Northeast Fisheries Science Center Reference Document 95-08

Report of the 19th Northeast Regional Stock Assessment Workshop(19th SAW)

Stock Assessment Review Committee (SARC) Consensus Summary of Assessments

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Northeast Fisheries Science Center
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The complete activities of SAW 19 are documented in the following reports:

CRD 95-02	Assessment of the Gulf of Maine cod stock for 1994 R. K. Mayo
CRD 95-03	A preliminary assessment for white hake in the Gulf of Maine-Georges Bank Region K.A. Sosebee, L. O'Brien, and L.C. Hendrickson
CRD 95-04	Assessment of scup (Stenotomus chrysops), 1994 Report of the Pelagic/Coastal Subcommittee
CRD 95-05	Analytical assessment of surfclam populations in the Middle Atlantic region of the United States in 1994 R.J. Weinberg, S.A. Murawski, R. Conser, J. Brodziak, L. Hendrickson, H.-L. Lai, and P. Rago
CRD 95-06	Bayesian framework for modified DeLury Models Ray Conser
CRD 95-07	Ocean quahog populations from the Middle Atlantic to the Gulf of Maine in 1994 S. Murawski, J. Weinberg, P.Rago, J. Brodziak, L. Hendrickson, R. Conser, H.-L. Lai
CRD 95-08	Report of the 19th Northeast Regional Stock Assessment Workshop (19th SAW) Stock Assessment Review Committee (SARC) Consensus Summary of Assessments
CRD 95-09	Report of the 19th Regional Stock Assessment Workshop (19th SAW) The Plenary

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MEETING OVERVIEW

The Stock Assessment Review Committee (SARC) Meeting of the 19th Northeast Regional Stock Assessment Workshop (19th SAW) was held at the Northeast Fisheries Science Center (NEFSC), Woods Hole, Massachusetts during 28 November - 3 December 1994. SARC Chairman was Dr. Terrence P. Smith (NEFSC). The composition of the SARC is presented in Table 1. In addition to SARC members, more than thirty other individuals attended the meeting, some of whom participated as presenters or rapporteurs while others contributed to discussion (Table 2). The agenda for the meeting is presented in Table 3.

Opening

Dr. Terry Smith welcomed the participants and invited the SARC members to introduce themselves. In addition to the SARC, Dr. Fred Serchuk was introduced as Chief of the NEFSC Conservation and Utilization Division and Dr. Steve Murawski (head of the NEFSC Population Dynamics Branch) as advisor.

Dr. Smith reviewed the SAW process, responsibilities of the SARC members, presenters, rapporteurs, and SARC leaders, as well as the documents which the SARC would prepare. As chair, Dr. Smith will edit the Advisory Report, a service which he provided as editor at previous SAWs. The meeting can be streamlined by limiting presentations to one hour and, in the first round of documentation development, agreeing on points to include in the Advisory Report before these are blended into the stylized version. The role of SARC leaders would be especially important in the second round of documentation, when the leaders would make sure that the information in both the SARC and Advisory reports accurately reflects the consensus of the SARC.

Agenda and Reports

The meeting agenda included five species/stocks as well as an overview of models used in current assessments. Reviewed were analyses for Gulf of Maine cod, Gulf of Maine - Georges Bank white hake, scup (in waters between Cape Cod and Cape Hatteras), surf clam (along the Atlantic seaboard, Maine through North Carolina), and ocean quahog (offshore waters from Long Island to Delmarva). A map of U.S. commercial statistical areas used to report landings in the Northwest Atlantic is presented in Figure 1.

The SARC reviewed Subcommittee reports on each of the above species, including a number of virtual population analyses and DeLury runs; detailed assessment papers on cod and white hake, as well as a paper on short-term and medium-term stochastic projections for cod; and a Bayesian framework for the modified DeLury Model. The Subcommittee reports were developed in a series of meetings (Table 4) and form the basis of the "SARC Consensus Summary of Assessments." From the materials reviewed, the SARC endorsed six papers for publication in the NEFSC Reference Documents series (Table 5).

Before the meeting adjourned the SARC reviewed all second drafts of the species sections for the SARC and Advisory reports as well as available final drafts. The remaining drafts were mailed to the SARC members for further comment and approval within a week.

Both the SARC and Advisory reports will be available at the 19th SAW Plenary Meeting which will be held prior to a scheduled meeting of the Mid-Atlantic Fishery Management Council in Ocean City MD on 30 - 31 January 1995. The two reports will be published after the Plenary Meeting as NEFSC Reference Documents, with the Advisory Report as a section of the Plenary Report.

Presentations and Discussion

Overview of Current Assessment Models

An overview of current assessment models implemented at the NEFSC with special focus on Modified DeLury and Surplus Production models was provided by Dr. Ray Conser as technical background for the species analyses that would follow.

A number of models are used to address assessment problems. The choice of model depends on data availability and management requirements. The three assessment models most commonly used at the NEFSC were described:

- The ADAPT framework models stock size in numbers. It is age-structured and based on virtual population analysis (VPA). The framework is modular in design, flexible, and easy to modify. ADAPT, requires extensive catch-at-age data and is used in the assessment of most principal groundfish stocks in the Northeast. Currently, assessments for twelve out of thirty-eight stocks in the region are based on age-structure information.

- The Modified DeLury Model is a non-age-structured model which is based on the Leslie-DeLury difference equations and models stock size in number. The model is useful for the assessment of animals that cannot be aged routinely, such as lobster and scallops.

- The Surplus Production Model (SPROD) is another non-age-structured model based on surplus production difference equations and models stock size in weight. Model results are complementary to the results of other models in that SPROD provides an additional perspective (biomass) that is absent from the DeLury model. Of regional importance, relative to current management of species already overfished, is the fact that this kind of modelling can provide a better perspective of K, a parameter useful in addressing whether a stock is recruitment overfished. The SPROD can provide other reference points on biomass and may be used to characterize biomass as low medium and high abundance. Used to assess such species as swordfish, the model is at the present time the least used of the three, but is being explored for use in lobster and squid assessments.

Dr. Conser discussed the background and modelling process of each of the three models, gave examples of their application and explained how they fit within the general NEFSC Stock Assessment Systems Model (Figure 2).

Species/Stock Presentations and Discussion

The species/stock presentations are summarized in detail in the sections that follow. Each section includes the terms of reference, Subcommittee and/or SARC comments, sources of uncertainty, and research recommendations. Many of the research recommendations in this report have appeared in previous SARC reports and several are relevant to more than one species/stock.

The issues of sea and port sampling were common to almost all the species reviewed. Concerns under sea sampling included appropriate sampling levels, sampling precision, and the representativeness of the samples collected, as well as the present inability to develop precise estimates of discards. It was suggested that the Assessment Methods Subcommittee might take a closer look at the discard situation. Also expressed was the need to maintain or increase port sampling for the characterization of the length composition of both landings and discards and to improve the basis of age sampling.

For white hake, joint research with Canada, including a possible exchange of otoliths, was recommended so as to delineate the stocks of the Scotian Shelf and Southern New England. For a number of species, it was recommended to use non-age based assessment techniques such as DeLury and Surplus Production Models to extend the estimates of stock biomass and fishing mortality. Explored also was the possibility of cooperative research with CMER (Cooperative Marine Education and Research) programs at several universities in the region, particularly in ageing scup.

Possible standardization and implications of General Linear Models (GLMs) for standardizing effort was discussed, as this is applicable to nearly all stocks reviewed by the SARC. The models should be reviewed with two possible objectives: (1) to unify the various species-specific GLM procedures with a goal to arrive at a standard approach applicable to most stocks; and, (2) to examine the incorporation of multispecies effects into the standard GLM procedure.

