133	9891	Gloria Michelle
1999	140	9991	Gloria Michelle
2000	140	2091	Gloria Michelle
2001	137	2191	Gloria Michelle

Table A9. NEFSC fall bottom trawl survey data for longfin squid. Data are mean KG per standard tow for all squid and mean number per tow for "pre-recruits" <= 8.9 cm DML (both adjusted to daytime equivalents using diel correction factors in Hatfield and Cadrin, in press). "Survey Area" and "Survey Strata" give the number of strata and total area of strata sampled in each year. Average temperatures are from survey records at each tow location used for longfin squid.

Year	Average Surface Temp. (°C)	Average Bottom Temp. (°C)	KG/Tow	CV	Pre-Recruit N/Tow	CV	N Tows	Survey Strata Sampled	Survey Area
1967	15.3	11.8	5.2	0.28	184	0.25	187	40	40,586
1968	17.5	13.0	8.7	0.24	199	0.25	187	40	40,586
1969	14.5	13.6	11.2	0.14	270	0.18	186	40	40,586
1970	18.9	11.5	5.2	0.20	124	0.23	184	40	40,586
1971	18.3	12.6	3.6	0.18	193	0.23	191	40	40,586
1972	17.5	14.4	10.0	0.22	444	0.25	181	40	40,586
1973	18.3	13.7	15.0	0.12	463	0.24	177	40	40,586
1974	18.5	13.7	12.6	0.14	411	0.36	176	40	40,586
1975	16.0	12.9	17.9	0.22	895	0.30	181	40	40,586
1976	17.1	13.5	16.0	0.19	641	0.17	185	40	40,586
1977	17.5	13.1	12.8	0.18	601	0.20	208	40	40,586
1978	17.0	11.6	6.4	0.14	194	0.17	266	40	40,586
1979	16.5	12.7	6.4	0.11	357	0.18	258	40	40,586
1980	18.3	12.9	12.0	0.18	1,325	0.36	189	39	40,526
1981	16.5	12.4	7.9	0.15	307	0.16	170	40	40,586
1982	18.7	12.5	9.8	0.18	446	0.32	166	40	40,586
1983	19.1	12.4	15.3	0.14	472	0.17	169	40	40,586
1984	18.8	12.4	17.1	0.12	319	0.16	167	39	40,500
1985	19.0	14.3	17.0	0.20	649	0.23	167	40	40,586
1986	18.6	13.6	13.0	0.12	616	0.17	167	40	40,586
1987	19.3	12.3	3.2	0.24	81	0.21	154	39	40,534
1988	19.0	11.6	11.7	0.16	637	0.23	152	40	40,586
1989	18.9	13.1	15.6	0.12	531	0.21	151	40	40,586
1990	21.0	14.0	13.8	0.14	548	0.20	159	39	40,481
1991	20.0	12.7	13.2	0.12	430	0.22	152	40	40,586
1992	18.5	12.5	10.7	0.17	1,252	0.21	150	38	40,429
1993	19.9	12.3	6.4	0.13	177	0.23	151	39	40,526
1994	18.1	13.7	19.8	0.16	607	0.21	158	40	40,586
1995	19.6	14.8	8.2	0.14	440	0.27	151	40	40,586
1996	18.1	12.0	4.4	0.15	219	0.23	153	40	40,586
1997	19.8	13.6	8.9	0.28	386	0.26	155	40	40,586
1998	18.5	12.2	6.2	0.19	267	0.18	154	40	40,586
1999	18.7	14.9	15.6	0.11	1,018	0.15	153	40	40,586
2000	19.6	14.1	17.2	0.12	843	0.15	153	40	40,586
2001	na	na	18.3	0.18	1,578	0.37	154	40	40,586
Average	18.3	13.0	11.3	0.17	518	0.23	173	40	40,571
Min	14.5	11.5	3.2	0.11	81	0.15	150	38	40,429
Max	21.0	14.9	19.8	0.28	1,578	0.37	266	40	40,586

Table A10. NEFSC spring bottom trawl survey data for longfin squid. Data are mean KG per standard tow for all squid and mean number per tow for "pre-recruits" <= 8.9 cm DML (both adjusted to daytime equivalents using diel correction factors in Hatfield and Cadrin, in press). "Survey Area" and "Survey Strata" give the number of strata and total area of strata sampled in each year. Average temperatures are from survey records at each tow location used for longfin squid.

Year	Average Surface Temp. (°C)	Average Bottom Temp. (°C)	KG/Tow	CV	Pre-Recruit N/Tow	CV	N Tows	Survey Strata Sampled	Survey Area
1968	5.6	8.7	1.6	0.75	10	0.57	174	40	40,586
1969	6.4	9.2	1.1	0.54	3	0.57	178	40	40,586
1970	7.1	9.9	0.9	0.69	20	0.88	188	40	40,586
1971	6.1	9.5	1.7	0.38	23	0.33	183	40	40,586
1972	7.5	10.2	3.1	0.32	43	0.47	189	40	40,586
1973	7.1	10.4	2.9	0.39	22	0.70	210	40	40,586
1974	8.7	10.6	4.3	0.30	219	0.43	153	40	40,586
1975	6.7	9.4	4.6	0.42	147	0.54	157	36	38,879
1976	7.9	9.8	5.7	0.22	187	0.42	185	40	40,586
1977	9.1	8.8	0.9	0.75	11	0.53	183	40	40,586
1978	6.6	8.4	1.4	0.71	44	0.92	185	40	40,586
1979	7.2	9.0	2.4	0.44	103	0.63	239	40	40,586
1980	8.7	9.7	1.9	0.41	45	0.52	225	40	40,586
1981	7.6	9.7	1.9	1.01	34	1.19	163	39	40,414
1982	6.4	9.2	2.2	0.47	58	0.93	174	40	40,586
1983	8.0	9.7	2.6	0.52	23	0.52	169	40	40,586
1984	7.6	10.0	2.9	0.52	61	0.64	172	40	40,586
1985	8.2	10.2	2.4	0.57	76	0.58	167	40	40,586
1986	8.9	10.4	3.2	0.38	83	0.44	172	40	40,586
1987	7.4	9.6	2.1	0.41	15	1.18	173	40	40,586
1988	6.0	9.1	3.9	0.39	106	0.66	154	39	40,481
1989	8.1	9.5	5.3	0.43	104	0.60	149	40	40,586
1990	8.0	9.6	3.8	0.56	119	0.40	151	39	40,414
1991	9.4	10.8	4.7	0.30	156	0.40	154	40	40,586
1992	6.9	9.5	2.5	0.55	78	0.59	150	38	40,350
1993	6.3	8.7	2.0	0.54	33	0.56	151	38	40,350
1994	7.3	10.0	1.2	0.49	28	0.58	152	39	40,410
1995	8.7	10.5	2.2	0.31	55	0.37	150	40	40,586
1996	7.5	9.6	0.6	0.47	23	0.50	163	40	40,586
1997	7.2	10.2	2.2	0.59	67	0.49	152	38	40,305
1998	6.5	8.1	1.5	0.50	53	0.49	154	39	40,526
1999	8.1	10.8	3.6	0.43	216	0.42	154	40	40,586
2000	9.0	10.3	2.9	0.38	115	0.49	154	40	40,586
2001	7.2	9.8	2.1	0.40	106	0.38	154	40	40,586
Average	7.5	9.7	2.6	0.49	73	0.59	170	40	40,494
Min	5.6	8.1	0.6	0.22	3	0.33	149	36	38,879
Max	9.4	10.8	5.7	1.01	219	1.19	239	40	40,586

Table A11. NEFSC winter bottom trawl survey data for longfin squid. Data are mean KG per standard tow for all squid and mean number per tow for "pre-recruits" <= 8.9 cm DML (both adjusted to daytime equivalents using diel correction factors in Hatfield and Cadrin, in press). "Survey Area" and "Survey Strata" give the number of strata and total area of strata sampled in each year. Average temperatures are from survey records at each tow location used for longfin squid.

Average Surface Temp. (^oC)	Average Winter Temp. (^oC)	KG/Tow	CV	Pre-Recruit N/Tow	CV	N Tows	Survey Strata Sampled	Survey Area
7.0	9.2	2.2	0.33	44	0.49	105	24	32,994
6.7	8.4	4.9	0.33	100	0.46	109	23	29,988
7.5	9.4	2.2	0.35	45	0.53	78	24	32,994
15.6	9.5	3.7	0.31	67	0.37	118	27	33,772
6.5	9.1	2.7	0.52	45	0.55	123	25	33,354
7.1	9.7	1.9	0.26	38	0.33	119	31	34,343
7.0	8.7	1.7	0.35	25	0.38	134	32	34,267
8.5	10.8	2.9	0.20	107	0.33	134	33	34,455
9.4	10.3	7.2	0.24	295	0.38	123	28	30,479
7.6	10.0	4.1	0.30	150	0.32	166	33	34,455
8.3	9.5	3.4	0.32	92	0.42	121	28	33,110
6.5	8.4	1.7	0.20	25	0.32	78	23	29,988
15.6	10.8	7.2	0.52	295	0.55	166	33	34,455

Table A12. Massachusetts inshore spring bottom trawl survey data for longfin squid. Data are mean KG per standard tow for all squid and mean number per tow for "pre-recruits" <= 8.9 cm DML (both adjusted to daytime equivalents using diel correction factors in Hatfield and Cadrin, in press). "Survey Area" and "Survey Strata" give the number of strata and total area of strata sampled in each year. Average temperatures are from survey records at each tow location used for longfin squid.

Year	Average Surface Temp. (^oC)	Average Bottom Temp. (^oC)	KG/Tow	CV	Pre-Recruit N/Tow	CV	N Tows	Survey Strata Sampled	Survey Area
1978	14.1	13.5	1.3	0.31	2	0.23	56	11	1,044
1979	13.9	13.3	4.1	0.30	7	0.41	51	11	1,044
1980	11.4	12.1	6.1	0.47	3	0.25	53	11	1,044
1981	11.3	10.8	1.2	0.42	5	0.43	55	11	1,044
1982	11.6	11.2	1.5	0.50	5	0.36	51	11	1,044
1983	12.2	11.8	8.1	0.43	38	0.21	53	11	1,044
1984	12.4	11.8	4.6	0.31	14	0.17	54	11	1,044
1985	12.4	11.7	7.0	0.28	38	0.31	52	11	1,044
1986	10.8	10.2	7.4	0.37	2	0.32	56	11	1,044
1987	11.7	11.4	6.7	0.36	3	0.32	51	11	1,044
1988	11.7	10.9	17.7	0.31	79	0.24	49	11	1,044
1989	10.7	9.4	6.0	0.22	12	0.33	49	11	1,044
1990	11.4	11.0	9.6	0.26	54	0.17	53	11	1,044
1991	13.6	13.0	4.7	0.28	3	0.29	51	11	1,044
1992	10.6	10.4	1.3	0.39	1	0.28	51	11	1,044
1993	12.5	11.8	3.2	0.31	1	0.38	54	11	1,044
1994	10.5	9.9	1.8	0.35	4	0.34	53	11	1,044
1995	10.8	10.5	5.0	0.28	64	0.24	53	11	1,044
1996	12.3	11.5	3.7	0.47	6	0.26	56	11	1,044
1997	11.1	10.7	1.5	0.20	15	0.40	55	11	1,044
1998	10.9	10.5	0.9	0.19	40	0.28	52	11	1,044
1999	14.1	13.9	2.6	0.27	9	0.31	52	11	1,044
2000	12.5	12.3	5.7	0.35	173	0.30	53	11	1,044
2001	12.6	12.3	1.6	0.33	1	0.32	54	11	1,044
Average	12.0	11.5	4.7	0.33	24	0.30	53	11	1,044
Min	10.5	9.4	0.9	0.19	1	0.17	49	11	1,044
Max	14.1	13.9	17.7	0.50	173	0.43	56	11	1,044

Table A13. Time in length group (Dt_L) and assumed natural mortality rates (M_L) used in length based virtual population analyses (LVPA) for longfin squid.

Length Groups (cm)	Summer fishery / Winter Hatch M_L (quarter^{-1})	Winter Fishery / Summer Hatch M_L (quarter^{-1})	Summer Fishery / Winter Hatch Age at Lower Bound of Length Group (months)	Dt_L (months)	Winter Fishery / Summer Hatch Age at Lower Bound of Length Group (months)	Dt_L (months)
31+	NA	NA	10.276	NA	8.351	NA
29 to 30.9	1.5	1.98	10.006	0.271	8.179	0.172
27 to 28.9	0.75	0.99	9.716	0.290	7.995	0.184
25 to 26.9	0.75	0.99	9.403	0.312	7.797	0.198
23 to 24.9	0.75	0.99	9.065	0.338	7.583	0.215
21 to 22.9	0.75	0.99	8.696	0.369	7.349	0.234
19 to 20.9	0.75	0.99	8.290	0.406	7.091	0.258
17 to 18.9	0.75	0.99	7.839	0.451	6.805	0.286
15 to 16.9	0.75	0.99	7.331	0.508	6.483	0.322
13 to 14.9	0.75	0.99	6.751	0.581	6.114	0.368
11 to 12.9	0.75	0.99	6.073	0.678	5.685	0.430
9 to 10.9	0.75	0.99	5.259	0.814	5.168	0.516

Table A14. Summary of bounds for factors affecting catchability of longfin squid in the NEFSC fall bottom trawl survey (survey data adjusted for diel catchability patterns).

Factor	Lower Bound	Upper Bound	Comment
Tow distance (d)	5% smaller than the nominal value (0.95 x 3.52 km/tow =3.3450)	10% larger than the nominal value (1.1 x 3.52 km/tow =3.8732)	Units km/tow, based on information from clam and scallop studies
Effective survey bottom trawl width (w)	Mean wing spread (0.01164 km)	Mean door spread (0.02380 km)	Units km, based on field measurements
Survey bottom trawl efficiency e	0.1	0.9	Dimensionless; choices close to minimum and maximum possible values ($0< e \leq 1$)
Effective stock area (A)	5% larger than area surveyed (1.1 S =1.1 x 139,357 = 146,324 km^2)	30% larger than area surveyed (1.3 S =1.5 x 139,357 = 181,163 km^2)	Units km^2, for fall NEFSC survey with diel catchability adjustments
Weight units (u)	106	106	Survey data in kg/tow, stock biomass in 1000 MT
Fall survey daytime catchability (Q)	$Q^{min} = [d_{min}\ w_{min}\ e_{min}] / A_{max}$ = (3.3450 x 0.01164 x 0.1 x 106) / 181,163 = 0.02149	$Q^{max} = [d_{max}\ w_{max}\ e_{max}] / A_{min}$ = (3.8732 x 0.02380 x 0.9 x 106) / 146,324 = 0.5569	Units km^{-1}, lower bound is minimum/maximum factor values; upper bound is maximum/minimum factor values

Table A15. Scaled autumn catch-survey biomass and fishing mortality (F) estimates for longfin squid. F estimates not calculated prior to 1987 because quarterly catch data not available.

Minimum "most likely" Q_{Fall}	0.050
Maximum "most likely" Q_{Fall}	0.220
Upper feasible bound for Q_{Fall}	0.547
Discard rate	6%

Year	Adusted (daytime) KG/Tow	Minimum "Most Likely" Biomass (1000 mt)	Maximum "Most Likely" Biomass (1000 mt)	Lowest Feasible Biomass (1000 mt)	October-December Catch (1000 mt)	October-December Catch + Discard (1000 mt)	Minimum "Most Likely" F (quarter^{-1})	Maximum "Most Likely" F (quarter^{-1})	Maximum Feasible F (quarter^{-1})
1967	5.15	23	103	9					
1968	8.66	39	173	16					
1969	11.22	51	224	21					
1970	5.22	24	104	10					
1971	3.64	17	73	7					
1972	10.05	46	201	18					
1973	14.99	68	300	27					
1974	12.62	57	252	23					
1975	17.90	81	358	33					
1976	15.98	73	320	29					
1977	12.85	58	257	23					
1978	6.36	29	127	12					
1979	6.44	29	129	12					
1980	12.02	55	240	22					
1981	7.87	36	157	14					
1982	9.80	45	196	18					
1983	15.29	70	306	28					
1984	17.13	78	343	31					
1985	17.04	77	341	31					
1986	12.97	59	259	24					
1987	3.15	14	63	6	1.78	1.89	0.03	0.13	0.33
1988	11.75	53	235	21	4.15	4.40	0.02	0.08	0.20
1989	15.59	71	312	28	5.81	6.16	0.02	0.09	0.22
1990	13.81	63	276	25	4.08	4.33	0.02	0.07	0.17
1991	13.21	60	264	24	7.68	8.14	0.03	0.14	0.34
1992	10.68	49	214	20	6.21	6.59	0.03	0.14	0.34
1993	6.39	29	128	12	5.12	5.43	0.04	0.19	0.46
1994	19.82	90	396	36	9.83	10.42	0.03	0.12	0.29
1995	8.15	37	163	15	5.31	5.63	0.03	0.15	0.38
1996	4.43	20	89	8	1.16	1.23	0.01	0.06	0.15
1997	8.90	40	178	16	7.25	7.68	0.04	0.19	0.47
1998	6.15	28	123	11	5.20	5.52	0.04	0.20	0.49
1999	15.59	71	312	29	6.31	6.69	0.02	0.09	0.23
2000	17.18	78	344	31	3.40	3.60	0.01	0.05	0.11
2001	18.33	83	367	34	5.42	5.74	0.02	0.07	0.17
Min	3.15	14	63	6	1.16	1.23	0.01	0.05	0.11
Max	19.82	90	396	36	9.83	10.42	0.04	0.20	0.49
Mean All Years	11.32	51	226	21	5.24	5.55	0.03	0.12	0.30

Table A16. Unscaled relative catch-survey F estimates for longfin squid from winter survey and catch data, and from spring survey and catch data.

Year	Spring Survey (KG/Tow)	April-June Catch	Unscaled Relative Spring F	Winter Survey (KG/Tow)	January-March Catch	Relative Winter F
1987	2.60	4.265	1.64			
1988	3.77	7.589	2.02			
1989	5.29	6.919	1.31			
1990	3.67	3.847	1.05			
1991	4.42	6.297	1.42			
1992	2.53	3.531	1.40	3.14	7.211	2.29
1993	2.27	4.736	2.09	5.85	11.438	1.95
1994	1.24	2.285	1.85	2.68	4.762	1.78
1995	2.10	3.820	1.82	4.38	5.815	1.33
1996	0.74	4.648	6.31	3.25	5.201	1.60
1997	2.27	2.961	1.31	2.26	3.347	1.48
1998	1.39	2.128	1.53	2.08	10.692	5.14
1999	3.63	3.152	0.87	3.23	4.927	1.52
2000	2.78	3.345	1.20	8.03	6.408	0.80
2001	2.35	3.024	1.29	4.82	3.391	0.70

Table A17. CV's for longfin squid abundance data with assumed CV's for catchability process errors and goodness of fit CV's from the basecase PDQ model run.

Abundance Index	Minimum Data CV	Mean Data CV	Maximum Data CV	Assumed CV for Catchability Process Errors	Goodness of Fit CV for Basecase Run
NEFSC autumn bottom trawl survey (1987-2001)	0.11	0.16	0.28	0.15	0.26
NEFSC spring bottom trawl survey (1987-2001)	0.3	0.45	0.6	0.05	0.51
NEFSC winter bottom trawl survey (1987-2001)	0.2	0.32	0.52	0.1	0.37
Massachusetts spring bottom trawl survey (1987-2001)	0.19	0.3	0.47	0.35	0.36
Standardized winter LPUE	0.2	0.2	0.2*	0	0.21
Standardized summer LPUE	0.2	0.2	0.2*	0	0.24
Winter LVPA biomass trend	0.3	0.3	0.3*	0.15	0.34
Summer LVPA biomass trend	0.3	0.3	0.3*	0.05	0.37

*Assumed constant value

Table A18. Basecase run and likelihood profile analysis for the simple PDQ model with catchability process errors. The likelihood profile analysis was carried out by fixing Q_{FALL} at a serious of values that spanned the feasible range and with process error CV's as in the basecase run (see Table A17). Goodness of fit (GOF) is measured by negative log likelihood. Smaller negative log likelihood values mean better fit. The smallest negative log likelihood value in each row is identified by ***large-bold-italic-outline*** font.

	Profile Q=0.02	**Profile Q=0.05**	**Profile Q=0.11**	**Profile Q=0.2**	**Profile Q=0.22**	**Profile Q=0.29**	**Profile Q=0.39**	**Best Fit, Basecase**	**Profile Q=0.48**	**Profile Q=0.56**
NEFSC Fall Survey Catchabillity	0.02	0.05	0.11	0.20	0.22	0.29	0.39	0.45	0.48	0.56
Goodness of fit (GOF) for surveys:										
GOF NEFSC Fall Survey	21.78	21.78	19.84	20.18	17.22	15.89	14.91	14.48	14.36	***14.06***
GOF NEFSC Spring Survey	12.23	11.10	11.15	12.42	10.26	10.04	9.85	9.71	9.65	***9.44***
GOF NEFSC Winter Survey	9.59	9.98	9.34	8.08	8.49	8.17	***8.10***	8.19	8.24	8.46
GOF Mass. Spring Survey	9.82	***9.16***	10.45	10.95	9.94	10.13	10.23	10.24	10.22	10.13
GOF Winter LPUE	6.40	7.47	6.60	5.22	5.52	4.80	4.09	3.68	3.55	***3.15***
GOF Summer LPUE	4.79	***3.68***	3.99	4.47	3.98	4.28	4.66	4.92	5.01	5.33
GOF Winter LVPA Biom. Trend	9.74	10.05	10.12	11.20	10.03	9.77	9.36	9.04	8.93	***8.51***
GOF Summer LVPA Biom. Trend	***11.01***	9.61	10.73	13.91	10.61	10.63	10.59	10.61	10.63	10.82
GOF all surveys:	85.35	82.83	82.22	86.42	76.06	73.72	71.78	70.86	70.59	***69.90***
Prior GOF Qfall:	4.31	1.96	***1.54***	1.60	1.67	2.02	2.77	3.71	4.22	11.68
Survey Q process errors:	38.61	38.28	37.44	38.19	35.29	34.17	33.18	32.67	32.50	***32.02***
Production process errors:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Catch:	0.00	1.00	0.03	0.17	0.00	0.00	0.00	0.00	0.00	0.00
Catch/Biomass Constraint:	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOF everything	128.27	124.07	121.24	126.38	113.02	109.92	107.74	***107.23***	107.32	113.60
Biomass and F:										
Average biomass in 2001	500.00	205.98	104.04	91.37	61.30	50.26	41.38	36.43	34.80	***29.70***
Average F 2000	***0.01***	0.02	0.05	0.06	0.09	0.12	0.16	0.20	0.21	0.26
Average catch in 2000	4.78	4.79	4.94	4.72	4.78	4.78	4.78	4.79	4.79	4.79
Production model:										
Geom. Mean surplus production rate	***0.02***	0.02	0.06	0.10	0.12	0.16	0.21	0.25	0.26	0.31

Table A19. Longfin squid biomass, surplus production and fishing mortality rates for basecase PDQ model with catchability process errors. CV's for biomass and fishing mortality estimates calculated by the delta method with assymptotic variances for parameters, and by bootstrapping (500 boostrap iterations). Estimates for 2001 not reliable.

Year	Biomass (1000 MT)	Asymptotic CV	Bootstrap CV	Surplus Production (Thousand MT per quarter)	Fishing Mortality (*F*) per quarter	Asymptotic CV	Bootstrap CV
1987.00	16.42	0.17	0.20	4.58	0.16	0.17	0.18
1987.25	17.82	0.17	0.19	4.97	0.27	0.17	0.18
1987.50	17.35	0.18	0.20	4.83	0.11	0.17	0.18
1987.75	19.87	0.16	0.18	5.54	0.09	0.15	0.16
1988.00	23.15	0.14	0.16	6.45	0.16	0.13	0.14
1988.25	25.28	0.13	0.15	7.04	0.36	0.13	0.14
1988.50	22.63	0.14	0.16	6.31	0.16	0.13	0.14
1988.75	24.55	0.13	0.15	6.84	0.18	0.12	0.13
1989.00	26.12	0.11	0.14	7.28	0.47	0.13	0.14
1989.25	20.80	0.14	0.17	5.80	0.40	0.15	0.16
1989.50	17.75	0.17	0.19	4.95	0.07	0.15	0.16
1989.75	21.22	0.14	0.17	5.91	0.32	0.15	0.16
1990.00	19.72	0.16	0.18	5.50	0.26	0.16	0.17
1990.25	19.43	0.16	0.19	5.41	0.22	0.16	0.17
1990.50	19.94	0.16	0.19	5.56	0.16	0.16	0.17
1990.75	21.77	0.15	0.18	6.07	0.21	0.15	0.16
1991.00	22.63	0.15	0.17	6.31	0.14	0.14	0.15
1991.25	25.29	0.14	0.16	7.05	0.29	0.14	0.15
1991.50	24.30	0.14	0.16	6.77	0.15	0.13	0.14
1991.75	26.70	0.13	0.15	7.44	0.34	0.13	0.14
1992.00	24.33	0.14	0.16	6.78	0.35	0.14	0.15
1992.25	21.90	0.15	0.17	6.10	0.17	0.15	0.15
1992.50	23.51	0.14	0.16	6.55	0.09	0.13	0.14
1992.75	27.44	0.12	0.14	7.65	0.26	0.12	0.13
1993.00	27.18	0.11	0.13	7.57	0.55	0.13	0.14
1993.25	20.09	0.15	0.17	5.60	0.27	0.15	0.16
1993.50	19.65	0.16	0.18	5.48	0.09	0.15	0.15
1993.75	22.93	0.14	0.16	6.39	0.25	0.14	0.14
1994.00	22.80	0.14	0.16	6.36	0.23	0.14	0.14
1994.25	23.10	0.13	0.15	6.44	0.10	0.12	0.13
1994.50	26.63	0.11	0.13	7.42	0.28	0.11	0.12
1994.75	25.64	0.11	CV	7.15	0.48	0.12	0.13
1995.00	20.21	0.13	0.13	5.63	0.34	0.14	0.15
1995.25	18.42	0.14	0.16	5.13	0.23	0.14	0.15
1995.50	18.69	0.14	0.17	5.21	0.24	0.14	0.15
1995.75	18.88	0.14	0.17	5.26	0.33	0.14	0.16
1996.00	17.37	0.15	0.17	4.84	0.36	0.16	0.17
1996.25	15.57	0.17	0.18	4.34	0.35	0.19	0.20
1996.50	13.97	0.20	0.20	3.89	0.08	0.19	0.20
1996.75	16.57	0.18	0.23	4.62	0.07	0.17	0.18
1997.00	19.72	0.16	0.21	5.50	0.19	0.16	0.17
1997.25	20.96	0.15	0.19	5.84	0.15	0.15	0.16
1997.50	22.99	0.14	0.18	6.41	0.13	0.13	0.15
1997.75	25.90	0.12	0.17	7.22	0.33	0.12	0.14
1998.00	23.88	0.13	0.15	6.65	0.60	0.15	0.17
1998.25	16.83	0.18	0.16	4.69	0.13	0.18	0.20
1998.50	18.81	0.17	0.22	5.24	0.06	0.16	0.19
1998.75	22.63	0.15	0.21	6.31	0.26	0.15	0.18
1999.00	22.31	0.15	0.19	6.22	0.25	0.16	0.19
1999.25	22.25	0.16	0.20	6.20	0.15	0.15	0.20
1999.50	24.45	0.15	0.20	6.81	0.23	0.15	0.21
1999.75	24.90	0.15	0.20	6.94	0.29	0.15	0.24
2000.00	23.80	0.16	0.21	6.63	0.31	0.17	0.31
2000.25	22.26	0.18	0.23	6.20	0.16	0.18	0.39
2000.50	24.20	0.18	0.28	6.75	0.17	0.18	0.47
2000.75	26.01	0.18	0.29	7.25	0.14	0.18	0.59
Minimum	13.97	0.11	0.13	3.89	0.06	0.11	0.12
Average	21.78	0.15	0.18	6.07	0.24	0.15	0.18
Maximum	27.44	0.20	0.29	7.65	0.60	0.19	0.59

Table A20. Per recruit model data for longfin squid.

Age	Fishery Selectivity	Natural Mortality (quarter-1)	Maturity	Body Weight (KG)
Winter hatch (summer fishery)				
1	0.008	0.750	0.006	0.004
2	0.011	0.750	0.008	0.007
3	0.017	0.750	0.012	0.011
4	0.029	0.750	0.019	0.019
5	0.057	0.750	0.035	0.033
6	0.132	0.750	0.076	0.056
7	0.328	0.750	0.189	0.095
8	0.686	0.750	0.468	0.162
9	0.937	0.750	0.828	0.275
10	0.994	0.750	0.977	0.468
11	1.000	1.500	0.999	0.795
12	1.000	1.500	1.000	1.351
Summer hatch (winter fishery)				
1	0.005	1.000	0.004	0.001
2	0.007	1.000	0.005	0.003
3	0.011	1.000	0.008	0.007
4	0.024	1.000	0.016	0.017
5	0.071	1.000	0.043	0.038
6	0.289	1.000	0.165	0.088
7	0.826	1.000	0.636	0.204
8	0.994	1.000	0.977	0.471
9	1.000	2.000	1.000	1.086
10	1.000	2.000	1.000	2.506

Table A21. Per recruit model results for longfin squid.

Biological Reference Point	Yield Per Recruit (Proportion of Maximum)	Spawning Biomass Per Recruit (Proportion of Maximum)	Fully Recruited Fishing Mortality (quarter^{-1})	Biomass Weighted Fishing Mortality (quarter^{-1})
Winter hatch / summer fishery				
F_{MAX}	0.029	0.052	1.392	0.767
$F_{0.1}$	0.027	0.076	0.940	0.581
$F_{SPR\%}$:				
5%	0.021	0.010	4.421	1.256
10%	0.025	0.019	2.886	1.103
15%	0.027	0.029	2.207	0.989
20%	0.028	0.038	1.790	0.890
25%	0.028	0.047	1.495	0.802
30%	0.028	0.057	1.268	0.721
35%	0.028	0.066	1.086	0.647
40%	0.027	0.076	0.934	0.578
45%	0.026	0.085	0.803	0.514
50%	0.025	0.095	0.690	0.453
55%	0.023	0.104	0.590	0.397
60%	0.021	0.114	0.500	0.343
65%	0.019	0.123	0.419	0.293
70%	0.017	0.133	0.344	0.245
75%	0.014	0.142	0.276	0.199
80%	0.012	0.152	0.213	0.156
85%	0.009	0.161	0.155	0.115
90%	0.006	0.171	0.100	0.075
95%	0.003	0.180	0.049	0.037
Summer hatch / winter fishery				
F_{MAX}	0.030	0.050	1.560	1.095
$F_{0.1}$	0.029	0.071	1.084	0.816
$F_{SPR\%}$:				
5%	0.021	0.009	4.955	2.095
10%	0.025	0.017	3.328	1.768
15%	0.027	0.026	2.574	1.540
20%	0.029	0.035	2.101	1.356
25%	0.030	0.044	1.761	1.199
30%	0.030	0.052	1.499	1.063
35%	0.029	0.061	1.286	0.941
40%	0.029	0.070	1.108	0.832
45%	0.028	0.078	0.955	0.732
50%	0.026	0.087	0.821	0.641
55%	0.024	0.096	0.702	0.557
60%	0.023	0.104	0.596	0.479
65%	0.020	0.113	0.499	0.406
70%	0.018	0.122	0.411	0.338
75%	0.015	0.131	0.329	0.273
80%	0.013	0.139	0.254	0.213
85%	0.010	0.148	0.185	0.155
90%	0.007	0.157	0.119	0.101
95%	0.003	0.165	0.058	0.049

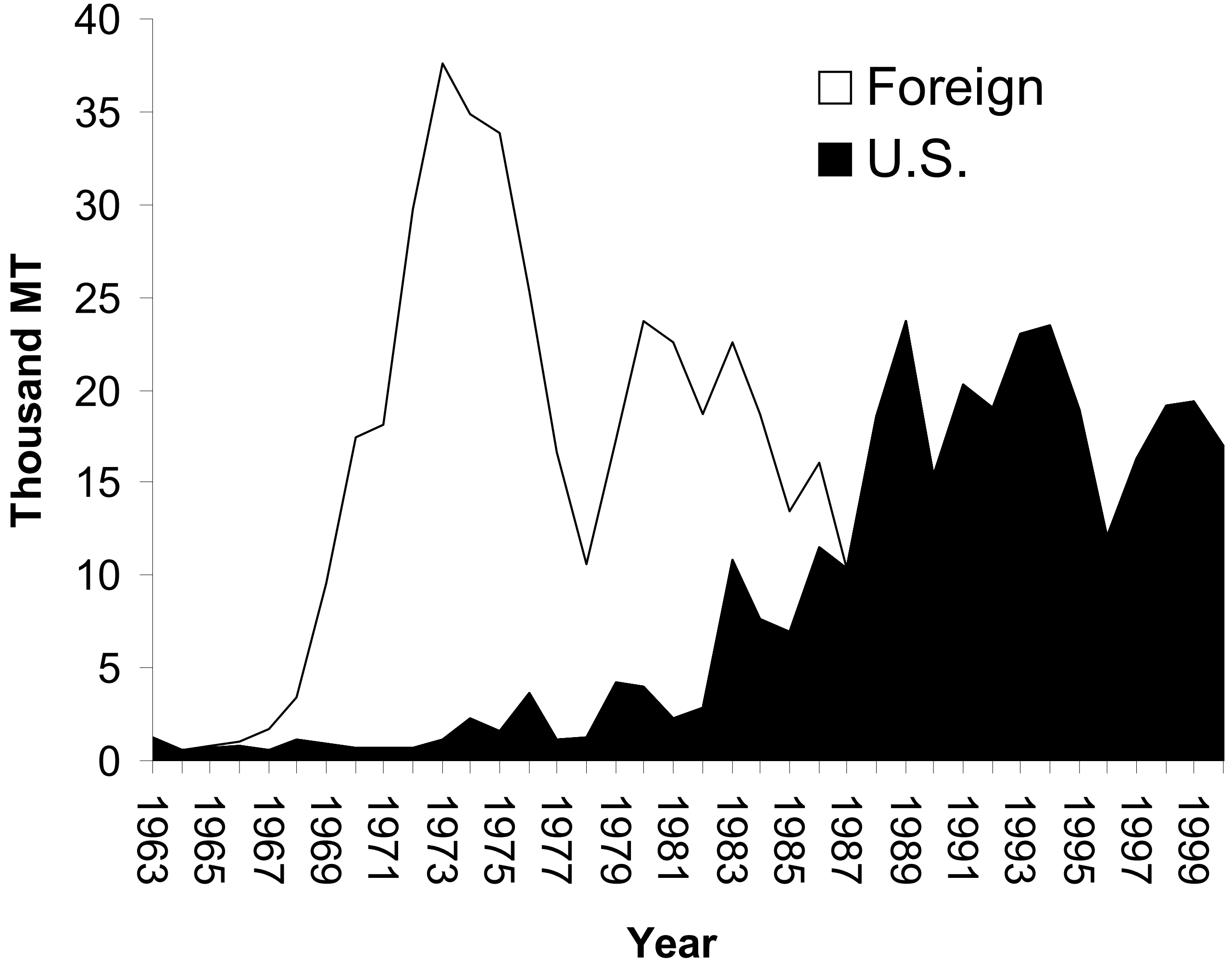


Figure A1. Longfin squid landings.

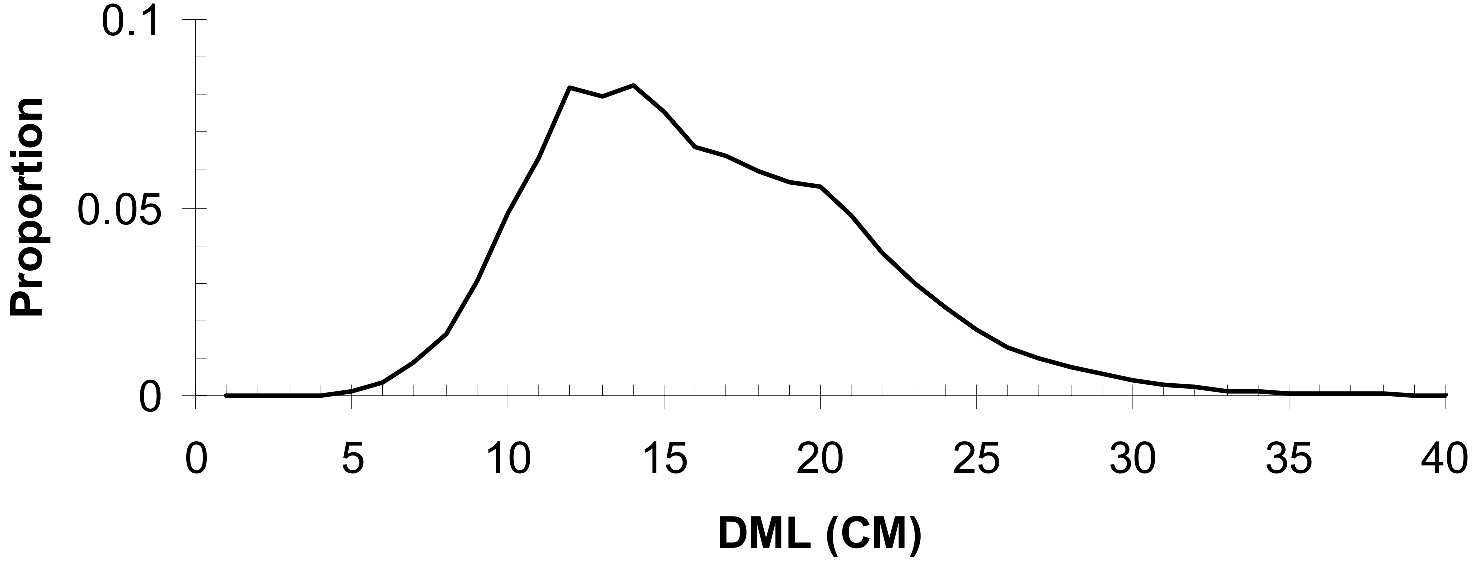


Figure A2. Commercial length composition data for longfin squid, 1975-2001 from port samples.

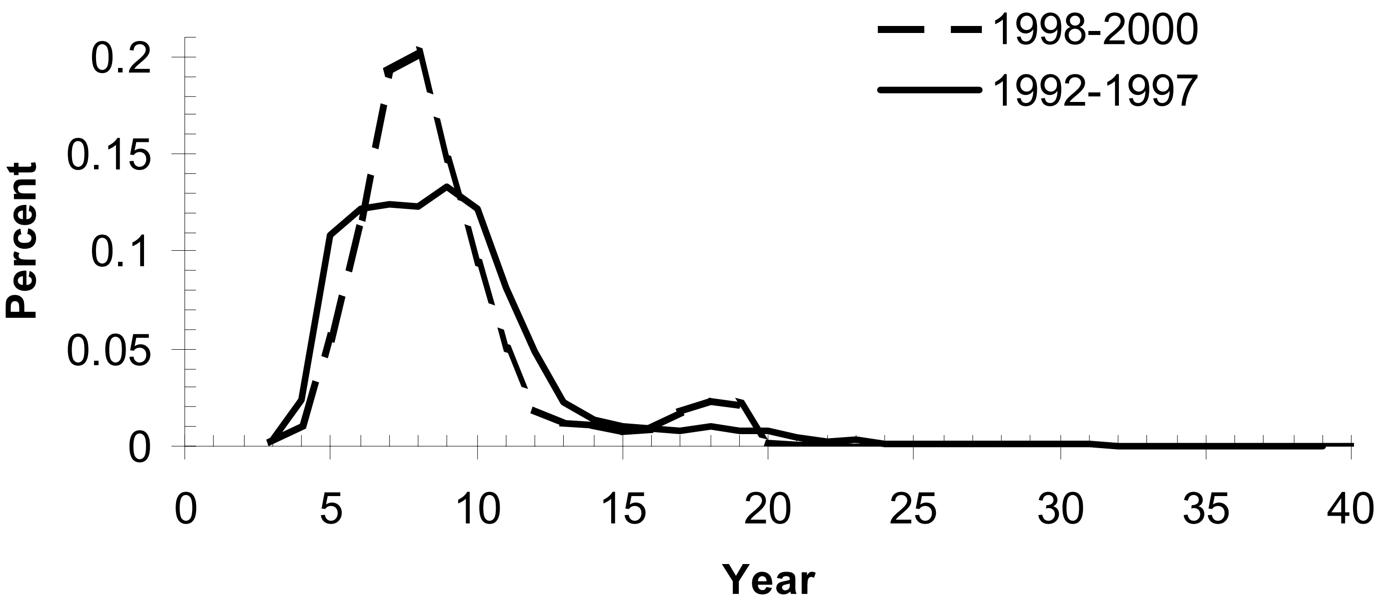


Figure A3. Sea sample observer data for longfin squid discarded at sea, 1992-2000 (scaled to average proportions).

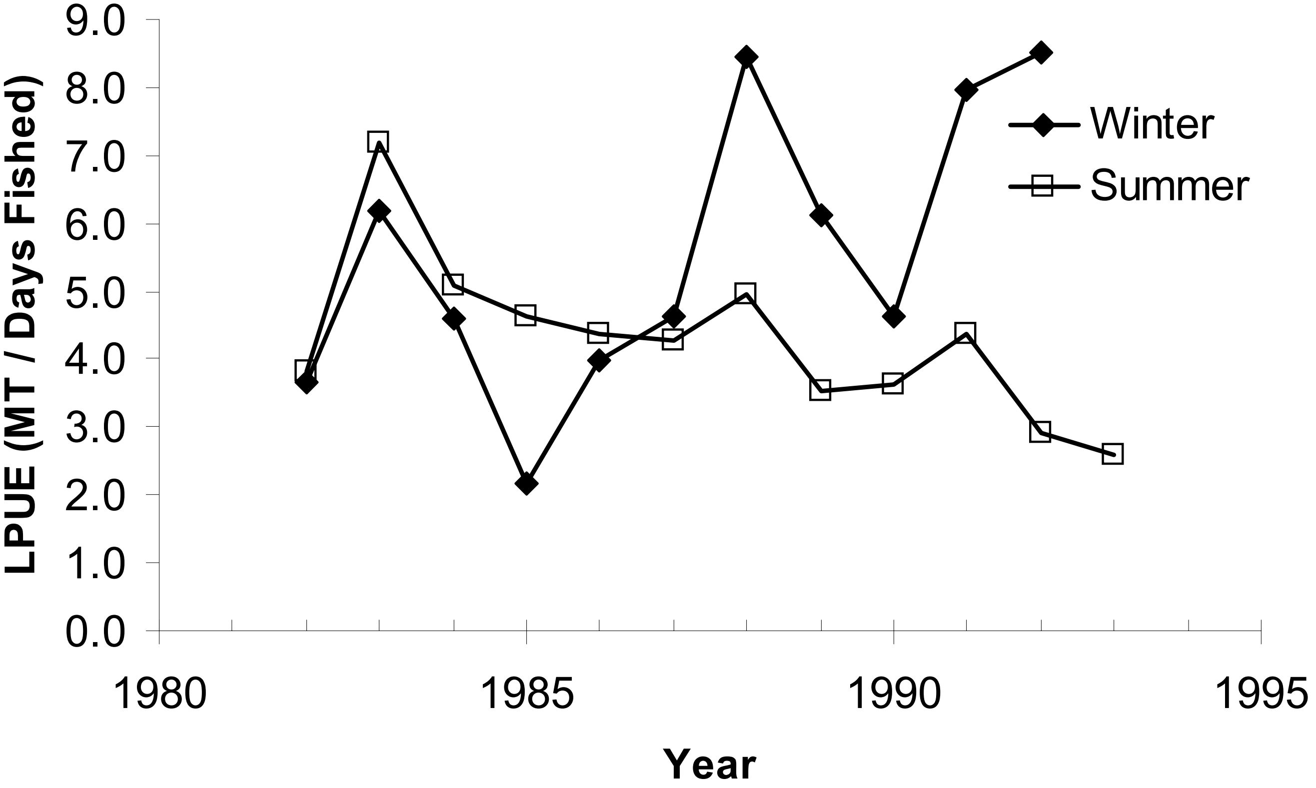


Figure A4. Standardized LPUE for Loligo.

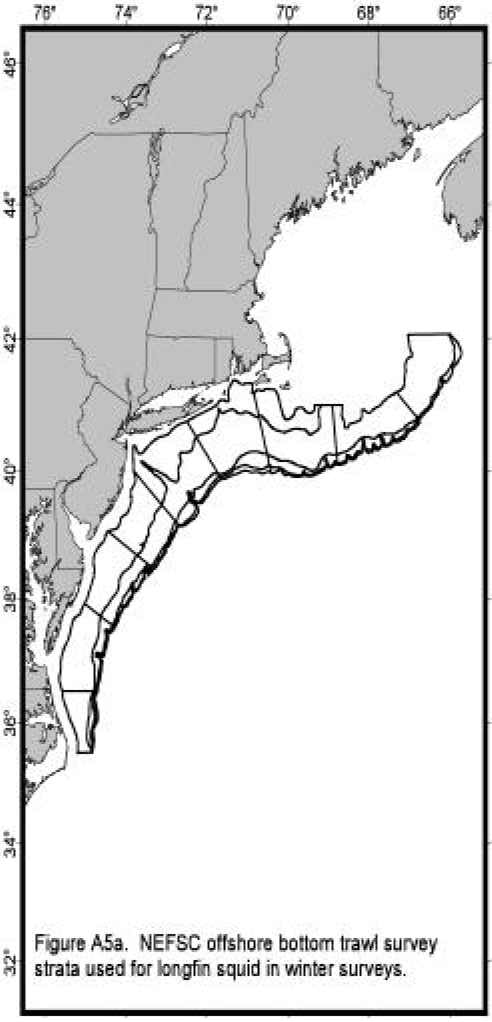


Figure A5a. NEFSC offshore bottom trawl survey strata used for longfin squid in winter surveys.

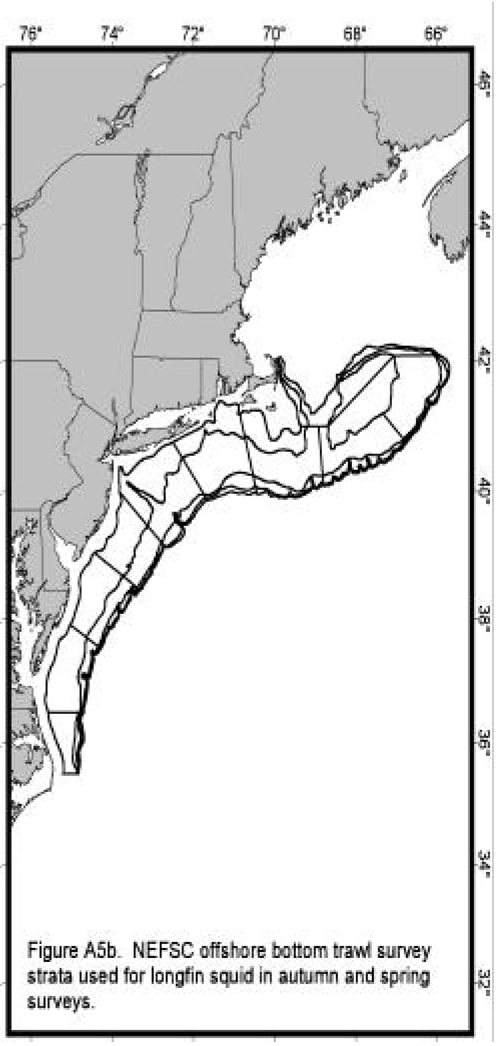


Figure A5b. NEFSC offshore bottom trawl survey strata used for longfin squid in autumn and spring surveys.

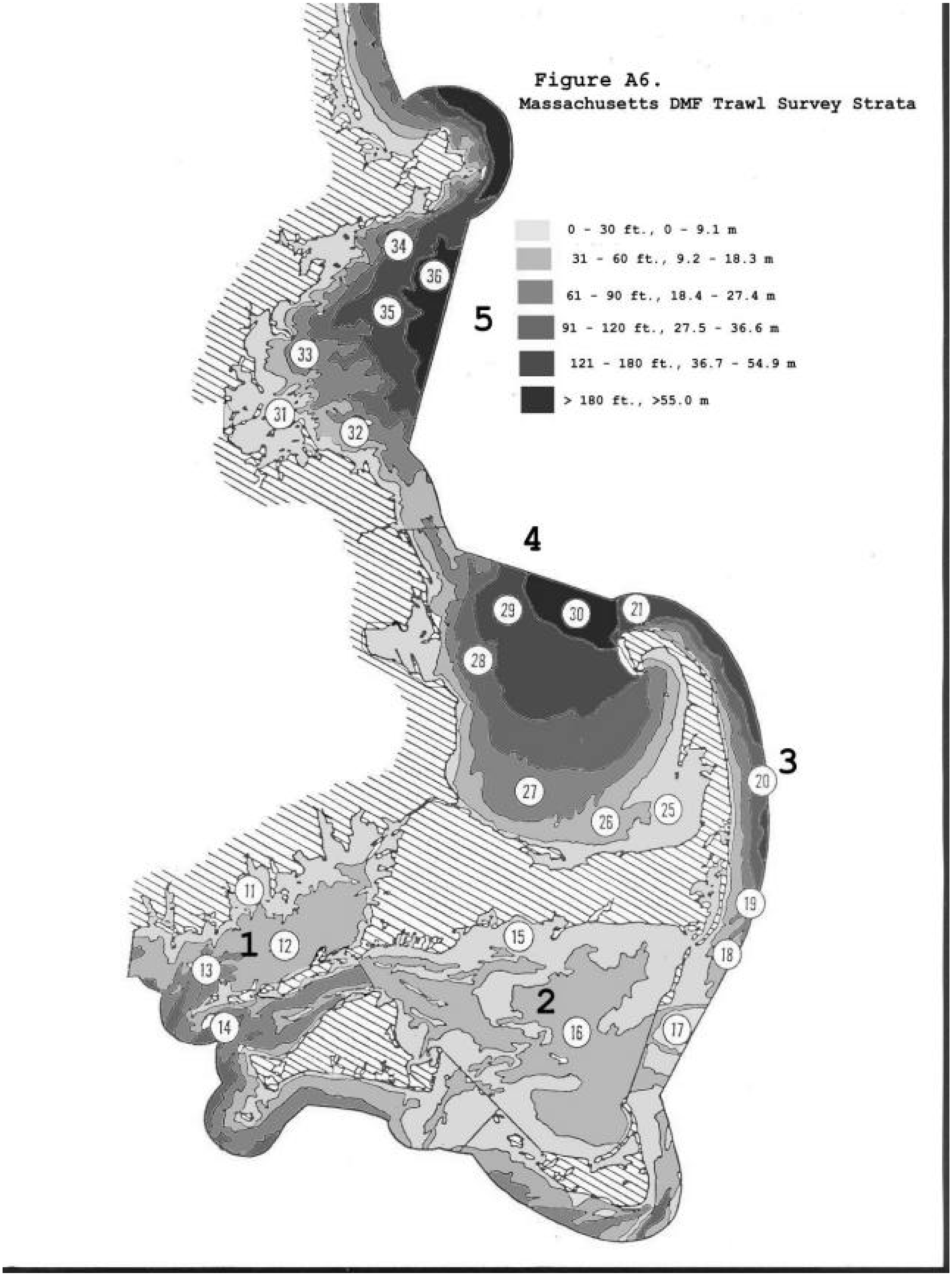


Figure A6.
Massachusetts DMF Trawl Survey Strata

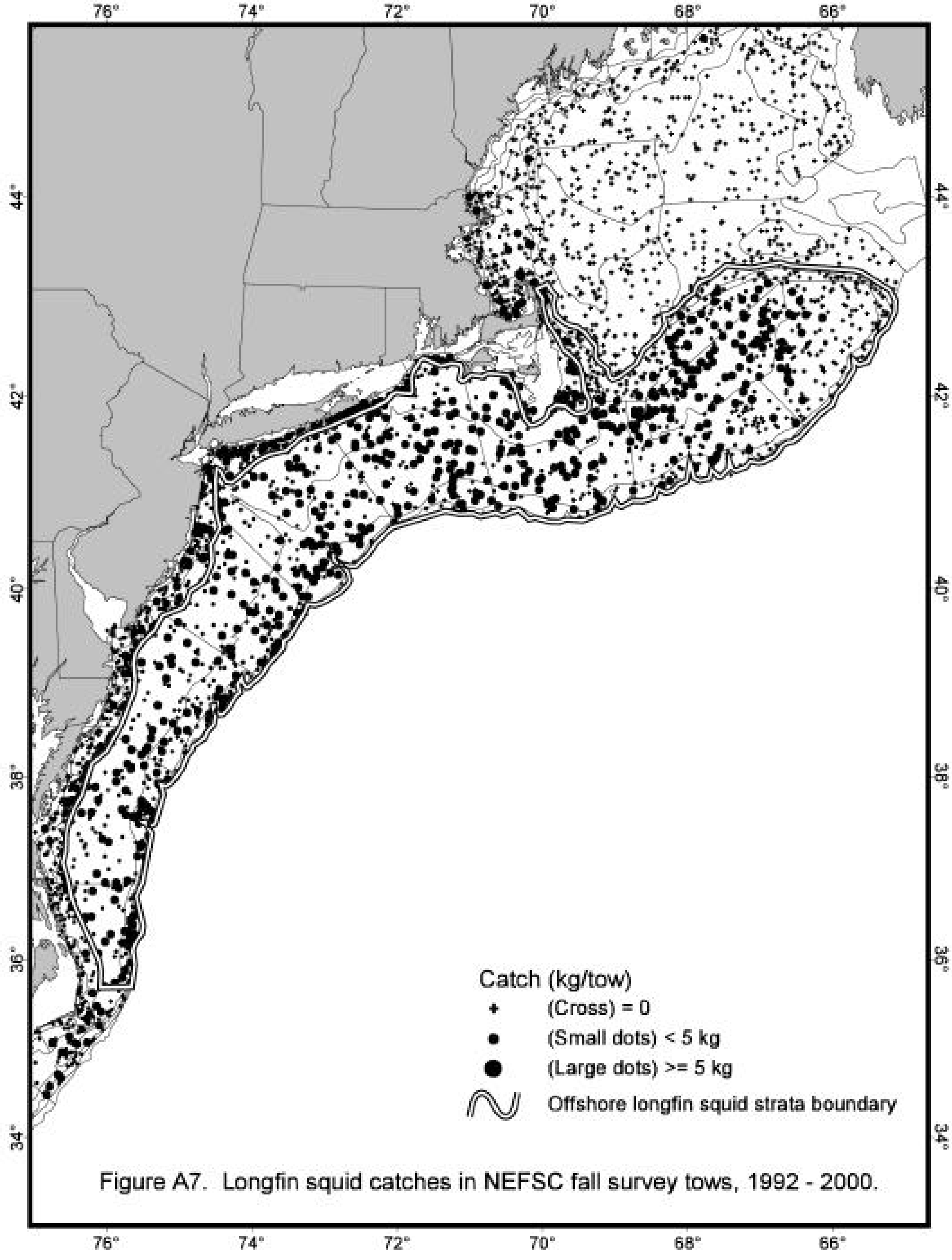


Figure A7. Longfin squid catches in NEFSC fall survey tows, 1992 - 2000.

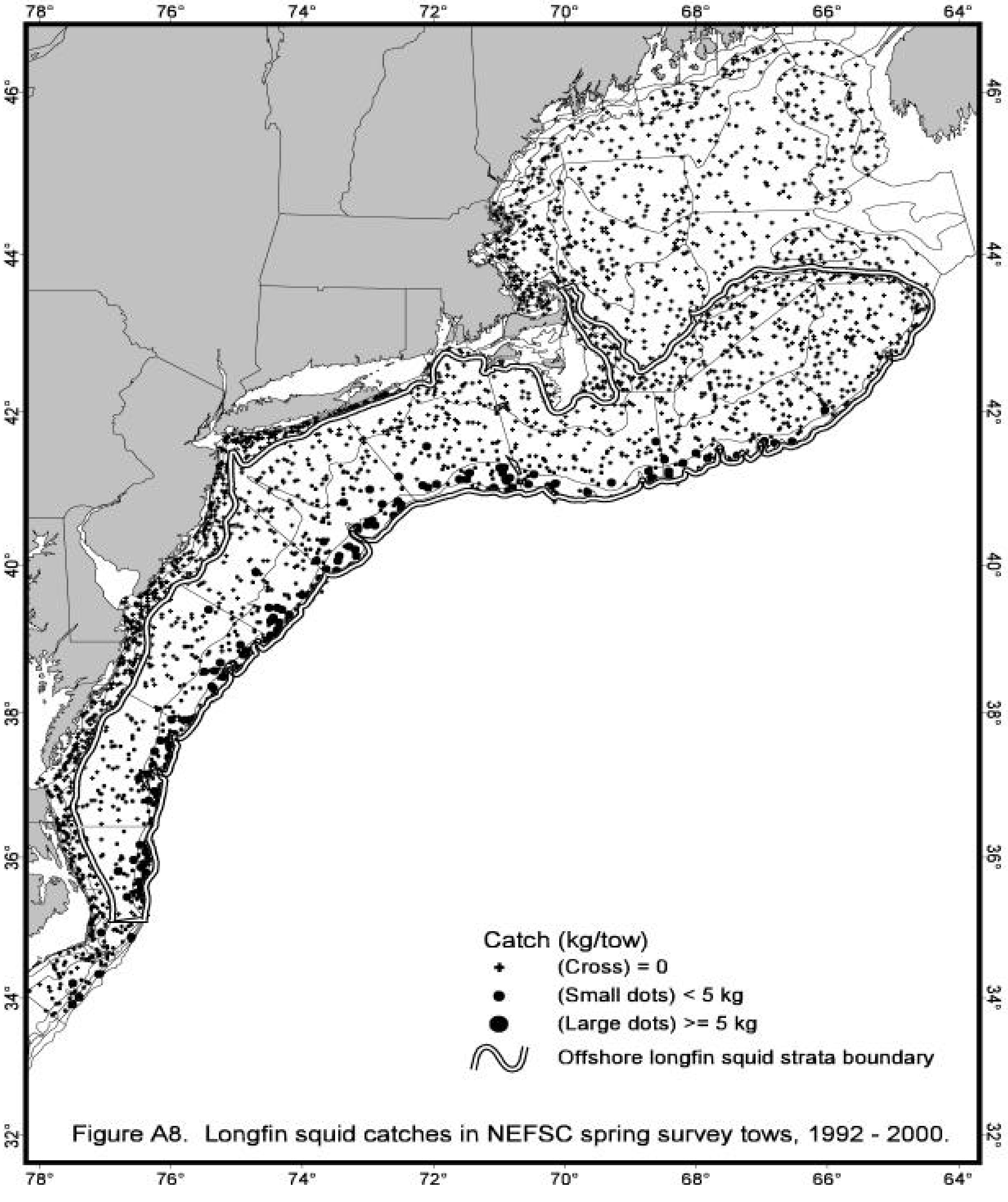


Figure A8. Longfin squid catches in NEFSC spring survey tows, 1992 - 2000.

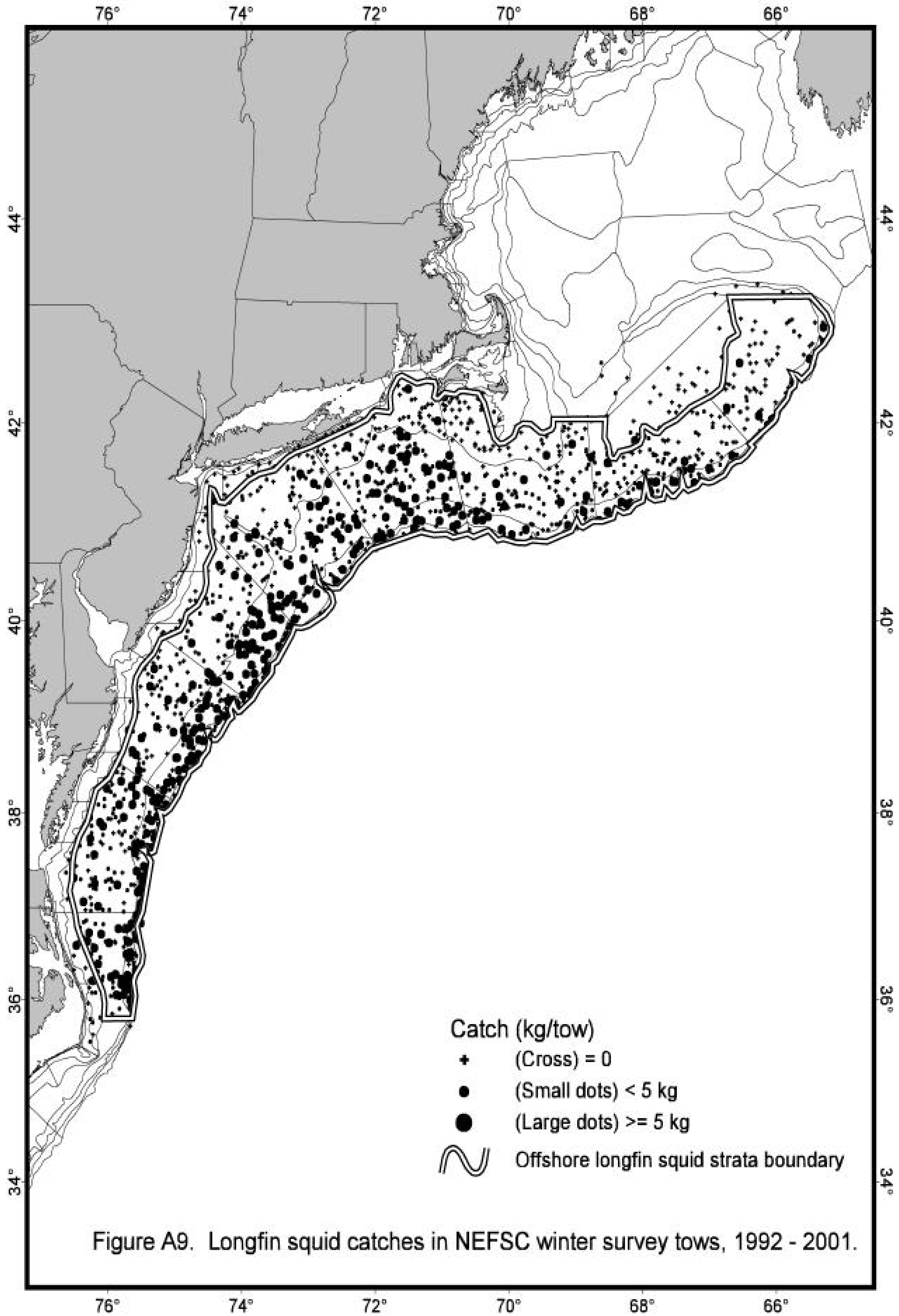


Figure A9. Longfin squid catches in NEFSC winter survey tows, 1992 - 2001.

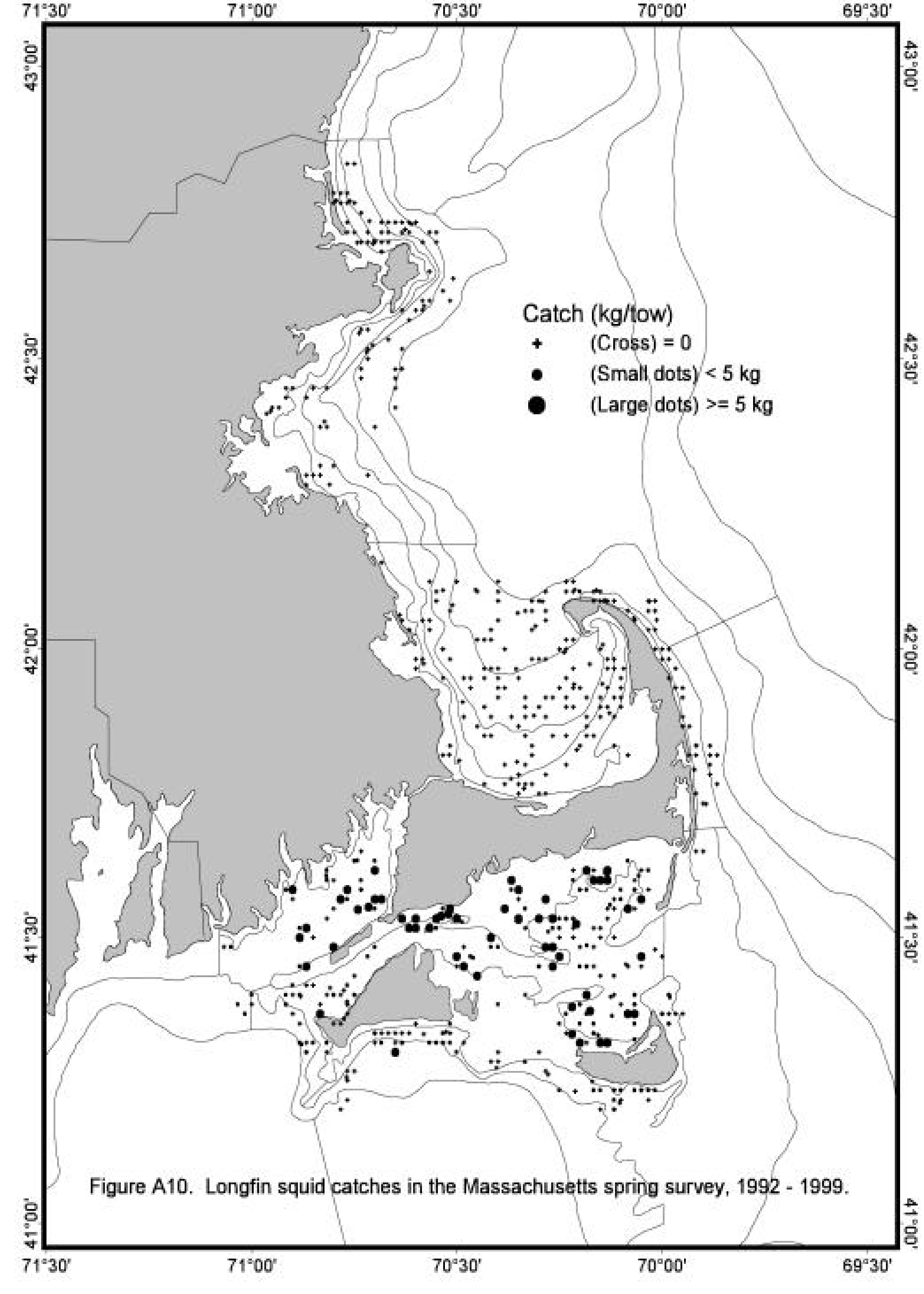


Figure A10. Longfin squid catches in the Massachusetts spring survey, 1992 - 1999.

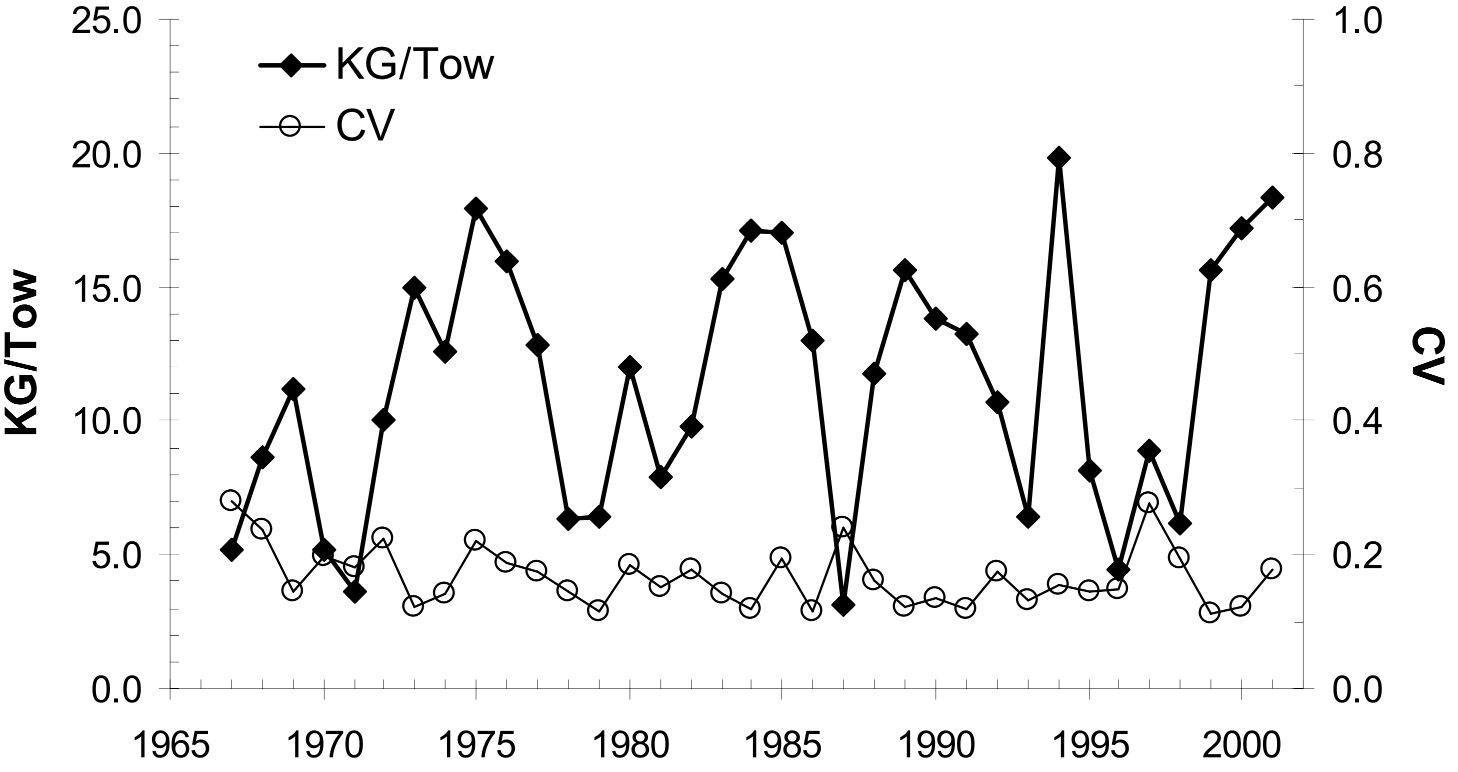


Figure A11. Longfin squid in the NEFSC fall survey.

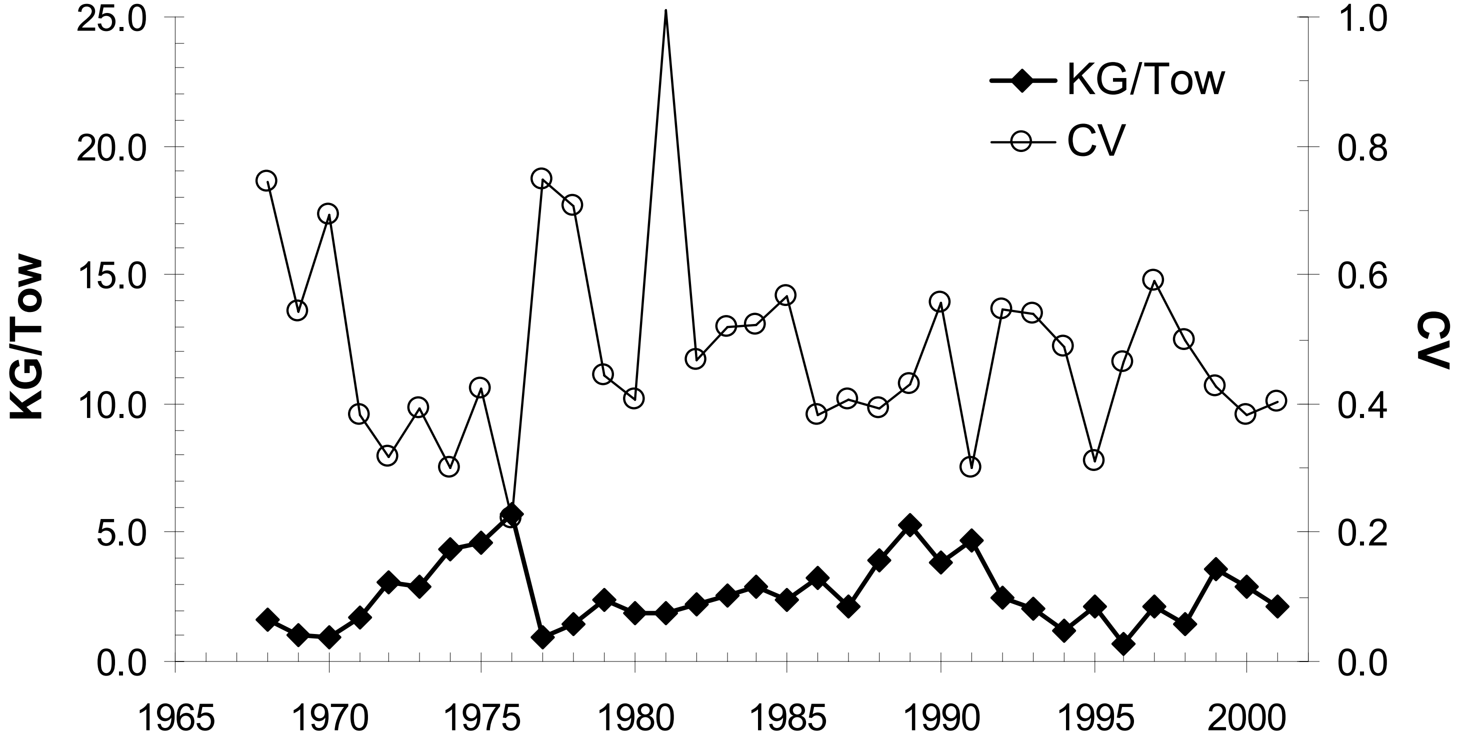


Figure A12. Longfin squid in the NEFSC spring survey.

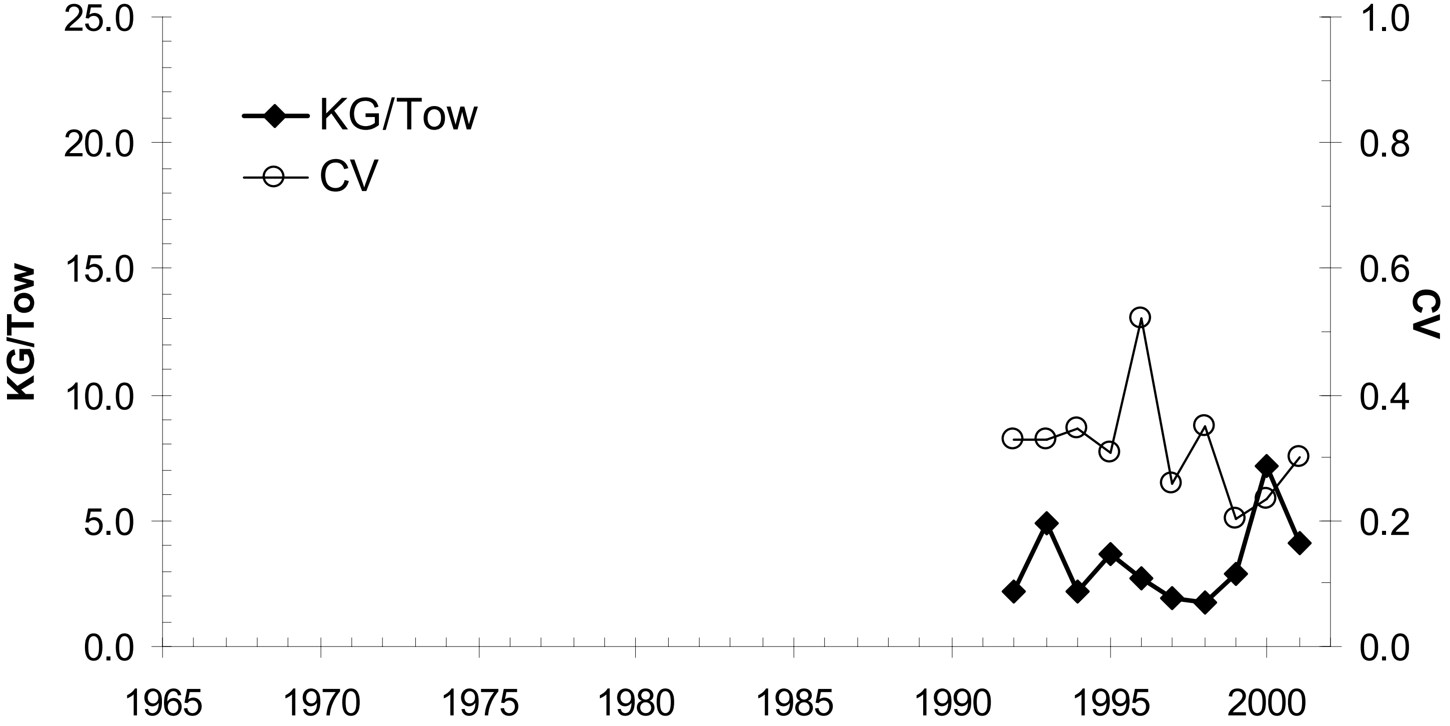


Figure A13. Longfin squid in the NEFSC winter survey.

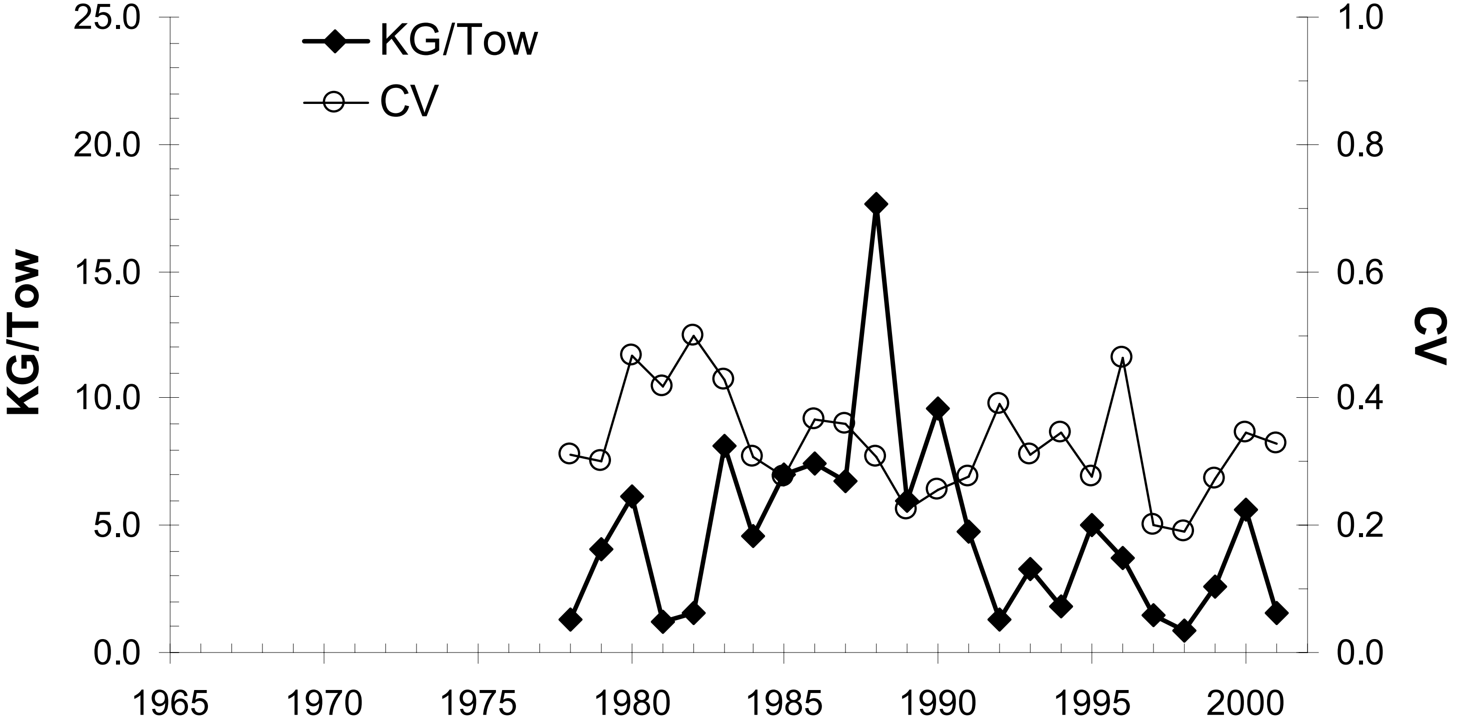


Figure A14. Longfin squid in the Massachusetts spring survey.

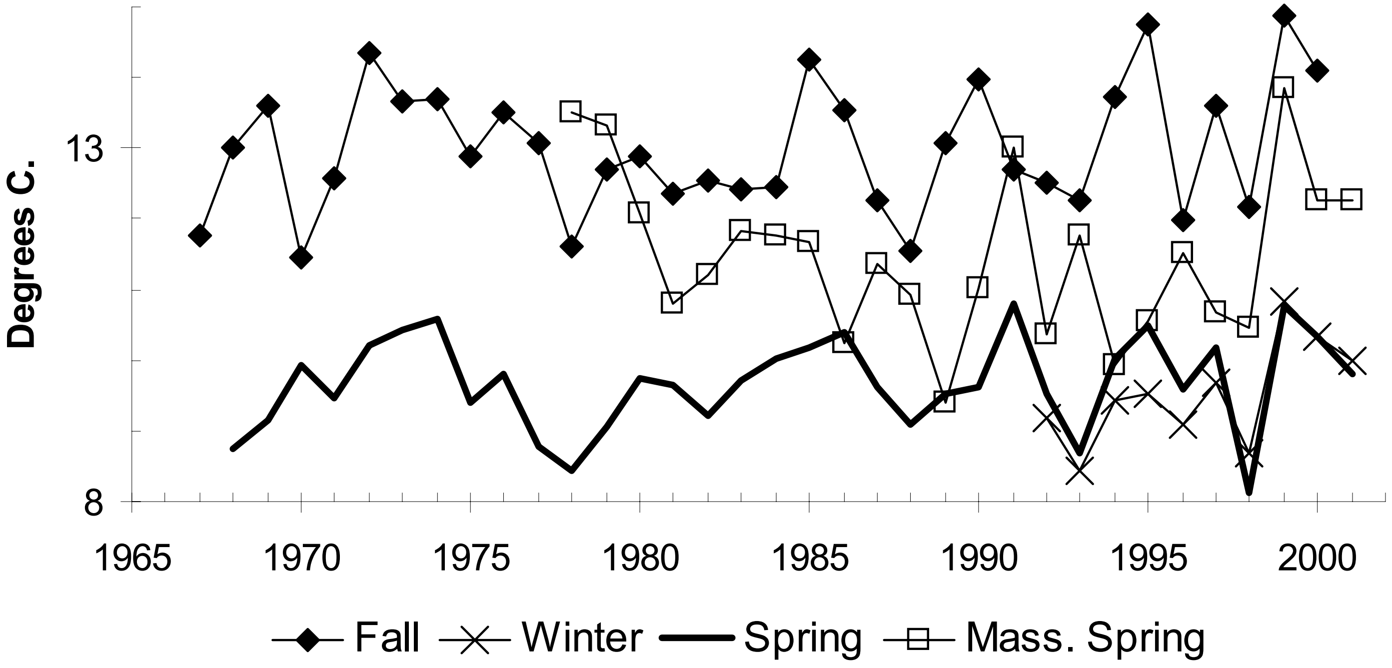


Figure A15. Bottom temperatures for longfin squid survey tows.

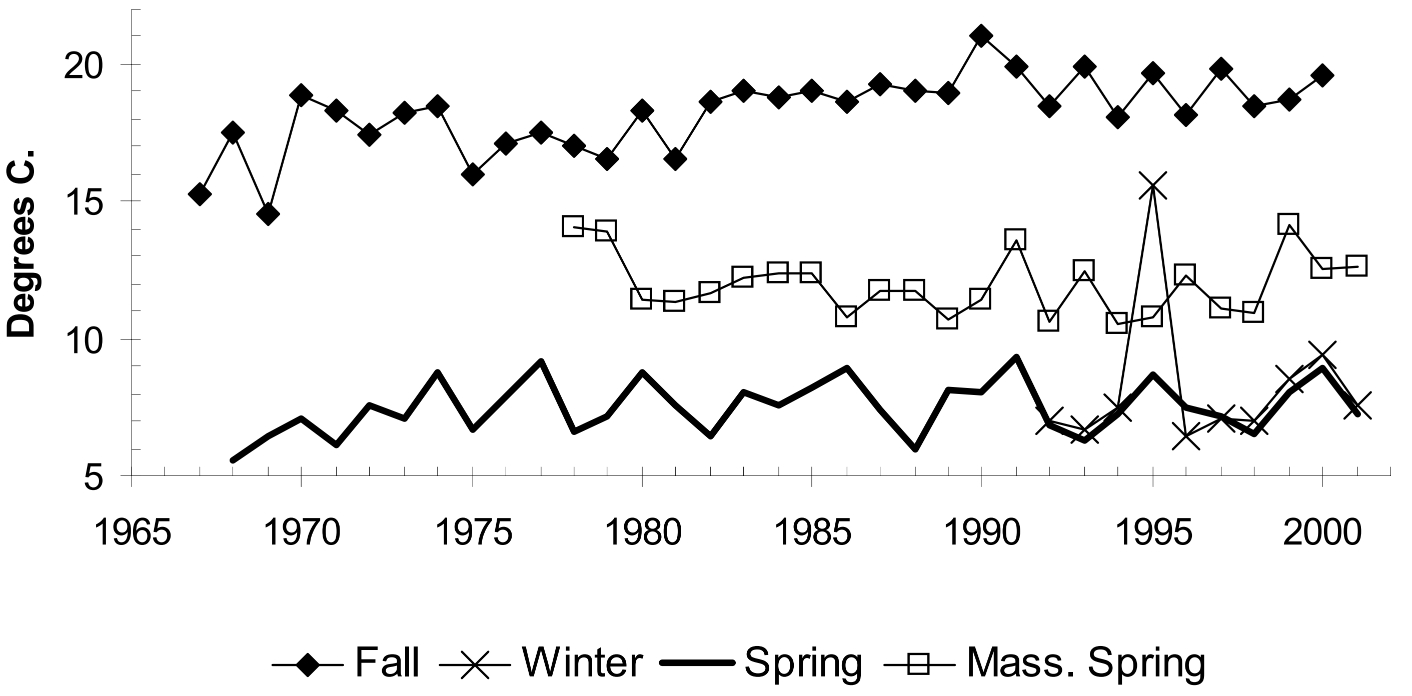


Figure A16. Surface temperatures for longfin squid survey tows.

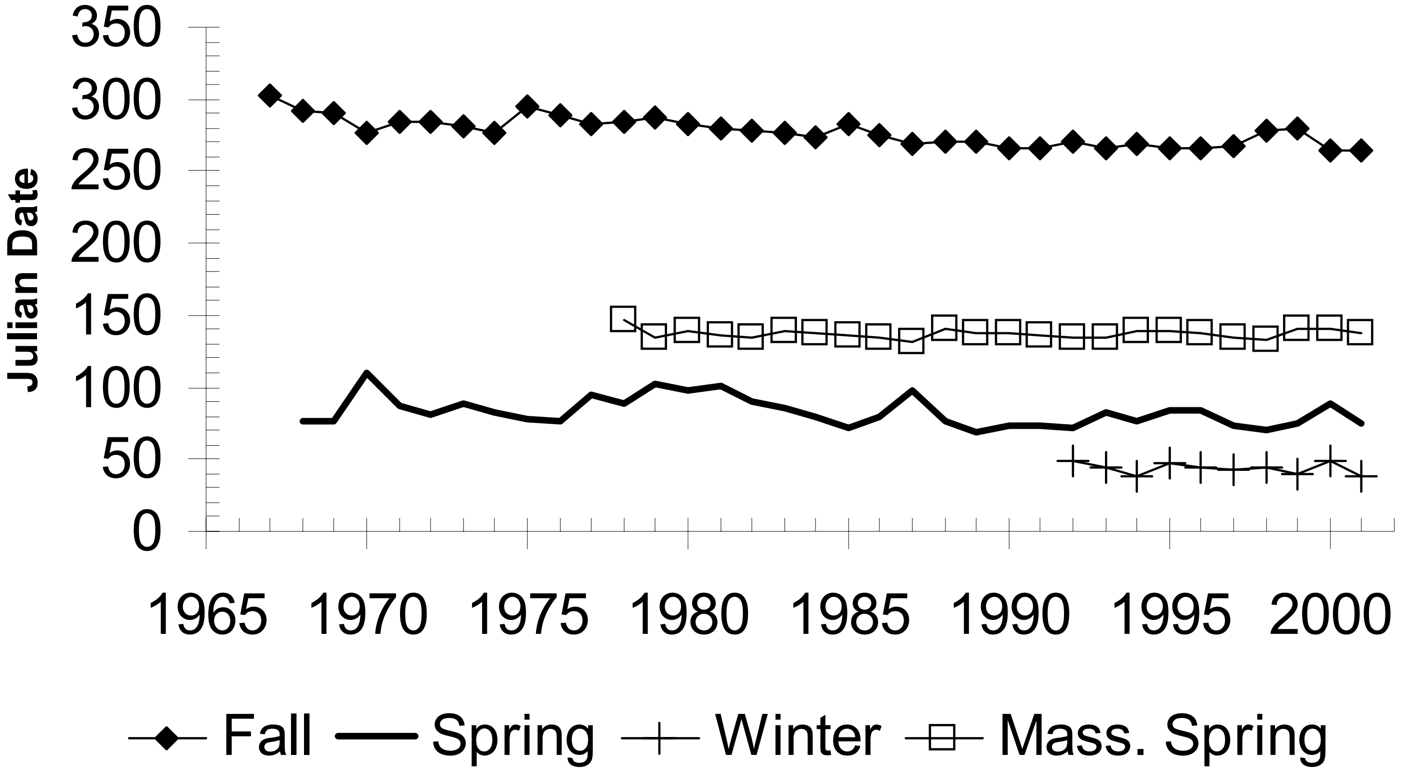


Figure A17. Mean survey dates for longfin squid.

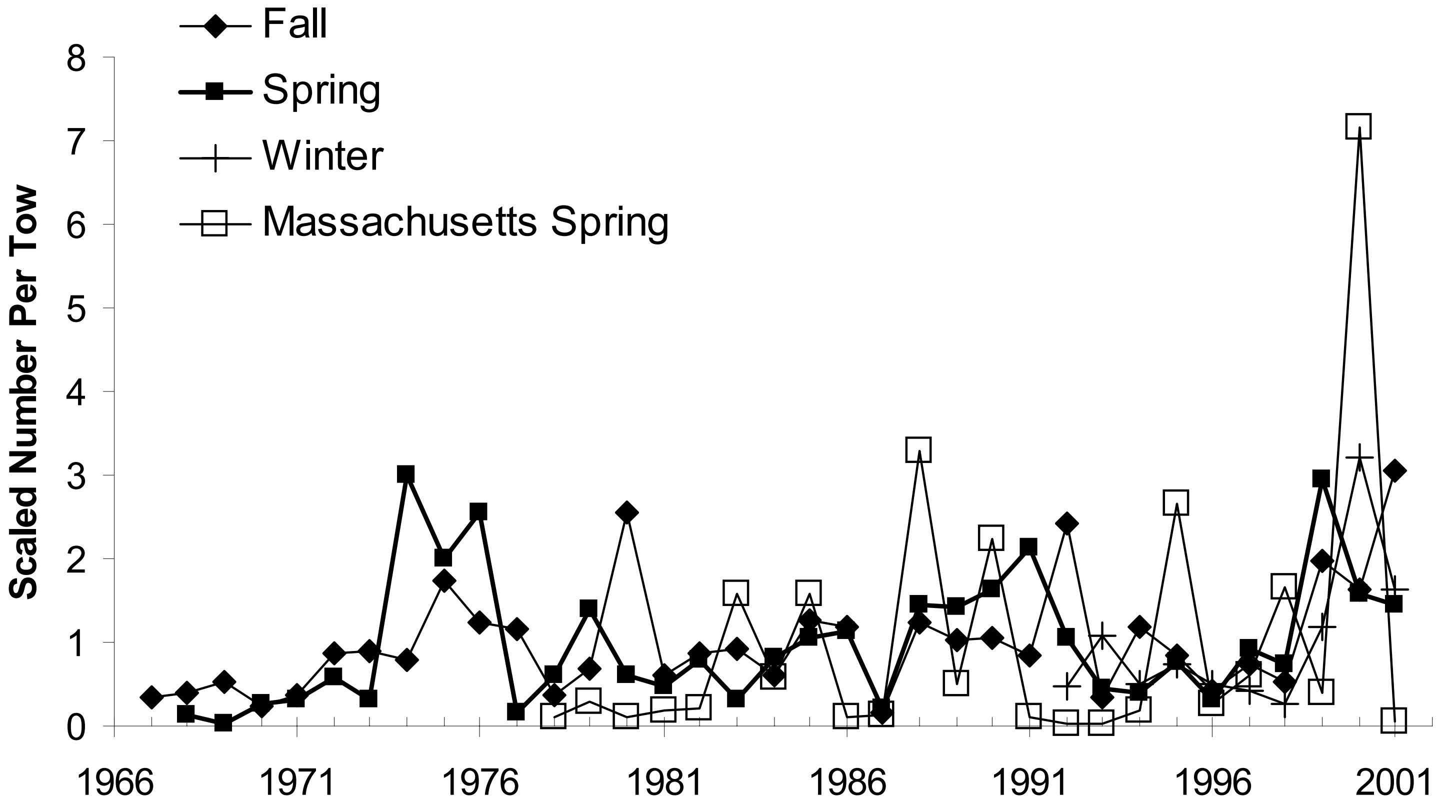


Figure A18. Fall survey recruitment index (rescaled number per tow <8 cm DML)

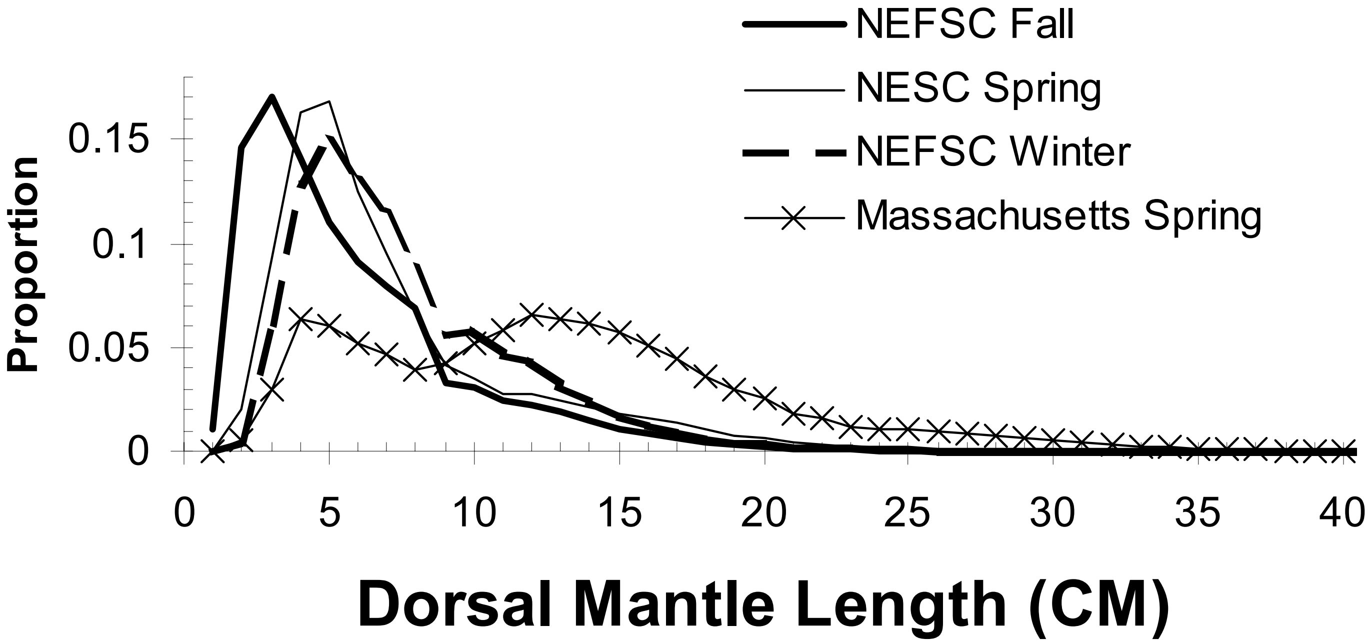


Figure A19. Bottom trawl survey length composition data for longfin squid (all years).

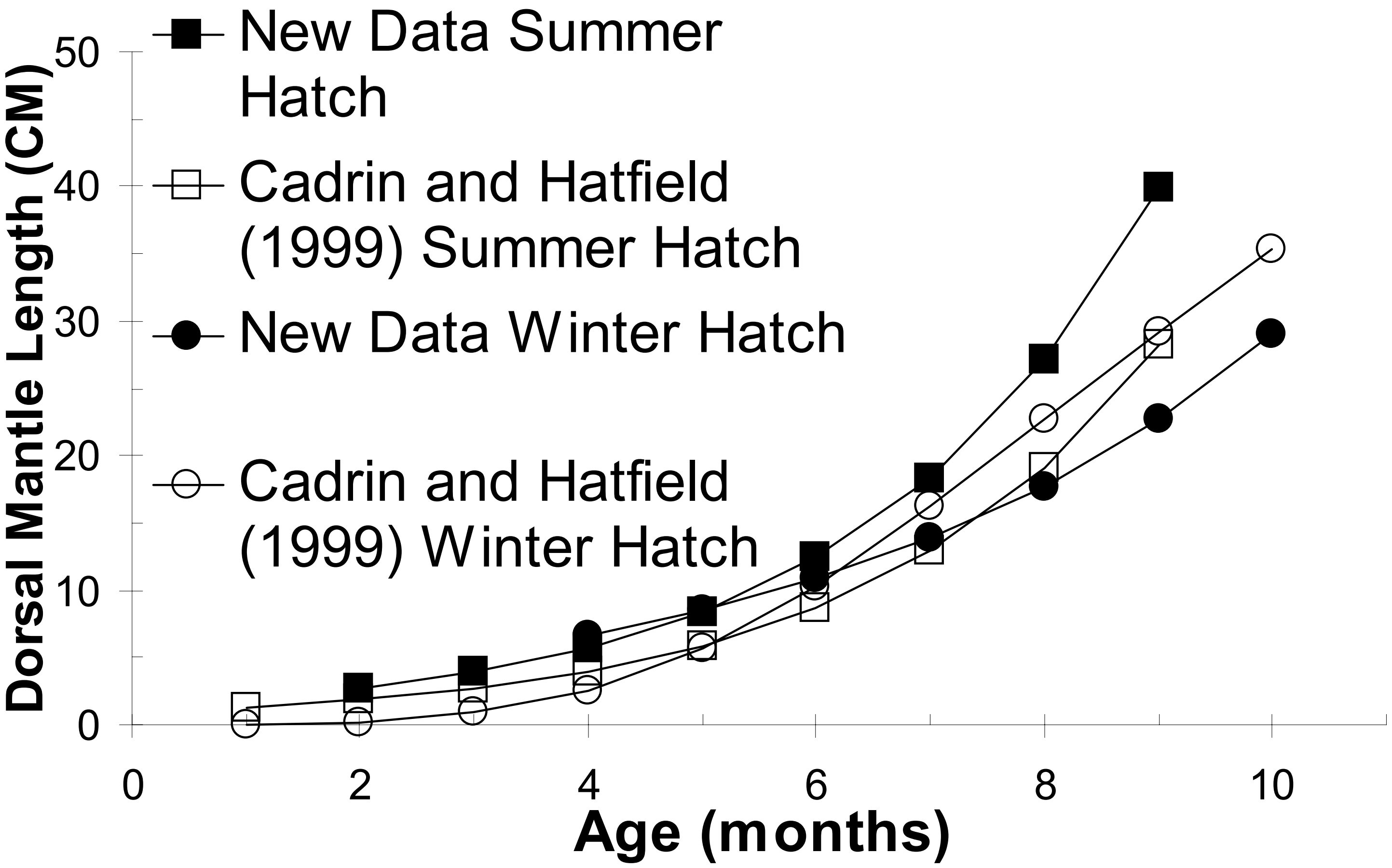


Figure A20. Growth curves for longfin squid.

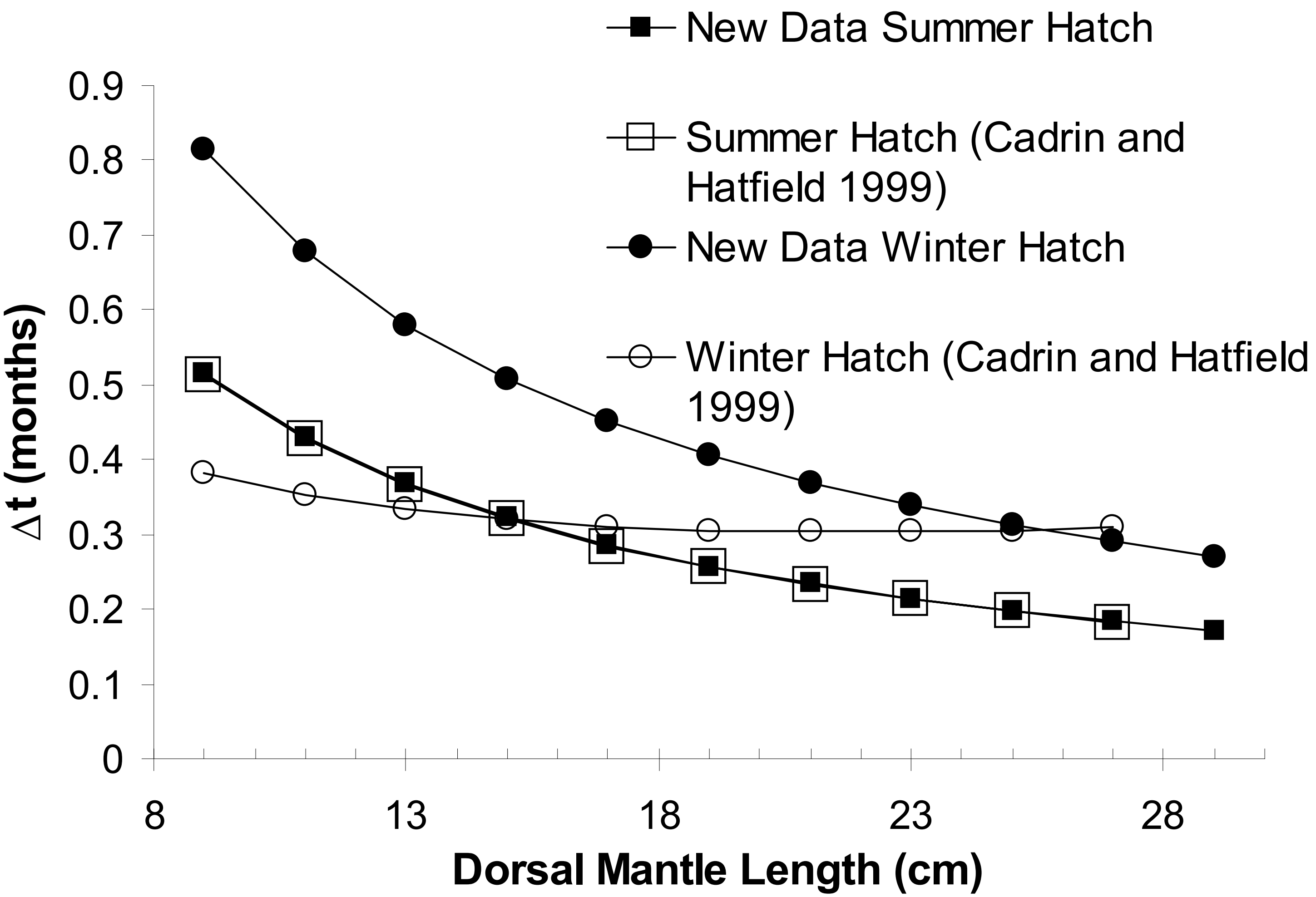


Figure A21. Delta-t values for longfin squid.

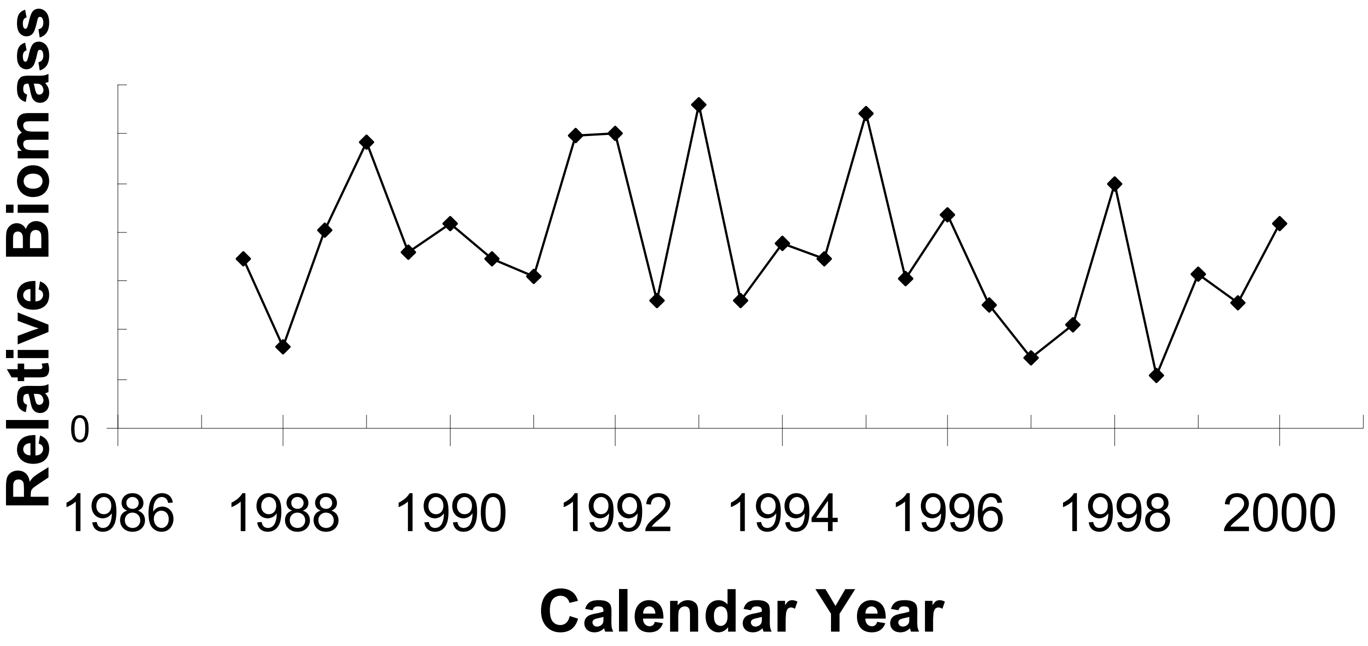


Figure A22. Relative biomass for longfin squid from LVPA.

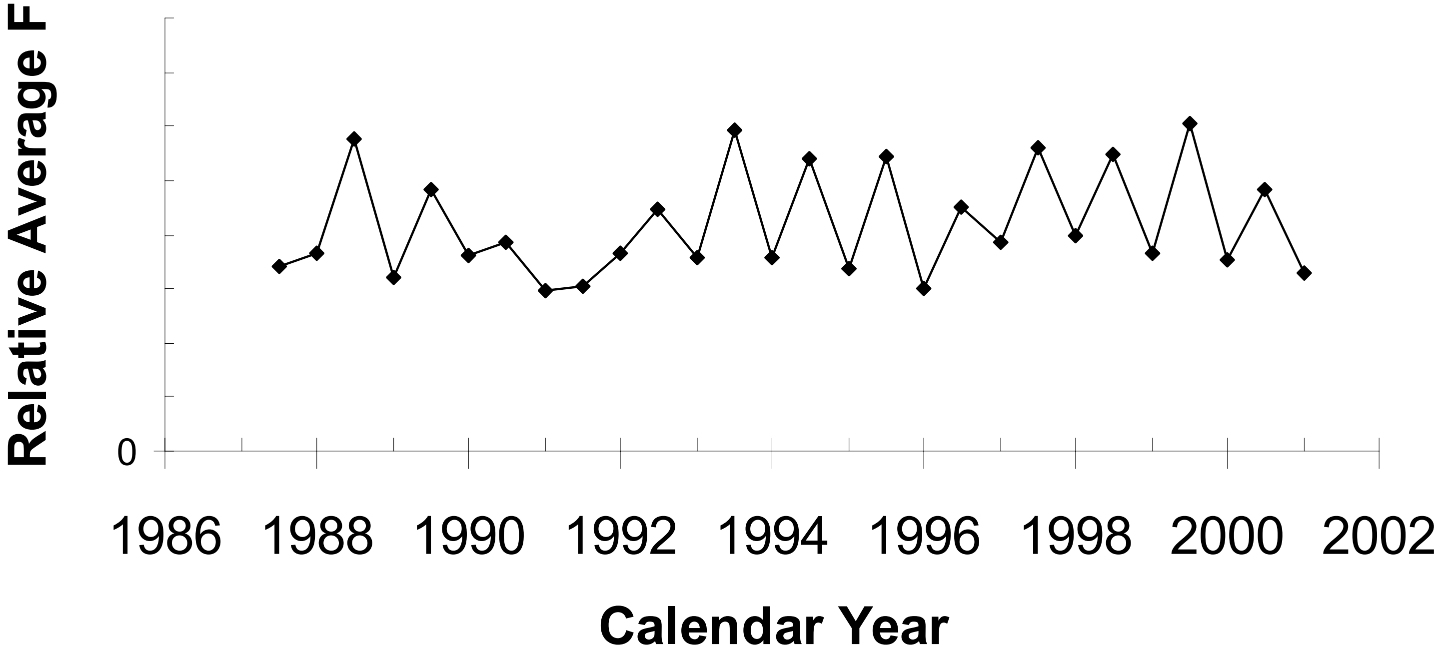


Figure A23. Relative biomass weighted F for longfin squid from LVPA

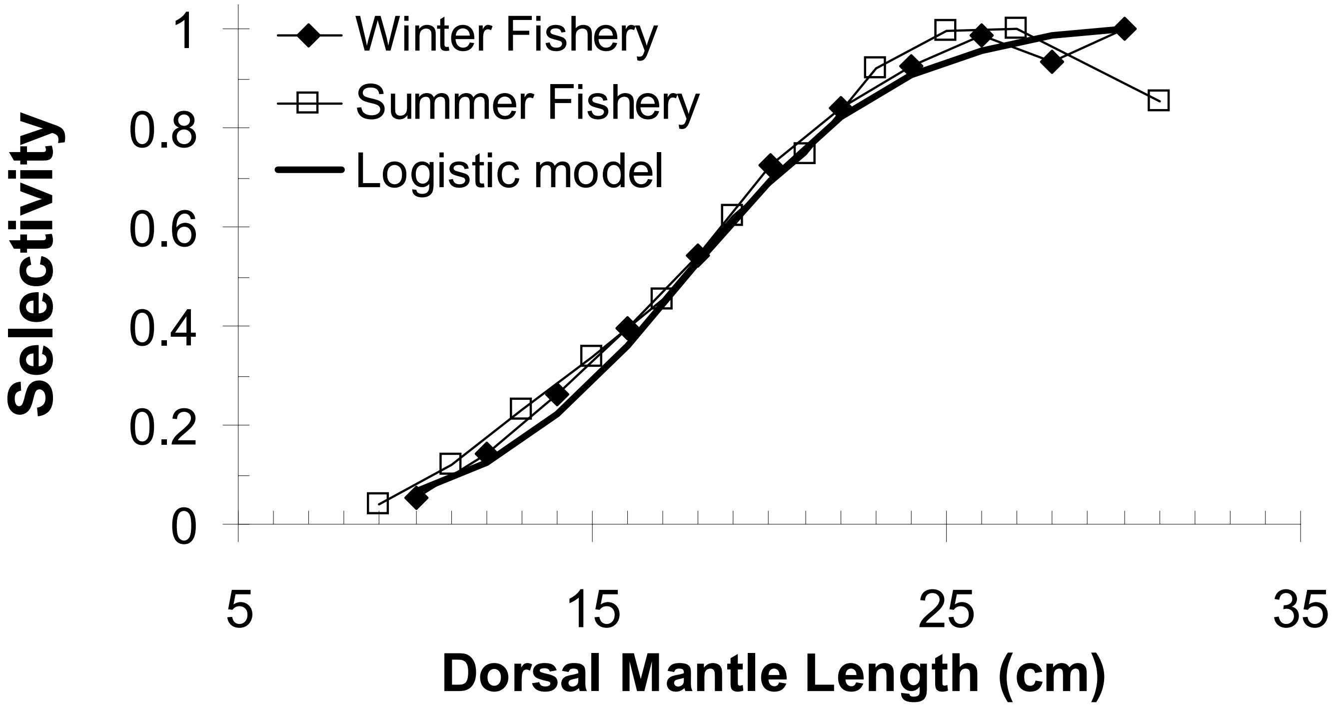


Figure A24. Fishery selectivity for longfin squid from LVPA

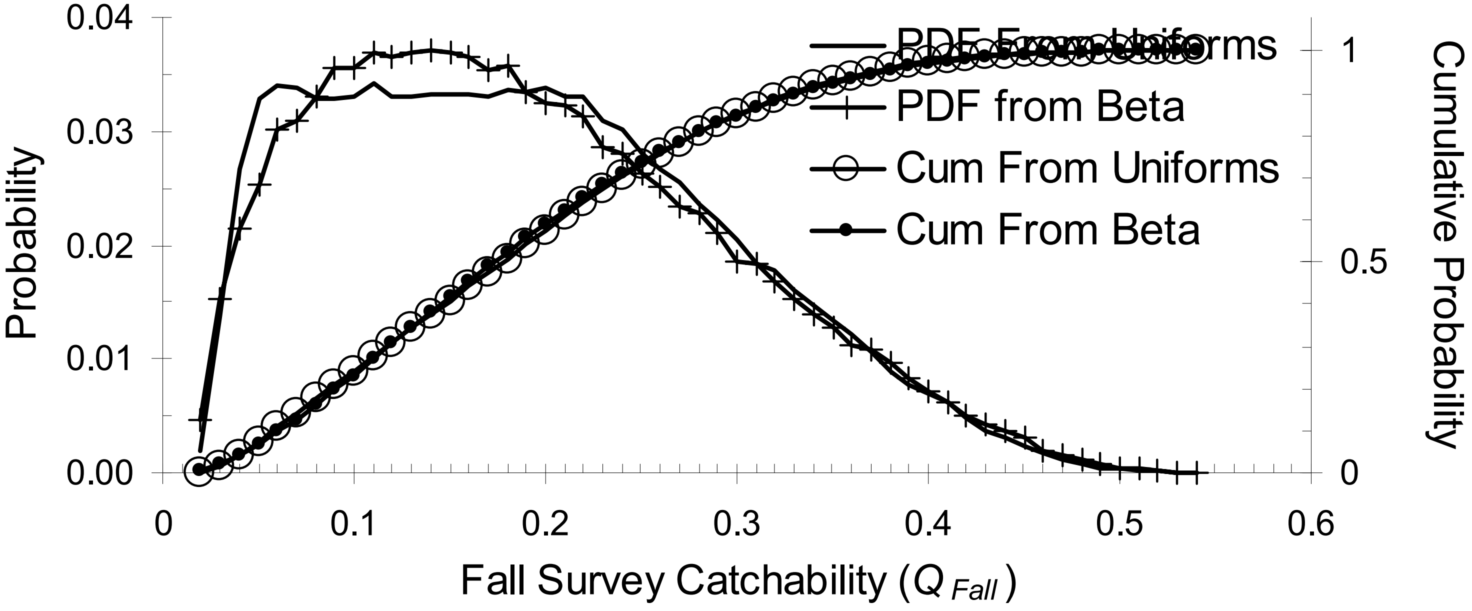


Figure A25. Uncertainty in NEFSC autumn survey catchability based on 100,000 simulated values.

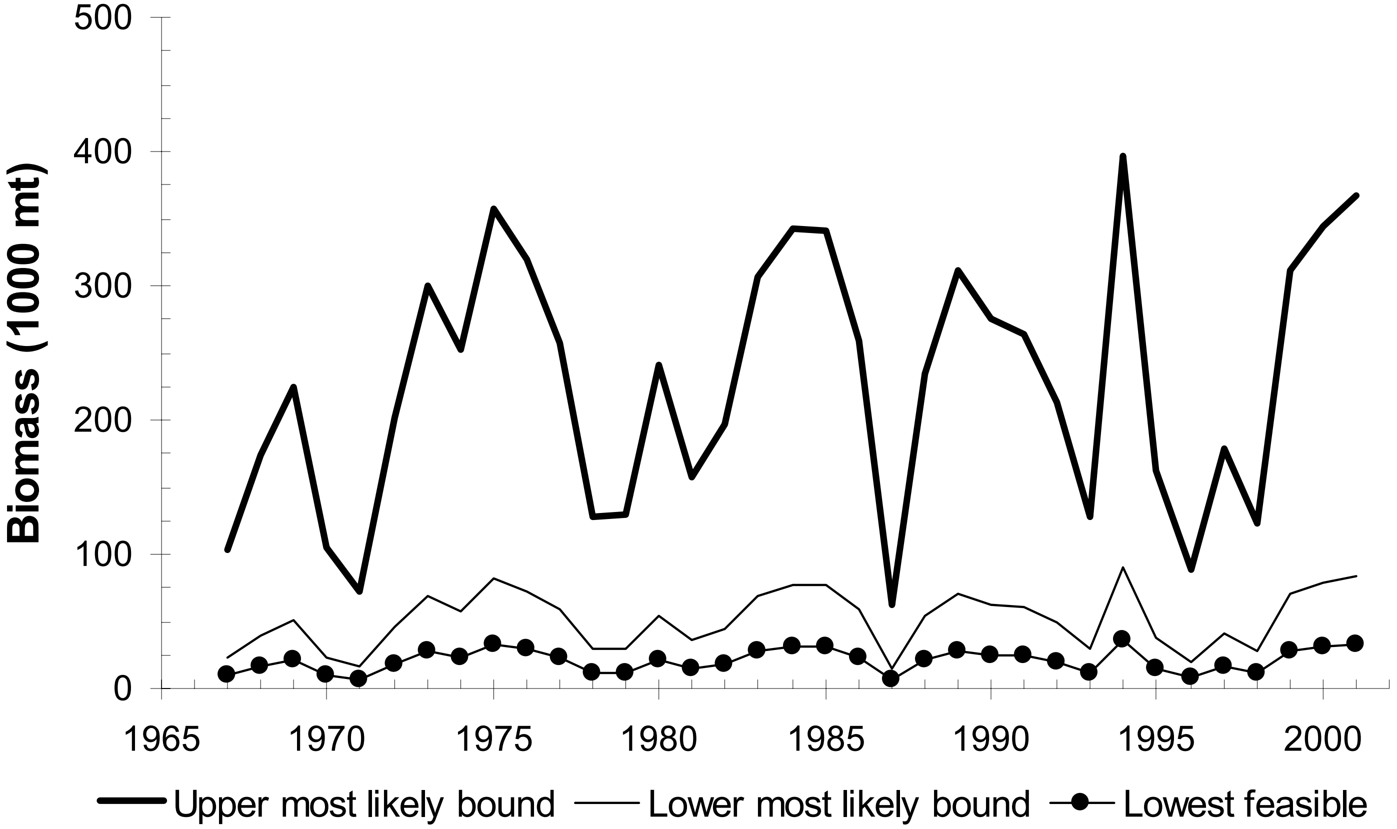


Figure A26. Scaled autumn longfin squid catch-survey biomass estimates.

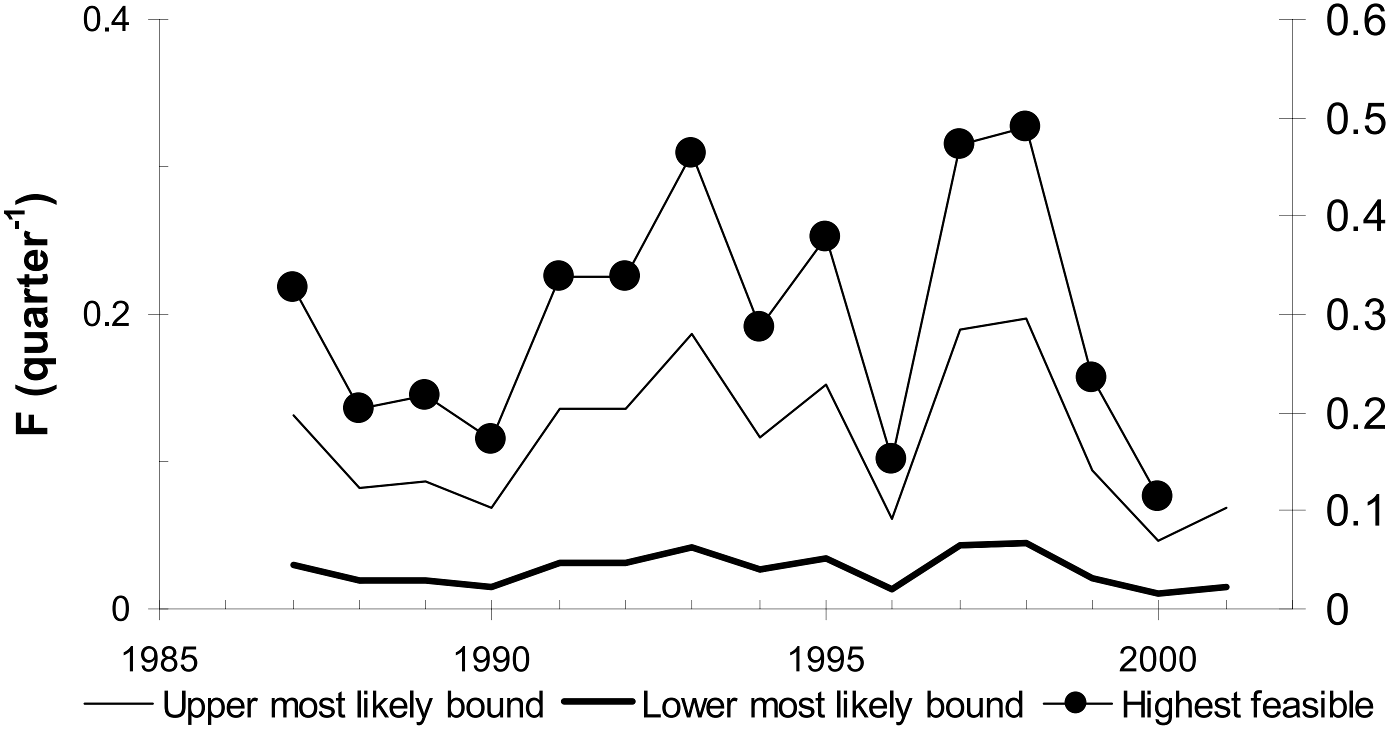


Figure A27. Scaled autumn catch-survey fishing mortality rates for longfin squid.

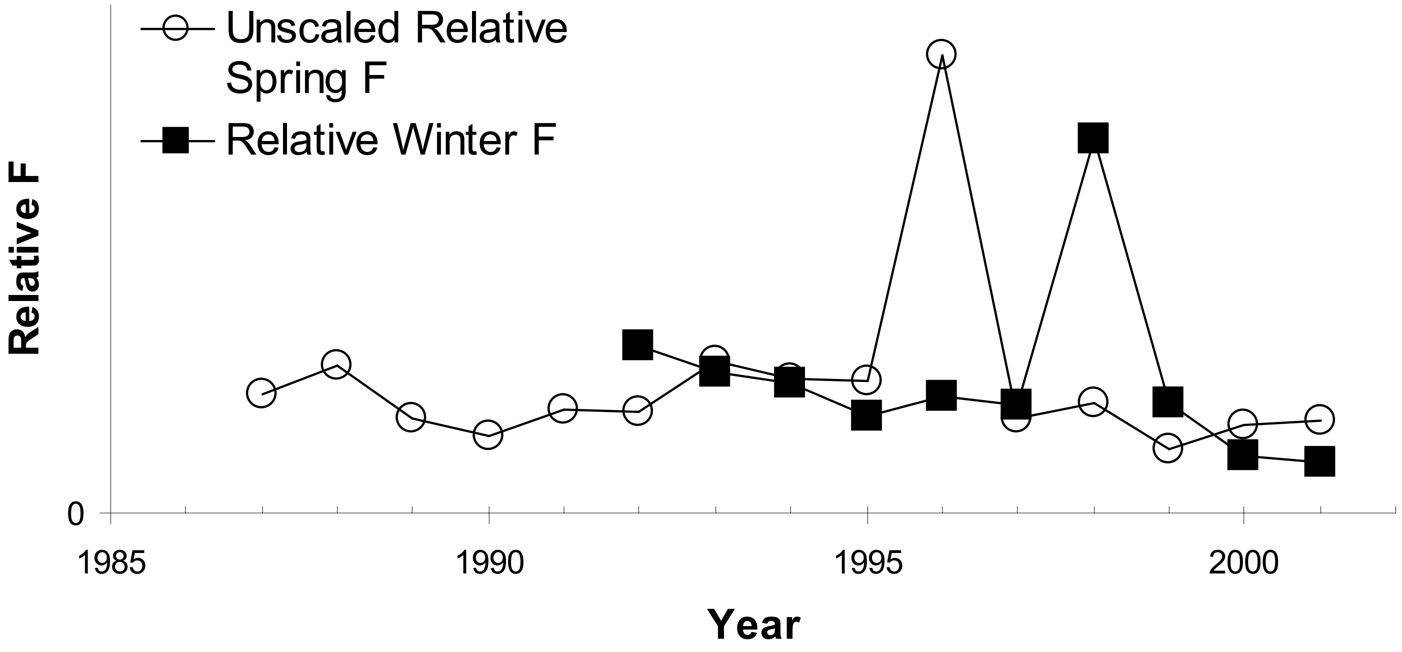


Figure A28. Unscaled relative spring and winter catch-survey F for longfin squid.

