

A Report of the 21st Northeast Regional Stock Assessment Workshop

**21st Northeast Regional
Stock Assessment Workshop
(21st 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**

June 1996

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This report is a product of the 21st Northeast Regional Stock Assessment Workshop (21st SAW). Proceedings and products of the 21st SAW are scheduled to be documented and released as subissues (denoted by a lower case letter) of *Northeast Fisheries Science Center Reference Document* 96-05 (e.g., 96-05a). Tentative titles for the 21st SAW are:

An index-based assessment of winter flounder populations in the Gulf of Maine

Assessment of winter flounder in Southern New England and the Mid-Atlantic

Influence of temperature and depth on the distribution and catches of yellowtail flounder, Atlantic cod, and haddock in the NEFSC bottom trawl survey

Predicting spawning stock biomass for Georges Bank and Gulf of Maine Atlantic cod stocks with research vessel survey data

Preliminary results of a spatial analysis of haddock distribution applying a generalized additive model

Report of the 21st Northeast Regional Stock Assessment Workshop (21st SAW): Public Review Workshop

Report of the 21st Northeast Regional Stock Assessment Workshop (21st SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments

Stock assessment of northern shortfin squid in the Northwest Atlantic during 1993

The Lorenz curve method applied to NEFSC bottom trawl survey data

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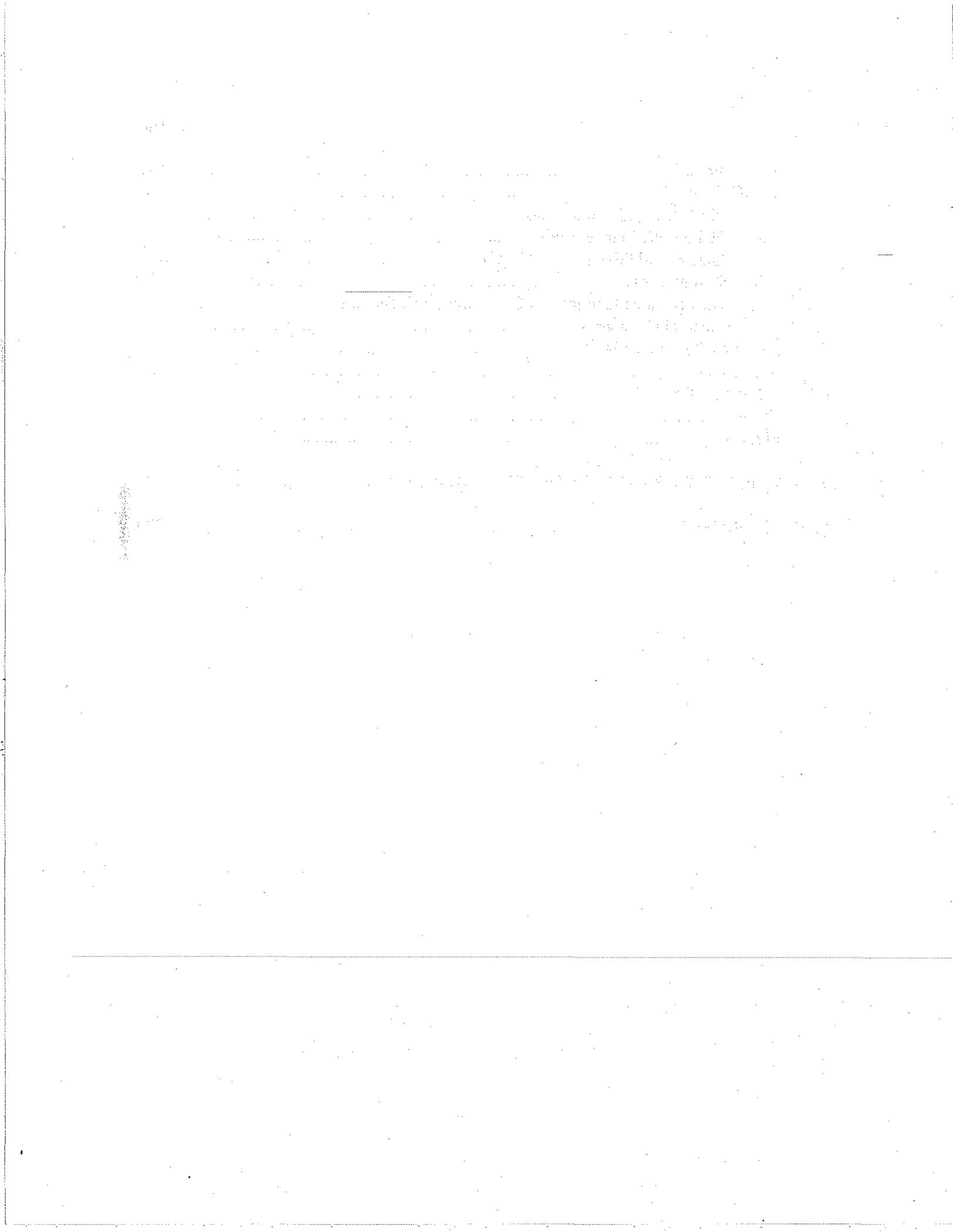
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MEETING OVERVIEW

The Stock Assessment Review Committee (SARC) Meeting of the 21st Northeast Regional Stock Assessment Workshop (21st SAW) was held at the Northeast Fisheries Science Center (NEFSC), Woods Hole, Massachusetts during 27 November -1 December 1995. SARC Chairman was Dr. Terrence P. Smith (NEFSC). Members of the SARC included scientists from NMFS/NEFSC, NERO and NWFSC, Mid-Atlantic (MAFMC) and New England (NEFMC) Fishery Management Councils, Atlantic States Marine Fisheries Commission (ASMFC), the States of MA and NY, and Canada (Table 1). In addition, more than 30 other persons attended all or part of the meeting (Table 2). The meeting agenda is presented in Table 3.

Table 1. Composition of the SARC.

Chair: Terry Smith, NEFSC (SAW Chairman)
Four ad hoc experts chosen by the Chair:
Jon Brodziak, NMFS, Hatfield Marine Science Center John Kocik, NEFSC Loretta O'Brien, NEFSC William Overholtz, NEFSC
One person from NMFS, Northeast Regional Office:
Peter Colosi, NERO
One person from each Regional Management Council:
Andy Applegate, NEFMC Richard Seagraves, MAFMC
Atlantic States Marine Fisheries Commission/State personnel:
Steve Cadrin, MA DMR Frank Lockhart, ASMFC Kim McKown, NY DEC
One scientist from Canada:
Mark Showell, DFO Academia - No participation Other Region - No participation

Table 2. List of participants.

National Marine Fisheries Service <u>Northeast Fisheries Science Center</u> Frank Almeida Marinelle Basson John Boreman Russell Brown Stephen Clark Kevin Friedland Wendy Gabriel Tom Helser Lisa Hendrickson Josef Idoine Shih-Wei Ling Ralph Mayo Steve Murawski Helen Mustafa Paul Rago Fred Serchuk Gary Shepherd Katherine Sosebee Mark Terceiro Jim Weinberg Susan Wigley <u>NMFS Headquarters</u> John Witzig	Mid -Atlantic Fishery Management Council Alan Weiss Connecticut Department of Environmental Protection Penny Howell Massachusetts Department of Marine Fisheries Steve Correia Tom Currier Arnold Howe Jeremy King Dan McKiernan David Pierce Maine Department of Marine Resources David Stevenson Rhode Island Department of Fish and Wildlife Mark Gibson Conservation Law Foundation Ellie Dorsey Manomet Bird Observatory Dave Martins University of Massachusetts Paul Nitschke Cape Oceanic Peter Spalt
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Table 3. Agenda of the 21st Northeast Regional Stock Assessment Workshop (SAW-21) Stock Assessment Review Committee (SARC) Meeting.

NEFSC Aquarium Conference Room
 166 Water Street
 Woods Hole, Massachusetts
 Telephone: 508-548-5123
 27 November (1:00 PM) - 1 December (6:00 PM) 1995

AGENDA

SPECIES/STOCK	SUBCOMMITTEE & PRESENTER	SARC LEADER	RAPPORTEUR
MONDAY, November 27 (1:00 PM - 7:30 PM).....			
Opening		T.P. Smith, Chairman	H. Mustafa
Welcome			
Agenda			
Conduct of Meeting			
Long-finned Squid (A)	Invertebrate P. Rago	J. Brodziak	J. Weinberg
Discuss Advisory Report			
TUESDAY, November 28 (9:00 AM - 6:00 PM).....			
Short-finned Squid (B)	Invertebrate P. Rago	W. Overholtz	L. Hendrickson
Discuss Advisory Report			
Atlantic Herring (C)	Coastal/Pelagic D. Stevenson K. Friedland	S. Cadrin	K. Friedland M. Terceiro
Discuss Advisory Report			
Review available drafts			
WEDNESDAY, November 29 (9:00 AM - 6:00 PM).....			
Report of the Ad Hoc Working Group on Sea- Port-Sampling (F)	D. Pierce		H. Mustafa
Winter Flounder (D)	So. Demersal W. Gabriel	R. Seagraves	G. Shepherd
Discuss Advisory Report			
Review available draft report sections			
Complete Review/Discussion of above species			

Table 3. (Continued)

THURSDAY, November 30 (9:00 AM - 6:00 PM).....			
Northeast Groundfish Complex (E)	No. Demersal		
Discuss Advisory Report	R. Mayo	A. Applegate	R. Brown/R. Mayo
	K. Sosebee		
	T. Helser		
	L. O'Brien		
	S. Wigley		
	S. Cadrin		
Review all Research Recommendations			
Review list of publications for the SAW-21 series			
FRIDAY, December 1 (9:00 AM - 6:00 PM)			
Complete SARC Report sections			H. Mustafa (Coordinator)
Finalize sections and review final draft Advisory Report			
Other Business			H. Mustafa

Opening

Chairman Terry Smith welcomed the meeting participants and introduced the members of the SARC. He reviewed the SAW process and the composition and duties of the SAW Steering Committee, as well as the responsibilities of the SARC meeting participants (Subcommittee chairs, SARC leaders, and rapporteurs) and the SARC documentation. The Subcommittee report on each species/stock will form the basis of the SARC Consensus Summary of Assessments. Other working papers will be candidates for publication in the SAW-21 series of the Center Reference Documents. Dr. Smith outlined the general flow of the meeting, including the preparation of the SARC and Advisory reports. The agenda, he indicated, is intentionally front loaded to allow time for additional discussion, document preparation, and analyses that might be recommended by the SARC after each presentation.

The Chairman reviewed the recommended species on the agenda for this meeting and dates of other meetings in the SAW-22 cycle. Although

lobster was recommended for review at SAW-22, the Steering Committee concluded that there is a need to review lobster productivity and overfishing definitions prior to another stock assessment. NMFS will convene an international review panel to address the issue and suggest terms of reference for the next Lobster assessment. The Invertebrate Subcommittee and the SARC will meet following the Review Panel to discuss and respond to the Panel report.

Agenda and Reports

The SARC Agenda included four species from the waters off the Northeast U.S. coast (short- and long-finned squids, Atlantic herring and winter flounder), the Northeast groundfish complex, and a report of the Ad hoc Sea Sampling Working Group. A chart of U.S. commercial statistical areas used to report landings in the Northwest Atlantic is presented in Figure 1. Area of the Northwest Atlantic showing NMFS/NEFSC bottom trawl offshore survey strata is presented in Figure 2.

Table 4. NEFSC Reference Documents associated with the 21st Northeast Regional Stock Assessment Workshop (21st SAW)

Title/Author(s)

Stock assessment of Short Finned Squid, *Illex illecebrosus*, in the Northwest Atlantic during 1993
by L. Hendrickson, et al.

Assessment of Winter Flounder, *Pleuronectes americanus*, in Southern New England and the Mid-Atlantic
by G. Shepherd, et al.

An Index Based Assessment of Winter Flounder, *Pleuronectes americanus*, Populations in the Gulf of Maine
by S. Cadrin, et al.

Influence of Temperature and Depth on the Distribution and Catches of Yellowtail Flounder, Cod, and Haddock in the NEFSC Trawl Survey
by T. Helser and J. Brodziak

Preliminary Results of a Spatial Analysis of Haddock Distribution Applying a Generalized Additive Model
by L. O'Brien

The Lorenz Curve Method Applied to NEFSC Bottom Trawl Survey Data
by S. Wigley

Predicting Spawning Stock Biomass for Georges Bank and Gulf of Maine Cod Stocks with Research Vessel Survey Data
by S. Cadrin and R. Mayo

Report of the 21st Northeast Regional Stock Assessment Workshop (21st SAW), Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

Report of the 21st Northeast Regional Stock Assessment Workshop (21st SAW), Public Review Workshop

The SARC reviewed a total of 19 working papers, seven papers were recommended to be upgraded to NEFSC Reference Documents in the SAW-21 series (Table 4). Subcommittee reports were prepared in a number of meetings (Table 5)

and are the basis of the species sections in this report. The SARC Consensus Summary of Assessments, with SARC comments and research recommendations, and the draft "Advisory Report on Stock Status" will be available at the SAW-21 Public Review Workshop and will be published in the NEFSC Reference Document series after the SAW-21/22 Steering Committee Meeting.

Presentations and Discussion

Highlights of Presentations

As assessment methods for both the long- and short-finned squids have changed since these species were last assessed during SAW-17, the SARC focused on the differences in assessment methodology between the previous and current assessments. Real-time management was recommended for both squids, as the highly variable recruitment of these species with an annual life span makes their populations susceptible to recruitment overfishing. This form of management would permit in-season adjustment to maintain precautionary levels of spawning potential. Presented was an exploratory analysis in real-time management options for squid stocks based on the example of the squid fishery in Falkland Islands. The Committee requested that a summary of this analysis (Working Paper B2) be presented to the MAFMC and concluded that a detailed data collection plan and cost-benefit analysis should be drafted to determine the feasibility of implementing real-time management for the two squids. As current data availability, including survey data, is not adequate for real-time management, data inadequacy is reflected in the research recommendations under both species. Among the recommendations under the short-finned squid, a transboundary stock, is development of a joint U.S. and Canada research program to improve the biological basis for management and assessment.

Table 5. SAW-21 Subcommittee meetings.

Subcommittee - Species Analysis Attendance	Meeting Date and Place
Invertebrate Subcommittee - LONG-FINNED SQUID M. Basson, NEFSC/NMFS J. Brodziak, NEFSC/NMFS R. Hanlon, MBL L. Hendrickson, NEFSC/NMFS W. Macy, URI P. Rago, NEFSC/NMFS (Chair) R. Seagraves, MAFMC - SHORT-FINNED SQUID All above, and - James Weinberg, NEFSC/NMFS	10 - 12 October 1995 Woods Hole, MA
Southern Demersal Subcommittee - WINTER FLOUNDER S. Cadrin, MA DMF S. Correia, MA DMF W. Gabriel, NEFSC/NMFS (Chair) M. Gibson, RI DFW A. Howe, MA DMF P. Howell, CT DEP D. Grout, NH FG N. Lazar, ASMFC M. Lambert, NEFSC/NMFS W. Ling, NEFSC/NMFS P. Scarlett, NJ DEP G. Shepherd, NEFSC/NMFS	16 - 20 October 1995 Woods Hole, MA
Northern Demersal Subcommittee - NORTHEAST GROUND FISH COMPLEX A. Apllegate, NEFMC (³ part-time) R. Brown, NEFSC/NMFS (^{1,2,3}) S. Cadrin, MA DMF (³) T. Helser, NEFSC/NMFS (^{1,3}) R. Mayo, NEFSC/NMFS (Chair) (^{1,2,3}) L. O'Brien, NEFSC/NMFS (^{1,2,3}) K. Sosebee, NEFSC/NMFS (^{1,2,3}) S. Wigley, NEFSC/NMFS (^{1,2,3})	14 September 1995 ¹ 29 September 1995 ² 30 October - 3 November 1995 ³ Woods Hole, MA
Coastal Pelagic Subcommittee - ATLANTIC HERRING K. Friedland, NEFSC/NMFS D. Libby, ME DMR D. Stevenson, ME DMR [E. Anderson, NEFSC/NMFS (Chair) was unable to attend]	7 - 9 November 1995 Boothbay Harbor, ME

During the review of the herring coastal stock complex assessment, discussion focused on VPA calibrations in both ADAPT and ICA (Integrated Catch Analysis) assessment programs. Additional ADAPT and ICA runs were carried out during the meeting and the SARC chose to base the current assessment on VPA results from the ADAPT. The remarkable shift in the growth rate and weight of herring observed in the presented analyses may be a result of a large biomass. A major research recommendation of the SARC is to develop a long-term strategy for assessing individual spawning stocks as a basis for more effective management of any heavily exploited portions (s) of the herring stock complex.

Dr. David Pierce presented the Report of the Ad Hoc Sea-Sampling Working Group which included several preliminary products (tables). A summary of this presentation appears in this report.

The SARC agreed with the Southern Demersal Subcommittee's reasoning for changing the winter flounder stock structure from four to three stock complexes (Southern New England - Middle Atlantic, Georges Bank, and Gulf of Maine). Large differences were found in the growth and maturity rates among the complexes. Discussion of the species centered around estimation of discards, implications of projections, and the implication of management measures.

The analysis of the Northeast Demersal Complex included 16 species, or 25 stocks, (10 regulated large mesh species in the Northeast Multispecies Fishery Management Plan, three small mesh species in the Plan, and three additional species, often taken in the Northeast demersal fishery). Reviewed was a summary of recent and historical temporal and spatial trends for aggregated species, as well as several technical papers on methods used to address the terms of reference for the Northern Demersal Complex. The Subcommittee addressed all terms of

reference, with the exception of the fourth, "Evaluate the by-catch implications of the multispecies trawl and fixed gear fisheries for Northeast groundfish on the ability to meet fishing mortality rate (F) goals for individual species/stocks." To address this term of reference would be a long-term project which would require a research recommendation from the SARC and a scoping document. The analytical methods described by members of the Subcommittee may be applied to a number of species and include: a habitat preference analysis to test species affinity to temperature and depth; a General Additive Models approach for smoothing data collected with measurement error and to stabilize variance used to analyze the distribution of haddock; an econometrics method (Lorenz Curve Method), developed to study the distribution of income, applied to NEFSC bottom trawl survey data; and, an objective statistical method (ARIMA approach) for selecting smoothing parameters to stabilize variance caused by measurement error used for predicting spawning stock biomass for Georges Bank and Gulf of Maine cod stocks using research vessel survey data. The SARC complimented members of the Northern Demersal Subcommittee on the quality of their work and the production of original and integrative approaches in addressing the terms of reference. Meeting participants indicated that dealing with a complex of species was interesting to the SARC and informative to the audience and suggested that future SAWs include subject oriented terms of reference that incorporate analyses from several species or take a multispecies approach to addressing certain questions.

Before the meeting adjourned, participants discussed the SAW process and the SARC meeting schedule, the need to continue the Assessment Methods Subcommittee and to replace its chair, as well as a number of possible theme topics for SAW-22. This discussion is summarized in the Other Business section of this report.

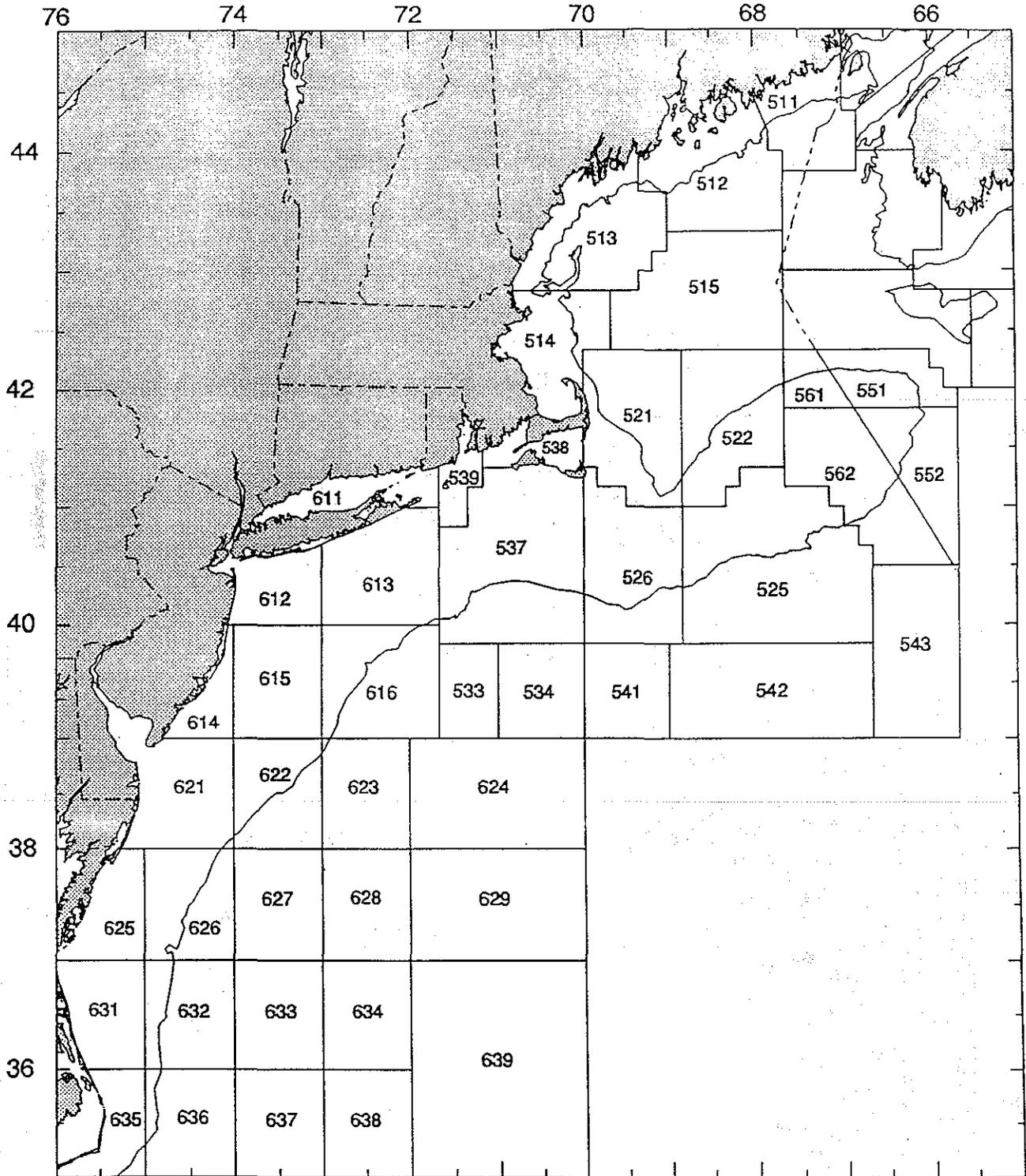


Figure 1. Statistical areas used for catch monitoring in offshore fisheries in the Northeast United States.

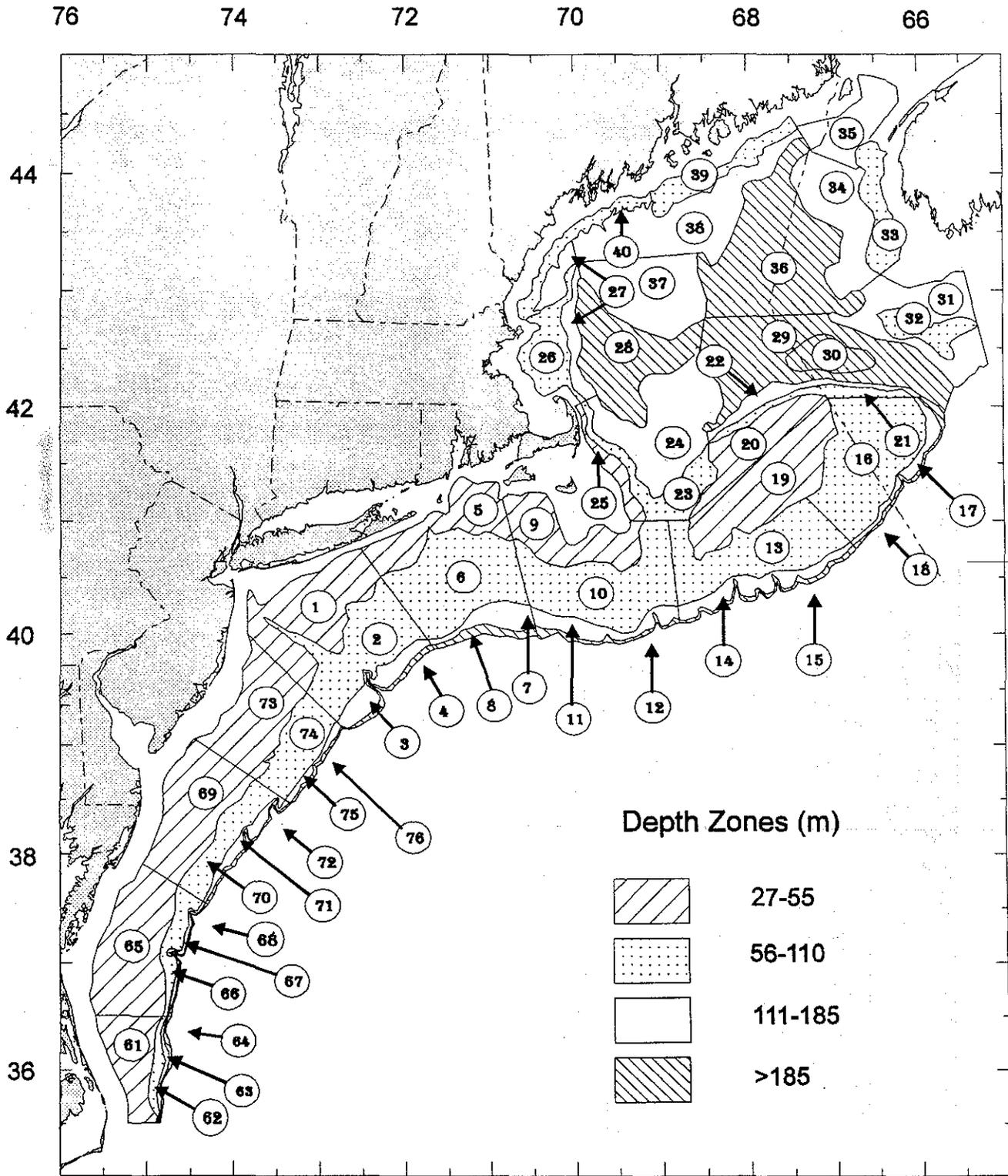


Figure 2. Area of the Northwest Atlantic showing NMFS/NEFSC bottom trawl offshore survey strata.

A. LONG-FINNED (*Loligo*) SQUID

Terms of Reference

The following Terms of Reference were addressed for long-finned squid:

- a. Examine the seasonal and annual distribution patterns and relationship to environmental parameters, especially temperature.
- b. Estimate the relative abundance, biomass, and mortality rates.
- c. Review the overfishing definition and incorporate recently revised life history information.
- d. Examine harvesting strategies in relation to stock dynamics.

Introduction

The fishery for long-finned squid is managed under the Mid-Atlantic Fishery Management Council's Atlantic mackerel, Squid, and Butterfish Fishery Management Plan (FMP). The FMP provides for the annual specification of optimum yield based on the most recent information on the status of the stock. *Loligo pealei* was last assessed by the 17th Stock Assessment Review Committee during December, 1993 (NEFSC 1994) which found that the stock was probably fully-exploited and at a medium level of biomass. Amendment 5 to the FMP was developed in recognition of these findings and under the premise that additional expansion of US fleet capacity was no longer necessary or desirable. Amendment 5 proposes to limit entry into the directed fishery, establish trip limits for non-moratorium vessels, require mandatory reporting for all permitted vessels, and establish minimum mesh requirements and seasonal quotas for the *Loligo* fishery.

This assessment of the *Loligo* squid (*Loligo pealei*) stock in the Northwest Atlantic for 1967-1994 incorporates recent biological information that dramatically alters our understanding of *Loligo* biology. New data on estimated maximum age, revised growth rates, and evidence of seasonal cohorts have major implications for stock dynamics and the development of biological reference points.

Stock Structure

For the purposes of discussing stock structure, a unit stock is taken to mean 'an intraspecific group of randomly mating individuals with temporal or spatial integrity' (Ihssen *et al.* 1981). The *Loligo* population from Cape Hatteras to the Gulf of Maine has been assumed to constitute a unit stock, although there have been few studies of *Loligo* stock structure. Verril (1882) suggested that there might be two forms of *Loligo* based on morphological differences of squid collected in Vineyard Sound. Such differences, however, would also be consistent with multiple life history strategies within the species, where cohorts with different hatch seasons and growth rates were mixed in an area.

More recently, Garthwaite *et al.* (1989) examined allele frequencies of *Loligo* collected during NEFSC surveys and found low levels of genetic variation that may be typical of squid (Brierley and Thorpe 1994). At one polymorphic locus, however, Garthwaite *et al.* detected significant differences between allele frequencies of Georges Bank, Cape Cod, and Virginia collections and inferred that three distinct subpopulations of *Loligo* existed. While there may be some level of spatial structure within the *Loligo*, the data in Garthwaite *et al.* were not sufficient to delineate such structure. Moreover, no persistent barriers to migration and gene flow have been identified among groups of *Loligo* squid

inhabiting the continental shelf from Cape Hatteras to the Gulf of Maine. The fact that some spatially separated collections differed in allele frequencies at a single locus was insufficient to reject the working hypothesis of a unit stock. Nonetheless, there exists the possibility of spatial structure within the *Loligo* population with further research on the population genetic structure desirable. In summary, the *Loligo* population was assumed to be a unit stock for population assessment in the absence of further information on its mating system and genetic structure.

The Fishery

Commercial Landings

Loligo have been exploited in the northwest Atlantic since the 1800's with annual landings of squid (including *Illex illecebrosus*) averaging roughly 2,000 mt from Cape Hatteras to the Gulf of Maine. During 1963-1971, a foreign distant water fishery developed for *Loligo* as landings increased from 1,294 mt in 1963 to 18,169 mt in 1971 (Figure A1). The peak of the foreign fishery occurred during 1972-1976 when landings averaged roughly 32,000 mt per year. Landings declined and averaged only 15,000 mt during 1977-1979, less than 50% of the peak level. Landings increased to an average of 24,000 mt during 1980-1984, but then declined again to an average of 15,000 mt during 1985-1987. Directed foreign fishing was curtailed in 1986, and during 1988-1989, landings increased again to an average of 21,000 mt. There was a moderated decrease in landings during 1990-1992 when annual landings averaged 17,500 mt. Landings have since increased to an average of 22,000 mt during 1993-1994.

Commercial landings of *Loligo* totaled 22,273 mt in 1993 (Table A1), a 23% increase over 1992 landings, while preliminary 1994 landings were 22,468 mt. As in previous years, in 1993 almost all (98%) commercial landings were taken with otter trawl gear (Table A2). A similar pattern was expected for 1994. The spatial pattern of landings in

1993 was similar to that of recent years with the majority of landings taken from Southern New England to the Mid-Atlantic Bight (Table A3). In 1993, statistical areas 616 and 622 (Hudson Canyon to Baltimore Canyon) accounted for 56% of the commercial landings, while 50% of total landings occurred during January-March. No information is available to describe the spatial or temporal distribution of *Loligo* landings in 1994.

The fishery consists of an inshore and offshore component with inshore landings occurring primarily between April and September. Offshore landings are generally about three-fold greater and occur from October through March. The general seasonal and spatial pattern of landings is summarized for two time periods: 1987-1990, and 1990-1993 (Figures A2-A5). Increases in the winter fishery between 1987-1990 and 1990-1993 (Figure A2 versus Figure A4) appear to have come from increased landings in the New York Bight. For the summer fishery, a reduction in the areal extent of the high landings category (141-2,400 mt) is evident between 1988-1990 (Figure A3) and 1991-1993 (Figure A5) in statistical areas 537 and 538.

Commercial Discards

Discards of *Loligo* occur in the commercial fishery, however limited data are available to quantify the extent of discarding by vessels targeting *Loligo*. In one winter sea sampling trip that targeted *Loligo* and landed over 10% *Loligo* by weight, the percentage of *Loligo* catch discarded was approximately 4% by weight. In another winter trip that targeted summer flounder and landed over 10% *Loligo* by weight, the percentage of *Loligo* catch discarded was approximately 19% by weight. For both trips, the common reason for discarding was that the squid were below market size. Whether the levels of discarding observed on these trips were representative of the winter *Loligo* fishery is unknown. Additional data, collected from Nantucket and Vinyard Sounds by the Massachusetts Division of Marine Fisheries, indicated that the percent discard of *Loligo* by weight was less than 2% during

May of 1990-1992 (McKiernan and Pierce, 1995). Guidelines for improving the estimation of discards are presented in the **Research Recommendations** section at the end of this report.

Recreational Catch

Recreational catches of *Loligo* with hand lines are generally limited to coastal bays and nearshore waters. Total recreational catches were considered to be negligible.

Length and Age Compositions

Estimated total numbers of long-finned squid landed from 1982-1992 are summarized in Table A4. Data on the size composition of 1993 landings had not yet been analyzed and no size composition data were available for 1994. No age data were collected by NMFS from the commercial fishery in 1993 or 1994, but over 450 statoliths were collected from the commercial fishery for age analysis at URI as part of a Rhode Island Sea Grant Project (Brodziak and Macy, in press).

Stock Abundance Indices

Commercial LPUE

Commercial LPUE was characterized with a general linear model (GLM) analysis of the domestic *Loligo* fishery during 1982-1993 based on NEFSC weighout data. Detailed trip records were not available to characterize LPUE in 1994. Commercial landings and effort data were partitioned into two seasons to reflect geographical differences in *Loligo* distribution. In general, *Loligo* are distributed offshore during winter and are often associated with relatively warm waters found near the continental shelf-slope front, while during summer, *Loligo* are generally distributed in waters of the continental shelf and nearshore areas. In particular, commercial LPUE data were partitioned into October-March (winter) and April-September (summer) seasonal fisheries.

For the analysis of winter LPUE, otter trawl trips that landed at least 10% of *Loligo* by weight were selected from the NEFSC weighout database. Landings and effort data for the months of October-December were assigned to the next calendar year so that the data were analyzed in contiguous 6 month blocks where, for example, the winter of 1983 included data from October-December of 1982. Primary winter *Loligo* fishery areas were identified in the last assessment (NEFSC 1994) as statistical areas 526, 537, 538, 539, 612, 613, 615, 616, 621, 622, 626, and 632 and trips to these areas were used in the LPUE analysis (Figure A2). Vessels were characterized by their gross registered tonnage to reflect relative fishing power. The tonnage class categories were: ton class 2 (5-50 GRT), ton class 3 (51-150 GRT), and ton class 4 (151-900 GRT). A main effects GLM of log-transformed CPUE (cf. Gavaris 1980) with factors of year, 3-digit area, month and ton class was estimated for the winter seasons of 1983-1993. A total of 17,090 trips, representing roughly 71% of NEFSC otter trawl weighout data for October-March, were used. The GLM model fit was highly significant ($F=267.7$, $P=0.0001$, $R^2=0.27$) (Table A5). Back-transformed area and tonnage class coefficients were bias-adjusted and applied to effort by trip to compute standardized fishing effort. Standardized effort was divided into total landings for the trips used to fit the GLM model to give a standardized LPUE index (Table A6).

For the analysis of summer LPUE, otter trawl trips that landed at least 10% of *Loligo* by weight were taken from the NEFSC weighout database. Landings and effort data for the months of April-September of 1982-1993 were collected. Primary summer *Loligo* fishery areas were identified in the last assessment (NEFSC 1994) as statistical areas 537, 538, 539, 611, 612, 613, and 621 and trips to these areas were used in the LPUE analysis. Vessels were characterized by their gross registered tonnage as above. As above, main effects GLM of log-transformed LPUE with factors of year, 3-digit area, month, and ton class was estimated for the summer seasons of 1982-1993. A total of 16624 trips

representing roughly 66% of NEFSC otter trawl weighout data for April-September were used. The GLM model fit was highly significant ($F=408.2$, $P=0.0001$, $R^2=0.37$) (Table A7). Back-transformed area, month, and tonnage class coefficients were bias-adjusted and applied to effort by trip to compute standardized fishing effort. Standardized effort was divided into total landings for the trips used to fit the GLM model to give a standardized LPUE index (Table A8).

The winter and summer LPUE analyses conducted for this assessment provided a more comprehensive and consistent characterization of the *Loligo* fishery than in the previous assessment. In the previous assessment (NEFSC 1994), the *Loligo* fishery was partitioned into a small-vessel inshore component and a large vessel component for GLM analysis. The small-vessel inshore component was composed of trips by ton class 2 vessels to statistical areas 537, 538, 539, 611, 612, 613, or 621 during May-July that landed at least 4.3% *Loligo* by weight. The GLM analysis for the small-vessel inshore fishery was a main effects model with factors for year and area. In contrast, the summer LPUE analysis conducted for the current assessment included trips by ton class 2, 3, and 4 vessels during April-September with a landings cutoff of 10% *Loligo* by weight, where the GLM analysis for the summer fishery was a main effects model with factors for year, area, ton class and month. In the previous assessment, the large-vessel fishery was composed of trips by ton class 3 and 4 vessels to statistical areas 526, 537, 538, 539, 612, 613, 615, 616, 621, 622, 626 or 632 during any quarter that landed at least 3.2% *Loligo* by weight. The GLM analysis for the large-vessel fishery was a main effects model with factors of year, area, ton class, and quarter. In contrast, the winter LPUE analysis conducted for the current assessment included trips by ton class 2, 3, and 4 vessels during October-March with a landings cutoff of 10% *Loligo* by weight, where the GLM analysis for the winter fishery was a main effects model with factors for year, area, ton class and month.

Research Vessel Indices

The NEFSC autumn bottom trawl survey indices suggest no obvious temporal trends in either numbers or weight per tow (Figure A6, A7). Fall catch estimates, unadjusted for vessel class (see below) and diurnal (see Brodziak and Hendrickson, WP A2), suggest relatively high abundance levels in 1994 (Table A9). *Loligo* catches in the NEFSC spring survey are typically much lower than the fall survey, averaging about 25% by number/tow and 30% by weight/tow of the fall survey (Table A10). Numbers and weight per tow in the spring 1994 were only 20% and 26% of the 1988-91 averages, respectively (Figure A6, A7). Spring 1995 estimates of number and weight per tow were about twice as high as 1994 values and are consistent with the observed increases in the fall 1994 survey. Owing to the pronounced diel vertical migrations of squid, unadjusted survey indices must be interpreted with caution. The remainder of this section re-examines the results of vessel comparison studies (*R/V Albatross IV* versus *Delaware II*) and Brodziak and Hendrickson (WP A2) estimate correction factors for day versus night catch rates.

Potential differences in the catchability of *Loligo* by the research vessels Delaware II and Albatross IV were examined to confirm results of a preliminary analysis of vessel catchability presented at SAW-12 SARC (NEFSC 1991). In particular, the Delaware II was suggested to have higher fishing power, although the 95% confidence intervals for the estimated vessel conversion coefficient for numbers (0.71, 1.03) and weight per tow (0.74, 0.99), suggested that the difference was marginally significant at the 5% level. Here the relative fishing power of the vessels was examined using a similar data set of paired tows (the vessels fished side by side) from NEFSC gear comparison cruises in 1982, 1983, 1987, and 1988. *Loligo* catch per tow in total numbers, pre-recruits (≤ 8 cm) and recruits (≥ 9 cm), and weight were compared to evaluate whether there was a difference in average catch per tow between vessels. Only tows where both vessels had positive catches of *Loligo* were used, with the exception of

the pre-recruit and recruit comparisons where both pre-recruits and recruits had to be captured by both vessels. The sample sizes for the comparison of total numbers, pre-recruits and recruits, and weight per tow were 266, 185, and 263 tows, respectively.

The ratios of the mean number per tow and log-transformed mean number per tow by vessel were examined first where N_{AL} and N_{DE} were the number per tow for the Albatross IV and the Delaware II. These ratios were: $E[N_{AL}]/E[N_{DE}] = 1.18$ and $E[\ln(N_{AL})]/E[\ln(N_{DE})] = 0.96$. The ratio of mean catches was greater than 1 and suggested higher average fishing power for the Albatross IV while the ratio of log-transformed mean catches was slightly less than 1 and suggested no apparent difference. The mean of the ratio of the number per tow was computed to be $E[N_{AL}/N_{DE}] = 1.81$ which suggested higher fishing power for the Albatross IV. The mean paired difference in catch per tow was also computed to be $E[N_{AL} - N_{DE}] = 120.7$ and a t-test indicated that this mean was not significantly different from 0 ($P=0.35$). A Wilcoxon sign-rank test of the paired difference in catch per tow also indicated that the median difference was not significantly different from 0 ($P=0.22$). However, when a logarithmic transformation was applied to the catches, the results were different with the t-test indicating a significant difference ($P=0.01$) and the Wilcoxon test also indicating one ($P=0.02$). While the results of the comparisons were somewhat equivocal, the mean ratios of catch per tow suggested that the Albatross IV was at least as powerful as the Delaware II for catching total numbers of *Loligo* and that no conversion for numbers was needed.

A similar examination of the catch rates of pre-recruits (P_{AL} and P_{DE}) and recruits (R_{AL} and R_{DE}) was performed. The ratios of mean number per tow were $E[P_{AL}]/E[P_{DE}] = 1.39$ and $E[\ln(P_{AL})]/E[\ln(P_{DE})] = 0.97$ for pre-recruits, and $E[R_{AL}]/E[R_{DE}] = 0.85$ and $E[\ln(R_{AL})]/E[\ln(R_{DE})] = 0.96$ for recruits. Mean paired differences in the log-transformed catch per tow were also computed to be $E[\ln(P_{AL}) - \ln(P_{DE})] = -0.133$ for pre-recruits and $E[\ln(R_{AL}) - \ln(R_{DE})] =$

-0.136 for recruits, and the t-test indicated that these means were not significantly different from 0 ($P=0.18$ and $P=0.08$, respectively). A Wilcoxon sign-rank test of the paired difference in log-transformed catch per tow also indicated that the median difference for pre-recruits was not significantly different from 0 ($P=0.23$) while the median difference was for recruits was different from 0 ($P=0.03$). Overall, the results were similar to those for total numbers per tow. It appeared that the Albatross IV was as powerful as the Delaware II for catching pre-recruits and recruits.

For weight per tow (W_{AL} and W_{DE}), the ratio of mean catch per tow was $E[W_{AL}]/E[W_{DE}] = 0.88$ and the mean ratio was $E[W_{AL}/W_{DE}] = 1.67$. The mean paired difference in catch per tow was also computed to be $E[W_{AL} - W_{DE}] = -1.29$ and a t-test indicated that this mean was not significantly different from 0 ($P=0.15$). A Wilcoxon sign-rank test of the paired difference in weight per tow indicated that the median difference was significantly different from 0 ($P=0.02$). The results for weight per tow were similar to those for numbers per tow and it appeared that the Albatross IV was probably as powerful as the Delaware II in catching *Loligo* by weight. Overall, no vessel adjustment was considered to be necessary for *Loligo* catches; this was consistent with previous assessments.

The effects of depth, surface temperature, bottom temperature, and time of day on *Loligo* catches during the NEFSC fall survey was also examined (Brodziak and Hendrickson, WP A2). The results indicated that *Loligo* catches were associated with depth and that the survey design of stratification by depth was appropriate for *Loligo*. The results also indicated that *Loligo* catches were significantly associated with relatively warm surface and bottom temperature consistent with the characterization of *Loligo* as a warm-water migratory species (Murawski 1993). Further, the results indicated that *Loligo* catches were significantly associated with time of day and diurnal expansion factors were computed to standardize catches of pre-recruits, recruits, and weight per tow during dawn/dusk and

night periods to a standard day catch rate (Brodziak and Hendrickson, WP A2).

As in previous assessments, relative abundance indices for the *Loligo* stock during the fall (Table A9, Figure A6), spring (Table 10A, Figure 7A), and winter (Table A11) NEFSC bottom trawl surveys were the stratified mean catches per tow from Cape Hatteras to Georges Bank (offshore strata 1-23, 25, and 61-76). Diurnal expansion factors were not applied to calculate relative abundance indices because revised software was not available (see Research Recommendations). Diurnal expansion factors were applied (Brodziak and Hendrickson, WP A2) to compute swept-area estimates of *Loligo* stock biomass from Cape Hatteras to the Gulf of Maine (offshore strata 1-30, 33-40, and 61-76) during the fall (Table A12) and spring (Table A13) bottom trawl surveys. The diurnal expansion factors were used to account for the differences in catch rates between day and night tows in the calculation of stock biomass. Although the relatively cool waters of the Gulf of Maine are not primary *Loligo* habitat, this region was included in the calculation of stock biomass to give as accurate an estimate as possible. The variance of the estimate of catchability was not incorporated into the variance estimate of swept area biomass estimates.

Current Stock Distribution

The distribution of *Loligo* is influenced by water temperature and depth (Brodziak and Hendrickson, WP A2), and can be expected to vary seasonally as water temperatures change. Seasonal distribution plots of small (≤ 8 cm) and large (≥ 9 cm) squid in the NEFSC spring and fall bottom trawl surveys are summarized in Figures A8 to A11. In general, *Loligo* move to the relatively warmer waters near the continental shelf-slope front as continental shelf waters cool in the late fall. Catches were infrequent north of 41° N in the fall surveys for both small (≤ 8 cm) (Figure A8) and large (≥ 9 cm) (Figure A10). During spring, as continental shelf waters warm, *Loligo* move inshore to feed and spawn with larger squid generally moving inshore before smaller ones

(Lange 1982) (see Figures A8-A10). During fall, both small (Figure A9) and large (Figure A11) squid are ubiquitous from Georges Bank south. *Loligo* are rarely caught in the Gulf of Maine except in nearshore strata and in Cape Cod Bay.

The distribution of *Loligo* squid south of Cape Hatteras has not been characterized in recent years, although Whitaker (1980) provides a summary of earlier trawl survey data. At present, *Loligo* are not actively fished south of Cape Hatteras. It should also be noted that Cape Hatteras is the southern zoogeographic boundary of the Mid-Atlantic Bight to Georges Bank *Loligo* fishery.

The spatial distribution of *Loligo* during the fall was characterized by computing the percentage of NEFSC fall survey tows that captured at least 1 squid. This was done for each of 4 regions: the Mid-Atlantic Bight (offshore strata 61-76), Southern New England (offshore strata 1-12), Georges Bank (offshore strata 13-23, 25), and the Gulf of Maine (offshore strata 24, 26-30, 33-40). Results (Table A14) indicate that there is a persistent latitudinal gradient in distribution with the highest densities occurring in the south and lower densities in the north. *Loligo* can sometimes range as far north as Newfoundland between 47° N and 48° N, where 44 squid were captured in a fish trap at Holyrood in 1986 (Dawe *et al.* 1990). Dawe *et al.* (1990) speculated that this apparent northward expansion of the range of *Loligo* was related to the low abundance of its sympatric competitor, *Illex illecebrosus*. Dawe noted that there were likely persistent small populations of *Loligo* along the eastern coast of Nova Scotia and also reported the presence of viable eggs which hatched at 9° C. Recording the occurrence of egg mops on winter fishing grounds would be useful for estimating the temporal and spatial extent of winter spawning.

Unusually cold water temperatures may have had a substantial impact on the distribution of the *Loligo* stock. In 1987, the annual cold pool that forms at the bottom of the mid- to outer-shelf in the Mid-Atlantic Bight (Bowman 1977) appeared to be larger than

normal as bottom water temperatures reported during the NEFSC fall bottom trawl survey were anomalously low (Holzwarth and Mountain 1990). This cold water appeared to affect *Loligo* distribution and abundance as estimates of stock abundance taken from NEFSC surveys (Tables A12 and A13) and commercial landings (Table A1) were very low during 1987.

Life History Parameters

Age

Statolith increment analysis has provided a wealth of biological information on the age structure of squid populations in recent years (Jackson 1994). Macy (1992, 1995) has applied statolith increment analysis to *Loligo* squid and found that the species lives for less than 1 year. Further research has shown that growth is rapid and exponential (Brodziak and Macy, in press).

Growth

The pattern of growth of *Loligo* has recently been characterized with statolith ageing (Brodziak and Macy, in press). *Loligo* exhibit sexual dimorphism as adults with males growing more rapidly and attaining greater sizes than females. Seasonal differences in growth rates are also apparent with summer-hatched squid growing more rapidly than winter-hatched squid (Figure 12A). Latitudinal differences in growth may also exist but have not been characterized. Two seasonal growth curves were used to compute mean weight at age for yield-per-recruit analyses. The growth curve for *Loligo* weight at age for summer-hatched squid was

$$W(t) = 0.3543 \cdot \exp [8.3843 - 23.9115 \exp [-0.3038 t]]$$

where $W(t)$ was weight (g) at age t (months), while the growth curve for winter-hatched squid was

$$W(t) = \{ 0.5271 + 0.1657 t \}^{7.6046}$$

Natural Mortality

Monthly instantaneous natural mortality (M_m) of *Loligo* squid was estimated to be roughly 0.34 per month based on Hoenig's regression method (Hoenig 1983) and a maximal age of 296 d (NEFSC 1994). An alternative approach was to infer natural mortality rate based on analogy with other commercially exploited species. Rosenberg et al. (1990) reported a weekly M of 0.06 which gave a monthly M_m of roughly 0.26. Another alternative was to evaluate mortality rate based on animal size and bioenergetic constraints (Peterson and Wroblewski 1984). With an assumed weight coefficient of growth of $k=0.018$ per day taken from the estimated instantaneous daily growth rate for female *Loligo* (Brodziak and Macy, in press), the Peterson and Wroblewski method gave a monthly M_m of 0.30 for a 25 g squid where 25 g was the mean weight of *Loligo* captured during the NEFSC fall survey to the nearest 5 g. The average value of M_m for the three methods was 0.30 which was the value used for the yield-per-recruit analyses. The relative importance of alternative mortality estimates for biological reference points is addressed in the section **Yield and Spawning Stock Biomass per Recruit**.

Maturity

Data on the fraction of *Loligo* mature at age were available from statolith ageing (Macy, pers. com.), where mature animals were considered to be fully-mature (stage 4) or maturing (stage 3) based on morphological measurements and the classification method of Macy (1982). For squid hatched during summer/fall months (June-October), the percent mature at ages 1-4 months was 0%, while for ages 5-9 months the percent mature at age was 40%, 80%, 88%, 87%, and 100%, respectively. In contrast, for squid hatched during winter/spring months

(November-May), the percent mature at ages 1-3 months was 0%, while for ages 4-9 months the percent mature at age was 21%, 25%, 27%, 40%, 100%, and 100%, respectively.

The percent mature at age for the spawning stock biomass per recruit analyses were taken to be 0% for ages 1-4 months for squid hatched during summer/fall and winter/spring. For ages 5-9 months, the percent mature at age of summer/fall hatched squid were taken to be 40%, 80%, 90%, 90%, and 100%, respectively. For winter/spring hatched squid the percent mature at ages 5-9 were set at 25%, 25%, 40%, 100%, and 100%, respectively. Macy's observation of 21% mature at age 4 months for winter hatched squid was based on a small sample size and considered provisional. Further work on estimation of maturation at length is needed.

Mortality and Stock Size Estimates

Exploitation rates for winter (October-March) and summer (April-September) of 1987-1993 were estimated based on the diurnally-adjusted, swept-area biomass estimate from the fall and spring NEFSC bottom trawl surveys (Table A15). In this calculation, the swept-area biomass from the spring survey provides an estimate of population size at the beginning of the summer fishing season while the swept-area biomass estimate from the fall survey is used as an estimate of population size at the beginning of the winter fishing season.

Loligo biomass estimates taken from the fall survey (Table A12) show several periods of high and low abundance during 1967-94. In particular, stock biomass was relatively low during the fall of 1967-1972 when biomass averaged 31,000 mt. Stock biomass was much higher during the fall of 1973-1976 when it averaged 62,000 mt. Stock biomass in the fall declined again during 1977-1982 to an average of 33,000 mt. Stock biomass increased to an average of 72,000 mt during the fall of 1983-1985, but then declined again to an average of 33,000 mt during 1986-1988. Stock biomass

increased to an average of 59,000 mt during the fall of 1989-1991 but has declined to an average of 45,000 mt during 1992-1994, although the 1994 fall biomass level was the highest recorded.

Loligo biomass estimates taken from the spring survey (Table A13) also showed several periods of high and low abundance during 1968-1994. In particular, stock biomass was relatively low during the spring of 1967-1971 when biomass averaged 7,000 mt. Stock biomass was much higher during the spring of 1972-1976 when it averaged 22,000 mt. Stock biomass in the spring declined again during 1977-1982 to an average of 10,000 mt. Stock biomass increased to an average of 16,000 mt during the spring of 1983-1987, and increased further to an average of 26,000 mt during 1988-1991. Stock biomass in the spring declined to an average of 12,000 mt during 1992-1994, and the 1994 spring biomass level was the lowest since 1977.

Estimated instantaneous monthly utilization rates during the summer fishery ranged from 0.12 to 0.34 (Figure A13). The summer utilization rate averaged 0.33 in 1987-1988, declined to 0.13 in 1989-1990, and increased to an average of roughly 0.20 during 1991-1993. Overall, the average summer utilization rate (0.22) was greater than $F_{50\%}$ (0.13). Estimated monthly utilization rates for the summer fishery ranged from 0.05 to 0.47. Winter utilization rates averaged 0.22 during 1988-1989 and then declined to an average of 0.07 during 1990-1992. Winter utilization rate in 1993 (0.465) was the highest on record and exceeded both $F_{50\%}$ (0.14) and F_{\max} (0.36).

Estimates of 6-month exploitation rates, derived from 6-months of landings divided by the swept-area-biomass estimate for the start of that period, suggested that the fall/winter fishery mortality rate in 1993 about 50% greater (60%) than the summer spring inshore rate (41%). From 1983-1990, stock biomass estimates in April (at start of the summer fishery) have varied considerably from (Figure A13).

Brodziak and Rosenberg (1993) developed an extension of the Leslie-DeLury model described in Rosenberg *et al.* (1990) to include migration and applied it to the statistical area 538 *Loligo* fishery during 1983-1990. Their results showed that the initial available population at the start of the fishery in April varied considerably from year to year. Their results also indicated that the average F (over 10 consecutive 10 day periods beginning April 21) for 1983 was very high with $F_{avg}=0.39$. In contrast, the average 10-day F during 1985 and 1987 was 0.05, while the average F during 1984, 1986, and 1988-90 ranged from 0.10 to 0.18.

Biological Reference Points

Current Overfishing Definition

The current overfishing definition for the *Loligo* stock is based upon examination of the 3-year moving average of the NEFSC fall survey pre-recruit number-per-tow index. When the 3-year average falls within the first quartile of the empirical cumulative distribution of the pre-recruit numbers-per-tow index, the stock is considered to be overfished. The basic notion of this definition is to avoid recruitment overfishing by monitoring the abundance of juvenile squid prior to the winter fishery. This definition has been characterized as 'risky' by a review panel considering overfishing definitions for U.S. Fishery Management Plans (Rosenberg *et al.* 1994) because the use of a 3-year average was inappropriate for a species with a lifespan of less than 1 year.

Yield and Spawning Stock Biomass Per Recruit

Yield and spawning stock biomass per recruit were computed for the *Loligo* stock in two hatch seasons: summer (June-October) (Table A16) and winter (November-May) (Table A17). For the summer-hatch analysis, the growth curve for June-October hatched squid was used while the growth curve for November-May hatched squid was used for the winter-hatch analysis. Average weight-at-age was computed for squid at age $t+1/2$ where t was the

age of the squid. Data on the average percent mature at age (months) were provided by Macy (unpublished data). For winter-hatched squid, the average percent mature at ages 5 to 9 and older were taken to be: 25%, 25%, 40%, 100%, and 100%. For summer-hatched squid, the average percent mature at ages 5 to 9 and older were: 40%, 80%, 90%, 90%, and 100%. A growth model by Schnute (1981) was used by Brodziak and Macy (in press) to estimate parameters in length (Y) at age (t) equations, for summer- and winter-hatched squid, respectively:

$$Y(t) = Y_{min} \cdot \exp \left[\ln \left(\frac{Y_{max}}{Y_{min}} \right) \frac{1 - \exp \left[-\alpha (t - t_{min}) \right]}{1 - \exp \left[-\alpha (t_{max} - t_{min}) \right]} \right]$$

and

$$Y(t) = Y_{min} \cdot \exp \left[\ln \left(\frac{Y_{max}}{Y_{min}} \right) \frac{t - t_{min}}{t_{max} - t_{min}} \right]$$

Parameter estimates for the first (summer-hatch) equation were $\alpha=0.2867$, $t_{min}=3.4497$, $y_{min}=1.4801$, $t_{max}=9.2320$, and $y_{max}=30.6814$. Parameter estimates for the second (winter-hatch) equation were $t_{min}=1.6427$, $y_{min}=1.5796$, $t_{max}=9.7249$, and $y_{max}=37.4441$. The equations were used to determine the age at which *Loligo* would reach 9 cm, the size of full vulnerability to fishing. The estimated ages for summer- and winter-hatched *Loligo* were 5.8 and 6.1 months respectively.

Given a monthly natural mortality rate of 0.30, the yield-per-recruit analysis indicated that the F level that would produce the maximum yield per recruit for the winter-hatched squid was $F_{max}=0.38$ (exploitation rate = 28%) (Figure A14, Table A17). The F level that would produce 50% of the maximum spawning potential for winter-hatched squid was $F_{50\%}=0.13$ (exploitation rate = 11%). For summer-hatched squid, F_{max} was calculated to be $F_{max}=0.36$ (exploitation rate = 26%), while $F_{50\%}=0.14$ (exploitation rate = 11%) (Figure A14, Table A16). Fishing mortality rates that exceed the F_{max} level will

reduce the average yield-per-recruit and the estimated F_{max} levels for winter- and summer-hatched squid can be used as seasonal definitions of growth overfishing for the *Loligo* stock. In contrast, the F levels that would produce 50% of the maximum spawning potential per recruit can be considered target harvest rates that are likely to produce sustainable fishery yields. By way of comparison, squid populations in the vicinity of the Falkland Islands are managed under a similarly conservative policy designed to ensure 40% proportional escapement (Basson, WP B2). It was also noted that there are currently no reliable inseason indicators of fishing mortality rates in either fishing season.

The high rates of monthly natural mortality emphasize the importance of *Loligo* in the marine food web. Given the large-scale changes in finfish species assemblages in recent decades, it is important to examine the implications of alternative estimates of M for yield and spawning stock biomass estimates of M . Similarly, it is important to investigate the impact of post spawning mortality in *Loligo*. Sensitivity analysis was carried out to examine the impact of changes in M over the range 0.26 - 0.34. Furthermore, sensitivity to the assumption that squid die immediately after spawning was examined by carrying out a set of runs in which M was doubled once the age of 100% maturity was reached (this is labelled "With Post-spawning Mortality"). Results are summarized below:

WINTER-HATCHED (NOV.-MAY) *LOLIGO*

Post-Spawning Mortality

<u>WITHOUT</u>			<u>WITH</u>	
M	F_{max}	$F_{50\%}$	F_{max}	$F_{50\%}$
0.26	0.35	0.12	0.55	0.18
0.30	0.38	0.13	0.75	0.19
0.34	0.43	0.14	1.29	0.20

SUMMER-HATCHED (JUN.-OCT.) *LOLIGO*

Post-Spawning Mortality

<u>WITHOUT</u>			<u>WITH</u>	
M	F_{max}	$F_{50\%}$	F_{max}	$F_{50\%}$
0.26	0.33	0.13	0.44	0.18
0.30	0.36	0.14	0.48	0.19
0.34	0.39	0.15	0.52	0.21

For winter-hatched *Loligo* with post-spawning mortality, F_{max} was sensitive to the level of M (F_{max} range = 0.55 to 1.29). F_{max} was relatively insensitive to the level of M for the other categories examined (F_{max} range = 0.33 to 0.52). Values of $F_{50\%}$ ranged from 0.12 to 0.21. The magnitude of $F_{50\%}$ was more sensitive to assumptions about post-spawning mortality than to assumptions about season of hatching.

Computation of Long Term Potential Yield

Long-term potential yield (LTPY) of *Loligo* was computed as the sum of the expected LTPYs for summer- and winter-hatched pre-recruits, estimated from abundances in the Fall and Spring NEFSC surveys, respectively. The expected LTPY of the summer-hatched pre-recruits (≤ 8 cm) *Loligo* was computed as the product of the average number of pre-recruits in the stock and the predicted yield per pre-recruit at $F_{50\%}$ for summer-hatched *Loligo* (Table A16). The expected LTPY of the winter-hatched pre-recruits (≤ 8 cm) *Loligo* was computed as product of the average number of pre-recruits in the stock at the time of the Spring survey and the predicted yield per pre-recruit at $F_{50\%}$ for winter-hatched *Loligo* (Table A17). Absolute numbers of spring and fall pre-recruits were computed from the diurnally-adjusted swept-area estimates from the spring and fall NEFSC surveys for the period 1968-1994 (Tables A12 and A13). The expected yield-per-recruit represents yields that will be realized over a 10 month period (based on maximum age). Therefore the yield from a seasonally-hatched cohort will span two fishing seasons (e.g., some winter-hatched pre-recruits will be captured by the summer fishery, and some will be captured later by the winter fishery). As a result of this overlap across

fishery periods for the projected yield, it is not possible to attribute all of the cohort-specific yield to a single fishery. While it is appropriate to add the expected yields to obtain LTPY, the methodology to specify appropriate fishery-specific levels requires further refinement. The overall LTPY was estimated to be 20,678 mt with 2,950 mt coming from the winter-hatched pre-recruits and the balance coming from the summer-hatched pre-recruits.

Maximum Optimum Yield

The maximal yield-per-recruit attainable with the current fishing pattern applied to average cohort sizes of summer- and winter-hatched *Loligo* would produce roughly 26,000 mt of landings. This level of landings can be considered the maximum optimal yield for the stock. Historically, landings in excess of 25,000 mt have not been sustained by the *Loligo* fishery due to fluctuations in stock abundance. The maximum optimum yield level should be considered as an upper bound on the allowable annual quota and should not be construed to be a target that can be attained each year. The previous estimate of maximum optimum yield was based on work by Lange and Sissenwine (1983). That work was completed before it was recognized that *Loligo* has a one-year life-span.

Risk Analysis for LTPY

As noted in Basson (WP A2) setting a specific catch level could impose risk to the population in years when recruitment is below average. The probability of exceeding the $F_{50\%}$ level for varying levels of LTPY was estimated from the distribution of observed spring and fall pre-recruit estimates. The probability of exceeding the target F was approximated as the fraction of the total number of years (1968-1994) that the predicted year-specific yields fell below the LTPY. Results of these computations are summarized in Table A18 and Figure A16. A catch level of 25,000 mt would result in 67% chance of exceeding $F_{50\%}$. As noted earlier, catches in excess of 25,000 mt do not appear to have been sustainable since the fishery first

exceeded 10,000 mt in 1970.

Prediction of Fishery Success

The previous assessment found that high levels of offshore winter fishing effort were associated with low levels of LPUE during the subsequent spring inshore fishery (NEFSC 1994). Because the LPUE standardization in this assessment differed from the previous assessment, the relationship between winter fishing effort and LPUE during the subsequent spring fishery was re-examined. The relationship between summer fishing effort and LPUE during the subsequent winter fishery was also investigated.

A linear regression of summer (April-September) domestic LPUE on standardized domestic fishing effort the previous winter (October-March) taken from the GLM analysis during 1988-1993 was highly significant ($R^2 = 0.82$, $F = 24.23$, $P = 0.008$) (Figure A15). The regression relationship was:

$$LPUE_{\text{summer}} = 7.717 - 0.003 \cdot \text{EFFORT}_{\text{winter}}$$

A linear regression of winter LPUE on standardized fishing effort the previous summer taken from the GLM analysis during 1983-1992 was not significant. Since the winter fishery depends on squid hatched during the summer period, the level of effort in the summer fishery does not appear to be adversely affecting winter abundance. Conversely, reductions in effort or discards in the winter fishery would likely increase abundance in the summer fishery and, more importantly, increase the number of summer spawners.

Summary and Conclusions

Stock biomass and recruitment are highly variable through time. The stock is fully-exploited. In the summer fishery, $F_{50\%}$ has been exceeded in 5 of the last 7 years. For the winter fishery, $F_{50\%}$ has been exceeded in 3 of the last 6 years. Failure to maintain a precautionary level of spawning potential may jeopardize the productivity of the stock and the

fishery. After the 1972-1976 fisheries with landings in excess of 32,000 mt, there was a marked decline in stock biomass. Spring and fall swept area biomass estimates were below average from 1977 to 1982, with the exception of fall 1980.

Growth overfishing rates (per month) for the *Loligo* stock were estimated to be $F_{\max}=0.38$ (exploitation rate =28%) for winter-hatched squid and $F_{\max}=0.36$ (exploitation rate =26%) for summer-hatched squid. The utilization rate estimated for the winter period of 1992-3 was greater than the threshold value for growth overfishing of the stock (Table A15). Growth overfishing was not indicated for other periods between 1987 and 1993. Based on data from 1987 to 1993, high effort levels in the winter (Oct-Mar) are negatively correlated with LPUE estimates in the subsequent Apr-Sep period. Following the winter fisheries in 1991-1992 and 1992-1993, the respective yields in the subsequent summer fishery seasons in 1992 and 1993 were 2,300 and 1,600 mt below the average summer yields since 1987.

Discarding is a substantial uncertainty in the *Loligo* assessment. Given rapid growth of *Loligo* in the final six months of life, and given the high reproductive and economic value of large squid, reductions in discarding would have both ecological and economic benefits.

Based on maintenance of 50% of the maximum spawning potential for this annual species, longterm potential total annual yield (LTPY) is approximately 21,000 mt, with approximately 3,000 mt coming from the spring pre-recruits and the balance coming from the fall pre-recruits. A constant annual catch of 26,000 mt, the maximum optimal yield for the stock, would probably not be sustainable because it would exceed the target $F_{50\%}$ 74% of the time. Moreover, persistent landings in excess of the LTPY may have deleterious effects on *Loligo* predators and unintended consequences for marine food webs.

Sources of Uncertainty and SARC Comments

If managers wish to capitalize on above average recruitment events to increase short-term yields, or to avoid overfishing when recruitment is low, development of an intensive in-season management program would be necessary.

The observed negative relationship between winter fishing effort and LPUE in the subsequent season has significant implications for management. The SARC recommended additional analyses (using alternative response variables or other data sets) be performed to try to determine whether this was merely a correlation or, in fact, a cause and effect relationship.

Discarding was a significant uncertainty in this assessment. The SARC recommended that data be collected to determine the magnitude of discards, especially in the winter fishery.

Noting that survey catches are influenced by water temperature and daylight, the SARC felt adjustments for such factors were useful. However, the SARC was not sure whether incorporation of environmental variables into assessments would be an important part of future in-season management programs.

The SARC noted that this assessment differed in methods from the previous assessment, and that changes need to be explained and justified to provide consistency. These included choice of survey strata sets, commercial vessels and their landings, and *Loligo* growth equations.

The SARC felt that $F_{50\%}$ was an acceptable overfishing target. Primary reasons for selecting this level of % MSP included 1) analogy with squid management in the Falkland Islands, 2) *Loligo*'s low fecundity and 3) the fact that *Loligo*'s annual

life span makes the population susceptible to recruitment overfishing and unpredictable fluctuations.

The SARC noted that it was not presently possible to characterize absolute removals from the *Loligo* stock because the level of discarding was unknown. The SARC emphasized that the 6-month utilization rates should not be interpreted as exploitation rates. The SARC also felt that the estimated utilization rates should be interpreted with caution due to the short lifespan and rapid growth of *Loligo*. The SARC reasoned that additions to stock biomass due to recruitment and growth would need to approximately equal removals due to natural mortality during the 6 months after the survey for the estimated utilization rates to be unbiased. The SARC noted, however, that it was not clear whether the estimates were consistently biased and recommended that other methods to estimate mortality rates on a finer temporal scale be explored.

Given the importance of survey data in this assessment to estimate swept area biomass, the SARC noted that there was considerable uncertainty regarding catchability of *Loligo* by survey gear.

Given available data, there is uncertainty about whether this population is best modelled as producing two cohorts per year, or whether the cohorts are produced over a long enough time period that they blend. The probability of migration by an individual between inshore and offshore areas during particular months is also uncertain.

Research Recommendations

- o Conduct research related to mating/spawning activities. Specifically, determine the length of the spawning period of individual females, magnitude of post-spawning mortality, the influence of seasonal variability, and

interactions between season, body size and maturity. Direct observational studies could also compare potential to actual fecundity.

- o Obtain more data on the magnitude and composition of discards. Inadequate data exist to characterize the level of discards in the directed fishery for *Loligo*. For example, prior to 1994 only three trips which targeted squid (note: there is no sea sampling code for *Illex* or *Loligo*, it is simply called "squid") were available from the NEFSC sea sampling program; only two commercial trips were sampled thus far in 1995. A sampling program should be instituted as soon as possible to develop preliminary estimates of the nature and level of discarding in the directed otter trawl fishery for *Loligo*. High priority should be given to sampling the offshore component of the fishery, including the freezer trawler fleet. Initially the program should focus on placing sea samplers onboard vessels from the ports of Pt. Judith and Davisville, Rhode Island, and Cape May, New Jersey. Sea sampling data obtained from this pilot program will provide preliminary estimates of the magnitude and variability of discards in the directed *Loligo* fishery which could then be used to design a more comprehensive sea sampling program for this fishery. The MADMF inshore sea-sampling program should continue as well.
- o Modify the SURVAN software to include an option to adjust the catch for the time of day that a tow was taken.
- o To better understand factors affecting squid catches, examine existing data on harvesting by non-US vessels to see if catches were related to physical characteristics of water masses or time of day.
- o Investigate the utility of a seasonal stock production model with season-specific production functions.

- o Examine the relationship between individual body size and market value. This could be an important management consideration relating size composition of the stock to fishery revenues.
- o Carry out additional analyses pertaining to development of a real-time management policy. These include examining the precision of survey biomass estimates with and without adjustments for light and temperature, considering the need for data on age-composition of the population through time, and trying to determine whether the relationship between the performance of inshore and offshore squid fisheries is one of association or cause and effect.
- o If a fishery develops south of Hatteras it will be necessary to record squid catch by species due to presence of at least one other loliginid, *L. plei*, as well as ommastrephids.
- o A fishery-dependent program for recording the occurrence of egg mops on winter fishing grounds would be useful for characterizing the temporal and spatial extent of winter spawning.
- o Examine catchability of *Loligo* with respect to survey gear to determine whether estimates of biomass and exploitation rate are biased.

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Table A1. Annual *Loligo pealei* landings (metric tons) from the Northwest Atlantic (Cape Hatteras to Gulf of Maine) by the U.S.¹ and foreign fleets, 1963-1993 with preliminary 1994 landings.

Year	US	Foreign	Total
1963	1,294	0	1,294
1964	576	2	578
1965	709	99	808
1966	772	226	948
1967	547	1,130	1,167
1968	1,084	2,327	3,411
1969	899	8,643	9,542
1970	653	16,732	17,385
1971	727	17,442	18,169
1972	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	5,464	15,805	21,269
1983	15,943	11,720	27,663
1984	11,592	11,031	22,623
1985	10,155	6,549	16,704
1986	13,292	4,598	17,890
1987	11,475	2	11,477
1988	19,072	3	19,075
1989	23,650	5	23,655
1990	14,954	0	14,954
1991	19,409	0	19,409
1992	18,177	0	18,177
1993	22,273	0	22,273
1994	22,468	0	22,468

¹Includes joint venture landings made by U.S. vessels

Table A2. Summary of *Loligo pealei* landings (mt) by fishing gear within the NEMFIS database, 1982-1993

Year	Bottom otter trawl	Floating trap	Pound net	Paired midwater otter trawl	Other	Totals
1982	2445	1	75	1	3	2525
1983	8266	23	2	2	439	8732
1984	6649	67	438	<1	4	7158
1985	6217	359	281	2	5	6864
1986	10867	77	522	11	35	11512
1987	9688	96	552	1	6	10343
1988	16811	649	1007	84	11	18562
1989	22416	450	725	55	5	23650
1990	14354	306	280	9	4	14954
1991	18849	318	161	44	37	19409
1992	17914	44	119	20	81	18177
1993	21,885	84	204	28	72	22273

Table A3. *Loligo* squid landings (metric tons) in 1993 by area and month.¹

Area	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Totals
514	-	-	-	-	0.7	-	-	-	-	0.5	15.8	0.2	17.1
521	-	-	-	-	0.4	0.3	-	-	-	0.3	0.8	0.1	1.9
522	-	-	-	-	0.2	0.3	0.2	0.2	2.7	0.1	-	-	3.6
525	-	-	0.1	10.8	4.0	1.4	-	-	-	-	2.5	-	18.9
526	-	2.4	10.2	-	68.4	0.2	6.7	0.5	5.3	18.1	-	4.3	115.9
533	0.8	-	-	6.8	-	-	-	-	-	-	-	-	7.6
537	779.6	338.8	352.8	191.4	228.2	48.2	194.2	54.4	485.8	404.1	375.1	423.5	3876.0
538	-	-	-	13.8	773.1	41.1	3.5	1.0	4.0	6.6	1.4	-	844.5
539	14.8	0.5	3.0	2.0	93.9	67.3	24.9	35.6	47.8	79.2	152.0	54.3	575.2
561	-	-	-	-	0.1	-	-	-	-	-	-	-	0.1
562	1.2	-	-	-	3.3	-	0.3	0.1	-	-	-	-	4.9
611	-	2.0	-	-	23.5	10.7	10.1	14.5	8.3	40.2	9.4	1.6	120.3
612	0.3	0.1	1.1	0.4	10.6	38.6	44.2	21.5	2.8	41.0	52.9	21.6	235.0
613	8.1	25.0	0.3	17.0	226.8	264.6	75.4	148.3	199.1	758.3	155.7	152.4	2030.9
614	0.1	-	-	-	0.1	146.4	91.3	39.8	0.2	0.1	-	-	278.0
615	-	3.3	-	0.5	0.3	0.6	0.6	-	0.2	-	0.1	4.6	10.1
616	2085.4	1808.6	1482.6	733.1	100.1	65.6	127.4	0.8	0.4	143.1	521.6	160.3	7228.9
621	0.1	-	-	1.5	15.5	12.5	2.5	0.5	1.4	2.2	0.5	1.2	37.7
622	683.1	1395.1	1777.9	603.1	2.7	0.7	-	1.2	2.6	2.1	18.5	690.7	5177.6
623	6.2	20.1	56.9	-	-	-	-	-	-	-	-	-	83.2
625	-	-	-	-	-	0.4	0.2	-	-	1.3	0.6	0.5	3.0
626	52.8	23.0	143.3	741.0	8.4	-	-	1.7	3.8	100.8	217.3	89.5	1381.4
627	-	-	2.8	-	-	-	-	-	-	-	-	-	2.8
631	-	0.3	-	-	-	-	-	-	-	0.1	1.3	1.1	2.8
632	0.3	0.5	3.7	0.3	-	-	-	-	-	103.9	95.6	0.1	204.3
635	-	-	-	-	-	-	-	-	-	-	0.5	0.6	1.1
636	-	-	-	-	-	-	-	1.2	-	3.2	-	-	4.4
Totals	3632.8	3619.6	3834.6	2321.6	1560.1	698.7	581.3	321.1	764.3	1705.0	1621.6	1606.5	22271.6
%	16	16	17	10	7	3	3	1	3	8	7	7	

¹Excludes 2.72 metric tons landed during unknown months.

Table A4. Total numbers and mean weights of *Loligo pealei* landed in the Northwest Atlantic from 1982 to 1992.

Year	Total Number (000's)	Mean Weight (g)
1982	162,231	131
1983	216,122	128
1984	183,213	123
1985	151,739	110
1986	139,173	129
1987	106,720	108
1988	194,430	98
1989	195,167	118
1990	113,828	138
1991	144,180	134
1992	137,508	128
AVERAGE		
1982-92	158,574	122

Table A5. Results of GLM effort standardization for October-March (winter) effort standardization for the domestic Loligo squid fishery. Factors are YEAR, MONTH, AREA, and TONCLASS; analyses restricted to ottwee trawl trips with landings of at least 10% Loligo by weight. Number of observations in data set = 17090.

SAS General Linear Models Procedure					
Dependent Variable: LNCPUEDF					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	28	7463.1840354	266.5422870	235.17	0.0001
Error	17061	19336.7021323	1.1333862		
Corrected Total	17089	26799.8861677			
	R-Square	C.V.	Root MSE	LNCPUEDF Mean	
	0.278478	208.7029	1.0646061	0.5101060	
Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	10	927.5667810	92.7566781	81.84	0.0001
AREA	11	4133.4726464	375.7702406	331.55	0.0001
TONCLASS	2	2044.5084531	1022.2542265	901.95	0.0001
MONTH	5	357.6361549	71.5272310	63.11	0.0001
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	10	611.7480136	61.1748014	53.98	0.0001
AREA	11	3184.4948705	289.4995337	255.43	0.0001
TONCLASS	2	2022.7734750	1011.3867375	892.36	0.0001
MONTH	5	357.6361549	71.5272310	63.11	0.0001
Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate	
INTERCEPT	1.293652173 B	29.15	0.0001	0.04438632	
YEAR 84	0.266421128 B	5.51	0.0001	0.04835452	
85	0.031582411 B	0.72	0.4731	0.04401901	
86	-0.481334873 B	-10.90	0.0001	0.04413959	
87	-0.231042666 B	-5.10	0.0001	0.04527442	
88	-0.226721996 B	-4.72	0.0001	0.04807114	
89	-0.011489121 B	-0.27	0.7907	0.04329924	
90	0.031134318 B	0.71	0.4776	0.04384122	
91	-0.184828674 B	-4.20	0.0001	0.04403353	
92	0.034534778 B	0.77	0.4391	0.04463126	
93	0.123052116 B	2.80	0.0052	0.04401763	
983	0.000000000 B				

Table A5. (Continued)

AREA	526	-0.483133827 B	-6.96	0.0001	0.06937702
	538	-0.922385783 B	-10.47	0.0001	0.08805900
	539	-0.428495648 B	-16.20	0.0001	0.02645052
	612	0.182861711 B	4.67	0.0001	0.03915159
	613	0.503498244 B	12.56	0.0001	0.04009227
	615	0.646298009 B	6.70	0.0001	0.09642841
	616	0.395881110 B	14.71	0.0001	0.02691716
	621	-0.577227582 B	-7.82	0.0001	0.07378094
	622	0.225796053 B	6.89	0.0001	0.03274908
	626	-1.455191971 B	-33.49	0.0001	0.04344718
	632	-0.805992633 B	-16.63	0.0001	0.04845983
	9537	0.000000000 B			
TONCLASS	2	-1.276753240 B	-38.64	0.0001	0.03304424
	3	-0.746800236 B	-35.63	0.0001	0.02095736
	4	0.000000000 B			
MONTH	1	-0.182461938 B	-6.30	0.0001	0.02896843
	2	-0.188955849 B	-5.96	0.0001	0.03168538
	3	-0.054261004 B	-1.75	0.0810	0.03109160
	10	0.317731892 B	11.29	0.0001	0.02814385
	11	0.064472331 B	2.48	0.0130	0.02594736
	12	0.000000000 B			

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

Table A6. Standardized landings (mt) per unit of effort (LPUE) and standardized fishing effort (standard days fished) in the winter (October-March) otter trawl fishery for *Loligo* squid.

Year ¹	Domestic LPUE ² (mt/days fished)	Standardized effort (days fished)
1983	3.66	231.3
1984	6.17	388.9
1985	4.61	665.2
1986	2.18	905.3
1987	3.99	1075.9
1988	4.63	1075.9
1989	8.45	1405.7
1990	6.13	1254.4
1991	4.64	1230.8
1992	7.96	1564.3
1993	8.52	1868.4
AVERAGE 1983-93	5.54	1060.5

¹ Winter year includes January to March of the calendar year and October to December of the previous year.

² Ratio of total landings (mt) to standardized effort for trips used in the general linear model.

Table A7. Results of GLM effort standardization for April-September effort standardization for the domestic Loligo squid fishery. Factors are YEAR, MONTH, AREA, and TONCLASS; analyses restricted to ottwee trawl trips with landings of at least 10% *Loligo* by weight. Number of observations in data set = 16624

SAS General Linear Models Procedure					
Dependent Variable: LNCPUEDF					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	11449.714051	477.071419	408.21	0.0001
Error	16599	19399.207508	1.168697		
Corrected Total	16623	30848.921559			
	R-Square	C.V.	Root MSE	LNCPUEDF Mean	
	0.371154	191.7264	1.0810631	0.5638573	
Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	11	2294.8160729	208.6196430	178.51	0.0001
MONTH	5	1653.3100611	330.6620122	282.93	0.0001
AREA	6	6587.7188162	1097.9531360	939.47	0.0001
TONCLASS	2	913.8691012	456.9345506	390.98	0.0001
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	11	1488.2285748	135.2935068	115.76	0.0001
MONTH	5	468.3117353	93.6623471	80.14	0.0001
AREA	6	4623.1142545	770.5190424	659.30	0.0001
TONCLASS	2	913.8691012	456.9345506	390.98	0.0001
Parameter	Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate	
INTERCEPT	1.122738638 B	22.91	0.0001	0.04901239	
YEAR 83	0.465539844 B	8.66	0.0001	0.05375258	
84	0.122422523 B	2.22	0.0264	0.05512476	
85	-0.032027618 B	-0.57	0.5685	0.05616241	
86	0.078092030 B	1.46	0.1432	0.05334483	
87	-0.189575383 B	-3.48	0.0005	0.05448035	
88	0.035998044 B	0.67	0.5006	0.05343857	
89	-0.178931668 B	-3.27	0.0011	0.05463933	
90	-0.221660500 B	-3.98	0.0001	0.05563706	
91	-0.012763865 B	-0.23	0.8146	0.05441703	
92	-0.541679371 B	-9.53	0.0001	0.05683023	
93	-0.732355786 B	-13.56	0.0001	0.05399101	
982	0.000000000 B				
MONTH 4	-0.562677880 B	-13.47	0.0001	0.04176187	
6	-0.243766328 B	-9.28	0.0001	0.02627073	
7	-0.315051156 B	-10.45	0.0001	0.03013621	
8	-0.577401007 B	-17.69	0.0001	0.03263498	
9	-0.484938954 B	-14.55	0.0001	0.03333407	
95	0.000000000 B				
AREA 537	-0.203177702 B	-6.74	0.0001	0.03013306	
539	-1.463507579 B	-50.53	0.0001	0.02896314	
611	-1.189200350 B	-30.12	0.0001	0.03947885	
612	-0.160803122 B	-3.37	0.0008	0.04770658	
613	-0.276063058 B	-6.39	0.0001	0.04321289	
621	-0.962394111 B	-18.53	0.0001	0.05192318	
9538	0.000000000 B				
TONCLASS 3	0.441057648 B	22.31	0.0001	0.01976790	
4	0.909074230 B	24.83	0.0001	0.03661646	
92	0.000000000 B				

NOTE: The X'X matrix has been found to be singular and a generalized inverse was used to solve the normal equations. Estimates followed by the letter 'B' are biased, and are not unique estimators of the parameters.