In a discussion of forecasts and long-term projections, the utility of documenting current year (e.g., 1994) forecasts in the Advisory Report was discussed. Because of the uncertainty in current year assessments of landings, spawning stock biomass, and fishing mortality rate, such forecasts are limited in their use. The use of long-term projections was cautioned, as projecting too far into the future will ultimately produce spurious results. Mid-term projections, already endorsed by the SARC, were, however, deemed to be appropriate.

Some consideration was given to ecosystem and environmental implications regarding the fisheries. Record low stock levels of important commercial species could have certain ecosystem implications, including their replacement or displacement. The relationship between stock size and environmental factors in addition to stock size and recruitment was briefly discussed.

The identification of appropriate biological reference points and better maturity data were determined to be major issues that concern both the surfclam and ocean quahog. There also remain questions relative to the recruitment of these species, particularly ocean quahog. In Canada, managers and industry representatives contribute to the financial support of ageing these animals as well as exploratory work to locate the resource. To compensate for their work, industry participants are rewarded with a quota.

Other Business

Discussions under Other Business primarily dealt with the recurring research recommendations and the SAW process itself, as it is important to continue to make the process as efficient as possible in the effort to address changing management needs. Formation of ad hoc SARC working groups to examine sampling issues and to look into further streamlining the SAW process and documentation was proposed. The discussions are summarized in the last section of this report.

Table 1.

SAW-19 SARC COMPOSITION

Chair:

Terry Smith, NEFSC

Four ad hoc assessment members chosen by the Chair:

Han-Lin Lai, NEFSC
Paul Rago, NEFSC
Wally Morse, NEFSC
Mark Terceiro, NEFSC

One person from NMFS, Northeast Regional Office:

Andy Rosenberg, NERO

One person from each Regional Management Council:

Andy Applegate, NEFMC
Tom Hoff, MAFMC

Atlantic States Marine Fisheries Commission/State personnel:

Najih Lazar, ASMFC
Steve Cadrin, MA DMF

One Scientist from:

Canada - **Kees Zwanenburg, DFO, Dartmouth NS**
Academia - **Judy Grassle, Rutgers State University**
Other Region - **Glen Jamieson, DFO, Nanaimo, BC**

Table 2.

LIST OF PARTICIPANTS

National Marine Fisheries Service

Northeast Fisheries Science Center
Frank Almeida
Emory Anderson
Marinelle Basson
Jon Brodziak
Russell Brown
Steve Clark
Ray Conser
Kevin Friedland
Wendy Gabriel
Ruth Haas-Castro
Thomas Helser
Lisa Hendrickson
Joseph Idoine
Ambrose Jearld
John Kocik
Han-Lin Lai
Marjorie Lambert
Amy Lesen
Shih-Wei Ling
Ralph Mayo
Wally Morse
Steve Murawski
Helen Mustafa
Vic Nordahl
Loretta O'Brien
Paul Rago
Gary Shepherd
Terrence Smith
Katherine Sosebee
Mark Terceiro
Eric Thunberg
James Weinberg
Susan Wigley

Northeast Regional Office
Myles Raizin
Andy Rosenberg

Fishing Family Assistance Center-Chatham

Carlos Castro

Atlantic States Marine Fisheries Commission
Najih Lazar

Mid-Atlantic Fishery Management Council
Tom Hoff

New England Fishery Management Council
Andy Applegate

Massachusetts Department of Marine Fisheries
Steve Cadrin
Steve Correia
Tom Currier
Arnold Howe
David Pierce

Connecticut Department of Marine Fisheries
David Simpson

New York Department of Environmental Conservation
Sherri Archer

Conservation Law Foundation
Ellie Dorsey

National Fisheries Institute
Marc Landau

Department of Fisheries and Oceans, Dartmouth, NS
Kees Zwanenburg

Department of Fisheries and Oceans, Nanaimo, BC
Glen Jamieson

Rutgers State University
Judy Grassle

Table 3.

19th Northeast Regional Stock Assessment Workshop (SAW-19) Stock Assessment Review Committee (SARC) Meeting

Woods Hole, Massachusetts 28 November - 2 December 1994

AGENDA

SPECIES/STOCK	SUBCOMMITTEE & PRESENTER	SARC LEADER	RAPPORTEUR
<u>MONDAY, November 28</u> (1:00PM - 7:30 PM)........			
Opening Welcome Agenda Conduct of Meeting	Chairman,	T.P. Smith	H. Mustafa
Scup (C)	Pelagic/Coastal E. Anderson	N. Lazar	J. Kocik
Overview of DeLury and Surplus Production Model Used in Current Assessments	R. Conser		H. Mustafa
<u>TUESDAY, November 29</u> (9:00 AM - 6:00 PM)........			
White Hake (B)	Northern Demersal R. Mayo	S. Cadrin	T. Helser
Gulf of Maine Cod (A)	Northern Demersal R. Mayo	K. Zwanenburg	R. Brown
Review available draft sections for the SARC report			
<u>WEDNESDAY, November 30</u> (9:00 AM - 6:00 PM)........			
Surf Clam (D)	Invertebrate S. Murawski	J. Grassle	J. Weinberg
Ocean Quahog (E)	Invertebrate S. Murawski	G. Jamieson	J. Brodziak
Review available draft sections for the SARC report			

Table 3. (Continued)

THURSDAY, December 1 (9:00 AM - 6:00 PM)..

Discuss and approve all "points" for the Advisory Report

Review available figures and drafts for the Advisory Report

Review all Research Recommendations

FRIDAY, December 2 (9:00 AM - 6:00 PM)

Complete unfinished business

Complete SARC Report sections — H. Mustafa (Coordinator)

Complete Advisory Report final review

Other Business — H. Mustafa

Table 4.

SAW-19 SUBCOMMITTEE MEETINGS

Subcommittee - Species Analysis Participants		Meeting Date and Place
Northern Demersal Subcommittee - Gulf of Maine Cod Gulf of Maine/Georges Bank White Hake		
A. Applegate, NEFMC	L. Hendrickson, NEFSC	17 - 21 October 1994
R. Brown, NEFSC	R. Mayo, NEFSC (Chair)	Woods Hole, MA
J. Burnett, NEFSC (White Hake only)		
S. Cadrin, MA DMF	L. O'Brien, NEFSC	
R. Conser, NEFSC	K. Sosebee, NEFSC	
T. Helser, NEFSC	S. Wigley, NEFSC	
Coastal/Pelagic Subcommittee - Scup		
E. Anderson, NEFSC (Chair)	S.-W Ling, NEFSC	1 - 4 November 1994
S. Correia, MA DMF	J. Mason, NY DEC	Woods Hole, MA
T.Currier, MA DMF	C. Moore, MAFMC	
W. Gabriel, NEFSC	J. Musick, VIMS	
J. Kocik, NEFSC	D. Simpson CT DEP	
M. Lambert, NEFSC	M. Terceiro, NEFSC	
N. Lazar, ASMFC		
Invertebrate Subcommittee - Surfclam Ocean Quahog		
J. Brodziak, NEFSC	S. Murawski, NEFSC (Chair)	31 October -
R. Conser, NEFSC	V. Nordahl, NEFSC	3 November 1994
L. Hendrickson, NEFSC	P. Rago, NEFSC	Woods Hole, MA
T. Hoff, MAFMC	C. Weidman, WHOI	
H.-L. Lai, NEFSC	J. Weinberg, NEFSC	
A. Lesen, NEFSC		

Table 5.