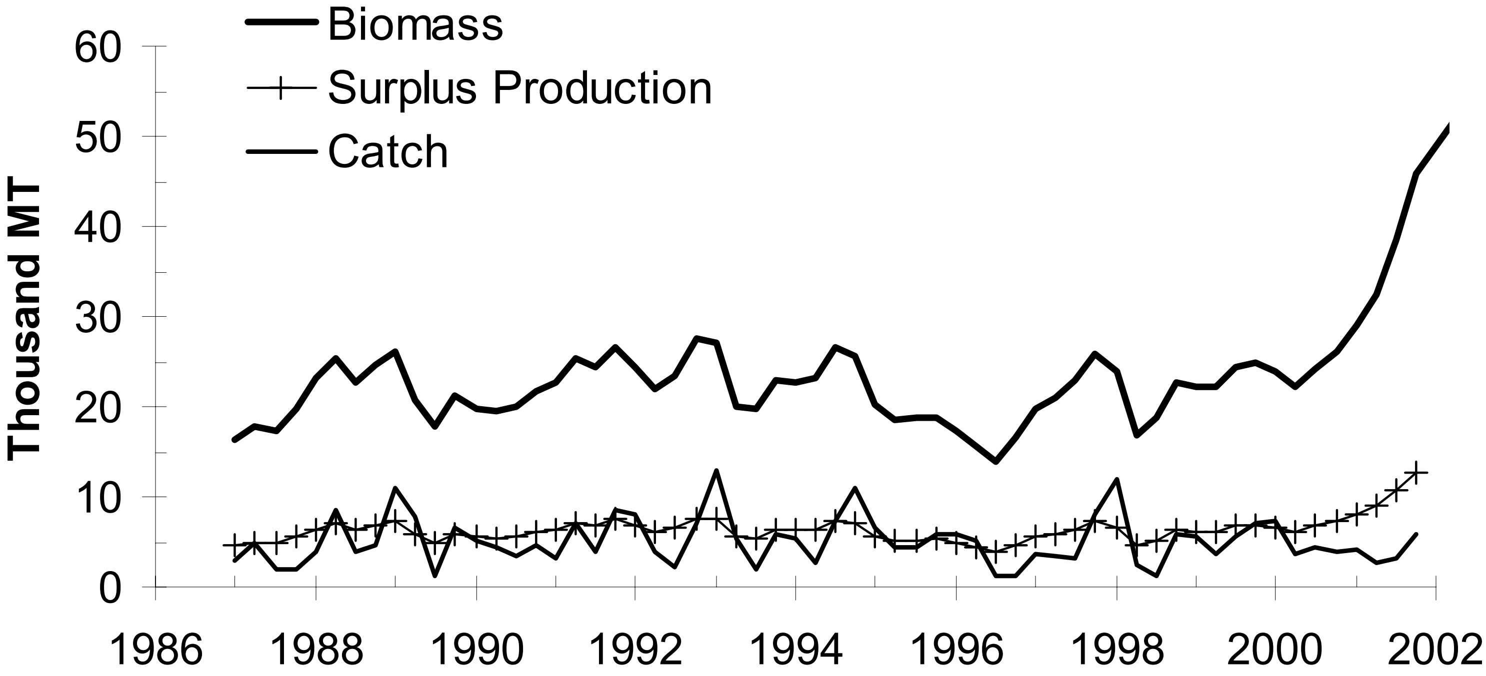


Figure A29. PDQ basecase estimates of biomass, catch and surplus production for longfin squid.

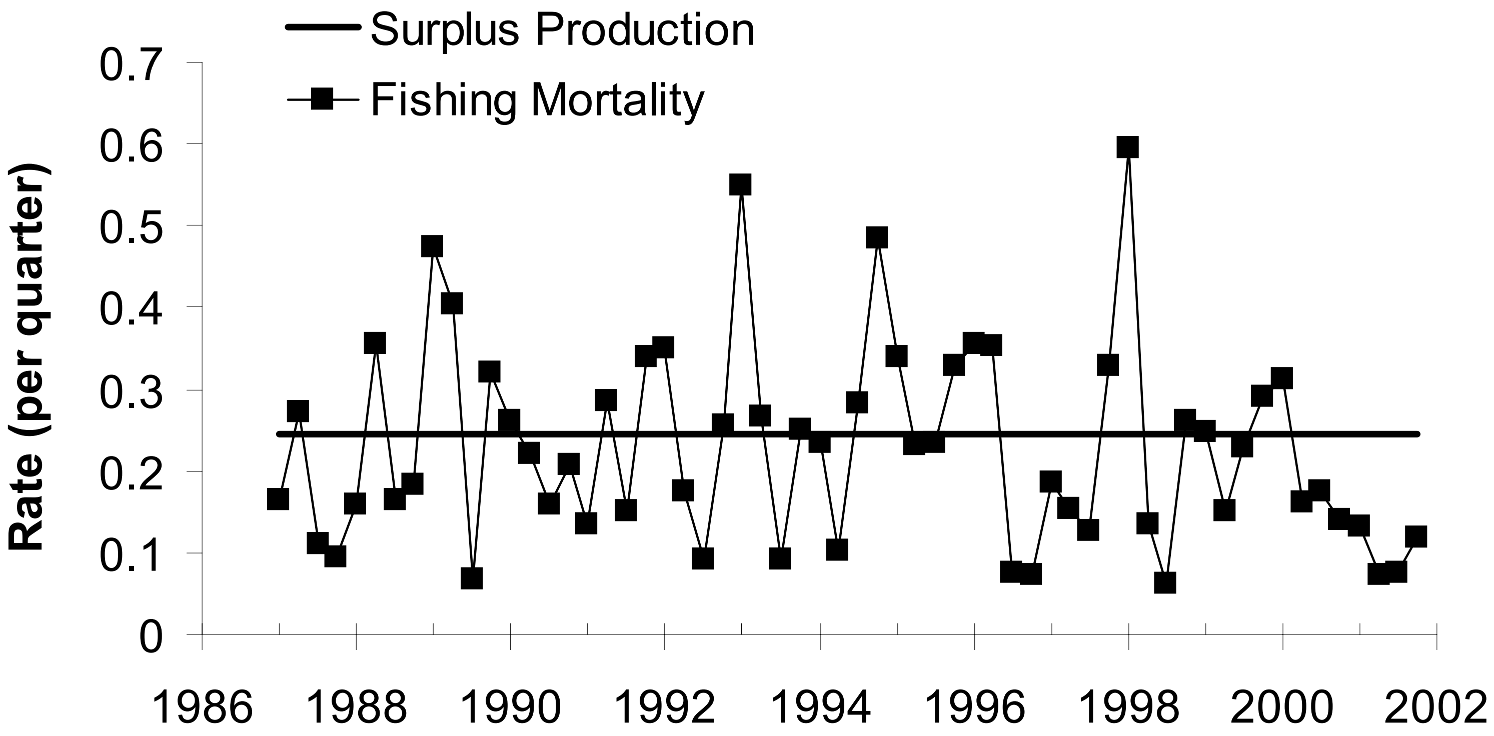


Figure A30. PDQ basecase estimates of surplus production and fishing mortality rates for longfin squid.

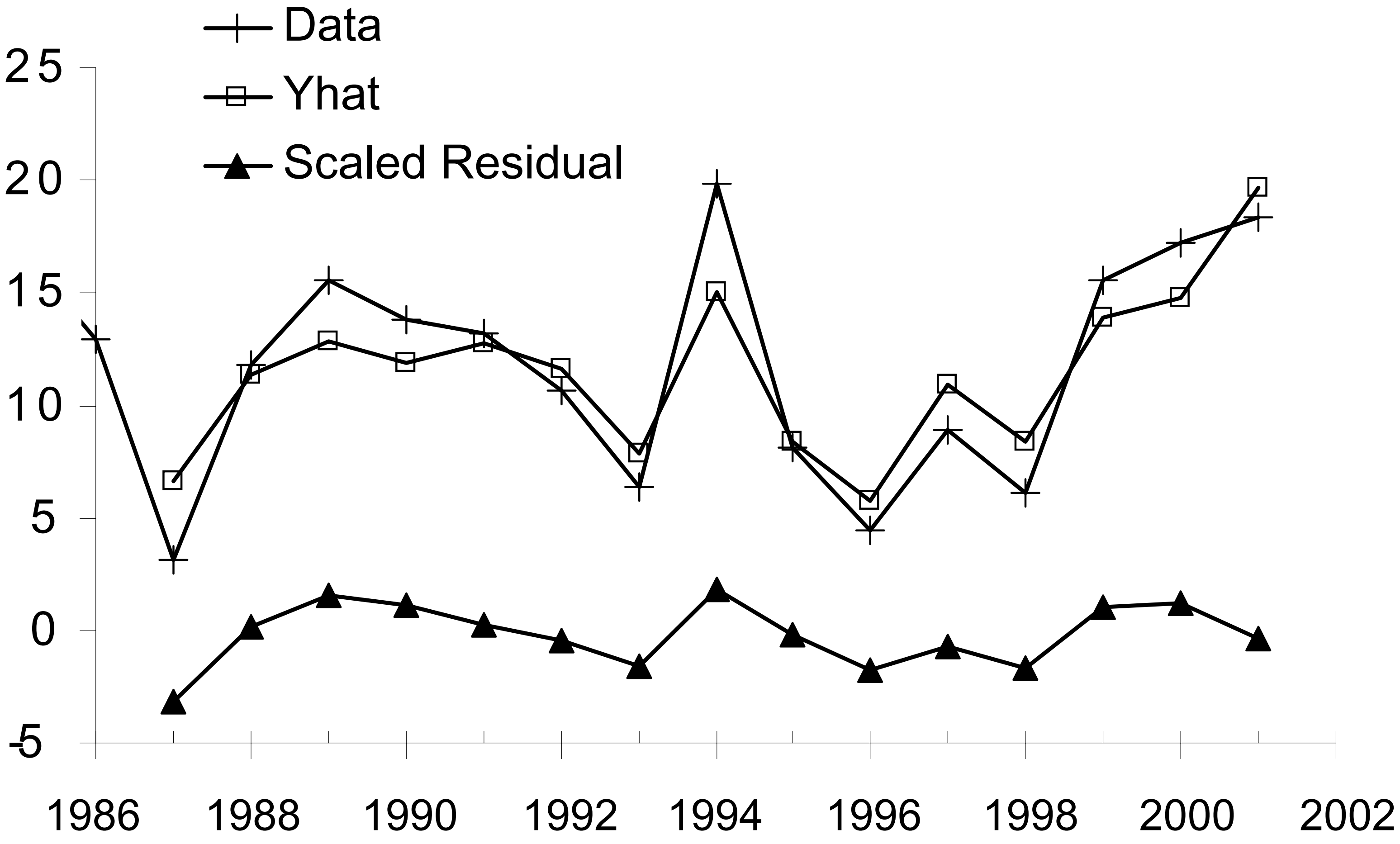


Figure A31. NEFSC autumn bottom trawl survey data, predicted values and residuals for longfin quid from basecase PDQ model.

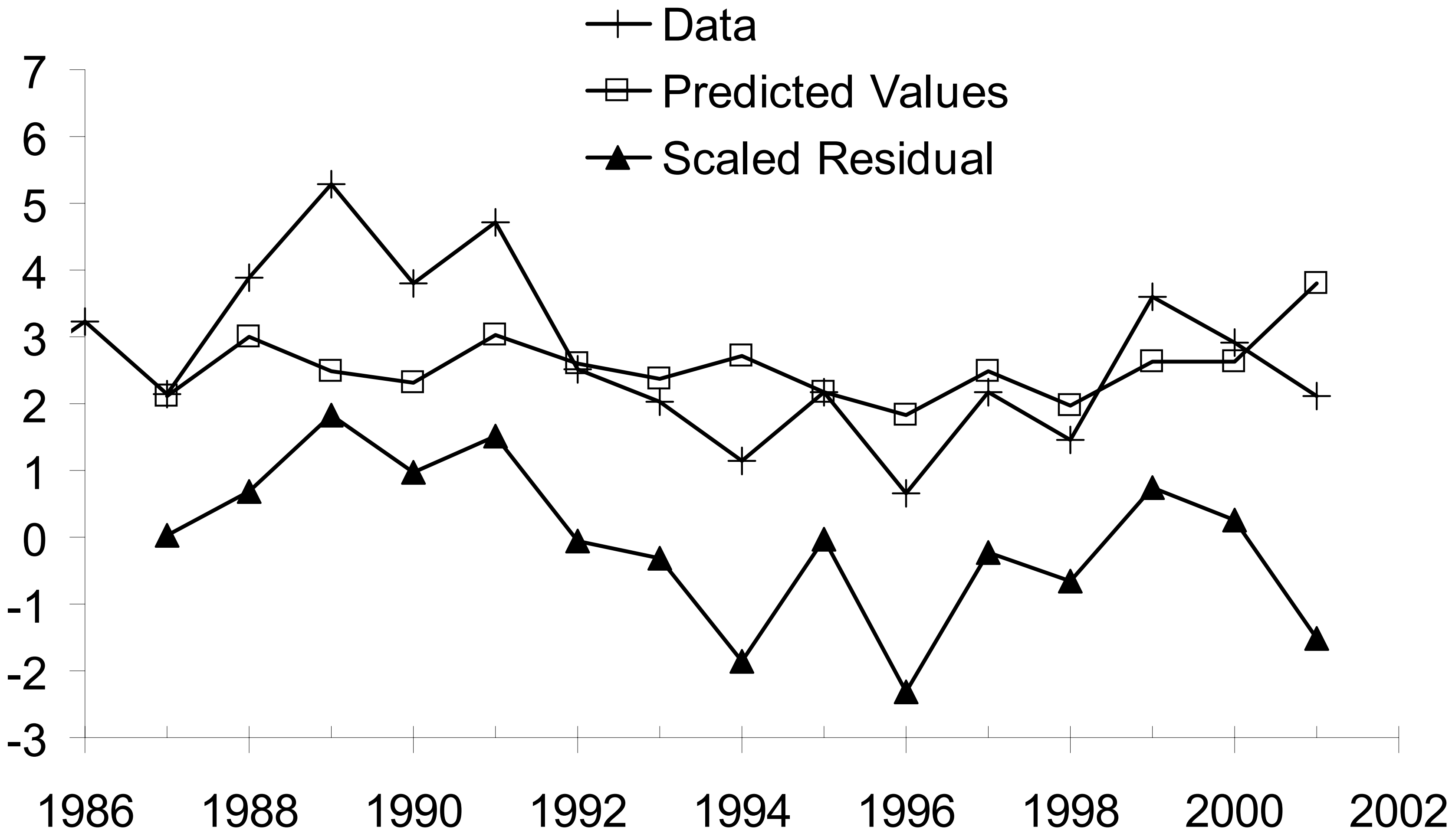


Figure A32. NEFSC spring bottom trawl survey data, predicted values and residuals for longfin squid from the basecase PDQ model.

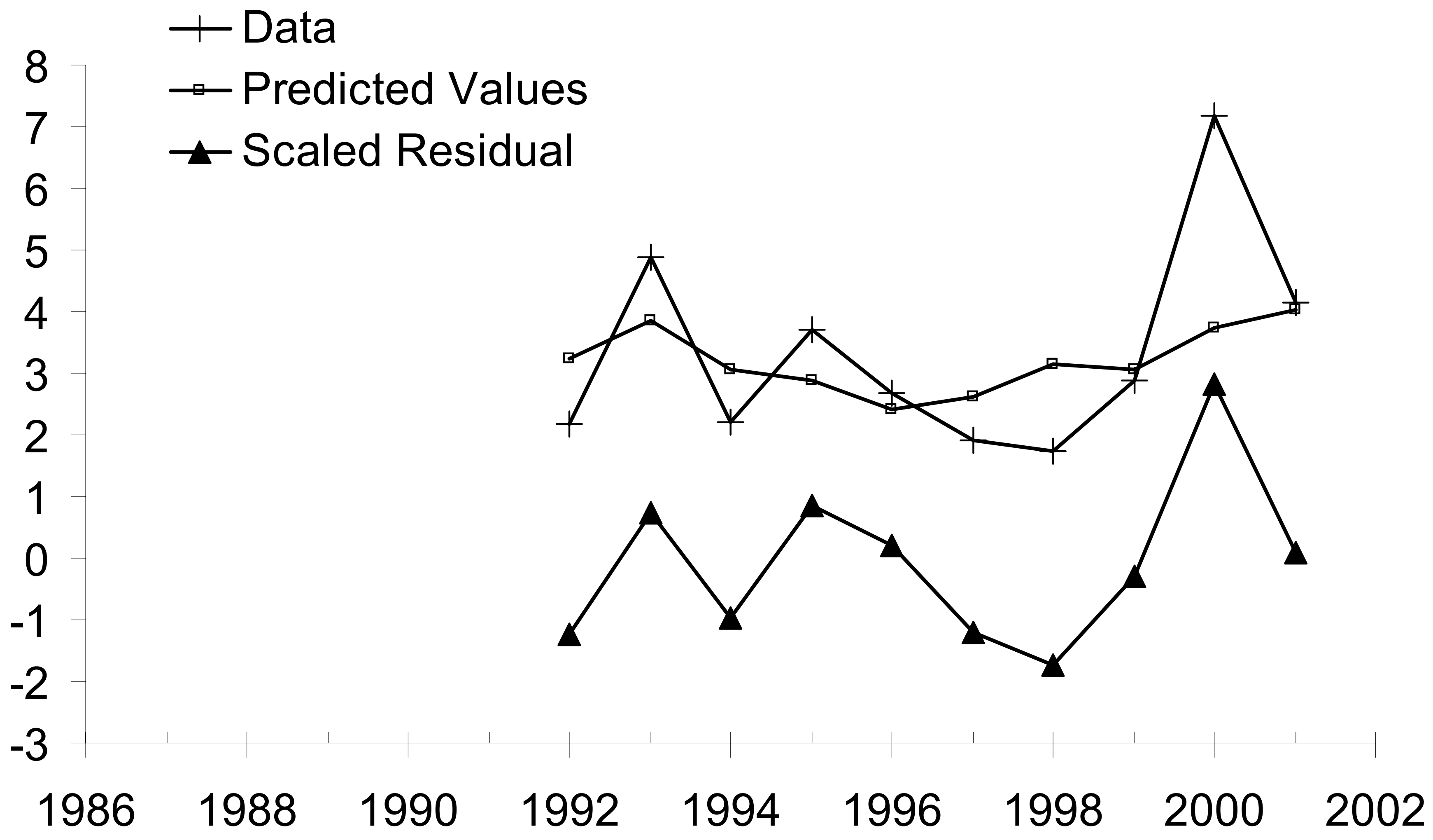


Figure A33. NEFSC winter bottom trawl survey data, predicted values and residuals for longfin squid from the basecase PDQ model.

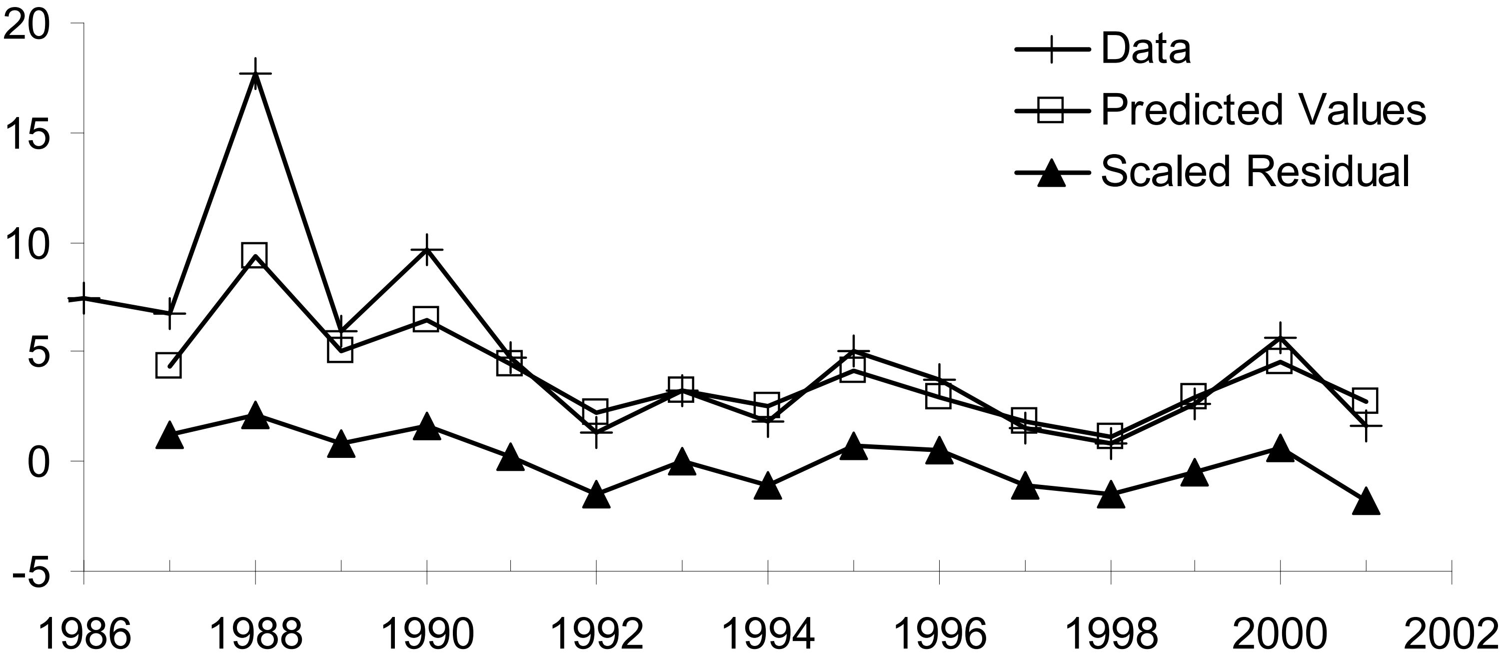


Figure A34. Massachusetts spring bottom trawl survey data, predicted values and residuals for longfin squid from the basecase PDQ model.

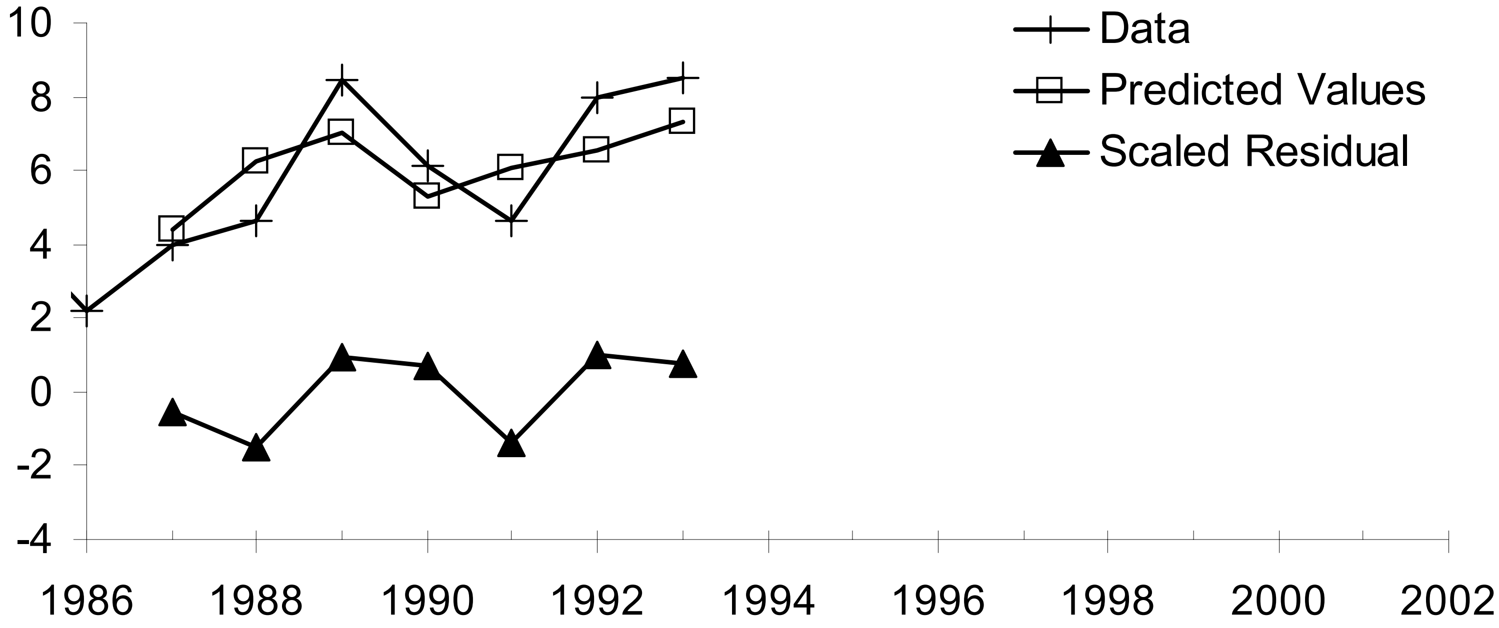


Figure A35. Winter LPUE data, predicted values and residuals for longfin squid from the basecase PDQ model.

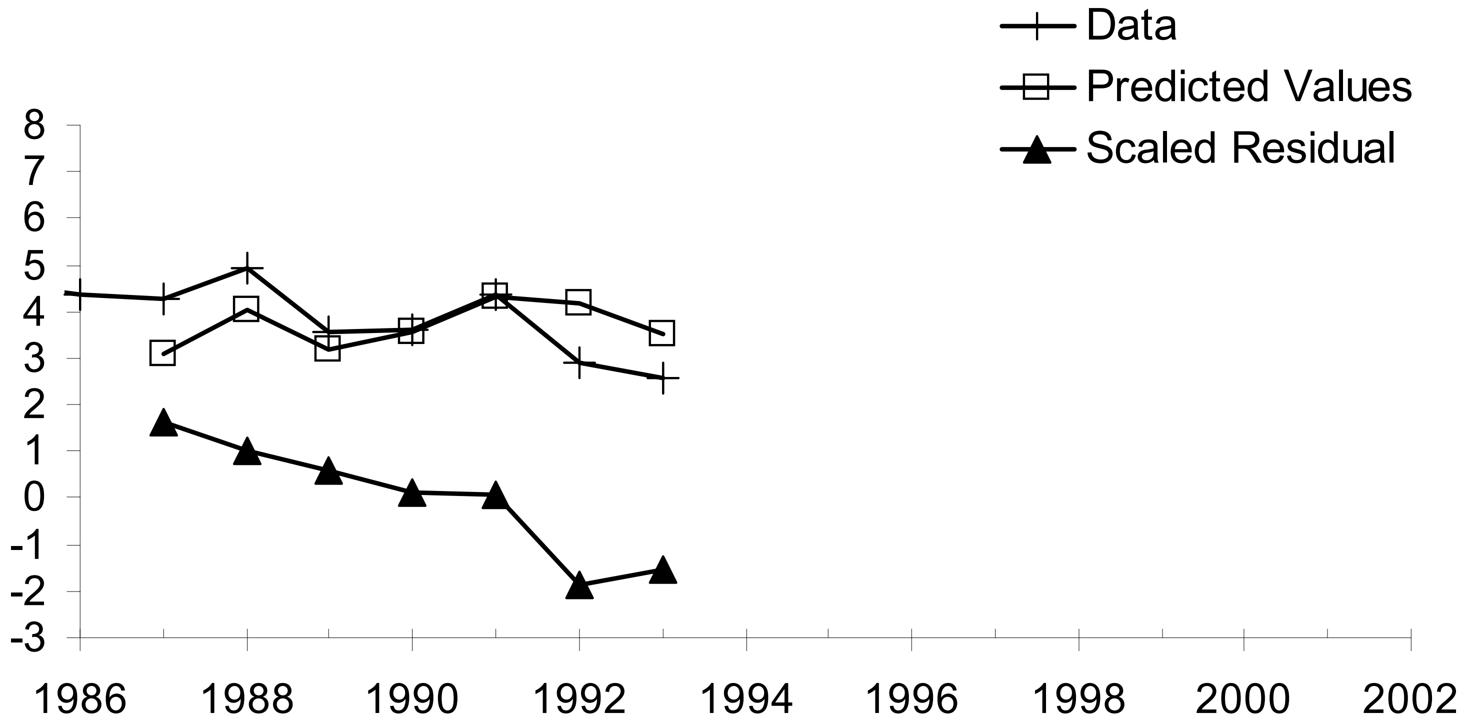


Figure A36. Summer LPUE data, predicted values and residuals for longfin squid from the basecase PDQ model.

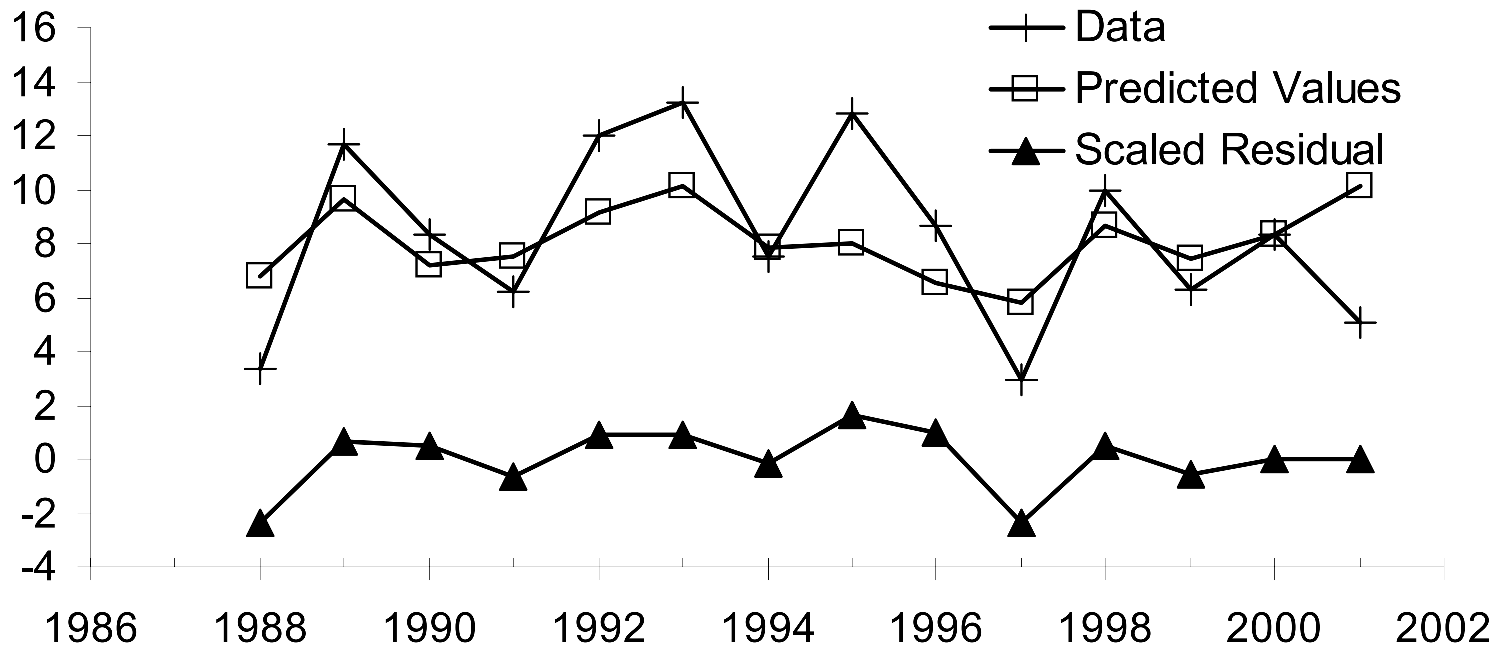


Figure A37. Winter LVPA data, predicted values and residuals for longfin squid from the basecase PDQ model.

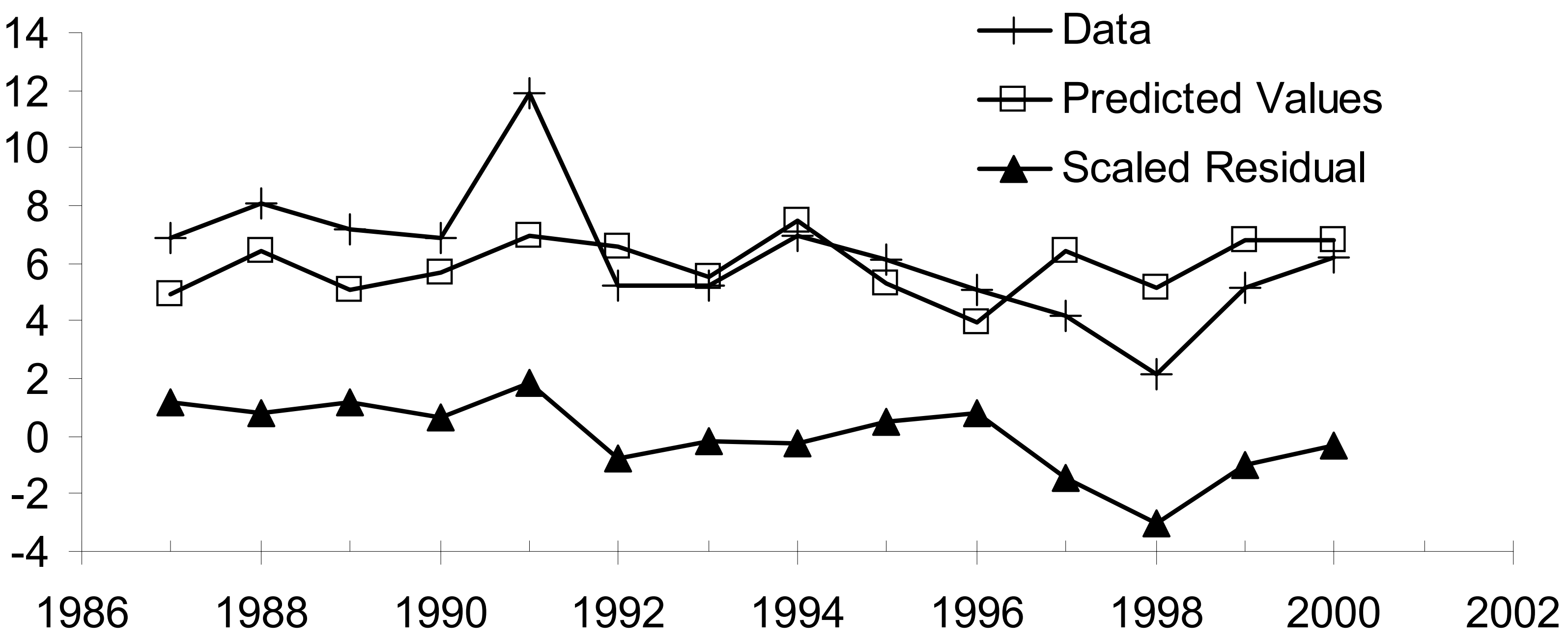


Figure A38. Summer LVPA data, predicted values and residuals for longfin squid from the basecase PDQ model.

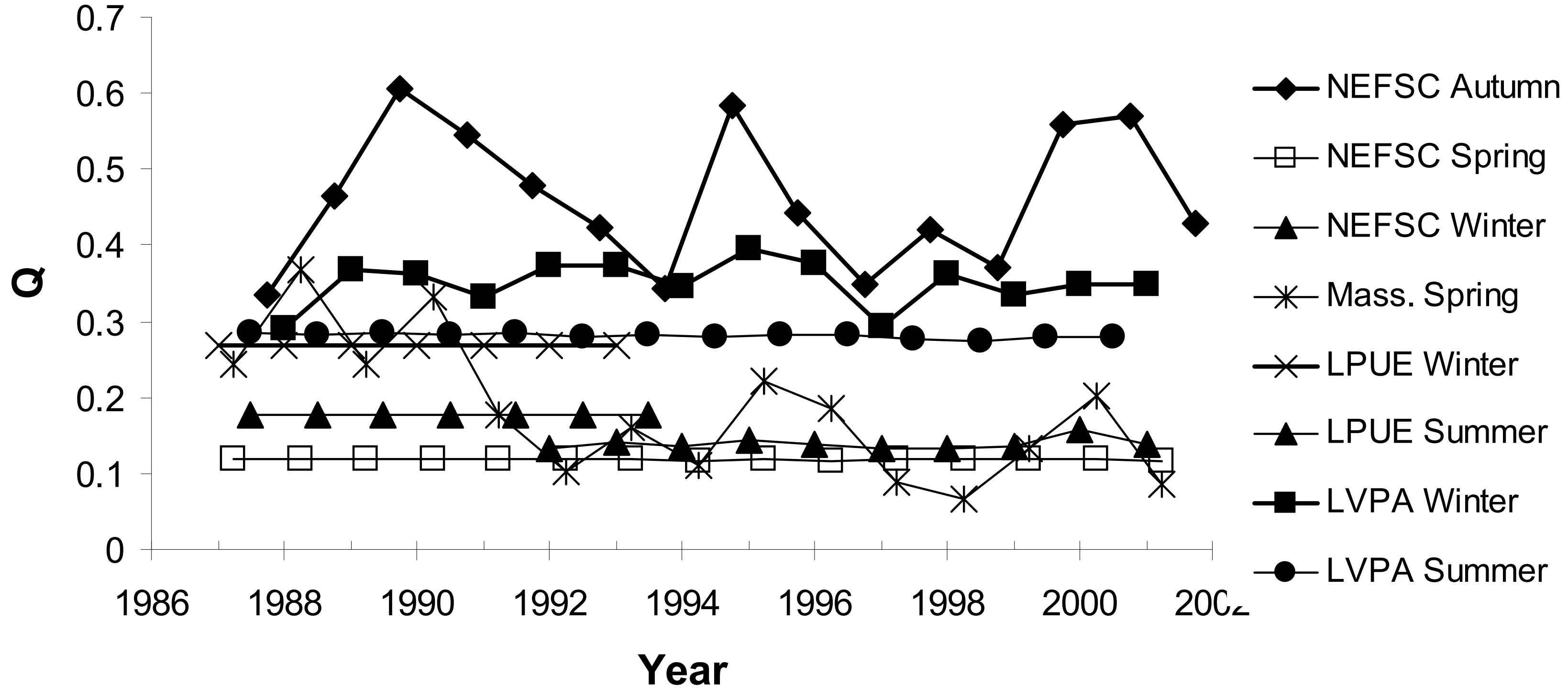


Figure A39. Q estimates for longfin squid abundance indices in the basecase PDQ model.

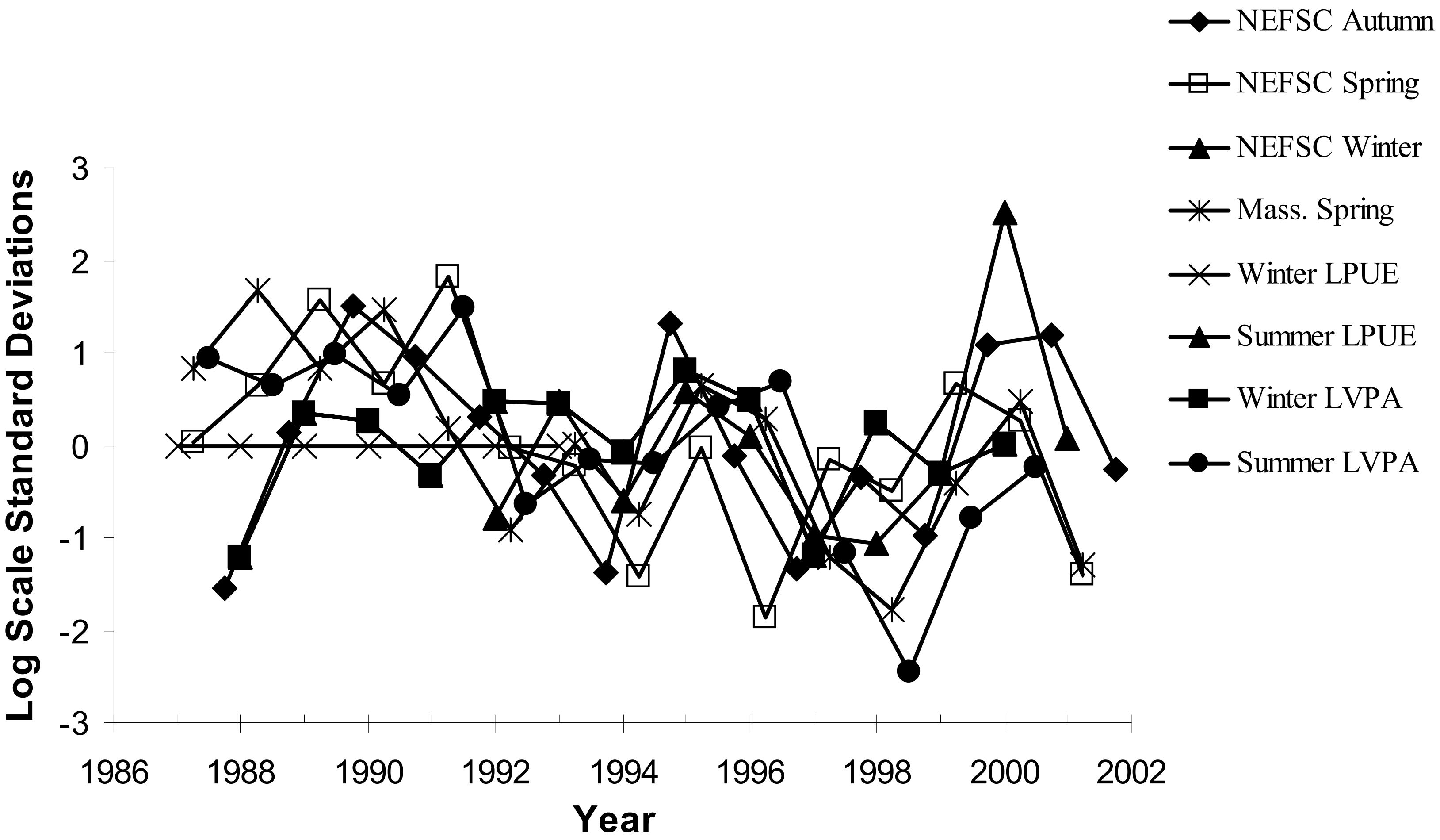


Figure A40. Anomalies in log scale Q for longfin squid abundance indices in the PDQ model.

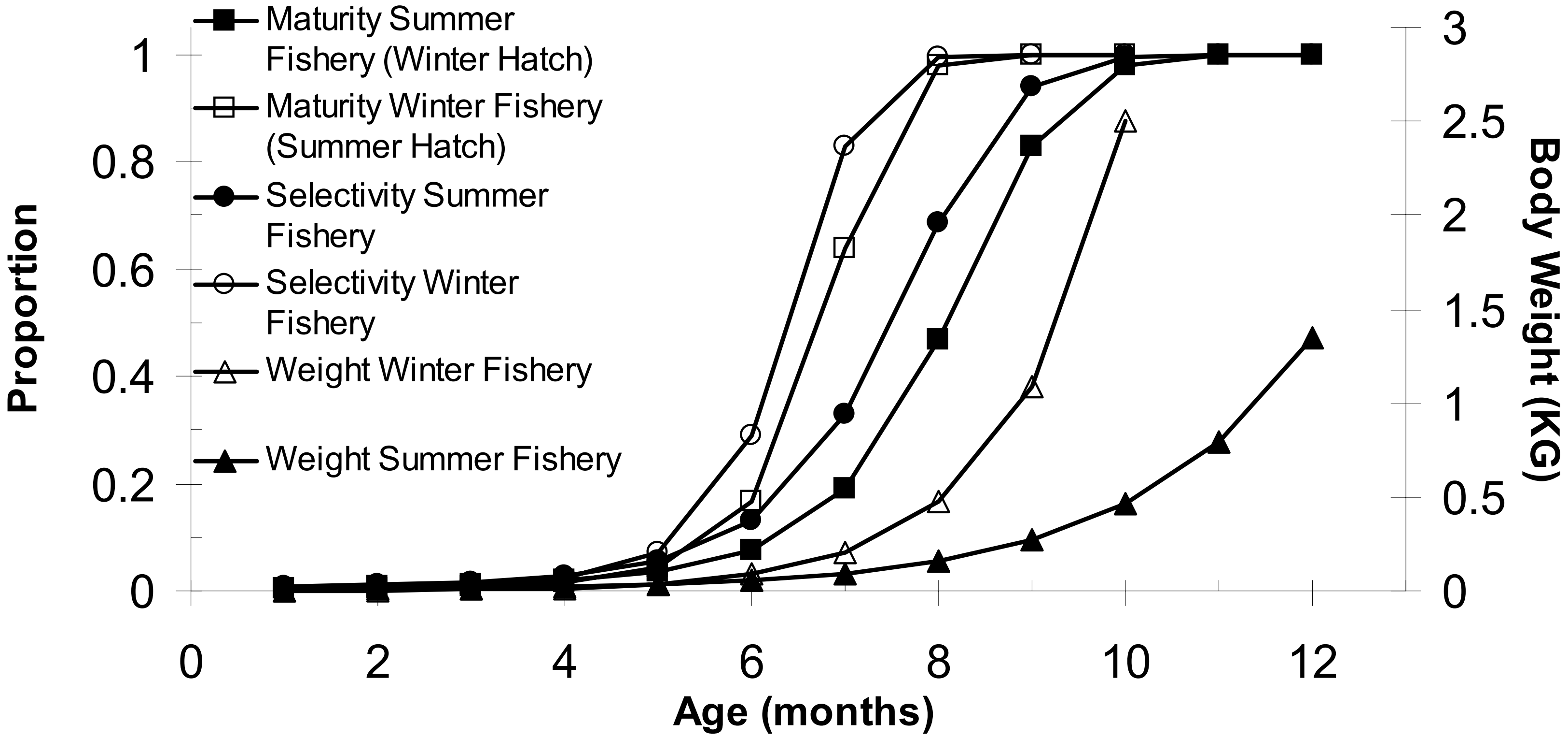


Figure A41. Data for longfin squid per-recruit model.

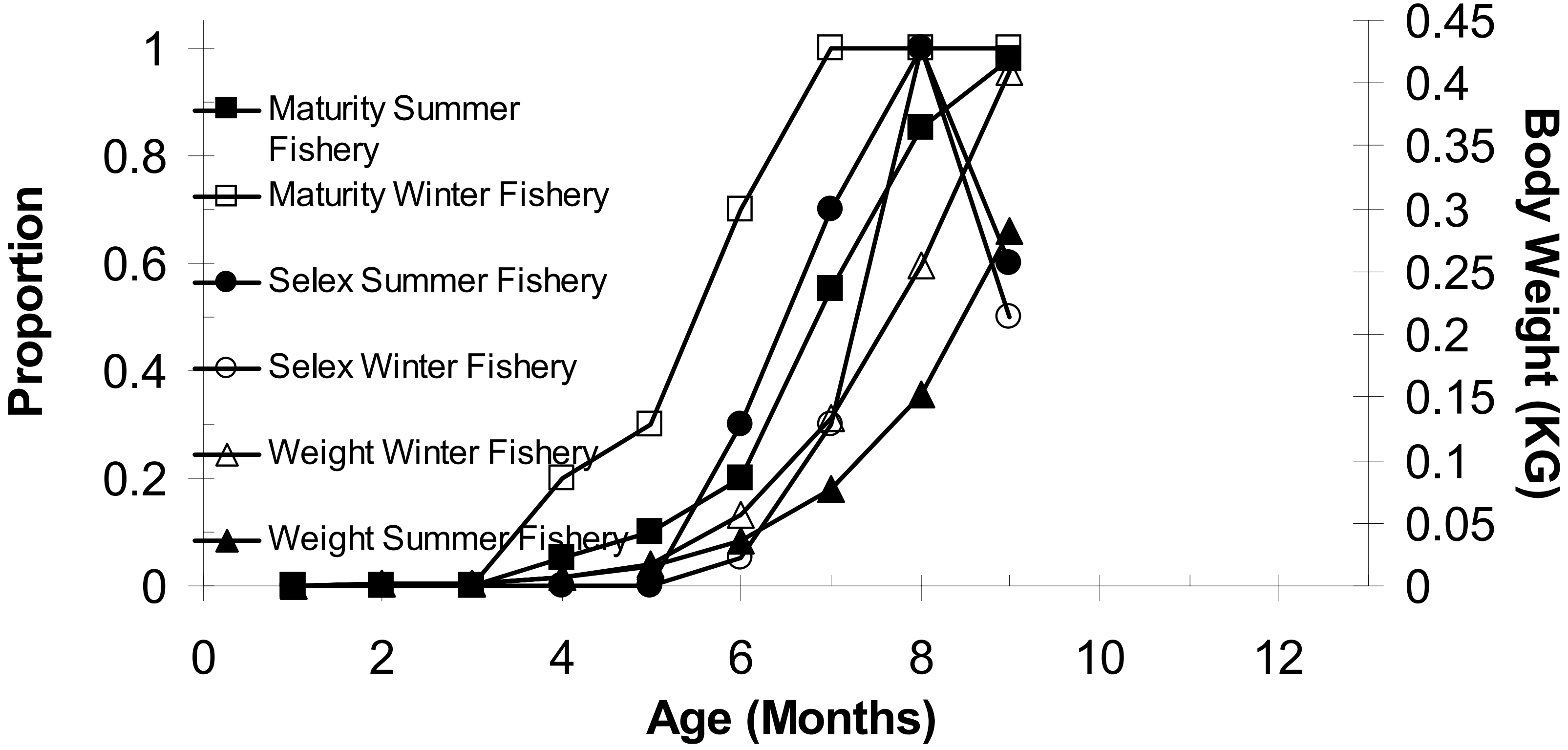


Figure A42. Data for longfin squid per-recruit model in Cadrin and Hatfield (1999)

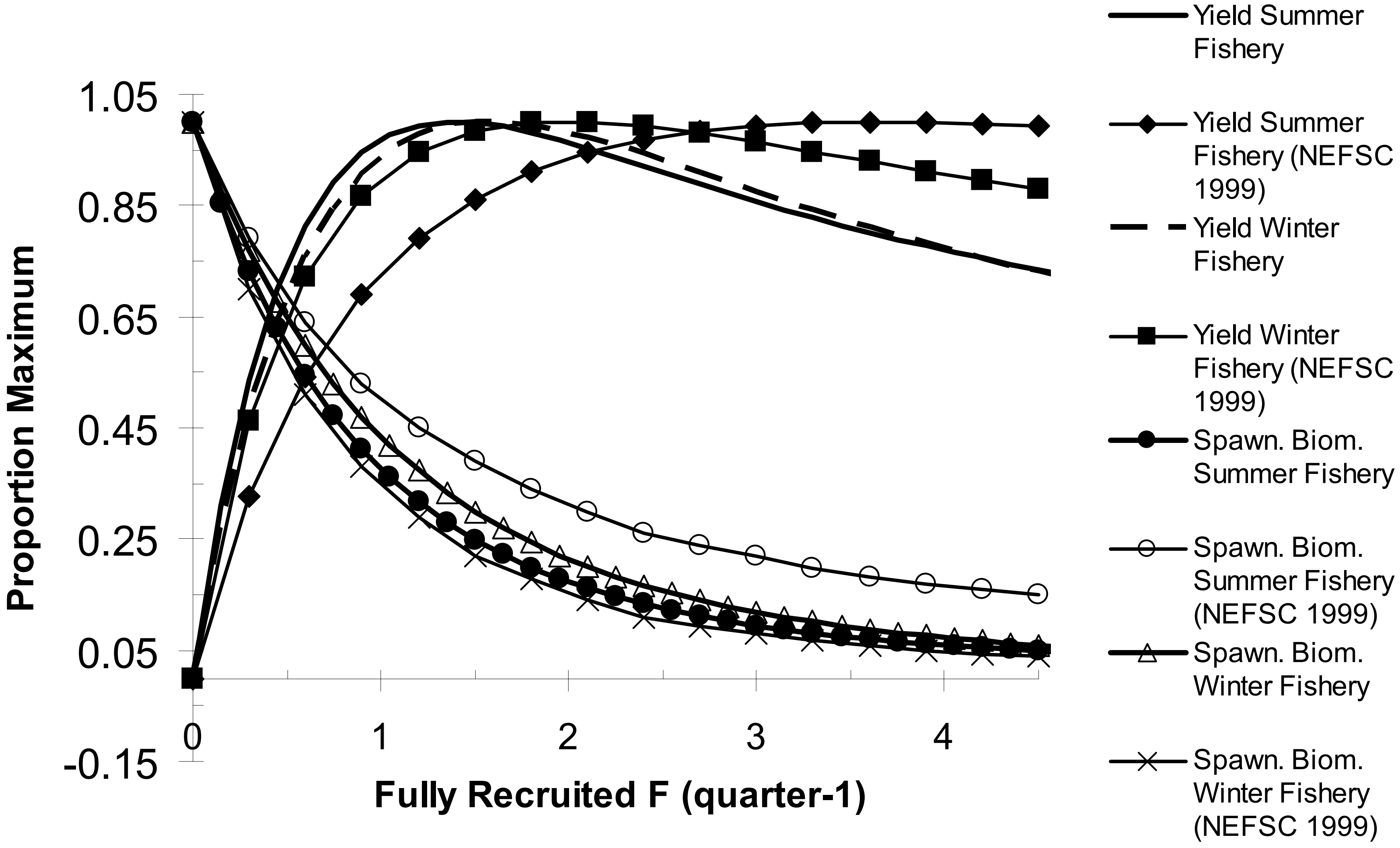


Figure A43. Per recruit results for longfin squid (full recruit F's).

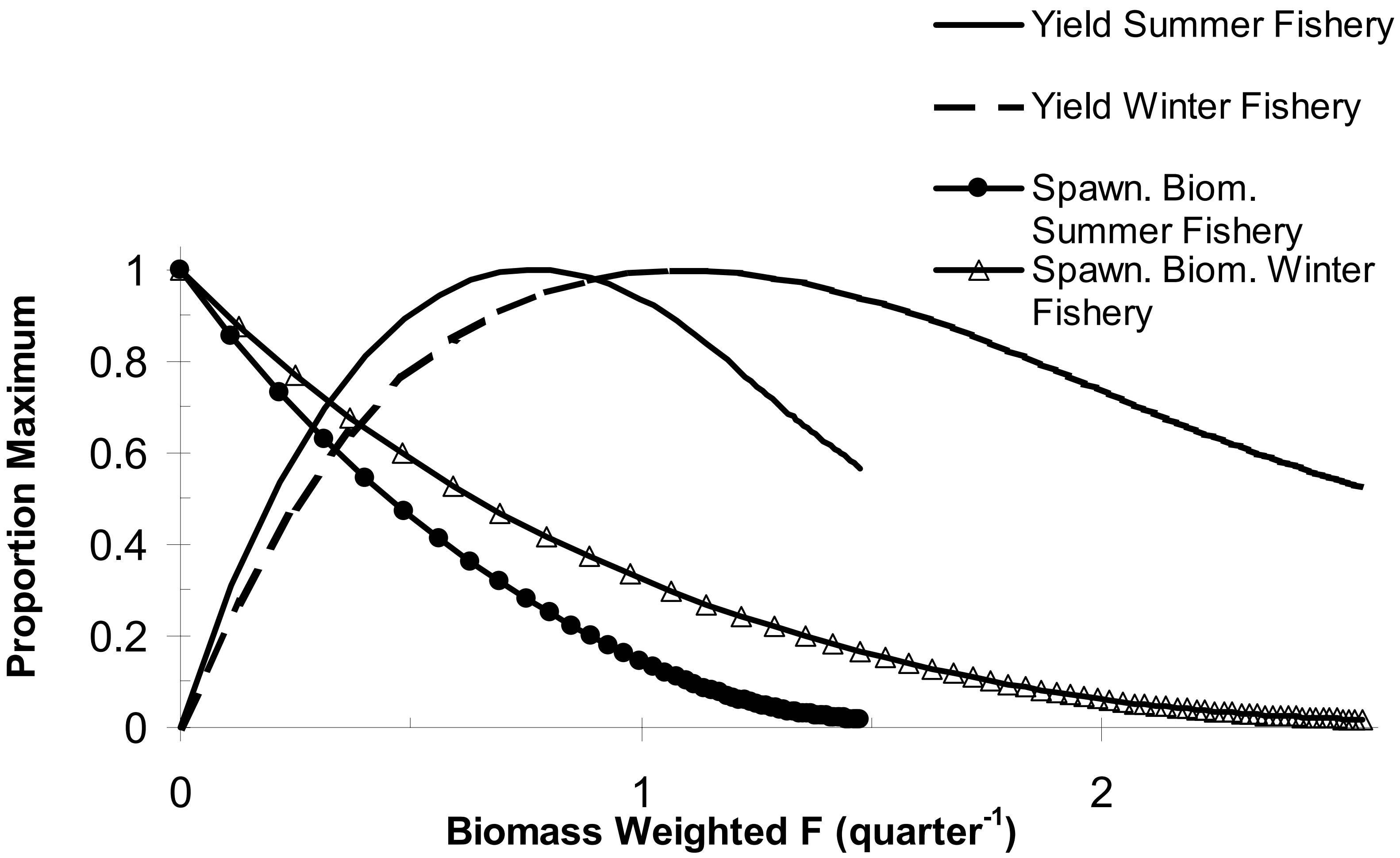


Figure A44. Per recruit result for longfin squid (biomass weighted F's).

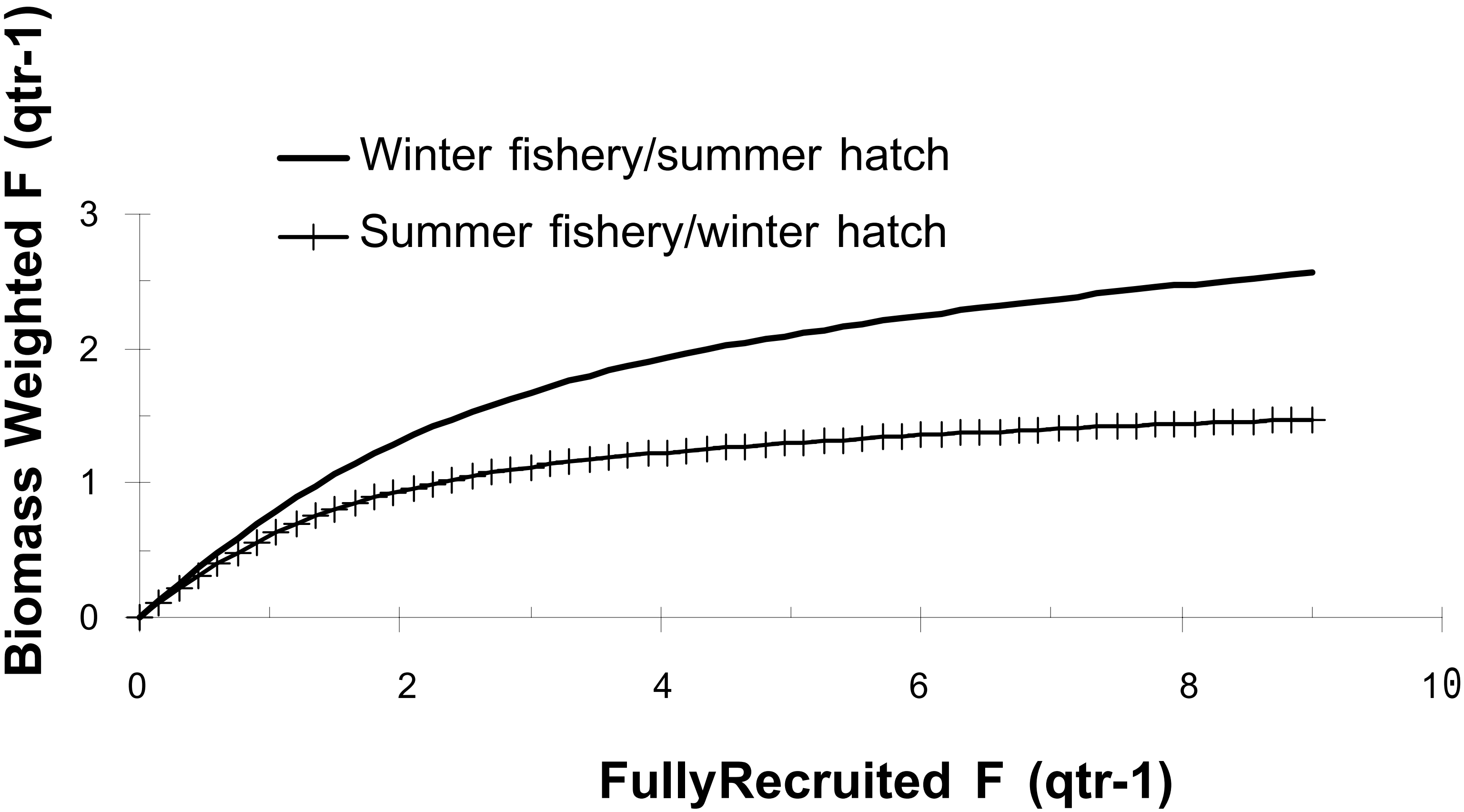


Figure A45. Biomass weighted and fully recruited F from per recruit models for longfin squid.

B. GEORGES BANK WINTER FLOUNDER

TERMS OF REFERENCE

The Steering Committee of the 34th Northeast Regional Stock Assessment Workshop established the following terms of reference for the Georges Bank winter flounder assessment:

1. Update the status of the Georges Bank winter flounder stock through 2000 and characterize the variability of estimates of stock size and fishing mortality.

2. On the basis of anticipated catches and abundance indicators in 2001, estimate stock size at the beginning of 2002 and provide projected estimates of catch and spawning biomass for 2003-2004 at various levels of F.

3. Evaluate and re-estimate the overfishing definition reference points for Georges Bank winter flounder.

SUMMARY

The most recent assessment of the Georges Bank winter flounder stock was conducted during autumn of 1998, at SARC/SAW 28, and represented an initial age-based assessment of the stock. Based on the results of a Virtual Population Analysis (VPA), for 1982-1997, it was concluded at SAW 28 that the stock was overexploited and at a low level of biomass. Relative to the Amendment 9 control rule, overfishing was occurring in 1997. Spawning stock biomass levels and the age composition of the stock were noted to have improved since 1993, but recruitment, particularly the 1995 and 1996 year classes, was poor.

Winter flounder inhabiting Georges Bank represent a discrete offshore stock distributed in the shallower areas of the Bank. There is some directed fishing on the stock, but exploitation is primarily as by-catch, in the large and small mesh otter trawl fisheries, and to a lesser degree in the sea scallop dredge fishery. Management measures directed at other principal stocks in the New England groundfish complex, including area closures, mesh size restrictions, effort controls, and retention restrictions on specific gear sectors, have likely effected the condition of the Georges Bank winter flounder resource.

During 1964-1977, the Georges Bank winter flounder stock was exploited by the United States (U.S.), Canada, and the former Soviet Union (USSR). However, total landings have been dominated by the U.S. fishery since 1964. Total landings during the 1970s and 1980s ranged between 1,800 and 4,500 mt. Since 1989, total landings (U.S. and Canada) have been less than 2000 mt, and in 1995, declined to their lowest level (800 mt) since 1964. Otter trawl gear accounted for greater than 95% of the total landings during most years. Landings from the scallop dredge sector increased to 5-7.8%, during 1989-1997, but declined to approximately 1% during 1998-2000 as a result of bycatch limitations in the sea scallop dredge fishery. Discarding occurs in both the otter trawl and scallop dredge fisheries. Data were insufficient to estimate either the magnitude of discards or to characterize their size or age distribution.

Annual indices of relative abundance and biomass from research vessel bottom trawl surveys are quite variable. The U.S. autumn and Canadian spring bottom trawl surveys indicate that biomass and abundance have steadily increased since 1998. The U.S. spring survey indices show similar increases, with the exception of a decline in the 2001 indices. All three surveys indicate that age 2 recruitment has been low since the appearance of 1994 year class.

The most reliable estimates of stock biomass and fishing mortality were obtained from an ASPIC surplus production model. Mean biomass has increased steadily since 1994, reaching 8,800 mt in 2000, and fishing mortality rates have been declining since 1996, to 0.21 in 2000.

A Virtual Population Analysis (VPA), calibrated with research survey indices from 1982-2000, was reviewed, but not adopted by the SARC to evaluate stock status. Model fit was poor (high CVs on stock size at age), there were inconsistent patterns in mean weights at age and fishing mortality rates at age, and a retrospective pattern was present in estimated fishing mortality rates in recent years. The primary reason for these factors was insufficient sampling, in the primary port of New Bedford, to reliably characterize the age composition of the landings.

A second age-based model (WIN), which involved a forward-projection of the catch-at-age, was also reviewed. However, the SARC decided that further sensitivity testing of the model was warranted.

The ASPIC model results were also used to re-estimate biological reference points. Maximum sustainable yield (MSY) was estimated as 3,020 mt and B_{MSY} was estimated at 9,355 mt. Proposed threshold and target biomass proxies (in survey-based equivalents of kg/tow) were estimated as 1.25 and 2.49, respectively. The corresponding survey proxy equivalent threshold and target fishing mortality rates are 1.21 and 0.91, respectively. Relative to the proposed harvest control rule, the stock is not overfished and overfishing is not occurring ($B_{1998\text{-}2000\ proxy} = 2.29$, $F_{1998\text{-}2000\ proxy} = 0.65$).

INTRODUCTION

Winter flounder (*Psueudopleuronectes americanus*) is a demersal flatfish species distributed in the Northwest Atlantic from Labrador to Georgia (Bigelow and Schroeder 1953, Klein-MacPhee 1978). Although primarily distributed in shallow inshore waters where estuarine habitat serves as important spawning and nursery areas, winter flounder are also distributed on some shallow offshore banks, at depths less than 80 m, such as Nantucket Shoals and Georges Bank. Adult winter flounder feed primarily on benthic invertebrates including annelids (predominately polychaetes), cnidarids, and anthoza (Langton and Bowman 1981). Principal predators include striped bass (*Morone saxatilis*), bluefish (*Pomatomus saltatrix*), goosefish (*Lophius americanus*), spiny dogfish (*Squalus acanthias*), and sea raven (*Hemitripterus americanus)*; (Dickie and McCraken 1955, Grosslein and Azarovitz 1982). Spawning peaks on Georges Bank during March and April, as evidenced by the presence of spawning condition fish in the Northeast Fisheries Science Center (NEFSC) spring research vessel bottom trawl survey and high densities of eggs and larvae detected by MARMAP ichthyoplankton surveys (Pereira *et al.* 1999).

Stock Structure

Tagging studies, differences in life history characteristics, and meristic studies all provide evidence for discrete stocks of winter flounder in the U.S. waters of the Northwest Atlantic. Winter flounder on Georges Bank have considerably higher growth rates than fish from inshore waters (Bigelow and

Shroeder 1953, Lux 1973), and historically, the Georges Bank stock was considered as a separate species (*Psudopleuronectes dignabilis*; Kendall 1912). Meristic studies indicate that fin ray counts differ for fish from Georges Bank and inshore areas indicating further evidence for a discrete offshore stock (Perlmutter 1947, Lux *et al.* 1970). Extensive tagging studies of winter flounder indicate little mixing of fish between Georges Bank and inshore areas (Coates *et al.* 1970, Howe and Coates 1975) , providing further evidence for discrete stock structure (Pierce and Howe 1977).

For this assessment, the Georges Bank winter flounder stock boundaries used to evaluate fisheries data included U.S. statistical areas 522, 525, 551, 552, 561, and 562 (Figure B1), which correspond to Canadian unit areas 5Zh, j, m, and n.

Fishery Description

Winter flounder, often known as blackback or lemon sole within the fishing industry, are harvested primarily using otter trawl gear, and landings occur in a directed fishery as well as by-catch in fisheries targeting other species. Bycatch landings and discards occur in trawl fisheries targeting other groundfish species and in the scallop dredge fishery. Although recreational landings are a significant source of fishing mortality in inshore waters for the Southern New England stock complex, recreational landings from the Georges Bank stock are insignificant and are not included in this assessment.

Management History

Over the past 25 years, management of the commercial fishery for Georges Bank winter flounder has focused on minimum size limits and management measures (seasonal and year-round area closures, mesh size regulations, effort control measures, and fleet capacity reduction programs) primarily intended to address management needs for other demersal species (Atlantic cod, haddock, and yellowtail flounder). Seasonal spawning closures of haddock spawning grounds, which increased in temporal and spatial coverage since their inception in 1970 (Clark 1976), have provided some measure of protection for the stock.

Winter flounder was included in the New England Fishery Management Council's Atlantic Groundfish Fishery Management Plan (1977-1982). The initial plan established a minimum commercial size limit (11 inches, 28 cm), imposed minimum mesh sizes for trawls, and established spawning stock biomass per recruit targets. In 1982 the Council adopted an Interim Groundfish Plan, which established a minimum mesh size of 130 mm (5 1/8"). In 1983 the minimum mesh size was increased to 140 mm (5.5") In 1986 the Council's Multispecies Fishery Management Plan increased the minimum legal size to 30 cm (12 in) and imposed seasonal area closures. Amendment 5, adopted in 1994, and Amendment 7, adopted in 1996, established effort controls (days at sea limits), further increased minimum mesh size to 142 mm (6" diamond or square mesh), imposed trip limits for regulated groundfish bycatch in the sea scallop fishery, and prohibited small-mesh fisheries from landing regulated groundfish. In December 1994 two large areas on Georges Bank were closed to fishing on a year-round basis to protect overfished groundfish species. These areas include both the eastern and western edges of the distribution of winter flounder on the bank. Since June of 1994, vessel operators have been required to submit their catch and effort information, by gear type and statistical area, on Vessel Trip Reports (VTR) and dealers have been required to submit reports of groundfish purchases. Prior to this mandatory reporting requirement, landings and fishing effort data were collected by port agents who interviewed a percentage of the fishing fleets.

Amendment #9 to the Multispecies Fishery Management Plan was approved in 1999 and resulted in a revision of the overfishing definition in accordance with the Sustainable Fisheries Act (SFA). The Overfishing Definition Review Panel (Applegate *et al.* 1998) recommended a control rule for Georges Bank winter flounder derived from survey-based proxies of MSY-reference points. Biomass-based reference points were based on the NEFSC Autumn research survey biomass index (stratified mean kg per tow) and fishing mortality reference points were based on an exploitation index (catch/NEFSC Autumn research vessel biomass index).

The SFA also required regional fishery management councils to describe and identify essential fish habitat (EFH), to specify actions to conserve and enhance EFH, and to minimize the adverse effects of fishing on EFH. Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." EFH for Georges Bank winter flounder is described in Pereira *et al.* (1999).

THE FISHERY

Commercial Landings

Fisheries data evaluated for this assessment included U.S. statistical areas 522, 525, 551, 552, 561, and 562 (Figure B1) and the corresponding Canadian unit areas 5Zh, j, m, and n. Prior to 1985, U.S. landings also occurred in statistical areas 551 and 552, which are now located within Canadian waters. Prior to 1977, commercial landings of Georges Bank winter flounder were reported from the United States, Canada, and distant water fleets including the former Soviet Union. From 1964 to 1971, total landings increased, reaching a peak of 4,500 mt in 1972 (Figure B2, Table B1). Landings declined from 1971 to 1976, before increasing sharply to 3,600 mt in 1977. Commercial landings were high during 1980 -1984 (averaging 3,800 mt/yr), but declined sharply in 1985 to 2,200 mt. Landings have been less than 2,000 mt since 1985, with the exception of landings from the strong 1984 year class in 1987 and 1988. Landings in 1995 (760 mt) were the lowest recorded since 1964, but have ranged between 1,00 mt and 1,800 mt since then. U.S. landings have been the dominant component of the total landings since the late 1960's. Canadian landings ranged between 0.1% and 2.8% of the total landings during 1970-1993. Since 1994, total landings have been lower and Canadian landings have been increasing, representing 5-10% of the total landings.

During 1982-1993 approximately 20-25% of the U.S. landings occurred during quarter one. However, since 1995, less than 5% of the landings have occurred during quarter one (Figure B3). The SARC investigated this change in the temporal distribution of the landings by examining whether it might be an artifact of the proration scheme (stratification by month and state), which came into use in mid-1994. Information on vessel tonnage class (a proxy for vessel size) was included in the proration scheme to evaluate the potential impact on distribution by stock if larger vessels tend to fish more often on Georges Bank than in the other two winter flounder stock areas (southern New England and Gulf of Maine). The SARC found that this proration revision had little effect on the amount of landings assigned to the stock. Other potential causes for the change in seasonal landings pattern might be a reduction in fishing effort during quarter one, either due to boats having expended their days at sea allocations for the fishing year or due to fewer offshore trips due to increases in bad weather and potential loss of days at sea during the winter. No definitive explanation for the fishing pattern change could be determined by the SARC.

Otter trawls have been the dominant gear accounting for greater than 98% of landings in the U.S. fishery through 1985 and 100% of the Canadian landings (Table B2). During 1985-1991, the proportion of landings taken by scallop dredges increased steadily, from less than 1% to 7.8%. The proportion of total landings accounted for by scallop dredges subsequently declined during 1994-1997, to around 5%, and to less than 1% since 1998, possibly due to U.S. groundfish retention limits imposed on the scallop fishery. Tonnage class 3 (51-150 GRT) otter trawlers generally account for approximately 60-80% of U.S. landings, while tonnage class 4 (151-500 GRT) otter trawlers generally account for all but a few percent of the remaining U.S. landings (Table B3).

Since 1982, U.S. landings have been reported as eight market categories (unclassified, lemon sole, small, large, extra-large, large/mixed, medium, and peewee), based primarily on fish size. Three categories (lemon sole, small, and large) comprised approximately 85% of the commercial landings from 1982-2000 (Table B4). Prior to 1997, fish classified as mediums represented 1-3% of the U.S. landings, but landings of medium fish has since increased to 7-10 %. Canadian landings are not reported by size.

Commercial Discards

Commercial discarding has occurred in the otter trawl and scallop dredge gear sectors due to marketability (size and condition), minimum size limit regulations, and groundfish retention limits in some small mesh fisheries and the scallop fishery. Discard information is available from two primary sources: the sea sampling database, which summarizes information collected by trained observers aboard commercial vessels, and the Vessel Trip Reports (VTR) database, which contains discards reported by vessel operators.

Sea sampling data are available for 1989-2000 and represent the most reliable source of information available for estimating commercial discards. During 1989-2000, the total number of Georges Bank otter trawl trips where winter flounder weights were collected ranged from 3 to 17 trips annually (Table B5). Sea sampling of scallop dredge trips occurred during 1992-2000, but observations are very limited, ranging from 1 to 9 trips available annually where weights of landed and discarded winter flounder were sampled. Based on this limited amount of information, estimated total discards in the trawl gear sector ranged from 1.2 to 24.9 mt annually, representing 0.2 to 1.6% of the otter trawl landings. Limited sampling of sea scallop trips precludes even preliminary estimates of discards for this fleet sector. Discards in the sea-sampled scallop dredge trips that occurred in the Georges Bank groundfish closure areas during 2000 were also examined. The SARC determined that the temporal and spatial distribution of these trips was limited and, as a result, could not be used to produce a reliable estimate of discards from the entire scallop dredge fishery during 2000 (Table B6, Figure B4).

Length frequency information available in the sea sampling database were examined to determine the feasibility of partitioning discard weight estimates into numbers at length. During 1989-2000, the number of discarded winter flounder measured annually by the Sea Sampling Program ranged from zero in 1997 to 103 in 2000 (Table B7). These data were determined to be insufficient, at SARC 28 (NEFSC 1999), to characterize the overall length frequency distribution of the discarded portion of the catch. The number of discarded winter flounder measured in the scallop dredge gear sector during 1992-2000 was insignificant in every year except 1997, when 239 discarded winter flounder were measured in the second quarter and a total of 274 were measured across all quarters. Based on the limited data available to either estimate the magnitude of total discards or to characterize their size distribution, it was concluded at SARC 28 (NEFSC 1999) that it would be inappropriate to generate estimates of discards from these data. The SARC determined that the additional 21 otter trawl and 14 scallop dredge trips sampled during 1998-2000 were inadequate to attempt to re-estimate discards from either fishery (Tables B5 and B7).

Commercial operator-reported discards in the VTR database, available during the 2nd quarter of 1994-2000, represented the next best available source for estimating discards. Reporting rates in the VTR database are known to be incomplete because many operators fail to reliably report discards. To avoid problems associated with incomplete reporting, we estimated discard ratios using VTR data based on a subset of logbook records that reported at least 1 pound of discards for any species (NEFSC 1997, Brown 2000). By using this subset to characterize discard ratios, three basic assumptions were made: 1) it is highly unlikely that a groundfish trip could operate within the Georges Bank stock area without generating discards of some species, 2) for those trips where discards were reported, discards of winter flounder were reliably reported, and 3) the ratio of landed to discarded weight from this VTR subset was representative of the discarding behavior of the entire fleet. Thus, the VTR subset used to estimate discard ratios included: 1) trips reporting both landings and discards of winter flounder, 2) trips reporting winter flounder discards but no landings, and 3) trips reporting winter flounder landings and discards for some other species.

For the otter trawl gear sector, the number of trips included in the discard ratio estimate ranged from 73 to 182 trips annually (Table B8). During 1994-1997, total discards estimated from the VTR in the trawl gear sector ranged from 7 to 22 mt annually, representing 0.5 to 3.0% of the otter trawl landings. The number of scallop dredge trips where discards of winter flounder were reported was much lower, ranging from 17-112 trips annually.

A third approach to estimating discards was attempted during the SARC 28 stock assessment (NEFSC 1999). This approach involved using a combination of commercial sea sample data and research vessel survey data to estimate the total numbers discarded at length (Mayo *et al.* 1992). However, the results were not considered reliable because during nearly half the years sampled, fewer than 70 fish were captured in the U.S. research bottom trawl surveys, resulting in length frequency distributions which may not be representative of the population. In addition, the limited discard length frequency information available from sea sampling resulted in a poor determination of the discard selectivity ogive used in the analysis. Even if the number discarded at length could be reliably estimated, the number of age determinations for sublegal-sized winter flounder from the survey data is limited.

In summary, survey, vessel trip report, and sea sampling data were insufficient to produce reliable estimates of the magnitude or age composition of winter flounder discards occurring in the Georges Bank otter trawl or scallop dredge fisheries. However, both the sea sampling and vessel trip record approaches produced consistent information concerning the magnitude of discards occurring in the otter trawl and scallop dredge fisheries. Both approaches produced relatively low estimates of discards relative to landings (sea sampled trips: 0.2% to 1.6%; VTR trips: 0.5 to 3.0%) for the otter trawl fishery.

Although discarding of winter flounder in the sea scallop dredge fishery could not be estimated due to poor sea sampling coverage of this fishery, a SARC 28 analysis of the spatial overlap between exploitable scallop resources and winter flounder indicated little spatial overlap. As a result of the uncertainty in both the underlying data and the performance of the discard estimation approaches, no commercial discards were included in the catch-at-age analyzed in this assessment.

Sampling Intensity of Commercial Landings

There is no commercial sampling program for Canadian landings of Georges Bank winter flounder. Poor sampling intensity of U.S. landings prior to 1982 precluded extension of the landings at age time series prior to 1982 (Table B4). Since 1982, U.S. landings of Georges Bank winter flounder have been reported for 8 market categories (unclassified, lemon sole, small, large, extra-large, large/mixed, medium, and peewee). However, three categories (lemon sole, small, and large) comprised 85% of the landings during 1982-2000. Based on similarities in length frequency distributions across years, peewee and medium market categories were combined with the small market category, extra-large was combined with lemon sole, and large/mixed was combined with the large market category to estimate the catch-at-age during most years (Table B9). Since 1982 annual sampling intensity for the three combined market categories ranged from 10 to 902 mt of landings per sample. During 1982-1992 sampling intensity was lower for lemon sole than for the small and large market categories. Since 1993, sampling intensity of all market categories has been poor in the primary port of New Bedford. During 1998 and 1999 sampling of was inadequate to characterize the age composition of the landings for the catch-at-age. There were no lemon sole samples collected during either year and only one large sample was collected during the two years. The large and lemon sole market categories during these two years represented 44% and 48% of the total U.S. landings, respectively. In addition, sampling of the small market category during 1998 and 1999, which comprised 44% and 38% of the U.S. landings, respectively, consisted of three and four samples, respectively.

Landings at Age

Age composition of the 1982-2000 commercial landings from Georges Bank were estimated by applying commercial age-length keys to quarterly commercial numbers at length, aggregated by market category. During 1993-2000, landings at age data was pooled across quarters to varying degrees, due to insufficient length frequency sampling (Table B10). During 1998 and 1999 sampling was so poor that landings at age data had to be pooled across all quarters and market categories. In addition, the 1998 and 1999 landings at age matrix was supplemented with winter flounder length data from all otter trawl trips in the sea sampling database for those years. The length frequency distributions of the 1998 catch-at-age and the sea samples of winter flounder were similar. Mean weights at age were estimated by applying the length-weight equations to the quarterly length frequency samples by market category. Total numbers landed per quarter were estimated by applying the mean weights to the quarterly landings by market category and prorated according to sampled length frequencies. Numbers at age were summed over market category for each quarter and annual estimates of landings at age were obtained by summing values across quarters. Landings from both the unclassified market category for U.S. landings and total reported Canadian landings were assumed to have the same age composition as the sampled U.S. landings, and the estimated landings at age was adjusted to incorporate these landings. The unsampled portion of the landings generally accounted for less than 10% of the total landings at age.

Estimated total landings at age for 1982-2000, for age 1-10+ fish, are summarized in Table B11. Landings of age 2-4 fish dominate the landings, and two relatively large year classes appear to track well through the landings at age matrix. Landings of age 1 fish are insignificant except in 1995 when 264,000 age 1 fish were estimated. Examination of the U.S. commercial samples indicated that large numbers of age 1 fish were present in multiple samples occurring in the third and fourth quarters of 1995. In addition, relatively large numbers of the 1994 cohort were landed as age 2 fish in 1996 and age 3 fish in 1997. Estimated landed weight (mt) of Georges Bank winter flounder by age and year is also summarized in Table B11.

Mean Weights at Age

Mean length and weight at age from the analysis of total landings at age are summarized in Table B12. The effects of poorly-sampled landings are evident in the mean weight at age table as some of the smallest fish in the time series appear in all age groups during 1998, particularly in the age 4 and older fish. The poor sampling since 1993 is also evidenced by the decrease in mean weight of some cohorts as they age (e.g. 1993 cohort at age 4 in 1997 and age 5 in 1998; 1994 cohort at age 3 in 1997 and age 4 in 1998).

STOCK ABUNDANCE AND BIOMASS INDICES

U.S. Landings per Unit of Effort Indices

Landings per unit of effort (landed metric tons per day fished, LPUE) indices were computed by tonnage class using data from the dealer database, for 1964-1993, for all otter trawl trips landing winter flounder (Table B13)and for directed trips (trips with >= 50% winter flounder landings) (Table B14). LPUE indices for all trips increased during 1964-1980 and those for directed trips fluctuated without trend during this time period.(Figure B5). After 1980, LPUE indices for all trips and directed trips declined sharply, reaching their lowest levels in the time series in 1993.

The LPUE time series was not updated beyond 1993 because the methodology for collecting landings and fishing effort data changed to logbook reporting (VTR database).

U.S. Research Vessel Bottom Trawl Survey Indices

The Northeast Fisheries Science Center (NEFSC) of the U.S. National Marine Fisheries Service has conducted a depth-based, stratified random bottom trawl survey of continental shelf waters (maximum sampling depth of 366 m) from the Scotian Shelf to Cape Hatteras, during autumn, since 1963 (Azarovitz 1981, Despres *et al.* 1988, Azarovitz *et al.* 1997). A spring survey has been conducted during March-April since 1968. Catch data from these surveys were used to estimate changes in abundance (stratified mean number per tow) and biomass (stratified mean weight (kg) per tow) of winter flounder on Georges Bank. The strata set used to calculate these indices included NEFSC offshore strata 13-22 (Figure B6). Significant changes in the catchability of winter flounder, due to a trawl door change in 1985, necessitated adjusting pre-1985 indices with standardization coefficients of 1.46 for numbers per tow and 1.39 for weight per tow (NEFSC 1991). Fishing power experiments indicated no significant differences in the catchability of winter flounder between the two research vessels (*Delaware II* and *Albatross IV*) used during the survey time series (NEFSC 1991).

Winter flounder distribution during the U.S. spring and autumn surveys was evaluated in relation to the survey strata boundaries used to define the stock area. Numbers per standardized tow, for fish ≤ 40 cm and > 40 cm (mean length of age 4 fish), were plotted for 1982-2000. Figure B7 indicates that winter flounder exhibit a seasonal habitat preference. In comparison with the spring survey, larger numbers of fish from both size categories are distributed outside the Georges Bank survey strata boundaries, in stratum 23, during the autumn of some years and this phenomenon is more predominant in fish from the larger size category. During the spring surveys, fish from both size categories are distributed throughout survey strata 16, 19 and 20. Despite these migrations outside the stock area boundaries, the SARC concluded that winter flounder from stratum 23 should be excluded from the computations of U.S. survey indices. If included, the SARC was concerned that catches in stratum 23 may include fish from the Gulf of Maine and southern New England winter flounder stocks, which grow much more slowly than fish from the Georges Bank stock.

Standardized, stratified abundance and biomass indices for Georges Bank winter flounder from the U.S. spring and autumn research vessel bottom trawl surveys are shown in Table B15. Abundance and biomass indices exhibit a considerable amount of variability but generally exhibit intermediate levels of abundance from the early 1960s to early 1980s. Since the mid-19802 levels of abundance have declined (Figure B8). Both surveys indicate an increasing trend in abundance and biomass since the early 1990s, but abundance and biomass indices from the spring survey show a decline in 2001. Stratified mean numbers at age for the NEFSC spring and autumn surveys are shown in Tables B16 and B17, respectively. Although these indices are highly variable, larger cohorts appear to track through the numbers at age matrix for the 1985, 1987, and 1994 cohorts.

Canadian Research Vessel Bottom Trawl Survey

The Department of Fisheries and Oceans (DFO) of Canada, has conducted a stratified random bottom trawl survey on Georges Bank since 1987. The Canadian survey is conducted during February or early March and occupies stations in both U.S. and Canadian waters. In comparison to the U.S. surveys, station densities in the Canadian spring surveys are generally higher on the Canadian side of Georges Bank and along the southern flank (Figure B9).

Canadian survey indices of abundance and biomass were computed using strata set 5Z1-4 rather than the SARC 28 strata set of 5Z1-8 (Figure B10). The SARC determined that use of the 5Z1-4 strata set was more appropriate because these strata were sampled during all years included in the time series and because these strata lie entirely within the boundary of the stock area. It was noted that the use of this strata set would omit some winter flounder catches from the western portion of the stock area, but would ensure that winter flounder catches from the southern New England stock were not included in the survey indices. Relative abundance and biomass indices for strata 5Z1-4 were computed by staff from the DFO as stratified mean numbers and weights (kg) per tow, respectively, for 1987-2001 (B15, Figure B8).

Stratified mean numbers per tow at age from the Canadian spring survey are presented in Table B18. Winter flounder captured during the Canadian survey are counted and measured, but are not aged. U.S. spring survey and commercial age keys from quarter one were used to partition stratified mean numbers at length into stratified mean numbers at age. During most years, sufficient age determinations were available from U.S. spring survey data to partition stratified mean numbers at length from the Canadian survey into numbers at age. However, U.S. commercial age keys from the first quarter of the corresponding year were applied for fish larger than 48 cm during 2000 and greater than 39 cm during 2001. The application of commercial age keys will provide unbiased estimates of catch at age if both the U.S. commercial fleet and the Canadian survey are catching fish that grow at the same rate. This assumption appears to be valid because the principal winter flounder habitat is located on the U.S. side of Georges Bank and sampling in the Canadian survey occurs across the entire Bank.

The Canadian spring surveys indicate a pattern in year class strength that is different from the U.S. spring surveys (Figure B11). Stratified mean numbers per tow of age two fish from the U.S. spring survey indicate that the 1981, 1983, 1985, and 1994 year classes were above average. The SARC discussed the fact that the diameter of the cookies on the Canadian trawl are smaller than those used on the U.S. trawls. As a result, the Canadian trawl may not be able to sample winter flounder habitat in the center of the Bank (U.S. survey strata 19 and 20) where the bottom is uneven. All three surveys indicate poor year class strength since the 1994 year class.

MORTALITY AND MATURATION

Natural Mortality

Natural mortality was assumed to be constant and equal to 0.2 throughout the time series used in this assessment. This assumption would seem appropriate given the observation of maximum ages in the population that occasionally exceed 15 years and, when applying the 3/M “rule of thumb”, results in a similar estimate of natural mortality.

Total Mortality

Estimates of instantaneous total mortality (Z) and fishing mortality (F) were estimated from the NEFSC Spring and Autumn surveys

(1981-2000) and the Canadian Spring survey (1988-2000). Due to high interannual variability in the survey indices, pooled estimates of mortality rates were estimated based on three-year moving averages (Table B19). Total mortality (Z) was calculated as F + M, where M = 0.2 and:

F from spring surveys = ln(∑age 4+ for years i to j / ∑age 5+ for years i+1 to j+1)

F from autumn surveys = ln(∑age 3+ for years i-1 to j-1 / ∑age 4+ for years i to j)

The three surveys exhibited different trends in total mortality rates. The U.S. autumn survey indicated a decline in total mortality rates since 1992 and the U. S. spring survey indicated a decline since 1997. Total mortality rates derived from the Canadian spring survey indices declined during 1990-1997. Since 1997, total mortality rates estimated from the U.S. surveys have declined, but those estimated from the Canadian survey show an increase during 1998 and 1999, followed by a decline in 2000. A geometric mean of the two U.S. surveys indicates a decline in total mortality since the early 1990s (Figure B12).

Maturity

Maturation determinations for female winter flounder were collected on the NEFSC Spring survey from 1982-2001. The annual number of maturation determinations is limited, particularly in terms of those for age 2 and 3 fish which determine the character of the maturation relationship at age. A logistic regression approach (O'Brien *et al* 1993) was used to estimate the proportion of females mature at age for 1982-1998 (Table B20) and resulted in an estimation of age at 50% maturity of 1.83 years (Brown *et. al* 2000). The resulting maturity ogive (0.00 at age 1, 0.62 at age 2, 0.92 at age 3, 1.00 at age 4) was assumed constant during 1982-2000 and used in the VPA contained herein.

ESTIMATES OF STOCK SIZE AND FISHING MORTALITY

The SARC reviewed the results of a Virtual Population Analysis and a non-equilibrium surplus production model (ASPIC) that represented updates of the SARC 28 versions of these analyses (NEFSC 1999). The results from a second age-structured model that involved forward-projection of the catch-at-age data were also reviewed.

ASPIC Model

A non-equilibrium surplus production analysis was completed using ASPIC software (Prager 1993, 1994). The model was used to estimates stock biomass and fishing mortality rate trajectories during 1964-2000 and to re-estimate biological reference points. Initial biomass (*B1*), *MSY*, intrinsic rate of increase (*r*), and catchability (*q)* for each biomass index were estimated via nonlinear least squares of biomass index residuals.

Stock biomass indices available for model calibration included stratified mean weight per tow indices for the following research vessel bottom trawl surveys: the NEFSC autumn (1964-2000), NEFSC spring (1968-2001) and Canadian spring surveys (1987-2001). In all model runs, indices from both of the spring surveys were lagged back one year and used as an end-of-year index. (Table B21) An update of the final run accepted at SARC 28, which included all three survey indices, was conducted. However, Canadian survey strata 5Z1-4 were included rather than strata 5Z1-8 and this change resulted in a negative

R^2 value for the Canadian survey series. The same result also occurred when the SARC 28 model was re-run with biomass indices from Canadian survey strata 5Z1-4. As a result, the Canadian spring survey indices were omitted from the final run (Run 3) examined by the SARC, which included total landings during 1964-2000 and the NEFSC spring (1968-2001) and autumn (1964-2000) survey biomass indices.

The results from Run 3 of the surplus production analysis indicated a reasonable fit to the input data (Table B22). A maximum sustainable biomass (MSY) of 3,020 mt was estimated to be produced by a biomass (B_{msy}) of 9,355 mt. A time trajectory of results from the surplus production model indicates that yield has been below the estimated surplus production since 1994 (Figure B13). Relative estimates of mean biomass (B_t/B_{MSY}) declined sharply during 1977-1994, but increased since then to a level near B_{MSY} in 2000. Relative fishing mortality rates (F_t/F_{MSY}) showed the opposite pattern (Figure B14).

A retrospective analysis of Run 3 of the ASPIC model, for terminal years 1995-2000, indicated there was no retrospective pattern in the annual estimates of average biomass or fishing mortality rates (Figure B15). However, the retrospective analysis indicated that estimates of F_{MSY} and B_{MSY} were more variable than the annual estimates of fishing mortality and biomass as a result of the high variability in the estimates of *r* (Table B23).

Virtual Population Analysis

The ADAPT VPA calibration method (Parrick 1986, Gavaris 1988, Conser and Powers 1990) was used to estimate terminal stock abundance for ages 2-6 and to derive age-specific estimates of fishing mortality in 2000 and stock sizes at the beginning of 2001. The catch at age in the VPA consisted of combined U.S. and Canadian landings during 1982-2000 for ages 1-6 with a 7+ age group. Indices available to calibrate the VPA included stratified mean number per tow at age indices from the U.S. Spring research vessel survey (1968-2001, ages 1-7), the Canadian Spring research vessel survey (1987-2001, ages 1-7), and the U.S. Autumn research vessel survey (1982-2000, ages 0- 6) brought forward one age and one year.

A summary of the various model calibrations, including key diagnostics and terminal year results, is presented in Table B24. All four runs contained only sea sampling data in the 1999 catch-at-age. Runs 3 and 4 were conducted to determine the effects of the different calibration indices on the model results. It was concluded from the poor fit of Runs 3 and 4 that all three surveys were important in tuning the model. The SARC determined that Run 2, which included estimates for ages 2-6 and the U.S. Spring survey indices (ages 1-7), the Canadian Spring survey indices (ages 4-7), and the U.S. Autumn survey indices (ages 3-6, brought forward one age and one year), represented the run with the best fit. This calibration was successful in reducing the coefficients of variation (CVs) on the older ages (4-6), but the diagnostics of all the runs were relatively poor (Table B24).

The VPA results indicated that stock numbers declined during 1982-1993, from approximately 26 million fish to 8 million fish. Stock size doubled between 1993 and 1999, then declined to13 million fish in 2000 (Table B25).

After 1993, the pattern of fishing mortality at age became erratic. In 1998 and 1999, the effects of poor characterization of the catch at age during these years is indicated by high fishing mortality rates on the younger age groups rather than the older ones (Table B25).

Mean biomass of age 1+ fish declined during 1982-1994, but has increased steadily since then. Spawning stock biomass declined from levels exceeding 8,000 mt in the early 1980's to less than 2,000 mt in 1994 and 1995, but since then has increased to almost 6,000 mt in 2000 (Table B26). In the early 1980s, spawning stock biomass consisted of a wide range of ages and the youngest mature ages (2 and 3) comprised less than 40% of the total spawning stock biomass. The age structure of the spawning stock biomass became truncated in the mid 1980s to mid 1990s, when age 2 and 3 fish comprised 45-75% of the spawning stock biomass.

A retrospective analysis of VPA Run 2 was performed, from 2000 to 1993, by sequentially re-analyzing the ADAPT calibration after removing the terminal year of input data. Retrospective patterns for fishing mortality rates indicate a pattern of underestimation during the terminal year that increases in severity back to 1997 (Figure B17a). There was no evidence of retrospective patterns in terminal year spawning stock biomass or age 2 recruitment (Figures B17b and B17c).

Based on relatively poor fit of the VPA (high CVs on stock size at age), inconsistent patterns in mean weights at age and fishing mortality rates at age, and a retrospective pattern in fishing mortality in recent years, the SARC did not adopt the VPA results as a basis for evaluating current stock status.

In general, trends in average stock biomass and biomass-based fishing mortality rates were similar between the VPA and ASPIC models during 1982-2000 (Figure B17). The results from both models indicate a steady increase in biomass during 1994-2000 and a substantial decrease in fishing mortality since 1993.

Forward Projection of Catch at Age

A second age-structured population dynamics model, based on forward projection of population numbers at age, was conducted as an exploratory analysis (Fournier and Archibald 1982, Methot 1990, Ianelli and Fournier 1998, Quinn and Deriso 1999). The underlying methodology, including the population dynamics model, statistical estimation approach, model diagnostics are presented in the redfish section of the SARC 33 Consensus Summary Report (NEFSC 2001).

The SARC suggested that this model may provide insight into the dynamics of the stock in future assessments, but that further sensitivity testing of the model under different assumptions and configurations is warranted.

BIOLOGICAL REFERENCE POINTS

Current

The current control rule defines MSY-based fishing targets and thresholds, incorporating the results of an ASPIC surplus production model (Applegate *et al.* 1998), and was adopted by the New England Fishery Management Council (NEFMC) in

Amendment 9 to the Northeast Multispecies Fishery Management Plan. As a result of the imprecision of absolute estimates of biomass and fishing mortality from the ASPIC model, biological reference points are defined in terms of survey-based equivalents. The ASPIC model estimate of B_{MSY} is multiplied by the autumn survey *q* estimated from the ASPIC model to convert to a survey-based equivalent. The current target biomass level is defined as a B_{MSY} proxy that equals 2.73 kg/tow. The current threshold biomass proxy is defined as 50% of the target B_{MSY} proxy and equals 1.37 kg/tow. Target and threshold fishing mortality proxies are defined as exploitation indices calculated as catch/autumn survey biomass index. The current threshold fishing mortality rate is defined as an F_{MSY} proxy that equals 1.13 and is calculated as the ASPIC estimates of MSY/B_{MSY}. The current target fishing mortality rate is defined as 75% of the threshold fishing mortality proxy and equals 0.84. Stock status is defined as an exploitation index and is calculated as a three-year, moving average of the autumn survey biomass indices divided by a three-year, moving average of the catches.

Proposed

Biological reference points were re-estimated based on the results of an updated ASPIC model (Run 3), biomass indices from the NEFSC autumn bottom trawl survey, and commercial fishery landings (Table B27). The target biomass index was calculated as the product of the ASPIC model estimate of B_{msy} (9.355 thousand mt) and the estimate of the NEFSC autumn bottom trawl survey biomass index catchability coefficient (q = 0.2658), providing an index of B_{msy} of 2.49 (= 9.355 * 0.2658). The threshold biomass index of 1.24 was calculated as 50% of the target biomass index.

The threshold fishing mortality index of 1.21 was calculated as the quotient of the ASPIC model estimate of MSY (3.020 thousand mt) and the index of B_{msy} (2.49), or (3.020/2.49). The target fishing mortality index of 0.91 was calculated as 75% of the threshold fishing mortality index.

Average relative exploitation indices (3-year average catch/3-year average autumn survey biomass index) were above the revised $F_{threshold}$ during 1981-1995 but have since declined to 71% of the of the F_{target} (Figure B18, Table B28). During 1998-2000, the three-year average relative exploitation index was 0.65. Relative to the proposed harvest control rule, the stock is not overfished and overfishing is not occurring ($B_{1998\text{-}2000\ proxy}$ = 2.29, $F_{1998\text{-}2000\ proxy}$ = 0.65) (Figure B19).

PROJECTIONS

Projections of stock size were not performed based on the ASPIC model results because of the inability to explicitly model recruitment.

CONCLUSIONS

The Georges Bank winter flounder stock was not overfished and overfishing was not occurring in 2000. Stock biomass in 2000 was 92% of the re-estimated B_{MSY} target and fishing mortality in 2000 was 71% of the re-estimated fishing mortality rate target. Fishing mortality rates were very high during 1984-1993, but have been declining since 1994. Stock biomass has been increasing steadily since 1994. US and Canadian research surveys indicate recruitment has been below average since 1994. Research survey indices indicate the age structure became truncated in the early 1990s but is beginning to broaden.

SARC COMMENTS

The SARC recommended investigating possible day/night catch differences for winter flounder in the survey which might explain some of the variation in the survey index. The SARC noted that the large market categories were not adequately sampled in recent years (1998-1999). Over 40% of the landings occur in the large market categories. If length distributions are relatively stable within market category, using market category length information from adjacent years may be a better way for pooling instead of combining market categories on an annual basis. This could be investigated. The SARC commented that not incorporating discard estimates in the VPA may produce a biased estimate of removals.

Discussion occurred on why the VPA was rejected, i.e., unstable mean weights at age, retrospective pattern in fishing mortality, failure to track cohorts in the catch at age matrix, low catchability in the surveys. Why the VPA uses all three survey indices while the accepted ASPIC run 3 used only the US indices was also discussed. It was noted that the Canadian survey uses a flatfish net which prevents the survey from sampling the hard bottom habitat in the center of Georges Bank where smaller winter flounder (ages 1-3) are concentrated. The Canadian survey is comprised of mostly larger winter flounder sampled on the eastern part of Georges Bank. Therefore, the Canadian and US surveys may be measuring different components of the population.

The SARC noted that all three models (VPA, ASPIC, and the forward projecting age-structure model, WIN) produced similar trends. However the SARC could not explain why the forward projecting age-structure model results were scaled about two times higher in terms of biomass.

The SARC discussed the utility of the forward projecting age-structure model. The SARC felt the model provides valuable insight to the dynamics of the stock. However concern was expressed with the sensitivity of the model to different assumptions and model configuration. The SARC recommended that more work on the sensitivity of the model to assumptions and model configuration be performed. The choice of error structure (lognormal) used to model F deviations was discussed. Sensitivity of the model is to the initial population size was also questioned. Some SARC members felt that the stock was not at virgin biomass levels in the early 1960s. The SARC recommended investigating the existence of landings data prior to 1964 which should be incorporated in the model. An investigation on why the model was so sensitive to small deviations in natural mortality was also suggested. The SARC discussed the model's estimation of fishery and survey selectivity patterns. Differences in estimated selectivity between the fall and spring survey may be an artifact of the fall survey being a longer time series and the accumulation of older fish in the catch at age matrix at the beginning of the time series.

Further examination of the sensitivity of the model to selectivity should be examined.

The SARC considered the estimation of reference points. It was suggested that estimation of reference points should be decoupled from the analysis of stock status to avoid changes in reference point targets each time the stock is assessed. The SARC recommended that an analysis of the performance of control rules be done.

The SARC reviewed a retrospective analysis on the ASPIC model and noted that estimates of B_{msy} and F_{msy} were more variable than estimates of F and biomass. The SARC accepted ASPIC run 3 which uses the Spring and Fall US surveys. The survey based reference point proxies were updated using the q's from ASPIC run 3 and the status of the stock was determined using survey-based indices of current biomass and F. The SARC recommended that absolute estimates from ASPIC be used directly (without translations to survey proxies) in the future to estimate biological reference points and evaluation of stock status. The SARC concluded that no projections should be run at this time since the VPA was not accepted and ASPIC model projections were thought to be unreliable due to poor recruitment in recent years.

SOURCES OF UNCERTAINTY

1. Sampling of U.S. commercial landings in the primary port of New Bedford was insufficient during 1998 and 1999, such that the age composition of the catch could not be accurately characterized and a reliable Virtual Population Analysis could not be conducted. Inadequate sampling of winter flounder in the Canadian landings was also a source of uncertainty in the catch at age.

2. There is some uncertainty about the Canadian landings because of the non-targeted nature of the Canadian fishery and the tendency to report landings of some flatfish species including winter flounder as unclassified flounders.

3. The Canadian fishery has no formal sampling program to estimate the size and age composition of Canadian landings. This assessment assumed that the size and age composition of Canadian landings was identical to the overall size and age composition in the U.S. fishery. However, selectivity patterns in the two fisheries may be different.

4. Canadian spring survey indices do not include winter flounder catches from the eastern half of strata 5Z6 and 5Z7. The western boundary of the Georges Bank winter flounder stock area bisects both strata. In addition, US survey indices do not include winter flounder catches from stratum 23 which is comprised of catches from both the Georges Bank and the Southern New England stock.
5. The lack of discard estimates, due to insufficient sampling, results in uncertainty of total fishery removals from the stock.

6. Abundance and biomass indices in the US bottom trawl surveys exhibit a considerable amount of variability. The overall low catchability of winter flounder in the U.S. surveys on Georges Bank is a source of concern.

RESEARCH RECOMMENDATIONS

1. Increase the sampling of commercial landings (number of samples by market category and quarter) especially at the primary port of New Bedford.

2. Improve sampling of discards of winter flounder in the otter trawl and scallop dredge fisheries.

3. Examine the distribution of winter flounder resources in Stratum 23 in the US survey and the prospects for splitting this stratum across the stock area boundary. Differences in growth rates between the two stocks is evident from aging which can be used to determine the location of the boundary. The intensity of age sampling for winter flounder from stratum 23 should be increased to carry out this task. This boundary determinations should be coordinated for all species where the stock boundary is split across the area 521/526 - 522/525 boundary, particularly yellowtail flounder. Similar work should be conducted in strata which cover more than one stock in the Canadian survey.

4. Using the VTR database, derive a second LPUE time series for directed trips and all trips.

5. Work on the forward projecting age-structure model should be continued. The sensitivity of the model to different assumptions and model configurations should be examined further. For instance, sensitivity of the model to small deviations in natural mortality, initial population size, and differences in the estimated selectivity patterns between the surveys should be investigated. If available, landings data prior to 1964 should be incorporated in the model.

6. Measures should be taken to improve the representativeness of the U.S. survey indices for this stock and other Georges Bank flatfish stocks, either by changing the existing spring and autumn survey sampling design in key Georges Bank strata (e.g. a north-to-south split of stratum 23 and assigning random stations within each of the two substrata) or designing a standardized survey on Georges Bank that utilizes chartered commercial vessels. The logistics of extending the winter bottom trawl survey to cover all Georges Bank strata should also be examined.

REFERENCES

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 of the Overfishing Definition Review Panel. June 17, 1998, 179 p.

Azarovitz, T.R. 1981. A brief historical review of the Woods Hole Laboratory trawl survey time series. *In:* W.G. Doubleday and D. Rivard (Eds.). Bottom Trawl Surveys. *Can. Spec. Publ. Fish. Aquat. Sci.* 58:62-67.

Azarovitz, T.R., S. Clark, L. Despres, and C. Byrne. 1997. The Northeast Fisheries Science Center Bottom Trawl Survey Program. *ICES C.M.* 1997/Y:33.

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. *U.S. Fish and Wildlife Service Fishery Bulletin* 74(V.53):577 p.

Brown, R.W., J. M. Burnett, G. A. Begg, and S. X. Cadrin. 2000. Assessment of the Georges Bank winter flounder stock, 1982-1997. *Northeast Fish. Sci. Cent. Ref. Doc.* 00-16.

Clark, S.H. 1976. Compendium of haddock regulations affecting ICNAF Subareas 4 and 5, 1972-1976. *Northeast Fish. Sci. Cent. Ref. Doc.* 76-02.

Coates, P.G., A.B. Howe, and A.E. Peterson, Jr. 1970. Analysis of winter flounder tagging off Massachusetts, 1960-1965. Commonwealth of Massachusetts, Division of Marine Fisheries Final Report, U.S. Bureau of Commercial Fisheries Research and Development Act (P.L. 88-309) Project 3-38-R, 47 p.

Conser, R. J. and J. E. Powers. 1990. Extensions of the ADAPT VPA tuning method designed to facilitate assessment work on tuna and swordfish stocks. *International Commission for the Conservation of Atlantic Tunas, Coll. Vol. Sci. Pap.* 32:461-467.

Dickie, L.M. and F.D. McCracken. 1955. Isopleth diagrams to predict yields of a small flounder fishery. *J. Fish. Res. Board of Canada* 12:187-209.

Despres, L.I., T.R. Azarovitz, and C.J. Byrne. 1988. Twenty-five years of fish surveys in the northwest Atlantic: the NMFS Northeast Fisheries Center's bottom trawl survey program. *Mar. Fish. Rev.* 50(4):69-71.

Fournier, D. A. and C. P. Archibald. 1982. A general theory for analyzing catch at age data. *Can. J. Fish. Aquat. Sci.* 39:1195-1207.

Gabriel, W.L. and K.L. Foster. 1986. Preliminary assessment of winter flounder (*Pseudopleuronectes americanus* Walbaum) on Georges Bank. *Woods Hole Lab. Ref. Doc.* 86-16:31 pp.

Gabriel, W.L., M.P. Sissenwine, and W.J. Overholtz. 1989. Analysis of spawning stock biomass per recruit: an example for Georges Bank haddock. *N. Am. J. Fish. Man.* 9:383-391.

Gavaris, S. 1988. An adaptive framework for the estimation of population size. CAFSAC Res. Doc. 88/29: 12 pp.

Granger, C.W. and P. Newbold. 1977. *Forecasting Economic Time Series.* New York: Academic Press.

Grosslein, M.D. and T.R. Azarovitz. 1982. Fish distribution. MESA New York Bight Atlas Monograph 15. New York Sea Grant Institute. Albany, New York. 182 pp.

Howe, A.B. and P.G. Coates. 1975. Winter flounder movements, growth, and mortality off Massachusetts. *Trans. Am. Fish. Soc.* 104(1):13-29.

Ianelli, J. N. and D. A Fournier. 1998. Alternative age-structured analyses of NRC simulated stock assessment data. NOAA Tech. Memo. NMFS-F/SPO-30. p. 81-96.

Kendall, W.C. 1912. Notes on a new species of flatfish from off the coast of New England. *Bulletin of the United States Bureau of Commercial Fisheries* 30:391-394.

Klein-MacPhee, G. 1978. Synopsis of biological data for the winter flounder *Pseudopleuronectes americanus* (Walbaum). DOC/NOAA/NMFS Technical Report, NMFS Circular 414:43 pp.

Lange, A.M.T. and F.E. Lux. 1978. Review of other flounder stocks (winter flounder, American plaice, witch flounder, and windowpane flounder) off the northeast United States, August 1978. NEFSC Lab. Ref. Doc. 78-44, 19 pp.

Langton, R. and R. Bowman. 1981. Food of eight northwest Atlantic pleuronectiform fishes. NOAA Technical Report NMFS SSRF-749: 16 pp.

Lux, F.E. 1973. Age and growth of the winter flounder, *Pseudopleuronectes americanus*, on Georges Bank. *Fish. Bull.* 71(2):505-512..

Lux, F.E., A.E. Peterson, Jr., and R.F. Hutton. 1970. Geographical variation in fin ray number in winter flounder, *Pseudopleuronectes americanus* (Walbaum) off Massachusetts. *Trans. Am. Fish. Society* 99:483-488.

Mayo, R.K., L. O'Brien, and N. Buxton. 1992. Discard estimates of American Plaice, *Hippoglossoides platessoides*, in the Gulf of Maine northern shrimp fishery and the Gulf of Main-Georges Bank large-mesh otter trawl fishery. Appendix to *Northeast Fish. Sci. Cent. Ref. Doc*. 92-07, NEFSC SAW Res. Doc. 14/3.

Mayo, R.K., T.E. Helser, L. O'Brien, K.A. Sosebee, B.F. Figuerido, and D. Hayes. 1994. Estimation of standardized otter trawl effort, landings per unit effort, and landings at age for Gulf of Maine and Georges Bank cod. *Northeast Fish. Sci. Cent. Ref. Doc.*94-12.

Methot, R. D. 1990. Synthesis model: an adaptive framework for analysis of diverse stock assessment data. *Int. Pac. Fish. Comm. Bull.* 50:259-277.

Northeast Fisheries Science Center. 2001. Draft report of the 33rd Northeast Regional Stock Assessment Workshop (33rd SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. *Northeast Fish. Sci. Cent. Ref. Doc.* 01-18; 272 pp.

Northeast Fisheries Science Center. 1999. Report of the 28th Northeast Regional Stock Assessment Workshop (28th SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. *Northeast Fish. Sci. Cent. Ref. Doc.* 99-08; 304 pp.

Northeast Fisheries Science Center. 1997. Report of the 24rth Northeast Regional Stock Assessment Workshop (24rth SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. *Northeast Fish. Sci. Cent. Ref. Doc.* 97-12, 291 pp.

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 Technical Report NMFS* 113:66 pp.

Parrack, M.F. 1986. A method of analyzing catch and abundance indices from a fishery. International Commission for the Conservation of Atlantic Tunas, Coll. Vol. Sci. Pap. 24:209-221.

Pereira, Jose J., R. Goldberg, J. J. Ziskowski, P. L. Berrien, W. W. Morse and D. L. Johnson. 1999. Essential fish habitat source document: winter flounder, *Pseudopleuronectes americanus*, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-138, 39 pp.

Perlmutter, A. 1947. The blackback flounder and its fishery in New England and New York. Bulletin of the Bingham Oceanographic Collection, Yale University 11(2):92 pp.

Pierce, D.E. and A.B. Howe. 1977. A further study on winter flounder group identification off Massachusetts. *Trans. Am. Fish. Soc.* 106(2):131-139.

Prager, M.H. 1993. A nonequilibrium production model of swordfish: data reanalysis and possible further directions. ICCAT Collection Vol. Scientific Papers 40(1):433-437.

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

Quinn. T. P. II and R. B. Deriso. 1999. *Quantitative fish dynamics.* Oxford University Press. New York, 542 p.

Schnute, J. T. and L. J. Richards. 1995. The influence of error on population estimates from catch-age models. *Can. J. Fish. Aquat. Sci.* 52:2063-2077.

Thompson, W. F. and F. H. Bell. 1934. Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield and yield per unit of gear. Report of the International Pacific Halibut Commission 8: 49 pp.

Thompson, G. G. 1994. Confounding of gear selectivity and the natural mortality rate in cases where the former is a non-monotone function of age. *Can. J. Fish. Aquat. Sci.* 51:2654-2664.

Table B1. Landings (mt) of Georges Bank winter flounder, by statistical area and country, during 1964-2000.

	522-525 561-562	5Ze[2] (521-526 and 541-562)		5Z (521-562)		
YEAR	USA[1]	CANADA	USSR	CANADA	USSR	TOTAL
1964	1,371			146		1,517
1965	1,176			199	312	1,687
1966	1,877			164	156	2,197
1967	1,917			83	349	2,349
1968	1,570	57	372			1,999
1969	2,167	116	235			2,518
1970	2,615	61	40			2,716
1971	3,092	62	1,029			4,183
1972	2,805	8	1,699			4,512
1973	2,269	14	693			2,976
1974	2,124	12	82			2,218
1975	2,409	13	515			2,937
1976	1,877	15	1			1,893
1977	3,572	15	7			3,594
1978	3,185	65				3,250
1979	3,045	19				3,064
1980	3,931	44				3,975
1981	3,993	19				4,012
1982	2,961	19				2,980
1983	3,894	14				3,908
1984	3,927	4				3,931
1985	2,151	12				2,163
1986	1,762	25				1,787
1987	2,637	32				2,669
1988	2,804	55				2,859
1989	1,880	11				1,891
1990	1,898	55				1,953
1991	1,814	14				1,828
1992	1,822	27				1,849
1993	1,662	21				1,683
1994	907	65				972
1995	706	54				760
1996	1,265	71				1,336
1997	1,287	143				1,430
1998	1,243	93				1,336
1999	938	104				1,042
2000	1,677	161				1,838

---

[1] USA landings prior to 1985 include those from Statistical Areas 551 and 552 and landings during 1994-2000 were prorated from Vessel Trip Reports based on gear, month and state.

[2] Includes landings from statistical areas 521 and 526; outside of the Georges Bank winter flounder stock area.

Table B2. U.S. landings (mt) and percentage of landings of Georges Bank winter flounder (statistical areas 522-525, 551-552, 561-562), by gear type, during 1964-2000. General canvas landings are not included.

	Landings by Gear Type (mt)				Percentage of Landings		
	Trawl	Scallop Dredge	Other	Total	Trawl	Scallop Dredge	Other
1964	**1,360.2**	**--**	**11.2**	**1,371**	**99.2**	**--**	**0.8**
1965	**1,175.1**	**--**	**0.8**	**1,176**	**99.9**	**--**	**0.1**
1966	**1,851.3**	**--**	**25.8**	**1,877**	**98.6**	**--**	**1.4**
1967	**1,915.5**	**--**	**1.8**	**1,917**	**99.9**	**--**	**0.1**
1968	**1,565.3**	**--**	**4.6**	**1,570**	**99.7**	**--**	**0.3**
1969	**2,165.0**	**--**	**1.8**	**2,167**	**99.9**	**--**	**0.1**
1970	**2,610.6**	**--**	**4.4**	**2,615**	**99.8**	**--**	**0.2**
1971	**3,086.9**	**--**	**4..8**	**3,092**	**99.8**	**--**	**0.2**
1972	**2,796.6**	**--**	**7.9**	**2,805**	**99.7**	**--**	**0.3**
1973	**2,265.2**	**--**	**3.5**	**2,269**	**99.8**	**--**	**0.2**
1974	**2,116.5**	**--**	**7.7**	**2,124**	**99.6**	**--**	**0.4**
1975	**2,386.6**	**--**	**22.6**	**2,409**	**99.1**	**--**	**0.9**
1976	**1,874.7**	**--**	**2.6**	**1,877**	**99.9**	**--**	**0.1**
1977	**3,570.4**	**--**	**1.6**	**3,572**	**100.0**	**--**	**<0.1**
1978	**3,166.5**	**17.9**	**1.1**	**3,186**	**99.4**	**0.6**	**<0.1**
1979	**3,019.8**	**24.9**	**0.0**	**3,045**	**99.2**	**0.8**	**<0.1**
1980	**3,887.9**	**42.5**	**0.3**	**3,931**	**98.9**	**1.1**	**<0.1**
1981	**3,935.3**	**53.5**	**3.7**	**3,993**	**98.6**	**1.3**	**0.1**
1982	**2,919.5**	**41.2**	**0.1**	**2,961**	**98.6**	**1.4**	**<0.1**
1983	**3,864.0**	**25.4**	**7.2**	**3,897**	**99.2**	**0.7**	**0.2**
1984	**3,899.9**	**18.5**	**11.1**	**3,930**	**99.2**	**0.5**	**0.3**
1985	**2,146.3**	**3.1**	**3.2**	**2,153**	**99.7**	**0.1**	**0.1**
1986	**1,724.3**	**36.0**	**2.3**	**1,763**	**97.8**	**2.0**	**0.1**
1987	**2,560.6**	**77.6**	**0.0**	**2,639**	**97.0**	**2.9**	**<0.1**
1988	**2,699.5**	**106.5**	**0.0**	**2,806**	**96.2**	**3.8**	**<0.1**
1989	**1,761.7**	**119.7**	**0.1**	**1,881**	**93.6**	**6.4**	**<0.1**
1990	**1,779.6**	**118.2**	**1.6**	**1,899**	**93.7**	**6.2**	**0.1**
1991	**1,673.7**	**141.2**	**1.8**	**1,816**	**92.2**	**7.8**	**<0.1**
1992	**1,677.8**	**136.4**	**8.7**	**1,823**	**92.0**	**7.5**	**0.5**
1993	**1,535.2**	**115.5**	**12.4**	**1,663**	**92.3**	**6.9**	**0.7**
1994	**909.4**	**52.9**	**9.4**	**972**	**93.6**	**5.4**	**1.0**
1995	**713.1**	**37.0**	**10.0**	**760**	**93.8**	**4.9**	**1.3**
1996	**1,243.8**	**71.2**	**20.6**	**1,336**	**93.1**	**5.3**	**1.5**
1997	**1,337.9**	**80.0**	**11.9**	**1,430**	**93.6**	**5.6**	**0.8**
1998	**1,241.7**	**0.7**	**0.6**	**1,243**	**99.9**	**<0.1**	**<0.1**
1999	**924.8**	**9.3**	**3.7**	**938**	**98.6**	**1.0**	**0.4**
2000	**1,658.5**	**18.4**	**0.0**	**1,677**	**98.9**	**1.1**	**0.0**

Table B3. USA landings (mt) of Georges Bank winter flounder, during 1964-1993, by tonnage class (TC2 = 5-50 GRT, TC3 = 51-150 GRT, TC4 = 151-500 GRT) for otter trawl and scallop dredge landings.[1]

	Landings (mt)							Percentage of Total Landings						
	Otter Trawl Tonnage Class			Scallop Dredge Tonnage Class			All Others	Otter Trawl Tonnage Class			Scallop Dredge Tonnage Class			All Others
												-		
Year	2	3	4	2	3	4		2	3	4	2	3	4	
1964	74.0	927.8	358.4	0.0	0.0	0.0	11.2	5.4	67.7	26.1	0.0	0.0	0.0	0.8
1965	81.4	694.3	399.4	0.0	0.0	0.0	0.9	6.9	59.0	34.0	0.0	0.0	0.0	0.1
1966	54.2	1188.	630.0	0.0	0.0	0.0	4.2	2.9	63.3	33.6	0.0	0.0	0.0	0.2
1967	46.4	1074.	794.9	0.0	0.0	0.0	1.8	2.4	56.0	41.5	0.0	0.0	0.0	0.1
1968	34.4	1039.	491.4	0.0	0.0	0.0	4.6	2.2	66.2	31.3	0.0	0.0	0.0	0.3
1969	6.6	1542.	616.2	0.0	0.0	0.0	1.8	0.3	71.2	28.4	0.0	0.0	0.0	0.1
1970	16.2	2003.	590.6	0.0	0.0	0.0	4.4	0.6	76.6	22.6	0.0	0.0	0.0	0.2
1971	66.8	2282.	737.6	0.0	0.0	0.0	4.8	2.2	73.8	23.9	0.0	0.0	0.0	0.2
1972	36.4	2233.	527.1	0.0	0.0	0.0	7.9	1.3	79.6	18.8	0.0	0.0	0.0	0.3
1973	22.0	1726.	516.7	0.0	0.0	0.0	3.5	1.0	76.1	22.8	0.0	0.0	0.0	0.2
1974	15.8	1532.	568.4	0.0	0.0	0.0	7.7	0.7	72.1	26.8	0.0	0.0	0.0	0.4
1975	9.5	1855.	544.6	0.0	0.0	0.0	0.0	0.4	77.0	22.6	0.0	0.0	0.0	0.0
1976	2.2	1487.	386.1	0.0	0.0	0.0	1.6	0.1	79.2	20.6	0.0	0.0	0.0	0.1
1977	33.2	2901.	636.4	0.0	0.0	0.0	1.1	0.9	81.2	17.8	0.0	0.0	0.0	<0.1
1978	10.5	2541.	615.7	0.0	7.6	10.3	0.2	0.3	79.8	19.3	0.0	0.2	0.3	<0.1
1979	34.7	2436.	548.8	0.0	18.1	6.8	0.2	1.1	80.0	18.0	0.0	0.6	0.2	<0.1
1980	70.3	3112.	705.3	2.9	19.6	20.1	0.4	1.8	79.2	17.9	<0.1	0.5	0.5	<0.1
1981	26.3	3087.	822.5	0.0	19.0	34.5	2.5	0.7	77.3	20.6	0.0	0.5	0.9	0.1
1982	29.2	2194.	693.4	0.0	26.9	14.2	2.5	1.0	74.1	23.4	0.0	0.9	0.5	0.1
1983	10.7	2641.	1218.	0.0	4.7	20.7	0.8	0.3	67.8	31.3	0.0	0.1	0.5	<0.1
1984	10.3	2551.	1349.	0.0	8.2	10.2	0.4	0.3	64.9	34.3	0.0	0.2	0.3	<0.1
1985	4.1	1316.	829.0	0.0	1.8	1.4	0.0	0.2	61.2	38.5	0.0	0.1	0.1	0.0
1986	0.0	1222.	504.2	0.1	6.6	29.3	0.0	0.0	69.4	28.6	<0.1	0.4	1.7	0.0
1987	0.4	1899.	660.7	0.0	14.5	63.5	0.0	<0.	72.0	25.0	0.0	0.5	2.4	<0.1
1988	2.6	1917.	778.9	0.1	29.2	77.2	0.0	0.1	68.4	27.8	<0.1	1.0	2.8	<0.1
1989	0.0	1250.	511.2	0.1	24.4	95.3	0.1	0.0	66.5	27.2	<0.1	1.3	5.1	<0.1
1990	0.3	1256.	524.1	0.0	27.6	90.6	0.1	<0.	66.2	27.6	<0.1	1.5	4.8	<0.1
1991	4.5	1225.	444.8	0.7	22.7	117.9	0.0	0.2	67.5	24.5	<0.1	1.2	6.5	<0.1
1992	0.6	1221.	464.7	0.1	29.8	106.5	0.0	<0.	67.0	25.5	<0.1	1.6	5.8	<0.1
1993	0.0	1145.	402.1	0.0	26.7	88.8	0.0	<0.	68.9	24.2	0.0	1.6	5.3	0.0

[1] Vessel tonnage class was not used to prorate the landings during 1994-2000.

Table B4. U.S. landings (mt) of Georges Bank winter flounder, by market category, during 1980 -2000.

	Landings (mt) by Market Category								Landings (%) by Market Category							
	1200 Unclassified	1201 Lemon Sole	1204 Extra Large	1202 Large	1205 Large/ Mixed	1203 Small	1206 Medium	1207 Peewee	1200 Unclassified	1201 Lemon Sole	1204 Extra Large	1202 Large	1205 Large/ Mixed	1203 Small	1206 Medium	1207 Peewee
1980	101	824	0	745	0	2,257	0	0	2.6	21.0	0.0	19.0	0.0	57.4	0.0	0.0
1981	31	902	0	748	0	2,310	0	0	0.8	22.6	0.0	18.7	0.0	57.9	0.0	0.0
1982	137	517	33	549	10	1,666	47	1	4.6	17.5	1.1	18.5	0.3	56.3	1.6	<0.1
1983	68	1,506	160	361	25	1,758	14	1	1.7	38.6	4.1	9.3	0.6	45.1	0.4	<0.1
1984	154	370	6	2,029	4	1,231	28	108	3.9	9.4	0.2	51.6	0.1	31.3	0.7	2.7
1985	76	573	110	264	46	1,076	2	3	3.5	26.6	5.1	12.3	2.1	50.0	0.1	0.1
1986	183	176	2	741	0	540	45	76	10.4	10.0	0.1	42.0	0.0	30.6	2.6	4.3
1987	118	241	2	1,027	0	974	38	238	4.5	9.1	0.1	38.6	0.0	36.9	1.4	9.0
1988	149	164	1	995	<1	1,269	34	194	5.3	5.8	<0.1	35.5	<0.1	45.2	1.2	6.9
1989	127	110	<1	717	<1	751	37	138	6.8	5.8	<0.1	38.1	<0.1	39.9	2.0	7.3
1990	112	71	<1	629	0	882	57	149	5.9	3.7	<0.1	33.1	0	46.4	3.0	7.8
1991	152	54	<1	680	0	792	46	92	8.4	3.0	<0.1	37.5	0	43.6	2.5	5.1
1992	151	64	<1	673	<1	767	26	140	8.3	3.5	<0.1	36.9	<0.1	42.1	1.4	7.7
1993	119	89	<1	634	<1	712	22	86	7.2	5.4	<0.1	38.1	0.1	42.8	1.3	5.2
1994	33	60	***	380	***	433	2	***	3.6	6.6	***	41.9	***	47.7	0.2	***
1995	70	40	***	245	***	351	<1	***	9.9	5.7	***	34.7	***	49.7	<0.1	***
1996	191	67	***	414	***	577	15	***	15.1	5.3	***	32.8	***	45.6	1.2	***
1997	424	45	0	453	1	215	91	58	32.9	3.5	0.0	35.2	<0.1	16.7	7.1	4.5
1998	18	54	1	490	0	543	120	16	1.4	4.3	0.1	39.5	0	43.7	9.7	1.3
1999	36	49	0	404	0	356	71	22	3.8	5.2	0.0	43.1	0.0	38.0	7.6	2.3
2000	36	111	2	684	0	678	143	24	2.1	6.6	0.1	40.8	0.0	40.4	8.5	1.4

*** Prorated into other market categories.

Table B5. Estimates of kept weight (mt), discarded weight (mt) and discard ratios (discards/kept) for Georges Bank winter flounder collected by the NEFSC Sea Sampling Program observers. Estimates of total discards (mt) are based on the product of discard ratios and reported landings (mt) by quarter and gear type (trawl, scallop dredge).

