Northeast Fisheries Science Center Reference Document 97-14

25th Northeast Regional Stock Assessment Workshop (25th SAW)

Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

December 1997

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A Report of the 25th Northeast Regional Stock Assessment Workshop

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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

December 1997

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MEETING OVERVIEW

The Stock Assessment Review Committee (SARC) meeting of the 25th Northeast Regional Stock Assessment Workshop (25th SAW) was held at the Northeast Fisheries Science Center (NEFSC), Woods Hole, MA during 21 - 25 July 1997. The SARC Chairman was Dr. Emory Anderson (NEFSC). Members of the SARC included scientists from the NMFS Northeast and Southeast Fisheries Science Centers (NEFSC and SEFSC), Mid-Atlantic and New England Fishery Management Councils (MAFMC and NEFMC), Atlantic States Marine Fisheries Commission (ASMFC), the States of Maryland and North Carolina, and the University of Maryland (Table 1). In addition, about 20 other persons attended some or all of the meeting (Table 2). The meeting agenda is presented in Table 3.

Table 1. Composition of the SARC.

Chair:
Emory Anderson, NMFS/NEFSC
(SAW Chairman)

Four *ad hoc* experts chosen by the Chair:
Russell Brown NMFS/NEFSC
Pamela Mace, NMFS/SEFSC
Ralph Mayo, NMFS/NEFSC
Loretta O'Brien, NMFS/NEFSC

One person from each regional Fisheries Management Council:
Andrew Applegate, NEFMC
Christopher Moore, MAFMC

Atlantic States Marine Fisheries Commission/State personnel:
John Carmichael, ASMFC
Steve Doctor, MD DNR
Rick Monaghan, NC DMF

One or more scientists from:
Academia - **Tom Miller, CEES/UMD**
Other Regions - **John Merriner, NMFS/SEFSC**

Opening

Dr. Emory Anderson welcomed the participants and introduced the SARC members, as well as Dr. Steven Murawski, Chief of the NEFSC Population Dynamics Branch, the "*ex officio*" member. As he reviewed the composition of the SARC, Dr. Anderson noted that, in numbers, this was one of the smaller SARCs.

Table 2. List of participants.

National Marine Fisheries Service
Northeast Fisheries Science Center
Frank Almeida
Gavin Begg
Steve Cadrin
Steve Clark
Kevin Friedland
Wendy Gabriel
Ralph Mayo
Helen Mustafa
William Overholtz
Fred Serchuk
Gary Shepherd
Mark Terceiro

Atlantic States Marine Fisheries Commission
Najih Lazar

Massachusetts Division of Marine Fisheries
Mike Armstrong
Steven Correia
Tom Currier
Arnold Howe
Jeremy King
David Pierce

Maine Department of Marine Resources
Dan Schick

The Process

The Chairman reviewed the SAW process and the individual responsibilities of the presenters, rapporteurs, and SARC leaders. SARC leaders ensure that final documents appropriately reflect the consensus of the SARC and that research recommendations are properly recorded.

The SAW process has evolved since its establishment in 1985 and, for the past few years, has been operating under a formalized partnership among NMFS (NEFSC and Northeast Regional Office), MAFMC, NEFMC, and the ASMFC. The four major elements of the process are a Steering Committee, Working Groups, SARC, and Public Review Workshop. The SAW cycle is normally repeated twice a year. This year, however, was an exception in that an additional third SAW was held to accommodate the needs of a Congressionally mandated peer review of Northeast groundfish assessments by the National Research Council (NRC).

Table 3. Agenda of the 25th Northeast Regional Stock Assessment Workshop (25th SAW) Stock Assessment Review Committee (SARC) meeting.

NEFSC Aquarium Conference Room
166 Water Street
Woods Hole , MA
21 (1:00 PM) - 25 (6:00 PM) July, 1997

AGENDA

TOPIC	WORKING GROUP & PRESENTER	SARC LEADER	RAPPORTEUR
MONDAY, 21 July (1:00 PM - 6:00 PM)...			
Opening Welcome Agenda Conduct of Meeting	E. Anderson, Chairman		H. Mustafa
Black Sea Bass ©	Coastal/Pelagic W. Overholtz	J. Merriner	G. Shepherd
TUESDAY, 22 July (9:00 AM - 6:00 PM)...			
Northern Shrimp (D)	ASMFC Technical Committee D. Schick	J. Carmichael	S. Cadrin
Scup (B)	Coastal/Pelagic W. Overholtz	P. Mace	T. Currier
WEDNESDAY, 23 July (9:00 AM - 6:00 PM)...			
Summer Flounder (A)	Southern Demersal W. Gabriel	C. Moore	M. Terceiro
Review Advisory Report Section Review Available SARC Consensus Summary Section			
THURSDAY, 24 July (9:00 AM - 6:00 PM)...			
Review Available Advisory Report Sections Review Available SARC Consensus Summary Sections			
SOCIAL at the Sissenwines' (7:00 PM)			
FRIDAY, 25 July (9:00 AM - 6:00 PM)...			
Complete Advisory Report Sections Review Research Recommendations Complete SARC Consensus Summary Sections Review List of Recommended Publications for SAW-25			
Other Business			H. Mustafa

Steering Committee

The Steering Committee consists of five members representing the partners in the SAW process and is chaired by the SAW Chairman. The Committee is responsible for managing the process and setting the agenda and terms of reference for each SAW cycle.

Working Groups

There are currently five SAW Working Groups: Northern Demersal, chaired by Ralph Mayo; Southern Demersal, chaired by Wendy Gabriel; Coastal/Pelagic, chaired by William Overholtz; Invertebrate, chaired by Paul Rago; and Assessment Methods, which is currently without a chair and has been inactive for several years. Working Groups assemble input data, agree on analytical methodology, and prepare stock assessments, working papers, and draft advice for SARC review. ASMFC Technical Committees (or their assessment subcommittees) also provide input to the SARC in the same way as SAW Working Groups. For SAW-25, the ASMFC Northern Shrimp Technical Committee performed the northern shrimp assessment, assembled a report, and prepared draft advice for consideration by the SARC.

The Working Group meetings and meeting participants associated with SAW-25 are presented in Table 4.

Stock Assessment Review Committee (SARC)

The SARC peer reviews assessments and other information prepared by the Working Groups, formulates management advice, develops and approves research recommendations, and specifies Working Papers for publication in the NEFSC Research Document series. This diverse group of experts from within and outside the Region, by virtue of its consensus peer review, places a "stamp of approval" on the assessments which it considers.

Public Review Workshop

The SAW Public Review Workshop is a forum for the public presentation of the results from the SARC meeting, including the management advice. Each Workshop is held in two sessions at meetings of the NEFMC and MAFMC.

Agenda and Reports

The SAW-25 SARC agenda was devoted to the peer review of assessments for summer flounder, scup, black sea bass, and Gulf of Maine northern shrimp (Table 3). A chart of US commercial statistical areas used to report landings in the Northwest Atlantic is presented in Figure 1. A chart showing the sampling strata used in NEFSC bottom trawl surveys is presented in Figure 2.

Draft sections of this report, as well as the advisory document, were reviewed before the SARC adjourned and were assembled into the draft *Report of the 25th Northeast Regional Stock Assessment Workshop (25th SAW) Stock Assessment Review Committee (SARC) Consensus Summary of Assessments* and the *Advisory Report on Stock Status* for distribution to the SAW Steering Committee and subsequently to the participants of the SAW-25 Public Review Workshop. Only one Working Paper was recommended for publication in the NEFSC Reference Document series: "Stock assessment of Gulf of Maine northern Shrimp" by S. Cadrin, D. Schick, D. McCarron, S. Clark, M. Armstrong, B. Smith, and B. O'Gorman.

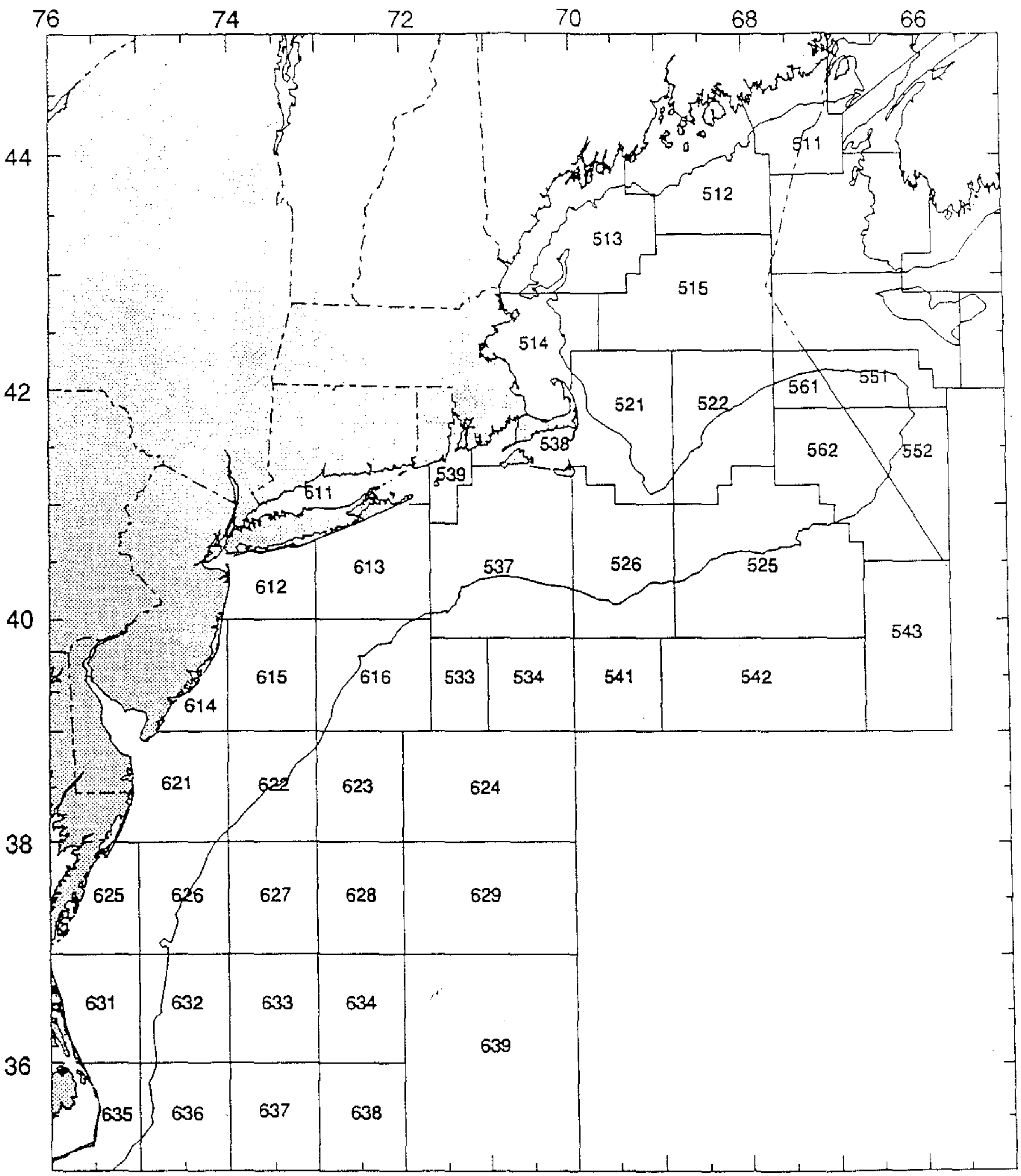

Figure 1. Statistical areas used for catch monitoring offshore fisheries in the Northeast United States.

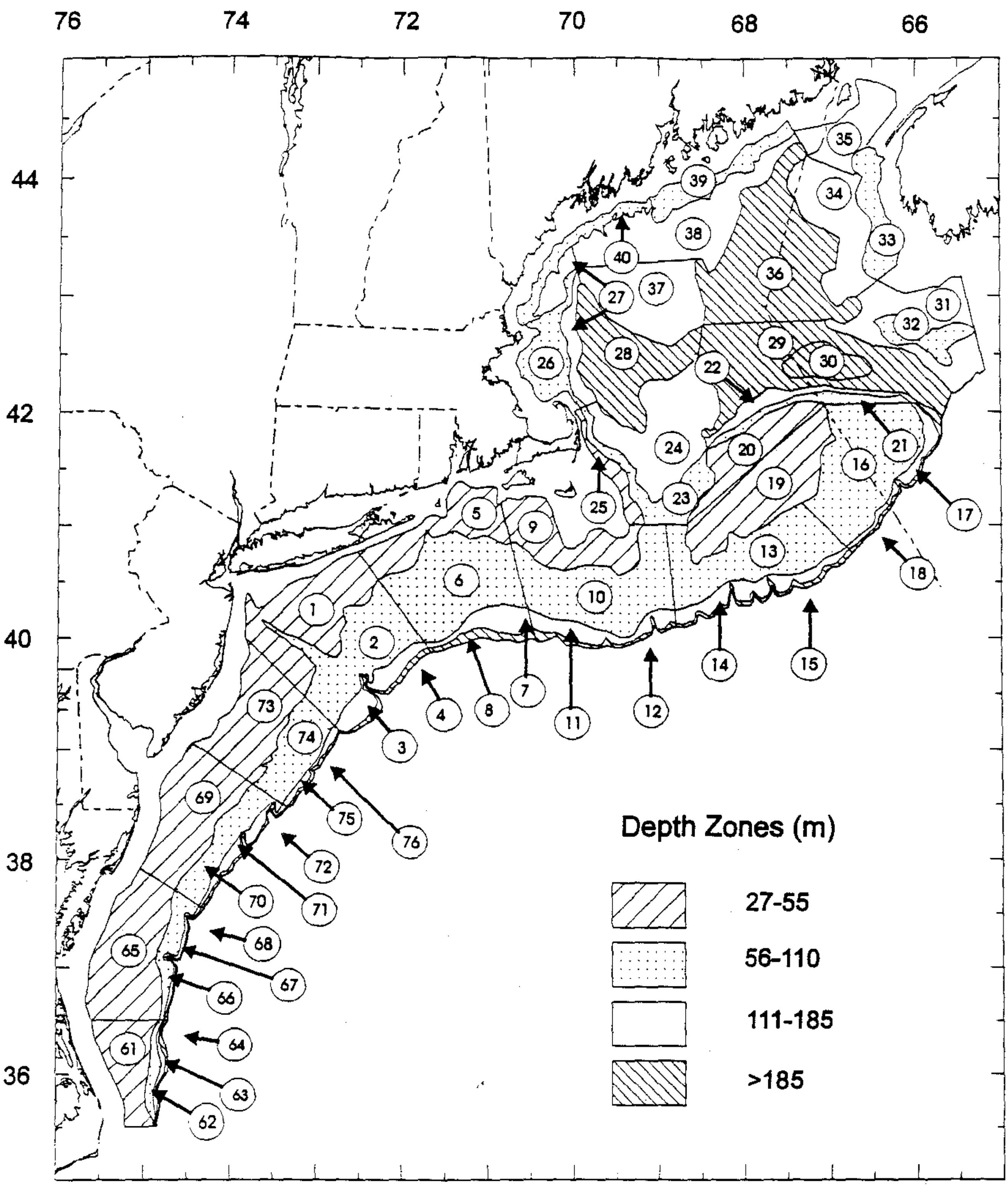

Figure 2. Offshore sampling strata used in NEFSC bottom trawl surveys.

A. SUMMER FLOUNDER

Terms of Reference

a. Assess the status of summer flounder through 1996 and characterize the variability of estimates of stock abundance and fishing mortality rates.

b. Provide projected estimates of catch for 1997-1998 and SSB for 1998-1999 at various levels of F, including F_{target}.

c. Provide medium- to long-term stock size and catch projections under various constant fishing mortality or constant catch scenarios with the aim of achieving stock rebuilding at an MSY level.

Introduction

For assessment purposes, the previous definition of Wilk *et al.* (1980) of a unit stock extending from Cape Hatteras north to New England was accepted. The Mid-Atlantic Fishery Management Council (MAFMC) Fishery Management Plan (FMP) for summer flounder has as a management unit all summer flounder from the southern border of North Carolina, northeast to the US-Canada border. Amendment 1 to the FMP (1990) established the overfishing definition for summer flounder as F_{max} = 0.23. Amendment 2 to the FMP (August 1992) set target fishing mortality rates for summer flounder for 1993-1995 (F_{target} = 0.53) and 1996 and beyond (F_{max} = 0.23). Major regulations enacted under Amendment 2 to meet those fishing mortality rate targets included: 1) an annual fishery landings quota, with 60% allocated to the commercial fishery and 40% to the recreational fishery based on the historical (1980-1989) division of landings, with the commercial allocation further distributed among states based on their share of commercial landings during 1980-1989; 2) commercial minimum landed fish size limit at 13 in (33 cm), as established in the original FMP; 3) a minimum mesh size of 5.5 in (140 mm) diamond or 6.0 in (152 mm) square for commercial vessels using otter trawls that possess 100 lb (45 kg) or more of summer flounder, with exemptions for the flynet fishery and vessels fishing in an exempted area off Southern New England (the Northeast Exemption Area) during 1 November - 30 April; 4) permit requirements for the sale and purchase of summer flounder; and 5) annually adjustable regulations for the recreational fishery, including seasons, a 14-in (36-cm) minimum landed fish size, and possession limits.

Amendment 3 to the FMP revised the western boundary of the Northeast Exemption Area to 72°30' W (west of Hudson Canyon), increased the large mesh net possession threshold to 200 lbs during 1 November - 30 April, and stipulated that only 100 lbs could be retained before using a large mesh net during 1 May - 31 October. Amendment 4 adjusted Connecticut's commercial landings of summer flounder and revised the state-specific shares of the commercial quota accordingly. Amendment 5 allowed states to transfer or combine the commercial quota. Amendment 6 allowed multiple nets on board commercial fishing vessels if properly stowed, and changed the deadline for publication of overall catch limits and annual commercial management measures to 15 October and of recreational management measures to 15 February.

The results of previous assessments indicated that summer flounder abundance was not increasing as rapidly as projected when Amendment 2 regulations were implemented. In anticipation of the need to drastically reduce fishery quotas in 1996 to meet the management target of F_{max} = 0.23, the MAFMC and Atlantic States Marine Fisheries Commission (ASMFC) modified the fishing mortality rate reduction schedule in 1995 to allow for more stable landings from year to year while slowing the rate of stock rebuilding. Amendment 7 to the FMP set a target fishing mortality rate (F_{target}) of 0.41 for 1996 and 0.30 in 1997, with a target of F_{max} = 0.23 in 1998 and beyond. Total landings were to be capped at 8,400 mt (18.51 million lbs) in 1996-1997 unless that quota provided a realized F = 0.23.

The Fishery

Northeast Region (NER: Maine-Virginia) commercial landings data for summer flounder in years prior to 1994 were obtained from trip-level detailed landings records contained in master data files maintained by the Northeast Fisheries Science Center

(NEFSC; the weighout system; 1963-1993) and from summary reports of the Bureau of Commercial Fisheries and its predecessor the US Fish Commission (1940-1962). Prior to 1994, summer flounder commercial landings were allocated to statistical area according to port agent interview data (Burns *et al.* 1983).

Beginning in 1994, landings estimates were derived from mandatory dealer reports under the current National Marine Fisheries Service (NMFS) NER summer flounder quota monitoring system. For 1994-1996, dealer landings were allocated to statistical area using fishing vessel trip reports (VTR data) according to the general procedures developed by Wigley *et al.* (1997) in which a matched set of dealer and VTR data is used as a sample to characterize the statistical area distribution of monthly state landings. Thus, similar to the way information from port agent interviews was used to characterize the 1982 - April 1994 weighout landings under the voluntary reporting system, the data from the May 1994 - December 1996 vessel logs were used to characterize the spatial distribution of the market category landings reported by dealers.

The reported total commercial landings in 1996 were 5,770 mt (about 12.7 million lb), about 14% over the initial 1996 commercial fishery quota of 5,040 mt (11.1 million lbs) (Table A1). Recreational landings (catch types A - catch available for inspection, plus B1 - catch reported by anglers as landed) were based on statistics from the NMFS Marine Recreational Fishery Statistics Survey (MRFSS). Recreational fishery landings increased 118% by number and 89% by weight from 1995 to 1996, with the fishery landing 140% (4,704 mt, 10.4 million lbs) of the 3,360 mt (7.4 million lbs) quota established for 1996. The 1996 recreational landings of summer flounder were the highest since 1988. Total commercial and recreational landings were 10,474 mt, exceeding the 1996 total landings quota of 8,400 mt by 25% (Table A1).

Length and age samples were available to construct the landings-at-age matrix for the NER commercial landings for the period 1982-1996 (Tables A2-A5). A landings-at-age matrix for 1982-1996 was also developed for the North Carolina winter trawl fishery (Table A6) which historically accounts for about 99% of the summer flounder commercial landings in North Carolina. The matrix is based on North Carolina Division of Marine Fisheries (NCDMF) fishery length frequency samples and age-length keys from NEFSC commercial and spring survey data (1982-1987) or NCDMF commercial fishery data (1988-1996).

Changes in the estimation of commercial fishery discards have been made for this assessment. First, NER sea sampling data for 1994-1996 are now available enabling estimates for 1994-1995 to be revised using those data rather than assuming the 1989-1993 average rate and length composition as in the SAW-22 assessment (NEFSC 1996b). Second, as a result of comments from representatives of the commercial fishing industry (J. Fletcher, personal communication), estimates of discard are now stratified by two gear types (scallop dredge and trawl) for years when data are adequate (1992-1996). Estimates at length and age are stratified by gear only for 1994-1996, again due to sample size considerations.

While estimates of catch rates from the NER sea sampling data are used in this assessment to estimate total discards, information on catch rate is also reported in the VTR data. A comparison of discard-to-kept ratios for the sea sampling and VTR data sets for trawl and scallop dredge gear indicated very similar discard rates in the trawl fishery from the two data sources, while discard rates in the scallop dredge fishery were higher in the sea sampling data. Overall, sea sampling and VTR discard-to-kept ratios were very similar during 1994-1996 (Tables A7-A8).

Discards from the commercial fishery during 1989-1996 were estimated using observed discards and days fished from NEFSC sea sampling trips to calculate fishery discard rates by two-digit statistical area and calendar quarter (estimates were calculated separately for trawl and scallop gear for 1992-1996). These rates were applied to the total days fished (days fished on trips landing any summer flounder) from the weighout (1989-1993) and VTR (1994-1996) data bases in the corresponding area-quarter cell to provide estimates of fishery discard by cell. Discard estimates were aggregated over all cells. That total was then raised to reflect potential discard associated with general canvas and North Carolina state waters landings and for fishing activity resulting in discard when summer flounder landings are prohibited (Table A9). Because existing sea sampling length-age data are not adequate to characterize discards at this level of resolution, with large amounts of estimated discard represented by one or no length-age samples, length-age samples are applied at a coarser stratum level as needed.

A NER commercial fishery discard-at-age matrix for 1989-1996 was developed using sea sampled length frequency and age-length distribution samples from 1989-1996, assuming a commercial fishery discard mortality rate of 80%, as recommended by SAW-16 (NEFSC 1993)(Table A10). Sampling intensity was at least one sample of 100 lengths per 34 mt. Although data are inadequate to develop a commercial discard-at-age matrix for 1982-1988, it is likely that discard numbers were small relative to landings during that period because there was no minimum size limit for fish caught in the EEZ. Discards likely increased with the implementation of minimum size regulations for the EEZ beginning in 1989. Not accounting directly for commercial fishery discards will result in a small underestimation of fishery mortality and stock sizes in 1982-1988.

Estimates of recreational landings at age (catch types A+B1) were developed from MRFSS estimates of total catch, MRFSS sample length frequencies, and NEFSC commercial and survey age-length data (Tables A11-A13). Estimates of recreational discards at age were based on assumptions that the ratio of age 0 to age 1 fish in type B2 catches (fish reported by anglers as released alive) were the same as in the landings and that 25% of type B2 catches die of hooking mortality (Table A14). Type B2 catches have become a more significant component of the total recreational catches (up to 79% in 1995) as minimum size regulations have been implemented on a state-by-state basis. Because discard lengths and weights are unobserved, mean weight at age in the discard was set equal to mean weight at age in the landings. The SARC noted that discard weight at age consequently would be overestimated (although sub-legal sized fish are observed in landings).

NER total commercial landings and discards at age, North Carolina winter trawl landings and discards at age, and MRFSS recreational landings and discards at age totals were summed to provide a total fishery catch-at-age matrix for 1982-1995 (Table A15). The numbers and proportions at age of fish age 4 and older are low and quite variable, reflecting the limited numbers of fish available to be sampled. Overall, mean lengths and weights at age for the total catch were calculated as weighted means (by number in the catch at age) of the respective mean values at age from the NER commercial (Maine - Virginia), North Carolina commercial winter trawl, and recreational (Maine - North Carolina) fisheries (Tables A16-A17).

Biological Data

Work performed for the SAW-22 assessment (NEFSC 1996b) indicated a major expansion in the size range of 1-year-old summer flounder collected during the 1995 and 1996 NEFSC winter bottom trawl surveys and brought to light differences between ages determined by the NEFSC and NCDMF age readers. Research and age structure exchanges have been performed since the SAW-22 assessment to explore these aspects of summer flounder biology. The results of the first two exchanges, which were reported at SAW-22, indicated low levels of agreement between age readers at the NEFSC and NCDMF (31 and 46%). In 1996, research was conducted to determine inter-annular distances and to back-calculate mean length at age from scale samples collected on all NEFSC bottom trawl surveys (winter, spring, and fall) for comparison with NCDMF samples. While mean length at age remained relatively constant from year to year, inter-annular distances increased sharply in the samples from the 1995-1996 winter surveys and increased to a lesser degree in samples from other 1995-1996 surveys as well.

Age data from the winter 1997 bottom trawl survey, aged utilizing both scales and otoliths, initially indicated a similar pattern as the previous two winter surveys (i.e., several large age 1 individuals) from scale readings and some disagreement between scale and otolith ages obtained from the same fish. Because of these problems, a team of five experienced NEFSC age readers was formed to re-examine the scales aged from the winter survey. After examining several hundred scales, the team determined that re-ageing all samples from 1995-1997, including all winter, spring, and fall samples from the NEFSC and MA state bottom trawl surveys and all samples from the commercial fishery would be appropriate. The age determination criteria used remained the same as those developed at the 1990 summer flounder workshop (Almeida *et al.* 1992) and described in the standard ageing manual utilized by NEFSC staff (Dery 1997). Only those fish for which a 100% consensus was reached by all group members were included in the revised database. The re-aged database was used in the compilation of fishery and survey catch-at-age matrices used in the SAW-25 analyses. Age structure exchanges between the NEFSC and NCDMF were re-initiated during SAW-25. The results of these exchanges will be provided to the SAW Southern Demersal Working Group as soon as they are available.

Research Survey Abundance and Biomass Indices

Age-specific mean catch rates (in numbers) from the NEFSC spring offshore survey (Table A18, 1976-1997, 1997 preliminary), NEFSC fall inshore/offshore survey (Table A19, 1982-1996), NEFSC winter offshore survey (Table A20, 1992-1997), Rhode Island Department of Fish and Wildlife fall survey (Table A21, 1980-1996), Massachusetts Department of Marine Fisheries (MADMF) spring and fall inshore surveys (Tables A22-A23, 1978-1996), Connecticut Department of Environmental Protection (CTDEP) spring and fall trawl surveys (Tables A24-A25, 1984-1996), and New Jersey Bureau of Marine Fisheries spring to fall trawl survey (Table A26, 1988-1996) were used as indices of abundance in VPA tuning.

Young-of-year (YOY) indices from the NCDMF Pamlico Sound trawl survey (1987-1996), Virginia Institute of Marine Science (VIMS) juvenile fish trawl survey (1979-1996), and Maryland Department of Natural Resources (MDDNR) trawl survey (1972-1996) were also used in VPA tuning (Table A27).

Although some surveys may not reflect the coast-wide trends in the abundance of summer flounder indicated by VPA, the surveys may provide accurate indices of localized summer flounder abundance and serve as useful tools for local fisheries management.

Estimates of Mortality and Stock Size

Natural Mortality Rate

Instantaneous natural mortality rate (M) for summer flounder was assumed to be 0.2 in all analyses, although alternative estimates of M were considered in the SAW-20 assessment (NEFSC 1996a). In the SAW-20 work, estimates were derived with the methods described by 1) Pauly (1980) using growth parameters derived from NCDMF age-length data and a mean annual bottom temperature (17.5° C) from NC coastal waters, 2) Hoenig (1983) using a maximum age for summer flounder of 15 years, and consideration of age structure expected in unexploited populations (5% rule, 3/M rule, e.g., Anthony 1982). SAW-20 concluded that M = 0.2 was a reasonable value given the mean (0.23) and range (0.15-0.28) obtained from the various analyses.

Virtual Population Analysis (VPA) Calibration

ADAPT tuning for the summer flounder VPA was used (Parrack 1986, Gavaris 1988, Conser and Powers 1990). As in the SAW-22 summer flounder assessment (NEFSC 1996b), research survey indices with trends that did not reasonably match corresponding patterns in abundance, as estimated by the VPA, were eliminated from the VPA tuning. All indices in the VPA tuning were given equal weight. Instantaneous natural mortality rate (M) was assumed to be 0.2. Fishing mortality rates in 1996 and abundances of ages 1-4 in 1997 were directly estimated, while abundance of age 5+ was estimated from Fs estimated in 1996. Stock size at age 0 in 1997 was not estimated. The F on age 4 (oldest true age) was estimated from back-calculated stock sizes for ages 2-4. The F on the age 5+ group was set equal to the rate for age 4.

Fishing mortality rates on fully recruited ages of summer flounder have been high during 1982-1996, varying between 1.0 and 2.1 (58-85% exploitation rate). The fishing mortality rate peaked in 1992 at 2.1, but has since declined to 1.2 in 1994, 1.1 in 1995, and 1.0 in 1996 (Table A28, Figure A1).

Summer flounder spawn in the late autumn and into early winter (peak spawning on November 1), and age 0 fish recruit to the fishery the autumn after they are spawned. For example, summer flounder spawned in autumn 1987 (from the November 1, 1987 spawning stock biomass) recruit to the fishery in autumn 1988 and appear in VPA tables as age 0 fish in 1988. This assessment indicates that the 1982 and 1983 year classes were 76 and 83 million fish, respectively, the largest of the VPA series. The 1988 year class was the smallest of the series at only 13 million fish. The 1994 year class is estimated at about 40 million fish and the 1995 year class at 47 million fish, the largest since 1983. The 1996 year class, however, at about 23 million, is estimated to be the weakest since 1988 (Table A28, Figure A2).

Total stock size in 1996 (ages 0 and older) was estimated at about 84 million fish, about 52% of the peak abundance estimated for 1983 (163 million). Spawning stock biomass (SSB) on November 1, 1996 was estimated to be 17,402 mt, 92% of the peak estimated for 1983 (18,939 mt). Age 2-5+ SSB, which may be a more realistic estimate of viable spawners given the uncertain spawning potential of age 0 and age 1 summer flounder, was estimated to be 5,877 mt, about 3% higher than the age 2-5+ SSB estimated for 1983 (5,703 mt) (Table A28, Figure A2). A comparison between catch biomass calculated in the VPA and reported landings plus estimated discard is presented in Table A29.

In summary, the VPA results indicate that fishing mortality rates on summer flounder have declined since 1992, but are currently above the management target (F_{target} = 0.41 in 1996) and the overfishing definition (F_{max} = 0.24). Fishing mortality rates on age 1 fish in 1995-1996 are lower relative to fully recruited ages (2-4) than in 1993-1994. Spawning stock biomass has tripled since 1989, but this biomass continues to be concentrated in a few age classes, with about 34% of the total SSB at ages 2 and older in 1996. In contrast, about 85% of the spawning stock would be expected to be age 2 and older if the stock were rebuilt and fished at F_{max} = 0.24. Spawning stock biomass and corresponding recruitment estimates are summarized in Figure A3.

A bootstrap procedure (Efron 1982) was used to evaluate the precision of the current 1996 VPA estimates with respect to random variation in tuning data (survey abundance indices). The procedure does not reflect uncertainty in the catch-at-age data. Two hundred bootstrap iterations were used to generate distributions of the 1996 fishing mortality rate and SSB. The bootstrap estimate of the 1996 SSB was relatively precise, with a corrected CV of 14%. The bootstrap mean (17,771 mt) was slightly higher than the VPA point estimate (17,402 mt). The bootstrap results suggest a high probability (>90%) that SSB in 1996 was at least 15,000 mt, reflecting only variability in survey observations (Figure A4).

The corrected coefficients of variation for the Fs in 1996 on individual ages were 28% for age 0, 20% for age 1, and 15% for fully recruited ages. The distribution of bootstrap Fs was not strongly skewed, resulting in the bootstrap mean F for 1996 (1.00) being about equal to the point estimate from the VPA (0.99). There is an 80% chance that F in 1996 was between about 0.8 and 1.2, given the variability in survey observations (Figure A5).

VPA Retrospective Analysis

Retrospective analysis of the summer flounder VPA was carried out for terminal catch years 1990-1996 using the final configuration of the current VPA. Convergence is generally evident within 4 years prior to a given terminal year. As in the SAW-22 assessment, F was underestimated and stock sizes overestimated for the years 1991-1993. This pattern has reversed for the 1994-1995 estimates in the current assessment, with a tendency to overestimate F in those years. This is different from the pattern for those estimates that was indicated in the SAW-22 assessment and may reflect more accurate 1995-1996 estimates of catch and indices of stock size due to revised ages and better accounting of landings and estimation of discards.

The retrospective analysis shows that fully recruited F (ages 2-4) was underestimated for 1991-1993, but overestimated in 1994-1995 (Table A30). The largest retrospective difference occurred for 1992 (1992 terminal year estimate of F = 1.1, 1996 terminal year estimate of F = 2.1). Over the terminal catch years of 1990-1996, fully recruited F was underestimated by an average of 0.02.

Spawning stock biomass was overestimated since 1990, except for 1994 (Table A30). The largest retrospective error occurred for 1992, with SSB overestimated by 5,300 mt relative to the 1992 estimate with a 1996 terminal year. Over the terminal catch years of 1990-1995, SSB was overestimated by an average of 1,128 mt.

Summer flounder recruitment at age 0 was underestimated for 1992 and 1993, but overestimated for the years 1990, 1991, 1994, and 1996 (Table A30). No pattern for the 1995 year class was evident. The largest retrospective error occurred for 1994, with age 0 recruitment overestimated by 20.6 million fish relative to the 1994 estimate with a 1996 terminal year. Over the terminal catch years of 1990-1996, recruitment was overestimated by an average of 6.9 million fish. For average recruitment of 34.7 million fish during 1990-1996, recruitment has been overestimated by an average of 20%.

Integrated Catch-at-Age Analysis (ICA Model)

The ADAPT calibration of the VPA assumes no error is present in the fishery catch data. Given that the recreational fishery landings and discard and commercial fishery discard components of the summer flounder catch-at-age matrix are estimated quantities, an alternative assessment model which can estimate the error in the catch at age was considered. Integrated catch-at-age analysis (ICA) is a hybrid method which can use a separable catch model for a variable number of years at the end of the catch time series, combined with a VPA for the earlier years (Patterson 1995, Patterson and Melvin 1995). The separable portion is a log catch model where the objective function to be minimized is the deviations of the observed minus the predicted catches. Predicted catch is a function of abundance, mortality rate, and partial selection. Relaxation of the true catch assumption for the most recent years (1993-1996) was made for summer flounder (separable model for 1993-1996), with the thought that this might provide a better solution capability and appraisal of uncertainty in the terminal catch year estimates.

An ICA run was configured using the same catch at age, natural mortality rate, mean weights at age, and maturity vector as in the current ADAPT-tuned VPA. A limitation on the number of tuning indices possible in ICA required the use of a reduced set. Five age-structured indices (NEFSC spring, NEFSC fall, CTDEP spring, CTDEP fall, and NJBMF survey series) were included as the longest available age-structured series. The MADMF spring, MADMF fall, and RIDFW fall surveys were aggregated to biomass indices. Flat-topped partial recruitment was assumed, with a reference age for full recruitment to the fishery assumed at age 2. Other model configuration details included linear catchability relationships between survey indices and estimated stocks sizes, within-survey error correlations set at 0.50 (degree to which indices at age within a survey series vary together), and equal weighting among indices, as in the previous assessment.

The magnitude of and trends in SSB and recruitment estimated by ICA are comparable to those estimated by the ADAPT-tuned VPA model. The magnitude of and trend in fishing mortality estimated by ICA is comparable to that of the ADAPT-tuned VPA for the 1982-1993 period. The ICA model estimates a substantially higher F in 1994 (2.6) than the ADAPT-tuned VPA (1.2) and indicates a steeper decline to an estimated F of 0.7 in 1996.

Estimates of Mortality from ALS Tagging Data

Tagging data for summer flounder from the American Littoral Society (ALS) angler program were used to estimate fishing mortality. Since 1983, a total of 23,930 summer flounder have been tagged by ALS anglers, of which a total of 1,758 had been recovered through 1996. Based on reported length at tagging, most summer flounder tagged by anglers were ages 0 to 2. Tag release and recapture data were compiled for 1983-1996. Estimates of survival rates were made using the MARK framework (White and Burnham, 1996), recently adopted by the ASMFC Tagging

Working Group for striped bass mortality estimates. The statistical framework consists of a series of models which consider tag recoveries in sequential years following release to be multinomial random variables. Model structure in terms of recovery rate and survival probability proceeds from most restrictive (no time dependence) to most general (time-dependent parameters). Maximum likelihood methods are used to estimate parameters and provide a covariance matrix for the estimates. Goodness of fit, likelihood ratio tests, and Akaike's Information Criteria (AIC) are used to select the most parsimonious model which adequately fits the data. The models estimate survival rate directly, which is transformed into total instantaneous mortality rate (Z). Total mortality rate was corrected for tag loss on the basis of Sprankle's (1994) study on striped bass which indicated an instantaneous loss of 0.48 per year for the ALS tags. Fishing mortality rate was estimated by subtracting M = 0.20 from corrected Z values.

The model allowed estimates of survival and recoveries for the entire time series (1983-1996) via numerical maximum likelihood techniques. The selected model that best fit the data assumed time-independent recovery and survival rate, also known as a general model. Survival rate (S) ranged from 0.11 (SE = 0.04) in 1985-1986 to 0.38 (SE = 0.12) in 1988-1989 without a trend. The period of inference for the survival estimate was from July of one year to July of the next year. The estimated survival rates correspond to a total instantaneous loss rate ranging from Z = 0.46 to Z = 1.7. Allowing for tag loss, as estimated in the Sprankle (1994) retention study and natural mortality losses, fishing mortality rate ranged from F = 0.26 to 1.5, and the estimate of F in the terminal year (July 1995 - July 1996) was 0.91 for ages 1 and 2. Assuming no uncertainty in the natural mortality or tag loss adjustment rates, a 95% confidence interval on F in 1995-1996 was 0.60 - 1.36.

Biological Reference Points

The calculation of biological reference points for summer flounder, using the Thompson and Bell (1934) model, was detailed in NEFC (1990). The 1990 (SAW-11) analysis indicated that $F_{0.1}$ = 0.136 and F_{max} = 0.232. A revised yield-per-recruit analysis reflecting recent conditions in the fisheries was conducted for the current assessment. The partial recruitment pattern (including discards) was estimated as the geometric mean of F at age for 1995-1996. Mean weights at age were estimated as the arithmetic means of 1995-1996 values. The current analysis indicates that $F_{0.1}$ = 0.141 and F_{max} = 0.242 (Table A31, Figure A6).

Projections

Stochastic projections of landings, discards, SSB, and fishing mortality were made for 1997-1999 starting with three different levels of exploitation in 1997 (projection sets), and four subsequent levels of exploitation during 1998-1999 (projection options). One hundred projections were made for each of the 200 bootstrapped realizations of 1997 stock sizes from VPA runs using algorithms and software described by Brodziak and Rago (MS 1994). Recruitment in 1997-1999 was generated randomly from recruitment levels estimated by VPA for 1982-1996. The partial recruitment pattern (including discards) used in the projections was estimated as the geometric mean of F at age for 1995-1996 to reflect the most recent conditions in the fisheries resulting from the implementation of FMP Amendment regulations. Mean weights at age were estimated as the arithmetic means of 1995-1996 values. Separate mean weight-at-age vectors were developed for the SSB, landings, and discards (Table A32). Uncertainty in partial recruitment patterns, discard rates, reported landings, or components other than survey variability was not reflected.

The first projection set assumes the adjusted 1997 quota of 7,162 mt will be landed, and estimates a median (50% probability) F = 0.40 and a median spawning stock biomass of 25,200 mt, with a 95% probability that the target F for 1997 (i.e., F = 0.30) will be exceeded. Under Option 1, landings of 6,276 mt and discards of 622 mt in 1998 will result in a median F = 0.24 and a median SSB of 36,100 mt in 1998 (Tables A32-A33; Figure A7). Landings of 9,185 mt and discards of 628 mt in 1999 will generate a median F = 0.24 and a median SSB of 47,700 mt in 1999. Additional projection options for 1998-1999 were:

Option 2: landings of 8,400 mt in 1998, equal to the original 1995-1996 quotas, and F level of 0.24 in 1999;

Option 3: landings of 9,000 mt in 1998-1999, a level 25% higher than the adjusted 1997 quota;

Option 4: landings of 14,400 mt in 1998-1999, the total quota associated with commercial landings of 19 million lbs (8,600 mt), a level indicated as desirable by the commercial fishing industry in North Carolina (J. Fletcher, personal communication).

The second set of projections assumes the 1997 landings will exceed the adjusted quota by the same percentage as in 1996 (25%) and will be 9,000 mt. Option 1 of the second projection set estimates a median F = 0.53 and a median SSB of 23,600 mt, with a 99% probability that the target F for 1997 will be exceeded. Landings of 5,750 mt and discards of 605 mt in 1998 will result in a median F = 0.24 and a median SSB of 34,200 mt in 1998. Landings of 8,667 mt and discards of 625 mt in 1999 will generate a median F = 0.24 and a median SSB of 45,800 mt in 1999 (Table A32).

The third set of projections assumes the 1997 fishing mortality rate will be the same as in 1996 (i.e., F = 1.0) which will result in landings of 14,280 mt and a median SSB of 18,900 mt, with a 100% probability that the target F for 1997 will be exceeded. Option 1 of the third set indicates that landings of 4,270 mt and discards of 558 mt in 1998 will generate a median F = 0.24 and a median SSB of 28,700 mt in 1998. Landings of 7,167 mt and discards of 612 mt in 1999 will result in a median F = 0.24 and a median SSB of 40,500 mt in 1999 (Table A32).

Medium-term projection results (10 years, 1997-2006) must be viewed with caution because the effects of density dependence, future environmental conditions, and stock age structure on the stock-recruitment relationship at higher stock sizes are unknown for summer flounder. Medium-term projections involve extrapolation of patterns in recruitment, growth, and maturity to levels of summer flounder stock abundance as much as four times higher than the population sizes estimated from VPA. Hind-cast estimates of stock and recruitment using NEFSC spring survey (kg/tow) as a proxy for spawning stock biomass and using Maryland age 0 indices as a proxy for recruitment did not provide estimates of SSB and recruitment (1972-1981) substantially larger than the ranges estimated by the VPA (1982-1996).

If the landings in 1997 are 7,162 mt, medium-term (10-year) projections at F = 0.24 and assuming current stock productivity levels (median recruitment of 41 million fish at age 1) indicate median landings of 18,500-19,400 mt during 2004-2006, with median SSB of 81,200-84,400 mt (Table A34, Figure A8). Landings of 8,400 mt in 1998 and fishing mortality at F = 0.24 during the 1999-2006 period provide median landings of 16,400-17,300 mt during 2004-2006, with a median SSB of 80,700-84,200 mt. Landings of 9,000 mt during 1998-2000 and fishing mortality at F = 0.24 during the 2001-2006 period provide median landings of 18,600-19,400 mt during 2004-2006, with a median SSB of 81,600-84,500 mt. Landings of 14,400 mt during the entire 1998-2006 period provide a fishing mortality rate meeting the target of F_{max} = 0.24 by 2005, with a median SSB of 72,800 mt.

Conclusions

The stock is at a medium level of historical (1968-1996) abundance and is over-exploited. Estimates from ALS tagging data, the ICA model, and the ADAPT-tuned VPA model indicate that the fishing mortality rate on summer flounder is high. The fishing mortality rate estimated by VPA was 1.0 (58% exploitation) in 1996 (Figure A1). This estimate is above the FMP management target (F_{target} = 0.41 in 1996) and overfishing definition (F_{max} = 0.24). There is an 80% chance that the 1996 F was between 0.8 and 1.2 (Figure A5). Spawning stock biomass (age 0 and older) has increased from 5,200 mt in 1989 to 17,400 mt in 1996, the highest level since 1983. The age structure of the spawning stock has begun to expand, with 34% of the SSB at ages 2 and older in 1996, although about 85% of the SSB would be expected to be age 2 and older under equilibrium conditions at F_{max}. There is an 80% chance that the 1996 SSB was between 15,000 mt and 21,000 mt (Figure

A4). The 1995 year class is about average (1982-1996), but the 1996 year class is estimated to be the smallest since the poor 1988 year class (Figure A2). Fishing mortality needs to be reduced to meet the FMP target F level of 0.24 in 1998. If the adjusted quota for 1997 is not exceeded, total landings in 1998 should not exceed 6,276 mt to meet the management target. Additional measures to minimize commercial and recreational discard mortality should be considered.

Sources of Uncertainty

The following major sources of uncertainty in the current assessment were identified:

1) VPA estimates of stock size in 1997 are not precise (e.g., with coefficients of variation from 26 to 35%) because they depend on imprecise and, in some cases, preliminary research survey indices. The landings from the commercial fisheries used in this assessment assume no under-reporting of summer flounder landings. Therefore, reported landings from the commercial fisheries should be considered minimum estimates. The SARC noted that the fishing mortality rate in the terminal year of the VPA was underestimated in previous assessments (NEFSC 1993, 1994, 1996a, 1996b), and underestimation of the true catch is a plausible cause of this pattern. An historical review of previous assessments shows that projections have consistently underestimated future fishing mortality rates and overestimated stock sizes (Table A35). Uncertainty in partial recruitment patterns, discard rates, reported landings, or components other than survey variability is not reflected in the projections. Projected landings should be considered with caution.

2) There is evidence of inconsistency in the ageing of summer flounder by the NEFSC and NCDMF age readers. The impact of this inconsistency on assessment results has not been quantified. The SARC supports the ongoing cooperative work between the NEFSC and NCDMF to ensure consistent ageing of summer flounder.

3) Northeast Region (NER) commercial fishery landings-at-age estimates are based on preliminary vessel logbook data. The NER landings at age for 1994-196 will again be revised in the next assessment if the vessel logbook database for 1994-196 is complete and ready for routine use.

4) The current assumptions accepted to allow characterization of the age composition of the recreational live discard (catch type B2) are based on data from a limited geographic area (Long Island, New York).

SARC Comments

SARC discussion focused on the options used in the short- and medium-term projections. In addition to projections starting with 1997 landings of 7,162 mt, which assume that the adjusted quota level will not be exceeded, the SARC performed two additional sets of projections. The second set of projections assumes that the 1997 total landings quota will be exceeded by the same percentage as in 1996 (25%); accordingly the assumed 1997 total landings were set at 9,000 mt. The third set of projections assumes that F in 1997 will be the same as in 1996 (i.e., F = 1.00).

The SARC noted that the medium-term projections (10 years, 1997-2006) involved extrapolation of patterns in recruitment, growth, and maturity to levels of stock abundance as much as four times higher than the population sizes estimated from VPA. The SARC emphasized that the medium-term projection results must be viewed with caution because the effects of density dependence, future environmental conditions, and stock age structure on the summer flounder stock-recruitment relationship at higher stock sizes are unknown. The SARC recommended that the Southern Demersal Working Group continue to investigate the utility of alternative SSB-R models in medium-term summer flounder projections for the next assessment.

Research Recommendations

- The SARC supports the ongoing comparison of NEFSC age-length samples with those collected by the NCDMF to ensure consistent ageing of summer flounder.

- The NEFSC sea sampling program should continue collecting data for summer flounder, with special emphasis on a) comprehensive areal and temporal coverage, b) adequate length and age sampling, c) continued sampling after commercial fishery areal and seasonal quotas are reached and fisheries are limited or closed, and d) estimation of summer flounder discard in the scallop dredge fishery. Maintaining adequate sea sampling will be especially important in order to monitor a) the effects of implementation of gear and area restrictions, both in terms of the response of the stock and the fishermen, b) potential continuing changes in "directivity" in the summer flounder fishery, as a result of changes in stock levels and regulations, and c) discards of summer flounder in the commercial fishery after quota levels have been attained and the summer flounder fishery is closed or restricted by trip limits.

- The SARC encourages research to determine length and age frequency of summer flounder discards and discard mortality rates in the commercial and recreational fisheries.

- The SARC encourages research to evaluate gear and handling modifications to reduce hooking mortality in the recreational fishery.

- The present maturity ogive for summer flounder is based on simple gross examination of ovaries and may not accurately reflect the spawning potential of summer flounder, especially for age 0 and 1 fish. The SARC encourages ongoing work (i.e., at the University of Rhode Island and elsewhere) using various methodologies that may provide information to better characterize the spawning contribution of young summer flounder.

- Although NER commercial fishery biological sampling intensity meets the traditional standards for adequate sampling, when considered on an overall annual basis, the sample distribution is sparse for some strata of the fishery. Sampling intensity and coverage improved in 1996, and the SARC recommends this level of coverage be continued in the future.

- The Southern Demersal Working Group should update the correlation analyses for candidate VPA tuning indices to formalize criteria for inclusion in VPA, and continue research on use of alternative SSB-R models in medium-term summer flounder projections.

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Table A1. Commercial and recreational landings (metric tons, A+ B1 recreational type) of summer flounder, Maine to North Carolina.

Year	Comm.	Rec.	Total	% Comm.	% Rec.
1980	14,159	14,149	28,308	50	50
1981	9,551	4,852	14,403	66	34
1982	10,400	8,267	18,667	56	44
1983	13,403	12,687	26,090	51	49
1984	17,130	8,512	25,642	67	33
1985	14,675	5,665	20,340	72	28
1986	12,186	8,102	20,288	60	40
1987	12,271	5,519	17,790	69	31
1988	14,686	6,733	21,419	69	31
1989	8,125	1,435	9,560	85	15
1990	4,199	2,329	6,528	64	36
1991	6,224	3,611	9,835	63	37
1992	7,529	3,242	10,771	70	30
1993	5,715	3,484	9,199	62	38
1994	6,588	4,111	10,699	62	38
1995	6,977	2,496	9,473	74	26
1996	5,770	4,704	10,474	55	45
Ave.	9,976	5,876	15,852	63	37

Table A2. Summary distribution of 1994 NER commercial fishery landings and length samples.