19th SAW NEFSC Reference Documents

CRD 95-02	Assessment of the Gulf of Maine Cod Stock for 1994 by R.K. Mayo
CRD 95-03	A Preliminary Analytical Assessment of White Hake in the Gulf of Maine - Georges Bank Region by K.A. Sosebee, L. O'Brien, and L.C. Hendrickson
CRD 95-04	Assessment of Scup (*Stenotomus chrysops*), 1994, Report of the Pelagic/Coastal Subcommittee
CRD 95-05	Analytical Assessment of Surfclam Populations in the Middle Atlantic Region of the United States in 1994 R.J. Weinberg, S.A. Murawski, R. Conser, J. Brodziak, L. Hendrickson, H.-L. Lai, and P. Rago
CRD 95-06	Bayesian Framework for the Modified DeLury Model by R. Conser
CRD 95-07	Ocean Quahog Populations from the Middle Atlantic to the Gulf of Maine in 1994 by S. Murawski, J. Weinberg, P. Rago, J. Brodziak, L. Hendrickson, R. Conser, H.-L. Lai.
CRD 95-08	Report of the 19th Northeast Regional Stock Assessment Workshop (19th SAW) , Stock Assessment Review Committee (SARC) Consensus Summary of Assessments
CRD 95-09	Report of the 19th Northeast Regional Stock Assessment Workshop (19th SAW), The Plenary

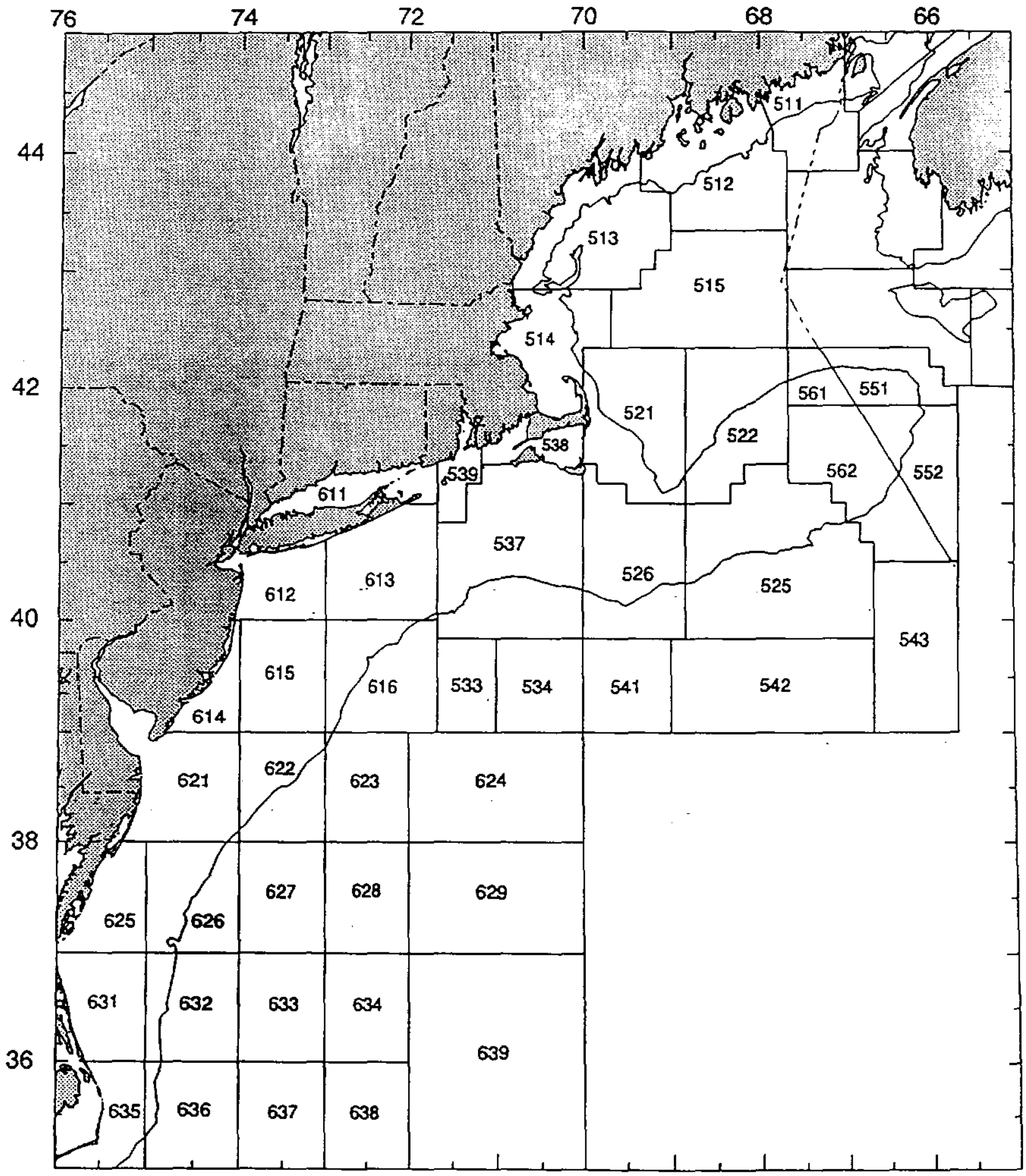

Figure 1. Statistical areas used for catch monitoring in offshore fisheries in the northeast United States