Table A8. Standardized landings (mt) per unit of effort (LPUE) and standardized fishing effort (standard days fished) in the summer (April-September) otter trawl fishery for *Loligo* squid.

Year	Domestic LPUE ¹ (mt/days fished)	Standardized effort (days fished)
1982	3.82	271.4
1983	7.18	763.9
1984	5.09	548.5
1985	4.62	636.3
1986	4.38	1480.7
1987	4.27	1016.9
1988	4.95	1139.7
1989	3.54	1133.9
1990	3.63	1097.8
1991	4.38	1274.9
1992	2.90	797.3
1993	2.59	1046.9
AVERAGE 1982-93	4.28	934.0

¹ Ratio of total landings (mt) to standardized effort for trips used in the general linear model.

Table A9. All sizes, pre-recruit (≤ 8 cm), and recruit (> 8 cm) stratified mean numbers per tow and stratified mean weight (kg) per tow of *Loligo pealei* from the NEFSC fall bottom trawl survey (offshore strata 1-23, 25 and 61-76, Cape Hatteras to Georges Bank) during 1967-94.

Individual Year	All sizes Number/tow	CV ¹ (%)	Pre-recruits Number/tow	Recruits Number/tow	All sizes Kg/tow	Mean Weight (g)
1967	143.1	22	123.4	19.6	4.1	29
1968	187.7	13	118.8	68.9	7.6	41
1969	252.3	15	160.1	92.2	10.2	40
1970	90.9	14	54.1	36.9	3.3	36
1971	173.6	15	141.7	31.9	3.2	18
1972	288.6	18	220.1	68.4	6.9	24
1973	395.6	15	275.4	120.2	11.4	29
1974	267.7	18	186.4	81.2	8.7	32
1975	653.3	20	543.0	110.3	11.4	17
1976	436.7	14	321.4	115.3	12.0	28
1977	413.1	13	316.6	96.6	8.5	21
1978	153.3	16	99.2	54.2	4.5	29
1979	205.9	15	166.4	39.5	4.0	19
1980	387.2	16	297.5	89.7	8.3	22
1981	241.3	15	171.5	69.8	6.1	25
1982	270.9	22	216.4	54.5	5.8	21
1983	384.7	15	261.8	122.9	11.6	30
1984	316.4	17	160.4	155.9	12.8	41
1985	460.2	15	322.2	138.0	13.1	28
1986	459.6	16	364.6	95.0	8.9	19
1987	59.8	14	33.9	25.9	2.2	37
1988	405.3	16	316.0	89.3	7.7	19
1989	450.6	15	291.3	159.3	11.9	26
1990	385.8	14	286.6	99.2	9.2	24
1991	320.1	11	194.7	126.3	10.9	34
1992	788.9	30	755.8	33.1	5.3	7
1993	198.8	23	130.0	68.8	5.3	27
1994	494.6	13	318.1	176.5	15.5	31
Average 1967-94	331.6	16	244.6	87.1	8.2	27

¹ Coefficient of variation for the all sizes index.

Table A10. All sizes, pre-recruit (≤ 8 cm), and recruit (> 8 cm) stratified mean numbers per tow and stratified mean weight (kg) per tow of *Loligo pealei* from the NEFSC spring bottom trawl survey (offshore strata 1-23, 25 and 61-76, Cape Hatteras to Georges Bank) during 1968-95.

Year	All sizes Number/tow	CV ¹ (%)	Pre-recruits Number/tow	Recruits Number/tow	All sizes Kg/tow	Individual Mean Weight (g)
1968	26.9	25	5.7	21.1	1.4	53
1969	14.8	21	2.0	12.8	1.2	82
1970	26.6	22	17.7	8.9	.9	34
1971	35.0	24	20.3	14.7	1.6	46
1972	65.2	21	37.0	28.2	3.2	49
1973	42.4	27	19.2	23.2	2.9	67
1974	231.2	30	196.0	35.3	4.1	18
1975	166.6	31	126.0	40.6	4.2	25
1976	200.1	17	153.6	46.5	5.2	26
1977	18.8	30	10.0	8.8	.8	42
1978	49.1	34	36.0	13.2	1.5	30
1979	113.8	34	95.5	18.4	2.3	20
1980	54.6	34	39.6	15.0	1.9	35
1981	48.1	27	28.1	20.0	1.9	40
1982	70.6	27	50.0	22.6	2.1	30
1983	46.9	24	17.5	29.4	2.1	44
1984	78.1	31	54.0	24.1	2.6	33
1985	83.4	21	61.5	22.0	2.4	28
1986	99.6	24	70.8	28.8	2.9	30
1987	31.0	16	12.7	18.3	2.1	67
1988	130.1	28	94.7	35.4	3.6	28
1989	153.0	30	92.4	60.6	5.2	34
1990	136.2	23	102.6	33.6	3.7	27
1991	181.2	24	131.7	49.4	4.5	25
1992	90.4	30	69.9	20.5	2.7	30
1993	46.5	28	26.3	20.2	1.8	40
1994	32.1	15	21.7	10.4	1.1	33
1995	65.1	14	45.0	20.1	1.9	29
1968-95 Average	83.5	25	58.5	25.1	2.6	37

¹ Coefficient of variation for the all sizes index.

Table A11. All sizes, pre-recruit (≤ 8 cm), and recruit (> 8 cm) stratified mean numbers per tow and stratified mean weight (kg) per tow of *Loligo pealei* from the NEFSC winter bottom trawl survey (offshore strata 1-23, 25 and 61-76, Cape Hatteras to Georges Bank) during 1992-94.

Year	All sizes Number/tow	CV ¹ (%)	Pre-recruits Number/tow	Recruits Number/tow	All sizes Kg/tow	Individual Mean Weight (g)
1992	57.2	20	35.5	21.7	2.5	44
1993	166.4	21	85.0	81.4	5.9	35
1994	57.7	13	33.5	24.0	2.5	44
1992-94 Average	93.8	18	51.3	42.4	3.6	41

¹ Coefficient of variation for the all sizes index.

Table A12. Diurnal-adjusted, swept-area estimates of *Loligo* biomass (mt), numbers of pre-recruits (≤ 8 cm), and numbers of recruits (> 8 cm) from the NEFSC fall bottom trawl survey (offshore strata 1-30, 33-40, and 61-76, Cape Hatteras to the Gulf of Maine) during 1967-94.

Year	Biomass (mt)	CV (%)	Pre-recruits (x 10 ⁸)	Recruits (x 10 ⁸)
1967	23881	17	5.53	1.60
1968	39816	16	5.86	3.24
1969	53656	14	7.96	4.19
1970	19941	14	3.16	2.00
1971	15140	12	6.44	1.44
1972	34767	12	11.84	3.01
1973	62028	9	13.65	5.79
1974	54669	12	10.61	4.21
1975	66045	15	26.67	5.68
1976	66920	19	17.50	5.73
1977	42247	16	16.62	4.28
1978	22151	14	5.28	2.63
1979	21721	10	9.28	1.90
1980	46923	13	26.07	4.47
1981	30751	11	9.11	3.20
1982	31441	15	11.92	2.57
1983	70524	16	13.44	6.30
1984	75063	11	8.62	7.76
1985	70809	12	17.68	6.70
1986	48220	13	18.05	4.50
1987	12084	14	2.01	1.19
1988	39563	11	17.15	4.02
1989	61372	15	14.99	7.36
1990	57285	12	15.02	5.20
1991	57669	11	11.05	5.84
1992	27792	17	36.85	1.91
1993	27434	7	5.90	3.12
1994	80894	12	16.74	7.98

¹ Coefficient of variation for the all sizes index.

Table A13. Diurnal-adjusted, swept-area estimates of *Loligo* biomass (mt), numbers of pre-recruits (≤ 8 cm), and numbers of recruits (> 8 cm) from the NEFSC spring bottom trawl survey (offshore strata 1-30, 33-40, and 61-76, Cape Hatteras to the Gulf of Maine) during 1968-94.

Year	Biomass (mt)	CV (%)	Pre-recruits ($\times 10^8$)	Recruits ($\times 10^8$)
1968	9296	28	0.51	1.13
1969	6766	18	0.17	0.61
1970	5058	19	0.92	0.42
1971	7920	19	1.01	0.67
1972	21053	15	2.23	1.52
1973	17894	20	1.09	1.20
1974	20848	21	9.95	1.58
1975	23025	17	6.38	1.98
1976	29184	10	8.68	2.36
1977	4258	31	0.48	0.41
1978	8225	25	1.97	0.64
1979	11157	20	4.32	0.79
1980	12969	20	2.01	0.85
1981	11216	17	1.96	0.97
1982	13295	13	2.76	1.26
1983	14766	25	1.50	1.79
1984	15543	30	3.06	1.27
1985	15250	19	4.14	1.21
1986	19364	17	4.07	1.71
1987	12983	16	0.81	0.96
1988	22577	13	5.14	1.92
1989	30190	14	5.20	3.02
1990	23436	31	5.93	1.95
1991	25994	15	8.18	2.41
1992	14150	21	3.49	0.98
1993	14772	34	1.62	1.36
1994	7928	19	1.63	0.64

¹ Coefficient of variation for the all sizes index.

Table A14. Proportion of NEFSC autumn survey tows, by region, in which *Loligo* were caught.

Year	Mid-Atlantic	Southern New England	Georges Bank	Gulf of Maine
1967	83.3	46.2	21.0	3.1
1968	88.7	74.2	39.7	6.0
1969	86.8	84.6	40.3	8.8
1970	88.1	76.2	35.5	9.6
1971	77.8	77.5	56.1	10.7
1972	88.0	76.6	52.2	2.7
1973	92.3	89.7	75.8	13.9
1974	100.0	89.7	47.1	12.8
1975	94.5	91.7	22.7	13.8
1976	87.1	73.8	66.1	35.2
1977	93.5	70.2	43.8	10.8
1978	74.0	75.0	34.6	5.7
1979	87.2	79.8	72.1	13.7
1980	83.0	75.0	38.4	11.4
1981	71.4	89.3	33.8	9.6
1982	93.8	74.1	45.0	4.0
1983	94.0	80.4	41.3	15.9
1984	95.8	91.1	57.1	16.9
1985	96.1	98.1	63.5	19.1
1986	98.0	96.4	58.1	9.6
1987	86.7	77.6	26.7	8.7
1988	91.1	87.5	47.5	14.5
1989	97.7	87.5	60.3	17.4
1990	95.6	91.8	46.2	8.6
1991	97.8	89.8	67.9	14.1
1992	93.2	81.6	52.6	1.5
1993	97.8	95.9	66.7	13.0
1994	95.7	96.0	56.5	11.6

Table A15. Stock size and exploitation rates for *Loligo* squid during winter (October-March) and summer (April-September) of 1987-1993.

Year	Fishing Season	Landings (mt)	Minimum Biomass (mt)			6-Month Exploitation Rate			1-Month Instantaneous Utilization Rate			Lower 80% CI Exceeds $F_{50\%}$ MSP?	Lower 80% CI Exceeds F_{MAX} ?
			Lower 80% CI	Point Estimate	Upper 80% CI	Lower 80% CI	Point Estimate	Upper 80% CI	Lower 80% CI	Point Estimate	Upper 80% CI		
1987	SUMMER	6739	10263	12983	15703	43%	52%	66%	0.240	0.340	0.580	YES	NO
1988	WINTER	5462	9876	12084	14292	38%	45%	55%	0.200	0.265	0.385	YES	NO
1988	SUMMER	11342	18696	22577	26458	43%	50%	61%	0.240	0.320	0.475	YES	NO
1989	WINTER	14049	33863	39563	45263	31%	36%	41%	0.150	0.180	0.230	YES	NO
1989	SUMMER	8053	24742	30190	35638	23%	27%	33%	0.100	0.120	0.160	NO	NO
1990	WINTER	10222	49945	61372	72799	14%	17%	20%	0.055	0.070	0.090	NO	NO
1990	SUMMER	6549	14269	23436	32603	20%	28%	46%	0.085	0.130	0.270	NO	NO
1991	WINTER	6728	48168	57284	66400	10%	12%	14%	0.040	0.045	0.055	NO	NO
1991	SUMMER	9315	21108	25994	30880	30%	36%	44%	0.145	0.185	0.255	YES	NO
1992	WINTER	14249	49220	57669	66118	22%	25%	29%	0.095	0.110	0.135	NO	NO
1992	SUMMER	5344	10392	14150	17908	30%	38%	51%	0.140	0.200	0.335	YES	NO
1993	WINTER	16734	21811	27792	33773	50%	60%	77%	0.310	0.465	0.996	YES	NO
1993	SUMMER	6018	8382	14772	21162	28%	41%	72%	0.135	0.225	0.770	NO	NO

Fishing Season	Average Landings (mt)	Hatch Season	Biological Reference Points			
			Exploitation Rates (U)		Instantaneous Fishing Mortality Rates (F)	
			$U_{50\%}$ MSP	U_{MAX}	$F_{50\%}$	F_{MAX}
SUMMER	7623	Winter	11%	28%	0.13	0.38
WINTER	11241	Summer	11%	26%	0.14	0.36

Table A16. Yield and spawning stock biomass per recruit estimates for summer-hatched
(June-October) *Loligo pealei*.

Yield and Spawning Stock Biomass per Recruit LOLIGO_Summer:_YPR_SSB/R_11/28/95

Proportion of F before spawning: 1.0000

Proportion of M before spawning: 1.0000

Natural mortality is constant at: 0.3000

Initial age is: 1 Last age is: 9

Last age is a PLUS group

Input data from file: lol_sum2.dat (uses winter weights through age 4)

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Stock	Weights Catch
1	0.0000	1.0000	0.0000	0.0001	0.0001
2	0.0000	1.0000	0.0000	0.0006	0.0006
3	0.0000	1.0000	0.0000	0.0022	0.0022
4	0.0000	1.0000	0.0000	0.0063	0.0063
5	0.2000	1.0000	0.4000	0.0173	0.0173
6	1.0000	1.0000	0.8000	0.0562	0.0562
7	1.0000	1.0000	0.9000	0.1340	0.1340
8	1.0000	1.0000	0.9000	0.2546	0.2546
9+	1.0000	1.0000	1.0000	0.4088	0.4088

Summary of Yield per Recruit Analysis for:

LOLIGO_Summer:_YPR_SSB/R_11/28/95

The slope of the yield per recruit curve at F=0: 0.181424

F level at slope=1/10 of the above slope (F0.1): 0.223933

Yield/Recruit corresponding to F0.1: 0.016301

F level to produce Maximum Yield/Recruit (Fmax): 0.357255

Yield/Recruit corresponding to Fmax: 0.017292

F level at 0.50 of max spawning potential: 0.138564

SSB/Recruit corresponding to F=0.138564: 0.075266

FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	%MSP
0.000	0.00000	0.00000	3.8583	0.2185	0.6726	0.1505	100.00
0.050	0.03415	0.00714	3.7455	0.1777	0.5657	0.1149	76.32
0.100	0.05983	0.01152	3.6608	0.1482	0.4864	0.0898	59.66
0.150	0.07987	0.01419	3.5949	0.1259	0.4256	0.0716	47.54
0.200	0.09597	0.01580	3.5422	0.1088	0.3775	0.0579	38.49
0.250	0.10918	0.01670	3.4991	0.0952	0.3387	0.0476	31.59
0.300	0.12024	0.01715	3.4631	0.0844	0.3068	0.0395	26.24
0.350	0.12965	0.01729	3.4327	0.0755	0.2801	0.0332	22.03
0.400	0.13775	0.01723	3.4065	0.0682	0.2575	0.0281	18.67
0.450	0.14480	0.01704	3.3839	0.0621	0.2382	0.0240	15.96
0.500	0.15101	0.01677	3.3640	0.0570	0.2214	0.0207	13.75
0.550	0.15652	0.01645	3.3465	0.0526	0.2069	0.0180	11.94
0.600	0.16145	0.01610	3.3309	0.0489	0.1941	0.0157	10.43
0.650	0.16588	0.01573	3.3169	0.0457	0.1827	0.0138	9.18
0.700	0.16990	0.01537	3.3043	0.0429	0.1726	0.0122	8.12
0.750	0.17356	0.01501	3.2928	0.0405	0.1636	0.0109	7.23
0.800	0.17691	0.01466	3.2824	0.0384	0.1555	0.0097	6.47
0.850	0.17999	0.01432	3.2729	0.0365	0.1481	0.0088	5.82
0.900	0.18284	0.01399	3.2641	0.0348	0.1415	0.0079	5.26
0.950	0.18548	0.01369	3.2560	0.0333	0.1354	0.0072	4.77
1.000	0.18793	0.01339	3.2485	0.0320	0.1298	0.0066	4.35

Table A17. Yield and spawning stock biomass per recruit estimates for winter-hatched
(November-May) *Loligo pealei*.

Yield and Spawning Stock Biomass per Recruit LOLIGO_Winter: YPR_SSB/R_11/28/95

Proportion of F before spawning: 1.0000
 Proportion of M before spawning: 1.0000
 Natural mortality is constant at: 0.3000
 Initial age is: 1 Last age is: 9
 Last age is a PLUS group
 Input data from file named: lol_win.dat

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Stock	Weights Catch
1	0.0000	1.0000	0.0000	0.0001	0.0001
2	0.0000	1.0000	0.0000	0.0006	0.0006
3	0.0000	1.0000	0.0000	0.0022	0.0022
4	0.0000	1.0000	0.0000	0.0063	0.0063
5	0.0000	1.0000	0.2500	0.0159	0.0159
6	0.9000	1.0000	0.2500	0.0364	0.0364
7	1.0000	1.0000	0.4000	0.0768	0.0768
8	1.0000	1.0000	1.0000	0.1517	0.1517
9+	1.0000	1.0000	1.0000	0.2833	0.2833

Summary of Yield per Recruit Analysis for:
 LOLIGO_Winter: YPR_SSB/R_11/28/95

The slope of the yield per recruit curve at F=0: 0.119000
 F level at slope=1/10 of the above slope (F0.1): 0.234015
 Yield/Recruit corresponding to F0.1: 0.011077
 F level to produce Maximum Yield/Recruit (Fmax): 0.384645
 Yield/Recruit corresponding to Fmax: 0.011796
 F level at 0.50 of max spawning potential: 0.133293
 SSB/Recruit corresponding to F=0.133293: 0.046687

FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	%MSP
0.000	0.00000	0.00000	3.8583	0.1477	0.4961	0.0934	100.00
0.050	0.03107	0.00471	3.7556	0.1215	0.4056	0.0707	75.72
0.100	0.05440	0.00764	3.6788	0.1025	0.3400	0.0548	58.66
0.150	0.07257	0.00946	3.6191	0.0882	0.2908	0.0432	46.27
0.200	0.08713	0.01059	3.5714	0.0771	0.2529	0.0346	37.06
0.250	0.09906	0.01125	3.5325	0.0683	0.2231	0.0281	30.06
0.300	0.10901	0.01161	3.5002	0.0613	0.1993	0.0230	24.66
0.350	0.11745	0.01177	3.4729	0.0555	0.1799	0.0191	20.43
0.400	0.12470	0.01179	3.4496	0.0508	0.1640	0.0160	17.09
0.450	0.13100	0.01172	3.4295	0.0468	0.1508	0.0135	14.42
0.500	0.13651	0.01160	3.4119	0.0435	0.1397	0.0114	12.26
0.550	0.14139	0.01144	3.3965	0.0406	0.1303	0.0098	10.51
0.600	0.14573	0.01125	3.3828	0.0382	0.1224	0.0085	9.07
0.650	0.14963	0.01106	3.3707	0.0361	0.1155	0.0074	7.89
0.700	0.15314	0.01086	3.3598	0.0342	0.1096	0.0065	6.91
0.750	0.15632	0.01066	3.3500	0.0326	0.1045	0.0057	6.10
0.800	0.15922	0.01047	3.3411	0.0313	0.1000	0.0051	5.41
0.850	0.16188	0.01029	3.3331	0.0300	0.0960	0.0045	4.84
0.900	0.16432	0.01011	3.3258	0.0289	0.0926	0.0041	4.35
0.950	0.16656	0.00994	3.3191	0.0280	0.0895	0.0037	3.94
1.000	0.16864	0.00979	3.3129	0.0271	0.0868	0.0033	3.59

Table A18. Comparison of predicted potential yield from diurnally-adjusted survey estimates and yield-per-recruit with total landings. See section on Computation of Long-term Potential Yield for details.

Year	Survey Pre-recruit No.		Potential Yield			Total Landings (mt)
	Spring (x e+8)	Fall (x e+8)	Spring (mt)	Fall (mt)	Total (mt)	
68	0.51	5.86	328	7999	8327	3411
69	0.17	7.96	109	10865	10975	9542
70	0.92	3.16	592	4313	4906	17385
71	1.01	6.44	650	8791	9441	18169
72	2.23	11.84	1436	16162	17598	29734
73	1.09	13.65	702	18632	19334	37613
74	9.95	10.61	6408	14483	20890	34850
75	6.38	26.67	4109	36405	40513	33801
76	8.68	17.5	5590	23888	29477	25284
77	0.48	16.62	309	22686	22995	16674
78	1.97	5.28	1269	7207	8476	10646
79	4.32	9.28	2782	12667	15449	17320
80	2.01	26.07	1294	35586	36880	23746
81	1.96	9.11	1262	12435	13697	22528
82	2.76	11.92	1777	16271	18048	21269
83	1.5	13.44	966	18346	19312	27663
84	3.06	8.62	1971	11766	13737	22623
85	4.14	17.68	2666	24133	26799	16704
86	4.07	18.05	2621	24638	27259	17890
87	0.81	2.01	522	2744	3265	11477
88	5.14	17.15	3310	23410	26720	19075
89	5.2	14.99	3349	20461	23810	23655
90	5.93	15.02	3819	20502	24321	14954
91	8.18	11.05	5268	15083	20351	19409
92	3.49	36.85	2248	50300	52548	18177
93	1.62	5.9	1043	8054	9097	22273
94	1.63	16.74	1050	22850	23900	22468
Mean	3.30	13.31	2128	18173	20301	20679
Median	2.23	11.92	1436	16271	19334	19409
Min	0.17	2.01	109	2744	3265	3411
Max	9.95	36.85	6408	50300	52548	37613

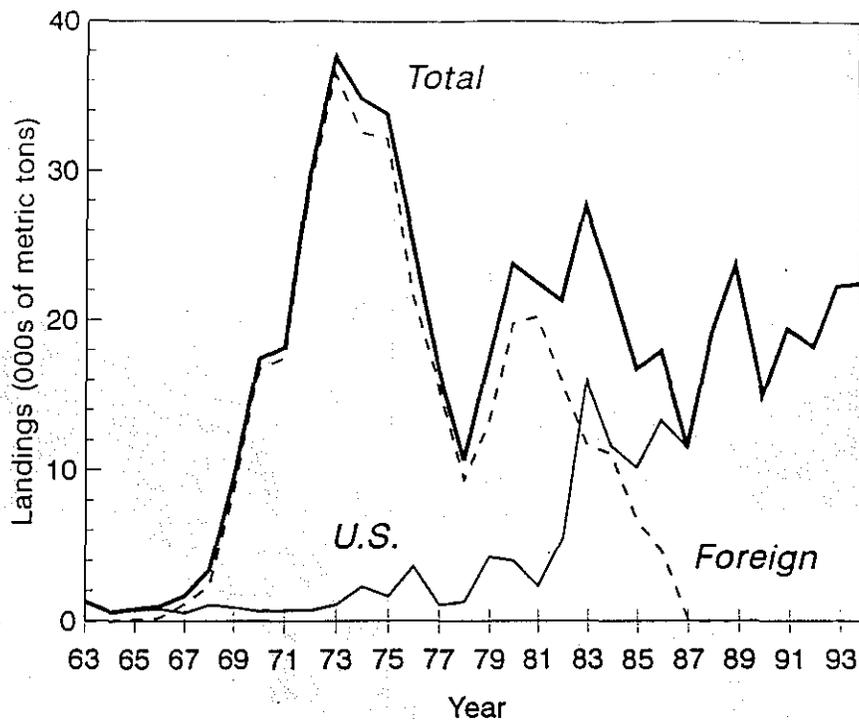


Figure A1. Total, US and foreign landings of *Loligo* squid during 1963-1994.

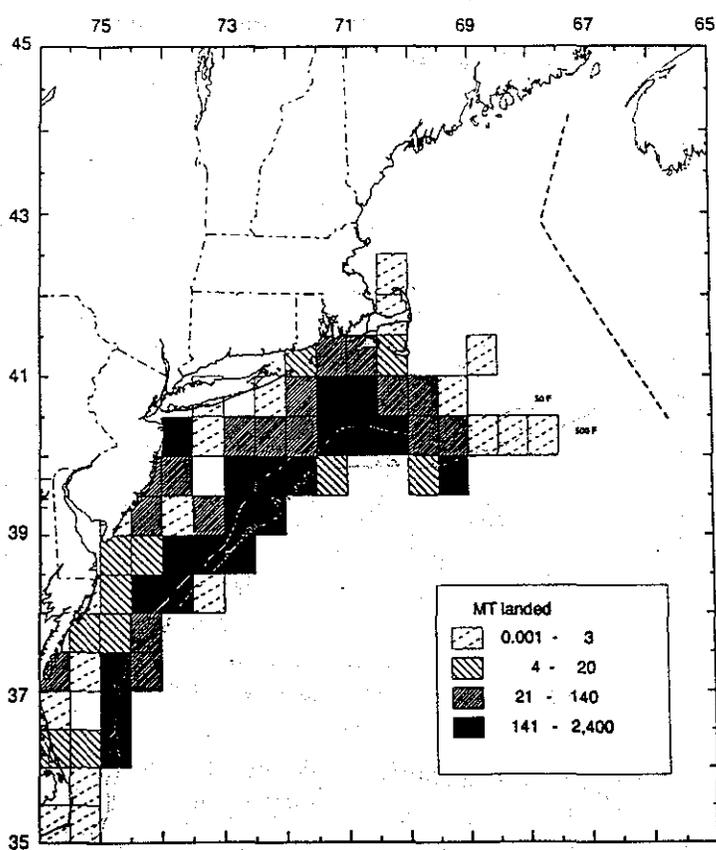


Figure A2. Distribution of *Loligo* squid landings (mt), by quarter-degree square, during October-March, 1987-1990.

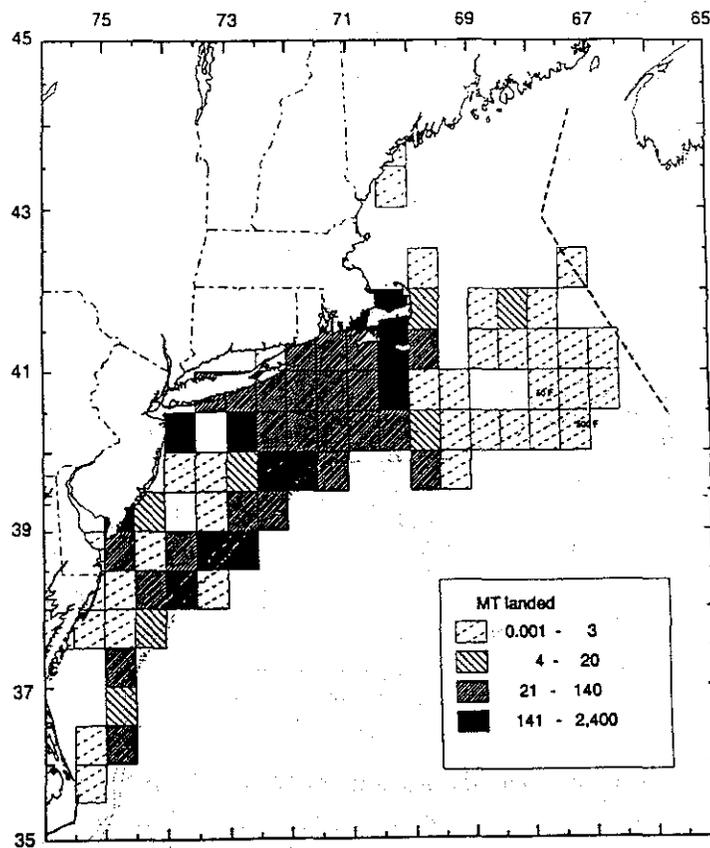


Figure A3. Distribution of *Loligo* squid landings (mt), by quarter-degree square, during April-September, 1988-1990.

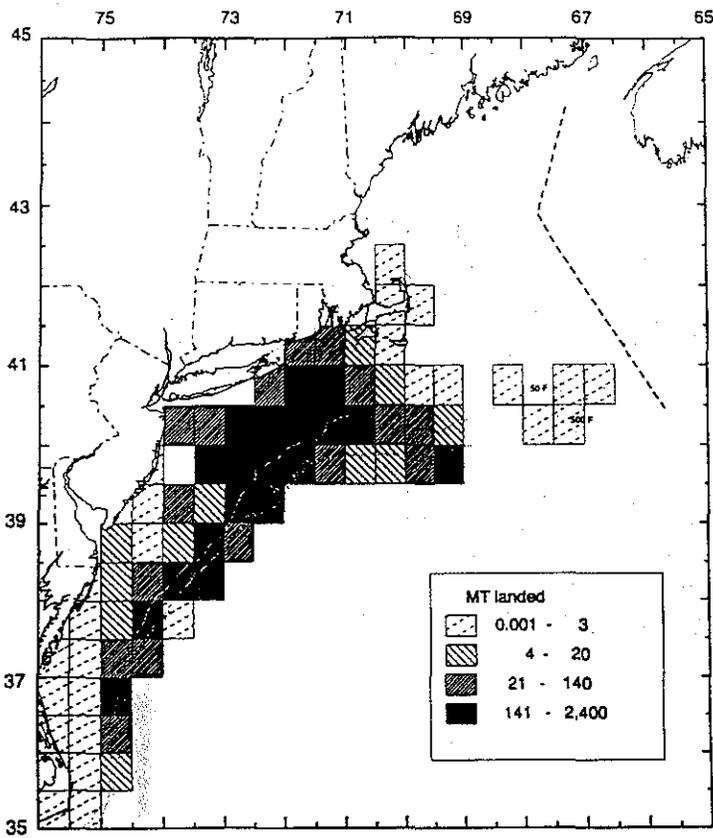


Figure A4. Distribution of *Loligo* squid landings (mt), by quarter-degree square, during October-March, 1990-1993.

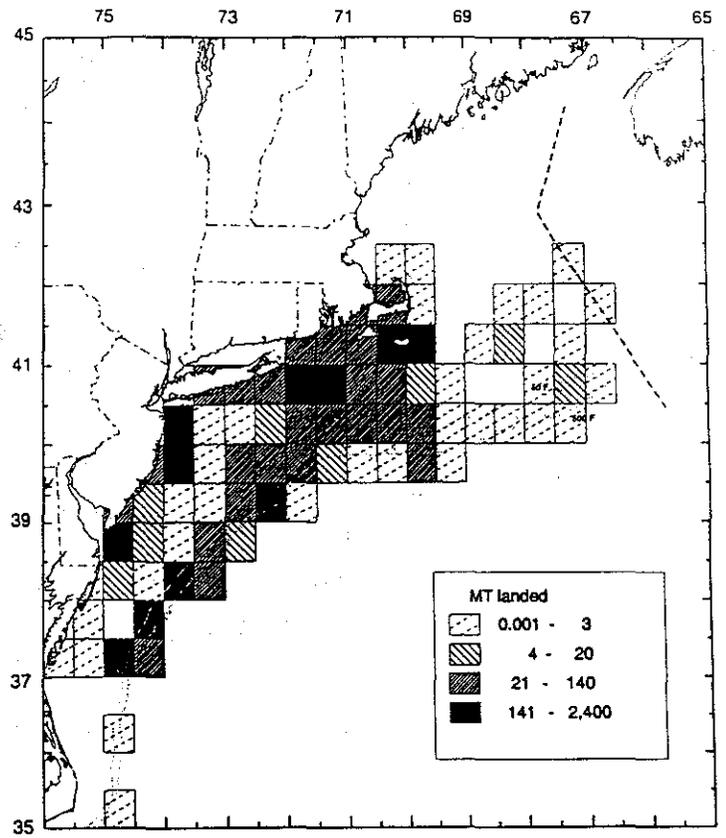


Figure A5. Distribution of *Loligo* squid landings (mt), by quarter-degree square, during April-September, 1991-1993.

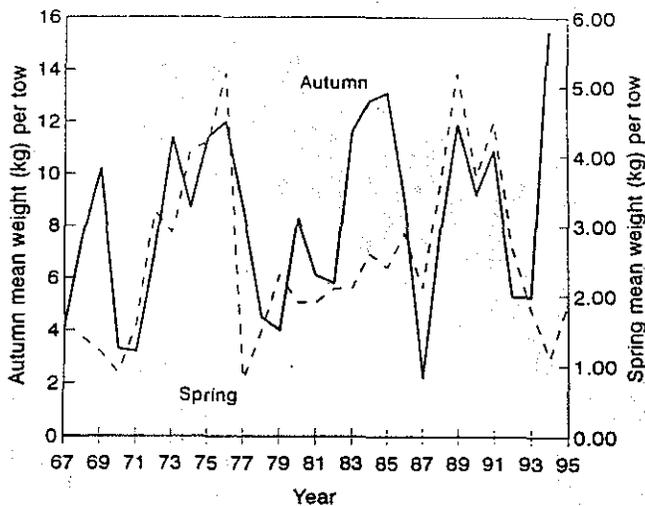


Figure A6. Stratified mean weight per tow (kg) of *Loligo pealei* from NEFSC autumn (1967-1994) and spring (1968-1995) bottom trawl surveys.

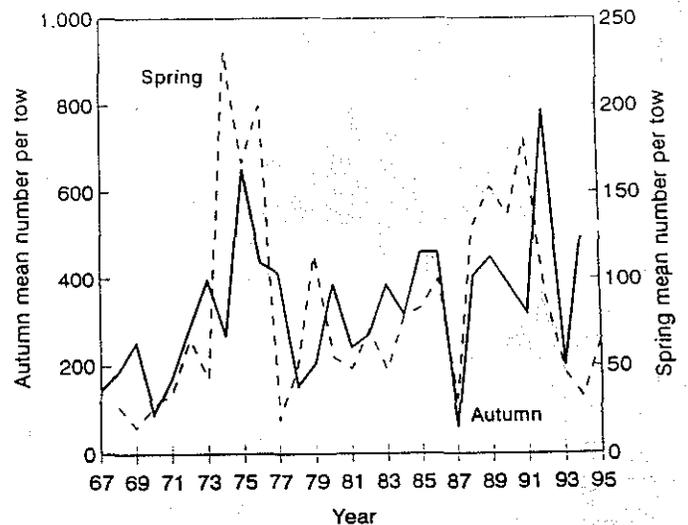


Figure A7. Stratified mean number per tow of *Loligo pealei* from NEFSC autumn (1967-1994) and spring (1968-1995) bottom trawl surveys.

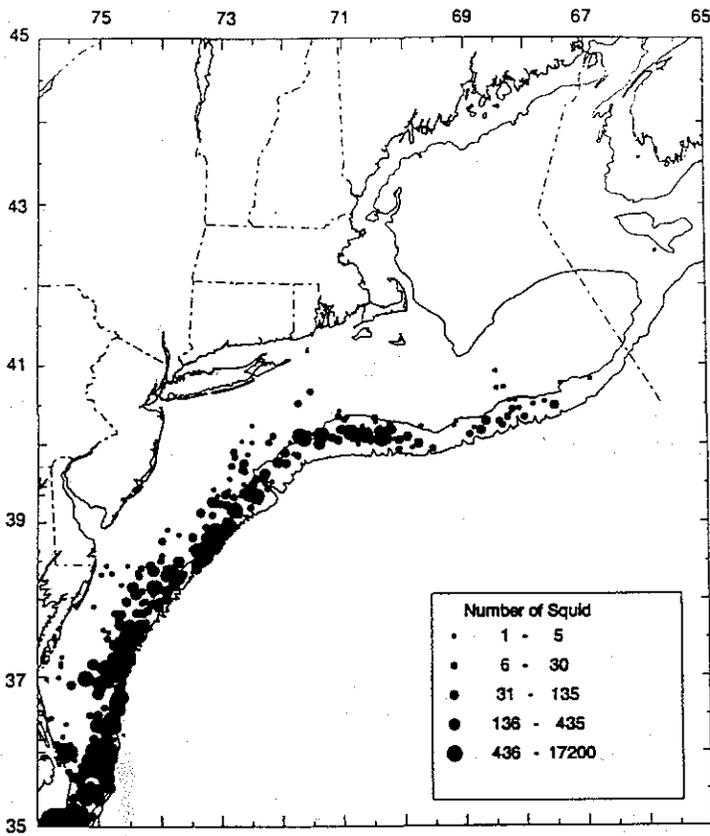


Figure A8. Distribution of *Loligo* squid <9 cm caught during NEFSC spring bottom trawl surveys, 1987-1993.

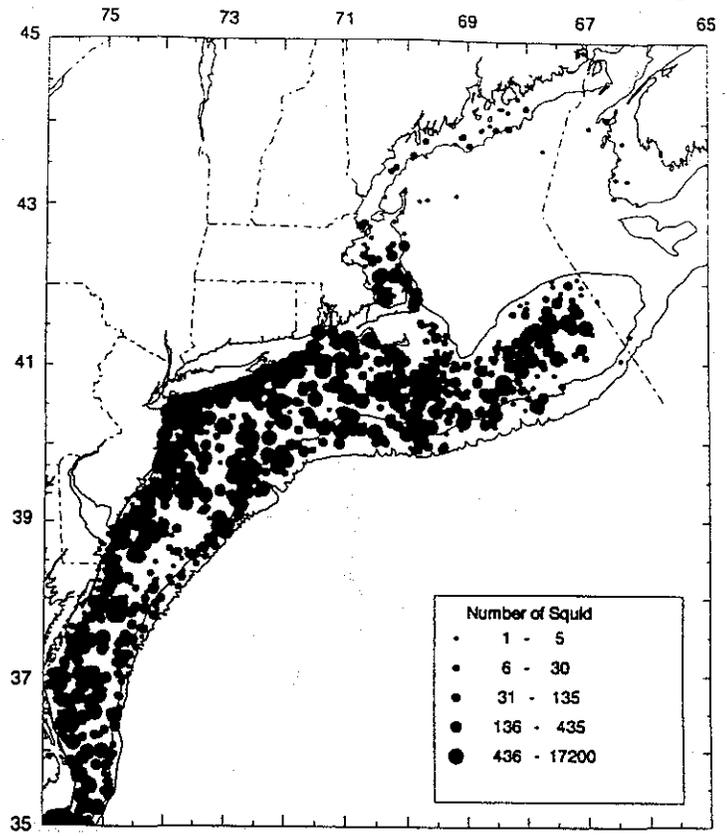


Figure A9. Distribution of *Loligo* squid <9 cm caught during NEFSC autumn bottom trawl surveys, 1987-1993.

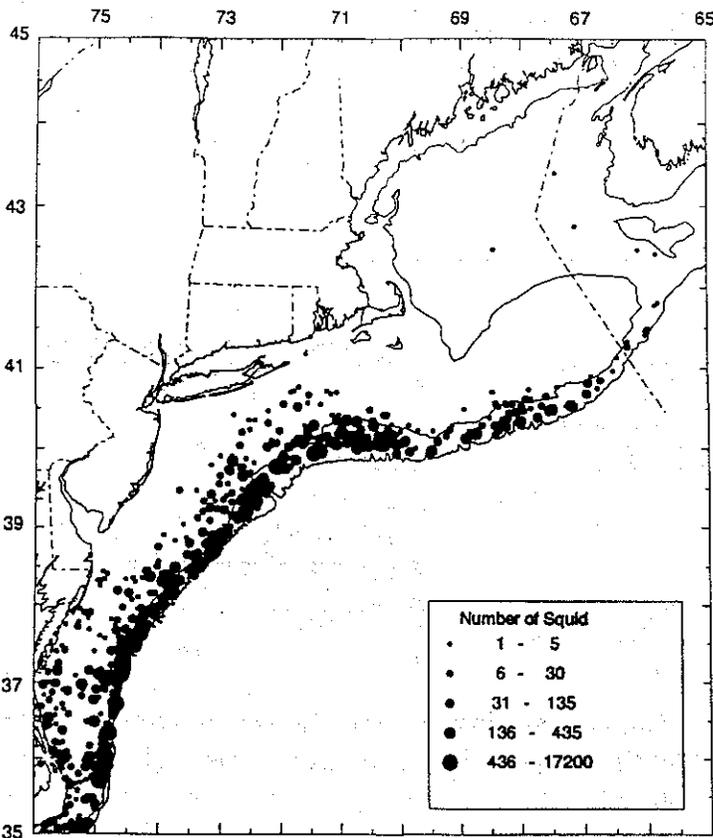


Figure A10. Distribution of *Loligo* squid >8 cm caught during NEFSC spring bottom trawl surveys, 1987-1993.

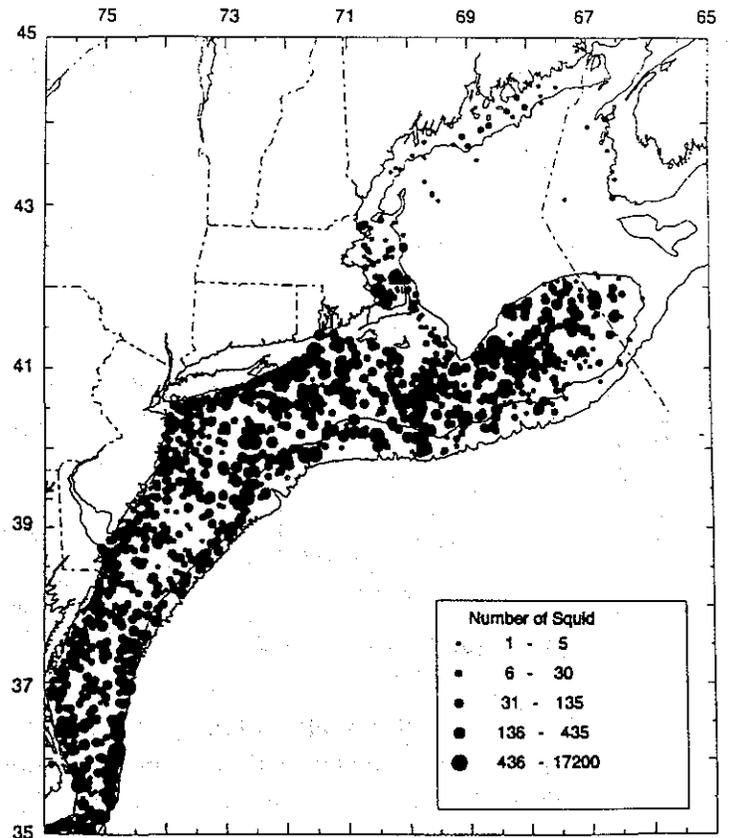


Figure A11. Distribution of *Loligo* squid >8 cm caught during NEFSC autumn bottom trawl surveys, 1987-1993.

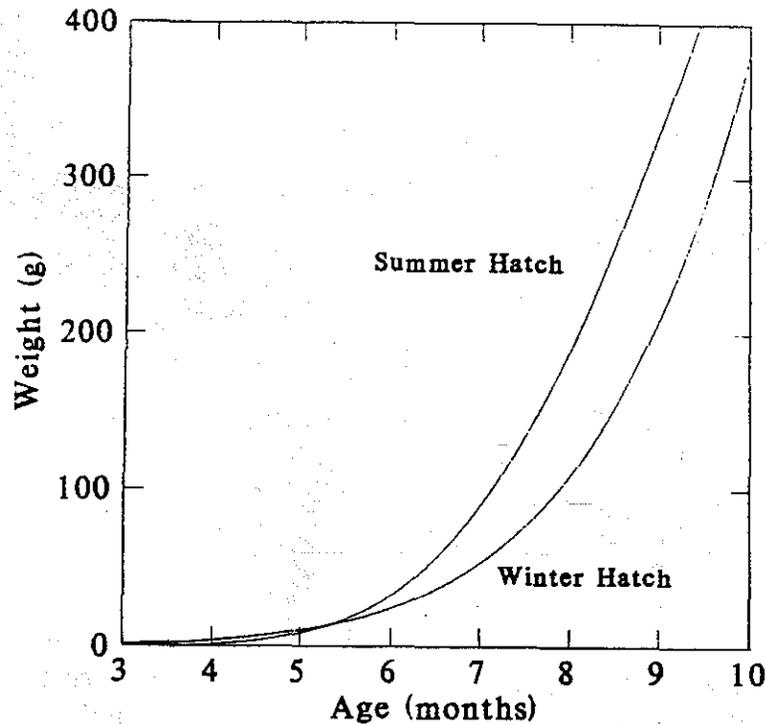


Figure A12. Comparison of growth curves (weight vs age) for summer-hatched (June-October) and winter-hatched (November-May) *Loligo* squid. Growth models derived in Brodziak and Macy (In press).

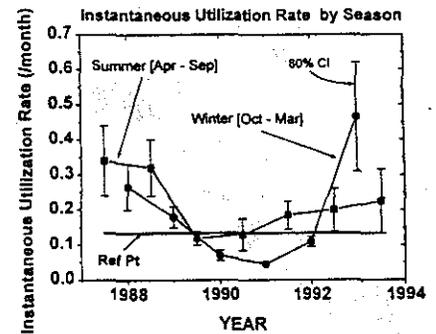
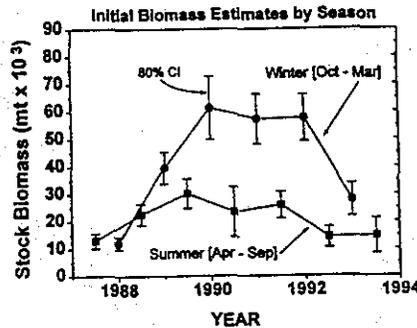
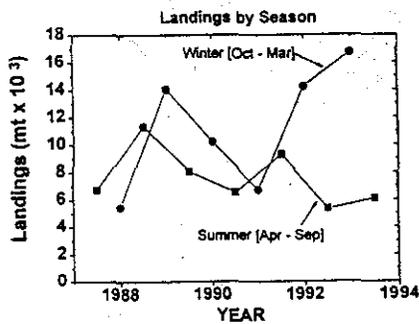


Figure A13. Summary of *Loligo* landings, biomass estimates and instantaneous utilization rates by summer (April-September) and winter (October-May) fishery periods. Landings by season (1987-1993); initial biomass estimates by season; (C) instantaneous utilization rates (per month) by season.

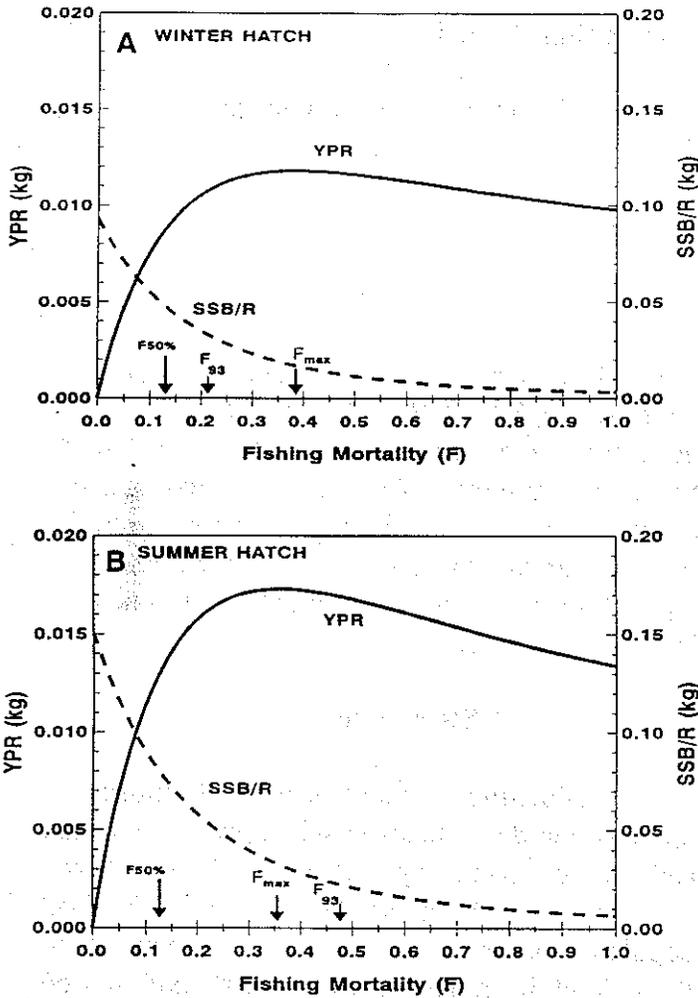


Figure A14. Yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) for (A) winter-hatched (November-May) and (B) summer-hatched (June-October) *Loligo pealei*.

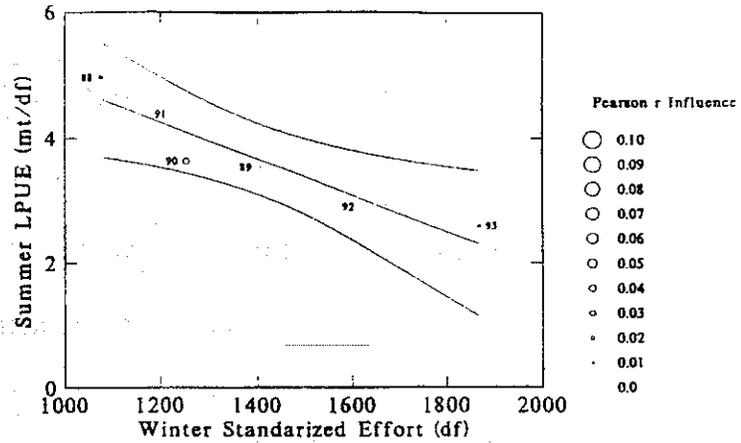


Figure A15. Standardized landings per unit effort (LLPUE) mt/df in summer fishery (April-September) vs standardized effort (df) in the preceding 6 month period (October-March). Linear regression has 95% confidence bands. Symbol size is proportional to statistical influence of data point on correlation coefficient, using scale on right side of graph. Year label refers to calendar year of LPUE.

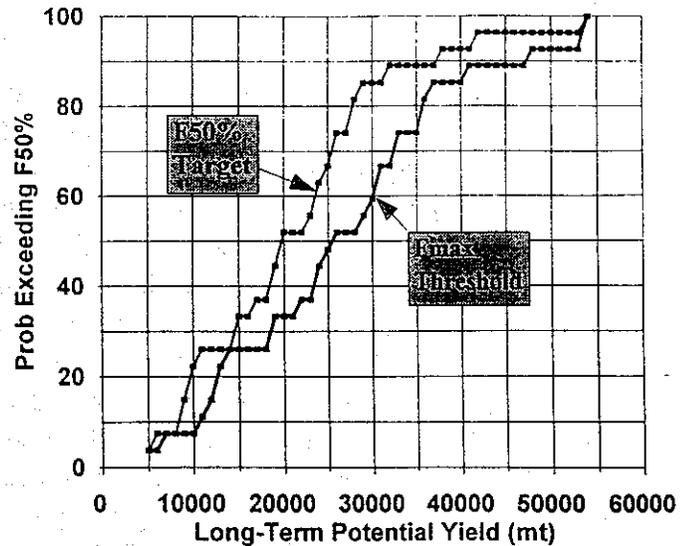


Figure A16. Probability that a specified catch level for long-term potential yield would exceed the expected annual yield derived from estimated abundance of long-finned squid in the NEFSC spring and fall research trawl surveys.

B. SHORT-FINNED (*Illex*) SQUID

Terms of Reference

The following Terms of Reference were addressed for short-finned squid:

- a. Examine the seasonal and annual distribution patterns and relationship to environmental parameters, especially temperature.
- b. Estimate relative abundance and mortality rates.
- c. Review overfishing definition.

Introduction

An assessment of the *Illex illecebrosus* stock was last conducted for review by the 17th Stock Assessment Review Committee (SARC), in December, 1993 (NEFSC 1994). The SARC found that the stock was under-exploited and was at a medium biomass level. This report presents an updated and revised analytical assessment of the U.S. EEZ portion of the stock, for the period 1967-1993, based on analyses of statolith ageing, commercial fishery, and research survey data.

A commercial fishery for *Illex illecebrosus* occurs from Newfoundland to Cape Hatteras. The fishery is managed, in the U.S. EEZ (NAFO Subareas 5 and 6), by the Mid-Atlantic Fishery Management Council (MAFMC) and, in NAFO Subareas 2, 3 and 4, by the Northwest Atlantic Fisheries Organization (NAFO). The current NAFO total allowable catch (TAC) is 150,000 mt (NAFO 1980, cited by O'Dor and Dawe *in press*). Annual levels of allowable biological catch and domestic allowable harvest in the U.S. EEZ are determined, in accordance with the Atlantic Mackerel, Squid and Butterfish Fishery Management Plan (FMP), and are based on the best available information on the current status of the stock. In 1995, the allowable biological catch and domestic allowable harvest were 30,000 mt. The proposed domestic allowable harvest has been decreased to 21,000 mt for 1996. In recognition that the domestic resource is rapidly approaching full utilization and that expansion of the

U.S. fleet would lead to overcapitalization, Amendment 5 (MAFMC 1995) to this FMP was developed and recently submitted for NMFS Secretarial approval. Amendment 5 would limit entry into the directed fishery, establish trip limits for non-moratorium vessels, and require mandatory logbook reporting by all permitted vessels engaged in the *Illex* fishery.

Stock Structure

The short-finned squid is a highly-migratory ommastrephid that tends to school by sex and size and lives for up to one year (Dawe et al. 1985; Dawe and Beck 1992; O'Dor and Dawe *In Press*). The *Illex* population is assumed to constitute a unit stock throughout its range of commercial exploitation from Cape Hatteras to Newfoundland. Coelho and O'Dor (1993) found that determination of *Illex* stock structure may be complicated by the overlap of seasonal cohorts. They found that mean size at sexual maturity varied between northern and southern geographic regions in some years. However, it was unknown whether these differences were due to inherent population structure. O'Dor and Coelho (1993) speculated that changes in the seasonal breeding patterns of the *Illex* population could have played a role in the collapse of the Canadian fishery during the early 1980's (Table B1). Regardless of this speculation, the proportion of tows capturing *Illex* during the 1967-1994 NEFSC autumn surveys (Figure B1), showed a synchronous pattern of changes in relative abundance across

broad geographic regions within the U.S. EEZ. Further, all six possible pairings of the regional proportion of tows capturing *Illex* were significantly positively correlated at the $\alpha=0.01$ significance level. These significant associations suggested that *Illex* recruitment from Cape Hatteras to the Gulf of Maine was affected by similar processes, as expected under the hypothesis of a unit stock.

The Fishery

Commercial Landings

Domestic and foreign landings (mt) of *Illex* during 1963-1994 (Table B1) were collected from various sources. U.S. EEZ landings for 1963-1988 were taken from the Report of the 10th SAW (NEFSC 1990), while the NEFSC (NEMFIS) database provided domestic landings for 1989-1994. Landings for NAFO Subareas 2, 3 and 4, during 1973-1993, were taken from NAFO Scientific Council Summary reports.

The magnitude and spatial pattern of *Illex* landings has varied considerably during 1963-1993. During 1973-1982, total landings averaged 70,954 mt and were predominately taken from NAFO Subareas 2, 3 and 4 (73%) (Figure B2A). Following the collapse of the fishery in NAFO Subareas 3 and 4, total landings during 1983-89 averaged only 9,179 mt. Since 1983, total landings have been dominated by the domestic fishery, which averaged 6,956 mt (76% total landings) and 14,766 mt (75% total landings) during 1983-1989 and 1990-1993, respectively. Since 1987, there has been no foreign participation in the *Illex* fishery within the U.S. EEZ (Cape Hatteras to the Gulf of Maine).

Domestic *Illex* landings have increased every year since 1988, to a record high of 18,012 in 1993 (Figure B2B). This represented 87% of total landings and a 2% increase over the 1992 domestic landings. Preliminary estimates of 1994 domestic landings are 18,322 mt. In 1993, domestic landings were reported for a total of 438 trips made by 53 vessels. Otter trawl gear was used to harvest 99.9%

of this total during 428 trips made by 49 vessels.

The pattern of domestic *Illex* landings in 1993, by statistical reporting area (Figure 1) and month, were collected from the NEFSC weigh-out database (Table B2). Since 1982, this fishery has occurred primarily in offshore areas during the summer and early fall. Similar to recent years, most of the 1993 landings (84%) occurred during July-September and were predominately taken from statistical area 622 (73%). Based on a monthly proration of the 1993 domestic landings of *Illex* and *Loligo* squid, by month and 2-digit statistical area, an additional 13 mt of unclassified squid were considered likely to have been *Illex* squid.

Commercial Discards

Discard data were not available for directed *Illex* trips, although anecdotal reports by some fishermen have suggested that *Illex* discard was minimal. Confidential bycatch observations collected during foreign and Joint Venture fishing operations have indicated that discarding of *Illex* was negligible in comparison to landings. In general, the tendency of *Illex* to school by size, and targetting of larger squid by the fishery (16-28 cm), suggests low discard rates of smaller squid.

Recreational Landings

There are no known recreational landings of *Illex* squid.

Commercial Fishery Sampling Intensity

The annual number of U.S. commercial length samples, trips, landings and sampling intensity (length samples per metric ton of *Illex* landed), during 1982-1993, are presented in Table B3. Commercial length composition was assessed for all sizes combined since there are no market categories for this species. A total of 1,154 squid lengths were collected in 1993; this constituted roughly 23 length frequency samples of 50 squid each. Overall, sampling intensity in 1993 was relatively low with

roughly 1 length frequency sample collected for every 780 mt of *Illex* landed. Length samples were collected during all months of the fishing season, with the exception of June. Overall, the monthly distribution of length samples were generally concordant with the monthly landings distribution; 92% of the length samples were collected during July-October when 90% of the landings occurred.

Commercial Length and Age Composition

Monthly mean weights in the U.S. catch were obtained by pooling commercial length-frequency samples by month, then applying the length-weight equation for combined areas, seasons and sizes ($\ln(\text{weight}) = -3.03444 + 2.71990 \ln(\text{length})$, weight in g and length in cm) which was derived from NEFSC survey data (Lange and Johnson 1981). Month-specific averages for the 1982-92 time series were substituted as mean weights for months in which no length samples were collected during 1993. An estimate of the annual mean weight of harvested *Illex* (W_a), stratified by month, was computed as the weighted average of these monthly mean weights (W_m), where the weighting coefficient was the fraction of the annual landings which occurred during that month (f_m):

$$W_a = \sum_{m=1}^{12} f_m W_m$$

Total numbers of *Illex* squid landed by the domestic fishery, during 1982-1993, were then computed by dividing annual mean weights into annual yields (Table B4). Similar to landed weight, the numbers of *Illex* squid landed have been increasing since 1988, reaching a time series peak in 1993.

Stock Abundance Indices

Commercial LPUE

Standardized fishing effort and LPUE (metric tons landed per standard day fished), during 1982-1993, were estimated for the domestic fishery with a four-factor (year, month, area, and vessel tonnage

class) main effects General Linear Model (GLM) applied to log-transformed LPUE data. Otter trawl trips landing at least 25%, by weight, of *Illex* squid during May-November were partitioned by vessel tonnage class according to vessel Gross Registered Tonnage (GRT) designation. The GLM included trips that targeted *Illex*; Class 3 (51-150 GRT) and Class 4 (151-500 GRT) vessels fishing in statistical areas (SAs) 526, 616, 622, 626 and 632. Although some trips that landed *Illex* were excluded based on these criteria, in particular Class 2 vessel trips in the Gulf of Maine, the trips included in the GLM accounted for 92 % of the total domestic landings during 1982-1993. This analysis was considered to be an improvement over the GLM analysis used in SARC 17 because: (1) only trips targeting *Illex* were used while trips that landed minor amounts of *Illex* were excluded; (2) a finer scale was used to evaluate the area effect (3-digit SAs instead of 2-digit SAs); (3) a significant month effect was added to characterize in-season fishing success. These improvements reduced the mean square error (MSE) and coefficient of variation (CV) from MSE=2.83 and CV=195% in the previous model to MSE=0.60 and CV=21% (Table B5).

Standardized effort for the domestic fishery declined to a low of 29 days fished in 1988, but has been increasing markedly since then (Table B6, Figure B3A). Fishing effort has been above the 1982-1993 average (225 days fished) since 1990 and reached a near-record 390 days fished in 1993. Concurrently, since 1988, LPUE has been gradually declining (Figure B3B). Standardized LPUE remained stable in 1993 at 46 mt/day fished; slightly below the 1982-1993 average (47 mt/day fished).

Spatial patterns in nominal LPUE by quarter-degree square, for 4-year time blocks during 1982-1993, were depicted using a geographic information system (GIS) (Figures B4-B6). Weighted LPUE values were computed as a ratio of the sum of the metric tons landed within each quarter-degree square to the sum of the days fished within each quarter-degree square. During 1982-85, the bottom trawl fishery predominately took place in the offshore

waters of the Mid-Atlantic region, with a minor component occurring along the western Gulf of Maine; the latter being comprised of Class 2 and Class 3 vessels. During 1986-1989, a period of declining fishing effort, the fishery expanded into southern New England (primarily SA 537), at fairly high LPUE levels, with minor activity on Georges Bank. During 1990-93, areas of high LPUE extended throughout most of southern New England, particularly in waters deeper than 500 fathoms. High LPUE levels occurred throughout most of the offshore shelf waters between Cape Hatteras and Cape Cod. Fishing on Georges Bank was still sparse, but LPUE in these areas increased. This progressive increase in the number and size of areas of high LPUE indicates a northward expansion of the fishery, from the Mid-Atlantic region, since 1982.

Research Vessel Survey Indices

Relative indices of *Illex* abundance and biomass, within the U.S. EEZ from Cape Hatteras to the Gulf of Maine, were computed from NEFSC spring and autumn bottom trawl surveys. The survey procedures and details of the stratified random sampling design are provided in Azarovitz (1981). A review of the percentage of tows catching *Illex* in the Gulf of Maine (Figure B1) showed that *Illex* consistently utilized this habitat, and for this reason, in contrast to previous assessments, Gulf of Maine strata were included in the computation of relative abundance indices. Overall, standard survey tows in offshore strata 1-40 and 61-76 (Figure 2) were used to compute indices of relative abundance.

A vessel catchability analysis presented at SAW 12 (NEFSC 1991) suggested that the *Delaware II* exhibited greater fishing power than the *Albatross IV* research vessel. Potential differences in the catchability of *Illex* by these two research vessels were re-examined, in the current assessment, by analyzing catch data from paired tows (the vessels fished side by side) from NEFSC gear comparison cruises in 1982, 1983, 1987 and 1988. Total number per tow, number per tow of *Illex* pre-recruits (≤ 10

cm) and recruits (≥ 11 cm), and weight per tow were compared to determine whether there was a difference in average catch per tow between the two vessels. Only tows where both vessels caught both recruits and pre-recruits ($N=38$) were used in the size-based analysis, whereas only tows with positive *Illex* catch by both vessels were used in the total number per tow ($N=226$) and weight per tow ($N=205$) analyses.

The ratios of the mean number per tow and log-transformed mean number per tow were examined first, where N_{AL} and N_{DE} were the number per tow for the *Albatross IV* and the *Delaware II*. These ratios were: $E[N_{AL}]/E[N_{DE}] = 0.79$ and $E[\ln(N_{AL})]/E[\ln(N_{DE})] = 0.78$. Both, the ratio and log-transformed ratio of mean catches were less than 1 and suggested greater fishing power for the *Delaware II*. We also computed the mean of the ratio of the number per tow to be $E[N_{AL}/N_{DE}] = 1.09$, which suggested slightly higher fishing power for the *Albatross IV*. The mean paired difference in catch per tow was also computed to be $E[N_{AL} - N_{DE}] = -9.5$ and a t-test indicated that this mean was not significantly different from 0 ($P=0.43$). A Wilcoxon signed rank test of the paired difference in catch per tow also indicated that the median difference was not significantly different from 0 ($P=0.0001$). When a logarithmic transformation was applied to the catches, significant differences were detected with the t-test ($P=0.001$) and Wilcoxon test ($P=0.0001$). The results of these comparisons and the mean ratios of catch per tow suggested that the *Albatross IV* was not as powerful as the *Delaware II* for catching total numbers of *Illex* and that a vessel conversion factor for numbers was necessary. Thus, a vessel conversion coefficient of 0.78 was applied to the *Delaware II* stratified mean number per tow values prior to computing the autumn survey indices in order to standardize these tows to *Albatross IV* catches.

A similar examination of the catch rates of pre-recruits (P_{AL} and P_{DE}) and recruits (R_{AL} and R_{DE}) was performed. The ratios of mean number per tow were $E[P_{AL}]/E[P_{DE}] = 0.45$ and $E[\ln(P_{AL})]/E[\ln(P_{DE})] = 0.67$

for pre-recruits, and $E[R_{AL}]/E[R_{DE}] = 0.38$ and $E[\ln(R_{AL})]/E[\ln(R_{DE})] = 0.79$ for recruits. Mean paired differences in the log-transformed catch per tow were computed to be $E[\ln(P_{AL}) - \ln(P_{DE})] = -0.539$ for pre-recruits and $E[\ln(R_{AL}) - \ln(R_{DE})] = -0.497$ for recruits, and the t-test indicated that these means were significantly different from 0 ($P=0.006$ and $P=0.037$, respectively). A Wilcoxon signed rank test of the paired difference in log-transformed catch per tow also indicated that the median difference for pre-recruits was significantly different from 0 ($P=0.004$) while the median difference was for recruits was likely different from 0 ($P=0.051$). It appeared that the *Albatross IV* was not as powerful as the *Delaware II* for catching both pre-recruits and recruits.

For weight per tow (W_{AL} and W_{DE}), the ratio of mean catch per tow was $E[W_{AL}]/E[W_{DE}] = 0.81$ and the mean ratio was $E[W_{AL}/W_{DE}] = 1.34$. The mean paired difference in catch per tow was also computed to be $E[W_{AL} - W_{DE}] = -1.05$ and a t-test indicated that this mean was not significantly different from 0 ($P=0.436$). A Wilcoxon signed rank test of the paired difference in weight per tow indicated that the median difference was significantly different from 0 ($P=0.0001$). The results for weight per tow were similar to those for numbers per tow and it appeared that the *Albatross IV* was probably not as powerful as the *Delaware II* in catching *Illex* by weight. Thus, a vessel conversion coefficient of 0.81 was applied to the *Delaware II* stratified mean weight per tow values prior to computing the autumn survey indices in order to standardize these tows to *Albatross IV* catches.

The effects of depth, surface temperature, bottom temperature, and time of day on *Illex* catches during the NEFSC fall survey were also examined (Brodziak and Hendrickson, WP A2), based on the univariate habitat association test of Perry and Smith (1994). The results indicated that *Illex* catches were moderately associated with depth, with highest catches occurring in shelf edge waters greater than 185 m deep, and that the current survey design of

stratification by depth was appropriate for *Illex*. The results also indicated that *Illex* catches were significantly associated with surface temperature during roughly half of the years examined and generally occurred in waters with surface temperatures of 13-20°C. Bottom temperature had a lesser influence on *Illex* distribution during the autumn survey, with most catches occurring in waters with bottom temperatures of 9-13°C. This suggested that *Illex* catches were associated with cooler water temperatures in comparison to *Loligo*.

The results also indicated that *Illex* catches were significantly associated with time of day during roughly half of the years analyzed, and appeared to be size-specific. Catch per tow of pre-recruits was highest during the day, while catch per tow of recruits was highest during dawn/dusk. The relationship between catch per tow and time of day was significant at the $\alpha = 0.05$ level for 13 out of the 28 years in the time series. These results differed from similar analyses for *Loligo* squid, where this relationship was significant for all years of the time series. Diurnal catch rate adjustment factors were not applied to compute abundance indices because the indices were not used to estimate absolute population size and because it was assumed that stations were randomly distributed by time period among survey strata during the 24-hour continuous operation of the NEFSC bottom trawl survey. Whether the application of diurnal adjustment factors are warranted for *Illex* catch rates requires further investigation.

Vessel-adjusted, stratified mean numbers per tow and mean weights (kg) per tow from the autumn and spring bottom trawl surveys exhibit considerable annual variability (Tables B7 and 8, Figure B6). Although high inter-annual variability might be expected for an annual species if fluctuations in recruitment were substantial, the outer shelf and continental slope are important *Illex* habitats (O'Dor and Dawe *in press*) that are not intensively sampled by NEFSC bottom trawl surveys. Further it should be noted that bottom otter trawl gear is not likely to be an efficient sampling gear for *Illex* distributed

vertically in the water column. Although neither survey tracks pre-recruit (≤ 10 cm) abundance very well, the autumn survey appears to provide a better measure of relative abundance of recruited squid (≥ 11 cm) than the spring survey. The CVs for the spring number per tow indices were much higher than those from the autumn survey and no significant autocorrelation in biomass was evident for the total weight per tow index. Lower catch rates and lower precision of the spring survey estimates occur primarily because the distribution of *Illex* extends beyond the range of the survey. No significant cross-correlation was detected at any lag between the stratified mean weight per tow values of the spring and fall series. However, a significant positive correlation ($r = 0.3805$, $p < 0.05$) did exist between the autumn biomass index for the current year and the previous year. Overall, indices taken from the autumn survey provide a more consistent measure of relative *Illex* abundance in the U.S. EEZ due to higher overlap between stock distribution and survey coverage.

The autumn number per tow and weight per tow indices both indicate two distinct periods of high abundance which were well above the long-term average; during 1976-1981 and during 1987-1990. Although the stratified mean numbers per tow during this earlier period were similar to those from the latter period, individual mean weights of animals from the earlier period were more than double those from the latter period. The observed difference in mean weights may be due to differing contributions of seasonal breeding components or differing growth conditions during these periods. More recently, the numbers per tow index was slightly above the long-term average (9.6 squid/tow), during 1993, and slightly below it during 1994.

Stock Distribution

Offshore shelf and continental slope waters are primary habitat for *Illex* during most of its life (O'Dor and Dawe 1993). Consistent with Lange et al. (1984), the highest catch rates during the autumn survey occurred in the shelf-slope convergence zone

at depths greater than 185 m (Brodziak and Hendrickson, WP A2). *Illex* undergo a lengthy southward migration to spawn south of Cape Hatteras, with a spawning peak during winter, after which the spent squid reportedly die (Trites 1983; Rowell et al. 1985; O'Dor and Dawe *in press*).

The seasonal spatial distribution of *Illex* pre-recruits (≤ 10 cm) (Figures B8-B11) and recruits (≥ 11 cm) (Figures B12-B15) was characterized from NEFSC research surveys. Survey strata are shaded according to the density of squid (mean number/tow) captured in each stratum. Shading categories were based on the number per tow quartiles for the entire survey time series. Although the number of years of survey data depicted differ by season due to fewer winter and summer surveys, a seasonal distribution pattern is evident from these figures. Although the Gulf of Maine was not sampled during the winter survey (Figure B9), *Illex* pre-recruits appear to be beyond survey coverage either further offshore or south of Cape Hatteras. During the spring (Figure B10), densities were highest in the southernmost offshore strata, with very low densities occurring further inshore and in the northern areas of their range. These results suggest a northerly migration of juveniles. During the peak of the summer fishery (Figures B11 and B15), the stock becomes dispersed over a broader geographic region throughout the continental shelf, generally moving further inshore. By autumn (Figures B12 and B16), *Illex* have generally begun to move offshore and migrate south.

Life History Parameters

Growth

Statolith aging methods have been validated for this species (Dawe et al. 1985; Hurley et al. 1985). Dawe and Beck (1992) applied statolith increment analysis to *Illex* squid and found that this species appears to live for up to roughly one year. Weight and length-at-age curve were estimated for *Illex* using techniques described in Brodziak and Macy (*in press*), based on size-at-age data (N=202)

collected from the Newfoundland jigging fishery and reported in Dawe and Beck (1992). *Illex* growth in length and weight is very rapid and can be described as exponential for both length and weight (Figure B16). The maximum age reported in this data set was 250 days. The growth curve for weight (W) in grams at age (d) in days is:

$$W(d) = 20.003509 \cdot \exp(0.012555 \cdot d)$$

while the growth curve for mantle length (L) in cm at age (d) is:

$$L(d) = 11.56955 \cdot \exp(0.00347 \cdot d)$$

Natural Mortality

Short-finned squid are highly migratory, school by size, exhibit cannibalism and live less than one year (Dawe and Beck 1992; O'Dor and Dawe *in press*). As a result, a high natural mortality rate is expected. A monthly instantaneous natural mortality rate (M_m) of $M_m = 0.30$ ($M_d = 0.01$) has been used in this assessment of *Illex*. As for *Loligo* squid (see previous section), this value represents the average of three estimates. First, Hoening's (1983) regression method, applying a maximum age of 250 days to his predictive equation for mollusks, results in a monthly instantaneous natural mortality rate of $M_m = 0.39$. A second method, based on animal size and bioenergetic constraints (Peterson and Wroblenski 1984), gave an estimate of $M_m = 0.22$ for an animal weighing 20 grams. A third method, by analogy with another commercially-exploited *Illex* species (*Illex argentinus*), gave a value of $M_m = 0.26$ (Rosenberg et al., 1990).

Sexual Maturity

Spawning probably occurs throughout the year, with a strong peak during the winter and a secondary peak during the summer (Coelho and O'Dor 1993; Dawe et al. 1985). Summer spawning appears to be more important in the southern portion of the stock's range, where it may contribute to the greater stability of stock abundance within the Mid-Atlantic

Bight (Lange and Sissenwine 1981). Sexual maturity stages have been described for male *Illex* squid (Mercer 1973) and a nidamental gland index has been derived for females (Durward et al. 1979). However, sexual maturity observations are not regularly made at sea during NEFSC research survey cruises. Coelho and O'Dor (1993) found that mean size at maturity varies latitudinally and interannually. They gave a range of mean sizes at sexual maturity for male squid from NAFO Subareas 5 and 6 as 200-215 mm. Applied to a length-at-age equation for *Illex* (refer to Growth section), 50% maturity for males occurs at approximately 6 months of age.

Estimates of Stock Size and Fishing Mortality

Surplus Production Analysis

Parameters of the difference equation form of the Schaefer surplus production model (Walters and Hilborn 1976) were estimated for the *Illex* fishery within the U.S. EEZ during 1982-1993. The form of the difference equation was:

$$B_{t+1} = B_t + rB_t \left(1 - \frac{B_t}{K}\right) - C_t - qE_t B_t \quad (1)$$

where B_t is stock biomass at the beginning of year t , C_t was the catch biomass harvested in year t , E_t is standardized fishing effort in year t , q is the biomass catchability coefficient, r is the intrinsic rate of biomass growth, and K is the carrying capacity of the stock. The parameters (q , r , and K) of this model were estimated using the regression method described in Hilborn and Walters (1992, see Eq. 8.4.10, p. 308) where standardized LPUE from the domestic fishery during 1982-1993, was the relative abundance index proportional to stock biomass and the catch and effort totals were total landed biomass and expanded standardized effort within the U.S. EEZ.

The regression was significant ($F=7.16$, $P=0.017$, $R^2=0.64$) and the residuals were normally distributed. The point estimate of q was used to estimate the stock biomass at the beginning of 1982 ($B_{82}=25,049$ mt) and the process equation was used to calculate B_{83} to B_{93} . Average annual stock biomass ($E[B_t]$) was computed as the initial stock biomass plus one-half the surplus production for that year. Annual fishing mortality rates were estimated as the total landings, in weight, divided by $E[B_t]$. Results of this model are summarized in Table B9.

Bootstrapping procedures were applied to estimate the uncertainty of model parameters. A total of 1,000 bootstrap replicates were applied to the residuals of the regression model. Of these replicates, a total of 221 estimates resulted in either infeasible q estimates (i.e. negative) or generated negative biomass estimates at some point in the time series. Infeasible estimates were excluded from further consideration although they do provide some insight into the model fit. Infeasible estimates in surplus production models are often due to a lack of sufficient range in the time series values, rather than inappropriateness of the model (Hillborn and Walters 1992).

Standard deviations of the parameter estimates were estimated from the bootstrap replicates. The parameter estimates were $q=1.537 \cdot 10^{-3}$ ($\sigma_q=0.786 \cdot 10^{-3}$), $r=2.44$ ($\sigma_r=0.56$), and $K=39,793$ ($\sigma_K=129,129$), where the standard deviations are reported for values of q , r , and K that led to feasible population sizes throughout 1982-1993 ($N=779$). Comparison of median bootstrap estimates of r , q and K with the original point estimates suggested a maximum bias of less than 2.1 %.

Uncertainty in the initial stock biomass and average stock biomass series was characterized with the bootstrapped parameters estimates by first computing B_{82} and $E[B_{82}]$ and then iterating the process equation for each triplet of parameters. Based on these computations, 50% CI's for fishing mortality and stock biomass were derived (Figure B17A and B).

Results indicated that stock biomass was lowest in 1982 and highest in 1986 and that there was considerable uncertainty in the estimates of stock biomass. Average stock biomass was lowest in 1982 and highest in 1988 and was also imprecisely estimated.

Fishing Mortality Estimates

Estimated annual and monthly fishing mortality rates, during 1982-1993, are presented in Table B9. Monthly values were computed by dividing the annual fishing mortality rates by the number of months comprising the fishing season. The four months of June-September were used in this computation, since most (81%) of the 1982-1993 landings occurred during these months. Estimated monthly fishing mortality rates ranged from 0.01 to 0.13 during 1982-1993 with an average monthly F of 0.07 (Figure B17A). Monthly F decreased steadily from a 1982 peak of 0.13 to 0.04 in 1986. Monthly fishing mortality rates have been increasing since 1988, from 0.01 to 0.12 in 1993. During 1992, the monthly fishing mortality rate was equal to the $F_{50\%}$ target ($F_{50\%}=0.11$) (refer to **Biological Reference Points** below) and was just above it during 1993. The probability that F_{93} exceeded the $F_{50\%}$ target was 0.54 and the probability that it exceeded the $F_{20\%}$ threshold was 0.01. The average coefficient of variation of fishing mortality was roughly 55% during 1982-1993.

A comparison of model derived estimates of annual production and catch (Figure B17C) suggested that landings exceeded annual production during 1991-1993.

Biological Reference Points

The overfishing definition for *Illex*, as defined in the MAFMC Atlantic Mackerel, Squid and Butterfish Fishery Management Plan, occurs when the three-year moving average of pre-recruits from the NEFSC autumn bottom trawl survey is within the first quartile of this series. According to this

overfishing definition, *Illex* was not overfished in 1993, since the largest index in the first quartile of the pre-recruit time series was 0.19, which is less than the three-year moving average of 0.72. During 1994, the largest index in the first quartile was also 0.19 and the three-year moving average was 0.72, suggesting that *Illex* was not overfished in 1994. Assuming a pre-recruit index of zero in 1995, the three-year moving average of the pre-recruit index would be 0.12, which is less than the largest index in the first quartile (0.19 number per tow). This suggests that *Illex* has the potential to be overfished in 1995.

However, because the NEFSC autumn survey does not provide reliable indices of *Illex* pre-recruit abundance, the current overfishing definition does not provide an adequate measure of recruitment overfishing. Moreover, the use of a three-year moving average is inappropriate for a species with a lifespan of less than one year. Given the highly variable recruitment of this species, recruitment failure in a single year could lead to stock collapse. The current overfishing definition for *Illex* has been characterized as 'risky' by a scientific review panel (Rosenberg et al. 1994) and should be changed to reflect its one-year life cycle. A more appropriate overfishing definition should minimize the risk of recruitment overfishing, by ensuring that escapement exceeds a threshold minimum spawning stock biomass (SSB_{min}). Given the flat-topped nature of the yield-per-recruit curve (Figure B18) for this species, an appropriate threshold would be a monthly $F_{20\%}$ (0.28), with fishing intensity such that escapement is above this threshold, and a monthly target level of $F_{50\%}$ (0.11). Although environmental factors also affect the recruitment process, they cannot be predicted or controlled. These biological reference points should allow sufficient spawning biomass to survive each year to ensure a high probability of successful recruitment in the following year. A similar target of 40% proportional escapement was set for the Falkland Islands *Illex argentinus* fishery (Beddington et al. 1990).

Yield and Spawning Stock Biomass per Recruit

A monthly yield and spawning stock biomass per recruit analysis was conducted based on the estimated growth curves. A plus-group of squid 8 months and older was used. Based on the observed mean weight in the fishery and the mean weight at age taken from the estimated growth curve, the mean age at exploitation in the commercial fishery was approximately 4.5 months during 1982-1993. This indicated that an age of 4 months would be a reasonable value to assume for knife-edged recruitment to the fishery. This analysis incorporated an age at 50% maturity of 6 months, based on a mean length at maturity for *Illex* squid collected from Subareas 5 and 6 (O'Dor and Coelho 1993) and a monthly natural mortality rate of 0.30. Results (Table B10) indicated that the fishing mortality that maximized yield per recruit (F_{max}) was 0.61, while $F_{20\%} = 0.28$ and $F_{50\%} = 0.11$ (Figure B18).