Market category	1-digit area	Item	Quarters 1 & 2	Quarters 3 & 4	Total
Small	5	Metric tons	6	5	11
		No. samples	1	0	1
		No. lengths	103	0	103
Small	6	Metric tons	328	173	501
		No. samples	2	3	5
		No. lengths	100	208	308
Medium	5	Metric tons	541	311	852
		No. samples	7	7	14
		No. lengths	732	708	1440
Medium	6	Metric tons	964	394	1358
		No. samples	2	5	7
		No. lengths	200	496	696
Large	5	Metric tons	260	200	460
		No. samples	3	3	6
		No. lengths	288	203	491
Large	6	Metric tons	515	349	864
		No. samples	1	4	5
		No. lengths	100	392	492
Jumbo	5	Metric tons	95	59	154
		No. samples	1	2	3
		No. lengths	36	79	115
Jumbo	6	Metric tons	108	53	161
		No. samples	0	2	2
		No. lengths	0	118	118
Unclass	5	Metric tons	31	18	49
		No. samples	0	0	0
		No. lengths	0	0	0
Unclass	6	Metric tons	259	300	559
		No. samples	1	3	4
		No. lengths	46	141	187
All	5	Metric tons	933	593	1526
		No. samples	12	12	24
		No. lengths	1159	990	2149
All	6	Metric tons	2174	1269	3443
		No. samples	6	17	23
		No. lengths	446	1355	1801
All	All	Metric tons	3107	1862	4969
		No. samples	18	29	47
		No. lengths	1605	2345	3950

Table A3. Summary distribution of 1995 NER commercial fishery landings and length samples.

Market category	1-digit area	Item	Quarters 1 & 2	Quarters 3 & 4	Total
Small	5	Metric tons	3	3	6
		No. samples	0	0	0
		No. lengths	0	0	0
Small	6	Metric tons	176	163	339
		No. samples	3	2	5
		No. lengths	194	100	294
Medium	5	Metric tons	380	236	616
		No. samples	9	0	9
		No. lengths	748	0	748
Medium	6	Metric tons	984	388	1372
		No. samples	4	3	7
		No. lengths	399	269	668
Large	5	Metric tons	321	354	675
		No. samples	3	0	3
		No. lengths	289	0	289
Large	6	Metric tons	760	365	1125
		No. samples	5	3	8
		No. lengths	439	239	678
Jumbo	5	Metric tons	86	88	174
		No. samples	0	0	0
		No. lengths	0	0	0
Jumbo	6	Metric tons	107	89	196
		No. samples	2	0	2
		No. lengths	187	0	187
Unclass	5	Metric tons	16	41	57
		No. samples	0	0	0
		No. lengths	0	0	0
Unclass	6	Metric tons	159	192	351
		No. samples	1	1	2
		No. lengths	62	56	118
All	5	Metric tons	806	722	1528
		No. samples	12	0	12
		No. lengths	1037	0	1037
All	6	Metric tons	2186	1197	3383
		No. samples	15	9	24
		No. lengths	1281	664	1945
All	All	Metric tons	2992	1919	4911
		No. samples	27	9	36
		No. lengths	2318	664	2982

Table A4. Summary distribution of 1996 NER commercial fishery landings and length samples.

Market category	1-digit area	Item	Quarters 1 & 2	Quarters 3 & 4	Total
Small	5	Metric tons	3	2	5
		No. samples	2	0	2
		No. lengths	105	0	105
Small	6	Metric tons	237	192	429
		No. samples	4	5	9
		No. lengths	231	250	481
Medium	5	Metric tons	332	140	472
		No. samples	4	3	7
		No. lengths	408	304	712
Medium	6	Metric tons	770	470	1240
		No. samples	6	7	13
		No. lengths	576	626	1202
Large	5	Metric tons	372	151	523
		No. samples	6	1	7
		No. lengths	338	100	438
Large	6	Metric tons	402	270	672
		No. samples	7	3	10
		No. lengths	576	300	876
Jumbo	5	Metric tons	138	62	200
		No. samples	4	2	6
		No. lengths	226	131	357
Jumbo	6	Metric tons	106	75	181
		No. samples	4	1	5
		No. lengths	232	100	332
Unclass	5	Metric tons	25	41	66
		No. samples	0	0	0
		No. lengths	0	0	0
Unclass	6	Metric tons	28	41	69
		No. samples	1	1	2
		No. lengths	32	45	77
All	5	Metric tons	870	396	1266
		No. samples	16	6	22
		No. lengths	1077	535	1612
All	6	Metric tons	1543	1048	2591
		No. samples	22	17	39
		No. lengths	1647	1321	2968
All	All	Metric tons	2413	1444	3857
		No. samples	38	23	61
		No. lengths	2724	1856	4580

Table A5. Commercial landings at age of summer flounder ('000), ME-VA. Does not include discards, assumes catch not sampled by NEFSC has same biological characteristics as port sampled catch.

	Age										
Year	0	1	2	3	4	5	6	7	8	9	Total
1982	1,441	6,879	5,630	232	61	97	57	22	2	0	14,421
1983	1,956	12,119	4,352	554	30	62	13	17	4	2	19,109
1984	1,403	10,706	6,734	1,618	575	72	3	5	1	4	21,121
1985	840	6,441	10,068	956	263	169	25	4	2	1	18,769
1986	407	7,041	6,374	2,215	158	93	29	7	2	0	16,326
1987	332	8,908	7,456	935	337	23	24	27	11	0	18,053
1988	305	11,116	8,992	1,280	327	79	18	9	5	0	22,131
1989	96	2,491	4,829	841	152	16	3	1	1	0	8,430
1990	0	2,670	861	459	81	18	6	1	1	0	4,096
1991	0	3,755	3,256	142	61	11	1	1	0	0	7,227
1992	114	5,760	3,575	338	19	22	0	1	0	0	9,829
1993	151	4,308	2,340	174	29	43	19	2	1	0	7,067
1994	119	3,698	3,692	272	64	12	6	0	5	0	7,868
1995	46	2,566	4,280	241	40	8	0	1	0	0	7,182
1996	0	1,401	3,187	798	156	15	3	0	1	0	5,559

Table A6. Number ('000) of summer flounder at age landed in the North Carolina commercial winter trawl fishery. The 1982-1987 NCDMF length samples were aged using NEFSC age-length keys for comparable times and areas (i.e., same quarter and statistical areas). The 1988-1996 NCDMF length samples were aged using NCDMF age-length keys.

	Age									
Year	0	1	2	3	4	5	6	7	8	Total
1982	981	3,463	1,021	142	52	19	6	4	2	5,691
1983	492	3,778	1,581	287	135	41	3	3	<1	6,321
1984	907	5,658	3,889	550	107	18	<1	0	0	11,130
1985	196	2,974	3,529	338	85	24	5	<1	0	7,152
1986	216	2,478	1,897	479	29	32	1	1	<1	5,134
1987	233	2,420	1,299	265	28	1	0	0	0	4,243
1988	0	2,917	2,225	471	227	39	1	6	<1	5,887
1989	2	49	1,437	716	185	37	1	2	0	2,429
1990	2	142	730	418	117	12	1	<1	0	1,424
1991	0	382	1,641	521	116	20	2	<1	0	2,682
1992	0	36	795	697	131	21	2	<1	0	1,682
1993	0	515	1,101	252	44	1	<1	0	0	1,913
1994	6	258	1,262	503	115	14	3	<1	0	2,161
1995	<1	181	1,391	859	331	53	2	<1	0	2,817
1996	0	580	2,187	554	132	56	13	<1	2	3,526

Table A7. Summary NER sea sampling data for trips catching summer flounder. Total trips (trips are not split for multiple areas), observed tows, catch, kept, and discard (lbs), and discard-to-kept ratio (%).

Year	Gear	Trips	Tows	Total catch	Total kept	Total discard	Discard: kept (%)
1989	All	57	413	53,714	48,406	5,308	11.0
1990	All	61	463	47,954	35,972	11,982	33.3
1991	All	82	635	61,650	50,410	11,240	22.3
1992	Trawl	66	643	136,632	118,026	18,606	15.8
	Scallop	8	178	1,477	767	710	92.6
	All	74	821	138,109	118,793	19,316	16.3
1993	Trawl	37	410	74,982	67,603	7,379	10.9
	Scallop	15	671	2,967	1,158	1,809	156.2
	All	52	1,081	77,949	68,761	9,188	13.4
1994	Trawl	51	574	174,347	163,734	10,612	6.5
	Scallop	14	651	5,811	435	5,376	1235.9
	All	65	1,225	180,158	164,169	15,988	9.7
1995	Trawl	134	1,004	242,784	235,011	7,773	3.3
	Scallop	19	1,051	10,044	2,247	7,778	346.2
	All	153	2,055	252,828	237,258	15,551	6.6
1996	Trawl	111	653	101,389	90,789	10,600	11.7
	Scallop	24	1,083	9,575	1,345	8,230	611.9
	All	135	1,736	110,964	92,134	18,830	20.4

Table A8. Summary NER Vessel Trip Report (VTR) data for trips reporting discard of any species and catching summer flounder. Total trips, catch, kept, and discard (lbs), and discard-to-kept ratio (%).

Year	Gear	Trips	Total catch	Total kept	Total discard	Discard: kept (%)
1994	Trawl	4,267	2,149,332	2,015,296	134,036	6.7
	Scallop	85	70,353	22,877	47,476	207.5
	All	4,352	2,219,685	2,038,173	181,512	8.9
1995	Trawl	3,733	2,444,231	2,332,516	111,715	4.8
	Scallop	113	78,758	25,084	53,674	214.0
	All	3,846	2,522,989	2,357,600	165,389	7.0
1996	Trawl	2,990	1,662,313	1,459,155	203,158	13.9
	Scallop	79	69,557	16,657	52,900	317.6
	All	3,069	1,731,870	1,475,812	256,058	17.4

Table A9. Summary of Northeast Region sea sampling data to estimate summer flounder discard at age in the commercial fishery. Estimates developed using sea sampling length samples, age-length data, and estimates of total discard in mt. An 80% discard mortality rate is assumed. Lengths for 1995-1996 converted to age using 1995-1996 NEFSC trawl survey ages. NA = not available.

Year	Gear	Lengths	Ages	Sea sampling discard estimate (mt)	Sampling intensity (mt per 100 lengths)	Raised discard estimate (mt)	Raised estimate with 80% mortality rate (mt)	SAW-22 raised estimate with 80% mortality rate (mt)
1989	All	2,337	54	642	27	886	709	709
1990	All	3,891	453	1,121	29	1,517	1,214	1,213
1991	All	5,326	190	993	19	1,315	1,052	1,052
1992	All	9,626	331	755	8	862	690	918
1993	All	3,410	406	817	24	1,057	846	650
1994	Trawl	2,338	-	429	18	542	434	NA
	Scallop	660	-	590	89	590	472	NA
	All	2,998	354	1,019	34	1,132	906	941
1995	Trawl	1,822	-	130	7	173	138	NA
	Scallop	731	-	212	29	212	170	NA
	All	2,553	NA	342	13	385	308	947
1996	Trawl	1,873	-	319	17	444	355	NA
	Scallop	854	-	135	16	135	108	NA
	All	2,727	NA	454	17	579	463	NA

Table A10. Estimated summer flounder discard at age, mean length at age, and mean weight at age in the commercial fishery.

Discard numbers at age (000s)

Year	Gear	0	1	2	3+	Total
1989	All	775	1,628	94	0	2,497
1990	All	1,441	2,755	67	0	4,263
1991	All	891	3,424	<1	0	4,315
1992	All	1,155	1,544	36	3	2,738
1993	All	1,041	1,532	179	1	2,753
1994	Trawl	571	1,014	95	0	1,680
	Scallop	0	663	398	36	1,098
	All	571	1,677	493	36	2,778
1995	Trawl	141	294	58	2	495
	Scallop	0	114	148	20	282
	All	141	408	206	22	777
1996	Trawl	23	417	167	56	663
	Scallop	<1	221	72	5	298
	All	23	638	239	61	961

Discard mean length at age

Year	Gear	0	1	2	3+	All
1989	All	25.9	31.5	44.2	-	30.2
1990	All	29.0	31.7	38.9	-	30.9
1991	All	24.0	30.9	37.0	-	29.5
1992	All	29.3	30.0	36.6	51.2	29.8
1993	All	30.0	32.5	34.8	55.0	31.7
1994	Trawl	26.0	31.3	34.5	-	29.7
	Scallop	-	30.8	38.2	52.1	34.2
	All	26.0	31.1	37.5	52.1	31.5
1995	Trawl	29.6	29.4	37.0	50.9	30.4
	Scallop	-	30.7	40.6	52.4	37.4
	All	29.6	29.8	39.6	52.5	33.0
1996	Trawl	28.9	32.0	38.1	55.8	35.5
	Scallop	31.4	30.7	38.2	48.5	32.8
	All	29.0	31.6	38.1	55.2	34.7

Discard mean weight at age

Year	Gear	0	1	2	3+	All
1989	All	0.182	0.296	0.909	-	0.284
1990	All	0.235	0.304	0.559	-	0.285
1991	All	0.124	0.275	0.491	-	0.244
1992	All	0.238	0.256	0.498	1.450	0.252
1993	All	0.253	0.332	0.413	-	0.307
1994	Trawl	0.177	0.291	0.392	-	0.258
	Scallop	-	0.287	0.565	1.565	0.430
	All	0.177	0.289	0.532	1.565	0.326
1995	Trawl	0.244	0.242	0.522	1.505	0.280
	Scallop	-	0.281	0.702	1.604	0.595
	All	0.244	0.253	0.651	1.597	0.395
1996	Trawl	0.226	0.312	0.586	2.004	0.521
	Scallop	0.305	0.274	0.572	1.254	0.363
	All	0.227	0.299	0.582	1.937	0.472

Table A11. Estimated total landings [catch types A + B1, (000s)] of summer flounder by recreational fishermen. Shore mode includes fish taken from beach/bank and man-made structures. P/C indicates catch taken from party/charter boats, while P/R indicates fish taken from private/rental boats.

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
North															
Shore	167	144	62	10	70	39	42	4	16	9	26	36	49	19	22
P/C boat	138	201	5	3	48	7	1	1	1	8	1	10	24	6	7
P/R boat	1,293	747	568	382	2,562	648	379	137	99	173	211	250	596	449	717
Total	1,598	1,092	635	395	2,680	694	422	142	116	190	238	296	669	474	746
Mid															
Shore	682	3,296	977	272	478	251	594	84	96	505	200	176	195	175	137
P/C boat	5,745	3,321	2,381	1,068	1,541	1,143	1,164	141	412	589	374	872	773	267	1,167
P/R boat	5,731	12,345	11,764	8,454	5,924	5,499	7,271	1,141	2,658	4,573	3,983	3,969	4,372	2,312	4,999
Total	12,158	18,962	15,122	9,794	7,943	6,893	9,029	1,366	3,166	5,667	4,557	5,017	5,340	2,754	6,303
South															
Shore	272	523	316	504	689	115	306	91	150	51	50	113	180	48	46
P/C boat	53	52	110	81	20	1	1	1	1	1	1	1	2	1	5
P/R boat	1,392	367	1,292	292	289	162	355	117	361	159	156	236	197	100	274
Total	1,717	942	1,718	877	998	278	662	209	512	211	207	350	379	149	325
All															
Shore	1,121	3,963	1,355	786	1,237	405	942	179	262	565	276	325	424	242	205
P/C boat	5,936	3,574	2,496	1,152	1,609	1,151	1,166	143	414	598	376	883	799	274	1,179
P/R boat	8,416	13,459	13,624	9,128	8,775	6,309	8,005	1,395	3,118	4,905	4,350	4,455	5,165	2,861	5,990
Total	15,473	20,996	17,475	11,066	11,621	7,865	10,113	1,717	3,794	6,068	5,002	5,663	6,388	3,377	7,374

Table A12. Estimated total landings [catch types A + B1, (mt)] of summer flounder by recreational fishermen. Shore mode includes fish taken from beach/bank and man-made structures. P/C indicates catch taken from party/charter boats, while P/R indicates fish taken from private/rental boats.

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
North															
Shore	87	59	17	7	25	21	32	2	16	6	20	25	30	14	15
P/C boat	85	87	4	2	45	4	<1	<1	<1	6	<1	7	14	5	13
P/R boat	875	454	388	328	2,597	582	289	141	89	150	175	181	424	371	531
Total	1,047	600	409	337	2,667	607	322	144	106	162	196	213	468	390	559
Mid															
Shore	295	1,254	399	140	293	129	329	52	56	306	126	88	112	108	80
P/C boat	3,112	2,196	1,426	609	1,093	1,098	799	125	264	364	267	534	478	185	746
P/R boat	3,085	8,389	5,686	4,187	3,521	3,596	5,003	985	1,665	2,673	2,536	2,453	2,849	1,699	3,155
Total	6,492	11,839	7,511	4,936	4,907	4,823	6,131	1,162	1,985	3,343	2,929	3,075	3,439	1,992	3,981
South															
Shore	87	134	98	230	425	34	113	57	76	25	25	59	100	29	24
P/C boat	12	12	23	20	7	1	<1	<1	<1	<1	<1	<1	1	<1	2
P/R boat	629	102	471	142	96	54	166	71	161	80	91	136	103	84	138
Total	728	248	592	392	528	89	280	129	238	106	117	196	204	114	164
All															
Shore	469	1,447	514	377	743	184	474	111	148	337	171	172	242	151	119
P/C boat	3,209	2,295	1,453	631	1,145	1,103	801	127	266	371	269	542	493	191	761
P/R boat	4,589	8,945	6,545	4,657	6,214	4,232	5,458	1,197	1,915	2,903	2,802	2,770	3,376	2,154	3,824
Total	8,267	12,687	8,512	5,665	8,102	5,519	6,733	1,435	2,329	3,611	3,242	3,484	4,111	2,496	4,704

Table A13. Estimated recreational landings at age of summer flounder (000s), (catch type A + B1).

	Age									
Year	0	1	2	3	4	5	6	7	8	Total
1982	2,750	8,445	3,498	561	215	<1	4	0	0	15,473
1983	2,302	11,612	4,978	1,340	528	220	0	16	0	20,996
1984	2,282	9,198	4,831	1,012	147	5	<1	0	0	17,745
1985	1,002	5,002	4,382	473	148	59	0	0	0	11,066
1986	1,169	6,404	2,784	1,088	129	15	28	0	0	11,621
1987	466	4,674	2,083	448	182	1	5	0	0	7,865
1988	434	5,855	3,345	386	90	3	0	0	0	10,113
1989	74	539	946	135	16	2	5	0	0	1,717
1990	353	2,770	529	118	23	<1	1	0	0	3,794
1991	86	3,611	2,251	79	40	1	0	0	0	6,068
1992	82	3,183	1,620	90	<1	27	0	0	0	5,002
1993	71	3,470	1,981	139	<1	2	0	0	0	5,663
1994	765	3,872	1,549	171	26	<1	5	0	0	6,388
1995	235	1,557	1,426	117	26	16	<1	0	0	3,377
1996	115	3,093	3,664	372	129	1	0	0	0	7,374

Table A14. Estimated recreational fishery discard at age of summer flounder, (catch type B2). Discards allocated to age groups in same relative proportions as ages 0 and 1 in the subregional catch, the same mean weight at age as in the landings, and assuming 25% hooking mortality.

	Numbers at age			Metric tons at age		
Year	0	1	Total	0	1	Total
1982	431	1,591	2,022	97	643	740
1983	437	2,329	2,766	77	862	939
1984	526	2,551	3,077	108	929	1,037
1985	101	514	615	24	205	229
1986	375	3,043	3,418	84	1,360	1,444
1987	265	3,024	3,289	61	1,246	1,307
1988	139	1,673	1,812	41	816	857
1989	32	208	240	8	106	114
1990	151	1,176	1,327	46	541	587
1991	59	2,443	2,502	16	1,058	1,074
1992	43	1,684	1,727	10	849	859
1993	55	3,525	3,580	14	1,826	1,840
1994	443	2,143	2,586	193	1,249	1,442
1995	425	2,790	3,215	181	1,604	1,785
1996	60	3,032	3,092	21	1,613	1,634

Table A15. Total catch at age of summer flounder (000s), ME-NC. Total catch estimates for 1992-1995 revised since the SAW-22 assessment are listed at the bottom for comparison.

	Age										
Year	0	1	2	3	4	5	6	7	8	9	Total
1982	5,604	20,378	10,149	935	328	116	67	26	4	0	37,607
1983	5,187	29,838	10,911	2,181	693	323	16	36	5	2	49,193
1984	5,118	28,113	15,454	3,180	829	95	4	5	1	4	52,803
1985	2,139	14,931	17,979	1,767	496	252	30	5	2	1	37,602
1986	2,167	18,966	11,055	3,782	316	140	58	12	3	0	36,498
1987	1,296	19,026	10,838	1,648	544	25	29	33	11	0	33,450
1988	878	21,561	14,562	2,137	644	121	19	15	6	0	39,943
1989	979	4,915	7,306	1,692	353	55	9	3	1	0	15,313
1990	1,947	9,514	2,187	995	221	30	8	2	1	0	14,905
1991	1,036	13,615	7,148	742	217	32	3	1	0	0	22,795
1992	1,394	12,207	6,026	1,125	151	70	2	1	0	0	20,975
1993	1,318	13,350	5,601	566	73	45	20	2	1	0	20,976
1994	1,904	11,648	6,996	982	205	26	14	0	5	0	21,780
1995	847	7,502	7,303	1,239	397	77	2	1	0	0	17,369
1996	198	8,744	9,278	1,785	417	71	16	1	3	0	20,512
SAW-22											
1992	2,205	12,269	6,047	1,125	151	70	2	1	0	0	21,869
1993	1,473	12,732	5,523	565	73	45	20	2	1	0	23,435
1994	2,645	12,283	6,431	925	207	25	13	0	5	0	22,534
1995	2,719	10,375	5,276	1,125	402	75	3	0	2	0	19,977

Table A16. Mean length (cm) at age of summer flounder catch, ME-NC.

Year	Age 0	1	2	3	4	5	6	7	8	9	All
1982	29.4	34.5	38.8	50.7	55.3	61.0	60.7	68.0	71.2	-	35.7
1983	28.7	34.5	40.9	46.5	48.8	51.6	60.7	60.9	69.3	72.0	36.2
1984	29.3	33.8	39.1	45.9	51.3	57.9	66.8	68.4	74.0	70.7	36.0
1985	30.5	34.8	38.8	46.8	53.9	58.6	61.5	74.5	73.3	75.0	37.5
1986	29.6	35.6	39.9	47.5	54.0	56.2	65.8	66.4	72.8	-	38.1
1987	29.8	35.3	39.7	46.9	55.8	63.3	65.9	63.2	73.5	-	37.5
1988	32.3	35.8	39.1	46.6	53.1	60.2	69.6	68.5	72.7	-	37.9
1989	27.1	35.8	40.8	45.5	50.6	58.5	59.1	63.1	59.0	-	39.1
1990	29.7	35.2	41.9	46.8	51.4	57.4	66.4	71.7	75.2	-	36.5
1991	25.0	34.6	40.4	47.1	54.3	61.0	61.7	68.1	-	-	36.6
1992	29.6	36.1	41.2	46.9	49.7	61.0	58.8	72.2	-	-	37.9
1993	30.3	36.7	40.6	50.4	52.9	54.7	62.6	70.6	75.5	-	37.9
1994	32.7	37.3	39.3	49.6	57.3	63.4	66.3	-	68.5	-	38.3
1995	34.2	37.5	39.9	44.9	52.4	62.2	70.5	71.9	-	-	39.3
1996	32.7	37.2	38.3	45.7	51.3	54.4	58.5	63.0	66.0	-	38.7

Table A17. Mean weight (kg) at age of summer flounder catch, ME-NC.

Year	Age 0	1	2	3	4	5	6	7	8	9	All
1982	0.254	0.418	0.616	1.447	1.907	2.795	2.673	3.758	4.408	4.370	[illegible]
1983	0.240	0.417	0.716	1.075	1.257	1.495	2.572	2.594	3.849	4.030	[illegible]
1984	0.248	0.396	0.632	1.046	1.500	2.163	3.302	3.620	4.640	4.800	0.512
1985	0.289	0.428	0.613	1.109	1.726	2.297	2.671	4.682	4.780	-	0.573
1986	0.253	0.453	0.668	1.160	1.739	1.994	3.311	4.000	4.432	-	0.602
1987	0.259	0.442	0.651	1.140	1.941	2.855	3.326	3.314	4.140	-	0.570
1988	0.316	0.463	0.624	1.130	1.739	2.485	3.888	3.545	4.316	-	0.584
1989	0.208	0.460	0.723	1.044	1.479	2.249	2.399	2.861	2.251	-	0.666
1990	0.252	0.431	0.810	1.169	1.538	2.121	3.461	3.951	5.029	-	0.535
1991	0.145	0.407	0.702	1.186	1.811	2.527	2.837	3.586	-	-	0.530
1992	0.245	0.470	0.749	1.222	1.390	2.696	2.302	4.479	-	-	0.590
1993	0.264	0.486	0.699	1.461	1.659	1.859	2.816	4.136	5.199	-	0.565
1994	0.355	0.528	0.628	1.353	2.096	2.736	3.437	-	3.703	-	0.602
1995	0.390	0.537	0.678	1.056	1.639	2.628	3.750	4.047	-	-	0.661
1996	0.330	0.510	0.570	1.080	1.545	1.957	2.546	3.200	3.164	-	0.613

Table A18. NEFSC spring trawl survey (offshore strata 1-12, 61-76) stratified mean number of summer flounder per tow at age. Values for 1995 and 1996 revised since the SAW-22 assessment are listed at the bottom. Indices for 1997 are preliminary and use the 1997 age-length key.

	Age										
Year	1	2	3	4	5	6	7	8	9	10	All
1976	0.03	1.70	0.68	0.28	0.01	0.01	0.01	-	-	-	2.72
1977	0.61	1.30	0.70	0.10	0.09	0.01	-	0.01	-	-	2.82
1978	0.70	0.95	0.66	0.19	0.04	0.03	0.03	-	-	0.02	2.62
1979	0.06	0.18	0.08	0.04	0.03	-	-	0.01	-	-	0.40
1980	0.01	0.71	0.31	0.14	0.02	0.06	0.03	0.02	-	0.01	1.31
1981	0.59	0.53	0.17	0.08	0.05	0.03	0.02	0.01	-	-	1.48
1982	0.69	1.41	0.12	0.02	-	-	-	-	-	-	2.24
1983	0.32	0.39	0.19	0.03	0.01	-	-	-	0.01	-	0.95
1984	0.17	0.33	0.09	0.05	-	0.01	0.01	-	-	-	0.66
1985	0.55	1.56	0.21	0.04	0.02	-	-	-	-	-	2.38
1986	1.49	0.43	0.20	0.02	0.01	-	-	-	-	-	2.15
1987	0.46	0.43	0.02	0.01		-	-	-	-	-	0.92
1988	0.59	0.79	0.07	0.02	-	-	-	-	-	-	1.47
1989	0.06	0.23	0.02	0.01	-	-	-	-	-	-	0.32
1990	0.62	0.03	0.06	-	-	-	-	-	-	-	0.71
1991	0.79	0.27	-	0.02	-	-	-	-	-	-	1.08
1992	0.76	0.41	0.01	-	0.01	-	-	-	-	-	1.19
1993	0.73	0.50	0.04	-	-	-	-	-	-	-	1.27
1994	0.35	0.53	0.04	0.01	-	-	-	-	-	-	0.93
1995	0.79	0.27	0.02	-	-	-	0.01	-	-	-	1.09
1996	1.08	0.56	0.12	-	-	-	-	-	-	-	1.76
1997	0.04	0.58	0.32	0.12	-	-	-	-	-	-	1.06
SAW-22											
1995	0.85	0.23	-	-	-	-	0.01	-	-	-	1.09
1996	0.66	1.16	0.10	0.03	-	-	-	-	-	-	1.95

Table A19. NEFSC fall trawl survey (inshore strata 1-61, offshore strata ≤55 m (1, 5, 9, 61, 65, 69, 73) mean number of summer flounder per tow at age.

	Age						
Year	0	1	2	3	4	5+	All
1982	0.55	1.52	0.40	0.03	-	-	2.50
1983	0.96	1.46	0.34	0.12	0.01	0.01	2.90
1984	0.18	1.39	0.43	0.07	0.01	0.01	2.09
1985	0.59	0.80	0.46	0.05	-	0.02	1.92
1986	0.39	0.83	0.11	0.11	-	-	1.44
1987	0.07	0.58	0.20	0.03	0.02	-	0.90
1988	0.06	0.62	0.18	0.03	-	-	0.89
1989	0.31	0.21	0.05	-	-	-	0.57
1990	0.44	0.38	0.03	0.04	-	-	0.89
1991	0.76	0.84	0.09	-	0.01	-	1.70
1992	0.99	1.04	0.25	0.03	0.01	-	2.32
1993	0.23	0.80	0.03	0.01	-	-	1.07
1994	0.75	0.67	0.09	0.01	0.01	-	1.53
1995	0.93	1.16	0.28	0.02	0.01	-	2.40
1996	0.11	1.24	0.57	0.04	-	-	1.96

Table A20. NEFSC Winter trawl survey (offshore strata from 27-185 meters (15-100 fathoms): 1-3, 5-7, 9-11, 13-14, 61-63, 65-67, 69-71, 73-75; Southern Georges Bank to Cape Hatteras), mean number, mean weight (kg), and mean number at age per tow.

Year	Stratified mean number per tow	Coefficient of variation	Stratified mean weight (kg) per tow	Coefficient of variation
1992	12.295	15.6	4.898	15.4
1993	13.604	15.2	5.497	11.9
1994	12.051	17.8	6.033	16.1
1995	10.930	12.0	4.808	11.6
1996	31.246	24.2	12.351	22.0
1997	9.990	24.0	5.386	16.6

	Age								
Year	1	2	3	4	5	6	7	8	Total
1992	7.15	4.74	0.33	0.04	0.01	0.03	0.00	0.00	12.29
1993	6.50	6.70	0.31	0.05	0.02	0.02	0.00	0.00	13.60
1994	3.42	6.95	1.22	0.27	0.15	0.03	0.01	0.00	11.92
1995	6.07	4.59	0.25	0.02	0.00	0.02	0.00	0.00	10.93
1996	22.17	8.33	0.60	0.12	0.03	0.00	0.00	0.00	31.25
1997	3.75	4.67	1.00	0.42	0.11	0.04	0.00	0.00	9.99
SAW-22									
1995	7.70	3.01	0.08	0.01	0.00	0.00	0.00	0.00	10.80
1996	24.60	6.35	0.40	0.11	0.01	0.00	0.00	0.00	31.46

Table A21. RIDFW fall trawl survey summer flounder index of abundance.

Year	Mean number/tow	Mean kg/tow	Mean age 0 number/tow[1]	Mean age 1 number/tow[2]	Mean age 2+ number/tow
1979	0.00	0.00	0.00	0.00	0.00
1980	0.81	1.37	0.08	0.25	0.48
1981	3.24	2.13	0.16	2.10	0.97
1982	0.83	0.68	0.00	0.36	0.47
1983	0.62	0.57	0.02	0.25	0.35
1984	1.35	0.95	0.16	0.85	0.34
1985	0.95	0.52	0.33	0.33	0.29
1986	3.49	2.05	0.63	2.20	0.66
1987	1.41	0.90	0.44	0.72	0.25
1988	0.57	0.42	0.02	0.41	0.15
1989	0.07	0.10	0.00	0.04	0.03
1990	0.83	0.54	0.06	0.47	0.30
1991	0.23	0.23	0.04	0.07	0.12
1992	1.37	1.20	0.00	0.77	0.60
1993	0.74	0.84	0.00	0.21	0.53
1994	0.19	0.15	0.00	0.12	0.07
1995	0.76	0.76	0.00	0.29	0.48
1996	2.09	1.44	0.09	1.00	1.00

[1]Proportion of catch < 30 cm
[2]Proportion of 30 cm $\leq$ catch < 40 cm

Table A22. MADMF spring survey cruises: stratified mean number per tow at age.

Year	Age									
	0	1	2	3	4	5	6	7	8+	Total
1978	-	0.097	0.520	0.274	0.221	-	0.042	-	-	1.154
1979	-	-	0.084	0.087	0.147	0.048	0.011	-	-	0.377
1980	-	0.055	0.061	0.052	0.075	0.053	0.055	0.011	-	0.362
1981	-	0.405	0.558	0.074	0.031	0.043	0.060	-	0.031	1.202
1982	-	0.376	1.424	0.118	0.084	0.020	-	0.010	-	2.032
1983	-	0.241	1.304	0.544	0.021	0.009	0.003	-	-	2.122
1984	-	0.042	0.073	0.063	0.111	0.010	-	-	-	0.299
1985	-	0.142	1.191	0.034	0.042	-	-	-	-	1.409
1986	-	0.966	0.528	0.140	0.008	-	-	-	-	1.642
1987	-	0.615	0.583	0.012	-	-	0.011	-	-	1.221
1988	-	0.153	0.966	0.109	0.012	-	-	-	-	1.240
1989	-	-	0.338	0.079	-	-	0.010	-	-	0.427
1990	-	0.247	0.021	0.079	0.012	-	-	-	-	0.359
1991	-	0.029	0.048	0.010	-	-	-	-	-	0.087
1992	-	0.274	0.320	0.080	-	0.011	0.011	-	-	0.696
1993	-	0.120	0.470	0.060	0.010	-	0.020	-	-	0.680
1994	-	1.770	1.160	0.050	0.020	-	0.020	-	-	3.020
SAW-22 95		0.450	0.890	0.040	-	-	-	-	-	1.380
1995	-	0.089	1.245	0.050	-	-	-	-	-	1.384
1996	-	0.072	0.641	0.110	0.012	-	-	-	-	0.835

Table A23. MADMF fall survey cruises: stratified mean number per tow at age.

Year	Age								
	0	1	2	3	4	5	6	7	8+	Total
1978	-	0.011	0.124	0.024	-	0.007	-	-	-	0.166
1979	-	-	0.047	0.101	-	0.019	-	-	-	0.167
1980	-	0.114	0.326	0.020	0.020	0.010	-	-	-	0.490
1981	0.009	0.362	0.367	0.011	-	-	-	-	-	0.749
1982	-	0.255	1.741	0.016	-	-	-	-	-	2.012
1983	-	0.026	0.583	0.140	0.004	-	-	-	-	0.753
1984	0.033	0.453	0.249	0.120	0.008	-	-	-	-	0.863
1985	0.051	0.108	1.662	0.033	-	-	-	-	-	1.854
1986	0.128	2.149	0.488	0.128	-	-	-	-	-	2.893
1987	-	1.159	0.598	0.010	0.004	-	-	-	-	1.771
1988	-	0.441	0.414	0.018	-	-	-	-	-	0.873
1989	-	-	0.286	0.024	-	-	-	-	-	0.310
1990	-	0.108	-	0.012	-	-	-	-	-	0.120
1991	0.021	0.493	0.262	0.010	-	-	-	-	-	0.786
1992	-	1.110	0.170	-	-	-	-	-	-	1.280
1993	0.010	0.300	0.430	0.020	0.020	-	-	-	-	0.780
1994	0.050	2.130	0.070	-	-	-	-	-	-	2.250
SAW-22 95	0.032	0.401	0.323	0.013	-	-	-	-	-	0.769
1995	0.011	0.316	0.445	-	-	-	-	-	-	0.772
1996	-	0.717	1.196	0.101	0.004	-	--		-	2.018

Table A24. CTDEP spring trawl survey: summer flounder index of abundance, geometric mean number per tow at age.

Year	Age								
	0	1	2	3	4	5	6	7	Total
1984	0.000	0.314	0.271	0.044	0.000	0.000	0.000	0.000	0.63
1985	0.000	0.015	0.282	0.028	0.052	0.000	0.000	0.000	0.38
1986	0.000	0.751	0.090	0.074	0.008	0.005	0.000	0.000	0.93
1987	0.000	0.951	0.086	0.014	0.004	0.001	0.000	0.001	1.06
1988	0.000	0.232	0.223	0.035	0.009	0.001	0.000	0.000	0.50
1989	0.000	0.013	0.049	0.024	0.016	0.000	0.000	0.000	0.10
1990	0.000	0.304	0.022	0.013	0.006	0.001	0.000	0.001	0.35
1991	0.000	0.392	0.189	0.029	0.028	0.001	0.000	0.000	0.64
1992	0.000	0.319	0.188	0.021	0.004	0.023	0.000	0.000	0.56
1993	0.000	0.320	0.151	0.015	0.018	0.003	0.000	0.001	0.51
1994	0.000	0.496	0.314	0.025	0.018	0.005	0.000	0.002	0.86
SAW-22 95	0.000	0.231	0.029	0.014	0.000	0.000	0.000	0.006	0.28
1995	0.000	0.199	0.051	0.020	0.005	0.000	0.000	0.006	0.28
1996	0.000	0.578	0.266	0.086	0.023	0.004	0.000	0.004	0.96

Table A25. CTDEP fall trawl survey: summer flounder index of abundance, geometric mean number per tow at age.

Year	Age								
	0	1	2	3	4	5	6	7	Total
1984	0.000	0.571	0.331	0.072	0.014	0.004	0.004	0.003	1.00
1985	0.238	0.351	0.485	0.078	0.000	0.008	0.000	0.000	1.16
1986	0.170	1.170	0.268	0.068	0.004	0.000	0.000	0.000	1.68
1987	0.075	1.067	0.223	0.033	0.003	0.000	0.000	0.000	1.40
1988	0.015	0.884	0.481	0.037	0.002	0.001	0.000	0.000	1.42
1989	0.000	0.029	0.095	0.015	0.001	0.000	0.000	0.000	0.14
1990	0.032	0.674	0.110	0.042	0.007	0.005	0.000	0.000	0.87
1991	0.036	0.826	0.340	0.036	0.013	0.005	0.004	0.000	1.26
1992	0.013	0.570	0.366	0.046	0.016	0.009	0.000	0.000	1.02
1993	0.084	0.827	0.152	0.039	0.003	0.001	0.002	0.001	1.11
1994	0.132	0.300	0.085	0.024	0.009	0.000	0.000	0.000	0.55
SAW-22 95	0.149	0.312	0.058	0.018	0.002	0.001	0.000	0.000	0.54
1995	0.023	0.384	0.117	0.012	0.002	0.001	0.000	0.002	0.54
1996	0.069	0.887	1.188	0.042	0.005	0.000	0.000	0.000	2.19

Table A26. NJBMF trawl survey, April - October: index of summer flounder abundance.

Year	Age					
	0	1	2	3	4+	Total
1988	0.29	4.22	1.19	0.01	0.00	5.71
1989	1.25	0.54	0.40	0.01	0.01	2.21
1990	1.88	1.89	0.15	0.05	0.00	3.97
1991	1.50	3.11	0.32	0.02	0.01	4.96
1992	1.34	3.76	0.76	0.08	0.05	5.99
1993	3.52	6.95	0.27	0.04	0.02	10.80
1994	2.22	1.46	0.13	0.01	0.03	3.85
1995	4.95	2.93	0.28	0.05	0.16	8.37
1996	1.65	5.16	2.71	0.18	0.05	9.75

Table A27. Summary of age 0 summer flounder recruitment indices from NEFSC and state surveys, Massachusetts to North Carolina.

	Year class																
Survey	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
CT fall	-	-	-	-	-	0.24	0.17	0.08	0.02	-	0.03	0.04	0.01	0.08	0.13	0.15	0.08
RI trawl	0.08	0.16	-	0.02	0.16	0.33	0.63	0.44	0.02	-	0.06	0.04	-	-	-	-	0.09
MA seine	-	-	3	3	1	19	5	5	2	3	11	4	-	2	1	13	7
NJ trawl	-	-	-	-	-	-	-	-	0.29	1.25	1.88	1.50	1.34	3.52	2.22	4.95	1.65
DE: 16 ft trawl	0.12	0.06	0.11	0.03	0.08	0.06	0.10	0.14	0.01	0.12	0.23	0.07	0.31	0.03	0.29	0.17	0.03
DE: 30 ft trawl	-	-	-	-	-	-	-	-	-	-	-	1.44	0.47	0.04	2.03	0.95	0.46
MD	4.2	3.9	2	10.6	5.4	5.6	16.2	4.6	0.5	1.3	2.1	3.1	3.5	1.6	8.2	5	2.6
VIMS rivers only	7.64	5.29	3.22	5.21	1.90	0.92	1.17	0.45	0.54	0.96	2.61	1.42	0.49	0.49	1.08	0.74	0.62
VIMS rivers and bay	-	-	-	-	-	-	-	-	0.53	1.23	2.54	2.78	0.91	0.53	2.50	0.72	0.86
NC Pamlico trawl	-	-	-	-	-	-	-	19.86	2.61	6.63	4.27	5.85	9.41	5.13	8.17	5.59	30.88
NEFSC fall trawl	-	-	0.55	0.96	0.18	0.59	0.39	0.07	0.06	0.31	0.44	0.76	0.99	0.23	0.75	0.93	0.11

Table A28. SAW-25 VPA summary results for summer flounder.

CATCH AT AGE (thousands)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
0	5604	5187	5118	2139	2167	1296	878	979	1947	1036	1394	1318	1904	847	198
1	20378	29838	28113	14931	18966	19026	21561	4915	9514	13615	12207	13350	11648	7502	8744
2	10149	10911	15454	17979	11055	10838	14562	7306	2187	7148	6026	5601	6996	7303	9278
3	935	2181	3180	1767	3782	1648	2137	1692	995	742	1125	566	982	1239	1785
4	328	693	829	496	316	544	644	353	221	217	151	73	205	397	417
5	213	382	109	290	213	98	161	68	41	36	73	68	44	81	91
0+	37607	49192	52803	37602	36499	33450	39943	15313	14905	22794	20976	20976	21779	17369	20513

STOCK NUMBERS (Jan 1) in thousands

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
0	76468	82679	49173	51168	56273	45218	13127	28219	32296	30232	35228	34366	40696	46565	23361	0
1	43770	57536	62998	35628	39957	44112	35849	9953	22218	24680	23814	27581	26944	31596	37358	18948
2	15736	17397	20108	26141	15660	15553	18900	9841	3701	9582	7887	8452	10501	11520	19081	22674
3	2370	3701	4371	2480	5134	2818	2927	2298	1447	1052	1377	1005	1852	2268	2824	7227
4	525	1094	1056	701	431	781	816	463	350	284	190	109	311	628	735	697
5	334	591	134	400	283	137	197	86	64	46	89	100	65	125	158	273
0+	139204	162997	137841	116517	117738	108620	71816	50860	60076	65875	68584	71612	80369	92702	83517	49818

Summaries for ages 2-5

1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
18965	22783	25670	29722	21508	19290	22841	12689	5562	10963	9542	9666	12729	14541	22797	30871

FISHING MORTALITY

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
0	0.08	0.07	0.12	0.05	0.04	0.03	0.08	0.04	0.07	0.04	0.04	0.04	0.05	0.02	0.01
1	0.72	0.85	0.68	0.62	0.74	0.65	1.09	0.79	0.64	0.94	0.84	0.77	0.65	0.30	0.30
2	1.25	1.18	1.89	1.43	1.51	1.47	1.91	1.72	1.06	1.74	1.86	1.32	1.33	1.21	0.77
3	0.57	1.05	1.63	1.55	1.68	1.04	1.64	1.68	1.43	1.51	2.33	0.97	0.88	0.93	1.20
4	1.17	1.20	2.02	1.52	1.66	1.47	2.06	1.85	1.19	1.86	2.12	1.34	1.31	1.20	0.99
5	1.17	1.20	2.02	1.52	1.66	1.47	2.06	1.85	1.19	1.86	2.12	1.34	1.31	1.20	0.99

Avg F for ages 2-4,u

1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1.00	1.14	1.85	1.50	1.62	1.33	1.87	1.75	1.23	1.70	2.10	1.21	1.17	1.11	0.99

BACKCALCULATED PARTIAL RECRUITMENT

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
0	0.07	0.06	0.06	0.03	0.03	0.02	0.04	0.02	0.05	0.02	0.02	0.03	0.04	0.02	0.01
1	0.58	0.71	0.34	0.40	0.44	0.44	0.53	0.43	0.45	0.51	0.36	0.57	0.49	0.25	0.25
2	1.00	0.98	0.94	0.92	0.90	1.00	0.93	0.93	0.74	0.94	0.80	0.99	1.00	1.00	0.64
3	0.46	0.88	0.81	1.00	1.00	0.71	0.80	0.91	1.00	0.81	1.00	0.73	0.66	0.77	1.00
4	0.94	1.00	1.00	0.98	0.99	1.00	1.00	1.00	0.84	1.00	0.91	1.00	0.98	0.99	0.82
5	0.94	1.00	1.00	0.98	0.99	1.00	1.00	1.00	0.84	1.00	0.91	1.00	0.98	0.99	0.82

SSB AT THE START OF THE SPAWNING SEASON - males & females (mt)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
0	5829	6017	3547	4576	4420	3670	1253	1829	2474	1366	2677	2817	4450	5748	2462
1	6125	7219	8655	5550	5955	6947	4087	1450	3430	2806	3411	4330	5060	8038	9064
2	2624	3562	2013	3735	2268	2278	1846	1304	949	1210	961	1508	1663	2188	4373
3	1806	1405	1001	644	1248	1149	716	504	438	301	206	554	1021	941	955
4	321	429	251	290	160	380	218	125	169	93	38	51	186	322	425
5	311	307	50	230	151	114	86	36	50	21	35	60	57	105	124
0+	17015	18939	15518	15026	14203	14538	8206	5248	7512	5798	7328	9321	12437	17342	17402
2+	5062	5703	3315	4899	3827	3921	2866	1969	1606	1625	1240	2173	2927	3556	5877

Table A29. Commercial and recreational fishery landings, estimated discard, and total catch statistics (metric tons) as used in the assessment of summer flounder, Maine to North Carolina, compared with VPA estimates of total catch biomass.

	Commercial			Recreational			Total				
Year	Landings	Discard	Catch	Landings	Discard	Catch	Landings	Discard	Catch	VPA catch	VPA:Catch ratio
1982	10,400	NA	10,400	8,267	740	9,007	18,667	740	19,407	19,077	0.983
1983	13,403	NA	13,403	12,687	939	13,626	26,090	939	27,029	25,788	0.954
1984	17,130	NA	17,130	8,512	1,037	9,549	25,642	1,037	26,679	27,590	1.034
1985	14,675	NA	14,675	5,665	229	5,894	20,340	229	20,569	21,970	1.068
1986	12,186	NA	12,186	8,102	1,444	9,546	20,288	1,444	21,732	22,449	1.033
1987	12,271	NA	12,271	5,519	1,307	6,826	17,790	1,307	19,097	19,406	1.016
1988	14,686	NA	14,686	6,733	857	7,590	21,419	857	22,276	23,928	1.074
1989	8,125	709	8,834	1,435	114	1,549	9,560	823	10,383	10,446	1.006
1990	4,199	1,214	5,413	2,329	587	2,916	6,528	1,801	8,329	8,091	0.971
1991	6,224	1,052	7,276	3,611	1,074	4,685	9,835	2,126	11,961	12,354	1.033
1992	7,529	690	8,219	3,242	859	4,101	10,771	1,549	12,320	12,665	1.028
1993	5,715	846	6,561	3,484	1,840	5,324	9,199	2,686	11,885	12,048	1.014
1994	6,588	906	7,494	4,111	1,442	5,553	10,699	2,348	13,047	13,325	1.021
1995	6,977	308	7,285	2,496	1,785	4,281	9,473	2,093	11,566	11,656	1.008
1996	5,770	463	6,233	4,704	1,634	6,338	10,474	2,097	12,571	12,735	1.013
Mean 1982-96	9,725	774	10,138	5,393	1,059	6,452	15,118	1,472	16,590	16,902	1.017

Table A30. SAW-25 VPA retrospective analysis.