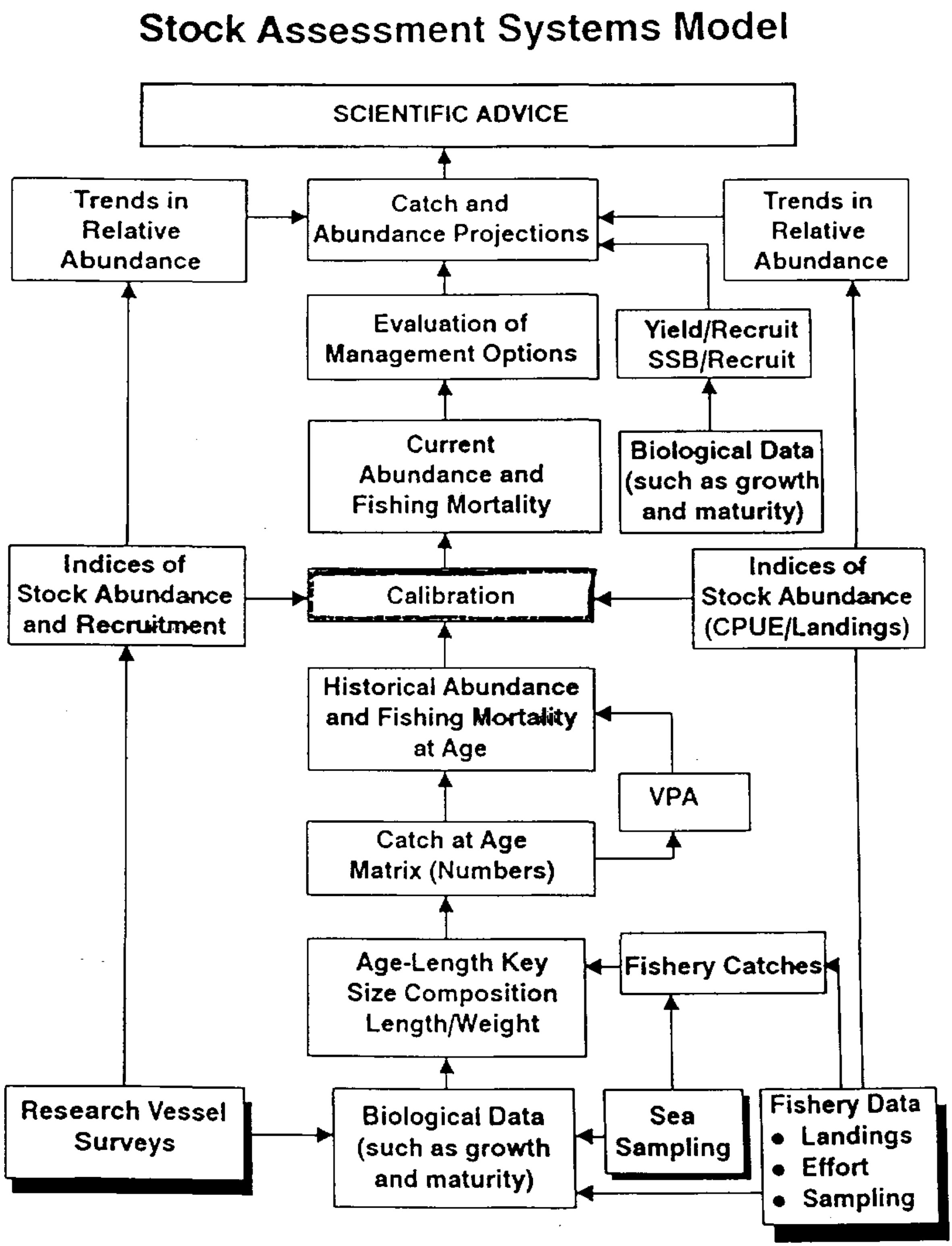

Figure 2. NEFSC Stock Assessment Systems Model.

A. GULF OF MAINE COD

Terms of Reference

The following terms of reference were addressed:

a. Assess the status of Gulf of Maine cod through 1993 and characterize the variability of estimates of abundance and fishing mortality rates.

b. Provide 1995 projected estimates of catch and 1996 SSB options at various levels of 1995 F.

Introduction

Atlantic cod (*Gadus morhua*) in the Gulf of Maine region have been commercially exploited since the 17th century. Reliable landings statistics are available since 1893. Historically, the Gulf of Maine fishery can be separated into four periods (Figure A1): (1) an early era from 1893-1915 in which record-high landings (> 17,000 mt) in 1895 and 1906 were followed by 10 years of sharply-reduced catches; (2) a later period from 1916-1940 in which annual landings were relatively stable, fluctuating between 5,000 - 11,500 mt and averaging 8,300 mt per year; (3) a period from 1941-1963 when landings sharply increased (1945: 14,500 mt) and then rapidly decreased, reaching a record-low of 2,600 mt in 1957; and (4) the most recent period from 1964 onward during which Gulf of Maine landings have generally increased. Total landings doubled between 1964 and 1968, doubled again between 1968 and 1977, and averaged 12,200 mt per year during 1976-1985 (Table A1). Although Gulf of Maine landings declined between 1984 and 1987, landings subsequently increased, reaching 17,800 mt in 1991, the highest level since the early 1900s. Total landings declined sharply in 1992 to 10,892 mt, and decreased further in 1993 to 8,287 mt.

This report presents an updated and revised analytical assessment of the Gulf of Maine cod stock (NAFO Division 5Y) for the period 1982-1993 based on analyses of commercial and research vessel survey data through 1993. An initial analytical assessment of this stock was presented at the Seventh NEFC Stock Assessment Workshop in November 1988 (NEFC 1989) and subsequent revisions were presented at the Twelfth and Fifteenth Northeast Regional Stock Assessment Workshops in June, 1991 and December, 1992 (NEFSC 1991, 1993). Recreational cod landings have not been included in any of the analyses due to limited data on recreational cod landings by stock (Serchuk and Wigley 1990).

The Fishery

Commercial Landings

Total commercial landings in 1993 were 8,287 mt, 24% less than in 1992 and 53% less than in 1991 (Table A1). Since 1977, the USA fishery has accounted for all of the commercial catch. Canadian landings reported as Gulf of Maine catch during 1977-1990 are believed by Canadian scientists to be misreported catches from the Scotian Shelf stock (Campana and Simon 1985; Campana and Hamel 1990). Although otter trawl catches accounted for most of the landings in 1993 (59% by weight), the quantity taken gill nets increased to 38% from a low of 23% in 1991; the 1993 gill net catches were at a percentage comparable to the 1987-1989 period (Table A2).

Discards

Discard estimates of Gulf of Maine Cod are not currently available.

Recreational Landings

Landings Trends

Estimates of the recreational cod landings were derived from the Marine Recreational Fishery Statistics Survey (MRFSS) conducted since 1979. Gulf of Maine cod landings were estimated on the assumption that the catches of cod recorded by the intercept survey were removed from the ocean in statistical areas adjacent to the state or county of landing. Further information on the details of the allocation scheme and sampling intensity is given in NEFSC (1992). Recreational cod landings from the Gulf of Maine region were 2,667 mt in 1993 (Table A3). The estimated landings from the Gulf of Maine cod stock declined from over 5,000 mt in 1980 and 1981 to 2,400 mt in 1986, increased to 4,200 mt in 1989 and have fluctuated between 1,000 and 3,000 mt since 1990.

Commercial Fishery Sampling Levels

A summary of USA length frequency and age sampling of Gulf of Maine cod landings during 1982-1993 is presented in Table A4. USA length frequency sampling averaged one sample per 155-200 t landed during 1983-1987 but the sampling intensity has declined in recent years (1990: 1 sample per 387 mt; 1993: 1 sample per 360 mt). Only 23 samples were taken in 1993. Nearly all of the USA samples have been taken from otter trawl landings but sampling is stratified by market category (scrod, market, and large). Of the 23 samples collected in 1993, 10 were scrod samples (43%), 8 were market (35%), and 5 were large (22%). Compared with the 1993 market category landings distribution (by weight - scrod: 21%; market: 44%; large: 32%), 'scrod cod' were over-sampled and 'market' and 'large cod' were under-sampled.

Commercial Landings at Age

Age composition of landings during 1982-1993 was estimated, by market category, from monthly length frequency and age samples, pooled by calendar quarter. Quarterly mean weights, by market category, were obtained by applying the USA cod length-weight equation ($\ln Weight_{(kg,live)} = -11.7231 + 3.0521 \ln Length_{(cm)}$) to the quarterly market category sample length frequencies. Mean weight values were then divided into quarterly market category landings to derive estimated numbers landed by quarter, by market category. Quarterly age/length keys were then applied to the quarterly market category numbers at length distributions to provide numbers at age. These values were summed over market categories and quarters to derive the annual catch-at-age matrix (Table A5).

Gulf of Maine cod landings were dominated by fish from the 1987 year class in 1992 but, by 1993, fish from the 1990 year class accounted for the greatest proportion of the total number landed (Table A5). In terms of weight, the 1993 landings were equally distributed between the 1987 and 1990 year classes. In 1993, these two year classes accounted for approximately 70% of the total number and weight landed. Although traditionally low in terms of their contribution to the total landings, age 10 and 11+ fish were completely absent in 1993, and numbers of age 8 and 9 fish were unusually low. Although this pattern may be partly a result of the poor sampling of 'large' category cod in 1993, a trend towards fewer older fish in the landings has been apparent since 1991.