	Trawl					Dredge				
	Qtr1	Qtr2	Qtr3	Qtr4	Total	Qtr1	Qtr2	Qtr3	Qtr4	Total
1989										
Trips	2	5	6	2	15	0	0	0	0	0
Total kept (mt)	1.333	2.663	2.391	2.381	8.769	0.000	0.000	0.000	0.000	0.000
Total discard (mt)	0.005	0.053	0.041	0.000	0.099	0.000	0.000	0.000	0.000	0.000
Ratio discard/kept	0.004	0.020	0.017	0.000	0.011	0.000	0.000	0.000	0.000	0.000
Total landings (mt)	486.750	567.164	374.791	331.684	1760.389	13.191	15.824	39.213	51.428	119.656
Total discards (mt)	1.822	11.206	6.399	0.063	19.491	0.000	0.000	0.000	0.000	0.000
1990										
Trips	3	2	2	2	9	0	0	0	0	0
Total kept (mt)	1.014	1.865	3.034	1.051	6.964	0.000	0.000	0.000	0.000	0.000
Total discard (mt)	0.015	0.017	0.004	0.003	0.039	0.000	0.000	0.000	0.000	0.000
Ratio discard/kept	0.015	0.009	0.001	0.003	0.006	0.000	0.000	0.000	0.000	0.000
Total landings (mt)	437.928	729.250	382.837	229.805	1779.820	14.341	15.458	44.892	43.410	118.101
Total discards (mt)	6.662	6.739	0.515	0.595	14.511	0.000	0.000	0.000	0.000	0.000
1991										
Trips	4	0	4	1	9	0	0	0	0	0
Total kept (mt)	2.629	0.000	0.040	0.358	3.027	0.000	0.000	0.000	0.000	0.000
Total discard (mt)	0.007	0.000	0.000	0.005	0.012	0.000	0.000	0.000	0.000	0.000
Ratio discard/kept	0.003	0.000	0.000	0.013	0.004	0.000	0.000	0.000	0.000	0.000
Total landings (mt)	442.979	634.951	226.476	368.799	1673.205	18.271	25.179	58.600	39.033	141.083
Total discards (mt)	1.223	0.000	0.000	4.668	5.891	0.000	0.000	0.000	0.000	0.000
1992										
Trips	5	2	1	2	10	0	2	0	2	4
Total kept (mt)	2.427	2.295	0.105	1.133	5.959	0.000	0.021	0.000	0.298	0.319
Total discard (mt)	0.018	0.033	0.000	0.001	0.051	0.000	0.002	0.000	0.039	0.041
Ratio discard/kept	0.007	0.014	0.000	0.001	0.009	0.000	0.087	0.000	0.131	0.128
Total landings (mt)	366.970	726.073	315.390	276.801	1685.234	6.883	25.454	52.863	51.089	136.289
Total discards (mt)	2.675	10.333	0.000	0.222	13.230	0.000	2.212	0.000	6.687	8.900
1993										
Trips	3	6	1	2	12	1	2	1	1	5
Total kept (mt)	0.152	3.699	0.046	1.039	4.937	0.000	0.085	0.150	0.003	0.238
Total discard (mt)	0.001	0.003	0.004	0.010	0.018	0.000	0.023	0.000	0.000	0.024
Ratio discard/kept	0.006	0.001	0.078	0.010	0.004	0.000	0.271	0.003	0.000	0.101
Total landings (mt)	344.453	719.568	255.278	224.887	1544.186	24.977	20.373	34.293	35.781	115.424
Total discards (mt)	2.056	0.618	20.022	2.159	24.855	0.000	5.527	0.104	0.000	5.631
1994										
Trips	7	6	2	2	17	0	1	1	2	4
Total kept (mt)	0.605	1.557	0.332	0.735	3.229	0.000	0.093	0.068	0.011	0.171
Total discard (mt)	0.012	0.024	0.000	0.015	0.051	0.000	0.063	0.015	0.005	0.083
Ratio discard/kept	0.020	0.015	0.000	0.020	0.016	0.000	0.677	0.228	0.458	0.485
Total landings (mt)	122.622	238.031	235.972	312.760	909.385	4.766	13.126	15.395	19.611	52.898
Total discards (mt)	2.484	3.675	0.000	6.174	12.333	0.000	8.880	3.513	8.986	21.379
1995										
Trips	5	3	1	1	10	1	0	2	0	3
Total kept (mt)	1.666	3.579	1.701	4.560	11.505	0.040	0.000	0.023	0.000	0.063
Total discard (mt)	0.011	0.005	0.002	0.002	0.020	0.001	0.000	0.000	0.000	0.001
Ratio discard/kept	0.007	0.001	0.001	0.000	0.002	0.034	0.000	0.000	0.000	0.022
Total landings (mt)	72.654	232.642	298.806	108.966	713.068	2.568	11.066	18.090	5.321	37.045
Total discards (mt)	0.495	0.295	0.319	0.043	1.151	0.088	0.000	0.000	0.000	0.088

Table B5 (Cont.). Estimates of kept weight, discarded weight and discard ratios (discards/kept) for Georges Bank winter flounder collected by the NEFSC Sea Sampling Program observers. Estimates of total discards are based on the product of discard ratios and reported landings by quarter and gear type (trawl, scallop dredge).

	Trawl					Dredge				
	Qtr1	Qtr2	Qtr3	Qtr4	Total	Qtr1	Qtr2	Qtr3	Qtr4	Total
1996										
Trips	2	6	0	1	9	1	0	1	1	3
Total kept (mt)	0.064	8.605	0.000	2.948	11.617	0.058	0.000	0.000	0.008	0.066
Total discard (mt)	0.000	0.074	0.000	0.002	0.077	0.006	0.000	0.067	0.000	0.074
Ratio discard/kept	0.000	0.009	0.000	0.001	0.007	0.109	0.000	0.000	0.035	1.120
Total landings (mt)	53.485	543.636	355.963	290.765	1,243.849	2.074	37.695	22.030	9.429	71.228
Total discards (mt)	0.000	4.700	0.000	0.224	4.924	0.227	0.000	0.000	0.326	0.553
1997										
Trips	2	0	2	0	4	0	1	1	0	2
Total kept (mt)	0.076	0.000	0.362	0.000	0.439	0.000	0.041	0.067	0.000	0.108
Total discard (mt)	0.000	0.000	0.000	0.000	0.000	0.000	0.131	0.473	0.000	0.604
Ratio discard/kept	0.000	0.000	0.000	0.000	0.000	0.000	3.165	7.052	0.000	5.572
Total landings (mt)	55.469	546.706	424.702	310.990	1,337.867	1.672	37.908	26.714	13.735	80.029
Total discards (mt)	0.000	0.000	0.000	0.000	0.000	0.000	119.969	188.395	0.000	308.363
1998										
Trips	1	0	2	0	3	0	2	0	2	4
Total kept (mt)	0.001	0.000	10.520	0.000	10.521	0.000	0.086	0.000	0.000	0.086
Total discard (mt)	0.000	0.000	0.008	0.000	0.008	0.000	0.174	0.000	0.005	0.180
Ratio discard/kept	0.000	0.000	0.001	0.000	0.001	0.000	2.038	0.000	0.000	2.038
Total landings (mt)	63.356	482.347	373.759	322.238	1,241.700	0.120	0.176	0.264	0.140	0.700
Total discards (mt)	0.000	0.000	0.374	0.000	0.374	0.000	0.366	0.000	0.000	0.366
1999										
Trips	0	2	1	2	5	0	1	8	0	9
Total kept (mt)	0.000	5.665	0.055	3.032	8.752	0.000	0.007	0.030	0.000	0.037
Total discard (mt)	0.000	0.170	0.001	0.006	0.177	0.000	0.035	0.010	0.000	0.045
Ratio discard/kept	0.000	0.021	0.003	0.024	0.048	0.000	5.200	0.322	0.000	5.522
Total landings (mt)	56.749	372.190	209.096	286.765	924.800	0.401	1.007	1.408	6.484	9.300
Total discards (mt)	0.000	7.816	0.627	6.882	15.325	0.000	5.236	0.453	0.000	5.689
2000										
Trips	4	2	3	4	13	0	1	0	0	1
Total kept (mt)	2.586	0.722	11.834	13.341	28.483	0.000	0.000	0.000	0.000	0.000
Total discard (mt)	0.002	0.015	0.036	0.315	0.368	0.000	0.002	0.000	0.000	0.002
Ratio discard/kept	0.001	0.021	0.003	0.024	0.049	0.000	0.000	0.000	0.000	0.000
Total landings (mt)	83.612	718.009	408.291	448.588	1,658.500	0.392	1.010	1.196	15.802	18.400
Total discards (mt)	0.0854	15.078	1.225	10.766	27.154	0.000	0.000	0.000	0.000	0.000

Table B6. Distribution of trips and tows where Georges Bank winter flounder were sampled in the sea scallop dredge fishery, by NEFSC observers in 2000, in re-opened portions of Closed Areas 1 and 2 combined. Monthly kept weight (mt), discarded weight (mt) and ratios of discarded/kept weight of Georges Bank winter flounder are also presented.

	Month							
	6	7	8	9	10	11	12	Total
Trips	20	29	5	0	43	27	18	176
N and (%) tows with winter flounder catch	249 (15.9%)	254 (8.2%)	16 (2.0%)	0	624 (59.5%)	528 (79.4%)	440 (81.3%)	2,111 (27.3%)
Total kept (mt)	0.040	0.057	0.005	0	3.624	1.622	12.908	18.256
Total discard (mt)	0.919	0.543	0.020	0	3.306	3.277	2.549	10.614
Ratio discard/kept	22.975	9.526	4.000	0	0.912	2.020	0.197	0.581

Table B7. Length frequency data, by quarter, for Georges Bank winter flounder collected by the NEFSC Sea Sampling Program observers during 1989-2000.

	Trawl					Dredge					Other				
	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
1989															
No. trips (kept)	1	2	2	1	**6**					**0**					**0**
No. trips (discards)	1	1	1	0	**3**					**0**					**0**
No. lengths (kept)	28	298	20	54	**400**					**0**					**0**
No. lengths (discards)	2	48	20	0	**70**					**0**					**0**
1990															
No. trips (kept)	3	1	1	2	**7**					**0**					**0**
No. trips (discards)	1	1	1	0	**3**					**0**					**0**
No. lengths (kept)	121	529	593	287	**1,530**					**0**					**0**
No. lengths (discards)	3	15	4	0	**22**					**0**					**0**
1991															
No. trips (kept)	3	0	0	1	**4**					**0**					**0**
No. trips (discards)	2	0	0	0	**2**					**0**					**0**
No. lengths (kept)	474	0	0	21	**495**					**0**					**0**
No. lengths (discards)	5	0	0	0	**5**					**0**					**0**
1992															
No. trips (kept)	2	0	1	1	**4**	0	0	0	2	**2**					**0**
No. trips (discards)	2	0	0	0	**2**	0	0	0	1	**1**					**0**
No. lengths (kept)	308	0	20	10	**338**	0	0	0	39	**39**					**0**
No. lengths (discards)	15	0	0	0	**15**	0	0	0	1	**1**					**0**
1993															
No. trips (kept)	1	2	0	1	**4**	0	0	1	0	**1**	0	1	1	0	**2**
No. trips (discards)	1	1	0	1	**3**	1	1	0	0	**2**	0	1	0	0	**1**
No. lengths (kept)	4	100	0	169	**273**	0	0	6	0	**6**	0	23	7	0	**30**
No. lengths (discards)	2	1	0	2	**5**	1	2	0	0	**3**	0	24	0	0	**24**
1994															
No. trips (kept)	4	3	0	1	**8**	0	1	0	2	**3**					**0**
No. trips (discards)	2	0	0	0	**2**	0	1	0	1	**2**					**0**
No. lengths (kept)	82	27	0	94	**203**	0	22	0	2	**24**					**0**
No. lengths (discards)	6	0	0	0	**6**	0	32	0	1	**33**					**0**
1995															
No. trips (kept)	3	3	1	1	**8**	1	0	1	0	**2**	1	0	0	0	**1**
No. trips (discards)	0	2	1	1	**4**					**0**					**0**
No. lengths (kept)	700	869	611	950	**3,130**	7	0	2	0	**9**	28	0	0	0	**28**
No. lengths (discards)	0	5	2	4	**11**					**0**					**0**
1996															
No. trips (kept)	2	5	0	1	**8**	1	0	0	0	**1**					**0**
No. trips (discards)	0	3	0	1	**4**	1	0	0	0	**1**					**0**
No. lengths (kept)	16	1778	0	106	**1,900**	13	0	0	0	**13**					**0**
No. lengths (discards)	0	38	0	1	**39**	2	0	0	0	**2**					**0**
1997															
No. trips (kept)	1	0	1	0	**2**	0	1	1	0	**2**					**0**
No. trips (discards)	0	0	0	0	**0**	0	1	1	0	**2**					**0**
No. lengths (kept)	4	0	91	0	**95**	0	14	11	0	**25**					**0**
No. lengths (discards)	0	0	0	0	**0**	0	35	239	0	**274**					**0**
1998															
No. trips (kept)	0	0	2	0	**2**	0	1	0	0	**1**					**0**
No. trips (discards)	0	0	1	0	**1**	0	1	1	0	**2**					**0**
No. lengths (kept)	0	0	143	0	**143**	0	44	0	0	**44**					**0**
No. lengths (discards)	0	0	1	0	**1**	0	70	1	0	**71**					**0**
1999															
No. trips (kept)	0	1	1	1	**3**	0	1	1	0	**2**					**0**
No. trips (discards)	0	1	1	1	**3**	0	1	1	0	**2**					**0**
No. lengths (kept)	0	83	18	89	**190**	0	3	1	0	**4**					**0**
No. lengths (discards)	0	16	10	9	**35**	0	10	2	0	**12**					**0**
2000															
No. trips (kept)	2	2	3	4	**11**					**0**					**0**
No. trips (discards)	0	0	2	2	**4**	0	1	0	0	**1**					**0**
No. lengths (kept)	113	54	324	184	**675**					**0**					**0**
No. lengths (discards)	0	0	72	31	**103**	0	2	0	0	**2**					**0**

Table B8. Estimates of kept and discarded weight (mt) and discard ratios (discards/kept), by quarter, of Georges Bank winter flounder reported by commercial operators in the Vessel Trip Report database. Estimates of total discards (mt) are based on the product of discard ratios and reported landings by quarter and gear type (trawl, scallop dredge).

	Trawl					Dredge				
	1	2	3	4	Total	1	2	3	4	Total
1994										
Trips	1	64	67	50	182	0	11	9	4	24
Total kept (mt)	0.544	76.865	84.908	73.636	235.952	0.000	0.832	0.794	0.395	2.021
Total discard (mt)	0.000	1.525	1.963	2.112	5.600	0.000	0.351	1.169	0.710	2.229
Ratio discard/kept	0.000	0.020	0.023	0.029	0.024	0.000	0.421	1.473	1.799	1.103
Total landings (mt)	122.622	238.031	235.972	312.760	909.385	4.766	13.126	15.395	19.611	52.898
Total discards (mt)	0.000	4.723	5.456	8.968	19.147	0.000	5.529	22.670	35.277	63.477
1995										
Trips	23	29	26	26	104	0	0	11	6	17
Total kept (mt)	21.809	36.147	29.643	42.697	130.296	0.000	0.000	0.640	0.329	0.969
Total discard (mt)	0.281	0.714	0.774	3.342	5.112	0.000	0.000	1.769	0.138	1.907
Ratio discard/kept	0.013	0.020	0.026	0.078	0.039	0.000	0.000	2.766	0.420	1.969
Total landings (mt)	72.654	232.642	298.806	108.966	713.068	2.568	11.066	18.090	5.321	37.045
Total discards (mt)	0.937	4.598	7.801	8.529	21.865	0.000	0.000	50.036	2.235	52.272
1996										
Trips	22	45	59	34	160	0	4	11	4	19
Total kept (mt)	7.317	83.146	123.483	50.979	264.924	0.000	0.143	0.946	0.277	1.365
Total discard (mt)	0.032	1.867	1.498	0.215	3.612	0.000	0.721	2.676	0.068	3.466
Ratio discard/kept	0.004	0.022	0.012	0.004	0.014	0.000	5.048	2.830	0.246	2.538
Total landings (mt)	53.485	543.636	355.963	290.765	1,243.849	2.074	37.695	22.030	9.429	71.228
Total discards (mt)	0.232	12.204	4.318	1.229	17.983	0.000	190.270	62.339	2.319	254.928
1997										
Trips	23	0	29	21	73	0	10	8	2	20
Total kept (mt)	16.370	0.000	63.921	37.388	117.680	0.000	0.458	0.562	0.091	1.111
Total discard (mt)	0.150	0.000	0.311	0.559	1.019	0.000	0.968	0.469	0.045	1.483
Ratio discard/kept	0.009	0.000	0.005	0.015	0.009	0.000	2.114	0.835	0.500	1.335
Total landings (mt)	55.469	546.706	424.702	310.990	1,337.867	1.672	37.908	26.714	13.735	80.029
Total discards (mt)	0.507	0.000	2.064	4.648	7.220	0.000	80.132	22.298	6.868	109.297
1998										
Trips	2	10	8	10	30	5	4	1	7	17
Total kept (mt)	0.071	38.190	34.208	31.003	103.472	0.293	0.198	0.136	0.361	0.988
Total discard (mt)	0.002	0.188	0.138	0.179	0.507	0.363	3.280	0.454	2.908	7.005
Ratio discard/kept	0.028	0.005	0.004	0.006	0.005	1.239	16.566	3.338	8.055	7.090
Total landings (mt)	63.356	482.347	373.759	322.238	1,241.7	0.120	0.176	0.264	0.140	0.700
Total discards (mt)	1.785	2.374	1.508	1.860	7.527	0.149	2.916	0.881	1.128	5.073
1999										
Trips	0	8	7	9	24	4	9	9	8	30
Total kept (mt)	0.000	29.178	13.267	12.630	55.075	0.181	0.267	0.045	0.136	0.629
Total discard (mt)	0.000	0.123	0.168	0.059	0.350	1.428	1.603	0.539	0.682	4.252
Ratio discard/kept	0.000	0.004	0.013	0.005	0.006	7.890	6.004	11.978	5.015	6.760
Total landings (mt)	56.749	372.190	209.096	286.765	924.800	0.401	1.007	1.408	6.484	9.300
Total discards (mt)	0.000	1.569	2.648	1.340	5.556	3.164	6.046	16.865	32.515	58.590
2000										
Trips	4	14	8	12	38	1	8	4	5	18
Total kept (mt)	2.091	55.668	26.308	28.620	112.687	0.000	0.009	0.136	0.045	0.190
Total discard (mt)	0.181	0.177	0.310	0.118	0.786	0.005	0.701	0.186	1.343	2.235
Ratio discard/kept	0.087	0.003	0.012	0.004	0.007	0.000	77.889	1.368	29.844	11.763
Total landings (mt)	83.612	718.009	408.291	448.588	1,658.500	0.392	1.010	1.196	15.802	18.400
Total discards (mt)	7.238	2.283	4.811	1.850	16.181	0.000	78.668	1.636	471.602	551.905

Table B9. Port sampling of U.S. winter flounder landings for length and age composition from Georges Bank (Statistical Areas 522-525, 551-562), 1980-2000. Total number of samples does not include 15 unclassified (market category 1200) samples from 1980 (1), 1981 (2), 1982 (4), 1985 (1), 1986 (1), 1990 (4), 1991 (1).

				Number of Samples by Market Category and Quarter															Annual Sampling Intensity (mt landed/sample)		
		Number of	Number of	Lemon Sole (1201) Extra-Large (1204)					Large (1202) Large/Mixed (1205)					Small (1203) Medium (1206) Pee-Wee (1207)					1201 1204	1202 1205	1203 1206 1207
Year	Total Samples	Length Samples	Age Samples	Q1	Q2	Q3	Q4	Tot	Q1	Q2	Q3	Q4	Tot	Q1	Q2	Q3	Q4	Tot	Lemon	Large	Small
1980	8	863	226	0	0	1	0	**1**	2	2	1	0	**5**	1	0	1	0	**2**	445	217	-----
1981	1	268	77	0	1	0	0	**1**	0	0	0	0	**0**	0	0	0	0	**0**	355	-----	-----
1982	26	2,900	739	0	1	6	2	**9**	0	1	6	3	**10**	0	1	5	1	**7**	26	71	190
1983	36	4,493	874	0	3	2	1	**6**	2	5	6	2	**15**	2	3	9	1	**15**	37	42	84
1984	24	2,855	593	0	1	3	1	**5**	3	3	4	3	**13**	1	2	0	3	**6**	135	111	48
1985	38	3,927	827	1	2	5	1	**9**	2	4	9	1	**16**	2	3	7	1	**13**	50	28	75
1986	29	2,822	563	1	1	0	3	**5**	2	3	3	2	**10**	1	6	3	4	**14**	178	67	144
1987	33	3,108	618	2	1	1	2	**6**	4	3	3	1	**11**	5	3	4	4	**16**	87	51	131
1988	34	2,959	693	2	2	1	2	**7**	4	3	3	1	**11**	4	4	4	4	**16**	86	61	111
1989	16	1,470	280	1	1	0	0	**2**	3	2	0	1	**6**	1	3	3	1	**8**	412	124	282
1990	34	3,469	737	0	0	0	1	**1**	3	3	4	3	**13**	6	7	3	4	**20**	902	58	116
1991	35	3,137	698	1	1	1	1	**4**	6	6	2	2	**16**	6	3	3	3	**15**	129	37	114
1992	35	3,034	688	1	2	1	1	**5**	5	4	3	3	**15**	6	5	3	1	**15**	301	36	118
1993	16	1,435	338	1	2	0	1	**4**	3	2	0	0	**5**	1	5	0	1	**7**	93	408	195
1994	17	1,345	330	0	1	1	1	**3**	1	2	2	1	**6**	1	3	3	1	**8**	20	64	54
1995	14	1,137	274	1	1	0	2	**4**	1	0	0	3	**4**	2	1	0	3	**6**	10	17	104
1996	11	1,064	236	0	2	1	1	**4**	0	2	1	1	**4**	0	1	1	1	**3**	17	104	192
1997	15	1,155	225	0	0	0	1	**1**	1	0	1	0	**2**	3	2	1	5	**11**	45	227	33
1998	4	317	60	0	0	0	0	**0**	0	1	0	0	**1**	0	1	1	1	**3**	-----	490	340
1999[1]	5	296	66	0	0	0	0	**0**	0	0	0	0	**0**	2	1	0	1	**4**	-----	-----	112
2000	23	1,659	385	0	0	1	5	**6**	1	0	0	4	**5**	4	5	2	1	**12**	19	137	70

1 Includes one unclassified sample (market category 1200) during Quarter 2.

Table B10. Data pooling procedures used to apply frequency samples to landings by market cateogory to estimate catch (numbers) at age of Georges Bank winter flounder, 1982-2000.

	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Market Category Comments
Year					
1982	Pooled		X	X	1204 (Extra Large) pooled with 1201 Lemon Sole 1205 (Large/Mixed) pooled with 1202 (Large) 1206 (Medium) and 1207 (Peewee) pooled with 1203 (Small)
1983	Pooled		X	X	
1984	Pooled		Pooled		
1985	X	X	X	X	
1986	X	X	Pooled		
1987	X	X	X	X	
1988	X	X	X	X	
1989	X	X	Pooled		
1990	X	X	X	X	
1991	X	X	X	X	
1992	X	X	X	X	
1993	X	Pooled			
1994	Pooled		X	X	1201 (Lemon Sole) and 1204 (Extra Large) pooled with 1202 (Large) and 1205 (Large/Mixed) 1206 (Medium) and 1207 (Peewee) pooled with 1203 (Small)
1995	X	X	Pooled		
1996	Pooled		X	X	
1997	X	X	Pooled		
1998	Pooled				Pooled all market categories and included all length data from otter trawl observer trips
1999	Pooled				
2000	Pooled		Pooled		Pooled market categories as in 1994-97

Table B11. Estimated landings (in numbers, thousands) at age and weight (mt) at age of Georges Bank winter flounder during 1982-2000.

Landings at Age

	1	2	3	4	5	6	7	8	9	10+	Total
1982	**---**	**353**	**1,707**	**1,048**	**511**	**258**	**117**	**101**	**30**	**33**	**4,157**
1983	**10**	**787**	**2,902**	**1,454**	**551**	**206**	**221**	**134**	**47**	**127**	**6,438**
1984	**---**	**282**	**570**	**1,371**	**1,408**	**635**	**303**	**230**	**169**	**217**	**5,186**
1985	**20**	**805**	**693**	**812**	**491**	**112**	**51**	**22**	**20**	**8**	**3,031**
1986	**---**	**665**	**1,328**	**235**	**229**	**131**	**49**	**23**	**7**	**9**	**2,675**
1987	**---**	**1,294**	**1,681**	**899**	**133**	**89**	**40**	**35**	**25**	**21**	**4,217**
1988	**---**	**835**	**2,774**	**843**	**197**	**90**	**46**	**24**	**7**	**17**	**4,832**
1989	**---**	**1,381**	**1,222**	**509**	**147**	**107**	**29**	**22**	**6**	**4**	**3,427**
1990	**---**	**295**	**2,032**	**668**	**185**	**46**	**8**	**7**	**0**	**3**	**3,241**
1991	**---**	**593**	**1,270**	**951**	**136**	**38**	**30**	**18**	**9**	**4**	**3,047**
1992	**---**	**796**	**756**	**727**	**468**	**92**	**32**	**15**	**11**	**4**	**2,902**
1993	**37**	**301**	**1,143**	**451**	**320**	**163**	**21**	**13**	**5**	**7**	**2,461**
1994	**---**	**533**	**582**	**246**	**67**	**57**	**34**	**9**	**4**	**3**	**1,536**
1995	**264**	**679**	**267**	**188**	**76**	**19**	**14**	**4**	**3**	**1**	**1,513**
1996	**---**	**737**	**567**	**240**	**157**	**104**	**38**	**29**	**10**	**6**	**1,888**
1997	**---**	**480**	**1,115**	**590**	**132**	**35**	**11**	**7**	**2**	**13**	**2,385**
1998	**8**	**112**	**1,421**	**629**	**76**	**20**	**7**	**0**	**3**	**0**	**2,275**
1999	**32**	**599**	**814**	**274**	**136**	**30**	**8**	**0**	**0**	**0**	**1,893**
2000	**0**	**484**	**1,282**	**474**	**285**	**213**	**55**	**27**	**25**	**7**	**2,852**

Weight at Age

	1	2	3	4	5	6	7	8	9	10+	Total
1982	**---**	**100**	**761**	**818**	**531**	**317**	**161**	**164**	**61**	**68**	**1,713**
1983	**2**	**220**	**1,308**	**971**	**495**	**204**	**253**	**169**	**69**	**218**	**3,908**
1984	**---**	**82**	**266**	**803**	**1,049**	**566**	**318**	**272**	**221**	**354**	**3,931**
1985	**3**	**326**	**360**	**634**	**515**	**152**	**78**	**38**	**40**	**16**	**2,163**
1986	**---**	**264**	**810**	**183**	**235**	**156**	**69**	**37**	**13**	**21**	**1,786**
1987	**---**	**500**	**924**	**781**	**148**	**108**	**64**	**56**	**47**	**42**	**2,669**
1988	**---**	**292**	**1,416**	**641**	**227**	**119**	**74**	**42**	**14**	**34**	**2,859**
1989	**---**	**498**	**565**	**422**	**159**	**142**	**44**	**40**	**12**	**10**	**1,891**
1990	**---**	**135**	**1,035**	**505**	**183**	**61**	**15**	**12**	**1**	**6**	**1,953**
1991	**---**	**249**	**615**	**671**	**134**	**54**	**47**	**33**	**16**	**9**	**1,828**
1992	**---**	**310**	**373**	**541**	**425**	**110**	**43**	**24**	**17**	**6**	**1,849**
1993	**9**	**116**	**614**	**342**	**301**	**211**	**34**	**25**	**12**	**17**	**1,683**
1994	**---**	**201**	**318**	**218**	**75**	**76**	**52**	**17**	**8**	**6**	**972**
1995	**75**	**268**	**159**	**124**	**76**	**24**	**21**	**6**	**5**	**1**	**760**
1996	**---**	**304**	**348**	**217**	**172**	**150**	**60**	**51**	**20**	**13**	**1,336**
1997	**---**	**174**	**596**	**414**	**133**	**50**	**18**	**13**	**4**	**28**	**1,430**
1998	**2**	**48**	**653**	**400**	**80**	**25**	**11**	**0**	**6**	**0**	**1,225**
1999	**7**	**224**	**332**	**187**	**132**	**43**	**13**	**0**	**0**	**0**	**938**
2000	**---**	**183**	**533**	**236**	**261**	**259**	**78**	**42**	**38**	**12**	**1,641**

Table B12. Estimated mean length (cm) at age and mean weight (kg) at age for Georges Bank winter flounder from the commercial landings at age.

	Mean Length at Age										All
	1	2	3	4	5	6	7	8	9	10+	Ages
1982	**--**	**30.68**	**35.36**	**42.42**	**46.54**	**49.11**	**50.91**	**53.68**	**57.46**	**58.03**	**40.21**
1983	**26.67**	**30.53**	**35.49**	**40.29**	**44.40**	**45.78**	**47.88**	**49.40**	**52.00**	**54.51**	**38.26**
1984	**--**	**31.05**	**36.05**	**38.72**	**41.75**	**44.31**	**46.61**	**48.42**	**50.00**	**53.61**	**41.41**
1985	**26.07**	**34.12**	**36.74**	**42.27**	**46.62**	**50.72**	**52.72**	**54.85**	**57.61**	**57.50**	**40.15**
1986	**--**	**33.99**	**39.13**	**42.18**	**46.12**	**48.37**	**51.04**	**53.37**	**55.08**	**60.42**	**39.53**
1987	**--**	**33.72**	**37.77**	**43.88**	**47.44**	**48.70**	**53.17**	**53.34**	**56.02**	**57.67**	**38.87**
1988	**--**	**32.77**	**36.76**	**41.95**	**48.01**	**50.16**	**53.28**	**55.15**	**57.79**	**58.16**	**38.05**
1989	**--**	**32.95**	**35.45**	**43.16**	**46.86**	**50.32**	**52.52**	**55.52**	**58.64**	**61.33**	**36.93**
1990	**--**	**35.72**	**36.93**	**41.91**	**45.74**	**50.39**	**57.26**	**56.46**	**62.00**	**60.83**	**38.64**
1991	**--**	**34.65**	**36.06**	**40.85**	**45.69**	**51.67**	**53.27**	**56.00**	**56.35**	**59.56**	**38.35**
1992	**--**	**33.90**	**36.53**	**41.71**	**44.37**	**48.43**	**49.74**	**53.89**	**52.20**	**54.73**	**39.07**
1993	**29.66**	**33.68**	**37.57**	**41.80**	**44.74**	**49.83**	**54.10**	**56.30**	**60.05**	**60.23**	**39.86**
1994	**---**	**33.53**	**37.75**	**44.09**	**47.56**	**50.36**	**52.13**	**56.16**	**56.64**	**58.48**	**38.73**
1995	**30.80**	**33.94**	**38.93**	**40.05**	**45.41**	**49.35**	**52.23**	**55.52**	**56.88**	**63.00**	**36.07**
1996	**---**	**34.65**	**39.32**	**44.42**	**47.08**	**51.64**	**53.20**	**55.39**	**57.29**	**57.53**	**40.15**
1997	**---**	**33.19**	**37.42**	**40.90**	**45.75**	**51.51**	**52.96**	**56.36**	**59.00**	**58.25**	**38.36**
1998	**30.00**	**35.82**	**36.60**	**40.45**	**47.77**	**50.93**	**55.60**	**---**	**59.00**	**---**	**38.18**
1999	**29.68**	**34.51**	**35.53**	**41.85**	**46.91**	**52.88**	**56.08**	**---**	**---**	**---**	**37.21**
2000	**---**	**34.87**	**35.89**	**37.95**	**46.13**	**50.74**	**53.48**	**54.54**	**54.67**	**---**	**38.92**

	Mean Weight at Age										All
	1	2	3	4	5	6	7	8	9	10+	Ages
1982	**--**	**0.283**	**0.444**	**0.779**	**1.041**	**1.228**	**1.375**	**1.623**	**2.007**	**2.078**	**0.717**
1983	**0.181**	**0.279**	**0.451**	**0.668**	**0.899**	**0.991**	**1.144**	**1.261**	**1.475**	**1.713**	**0.607**
1984	**--**	**0.292**	**0.467**	**0.585**	**0.744**	**0.891**	**1.050**	**1.180**	**1.308**	**1.626**	**0.758**
1985	**0.168**	**0.405**	**0.522**	**0.782**	**1.050**	**1.366**	**1.541**	**1.743**	**2.035**	**2.011**	**0.714**
1986	**--**	**0.398**	**0.617**	**0.778**	**1.029**	**1.194**	**1.420**	**1.601**	**1.764**	**2.351**	**0.668**
1987	**--**	**0.385**	**0.549**	**0.868**	**1.107**	**1.217**	**1.582**	**1.605**	**1.861**	**2.038**	**0.633**
1988	**--**	**0.350**	**0.510**	**0.760**	**1.149**	**1.323**	**1.594**	**1.770**	**2.053**	**2.090**	**0.592**
1989	**--**	**0.359**	**0.459**	**0.826**	**1.076**	**1.332**	**1.522**	**1.804**	**2.131**	**2.450**	**0.552**
1990	**--**	**0.457**	**0.510**	**0.757**	**0.992**	**1.339**	**1.983**	**1.909**	**2.531**	**2.388**	**0.603**
1991	**--**	**0.418**	**0.479**	**0.702**	**0.985**	**1.438**	**1.582**	**1.853**	**1.897**	**2.250**	**0.600**
1992	**--**	**0.390**	**0.494**	**0.744**	**0.906**	**1.185**	**1.321**	**1.656**	**1.552**	**1.727**	**0.637**
1993	**0.250**	**0.384**	**0.537**	**0.758**	**0.941**	**1.294**	**1.657**	**1.880**	**2.299**	**2.324**	**0.684**
1994	**---**	**0.377**	**0.546**	**0.886**	**1.118**	**1.338**	**1.499**	**1.867**	**1.910**	**2.133**	**0.633**
1995	**0.283**	**0.394**	**0.597**	**0.660**	**0.999**	**1.287**	**1.582**	**1.798**	**1.941**	**2.662**	**0.503**
1996	**---**	**0.413**	**0.614**	**0.903**	**1.096**	**1.442**	**1.582**	**1.788**	**1.982**	**2.013**	**0.707**
1997	**---**	**0.363**	**0.534**	**0.702**	**1.011**	**1.429**	**1.555**	**1.879**	**2.167**	**2.092**	**0.600**
1998	**---**	**0.259**	**0.458**	**0.494**	**0.684**	**1.134**	**1.375**	**1.806**	**---**	**2.167**	**0.579**
1999	**0.252**	**0.415**	**0.454**	**0.758**	**1.079**	**1.551**	**1.854**	**---**	**---**	**---**	**0.550**
2000	**---**	**0.423**	**0.466**	**0.558**	**1.024**	**1.361**	**1.602**	**1.702**	**1.712**	**1.902**	**0.645**

Table B13. Nominal landings per unit effort (mt landed/day fished) of winter flounder, by ton class, for all Georges Bank otter trawl trips landing winter flounder from 1964 to 1993.

	Ton Class 2			Ton Class 3			Ton Class 4			Total		
Year	L	DF	LPUE	L	DF	LPUE	L	DF	LPUE	L	DF	LPUE
1964	74	350	0.21	927	3,101	0.30	358	2,297	0.16	1,359	5,748	0.24
1965	81	280	0.24	694	3,652	0.19	399	2,782	0.14	1,174	6,714	0.17
1966	54	216	0.25	1,189	3,798	0.37	630	2,766	0.23	1,873	6,780	0.28
1967	46	142	0.32	1,073	3,187	0.34	794	2,268	0.35	1,914	5,596	0.34
1968	34	120	0.28	1,039	3,518	0.29	491	1,521	0.32	1,564	5,159	0.30
1969	7	49	0.14	1,541	4,147	0.37	616	1,404	0.44	2,163	5,600	0.39
1970	16	55	0.29	2,002	4,380	0.46	590	1,142	0.52	2,609	5,576	0.47
1971	67	162	0.41	2,281	5,046	0.45	737	1,351	0.54	3,085	6,558	0.47
1972	36	103	0.35	2,232	5,239	0.43	527	1,118	0.47	2,795	6,461	0.43
1973	22	99	0.22	1,725	4,084	0.42	516	906	0.57	2,264	5,089	0.44
1974	16	72	0.22	1,531	5,170	0.30	568	1,231	0.46	2,115	6,473	0.33
1975	9	52	0.17	1,854	5,316	0.35	544	1,076	0.50	2,407	6,445	0.37
1976	2	24	0.09	1,486	4,992	0.30	386	607	0.64	1,874	5,624	0.33
1977	33	103	0.32	2,899	5,548	0.53	636	728	0.87	3,568	6,379	0.56
1978	11	48	0.23	2,539	4,496	0.56	615	798	0.77	3,165	5,242	0.59
1979	35	120	0.29	2,434	3,992	0.62	548	948	0.58	3,018	5,060	0.60
1980	70	148	0.48	3,110	4,182	0.75	705	1,241	0.57	3,885	5,571	0.70
1981	26	134	0.19	3,085	4,370	0.71	823	1,836	0.45	3,934	6,340	0.62
1982	29	78	0.37	2,193	4,452	0.49	692	1,815	0.38	2,914	6,345	0.46
1983	11	22	0.48	2,634	4,320	0.61	1,21	2,394	0.51	3,864	6,736	0.57
1984	10	24	0.43	2,549	6,472	0.39	1,33	3,329	0.40	3,897	9,825	0.40
1985	4	29	0.14	1,312	5,393	0.24	828	2,668	0.31	2,145	8,090	0.27
1986	0	0	------	1,219	4,845	0.25	504	1,957	0.26	1,723	6,802	0.25
1987	<1	3	0.13	1,898	6,647	0.29	660	2,290	0.29	2,559	8,940	0.29
1988	3	12	0.23	1,917	7,594	0.25	778	2,665	0.29	2,697	10,27	0.26
1989	<1	<1	<0.01	1,242	5,866	0.21	488	2,246	0.22	1,730	8,112	0.21
1990	<1	9	0.04	1,256	5,030	0.25	522	2,257	0.23	1,778	7,295	0.24
1991	5	5	0.42	1,224	5,351	0.23	444	2,175	0.20	1,672	7,537	0.22
1992	<1	1	0.12	1,216	6,160	0.20	460	2,472	0.19	1,677	8,638	0.19
1993	<1	1	0.02	1,139	7,097	0.16	393	2,291	0.17	1,532	9,388	0.16

Table B14. Nominal landings per unit effort (landed/day fished) of winter flounder by ton class for directed winter flounder otter trawl trips (landings >= 50% of trip) on Georges Bank from 1964 to 1993.

	Ton Class 2			Ton Class 3			Ton Class 4			Total		
Year	L	DF	LPUE	L	DF	LPUE	L	DF	LPUE	L	DF	LPUE
1964	10	5	2.00	131	66	1.98	30	7	2.86	161	78	2.06
1965	0	0	------	242	98	2.47	28	8	3.50	207	106	2.55
1966	2	2	1.00	108	52	2.08	5	2	2.50	115	56	2.05
1967	6	4	1.50	151	96	1.57	33	14	2.36	190	114	1.67
1968	9	14	0.64	162	90	1.80	18	9	2.00	189	113	1.67
1969	0	0	------	140	61	2.30	86	24	3.58	226	85	2.66
1970	0	0	------	431	186	2.32	80	30	2.67	511	216	2.36
1971	24	14	1.71	457	212	2.16	121	61	1.98	602	287	2.10
1972	14	7	2.00	515	267	1.93	84	47	1.79	613	321	1.91
1973	0	0	------	465	251	1.85	94	45	2.09	559	296	1.89
1974	0	0	------	294	174	1.69	132	52	2.54	426	226	1.88
1975	5	4	1.25	654	381	1.72	158	84	1.88	817	469	1.74
1976	0	0	------	496	302	1.64	143	90	1.59	639	392	1.63
1977	6	6	1.00	743	328	2.26	200	74	2.70	949	408	2.32
1978	5	6	0.83	678	340	1.99	50	25	2.00	733	371	1.98
1979	9	5	1.80	759	398	1.91	55	23	2.39	823	426	1.93
1980	28	18	1.55	1,33	642	2.08	137	36	3.80	1,502	696	2.16
1981	6	3	2.00	1,31	670	1.96	138	58	2.38	1,460	731	2.00
1982	8	6	1.35	894	533	1.68	158	62	2.54	1,060	601	1.76
1983	9	7	1.23	1,22	685	1.79	277	116	2.39	1,509	807	1.87
1984	6	4	1.48	913	860	1.06	333	242	1.38	1,252	1,106	1.13
1985	0	0	------	400	657	0.61	208	246	0.84	607	904	0.67
1986	0	0	------	435	827	0.53	100	157	0.64	535	983	0.54
1987	0	0	------	508	925	0.55	112	160	0.70	621	1,085	0.57
1988	2	7	0.27	403	769	0.52	150	215	0.70	554	991	0.56
1989	0	0	------	251	530	0.47	59	95	0.63	310	625	0.50
1990	0	0	------	259	463	0.56	58	79	0.74	317	542	0.59
1991	0	0	------	306	489	0.63	61	68	0.89	366	557	0.66
1992	0	0	------	292	564	0.52	61	80	0.76	353	644	0.55
1993	0	0	------	209	481	0.43	32	49	0.65	241	530	0.45

Table B15 . Standardized, stratified abundance (numbers) and biomass (weight) indices for Georges Bank winter flounder from the U.S. NEFSC Spring and Autumn (offshore strata 13-22) and Canadian Spring (strata 5Z1-Z4) research vessel bottom trawl surveys. Door standardization coefficients of 1.46 (numbers) and 1.39 (weight) were applied to pre-1985 U.S. survey indices to account for catchability differences between survey trawl doors.

	U.S. Spring Survey		**U.S. Autumn Survey**		**Canadian Spring Survey**	
	Number per tow	Weight (kg) per tow	Number per tow	Weight (kg) per tow	Number per tow	Weight (kg) per tow
1963			**1.20**	**1.82**		
1964			**1.30**	**1.82**		
1965			**2.15**	**2.05**		
1966			**5.16**	**5.66**		
1967	***Spring Survey initiated in 1968***		**1.79**	**2.07**		
1968	**2.70**	**3.11**	**1.31**	**1.07**		
1969	**3.14**	**4.29**	**2.37**	**2.39**		
1970	**1.86**	**2.29**	**5.62**	**6.49**		
1971	**1.84**	**2.17**	**1.32**	**1.26**		
1972	**4.95**	**5.32**	**1.26**	**1.58**		
1973	**2.95**	**3.51**	**1.22**	**1.20**		
1974	**6.05**	**5.78**	**1.19**	**1.46**		
1975	**1.96**	**1.41**	**3.79**	**2.06**		
1976	**4.67**	**3.01**	**5.99**	**3.93**		
1977	**3.79**	**1.58**	**4.86**	**3.99**		
1978	**7.07**	**5.06**	**4.06**	**3.10**		
1979	**1.74**	**2.21**	**5.07**	**3.83**		
1980	**3.22**	**2.80**	**1.66**	**1.87**		
1981	**3.73**	**3.75**	**3.83**	**2.43**		
1982	**2.30**	**1.52**	**5.30**	**2.69**		
1983	**8.41**	**7.11**	**2.73**	**2.36**		
1984	**5.53**	**5.60**	**3.93**	**2.45**		
1985	**3.84**	**2.65**	**1.98**	**1.12**		
1986	**2.00**	**1.21**	**3.58**	**2.18**	***Canadian Survey initiated in 1987***	
1987	**2.80**	**1.25**	**0.76**	**0.89**	**1.24**	**1.74**
1988	**2.93**	**1.65**	**4.08**	**1.27**	**4.31**	**2.75**
1989	**1.30**	**0.76**	**1.56**	**1.05**	**4.05**	**1.95**
1990	**2.80**	**1.57**	**0.50**	**0.35**	**4.93**	**2.64**
1991	**2.40**	**1.32**	**0.27**	**0.14**	**1.98**	**1.38**
1992	**1.42**	**0.90**	**0.68**	**0.38**	**0.51**	**0.59**
1993	**1.02**	**0.57**	**1.17**	**0.66**	**3.53**	**1.76**
1994	**1.29**	**0.58**	**0.87**	**0.58**	**5.10**	**2.01**
1995	**2.61**	**1.49**	**2.36**	**1.34**	**5.63**	**1.96**
1996	**2.31**	**1.50**	**1.54**	**1.76**	**4.12**	**2.30**
1997	**1.61**	**1.19**	**1.74**	**1.53**	**4.58**	**3.09**
1998	**0.76**	**0.72**	**1.78**	**1.57**	**1.14**	**1.21**
1999	**3.83**	**3.48**	**2.60**	**2.64**	**1.25**	**1.89**
2000	**4.42**	**3.69**	**2.16**	**2.66**	**1.48**	**2.22**
2001	**1.29**	**1.22**			**2.28**	**2.54**

Table B16. Stratified mean numbers per tow at age of Georges Bank winter flounder caught in the NEFSC spring research vessel bottom trawl surveys (offshore strata 13-22) during 1982-2001. A trawl door standardization coefficient of 1.46 has been applied to indices prior to 1985 to account for changes in catchability due to a change in trawl doors.

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10 +	Total
1982	0.00	0.07	0.78	0.38	0.59	0.17	0.15	0.04	0.01	0.03	0.0	2.259
1983	0.00	0.02	1.02	3.13	1.58	0.67	0.69	0.56	0.42	0.12	0.1	8.405
1984	0.00	0.03	0.14	1.91	1.53	0.45	0.54	0.47	0.26	0.02	0.1	5.530
1985	0.00	0.00	1.85	0.62	0.62	0.39	0.22	0.04	0.02	0.04	0.0	3.837
1986	0.00	0.25	0.66	0.73	0.11	0.16	0.07	0.00	0.00	0.00	0.0	2.003
1987	0.00	0.16	1.64	0.58	0.29	0.09	0.00	0.00	0.02	0.00	0.0	2.803
1988	0.00	0.07	0.53	1.43	0.68	0.11	0.04	0.01	0.00	0.02	0.0	2.925
1989	0.00	0.04	0.53	0.26	0.22	0.15	0.01	0.00	0.05	0.00	0.0	1.299
1990	0.00	0.12	0.61	1.56	0.33	0.09	0.07	0.00	0.00	0.00	0.0	2.803
1991	0.00	0.27	0.34	0.82	0.58	0.27	0.03	0.02	0.00	0.04	0.0	2.403
1992	0.00	0.07	0.60	0.29	0.13	0.14	0.10	0.00	0.02	0.02	0.0	1.416
1993	0.00	0.17	0.27	0.33	0.15	0.00	0.04	0.01	0.02	0.00	0.0	1.018
1994	0.00	0.12	0.57	0.40	0.10	0.03	0.04	0.00	0.00	0.00	0.0	1.292
1995	0.00	0.14	0.78	1.25	0.29	0.10	0.02	0.00	0.00	0.00	0.0	2.613
1996	0.00	0.03	1.21	0.43	0.48	0.06	0.02	0.04	0.00	0.00	0.0	2.314
1997	0.00	0.02	0.19	0.53	0.66	0.11	0.02	0.02	0.00	0.02	0.0	1.609
1998	0.00	0.00	0.02	0.16	0.42	0.12	0.00	0.02	0.00	0.00	0.0	0.762
1999	0.00	0.22	0.54	0.61	1.29	0.88	0.19	0.05	0.01	0.00	0.0	3.831
2000	0.00	0.01	0.61	1.01	0.62	1.13	0.65	0.11	0.07	0.00	0.0	4.419
2001	0.00	0.00	0.07	0.32	0.27	0.16	0.19	0.26	0.00	0.00	0.0	1.293

Table B17. Stratified mean numbers per tow at age of Georges Bank winter flounder caught in the NEFSC autumn research vessel bottom trawl surveys (offshore strata 13-22) during 1982-2000. A trawl door standardization coefficient of 1.46 has been applied to indices prior to 1985 to account for changes in catchability due to a change in trawl doors.

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10+	Total
1982	0.28	1.96	2.14	0.43	0.33	0.12	0.01	0.00	0.00	0.00	0.0	5.301
1983	0.08	0.06	0.58	1.13	0.49	0.05	0.19	0.08	0.03	0.00	0.0	2.726
1984	0.23	0.66	0.99	0.91	0.81	0.23	0.05	0.01	0.01	0.00	0.0	3.933
1985	0.10	0.32	0.99	0.41	0.07	0.02	0.02	0.00	0.00	0.00	0.0	1.979
1986	0.20	1.09	1.56	0.36	0.20	0.04	0.02	0.02	0.00	0.00	0.0	3.575
1987	0.00	0.05	0.20	0.21	0.12	0.00	0.07	0.06	0.02	0.00	0.0	0.762
1988	0.04	2.92	0.63	0.38	0.04	0.00	0.02	0.02	0.00	0.00	0.0	4.084
1989	0.02	0.09	1.06	0.07	0.14	0.07	0.05	0.00	0.02	0.00	0.0	1.560
1990	0.00	0.08	0.06	0.30	0.00	0.05	0.00	0.00	0.00	0.00	0.0	0.498
1991	0.10	0.04	0.00	0.06	0.05	0.00	0.00	0.00	0.00	0.00	0.0	0.268
1992	0.00	0.02	0.46	0.15	0.00	0.02	0.00	0.00	0.00	0.00	0.0	0.677
1993	0.00	0.59	0.13	0.24	0.17	0.02	0.00	0.00	0.00	0.00	0.0	1.166
1994	0.00	0.16	0.42	0.15	0.08	0.03	0.00	0.00	0.00	0.00	0.0	0.870
1995	0.01	0.96	0.89	0.36	0.04	0.04	0.00	0.00	0.01	0.00	0.0	2.357
1996	0.00	0.12	0.33	0.62	0.24	0.05	0.09	0.06	0.00	0.00	0.0	1.539
1997	0.01	0.07	0.68	0.57	0.29	0.06	0.02	0.00	0.00	0.00	0.0	1.744
1998	0.09	0.27	0.24	0.62	0.35	0.16	0.01	0.02	0.00	0.00	0.0	1.784
1999	0.01	0.38	0.78	0.34	0.32	0.60	0.08	0.02	0.02	0.00	0.0	2.595
2000	0.01	0.05	0.49	0.49	0.30	0.45	0.21	0.05	0.06	0.00	0.0	2.164

Table B18. Stratified mean numbers per tow at age of Georges Bank winter flounder in Canadian Spring research vessel bottom trawl surveys (strata 5Z1-5Z4). Indices of stratified mean number per tow at length were partitioned by age using NEFSC spring survey age keys. The 2000 and 2001 survey age keys were supplemented with quarter one commercial ages for fish greater than 48 and 39 cm in length, respectively.

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10+	Total
1987	0.00	0.00	0.11	0.21	0.64	0.27	0.00	0.00	0.00	0.00	0.0	1.241
1988	0.00	0.16	0.82	2.23	0.89	0.16	0.01	0.02	0.00	0.00	0.0	4.306
1989	0.00	0.08	1.96	1.00	0.71	0.22	0.05	0.00	0.00	0.00	0.0	4.050
1990	0.00	0.08	1.24	3.12	0.26	0.14	0.05	0.00	0.00	0.00	0.0	4.925
1991	0.00	0.06	0.33	0.40	0.93	0.20	0.02	0.00	0.00	0.00	0.0	1.984
1992	0.00	0.00	0.02	0.06	0.20	0.07	0.13	0.00	0.00	0.00	0.0	0.513
1993	0.00	1.18	0.66	0.97	0.41	0.03	0.17	0.06	0.00	0.00	0.0	3.529
1994	0.00	0.01	3.31	1.15	0.31	0.19	0.07	0.03	0.00	0.00	0.0	5.100
1995	0.00	1.57	2.45	1.27	0.21	0.08	0.00	0.01	0.00	0.00	0.0	5.630
1996	0.00	0.89	1.25	0.93	0.64	0.21	0.08	0.08	0.00	0.01	0.0	4.124
1997	0.00	0.00	0.98	1.57	1.55	0.39	0.01	0.01	0.02	0.01	0.0	4.579
1998	0.00	0.01	0.00	0.19	0.62	0.25	0.03	0.00	0.00	0.00	0.0	1.135
1999	0.00	0.05	0.24	0.23	0.40	0.23	0.05	0.01	0.00	0.00	0.0	1.247
2000	0.00	0.01	0.01	0.14	0.13	0.35	0.38	0.11	0.24	0.08	0.0	1.482
2001	0.00	0.31	0.20	0.36	0.41	0.30	0.29	0.31	0.04	0.02	0.0	2.276

Table B19. Estimates of instantaneous total mortality (Z) and fishing mortality (F) for Georges Bank winter flounder derived from NEFSC spring and autumn and Canadian spring research vessel bottom trawl survey data. Estimates were made using 3-year running sums of numbers at age.

	NEFSC Spring[2]		NEFSC Autumn[2]		Canadian Spring		Geometric Mean[3]	
	Z	F[1]	Z	F[1]	Z	F[1]	Z	F[1]
1981-83	0.382	0.182	0.409	0.209	----	---	0.395	0.195
1982-84	0.501	0.301	0.510	0.310	---	---	0.505	0.305
1983-85	1.144	0.944	0.848	0.648	---	---	0.985	0.785
1984-86	0.558	1.358	1.047	0.847	---	---	1.277	1.077
1985-87	1.350	1.150	1.463	1.263	---	---	1.405	1.205
1986-88	1.107	0.907	0.895	0.695	---	---	0.995	0.795
1987-89	1.067	0.867	0.906	0.706	---	---	0.984	0.784
1988-90	0.855	0.655	1.112	0.912	1.467	1.267	0.975	0.775
1989-91	0.802	0.602	1.079	0.879	1.265	1.065	0.930	0.730
1990-92	0.899	0.699	1.806	1.606	1.388	1.188	1.274	1.074
1991-93	1.247	1.047	0.834	0.634	1.042	0.840	1.020	0.820
1992-94	1.066	0.866	0.758	0.558	1.059	0.859	0.899	0.699
1993-95	0.891	0.691	0.752	0.552	0.922	0.722	0.819	0.619
1994-96	0.994	0.794	0.555	0.355	0.722	0.522	0.742	0.542
1995-97	1.388	1.188	0.648	0.448	0.712	0.512	0.948	0.748
1996-98	0.322	0.122	0.586	0.386	1.081	0.881	0.434	0.234
1997-99	0.119	-0.081	0.472	0.272	1.303	1.103	0.237	0.037
1998-2000	0.391	0.191	0.481	0.281	0.712	0.512	0.434	0.234

[1] Instantaneous natural mortality (M) assumed to be 0.20.

[2] Estimates derived from:

Spring: ln (∑ age 4+ for years i to j / ∑ age 5+ for years i+1 to j+1)

Autumn: ln (∑ age 3+ for years i-1 to j-1 / ∑ age 4+ for years i to j)

[3] Geometric mean computed from U.S. survey indices

Table B20. Proportion mature at age for female winter flounder sampled by the NEFSC spring research vessel survey from 1982 to 1998. Logistic regression equations and age at 50% maturation are presented annually and for data pooled across the entire time series.

		Age					Logistic Regression Coefficients		
Year	N	1	2	3	4	5	a	b	A_{50}
1982	23	0.00	0.44	1.00	1.00	1.00	18.30	9.04	2.02
1983	79	0.00	0.14	0.56	1.00	1.00	6.38	2.22	2.87
1984	54	0.00	0.80	1.00	0.93	0.93	17.70	9.54	1.85
1985	40	0.03	0.62	0.99	1.00	1.00	----	----	----
1986	39	0.00	1.00	1.00	1.00	1.00	19.83	13.59	1.46
1987	67	0.00	0.83	1.00	1.00	1.00	18.44	10.00	1.84
1988	42	0.00	0.13	0.95	1.00	1.00	11.88	4.96	2.39
1989	15	0.00	0.20	1.00	1.00	1.00	24.56	11.58	2.12
1990	43	0.00	0.44	1.00	1.00	1.00	23.80	11.79	2.02
1991	34	0.00	0.00	1.00	1.00	1.00	34.25	14.10	2.43
1992	31	0.00	0.54	0.78	1.00	1.00	3.28	1.64	2.00
1993	21	0.00	1.00	1.00	1.00	1.00	—	—	---
1994	30	0.00	0.79	0.86	1.00	1.00	3.49	2.16	1.62
1995	21	0.00	0.33	1.00	1.00	1.00	24.48	11.90	2.06
1996	43	0.00	0.76	1.00	1.00	1.00	18.23	9.70	1.88
1997	9	0.00	0.67		1.00	1.00	13.98	7.34	1.91
1998	10	0.00		1.00	1.00	1.00	—	—	---
1982-98	**561**	**0.00**	**0.62**	**0.92**	**0.99**	**1.00**	**3.99**	**2.18**	**1.83**

Table B21. Sequential history of ASPIC surplus production model runs for Georges Bank winter flounder.

	SAW 28 Run	SAW 28 Run	SAW 28 Update	Run 3[1]
Input Data	Total landings, 1964-1997 US Autumn survey, 1964-1997 US Spring survey, 1968-1998, lagged back one year CA Spring survey, 1987-1998, lagged back one year	Total landings, 1964-1997 US Autumn survey, 1964-1997 US Spring survey, 1968-1998, lagged back one year CA Spring survey, 1987-1998, lagged back one year	Total landings, 1964-2000 US Autumn survey, 1964-2000 US Spring survey, 1968-2001, lagged back one year CA Spring survey, 1987-2001, lagged back one year	Total landings, 1964-2000 US Autumn survey, 1964-2000 US Spring survey, 1968-2001, lagged back one year
CA survey strata	5Z1-8	5Z1-4	5Z1-4	
Total Objective Function	1.873	2.040	2.241	1.942
B coverage	0.802	0.824	0.785	0.917
B nearness	1.000	1.000	1.000	1.000
R^2 in CPUE				
U.S. Autumn Survey	0.323	0.319	0.316	0.340
U.S. Spring Survey	0.273	0.262	0.226	0.208
CA Spring Survey	0.508	-0.128	-0.537	-
B1 Ratio	0.551	0.603	0.585	0.582
r	0.538	0.520	0.508	0.646
F_{2000}			0.217	0.208
F_{msy}	0.269	0.260	0.254	0.323
B_{msy} (mt)	11,410	11,570	11,950	9,355
MSY (mt)	3,068	3,011	3,034	3,020

[1] Run 3 was used to re-estimate biological reference points and to evaluate stock status in 2000.

Table B22. Estimates of fishing mortality, biomass (000s mt), and surplus production (000s mt) from an ASPIC surplus production model (Run 3) for the Georges Bank winter flounder stock during 1964-2000.

Year	Estimated Total Fishing Mortality	Estimated Starting Biomass (000s mt)	Estimated Average Biomass (000s mt)	Observed Total Yield (000s mt)	Estimated Surplus Production (000s mt)	Ratio of F to FMSY	Ratio of B to BMSY
1964	0.253	5.447	6.005	1.517	2.629	0.783	0.582
1965	0.236	6.559	7.147	1.687	2.848	0.731	0.701
1966	0.271	7.720	8.116	2.197	2.965	0.839	0.825
1967	0.266	8.488	8.831	2.349	3.009	0.824	0.907
1968	0.207	9.148	9.674	2.001	3.013	0.641	0.978
1969	0.242	10.160	10.400	2.518	2.981	0.750	1.086
1970	0.253	10.620	10.750	2.719	2.953	0.784	1.136
1971	0.410	10.860	10.210	4.183	2.990	1.269	1.161
1972	0.510	9.665	8.852	4.512	3.005	1.579	1.033
1973	0.365	8.158	8.155	2.976	2.970	1.131	0.872
1974	0.259	8.152	8.554	2.218	2.996	0.803	0.871
1975	0.327	8.930	8.971	2.937	3.015	1.014	0.955
1976	0.197	9.008	9.590	1.889	3.014	0.610	0.963
1977	0.366	10.130	9.823	3.594	3.011	1.133	1.083
1978	0.345	9.551	9.429	3.250	3.020	1.068	1.021
1979	0.330	9.320	9.297	3.064	3.020	1.021	0.996
1980	0.454	9.276	8.758	3.975	3.005	1.406	0.992
1981	0.519	8.306	7.725	4.012	2.925	1.609	0.888
1982	0.417	7.219	7.152	2.980	2.852	1.291	0.772
1983	0.606	7.091	6.459	3.911	2.726	1.876	0.758
1984	0.776	5.907	5.068	3.933	2.379	2.404	0.631
1985	0.498	4.352	4.347	2.165	2.155	1.543	0.465
1986	0.392	4.342	4.564	1.788	2.227	1.214	0.464
1987	0.587	4.781	4.547	2.671	2.222	1.820	0.511
1988	0.741	4.332	3.863	2.861	1.977	2.294	0.463
1989	0.557	3.448	3.398	1.892	1.795	1.725	0.369
1990	0.604	3.351	3.234	1.954	1.727	1.872	0.358
1991	0.605	3.124	3.025	1.830	1.637	1.874	0.334
1992	0.671	2.931	2.759	1.850	1.518	2.077	0.313
1993	0.692	2.599	2.435	1.684	1.367	2.142	0.278
1994	0.390	2.283	2.490	0.972	1.393	1.209	0.244
1995	0.241	2.704	3.155	0.760	1.691	0.746	0.289
1996	0.336	3.635	3.975	1.336	2.020	1.041	0.389
1997	0.301	4.318	4.744	1.430	2.284	0.934	0.462
1998	0.230	5.173	5.792	1.335	2.577	0.714	0.553
1999	0.142	6.415	7.329	1.042	2.869	0.440	0.686
2000	0.208	8.242	8.843	1.839	3.007	0.644	0.881

Table B23. Results from a retrospective analysis of an ASPIC surplus production model (Run 3) for Georges Bank winter flounder.

Terminal Year	1995	1996	1997	1998	1999	2000
Total Objective Function	1.676	1.711	1.804	1.827	1.835	1.942
B coverage	1.058	1.015	0.883	0.935	0.962	0.917
B nearness	1.000	1.000	1.000	1.000	1.000	1.000
R^2 in CPUE						
U.S. Autumn Survey	0.340	0.338	0.329	0.336	0.342	0.340
U.S. Spring Survey	0.203	0.221	0.258	0.241	0.247	0.208
B1 Ratio	0.590	0.573	0.569	0.565	0.553	0.582
r	0.847	0.790	0.613	0.684	0.729	0.646
F_{msy}	0.423	0.395	0.307	0.342	0.365	0.323
B_{msy} (mt)	7,206	7,697	9,886	8,870	8,343	9,355
MSY (mt)	3,050	3,041	3,031	3,032	3,041	3,020
B_{1995}/B_{MSY}	0.333	0.316	0.272	0.286	0.288	0.289
F_{1995}/F_{MSY}	0.600	0.646	0.802	0.742	0.726	0.746

Table B24. Virtual Population Analyses (VPA) sensitivity runs pertaining to Georges Bank winter flounder for estimated ages 2-6 during 1982-2000.

	Base Run	Run 2	Run 3	Run 4
Catch at Age	Observer data only in 1999	Observer data only in 1999	Observer data only in 1999	Observer data only in 1999
Survey Tuning Indices	US spring, ages 1-7 CA spring, ages 1-7 US autumn, ages 2-7, lagged	US spring, ages 1-7 CA spring, ages 4-7 US autumn, ages 3-6, lagged	US spring, ages 1-7 US autumn, ages 2-7, lagged	US spring, ages 1-7

Mean Square Residual	1.03197	0.66895	0.78429	0.56738

CV (%)

N age 2	47	60	53	55
N age 3	43	45	44	49
N age 4	51	43	51	64
N age 5	36	31	36	46
N age 6	33	28	34	43

2000 F_{4-6}	0.35	0.32	0.29	0.36
1997 F_{4-6}	0.86	0.85	0.82	0.89

2000 Biomass (mt)	5,162	6,322	6,889	5,789

Table B25. Stock size (numbers, thousands) and fishing mortality rates, during 1982-2001, of Georges Bank winter flounder estimated from a Virtual Population Analysis (Run 2).

Stock numbers (January 1, thousands)

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1	4,627	2,725	6,089	5,962	8,025	5,293	8,964	5,150	3,286	4,211	2,317	2,210	4,058	7,192	7,577	3,591	5,149	5,206	812	0
2	8,236	3,788	2,222	4,985	4,863	6,570	4,333	7,339	4,216	2,690	3,447	1,897	1,776	3,322	5,650	6,203	2,940	4,209	4,258	665
3	6,532	6,424	2,389	1,564	3,353	3,380	4,208	2,792	4,759	3,185	1,667	2,102	1,281	972	2,106	3,959	4,645	2,306	3,158	3,048
4	3,382	3,803	2,634	1,440	654	1,544	1,246	936	1,180	2,059	1,459	680	686	522	554	1,211	2,233	2,517	1,478	1,426
5	1,263	1,821	1,799	916	445	322	451	258	305	362	825	536	149	339	257	236	458	1,259	1,771	781
6	762	572	992	198	306	157	143	191	78	83	173	252	150	61	210	69	74	306	867	1,192
7	822	1,453	1,406	175	204	211	146	106	28	131	113	71	133	65	165	66	36	80	460	791
1+	25,624	20,586	17,530	15,240	17,849	17,478	19,493	16,772	13,853	12,721	10,002	7,749	8,233	12,474	16,519	15,335	15,535	15,883	12,804	7,904

Fishing Mortality

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.00	0.00	0.00	0.00	0.00
2	0.05	0.26	0.15	0.20	0.16	0.25	0.24	0.23	0.08	0.28	0.29	0.19	0.40	0.26	0.16	0.09	0.04	0.09	0.13
3	0.34	0.69	0.31	0.67	0.58	0.80	1.30	0.66	0.64	0.58	0.70	0.92	0.70	0.36	0.35	0.37	0.41	0.24	0.59
4	0.42	0.55	0.86	0.97	0.51	1.03	1.38	0.92	0.98	0.71	0.80	1.32	0.50	0.51	0.65	0.77	0.37	0.15	0.44
5	0.59	0.41	2.00	0.90	0.84	0.61	0.66	1.00	1.10	0.54	0.99	1.08	0.69	0.28	1.12	0.96	0.20	0.17	0.20
6	0.47	0.51	1.23	0.97	0.64	0.97	1.17	0.96	1.04	0.70	0.89	1.26	0.54	0.42	0.80	0.82	0.34	0.16	0.32
7	0.47	0.51	1.23	0.97	0.64	0.97	1.17	0.96	1.04	0.70	0.89	1.26	0.54	0.42	0.80	0.82	0.34	0.16	0.32
Average F (4-6)	0.49	0.49	1.36	0.95	0.66	0.87	1.07	0.96	1.04	0.65	0.89	1.22	0.58	0.40	0.86	0.85	0.31	0.16	0.32

Table B26. Mean biomass (mt) and spawning stock biomass (mt), during 1982-2000, of Georges Bank winter flounder estimated from a Virtual Population Analysis (Run 2).

Mean Biomass

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	839	446	1,104	906	1,455	959	1,625	934	596	763	420	496	736	1,808	1,374	651	933	1,250	147
2	2,056	847	547	1,667	1,623	2,047	1,227	2,150	1,677	896	1,058	603	503	1,051	1,964	1,955	676	1,822	1,531
3	2,250	1,917	876	543	1,423	1,176	1,110	865	1,644	1,070	544	679	462	444	993	1,610	1,591	1,003	1,015
4	1,967	1,788	953	662	364	771	477	466	530	953	686	266	437	247	337	543	840	1,692	610
5	908	1,227	541	584	285	245	348	162	170	252	438	286	110	269	157	142	258	1,136	1,498
6	682	406	471	160	246	113	103	150	60	79	126	172	141	59	191	62	65	398	921
7	969	1,395	948	178	218	215	140	109	33	152	102	71	154	82	182	77	27	124	599
1+	9,671	8,026	5,439	4,698	5,613	5,526	5,031	4,836	4,707	4,164	3,373	2,572	2,542	3,960	5,196	5,039	4,389	7,425	6,322

Spawning Stock Biomass

Age	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	39	19	43	32	58	40	67	34	23	30	17	22	29	83	56	32	36	51	5
2	1,128	526	307	847	756	1,078	679	1,168	777	456	562	314	312	550	1,161	1,016	412	739	838
3	2,177	1,957	795	523	1,456	1,322	1,411	964	1,761	1,306	647	783	500	420	946	1,693	1,710	738	1,209
4	2,261	1,861	1,141	716	375	915	612	506	576	1,071	746	320	428	283	357	681	1,065	1,439	681
5	1,197	1,405	849	600	337	264	395	191	222	282	542	362	120	302	175	186	305	888	1,500
6	785	525	694	165	301	145	137	195	76	86	157	212	151	68	214	73	74	305	986
7	1,209	1,758	1,393	248	283	300	204	153	46	200	139	104	196	101	245	104	33	143	720
1+	8,795	8,050	5,223	3,131	3,565	4,064	3,504	3,211	3,481	3,431	2,810	2,118	1,735	1,807	3,154	3,786	3,635	4,302	5,940

Table B27. Summary of target and threshold biomass (kg/tow) and fishing mortality rate proxies for the current and proposed control rules, derived from ASPIC surplus production models, for Georges Bank winter flounder.

	Target Biomass Proxy (kg/tow)	Threshold Biomass Proxy (kg/tow)	Target Fishing Mortality Proxy	Threshold Fishing Mortality Proxy
Proposed	2.49	1.24	0.91	1.21
Current	2.73	1.37	0.84	1.13

Table B28. Annual relative exploitation rates (catch/autumn survey biomass index), during 1964-2000, for Georges Bank winter flounder.

Year	Landings (000s kg)	Autumn Survey (kg/tow)	Exploitation Index (catch/survey index)
1964	1.517	1.822	0.833
1965	1.687	2.050	0.823
1966	2.197	5.655	0.389
1967	2.349	2.074	1.133
1968	1.999	1.072	1.865
1969	2.518	2.385	1.056
1970	2.716	6.490	0.418
1971	4.183	1.259	3.322
1972	4.512	1.580	2.856
1973	2.976	1.195	2.490
1974	2.218	1.464	1.515
1975	2.937	2.061	1.425
1976	1.893	3.925	0.482
1977	3.594	3.992	0.900
1978	3.250	3.100	1.048
1979	3.064	3.829	0.800
1980	3.975	1.865	2.131
1981	4.012	2.434	1.648
1982	2.980	2.692	1.107
1983	3.908	2.363	1.654
1984	3.931	2.445	1.608
1985	2.163	1.119	1.933
1986	1.787	2.178	0.820
1987	2.669	0.889	3.002
1988	2.859	1.273	2.246
1989	1.891	1.051	1.799
1990	1.953	0.346	5.645
1991	1.828	0.136	13.441
1992	1.849	0.384	4.815
1993	1.683	0.663	2.538
1994	0.972	0.578	1.682
1995	0.760	1.337	0.568
1996	1.336	1.756	0.761
1997	1.430	1.534	0.932
1998	1.336	1.565	0.854
1999	1.042	2.641	0.395
2000	1.838	2.660	0.690

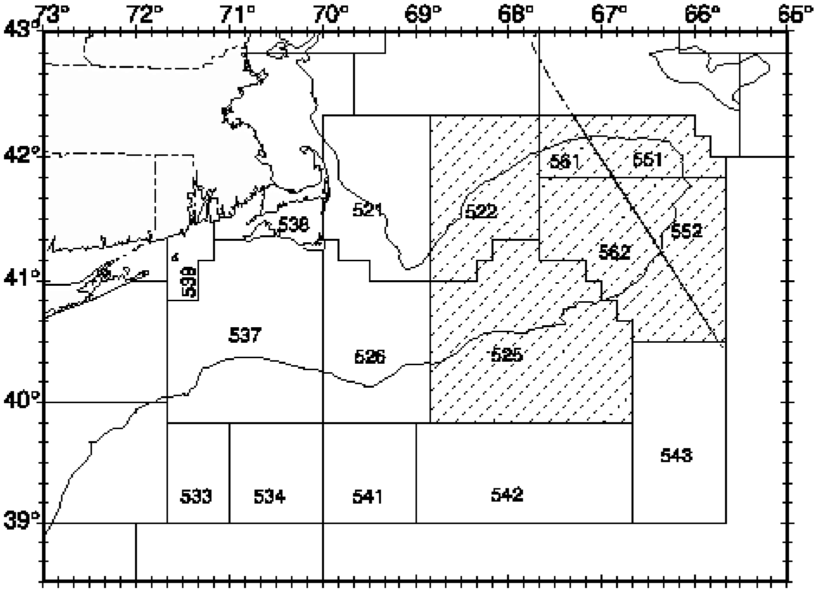


Figure B1. NEFSC statistical areas included in the Georges Bank Winter flounder stock assessment.

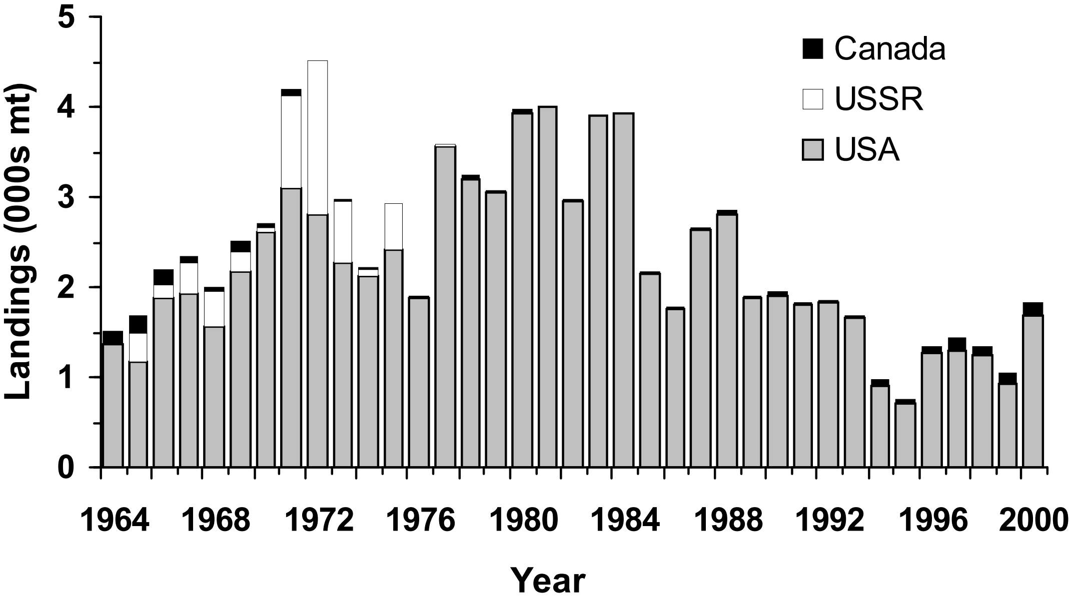


Figure B2. Commercial landings of winter flounder from the Georges Bank stock (U. S. statistical areas 522, 525, 551-562) during 1964-2000.

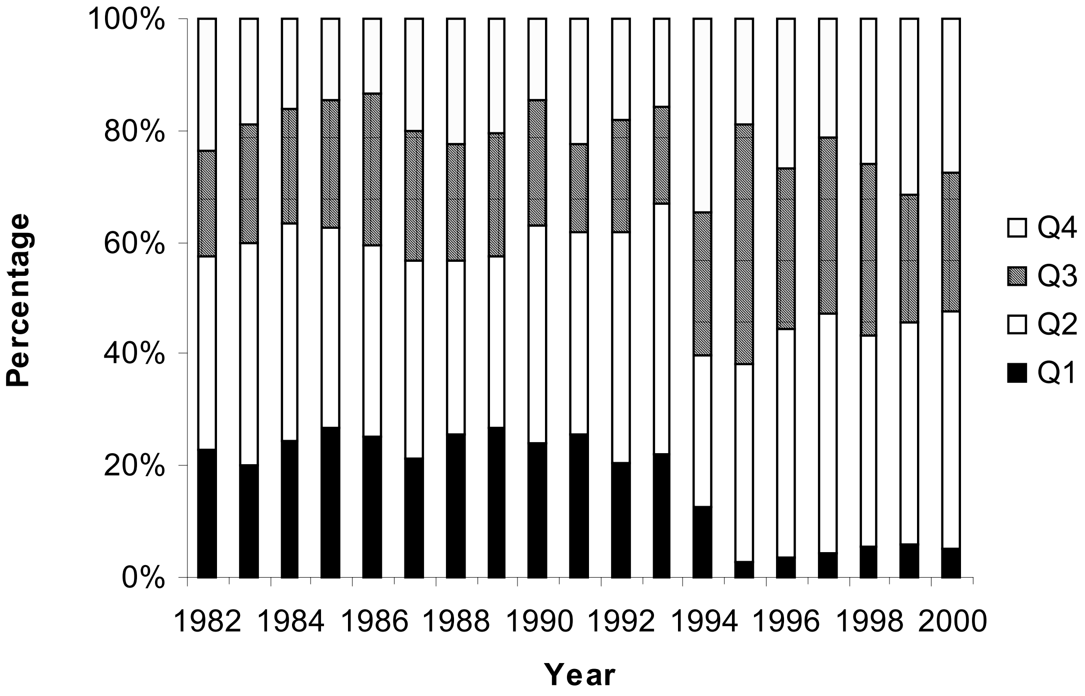


Figure B3. Percentage of USA landings (mt) of Georges Bank winter flounder, by quarter, during 1982-2000.

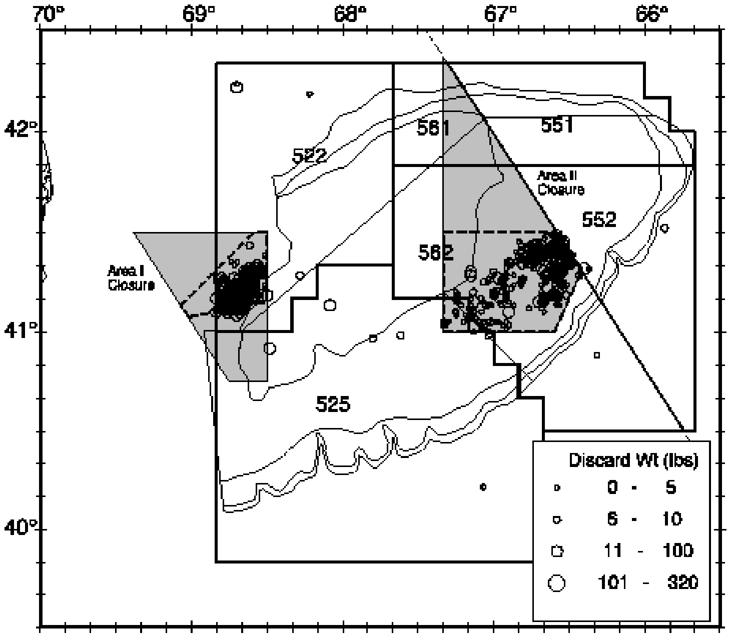


Figure B4. Discard weight for Scallop dredge observed tows in closed areas during 2000.

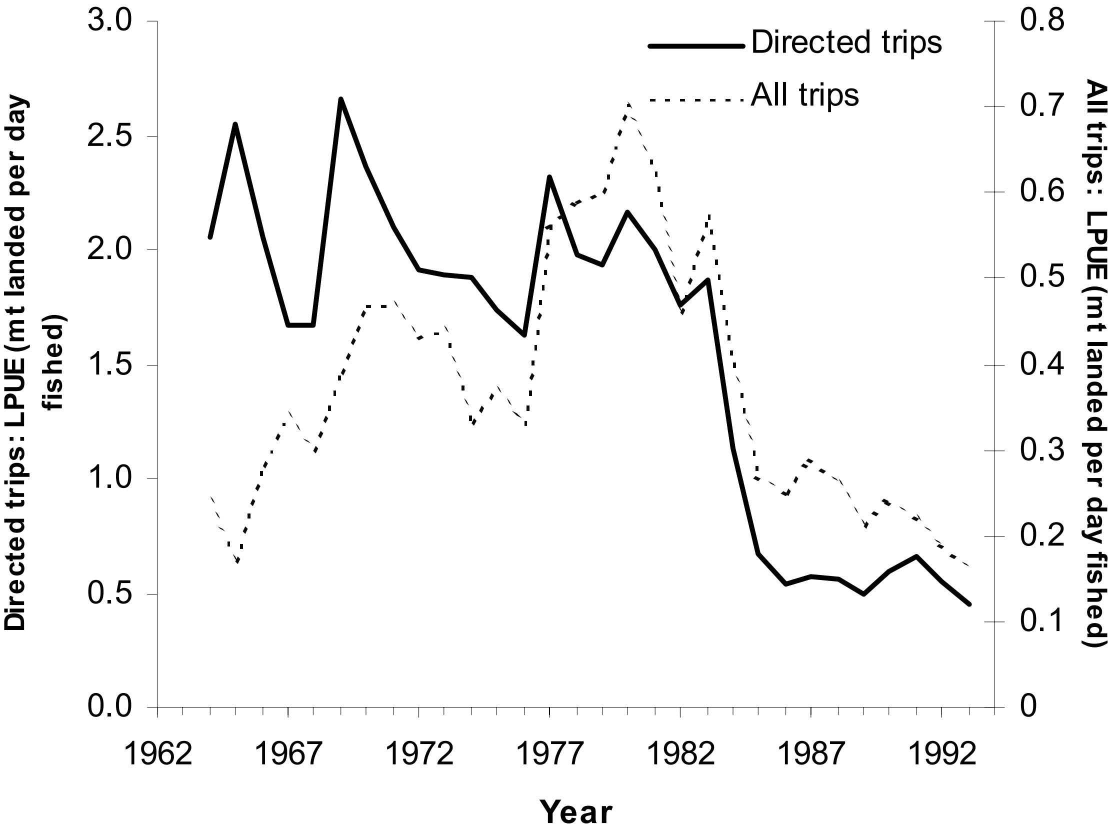


Figure B5. Trends in nominal LPUE (mt landed per day fished) for all otter trawl trips that landed winter flounder and for directed trips (landings of winter flounder greater than or equal to 50% by weight) during 1964-1993.

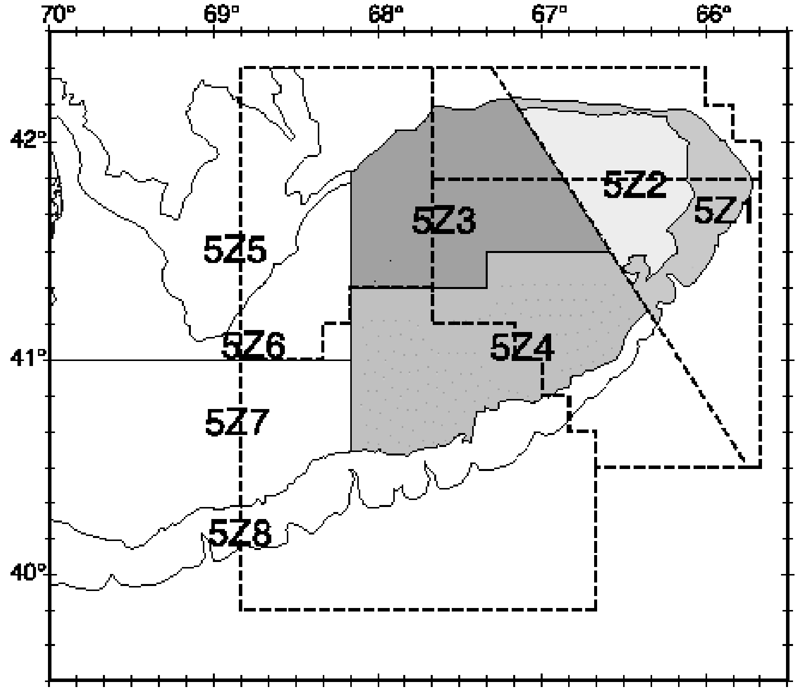


Figure B6. NEFSC offshore survey strata (13-22) located within the Georges Bank Winter flounder stock boundary (dashed line).

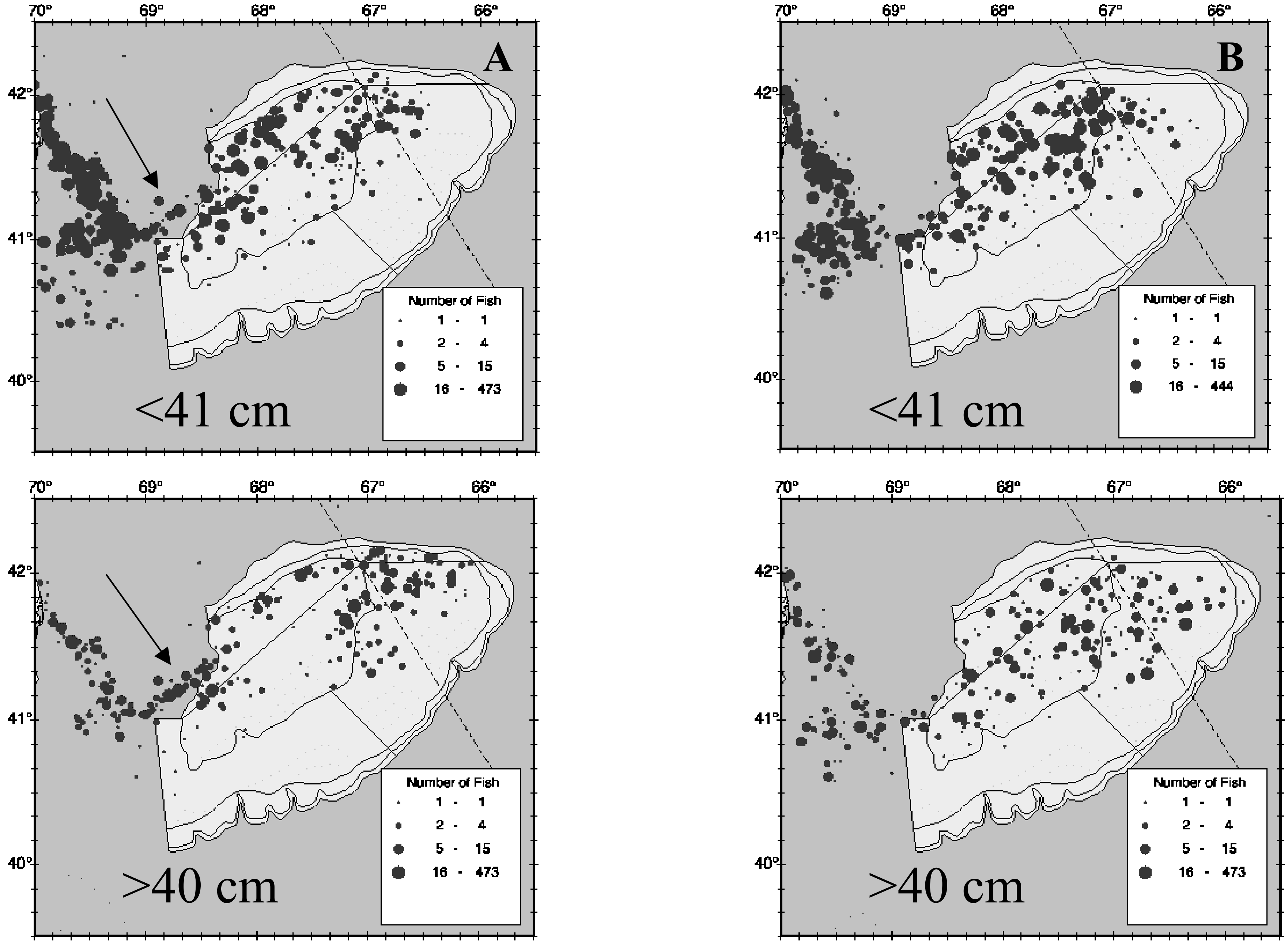


Figure B7. Distribution of Georges Bank winter flounder during the (A) autumn and (B) spring NEFSC research surveys, 1982-2000.

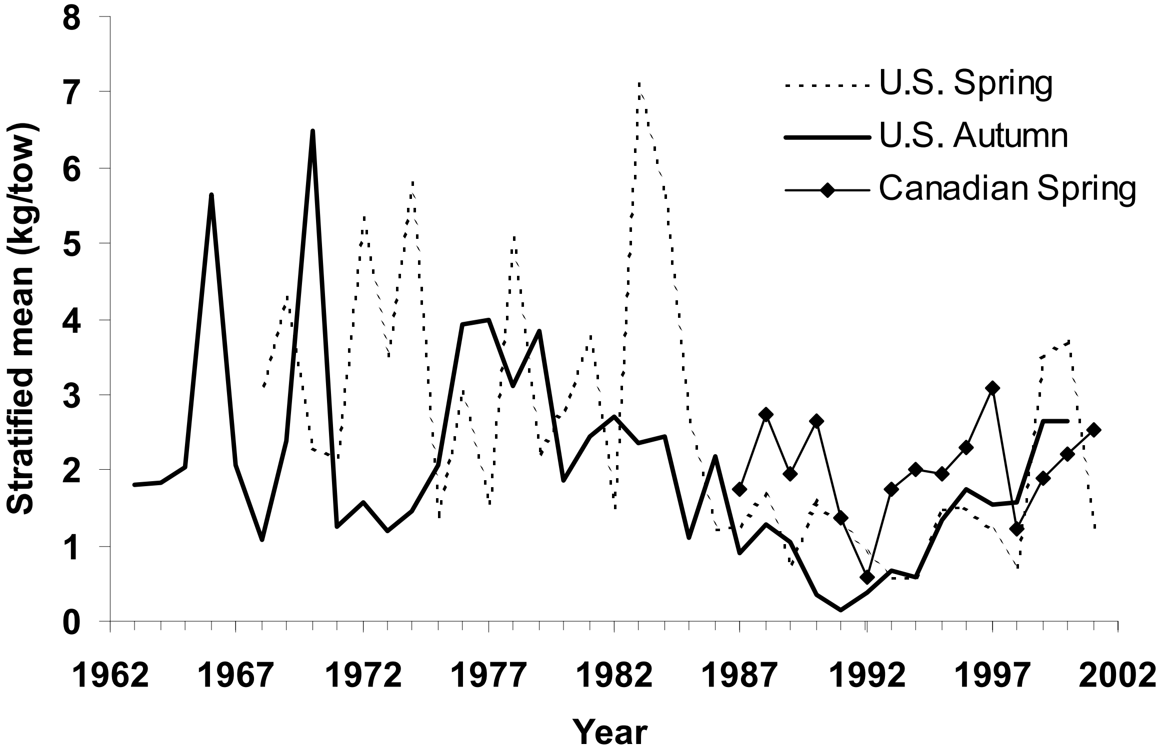


Figure B8. Relative abundance (number/tow) (A) and biomass (kg/tow) (B) indices from the NEFSC spring (1968-2001) and autumn (1963-2000) research vessel bottom trawl surveys and the Canadian spring surveys (1987-2001). U.S. indices include offshore strata 13-22 and Canadian indices include strata 5Z1-Z4.

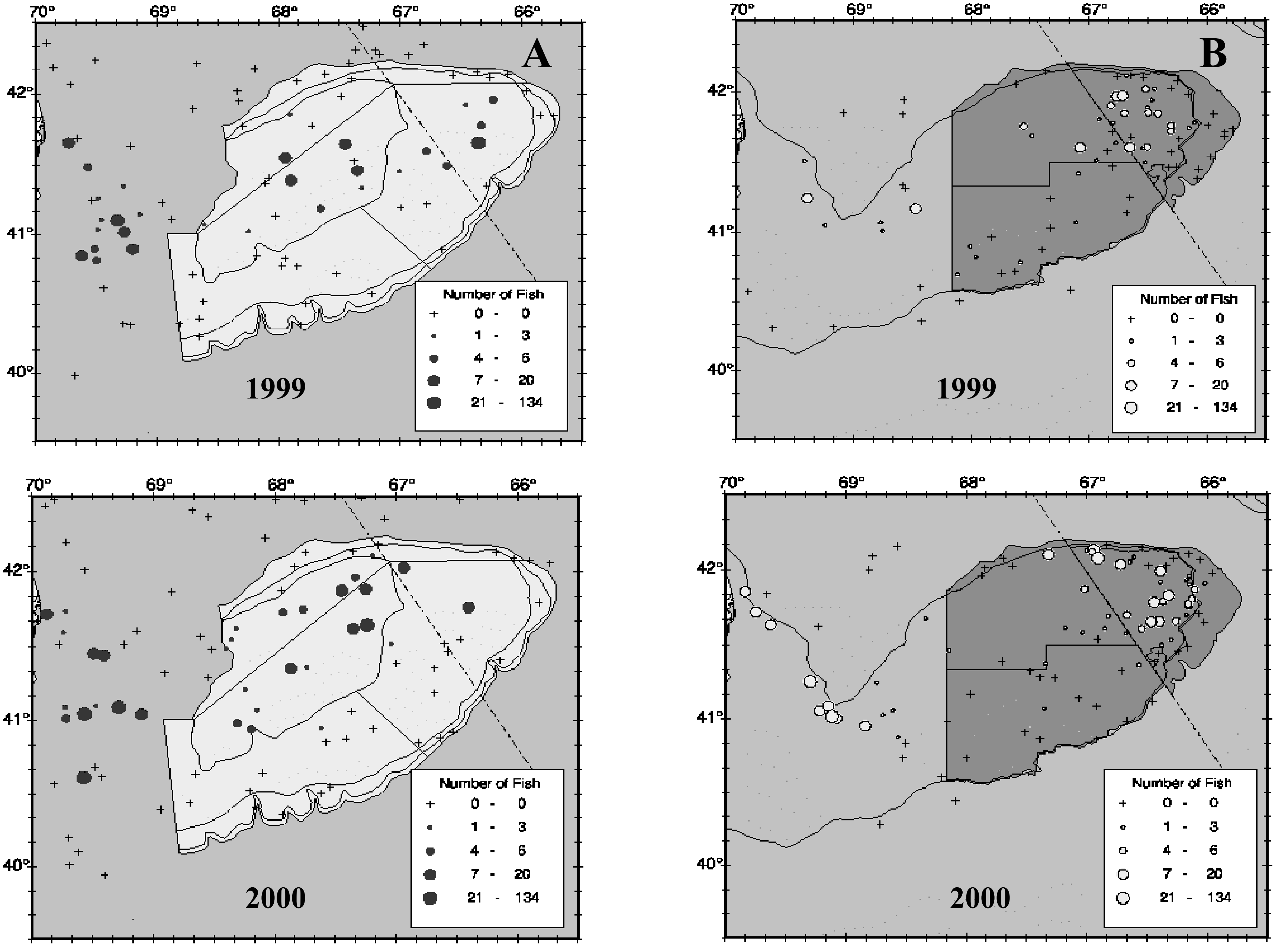


Figure B9. Distribution of Georges Bank winter flounder caught in the (A) NEFSC and B) Canadian spring bottom trawl surveys during 1999 and 2000.

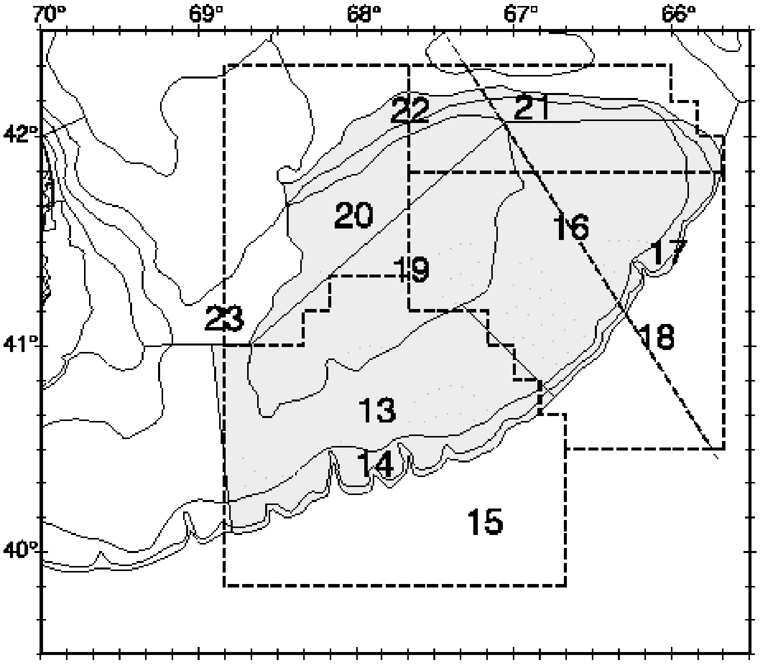


Figure B10. Canadian spring survey strata (5Z 1-4) located entirely within the Georges Bank winter flounder stock boundary (dashed line).

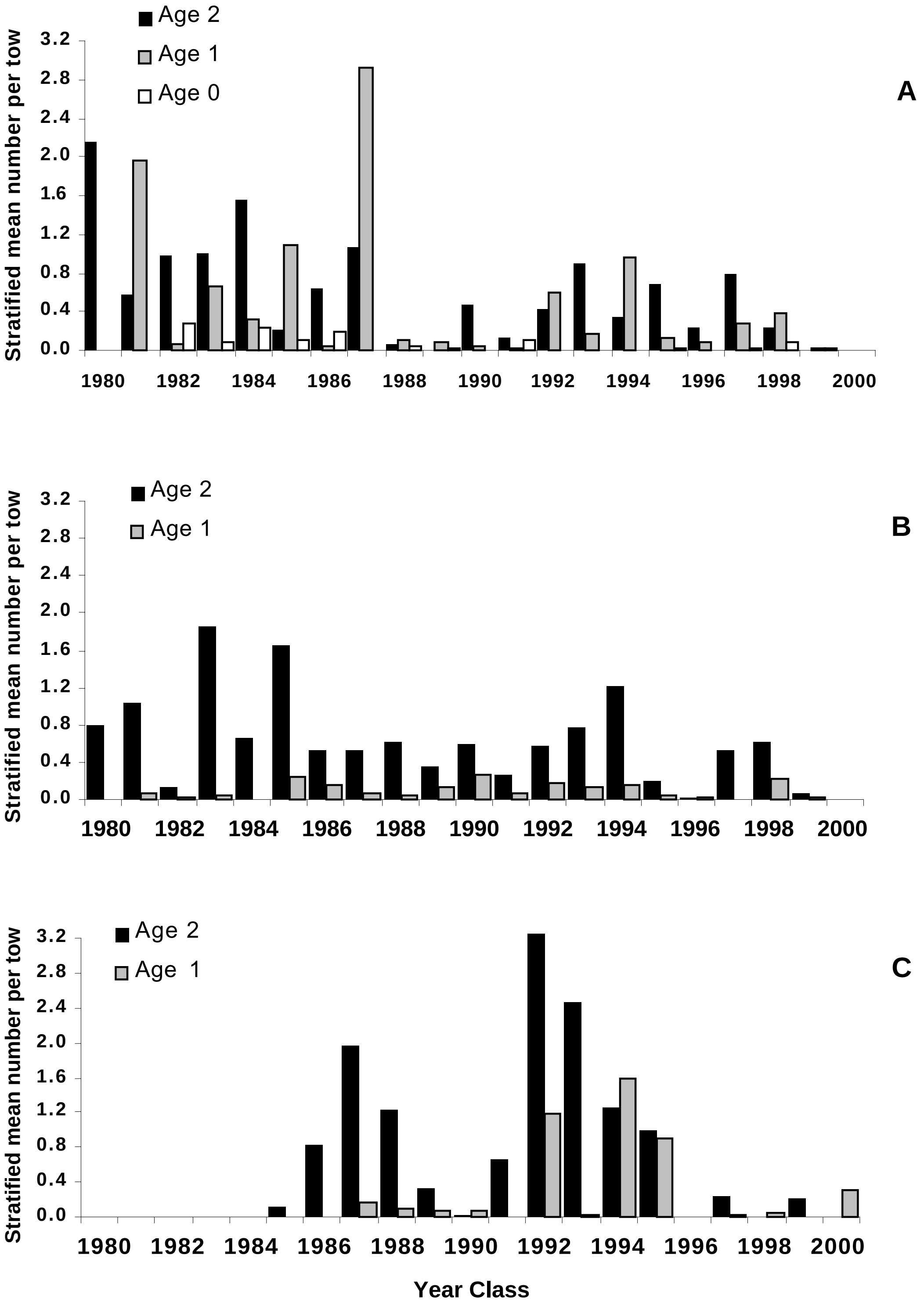


Figure B11. Recruitment in the NEFSC (A) autumn and (B) spring bottom trawl surveys (offshore strata 13-22, 1980-2000) and the (C) Canadian spring bottom trawl surveys (strata 5Z1-4, 1985-2000).

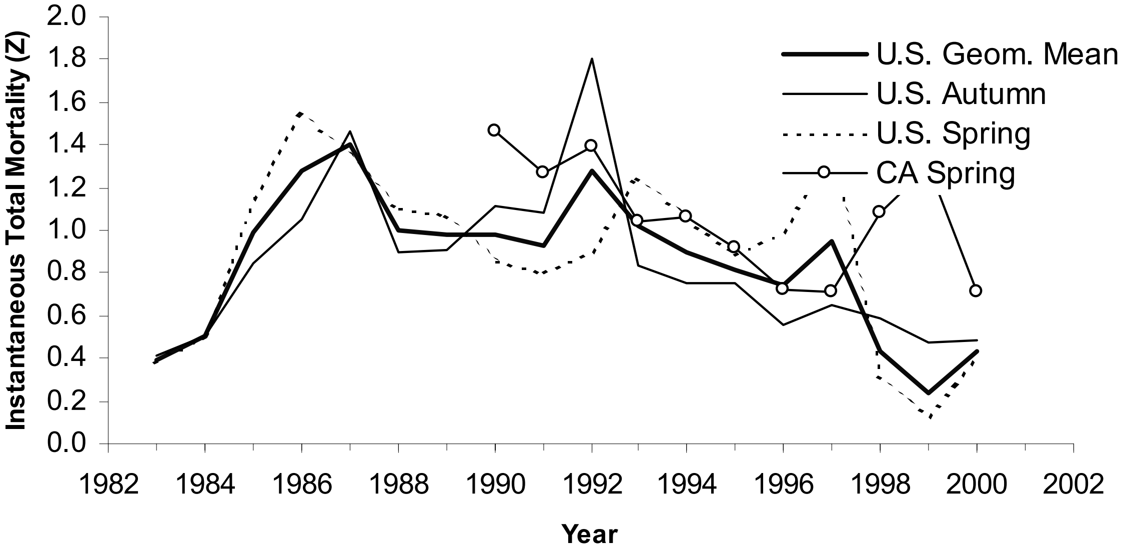


Figure B12. Trends in three-year moving averages of instantaneous total mortality (Z) of Georges Bank winter flounder derived from U.S. autumn and spring (1980-2000) and Canadian Spring (1987-2000) research vessel bottom trawl surveys during 1980-2000.

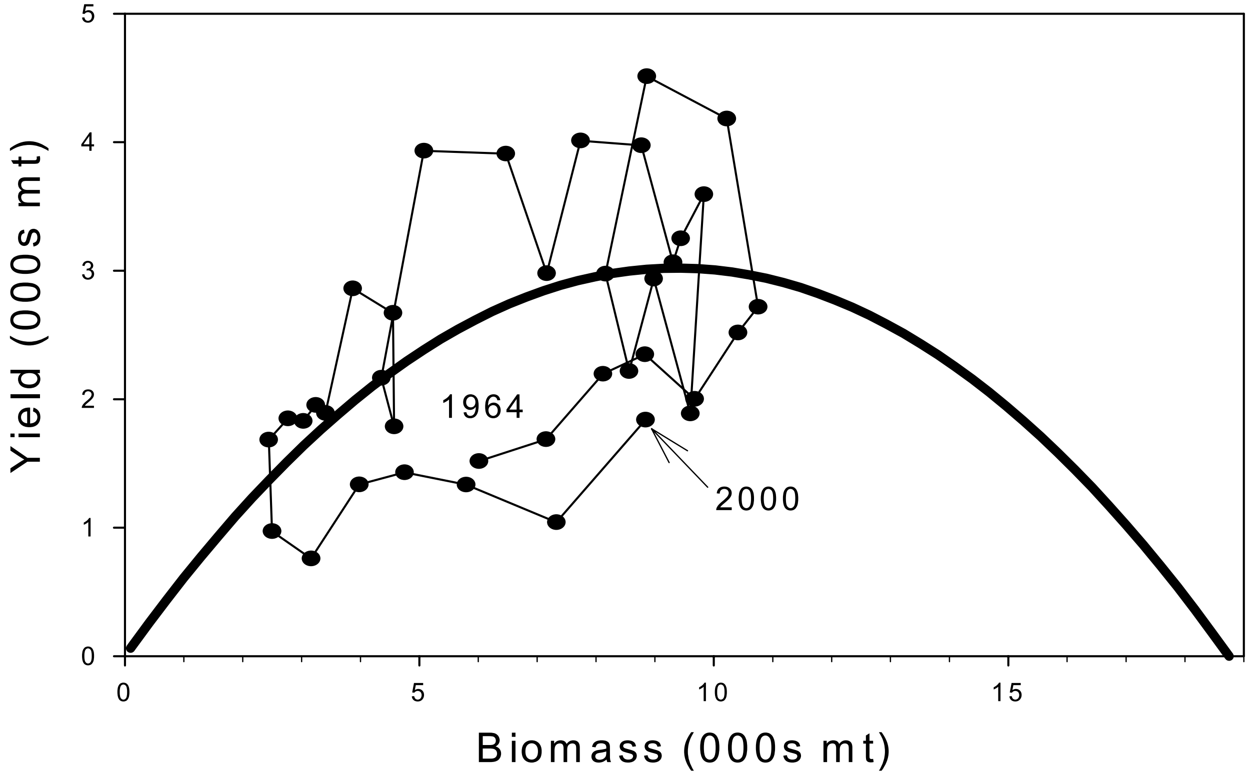


Figure B13. Time trajectory of yield from the Georges Bank winter flounder stock relative to the surplus production curve estimated from an ASPIC surplus production model.

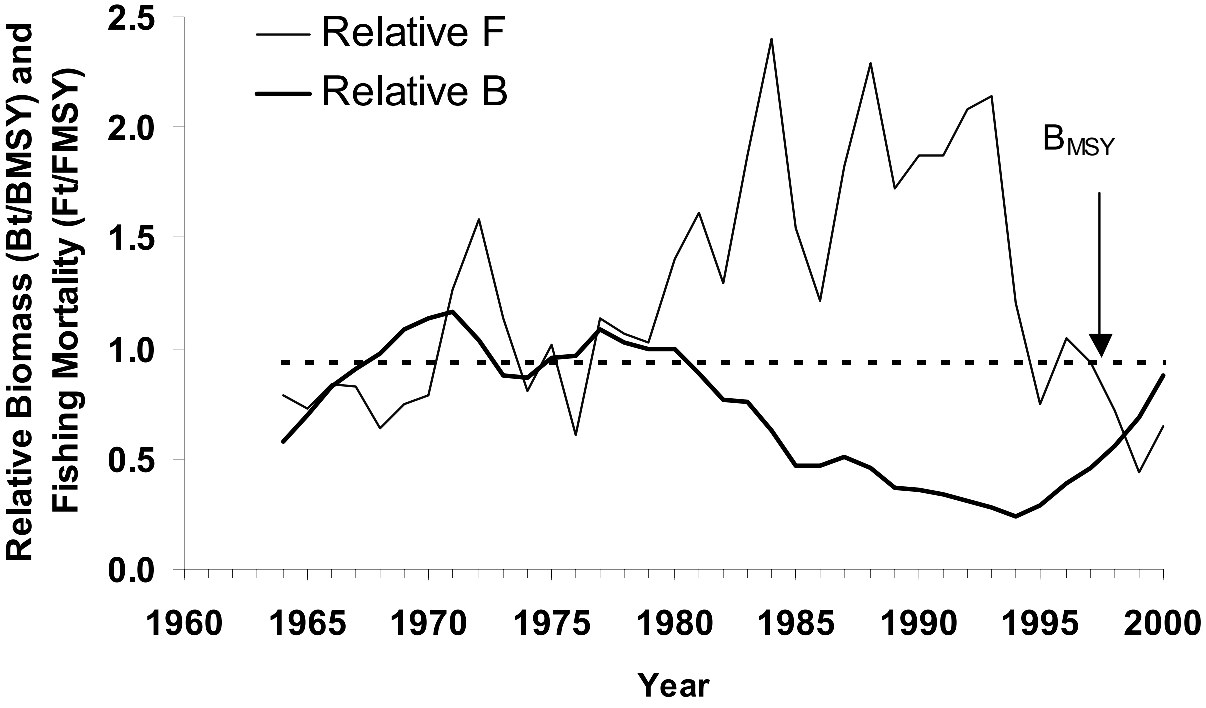


Figure B14. Trends in relative biomass (B_t/B_{MSY}) and relative fishing mortality rates (Ft/FMSY) estimated from an ASPIC surplus production model, for Georges Bank winter flounder, during 1964-2000.

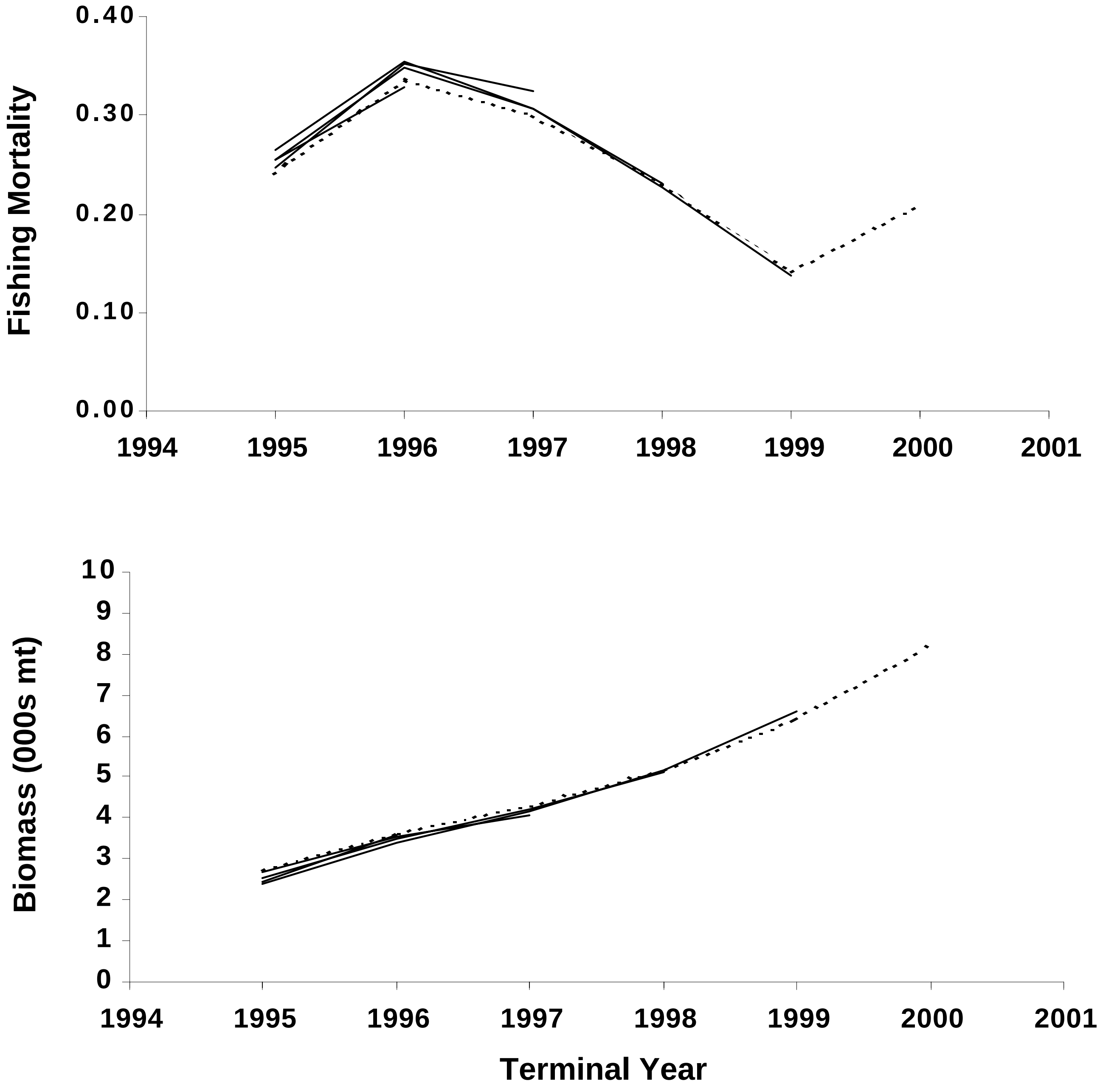


Figure B15. Retrospective patterns in (A) average fishing mortality and (B) stock biomass, during terminal years 1995-2000, from an ASPIC surplus production model (Run 3) for Georges Bank winter flounder.

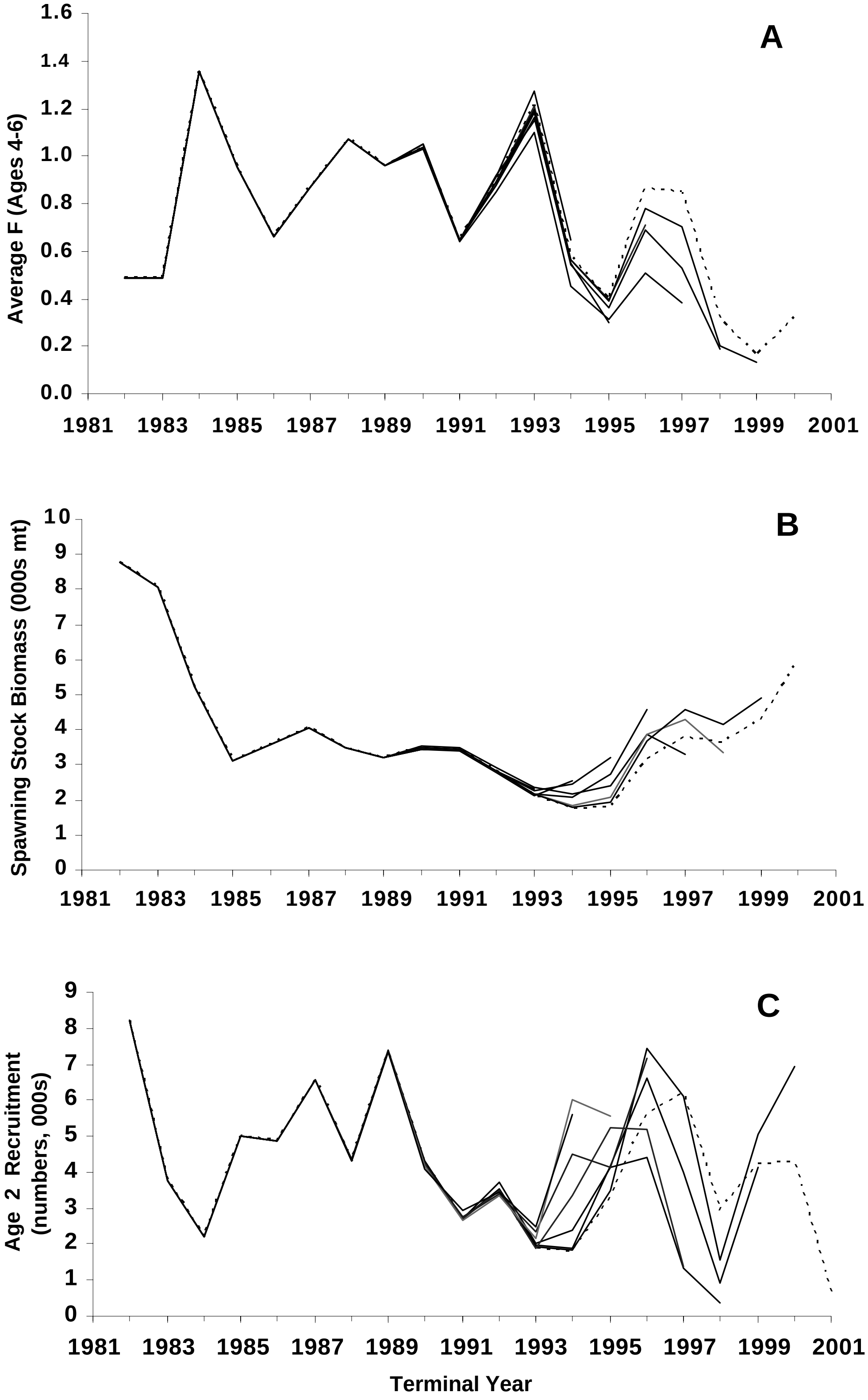


Figure B16. Retrospective patterns in (A) average fishing mortality rates, (B) spawning stock biomass and (C) age 2 recruitment from Run 2 of a Virtual Population Analysis of Georges Bank winter flounder for terminal years 1982-2000.

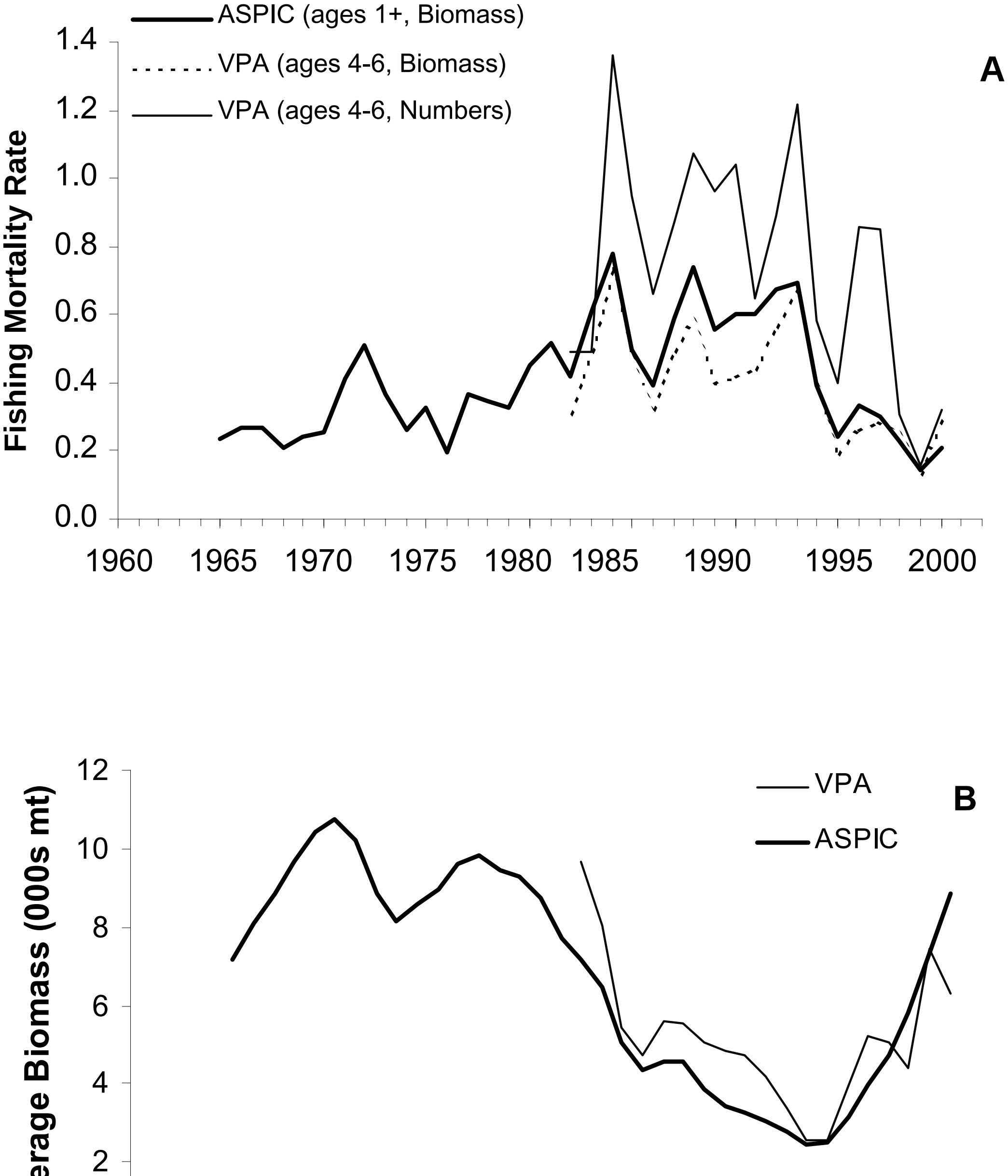


Figure B17. Trends in (A) fishing mortality rates and (B) biomass from an ASPIC surplus production model (1964-2000) and a VPA model (1982-2001). Biomass estimates from both models are for ages 1+.

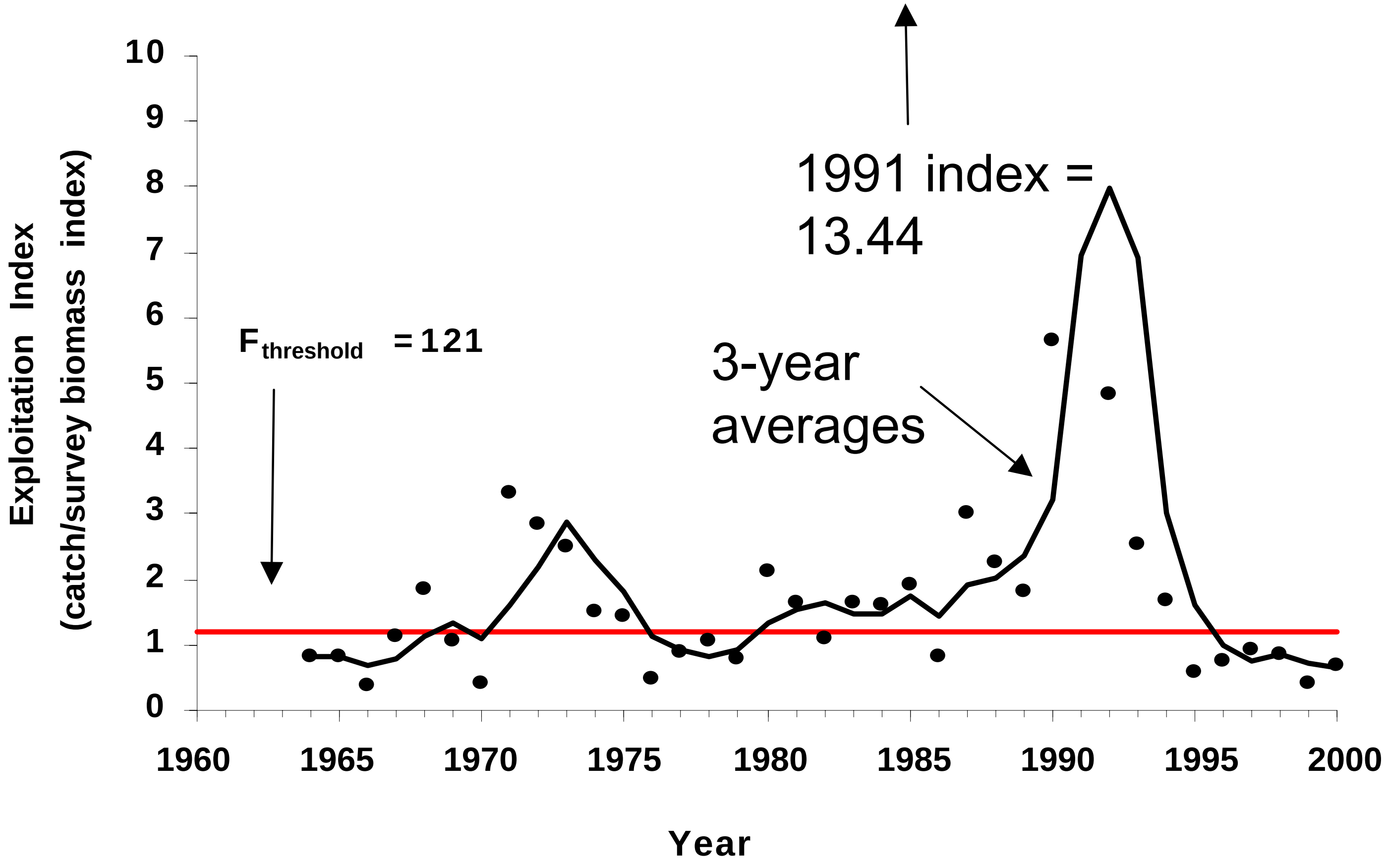


Figure B18. Trends in annual and 3-year average relative exploitation indices (catch/autumn survey biomass index) of Georges Bank winter flounder during 1964-2000.