Fishing Mortality

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1990	1.0	1.2	1.9	1.5	1.6	1.4	1.9	1.7	1.2						
1991	1.0	1.2	1.9	1.5	1.6	1.4	1.9	1.8	1.2	1.4					
1992	1.0	1.2	1.9	1.5	1.6	1.4	1.9	1.8	1.2	1.4	1.0				
1993	1.0	1.2	1.9	1.5	1.6	1.4	1.9	1.8	1.2	1.7	1.9	0.9			
1994	1.0	1.2	1.9	1.5	1.6	1.4	1.9	1.8	1.2	1.8	2.2	1.4	1.7		
1995	1.0	1.2	1.9	1.5	1.6	1.4	1.9	1.8	1.2	1.7	2.1	1.3	1.4	1.6	
1996	1.0	1.2	1.9	1.5	1.6	1.4	1.9	1.8	1.2	1.7	2.1	1.2	1.2	1.1	1.0

Spawning Stock Biomass ('000 mt)

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1990	17.0	18.9	15.5	15.0	14.2	14.6	8.3	5.3	8.4						
1991	17.0	18.9	15.5	15.0	14.2	14.6	8.3	5.4	8.5	8.8					
1992	17.0	18.9	15.5	15.0	14.2	14.6	8.2	5.4	8.1	7.5	12.6				
1993	17.0	18.9	15.5	15.0	14.2	14.5	8.2	5.3	7.6	6.0	8.1	10.6			
1994	17.0	18.9	15.5	15.0	14.2	14.5	8.2	5.2	7.5	5.7	6.9	7.9	10.0		
1995	17.0	18.9	15.5	15.0	14.2	14.5	8.2	5.2	7.5	5.8	7.2	8.9	12.1	18.2	
1996	17.0	18.9	15.5	15.0	14.2	14.5	8.2	5.2	7.5	5.8	7.3	9.3	12.4	17.3	17.4

Age 0 Recruitment (N, millions)

Terminal Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
1990	76.5	82.7	49.2	51.2	56.3	45.7	12.3	28.5	43.1	41.7					
1991	76.5	82.7	49.2	51.2	56.3	45.2	13.3	29.2	40.3	47.1	34.2				
1992	76.5	82.7	49.2	51.2	56.3	45.2	13.3	29.4	35.0	41.7	40.7	33.2			
1993	76.5	82.7	49.2	51.2	56.3	45.2	13.1	28.3	32.7	31.0	39.6	28.0	61.3		
1994	76.5	82.7	49.2	51.2	56.3	45.2	13.1	28.2	32.2	29.4	33.1	28.7	53.6	42.5	
1995	76.5	82.7	49.2	51.2	56.3	45.2	13.1	28.2	32.2	30.1	34.1	33.8	44.2	53.8	34.9
1996	76.5	82.7	49.2	51.2	56.3	45.2	13.1	28.2	32.3	30.2	35.2	34.4	40.7	46.6	23.4

Table A31. SAW-25 yield-per-recruit analysis for summer flounder.

```
 The NEFC Yield and Stock Size per Recruit Program - PDBYPRC
  PC Ver.1.2 [Method of Thompson and Bell (1934)] 1-Jan-1992
          -------------------------------------
SUMMER FLOUNDER - SD 25 1995-96 PR, MEAN WEIGHTS AT AGE

Proportion of F before spawning:  .8300
Proportion of M before spawning:  .8300
Natural Mortality is Constant at:  .200
Initial age is: 0; Last age is: 15
Last age is a PLUS group;
-------------------------------------------------------
Age-specific Input data for Yield per Recruit Analysis
-------------------------------------------------------
```

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
0	.0100	1.0000	.3800	.360	.360
1	.2800	1.0000	.7200	.524	.524
2	.8900	1.0000	.9000	.624	.624
3	1.0000	1.0000	.9700	1.068	1.068
4	1.0000	1.0000	.9900	1.592	1.592
5	1.0000	1.0000	1.0000	2.441	2.441
6	1.0000	1.0000	1.0000	3.244	3.244
7	1.0000	1.0000	1.0000	4.342	4.342
8	1.0000	1.0000	1.0000	4.592	4.592
9	1.0000	1.0000	1.0000	4.841	4.841
10	1.0000	1.0000	1.0000	5.336	5.336
11	1.0000	1.0000	1.0000	5.767	5.767
12	1.0000	1.0000	1.0000	6.135	6.135
13	1.0000	1.0000	1.0000	6.445	6.445
14	1.0000	1.0000	1.0000	6.704	6.704
15+	1.0000	1.0000	1.0000	6.917	6.917

```
-------------------------------------------------------
Summary of Yield per Recruit Analysis for:
SUMMER FLOUNDER - SD 25 1995-96 PR, MEAN WEIGHTS AT AGE

 Slope of the Yield/Recruit Curve at F=0.00: -->    10.1271
   F level at slope=1/10 of the above slope (F0.1): ----->     .141
     Yield/Recruit corresponding to F0.1: ----->      .5631
   F level to produce Maximum Yield/Recruit (Fmax): ----->     .242
     Yield/Recruit corresponding to Fmax: ----->      .6031
   F level at 20 % of Max Spawning Potential (F20): ----->     .298
     SSB/Recruit corresponding to F20: -------->     1.9440

At Fmax =  .242
---------------
```

Age	Catch Number	Catch Weight	Stock Number	Stock Weight	SpStock Number	SpStock Weight
0	.0022	.0008	1.0000	.3600	.3212	.1156
1	.0486	.0254	.8168	.4280	.4709	.2467
2	.1101	.0687	.6249	.3899	.3984	.2486
3	.0807	.0862	.4125	.4405	.2772	.2961
4	.0519	.0826	.2651	.4221	.1819	.2895
5	.0333	.0814	.1704	.4159	.1181	.2882
6	.0214	.0695	.1095	.3553	.0759	.2462
7	.0138	.0598	.0704	.3057	.0488	.2118
8	.0089	.0406	.0452	.2078	.0314	.1440
9	.0057	.0275	.0291	.1408	.0202	.0975
10	.0037	.0195	.0187	.0997	.0130	.0691
11	.0024	.0136	.0120	.0693	.0083	.0480
12	.0015	.0093	.0077	.0474	.0054	.0328
13	.0010	.0063	.0050	.0320	.0034	.0222
14	.0006	.0042	.0032	.0214	.0022	.0148
15+	.0011	.0078	.0057	.0397	.0040	.0275
Tot	.3867	.6031	3.5962	3.7754	1.9801	2.3987

Table A32. Input parameters and short-term stochastic projection results for summer flounder. Starting stock sizes for ages 1 and older on January 1, 1997 are as estimated by VPA bootstrap procedure. Age 0 recruitment levels in 1996-1998 are estimated as the mean of 200 random estimates selected from VPA estimated numbers at age 0 during 1982-1996. Fishing mortality was apportioned among landings and discard based on the proportion of F associated with landings and discard at age during 1995-1996. Mean weights at age (spawning stock, landings, and discards) are weighted (by fishery) arithmetic means of 1995-1996 values. F_{97} is the F realized for different levels of total catch (landings plus discards) in 1997 (e.g., for set 1 total catch = 7,802 mt). Proportion of F and M before spawning = 0.83 (spawning peak at 1 November).

Age	Median stock size in 1997 (000s)	Fishing mortality pattern	Proportion landed	Proportion mature	Mean weights spawning stock (kg)	Mean weights landings (kg)	Mean weights discards (kg)
0	40696	0.01	0.38	0.38	0.360	0.376	0.346
1	18220	0.28	0.58	0.72	0.524	0.531	0.513
2	22764	0.89	0.97	0.90	0.624	0.624	0.617
3	7235	1.00	0.97	1.00	1.068	1.048	1.767
4	713	1.00	1.00	1.00	1.592	1.592	-
5+	271	1.00	1.00	1.00	2.612	2.395	-

Forecast medians (50% probability level) (landings, discards, and SSB in '000 mt)

1997 Landings = 7,162 mt

Option	1997 F	1997 Land.	1997 Disc.	1997 SSB	1998 F	1998 Land.	1998 Disc.	1998 SSB	1999 F	1999 Land.	1999 Disc.	1999 SSB
1	0.40	7.2	0.6	25.2	0.24	6.3	0.6	36.1	0.24	9.2	0.6	47.7
2	0.40	7.2	0.6	25.2	0.34	8.4	0.8	34.4	0.24	8.6	0.6	45.5
3	0.40	7.2	0.6	25.2	0.37	9.0	0.9	33.9	0.26	9.0	0.7	44.5
4	0.40	7.2	0.6	25.2	0.65	14.4	1.5	29.1	0.57	14.4	1.3	33.1

1997 Landings = 9,000 mt

Option	1997 F	1997 Land.	1997 Disc.	1997 SSB	1998 F	1998 Land.	1998 Disc.	1998 SSB	1999 F	1999 Land.	1999 Disc.	1999 SSB
1	0.53	9.0	0.8	23.6	0.24	5.8	0.6	34.2	0.24	8.7	0.6	45.8
2	0.53	9.0	0.8	23.6	0.34	8.4	0.9	32.0	0.24	7.9	0.6	43.1
3	0.53	9.0	0.8	23.6	0.37	9.0	1.0	31.5	0.26	9.0	0.7	41.5
4	0.53	9.0	0.8	23.6	0.65	14.4	1.7	26.7	0.57	14.4	1.5	30.2

1997 F = 1.00

Option	1997 F	1997 Land.	1997 Disc.	1997 SSB	1998 F	1998 Land.	1998 Disc.	1998 SSB	1999 F	1999 Land.	1999 Disc.	1999 SSB
1	1.00	14.3	1.4	18.8	0.24	4.3	0.6	28.7	0.24	7.2	0.6	40.5
2	1.00	14.3	1.4	18.8	0.34	8.4	1.2	25.1	0.24	6.0	0.6	36.2
3	1.00	14.3	1.4	18.8	0.37	9.0	1.2	24.6	0.26	9.0	0.9	32.9
4	1.00	14.3	1.4	18.8	0.65	14.4	2.1	20.5	0.57	14.4	2.1	22.1

Table A33. Stochastic projection results for summer flounder from Bootstrapped SAW-25 VPA stock sizes. Probability of exceeding 1998 target F level (0.24) for 1997 landings = 7,162 mt and alternative 1998 quota levels.

Quota level, 1998 (metric tons)	Probability F > 0.24	Median F
1,000	0.00	0.04
2,000	0.00	0.07
3,000	0.00	0.11
4,000	0.01	0.15
5,000	0.23	0.19
6,000	0.46	0.23
6,276	0.50	0.24
7,162	0.88	0.28
8,400	0.96	0.34
9,000	0.97	0.37
10,000	0.99	0.41
14,400	1.00	0.65

Table A34. Stochastic medium-term projections of fishing mortality (F), landings (total, mt), and spawning stock biomass (SSB, mt) for summer flounder under various projection options. Input parameters are the same as for short-term projections in Table A32. The lower and upper quartiles and the median of bootstrap simulations are given. In all projections, median recruitment is 40.7 million fish, with upper and lower quartiles of 30.2 and 51.2 million fish, respectively.

Option 1: Land quota (7,162 mt landings) in 1997, F_{max} = 0.24 in 1998-2006

	F			Landings			SSB		
Year	L-25	Median	U-75	L-25	Median	U-75	L-25	Median	U-75
1997	0.36	0.4	0.45	7,162	7,162	7,162	22,104	25,182	28,143
1998	0.21	0.24	0.28	6,276	6,276	6,762	31,644	36,143	41,007
1999	0.24	0.24	0.24	7,925	9,185	10,472	42,104	47,663	53,660
2000	0.24	0.24	0.24	10,619	12,050	13,676	51,939	58,361	65,294
2001	0.24	0.24	0.24	12,638	14,280	16,143	59,318	66,354	73,906
2002	0.24	0.24	0.24	14,452	16,310	18,352	65,916	73,491	81,704
2003	0.24	0.24	0.24	15,704	17,665	19,788	70,236	78,263	86,698
2004	0.24	0.24	0.24	16,515	18,520	20,682	73,026	81,173	89,921
2005	0.24	0.24	0.24	17,018	19,061	21,239	74,952	83,107	91,879
2006	0.24	0.24	0.24	17,352	19,380	21,606	76,116	84,352	93,160

Option 2: Land quota (7,162 mt landings) in 1997, land 8,400 mt in 1998, F_{max} = 0.24 in 1999-2006

	F			Landings			SSB		
Year	L-25	Median	U-75	L-25	Median	U-75	L-25	Median	U-75
1997	0.36	0.4	0.45	7,162	7,162	7,162	22,104	25,182	28,143
1998	0.30	0.34	0.40	8,400	8,400	8,400	29,849	34,356	39,216
1999	0.24	0.24	0.24	7,340	7,340	8,599	39,946	45,520	51,508
2000	0.24	0.24	0.24	10,069	10,069	11,497	49,984	56,391	63,298
2001	0.24	0.24	0.24	12,202	12,202	13,843	57,775	64,805	72,343
2002	0.24	0.24	0.24	14,146	14,146	15,996	64,799	72,369	80,588
2003	0.24	0.24	0.24	15,506	15,506	17,463	69,523	77,537	85,966
2004	0.24	0.24	0.24	16,390	16,390	18,390	72,565	80,704	89,467
2005	0.24	0.24	0.24	16,934	16,934	18,977	74,652	82,797	91,577
2006	0.24	0.24	0.24	17,298	17,298	19,327	75,933	84,158	92,974

Table A34. Continued.

Option 3: Land quota (7,162 mt landings) in 1997, land 9,000 mt in 1998-00, F_{max} = 0.24 in 2001-2006

	F			Landings			SSB		
Year	L-25	Median	U-75	L-25	Median	U-75	L-25	Median	U-75
1997	0.36	0.40	0.45	7,162	7,162	7,162	22,104	25,182	28,143
1998	0.32	0.37	0.43	9,000	9,000	9,000	29,326	33,850	38,709
1999	0.22	0.26	0.31	9,000	9,000	9,000	37,960	44,452	51,372
2000	0.16	0.19	0.23	9,000	9,000	9,000	48,474	57,058	66,497
2001	0.24	0.24	0.24	11,903	14,280	16,658	56,971	65,979	75,807
2002	0.24	0.24	0.24	14,021	16,295	18,819	64,531	73,518	83,262
2003	0.24	0.24	0.24	15,544	17,753	20,140	69,622	78,547	87,801
2004	0.24	0.24	0.24	16,470	18,599	20,879	72,880	81,564	90,557
2005	0.24	0.24	0.24	17,033	19,118	21,337	74,964	83,347	92,154
2006	0.24	0.24	0.24	17,365	19,429	21,648	76,215	84,504	93,280

Option 4: Land quota (7,162 mt landings) in 1997, land 14,400 mt (19.0 million lbs commercial) in 1998-2006

	F			Landings			SSB		
Year	L-25	Median	U-75	L-25	Median	U-75	L-25	Median	U-75
1997	0.36	0.40	0.44	7,162	7,162	7,162	22,104	25,182	28,202
1998	0.56	0.65	0.78	14,400	14,400	14,400	25,045	29,500	34,255
1999	0.46	0.57	0.72	14,400	14,400	14,400	27,447	33,573	40,336
2000	0.37	0.48	0.64	14,400	14,400	14,400	30,228	38,492	47,684
2001	0.31	0.40	0.56	14,400	14,400	14,400	33,465	43,799	55,402
2002	0.25	0.38	0.48	14,400	14,400	14,400	37,675	50,492	64,660
2003	0.22	0.29	0.41	14,400	14,400	14,400	42,550	57,835	74,302
2004	0.19	0.25	0.36	14,400	14,400	14,400	47,722	65,285	83,774
2005	0.17	0.22	0.31	14,400	14,400	14,400	53,381	72,780	93,077
2006	0.15	0.20	0.28	14,400	14,400	14,400	59,381	79,955	101,591

Table A35. Summary of summer flounder quotas, reported landings, projections, and subsequent estimates of the fully-recruited fishing mortality rate (F).

Assessment	Terminal catch year Year T	Forecast landings/ quota Year T+1 (mt)	Reported landings Year T+1 (mt)	Terminal F estimate Year T	Projected F Year T+1	SAW-25 VPA F	Percent difference in F SAW-25 projection
SAW-11	1988	9,700	9,560	F88 = 1.42	F89 = 1.42	F89 = 1.78	+25%
SAW-13	1990	12,330	9,835	F90 = 1.07	F91 = 1.07	F91 = 1.74	+63%
SAW-16	1992	9,400	9,199	F92 = 1.08	F93 = 0.48	F93 = 1.24	+158%
SAW-18	1993	12,100	10,699	F93 = 0.54	F94 = 0.77	F94 = 1.21	+57%
SAW-20	1994	10,200	9,473	F94 = 0.69	F95 = 0.50	F95 = 1.13	+126%
SAW-22	1995	8,400	10,474	F95 = 1.50	F96 = 0.52	F96 = 0.99	+90%
SAW-25	1996	7,162	NA	F96 = 0.99	F97 = 0.40	F97 = 0.75	Mean = +87%

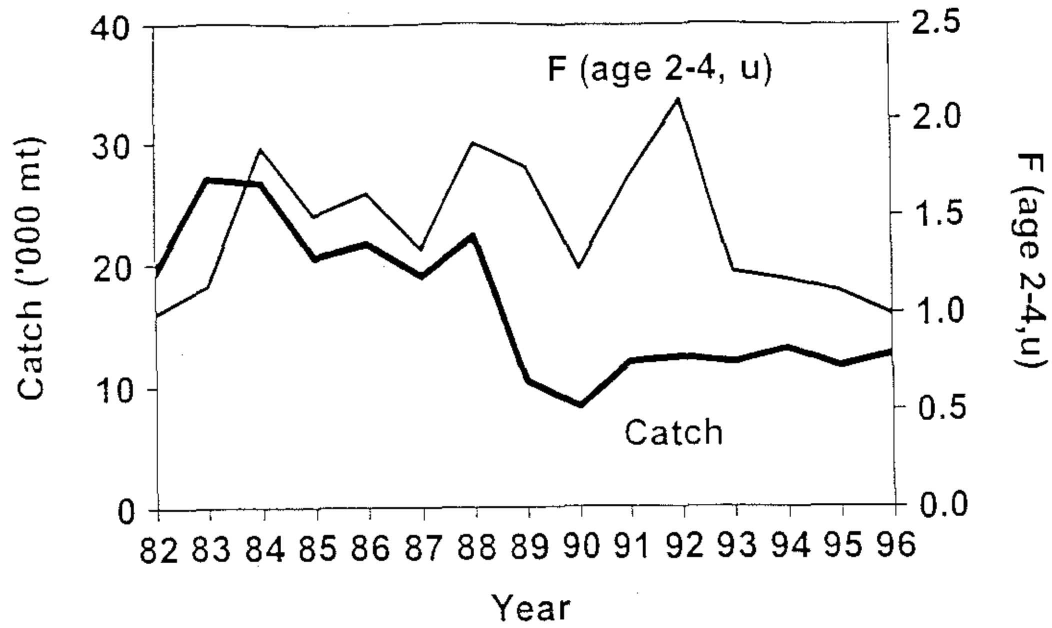

Figure A1. Total catch (landings and discard, thousands of metric tons) and fishing mortality rate (fully recruited F, ages 2-4, unweighted) for summer flounder.

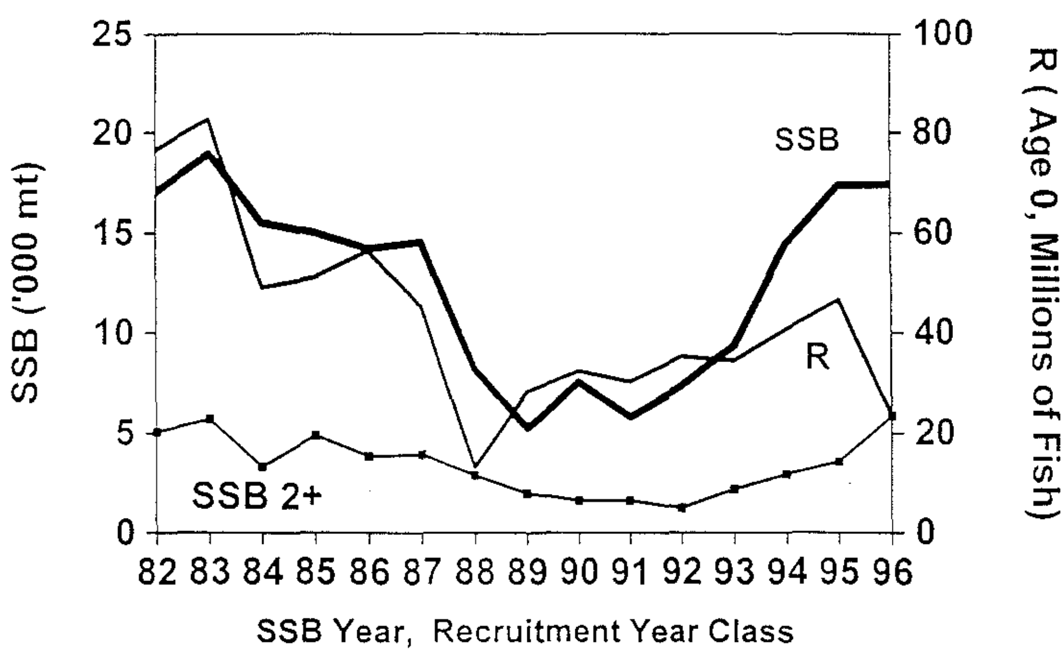

Figure A2. Spawning stock biomass (SSB ages 0 to 5+, thousands of metric tons) and recruitment (millions of fish at age-0) for summer flounder. Note that because summer flounder spawn in late autumn, fish recruit to the fishery at age-0 the following autumn. For example, fish spawned in autumn 1987 recruit to the fishery in autumn 1988 and appear in VPA tables at age-0 in 1988.

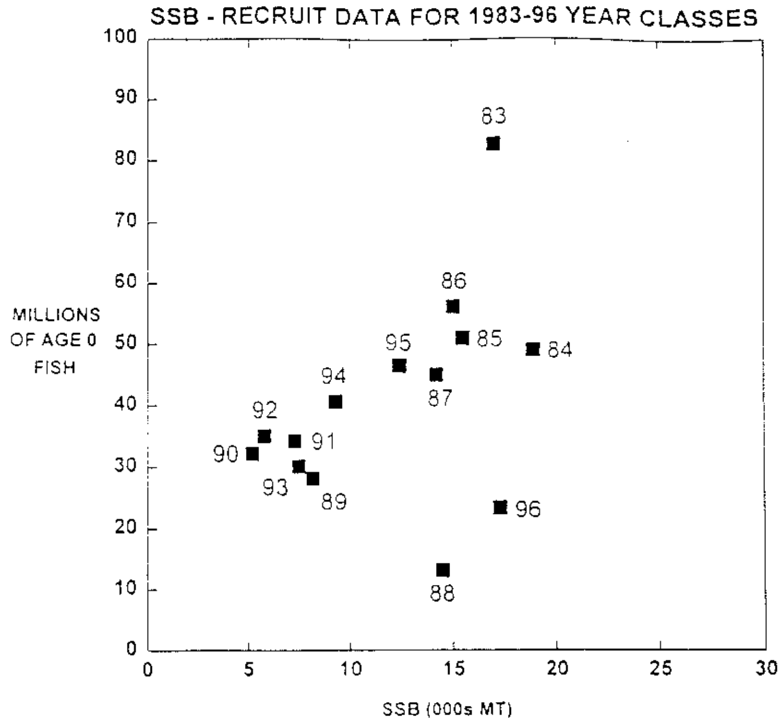

Figure A3. Summer flounder SARC 25 VPA spawning stock biomass and recruitment estimates.

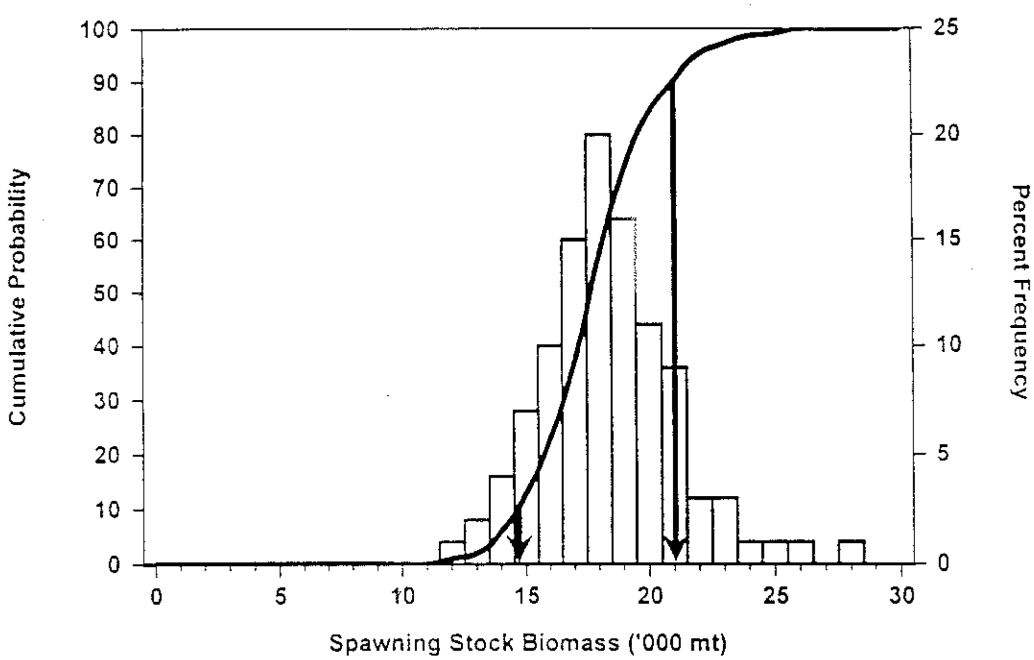

Figure A4. Precision of the estimates of spawning stock biomass on November 1, 1996 for summer flounder. Vertical bars display the range of the bootstrap estimates and the probability of individual values in the range. The dashed line gives the probability that SSB is less than any value along the X axis.

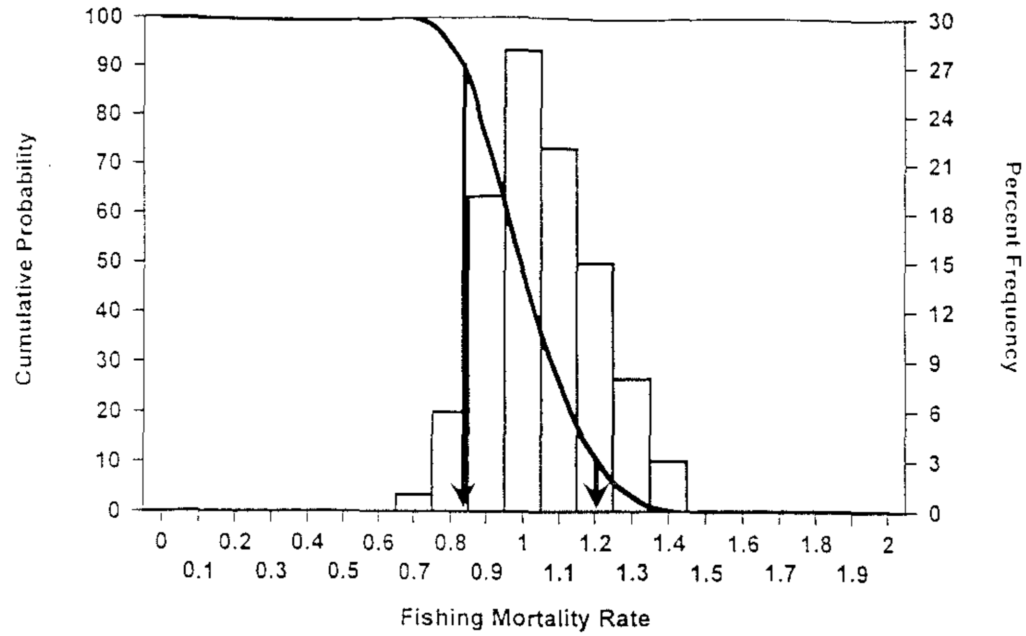

Figure A5. Precision of the estimates of fully recruited F (ages 2-4, u) in 1996 for summer flounder. Vertical bars display the range of the bootstrap estimates and the probability of individual values in the range. The dashed line gives the probability that F is greater than any value along the X axis.

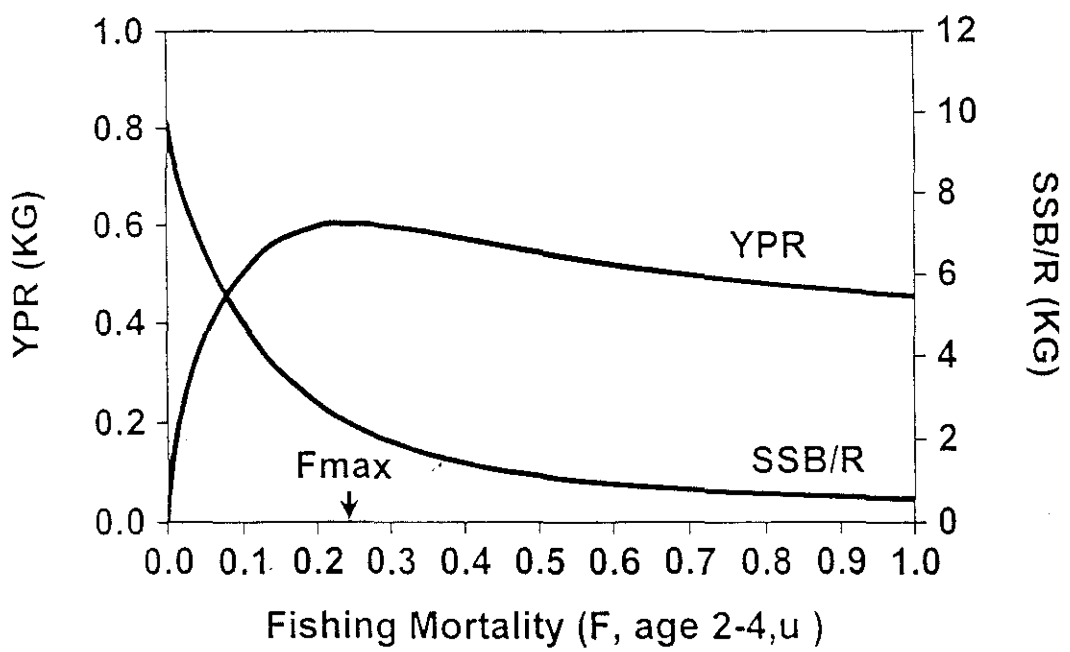

Figure A6. Yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) for summer flounder.

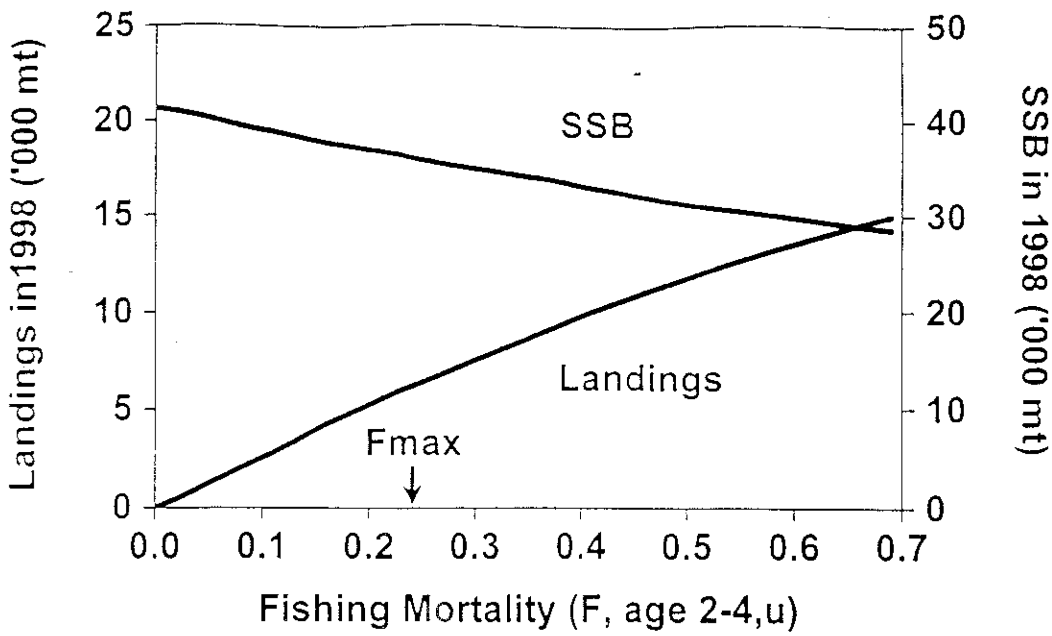

Figure A7. Projection Set 1, Option 1: Assumes landings in 1997 = 7,162 mt. Projected landings and spawning stock biomass (SSB) in 1998 of summer flounder over a range of fishing mortalities in 1998, from F=0.0 to F=0.7

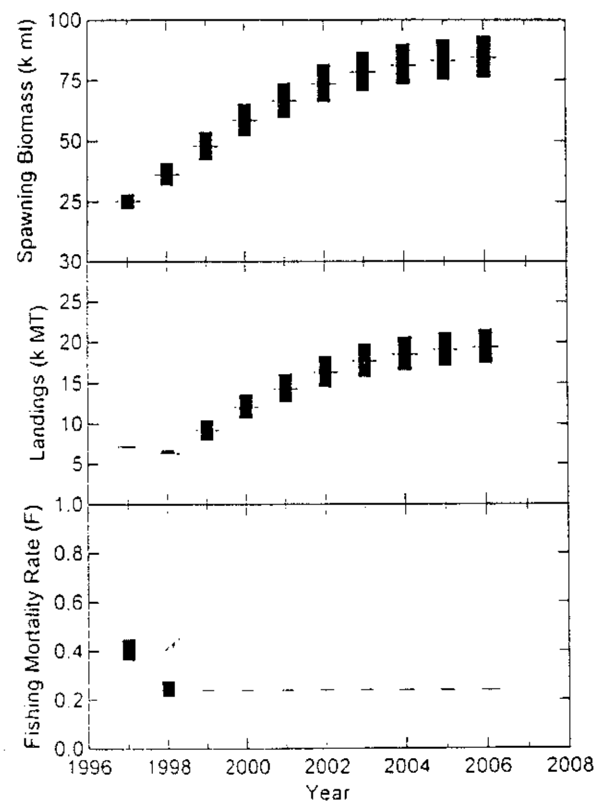

Figure A8. Medium-term projection Set 1, Option 1: Assumes landings in 1997 = 7,162 mt, and fishing mortality = 0.24 during 1998-2006. Horizontal lines are median (50% probability) levels of spawning stock biomass, landings, and fishing mortality during 1997-2006. Vertical bars indicate the upper and lower quartiles (50% of the values estimated fall within the range of the bar).

B. SCUP

Terms of Reference

a. Assess the status of scup through 1996 and characterize the variability of estimates of stock abundance and fishing mortality rates.

b. To the extent feasible, provide projected estimates of catch for 1997-1998 and SSB for 1998-1999 and characterize the variability of estimates of stock abundance and fishing mortality rates.

Introduction

Scup (*Stenotomus chrysops*) is a schooling, continental shelf species of the Northwest Atlantic that is distributed primarily between Cape Cod and Cape Hatteras (Morse 1978). Inshore/offshore seasonal migrations occur in the spring and autumn, with scup found mainly in coastal waters during the summer and offshore waters in the winter. Sexual maturity occurs at age 2, with spawning occurring during May-August. Scup reach a maximum length of about 40 cm and a maximum age of about 20 years (Dery and Rearden 1979). Tagging studies (e.g., Neville and Talbot 1964; Cogswell 1960, 1961; Hamer 1970, 1979) have indicated the possibility of two stocks of scup, one in Southern New England and another extending south from New Jersey. However, a lack of definitive tag-return data coupled with distributional data from the NEFSC bottom trawl surveys support the concept of a single unit stock extending from Cape Hatteras north to New England (Mayo 1982).

The Mid-Atlantic Fishery Management Council (MAFMC) and the Atlantic States Marine Fisheries Commission (ASMFC) manage scup under Amendment 8 to the Summer Flounder, Scup, and Black Sea Fishery Management Plan (FMP). In, 1996, the FMP implemented minimum size requirements of 9 in for commercially-landed scup and 7-in size limits for recreationally-landed scup, and a minimum mesh size of 4.0 in for vessels retaining more than 4,000 lbs of scup. Exploitation rates are to be reduced to 47% in 1997, 33% in 2000, and 19% in 2002 through coastwide commercial quotas, and season and possession limits in the recreational fisher. Overfishing for scup is defined as fishing in excess of F_{max}. The 19% exploitation rate corresponds to the current estimate of F_{max}. The FMP has as a management unit all scup from Cape Hatteras northward to the US-Canadian border.

The Fishery

Commercial Landings

US commercial landings averaged less than 10,000 mt annually during 1930-1947 (Figure B1), averaged over 19,000 mt per year during 1953-1964 (peaking at over 22,000 mt in 1960), and declined to around 4,000 mt per year in the early 1970s. From 1974 to 1986, landings fluctuated between 7,000 and 10,000 mt and have since declined to between 3,700 and 6,900 mt (Table B1). Landings in 1996 were about 2,500 mt, the lowest observed in the time series beginning in 1930.

Commercial landings in 1994-1996 were reported by dealers, by market category, but not by area of catch. Procedures developed by Wigley *et al.* (1997) were used to allocate those landings by market category to statistical area based on information collected under the Vessel Trip Report (VTR) system. In those procedures, a monthly set of landings reported in both dealer and VTR databases are used to characterize the distribution of dealer-reported landings by statistical area. This proration procedure contributes to uncertainty in the attribution of market category landings by area, especially if vessels which are not participating in any fishery with mandatory VTR requirements land scup from different areas than those which produce landings for participating vessels. Other sources of uncertainty include unreported landings by dealers.

Distant-water-fleet landings (principally from the Southern New England area) were reported for 1963-1981 (Figure B1). Landings peaked at about 5,900 mt in 1963, averaged only about 1,100 mt per year during 1964-1975, and were only a few mt annually in 1976-1981.

Landings of scup in Rhode Island and New Jersey have accounted for about 68% of the total during 1979-1996 (Table B2), with Rhode Island averaging about 39% of the total and New Jersey about 29% of the total. New York landings comprised an average of 15% of the total.

The principal commercial fishing gear is the otter trawl, accounting for an average of 77% of the total catch during 1979-1996 (Table B3). The remainder of the commercial landings are taken by floating trap (12%), with pair trawl, pound net, pots and traps, and hand lines each contributing between 2 and 3%. Approximately 30% of the commercial landings during this period have occurred in state waters and 70% in the EEZ.

Commercial Discards

The NEFSC sea sampling program has collected information on landings and discards in the commercial fishery during 1989-1996. The number of trips in which scup were landed and/or discarded is tabulated in Table B4. Between 7 and 91 otter trawl trips per year were sampled in which scup were landed or discarded. The number of sampled trips was especially low in 1994-1996, with between 7 and 27 otter trawl trips sampled per year.

The intensity of length frequency sampling of discarded scup from sea sampling has declined in 1992-1995 relative to 1989-1991. In the first half of 1992, length frequency samples were collected from 16 tows, but in the second half of 1992, no length frequency data were collected (Table B4). In 1993 and 1994, samples were collected from only 7 and 10 tows, respectively; in 1995, 31 tows were sampled. Depending on how discard tonnage is estimated, this level of sampling corresponds to 100 lengths sampled per 330-500 mt in 1992-1995, which does not meet the informal criterion of 100 lengths sampled per 200 mt. No age data are available from sea samples.

Previous analyses reviewed during SAW-19 indicated that the NEFSC sea sampling data are inadequate to develop reliable estimates of discard at age in the commercial fishery. As in the previous assessment, ratios of discards/landings by landings level (for trips landings < 0.3 mt or > 0.3 mt) and half-year were also calculated (uncorrected geometric mean by cell) and multiplied by corresponding observed landings levels from the weighout data base to provide estimates of discards (Table B4). In 1995-1996, however, no sea-sampled observations were available for trips landing more than 0.3 mt per trip in the first half of 1995 and the second half of 1996, one observation was available for trips landing more that 0.3 mt per trip in the second half of 1995 and two observations at that landings level were available for the first half of 1996. Consequently, the 1989-1994 average rate for trips with landings greater than 0.3 mt (from both half-years) was used for 1995-1996 rates in both half-years. Because 1994-1996 NEFSC landings estimates included all currently available data from ME-VA, 1994-1996 discard estimates were only raised to account for North Carolina data.

Total weight of commercial discard is displayed in Table B5, and estimated discard at age is displayed in Table B7. For 1989-1996, the total weight (mt) of discard was estimated from the observed ratios of discard to landings (as described above), and an aggregate length frequency distribution was developed by half-year (where component length frequency samples were weighted by weight of discard in the tow sampled). Mean weight was estimated from length frequency data and a length-weight equation, total numbers were estimated by dividing total weight by mean weight, and numbers at length were then calculated from the length frequency distribution. Numbers at length were converted to numbers at age by applying age-length keys derived from NEFSC survey catches of scup. Age-length keys from spring surveys were applied to numbers at length from the first half of the year, while age-length keys from autumn surveys were applied to numbers at length from the second half of the year. For years in which no discard data were collected (1984-1988 and the second half of 1992), commercial landings at age were raised by the geometric mean of the ratios of discards to landings at age for 1989-1993. In the absence of any published estimates of discard mortality rates for this species, a discard mortality rate of 100% was assumed.

No clear pattern of age- or cohort-specific trends emerged from examination of the example calculation of discards at age (Table B7). Discards were dominated by scup at ages 0, 1, or 2, depending on the year under consideration. There is some evidence for a strong 1994 year class, based on the changes in age composition of discards between 1994 and 1996, but tempered by uncertainty due to poor sampling in those years.

Recreational Catch

Scup is an important recreational species, with the greatest proportion of catches taken in the Southern New England states and New York. Estimates of the recreational catch in numbers were obtained from the NMFS Marine Recreational Fishery Statistics Survey (MRFSS) for 1979-1996. These estimates were available for three categories: type A - fish landed and available for sampling, type B1 - fish landed but not available for sampling, and type B2 - fish caught and released). The numbers of type A and B1 were combined and converted to weight (mt) by estimating numbers at length from the length samples taken from the recreational landings and by applying a length-weight equation (Morse, 1978) to those estimated numbers at length.

The estimated recreational landings (types A and B1) in weight during 1979-1996 ranged between 600 and 5,300 mt (Table B1) and averaged about 2,250 mt per year. The 1995 estimate was 600 mt, a 50% decrease from 1993 and the lowest value in the 1979-1996 time series. The 1996 estimate of 1,015 mt is the second lowest value in the time series. Since 1979, the MRFSS data indicate that the recreational landings have comprised approximately 1/3 of the commercial and recreational total.

The estimated recreational discard removals in weight during 1984-1996 ranged from 30 mt in 1984 to a high of 87 mt in 1986, while averaging about 45 mt per year (Table B5), based on the assumption that 15% of the discards (type B2) die. The 1995 and 1996 estimates were 33 mt and 47 mt, respectively. Mortality due to discarding in the recreational fishery has been reported to range from 0 to 15% (Howell and Simpson 1985) and from 0 to 13.8% (Williams, pers. comm.). Howell and Simpson found mortality rates positively correlated with size, due largely to the tendency for larger fish to take the hook deep in the esophagus or gills. Williams more clearly demonstrated increased mortality with depth of hook location as well as handling time, but found no association with fish size. Based on these studies, discard mortality in the recreational fishery between 5% and 15% appears reasonable. In this report, 15% was assumed.

Total Catch

Estimates of the total catch of scup during 1984-1996 are given in Table B5. These estimates include commercial and recreational landings and discards. The total catch during this period varied from a high of nearly 14,300 mt in 1986 to a low of about 5,000 mt in 1996. The total catch decreased by nearly 65% from 1991 (14,100 mt) to 1996.

During this 13-year period, commercial landings averaged about 50% of the total catch, with discards and recreational landings each accounting for about 25%.

Sampling Intensity

Length samples of scup are available from both commercial and recreational landings. The intensity of sampling during 1979-1996 is summarized in Table B6. In the commercial fishery, annual sampling intensity varied from 35 to 481 mt per 100 lengths. In nearly all years, the overall sampling exceeded the informal criterion of 100 lengths sampled per 200 mt. This alone does not indicate adequate sampling because scup are landed in seven commercial market categories from over 20 statistical areas.

In the recreational fishery, sampling intensity varied from 48 to 443 mt per 100 lengths. Sampling in all years except one during 1979-1987 failed to satisfy the above informal criterion, but during 1988-1993, sampling averaged 77 mt per 100 lengths. Since no length frequency distribution data on scup discard are collected under the MRFSS program, recreational discards were assumed to be fish age 0 and 1, in the same relative proportions as in the landed catch, consistent with regulated minimum fish sizes and informal inspection of samples collected from the New York recreational fishery.

Age Compositions

Numbers at age were estimated for 1984-1996 for the commercial landings (separately for Maine - Virginia, i.e., NEFSC weighout landings; and North Carolina), commercial discards, recreational landings, and recreational discards (Tables B7-B9, and summarized over all sources in Table B10). Numbers at length for each of these categories were determined based on available length frequency samples and were converted to numbers at age by applying age-length keys derived from NEFSC survey catches of scup and commercial samples (the latter available for 1990-1996). Age-length keys from spring surveys and first and second quarter commercial samples (1990-1996) were applied to numbers at length from the first half of the year, while age-length keys from autumn surveys and third and fourth quarter commercial samples (1990-1996) were applied to numbers at length from the second half of the year.

Mean weights at age for the commercial landings, commercial discards, recreational landings, and recreational discards for 1984-1996 are given in Tables B11-B13, and estimates of mean weight at age of removals from all sources are given in Table B14. Variability in mean weights at age in catch is partially a function of the relative magnitude of discards in any particular year, e.g., age 1 in 1995.

Stock Abundance and Biomass Indices

Research Vessel Survey Indices

Indices of scup abundance and biomass were calculated from catch-per-tow data from research vessel surveys conducted by the NEFSC, Massachusetts Division of Marine Fisheries, Rhode Island Division of Fish, Wildlife, and Estuarine Resources, Connecticut Department of Environmental Protection, and Virginia Institute of Marine Science.

NEFSC surveys

Mean number-per-tow and weight-per-tow indices were determined from autumn (1963-1996), spring (1968-1996), and winter (1992-1996) NEFSC bottom trawl surveys. Indices from the spring and autumn surveys were based on tows in offshore strata 1-12, 23, 25, and 61-76 and inshore strata 1-61. The indices from the relatively short winter survey series were based on tows in only the above-indicated offshore strata.

Mean weight-per-tow indices for the spring and autumn survey time series are illustrated in Figure B2, which include only offshore strata for consistency over the early part of the time series. Although the indices exhibit considerable year-to-year variability, both surveys indicate that current levels of biomass are much lower than previously. The spring indices show a high level from the late 1960s to the late 1970s followed by a sharp, almost continuous decline to the present time. The autumn indices, although much more variable, may indicate an increase in biomass from the early 1960s to the mid-1970s, dropping thereafter, and have declined to lowest observed levels in the time series in 1996. The winter indices fluctuate without trend, although a downward trend would be indicated with a delta transformation of the data.

Catch per tow in numbers at age from the NEFSC spring and autumn surveys in 1984-1996 are presented in Table B15.

State surveys

Massachusetts:

The Massachusetts Division of Marine Fisheries (MADMF) has, since 1978, conducted a semi-annual bottom trawl survey of Massachusetts territorial waters in May and September. Survey coverage extends between the boundaries of New Hampshire and Rhode Island and seaward to three nautical miles, including Cape Cod Bay and Nantucket Sound. The study area is stratified into geographic zones based on depth and area. Pre-determined trawl sites are allocated in proportion to stratum area and are chosen randomly within each sampling stratum.

A 20-minute tow at 2.5 knots is made at each station with a 3/4-size North Atlantic two-seam otter trawl (11.9-m headrope, 15.5-m footrope) rigged with a 19.2-m chain sweep with 7.6-cm rubber discs. The net contains a 6.4-mm mesh codend liner to retain small fish. Approximately 95 stations are sampled during each survey.

Standard bottom trawl survey techniques are used to process the catch of each species. Generally, the total weight (nearest 0.1 kg) and length frequency (nearest cm) are recorded for each species on standard trawl logs. Collections of age and growth structures, maturity observations, and pathology observations are taken.

The MADMF spring indices dropped sharply from a high in 1980 to remain at fairly low levels until increasing briefly in 1989 and 1990 (Figure B3A). Indices in the last two years have been low. Catch per tow in numbers at age for the spring and autumn surveys are given in Table B16.

Rhode Island:

The Rhode Island Division of Fish, Wildlife, and Estuarine Resources (RIDFW) has conducted an autumn and spring survey since 1979 based on a stratified random sampling design. Three major fishing grounds are considered in the spatial stratification, including Narragansett Bay (NB), Rhode Island Sound (RIS), and Block Island Sound (BIS). Stations are either fixed or randomly selected for each stratum. In order to maintain continuity in the number of stations sampled per stratum each season, an alternate list is generated for substitution in the event of an unexpected hang-up or questionable bottom type. At each station, a 3/4-scale high rise bottom trawl is towed for 20 minutes at an average speed of 2.5 knots using the R/V *Thomas J. Wright*, a 42-ft Bruno Stillman western-rigged dragger. The average vertical opening of the net is estimated at 10 feet. The doors are 2 ft by 4 ft running 7.5 fathoms ahead of the wings.

Survey results are expressed as unweighted arithmetic mean weight and number per tow for the three major areas (NB, RIS, and BIS). Indices have shown a modest increase in the mean number of scup per tow since 1989, particularly in the autumn surveys. Analysis of length frequency data indicates seasonal variability in mean length, with a spring mean of 23 cm and an autumn mean of 10 cm. Further examination indicates that about 99% of the scup caught in the autumn survey are ages 0 and 1. Because the index is dominated by the autumn component of the survey, that portion of the index was used as the index of abundance for VPA tuning.

The mean weight-per-tow index for the Rhode Island survey was relatively high in 1980, but has since remained at low levels. Number-per-tow indices (Figure B3B) indicate a potential increase in the early 1990s, but declines in recent years. Catch per tow in numbers at age for the autumn survey are given in Table B17.

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. The stratified random design survey is currently conducted in the spring (April-June) and autumn (September-October). Each survey consists of three cruises, with 40 stations sampled during each cruise, providing a sampling density of one station per 20 sq nmi per cruise. Prior to 1990, the survey was conducted monthly from April to November.

Scup are caught in all months sampled, but are most common in the autumn when 4,000-40,000 fish between 4 and 38 cm are taken. Large autumn catches can be attributed to age 0 fish (<12 cm) which comprise 80-90% of the catches. In May and June, 2,000-4,000 age 1+ (9-37 cm) scup are typically collected during the 120 tows. Scup occur in 40-50% of the spring tows and more than 95% of the autumn samples. Proportional standard errors (PSE) of spring log mean number/tow indices range from 12 to 14%, whereas autumn PSEs are between 2 and 7%.

Age-length keys have been developed for both spring and autumn for 1984-1993 and for summer (July-August) and November 1984-1990. A total of 4,054 fish have been aged since 1984 (spring 1,370, summer 1,109, autumn 1,304, and November 334). Because the pooled index is dominated by the autumn component, that portion of the index was used as the index of abundance for VPA tuning.

The mean weight-per-tow index remained relatively stable during 1984-1989, increased to a peak in 1991, and has since declined. Number-per-tow indices (Figure B3B) indicate potential increases during 1984-1991, but abundance has been stable or declining thereafter. Catch per tow in numbers at age for the autumn surveys are presented in Table B18.

Virginia Institute of Marine Science:

The Virginia Institute of Marine Science has conducted a juvenile scup survey in lower Chesapeake Bay during June-September since 1988. Age 0 geometric mean indices based on an average of 104 samples per survey are presented in Table B19. The 1989 index is about 6 times higher than the mean level in the other six years.

New York:

The New York Department of Environmental Conservation initiated a small-mesh trawl survey in 1985 to collect fisheries-independent data on the age and size composition of scup in local waters. This survey is conducted in the Peconic Bays, the estuarine waters which lie between the north and south forks of eastern Long Island. The R/V *David H. Wallace*, a 35-ft Bruno Stillman, is used to sample sixteen stations each week during May - October. Tows are 20 min in duration. The net used has a 16-ft headrope and a 19-ft footrope and is constructed of polypropylene netting with 1.5-in stretch mesh in the body and 1.25-in stretch mesh in the codend.

For this analysis, a young-of-the-year index was provided based on slicing at length. Fish were categorized as young of the year if they were ≤ 75 mm in the July survey, ≤ 100 mm in August, and ≤ 125 mm in September. The time series extends from 1987 to 1996.

The young-of-the-year index peaked in 1991-1992 and declined thereafter. Geometric mean catch per station in numbers at length pooled over the survey season are presented in Table B19.

New Jersey:

The New Jersey Bureau of Marine Fisheries has conducted a stratified random bottom trawl survey of New Jersey coastal waters from Ambrose Channel south to Cape Henlopen Channel , and from about the 18-ft isobath to approximately the 15-ft isobath offshore. Latitudinal strata boundaries correspond to those in the NMFS groundfish survey; longitudinal boundaries correspond to the 30-, 60-, and 90-ft isobaths. Each survey includes two tows per stratum plus one additional tow in each of nine larger strata for a total of 39 tows. A three-in-one trawl with a 100-ft footrope, 82-ft headrope, 3-4.7-in mesh throughout most of the body, and a 0.25-in mesh codend liner is used. Two vessels have been used during the survey, the F/V *Amy Diane* during 1988-1991 and the F/V *ARGO Marine* from 1991 to the present. From 1991 to the present, the area has been surveyed in January, April, June, August, and October; during 1988-1990, February and December surveys were incorporated instead of the January survey.