Commercial Mean Weights at Age

Mean weights at-age in the catch for ages 1-11+ during 1982-1993 are given in Table A5 and, based on landings patterns, are considered mid-year values. Apart from 1990, only slight variations are apparent among years with no consistent trends evident. In 1990, mean weights at age for age groups 2-4 were the lowest in the nine-year time series while mean weights for age groups 6 and 7 were the highest. These changes, however, may be artifacts of the reduced sampling intensity of the landings in 1990 as suggested by the increase in mean weights at ages 2 and 4 in 1991. In 1993, mean weights at ages 8 and 9 were the highest in the series, but these anomalies are likely the result of poor sampling. Mean weights at age for calculating stock biomass at the beginning of the year are provided in Table A6. These values were derived from the catch mean weight at age data (Table A5) using the procedures described by Rivard (1980).

Stock Abundance and Biomass Indices

Commercial Landings Per Unit Effort

USA commercial LPUE indices (landings per unit effort, expressed in metric tons landed per day fished) were calculated, by tonnage class (Class 2: 5-50 GRT; Class 3: 51-150 GRT; Class 4: 151-500 GRT), from otter trawl trips landing cod from the Gulf of Maine (Division 5Y).

Indices were derived based on all trips landing cod, and for "directed" trips in which cod comprised 50% or more of the total trip catch by weight. "Directed trips" have generally accounted for less than 45% (and as low as 14%) of USA Gulf of Maine otter trawl landings of cod, but after 1988 "directed trips" began to account for an increasing percentage of the total catch. The fraction of the otter trawl catch taken on "directed trips" increased from 35% of the total in 1988 to 71% in 1991. The "directivity" of the otter trawl fishery declined in 1992 and 1993 to pre-1989 levels. The temporary increase in directivity, which peaked in 1991, is the likely result of the dominant influence of the unusually strong 1987 year class in the fishery. This trend is apparent in all vessel class categories.

Both total and directed USA LPUE indices have generally exhibited similar trends (Figure A2). LPUE values increased during the late 1960s, declined during the early 1970s, sharply increased in 1974, and then stabilized during 1975-1983 at a relatively high level. After 1983, LPUE indices trended downward, reaching record-low levels in 1987. Both total and directed LPUE indices increased between 1988 and 1991; in 1991, the total LPUE index was the highest since 1977 (and among the highest in the time-series) while the directed index declined from the 1990 level. In 1992 and 1993, both indices declined and the total index reached a level close to the lowest on record in 1993. Between 1988 and 1991, the percentage of total trips qualifying as directed trips quadrupled (8% to 33%), but the proportion qualifying declined sharply by 1993 (14%).

Although the total number of cod trips has been generally declining compared to 1988, the number of directed trips increased 7-fold between 1987 and 1991 (300 trips in 1988 vs. 2147 trips in 1991). This suggests that the very high total LPUE index for 1990 and 1991 is rather inflated due to a marked change in fleet "directivity", particularly by Class 4 vessels. In 1988, 5% of Class 4 cod trips were "directed" while in 1991, 57% of Class 4 trips qualified as "directed". The number of "directed" trips declined markedly in 1992 and 1993, reflecting both a decline in overall effort and a decrease in the directivity of the fishery.

In terms of calculated effort (total landings/total USA LPUE index), total fishing effort reached a record-high level in 1987 declined from 1988 to 1990 and had since increased well above the 1990 level (Table A7). To the extent that the 1990 and 1991 total LPUE indices are 'inflated' (due to increased fleet directivity for cod), the calculated effort values for 1990 and 1991 are underestimated. Therefore, the total calculated effort on Gulf of Maine cod since 1984 appears to have remained at a consistently high level when compared to the 1960s and 1970s.

Standardized fishing effort and LPUE were estimated for a sub-fleet by applying a five-factor (year, area, quarter, tonnage class and depth) General Linear Model (GLM) to log LPUE data derived for all interviewed otter trawl trips taking cod from 1982 through 1992 (Table A8). Details regarding data selection and preparation and model formulation are provided by Mayo *et al.* (1994). The model accounted for just under 25% of the total sum of squares, although all five factors were highly significant. For each year between 1982 and 1993 standardized effort in each area-quarter-tonnage class-depth category was estimated by multiplying the sum of the nominal effort for that cell by the product of the re-transformed GLM coefficients for each factor. The estimated standardized sub-fleet effort was then accumulated over all categories to provide annual estimates as provided in Table A9. Total standardized effort was then calculated by raising the sub-fleet effort to account for all cod landings. Both the calculated and the standardized series of USA effort estimates (Table A9) show the same trends over time, i.e., an increase during the 1980s with peak effort occurring in 1987 followed by a decline, with effort rather variable since 1991 (Figure A3). Both results also reveal a sharp decline in LPUE of about 50-60% between 1991 and 1993 (Table A9; Figure A2).

The 1982-1993 age composition of the landings corresponding to the effort sub-fleet was estimated and used with standardized effort estimates to calculate an LPUE at age index. Numbers landed at age were estimated by applying quarterly commercial age-length keys to quarterly commercial numbers landed at length by market category. The LPUE at age indices were derived by dividing the estimated numbers landed at age by corresponding 1982 through 1993 standardized fishing effort. Further details regarding data selection and preparation and estimation procedures are provided in Mayo *et al.* (1994).

Research Vessel Survey Indices

Indices of cod abundance (stratified mean catch per tow in numbers) and biomass (stratified mean weight per tow in kilograms), developed from Northeast Fisheries Science Center (NEFSC) and State of Massachusetts research vessel bottom trawl surveys, have been used to monitor changes and assess trends in population size and recruitment of USA cod populations since 1963. Prior to 1985, BMV oval doors (550 kg) were used in all NEFSC surveys; since 1985, Portuguese polyvalent doors (450 kg) have been used. Details on NEFSC survey sampling design and procedures are provided in Azarovitz (1981) and Clark (1981). The State of Massachusetts inshore bottom trawl sampling program is described in Howe et al. (1981). No adjustments in the survey catch per tow data for cod have been made for any of the gear differences, but vessel and door coefficients have been applied to adjust the stratified mean number and weight per tow as described in Table A10. Standardized catch per tow (number) at age indices from NEFSC spring and autumn surveys are listed in Table A11. Catch per tow (number) at age indices from Massachusetts spring and autumn surveys are listed in Table A12.

NEFSC spring and autumn offshore catch per tow indices for Gulf of Maine cod have generally exhibited similar trends throughout the survey time series (Table A10, Figure A4). Number per tow indices declined during the mid and late 1960s but since 1972-1973 have fluctuated due to a series of recruitment pulses. Sharp increases in the number per tow indices reflect above average recruitment of the 1971, 1973, 1977-1980, 1983, and 1985-1987 year classes at ages 1 and 2 (Table A11, Figure A5). The sequential dominance of these cohorts at older ages can be discerned from number per tow at age values in both spring and autumn NEFSC surveys (Table A11).

Spring NEFSC number per tow indices have remained relatively stable since 1985 at a level below the 1981-1984 period (Table A10); spring weight per tow indices have also remained relatively low through 1991 but the index increased substantially in 1992, and remained relatively high in 1993, due to a large contribution from the 1987 year class (Table A11). The 1994 spring index, however, declined markedly. Autumn number and weight per tow indices declined sharply in 1991 to unprecedented low levels, and weight per tow has continued to decline to new record low levels through 1993. The increased abundance levels in 1988 and 1989, resulting from recruitment of the strong 1986 and 1987 year classes, was depleted by 1991, resulting in the sharp declines in the overall index. This reduction, combined with a general paucity of large fish in the survey indices in recent years (Table A11) has resulted in the sharp decline in the weight per tow indices since 1991 as well. Overall, the 1987 year class appears to have been one of the strongest ever produced; catch per tow indices of this cohort at ages 1-3 in the NEFSC autumn surveys and at ages 0 and 1 in the Massachusetts DMF autumn inshore surveys were nearly all record-high values (Tables A11 and A12). Based on Massachusetts DMF survey catch per tow indices in 1989-1994, the 1993 year class may be above average, but the remaining year classes of Gulf of Maine cod appear to be only average or below-average.