Sensitivity analyses were conducted to evaluate the importance of monthly natural mortality, M_m , in the determination of F_{max} and $F_{20\%}$. These reference points were recalculated based on three point estimates of M_m and compared with the results for the value of $M_m = 0.30$ used in the assessment. Clearly, the F_{max} reference point was much more sensitive to changes in the value of M_m :

M_m	F_{max}	$F_{20\%}$
0.22	0.38	0.25
0.26	0.47	0.27
0.30	0.61	0.28
0.39	> 4.00	0.31

A similar analysis was conducted to evaluate the potential importance of post-spawning mortality through the application of a non-constant instantaneous natural mortality rate to calculate F_{max} and $F_{20\%}$ values. Post-spawning mortality was assumed to occur one month after the attainment of full maturity and consisted of a doubling of the natural mortality rate for squid in the plus-group

(8+ months old). Again, the F_{max} reference point was much more sensitive to changes in the value of M_m with the inclusion of post-spawning mortality:

M_m	F_{max}	$F_{20\%}$
0.22	0.56	0.32
0.26	0.69	0.33
0.30	0.91	0.35
0.39	> 4.00	0.37

In comparison to the analyses without post-spawning mortality, it was evident that the inclusion of post-spawning mortality would generally increase the values of F_{max} and $F_{20\%}$. The increase in F_{max} would be due to the fact that less yield could be taken from the plus-group, forcing more yield to be taken from younger, recruited age classes. The increase in $F_{20\%}$ would be due to the fact that there would be a reduced contribution of spawning stock from the plus-group, thereby reducing the importance of substantial survival to the plus-group age.

Long-Term Potential Yield

Provisional estimates of long-term potential yield were derived from the expected yields predicted by the biomass dynamics model with respect to the biological reference point F levels. These estimates differ from earlier ones in that the annual life cycle of *Illex* and the seasonal distribution of current fishing effort are addressed. The monthly target fishing mortality rate of $F_{50\%} = 0.11$ was converted to an annual rate by adjusting for the average seasonal distribution of landings. During 1982-1993, approximately 91% of the landings occurred between June and September. Applying $F_{50\%}$ for four months and allowing for additional mortality outside the period, the effective annual F was computed as $4(0.11)/0.91 = 0.4835$. Applying the same method to the threshold monthly fishing mortality rate of $F_{20\%} = 0.28$ resulted in an annual threshold F of 1.2308.

The yield that would be realized under these

fishing mortality rates is dependent upon the structural form of the biomass dynamics equation and the parameter estimates. The biomass dynamics equation (Eq. 1) can be re-expressed as:

$$B_{t-1} = B_t + rB_t \left(1 - \frac{B_t}{K} \right) - F_{ref} B_t$$

(2)

where F_{ref} represents the biological reference point. The expected yield ($E[C_t]$) is the product of the reference fishing mortality rate and the average biomass during the year. Average biomass was defined as the initial biomass plus one half of the production elaborated during the year. Expected catch biomass ($E[C_t]$) was thus defined as:

$$E[C_t] = F_{ref} \left[B_t + \left(\frac{rB_t}{2} \right) \left(1 - \frac{B_t}{K} \right) \right]$$

The initial condition, B_0 , for Eq. 2 was estimated as the CPUE value in 1982 divided by the estimated catchability parameter (q) from Eq. 1. As long as F_{ref} is less than the parameter r , the population will stabilize to an equilibrium level unless B_0 greatly exceeds K . The long-term yield for the point estimates of r , q , and K was defined as the average yield for the time period 2000 to 2018 given an initial condition for 1982 as $38.5/0.001537 = 25,049$ mt where 38.5 (mt/dfay fished) is the GLM-adjusted LPUE (Table B6).

Bootstrapping was applied to characterize the empirical distribution of long-term yield for the biomass dynamics model. The empirical distribution of long-term yield was computed by applying Eq. 2 and Eq. 3 to each bootstrap realization of r , q , and K .

The point estimate of the long-term potential yield for the target fishing mortality rate, $F_{50\%}$, was 15,392 mt and was 24,272 mt for the threshold fishing rate of $F_{20\%}$. Median long-term yields from the bootstrap estimates, for $F_{50\%}$ and $F_{20\%}$, were

14,579 mt and 21,325 mt, respectively. Interquartile ranges for the target and threshold fishing rates were:

Fishing Mortality Rate (per month)	Median Long-term Yield (mt)	Interquartile Range of Yield (mt)
Target: $F_{50\%} = 0.11$	14,579	{10,754,23,237}
Threshold: $F_{20\%} = 0.28$	21,325	{18,150,28,183}

Cumulative distribution plots for expected yields in Figure B18 illustrate the substantial overlap between yields for the two reference points. Average landings for 1988-1993 of 11,305 mt were below the target median level. Average landings for 1992-1994 (Table B1), of 18,053 mt, exceeded the target level but were within the predicted interquartile yield range for the target fishing mortality rate.

It should be noted that the long-term potential yields from the biomass dynamics model are consistent with the recent history of resource productivity but could vary depending on the favorability of environmental conditions for recruitment and growth.

Real-Time Management

Real-time management is particularly desirable for annual stocks such as *Illex* and *Loligo* squid because population abundance can be highly variable and a single recruitment failure could imply stock collapse. Stock size is generally unknown before the start of the fishing season and can only be estimated once the fishing season is underway. In-season adjustments of catch or effort could provide biological and economic benefits such as the preservation of adequate spawning biomass each year, avoidance of overfishing during periods of poor recruitment, and increased landings during periods of good recruitment. Under the existing quota-based management system, the catch limit would have to be set ultraconservatively in order to

avoid reducing spawning biomass to a dangerously low level. Furthermore, no advantage can be taken of periods of good recruitment.

A real-time management plan which incorporates effort controls has been implemented in the Falkland Islands for the *Illex argentinus* fishery (Basson et al *In Press*; Beddington et al 1990; Rosenberg et al 1990). Effort controls were selected rather than catch quotas because effort management allows catches to vary with population size, which permits taking advantage of good recruitment. The *Illex argentinus* management plan is based on ensuring that proportional escapement remains at a selected target level which is above a threshold minimum spawning stock biomass. Proportional escapement, P , is defined as the ratio between the number of spawners surviving under a given level of fishing mortality and the number of spawners with no fishing mortality:

$$P = \frac{N_0 \cdot e^{-mT-F}}{N_0 \cdot e^{-mT}} = e^{-F}$$

where N_0 is the number of recruits at the start of the season, m is the natural mortality rate per week, T is the total number of weeks to the end of the fishing season and the start of the spawning period, and F is total fishing mortality over the entire fishing season. This proportional escapement target (in this case, 40%) was used to set fishing effort limitations prior to the start of the fishing season, which is when population abundance is unknown. For example, the number of licenses was determined via the target fishing mortality using effort and estimates of catchability:

$$F_{\text{target}} = -\ln(0.40)$$

Once the fishing season started, catch (in weight) and effort data were radioed in on a daily basis and weekly biological data were collected from a subset of vessels, by observers at sea, as part of fishing license agreements. The biological data is critical to

the conversion of catch weight to numbers, due to the rapid growth of *Illex* during the fishing season. After several weeks of data collection, these data were then incorporated in a Leslie-Delury model to compute in-season estimates of initial population size (or recruitment), current population size and catchability coefficients. These results were used to project, under different fishing effort scenarios, levels of effort through the end of the fishing season. If the projected absolute escapement was below the threshold, an early closure was considered. If escapement was above the threshold, then in-season adjustments were considered in order to take advantage of good recruitment.

Given the similar life history of *Illex illecebrosus*, a single fishing season, and small number of vessels participating in the domestic fishery, the U.S. *Illex* fishery would be a feasible test case for implementing a similar real-time management plan. The details of a specific real-time management plan for the U.S. *Illex* fishery would require further research and should be specified prior to implementation. The basics of establishing such a plan are presented in Table B11. Based on preliminary analyses, using a Leslie-Delury assessment model with standardized monthly LPUE data appeared to be a useful method for measuring in-season population abundance. These results agreed well with the surplus production model results from the current assessment. The long autumn survey time series might be useful in setting a threshold spawning biomass level. Since this survey is conducted following the fishing season, it should provide a good index of relative spawning biomass. However, absolute measures of biomass (i.e. swept area estimates) from the autumn survey data should also be investigated. An LPUE index could be used to predict the autumn level of abundance since LPUE and these survey indices show a high correlation, particularly for tonnage class 4 vessels. The results of the preliminary Delury model analysis and additional real-time management information can be found in Basson (WP B2).

Summary and Conclusions

(1) The U.S. EEZ portion of this transboundary stock is fully-exploited and probably at a medium biomass level. Spatial expansion of the fishery has occurred since 1982. Since 1988, effort has been increasing to a near-record high in 1993, while LPUE has been gradually decreasing. The potential consequences of increased effort should be evaluated before further effort is directed toward the U.S. EEZ portion of this stock.

(2) The current NAFO (Subareas 2-4) TAC of 150,000 mt may not be sustainable. Landings of this magnitude were achieved only once, in 1979, during a period of exceptional *Illex* abundance. During the historic peak of the entire *Illex* fishery, 1976-1980, average landings of only 90,000 mt were sustained. The fact that landings and apparent abundance declined markedly following this peak suggests that landings above 90,000 mt may not, in fact, be sustainable either. Return of the *Illex illecebrosus* fishery in NAFO Subareas 3 and 4 (Beck et al. 1994) has not yet occurred for unknown reasons. It has been speculated that the relative contribution of seasonal breeding components within the stock may have been altered through intensive harvest (O'Dor and Coelho 1993). The NAFO TAC should be reconsidered along with additional management measures. *Illex illecebrosus* is a highly-migratory, transboundary species and a joint assessment between U.S. and Canadian scientists is critical to resolving management differences between NAFO Subareas 2-4 and the U.S. EEZ.

(3) The current overfishing definition does not provide adequate protection for this species given its annual life cycle. Instead, an appropriate threshold would be a monthly $F_{20\%}$ (0.28), due to the flat-topped nature of the yield-per-recruit curve, with a monthly fishing mortality rate target of $F_{50\%}$ (0.11). Landings in excess of the threshold may jeopardize the stock and have deleterious ecosystem-level effects. Fishing mortality has been increasing since 1988 and, in 1993 ($F_{93}=0.12$ per month), exceeded the $F_{50\%}$ target.

(4) Provisional estimates of long-term potential yield (LTPY) were derived from the expected yields, during 1982-1993, which were predicted by a biomass dynamics model with 14,579 mt and 21,325 mt, for the target ($F_{50\%}$) and threshold ($F_{20\%}$) fishing mortality rates, respectively, were computed from the model bootstrap estimates of r , q , and K . Average landings during 1988-1993, of 11,305 mt, were below the target median yield. Landings during 1992-1994 exceeded this target, but lie within the predicted interquartile yield range for $F_{50\%}$. These LTPY estimates are consistent with recent resource productivity, but could vary depending on the favorability of environmental conditions for recruitment and growth.

(5) Recruitment for this annual species may vary substantially between years due to natural environmental variation. *Illex* recruitment in the northern portion of its range appears to be related to ocean climate (Dawe and Warren, 1992), with poor recruitment coinciding with extremely cold conditions (Beck et al., 1994). In addition to commercial resource value, the significant ecosystem role of *Illex*, as both predator and prey, is an important reason for understanding the population dynamics of this species. For example, *Illex* abundance may increase when niche space becomes available due to decreases in predators and competitors or increases in prey (Dawe and Brodziak, *In Press*). Real-time management for an annual species with highly variable recruitment and no overlap of generations would permit in-season adjustments via catch or effort limitations. These adjustments would ensure preservation of adequate levels of spawning biomass each year, avoidance of overfishing during periods of poor recruitment, and increased landings during periods of good recruitment. A real-time management plan has been implemented in the Falkland Islands for *Illex argentinus* and preliminary analyses which utilized LPUE data from the U.S. *Illex illecebrosus* fishery appear to agree well with the results of the Hilborn-Walters production model. This suggests that a similar type of management plan may be possible for the U.S. EEZ *Illex illecebrosus* fishery.

SARC Comments

Most of the discussion of the SARC members focused on the differences between this assessment and that of the SAW 17. Minimum biomass estimates were derived, during SAW 17, from area-swept calculations using autumn survey indices. However, due to *Illex*'s offshore distribution during NEFSC surveys, stock abundance is not accurately characterized by either the spring or autumn research survey. Rather, the autumn survey provides only a measure of spawning biomass escapement. The current assessment utilized the standardized LPUE indices (GLM output) as a measure of abundance which was incorporated into a surplus production model to derive annual biomass estimates and fishing mortality rates. This method was accepted by the SARC, but due to concerns about the termination of the LPUE time series, with the 1994 implementation of effort data collection from logbooks, it was recommended that other measures of population abundance be investigated for the next assessment.

In addition, interpretation of the surplus production model results given that 22% of the bootstrap replicates produced either negative q values or negative biomass estimates is problematic. Infeasible estimates may be attributable to the lack of sufficient range in the magnitude of the LPUE time series. It was also noted that surplus production models are generally designed for species with overlapping generations.

The importance of continuing to collect, or even increasing, the number of commercial length-frequency samples was also emphasized as a necessity for converting catch biomass into numbers. Commercial discarding practices, particularly aboard freezer trawlers, should be characterized by placing at-sea observers aboard vessels targeting *Illex*. Additionally, the amount of *Illex* bycatch occurring, in the silver hake and other non-directed fisheries, should be determined.

The SARC agreed that the new GLM effort

standardization method represented an improvement over that from the last assessment. This new method included only those trips which targetted *Illex* (*Illex* comprised 25% or greater of total trip weight) and accounted for finer scale changes in spatial and temporal patterns. Although catches from NAFO Subareas 2-4 represented only a minor portion of the total catch during 1982-1993, catch from these areas should be included in the next assessment. The SARC recommended that effort standardization by individual vessel, instead of by tonclass, be investigated.

Another change from the previous assessment involved the application of vessel standardization coefficients to stratified mean number and weight per tow values from the NEFSC autumn survey. The SARC accepted these coefficients, and requested that the details of the vessel fishing power analysis be included in the final SARC document. In addition, the SARC requested further investigation of applying diurnal adjustment factors to autumn research survey catches of *Illex*, since the results of a habitat study (Brodziak and Hendrickson, WP A2) showed that the relationship between time of day and catch per tow from the autumn survey was significant in some years.

The appropriateness of various targets and overfishing definitions were discussed at length. It was agreed that the current overfishing definition does not offer adequate protection for the stock since the autumn survey does not track pre-recruits well and that either a rate-based or biomass-based definition might offer better protection for this annual species. One proposal was an F_{max} overfishing definition and $F_{20\%}$ target. A more risk-averse quota-based method which could utilize the lower quartile from the MSY model, in combination with $F_{20\%}$, was also proposed. However, caution was urged in using a yield-per-recruit reference point and associated estimate of average recruitment since the autumn survey only provides an approximate measure of escapement from the fishery. Given the variability in abundance for this annual species, the lower quartile of the MSY series might turn out to

be too conservative in some years.

The appropriateness of selecting $F_{20\%}$ as a biological reference point by analogy to another *Illex* species was questioned given the lack of knowledge about *Illex* recruitment. It was agreed that substantiating any %MSP value would be difficult, but that choosing $F_{50\%}$ would be more precautionary and similar to the Falkland Islands reference point (40% proportional escapement) used for real-time management of the *Illex argentinus* fishery. Further, it was noted that $F_{20\%}$ might be a reasonable reference point given that female *Illex* produce 20 times as many eggs as *Loligo*, for which a target of $F_{50\%}$ was selected. In conclusion, the SARC decided on a threshold monthly fishing mortality rate of $F_{20\%}$ (0.28) and a target of $F_{50\%}$ (0.11) for the U.S. EEZ *Illex* fishery.

Real-time management methods presented in Working Paper B2 were also discussed. SARC members felt real-time management was critical for annual species such as the squids, given the fact that a single recruitment failure could imply stock collapse and that stock size is generally unknown before the start of the fishing season and highly variable between years. Preliminary analyses utilizing the monthly coefficients from the standardized LPUE model suggest that there is good agreement between the Leslie-Delury depletion model and the 1982-1993 surplus production model values from the current assessment. The pros and cons of effort versus catch quota controls were discussed. Concerns about adequate data collection methods, including at-sea observers, and their costs were expressed. It was noted that catch information from dealer reports would be easier to extract than the use of effort data from logbooks and that the collection of early-season catch and effort data, for only a representative portion of the fleet, might be more cost-effective for determining in-season effort or catch quota adjustments. The SARC requested the summarization and presentation of the real-time management information in Working Paper B2 to the MAFMC. They also determined that a detailed data collection plan and a cost-benefit analysis

should be drafted to determine the feasibility of implementing real-time management measures for *Loligo* and *Illex* squid. It was recommended that the *Illex* fishery, due to its single-season and small number of vessels, be used as a test case.

Research Recommendations

- o Total catch (U.S. EEZ and NAFO Subareas 2-4) should be incorporated into future surplus production model analyses for this unit stock.
- o Investigate effort standardization for individual vessels, or 2-digit vessel size classes.
- o A joint research program for this transboundary stock, involving US and Canadian scientists, would improve the biological basis for management and assessment.
- o Joint transboundary management measures should be considered.
- o The level of length frequency sampling is low (1 sample of 50 lengths per 800 mt landed) and should be increased. Given the variability in mean weights, by month and statistical area, increased sampling effort is recommended to characterize the fishery, particularly if real-time management measures are implemented. Mean weights would be necessary to convert catch biomass to numbers for input to a Leslie-DeLury model. Industry participation in the collection of length frequency data should be explored through provisions of the mandatory logbook requirement. Voluntary collection of biological data at sea would help address sampling needs and foster industry/scientist communication.
- o Examine factors related to the formation of daily growth increments, such as temperature, light and vertical migration.
- o Increase knowledge of the stock structure by studying the range of the population throughout the year and determining spawning locations.
- o Establish a pilot study to collect *Illex* statoliths during research surveys to determine length-at-age and weight-at-age relationships for squid from Cape Hatteras to the Gulf of Maine.
- o Schedule the collection of at-sea observer data for trips targeting *Illex*, particularly aboard freezer boats, to evaluate fishery catch and discarding practices. Also investigate *Illex* bycatch in the silver hake fishery and other fisheries.
- o Determine whether abundance indices require adjustment factors for time of day in all survey years.
- o *Illex* has been reported to school by sex and size. Record the sex and sexual maturity of squid caught during research surveys for use in determining differences in growth rates, and timing of spawning and mean length at sexual maturity of females, respectively, in the U.S. EEZ.
- o If an *Illex* fishery develops south of Cape Hatteras, it would be desirable to characterize the species composition of the catch and to identify the extent of co-occurrence of other *Illex* species off the southeastern U.S. coast.

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Table B1. Short-finned squid (*Illex illecebrosus*) landings (mt) from Cape Hatteras to the Gulf of Maine during 1963-1994 and from NAFO Subareas 2, 3 and 4, during 1973-1994^{1,2,3,5}

Year	Cape Hatteras to the Gulf of Maine			NAFO Subareas 2, 3 and 4	All Areas
	Domestic	Foreign	Subtotal	Subtotal	Total
1963	810	0	810	- ¹	810
1964	358	2	360	- ¹	360
1965	444	78	522	- ¹	522
1966	452	118	570	- ¹	570
1967	707	285	992	- ¹	992
1968	678	2,593	3,271	- ¹	3,271
1969	562	975	1,537	- ¹	1,537
1970	408	2,418	2,826	- ¹	2,826
1971	455	159	614	- ¹	614
1972	472	17,169	17,641	- ¹	17,641
1973	530	18,625	19,155	641	19,796
1974	148	20,480	20,628	283	20,911
1975	107	17,819	17,926	17,696	35,622
1976	229	24,707	24,936	41,767	66,703
1977	1,024	23,771	24,795	83,480	108,275
1978	385	17,310	17,695	94,064	111,759
1979	1,780	15,742	17,522	162,092	179,614
1980	349	17,529	17,878	69,606	87,484
1981	631	14,723	15,354	32,862	48,216
1982	5,902	12,350	18,252	12,908 ³	31,160
1983	9,944	1,776	11,720	421	12,141
1984	9,547	676	10,223	715	10,938
1985	4,997	1,053	6,050	673	6,723
1986	5,176	250	5,422	111	5,533
1987	10,260	0	10,260	1,718	11,978
1988	1,966	1	1,967	846	2,813
1989	6,801	0	6,801	7,327	14,128
1990	11,316	0	11,316	10,843	22,159
1991	11,908	0	11,908	3,838	15,746
1992	17,827	0	17,827	1,851 ²	19,678 ²
1993	18,012	0	18,012	2,759 ²	20,771 ²
1994	18,322 ⁴	0	18,322	- ⁵	- ⁵
AVERAGES					
1963-93	4,006	6,794	10,774	- ¹	28,429 ^{1,2,5}
1973-82	1,109	18,306	19,414	51,540	70,954
1983-89	6,956	537	7,492	1,687	9,179
1990-93	14,766	0	14,766	4823 ^{2,4,5}	19,589 ^{2,5}

¹ ICNAF squid landings were not reported by species before 1973.

² *Illex* landings from NAFO Subareas 2, 3 and 4 in 1992 and 1993 are provisional.

³ Landings during 1982-1992 have been updated by NAFO.

⁴ Landings for 1994 are preliminary.

⁵ Landings from NAFO Subareas 2, 3 and 4 in 1994 are unavailable.

Table B2. Landings (mt) of *Illex* squid (*Illex illecebrosus*) by 3-digit US statistical area and month during 1993.

AREA	MONTH												TOTAL	AVG % 1993	AVG % 1982-93
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC			
512	-	-	-	-	-	-	-	-	-	0.1	-	-	0.1	<1	<1
513	-	-	-	-	-	-	-	-	0.3	-	-	-	0.3	<1	<1
514	-	-	-	-	-	-	-	0.3	0.1	-	-	-	0.4	<1	<1
521	-	-	-	-	-	-	-	-	0.2	-	-	-	0.2	<1	<1
522	-	-	-	-	-	-	0.4	8.4	-	-	-	-	8.8	<1	<1
526	-	-	-	0.1	-	-	0.3	-	1966.0	681.7	-	-	2648.1	15	4
537	1.3	-	-	-	-	0.8	4.9	10.3	162.7	-	-	2.9	182.9	1	<1
538	-	-	-	-	0.1	-	0.3	-	-	-	-	-	0.4	<1	<1
561	-	-	-	-	-	-	-	0.4	-	-	-	-	0.4	<1	<1
616	33.3	0.3	-	1.7	0.1	-	159.8	1186.9	57.4	2.7	55.1	-	1497.3	8	4
621	-	-	-	-	-	-	0.1	-	-	-	-	-	0.1	<1	<1
622	6.4	3.8	1.8	3.0	5.2	1525.9	4690.8	4442.2	1925.9	349.5	35.4	14.8	13054.7	73	74
623	-	-	-	-	-	-	105.3	22.4	-	-	-	-	127.8	<1	1
626	-	-	-	0.4	3.6	-	199.3	46.6	117.3	40.7	24.4	3.0	435.3	2	9
627	-	-	-	-	-	-	-	-	-	15.7	-	-	15.7	<1	1
631	-	-	-	-	-	-	-	-	-	-	0.3	-	0.3	<1	<1
632	-	-	-	-	-	21.9	-	-	-	17.5	0.1	-	39.5	<1	4
TOTAL	41.0	4.1	1.8	5.2	9.0	1548.6	5161.2	5717.5	4229.9	1107.9	165.3	20.7	18,012.2		
AVG %	<1	<1	<1	<1	<1	9	29	32	23	6	<1	<1			
AVG % 1989-93	<1	<1	<1	<1	1	12	28	30	20	7	1	<1			
AVG % 1982-93	<1	<1	<1	<1	4	15	27	27	22	5	<1	<1			

Table B3. Summary of *Illex* squid commercial fishery sampling, during 1982-1993, in the U.S. EEZ.

YEAR	SAMPLE SIZE	TRIPS SAMPLED	U.S. LANDINGS (mt)	SAMPLES PER TON LANDED
1982	2961	59	5,902	2
1983	920	18	9,944	11
1984	1690	33	9,547	6
1985	411	8	4,997	12
1986	866	17	5,176	6
1987	600	12	10,260	17
1988	759	15	1,966	3
1989	159	3	6,801	43
1990	324	6	11,316	35
1991	751	15	11,908	16
1992	800	16	17,827	22
1993	1154	23	18,012	16

Table B4. Total numbers of *Illex illecebrosus* landed (millions) from Cape Hatteras to the Gulf of Maine during 1982-1993.

Year	Mean Weight (g)	Total Landings (mt)	Number of Squid Landed (x10 ⁶)
1982	154	18,252	118.6
1983	130	11,720	90.2
1984	128	10,223	79.8
1985	130	6,050	46.4
1986	110	5,422	49.4
1987	132	10,260	77.4
1988	139	1,967	14.1
1989	126	6,801	54.0
1990	126	11,316	89.7
1991	140	11,908	85.1
1992	128	17,827	139.3
1993	123	18,012	146.4
AVERAGE 1982-93	131	10,813	82.5

Table B5. Results of General Linear Model for the domestic *Illex* squid fishery during 1982-1993.

Dependent Variable: LNCPUEDF					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	342.13836128	15.55174369	26.12	0.0001
Error	1579	940.18543422	0.59543093		
Corrected Total	1601	1282.32379550			
	R-Square	C.V.	Root MSE	LNCPUEDF Mean	
	0.266811	21.34403	0.7716417	3.6152583	
Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	11	168.67814841	15.33437713	25.75	0.0001
TONCLASS	1	15.92235389	15.92235389	26.74	0.0001
AREA	4	59.63406930	14.90851733	25.04	0.0001
MONTH	6	97.90378968	16.31729828	27.40	0.0001
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	11	127.40487918	11.58226174	19.45	0.0001
TONCLASS	1	8.83076436	8.83076436	14.83	0.0001
AREA	4	52.70598304	13.17649576	22.13	0.0001
MONTH	6	97.90378968	16.31729828	27.40	0.0001
Parameter	Estimate		T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT	3.724923867	B	50.64	0.0001	0.07355282
YEAR					
83	-0.715042849	B	-6.78	0.0001	0.10549186
84	0.383029198	B	4.32	0.0001	0.08869290
85	-0.576149911	B	-4.84	0.0001	0.11894811
86	-0.091549845	B	-0.99	0.3199	0.09201788
87	0.469253839	B	4.76	0.0001	0.09850293
88	0.430926944	B	3.23	0.0013	0.13347011
89	0.350937135	B	3.03	0.0025	0.11588224
90	-0.396321637	B	-4.10	0.0001	0.09663468
91	0.142449705	B	1.55	0.1213	0.09188585
92	0.027741936	B	0.36	0.7154	0.07607145
93	-0.004786929	B	-0.06	0.9491	0.07498800
982	0.000000000	B			
TONCLASS					
3	0.163917128	B	3.85	0.0001	0.04256385
4	0.000000000	B			
AREA					
526	1.390260548	B	8.22	0.0001	0.16916136
616	-0.005269795	B	-0.05	0.9640	0.11670176
626	-0.158211407	B	-2.36	0.0184	0.06703520
632	-0.309451927	B	-3.67	0.0002	0.08421010
9622	0.000000000	B			
MONTH					
5	-0.884058218	B	-9.25	0.0001	0.09554736
6	-0.033911156	B	-0.53	0.5992	0.06451520
7	-0.114140530	B	-2.04	0.0414	0.05591629
9	-0.161420188	B	-2.70	0.0069	0.05969926
10	-0.679510681	B	-7.30	0.0001	0.09313807
11	-1.246089309	B	-6.02	0.0001	0.20695364
98	0.000000000	B			

Table B6. Standardized fishing effort and LPUE for *Illex squid (Illex illecebrosus)* landed in the U.S. EEZ, between Cape Hatteras and the Gulf of Maine, during 1982-1993.

Year	GLM Model Results (Sub-fleet)					
	Landings (mt)	Standardized Effort ¹ (days fished)	Domestic LPUE ² (mt/df)	Total Landings (mt)	Ratio Total Landings/ Model Landings	U.S. Standardized Effort ³ (daysfished)
1982	3,412	88.6	38.5	18,252	5.3	474
1983	1,266	53.7	23.6	11,720	9.3	497
1984	3,262	57.8	56.4	10,223	3.1	181
1985	1,154	46.6	24.8	6,050	5.2	244
1986	4,210	93.2	45.2	5,422	1.3	120
1987	6,403	95.6	66.9	10,260	1.6	153
1988	1,749	25.8	67.7	1,967	1.1	29
1989	5,769	87.7	65.8	6,801	1.2	103
1990	10,401	333.2	31.2	11,316	1.1	362
1991	10,599	193.7	54.7	11,908	1.1	218
1992	17,530	379.4	46.2	17,827	1.0	386
1993	17,078	369.7	46.2	18,012	1.1	390
AVERAGE 1982-93			47.3	10,813		263

¹ Effort for 1982-1987 has been prorated to account for Joint Venture landings.

² Ratio of total landings (mt.) to standardized effort for *Illex* trips used in the GLM.

³ Calculated total standardized effort for the domestic fishery.

Table B7. All sizes, pre-recruit (≤ 10 cm), and recruit (> 10 cm) stratified mean numbers per tow and mean weights per tow (kg) of *Illex illecebrosus* from the NEFSC fall bottom trawl survey (offshore strata 1-40 and 61-76, Cape Hatteras to the Gulf of Maine) during 1967-94.

Year	All sizes Number/tow	CV ¹ (%)	All sizes Kg/tow	Individual Mean Weight (g)	Pre-recruits Number/tow	Recruits Number/tow
1967	1.64	19	0.24	147	0.04	1.56
1968	1.66	21	0.31	186	0.10	1.56
1969	0.61	25	0.07	121	0.09	0.52
1970	2.45	26	0.27	110	0.93	1.51
1971	1.69	12	0.35	206	0.19	1.50
1972	2.57	25	0.32	123	0.68	1.89
1973	1.46	23	0.35	242	0.04	1.42
1974	3.06	41	0.44	145	1.20	1.87
1975	9.85	43	1.41	143	3.98	5.87
1976	23.94	22	7.59	317	0.42	23.52
1977	12.72	19	3.80	299	0.72	12.00
1978	20.18	20	4.43	219	3.29	16.89
1979	20.75	13	6.34	305	1.31	19.44
1980	14.24	16	3.38	238	0.43	13.81
1981	27.62	34	9.02	327	0.22	27.40
1982	3.80	13	0.59	155	0.71	3.09
1983	1.75	15	0.23	134	0.16	1.58
1984	4.61	17	0.52	113	0.32	4.28
1985	2.37	16	0.35	147	0.19	2.21
1986	2.14	16	0.25	119	0.26	1.84
1987	19.97	40	1.84	92	0.89	19.11
1988	29.18	43	3.53	121	0.43	28.77
1989	13.47	24	1.59	118	1.04	12.46
1990	16.19	9	2.29	141	0.61	15.58
1991	5.33	13	0.69	129	0.23	5.07
1992	8.42	14	0.83	98	1.78	6.62
1993	10.87	21	1.73	159	0.15	10.76
1994	6.99	24	0.89	128	0.22	6.78
Average 1967-1994	9.63	22	1.92	171	0.74	8.89

¹ Coefficient of variation for the all sizes index.

Table B8. All sizes, pre-recruit (≤ 10 cm), and recruit (> 10 cm) stratified mean numbers per tow and mean weights per tow (kg) of *Illex illecebrosus* from the NEFSC spring bottom trawl survey (offshore strata 1-40 and 61-76, Cape Hatteras to the Gulf of Maine) during 1967-95.

Year	All sizes Number/tow	CV ¹ (%)	All sizes Kg/tow	Individual Mean Weight (g)	Pre-recruits Number/tow	Recruits Number/tow
1968	0.19	42	0.010	54	0.019	0.17
1969	1.67	50	0.027	16	1.457	0.21
1970	0.56	43	0.023	41	0.150	0.41
1971	0.06	37	0.009	138	0.008	0.06
1972	0.02	39	0.001	53	0.004	0.02
1973	0.03	52	0.007	196	0.000	0.03
1974	0.74	39	0.045	60	0.066	0.68
1975	0.18	33	0.012	70	0.087	0.09
1976	0.57	52	0.035	62	0.007	0.56
1977	0.18	18	0.010	57	0.035	0.15
1978	0.85	46	0.045	52	0.014	0.84
1979	0.46	25	0.041	88	0.078	0.38
1980	0.33	22	0.021	65	0.107	0.22
1981	0.91	30	0.053	58	0.045	0.87
1982	0.62	26	0.039	63	0.050	0.57
1983	0.07	29	0.003	41	0.011	0.06
1984	0.24	69	0.004	17	0.210	0.03
1985	0.96	78	0.023	24	0.824	0.14
1986	0.23	69	0.007	29	0.190	0.04
1987	0.33	45	0.012	36	0.187	0.14
1988	0.16	40	0.010	66	0.066	0.09
1989	0.25	30	0.028	111	0.004	0.25
1990	0.34	36	0.019	55	0.019	0.32
1991	1.03	41	0.043	42	0.233	0.80
1992	0.60	31	0.022	37	0.112	0.49
1993	0.41	23	0.030	74	0.010	0.40
1994	0.71	41	0.038	54	0.188	0.52
1995	0.93	29	0.020	22	0.592	0.34
Average						
1968-1995	0.5	40	0.023	60	0.170	0.3

¹ Coefficient of variation for the all sizes index.

Table B9. Results of the surplus production model, for *Illex* squid landed in the U.S. EEZ, during 1982-1993.

Year	Calculated Biomass (mt)	Biomass Production (mt)	Catch (mt)	Average Biomass (mt)	Annual Fishing Mortality Rate	Monthly Fishing Mortality Rate ¹
1982	25,049	22,649	18,252	36,373	0.50	0.13
1983	29,446	18,685	11,720	38,789	0.30	0.08
1984	36,411	7,553	10,223	40,187	0.25	0.06
1985	33,741	12,524	6,050	40,003	0.15	0.04
1986	40,215	-1,039	5,422	39,695	0.14	0.04
1987	33,754	12,502	10,260	40,005	0.26	0.07
1988	35,995	8,384	1,967	40,187	0.05	0.01
1989	42,412	-6,811	6,801	39,007	0.17	0.04
1990	28,800	19,416	11,316	38,508	0.29	0.07
1991	36,900	6,547	11,908	40,174	0.30	0.08
1992	31,539	15,964	17,827	39,522	0.45	0.11
1993	29,677	18,411	18,012	38,883	0.46	0.12

¹ Assumes a 4-month fishing season

Table B10. Yield and spawning stock biomass per recruit estimates for *Illex illecebrosus*.

Yield and Spawning Stock Biomass per Recruit

Proportion of F before spawning: 1.0000
 Proportion of M before spawning: 1.0000
 Natural mortality is constant at: 0.3000
 Initial age (months) is: 1 Last age is: 8
 Last age is a PLUS group
 Input data from file named: illypr.in

Age-specific Input data for Yield per Recruit Analysis

Age (mos)	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Stock	Weights Catch
1	0.0000	1.0000	0.0000	0.0355	0.0355
2	0.0000	1.0000	0.0000	0.0520	0.0520
3	0.0000	1.0000	0.0000	0.0762	0.0762
4	1.0000	1.0000	0.0000	0.1117	0.1117
5	1.0000	1.0000	0.0000	0.1636	0.1636
6	1.0000	1.0000	0.5000	0.2398	0.2398
7	1.0000	1.0000	1.0000	0.3514	0.3514
8+	1.0000	1.0000	1.0000	0.5149	0.5149

Summary of Yield per Recruit Analysis

The slope of the yield per recruit curve at F=0: 0.388391
 F level at slope = 1/10 of the above slope (F0.1): 0.262287
 Yield/Recruit corresponding to F0.1: 0.038676
 F level to produce Maximum Yield/Recruit (Fmax): 0.609939
 Yield/Recruit corresponding to Fmax: 0.042654
 F level at 0.20 of max spawning potential: 0.280629
 SSB/Recruit corresponding to F=0.280629: 0.048615

Yield per Recruit Results

FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
0.000	0.00000	0.00000	3.8583	0.5654	0.5551	0.2431	100.00
0.050	0.05808	0.01542	3.6664	0.4813	0.4106	0.1755	72.19
0.100	0.10164	0.02514	3.5229	0.4209	0.3102	0.1295	53.26
0.150	0.13552	0.03140	3.4116	0.3758	0.2382	0.0971	39.96
0.200	0.16263	0.03549	3.3229	0.3413	0.1852	0.0739	30.40
0.250	0.18480	0.03817	3.2507	0.3144	0.1455	0.0568	23.38
0.300	0.20328	0.03993	3.1907	0.2928	0.1153	0.0441	18.15
0.350	0.21892	0.04107	3.1403	0.2754	0.0921	0.0345	14.21
0.400	0.23233	0.04179	3.0973	0.2611	0.0740	0.0272	11.20
0.450	0.24394	0.04223	3.0602	0.2492	0.0598	0.0216	8.88
0.500	0.25411	0.04248	3.0279	0.2393	0.0485	0.0172	7.08
0.550	0.26307	0.04261	2.9997	0.2309	0.0396	0.0138	5.67
0.600	0.27105	0.04265	2.9747	0.2237	0.0324	0.0111	4.57
0.650	0.27818	0.04264	2.9526	0.2175	0.0266	0.0090	3.69
0.700	0.28460	0.04259	2.9328	0.2121	0.0219	0.0073	2.99
0.750	0.29041	0.04252	2.9151	0.2074	0.0181	0.0059	2.44
0.800	0.29569	0.04244	2.8991	0.2033	0.0150	0.0048	1.99
0.850	0.30051	0.04236	2.8846	0.1997	0.0124	0.0040	1.63
0.900	0.30493	0.04227	2.8714	0.1965	0.0103	0.0033	1.34
0.950	0.30899	0.04219	2.8595	0.1937	0.0086	0.0027	1.10
1.000	0.31275	0.04212	2.8485	0.1911	0.0072	0.0022	0.91

Table B11. The basics of real-time management of *Illex illecebrosus*.

COMPONENT	APPROACH	EVALUATION
Set Target	Biological reference point	Rigorous justification may be difficult
	Avoid in-season closure	May be favored by industry if interannual variability is reduced
Set Threshold (to avoid)	Spring survey index	Not useful
	Leslie-Delury models	LPUE patterns useful for 7 of 12 years. Finer temporal scale (weeks) might clarify problems. Agreement with current surplus production model (same magnitude)
	Fall survey index	Promising, but need improved analytical model.(constraints)
	Indirect approach	Markov-type approach for estimating probability of meeting recruitment targets. Needs simulation study.
In-season Adjustments: Decision to Act	Delury estimator	** Limited data at present. Should improve with weekly LPUE data collection.
	Monthly LPUE vs later survey	Prediction of autumn survey index from June LPUE may work for Class 4 vessels.
In-season Adjustment: How to do it	Reduce TAC	
	Reduce effort	Used in Falkland Islands but controversial
Post Season Assessment	Surveys	Autumn survey may be useful

** Requirements for catch and effort data collection:

- By individual vessel
- Daily (though weekly or 10-day period may be adequate)
- By fishing area (e.g. 3-digit statistical area)
- Total removals (catch + discards)
- One or more measures of effort (e.g. hours jigged, days fished).

Requirements for weekly biological data collection, by at-sea observers, on selected vessels:

- Length frequency of the catch (usually by sex)
- Weight-length sub-samples (usually by sex) *{Essential!}*
- Sexual maturity
- Sex ratio

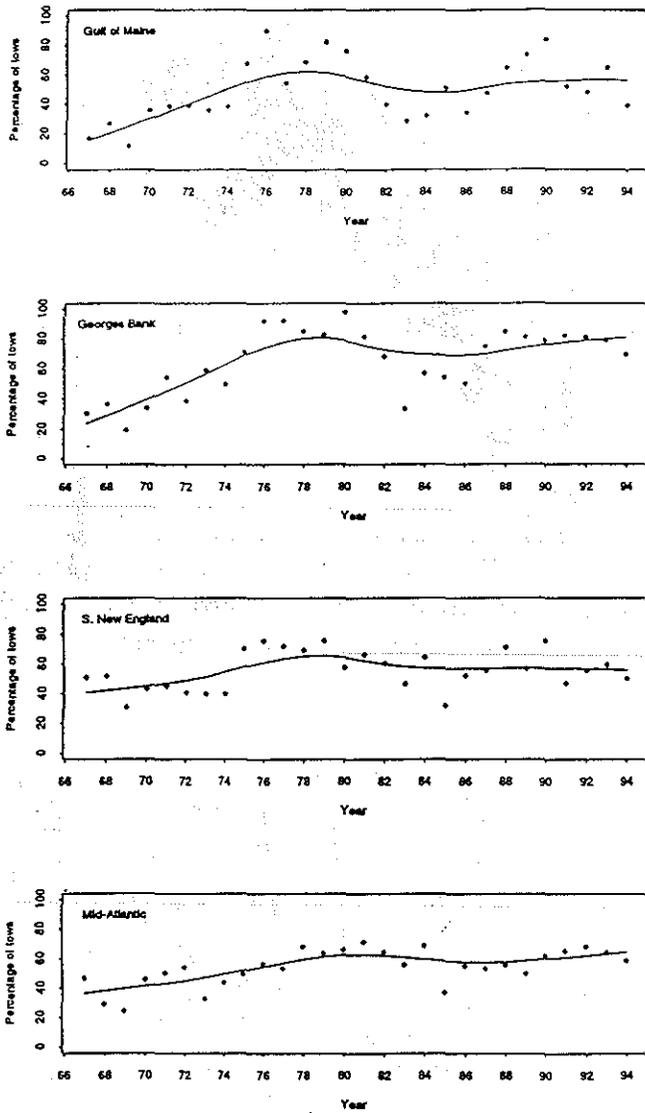


Figure B1. Proportion of tows, by region, in which *Illex illecebrosus* were caught during NEFSC autumn bottom trawl surveys, 1967-1994. Line represents LOWESS smoothed estimate with tension parameter of 0.5.

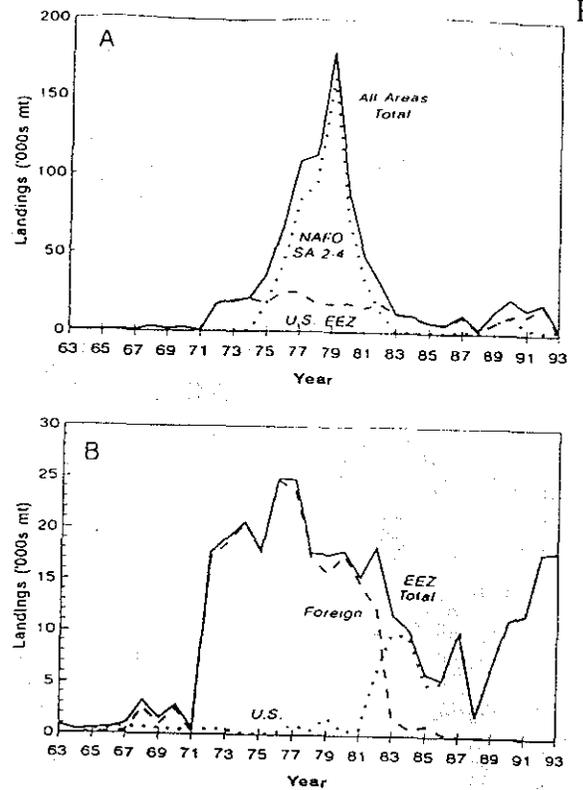


Figure B2. Trends in *Illex* squid landings for (A) total US EEZ, NAFO Subareas 2-4 (1973-1993) and landings for all areas combined and (B) US, foreign, and total US EEZ during 1963-1993.

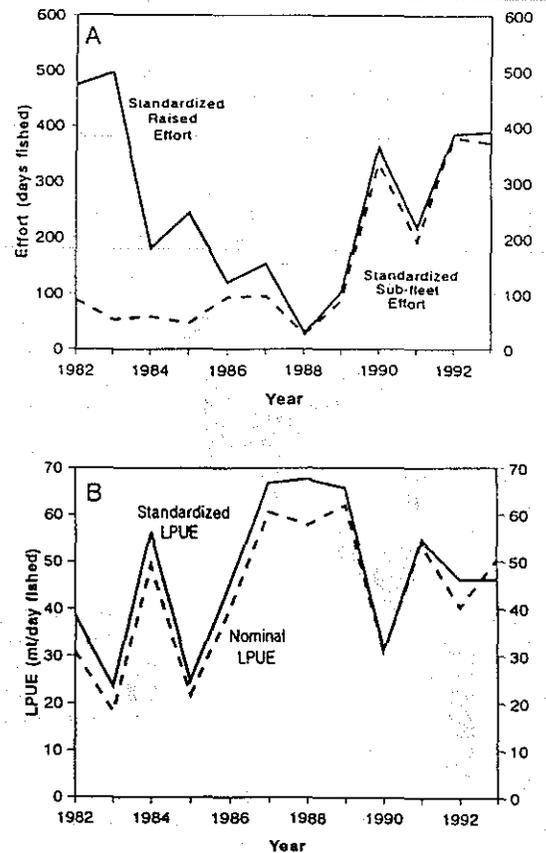


Figure B3. Trends in standardized and nominal (A) effort (days fished) and (B) LPUE (mt/day fished) for vessels whose landings of *Illex* squid exceeded 25% (by weight) of their trip landings, 1982-1993.

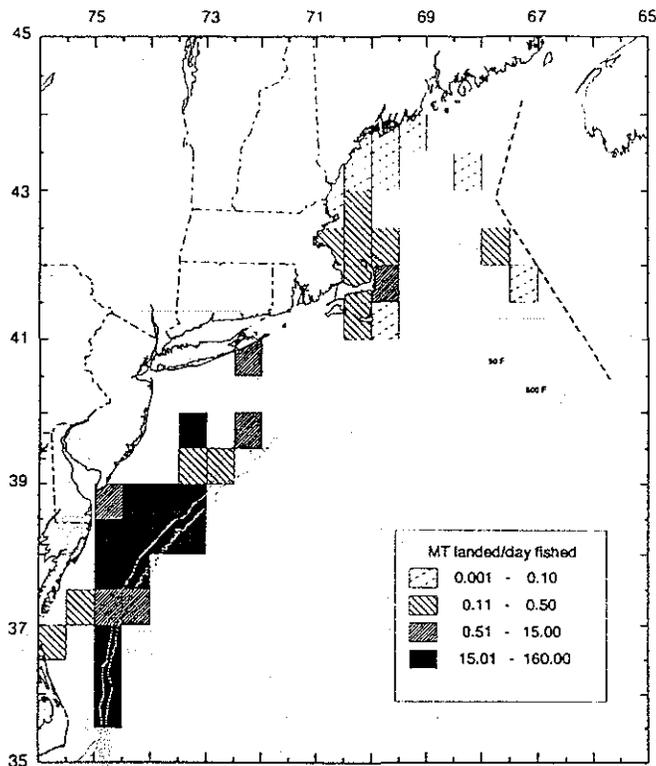


Figure B4. Landings per unit effort (mt landed per day fished) of *Illex illecebrosus* caught by the domestic bottom trawl fishery during 1982-1985.

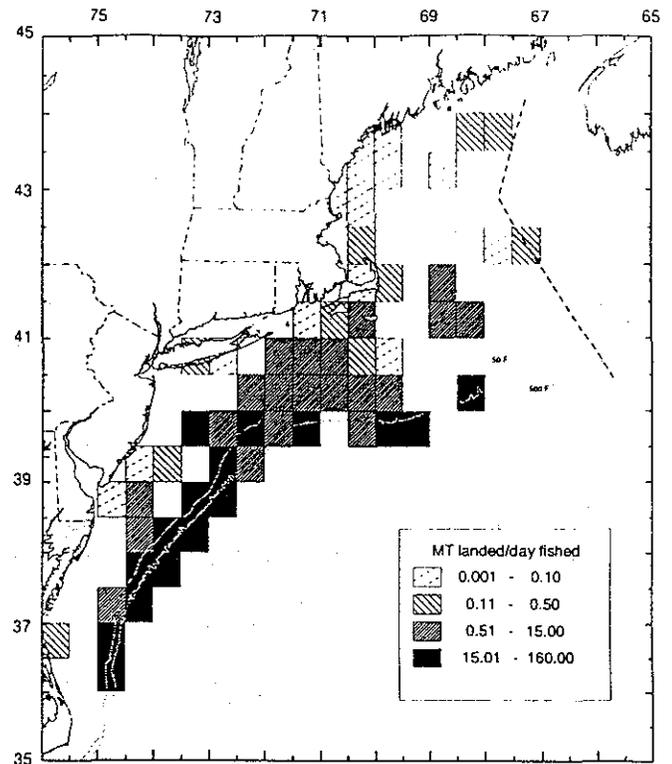


Figure B6. Landings per unit effort (mt landed per day fished) of *Illex illecebrosus* caught by the domestic bottom trawl fishery during 1990-1993.

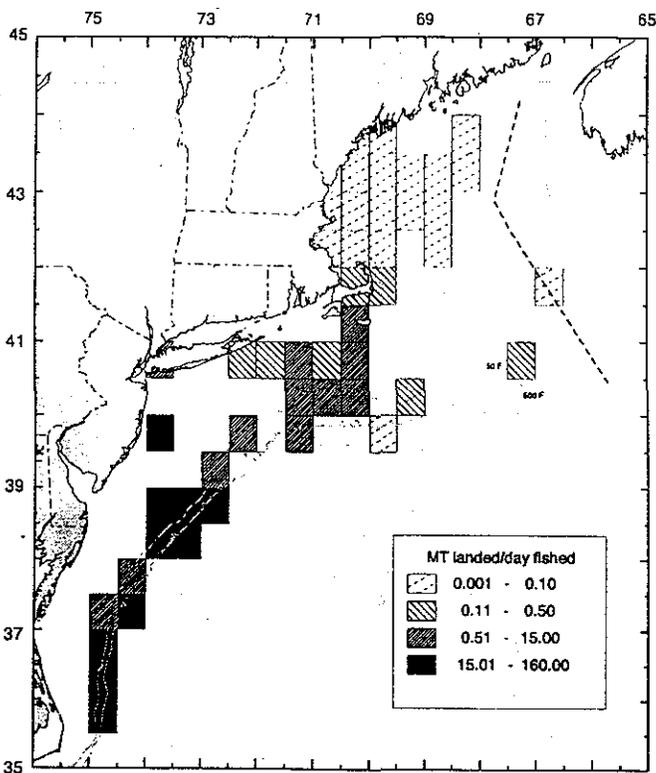


Figure B5. Landings per unit effort (mt landed per day fished) of *Illex illecebrosus* caught by the domestic bottom trawl fishery during 1986-1989.

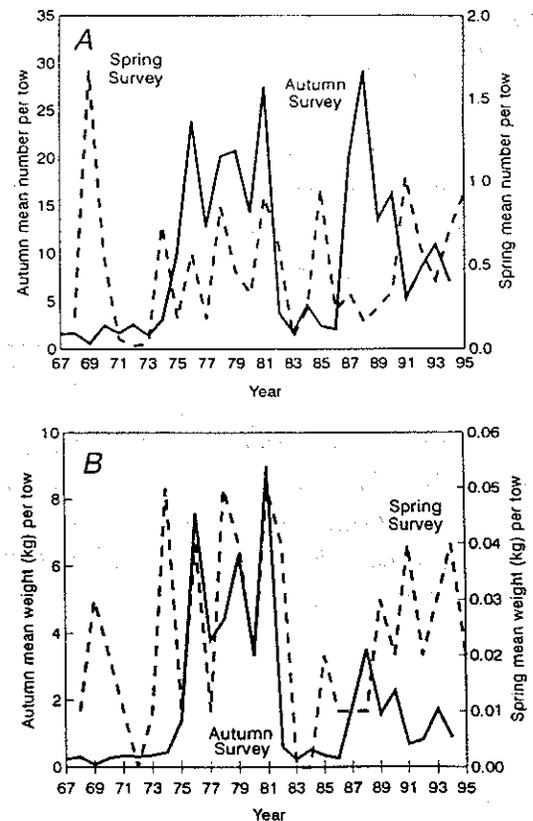


Figure B7. Stratified mean number per tow (A) and mean weight per tow (kg) (B) of *Illex illecebrosus* from the NEFSC autumn (1967-1994) and spring (1968-1995) bottom trawl surveys.

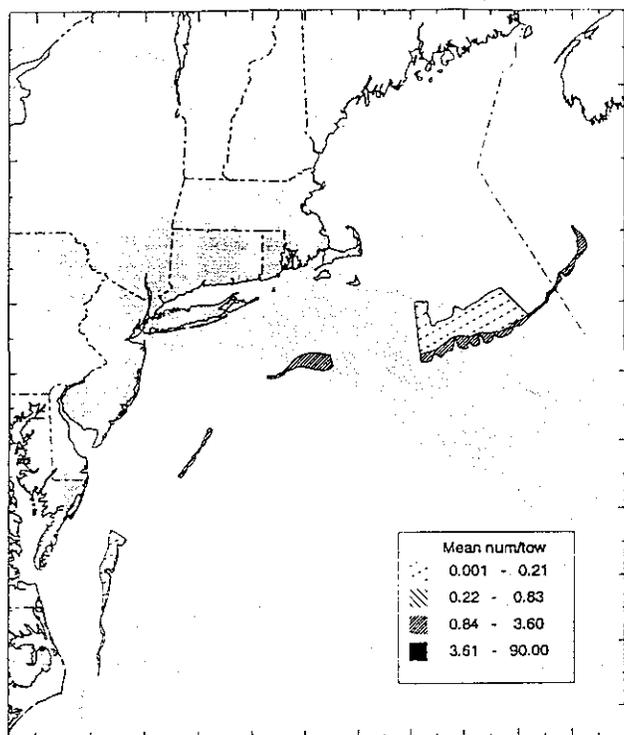


Figure B8. Mean number per tow of *Illex illecebrosus* pre-recruits (≤ 10 cm), by survey stratum, during NEFSC winter surveys, 1992-1994.

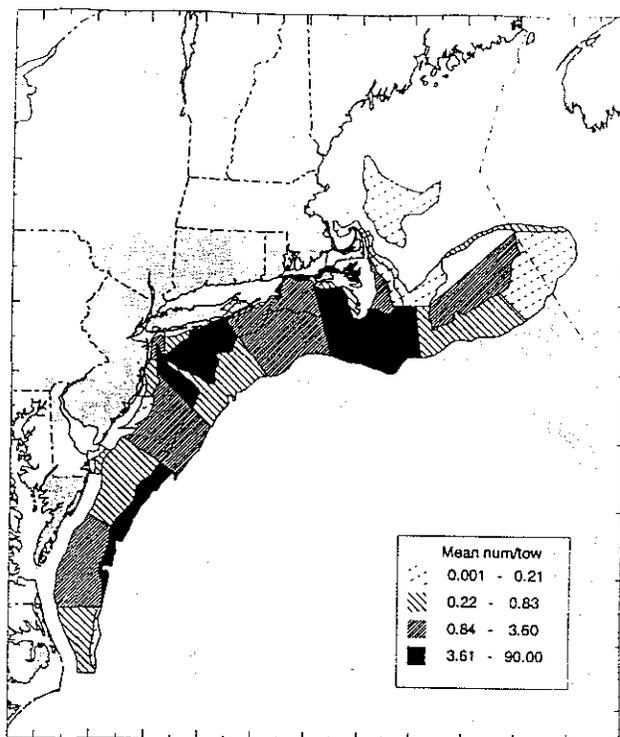


Figure B10. Mean number per tow of *Illex illecebrosus* pre-recruits (≤ 10 cm), by survey stratum, during NEFSC summer surveys, 1977-1980.

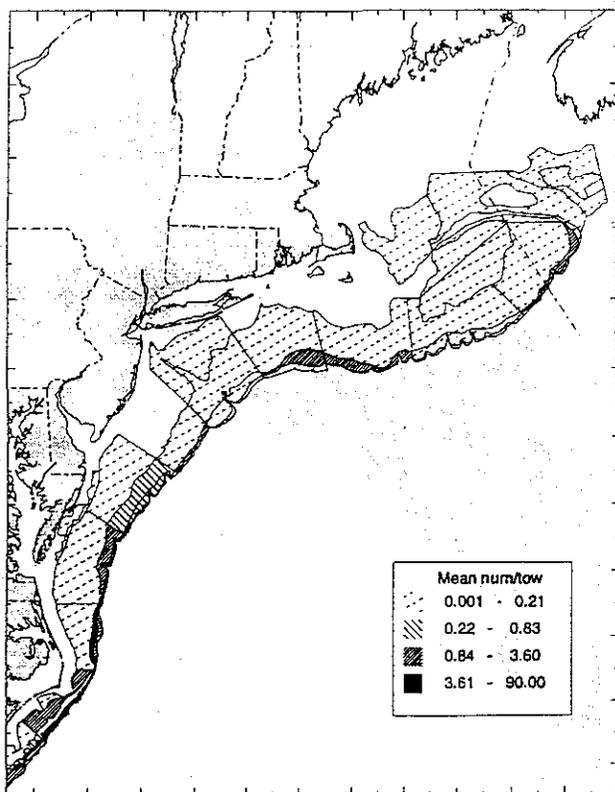


Figure B9. Mean number per tow of *Illex illecebrosus* per-recruits (≤ 10 cm), by survey stratum, during NEFSC spring surveys, 1968-1994.

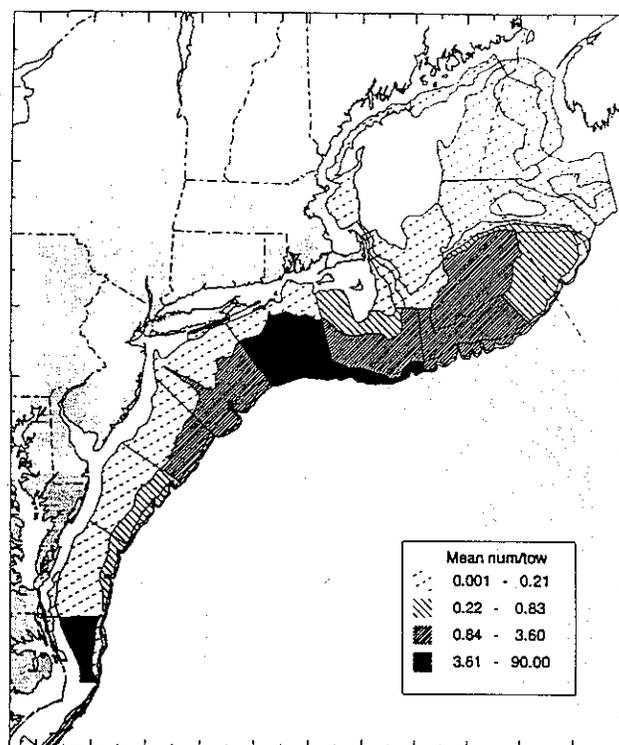


Figure B11. Mean number per tow of *Illex illecebrosus* pre-recruits (≤ 10 cm), by survey stratum during NEFSC autumn surveys, 1967-1994.

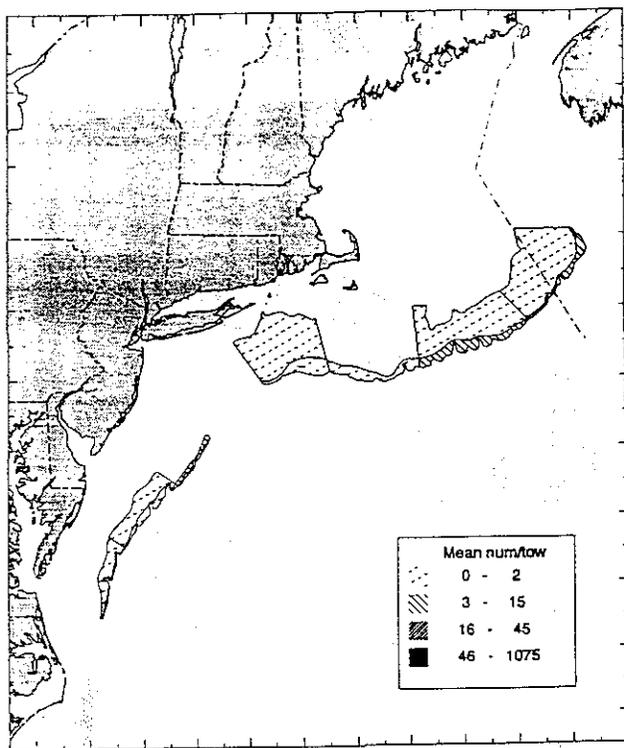


Figure B12. Mean number per tow of *Illex illecebrosus* pre-recruits (≥ 11 cm), by survey stratum, during NEFSC winter surveys, 1992-1994.

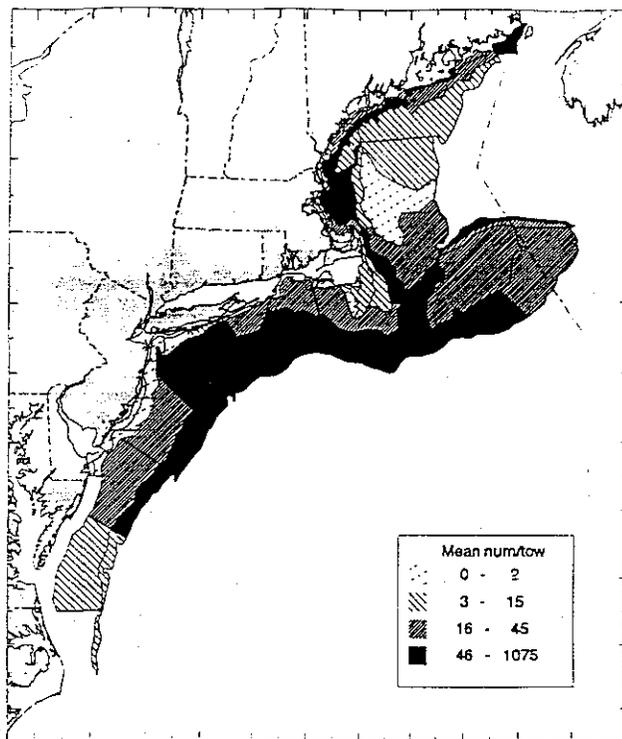


Figure B14. Mean number per tow of *Illex illecebrosus* pre-recruits (≥ 11 cm), by survey stratum, during NEFSC summer surveys, 1977-1980.

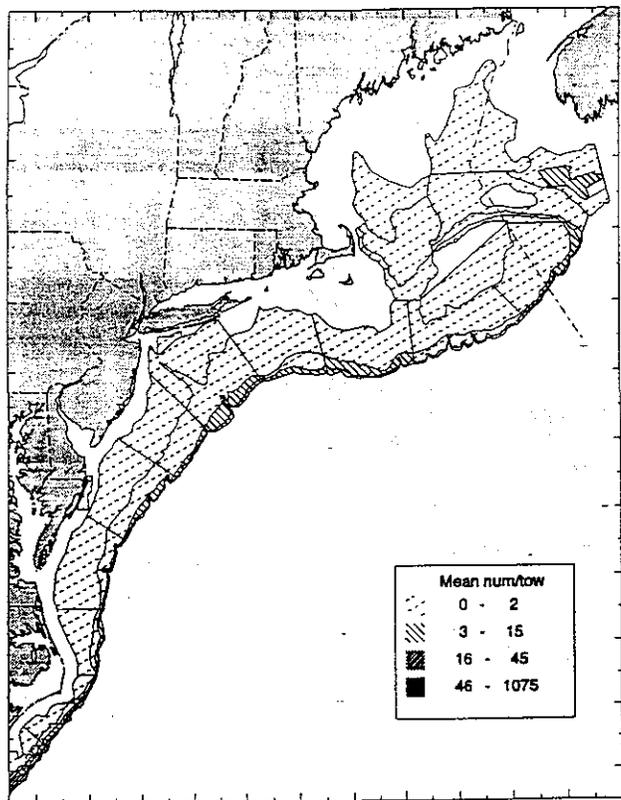


Figure B13. Mean number per tow of *Illex illecebrosus* pre-recruits (≥ 11 cm), by survey stratum, during NEFSC spring surveys, 1968-1994.

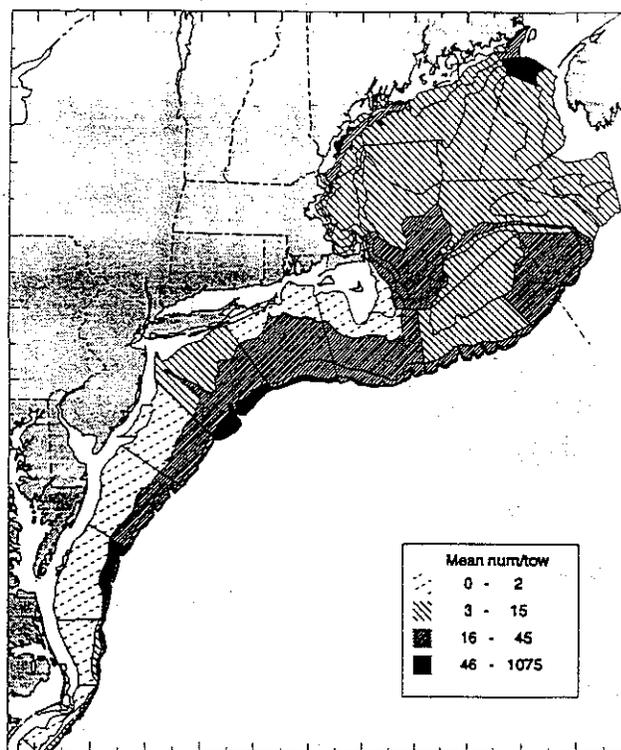


Figure B15. Mean number per tow of *Illex illecebrosus* pre-recruits (≥ 11 cm), by survey stratum, during NEFSC autumn surveys, 1967-1994.

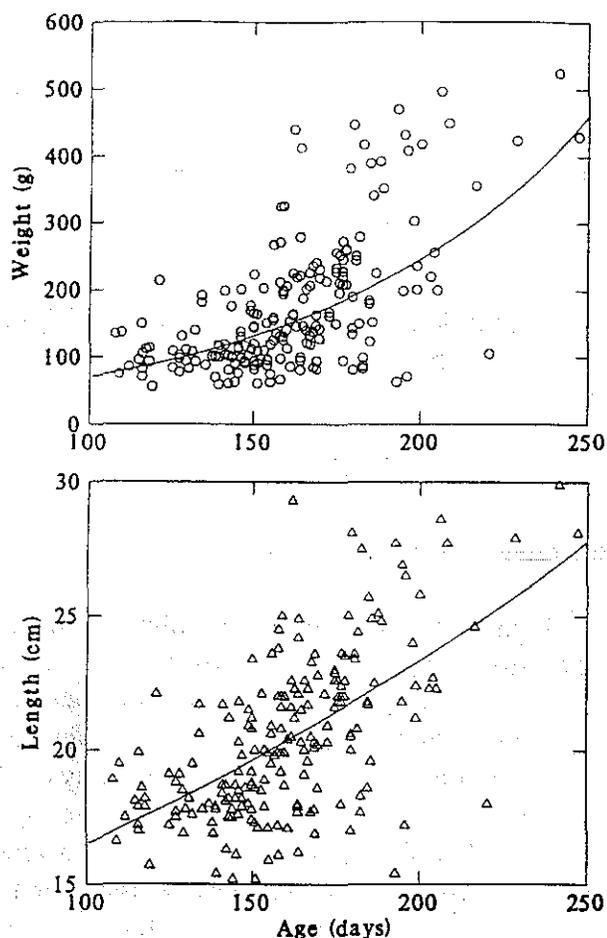


Figure B16. Observed and predicted weight-at-age (top) and length-at-age (bottom), for *Illex illecebrosus*. Weight = $20 \cdot \exp(0.01255 d)$ and length = $11.64 \cdot \exp(0.00348 d)$. Raw data from E. Dowe (ers. comm., DFO, St. John's).

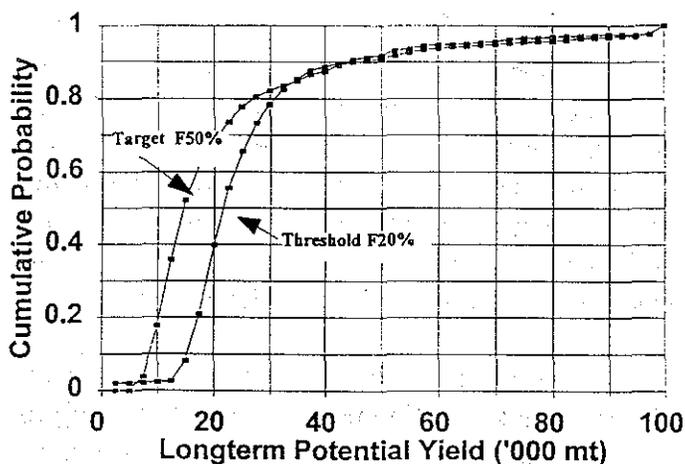


Figure B18. Distribution of long-term potential yields expected from the U.S. EEZ *Illex illecebrosus* fishery for target (F50%) and threshold (F20%) fishing mortality rates.

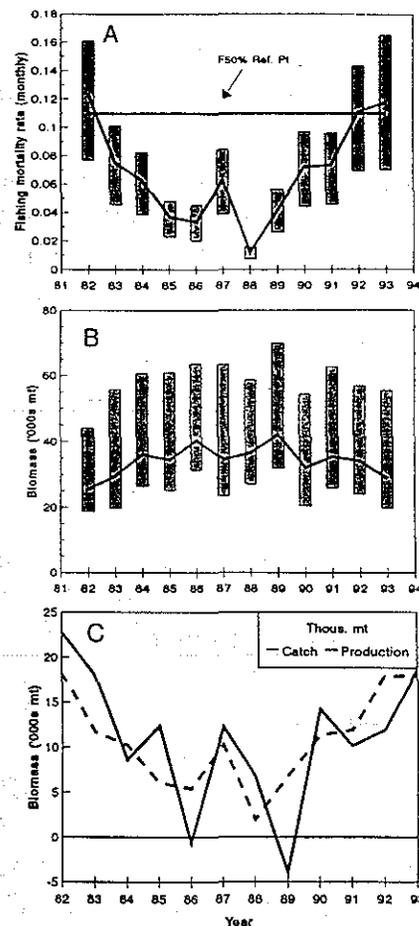


Figure B17. Median annual fishing mortality estimates, for *Illex* squid, with interquartile range derived from bootstrap estimation method (A); median initial biomass estimates with interquartile range (B) and comparison of annual catch with estimated median annual production (C). Negative production in year t implies a decrease in initial biomass in year $t+1$.

C. ATLANTIC HERRING

Terms of Reference

The following terms of reference were addressed:

- a. Provide an age-structured assessment of the herring stock complex, including estimates of fishing mortality, spawning stock biomass, and exploitable biomass through 1994, and characterize the uncertainty of the terminal estimates of F and SSB.
- b. Provide short-term projections of catch and SSB at various levels of F.
- c. Review the overfishing definition and long-term harvest strategy for this stock complex.

Introduction

Results of an analytical assessment of the aggregated coastal stock complex of Atlantic herring (*Clupea harengus*) from the Gulf of Maine to Cape Hatteras are summarized in this report. This assessment constitutes a revision of an assessment of the same stock complex reviewed by the Stock Assessment Review Committee (SARC) in the fall of 1993 (SAW 16, NEFSC 1993). Following the advice of the SARC when an assessment of this stock complex was first reviewed in the fall of 1991 (SAW 14, NEFSC 1992), historical catch-at-age data from Georges Bank were combined with data from U.S. coastal fisheries in the Gulf of Maine and south of Cape Cod and with fixed-gear catches from New Brunswick into a single catch-at-age matrix. This approach is based on the fact that the primary data used to tune the virtual population analysis (VPA) are derived from the spring NMFS bottom trawl survey and are collected at a time of year when Atlantic herring, which might otherwise be assigned to individual spawning stocks (e.g., Gulf of Maine or Georges Bank), have migrated south and occupy Massachusetts Bay and continental shelf waters in southern New England and the mid-Atlantic region. New Brunswick fixed-gear catches which are included in this assessment are not included in the Nova Scotian 4WX stock assessment (Stephenson *et al.* 1995).

Herring which spawn off southwest Nova Scotia,

on Georges Bank and Nantucket Shoals, and in coastal waters of the Gulf of Maine stock have historically been recognized as separate stocks. Assessments performed prior to 1991 (Anthony and Waring 1980, Fogarty and Clark 1983, Fogarty *et al.* 1989) were specific to either the Georges Bank/Nantucket Shoals stock or the Gulf of Maine stock. The early Gulf of Maine stock assessments were tuned, however, with the spring bottom trawl survey data even though it was recognized at the time that herring from both stocks mixed in unknown proportions south of Cape Cod in the winter and spring. It was precisely for this reason that this approach was abandoned in 1991 in favor of a single assessment for the Atlantic coast stock complex.

Assessments of the Nova Scotia (4WX) stock are performed by the Canadian Department of Fisheries and Oceans (e.g., Stephenson *et al.* 1995), which also provides biological advice concerning the status of the Georges Bank (5Z) stock and monitors landings and biological characteristics of the "non stock" herring resource in New Brunswick.

Interest in an offshore fishery for herring on Georges Bank and Nantucket Shoals is growing in both the U.S. and Canada as groundfish resources have become depleted. Although there has been no harvest of Atlantic herring on Georges Bank since the collapse of this stock in the early 1970s (Anthony and Waring 1980), herring was removed

from protected species status in the summer of 1995 and a Preliminary Management Plan was approved which allows for joint venture processing operations (but no foreign fishing) on Georges Bank and in southern New England and the mid-Atlantic region (USDC 1995).

Herring have been harvested by U.S. fishermen for sale to foreign processing ships which have anchored in internal waters of Maine, Massachusetts, Rhode Island, New York, and New Jersey at various times since 1986. Allocations of adult surplus biomass for these Internal Waters Processing (IWP) operations are based on assessment results for the stock complex and an allocation procedure that is implemented by the Atlantic States Marine Fisheries Commission (ASMFC), as described in a Fisheries Management Plan for Atlantic herring approved by the Commission in 1993 (ASMFC 1993).

The methodology used to derive input data for this assessment was basically the same as in previous assessments (NEFSC 1993). A biostatistical program (BIOSTAT) was used to derive the estimated numbers of fish caught at each age for individual gear/area categories for each month of the year based on age-length keys, catch data, and estimated mean weight-at-age data. These input parameters form the basis for a VPA for estimating stock abundance, recruitment, and fishing mortality. The analysis also relies on fishery-independent estimates of stock abundance, in this case provided by historical NMFS spring bottom trawl survey data and NMFS larval herring abundance estimates.

The Fishery

Commercial Landings

The commercial fishery for Atlantic herring is currently most active in coastal waters of the Gulf of Maine, with shoreside landings principally in New Brunswick, Maine, and Massachusetts, and with some additional activity in southern New England

and the mid-Atlantic region (Table C1). Landings remained at 70,000-90,000 metric tons (mt) a year during 1991-1994, with an additional 3,000-5,000 mt in IWP landings (Figure C1). Landings in 1994 were about 70,300 mt, the lowest level since 1987.

Catches on Georges Bank in the late 1960s and early 1970s far exceeded historical catches along the coast, but there has been no significant fishing on Georges since that stock collapsed in the early 1970s. Herring began returning to the Bank to spawn in 1986 and, according to larval survey results, the population has recovered dramatically since then. There is still no significant commercial fishery for herring on Georges Bank or in the southern New England or mid-Atlantic areas, due to the limited market demand for this species and the availability of herring in the coastal waters of the Gulf of Maine.

Atlantic herring are utilized in the Maine and New Brunswick canning industry and for bait throughout New England and along the U.S. east coast, mostly in the lobster fishery. They are caught primarily with purse seines and mid-water trawls, although there is still a small quantity taken in Maine in weirs and stop seines. The summer-fall fishery takes place primarily in the Gulf of Maine between April and December, while fishing south of Cape Cod is primarily from January - March. Large quantities of two- and three-year-olds are harvested in New Brunswick, whereas the harvest in U.S. waters is composed of a variety of age groups. The U.S. catch in recent years has included a growing number of older (ages 3-10) fish as the canneries have diversified their products to include juveniles (age 2) as well as small adults, and as demand has grown for bait and for large fish to supply foreign processing ships.

Recreational Landings

Some estimates of recreational landings are available in southern New England and the mid-Atlantic states from the Marine Recreational Fishery Statistical Survey, but the quantities are so small

relative to the commercial landings that they were not considered relevant to this assessment.

Sampling

Herring samples are obtained from commercial catches landed in Maine, primarily from May to October, in Massachusetts (Gloucester) and Rhode Island in the winter and early spring, and aboard foreign processing vessels participating in the IWP fishery. All samples include fish which are measured for total length (usually either 50 or 100) and a subsample which is aged (usually 30 fish). Additional information on sex, state of maturity, and weight is also recorded. These data are used, along with catch data, to estimate the age composition of the catch.

A total of 151 samples were processed from the 1993 commercial herring fishery (Table C2). Most of these (119) were from mobile gear landings, which represented 95% of the annual landings. Twenty-one samples (18% of the mobile gear samples or 14% of all samples) were taken from mid-water trawl landings, which represented 10% of the total landings in 1993. Thirty-two fixed gear samples were processed in 1993 (21% of all samples), although fixed gear only accounted for 5% of the total landings.

A total of 96 samples were processed from the 1994 commercial herring fishery (Table C3), 80 from mobile gear and 16 from fixed gear. An additional 15 samples collected in Gloucester were lost when a freezer at the DMR Laboratory in Boothbay Harbor malfunctioned. Most of these lost samples were collected at the end of the year, consequently December catches were under-sampled.

Age Composition

Catch at age in numbers for 1993 and 1994 were estimated from U.S. sample and catch data and combined with published New Brunswick catch-at-age estimates (Tables C4, C5, and C6) for incorporation into the existing time series (Table C7). U.S. catches were summed by month and gear

type (mobile versus fixed gear) according to where the fish were caught, i.e., in eastern, central, and western Maine, in Massachusetts Bay (NMFS statistical area 514, Figure 1), southern New England, and in the mid-Atlantic region. Catches from Jeffreys Ledge, an important fishing ground located east of Portsmouth, NH, were assigned to western Maine (NMFS area 513) for the first time: in previous assessments, catches from this area were combined with catches from Massachusetts coastal waters. Catches at age for 1992 (but not for any earlier years) were adjusted to account for this new distribution of catch data and means of estimation. Also, an attempt was made to account for unreported bait landings for southern New England in 1993 and 1994. As was done previously, IWP landings were also incorporated into the 1993 and 1994 catch-at-age estimates.

Mean Weights at Age

Mean weights at age in the U.S. portion of the catch were calculated (Table C8), as in previous assessments, by summing the estimated monthly catches (mt) for each age and dividing by the estimated total numbers of fish caught at the same age. The reduction in U.S. mean weights which began in 1987 was still apparent in 1993 and 1994. The SARC attributes this reduction in weight-at-age to reduced growth rate in response to rapidly increasing stock sizes in recent years.

Percent Maturity at Age

Male and female herring in samples collected from the commercial fishery during August, September, and October were examined for state of maturity. The percentages of three- and four-year-olds that were either mature, in a state of gonad development that leads to maturity, or had spawned (i.e., fish in gonad stages III-VIII) were calculated as a ratio of the total number of three- or four-year-olds in the samples (Table C9). In 1993, the percentage of mature three-year-olds was 30%; in 1994 it was 15%. All (100%) of the four-year-olds were mature in both years.

Stock Abundance Indices

Spring Bottom Trawl Survey Indices

NMFS spring bottom trawl survey (BTS) abundance indices (mean number caught per tow for all tows in all strata) were available for ages 2-8 (Table C10) for the entire time series (1968-1995). These estimates were adjusted in 1991 to account for a substantial difference in the fishing powers of the two survey vessels (SAW 14, NEFSC 1992). For this analysis, indices were not transformed or smoothed. The 1993 catch rates were unusually high, particularly for ages 3-5 (Figure C2). The 1994 and 1995 catch rates were similar to the 1991 and 1992 values. Catch rates since 1991 have been considerably higher than in previous years, indicating that abundance is high. The older age groups (ages 6-8) are particularly abundant in the last two years of the time series, a further indication of stock recovery. The 1989 year class was abundant at ages 3-6 during 1992-1995. The 1990 year class was abundant at ages 2 and 3 in 1992 and 1993, but not in 1994 and 1995. The 1968-1994 bottom trawl survey data were used as an age-disaggregated tuning index (ages 2-6 only) in the VPA.

Larval Survey Indices

Larval surveys conducted by NMFS from 1971-1994 have provided a valuable record of the collapse and recovery of the Georges Bank and Nantucket Shoals spawning stocks (Smith and Morse 1993), and, in more recent years, of spawning on the north-east peak of Georges Bank, the last area on the Bank to be re-occupied by this stock. The abundance of recently-hatched larvae in the entire survey area increased significantly in 1989 and remained high during the following five years (Table C11 and Figure C3). Small larvae were particularly abundant on Nantucket Shoals in 1992 and 1994.

Catch rates are presented as annual weighted mean catches of 4-7 mm larvae per 10 m²; weighting was applied to account for differences in the three

survey areas (Massachusetts Bay, Georges Bank, and Nantucket Shoals). The overall weighted mean catch rates (1971-1994) were used as an index of spawning stock biomass in the VPA.

Mortality and Stock Size Estimates

Natural Mortality

Instantaneous natural mortality (M) was assumed to equal 0.2 at all ages, as has been assumed in previous Atlantic herring assessments.

Virtual Population Analysis Calibration

The ADAPT VPA calibration method was used to estimate values of terminal F in 1994 (Gavaris 1988, Conser and Powers 1990). Model formulation was nearly identical to that used in the last assessment of the herring coastal stock complex (NEFSC 1993). The full age structure (age 1-11+) and time series (1967-1994) of available herring catch at age data was used in the assessment. Catch data were tuned against age-disaggregated catch in numbers from the NEFSC bottom trawl survey and a spawning stock biomass index derived from larval herring catch rates. The consensus run applied inverse-variance weighting to the tuning indices. The only change made to the model was replacement of the partial recruitment vector used during SARC 16 with one suggesting full recruitment at age 2. This change was based on separable VPA runs that suggested a complex pattern of partial recruitment that is dome shaped through age 4 for recent years of the fishery. The vector was entered into ADAPT as flat topped because age 4, 5, 6 stock sizes are estimated directly and thus not affected by the partial recruitment vector. In previous assessments, fish were assumed to be fully recruited at age 3 (NEFSC 1993). Tuning diagnostics are provided in Table C12. The coefficient of variations for all stock size estimates were improved over the previous assessment (NEFSC 1993) and no significant correlation between parameters was noted.