Catch per tow at length was reported by survey, pooled, and aged using NEFSC survey age-length keys (augmented with commercial age-length keys when available and necessary). Results are reported in Table B20. The index increased overall from 1989 to 1993, then declined to the lowest levels in the 1989-1996 series in 1995-1996 (Figure 3B).

Coherence among surveys

The surveys conducted by the NEFSC and several states have each produced indices of scup abundance and biomass. Since each of these surveys samples distinct geographic regions, it is possible that they provide indices for different components of the overall stock. In addition, seasonal movements can influence the availability of scup and the effectiveness of the various surveys in producing indices that accurately reflect total stock abundance or biomass. Since the objective of this assessment was to employ these survey indices to interpret scup abundance from Massachusetts to North Carolina, it is important to examine the coherence between these indices. An earlier examination of correlation analyses of average catch per tow in number at each age was continued to determine if the indices exhibited comparable trends and patterns. Pearson correlations indicated sporadic significant relationships, but these were not consistent between ages, and no strong trends emerged. Various indices were likely measuring different components of the stock distributed differentially in time and space. No clear indication of which survey time series was most indicative of the total stock emerged from the analysis. In light of this, all relevant tuning indices were included in the ADAPT tuning model for estimating stock size and fishing mortality.

Overall, stock sizes (as indexed by mean weight per tow) appear to have dropped during the late 1970s (NEFSC spring survey) to early 1980s (MADMF spring survey) (Figures B2 and B3). Since then, biomass has continued to trend downward to the lowest observed levels in 1996 (NEFSC and MADMF spring surveys). Intermittent increases in biomass were not sustained for more than three years in either index. In recent years, the fluctuating NEFSC autumn survey index has included several of the lowest observations in the 34-year time series. Other indices of abundance, based on number per tow, are much shorter, beginning in 1984 (Figure B3). While several of those indices show increasing trends from 1985 to 1993, indices in 1996 are at or near the lowest values in the survey series.

Mortality and Stock Size Estimates

Natural Mortality

Instantaneous natural mortality (M) for scup was assumed to be 0.20 (Crecco *et al.* 1981, Simpson *et al.* 1990).

Virtual Population Analysis

Tuning

Numbers at age on 1 January 1997 and corresponding fishing mortality (F) rates in 1996 were estimated using a non-linear least squares technique to calibrate VPA estimates of numbers at age with survey abundance indices (ADAPT, Parrack 1986, Gavaris 1988, Conser and Powers 1990). Abundance at ages 0-5 was estimated separately; ages 6 and older were combined as a plus group because, on average, less than 1% of the catch was ages 6 and older. Stock sizes in 1997 were directly estimated for ages 1-4, with abundance of ages 5 and 6+ calculated from F estimated for age 4 in 1993. Stock size at age 0 in 1997 could not be estimated because no 1997 survey indices of age 0 abundance were available. Initial partial recruitment patterns from separable VPA indicated full recruitment at age 3. F at age 5 was estimated from back-calculated stock sizes at ages 3-4; F at age 6+ was assumed equal to F at age 5.

Performance of the following research trawl survey indices was inspected for use in tuning:

1) NEFSC spring survey, ages 1-4
2) NEFSC autumn survey, ages 0-4
3) MADMF spring survey, ages 1-4
4) MADMF autumn survey, ages 0-2+
5) RIDFW autumn survey, ages 0-4
6) CTDEP autumn survey, ages 0-5
7) VIMS autumn survey, age 0
8) NEFSC winter trawl survey, ages 1-4
9) NYDEC spring-autumn survey, age 0
10) NJBMF spring-autumn, ages 0-3

Spring and NEFSC winter survey indices at age were compared to stock sizes at age at 1 January of the survey year; spring-autumn survey indices were compared to stock sizes at age at mid-year, and autumn survey indices were compared to stock sizes one year older on 1 January the following year. In the previous assessment, residual patterns and partial variances contributed by individual indices lead to the elimination of the MADMF age 1, RIDFW age 3-4, and NEFSC winter survey age 1-4 indices based on high partial variances, and CTDEP age 0 based on a trend in residual patterns. Because there was considered to be uncertainty in both catch-at-age (e.g., commercial discard-at-age component) and tuning-index components, iterative re-weighting was not incorporated in the final run.

Approximate coefficients of variation for estimates of numbers at ages 1-3 ranged from 36 to 57% and increased to 82% for estimates of age 4 abundance.

Approximate coefficients of variation for survey catchability coefficients ranged from 27 to 50%. Absolute values of correlation coefficients between estimated parameters were all less than 0.29, with nearly all below 0.15. No trends in standardized residuals were observed.

Exploitation pattern

The exploitation pattern has been variable from year to year, but full recruitment has occurred between ages 2-3 during 1989-1994, influenced by the magnitude of annual commercial discard-at-age patterns. An average exploitation pattern was calculated as the ratio of the geometric means (1992-1996) of the fishing mortality rates at ages 0-2 to the geometric means of the fishing mortality rates at ages 3-5. The resulting pattern indicates, on recent average, 6% recruitment at age 0, 21% at age 1, and 87% at age 2. In previous yield-per-recruit calculations, full (100%) recruitment was assumed at ages 2 and older, consistent with these observations.

Evaluation of VPA adequacy

The SARC believed that the exploratory VPA integrated existing data to produce estimated trends in fishing mortality rates and biomass that were generally indicative of actual trends, but due to gross inadequacies in the input data, the SARC rejected the exploratory VPA as a basis for formal projections. Similar to other assessments in the region, the amount of variance in each component of the catch-at-age matrix had not been estimated. In the case of scup, this amount of variance was believed by the SARC to be unreasonably large. In the case of the 1993-1994 commercial landings reported through the NEFSC system, 37-46% of the total tonnage was unsampled at the resolution of market category, quarter, and two-digit statistical area, and consequently was characterized by size compositions from landings of market categories from different statistical areas or quarter, or from a combination of market categories. While market category is more likely to be related to size composition of landings rather than statistical area of catch, that SARC felt that, overall undersampling produced a significant source of uncertainty in the development of the NEFSC commercial landings-at-age component. In the case of commercial discard-at-age estimates, sampling was not adequate to cover all cells in the stratification scheme (landings level and half-year) in the past two years, requiring substitution of long-term average cell means; in 1993, only seven otter trawl trips catching scup were sampled. For years before the implementation of the sea sampling program, the discard-at-age matrix was estimated using average observed ratios of discard to landings from later years; consequently, early estimates of discard do not include any direct observations. Because discard levels appear to be highly variable even between tows on the same sea-sampled trip, typical estimators such as ratios of discards to landings or discards per day fished are highly variable and can range over three orders of magnitude simply depending on the form of the mean used, based on comparisons in the previous assessment. Identification of specific mechanisms or factors which lead to differences in discard rates is complicated by the wide spatial and temporal range of the component fisheries as well as operational characteristics of fisheries, e.g., target species, gear type. This combination of variable discard rates within trip and the range of temporal, spatial, and operational characteristics of component fisheries will continue to make accurate characterization of discard levels difficult, even if sampling levels were to increase. Performance of tuning indices was also generally poor: year classes are poorly tracked over time by individual surveys, and indices may reflect local patterns in availability or recruitment rather than abundance of the stock. Even surveys which cover the entire range of the stock (NEFSC spring and autumn surveys) exhibit large interannual fluctuations, in part due to domination of indices by incoming year classes which are rarely abundant in surveys in following years, and in part due to availability. The coefficients of variation for parameter estimates obtained from the exploratory VPA were larger than those obtained in the previous assessment (SAW-19), and ranged from 36 to 82%, depending on the age-specific stock size being estimated. That SARC concluded that the precision of the estimates of fishing mortality and stock size was unacceptably low and would provide an unreliable basis for any forecasts.

Fishing mortality

Fishing mortality (F) rates averaged over ages 2-5 have fluctuated above 1.0 without trend from 1984 to

1996 and could have been as high as 2 in some years, based on trends in the exploratory VPA and on catch-curve analyses of survey data in the 1995 assessment.

Stock biomass

Indices of spawning stock biomass have fluctuated widely over time, but have trended downward since 1984. The 1995-1996 levels are the lowest observed in the 1984-1996 exploratory VPA time series and are among the lowest in the 1968-1996 NEFSC spring survey series (Figure B4).

Recruitment

The 1996 index of age 0 abundance from the NEFSC autumn survey is the lowest of the 1984-1996 (age-based) series, and the five most recent years include the four lowest indices of age 0 abundance in the 1984-1996 series. The 1996 index of age 1 abundance from the NEFSC spring survey is the second lowest in the 1984-1996 (age-based) series.

Biological Reference Points

Yield and Spawning Stock Biomass per Recruit

The MAFMC and ASMFC have jointly adopted an F_{max} overfishing definition. Analysis from the SAW-19 assessment indicated that $F_{0.1}$ = 0.141 and F_{max} = 0.236, with yield including both landings and discard. At F_{max}, about 24% of the maximum spawning potential (%MSP) is obtained, while at $F_{0.1}$, 39% MSP is obtained. Yield-per-recruit analyses were not re-evaluated in the current assessment.

Projections of Catch and Stock Biomass

Recent levels of fishing mortality are likely to result in further declines in stock biomass to new record low levels. If F were reduced by 50% (i.e., 34% reduction in exploitation rate), fishing mortality would likely be reduced to below 1.0. This would imply a 34% reduction in catch from the 1996 level of 5,000 mt to 3,300 mt in 1998. Given recent declines in stock biomass and uncertainties in the assessment input data, a reduction in catch to 3,300 mt in 1998 may be insufficient to achieve the target level of fishing mortality. Reversing the decline in stock size will also depend on levels of incoming recruitment, but survey indices indicate that recent year classes have been low.

Conclusions

The results of analyses presented in this report indicate that the scup stock is over-exploited and near record low abundance levels. This conclusion is based on a truncated age structure (less than 1% of the landed fish are older than age 5, on average), estimates of fishing mortality from exploratory VPA and previous survey catch-curve analysis in excess of 1.0, and declining trends in spawning stock biomass as estimated by exploratory VPA and survey indices.

SARC Comments

The SARC discussed at length the poor quality of the input data. Agreement on the uncertainties associated with the data and lack of confidence in the VPA results led the SARC to conclude that an analytical assessment (VPA) would be inappropriate. VPA results can be used to identify data needs and to corroborate other data sources. The SARC noted the potential for under-reporting of historical landings, but the degree is unknown. The SARC concluded that high levels of sampling will be required to characterize commercial catch at age due to the large number of market categories, wide geographical range, and many types of fisheries that prosecute this species. Discards of ages 0-3 from directed and non-directed fisheries are a significant component of the catch at age. However, discards are poorly estimated because sea sampling is not adequate to characterize discards in various components of this fishery. A VPA and catch projection will not be feasible until the quality of the input data, particularly the precision of discard estimates, is significantly improved.

Despite the high degree of imprecision of point estimates in the exploratory VPA, the SARC felt that the general trends and magnitude of the fishing mortality and biomass estimates were useful. A truncated age distribution of the catch at age and declines in survey biomass indices suggest that fishing mortality is well above reference points. Biomass will not rebuild unless the exploitation pattern improves significantly and fishing mortality is reduced.

The use of a constant maturity ogive across years may be problematic when the stock has a truncated age distribution. Age at maturity may have changed in response to the truncated age distribution and decline in biomass.

Mean weights in the stock may not correspond to mean weights in the catch because mean weights in the catch depend on discard rates which may vary annually. More accurate estimates of mean weight at age in the stock may be obtained from research vessel survey data.

Research Recommendations

- Increased and more representative sea and port sampling data from the various fisheries in which scup are landed and discarded is critical to characterize adequately the length composition of both landings and discards. The current level of sampling, particularly of discards, seriously impedes the development of analytic assessment and forecasts of catch and stock biomass for this stock. A pilot study to develop a sampling program to estimate discards should be implemented. This would quantify the advantages to obtaining sea samples from freezer trawlers and other small mesh fleets from which few samples have been collected, and would provide an opportunity for joint industry research programs. Use of port of landing rather than statistical areas to characterize length compositions by market categories should also be examined.

- Additional information on compliance with regulations (e.g., length limits) and hooking mortality is needed to interpret recreational discard data.

- Commercial discard mortality was assumed to be 100%. Studies to better characterize the mortality of scup in different gear types should be conducted to more accurately assess discard mortality.

- Expanded age sampling of scup from commercial and recreational catches is required, with special emphasis on the acquisition of large specimens.

- Further biological studies are needed to examine factors affecting annual availability to research surveys and maturity schedules.

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Table B1. Landings (mt) of scup from Maine through North Carolina, 1979-1996.

Year	Commercial	Recreational	Total
1979	8,584	1,198	9,782
1980	8,424	3,109	11,533
1981	9,856	2,636	12,492
1982	8,703	2,361	11,064
1983	7,794	2,836	10,630
1984	7,769	1,096	8,865
1985	6,726	2,764	9,490
1986	6,918	5,264	12,182
1987	6,069	2,806	8,875
1988	5,728	1,936	7,664
1989	3,716	2,521	6,237
1990	4,318	1,878	6,196
1991	6,867	3,668	10,535
1992	6,002	2,001	8,003
1993	4,463	1,450	5,913
1994	4,151	1,192	5,343
1995	2,894	596	3,490
1996	2,545	1,015	3,560

Table B2. Commercial landings (mt) of scup by state, 1979-1996. One mt was landed in DE in 1995.

Year	ME	MA	RI	CT	NY	NJ	MD	VA	NC	Total
1979	-	782	3,123	91	1,422	2,159	21	397	589	8,584
1980	1	706	2,934	17	1,294	2,310	32	531	599	8,424
1981	-	523	2,959	44	1,595	2,990	9	1,054	682	9,856
1982	-	545	3,202	25	1,473	1,746	2	1,042	668	8,703
1983	-	672	2,583	49	1,103	2,536	13	536	302	7,794
1984	-	540	2,919	32	904	2,217	6	673	478	7,769
1985	-	387	3,583	41	861	1,492	17	74	271	6,726
1986	-	619	2,987	67	893	1,894	14	272	172	6,918
1987	5	529	2,162	301	911	1,816	-	232	113	6,069
1988	9	320	2,833	359	687	1,334	1	127	58	5,728
1989	31	311	1,402	89	603	1,219	1	45	15	3,716
1990	4	443	1,786	165	755	1,005	4	75	81	4,318
1991	15	340	2,902	287	1,223	1,960	15	56	69	6,867
1992	-	398	2,676	193	1,043	1,475	17	73	127	6,002
1993	-	296	1,332	148	729	1,822	10	73	53	4,463
1994	-	112	1,514	142	688	1,455	7	93	139	4,150
1995	-	128	1,048	89	511	1,085	1	20	11	2,893
1996	-	176	764	NA	347	1,141	20	70	27	2,545

Table B3. Commercial landings (mt) of scup by major gear types, 1979-1996. All North Carolina landings in 1990-1996 are assumed to be taken by otter trawls. Midwater pairtrawl landings are combined with other gears in 1994-1996.

Year	Otter trawl	Pair trawl	Floating trap	Pound net	Pots and traps	Hand lines	Other gear	Total
1979	6,387	146	1,305	429	26	215	76	8,584
1980	6,192	160	1,559	194	8	303	8	8,424
1981	7,836	79	1,291	246	49	306	49	9,856
1982	6,563	104	1,514	244	9	226	43	8,703
1983	5,861	398	850	390	8	265	22	7,794
1984	5,617	272	1,266	295	8	287	24	7,769
1985	4,856	417	1,022	229	5	182	15	6,726
1986	5,189	540	630	332	7	208	12	6,918
1987	4,607	237	589	194	237	188	17	6,069
1988	4,142	166	1,054	52	115	155	44	5,728
1989	3,174	89	193	74	104	67	15	3,716
1990	3,205	200	505	60	239	87	21	4,317
1991	5,217	152	988	40	258	182	30	6,867
1992	4,371	94	934	67	303	190	42	6,001
1993	3,865	46	166	24	202	85	74	4,462
1994	3,416	-	331	79	76	97	152	4,151
1995	2,208	-	331	41	146	26	142	2,894
1996	2,088	-	229	6	111	101	10	2,545

Table B4. Summary of sampling in the Northeast Region sea sampling program, 1989-1996. OT = number of trips sampled in which otter trawl gear was used. H1 = first half year; H2 = second half year. SS discard reflects the estimate of discard based on applying ratios of discards to landings by trip, stratified by landings level (< 0.3 mt per trip, > 0.3 mt per trip) to reported weighout landings. Estimates of tonnage reflecting potential discard in the entire fishery are reported in Table B5. (Eleven length measurements from scallop dredges were not used in 1995.)

Year	Trips		Lengths			SS discard	Intensity
	All	OT	H1	H2	Total	(mt)	(mt/100 lengths)
1989	63	61	4,449	2,910	7,359	2,173	30
1990	52	52	2,582	781	3,363	3,877	115
1991	104	91	1,237	1,780	3,017	3,535	117
1992	106	53	1,158	0	1,158	5,749	496
1993	64	29	275	154	429	1,434	334
1994	7	7	99	119	218	773	355
1995	20	18	162	383	556	2,046	368
1996	32	27	1,093	435	1,528	1,423	93

Table B5. Total catch (mt) of scup from Maine through North Carolina, 1984-1996.

Year	Commercial landings	Commercial discards[1]	Recreational landings	Recreational discards[2]	Total catch
1984	7,767	[3] 2,158	1,096	30	11,051
1985	6,723	[3] 4,184	2,764	54	13,725
1986	6,918	[3] 2,005	5,264	87	14,274
1987	6,070	[3] 2,537	2,806	38	11,451
1988	5,726	1,657	1,936	31	9,350
1989	3,711	2,229	2,521	39	8,499
1990	4,318	3,909	1,878	38	10,143
1991	6,868	3,530	3,668	78	14,144
1992	6,001	[4] 5,668	2,001	47	13,717
1993	4,463	1,436	1,450	28	7,378
1994	4,150	807	1,192	37	6,186
1995	2,893	2,057	596	33	5,579
1996	2,545	1,441	1,015	47	5,048

[1]Based on the assumption of 100% mortality of all scup discards from commercial fishing.

[2]Based on the assumption of 15% mortality of all scup discards from recreational fishing.

[3]Estimated using geometric mean ratio of discards to landings at age (numbers), 1989-1993.

[4]Discards for second half of 1992 estimated using geometric mean ratio of discards to landings at age (numbers) for 1989-1993.

Table B6. Summary of the sampling intensity for scup in the commercial and recreational fisheries, 1979-1996.

Year	Commercial fishery				Recreational fishery		
	No. of samples	No. of lengths	Weighout landings (mt)	Sampling intensity (mt/100 lengths)	No. of lengths	Estimated landings (A+B1) (mt)	Sampling intensity (mt/100 lengths)
1979	10	1,250	6,010	481	322	1,198	372
1980	26	3,478	5,870	169	1,263	3,109	246
1981	16	2,005	6,400	319	642	2,068	322
1982	81	9,896	6,470	65	1,057	3,100	293
1983	72	7,860	6,270	80	1,384	3,432	248
1984	60	6,303	6,310	100	943	1,434	152
1985	31	3,058	5,500	180	741	3,282	443
1986	54	5,467	4,960	91	2,580	5,908	229
1987	61	6,491	5,600	86	777	2,980	384
1988	85	8,691	5,250	60	2,156	2,414	112
1989	46	4,806	3,392	71	4,111	3,248	79
1990	46	4,736	3,930	83	2,698	2,007	74
1991	31	3,150	6,340	201	4,230	3,634	86
1992	33	3,260	4,200	129	4,419	2,110	48
1993	23	2,287	4,180	183	2,206	1,341	61
1994	22	2,163	3,188	147	1,374	1,188	86
1995	22	2,487	2,357	95	822	595	72
1996	61	6,544	2,261	35	526	1,015	193

Table B7. Commercial landings and discard at age of scup, ME-VA, 1984-1996 ('000). Assumes landings not sampled by NEFSC weighout have same biological characteristics as weighout landings.

Landings

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	-	2679	5291	6560	5437	1340	490	213	1	-	-	22011
1985	69	3239	5439	7542	2594	343	516	157	-	-	-	19899
1986	-	297	11899	4361	767	75	84	254	5	-	-	17742
1987	-	1662	9890	10256	1666	161	102	14	17	-	-	23768
1988	2	416	7623	9437	2406	58	122	34	-	-	-	20098
1989	-	1483	4887	7053	683	22	69	24	-	-	-	14221
1990	-	245	10079	6609	1002	349	144	-	-	-	-	18427
1991	-	2405	12831	10124	2149	409	193	-	-	-	-	28112
1992	-	1485	10409	3686	3772	1214	136	-	-	-	-	20703
1993	-	226	6347	6826	1486	1141	123	-	-	-	-	16149
1994	-	1051	13399	6211	752	64	23	-	-	-	-	21499
1995	-	2198	8329	2873	883	245	31	7	-	-	-	14565
1996	-	346	6343	1627	747	454	59	-	-	-	-	9576

Discard

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	78	10847	6367	924	21	-	-	-	-	-	-	18237
1985	52773	13093	6534	1060	10	-	-	-	-	-	-	73470
1986	78	1180	14040	602	3	-	-	-	-	-	-	15903
1987	78	6814	12215	1366	5	-	-	-	-	-	-	20478
1988	1552	1698	9242	1339	10	-	-	-	-	-	-	13841
1989	387	8943	13603	813	28	-	-	-	-	-	-	23774
1990	822	8269	17249	2801	-	-	-	-	-	-	-	29141
1991	1794	17231	5397	1733	5	-	-	-	-	-	-	26160
1992	38804	10023	26380	72	-	-	-	-	-	-	-	75279
1993	5386	1549	6960	224	-	-	-	-	-	-	-	14119
1994	6858	3099	3422	74	-	-	-	-	-	-	-	13486
1995	1855	50174	335	108	14	-	-	-	-	-	-	52486
1996	188	2849	5671	654	20	1	-	-	-	-	-	9383

Table B8. Recreational landings and discard at age of scup, Cape Cod to North Carolina, 1984-1996 ('000).

Landings					Age						
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	23	3036	1353	570	182	219	442	86	51	30	66	6057
1985	431	4478	3054	1330	788	441	137	33	-	-	115	10810
1986	538	4353	15570	2617	845	431	87	5	4	57	315	24823
1987	77	2299	4686	1261	824	598	112	-	-	11	46	9914
1988	9	1001	2229	1824	460	216	123	92	20	-	86	6061
1989	311	3978	3371	823	86	235	154	13	-	50	148	9168
1990	169	1352	5091	1102	147	112	36	7	2	3	22	8043
1991	299	4838	3797	3319	700	210	19	-	2	20	68	13272
1992	99	1850	4457	530	672	84	12	6	8	7	30	7755
1993	46	1245	3051	908	25	133	2	2	-	2	7	5651
1994	31	1473	1840	691	95	88	21	6	-	-	-	4245
1995	16	803	1193	200	106	37	3	6	-	-	-	2362
1996	9	580	1735	422	200	117	11	-	-	-	5	3080

Discard

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	2	255	-	-	-	-	-	-	-	-	-	257
1985	40	417	-	-	-	-	-	-	-	-	-	458
1986	100	807	-	-	-	-	-	-	-	-	-	907
1987	12	357	-	-	-	-	-	-	-	-	-	369
1988	2	219	-	-	-	-	-	-	-	-	-	222
1989	24	308	-	-	-	-	-	-	-	-	-	333
1990	36	284	-	-	-	-	-	-	-	-	-	319
1991	31	505	-	-	-	-	-	-	-	-	-	536
1992	17	325	-	-	-	-	-	-	-	-	-	343
1993	8	204	-	-	-	-	-	-	-	-	-	212
1994	4	203	-	-	-	-	-	-	-	-	-	207
1995	4	192	-	-	-	-	-	-	-	-	-	196
1996	4	262	-	-	-	-	-	-	-	-	-	266

Table B9. North Carolina landings at age of scup, 1984-1996 ('000).

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10+	Total
1984	1	12	823	530	356	78	46	38	-	-	-	1884
1985	10	6	1328	154	46	3	4	2	-	-	-	1553
1986	9	4	422	412	237	-	22	83	-	-	-	1189
1987	2	17	62	143	59	16	22	7	1	-	1	330
1988	15	7	86	89	18	-	5	5	-	-	-	225
1989	17	0.5	56	18	2	-	0.2	-	-	-	-	94
1990	-	2	124	172	20	6	5	2	-	0.2	-	331
1991	-	7	125	78	12	0.3	0.4	-	-	-	-	223
1992	21	92	474	51	25	29	2	-	-	0.1	-	694
1993	0.8	4	211	51	14	2	0.7	-	-	-	-	284
1994	-	1	145	147	84	18	16	-	-	-	-	411
1995	-	-	16	5	8	3	0.4	-	-	-	-	32
1996	-	-	-	13	23	15	3	-	-	-	-	54

Table B10. Total catch at age of scup, Maine to North Carolina, 1984-1996 ('000).

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	103	16830	13834	8584	5996	1637	978	337	52	30	66	48446
1985	53324	21234	16355	10086	3438	787	657	192	-	-	115	106190
1986	725	6641	41931	7992	1852	506	193	342	9	57	315	60564
1987	169	11149	26853	13026	2554	775	236	21	18	11	47	54859
1988	1580	3342	19180	12689	2894	274	250	131	20	-	86	40447
1989	739	14713	21917	8707	799	257	223	37	-	50	148	47589
1990	1027	10151	32543	10684	1168	467	185	9	2	3	22	56262
1991	2124	24986	22150	15254	2867	620	212	-	2	20	68	68302
1992	38942	13776	41720	4339	4469	1327	150	6	8	7	30	104774
1993	5441	3228	16569	8008	1754	1277	126	2	-	2	7	36415
1994	6893	5826	18806	7123	931	170	59	6	-	-	-	39815
1995	1875	53368	9872	3186	1010	284	34	13	-	-	-	69642
1996	202	4036	13749	2717	989	588	73	-	-	-	5	22359

Table B11. Mean weight at age of scup landed and discarded in the commercial fishery, ME-VA, 1984-1996 (kg).

Landings					Age						
Year	0	1	2	3	4	5	6	7	8	9	10
1984	-	0.156	0.199	0.296	0.344	0.400	0.766	1.040	1.545	-	-
1985	0.045	0.134	0.213	0.294	0.410	0.517	0.739	1.042	-	-	-
1986	0.075	0.141	0.220	0.352	0.672	0.670	1.012	1.123	1.616	-	-
1987	-	0.137	0.203	0.244	0.406	0.540	0.754	1.220	1.072	-	-
1988	0.028	0.124	0.201	0.263	0.441	0.636	0.713	0.949	1.545	-	-
1989	0.070	0.144	0.189	0.275	0.367	0.651	0.721	1.036	-	-	-
1990	-	0.140	0.189	0.246	0.366	0.517	0.849	-	-	-	-
1991	-	0.187	0.195	0.263	0.389	0.511	0.729	-	-	-	-
1992	-	0.179	0.201	0.325	0.419	0.506	0.860	-	-	-	-
1993	-	0.142	0.199	0.261	0.442	0.510	0.782	-	-	-	-
1994	-	0.203	0.193	0.257	0.425	0.645	0.717	-	-	-	-
1995	-	0.161	0.209	0.295	0.395	0.479	0.724	-	-	-	-
1996	-	0.206	0.200	0.324	0.468	0.554	0.792	-	-	-	-

Discards

Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.033	0.108	0.125	0.198	0.222	-	-	-	-	-	-
1985	0.033	0.108	0.125	0.198	0.222	-	-	-	-	-	-
1986	0.033	0.108	0.125	0.198	0.222	-	-	-	-	-	-
1987	0.033	0.108	0.125	0.198	0.222	-	-	-	-	-	-
1988	0.033	0.108	0.125	0.198	0.222	-	-	-	-	-	-
1989	0.039	0.06	0.111	0.198	0.217	-	-	-	-	-	-
1990	0.026	0.121	0.137	0.187	-	-	-	-	-	-	-
1991	0.057	0.127	0.163	0.207	0.252	-	-	-	-	-	-
1992	0.033	0.078	0.136	0.243	-	-	-	-	-	-	-
1993	0.026	0.106	0.154	0.269	-	-	-	-	-	-	-
1994	0.024	0.068	0.122	0.198	-	-	-	-	-	-	-
1995	0.038	0.037	0.229	0.310	0.331	-	-	-	-	-	-
1996	0.033	0.110	0.169	0.240	0.268	0.532	-	-	-	-	-

Table B12. Mean weight at age of scup landed and discarded in the recreational fishery, Cape Cod to North Carolina, 1984-1996, (kg).

Landings	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.044	0.117	0.266	0.373	0.472	0.557	0.678	0.825	0.912	1.002	1.145
1985	0.038	0.125	0.253	0.340	0.573	0.718	0.913	1.087	-	-	1.673
1986	0.052	0.101	0.234	0.374	0.534	0.654	0.801	0.912	1.003	1.003	1.638
1987	0.029	0.105	0.242	0.381	0.548	0.698	0.737	-	-	1.003	3.808
1988	0.026	0.142	0.240	0.325	0.497	0.663	0.794	1.144	1.099	-	1.532
1989	0.035	0.123	0.234	0.376	0.433	0.653	0.696	0.657	-	1.003	1.332
1990	0.057	0.128	0.208	0.325	0.461	0.567	0.761	0.939	1.088	1.202	1.947
1991	0.064	0.150	0.275	0.361	0.474	0.714	0.675	-	1.003	1.003	1.305
1992	0.092	0.140	0.240	0.373	0.454	0.598	0.804	0.859	1.311	1.003	2.117
1993	0.087	0.135	0.226	0.336	0.460	0.524	0.912	0.827	-	1.026	1.100
1994	0.054	0.180	0.281	0.357	0.467	0.674	0.905	1.430	-	-	-
1995	0.065	0.169	0.291	0.456	0.529	0.532	0.912	1.205	-	-	-
1996	0.095	0.178	0.274	0.419	0.529	0.643	0.881	-	-	-	1.311

Discards

Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.044	0.117	-	-	-	-	-	-	-	-	-
1985	0.038	0.125	-	-	-	-	-	-	-	-	-
1986	0.052	0.101	-	-	-	-	-	-	-	-	-
1987	0.029	0.105	-	-	-	-	-	-	-	-	-
1988	0.026	0.142	-	-	-	-	-	-	-	-	-
1989	0.035	0.123	-	-	-	-	-	-	-	-	-
1990	0.057	0.128	-	-	-	-	-	-	-	-	-
1991	0.064	0.150	-	-	-	-	-	-	-	-	-
1992	0.092	0.140	-	-	-	-	-	-	-	-	-
1993	0.087	0.135	-	-	-	-	-	-	-	-	-
1994	0.054	0.180	-	-	-	-	-	-	-	-	-
1995	0.065	0.169	-	-	-	-	-	-	-	-	-
1996	0.095	0.178	-	-	-	-	-	-	-	-	-

Table B13. Mean weight at age of scup landed in the North Carolina commercial fishery, 1984-1996 (kg).

	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.033	0.033	0.132	0.258	0.349	0.368	0.778	1.066	-	-	-
1985	0.029	0.370	0.133	0.248	0.366	0.481	0.772	1.051	-	-	-
1986	0.036	0.055	0.201	0.410	0.691	-	1.000	1.623	-	-	-
1987	0.034	0.077	0.152	0.263	0.431	0.579	0.713	1.141	1.000	-	-
1988	0.046	0.069	0.170	0.242	0.488	-	0.766	1.207	-	-	-
1989	0.025	0.037	0.122	0.232	0.269	-	0.843	0.962	-	-	-
1990	-	0.155	0.190	0.244	0.408	0.599	0.650	0.846	-	1.096	-
1991	0.158	0.049	0.142	0.246	0.323	0.685	0.672	0.632	-	-	-
1992	0.039	0.078	0.162	0.322	0.395	0.385	0.778	1.236	-	1.096	-
1993	0.031	0.043	0.140	0.291	0.471	0.661	0.798	1.159	-	1.096	-
1994	-	0.154	0.171	0.325	0.475	0.728	0.777	1.200	1.264	-	-
1995	-	-	0.195	0.343	0.485	0.598	0.746	-	-	-	-
1996	-	-	0.206	0.418	0.483	0.562	0.618	-	-	-	-

Table B14. Mean weight at age of scup caught in commercial and recreational fisheries, ME-NC, 1984-1996 (kgs).

	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.036	0.117	0.168	0.288	0.348	0.419	0.727	0.988	0.924	1.002	1.145
1985	0.033	0.116	0.179	0.289	0.446	0.630	0.776	1.050	-	-	1.673
1986	0.050	0.104	0.193	0.351	0.611	0.656	0.915	1.241	1.341	1.003	1.638
1987	0.031	0.112	0.174	0.253	0.452	0.662	0.742	1.194	1.068	1.003	3.727
1988	0.033	0.122	0.169	0.265	0.449	0.658	0.754	1.096	1.099	-	1.532
1989	0.037	0.087	0.147	0.277	0.369	0.653	0.704	0.903	-	1.003	1.332
1990	0.032	0.123	0.164	0.239	0.379	0.530	0.827	0.917	1.088	1.195	1.947
1991	0.058	0.138	0.201	0.278	0.409	0.580	0.724	-	1.003	1.003	1.305
1992	0.033	0.099	0.164	0.329	0.424	0.509	0.854	0.859	1.311	1.004	2.117
1993	0.027	0.121	0.184	0.270	0.445	0.512	0.785	0.827	-	1.026	1.100
1994	0.024	0.124	0.188	0.267	0.434	0.669	0.799	1.430	-	-	-
1995	0.038	0.045	0.220	0.306	0.409	0.487	0.740	0.528	-	-	-
1996	0.037	0.132	0.197	0.319	0.477	0.572	0.798	-	-	-	1.311

Table B15. NEFSC spring and autumn trawl survey mean number of scup per tow at age, 1984-1996.

Spring						Age							
Year	0	1	2	3	4	5	6	7	8	9	10	11	Total
1984	-	5.00	1.55	0.18	0.10	0.05	-	-	-	-	-	-	6.88
1985	-	9.89	1.89	0.17	0.02	0.01	-	-	-	-	-	-	11.98
1986	-	0.85	8.40	0.19	0.02	-	-	-	-	-	-	-	9.47
1987	-	3.76	2.96	1.49	0.61	0.03	0.02	0.02	0.01	-	-	0.01	8.90
1988	-	13.82	6.90	0.14	0.02	0.01	0.02	0.05	-	-	-	0.01	20.98
1989	-	0.66	0.61	0.08	0.01	-	-	-	-	-	-	-	1.36
1990	-	0.14	0.24	0.25	0.15	0.08	0.11	0.03	0.01	-	-	-	1.01
1991	-	8.55	0.57	0.89	0.16	-	-	-	-	-	-	-	10.17
1992	-	4.60	0.71	0.06	0.04	0.05	0.01	-	-	-	-	-	5.46
1993	-	0.50	1.62	0.14	0.09	0.02	-	-	-	-	-	-	2.37
1994	-	1.13	0.09	0.03	-	-	-	-	-	-	-	-	1.24
1995	-	1.84	0.36	0.08	0.04	-	-	-	-	-	-	-	2.35
1996	-	0.35	0.04	0.02	0.01	-	-	-	-	-	-	-	0.42

Autumn

Year	0	1	2	3	4	5	6	7	8	9	10	11	Total
1984	50.29	9.20	0.38	0.07	0.01	-	0.01	-	-	-	-	-	59.96
1985	61.72	11.53	1.10	0.26	0.06	0.05	-	-	-	-	-	-	74.71
1986	70.19	6.58	0.57	-	0.01	-	-	-	-	-	-	-	77.36
1987	50.14	29.85	0.46	0.01	-	-	-	-	-	-	-	-	80.45
1988	47.49	15.95	0.67	0.10	-	-	-	-	-	-	-	-	64.22
1989	176.38	25.92	0.66	0.03	-	-	-	-	-	-	-	-	202.99
1990	77.45	9.21	0.75	0.05	-	-	-	-	-	-	-	-	87.46
1991	151.63	12.51	0.07	0.02	-	-	-	-	-	-	-	-	164.24
1992	25.92	14.51	1.66	0.04	0.02	-	-	-	-	-	-	-	42.15
1993	46.78	9.76	0.32	-	-	-	-	-	-	-	-	-	56.86
1994	39.54	3.92	0.04	0.01	-	-	-	-	-	-	-	-	43.52
1995	33.04	2.61	0.08	0.01	-	-	-	-	-	-	-	-	35.74
1996	24.42	2.86	0.43	0.01	-	-	-	-	-	-	-	-	27.73

Table B16. MADMF spring and autumn trawl survey mean number of scup per tow at age.

Spring	Age					
Year	0	1	2	3	4	Total
1984	-	0.07	4.18	1.95	2.14	8.34
1985	-	55.75	8.08	0.83	0.20	64.86
1986	-	0.15	38.48	3.07	0.20	41.90
1987	-	0.33	2.20	2.61	0.45	5.59
1988	-	-	10.75	2.33	0.30	13.38
1989	-	0.08	125.62	16.40	0.43	142.53
1990	-	3.71	107.96	24.33	2.26	138.26
1991	-	0.58	7.80	17.65	1.82	27.85
1992	-	0.05	12.50	0.84	0.40	13.79
1993	-	0.05	10.01	6.77	0.92	17.75
1994	-	0.24	2.52	2.61	-	5.37
1995	-	42.60	4.58	0.72	0.33	48.23
1996	-	0.38	4.50	0.12	0.04	5.04

Autumn	Age			
Year	0	1	2+	Total
1984	881.8	24.3	1.1	907.2
1985	544.6	33.4	15.4	593.4
1986	692.3	27.9	7.2	727.4
1987	518.8	7.8	2.3	528.9
1988	1255.2	13.3	1.2	1269.7
1989	487.8	39.6	1.2	528.6
1990	1039.0	9.8	3.1	1051.9
1991	1076.7	10.5	0.6	1087.8
1992	2258.6	12.7	1.2	2272.5
1993	947.3	1.6	1.0	949.9
1994	778.4	2.0	0.7	781.1
1995	472.9	8.5	0.4	481.8
1996	958.2	5.6	1.2	965.0

Table B17. RIDFW autumn trawl survey mean number of scup per tow at age.

Autumn	Age							
Year	0	1	2	3	4	5	6	Total
1984	539.56	45.58	3.23	0.92	0.32	0.05	-	589.67
1985	71.42	2.62	0.17	0.04	-	0.02	-	74.27
1986	262.97	54.40	9.25	18.63	1.22	-	-	346.47
1987	289.99	23.52	1.39	-	-	-	-	314.90
1988	759.01	44.68	0.00	0.31	-	-	-	804.00
1989	263.55	61.77	1.53	-	-	-	-	326.85
1990	512.39	14.01	0.91	-	-	-	-	527.31
1991	557.85	97.81	-	-	-	-	-	655.66
1992	976.65	12.05	0.55	2.88	-	-	-	992.13
1993	1234.70	11.03	0.63	-	-	-	-	1246.35
1994	227.63	8.47	0.02	-	-	-	-	236.12
1995	400.77	22.09	0.16	-	-	-	-	423.02
1996	170.10	13.95	0.65	0.01	-	-	-	184.71

Table B18. CTDEP autumn trawl survey, mean number of scup per tow at age.

Autumn	Age							
Year	0	1	2	3	4	5	6	Total
1984	7.47	0.97	0.73	0.49	0.26	0.08	0.02	10.02
1985	23.96	4.65	0.39	0.53	0.19	0.04	0.03	29.80
1986	12.88	9.89	2.68	0.26	0.01	0.01	0.01	25.74
1987	12.57	3.97	1.27	0.61	0.08	0.01	0.02	18.53
1988	31.70	5.88	1.81	0.24	0.05	-	-	39.68
1989	38.71	24.67	1.53	0.11	0.03	-	-	65.05
1990	54.19	6.83	7.57	0.84	0.03	-	0.02	69.47
1991	291.25	17.32	1.67	1.21	0.11	0.02	-	311.57
1992	47.04	29.45	6.39	0.52	0.29	0.04	-	83.72
1993	73.91	1.74	1.09	0.16	0.01	0.01	-	77.04
1994	90.64	1.08	0.52	0.22	0.01	-	-	92.00
1995	32.39	26.60	0.15	0.01	-	-	-	59.14
1996	51.50	8.39	1.53	0.03	-	0.01	-	61.46

Table B19. New York State Department of Environmental Conservation young-of-year index, geometric mean catch per station (August - September); Virginia Institute of Marine Science juvenile fish survey, lower Chesapeake Bay, mean number of scup per tow at age 0.

Year	NY	VIMS
1984	-	-
1985	-	-
1986	-	-
1987	0.12	-
1988	0.24	0.179
1989	0.22	0.909
1990	0.70	0.043
1991	1.47	0.030
1992	1.26	0.163
1993	0.09	0.258
1994	0.69	-
1995	0.18	-
1996	0.13	-

Table B20. New Jersey Division of Fish, Game and Wildlife bottom trawl survey index.

	Age					
Year	0	1	2	3	4	Total
1989	198.97	146.30	6.82	0.05	-	352.14
1990	190.53	153.24	20.82	0.87	-	365.45
1991	681.32	273.69	0.25	0.06	0.01	955.33
1992	643.83	413.83	11.74	0.04	0.02	1069.46
1993	987.49	211.95	8.31	0.01	-	1207.75
1994	305.69	101.34	0.15	-	-	407.17
1995	40.77	86.97	0.58	0.02	-	128.34
1996	15.06	127.95	2.22	0.10	-	145.33

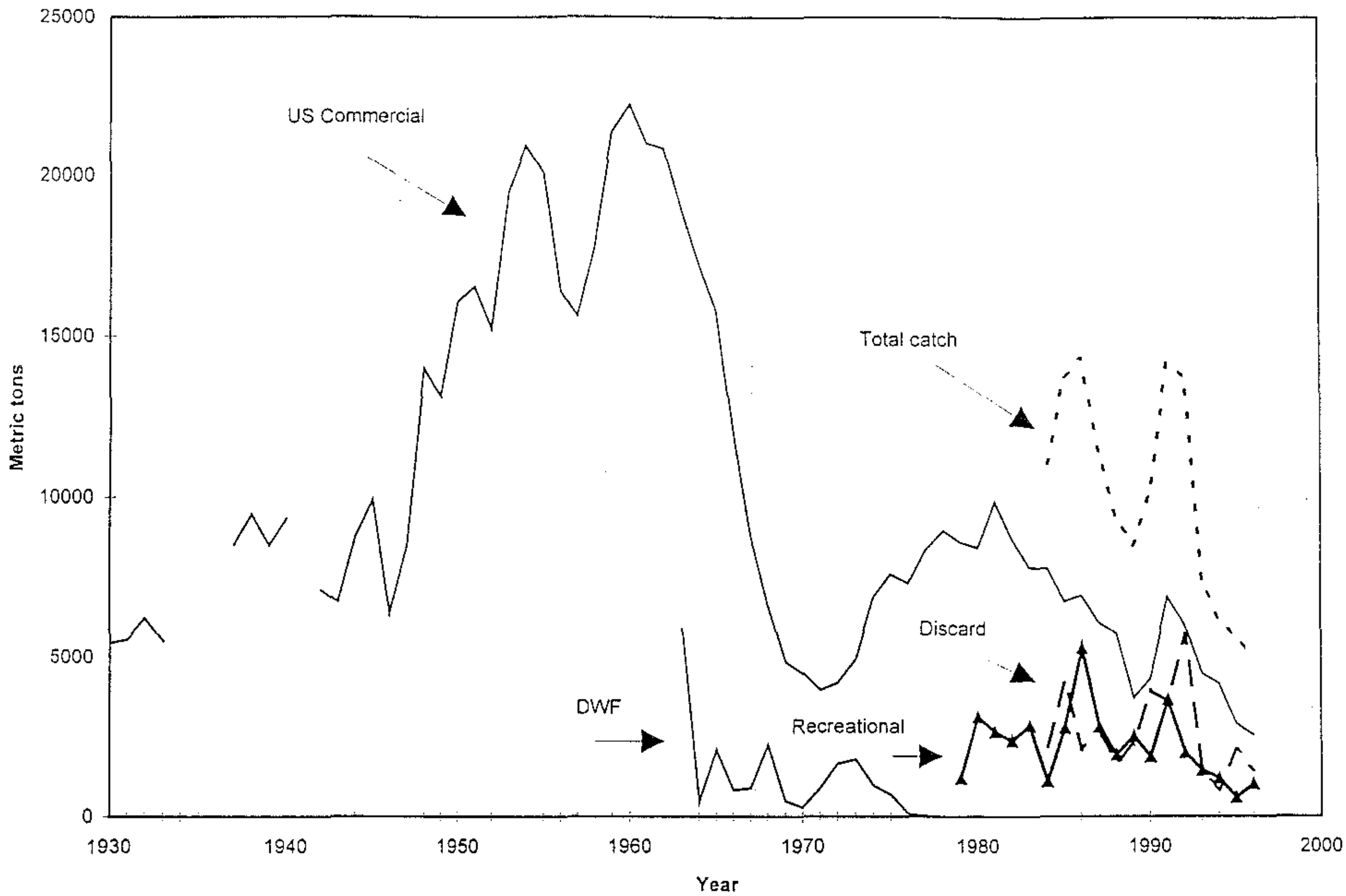

Figure B1. Total catch of scup from Maine through North Carolina, 1930 - 1996, including US commercial landings (does not include North Carolina prior to 1979), distant water fleet (DWF) landings, recreational landings, and commercial and recreational discard combined.

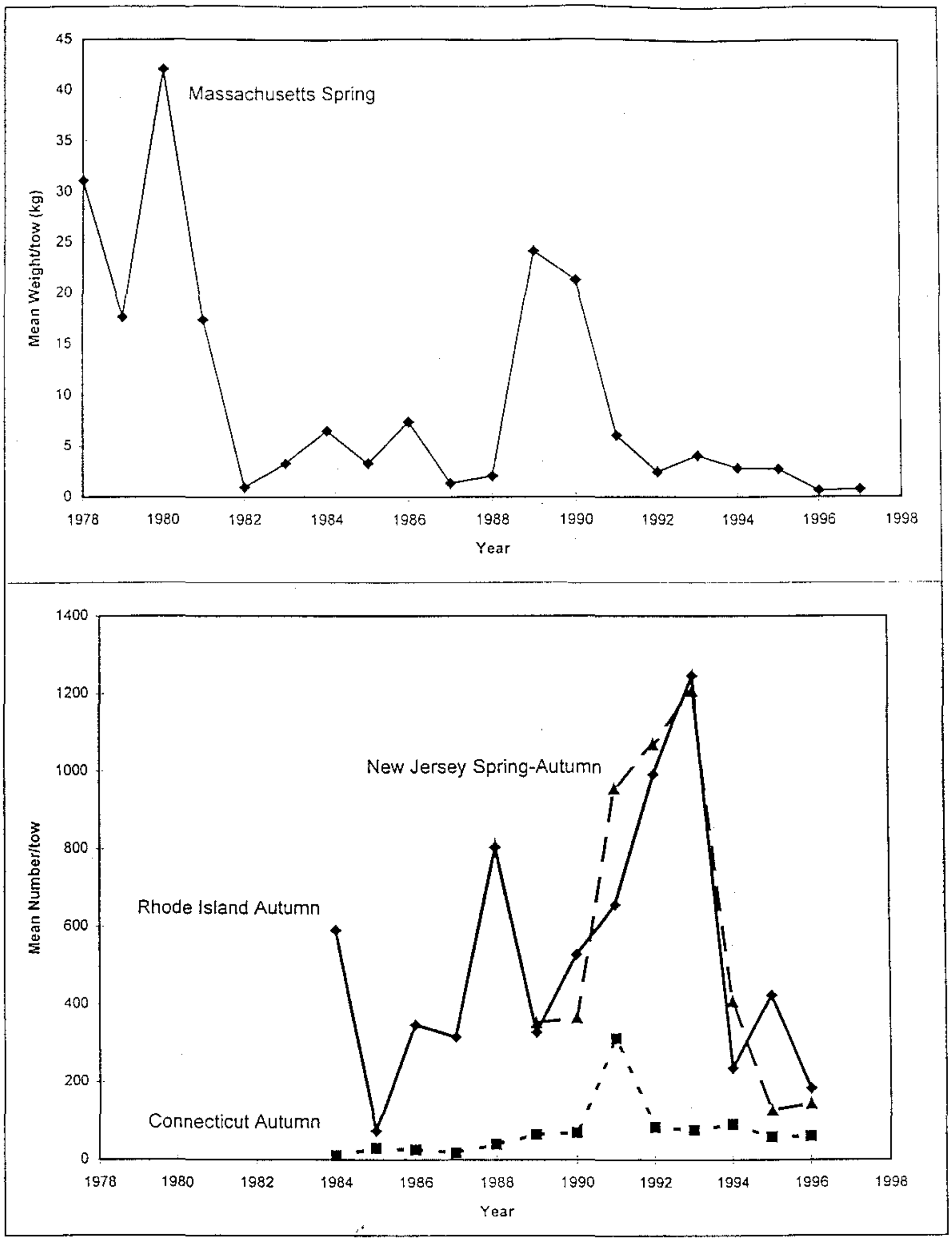

Figure B3. Mean catch-per-tow indices for scup. A. Massachusetts spring research vessel survey, stratified mean kg/tow; B. Rhode Island autumn, Connecticut autumn, and New Jersey spring-autumn research vessel surveys, stratified mean number/tow.