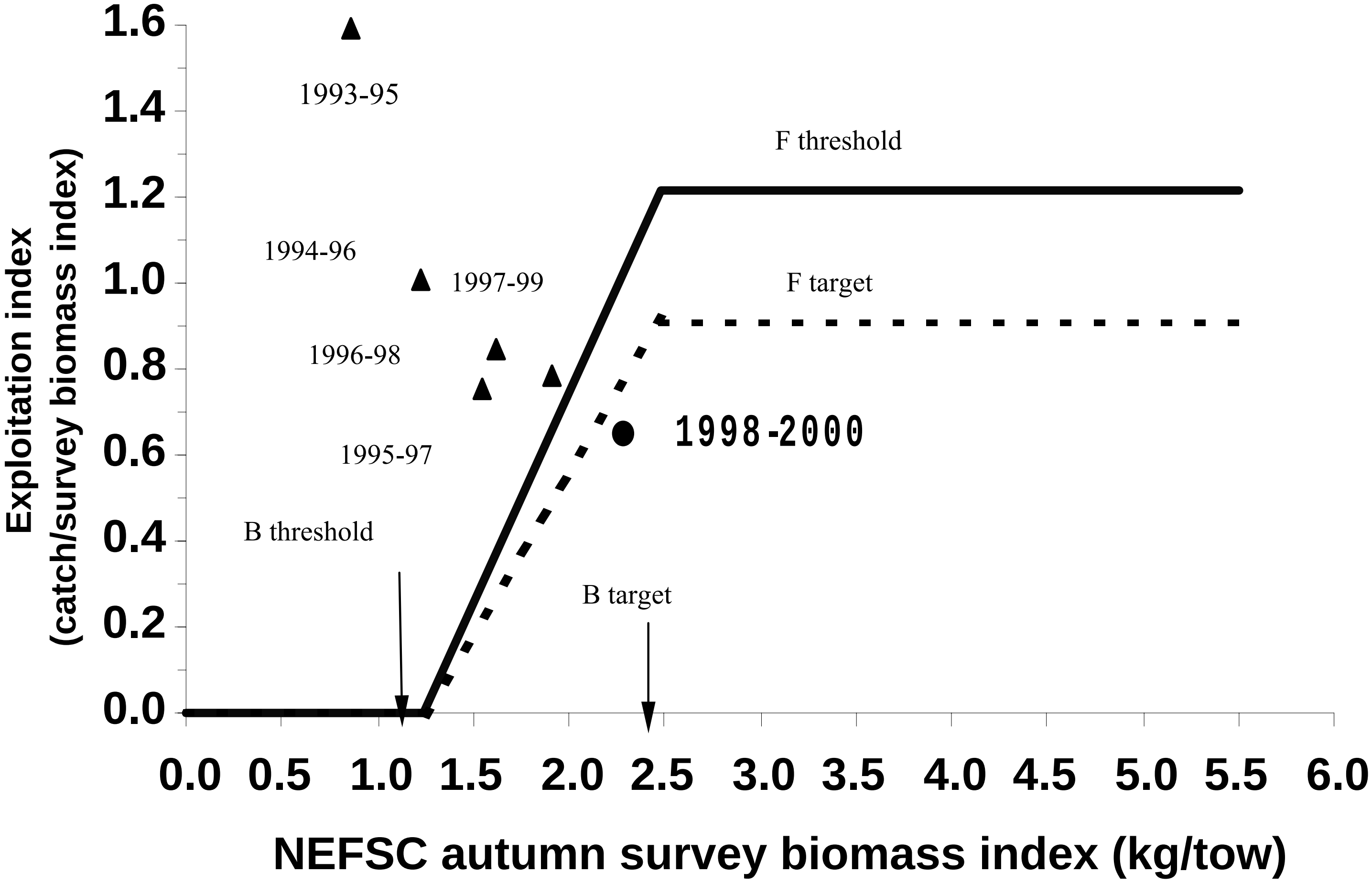


Figure B19. Revised overfishing control rule and three-year average exploitation and survey biomass indices.

C. GOOSEFISH

TERMS OF REFERENCE

The following terms of reference were addressed for goosefish:

1. Summarize results of cooperative NEFSC-industry goosefish survey conducted during 2001.

2. Update fishery-independent information from SARC 31 assessment.

3. Update commercial fishery data, including landings and discard sampling information.

4. Evaluate stock status relative to reference points.

INTRODUCTION

Goosefish fisheries are managed in the Exclusive Economic Zone (EEZ) through a joint New England Fishery Management Council - Mid-Atlantic Fishery Management Council Monkfish Fishery Management Plan (FMP). The overfishing definition for goosefish is:

> *Monkfish in the northern and southern management areas are defined as being overfished when the three-year moving average autumn survey weight per tow falls below the 33rd percentile of the time series, 1963-1994, or when fishing mortality exceeds* $F_{threshold}$. *Monkfish are in danger of becoming overfished when the three-year moving average autumn survey weight per tow falls below the median of the three-year moving average during 1965-1981 and when fishing mortality is between* F_{target} *and* $F_{threshold}$.
>
> *For the northern and southern areas,* $F_{threshold}$ *is based on conditions of stock stability at high abundance, calculated at the fishing mortality rate that prevailed during 1970-1979.* F_{target} *for the southern area is* $F_{0.1}$. *For the northern area,* F_{target} *is currently undefined.*

There are currently two assessment units for goosefish which are based on differences in the temporal pattern of recruitment (NEFSC survey indices for 10-20 cm goosefish), the spatial and temporal distribution of all sizes of goosefish in NEFSC surveys, perceived differences in growth patterns, and differences in the contribution of fishing gear types (mainly trawl, gill net, and dredge) to the landings. NEFSC surveys continue to indicate different recruitment patterns in the two units in the most recent years. The perceived differences in growth were based on studies about 10 years apart and under different stock conditions (Armstrong (1987): Georges Bank to Mid-Atlantic Bight, 1982-1985; Hartley (1995): Gulf of Maine, 1992-1993). Age, growth, and maturity information recently available from the NEFSC 1992-2001 surveys and the Industry Cooperative 2001 survey now indicate small differences in age, growth, and maturity between the areas. There continue to be significant differences in the contribution of different gear types to the landings. A recent genetics study (Chickarmane et al. 2000) indicated no genetic differences among goosefish collected from North Carolina to Maine in depths up to 300 m.

Because of the uncertainty re. stock structure, this assessment was conducted under the two assessment unit hypothesis and as a combined stock. The preponderance of the biological evidence (recent age, growth, maturity, and genetic information) suggests that use of a single stock hypothesis in the assessment might be appropriate. However, substantial differences in the fisheries exist, and it may be desirable to maintain separate management areas to accommodate these differences.

The research survey strata and statistical areas used to define the northern and southern management regions were as follows:

Survey	Northern Area	Southern Area
NEFSC Offshore bottom trawl	20-30, 34-40	1-19, 61-76
ASMFC Shrimp	1 -12	
Shellfish	49-54, 65-68, 71-72, 651,661	1-48, 55-64, 69-70 73-74, 621, 631
Statistical areas	511-515, 521-523 561	525-526, 562, 537-543, 611-636

The southern deepwater extent of the range of goosefish (*Lophius americanus*) overlaps with the northern extent of the range of blackfin goosefish (*Lophius gastrophysus*) (Caruso, 1983). These two species are very similar morphologically, and this may create a problem in identification of survey catches and landings from the southern extent of the range of goosefish. The potential for a problem however is believed to be small. The NEFSC closely examined winter and spring 2000 survey catches for the presence of blackfin goosefish and found none. The cooperative goosefish survey conducted in 2001 caught only 8 blackfin goosefish out of a total of 6,364 goosefish captured in the southern management region.

The spatial distribution of goosefish catches in winter, spring, and autumn bottom trawl surveys and the summer scallop survey is shown in Figure C9. The winter and scallop surveys do not sample in the Gulf of Maine.

Larval distributions have been inferred from collections by the NEFSC Marine Resources Monitoring, Assessment and Prediction (MARMAP) ichthyoplankton survey (Steimle et al. 1999). Larvae were collected during March-April over deeper (< 300 m) offshore waters of the Mid-Atlantic Bight. Later in the year, they were most abundant across the continental shelf at 30 to 90 m. Larvae were most abundant at integrated water column temperatures between 10-16^{o} C, and peak catches were at 11-15^{o} C regardless of month or area. Relatively few larvae were caught in the northern stock area.

FISHERY DATA

U.S. Landings

Landings statistics for goosefish are sensitive to conversion from landed weight to live weight, because a substantial fraction of the landings occur as tails only (or other parts). The conversion of landed weight of tails to live weight of goosefish in the NEFSC weigh out database is made by multiplying landed tail weight by a factor of 3.32.

For 1964 through 1989, there are two potential sources of landings information for goosefish; the NEFSC "weight-out" database, which consists of fish dealer reports of landings, and the "general canvass" database, which contains landings data collected by NMFS port agents (for ports not included in the weight-out system) or reported by states not included in the weight-out system (Table

C1). All landings of goosefish are reported in the general canvass data as "unclassified tails." Consequently, some landed weight attributable to livers or whole fish in the canvass data may be inappropriately converted to live weight. This is not an issue for years 1964 through 1981 when only tails were recorded in both databases. However, for years 1982 through 1989, the weight-out database contains market category information which allows for improved conversions from landed to live weight. The two data sources produce the same trends in landings, with general canvass landings slightly greater than the weight-out system. It is not known which of the two measures more accurately reflects landings, but the additional data sources argue for use of the general canvass landings for years 1964 through 1981 while market category details available in the weight-out system argue for use of this database for years 1982 through 1989. Until the mid-1970's, many of the goosefish caught were sold outside of dealers or used for personal consumption, introducing further uncertainty into the early estimates of landings.

Beginning in 1990, most of the extra sources of landings in the general canvass database were incorporated into the NEFSC weight-out database. However, North Carolina reported landings of goosefish to the Southeast Fisheries Science Center and until 1997 these landings were not added to the NEFSC general canvass database. Since these landings most likely come from the southern management region, they have been added to the weight-out data for the southern management region for 1977-1997 (Table C1).

Beginning in July 1994, the NEFSC commercial landings data collection system was redesigned to consist of vessel trip reports (VTR data) and dealer weigh-out records. The VTRs include area fished for each trip which is used to apportion dealer-reported landings to statistical areas. Each VTR trip should have a direct match in the dealer data base; however, this is not always true. For data with no matches, we dropped the record if there was a VTR with no dealer landings and retained the record if there were dealer landings but no VTR. For dealer landings with no matching VTR, we apportioned the landings to area using proportions calculated from successfully matched trips pooled over gear, state and quarter.

Total landings (live weight) remained at low levels until the middle 1970s, increasing from hundreds of metric tons to around 6000 mt in 1978 (Table C1, Figure C1). Landings remained stable at between 8,000-10,000 mt until the late 1980s. Landings increased steadily from the late 1980s through 1992, and have fluctuated around 26,000 mt since 1993. Peak landings occurred in 1997 (28,517 mt) and have declined slightly since then. By region, landings began to increase in the north in the mid-1970s, and began to increase in the south in the late 1970s. Most of the increase in landings in recent years has been from the southern region.

Trawls, scallop dredges and gill nets are the primary gear types that land goosefish (Table C2, Figure C2). During 1998-2000, trawls accounted for 54% of the total landings, scallop dredges about 17%, and gill nets 29%. In recent years trawl landings (mt) are greater in the northern than southern areas, while scallop dredges and gill nets have landed more from the south than from the north.

Until the late 1990s, total landings were dominated by landings of goosefish tails.

From 1964 to 1980 landings of tails rose from 19 mt to 2,302 mt, and to 7,191 mt in 1997 (Table C3). Landings of tails have declined since 1997 (to 3,582 mt in 2000), while landings of gutted whole fish have increased steadily. On a regional basis, most tails were landed from the northern component in the 1960's (75 to 90%) through to the late 1970's (74% in 1978) (Tables C4, C5). From 1979 to 1989, landings of tails were about equal from both regions. In the 1990's, landings of tails from the south began to predominate, providing 60% or more of tails. In 2000, landings of tails from the two areas were approximately equal.

Beginning in 1982, several market categories were added to the system (Table C3). Tails were broken down into large (> 2.0 lbs), small (0.5 to 2.0 lbs), and unclassified categories and the liver market category was added. In 1989, unclassified round fish were added; and in 1991, peewee tails (<0.5 lbs) and cheeks appeared. Finally, in 1992 belly flaps were also recorded. Whole gutted fish were first recorded in 1993.

Goosefish livers have become a very valuable product. Landings of livers increased from 10 mt in 1982 to an average of over 600 mt during 1998 - 2000. During 1982-1994, ex-vessel prices for livers rose from an average of \$0.97/lb to over \$5.00/lb, with seasonal variations as high as \$19.00/lb. Landings of unclassified round (whole) or gutted whole fish jumped in 1994 to 2,045 mt and 1,454 mt, respectively; landings of gutted fish continued to increase through 2000. The tonnage of peewee tails landed increased through 1995 to 364 mt and then declined to 153 mt in 1999 and 4 mt in 2000 when the category was essentially eliminated by regulations.

Foreign Landings

Landings (live wt) from NAFO areas 5 and 6 by countries other than the US are shown in Table C1 and Figure C1. Reported landings were high but variable in the 1960s and 1970s with a peak in 1973 of 6,818 mt. Landings were low but variable in the 1980s, declined in the early 1990s, and have been below 200 mt in recent years.

Size Composition of U.S. Landings and Catch

Table C6 shows the number of commercial samples taken through the port sampling program for 1996-2000. Length frequencies of the samples are shown in Figure C4; these were expanded to landings using the length-weight equations in Almeida et. al. (1995) (Figure C5). In 1996 “unclassified round” landings from the south were expanded using the “unclassified round” samples (n=2) from the north. In 1997 there were no samples for “tail only”, so landings in this market category were distributed according to the proportion of peewee, small and large tail landings within each stock area. Sampling intensity and coverage was low in 1998. Length frequency of landings for unsampled market categories was estimated according to the proportion of peewee, small, and large tail landings in the north and large and small tails in the south. In 1999 “tail small” was used to expand “tail peewee” landings within each stock component. “Head on gutted” was used for unclassified round, and “tail only” landings were redistributed according to the proportion of small and large tail landings. In 2000, sampling increased but sampling intensity varied widely among market categories and ports.

Length composition data collected by the NEFSC fishery observer program (sea sampling data) were summarized for 1996-2000. Sea sampling data for goosefish were collected aboard trawls, scallop dredges and gill nets (drift and sink). Figures C6 and C7 show length frequency distributions from sea sampling data by major gear type, stock region and year. Discards were generally between 20-40 cm, while kept fish were greater than 40 cm.

Discard Estimates

Catch data from the fishery observer and VTR databases were used to investigate discarding frequencies and rates. The number of tows or trips with goosefish discards available for analysis varied widely among stocks and gear types (Tables C7 and C8). Discard ratios (kg discarded / kg kept) from the two data sources were consistent (Figure C8). Scallop dredges generally had the highest discard ratio while gill nets had the lowest. The most frequent reasons for discarding in the trawl and scallop fisheries were that the fish were too small, either for the market or for regulations. In the gill net fisheries, poor quality was the primary reason for discarding.

We estimated annual mt of goosefish discarded by calculating discard ratios from the observer program on a management region, gear type and half-year basis. We applied the discard ratios to reported landings (live weight, by stock, gear type and half-year cells) to derive metric tons discarded and total catch (Tables C9 and C10). If no sampling data were available for a cell, we applied the overall mean discard ratio for all gears and years. The overall annual discard ratio (Table C10) ranged from 0.07 - 0.27 mt discarded per mt kept. The percentage of the catch discarded has ranged from 6-21%, with the highest rates occurring in 2000.

Catch per Unit Effort by Gear and Depth

Commercial catch per unit effort (CPUE) from the VTR database was examined by gear type in order to determine if a depth effect was present, especially in the deepest waters. Scallop dredge, large and small mesh gill net, and otter trawls were examined separately. Depth zones were categorized in 20 fathom increments starting with 0-20 fathoms (zone 1) and ending with zone 10 (greater than 180 fathoms). Obvious outliers were removed before analysis based on examination of the actual logbooks.

Table C11 presents the number of observations, median CPUE by depth zone and the estimated depth effect from a generalized linear model incorporating year, quarter, vessel ton class and depth zone. Dredge gear does not fish in deep waters and does not show changes in CPUE with depth. Large and small mesh gill nets fish in deeper waters, but do not show a trend in CPUE with depth. In contrast, trawls fish in deep waters and show an increasing trend in CPUE with depth. However, this apparent trend is due to a loss of low CPUE values at greater depths; maximum catch rate is consistent over all depths. Examining only directed trips (trips in which at least half of the catch (kg) was goosefish) removes the apparent trend with depth by removing most of the low catch rates in shallow water (Table C12). Thus catch per unit effort does not appear to have a depth effect associated with any gear. However, the low sample sizes in the deepest water do not allow definite conclusions to be reached.

During the examination of catch rates by depth, it was observed that few trawl trips fall into the directed category, as defined above. Table C13 shows the number of directed and total trips by gear and stock area and the associated landings. Although trawl trips are infrequently directed in both the north and south, 6.1% and 8.8%, respectively, the proportion of catch associated with these trips is much higher in the south, 24% north and

76% south. This difference between north and south was not apparent in either gill net fishery.

Selectivity of Trawls and Scallop Dredges

An exploratory analysis of selectivity patterns of trawls and scallop dredges was performed for SARC 31 (NEFSC 2000). The analysis was based on the following assumptions:

1) The index of abundance in a given length category is proportional to the population. That is, $n_i = c\ N_i$, where c is a constant of proportionality over all length categories and years, and n_i and N_i, respectively, are the abundance index and population size of the ith length category.

(2) The proportion of the population vulnerable to the fishing gear (vulnerability) is an S-shaped function of length, which can be described by a half-gaussian curve:

$$v_i = \exp[-0.5(l_i - L_{full})^2/s], \text{ if } l_i < L_{full}$$
$$= 1, \qquad \text{if } l_i \geq L_{full}$$

where l_i is the length of the ith category and L_{full} is the length of fully vulnerable individuals.

(3) The exploitation rate (u) operates equally on all vulnerable individuals in the population, and thus, the catch in number of the ith length category is

$$C_i = u\ v_i\ N_i.$$

The length-frequency distributions in proportion (p_i) are then expressed by the equations in assumptions (1) and (3):

$$p_i = C_i / \Sigma\ C_i = v_i\ n_i / \Sigma\ v_i\ n_i.$$

If P_i is the observed proportion of catch in the ith length category, which is a measurement of population's p_i with an error of e_i, it implies that $P_i = p_i + e_i$.

The method of least squares was used to estimate the location parameter L_{full} and the shape parameter s of the vulnerability, or selection, curve. In order to apply the method, the number of samples for the abundance index should be sufficient, i.e. the values of n_i's of all length categories should be large enough to make a smoothed length-frequency distribution without too many null categories. Gillnets were not included in the analysis because the upper range of survey length-frequency distributions does not extend to that sampled from the gillnets.

For the northern stock, the vulnerability of kept goosefish sampled from vessels using scallop dredges was consistent during 1996-1998, with less than 10% vulnerable at 40 cm and almost 100% vulnerable near 45 cm. Vulnerability curves of kept goosefish from trawlers were similar in 1997 and 1998 but different from that in 1996 (Table C14). Some discards in 1996 may have been mis-coded as kept, resulting in a less steep curve.

For the southern stock, the vulnerability of kept goosefish to trawls and scallop dredges was similar in 1996 and 1997, when compared with data from scallop and winter surveys (Table C14). Differences occurred after 1998 although some were similar. It should be noted that relatively small samples were collected in 1998-1999 compared to 1996-1997. The small samples probably biased the length-frequency distributions of the kept portion of the catch.

RESEARCH SURVEY ABUNDANCE AND BIOMASS INDICES

NEFSC Survey Indices

NEFSC spring and autumn bottom trawl survey indices were standardized to adjust for statistically significant effects of trawl type and vessel on catch rates as noted below. The trawl conversion coefficients apply only to the spring survey during 1973-1981.

Effect	Coefficient	Source
Trawl	Weight: 0.2985 Number: 0.4082	Sissenwine and Bowman, 1977
Vessel	Weight: Not significant Number: 0.83	NEFSC, 1991

Northern Region

Indices from NEFSC autumn research trawl surveys indicate that biomass fluctuated without trend between 1963-1975, appears to have increased briefly in the late 1970's, but declined thereafter to near historic lows during the 1990's. In 2000 the index increased to its highest level since 1984 (Table C15, Figure C10). The three year moving average of the index (1998-2000) is currently at 57% of the 1965-1981 biomass target (Table C49). Abundance in numbers (Table C15, Figure C11) declined during the early 1960s, and then fluctuated without trend until the late 1980s. Abundance increased steadily from the late 1980s to a peak in 1994, declined to 1997, increased in 1998 and 1999 and increased sharply in 2000. The 2000 point estimate for numbers is the highest in the series.

Indices from the NEFSC spring research trawl surveys reflect similar trends of relatively high biomass levels in the mid 1970s (but with possible declines in the late 1970s), a declining trend from the early 1980s to the lowest values in the time series in 1998 and an increasing trend since then (Table C16, Figure C12). As in the autumn survey series, abundance in numbers fluctuated until the early 1980s (Table C16, Figure C13). Since 1996, numbers have trended upwards and reached the highest levels in the time series in 2000 and 2001. Figure C14 shows the fall and spring survey indices plotted together for comparison of trends.

Other surveys conducted in the northern management region cover shorter periods of time and/or smaller portions of the region, and are not included in this assessment because of their limited coverage. For example, the NEFSC sea scallop survey in the northern goosefish management region includes only a few strata on the northern edge of Georges Bank and the ASMFC shrimp survey covers only the western Gulf of Maine.

Length distributions have become increasingly truncated over time (Figure C15). By 1990, fish greater than 80 cm long were uncommon in length frequency distributions, and by 1996, fish greater than 60 cm had become relatively uncommon as well. The minimum, mean and maximum lengths in the trawl surveys have declined steadily over time (Figure C16).

Several modes potentially representing strong year classes have appeared consistently in survey distributions in recent years. Abundance indices for goosefish 10-20 cm TL (corresponding approximately to age 1 goosefish) were estimated to help identify potential recruitment patterns (Figure C17,

Table C17). To the extent that these indices reflect recruitment, recruitment in the northern area has increased in the past decade. Relatively strong year-classes were produced in 1992, 1993, 1998 and 1999. Length frequencies and survey abundance at age data corroborate the suggestion of relatively strong 1998 and 1999 year-classes (Figure C15, Table C18) in the northern area.

Survey age data are available for 1993-2000 from the autumn trawl survey and for 1995-2001 for the spring trawl survey. The mean length at age is shown in Table C18 and Figures C18-C20). Within the range of ages observed in the surveys, growth is essentially linear and there are no obvious differences with gender or stock. The stratified mean number per tow at age is shown in Table C19.

Southern Region

Biomass indices from the NEFSC autumn research survey declined rapidly in the second half of the 1960s, and then fluctuated until the early 1980s (Table C20, Figure C21). In the mid-1980s, biomass declined and has remained low since 1987. The three year moving average of the index (1998-2000) is currently at 23% of the 1965-1981 biomass target (Table C49). Abundance in numbers shows similar declines after the mid-1960s, with a spike in 1972, slight increases in the late 1970s-early 1980s and a decline thereafter (Figure C22). In recent years, abundance in numbers has fluctuated without trend at low levels.

The Overfishing Definition biomass target and thresholds for the southern component are based on NEFSC autumn survey indices beginning in 1963. NEFSC survey strata south of Hudson Canyon were not sampled during 1963-1966, and so indices for those years are not directly comparable to indices for 1967 and later years. SARC 31 recommended the adoption of southern component biomass target and thresholds based on indices for 1967-1981 and 1967-1994, respectively. This revision changes the biomass target from 1.848 kg per tow to 1.846 kg per tow, and the biomass threshold from 0.750 kg per tow to 0.704 kg per tow.

The NEFSC spring research survey data reflects similar trends as the autumn series: stock levels remained fairly high during the mid 1970s - early 1980s, but declined to record low levels in the early 1980s and have fluctuated at low levels in recent years (Table C21, Figures C23 and C24).

Indices based on the NEFSC winter flatfish survey have fluctuated without trend, consistent with lack of trend in other surveys during 1992-2001 (Table C22, Figures C21, C23, C29); however, the 2001 biomass index was the highest in this series. The abundance index did not increase to a similar degree. Age data are available for the winter survey for 1997-2001 (Table C23, Figure C27). The mean length at age for the winter survey samples is similar to mean length at age from NEFSC spring surveys (Figure C20).

Abundance indices based on the NEFSC sea scallop survey show an increasing trend during 1984-1994 followed by a rapid decline from 1994-1998; however, the abundance index increased in 1999 (Table C24, Figure C28). Finfish data for scallop surveys conducted during 2000 and 2001 are not yet available.

Figure C29 compares biomass and abundance indices from all NEFSC surveys in the southern management region.

Length distributions from the southern region show increasing truncation over time (Figure C30), which is reflected in declines in minimum, mean and maximum length over time (Figures C31 and C32). Maximum lengths declined by approximately 20 cm or more over the time series.

As in the northern region, recent year class events are rarely observable in survey length frequency distributions at lengths greater than 40 cm, Currently, fish greater than 60 cm are rare, especially when compared to the 1960s. Any recent strong recruitment does not appear to survive long enough to contribute substantially to increased stock biomass.

Management Areas Combined

Tables C25-C27 and Figures C33-41 present survey information from the fall, spring and scallop surveys for the northern and southern management regions combined.

MA DMF Survey Indices

Surveys conducted by the Massachusetts Division of Marine Fisheries show trends in biomass and abundance broadly similar to NEFSC surveys in the northern region (Figure C42). Biomass indices for the state waters north of Cape Cod show a declining trend in both the spring and the fall. Abundance indices fluctuated at low levels until the 1990s when there was a small peak in 1991 and a large spike in 1995. Abundance of goosefish in inshore waters appears lower during the spring; however, the highest point in the spring series is also 1995. A peak in abundance was observed in 1994 in the NEFSC fall survey. The MADMF index shows an increase in biomass in 2000, but does not indicate the increased abundance in 2000 that the NEFSC survey index does.

In Massachusetts waters south of Cape Cod, biomass indices have remained at or near their lowest levels since around 1990 and abundance has been consistently very low.

2001 COOPERATIVE GOOSEFISH SURVEY

Methods

A directed survey for goosefish was conducted in cooperation with the fishing industry during Feb 27 -May 17, 2001. The F/V Drake (87 ft. trawler, home port Portland, ME) and the F/V Mary K (96 ft. trawler, home port New Bedford, MA) were chartered to conduct the survey. The Drake had two nets which were alternated depending on bottom type (Figure C43); the Mary K used one net for all tows (Table C28). The Drake sampled the Gulf of Maine and Georges Bank, the Mary K sampled southern New England and the mid-Atlantic shelf down to Cape Hatteras.

The basis for the survey was a stratified random design with sampling effort proportional to reported fishing effort during 1995-1999. Additional station locations were assigned by fishermen. The stratum boundaries were those used in NEFSC bottom trawl surveys (defined by depth), with an additional set of strata from Georges Bank south in 100 to 500 fathoms. The realized distribution of the 284 survey stations successfully occupied is shown in Figure C44. The survey stations were completed during Feb. 27 to April 6.

Standard operating procedures were followed by each vessel. These specified such variables as tow time, tow speed, scope ratios, sampling protocols, etc. Ancillary data collected for each tow included bottom contact time, measured using an inclinometer hung from the footrope of the net, boat position (GPS), and temperature. The electronic data were collected at intervals ranging from 1 to 6 seconds; clocks were synchronized among the sensors. Survey catches were processed using standard procedures for NEFSC surveys.

In addition to the survey stations, 64 tows were conducted for mensuration of the three nets, efficiency estimation, inter-net and inter-vessel calibration, video work and to examine the outer depth distribution of goosefish (Table C29). The tows were conducted in waters off southern New England (Figures C45-C50).

The net mensuration work was done using a NetMind trawl mensuration system for measuring wing spread, door spread, and headrope height on both vessels. The general protocol was to conduct a pair of 30-minute tows at approximately 40-fathom depth increments (30-150 fathoms for the Drake and 30-280 fathoms for the Mary K, Figure C45). The second tow of each pair was fished in the opposite direction of the initial tow to account for variation in tow direction relative to current direction. Nets were set and towed along the depth contour.

To compare catch rates between net types on the Drake, a series of tows done on soft bottom with net 1 were repeated using net 2 (Figure C46). The tows with net 1 were completed on May 11 and the tows with net 2 on May 12-13. Tows were done at 40, 70, 100 and 140 fathoms. Repeated tows were adjacent to the first tow, not on the original tow path.

A series of depletion tows were conducted on the Mary K and the Drake (net 1) to estimate absolute efficiency of the gear (Figure C47). Standard 30-minute tows were repeated in alternate directions along a single tow path (different tow paths for each vessel) until the catch rates dropped to zero or near zero.

Comparisons between the two vessels (Drake using net 1) were made by conducting a series of paired tows in which the vessels fished next to each other at tow locations in depths ranging from 30 to 140 fathoms (Figure C48). In another set of experiments, the Mary K repeated 7 tows completed by the Drake about 5 days earlier (Figure C49). These experiments were not used in estimating biomass and population size, but provided a direct estimate of relative performance of the two vessels and nets.

Video camera observations were made using an underwater camera system to evaluate the catchability of goosefish by the three nets used in the cooperative survey (Figure C50). The video tapes were used to examine the behavior of goosefish as they encounter the gear, to assess the degree to which herding occurs and to obtain a qualitative sense of the efficiency of the gear. A third wire camera system was mounted on the headrope of the net and videos were viewed in real time and recorded. The camera system's pan and tilt unit allowed the operator to change the field of view of the camera and thus view separate areas of the net (i.e. wings, center of sweep, groundcables) to provide a broader understanding of goosefish behavior in response to the gear. Camera tows were conducted in daylight in water depths of 27-37 fathoms. The net was towed with the codend open until the scientists and fishermen felt they had enough video data to adequately describe the behavior of the goosefish within the trawl.

Area swept biomass and population numbers were estimated for each survey tow. The distance covered by each tow was estimated from bottom contact time (based on inclinometer data) and speed of the vessel as derived from GPS position data during bottom contact (Figures C51-C54). Width of the tow path for each tow was estimated from wingspread-depth relationships developed from the mensuration work (Figures C55-C57). Where inclinometer data were missing for a tow, we adjusted nominal tow distances according to inclinometer:nominal distance relationships from tows with high quality sensor data. For the Mary K, this relationship was depth-dependent (Figure C58). Where GPS data were missing, we used average speed from tows with good quality sensor data (by vessel) to calculate the distance covered. A second set of area swept estimates was derived using nominal tow distance (distance covered in the time between winch lock and re-engage) for the Mary K because it is uncertain how much of the bottom contact time after winch lock is actually fishing time (with the net moving forward).

To estimate population biomass (numbers), we calculated goosefish densities in each stratum as the sum of the numbers caught divided by the sum of the area swept. Biomass in each stratum was estimated as the product of number of fish and mean weight of fish in the stratum. Biomass and numbers were summed over strata to arrive at minimum biomass and population size. Biomass and population size were also estimated under a range of assumptions regarding net efficiencies. The efficiency assumptions were derived from the depletion and calibration experiments. We used the depletion experiments to estimate efficiency of the Mary K's net and the Drake's net 1. The Drake's net 2 was adjusted to the Drake's net 1 based on the paired tow experiments.

RESULTS - COOPERATIVE GOOSEFISH SURVEY EXPERIMENTAL TOWS

Results of the Drake net calibration experiments are summarized in Table C30 and Figure C59. There was not a strong correspondence between catch rates with the two nets, but net 2 tended to catch slightly less than net 1. We used the overall ratio of net 2 : net 1 catches (0.92) as the estimate of efficiency of net 2 relative to net 1.

The paired tows between the Drake (net 1) and the Mary K were analyzed under both assumptions regarding tow distance for the Mary K (inclinometer distance estimates, nominal distance estimates) (Figures C60 and C61, Table C31). Assuming inclinometer distances for both vessels, the ratio of numbers per nm^2 Drake:Mary K was 1.10; assuming nominal distances for the Mary K brought the ratio to 0.93. The repeated tow experiments indicated Drake:Mary K ratios for numbers per nm^2 of 0.76 - 0.88 (Figure C62).

The video footage provided no evidence of herding of goosefish by the gear, nor of strong escape responses. Goosefish generally were not visible before being contacted by the tickler chain, but when hit by the chain would flip up into the water column and then drift passively into the net.

RESULTS - COOPERATIVE GOOSEFISH SURVEY

A total of 310 survey tows were completed during the project. Of these, 284 tows had no gear problems or other major difficulties, and could be used to estimate goosefish abundance (125 tows in the northern management region, 159 tows in the southern management region). Over 9,000 goosefish (16,500 kg) were caught during the survey. More than 3,000 of the goosefish were sampled for age and sex determination, maturity, and food habits. The size of goosefish ranged from 13 cm to 110 cm; ages ranged from 2 to 10 years.

Eight blackfin goosefish were caught in the southern management region (Figure C63). Their identification was later confirmed by systematists at Harvard's Museum of Comparative Zoology (K. Hartel, personal communication).

Nine incidences of cannibalism by goosefish were recorded (Table C32). The evidence of cannibalism ranged from goosefish skeletal remains in stomachs to partially digested goosefish. One stomach contained two goosefish prey. Size of the cannibals ranged from 63-105 cm, all were female; sizes of the prey were 45-49 cm.

Length-weight relationships for male and female goosefish by management area and the entire region are shown in Figure C64. Females in the south appear to be heavier for a given length after reaching about 60 cm total length; however this is likely due to the advanced stage of gonadal development in many of the females sampled in the southern region. In 96 females from the southern region whose gonads were weighed, an average of 27% of the total body weight was egg veil.

Mean length at age by sex and management area are shown in Figure C65. Differences in growth between males and females are undetectable before age 7, when growth in males appears to slow, while female growth continues to increase almost linearly. Few males greater than 65 cm (predicted age 7) were captured. Mean length at age by region and for sexes combined is shown in Figure C66 and Table C33. Size at age was slightly higher in the southern management region. This is consistent with seasonal changes in growth seen in NEFSC survey data for goosefish. Mean weight at age (Figure C67) increases exponentially up through the oldest ages observed in the survey (10 years).

Sex ratios at length (Figure C68) indicate that in both management regions, all individuals larger than about 70 cm are female. In the north, sex ratios average around 50:50 for goosefish 20-60 cm. In the south, sex ratios are about 50:50 for goosefish 20-40 cm total length; for goosefish 40-60 cm, the percent of females drops to 30-40%, and thereafter rises to 100% females by around 70 cm.

Maturity ogives for females and males were fit using probit analysis (Figures C69 and C70). Fifty percent of females are mature at 40 cm (4.7 years) in the northern region and at 46 cm (5.1 years) in the southern region. The estimates of 50% female maturity for regions combined is 43 cm and 4.8 years. These estimates correspond closely with other studies conducted using macroscopic inspection of female gonads; however a study done using histological methods indicated a higher size at 50% female maturity (57 cm, Martinez 1999). Fifty percent maturity for males is estimated to be 35 cm (4.1 years) in the northern region and 37 cm (4.3 years) in the southern region (Figure C70). For regions combined, 50% of males are estimated to be mature at 36 cm (4.2 years).

Swept area biomass and population size estimates under varying assumptions about net efficiencies (Table C34) and tow distance for the Mary K are shown in Table C35 and

Figure C71. Minimum estimates (assuming 100% efficiency of nets) range 64-72 thousand metric tons and 43-48 million goosefish for both areas combined. The range in these estimates is due to the method of estimating distance towed by the Mary K (nominal vs. inclinometer distances).

The length composition of the monkfish population estimated from the cooperative survey (based on minimum population size and assuming inclinometer distances for all nets) is shown in Figure C72. In both management regions, most of the population is less than the minimum landing size required under the FMP. Length frequencies from the NEFSC winter survey for 2001 are very similar to the length frequencies derived from the cooperative survey (Figure C73). Minimum spawning biomass was estimated under the inclinometer distance assumption from numbers at length in each management region, sex ratio at length, maturity at length and the length-weight relationship from the cooperative survey samples (Figure C74).

Age composition of the goosefish population by management region and areas combined (Figure C75) was derived from the age-length key for areas combined applied to the number of goosefish at length (by region and for areas combined).

RELATIVE PRECISION OF F/V COOPERATIVE SURVEY AND COMPARISONS WITH NMFS RESEARCH TRAWL SURVEY

The precision of abundance estimates is an important aspect of research surveys. When the underlying assumptions of stratified random surveys are satisfied, such surveys can provide valid inferences about the true population densities. This section provides estimates of the relative precision of stratified random surveys using the sampling theory summarized in Cochran (1977). The applicability of standard sampling theory to fish populations has been the subject of considerable debate, particularly with respect to the alternatives of model-based estimates (e.g., Pennington 1983, 1986) or explicit spatial models (e.g., Conan and Wade 1989). The choice of design vs model-based methods of estimation usually is motivated by the presence of high variation in the observed catch data . Conventional estimates of the precision, e.g., the standard error of the estimate, can lead to confidence intervals with negative lower bounds. Model-based estimators of abundance account for such variations by assuming a particular statistical model (e.g. lognormal, poisson or delta distribution) for the underlying distribution of the resource. Subsequent inferences are therefore conditional on the validity of the assumed model. Smith (1990) and Myers and Pepin (1990) demonstrated that model-based estimates can result in biased estimates of population means and variances when the underlying model is not supported by the data.

Alternatively, bootstrap resampling methods may be used to estimate the relative precision in complex survey designs (Smith 1997). The bootstrap approach avoids the need to explicitly choose (and justify) an underlying statistical distribution, and it leads to a realistic characterization of the sampling distribution of the mean and variance estimates. This section relies heavily on the theory and applications described in Cochran (1977), Smith (1996, 1997, 2000) and Smith and Gavaris (1993). All of the computations of design efficiency and bootstrap estimators were conducted in Splus using a library of functions written by Stephen Smith, DFO, Dartmouth, NS.

Methods

Estimates of the mean, standard error, and effective degrees of freedom for stratified random surveys were based on standard equations in Cochan (1977). Under the assumption that the stratified mean would exhibit a Student's t distribution under repeated sampling, an approximate parametric confidence interval for the mean can be constructed. The relative efficiency of the design can be computed by comparing the variance of the stratified random estimate with that which would be obtained under simple random sampling. The computation of a simple random sampling variance for data collected in a stratified random survey is easily computed but complicated (see Smith 2000, Eq. 6).

As shown in Smith and Gavaris (1993), the reduction in variance associated with the use of a stratified random design can be decomposed into two components related to the allocation of samples to strata, and the differences among stratum means. The contribution associated with differences in stratum means is always positive. In contrast, inappropriate allocation of samples to strata can lead to negative values, such that the variance of a stratified random design can be greater than a simple random sample. Such differences can occur when the overall design targets another species or when the survey design reflects a compromise among many target species. Finally, it is possible to estimate a minimum variance that would be obtainable under optimal allocation. Optimal allocation of samples is based on the relative size of the strata and the estimated stratum variance. Minimum variance estimates are useful when contemplating revisions to future sampling designs, and as metric of evaluating the relative efficiency of the realized survey.

Bootstrap sampling of complex survey designs is complicated by the known bias properties of stratified variances of the mean (Rao and Wu 1988). Smith(1997) applied the so-called "mirror-match" of Sitter (1992) to reduce the bias associated with bootstrap variance estimates from small samples. Essentially this approach randomly uses n_h and n_h -1 resamples from each stratum when deriving the bootstrap values. Confidence limits are derived using percentile methods. Smith (1997) demonstrated that this method of computing was preferable to other methods that attempt to correct for differences between the point estimate and the median of the sampling distribution.

Comparisons with NMFS R/V Trawl Surveys

The results of the cooperative survey were compared to spring, autumn and winter NMFS trawl surveys. Comparisons were made with the most recent NMFS survey and with an additional year, selected for its low mean catch of goosefish. The surveys compared were spring (2001, 1987), fall (2000, 1997) and winter (2001, 1998). Fall and spring surveys were analyzed for the northern and southern management regions and for regions combined. The winter survey does not sample the northern strata, so was analyzed for the southern region only. Catch estimates of monkfish in the NMFS surveys were adjusted to a standard area swept, defined by net width, standard tow duration and standard towing speed. Individual variation in tow distance could not be adjusted for because detailed data on gear performance (e.g. actual bottom contact time) is not available for all surveys.

The cooperative survey results were also analyzed for northern, southern and combined regions. The southern strata in the cooperative survey were reduced to coincide exactly with NMFS survey coverage. This eliminated the deepwater strata and was done to provide comparable strata sets for the comparisons. The response variable for each survey was either the number or weight (kg) caught per tow. To account for differences among the three nets used in the cooperative survey, the catch rates were adjusted according to a range of assumptions re. variations in net width with depth, distance covered during net deployment, and adjustments for estimated contact time (Tables C36 and C37).

Results

Mean catch rates per tow in the cooperative survey were much greater than those observed in the NMFS surveys (Tables C36 and C37). These differences reflect smaller net width and lower efficiency of the rollers on the NMFS fall and spring surveys. The coefficient of variation (CV) of catch rates in the cooperative surveys ranged from 4 to 7%, suggesting a high degree of precision. The NMFS winter survey had CVs about twice as large (11-14%). CV's for the NMFS fall and spring surveys varied from 15% to 50%.

The cooperative survey achieved variance reductions ranging from 50 to 86% over simple random sampling. Most of the gain in precision was attained through stratification, rather than allocation. This suggests that the survey strata were appropriate for the cooperative survey, and that the variations in sample allocations to strata were less important. While the survey strata were also appropriate for the NMFS survey, the allocation of samples to these strata often resulted in reduced precision. In 8 of the 12 comparisons for the spring and autumn surveys, the negative effect of sample allocation resulted in higher variance than would have been obtained via simple random sampling. This inefficiency in allocation for goosefish probably results from an overall allocation scheme for NMFS surveys which targets a wide range of species.

Bootstrap estimation of confidence limits (Tables C38 and C39, Figures C76-C78) resulted in a slight reduction in the length of the interval and provided a non-parametric estimate of the sampling distribution percentiles. No strong evidence of bias (i.e., difference between the bootstrap estimate and the point estimate) was evident for either the mean or variance. Side-by-side comparisons of the parametric and bootstrap confidence intervals revealed only slight differences (Table C40). The length of the putative confidence interval (upper-lower estimates) was slightly larger for the cooperative survey bootstrap estimates and slightly smaller for the NMFS survey bootstrap estimates. The near equivalency of the bootstrap and design-based estimates contrasts with other applications of Smith's methodology (eg. Smith 1996, 1997), and is perhaps due to the spatial dispersion of monkfish. None of the surveys observed wide variations in the number of monkfish per tow as compared with other groundfish and pelagic species. This may reflect a relatively uniform spacing of monkfish in areas of suitable habitat.

Comparisons between the cooperative survey and NMFS winter survey results are highlighted in Table C41 and Figure C79. For this comparison, the cooperative survey was restricted to the strata sampled by the NMFS winter survey in 2001. The estimates from the NMFS winter survey are less precise than the cooperative survey's, but are still considered very good for a multispecies resource survey. Revision of sample allocation in the winter survey could improve the survey's precision for goosefish. However the biggest contrast in the survey estimates is the difference in the total biomass estimates. The ratio of these estimates, assuming that variations in net width and tow path duration have been properly accounted for, suggests that the NMFS winter trawl is about half as efficient (i.e., probability of capture given encounter) as the "average" commercial net. As an exploratory calculation, the distribution of bootstrap estimates of biomass for the winter survey were rescaled to the mean of the cooperative survey. The results, shown in the lower panel of Figure C79 illustrate the that the winter survey has precision comparable to that observed in the cooperative survey.

The net used in NMFS fall and spring surveys appears to be less efficient compared to the cooperative survey nets but more detailed examination is necessary. In particular, analysis of differences between catch rates with the large roller net used by the F/V Drake in the Gulf of Maine and the NMFS survey nets would be instructive.

EGG PRODUCTION INDICES FROM NEFSC SURVEY LENGTH COMPOSITION DATA

NEFSC survey indices were used to develop indices of egg production. Composite length frequencies, based on a five year summation of catch per tow at length, $\bar{I}(L,t)$ were multiplied by predicted eggs at length Egg(L) and the fraction mature (PMAT(L)). The computational formula is:

$$SSB(t) = \sum_{L} SSB(L,t) = \sum PMAT\ (L) * Eggs(L) * \bar{I}(L,t)$$

where

$$PMAT\ (L)\ =\ \frac{1}{1 + e^{13.9568 - 0.03862325L}}$$

Parameters for PMAT(L) were derived by fitting the logistic function to derived percentiles of fraction mature described in Hartley (1995). The fecundity-length relationship was obtained from Armstrong (1987).

$$Eggs\ (L) = 0.0683\ L^{3.74}$$

$$L = length(mm)$$

Results for the indices of egg production (Figures C80-C82, Table C42) mirror the progressive decline in mean length and have declined steadily over the past two decades.

Currently, about 13% of SSB is produced by fish less than L_{50}. In the north, about 10-13% of the egg production is by the partially mature component of the length distribution; in the south, 13-17% of the spawning stock biomass is from the partially mature component of the length distribution.

ESTIMATION OF MORTALITY AND STOCK SIZE

Natural Mortality Rate

The instantaneous natural mortality rate for monkfish is assumed to be 0.2, based on an expected maximum age of 15-20 years given previous studies of age and growth (Armstrong 1987, Armstrong et al. 1992, Hartley 1995).

Mortality estimates from NEFSC Surveys

Instantaneous total mortality rates (Z) for goosefish were estimated using a length-based method by Beverton and Holt (1956):

$$z = \frac{K(L_\infty - \bar{L})}{(\bar{L} - L')}$$

where K and L_∞ are from von Bertalanffy growth models and LBar is the mean length of individuals in the region (as stratified delta mean catch per tow at length, adjusted for trawl and vessel effects, when significant). L' is the smallest fully recruited length, and was estimated from inspection of LOWESS smoothed length frequency data (Cleveland, 1979) . The value of L' established in the SAW 31 assessment was 30 cm for both management regions.

Parameter	North	South
L_∞	126.0 cm.	129.2 cm.
K	0.1080	0.1198
L'	30 cm.	30 cm.

The standard deviation of the mean length (above L') was used to develop a standardized normal distribution with mean 0 and standard deviation 1. The truncated distribution was rescaled so that unit area was obtained between the values of the standardized normal distribution corresponding to $L = L'$ and $L = L_\infty$. The median of the resulting distribution and boundaries of 95% of the distribution were estimated conditional on given values of L_∞, K and L'. The corresponding range in Z thus does not reflect variance contributed by error in estimation of L_∞, K or L', nor any covariance among terms. These estimates should be considered minimum estimates of the potential range in Z.

Estimates of Z by area and year, and minimum 95% confidence intervals are presented in Tables C43 and C44. SARC 31 recognized that if the assumption of M=0.2 is correct, the Beverton-Holt length-based method using L'=30 gives unreasonable estimates of $F_{threshold}$. However, the analysis showed an underlying trend in total mortality consistent with increasing landings and decreases in average and maximum size in survey time series, and the SARC considered the Beverton-Holt estimates as a useful index of trends in total mortality.

Mortality rates were estimated using Heinke's method from NEFSC bottom trawl survey abundance at age data (Table C45). The annual estimates are highly variable and many result in unreasonable estimates. This is probably due to inter-annual variations in catchability coupled with the overall low catch rates of goosefish in the NEFSC surveys.

Catch curve estimates of Z were calculated from the NEFSC winter survey by following the 1993-1995 cohort abundances over time (Figure C83). The estimates of total mortality (Z) ranged 0.29 - 0.40.

Catch curves were also fit to abundance at age data from the cooperative survey (Figure C84). The resulting estimates were Z=0.43 for both management regions and for the regions combined.

Exploitation ratios were calculated from the cooperative survey (Table C46). The estimates were produced using two methods: using landings and exploitable biomass from the cooperative survey (> 40 cm north, > 52 cm south), and using catch (landings plus discards) and total biomass from the cooperative survey. In each case, landings (catch) were added to the cooperative survey estimate of biomass to derive a proxy for biomass at the beginning of 2000, and the cooperative survey biomass was taken as biomass at the beginning of 2001. The exploitation ratio was calculated using the average between 2000 and 2001 biomass estimates. The estimates were produced under varying assumptions re. net efficiency and methods for estimating tow distance for the Mary K. This produced estimates of F ranging from 0.10 (north, low efficiency net assumption, total biomass method) to 0.43 (south, 100% net efficiency assumption, inclinometer data for Mary K, exploitable biomass method). Not surprisingly, the catch and biomass method produced lower estimates of F than the exploitable biomass method.

Yield Per Recruit

In response to the SARC 31 research recommendation to re-evaluate reference points for goosefish, the Working Group developed an age-based yield per recruit analysis (Thompson-Bell model) to provide potential alternative reference points. Yield per recruit reference points (Fmax as a proxy for Fmsy, F0.1 as Ftarget) are suggested by the WG as potential alternatives to the current fishing mortality reference points, which have not proven to be very useful in practice. Another potential source of reference points and evaluation of current status is the Bayesian production model (below), for which reference points expressed on a ratio basis (F/Fmsy, B/Bmsy) are likely to prove more stable and reliable than absolute estimates of F, Fmsy, B and Bmsy.

Since the SARC 31 assessment, new information is available on age, growth, and maturity of goosefish from NEFSC research trawl surveys during 1992-2001 and the cooperative survey in 2001. Age, growth, and maturity data from NEFSC winter, spring and autumn surveys during 1992-2001, from the cooperative survey, and from the studies of Armstrong (1987; Georges Bank to Mid-Atlantic Bight) and Hartley (1995; Gulf of Maine) provided information on age and growth used for the yield per recruit analysis.

Mean weights at age for the catch and stock were based on age and individual fish weight data collected in NEFSC winter, spring, and autumn surveys during 1992-2001 (n = 3538 fish). Data were available for ages 0-10, for fish from 9 to 96 cm total length, and 0.01 to 14.08 kg. These data showed very similar patterns in length and weight at age as those from the Hartley (1995) study and the cooperative survey. Patterns in length and weight at age were very similar for fish in the northern and southern management areas in both the NEFSC surveys and the cooperative survey. Mean weights at age in the catch and stock for ages 11-15 were estimated from a Gomphertz regression based on NEFSC survey 1992-2001 individual fish mean weights at age (Table C47).

Maturity estimates from the cooperative survey were similar to those reported by Armstrong (1987) and Hartley (1995), with L_{50} for female goosefish at 40 cm (age 4.7) in the northern area and 46 cm (age 5.1) in the southern management area. NEFSC survey data for 1992-2001 (n=3302) indicated an L_{50} of 41.0 cm for females (age 4), 35.2 cm for males (age 3), and 37.7 cm (age 4) for combined sexes. Guided by this information, the analysis assumed no mature fish at ages 0 to 3, 50% maturity at age 4, and 100% maturity at ages 5 and older (Table C47).

Selection patterns were based on length frequencies of kept and discarded goosefish from sea sampling, length frequencies from port sampling, consideration of the NEFSC and cooperative survey length frequencies for

2001, and work performed for the SARC 31 assessment to estimate selection patterns for different components of the fishery (Table C14, Figures C6 and C7). Age 5 fish were considered nearly fully recruited to the fisheries (S = 0.90) and age 6 fish fully recruited (S = 1.0). Selection at ages 2-4 were roughly based on the "Trawl catch vs Winter Survey" selectivities at length provided in Table C14, with an upward adjustment to nominally account for some discarding at those ages. Ages 0-1 (fish < 20 cm) were assumed to have zero selection by the fisheries (Table C47).

Yield per recruit for the above combination of mean weights, maturities, selection at age, and natural mortality rate assumed= 0.2 provided estimates of F0.1 = 0.138, Fmax = 0.197, and F20% = 0.295 (Table C47).

Sensitivity of the analysis to alternative ages of knife edge recruitment to the fisheries indicated that significant gains in yield per recruit could be realized by increasing the age of entry to the fisheries (Figure C85). The partial selection pattern analysis (Table C47) provides a comparable maximum yield per recruit (0.93 kg/recruit) as knife-edged entry to the fisheries at age 3 to 4 (about 0.9 kg/recruit; Figure C85).

Using the partial selection pattern analysis (Table C47) as a starting point, yield per recruit was also examined under the assumption that discards cause mortality but do not contribute to landings. This was done by splitting the selection pattern into "landings" and "discard" components. The minimum size regulations in the northern (43 cm or 17 inches total length, age 3) and southern (53 cm or 21 inches total length, age 4) management regions were used to determine the proportion of catch at each age that would be discarded. In the north, all fish less than or equal to age 3, 90% of fish age 4, 40% of fish age 5, and a small percentage of ages 6 and 7 would be discarded. In the south this discard ogive was shifted one age older.

Explicitly accounting for discards causes Fmax to decrease from 0.197 (Table C47) to 0.187 in the north and 0.177 in the south. The associated yield per recruit also decreases from 0.931 (Table C47) to 0.890 in the north and 0.842 in the south (Figure C86). Given a fixed minimum size regulation, increasing the age at 50% selection causes increases in the landed yield per recruit (Figures C85 and C87).

BAYESIAN SURPLUS PRODUCTION MODEL ANALYSES

The Southern Demersal Working Group developed surplus production models for northern-area, southern-area, and combined area monkfish using the most recent assessment data for review by the SARC. This work is an extension of the working paper "*A discard with catch error model of monkfish biomass dynamics*" presented at SARC 31. The primary differences in the new modeling approach compared to the approach documented at SARC 31 are:

- discard fractions are lower (assumed to be 10% of total catch weight) during 1964-1994 as suggested by the SARC 31 review
- a combined-area model is also developed to address the possibility that biomass dynamics are better approximated with a single population approach
- the surplus production curve may be right or left skewed (Pella-Thomlinson

production model) to account for the possibility that the stock is more or less resilient to harvest as biomass declines

- the revised model includes the swept-area biomass estimates from the cooperative survey as an index of total stock biomass with measurement error

Four surplus production models with similar underlying assumptions were initially developed. Each of the four models used the NEFSC autumn survey weight per tow index as a measure of relative population biomass to fit a Pella-Thomlinson surplus production model. The four models represented:

1. Northern stock area biomass dynamics during 1964-2000
2. Southern stock area biomass dynamics during 1967-2000
3. Combined area stock dynamics during 1964-2000
4. Combined area stock dynamics during 1964-2000 including another relative abundance index from the NEFSC sea scallop survey during 1982-1999

Together, these 4 models represented three different scenarios:

(i) a two stock scenario (models 1 and 2);
(ii) a one stock scenario where the fall groundfish survey measured relative abundance trends;
(iii) a one stock scenario where the fall groundfish and the scallop survey both measured relative abundance trends.

Each of the four models was fit using total catch (as adjusted for discard) and survey indices for the relevant stock area . A total of 60,000 MCMC samples were generated from the posterior distribution using two chains with different starting points and thinning the chains by 2 to remove autocorrelation. Of these, the first 5,000 - 10,000 samples were discarded to burn-in the model, e.g. remove dependence on the initial parameter values. The next 20,000 samples were used to evaluate the convergence of the MCMC algorithm for the key model parameters. The remaining 30,000 samples were also thinned by a factor of 2 to remove autocorrelation and these, along with the samples from the convergence check, were used to compute the posterior distribution of model parameters and associated outputs.

After reviewing the initial model diagnostics and results, the Southern Demersal Working Group recommended several changes to the model to improve consistency with expected stock dynamics and fishery trends. In particular, the SDWG recommended that any foreign landings of monkfish, as reported in the online NAFO statistical databases, should be included in the input catch time series. It was agreed that this could be done only for the combined-area monkfish models because there was no way to apportion the NAFO foreign catches to the appropriate northern or southern stock area. The SDWG also indicated that the assumption about catch errors due to misreporting or discarding were probably appropriate and recommended that these be included in the final model runs. The SDWG also considered the assumed discard fraction for 1964-1992 to be reasonable and recommended that this be applied to the domestic fishery landings totals. Similarly, the SDWG recommended using the observed fishery discard fractions for 1996-2000. The SDWG also indicated that it was most appropriate to incorporate the swept-area estimates of stock biomass in 2000 as an index of absolute stock biomass if possible.

Last, the SDWG recommended that the four baseline models be run for the time period 1980-2000 to provide a sensitivity analysis of the effects of excluding the earlier portion of the time series where some questions were raised about the accuracy of the reported catches.

All of the SDWG recommendations were addressed in the final model runs. Results of the final runs for the northern and southern stock areas are presented in Table C48. Each of the runs included the cooperative survey biomass estimate as an index of total biomass in the stock area using a multiplicative lognormal error term.

Results-Bayesian Surplus Production Model
Convergence diagnostics were the GR plots showing the ratio of model estimates of within chain variance to mixed-chain variance for key model parameters. In most cases the two ratios either approached unity or stayed within the interval of [½, 2]. This suggested that the chains were reasonably well-mixed, since the expected value of the variance ratio approaches unity in the limit as the chain length becomes very large. Given the large number of parameters in the model (80+ parameters/unobservables), this was considered to be very satisfactory convergence for the purpose of evaluating the relative trends in biomass and/or fishing mortality, e.g., biomass relative to the biomass that would produce maximum surplus production.

Estimates of the mean and quantiles of the posterior distributions of key model parameters and important outputs are listed in Table C48. There the variable BRATIO is the ratio of stock biomass in year 2000 to the biomass that would produce maximum surplus production. The variable HRATIO is the ratio of the harvest rate in year 2000 to the harvest rate that would produce maximum surplus production. The parameter K is the carrying capacity. The parameter M is the shape parameter for the production curve in the Pella-Thomlinson model. The variable B2001 is population biomass at the start of year 2001. The variable BMSP is the population biomass that would produce maximum surplus production (MSP). The variables qFALL and qSCALLOP are the catchability coefficients for the fall groundfish and the scallop survey biomass time series. The parameter r is the intrinsic growth rate of the stock. The parameter sigma2 is the process error variance, while the parameters tau2FALL and tau2SCALLOP are the observation error variances for the fall groundfish and the scallop survey biomass time series.

Model results indicated that fishing mortality has increased and stock biomass has decreased during the assessment time series of 1964-2000. Current stock biomass appears to be at or below BMSP. In particular, the median estimates of BRATIO for the northern and southern stock areas were 1.02 and 0.57, respectively. Current fishing mortality appears to be above HMSP. In particular, the median estimates of HRATIO for the northern and southern stock areas were 1.85 and 3.82, respectively. In addition, the SARC noted that the estimated production curve was right-skewed in each scenario; this indicated greater resilience to fishing pressure than would be expected under a Schaefer surplus production model.

The evaluation of monkfish status in relation to surplus production reference points for overfished condition and overfishing was conditional on which model scenario, e.g. scenarios (i) or (ii) or (iii), was considered to be most representative. The SARC did not reach a consensus as to which model scenario was most appropriate. However, the SARC did note that scenario (iii) had poor residual patterns for the relative abundance indices and that, under this scenario, the model predictions did not fit the observed data very well. Regardless, each of the model scenarios was consistent with the observed trends in the fall groundfish biomass time series which indicated a long-term decline in biomass. Similarly, each of the model scenarios showed an increasing trend in exploitation rate through time with peak values in the 1990s.

EVALUATION OF STOCK STATUS WITH RESPECT TO REFERENCE POINTS

Northern Region

For SAW 23 and SAW 31, fishing mortality for goosefish was estimated from autumn survey length frequencies (NEFSC 1997; NEFSC 2000). This approach resulted in an unfeasible estimate of $F_{threshold}$ for the northern component. The analysis showed an underlying trend in total mortality consistent with increasing catches and decreases in average and maximum size but F could not be estimated reliably. Therefore, SARC 31 concluded that although current proxies are considered unreliable, the estimates of Z could be taken as a total mortality index, and concluded that overfishing was occurring. By these same criteria, the current assessment indicates that overfishing is occurring (Table C43, 1997-2000 average).

The current three-year moving average catch per tow (kg/tow from NEFSC offshore autumn research vessel survey) of 1.43 kg/tow is below the 33rd percentile of the 1963-1994 series, 1.460 kg/tow (Table C49), the biomass threshold below which the stock component is defined to be overfished. The moving average has been below the 33rd percentile since 1989, and is well below the biomass target of 2.496 kg/tow (median of three-year moving average during 1965-1981).

Southern Region

For SAW 23 and SAW 31, fishing mortality for goosefish was estimated from autumn survey length frequencies (NEFSC 1997; NEFSC 2000). The analysis showed an underlying trend in total mortality consistent with increasing catches and decreases in average and maximum size but point estimates of F were not considered reliable. Therefore, SARC 31 concluded that although current F proxies were considered unreliable, the estimates of Z could be taken as a total mortality index, and concluded that overfishing was occurring. By these same criteria, the current assessment indicates that overfishing is occurring (Table C44, 1997-2000 average).

The current three-year moving average catch per tow (kg/tow from NEFSC offshore autumn research vessel survey) of 0.427 is below the 33rd percentile of the 1963-1994 series of 0.750 kg/tow (Table C49), the biomass threshold below which the stock component is defined to be overfished. The moving average has been below the 33rd percentile since 1987, and is well below the biomass target of 1.848 kg/tow (median of three-year moving average during 1965-1981). The current three-year moving average biomass indices are also well below the proposed revised biomass target for the southern region of 1.846 kg per tow, and the proposed revised biomass threshold of 0.704 kg per tow (Table C49).

Trends in stock biomass, recruitment, and mortality

For the northern component, NEFSC autumn and spring research survey indices show an overall decline in biomass between 1984 and 1999; however, biomass indices in the north increased in 2000 (Tables C15 and C16, Figures C10 and C12). The increase in 2000 reflects increases in both spring and autumn survey abundance indices since 1998 (numbers per tow, Figures C11 and C13). The improved recruitment during the 1990s reflects contributions from the 1992, 1993, 1998 and 1999 year classes. However, the maximum and mean lengths of goosefish in survey catches (Figure C16) remain low.

For the southern component, the NEFSC spring and autumn surveys indicate that stock biomass and abundance have fluctuated around the time series low since the mid-1980s (Tables C20 and C21, Figures C21 and C23) . As for the northern component, decreases in the abundance of large fish in the spring and autumn surveys and decreases in the maximum and mean lengths of the survey catches suggest increasing fishing mortality rates over the time series (Figures C31 and C32). The NEFSC winter flatfish survey indicates no trend in biomass during the 1990s (Table C22, Figure C26); however, the survey has only been conducted since 1992.

For both stock components, indices of egg production (Figures C80-C82) mirror the progressive decline in abundance of larger fish in survey catches.

SARC COMMENTS

The SARC discussed the basis for assessing goosefish as a single stock versus two stocks but did not feel sufficient information exists to make this biological determination. Information presented in favor of two stocks was the recruitment series and minimal adult migration while similar growth patterns and maturity schedules as well as a genetic study favored the one stock hypothesis. In the previous assessment, growth was thought to be different between the two areas, but the industry cooperative survey did not find a difference. It was noted that the genetic study did not provide definitive evidence because low rates of mixing could produce the appearance of a single stock when in fact there were two. Given that there is insufficient information to make the determination, it was decided that the two assessment units approach would be continued. In addition a combined unit is considered.

The SARC noted that the choice of number of management units for this species is independent of the number of assessment units. The use of two management units may be required because landings by gear type differ in the two current regions. Of special note is the apparent distinction between the proportion of landings coming from directed trips in the north versus south and the associated discarding implications of size regulations. In contrast, the use of a single management unit provides consistent regulations for all areas, reducing the complexity of management, but could potentially allow overfishing of one stock if in fact multiple stocks are contained in the management unit.

The SARC discussed potential alternatives for goosefish overfishing definitions because the method used to set the values, i.e. length based Z, has inherent flaws and $F_{threshold}$ in the north is implausibly low. Sufficient information now exists to estimate current fishing mortality rates by age and so yield per recruit analyses, perhaps using different natural mortality rates by sex, could be used to set the reference points. It was noted that the overfishing definition needs to be set in a metric that can be measured in the current year of an assessment to allow determination of current status. Consensus was reached that many lines of evidence point towards overfishing occurring in both the northern and southern units.

The SARC continues to support further development of the Bayesian surplus production model for goosefish assessment. Questions arose as to the appropriateness of the catch data for years 1964 to 1979 when landings are thought to be severely under-reported. However, truncating the time series used in the model to 1980-2000 resulted in unrealistic values for the intrinsic growth rate. Thus, while the SARC does not find a problem with the modeling approach, the data appear to be insufficient to support such modeling at this time.

The SARC commends the collaboration exhibited in the goosefish industry cooperative survey conducted in 2001. This cooperative venture produced new information on growth, maturity, distribution, cannibalism, catch rates, and selectivity that was directly applicable to this assessment.

RESEARCH RECOMMENDATIONS

1) Research should be continued to define stock structure, including genetic studies, reproductive behavior analyses, morphometric studies, parasite studies, elemental analyses, and studies of egg and larvae transport.

2) The SARC recommends changing the overfishing definitions for goosefish. Research on yield per recruit for goosefish should examine the effect and possible causes of differential natural mortality rates by sex, methods to estimate gear selectivity, and the incorporation of discards.

3) Surplus production modeling should continue with special emphasis placed on uncertainty in under-reported catches and population size prior to 1980.

4) Size selectivity studies should be conducted in the trawl fishery to investigate the potential effectiveness of minimum mesh size and shape regulations to reduce discards of undersize monkfish. Additionally, comparative studies of the size selectivity and catchability of trawls and gill nets should be undertaken in order to understand the differences in the numbers of large fish captured in the two gear types.

5) Another cooperative survey for monkfish should be conducted in 2004.

6) Improved sampling rates (as observed in 2000-2001) for commercial landings should be maintained, which should eventually lead to an age-based assessment approach for this species.

7) Tagging studies should be considered as a basis to evaluate adult movement and rates of growth.

8) Spatial distribution of mature and immature fish and the potential effects of size limits on fishing behavior should be evaluated as a basis for advising on strategies to minimize catch and discard of immature fish.

9) Indices of abundance should be developed from industry “study fleets,” including coverage from outside the depth and spatial range of the NEFSC research surveys.

LITERATURE CITED

Almeida, F. P., D.-L. Hartley, and J. Burnett. 1995. Length-weight relationships and sexual maturity of goosefish off the northeast coast of the United States. N. Am. J. Fish. Manage. 15:14-25.

Armstrong, M. P. 1987. Life history of the goosefish, *Lophius americanus*. M. Sc. Thesis, College of William and Mary in Virginia. 80 pp.

Armstrong, M. P., J. A. Musick, and J. A. Colvocoresses. 1992. Age, growth and reproduction of the goosefish, *Lophius americanus* (Pisces: Lophiiformes) U. S. Fishery Bulletin. 90:217-230.

Beverton, R. J. H. and S. J. Holt. A review of methods for estimating mortality rates in exploited fish populations, with special reference to sources of bias in catch sampling. Rapprts et Proces-Verbaux des Reunions 140: 67-83.

Caruso, J. H. 1983. The systematics and distribution of the lophiid angler fisher: II. Revision of the genera *Lophiomus* and *Lophius*. Copeia 1:11-30.

Chikarmane, H.M. , Kuzirian, A.M, Kozlowksi, R, Kuzirian, M. and Lee, T. 2000. Population genetic structure of the goosefish, *Lophius americanus.* Biol. Bull. 199: 227-228.

Cleveland, W. S. 1979. Robust locally weighted regression and smoothing scatterplots. J. Am. Stat. Assoc. 74(368): 829-836.

Cochran, W. G. 1977. Sampling techniques. Wiley. NY.

Conan, G. Y. and E. Wade. 1989. Geostatistical mapping and global estimation of harvestable resources in a fishery of northern shrimp (Pandalus borealis). Int. Coun. Explor. Sea C.M. 1989/D:1, 11p.

Hartley, D. 1995. The population biology of the goosefish, *Lophius americanus*, in the Gulf of Maine. M. Sc. Thesis, University of Massachusetts, Amherst. 142 p.

Martinez, C.M. 1999. The reproductive biology of the goosefish, *Lophius americanus*. M.S. Thesis, University of Rhode Island.

Myers R. A. and P. Pepin. 1990. The robustness of lognormal-based estimators of abundance. Biometrics 46:1185-1192.

NEFSC. 1991. Report of the twelfth northeast regional stock assessment workshop (12th SAW). NEFSC Ref. Doc. 91-03.

NEFSC. 1997. Report of 23rd Northeast Regional Stock Assessment Workshop(23rdSAW). NEFSC Reference Document 97-05.

NEFSC. 2000. 31st Northeast Regional Stock Assessment Workshop(31st SAW). NEFSC Reference Document 00-15.

Pennington, M. 1983. Efficient estimators of abundance, for fish and plankton surveys. Biometrics 39:281-286.

Pennington, M. 1986. Some statistical techniques for estimating abundance indices from trawl surveys. Fishery Bulletin US 84:519-525.

Rao J. N. K. and C. F. J. Wu. 1988. Resampling inference with complex survey data. J. Amer. Stat. Assoc. 83:231-241.

Sissenwine, M. P. and E. W. Bowman. 1977. Fishing power of two bottom trawls towed by research vessels off the northeast coast of the USA during day and night. ICES C.M. 1977:B30.

Sitter R. R. 1992. A resampling procedure for complex survey data. J. Amer. Stat. Assoc. 97:755-765.

Smith S. J. 1990. Use of statistical models for the estimation of abundance from groundfish trawl surveys. Can. J. Fish. Aquat. Sci. 47:894-903.

Smith S. J. 1996. Analysis of data from bottom trawl surveys, in H. Lassen, ed., “Assessment of groundfish stocks based on bottom trawl surveys” NAFO Scientific Council Studies, 28, pp 25-53.

Smith S. J. 1997. Bootstrap confidence limits for groundfish trawl survey estimates of mean abundance. Can. J. Fish. Aquat. Sci. 54:616-630.

Smith S. J. 2000. Notes for National Graduate School Fish Biology and Fisheries Course on: Design and analysis of trawl/dredge surveys for abundance. Sep. 20-25 1998, Tvarminne, Finland.

Smith S. J. and S. Gavaris. 1993. Improving the precision of fish abundance estimates of Eastern Scotian Shelf cod from bottom trawl surveys. N. Amer. J. Fish. Manage. 13:35-47.

Steimle, F.W., W.W. Morse, and D.L. Johnson. 1999. Essential fish habitat source document: goosefish, Lophius americanus, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-127.

Table C1. Landings (calculated live weight, mt) of goosefish as reported in NEFSC weighout data base (1964-1993) and vessel trip reports (1994-2000) (North = SA 511-523, 561; South = SA 524-639 excluding 551-561 plus landings from North Carolina for years 1977-1995); General Canvas database (1964-1989, North = ME, NH, n northern weigh out proportion of MA; South = Southern weigh out proportion of MA, RI-VA); Foreign landings from NAFO database areas 5 and 6. Shaded cells denote suggested source for landings which are used in the total column at the far right (see text for details).

	Weigh Out Plus NC			General Canvas				
Year	US North	US South	US Total	US North	US South	US Total	Foreign	Total
1964	45	19	64	45	61	106	0	106
1965	37	17	54	37	79	115	0	115
1966	299	13	312	299	69	368	2,397	2,765
1967	539	8	547	540	59	598	11	609
1968	451	2	453	449	36	485	2,231	2,716
1969	258	4	262	240	43	283	2,249	2,532
1970	199	12	211	199	53	251	477	728
1971	213	10	223	213	53	266	3,659	3,925
1972	437	24	461	437	65	502	4,102	4,604
1973	710	139	848	708	240	948	6,818	7,766
1974	1,197	101	1,297	1,200	183	1,383	727	2,110
1975	1,853	282	2,134	1,877	417	2,294	2,548	4,842
1976	2,236	428	2,663	2,256	608	2,865	341	3,206
1977	3,137	830	3,967	3,167	1,314	4,481	275	4,756
1978	3,889	1,384	5,273	3,976	2,073	6,049	38	6,087
1979	4,014	3,534	7,548	4,068	4,697	8,765	70	8,835
1980	3,695	4,232	7,927	3,623	6,035	9,658	132	9,790
1981	3,217	2,380	5,597	3,171	4,142	7,313	381	7,694
1982	3,860	3,722	7,582	3,757	4,492	8,249	310	7,892
1983	3,849	4,115	7,964	3,918	4,707	8,624	80	8,044
1984	4,202	3,699	7,901	4,220	4,171	8,391	395	8,296
1985	4,616	4,262	8,878	4,452	4,806	9,258	1,333	10,211
1986	4,327	4,037	8,364	4,322	4,264	8,586	341	8,705
1987	4,960	3,762	8,722	4,995	3,933	8,926	748	9,470
1988	5,066	4,595	9,661	5,033	4,775	9,809	909	10,570
1989	6,391	8,353	14,744	6,263	8,678	14,910	1,178	15,922
1990	5,802	7,204	13,006				1,557	14,563
1991	5,693	9,865	15,558				1,020	16,578
1992	6,923	13,942	20,865				473	21,338
1993	10,645	15,098	25,743				354	26,097
1994	10,950	12,126	23,076				543	23,619
1995	12,032	14,625	26,657				418	27,075
1996	10,762	16,032	26,794				184	26,978
1997	9,794	18,534	28,328				189	28,517
1998	7,367	19,309	26,676				190	26,866
1999	9,260	15,953	25,213				151	25,364
2000	10,689	10,175	20,864				176	21,040

Table C2. U.S. landings of goosefish (calculated live weight) by gear type.

	North					South					Regions Combined				
Year	Trawl	Gill Net	Scallop Dredge	Other	Total	Trawl	Gill Net	Scallop Dredge	Other	Total	Trawl	Gill Net	Scallop Dredge	Other	Total
1964	44.93	0.02			44.95	18.99				18.99	63.92	0.02			63.94
1965	36.41	0.20			36.61	16.61				16.61	53.23	0.20			53.43
1966	298.80	0.17		0.05	299.03	12.63			0.08	12.71	311.43	0.17		0.14	311.74
1967	531.85		7.61		539.46	7.58				7.58	539.64		7.61		547.25
1968	447.19		4.11		451.30	2.07				2.07	449.26		4.11		453.37
1969	253.14	1.35	3.98		258.47	4.02				4.02	257.16	1.35	3.98		262.49
1970	198.25	0.32		0.06	198.63	12.16				12.16	210.41	0.32		0.06	210.79
1971	212.57		0.17		212.74	10.11				10.11	222.68		0.17		222.85
1972	426.45	7.74	1.30	1.57	437.06	24.43				24.43	450.87	7.74	1.30	1.57	461.48
1973	660.85	28.68	12.24	7.96	709.73	131.51		4.88	1.00	137.39	793.54	28.68	17.11	8.96	848.29
1974	1059.61	104.95	7.27	24.73	1196.56	98.03			0.10	98.13	1160.09	104.95	7.27	24.82	1297.13
1975	1711.64	122.83	9.51	8.57	1852.55	265.48	0.24	2.16	1.56	269.44	1989.84	123.07	11.67	10.13	2134.71
1976	2031.30	142.96	46.73	14.62	2235.61	333.09		6.97	0.24	340.30	2458.97	142.96	53.70	14.86	2670.49
1977	2736.74	230.22	142.08	27.56	3136.60	508.08		57.11	25.54	590.73	3487.32	230.22	202.46	53.11	3973.11
1978	3254.89	367.96	212.00	54.17	3889.02	604.78	0.14	507.29	25.50	1137.71	4016.02	368.10	774.35	79.66	5238.13
1979	2966.80	393.04	583.69	70.63	4014.16	943.68	6.13	1015.27	16.33	1981.41	3988.97	399.18	2069.76	86.96	6544.87
1980	2525.97	518.24	595.68	55.66	3695.55	1138.82	10.04	1273.50	6.81	2429.17	3723.11	528.28	2275.51	62.47	6589.37
1981	2266.33	460.64	443.42	46.77	3217.16	1100.10	16.03	781.53	105.45	2003.11	3483.30	477.28	1399.19	152.22	5511.99
1982	3039.51	420.92	367.07	32.41	3859.90	1805.81	11.88	1507.13	27.27	3352.09	4998.08	432.80	2060.73	59.68	7551.29
1983	3233.10	313.69	265.70	36.96	3849.45	1818.58	11.38	2118.86	17.16	3965.98	5165.97	325.07	2430.74	55.54	7977.32
1984	3647.80	314.93	196.37	42.84	4201.94	1714.49	15.46	1704.40	17.97	3452.32	5512.58	330.39	1967.53	60.81	7871.31
1985	3982.26	314.52	263.58	55.33	4615.69	1739.05	17.33	2347.22	2.88	4106.48	5756.74	331.85	2610.80	58.21	8757.60
1986	3412.10	326.21	552.69	35.64	4326.64	1841.10	32.11	2068.22	12.15	3953.58	5317.97	358.32	2620.90	47.79	8344.98
1987	3853.06	373.99	695.43	37.57	4960.05	1679.88	26.25	1996.95	3.42	3706.50	5560.79	400.24	2692.39	40.99	8694.41
1988	3553.90	304.08	1171.59	36.23	5065.80	1828.37	58.22	2593.83	3.02	4483.44	5399.48	362.50	3765.42	39.26	9566.66
1989	3428.68	348.65	2584.13	29.72	6391.18	3240.35	16.89	5035.79	3.47	8296.50	6679.05	366.02	7619.92	33.20	14698.19
1990	3297.60	338.43	2140.73	25.20	5801.97	2361.40	32.11	4744.23	4.75	7142.49	5697.44	371.82	6884.97	29.96	12984.19
1991	3298.76	337.64	2033.44	23.73	5693.57	5515.03	362.60	3907.06	15.72	9800.41	8847.11	700.47	5940.50	39.45	15527.53
1992	4329.96	358.97	2210.53	23.89	6923.36	6527.85	977.16	6408.94	10.80	13924.75	10859.54	1336.14	8619.48	34.69	20849.85
1993	5889.87	695.02	4034.08	26.26	10645.23	5986.62	1722.40	7158.01	192.14	15059.17	11878.65	2417.42	11192.09	218.40	25706.56
1994	7573.88	1571.26	1807.84	86.42	11039.40	5233.06	2342.47	3994.91	555.96	12126.40	12707.47	3883.88	5758.86	637.57	22987.78
1995	9257.30	1528.60	1188.90	56.80	12031.60	5725.40	3804.60	4109.40	742.80	14382.20	14982.76	5333.24	5298.25	799.62	26413.87
1996	8436.50	1391.00	889.30	45.00	10761.80	7173.20	4220.40	4362.30	32.70	15788.60	15609.69	5611.39	5251.52	77.67	26550.27
1997	7399.90	1004.00	1344.60	45.20	9793.70	8234.10	5201.80	4894.50	203.50	18533.90	15633.97	6205.74	6239.05	248.67	28327.43
1998	5443.70	905.50	990.40	26.90	7366.50	7831.90	6195.70	5148.00	133.70	19309.30	13275.58	7101.15	6138.46	160.65	26675.84
1999	7002.20	1492.30	739.50	25.80	9259.80	6398.70	6163.90	3339.10	51.80	15953.50	13400.93	7656.17	4078.59	77.58	25213.27
2000	8172.20	2091.90	345.90	79.10	10689.10	4068.60	4015.30	1944.60	146.70	10175.20	12240.80	6107.18	2290.53	225.84	20864.35

Table C3. Landed weight (mt) of goosefish by market category for 1964-2000 for combined assessment areas SA 511-636), NEFSC weightout database and vessel trip reports (1994-2000).

Year	Belly Flaps	Cheeks	Livers	Gutted	Round	Tails Unc.	Tails Large	Tails Small	Tails Peewee	All Tails
1964	0.0	0.0	0.0	0.0	0.0	19.3	0.0	0.0	0.0	19.3
1965	0.0	0.0	0.0	0.0	0.0	16.1	0.0	0.0	0.0	16.1
1966	0.0	0.0	0.0	0.0	0.0	93.9	0.0	0.0	0.0	93.0
1967	0.0	0.0	0.0	0.0	0.0	164.8	0.0	0.0	0.0	164.8
1968	0.0	0.0	0.0	0.0	0.0	136.6	0.0	0.0	0.0	136.6
1969	0.0	0.0	0.0	0.0	0.0	79.1	0.0	0.0	0.0	79.1
1970	0.0	0.0	0.0	0.0	0.0	63.5	0.0	0.0	0.0	63.5
1971	0.0	0.0	0.0	0.0	0.0	67.1	0.0	0.0	0.0	67.1
1972	0.0	0.0	0.0	0.0	0.0	139.0	0.0	0.0	0.0	139.0
1973	0.0	0.0	0.0	0.0	0.0	255.5	0.0	0.0	0.0	255.5
1974	0.0	0.0	0.0	0.0	0.0	390.7	0.0	0.0	0.0	390.7
1975	0.0	0.0	0.0	0.0	0.0	642.8	0.0	0.0	0.0	642.8
1976	0.0	0.0	0.0	0.0	0.0	802.2	0.0	0.0	0.0	802.2
1977	0.0	0.0	0.0	0.0	0.0	1194.4	0.0	0.0	0.0	1194.4
1978	0.0	0.0	0.0	0.0	0.0	1574.5	0.0	0.0	0.0	1574.5
1979	0.0	0.0	0.0	0.0	0.0	2224.7	0.0	0.0	0.0	2224.7
1980	0.0	0.0	0.0	0.0	0.0	2302.4	0.0	0.0	0.0	2302.4
1981	0.0	0.0	0.0	0.0	0.0	1654.2	0.0	0.0	0.0	1654.2
1982	0.0	0.0	10.2	0.0	0.0	2059.8	153.1	53.3	0.0	2266.2
1983	0.0	0.0	11.6	0.0	0.0	2009.9	241.4	138.6	0.0	2390.0
1984	0.0	0.0	25.0	0.0	0.0	2121.6	186.8	44.5	0.0	2352.9
1985	0.0	0.0	28.0	0.0	0.0	2467.0	86.7	73.4	0.0	2627.1
1986	0.0	0.0	36.3	0.0	0.0	2365.4	76.4	52.2	0.0	2494.0
1987	0.0	0.0	54.2	0.0	0.0	2463.7	139.9	6.7	0.0	2610.3
1988	0.0	0.0	112.8	0.0	0.0	2646.3	195.1	34.8	0.0	2876.2
1989	0.0	0.0	146.3	0.0	15.6	3501.8	557.4	360.0	0.0	4419.2
1990	0.0	0.0	179.7	0.0	217.7	2601.8	854.1	377.4	0.0	3833.3
1991	0.0	8.6	270.3	0.0	415.4	2229.1	1661.9	614.1	36.6	4541.6
1992	0.2	3.7	321.5	0.0	386.0	2778.7	1908.1	1293.0	183.3	6163.1
1993	0.0	1.7	459.9	98.2	528.7	3503.2	1933.0	1851.1	262.4	7549.8
1994	0.0	5.3	458.1	1453.6	2044.8	1256.9	2230.7	2063.3	258.0	5808.9
1995	2.3	1.0	500.1	2763.2	2652.6	895.6	2524.6	2424.4	363.5	6208.1
1996	0.4	0.6	571.6	3475.9	1064.3	1086.9	2094.1	3032.1	269.8	6482.9
1997	0.1	0.1	630.7	3210.0	795.2	675.5	3067.7	3295.7	151.6	7190.6
1998	0.0	0.5	607.4	3592.1	581.8	862.3	3013.6	2654.8	95.5	6626.2
1999	0.1	0.2	597.4	5748.1	1131.4	537.2	2388.3	2200.8	153.4	5279.8
2000	0.0	3.7	624.0	6913.2	1091.0	291.3	1579.2	1707.2	4.3	3582.0

Table C4. Landed weight (mt) of goosefish by market category for 1964-2000 for northern assessment area (SA 511-523 and 561), NEFSC weightout database and vessel trip reports (1994-2000).

Year	Belly Flaps	Cheeks	Livers	Gutted	Round	Tails Unc.	Tails Large	Tails Small	Tails Peewee	All Tails
1964	0.0	0.0	0.0	0.0	0.0	13.5	0.0	0.0	0.0	13.5
1965	0.0	0.0	0.0	0.0	0.0	11.0	0.0	0.0	0.0	11.0
1966	0.0	0.0	0.0	0.0	0.0	90.1	0.0	0.0	0.0	90.1
1967	0.0	0.0	0.0	0.0	0.0	162.5	0.0	0.0	0.0	162.5
1968	0.0	0.0	0.0	0.0	0.0	135.9	0.0	0.0	0.0	135.9
1969	0.0	0.0	0.0	0.0	0.0	77.8	0.0	0.0	0.0	77.8
1970	0.0	0.0	0.0	0.0	0.0	59.8	0.0	0.0	0.0	59.8
1971	0.0	0.0	0.0	0.0	0.0	64.1	0.0	0.0	0.0	64.1
1972	0.0	0.0	0.0	0.0	0.0	131.6	0.0	0.0	0.0	131.6
1973	0.0	0.0	0.0	0.0	0.0	213.8	0.0	0.0	0.0	213.8
1974	0.0	0.0	0.0	0.0	0.0	360.4	0.0	0.0	0.0	360.4
1975	0.0	0.0	0.0	0.0	0.0	558.0	0.0	0.0	0.0	558.0
1976	0.0	0.0	0.0	0.0	0.0	673.4	0.0	0.0	0.0	673.4
1977	0.0	0.0	0.0	0.0	0.0	944.7	0.0	0.0	0.0	944.7
1978	0.0	0.0	0.0	0.0	0.0	1171.4	0.0	0.0	0.0	1171.4
1979	0.0	0.0	0.0	0.0	0.0	1209.1	0.0	0.0	0.0	1209.1
1980	0.0	0.0	0.0	0.0	0.0	1113.1	0.0	0.0	0.0	1113.1
1981	0.0	0.0	0.0	0.0	0.0	969.0	0.0	0.0	0.0	969.0
1982	0.0	0.0	10.0	0.0	0.0	1145.6	15.0	2.0	0.0	1162.6
1983	0.0	0.0	9.3	0.0	0.0	1152.3	4.8	2.4	0.0	1159.4
1984	0.0	0.0	14.7	0.0	0.0	1261.9	3.7	0.0	0.0	1265.6
1985	0.0	0.0	11.4	0.0	0.0	1385.9	1.6	2.6	0.0	1390.2
1986	0.0	0.0	13.7	0.0	0.0	1302.7	0.3	0.2	0.0	1303.2
1987	0.0	0.0	24.0	0.0	0.0	1491.5	1.7	0.7	0.0	1493.9
1988	0.0	0.0	47.4	0.0	0.0	1516.9	5.6	3.3	0.0	1525.8
1989	0.0	0.0	58.7	0.0	11.2	1464.5	327.0	130.2	0.0	1921.6
1990	0.0	0.0	77.9	0.0	30.3	1173.7	410.7	154.0	0.0	1738.4
1991	0.0	3.3	70.0	0.0	0.3	1013.9	538.6	153.2	9.1	1714.8
1992	0.0	0.7	83.0	0.0	0.1	910.5	589.9	505.4	79.4	2085.3
1993	0.0	0.6	208.3	98.2	350.6	1034.3	867.9	1061.8	102.9	3067.0
1994	0.0	1.4	207.6	532.7	981.3	403.0	1205.7	1074.8	136.2	2819.7
1995	0.0	0.7	176.1	1213.4	1122.0	369.7	1178.6	1015.5	305.6	2869.3
1996	0.3	0.4	196.2	1114.2	756.3	92.5	933.0	1381.5	224.1	2631.0
1997	0.0	0.1	154.6	628.5	247.0	29.0	1142.6	1368.9	119.2	2659.6
1998	0.0	0.1	129.4	558.5	145.5	18.2	1067.2	818.7	79.2	1983.3
1999	0.0	0.1	173.2	1670.7	510.1	28.9	1021.8	871.7	139.4	2061.7
2000	0.0	0.1	287.1	3209.0	906.0	17.3	779.1	1045.7	2.7	1844.8

Table C5. Landed weight (mt) of goosefish by market category for 1964-2000 for southern assessment area (SA 524-636 excluding 561), NEFSC weightout database and vessel trip reports (1994-2000).

Year	Belly Flaps	Cheeks	Livers	Gutted	Round	Tails Unc.	Tails Large	Tails Small	Tails Peewee	All Tails
1964	0.0	0.0	0.0	0.0	0.0	5.7	0.0	0.0	0.0	5.7
1965	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	5.0
1966	0.0	0.0	0.0	0.0	0.0	3.9	0.0	0.0	0.0	3.8
1967	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	2.3
1968	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.6
1969	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	1.2
1970	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0	3.7
1971	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	3.0
1972	0.0	0.0	0.0	0.0	0.0	7.4	0.0	0.0	0.0	7.4
1973	0.0	0.0	0.0	0.0	0.0	41.7	0.0	0.0	0.0	41.7
1974	0.0	0.0	0.0	0.0	0.0	30.3	0.0	0.0	0.0	30.3
1975	0.0	0.0	0.0	0.0	0.0	84.8	0.0	0.0	0.0	84.8
1976	0.0	0.0	0.0	0.0	0.0	128.8	0.0	0.0	0.0	128.8
1977	0.0	0.0	0.0	0.0	0.0	249.6	0.0	0.0	0.0	249.6
1978	0.0	0.0	0.0	0.0	0.0	403.1	0.0	0.0	0.0	403.1
1979	0.0	0.0	0.0	0.0	0.0	1015.6	0.0	0.0	0.0	1015.6
1980	0.0	0.0	0.0	0.0	0.0	1189.3	0.0	0.0	0.0	1189.3
1981	0.0	0.0	0.0	0.0	0.0	685.0	0.0	0.0	0.0	685.0
1982	0.0	0.0	0.2	0.0	0.0	912.4	138.1	51.3	0.0	1101.8
1983	0.0	0.0	2.3	0.0	0.0	857.7	236.6	136.2	0.0	1230.5
1984	0.0	0.0	10.3	0.0	0.0	859.7	183.1	44.5	0.0	1087.3
1985	0.0	0.0	16.7	0.0	0.0	1081.1	85.1	70.8	0.0	1236.9
1986	0.0	0.0	22.6	0.0	0.0	1062.6	76.1	52.0	0.0	1190.8
1987	0.0	0.0	330.2	0.0	0.0	972.2	138.2	6.0	0.0	1116.4
1988	0.0	0.0	65.4	0.0	0.0	1129.3	189.5	31.5	0.0	1350.4
1989	0.0	0.0	87.6	0.0	4.5	2037.4	230.4	229.8	0.0	2497.5
1990	0.0	0.0	101.8	0.0	187.3	1428.1	443.4	223.4	0.0	2094.9
1991	0.0	5.2	200.2	0.0	415.1	1215.2	1123.3	460.9	27.5	2826.8
1992	0.2	3.0	238.5	0.0	385.9	1868.2	1318.3	787.6	103.9	4077.9
1993	0.0	1.1	251.5	0.0	178.1	2468.9	1065.1	789.3	159.4	4482.8
1994	0.0	3.8	250.5	921.0	1063.5	853.9	1025.0	988.5	121.8	2989.2
1995	2.3	0.3	324.0	1549.8	1530.6	526.0	1346.0	1409.0	57.8	3338.8
1996	0.1	0.3	375.4	2361.7	308.0	994.4	1161.2	1650.6	45.7	3851.9
1997	0.1	0.0	476.1	2581.5	548.1	646.6	1925.2	1926.8	32.4	4531.0
1998	0.0	0.4	478.0	3033.6	436.3	844.1	1946.4	1836.1	16.3	4642.9
1999	0.1	0.1	424.2	4077.4	621.3	508.4	1366.5	1329.1	14.1	3218.0
2000	0.0	3.5	336.9	3704.2	185.0	274.0	800.2	661.4	1.6	1737.2

Table C6. Number of commercial samples and length measurements taken by year, market category, and stock area. Live metric tons are also shown.

	Market	NORTH				SOUTH				TOTAL			
Year	Category	Samples	Lengths	live mt	mt/sample	Samples	Lengths	live mt	mt/sample	Samples	Lengths	mt	mt/sample
1996	tails only	1	109	306	306	1	123	3,302	3,302	2	232	3,608	1,804
	tails large	13	1,383	3,097	238	6	618	3,856	643	19	2,001	6,953	366
	tails small	10	1,438	4,588	459	6	609	5,479	913	16	2,047	10,067	629
	tails peewee	9	1,258	744	83	4	415	152	38	13	1,673	896	69
	unclass round	2	252	752	376	-	-	313	-	2	252	1,065	533
	head on, gutted	3	478	1,284	428	7	1,287	2,679	383	10	1,765	3,963	396
	annual total	38	4,918	10,771	-	24	3,052	15,781	-	62	7,970	26,552	428
1997	tails only	-	-	104	-	-	-	2,139	-	-	-	2,243	-
	tails large	12	1,324	3,831	319	12	1,220	6,354	530	24	2,544	10,185	424
	tails small	12	1,262	4,529	377	14	1,451	6,413	458	26	2,713	10,942	421
	tails peewee	9	863	396	44	3	300	108	36	12	1,163	504	42
	unclass round	10	936	243	24	1	98	552	552	11	1,034	795	72
	head on, gutted	1	53	718	718	4	551	2,942	736	5	604	3,660	732
	annual total	44	4,438	9,821	-	34	3,620	18,508	-	78	8,058	28,329	363
1998	tails only	-	-	72	-	-	-	2,789	-	-	-	2,861	-
	tails large	6	713	3,548	591	5	487	6,457	1,291	11	1,200	10,005	910
	tails small	8	877	2,728	341	4	444	6,086	1,522	12	1,321	8,814	735
	tails peewee	1	136	263	263	-	-	54	-	1	136	317	317
	unclass round	-	-	142	-	-	-	440	-	-	-	582	-
	head on, gutted	-	-	659	-	-	-	3,436	-	-	-	4,095	-
	annual total	15	1,726	7,412	-	9	931	19,262	-	24	2,657	26,674	1,111
1999	tails only	-	-	158	-	-	-	1,224	-	-	-	1,382	-
	tails large	6	634	3,436	573	5	480	4,652	930	11	1,114	8,088	735
	tails small	19	1,997	2,926	154	8	814	4,533	567	27	2,811	7,459	276
	tails peewee	-	-	463	-	-	-	48	-	-	-	511	-
	unclass round	-	-	499	-	-	-	633	-	-	-	1,132	-
	head on, gutted	1	115	1,872	1,872	4	254	4,581	1,145	5	369	6,453	1,291
	annual total	26	2,746	9,354	-	17	1,548	15,671	-	43	4,294	25,025	582
2000	tails only	-	-	58	-	1	102	910	910	1	102	967	967
	tails large	6	567	2,587	431	7	667	2,657	380	13	1,234	5,243	403
	tails small	50	5,175	3,472	69	7	748	2,196	314	57	5,923	5,668	99
	tails peewee	-	-	9	-	-	-	5	-	-	-	14	-
	unclass round	16	1,839	906	57	-	-	185	-	16	1,839	1,091	68
	head on, gutted	21	2,095	3,658	174	14	1,175	4,223	302	35	3,270	7,881	225
	annual total	93	9,676	10,689	-	29	2,692	10,175	-	122	12,368	20,865	171

Table C7. Discard ratios (mt discarded / mt kept) of goosefish by gear and half year from fishery observer and VTR databases, northern area.

North			Observer Data				VTR Data			
GEAR	YEAR	HALF	No. Tows	Kept (mt)	Discard (mt)	Disc Ratio	No. Trips	Kept (mt)	Discard (mt)	Disc Ratio
Dredge	1996	1	150	0.680	0.324	0.476	10	2.074	0.696	0.336
		2	309	3.779	1.102	0.292	48	43.741	5.144	0.118
		Total	459	4.460	1.426	0.320	58	45.815	5.841	0.127
	1997	1	139	0.216	0.303	1.405	21	7.664	0.959	0.125
		2	437	9.421	1.210	0.128	31	39.441	3.562	0.090
		Total	576	9.637	1.514	0.157	52	47.105	4.521	0.096
	1998	1	79	0.470	0.061	0.131	21	3.540	1.511	0.427
		2	169	5.929	0.301	0.051	21	21.514	2.028	0.094
		Total	248	6.399	0.362	0.057	42	25.054	3.538	0.141
	1999	1	79	0.469	0.070	0.149	10	1.848	0.739	0.400
		2	28	0.164	0.000	0.000	23	11.530	0.742	0.064
		Total	107	0.633	0.070	0.110	33	13.378	1.481	0.111
	2000	1	2	0.044	0.006	0.140	13	3.180	0.356	0.112
		2	12	0.144	0.022	0.155	18	9.920	2.248	0.227
		Total	14	0.188	0.028	0.152	31	13.100	2.604	0.199
Gillnet	1996	1	70	1.818	0.248	0.136	178	35.861	0.866	0.024
		2	102	2.240	0.305	0.136	335	120.794	2.814	0.023
		Total	172	4.058	0.553	0.136	513	156.655	3.680	0.023
	1997	1	55	1.770	0.068	0.038	109	3.747	0.196	0.052
		2	76	1.430	0.278	0.194	193	16.664	0.519	0.031
		Total	131	3.200	0.345	0.108	302	20.411	0.715	0.035
	1998	1	83	1.098	0.032	0.029	110	10.678	0.613	0.057
		2	160	4.808	0.209	0.044	135	10.422	0.382	0.037
		Total	243	5.906	0.242	0.041	245	21.100	0.995	0.047
	1999	1	80	1.236	0.084	0.068	118	21.803	0.923	0.042
		2	136	5.828	0.072	0.012	274	99.446	6.441	0.065
		Total	216	7.064	0.156	0.022	392	121.249	7.364	0.061
	2000	1	117	3.091	0.106	0.034	141	39.352	2.357	0.060
		2	226	15.921	1.244	0.078	550	283.340	19.810	0.070
		Total	343	19.011	1.350	0.071	691	322.692	22.167	0.069
Trawl	1996	1	388	38.342	7.550	0.197	750	352.498	26.965	0.076
		2	159	3.540	0.467	0.132	1339	348.205	23.180	0.067
		Total	547	41.883	8.017	0.191	2089	700.703	50.146	0.072
	1997	1	212	20.731	2.169	0.105	733	238.566	17.178	0.072
		2	169	14.472	1.112	0.077	1066	228.037	13.476	0.059
		Total	381	35.203	3.281	0.093	1799	466.603	30.654	0.066
	1998	1	86	5.498	0.666	0.121	588	156.483	8.120	0.052
		2	25	1.313	0.115	0.087	913	149.004	7.561	0.051
		Total	111	6.811	0.780	0.115	1501	305.487	15.681	0.051
	1999	1	47	4.042	0.398	0.098	609	268.948	12.686	0.047
		2	205	12.692	0.781	0.062	1207	246.484	21.044	0.085
		Total	252	16.734	1.179	0.070	1816	515.432	33.730	0.065
	2000	1	433	52.684	3.691	0.070	723	320.608	37.027	0.115
		2	479	61.414	5.436	0.089	1502	410.703	59.302	0.144
		Total	912	114.098	9.127	0.080	2225	731.311	96.329	0.132

Table C8. Discard ratios (mt discarded / mt kept) of goosefish by gear and half year from fishery observer and VTR databases, southern area.

South			Observer Data				VTR Data			
GEAR	YEAR	HALF	No. Tows	Kept (mt)	Discard (mt)	Disc Ratio	No. Trips	Kept (mt)	Discard (mt)	Disc Ratio
Dredge	1996	1	1284	12.781	4.117	0.322	107	73.882	10.078	0.136
		2	1270	23.726	4.387	0.185	96	120.084	12.570	0.105
		Total	2554	36.506	8.504	0.233	203	193.966	22.649	0.117
	1997	1	1268	21.852	4.735	0.217	68	49.945	4.450	0.089
		2	709	11.072	3.774	0.341	78	71.017	5.885	0.083
		Total	1977	32.924	8.509	0.258	146	120.962	10.335	0.085
	1998	1	574	11.001	0.525	0.048	64	52.556	5.127	0.098
		2	651	15.453	0.927	0.060	44	38.554	5.596	0.145
		Total	1225	26.454	1.451	0.055	108	91.110	10.723	0.118
	1999	1	373	3.304	1.553	0.470	38	19.313	19.493	1.009
		2	478	6.939	1.148	0.165	51	25.051	4.980	0.199
		Total	851	10.243	2.701	0.264	89	44.364	24.473	0.552
	2000	1	564	12.897	2.706	0.210	40	14.964	3.463	0.231
		2	533	5.331	1.778	0.333	59	37.653	6.109	0.162
		Total	1097	18.228	4.484	0.246	99	52.617	9.572	0.182
Gillnet	1996	1	403	37.871	2.720	0.072	309	204.625	7.884	0.039
		2	45	8.111	0.426	0.053	178	119.753	4.376	0.037
		Total	448	45.981	3.147	0.068	487	324.378	12.260	0.038
	1997	1	508	85.563	6.014	0.070	236	176.233	7.126	0.040
		2	141	25.777	0.381	0.015	93	77.095	1.940	0.025
		Total	649	111.341	6.395	0.057	329	253.328	9.066	0.036
	1998	1	386	77.076	6.185	0.080	149	154.552	3.627	0.023
		2	46	5.930	0.373	0.063	149	161.675	7.605	0.047
		Total	432	83.006	6.558	0.079	298	316.227	11.231	0.036
	1999	1	90	12.193	0.643	0.053	236	273.963	21.121	0.077
		2	28	2.495	0.128	0.051	161	231.345	14.164	0.061
		Total	118	14.688	0.772	0.053	397	505.308	35.285	0.070
	2000	1	97	13.471	1.278	0.095	299	234.134	56.230	0.240
		2	37	6.228	0.322	0.052	111	63.333	5.744	0.091
		Total	134	19.699	1.600	0.081	410	297.467	61.974	0.208
Trawl	1996	1	276	6.422	1.084	0.169	268	139.753	8.706	0.062
		2	156	8.332	0.788	0.095	250	280.312	10.455	0.037
		Total	432	14.754	1.872	0.127	518	420.065	19.161	0.046
	1997	1	380	55.611	1.365	0.025	250	265.586	10.640	0.040
		2	152	24.789	2.153	0.087	177	125.820	4.496	0.036
		Total	532	80.399	3.518	0.044	427	391.406	15.136	0.039
	1998	1	209	4.439	0.480	0.108	194	149.583	3.439	0.023
		2	86	2.809	0.077	0.027	144	74.854	1.786	0.024
		Total	295	7.247	0.556	0.077	338	224.437	5.225	0.023
	1999	1	249	6.237	0.276	0.044	211	108.530	6.824	0.063
		2	77	12.318	1.460	0.119	118	54.879	2.036	0.037
		Total	326	18.556	1.736	0.094	329	163.409	8.859	0.054
	2000	1	344	3.536	2.547	0.720	182	54.788	8.693	0.159
		2	166	10.871	1.213	0.112	157	198.283	13.898	0.070
		Total	510	14.407	3.760	0.261	339	253.071	22.592	0.089

Table C9. Calculation of total catch by stock area, gear, and half year using observer discard ratios.

			Landings		Estimated				
	Discard Ratio		Live weight (mt)		Discards (mt)		Estimated Catch (mt)		
North	**Jan-June**	**July-Dec**	**Jan-June**	**July-Dec**	**Jan-June**	**July-Dec**	**Jan-June**	**July-Dec**	**Total**
Trawls									
1996	0.197	0.132	4411.5	4025.1	868.7	530.9	5280.2	4556.0	9836.2
1997	0.105	0.077	4087.1	3312.9	427.7	254.5	4514.7	3567.4	8082.1
1998	0.121	0.087	3173.5	2270.2	384.1	198.4	3557.6	2468.6	6026.2
1999	0.098	0.062	3958.3	3043.9	389.5	187.4	4347.9	3231.3	7579.2
2000	0.070	0.089	4011.6	4160.6	281.1	368.2	4292.7	4528.9	8821.5
Scallop Dredges									
1996	0.476	0.292	38.9	850.3	18.5	247.9	57.5	1098.2	1155.7
1997	1.405	0.128	210.9	1133.7	296.3	145.7	507.1	1279.4	1786.5
1998	0.131	0.051	263.2	727.2	34.4	36.9	297.6	764.1	1061.7
1999	0.149	0.000	261.7	477.8	39.0	0.0	300.7	477.8	778.5
2000	0.140	0.155	97.9	248.0	13.7	38.5	111.7	286.5	398.1
Gillnets									
1996	0.136	0.136	380.8	1010.2	51.9	137.7	432.6	1147.9	1580.5
1997	0.038	0.194	303.2	700.8	11.6	136.1	314.7	836.9	1151.6
1998	0.029	0.044	262.3	643.2	7.7	28.0	270.0	671.2	941.2
1999	0.068	0.012	349.2	1143.1	23.8	14.1	373.0	1157.2	1530.2
2000	0.034	0.078	383.6	1708.2	13.2	133.5	396.8	1841.7	2238.5
Other									
1996	0.199	0.196	34.2	10.8	6.8	2.1	41.0	12.9	53.9
1997	0.112	0.103	29.7	15.4	3.3	1.6	33.1	17.0	50.1
1998	0.107	0.052	14.3	12.7	1.5	0.7	15.8	13.3	29.1
1999	0.096	0.047	5.2	20.6	0.5	1.0	5.7	21.6	27.3
2000	0.068	0.087	20.9	58.3	1.4	5.0	22.3	63.3	85.6
South									
Trawls									
1996	0.169	0.095	3088.6	4084.6	521.4	386.2	3610.0	4470.7	8080.7
1997	0.025	0.087	3951.7	4282.4	97.0	371.9	4048.7	4654.3	8703.0
1998	0.108	0.027	3977.5	3854.4	429.8	105.2	4407.3	3959.6	8366.9
1999	0.044	0.119	4071.0	2327.7	180.0	275.9	4250.9	2603.6	6854.6
2000	0.720	0.112	2391.5	1677.1	1722.6	187.1	4114.1	1864.2	5978.3
Scallop Dredges									
1996	0.322	0.185	1790.9	2571.4	576.8	475.5	2367.7	3046.9	5414.6
1997	0.217	0.341	2226.9	2667.6	482.5	909.2	2709.5	3576.7	6286.2
1998	0.048	0.060	2492.7	2655.3	118.9	159.2	2611.6	2814.6	5426.1
1999	0.470	0.165	1831.9	1507.2	861.2	249.3	2693.2	1756.5	4449.6
2000	0.210	0.333	1074.4	870.2	225.5	290.2	1299.8	1160.4	2460.2
Gillnets									
1996	0.072	0.053	2770.6	1449.9	199.0	76.2	2969.6	1526.1	4495.7
1997	0.070	0.015	3712.6	1489.2	261.0	22.0	3973.6	1511.2	5484.7
1998	0.080	0.063	4133.3	2062.3	331.7	129.7	4465.0	2192.0	6657.0
1999	0.053	0.051	4375.3	1788.6	230.9	92.0	4606.2	1880.6	6486.8
2000	0.095	0.052	2810.5	1204.8	266.7	62.2	3077.2	1267.0	4344.2
Other									
1996	0.139	0.139	24.8	7.9	3.4	1.1	28.2	9.0	37.2
1997	0.074	0.102	151.3	52.2	11.2	5.3	162.6	57.5	220.1
1998	0.078	0.057	74.4	59.4	5.8	3.4	80.2	62.7	142.9
1999	0.114	0.126	6.8	44.9	0.8	5.7	7.6	50.6	58.2
2000	0.218	0.148	122.4	24.3	26.7	3.6	149.1	27.9	177.1

Table C10. Annual landings, discards and total catch summarized from table C9.

	Reported Landings (live wt mt)	Estimated Discards (mt)	Overall Discard Ratio	Percent of Catch Discarded	Estimated Catch (mt)
North					
1996	10762	1865	0.173	14.8	12626
1997	9794	1277	0.13	11.5	11070
1998	7367	692	0.094	8.6	8058
1999	9260	655	0.071	6.6	9915
2000	10689	855	0.08	7.4	11544
South					
1996	15789	2240	0.142	12.4	18028
1997	18534	2160	0.117	10.4	20694
1998	19309	1284	0.066	6.2	20593
1999	15953	1896	0.119	10.6	17849
2000	10175	2785	0.274	21.5	12960
Total					
1996	26550	4104	0.155	13.4	30655
1997	28327	3437	0.121	10.8	31764
1998	26676	1975	0.074	6.9	28651
1999	25213	2551	0.101	9.2	27764
2000	20864	3639	0.174	14.9	24504

Table C11. Sample size, median CPUE and GLM-estimated CPUE at depth by gear and area. Zones are 20 fathom depth increments starting with 0-20 fa (zone 1) and ending with >180 fa (zone 10).

		Depth Zone									
		1	2	3	4	5	6	7	8	9	10
Dredge											
All Areas	N	749	7798	757	14	3					
	Median	2	2.22	2.39	2.55	1.87					
	LSMEAN	1.85	2.06	2.17	2.25	1.62					
North	N	136	1531	285	3	2					
	Median	1.68	2.22	2.42	2.55	1.94					
	LSMEAN	1.56	1.82	1.97	2.05	1.22					
South	N	613	6267	472	11	1					
	Median	2.03	2.22	2.38	2.55	1.87					
	LSMEAN	1.84	2.04	2.17	2.15	1.72					
Small Mesh Gill Net											
All Areas	N	6560	14190	3831	1639	1407	335	47	50	19	28
	Median	1.54	1.48	1.48	1.62	2	2	1.29	1.32	1.35	1.77
	LSMEAN	1.78	1.67	1.64	1.8	2.06	2.15	1.68	1.51	1.4	2.04
North	N	4391	13377	3800	1624	1361	304	39	44	17	6
	Median	1.48	1.46	1.48	1.62	2	2.06	1.27	1.18	1.29	1.07
	LSMEAN	1.67	1.62	1.61	1.79	2.04	2.19	1.61	1.43	1.25	1.65
South	N	2169	813	31	15	46	31	8	6	2	22
	Median	1.75	1.9	1.77	1.38	2.09	1.48	1.56	1.74	2.23	1.95
	LSMEAN	1.72	1.85	2.03	1.57	2.11	1.53	1.54	1.8	2.15	1.87
Large Mesh Gill Net											
All Areas	N	9093	6197	1043	390	464	179	195	77	5	8
	Median	2.78	2.9	2.83	2.67	3.25	3.07	2.65	2.82	2.81	2.73
	LSMEAN	2.98	3.11	3.1	2.91	3.23	3.1	2.93	2.98	3.12	2.84
North	N	504	1404	615	84	76	14	1			
	Median	2.76	2.66	2.69	2.61	3.11	2.77	2.82			
	LSMEAN	2.86	2.65	2.7	2.66	2.99	2.9	3.36			
South	N	8589	4793	428	306	388	165	194	77	5	8
	Median	2.78	2.98	3.09	2.69	3.26	3.1	2.65	2.82	2.81	2.73
	LSMEAN	2.98	3.17	3.18	2.91	3.21	3.1	2.93	2.98	3.11	2.85
Trawl											
All Areas	N	9942	18945	11257	4782	7958	2763	840	245	100	284
	Median	1.78	1.98	2.08	2.4	2.55	2.72	2.88	3.12	3.21	3.29
	LSMEAN	1.85	1.99	2.16	2.39	2.53	2.67	2.73	2.95	2.9	3.11
North	N	3462	11329	10174	4500	7854	2725	735	104	20	19
	Median	1.82	1.84	2.02	2.41	2.55	2.71	2.83	2.86	2.73	2.7
	LSMEAN	1.84	1.86	2.1	2.39	2.54	2.7	2.73	2.84	2.67	2.71
South	N	6480	7616	1083	282	104	38	105	141	80	265
	Median	1.78	2.22	2.52	2.19	2.47	3.09	3.28	3.27	3.28	3.31
	LSMEAN	1.85	2.15	2.42	2.16	2.34	2.84	3.11	3.04	2.94	3.06

Table C12. Sample size, median CPUE, and GLM-estimated CPUE at depth for directed trawl trips (directed trip defined by goosefish catch at least half of total catch in weight). Zones are 20 fathom depth increments starting with 0-20 fa (zone 1) and ending with >180 fa (zone 10).

		Depth Zone									
		1	2	3	4	5	6	7	8	9	10
Directed Trawl											
All Areas	N	107	804	1035	537	498	255	212	153	73	239
	Median	3.24	3.18	3	3.05	3.26	3.29	3.28	3.3	3.33	3.36
	LSMEAN	3.21	3.1	3.1	3.17	3.19	3.18	3.17	3.22	3.2	3.24
North	N	55	258	816	502	482	232	120	22	3	5
	Median	3.3	3	2.92	3.04	3.24	3.29	3.26	3.27	3.32	3.35
	LSMEAN	3.16	3.07	3.1	3.18	3.18	3.19	3.14	3.13	3.25	3.09
South	N	52	546	219	35	16	23	92	131	70	234
	Median	3.18	3.23	3.2	3.16	3.39	3.22	3.32	3.3	3.33	3.37
	LSMEAN	3.32	3.28	3.26	3.18	3.33	3.3	3.37	3.4	3.38	3.41

Table C13. Sample size and associated reported catch for all trips and only "directed" trips (denoted subset) from VTR database for three gears. A "directed" trip is defined as one in which the catch of goosefish comprises at least half of the total catch for the trip. Data is summed over years 1995-2000.

Trawl

Area	N (all data)	N (subset)	subset/all	kept mt (all data)	kept mt (subset)	subset/all
All	57,116	3,913	6.90%	23,186	9,558	41%
North	40,922	2,495	6.10%	15,649	3,794	24%
South	16,194	1,418	8.80%	7,537	5,764	76%

Large Mesh Gill Net

Area	N (all data)	N (subset)	subset/all	kept mt (all data)	kept mt (subset)	subset/all
All	17,651	15,284	86.60%	4,941	4,678	95%
North	2,698	2,286	84.70%	2,471	2,339	95%
South	14,953	12,998	86.90%	14,570	14,083	97%

Small Mesh Gill Net

Area	N (all data)	N (subset)	subset/all	kept mt (all data)	kept mt (subset)	subset/all
All	28,106	743	2.60%	3,224	765	24%
North	24,963	527	2.10%	1,612	382	24%
South	3,143	216	6.90%	377	124	33%

Table C14 . Estimated parameters (L_{full} and shape parameters) of the vulnerability function and length (cm) at 90%, 75%, 50%, 25%, and 10% vulnerability for goosefish kept by commercial vessels using trawls and scallop dredges, compared with length frequency vulnerability for goosefish distributions obtained from NEFSC scallop, winter and autumn trawl surveys during 1996-1999.

Northern Stock	Trawl catch vs Scallop Survey				Dredge Catch vs Scallop Survey			
	1996	1997	1998	1999	1996	1997	1998	1999
SS	0.0233	0.0158	0.0272	Incomplete	0.0498	0.0099	0.0231	Incomplete
L_{full} (cm)	58.08	40.8	38.72	Survey	49.74	55.54	47.04	Survey
s	291.06	0.83	1.13		6.68	58.57	3.02	
Length (cm) at:								
90% Vulnerability	50.24	40.38	38.23		48.55	52.03	46.25	
75% Vulnerability	45.13	40.11	37.91		47.78	49.73	45.73	
50% Vulnerability	37.99	39.72	37.46		46.7	46.53	45	
25% Vulnerability	29.67	39.28	36.95		45.44	42.8	44.15	
10% Vulnerability	21.46	38.84	36.43		44.19	39.12	43.31	

Southern Stock	Trawl catch vs Scallop Survey				Dredge catch vs Scallop Survey				Trawl Catch vs Winter Survey				Dredge Catch vs Winter Survey			
	1996	1997	1998	1999	1996	1997	1998	1999	1996	1997	1998	1999	1996	1997	1998	1999
SS	0.0091	0.0126	0.0059	0.039	0.0087	0.0088	0.0113	0.0219	0.0068	0.0027	0.0071	0.0104	0.0112	0.0051	0.0067	0.0076
L_{full} (cm)	43.4	43.13	37.59	53.06	47.89	43.16	67.94	53.97	43.04	40.04	48.67	60.22	44.92	40.01	48.9	80.63
s	14.82	5.15	4.96	44.82	35.6	5.14	375.99	76.23	3.09	3.15	31.5	56.72	6.37	2.71	16.53	244.44
Length (cm) at:																
90% Vulnerability	41.63	42.08	36.57	49.99	45.15	42.12	59.04	49.96	42.23	39.22	46.1	56.76	43.76	39.26	47.03	73.45
75% Vulnerability	40.48	41.4	35.9	47.98	43.36	41.44	53.24	47.34	41.71	38.69	44.42	54.5	43	38.76	45.81	68.77
50% Vulnerability	38.87	40.45	34.97	45.18	40.86	40.49	45.11	43.69	40.97	37.95	42.07	51.35	41.94	38.07	44.11	62.22
25% Vulnerability	36.99	39.35	33.88	41.91	37.96	39.39	35.66	39.43	40.11	37.08	39.33	47.68	40.71	37.27	42.13	54.6
10% Vulnerability	35.14	38.25	32.81	38.7	35.08	38.3	26.33	35.23	39.27	36.23	36.63	44.06	39.5	36.48	40.17	47.08

Table C15. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC offshore autumn research vessel bottom surveys in the northern management region (strata 20-30, 34-40); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed in each year.

	Biomass						Abundance															
	Raw Index			Smoothed			Raw Index			Smoothed				Length								
	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Number of Fish	Number of Nonzero Tows	Number of Tows
1963	3.757	2.161	5.353	2.843			0.801	0.508	1.094	0.568			4.661	11	14	59	58.3	103	111	86	39	90
1964	1.712	0.896	2.528	2.357			0.392	0.219	0.564	0.451			4.354	21	21	58	59.4	92	102	32	23	87
1965	2.509	1.350	3.667	2.422			0.347	0.230	0.463	0.394			7.137	28	36	70	71.6	96	110	40	30	88
1966	3.266	2.102	4.431	2.432	1.628	3.631	0.492	0.331	0.653	0.375	0.258	0.544	6.532	37	48	73	73.1	90	96	55	33	86
1967	1.283	0.441	2.125	2.002	1.341	2.990	0.189	0.090	0.288	0.297	0.205	0.431	6.799	48	48	69	70.3	91	92	18	14	86
1968	2.036	0.521	3.552	2.223	1.489	3.320	0.286	0.115	0.457	0.319	0.220	0.463	7.121	11	26	72	71.4	105	106	32	16	86
1969	3.705	1.781	5.628	2.618	1.753	3.910	0.418	0.277	0.559	0.368	0.254	0.534	8.718	13	41	78	78.8	101	110	39	30	88
1970	2.237	0.947	3.527	2.442	1.635	3.647	0.395	0.222	0.569	0.391	0.269	0.567	5.754	22	36	67	67.2	90	98	41	21	92
1971	2.914	1.436	4.391	2.416	1.618	3.607	0.491	0.312	0.670	0.411	0.283	0.596	5.864	15	22	69	67.0	97	101	44	27	94
1972	1.404	0.651	2.157	2.106	1.410	3.145	0.318	0.195	0.442	0.384	0.264	0.557	4.354	21	21	61	56.9	97	99	29	22	94
1973	3.114	1.782	4.446	2.412	1.615	3.602	0.514	0.320	0.709	0.406	0.280	0.590	5.992	16	16	58	65.2	109	112	63	29	92
1974	2.063	1.114	3.011	2.327	1.558	3.475	0.313	0.189	0.436	0.367	0.253	0.533	6.362	13	13	69	64.9	109	111	37	23	97
1975	1.711	1.003	2.418	2.434	1.630	3.635	0.298	0.178	0.418	0.369	0.254	0.536	5.721	11	11	60	62.9	97	102	40	27	106
1976	3.387	1.555	5.219	3.227	2.161	4.819	0.422	0.244	0.601	0.429	0.296	0.623	7.620	29	30	71	72.1	106	121	32	24	87
1977	5.568	3.489	7.646	4.140	2.772	6.183	0.626	0.458	0.794	0.504	0.347	0.731	8.635	21	35	73	71.1	107	119	112	56	126
1978	5.101	3.487	6.714	4.353	2.915	6.501	0.579	0.429	0.729	0.511	0.352	0.742	8.106	10	24	70	67.6	104	116	146	78	201
1979	5.133	3.566	6.700	4.114	2.755	6.143	0.474	0.364	0.584	0.477	0.329	0.693	10.233	15	19	77	73.5	103	115	125	78	211
1980	4.458	2.234	6.682	3.350	2.244	5.003	0.535	0.366	0.703	0.448	0.309	0.650	7.549	6	16	66	63.9	101	111	65	39	97
1981	1.984	1.183	2.786	2.252	1.508	3.363	0.406	0.288	0.523	0.373	0.257	0.541	4.892	9	13	55	57.5	93	101	46	30	93
1982	0.936	0.379	1.492	1.648	1.104	2.461	0.142	0.070	0.213	0.293	0.202	0.425	6.606	29	29	71	68.9	97	100	17	14	95
1983	1.617	0.927	2.308	1.764	1.182	2.635	0.470	0.284	0.656	0.375	0.258	0.544	3.415	13	17	54	53.0	88	96	38	27	82
1984	3.010	1.413	4.607	2.003	1.341	2.991	0.483	0.353	0.613	0.412	0.284	0.599	5.803	11	26	63	62.7	102	106	36	29	88
1985	1.441	0.419	2.463	1.729	1.158	2.582	0.369	0.190	0.548	0.408	0.281	0.592	3.985	12	15	55	53.1	101	102	32	23	88
1986	2.353	1.099	3.608	1.687	1.130	2.520	0.604	0.379	0.829	0.431	0.297	0.626	3.703	19	23	52	53.8	82	100	46	26	90
1987	0.873	0.256	1.491	1.317	0.882	1.967	0.264	0.116	0.411	0.363	0.250	0.527	3.324	15	15	53	52.2	92	96	22	15	87
1988	1.525	0.484	2.565	1.355	0.907	2.023	0.313	0.130	0.496	0.379	0.261	0.550	4.870	11	11	53	57.1	92	93	26	17	89
1989	1.384	0.478	2.290	1.287	0.862	1.922	0.428	0.266	0.590	0.449	0.310	0.652	3.096	9	9	39	40.8	93	96	39	25	87
1990	1.001	0.439	1.562	1.165	0.780	1.739	0.593	0.383	0.804	0.551	0.380	0.800	1.705	9	10	25	32.3	72	89	55	35	89
1991	1.235	0.568	1.903	1.166	0.781	1.742	0.576	0.383	0.768	0.643	0.443	0.933	2.067	9	10	31	38.3	83	95	62	33	88
1992	1.104	0.557	1.651	1.124	0.753	1.679	0.938	0.602	1.274	0.808	0.556	1.172	1.183	9	9	26	33.0	79	86	78	37	86
1993	1.044	0.343	1.746	1.097	0.735	1.638	0.989	0.691	1.287	0.918	0.632	1.332	1.077	6	9	20	27.1	71	94	103	45	86
1994	0.973	0.378	1.569	1.107	0.741	1.653	1.351	0.969	1.732	0.991	0.683	1.439	0.668	9	9	19	24.9	55	98	110	51	87
1995	1.711	0.663	2.759	1.218	0.815	1.818	0.922	0.688	1.155	0.869	0.599	1.262	1.724	10	12	34	39.6	84	91	87	40	93
1996	1.071	0.498	1.645	1.066	0.713	1.592	0.630	0.407	0.853	0.733	0.505	1.064	1.688	8	11	38	40.3	63	95	51	30	88
1997	0.669	0.321	1.017	0.929	0.622	1.389	0.498	0.304	0.693	0.684	0.471	0.993	1.335	8	9	35	35.4	70	86	39	27	90
1998	0.974	0.522	1.425	1.011	0.675	1.515	0.609	0.397	0.820	0.789	0.542	1.150	1.531	10	10	30	35.5	68	77	56	38	104
1999	0.825	0.303	1.348	1.128	0.742	1.714	1.084	0.737	1.431	1.085	0.735	1.601	0.716	8	8	22	25.7	58	81	111	44	106
2000	2.495	1.284	3.707	1.552	0.957	2.515	2.398	1.564	3.232	1.492	0.953	2.338	1.032	9	11	25	30.3	70	88	165	43	87
2001	2.052*	1.151*	2.952*				1.625*	1.217*	2.032*													

* preliminary data

Table C16. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC offshore spring research vessel bottom trawl surveys in the northern management region (strata 20-30, 34-40); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed in each year.