Fishing Mortality, Recruitment, and Spawning Stock Biomass

The average fishing mortality rate (ages 3-7) in 1994 was only 0.03 (Table C13 and Figure C1), having dropped steadily from levels approaching 1.0 in the early 1980s. Landings have remained fairly stable suggesting stock size has increased dramatically. Spawning stock size appears to have increased to levels approaching 2 million mt and age 1 recruitment has increased to record levels since the late 1980s (Table C14 and Figure C1). The 1992 and 1993 year classes (23 and 30 billion fish at age 1, respectively) appear to be very large (Figure C1). However, these estimates are not very accurate and should be interpreted with caution until additional catch and survey data are available.

Total stock biomass at the beginning of the year was estimated at approximately 3.6 million mt in 1994 and spawning stock biomass at spawning time in 1994 was approximately 2 million mt (Table C15 and Figure C1). These estimates reflect an exponential increase in stock biomass from lows of 110,000 mt (total stock biomass) and 21,000 mt (spawning stock biomass) in 1982. These results indicate that the U.S. Atlantic coast herring resource is increasing in size and is extremely under-utilized. Biomass estimates for the stock complex have nearly doubled in two years.

Precision of F and SSB Estimates

To evaluate the precision of the final estimates of spawning stock biomass and fishing mortality, bootstrap resampling was used to generate probability distributions for SSB and terminal year F (Efron 1982). The distribution of bootstrap estimates and the cumulative probability functions for SSB and fishing mortality are shown in Figure C4. The spawning stock biomass 80% confidence interval is approximately 1.5 to 3 million mt (Figure C4A). The fishing mortality 80% confidence interval is approximately 0.019 to 0.034 (Figure C4B). The cumulative probability expresses the likelihood that spawning stock biomass is less or

fishing mortality is greater than a given level when measurement error is considered.

Biological Reference Points

Yield and Spawning Stock Biomass Per Recruit

Biological reference points were last computed for the herring coastal stock complex (CSC) during SARC 16 (NEFSC 1993). Values determined then were $F_{0.1} = 0.19$, $F_{20\%} = 0.29$, and $F_{\max} = 0.34$.

In the current analysis, parameter inputs included a partial recruitment vector suggesting full recruitment to the fishery by age 2 and weight and maturity data from the period 1988-1992. Stock mean weights were assumed to equal catch mean weights at age. The biological reference points were recomputed using the selection pattern suggested by the separable VPA and mean weights from the period 1988-1994. The results of the YPR analysis indicate that $F_{0.1} = 0.20$, $F_{20\%} = 0.34$, and $F_{\max} = 0.40$ (Table C16 and Figure C1). The YPR curve is not strongly peaked, thus the reference points are poorly defined. The current reference points are all higher than those determined in the previous assessment, reflecting the different selection patterns in the two analyses.

Projections of Catch and Stock Biomass

Deterministic projections of landings and spawning stock size were computed to illustrate the expected effects of a range of fishery management options on the stock. Status quo fishing mortality (0.025), $F_{0.1}$, and $F_{20\%}$ fishing mortalities were applied to the stock for the years 1995 and 1996. Forecasts were only carried out for two years to 1996 due to concerns over the low precision of stock size estimates. Expected landings in 1996 ranged from 121,000 to 1,154,000 mt depending upon the fishing mortality applied (Table C17 and Figure C1). Spawning stock biomass increased in all three scenarios to levels higher than observed for 1994. This analysis suggests that over the short term, SSB

levels can be expected to stay at robust levels even with high rates of fishing removals from the stock.

Management Considerations

Long-Term Harvest Strategy

The present harvest strategy for the herring coastal stock complex simply limits catch so that the fishing mortality rate does not exceed the overfishing definition for the stock (F at 20%MSP). Though the herring fisheries utilizing the stock complex have not caught the full precautionary TACs in recent years, if these TACs had been fully utilized the management regime would have resulted in a proportional utilization of the stock between catch and spawning escapement (Figure C5). This pattern of stock utilization would result from any management policy based on a target fishing mortality such as F_{max} or $F_{0.1}$ (Hilborn and Walters 1992, FAO 1993).

The use of constant fishing rate management strategies for herring raises a number of concerns. Constant rate strategies based on F_{max} have been specifically discouraged for small pelagic species due to their tendency to reduce spawning stock and lead to recruitment failure (Anon. 1983). Small pelagic species tend to be fast growing and subject to high natural mortality, and thus are particularly sensitive to recruitment overfishing. Similar concerns have also been raised about $F_{0.1}$ policies despite lower mortality rates associated with these reference points (Patterson 1992). Citing these concerns, Patterson (1992) examined the levels of exploitation that resulted in stable spawning stock biomass levels for a variety of small pelagic species and stocks. It was found that when fishing mortality exceeded the natural mortality for a stock, spawning stock biomass declined. Therefore, it can be argued that fishing mortality should be less than natural mortality for small pelagic stocks. Constant rate-based strategies do not include provisions to deal with threshold effects at extremely low or high stock levels. When a stock falls below a minimum

biologically acceptable level (MBAL), however defined, mechanisms to allow for stock recovery are often absent from the management plan. At the other extreme, when stock levels are high, cropping strategies that will improve yield and avoid the accumulation of excess effort in the fishery are lacking.

The SARC considered a number of alternative strategies and how they relate to the situation with the herring coastal stock complex. Numerous studies have demonstrated the disadvantages of fixed catch levels as a harvest strategy and suggest they are inferior to constant rate-based approaches at holding stock levels in equilibrium (Reeves 1974, Beddington and May 1977). The SARC recognized the appeal of stable catch levels, but agreed they must be achieved in a more sustainable fashion. Saville (1980) made the argument that it is desirable to maintain stable spawning stock biomass with pelagic fish stocks as a means to dampen environmental fluctuation and stabilize catch levels. In part, this is the intent of the current management of the CSC in selecting fishing mortality rates based on stock and recruitment data (Sissenwine and Shepherd 1987). However, the dilemma of conserving and utilizing the stock at extreme levels of abundance still remains.

The SARC suggests that consideration be given to two principles in the formulation of a long-term harvest strategy for the CSC. First, a MBAL for the CSC should be developed that draws upon the stock and recruitment properties of the stock complex. Second, it would be desirable to harvest the complex to maintain a constant spawning stock size, on the assumption that constant-rate approaches may be inadequate. One such approach would be development of a management plan with constant spawning escapement by only allowing harvest on that portion of the stock above the spawning target (Figure C6). The spawning target could be the MBAL for the stock or a minimum level of spawning stock size that would be expected to produce adequate recruitment, i.e., the spawning target. Similar results could be achieved by staging

the fishing rate used to set harvest based on the standing stock size.

Current scientific advice formulation procedures used by the SARC require characterization of stock size and exploitation level. This procedure draws on a three-by-three matrix of stock size and exploitation levels. The SARC considered harvest strategies that would stage the fishing mortality applied to the stock based on the stock size. For example, a range of stock sizes associated with low, medium, and high stock could be associated with rebuilding, maintenance, and a cropping fishing mortality rate, respectively (Figure C7).

Summary and Conclusions

The Atlantic coast stock complex of Atlantic herring is increasing in size and is presently extremely under-utilized. Recruitment and stock biomass have been increasing steadily since 1986, when the first signs of stock recovery on Georges Bank and Nantucket Shoals became evident. Estimates of spawning stock biomass reached 2.2 million mt in 1994 (compared to 1.2 million mt in 1992) and fishing mortality remained at very low levels (0.03). The precision of this assessment is low, with a possible 80% confidence level around SSB of 1.5 and 3.0 million mt.

SARC Comments

SARC discussion focussed on the VPA calibrations done in both ADAPT and ICA (Integrated Catch Analysis program, see Patterson and Melvin 1995). The base ICA runs were performed with a reference age of full recruitment to the fishery of age 7 for the 1989-1994 period, and a variable selection pattern at younger ages, with selection at less than 0.01 for age 1, 0.61 for age 2, and ranging from 0.43 to 0.97 for ages 3 to 6. In contrast, the SAW 16 assessment (NEFSC 1993) assumed full recruitment at age 3, although it was noted that the selection pattern estimated in that assessment (using the ADAPT VPA model) was

also variable. The SARC noted that changes in the selection pattern can have an important effect on the estimation of biological reference points and on projections.

The SARC noted that the variable nature of the selection pattern and the differences between the ADAPT (following from the SAW 16 assessment) and the ICA analysis might be due to: 1) estimation of fishing mortality rates using a separable model for the 1989-1994 period in the ICA model, in contrast to the standard VPA estimation used in ADAPT, 2) the low and variable numbers of fish in the catch at the relatively high reference age used in the ICA run (age 7), or 3) varying contributions of different fisheries to the total catch over time (e.g., New Brunswick weir fishery which catches younger fish, in contrast to the coastal Maine bait fishery which targets older fish), which might violate the constant separability assumption. The SARC suggested further ICA analyses including: 1) changing the reference age in the ICA model, testing response of the model to reference ages from 2 to 4, and 2) reducing the number of years to which the separable component of the model is applied, perhaps to a range of 3-4 years, depending on resulting residual patterns.

The SARC noted that the catch-at-age matrix included true ages 1-10, with an age 11 plus group (11+). Fishing mortality rates estimated for ages 8 and older were highly variable, reflecting relatively low catches for these age groups. The SAW 16 assessment justified retention of ages 9-11+ in the analysis based on the expectation that the catch of older fish will increase and that these ages can be adequately aged. The SARC noted that the benefits of including older fish in the analysis may be outweighed by the variability in the catch of these older ages, which may be due to low sample size. The SARC suggested an additional ICA run with older fish aggregated into an age 8 plus group (8+). It was also suggested that in ADAPT runs, a different range of ages used to calculate F on the oldest true age (ages 5-7 in initial runs) be expanded to include more younger ages (e.g., ages 3-7).

The SARC noted that due to the constraints of the ICA model as programmed, only 19 years of catch-at-age data are included (1976-1994). The SAW 16 time series using the ADAPT VPA extended back to 1967. Elimination of the 1967-1975 period excluded informative spawning stock biomass (SSB) and recruitment (R) estimates which may have a large effect on attempts to quantify the SSB-R relationship, which might in turn be important in determining future management strategies. It was noted, however, that ICA can incorporate auxiliary SSB and R data in the estimation of SSB-R parameters that could be used in calibration and projections.

The SARC suggested that additional ICA and ADAPT runs over the 1976-1994 period should be made to facilitate comparison of results of the models. Several ICA and ADAPT runs were subsequently examined, and the SARC noted some convergence of results between the two models as the initial conditions were made more comparable. The SARC weighed the advantages of the ICA and ADAPT VPA models and decided to use ADAPT VPA results for the following reasons: 1) ADAPT currently allowed a longer time series of catch at age to be used, 2) the variability in the selection pattern, due to varying contributions of different fisheries to the total catch over time, suggested use of a short recent time period for application of the separable model in ICA, negating some of the advantage (estimation of the error in the catch) in using the ICA model, and 3) this was the first time the SARC had reviewed an ICA-based assessment and most members were not familiar with the model formulation. As a result, a full comparison between ICA and ADAPT over a range of stock characteristics, which might justify a move to ICA-based assessments, was not made. The final ADAPT VPA configuration accepted for the assessment used the full time series and did not collapse the catch at age to an 8+ group.

The SARC noted that the only discard estimates included in the catch at age were those herring discarded in the late 1980s and early 1990s during

joint venture fishing operations for mackerel. Herring discards in that fishery peaked at about 1,000 mt during 1988-1989. The SARC noted that it will be important to consider potential discards if fishing mortality increases in the future.

The SARC noted that Atlantic herring mean weights at age and maturity rates (for age 3 fish) showed a decreasing trend since the late 1980s. The SARC suggested averaging maturity rates over blocks of years to help smooth some of the interannual variability in the calculation of the spawning stock biomass. A suggestion was also made to consider using NEFSC fall survey mean weights at age as the spawning stock mean weight at age in the estimation of biological reference points, since those weights might more accurately reflect the condition of spawning fish than the mid-year mean weights in the catch. The SARC also noted that the potential for increased growth rates and increases in yield per recruit due to compensation should be recognized in the development of management strategies for the increased utilization of this stock.

The SARC noted that basing management decisions on the usual short-term projections of yield and SSB may be inappropriate for this stock because recent low fishing mortality rates results in imprecisely estimated 1995 stock sizes. An alternative approach would be to 'probe' the resource with a 'sentinel' fishery to provide more substantial catch information and, in turn, more precise estimates of projected stock size.

Research Recommendations

- o Develop a long-term strategy for assessing individual spawning stocks as a basis for more effective management of any heavily exploited portion(s) of the stock complex. Evaluate the merit of acoustic surveys and other techniques to achieve sub-stock complex monitoring.
- o Evaluate the concept of a minimum biologically-acceptable level biomass (MBAL) for the

- herring coastal stock complex. Determine the adequacy of present methods and data to determine MBAL if appropriate.
- o Evaluate the concept of a fixed spawning stock size or spawning target for the herring coastal stock complex. Determine the adequacy of present methods and data to set a target if appropriate.
- o Consider potential discards if fishing mortality increases in the future.
- o Investigate the effects of averaging maturity rates over blocks of years to help smooth some of the interannual variability in the calculation of spawning stock biomass
- o Consider using NEFSC fall survey mean weights at age as the spawning stock mean weight at age in the estimation of biological reference points.

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Table C1. Landings (mt) of Atlantic herring from fisheries on Georges Bank (GB), in the Gulf of Maine (GOM), Southern New England (SNE), Middle Atlantic (MAT) and New Brunswick, Canada (NB) areas. Includes landings for Internal Waters Processing operations.

YEAR	GB ¹	GOM ²	SNE ³	MAT ⁴	NB ⁵	TOTAL
1960	0	60237	261	152	34304	94954
1961	67655	25548	197	101	8054	101555
1962	152242	69980	131	98	20698	243149
1963	97968	67736	195	78	29366	195343
1964	131438	27226	200	148	29432	188444
1965	42882	34104	303	208	3346	80843
1966	142704	29167	3185	176	35805	211037
1967	218743	35417	247	524	30032	284963
1968	373598	62425	245	122	33145	469535
1969	310758	53420	2104	193	26539	393014
1970	247294	41786	1037	189	15840	306146
1971	267347	52129	1318	1151	12660	334605
1972	174190	61664	2310	409	32699	271272
1973	202335	32492	4249	233	19935	259244
1974	149525	37356	2918	200	20602	210601
1975	146096	37187	4119	117	30819	218338
1976	43502	50808	191	57	29206	123764
1977	2157	50730	301	33	23487	76708
1978	2059	49316	1730	46	38842	91993
1979	1270	63492	1341	31	37828	103962
1980	1700	82244	1200	21	13525	98690
1981	672	64324	749	16	19080	84841
1982	1378	32157	1394	20	25963	60912
1983	53	24824	72	21	11383	36353
1984	58	33958	79	10	8698	42803
1985	316	27157	196	13	27863	55545
1986	586	27942	632	20	27883	57063
1987	11	39179	376	87	27320	66973
1988		39382	1307	365	33421	74475
1989		52656	269	39	44112	97076
1990		62150	761	48	38778	101737
1991		50261	4007	402	24576	79246
1992		54411	716	4564	31968	91659
1993		52953	1829	1347	31572	87709
1994		50340	1935	502	22241	75018

¹mostly foreign catches, includes some U.S. landings (<5,000 mt/yr; ²ME, MA, & NH landings + foreign catches from Jeffreys Ledge (1967-1978); ³RI, CT, NY; ⁴NJ, DE, MD, VA; ⁵fixed gear only.

Table C2. Distribution of estimated 1993 U.S. Atlantic herring landings (mt) and samples (in parentheses) by month, gear type, and fishing area.

LOCATION	GEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
EASTERN MAINE	FIXED						4 (0)	60 (4)	4 (4)	14 (0)				82 (8)
CENTRAL MAINE	FIXED					10 (0)	727 (9)	585 (8)						1322 (17)
CENTRAL MAINE	MOBILE					284 (0)	2819 (13)	3531 (10)	2698 (9)	3340 (6)	100 (1)			12772 (39)
WESTERN MAINE	FIXED						196 (4)	708 (3)	38 (0)					942 (7)
WESTERN MAINE	MOBILE					1181 (5)	841 (8)	1328 (2)	3682 (9)	4037 (3)	4893 (7)	461 (0)	9 (0)	16432 (34)
MA/NH	MOBILE	1570 (0)			932 (6)	1286 (2)	272 (2)	429 (4)	3051 (9)	1861 (5)	2906 (2)	5192 (11)	3455 (4)	20954 (45)
S. NEW ENGLAND	MOBILE	22 (0)	135 (0)	164 (1)		17 (0)	50 (0)					8 (0)		396 (0)
MID-ATL	MOBILE	729 (0)	161 (0)	304 (0)	115 (0)	3 (0)							3 (0)	1315 (0)
TOTAL		2321 (0)	296 (0)	468 (1)	1047 (6)	2781 (7)	4909 (36)	6641 (31)	9473 (31)	9252 (14)	7899 (10)	5661 (11)	3467 (4)	54215 (151)

Table C3. Distribution of estimated 1994 U.S. Atlantic herring landings (mt) and samples (in parentheses) by month, gear type, and fishing area.

LOCATION	GEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
EASTERN MAINE	FIXED						56 (2)	83 (6)	241 (5)	50 (2)	8 (0)			439 (15)
CENTRAL MAINE	FIXED						22 (1)							22 (1)
WESTERN MAINE	FIXED					19 (0)								19 (0)
EASTERN MAINE	MOBILE							454 (1)			19 (0)			473 (1)
CENTRAL MAINE	MOBILE					252 (1)	3754 (12)	4836 (7)	2197 (2)	2233 (1)	935 (1)			14206 (24)
WESTERN MAINE	MOBILE				345 (2)	1331 (3)	297 (2)	845 (3)	2770 (8)	2568 (1)	5758 (6)	3548 (4)	1597 (0)	19058 (29)
MA/NH	MOBILE	385 (0)	82 (0)		1149 (7)	710 (0)	624 (0)	654 (1)	530 (1)	349 (1)	693 (2)	2200 (1)	2479 (0)	9856 (13)
S. NEW ENGLAND	MOBILE	2231 (5)	1410 (1)	1104 (2)	822 (3)	59 (2)								5625 (13)
TOTAL		385 (1)	82 (0)	0	1485 (9)	2308 (4)	4736 (17)	6854 (18)	5722 (16)	5195 (5)	7404 (9)	5743 (5)	4076 (0)	49602 (96)

Table C4. Catch at age (millions) for Georges Bank Atlantic herring fishery.

Year	1	2	3	4	5	6	7	8	9	10	11
67	0.00	1.80	6.90	60.60	108.00	250.70	379.20	49.40	11.10	10.00	0.00
68	0.00	2.50	52.10	133.30	336.00	233.40	432.90	336.40	21.80	6.60	0.00
69	0.00	0.00	73.40	210.80	277.10	278.10	188.50	190.50	109.70	23.60	0.00
70	0.00	12.60	125.40	450.50	270.30	122.30	92.90	51.60	29.60	17.70	0.00
71	0.00	12.90	332.50	275.50	284.60	175.80	103.90	50.40	13.90	21.80	0.00
72	0.00	28.00	35.00	110.00	214.00	158.00	100.00	45.00	29.00	21.00	0.00
73	0.00	10.00	1026.00	266.00	64.00	33.00	23.00	12.00	3.00	5.00	0.00
74	0.00	1.90	39.90	608.90	68.60	12.90	6.10	3.50	2.10	0.00	0.00
75	0.00	1.40	11.30	76.80	503.00	34.60	12.50	6.20	4.20	0.10	0.00
76	0.00	0.50	7.50	6.80	18.60	140.80	5.10	2.30	1.20	0.30	0.00
77	0.00	0.10	0.30	6.70	1.20	0.20	1.90	0.10	0.10	0.00	0.00
78	0.00	0.10	5.60	2.30	4.30	0.50	0.30	1.20	0.00	0.00	0.00
79	0.00	0.10	5.10	2.10	0.40	0.40	0.00	0.10	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table C5. Catch at age (millions) for coastal US Atlantic herring fishery.

Year	1	2	3	4	5	6	7	8	9	10	11+
67	6.83	261.94	166.40	42.60	10.64	15.53	9.05	0.67	0.45	0.39	0.17
68	13.29	695.48	177.37	24.09	32.00	29.87	28.93	19.01	3.24	2.49	0.65
69	10.02	231.06	229.66	18.80	14.41	24.28	22.29	22.85	20.03	5.73	1.03
70	2.02	168.93	55.35	30.74	20.29	25.96	33.00	26.75	21.09	14.70	2.88
71	73.72	55.51	44.23	45.07	44.84	44.01	29.17	17.86	12.18	8.55	3.53
72	0.68	357.84	23.73	45.07	43.79	49.60	25.20	9.49	2.89	2.68	1.65
73	11.36	143.56	96.75	7.64	11.85	13.75	13.09	7.47	1.80	0.55	0.34
74	31.36	181.33	63.52	110.36	8.82	5.46	2.96	2.05	0.94	0.44	0.35
75	28.26	181.47	49.20	25.75	90.98	9.54	3.81	2.27	1.09	0.45	0.27
76	23.59	331.48	137.18	20.55	15.88	57.96	3.70	0.68	0.89	0.18	0.09
77	82.21	454.92	72.68	42.87	12.48	10.79	42.90	2.30	0.56	0.39	0.32
78	56.02	328.01	80.67	20.10	37.80	4.62	7.68	30.85	1.10	0.65	0.22
79	4.16	750.35	170.08	43.40	14.86	15.84	5.67	3.42	6.90	0.34	0.00
80	67.15	224.72	301.08	163.46	20.85	6.03	8.09	0.78	0.62	4.43	0.12
81	8.37	874.47	15.58	57.90	41.52	4.55	1.31	1.17	0.04	0.14	0.81
82	22.49	274.05	36.94	3.52	28.47	17.70	1.98	0.38	0.75	0.12	0.15
83	30.28	132.19	37.42	21.37	0.81	6.22	7.17	0.33	0.19	0.13	0.00
84	4.53	98.45	113.11	32.12	22.00	1.00	3.13	1.35	0.37	0.04	0.00
85	9.90	177.30	36.89	31.60	17.81	8.92	0.25	1.51	0.49	0.00	0.00
86	37.47	111.15	103.49	24.21	27.30	11.52	5.38	0.00	0.34	0.00	0.33
87	15.28	92.12	85.28	124.43	20.67	11.00	3.12	1.71	0.02	0.21	0.01
88	3.23	153.08	64.73	38.69	85.45	18.80	6.58	1.53	0.69	0.00	0.03
89	0.21	129.19	84.62	86.70	58.62	87.67	17.74	5.29	1.39	0.03	0.0
90	0.01	116.25	151.56	58.67	31.64	35.94	67.45	25.11	12.19	3.64	1.09
91	0.01	123.52	135.99	78.08	55.77	30.12	20.67	18.01	8.29	3.08	1.20
92	0.00	171.06	121.89	57.78	77.73	52.05	25.13	15.28	13.25	3.54	0.00
93	0.00	139.82	137.40	64.29	65.33	38.47	29.75	16.34	4.48	1.62	0.33
94	0.00	131.53	112.22	62.74	69.02	62.08	33.44	17.84	5.12	1.39	0.05

Table C6. Catch at age (millions) for New Brunswick Atlantic herring fishery.

Year	1	2	3	4	5	6	7	8	9	10	11+
67	129.72	160.35	55.31	105.56	11.89	4.09	1.11	0.11	0.00	0.00	0.00
68	2.20	694.45	47.71	23.16	29.24	3.65	2.90	0.70	0.07	0.01	0.00
69	61.44	350.73	94.54	4.72	9.22	7.22	6.06	1.90	0.28	0.00	0.00
70	3.97	312.87	9.23	11.63	5.57	3.51	2.18	0.82	0.06	0.01	0.00
71	80.94	164.99	33.70	7.33	3.82	2.03	2.86	1.12	0.31	0.05	0.00
72	7.57	615.19	6.00	10.09	3.94	1.87	0.96	1.08	0.33	0.03	0.00
73	26.06	197.68	178.60	20.37	1.02	0.59	0.09	0.13	0.06	0.00	0.00
74	3.26	246.04	43.48	31.15	1.23	0.05	0.05	0.04	0.04	0.03	0.04
75	16.88	462.98	57.23	9.56	16.38	2.18	1.11	0.92	0.29	0.16	0.17
76	51.79	199.27	104.62	19.99	14.91	10.13	1.60	0.37	0.46	0.19	0.11
77	514.97	124.29	10.35	20.99	7.27	7.46	4.87	0.23	0.01	0.00	0.00
78	213.78	894.37	52.13	3.67	0.81	1.06	0.28	0.13	0.00	0.00	0.00
79	2.40	423.73	247.36	12.24	0.82	0.84	0.48	1.01	0.19	0.00	0.00
80	276.00	5.33	62.09	21.62	0.92	0.13	0.12	0.07	0.06	0.06	0.00
81	53.34	294.72	18.78	10.20	5.37	0.31	0.05	0.03	0.03	0.00	0.00
82	30.21	395.42	73.20	3.20	1.80	1.60	0.20	0.04	0.07	0.00	0.00
83	2.53	135.28	21.68	7.53	0.44	0.40	0.19	0.00	0.00	0.00	0.00
84	14.35	86.59	19.99	8.22	6.48	1.14	1.19	0.37	0.15	0.08	0.04
85	20.30	385.45	47.43	19.47	9.36	4.63	0.93	0.88	0.23	0.00	0.07
86	3.21	136.31	121.66	24.29	10.70	4.73	2.33	0.36	0.12	0.09	0.02
87	35.71	131.66	49.53	56.08	24.19	7.43	2.57	0.64	0.19	0.11	0.00
88	76.05	349.17	46.21	23.43	41.16	16.06	2.56	0.65	0.39	0.10	0.07
89	26.86	331.01	81.41	21.44	22.72	93.02	11.53	3.10	0.81	0.12	0.25
90	12.58	454.80	69.00	30.69	6.36	7.23	15.03	3.42	2.52	0.62	0.31
91	5.53	338.26	44.45	23.62	9.53	3.15	2.62	3.44	1.46	0.27	0.15
92	0.80	375.77	97.68	36.44	10.38	3.99	1.61	1.36	0.56	0.25	0.04
93	1.72	244.08	106.10	37.19	23.22	12.26	4.92	1.12	1.10	0.86	0.18
94	1.97	291.96	63.90	9.97	16.26	9.33	3.89	1.48	1.08	0.54	0.33

Table C7. U.S. Atlantic herring stock complex total catch at age (000's of fish), 1976-1994.

Year	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11+
1976	75380	531250	249300	47340	49390	208890	10400	3350	2550	670	200
1977	597180	579310	83330	70560	20950	18450	49670	2630	670	390	320
1978	269800	1222480	138480	26070	42910	6180	8260	32180	1100	650	220
1979	6560	1174180	422540	57740	16080	17080	6150	4530	7090	340	1
1980	343150	230050	363170	185080	21770	6160	8210	850	680	4490	120
1981	61710	1169190	34360	68100	46890	4860	1360	1200	70	140	810
1982	52700	669470	110140	6720	30270	19300	2180	420	820	120	150
1983	32810	267470	59100	28900	1250	6620	7360	330	190	130	1
1984	18880	185040	133100	40340	28480	2140	4320	1720	520	120	40
1985	30200	562750	84320	51070	27170	13550	1180	2390	720	1	70
1986	40680	247460	225150	48500	38000	16250	7710	360	460	90	350
1987	50990	223780	134810	180510	44680	18430	5690	2350	210	320	11
1988	79280	502250	110940	62120	126610	34860	9140	2180	1080	100	100
1989	27060	460210	166030	108150	81340	180690	29270	8380	2200	150	250
1990	12590	571050	220560	89360	37990	43170	82480	28530	14710	5690	310
1991	5540	461780	180440	101700	65300	33270	23290	21440	9750	4960	150
1992	800	546830	219573	94225	88110	56042	26739	16640	13810	2720	40
1993	1720	383899	243499	101482	88554	50730	34668	17461	5585	2483	520
1994	1970	423492	176125	72705	85278	71409	37329	19316	6195	1934	379

Table C8. Catch mean weight at age (kg), U.S. Atlantic herring stock complex, 1976-1994.

Year	AGE 1	AGE 2	AGE 3	AGE 4	AGE 5	AGE 6	AGE 7	AGE 8	AGE 9	AGE 10	AGE 11+
1976	0.018	0.042	0.114	0.179	0.206	0.211	0.26	0.282	0.319	0.334	0.399
1977	0.016	0.042	0.103	0.161	0.189	0.219	0.228	0.260	0.304	0.294	0.281
1978	0.013	0.040	0.120	0.186	0.226	0.256	0.273	0.285	0.317	0.349	0.345
1979	0.008	0.032	0.089	0.198	0.255	0.281	0.182	0.325	0.332	0.313	0.313
1980	0.015	0.041	0.103	0.169	0.268	0.319	0.344	0.241	0.306	0.391	0.372
1981	0.012	0.045	0.114	0.190	0.232	0.293	0.316	0.342	0.470	0.304	0.373
1982	0.020	0.049	0.130	0.194	0.250	0.267	0.300	0.322	0.342	0.423	0.313
1983	0.022	0.055	0.133	0.216	0.223	0.310	0.348	0.368	0.390	0.397	0.313
1984	0.019	0.051	0.133	0.182	0.227	0.260	0.305	0.343	0.314	0.402	0.528
1985	0.013	0.049	0.139	0.181	0.203	0.229	0.281	0.273	0.289	0.292	0.313
1986	0.021	0.053	0.116	0.166	0.215	0.230	0.251	0.260	0.299	0.292	0.313
1987	0.018	0.044	0.093	0.141	0.178	0.218	0.233	0.227	0.251	0.265	0.320
1988	0.009	0.034	0.090	0.129	0.164	0.187	0.228	0.238	0.254	0.292	0.247
1989	0.005	0.046	0.101	0.136	0.168	0.196	0.235	0.248	0.244	0.313	0.300
1990	0.005	0.044	0.099	0.148	0.183	0.194	0.207	0.229	0.240	0.258	0.300
1991	0.005	0.053	0.087	0.133	0.166	0.193	0.214	0.225	0.229	0.243	0.300
1992	0.005	0.046	0.090	0.128	0.153	0.175	0.201	0.219	0.229	0.256	0.300
1993	0.005	0.044	0.096	0.132	0.158	0.182	0.211	0.238	0.258	0.282	0.300
1994	0.005	0.049	0.086	0.119	0.139	0.159	0.184	0.214	0.243	0.261	0.300

Table C9. Percent maturity at age, U.S. Atlantic herring stock complex.

Year	AGE1	AGE2	AGE3	AGE4	AGE5+
1976	0	0	0.65	0.99	1
1977	0	0	0.36	0.98	1
1978	0	0	0.17	0.95	1
1979	0	0	0.39	0.98	1
1980	0	0	0.13	0.93	1
1981	0	0	0.28	0.97	1
1982	0	0	0.59	0.99	1
1983	0	0	0.58	0.99	1
1984	0	0	0.51	0.99	1
1985	0	0	0.68	0.99	1
1986	0	0	0.34	0.98	1
1987	0	0	0.15	0.94	1
1988	0	0	0.40	1.00	1
1989	0	0	0.36	0.99	1
1990	0	0	0.12	0.89	1
1991	0	0	0.19	0.96	1
1992	0	0	0.30	0.89	1
1993	0	0	0.30	1.00	1
1994	0	0	0.15	1.00	1

Table C10. Spring NMFS bottom trawl survey catch rates (mean number per tow) for Atlantic herring, ages 2-8.

Year	AGE2	AGE3	AGE4	AGE5	AGE6	AGE 7	AGE 8
1976	0.9	0.3	0.1	0.1	0.3	0.2	0.0
1977	0.2	0.2	0.4	0.1	0.1	0.2	0.0
1978	0.2	1.9	0.3	0.3	0.0	0.1	0.2
1979	2.5	0.4	1.3	0.8	0.2	0.1	0.2
1980	0.1	1.4	3.6	0.7	0.1	0.1	0.0
1981	0.0	0.0	0.5	1.3	0.2	0.1	0.0
1982	0.4	0.1	0.1	0.1	0.0	0.0	0.0
1983	0.2	0.0	0.1	0.0	0.1	0.1	0.0
1984	1.8	0.4	0.3	0.1	0.0	0.0	0.0
1985	2.0	0.9	0.4	0.5	0.1	0.0	0.0
1986	1.4	25.4	3.2	1.1	0.5	0.4	0.0
1987	0.9	1.4	0.9	3.3	0.7	0.3	0.2
1988	2.5	2.2	1.7	4.9	1.6	0.7	0.2
1989	1.3	1.1	0.4	1.5	3.1	1.1	0.7
1990	2.3	1.8	1.8	1.7	1.0	0.4	0.0
1991	3.9	3.3	8.7	4.2	2.0	0.7	0.0
1992	7.0	15.1	4.6	5.4	2.2	1.0	0.1
1993	4.2	21.8	15.7	20.0	6.3	1.2	0.1
1994	3.0	2.6	3.5	8.7	10.7	4.0	0.6

Table C11. NMFS larval herring catch rates, numbers of 4-7 mm larvae per 10 m²

Year	Georges Bank	Mass Bay	Nantucket Shoals	Mean	Weighted Mean
1971	123.1	19.7	47.61	63.5	89.7
1972	37.4	78.7	165.2	93.8	81.4
1973	393.7	7.1	386.0	262.3	355.2
1974	427.6	20.4	156.6	201.5	304.5
1975	45.8	31.4	82.2	53.1	55.9
1976	2.1	2.8	2.3	2.4	2.2
1977	5.3	64.0	32.0	33.8	19.2
1978	1.4	16.4	0.2	6.0	2.4
1979	0.1	62.9	0.1	21.0	6.0
1980	0.2	16.7	0.7	5.9	1.9
1981	0.2	302.3	4.4	102.3	29.7
1982	0.6	184.6	1.8	62.3	18.2
1983	0.4	15.4	6.5	7.4	3.7
1984	0.7	17.5	0.7	6.3	2.3
1985	2.7	395.2	181.1	193.0	95.4
1986	12.9	319.3	73.1	135.1	60.4
1987	6.1	150.3	43.6	66.9	31.4
1988	196.1	153.2	173.1	174.1	184.9
1989	470.5	269.1	478.8	406.1	454.3
1990	181.9	140.5	870.3	397.6	394.1
1991	173.4	116.9	766.5	352.3	354.2
1992	72.0	81.1	1678.9	610.7	577.1
1993	205.1	153.0	834.1	397.4	397.6
1994	310.6	37.3	1346.0	564.6	610.0

Table C12. Summary statistics of final ADAPT VPA calibration for the HERRING CSC, terminal year 1994.

RESULTS

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

SUM OF SQUARES 28.280740
 ORTHOGONALITY OFFSET..... 0.013269
 MEAN SQUARE RESIDUALS 0.182456

	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.
N 4	3.42315E3	1.36531E3	2.50723E0	0.40
N 5	4.78747E3	2.70471E3	1.77005E0	0.56
N 6	4.69074E3	2.20031E3	2.13186E0	0.47
qNMFS_AG2	1.67606E ⁴	3.99518E ⁵	4.19520E0	0.24
qNMFS_AG3	2.27871E ⁴	5.16658E ⁵	4.41048E0	0.23
qNMFS_AG4	6.48182E ⁴	1.34567E ⁴	4.81680E0	0.21
qNMFS_AG5	1.02488E ³	2.07121E ⁴	4.94822E0	0.20
qNMFS_AG6	1.66524E ³	2.84502E ⁴	5.85316E0	0.17
qNMFSLARW	1.72683E ³	4.40025E ⁴	3.92440E0	0.25

CATCHABILITY ESTIMATES IN ORIGINAL UNITS

	ESTIMATE	STD. ERR.	C.V.
qNMFS_AG2	2.73676E ⁴	6.52355E ⁵	0.24
qNMFS_AG3	7.96572E ⁴	1.80609E ⁴	0.23
qNMFS_AG4	1.43919E ³	2.98787E ⁴	0.21
qNMFS_AG5	2.47874E ³	5.00936E ⁴	0.20
qNMFS_AG6	2.58825E ³	4.42197E ⁴	0.17
qNMFSLARW	2.97281E ¹	7.57521E ²	0.25

CORRELATION BETWEEN PARAMETERS ESTIMATED

1.00	0.22	0.21	0.19	0.20	0.21	0.16	0.24	0.19
0.22	1.00	0.01	0.11	0.11	0.12	0.15	0.06	0.07
0.21	0.01	1.00	0.09	0.10	0.11	0.13	0.16	0.11
0.19	0.11	0.09	1.00	0.09	0.09	0.09	0.10	0.08
0.20	0.11	0.10	0.09	1.00	0.10	0.09	0.10	0.08
0.21	0.12	0.11	0.09	0.10	1.00	0.10	0.11	0.09
0.16	0.15	0.13	0.09	0.09	0.10	1.00	0.10	0.08
0.24	0.06	0.16	0.10	0.10	0.11	0.10	1.00	0.09
0.19	0.07	0.11	0.08	0.08	0.09	0.08	0.09	1.00

CORRELATION BETWEEN PARAMETERS ESTIMATED (SYMBOLIC FORM)

N 4	*	-	-	-	-	-	-	-
N 5	-	*	.	.	.	.	.	.
N 6	-	.	*	.	.	.	.	.
qNMFS_AG2	.	.	.	*	.	.	.	.
qNMFS_AG3	-	.	.	.	*	.	.	.
qNMFS_AG4	-	.	.	.	.	*	.	.
qNMFS_AG5	.	.	.	.	.	.	*	.
qNMFS_AG6	-	.	.	.	.	.	.	*
qNMFSLARW	.	.	.	.	.	.	.	.

SYMBOLS: = LARGE NEGATIVE CORRELATION whenever -1 <= R < -L
 - MODERATE NEGATIVE CORRELATION whenever -L <= R < -M
 . SMALL CORRELATION whenever -M <= R <= +M
 + MODERATE POSITIVE CORRELATION whenever +M < R <= +L
 * LARGE POSITIVE CORRELATION whenever +L < R <= +1

Where R is the estimated correlation, M is 0.2 and L is 0.5

Table C14. Estimates of beginning of the year stock size for the HERRING CSC from VPA calibrated using ADAPT for the period 1967-1994.

STOCK NUMBERS (Jan 1) in millions - HERR95												
	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	5323	2657	2090	1413	7717	1184	1009	1663	1025	1290	3596	2764
2	2842	4235	2161	1647	1151	6178	962	792	1330	798	988	2404
3	1822	1943	2207	1243	901	731	4152	470	260	504	173	285
4	1835	1284	1340	1447	846	366	540	2222	252	106	187	66
5	1177	1314	888	885	739	396	150	176	1140	105	44	90
6	1522	846	716	455	457	304	87	54	73	381	41	17
7	1287	1001	451	306	235	173	59	29	27	18	123	17
8	189	701	399	173	135	70	28	16	15	7	5	56
9	42	109	252	132	70	48	7	5	8	4	2	2
10	51	24	67	89	62	33	10	1	1	1	1	1
11	1	2	2	8	7	2	1	1	1	0	1	0
1+	16091	14116	10575	7798	12320	9485	7005	5427	4132	3215	5162	5702
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1	410	2357	1587	1602	1417	3423	1756	2483	5129	7160	10141	14164
2	2019	329	1619	1243	1264	1130	2786	1410	1996	4153	5790	8279
3	862	590	62	268	412	793	758	1772	931	1431	2946	4324
4	108	323	155	19	120	284	529	544	1247	640	1072	2262
5	30	36	97	65	10	72	196	387	402	857	468	780
6	35	10	10	37	26	7	33	136	282	288	587	309
7	9	13	3	4	13	15	4	15	97	214	204	317
8	6	1	3	1	1	4	8	2	5	74	167	141
9	17	1	0	1	1	1	2	5	1	2	59	129
10	1	7	0	0	0	0	0	1	4	1	1	46
11	0	0	2	0	0	0	0	3	0	1	1	2
1+	3495	3670	3538	3242	3263	5729	6071	6756	10092	14822	21436	30753
	1991	1992	1993	1994	1995							
1	11947	7047	23013	29845	0							
2	11585	9776	5769	18840	24433							
3	6261	9067	7509	4376	15042							
4	3341	4963	7225	5928	3423							
5	1771	2643	3978	5824	4787							
6	604	1391	2084	3177	4691							
7	214	464	1088	1661	2536							
8	185	154	356	859	1326							
9	90	132	111	276	686							
10	93	64	96	86	220							
11	3	1	20	17	82							
1+	36093	35704	51250	70888	57227							

Table C15. Estimates of spawning stock biomass for the HERRING CSC from VPA calibrated using ADAPT for the period 1967-1994.

SSB AT THE START OF THE SPAWNING SEASON - males & females (MT)															
	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	2	4	25	28	16	14	95	14	6	12	2	2	10	2	1
4	90	90	53	99	65	27	33	181	18	7	14	5	7	15	11
5	129	126	102	56	75	26	14	17	90	10	4	8	3	3	9
6	293	98	87	68	58	22	9	7	6	33	4	2	4	1	1
7	231	126	58	47	25	14	6	4	2	2	15	2	0	1	0
8	48	87	47	28	18	4	2	3	1	1	1	6	1	0	1
9	8	23	31	23	13	4	1	1	1	0	0	0	3	0	0
10	11	4	10	15	10	3	1	0	0	0	0	0	0	1	0
11	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
1+	811	559	411	365	281	114	162	227	124	65	41	25	28	24	24
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994		
1	0	0	0	0	0	0	0	0	0	0	0	0	0		
2	0	0	0	0	0	0	0	0	0	0	0	0	0		
3	7	15	25	34	34	7	29	51	29	63	157	125	34		
4	2	14	34	65	64	114	55	92	206	308	397	670	540		
5	7	2	9	29	60	54	98	50	102	232	316	478	671		
6	4	5	1	4	23	50	41	66	42	93	197	293	425		
7	0	2	3	1	2	18	40	32	43	34	75	175	257		
8	0	0	1	2	0	1	15	33	23	31	26	64	154		
9	0	0	0	0	1	0	0	12	25	16	24	22	56		
10	0	0	0	0	0	1	0	0	9	19	13	21	19		
11	0	0	0	0	1	0	0	0	1	1	0	5	4		
1+	21	37	73	134	186	245	278	337	479	796	1204	1853	2159		

The above SSBs by age (a) and year (y) are calculated following the algorithm used in the NEFSC projection program, i.e.

$$SSB(a,y) = W(a,y) \times P(a,y) \times N(a,y) \times \exp[-Z(a,y)]$$

- where $Z(a,y) = 0.75 \times M(a,y) + 0.75 \times F(a,y)$
- $N(a,y)$ - Jan 1 stock size estimates (males & females)
- $P(a,y)$ - proportion mature (generally females)
- $W(a,y)$ - weight at age at the beginning of the spawning season

The $W(a,y)$ are assumed to be the same as the Jan1 weight at age estimates (see "WT AT AGE" table in input section).
 Jan1 weights at age are calculated as geometric means in ADAPT from the mid-year weight at age estimates (from the catch) of the cohort in successive years.

Table C16. Yield and spawning stock biomass per recruit estimates for the HERRING CSC.

The NEFC Yield and Stock Size per Recruit Program - PDBYPRC
PC Ver.1.2 [Method of Thompson and Bell (1934)] 1-Jan-1992

Run Date: 30-11-1995; Time: 21:37:37.32

SSB/R ANALYSIS - 1995

Proportion of F before spawning: .6700
Proportion of M before spawning: .6700
Natural Mortality is Constant at: .200
Initial age is: 1; Last age is: 11
Last age is a PLUS group;
Original age-specific PRs, Mats, and Mean Wts from file: ==> YH95.DAT

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort	Nat Mort	Proportion	Average Weights	
	Pattern	Pattern	Mature	Catch	Stock
1	.0029	1.0000	.0000	.006	.006
2	1.0000	1.0000	.0000	.045	.045
3	.7000	1.0000	.2600	.093	.093
4	.4764	1.0000	.9600	.132	.132
5	.7337	1.0000	1.0000	.162	.162
6	.8756	1.0000	1.0000	.184	.184
7	1.0000	1.0000	1.0000	.211	.211
8	1.0000	1.0000	1.0000	.230	.230
9	1.0000	1.0000	1.0000	.242	.242
10	1.0000	1.0000	1.0000	.272	.272
11+	1.0000	1.0000	1.0000	.292	.292

Summary of Yield per Recruit Analysis for:

SSB/R ANALYSIS - 1995

Slope of the Yield/Recruit Curve at F=0.00: --> .5980
F level at slope=1/10 of the above slope (F0.1): -----> .199
Yield/Recruit corresponding to F0.1: -----> .0448
F level to produce Maximum Yield/Recruit (Fmax): -----> .400
Yield/Recruit corresponding to Fmax: -----> .0491
F level at 20 % of Max Spawning Potential (F20): -----> .341
SSB/Recruit corresponding to F20: -----> .1151

Listing of Yield per Recruit Results for:

SSB/R ANALYSIS - 1995

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.00	.00000	.00000	5.5167	.7502	2.7811	.5758	100.00
	.03	.09897	.01581	5.0237	.6303	2.3228	.4634	80.48
	.06	.17534	.02635	4.6437	.5413	1.9761	.3812	66.21
	.10	.23636	.03355	4.3404	.4729	1.7048	.3191	55.43
	.13	.28645	.03856	4.0918	.4188	1.4869	.2709	47.04
	.16	.32845	.04206	3.8837	.3750	1.3083	.2325	40.38
	.19	.36428	.04453	3.7064	.3389	1.1595	.2015	34.99
F0.1	.20	.36862	.04479	3.6849	.3347	1.1417	.1978	34.35
	.23	.39527	.04625	3.5533	.3088	1.0337	.1759	30.56
	.26	.42239	.04743	3.4196	.2832	.9262	.1547	26.87
	.29	.44636	.04822	3.3016	.2612	.8335	.1368	23.76
	.32	.46772	.04871	3.1967	.2422	.7529	.1216	21.12
F20%	.34	.47717	.04887	3.1503	.2339	.7178	.1151	19.99
	.36	.48689	.04899	3.1027	.2256	.6822	.1086	18.86
	.39	.50420	.04910	3.0180	.2109	.6200	.0973	16.90
Fmax	.40	.50925	.04911	2.9934	.2067	.6021	.0941	16.35
	.42	.51993	.04908	2.9413	.1979	.5648	.0875	15.20
	.45	.53427	.04898	2.8715	.1864	.5158	.0790	13.72
	.49	.54742	.04880	2.8077	.1760	.4719	.0715	12.41
	.52	.55951	.04857	2.7492	.1666	.4326	.0648	11.26
	.55	.57067	.04829	2.6954	.1582	.3972	.0589	10.23
	.59	.58100	.04799	2.6457	.1505	.3652	.0537	9.32
	.62	.59059	.04767	2.5997	.1435	.3363	.0490	8.51
	.65	.59952	.04733	2.5571	.1371	.3100	.0448	7.78

Table C17. Deterministic stock biomass and catch projections for the HERRING CSC.

Starting Condition (see table C16)

Deterministic Forecasts
(000s mt)

Fishery	SSB (1995)	Landings (1996)	SSB (1996)
Status Quo $F(0.025)$	3,042	121	4,448
$F_{0.1}$ (0.20)	2,767	788	3,369
$F_{20\%}$ (0.34)	2,561	1,154	2,804

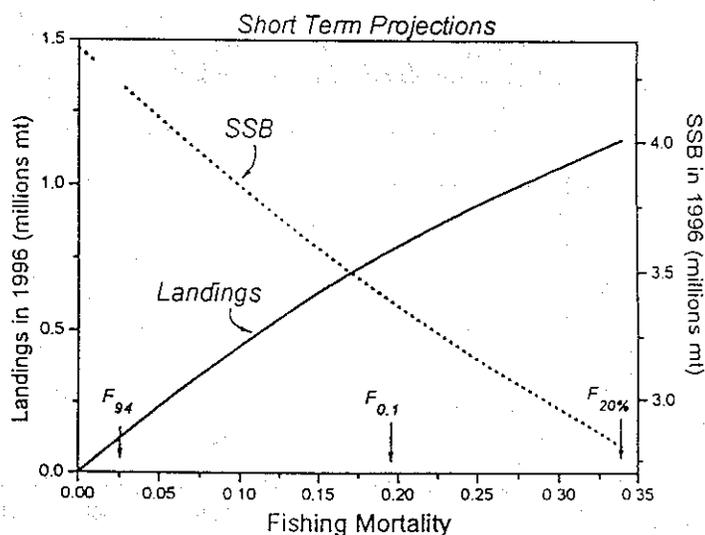
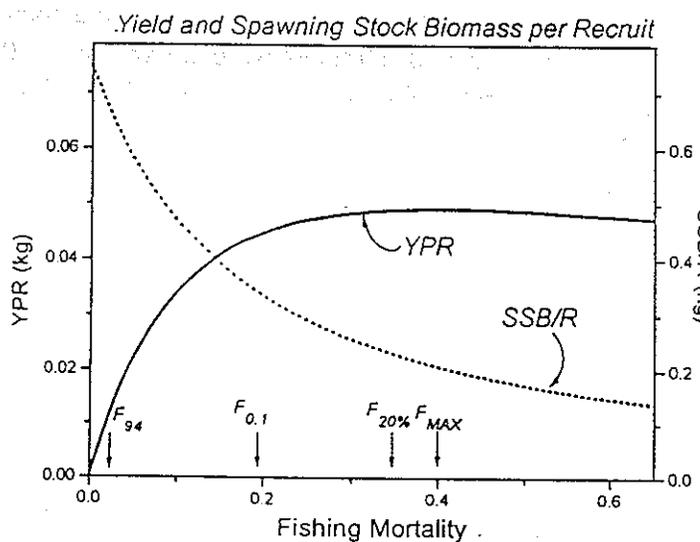
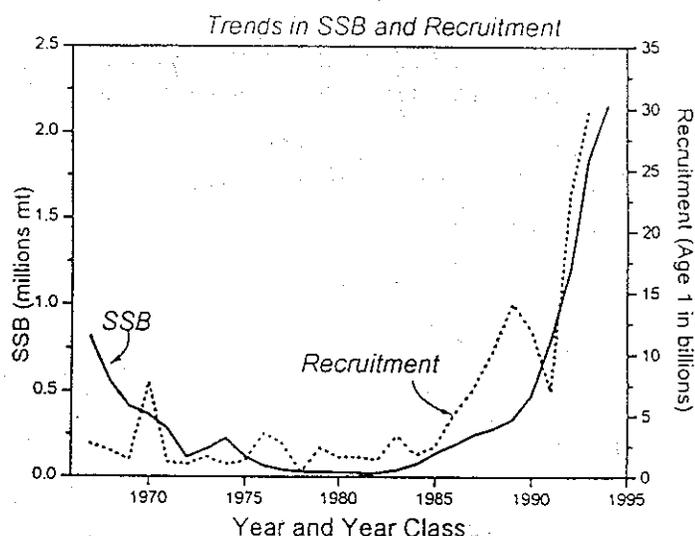
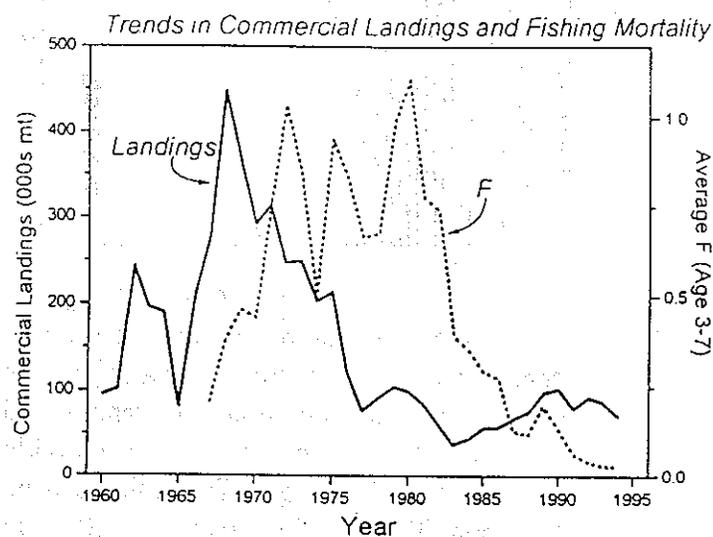


Figure C1. Atlantic herring-coastal stock complex: trends in commercial landings and fishing mortality; trends in spawning stock biomass and recruitment; yield and spawning stock biomass per recruit; and, short term projections.

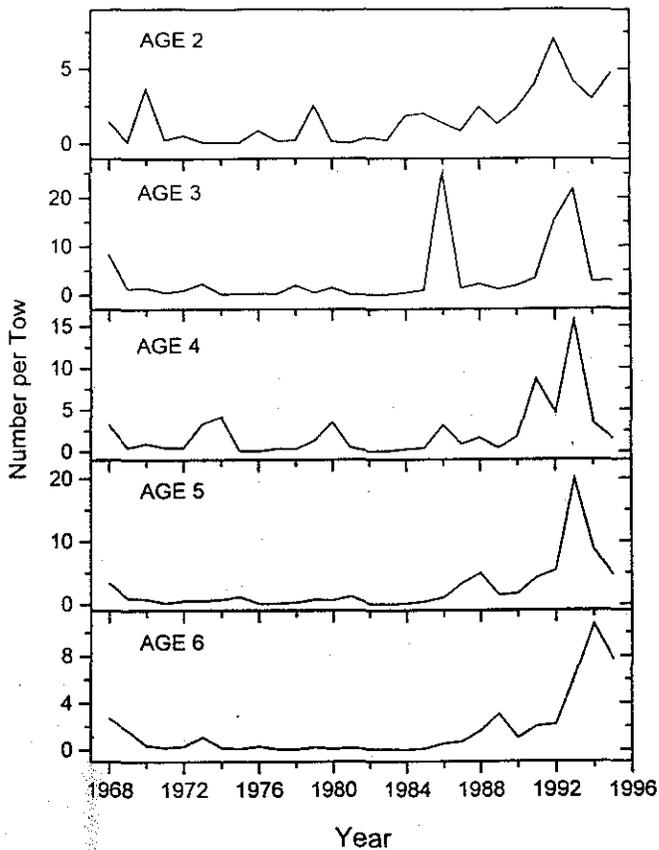


Figure C2. Spring bottom trawl survey index for Atlantic herring.

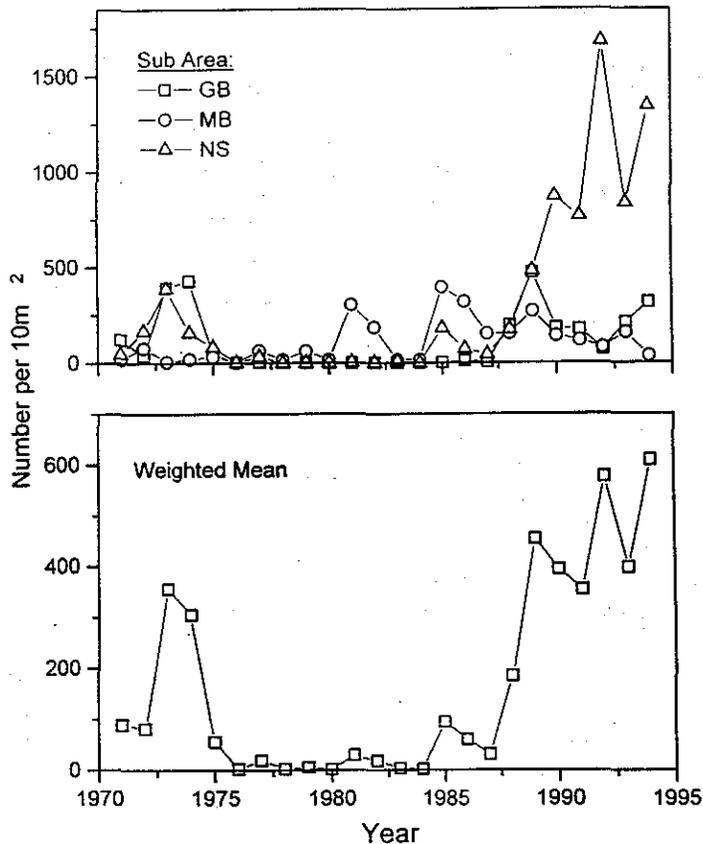


Figure C3. Larval abundance index for Atlantic herring.

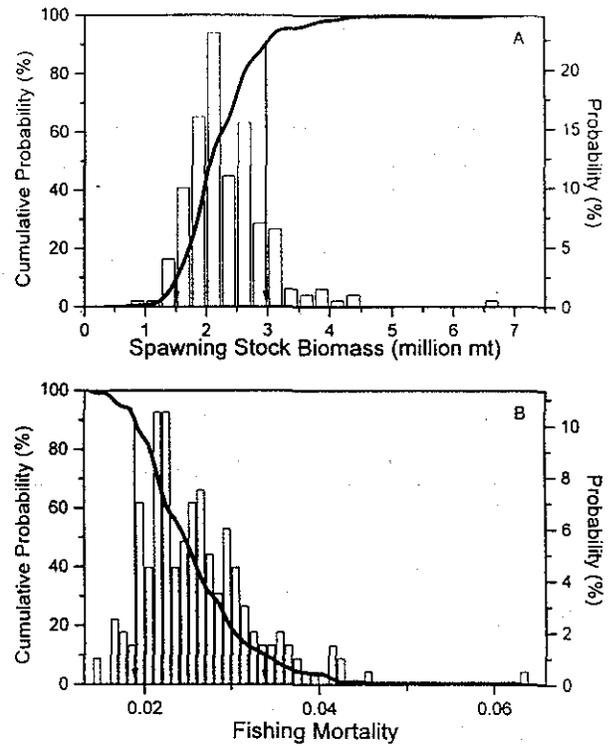


Figure C4. Precision estimates of spawning stock biomass and fishing mortality in 1994. Vertical bars display both the range of the estimator and the probability of individual values within the range. The solid lines give the probability that F is greater or SSB is less than any selected value on the respective x-axis. The precision estimates were derived from 200 bootstrap replications of the ADAPT model.

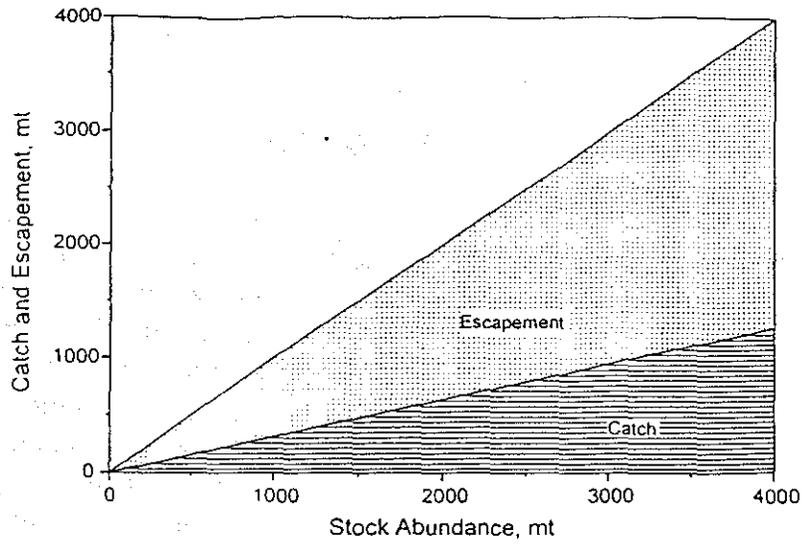


Figure C5. Management regime of constant fishing mortality.

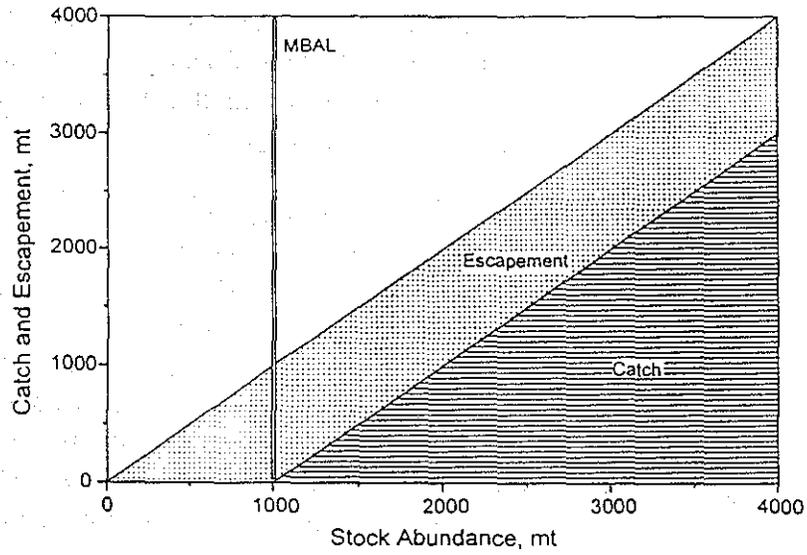


Figure C6. Management regime that maintains a constant escapement level.

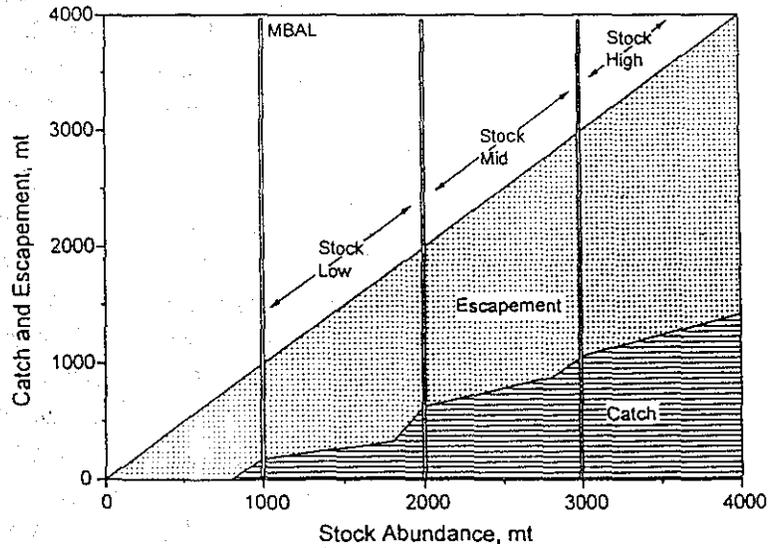


Figure C7. Management regime with adjustments in fishing mortality related to stock size.

D. WINTER FLOUNDER

Introduction

Winter flounder (*Pleuronectes americanus*) is a demersal flatfish species commonly found in estuaries and on the continental shelf. The species is distributed between the Gulf of St. Lawrence and North Carolina, although it is not abundant south of Delaware Bay. Winter flounder undergo migrations in and out of coastal estuaries where spawning occurs in the spring of the year. Winter flounder reach a maximum size of around 2.25 kg (5 pounds; Bigelow and Schroeder 1953) and 65 cm, with the exception of Georges Bank where growth rate is higher and fish may reach a maximum weight up to 3.6 kg (8 pounds).

Current fishery management (described in next section) is controlled by the Atlantic States Marine Fisheries Commission (ASMFC) in state waters and the New England Fishery Management Council in federal waters. Previous assessments have been confined to local populations in state waters and the results were the basis for the current ASMFC FMP followed by states. This report is a joint effort of the Stock Assessment Review Committee Southern Demersal Subcommittee and the ASMFC Winter Flounder Technical Committee.

Management Summary

Winter flounder fisheries in state waters are managed by Interstate Agreement under the auspices of the Atlantic States Marine Fisheries Commission's FMP for Inshore Stocks of Winter Flounder since approval in May, 1992. The plan includes states from Delaware to Maine, with Delaware granted *de minimus* status (habitat regulations applicable but fishery management not required). The Plan's goal is to rebuild spawning stock abundance and achieve a fishing mortality-based management target of $F_{40\%}$ (fishing rate that preserves 40% MSP) in three steps: $F_{25\%}$ in 1993, $F_{30\%}$ in 1995, and $F_{40\%}$ in 1999 through implementation of compatible, state-specific regulations.

Coastal states from New Jersey to New Hampshire, inclusive, are currently in compliance with the Plan, having promulgated a broad suite of indirect catch and effort controls. State agencies have set or increased minimum size limits for recreationally and commercially landed flounder (10"-12" and 12", respectively); enacted limited recreational closures and bag limits; and instituted seasonal, areal, or state-wide commercial landings/ gear restrictions. Minimum codend mesh regulations have been promulgated in directed winter flounder fisheries: 5" in NJ and NY, 5.5" in CT, 5" in RI, and 6" in MA. In Massachusetts, several regulations preceded the Plan and, in general, the suite of regulations are the most restrictive.

Winter flounder in the Exclusive Economic Zone are managed under the Northeast Multispecies Fishery FMP developed by the New England Fishery Management Council. This was an appropriate grouping for management purposes because the principal catch of winter flounder occurs as bycatch in directed demersal fisheries for Atlantic cod, haddock, and yellowtail flounder primarily of the northeast EEZ. The management unit encompasses the multispecies finfish fishery that operates from eastern Maine through Southern New England (72°30'). At least one offshore stock, on Georges Bank, has been identified. The Plan extends authority over vessels permitted under the Plan even while fishing in state waters if vessels are federally permitted.

The Multispecies Plan was implemented in September, 1986, imposing a codend minimum mesh size of 5.5" (previously 5.1") in the large-mesh regulatory area of Georges Bank and the offshore portion of Gulf of Maine. There were closed areas and seasons for haddock and yellowtail flounder. In the inner Gulf of Maine, vessels were required to enroll in an Exempted Fisheries Program in order to target small-mesh species such as shrimp, dogfish, or whiting. The by-catch restrictions specified area and season and limited groundfish bycatch to 25%

of trip and 10% for the reporting period. In southern New England waters, the groundfish bycatch on vessels fishing with small mesh was not limited in any way. There was a 11" minimum size for winter flounder which corresponded with the length at first capture for 5.5" diamond mesh. Though the Plan was amended four times by 1991, it was widely recognized that many stocks, including winter flounder, were being overfished.

Time-specific stock rebuilding schedules were a part of Amendment #5 which took effect in May, 1994. The rebuilding target for winter flounder, a so-called "large-mesh" species, was $F_{20\%}$ within 10 years. Along with a moratorium on issuance of additional vessel permits, the cornerstone of Amendment #5, was an effort reduction program that required "large-mesh" groundfish vessels to limit days at sea, which would be reduced each year; however, there was an exemption from effort reduction requirements for groundfishing vessels < 45' and for "day boats" (from 2:1 layover day ratio requirement). Dragger vessels retaining more than the "possession limit" of groundfish (10%, by weight, up to 500 lbs) were required to fish with either 5.5" diamond or square mesh in Southern New England or 6" throughout the net in the regulated mesh area of Georges Bank/ Gulf of Maine, respectively. The possession limit was allowed when using small mesh within the inner Gulf of Maine (except Jeffreys Ledge and Stellwagon Bank) and in Southern New England. Those boats fishing in EEZ West of 72° 30' (longitude of Shinnecock Inlet, NY) were required to abide by 5.5" diamond or 6" square mesh codend consistent with the Summer Flounder FMP. Minimum landed size of winter flounder increased to 12" appropriate to increased mesh size in order to reduce discards. There were many additional rules including time/area closures for sink gillnet vessels, seasonal netting closures of prime fishing areas on Georges Bank (Areas I and II), and on Nantucket Shoals to protect juvenile yellowtail flounder.

At the end of 1994, the Council reacted to collapsed stocks of Atlantic cod, haddock, and yellowtail flounder on Georges Bank by voting a number of emergency actions to tighten existing

regulations reducing fishing mortality. Prime fishing areas on Georges Bank (Areas I & II), and the Nantucket Lightship Area were closed. The Council also addressed expected re-direction of fishing effort into Gulf of Maine and Southern New England while, at the same time, developing Amendment # 7 to the FMP. Days-at-sea controls were extended. Currently, any fishing by an EEZ-permitted vessel must be conducted with not less than 6" diamond or square mesh in Southern New England east of 72° 30'. Winter flounder less than 12" in length may not be retained.

Stock Structure

Although stock groups consist of an assemblage of adjacent estuarine spawning units, the ASMFC Fishery Management Plan defined three coastal management units based on similar growth, maturity and seasonal movement patterns: Gulf of Maine, Southern New England and the Mid-Atlantic. In the initial phase of the Subcommittee assessment, the criteria for separation of the Southern New England and Mid-Atlantic stock boundaries were reconsidered in light of recent data available since the original stock designations.

Boundaries for four stock units were originally defined in the ASMFC management plan (Howell et al. 1992):

Gulf of Maine: Coastal Maine, New Hampshire, and Massachusetts north of Cape Cod

Southern New England: Coastal Massachusetts east and south of Cape Cod, including Nantucket Sound, Vineyard Sound, Buzzards Bay, Narragansett Bay, Block Island Sound, Rhode Island Sound, Rhode Island coastal ponds and eastern Long Island Sound to the Connecticut River, including Fishers Island Sound, NY.

Mid-Atlantic: Long Island Sound west of the Connecticut River to Montauk Point, NY, including Gardiners and Peconic Bays, coastal Long Island, NY, coastal New Jersey and Delaware.

Georges Bank

The Subcommittee retained a definition of a separate Gulf of Maine complex, based on results of tagging studies, and large differences in growth rates consistent with discrete oceanographic regimes between the Gulf of Maine and Southern New England (Howe and Coates, 1975). Additional analyses of life history characteristics and mixing within the Gulf of Maine may lead to refinement of the complex's definition within the Gulf of Maine in the future, however.

The Subcommittee combined the Southern New England and Mid-Atlantic units into a single stock complex for assessment purposes. Review of tagging studies (Gibson 1996b, Perlmutter 1947, Saila 1961, Saila 1962, Poole 1969, Howe and Coates 1975, NUSCo. 1987, Powell 1989, Crawford 1990, Black et al. 1988, and Phelan 1992) indicate dispersion (and hence mixing) occurred between previously defined Southern New England and Mid-Atlantic units. The Subcommittee considered that differences in growth and maturity among samples from Southern New England to the Mid-Atlantic may reflect discrete sampling along a gradient of changing growth and maturity rates over the range of a stock complex. The group also observed that differences in growth rates within the Mid-Atlantic units were greater than differences between Mid-Atlantic and Southern New England units (Howell 1996). Offshore, length structure of winter flounder caught in NEFSC research surveys is similar from Southern New England to New Jersey. Most commercial landings are obtained in these offshore (> 3 mi.) regions, which are not considered in the ASMFC management units (Table D2).

Stock Boundaries and associated Statistical Areas

The Gulf of Maine stock complex extends along the coast of eastern Maine alongshore to Provincetown, MA, corresponding to U. S. Statistical Division 51. Recreational landings from Maine, New Hampshire and northern Massachusetts (northern half of Barnstable County and north to New Hampshire border) are associated with this stock complex.

The Southern New England - Mid-Atlantic winter flounder stock complex extends from the coastal shelf east of Provincetown, MA southward along the Great South Channel (separating Nantucket Shoals and Georges Bank) to the southern geographic limits of winter flounder. Commercial statistical areas within this boundary are 521 and 526, and statistical divisions 53, 61, 62, and 63. The corresponding recreational areas are southern Massachusetts (the southern half of Barnstable County; Dukes, Nantucket and Bristol counties), Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland and Virginia.

The Georges Bank stock extends eastward of the Great South Channel, with statistical areas 522, 525, and 551-562.

WINTER FLOUNDER
D1. SOUTHERN NEW ENGLAND - MID-ATLANTIC STOCK COMPLEX

Terms of Reference

The following terms of reference were addressed for the Southern New England - Mid Atlantic stock complex of winter flounder:

- a. Review basis for stock complex definitions.
- b. Summarize landings, length composition and available age/length data; summarize discard and available length data.
- c. Summarize available indices of stock abundance/biomass based on commercial, recreational and research survey data sources.
- d. Estimate age composition of landings and discards.
- e. Conduct a virtual population analysis.
- f. Revise yield-per-recruit and spawning-stock-biomass-per-recruit analysis.

Data Sources

Fishery Data

Landings

Total U.S. commercial landings peaked at 11,200 mt in 1981 and have steadily declined since (Table D1). Landings in 1993 reached a record low level of 3,000 mt. Landings in 1994 by stock area are not currently available. Since 1989, an average of 42% of commercial landings have been taken from statistical area 521 (Table D2). About 13% of the total landings are obtained on average from each of areas 526 and 536, and an average of about 11% from area 539. The remaining landings (21%) are obtained from area 538 and divisions 61-62. Most landings are obtained from the EEZ (86%, 1989-1993 average) and the remaining 14% from state waters. The primary gear in the fishery is the otter trawl which accounts for an average of 93.7% of landings since 1989. Scallop dredges account for 4.4% with such gears as handlines, pound nets, fyke nets, and gill nets each accounting for less than 1%.

Recreational landings (Table D3) reached a peak in 1985 of 13.3 million fish (peak weight of 5,772 mt in 1984) but declined dramatically thereafter. Landings from 1986 to 1994 averaged 3.7 million fish (1,674 mt) with the lowest recorded landings in 1992 of 0.8 million fish (393 mt). Landings in 1994 from the southern New England - mid Atlantic stock complex were 1.1 million fish (548 mt). The principal mode of fishing is private/rental boats. With the exception of 1986, 65% - 85% of recreational landings occurred from January to June (1986 division was 46%/54% spring to fall).

Discards

There were too few sea sampling trips in which winter flounder were caught to characterize the overall ratio of discard to landings within the fishery. There were, however, adequate length frequency samples to characterize proportion discarded at length.

Commercial discards for 1985 to 1993 were estimated from length frequency data from NMFS and the Massachusetts Division of Marine Fisheries (MADMF) bottom trawl surveys, commercial port sampling of landings at length and sea sampling of landings and discard at length. The method follows an approach described by Mayo et al. (1992). The year was divided into half year periods. The survey length frequency data (MADMF survey in spring and NEFSC in autumn) were smoothed using a three point moving average, then filtered through a mesh selection ogive (Simpson 1989) for 4.5" mesh (1984-1989), 5" mesh (1990-1992, fall 1993) or 5.5" mesh (spring, 1993). The 5.5" mesh selection curve was calculated using the 5" curve adjusted to an L_{50} for 5.5". The choice of mesh sizes was based on sizes used in the yellowtail assessment for southern New England (Rago et al. 1994) and comparison to length frequencies of commercial landings. The mesh filtering process resulted in a survey length frequency of retained winter flounder. A logistic regression was used to model the percent discarded at length from sea sampling data (Figures D1-D2), and the resulting percentages at length were applied to the survey numbers at length data to produce the survey-based equivalent of commercial kept and discarded winter flounder. The survey numbers per tow at length "kept" were then regressed against commercial (weighout) numbers landed at length. The linear relationship was calculated for those lengths common to both length frequencies and fitted with an intercept of zero. The slope of the regression provided a conversion factor to re-scale the survey "discard" numbers per tow at length to equivalent commercial numbers at length. The resulting vector of number of fish discarded at length was multiplied by a discard mortality rate of 50% (as averaged in Howell et al. 1992) to produce the vector of fish discarded dead at length (commercial) per half year. The number of discards (dead) at length was adjusted by the ratio of weighout landings to total commercial landings and summed across seasons and lengths to produce the annual total number of commercial discards.

Total commercial discards (number) ranged from 11% (1987) to 21% (1989) of the annual catch of winter flounder between 1985 and 1993 (Table D4). An average of 13.0% of the commercial catch (number) was discarded per year. In absolute numbers, discards ranged from a low of 1.6 million fish in 1993 to a high of 5.7 million fish in 1989. Weight of discards ranged from 1,534 mt in 1985 to a low of 457 mt in 1993. There did not appear to be any trend in the proportion discarded.

A discard mortality of 15% was assumed for recreational discards (B2 category from MRFSS data), as assumed in Howell et al. 1992. Discard losses peaked in 1984-1985 with 0.7 million fish estimated to have been discarded each year. Discards have since declined reaching a low in 1992 of 83,000 fish. An average of 0.35 million fish were discarded annually between 1981 and 1994. In 1994, 121,271 fish were estimated to have been discarded. If recreational discards are assumed to have the same average weight per fish as spring commercial discards, the total weight of recreational discards ranged from 15 mt in 1992 to a high of 230 mt in 1985.

Total Catch

Estimates of the total catch of winter flounder during 1985-1993 are given in Table D4. These estimates include commercial and recreational landings and discards. The total catch during this period varied from a high of over 14,000 mt in 1985 to a low of 4,041 mt in 1993. The total catch has declined continuously since 1985.

Sampling Intensity

Length samples of winter flounder are available from both commercial and recreational landings. In the commercial fishery, annual sampling intensity varied from 96 to 224 mt landed per 100 lengths measured. In all years, overall sampling rates exceeded the informal criterion of 100 lengths sampled per 200 mt.

In the recreational fishery, sampling intensity varied from 36 to 231 mt per 100 lengths. With the exception of 1985 and 1987, all years exceeded the minimum level of sampling.

Age Compositions

Numbers at age were estimated for 1985-1993 for commercial landings, recreational landings, commercial discards and recreational discards. Quarterly commercial age-length samples were applied to corresponding commercial landings at length, with the exception of winter flounder in the unclassified market category. Unclassified landings and landings not represented in the weighout database were assumed to have the same age composition as the initial weighout commercial landings at age. Landings at lengths with no associated age data within the quarter were assigned ages based on age at length from adjacent quarters. Commercial discard at length was converted to discard at age by half year periods using NEFSC survey age-length keys.

A comparison was undertaken among age data collected from inshore regions (where the recreational fishery is prosecuted), to determine if all age data were comparable within the stock complex. Data for ages 3-5 from New Jersey, Connecticut, Massachusetts and NEFSC were compared for 1993-1994. Distributions of length at age from New Jersey and Connecticut were similar, while distributions of length at age from Massachusetts lacked smaller fish at age. Details of the analysis are presented in Howell 1996.

Recreational landings at length were estimated seasonally and geographically. Spring landings were divided into 2 regions; 1) Massachusetts and Rhode Island and 2) Connecticut and south. MADMF survey age-length keys were applied to MA-RI data while CTDEP age-length keys were applied to CT-south data, with the exception of 1993 landings which used a combined NJ/CT age-length key. Age composition of fall recreational data was developed

using the NEFSC autumn survey age-length keys for all areas combined. Recreational discard age data was developed using state survey age data (see Gibson 1996 for a complete description of computation of recreational discard numbers at length and age).

About 90-94% of commercial landings (in numbers) between 1985-1993 were composed of fish aged 2-4, with the contribution of age 2 fish declining in the 1990s compared to the mid-1980's (Table D5). Commercial discards were predominately fish aged 2-3. Between 55-85% (average = 74%) of recreational landings were composed of fish aged 2-4 from 1985-1993, with proportionately more fish contributed by ages 5-6 compared to the commercial fishery. Recreational discards were predominately age 2 with some age 1 and age 3 fish. No conspicuous year classes were observed in the total catch at age matrix.

Stock Abundance and Biomass Indices

Fishery-Dependent Indices

Commercial LPUE

A general linear model (GLM, SAS 1985) of commercial landings per unit effort (LPUE) was used to develop a standardized index of winter flounder abundance. Landings of winter flounder per day fished were calculated by interviewed trips where winter flounder was a part of the landed weight of the trip, as recorded in the Northeast Region commercial weighout data base from 1982-1993. The GLM included effects of year, quarter, depth, area, and ton class with 1993, quarter 3, depth ≤ 30 fathoms, division 62 and ton class 3 serving as the standard cell. The model explained 20% of the variance in observed LPUE over the period.

The LPUE indices for 1982-1993 are presented in Figure D3 and indicate a relatively rapid decline in the landings rate from 1982-1988. Since 1988, the

landings rate and abundance index has remained relatively steady at low levels.

Recreational LPUE

As an index of winter flounder abundance, mean recreational landings per angler per trip from 1981-1994, was calculated as the number of winter flounder landed per all fishing trips. LPUE has declined steadily from a high of 6.69 fish per angler per trip in 1982 to 3.16 fish per angler per trip in 1994 (Figure D4). However, increasing state management restrictions, such as bag limits, has likely affected the catch rate over this period.

Fishery-Independent Indices

State and federal surveys were evaluated as fishery independent indices of winter flounder abundance and biomass. Survey methods (with the exception of Rhode Island and the young-of-year surveys) are reviewed in the proceedings of a 1989 trawl survey workshop sponsored by the ASMFC (Azarovitz et al., 1989).

NEFSC

Mean number-per-tow and weight-per-tow indices were determined from autumn (1963-1995) and spring (1968-1995) NEFSC bottom trawl surveys. Indices from the spring and autumn surveys were based on tows in offshore strata 1-12, 25, 69-76 and inshore strata 1-29, and 45-56 (Figure 2). Spring indices prior to 1973 and fall indices prior to 1972 do not include inshore strata. In addition, offshore surveys from 1963-1966 were not conducted south of Hudson Canyon.

Mean weight-per-tow and number-per-tow indices for the spring and autumn time series are presented in Table D6. Although the indices exhibit considerable year-to-year variability, both surveys follow a trend similar to commercial landings. Indices dropped from the beginning of the time series to a low point in the early to mid- 1970s then rose to a peak by the early 1980s. Following several

years of high indices, abundance once again declined to below the low levels of the 1970s. After reaching near- or record low levels for the time series in the late 1980s- 1990s, indices in 1995 survey have increased only slightly.

Massachusetts

The Massachusetts Division of Marine Fisheries (MADMF) spring survey from 1978-1994 was used to characterize abundance of winter flounder. Survey areas from east and south of Cape Cod were used in the analysis. The MADMF mean number-per-tow indices steadily declined from a high value of 53.61 in 1979 to a low of 10.57 in 1992 (Table D7). Indices in 1994 have shown an increase to 48.43 fish per tow.

In addition, the MADMF conducts an annual juvenile winter flounder seine survey during June. The survey has been conducted since 1975 in coastal ponds and estuaries. The index has shown a general decline in production, with a high of 0.6 fish per haul in 1977 to a low of 0.05 fish per haul in 1995 (Table D8).

Rhode Island

The Rhode Island Division of Fish, Wildlife and Estuarine Resources (RIDFW) has conducted a spring and autumn survey since 1979 based on a stratified random sampling design. Three major fishing grounds are considered in the spatial stratification. Narragansett Bay, Rhode Island Sound and Block Island Sound.