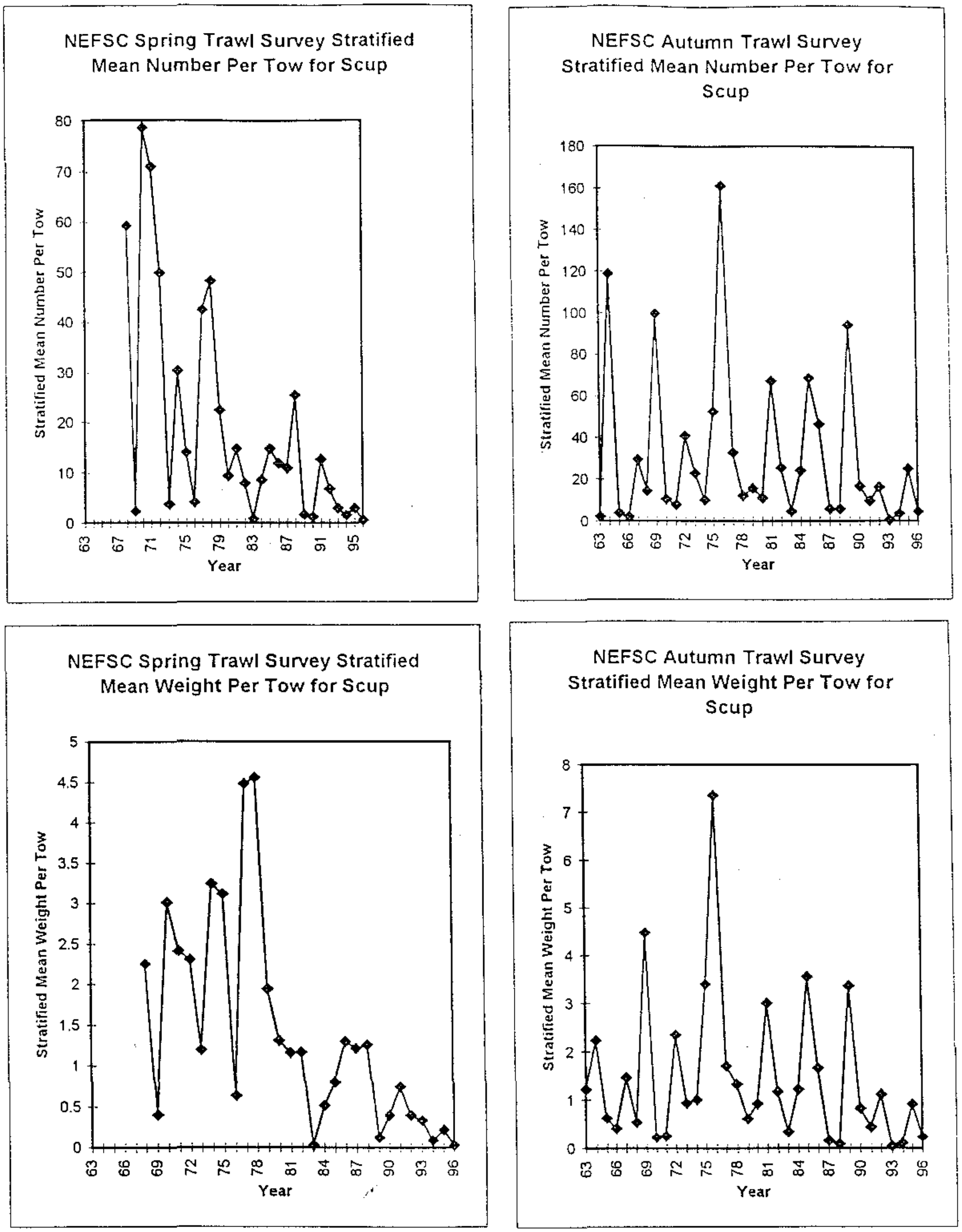

Figure B2. Mean catch-per-tow indices for scup from NEFSC spring and autumn research vessel surveys, offshore strata 1-12, 23, 25, 61-76, stratified mean kg/tow.

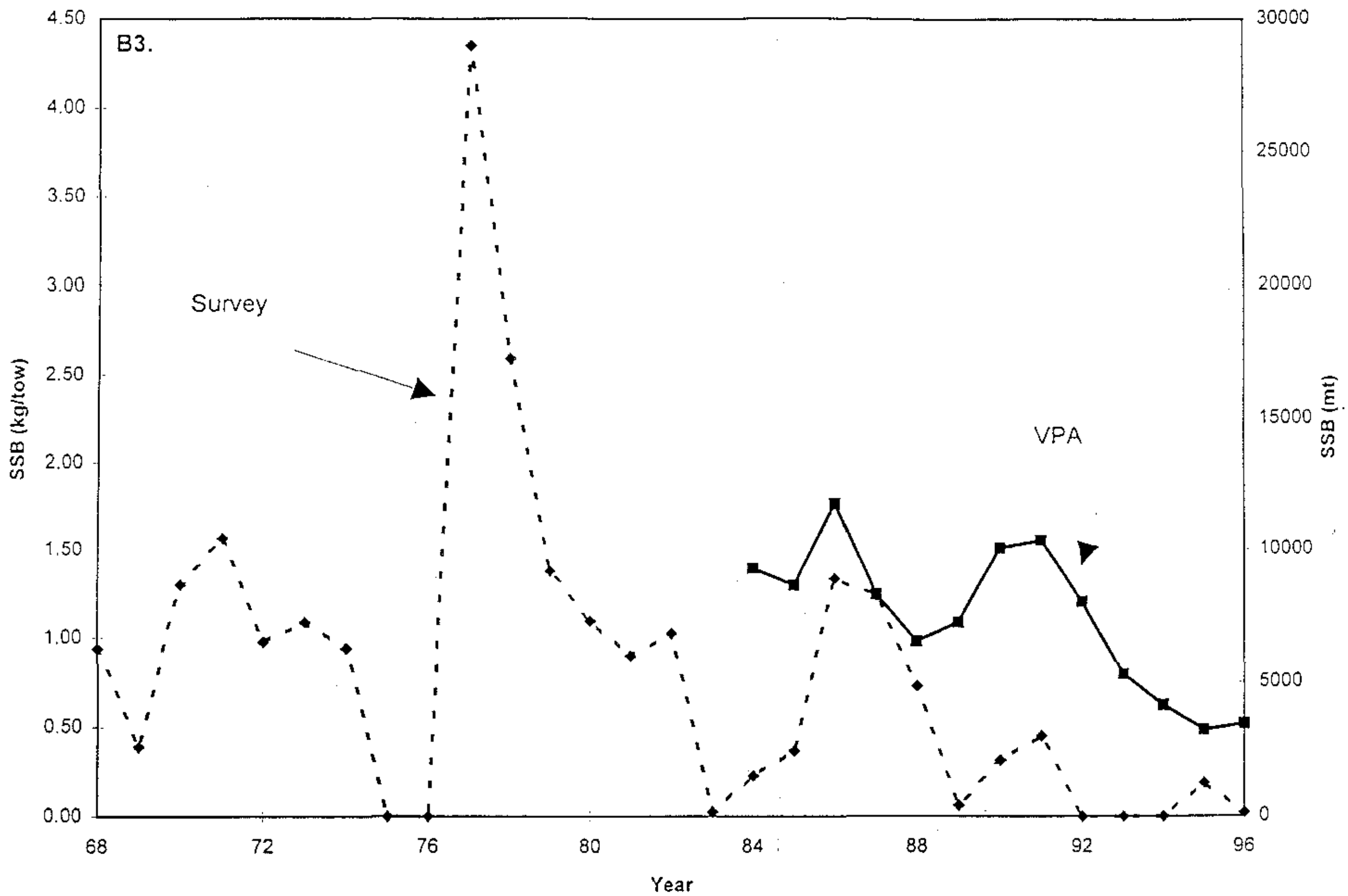

Figure B4. Indices of spawning stock biomass from NEFSC stratified mean catch per tow of at length of mature scup (kg/tow mature fish) and exploratory VPA (mt spawning stock biomass).

C. BLACK SEA BASS

Terms of Reference

a. Assess the status of black sea bass through 1996 and characterize the variability of estimates of stock abundance and fishing mortality rates.

b. To the extent feasible, provide projected estimates of catch for 1997-1998 and SSB for 1998-1999 and characterize the variability of estimates of stock abundance and fishing mortality rates.

Introduction

Black sea bass (*Centropristis striata*) is a demersal species inhabiting the continental shelf from Cape Cod, MA to southern Florida (Kendall and Mercer 1982). The species has been divided into two stock units, north and south of Cape Hatteras, NC (Mercer 1978), although there is some evidence of heterogeneity among the areas comprising the northern stock (Shepherd 1991). The northern stock undergoes seasonal migratory movements, moving northward and inshore to coastal waters during spring, and offshore and south to the edge of the continental shelf during the late autumn. Spawning occurs from May to August, with the season varying latitudinally. Juveniles inhabit coastal and estuarine areas and it is believed that most participate in the seasonal offshore migration during the fall (Able *et al.* 1995).

Sea bass are protogynous hermaphrodites, transforming from females to males between the ages of 2 and 5 (Lavenda 1949, Mercer 1978). Sexual maturity occurs at age 2 for both sexes. Male sea bass reach a maximum length of 60 cm and a maximum age of 15 years.

Black sea bass fisheries in the EEZ were originally to be managed under a summer flounder-scup-black sea bass plan implemented by the Mid-Atlantic Fishery Management Council. However, summer flounder management was initiated first, and a black sea bass plan was not begun until 1993. The results of that initiative are currently in the process of implementation. The plan instituted a number of management measures in 1997 including a minimum fish size, gear restrictions for otter trawl and pot fishermen, and a moratorium on commercial entrants. The plan calls for further restrictions, beginning in 1998, of the management program which will include commercial quotas and recreational possession limits. In addition, several states (MA, RI, NY, CT, and NJ) have historically had size limits on black sea bass. Minimum sizes range from 8 in. in New Jersey and Connecticut, 9 in. in New York, 10 in. in Rhode Island and 12 in. in Massachusetts.

The Fishery

<u>Commercial Landings</u>

Commercial landings north of Cape Hatteras fluctuated around 2,600 mt prior to 1948, in which year landings increased to 6,900 mt (NEFSC 1993). Landings peaked at 9,900 mt in 1952, declined steadily to 600 mt in 1971, and increased to 2,400 mt in 1977 (Table C1). Between 1983 and 1996, commercial landings ranged from 896 to 1,965 mt. Distant water fleet landings were 1,500 mt in 1964, but only ranged from 4 to 33 mt between 1983 and 1987 and have been non-existent since 1988.

The predominate gear types in the commercial fishery are otter trawls, which have accounted for 25-76% of the landings since 1983 (an average of 54%), and fish pots, which accounted for 17-62% (average of 36%) (Table C2). Handlines account for 3-11% of the commercial landings (average 6%), with minor contributions from lobster pots, floating trap nets, and pound nets.

The states of New Jersey and Virginia have accounted for the majority of the landings since 1994 with averages of 41% and 21% of the commercial landings, respectively. Among the remaining states, Massachusetts, Rhode Island, Maryland, and North Carolina each account for 9-14%.

The otter trawl landings are primarily the result of bycatch in the summer flounder and squid fisheries

(Shepherd and Terceiro 1994). The bulk of these fisheries occur during the winter months along the edge of the continental shelf. The pot fishery, which occurs in coastal waters from April to November, is directed towards black sea bass (Eklund and Targett 1991, Shepherd and Terceiro 1994).

Commercial Discards

The NEFSC sea sampling program has collected information on landings and discards in the commercial fishery since 1989. The number of otter trawl trips in which black sea bass were landed and/or discarded are tabulated by year, quarter, and division in Table C3. Between 28 and 67 otter trawl trips per year were sampled in which sea bass were landed or discarded. During 1994-1996, no pot fishery trips were sampled. The reason for discarding was generally undersized fish due to state regulations or marketability.

In addition to sea sampling data, a logbook program initiated in July 1994 has collected data from fishermen on the amount of fish discarded. A subset of vessel trip report (VTR) data was created from trip records where discards for at least one species were recorded (DeLong *et al.* 1997). This subset was evaluated for black sea bass discard information.

Discard data were pooled into half-year periods (January - June, July - December) across all areas for estimation of discards. Ratios of discards to landings from sea samples for the period 1989-1996 were calculated on a half-year basis (Table C4). The discard rate for the second half of 1992 (47.7%) was abnormally large and was replaced by an average of the rates for the second halves of 1991 and 1993. Prior to 1989, an average ratio from 1989-1993 was used as the ratio of discards to landings. For the period 1994-1996, discard ratios were calculated using sea sampling and VTR data. The sea sampling data produced unrealistically high discard ratios compared to previous years (average of 0.653 for 1994-1996 compared to 0.092 for 1989-1993). The expectation was for a decrease in the discard-to-landings ratio due to implementation of several management regulations in the summer flounder fishery, which is a major source of sea bass bycatch. Elimination of several sea sampling trips containing unusually high levels of discards resulted in a ratio similar to historic sea sample ratios and current ratios from VTR data. The VTR data had considerably larger sample sizes per period and ratios which were comparable to historic sea sampling data (Table C5). The logbooks from trawlers accounted for 86-87% of dealer reported landings in 1995 and 1996; logbook requirements were in place for only part of 1994 (Table C6). For that reason, the discard ratios from VTR data were chosen to calculate total discard weight in the trawl fishery for 1994-1996. Sea sampling ratios were used for estimations prior to 1994, as described. The shortcomings of the VTR data included concerns about correct reporting of discards in the logbooks and the high proportion of trips reporting zero sea bass discards (Table C7). In the trawl fishery, 97% of trips reporting some black sea bass landings reported no sea bass discards. This may be a result of misreporting or a reflection of gear regulations and no minimum sizes. A discard mortality of 100% in the trawl fishery was assumed (Rogers *et al.* 1986).

Landings from the pot fishery are primarily from New Jersey and Maryland (80-85%). New Jersey had an 8-in (20 cm) minimum size during 1994-1996 while Maryland had no minimum. SAW-20 accepted that pot fisheries north of New Jersey were primarily shallow water fisheries where discard mortalities approached 0. Data from a trap escape vent experiment conducted during 1994 off Delaware were the only length information available (Black Sea Bass FMP, June 1996). The length frequency suggested that all fish retained in traps would be marketable in states without minimum size restrictions. Therefore, no pot discard losses were assumed south of New Jersey. Discards from the New Jersey pot fishery were estimated using a subset of logbook data collected in New Jersey (Table C5). The ratios of discard to kept were applied to NJ landings in half-year periods.

Estimates of total commercial discards are shown in Table C8. SAW-20 concluded that discards from the commercial hook and line gear would likely be negligible due to the nature of the fishery (targeting larger fish, gear selectivity, etc).

Recreational Landings

Black sea bass is an important recreational species, with the greatest proportion of catches taken in the Mid-Atlantic states (New Jersey to Virginia). Estimates of catch in numbers were obtained from the NMFS Marine Recreational Fishery Statistics Survey (MRFSS) for 1979-1996. The 1979 and 1980 estimates have a higher degree of uncertainty due to different estimation procedures. Estimates were available for three categories: type A - fish landed and available for sampling, type B1 - fish landed but not available for sampling, and type B2 - fish caught and released. Catch estimates for North Carolina north of Cape Hatteras were determined based on the total catch from counties north of Cape Hatteras. Catch estimates in number for 1984-1996, the period covered by this assessment, are presented in Table C9. Landings ranged from 1.8 million in 1984 to 21.7 million in 1986; although the 1986 catch was unusually large, it has been considered legitimate by MRFSS analysts. The 1995 landings of 6.7 million were the highest since 1986. Periodic recreational surveys conducted prior to 1979 suggest that the percentage of recreational landings relative to total landings have been similar to the MRFSS time series (average 52% recreational landings) since the 1960s. The estimated recreational landings (types A and B1) in weight during 1984-1996 ranged between 667 mt and 5,622 mt (Table C1). The recreational landings in 1996 by weight were the highest since 1986.

Recreational Discards

The estimated recreational discards (type B2) in number during 1984-1996 ranged from 1.59 million in 1984 to 7.69 million in 1995 (Table C9). Mortality of black sea bass recreational discards has been estimated as 5% (Bugley and Shepherd 1991) in a shallow water fishery and 27% (Rogers *et al.* 1986) in deeper water. Since most of the recreational catch occurs in the EEZ, 25% mortality was assumed for this assessment. Based on that rate, discard mortality in number ranged from 397,175 in 1984 to 1,923,550 in 1995. Total discards by weight are presented in Table C10 (see section on **Recreational Age Composition** for information concerning calculation of mean weight of discards).

Total Catch

Estimates of total catch of black sea bass are given in Table C10. These estimates include commercial and recreational landings and discards. The total catch during this period varied from a high of 7,823 mt in 1986 (influenced primarily by a high recreational component) to a low of 2,421 mt in 1994. The current catch has increased to 4,287 mt. Except for 1986, the total catch has been relatively stable for the last 13 years.

Sampling Intensity

Length samples of black sea bass were available from both commercial and recreational landings. The sampling intensity for 1983-1996 is summarized in Table C11. In the commercial fishery, annual sampling intensity varied from 40-412 mt per 100 lengths. Length samples were available from North Carolina for 1994-1996. Since that sampling program is independent of NMFS commercial sampling, total sampling intensity was not calculated for that period. In all years except 1993, sampling exceeded the informal criterion of 100 lengths per 200 mt. The temporal and spacial distribution of lengths available for expansion are presented in Table C12 by quarter and NER statistical division. Samples for 1994-1996 were a combination of NER and NC samples and were not available by statistical division.

In the recreational fishery, sampling intensity varied from 37 to 228 mt per 100 lengths. In all years except 1995, sampling exceeded the minimum requirements.

Commercial Age Composition

Age samples for expansion of length data are summarized in Table C13. Numbers and mean weights at age were estimated for 1984-1996 for the commercial landings and discards (Tables C8 and C9). Expanded length frequencies of commercial landings were determined by market category in half-year intervals for all areas combined. The overall expanded length frequencies were assumed to be representative of the total landings and were applied to unsampled landings (general canvas data and unclassified landings). Where samples were available, the length frequencies by market category were expanded using a corresponding age-length key by market category. When commercial age data were not available, the summarized length frequencies by half-year periods were partitioned into ages using age-length keys derived from NEFSC survey data. Age-length keys from spring surveys, and winter surveys when available, were applied to numbers from the first half of the year, and keys from autumn surveys were applied to numbers at length from the second half of the year. Large fish with no associated age-length data were aged using ages from large fish from all surveys pooled into annual keys. This pooling applied to most fish greater than age 7. Landings were predominated by ages 2-4 (Table C14). These ages accounted for an average of 93% of the landings between 1984 and 1996.

Discard length frequency data for otter trawls collected by observers during sea sampling trips were expanded to total discard estimates by season. No samples were available in the first half of 1994, so second half length data was applied. Sample sizes were limited (number of discards measured by season were 1994: 26; 1995: 16 and 86; 1996: 438 and 86). Appropriate NEFSC survey age-length keys were applied to expanded trawl discards at length. Discards at age for 1994-1996 pot fisheries were disaggregated by age using lengths from the 1994 trap experiment and corresponding survey age-length keys. The results (Table C14) indicated that discards ranged in age from 1 to 4 with the majority of the discards at ages 1 and 2.

Commercial Weight at Age

Mean weights at age were calculated from the length-at-age data and length-weight equations derived from NEFSC survey data (SAW-20). Mean weights at age of the landings increased in 1994-1995 for ages 1-4 (Table C15). Mean weights at ages 1 and 2 nearly doubled compared to previous years. Discard mean weights at age were higher in 1994-1996, particularly at ages 0 and 1 (Table C15). Possible reasons include the inclusion of length frequency data from North Carolina, not included in previous years, with no corresponding age samples; increased commercial age samples available in 1996 which changed the age characterization of the length data; changes in management regulations influencing the proportion of discards at age; or density-dependent changes in the population dynamics of the stock. Changes in age 0 mean weight in 1996 was the result of larger age 0 fish in the autumn survey age-length key creating larger fish expanded to age 0 discards.

Recreational Age Composition

NEFSC age-length keys for spring and autumn were applied to the recreational length frequencies for the corresponding half-year periods. The weights at age were determined using annual length frequencies by age and NEFSC length-weight equations.

Length frequencies of kept and discarded black sea bass were available from the New York party boat fishery for 1992-1994, 1995, and 1996 (Table C16). Minimum size in the New York recreational fishery was 9 in (23 cm) during 1995 and 1996. Minimum size varied among states from New Jersey to Massachusetts. An average selection ogive was developed using the New York data and applied to the length frequency according to the minimum size of each state. Using the criteria developed in SAW-20, minimum discard lengths were truncated at 15 cm. An age-length key from NEFSC spring and autumn surveys was applied to the expanded discard length frequency. Survey length-weight equations were used to estimate mean weights at age.

The numbers at age from the recreational landings and discards are presented in Table C17. Recreational landings were dominated by ages 1-3. Young-of-the-year fish were generally absent from the landings. The large landings in 1986 were dominated by the 1985 year class. The discards as calculated were ages 1-3 and were dominated by age 2 fish.

Recreational Weight at Age

Recreational mean weights at age are presented in Table C18. Mean weights of landings at ages 1 and 3 increased in 1995 and 1996, while for other ages they were comparable to previous weights. Discard weights at age increased at age 1 in 1994-1996. Numbers at ages greater than 2 increased the annual variability in weights. Reasons for the increases may be due to changes in the dynamics of the population or age variability in the limited number of survey age samples.

Total Age Composition

The age composition of the catch has been dominated by ages 1-3 (Table C19). During 1994-1996, age 1 fish in the catch-at-age matrix accounted for 24% of the total, while age 2 fish accounted for 32%. Fish greater than age 4 comprised only 5% of the total catch.

Stock Abundance and Biomass Indices

Commercial LPUE

Due to the uncertainty in the effort information provided in logbooks, commercial LPUE (landings per unit effort) was not updated from the previous assessment.

Recreational LPUE

Recreational effort was considered to be all trips which landed black sea bass or in which sea bass was the primary or secondary species sought. LPUE was calculated as number landed divided by number of angler trips per year. The indices (Table C20) show an increasing LPUE since 1984. It was concluded that the nature of the fishery, which effectively targets sea bass habitat, prevents use of an LPUE as an unbiased index of population abundance. A GLM model was not applied to the LPUE values.

Research Vessel Indices

Indices of black sea bass abundance and biomass were calculated from catch-per-tow data of fishery-independent surveys conducted by the NEFSC during winter, spring, and autumn and Massachusetts Division of Marine Fisheries spring and autumn surveys (Table C21).

NEFSC spring survey

Long-term trends in black sea bass abundance were derived from stratified random bottom trawl surveys conducted between Cape Hatteras and Nova Scotia since 1963 (Clark 1978). Prior to 1972, the survey was not conducted in inshore strata. The strata area defined for black sea bass extends from Cape Cod, MA to Cape Hatteras, NC and includes inshore and offshore strata. During the spring period, black sea bass tend to be congregated offshore along the edge of the continental shelf (Shepherd and Terceiro 1993). Total indices show an overall reduction since the mid-1970s. Number-per-tow indices dropped from 7.151 in 1977 to 0.253 in 1994. Indices since 1994, including a preliminary 1997 index, have all been less than 1 fish per tow. Age composition data were only available since 1984. The 1997 index was aged using the fall 1996 age-length key advanced one year. The spring survey catches fish at ages 1-10, with age 1 fish averaging 6 cm in length. The high value for age 2 in 1986 corresponds with the high recreational landings in the same year. However, that year class (1984) did not exhibit a high index at age 3 in 1987. There is no indication of any large pulses of juvenile recruitment during this period. There was an indication of poor recruitment in 1992 and 1993. The overall age composition has remained relatively stable with few fish greater than age 5 (Table C22). An offshore spring survey index since 1968 was calculated for comparison with commercial landings trends.

NEFSC autumn survey

The autumn survey covers the period 1972-1996. The strata used for this survey are the same as for the NEFSC spring survey. The indices peaked in 1977, but have since shown considerable annual variation. During the autumn survey period, sea bass are distributed inshore in coastal and estuarine waters. The affinity of sea bass to structured habitat generally unsuitable for otter trawling may influence the availability of sea bass to the survey gear and subsequently cause significant annual variation in survey indices.

Age data for 1984-1996 includes fish at ages 0-7 (Table C22). Indices suggest above-average recruitment during 1985 and 1986. The majority of sea bass in the survey are less than age 4. The index for age 0 in 1993 indicates a poor 1993 year class, as suggested by the spring survey. However, the year class failure is not indicated by age 1. The juvenile abundance for 1994 appears above average and is also evident as age 1 in the 1995 spring survey. The 1995 autumn index at age 0 was the highest in the time series, but the spring 1996 age 1 index was not high.

NEFSC winter survey

A winter trawl survey was initiated in February 1992 using gear specifically designed to capture flatfish. Indices for 1992-1997 suggest that the gear modification was also effective for capturing black sea bass. With only six years of data it is difficult to determine any trends. The 1994 index was substantially lower than in previous years possibly due to a reduced sample size. The 1994 survey included a large number of 15-minute tows rather than the standard 30-minute tow; the 15-minute tows were not included in the index. The index rose sharply in 1996, but 1997 was the second lowest in the series. The index is composed primarily of fish between ages 1 and 5 (Table C23).

Massachusetts Division of Marine Fisheries spring survey

The MA Division of Marine Fisheries (MADMF) bottom trawl survey has been conducted within state waters from the New Hampshire to Rhode Island state borders since 1978. The strata used in the analysis of black sea bass comprised the area south of Cape Cod and Buzzards Bay. The overall index has declined steadily to a recent low value of 0.09 in 1992. Since the areas covered by this survey include black sea bass spawning grounds, immature fish (primarily age 1) are under-represented in the spring survey. Sea bass up to age 9 have been collected in this survey, although ages 2, 3, and 4 tend to be the most dominant. The survey indicated an above-average index for age 2 fish in 1986, similar to what was shown by the recreational landings data. In the 1993 and 1994 indices, there was a conspicuous absence of age 2 sea bass. No age data were available for the 1994-1996 indices.

Massachusetts Division of Marine Fisheries autumn survey

The strata evaluated from the autumn survey are the same as for the spring survey. The overall autumn index dropped steadily until 1989 and has since remained at a low level. The autumn index is dominated by young-of-the-year sea bass, probably the result of spring/summer spawning in local waters. Recruitment in 1993 was nearly absent, although the 1994 cohort appeared to be above average. The strong 1984 year class was evident in 1985 and 1986. No age data were available for the 1994-1996 indices. Young-of-the-year (YOY) indices (stratified mean number per tow) were developed based on length frequencies of fish <12 cm. The YOY index indicated very high recruitment in 1982-1985, followed by a declining index to a low in 1993. Recent indices have increased, but are still an order of magnitude below levels seen in the early 1980s (Table C24).

Summary of fishery-independent surveys

The five surveys (NEFSC spring, autumn, and winter, and MADMF spring and autumn) all show a decreasing trend in indices over the time series. The NEFSC spring and autumn indices were an order of magnitude higher in the mid 1970s than in the 1990s. The Massachusetts indices were an order of magnitude higher in the early 1980s than currently.

Mortality and Stock Size Estimates

Natural Mortality

A natural mortality rate of 0.2 was assumed based on a maximum age of 15.

Virtual Population Analysis

Tuning

A nonlinear least squares sequential population analysis available in the software ADAPT (Conser and Powers 1990, Gavaris 1988) was used to determine fishing mortality (F) and stock size estimates.

For all years prior to 1993, back-calculated stock sizes for ages 3, 4, and 5 were used to estimate mortality on the oldest age (5). The F at age 6+ was assumed equal to the F at age 5.

Tuning indices used were from the NEFSC spring, autumn, and winter surveys. Spring and winter survey indices at age were compared to stock size at age 1 in January of the survey year; autumn survey indices were compared to stock sizes one year older on January 1 the following year. Iterative re-weighting of the indices was not incorporated in the final run. Approximate coefficients of variation for estimates at ages 2-4 ranged from 44% to 53%, and for survey catchability, coefficients ranged from 29 to 54%.

Exploitation pattern

The exploitation pattern has been variable from year to year, but full recruitment has occurred between ages 3 and 4 since 1984. An average exploitation pattern was calculated as the ratio of the geometric means (1993-1996) of the fishing mortality rates at ages 0-2 to the geometric means of the fishing mortality rates at ages 3-5. The resulting pattern indicates <1% recruitment at age 0, 13% recruitment at age 1, 39% recruitment at age 2, and full recruitment (100%) at ages 3 and older.

Evaluation of VPA adequacy

The SARC believes that an exploratory VPA integrates existing data to produce estimated trends in fishing mortality rates and biomass that are generally indicative of actual trends, but due to gross inadequacies in the input data, the SARC rejects the exploratory VPA as a basis for formal projections. Similar to other assessments in the region, the amount of variance in each component of the catch-at-age matrix has not been estimated. In the case of black sea bass, this amount of variance is believed by the SARC to be unreasonably large. The SARC felt that, overall, undersampling of landings produces a significant source of uncertainty in the development of commercial landings at age. In the case of commercial discard-at-age estimates, sea sampling was not adequate to cover all cells in the stratification scheme (landings by gear and half year) and resulted in significantly different discard estimates than corresponding logbook data. For years before the implementation of the sea sampling program, the discard-at-age matrix was estimated using average observed ratios of discards to landings from later years. Consequently, early estimates of discards do not include any direct observations. Because discard levels appear to be highly variable even between tows on the same sea-sampled trip, typical estimators such as ratios of discards to landings or discards per day fished are highly variable. Identification of specific mechanisms or factors which lead to differences in discard rates is complicated by the wide spatial and temporal range of the component fisheries as well as the operational characteristics of fisheries, e.g., target species and gear type. This combination of variable discard rates within trips and the range of temporal, spatial, and operational characteristics of component fisheries will continue to make accurate characterization of discard levels difficult, even if sampling levels were to increase. The affinity of black sea bass to structured habitat could also result in biased sampling from gear unsuitable for sampling such habitat. Most of the age data was collected using trawls which, in the case of commercial samples, come from a bycatch fishery. The majority of catch occurs in directed fisheries using hook and line (recreational) and fish pots which can target removals from structured habitat. Performance of tuning indices was also generally poor. Year classes are poorly tracked over time by individual surveys, and indices may reflect local patterns in availability or recruitment rather than abundance of the stock. In addition, unique biological characteristics of black sea bass could affect conclusions of traditional age-based assessments. Sexually dimorphic growth coupled with density-dependant rates of sex transitions and potentially sex-specific or ontogenetically differing natural mortality rates could increase the variability of the results.

Fishing mortality

Fishing mortality for fully recruited ages (3-5) has been high throughout the time series (1984-1996) ranging without trend between 0.9 and 2.0. There was no indication of a reduction in F in recent years.

Stock biomass

In general, stock size was relatively stable between 1984 and 1996 (Figure C1). Spawning stock biomass (SSB), including both sexes, has remained constant with the exception of an increase in the terminal year (1996). Although stable during the time series, biomass levels remain low.

Recruitment

Variation in recruitment strength was evident with a strong year class in 1985 and poor recruitment in 1988, 1992, and 1993. The survey indices indicated a 1996 year class of average strength.

Alternative VPA runs

Alternative runs were made to determine the influence of several sources of uncertainty in the catch-at-age data. The first alternative reduced the extremely large recreational catch in 1986. The average catch in 1985 and 1987 was disaggregated using percent at age from the 1986 data. The second alternative VPA used observer discard ratios for 1994-1996 instead of VTR-based ratios to estimate discards from commercial otter trawls. Both runs resulted in an impact on estimates in the immediate years of data changes, but had little effect on terminal year estimates.

Biological Reference Points

Yield per Recruit

Estimates of biological reference points were derived from the Thompson and Bell (1934) model presented in the report of SAW-20. The estimate of F_{max} was 0.32 and of $F_{0.1}$ was 0.18 (Table C26). Partial recruitment was calculated using the GM of Fs for 1993-1996. The partial recruitment vector (1993-1996) decreased from the previous estimates (SAW-20) to include full recruitment at age 3. The percent maximum spawning potential at F_{max} is equivalent to 30% of the maximum.

Projections of Catch and Stock Biomass

Recent levels of fishing mortality are likely to result in further declines in stock biomass. If F were reduced by 50% (i.e., 33% reduction in exploitation rate), fishing mortality would likely be reduced to below 1.0. This would imply a 33% reduction in catch from the 1996 level of 4,100 mt to 2,800 mt in 1998. Given recent declines in stock biomass and uncertainties in the assessment input data, even a reduction in catch to 2,800 mt in 1998 may be insufficient to achieve the target level of fishing mortality. Reversing the decline in stock size will also depend on above-average levels of incoming recruitment, but survey indices indicate that recent year classes have been low.

Summary and Conclusions

The SARC concluded that the stock of black sea bass north of Cape Hatteras, NC was over-exploited and at a low biomass level. Estimated fishing mortality rates have been well above F_{max} since 1984, the first year in the time series considered in this assessment.

The analyses have shown continuous levels of fishing mortality in excess of 1.0. Although landings have been stable at the current level for at least 15 years, the stock is not expected to sustain this level of mortality indefinitely. Current levels of spawning stock biomass have increased due to recent pulses of recruitment, but are expected to decline. Some benefits may accrue from increased mesh size requirements in the summer flounder and scup fisheries, uniform 9-in minimum sizes for recreational and commercial landings, and trap/pot mesh and escape vent requirements.

SARC Comments

The SARC was concerned about the estimation of discards based on limited data. The observer data were not judged adequate in coverage of all gear types (pots and freezer trawlers) and geographic areas to sufficiently characterize the extent of commercial discarding. VTR data provided better coverage of the fishery, but the quality of the discard estimates remains unknown. Regardless of the estimation of discards with either VTR or observer data, the sea sampling data were necessary to characterize the length distribution of the discards. The length data from sea sampling were insufficient to use with any degree of certainty. In addition, the length and age of recreational discards was inadequately sampled. Ages and lengths of total recreational discards were based on a limited number of length samples from New York party boats, disaggregated using survey age-length keys.

There was also concern that the sampling of landings was not reflective of landings by area and gear types. In 1994-1996, the majority of commercial lengths were collected in North Carolina. The SARC questioned whether areas sampled in the NC data were representative of the Mid-Atlantic fisheries. Although the number of length samples from the recreational fishery were near the minimum standards, sample sizes have declined in recent years. Application of survey age-length keys, which were developed with relatively small sample sizes, to recreational landings also increased the uncertainty in the catch-at-age data. The SARC also noted that the natural mortality estimate of 0.2 used in the analysis may be inappropriate given the protogynous reproductive strategy of black sea bass.

The SARC concluded that future development of an age-based assessment for black sea bass cannot be done without adequate levels of sampling of landings and discards in both the commercial and recreational fisheries. This will require at least several years of sampling at appropriate levels to correct the current shortcomings in the black sea bass database.

Research Recommendations

- Sampling should be increased for commercial landings in black sea bass fisheries, specifically the fish pot fisheries in the Mid-Atlantic. Age sampling should be increased across all components of the commercial fishery.

- Sampling should be increased in the recreational fisheries. Age data should be collected from the total catch, and length sampling should be done to characterize size structure of discards. States should sample several party boat trips per year to gather discard and age samples. The trips could also provide the opportunity to sample scup and summer flounder.

- Increased sea sampling to verify information from commercial logbooks would provide better estimates of discards. Sea samples from fish pot trips would be beneficial.

- Alternative population models should be considered, including non-age-based methods.

- A large percentage of the commercial fishery occurs in offshore waters along the edge of the continental shelf. There is virtually no information available about habitat use by black sea bass during their offshore migration. Questions about availability to trawl gear and fish distributions should be addressed.

- Initiating new time series of abundance indices should be considered using alternative survey gear (e.g., fish pots).

- Many aspects of the biology of black sea bass are poorly understood. The implications of sexual dimorphic growth and natural mortality should be considered, as well as the impact on reproduction of removal of large males from the population. Closed areas encompassing natural or artificial reefs should be considered for use as research sites.

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Table C1. Landings (mt) of black sea bass from Maine to Cape Hatteras, NC.

Year	Commercial	Recreational	Foreign	Total
1950	5736	-	-	5736
1951	8361	-	-	8361
1952	9883	-	-	9883
1953	6521	-	-	6521
1954	5141	-	-	5141
1955	5131	-	-	5131
1956	5251	-	-	5251
1957	4320	-	-	4320
1958	5242	-	-	5242
1959	3655	-	-	3655
1960	3102	-	-	5801
1961	2483	-	-	2483
1962	3692	-	-	3692
1963	3798	-	-	3798
1964	3199	-	-	3199
1965	3604	-	-	5690
1966	1652	-	-	1652
1967	1302	-	-	1302
1968	1201	-	-	1201
1969	1199	-	-	1199
1970	1100	-	-	2762
1971	614	-	-	614
1972	760	-	-	760
1973	1161	-	-	1161
1974	1069	-	-	1069
1975	1885	-	-	1885
1976	1690	-	-	1690
1977	2424	-	-	2424
1978	2115	-	5	2115
1979	1875	560	41	2435
1980	1252	1002	14	2254
1981	1129	1062	39	2191
1982	1177	4499	21	5676
1983	1513	1967	14	3480
1984	1965	667	18	2632
1985	1551	1052	33	2603
1986	1901	5622	10	7523
1987	1890	901	4	2791
1988	1879	1241	-	3120
1989	1324	1509	-	2833
1990	1588	1268	-	2856
1991	1272	1887	-	3159
1992	1364	1199	-	2563
1993	1412	2031	-	3443
1994	896	1350	-	2246
1995	925	2592	-	3517
1996	1472	2637	-	4109

Table C2. Black sea bass percent of commercial landings by year and gear type.

Year	Otter trawl	Pots	Handline	Other
1983	67.7	22.8	4.7	4.8
1984	75.6	16.7	3.0	4.7
1985	66.9	17.0	7.0	9.1
1986	60.7	28.5	6.3	4.5
1987	61.5	32.6	3.5	2.4
1988	59.1	33.5	5.2	2.2
1989	51.9	39.4	6.6	2.1
1990	48.7	43.2	6.2	1.9
1991	24.6	61.9	10.7	2.8
1992	37.0	50.8	8.5	3.7
1993	61.8	33.3	2.3	2.6
1994	50.3	38.5	4.5	6.7
1995	38.1	45.5	9.3	7.1
1996	52.9	37.4	6.6	3.1

Table C3. Number of sea sampling trips by year, quarter, and division which caught black sea bass.

1989

Division	Quarter 1	2	3	4	
51	-	1	1	1	3
52	-	1	-	1	2
53	2	9	-	3	14
61	4	5	-	4	13
62	5	2	6	1	14
63	2	-	-	-	2
	13	18	7	10	48

1993

Division	Quarter 1	2	3	4	
51	-	-	-	-	-
52	1	1	-	-	2
53	6	3	-	6	15
61	6	2	-	2	10
62	1	-	-	1	2
63	-	-	-	2	2
	14	6	-	11	31

1990

Division	Quarter 1	2	3	4	
51	-	-	-	-	-
52	-	2	-	-	2
53	2	4	-	2	8
61	8	5	-	2	15
62	3	7	-	3	13
63	1	-	-	-	1
	14	18	-	7	39

1994

Division	Quarter 1	2	3	4	
51	-	-	-	-	-
52	-	-	-	-	-
53	3	1	-	4	8
61	7	2	-	-	9
62	6	1	1	-	8
63	-	-	-	3	3
	16	4	1	7	28

1991

Division	Quarter 1	2	3	4	
51	-	-	-	1	1
52	-	-	-	-	-
53	4	5	-	3	12
61	4	3	-	[illegible]	21
62	5	3	3	[illegible]	15
63	-	-	-	[illegible]	4
	13	11	3	26	53

1995

Division	Quarter 1	2	3	4	
51	1	-	-	-	1
52	-	1	-	-	1
53	1	-	1	3	5
61	4	8	[illegible]	6	24
62	11	5	[illegible]	6	24
63	-	-	-	2	2
	17	14	9	17	57

1992

Division	Quarter 1	2	3	4	
51	2	-	-	-	2
52	2	-	-	-	2
53	6	2	-	3	11
61	14	3	1	3	21
62	13	2	4	3	22
63	4	-	-	1	5
	41	7	5	10	63

1996

Division	Quarter 1	2	3	4	
51	1	1	-	-	2
52	-	-	-	-	-
53	1	4	2	3	10
61	4	6	12	8	30
62	4	9	5	3	21
63	1	2	-	1	4
	11	22	19	15	67

Table C4. Sum of black sea bass kept and discarded (lbs) and ratio of discard to kept by half-year periods from sea sampled otter trawl trips, 1989-1996.

Year	Discard lbs	Kept lbs	Ratio
1989			
1	824	4,648	0.177
2	167	4,575	0.037
1990			
1	547	5,477	0.100
2	71	564	0.126
1991			
1	64	3,055	0.021
2	227	1,397	0.179
1992			
1	1,059	11,651	0.091
2	average 1991 & 1993		0.094
1993			
1	247	2,834	0.087
2	4	518	0.008
1994			
1	227	2,144	0.106
2	164	330	0.498
1995			
1	197	2,224	0.088
2	351	693	0.506
1996			
1	14,450	17,864	0.809
2	106	467	0.228

Table C5. Sum of black sea bass kept (mt) and discarded (mt) as reported in VTR and observer data.

POT	VTR data				
		Discard wt	Kept wt	n (trips)	Ratio
	1994				
	1	0.61	4.88	8	0.126
	2	0.26	2.64	47	0.097
	1995				
	1	0.11	12.25	17	0.009
	2	0.14	31.85	100	0.004
	1996				
	1	0.00	7.16	11	0.000
	2	0.09	1.76	56	0.050
TRAWL	VTR data				
		Discard wt	Kept wt	n (trips)	Ratio
	1994				
	1	4.80	36.98	832	0.130
	2	6.74	24.25	592	0.278
	1995				
	1	1.27	218.95	1686	0.006
	2	0.35	23.75	566	0.015
	1996				
	1	6.69	536.77	2052	0.012
	2	5.56	90.46	1417	0.061
TRAWL	Observer data				
		Discard wt	Kept wt	n (trips)	Ratio
	1994				
	1	0.10	0.97	20	0.106
	2	0.07	0.15	8	0.498
	1995				
	1	0.09	1.01	31	0.088
	2	0.16	0.31	26	0.506
	1996				
	1	6.55	8.10	33	0.809
	2	0.05	0.21	34	0.228

Table C6. Proportion of landings (Maine to Virginia) reported in logbook data, 1994-1996.

Year/Gear	MT	% of total
1994[1]		
Trawl	61.2	14.55
Pot	7.5	2.26
1995		
Trawl	242.7	87.33
Pot	44.1	10.43
1996		
Trawl	627.2	85.88
Pot	8.9	16.37

[1] Logbooks in 1994 were not required for the entire year.

Table C7. Proportion of VTR trips reporting black sea bass landings with no discards among trips with reported discards of other species.

	Pot		Trawl	
Year	Pct.	No.	Pct.	No.
1994				
1	62.5%	8	96.3%	828
2	72.3%	47	98.5%	581
1995				
1	76.5%	17	95.9%	1682
2	100.0%	11	97.3%	566
1996				
1	57.1%	56	95.0%	2044
2	69.0%	100	96.7%	1411

Table C8. Commercial bycatch and discard estimates (mt) for otter trawl and pot fisheries, 1984-1996. Bycatch is weight caught. Pot discards estimated assuming 50% mortality.

	Discard		Discard mortality		
Year	Trawl	Pot	Trawl	Pot	Total
1984	168.3	12.5	168.3	6.2	174.5
1985	119.8	12.5	119.8	6.2	126.0
1986	131.8	22.0	131.8	11.0	142.8
1987	131.8	18.0	131.8	9.0	140.8
1988	125.2	21.0	125.2	10.5	135.7
1989	93.6	24.0	93.6	12.0	105.6
1990	83.4	30.4	83.4	15.2	98.6
1991	32.0	46.3	32.0	23.1	55.1
1992	124.4	45.0	124.4	22.5	146.9
1993	55.6	26.1	55.6	13.1	68.7
1994	62.8	13.0	62.8	6.5	69.3
1995	2.2	22.4	2.2	11.2	13.4
1996	13.3	4.4	13.3	2.2	15.5

Table C9. MRFSS black sea bass landed (A + B1 in 000s) and release (B2 in 000s) estimates, Maine to Cape Hatteras, NC.

Year	A + B1	B2	% B2
1984	1880.6	1588.7	45.7
1985	3770.6	2701.3	41.7
1986	21747.2	7114.4	24.6
1987	2935.7	2134.2	42.1
1988	2949.3	4965.7	62.7
1989	4285.5	2174.7	33.6
1990	3919.9	5196.4	57.0
1991	5237.4	5529	51.3
1992	3556.6	4112.8	53.6
1993	5539.9	2753.6	33.2
1994	3410.6	3963.9	53.8
1995	6705.3	7694.2	53.4
1996	5038.4	5044.8	50.0

Table C10. Catch (mt) of black sea bass from Maine to Cape Hatteras, NC. Discard mortality for trawls = 100%, pots = 50%, and hook and line = 25%.

	Landings			Discards		Total
Year	Commercial	Recreational	Foreign	Recreational	Commercial	catch
1984	1,965	667	18	34	175	2,859
1985	1,551	1,052	33	66	126	2,828
1986	1,901	5,622	10	147	143	7,823
1987	1,890	901	4	66	141	3,002
1988	1,879	1,241	-	137	136	3,393
1989	1,324	1,509	-	69	106	3,008
1990	1,588	1,268	-	135	99	3,090
1991	1,272	1,887	-	143	55	3,357
1992	1,364	1,199	-	153	147	2,863
1993	1,412	2,031	-	96	69	3,608
1994	896	1,350	-	112	69	2,427
1995	925	2,592	-	205	13	3,735
1996	1,472	2,637	-	165	16	4,290

Table C11. Summary of sampling intensity for black sea bass in the commercial and recreational fisheries, 1984-1996.

	Commercial			Recreational		
Year	No. lengths	Landings (mt)	Sample intensity (mt/100 lengths)	No. lengths	Landings (A+B1, mt)	Sample intensity (mt/100 lengths)
1984	3841	1965	1.95	953	667	1.43
1985	2509	1551	1.62	1887	1052	1.79
1986	2922	1901	1.54	3400	5622	0.60
1987	1545	1890	0.82	1087	901	1.21
1988	1376	1879	0.73	1058	1241	0.85
1989	883	1324	0.67	4096	1509	2.71
1990	1142	1588	0.72	2739	1268	2.16
1991	735	1272	0.58	2654	1887	1.41
1992	605	1364	0.44	2560	1199	2.14
1993	300	1412	0.21	1601	2031	0.79
1994	[1]3166	896	3.53	1559	1350	1.15
1995	[1]3233	925	3.50	1136	2592	0.44
1996	[1]5295	1472	3.60	1374	2637	0.52

[1]Includes NC length samples.

Table C12. Number of black sea bass commercial lengths by year, quarter, and division.

1984

Division	Quarter 1	2	3	4	
51	-	-	-	-	-
52	-	-	-	-	-
53	-	220	-	182	402
61	115	627	100	100	942
62	1426	530	-	88	2044
63	453	-	-	-	453
	1994	1377	100	370	3841

1985

Division	Quarter 1	2	3	4	
51	-	-	-	-	-
52	-	-	-	-	-
53	178	169	-	-	347
61	417	-	200	367	984
62	188	63	98	69	418
63	760	-	-	-	760
	1543	232	298	436	2509

1986

Division	Quarter 1	2	3	4	
51	-	-	-	-	-
52	-	-	-	-	-
53	-	-	95	315	410
61	490	200	200	279	1169
62	772	494	-	-	1266
63	77	-	-	-	77
	1339	694	295	594	2922

1987

Division	Quarter 1	2	3	4	
51	-	-	-	-	-
52	-	-	-	-	-
53	-	267	82	-	349
61	222	100	-	-	322
62	223	210	110	106	649
63	225	-	-	-	225
	670	577	192	106	1545

1988

Division	Quarter 1	2	3	4	
51	-	-	-	1	1
52	-	-	-	-	-
53	-	95	-	-	95
61	-	-	-	106	106
62	851	324	-	-	1175
63	-	-	-	-	0
	851	419	-	107	1377

1989

Division	Quarter 1	2	3	4	
51	-	-	-	-	-
52	-	-	-	-	-
53	-	100	-	-	100
61	-	101	-	-	101
62	682	-	-	-	682
63	-	-	-	-	-
	682	201	-	-	883

1990

Division	Quarter 1	2	3	4	
51	-	-	-	-	-
52	-	-	-	-	-
53	-	-	-	-	-
61	-	-	-	-	-
62	942	-	-	200	1142
63	-	-	-	-	-
	942	-	-	200	1142

1991

Division	Quarter 1	2	3	4	
51	-	-	-	-	-
52	-	-	-	-	-
53	-	224	-	-	224
61	-	-	-	-	-
62	511	-	-	-	511
63	-	-	-	-	-
	511	224	-	-	735

1992

Division	Quarter 1	2	3	4	
51	-	-	-	-	-
52	-	-	-	-	-
53	99	106	-	-	205
61	-	-	-	-	-
62	400	-	-	-	400
63	-	-	-	-	-
	499	106	-	-	605

1993

Division	Quarter 1	2	3	4	
51	-	-	-	-	-
52	-	-	-	-	-
53	-	-	-	-	-
61	-	-	-	-	-
62	300	-	-	-	300
63	-	-	-	-	-
	300	-	-	-	300

	Quarter 1	2	3	4	
1994	2549	465	-	152	3166
1995	1817	623	494	354	3288
1996	1798	994	1208	1295	5295

*1994-1996 data not available by division; includes NC.

Table C13. Number of black sea bass ages from commercial and survey sampling by season. Commercial samples stratified by market category.

Commercial	Jan-Jun						Jul-Dec					
Year	Ex-small	Small	Med	Large	Jumbo	Uncl.	Ex-small	Small	Med	Large	Jumbo	Uncl.
1984	-	-	-	-	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	-	-	-	-	-
1986	-	-	-	-	-	-	-	-	-	-	-	-
1987	-	-	-	-	-	-	-	-	-	-	-	-
1988	-	25	25	43	-	-	-	-	-	-	-	-
1989	-	-	-	25	-	-	-	-	-	-	-	-
1990	-	25	25	26	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	-	-	-	-	-
1993	-	-	-	-	-	-	-	-	-	-	-	-
1994	-	-	45	25	-	-	-	-	-	-	-	-
1995	-	-	50	25	-	53	-	65	68	75	-	-
1996	-	152	199	100	17	-	-	249	150	136	55	109

Survey

	Winter	Spring	Autumn
1984	-	54	52
1985	-	82	110
1986	-	119	92
1987	-	152	88
1988	-	156	83
1989	-	87	87
1990	-	76	142
1991	-	63	122
1992	189	128	78
1993	61	61	73
1994	40	58	67
1995	158	57	127
1996	335	64	63

Table C14. Commercial landings and discard at age (00s) for black sea bass from Cape Cod to North Carolina, 1984-1996. Otter trawl discard mortality assumed as 100% and pot/trap discard mortality assumed as 50%.

Landings (00s)	Age											
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	-	2672	11912	28600	15921	1328	370	219	7	2	-	61031
1985	-	298	11266	17133	11766	1897	1070	375	183	43	20	44051
1986	-	2017	53434	10586	2015	215	171	18	55	5	-	68516
1987	-	-	20146	32424	4945	1396	218	79	-	-	-	59208
1988	-	3305	30802	31052	7565	1868	-	-	-	-	-	74592
1989	-	239	9569	12818	7565	1187	353	-	-	-	-	31731
1990	-	13	10727	35775	5791	767	-	-	-	-	-	53073
1991	-	654	32468	8610	3305	3525	63	-	-	-	-	48625
1992	-	20	31632	20946	4924	64	38	-	-	-	-	57624
1993	-	902	41450	14926	828	-	2	-	-	-	-	58108
1994	-	885	4606	18284	5188	4619	1879	592	310	620	-	36983
1995	-	3467	11434	10599	2190	161	25	-	-	-	-	27876
1996	-	6680	22497	16040	6231	2132	991	218	7	-	-	54796

Discards (00s)

	Otter trawl						Pot			
	Age						Age			Discard
Year	0	1	2	3	4	Total	1	2	Total	total
1984	663	8175	10981	-	-	19819	679	196	875	20694
1985	16974	11593	7158	-	-	35725	744	173	917	36642
1986	11803	8237	5222	-	-	25262	1503	241	1744	27006
1987	1950	12147	7438	-	-	21535	610	346	956	22491
1988	2831	11177	8074	-	-	22082	1906	183	2089	24171
1989	2988	4168	7108	-	-	14264	1105	397	1502	15766
1990	1153	9501	4100	-	-	14754	2157	17	2174	16928
1991	1394	7416	511	-	-	9321	4515	445	4960	14281
1992	5275	3915	2297	-	-	11487	2952	270	3222	14709
1993	-	274	5696	-	-	5970	1654	76	1730	7700
1994	223	4074	967	539	-	5803	742	-	742	6545
1995	11	51	65	18	2	147	250	262	512	659
1996	4	170	680	94	-	948	252	-	252	1200

Table C15. Commercial landings and discard mean weight at age (kg) for black sea bass from Cape Cod to Cape Hatteras, 1984-1996.