	Biomass						Abundance							Length						Number of Fish	Number of Nonzero Tows	Number of Tows
	Raw Index			Smoothed			Raw Index			Smoothed												
	Mean	L95%CI	U95%CI	Mean	L95%CI	U95%CI	Mean	L95%CI	U95%CI	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max			
1968	0.973	0.260	1.686	1.187			0.178	0.074	0.283	0.201			5.427	50	51	68	70.4	89	90	13	11	86
1969	1.309	0.141	2.476	1.357			0.186	0.046	0.325	0.219			7.044	33	33	71	71.5	99	100	15	10	87
1970	1.967	0.712	3.221	1.590			0.344	0.216	0.472	0.265			5.709	30	30	62	65.4	98	99	32	22	90
1971	1.021	0.414	1.629	1.614	1.052	2.478	0.158	0.072	0.245	0.269	0.177	0.409	6.366	45	53	69	72.6	99	100	20	15	96
1972	4.644	3.021	6.266	2.230	1.453	3.424	0.643	0.453	0.832	0.391	0.258	0.594	7.064	13	39	74	72.7	100	105	59	38	96
1973	1.908	0.956	2.860	1.882	1.226	2.889	0.435	0.184	0.686	0.407	0.268	0.619	4.313	17	26	68	65.7	99	106	91	36	87
1974	1.476	0.863	2.090	1.573	1.025	2.415	0.438	0.315	0.561	0.406	0.267	0.616	3.391	20	23	58	58.3	97	111	86	41	83
1975	0.934	0.593	1.275	1.373	0.894	2.108	0.339	0.228	0.450	0.384	0.253	0.583	2.760	16	19	53	54.0	87	109	73	36	87
1976	2.826	1.691	3.962	1.552	1.011	2.383	0.673	0.469	0.877	0.394	0.260	0.599	3.759	14	20	60	61.5	95	106	158	52	99
1977	1.012	0.563	1.462	1.173	0.764	1.801	0.259	0.159	0.360	0.283	0.186	0.430	3.594	10	31	66	63.4	93	106	61	37	107
1978	0.626	0.340	0.913	0.979	0.638	1.503	0.141	0.095	0.186	0.216	0.142	0.328	4.014	15	19	73	65.5	89	92	37	30	113
1979	0.893	0.274	1.513	1.104	0.719	1.694	0.144	0.102	0.185	0.219	0.144	0.332	4.652	12	14	67	62.5	100	118	48	40	139
1980	1.622	0.787	2.458	1.434	0.934	2.201	0.379	0.270	0.488	0.294	0.194	0.447	3.748	17	22	43	53.3	98	107	84	38	85
1981	1.744	0.913	2.576	1.715	1.118	2.633	0.376	0.282	0.470	0.333	0.219	0.506	4.444	11	21	52	57.7	95	120	95	42	87
1982	3.015	1.273	4.758	2.029	1.322	3.115	0.346	0.155	0.536	0.348	0.229	0.529	8.594	25	36	61	68.8	105	108	33	22	92
1983	1.587	0.530	2.643	1.840	1.199	2.824	0.418	0.191	0.645	0.365	0.240	0.554	3.663	12	13	49	49.9	96	112	34	22	90
1984	1.696	0.596	2.796	1.842	1.200	2.828	0.328	0.181	0.474	0.349	0.230	0.530	4.732	17	19	62	60.8	93	100	26	19	86
1985	2.113	1.094	3.133	1.951	1.271	2.994	0.346	0.199	0.492	0.347	0.229	0.528	6.122	13	13	68	66.9	104	108	25	21	81
1986	2.165	0.951	3.378	1.957	1.275	3.004	0.340	0.200	0.481	0.347	0.229	0.527	6.244	11	14	63	65.4	109	121	30	22	90
1987	1.728	0.726	2.730	1.834	1.195	2.816	0.245	0.138	0.352	0.352	0.232	0.534	7.052	16	16	66	64.2	99	100	21	16	83
1988	2.111	0.906	3.315	1.790	1.166	2.748	0.610	0.398	0.822	0.454	0.299	0.690	3.343	10	20	49	49.8	89	110	43	26	90
1989	1.631	0.611	2.650	1.563	1.018	2.400	0.625	0.321	0.929	0.481	0.317	0.731	2.590	10	11	40	43.2	80	94	48	24	85
1990	1.005	0.366	1.643	1.327	0.865	2.037	0.282	0.157	0.406	0.427	0.281	0.649	3.587	15	18	47	49.1	106	107	25	17	90
1991	1.827	0.478	3.175	1.358	0.885	2.085	0.592	0.374	0.811	0.502	0.331	0.763	2.723	12	15	35	42.3	78	100	48	28	86
1992	0.890	-0.217	1.997	1.138	0.742	1.748	0.492	0.158	0.825	0.528	0.348	0.802	1.793	16	17	35	40.6	82	101	36	20	83
1993	1.162	0.693	1.630	1.126	0.734	1.728	0.684	0.475	0.893	0.582	0.383	0.885	1.695	10	11	44	41.0	71	90	59	27	87
1994	0.948	0.376	1.520	1.090	0.710	1.674	0.452	0.275	0.629	0.576	0.379	0.875	2.159	10	13	40	41.0	83	89	45	24	88
1995	1.713	0.789	2.638	1.160	0.756	1.781	0.984	0.662	1.305	0.671	0.442	1.020	1.817	15	16	33	39.9	73	97	83	39	88
1996	1.006	0.449	1.563	0.950	0.619	1.458	0.668	0.344	0.992	0.605	0.398	0.919	1.466	15	17	41	43.0	60	70	49	20	82
1997	0.532	0.146	0.918	0.748	0.487	1.148	0.339	0.158	0.520	0.510	0.336	0.775	1.595	9	9	36	39.4	75	89	34	19	89
1998	0.444	0.187	0.701	0.740	0.482	1.137	0.414	0.288	0.540	0.566	0.372	0.860	1.065	11	11	19	31.3	67	78	46	33	115
1999	1.202	0.625	1.780	1.032	0.670	1.591	0.824	0.547	1.102	0.775	0.508	1.181	1.389	9	14	31	35.5	71	97	62	33	87
2000	1.430	0.837	2.023	1.300	0.831	2.035	1.128	0.843	1.413	1.017	0.657	1.575	1.236	15	17	29	34.5	75	87	99	42	89
2001	1.969	0.681	3.257	1.536	0.917	2.574	1.686	1.221	2.151	1.246	0.753	2.062	1.113	9	11	24	31.4	75	86	151	48	91

Table C17. Indices of abundance (number per tow) of goosefish 10-20 cm TL from research surveys.

	Northern Area		Southern Area			
Year	Spring	Autumn	Spring	Autumn	Scallop	Winter
1963		0.12		0.11		
1964		0.00		0.07		
1965		0.00		0.09		
1966		0.00		0.19		
1967		0.00		0.05		
1968	0.00	0.01	0.00	0.02		
1969	0.00	0.01	0.00	0.05		
1970	0.00	0.00	0.00	0.04		
1971	0.00	0.02	0.02	0.06		
1972	0.03	0.00	0.01	0.96		
1973	0.01	0.03	0.05	0.20		
1974	0.01	0.03	0.02	0.02		
1975	0.02	0.02	0.01	0.05		
1976	0.03	0.00	0.01	0.02		
1977	0.01	0.00	0.01	0.04		
1978	0.01	0.02	0.05	0.03		
1979	0.01	0.02	0.05	0.12		
1980	0.01	0.03	0.01	0.03		
1981	0.02	0.02	0.03	0.09		
1982	0.00	0.00	0.09	0.09	0.11	
1983	0.05	0.03	0.00	0.12	0.89	
1984	0.03	0.02	0.00	0.05	0.34	
1985	0.02	0.03	0.00	0.08	0.28	
1986	0.02	0.02	0.01	0.05	0.65	
1987	0.01	0.03	0.01	0.22	1.97	
1988	0.03	0.02	0.03	0.00	0.10	
1989	0.11	0.09	0.01	0.05	0.28	
1990	0.03	0.22	0.01	0.09	0.75	
1991	0.10	0.07	0.02	0.21	1.38	
1992	0.06	0.11	0.02	0.08	0.63	0.15
1993	0.14	0.42	0.02	0.11	1.75	0.19
1994	0.08	0.68	0.02	0.21	1.88	0.25
1995	0.16	0.06	0.01	0.19	0.50	0.06
1996	0.04	0.05	0.01	0.02	0.80	0.08
1997	0.02	0.11	0.01	0.03	0.10	0.16
1998	0.21	0.13	0.06	0.09	0.43	0.07
1999	0.18	0.47	0.02	0.12	1.33	0.20
2000	0.18	0.74	0.03	0.06		0.09
2001	0.56		0.05			0.23

Table C18. Mean length (cm) at age for goosefish caught in NEFSC surveys

NEFSC Fall Offshore Survey

North	Age									
	0	1	2	3	4	5	6	7	8	9	10
1993	9.49	13.02	23.38	31.73	43.5	52.93		73.59	83.5	94	
1994	9.45	14.2	21.79	30.87	42.82	53.36	64	68.85	98		
1995		11.01	24.85	32.89	41.54	54.78	65.36	73.86	85.5	91	
1996	8	12.88	23.85	35.16	42.15	54.19	60.35	82	95		
1997	9.02	12.44	28	34.73	43.26	54.38	67.43		86		
1998		13	25.58	33.18	43.38	51.38	63.39	76.61			
1999	10.37	15.06	26.92	35.98	40.55	56.5	60.08	73.32	79		
2000	10.33	14.9	24.82	34.03	45.28	56.79	66.24	78.47	85.6		
mean	**9.4**	**13.3**	**24.9**	**33.6**	**42.8**	**54.3**	**63.8**	**75.2**	**87.5**	**92.5**	

NEFSC Fall Offshore Survey — Age

South	0	1	2	3	4	5	6	7	8	9	10
1993		16.21	19.85	34.27	43.31	51.54		68			
1994	8.19	14.89	21.13	34.48	44.47	51.97	60.29	68	83		
1995		14.51	21.09	34	40.84	52.15	65				
1996		18	22.58	33.08	44.53	51.84	64.67				
1997	9.53	11	24.83	35.36	47.82	54.37	64.38	71			
1998		14.02	21.92	32.26	45.09	53.96	62.73	72	87		
1999		17.08	25.11	36.09	46.61	55					
2000	5	17.66	22.45	36	45.42	55.74	64.07				
mean	**7.6**	**15.4**	**22.4**	**34.4**	**44.8**	**53.3**	**63.5**	**69.8**	**85.0**		

NEFSC Winter Survey — Age

South	0	1	2	3	4	5	6	7	8	9	10
1997		10.81	16.42	25.16	34.28	45.54	54.3	63.66	76.03	91	
1998		10.32	17.36	24.86	35.72	43.17	53.62	64.42	71.98	84	
1999		10.67	16.73	24.91	32.82	43.92	53.6	64.04	76.65	87	
2000			14.37	24.97	34.62	43.53	53.36	63.95	74.29		96
2001		9.66	16.77	26.41	34.43	45.18	53.88	64.92	76.49	82.73	
mean		**10.4**	**16.3**	**25.3**	**34.4**	**44.3**	**53.8**	**64.2**	**75.1**	**86.2**	**96.0**

NEFSC Spring Survey — Age

North	0	1	2	3	4	5	6	7	8	9	10
1995			16.96	25.77	32.91	43.48	53.59	62.84	76.14	97	
1996			15	28.48	34.8	46.09	57.34	64.56			
1997				27.36	32				89		
1998		12.12	16.76	25.1	36.07	45.84	53.74	65.99	78		
1999		9	17.04	26.63	35.5	47.98		63.58	73.81	97	
2000			19.08	25.77	36.51	48.65	56.15	67	75.37	86.03	
mean		**10.6**	**17.0**	**26.7**	**35.0**	**47.1**	**55.7**	**65.3**	**79.0**	**91.5**	

NEFSC Spring Survey — Age

South	0	1	2	3	4	5	6	7	8	9	10
1995				25.18	35.75	46.35	55.69	63.7	79.03		
1996		9	16.14	22.88	38.07	46.24	52.57	61.85	79.85		
1997			18	24.25	35.89	45	59		73.5		
1998		12	17.78	25.31	35.95	48.52	57.01	64.84	77		
1999			17.8	24.62	33.71	47.56	53.39	64.54	74.6	94	
2000			15.59	26.35	37.93	46.68	57.74	71	78		
mean		**10.5**	**17.1**	**24.7**	**36.3**	**46.8**	**55.9**	**65.6**	**76.6**	**94.0**	

Table C19. Delta distribution stratified mean number per tow at age, NEFSC autumn and spring offshore surveys.

Autumn Surveys

North

Age	0	1	2	3	4	5	6	7	8	9	Total
1993	0.149	0.308	0.176	0.104	0.094	0.102	0.000	0.031	0.013	0.012	0.989
1994	0.065	0.560	0.287	0.208	0.086	0.089	0.019	0.024	0.011	0.000	1.351
1995	0.000	0.059	0.163	0.285	0.234	0.092	0.021	0.014	0.054	0.000	0.922
1996	0.012	0.048	0.062	0.152	0.206	0.093	0.034	0.011	0.012	0.000	0.630
1997	0.039	0.094	0.016	0.122	0.136	0.052	0.031	0.000	0.007	0.000	0.498
1998	0.000	0.116	0.150	0.090	0.048	0.052	0.135	0.018	0.000	0.000	0.609
1999	0.192	0.310	0.292	0.179	0.015	0.033	0.020	0.040	0.003	0.000	1.084
2000	0.080	0.703	0.626	0.448	0.271	0.105	0.059	0.062	0.044	0.000	2.398

South

Age	0	1	2	3	4	5	6	7	8	9	Total
1993	0.007	0.060	0.064	0.076	0.062	0.014	0.000	0.007	0.000	0.000	0.290
1994	0.015	0.095	0.295	0.056	0.066	0.036	0.021	0.007	0.008	0.000	0.598
1995	0.000	0.102	0.151	0.120	0.053	0.049	0.017	0.000	0.000	0.000	0.493
1996	0.000	0.007	0.030	0.054	0.059	0.060	0.026	0.000	0.000	0.000	0.235
1997	0.017	0.008	0.041	0.055	0.035	0.105	0.031	0.016	0.000	0.000	0.308
1998	0.000	0.070	0.072	0.037	0.059	0.044	0.034	0.008	0.008	0.000	0.332
1999	0.005	0.101	0.172	0.118	0.040	0.014	0.000	0.000	0.000	0.000	0.450
2000	0.007	0.061	0.118	0.106	0.067	0.023	0.041	0.000	0.000	0.000	0.422

Combined Areas

Age	0	1	2	3	4	5	6	7	8	9	Total
1993	0.066	0.161	0.112	0.087	0.075	0.051	0.000	0.017	0.005	0.005	0.580
1994	0.035	0.284	0.270	0.160	0.059	0.058	0.020	0.014	0.009	0.000	0.910
1995	0.000	0.084	0.140	0.211	0.124	0.056	0.018	0.016	0.016	0.006	0.671
1996	0.005	0.024	0.045	0.093	0.119	0.071	0.032	0.005	0.005	0.000	0.399
1997	0.026	0.044	0.031	0.084	0.076	0.082	0.029	0.012	0.003	0.000	0.387
1998	0.000	0.093	0.112	0.058	0.058	0.043	0.066	0.013	0.004	0.000	0.447
1999	0.081	0.187	0.219	0.139	0.033	0.027	0.008	0.017	0.001	0.000	0.713
2000	0.044	0.320	0.328	0.248	0.153	0.056	0.049	0.025	0.018	0.000	1.242

Spring Surveys

North

Age	0	1	2	3	4	5	6	7	8	9	Total
1995	0.000	0.000	0.153	0.174	0.247	0.110	0.076	0.163	0.053	0.008	0.984
1996	0.000	0.000	0.036	0.014	0.231	0.263	0.059	0.065	0.000	0.000	0.668
1997	0.028	0.000	0.000	0.074	0.197	0.004	0.000	0.024	0.012	0.000	0.339
1998	0.000	0.040	0.162	0.045	0.044	0.045	0.025	0.046	0.008	0.000	0.414
1999	0.000	0.012	0.182	0.194	0.229	0.066	0.000	0.079	0.057	0.004	0.824
2000	0.000	0.000	0.238	0.386	0.254	0.121	0.033	0.012	0.060	0.024	1.128
2001	0.000	0.058	0.505	0.371	0.290	0.207	0.087	0.060	0.071	0.036	1.686

South

Age	0	1	2	3	4	5	6	7	8	9	
1995	0.000	0.000	0.000	0.058	0.043	0.014	0.031	0.018	0.032	0.000	0.196
1996	0.000	0.009	0.010	0.013	0.028	0.016	0.036	0.012	0.012	0.000	0.135
1997	0.000	0.000	0.008	0.031	0.052	0.025	0.005	0.000	0.003	0.000	0.124
1998	0.000	0.001	0.041	0.054	0.087	0.042	0.011	0.013	0.005	0.000	0.254
1999	0.000	0.000	0.018	0.073	0.061	0.104	0.024	0.020	0.034	0.001	0.335
2000	0.000	0.000	0.025	0.056	0.077	0.051	0.025	0.006	0.001	0.000	0.242
2001	0.000	0.007	0.018	0.056	0.070	0.039	0.041	0.003	0.000	0.000	0.234

Combined Areas

Age	0	1	2	3	4	5	6	7	8	9	
1995	0.000	0.000	0.069	0.100	0.128	0.047	0.056	0.078	0.041	0.003	0.523
1996	0.000	0.005	0.021	0.017	0.108	0.119	0.045	0.034	0.007	0.000	0.356
1997	0.007	0.004	0.005	0.049	0.093	0.013	0.026	0.000	0.017	0.000	0.213
1998	0.000	0.017	0.093	0.048	0.070	0.043	0.017	0.027	0.006	0.000	0.320
1999	0.000	0.005	0.085	0.120	0.128	0.092	0.014	0.044	0.043	0.003	0.535
2000	0.000	0.000	0.121	0.186	0.150	0.080	0.028	0.009	0.025	0.010	0.609
2001	0.000	0.028	0.220	0.180	0.168	0.108	0.061	0.027	0.029	0.015	0.836

Table C20. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC offshore autumn research vessel bottom trawl surveys in the southern management region (strata 1-19, 61-76); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed in each year.

	Biomass						Abundance													Number	Number of	
	Raw Index			Smoothed			Raw Index			Smoothed				Length						of	Nonzero	Number
	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Fish	Tows	of Tows
1963	3.724	1.786	5.663	4.168			1.257	0.745	1.769	1.304			2.926	7	17	53	50.4	91	97	102	36	73
1964	5.486	3.391	7.581	4.496			1.636	0.907	2.366	1.337			3.467	14	21	53	52.0	86	101	132	34	83
1965	5.163	2.731	7.594	4.242			1.148	0.778	1.519	1.197			4.199	10	15	59	56.3	91	104	83	39	85
1966	6.986	4.936	9.037	3.507	2.061	5.969	1.926	1.364	2.488	1.102	0.634	1.915	3.563	7	7	51	49.6	87	98	101	56	87
1967	1.122	0.588	1.655	1.825	1.072	3.105	0.519	0.324	0.715	0.697	0.401	1.211	2.173	14	19	31	40.6	83	100	98	42	163
1968	0.850	0.413	1.287	1.317	0.774	2.240	0.399	0.206	0.591	0.537	0.309	0.933	2.131	12	17	45	46.3	75	86	77	39	164
1969	1.138	0.483	1.793	1.275	0.749	2.169	0.497	0.281	0.714	0.505	0.291	0.878	2.273	10	14	41	45.4	88	96	101	43	163
1970	1.357	0.512	2.203	1.332	0.782	2.266	0.350	0.235	0.466	0.481	0.277	0.836	3.566	4	13	55	53.3	84	104	58	35	161
1971	0.786	0.196	1.377	1.374	0.807	2.337	0.282	0.150	0.414	0.567	0.326	0.985	2.813	5	8	39	42.3	95	98	55	28	168
1972	4.918	3.295	6.541	2.062	1.212	3.509	4.113	1.281	6.944	1.067	0.614	1.856	1.298	12	16	23	31.8	74	99	604	85	161
1973	1.986	0.994	2.978	1.725	1.014	2.936	1.176	0.857	1.494	0.812	0.467	1.411	1.568	13	14	32	37.7	77	93	280	70	154
1974	0.710	0.322	1.098	1.314	0.772	2.235	0.218	0.116	0.320	0.482	0.277	0.837	3.277	14	16	54	52.9	81	101	56	26	153
1975	2.043	1.326	2.759	1.512	0.889	2.573	0.653	0.434	0.871	0.486	0.280	0.845	3.030	8	17	45	46.3	87	105	127	51	158
1976	1.084	0.539	1.630	1.422	0.836	2.420	0.314	0.189	0.438	0.403	0.232	0.701	3.166	11	11	51	50.7	77	95	60	34	165
1977	1.873	1.192	2.554	1.605	0.943	2.731	0.372	0.265	0.479	0.395	0.227	0.687	5.024	5	16	55	53.1	95	106	94	50	172
1978	1.395	0.883	1.906	1.633	0.960	2.779	0.259	0.178	0.340	0.403	0.232	0.700	5.384	13	17	61	56.5	87	101	68	39	219
1979	2.275	1.278	3.272	1.847	1.085	3.143	0.694	0.483	0.905	0.553	0.318	0.961	2.779	7	16	34	40.5	84	109	182	70	205
1980	1.868	1.166	2.570	1.816	1.067	3.091	0.726	0.427	1.025	0.652	0.375	1.133	2.664	3	16	34	41.6	85	104	113	42	159
1981	2.858	0.883	4.834	1.752	1.030	2.982	0.965	0.578	1.352	0.714	0.411	1.241	2.363	6	17	38	40.7	71	99	176	59	146
1982	0.646	0.350	0.941	1.217	0.715	2.071	0.610	0.373	0.847	0.638	0.367	1.110	1.060	13	15	26	32.5	66	73	98	42	143
1983	2.150	0.693	3.608	1.294	0.760	2.201	0.776	0.470	1.080	0.589	0.339	1.023	2.304	7	16	45	44.4	72	100	109	49	146
1984	0.740	0.148	1.332	0.977	0.574	1.663	0.311	0.114	0.508	0.451	0.259	0.784	2.445	5	13	47	45.7	68	93	42	25	146
1985	1.318	0.752	1.884	0.890	0.523	1.514	0.524	0.356	0.692	0.443	0.255	0.770	2.444	17	17	40	42.0	72	96	100	46	145
1986	0.552	0.237	0.867	0.622	0.366	1.059	0.325	0.169	0.481	0.389	0.224	0.676	1.681	7	14	34	37.6	68	78	60	33	146
1987	0.274	0.117	0.432	0.472	0.277	0.802	0.482	0.307	0.657	0.385	0.222	0.670	0.575	12	13	20	25.0	56	61	67	27	132
1988	0.554	0.210	0.899	0.515	0.302	0.876	0.230	0.097	0.364	0.328	0.189	0.571	2.391	19	27	36	45.1	87	91	27	19	129
1989	0.625	0.278	0.972	0.535	0.314	0.910	0.382	0.181	0.583	0.356	0.205	0.618	1.646	7	7	42	38.0	57	77	57	23	129
1990	0.426	0.017	0.834	0.500	0.294	0.851	0.294	0.113	0.474	0.367	0.211	0.638	1.265	9	13	24	33.1	61	81	47	22	136
1991	0.783	0.206	1.360	0.520	0.306	0.885	0.690	0.245	1.136	0.440	0.253	0.765	1.085	14	15	23	30.8	57	81	106	27	131
1992	0.312	0.170	0.454	0.412	0.242	0.700	0.342	0.220	0.463	0.390	0.224	0.677	0.919	8	11	30	32.2	54	74	46	21	129
1993	0.294	0.055	0.532	0.392	0.230	0.667	0.290	0.135	0.445	0.377	0.217	0.655	0.944	10	13	32	30.4	52	68	46	24	130
1994	0.611	0.175	1.047	0.453	0.266	0.771	0.598	0.344	0.852	0.434	0.250	0.755	0.906	8	12	25	29.2	59	83	85	31	135
1995	0.386	0.160	0.612	0.429	0.252	0.729	0.493	0.258	0.728	0.403	0.232	0.701	0.777	11	13	25	29.4	54	66	72	29	129
1996	0.387	0.214	0.560	0.435	0.256	0.740	0.235	0.131	0.338	0.328	0.188	0.569	1.638	18	19	42	42.3	62	68	31	21	131
1997	0.592	0.325	0.858	0.477	0.280	0.813	0.308	0.186	0.430	0.332	0.191	0.578	1.914	9	9	49	44.6	70	71	43	24	131
1998	0.500	0.226	0.774	0.453	0.265	0.774	0.332	0.146	0.519	0.355	0.203	0.620	1.525	11	11	36	37.0	68	87	45	20	131
1999	0.304	0.167	0.441	0.402	0.231	0.701	0.450	0.289	0.612	0.396	0.223	0.706	0.672	12	14	27	29.2	52	55	109	44	106
2000	0.477	0.261	0.694	0.431	0.227	0.817	0.422	0.270	0.575	0.407	0.209	0.791	1.102	5	15	33	34.3	63	70	64	30	132
2001	0.708*	0.366*	1.051*				0.383*	0.239*	0.527*													

* preliminary data

Table C21. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC offshore spring research vessel bottom trawl surveys in the southern management region (strata 1-19, 61-76); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed in each year.

	Biomass						Abundance													Number of Fish	Number of Nonzero Tows	Number of Tows
	Raw Index			Smoothed			Raw Index			Smoothed				Length								
	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max			
1968	1.142	0.552	1.731	1.067			0.211	0.126	0.297	0.216			5.344	21	23	63	62.5	94	95	65	31	150
1969	0.938	0.427	1.448	1.020			0.221	0.138	0.305	0.220			4.064	7	25	47	54.3	91	111	41	31	155
1970	1.005	0.460	1.549	1.031			0.175	0.103	0.247	0.223			5.699	22	22	65	63.9	102	108	40	31	166
1971	0.762	0.313	1.211	1.061	0.679	1.658	0.204	0.104	0.304	0.265	0.173	0.406	3.675	13	16	50	53.3	101	115	42	24	160
1972	1.883	1.161	2.604	1.364	0.873	2.131	0.371	0.272	0.469	0.375	0.244	0.576	5.071	14	22	59	59.1	103	123	79	48	165
1973	1.857	1.494	2.220	1.412	0.903	2.205	1.051	0.854	1.249	0.536	0.349	0.822	1.744	11	19	32	41.1	80	110	589	128	187
1974	1.129	0.728	1.530	1.215	0.778	1.898	0.486	0.368	0.604	0.486	0.317	0.746	2.367	14	21	44	49.1	93	117	201	70	132
1975	0.936	0.562	1.310	1.098	0.703	1.716	0.447	0.326	0.568	0.442	0.288	0.678	2.044	10	22	44	47.6	87	107	169	61	134
1976	1.209	0.833	1.585	1.105	0.707	1.727	0.403	0.307	0.500	0.398	0.259	0.610	2.777	13	22	48	51.5	91	110	259	78	162
1977	1.205	0.754	1.657	1.047	0.670	1.637	0.302	0.232	0.372	0.355	0.231	0.545	3.803	16	21	51	56.8	95	116	173	75	160
1978	0.735	0.512	0.959	0.903	0.578	1.411	0.335	0.265	0.405	0.353	0.230	0.542	2.184	11	17	39	45.9	90	104	196	66	161
1979	0.733	0.441	1.026	0.895	0.573	1.398	0.281	0.164	0.397	0.364	0.237	0.559	2.589	10	14	37	44.4	98	124	125	50	194
1980	0.799	0.494	1.104	1.013	0.649	1.583	0.451	0.354	0.548	0.446	0.291	0.685	1.636	18	21	34	40.8	83	106	346	99	204
1981	1.816	1.145	2.486	1.347	0.862	2.104	0.784	0.540	1.029	0.544	0.354	0.834	2.259	12	22	40	44.6	89	113	345	74	141
1982	2.803	1.584	4.021	1.463	0.937	2.286	0.942	0.657	1.226	0.517	0.337	0.794	2.800	11	14	38	42.4	89	104	251	68	150
1983	0.955	0.421	1.489	1.027	0.658	1.605	0.270	0.176	0.365	0.329	0.215	0.505	3.514	24	24	47	51.8	97	112	55	36	147
1984	0.747	0.223	1.272	0.758	0.485	1.184	0.182	0.090	0.274	0.239	0.156	0.367	4.067	21	21	47	50.9	96	97	35	22	149
1985	0.327	0.089	0.565	0.564	0.361	0.881	0.159	0.072	0.247	0.209	0.136	0.321	2.052	22	22	39	42.3	85	90	31	21	147
1986	0.823	0.342	1.303	0.606	0.388	0.946	0.283	0.125	0.442	0.219	0.143	0.336	2.917	15	24	43	48.7	90	102	65	36	149
1987	0.496	-0.014	1.007	0.529	0.339	0.827	0.108	0.054	0.162	0.194	0.126	0.297	4.612	15	15	59	52.7	102	103	30	21	150
1988	0.427	0.264	0.590	0.483	0.309	0.755	0.440	0.280	0.601	0.253	0.165	0.389	0.971	17	18	30	34.0	61	82	67	33	132
1989	0.365	0.122	0.608	0.480	0.307	0.749	0.202	0.097	0.306	0.229	0.149	0.351	1.807	15	24	41	41.4	69	79	36	18	129
1990	1.005	0.431	1.579	0.572	0.366	0.893	0.205	0.099	0.311	0.224	0.146	0.344	4.861	16	21	53	56.5	86	93	39	23	128
1991	0.582	0.236	0.927	0.466	0.298	0.729	0.319	0.142	0.495	0.234	0.152	0.359	1.819	15	23	33	37.6	69	101	61	31	132
1992	0.210	0.067	0.353	0.328	0.210	0.512	0.177	0.089	0.266	0.198	0.129	0.304	1.235	14	19	28	35.0	69	85	28	17	128
1993	0.264	0.097	0.431	0.310	0.199	0.485	0.195	0.096	0.295	0.180	0.117	0.277	1.319	17	19	38	38.6	56	72	29	18	128
1994	0.321	0.117	0.525	0.328	0.210	0.513	0.114	0.057	0.172	0.156	0.102	0.239	2.866	13	13	41	43.8	91	93	24	18	131
1995	0.526	0.031	1.021	0.352	0.225	0.550	0.196	0.100	0.292	0.166	0.108	0.255	2.637	18	19	38	45.7	80	81	32	20	129
1996	0.284	0.112	0.457	0.288	0.184	0.450	0.135	0.070	0.200	0.158	0.103	0.243	2.083	9	9	44	43.7	80	81	27	20	143
1997	0.132	0.035	0.228	0.237	0.152	0.371	0.124	0.050	0.198	0.168	0.109	0.257	1.064	18	18	37	35.9	58	75	38	14	130
1998	0.282	0.157	0.407	0.291	0.186	0.455	0.254	0.164	0.344	0.217	0.142	0.334	1.110	12	16	35	35.9	64	77	40	30	131
1999	0.629	0.342	0.916	0.363	0.232	0.570	0.335	0.217	0.453	0.254	0.165	0.391	1.899	16	19	41	42.8	74	94	63	32	131
2000	0.293	0.163	0.424	0.314	0.197	0.500	0.242	0.153	0.330	0.246	0.157	0.385	1.222	14	14	38	37.9	61	78	32	25	131
2001	0.244	0.089	0.399	0.284	0.166	0.485	0.234	0.131	0.336	0.241	0.144	0.404	1.098	11	15	34	35.8	57	68	44	26	131

Table C22. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC winter flatfish surveys in the southern management region (strata 1-19, 61-76); confidence limits for indices; minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed.

	Biomass Raw Index			Abundance Raw Index				Length						No. of	No. Of Nonzero	No. of
	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Fish	Tows	Tows
1992	5.395	3.515	7.275	5.176	3.665	6.687	0.986	11	22	34	36.0	52	95	583	66	110
1993	6.317	4.565	8.070	5.002	3.941	6.062	1.188	9	21	36	37.7	53	98	585	77	109
1994	2.787	1.958	3.617	2.534	1.855	3.212	1.078	8	16	31	35.1	61	78	278	56	82
1995	3.398	2.249	4.457	2.738	1.859	3.617	1.245	19	21	36	37.9	57	101	390	76	123
1996	5.701	4.683	6.720	3.779	3.035	4.523	1.498	10	24	39	41.1	61	100	554	87	123
1997	5.390	3.781	6.998	3.172	2.445	3.900	1.667	10	20	43	42.0	62	91	455	89	119
1998	2.851	2.061	3.641	1.416	1.105	1.726	1.983	10	20	42	44.9	69	103	240	77	134
1999	3.792	2.869	4.715	2.803	2.183	3.423	1.340	10	18	35	38.3	61	87	459	83	138
2000	5.539	4.225	6.854	4.115	3.184	5.047	1.346	11	22	37	38.7	57	96	661	93	124
2001	7.324	4.892	9.755	4.346	3.126	5.565	1.451	8	19	37	40.0	60	84	1042	115	167

Table C23. NEFSC winter offshore survey, delta distribution stratified mean number per tow at age.

South	Age										
	0	1	2	3	4	5	6	7	8	9	10	Total
1997	0.000	0.052	0.111	0.672	0.459	0.800	0.830	0.188	0.043	0.017	0.000	3.172
1998	0.000	0.015	0.049	0.063	0.341	0.492	0.267	0.110	0.059	0.010	0.010	1.416
1999	0.000	0.026	0.143	0.654	0.730	0.534	0.532	0.133	0.044	0.008	0.000	2.803
2000	0.000	0.000	0.041	0.759	1.353	1.357	0.423	0.118	0.046	0.000	0.018	4.115
2001	0.000	0.025	0.189	0.743	1.379	0.982	0.803	0.151	0.060	0.014	0.000	4.346

Table C24. Stratified mean number and length (cm) per tow for goosefish from NEFSC summer scallop surveys in the southern management region (shellfish strata 1-48,55-64,69-70,73-74); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and the total number of tows completed in each year.

	Abundance												Number of Fish	Number of Nonzero Tows	Number of Tows
	Raw Index			Smoothed			Length								
	Mean	L95%	U95%	Mean	L95%	U95%	Min	5%	50%	Mean	95%	Max			
1984	1.068	0.911	1.225	1.111			6	12	28	30.6	60	82	523	232	389
1985	1.073	0.921	1.226	1.141			7	10	30	32.8	64	113	594	234	404
1986	0.934	0.714	1.155	1.221			8	10	16	22.1	53	95	465	203	371
1987	2.418	1.927	2.909	1.564	1.102	2.219	8	9	13	18.7	51	90	1429	313	433
1988	1.444	1.182	1.705	1.494	1.053	2.120	7	12	29	30.3	49	97	725	234	435
1989	1.241	1.078	1.405	1.461	1.029	2.073	6	10	34	33.7	54	101	373	175	352
1990	1.401	1.222	1.580	1.594	1.123	2.262	6	10	18	25.6	57	94	579	211	342
1991	2.216	1.935	2.496	1.896	1.336	2.691	7	9	14	21.0	45	94	809	242	323
1992	1.877	1.608	2.146	2.032	1.432	2.884	5	9	25	27.3	52	97	644	235	324
1993	2.639	2.387	2.892	2.298	1.619	3.261	8	10	15	22.4	49	79	1012	270	325
1994	3.095	2.738	3.452	2.366	1.667	3.358	8	10	15	22.5	51	87	1151	271	338
1995	2.093	1.826	2.361	2.035	1.434	2.888	7	9	28	30.0	58	92	776	252	338
1996	1.814	1.580	2.048	1.717	1.209	2.438	7	9	24	29.9	59	81	639	227	307
1997	1.046	0.904	1.188	1.395	0.980	1.987	7	13	33	37.2	65	76	398	204	336
1998	0.958	0.827	1.089	1.377	0.955	1.985	6	11	22	31.5	63	79	380	188	339
1999	2.441	2.047	2.835	1.733	1.137	2.642	6	9	17	24.6	60	84	859	250	311

Table C25. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC offshore autumn research vessel bottom trawl surveys in management regions combined (strata 1-30, 34-40, 61-76); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed in each year.

	Biomass						Abundance													Number	Number of	
	Raw Index			Smoothed			Raw Index			Smoothed				Length						of	Nonzero	Number
	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max	Fish	Tows	of Tows
1963	3.741	2.492	4.990	3.590			1.022	0.732	1.313	0.944			3.628	7	16	54	53.59	96	111	188	75	163
1964	3.509	2.424	4.594	3.492			0.985	0.626	1.343	0.895			3.658	14	20	54	53.52	89	102	164	57	170
1965	3.772	2.465	5.080	3.386			0.728	0.542	0.915	0.795			4.930	10	19	62	60.11	93	110	123	69	173
1966	5.038	3.886	6.189	3.053	2.113	4.409	1.175	0.894	1.455	0.750	0.493	1.140	4.209	7	8	56	54.73	89	98	156	89	173
1967	1.189	0.719	1.659	1.965	1.360	2.839	0.380	0.260	0.501	0.523	0.344	0.795	3.144	14	19	41	46.8	91	100	116	57	249
1968	1.348	0.663	2.033	1.773	1.228	2.562	0.351	0.219	0.484	0.451	0.297	0.686	3.835	11	20	53	54.85	89	106	109	55	250
1969	2.215	1.323	3.108	1.925	1.332	2.780	0.464	0.325	0.603	0.461	0.303	0.701	4.702	10	17	58	58.03	97	110	140	73	251
1970	1.727	0.996	2.457	1.900	1.315	2.745	0.369	0.270	0.468	0.469	0.309	0.714	4.552	4	17	58	59.52	90	104	99	56	253
1971	1.680	0.971	2.388	2.000	1.385	2.889	0.370	0.262	0.477	0.562	0.369	0.854	4.526	5	9	58	56.09	95	101	99	55	262
1972	3.443	2.449	4.436	2.368	1.639	3.420	2.520	0.876	4.163	0.890	0.585	1.353	1.475	12	16	23	33.14	75	99	633	107	255
1973	2.460	1.657	3.262	2.179	1.509	3.148	0.898	0.696	1.100	0.700	0.461	1.065	2.672	13	15	36	44.32	92	112	343	99	246
1974	1.278	0.820	1.735	1.849	1.280	2.670	0.258	0.179	0.337	0.466	0.307	0.709	4.860	13	14	63	59.04	97	111	93	49	250
1975	1.903	1.392	2.414	2.010	1.391	2.903	0.504	0.367	0.640	0.462	0.304	0.703	3.693	8	17	50	50.39	89	105	167	78	264
1976	2.051	1.219	2.883	2.267	1.569	3.274	0.359	0.255	0.464	0.432	0.284	0.657	5.359	11	27	62	61.27	94	121	92	58	252
1977	3.424	2.466	4.382	2.734	1.893	3.949	0.479	0.385	0.572	0.457	0.301	0.696	7.006	5	19	64	62.98	99	119	206	106	298
1978	2.951	2.211	3.690	2.835	1.962	4.095	0.393	0.315	0.472	0.470	0.309	0.714	7.067	10	18	65	63.36	99	116	214	117	420
1979	3.446	2.575	4.317	2.861	1.981	4.132	0.604	0.471	0.736	0.543	0.357	0.826	5.193	7	16	47	51.14	97	115	307	148	416
1980	2.956	1.937	3.976	2.548	1.764	3.680	0.645	0.458	0.833	0.585	0.385	0.889	4.414	3	16	40	49.38	98	111	178	81	256
1981	2.491	1.297	3.686	2.053	1.421	2.965	0.730	0.500	0.960	0.589	0.388	0.896	2.955	6	17	42	44.64	80	101	222	89	239
1982	0.767	0.478	1.057	1.453	1.006	2.098	0.413	0.273	0.554	0.515	0.338	0.783	1.859	13	15	32	37.74	75	100	115	56	238
1983	1.932	1.026	2.838	1.579	1.093	2.280	0.651	0.455	0.847	0.521	0.343	0.792	2.637	7	16	48	46.96	79	100	147	76	228
1984	1.694	0.940	2.448	1.498	1.037	2.164	0.383	0.257	0.510	0.454	0.298	0.690	4.216	5	13	56	54.67	93	106	78	54	234
1985	1.370	0.829	1.910	1.308	0.906	1.890	0.459	0.336	0.582	0.443	0.291	0.673	2.962	12	17	44	45.72	88	102	132	69	233
1986	1.308	0.751	1.866	1.108	0.767	1.600	0.442	0.311	0.573	0.422	0.277	0.642	2.841	7	17	43	46.86	81	100	106	59	236
1987	0.523	0.251	0.795	0.839	0.581	1.212	0.392	0.272	0.511	0.390	0.256	0.592	1.337	12	14	22	32.64	65	96	99	42	219
1988	0.957	0.480	1.433	0.873	0.604	1.261	0.265	0.156	0.374	0.358	0.236	0.545	3.607	11	23	46	50.96	89	93	53	36	218
1989	0.940	0.513	1.367	0.854	0.591	1.233	0.401	0.267	0.536	0.403	0.265	0.613	2.291	7	8	41	39.23	84	96	96	48	216
1990	0.665	0.331	0.998	0.782	0.542	1.130	0.418	0.281	0.555	0.455	0.299	0.692	1.525	9	10	25	32.62	70	89	102	57	225
1991	0.971	0.534	1.407	0.800	0.554	1.156	0.643	0.370	0.915	0.544	0.358	0.827	1.447	9	13	27	33.62	69	95	168	60	219
1992	0.641	0.399	0.883	0.718	0.497	1.037	0.590	0.433	0.746	0.581	0.382	0.883	1.094	8	8	27	32.74	72	86	124	58	215
1993	0.605	0.282	0.928	0.696	0.482	1.005	0.580	0.427	0.733	0.613	0.403	0.932	1.039	6	9	22	28.1	56	94	149	69	216
1994	0.761	0.406	1.116	0.741	0.513	1.070	0.910	0.693	1.127	0.672	0.442	1.022	0.761	8	10	21	26.52	56	98	195	82	222
1995	0.935	0.481	1.389	0.775	0.536	1.119	0.671	0.502	0.839	0.602	0.396	0.915	1.313	10	13	33	35.19	69	91	159	69	222
1996	0.671	0.412	0.929	0.714	0.494	1.031	0.399	0.288	0.509	0.500	0.329	0.760	1.671	8	14	40	40.97	63	95	82	51	219
1997	0.624	0.411	0.836	0.685	0.474	0.990	0.387	0.279	0.495	0.484	0.318	0.736	1.605	8	9	40	39.69	70	86	82	51	221
1998	0.696	0.450	0.943	0.700	0.483	1.015	0.447	0.307	0.587	0.544	0.356	0.830	1.529	10	10	30	36.16	68	87	101	58	235
1999	0.520	0.289	0.751	0.718	0.489	1.055	0.713	0.541	0.885	0.697	0.450	1.079	0.700	8	9	23	27.05	54	81	220	88	212
2000	1.314	0.796	1.832	0.916	0.588	1.426	1.242	0.884	1.599	0.879	0.531	1.456	1.047	5	11	25	31.07	65	88	229	73	219
2001	1.265	0.842	1.689				0.898	0.709	1.086													

Table C26. Stratified mean weight (kg), number, individual fish weight, and length (cm) per tow for goosefish from NEFSC offshore spring research vessel bottom trawl surveys in management regions combined (strata 1-30, 34-40, 61-76); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and total number of tows completed in each year.

	Biomass						Abundance													Number of Fish	Number of Nonzero Tows	Number of Tows
	Raw Index			Smoothed			Raw Index			Smoothed				Length								
	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Mean	L95%	U95%	Ind wt	Min	5%	50%	Mean	95%	Max			
1968	1.071	0.617	1.525	1.132			0.198	0.131	0.264	0.213			5.375	21	27	67	65.5	93	95	78	42	236
1969	1.093	0.521	1.666	1.175			0.206	0.130	0.282	0.223			5.177	7	25	67	60.8	99	111	56	41	242
1970	1.408	0.794	2.022	1.280			0.246	0.178	0.314	0.247			5.705	22	25	62	64.8	98	108	72	53	256
1971	0.871	0.506	1.235	1.308	0.907	1.887	0.185	0.117	0.253	0.274	0.189	0.397	4.647	13	20	58	60.3	99	115	62	39	256
1972	3.042	2.242	3.841	1.758	1.219	2.535	0.485	0.387	0.583	0.396	0.273	0.574	6.186	13	22	67	66.6	100	123	138	86	261
1973	1.878	1.427	2.330	1.633	1.132	2.355	0.792	0.637	0.948	0.500	0.345	0.724	2.342	11	20	41	46.8	88	110	680	164	274
1974	1.275	0.928	1.622	1.381	0.958	1.992	0.466	0.380	0.552	0.463	0.319	0.670	2.771	14	22	46	52.7	93	117	287	111	215
1975	0.935	0.675	1.196	1.233	0.855	1.778	0.402	0.318	0.487	0.426	0.294	0.617	2.295	10	21	47	49.9	87	109	242	97	221
1976	1.888	1.364	2.412	1.325	0.919	1.911	0.517	0.414	0.619	0.408	0.281	0.591	3.310	13	21	56	57.0	93	110	417	130	261
1977	1.124	0.801	1.447	1.122	0.778	1.619	0.284	0.224	0.341	0.332	0.229	0.482	3.723	10	23	58	59.3	93	116	234	112	267
1978	0.690	0.513	0.866	0.950	0.659	1.370	0.253	0.208	0.298	0.301	0.208	0.437	2.610	11	17	45	50.5	89	104	233	96	274
1979	0.801	0.490	1.111	0.997	0.691	1.437	0.223	0.153	0.293	0.308	0.212	0.446	3.162	10	14	40	49.3	99	124	173	90	333
1980	1.144	0.751	1.537	1.211	0.840	1.747	0.421	0.348	0.494	0.389	0.269	0.564	2.439	17	21	37	45.6	89	107	430	137	289
1981	1.786	1.263	2.308	1.530	1.061	2.206	0.612	0.465	0.759	0.467	0.322	0.677	2.832	11	22	42	48.0	93	120	440	116	228
1982	2.892	1.875	3.909	1.740	1.207	2.510	0.691	0.508	0.875	0.468	0.323	0.679	4.028	11	17	44	47.9	99	108	284	90	242
1983	1.220	0.679	1.761	1.408	0.976	2.030	0.332	0.222	0.442	0.361	0.249	0.523	3.593	12	19	49	50.8	96	112	89	58	237
1984	1.146	0.593	1.699	1.253	0.869	1.807	0.243	0.161	0.325	0.294	0.203	0.427	4.445	17	20	58	56.5	93	100	61	41	235
1985	1.077	0.627	1.527	1.185	0.822	1.709	0.238	0.158	0.317	0.273	0.188	0.396	4.540	13	21	55	57.3	104	108	56	42	228
1986	1.386	0.805	1.967	1.195	0.829	1.723	0.307	0.198	0.417	0.277	0.191	0.402	4.467	11	20	54	56.5	99	121	95	58	239
1987	1.007	0.495	1.519	1.090	0.756	1.572	0.165	0.110	0.219	0.263	0.182	0.382	6.118	15	15	65	59.8	99	103	51	37	233
1988	1.126	0.617	1.635	1.050	0.728	1.514	0.511	0.382	0.639	0.342	0.236	0.496	2.146	10	19	34	41.8	80	110	110	59	222
1989	0.890	0.444	1.336	0.964	0.668	1.390	0.377	0.237	0.517	0.339	0.234	0.492	2.343	10	11	40	42.6	74	94	84	42	214
1990	1.005	0.577	1.433	0.934	0.648	1.347	0.237	0.156	0.318	0.314	0.216	0.455	4.230	15	18	49	52.8	92	107	64	40	218
1991	1.098	0.503	1.692	0.861	0.597	1.242	0.432	0.295	0.570	0.350	0.241	0.507	2.332	12	15	33	40.3	78	101	109	59	218
1992	0.490	0.027	0.953	0.675	0.468	0.973	0.307	0.160	0.453	0.339	0.234	0.491	1.602	14	17	33	38.7	82	101	64	37	211
1993	0.638	0.420	0.855	0.656	0.455	0.945	0.399	0.294	0.503	0.351	0.242	0.509	1.587	10	12	42	40.3	71	90	88	45	215
1994	0.581	0.315	0.847	0.649	0.450	0.935	0.254	0.174	0.335	0.333	0.230	0.483	2.344	10	13	40	41.8	83	93	69	42	219
1995	1.018	0.538	1.499	0.691	0.479	0.997	0.523	0.378	0.667	0.379	0.262	0.550	1.993	15	16	34	41.2	75	97	115	59	217
1996	0.584	0.332	0.836	0.567	0.393	0.818	0.356	0.217	0.496	0.348	0.240	0.505	1.604	9	15	43	43.2	67	81	76	40	225
1997	0.298	0.128	0.469	0.457	0.317	0.659	0.213	0.127	0.300	0.315	0.217	0.456	1.417	9	11	36	38.2	75	89	72	33	219
1998	0.349	0.220	0.478	0.490	0.340	0.708	0.320	0.246	0.395	0.370	0.255	0.537	1.086	11	12	30	33.4	66	78	86	63	246
1999	0.864	0.573	1.155	0.661	0.457	0.957	0.535	0.402	0.669	0.479	0.330	0.697	1.577	9	15	32	38.2	71	97	125	65	218
2000	0.765	0.507	1.022	0.745	0.508	1.092	0.609	0.480	0.738	0.577	0.392	0.850	1.233	14	16	31	35.3	70	87	131	67	220
2001	0.959	0.418	1.501	0.825	0.531	1.282	0.836	0.634	1.038	0.670	0.428	1.047	1.111	9	12	27	32.0	71	86	195	74	222

Table C27. Stratified mean number and length (cm) per tow for goosefish from NEFSC summer scallop surveys in management regions combined (shellfish strata 1-74); confidence limits for both the raw index and the indices smoothed using an integrated moving average (theta = 0.45); minimum and maximum lengths; number of fish caught, number of positive tows, and the total number of tows completed in each year.

	Abundance						Length						Number of Fish	Number of Nonzero Tows	Number of Tows
	Raw Index			Smoothed											
	Mean	L95%	U95%	Mean	L95%	U95%	Min	5%	50%	Mean	95%	Max			
1984	1.030	0.884	1.176	1.078			6	12	28	31.8	64	115	576	266	475
1985	1.057	0.914	1.201	1.112			7	11	31	34.0	66	113	680	270	489
1986	0.916	0.713	1.120	1.186			8	10	16	24.3	61	97	554	244	469
1987	2.278	1.821	2.736	1.504	1.076	2.103	8	9	13	19.1	53	101	1472	342	529
1988	1.381	1.137	1.625	1.444	1.033	2.018	7	13	29	31.0	52	97	784	272	533
1989	1.267	1.100	1.435	1.428	1.021	1.996	6	10	36	35.1	55	101	456	203	412
1990	1.334	1.170	1.498	1.529	1.094	2.137	6	10	19	26.9	59	94	643	249	426
1991	2.047	1.801	2.292	1.795	1.284	2.509	7	9	14	21.9	49	94	920	290	422
1992	1.800	1.565	2.035	1.929	1.380	2.697	5	9	26	28.5	53	97	779	286	420
1993	2.456	2.229	2.683	2.173	1.555	3.037	8	10	15	22.6	49	79	1166	317	412
1994	2.877	2.562	3.192	2.254	1.612	3.150	8	10	15	23.3	54	93	1342	324	437
1995	2.106	1.856	2.357	1.984	1.419	2.773	7	9	29	31.2	58	92	1017	316	436
1996	1.765	1.551	1.979	1.677	1.199	2.345	7	10	27	31.2	59	81	794	280	401
1997	1.026	0.897	1.156	1.370	0.977	1.921	7	14	35	38.8	66	100	512	258	446
1998	0.956	0.837	1.074	1.359	0.958	1.928	6	11	25	33.4	67	89	483	235	435
1999	2.397	2.010	2.784	1.707	1.141	2.555	6	9	17	24.6	60	84	859	250	312

Table C28. Net dimensions for the monkfish net used on the Mary K.

	Measurements
Backstraps	14'+15'= 29'
Belly	100 meshes deep; Mesh measurements were 6, 6, 6, 6.25, 5.625, 6.25, 6.25, 6, 6, 6, 6.06
Codend	50 meshed deep by 27 across; Mesh measurements were 6.25, 5.75, 5.75, 5.875, 6.25, 5.625, 6, 6, 5.875, 6.06,
Corners	Each 5' from center
Droppers	2 links with shackles
Floats	65 - eight inch center hole floats - orange
Footrope	180' +100' (wing extensions) = 280'
Headrope	148' + 100' (wing extensions) = 248'
Legs	62' top (1/2" cable) and 62' bottom (3" chain)
Square	29.5 meshed deep
Sweep	5" cookies towards wings, 6" cookies in center, wing extensions had chain.
Tickler	Two ticklers both 64' 6" in length. Attached 50 and 54 feet back from the wing (not wing extension)
Twine	green polyethylene (4mm)
Up and Down line	6'
Wing Extensions	100' top and bottom with chain groundgear

Table C29. Summary of tows conducted for mensuration, calibration, gear efficiency and goosefish depth distribution. Total number of tows was 64; some tows collected more than one type of data.

Vessel	Type of Tow	Purpose	Number of tows completed
F/V Drake	Depletion	Efficiency	10
	Net mensuration - net 1	Wingspread estimates	15
	Net mensuration - net 2	Wingspread estimates	13
	Net comparisons (net 1 - net 2)	Calibration between nets	20
	Paired tows with Mary K	Calibration between vessels	16
	Video	Efficiency	6
F/V Mary K	Depletion	Efficiency	3
	Net mensuration	Wingspread estimates	16
	Paired tows with Drake	Calibration between vessels	15
	Repeated tows - Mary K after Drake	Calibration between vessels	7
	Video	Efficiency	4
	Depth transect	Outer depth limits of goosefish	10

Table C30. Results of comparative tows using Drake nets 1 and 2.

Net 1

Tow No.	Depth (fa)	Wingspread (nm)	Inclinometer Tow Distance	Area Swept (nm)	Catch (kg)	Catch (no.)	kg/nm**2	no./nm**2
180	39.8	0.0117513	1.7524663	0.020594	25.5	23	1238.24	1116.84
181	40.7	0.01177581	1.4912492	0.017561	27.8	23	1583.08	1309.74
182	70	0.01237021	1.6933007	0.020946	10.8	7	515.60	334.18
183	70	0.01237021	1.5796918	0.019541	19.8	9	1013.25	460.57
184	101	0.01277208	1.5759697	0.020128	25.6	10	1271.83	496.81
185	102	0.01278288	1.6325243	0.020868	26.2	10	1255.49	479.19
186	132	0.01306549	1.5990526	0.020892	29.5	12	1412.00	574.37
187	144	0.01316086	1.6339408	0.021504	14.6	11	678.94	511.53
190	98.2	0.01274126	1.4441112	0.018400	30.9	9	1679.37	489.14
188	138	0.01311421	1.6211078	0.021260	41.0	18	1928.54	846.68

Net 2

Tow No.	Depth (fa)	Wingspread (nm)	Inclinometer Tow Distance	Area Swept (nm)	Catch (kg)	Catch (no.)	kg/nm**2	no./nm**2
197	40	0.00885085	1.56271998	0.013831	26.5	27	1915.931	1952.081
198	40.9	0.00885815	1.59291377	0.01411	8.9	7	630.7465	496.0927
199	69.4	0.00903163	1.57005312	0.01418	21.8	8	1537.362	564.1696
200	70.5	0.00903679	1.55741445	0.014074	5.9	3	419.2121	213.1587
201	99.9	0.00915114	1.61549678	0.014784	6.7	5	453.2036	338.2117
202	102	0.00915797	1.6239688	0.014872	11.2	7	753.0802	470.6751
203	135	0.00924993	1.6228021	0.015011	17	5	1132.517	333.0933
204	148	0.0092801	1.62810763	0.015109	13.7	6	906.7447	397.1145
205	98	0.00914484	1.61681538	0.014786	13.7	7	926.5821	473.4361
206	137	0.00925476	1.6499683	0.01527	29.8	13	1951.532	851.3394

	ratio net 2: net 1 (kg)	ratio net 2: net 1 (no.)	ratio net 2: net 1 (wingsprd)
	1.55	1.75	0.75
	0.40	0.38	0.75
	2.98	1.69	0.73
	0.41	0.46	0.73
	0.36	0.68	0.72
	0.60	0.98	0.72
	0.80	0.58	0.71
	1.34	0.78	0.71
	0.55	0.97	0.72
	1.01	1.01	0.71
overall	0.84	0.92	0.72

Table C31. Results of paired tow experiments for Drake net 1 and Mary K. A. Assuming inclinometer distances.
B. Assuming nominal distances for Mary K.

A. Assuming inclinometer distances for all tows.

Mary K Tow No.	Drake Tow No.	Depth (fathoms)	Drake kg caught	Drake no. caught	Drake kg per n mi swept	Drake no. per area swept	Mary K kg caught	Mary K no. caught	Mary K kg per area swept	Mary K no. per area swept	Catch per Area Swept Drake:MK kg	Catch per Area Swept Drake:MK no.
162	178	27	12	10	677.9	564.9	51.9	33	1744.9	1109.5	0.39	0.51
163	179	27	35.9	21	1811.2	1059.5	39.3	26	1335.5	883.5	1.36	1.20
164	180	40	25.5	23	1238.2	1116.8	48.1	34	1501.3	1061.2	0.82	1.05
165	181	40	27.8	23	1583.1	1309.7	22.5	21	702.3	655.5	2.25	2.00
166	182	70	10.8	7	515.6	334.2	9.3	4	256.3	110.2	2.01	3.03
167	183	70	19.8	9	1013.2	460.6	14.8	7	406.5	192.3	2.49	2.40
168	184	100	25.6	10	1271.8	496.8	36.7	14	913.9	348.6	1.39	1.43
169	185	100	26.2	10	1255.5	479.2	57	24	1370.0	576.8	0.92	0.83
170	186	140	29.5	12	1412.0	574.4	33.5	15	767.8	343.8	1.84	1.67
171	187	140	14.6	11	678.9	511.5	52.5	25	1229.8	585.6	0.55	0.87
172	188	140	41	18	1928.5	846.7	36.9	19	881.8	454.1	2.19	1.86
173	189	140	52.9	21	2493.0	989.7	105.1	33	2491.4	782.3	1.00	1.27
174	190	100	30.9	9	1679.4	489.1	47.6	21	1191.5	525.7	1.41	0.93
175	191	40	10.5	6	526.5	300.9	33.7	39	1087.5	1258.6	0.48	0.24
176	192	40	13.3	13	717.5	701.3	20.2	14	630.5	437.0	1.14	1.60
										overall	1.14	1.10

B. Assuming nominal distances for Mary K tows.

Mary K station	Drake station	depth (fathoms)	Drake kg caught	Drake no. caught	Drake kg per n mi swept	Drake no. per area swept	Mary K kg caught	Mary K no. caught	Mary K kg per area swept	Mary K no. per area swept	Catch per Area Swept Drake:MK kg	Catch per Area Swept Drake:MK no.
162	178	27	12	10	677.9	564.9	51.9	33	1957.1	1244.4	0.35	0.45
163	179	27	35.9	21	1811.2	1059.5	39.3	26	1497.8	990.9	1.21	1.07
164	180	40	25.5	23	1238.2	1116.8	48.1	34	1713.2	1211.0	0.72	0.92
165	181	40	27.8	23	1583.1	1309.7	22.5	21	801.4	748.0	1.98	1.75
166	182	70	10.8	7	515.6	334.2	9.3	4	303.6	130.6	1.70	2.56
167	183	70	19.8	9	1013.2	460.6	14.8	7	482.2	228.1	2.10	2.02
168	184	100	25.6	10	1271.8	496.8	36.7	14	1129.2	430.7	1.13	1.15
169	185	100	26.2	10	1255.5	479.2	57	24	1694.8	713.6	0.74	0.67
170	186	140	29.5	12	1412.0	574.4	33.5	15	989.1	442.9	1.43	1.30
171	187	140	14.6	11	678.9	511.5	52.5	25	1574.8	749.9	0.43	0.68
172	188	140	41	18	1928.5	846.7	36.9	19	1060.2	545.9	1.82	1.55
173	189	140	52.9	21	2493.0	989.7	105.1	33	3153.1	990.0	0.79	1.00
174	190	100	30.9	9	1679.4	489.1	47.6	21	1468.7	647.9	1.14	0.75
175	191	40	10.5	6	526.5	300.9	33.7	39	1241.0	1436.2	0.42	0.21
176	192	40	13.3	13	717.5	701.3	20.2	14	719.5	498.6	1.00	1.41
										overall	0.95	0.93

Table C32. Incidences of goosefish cannibalism from cooperative survey.

Goosefish Predator						Goosefish Prey			
Vessel	**Station**	**Fish ID**	**Length (cm)**	**Sex**	**Weight (g)**	**Length (cm)**	**Weight (g)**	**Other Prey**	**Notes**
Mary K	55	1	63	F	4220		2.5	skate egg purses	well digested goosefish
Mary K	96	14	77	F	9610		1700.0		well digested goosefish
Mary K	179	12	81	F	10430	47	2000.0		well digested goosefish
Mary K	86	10	85	F	9760	45	1000.0		well digested goosefish
Mary K	14	3	86	F	12940	49			partly digested goosefish
Mary K	45	1	93	F	12030		185.0		well digested goosefish
Mary K	38	15	98	F	13870		40.0		goosefish bones; well digested
Mary K	44	1	102	F	17010	47	2200.0		partly digested goosefish
Mary K	11	28	105	F	21320	49			partly digested goosefish
Mary K	11	28	105	F	21320	49			partly digested goosefish

Table C33. Mean length at age in samples from cooperative survey.

A. By management area

Management Area	Age	Number of Samples	Mean Length (cm)	Standard Error
North	2	64	17.9	0.212
North	3	174	24.3	0.210
North	4	230	34.2	0.210
North	5	213	44.2	0.221
North	6	148	54.3	0.245
North	7	79	65.0	0.372
North	8	52	76.6	0.464
North	9	32	85.0	0.629
North	10	2	102.5	0.500
South	2	2	18.5	0.500
South	3	89	25.9	0.289
South	4	212	34.1	0.227
South	5	208	45.2	0.213
South	6	228	54.9	0.210
South	7	170	64.9	0.254
South	8	150	75.9	0.312
South	9	67	85.8	0.463
South	10	5	104.4	2.064

B. Entire survey area

Age	Number of Samples	Mean Length (cm)	Standard Error	95% Confidence Interval
2	66	18.0	0.206	17.6 - 18.4
3	263	24.8	0.176	24.5 - 25.2
4	442	34.2	0.154	33.9 - 34.5
5	421	44.7	0.155	44.3 - 45.0
6	376	54.7	0.160	54.4 - 55.0
7	249	64.9	0.209	64.5 - 65.3
8	202	76.1	0.261	75.6 - 76.6
9	99	85.5	0.373	84.8 - 86.2
10	7	103.9	1.471	101.0 - 106.7

Table C34. Efficiency assumptions used in estimating biomass from cooperative survey. Mary K used the same net throughout.

		Efficiency Assumption			
Vessel	Net	Low	Intermediate	High	Source
Drake	Net 1	0.30	0.47	0.63	depletion experiments, patch model
Drake	Net 2	0.28	0.43	0.58	net calibration tows, net 2 = 0.92(net 1)
Mary K		0.48	0.60	0.71	depletion experiments, Leslie-Davis model

Table C35. Swept area biomass and population number estimates from cooperative survey data under varying assumptions about net efficiencies. Nom=nominal distance assumed. Inc=inclinometer distance assumed.

A. Minimum biomass/numbers

	mt				Thousands			
	Using Inclinometer Distance for All Tows	Using Nominal Distance for Mary K	Nominal Minus Inclinom	% Difference Nom-Inc	Using Inclinometer Distance for All Tows	Using Nominal Distance for Mary K	Nominal Minus Inclinom	% Difference Nom-Inc
North	31,454	32,589	1,135	3.61	24,183	25,047	864	3.57
South	32,622	39,255	6,633	20.33	19,070	22,617	3,547	18.60
Combined	64,076	71,843	7,767	12.12	43,254	47,664	4,410	10.20

B. Under High Efficiency Assumptions

	mt				Thousands			
	Using Inclinometer Distance for All Tows	Using Nominal Distance for Mary K	Nominal Minus Inclinom	Percent Increase	Using Inclinometer Distance for All Tows	Using Nominal Distance for Mary K	Nominal Minus Inclinom	Percent Increase
North	51,211	51,211	0	0.0	39,395	39,395	0	0.0
South	46,358	55,493	9,135	19.7	27,035	31,936	4,901	18.1
Combined	97,570	106,705	9,135	9.4	66,430	71,331	4,901	7.4

C. Under Intermediate Efficiency Assumptions

	mt				Thousands			
	Using Inclinometer Distance for All Tows	Using Nominal Distance for Mary K	Nominal Minus Inclinom	Percent Increase	Using Inclinometer Distance for All Tows	Using Nominal Distance for Mary K	Nominal Minus Inclinom	Percent Increase
North	68,680	68,680	0	0.0	52,834	52,834	0	0.0
South	55,400	66,230	10,830	19.5	32,228	38,037	5,809	18.0
Combined	124,081	134,910	10,829	8.7	85,062	90,870	5,808	6.8

D. Under Low Efficiency Assumptions

	mt				Thousands			
	Using Inclinometer Distance for All Tows	Using Nominal Distance for Mary K	Nominal Minus Inclinom	% Difference Nom-Inc	Using Inclinometer Distance for All Tows	Using Nominal Distance for Mary K	Nominal Minus Inclinom	% Difference Nom-Inc
North	107,568	107,568	0	0.0	82,748	82,748	0	0.0
South	70,715	84,306	13,591	19.2	40,925	48,209	7,284	17.8
Combined	178,283	191,873	13,590	7.6	123,673	130,957	7,284	5.9

Table C36. Survey estimates of mean catch rates (kg/tow) and total biomass for cooperative industry and NMFS research trawl surveys. Adjustment factor refers to procedures for estimating area swept per tow: RAW assumes standard speed and tow duration could be maintained for each tow, NOM uses actual ship speed during tow as measured by GPS and standard tow duration to calculate distance

distance. For the southern region, the reduced strata set from the cooperative survey provides a direct comparison to the NMFS surveys.

			Design-based Estimates				Reduction in Variance				Total			
Survey	Year	Region	Mean kg/tow	SE	CV %	degrees of freedom	Allocation	Stratifica-tion	Total	Maximum Reduction in Variance	Minimum Swept Area Biomass	Lower Confidence Interval	Upper Confidence Interval	Adjustment Factor
Coop	2001	All	26.9	1.157	4.3	84.2	12.5	66.0	78.5	86.8	66,390	60,723	72,059	RAW
		North	33.8	2.143	6.3	64.8	2.3	47.2	49.5	63.1	30,851	26,946	34,756	RAW
		South	22.9	1.336	5.8	33.1	15.1	71.4	86.5	92.9	35,539	31,320	39,758	RAW
		South -reduced	19.8	1.335	6.7	30.6	14.9	71.0	85.9	92.7	29,629	25,555	33,703	RAW
Coop	2001	All	26.7	1.169	4.4	84.8	10.9	62.9	73.8	84.0	68,901	62,901	74,901	NOM
		North	33.1	2.075	6.3	66.1	2.9	47.3	50.2	63.2	31,596	27,636	35,555	NOM
		South	22.9	1.399	6.1	36.0	13.5	68.1	81.6	90.5	37,305	32,692	41,918	NOM
		South -reduced	20.3	1.412	7.0	33.6	13.3	67.3	80.6	90.0	31,780	27,282	36,279	NOM
Coop	2001	All	27.9	1.240	4.4	91.9	7.5	62.7	70.2	81.9	61,932	56,466	67,400	INC
		North	37.1	2.327	6.3	66.0	2.9	47.2	50.1	63.2	30,493	26,675	34,311	INC
		South	22.5	1.416	6.3	36.4	8.7	69.5	78.1	88.9	31,439	27,426	35,453	INC
		South -reduced	20.3	1.443	7.1	34.6	8.2	69.0	77.3	88.4	27,348	23,399	31,295	INC
Fall	2000	All	1.4	0.214	15.9	9.9	-33.7	29.7	-4.0	74.3	6,353	4,094	8,612	RAW
		North	2.8	0.652	23.1	7.8	-52.3	9.3	-43.0	50.4	5,038	2,340	7,736	RAW
		South	0.5	0.106	21.4	25.2	-4.6	19.1	14.5	69.3	1,446	808	2,083	RAW
	1997	All	0.7	0.108	15.4	31.0	-15.8	37.8	22.0	75.0	3,322	2,282	4,363	RAW
		North	0.8	0.215	26.5	13.1	-41.2	14.5	-26.6	59.4	1,447	618	2,277	RAW
		South	0.6	0.115	17.9	24.5	-3.1	51.5	48.4	82.6	1,875	1,182	2,568	RAW
Spring	2001	All	0.9	0.204	22.6	17.9	-27.5	14.1	-13.3	75.1	4,253	2,231	6,275	RAW
		North	1.9	0.514	27.0	14.9	-38.0	4.7	-33.3	52.9	3,389	1,434	5,344	RAW
		South	0.3	0.100	33.8	13.9	-12.3	27.9	15.6	81.1	864	237	1,491	RAW
	1987	All	0.9	0.250	28.8	17.5	-54.3	4.9	-49.3	70.4	4,091	1,613	6,569	RAW
		North	1.5	0.511	35.0	11.4	-54.0	6.4	-47.6	55.4	2,607	608	4,606	RAW
		South	0.5	0.255	50.1	6.3	-47.8	-0.3	-48.1	78.8	1,484	-317	3,285	RAW
Winter	2001	South	6.9	0.753	11.0	21.2	-3.6	31.7	28.1	64.9	14,988	11,567	18,409	RAW
	1998	South	3.0	0.408	13.7	25.0	-13.9	21.7	7.9	53.3	6,473	4,645	8,300	RAW

Table C37. Survey estimates of mean catch rates (number/tow) and total number for cooperative industry and NMFS research trawl surveys. Adjustment factor refers to procedures for estimating area swept per tow: RAW assumes standard speed and tow duration could be maintained for each tow, NOM uses actual ship speed during tow as measured by GPS and standard tow duration to calculate distance towed, INC uses actual ship speed during towand net bottom contact time derived from inclinometer sensor data to estimate tow distance.

			Design-based Estimates				Reduction in Variance				Total			
Survey	Year	Region	Mean kg/tow	SE	CV %	Degrees of Freedom	Allocation	Stratifica-tion	Total	Maximum Reduction in Variance	Minimum Swept Area Number	Lower Confidence Interval	Upper Confidence Interval	Adjustment Factor
Coop	2001	All	17.9	0.730	4.1	80.9	9.1	67.4	76.5	85.8	44,037	40,458	47,615	RAW
		North	25.8	1.376	5.3	77.0	10.1	46.1	56.3	64.6	23,529	21,029	26,029	RAW
		South	13.2	0.829	6.3	28.3	8.0	75.1	83.1	92.4	20,508	17,874	23,144	RAW
		South -reduced	12.1	0.845	7.0	26.6	8.2	75.5	83.7	92.8	18,141	15,545	20,737	RAW
Coop	2001	All	17.8	0.759	4.3	66.6	7.1	64.3	71.5	83.6	46,036	42,124	49,944	NOM
		North	25.3	1.355	5.4	74.4	11.1	45.4	56.5	64.9	24,154	21,574	26,732	NOM
		South	13.5	0.904	6.7	25.5	4.5	72.0	76.4	90.1	21,882	18,857	24,906	NOM
		South -reduced	12.6	0.928	7.4	24.4	5.0	72.2	77.2	90.4	19,673	16,677	22,670	NOM
Coop	2001	All	18.9	0.805	4.3	79.2	6.3	64.2	70.4	82.7	41,983	38,428	45,539	INC
		North	28.4	1.513	5.3	74.4	11.1	45.5	56.6	65.0	23,309	20,831	25,787	INC
		South	13.4	0.917	6.9	28.0	1.4	72.8	74.1	89.2	18,673	16,048	21,301	INC
		South -reduced	12.7	0.945	7.5	27.3	2.2	73.0	75.2	89.4	17,047	14,435	19,657	INC
Fall	2000	North	2.8	0.434	15.8	9.1	-41.6	28.3	-13.3	56.4	4,916	3,166	6,667	RAW
		South	0.4	0.082	18.4	22.2	1.7	21.7	23.4	69.7	1,307	809	1,804	RAW
	1997	All	0.4	0.058	13.4	27.2	-21.9	35.3	13.4	70.0	2,034	1,476	2,592	RAW
		North	0.6	0.119	20.4	13.5	-51.0	8.8	-42.2	36.1	1,037	581	1,492	RAW
		South	0.3	0.058	17.1	16.2	-6.4	51.3	45.0	84.5	998	636	1,359	RAW
Spring	2001	All	0.9	0.102	11.6	34.5	-15.9	41.9	25.9	69.4	4,130	3,157	5,103	RAW
		North	1.9	0.252	13.3	27.3	-26.2	27.5	1.3	38.0	3,370	2,448	4,291	RAW
		South	0.3	0.057	21.8	23.1	-7.8	21.7	13.9	64.2	760	417	1,104	RAW
	1987	All	0.2	0.030	18.0	49.2	-8.4	1.8	-6.7	50.7	778	497	1,060	RAW
		North	0.3	0.063	25.0	24.0	-41.3	3.9	-37.5	33.2	449	217	681	RAW
		South	0.1	0.029	25.5	40.2	26.8	-3.7	23.1	59.7	329	160	499	RAW
Winter	2001	South	4.7	0.581	12.3	18.5	-8.7	31.6	22.9	70.8	10,354	7,691	13,017	RAW
	1998	South	1.6	0.166	10.7	32.9	-6.5	44.3	37.7	66.9	3,372	2,640	4,105	RAW

Table C38. Bootstrap estimates of precision for average weight per tow (kg) for cooperative monkfish survey and NMFS surveys. Bootstrap estimates are based on 1000 replications. Adjustment factor refers to procedures for estimating area swept per tow. RAW assumes standard speed and tow duration could be maintained for each tow, NOM uses actual ship speed during tow as measured by GPS and standard tow duration to calculate distance towed, INC uses actual ship speed during tow and net bottom contact time derived from inclinometer sensor data to estimate tow distance.

			Original Estimates		Bootstrap Estimates		95% Conf. Interval		Percentiles			
Survey	Year	Region	Mean	Variance	Mean	Variance	Lower	Upper	25%-ile	50%-ile	75%-ile	Adjustment Factor
Coop	2001	All	26.94	1.34	25.88	1.62	23.49	28.53	25.06	25.87	26.72	RAW
		North	33.81	4.59	33.76	4.62	29.78	38.17	32.25	33.70	35.22	RAW
		South	22.89	1.79	21.32	2.52	18.29	24.32	20.19	21.31	22.46	RAW
		South-reduced	19.81	1.78	18.44	2.51	15.41	21.74	17.42	18.45	19.49	RAW
Coop	2001	All	26.69	1.37	25.82	1.59	23.52	28.22	24.97	25.80	26.70	NOM
		North	33.06	4.31	33.13	4.34	28.95	37.30	31.80	33.05	34.47	NOM
		South	22.94	1.96	21.56	2.29	18.75	24.48	20.51	21.47	22.60	NOM
		South-reduced	20.29	2.00	19.06	2.35	16.10	22.08	18.09	19.10	20.04	NOM
Coop	2001	All	27.90	1.54	27.06	1.83	24.46	29.73	26.17	27.01	27.98	INC
		North	37.11	5.42	37.18	5.28	32.74	41.80	35.61	37.16	38.75	INC
		South	22.49	2.01	21.17	2.43	18.38	24.21	20.08	21.09	22.25	INC
		South-reduced	20.30	2.08	19.10	2.36	16.18	22.19	18.07	19.06	20.13	INC
Fall	2000	All	1.38	0.07	1.39	0.07	0.91	1.98	1.21	1.37	1.55	RAW
		North	2.82	0.43	2.81	0.44	1.71	4.21	2.32	2.75	3.28	RAW
		South	0.49	0.01	0.50	0.01	0.29	0.72	0.42	0.49	0.57	RAW
	1997	All	0.71	0.01	0.67	0.01	0.45	0.88	0.59	0.67	0.75	RAW
		North	0.81	0.05	0.80	0.05	0.39	1.25	0.64	0.79	0.95	RAW
		South	0.64	0.01	0.59	0.02	0.37	0.84	0.50	0.58	0.67	RAW
Spring	2001	All	0.90	0.04	0.89	0.04	0.52	1.34	0.73	0.88	1.02	RAW
		North	1.90	0.26	1.91	0.27	1.03	3.01	1.54	1.87	2.23	RAW
		South	0.30	0.01	0.28	0.01	0.11	0.48	0.20	0.27	0.34	RAW
	1987	All	0.87	0.06	0.89	0.06	0.43	1.43	0.71	0.87	1.05	RAW
		North	1.46	0.26	1.45	0.27	0.54	2.58	1.08	1.40	1.79	RAW
		South	0.51	0.06	0.51	0.07	0.14	1.11	0.28	0.51	0.66	RAW
Winter	2001	South	6.86	0.57	6.81	0.57	5.43	8.33	6.29	6.80	7.33	RAW
	1998	South	2.98	0.17	2.87	0.16	2.13	3.72	2.58	2.85	3.12	RAW

Table C39. Bootstrap estimates of precision for average catch per tow (number) for cooperative monkfish survey and NMFS surveys. Bootstrap estimates are based on 1000 replications. Adjustment factor refers to procedures for estimating area swept per tow. RAW assumes standard speed and tow duration could be maintained for each tow, NOM uses actual ship speed during tow as measured by GPS and standard tow duration to calculate distance towed, INC uses actual ship speed during tow and net bottom contact time derived from inclinometer sensor data to estimate tow distance.

			Original Estimates		Bootstrap Estimates		95% Conf. Interval		Percentiles			
Survey	Year	Region	Mean	Variance	Mean	Variance	Lower	Upper	25%-ile	50%-ile	75%-ile	Adjustment Factor
Coop	2001	All	17.87	0.53	17.23	0.56	15.79	18.66	16.69	17.21	17.76	RAW
		North	25.79	1.89	25.77	1.91	23.15	28.47	24.83	25.74	26.71	RAW
		South	13.21	0.69	12.30	0.95	10.31	14.06	11.63	12.34	13.00	RAW
		South-reduced	12.13	0.71	11.21	0.91	9.41	13.04	10.51	11.22	11.89	RAW
Coop	2001	All	17.83	0.58	17.30	0.60	15.73	18.78	16.79	17.31	17.84	NOM
		North	25.27	1.84	25.21	1.94	22.43	27.81	24.25	25.22	26.21	NOM
		South	13.46	0.82	12.66	0.95	10.74	14.53	11.94	12.65	13.33	NOM
		South-reduced	12.56	0.86	11.83	0.95	9.93	13.79	11.18	11.86	12.47	NOM
Coop	2001	All	18.91	0.65	18.40	0.73	16.74	20.05	17.82	18.42	18.93	INC
		North	28.36	2.29	28.22	2.32	25.33	31.46	27.16	28.18	29.21	INC
		South	13.36	0.84	12.62	0.96	10.76	14.61	11.97	12.62	13.27	INC
		South-reduced	12.66	0.89	11.96	1.02	10.04	14.03	11.25	11.95	12.64	INC
Fall	2000	All	1.32	0.03	1.32	0.03	1.01	1.65	1.20	1.31	1.43	RAW
		North	2.76	0.19	2.75	0.17	2.01	3.61	2.44	2.74	3.03	RAW
		South	0.45	0.01	0.45	0.01	0.30	0.62	0.39	0.44	0.50	RAW
	1997	All	0.43	0.00	0.42	0.00	0.31	0.54	0.38	0.42	0.46	RAW
		North	0.58	0.01	0.58	0.01	0.36	0.83	0.50	0.58	0.67	RAW
		South	0.34	0.00	0.32	0.00	0.21	0.43	0.28	0.32	0.36	RAW
Spring	2001	All	0.88	0.01	0.87	0.01	0.68	1.08	0.80	0.87	0.95	RAW
		North	1.89	0.06	1.89	0.07	1.41	2.38	1.71	1.89	2.07	RAW
		South	0.26	0.00	0.25	0.00	0.14	0.36	0.21	0.25	0.29	RAW
	1987	All	0.17	0.00	0.17	0.00	0.11	0.22	0.14	0.17	0.19	RAW
		North	0.25	0.00	0.25	0.00	0.13	0.38	0.21	0.25	0.29	RAW
		South	0.11	0.00	0.11	0.00	0.06	0.17	0.09	0.11	0.13	RAW
Winter	2001	South	4.74	0.34	4.70	0.33	3.66	5.85	4.30	4.67	5.09	RAW
	1998	South	1.55	0.03	1.52	0.03	1.22	1.83	1.40	1.51	1.63	RAW

Table C40. Comparison of bootstrap and parametric confidence intervals to examine potential bias of point estimates for weight per tow (kg). The NOM adjustment factor was used to derive estimates for the cooperative survey.

			Parametric Estimates of Precision and Confidence Intervals						Bootstrap Estimates of Precision and Confidence Intervals						
						95% Parametric Confidence Interval						95% Confidence Interval			
Survey	Year	Region	mean	SE	CV %	Lower	Upper	CI Length	Mean	SE	CV %	Lower	Upper	CI Length	Ratio Boot Length to Parametric Length
Coop	2001	All	26.7	1.17	4.4	24.4	29.0	4.65	25.8	1.26	4.9	23.5	28.2	4.70	1.01
		North	33.1	2.08	6.3	28.9	37.2	8.29	33.1	2.08	6.3	29.0	37.3	8.35	1.01
		South	22.9	1.40	6.1	20.1	25.8	5.67	21.6	1.51	7.0	18.8	24.5	5.73	1.01
		South -redu	20.3	1.41	7.0	17.4	23.2	5.74	19.1	1.53	8.0	16.1	22.1	5.98	1.04
Fall	2000	All	1.4	0.21	15.9	0.9	1.8	0.96	1.4	0.27	19.3	0.9	2.0	1.06	1.11
		North	2.8	0.65	23.1	1.3	4.3	3.02	2.8	0.66	23.5	1.7	4.2	2.51	0.83
		South	0.5	0.11	21.4	0.3	0.7	0.44	0.5	0.11	21.8	0.3	0.7	0.42	0.97
	1997	All	0.7	0.11	15.4	0.5	0.9	0.44	0.7	0.11	16.3	0.4	0.9	0.43	0.97
		North	0.8	0.22	26.5	0.3	1.3	0.93	0.8	0.22	27.3	0.4	1.3	0.86	0.93
		South	0.6	0.12	17.9	0.4	0.9	0.47	0.6	0.12	21.0	0.4	0.8	0.47	0.99
Spring	2001	All	0.9	0.20	22.6	0.5	1.3	0.86	0.9	0.21	23.4	0.5	1.3	0.81	0.95
		North	1.9	0.51	27.0	0.8	3.0	2.19	1.9	0.52	27.2	1.0	3.0	1.99	0.91
		South	0.3	0.10	33.8	0.1	0.5	0.43	0.3	0.10	36.5	0.1	0.5	0.38	0.88
	1987	All	0.9	0.25	28.8	0.3	1.4	1.05	0.9	0.25	28.2	0.4	1.4	1.00	0.95
		North	1.5	0.51	35.0	0.3	2.6	2.24	1.4	0.52	35.6	0.5	2.6	2.05	0.91
		South	0.5	0.25	50.1	-0.1	1.1	1.23	0.5	0.26	50.6	0.1	1.1	0.96	0.78
Winter	2001	South	6.9	0.75	11.0	5.3	8.4	3.13	6.8	0.76	11.1	5.4	8.3	2.89	0.92
	1998	South	3.0	0.41	13.7	2.1	3.8	1.68	2.9	0.40	14.0	2.1	3.7	1.59	0.94

Table C41. Comparison of industry cooperative and NMFS winter trawl survey estimates of monfish biomass and numbers in 2001. For this comparison, the industry survey was restricted to survey strata covered by the NMFS winter survey. Bootstrap estimates are based on 1000 replicates. Estimates of the total are based on the parametric mean and 95% confidence intervals (CI).

			Parametric Estimates				95% Parametric CI		Bootstrap CI		Reduction in Variance				Param CI Total	
Survey	Response Variable	Adjustment Factor	mean	SE	CV %	df	Lower	Upper	Lower	Upper	Allocation	Stratification	Total	Min Swept Area Estimate (mt or 000's)	Lower Bound (mt or 000's)	Upper Bound (mt or 000's)
Coop	Weight	RAW	19.8	1.335	6.7	30.6	17.090	22.539	15.41	21.74	14.9	71.0	85.9	29,629	25,555	33,703
Coop	Weight	NOM	20.3	1.412	7.0	33.6	17.418	23.162	16.1	22.08	13.3	67.3	80.6	31,780	27,282	36,279
Coop	Weight	INC	20.3	1.443	7.1	34.6	17.373	23.236	16.18	22.19	8.2	69.0	77.3	27,348	23,399	31,295
Winter	Weight	std tow	6.9	0.753	11.0	21.2	5.290	8.419	5.432	8.325	-3.6	31.7	28.1	14,988	11,567	18,409
Coop	Number	RAW	12.1	0.845	7.0	26.6	10.396	13.868	9.408	13.043	8.2	75.5	83.7	18,141	15,545	20,737
Coop	Number	NOM	12.6	0.928	7.4	24.4	10.647	14.473	9.934	13.785	5.0	72.2	77.2	19,673	16,677	22,670
Coop	Number	INC	12.7	0.945	7.5	27.3	10.718	14.595	10.04	14.03	2.2	73.0	75.2	17,047	14,435	19,657
Winter	Number	std tow	4.7	0.581	12.3	18.5	3.518	5.953	3.663	5.853	-8.7	31.6	22.9	10,354	7,691	13,017

Table C42. Indices of egg production by goosefish 1967-1999 by region. Egg production index is a function of numbers at length, proportion mature at length, and fecundity at length, pooled over a 5-year interval. Proportion < L99 is proportion of egg production generated by fish smaller than the length at 99% maturity. Maturity rates from NEFSC (1992).

Year	North Spring EPI	North Spring $P < L_{99}$	North Autumn EPI	North Autumn $P < L_{99}$	South Spring EPI	South Spring $P < L_{99}$	South Autumn EPI	South Autumn $P < L_{99}$	Combined Spring EPI	Combined Spring $P < L_{99}$	Combined Autumn EPI	Combined Autumn $P < L_{99}$
1967	-	-	1.46	0.01	-	-	2.18	0.03	-	-	1.80	0.02
1968	-	-	1.23	0.00	-	-	1.86	0.03	-	-	1.51	0.02
1969	-	-	1.46	0.00	-	-	1.48	0.03	-	-	1.42	0.02
1970	-	-	1.41	0.00	-	-	1.11	0.03	-	-	1.20	0.02
1971	-	-	1.37	0.00	-	-	0.53	0.05	-	-	0.88	0.02
1972	1.15	0.01	1.39	0.01	0.63	0.02	0.86	0.04	0.85	0.01	1.08	0.02
1973	1.31	0.01	1.54	0.01	0.72	0.03	0.94	0.04	0.97	0.02	1.19	0.02
1974	1.40	0.01	1.33	0.01	0.77	0.04	0.89	0.04	1.03	0.02	1.08	0.02
1975	1.28	0.01	1.27	0.01	0.76	0.05	0.93	0.05	0.97	0.03	1.07	0.03
1976	1.54	0.01	1.32	0.01	0.81	0.05	0.93	0.04	1.11	0.03	1.09	0.03
1977	1.13	0.01	1.69	0.01	0.74	0.05	0.66	0.04	0.91	0.03	1.09	0.02
1978	0.94	0.02	1.75	0.01	0.64	0.05	0.61	0.03	0.77	0.03	1.09	0.01
1979	0.83	0.01	1.97	0.01	0.58	0.04	0.68	0.03	0.68	0.03	1.22	0.01
1980	0.88	0.01	2.19	0.01	0.54	0.04	0.64	0.03	0.69	0.03	1.29	0.01
1981	0.71	0.02	1.99	0.01	0.58	0.07	0.70	0.05	0.63	0.04	1.24	0.02
1982	0.86	0.01	1.58	0.01	0.63	0.08	0.57	0.07	0.73	0.05	0.99	0.03
1983	0.93	0.01	1.28	0.01	0.63	0.08	0.61	0.08	0.76	0.04	0.89	0.04
1984	1.00	0.02	1.11	0.01	0.62	0.07	0.53	0.09	0.78	0.04	0.77	0.04
1985	1.05	0.01	0.87	0.01	0.57	0.08	0.48	0.10	0.77	0.04	0.65	0.05
1986	1.12	0.01	0.92	0.02	0.48	0.06	0.38	0.09	0.75	0.03	0.60	0.04
1987	1.00	0.01	0.91	0.02	0.33	0.05	0.36	0.08	0.61	0.02	0.59	0.04
1988	1.05	0.01	0.90	0.02	0.26	0.07	0.26	0.07	0.59	0.03	0.53	0.03
1989	1.01	0.02	0.73	0.03	0.20	0.13	0.23	0.12	0.54	0.04	0.44	0.06
1990	0.88	0.02	0.64	0.04	0.26	0.09	0.17	0.15	0.52	0.04	0.36	0.07
1991	0.74	0.03	0.51	0.05	0.22	0.10	0.17	0.16	0.43	0.05	0.31	0.08
1992	0.67	0.05	0.52	0.07	0.18	0.13	0.17	0.17	0.38	0.07	0.32	0.10
1993	0.56	0.08	0.46	0.08	0.17	0.13	0.13	0.23	0.33	0.09	0.27	0.13
1994	0.50	0.08	0.41	0.09	0.18	0.09	0.13	0.19	0.31	0.08	0.25	0.12
1995	0.55	0.09	0.47	0.10	0.14	0.12	0.13	0.19	0.31	0.10	0.27	0.13
1996	0.49	0.12	0.46	0.12	0.12	0.10	0.11	0.18	0.28	0.12	0.26	0.13
1997	0.44	0.13	0.41	0.12	0.12	0.12	0.14	0.14	0.25	0.13	0.25	0.12
1998	0.38	0.13	0.40	0.12	0.12	0.10	0.17	0.11	0.23	0.12	0.27	0.12
1999	0.40	0.12	0.38	0.12	0.15	0.10	0.15	0.10	0.25	0.11	0.25	0.13
2000	0.36	0.12	0.44	0.13	0.13	0.14	0.17	0.13	0.22	0.13	0.28	0.13
2001	0.43	0.10	-	-	0.12	0.17	-	-	0.25	0.12	-	-

Table C43. Beverton-Holt length-based estimates of total instantaneous mortality rate (Z) using NEFSC fall survey data for the northern management region, 1963-2000; approximate upper and lower 95% confidence intervals (minimum variance estimate); mean length, standard deviation and number of fish at length of capture or above.

	Total Mortality (Z)			Length > 29		
Year	Median	L95% CI	U95%	Mean	SD(mean)	n
1963	0.17	0.13	0.21	68.14	2.77	58
1964	0.18	0.13	0.25	65.96	3.99	29
1965	0.13	0.10	0.17	73.44	3.57	29
1966	0.13	0.11	0.15	73.13	2.15	42
1967	0.15	0.12	0.19	70.25	3.05	16
1968	0.11	0.09	0.14	76.71	3.25	22
1969	0.10	0.08	0.12	79.92	2.70	36
1970	0.17	0.13	0.20	67.93	2.62	36
1971	0.15	0.12	0.17	71.26	2.48	42
1972	0.22	0.17	0.30	61.48	3.57	26
1973	0.16	0.12	0.21	68.92	3.43	44
1974	0.13	0.10	0.18	72.52	4.12	26
1975	0.17	0.13	0.22	66.76	3.43	29
1976	0.13	0.10	0.17	73.60	3.57	36
1977	0.14	0.12	0.17	71.85	2.20	78
1978	0.15	0.13	0.17	71.26	1.98	108
1979	0.11	0.09	0.12	78.46	2.01	91
1980	0.16	0.12	0.21	69.07	3.37	47
1981	0.20	0.16	0.25	63.71	2.92	32
1982	0.13	0.10	0.19	72.54	4.34	12
1983	0.27	0.22	0.35	57.14	2.73	34
1984	0.18	0.14	0.22	66.47	3.21	39
1985	0.23	0.17	0.33	60.27	3.90	27
1986	0.22	0.18	0.27	61.48	2.72	43
1987	0.27	0.20	0.39	57.25	3.97	20
1988	0.21	0.16	0.28	62.95	3.80	24
1989	0.28	0.20	0.42	56.47	4.37	23
1990	0.35	0.25	0.55	52.77	3.93	21
1991	0.42	0.30	0.60	50.14	3.21	31
1992	0.42	0.32	0.55	50.00	2.76	35
1993	0.37	0.28	0.55	51.14	3.11	27
1994	0.55	0.39	0.76	46.10	2.75	31
1995	0.59	0.45	0.76	44.99	2.03	66
1996	0.55	0.45	0.69	45.83	1.94	44
1997	0.59	0.45	0.76	45.25	2.17	31
1998	0.42	0.33	0.55	49.84	2.49	34
1999	0.69	0.51	1.03	42.64	2.27	41
2000	0.55	0.39	0.64	47.06	2.01	59

Mean	1970-1979	0.15
	1991-1995	0.47
	1996-2000	0.56

Table C44. Beverton-Holt length-based estimates of total instantaneous mortality rate (Z) using NEFSC fall survey data for the southern management region, 1963-2000; approximate upper and lower 95% confidence intervals (minimum variance estimate); mean length, standard deviation and number of fish at length of capture or above.

	Total Mortality (Z)			Length > 29		
Year	Median	L95% CI	U95%	Mean	SD(mean)	n
1963	0.27	0.24	0.33	59.76	1.97	70
1964	0.33	0.29	0.37	56.62	1.55	117
1965	0.24	0.21	0.29	62.85	2.02	82
1966	0.26	0.23	0.29	61.48	1.54	124
1967	0.37	0.29	0.49	54.05	3.02	48
1968	0.41	0.35	0.49	52.47	1.97	52
1969	0.39	0.32	0.49	52.98	2.38	62
1970	0.26	0.23	0.32	60.87	2.32	46
1971	0.32	0.24	0.44	57.30	3.78	31
1972	0.35	0.30	0.39	55.78	1.30	196
1973	0.57	0.46	0.65	42.72	1.62	112
1974	0.27	0.22	0.37	60.07	3.37	27
1975	0.32	0.27	0.39	56.83	1.95	72
1976	0.35	0.29	0.44	55.39	2.26	45
1977	0.20	0.17	0.25	67.03	2.66	45
1978	0.21	0.18	0.25	66.51	2.33	44
1979	0.35	0.30	0.44	55.25	2.10	80
1980	0.53	0.44	0.71	47.89	1.91	88
1981	0.49	0.44	0.61	48.93	1.52	98
1982	0.71	0.57	0.92	44.23	1.71	41
1983	0.39	0.35	0.46	53.05	1.43	84
1984	0.37	0.30	0.44	54.50	2.18	34
1985	0.44	0.37	0.57	51.22	2.05	53
1986	0.49	0.39	0.65	49.14	2.59	29
1987	0.71	0.49	1.02	44.82	2.89	14
1988	0.57	0.37	0.92	47.66	3.92	26
1989	0.61	0.53	0.71	46.50	1.25	35
1990	0.53	0.39	0.71	48.55	2.82	19
1991	0.57	0.46	0.77	46.92	1.88	35
1992	0.77	0.57	1.02	43.82	2.18	23
1993	0.92	0.71	1.29	41.26	1.91	20
1994	0.65	0.49	0.92	45.18	2.35	29
1995	0.84	0.65	1.14	42.29	1.85	28
1996	0.61	0.46	0.77	46.77	2.09	25
1997	0.46	0.37	0.57	50.78	2.03	33
1998	0.39	0.32	0.53	52.89	2.66	23
1999	1.14	0.84	1.48	39.68	1.51	26
2000	0.65	0.61	0.71	45.38	0.83	41

Mean	1970-1979	0.32
	1991-1995	0.75
	1996-2000	0.65

Table C45. Estimates of total mortality from NEFSC offshore surveys.

	NEFSC Fall Survey							NEFSC Spring Survey							NEFSC Winter Survey						
	Numbers at Age				Total Mortality (Z)			Numbers at Age				Total Mortality (Z)			Numbers at Age				Total Mortality (Z)		
	Age 3+	Age 4+	Age 5+	Age 6+	3+/4+	4+/5+	5+/6+	Age 3+	Age 4+	Age 5+	Age 6+	3+/4+	4+/5+	5+/6+	Age 3+	Age 4+	Age 5+	Age 6+	3+/4+	4+/5+	5+/6+
North																					
1993	0.36	0.25	0.16	0.06	0.44	0.57	1.07														
1994	0.44	0.23	0.14	0.05	0.05	0.23	0.47														
1995	0.70	0.42	0.18	0.09	0.67	1.01	1.16	0.83	0.66	0.41	0.30	0.30	0.53	1.20							
1996	0.51	0.36	0.15	0.06	0.81	1.37	1.37	0.63	0.62	0.39	0.12	0.98	2.73	2.37							
1997	0.35	0.23	0.09	0.04	0.32	0.10	-0.53	0.31	0.24	0.04	0.04	0.62	0.65	-0.67							
1998	0.34	0.25	0.20	0.15	1.12	0.97	1.17	0.21	0.17	0.12	0.08	-0.72	-0.21	-0.13							
1999	0.29	0.11	0.10	0.06	-0.62	-0.88	-0.54	0.63	0.44	0.21	0.14	0.22	0.55	0.47							
2000	0.99	0.54	0.27	0.16				0.89	0.50	0.25	0.13	0.17	0.09	-0.02							
2001								1.12	0.75	0.46	0.25										
Mean					0.40	0.48	0.60					0.26	0.72	0.54							
South																					
1993	0.16	0.08	0.02	0.01	0.15	0.15	-0.52														
1994	0.19	0.14	0.07	0.04	0.49	0.73	1.45														
1995	0.24	0.12	0.07	0.02	0.51	0.33	0.95	0.20	0.14	0.10	0.08	0.64	0.60	0.46							
1996	0.20	0.14	0.09	0.03	0.06	-0.05	0.60	0.12	0.10	0.08	0.06	0.31	1.14	2.26							
1997	0.24	0.19	0.15	0.05	0.46	0.69	1.11	0.12	0.09	0.03	0.01	-0.31	0.18	0.16	3.01	2.34	1.88	1.08	0.85	0.90	1.42
1998	0.19	0.15	0.09	0.05	1.26	2.37		0.21	0.16	0.07	0.03	-0.14	-0.15	-0.11	1.35	1.29	0.95	0.46	-0.38	0.03	0.28
1999	0.17	0.05	0.01	0.00	0.28	-0.16	-1.05	0.32	0.24	0.18	0.08	0.68	1.08	1.74	2.63	1.98	1.25	0.72	-0.23	0.01	0.73
2000	0.24	0.13	0.06	0.04				0.22	0.16	0.08	0.03	0.34	0.66	0.64	4.07	3.31	1.96	0.61	0.18	0.50	0.65
2001								0.21	0.15	0.08	0.04				4.13	3.39	2.01	1.03			
Mean					0.46	0.58	0.42					0.25	0.59	0.86					0.11	0.36	0.77
Combined																					
1993	0.24	0.15	0.08	0.03	0.40	0.41	0.59														
1994	0.32	0.16	0.10	0.04	0.31	0.36	0.59														
1995	0.45	0.24	0.11	0.06	0.65	0.73	0.98	0.45	0.35	0.23	0.18	0.37	0.55	0.97							
1996	0.33	0.23	0.11	0.04	0.48	0.62	0.95	0.33	0.31	0.20	0.09	0.80	1.73	1.58							
1997	0.29	0.20	0.13	0.04	0.44	0.47	0.41	0.20	0.15	0.06	0.04	0.20	0.48	0.12							
1998	0.24	0.18	0.13	0.08	1.03	1.23	1.57	0.21	0.16	0.09	0.05	-0.44	-0.20	-0.13							
1999	0.23	0.09	0.05	0.03	-0.29	-0.54	-0.55	0.44	0.33	0.20	0.10	0.39	0.76	1.00							
2000	0.55	0.30	0.15	0.09				0.49	0.30	0.15	0.07	0.18	0.23	0.14							
2001								0.59	0.41	0.24	0.13										
Mean					0.43	0.47	0.65					0.25	0.59	0.61							

Table C46. Exploitation ratios estimated under varying assumptions of net efficiency and areas swept for Mary K.

A. Using landings and exploitable biomass, biomass from inclinometer distances for all nets.

		100% efficiency		High efficiency		Intermediate Efficiency		Low Efficiency	
Management Area	Calendar 2000 landings (mt)	Exploitable Biomass midyear	Exploitation ratio	Exploitable Biomass midyear	Exploitation ratio	Exploitable Biomass midyear	Exploitation ratio	Exploitable Biomass midyear	Exploitation ratio
North	10689	27184.5	0.39	40926.5	0.26	53064.5	0.20	80082.5	0.13
South	10175	23788.5	0.43	31837.5	0.32	37296.5	0.27	46845.5	0.22
Combined	20864	50973	0.41	72764	0.29	90361	0.23	126928	0.16

B. Using landings and exploitable biomass, biomass from nominal distances for Mary K.

		100% efficiency		High efficiency		Intermediate Efficiency		Low Efficiency	
Management Area	Calendar 2000 landings (mt)	Exploitable Biomass midyear	Exploitation ratio	Exploitable Biomass midyear	Exploitation ratio	Exploitable Biomass midyear	Exploitation ratio	Exploitable Biomass midyear	Exploitation ratio
North	10689	27184.5	0.39	40926.5	0.26	53064.5	0.20	80082.5	0.13
South	10175	27588.5	0.37	37200.5	0.27	43655.5	0.23	54829.5	0.19
Combined	20864	54773	0.38	78127	0.27	96720	0.22	134912	0.15

C. Using catch and total biomass, biomass from inclinometer distances for all nets.

		100% efficiency		High efficiency		Intermediate Efficiency		Low Efficiency	
Management Area	Calendar 2000 catch (mt)	Biomass midyear	Exploitation ratio	Biomass midyear	Exploitation ratio	Biomass midyear	Exploitation ratio	Biomass midyear	Exploitation ratio
North	11544	37226	0.31	56983	0.20	74452	0.16	113340	0.10
South	12960	39102	0.33	52838	0.25	61880	0.21	77195	0.17
Combined	24504	76328	0.32	109822	0.22	136333	0.18	190535	0.13

D. Using catch and total biomass, biomass from nominal distances for Mary K

		100% efficiency		High efficiency		Intermediate Efficiency		Low Efficiency	
Management Area	Calendar 2000 catch (mt)	Biomass midyear	Exploitation ratio	Biomass midyear	Exploitation ratio	Biomass midyear	Exploitation ratio	Biomass midyear	Exploitation ratio
North	11544	38361	0.30	56983	0.20	74452	0.16	113340	0.10
South	12960	45735	0.28	61973	0.21	72710	0.18	90786	0.14
Combined	24504	84095	0.29	118957	0.21	147162	0.17	204125	0.12

Table C47. Yield per recruit analysis for goosefish, combined areas.

The NEFSC Yield and Stock Size per Recruit Program - PDBYPRC
PC Ver. 2.0 Method of Thompson and Bell (1934) 1-Jan-99
Run Date: 1-11-2001, Time: 17:54:27.64
Goosefish 2001
Proportion of F before spawning: 0.417
Proportion of M before spawning: 0.417
Natural Mortality is constant at: 0.2
Initial age is 0; last age is 15
Last age is a TRUE age;
Original age-specific PRs, Mats, and Mean Wts from file
C:\Program\Files\FACT\goose\ypr_01.dat

Summary of Yield per Recruit Analysis

Slope of the Yield/Recruit Curve at F=0.00: --> 15.0275
F level at slope=1/10 of the above slope (F0.1): -----> 0.138
Yield/Recruit corresponding to F0.1: ------> 0.8925
F level to produce Maximum Yield/Recruit (Fmax): ----->0.197
Yield/Recruit corresponding to Fmax: -----> 0.9311
F level at 20% of Max Spawning Potential (F20): -----> 0.295
SSB/Recruit corresponding to F20: -------> 3.0496

Age-specific input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Catch	Stock Weights
0	0.0100	1.0000	0.0000	0.016	0.016
1	0.0200	1.0000	0.0000	0.062	0.062
2	0.0500	1.0000	0.0000	0.184	0.184
3	0.2500	1.0000	0.0000	0.420	0.420
4	0.5000	1.0000	0.5000	0.845	0.845
5	0.9000	1.0000	1.0000	1.609	1.609
6	1.0000	1.0000	1.0000	2.703	2.703
7	1.0000	1.0000	1.0000	4.610	4.610
8	1.0000	1.0000	1.0000	7.953	7.953
9	1.0000	1.0000	1.0000	11.855	11.855
10	1.0000	1.0000	1.0000	14.080	14.080
11	1.0000	1.0000	1.0000	17.588	17.588
12	1.0000	1.0000	1.0000	20.456	20.456
13	1.0000	1.0000	1.0000	22.963	22.963
14	1.0000	1.0000	1.0000	25.087	25.087
15	1.0000	1.0000	1.0000	26.844	26.844

Listing of Yield per Recruit Results for:

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	0.0000	0.0000	0.0000	5.2918	17.1861	1.8669	15.2493	100.00
	0.1000	0.1435	0.8031	4.7328	9.8787	1.3155	8.1912	53.72
F0.1	0.1400	0.1785	0.8925	4.5840	8.1927	1.1722	6.6026	43.30
Fmax	0.2000	0.2202	0.9311	4.3995	6.2981	0.9972	4.8443	31.77
	0.2000	0.2223	0.9310	4.3903	6.2101	0.9886	4.7634	31.24
F20%	0.3000	0.2694	0.8785	4.1720	4.3185	0.7874	3.0496	20.00
	0.3000	0.2714	0.8743	4.1626	4.2465	0.7789	2.9854	19.58
	0.4000	0.3053	0.7821	4.0004	3.1249	0.6352	1.9999	13.11
	0.5000	0.3305	0.6958	3.8779	2.4427	0.5311	1.4177	9.30
	0.6000	0.3504	0.6243	3.7811	2.0030	0.4526	1.0529	6.90
	0.7000	0.3667	0.5669	3.7019	1.7043	0.3912	0.8121	5.33
	0.8000	0.3804	0.5210	3.6353	1.4917	0.3421	0.6457	4.23
	0.9000	0.3922	0.4839	3.5779	1.3344	0.3018	0.5261	3.45
	1.0000	0.4026	0.4536	3.5276	1.2138	0.2684	0.4373	2.87
	1.1000	0.4118	0.4285	3.4828	1.1186	0.2401	0.3694	2.42
	1.2000	0.4201	0.4073	3.4426	1.0416	0.2160	0.3161	2.07
	1.3000	0.4277	0.3892	3.4060	0.9778	0.1951	0.2736	1.79
	1.4000	0.4347	0.3736	3.3724	0.9240	0.1770	0.2390	1.57
	1.5000	0.4411	0.3599	3.3415	0.8780	0.1612	0.2104	1.38
	1.6000	0.4471	0.3477	3.3127	0.8380	0.1472	0.1864	1.22
	1.7000	0.4526	0.3369	3.2858	0.8029	0.1348	0.1662	1.09
	1.8000	0.4579	0.3271	3.2606	0.7717	0.1238	0.1488	0.98
	1.9000	0.4628	0.3182	3.2368	0.7438	0.1139	0.1339	0.88
	2.0000	0.4675	0.3101	3.2143	0.7186	0.1050	0.1210	0.79

Table C48. Monkfish surplus production results using cooperative survey biomass estimate in 2001 for northern for northern, southern, and combined-area monkfish stock units, where B[37] is stock biomass at the start of 2000 (000 mt), B2001 is stock biomass at the start of 2001 (000 mt), BMSP is the biomass that would maximize surplus production (000 mt), BRATIO is the ratio of B2001 to BMSP, H[37] is the exploitation rate in 2000, HMSP is the exploitation rate that would maximize surplus production, K is carrying capacity (000 mt), M is the shape parameter of the production curve, MSP is maximum surplus production (000 mt), qFALL is autumn survey catchability, r is the intrinsic growth rate, sigma2 is process error variance parameter, and tau2FALL is the survey error variance parameter.

Northern monkfish

node	mean	stdev	10.00%	25.00%	median	75.00%	90.00%
B[37]	80.06	23.71	53.08	63.22	76.65	93.2	111.3
B2001	74.6	23.34	48.28	57.93	71.07	87.31	105.5
BMSP	80.81	29.03	48.82	60.45	75.97	96.06	118.7
BRATIO	1.046	0.2772	0.714	0.8484	1.021	1.215	1.409
H[37]	0.1565	0.04542	0.104	0.1243	0.1505	0.182	0.2158
HMSP	0.1017	0.08304	0.02245	0.04502	0.08178	0.1338	0.2017
HRATIO	3.22	6.102	0.8125	1.179	1.849	3.192	6.09
K	181.9	62.23	111.2	138.4	173.5	216.4	262.6
M	1.524	0.4626	1.11	1.199	1.387	1.7	2.123
MSP	6.588	3.481	2.406	4.179	6.333	8.516	10.71
qFALL	0.01403	0.004963	0.008835	0.01058	0.01307	0.01642	0.02031
r	0.4966	0.462	0.06712	0.1483	0.3356	0.7035	1.22
sigma2	0.005236	0.008127	0.001759	0.002402	0.003594	0.005765	0.009465
tau2FALL	0.1913	0.05254	0.1321	0.1548	0.1841	0.2203	0.2598

Southern monkfish

node	mean	stdev	10.00%	25.00%	median	75.00%	90.00%
B[34]	65.51	19.36	43.48	51.77	62.81	76.13	90.99
B2001	58.48	19.69	36.11	44.52	55.82	69.29	84.29
BMSP	119.5	46.17	69.61	87.39	111.7	143.1	179.4
BRATIO	0.5984	0.2076	0.3662	0.4508	0.5651	0.711	0.8727
H[34]	0.2147	0.06299	0.1423	0.17	0.206	0.2504	0.2984
HMSP	0.07592	0.08066	0.01207	0.02583	0.05375	0.0985	0.1582
HRATIO	7.601	15.56	1.358	2.137	3.82	7.738	16.17
K	272.4	99.16	163.7	204.3	257.5	324.6	400.3
M	1.518	0.4767	1.095	1.186	1.375	1.697	2.133
MSP	6.815	4.213	1.852	3.585	6.265	9.299	12.29
qFALL	0.004142	0.001575	0.002622	0.003106	0.003793	0.004746	0.006033
r	0.3699	0.4173	0.03463	0.08095	0.2042	0.4979	0.9848
sigma2	0.01526	0.02642	0.002733	0.004195	0.007496	0.01469	0.02968
tau2FALL	0.1613	0.06084	0.095	0.1234	0.1561	0.1946	0.237

Combined monkfish

node	mean	stdev	10.00%	25.00%	median	75.00%	90.00%
B[37]	161.2	47.43	107.1	127.3	154.6	187.8	223.7
B2001	149.1	48.43	94.13	114.6	142.4	175.5	212.7
BMSP	278.3	124.1	144.2	189.8	254.8	340.7	441.7
BRATIO	0.6487	0.235	0.3873	0.4806	0.6106	0.7716	0.9565
H[37]	0.1665	0.04891	0.1102	0.1316	0.1599	0.1942	0.2311
HMSP	0.07098	0.07207	0.01076	0.02345	0.0496	0.09247	0.1539
HRATIO	6.428	13.77	1.124	1.806	3.201	6.527	13.73
K	637	284.2	334.4	439.7	585.6	777.9	996.4
M	1.52	0.4922	1.087	1.178	1.369	1.704	2.151
qFALL	0.004142	0.001575	0.002622	0.003106	0.003793	0.004746	0.006033
r	0.3699	0.4173	0.03463	0.08095	0.2042	0.4979	0.9848
sigma2	0.01526	0.02642	0.002733	0.004195	0.007496	0.01469	0.02968
tau2FALL	0.1613	0.06084	0.095	0.1234	0.1561	0.1946	0.237

Table C49. Stratified mean catch per tow in weight (kg), 33rd percentile, three-year moving averages, medians, NEFSC offshore autumn research vessel bottom trawl in northern region (survey strata 20-30, 34-40); and southern region (survey strata 1-19, 61-76); means from delta distribution.

	Northern Management/ Assessment Area				Southern Management/ Assessment Area			
	Mean Weight/Tow	33rd Percentile 1963-1994 series	Three-year Moving Average	Median, Three-Year Moving Average 1965-1981	Mean Weight/Tow	33rd Percentile 1963-1994 series	Three-Year Moving Average	Median, Three-Year Moving Average 1965-1981
1963	3.757				3.724			
1964	1.712				5.486			
1965	2.509	1.460	2.659	2.496	5.163	0.750	4.791	1.848
1966	3.266		2.496		6.986		5.878	
1967	1.283		2.353		1.122	**1967-1994:**	4.423	**1967-1981:**
1968	2.036		2.195		0.895	**0.704**	3.001	**1.846**
1969	3.705		2.341		1.138		1.051	
1970	2.237		2.659		1.357		1.130	
1971	2.914		2.952		0.786		1.094	
1972	1.404		2.185		4.918		2.354	
1973	3.114		2.477		1.986		2.564	
1974	2.063		2.193		0.710		2.538	
1975	1.711		2.296		2.043		1.580	
1976	3.387		2.387		1.084		1.279	
1977	5.568		3.555		1.873		1.667	
1978	5.101		4.685		1.395		1.451	
1979	5.133		5.267		2.275		1.848	
1980	4.458		4.897		1.868		1.846	
1981	1.984		3.859		2.858		2.334	
1982	0.936		2.459		0.646		1.791	
1983	1.617		1.513		2.150		1.885	
1984	3.010		1.855		0.740		1.179	
1985	1.441		2.023		1.318		1.403	
1986	2.353		2.268		0.552		0.870	
1987	0.873		1.556		0.274		0.715	
1988	1.525		1.584		0.554		0.460	
1989	1.384		1.261		0.625		0.485	
1990	1.001		1.303		0.426		0.535	
1991	1.235		1.207		0.783		0.611	
1992	1.102		1.113		0.312		0.507	
1993	1.044		1.127		0.294		0.463	
1994	0.973		1.040		0.611		0.406	
1995	1.711		1.243		0.386		0.430	
1996	1.07		1.252		0.387		0.461	
1997	0.669		1.150		0.592		0.455	
1998	0.974		0.904		0.500		0.493	
1999	0.825		0.823		0.304		0.465	
2000	2.495		1.431		0.477		0.427	
2001	2.052*		1.791*		0.708*		0.496*	

* preliminary data

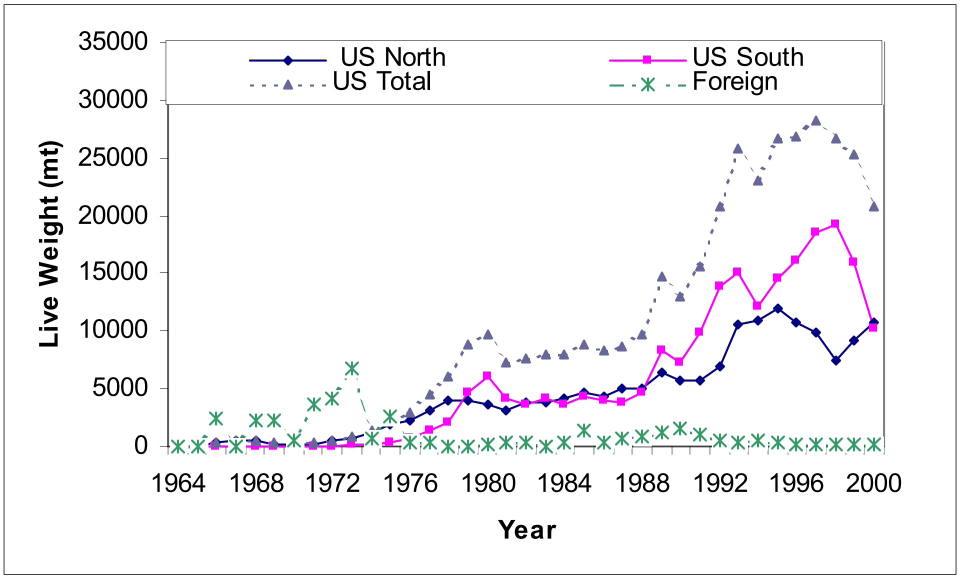
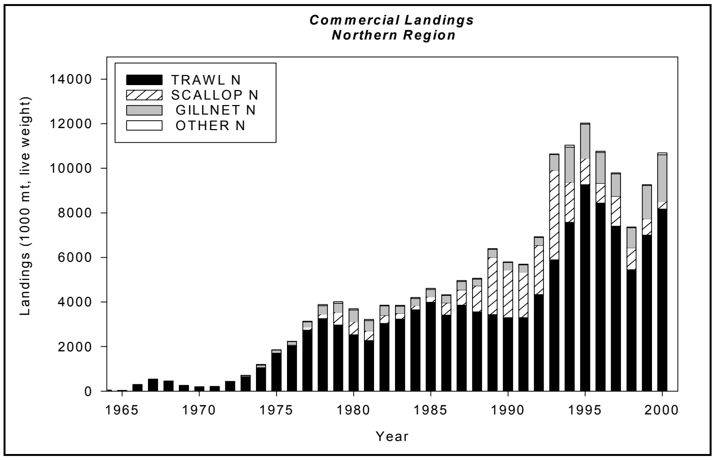
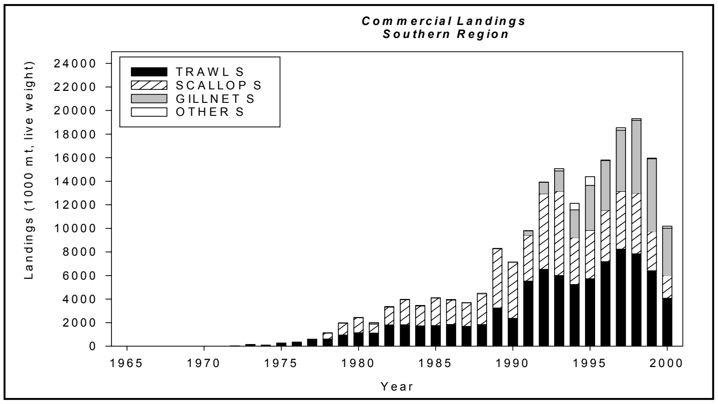


Figure C1. US and foreign commercial landings (calculated live weight, mt) of goosefish by assessment area.





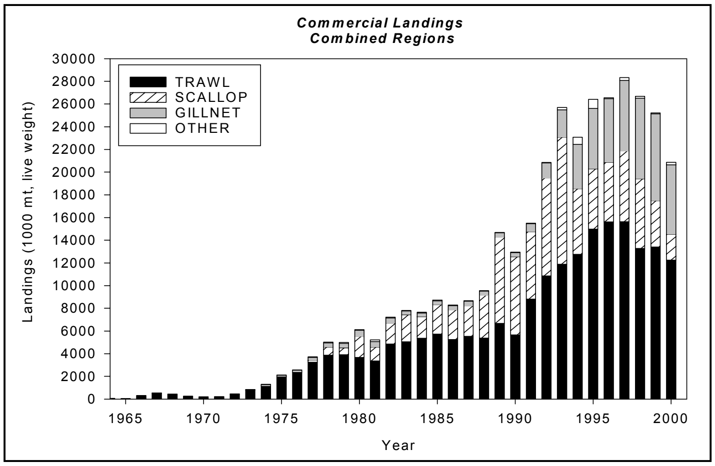


Figure C2. US landings (live weight, mt) by gear type, A. northern management region; B. southern management region, and C. both regions combined.

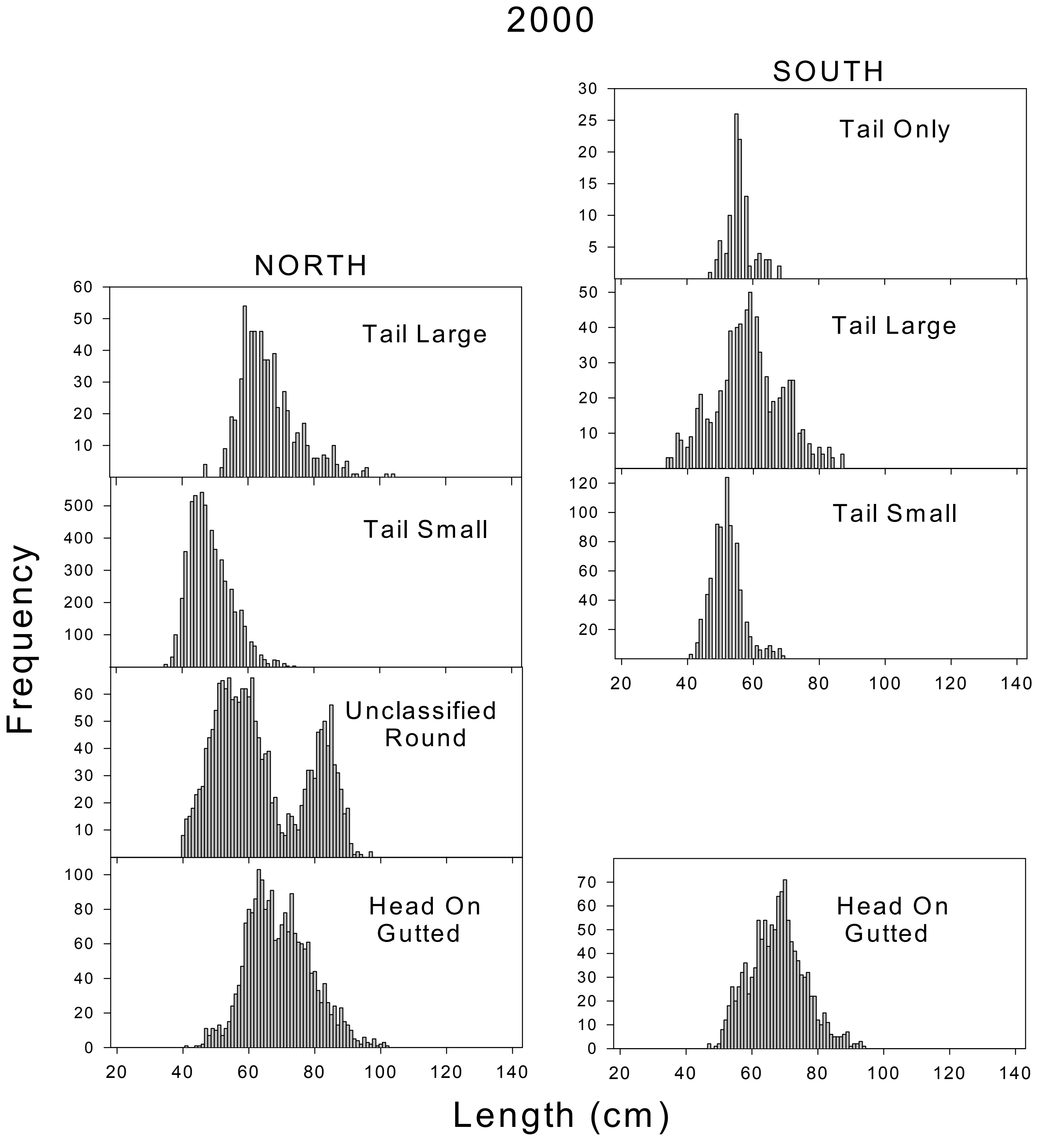


Figure C3. Length frequencies of goosefish in commercial samples taken during 2000.

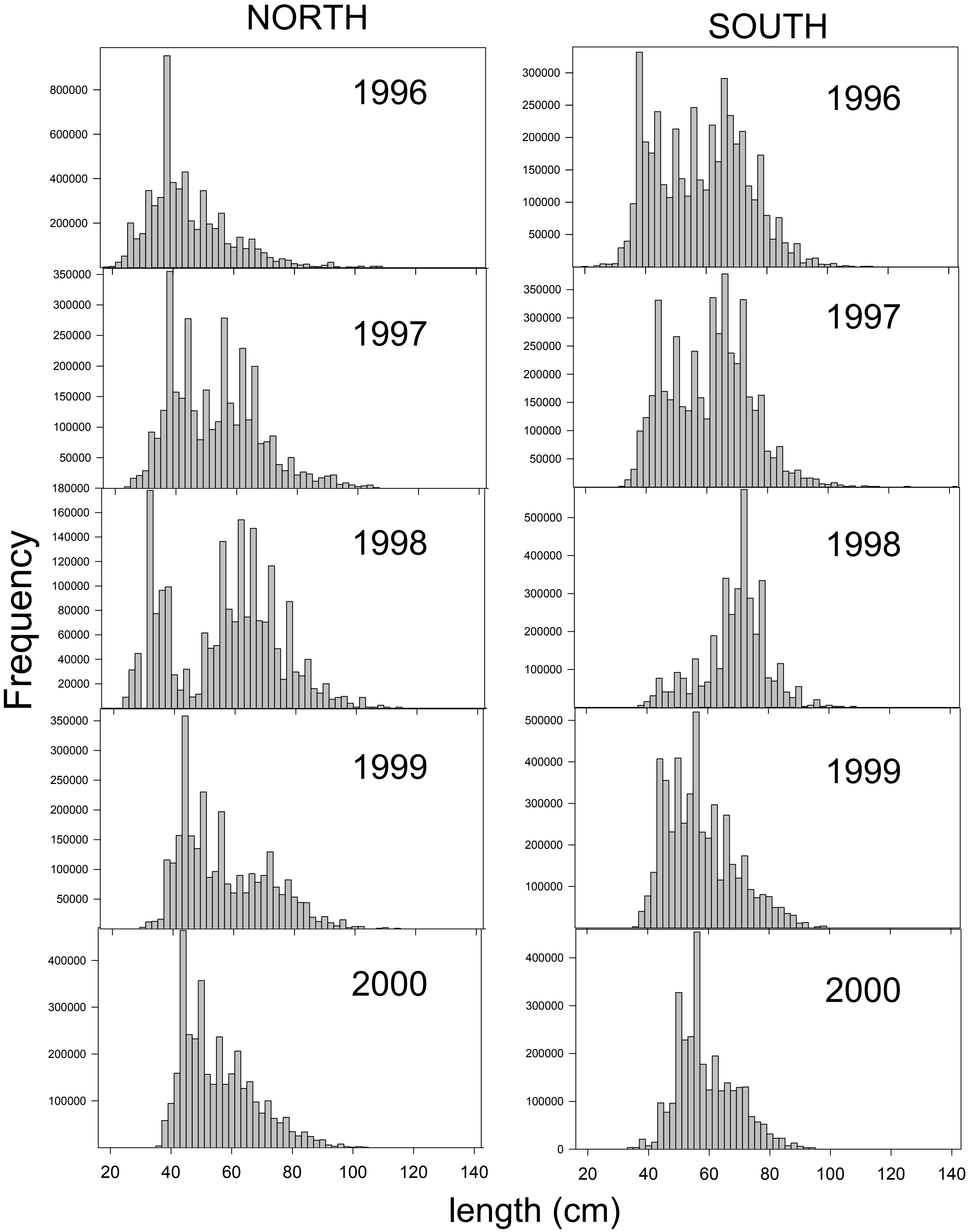


Figure C4. Estimated length frequency of goosefish commericial landings by management region, 1996-2000.