Survey results are expressed as unweighted arithmetic mean number per tow (Table D7). Indices from 1979-1995 have shown a steady decline from a high value of 130.2 fish per tow in 1979 to a low of 8.22 fish per tow in 1993. Recent indices have shown an increase to 32.47 fish per tow.

The autumn survey, conducted since 1978, provides an index of young-of-year winter flounder.

The index shows a great deal of annual variability, although in recent years there have been consistently low levels of recruitment.

Connecticut

The Connecticut Department of Environmental Protection (CTDEP) trawl survey program was initiated in May 1984 and encompasses both New York and Connecticut waters of Long Island Sound. Spring indices of mean number per tow were used as indices of winter flounder abundance (Table D7). CTDEP indices were elevated between 1988 and 1991 and peaked at 223.0 fish per tow in 1990. Index values have since declined to 48.1 in 1995 despite a brief increase in 1994.

New York

The New York Department of Environmental Conservation has conducted a small-mesh trawl survey in Peconic Bay since 1985. Winter flounder indices for ages 0 and 1 were evaluated for trends in winter flounder abundance (Table D7). Young of the year indices have increased in recent years from 0.7 in 1985 to 2.4 in 1994. The 1992 index of 11.4 indicated a large year class. The corresponding age 1 indices also indicated a strong 1992 year class.

New Jersey

The New Jersey Division of Fish, Game and Wildlife have been conducting a bottom trawl survey in coastal waters since 1988. Surveys are conducted bi-monthly from April to January, although the time sequence has undergone some modifications since 1988. Survey indices (Table D7), exemplified as mean number per tow in April, tended to decline between 1988 and 1994. The 1995 indices increased in number for the early part of the sampling year.

Delaware

The Delaware Division of Fish and Game conducts monthly surveys from April to October using

a 16 ft. semi-balloon otter trawl with a 0.5 inch stretch mesh liner. An index of young-of-year winter flounder was developed from stations sampled within Indian River and Rehoboth Bays. The re-transformed annual geometric means, presented in Table D8, indicate variable annual recruitment with a large year class in 1990. The 1994 index indicates above average recruitment.

Coherence among surveys

The surveys conducted by NEFSC and several states have each produced indices of winter flounder abundance. Since each of these surveys sample distinct geographical regions, it is possible that they provide indices for different components of the stock. The coherence among surveys was examined and results are presented in Correia (1996). Surveys all indicate declining trends in abundance, although performance of individual surveys in terms of tracking year class strength varies from survey to survey. This is a function of regional differences in interannual availability.

Mortality and Stock Size Estimates

Natural Mortality

Instantaneous natural mortality (M) for winter flounder was assumed to be 0.20 and constant across ages. (This represents a lower estimate of M than previous ASMFC assessments.) Commercial catch at age included fish to age 13, under conditions of relatively high fishing mortality. If $M = 0.25$, less than 5% of the population would reach age 12 under conditions of no fishing mortality. Therefore, the Subcommittee felt an $M = 0.2$, which represents a maximum age of 15, was more representative of the stock complex throughout its range.

Total Mortality

Total mortality in two components of the stock were evaluated using most recent tag and recapture data. Northeast Utilities Co. marked and recaptured winter flounder in Long Island Sound from 1983 to

1994 and the RIDFW conducted winter flounder tagging programs in Narragansett Bay from 1986 to 1990. Mortality estimates were made using a Brownie model of survivorship (Brownie et al. 1985). Average estimates of fishing mortality for Long Island Sound averaged 0.72 for 1984-1988 and 0.99 for 1989-1993 (dropping the negative mortality estimate of 1991 from the mean). Narragansett Bay estimates of fishing mortality ranged from 0.81 to 1.92 and averaged 1.19 from 1986 to 1989.

Virtual Population Analysis

Tuning

Total catch at age was calibrated using ADAPT (Conser and Powers 1990) with abundance at age indices from several bottom trawl surveys: NEFSC spring bottom trawl ages 1-7+, NEFSC autumn ages 1-4 (advanced to tune January 1 abundance of ages 2-5), Massachusetts spring ages 1-7+, Rhode Island autumn age 0 (advanced to tune age 1), Rhode Island spring ages 1-7+, Connecticut spring ages 1-7+, New York ages 0-1, Massachusetts summer seine index of age-0 (advanced to tune age 1), and Delaware juvenile trawl survey age-0 (advanced to tune age 1) (Table D10). NEFSC autumn survey catch of ages 5+ were not used because there was little contrast in that series and poor *a priori* correspondence with other indices. New Jersey trawl survey indices were excluded from calibration because the series began in 1992, although the survey may be useful in future assessments. New York indices were excluded from the final calibration because residuals in preliminary ADAPT runs were strongly trended and the survey covers a small geographic range. Estimated F varied little for eight alternative calibrations, which suggests that final results are stable and relatively robust to choice of tuning indices (Table D10).

Parameter estimates in the final calibration were moderately precise (initial coefficients of variation ranged from 0.22 to 0.37) and were not significantly correlated. There were, however, some patterns in

residuals. Nearly all surveys had years in which all observations deviated from predicted values in the same direction. For example, in 1987, all seven NEFSC spring residuals were negative. Similar residual patterns existed for NEFSC autumn 1993, Massachusetts 1991, and 1994; Rhode Island 1986, 1987, 1991-1994; and Connecticut 1985, 1986, and 1989-1991. As illustrated by *a priori* analyses of tuning indices, there are strong year effects in survey indices, due to annual distribution patterns or local recruitment events. However, in concert, the surveys appear to provide geographically balanced tuning. Although Connecticut age 1 residuals showed a negative trend over time, the index was included in the final calibration because it represented the Long Island Sound component of the stock complex. There was one extreme residual, NEFSC autumn age 4 in 1987, but there was no extrinsic justification for excluding the observation from the analysis. Iterative reweighting was not invoked because agreement with estimated catch at age was not considered an accurate indication of survey performance.

Exploitation Pattern

The exploitation pattern has been somewhat variable from year to year, but age 4 fish have been over 90% recruited since 1986. An average exploitation pattern was calculated as the ratio of the geometric mean fishing mortality rates at ages 1-3 to the geometric mean of the fishing mortality rates at age 4-6. The resulting pattern indicates, on average for 1992 and 1993, 0.5% recruitment at age 1, 19% at age 2 and 74% at age 3. For purposes of yield-per-recruit calculations and catch and stock biomass projections, full (100%) recruitment was assumed at ages 4 and older.

Fishing Mortality

Fishing mortality averaged over ages 4-5 has fluctuated without trend between 0.57 and 1.38 since 1985 and has averaged 1.07. Mean F in 1993 was 0.83 (Figure D5).

Spawning Stock Biomass

With maturity as estimated in O'Brien et al. (1993), spawning stock biomass has steadily declined over the period 1985 to 1993. Spawning stock biomasses in 1992 and 1993 at 3,999 and 3,792 mt, respectively, are the lowest in the time series and are 35-37% of the 1985 estimate (Figure D6).

Recruitment

Recruitment estimates, age 1 winter flounder, have followed a steady downward trend since 1985, from 35 million fish to 11 million fish at the start of 1994 (1993 year class) (Figure D6). The 1994 year class, as estimated from four available survey indices and survey catchabilities estimated from tuning, is about 11.5 million fish. The exception to the declining recruitment trend is the appearance of an above average (for this time series) 1992 year class, with 39 million recruits at age 1 in 1993. Historical young-of-the-year survey indices indicate year classes this size or larger occurred prior to 1985 (Tables D8, D9).

Precision of F and SSB estimates

The precision of the 1993 F and SSB estimates from VPA was evaluated using bootstrap techniques (Efron 1982). Two hundred bootstrap iterations were realized in which errors (differences between predicted and observed survey values) were resampled. Estimates of precision and bias are presented in Table D11. Bootstrapped estimates of spawning stock biomass indicate a CV of 9%, with low bias (bootstrap mean estimate of spawning stock biomass of 3,728 mt compared with VPA estimate of 3,792 mt). There is an 80% probability that spawning stock in 1993 was between 3,700 mt and 4,600 mt (Figure D7).

The bootstrap estimates of standard error associated with fishing mortality rates indicate high precision. Coefficients of variation for F estimates ranged from 16% at age 4 to 24% at age 6. There is

an 80% probability that F in 1993 was between 0.72 and 1.00 (Figure D8).

Projections

Stochastic projections were made based on 200 bootstrapped realizations of numbers at age in 1994. Weight at age in the landings was estimated as the weighted (by number landed) geometric mean weight at age from 1992-1993, to reflect any effects of increased minimum fish sizes. Percentage discarded was similarly estimated as the mean of percentages from 1992-1993. Recruitment was primarily treated deterministically: a Shepherd stock recruitment curve was fitted to all points excluding the 1992 year class (Figure D9). At random, but in about 9 cases of 10, recruitment was generated from the deterministic relationship, but recruitment of 39 million was allowed randomly in about 10% of the realizations.

Under the status quo level of fishing mortality ($F=0.83$, Figure D10), median spawning stock biomass would be expected to increase during 1995-1996 as the 1992 year class recruits to the spawning stock, decline somewhat thereafter, and reach about 8,000 mt in 1999-2000, well below 1984 levels. Landings similarly would increase in 1995, decline during 1996 and 1997, and stabilize around 6,000 mt in 1999-2000 (Figure D11).

If fishing mortality rates were reduced to $F_{0.1}$ ($F=0.22$) in 1996 and years following (Figure D10), median spawning stock biomass would increase continuously, exceeding 1984 levels by 1997. Landings in 1996 would decline to 2,000 mt (70% lower than in 1995) but would increase thereafter, exceeding the 1994 level (4,000 mt) by 1999 (Figure D11).

If fishing mortality rates were reduced to a lower level ($F=0.1$) in 1996 and years following (Figure D10), median spawning stock biomass would increase continuously exceeding 1984 levels by 1997, and continued to increase rapidly thereafter. Landings in 1996 would decline to only 1,000 mt,

but increase to 3,000 mt by the year 2000 (Figure D11).

Biological Reference Points

Yield and Spawning Stock Biomass per Recruit

Biological reference points were calculated using the Thompson-Bell yield per recruit model (Thompson and Bell, 1934). Input parameters are summarized in Table D12. Natural mortality was constant at 0.2. The partial recruitment at age was determined from the 1992-1993 exploitation pattern observed in the VPA results as described above. The proportion mature was based on the maturity ogive from O'Brien et al., 1993 (MA DMF spring survey). These proportions were intermediate among survey data from New Jersey, Connecticut, New York, Massachusetts, and NEFSC. Average stock weight was based on the geometric mean weight at age from 1992-1993 from the total catch. Due to low sample sizes among older ages, a curve was fitted to the data set and the fitted mean weights at age were used for ages 7 and greater. The average catch weight was the geometric mean weight at age of the catch for the period 1992-1993, with fitted mean weights used for ages 7 and greater. The proportion of the fishing and natural mortality assumed to occur prior to spawning was equal to 20% of the annual total. A model was fit using a maximum age of 15.

The calculated fishing mortality corresponding to maximum yield per recruit was 0.54 and $F_{0.1}$ was 0.22 (Table D12). At F_{max} , the maximum spawning potential was equal to 17%. The $F_{40\%}$ target defined in the ASMFC FMP occurs at an F equal to 0.21. Under fishing mortality rates of 1993, the spawning stock biomass per recruit is less than 11% of the maximum potential (Figure D12).

Conclusions

The winter flounder complex in the Southern New England - Mid-Atlantic region is over-ex-

ploited and at record low levels of spawning stock biomass. Recent recruitment, except for the 1992 year class, has been poor. Significant rebuilding opportunities will be foregone unless effective reductions in fishing mortality are implemented over the range of the fishery.

SARC Comments

The Committee reviewed the basis for changing the stock structure from four to three stock complexes. There was a consensus agreement that the evidence suggests the boundaries established for the current assessment are valid.

The estimation of discards in the commercial and recreational fisheries and some potential sources of bias were discussed. The recreational discard at length estimates assumed the minimum legal length was adhered to; fish below the limit were discarded and fish above the limit were all kept. An increasing conservation ethic among recreational fishermen may have increased the number of legal size fish discarded but a lack of data prevents incorporating that variation into the estimates. A concern about the commercial discard estimates was the comparability between the survey gear and the commercial gear. If survey gear does not catch small fish with equal efficiency, the current methodology may underestimate commercial discards. It was suggested that some external validation of the comparability of the gears was warranted.

In previous assessments of winter flounder in Southern New England and the Mid-Atlantic, natural mortalities other than the 0.2 in the current analysis were assumed. The SARC agreed that the current age structure of the stock complex would indicate that a natural mortality rate of 0.2 was appropriate.

The results of the VPA indicated a large 1992 year class. Although, survey indices in previous years also indicated large year classes which did not result in increased stock numbers, this year class

may still be present, based on preliminary indications from NEFSC fall survey. A concern was raised that since the VPA ends in 1993, the 1992 year class could have sustained high mortalities in following years and may not contribute to future biomass to the extent that the projections indicate. The SARC also suggested other projection scenarios, including developing an optimal re-building strategy, the impact of a fishing mortality reduced to $F=0.1$, examining the implications of areal changes in mesh size and the effect of altering the exploitation pattern. The SARC inspected results of two additional projection runs: the effect of $F=0.1$ and the effect of altering the exploitation pattern. Forecasts that assumed substantially reduced selection of age three and four fish (and status quo F) resulted in a SSB trajectory intermediate between the $F_{0.1}$ and F_{sq} scenarios. Landings from the improved selection pattern scenario were initially reduced, but exceeded those from the F_{sq} scenario after 1999.

Research Recommendations

- o Consider effects of catch-and-release components of recreational fishery on discard at age (e.g. American Littoral Society tagging database).
- o Evaluate effects of smoothed length-frequency distributions on relationship between survey and commercial catches at length.
- o Evaluate feasibility of virtual population analysis based only on ages fully recruited to landings (i.e. no discards).
- o Examine other biological reference points and rebuilding strategies in projection models.
- o Implement retrospective analysis of VPA to determine potential biases in terminal year estimates as time series become longer.
- o Evaluate size-selective performance of survey gear compared to typical commercial gear, and implications for estimation of commercial dis-

cards from research survey length frequency information (although not specific to this stock complex).

- o Maintain or increase sampling levels (currently supported by individual state funding) and collect age information from MRFSS samples.
- o Include years prior to 1985 and after 1993 in the catch at age analysis.
- o Further examine the comparability of age-length keys from different areas within the stock. Current comparisons are based on two years and three ages.
- o Develop a geographically more comprehensive data set to calculate maturity at age, reflecting any differential availability of mature fish to inshore and offshore surveys.
- o Examine the implications of anthropogenic mortalities in estimation of yield per recruit.
- o Examine the implications of stock mixing from data from Great South Channel region.
- o Expand sea sampling for estimation of commercial discards.

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Table D1. Winter flounder commercial landings (metric tons) 1964 - 1993 for Southern New England/Mid-Atlantic stock complex area (U.S. statistical reporting areas 521, 526, divisions 53, 61-63) as reported by NEFSC weighout, state bulletin and general canvas data.

Year	Metric Tons	Year	Metric Tons
1964	7,474	1981	11,176
1965	8,678	1982	9,438
1966	11,977	1983	8,659
1967	9,478	1984	8,882
1968	7,070	1985	7,052
1969	8,107	1986	4,929
1970	8,603	1987	5,172
1971	7,367	1988	4,312
1972	5,190	1989	3,670
1973	5,573	1990	4,232
1974	4,259	1991	4,823
1975	3,982	1992	3,816
1976	3,265	1993	3,010
1977	4,413		
1978	6,327		
1979	6,543		
1980	10,627		

Table D2. Distribution of commercial landings (percentage of annual total) of winter flounder from Southern New England/Mid-Atlantic stock complex area by U.S. statistical reporting area and distance from shore, 1989-1993.

YEAR	AREA								
	521	526	537	538	539	611	612	613	614-622
1989	33.2	10.8	18.9	7.0	12.1	7.1	5.5	4.2	1.2
1990	45.2	16.8	6.1	4.9	9.5	11.1	4.1	2.0	0.1
1991	46.4	14.7	10.8	1.7	13.7	5.7	3.6	2.9	0.4
1992	37.0	12.5	17.4	2.4	9.4	10.1	4.5	3.4	3.4
1993	46.6	10.0	10.8	2.4	8.2	7.7	4.2	8.0	2.1
AVG.	41.7	13.0	12.8	3.7	10.6	8.3	4.4	4.1	1.4
YEAR	DISTANCE FROM SHORE								
	Inland	< 3 miles	3-12 miles	> 12 miles					
1989	0.0	16.8	13.6	69.6					
1990	0.0	16.9	10.9	72.1					
1991	0.0	9.1	16.3	74.5					
1992	0.0	14.7	10.9	74.5					
1993	0.0	13.9	12.4	73.7					
AVG.	0.0	14.3	12.8	72.9					

Table D3. Estimated number (000's) and weight (mt) of winter flounder caught and discarded in recreational fishery, Southern Massachusetts to New Jersey, 1981-1994.

	-----Numbers (000s)-----				Metric Tons
	Catch A+B1+B2	Landings A+B1	Release B2	15% Release Mortality	Landings A=B1
1981	11005.7	8089.4	2916.2	437.4	3049.5
1982	10664.7	8392.2	2272.5	340.9	2457.1
1983	11010.0	8365.0	2645.0	396.7	3523.9
1984	17723.3	12756.0	4967.3	745.1	5772.0
1985	18056.0	13297.4	4758.6	713.8	5197.8
1986	9368.4	6994.5	2373.9	356.1	2940.2
1987	9213.2	6900.4	2312.8	346.9	3140.7
1988	10133.7	7358.4	2775.3	416.3	3423.1
1989	5917.9	3681.7	2236.2	335.4	1802.1
1990	3826.6	2486.3	1340.3	201.0	1062.6
1991	4324.8	2795.0	1529.9	229.5	1214.3
1992	1360.3	805.6	554.7	83.2	393.1
1993	2210.8	1180.3	1030.5	154.6	542.6
1994	1883.8	1075.3	808.5	121.3	548.1

Table D4. Total winter flounder recreational and commercial catch, 1985-1993 for Southern New England/ Mid-Atlantic stock in mt and (thousands of fish).

Year	Commercial Landings	Commercial Discards	Recreational Landings	Recreational Discards	Total Catch	% Discards
1985	7052 (14,211)	1534 (4,531)	5198 (13,297)	230 (714)	14014 (32,753)	12.6 (16.0)
1986	4929 (9,460)	1273 (4,902)	2940 (6,994)	66 (356)	9208 (21,712)	14.5 (24.2)
1987	5172 (10,524)	950 (3,545)	3141 (6,900)	61 (347)	9324 (21,316)	10.8 (18.3)
1988	4312 (8,377)	904 (3,728)	3423 (7,358)	69 (416)	8708 (19,879)	11.2 (20.9)
1989	3670 (7,888)	1404 (5,761)	1802 (3,682)	49 (335)	6925 (17,666)	21.0 (34.5)
1990	4232 (7,202)	673 (2,567)	1063 (2,486)	31 (201)	5999 (12,456)	11.7 (22.2)
1991	4823 (9,063)	784 (2,701)	1214 (2,795)	51 (229)	6872 (14,788)	12.2 (19.8)
1992	3816 (6,759)	511 (1,811)	393 (806)	15 (83)	4735 (9,459)	11.1 (20.0)
1993	3010 (5,336)	457 (1,580)	543 (1,180)	31 (155)	4041 (8,251)	12.1 (21.1)

Table D5. Winter flounder catch at age (number in 000s) for Southern New England/Mid-Atlantic stock complex.

Commercial Landings		Age											
year	1	2	3	4	5	6	7	8	9	10	11	12	13
1985	27	3936	5688	3052	1014	326	104	32	17	7	5	2	0
1986	0	2122	4187	2206	551	271	84	27	6	3	1	2	0
1987	0	2488	5465	1895	465	122	40	20	14	12	2	0	0
1988	0	2241	3929	1607	412	122	37	24	3	2	1	0	0
1989	0	1542	4057	1747	431	58	34	13	5	1	0	0	0
1990	0	1003	3977	1757	315	95	37	16	0	3	0	0	0
1991	0	1406	4756	2239	447	143	48	16	5	1	1	0	0
1992	0	484	3416	2127	574	111	32	11	3	0	0	0	0
1993	13	885	2516	1377	361	102	71	7	0	0	2	0	1
Commercial Discards		Age											
year	1	2	3	4	5	6	7	8	9	10	11	12	13
1985	22	1504	2516	442	43	4	0	0	0	0	0	0	0
1986	78	2220	2389	205	10	0	0	0	0	0	0	0	0
1987	11	1600	1755	170	9	0	0	0	0	0	0	0	0
1988	6	887	2540	276	20	0	0	0	0	0	0	0	0
1989	315	2724	2131	555	33	2	1	0	0	0	0	0	0
1990	16	781	1433	322	14	0	1	0	0	0	0	0	0
1991	17	1238	1205	227	12	1	0	0	0	0	0	0	0
1992	15	845	787	150	14	1	0	0	0	0	0	0	0
1993	201	849	467	57	6	0	0	0	0	0	0	0	0
Total Commercial Catch		Age											
year	1	2	3	4	5	6	7	8	9	10	11	12	13
1985	49	5440	8204	3494	1057	330	104	32	17	7	5	2	0
1986	78	4341	6576	2411	561	271	84	27	6	3	1	2	0
1987	11	4089	7220	2065	474	123	40	20	14	12	2	0	0
1988	6	3127	6468	1883	432	122	37	24	3	2	1	0	0
1989	315	4266	6187	2301	464	60	35	13	5	1	0	0	0
1990	16	1784	5410	2079	328	95	37	16	0	3	0	0	0
1991	17	2644	5962	2465	460	144	49	16	5	1	1	0	0
1992	15	1328	4203	2277	588	112	32	11	3	0	0	0	0
1993	214	1735	2983	1435	367	103	71	7	0	0	2	0	1
Recreational Landings		Age											
year	1	2	3	4	5	6	7	8	9	10	11	12	13
1985	219	1585	4270	2558	1895	1513	878	0	335	44	0	0	0
1986	106	1765	2432	1797	491	171	81	77	51	8	17	0	0
1987	16	926	1736	1023	2229	633	82	115	64	77	0	0	0
1988	21	534	2858	2078	775	857	128	51	37	20	0	0	0
1989	99	739	944	1200	385	161	91	36	16	8	3	1	0
1990	7	189	814	851	439	101	52	20	3	3	0	2	5
1991	13	232	1122	879	399	107	38	0	1	0	3	0	0
1992	3	123	235	303	85	50	7	0	0	0	0	0	0
1993	31	233	321	289	218	54	20	10	4	2	0	0	0

Table D5. (Continued)

Total Catch year	Age												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1985	277	7366	12836	6054	2953	1843	982	32	352	52	5	2	0
1986	215	6327	9102	4216	1053	442	165	104	57	10	19	2	0
1987	73	5268	8999	3091	2703	755	122	135	78	89	2	0	0
1988	84	3941	9402	3964	1207	979	165	75	39	22	1	0	0
1989	463	5246	7176	3503	849	222	126	49	21	9	3	1	0
1990	36	2109	6275	2931	767	196	89	36	4	5	0	2	5
1991	53	3027	7140	3344	858	251	87	16	6	1	4	0	0
1992	25	1503	4457	2581	674	162	38	11	3	0	0	0	0
1993	274	2062	3329	1728	585	157	91	17	4	2	2	0	1

Table D6. Winter flounder NEFSC survey index stratified mean number and mean weight (kgs) per tow for the Southern New England- Mid-Atlantic stock complex, strata set (offshore 1-12, 25, 69-76; inshore 1-29, 45 - 56)

YEAR	Spring		Fall	
	Number	Weight	Number	Weight
1963			8.554	3.283
1964			13.673	4.894
1965			15.537	4.435
1966			9.843	3.275
1967			9.109	2.745
1968	2.444	0.734	8.106	2.191
1969	5.640	3.414	6.842	1.939
1970	2.729	1.326	5.110	2.376
1971	2.035	0.756	3.862	1.232
1972	1.866	0.656	7.687	3.054
1973	7.459	2.013	2.691	0.776
1974	3.362	1.043	2.032	0.821
1975	1.136	0.354	2.358	0.742
1976	3.085	0.805	2.375	1.251
1977	4.168	1.190	4.722	1.735
1978	6.696	1.758	3.743	1.430
1979	2.965	1.069	10.058	2.606
1980	15.250	3.533	10.471	3.307
1981	18.234	4.762	10.205	3.109
1982	6.986	1.918	4.928	1.683
1983	6.262	2.469	8.757	2.691
1984	5.523	2.072	2.681	0.887
1985	5.360	1.983	2.727	0.991
1986	2.266	0.766	1.538	0.487
1987	1.763	0.568	1.167	0.419
1988	2.126	0.730	1.246	0.530
1989	2.485	0.582	1.435	0.341
1990	1.992	0.472	1.979	0.546
1991	2.473	0.692	1.950	0.708
1992	1.579	0.435	2.963	0.829
1993	0.961	0.219	1.382	0.392
1994	1.510	0.329	4.134	1.482
1995	2.097	0.592	2,253	0.626

NOTE: 1968-1972 spring index does not include inshore strata

1963-1971 fall index does not include inshore strata

Table D7. Winter flounder mean number per tow for annual state surveys.

Year	MADMF spring	RIDFW spring	CTDEP	NYDEC (age 0-1)	NJDEP (April)
1978	51.50				
1979	53.61	130.19			
1980	38.92	68.41			
1981	46.05	98.03			
1982	40.23	41.48			
1983	56.39	62.98			
1984	36.64	45.55	110.76		
1985	38.36	44.13	83.26	2.71	
1986	36.51	49.74	63.73		
1987	37.84	59.53	79.83	2.62	
1988	27.57	34.93	137.63	2.02	
1989	24.42	21.60	148.18	4.72	86.25
1990	25.75	20.36	222.96	4.53	32.59
1991	10.57	32.04	150.28	6.17	51.77
1992	28.69	9.82	61.25	12.54	18.24
1993	46.92	8.22	63.57	10.20	23.39
1994	48.43	10.05	84.59	5.61	17.88
1995		32.47	48.13		49.37

Table D8. State survey indices for young-of-year winter flounder in Southern New England/
Mid-Atlantic stock complex.

Year	CTDEP	RIDFW	DEL	MADMF	NYDEC
1975				0.30	
1976				0.32	
1977				0.60	
1978				0.34	
1979		29.61		0.49	
1980		1.64		0.40	
1981		8.56		0.32	
1982		10.10		0.37	
1983		1.98		0.23	
1984		3.06		0.32	
1985		5.08		0.34	0.75
1986		7.24	0.17	0.32	
1987		0.63	0.09	0.27	0.97
1988	15.50	0.41	0.02	0.18	0.69
1989	1.90	1.15	0.29	0.42	1.67
1990	2.90	1.01	0.63	0.33	2.73
1991	5.20	1.44	0.03	0.27	2.48
1992	11.90	6.27	0.27	0.29	11.43
1993	5.60	0.16	0.04	0.07	4.66
1994	14.20	0.07	0.31	0.15	2.44
1995	10.10	0.98		0.05	

Table D9. NEFSC and state surveys mean number per tow at age for winter flounder in the Southern New England/Mid-Atlantic stock complex.

NEFSC	Spring										
	AGE										
Year	0	1	2	3	4	5	6	7	8	9	10
1985		0.41	1.21	2.16	0.72	0.51	0.20	0.14	0.01		
1986		0.10	0.49	1.14	0.31	0.15	0.05	0.01			0.02
1987		0.14	0.54	0.70	0.28	0.06	0.02		0.01	0.01	
1988		0.09	0.48	0.98	0.37	0.16	0.02	0.02			
1989		0.14	0.94	0.90	0.34	0.11	0.02	0.02	0.01		
1990		0.23	0.49	0.91	0.28	0.05	0.04	0.01			
1991		0.14	0.60	1.23	0.41	0.05	0.02	0.02	0.01		
1992		0.14	0.39	0.62	0.36	0.05	0.02				
1993		0.14	0.36	0.27	0.12	0.07	0.01	0.01			
1994		0.16	0.76	0.43	0.11	0.04	0.02	0.01			

NEFSC	Autumn										
	AGE										
Year	0	1	2	3	4	5	6	7	8	9	10
1985		0.16	1.18	0.99	0.30	0.09	0.01				
1986		0.22	0.90	0.36	0.03	0.01		0.01			
1987		0.03	0.64	0.36	0.12	0.02					
1988		0.03	0.29	0.63	0.22	0.04	0.01	0.01			
1989		0.28	0.82	0.26	0.05	0.01	0.01				
1990		0.07	0.88	0.84	0.15	0.01					
1991		0.06	1.02	0.73	0.12	0.01					
1992		0.15	1.74	0.79	0.26	0.03	0.01				
1993		0.42	0.50	0.34	0.08						
1994		0.44	2.22	1.08	0.30	0.04	0.03				

Connecticut DEP	Spring											
	AGE											
Year	0	1	2	3	4	5	6	7	8	9	10	11
1984		9.45	46.42	27.70	18.17	6.59	1.43	0.46	0.44	0.05	0.01	0.04
1985		4.88	30.75	28.82	14.12	3.10	0.88	0.39	0.17	0.12	0.02	0.01
1986		6.75	26.03	16.73	10.41	2.53	0.68	0.24	0.23	0.10	0.01	0.02
1987		7.04	34.64	21.33	11.50	3.66	0.96	0.30	0.26	0.12	0.01	0.01
1988		15.21	69.95	39.50	9.12	1.81	1.69	0.22	0.04	0.07	0.02	0.00
1989		13.57	77.13	41.59	11.66	2.74	1.09	0.29	0.06	0.03	0.02	0.00
1990		15.91	127.97	63.42	9.40	4.04	1.91	0.22	0.07	0.00	0.02	0.00
1991		9.49	66.33	58.92	10.12	4.36	0.88	0.17	0.00	0.00	0.00	0.01
1992		6.51	31.78	12.88	8.60	1.10	0.33	0.05	0.00	0.00	0.00	0.00
1993		18.73	20.21	15.32	5.06	3.17	0.76	0.16	0.11	0.04	0.01	0.00
1994		9.97	63.49	6.33	2.90	1.19	0.47	0.17	0.05	0.01	0.01	0.00

Table DI9. (Continued)

Rhode Island DFW Spring											
Year	AGE										
	0	1	2	3	4	5	6	7	8	9	10
1979	29.61	52.81	31.04	10.88	2.7	2.27	0.54	0.16	0.08	0.08	0.02
1980	1.64	16.48	33.51	12.88	1.93	1.52	0.27	0.09	0.04	0.04	0.01
1981	8.56	22.42	36.35	18.92	5.3	4.68	1.1	0.34	0.15	0.16	0.05
1982	10.10	8.86	8.55	6.44	3.1	2.85	0.85	0.36	0.15	0.16	0.06
1983	1.98	20.6	17.23	10.37	5.21	4.82	1.51	0.66	0.26	0.27	0.07
1984	3.06	4.11	16.51	11.63	4.33	3.98	1.08	0.41	0.18	0.2	0.06
1985	5.08	5.48	15.21	10.71	3.47	3.01	0.71	0.22	0.11	0.1	0.03
1986	7.24	10.77	14.04	8.81	3.61	3.37	1.01	0.47	0.18	0.19	0.05
1987	0.63	13.75	21.24	13.62	4.45	4.07	1.06	0.36	0.16	0.16	0.03
1988	0.41	6.66	10.3	11.46	3.8	1.23	0.81	0.19	0	0.04	0.03
1989	1.15	5.56	7	5.18	1.66	0.57	0.31	0.07	0.03	0.02	0.05
1990	1.01	4.28	6.04	5.75	2.14	0.74	0.25	0.08	0.02	0	0.05
1991	1.44	5.88	10.13	9.95	2.9	1.11	0.43	0.15	0	0	0.05
1992	6.27	0.92	0.98	0.84	0.57	0.16	0.05	0	0.01	0.01	0.01
1993	0.16	4.85	2.19	0.53	0.27	0.16	0.04	0.01	0.01	0	0
1994	0.07	1.81	4.77	1.66	1.18	0.34	0.16	0.05	0.01	0	0
1995	0.98	4.66	12.73	7.63	4.35	1.38	0.55	0.13	0.06	0	0

New York DEC AGE
Year 0 1

1985	0.75	1.96
1986		
1987	0.97	1.65
1988	0.69	1.33
1989	1.67	3.05
1990	2.73	1.8
1991	2.48	3.69
1992	11.43	1.11
1993	4.66	5.54
1994	2.44	3.17

Massachusetts DMF Spring
Year 0 1 2 3 4 5 6 7 8 9

1978		9.90	9.70	15.71	9.31	3.14	1.09	1.33	0.51	0.81
1979		4.63	12.86	21.03	8.90	2.93	1.00	0.95	0.46	0.85
1980		1.63	8.21	14.48	9.13	3.01	0.96	0.79	0.28	0.43
1981		8.33	8.72	13.15	9.38	3.68	1.16	0.75	0.32	0.56
1982		2.68	6.23	15.98	9.22	3.32	1.00	0.83	0.41	0.56
1983		2.31	15.70	19.47	12.43	3.54	1.08	0.84	0.45	0.57
1984		1.23	6.92	14.12	10.14	2.64	0.72	0.51	0.17	0.19
1985		4.34	9.93	14.26	6.96	1.77	0.52	0.27	0.12	0.19
1986		3.62	8.07	17.42	5.37	1.21	0.35	0.27	0.08	0.12
1987		9.19	8.24	11.50	6.14	1.61	0.47	0.41	0.13	0.15
1988		2.91	7.06	13.71	3.05	0.53	0.15	0.08	0.02	0.06
1989		1.63	4.95	10.90	4.80	1.14	0.31	0.28	0.13	0.28
1990		4.18	10.66	7.60	2.87	0.30	0.02	0.10	0.00	0.02
1991		1.56	2.79	4.68	1.15	0.23	0.12	0.02	0.00	0.02
1992		7.78	7.55	6.68	4.16	1.64	0.59	0.07	0.08	0.14
1993		14.17	17.56	11.70	2.71	0.62	0.14	0.02	0.00	0.00
1994		11.37	16.12	14.65	4.66	0.61	0.58	0.37	0.05	0.02

Table D10. (Continued)

RESULTS

	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.
SUM OF SQUARES			160.028936	
ORTHOGONALITY OFFSET.....			0.001730	
MEAN SQUARE RESIDUALS			0.531658	
N 1	1.13863E4	3.36138E3	3.38740E0	0.30
N 2	3.19974E4	7.26557E3	4.40398E0	0.23
N 3	8.17072E3	1.77745E3	4.59688E0	0.22
N 4	3.83582E3	9.78661E2	3.91946E0	0.26
N 5	9.95556E2	3.12932E2	3.18138E0	0.31
N 6	5.15184E2	1.58402E2	3.25237E0	0.31
N 7	1.10696E2	4.14315E1	2.67178E0	0.37
qRV SPR 1	4.07078E-5	9.63515E-6	4.22492E0	0.24
qRV SPR 2	4.58066E-5	1.07319E-5	4.26826E0	0.23
qRV SPR 3	6.45843E-5	1.50762E-5	4.28385E0	0.23
qRV SPR 4	1.60543E-4	3.75108E-5	4.27991E0	0.23
qRV SPR 5	3.94543E-4	9.26076E-5	4.26037E0	0.23
qRV SPR 6	1.03675E-3	2.44153E-4	4.24633E0	0.24
qRV SPR 7	1.62308E-3	4.09160E-4	3.96687E0	0.25
qRV FAL 1	3.56164E-5	8.80646E-6	4.04435E0	0.25
qRV FAL 2	7.21348E-5	1.77640E-5	4.06074E0	0.25
qRV FAL 3	1.76514E-4	4.35130E-5	4.05659E0	0.25
qRV FAL 4	4.96510E-4	1.23018E-4	4.03607E0	0.25
qMA SPR 1	3.48712E-5	8.25369E-6	4.22492E0	0.24
qMA SPR 2	4.36873E-5	1.02354E-5	4.26826E0	0.23
qMA SPR 3	6.95378E-5	1.62325E-5	4.28385E0	0.23
qMA SPR 4	1.64247E-4	3.83764E-5	4.27991E0	0.23
qMA SPR 5	4.54889E-4	1.06772E-4	4.26037E0	0.23
qMA SPR 6	1.12782E-3	2.65600E-4	4.24633E0	0.24
qMA SPR 7	1.79700E-3	4.29208E-4	4.18679E0	0.24
qRI FAL 0	2.49809E-5	5.91275E-6	4.22492E0	0.24
qRI SPR 1	3.56451E-5	8.43687E-6	4.22492E0	0.24
qRI SPR 2	3.62829E-5	8.50062E-6	4.26826E0	0.23
qRI SPR 3	4.86152E-5	1.13485E-5	4.28385E0	0.23
qRI SPR 4	1.37897E-4	3.22197E-5	4.27991E0	0.23
qRI SPR 5	3.23864E-4	7.60178E-5	4.26037E0	0.23
qRI SPR 6	9.90564E-4	2.33276E-4	4.24633E0	0.24
qRI SPR 7	8.76000E-4	2.06296E-4	4.24633E0	0.24
qCT SPR 1	4.09188E-5	9.68510E-6	4.22492E0	0.24
qCT SPR 2	4.21006E-5	9.86363E-6	4.26826E0	0.23
qCT SPR 3	5.98792E-5	1.39779E-5	4.28385E0	0.23
qCT SPR 4	1.68385E-4	3.93432E-5	4.27991E0	0.23
qCT SPR 5	5.09461E-4	1.19581E-4	4.26037E0	0.23
qCT SPR 6	1.39870E-3	3.29391E-4	4.24633E0	0.24
qCT SPR 7	2.32618E-3	5.55600E-4	4.18679E0	0.24
qMA SEI 0	4.08999E-5	9.68063E-6	4.22492E0	0.24
qDEL SV 0	2.77800E-5	7.38940E-6	3.75945E0	0.27

STOCK NUMBERS (Jan 1) in thousands - WFLSNE95

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	34619	32799	25979	26752	23167	17168	14564	15001	39385	11386
2	28706	28093	26659	21203	21827	18549	14023	11877	12259	31997
3	26945	16838	17275	17060	13794	13124	13278	8743	8364	8171
4	10078	10446	5550	6001	5460	4801	5067	4410	3125	3836
5	4603	2773	4738	1747	1327	1301	1278	1122	1275	996
6	2944	1097	1318	1433	339	318	371	270	309	515
7	2229	875	730	432	311	223	165	86	225	191
1+	110125	92921	82249	74629	66225	55483	48747	41509	64942	57092

STOCK NUMBERS Summaries for ages 2-5 3-5 4-5 5-5

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
2	70332	58150	54222	46012	42407	37774	33646	26152	25024	45000
3	41626	30058	27563	24808	20580	19225	19623	14275	12765	13002
4	14681	13219	10288	7749	6787	6101	6345	5533	4401	4831
5	4603	2773	4738	1747	1327	1301	1278	1122	1275	996

Table DI10. (Continued).

FISHING MORTALITY									
	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	0.01	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.01
2	0.33	0.29	0.25	0.23	0.31	0.13	0.27	0.15	0.21
3	0.75	0.91	0.86	0.94	0.86	0.75	0.90	0.83	0.58
4	1.09	0.59	0.96	1.31	1.23	1.12	1.31	1.04	0.94
5	1.23	0.54	1.00	1.44	1.23	1.06	1.36	1.09	0.71
6	1.18	0.59	1.00	1.41	1.29	1.15	1.38	1.09	0.83
7	1.18	0.59	1.00	1.41	1.29	1.15	1.38	1.09	0.83
Avg F for ages 2-5 3-5 4-5 5-5									
	1985	1986	1987	1988	1989	1990	1991	1992	1993
2	0.85	0.58	0.76	0.98	0.91	0.77	0.96	0.78	0.61
3	1.02	0.68	0.94	1.23	1.11	0.98	1.19	0.99	0.74
4	1.16	0.57	0.98	1.38	1.23	1.09	1.33	1.07	0.83
5	1.23	0.54	1.00	1.44	1.23	1.06	1.36	1.09	0.71
BACKCALCULATED PARTIAL RECRUITMENT									
	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	0.01	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.01
2	0.27	0.31	0.25	0.16	0.24	0.12	0.20	0.14	0.22
3	0.61	1.00	0.85	0.65	0.66	0.65	0.65	0.76	0.61
4	0.88	0.65	0.95	0.91	0.96	0.98	0.95	0.96	1.00
5	1.00	0.60	0.99	1.00	0.95	0.92	0.98	1.00	0.75
6	0.95	0.65	1.00	0.98	1.00	1.00	1.00	1.00	0.88
7	0.95	0.65	1.00	0.98	1.00	1.00	1.00	1.00	0.88
MEAN BIOMASS (MT)									
	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	3468	3821	1081	944	2451	1274	1225	1073	6010
2	6274	6496	6172	4808	4414	4651	3543	2875	3366
3	6338	4048	4095	3574	3221	3335	3379	2332	2672
4	2729	3465	1813	1573	1473	1398	1397	1514	1102
5	1276	1340	1313	544	466	498	391	506	578
6	747	667	432	369	126	141	153	143	170
7	742	581	362	178	174	121	97	68	164
1+	21573	20419	15268	11990	12325	11419	10186	8511	14061
Summaries for ages 2-5 3-5 4-5 5-5									
	1985	1986	1987	1988	1989	1990	1991	1992	1993
2	16616	15350	13392	10500	9573	9882	8710	7226	7718
3	10343	8854	7220	5691	5160	5231	5168	4351	4352
4	4005	4805	3126	2118	1939	1895	1788	2019	1680
5	1276	1340	1313	544	466	498	391	506	578
CATCH BIOMASS (MT)									
	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	31	28	3	3	55	3	5	2	46
2	2092	1859	1521	1106	1363	625	965	433	692
3	4738	3683	3510	3357	2755	2507	3049	1932	1549
4	2975	2047	1733	2060	1818	1570	1827	1575	1040
5	1575	729	1307	784	573	526	530	551	408
6	879	393	434	518	162	162	212	156	140
7	873	343	364	250	224	139	134	74	135
1+	13163	9082	8872	8079	6950	5532	6721	4723	4012

Table DI10. (Continued).

CATCH BIOMASS Summaries for ages 2-5 3-5 4-5 5-5									
■	1985	1986	1987	1988	1989	1990	1991	1992	1993
2 ■	11380	8318	8071	7307	6509	5227	6371	4491	3690
3 ■	9288	6459	6550	6201	5146	4603	5405	4058	2997
4 ■	4550	2776	3040	2844	2391	2095	2357	2126	1449
5 ■	1575	729	1307	784	573	526	530	551	408

SSB AT THE START OF THE SPAWNING SEASON - males & females (MT)									
■	1985	1986	1987	1988	1989	1990	1991	1992	1993
1 ■	0	0	0	0	0	0	0	0	0
2 ■	0	0	0	0	0	0	0	0	0
3 ■	3865	2485	2570	2373	1991	1892	2061	1436	1414
4 ■	3122	3636	2036	1958	1724	1629	1717	1709	1234
5 ■	1458	1408	1853	786	605	616	555	592	704
6 ■	1156	651	670	543	178	185	212	164	219
7 ■	1086	737	510	274	261	176	148	97	221
1+■	10687	8917	7640	5934	4760	4500	4694	3999	3792

MEAN STOCK NUMBERS (thousands)									
■	1985	1986	1987	1988	1989	1990	1991	1992	1993
1 ■	31242	29623	23510	24206	20773	15543	13175	13584	35563
2 ■	22247	22247	21504	17234	17108	15767	11176	10018	10077
3 ■	17412	10171	10663	10182	8521	8466	8046	5461	5809
4 ■	5661	7220	3290	3097	2899	2662	2617	2527	1862
5 ■	2444	1956	2763	858	706	741	648	631	839
6 ■	1599	758	766	713	176	174	186	152	193
7 ■	1210	605	425	215	162	122	83	49	140
1+■	81816	72581	62922	56506	50345	43475	35931	32420	54483

Table D11. Results of bootstrap analysis of virtual population analysis of winter flounder in Southern New England/Mid-Atlantic stock.

NUMBER OF BOOTSTRAP REPLICATIONS ATTEMPTED: 200

N_hat Age-specific stock sizes (on Jan 1, 1994) estimated by NLLS

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN	BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLSS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
1.139E4	1.173E4	2.982E3	0.26	3.389E2	2.109E2	2.98	1.105E4	0.27
3.200E4	3.359E4	6.837E3	0.21	1.594E3	4.835E2	4.98	3.040E4	0.22
8.171E3	8.436E3	1.766E3	0.22	2.651E2	1.249E2	3.24	7.906E3	0.22
3.836E3	3.914E3	9.118E2	0.24	7.812E1	6.448E1	2.04	3.758E3	0.24
9.956E2	1.067E3	2.661E2	0.27	7.093E1	1.882E1	7.12	9.247E2	0.29
5.152E2	5.122E2	1.378E2	0.27	-2.991E0	9.744E0	-0.58	5.182E2	0.27
1.107E2	1.154E2	3.912E1	0.35	4.655E0	2.766E0	4.20	1.061E2	0.37

F_t Full vector of age-specific terminal F's (in 1993)

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN	BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLSS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
7.721E-3	7.664E-3	1.591E-3	0.21	-5.759E-5	1.125E-4	-0.75	7.779E-3	0.20
2.057E-1	2.071E-1	3.911E-2	0.19	1.358E-3	2.765E-3	0.66	2.044E-1	0.19
5.795E-1	5.894E-1	1.057E-1	0.18	9.896E-3	7.474E-3	1.71	5.696E-1	0.19
9.440E-1	9.290E-1	1.548E-1	0.16	-1.498E-2	1.095E-2	-1.59	9.589E-1	0.16
7.065E-1	7.371E-1	1.437E-1	0.20	3.064E-2	1.016E-2	4.34	6.758E-1	0.21
8.267E-1	8.501E-1	1.993E-1	0.24	2.335E-2	1.409E-2	2.82	8.034E-1	0.25
8.267E-1	8.501E-1	1.993E-1	0.24	2.335E-2	1.409E-2	2.82	8.034E-1	0.25

F_full_t Fully-recruited F in the terminal year (1993)

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN	BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLSS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
8.257E-1	8.387E-1	1.071E-1	0.13	1.300E-2	7.571E-3	1.57	8.127E-1	0.13

PR_mean Average partial recruitment over 1991-1993

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN	BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLSS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
3.439E-3	3.326E-3	4.295E-4	0.12	-1.132E-4	3.037E-5	-3.29	3.552E-3	0.12
1.811E-1	1.757E-1	1.741E-2	0.10	-5.420E-3	1.231E-3	-2.99	1.865E-1	0.09
6.730E-1	6.541E-1	5.384E-2	0.08	-1.889E-2	3.807E-3	-2.81	6.919E-1	0.08
9.668E-1	9.337E-1	4.851E-2	0.05	-3.311E-2	3.430E-3	-3.42	9.999E-1	0.05
9.020E-1	8.848E-1	5.585E-2	0.06	-1.727E-2	3.949E-3	-1.91	9.193E-1	0.06
9.558E-1	9.322E-1	5.584E-2	0.06	-2.365E-2	3.948E-3	-2.47	9.795E-1	0.06
9.558E-1	9.322E-1	5.584E-2	0.06	-2.365E-2	3.948E-3	-2.47	9.795E-1	0.06

B_mean_t Mean stock biomass during the terminal year (1993)

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN	BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLSS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
1.406E4	1.455E4	1.713E3	0.12	4.878E2	1.212E2	3.47	1.357E4	0.13

SSB_spawn_t SSB (males & females) at start of spawning season (1993)

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN	BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLSS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
3.792E3	3.856E3	3.254E2	0.09	6.365E1	2.301E1	1.68	3.728E3	0.09

Table D12. Yield per recruit and spawning stock biomass per recruit for winter flounder in Southern New England/Mid-Atlantic stock complex.

Proportion of F before spawning: .200
 Proportion of M before spawning: .200
 Natural Mortality is Constant at: .200
 Last age is a True Age;

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights	
				Stock	Catch
1	.0050	1.0000	.0000	.116	.116
2	.1890	1.0000	.0000	.309	.309
3	.7390	1.0000	.5300	.443	.443
4	1.0000	1.0000	.9500	.595	.595
5	1.0000	1.0000	1.0000	.743	.743
6	1.0000	1.0000	1.0000	.911	.911
7	1.0000	1.0000	1.0000	1.095	1.095
8	1.0000	1.0000	1.0000	1.291	1.291
9	1.0000	1.0000	1.0000	1.467	1.467
10	1.0000	1.0000	1.0000	1.620	1.620
11	1.0000	1.0000	1.0000	1.748	1.748
12	1.0000	1.0000	1.0000	1.855	1.855
13	1.0000	1.0000	1.0000	1.941	1.941
14	1.0000	1.0000	1.0000	2.011	2.011
15	1.0000	1.0000	1.0000	2.067	2.067

Summary of Yield per Recruit Analysis for:
 WINTER FLOUNDER

Slope of the Yield/Recruit Curve at F=0.00: ----->	3.053
F level at slope=1/10 of the above slope (F0.1): --->	.217
Yield/Recruit corresponding to F0.1: --->	.2554
F level to produce maximum Yield/Recruit (Fmax): --->	.536
Yield/Recruit corresponding to Fmax: --->	.2821

WINTER FLOUNDER YPR

Fishing Mortality	Total Catch Number	Total Catch Weight	Total Stock Number	Total Stock Weight	Spawn Stock Number	Spawn Stock Weight	Percent Max. Spawn Potential
.000	.00000	.00000	5.2420	3.7669	2.9600	3.1148	1.0000
.100	.21893	.18573	4.3519	2.5417	2.0732	1.9041	.6113
.200	.33474	.24961	3.8327	1.9001	1.5624	1.2787	.4105
F0.1 .217	.34949	.25545	3.7640	1.8208	1.4953	1.2020	.3859
.300	.40491	.27218	3.5016	1.5329	1.2409	.9253	.2970
.400	.45211	.27992	3.2742	1.3048	1.0232	.7086	.2275
.500	.48630	.28200	3.1086	1.1528	.8670	.5662	.1818
Fmax .536	.49652	.28211	3.0592	1.1099	.8209	.5264	.1690
.600	.51244	.28184	2.9823	1.0455	.7499	.4671	.1500
.700	.53320	.28076	2.8824	.9660	.6588	.3948	.1267
.800	.55020	.27934	2.8010	.9049	.5860	.3401	.1092
.900	.56444	.27780	2.7332	.8563	.5265	.2974	.0955
1.000	.57659	.27627	2.6757	.8168	.4770	.2633	.0845
1.100	.58714	.27479	2.6261	.7840	.4352	.2354	.0756
1.200	.59640	.27338	2.5827	.7562	.3994	.2123	.0682
1.300	.60464	.27205	2.5444	.7323	.3684	.1928	.0619
1.400	.61202	.27080	2.5102	.7116	.3414	.1762	.0566
1.500	.61870	.26962	2.4794	.6933	.3175	.1619	.0520
1.600	.62478	.26850	2.4514	.6770	.2963	.1494	.0480
1.700	.63035	.26746	2.4259	.6625	.2774	.1385	.0444
1.800	.63549	.26647	2.4025	.6494	.2604	.1288	.0413
1.900	.64025	.26553	2.3809	.6374	.2450	.1202	.0386
2.000	.64468	.26464	2.3608	.6265	.2311	.1125	.0361

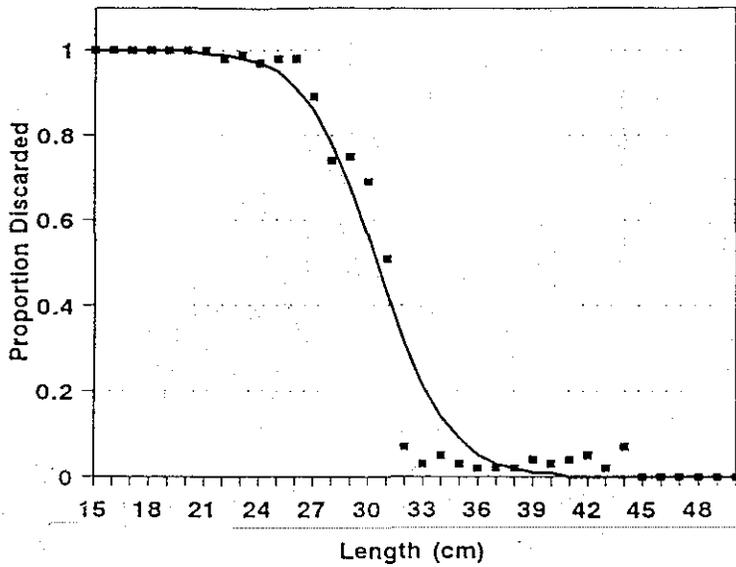


Figure D1. Proportion of winter flounder discarded at length, quarters 1 and 2, as estimated from 1989-1992 sea sampling data; logistic regression smoothing.

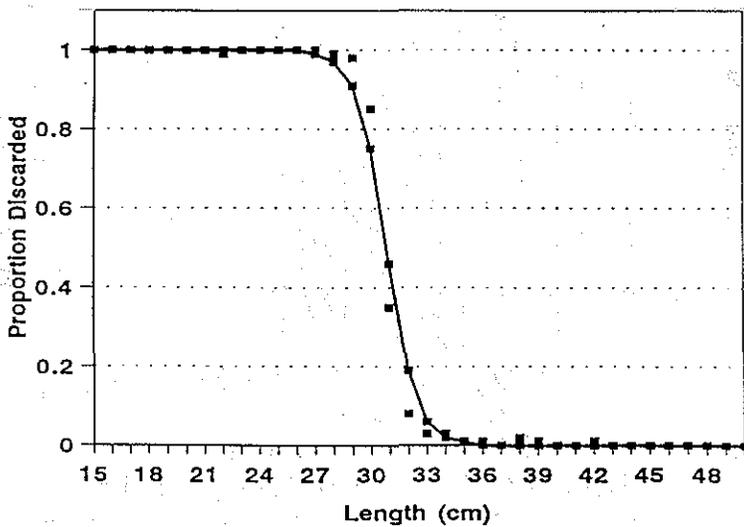


Figure D2. Proportion of winter flounder discarded at length, quarters 3 and 4 as estimated from 1989-1992 sea sampling data; logistic regression smoothing.

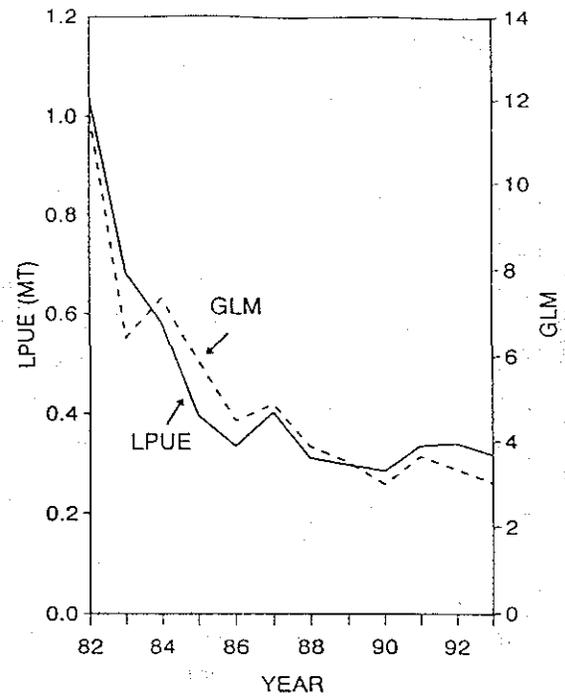


Figure D3. Commercial weighout landings per unit effort of winter flounder from otter trawl trips landing winter flounder, Southern New England/Mid-Atlantic stock complex, 1982-1993: raw LPUE and standardized index of abundance based on retransformed year coefficient, GLM.

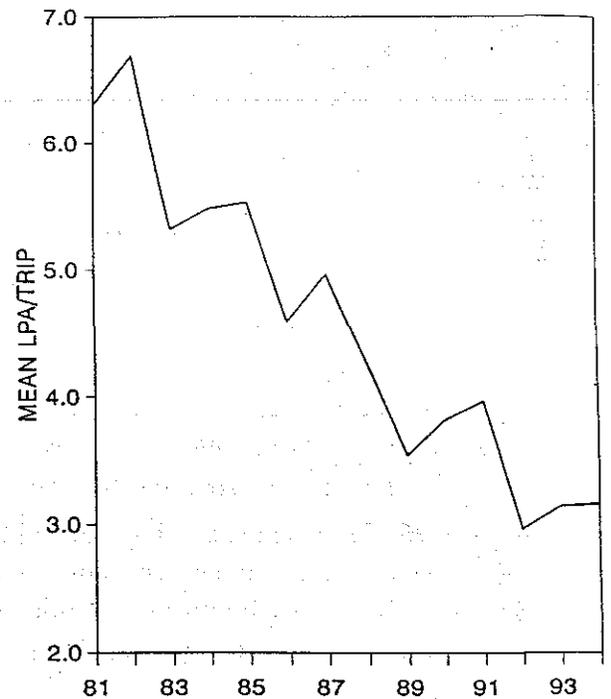


Figure D4. Recreational landings per unit effort of winter flounder as number landed per angler per trip, Southern New England/Mid-Atlantic stock complex, 1981-1994.

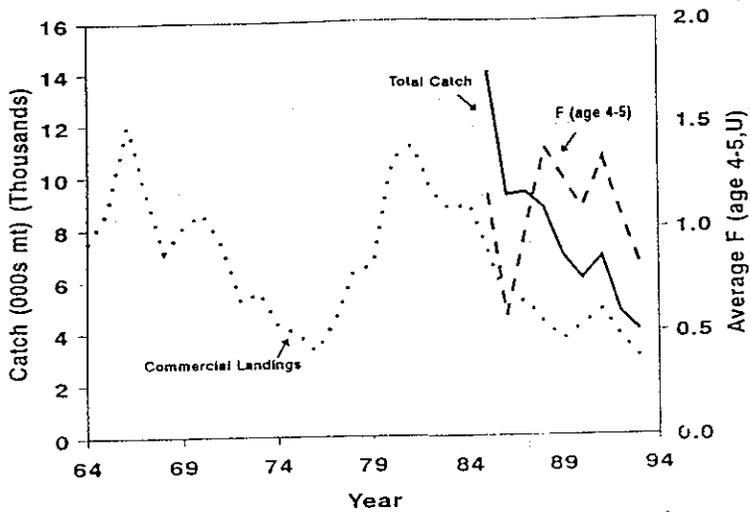


Figure D5. Trends in landings, catch, and fishing mortality rates (unweighted average F at ages 4-5), Southern New England/Mid-Atlantic stock complex of winter flounder, 1964-1993.

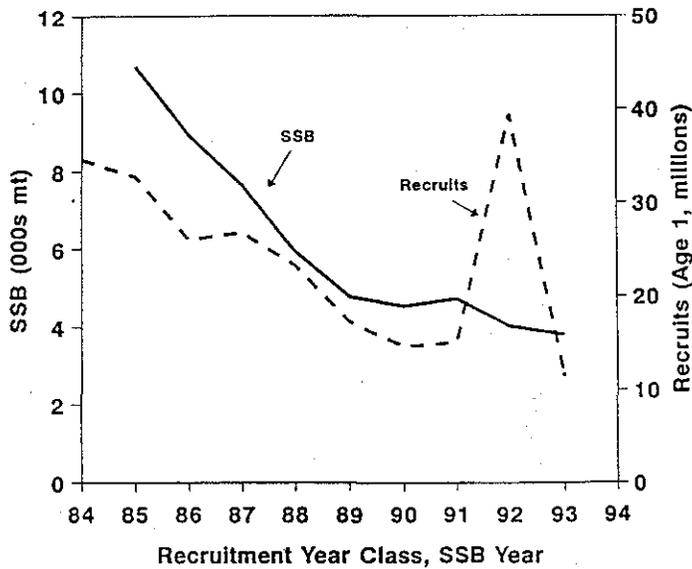


Figure D6. Trends in spawning stock biomass (000 mt) and recruitment (millions age 1), Southern New England/Mid-Atlantic stock complex of winter flounder, 1985-1993.

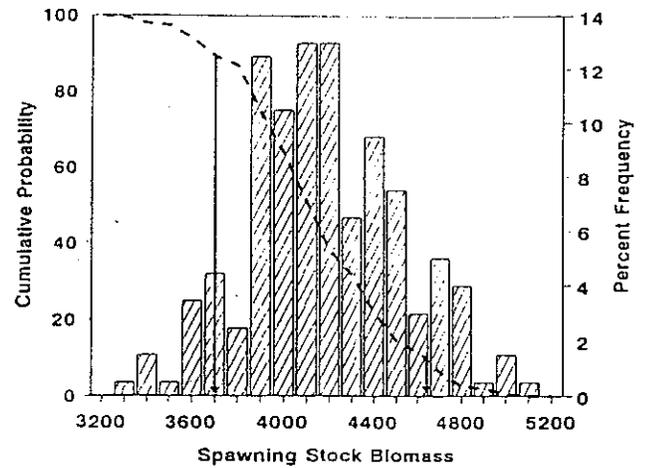


Figure D7. Precision of estimates of spawning stock biomass for Southern New England/Mid-Atlantic stock complex of winter flounder derived from bootstrap procedure. The vertical bars give the range and probability of individual values within that range. The dashed line gives the probability that SSB is less than any selected value on the x-axis.

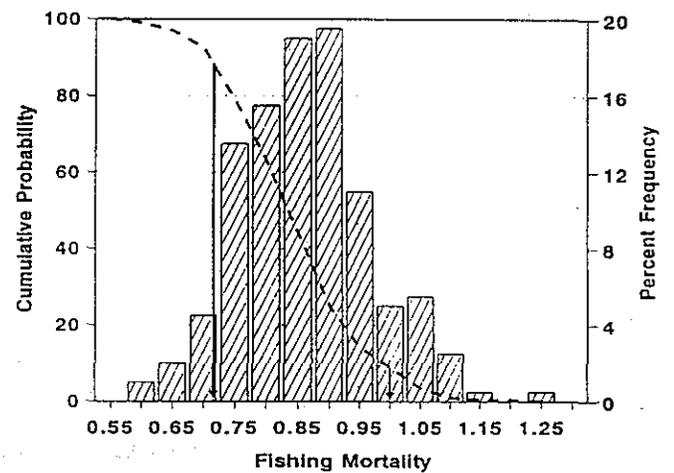


Figure D8. Precision of fishing mortality for Southern New England/Mid-Atlantic stock complex of winter flounder derived from bootstrap procedure. The vertical bars give the range and probability of individual values within that range. The dashed line gives the probability that F is less than any selected value on the x-axis.

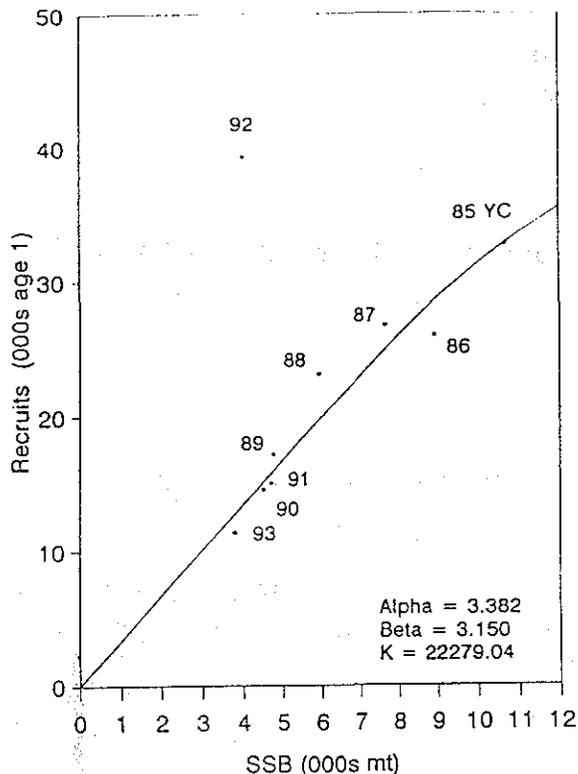


Figure D9. Spawning stock biomass (thousands of metric tons) and recruitment (millions at age 1), southern New England/Mid-Atlantic stock complex of winter flounder, 1985-1993. Points are labelled by year class. Shepherd stock-recruitment curve fitted excluding the 1992 year class: $\alpha=3.382$, $\beta=3.150$, $K=22279.04$.

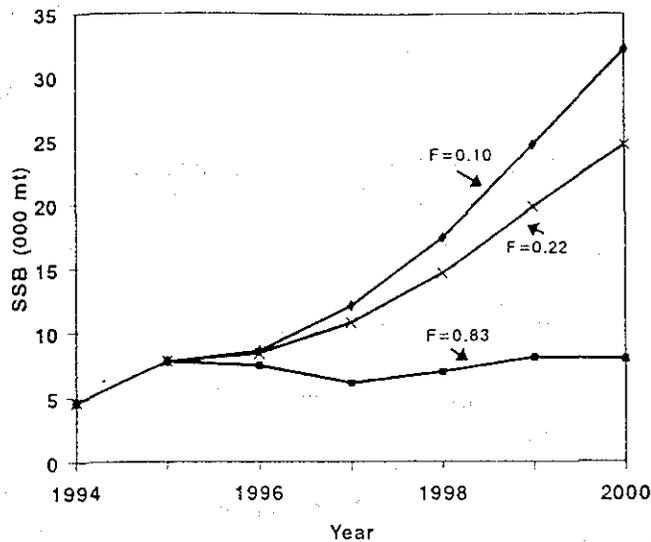


Figure D10. Medium term projections of median spawning stock biomass, Southern New England/Mid-Atlantic stock complex of winter flounder, 1994-2000, assuming $F=0.83$ (status quo), $F=0.22$ ($F_{0.1}$), and $F=0.10$.

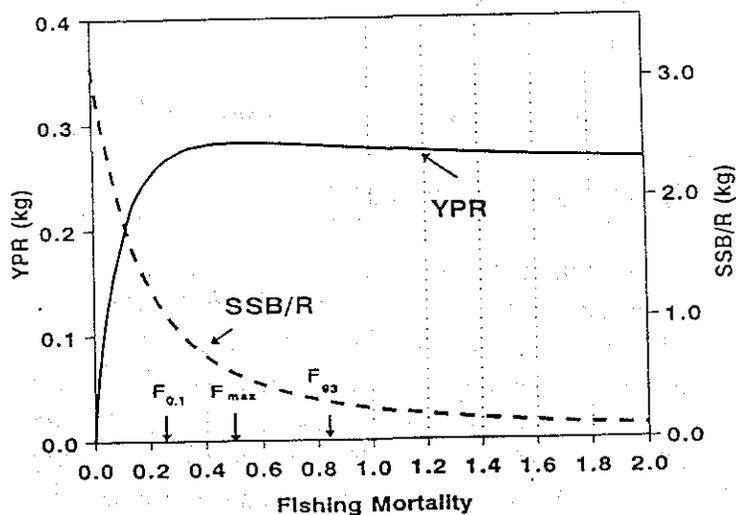


Figure D12. Yield per recruit and spawning stock biomass per recruit of winter flounder in the Southern New England/Mid-Atlantic stock complex.

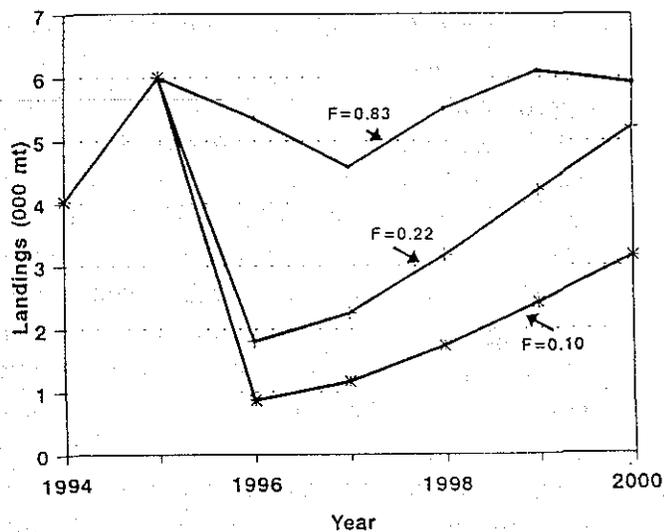


Figure D11. Medium term projections of median landings, Southern New England/Mid-Atlantic stock complex of winter flounder, 1994-2000, assuming $F=0.83$ (status quo), $F=0.22$ ($F_{0.1}$), and $F=0.10$.

WINTER FLOUNDER D2. GULF OF MAINE STOCK

Terms of Reference

The following terms of reference were addressed for the Gulf of Maine stock complex of winter flounder:

- a. Review basis for stock complex definitions.
- b. Summarize landings.
- c. Summarize available indices of stock abundance/biomass based on commercial, recreational and research survey data sources.

Data Sources

Fishery Data

Landings

Gulf of Maine winter flounder are distributed from Cape Cod to Nova Scotia, in estuaries and coastal waters out to 30 fathoms (Bigelow and Schroeder 1953). Annual commercial landings of winter flounder in the Gulf of Maine were approximately 1,000 mt in the 1960s and early 1970s, gradually increased to a maximum of 2,793 mt in 1982, and subsequently decreased to a record low 596 mt in 1993 (Table D13). In a more historical perspective, Bigelow and Schroeder (1953) report that commercial winter flounder landings in the Gulf of Maine were 1,800 mt in 1946. From 1979 to 1989, 13% of commercial landings were taken in state territorial waters, and 87% from the EEZ (Howell et al. 1992, NEFSC 1992). The landings analysis reported by Howell et al. (1992) and NEFSC (1992) involved assumptions concerning the proportion of Massachusetts landings in the Gulf of Maine and are slightly different than the data reported here, which were analyzed by statistical area.

Recreational landings of winter flounder in the Gulf of Maine peaked at 2,330 in 1980, and have since declined to 100 mt. From 1979 to 1989, 75% of recreational Gulf of Maine landings were taken in Massachusetts, 16% in Maine, and 9% in New

Hampshire (Howell et al. 1992). Total landings precipitously declined from 4,767 mt in 1980 to 727 mt in 1993 (Figure D13).

Recreational LPUE

As an index of winter flounder abundance, mean recreational landings per angler per trip from 1981-1994 was calculated as the number of winter flounder landed per all fishing trips. LPUE has declined steadily from a high of 7.09 fish per angler per trip in 1981 to 2.68 fish per angler per trip in 1994 (Figure D14). However, increasing state management restrictions, such as maximum catch limits, has likely affected the catch rate over this period.

Stock Abundance and Biomass Indices

Fishery-Independent Indices

Several bottom trawl surveys measure winter flounder abundance and biomass in the Gulf of Maine (Table D14). The Northeast Fisheries Science Center (NEFSC) has conducted autumn surveys since 1963 and spring surveys since 1968 (Grosslein 1969). NEFSC surveys prior to spring 1979 were not conducted in inshore strata. The Massachusetts Division of Marine Fisheries (MADMF) has operated inshore research surveys in spring and autumn since 1978 (Howe 1989). Normandeau Associates (1994) sampled demersal

fishes at three fixed coastal stations off Hampton Seabrook Harbor, four times each month, since 1976. Although autumn data from the Seabrook survey may be useful, the autumn series may be biased because sampling was sporadic from August to November in recent years due to avoidance of lobster gear. Canada Department of Fisheries and Oceans has conducted summer surveys in the northeast portion of the Gulf of Maine since 1970 (Simon and Comeau 1994).

Research survey indices reflect the pattern in landings: survey catch rates were generally below the time series average in the 1960s and early 1970s, increased to well above average in the late 1970s and early 1980s, and decreased to below average catch rates in recent years (Figures D15 and D16). Synchronous changes in catch rates produced moderate correspondence among abundance and biomass indices. The NEFSC spring indices were significantly correlated with all other survey indices, except the MADMF autumn indices - which were correlated with no other indices (Table D15).

The Canadian survey index for area 4X, which includes stations in the Bay of Fundy, northeast Gulf of Maine, and western Scotian Shelf, showed increasing winter flounder catch rates from the mid 1970s to a peak in 1982 and a subsequent decrease (Simon and Comeau 1994). However, since 1984, 4X indices have dramatically increased to record high catch rates. Survey catches of winter flounder in area 4X are predominantly from the Bay of Fundy, and some are from Browns Bank. Lack of corroboration of recent increases in Canadian survey indices by other Gulf of Maine survey indices suggests that stock structure information from the Bay of Fundy should be reviewed before using the Canadian survey as an index of Gulf of Maine abundance or biomass.

Bottom trawl surveys indicate a gradual truncation in size distribution. Mean individual

weight from the NEFSC spring survey decreased from approximately 0.9 kg in the late 1960s to 0.3 in recent years (Figure D17). Length frequency distributions of NEFSC autumn surveys shows frequent catches of fish larger than 50 cm in early years, and rare catches of fish larger than 40 cm in recent years (Figure D18).

Mortality Estimates

Fishing Mortality

The only information available on age composition of Gulf of Maine winter flounder is from the MADMF spring survey, aged cooperatively by MADMF and NEFSC (Table D16). Estimates of instantaneous fishing mortality were derived as log catch ratios of cohort catch at age minus natural mortality (0.2). From 1978-1993, estimates of fishing mortality fluctuated around a mean of 1.21, which confirms earlier results, and exceeds previously estimated biological reference points ($F_{msy} = 0.60$, $F_{25\% MSP} = 0.79$) (Howell et al. 1992, NEFSC 1992).

Conclusions

Excessive fishing mortality rates indicate that the Gulf of Maine winter flounder stock is overfished. Record low landings, low survey indices, and few large fish in recent years support the conclusion that the stock is overexploited.

SARC Comments

The SARC concurred that the Gulf of Maine winter flounder stock is overexploited. The committee recommended updating the biological reference points when necessary information, such as partial recruitment, becomes available.

Research Recommendations

- o Process archived age samples from NEFSC surveys and commercial landings, and develop an analytical age based assessment.
- o Examine growth variations within the Gulf of Maine, using results from the Gulf of Maine Biological Sampling Survey (1993-1994).
- o Further examine the stock boundaries to determine if Bay of Fundy winter flounder should be included in the Gulf of Maine stock complex.
- o Update biological reference points for this stock complex.

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Table D13. Winter flounder landings (mt) in the Gulf of Maine.

Year	Commercial	Recreational	Total
1964	1081		
1965	665		
1966	785		
1967	803		
1968	864		
1969	975		
1970	1092		
1971	1113		
1972	1085		
1973	1080		
1974	885		
1975	1181		
1976	1465		
1977	2161		
1978	2194		
1979	2021	1389	3410
1980	2437	2330	4767
1981	2406	2586	4992
1982	2793	1823	4616
1983	2096	848	2944
1984	1698	1103	2801
1985	1584	1775	3359
1986	1188	523	1711
1987	1142	1713	2855
1988	1252	559	1811
1989	1267	631	1898
1990	1085	369	1454
1991	981	101	1082
1992	806	93	899
1993	596	131	727

Table D14. Research Trawl Survey indices of biomass and abundance of Gulf of Maine winter flounder, in stratified mean weigh (kg) per tow, number per tow, and average size (kg).

Year	NEFSC Spring			NEFSC Autumn			MADMF Spring			MADMF Autumn			Seabrook Spring
	wt	#	avgwt	wt	#	avgwt	wt	#	avgwt	wt	#	avgwt	#
1963				0.25	0.60	0.41							
1964				0.12	0.17	0.72							
1965				1.16	1.04	1.12							
1966				0.17	0.17	0.95							
1967				0.07	0.08	0.81							
1968	0.54	0.60	0.90	0.32	0.28	1.12							
1969	0.44	0.63	0.70	---	---	---							
1970	0.54	0.57	0.95	0.38	0.36	1.06							
1971	0.32	0.42	0.78	0.13	0.31	0.44							
1972	0.71	1.14	0.62	0.33	0.82	0.40							
1973	0.17	0.36	0.47	0.18	0.32	0.56							
1974	0.24	0.53	0.46	0.63	1.34	0.47							
1975	0.02	0.05	0.41	0.03	0.04	0.85							
1976	0.35	0.50	0.70	0.25	0.36	0.71							1.5
1977	0.63	1.14	0.55	0.81	1.80	0.45							3.6
1978	0.16	0.37	0.45	0.22	0.38	0.59	18.37	86.78	0.21	9.89	43.36	0.23	5.5
1979	0.95	2.65	0.36	0.80	1.84	0.43	14.62	64.93	0.23	28.98	116.07	0.25	6.9
1980	1.91	4.29	0.45	1.95	3.89	0.50	17.49	66.23	0.26	15.94	74.68	0.21	8.9
1981	2.57	6.56	0.39	0.89	1.31	0.68	28.37	100.56	0.28	13.23	47.34	0.28	14.9
1982	0.95	2.34	0.40	0.63	1.53	0.41	14.69	60.68	0.24	23.64	106.05	0.22	5.1
1983	1.79	3.94	0.45	1.09	3.17	0.34	28.51	112.20	0.25	15.77	88.14	0.18	6.3
1984	0.60	1.52	0.40	0.96	2.31	0.42	15.98	66.20	0.24	10.82	35.96	0.30	3.8
1985	0.43	1.04	0.42	0.90	3.16	0.28	13.06	47.81	0.27	7.38	44.56	0.17	2.5
1986	0.30	0.71	0.42	0.29	0.76	0.38	14.96	63.94	0.23	6.60	41.91	0.16	3.8
1987	0.47	1.79	0.26	0.21	0.69	0.31	17.65	82.91	0.21	6.99	48.68	0.14	4.5
1988	0.68	3.23	0.21	0.26	0.76	0.34	10.62	52.70	0.20	9.87	43.14	0.23	3.9
1989	0.37	1.05	0.35	0.59	1.89	0.31	13.32	63.61	0.21	9.28	55.46	0.17	7.2
1990	0.61	1.36	0.45	0.30	0.76	0.40	12.97	74.00	0.18	13.45	67.87	0.20	4.3
1991	0.39	1.04	0.37	0.43	2.07	0.21	11.59	49.22	0.24	15.47	88.77	0.17	5.8
1992	0.36	1.13	0.32	0.81	2.77	0.29	13.94	68.69	0.20	12.43	75.25	0.17	2.1
1993	0.07	0.28	0.27	0.56	2.28	0.25	12.39	79.85	0.16	14.97	92.44	0.16	4.3
1994	0.25	0.88	0.28	0.26	0.82	0.32	10.04	69.39	0.14	13.56	67.35	0.20	2.3

Table D15. Correlations of Gulf of Maine winter flounder research trawl survey indices. (*significant at the 5% level).

Weight per tow

	NEFSC-S	NEFSC-F	MADMF-S	MADMF-F
NEFSC-S	1.00	0.67*	0.77*	0.30
NEFSC-F	0.67*	1.00	0.39	0.28
MADMF-S	0.77*	0.39	1.00	0.03
MADMF-F	0.30	0.28	0.03	1.00

Number per Tow

	NEFSC-S	NEFSC-F	MADMF-S	MADMF-F	Seabrook
NEFSC-S	1.00	0.40*	0.42*	0.05	0.80*
NEFSC-F	0.40*	1.00	0.05	0.31	0.16
MADMF-S	0.42*	0.05	1.00	0.00	0.45
MADMF-F	0.05	0.31	0.00	1.00	0.04
Seabrook	0.80*	0.16	0.45	0.04	1.00

Table D16. Stratified mean number per tow at age of winter flounder from the Massachusetts inshore bottom trawl survey and derived instantaneous mortality.

Year	Survey Number at Age								
	1	2	3	4	5	6	7	8	9+
1978	21.58	23.98	23.39	12.18	3.25	0.91	0.49	0.16	0.84
1979	10.87	21.77	16.84	11.15	2.80	0.68	0.27	0.16	0.39
1980	6.40	19.32	20.21	15.15	3.62	0.81	0.40	0.13	0.19
1981	11.62	24.68	30.27	24.30	6.82	1.58	0.54	0.22	0.53
1982	8.14	19.11	18.65	9.53	3.23	1.00	0.57	0.16	0.29
1983	15.13	25.87	41.03	21.01	5.69	1.47	0.90	0.46	0.64
1984	5.65	21.72	22.24	11.15	3.54	0.97	0.38	0.17	0.38
1985	9.01	8.33	14.36	11.28	3.19	0.88	0.41	0.17	0.18
1986	10.78	18.73	24.06	8.26	1.65	0.27	0.07	0.05	0.07
1987	15.30	20.18	28.50	14.67	2.82	0.68	0.37	0.16	0.23
1988	8.74	17.12	17.17	7.80	1.31	0.27	0.11	0.05	0.13
1989	10.35	22.76	16.78	9.44	2.97	0.60	0.25	0.16	0.30
1990	14.27	18.33	27.47	10.04	2.04	1.35	0.34	0.02	0.14
1991	4.82	19.21	13.00	7.84	3.17	0.50	0.24	0.17	0.27
1992	14.55	32.12	12.31	6.70	1.97	0.69	0.16	0.07	0.12
1993	17.86	37.10	15.09	6.46	2.03	1.09	0.15	0.00	0.07
1994	12.00	36.11	15.44	4.66	0.79	0.12	0.17	0.08	0.02

Year	Instantaneous Mortality				Fishing Mortality			
	Age				Wt.			
	4	5	6	7	Mean	Mean	Mean	Mean
1978	1.47	1.56	1.22	1.12	1.34	1.46	1.14	1.26
1979	1.12	1.24	0.53	0.73	0.91	1.11	0.71	0.91
1980	0.80	0.83	0.41	0.60	0.66	0.78	0.46	0.58
1981	2.02	1.92	1.02	1.22	1.54	1.94	1.34	1.74
1982	0.52	0.79	0.11	0.21	0.41	0.54	0.21	0.34
1983	1.78	1.77	1.35	1.67	1.64	1.75	1.44	1.55
1984	1.25	1.39	0.86	0.80	1.08	1.25	0.88	1.87
1985	1.92	2.47	2.53	2.10	2.26	2.07	2.06	1.84
1986	1.07	0.89	*	*	0.98	1.04	0.78	0.79
1987	2.42	2.35	1.82	2.00	2.15	2.38	1.95	2.18
1988	0.97	0.78	0.08	*	0.61	0.91	0.41	0.71
1989	1.53	0.79	0.57	2.53	1.35	1.34	1.15	1.14
1990	1.15	1.41	1.73	0.69	1.24	1.24	1.04	1.04
1991	1.38	1.52	1.14	1.23	1.32	1.41	1.12	1.21
1992	1.19	0.59	1.53	**	1.10	1.09	0.90	0.89
1993	2.10	2.83	1.86	0.63	1.85	2.20	1.65	2.00
Mean	1.42	1.45	1.12	1.19	1.28	1.41	1.08	1.21

* negative estimate

** no age-8 catch in 1993

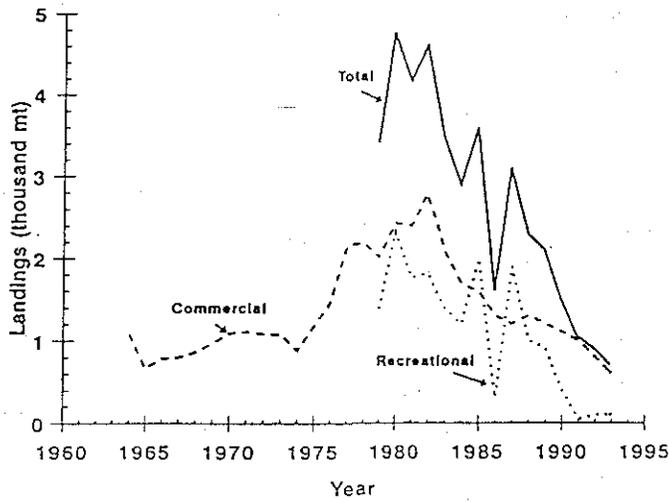


Figure D13. Winter flounder landings in the Gulf of Maine.