Landings	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
1984	-	0.122	0.178	0.261	0.456	0.839	1.183	0.834	1.290	1.722	-
1985	-	0.104	0.167	0.253	0.491	0.875	1.267	0.854	1.590	1.951	2.372
1986	-	0.101	0.162	0.404	0.585	0.978	1.232	1.190	1.595	1.722	-
1987	-	-	0.200	0.327	0.529	0.768	1.066	1.107	-	-	-
1988	-	0.112	0.182	0.285	0.382	0.440	-	-	-	-	-
1989	-	0.106	0.186	0.306	0.445	0.714	0.834	-	-	-	-
1990	-	0.083	0.197	0.315	0.501	0.701	-	-	-	-	-
1991	-	0.107	0.160	0.277	0.495	0.615	1.069	-	-	-	-
1992	-	0.113	0.189	0.274	0.517	0.998	1.106	-	-	-	-
1993	-	0.143	0.207	0.294	0.499	-	-	-	-	-	-
1994	-	0.295	0.313	0.419	0.434	0.508	1.102	1.560	1.807	1.810	-
1995	-	0.272	0.293	0.375	0.528	0.806	1.181	-	-	-	-
1996	-	0.237	0.376	0.520	0.656	0.738	0.729	0.721	1.096	-	-

Discards	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.004	0.044	0.120	-	-	-	-	-	-	-	-
1985	0.003	0.028	0.114	-	-	-	-	-	-	-	-
1986	0.003	0.043	0.177	-	-	-	-	-	-	-	-
1987	0.007	0.074	0.130	-	-	-	-	-	-	-	-
1988	0.006	0.026	0.117	-	-	-	-	-	-	-	-
1989	0.003	0.018	0.120	-	-	-	-	-	-	-	-
1990	0.004	0.033	0.126	-	-	-	-	-	-	-	-
1991	0.014	0.033	0.112	-	-	-	-	-	-	-	-
1992	0.004	0.060	0.117	-	-	-	-	-	-	-	-
1993	-	0.075	0.094	-	-	-	-	-	-	-	-
1994	0.011	0.084	0.177	0.206	-	-	-	-	-	-	-
1995	0.047	0.095	0.171	0.254	0.364	-	-	-	-	-	-
1996	0.041	0.111	0.138	0.181	-	-	-	-	-	-	-

Table C16. Black sea bass recreational fishery selection based on New York party/charter boat samples.

Length (cm)	1992-1994 n = 1156 % discard	1995 n = 484 % discard	1996 n = 975 % discard	Ave. discard with 9-in minimum
8	1.00	-	-	-
9	1.00	-	-	-
10	0.80	-	-	-
11	0.75	-	-	-
12	0.75	-	-	-
13	0.50	-	-	-
14	0.60	-	-	-
15	0.25	1.00	-	-
16	0.67	1.00	1.00	1.00
17	0.70	1.00	1.00	1.00
18	0.76	0.91	1.00	1.00
19	0.93	1.00	0.90	0.95
20	0.67	0.90	0.87	0.95
21	0.55	0.88	0.82	0.89
22	0.34	0.55	0.55	0.85
23	0.20	0.33	0.15	0.55
24	0.10	-	0.05	0.24
25	0.03	0.06	0.03	0.03
26	-	-	0.01	0.05
27	-	-	-	-
28	-	-	0.02	-
29	-	-	0.03	-
30	-	-	0.06	-
31	-	-	-	-
32	-	-	-	-

Table C17. Recreational landings (A+B1) and discard (B2) at age (00s) for black sea bass from Cape Cod to Cape Hatteras, 1984-1996. Discard mortality of 25% assumed.

Landings (00s)	Age											
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	62	4176	5825	7449	644	66	169	14	6	14	-	18425
1985	75	5088	18269	8209	4561	863	547	62	29	2	1	37706
1986	-	32210	136599	35369	7498	2117	2197	176	708	221	377	217472
1987	-	1430	14808	10850	914	218	912	18	15	-	147	29312
1988	-	2935	14542	8625	2170	826	250	15	121	1	7	29492
1989	14	1437	25273	13046	2134	339	418	60	55	58	15	42849
1990	-	5175	15074	15070	2770	857	186	5	21	-	41	39199
1991	19	1796	29178	12686	6039	2181	261	24	69	81	35	52369
1992	44	1172	18027	12580	3192	296	180	22	28	26	-	35567
1993	-	3914	34740	11612	4554	351	161	12	41	7	-	55392
1994	15	3046	5876	20216	3986	793	105	-	-	-	-	34037
1995	1873	18771	26482	16860	2668	390	-	-	-	-	-	67044
1996	45	9244	21476	13959	3060	1209	852	124	101	212	7	50289
Discards (00s)	**Age**											
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	-	3750	188	34	-	-	-	-	-	-	-	3972
1985	-	4951	1532	27-	-	-	-	-	-	-	-	6753
1986	-	14842	2944	-	-	-	-	-	-	-	-	17786
1987	-	2321	2944	7-	-	-	-	-	-	-	-	5335
1988	-	1-125	21-1	188	-	-	-	-	-	-	-	12414
1989	-	1951	3416	69	-	-	-	-	-	-	-	5436
199-	-	7546	5225	22-	-	-	-	-	-	-	-	12991
1991	6	5485	76-8	146	-	-	-	-	-	-	-	13245
1992	-	3199	6565	518	-	-	-	-	-	-	-	1-282
1993	-	27-3	3732	449	-	-	-	-	-	-	-	6884
1994	-	7223	11-9	1359	-	-	-	-	-	-	-	9691
1995	1293	16913	1-29	-	-	-	-	-	-	-	-	19235
1996	-	7598	5-14	-	-	-	-	-	-	-	-	12612

Table C18. Recreational landings and discard mean weight at age (kg) for black sea bass from Cape Cod to Cape Hatteras, 1984-1996.

Landings	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.026	0.115	0.230	0.415	0.816	1.114	1.282	1.154	1.290	1.722	-
1985	0.016	0.070	0.163	0.288	0.593	0.793	1.236	0.921	1.290	1.917	2.469
1986	-	0.083	0.194	0.391	0.684	0.999	1.341	1.200	1.531	1.832	2.369
1987	-	0.081	0.171	0.355	0.564	0.868	1.392	1.140	1.370	-	2.444
1988	-	0.094	0.252	0.442	0.519	0.693	1.164	1.184	1.265	1.878	2.223
1989	0.012	0.075	0.207	0.378	0.555	0.837	1.242	1.334	1.500	1.906	2.127
1990	-	0.091	0.179	0.340	0.553	0.684	1.179	1.128	1.529	-	2.460
1991	0.050	0.079	0.171	0.329	0.519	0.658	1.413	1.213	1.571	2.337	2.237
1992	0.083	0.083	0.211	0.362	0.568	0.994	1.322	1.176	1.290	1.898	-
1993	-	0.106	0.213	0.358	0.601	0.927	1.383	1.253	1.469	1.818	-
1994	0.016	0.101	0.233	0.377	0.546	0.809	1.093	-	-	1.717	-
1995	0.037	0.139	0.239	0.505	0.886	0.876	-	-	-	-	-
1996	0.042	0.180	0.294	0.535	0.690	0.721	0.754	0.750	0.795	0.968	0.659
Discards	**Age**										
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.016	0.078	0.177	0.379	0.390	-	-	-	-	-	-
1985	0.016	0.075	0.150	0.216	0.338	-	-	-	-	-	-
1986	-	0.070	0.148	0.296	0.294	-	-	-	-	-	-
1987	-	0.067	0.165	0.323	0.358	-	-	-	-	-	-
1988	0.016	0.083	0.212	0.461	0.332	-	-	-	-	-	-
1989	-	0.078	0.153	0.240	0.213	-	-	-	-	-	-
1990	-	0.056	0.163	0.357	0.703	-	-	-	-	-	-
1991	0.050	0.067	0.133	0.317	0.470	-	-	-	-	-	-
1992	-	0.075	0.164	0.396	0.338	-	-	-	-	-	-
1993	-	0.076	0.180	0.189	0.358	-	-	-	-	-	-
1994	-	0.110	0.182	[illegible]	-	-	-	-	-	-	-
1995	0.067	0.107	0.155	0.386	-	-	-	-	-	-	-
1996	-	0.111	0.162	0.459	0.418	-	-	-	-	-	-

Table C19. Total catch at age (00s) and mean weight at age (kg) for black sea bass from Cape Cod to Cape Hatteras, 1984-1996.

Total catch	Age										
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	725	19,453	29,102	36,083	16,565	1,395	539	232	13	15	-	104,122
1985	17,050	22,674	38,399	25,612	16,327	2,760	1,617	437	211	45	24	125,156
1986	11,803	58,809	198,439	45,955	9,513	2,333	2,367	194	763	226	377	330,779
1987	1,950	16,508	45,682	43,344	5,860	1,614	1,130	98	15	-	147	116,348
1988	2,831	29,448	55,702	39,865	9,735	2,694	250	15	121	1	7	140,669
1989	3,001	8,900	45,764	25,933	7,926	1,526	772	60	55	58	15	94,010
1990	1,154	24,393	35,143	51,066	6,075	1,624	186	5	21	-	41	119,708
1991	1,419	19,866	70,209	21,441	10,963	5,706	324	24	69	81	35	130,137
1992	5,319	11,259	58,791	34,044	5,791	360	218	22	28	26	-	115,858
1993	-	9,447	85,694	26,986	5,382	351	161	12	41	7	-	128,081
1994	239	15,970	12,557	40,398	9,174	5,412	1,984	592	310	620	-	87,256
1995	3,189	39,452	39,273	27,478	4,859	551	25	-	-	-	-	114,827
1996	52	23,944	49,667	30,093	9,291	3,341	1,844	342	108	212	66	118,959

Mean weight at age (kg)	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.006	0.077	0.166	0.293	0.470	0.852	1.214	0.853	1.290	1.722	-
1985	0.003	0.049	0.154	0.264	0.519	0.849	1.256	0.864	1.549	1.949	2.377
1986	0.003	0.073	0.172	0.394	0.663	0.997	1.333	1.199	1.536	1.830	2.369
1987	0.007	0.073	0.176	0.334	0.534	0.782	1.329	1.113	1.370	-	2.444
1988	0.006	0.062	0.192	0.320	0.413	0.518	1.164	1.184	1.265	1.878	2.223
1989	0.003	0.042	0.184	0.342	0.474	0.741	1.055	1.334	1.500	1.906	2.127
1990	0.004	0.052	0.176	0.323	0.527	0.692	1.179	1.128	1.529	-	2.460
1991	0.014	0.049	0.161	0.308	0.508	0.631	1.347	1.213	1.571	2.337	2.237
1992	0.001	0.067	0.190	0.308	0.545	0.994	1.284	1.176	1.290	1.898	-
1993	-	0.095	0.201	0.321	0.584	0.927	1.383	1.253	1.469	-	-
1994	0.005	0.112	0.254	0.387	0.483	0.552	1.101	1.560	1.807	1.810	-
1995	0.021	0.091	0.249	0.455	0.724	0.856	1.181	-	-	-	-
1996	0.042	0.173	0.315	0.526	0.667	0.732	0.741	0.731	0.814	0.968	0.659

Table C20. Recreational catch per angler, 1984-1996. Effort defined as trips targeting or catching black sea bass among interviewed trips.

Year	Catch/angler	N
1984	3.16	871
1985	4.78	1,956
1986	5.44	3,727
1987	4.66	1,261
1988	4.48	1,603
1989	4.81	4,189
1990	5.54	3,659
1991	6.39	4,508
1992	6.08	4,254
1993	4.79	2,672
1994	5.84	2,827
1995	8.04	2,807
1996	6.64	2,729

Table C21. NEFSC and Massachusetts DMF spring and autumn bottom trawl survey mean number and weight (kg) per tow. NEFSC strata set = 1-12, 25, 61-76 offshore and strata set 1-56 inshore. Massachusetts strata set = 11-21.

	NEFSC					Massachusetts			
	Mean number per tow			Mean weight per tow		Mean number per tow		Mean weight per tow	
Year	Spring	Autumn	Spring offshore	Spring	Autumn	Spring	Autumn	Spring	Autumn
1968	-	-	0.699	-	-	-	-	-	-
1969	-	-	1.245	-	-	-	-	-	-
1970	-	-	0.118	-	-	-	-	-	-
1971	-	-	0.262	-	-	-	-	-	-
1972	-	0.917	0.818	-	0.092	-	-	-	-
1973	0.912	1.596	0.969	0.290	0.090	-	-	-	-
1974	2.571	1.075	2.399	0.855	0.255	-	-	-	-
1975	2.016	2.570	2.149	0.796	0.161	-	-	-	-
1976	2.945	3.326	3.161	0.897	0.178	-	-	-	-
1977	7.151	8.872	8.213	1.223	0.156	-	-	-	-
1978	3.806	0.796	4.593	0.767	0.075	-	79.635	-	0.873
1979	4.311	1.651	5.258	1.153	0.066	0.988	74.554	0.728	1.111
1980	2.436	0.662	2.996	0.338	0.060	0.997	93.509	0.787	0.979
1981	0.871	1.128	1.076	0.290	0.172	2.233	63.842	1.334	0.314
1982	0.229	3.065	0.283	0.143	0.082	2.158	398.247	0.903	1.482
1983	0.578	0.802	0.715	0.124	0.072	4.291	215.300	1.387	1.180
1984	0.227	2.381	0.278	0.095	0.153	1.597	202.234	0.673	1.601
1985	0.447	2.641	0.537	0.140	0.093	1.208	197.966	0.573	0.900
1986	1.907	2.631	2.352	0.491	0.085	1.567	79.558	0.735	0.851
1987	1.171	0.814	1.418	0.343	0.138	0.705	34.826	0.203	0.329
1988	1.957	0.678	2.361	0.416	0.050	0.420	60.690	0.200	0.416
1989	0.764	0.855	0.757	0.143	0.057	1.067	6.610	0.354	0.054
1990	0.835	2.267	0.997	0.137	0.248	0.698	4.285	0.449	0.090
1991	0.937	1.889	1.131	0.066	0.113	0.381	9.459	0.428	0.053
1992	1.640	1.396	1.993	0.324	0.076	0.087	10.899	0.037	0.081
1993	1.399	0.313	1.728	0.188	0.048	0.112	1.073	0.081	0.007
1994	0.253	1.860	0.313	0.074	0.078	0.219	45.073	0.190	0.170
1995	0.596	2.612	0.735	0.139	0.115	0.465	32.657	0.153	0.198
1996	0.366	0.781	0.447	0.118	0.073	0.154	23.692	0.089	0.148
1997	0.711	-	-	-	-	-	-	-	-

Table C22. Mean catch per tow (numbers) at age for NEFSC spring and autumn research vessel surveys, 1983-1997.

Spring	Age											
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	0.000	0.006	0.053	0.082	0.051	0.010	0.013	-	-	-	-	0.227
1985	0.000	0.080	0.091	0.127	0.124	0.019	0.008	-	-	-	-	0.447
1986	0.000	0.146	1.182	0.502	0.063	0.000	-	-	0.002	-	-	1.907
1987	0.000	0.023	0.673	0.343	0.063	0.027	0.040	-	-	-	-	1.171
1988	0.000	0.401	0.703	0.620	0.127	0.079	0.020	-	0.008	-	-	1.957
1989	0.000	0.199	0.409	0.101	0.026	-	-	-	0.015	-	-	0.764
1990	0.000	0.355	0.199	0.229	0.030	0.014	-	-	-	-	-	0.835
1991	0.000	0.625	0.210	0.059	0.035	0.004	-	-	-	-	-	0.937
1992	0.000	0.320	0.564	0.635	0.095	0.007	-	-	-	-	0.011	1.640
1993	0.000	0.000	0.800	0.564	0.028	-	-	-	-	-	-	1.399
1994	0.000	0.005	0.029	0.141	0.062	0.011	0.004	-	-	0.001	-	0.253
1995	0.000	0.149	0.278	0.147	0.023	-	-	-	-	-	-	0.596
1996	0.000	0.062	0.087	0.126	0.043	0.021	0.015	-	-	-	-	0.366
1997	0.000	0.012	0.246	0.406	0.026	0.021	-	-	-	-	-	0.711
Autumn	Age											
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1983	0.531	0.065	0.138	0.050	0.020	-	-	-	-	-	-	0.800
1984	0.212	2.071	0.070	0.012	0.005	-	-	-	-	-	-	2.380
1985	1.961	0.494	0.108	0.030	0.020	0.011	-	-	-	-	-	2.640
1986	1.521	0.958	0.137	0.020	-	-	-	-	-	-	-	2.630
1987	0.135	0.298	0.279	0.060	0.012	0.030	0.002	-	-	-	-	0.810
1988	0.229	0.370	0.059	0.008	0.007	-	-	-	-	-	-	0.680
1989	0.428	0.189	0.218	0.027	0.001	-	-	-	-	-	-	0.860
1990	0.399	1.169	0.609	0.064	0.014	-	-	0.011	-	-	-	2.270
1991	0.276	1.190	0.408	0.013	0.002	-	-	-	-	-	-	1.890
1992	0.678	0.299	0.409	0.008	-	-	-	-	-	-	-	1.400
1993	0.000	0.137	0.171	0.002	0.001	-	-	-	-	-	-	0.310
1994	1.142	0.578	0.042	0.093	0.004	-	-	-	-	-	-	1.860
1995	2.006	0.460	0.100	0.034	0.005	-	-	-	-	0.007	-	2.610
1996	0.350	0.228	0.194	0.002	0.012	-	-	-	-	-	-	0.790

Table C23. Mean number per tow at age from NEFSC winter bottom trawl survey 1992-1997. Offshore strata 1-12,25,61-76; inshore strata 1-56.

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1992	-	0.658	3.321	1.157	0.120	0.010	-	-	-	-	-	5.286
1993	-	0.179	1.366	2.094	0.369	0.120	-	-	-	-	-	4.108
1994	-	0.207	0.256	0.410	0.044	-	-	-	-	-	-	0.930
1995	-	0.447	1.499	0.385	0.105	0.005	-	-	-	-	-	2.440
1996	-	1.904	3.042	0.924	0.074	0.027	0.039	0.029	0.003	0.005	0.020	6.070
1997	-	0.211	0.305	0.678	0.070	0.065	-	-	-	-	-	1.327

Table C24. Black sea bass age 0 (< 12 cm) stratfied mean number per tow, regions 1-5, fall MADMF surveys, 1978-1996.

Year	Number per tow
1978	42.8
1979	40
1980	51.8
1981	34.3
1982	216.7
1983	117
1984	109.9
1985	107.3
1986	42.9
1987	19.2
1988	33.7
1989	3.6
1990	2.3
1991	5.3
1992	6.1
1993	0.6
1994	24.6
1995	17.8
1996	12.9

Table C25. Black sea bass yield and stock size per recruit.

```
Proportion of F before spawning:  .3000
Proportion of M before spawning:  .5300
Natural Mortality is Constant at:  .200
Last age is a True Age;
Original age-specific PRs, Mats, and Mean Wts from file:
==> yprin.dat
```

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Stock	Average Weights Catch
1	0.1280	1.0000	0.1000	.064	.117
2	0.3910	1.0000	0.6500	.177	.254
3	1.0000	1.0000	0.9000	.321	.422
4	1.0000	1.0000	1.0000	.524	.615
5	1.0000	1.0000	1.0000	.798	.767
6	1.0000	1.0000	1.0000	1.254	1.102
7	1.0000	1.0000	1.0000	1.132	1.181
8	1.0000	1.0000	1.0000	1.437	1.363
9	1.0000	1.0000	1.0000	1.931	1.389
10	1.0000	1.0000	1.0000	1.997	1.997
11	1.0000	1.0000	1.0000	2.163	2.163
12	1.0000	1.0000	1.0000	2.380	2.380
13	1.0000	1.0000	1.0000	2.575	2.575
14	1.0000	1.0000	1.0000	2.747	2.747
15	1.0000	1.0000	1.0000	2.898	2.898

```
Summary of Yield per Recruit Analysis for:
Black Sea Bass YPR 1997

  Slope of the Yield/Recruit Curve at F=0.00: -------->      3.570
  F level at slope=1/10 of the above slope (F0.1): --->       .178
    Yield/Recruit corresponding to F0.1: --->      .2527
  F level to produce maximum Yield/Recruit (Fmax): --->       .324
    Yield/Recruit corresponding to Fmax: --->      .2717
```

Listing of Yield per Recruit Results for:
Black Sea Bass YPR 1997

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	PCNTMSP
	.000	.00000	.00000	5.2420	4.1171	3.5873	3.5863	1.0000
	.100	.24749	.20343	4.2141	2.4646	2.6010	2.0410	.5691
F0.1	.178	.35485	.25275	3.7280	1.7852	2.1392	1.4169	.3951
	.200	.37784	.25945	3.6207	1.6470	2.0377	1.2912	.3600
	.300	.45704	.27142	3.2437	1.2026	1.6831	.8905	.2483
Fmax	.324	.47191	.27175	3.1719	1.1260	1.6161	.8222	.2293
	.400	.51057	.26990	2.9845	.9391	1.4416	.6568	.1831
	.500	.54958	.26433	2.7951	.7709	1.2667	.5098	.1421
	.600	.57956	.25779	2.6497	.6567	1.1339	.4114	.1147
	.700	.60352	.25130	2.5340	.5752	1.0294	.3421	.0954
	.800	.62326	.24520	2.4391	.5145	.9446	.2914	.0812
	.900	.63991	.23959	2.3595	.4679	.8743	.2529	.0705
	1.000	.65422	.23445	2.2912	.4310	.8149	.2229	.0622
	1.100	.66672	.22974	2.2318	.4012	.7638	.1990	.0555
	1.200	.67778	.22543	2.1794	.3766	.7194	.1795	.0501
	1.300	.68768	.22147	2.1327	.3559	.6803	.1634	.0456
F97	1.400	.69662	.21781	2.0905	.3382	.6456	.1498	.0418
	1.500	.70477	.21441	2.0522	.3229	.6145	.1383	.0386
	1.600	.71224	.21125	2.0171	.3095	.5864	.1283	.0358

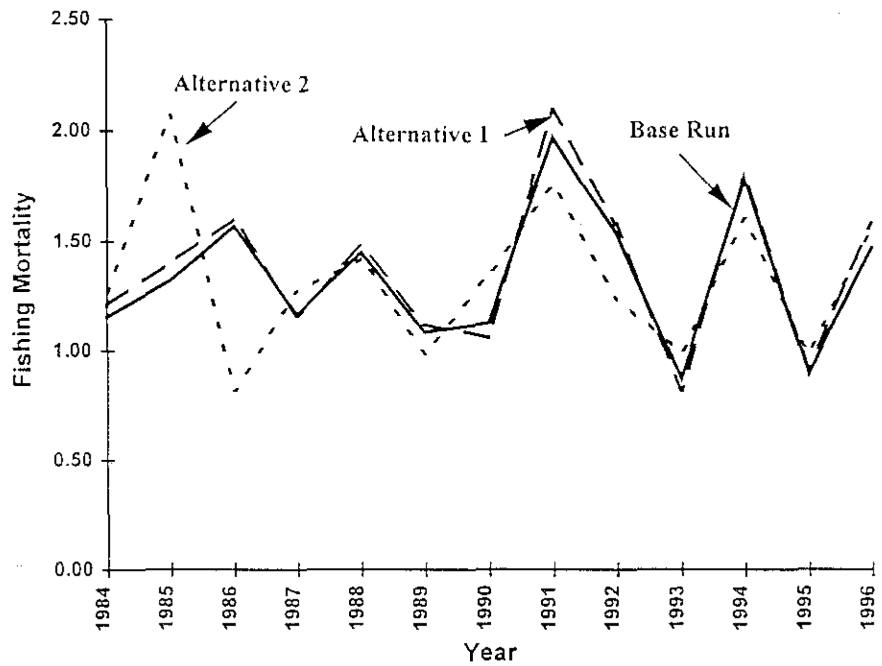

Figure C1. Black sea bass fishing mortality on fully recruited ages, 3-5. Alternative 1 with observer discard ratio; alternative 2 with modified 1986 recreational catch data.

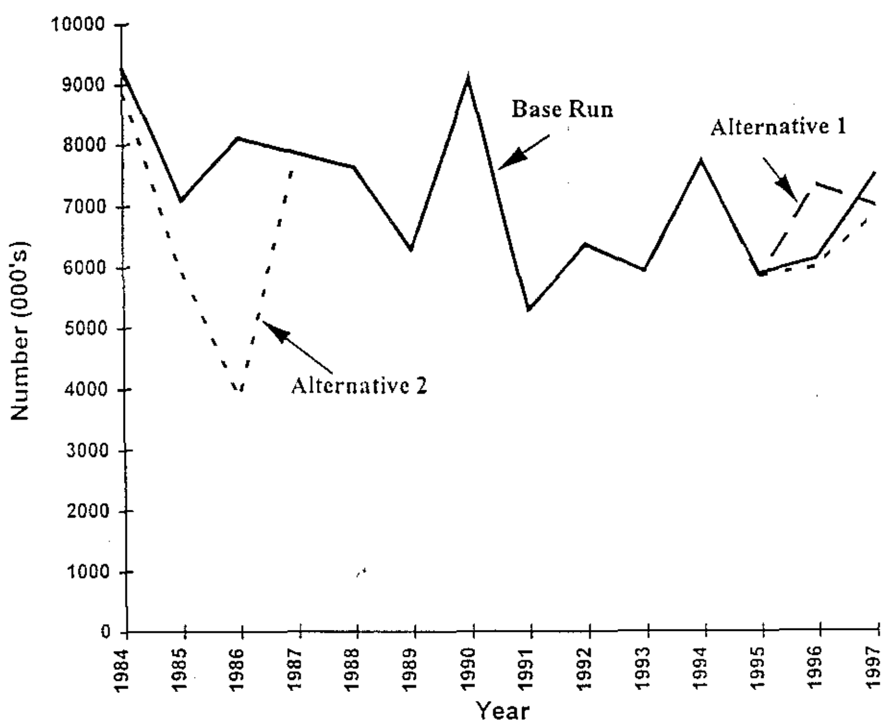

Figure C2. Black sea bass stock size. Numbers (000s) on January 1. Alternative 1 with observer discard ratio; alternative 2 with modified 1986 recreational catch data.

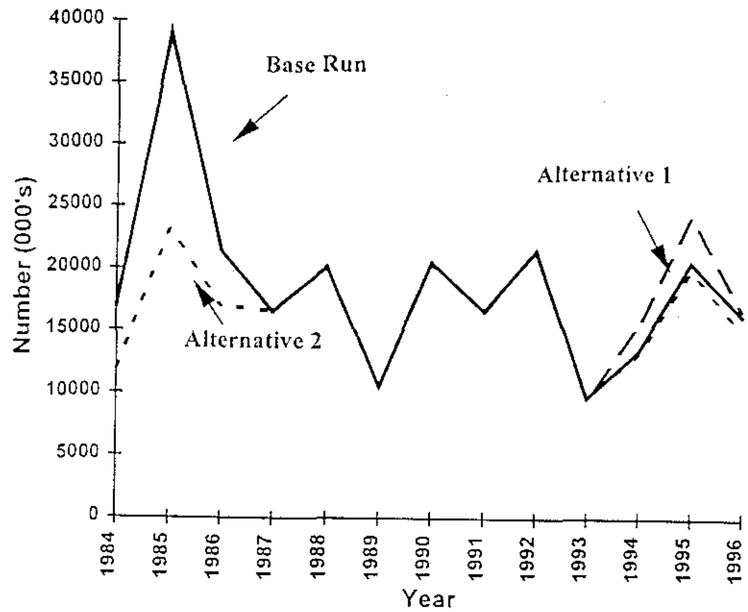

Figure C3. Black sea bass recruitment at age 1, numbers (000s) on January 1. Alternative 1 with observer discard ratio; alternative 2 with modified 1986 recreational catch data.

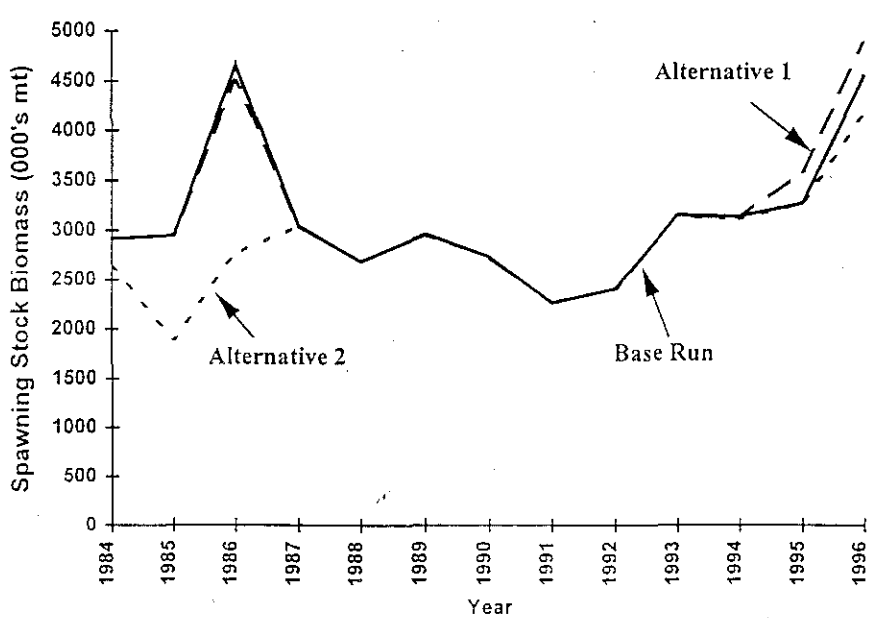

Figure C4. Black sea bass spawning stock biomass. Alternative 1 with observer discard ratio; alternative 2 with modified 1986 recreational catch data.

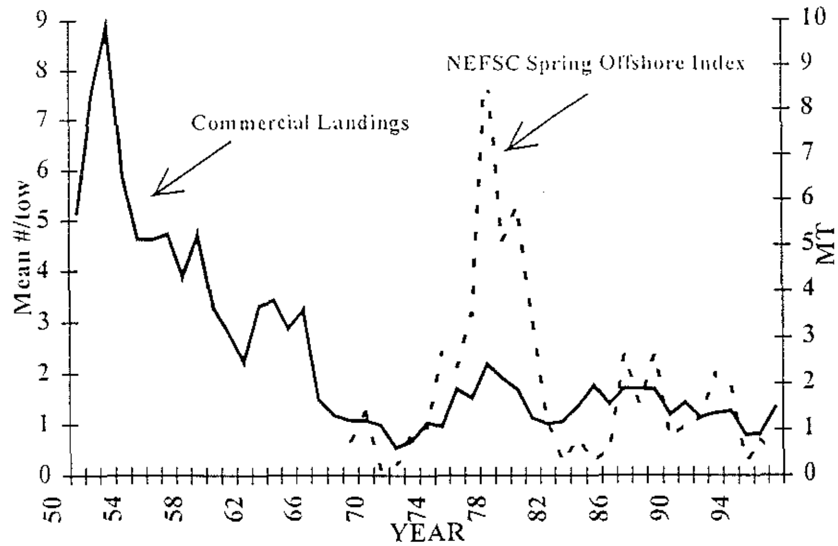

Figure C5. Relationship between NEFSC spring offshore survey index and black sea bass commercial landings.

D. GULF OF MAINE NORTHERN SHRIMP

Terms of Reference

a. Evaluate trends in stock abundance and fishing mortality rates for Gulf of Maine northern shrimp and characterize the variability of estimates.

b. Assess stock status relative to biological reference points based on yield-per-recruit (e.g., $F_{0.1}$, F_{max}) and percent maximum spawning potential (e.g., $F_{20\%}$).

c. Advise on long-term management strategies and overfishing definitions.

Introduction

Northern shrimp (*Pandalus borealis*) (also referred to as pink shrimp) are distributed discontinuously throughout boreal waters of the North Atlantic, North Pacific, and Arctic Oceans (Shumway *et al.* 1985). In the Gulf of Maine, northern shrimp are considered to comprise a unit stock. They inhabit soft mud bottom at depths of 9 to 329 m, most commonly in the cold waters of the southwest Gulf of Maine (Haynes and Wigley 1969, Schick 1991). Temperature is an important factor in ontogenetic rates and reproductive success for this stock because the Gulf of Maine is the southern limit of the distribution of this species in the North Atlantic (Shumway *et al.* 1985).

Northern shrimp are protandrous hermaphrodites. In the Gulf of Maine, they generally spawn as males in their second year, then begin to transform into mature females in their third year. Ovigerous females move to coastal waters in late autumn to spawn. Eggs hatch inshore, and juveniles migrate to deeper offshore waters as they begin to mature (Shumway *et al.* 1985).

A directed otter trawl fishery for northern shrimp began in coastal waters of Maine and Massachusetts during winter months in the 1930s and further developed in the 1940s, but inshore availability of shrimp soon declined (Scattergood 1952). An inshore winter fishery resumed in the late 1950s and steadily expanded to offshore areas throughout the year until the stock collapsed in the late 1970s (Clark and Anthony 1980; Clark 1981, 1982). After a regulated closure in 1978, the fishery continued and grew to its current magnitude, which is a relatively valuable industry in New England (1995 landed value was $13 million; NMFS 1996).

The Gulf of Maine fishery for northern shrimp is managed through interstate agreement among the States of Maine, New Hampshire, and Massachusetts. The management framework evolved from 1972 to 1979 under the auspices of the State/Federal Fisheries Management Program. In 1980, this program was restructured in the Northeast Region as the Interstate Fisheries Management Program of the ASMFC (McInnes 1986). Within the interstate structure, the Northern Shrimp Technical Committee (NSTC) provides annual stock assessments and related information to the ASMFC Northern Shrimp Section. Management has been conducted primarily by controlling the length of fishing seasons (within the time frame of December to June) and gear restrictions. Fishing seasons are labeled according to the calendar year for January of the fishing season (e.g., the 1996 season includes fishing from December 1995 to May 1996).

Stock assessments initially consisted of total landings estimates, indices of abundance from Northeast Fishery Science Center (NEFSC) groundfish surveys, fishing mortality estimates from Maine survey length frequencies, and yield-per-recruit modeling (Clark and Anthony 1980; Clark 1981, 1982). The NSTC developed a port sampling program in the early 1980s to characterize catch at length and developmental stage, and established a research trawl survey in the summer of 1983 to monitor relative abundance, biomass, size structure, and demographics of the stock. Subsequent stock assessments provided more detailed description of landings, size composition of catch, patterns in fishing effort, catch per unit effort, relative year-class strength, and survey indices of total abundance and biomass. Length distributions from the summer shrimp survey have been used for size composition analysis to estimate mortality rates, but did not fit the length-based models well because of variable recruitment and growth (Terceiro and Idoine 1990, Fournier *et al.* 1991). The present assessment is the first to integrate catch and survey indices of abundance for estimation of stock abundance and mortality rates, and provides estimates of egg production per recruit and revised estimates of yield per recruit.

The Fishery

Commercial Landings

Small quantities of northern shrimp have been incidentally caught in New England otter trawl fisheries since 1905 (Scattergood 1952). A directed winter fishery in coastal waters developed in the late 1930s which landed an annual average of 63 mt from 1938 to 1953, but no shrimp were landed from 1954 to 1957 due to lack of inshore availability (Wigley 1973) (Figure D1). The fishery resumed in 1958, and landings increased steadily to a peak of 12,100 mt during the 1969 season (August 1968 to July 1969) as an offshore, year-round fishery expanded. After 1972, landings declined rapidly, and the fishery was closed in 1978. The fishery reopened in 1979 and seasonal landings increased gradually to 5,300 mt by 1987 and averaged 3,300 mt from 1988 to 1994 (Table D1). Seasonal landings increased to 6,500 mt in 1995 and to 9,200 mt in 1996, which was only exceeded by the five years of landings prior to the stock collapse in the late 1970s. The preliminary estimate of landings for the 1997 fishing season is at least 6,500 mt.

Maine landings comprised 75% of the season totals in 1984-1996, and New Hampshire and Massachusetts landed 8% and 17%, respectively (Table D1). The majority of landings generally occurred in January and February (Figure D2).

Information on size and developmental stage of landed shrimp from intense port sampling (Tables D2 and D3) suggests that landings have been predominated by recruitment of three abundant year classes (Figure D3) (recruitment patterns are more pronounced in survey catches, described below). Landings more than tripled with recruitment of a strong 1982 year class in 1985 and 1986. Landings declined sharply in 1988 with the passage of this year class through the fishery. A strong 1987 year class began to recruit to the fishery in the spring of 1989 and was a major contributor to the 1990-1992 fisheries. The 1992 year class began recruiting to the fishery in 1995. The moderate-sized 1993 year class also contributed to relatively large annual landings in 1995 and 1996.

Landings from January to March consist primarily of mature female shrimp (presumably ages 3 and older), and December, April, and May landings have included higher proportions of males (assumed ages 1 and 2) (Figure D4). These patterns reflect shifts in distribution of fishing effort in response to seasonal movements of mature females: inshore in early winter and offshore after their eggs hatch.

Catch in numbers was derived as the quotient of landings (Table D1) and mean weight (Table D4) by year, state, and month. The general patterns in size composition of landings are reflected in mean weight of individual shrimp landed by year, state, and month: the size of landed shrimp generally increases from December to January, peaks in February, and decreases through the spring. Three percent of the total landings for 1984-1996 were from specific year-state-month strata with no port samples, generally from the beginning or end of a fishing season. Mean weight for these landings was estimated by a general linear model of mean weight by year, month, and state. Some June landings, which had no associated port samples (126 mt, 0.2% of total time-series landings), were described using May samples within the same year and state.

Discarded Catch

Sea sampling observations on shrimp otter trawl trips from 1984 to 1996 indicate that weight of discards is less that 1% of the total catch in all years (Table D5). Large year classes appear to contribute to discards as age 2 (e.g., the 1992 cohort produced almost 1% discards in 1994). Industry representatives report substantial discards of shrimp in the small-mesh whiting fishery east of Jeffreys Ledge. Sea sampling observations from finfish trawl fisheries in the Gulf of Maine suggest that bycatch of northern shrimp was inconsequential during 1984-1994. However, in 1995 and 1996, the amount of discarded shrimp per trip increased considerably, and the increase was from small-mesh trips sampled in the area of Jeffreys Ledge. Although the observed discards increased, the total was less than 60 kg per observed trip. Unfortunately, no shrimp lengths were measured during sea sampling, and estimates of total number discarded would be difficult. Therefore, discard estimates were not included in the present assessment.

Fishery Selectivity

Selectivity of commercial trawl gear was estimated from a field study conducted in July 1995, twenty miles south of Boothbay Harbor (Schick and Brown 1997). Five paired tows were sampled with a trouser trawl over a two-day period. The trouser body consisted of 47.6 mm (1⅞ in) diamond polypropylene mesh, as did the vertical septum which divided the trawl in half. The control codend was 12.7 mm (½ in) square polypropylene mesh with a 6.4 mm (¼ in) mesh liner. The experimental codend consisted of 47.6 mm (1⅞ in) diamond polypropylene mesh.

Three 5-kg samples from each codend were bagged, labeled, stored on ice at sea, and then frozen. Mid-dorsal carapace length (CL) was measured for 500 shrimp from each sample. Sample length frequencies were expanded to total catch length frequencies using the ratio of sample weight to catch weight. Observed retention ratios at length were derived by dividing the number at length from the experimental codend (large mesh) by the number at length from the control codend (small mesh). The average of five ratios, one from each tow, was used to fit a selectivity ogive (Nicolajsen 1988):

$$P = 1/[1+e^{-(a\mathrm{CL}+b)}] \qquad (1)$$

where P is the proportion retained at size. The parameters a and b were estimated using logistic regression. The CL range used in the regression was 13.5-28.5 mm.

Nominal Fishing Effort and Catch per Unit Effort

The number of vessels participating in the Gulf of Maine northern shrimp fishery was estimated to range between 300 and 400 in recent years. The distribution of vessel sizes in the shrimp fishery, as indicated by gross registered tonnage, has been relatively stable since 1986: approximately 20% of the vessels less than 10 tons, 60% 10-50 tons, and 20% greater then 50 tons. However, the relative proportion of smaller vessels (<5 tons) in the fishery appears to have been more variable than participation by larger vessels. Most fishing is conducted by otter trawls, although traps are also used off the central coast of Maine. Trapping operations generally account for 4-8% of Maine's total number of trips. Trap landings have remained below 5% of the annual total reported for the State.

From 1975 to 1994, nominal fishing effort (the number of trips which landed shrimp) was estimated from dealers' reported landings and landings-per-trip information from dockside interviews of vessel captains. For the 1995 and 1996 fishing seasons, the ratio of landings from vessel trip reports to total dealer weighout landings was used to expand reported trips to total trips. This expansion assumes that unreported trips have the same catch rates as reported trips. Smaller vessels that are not required to file logbooks may have lower catch rates than those reported, and effort may be overestimated for 1995 and 1996. The interview system used for the 1975-1994 effort estimates had a similar bias toward sampling larger boats. Nominal effort increased in the late 1960s to average 16,000 for the 1970-1972 fishing seasons. Effort decreased rapidly in the 1970s, but has increased considerably since the 1978 closure. The number of trips peaked at 12,300 during the 1987 season, decreased to 6,000 trips in 1994, and appears to have increased to 12,000 trips in 1996 (Figure D5). More detailed effort information has been evaluated over the past six years by port sampling interviews in Maine and New Hampshire. The series of total hours fished reflects the pattern of total trips, suggesting that recent estimates of nominal trips are not substantially overestimated (Figure D5). The amount of offshore fishing effort has varied seasonally, reflecting movements of mature females (inshore in early winter and offshore following larval hatching) and fishermen's choices for fishing on concentrations of shrimp.

Effort standardization was not possible because number of tows and haul duration data from vessel logbooks have not been audited (NEFSC 1996). However, 1984-1993 standardized effort mirrored nominal effort quite closely (Richards 1993).

Catch per unit effort (landings per hour fished) from Maine and New Hampshire port interviews indicates an increasing trend in catch rates and total hours fished since 1993 (Figure D5). The increase in catch rates may reflect increased biomass or denser aggregations of shrimp which make them much more available to the gear. Another possible cause for an increase in catch rate is an increase in vessel fishing power.

Research Trawl Surveys

Trends in abundance have been monitored since the late 1960s using data collected by NEFSC spring and autumn bottom trawl surveys and summer surveys by the State of Maine and the NSTC (Figure D6).

Maine Survey

Maine conducted summer surveys in the Gulf of Maine from 1967 to 1983. Fixed stations were sampled with an otter trawl during daylight at locations where shrimp abundance was historically high (Schick *et al.* 1981) (Figure D7). The Maine survey biomass index began declining in 1968 and depicts the stock collapse in the late 1970s (Figure D6) (Clark 1981, 1982; Schick *et al.* 1981).

Groundfish Surveys

NEFSC autumn bottom trawl surveys have been conducted since 1963 and spring bottom trawl surveys since 1968. Stations are sampled from Cape Hatteras to Nova Scotia according to a stratified random design (Figure D8) (Despres *et al.* 1988). Although these groundfish surveys catch relatively fewer northern shrimp and have more measurement error, they represent a longer time series than any of the shrimp surveys. Correspondence among research surveys and fishery indices of abundance suggests that the autumn survey monitors resource conditions more closely than the spring survey (Clark and Anthony 1980; Clark 1981, 1982). The autumn survey indicates a precipitous decline from peak biomass in the 1960s to 3% of peak levels in the late 1970s. The index subsequently increased in the 1980s and has fluctuated at approximately 40% of peak levels in the 1960s (Figure D6).

NSTC Shrimp Survey

The shrimp survey has been conducted each summer since 1983 employing a stratified random sampling design and gear specifically designed for Gulf of Maine conditions (Blott *et al.* 1983, Clark 1989). The summer survey is considered to provide the most reliable information available on abundance, distribution, population age structure, and other biological parameters of the Gulf of Maine northern shrimp resource. Indices of abundance and biomass are based on catches in the strata that have been sampled most intensively and consistently over time (strata 1, 3, and 5-8) (Figure D9). Survey catches have been highest in strata 1, 3, 6, and 8, the region from Jeffreys Ledge and Scantum Basin eastward to Penobscot Bay. The 1983 survey did not sample strata 6-8.

The statistical distribution of survey catch per tow (in numbers) was investigated to determine the best estimator of relative abundance. Catches within strata were distributed with significant positive skewness, and arithmetic stratum means were correlated to stratum variances. Log transformed catches [$\ln(n+1)$] were more normally distributed. Log transformation is a common practice for estimating relative abundance from trawl surveys because stratum means and variances are seldom independent, and log transformation generally normalizes observations, renders the variance independent, and reduces anomalous fluctuations (Grosslein 1971). Geometric means were estimated with more precision (mean CV = 2.4%) than arithmetic means (mean CV = 13.5%). Therefore, stratified geometric mean catch per tow was used to estimate relative abundance. The nontransformed and transformed indices have different magnitudes and temporal patterns, particularly in recent years (Figure D10). The 1996 arithmetic mean is slightly below the time-series mean, but the 1996 geometric mean is the lowest in the time series. Annual variation in the difference between the two series reflects varying degrees of skewness, or patchiness of shrimp aggregations from year to year, which is consistent with observations from the fishery.

Shrimp survey catches by length and developmental stage (Figure D11) reflect the predominance of the strong 1982, 1987, and 1992 cohorts in the stock. Although size at age 1.5 is annually variable, discrete length modes indicate the relative abundance of age 1.5 shrimp (generally around 12-18.5 mm CL) and age 2.5 shrimp (generally 19-23 mm CL). Length modes for older cohorts overlap extensively.

A "selectivity method" was used to derive indices of recruits and fully-recruited shrimp from survey length frequencies (NEFSC 1995). The number per tow at length was partitioned into three components: fully-recruited, recruits, and pre-recruits (as illustrated in Figure D12). The fishery selectivity curve (Schick and Brown 1997, described above) was used to define fully-recruited shrimp. The products of selectivity at length and survey catch per tow at length were summed to derive total catch per tow of fully-recruited shrimp. The carapace length of each interval was increased by one year of growth according to a von Bertalanffy growth curve:

$$CL_{t+1} = CL_t + (CL_\infty - CL_t)(1-e^{-K}) \tag{2}$$

where $CL_\infty = 35.2$ and $K = 0.36$ (McInnes 1986) to estimate fishery selectivity after a year of growth. The remaining length frequency of recruits and pre-recruits was then multiplied by the end-of-year selectivity at length to obtain an index of recruits. Using the selectivity method, age classes recruit to the fishery over several years, and recruitment in each year is composed of several cohorts. Therefore, the definition of recruitment used in this assessment is not synonymous with year-class strength (previous northern shrimp assessments defined recruitment as age 2.5 abundance).

Indices of recruits and fully-recruited shrimp reflect the aggregate survey index: 1996 values are among the lowest (observed values in Figure D13). Mean weight of recruits and fully-recruited shrimp were estimated according to length-weight equations for each developmental stage from Haynes and Wigley (1969) and 199[illegible] northern shrimp survey observations.

Abundance and Fishing Mortality Estimates

Methods

A modified DeLury model (Collie and Sissenwine 1983, Conser and Idoine 1992) was applied to the Gulf of Maine northern shrimp fishery:

$$N_{t+1} = (N_t + R_t - C_t)\, e^{-M} \tag{3}$$

where fully-recruited abundance at the end of the year (N_{t+1}) equals fully-recruited abundance at the beginning of the year (N_t), plus recruitment (R_t), minus catch (C_t), all reduced by one year of natural mortality (e^{-M}).

M was assumed to be 0.25, as approximated from the intercept of a regression of total mortality on effort (Rinaldo 1973, Shumway *et al.* 1985). Estimates of Z for age 2+ shrimp from visual inspection of length modes from the Maine summer survey equaled 0.17 for 1977-1978 when the fishery was closed (Clark 1981, 1982), suggesting, for the population as a whole, that M is low relative to other *Pandalus* stocks.

Catch was assumed to be taken at mid-year, whereby the summer survey marks the beginning of the "survey year" (August 1), and catch was taken on February 1 of the next calendar year (which was based on the time of 50% cumulative seasonal catch for 1985-1996 (Figure D2):

$$N_{t+1} = [(N_t + R_t)e^{-0.5M} - C_t]\, e^{-0.5M} \tag{4}$$

so that recruited shrimp ($N_t + R_t$) experience a half-year of natural mortality ($e^{-0.5M}$), catch is removed, then the survivors $[(N_t + R_t)e^{-0.5M} - C_t]$ experience another half-year of natural mortality.

Abundance is related to survey indices of relative abundance:

$$n_t' = q_n N_t e^{\eta t} \tag{5}$$

and

$$r_t' = q_r R_t e^{\delta t} \tag{6}$$

where r_t' and n_t' are observed survey indices of recruits and fully-recruited shrimp, q is catchability of the survey gear, and $e^{\eta t}$ and $e^{\delta t}$ are lognormally distributed measurement errors. The process equation is derived by substituting survey indices into equation 4 and including lognormally distributed process error ($e^{\epsilon t}$):

$$n_{t+1} = [(n_t + r_t/s_r)e^{-0.5M} - q_n C_t]\, e^{-0.5M}\, e^{\epsilon t} \qquad (7)$$

where

$$s_r = q_r / q_n \qquad (8)$$

is the relative selectivity of recruits to fully-recruited shrimp. Selectivity studies (Blott *et al.* 1983) and survey catch at length suggest that age 1.5 shrimp are sampled less efficiently than age 2+ shrimp because total catch per tow is greater at age 2.5 than at age 1.5 for some cohorts (Figure D11). There are two components to survey selectivity of age 1.5 shrimp: the 32-mm codend mesh in the survey trawl may not retain some small shrimp, and in some years, age 1.5 males may not completely migrate from inshore areas to the survey strata (Figure D9). Precise estimation of survey selectivity at size was precluded by large variability in catch at size and few comparative tows (Blott *et al.* 1983). For the present analysis, s_r was approximated from the relative sampling efficiency of <19-mm CL shrimp to that of larger shrimp, and the relative proportions of those sizes comprising total recruits and fully-recruited indices. Expected catch per tow of age 1.5 shrimp was estimated from the age 2.5 catch per tow in the next year, increased to account for one year of total mortality. The ratio of observed to expected age 1.5 catch per tow approximated the relative selectivity of <19-mm CL shrimp. The proportion of recruits and fully-recruited shrimp <19 mm and the relative selectivity of <19-mm CL shrimp were used to estimate q_r and q_n. An annually varying s_r was used in the DeLury analysis ranging from 0.7 to 1.0 because the proportion of recruits <19 mm varied according to year-class strength.