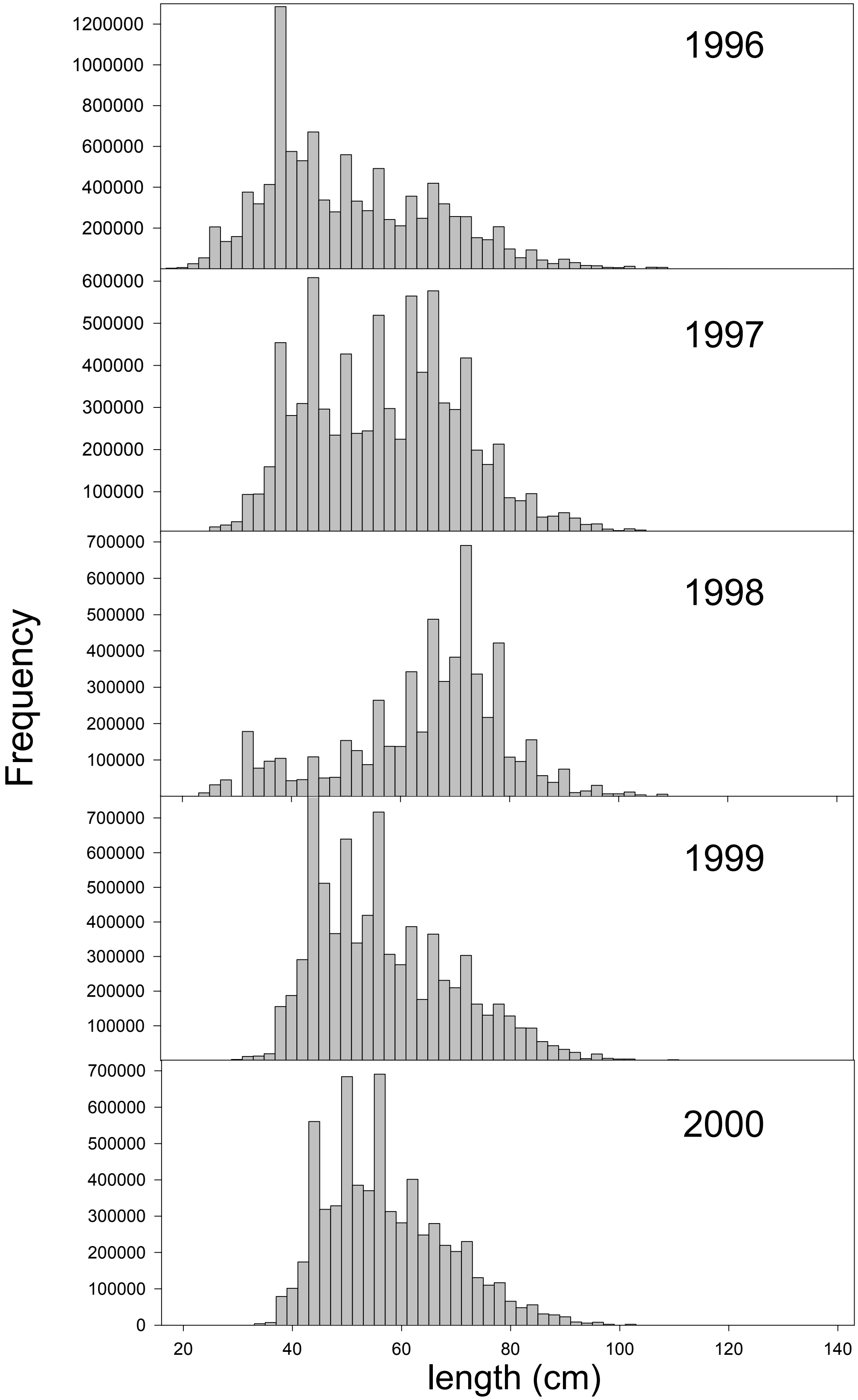


Figure C5. Estimated length frequency of goosefish commericial landings, management regions, combined, 1996-2000.

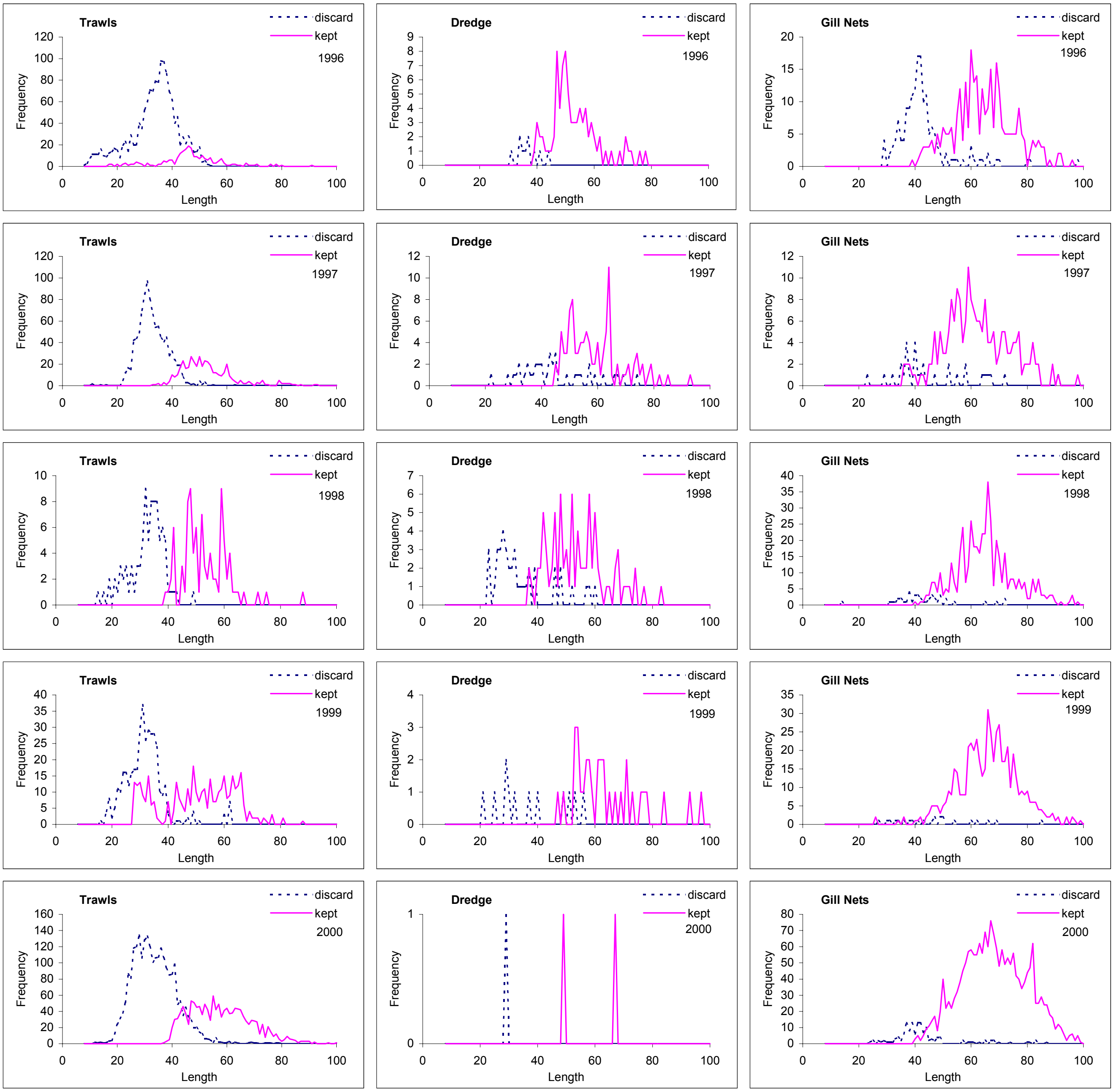


Figure C6. Size composition of discarded and kept goosefish estimated from sea sampling observations, northern region.

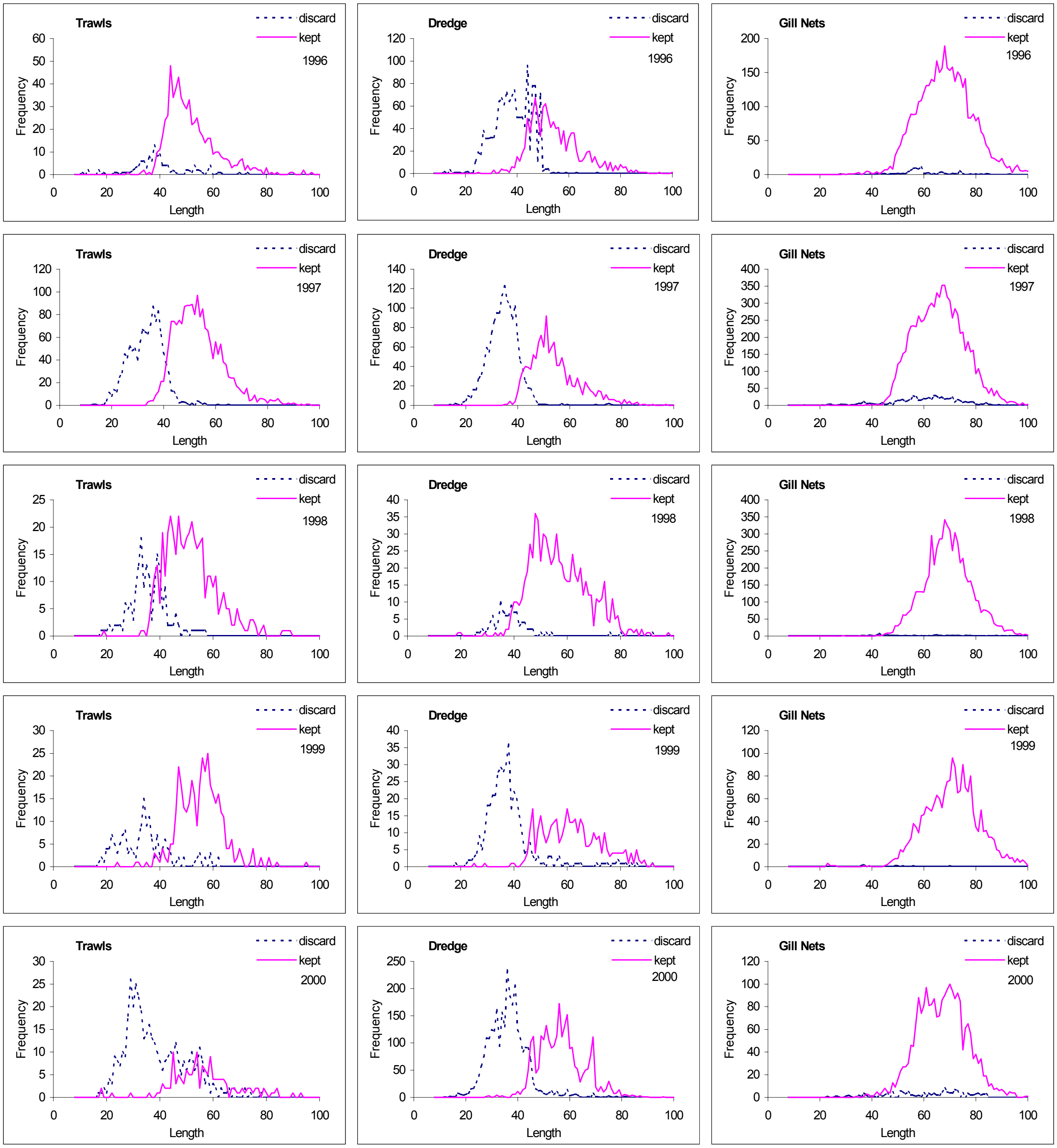


Figure C7. Size composition of discarded and kept goosefish estimated from sea sampling observations, southern region

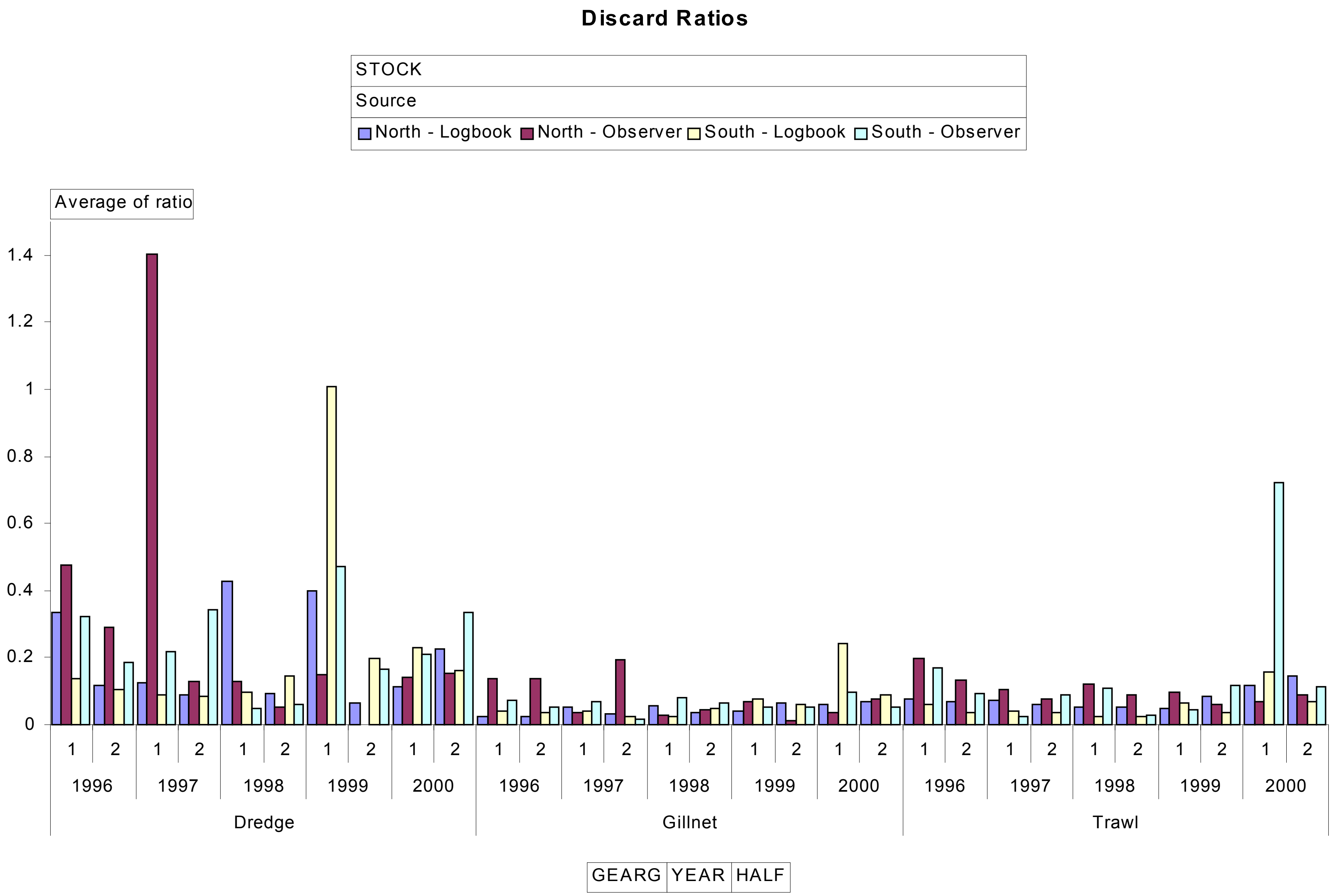
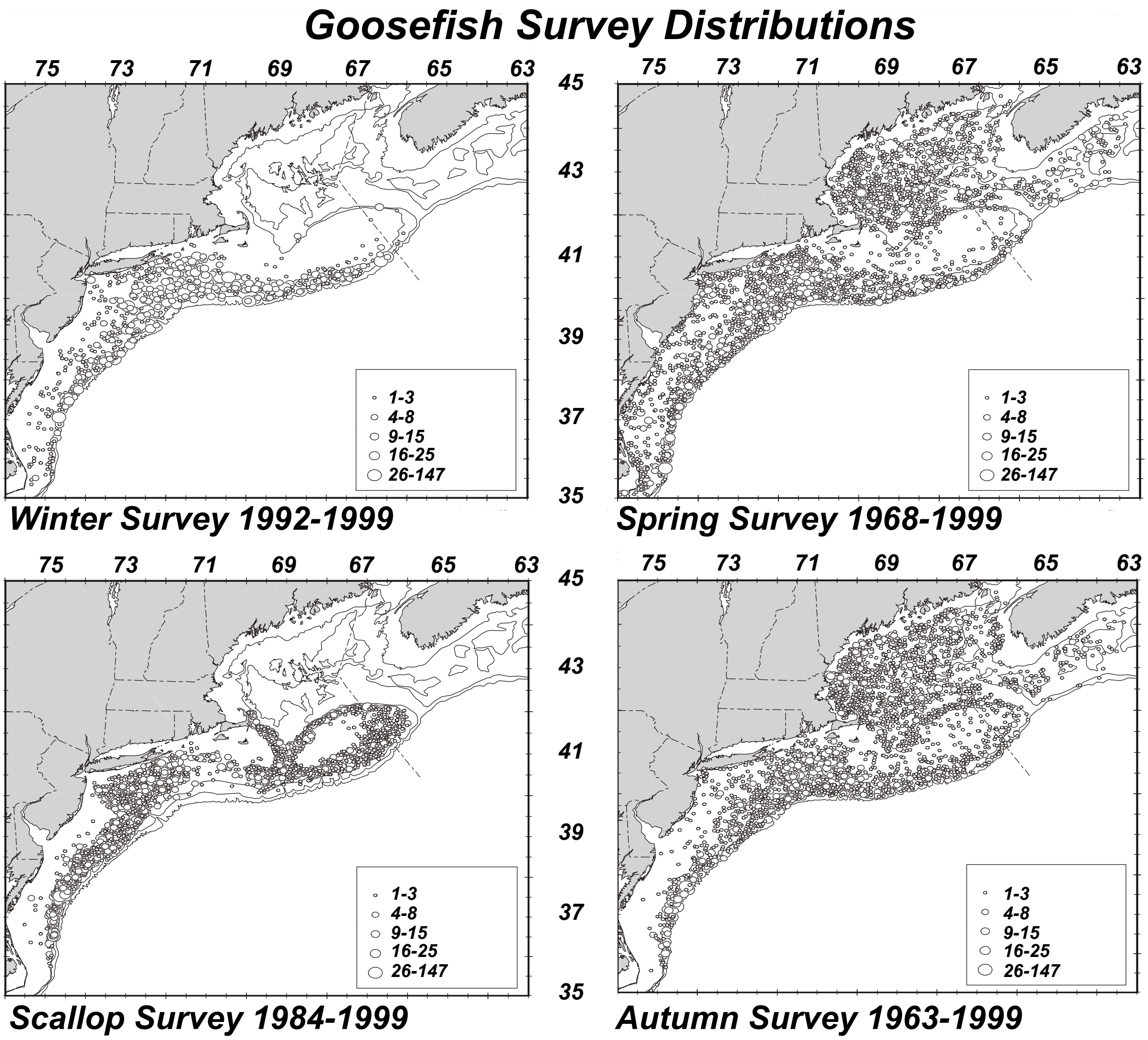


Figure C8. Discard ratios by stock area, gear, and half year from the observer program and VTR database.



Winter Survey 1992-1999

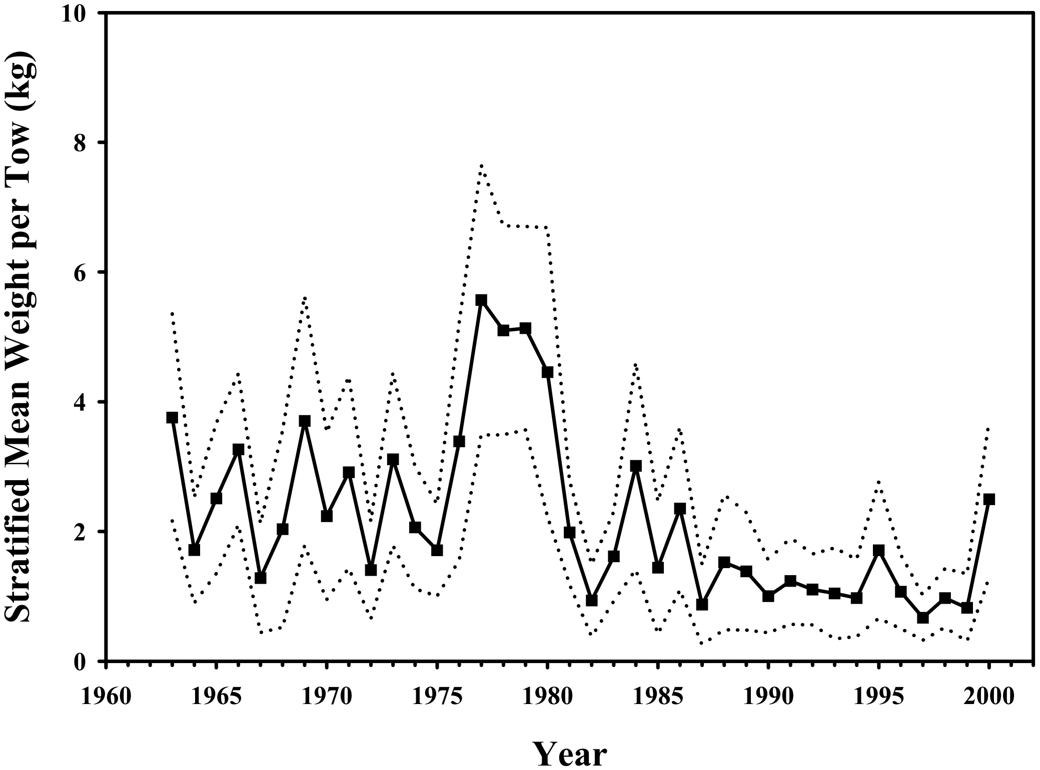
Spring Survey 1968-1999

Scallop Survey 1984-1999

Autumn Survey 1963-1999

Figure C9. Distribution of goosefish catches in NEFSC winter surveys (1992-1999), spring surveys (1968-1999), scallop surveys (1984-1999), and autumn surveys (1963-1999).-

Biomass Indices



Smoothed Biomass Indices

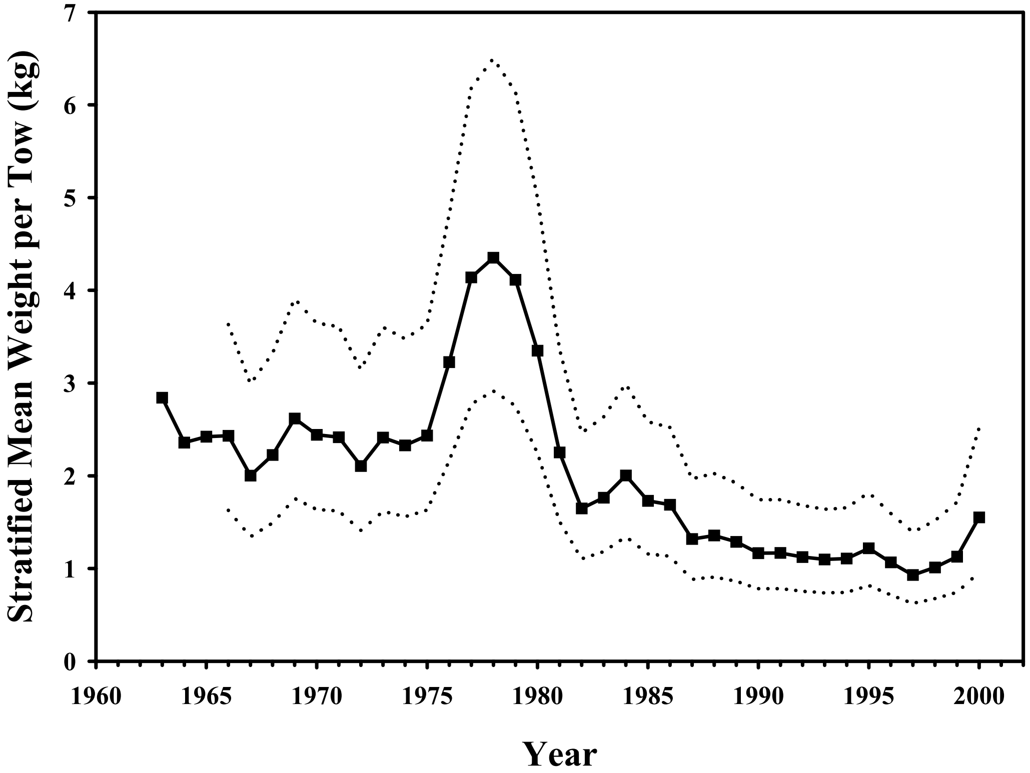
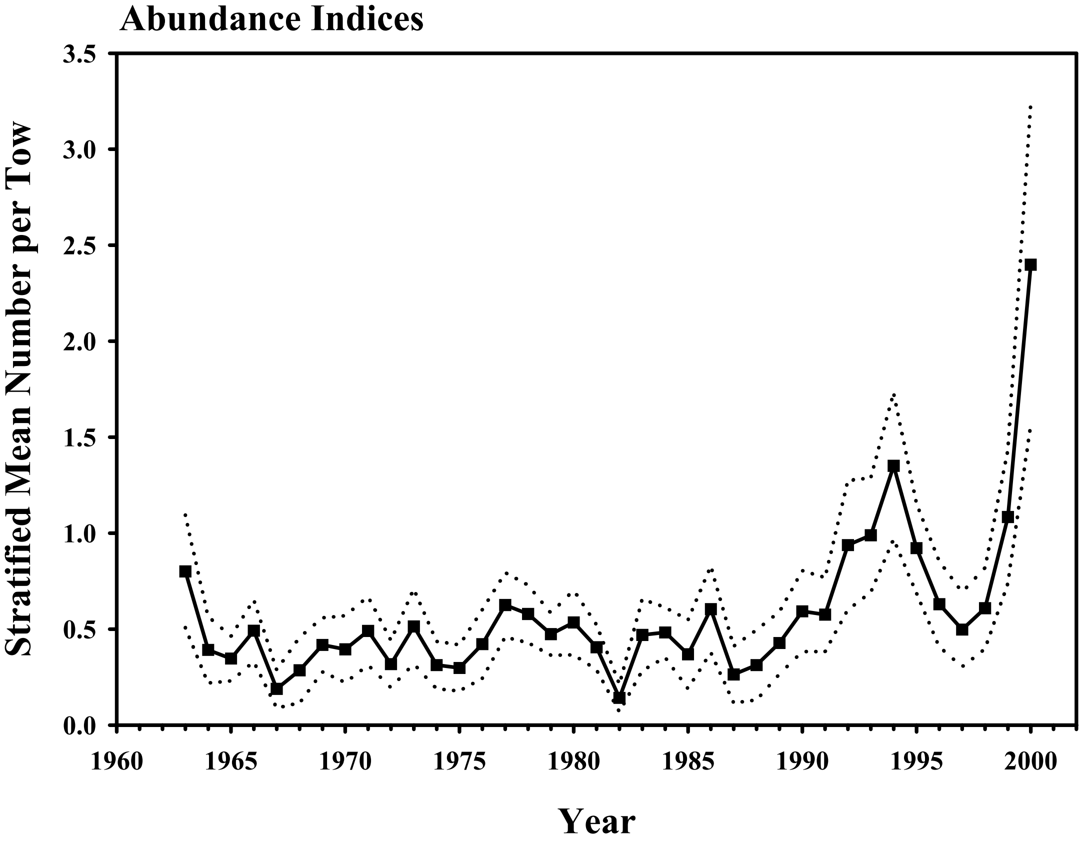


Figure C10. Biomass indices and smoothed indices from the NEFSC autumn bottom trawl survey for the northern management region from 1963-2000. The 95% confidence limits are shown by the dashed line.



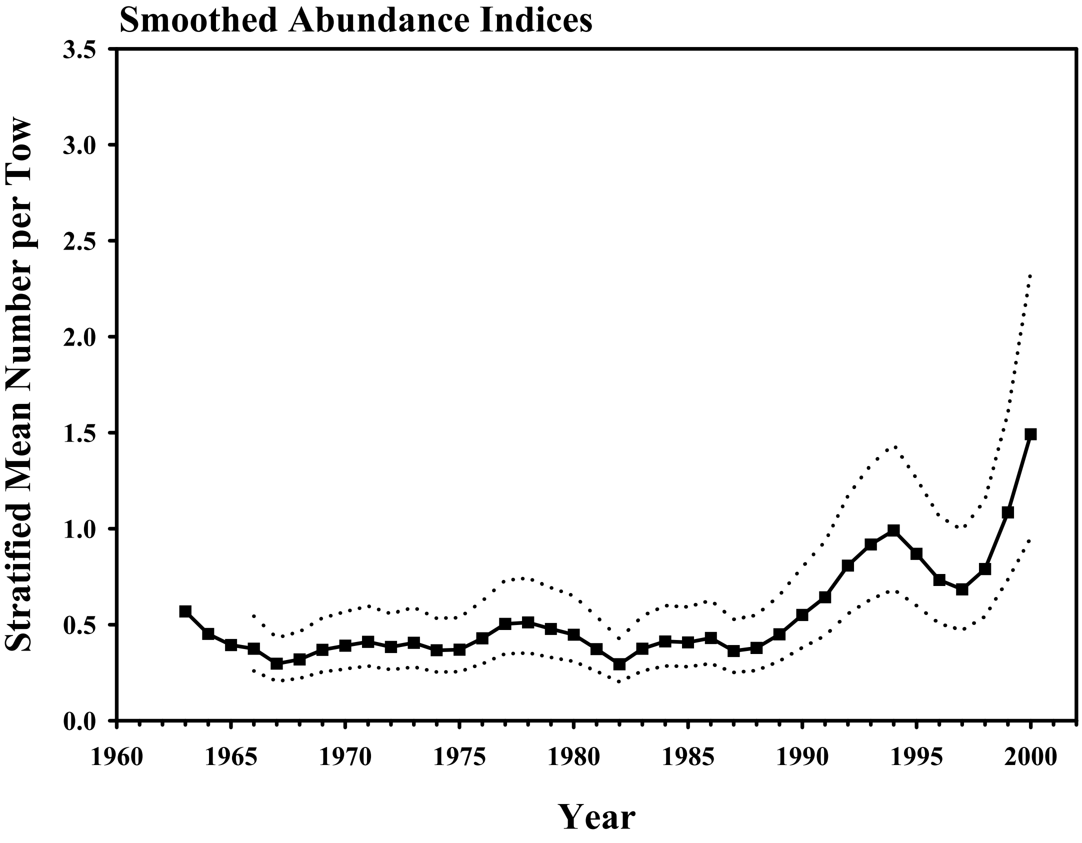
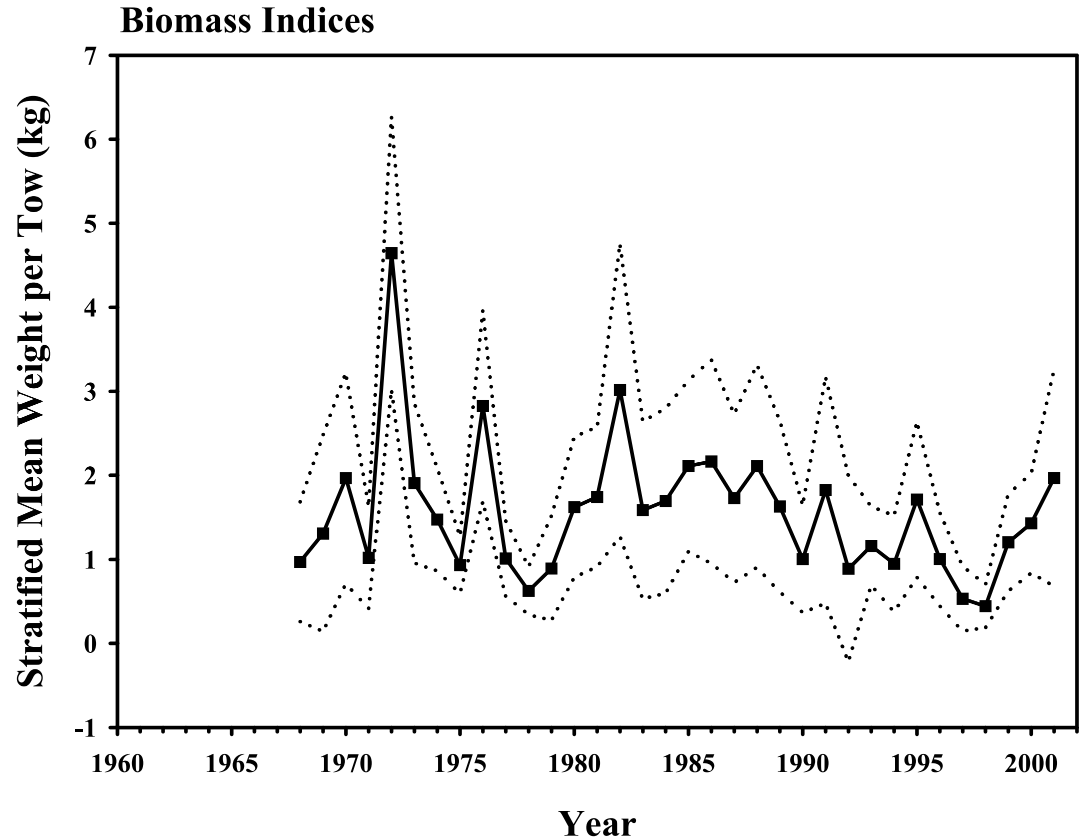


Figure C11. Abundance indices and smoothed indices from the NEFSC autumn bottom trawl survey for the northern management region from 1963-2000. The 95% confidence limits are shown by the dashed line.



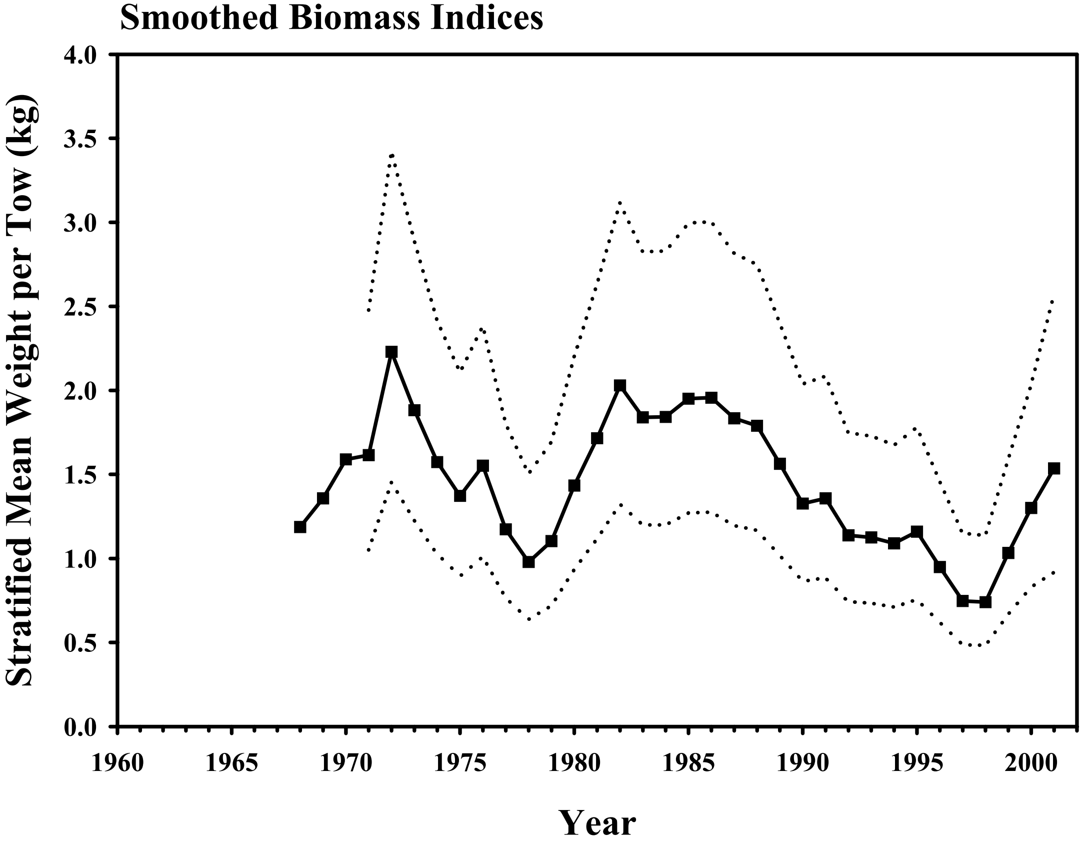


Figure C12. Biomass indices and smoothed indices from the NEFSC spring bottom trawl survey for the northern management region from 1968-2001. The 95% confidence limits are shown by the dashed line.

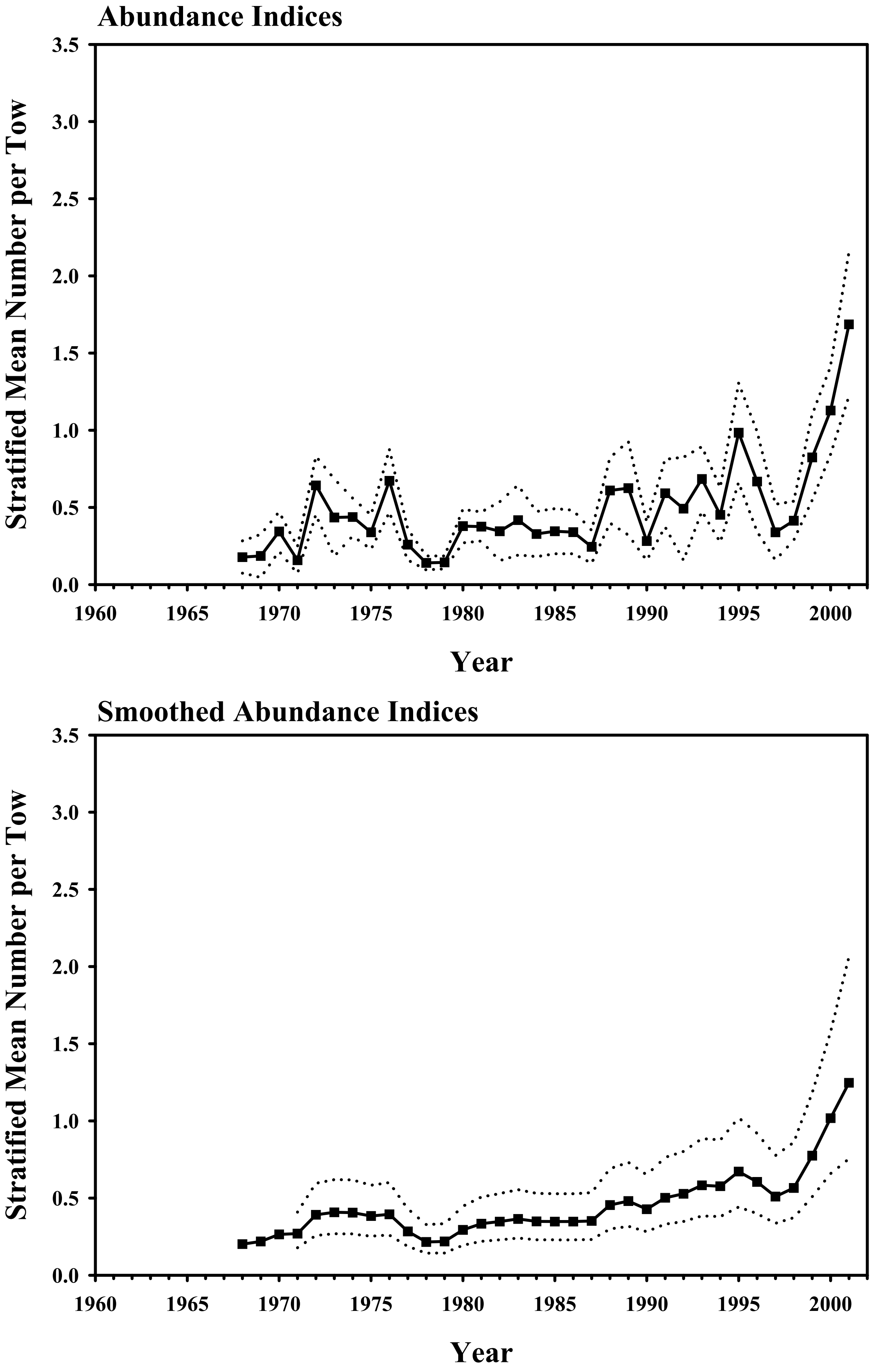
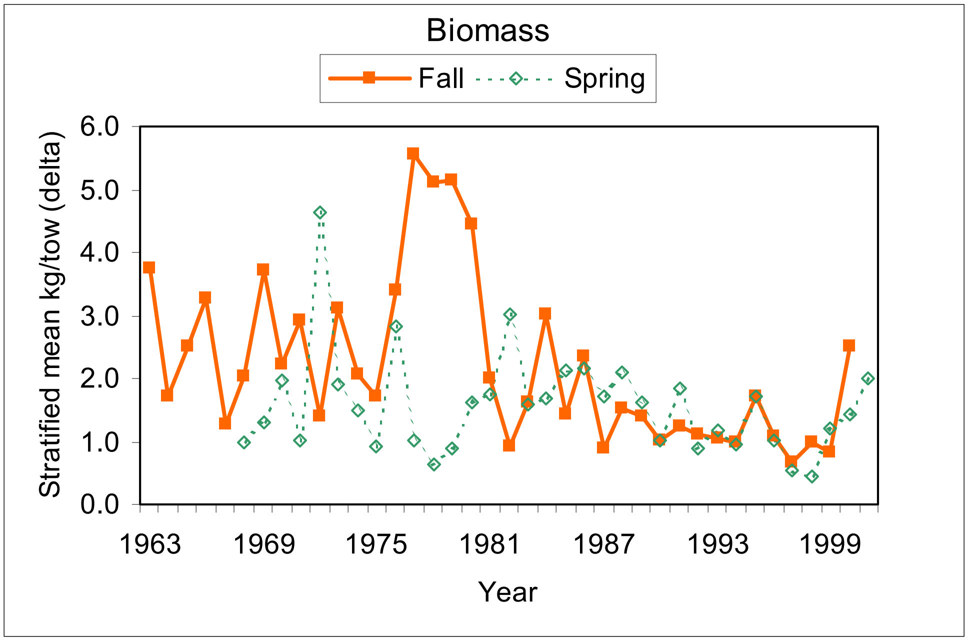


Figure C13. Abundance indices and smoothed indices from the NEFSC spring bottom trawl survey for the northern management region from 1968-2001. The 95% confidence limits are shown by the dashed line.

Northern Region



Northern Region

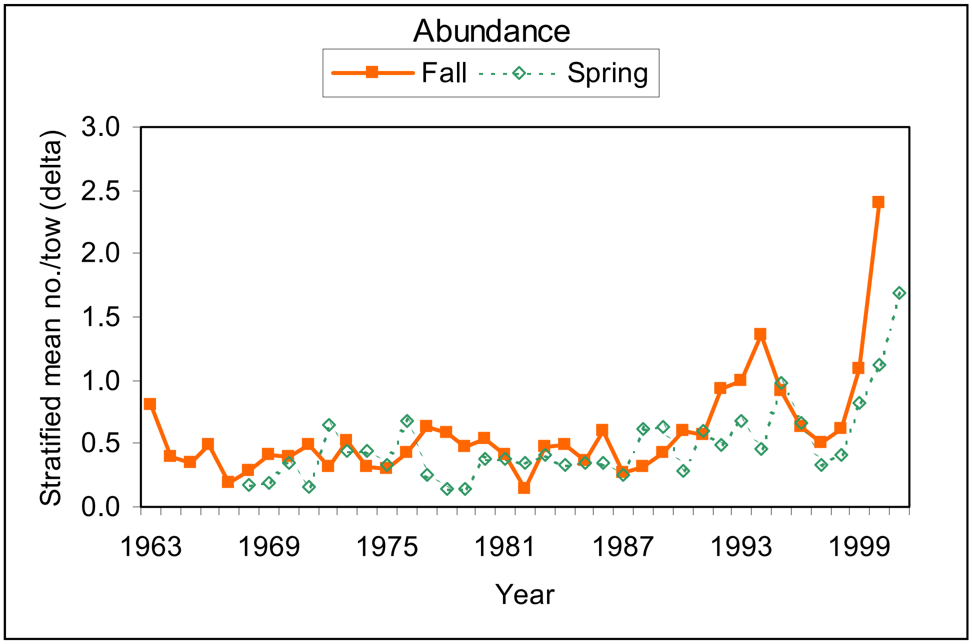


Figure C14. Biomass and abundance indices from NEFSC spring and autumn trawl surveys, northern management region.

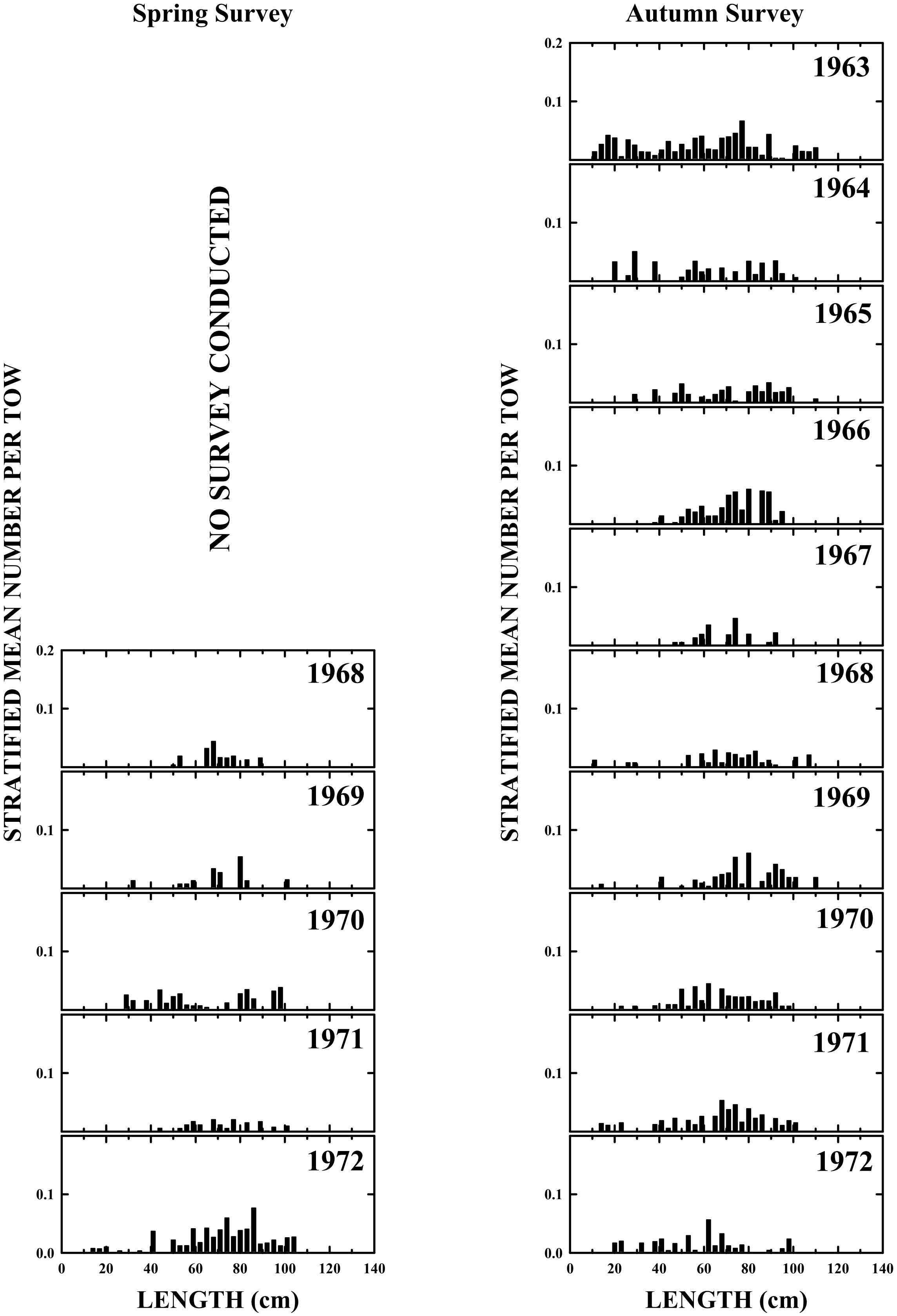


Figure C15a. Goosefish length composition from the NEFSC spring and autumn bottom trawl surveys in the northern management region, 1963-2001.

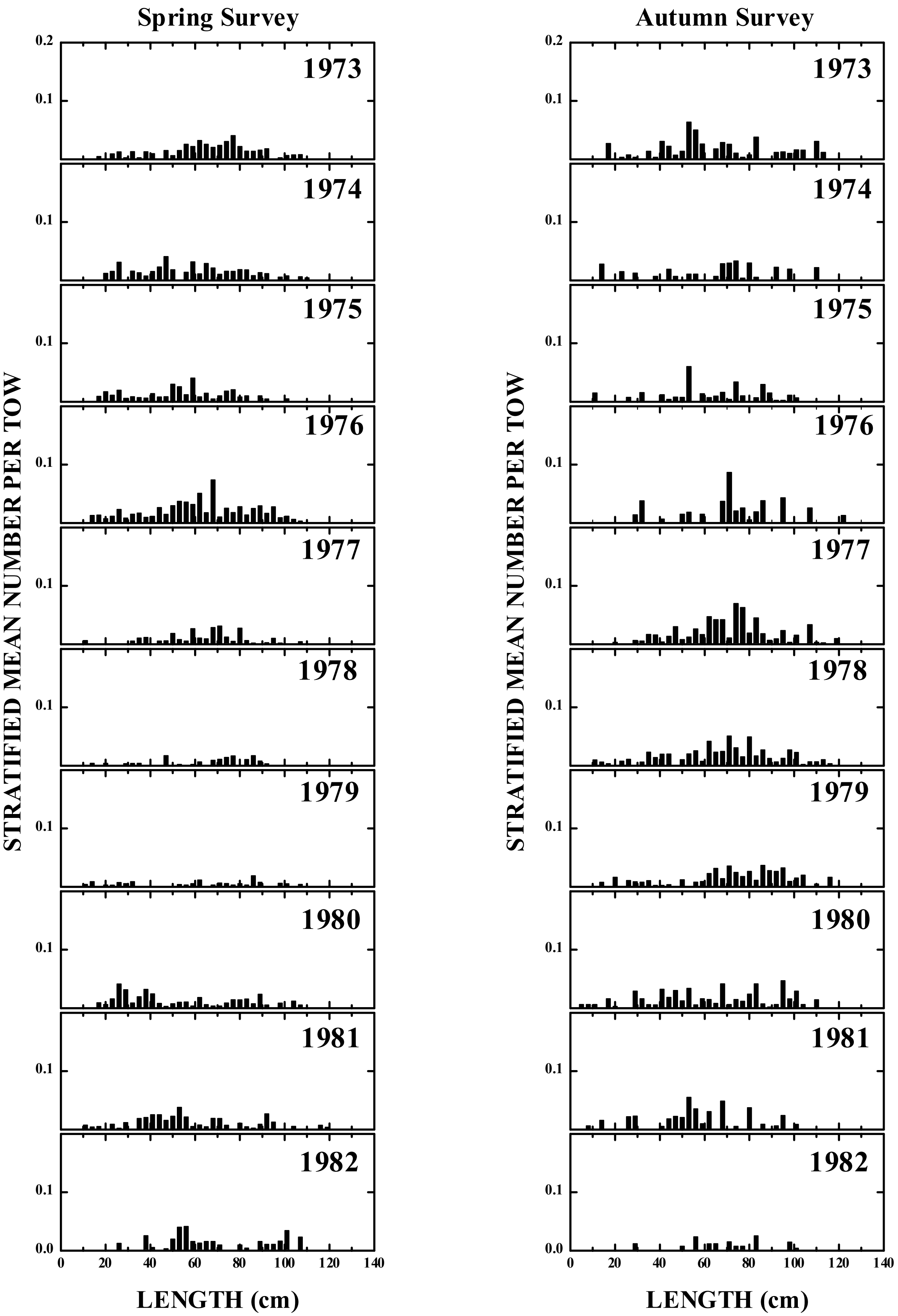


Figure C15, continued.

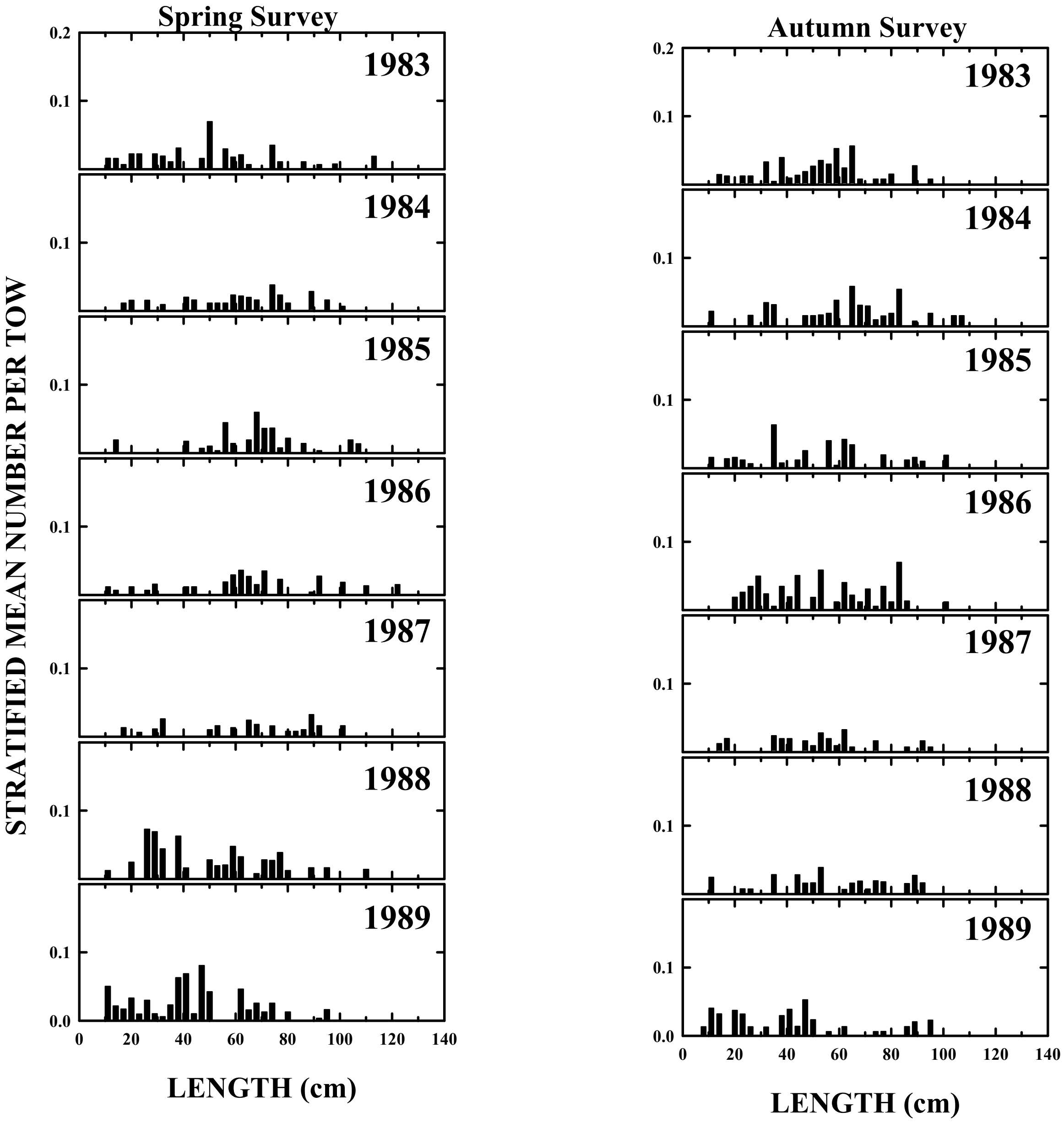


Figure C15c, continued.

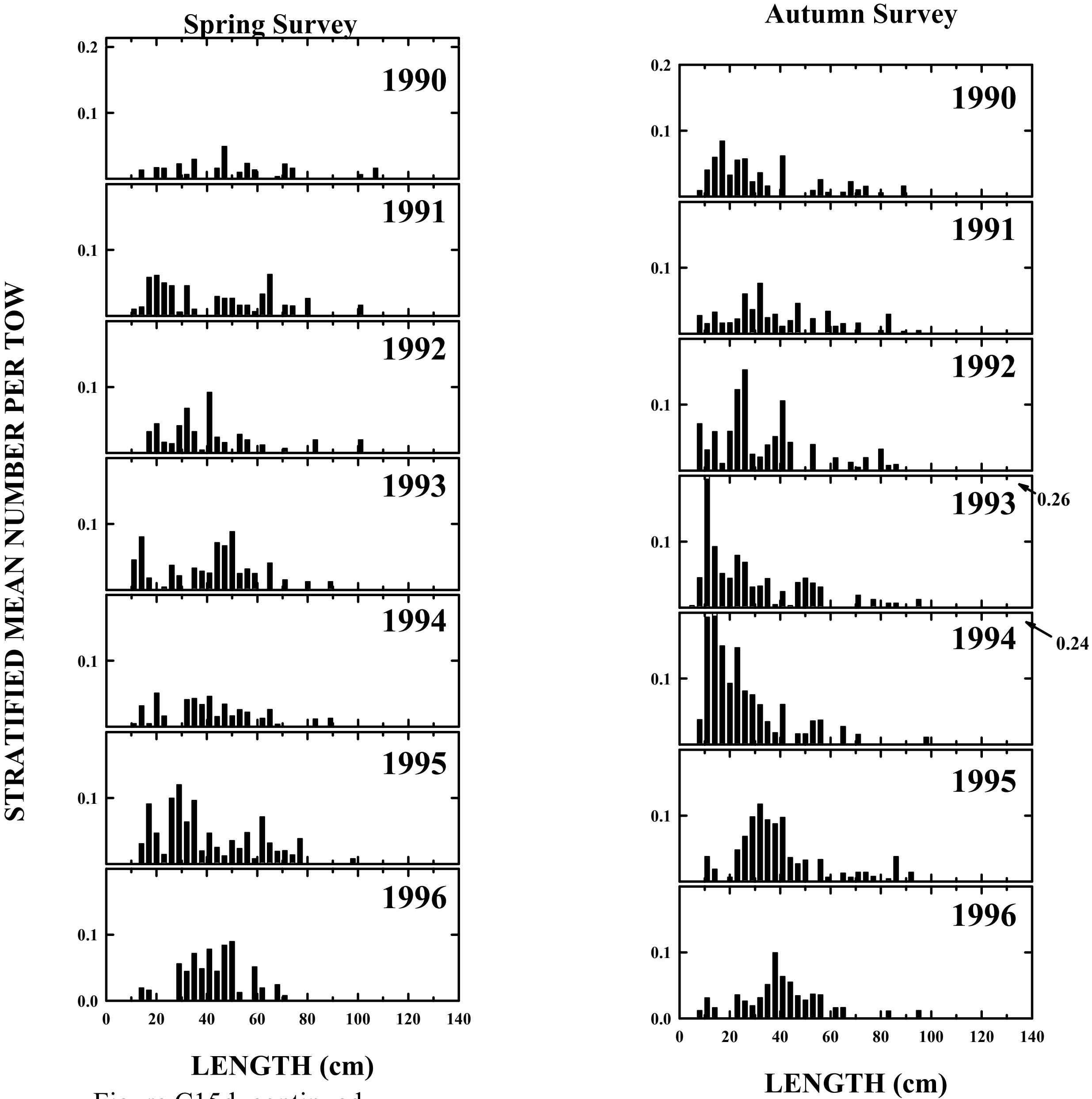


Figure C15d, continued.

NOTE: Y-AXIS SCALE CHANGES ON THIS PAGE

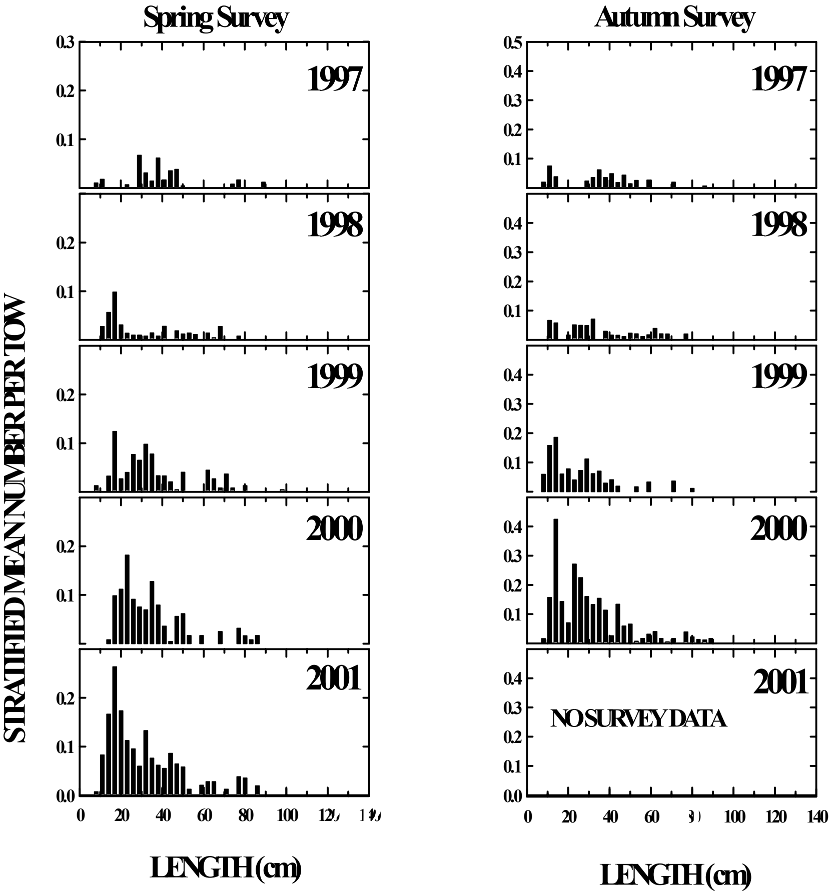


Figure C15e, continued.

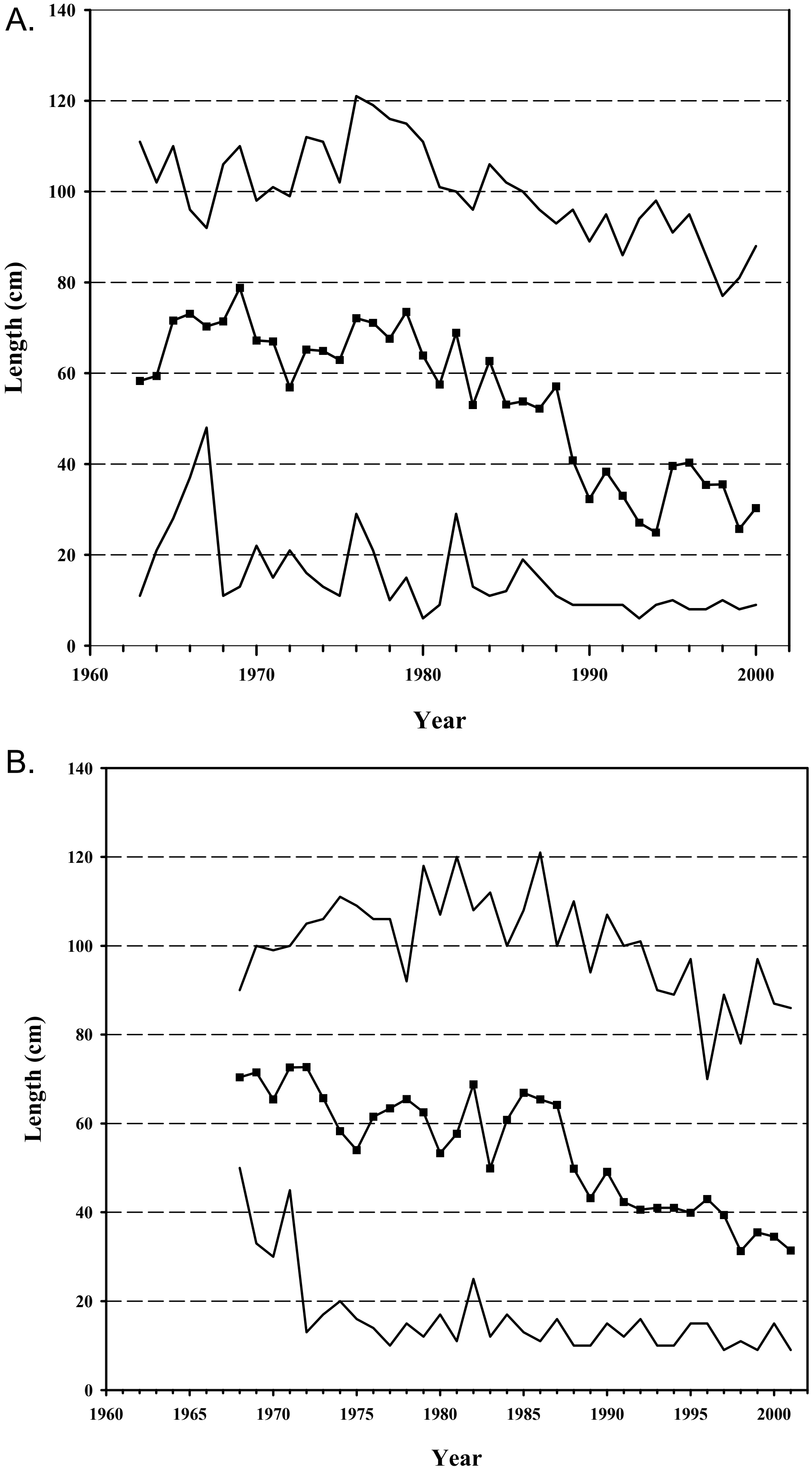
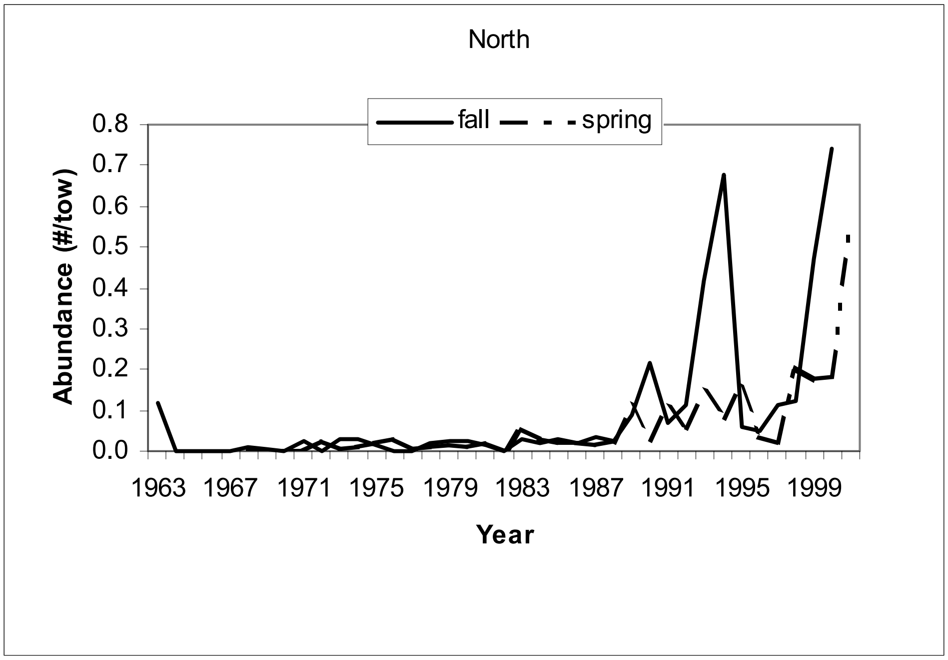


Figure C16. Minimum, mean, and, maximum lengths for the northern management region from (A) NEFSC autumn surveys and (B) NEFSC spring surveys.



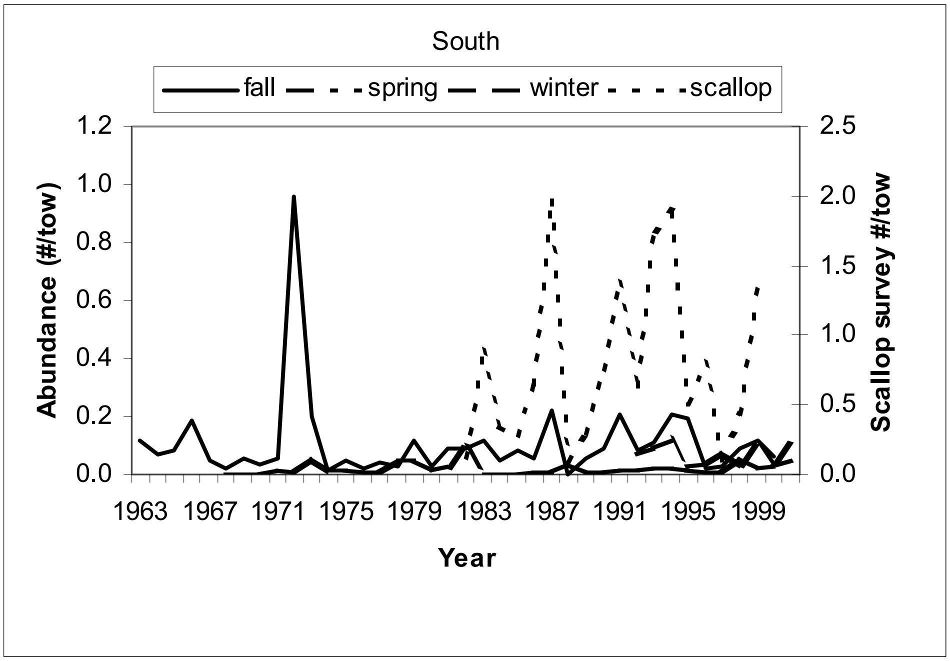


Figure C17. Abundance indices (stratified mean number per tow) for 10-20 cm goosefish.

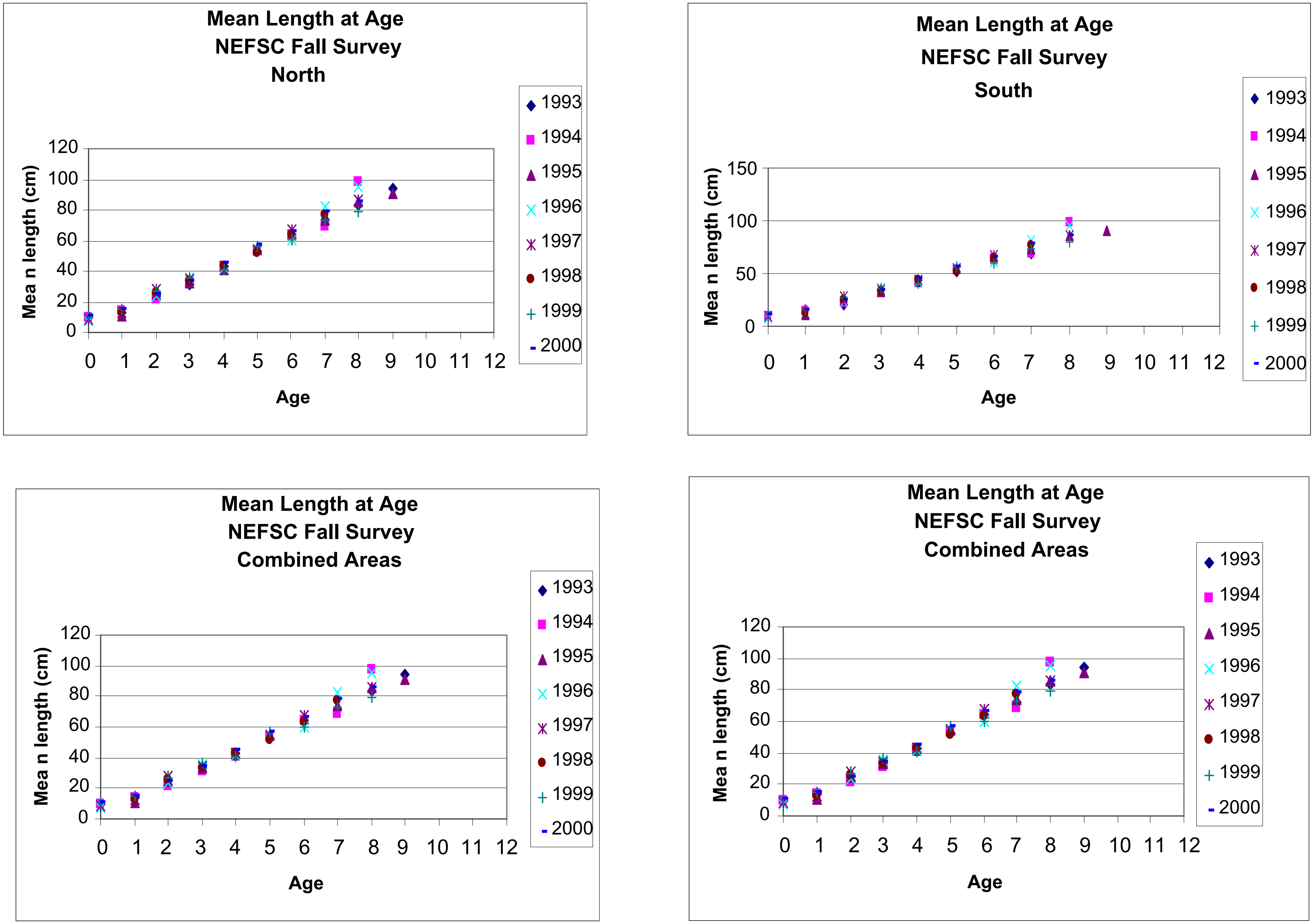


Figure C18. Mean length at age from NEFSC autumn offshore surveys.

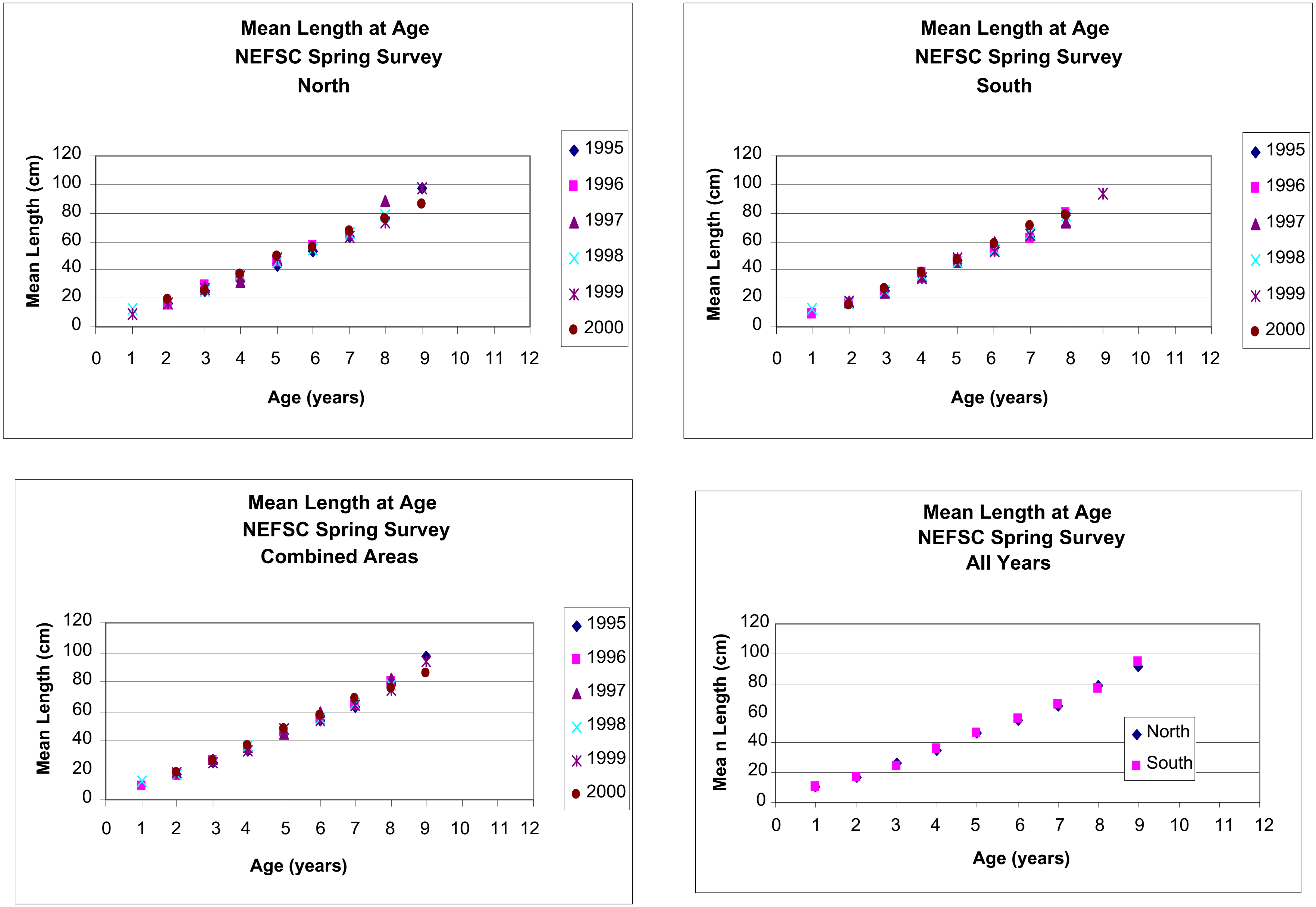
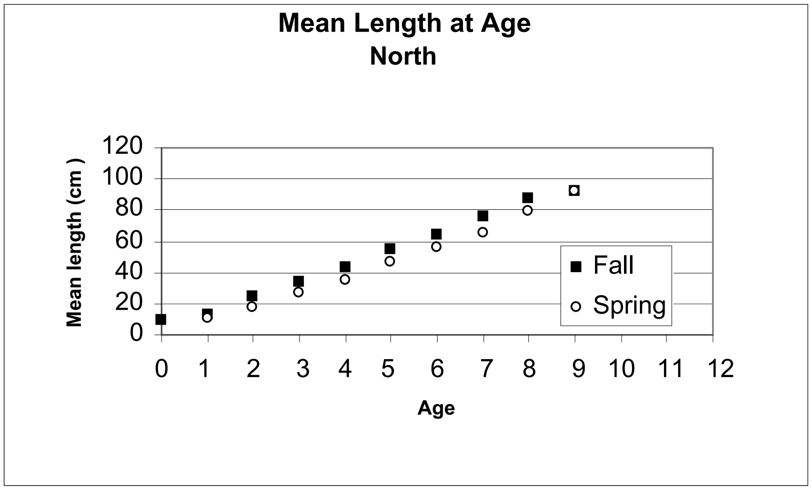
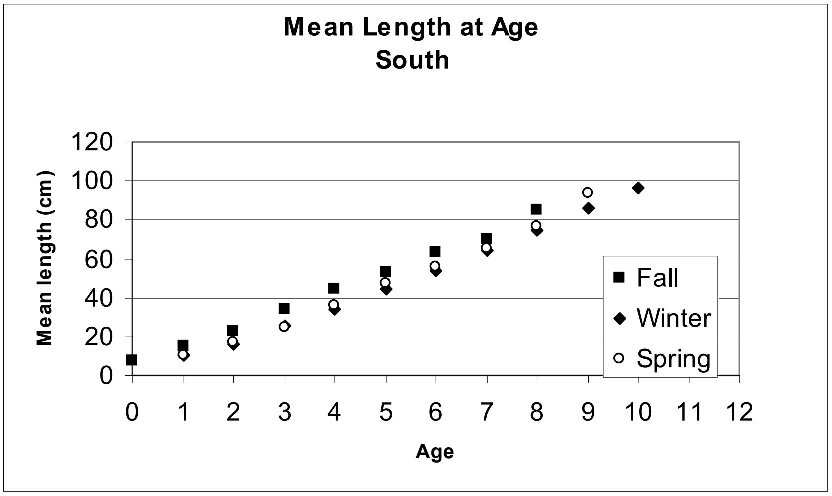


Figure C19. Mean length at age from NEFSC spring offshore surveys.





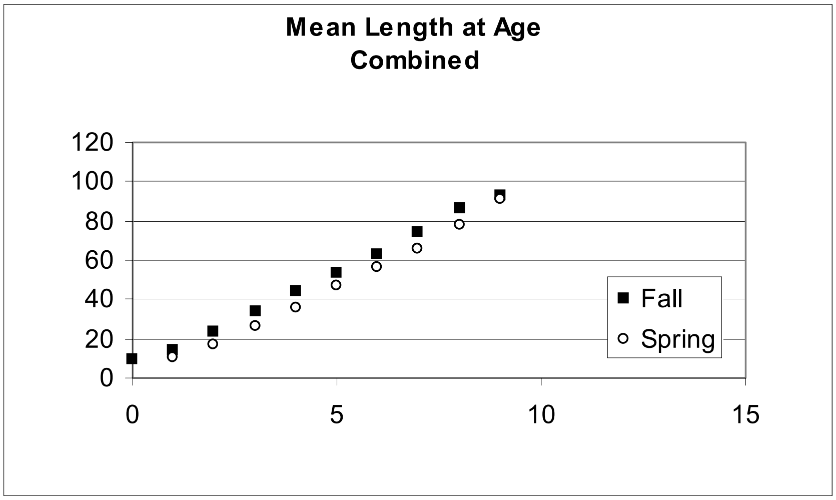


Figure C20. Comparison of mean length at age from NEFSC fall and spring surveys.

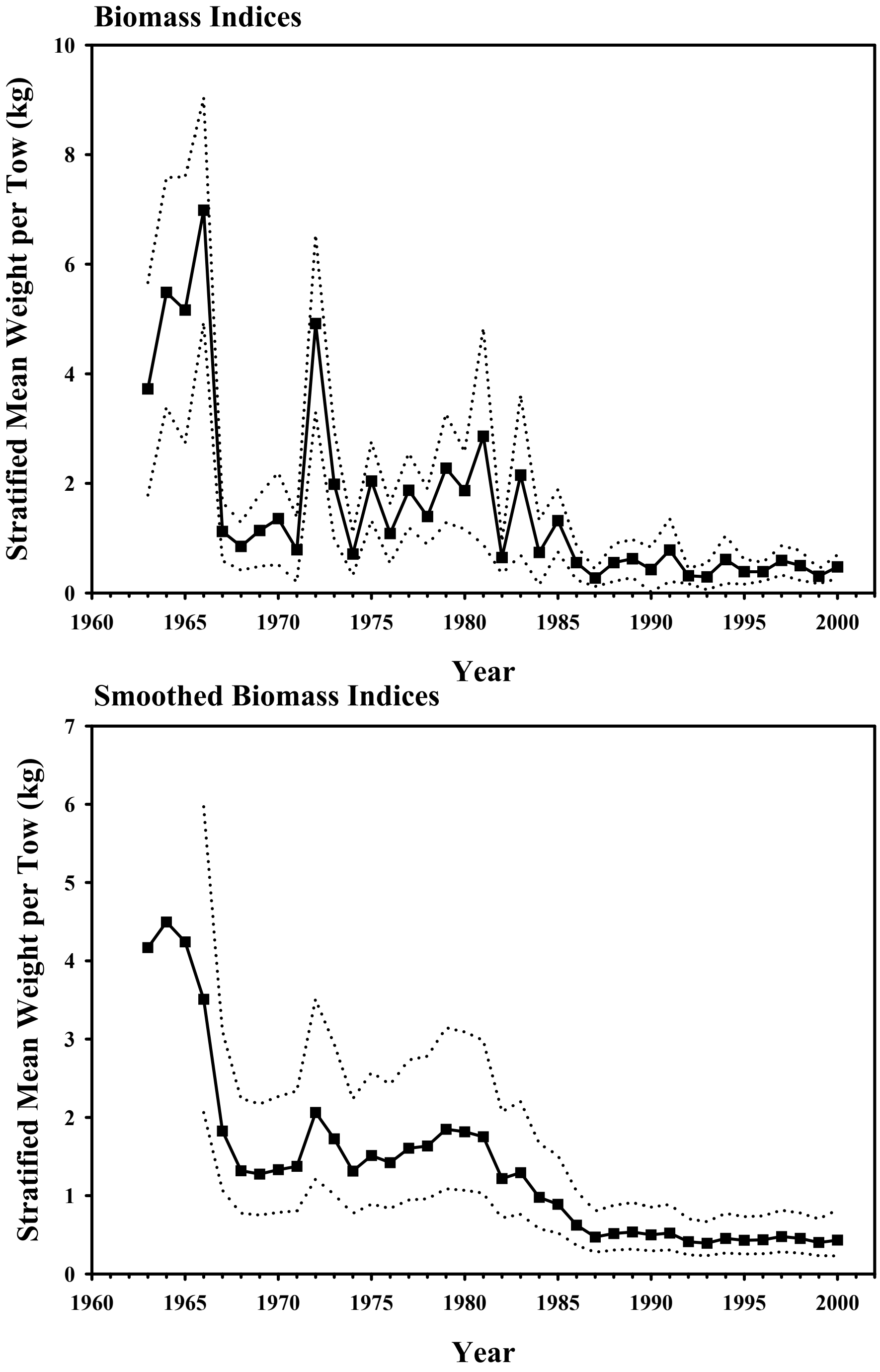
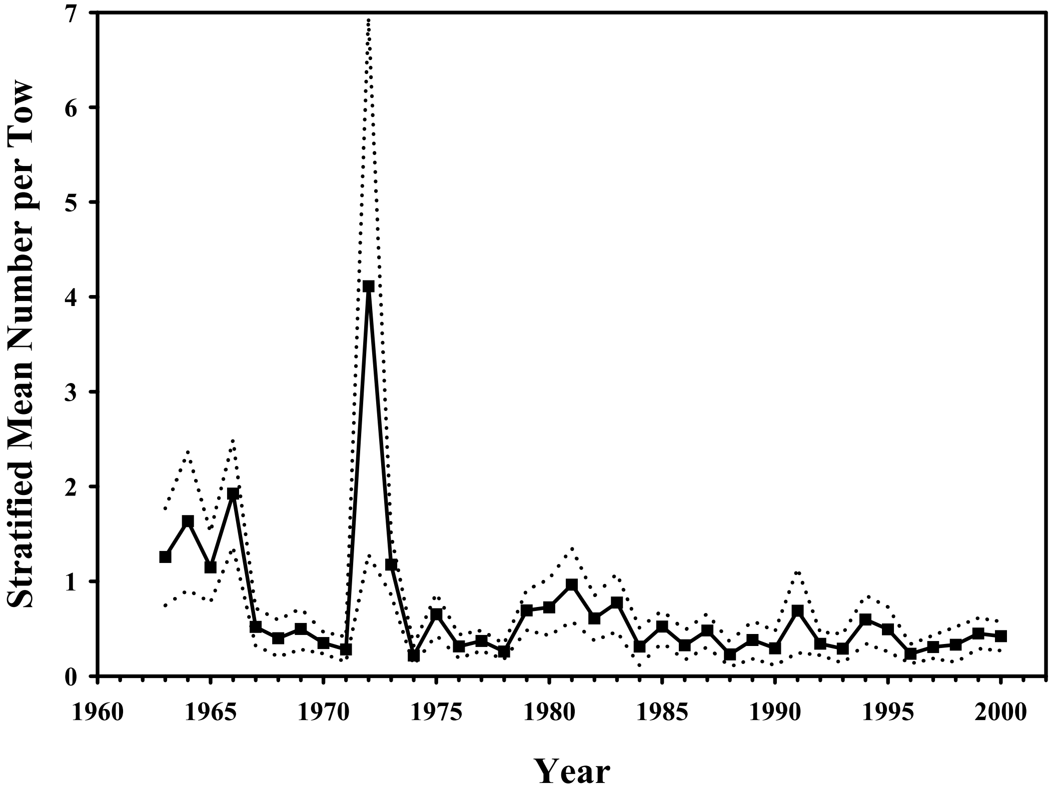


Figure C21. Biomass indices and smoothed indices from the NEFSC autumn bottom trawl survey for the southern management region from 1963-2000. The 95% confidence limits are shown by the dashed line.

Abundance Indices



Smoothed Abundance Indices

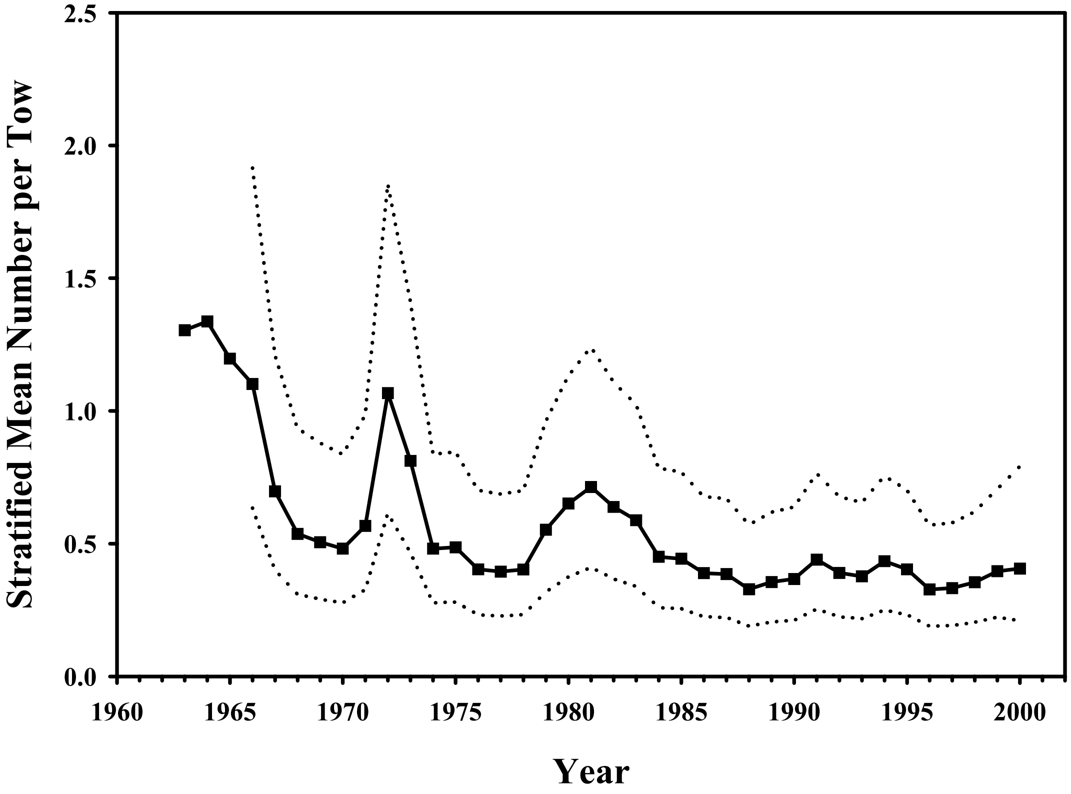
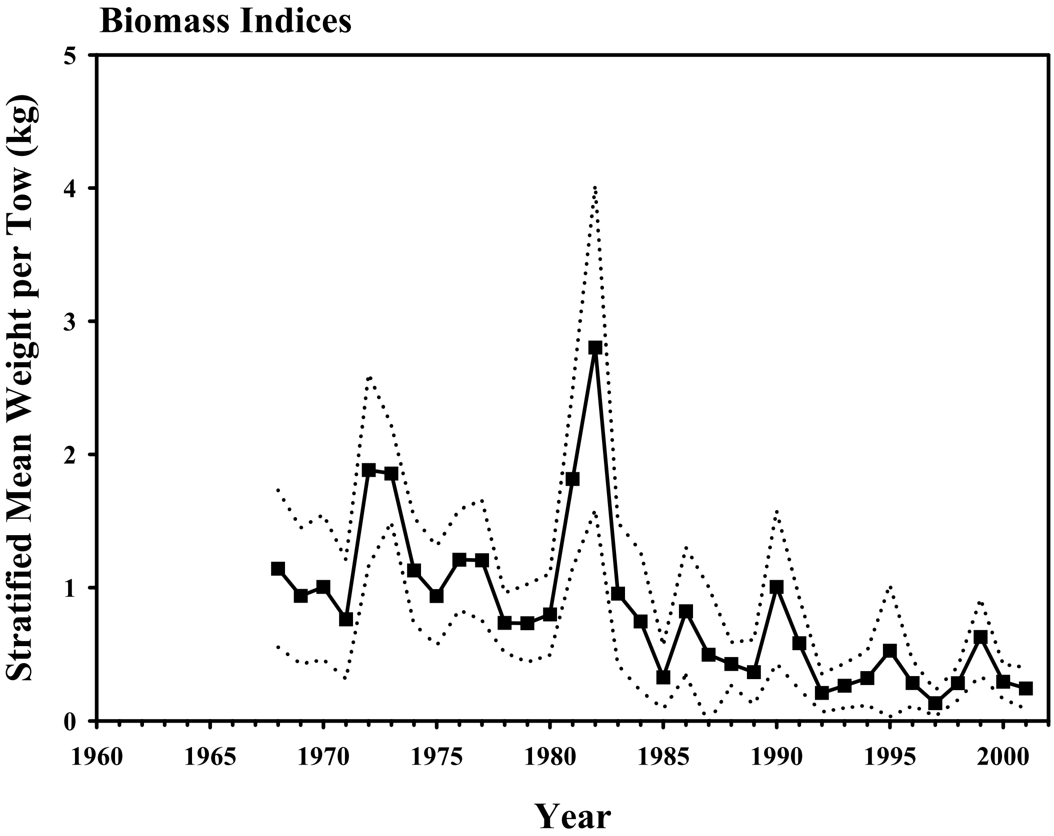


Figure C22. Abundance indices and smoothed indices from the NEFSC autumn bottom trawl survey for the southern management region from 1963-2000. The 95% confidence limits are shown by the dashed line.



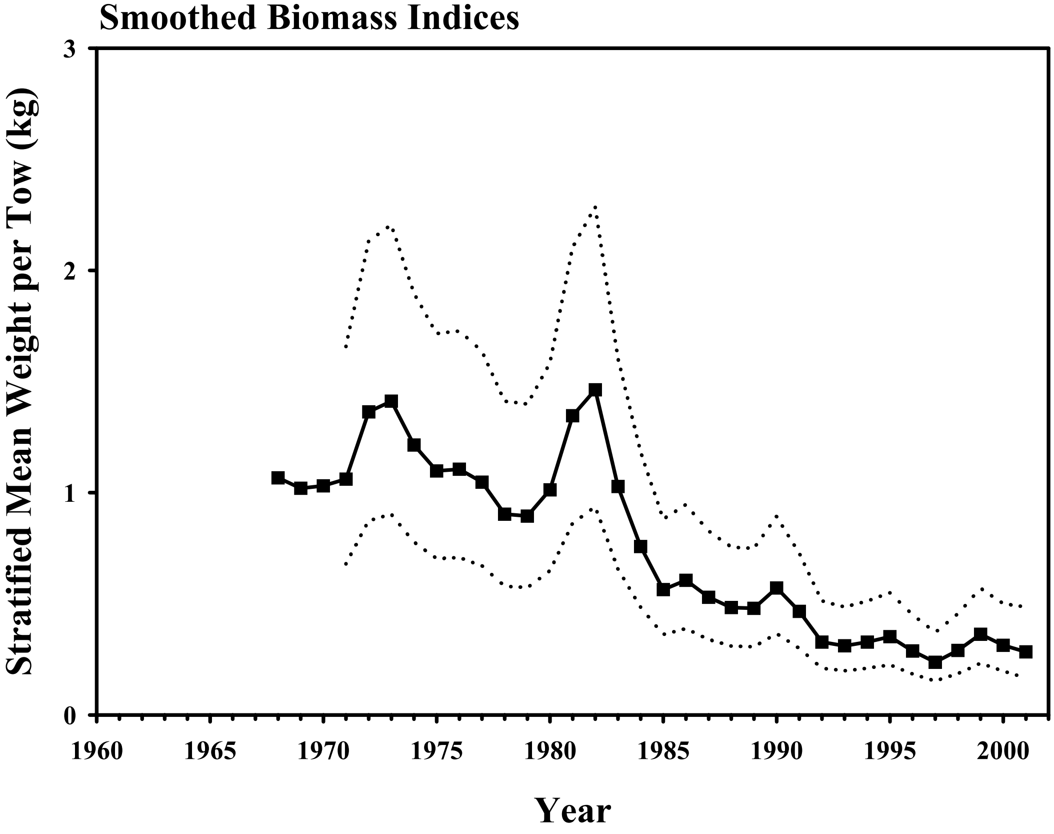
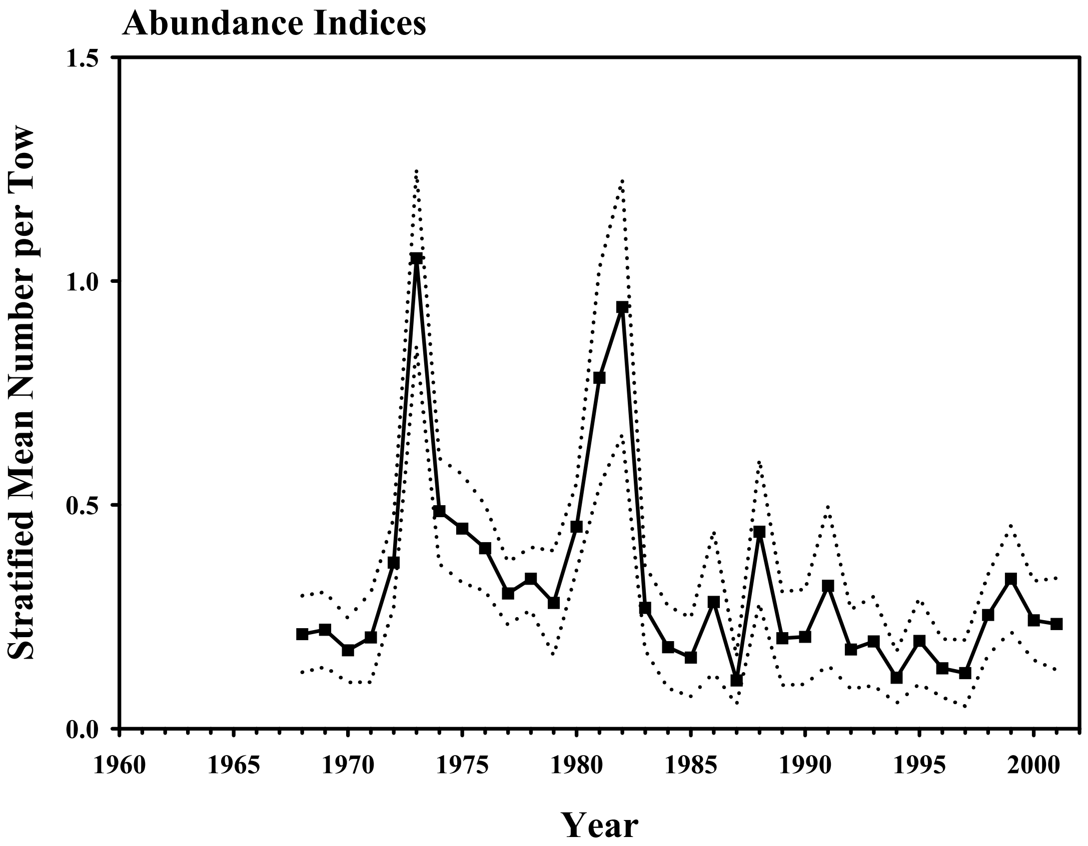


Figure C23. Biomass indices and smoothed indices from the NEFSC spring bottom trawl survey for the southern management region from 1968-2001. The 95% confidence limits are shown by the dashed line.



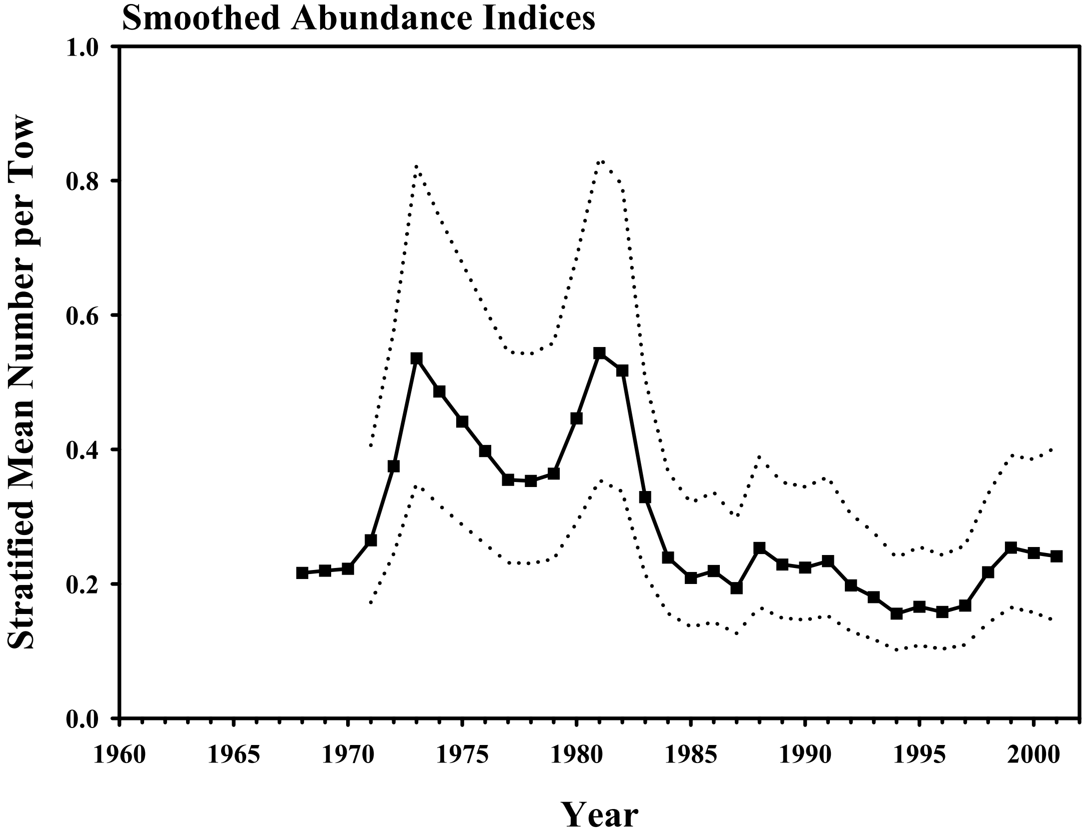


Figure C24. Abundance indices and smoothed indices from the NEFSC spring bottom trawl survey for the southern management region from 1968-2001. The 95% confidence limits are shown by the dashed line.

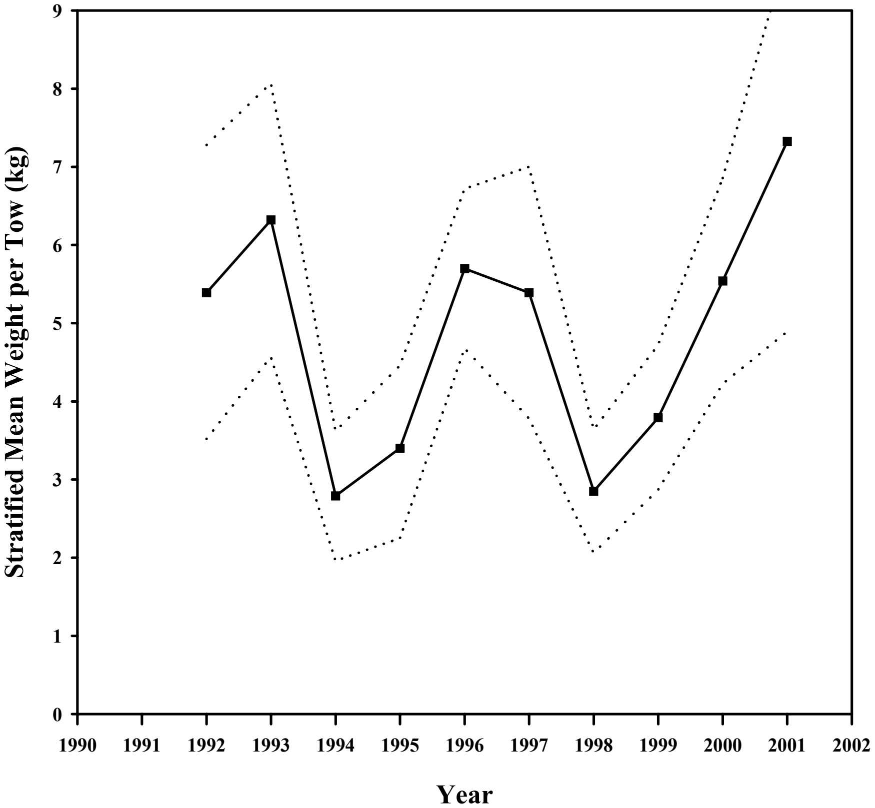


Figure C25. Biomass indices from the NEFSC winter flatfish survey for the southern management region from 1992-2001. The 95% confidence limits are shown by the dashed line.

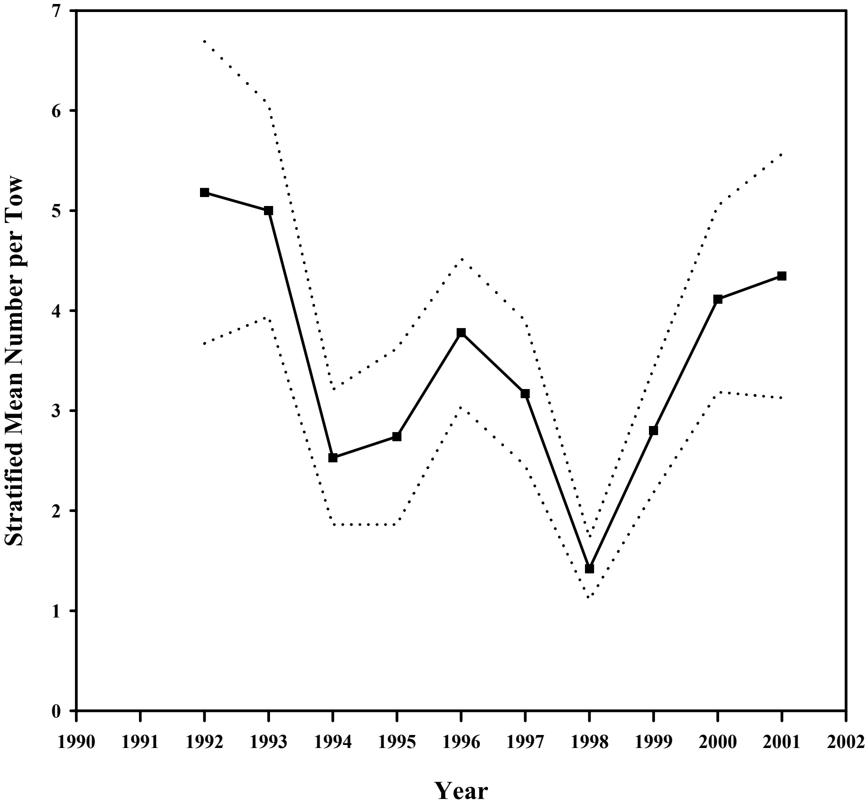


Figure C26. Abundance indices from the NEFSC winter flatfish survey for the Southern Georges Bank to Mid-Atlantic region from 1992-2001. The 95% confidence limits are shown by the dashed line.

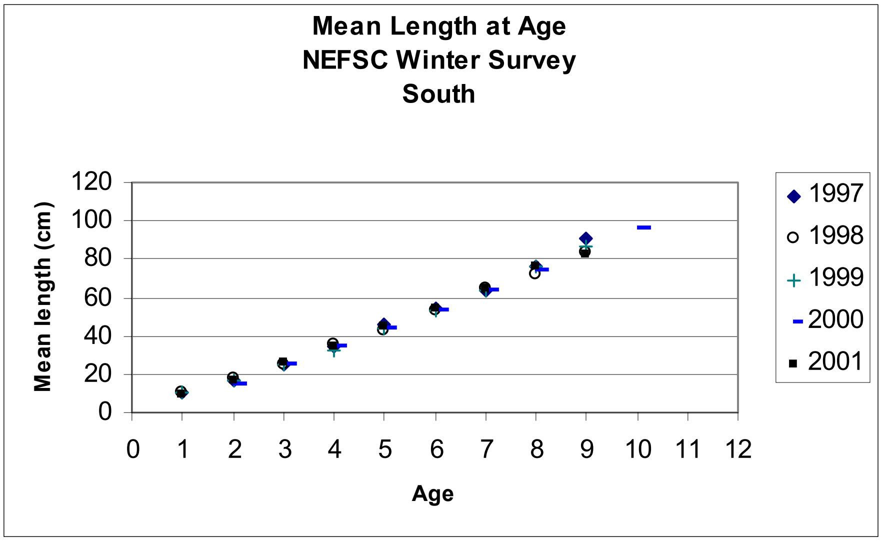


Figure C27. Mean length at age for goosefish in NEFSC winter surveys, southern management region.

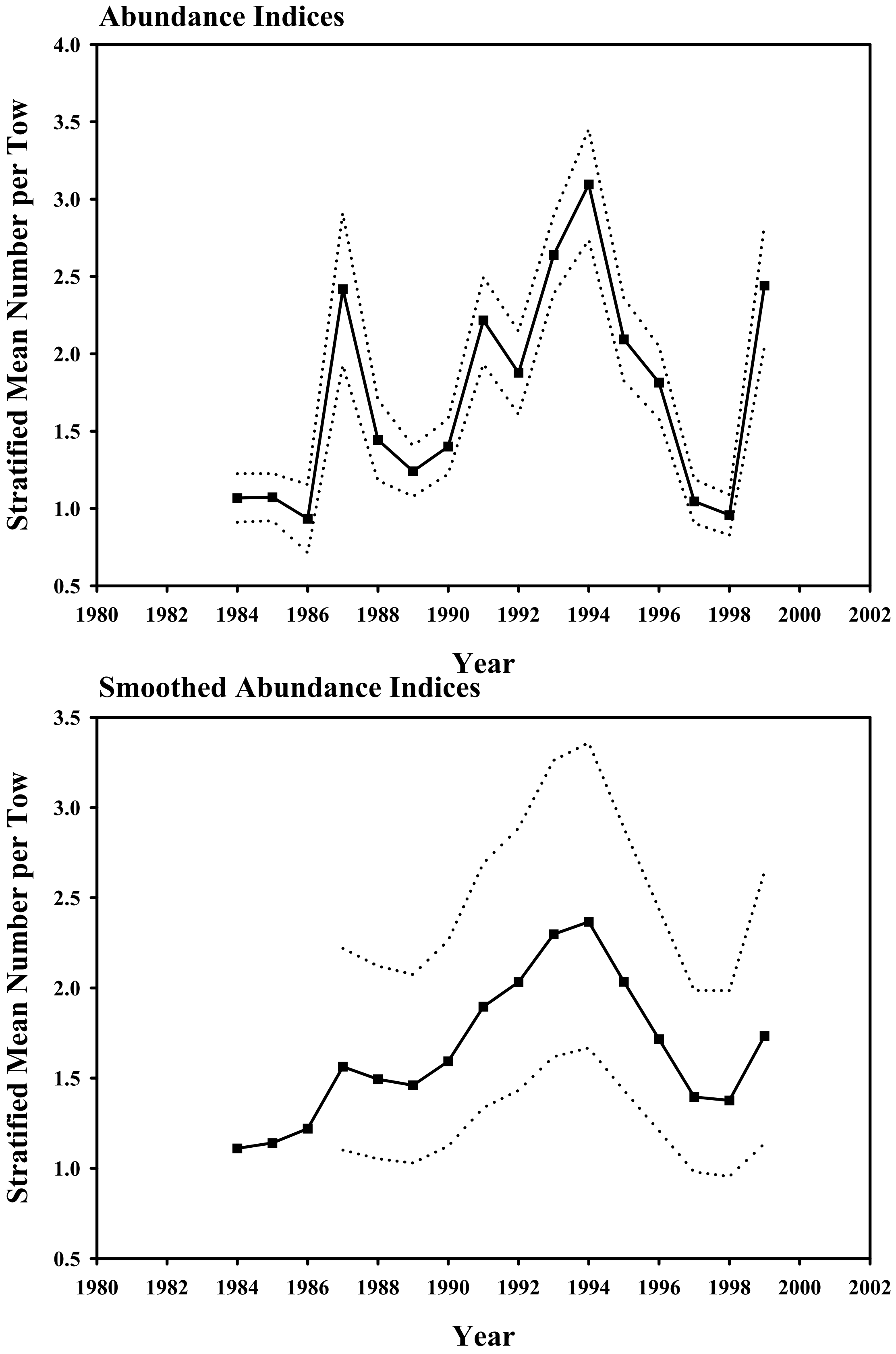


Figure C28. Abundance indices and smoothed indices from the NEFSC scallop dredge survey for the southern management region from 1984-1999. The 95% confidence limits are shown by the dashed line.

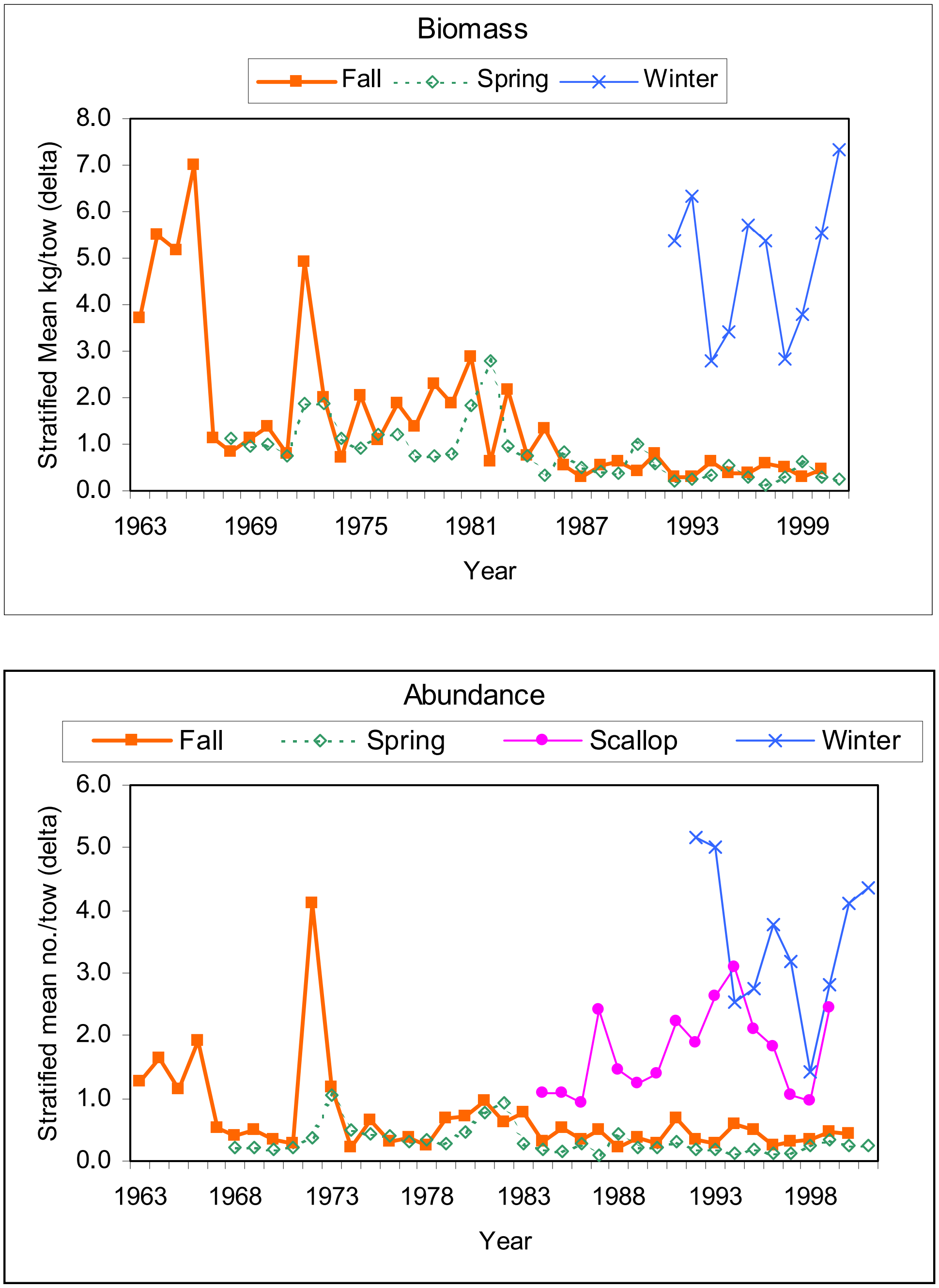


Figure C29. Biomass and abundance indices from NEFSC spring and autumn trawl surveys, southern management region.

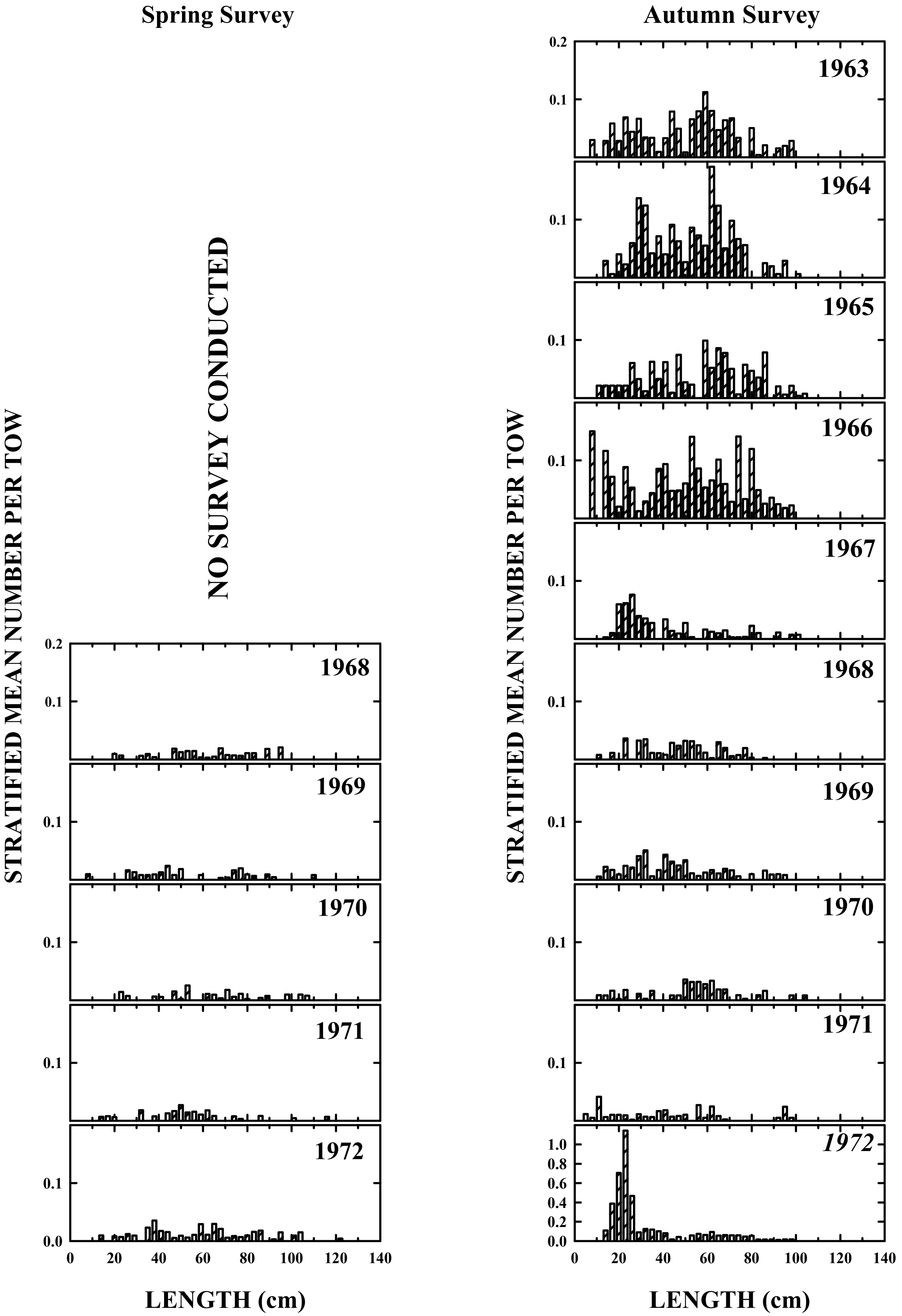


Figure C30a. Goosefish length composition from the NEFSC spring bottom trawl (March-April), winter flatfish (February), summer scallop (July-August), and autumn (September-October) bottom trawl surveys in the southern management region, 1963-2001.

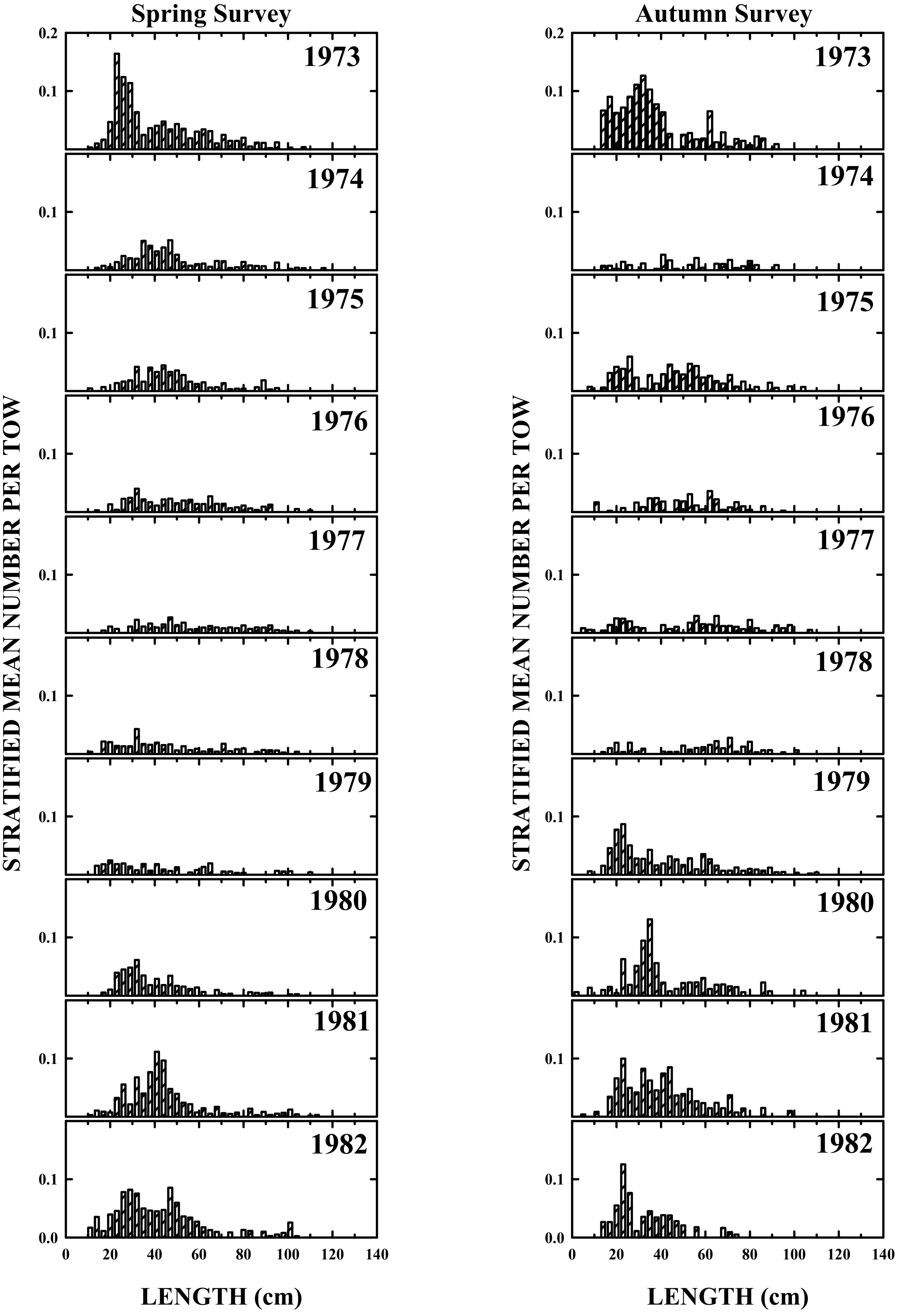


Figure C30b, continued.

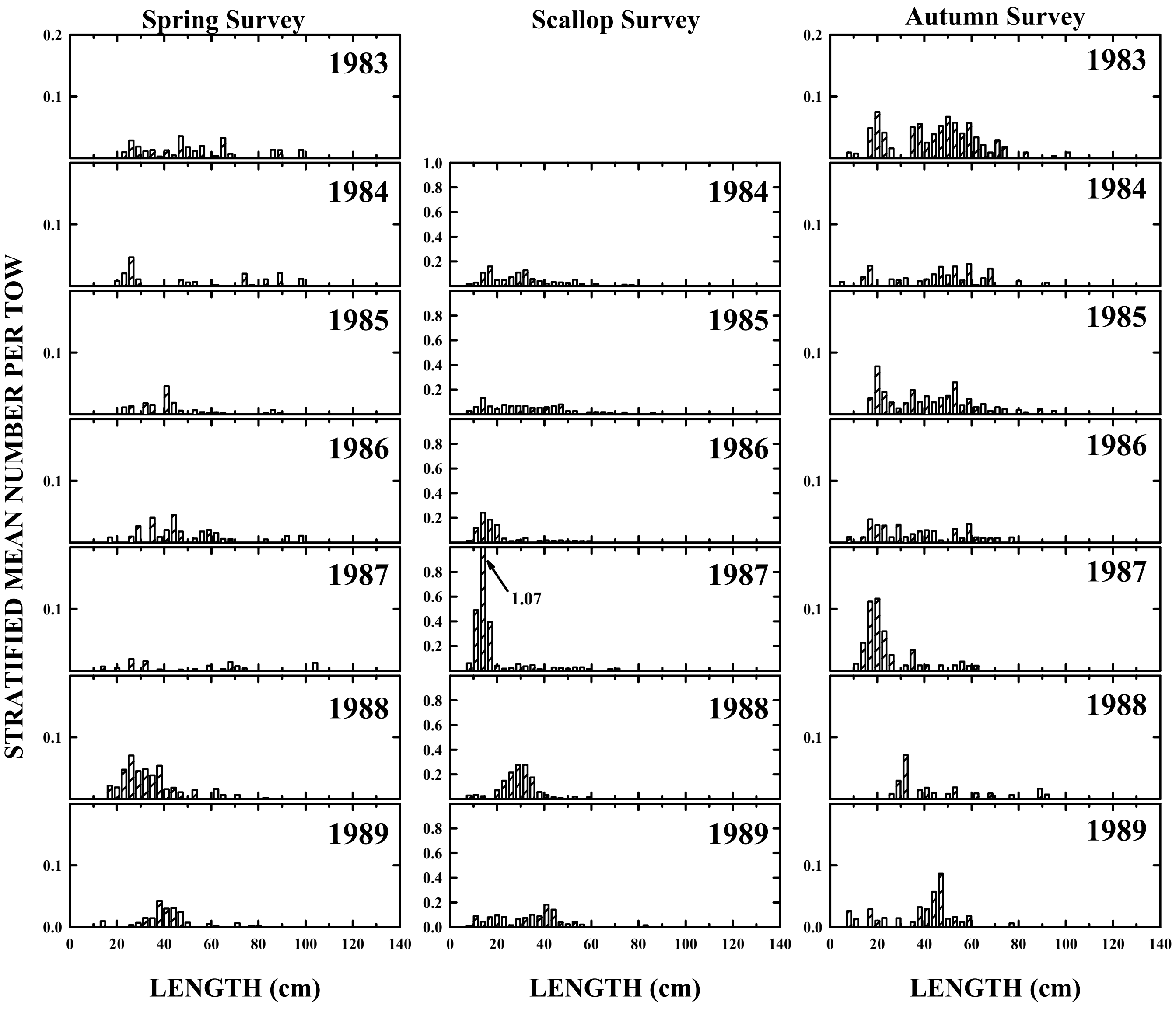


Figure C30c, continued.