Mortality

Total Mortality

Pooled estimates of instantaneous total mortality (Z) were calculated for eight time periods encompassed by the NEFSC autumn and spring offshore surveys: 1964-1967, 1968-1972, 1973-1976, 1977-1981, 1982-1984, 1985-1987, and 1988-1990. Total mortality was calculated from survey catch per tow at age data (Table A11) for fully recruited age groups (age 3+) by the $\log_e$ ratio of the pooled age 3+/age 4+ indices in the autumn surveys, and the pooled age 4+/age 5+ indices in the spring surveys. For example, the 1982-1984 values were derived from:

Autumn: ln (Σ age 3+ for 1981-83/ Σ age 4+ for 1982-84)

Spring: (Σ age 4+ for 1982-84/ Σ age 5+ for 1983-85)

Different age groups were used in the autumn and spring analyses so that Z could be evaluated over identical year classes within each time period.

Except for the 1988-1990 period, values of Z derived from the spring surveys are slightly lower than those calculated from the autumn data. Rather than selecting one survey series over the other, total mortality was calculated by taking a geometric mean of the spring and autumn estimates in each time period. The pooled estimates indicate that total mortality was relatively low (Z = 0.40) between 1964 and 1976 but significantly increased afterward to 0.75-0.78 during 1982-1987. Total mortality increased further to 0.94 during the 1988-1990 and to 1.10 during 1991-1993.

Natural Mortality

Instantaneous natural mortality (M) for Gulf of Maine cod is assumed to be 0.20, the conventional value of M used for all Northwest Atlantic cod stocks (Paloheimo and Koehler 1968; Pinhorn 1975; Minet 1978).

Estimates of Stock Size and Fishing Mortality

Virtual Population Analysis Calibration

The ADAPT (Gavaris 1988, Conser and Powers 1990) calibration method was used to derive estimates of terminal F values in 1993. As in previous assessments, age-disaggregated analyses were performed. Several exploratory ADAPT formulations were performed using NEFSC spring and autumn (ages 2-6), Massachusetts DMF spring (ages 2-4) and autumn (ages 2 and 3) and USA commercial LPUE (ages 3-6) abundance indices. The NEFSC and Massachusetts DMF autumn indices were lagged by one age and one year whereby age 1-6 indices were related to age 2-6 stock sizes in the subsequent year for corresponding cohorts. All NEFSC and Massachusetts DMF indices were related to January 1 stock sizes and USA commercial LPUE indices were related to mid-year stock sizes. In contrast to previous assessments, the USA commercial LPUE indices were derived from the catch at age corresponding to the effort subfleet used in the estimation of standardized fishing effort as described by Mayo et *al.* (1994).

The 1982-1993 landings at age as provided in Table A5 was included in the initial trial run. The initial calibration, employing the full age complement (true ages 2-9), produced high coefficients of variation (CV) on the 1994 stock size estimates and variable estimates of F on ages 7-9 in most years prior to the terminal year. Therefore, subsequent trial formulations employed reduced age ranges (2-6,7+ and 2-7,8+) as in the previous assessment (Mayo et *al.* 1993).

As in the past, Massachusetts DMF survey data were included in the VPA calibration primarily to improve the estimates of recruiting year class strength. In exploratory analyses the DMF autumn age 3 (age 2 before lagging) index often accounted for up to 40% of the total sum of squares; this index was, as in previous assessments, excluded from the final calibration. A summary of a series of trial formulations is provided in Table A13. All of the trial calibrations employed equal weighting among indices and in all years. The formulation identical to that employed in the previous assessment is presented first. As in all subsequent trials, a rather sharp decline in the 1993 F between ages 4 and 5 is evident in these results, although the CVs are similar among trials. The F pattern in 1992 was also rather unstable in all formulations carried out to a true age of 7 years. Therefore, a final set of trials was attempted with the last true age set at 6. These formulations produced a more stable F pattern in 1992, although the abrupt change between ages 4 and 5 in 1993 still remained. Noting the reduced contribution of older ages in the catch in recent years, a final calibration was performed with the age range reduced to ages 2-6 and a 7+ group as indicated by the last formulation in Table A13. This represents the only departure from the last assessment.

The ADAPT formulation employed in the final VPA calibration provided direct stock size estimates for ages 2 through 6 in 1994 and corresponding estimates of F on ages 1 through 5 in 1993. Since the age at full recruitment was defined as 4 years in the input partial recruitment vector, the terminal year F on age 6 was estimated as the mean of the age 4 and 5 Fs; age 6 is also the oldest true age in the terminal year. In all years prior to the terminal year, F on the oldest true age (age 6) was determined from weighted estimates of Z for ages 4 through 6. In all years, the age 6 F was applied to the 7+ group. Spawning stock biomass (SSB) was calculated at spawning time (March 1) by applying a series of period-specific maturity ogives provided by O'Brien (pers. comm.).

Stock size and spawning stock biomass derived from the VPA are presented in Table A14. Except for a few cases the final calibration yielded low correlations (< 0.10) among estimates of slopes (q) and moderately low correlations (< 0.20) between stock sizes and qs. The highest correlations were noted between stock size estimates and the NEFSC spring and autumn abundance index for the corresponding age. All parameter estimates were significant. Coefficients of variation on the stock size estimates ranged from 0.23 (age 3) to 0.39 (age 6), while CVs on the estimates of slopes were between 0.16 and 0.17. Slopes of the abundance index-stock size relationships increased with age generally up to age 4 for the NEFSC spring and autumn surveys and the USA commercial LPUE indices. Slopes from the Mass. DMF indices did not exhibit noticeable trends.

Fishing Mortality Estimates

Average (ages 4-5, unweighted) fishing mortality in 1993 was estimated at 0.93 (Table A14, Figure A6), a 10% decrease from 1992. This decrease in mean fully recruited F is consistent with the decrease in standardized fishing effort indicated by the General Linear Model (Figure A3).

Stock Size and Spawning Stock Biomass Estimates

Age 2+ spawning stock biomass declined from 22,400 t in 1982 to 14,100 t in 1987. Following the recruitment and maturation of the strong 1987 year class, SSB increased sharply in 1989 to a maximum of 26,135 but declined to 9,391 t in 1993 (Figure A7). The total stock size (ages 2+) has also declined sharply in recent years from 28 million fish in 1989 to 9.6 million in 1994.

Recruitment Estimates

Since 1982, recruitment at age 2 has ranged from approximately 2.6 million (1989 year class) to 17.8 million (1987 year class) fish. Over the 1982-1993 period, geometric mean recruitment for the 1980-1991 year classes equalled 5.4 million fish. The 1987 year class is the highest in the 1982-1993 series and about twice the size of the above average 1980 and 1986 year classes. Recent recruitment, however, has been poor as the 1988-1991 year classes (all $\leq$ 4.5

million at age 2) are estimated to be among the poorest in the series (Table A14). The 1990 year class, which accounted for a high proportion of the number of fish landed in 1993 (Table A5, Table A6) was estimated to be slightly below average.