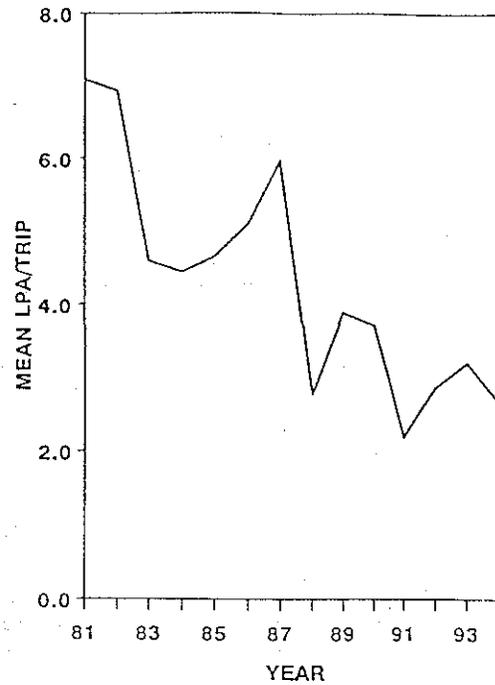


Figure D14. Winter flounder recreational landings per angler per trip from Gulf of Maine, 1981-1994.

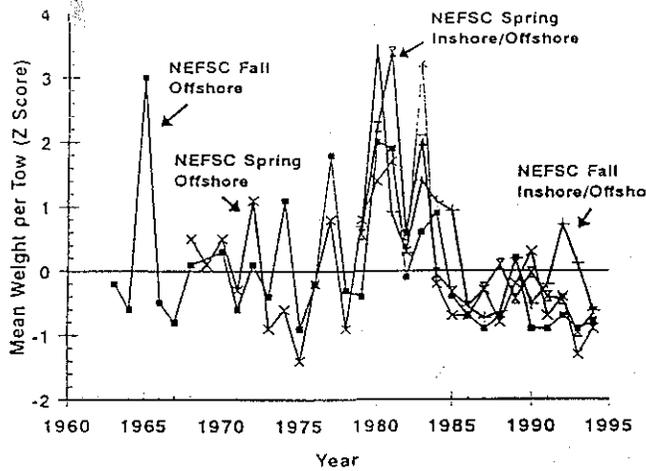


Figure D15. Standardized Research Trawl indices of Gulf of Maine winter flounder biomass.

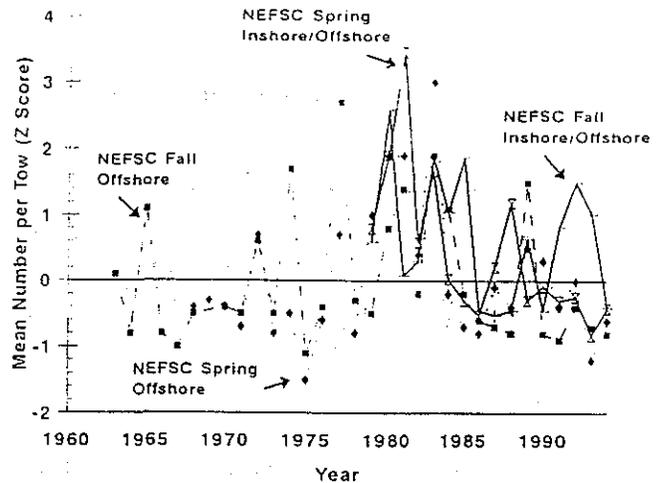
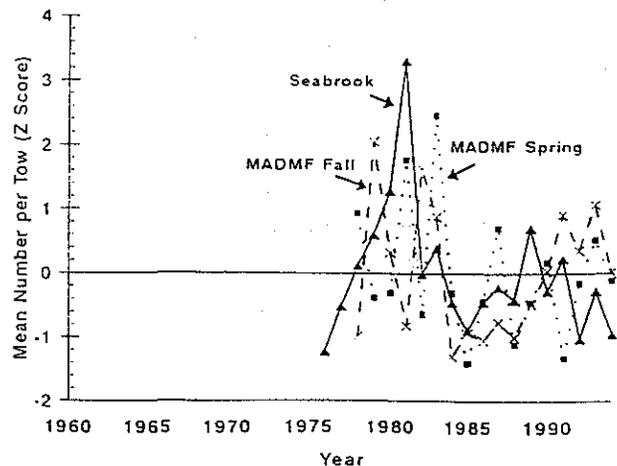
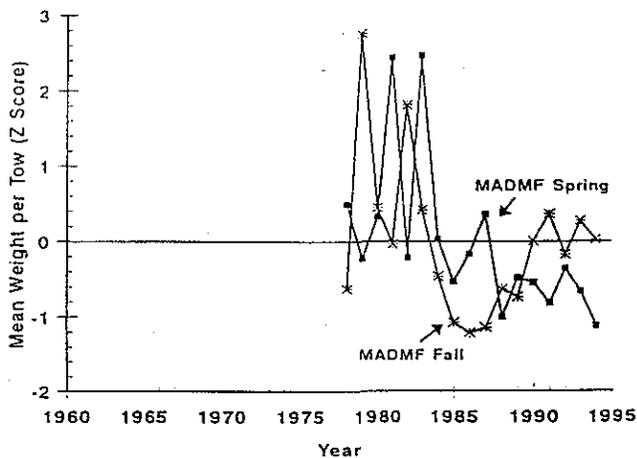


Figure D16. Standardized research trawl indices of Gulf of Maine winter flounder abundance.



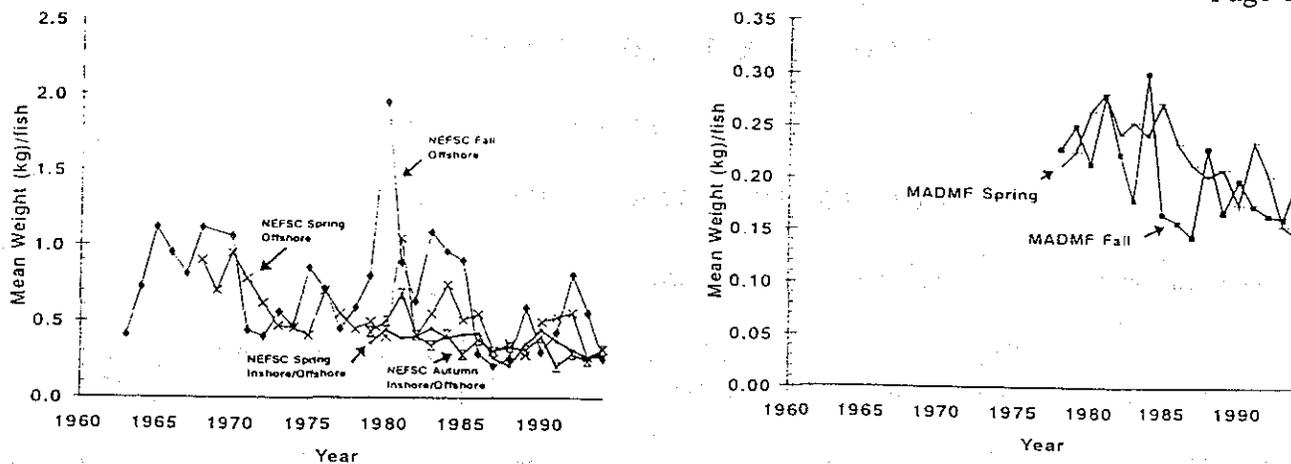


Figure D17. Research trawl indices of Gulf of Maine winter flounder average size.

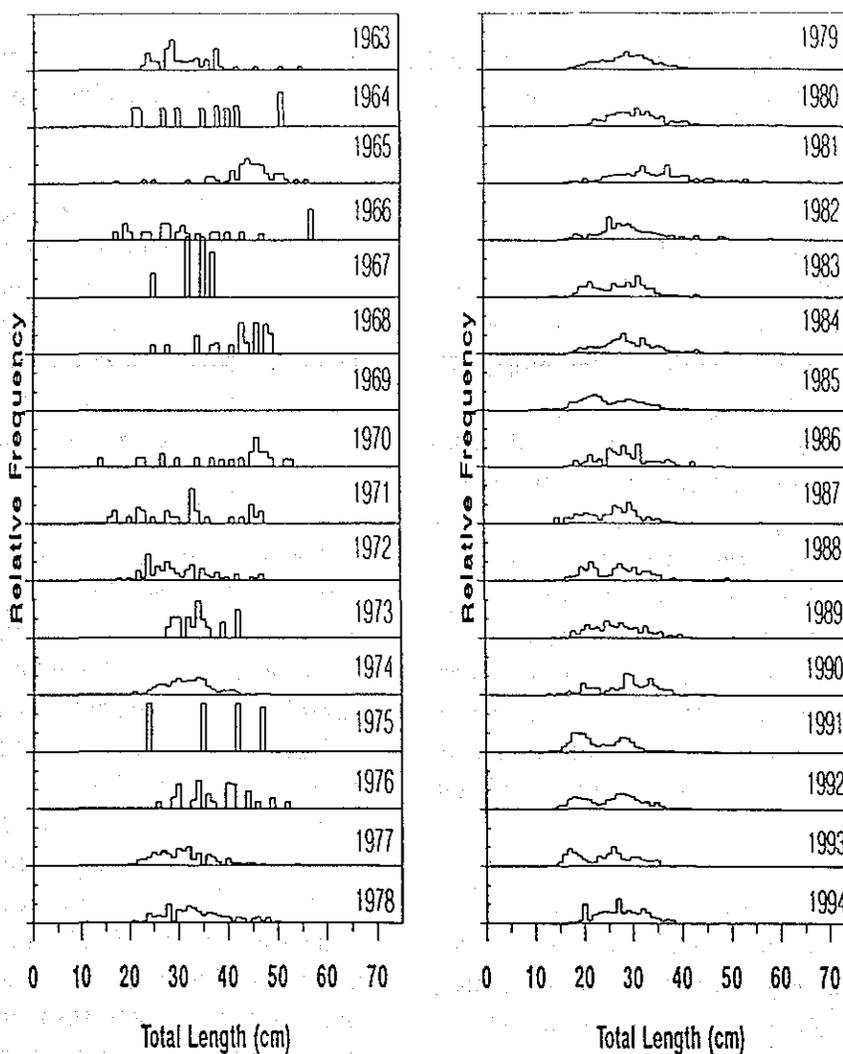


Figure D18. Length frequency distributions of Gulf of Maine winter flounder from NEFSC autumn survey.

E. NORTHEAST DEMERSAL COMPLEX

Terms of Reference

SAW-21 SPECIES TERMS OF REFERENCE

The following terms of reference were addressed:

- a. Provide current indices of abundance and biomass for individual stocks comprising the Northeast Demersal Complexes, especially the 10 regulated species in the Northeast Multispecies FMP;
- b. Provide an analysis of temporal and spatial trends in the distribution of species comprising the Northeast Demersal Complexes;
- c. Evaluate methods of forecasting spawning stock biomass, based upon historical relationships between research vessel survey data and virtual population estimates (including extending time-series backward to include years not used in analytical assessments);
- d. Evaluate the by-catch implications of the multispecies trawl and fixed gear fisheries for Northeast groundfish on the ability to meet fishing mortality rate (F) goals for individual species/stocks.

Background

The SARC discussed the list of species to include in the Northeast Demersal Complex and agreed that the species of primary importance are the 10 regulated (large mesh) species in the Northeast Multispecies Fishery Management Plan, i.e., cod, haddock, pollock, redfish, white hake, yellowtail flounder, American plaice, witch flounder, winter flounder, and windowpane flounder. The three remaining (small mesh) species in the Plan silver hake, red hake, and ocean pout are considered secondary in importance. The SARC agreed that three additional species, often taken in the Northeast demersal fishery, should also be considered: wolfish, cusk, and goosefish. The total number of species included in the analysis of temporal and spatial trends equals 16.

The SARC also considered how best to derive aggregate indices for the above species. It was agreed that 4 aggregate groupings could reasonably satisfy the requirements from both a management and a biological perspective. The 4 groups are:

- Group 1: Principal groundfish -- cod, haddock, pollock, white hake, redfish;
- Group 2: Flatfish -- yellowtail flounder, American plaice, witch flounder, winter flounder, windowpane flounder;
- Group 3: Small mesh groundfish -- silver hake, red hake, ocean pout;
- Group 4: Other groundfish -- wolfish, cusk, goosefish

Results presented in this report rely heavily on National Marine Fisheries Service, Northeast Fisheries Science Center (NEFSC) and Commonwealth of Massachusetts/DMF (MADMF) research vessel bottom trawl surveys. Stratification designs for these surveys are illustrated in Figures 2 and E2.1 through E2.3, and a description of gear and vessels employed is provided in the next section of this report. In addition to compiling a summary of recent and historic temporal and spatial trends for these species, the SARC reviewed several studies examining factors related to changing distribution patterns and explored some quantitative approaches examining depth and temperature "preference" and

extent of habitat occupation. The SARC agreed that relationships between VPA-derived spawning stock biomass estimates and indices of spawning biomass based on (NEFSC) bottom trawl surveys would be examined for key stocks. The remainder of this report summarizes the results of these studies and is presented in several sections.

Section II presents information on temporal trends for the 16 species comprising the Northeast Demersal Complex, individually and in aggregate form. Changes in spatial patterns are also examined via a series of distribution plots for select stocks grouped in 5-year time blocks. Information from National Marine Fisheries Service NEFSC inshore and offshore surveys spanning the period 1963-1995 and from Commonwealth of Massachusetts DMF inshore surveys covering the period 1978-1995 are presented.

Section III presents an investigation of a habitat association index based on catch weighted mean depth and temperature as described by Perry and Smith (1994). The influence of temperature and depth on the distribution of cod, haddock and yellowtail flounder based on NEFSC spring and autumn bottom trawl surveys was examined. The objective was to identify associations between the range of available temperature and depth measurements over the survey area and the temperature and depth at which these species were caught, and to test whether these were statistically different by year, thereby evaluating annual and seasonal influences of temperature and depth on the distribution of these groundfish species. Complete results are given in Helser and Brodziak (1996).

Section IV describes the use of a General Additive Model (GAM) to quantify the effects of temperature and depth on the distribution of haddock, and to use these covariates to smooth the empirical spatial distributions. This approach has been successfully applied to Pacific groundfish stocks by Swartzman *et al.* (1992). A GAM is a generalization of a linear model whereby the usual linear function of a

covariate is replaced with an unspecified smooth function. The model, which is currently implemented as part of SPLUS, also provides smoothed contour plots of the fitted distribution. The GAM technique was applied to haddock data collected on NEFSC offshore autumn research vessel survey data between 1963 and 1994. Detailed results are provided in O'Brien (1996).

Section V explores the use of a Lorenz curve and associated Gini index to examine the extent of species concentration over time as described by Myers and Cadigan (1995) and Myers *et al.* (1995). This approach quantifies the concentration effect by relating cumulative biomass to corresponding cumulative area, and is applied annually to NEFSC autumn bottom trawl survey data on a stratum basis for haddock over the period 1964-1994. When plotted, the Lorenz curve is concave with respect to the identity function and the area between the curve and the identity function is proportional to the degree of concentration of the species. Further results are provided in Wigley (1996).

Section VI applies methods relating VPA-based SSB estimates to a survey index of SSB using Georges Bank and Gulf of Maine cod. The intent is to develop methods of estimating SSB from bottom trawl survey data. The general approach was to estimate a series of mean weight per tow indices of mature fish from NEFSC bottom trawl surveys, reduce sampling error through time series modeling, and quantify the relationship between survey observations and VPA estimates. Two stocks of Atlantic cod were used to explore estimation methods. More detailed analyses are provided in Cadrin and Mayo (1996).

Section VII provides a summary of results and a comparative evaluation of the various methods described in this report for providing additional perspective on changes in survey indices versus changes in population status. SARC comments and recommendations are also included in this section.

II - Temporal and Spatial Trends for 16 Species and 4 Aggregate Groups

Methods

The NEFSC offshore bottom trawl survey has been conducted since the autumn of 1963 and the spring of 1968 (Azarovitz 1981). The addition of inshore stations occurred in the autumn of 1972 and the spring of 1973 from Southern New England to Cape Hatteras, and in 1979 for the Gulf of Maine. Sampling is based on a stratified random sampling design using area and depth strata (Figures 2, E2.1 and E2.2). During each survey, between 300 and 600 sampling stations are assigned to strata in proportion to stratum area. Standard tows are 30 minutes at 3.5 knots.

Several gear changes have occurred in the 33 years of the NEFSC bottom trawl survey. In 1985, Portuguese polyvalent doors replaced the BMV oval doors used since 1963. Two vessels have performed the survey, and from 1972 through 1981 in the spring, a 41' Yankee net was used instead of the standard 36' Yankee. Conversion factors for vessel and door (NEFSC 1991) and gear (Sissenwine and Bowman 1978) changes have been calculated for some species.

Massachusetts inshore bottom trawl surveys have been conducted since 1978 in spring and autumn (Howe 1989). Sampling is based on a stratified random design using five geographic regions and depth strata (Figure E2.3). During each survey, approximately 100 sampling stations are allocated to strata in proportion to stratum area. Standard tows are 20 minutes at 2.5 knots. The sampling gear consists of a 3/4 North Atlantic type two seam ('whiting') otter trawl.

Stock-Based Indices

Biomass (stratified mean weight per tow) and abundance (number per tow) indices were estimated for each stock (Cochran 1977). Where available,

indices were taken from published assessment documents; when necessary, all indices have been brought up-to-date through autumn 1994 and spring 1995. Table E2.1 lists the strata sets used for each index and provides an indication if vessel and door conversion factors were applied to the NEFSC survey indices.

Georges Bank cod have shown a steady decline in both biomass and abundance since the 1970s following an initial increase in the late 1960s (Figure E2.4; Serchuk *et al.* 1994). Current abundance and biomass of Georges Bank cod remains at or near record-low levels. This decline is also evident in the distribution of cod on Georges Bank both in the autumn and in the spring.

Biomass and abundance indices for **Gulf of Maine cod** in the NEFSC autumn survey have declined since the early 1980s following a ten-year period of relatively stable levels (Figure E2.4; Mayo 1995). Current abundance and biomass remains at or near record-low levels. The distribution of cod in the Gulf of Maine reveals highest biomass levels in inshore waters. Biomass of cod in the MADMF spring survey decreased throughout the time series despite large numbers in survey catches in 1989 and 1990 (Figure E2.4). The MADMF survey is considered to be a useful index of prerecruit cod abundance, and the majority of Gulf of Maine cod sampled by the inshore MADMF survey were caught in Massachusetts Bay at stations greater than 15 m.

Georges Bank haddock abundance and biomass declined rapidly from very high levels due to large year classes from the mid-1960s, increased in the 1970s following recruitment of relatively large year classes, but have since remained at a low level (Figure E2.4; O'Brien and Brown 1995). Current abundance and biomass have increased slightly in recent years, but remain well below historic levels. Not only has abundance declined over the long-term, but haddock appear to have become concentrated on the Northeast peak since the early 1980s.

Gulf of Maine haddock indices were recalculated using vessel and door conversion factors. Abundance and biomass have followed similar trends with a sharp decline in the 1960s followed by a subsequent increase in the late 1970s (Figure E2.4). A steady decrease has since occurred, and both abundance and biomass have fluctuated at extremely low levels since the mid-1980s and are presently at historic lows. MADMF indices of haddock abundance and biomass have also decreased (Figure E2.4). Inshore autumn MADMF indices for Gulf of Maine haddock have been used as recruitment indicators (NEFC 1986), but few haddock have been caught in recent MADMF autumn surveys, suggesting that the Massachusetts survey may no longer measure haddock recruitment adequately.

NEFSC **pollock** biomass and abundance indices declined sharply following a peak in the mid-1970s and currently remain among the lowest levels detected (Figure E2.5). The MADMF spring index of pollock abundance, which has also declined (Figure E2.5), has been used as a recruitment indicator (Mayo and Figuerido 1993). The majority of pollock caught by the MADMF survey were in Massachusetts Bay in the spring.

NEFSC biomass and abundance indices for **redfish** declined steadily from 1963 through 1982 (Figure E2.5; Mayo 1993). Since 1982 there has been a slight increasing trend. MADMF redfish indices have fluctuated without trend (Figure E2.5) but appear to detect relatively abundant year classes. The inshore survey may not adequately sample redfish for stock assessment purposes. The MADMF survey catches of redfish occur in deep waters of Massachusetts Bay.

Biomass and abundance indices for **white hake** from the NEFSC survey increased in the 1960s and fluctuated without trend throughout the 1970s (Figure E2.; Sosebee *et al.* 1995). During the remainder of the time series, the indices have continued to fluctuate without trend but at a slightly lower level than in the 1970s. White hake are

caught in shallower waters in the autumn, when young of the year are found in inshore areas. In the spring, white hake are located in deeper waters of the Gulf of Maine and off the southern slope of Georges Bank. MADMF white hake abundance and biomass indices have decreased (Figure E2.5). Most white hake caught by the Massachusetts survey were in Cape Cod and Massachusetts Bays in the fall.

Georges Bank yellowtail flounder exhibited a sharp but steady decline throughout the 1960s and 1970s. Both indices increased temporarily in 1980 and 1981 but have since declined (Figure E2.6; Rago *et al.* 1994). Since 1984, these indices have fluctuated without trend and currently remain at or near record-low levels.

Southern New England yellowtail flounder indices fluctuated without trend through the 1960s but declined precipitously in the early 1970s. An increase occurred in the late 1970s and early 1980s but the indices subsequently declined and currently remain among the lowest in the survey series (Figure E2.6; Rago *et al.* 1993). Spring MADMF abundance indices also declined (Figure E2.6) but Southern New England yellowtail flounder are rarely caught by the MADMF survey, and were entirely absent for years.

Abundance and biomass indices for **Cape Cod yellowtail flounder** (Lux 1961) decreased in the early 1960s (Figure E2.6). An increase in the early 1970s was followed by a steady decline beginning in the late 1970s; both indices have since fluctuated at low levels throughout the 1980s and 1990s. MADMF spring biomass and abundance indices for Cape Cod yellowtail flounder have also decreased since 1978, but there has been no evident change since 1987 (Figure E2.6). Yellowtail flounder in the Cape Cod group are generally caught at stations greater than 10 m by the inshore survey.

American plaice NEFSC survey indices declined from the 1960s through the early 1970s (Figure E2.6; O'Brien *et al.* 1992). A period of high relative abundance followed until the early 1980s

when abundance again began to decline. This decline continued throughout the 1980s reaching a low in 1987. Since that time there has been a generally increasing trend in both indices due to improved recruitment. Spring MADMF inshore indices increased in the early part of the time-series and have since shown a slight decline (Figure E2.6). Gulf of Maine American plaice are frequently caught by the MADMF survey at stations greater than 30 m.

Witch flounder indices have been variable but have exhibited an overall decline throughout most of the NEFSC survey series, reaching a record-low level in the late 1980s; both indices remained low until very recently (Figure E2.7; Wigley and Mayo 1994). MADMF biomass and abundance indices have steadily decreased since 1978 and currently remain among the lowest on record (Figure E2.7). Most witch flounder sampled by the inshore survey in the Gulf of Maine are caught in Massachusetts Bay at stations greater than 20 m.

Georges Bank winter flounder abundance and biomass indices fluctuated without trend until the late 1970s when biomass began to steadily decline while abundance continued to fluctuate in response to apparent variability in recruitment. However, both indices reached record-low levels in 1991 and currently remain at or near historic lows (Figure E2.7).

Gulf of Maine winter flounder indices fluctuated at low levels from the 1960s through the mid-1970s (Figure E2.7). An increase occurred in 1979 when Cape Cod Bay was first sampled by the NEFSC survey. These indices have since fluctuated although an overall decrease in biomass is evident. MADMF spring biomass indices have also decreased since 1983 (Figure E2.7).

Southern New England to Mid-Atlantic winter flounder abundance and biomass indices decreased during the 1960s to a low in the early 1970s (Figure E2.7). A short period of increasing abundance and biomass occurred until 1980 when

there was a rapid decline in both indices. Since that time these indices have fluctuated without trend at or near record-low levels except for slight increases in 1992 and 1994. MADMF inshore spring indices of southern New England abundance and biomass have also declined throughout the 1980s, although the indices increased after 1991 (Figure E2.7). Most southern New England winter flounder are caught at depths greater than 10 m in MADMF surveys.

Gulf of Maine - Georges Bank windowpane flounder indices increased from the early part of the time series through the early 1970s (Figure E2.8). Subsequently, both indices fluctuated without trend until the mid-1980s when a steady decline began to occur. Current indices are among the lowest on record.

Southern New England - Mid-Atlantic windowpane flounder indices exhibited a different pattern, decreasing in the early part of the time series and remaining at relatively low levels until the present (Figure E2.8). Current indices are among the lowest in the series.

MADMF indices of biomass and abundance for windowpane flounder for the entire area decreased steadily between 1982 and 1991, but spring abundance and biomass indices have since increased (Figure E2.8). The majority of windowpane flounder sampled by the inshore survey are caught in the spring at stations less than 15 m in depth.

Gulf of Maine - Northern Georges Bank silver hake indices declined sharply in the early 1960s but have generally increased since the late 1960s (Figure E2.9; Helser and Mayo 1994). Abundance indices have increased more dramatically than corresponding biomass indices, suggesting a decrease in overall mean weight of the stock.

Southern Georges Bank - Mid-Atlantic silver hake indices also decreased in the early part of the time series, fluctuated without trend from the 1970s to the mid-1980s, but have generally decreased since 1985 (Figure E2.9).

MADMF inshore biomass and abundance indices for silver hake have fluctuated without trend (Figure E2.9). Most silver hake sampled by the Massachusetts survey are caught at stations greater than 10 m in spring and are found throughout the Gulf of Maine in autumn.

The trend in the **Gulf of Maine - Northern Georges Bank red hake** stock resembles that of the northern stock of silver hake except that biomass has continued to increase at the same rate as abundance, indicating a relatively constant mean weight in the stock (Figure E2.9).

Southern Georges Bank - Mid-Atlantic red hake indices also followed a pattern similar to the southern stock of silver hake (Figure E2.9). Following a decline in abundance and biomass in the 1960s, the 1970s represented a period of relative stability as both biomass and abundance indices fluctuated without trend. In the mid-1980s a slight decline occurred and the indices are now fluctuating without trend at a lower level.

MADMF spring indices of biomass and abundance for all red hake also decreased (Figure E2.9). The majority of red hake sampled by the inshore survey are caught at stations greater than 10 m in spring and greater than 15 m in autumn.

The spring biomass and abundance indices of **ocean pout** declined in the early part of the time-series until the mid-1970s when a sharp increase occurred (Figure E2.10). In the mid-1980s, however, a decline began that has since continued. Current levels of abundance and biomass are among the lowest on record. The NEFSC survey does not sample ocean pout well in the autumn and, therefore, the spring survey is used to characterize trends in abundance. MADMF abundance indices from spring surveys also decreased sharply during the mid-1980s and continue to remain low (Figure E2.10). Most ocean pout in the Massachusetts survey are caught in the spring, predominantly in Cape Cod and Massachusetts Bays, at stations greater than 15 m.

Wolffish abundance and biomass indices fluctuated without trend until the 1980s when they declined precipitously, and currently remain at or near record-low levels (Figure E2.10). MADMF spring biomass and abundance indices are more variable but indicate the same sharp decline (Figure E2.10). The Massachusetts survey catches wolffish primarily in the spring in deep waters of Massachusetts Bay.

Goosefish biomass and abundance indices fluctuated without trend throughout most of the time series (Figure E2.10). Recently there has been a decline in the biomass index but an increasing trend in abundance, signifying a decline in the mean weight of the stock. MADMF biomass and abundance indices have generally decreased, except for the autumn abundance index, which increased (Figure E2.10). Goosefish are caught in almost all Massachusetts survey strata in spring and most are caught at stations greater than 15 m in depth in autumn.

Cusk indices have fluctuated greatly but abundance and biomass indices have exhibited a steady decline since 1985, and both indices currently remain at or near record-low levels (Figure E2.10). Cusk is not sampled by the MADMF inshore survey.

Aggregate Indices

Abundance and biomass indices were calculated for four aggregate groups: principal groundfish (cod, haddock, pollock, redfish, and white hake), flatfish (yellowtail flounder, American plaice, witch flounder, winter flounder, and windowpane flounder), small-mesh groundfish (silver hake, red hake, and ocean pout), and other groundfish (wolffish, goosefish, and cusk) in three areas: Gulf of Maine (strata 01260-01300, 01360-01400), Georges Bank (strata 01130-01250), and Southern New England (strata 01010-01120) for both seasons of the NEFSC survey (Figure 2).

Gulf of Maine

Abundance and biomass of the **principal groundfish** has declined steadily over the time series in both the spring and the autumn (Figures E2.11 and E2.12). These indices were dominated mostly by haddock and redfish at the beginning of the time series; by pollock, cod and white hake during the 1970s; and mostly by white hake in the later part of the time series. As a result of the shift in species composition from cod and haddock to white hake and, to a lesser extent, redfish during the 1980s, the aggregate biomass index for this group has stabilized at a record-low level and the aggregate abundance index has increased slightly in recent years.

The Gulf of Maine **flatfish** indices (Figures E2.11 and E2.12), dominated by American plaice and witch flounder, decreased in the early 1960s and increased in the 1970s. Both indices declined sharply in the early 1980s and have remained relatively low through 1994. The abundance index, however, has fluctuated sharply since 1985, particularly in the autumn, in response to apparent variability in recruitment. The deviation between the trend in biomass and abundance implies a sharp reduction in mean weight of this group in recent years.

The autumn biomass and abundance indices for **small-mesh groundfish** show a similar pattern to silver and red hake, since they are dominated by these two species (Figures E2.11 and E2.12). Both indices have fluctuated considerably since 1980, but indicate a general increase in both abundance and biomass for this group.

The spring indices for **other groundfish** in the Gulf of Maine show an increase in the early part of the time series to a high level in the mid-1970s (Figure E2.11). In the early 1980s, a sharp decrease occurred in both biomass and abundance. Biomass has since continued to decline while abundance has remained constant. The autumn indices fluctuated without trend for most of the time series (Figure E2.12) until the mid-1980s when a decline in

biomass and an increase in abundance occurred. This group of species is dominated by goosefish but also reflects the declines noted earlier for wolffish and cusk beginning in the mid-1980s.

Georges Bank

Abundance and biomass indices for **principal groundfish** on Georges Bank show similar patterns in both seasons (Figures E2.13 and E2.14). This group has been dominated by cod and haddock throughout the survey period. The spring indices are highly variable, but the autumn indices reveal a consistent pattern of increased abundance and biomass during the late 1970s, followed by sharp declines in both indices to historic low levels during the mid-1980s. An increase and subsequent decline in biomass during the late 1980s reflects recruitment of several low to moderate year classes of cod and haddock on Georges Bank during the 1980s. Current levels of abundance and biomass remain at or near record-lows.

Indices for **flatfish** on Georges Bank have fluctuated considerably over the survey period but reveal consistent declines in abundance and biomass (Figures E2.13 and E2.14). This group is dominated by yellowtail flounder and winter flounder. Much of the variability in the abundance index is due to fluctuations in winter flounder recruitment, but both species have experienced consistent declines in both indices since late 1970s or early 1980s. Both indices are currently at or near historic lows with respect to the autumn series, and the recent increases in the spring indices reflect slightly higher catches of yellowtail flounder on the Southeast part of Georges Bank in 1994 and 1995.

Both indices for **small-mesh groundfish** fluctuate considerably without any distinct trends throughout both spring and autumn series (Figures E2.13 and E2.14). These indices reflect trends in both stocks of silver hake and red hake throughout Georges Bank. As a result, the aggregate indices are not likely to depict consistent trends for either of the stocks.

Abundance and biomass indices for **other fish** on from both spring and autumn surveys on Georges Bank display similar patterns (Figures E2.13 and E2.14). This group is dominated by goosefish in this region and the aggregate indices reflect the recent decline in mean weight of this stock. Both surveys indicate that current biomass for this group on Georges Bank is at or near record-low levels.

Southern New England

Spring indices for **principal groundfish** off Southern New England are highly variable, but indicate a general decline in abundance and biomass throughout the survey period (Figure E2.15). The autumn survey also fluctuates but reveals more consistent declines during the 1960s and 1970s (Figure E2.16). However, the trend in abundance has been affected by the one large index value in 1987, caused by three very large tows of small haddock. Species in this group are at the southern end of their geographic range and, therefore, occur more sporadically in survey catches.

Indices for **flatfish** are dominated primarily by yellowtail flounder and reflect the overall trend for this species. Abundance and biomass declined sharply in the early 1970s, increased during the late 1970s and early 1980s due to improved recruitment, but have since declined to historic low levels (Figures E2.15 and E2.16). The slight increase in the aggregate index in 1994 (autumn) and 1995 (spring) is due to increases in the winter flounder and windowpane flounder indices.

Spring and the autumn indices for **small-mesh groundfish** are highly variable (Figures E2.15 and E2.16), reflecting trends in the southern stocks of red and silver hake. The sharp but consistent decline in spring abundance and biomass reflects overall trends for ocean pout.

Abundance and biomass indices from spring surveys for **other groundfish** suggest a sharp decline since the 1970s (Figures E2.15 and E2.16). The large increase in both indices in 1981 is due to

variability in the goosefish indices. Current abundance and biomass for this group off Southern New England remains among the lowest on record.

Stratified mean weight per tow of principal groundfish (cod, haddock, and white hake), flatfish (yellowtail flounder, American plaice, witch flounder, winter flounder, and windowpane flounder) and small-mesh groundfish (silver hake, red hake, and ocean pout) were derived for the entire Massachusetts inshore strata set (Figure E2.17). MADMF spring biomass indices for each species group declined, and the inshore autumn index for wolffish and goosefish declined. The MADMF principal groundfish index reflects the MADMF cod index (Figure E2.4), because the inshore catch is dominated by cod. Similarly, the other groundfish inshore indices are dominated by goosefish and ocean pout, respectively.

Subcommittee Comments

Of the 25 stocks examined, only two have shown a consistent increase in abundance and biomass in the NEFSC surveys over the survey period. Five stocks have been fluctuating without trend. However, 18 stocks (72%) have been declining throughout most of the period. This is a cause for concern, since some of these stocks such as cusk, wolffish, and ocean pout are considered to be "under-utilized".

The Subcommittee noted that several indices for individual species, as well as aggregate groups, exhibited considerable inter-annual variability. Variability in non-standardized survey indices is relatively common, particularly when stocks are at very low abundance levels. Inter-annual variability in survey indices may be due to several factors including: recruitment variability, sharp increases in total mortality, changes in availability to survey gear, and spatially-related sampling variability. To reflect real changes in abundance of the stock, survey indices must be structurally consistent from year to year, i.e., they must properly embrace changes in size and age structure of the population.

Otherwise, large increases in abundance (numbers of fish) may simply reflect increased availability of the stock in a given year or may be due to the effect of a few large catches on the overall index.

III - Habitat Association Indices for Cod, Haddock and Yellowtail Flounder

Methods

Research survey data from the NEFSC spring (1968-1994) and autumn (1963-1994) bottom trawl surveys were collected from strata north of New Jersey (offshore strata 1-30, 36-40, 73-76, Figure 2). Strata south of this region were not considered for analysis because historically these strata are beyond the geographical range of yellowtail flounder, cod and haddock. Depths over the survey area ranged from 30 to greater than 300 meters (Figure 2). For each useable tow or station, measurements of bottom temperature and average depth were taken. Bottom temperatures were obtained from XBT or CTD casts deployed at the beginning of each trawl set, and average depth was taken as the sum of the set depth and the end depth divided by two. Total catch (numbers) of yellowtail, cod and haddock associated with a given station were expressed as the catch-per-tow in numbers and no conversion adjustments were made to catches to account for door or vessel changes.

Perry and Smith (1994) developed a nonparametric univariate test of association between the cumulative distribution function of the environmental variable ($f(t)$) and the catch-weighted cumulative distribution function ($g(t)$). The cumulative distribution function for any habitat variable (x_{hi}) is constructed as

$$f(t) = \sum_h \sum_i \frac{W_h}{n_h} I(x_{hi}) \quad (1)$$

where:

- W_h = proportion of the survey area in stratum h .
- n_h = number of tows or sets in stratum h ($h=1, \dots, L$)

x_{hi} = value of a hydrographic variable in tow i and stratum h .

$I(x_{hi}) = 1$ if $x_{hi} \leq t$; 0 otherwise.

Here, t represents an index, ranging from the lowest to the highest value of the environmental variable and (1) is calculated over all habitat measurements (x_{hi}) collected. The value of t is chosen depending on the desired resolution of the habitat variable (i.e. 0.10° C). The cumulative distribution functions in (1) can be used to calculate the interquartiles (25th, 50th and 75th percentiles) of the observed habitat variable collected over the survey area. The catch of a given species is associated or paired with each habitat variable at a given station and can be used as a weighting factor. Then, as in equation (1), the cumulative distribution function for the catch-weighted habitat variable is computed as

$$g(t) = \sum_h \sum_i \frac{W_h}{n_h} \frac{y_{hi}}{y_{st}} I(x_{hi}) \quad (2)$$

where: y_{hi} = number of fish of a particular species caught in tow i ($i=1, \dots, n_h$) and stratum h , and y_{st} = is the stratified mean number per tow of fish caught in the defined survey area. Here, the habitat value is weighted by the catch and is scaled by the stratified mean number of fish caught so that the cumulative distribution function's sum to 1 over all habitat values. The difference between the catch-weighted and habitat cumulative distribution functions provide a measure of the degree to which catch of a given species is associated with a certain habitat type; the greater the deviation between the two curves the greater the association. Perry and Smith (1994) suggest the use of the maximum absolute vertical distance between $g(t)$ and $f(t)$ as a statistic of the strength of association as

$$\delta_o = \max_{vt} |g(t) - f(t)| \quad (3)$$

Where, δ_o is the observed value of the maximum vertical distance between $g(t)$ and $f(t)$ at any point t within the range of the habitat values. To determine whether $g(t)$ is different from $f(t)$, as measured by

the δ_o statistic, Perry and Smith (1994) employed a randomization procedure (Noreen 1989) to evaluate whether a significant association exists. Randomization tests are based on the concept that when the null hypothesis is true (no difference between $g(t)$ and $f(t)$) a test statistic generated by random assignment of the paired catch and habitat value pairs is of the same magnitude as the value actually observed. Alternatively, the null hypothesis is rejected when the observed value is "unusual" relative to the distribution of the test statistic, generated by repeating the randomization many times. In particular, the randomization test proceeds as follows. First, the observed cumulative distribution functions for the habitat variable and the associated catch-weighted habitat variable are generated and the test statistic (δ_o) is computed as in (3). Second, environmental measurements are randomly sampled with replacement and reassigned to the catches, and the CDF's are again generated along with the corresponding test statistic, denoted as

$$\delta_o = \max_{vt} |g(t) - f(t)| \quad (4)$$

where all symbols are defined as above in (3) but * indicates that computations are based on randomized data. This step is repeated a large number of times to generate the probability density function of the test statistic ($\delta(t)^*$) under the null hypothesis of random association between catch and the environmental factor. Third, the observed test statistic (δ_o) is compared to the distribution of test statistics ($\delta(t)^*$) from the randomization procedure to evaluate whether the null hypothesis of random association can be rejected. The null hypothesis is rejected in favor of the alternative at significance level α when $[\delta_o > \delta_\alpha]$, where the critical value, δ_α , is chosen so that

$$\text{prob} [\delta(t)^* \geq \delta_\alpha] = \alpha \quad (5)$$

calculated under H_o . For randomization tests no assumptions concerning the shape of a presupposed probability distribution function of a statistic is necessary; rather the distribution is derived

empirically by repeated randomization and allocation of the original data. The randomization test does however assume that samples were taken randomly from the population (Manly 1991), an assumption which seems reasonable considering the stratified random sampling design used in the NEFSC trawl survey. In addition, randomization tests are often more powerful than their parametric counterparts when standard parametric assumptions are violated (Manly 1991).

The univariate randomization test was applied to yellowtail flounder, cod and haddock catches from the spring survey since 1968 and autumn survey since 1963 with bottom temperatures and average depths for each season using a program developed by Brodziak and Ling (1995). Stations where an environmental variable was not measured were excluded from analysis for that variable. A total of 2,000 randomizations were used for a total of 2001 test statistics (the original data pairing was included, cf. Perry and Smith (1994)). Results of the randomization test for differences in associations between the environmental variable CDF and the catch-weighted CDF were significant at the $\alpha=0.05$ experimentalwise level. The randomization test is two-sided, since it is the magnitude of the absolute differences between $g(t)$ and $f(t)$ that is of interest.

Results

Results of the univariate randomization test of association between catches of yellowtail, cod and haddock and depth and bottom temperature indicate significant associations existed both during the spring and the autumn survey (Tables E3.1 and E3.1). An illustration of these associations and the randomization procedure is shown in Figure E3.1 using haddock catches during the 1965 autumn survey with bottom temperature. Haddock catches during this survey were associated with warmer bottom temperatures (50% of the observed catches had temperatures $> 12.2^\circ\text{C}$) compared to the bottom temperatures over the area surveyed (50% of the observed temperatures were $> 8.6^\circ\text{C}$) (Figure E3.1a). For this example the observed test statistic (δ_o) or

the maximum absolute difference (labelled "max") between the cumulative distribution functions of environment temperatures [$f(t)$; equation 1] and the catch-weighted temperatures [$g(t)$; equation 2] was 0.403 (Figure E3.1a) and occurred at a bottom temperature of 12.0°C. Comparison of the observed test statistic to the cumulative distribution function of the test statistic ($\delta(t)^*$) generated by repeated randomization of the data indicate a highly significant difference ($p < 0.001$), i.e., a test statistic as large or larger than 0.403 was obtained in only 1 out of 2000 randomizations (Figure E3.1b).

During the spring survey, yellowtail flounder catch was significantly associated with bottom temperatures in 20 out of the 27 years (74%) and with depth in 25 out of the 27 years (93%) (Table E3.1). Also during the spring, cod showed significant associations with bottom temperature and with average depth for 19 of the 27 years (70%). In contrast to yellowtail flounder and cod, haddock distribution showed less of an association with bottom temperature and average depth; in only 9 years and 8 years (roughly 30%) haddock catch was significantly associated with those variables, respectively (Table E3.1).

Compared to the spring survey, associations between bottom temperature and depth and the catches yellowtail and cod were markedly reduced during the autumn survey and at generally lower levels of statistical significance (Table E3.2). Here, yellowtail flounder catch was significantly associated with bottom temperature in only 5 of the 32 years (16%) and with depth in 16 of the 32 years (56%) of the autumn survey. Additionally, associations between bottom temperature and cod catches were significant in only 15 years (47%) and associations between depth and cod catches were significant in only 4 years (13%) during the 32 years of the autumn survey. During the autumn survey, however, catches of haddock appeared to exhibit a greater association with bottom temperature and depth as 14 of the 32 years (44%) of the survey were statistically significant (Table E3.2). It should be noted that bottom temperatures and depths were not

necessarily concordant for those years when significant (or insignificant) associations occurred between catches and the environmental variable. This may suggest one variable such as depth may be a greater ecological determinant in structuring the distribution of a species over its range. These tests of random association between yellowtail flounder, cod and haddock catches and environmental variables were for univariate comparisons only.

These data suggest that depth preferences of yellowtail flounder, cod and haddock are relatively constant through time and that these species are associated with shallower depths compared to the sampled environment. In addition, depth preferences among the species vary in order of increasing the average depth from yellowtail to cod to haddock (Table E3.3 and Figure E3.2). Table E3.3 gives 25th, 50th and 75th percentiles of the environment and catch-weighted depth variables and Figure E3.2 compares the 50th percentiles of the catch-weighted depths to the interquartiles of the environment depths during the spring survey from 1968-1994. In general, the catch-weighted depths (50% percentiles) of all species occurred in shallower waters than in the available habitat; the 50th percentile depth for cod and haddock occurred between the 25th (59 meters) and the 50th percentile (92 meters) of the environment and the 50th percentile depth for yellowtail flounder was slightly above the 25th percentile of the environment (59 meters; Table E3.3 and Figure E3.2). Relative to the other species, yellowtail flounder catches during the spring occurred almost consistently over the years in the shallowest depths (average of the 50th percentile = 55 meters); most often below the 25th percentile of the environment (≤ 60 meters). Atlantic cod were associated with slightly greater depths than yellowtail (average of the 50th percentile = 72 meters) and haddock catches occurred at the greatest depth of all the species (average of the 50th percentile = 81 meters); close to the 50th percentile of the environment depths (90 meters).

Although environment and catch-weighted depths for yellowtail, cod and haddock were

consistent over time, bottom temperatures exhibited greater variation. On average, the interquartiles (25th and 75th percentiles) of bottom temperatures (environment) ranged from 4.5° C to 7.6° C with a pronounced increase during the early to mid-1970s (Table E3.4 and Figure E3.3). Catch-weighted bottom temperatures for yellowtail, cod and haddock were generally concordant with environment temperatures through time. As for the depth distributions, the catch-weighted bottom temperatures of yellowtail, cod and haddock were generally less than the 50% percentile of the environment (5.8° C). In many years, yellowtail and cod were distributed at temperatures less than the 25th percentile of the environment (4.5° C) while haddock catch-weighted bottom temperatures generally ranged within the 25th and 50th percentile of the environment. However, unlike the depth results, no clear consistent patterns were evident in the catch-weighted bottom temperature among the three species. On average, the 50th percentile of the catch-weighted bottom temperatures for yellowtail, cod and haddock were 4.8° C, 4.9° C and 5.2° C, respectively.

Catch-weighted depths and bottom temperatures for yellowtail, cod and haddock exhibited marked changes between spring and autumn. Compared to the spring survey, catch-weighted depths for cod and haddock in the autumn were generally greater, and these species appeared to exhibit much greater inter-annual variation in their depth preferences (Table E3.5; Figure E3.4). On average, the 50th percentiles of catch-weighted depths for cod and haddock during the autumn were 84 and 95 meters, respectively, closer to the 50th percentile of the environment (91 meters). Yellowtail flounder catch-weighted depths remained remarkably similar during both the spring (55 meters) and autumn (58 meters) surveys with very little inter-annual variation in their depth preferences.

Environment and catch-weighted bottom temperatures during the autumn again showed greater variation than that of average depth. Also, as in the spring survey, bottom temperatures during the

autumn survey increased from the early 1960s to the mid-1970s; the 50th percentile increased from 7.5° C in 1964 to 10.7° C in 1974 (Table E3.6 and Figure E3.5). However, in contrast to the spring survey, catch-weighted bottom temperatures for yellowtail, cod and haddock in the autumn survey were generally not concordant with this increase in the environmental temperature. On average, the interquartile (25th and 75th percentiles) of bottom temperatures (environment) during the autumn survey ranged from 7.5° C to 11.9° C. Yellowtail, cod and haddock were distributed over a wide range of bottom temperatures, mostly between the interquartiles of the environment temperature. This is in contrast to the spring survey during which all species were distributed at bottom temperatures closer to the lower quartile of the environment temperature. With the exception of a few years, catch-weighted yellowtail flounder bottom temperatures were generally between the 50th and 75th percentile of the environment temperature, while cod and haddock were distributed in cooler waters between the 25th and 50th percentiles of the environment. On average, the 50th percentiles of the catch-weighted yellowtail flounder, cod and haddock temperatures were 11.2° C, 8.9° C and 8.5° C, respectively.

Subcommittee Comments

Results from this analysis indicate that yellowtail flounder, cod and haddock show, to a greater or lesser extent, a "preference" or association to a certain depth or temperature regime, suggesting that temperature and depth are important ecological determinants for the distribution of these species in the Northwest Atlantic. This is consistent with earlier studies (Murawski and Finn 1988; Gabriel 1992; Perry and Smith 1994). Yellowtail flounder maintained a rather constant preference for depth (< 55 meters) different from the environment and tolerated a wide range in temperatures (4.8° C to 10.5° C) between the spring and autumn. This may suggest that depth is a more important determinant than temperature in structuring the distribution of yellowtail flounder. Atlantic cod were strongly

associated with particular depth (< 72 meters) and temperature (< 4.9°C) ranges during the spring but showed comparatively little association between depth and temperature during the autumn. This suggests that, while cod may be regarded as having "preferred" depth/temperature regimes, such an interpretation is dependent upon a particular season. The lack of association during the autumn is probably due to the fact that Atlantic cod on Georges Bank and in the Gulf of Maine occur over a wider range of depths and temperatures compared to the spring. While not showing much of a depth preference during either season, haddock catches during both spring and autumn surveys were generally significantly associated with certain temperature ranges (different from that of the environment) that varied over season. On average, 50% of the catch was distributed at temperatures less than 5.2°C during the spring and at temperatures less than 8.6°C during the autumn.

Identification of habitat associations for the Northeast groundfish complex has several important implications for sampling programs and stock assessment methods. First, an understanding of how fish are spatially and temporally distributed in response to oceanographic features can provide insight into some of the sampling variation that is observed in large-scale trawl surveys. For instance, large variations in abundance estimates from year to year may be explained by changes in the catchability of fish to the trawl survey due to distribution changes in temperature/depth regimes. Knowledge of fish distribution patterns can be used to test the veracity of constant catchability assumptions made in some stock assessment models. Secondly, this information may provide a means a correcting or improving estimates of survey abundance (Smith *et al.* 1991) and, where strong associations exist with particular habitat conditions, habitat variables may be incorporated in spatially explicit models as covariates to predict fish distribution (Swartzman *et al.* 1992). Such an application to the Georges Bank haddock stock during autumn is described in the next section 4 below.

IV - General Additive Model (GAM) for Haddock

Methods

Data

Data for the number of haddock caught per station were obtained from the NEFSC autumn bottom trawl research surveys for the offshore strata only (1963-1994). Stations where haddock were not caught were also included. The area used in the analysis, however, was delimited by the range of occurrence of haddock within the 32 year time series. Stations occurring outside of this range were excluded from the analysis; the area of the study was defined by 63° to 75° longitude and 37° to 45° latitude. Catch numbers were adjusted for vessel and gear differences using the coefficients of 0.82 and 1.49, respectively, for the appropriate years (NEFSC 1991). Only usable hauls were included in the analysis, and records without a bottom temperature observation were deleted.

Abundance indices of stratified mean number per tow, and the associated variance were estimated for both the observed and fitted values of catch number using the same methodology as NEFSC (Cochran 1977). The indices were derived for offshore strata 13-40, which is different from the NEFSC estimate presented in the current assessment (O'Brien and Brown 1995), derived for strata 13-25 and 29-30.

Model Description

A GAM is a generalization of a linear model, where the usual linear function of a covariate is replaced with an unspecified smooth function. An additive model is defined as:

$$Y = \alpha + \sum f_j(X_j) + \epsilon$$

where f_j can be a smooth function.

The algorithms for fitting a GAM include:

- 1) scatterplot smooth
- 2) backfitting algorithm - smoothing partial residuals
- 3) local scoring algorithm

A scatterplot smooth works as an iterative process:

Given $\hat{f}(x_1)$, estimate $f_2(x_2)$, smooth the residual of $Y - \hat{f}_1(x_1)$ on x_2 .

With $\hat{f}_2(x_2)$, an improved estimate of $\hat{f}_1(x_1)$ is obtained by smoothing $Y - \hat{f}_2(x_2)$ on x_1 .

Smoothing is continued until

$Y - \hat{f}_1(x_1)$ on x_2 is $\hat{f}_2(x_2)$ and

$Y - \hat{f}_2(x_2)$ on x_1 is $\hat{f}_1(x_1)$.

The iterative smoothing process of the partial residuals is called backfitting and is the main tool for estimation in GAM (Hastie and Tibshirani 1986). The model is fit using the local scoring algorithm, which uses backfitting to iteratively fit weighted additive models (Stat. Sci. 1993).

The underlying distribution used within the GAM was a Poisson, which is appropriate for describing random occurrences and count data (Zar 1974, Sokal and Rohlf 1981). The predictive variable of abundance was provided to the model as catch in numbers and the explanatory variables were location, indicated by latitude and longitude, and the environmental variables of average depth and bottom temperature. A step-wise GAM was performed to determine the best fitting model and was selected based on the criteria of the lowest Akaike Information Criterion test statistic. Both the linear and the smooth functions for depth and temperature were among the possible choices in the step-wise procedure. The final model was:

Catch number = Intercept + s(avedepth) + s(bottom temperature) + latitude + longitude.

where s is a smoothing spline. A second model, that excluded the location variables was also fit to the data. A pseudocoefficient of determination, R^2 ,

was estimated as 1.0 - the ratio of the deviance of the model to the deviance of the null model (Swartzman *et al.* 1992). The R^2 values for the two models were compared, by year, to determine the effect of depth and temperature, alone, on abundance.

Results

Distribution plots of observed and fitted catch numbers of haddock for selected years (1965, 1970, and 1985) are presented in Figures E4.1 through E4.3. Both the observed and fitted values, and the temperature and average depth are interpolated in the plots, and contour lines are included. Comparison of the observed and fitted catch numbers indicate the effect of location and environment on the distribution of haddock. In the earliest year when the distribution of haddock was more protracted (1965) there is a noticeable shift in the fitted distribution compared to the observed. The effect becomes less pronounced as the distribution becomes less dispersed as in 1970, and in the more recent period (1985) when the population is relatively smaller with a very contracted range, there is little difference between the observed and fitted distribution.

Plots in Figures E4.4 through E4.6 represent the contribution of average depth and bottom temperature to the fitted additive predictor -- catch in numbers. The curves are drawn by connecting the points of the fitted values for each function against the predictor. The y-scale is not of importance given that there is an intercept in the model; the fitted values are adjusted to average zero (Hastie 1992). In all years, catch in numbers is negatively correlated with depth where the preferred depth is less than 100 m. The preferred bottom temperature varied between years but was generally around 8°-12° C.

R^2 values for each model and for the difference between models is presented in Table E4.1. Model 2 always has an R^2 greater than model 1, indicating that model 2 is the better fitting model as previously

determined by the AIC in the step-wise GAM. Small differences in R^2 between the two models indicates little additional information is provided by including latitude and longitude in the model (1963,1969,1974,1977,1987,1990). When R^2 is greater than 50% in model 1 (1969, 1977,1987,1990), the environment appears to influence the spatial distribution of haddock. When the R^2 is large between the two models (1983, 1994), some factor other than depth and temperature is influencing the spatial distribution.

The GAM fitted stratified mean number per tow index follows the same trend and is generally less than that of the observed abundance index (Table E4.2, Figure E4.7). The mean index and the variation about the mean, calculated as 2 times the standard error are also presented. The GAM fitted index has a lower variance than that of the observed and is most evident by the consistently lower coefficients of variation (Table E4.2).

Subcommittee Comments

The variability in R^2 values over the time series indicates that factors other than depth and temperature are influencing the spatial distribution of haddock. Recruitment and the age structure of the stock would likely influence the distribution of fish if depth and temperature preferences are different among age classes. The abundance indices derived using the GAM fitted values provides an improved estimate compared to the observed values. The actual indices only vary slightly between the two, but, the GAM fitted index uses the spatial trend information and the variation about the estimate is within the bounds of the variation of the observed index. The analyses would be more representative if another temperature database was available to supplement those haddock catch stations where temperature observations are missing. Also, by applying bootstrapping to the GAM the variability of the fitted abundance estimates would improve.

V- Concentration Indices based on Lorenz Curves for Georges Bank Haddock

Methods

The Lorenz curve is an econometrics method developed to study the distribution of income among individuals (Lorenz 1905, Dagum 1985). When this method is applied to fish distribution, the Lorenz curve method simultaneously takes into account biomass and area and puts them on a comparable basis. Myers and Cadigan (1995) applied this method to northern cod off Newfoundland using 76 strata from a 12 year research survey time series. Changes in concentration of flatfish off Newfoundland were examined by Myers *et al.* (1995) using this technique. In the present exploratory analysis, NEFSC autumn bottom trawl survey data were examined to detect changes in haddock distribution over a 32 year period.

As described by Myers and Cadigan (1995), a Lorenz curve is calculated as follows: for a set of n strata, let x_i be the biomass and a_i be the area of stratum i , $i=1,2,\dots,n$, ranked by biomass. The Lorenz curve is the polygon joining the points $(A_h/A_n, L_h/L_n)$, $h=(0,1,2 \dots n)$ where $L_0 = 0$ and $L_h = \sum_{i=1}^h x_i$ is the total biomass in the h strata with the lowest biomass, and $A_0 = 0$ and $A_h = \sum_{i=1}^h a_i$ is the total area of the h strata with the lowest biomass. The Lorenz curve has as its x-axis the cumulative percentage of area, and the cumulative percentage of biomass as the y-axis (Figure E5.1). If fish were evenly distributed among strata, the Lorenz curve would be the identity function (Figure E5.1). If fish were unevenly distributed (i.e., concentrated) the Lorenz curve bows downward and to the right within the unit square (Figure E5.1). The Gini index, a common measure of concentration, was derived by doubling the area between the identity function and the Lorenz curve (Dagum 1985).

As given above, this method does not fully account for strata of unequal size. Since the NEFSC

survey has a wide range of strata sizes, a modification to this method was explored by ranking the strata by mean weight per tow (kg/tow) instead of biomass, and then calculating the cumulative percentage of biomass and area. A comparison of the ranking by biomass and mean weight per tow was conducted for Georges Bank haddock for 1972. Input data for the comparison is given in Table E5.1. Strata ordered by biomass (as in Myers and Cadigan 1995) is given in Table E5.2, and strata ranked by mean weight per tow is given in Table E5.3.

Lorenz curves (ordered by mean weight per tow) were calculated for each NEFSC autumn bottom trawl survey between 1963 and 1994 to determine changes in concentration of haddock (*Melanogrammus aeglefinus*) on Georges Bank. The strata set used (strata 13-25, 29-30) corresponds to that used in the most recent stock assessment (O'Brien and Brown 1995). Biomass indices used in the analysis were estimates of minimum population biomass (kg) calculated for each stratum in each year. Haddock biomass indices were adjusted for fishing power and door conversion factors at the stratum level. The Gini index was plotted over time.

Results

Comparison of Lorenz Curves

How the data are ranked affects the shape of the Lorenz curve and the resulting Gini index. The Lorenz curve ranked by biomass has a 'stepped' or irregular shape whereas the Lorenz curve ranked by mean weight per tow has a smooth shape (Figure E5.1). The Gini index for the Lorenz curve ordered by biomass was 0.45 and 0.62 for the Lorenz curve ordered by mean weight per tow. The difference in concentration indices for 1972 is due to high densities of haddock in some of the smaller strata (i.e., strata 21, 22, and 25; Tables E5.2 and E5.3). As a result of ordering by mean weight per tow, the more dense strata are shifted further out on the x and y axis (regardless of the strata size) and the curve becomes more bowed. The slope between strata points increases. Ranking by mean weight per tow

disassociates area from biomass since mean weight per tow is independent of stratum size, making this application of the method more in keeping with the original application of income per individual. Additional refinements to this method to address the issue of unequal stratum size are ongoing.

Haddock

Annual Lorenz curve plots (Figure E5.2) reveal even distributions of haddock among the strata area in the early-mid 1960s but becoming more unevenly distributed in the early-mid 1970s. Haddock distributions appear more evenly distributed in the late 1970s and early 1980s but in subsequent years haddock distribution appears unevenly distributed (Figure E5.2). Over the 32 year study period, haddock distribution on Georges Bank has become more concentrated over time and there appears to be two periods of increasing concentration, with the later phase higher in concentration than the first (Figure E5.3). The first period probably corresponds to the fishing down of the extremely strong 1963 year class until 1974. Improved recruitment from the 1975 and 1978 year classes resulted in a more evenly distributed pattern during the late 1970s and early 1980s; however, as these cohorts were fished down, the degree of concentration gradually increased.

Subcommittee Comments

Use of the Lorenz Curve for measuring concentration of fish as applied in this report is an extension of the approach described by Myers and Cadigan (1995) as applied to the Northern Cod stock. Both applications represent a modification of the original application in econometrics to measure the concentration of individual income. The application to fisheries involves the measurement of accumulated biomass, as estimated for individual survey strata of unequal size, against the estimate of accumulated area.

The Subcommittee discussed the impact of unequal strata size on the resulting concentration

index and noted that the irregularity in the shape of the Lorenz curve as used by Myers and Cadigan (1995) is a result of the cumulative effect of unequal strata areas versus cumulative biomass. After considerable discussion, the Subcommittee agreed that the unit of accumulated biomass is measured by the individual sampling unit, which for trawl surveys is the area covered by a single tow. The Subcommittee, therefore, concluded that biomass per unit area (i.e., kg/tow) is a more appropriate measure of the "individual wealth" of a given stratum. The Subcommittee agreed that ordering the inclusion of individual strata by density (i.e., kg/tow) would mitigate the effect of unequal strata size on the calculation of the Gini index, allowing the full extent in the inter-annual variation in concentration to be measured.

For species in which changes in concentration are evident, possible changes in catchability (q) may have also occurred with respect to the commercial fishery. If so, then the relationship between fishing effort and fishing mortality rates may be affected. The impact of changes in concentration on catchability may warrant further investigation.

VI - Relationship Between SSB and Survey Indices of SSB for Georges Bank Cod and Gulf of Maine Cod

Methods

Virtual population analysis has been used to estimate Atlantic cod spawning stock biomass for the Georges Bank stock, 1978-1994 (Serchuk *et al.* 1994), and the Gulf of Maine stock, 1982-1994 (Mayo 1995). Spring and autumn NEFSC bottom trawl surveys were used to indicate relative abundance at age for VPA calibration in both stock assessments. Therefore, SSB estimates from VPA are not completely independent from age-aggregated survey indices.

Conventional survey analysis was modified to calculate SSB indices. Indices of mature biomass

were computed for Gulf of Maine and Georges Bank cod from spring 1968-1995 and autumn 1963-1994 NEFSC bottom trawl survey data. Biomass indices (stratified mean weight per tow; Cochran 1977) of mature cod were derived by first calculating the proportion of mature cod at length from fitted logistic equations taken from O'Brien *et al.* (1993) as follows:

$$P = \frac{1}{1 + e^{-[a+(bL)]}}$$

where P = proportion mature, L = length (cm), and a and b are intercept and shape parameters, respectively, from the fitted logistic regression. For Georges Bank cod the logistic parameters were: $a = -4.932$ and $b = 0.127$. Parameters for Gulf of Maine cod were $a = -5.500$ and $b = 0.171$ (O'Brien *et al.* 1993).

Stratified mean number of mature fish per tow was then computed by applying the logistic equation at the strata set level to the stratified mean number of fish per tow at length. Mean numbers per tow at length were converted to mean weight per tow at length by applying an exponential length-weight equation (Serchuk *et al.* 1994) to each length.

The equation for converting length to weight was:

$$W = aL^b$$

where W = weight (kg), L = length (cm), and a and b are intercept and slope parameters, respectively, from the fitted regression. For both cod stocks, the length-weight parameters were: $a = 8.104 \times 10^{-6}$ and $b = 3.052$. Stratified mean weight per tow of all fish was then obtained by summing over all lengths.

Predictive relationships between VPA estimates of SSB and survey indices of mature biomass were quantified using linear least squares regressions. In all regressions, survey indices were assumed to be dependent on SSB, as estimated by VPA (Cook

1995). Observations were transformed to natural logarithms to homogenize variance and linearize relationships, and were first order differenced to remove negative trends (Fogarty 1989). Relationships between integrated moving average logarithmic indices and log transformed SSB from VPA were tested using linear least squares. Linear equations were rearranged to predict the independent variable: $X=(Y-a)/b$ (Sokal and Rohlf 1981). Regressions were jackknifed (Efron and Gong 1981) to estimate extrinsic prediction accuracy and assess stability of parameter estimates.

Georges Bank Cod

VPA estimates and survey indices of Georges Bank cod SSB are presented in Figure E6.1. Time series models (ARIMA; Pennington 1985) were developed for spring and autumn survey indices of mature Georges Bank cod. Significant autocorrelation at a lag of one year and gradually decaying partial autocorrelation from a one year lag suggested first order moving average models. Conditional least square estimates of moving average parameters (θ) were 0.58 for both surveys, which is within the range of θ estimated for NEFSC survey indices of other fish stocks.

Predicted values from time series models had relatively strong relationships with SSB ($R^2 = 0.74$, autumn $R^2 = 0.69$; Figures E6.2a and E6.3a). Logarithmic transformation produced improved fit, linearized relationships and homogenized residual variance, suggesting a lognormal error structure. Although 95% confidence intervals of predicted SSB showed considerable uncertainty in survey predictions, the two surveys produced very similar estimates (Figure E6.2b and E6.3b). The spring survey predicted SSB with 16% error, and the autumn survey had 18% prediction error. Extrinsic prediction errors of jackknifed observations increased to 18% and 21%, respectively. Both surveys overestimated SSB from 1984 to 1986 and underestimated 1987-1992 SSB.

Gulf of Maine cod

VPA estimates and survey indices of Gulf of Maine cod SSB are presented in Figure E6.4. Time series models (ARIMA; Pennington 1985) were developed for spring and autumn indices of mature Gulf of Maine cod. Differenced observations had insignificant autocorrelation. An *a priori* first order moving average model was specified, and model adequacy was confirmed by uncorrelated residuals (Pennington 1986). Marginally significant moving average parameters were estimated as 0.52 and 0.33, and integrated moving average models produced residuals with no autocorrelation.

The relationship between the fitted spring index was not significant and regression of the autumn series was weak (autumn $R^2 = 0.37$; Figure E6.5). Although the autumn regression was significant, and predicted SSB provides some indication of previous levels of SSB, it appears that survey indices of mature biomass cannot predict SSB for Gulf of Maine cod with sufficient precision to assess current conditions relative to desired SSB thresholds.

Subcommittee Comments

Although smoothed survey estimates of spawning stock use a simple log-log regression with VPA as the independent variable, VPA does not estimate SSB without error. Both survey indices and VPA estimates are dependent on actual levels of SSB. Bootstrapped estimates of precision for cod VPAs (which may be optimistic because catch at age is assumed to be without error) suggest a low coefficient of variation (CV) for estimates of SSB (10% for Georges Bank, Serchuk *et al.* 1994, and 9% for Gulf of Maine, Mayo 1995), whereas CVs of survey indices estimated by the present integrated moving average models were greater than 25%. Although both variables are measured with error, model I regression is the proper method for a predictive model (Sokal and Rohlf 1981). Jackknifed parameter estimates suggest that the present regression estimates are robust to statistical violations.

The linear equations used to predict SSB from survey indices in the present analysis may be viewed as estimating catchability ($b=q$) and a threshold SSB (intercept= e^{-ab} mt) below which the survey does not catch mature fish. Linear regression through the origin would eliminate the need to justify a SSB threshold. More complicated functional models may fit the present relationships better, but would imply variable survey catchability (Pennington and Godø 1995). For example, quadratic regression of mature biomass indices on SSB would imply that q is linearly related to SSB. Allowing q to vary for the purpose of scaling mature biomass indices to units of SSB would link contradictory models because the independent estimates of SSB were calibrated assuming constant q .

Size and age at maturity of Georges Bank and Gulf of Maine cod has decreased within cohorts from the 1970 year class to the 1991 year class due to declining stock abundance (O'Brien 1990 and 1995). Accordingly, Georges Bank and Gulf of Maine stock assessments included changing maturity at age to estimate SSB (Serchuk *et al.* 1994 and Mayo 1995, respectively). The maturity at length ogive used in the present study may only represent the period from which it was derived, 1985-1990. These analyses should be considered provisional until more appropriate annual maturity ogives are developed. Predicting SSB with current survey indices of mature biomass may lead to overestimates of SSB if stock abundance and maturity at size increase.

Although SSB predictions may be improved through more accurate estimates of maturity at length, alternative models or, more elaborate estimation procedures, these analyses show that time series fitting of survey indices improves relationships with VPA estimates of SSB, and performance of these methods for predicting SSB is variable between stocks and surveys.

VII - Summary

Of the 25 stocks of 16 species examined in the

Northeast demersal complex, 18 (72%) have exhibited significant declines in biomass since the 1970s. The biomass of 13 stocks may be considered to be presently at or near record-low levels and the biomass of 5 other stocks has increased slightly in recent years, but still remains well below historic levels. These 18 stocks include traditional groundfish species such as cod, haddock, pollock, yellowtail flounder as well as other less traditional species such as cusk, wolffish and ocean pout. Only two stocks, the northern stocks of red and silver hake, have exhibited consistent increases in biomass over the past decade.

Depending on region and survey season, the biomass of aggregate group 1 (comprising cod, haddock, pollock, white hake and redfish) has declined by about 70-80% since the mid-1960s and by 50-60% since the late 1970s. Aggregate group 2 biomass (comprising yellowtail flounder, American plaice, witch flounder, winter flounder and windowpane flounder) has also declined by about 60-80% since the late 1970s. In contrast, the biomass of aggregate group 3 (comprising silver hake, red hake and ocean pout) has increased approximately 2 to 4-fold over the past 2-3 decades. The decline in biomass for aggregate group 4 (comprising cusk, wolffish and goosefish) has been equally severe as that for group 1, decreasing by about 80% since the mid-1970s. On average, the total biomass of the 16 species comprising the complex currently remains at about 30% of the biomass level estimated during the late 1970s.

In the Gulf of Maine, the total biomass of principal groundfish currently remains at about 20-30% of the late 1960s level, flatfish biomass remains at about 20-25% of the late 1970s level, the biomass of small-mesh groundfish has experienced a 4-fold increase since the late 1960s, and aggregate group other groundfish is at about 20% of the late 1970s level. In this region, cod biomass has declined by 80%, haddock by 90%, pollock by 80%, witch flounder by 80%, and cusk and wolffish by 90% over the past 2 or 3 decades. Redfish biomass has increased slightly from record-low levels in the mid-

1980s, but remains at about 30% of the level detected during the 1970s.

On Georges Bank, the total biomass of principal groundfish currently remains at about 15-20% of the late 1970s level, and flatfish biomass remains at about 25-30% 1970 level; the biomass of small-mesh groundfish has experienced a 4-fold increase since the late 1960s, and other groundfish biomass is at about 20-25% of the late 1970s level. In this region, biomass levels of cod, haddock, yellowtail flounder and winter flounder biomass has declined by about 80-90% over the past 2 or 3 decades. During the same period, silver hake and red hake biomass levels have increased 4-fold on northern Georges Bank and in the Gulf of Maine.

Off Southern New England, the total biomass of principal groundfish currently remains at about 20% of the late 1960s level, and flatfish biomass remains at only 5% of late 1960s level; the biomass of small-mesh groundfish has declined to about 20% of the late 1960s to mid-1970s levels, and other groundfish biomass remains at about 20-25% of the 1960s level. In this region, yellowtail flounder biomass has declined by over 90%, winter flounder biomass has declined by about 80%, and ocean pout biomass has declined by about 60-70% over the past 2 or 3 decades. During the same period, silver hake and red hake biomass levels have declined by about 50% in the Southern New England - Georges Bank-Middle Atlantic region.

Several of the species which exhibited severe declines in overall biomass also displayed considerable contraction in range of habitat occupied, most notably haddock (Figure 2.19). Haddock are now distributed primarily on the Northeast peak of Georges Bank whereas during the 1960s and early 1970s, this species was found in considerable numbers in the region of the South Channel and in the western Gulf of Maine. Pollock presently occur sporadically in the western Gulf of Maine in contrast to their previous distribution along the 50 fathom line throughout the Gulf of Maine and along the Northern Edge of Georges Bank.

Yellowtail flounder are presently found in a few locations off Southern New England compared to their earlier distribution throughout the 30-60 fathom range.

Coincident with changes in abundance, certain species have exhibited an apparent compensation in their distribution in order to remain within their "preferred" depth and temperature range. For example, following short-term increases in median ambient temperatures during the early 1970s and again during the mid-1980s, yellowtail flounder were found to occupy temperature zones which were slightly below their previous quartile ranges relative to the ambient habitat (i.e., from above to below the 25th percentile in spring, and from the 75th to the 50th percentile during autumn. This temperature shift coincided with a slight increase in occupied depth, from below to about the 25th percentile during spring surveys.

In contrast, as ambient temperatures declined during the late 1970s, cod appeared to occupy zones of slightly warmer temperature percentiles of the ambient habitat than in previous years. Cod also exhibited a shift in its median temperature during autumn from about the 75th percentile to the 50th percentile of ambient temperature habitat. Haddock appeared to be distributed among a wider range of ambient temperature zones, but strong patterns in depth preference were evident, particularly in autumn. In particular, the median depth for haddock shifted sharply following strong recruitment events during the 1960s and 1970s; median depth decreased immediately following recruitment of a strong year class but increased subsequently as fish from these year classes dispersed into deeper water over time.

Temperature and depth when employed as explanatory variates of the distribution of haddock accounted for varying amounts of the annual spatial variability of catch. The General Additive Model appears to have the greatest smoothing effect when the observed distribution covers a wider geographic range. During these periods, the CVs of the

observed distributions are relatively low compared to later periods when haddock appeared highly concentrated in a few locations. In the latter case, the GAM is less effective in smoothing the observed catch numbers, as reflected in the relatively high coefficients of variation of the fitted index of abundance derived from the GAM-smoothed catch numbers.

Results presented in Sections III and IV, addressing distribution of haddock, illustrate how variability in observed annual abundance indices can be taken into account when interpreting overall trends. Habitat preferences, computed by comparing catch-weighted cumulative frequency distributions of environmental variables such as temperature and depth and the corresponding ambient cumulative frequency distributions of the same variables, indicated that the distribution of haddock may in some years be affected by anomalous temperature regimes. These shifts in distribution may affect the observed abundance indices. These temperature and depth variables, when treated formally in a spatial-oriented model such as the GAM, may be used to smooth the observed distribution of catches and reduce the variability about the estimates of mean annual abundance.

A concentration index as derived from Lorenz curves, can provide further insight into the effects of fish concentration on the interpretation of mean abundance derived from survey indices. If concentration increases over time as stocks are depleted, the relationship between absolute stock abundance and CPUE derived from fishery-dependent sources may change, altering the interpretation of trends in mean abundance derived from these measures. As this effect increases, the importance of statistically sound surveys becomes more important as a means of providing an unbiased measure of true stock abundance.

Inter-annual variability in survey indices may also be addressed by employing time-series smoothing techniques such as ARIMA. The use of smoothed indices of mature biomass for Georges

Bank cod in the regression of survey indices on VPA-based estimates of SSB reduced the effects of sampling variability and improved the predictability of the relationship. This technique may not be appropriate for all stocks as indicated for Gulf of Maine cod by the relatively poor fit between the survey indices and the VPA estimates of SSB. The VPA series for this stock is relatively short and the stock was dominated by a single very large year class in the second half of the time period used in the regressions. This resulted in a strong cyclical pattern in the biomass estimates which was out of phase in the survey and the VPA. The reasons for this lag in the survey biomass index should be investigated.

SARC Discussion

Northeast Groundfish Complex:

The SARC examined trends in abundance and biomass for aggregated species groups. In some cases, contradictory trends in abundance and biomass were noted. These patterns were due to changes in the relative abundance of light versus heavy-bodied species, age truncation from exploitation, and strong year classes. Vessel and door corrections were not possible for the aggregate indices, and it was noted that these corrections would accentuate the downward trends in most figures. It was suggested that the application of species-specific catchability coefficients could be used to refine the aggregate indices.

Habitat Preference Analysis:

Application of the Perry and Smith habitat preference model to test species affinity to temperature and depth revealed that some species show stability with regard to these habitat features. While the SARC accepted the randomizing procedure to produce a test statistic, the SARC thought that the maximum distance between the curves, had less information about potential differences than the area between the cumulative frequency distributions. Food preference data and

the distribution of prey items could be used to refine the habitat preference model and improve its explanatory capabilities for species that show low affinity for certain temperatures or depths. The catch weighted value will be sensitive to large cohorts. Changes in habitat preferences for aggregated ages may be related to year class strength. Age specific analyses were suggested. The SARC noted that when stocks are in a collapsed state, much of the preferred habitat may be unoccupied. Inclusion of outside sources of temperature data (such as existing oceanographic models) could allow for inclusion of tows omitted because temperature data were lacking. The SARC felt that the approach produced an effective measure of preference, but questioned whether it was effective in measuring shifts in preferences. With additional development of the analysis technique, the SARC felt that habitat preference studies could be useful to delineate the properties of closed areas.

General Additive Models (GAM):

GAM was a potentially useful analysis approach for smoothing data collected with measurement error and to stabilize variance. The SARC noted that the GAM model smoothing results in lower variance in the survey indices, but it produced a substantial spatial redistribution of fish. It was noted that the entire observed range of haddock was used in the analysis and that other factors can influence the ability of haddock to utilize preferred habitat such as an inability to cross natural barriers (e.g., deep channels) or from preference to other physical features. The GAM analysis approach allows the investigator to adjust the degrees of freedom so that the model is more sensitive to physical parameters versus observed catch. Changes to this input could reduce the observed redistribution as a result of smoothing. Since some species may undergo ontogenetic shifts in habitat preference, age specific analyses were recommended. The SARC noted that the approach demonstrated considerable promise as an approach to developing dynamic survey strata based on temperature, and urged the Coastal and Pelagic Subcommittee to investigate GAM models

for use in pelagic species assessments.

Lorenz Curves:

The SARC commented that the Lorenz Curve Concentration Index approach could also be applied to commercial landings data on a 10-minute scale to evaluate changes in commercial catchability and its potential effect on mortality estimates from VPA methods. The SARC noted the strong relationship between increased concentrations and declining levels of haddock abundance. It was also noted that the concentration index may be a useful signal to evaluate stock rebuilding. Although the GINI index for haddock trended higher as abundance declined, this response may not be generally applicable to species that have less affinity for optimal habitat.

Survey Index Estimates of Spawning Stock Biomass:

The SARC reviewed and accepted the ARIMA approach as an objective method of selecting smoothing parameters to stabilize variance caused by measurement error. When applied to survey indices of SSB, autocorrelation with a one year lag was consistent with successive measurements of the adult population. The use of an intercept term in the regression equations was accepted. Theoretically, this intercept term implies that there may be a threshold level of biomass below which the survey would be unable to detect the presence of SSB. The SARC suggested that a similar approach could be used to estimate fishing mortality by regressing exploitation rates derived from the VPA against the catch divided by the survey index. Future investigations could incorporate multiple surveys using a multiple regression or canonical correlation approach. Concerns were raised concerning the circularity of using survey indices to tune the VPA and then regressing VPA results against some derivation of the same survey.

General Comments:

The SARC specifically complimented members

of the Northern Demersal Subcommittee for producing original and integrative approaches in addressing the terms of reference. It was suggested that future SAWs could include subject oriented terms of reference that incorporate analyses from several species or take a multispecies approach to addressing these types of questions.

Research Recommendations

- o Evaluate trends in habitat presence by performing segregated analyses by life history stages.
- o Additional factors including summarizations of food habits data, finer scale temperature and depth data, and MARMAP larval data sets could be incorporated into the Habitat Preference and GAM modeling approaches and provide additional information characterizing the demersal complex.
- o Apply the General Additive Model approach to developing dynamic survey strata based on temperature for pelagic species (mackerel) and highly aggregated demersal species (scup).
- o Investigate the sensitivity of the Gini index from the Lorenz curve to unequal strata size.
- o Investigate the use of the Bin Index based on the Lorenz curve to measure the contraction of commercial landings data on a 10-minute scale.
- o Investigate other parametric measures of dispersion and compare these with the Lorenz curve method.
- o Consider the application of mature survey biomass/VPA-SSB regressions to other species, preferably a species, with a longer time series such as Georges Bank haddock.
- o Investigate the effect of using a single length-weight equation in converting number to

biomass at length for both stocks of cod in the prediction of SSB analysis.

- o Investigate the potential for estimating mortality by regressing exploitation rates derived from the VPA against the catch divided by the survey index subsequent to smoothing algorithms using time series analysis.

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Table E2.1. Strata sets used for the NEFSC and the Massachusetts Inshore surveys. Conversion factors are also listed if any were applied to the NEFSC data (V = Vessel, D = Door).