The parameters n_t, r_t, and q_n were estimated by iteratively minimizing the sum of measurement errors (equations 5 and 6) and process errors (from equation 7) for the entire time series. Total mortality (Z) and fishing mortality (F) were calculated from abundance estimates:

$$Z_{R+N,t} = \mathrm{Ln}\ [(N_t + R_t) / N_{t+1}] \qquad (9)$$

and

$$F_{R+N,t} = Z_{R+N,t} - M \qquad (10)$$

The fishing mortality can be partitioned according to the average partial recruitment (p) of recruits over the survey year:

$$F_{N,t} = [F_{R+N,t}(R_t+N_t)] / pR_t \qquad (11)$$

and

$$F_{R,t} = pF_{N,t} \qquad (12)$$

Average partial recruitment was derived from the schedule of growth into fully-recruited sizes over the survey year, as approximated by observations of monthly growth of age 1.5 shrimp from a mean carapace length of 14.5 mm in July to 21.9 mm CL the next July (Haynes and Wigley 1969).

Results

DeLury results are summarized in Table D6, and more detailed model output is reported in Cadrin *et al.* (1997). Parameters were relatively well estimated. Coefficients of variation for fully-recruited abundance estimates ranged from 19% to 25%, estimates of recruitment were slightly less precise (CV = 23-25%), and q_n was estimated with moderate precision (CV = 21%). There were no large correlations among the 26 parameter estimates, but q_n was weakly correlated to recruitment in 1996 and 1997 (r = 0.4). Standardized residuals ranged from -1.1 to 1.0 without significant annual patterns, indicating that the data fit the model well (Figure D13).

Recruitment estimates averaged 0.7 billion, peaked at 1.0 billion in 1990, but decreased in recent years to 0.4 billion in 1997. Fully-recruited abundance averaged 0.8 billion, peaked at 1.2 billion in 1991, and decreased to 0.5 billion in 1997, the lowest level in the time series. Comparison of DeLury estimates of fully-recruited abundance to minimum abundance estimates from area-swept expansion suggests that the q estimate is realistic because area-swept estimates were less than DeLury estimates in all years, ranging from 0.2 billion to 0.5 billion. Total stock biomass estimates averaged 12,500 mt, peaked at over 17,000 mt in 1991, and decreased to 7,300 mt in 1997. The pattern of biomass estimates is similar to those in biomass indices from the autumn groundfish survey, and the magnitude of biomass estimates is similar to those estimated for the early 1970s using total catch and survey estimates of F (Anthony and Clark 1980).

Annual estimates of F_{R+N} averaged 0.36 from the 1985-1995 fishing seasons and increased to 0.90 in the 1996 fishing season (Figure D14). The increased F in the 1996 season reflects the pattern in nominal fishing effort (Figure D5). Estimates of mortality in the first and last years are the least reliable in DeLury analysis because n_{84} and n_{96} each contributed to only one process residual, whereas n_{85} to n_{95} were each used to calculate two process residuals (i.e., as n_t and n_{t+1}). Averages of terminal mortality estimates (e.g., $F_{95\text{-}96} = 0.65$ or $F_{94\text{-}96} = 0.54$) are less sensitive to measurement error in the 1996 survey observation of fully-recruited shrimp. However, averaging F_{96} with previous years may be inappropriate because of the apparently significant increase. Total mortality estimates were within the range of previous estimates using visual inspection of survey length frequencies [previous NSTC reports), Shepherd's length composition analysis (Terceiro and Idoine 1990), and MULTIFAN (Fournier *et al.* 1991)].

Two hundred bootstrapped estimates, which were derived by randomly resampling model residuals, suggest that estimates of abundance, biomass, and mortality were relatively precise. The median bootstrapped value for F_{96} was 0.93 with an 80% confidence interval of 0.74-1.14 (Figure D15). The median $F_{95\text{-}96}$ was 0.72 (80% CI = 0.59-0.84) and the median $F_{94\text{-}96}$ was 0.58 (80% CI = 0.47-0.67). Abundance estimates were not bias-corrected because estimates of bias were not substantial (<10% in most years) and did not indicate systematic model bias.

Sensitivity Analyses

Alternative DeLury analyses were conducted to evaluate the sensitivity of results to several assumptions. Exploratory DeLury runs were made with alternative estimates of M, fishery selectivity, relative survey selectivity of recruits, and survey catches (Table D7, Figure D16).

The level of M for northern shrimp is uncertain. As described above, there are two sources of information for the Gulf of Maine stock: M was estimated as 0.25 by regressing Z on effort, and as 0.17 from survey catches before and after the fishery closure. These M estimates are below most levels estimated for other stocks of northern shrimp (*Pandalus borealis*). An international working group was unable to precisely determine M, but used 0.5 for an Icelandic stock based on catch curves of survey length frequencies, and assumed M for other stocks based on the relative abundance of cod in the area (ICES 1977). An estimate for the Gulf of Alaska stock was 0.35 (Abramson 1980). Frechette and Labonte (1980) reported several estimates of M for the Gulf of St. Lawrence stock using three years of survey length distributions: 0.4 for age 2+ and 0.2-0.8 for age 3+. A DeLury analysis with M = 0.35 was conducted to investigate sensitivity of results to M. Greater values for M would exceed some estimates of total mortality. Z does not appear to be sensitive to the assumed value of M (Figure D16), but q and abundance estimates were sensitive. Results from this sensitivity run suggest that substantial catch was produced with negligible F (0.03) because stock abundance and biomass estimates were much greater than those from the base run (M = 0.25).

Estimates of fishery selectivity from trouser trawl experiments described above (Schick and Brown 1997) produced a very gradual selectivity curve (Figure D12). Survey and commercial data were used to derive retention ratios at length as an alternative method of approximating vulnerability at size (NEFSC 1995). The ratio of cumulative length frequencies from the 1996 NEFSC spring survey and April 1996 port samples was used to approximate a vulnerability-at-size curve. The resulting vulnerability curve is steeper than the selectivity curve, and the estimated length at 50% retention is slightly smaller. The "selectivity method" of estimating recruits and fully-recruited shrimp from summer survey catch at length, described above, was revised using the vulnerability curve for an exploratory DeLury analysis. The results from the sensitivity run were similar to the results using the selectivity experiment data (Figure D16), suggesting that these results are not very sensitive to slight changes in L_{50} or substantial changes in the steepness of the assumed selectivity curve.

Previous NSTC stock assessments did not log transform survey catches to derive abundance indices. Sensitivity of log transformation was evaluated by processing untransformed catch-at-length data to derive alternative indices of recruits and fully-recruited shrimp for an alternative DeLury analysis. Abundance and mortality estimates from this sensitivity run were similar to those using log transformed survey indices (Figure D16) because the greater magnitude of non-transformed survey indices was compensated by a greater estimate of q.

Sensitivity to the estimates of annually variable s_r was evaluated by setting a time-series average (s_r = 0.9) to all years. Results using s_r = 0.9 were nearly identical to the base run (Figure D16). Increasing s_r to 1.0 decreased mortality estimates slightly, and decreasing s_r to 0.8 slightly increased mortality estimates (Figure D16).

Statistical diagnostics of all DeLury runs for sensitivity analyses were similar. All sensitivity analyses resulted in an average total mortality of approximately 0.6. Estimated F was greatest in 1996 from all model runs. Therefore, the reported level and temporal pattern of mortality estimates are robust to all assumptions which were evaluated.

Retrospective Analysis

Comparison of results from eight retrospective DeLury analyses to the results reported above was completed to investigate the stability of estimates in the last year of the analysis and the possibility that terminal mortality estimates are systematically inconsistent. The analysis was sequentially truncated by deleting the last year of survey and catch data to create a retrospective series of DeLury estimates (Figure D17). Terminal mortality estimates were quite stable in most years. Retrospective differences in Z were positive for the first two terminal estimates (1988 and 1989), negative for the next three (1990-1992), and positive for the last three (1993-1995).

Confirmatory Analysis

An alternative method of estimating stock size and F was explored to corroborate results from the DeLury analysis. A nonequilibrium surplus production model (Prager 1994, 1995) was fit to seasonal catch and survey biomass indices from 1968-1996 (Table D8, more detailed output in Cadrin *et al.* 1997). The model assumes logistic population growth in which the change in stock biomass over time (dB_t/dt) is a quadratic function of biomass (B_t):

$$dB_t/dt = rB_t - (r/K)B^2_t \tag{13}$$

where r is the intrinsic rate of population growth and K is the carrying capacity. For a fished stock, the rate of change is also a function of F:

$$dB_t/dt = (r\text{-}F_t)B_t - (r/K)B_t^2 \tag{14}$$

For discrete time increments, such as annual fishing seasons, the difference equation is:

$$B_{t+1} = B_t + (r\text{-}F_t)B_t - (r/K)B_t^2 \tag{15}$$

Initial biomass (B_1), r, and K were estimated using nonlinear least squares of survey residuals. The fall groundfish survey catch per unit effort (CPUE) contributed to the total sum of squares as a series of observed effort (E = CPUE/C); the Maine summer survey and the NSTC shrimp surveys contributed as independent indices of biomass at the start of the fishing season. Note that no assumption about M is needed for the biomass dynamics analysis.

One survey observation (fall 1982) was a statistical outlier, and Maine and NSTC survey residuals suggest autocorrelation (Figure D18). The majority of the variance in the fall and Maine surveys was explained by the model ($R^2 = 0.6$ and 0.7, respectively), but much of the variation in the summer shrimp survey was not resolved ($R^2 = 0.2$). The model did not account for peaks in biomass from strong recruitment.

Estimates of F from the biomass dynamics model generally confirm the pattern and magnitude of estimates from the DeLury model; F_{96} was the highest value since 1975 (Figure D19). Recruitment of the strong 1982, 1987, and 1992 cohorts is not as pronounced in the biomass trajectory from the production model because dynamic recruitment is not explicitly estimated, as it is in the DeLury analysis. The biomass dynamics model suggests that a maximum sustainable yield (MSY) of 5,000 mt can be produced when stock biomass is approximately 31,000 mt (B_{MSY}) and F is approximately 0.2 (F_{MSY}) (Figure D20). However, B_{MSY} was only exceeded in the first three years in the analysis, which are not reliable (Prager 1994, 1995).

Survey residuals were randomly resampled 200 times to estimate precision and model bias. Bootstrap results suggest that *r*, MSY, and F_{MSY} were relatively well estimated (relative interquartile ranges were <17% and bias was <3%). Estimates of *K*, B_{MSY}, and *q* were moderately precise (relative IQS were 23-25%, bias was <2%), and B_1 was not as precisely estimated (relative IQ = 45%). F_{96} was estimated with less precision than in the DeLury analysis (relative IQS were 24% from the DeLury analysis and 59% from the production model). Similarly, B_{96} was estimated with less precision than in the DeLury analysis (relative IQS were 24% from the DeLury analysis and 76% from the production model).

Biological Reference Points

Yield per recruit (Thompson and Bell 1934) and percent maximum spawning potential (Gabriel *et al.* 1989) were estimated for the Gulf of Maine northern shrimp fishery (Table D9, Figure D21). Yield and egg production were derived as a function of abundance at the time of spawning (i.e., abundance at the start of the year, approximately February 1) to reflect size and weight at age during spawning and the fishery. The model assumes that annual growth and ontogenetic transition occur before oviposition and the onset of the fishing season. As described above, M was assumed to be 0.25 (Rinaldo 1973). Length at age was estimated using the von Bertalanffy growth parameters $L_\infty = 35.2$ mm and $K = 0.36$ (McInnes 1986). Proportion female at the time of hatch was estimated by the average of 1984-1996 observed sex ratios at length from the summer survey applied to a carapace length which was increased by a half-year of growth using equation (2). Selectivity at size was estimated using the selectivity curve from Schick and Brown (1997), described above. Mean weight at length for males and females was estimated using relationships developed by Haynes and Wigley (1969). Estimates of fecundity at oblique CL were from a linear relationship developed by Apollonio *et al.* (1984).

Yield per recruit was maximum at F = 0.77 (F_{max}) (Table D9). The increase in yield per unit F decreased to one tenth the initial increase at F = 0.46 ($F_{0.1}$). Maximum spawning potential (i.e., with no F) was 2,395 eggs per recruit. Spawning potential was reduced by half at F = 0.25 ($F_{50\%}$).

Information from the stock collapse in the 1970s may provide guidance on the level of sustainable F for Gulf of Maine northern shrimp. Biomass indices from the Maine survey and the biomass dynamics model suggest that biomass was declining as early as 1968. Log catch ratios of assumed age 2+ shrimp from survey length frequencies suggested that F was 0.7-0.8 during 1968-1970, and continued annual harvests of over 5,000 mt increased F to an annual average of 1.6 during 1971-1975 (Clark and Anthony 1980). Estimates of F from the first several years of the production model time series (e.g., 1968-1972) are imprecise and are not considered reliable (Prager 1994, 1995), but F estimates for 1973-1975 ranged from 0.6 to 1.1 (Figure D19). According to the present egg-production-per-recruit analysis and historical F estimates, the stock was not replacing itself when spawning potential was reduced to less than 18% of maximum, and the stock collapsed when egg production was reduced further. Therefore, $F_{20\%}$ may be an appropriate overfishing threshold, which would result in target Fs well below 0.6.

Reproductive success for Gulf of Maine northern shrimp is a function of population fecundity and spring seawater temperature (Richards *et al.* 1996, Richards and Clark 1996). Landings are also correlated to lagged population fecundity (Stickney 1980, Richards *et al.* 1996). Although temperature conditions affect survival and growth during the early life history, the shrimp survey index of age 1.5 biomass is significantly correlated to the biomass index of females from two years earlier (r = 0.6) (Figure D22). A survey index of egg production, derived as the sum of catch per tow of females at length multiplied by fecundity at length (Apollonio *et al.* 1984), had a similar relationship to recruitment. The two dominant cohorts in the time series were produced when spawning stock biomass was among the highest levels in the time series. When spawning stock indices were greater than 6 kg/tow, two of four cohorts were abundant. These relationships suggest that poor recruitment is more likely at low levels of spawning stock biomass and egg production, and adequate egg production per recruit should be conserved. The 1996 spawning stock index was 3 kg/tow; all cohorts produced by spawning indices of 3 kg/tow or less were below average.

SARC Comments

The SARC concluded that the high F in 1996 was the result of a large removal from a low stock size and an increase in catchability. This interpretation was based on patterns in catch, effort, and survey indices. Landings and effort increased sharply in 1995 and continued to increase in 1996 (Figures D1 and D5), but the pattern of F showed a moderate increase in 1995 and a more substantial increase in 1996 (Figure D14). Survey indices suggest that abundance increased in 1995 and then declined in 1996 (Figure D13). Catch per unit effort has steadily increased since 1993 (Figure D5).

The SARC noted that the patterns of F and abundance were similar between the runs with transformed and untransformed survey indices. However, inspection of the statistical distribution of survey catch per tow, the relationship between stratum means and variances, and aggregated distributions targeted by the fishery suggested that ln transformation was appropriate.

The SARC recognized that terminal estimates from DeLury analysis are typically sensitive to the statistical weighting of process and measurement errors (e.g., NEFSC 1995). The northern shrimp DeLury analyses had equal weighting of error components. There was a slight pattern of positive process residuals in the middle of the time series, and process errors accounted for 45% of the total model error. A model run with double weighting of process error was attempted to assess the sensitivity of F_{96} to weighting, decrease the proportion of process error, and perhaps reduce the residual pattern. The sensitivity run indicated an increase in F_{96} to 0.96 (from 0.90 with equal weighting), 31% process error, and the same pattern of residuals. The SARC concluded that increasing the weight of the process error would increase F_{96} and downweighting the process error would not be appropriate because it is unlikely that process errors are greater than survey measurement errors.

The SARC noted that updating the analysis with 1997 catch and survey information may change the estimates of abundance and F in 1996. However, given the magnitude of past measurement errors in survey indices and the large catch in 1996, it is unlikely that revised estimates of F_{96} will be substantially lower.

Three alternative production model runs were requested. The first sensitivity run removed the summer shrimp survey, which did not fit the model well, to provide a more independent confirmation of the DeLury analysis; the revised analysis had very similar parameter estimates and trajectories of F and biomass. The second alternative run removed both the summer shrimp and Maine surveys; the model did not converge well, but did produce similar parameter estimates and slightly lower biomass trajectories. The third alternative run included the preliminary estimate of 1997 landings (6,500 mt); parameter estimates and trajectories did not change from the base run, and F_{97} increased to 2.5. The original run, with three series of survey indices and 1968-1996 landings, was accepted as the best run.

The SARC observed that recent temperatures in the Gulf of Maine, as illustrated by Boothbay Harbor observations, were well above average. Correlation analyses indicate that, although spawning stock is the principal determinant of year-class strength, larval survival is reduced at high temperatures (Richards *et al.* 1996, Richards and Clark 1996). It was also reported that catchability decreased in 1997 due to high winter temperatures. The SARC was concerned that, at high temperatures and low stock sizes, the probability of a strong year class may be poor in the near future. Under conditions of high temperature, the risk of stock collapse at high F is greater.

Appropriate target and threshold reference points for long-term management were discussed. The SARC noted that the production model estimate of F_{MSY} (0.17) was much lower than the yield-per-recruit reference points (F_{max} = 0.77, and $F_{0.1}$ = 0.46), and requested F_{med} estimates from available stock and recruitment data. Survey indices of egg production and recruitment, spawning biomass and recruitment (Figure D22), and historical estimates of spawners and recruits (Richards *et al.* 1996, Richards and Clark 1996) suggested that, at median survival rates, greater than 50% of maximum spawning potential is needed to replace the stock. Provisional F_{med} estimates averaged 0.2 (0.10 based on eggs per recruit, 0.16 based on spawning biomass per recruit, and 0.35 based on the extended series of spawners per recruit), which is similar to F_{MSY}. However, survival ratios and estimates of F_{med} may be underestimated because of not accounting for partial selectivity of recruits to the survey.

The SARC noted that compensation in growth and transition/maturity are important considerations for determining the dynamics of spawning potential and should be investigated. There is some evidence of accelerated maturation after the stock collapse in the 1970s and, conversely, delayed maturation of large year classes. Examination of maturity at size from historical surveys before and after the stock collapse may offer guidance on compensatory maturation.

The SARC concluded that yield-per-recruit reference points may be too high to use as overfishing thresholds, and that spawner-recruit information is too preliminary to use for determining the level of F which will provide adequate stock replacement. The SARC observed that the 1985-1995 mean F (0.36) produced relatively stable stock sizes. An F of 0.36, which corresponds to 38% of maximum egg production per recruit and is slightly below $F_{0.1}$, was suggested as an interim management target pending more definitive analyses

The SARC concluded that the DeLury model appropriately describes the biology and fishery dynamics of the stock. Regular assessments of the Gulf of Maine shrimp stock with these methods should provide a reliable basis for management of the fishery.

Research Recommendations

- The potential for improving estimates of mortality, abundance, and biomass from historical fishery and survey data from the 1960s should be investigated for further guidance on appropriate biological reference points.

- Development of a time series of standardized effort would help to corroborate patterns of estimated F. Such analyses depend on completion of audits and processing of vessel logbook data. Standardized effort may also be useful to update the derivation of M from the relationship of Z to effort.

- Methods for age determination from length and ontogenetic stage information should be continued to develop the possibility of using age-based assessment methods.

- A standard set of non-random stations has been sampled during the northern shrimp survey since 1995. When an adequate time series is achieved, catch data from these stations should be incorporated into survey indices of abundance and biomass.

- Estimates of fecundity at length should be updated, and the potential for annual variability should be explored.

- Power analysis of estimates of mean weight from port sampling should be investigated to optimize sample design.

- Explore gear modifications, such as larger mesh, to minimize shrimp bycatch in finfish trawl fisheries.

- Modify sea sampling protocol to characterize discards of shrimp in the shrimp trawl fishery and the small-mesh whiting fishery.

- Expand the time series of stock and recruitment data using catchability estimates from the production model.

- Investigate changes in transition and maturation as a function of stock size and temperature.

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Table D1. Gulf of Maine northern shrimp landings (mt) from dealers' records.

		Fishing season											
Month	State	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Dec	ME	335.7	346.9	485.9	339.7	353.6	512.4	238.2	181.1	100.9	171.5	747.6	1124.1
	MA	91.7	154.3	103.5	14.4	26.2	75.6	90.5	17.1	19.6	27.1	160.6	167.9
	NH	67.0	57.7	18.4	13.0	28.5	111.3	107.3	33.4	33.5	117.2	210.7	189.8
Jan	ME	851.8	747.8	906.2	793.9	770.5	778.2	509.1	880.9	369.0	647.7	1397.7	1678.3
	MA	283.9	213.4	260.0	225.8	197.5	344.4	174.7	148.2	82.0	68.0	154.0	106.7
	NH	86.2	75.9	53.6	72.6	106.9	191.7	104.4	47.0	85.4	124.3	186.8	169.5
Feb	ME	1095.5	1405.3	1192.7	788.1	700.6	509.7	884.0	1278.9	597.0	971.9	1338.2	3004.6
	MA	238.3	221.2	384.9	255.0	154.9	184.8	175.9	73.3	81.9	100.8	104.1	188.7
	NH	50.4	70.8	62.8	53.7	77.0	116.1	33.8	11.9	101.7	128.7	118.3	234.0
Mar	ME	525.1	415.4	672.9	243.6	246.4	638.5	454.9	462.5	297.5	399.5	912.0	785.2
	MA	239.3	200.7	310.2	104.9	104.8	100.2	131.2	47.5	62.3	38.8	111.0	67.8
	NH	11.6	14.2	15.7	14.9	15.4	30.7	27.8	6.8	77.0	49.6	158.5	81.9
Apr	ME	116.8	104.2	287.6	24.6	218.7	514.0	251.7	163.6	127.8	48.7	627.2	350.4
	MA	57.8	111.2	180.8	8.6	160.9	158.9	93.3	2.9	42.0	12.8	140.7	66.5
	NH	1.3	1.3	7.3	0.3	3.7	1.4	7.8	1.0	59.8	8.2	99.0	78.8
May	ME	21.5	149.2	127.9	67.3	94.2	282.8	148.2	87.2	-	-	-	794.5
	MA	57.0	84.8	182.8	10.9	55.6	110.0	133.8	-	5.0	-	-	60.3
	NH	-	-	-	-	-	-	1.0	-	-	-	-	17.1
Jun	ME	-	99.4	7.0	1.2	-	0.1	2.0	-	-	-	-	-
	MA	0.8	150.7	5.7	-	-	4.3	1.6	0.1	-	-	-	-
	NH	0.2	10.6	0.1	3.1	-	-	-	-	-	-	-	-
Total		4131.9	4635.0	5266.0	3035.6	3315.4	4665.1	3571.2	3443.4	2142.4	2914.8	6466.4	9166.1

Table D2. Sample size (number of lengths measured) of Gulf of Maine northern shrimp port samples.

		Fishing season												
Month	State	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Mean
Dec	ME	212	67	318	497	-	502	820	417	278	394	1149	904	505
	MA	92	441	287	101	-	446	205	-	310	269	1611	1528	529
	NH	-	602	884	370	639	761	760	306	331	541	560	389	559
Jan	ME	326	519	849	825	1204	460	2191	2327	2136	1717	1498	2718	1,398
	MA	1108	-	426	354	741	1137	819	642	789	903	1342	1231	863
	NH	283	876	672	674	631	990	953	551	427	418	499	450	619
Feb	ME	642	283	187	667	898	190	2816	2058	1915	2722	1420	4862	1,555
	MA	776	195	161	512	900	515	726	198	714	277	835	1709	627
	NH	585	788	459	517	551	513	336	480	422	439	370	355	485
Mar	ME	368	205	127	506	571	1407	1419	1570	1502	1572	944	3378	1,131
	MA	830	388	414	149	-	232	358	652	1133	607	-	633	540
	NH	91	298	499	75	-	639	508	97	375	550	598	392	375
Apr	ME	38	58	-	-	303	-	1076	526	108	563	2789	2882	927
	MA	647	236	245	81	313	103	377	-	1009	104	-	-	346
	NH	-	-	-	-	-	-	-	-	107	-	362	186	218
May	ME	-	-	-	751	1218	226	1031	287	-	-	-	5638	1,525
	MA	-	429	75	-	1382	127	216	-	-	-	-	648	480
	NH	-	-	-	-	-	-	-	-	-	-	-	-	-
Jun	ME	-	-	-	-	-	-	-	-	-	-	-	-	-
	MA	-	436	-	-	-	-	-	-	-	-	-	-	436
	NH	-	438	-	-	-	-	-	-	-	-	-	-	438
Total		5997	6260	5603	6080	9352	8246	14611	10113	11557	11075	13978	27904	13554

Table D3. Sampling intensity (number of lengths per million landed) of Gulf of Maine northern shrimp port samples.

		Fishing season												
Month	State	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Mean
Dec	ME	7.64	2.66	9.11	13.64	-	9.60	44.14	35.76	32.42	24.94	18.66	11.10	19.06
	MA	11.12	31.81	32.95	65.28	-	52.99	25.41	-	160.71	80.81	88.57	96.13	64.58
	NH	-	128.06	569.24	313.23	292.63	72.31	86.60	102.54	85.04	28.01	25.96	19.59	156.66
Jan	ME	4.93	10.22	12.72	15.95	19.75	7.33	55.47	38.06	61.70	30.24	14.16	20.38	24.24
	MA	38.85	-	16.42	23.38	34.63	28.57	42.70	51.82	83.54	108.72	76.62	122.53	57.07
	NH	40.65	150.33	148.04	110.90	85.21	53.83	106.93	133.62	52.92	28.06	26.46	27.29	80.35
Feb	ME	7.30	2.86	2.22	13.06	20.68	3.39	44.76	23.06	45.95	38.63	13.67	19.83	19.62
	MA	35.42	10.67	5.95	28.55	36.86	30.84	30.98	32.37	86.69	29.05	72.24	112.38	42.67
	NH	132.22	147.73	96.69	128.16	105.84	52.33	118.73	388.23	39.22	28.67	25.80	16.88	106.71
Mar	ME	7.93	5.83	2.01	21.01	31.69	27.76	38.63	37.42	53.93	39.46	9.31	43.90	26.57
	MA	37.90	21.47	14.73	18.97	-	20.36	19.28	141.89	174.96	159.56	-	107.30	65.13
	NH	93.53	222.54	311.40	68.12	-	200.26	217.01	150.15	39.88	96.50	31.96	41.47	133.89
Apr	ME	3.03	6.13	-	-	11.10	-	44.35	35.42	10.40	104.25	35.83	75.31	32.52
	MA	118.51	20.50	12.00	98.84	23.24	6.99	36.33	-	198.57	107.81	-	-	69.20
	NH	-	-	-	-	-	-	-	-	13.63	-	29.22	26.22	45.00
May	ME	-	-	-	124.49	106.27	8.37	80.98	30.43	-	-	-	67.16	69.61
	MA	-	36.09	4.21	-	217.45	11.09	9.94	-	-	-	-	64.06	57.14
	NH	-	-	-	-	-	-	-	-	-	-	-	-	-
Jun	ME	-	-	-	-	-	-	-	-	-	-	-	-	-
	MA	-	35.36	-	-	-	-	-	-	-	-	-	-	35.36
	NH	-	567.36	-	-	-	-	-	-	-	-	-	-	567.36
Total		17.00	17.33	13.17	26.61	32.97	18.64	45.62	38.53	59.33	40.96	22.72	34.91	35.78

Table D4. Mean weight (g) of Gulf of Maine northern shrimp from trip-weighted port samples.

		Fishing season												
Month	State	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Mean
Dec	ME	12.120	13.761	13.913	[illegible]	-	9.798	12.825	15.531	11.756	-	12.142	13.793	12.497
	MA	11.087	11.130	11.900	9.307	-	8.982	11.228	-	10.161	8.141	8.830	10.560	10.133
	NH	-	12.276	11.849	11.009	13.042	10.578	12.223	11.189	8.598	6.071	9.759	9.555	10.559
Jan	ME	12.881	14.734	13.568	15.340	12.639	12.401	12.887	14.406	10.658	11.409	13.214	12.582	13.060
	MA	9.959	-	10.018	14.905	9.228	8.652	9.109	11.962	8.677	8.184	8.790	10.624	10.010
	NH	12.395	13.024	11.815	11.944	14.439	10.425	11.718	11.396	10.591	8.349	9.905	10.278	11.357
Feb	ME	12.456	14.185	14.161	15.421	16.134	9.086	14.050	14.324	[illegible]	13.793	12.886	12.256	13.590
	MA	10.871	12.076	14.232	14.217	6.346	11.077	7.507	11.962	9.939	10.552	9.007	12.408	10.850
	NH	11.383	13.265	13.219	13.322	14.781	11.850	11.927	9.627	9.456	8.412	8.247	11.133	11.385
Mar	ME	11.323	11.836	10.651	10.113	13.678	12.596	12.387	11.021	10.684	10.029	8.992	10.204	11.126
	MA	10.922	11.103	11.037	13.338	-	8.808	7.060	10.340	9.617	10.199	-	11.502	10.393
	NH	11.923	10.600	9.790	13.533	-	9.629	11.886	10.526	8.190	8.704	8.468	8.654	10.173
Apr	ME	9.321	11.010	-	-	8.020	-	10.376	11.011	12.318	9.021	8.058	9.157	9.810
	MA	10.592	9.670	8.870	10.494	11.948	10.777	8.984	-	8.263	13.269	-	-	10.319
	NH	-	-	-	-	-	-	-	-	7.617	-	7.989	11.111	8.905
May	ME	-	-	-	11.156	8.215	10.469	11.637	9.241	-	-	-	9.465	10.031
	MA	-	7.133	10.267	-	8.749	9.606	6.157	-	-	-	-	5.960	7.979
	NH	-	-	-	-	-	-	-	-	-	-	-	-	9.005
Jun	ME	-	-	-	-	-	-	-	-	-	-	-	-	12.973
	MA	-	12.223	-	-	-	-	-	-	-	-	-	-	12.223
	NH	-	13.723	-	-	-	-	-	-	-	-	-	-	13.723
Mean		11.326	11.984	11.806	12.387	11.435	10.316	10.748	11.734	10.057	9.703	9.714	10.578	10.982

Table D5. Observed northern shrimp discards from the shrimp trawl fishery and finfish trawl fisheries.

Shrimp trawl fishery

Fishing season	Sampled trips	lb kept	lb discarded	Proportion discarded
1985	1	2400	-	0.000
1986	3	4300	3	0.001
1987	4	3575	-	0.000
1988	9	18935	-	0.000
1989	17	23260	24	0.001
1990	17	22004	-	0.000
1991	37	66936	159	0.002
1992	57	67433	56	0.001
1993	80	91636	32	0.000
1994	80	101625	795	0.008
1995	57	77346	20	0.000
1996	31	49362.5	-	0.000
Average				0.001

Large-mesh fish trawl fishery

Year	Sampled trips	lb discard	Discard/ trip (lb)	Discard/ trip (mt)
1989	63	5	0.08	-
1990	36	1	0.03	-
1991	71	35	0.49	-
1992	56	5	0.09	-
1993	25	9	0.36	-
1994	15	-	-	-
1995	43	22	0.51	-
1996	22	-	-	-
1997	10	-	0.01	-
Average		9	0.17	-

Small-mesh fish trawl fishery

Year	Sampled trips	lb discard	Discard/ trip (lb)	Discard/ trip (mt)
1989	32	30	0.94	-
1990	16	-	-	-
1991	38	43	1.13	0.001
1992	28	11	0.39	-
1993	17	-	-	-
1994	4	-	-	-
1995	37	1,084	29.30	0.013
1996	47	5,355	113.94	0.052
1997	34	33	0.96	-
Average		728	16.30	0.007

Table D6. Summary of modified DeLury model input data, estimates, and coefficient of variation (CV) and relative interquartile range (IQR) from bootstrap estimates of fishing mortality.

	Input			Results		q = 0.7081 (CV = 8%, IQR = 11%)			
Fishing season	Recruits (#/tow)	Fully-recruited (#/tow)	Catch (millions)	Recruits (millions)	Fully-recruited (millions)	Biomass (mt)	F(N+R)	CV	IQR
1985	447.6	479.1	352.793	787.82	755.36	11,210	0.13	69%	94%
1986	619.5	925.4	361.171	929.21	1051.60	16,850	0.31	29%	34%
1987	533.4	848.7	425.294	765.85	1134.18	17,180	0.46	19%	23%
1988	436.3	693.6	228.434	545.74	937.35	13,560	0.46	21%	25%
1989	459.9	387.9	283.647	941.62	726.83	10,840	0.19	45%	58%
1990	700.7	817.5	442.429	1043.44	1071.36	16,030	0.35	23%	29%
1991	511.6	907.7	320.290	652.22	1159.05	17,080	0.45	21%	28%
1992	374.1	611.9	262.434	478.29	899.32	13,050	0.47	21%	28%
1993	313.6	444.4	194.788	403.52	672.51	9,546	0.43	23%	29%
1994	410.0	320.6	270.406	574.64	547.20	7,200	0.33	31%	41%
1995	368.7	364.4	604.137	837.16	628.26	10,080	0.40	23%	31%
1996	485.9	653.1	799.368	720.77	768.81	12,190	0.90	18%	24%
1997	257.7	348.6	-	404.38	473.12	7,301	-	-	-

Table D7. Summary of results from sensitivity DeLury analyses of Gulf of Maine northern shrimp.

Run no.	[1]**104**	184	124	144	164	174	134
M	0.25	0.35	0.25	0.25	0.25	0.25	0.25
Selectivity	S&B 1997	S&B 1997	'96 retention	S&B 1997	S&B 1997	S&B 1997	S&B 1997
Survey	Ln	Ln	Ln	Nontrans.	Ln	Ln	Ln
Sr	0.7-1.0	0.7-1.0	0.7-1.0	0.7-1.0	0.9	1.0	0.8
Estimates							
Mean Z	0.66	0.66	0.60	0.63	0.66	0.61	0.71
Min. Z	0.39	0.39	0.29	0.44	0.38	0.34	0.44
Max. Z[2]	1.15	1.07	1.04	0.93	1.14	1.05	1.25
q	0.7081	0.5439	0.7032	1.6279	0.7081	0.6091	0.8359
Min. N[3]	473.12	640.70	573.65	573.20	483.05	571.24	402.00
Max. N	1159.05	1514.08	1447.82	953.84	1136.15	1311.24	970.03
Min. R	403.52	526.43	407.65	321.90	404.35	423.12	385.35
Max. R	1043.44	1392.49	1191.35	937.80	1049.42	1110.79	986.40
Diagnostics							
TSS	0.08736	0.06541	0.07925	0.06502	0.09952	0.08839	0.11473
RSS	0.02028	0.01668	0.01975	0.01090	0.02479	0.02361	0.02634
~Rsq	0.77	0.74	0.75	0.83	0.75	0.73	0.77
%SSn	0.37	0.42	0.43	0.39	0.41	0.44	0.37
%SSr	0.18	0.15	0.13	0.18	0.17	0.14	0.21
%SS process	0.45	0.43	0.44	0.44	0.43	0.42	0.42
CVq	0.21	0.24	0.23	0.16	0.23	0.25	0.21
Min. CVn	0.19	0.17	0.18	0.13	0.21	0.20	0.22
Max. CVn	0.25	0.22	0.24	0.18	0.27	0.26	0.28
Min. CVr	0.23	0.21	0.23	0.16	0.26	0.25	0.26
Max. CVr	0.25	0.23	0.25	0.18	0.28	0.27	0.28
No. r>0.4;<-0.4	2	-	-	-	1	1	2
No. std.res.>2	-	-	-	-	-	-	-
No. iterations	6	5	5	6	6	5	7

[1]Accepted run. [2]Maximum mortality was in 1996 for all runs. [3]Minimum abundance was in 1997 for all runs.

Table D8. Summary of biomass dynamics model input data, results, and bootstrap interquartile ranges (IQR).

	Input			Results					
Fishing season	Fall (kg/tow)	Maine (kg/tow)	Summer (kg/tow)	Catch (mt)	Biomass (mt)	F	Parameter	Estimate	IQR
1968	3.2	45.8	-	5,708	45,140	0.128	B1969	45,140	45%
1969	2.7	31.2	-	12,140	43,780	0.304	K (mt)	59,080	25%
1970	3.7	40.8	-	11,330	36,520	0.340	r	0.3421	12%
1971	3.0	9.4	-	10,590	30,470	0.383	q fall	0.0984	23%
1972	3.3	7.0	-	11,220	25,130	0.517	q Maine	0.5669	23%
1973	1.9	7.8	-	9,691	18,740	0.618	q summer	0.8878	23%
1974	0.8	4.9	-	8,024	13,050	0.781			
1975	0.9	6.7	-	6,142	7,961	1.132	MSY	4,925	17%
1976	0.6	4.8	-	1,387	3,509	0.413	Bmsy	29,540	25%
1977	0.2	1.6	-	372	3,212	0.103	Fmsy	0.171	12%
1978	0.4	3.2	-	17	4,003	0.004	B1997	6,381	76%
1979	0.5	4.4	-	487	5,477	0.079	F1996	0.994	59%
1980	0.5	2.7	-	339	6,895	0.043			
1981	1.5	3.0	-	1,071	8,912	0.110			
1982	0.3	-	-	1,530	10,670	0.133			
1983	1.0	-	-	1,397	12,350	0.104			
1984	1.9	-	10.5	2,951	14,560	0.196			
1985	1.6	-	17.7	4,131	15,530	0.267			
1986	2.5	-	19.6	4,635	15,380	0.309			
1987	1.7	-	14.8	5,253	14,650	0.379			
1988	1.2	-	12.8	3,031	13,090	0.227			
1989	1.8	-	17.0	3,315	13,660	0.239			
1990	2.0	-	18.1	4,662	14,040	0.345			
1991	0.9	-	11.7	3,571	13,000	0.275			
1992	0.6	-	9.4	3,444	12,960	0.265			
1993	1.6	-	9.1	2,143	13,040	0.155			
1994	2.2	-	8.7	2,915	14,580	0.193			
1995	1.8	-	13.3	6,466	15,590	0.456			
1996	1.1	-	8.8	9,166	12,870	0.994			
1997	-	-	-	-	6,381	-			

Table D9. Yield and egg production per recruit of Gulf of Maine northern shrimp.

									M = 0.25			$F_{example}$ = 0.20	
Age	Length	Transition rate	Selectivity	Total N	Male N	Female N	Male catch	Female catch	Male wt	Female wt	Yield	Fecundity at length	Egg production
1	11.17	0.000	0.033	774	774	-	4	-	0.84	1.24	4	-	-
2	18.43	0.000	0.230	575	575	-	31	-	3.79	4.82	117	-	-
3	23.50	0.081	0.579	399	367	32	56	-	7.87	9.30	439	1,286	41,581
4	27.04	0.922	0.799	265	21	244	48	4	12.00	13.58	635	1,876	458,156
5	29.51	0.997	0.893	173	-	172	3	35	15.60	17.19	657	2,287	393,661
6	31.23	1.000	0.933	112	-	111	-	26	18.50	20.04	523	2,574	287,027
7	32.43	1.000	1.000	71	-	71	-	18	20.72	22.19	399	2,775	197,299
										Total	2,773		1,377,725
										Total/rec.	2.773		1,378
												%max	57.52

Ref. point	F	YPR	%EPR
Fmax	0.77	4.2482	14.77
F0.1	0.46	3.9897	29.83
F50%	0.25	3.1449	50.00
F40%	0.34	3.6213	40.00
F30%	0.45	3.9676	30.00
[illegible]	0.63	4.2087	20.00
F10%	0.95	4.2111	10.00

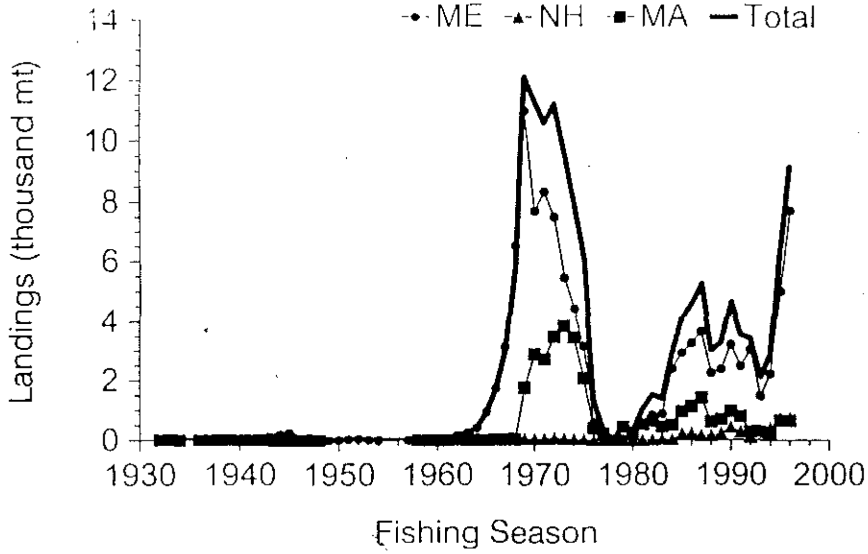

Figure D1. Gulf of Maine northern shrimp landings by fishing season (August to July).

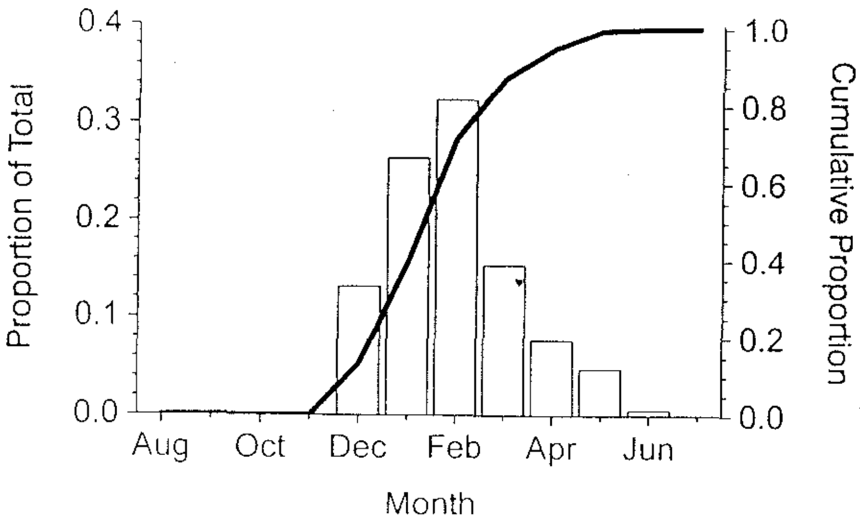

Figure D2. Distribution of monthly landings of Gulf of Maine northern shrimp, 1984-1996.

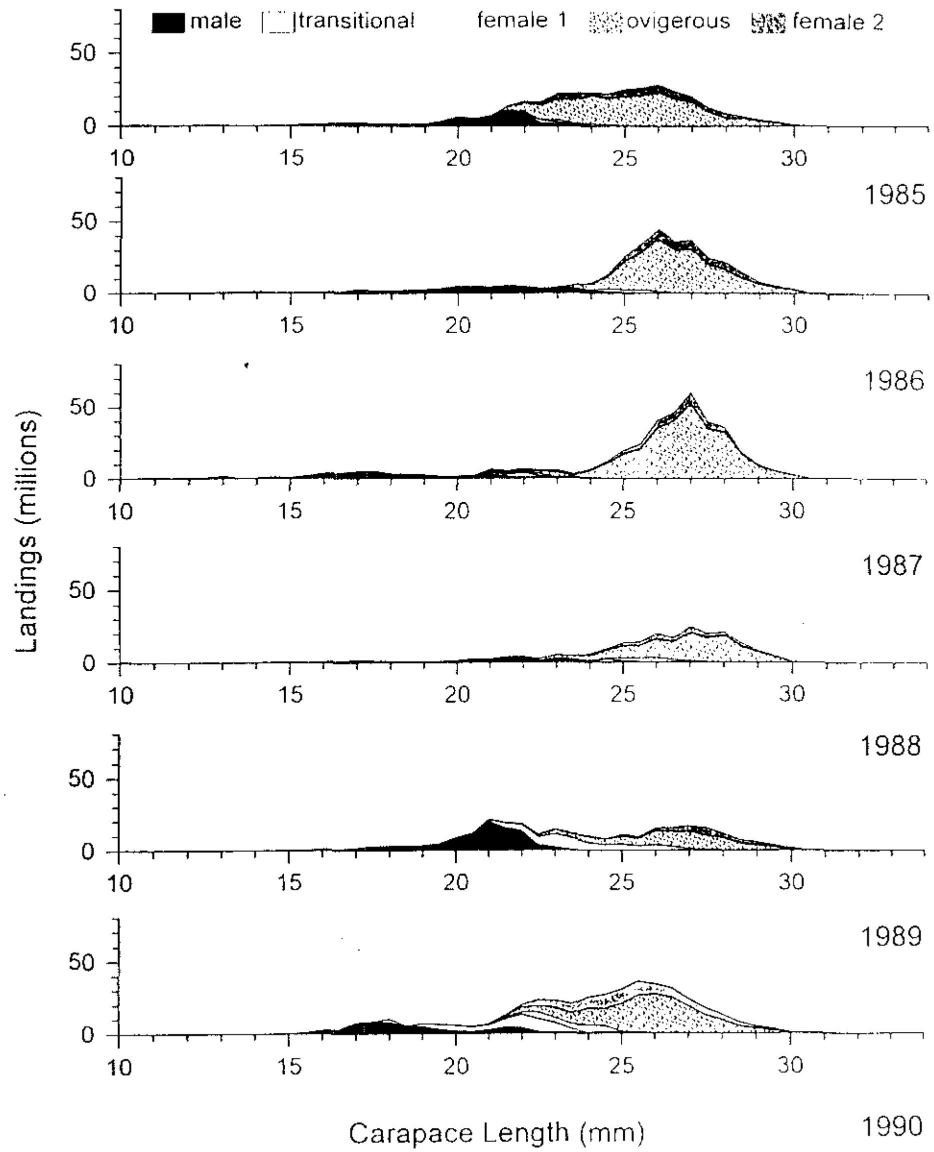

Figure D3. Gulf of Maine northern shrimp landings by length, developmental stage, and fishing season.

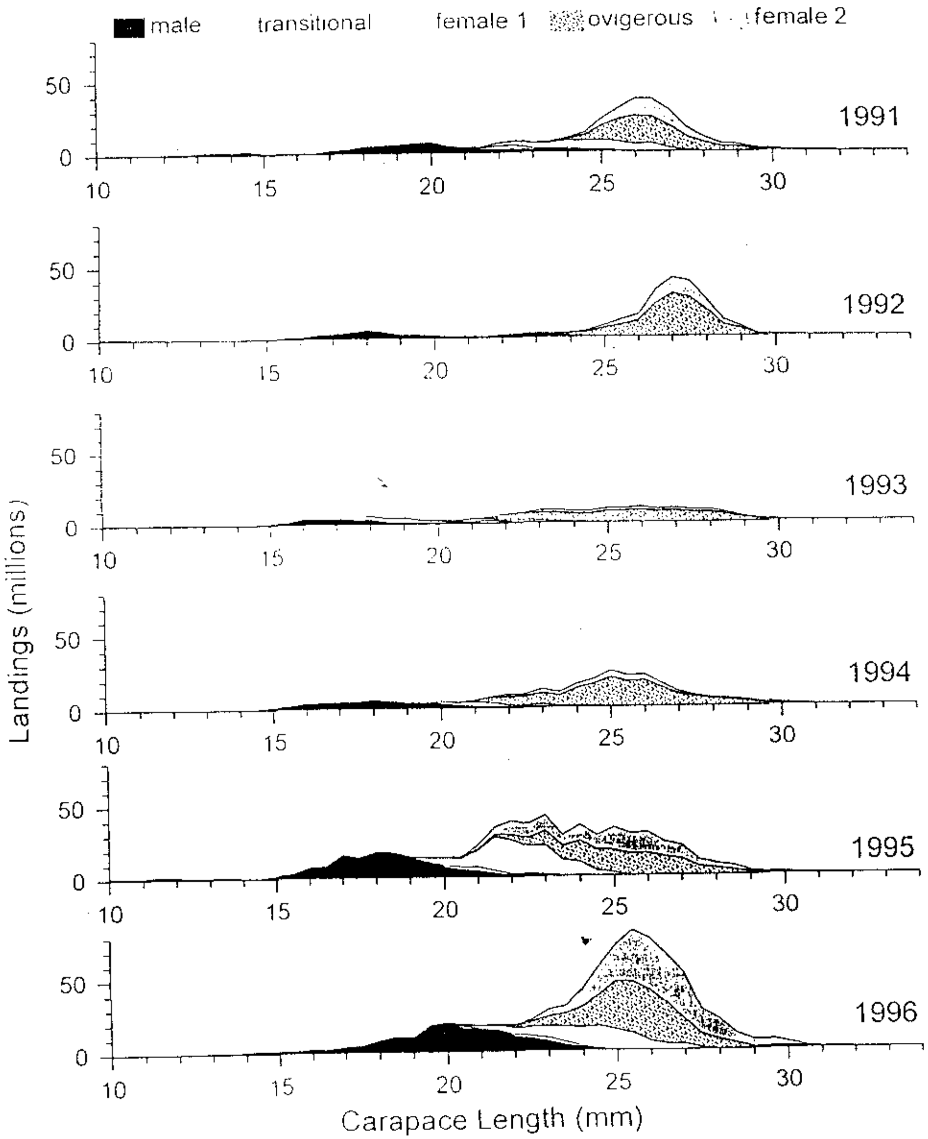

Figure D3. Continued.