Precision of F and SSB

To evaluate the precision of the final estimates, a bootstrap procedure (Efron 1982) was used to generate distributions of the 1993 fishing mortality rate and spawning stock biomass. Figures A8 and A9 show the distribution of the bootstrap estimates and a cumulative probability curve. The cumulative probability expresses the likelihood that the fishing mortality rate was greater than a given level (Figure A8) or the likelihood that spawning stock biomass was less than a given level (Figure A9) when measurement error is considered.

Coefficients of variation (C.V.) for the 1994 stock size estimates ranged from 23% (age 3) to 42% (age 6), and C.V.s for 9s among all indices ranged from 15 to 17%. The fully recruited fishing mortality for ages 4+ was reasonably well estimated (C.V. = 0.16). The mean bootstrap estimate of F (0.939) was slightly higher than the point estimate (0.928) from the VPA and ranged from 0.60 to 1.5 (Figure A8). $F_{20\%}$ is much lower than the lowest bootstrap estimate and F_{1993} is almost certainly above the overfishing definition mortality rate.

Although the abundance estimates of individual ages in 1994 had wider variances (C.V. = 0.23 to 0.42), the estimate of 1993 spawning stock biomass was robust (C.V. = 0.09). The bootstrap mean (9,882 mt) was slightly higher than the VPA point estimate (9,727) and ranged from 7,500 mt to 13,000 mt. Current spawning stock biomass is the lowest observed in the series.

Retrospective Analysis

Retrospective analyses of the Gulf of Maine cod VPA were carried out using the final ADAPT formulation with the terminal year ranging from 1993 back to 1988 (see Mayo, 1995, for results). Convergence of estimates is generally evident within 3 years, and often within 2 years, prior to any given terminal year. Retrospective patterns are evident for Gulf of Maine cod, particularly with respect to terminal F. Mean (ages 4-5, unweighted) F was generally over-estimated by the ADAPT calibration in most years and age 2 recruits and SSB were most often under-estimated. Terminal Fs appear to have been well estimated since 1989. Despite these patterns, the retrospective analysis provides additional evidence to substantiate the current high levels of F.

Retrospective patterns for age 2 recruits and SSB are similar, both indicating relatively consistent estimates of terminal year values from 1988-1993. Although subject to some variability, terminal year recruitment and SSB appear to have been estimated with a high degree of reliability.

Biological Reference Points

Yield and Spawning Stock Biomass Per Recruit

Yield-per-recruit, total stock biomass per recruit, and spawning stock biomass per recruit analyses were performed using the Thompson and Bell (1934) method. Mean weights at age for application to yield per recruit were computed as a four-year arithmetic average of catch mean weights at age (Table A5) over the 1990-1993 period. Mean weights at age for application to SSB per recruit were computed as a four-year arithmetic average of stock mean weights at age (Table A6) over the 1990-1993 period. The maturation ogive was the same as used in computing SSB during the 1990-1993 period in the VPA. To obtain the exploitation pattern for these analyses, a five-year geometric mean F at age was first computed over the period 1988-1992 from the final converged VPA results. A smoothed exploitation pattern was then obtained by dividing the F at age by the mean unweighted F for ages 4-5. The final exploitation pattern is:

Age 1 - 0.000, Age 2 - 0.053, Age 3 - 0.421, Age 4 - 0.874, Age 5+ - 1.000

This pattern is similar to that presented in the 1992 Gulf of Maine cod assessment (Mayo et *al*. 1993), and was used in yield and SSB per recruit calculations. Input data and results of the yield and SSB per recruit calculations are listed in Table A15 and are illustrated in Figure A10. The yield per recruit analyses indicate that $F_{0.1}$ = 0.16, F_{MAX} = 0.27, and SSB per recruit calculations indicate that $F_{20\%}$ = 0.35.

Short-Term and Medium-Term Projections

Recruitment

Short-term and medium-term projections of spawning stock biomass, recruitment at age 2 and commercial landings were performed using the VPA-calibrated 1993 fully recruited mean F (ages 4-5, u) and 1994 stock size estimates from the 300 bootstrap replications as starting conditions. Recruitment was generated based on the model 2 formulation of Brodziak and Rago (1994). In this model age 2 recruitment is estimated two years ahead as a function of the existing level of SSB and a R/SSB ratio drawn from the empirical distribution of R/SSB ratios from 1982-1993 (1980-1991 year classes). The stochastic simulations were repeated 50 times to obtain a series of probability profiles for each projected variable. The exploitation pattern, mean weights and maturation rates were as described above for the yield and SSB per recruit analyses.

Short-Term Projection Results

Short-term projections are provided over a range of F levels which includes $F_{0.1}$, $F_{20\%}$, 50% of F_{SQ}, and F_{SQ}. Input and output from the projections are given in Table A16. The assumption of status quo F in 1994 of 0.93 resulted in a 1994 catch of approximately 6,600 mt. Given the delayed implementation of Amendment 5 effort restrictions in 1994, the assumption of status quo F in 1994 appears reasonable.

Continued fishing at F = 0.93 in 1995 will result in projected 1995 landings of about 6,900 mt and will result in a continued decline in SSB to 6,500 mt in 1996 from the record low 1994 level of 8,100 mt (Table A16, Figure A11). SSB is projected to decline even further in 1997 if F remains at the current level in 1996. If fishing mortality is reduced to $F_{20\%}$ (0.35) in 1995 and 1996, SSB is projected to increase from the low 1994 level to 10,400 t in 1996 (Table A16, Figure A11) and 12,400 mt in 1997.

Medium-Term Projection Results

Stock sizes and landings were projected through 2005 from starting conditions described above with the same age-specific mean weights, maturity and partial recruitment used for the short-term projections. Results are presented graphically for spawning stock biomass, recruitment at age 2 and commercial landings in Figures A12 and A13. The central heavy line represents the 50% probability (median) outcomes and the accompanying lighter lines represent the 10% and 90% probability outcomes. Medium-term projections were run for only 2 F levels: 1) status quo F (0.93) applied throughout 1995-2005 (Figure A12), and 2) $F_{20\%}$ (0.35) applied throughout 1995-2005 (Figure A13). The status quo F (0.93) was applied in all cases in 1994.

Under status quo F levels, the median outcomes suggest that SSB will decline to about 2,000 t in 2005 as recruitment declines to less than 1 million fish per year after 2000. Commercial landings follow a similar trajectory (Figure A12). Under $F_{20\%}$, the median projection results indicate a steady increase in SSB, reaching about 28,000 mt by 2005 as recruitment increases to about 7 million fish (Figure A13). This level of SSB is equivalent to that observed in 1989 following the recruitment of the very large 1987 year class. After declining initially, landings are projected to increase to about the 10,000 mt level by 2005.

The medium-term projections do not account for compensatory growth or maturation effects. Therefore, it is very possible that the increase in SSB projected through 2005 under the $F_{20\%}$ scenario may not be realized. In addition, the projected declines in SSB under the status quo F scenario are well below the range of observed values; the behavior of the stock and recruitment trajectories at such low stock sizes cannot be predicted from prior observation.

Conclusions

The Gulf of Maine cod stock is presently at a low biomass level and is over exploited. Fishing mortality in 1993 (0.93) declined slightly from the 1992 level (1.03) while spawning stock biomass (SSB) in 1993 and 1994 declined to a record-low. Accounting for the estimation uncertainty associated with the 1993 SSB (9,727 mt) and 1993 F (0.93) estimates, there is an 80% probability that the 1993 SSB lies between 8,800 mt and 11,200 mt, and that the 1993 F lies between 0.75 and 1.15. This further implies a 90% probability that the 1993 F is greater than 0.75, or about two times greater than the over fishing definition ($F_{20\%}$=0.35).