Stock	NEFSC Strata Set	Conversion	Massachusetts Strata Set
GB Cod	01130-01250	D,V	-
GM Cod	01260-01300, 01360-01400	D,V	25-36
GB Haddock	01130-01250, 01290-01300	D,V	-
GM Haddock	01260-01280, 01360-01400	D,V	25-36
Pollock	01130-01400	-	11-36
Redfish	01240, 01260-01300, 01360-01400	-	11-36
White Hake	01210-01300, 01330-01400	-	11-36
GB Yellowtail Flounder	01130-01210	D,V	-
SNE Yellowtail Flounder	01050-01060, 01090-01100	D,V	11-16
GM Yellowtail Flounder	01240-01260	D,V	17-36
American Plaice	01130-01300, 01360-01400	-	25-36
Witch Flounder	01220-01300, 01360-01400	-	25-36
GB Winter Flounder	01130, 01160, 01190-01210	D	-
SNE-MA Winter Flounder	01010-01120, 01250, 01690-01760 03010-03290, 03450-03560	D	11-21
GM Winter Flounder	01240, 01260-01290, 01350-01400 03570-03660	D	25-36
GM-GB Windowpane Flounder	01130-01290, 01370-01400	-	11-36
SNE-MA Windowpane Flounder	01010-01120, 01610-01760	-	-
GM-NGB Silver Hake	01200-01300, 01360-01400	-	11-36
SGB-MA Silver Hake	01010-01190, 01610-01760, 03010-03460, 03520, 03550	-	-
GM-NGB Red Hake	01200-01300, 01360-01400	-	11-36
SGB-MA Red Hake	01010-01190, 01610-01760, 03010-03460, 03520, 03550	-	-
Ocean Pout	01010-01260, 01730- 01760	-	11-36
Wolffish	01210-01400	-	11-36
Goosefish	01010-01300, 01340-01400, 01610-01760	-	11-36
Cusk	01210-01400	-	-

Table E3.1. Results of univariate randomization test of association between catches of yellowtail flounder, cod and haddock and average temperature and depth during the NEFSC spring bottom trawl survey, 1968-1994. Table entries are probabilities levels of random association (of having a test statistic greater than or equal to the observed value by chance alone) between catches and the environmental factor.

Year	Bottom Temperature			Average Depth		
	Yellowtail	Cod	Haddock	Yellowtail	Cod	Haddock
1968	<0.001	<0.01	ns	<0.001	ns	ns
1969	<0.001	<0.001	<0.05	<0.001	<0.01	ns
1970	ns	<0.001	<0.01	<0.001	<0.001	ns
1971	<0.001	<0.001	ns	<0.001	<0.01	ns
1972	ns	<0.001	<0.05	<0.001	<0.001	ns
1973	<0.01	<0.001	ns	<0.001	ns	ns
1974	<0.001	<0.001	<0.001	<0.001	<0.001	<0.05
1975	<0.001	<0.001	<0.01	<0.01	<0.01	<0.05
1976	<0.001	<0.001	<0.001	<0.05	<0.001	ns
1977	<0.01	ns	ns	<0.05	<0.001	ns
1978	<0.001	<0.001	<0.01	<0.001	<0.01	ns
1979	<0.001	<0.001	ns	<0.001	<0.05	ns
1980	<0.01	<0.05	ns	ns	<0.05	<0.05
1981	<0.05	ns	ns	<0.001	<0.01	<0.05
1982	ns	ns	<0.001	<0.001	ns	ns
1983	<0.01	ns	ns	<0.001	<0.01	<0.05
1984	<0.01	<0.01	ns	<0.001	<0.01	ns
1985	ns	ns	ns	ns	<0.01	ns
1986	<0.05	<0.01	ns	<0.01	<0.05	<0.01
1987	<0.05	<0.01	ns	<0.01	<0.01	ns
1988	<0.01	<0.001	ns	<0.01	<0.001	<0.01
1989	<0.05	<0.01	ns	<0.001	<0.05	ns
1990	ns	<0.05	ns	<0.001	ns	ns
1991	ns	<0.001	<0.01	<0.001	ns	ns
1992	<0.005	ns	ns	<0.05	ns	<0.01
1993	<0.001	ns	ns	<0.05	ns	ns
1994	ns	ns	ns	ns	ns	ns

ns = not significant at the $\alpha = 0.05$ level.

Table E3.2. Results of univariate randomization test of association between catches of yellowtail flounder, cod and haddock and average temperature and depth during the NEFSC autumn bottom trawl survey, 1963-1994. Table entries are probabilities levels of random association (of having a test statistic greater than or equal to the observed value by chance alone) between catches and the environmental factor.

Year	Bottom Temperature			Average Depth		
	Yellowtail	Cod	Haddock	Yellowtail	Cod	Haddock
1963	ns	ns	<0.05	<0.001	ns	ns
1964	<0.01	<0.05	<0.05	<0.05	ns	<0.001
1965	ns	<0.05	<0.001	<0.01	ns	<0.001
1966	<0.001		<0.05	<0.05	<0.001	ns
1967	<0.05	ns	ns	<0.001	<0.01	ns
1968	ns	ns	<0.05	<0.001	ns	ns
1969	ns	<0.01	<0.001	<0.001	ns	<0.01
1970	ns	ns	ns	<0.01	ns	ns
1971	ns	ns	<0.05	<0.001	ns	ns
1972	ns	ns	<0.01	ns	ns	<0.01
1973	ns	ns	ns	ns	<0.05	ns
1974	ns	<0.01	<0.001	<0.01	ns	ns
1975	<0.05	<0.05	ns	ns	ns	ns
1976	ns	ns	ns	ns	ns	ns
1977	ns	<0.001	<0.001	ns	ns	ns
1978	<0.01	<0.001	ns	<0.001	ns	ns
1979	ns	ns	ns	<0.001	<0.05	ns
1980	ns	<0.001	ns	ns	ns	ns
1981	ns	ns	<0.001	<0.01	ns	<0.01
1982	ns	ns	ns	<0.01	ns	<0.05
1983	ns	ns	ns	<0.05	ns	ns
1984	ns	ns	ns	<0.01	ns	ns
1985	ns	<0.01	ns	<0.01	ns	ns
1986	ns	<0.001	<0.05	ns	ns	ns
1987	ns	<0.05	ns	ns	ns	ns
1988	ns	ns	ns	<0.001	ns	ns
1989	ns	ns	ns	ns	ns	ns
1990	ns	ns	ns	ns	ns	ns
1991	ns	<0.001	ns	ns	ns	ns
1992	ns	<0.01	ns	ns	ns	ns
1993	ns	<0.001	<0.05	ns	ns	ns
1994	ns	ns	<0.05	ns	ns	ns

ns = not significant at the $\alpha = 0.05$ level.

Table E3.3. Percentiles of average depths and catch-weighted average depths of yellowtailflounder cod and haddock from Southern New England, Georges Bank and the Gulf of Maine during the NEFSC spring bottom trawl survey, 1968-1994.

Year	Environment			Yellowtail			Atlantic Cod			Haddock		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
1968	60.00	95.00	180.00	45.00	50.00	60.00	60.00	85.00	130.00	75.00	110.00	175.00
1969	60.00	95.00	180.00	35.00	45.00	55.00	40.00	65.00	105.00	65.00	80.00	165.00
1970	60.00	95.00	195.00	35.00	45.00	55.00	45.00	75.00	115.00	70.00	75.00	90.00
1971	60.00	95.00	175.00	40.00	50.00	65.00	50.00	65.00	110.00	80.00	85.00	160.00
1972	60.00	85.00	180.00	40.00	50.00	50.00	50.00	65.00	80.00	75.00	80.00	85.00
1973	60.00	90.00	185.00	40.00	50.00	65.00	55.00	60.00	70.00	75.00	75.00	80.00
1974	60.00	95.00	175.00	40.00	50.00	65.00	50.00	70.00	90.00	65.00	85.00	90.00
1975	60.00	95.00	170.00	50.00	60.00	75.00	50.00	55.00	80.00	70.00	75.00	85.00
1976	55.00	90.00	180.00	40.00	60.00	80.00	45.00	65.00	90.00	65.00	70.00	80.00
1977	60.00	90.00	180.00	35.00	50.00	65.00	45.00	60.00	100.00	60.00	75.00	85.00
1978	55.00	90.00	170.00	40.00	50.00	60.00	45.00	60.00	85.00	55.00	70.00	85.00
1979	55.00	90.00	180.00	50.00	60.00	65.00	55.00	90.00	140.00	85.00	85.00	90.00
1980	60.00	90.00	175.00	50.00	65.00	95.00	50.00	80.00	100.00	55.00	65.00	75.00
1981	60.00	90.00	180.00	40.00	50.00	60.00	50.00	60.00	90.00	60.00	70.00	105.00
1982	60.00	95.00	185.00	50.00	60.00	70.00	80.00	80.00	85.00	80.00	100.00	110.00
1983	60.00	95.00	180.00	45.00	55.00	65.00	45.00	55.00	100.00	60.00	85.00	130.00
1984	60.00	95.00	180.00	45.00	50.00	65.00	50.00	60.00	115.00	70.00	85.00	95.00
1985	60.00	95.00	185.00	45.00	60.00	75.00	45.00	75.00	120.00	70.00	75.00	85.00
1986	60.00	95.00	180.00	45.00	55.00	65.00	55.00	75.00	125.00	70.00	75.00	90.00
1987	60.00	90.00	185.00	45.00	55.00	60.00	55.00	65.00	90.00	55.00	60.00	65.00
1988	60.00	90.00	185.00	45.00	55.00	65.00	50.00	70.00	90.00	65.00	70.00	85.00
1989	55.00	95.00	180.00	45.00	55.00	65.00	55.00	80.00	110.00	80.00	90.00	100.00
1990	55.00	90.00	185.00	40.00	55.00	60.00	45.00	75.00	115.00	80.00	95.00	100.00
1991	60.00	90.00	190.00	50.00	50.00	65.00	60.00	90.00	135.00	90.00	95.00	100.00
1992	55.00	85.00	180.00	50.00	60.00	65.00	60.00	105.00	170.00	70.00	95.00	100.00
1993	55.00	90.00	180.00	50.00	60.00	75.00	55.00	80.00	160.00	80.00	80.00	120.00
1994	60.00	95.00	185.00	60.00	75.00	80.00	70.00	85.00	150.00	80.00	95.00	110.00
Ave	58.70	92.04	180.93	44.26	54.81	66.30	52.41	72.22	109.26	70.56	81.48	101.48

Table E3.4. Percentiles of bottom temperatures and catch-weighted bottom temperatures of yellowtail flounder, cod and haddock from Southern New England, Georges Bank and the Gulf of Maine during the NEFSC spring bottom trawl survey, 1968-1994.

Year	Environment			Yellowtail			Atlantic Cod			Haddock		
	25%	50%	75%	Percentile			25%	50%	75%	25%	50%	75%
				25%	50%	75%						
1968	3.30	5.00	6.30	2.20	3.80	4.20	2.10	3.30	5.10	3.60	4.40	5.10
1969	4.10	5.10	6.90	2.30	2.90	4.20	3.10	4.40	4.90	4.30	4.80	5.10
1970	4.50	5.70	7.20	4.30	4.90	5.40	3.90	4.50	5.00	3.90	4.30	5.40
1971	3.90	6.20	7.30	3.40	4.10	4.90	3.70	3.90	4.70	3.70	3.90	5.80
1972	4.80	5.90	8.10	4.90	5.70	6.30	4.10	4.50	4.80	4.50	4.60	5.80
1973	4.60	5.80	8.00	4.60	5.20	5.90	4.50	4.70	4.90	6.00	6.70	7.10
1974	6.20	7.20	8.20	5.80	6.20	7.10	5.80	6.20	6.90	6.10	6.60	6.80
1975	5.50	6.40	8.00	4.80	5.20	5.70	5.10	5.50	5.70	5.10	5.50	5.70
1976	5.60	7.00	8.50	5.20	5.30	5.60	5.20	5.40	5.90	5.40	5.50	5.60
1977	4.90	5.50	6.50	3.70	4.80	5.40	4.90	5.70	6.40	4.80	5.30	5.90
1978	4.30	5.10	6.30	2.80	3.80	4.30	4.40	4.80	5.20	4.60	4.70	4.80
1979	4.60	5.50	7.10	4.30	4.50	5.20	4.00	4.60	5.30	4.80	5.00	5.80
1980	5.00	5.80	6.70	4.90	5.60	5.80	4.90	5.70	6.00	5.70	5.90	6.00
1981	4.90	5.70	6.60	4.60	5.10	5.80	5.00	5.70	6.20	5.10	5.40	6.00
1982	4.50	5.50	6.90	4.40	4.70	5.70	4.20	4.30	4.80	4.10	4.20	4.40
1983	5.40	6.10	7.20	4.70	5.60	6.20	3.90	4.30	4.90	5.40	6.00	6.20
1984	5.00	5.70	7.40	4.00	5.00	5.60	3.50	4.50	5.50	5.50	5.70	6.70
1985	5.00	5.50	7.50	5.00	5.20	5.40	5.00	5.10	5.00	5.00	5.00	5.10
1986	5.80	6.50	9.20	4.40	6.00	6.40	5.80	6.00	6.00	6.00	6.20	6.80
1987	5.00	5.60	6.90	3.90	4.40	5.10	4.10	5.10	5.30	5.20	5.20	5.30
1988	4.70	6.20	7.80	4.20	4.80	5.10	4.30	4.70	5.00	4.00	5.40	7.90
1989	4.40	5.20	7.70	4.00	4.10	4.40	4.00	4.50	4.70	4.50	4.80	5.10
1990	4.90	5.50	7.20	4.70	5.30	5.70	4.70	5.30	5.50	5.40	5.60	6.70
1991	5.40	5.90	7.30	5.40	5.70	6.40	5.00	5.40	5.70	5.10	5.20	5.30
1992	4.30	5.80	7.50	3.90	4.20	5.10	4.30	4.90	6.60	4.10	4.60	5.30
1993	4.00	4.70	7.00	3.20	3.60	4.50	3.30	4.50	5.30	4.50	4.70	5.20
1994	4.80	5.80	8.70	3.90	4.20	5.10	4.00	5.20	6.10	6.00	6.10	6.10
Ave	4.79	5.77	7.41	4.20	4.81	5.43	4.33	4.91	5.46	4.90	5.23	5.81

Table E3.5. Percentiles of average depths and catch-weighted average depths of yellowtail flounder cod and haddock from Southern New England, Georges Bank and the Gulf of Maine during the NEFSC autumn bottom trawl survey, 1963-1994.

Year	Environment			Yellowtail			Atlantic Cod			Haddock		
	25%	50%	75%	25%	50%	75%	Percentile			25%	50%	75%
							25%	50%	75%			
1963	60.00	90.00	175.00	45.00	50.00	65.00	55.00	80.00	155.00	55.00	85.00	155.00
1964	60.00	95.00	180.00	45.00	50.00	75.00	75.00	130.00	195.00	55.00	70.00	85.00
1965	60.00	95.00	185.00	45.00	45.00	55.00	55.00	105.00	125.00	45.00	55.00	80.00
1966	60.00	95.00	175.00	40.00	45.00	55.00	55.00	85.00	100.00	55.00	70.00	150.00
1967	55.00	90.00	180.00	45.00	50.00	55.00	50.00	55.00	80.00	65.00	75.00	185.00
1968	55.00	90.00	175.00	40.00	50.00	60.00	55.00	95.00	140.00	75.00	120.00	205.00
1969	60.00	90.00	175.00	50.00	55.00	65.00	60.00	105.00	155.00	95.00	165.00	190.00
1970	60.00	90.00	185.00	50.00	60.00	65.00	45.00	60.00	125.00	60.00	65.00	160.00
1971	60.00	90.00	180.00	45.00	50.00	55.00	55.00	85.00	110.00	55.00	70.00	175.00
1972	55.00	90.00	165.00	55.00	65.00	70.00	50.00	65.00	90.00	80.00	95.00	115.00
1973	60.00	95.00	175.00	55.00	65.00	75.00	50.00	75.00	95.00	80.00	85.00	100.00
1974	55.00	90.00	185.00	60.00	65.00	75.00	60.00	75.00	115.00	65.00	90.00	150.00
1975	60.00	95.00	170.00	65.00	70.00	90.00	55.00	80.00	100.00	60.00	70.00	155.00
1976	60.00	90.00	175.00	55.00	60.00	65.00	75.00	80.00	125.00	75.00	75.00	85.00
1977	55.00	90.00	180.00	45.00	55.00	75.00	65.00	85.00	140.00	80.00	85.00	130.00
1978	60.00	90.00	175.00	65.00	60.00	65.00	65.00	95.00	135.00	55.00	100.00	190.00
1979	55.00	90.00	175.00	45.00	55.00	70.00	75.00	95.00	155.00	120.00	125.00	145.00
1980	55.00	90.00	180.00	55.00	70.00	85.00	60.00	70.00	120.00	60.00	140.00	195.00
1981	60.00	90.00	175.00	45.00	55.00	65.00	70.00	110.00	120.00	95.00	135.00	175.00
1982	55.00	90.00	180.00	45.00	50.00	60.00	25.00	30.00	105.00	105.00	130.00	110.00
1983	60.00	90.00	180.00	55.00	65.00	70.00	50.00	85.00	130.00	75.00	85.00	145.00
1984	60.00	95.00	185.00	50.00	60.00	70.00	85.00	95.00	120.00	95.00	120.00	200.00
1985	65.00	95.00	180.00	50.00	65.00	70.00	70.00	90.00	130.00	70.00	80.00	90.00
1986	60.00	95.00	175.00	50.00	60.00	70.00	85.00	120.00	140.00	85.00	105.00	200.00
1987	60.00	90.00	175.00	50.00	65.00	75.00	70.00	75.00	100.00	60.00	65.00	75.00
1988	60.00	95.00	180.00	40.00	50.00	65.00	40.00	75.00	110.00	80.00	90.00	115.00
1989	60.00	90.00	185.00	55.00	60.00	70.00	65.00	90.00	105.00	100.00	140.00	265.00
1990	60.00	90.00	175.00	55.00	60.00	70.00	75.00	80.00	110.00	80.00	95.00	195.00
1991	60.00	90.00	180.00	60.00	70.00	80.00	80.00	95.00	150.00	85.00	90.00	115.00
1992	55.00	85.00	185.00	45.00	60.00	75.00	65.00	70.00	95.00	55.00	70.00	80.00
1993	60.00	90.00	180.00	45.00	55.00	80.00	70.00	75.00	105.00	80.00	80.00	85.00
1994	60.00	95.00	180.00	55.00	65.00	80.00	65.00	80.00	120.00	85.00	125.00	255.00
Ave	58.75	91.41	178.28	50.16	58.13	69.38	61.72	84.06	121.88	74.53	95.31	148.59

Table E3.6. Percentiles of bottom temperatures and catch-weighted bottom temperatures of yellowtail flounder, cod and haddock from Southern New England, Georges Bank and the Gulf of Maine during the NEFSC autumn bottom trawl survey, 1963-1994.

Year	Environment			Yellowtail			Atlantic Cod			Haddock		
	Percentile											
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
1963	6.80	8.40	10.10	8.70	9.50	10.30	6.70	8.70	9.00	6.50	7.40	9.00
1964	5.70	7.50	10.30	8.40	11.00	11.70	5.70	6.30	7.20	7.30	8.60	10.70
1965	5.90	8.60	10.50	9.40	10.20	12.00	4.60	5.50	9.00	9.10	12.20	13.50
1966	5.40	8.00	9.70	9.80	10.90	12.20	4.80	5.60	10.90	5.30	8.90	12.00
1967	6.30	8.00	9.30	8.70	9.00	10.60	6.90	8.80	9.00	5.70	7.00	8.90
1968	7.30	9.00	11.90	8.80	9.70	11.60	6.30	8.60	10.00	6.20	8.20	9.10
1969	7.10	9.70	12.20	10.80	12.00	13.20	6.90	8.30	10.10	6.00	7.10	8.30
1970	7.20	8.80	10.70	8.00	9.30	10.50	8.10	9.80	11.80	7.30	10.90	11.80
1971	7.70	9.10	11.90	7.70	9.20	11.60	7.80	8.50	10.20	6.90	7.90	10.20
1972	8.50	9.90	12.60	10.50	10.60	11.60	8.40	9.80	10.00	8.30	9.20	10.20
1973	8.10	10.50	13.30	10.50	12.10	13.20	7.30	8.90	10.90	7.50	9.90	10.90
1974	8.50	10.70	13.20	10.80	12.10	13.60	7.40	7.90	10.60	6.80	7.90	9.00
1975	8.20	10.30	12.00	9.70	10.50	11.50	7.60	7.90	10.50	8.30	10.50	11.70
1976	8.70	10.40	12.90	9.90	10.70	13.00	7.80	10.80	11.80	11.50	11.70	11.80
1977	8.20	10.50	12.70	10.00	10.50	11.80	7.20	8.90	10.40	7.30	8.30	9.30
1978	7.20	9.00	11.40	10.70	11.30	12.70	6.70	8.40	9.40	6.40	8.40	12.50
1979	7.60	10.10	12.60	10.10	11.10	12.90	7.20	9.70	12.00	7.10	7.20	8.30
1980	7.80	9.80	12.40	9.20	11.70	12.90	6.80	8.60	9.20	8.20	9.20	11.60
1981	7.00	9.40	11.30	9.60	10.70	12.30	5.80	7.10	9.70	5.80	7.10	8.30
1982	7.50	10.00	12.20	10.10	10.40	13.20	9.40	10.60	10.70	7.20	8.00	10.10
1983	8.20	9.60	12.10	10.10	10.80	12.20	7.70	8.60	9.80	8.30	9.20	9.30
1984	8.10	9.90	12.90	9.40	12.10	12.50	6.30	8.30	8.50	6.30	8.30	11.30
1985	8.40	11.50	13.70	10.00	13.20	13.40	7.80	9.00	9.50	9.20	9.90	11.20
1986	8.20	10.70	13.00	11.10	12.10	13.00	7.60	8.10	8.80	8.20	9.10	9.20
1987	7.50	9.00	11.20	8.10	9.10	10.30	7.10	7.90	8.10	8.10	8.30	8.30
1988	7.40	8.80	11.40	8.60	8.70	10.90	7.40	7.40	8.80	6.00	7.20	8.60
1989	7.20	8.80	11.30	7.70	8.60	10.30	6.90	7.50	7.70	7.70	7.80	8.80
1990	6.70	7.80	11.30	7.00	9.90	11.30	7.50	8.90	9.30	6.00	6.10	6.10
1991	8.00	9.40	12.40	9.90	10.40	10.40	6.80	7.40	8.90	7.40	9.90	11.10
1992	7.40	9.30	12.80	7.00	9.20	9.20	6.50	7.10	9.20	7.00	8.70	10.00
1993	8.00	9.10	12.50	10.00	10.50	10.50	5.90	6.10	7.40	6.90	7.00	8.60
1994	8.50	10.70	13.30	9.50	10.20	13.00	7.60	10.20	13.40	7.30	9.40	9.50
Ave	7.51	9.45	11.91	9.37	10.54	11.86	7.02	8.29	9.74	7.28	8.64	9.98

Table E4.1. R^2 values for two GAMs¹, the difference in R^2 between the models, and number of fish captured and number of stations with bottom temperature recorded for Georges Bank-Gulf of Maine haddock (strata 13-40), 1963-1994.

Year	Model 1	Model 2	Difference	Fish	Stations w/temperature	Catch stations w/o temperature
1963	0.39	0.45	0.06	21105	131	1
1964	0.36	0.48	0.12	15501	118	2
1965	0.35	0.54	0.19	10712	123	5
1966	0.24	0.54	0.30	5622	100	4
1967	0.28	0.44	0.16	2952	102	18
1968	0.30	0.51	0.21	1979	85	11
1969	0.53	0.62	0.09	1751	80	14
1970	0.20	0.50	0.30	1676	109	3
1971	0.32	0.53	0.21	2507	120	1
1972	0.50	0.67	0.17	3695	104	4
1973	0.54	0.63	0.09	3318	91	6
1974	0.32	0.53	0.21	2052	89	5
1975	0.21	0.45	0.24	5898	129	0
1976	0.59	0.74	0.15	7496	80	3
1977	0.54	0.62	0.08	9867	130	3
1978	0.06	0.38	0.32	7712	199	8
1979	0.42	0.59	0.17	18171	169	9
1980	0.11	0.39	0.28	8266	111	7
1981	0.40	0.71	0.31	3995	91	1
1982	0.60	0.73	0.13	305	73	12
1983	0.46	0.81	0.35	3231	67	27
1984	0.55	0.80	0.25	1206	39	94
1985	0.49	0.66	0.17	598	30	54
1986	0.58	0.79	0.21	798	35	20
1987	0.65	0.70	0.05	3464	32	41
1988	0.71	0.88	0.17	301	15	30
1989	0.53	0.74	0.21	317	22	24
1990	0.93	0.99	0.06	88	4	40
1991	0.41	0.69	0.28	1155	39	1
1992	0.31	0.49	0.18	760	62	9
1993	0.58	0.81	0.23	1292	52	5
1994	0.41	0.90	0.49	2145	33	8
1963-1994	0.16	0.29	0.13	152684	2664	

Model 1: Catch number = $s(\text{average depth}) + s(\text{bottom temperature})$

Model 2: Catch number = $s(\text{average depth}) + s(\text{bottom temperature}) + \text{latitude} + \text{longitude}$

Table E4.2. Stratified mean number per tow and coefficient of variation (CV) for observed and GAM fitted catch numbers for Georges Bank-Gulf of Maine haddock (strata 13- 40), 1963-1994.

Year	OBSERVED		GAM FIT	
	Mean	CV	Mean	CV
1963	145.77	0.16	127.38	0.04
1964	180.46	0.19	154.83	0.06
1965	101.56	0.15	89.78	0.08
1966	33.11	0.19	32.88	0.07
1967	16.17	0.31	14.50	0.04
1968	6.17	0.39	6.12	0.07
1969	3.45	0.31	6.71	0.22
1970	8.08	0.55	6.80	0.09
1971	4.13	0.22	6.14	0.10
1972	10.85	0.21	10.64	0.17
1993	15.98	0.35	9.44	0.18
1974	4.23	0.24	4.47	0.08
1975	30.74	0.24	23.91	0.05
1976	70.78	0.48	53.79	0.26
1977	23.41	0.33	21.77	0.16
1978	25.30	0.20	28.05	0.04
1979	57.07	0.59	48.45	0.15
1980	28.75	0.23	37.79	0.07
1981	13.38	0.31	12.52	0.11
1982	5.36	0.32	6.95	0.27
1983	7.97	0.38	8.40	0.21
1984	3.42	0.40	5.90	0.11
1985	10.77	0.38	11.22	0.28
1986	6.58	0.52	5.62	0.30
1987	4.91	0.36	3.16	0.05
1988	2.57	0.66	4.10	0.55
1989	6.33	0.46	6.76	0.33
1990	1.77	0.52	1.78	0.50
1991	6.98	0.38	7.21	0.14
1992	4.39	0.30	3.94	0.14
1993	6.33	0.30	6.62	0.20
1994	10.34	0.56	10.28	0.35

Table E5.1. Input data for Lorenz curves analyses of NEFSC bottom trawl survey data for Georges Bank haddock in 1974. Area is in square nautical miles.

Stratum	Area	Percent Area	Biomass kg	Percent Biomass	Mean Weight (kg) per tow
13	2374	12.4	0	0.0	0.00
14	656	3.4	0	0.0	0.00
15	230	1.2	0	0.0	0.00
16	2980	15.5	749967	9.8	2.52
17	360	1.9	93771	1.2	2.60
18	172	0.9	31166	0.4	1.81
19	2454	12.8	0	0.0	0.00
20	1221	6.4	0	0.0	0.00
21	424	2.2	565012	7.4	13.33
22	454	2.4	1134569	14.8	24.99
23	1016	5.3	770148	10.1	7.58
24	2569	13.4	2586132	33.8	10.07
25	390	2.0	519704	6.8	13.33
29	3245	16.9	1194363	15.6	3.68
30	619	3.2	15578	0.2	0.25
Total	19164	100.0	7660410	100.0	

Table E5.2. Input data for Lorenz curve analysis of 1974 Georges Bank haddock from the NEFSC autumn bottom trawl survey, **ordered by biomass**. Area is in square nautical miles.

Stratum	Area	Percent Area	Biomass kg	Percent Biomass	Mean	Cumulative %	
					Weight (kg) per tow	Area	Biomass
19	2454	12.8	0	0.0	0.00	12.81	0.00
20	1221	6.4	0	0.0	0.00	19.18	0.00
14	656	3.4	0	0.0	0.00	22.60	0.00
13	2374	12.4	0	0.0	0.00	34.99	0.00
15	230	1.2	0	0.0	0.00	36.19	0.00
30	619	3.2	15578	0.2	0.25	39.42	0.20
18	172	0.9	31166	0.4	1.81	40.32	0.61
17	360	1.9	93771	1.2	2.60	42.19	1.83
25	390	2.0	519704	6.8	13.33	44.23	8.62
21	424	2.2	565012	7.4	13.33	46.44	15.99
16	2980	15.5	749967	9.8	2.52	61.99	25.78
23	1016	5.3	770148	10.1	7.58	67.29	35.84
22	454	2.4	1134569	14.8	24.99	69.66	50.65
29	3245	16.9	1194363	15.6	3.68	86.59	66.24
24	2569	13.4	2586132	33.8	10.07	100.00	100.00
Total	19164	100.0	7660410	100.0			

Gini Index = 0.45

Table E5.3. Input data for Lorenz curve analysis of 1974 Georges Bank haddock from the NEFSC autumn bottom trawl survey, **ordered by mean weight per tow**. Area is in square nautical miles.

Stratum	Area	Percent Area	Biomass kg	Percent Biomass	Mean	Cumulative %	
					Weight (kg) per tow	Area	Biomass
19	2454	12.8	0	0.00	0.00	12.81	0.00
14	656	3.4	0	0.00	0.00	16.23	0.00
13	2374	12.4	0	0.00	0.00	28.62	0.00
15	230	1.2	0	0.00	0.00	29.82	0.00
20	1221	6.4	0	0.00	0.00	36.19	0.00
30	619	3.2	15578	0.2	0.25	39.42	0.20
18	172	0.9	31166	0.4	1.81	40.32	0.61
16	2980	15.5	749967	9.8	2.52	55.87	10.40
17	360	1.9	93771	1.2	2.60	57.74	11.62
29	3245	16.9	1194363	15.6	3.68	74.68	27.22
23	1016	5.3	770148	10.1	7.58	79.98	37.27
24	2569	13.4	2586132	33.8	10.07	93.38	71.03
21	424	2.2	565012	7.4	13.33	95.60	78.40
25	390	2.0	519704	6.8	13.33	97.63	85.19
22	454	2.4	1134569	14.8	24.99	100.00	100.00
Total	19164	100.0	7660410	100.0			

Gini Index = 0.62

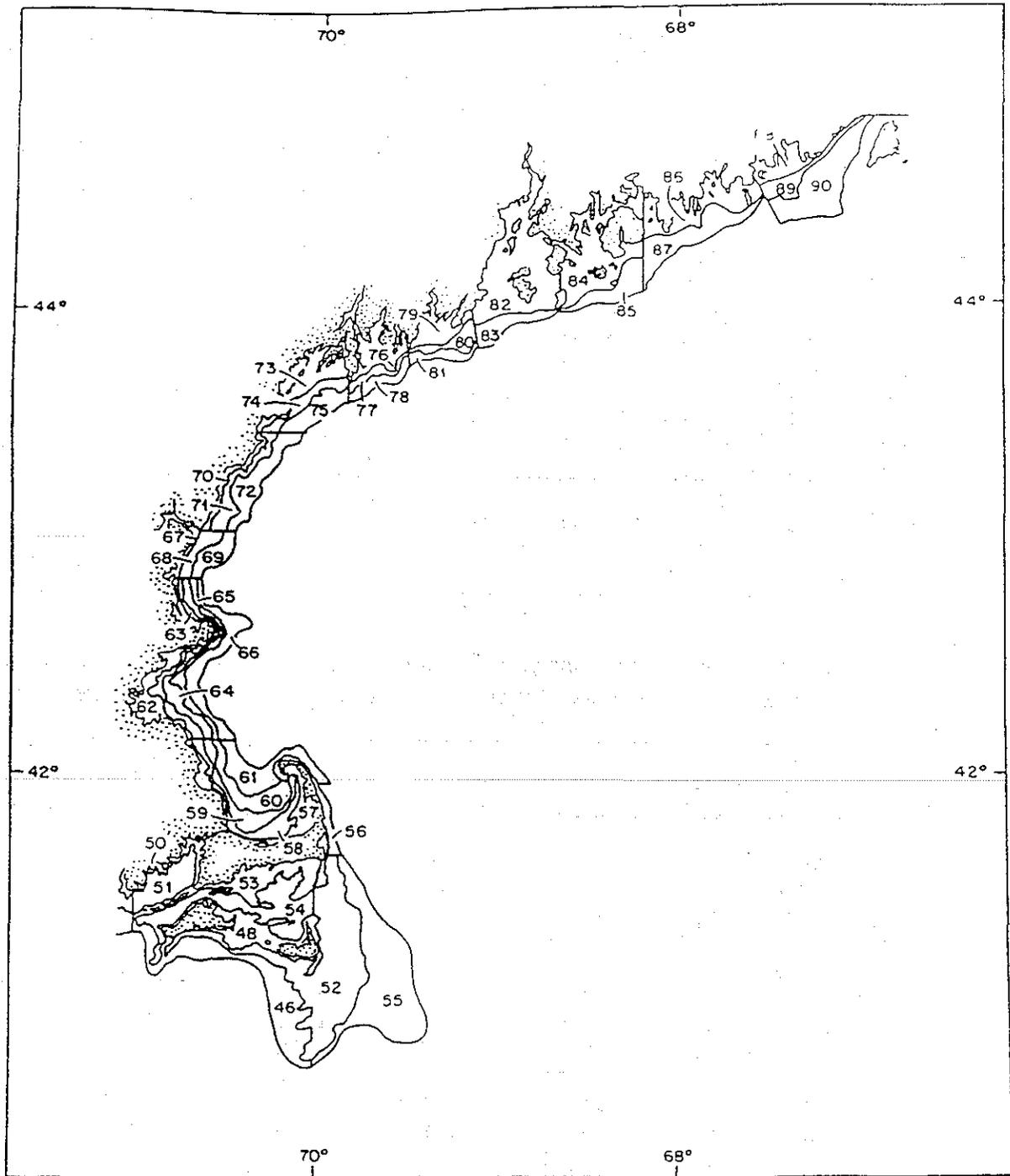


Figure E2.1. Strata sampled on NEFSC inshore bottom trawl surveys from Eastport, Maine to Buzzards Bay, Massachusetts.

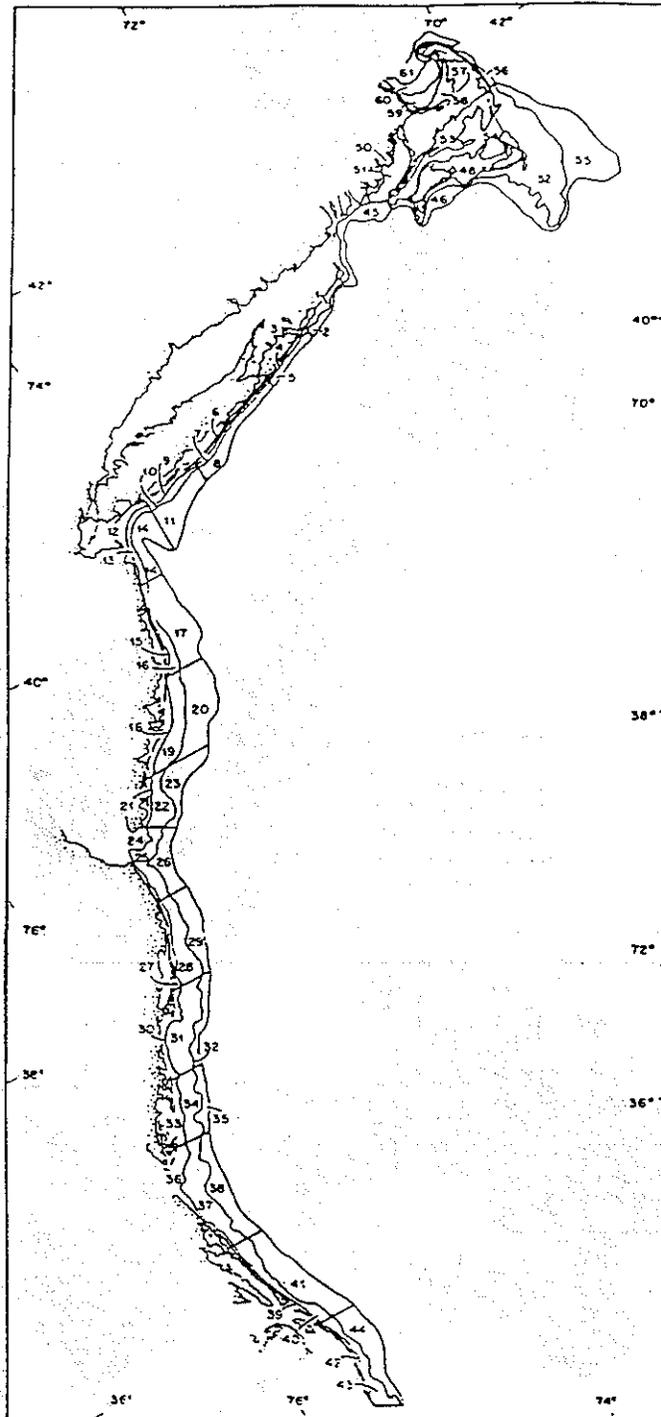


Figure E2.2. Strata sampled on NEFSC inshore bottom trawl surveys from Cape Cod Bay, Massachusetts to Cape Hatteras, North Carolina.

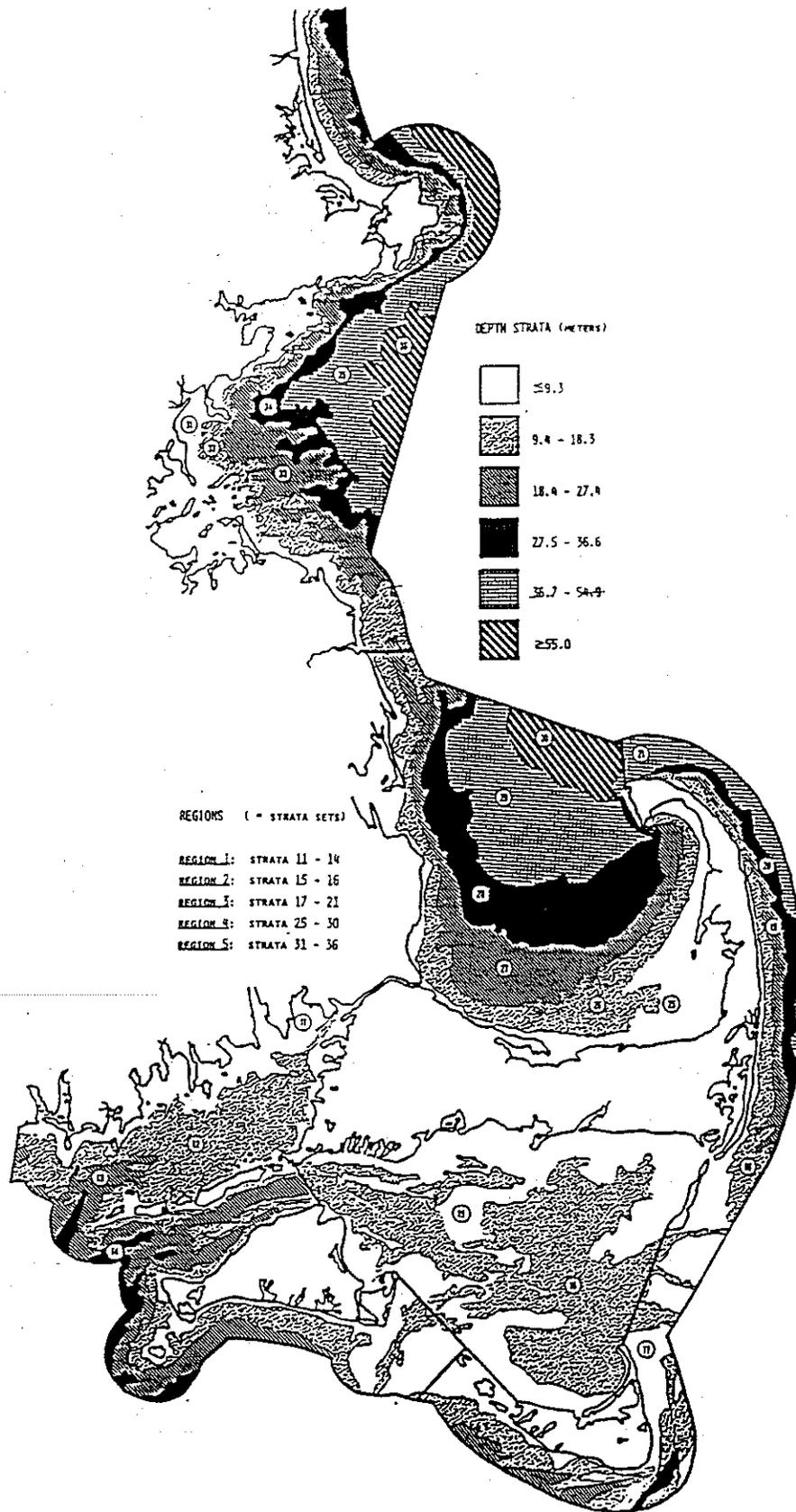


Figure 2.3. Sampling strata used in Massachusetts DMF inshore bottom trawl surveys.

NEFSC Surveys

MASS Surveys

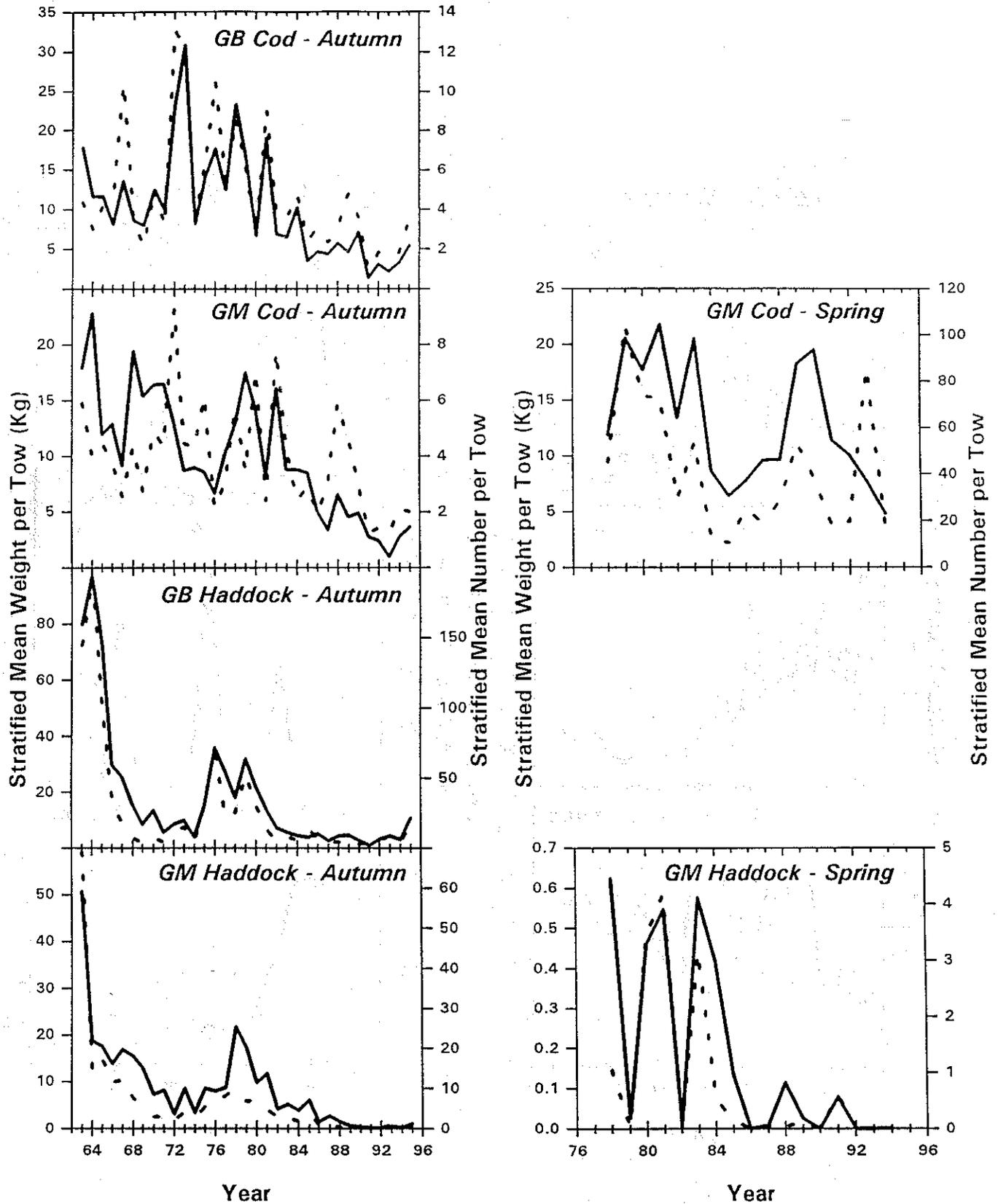


Figure E2.4. Abundance and biomass indices for Cod and haddock from the NEFSC and Massachusetts surveys (solid line - biomass, dotted line - abundance)

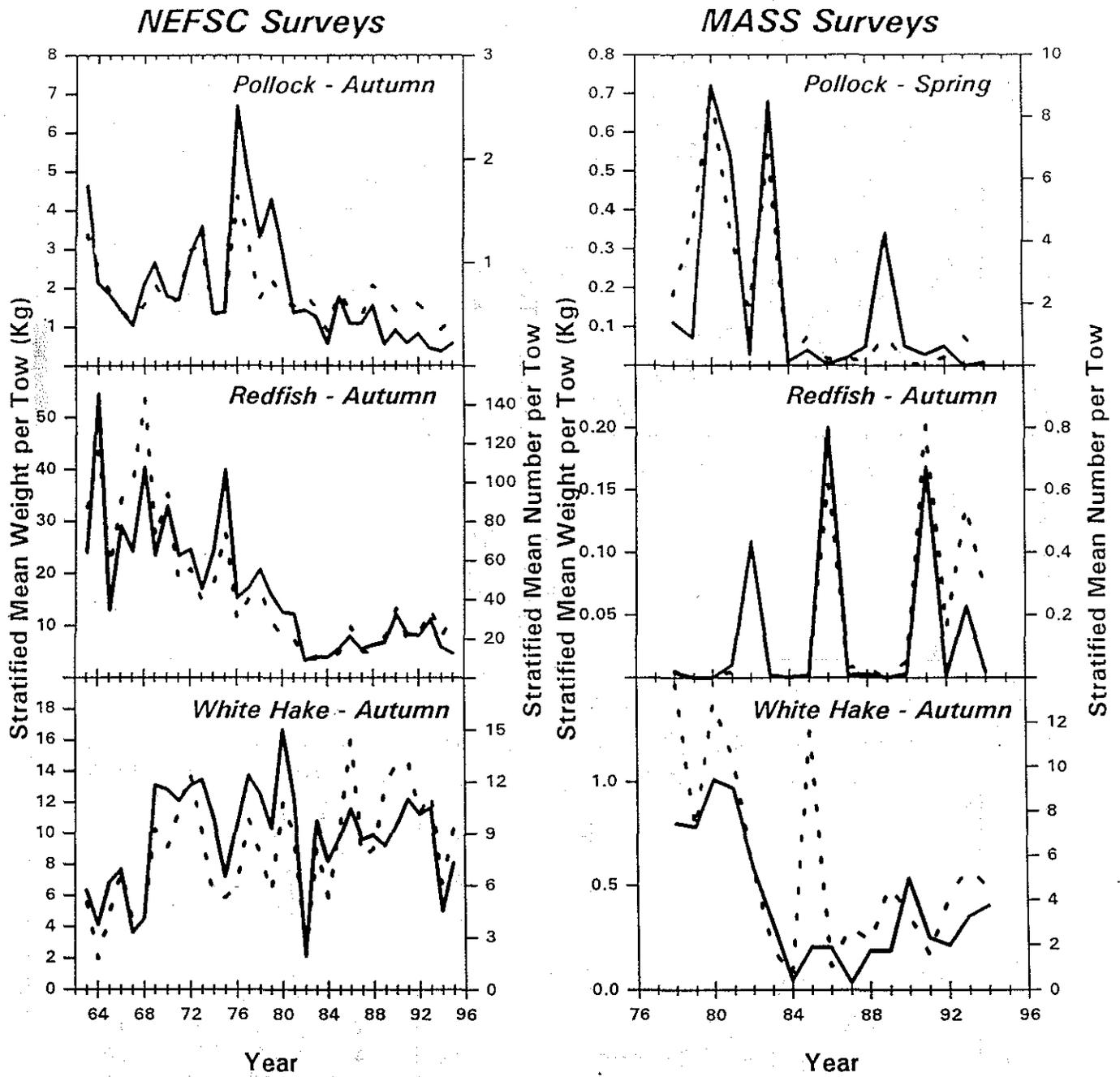


Figure E2.5. Abundance and biomass indices for pollock, redfish and white hake from the NEFSC and Massachusetts surveys (solid line - biomass, dotted line - abundance).

NEFSC Surveys

MASS Surveys

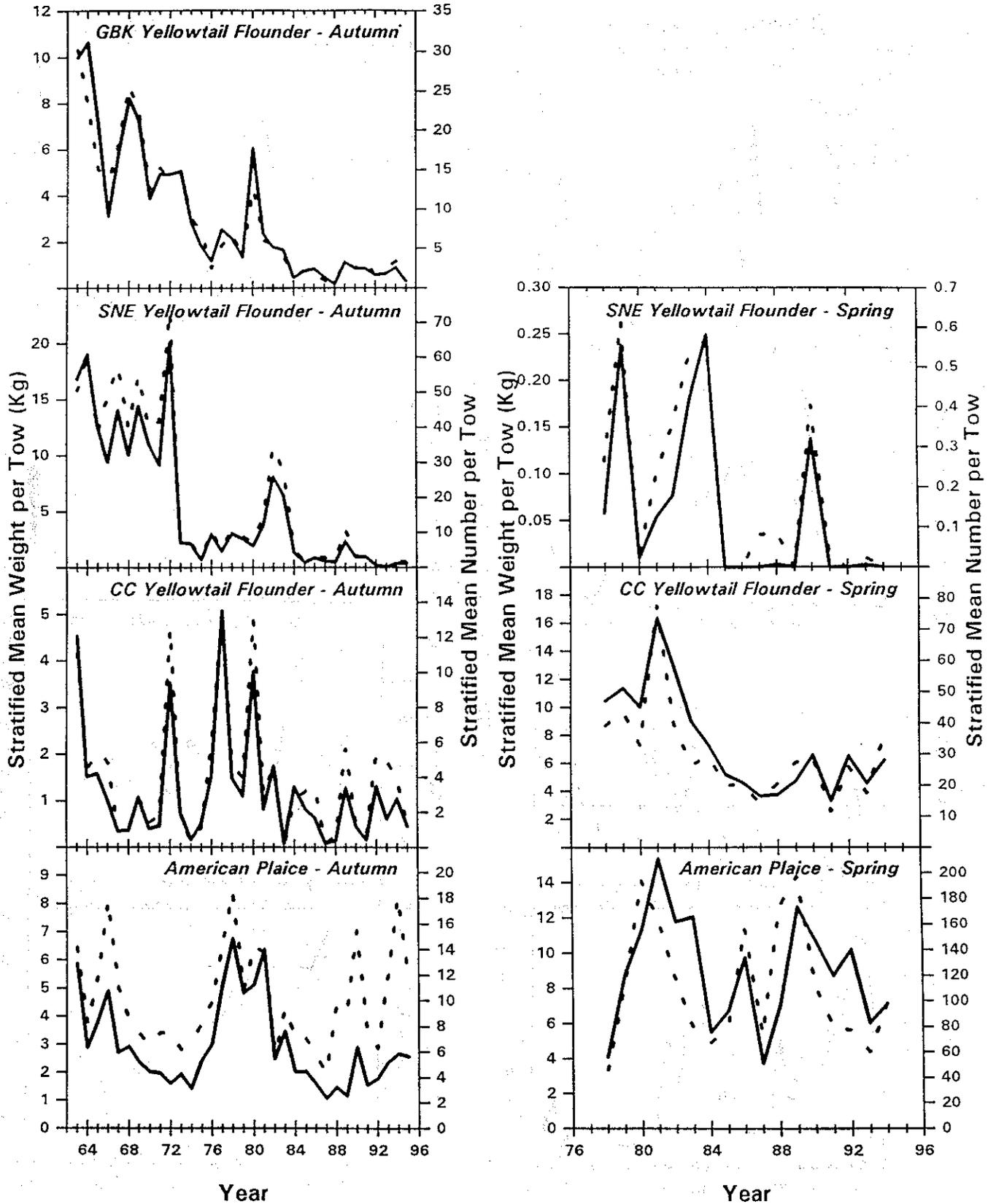


Figure E2.6. Abundance and biomass indices for yellowtail flounder and American plaice from the NEFSC and Massachusetts surveys (solid line - biomass, dotted line - abundance).

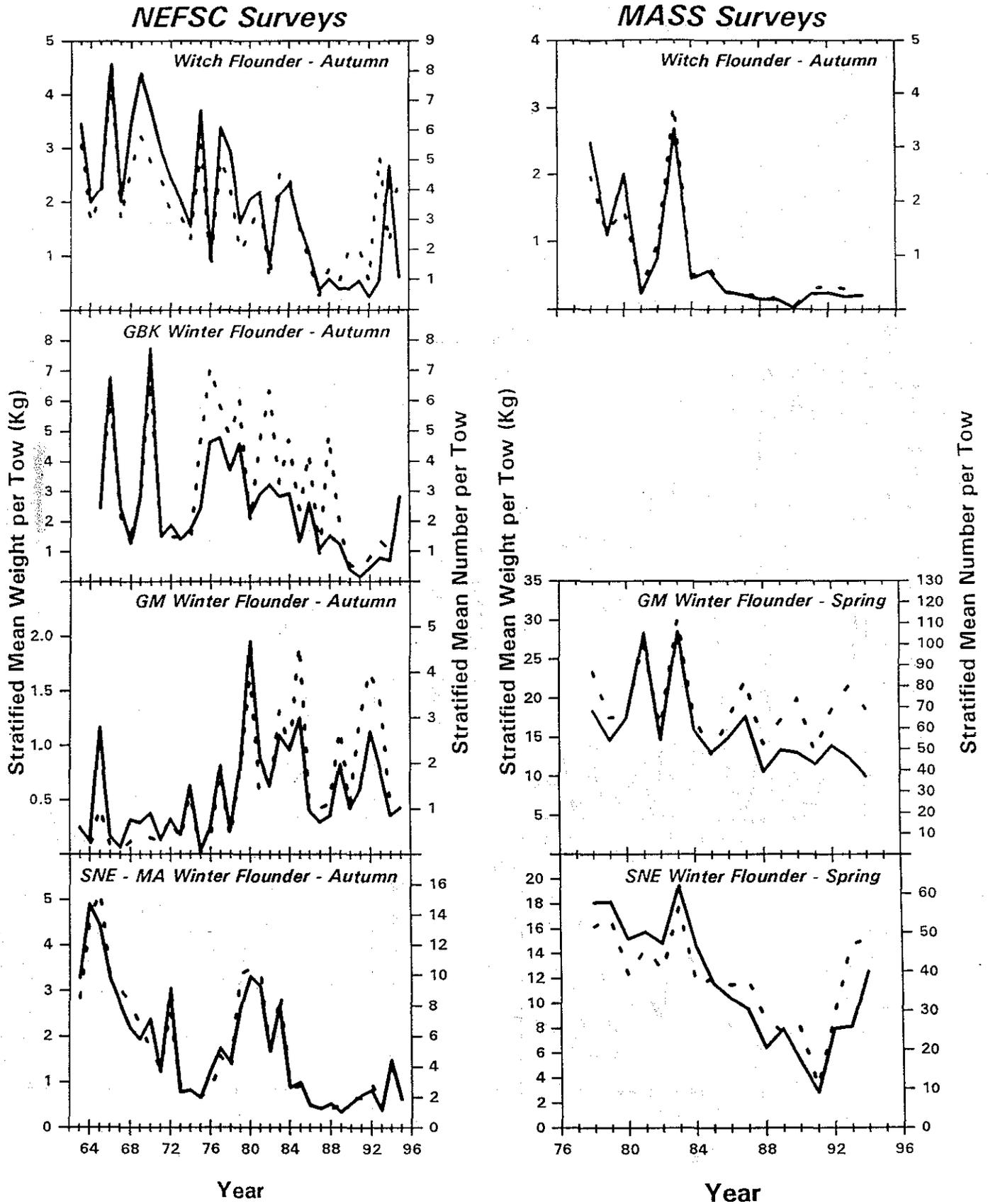


Figure E2.7. Abundance and biomass indices for witch flounder and winter flounder from the NEFSC and Massachusetts surveys (solid line - biomass, dotted line - abundance).

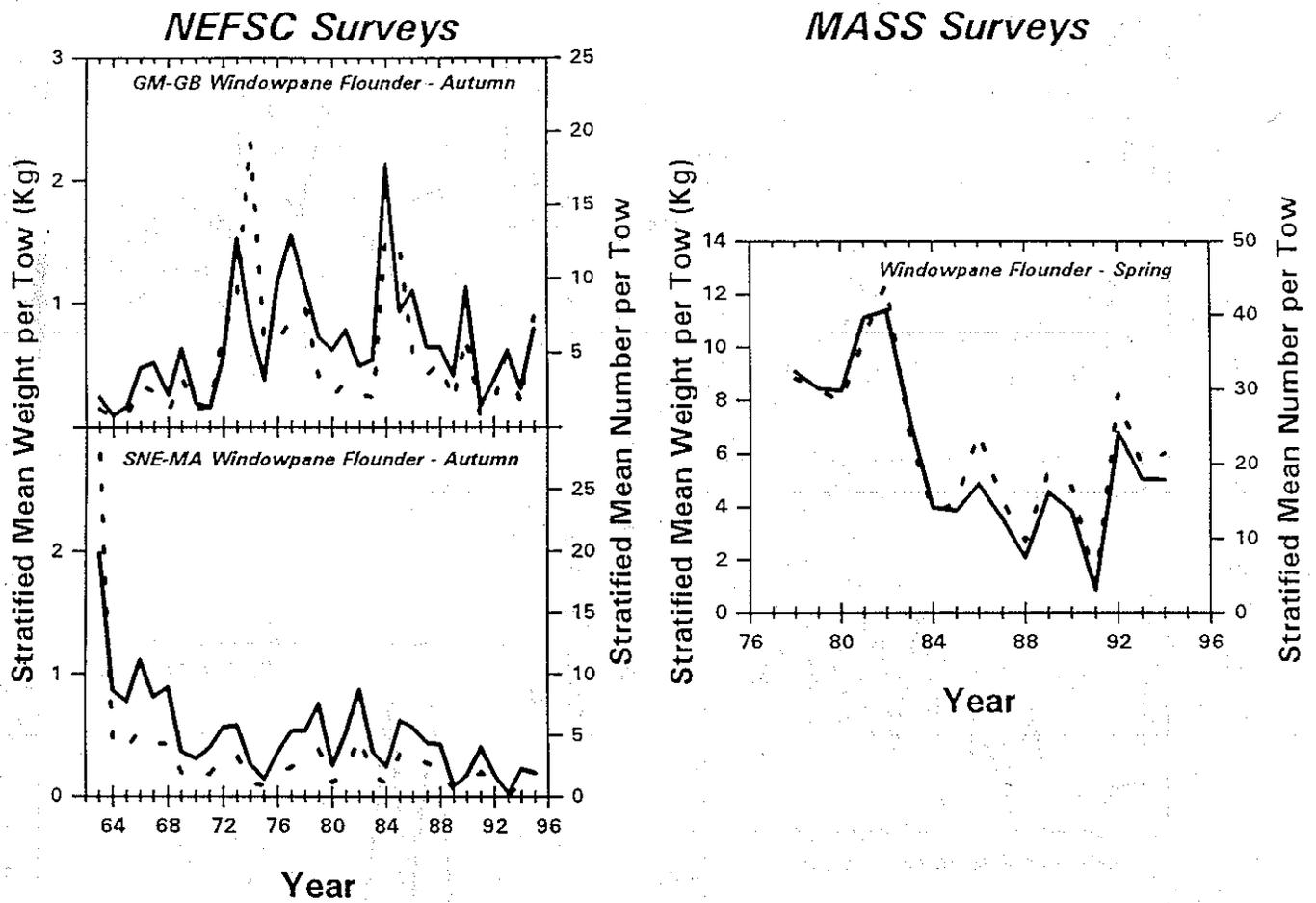


Figure E2.8. Abundance and biomass indices for windowpane flounder from the NEFSC and Massachusetts surveys (solid line - biomass, dotted line - abundance).

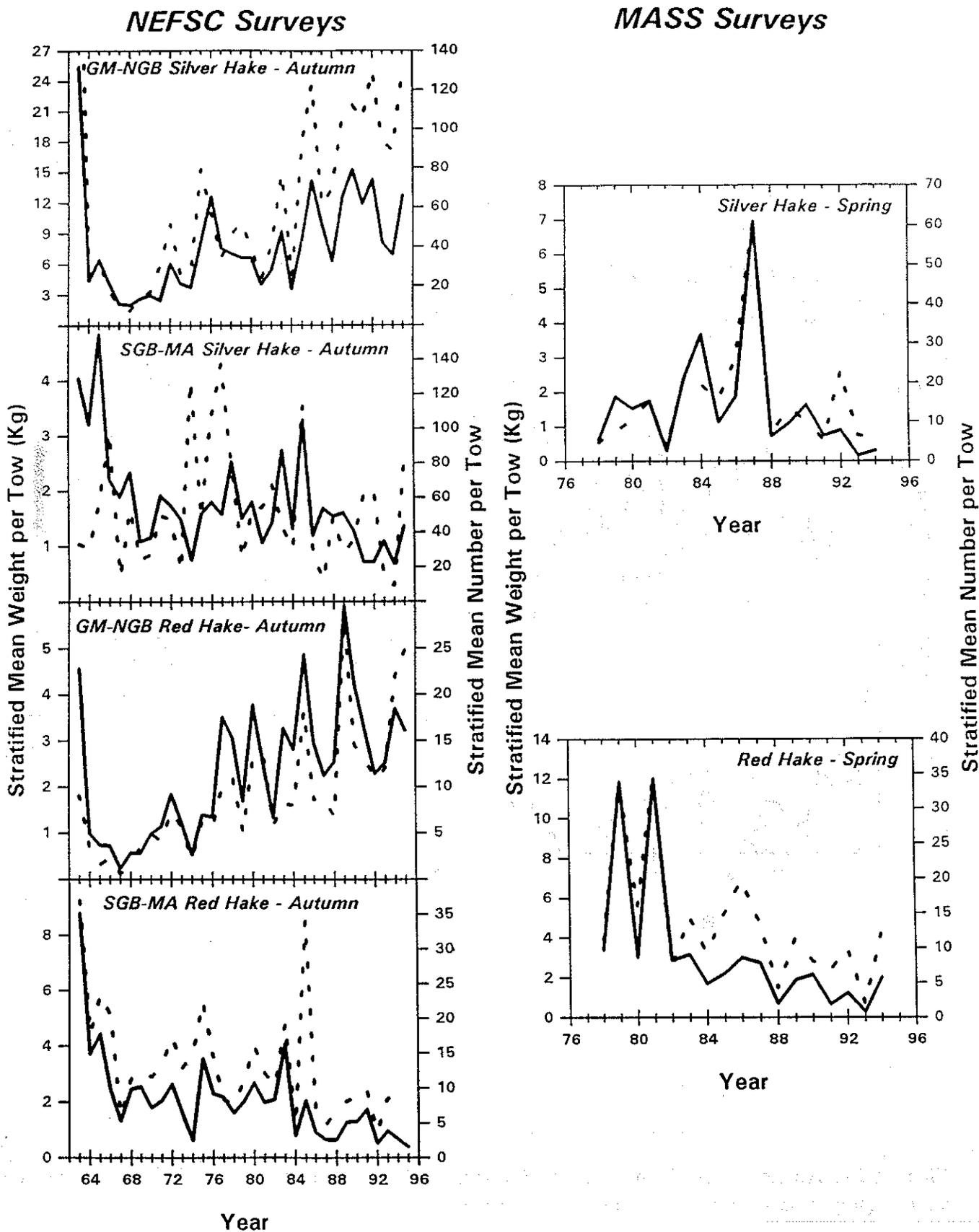


Figure E2.9. Abundance and biomass indices for silver hake and red hake from the NEFSC and Massachusetts surveys (solid line - biomass, dotted line - abundance).

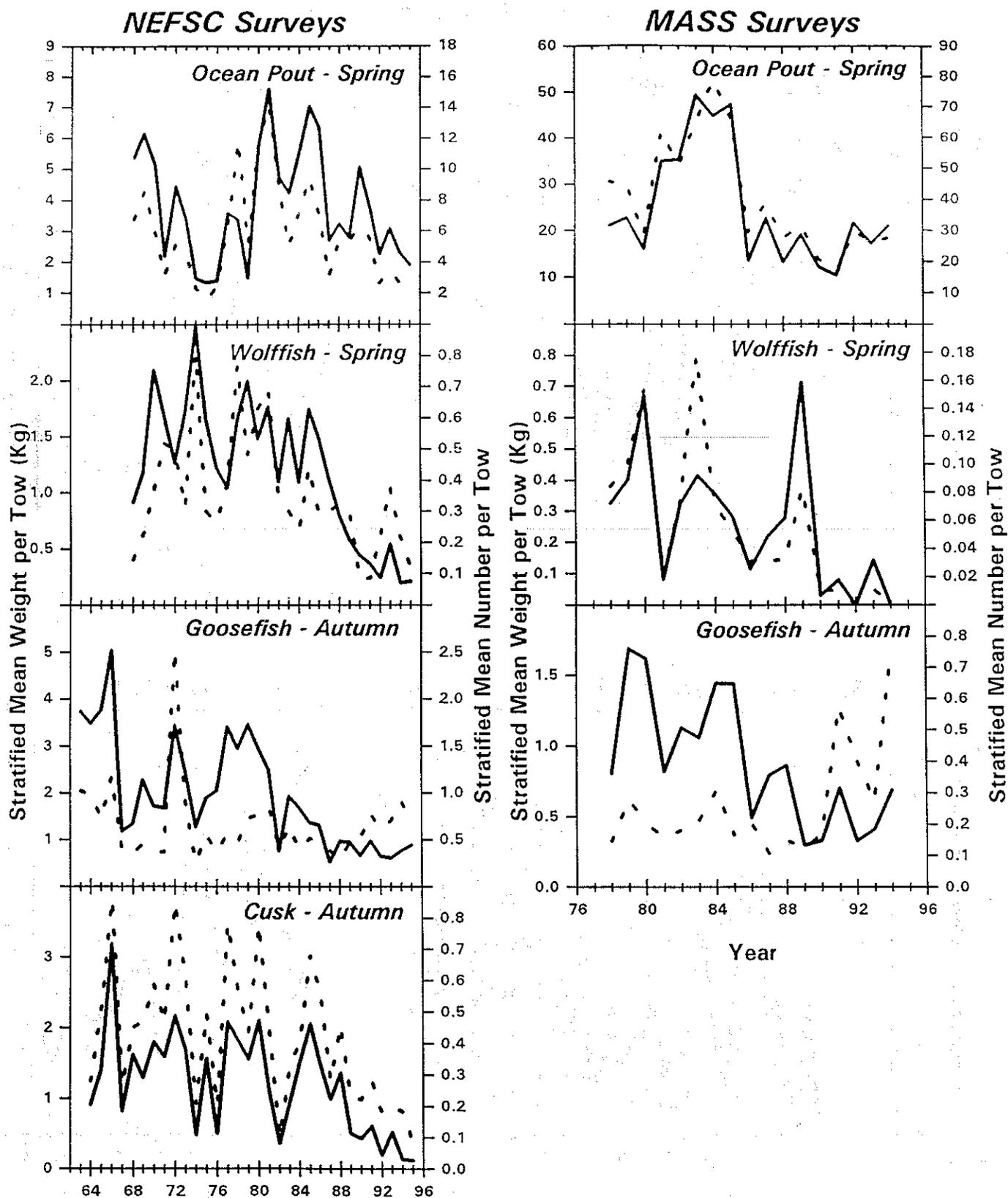


Figure E2.10. Abundance and biomass indices for ocean pout, wolffish, goosefish, and cusk from the NEFSC and Massachusetts surveys (solid line - biomass, dotted line - abundance).

Gulf of Maine NEFSC Spring Survey

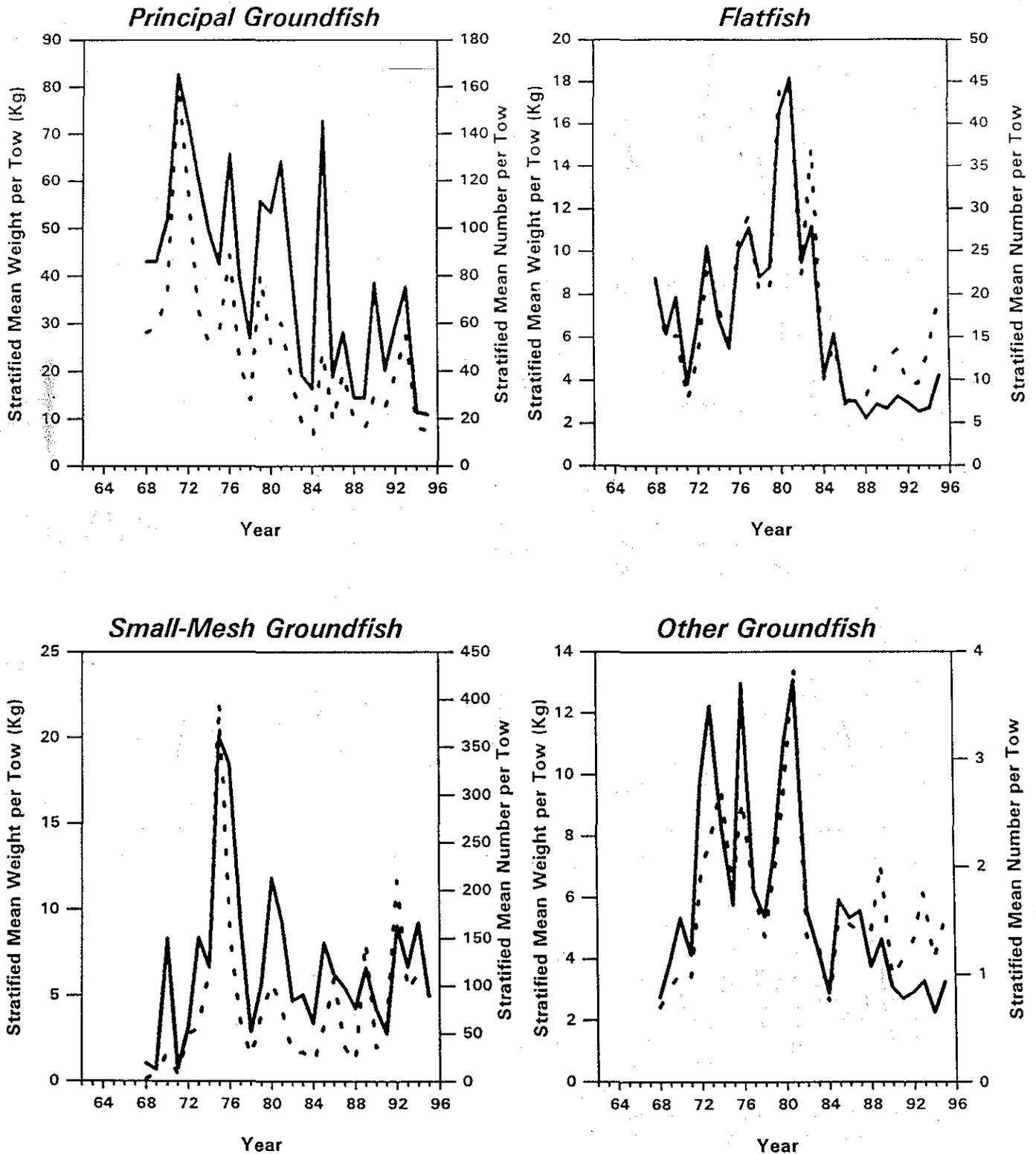


Figure E2.11. Abundance (dotted line) and biomass (solid line) of principal groundfish, flatfish, small-mesh groundfish and other groundfish in the Gulf of Maine during the NEFSC spring survey.

Gulf of Maine NEFSC Autumn Survey

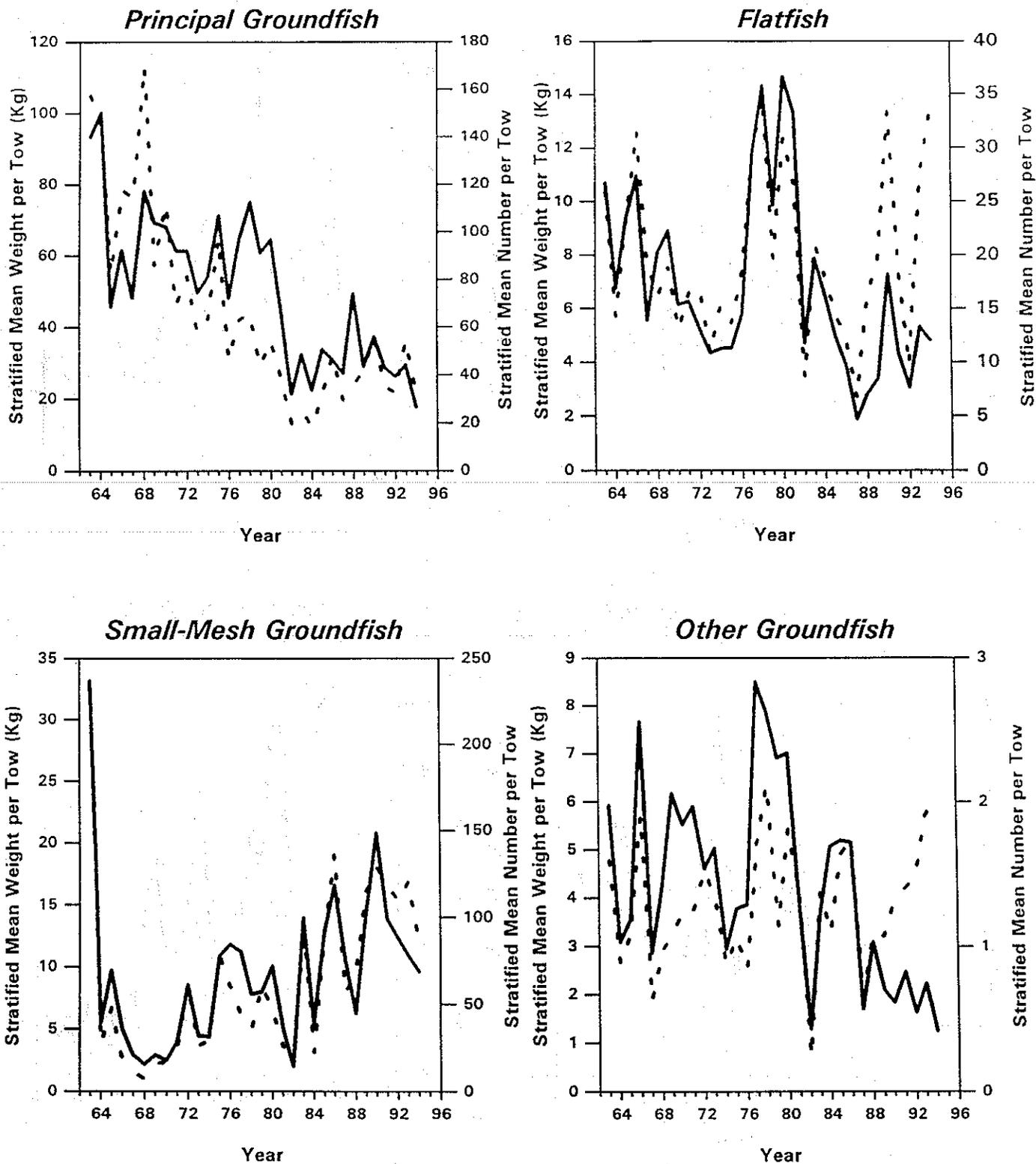


Figure E2.12. Abundance (dotted line) and biomass (solid line) of principal groundfish, flatfish, small-mesh groundfish and other groundfish in the Gulf of Maine during the NEFSC autumn survey.

Georges Bank NEFSC Spring Survey

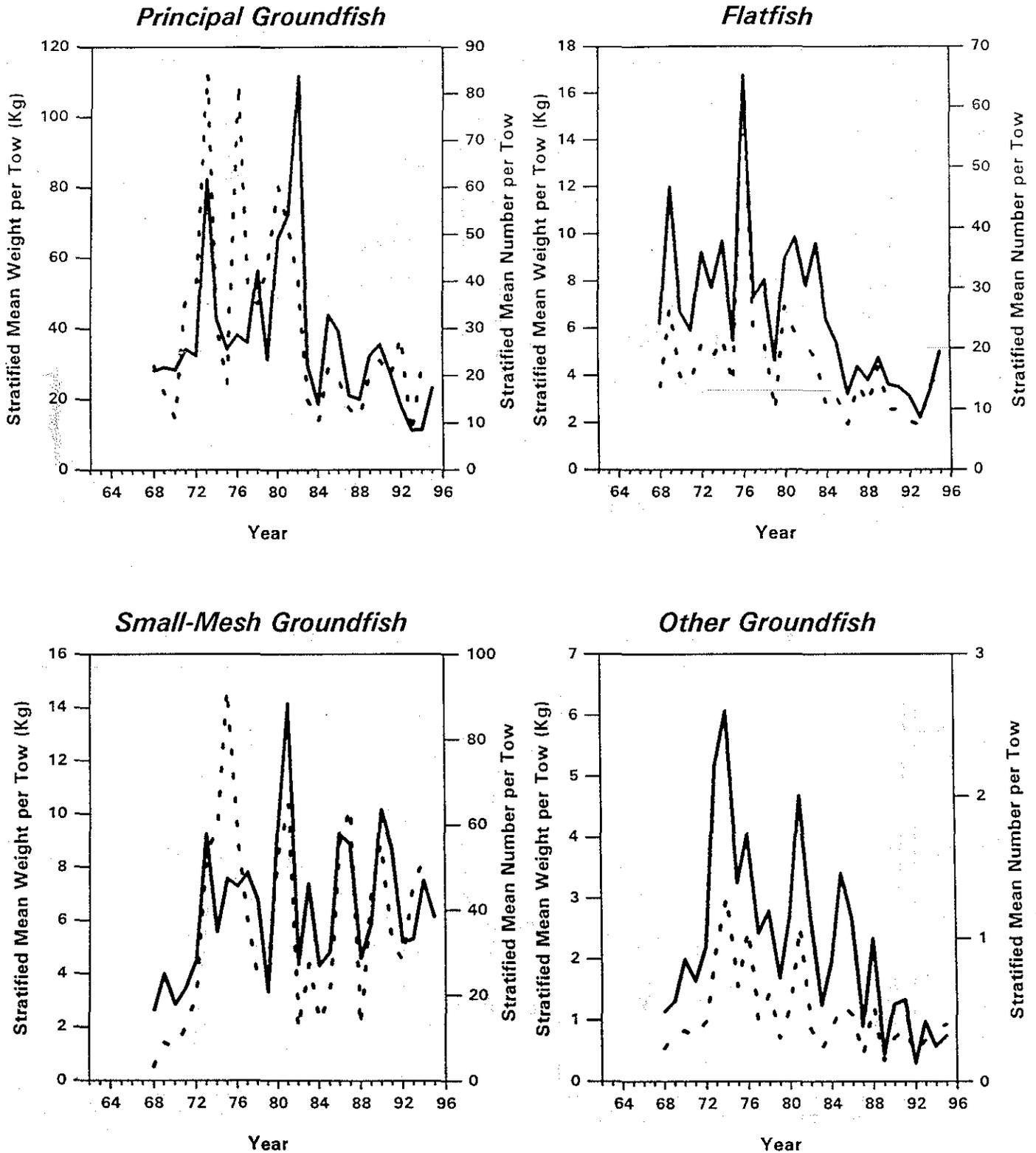


Figure E2.13. Abundance (dotted line) and biomass (solid line) of principal groundfish, flatfish small-mesh groundfish and other groundfish on Georges Bank during the NEFSC spring survey.