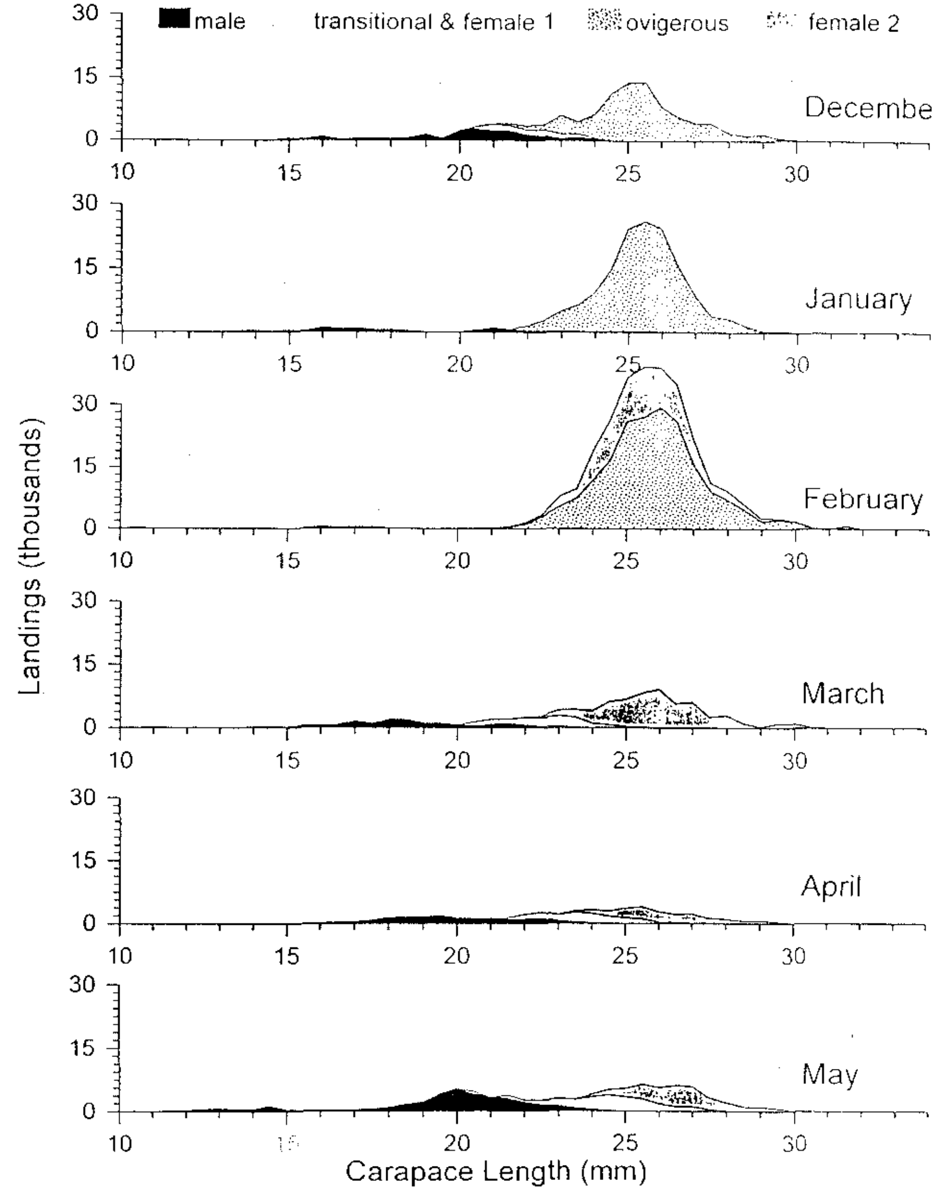

Figure D4. Gulf of Maine northern shrimp 1996 landings by length, developmental stage, and month.

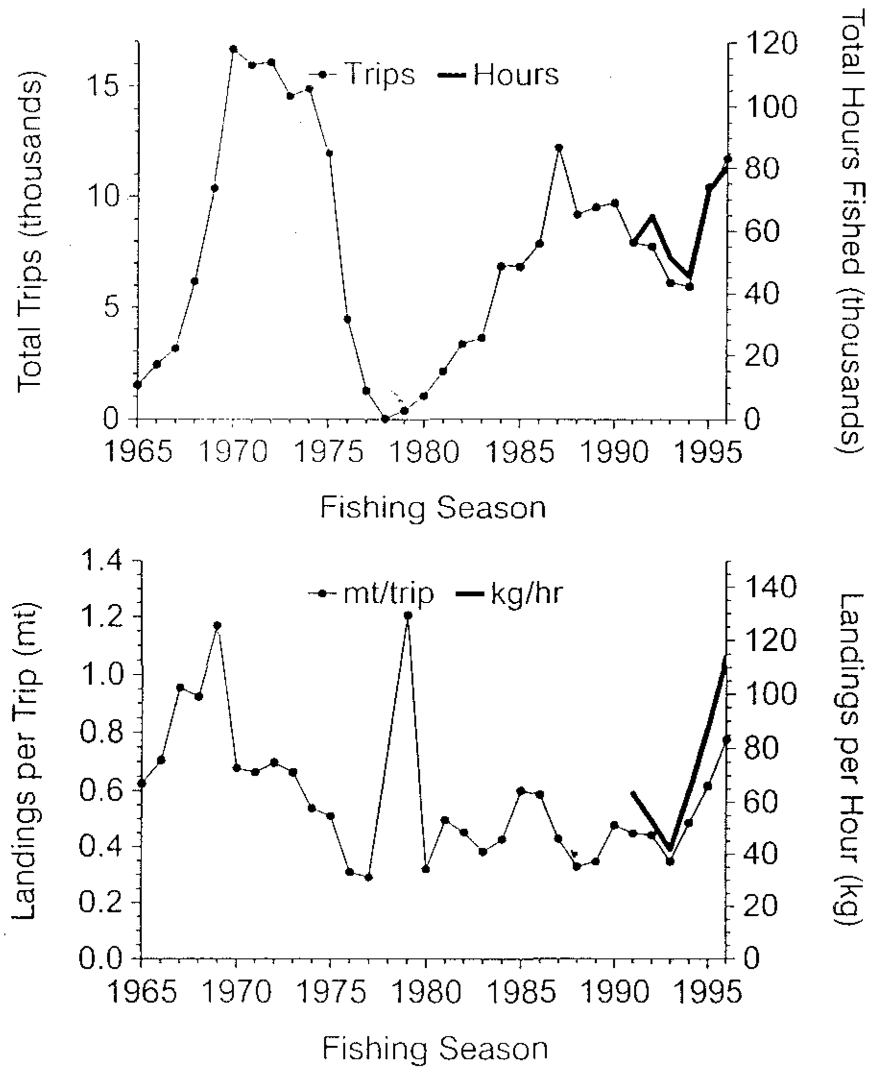

Figure D5. Nominal fishing effort (above) and catch per unit effort (below) in the Gulf of Maine northern shrimp fishery.

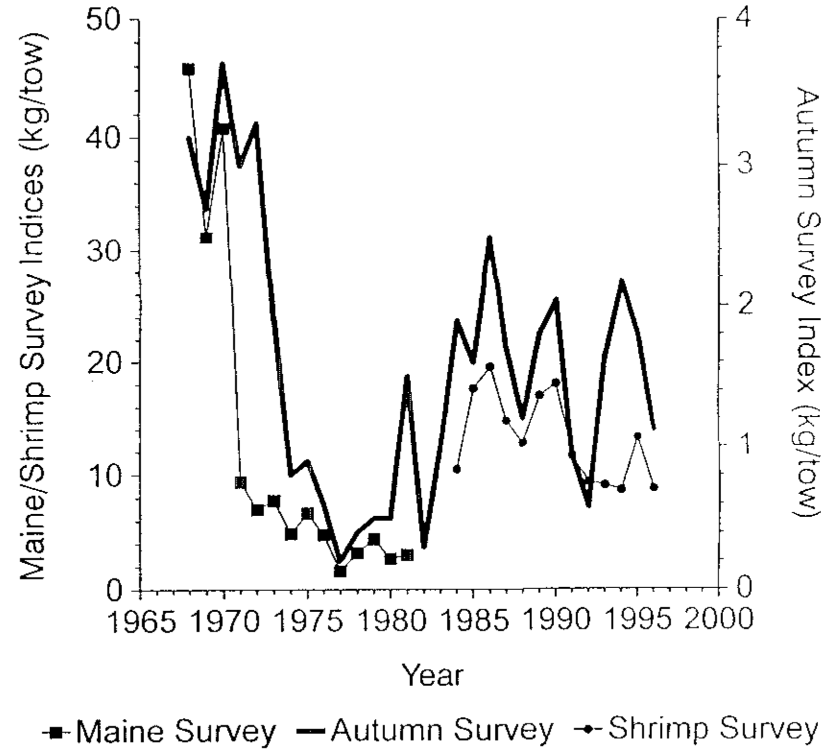

Figure D6. Research trawl survey indices of Gulf of Maine northern shrimp biomass.

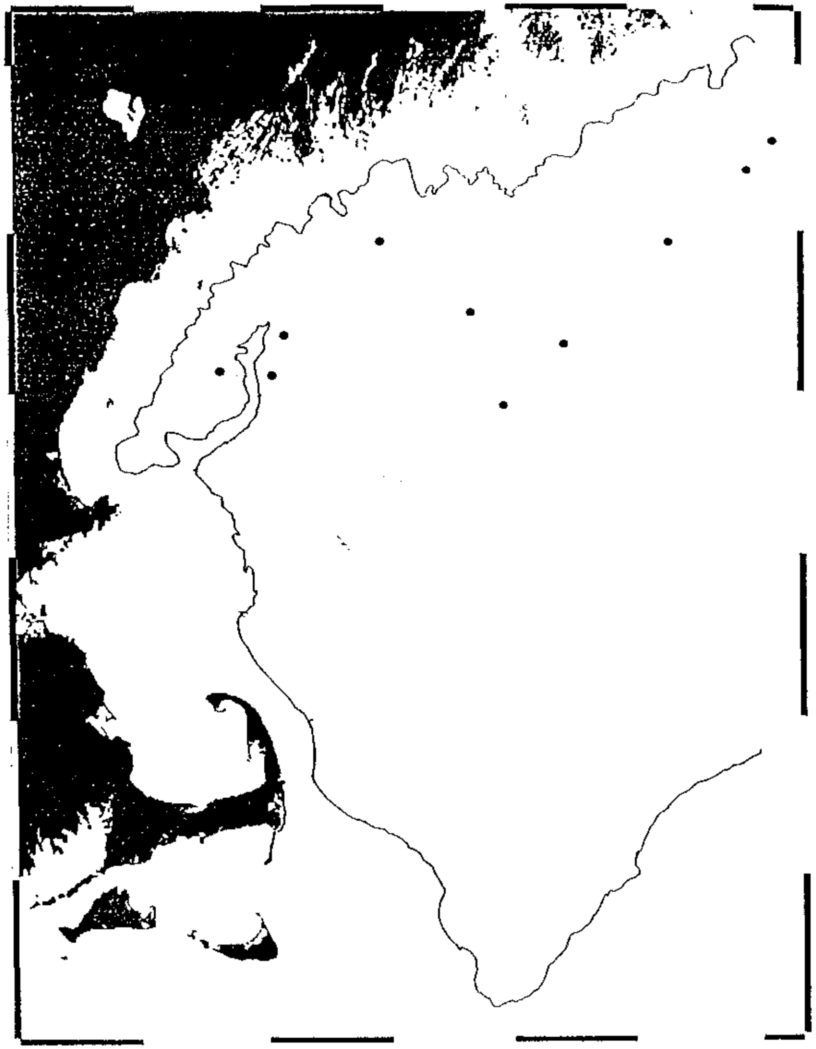

Figure D7. State of Maine summer survey fixed station locations.

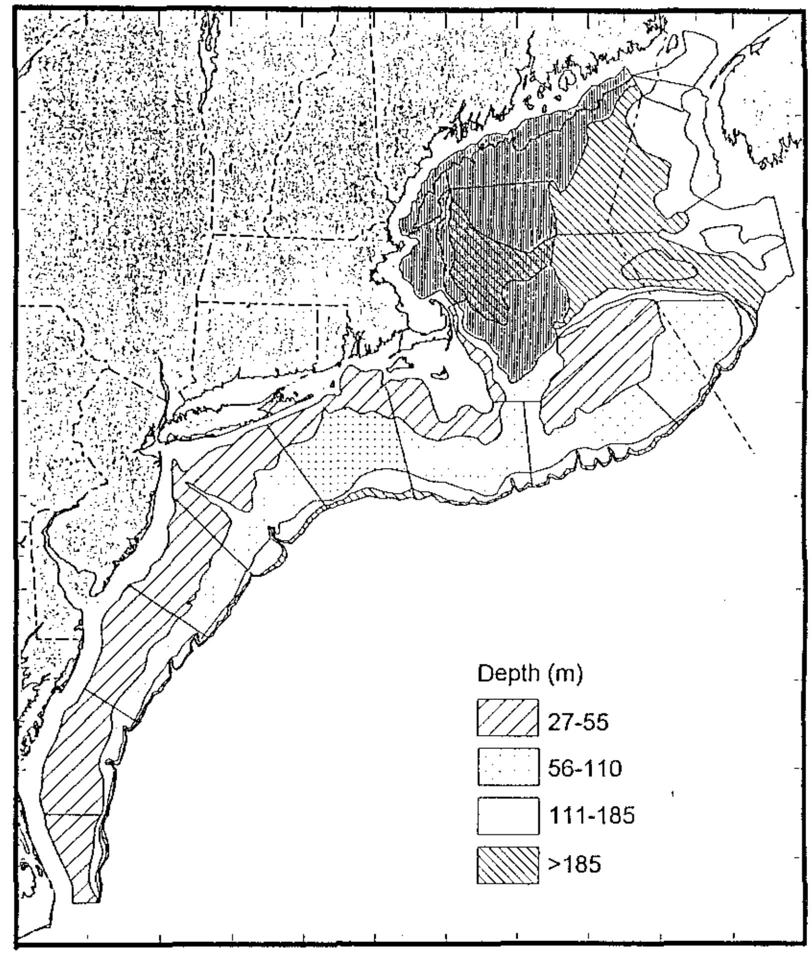

Figure D8. NEFSC groundfish survey strata. Catches from shaded strata are included in the assessment.

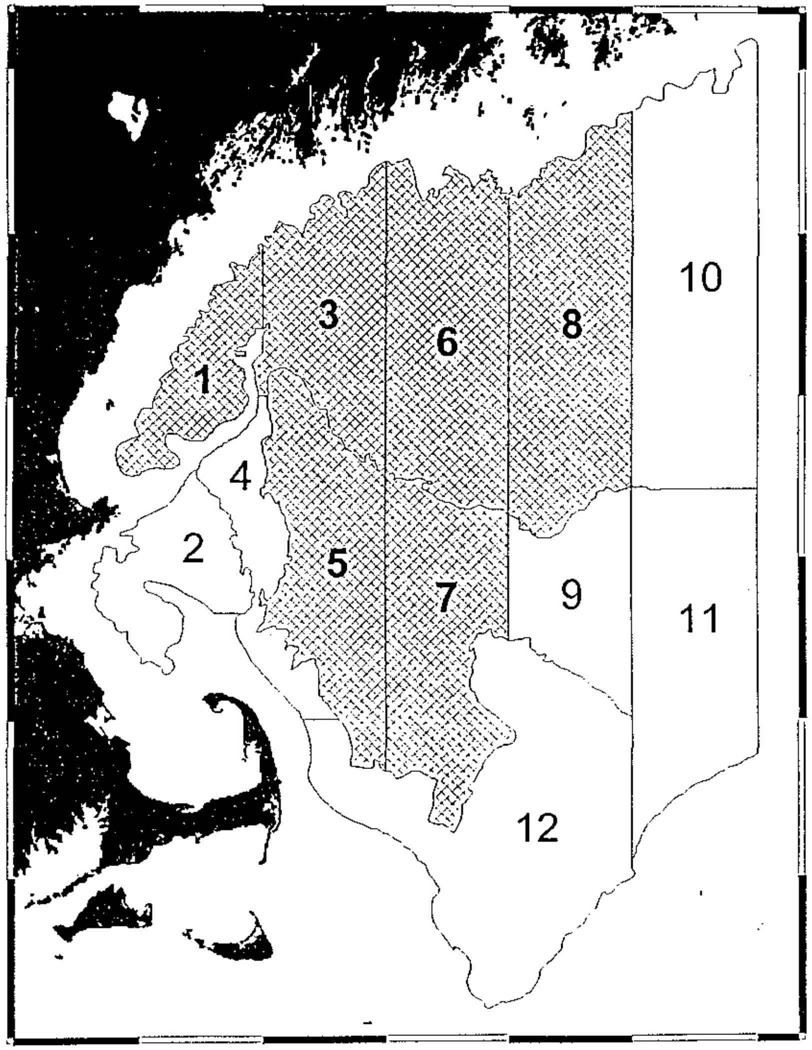

Figure D9. Gulf of Maine northern shrimp summer survey strata. Catches from shaded strata are included in the assessment.

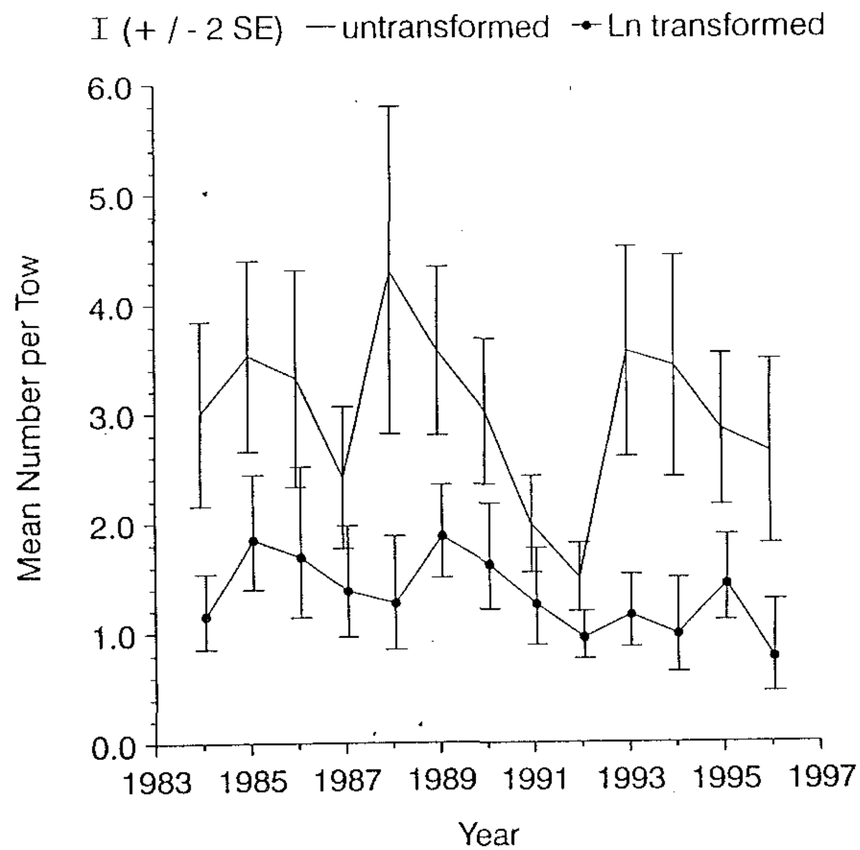

Figure D10. Gulf of Maine northern shrimp summer survey indices of abundance.

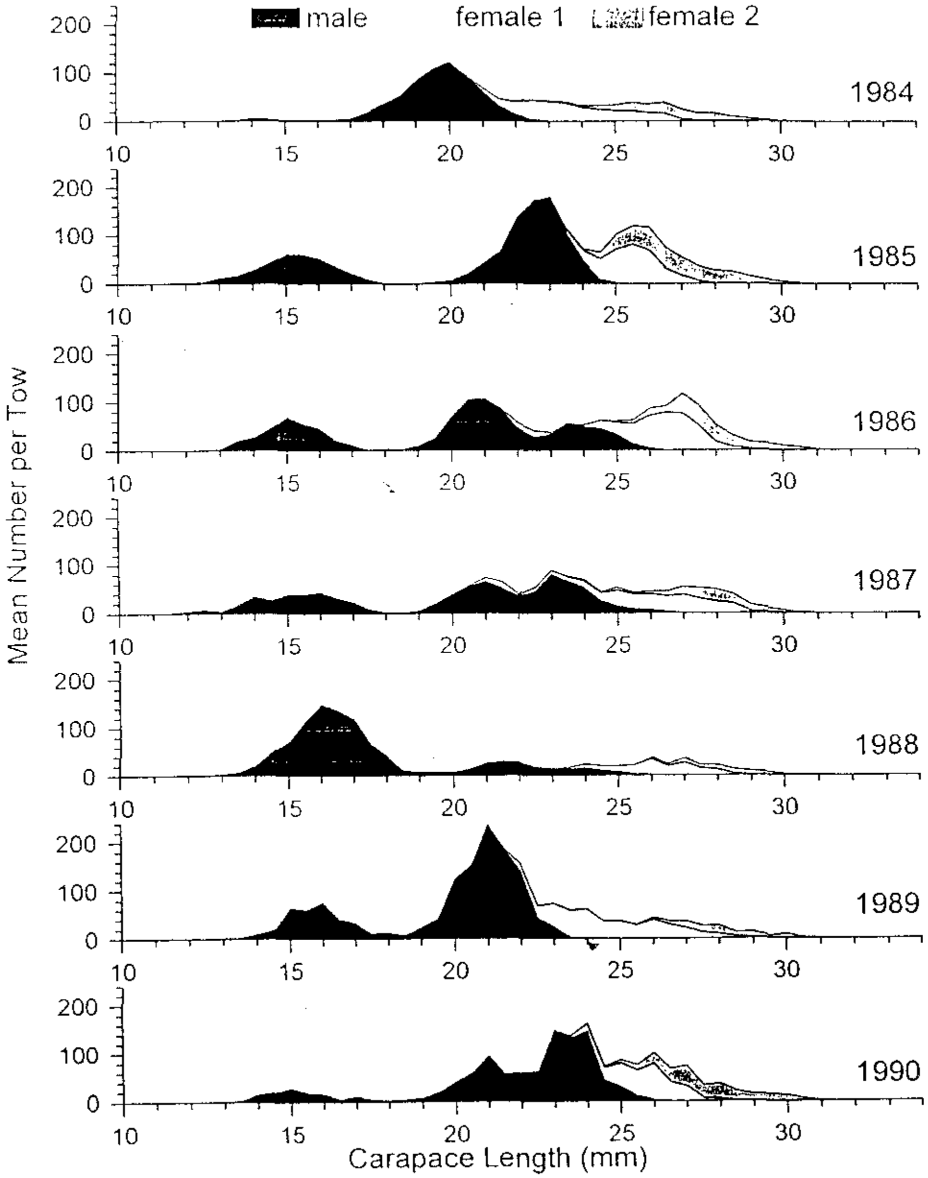

Figure D11. Gulf of Maine northern shrimp summer survey mean catch per tow by length and developmental stage.

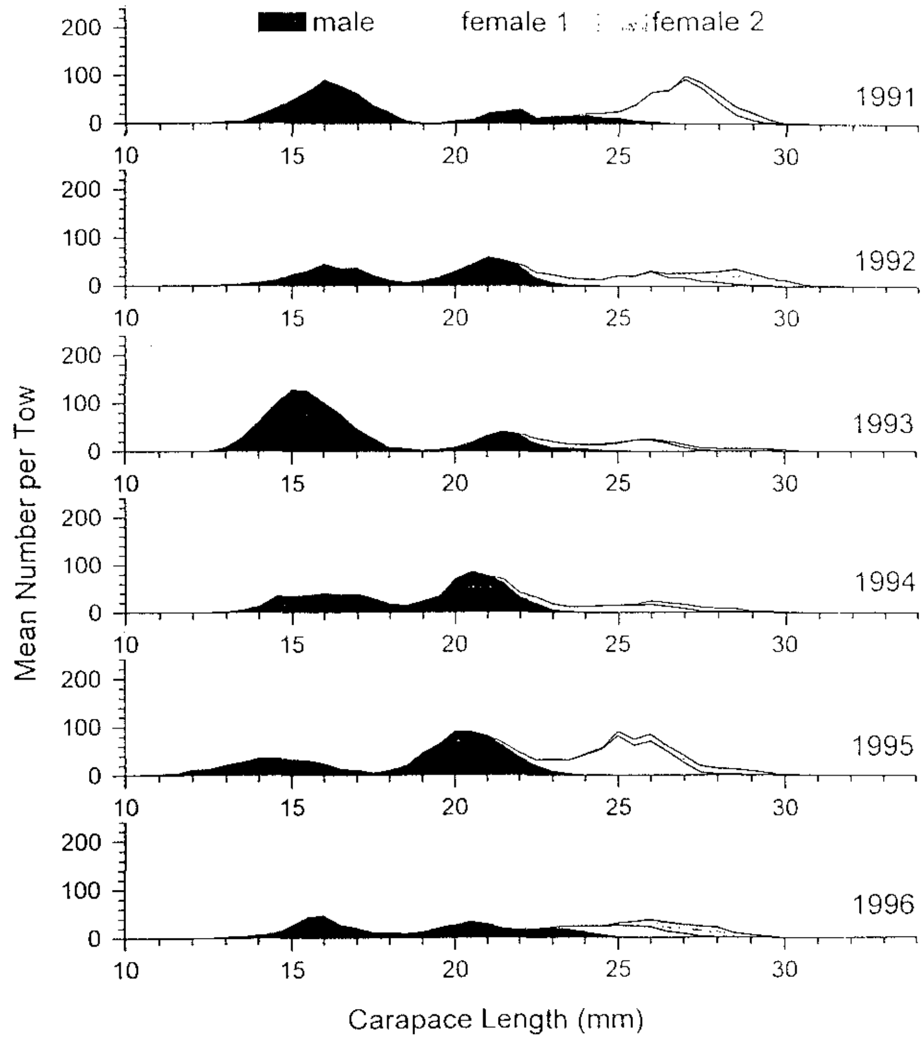

Figure D11. Continued.

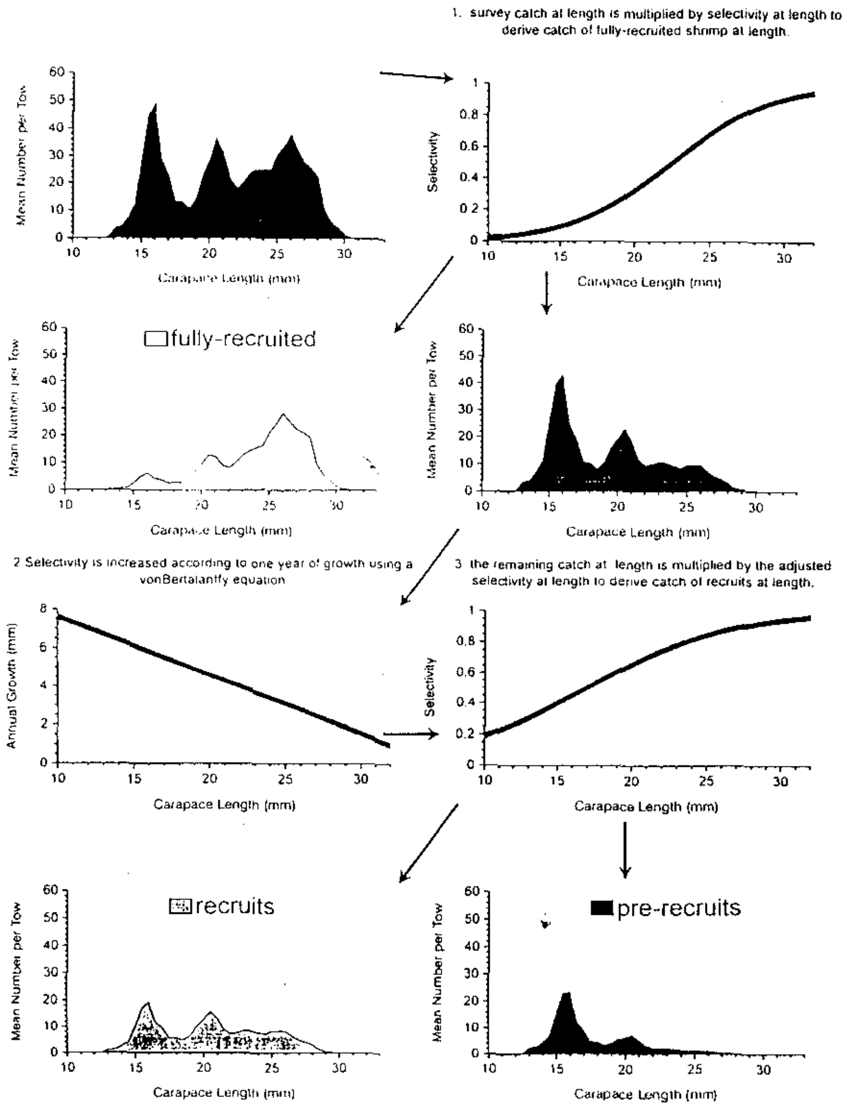

Figure D12. The "selectivity" method of driving indices of abundance for fully-recruited and recruit Gulf of Maine northern shrimp from summer survey length frequencies (example used in 1996).

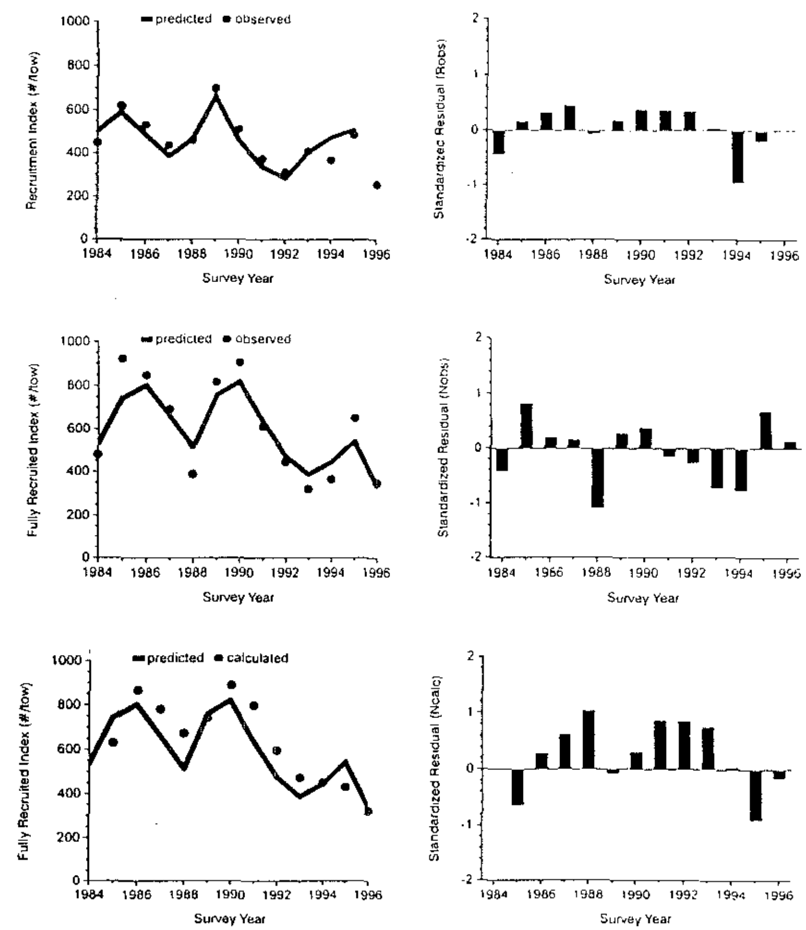

Figure D13. Summary of results from DeLury analysis of Gulf of Maine northern shrimp.

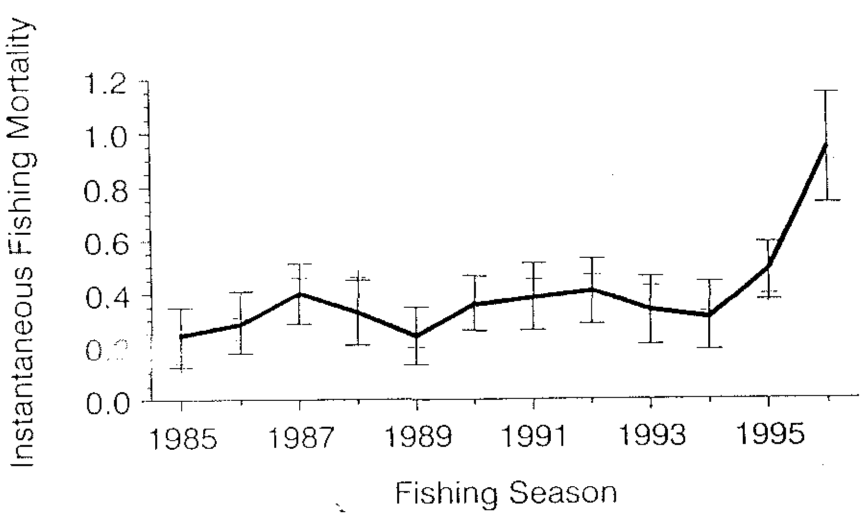

Figure D14. Fishing mortality estimates for Gulf of Maine northern shrimp catch, least-squares estimates, bootstrapped mean, and 80% confidence limits.

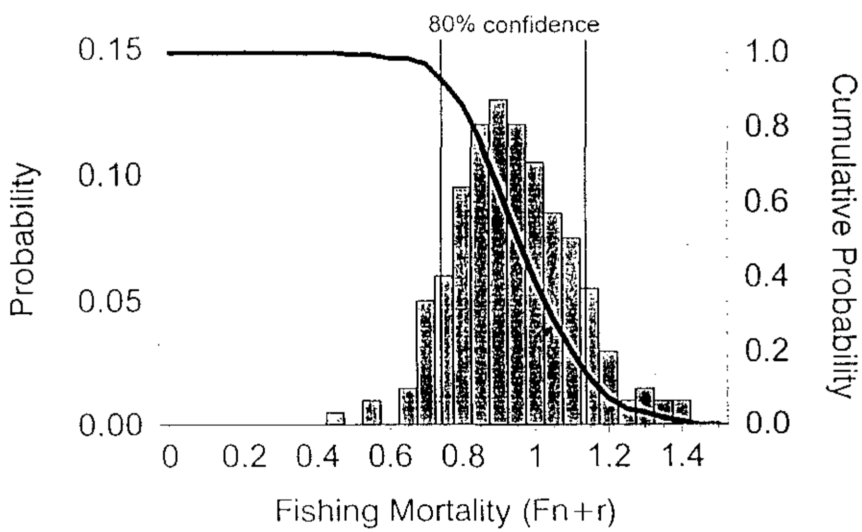

Figure D15. Bootstrapped DeLury estimates of fishing mortality for the 1996 fishing season (i.e., 1995 survey year) for Gulf of Maine northern shrimp.

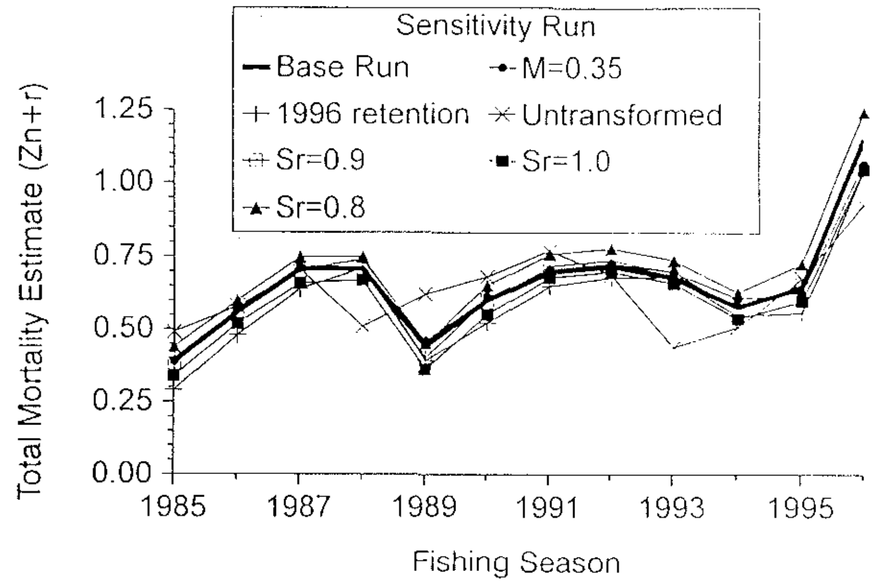

Figure D16. Total mortality estimates from sensitivity analysis of Gulf of Maine northern shrimp.

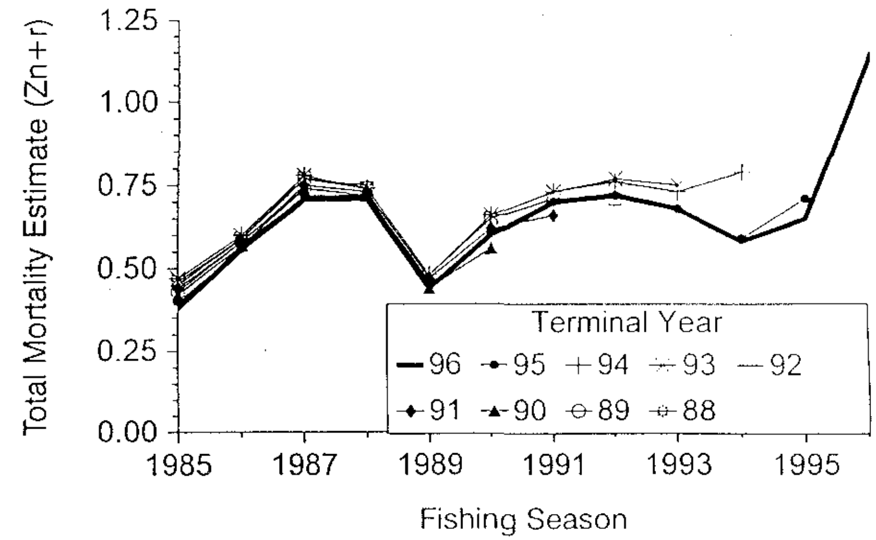

Figure D17. Retrospective DeLury estimates of total mortality for Gulf of Maine northern shrimp.

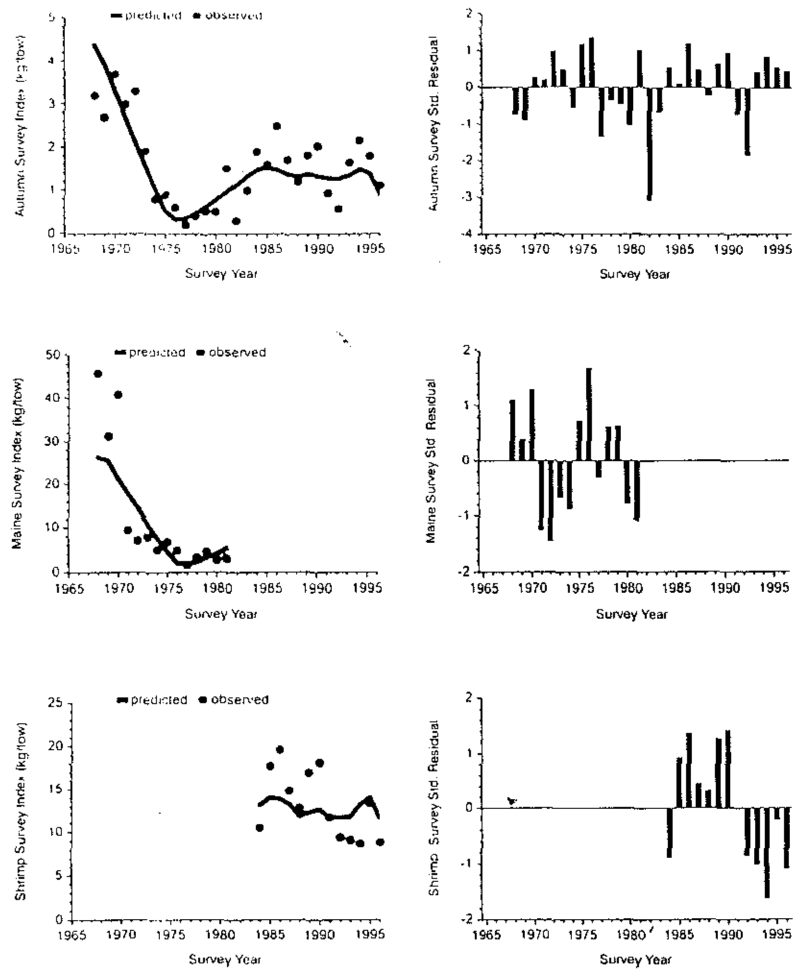

Figure D18. Summary of results from ASPIC analysis of Gulf of Maine northern shrimp biomass dynamics.

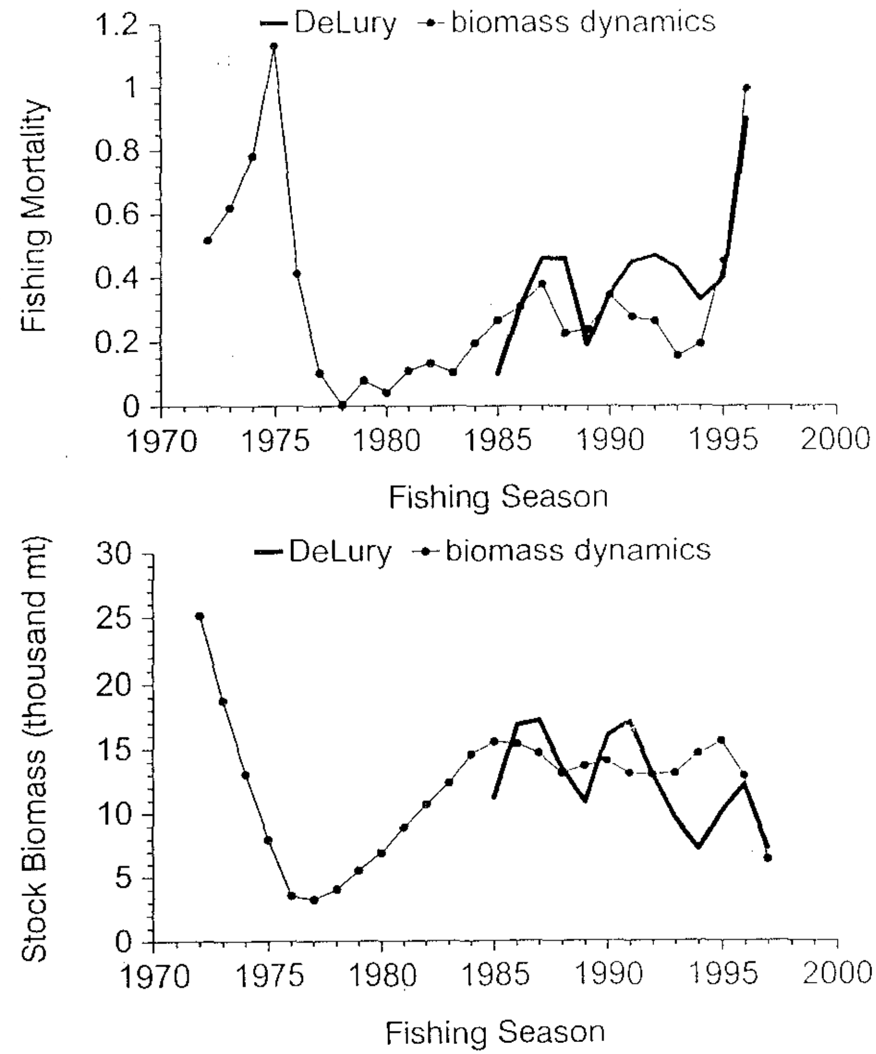

Figure D19. Estimates of fishing mortality (above) and stock biomass (below) for Gulf of Maine northern shrimp from DeLury analysis and biomass dynamics modeling.

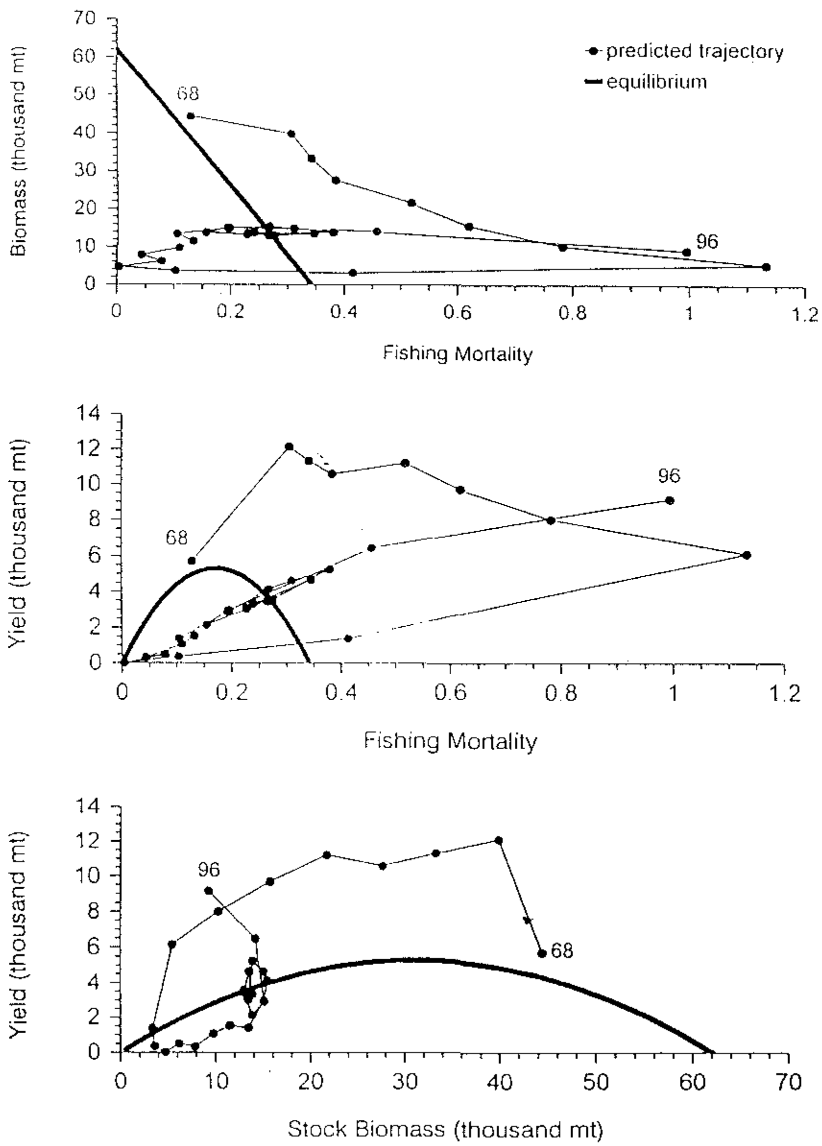

Figure D20. Biomass dynamics of Gulf of Maine northern shrimp.

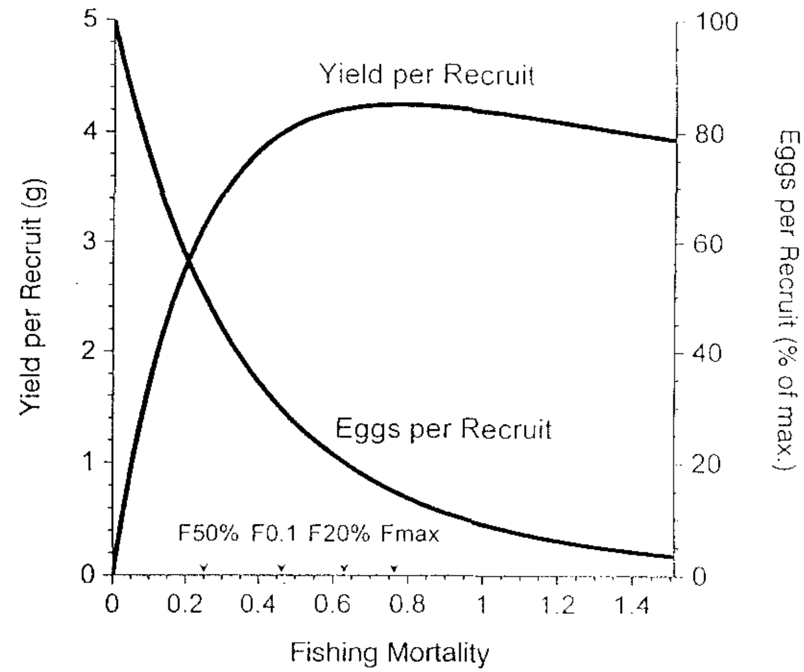

Figure D21. Yield and egg production per recruit for Gulf of Maine northern shrimp.

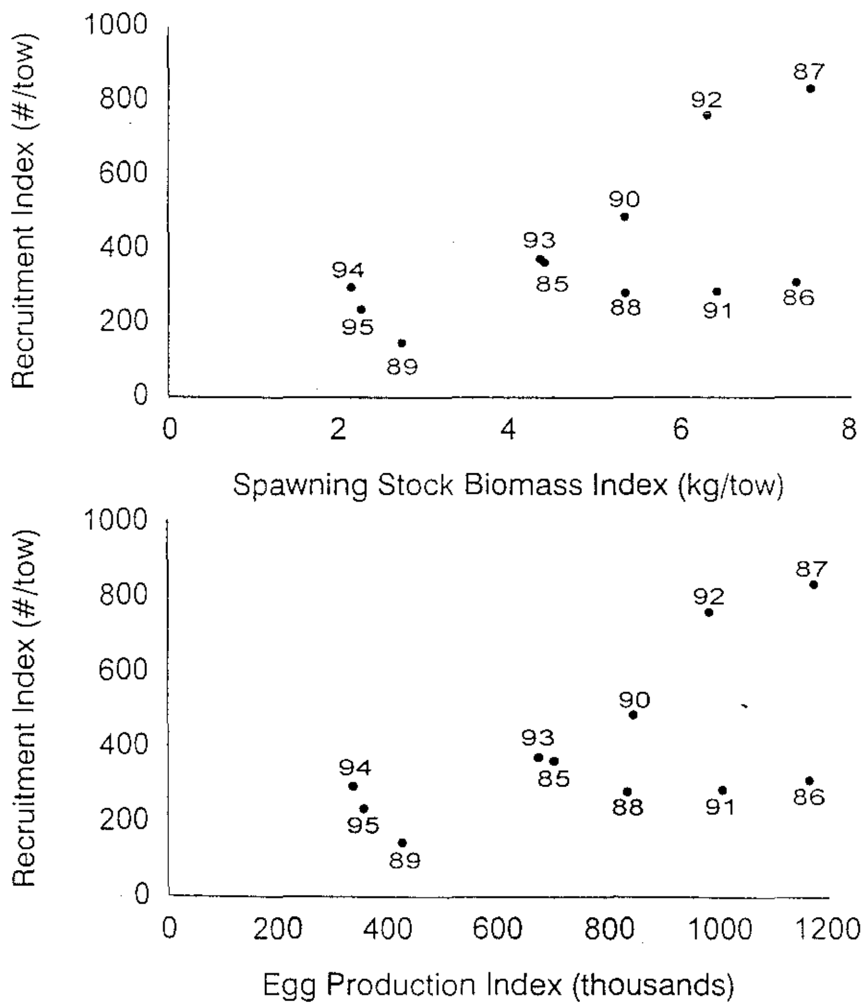

Figure D22. Relationships between summer survey indices of Gulf of Maine northern shrimp female biomass the summer before spawning and survey egg production index to age-1.5 abundance two years later. Data labels indicate year of spawn.