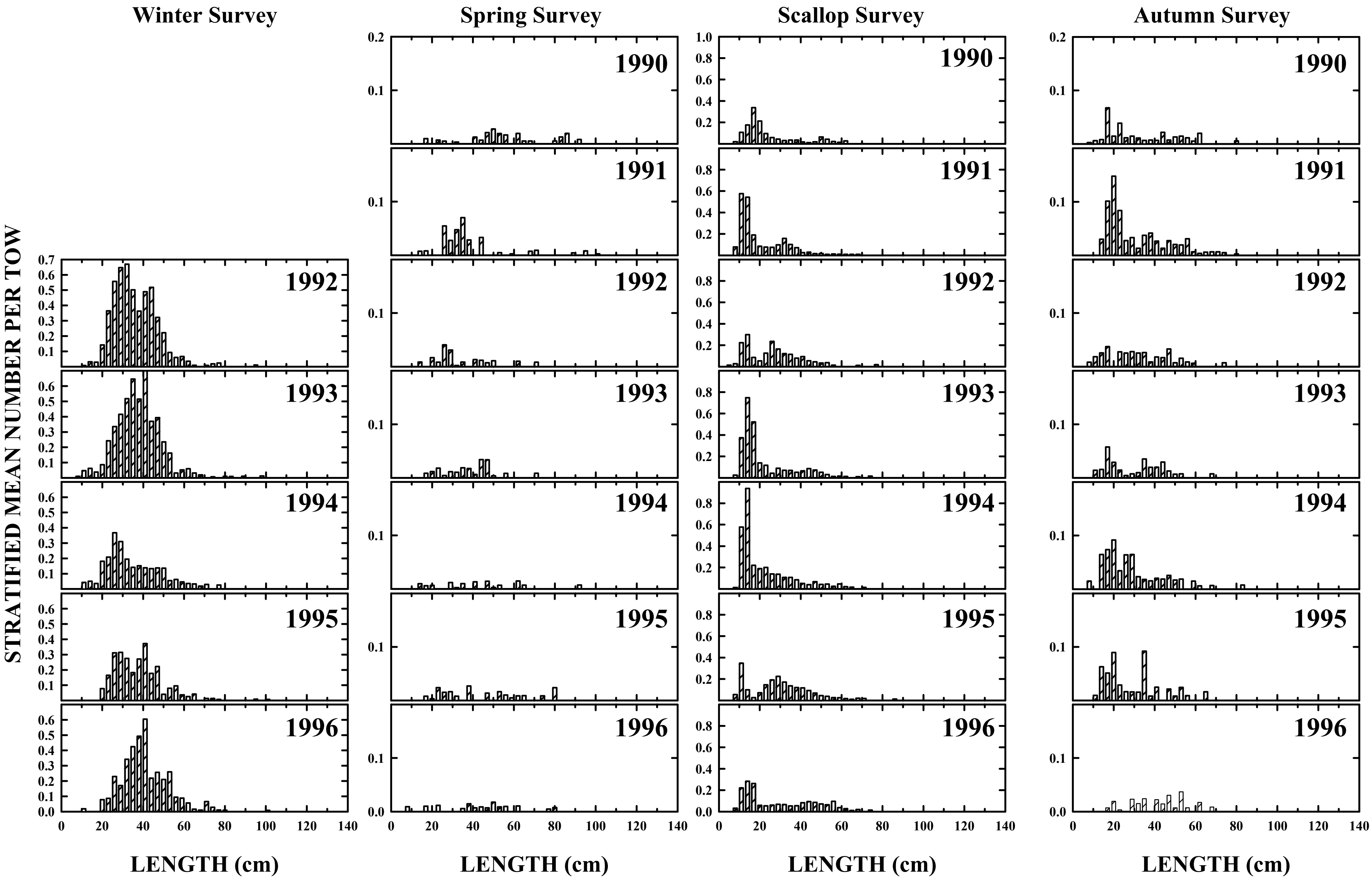


Figure C30d, continued.

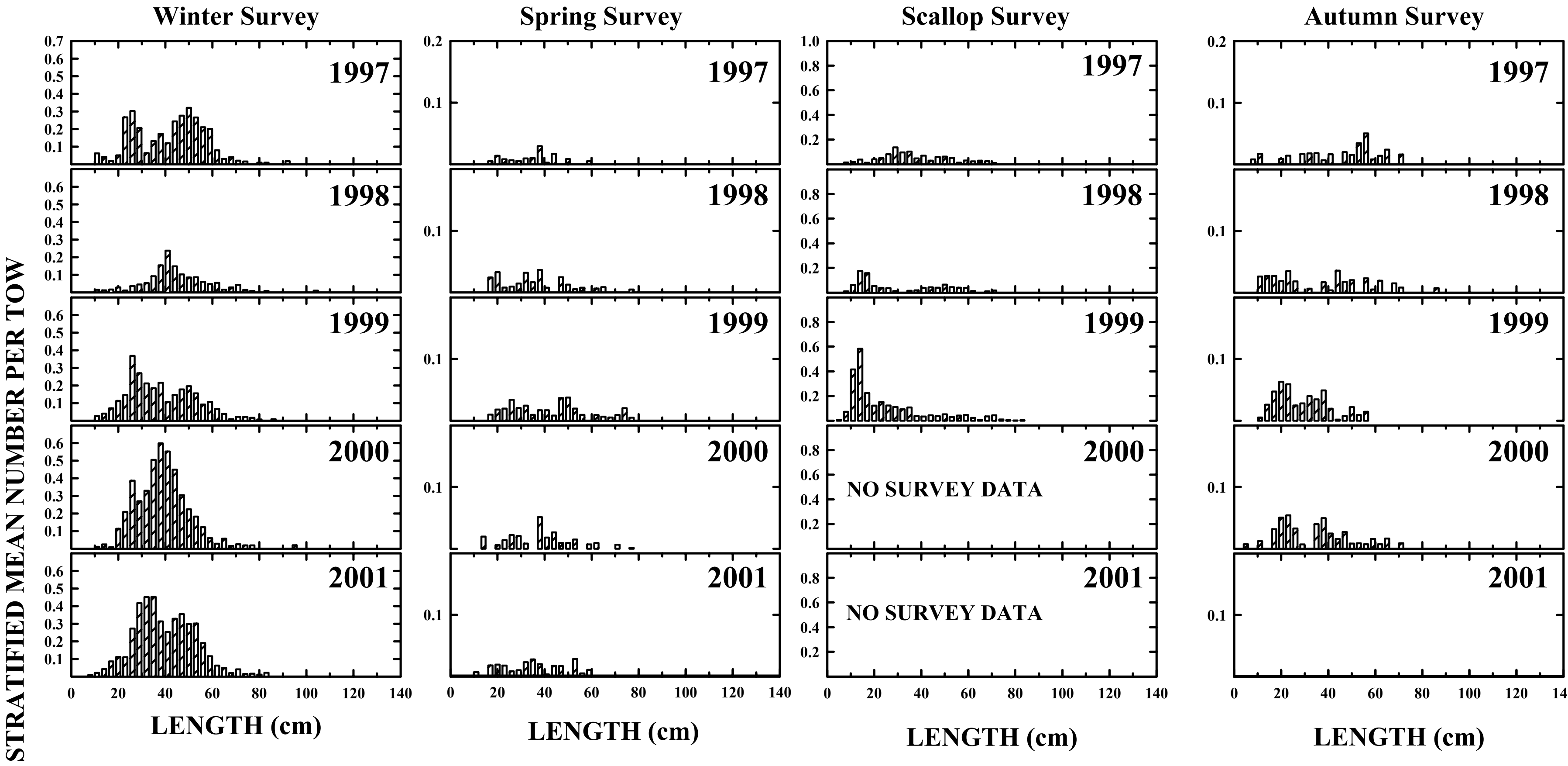


Figure C30e, continued.

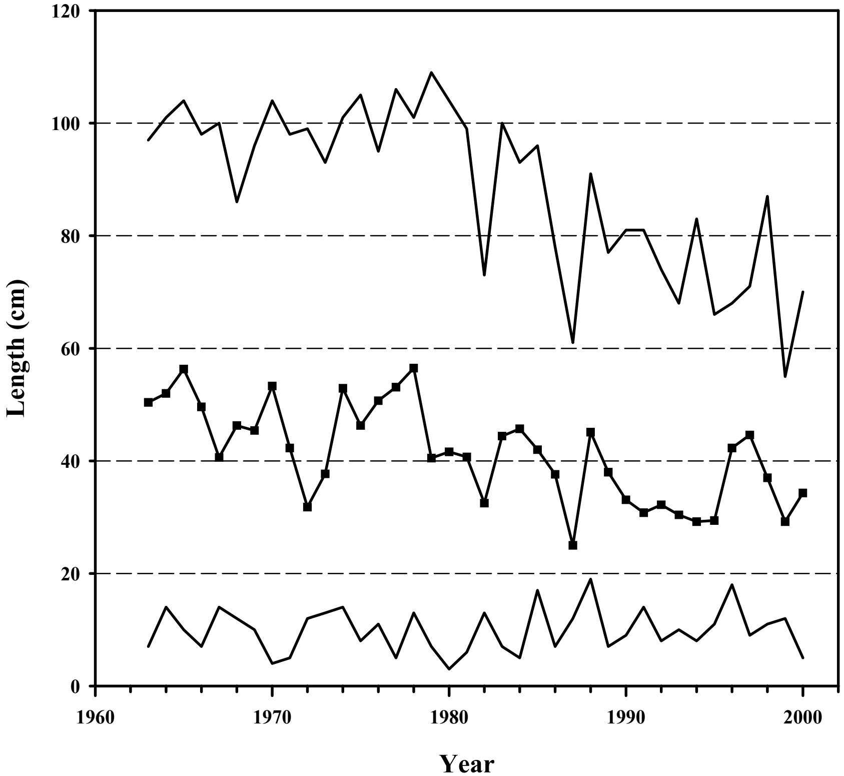


Figure C31. Minimum, mean, and, maximum lengths for the southern management region from the NEFSC autumn surveys.

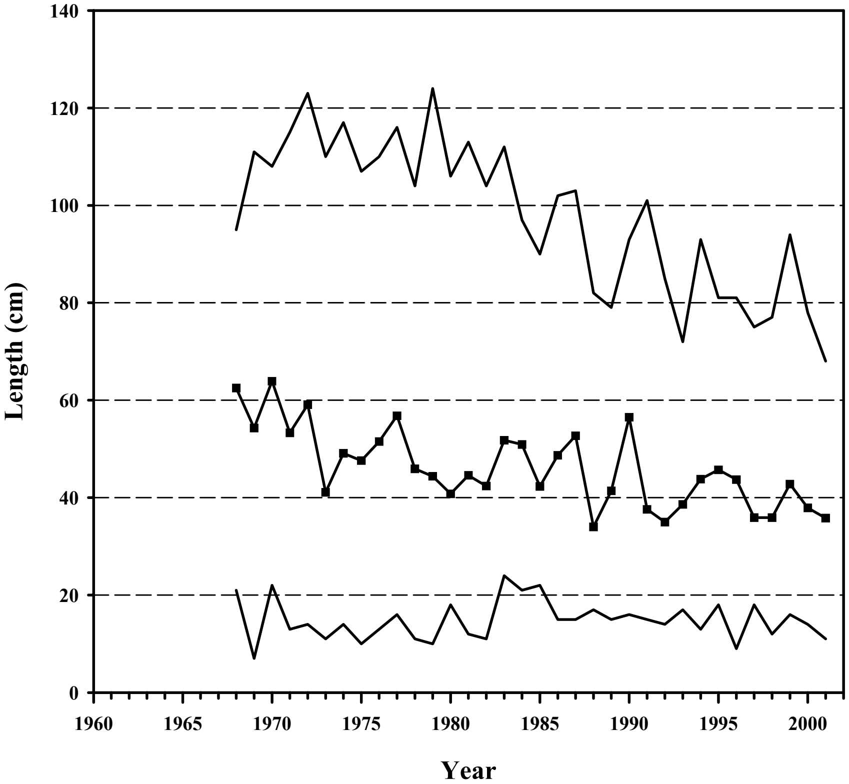
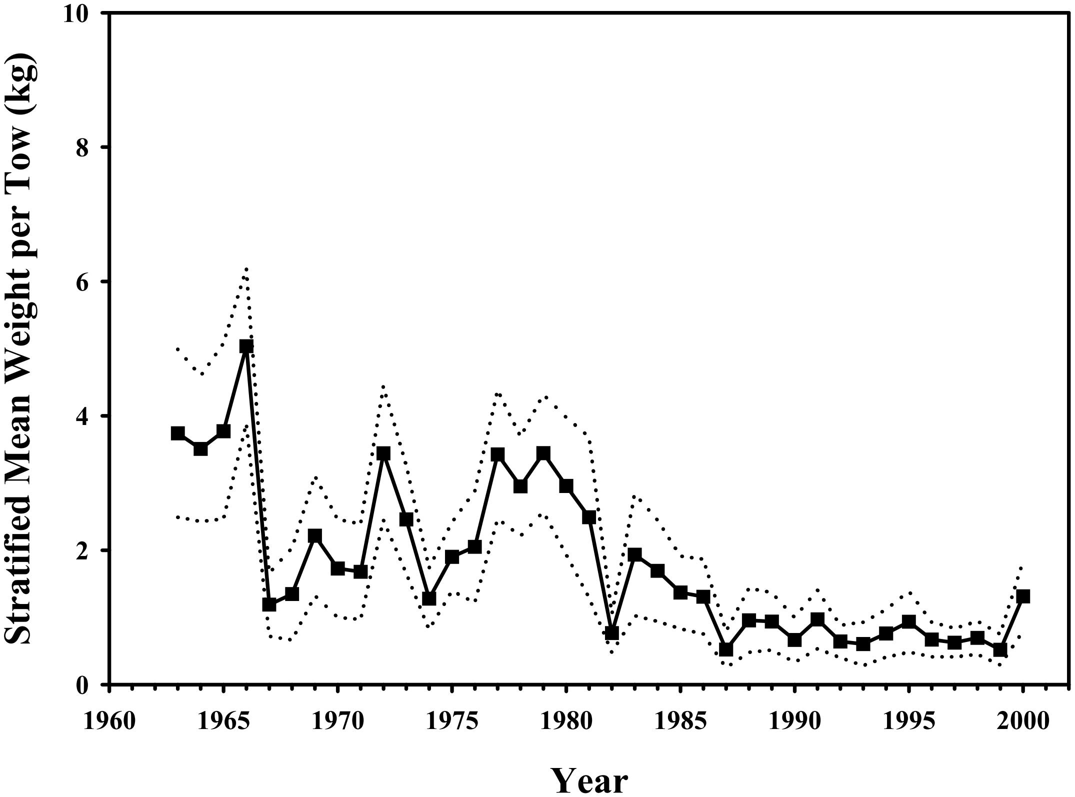


Figure C32. Minimum, mean, and, maximum lengths for the southern management region from the NEFSC spring surveys.

Biomass Indices



Smoothed Biomass Indices

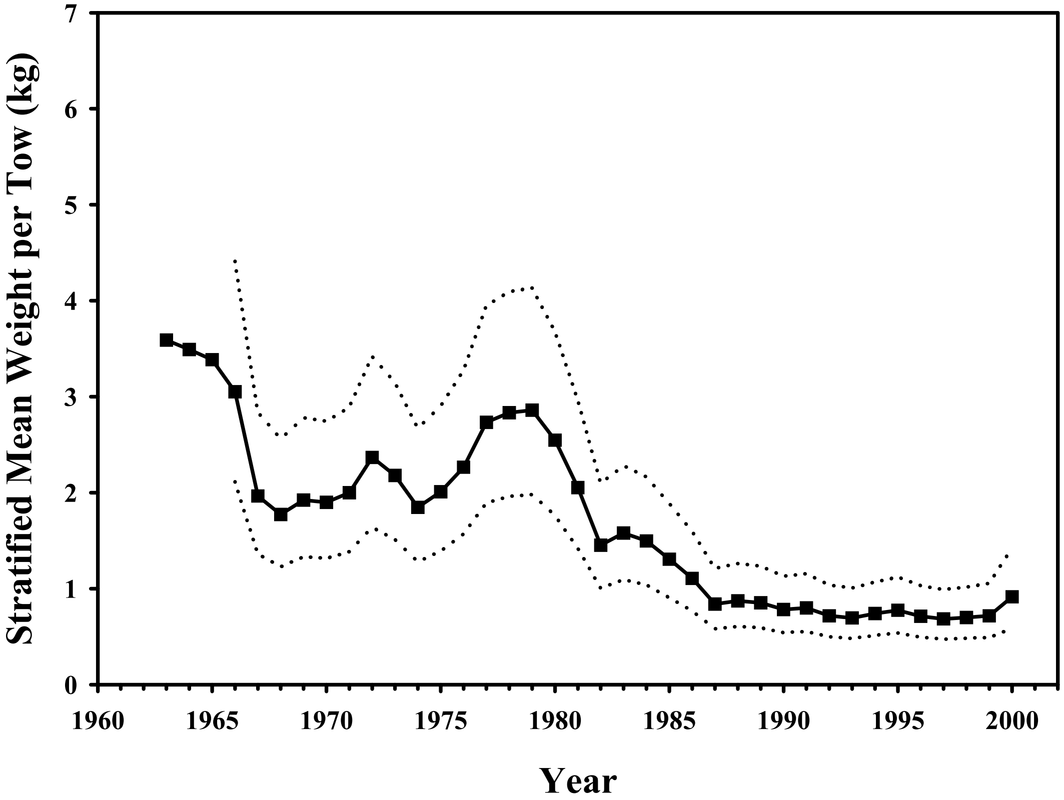
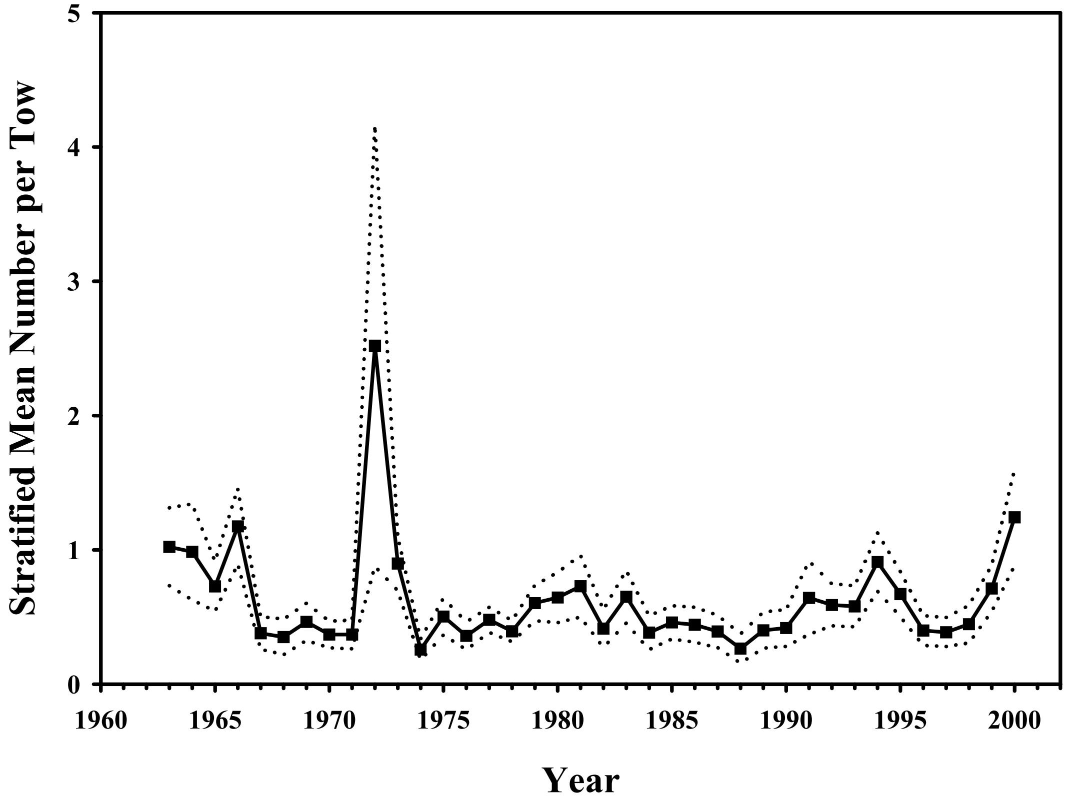


Figure C33. Biomass indices and smoothed indices from the NEFSC autumn bottom trawl survey for management regions combined,1963-2000. The 95% confidence limits are shown by the dashed line.

Abundance Indices



Smoothed Abundance Indices

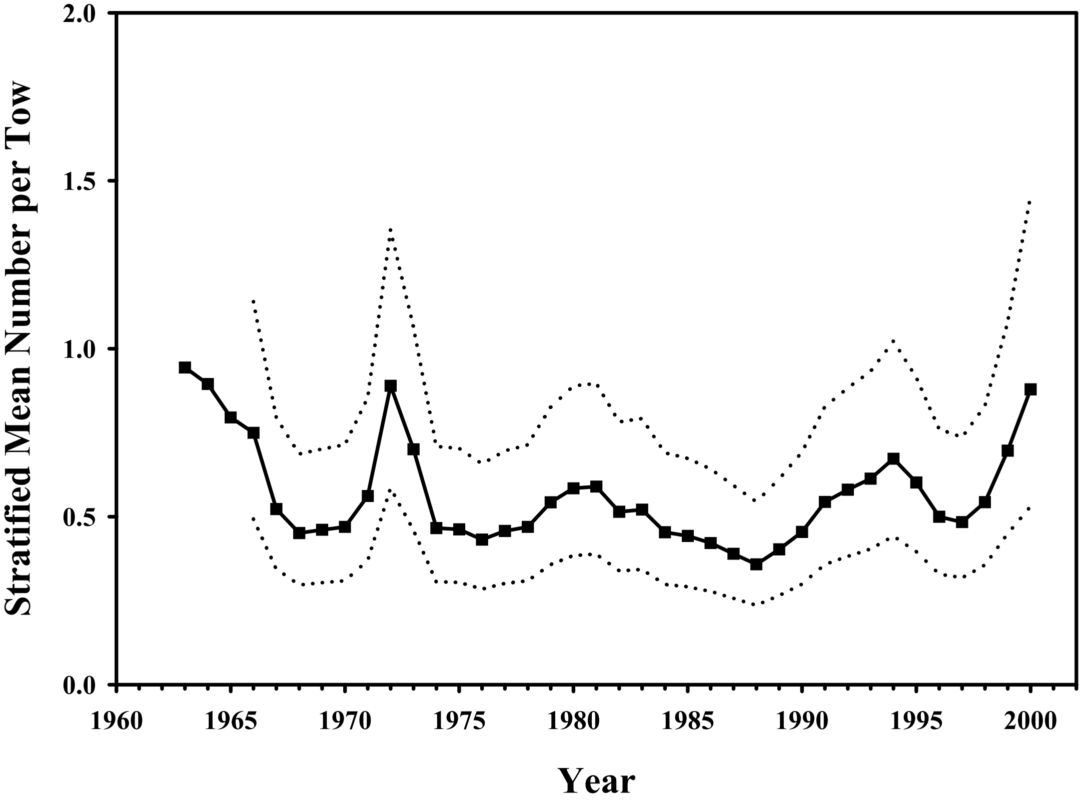
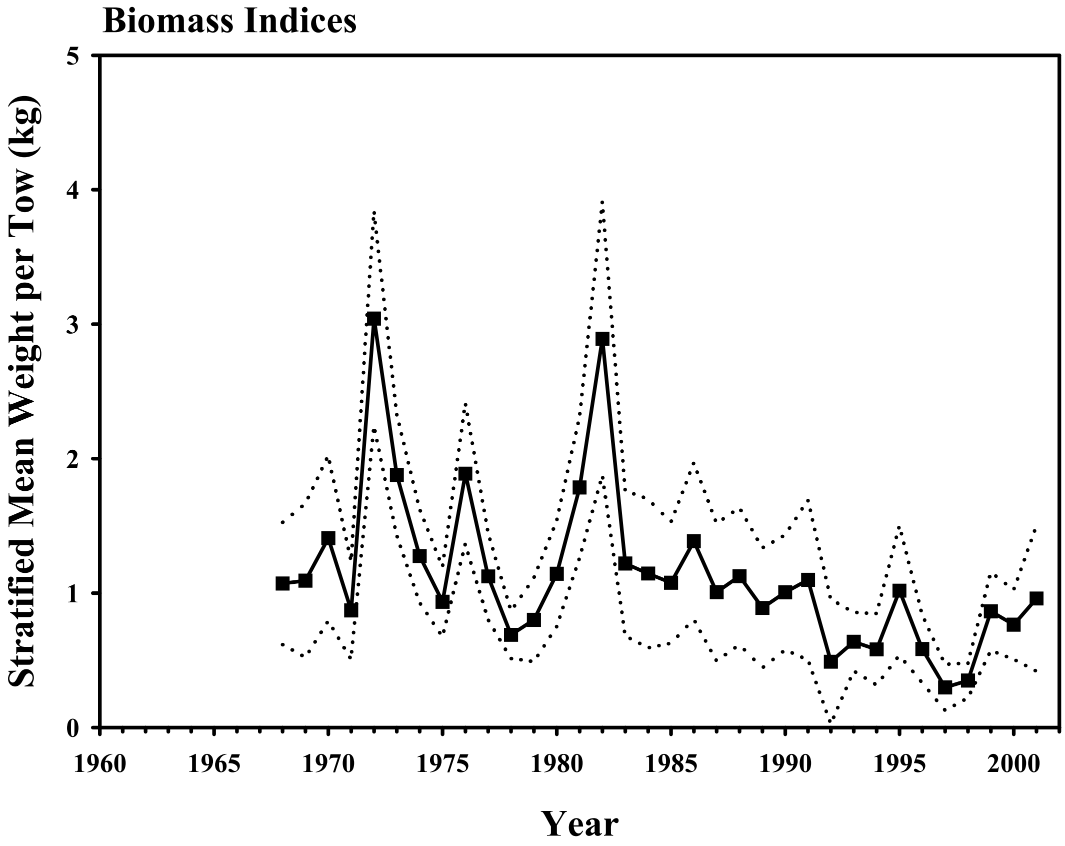


Figure C34. Abundance indices and smoothed indices from the NEFSC autumn bottom trawl survey for management regions combined, 1963-2000. The 95% confidence limits are shown by the dashed line.



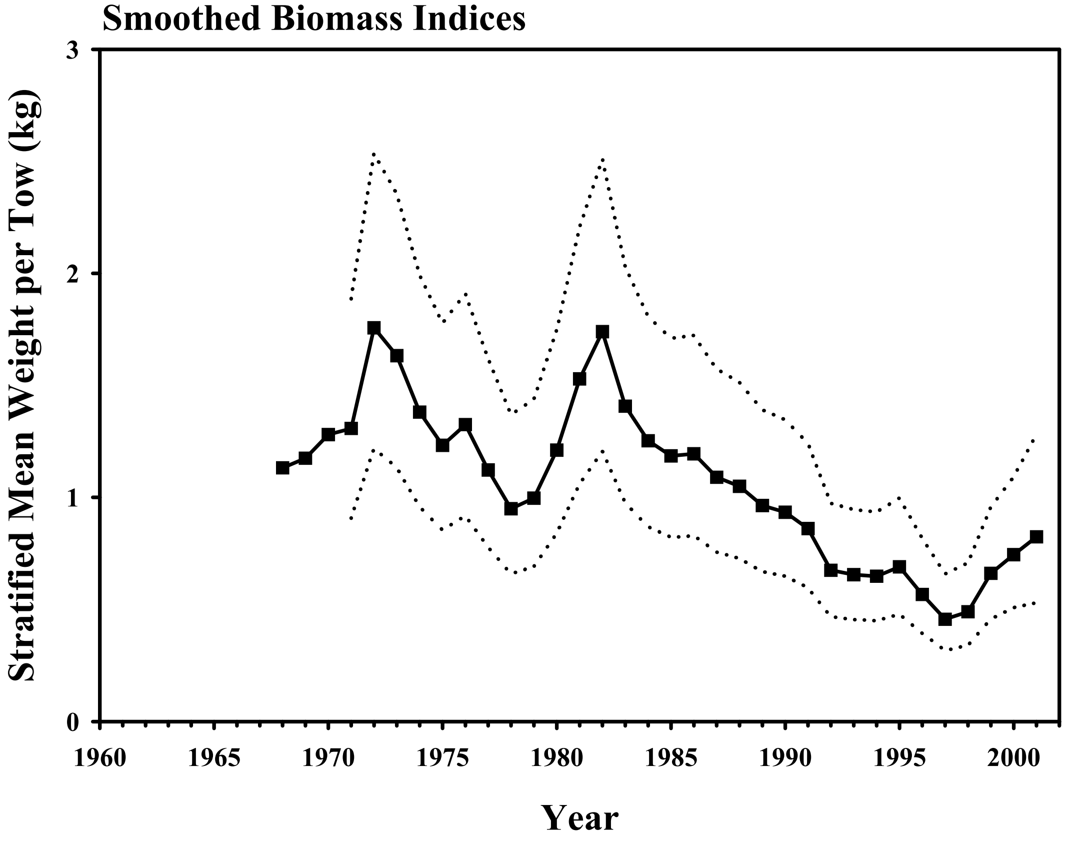


Figure C35. Biomass indices and smoothed indices from the NEFSC spring bottom trawl survey for management regions combined,1968-2001. The 95% confidence limits are shown by the dashed line.

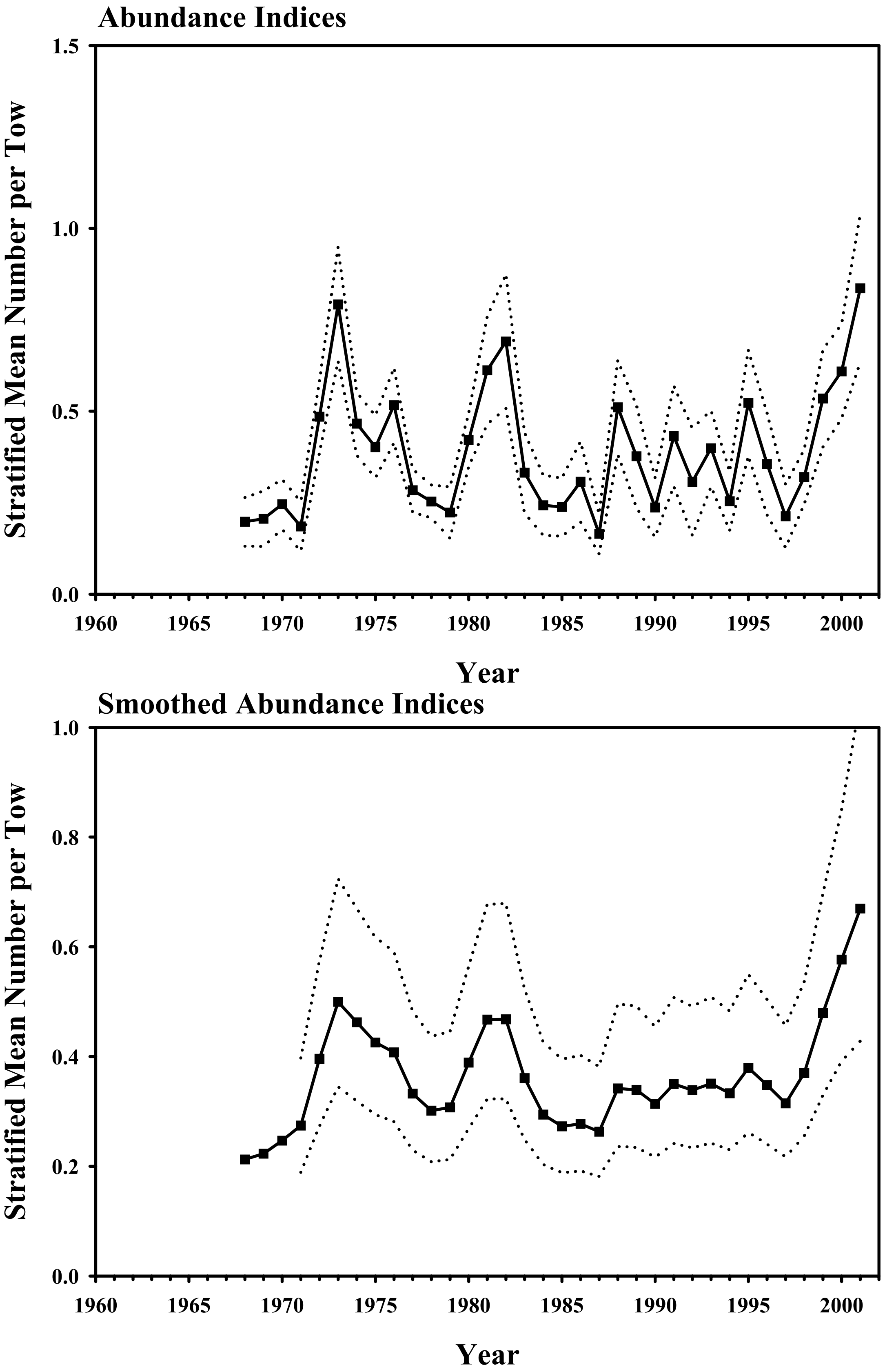


Figure C36. Abundance indices and smoothed indices from the NEFSC spring bottom trawl survey for management regions combined, 1968-2001. The 95% confidence limits are shown by the dashed line.

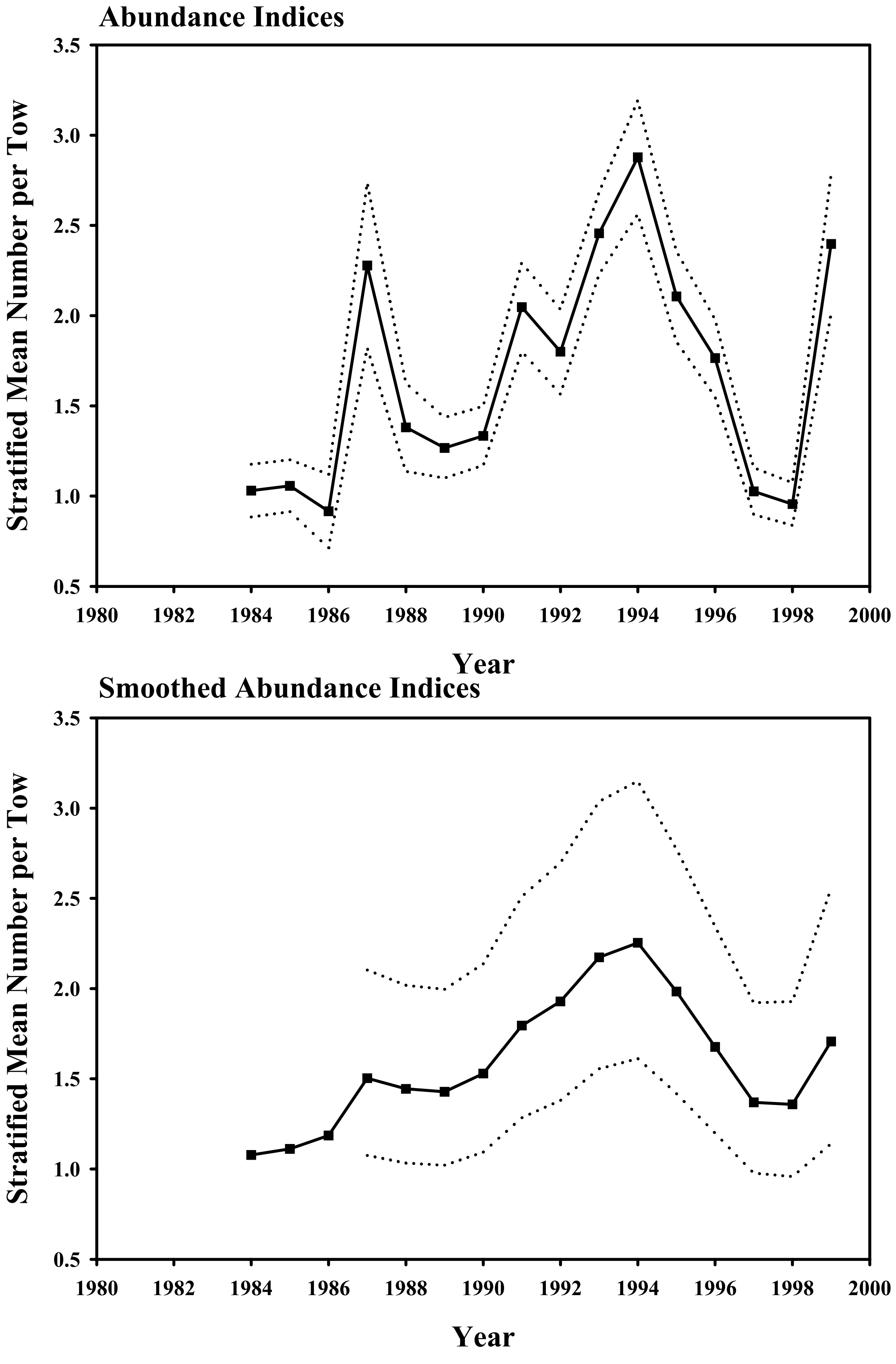


Figure C37. Abundance indices and smoothed indices from the NEFSC scallop dredge survey for management regions combined, 1984-1999. The 95% confidence limits are shown by the dashed line.

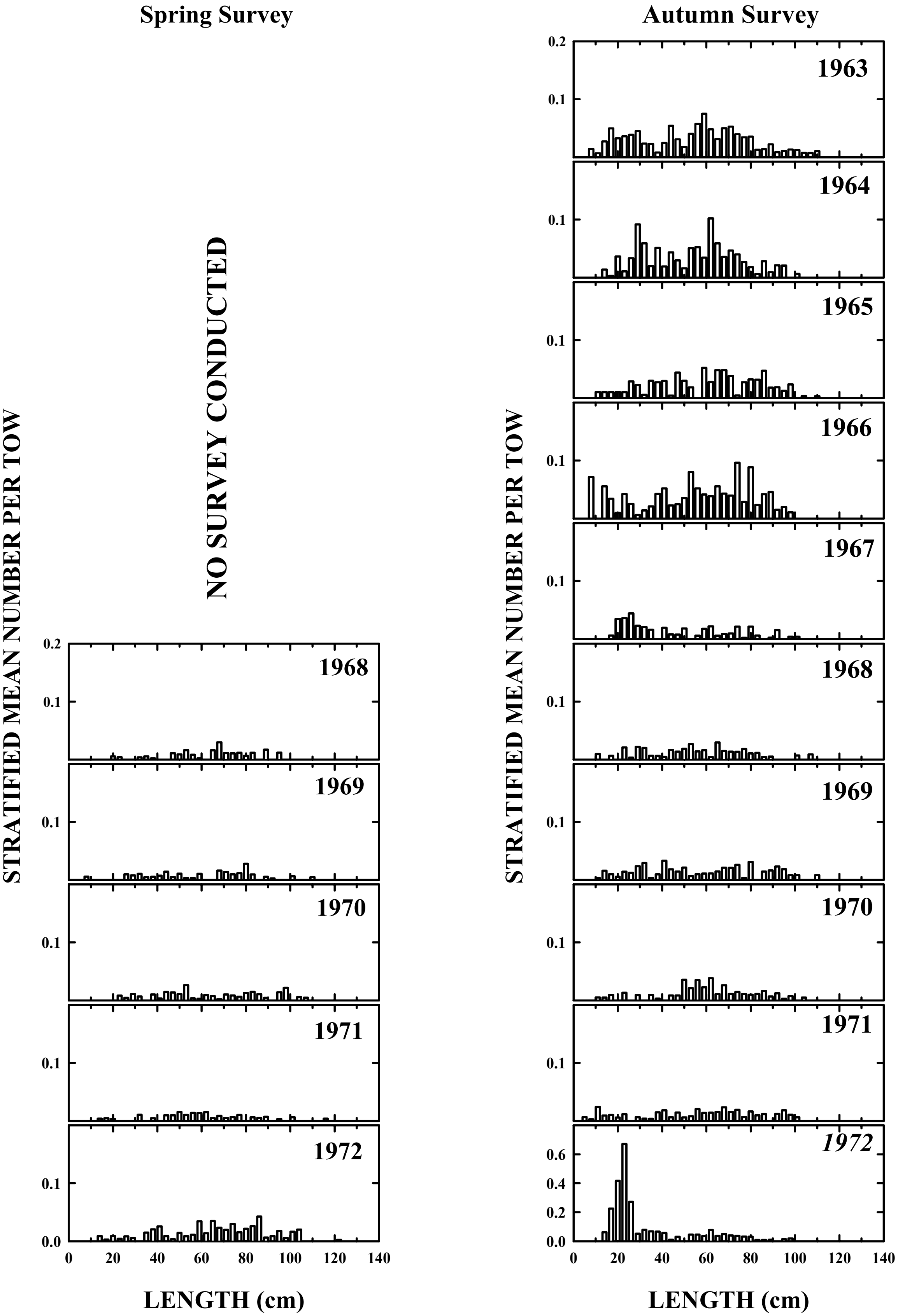


Figure C38. Goosefish length composition from the NEFSC spring bottom trawl, summer scallop, and autumn bottom trawl surveys in the management regions combined, 1963-2001.

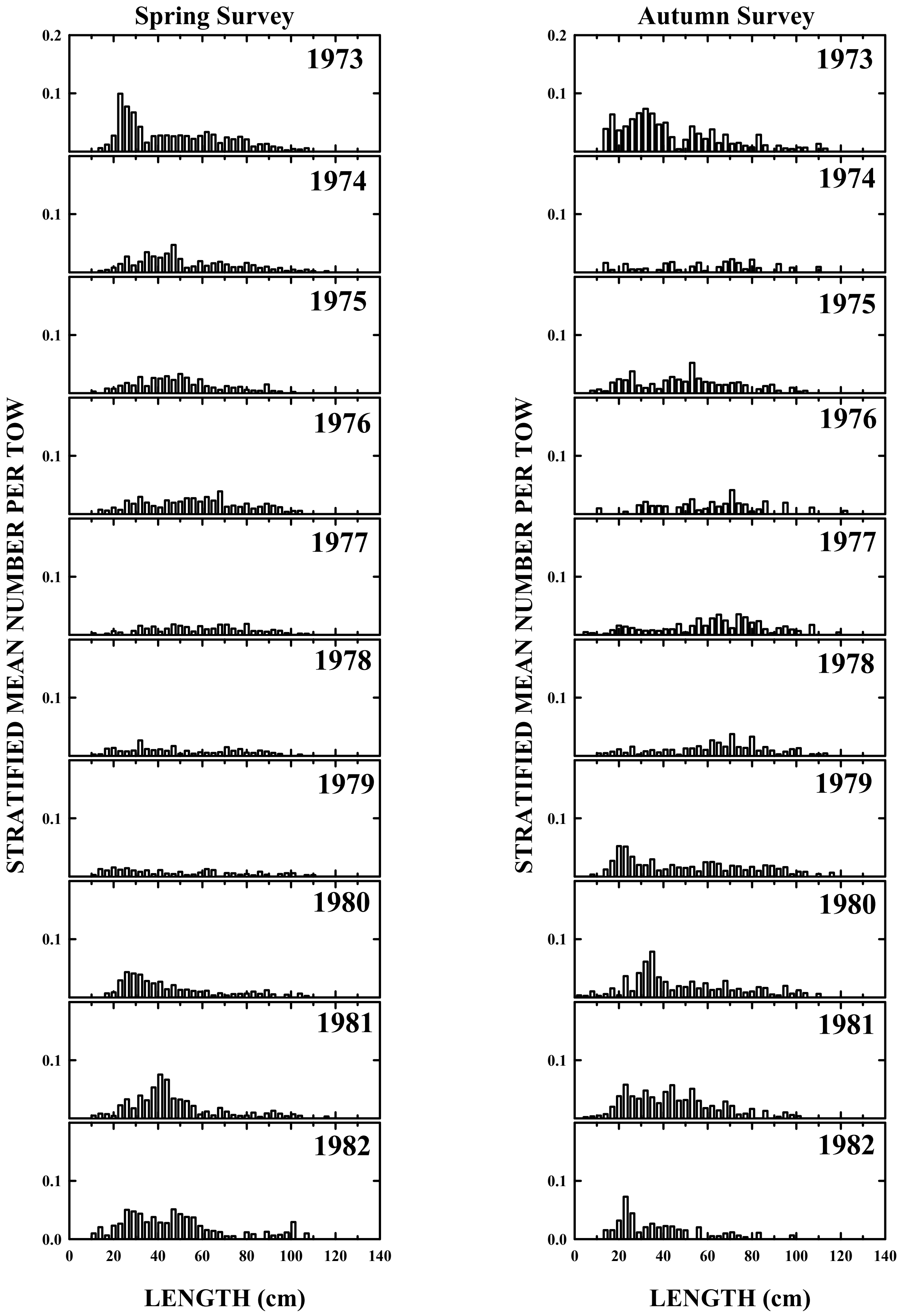


Figure C38b, continued.

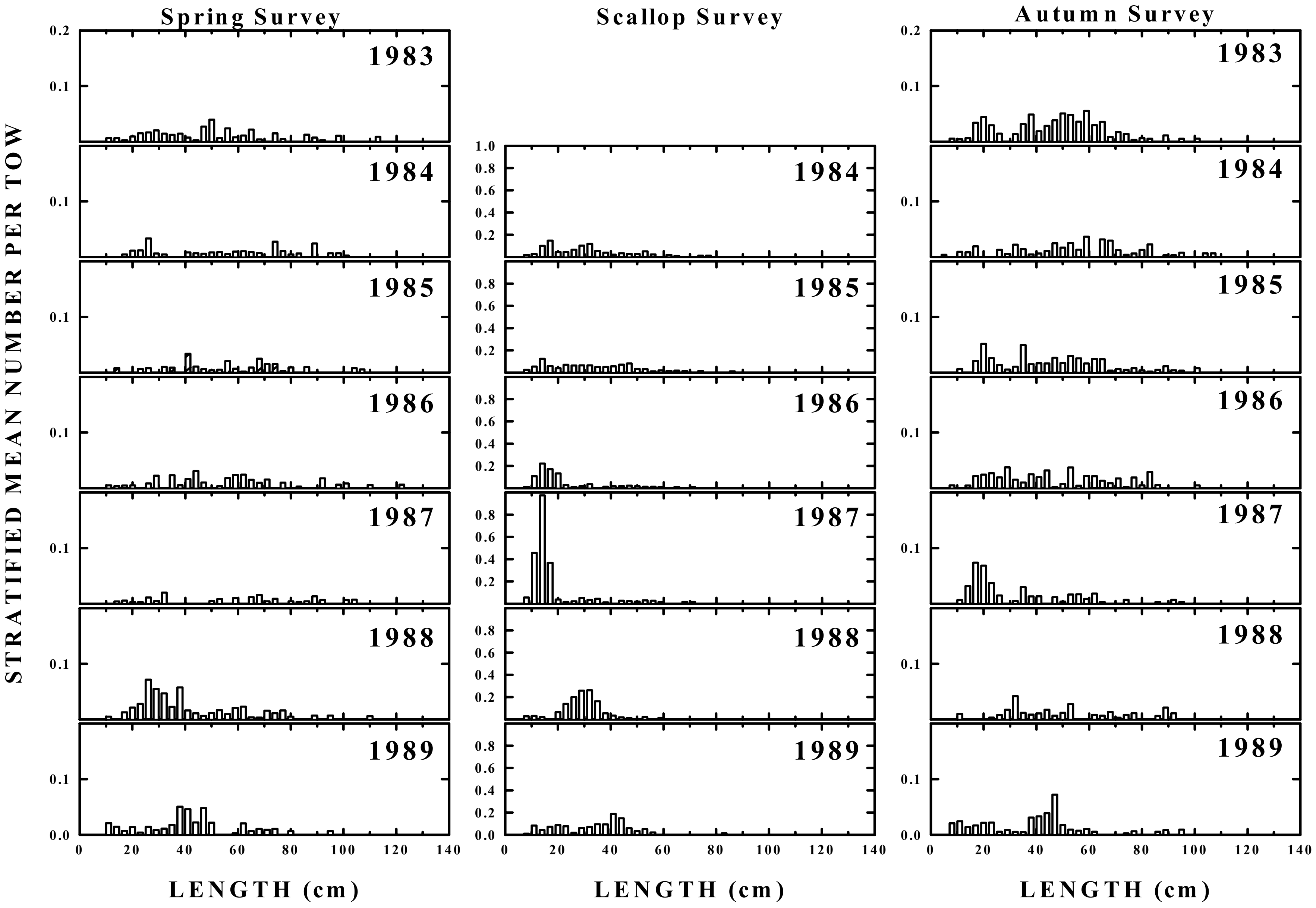


Figure C38c, continued.

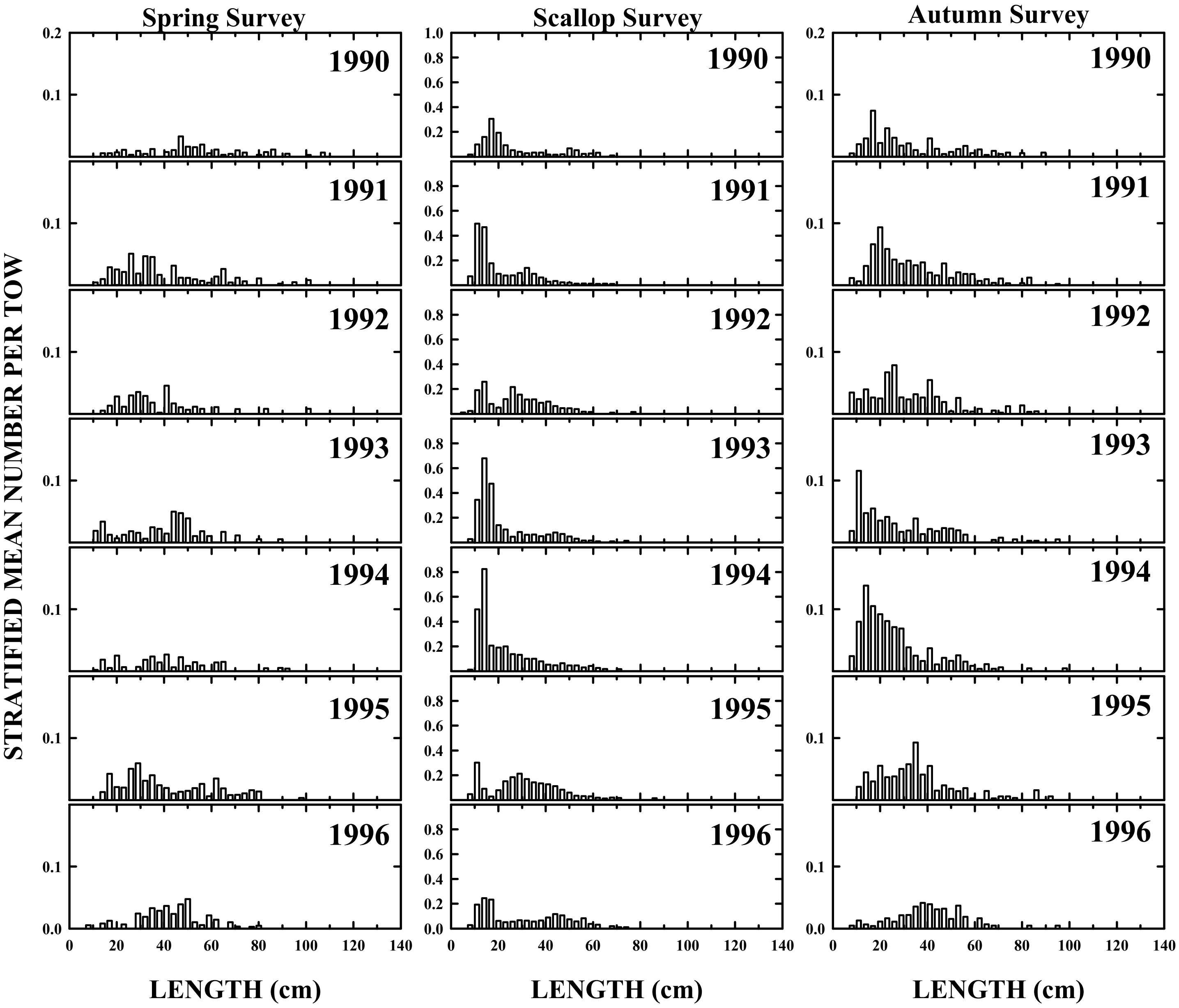


Figure C38d, continued.

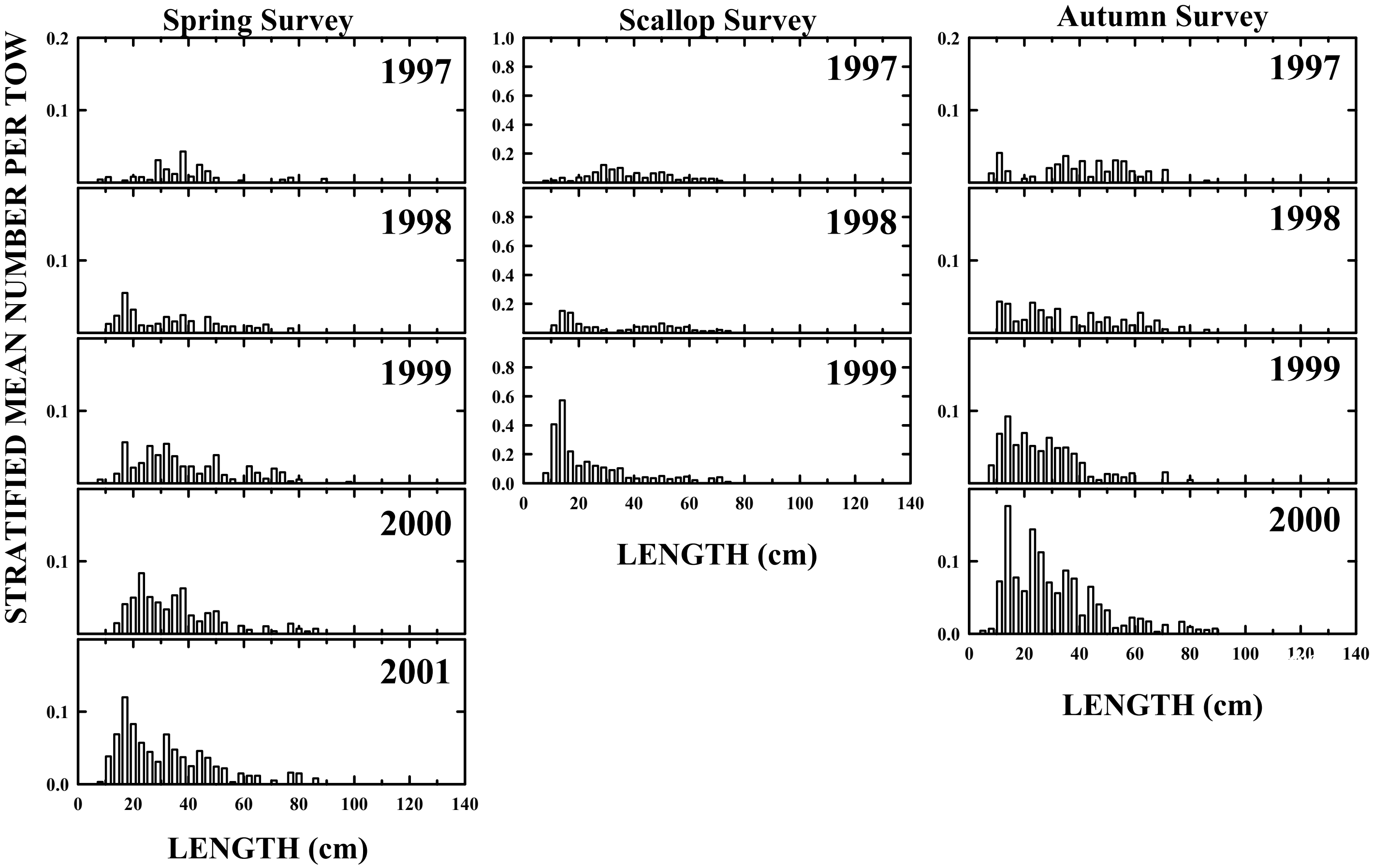


Figure C38e, continued.

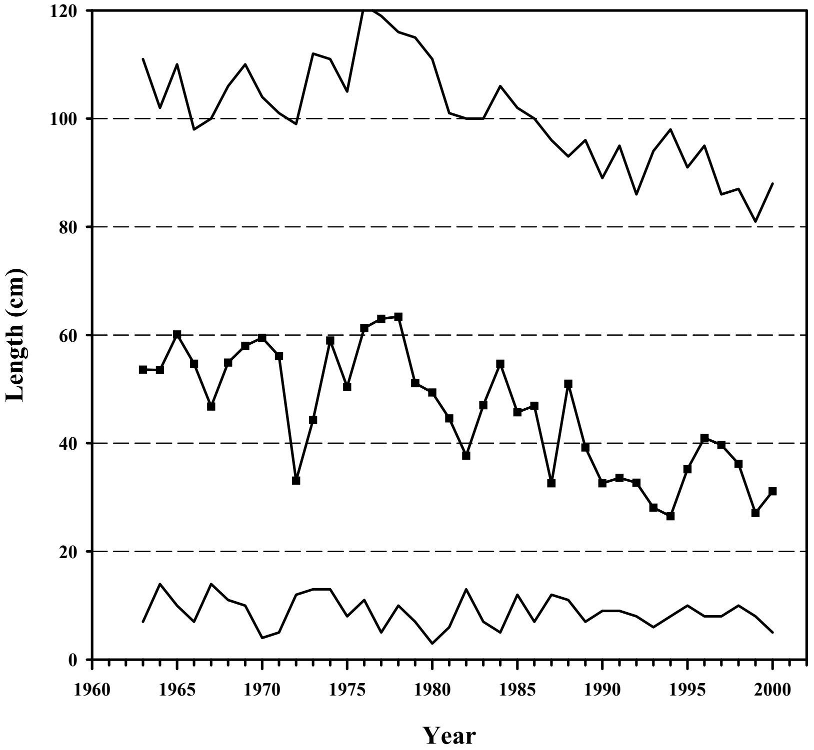


Figure C39. Minimum, mean, and, maximum lengths for managment regions combined from the NEFSC autumn surveys.

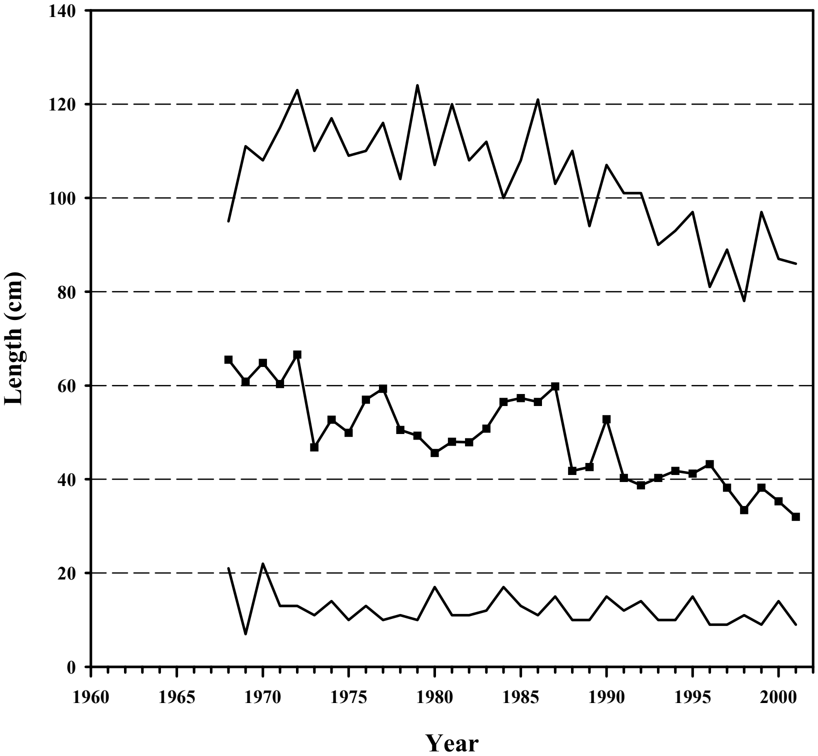


Figure C40. Minimum, mean, and, maximum lengths for managment regions combined from the NEFSC spring surveys.

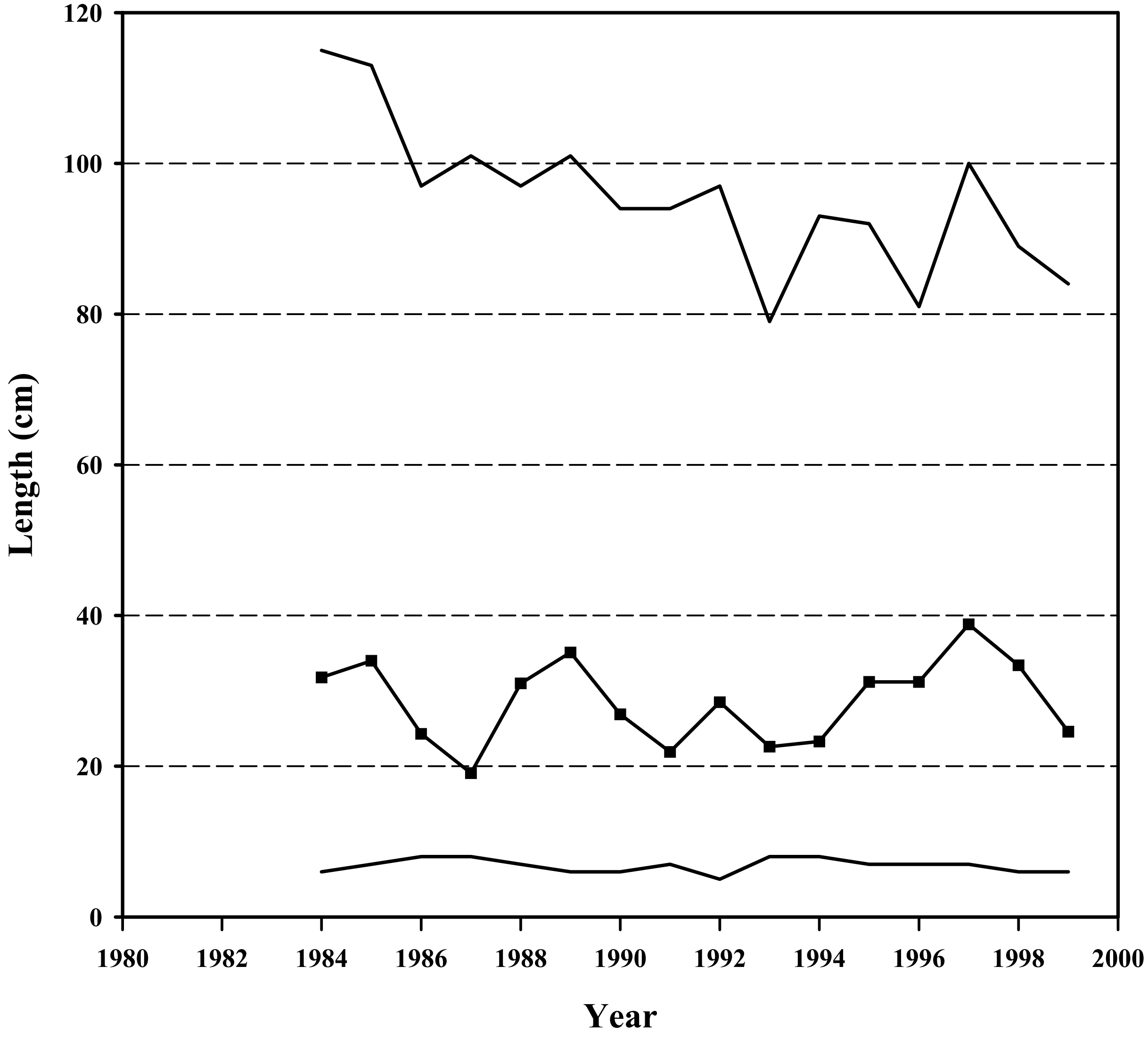


Figure C41. Minimum, mean, and, maximum lengths for management regions combined from the NEFSC scallop surveys.

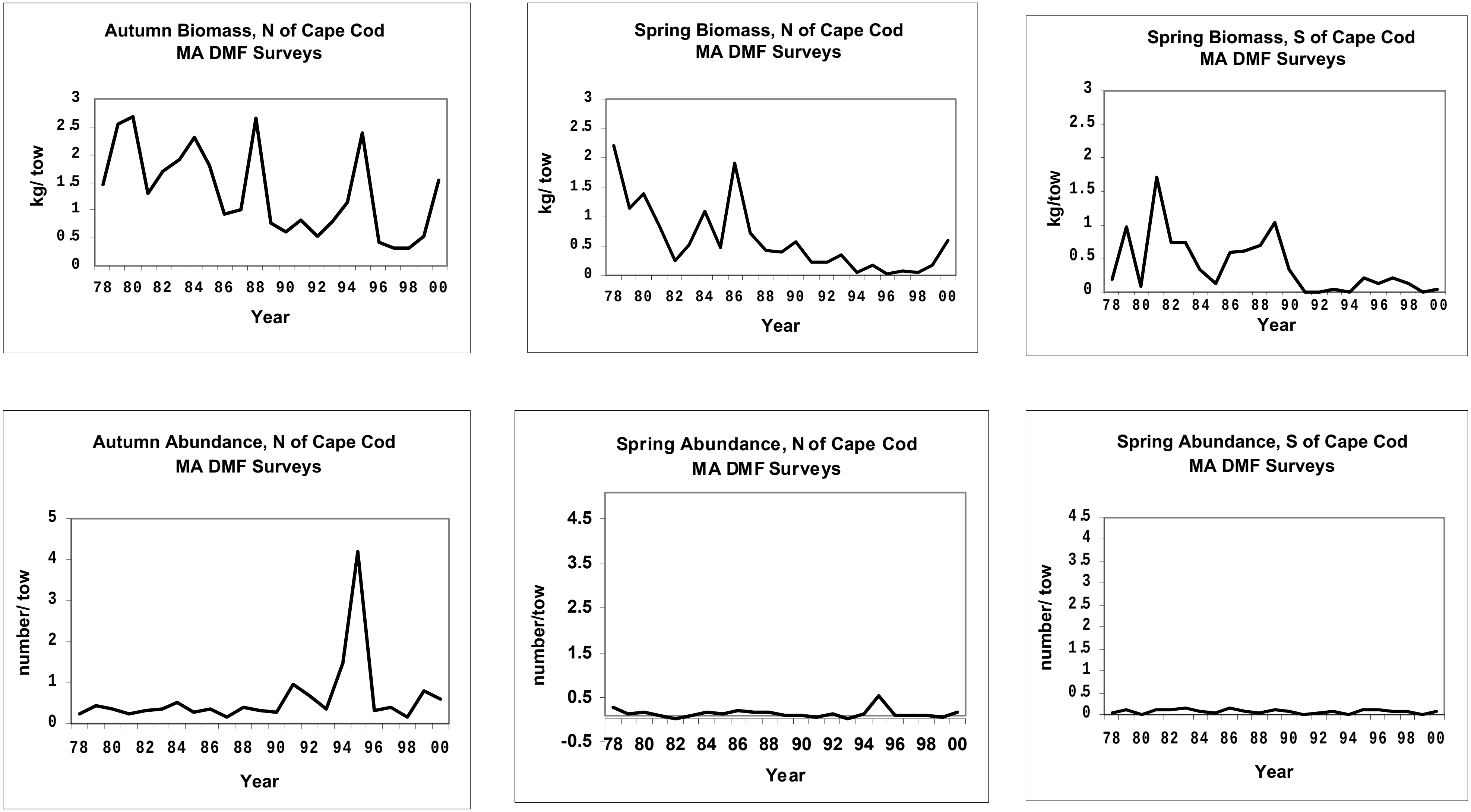
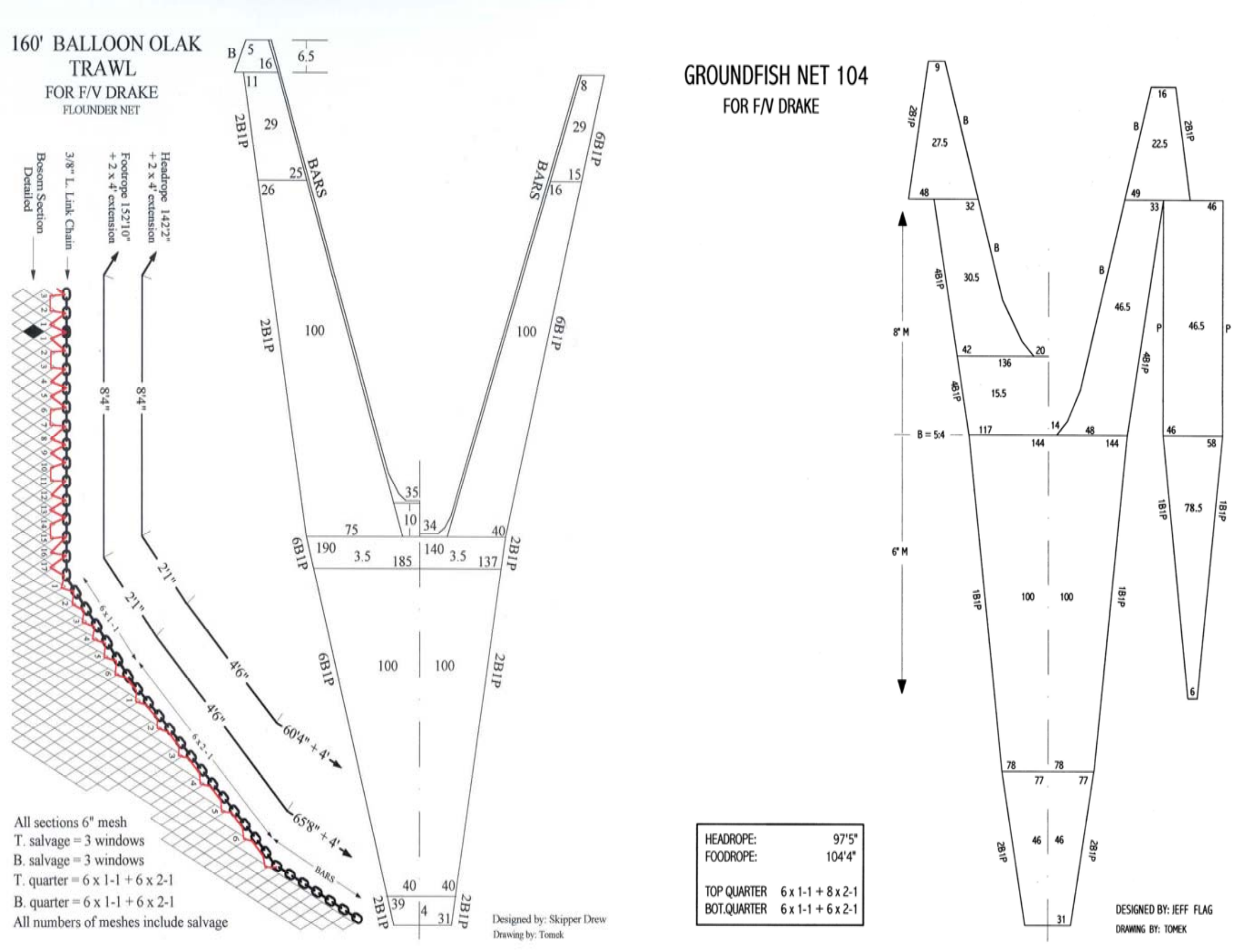


Figure C42. Biomass and abundance indices for goosefish from Massachusetts state bottom trawl surveys.



All sections 6" mesh
T. salvage = 3 windows
B. salvage = 3 windows
T. quarter = 6 x 1-1 + 6 x 2-1
B. quarter = 6 x 1-1 + 6 x 2-1
All numbers of meshes include salvage

HEADROPE:	97'5"
FOODROPE:	104'4"
TOP QUARTER	6 x 1-1 + 8 x 2-1
BOT.QUARTER	6 x 1-1 + 6 x 2-1

Figure C43. Diagram of nets used on the F/V Drake. (A.) Net number 1; (B.) Net number 2.

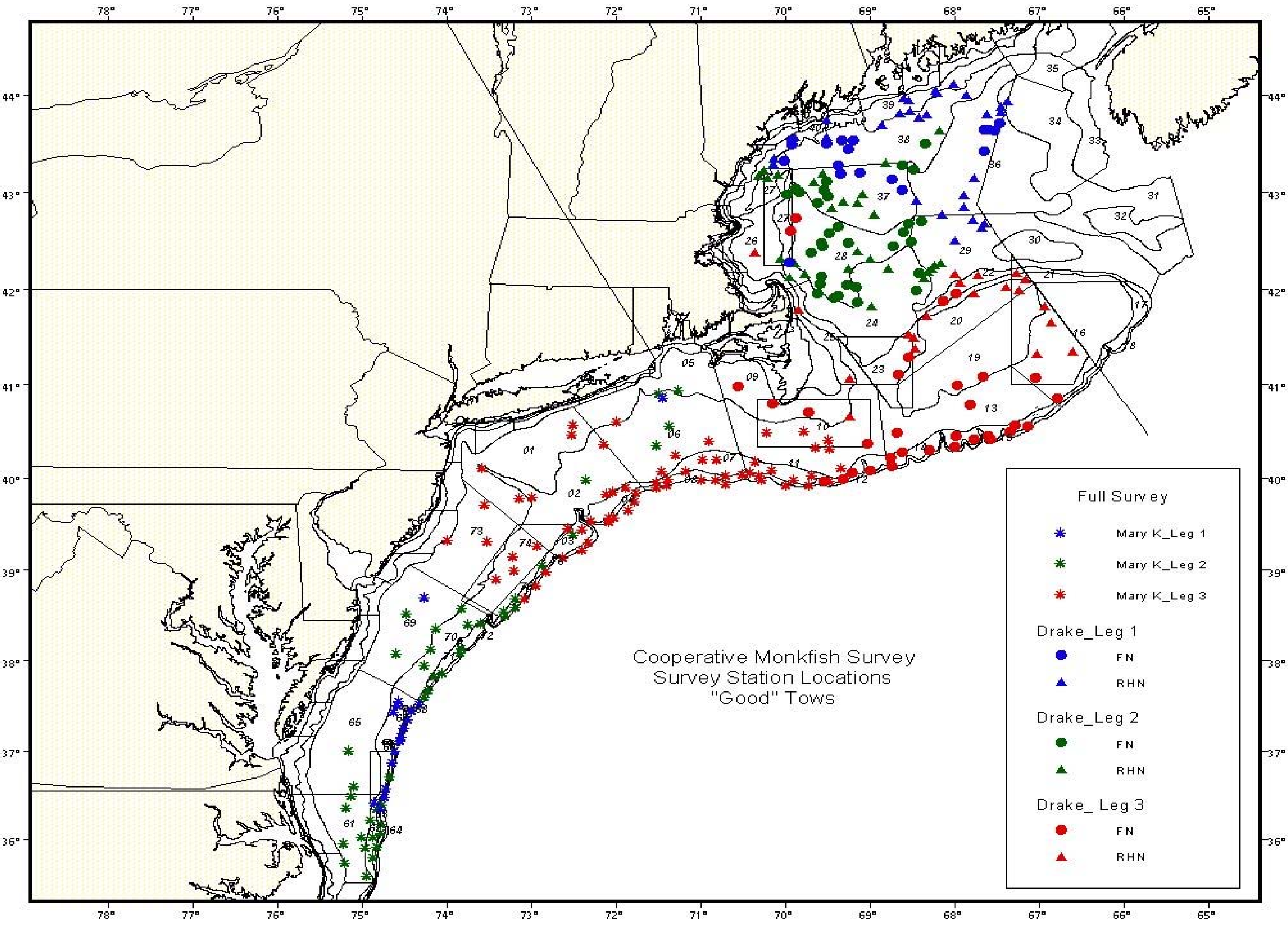


Figure C44. Survey stations successfully sampled during cooperative monkfish survey. Experimental tows not shown.

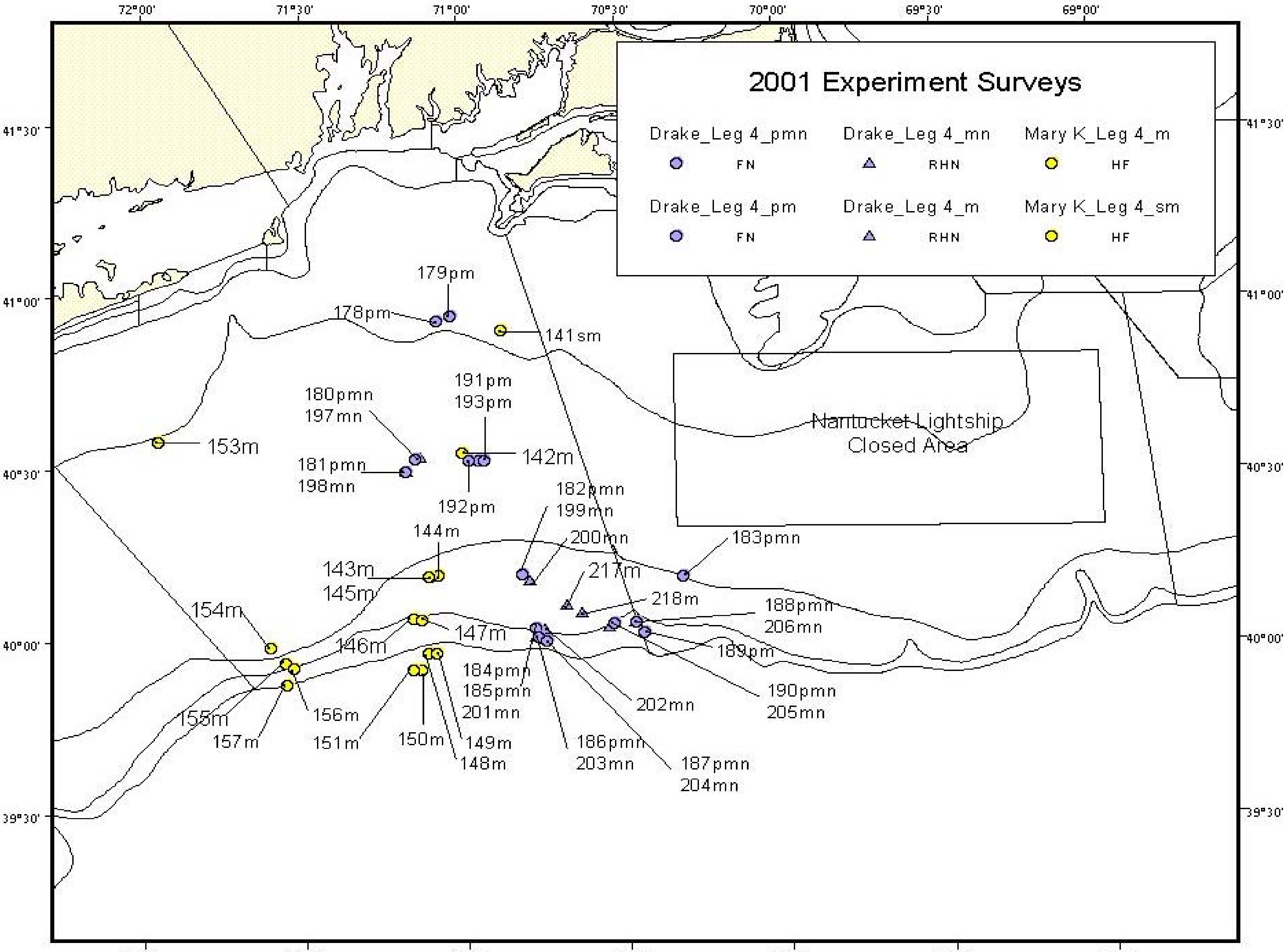


Figure C45. Locations of experimental tows conducted for net mensuration studies on F/V Drake and F/V Mary K.

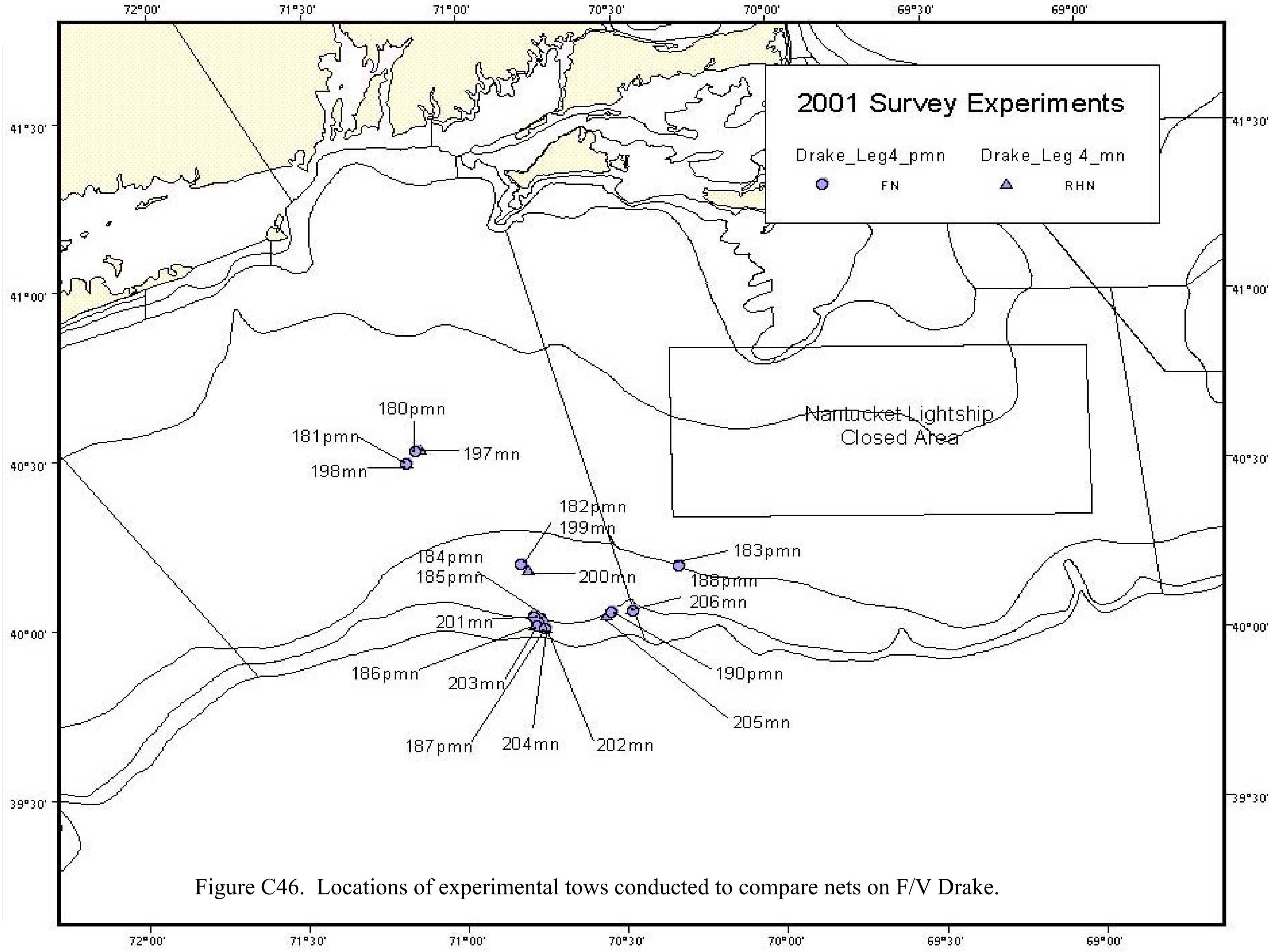


Figure C46. Locations of experimental tows conducted to compare nets on F/V Drake.

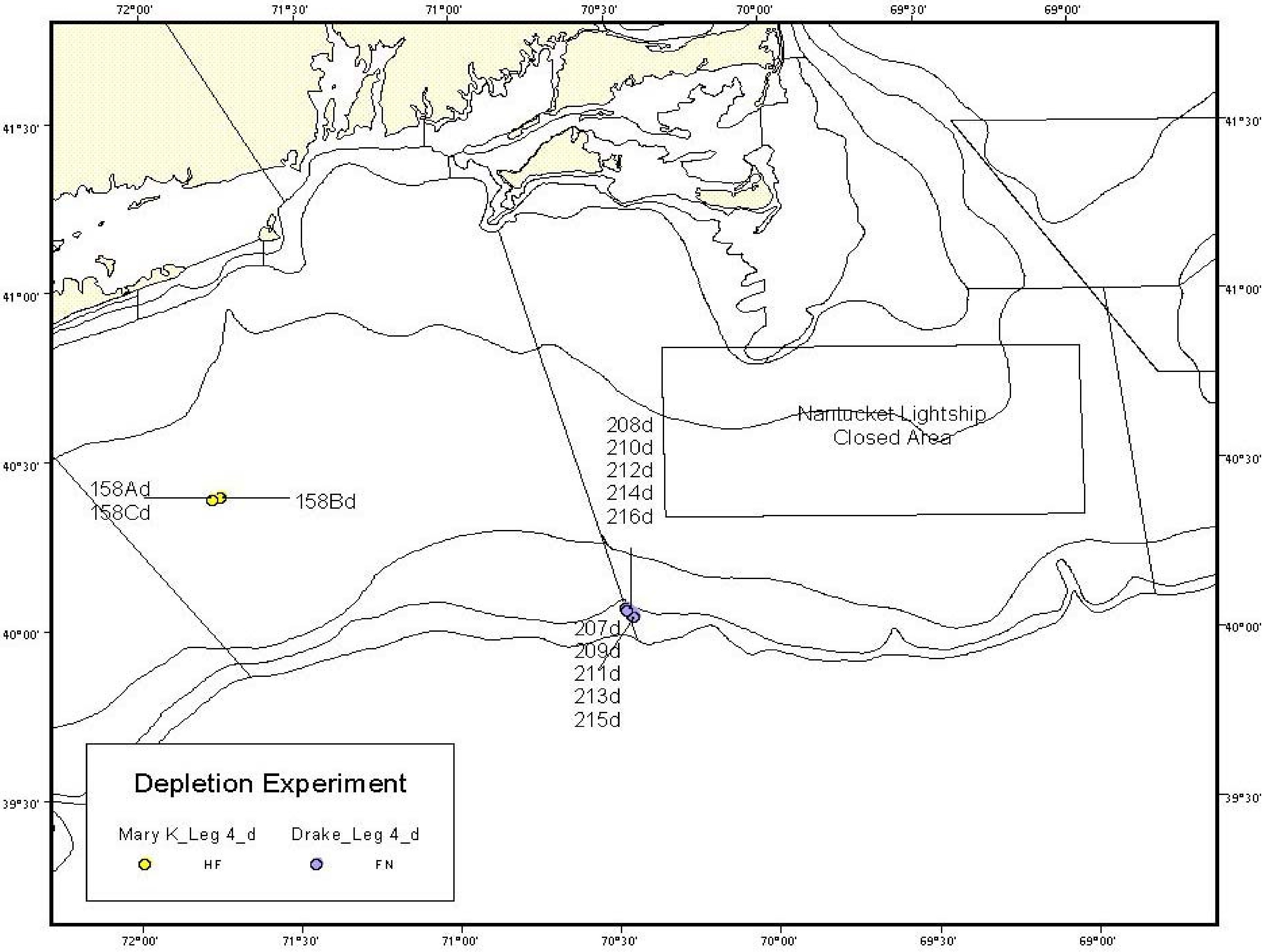


Figure C47. Location of depletion experiment tows conducted on F/V Drake and F/V Mary K.

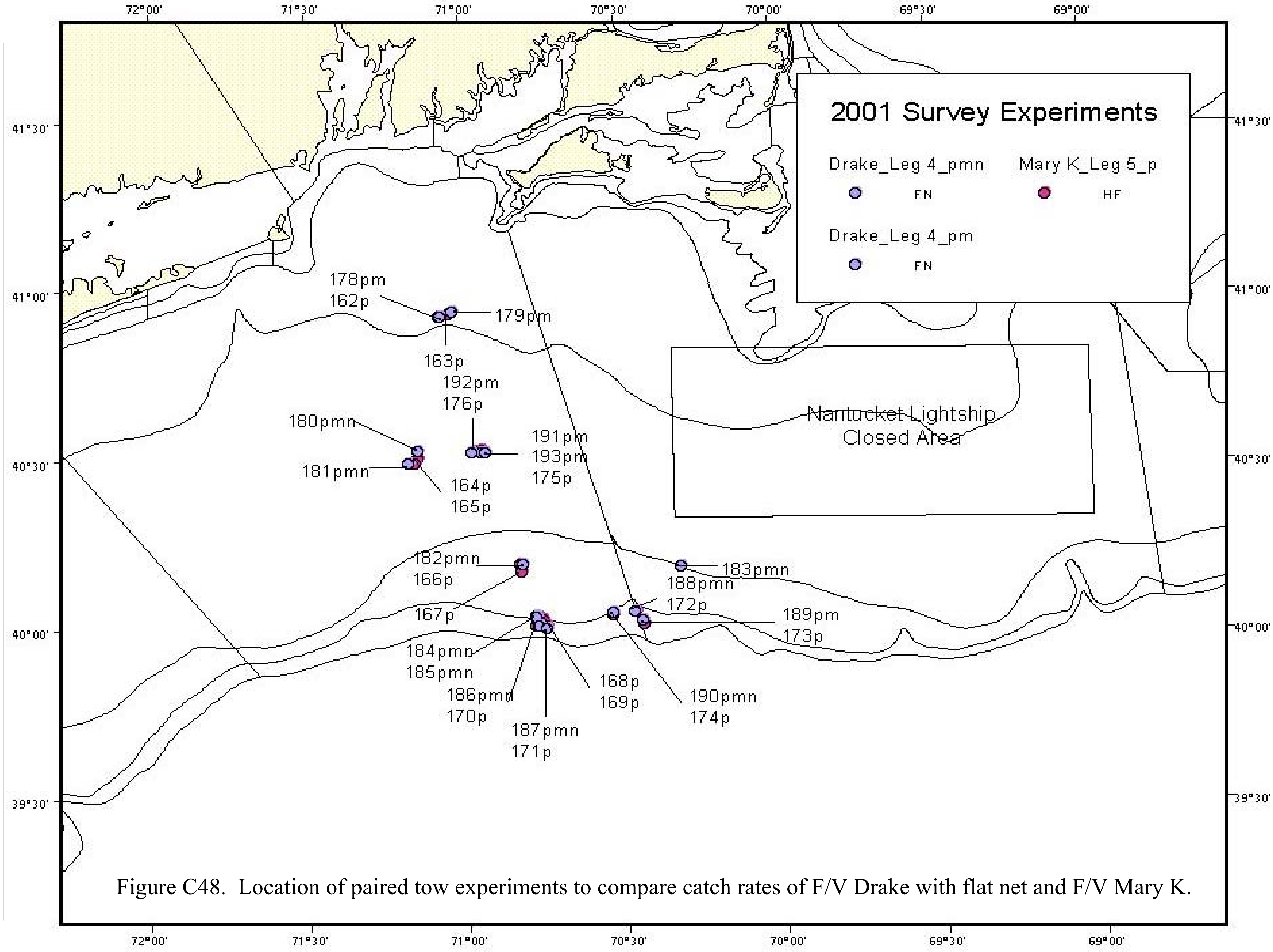


Figure C48. Location of paired tow experiments to compare catch rates of F/V Drake with flat net and F/V Mary K.

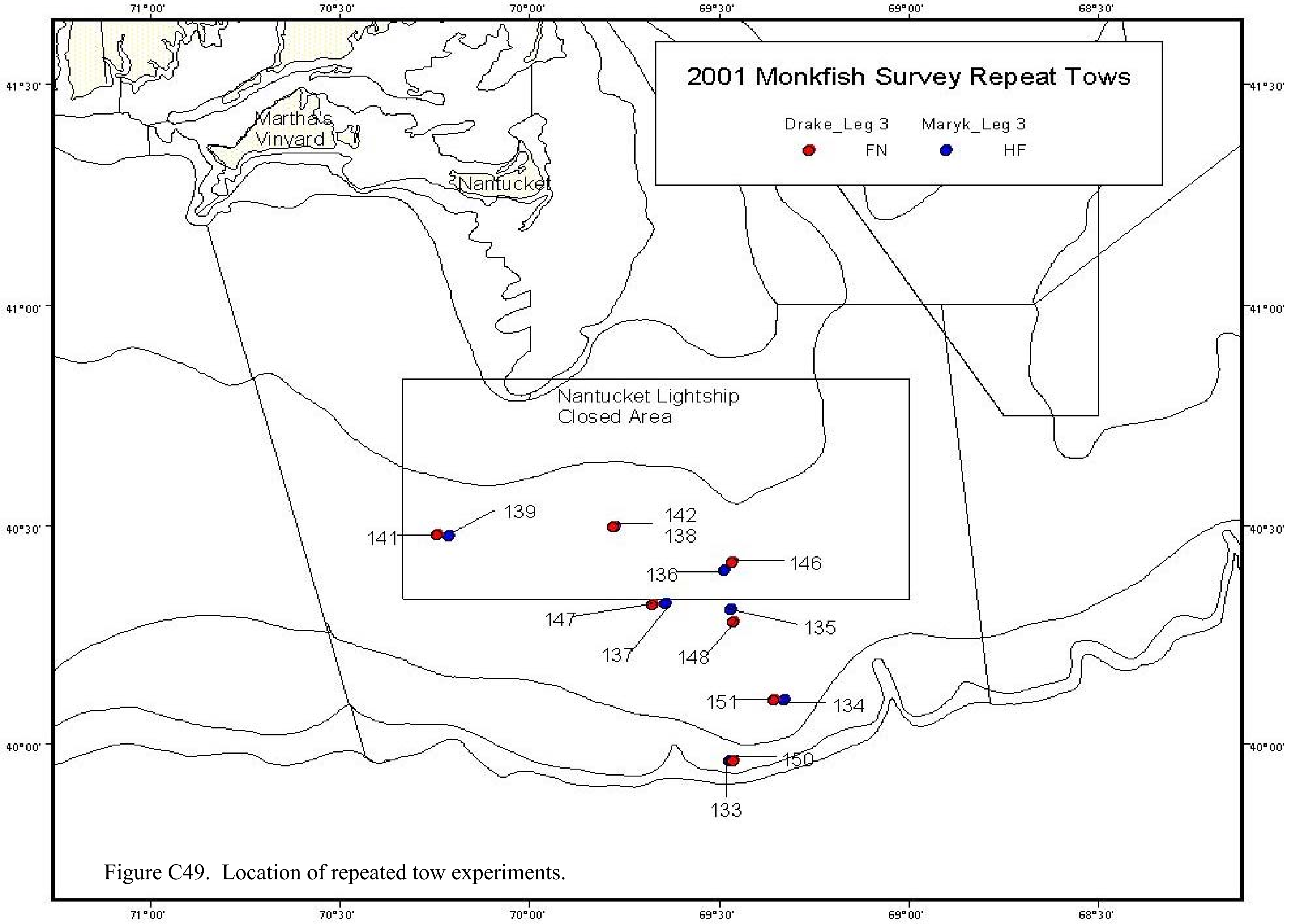


Figure C49. Location of repeated tow experiments.

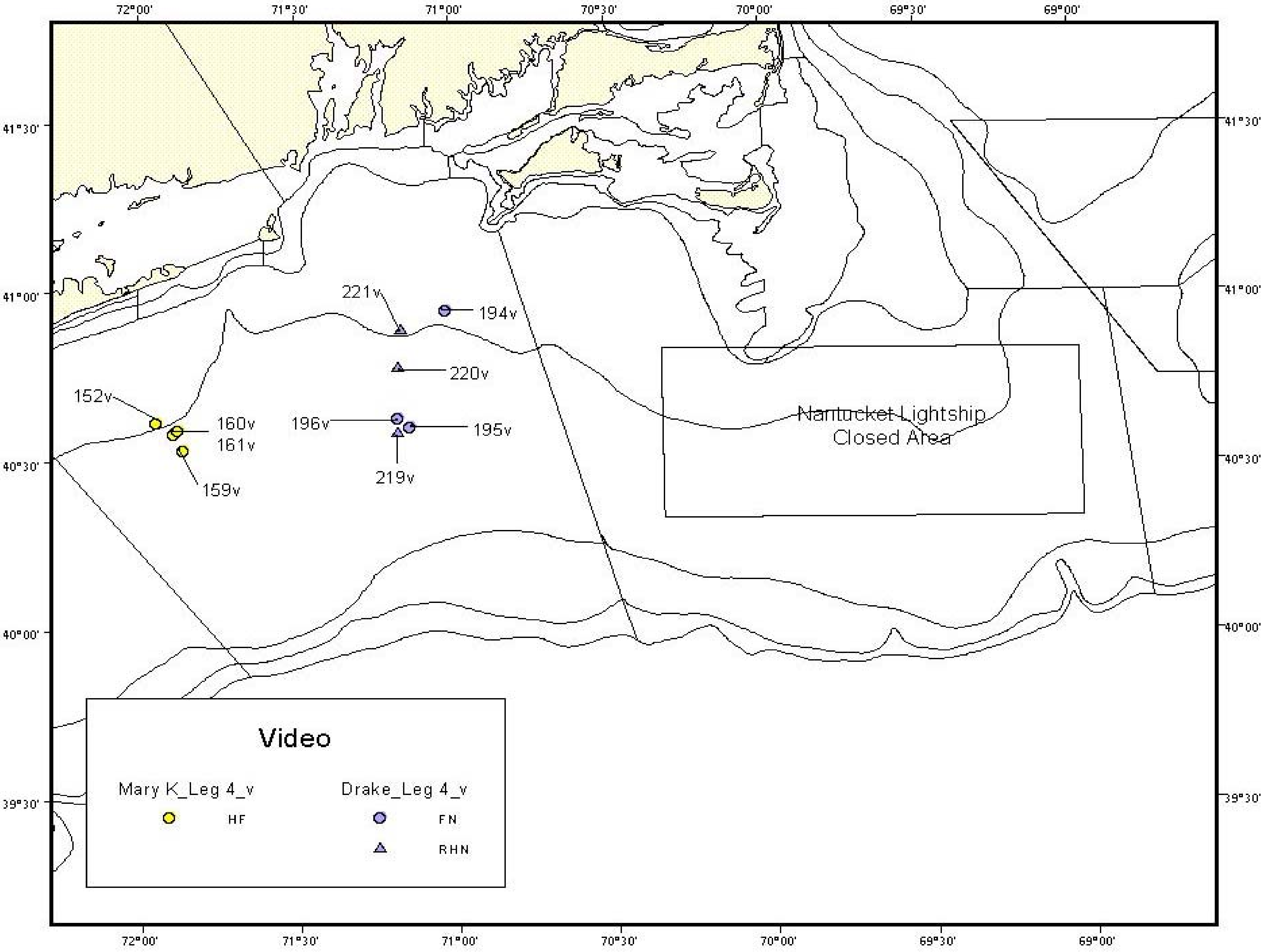


Figure C50. Location of tows made using video camera attached to net.

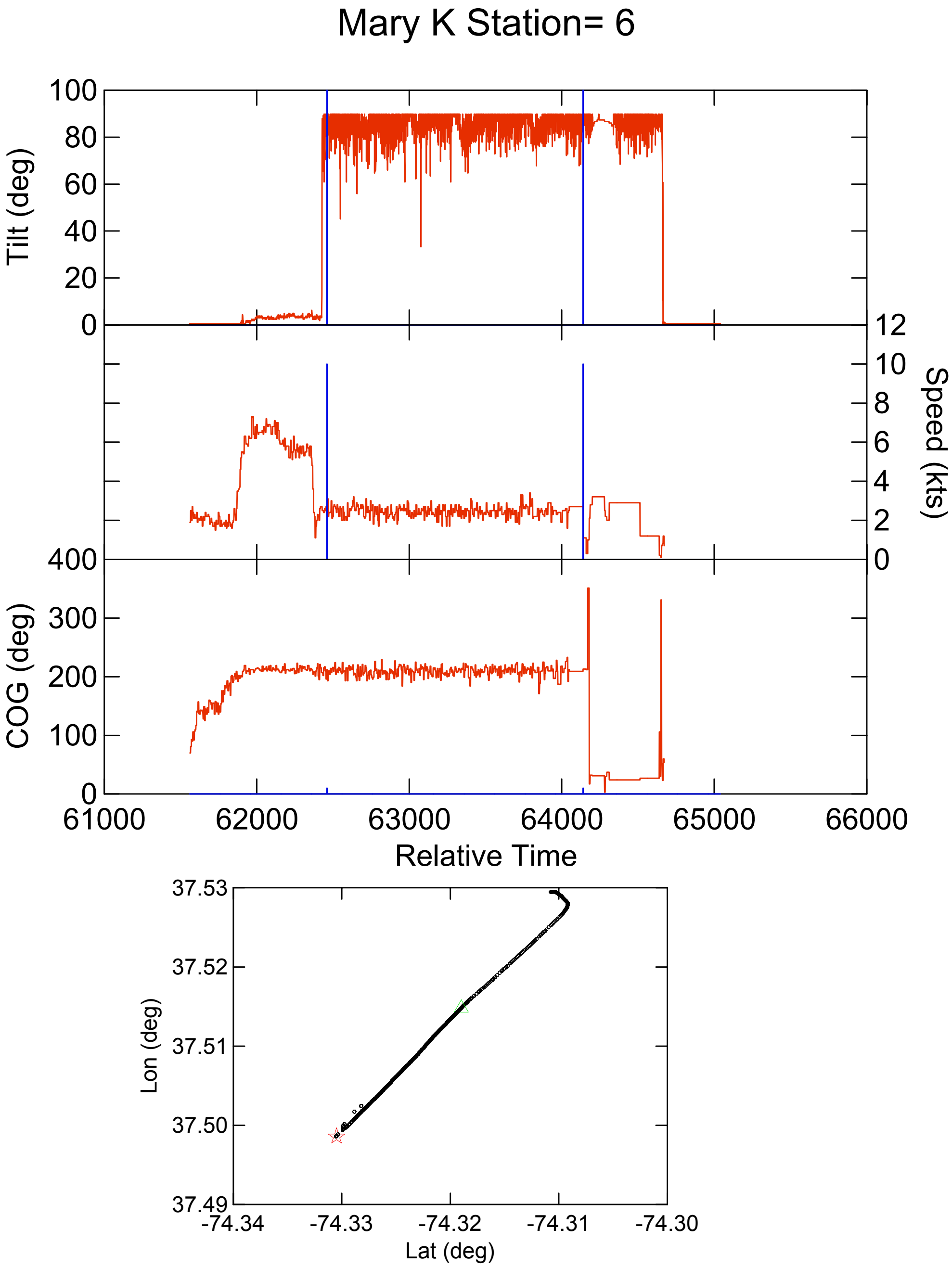


Figure C51. Example of sensor traces from a tow on the Mary K. From the top panel: inclinometer tilt angle, vessel speed, course over ground, and plot of ship's track. Triangle marks ship's position at start of tow, star marks position at end of tow.

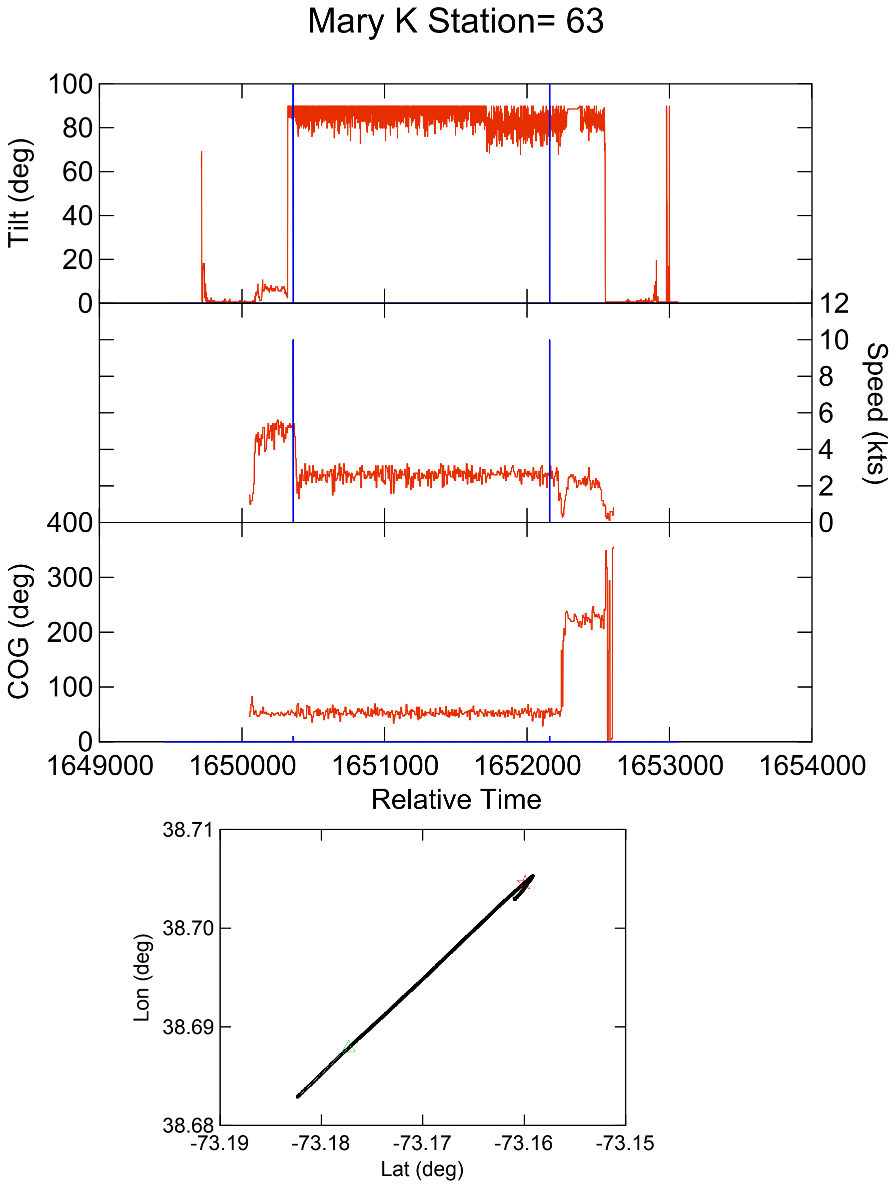


Figure C52. Example of sensor traces from a tow on the Mary K. From the top panel: inclinometer tilt angle, vessel speed, course over ground, and plot of ship's track. Triangle marks ship's position at start of tow, star marks position at end of tow.

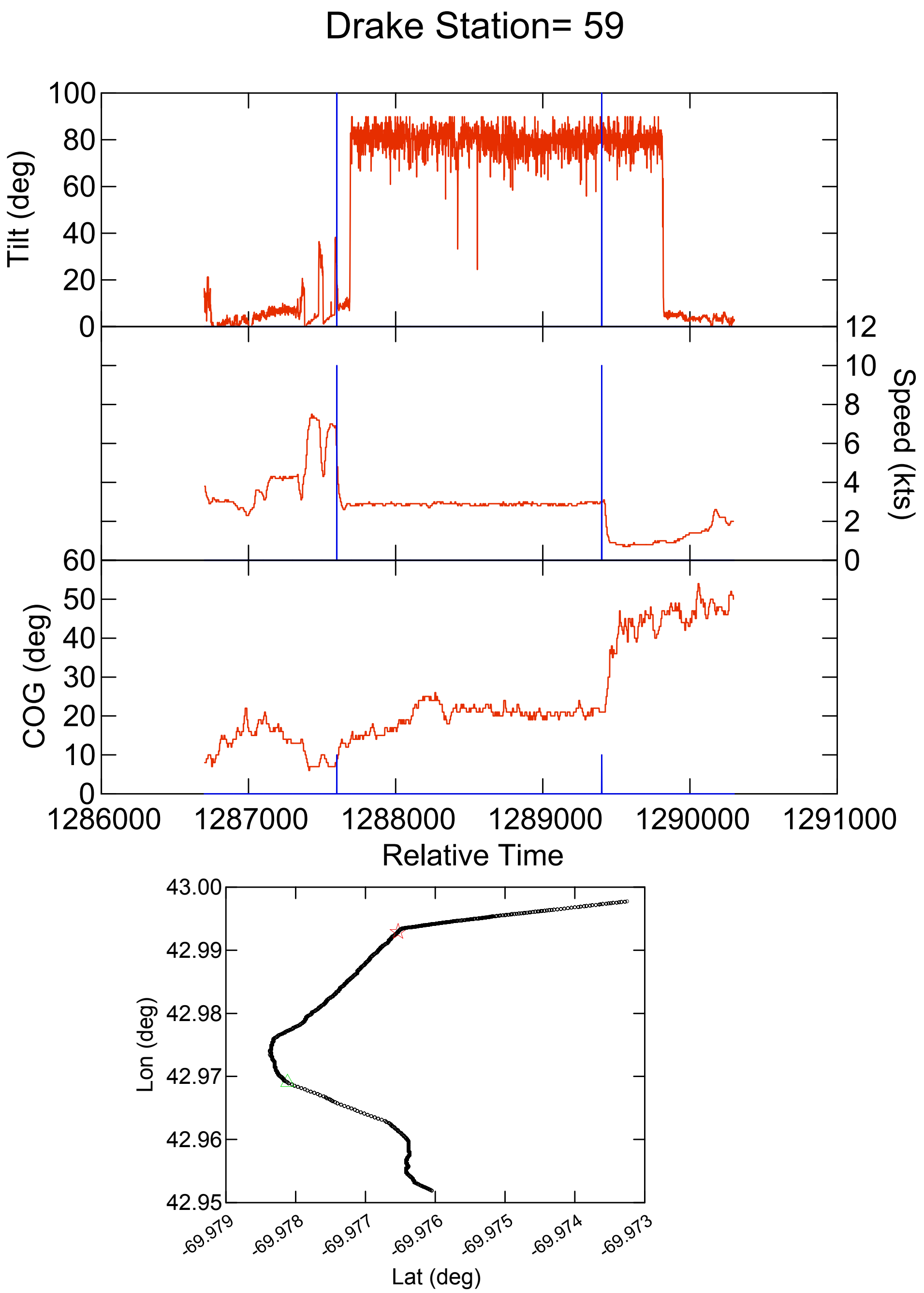


Figure C53. Example of sensor traces from a tow using net 1 on the Drake. From the top panel: inclinometer tilt angle, vessel speed, course over ground, and plot of ship's track. Triangle marks ship's position at start of tow, star marks position at end of tow.

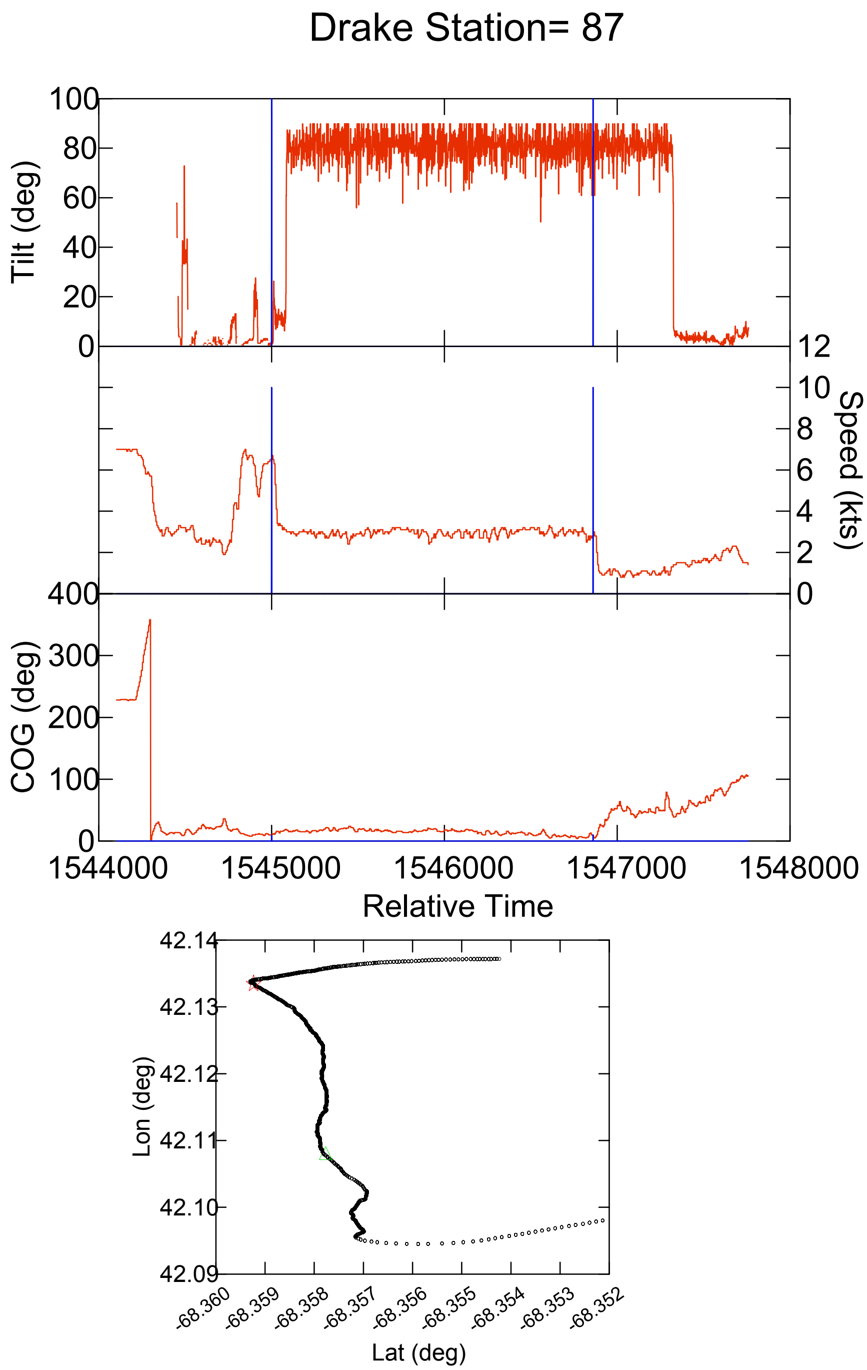
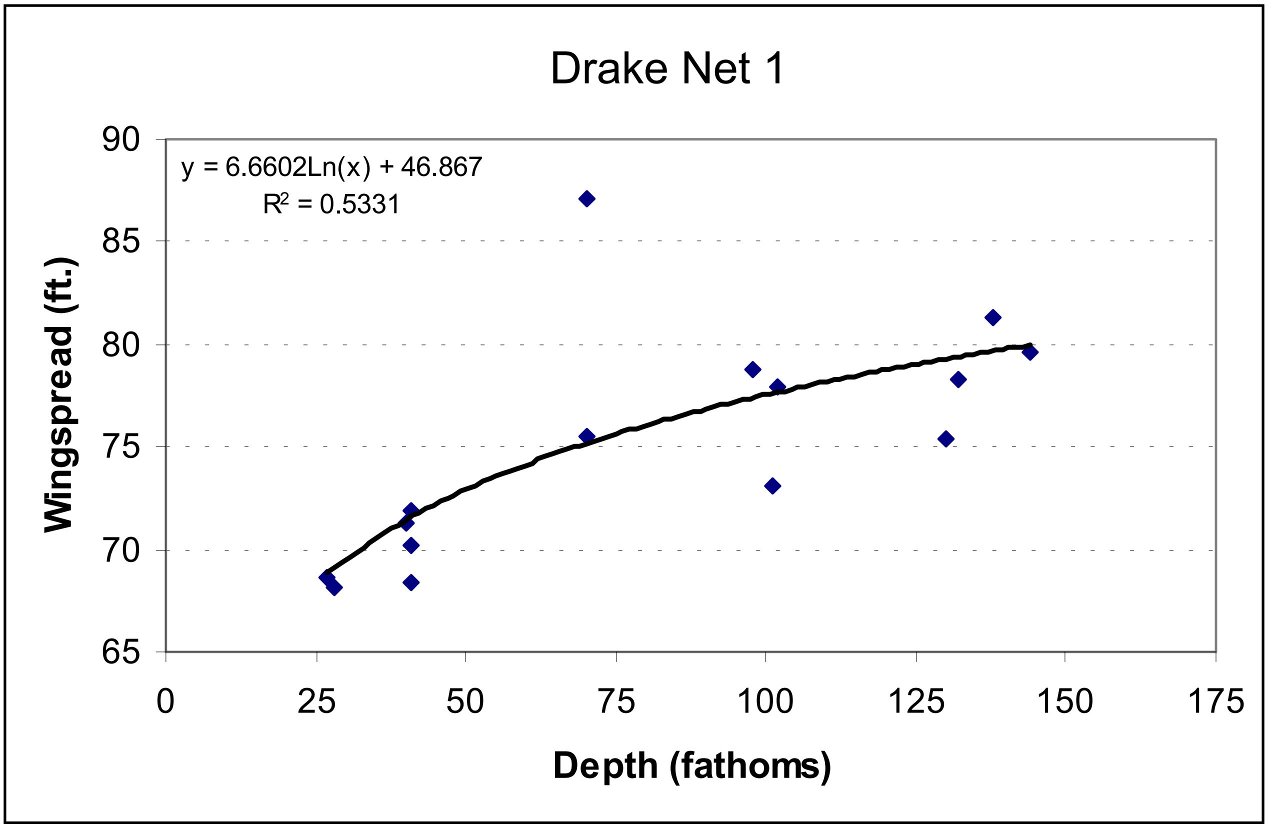


Figure C54. Example of sensor traces from a tow using net 2 on the Drake. From the top panel: inclinometer tilt angle, vessel speed, course over ground, and plot of ships track Triangle marks ship's position at start of tow, star marks position at end of tow.



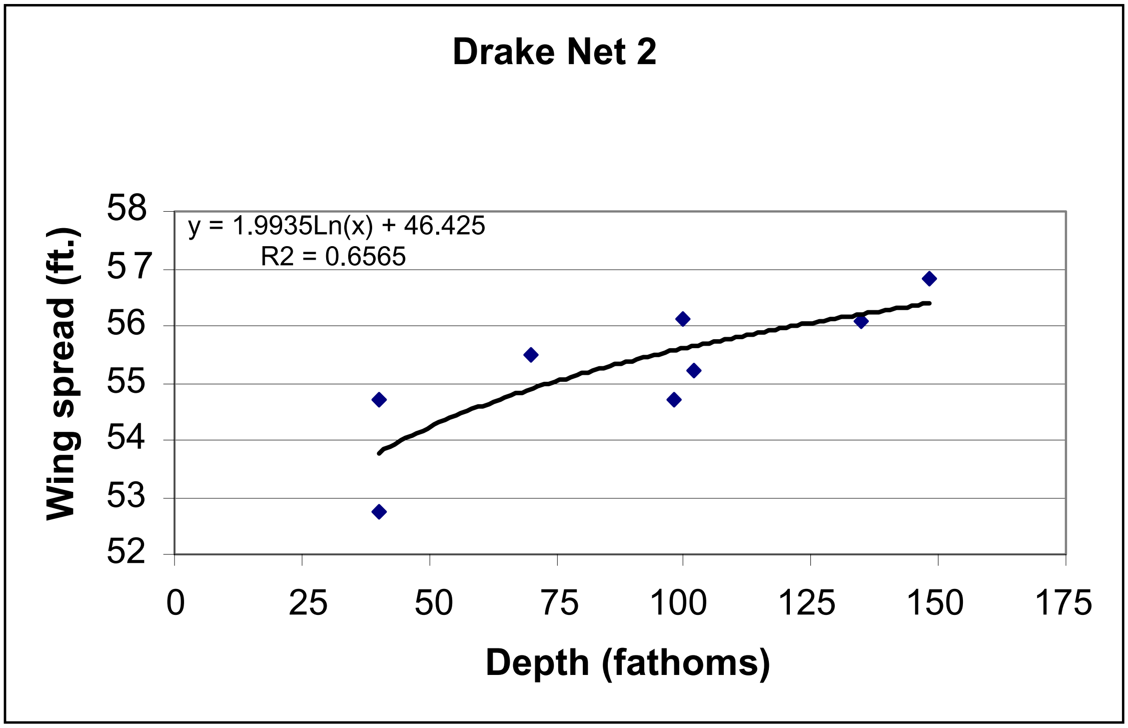


Figure C55. Wingspread vs. depth for Drake nets

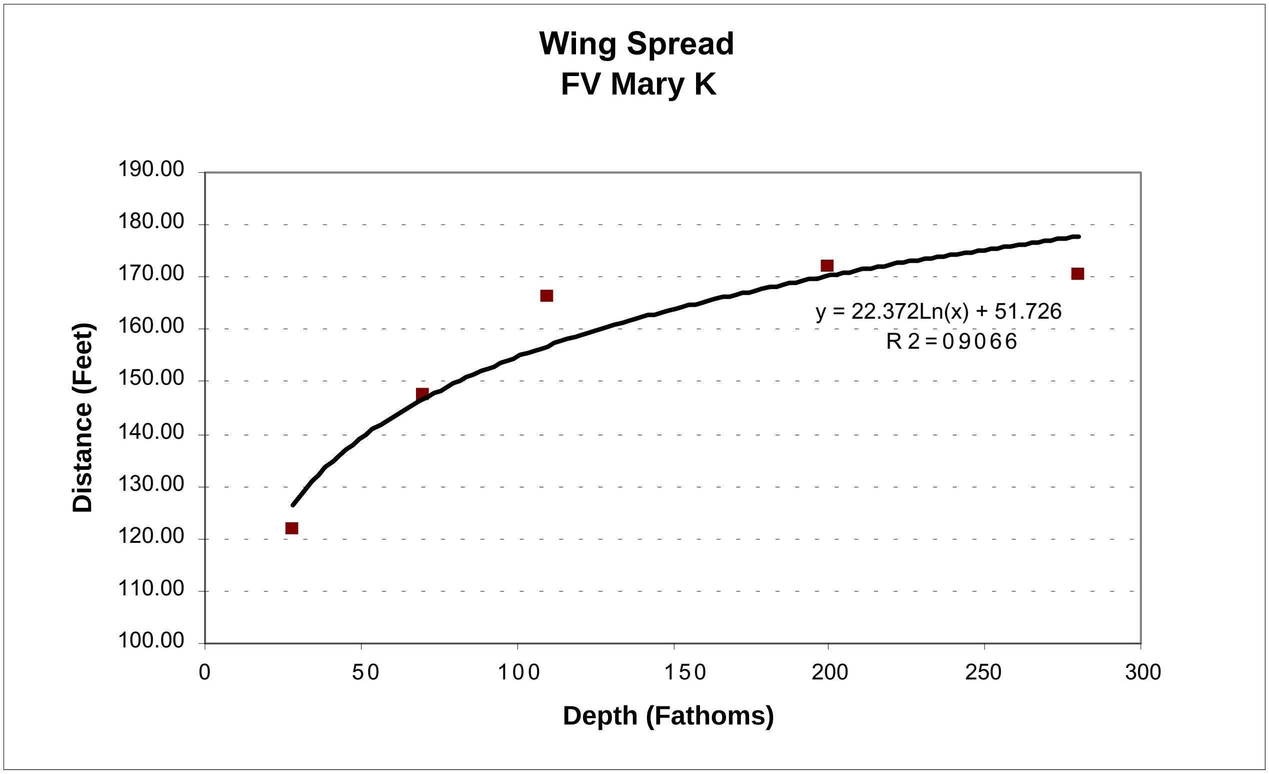


Figure C56. Wingspread-depth relationship for net used on the Mary K.