NEFSC Autumn Survey

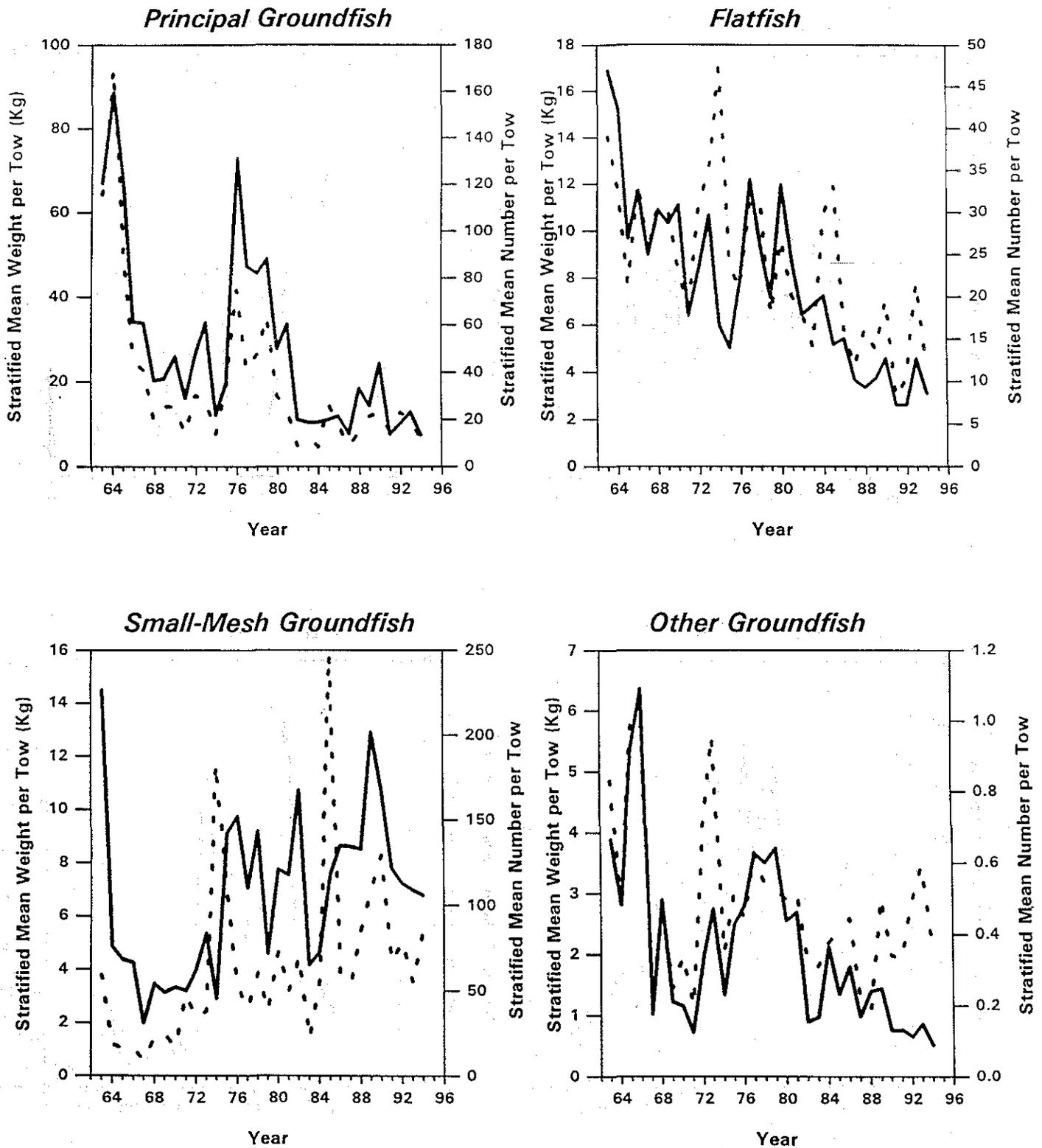


Figure E2.14. Abundance (dotted line) and biomass (solid line) of principal groundfish, flatfish, small-mesh groundfish and other groundfish on Georges Bank during the NEFSC autumn survey

Southern New England NEFSC Spring Survey

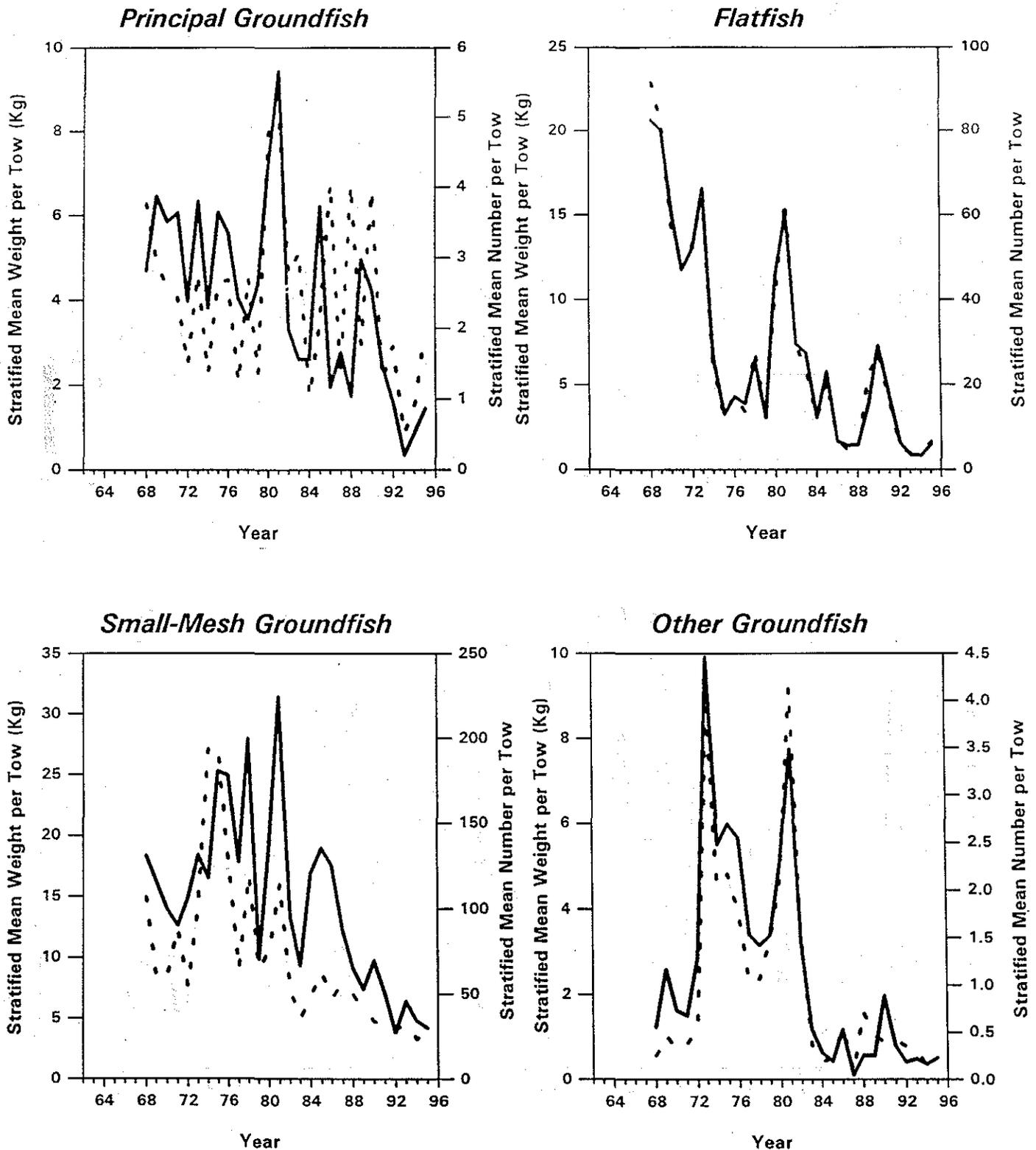


Figure E2.15. Abundance (dotted line) and biomass (solid line) of principal groundfish, flatfish, small-mesh groundfish and other groundfish in Southern New England during the NEFSC spring survey.

Southern New England NEFSC Autumn Survey

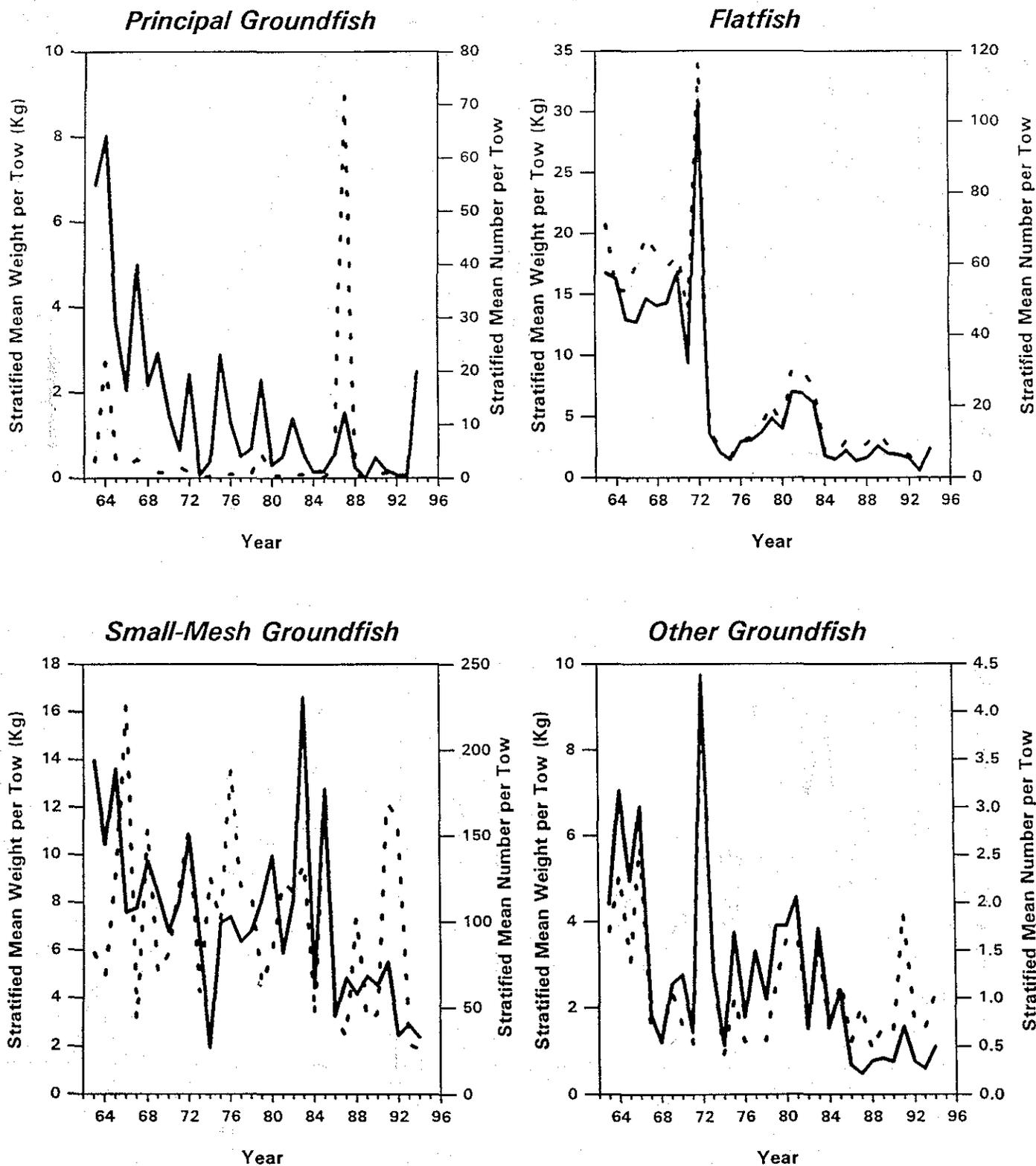


Figure E2.16. Abundance (dotted line) and biomass (solid line) of principal groundfish, flatfish, small-mesh groundfish and other groundfish in Southern New England during the NEFSC autumn survey.

Massachusetts Survey

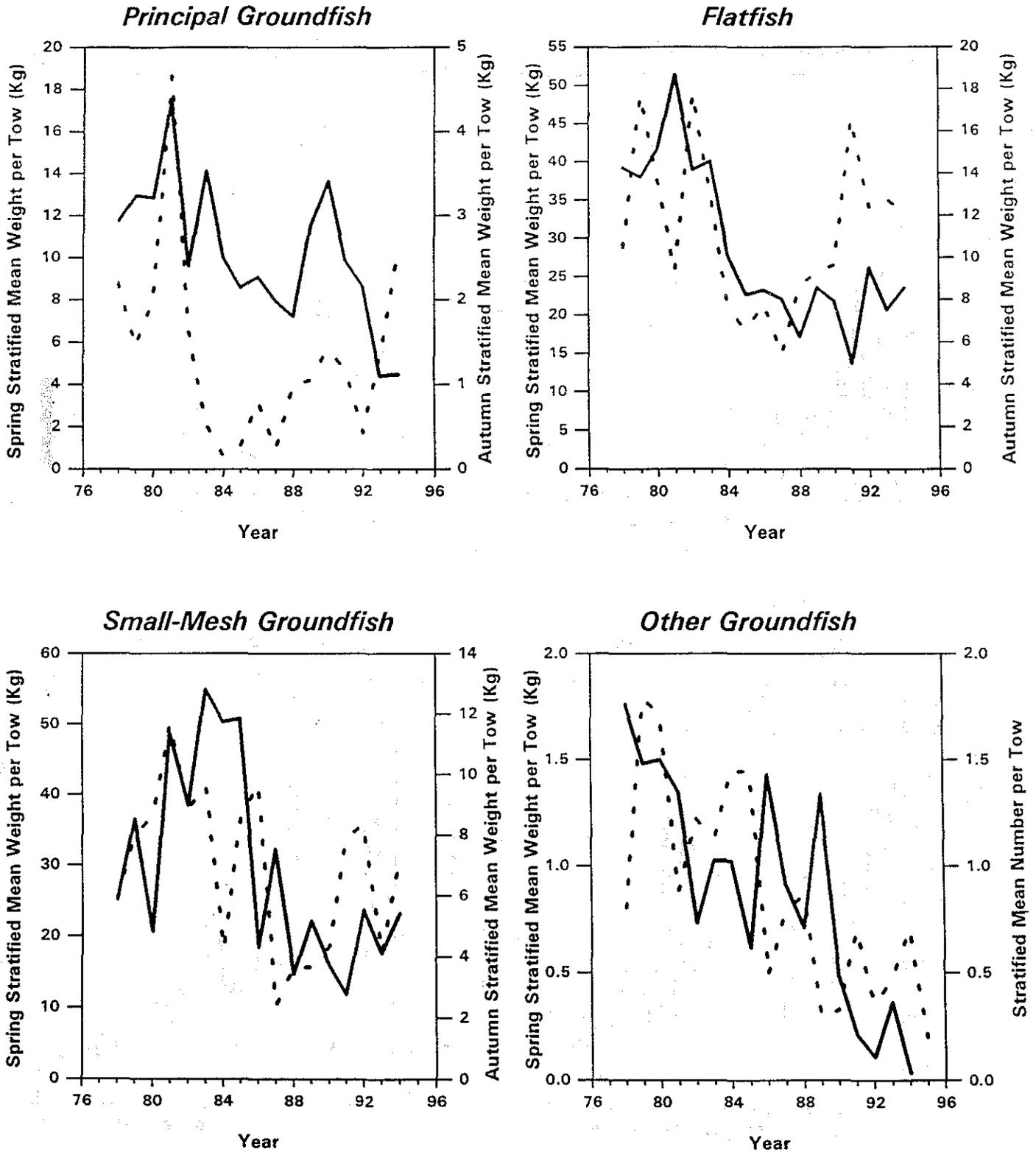
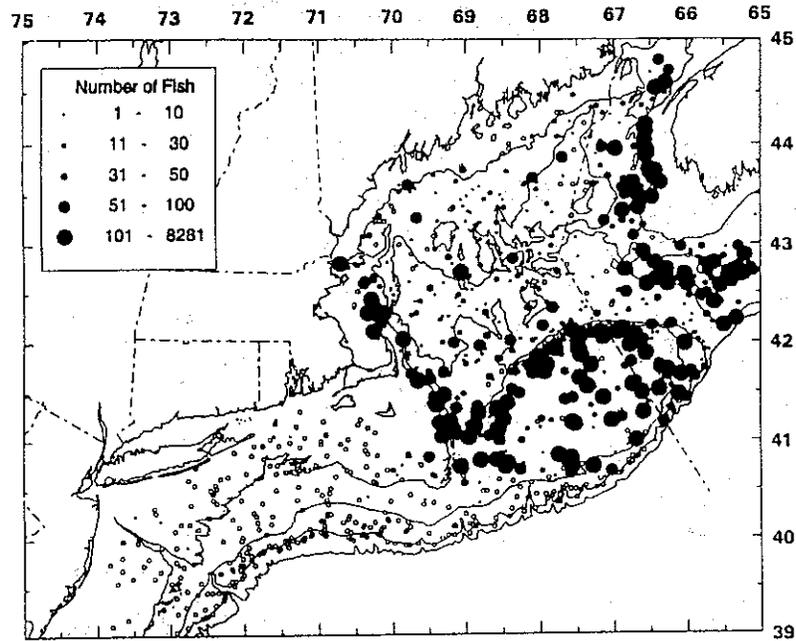
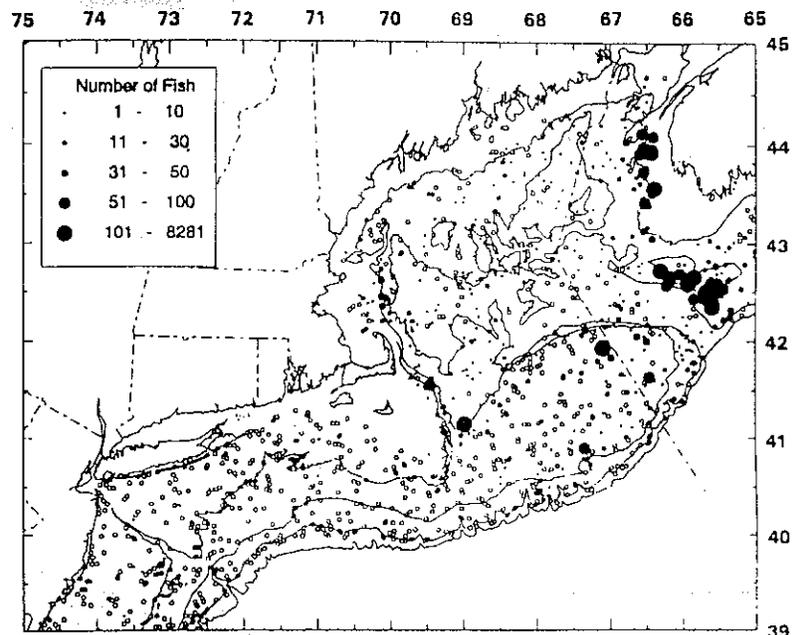


Figure E2.17. Biomass of principal groundfish, flatfish, small-mesh groundfish and other groundfish in Southern New England from the Massachusetts inshore spring (solid line) and autumn (dotted line) surveys.

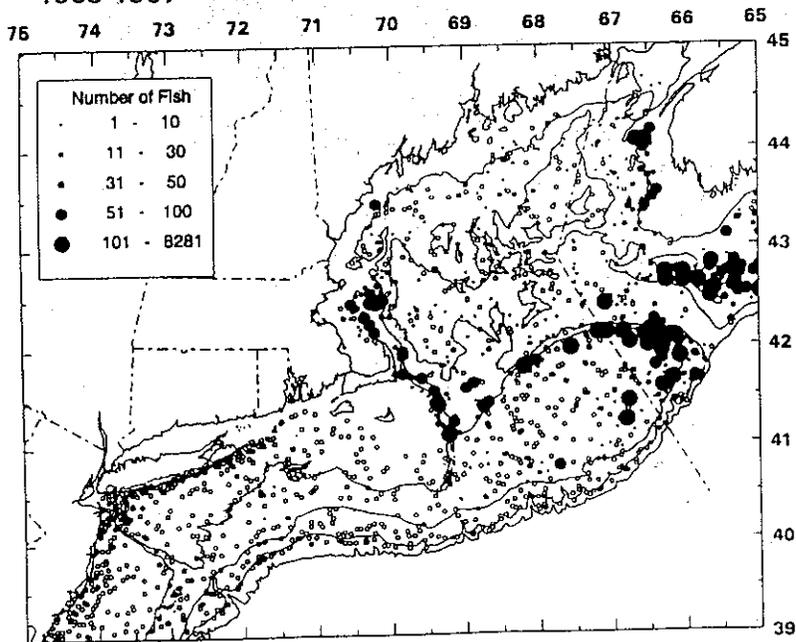
Haddock NMFS Autumn Bottom Trawl Survey



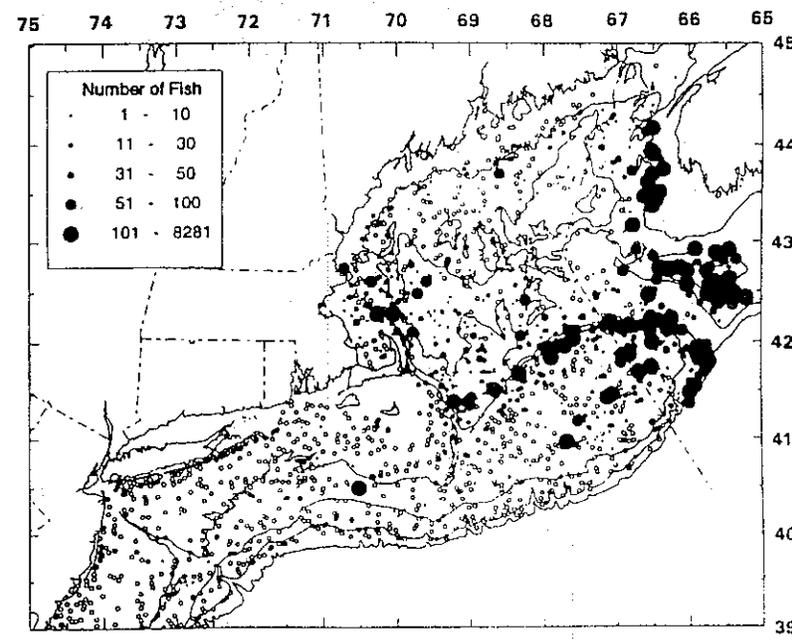
1963-1967



1968-1972



1973-1977



1978-1982

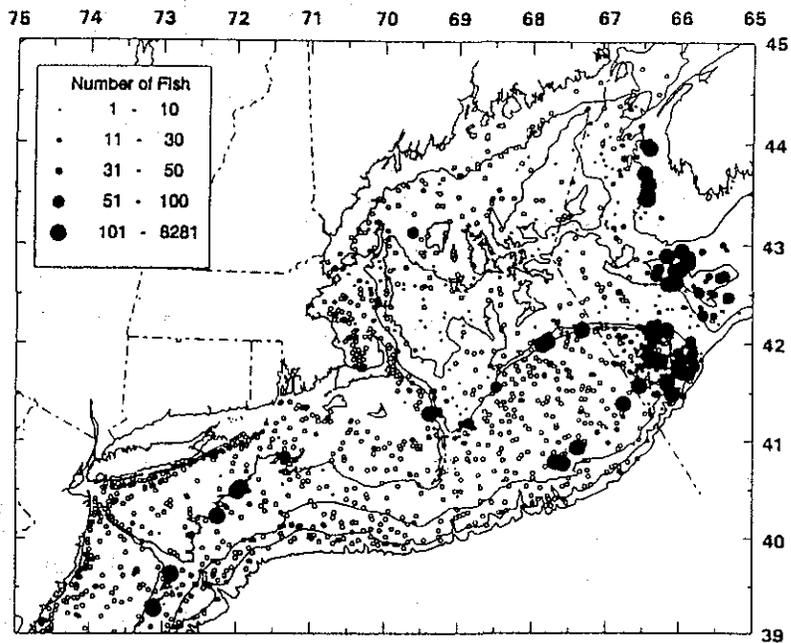
Figure E2.18. Distribution of haddock in the NEFSC autumn bottom trawl surveys from 1963 through 1994.

Haddock

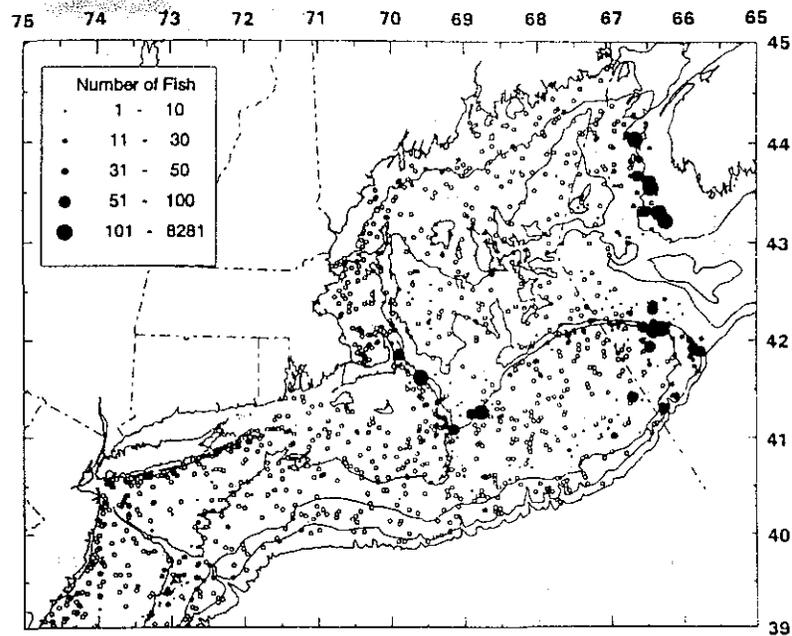
NMFS Autumn Bottom Trawl Survey

Figure E2.18. (Continued)

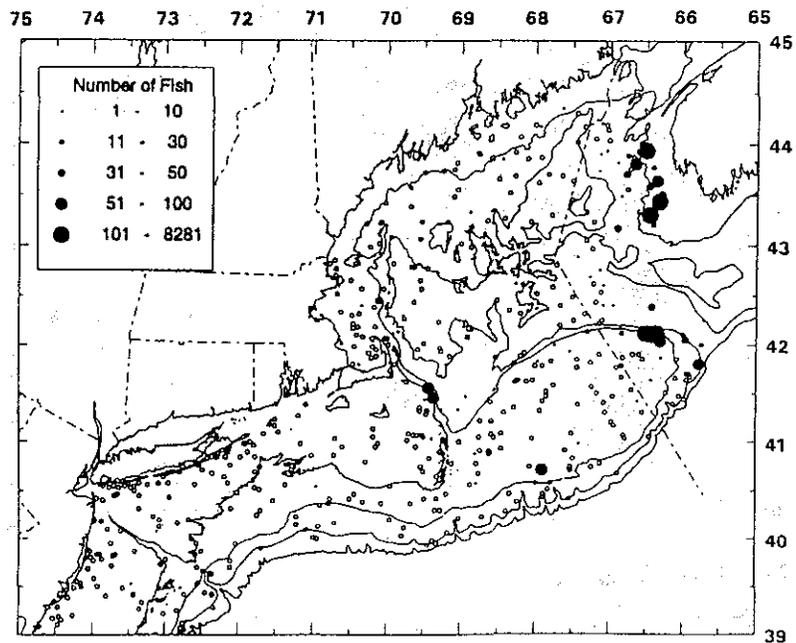
Page 188



1983-1987



1988-1992



1993-1994

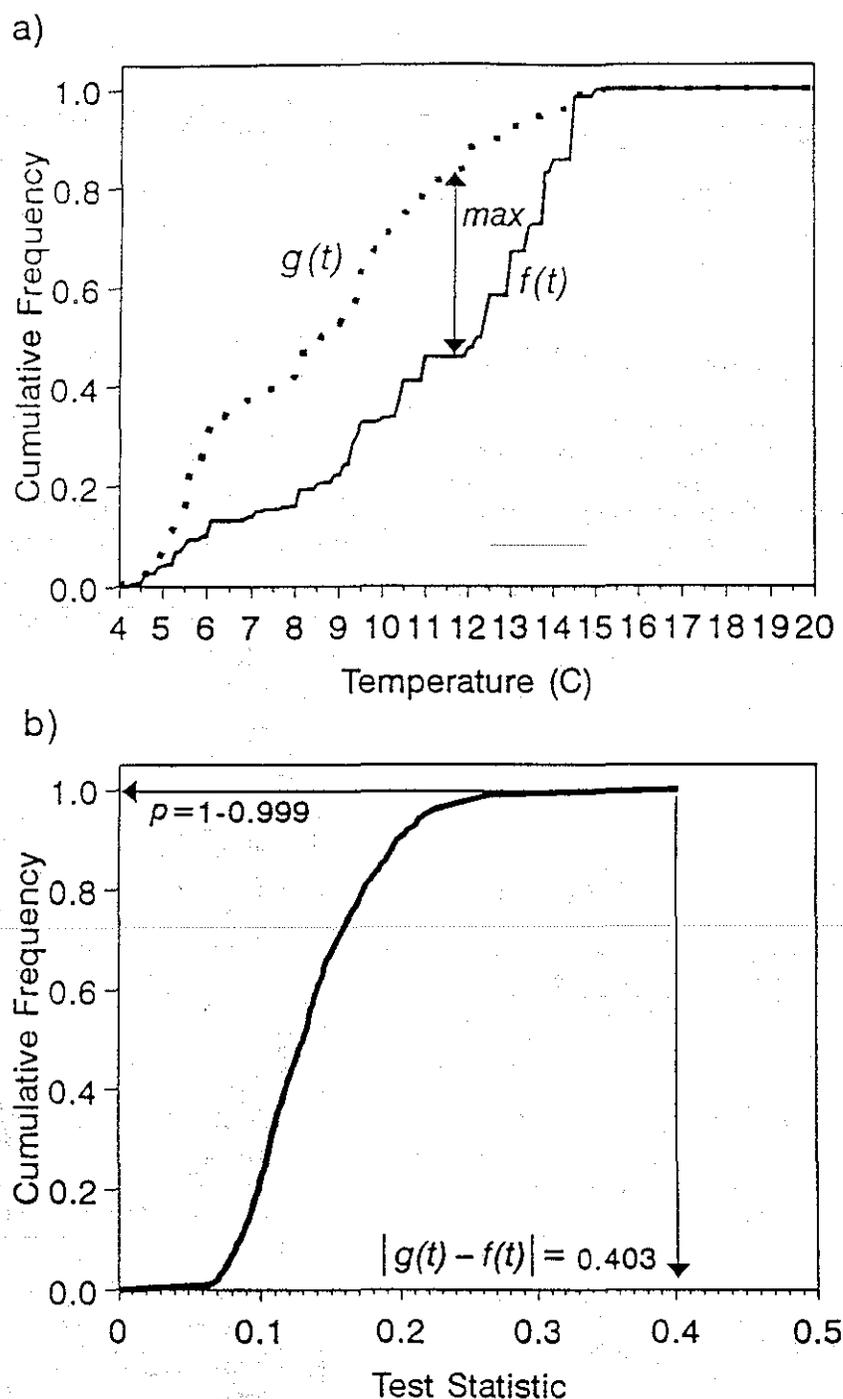


Figure E3.1. (a) Cumulative distribution functions for observed environment bottom temperatures ($f(t)$; equation 1) and catch-weight bottom temperatures for haddock ($g(t)$; equation 1) during the 1965 autumn survey. Coordinate labeled "max" represents the absolute maximum distance ($f(t) - g(t)$) between the two curves. (b) Cumulative distribution function of the test statistic ($\delta(t)^*$; equation 4) generated by repeated randomization of the data. Here results indicate a highly significant difference ($p < 0.001$); i.e., a test statistic as large or larger than 0.403 was obtained in only 1 out of 2,000 randomizations.

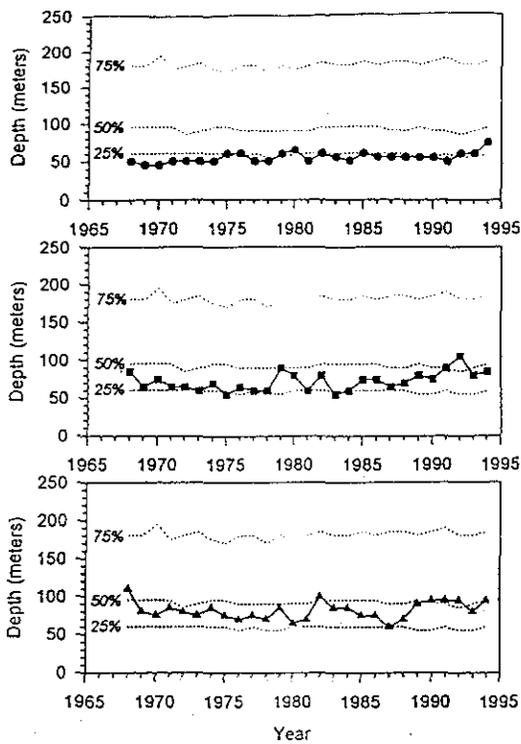


Figure E3.2. Spring habitat average depths (meters) and catch-weighted depths for yellowtail flounder (circle), cod (square) and haddock (triangle), 1968-1994. Interquartiles (25th and 75th percentiles) of habitat depth are shown as dotted lines and 50th percentiles of catch-weighted depths are given for comparison.

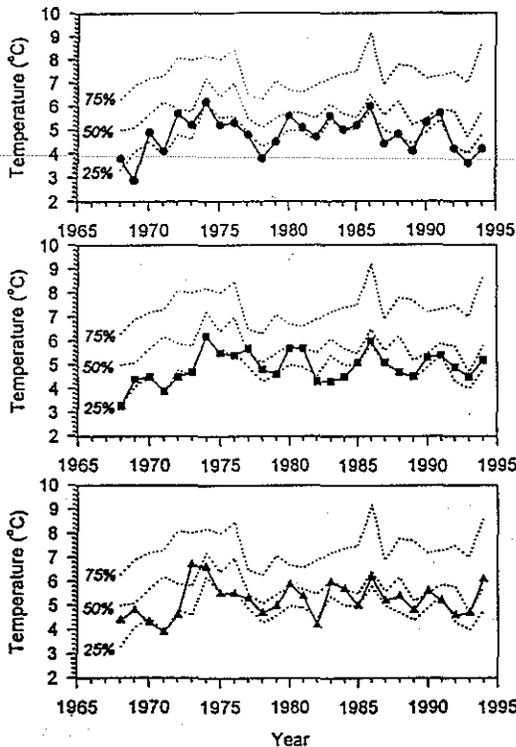


Figure E3.3. Spring habitat bottom temperatures (°C) and catch-weighted temperatures for yellowtail flounder (circle), cod (square) and haddock (triangle), 1968-1994. Interquartiles (25th and 75th percentiles) of habitat temperatures are shown as dotted lines and 50th percentiles of catch-weighted temperatures are given for comparison.

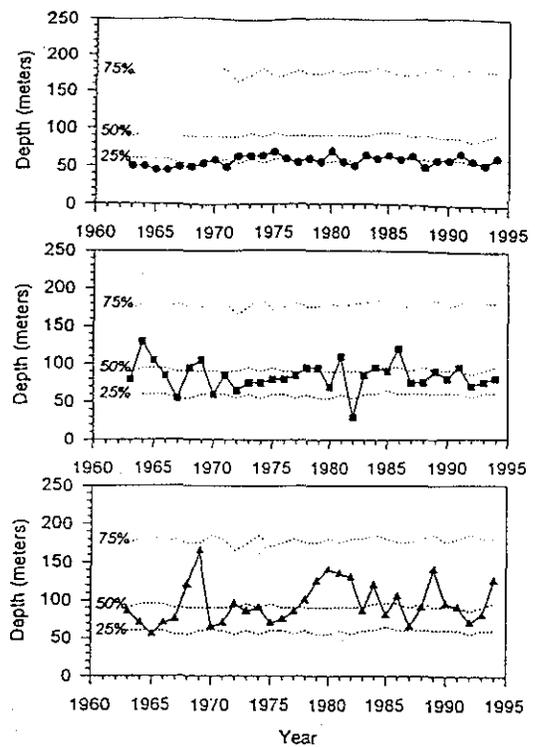


Figure E3.4. Autumn habitat average depths (meters) and catch-weighted depths for yellowtail flounder (circle), cod (square) and haddock (triangle), 1968-1994. Interquartiles (25th and 75th percentiles) of habitat depth are shown as dotted lines and 50th percentiles of catch-weighted depths are given for comparison.

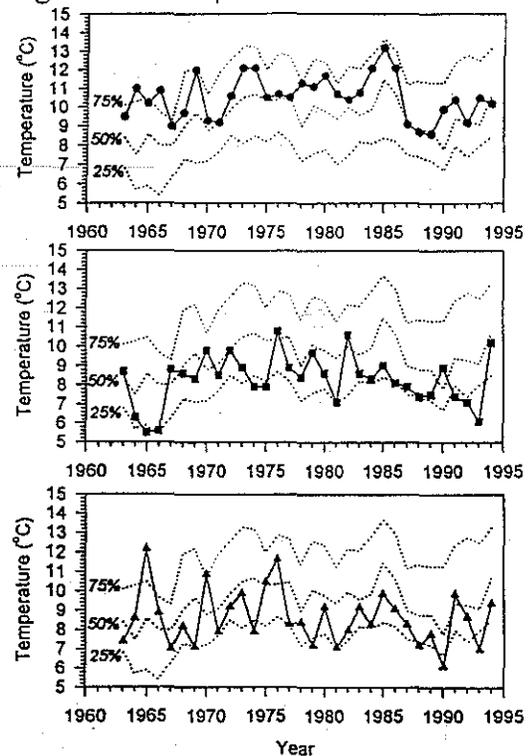
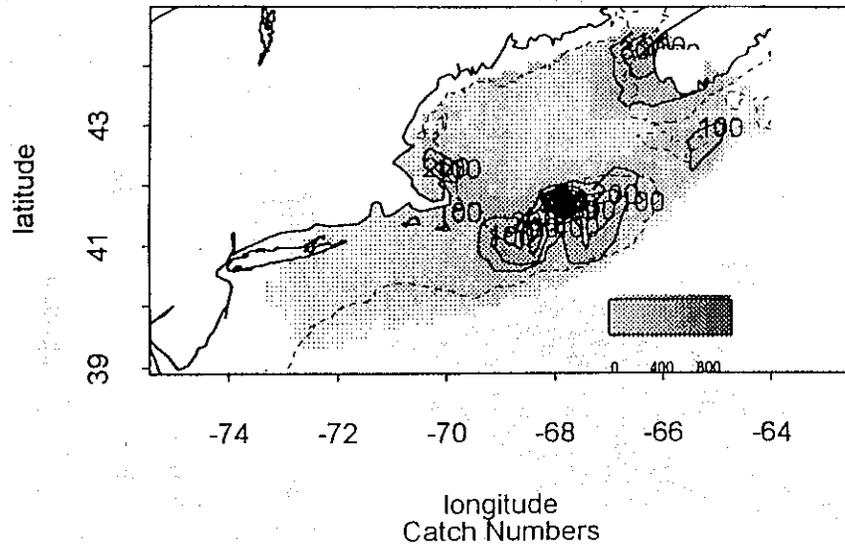
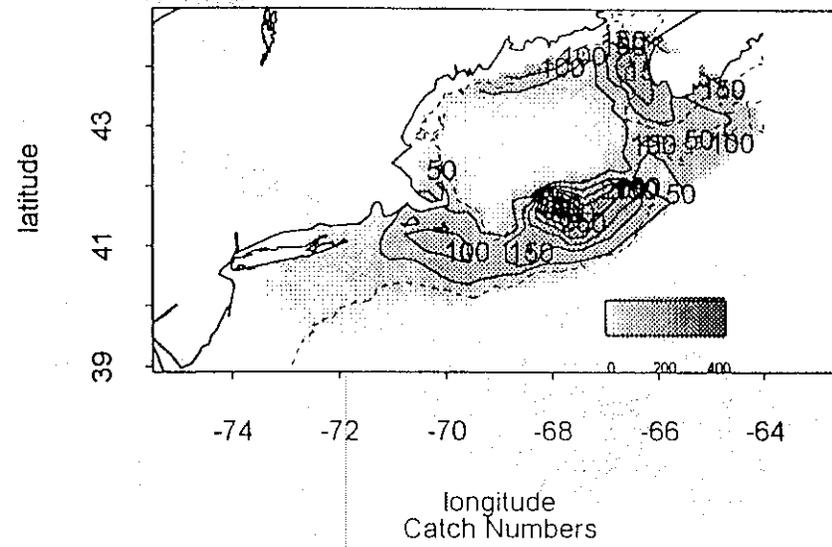


Figure E3.5. Autumn habitat bottom temperatures (°C) and catch-weighted temperatures for yellowtail flounder (circle), cod (square) and haddock (triangle), 1968-1994. Interquartiles (25th and 75th percentiles) of habitat temperatures are shown as dotted lines and 50th percentiles of catch-weighted temperatures are given for comparison.

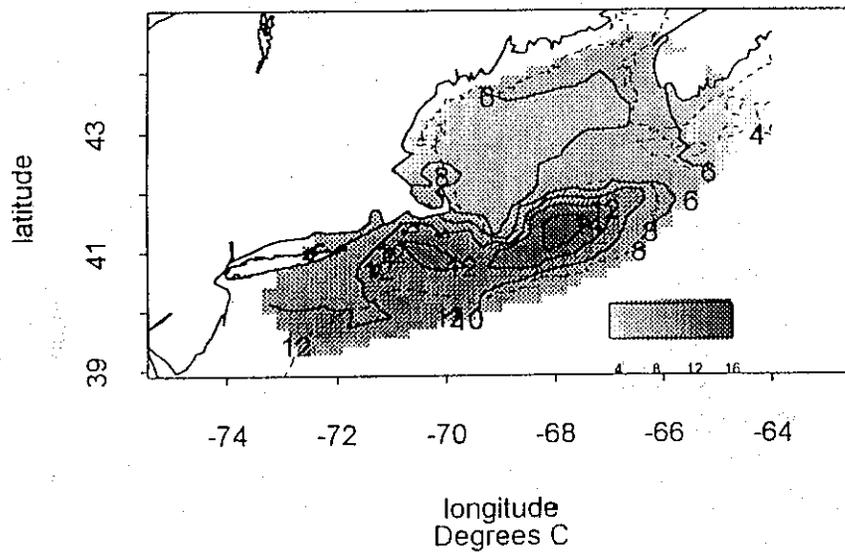
Observed 1965



GAM Fit 1965



Temperature 1965



Average Depth 1965

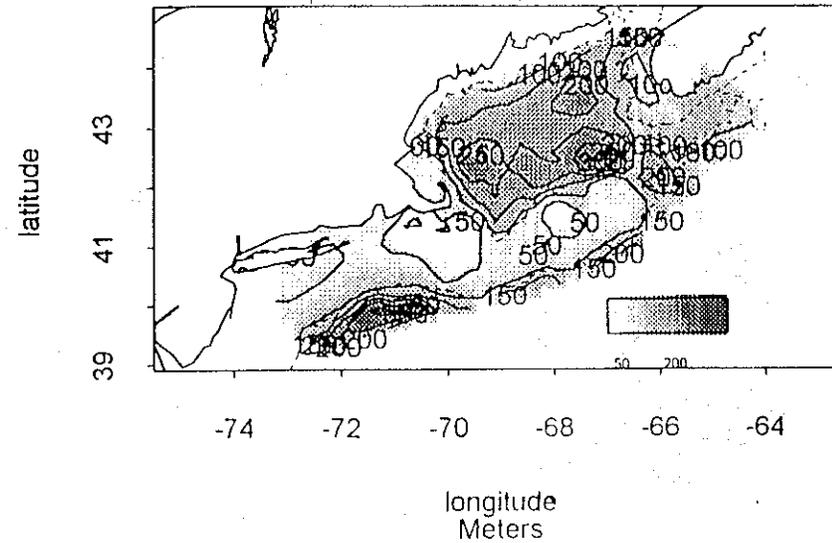
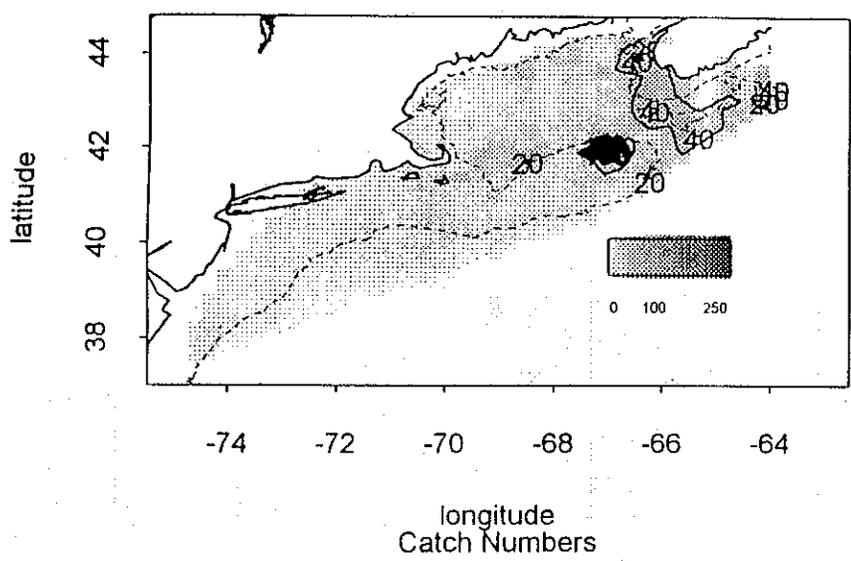
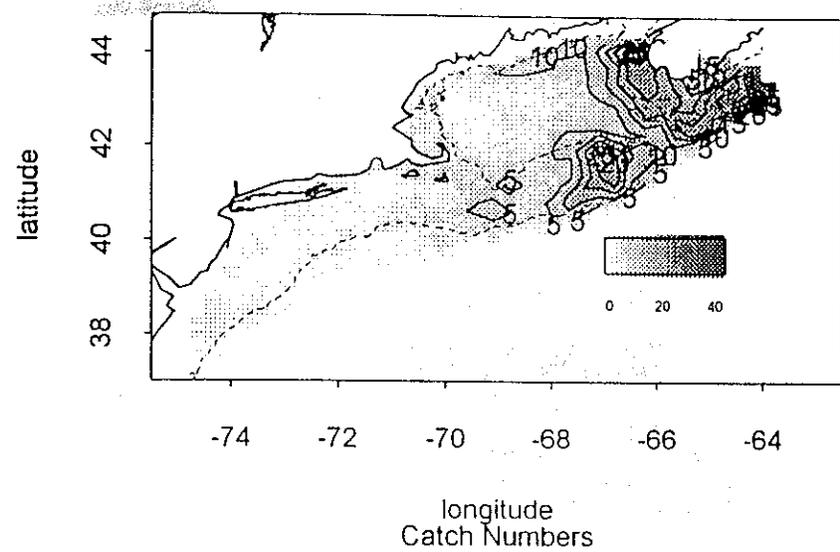


Figure E4.1. Interpolated observed and GAM fitted catch numbers of haddock and corresponding bottom temperature and average depth for 1965.

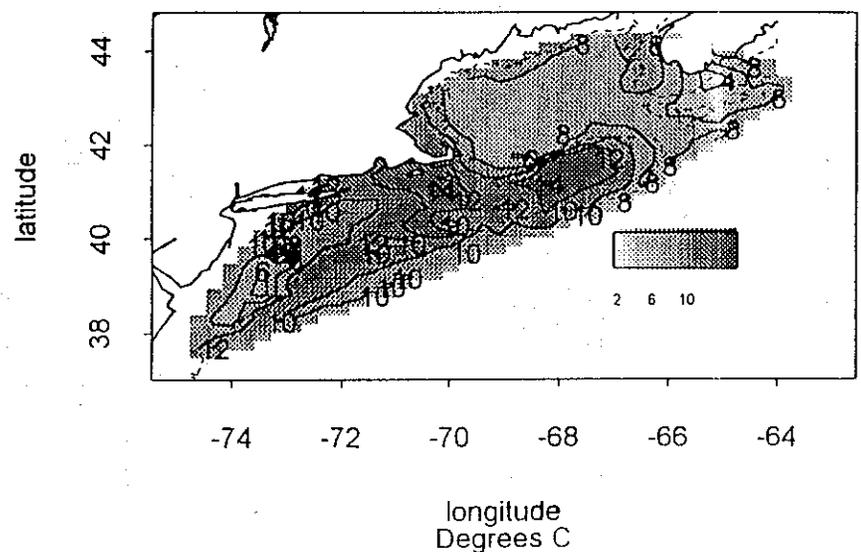
Observed 1970



GAM Fit 1970



Temperature 1970



Average Depth 1970

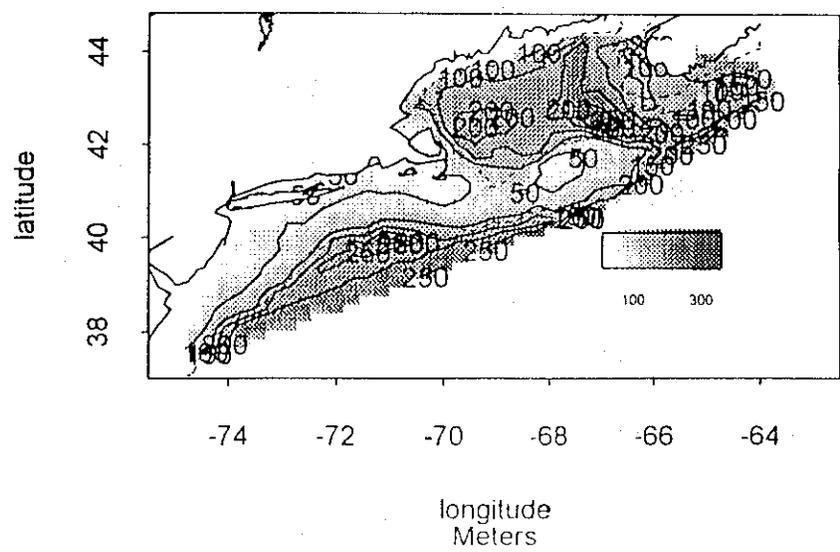
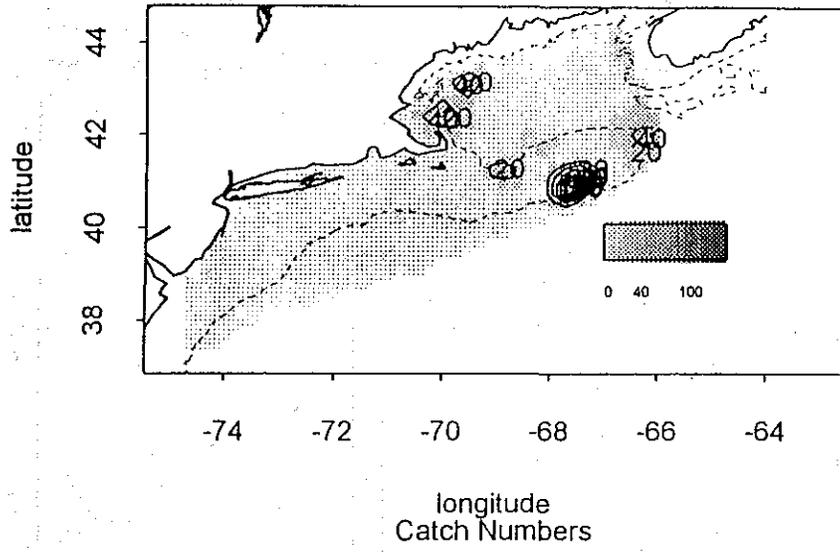
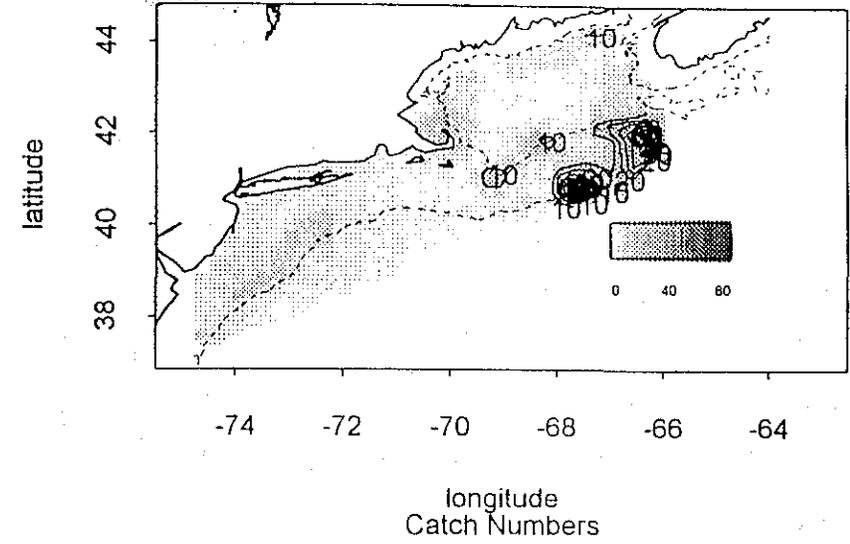


Figure E4.2. Interpolated observed and GAM fitted catch numbers of haddock and corresponding bottom temperature and average depth for 1970.

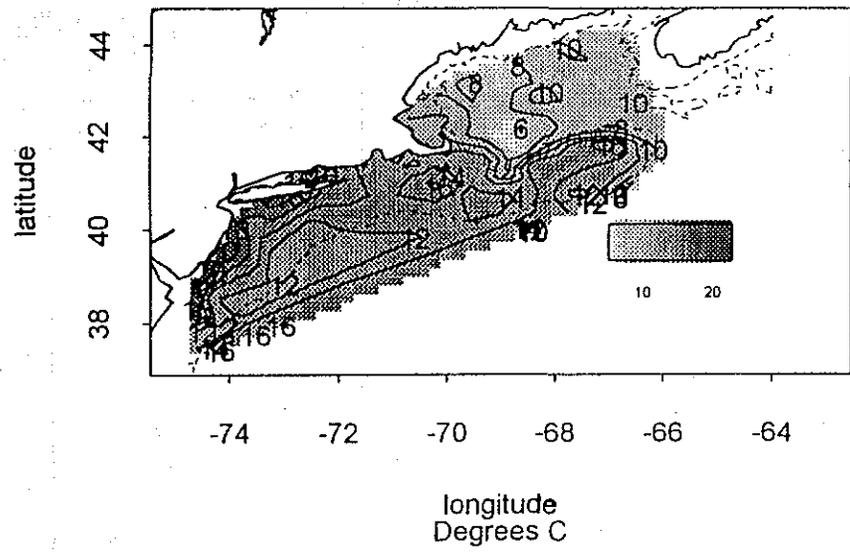
Observed 1985



GAM Fit 1985



Temperature 1985



Average Depth 1985

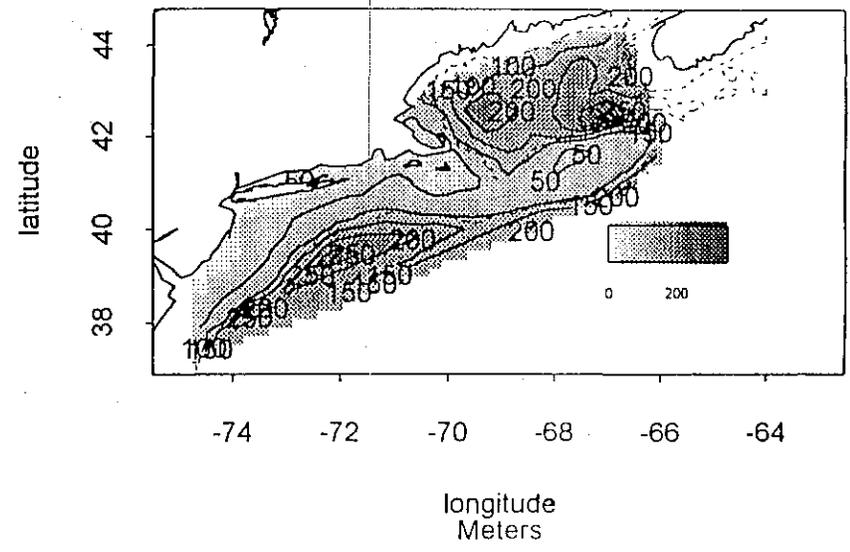


Figure E4.3. Interpolated observed and GAM fitted catch numbers of haddock and corresponding bottom temperature and average depth for 1985

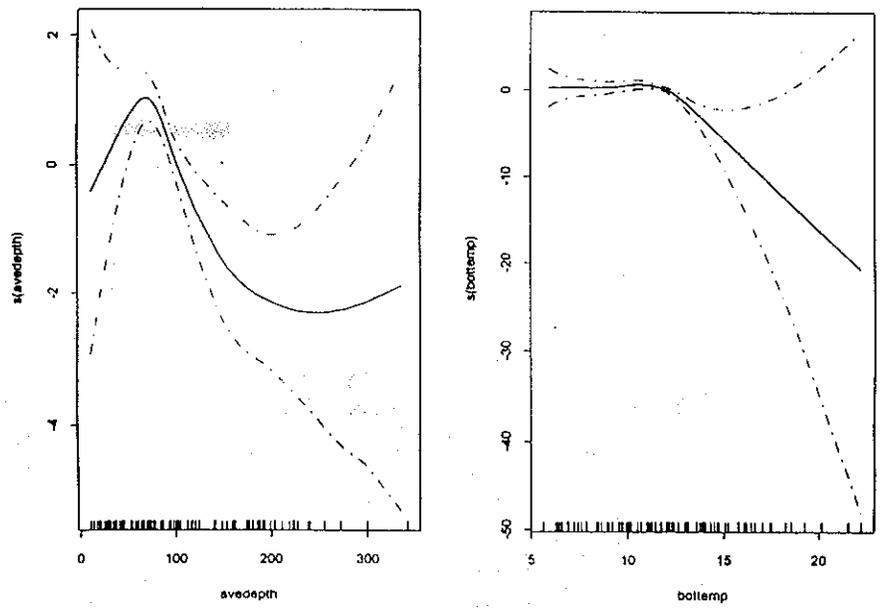
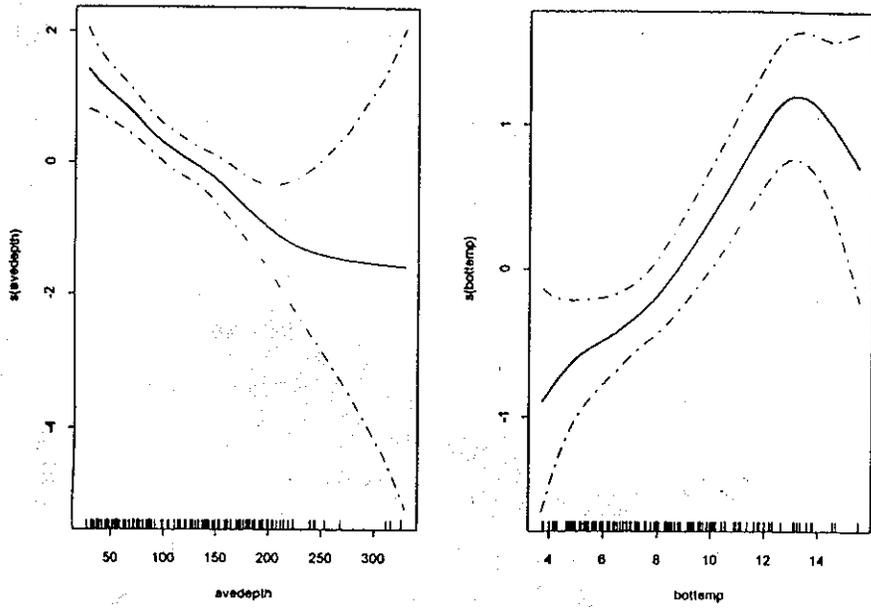


Figure E4.4. Scatterplot smooths of average depth and bottom temperature from GAM fit for haddock with standard errors (dotted line), autumn 1965. Y-axis is scaled to zero, rugplot along x-axis indicates number of observations.

Figure E4.6. Scatterplot smooths of average depth and bottom temperature from GAM fit for haddock with standard errors (dotted line), autumn 1985. Y-axis is scaled to zero, rugplot along x-axis indicates number of observations.

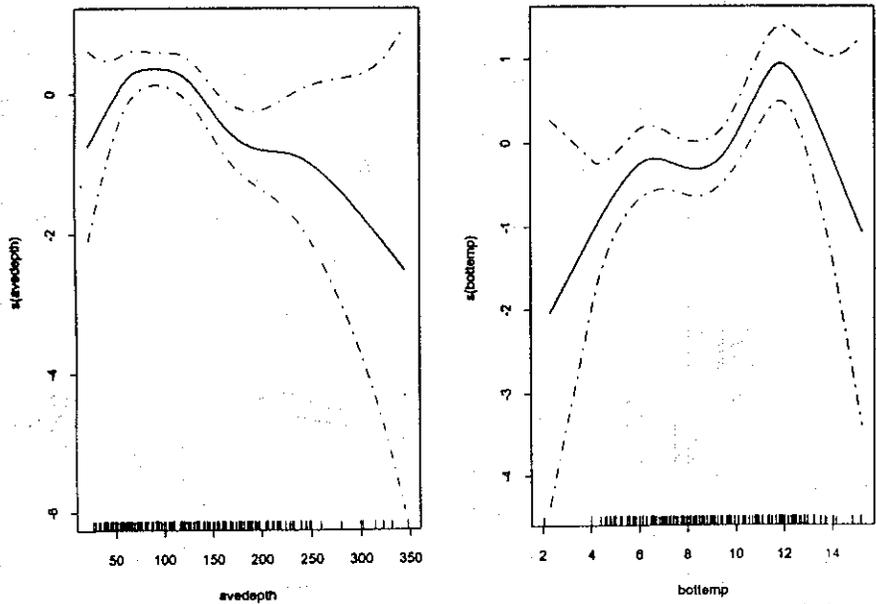


Figure E4.5. Scatterplot smooths of average depth and bottom temperature from GAM fit for haddock with standard errors (dotted line), autumn 1970. Y-axis is scaled to zero, rugplot along x-axis indicates number of observations.

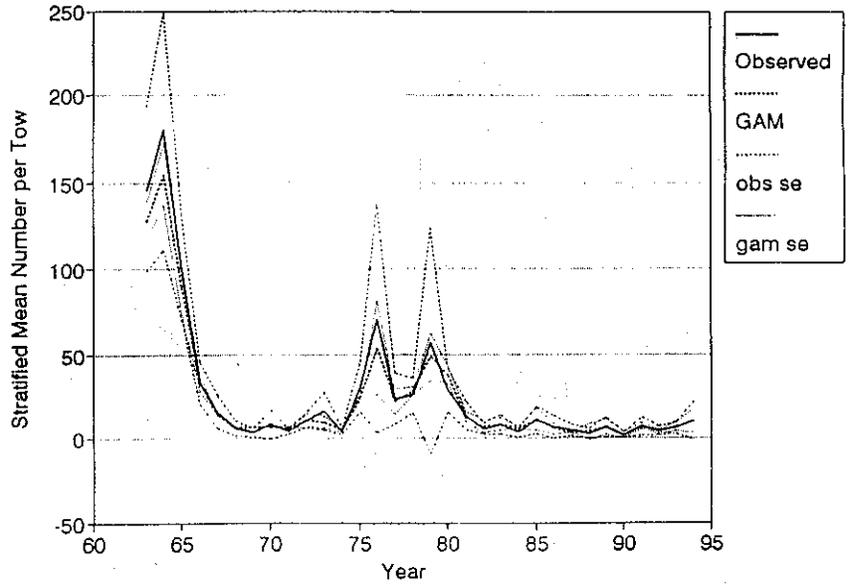


Figure E4.7. Stratified mean number per tow with standard errors for observed and Gam fit catch numbers for haddock, 1963-1994.

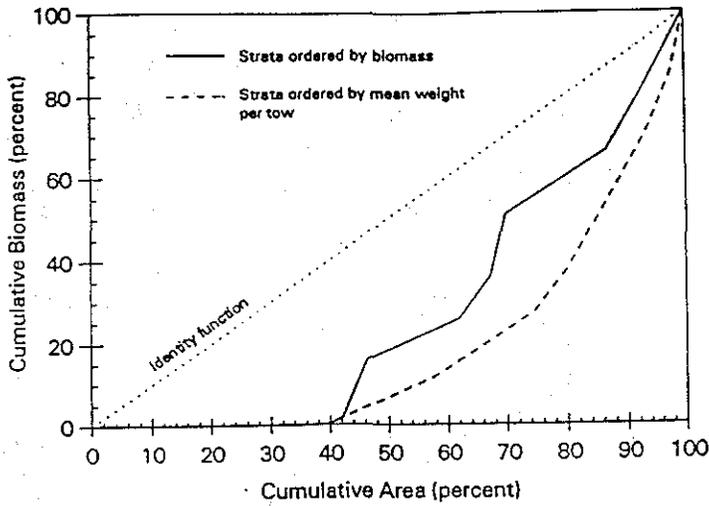


Figure E5.1. A comparison of Lorenz curves for Georges Bank haddock, 1974.

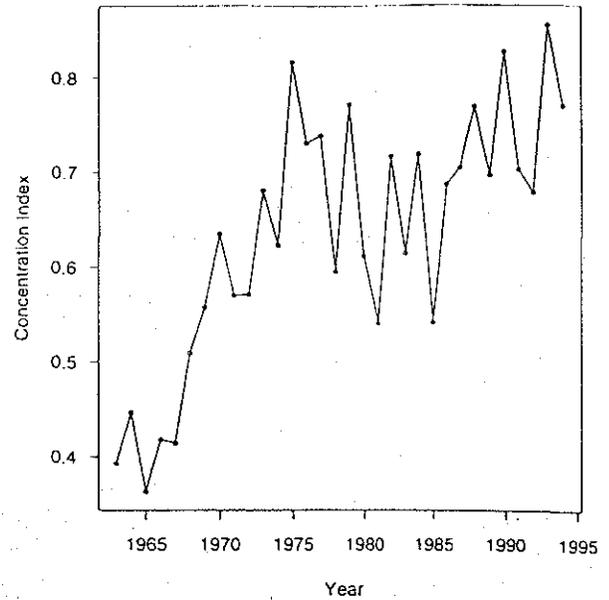


Figure E5.3. Gini index for Georges Bank haddock from 1963 to 1994.

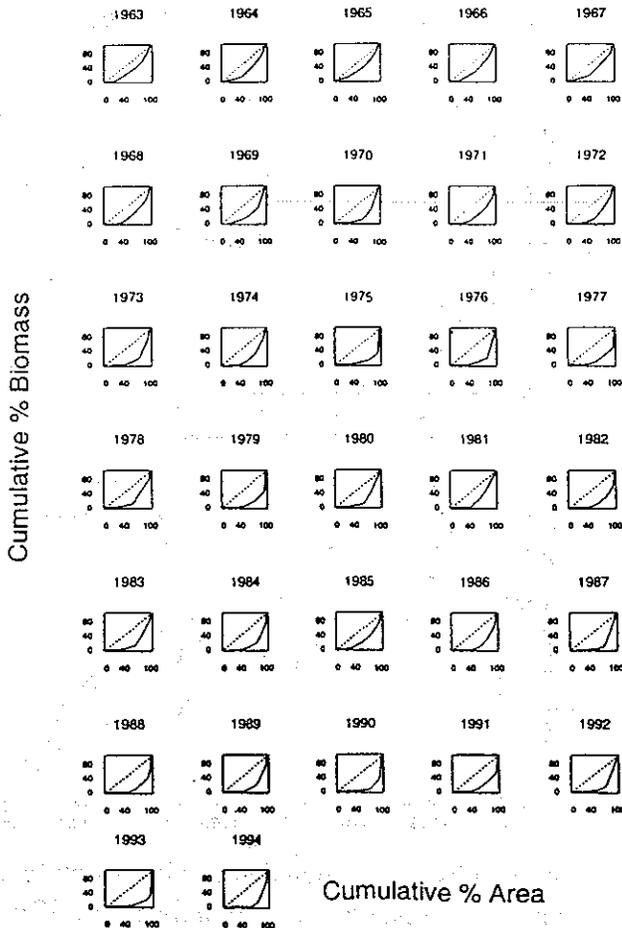


Figure E5.2. Lorenz curves (ordered by mean weight per tow) for Georges Bank haddock from 1963 to 1994.

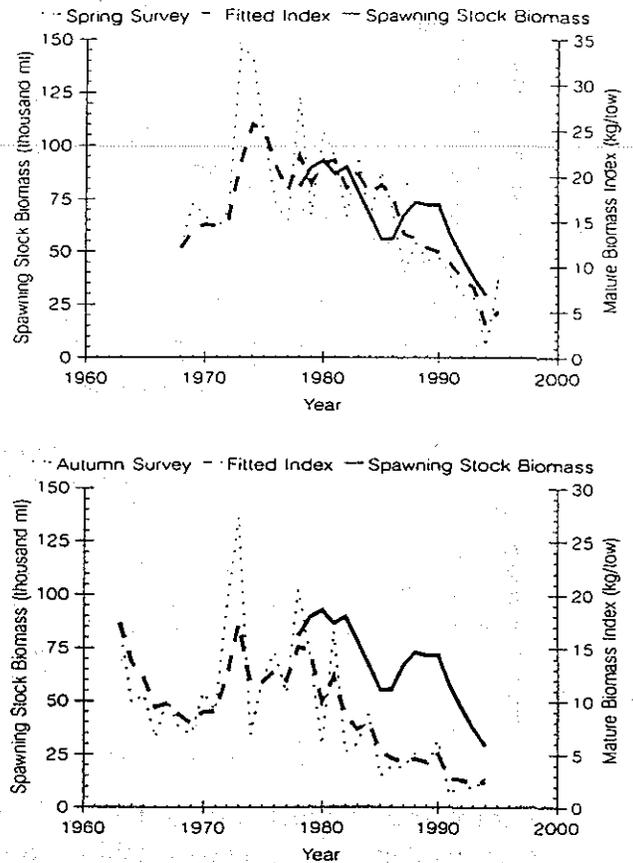


Figure E6.1. Georges Bank cod spawning stock biomass from VPA and NEFSC survey indices.

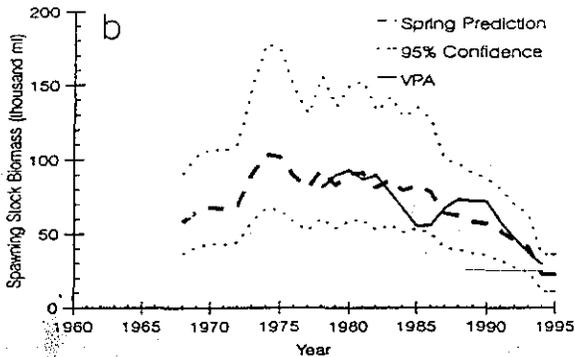
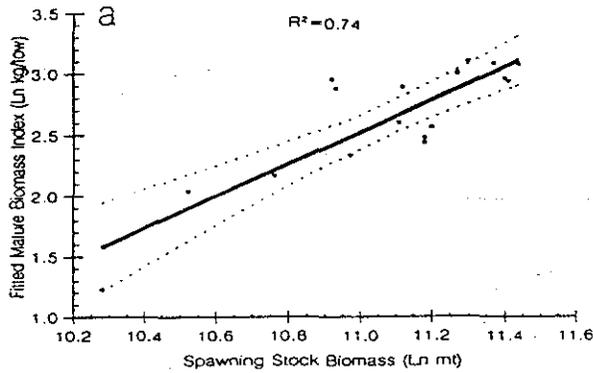


Figure E6.2. Predicted spawning stock biomass of Georges Bank cod: (a) relationship of SSB and the spring survey index with 95% prediction limits, (b) predicted SSB, 1968-1995.

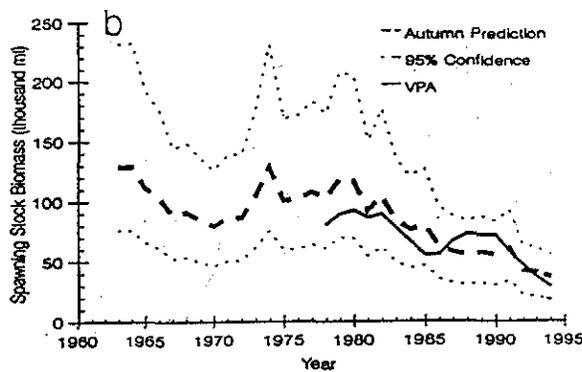
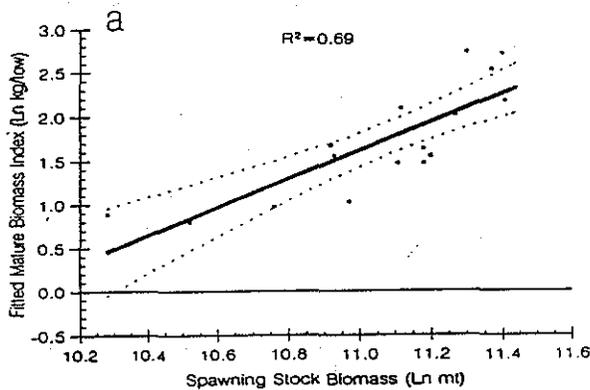


Figure E6.3. Predicted spawning stock biomass of Georges Bank cod: (a) relationship of SSB and the autumn survey index with 95% prediction limits, (b) predicted SSB, 1963-1994.

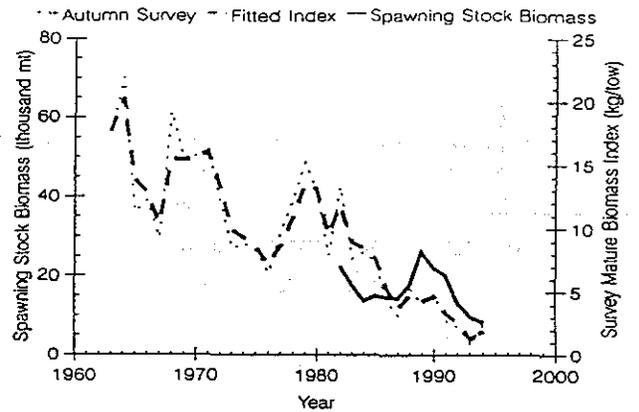
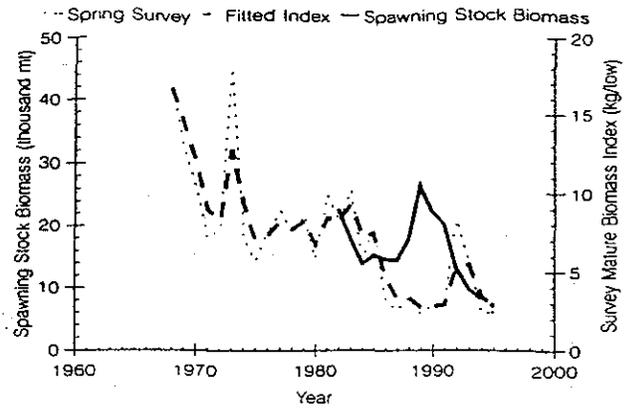


Figure E6.4. Gulf of Maine cod spawning stock biomass from VPA and NEFSC survey indices.

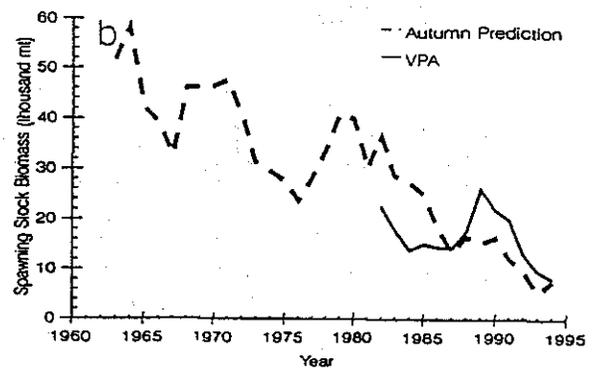
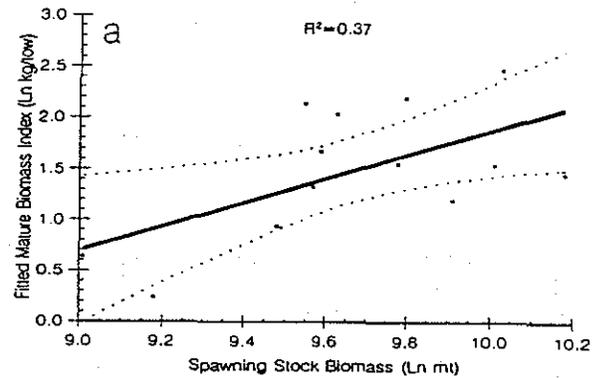


Figure E6.5. Predicted spawning stock biomass of Gulf of Maine cod: (a) relationship of SSB and the autumn survey index with 95% prediction limits, (b) predicted SSB, 1963-1994 (95% confidence limits of predicted SSB range from 0 to 8,250,000 mt).

SEA SAMPLING WORKING GROUP: PROGRESS REPORT

David Pierce (Massachusetts Department of Marine Fisheries), Chairman of the Sea Sampling Working Group summarized the events that led to the establishment of this Working Group and its terms of reference. Examination of sampling precision, sampling design, and representativeness of sea sampling for the estimation of discards was an "overarching" research recommendation of the 19th SAW Stock Assessment Review Committee that was determined to be in need of special action. The issue was brought to the attention of the SAW Steering Committee Meeting in February 1995 and the Steering Committee adopted the following terms of reference:

- (1) Summarize 1989-1993 (1994 if possible) sea sampling activity by fishery and season including fraction of trips and catch sampled;
- (2) Develop a framework for sea sampling program statistical designs after an evaluation of effects of sample size on precision of discard estimates and protocols for biological sampling of catch;
- (3) Evaluate effects of discard estimates' imprecision and bias on stock assessments and biological reference points; and,
- (4) After recognizing ad hoc needs, mandated requirements (e.g., marine mammals incidental catches) management needs, assessment needs, and the dynamics of those needs, establish sea sampling priorities and the strategy for allocation of days-at-sea.

The Working Group met three times to address these terms of reference. Group members (with area of expertise) are:

Kathryn Bisack (NEFSC)
Marine mammal interactions/sampling design

Jon Brodziak (NEFSC), first meeting only
Assessment/SARC Methods Subcommittee
Darryl Christensen (NEFSC)
Data collection/sea and port sampling
Phil Logan (NEFSC)
Economics
Steve Kennelly (Manomet Bird Obs)
Sea sampling/sampling design
Mike Pennington (NEFSC)
Sampling design
David Pierce (MA DMF), Chairman
Sea sampling
Mark Terceiro (NEFSC)
Assessment
Susan Wigley (NEFSC)
Assessment

The importance of sea sampling in stock assessment was last addressed during SAW-12. At the time, 5 presentations were made at the Plenary session which related to whether or not and how discard data from sea sampling can be used to improve the accuracy of stock assessments. Since SAW-12, the importance of sea sampling data has increased for fisheries managers and scientists, due to a need to provide more timely and quantitative assessments of catch bycatch and discard. Unfortunately discretionary funding for sea sampling work has decreased.

Working Group Chairman Pierce discussed the group's progress to date and presented examples of some very preliminary products developed to address the terms of reference:

Term of Reference #1 - Summarize recent activity

An overview of sea sampling by fishery for 1989-1993 was discussed. The broadly defined fisheries included: New England gillnet, Mid-Atlantic coastal gillnet, swordfish gillnet, tuna pair trawl, swordfish longline, otter trawl (Northern shrimp, Gulf of

Maine, Georges Bank, Southern New England, and Mid-Atlantic), sea scallop dredge, sea bass pot, lobster pot, and groundfish longline. The sink gillnet fishery was broken down by days and trips for the period April 1994 through March 1995 and by month area and gear type. A scheduled number of trips and days for shrimp trawl, otter trawl, scallop dredge and lobster pot fisheries were presented by month and area, or combination of areas. The Working Group will provide a more detailed historical description of 1989-1993 sea sampling data. The unclear definition of a "fishery" has been a hurdle to progress, as well as changing fishery definitions.

The Working Group took a close look at two well-defined fisheries, shrimp and sea scallop. Discussed was a preliminary table on the shrimp fishery, providing monthly summaries (1989-1994) of number of trips, days fished, pounds of shrimp landed per trip, and percent sampled. Summaries of sea scallop fishery sea sampling and weighout data versus total trips, days fished, and metric tons of meats are being developed. In discussion, it was cautioned that such very preliminary data and the small number of samples may not adequately describe what is happening in a fishery.

The need to monitor at an established sampling level was discussed. In cases where discarding is insignificant, it may not be necessary to continue the established level of sampling. If the shrimp sampling results, for example, suggest that discards have dropped, there may be no need to continue the monitoring program on a regular basis. The effect of sampling on the precision of discards also should be investigated, as "Trips", as a basic sampling unit, were suggested to be more appropriate than days at sea or tows.

Term of Reference #2 - Develop a framework

The effect of sample size on precision of discard estimates using 1989 data was evaluated at SAW-12. The Working Group will further benefit from Steve

Kennelly's analyses of sea sampling data for sink gillnets and bottom otter trawls for a long list of species, including cod, haddock, winter flounder, yellowtail flounder, summer flounder, lobster, tautog, bluefish, striped bass, silver hake, white hake, squids, butterfish, scup, and black sea bass. His summaries for the period July 1990 through June 1994 will be completed in February 1996. The work will provide better estimates of discards for a number of species and add discard information on at least 15 other species for which we currently have no discard estimates.

Term of Reference #3 - Evaluate precision and bias

As the amount of discards can be a significant factor in an assessment, the group revisited a few stock assessments by making adjustments in the catch-at-age tables to examine the consequences of higher levels of discards, especially of younger fish. These sorts of analyses will be useful to fisheries managers. A preliminary summary of the sensitivity of the summer flounder VPA to three alternate levels of commercial fishery discard was presented. The group has yet to evaluate effects of different levels of discard on biological reference points, however.

Term of Reference #4 - Balance needs

The Working Group has only begun to address this very broad term of reference. Many questions must be asked and managers must clearly express their management needs and priorities.

Discussion -

Questions were raised concerning the need to include information from recreational fisheries. Should the terms of reference be modified to include recreational fisheries? Information from party and charter boats, may be useful in developing assessments of certain species.

Discussed also were the implications of information forthcoming from the mandatory logbook system. Validation of logbook information

is important, particularly if port and biological sampling are cut. Will it be possible to characterize landings from logbook information, as the scale of at-sea observation and the structure for sample collection will be different? To clarify the impact of information from the new data collection system, it was suggested that it may be useful to expand the working group's terms of reference, or for another group, to evaluate the design of the mandated program.

Evaluation of alternatives for obtaining sea sampling data was suggested. Participants were, however, cautioned about reinventing the wheel and

encouraged to learn from the experience of others. Reference was made to a section (Fishery Observe Program) highlighted in the 1994 Status of the Fishery Resources report, proceedings of a west coast symposium, and FAO report which shed insight into the bycatch and discard problems.

It was noted that the current sea sampling program is actually two separate programs, the mandated program and a discretionary program.

Due to the preliminary nature of the information developed by the Sea Sampling Working Group to date, the SARC invited the group to present another progress report at the next SARC meeting.

OTHER BUSINESS

SARC Meeting Schedule

It was proposed that the SARC schedule be changed, as the fall meetings immediately follow the Thanksgiving weekend and the spring meetings fall at the beginning of the academic summer research schedule, making it difficult to get outside participation, particularly from the academic community. The timing of other meetings, the availability of survey and other data, and the composition of the stocks to be reviewed at any one meeting constrain the timing of the SARC meeting. These constraints, however, have a greater impact on Subcommittee meetings and the SARC meetings could be held one week earlier. Thus, the fall meeting could take place one week before Thanksgiving and the spring meeting in the first half of June. This change will be suggested to the Steering Committee at its meeting in March.

Chair for the Methods Subcommittee

The need to continue the Methods Subcommittee and to replace its Chair was discussed. As both former chair Ray Conser and candidate chair Jon Brodziak left NEFSC, the Center or another fisheries organization within the region may nominate someone to fill the position.

Various tasks for the Assessment Methods Subcommittee were discussed. These included, further investigation of overview assessments used at SAW-21, as well as topics related to the usefulness/credibility of data obtained through the mandatory logbook system.

SAW-22

The next SAW, in so far as possible, should focus on methods and options dealing with the new data collection system.

Since the NEFSC Population Dynamics Branch will have to evaluate logbook data, it was noted that it "would be good to pull this into the SAW process", as certain identifiable tasks in the evaluation are clearly within the purview of the Assessment Methods Subcommittee.

The development and possible prioritization of the SARC Terms of Reference was discussed.

It was suggested to remove sea scallops from SAW-22.

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STANDARD MAIL A

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