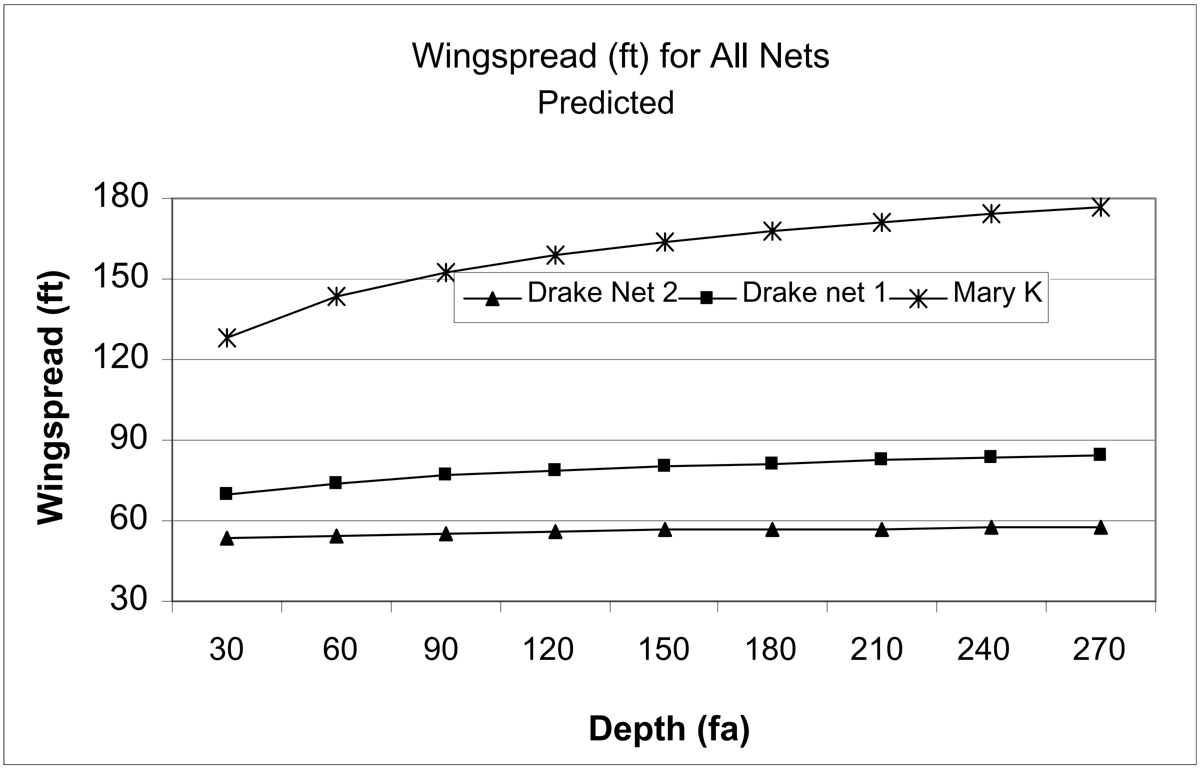
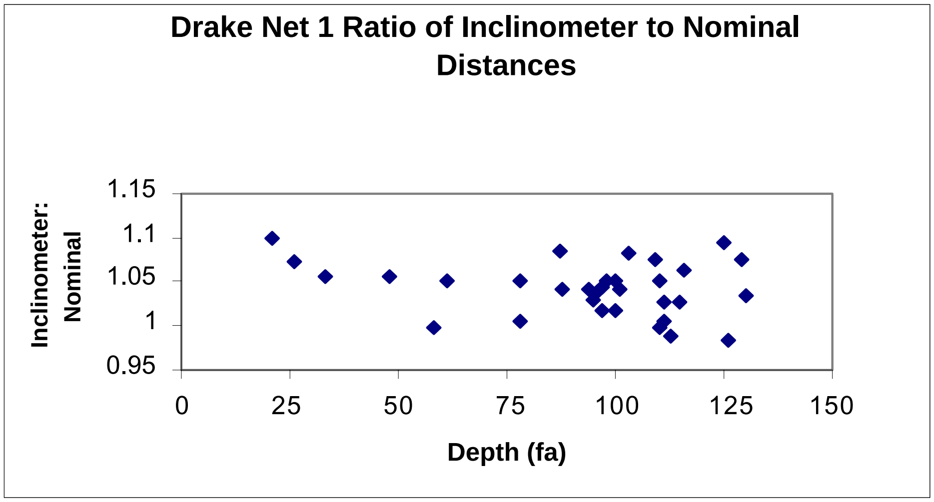
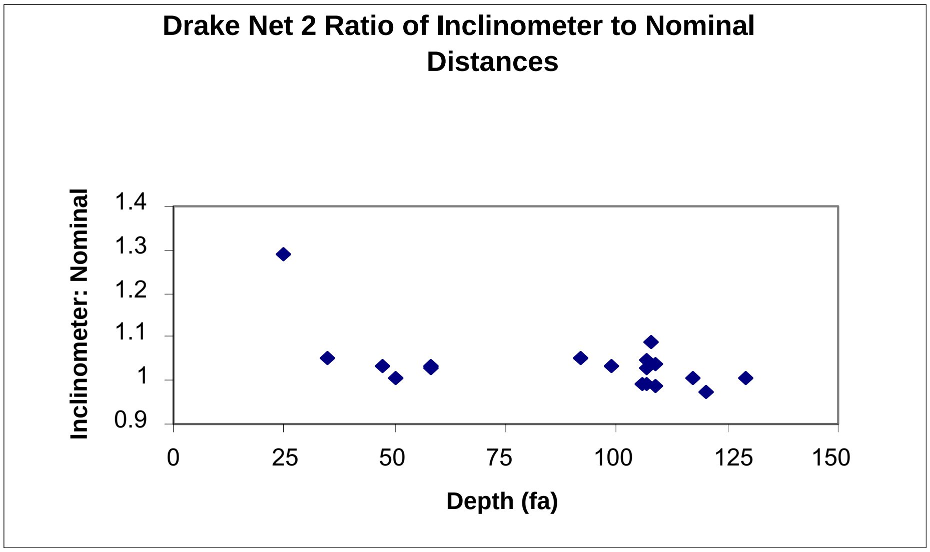


Figure C57. Wingspread-depth relationships for all 3 nets used in the cooperative monkfish survey.





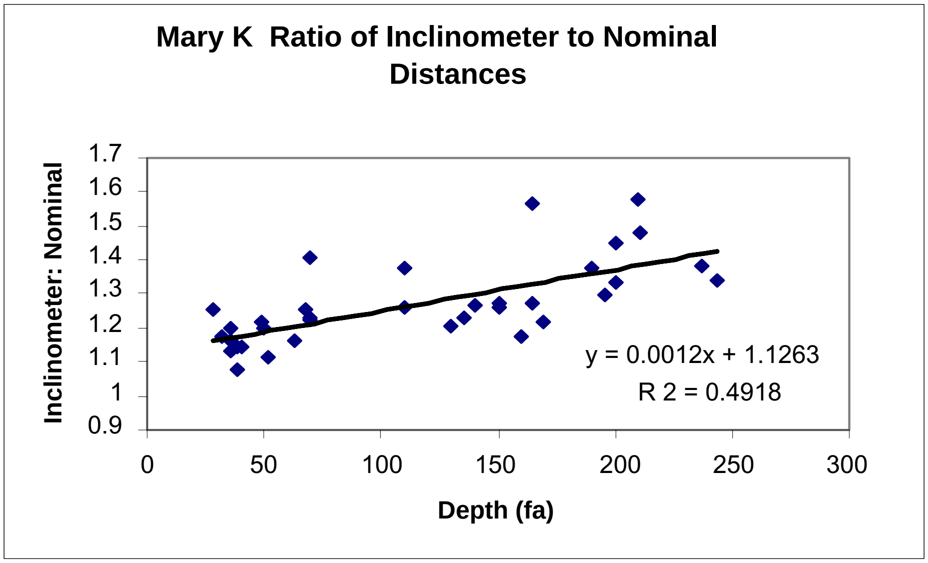


Figure C58. Ratio of inclinometer : nominal tow distances vs. depth for Drake and Mary K nets.

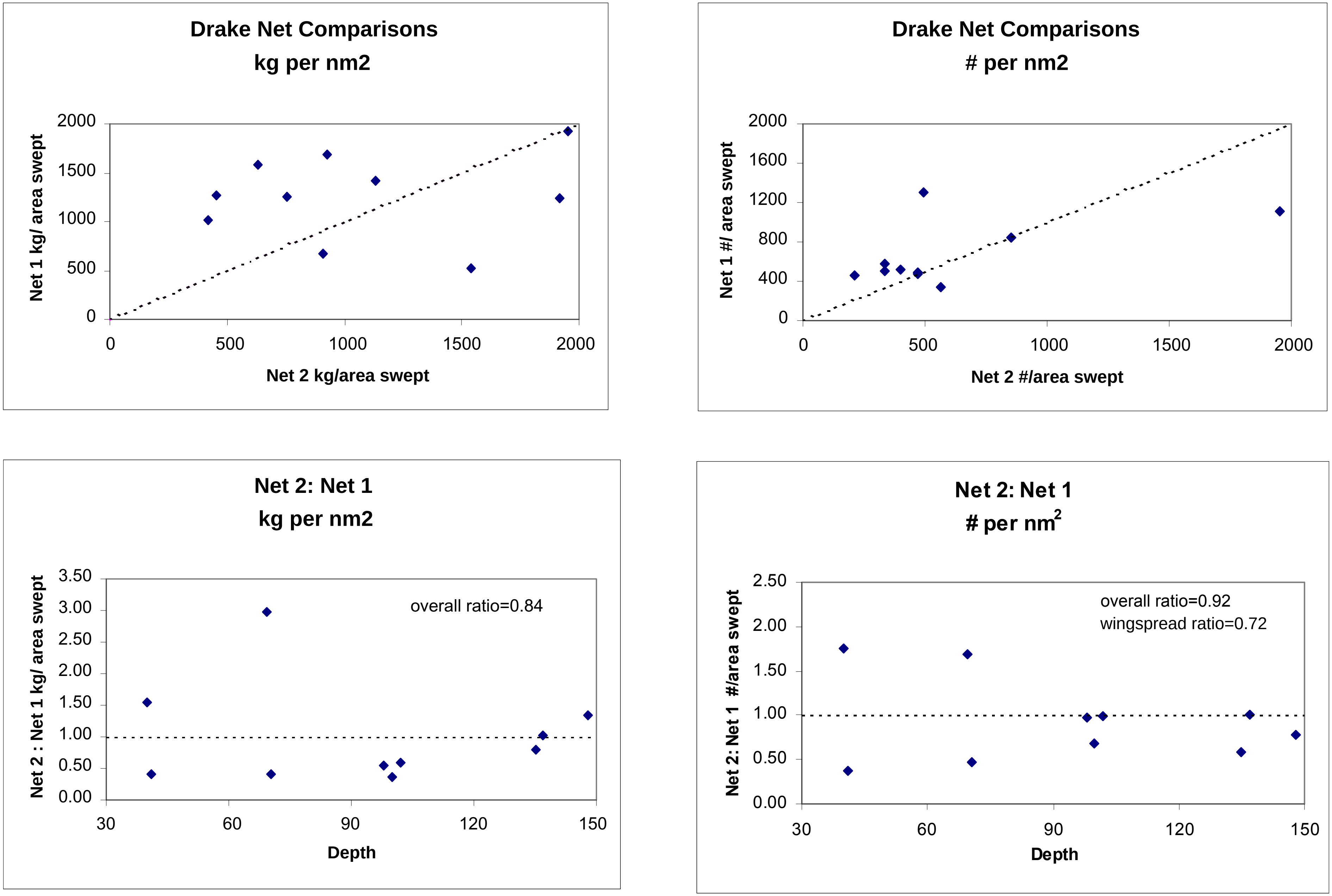


Figure C59. Results of calibration tows for Drake nets (10 tows each net).

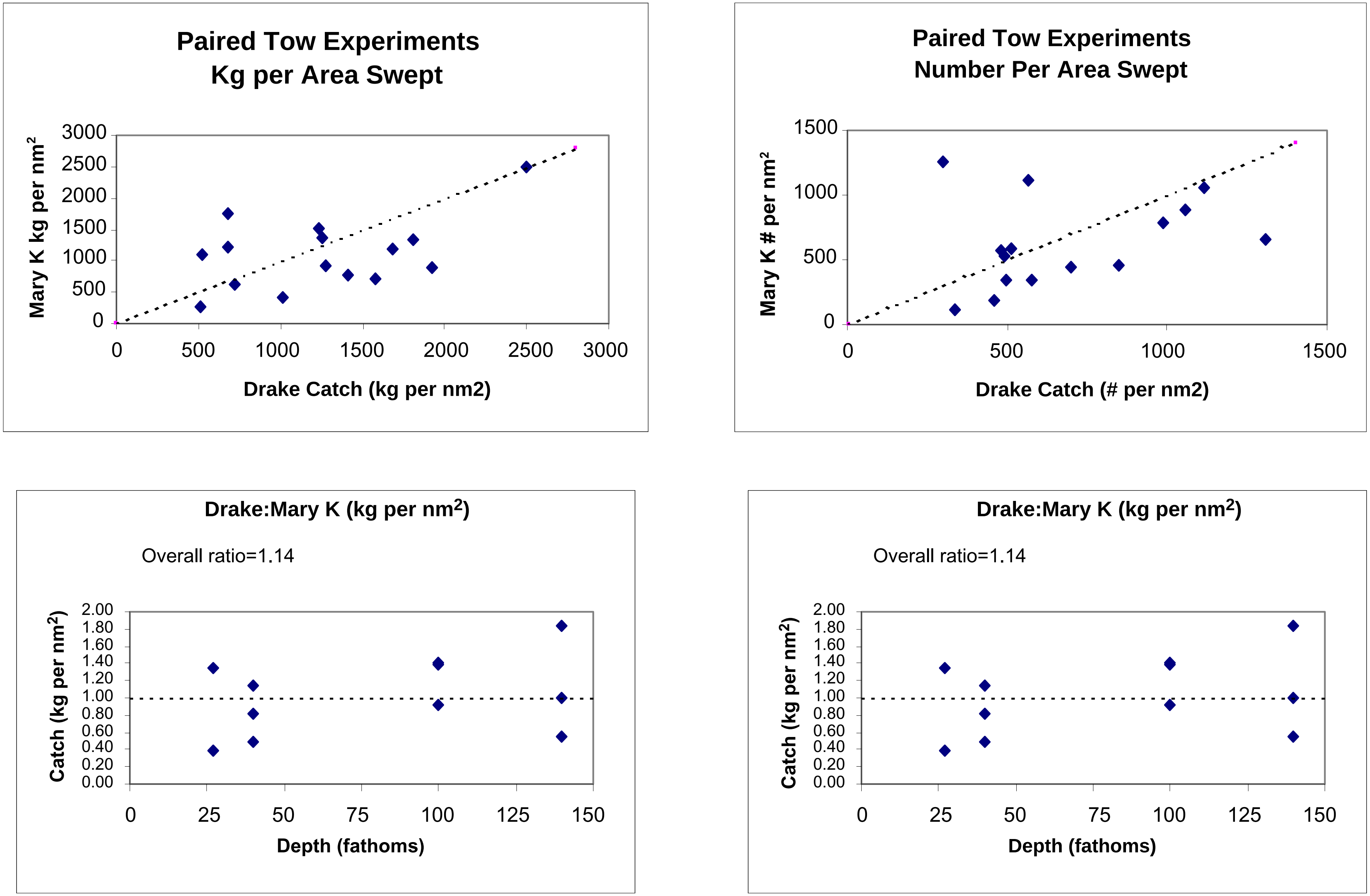


Figure C60. Comparison of catches in paired tows conducted by the Drake (net 1) and Mary K. Inclinometer distances assumed for Mary K and Drake tows.

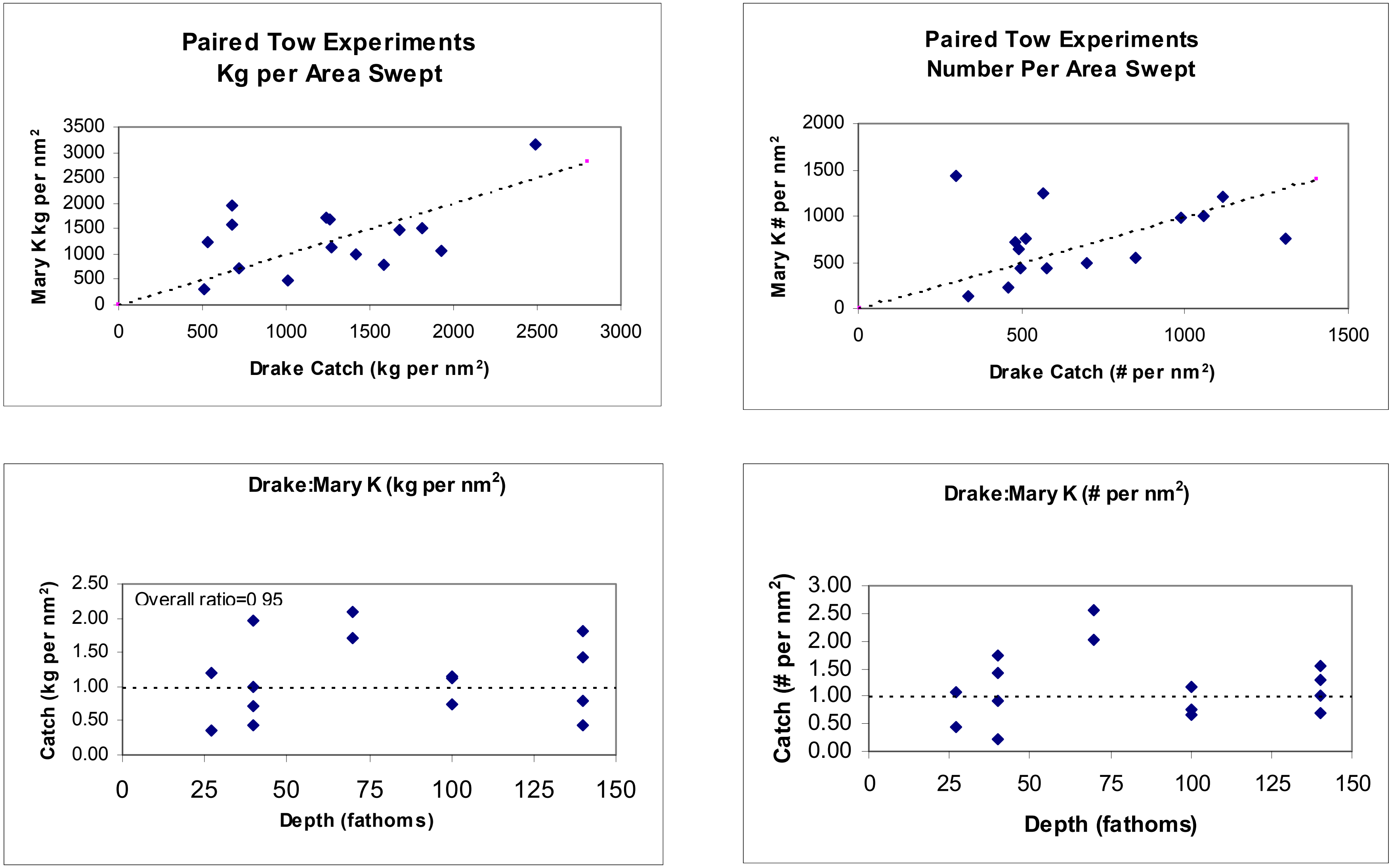


Figure C61. Comparison of catches in paired tows conducted by the Drake (net 1) and Mary K. Nominal distances assumed for Mary K tows.

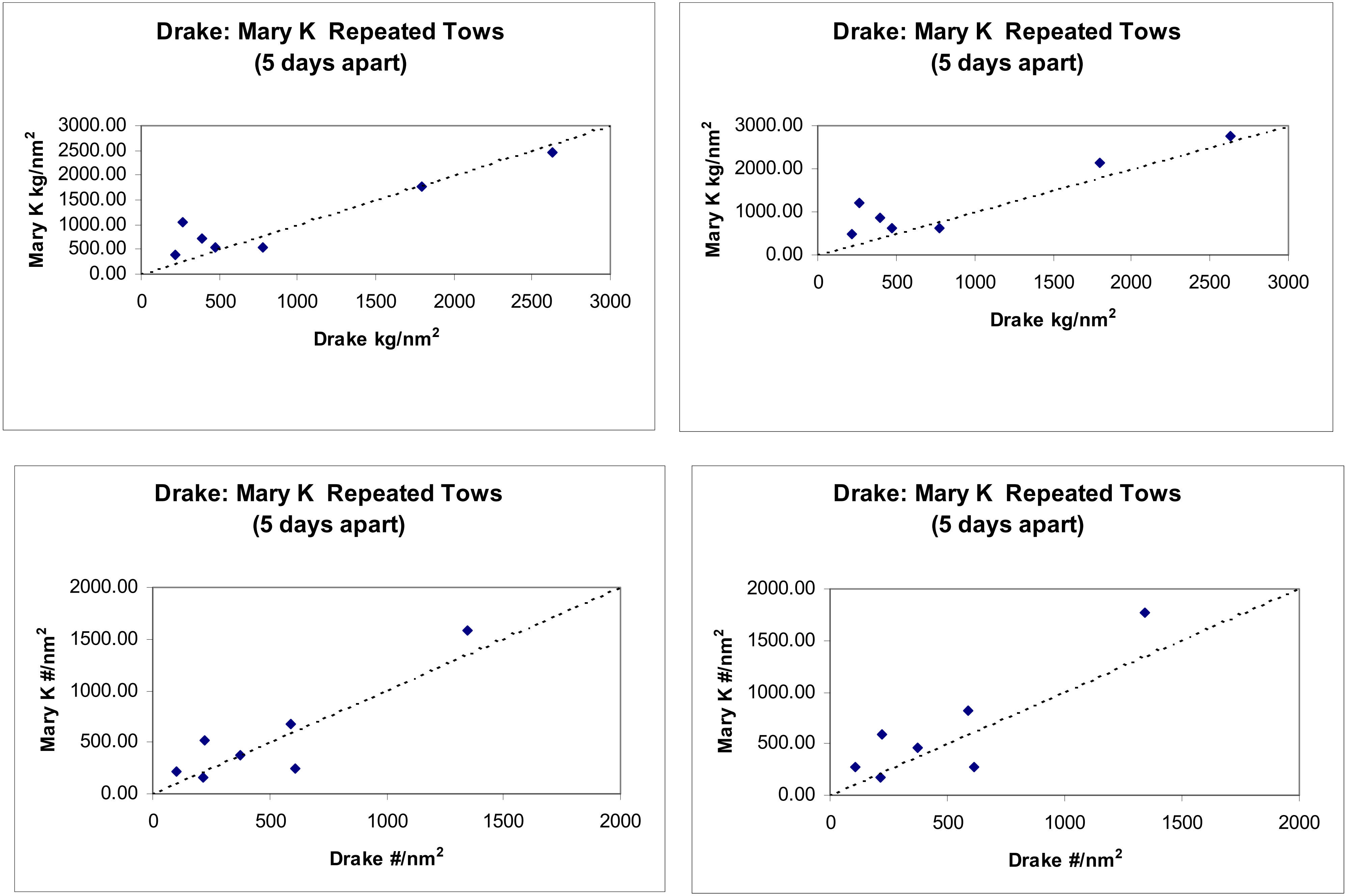


Figure C62. Results of repeated tow experiments where Mary K occupied Drake stations after approximately 5 days.

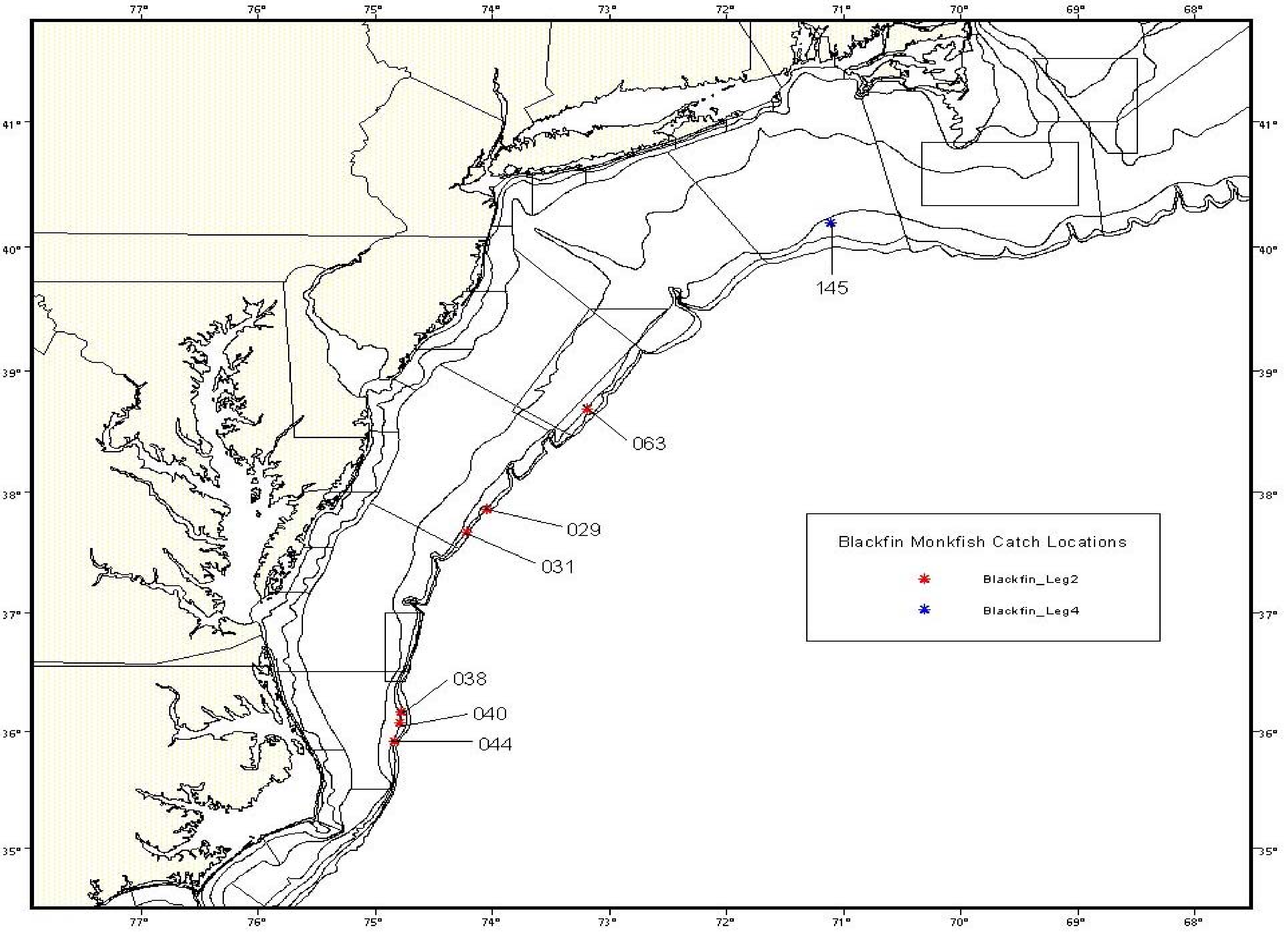


Figure C63. Locations of stations where blackfin monkfish were captured.

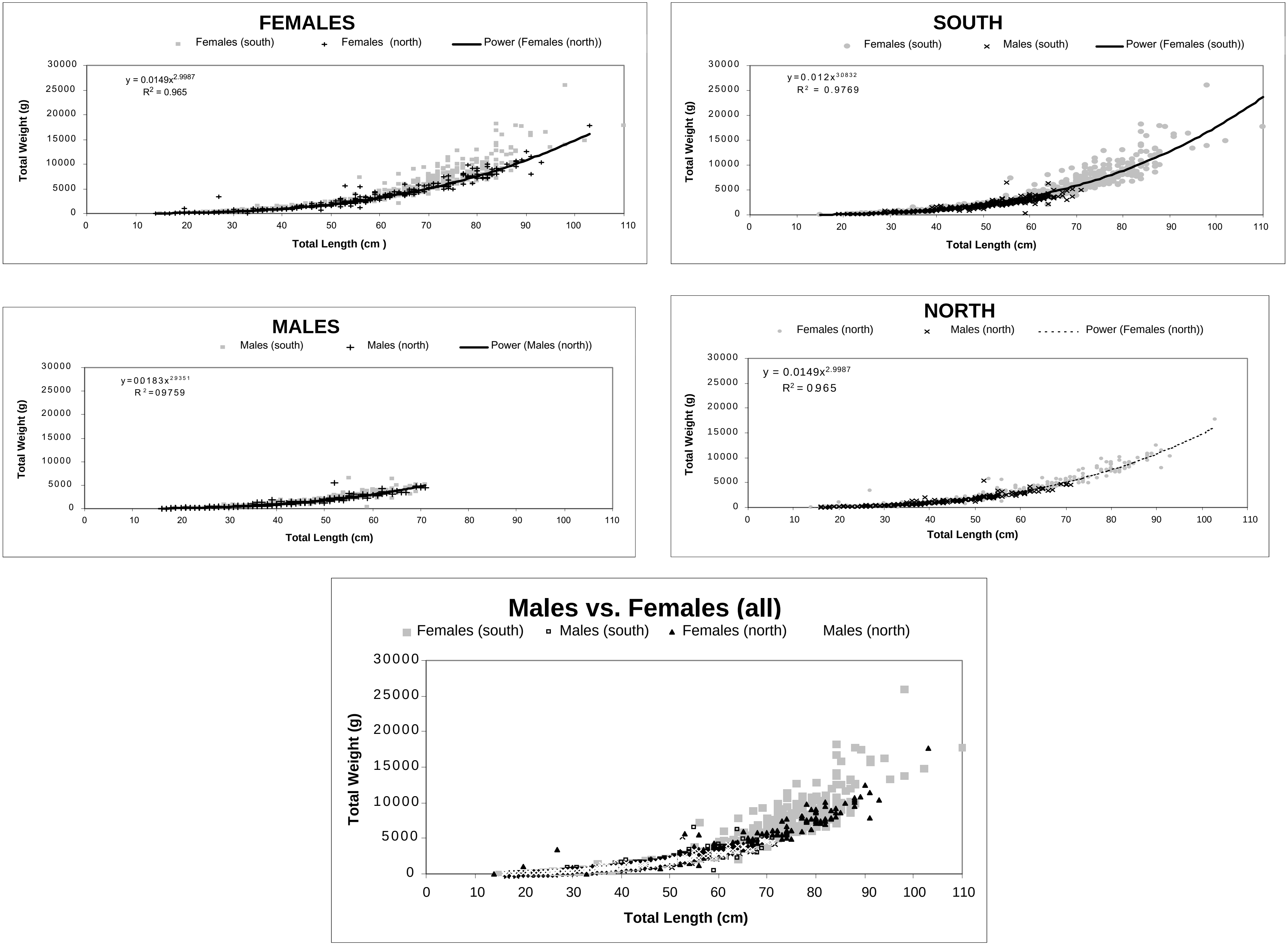


Figure C64. Length-weight relationships for monkfish captured during cooperative survey.

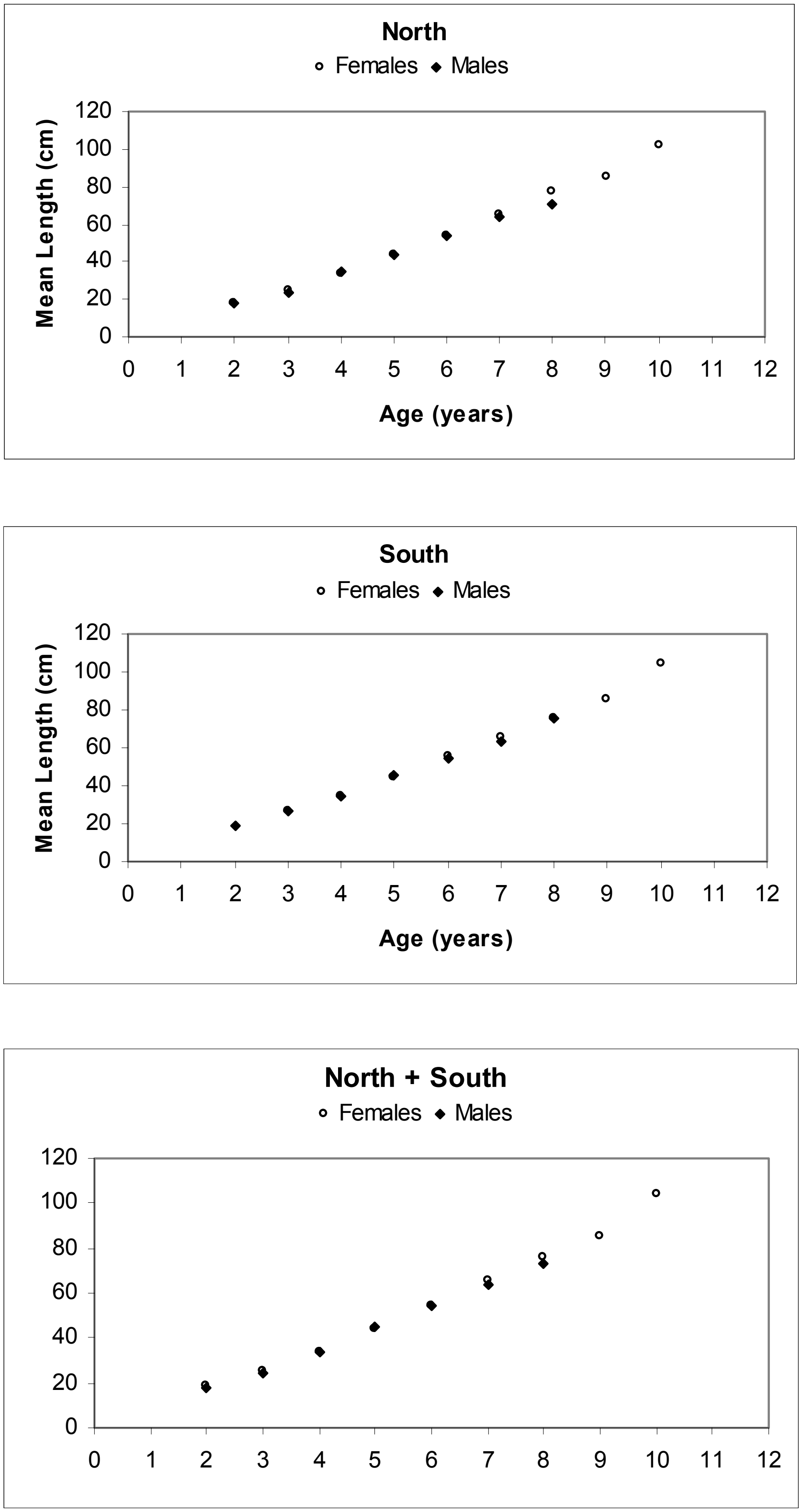
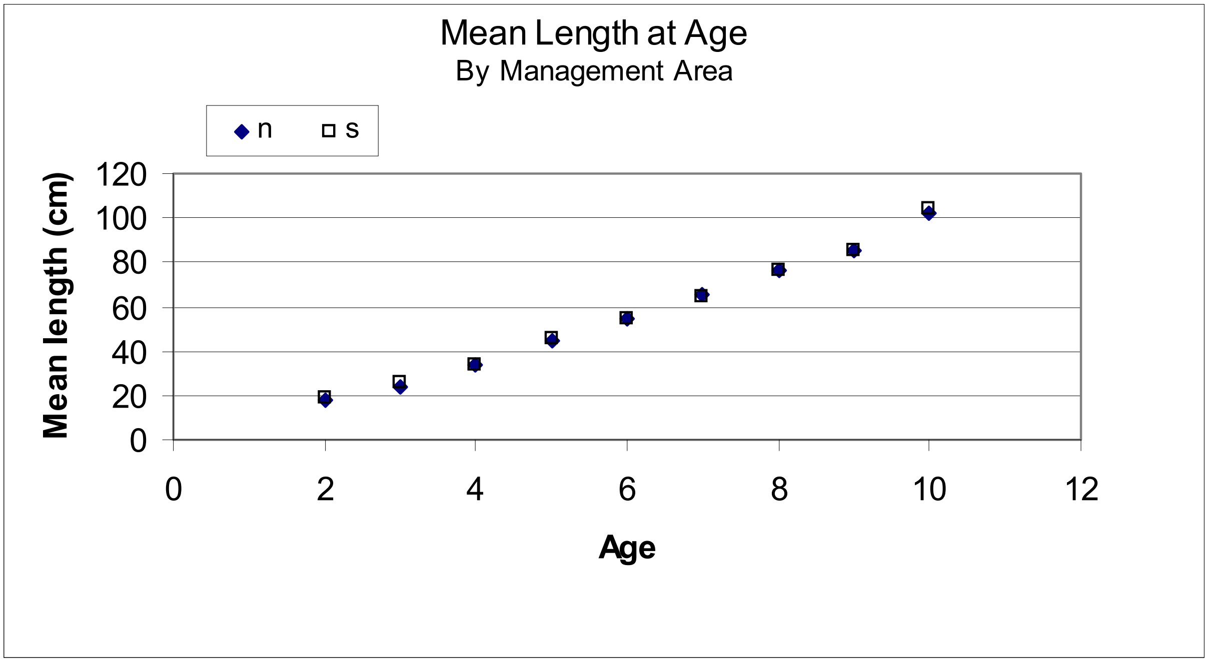


Figure C65. Age-length relationships for males and females by region.



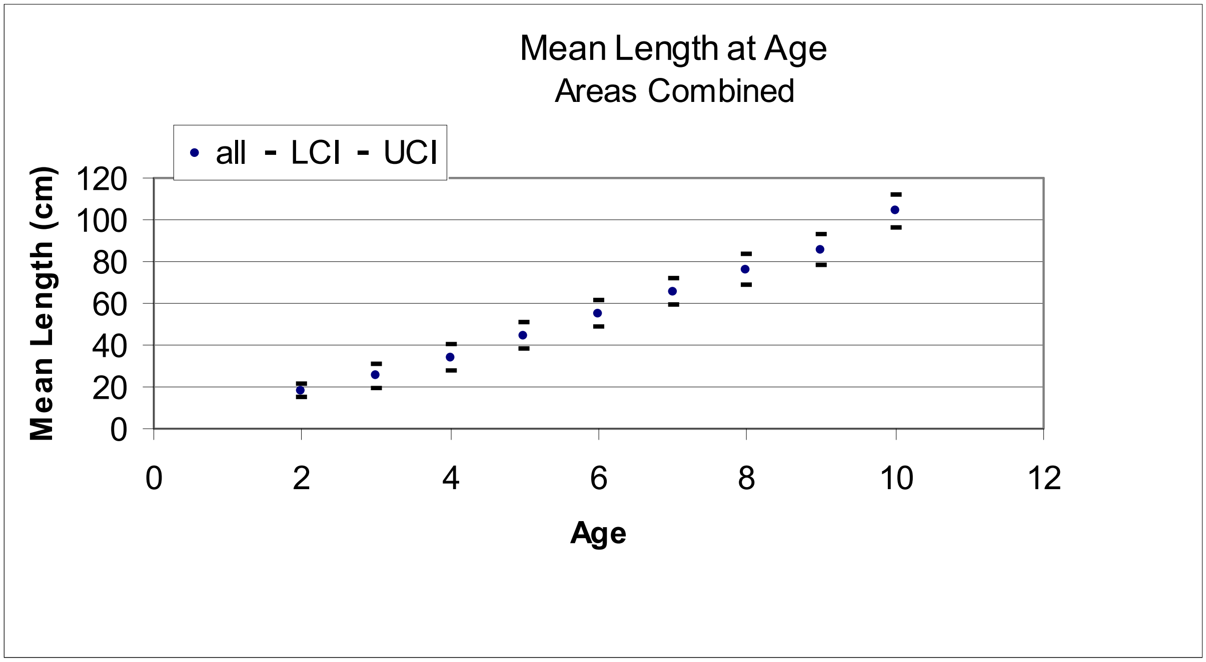
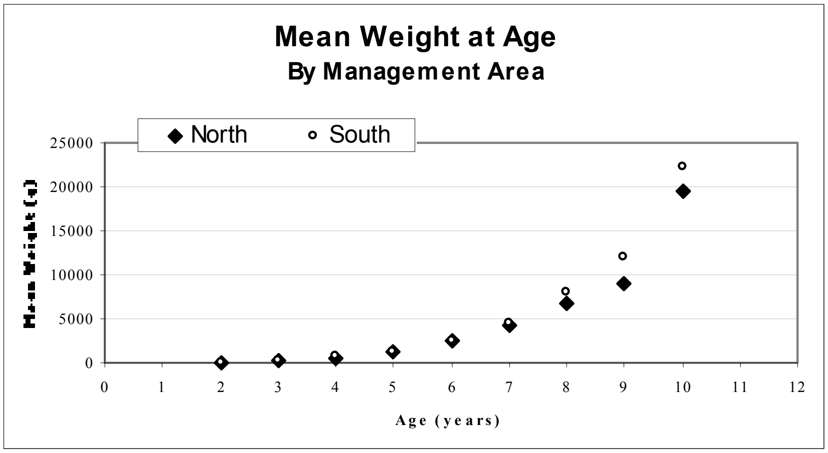


Figure C66. Mean length at age from cooperative survey data.
LCI=lower 95% confidence interval;
UCI= upper 95% confidence interval.



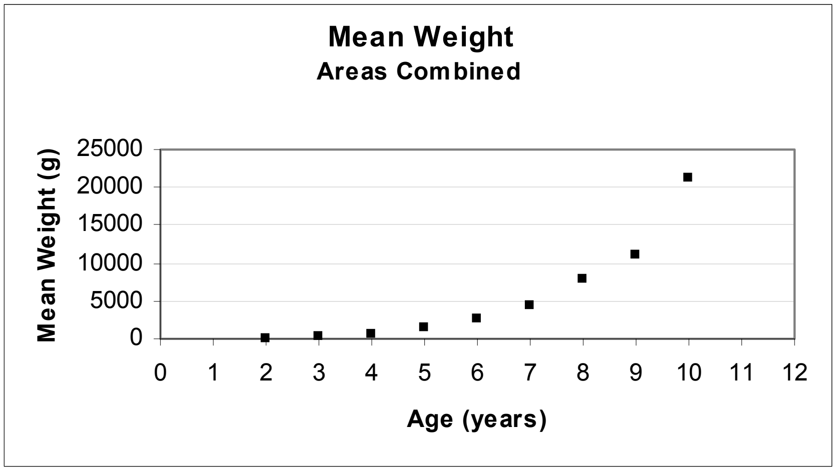
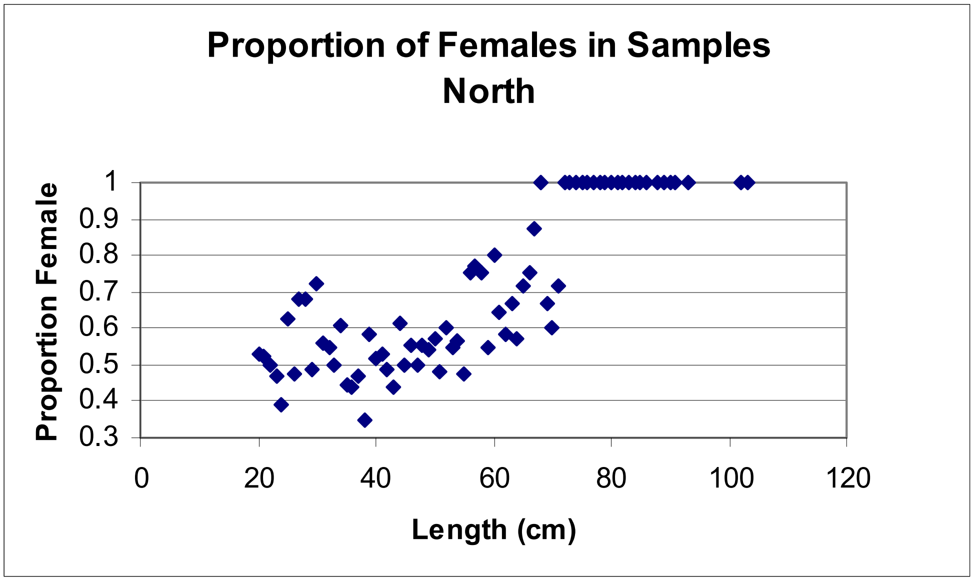


Figure C67. Mean goosefish weight at age, by region from cooperative survey.



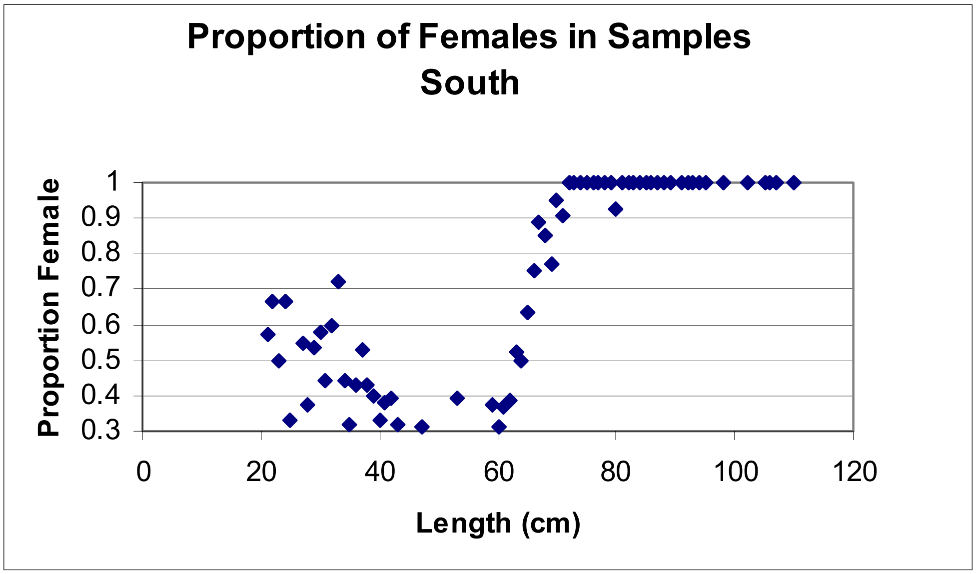


Figure C68. Proportion of females at length by management area.

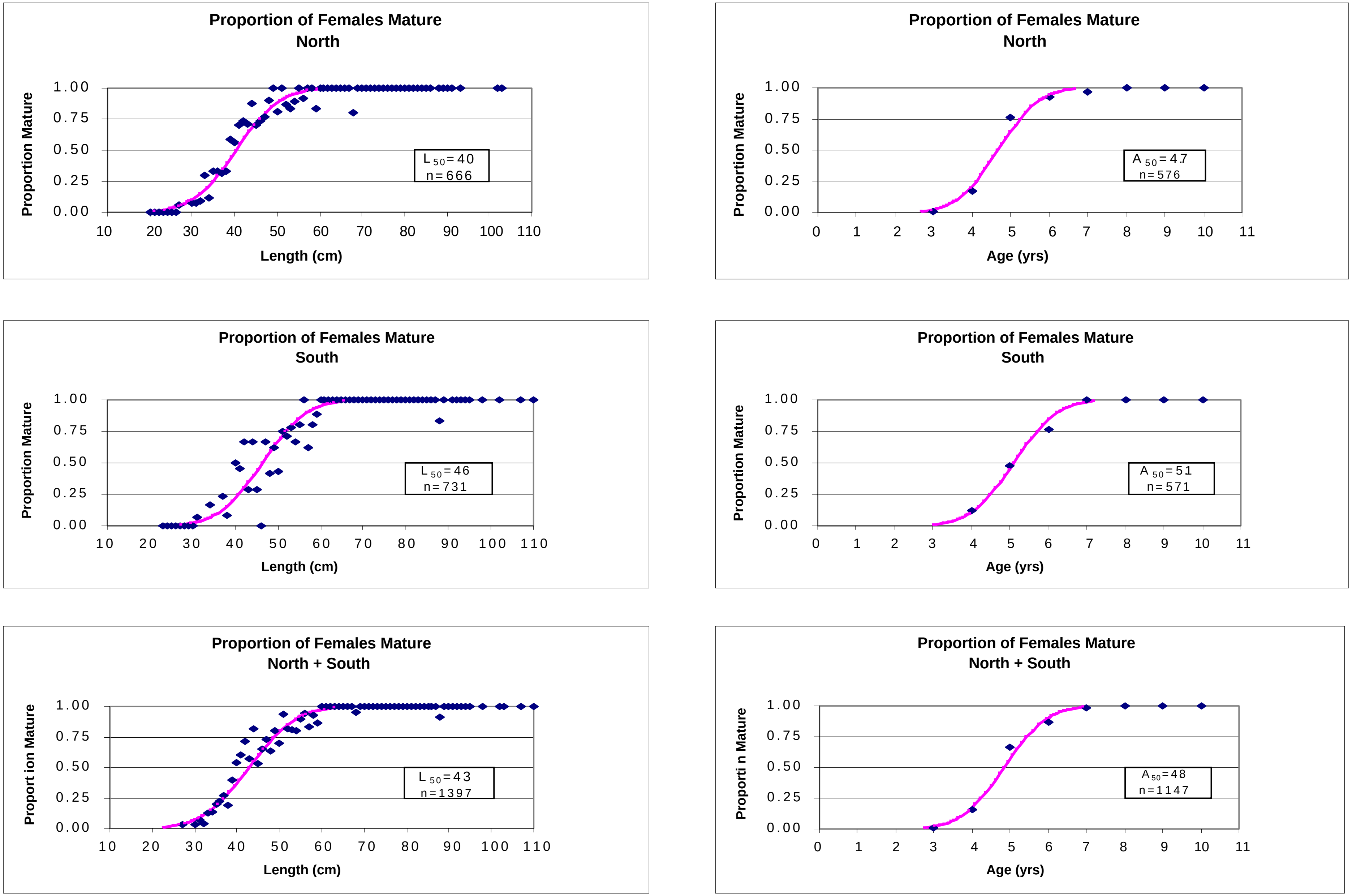


Figure C69. Proportion of females mature at length and age, by region and by areas combined.

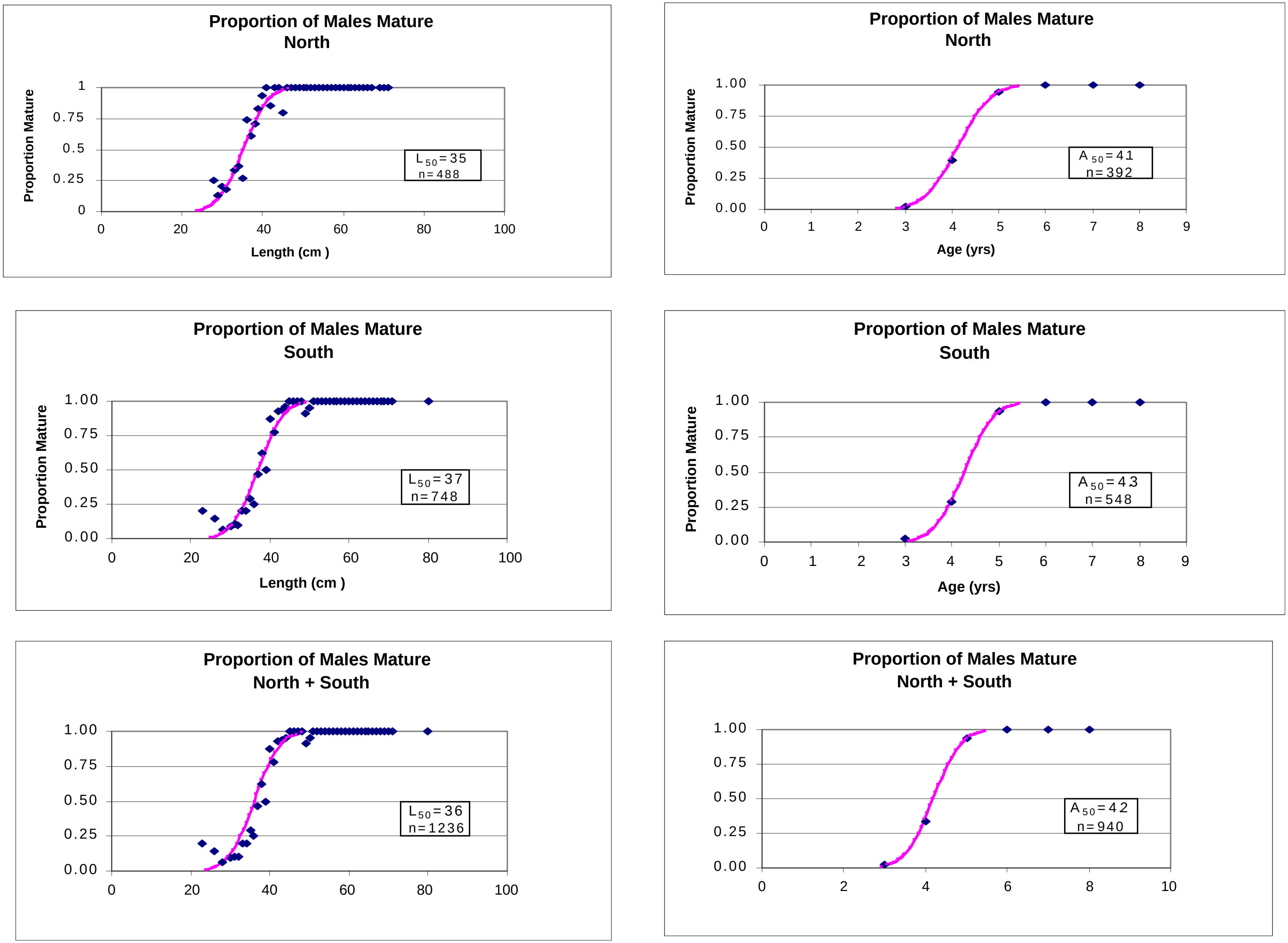
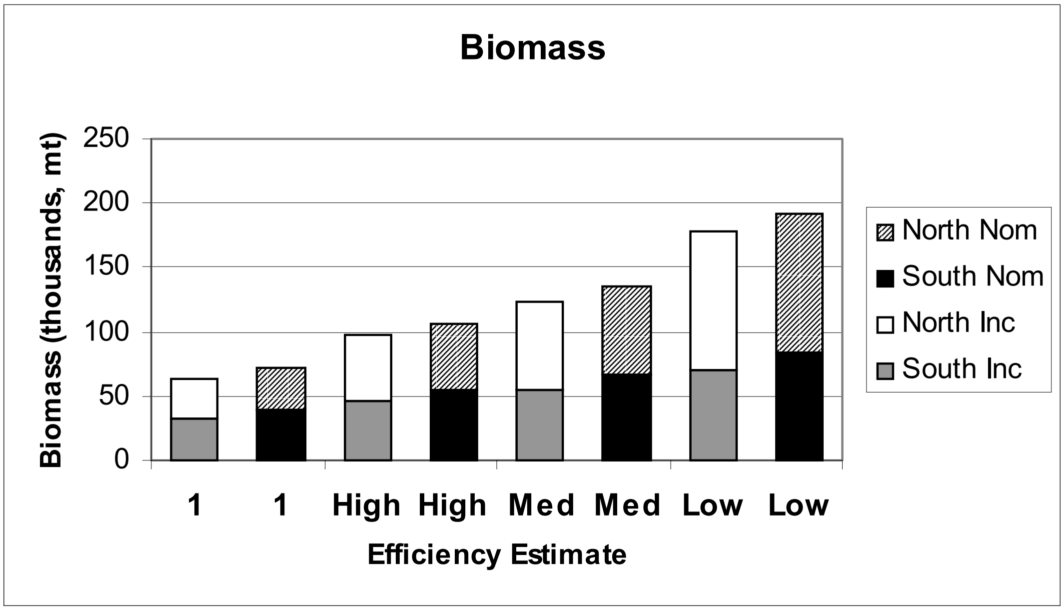


Figure C70. Proportion of males mature at length and age, by region and by areas combined.



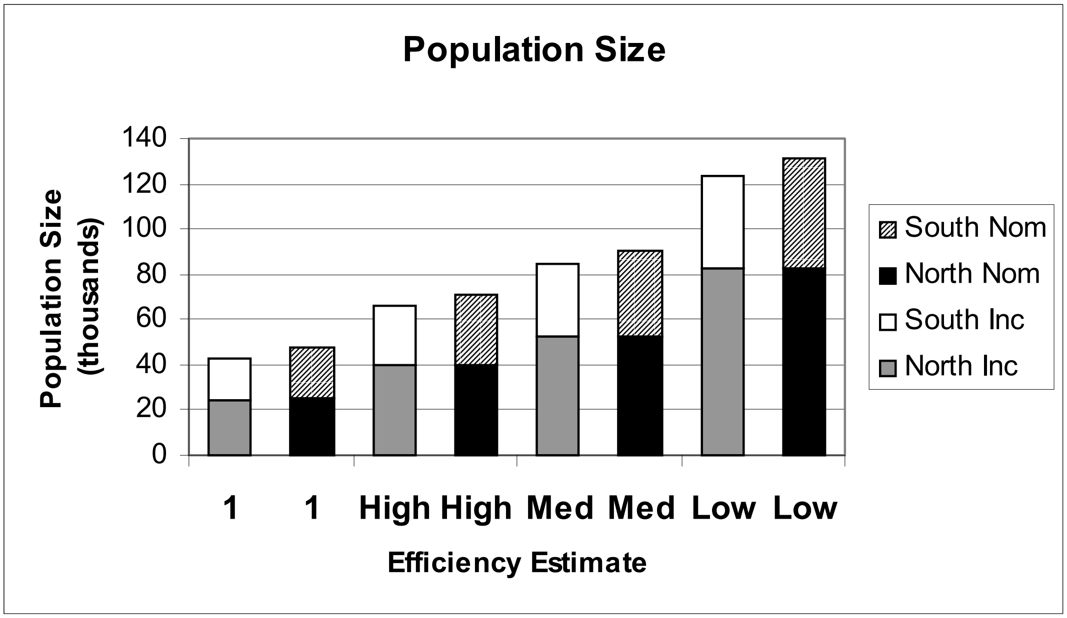


Figure C71. Biomass and population size estimates from cooperative surveys under varying assumptions of net efficiency, calculated using inclinometer and nominal distances for the Mary K. Nom = nominal distance assumed, Inc = inclinometer distance assumed.

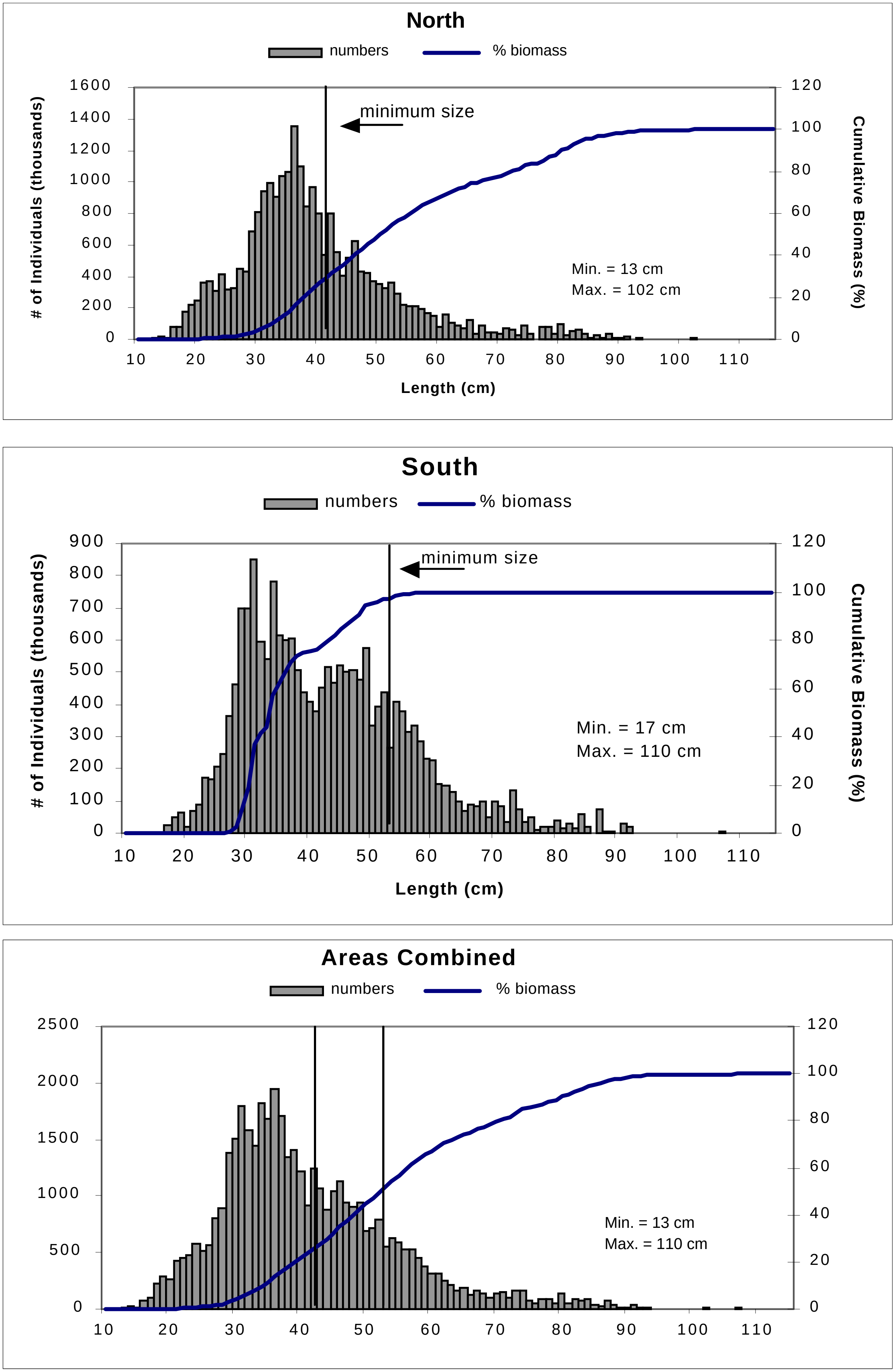


Figure C72. Length frequency of monkfish population based on cooperative survey, area swept from inclinometer tows, with cumulative biomass shown.

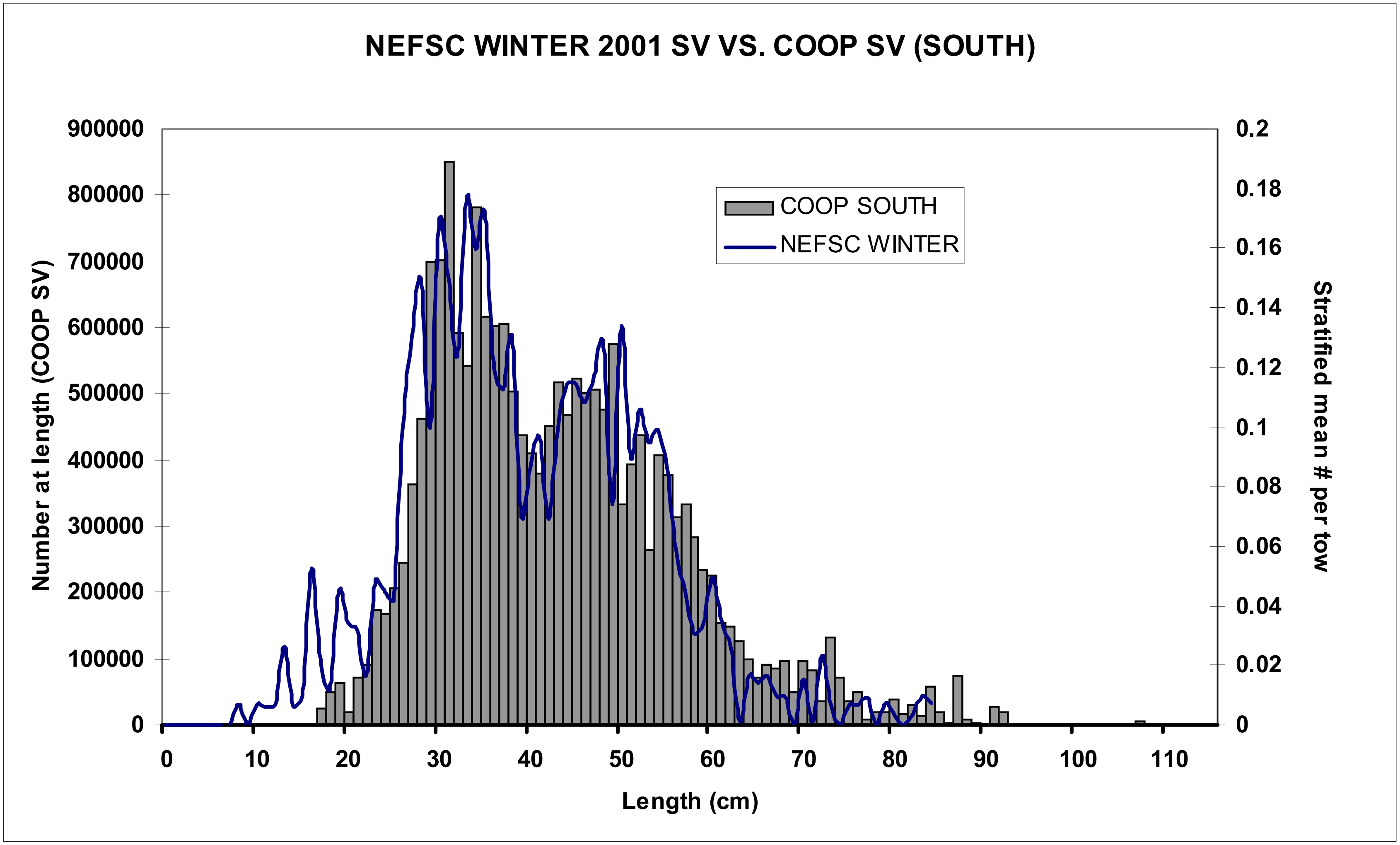


Figure C73. Comparison of length frequency distribution of monkfish estimated from the NEFSC winter survey 2001 and the cooperative industry survey.

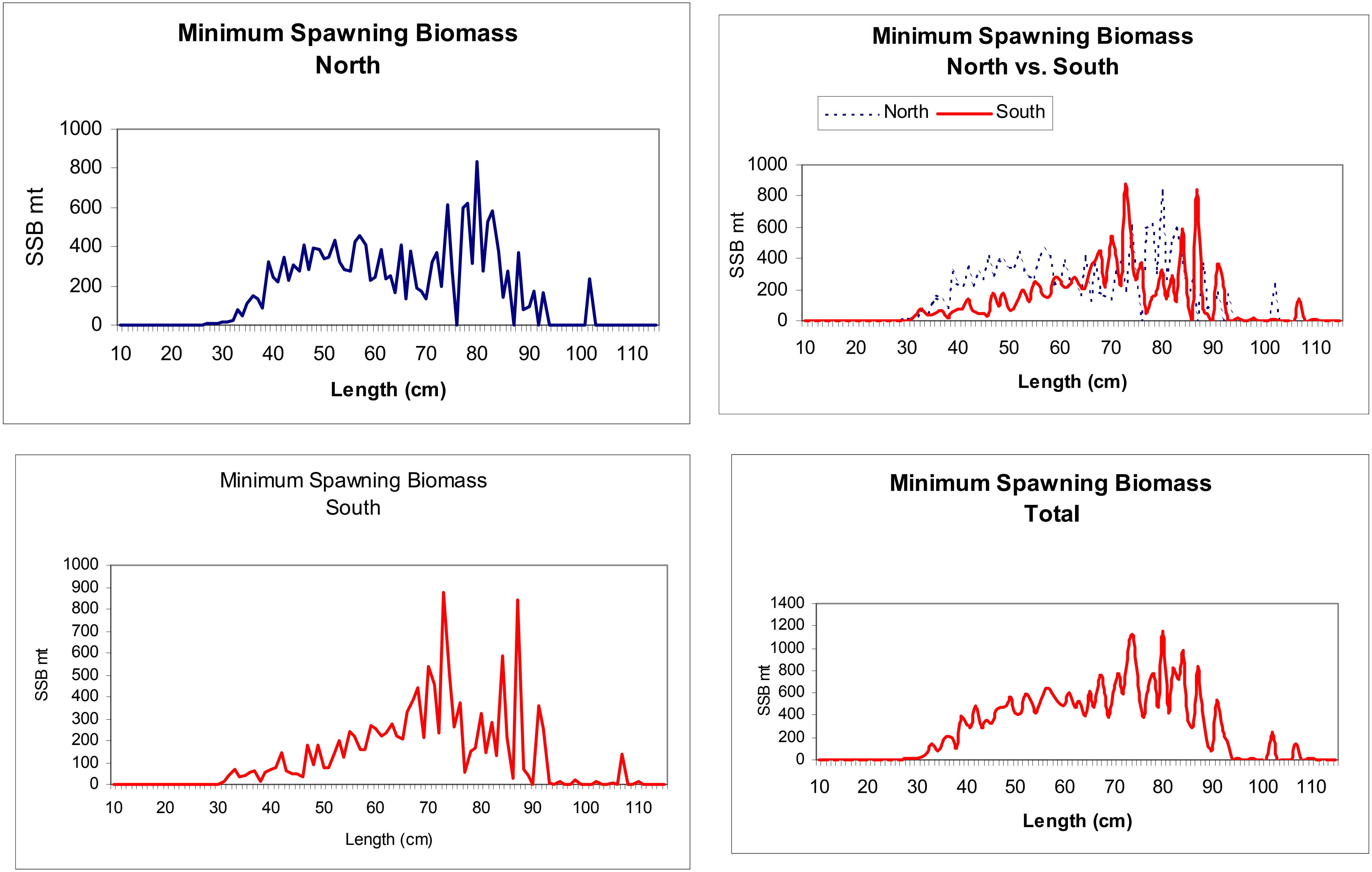


Figure C74. Minimum spawning biomass estimated from cooperative survey data.

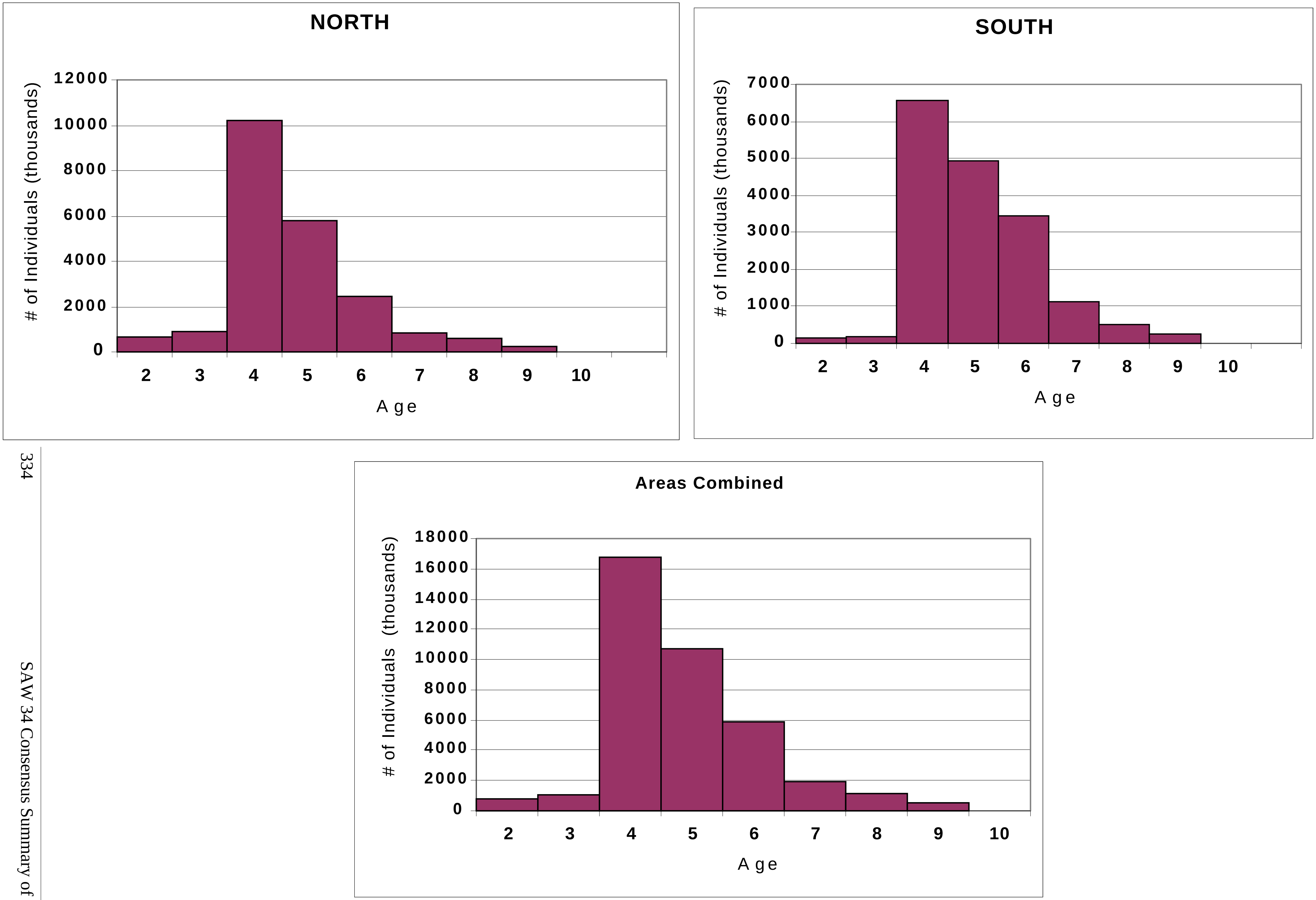


Figure C75. Minimum number of goosefish by age from cooperative survey, inclinometer distances used to calculate numbers in population.

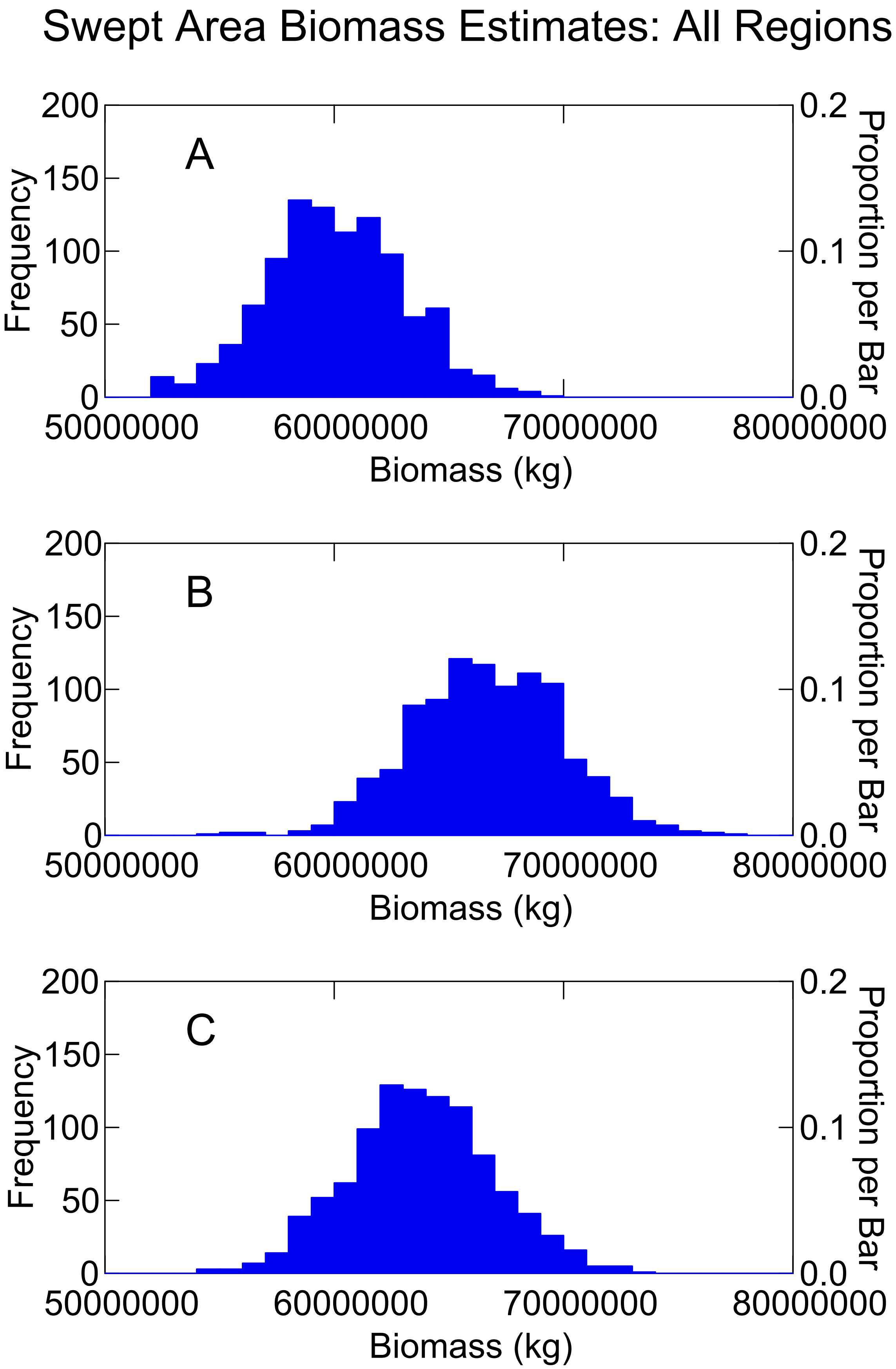


Figure C76. Distribution of bootstrap estimates of area swept biomass for management regions combined

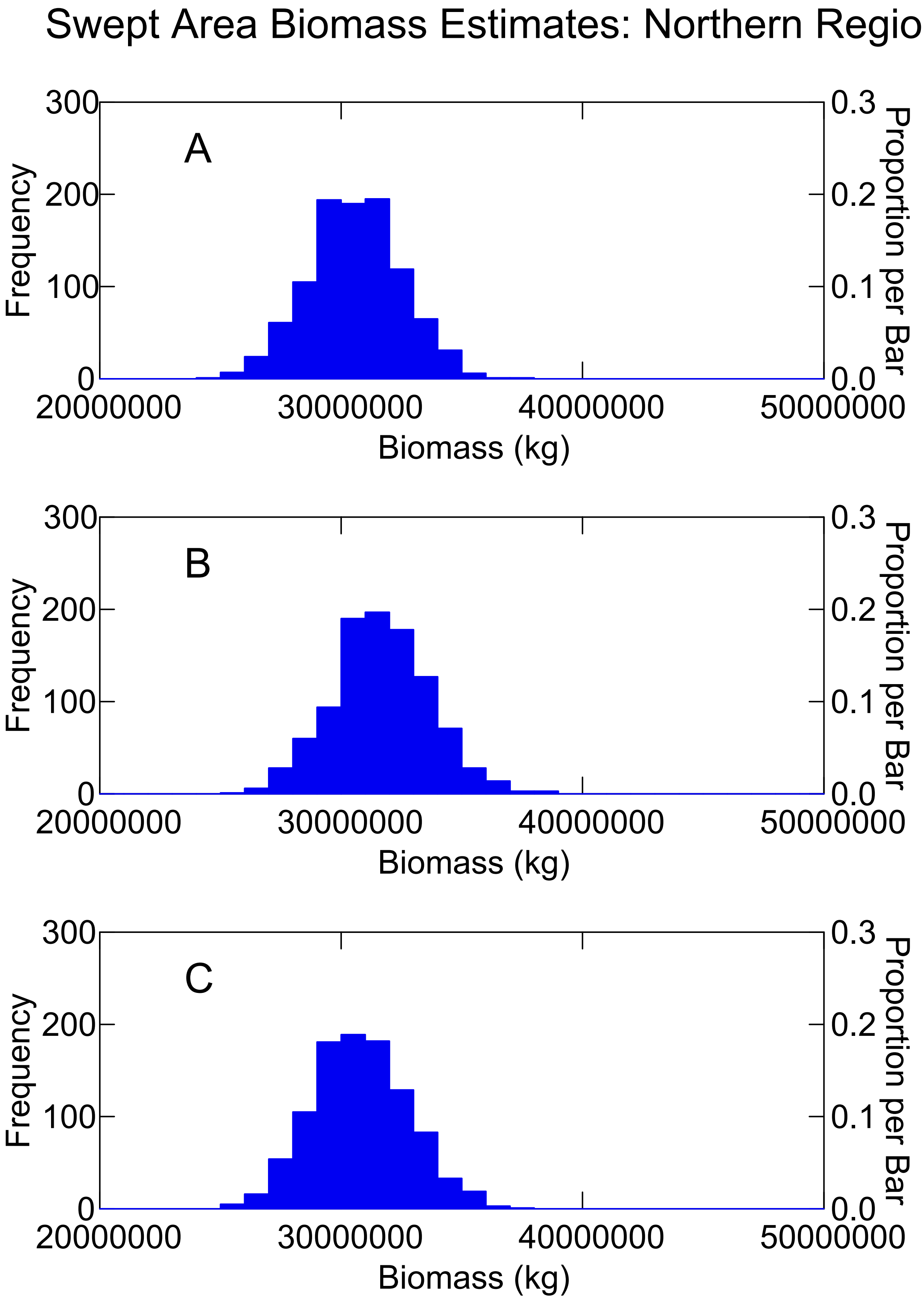


Figure C77. Distribution of bootstrap estimates of area swept biomass for the northern management region.

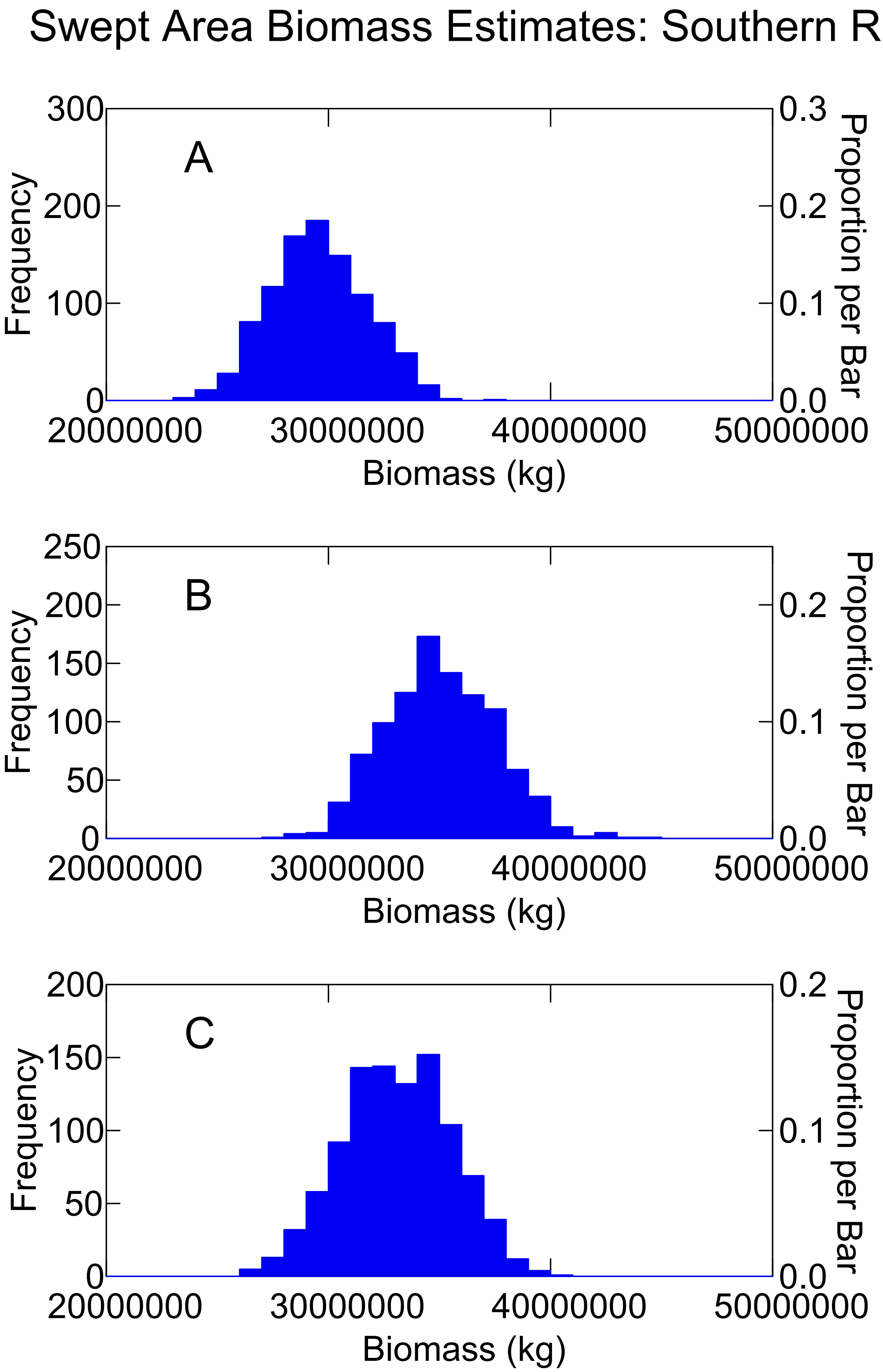


Figure C78. Distribution of bootstrap estimates of area swept biomass for the southern management region.

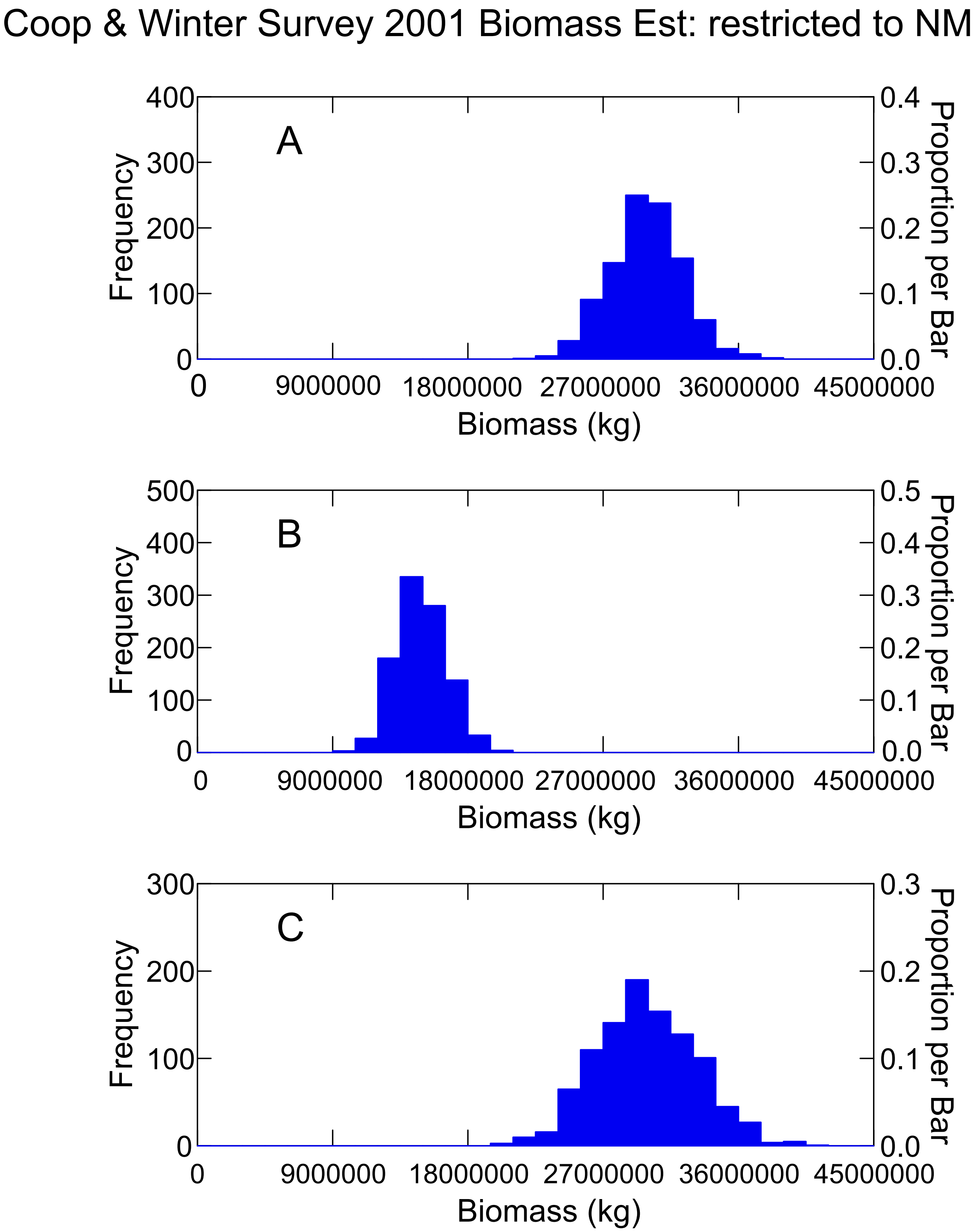
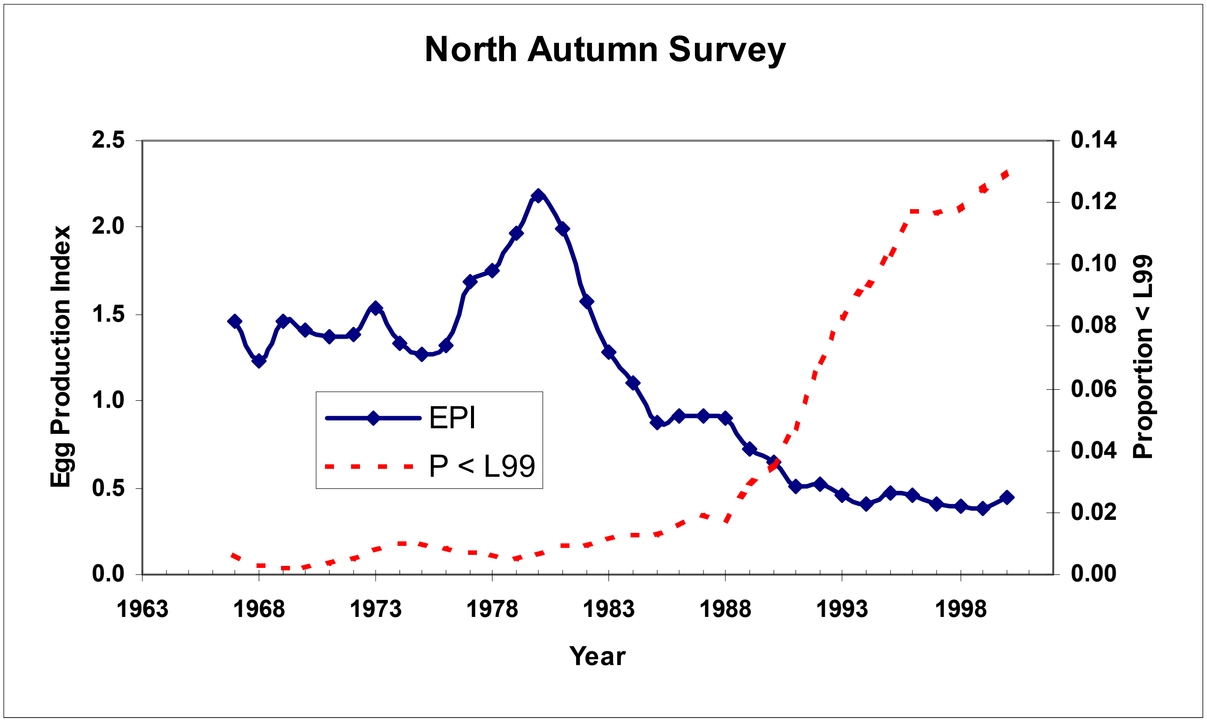


Figure C79. Distribution of bootstrap estimates of area swept biomass for NMFS Winter survey and the cooperative survey (subsetted to match aerial coverage of NMFS winter survey).



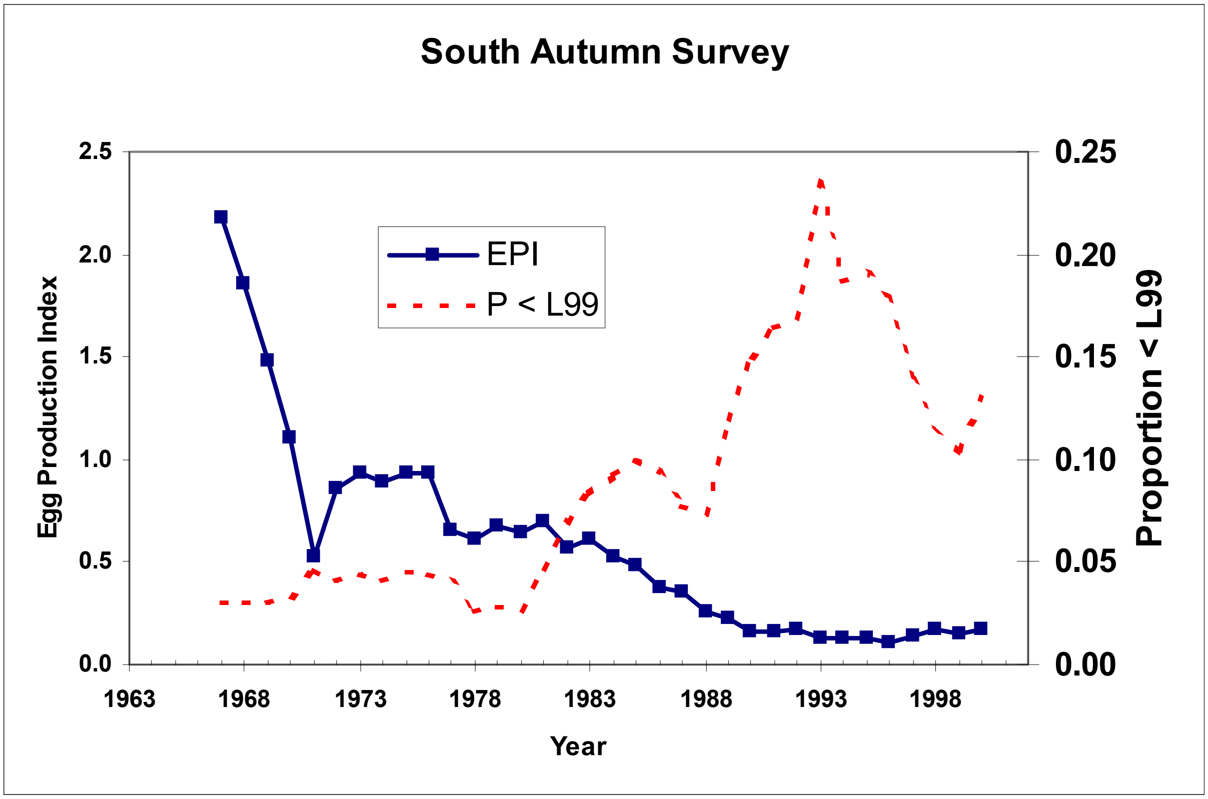
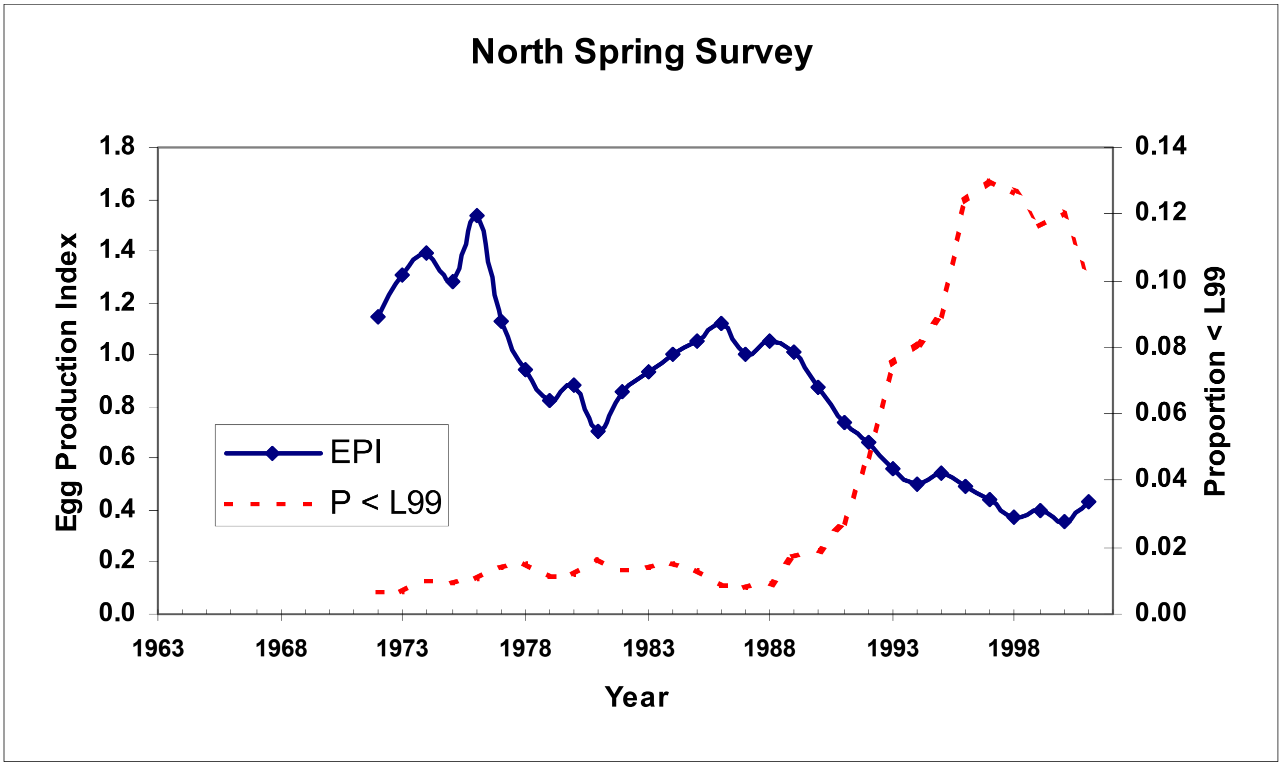


Figure C80. Indices of egg production by goosefish based on composite length frequency distributions from survey indices (number per tow at length), proportion mature at length, and fecundity at length. Year represents the terminal year of a 5-year pooled length frequency sample. Proportion < L99 is the fraction of egg production from goosefish smaller than the size at 99% maturity.



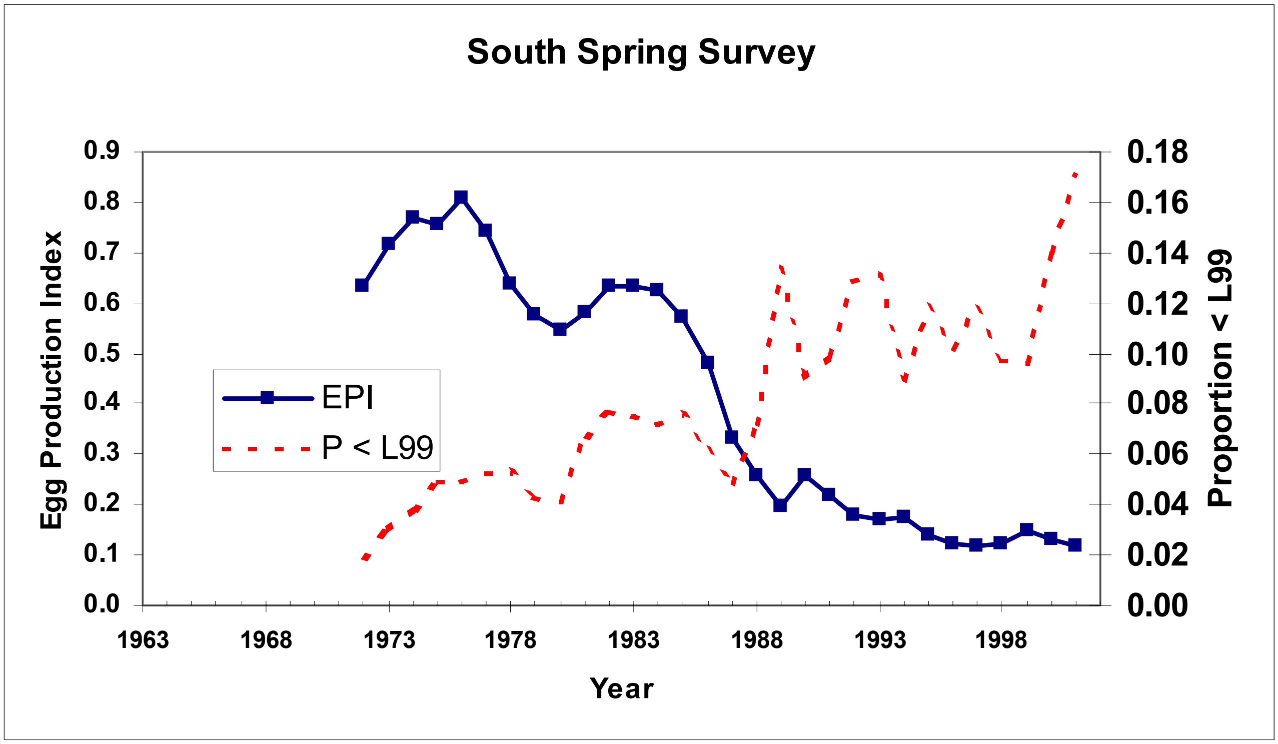
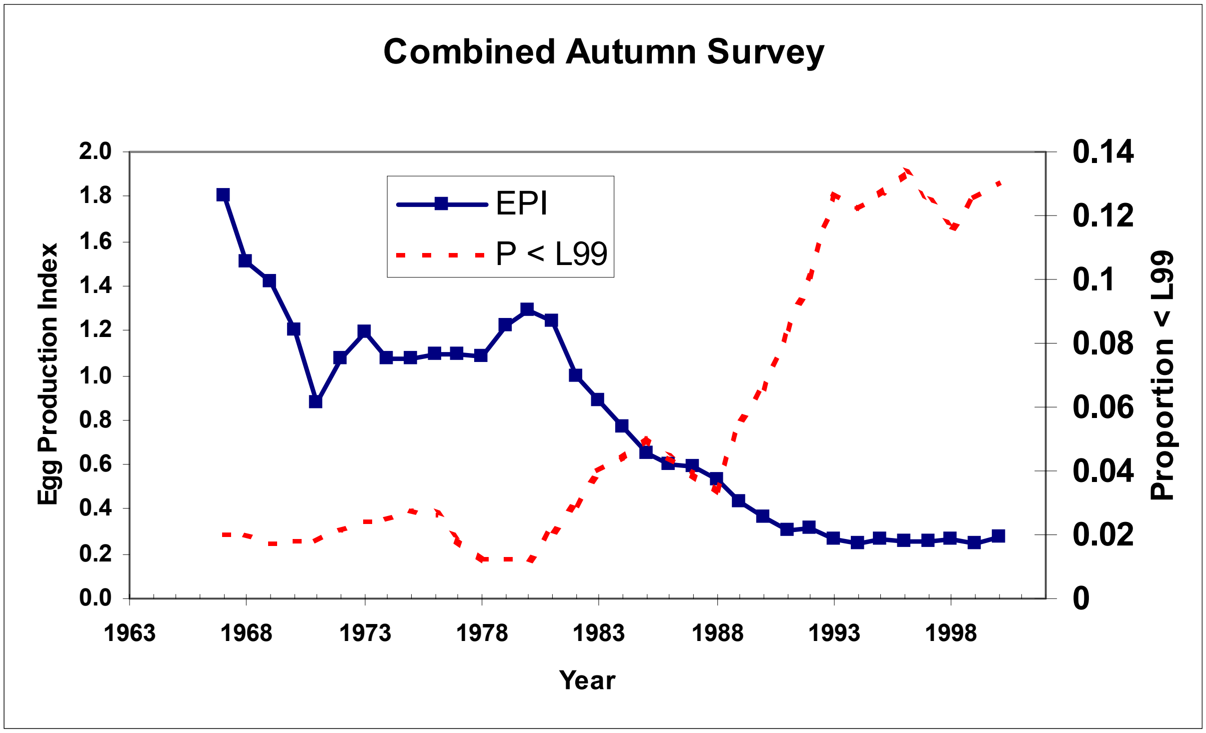


Figure C81. Indices of egg production by goosefish based on composite length frequency distributions from survey indices (number per tow at length), proportion mature at length, and fecundity at length. Year represents the terminal year of a 5-year pooled length frequency sample. Proportion < L99 is the fraction of egg production from goosefish smaller than the size at 99% maturity.



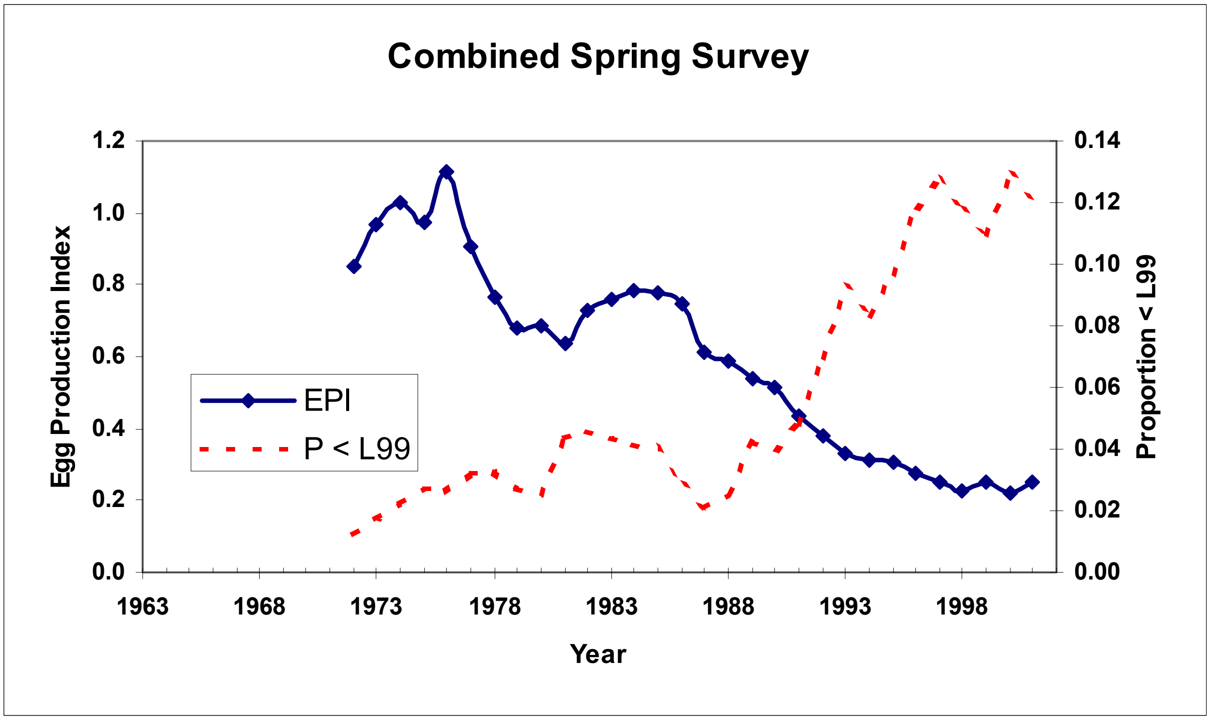
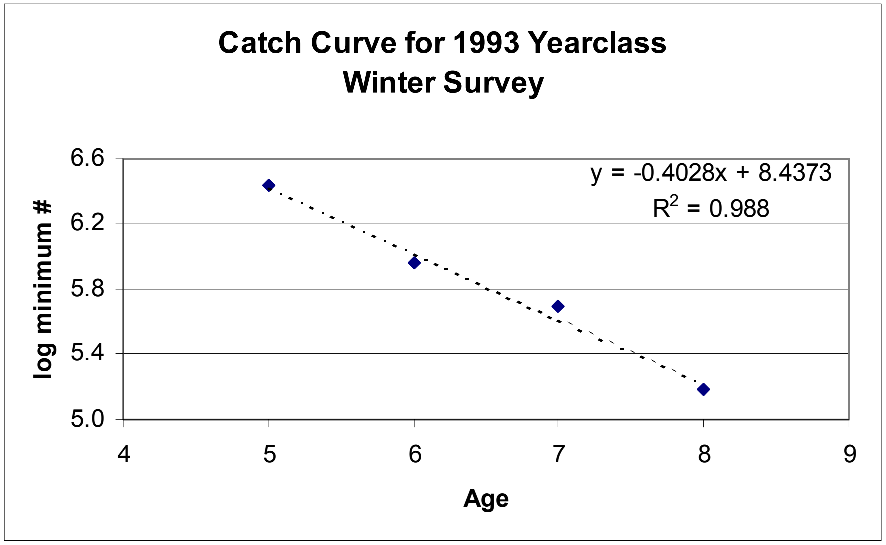
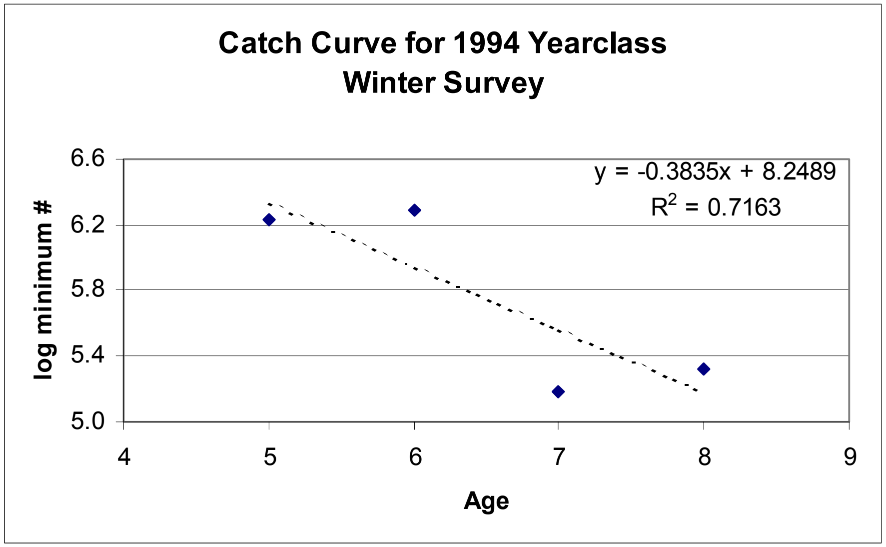


Figure C82. Indices of egg production by goosefish based on composite length frequency distributions from survey indices (number per tow at length), proportion mature at length, and fecundity at length. Year represents the terminal year of a 5-year pooled length frequency sample. Proportion < L99 is the fraction of egg production from goosefish smaller than the size at 99% maturity.

	mean # per tow at age				
cohort	5	6	7	8	9
92	0.800	0.267	0.133	0.046	0.014
93	0.492	0.532	0.118	0.060	
94	0.534	0.423	0.151		
	minimum pop size estimate in year				
sv year	97	98	99	2000	2001
	10,895,000	4,850,900	10,346,000	13,764,000	15,048,000
number at age in					
cohort at age	5	6	7	8	9
92	2,748,792	913,046	489,659	153,689	49,095
93	1,686,675	1,963,381	153,689	207,680	
94	1,972,510	1,413,557	522,380		
	log(# at age)				
cohort	5	6	7	8	
93	6.439	5.960	5.690	5.187	
94	6.227	6.293	5.187	5.317	
95	6.295	6.150	5.718		


Catch Curve for 1993 Yearclass
Winter Survey


Catch Curve for 1994 Yearclass
Winter Survey

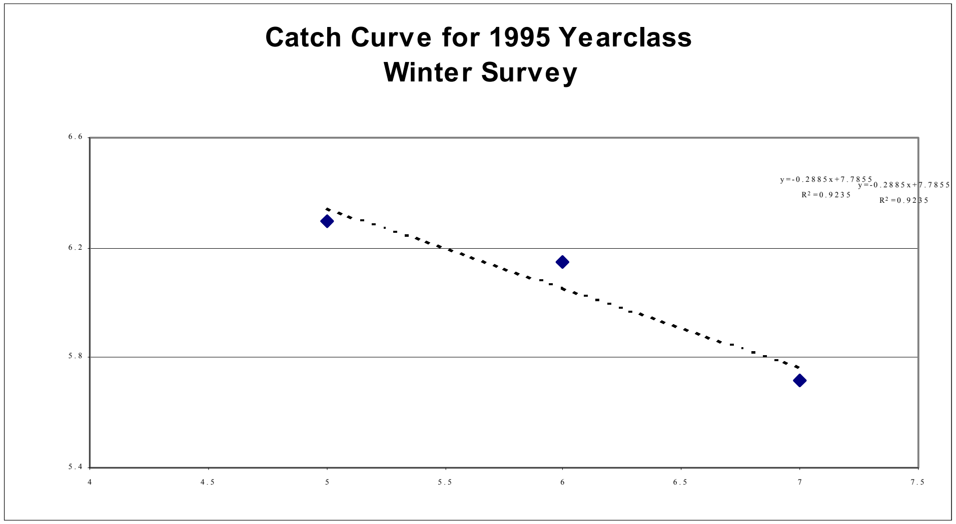

Catch Curve for 1995 Yearclass
Winter Survey

Figure C83. Catch curve estimates of total mortality (Z) for 1993-1995 cohorts of goosefish from NEFSC winter survey.

	yc	1997	1996	1995	1994	1993	1992	1991
	Age	4	5	6	7	8	9	10
north	log(#)	7.0083	6.7618	6.3886	5.9074	5.7724	5.3876	4.1028
south		6.817	6.6945	6.5367	6.0476	5.7167	5.3916	3.9251
all		7.2241	7.0305	6.7699	6.2842	6.0465	5.6907	4.324

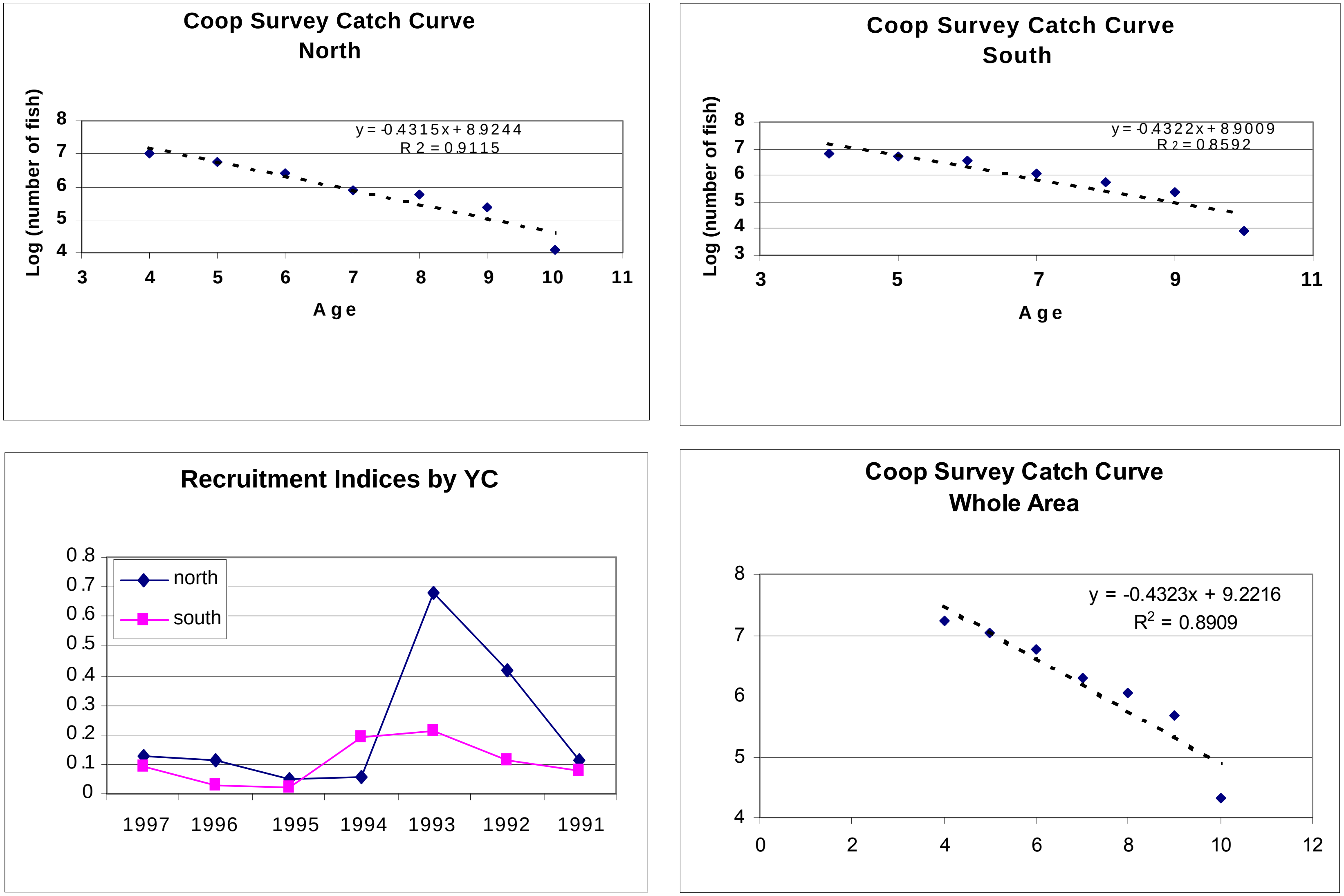


Figure C84. Catch curve estimates of Z using cooperative survey numbers at age. Inclinometer distances assumed for Mary K.

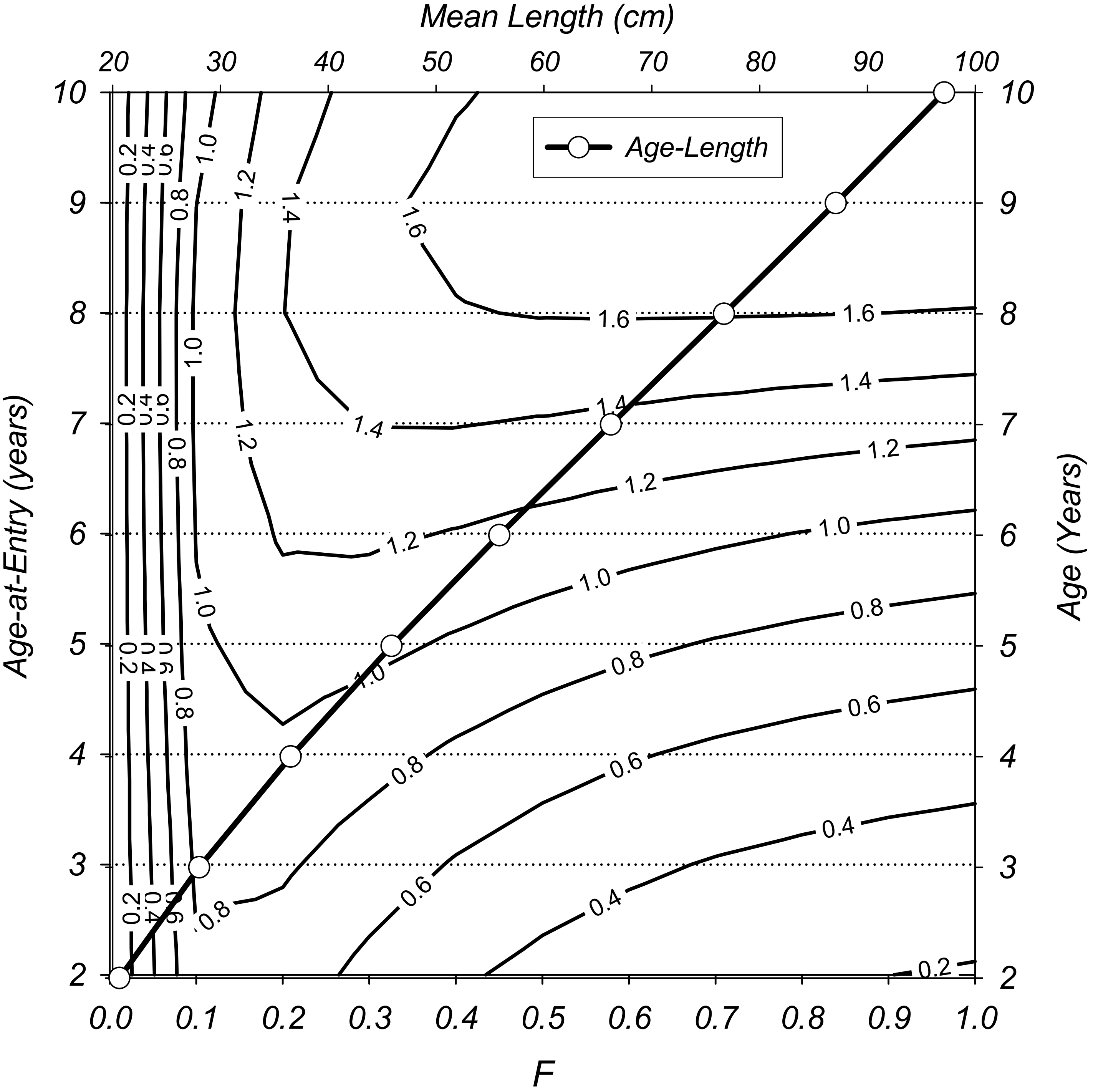


Figure C85. Yield per recruit for goosefish for varying ages of knife-edge recruitment and varying fishing mortality rates.

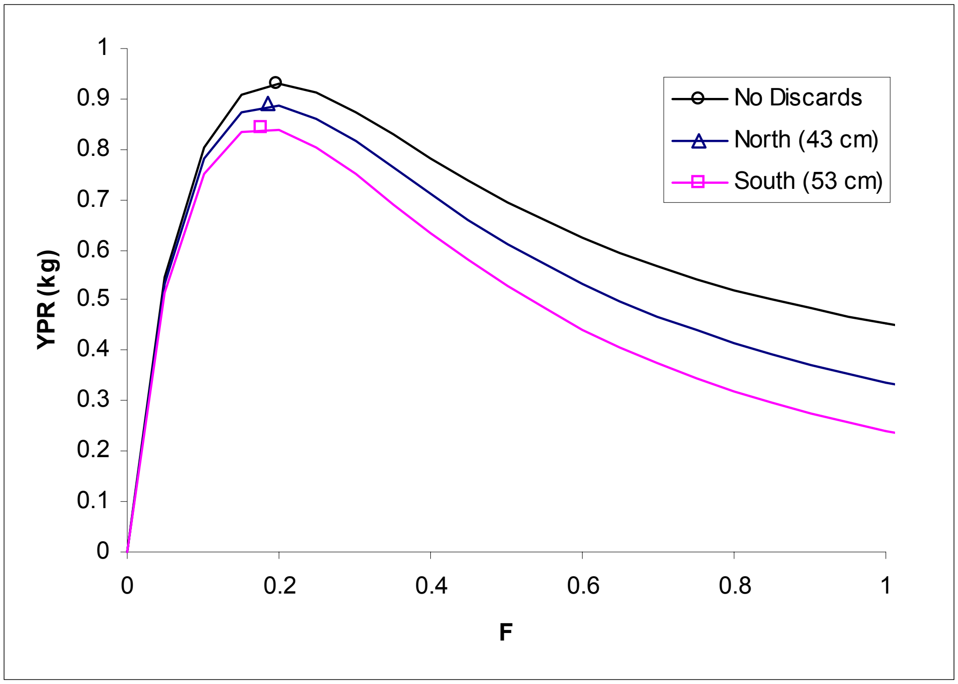


Figure C86. Yield per recruit curves for goosefish showing the effect of discarding on yield.

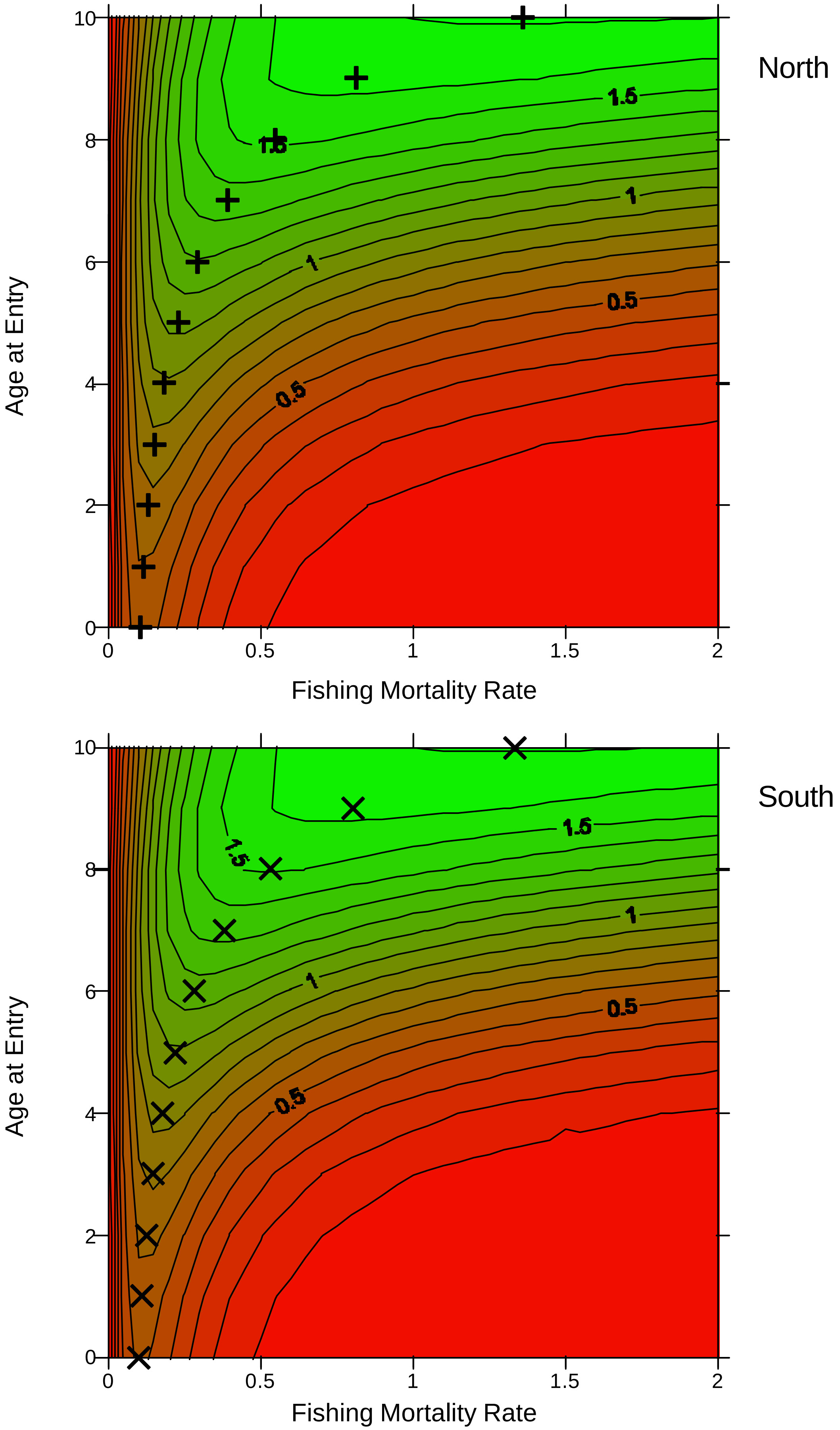


Figure C87. Yield-per-recruit for varying age at entry (with selection ogive) and fishing mortality rates.

Research Communications Unit
Northeast Fisheries Science Center
National Marine Fisheries Service, NOAA
166 Water St.
Woods Hole, MA 02543-1026

STANDARD
MAIL A

Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "planning, developing, and managing multidisciplinary programs of basic and applied research to: 1) better understand the living marine resources (including marine mammals) of the Northwest Atlantic, and the environmental quality essential for their existence and continued productivity; and 2) describe and provide to management, industry, and the public, options for the utilization and conservation of living marine resources and maintenance of environmental quality which are consistent with national and regional goals and needs, and with international commitments." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Those media are in four categories:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term or large area studies; synthesis reports for major resources or habitats; annual reports of assessment or monitoring programs; documentary reports of oceanographic conditions or phenomena; manuals describing field and lab techniques; literature surveys of major resource or habitat topics; findings of task forces or working groups; summary reports of scientific or technical workshops; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

Northeast Fisheries Science Center Reference Document -- This series is issued irregularly. The series typically includes: data reports on field and lab observations or experiments; progress reports on continuing experiments, monitoring, and assessments; background papers for scientific or technical workshops; and simple bibliographies. Issues receive internal scientific review, but no technical or copy editing.

Fishermen's Report -- This information report is a quick-turnaround report on the distribution and relative abundance of commercial fisheries resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. There is no scientific review, nor any technical or copy editing, of this report.

The Shark Tagger -- This newsletter is an annual summary of tagging and recapture data on large pelagic sharks as derived from the NMFS's Cooperative Shark Tagging Program; it also presents information on the biology (movement, growth, reproduction, etc.) of these sharks as subsequently derived from the tagging and recapture data. There is internal scientific review, but no technical or copy editing, of this newsletter.

OBTAINING A COPY: To obtain a copy of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, or to subscribe to the *Fishermen's Report* or the *The Shark Tagger*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2228) or consult the NEFSC webpage on "Reports and Publications" (*http://www.nefsc.nmfs.gov/nefsc/publications/*).