If the current level of fishing mortality (F=0.93) is maintained in 1995, SSB will continue to decline in 1996 and 1997 from the already record-low 1993-1994 levels; furthermore, landings will continue to decline in 1995 and 1996 regardless of the level of F. At a minimum, fishing mortality should be reduced by at least 50% in order to rebuild the SSB to pre-1993 levels. A 10% reduction in fishing mortality in 1995 would not result in any appreciable short-term increase in SSB between 1994 and 1996. A 60% reduction in F to $F_{20\%}$ in 1995 would increase SSB in 1996 to about 10,000-12,000 mt, but SSB would still remain well below the long-term (1982-1993) mean (17,400 mt). Current SSB is no longer dominated by the 1987 year class, but by a series of very low to below average year classes from 1988-1991.

Subcommittee Comments

The subcommittee reviewed background data on the status of survey, commercial and recreational data for the Gulf of Maine cod population. Long term trends (1963-1993) suggest greatly reduced biomass per tow in the NEFSC trawl survey indices in recent years. The subcommittee commented that although recreational catch was declining, the relative contribution of recreational catch to total landings is increasing. The subcommittee also noted that port sampling data in 1993 was markedly reduced, with only 23 samples taken. Although the committee noted that declines in catch at age of older age classes in 1993 may be an artifact of poor sampling coverage, similar truncated catch at age trends were noted in the survey indices in recent years.

Although changes in technology were not specifically accounted for in the GLM analysis, the subcommittee noted that the year effect in the GLM encompassed both increases in technology and changes in abundance. Use of the subfleet index to revise the LPUE index was discussed, and the committee concluded that this approach is useful when the selectivity caused by targeting is not a consideration.

The committee suggested several alternative formulations of the VPA to stabilize estimates of F, particularly between ages 4 and 5. One alternative formulation was to exclude all commercial indices from the VPA, because commercial LPUE trends were not consistent with survey indices. The subcommittee discussed shifting the plus group from 8+ to 7+ to stabilize noisy estimates of F in the VPA analysis. The subcommittee also requested an additional ADAPT run in which an intermediate age class (4 or 5) would be dropped from the F estimation procedure. After considering alternative formulations, the subcommittee accepted an ADAPT run with the initial formulation, modified with a 7+ group and a revised maturation schedule, as being most representative of the current stock status for Gulf of Maine cod (Table A13). It was noted that the directional trends of F from this analysis were highly correlated with directional changes in effort for the commercial fishery.

The subcommittee noted the large contribution to total variance by the Massachusetts fall trawl survey index. Discussions focused on the appropriateness of using transformed (geometric mean) versus untransformed stratified mean catch per tow for the Massachusetts survey indices. The decision to use transformed indices was deferred until further analysis by age can be completed. It was suggested that the Methods subcommittee should consider the treatment of outliers and the appropriate use of transformed versus untransformed indices.

The subcommittee discussed changes in the maturation schedule caused by delayed maturation of the large 1987 year class. The subcommittee decided to use a moderately delayed maturation schedule from 1982-1984, an accelerated schedule to reflect low biomass levels from 1985-1989, and a highly delayed maturation schedule to reflect recruitment of the 1987 year class from 1990-1991. The committee recommended further analysis to determine if the maturation schedule for 1992-1993 should revert to the accelerated schedule observed prior to recruitment of the 1987 year class. Final estimates and future projections of SSB were made based on a combined 1990-1993 maturation schedule.

The subcommittee examined a retrospective analysis of F, recruitment, and SSB presented for the first time for Gulf of Maine cod. The retrospective analysis suggested a tendency to overestimate F, but reflected consistent estimates for recruitment and SSB.

The subcommittee considered three options for projections of future recruitment for 1995 and 1996: (1) average recruitment of 5.4 million based on the geometric mean of age 2 fish from the 1980-1991 year classes; (2) average recruitment of 4.8 million based on the geometric mean age 2 recruitment from 1980-1991 year classes excluding the large 1987 year class; and (3) average recruitment of 3.4 million based on mean age 2 recruitment from the 1988-1991 year classes. There were discussions concerning some very preliminary indications from the Massachusetts survey that the 1993 year class may be moderately large. There is no evidence that this year class is exceptional from the NEFSC survey, but the NEFSC survey is generally unreliable in detecting year class strength before age 2. Regardless of its relative size, the 1993 year class will not contribute to the exploitable biomass until 1996 or later. The subcommittee decided to use option 1, recruitment of 5.4 million for 1995-1996 based on long-term geometric mean of age 2 recruitment for future projections.

The subcommittee discussed summary views of the current status of cod stocks in the Gulf of Maine. It was the consensus of the subcommittee that the stock is overfished ($F \sim 0.9$), and that SSB is among the lowest observed historically. Discussions centered on short-term and long-term considerations for recovery of the stock. The subcommittee expressed concern that high current F's and discarding in the small mesh fishery will reduce survival of recruiting year classes and result in rapid depletion of biomass once recruitment occurs.

The subcommittee observed that while short term reductions in F to $F_{20\%}$ could result in slight increases in SSB, even if recruitment is average. However, long term recovery of SSB to average levels in the 1970's will require F to be reduced substantially below $F_{20\%}$.

The subcommittee discussed ideas for future modifications of data collection procedures. Use of sea sampling data to augment port sampling data in the estimation of catch at age will require an analysis of the unclassified data into market categories. Lack of available 1994 landings precluded a calibration of F_{1994} to commercial landings.

Sources of Uncertainty

- o The omission of commercial fishery discards and recreational catch estimates from the catch at age matrix continues to introduce uncertainty into the results. Commercial fishery discard mortality may be a significant component of total mortality in certain years, but estimates were not available for this assessment. Omission of commercial discards and recreational catch may result in an underestimation of total fishery removals from the stock.

- o Residual patterns in the VPA analysis indicated blocks of negative residuals that are indicative of conflicting signals among the tuning indices.

SARC Comments

Members of the SARC questioned the shifts in the maturity ogive used in the analysis. Major shifts in the maturity ogive between 1989 and 1990 were related to the late maturation pattern of the exceptionally large 1987 year class. SARC members made several suggestions including using a 3-year running average or cohort based shifts to account for changes in the maturation schedule.

The SARC members discussed residual patterns in the VPA results. These patterns were indicative of conflicting signals among the indices used to tune the VPA. Alternative formulations of the VPA did not result in significant shifts in this residual pattern. The SARC discussed data indicating that recreational landings were becoming a significant portion of the total landings, and recommended the addition of information concerning the contribution of recreational landings to overall landings.

The SARC panel discussed the validity and format for medium-term stochastic projections introduced with this assessment. The discussions focused on four basic questions:

1. Is the production of medium-term stochastic projections a valid methodology?
2. How many years into the future should these projections extend?
3. Should these projections be incorporated in the Gulf of Maine Cod assessment?
4. If incorporated, what levels of F should be examined?

SARC members expressed concern that projections from SSB levels outside the range of observed R/SSB would be tenuous. It was the consensus of the SARC panel that the projection approach was valid, that the time frame of 10 years was appropriate, and that the projections should be incorporated into the current assessment. Considerable time was spent discussing the potential implications of displaced fishing effort as a result of proposed restrictions on Georges Bank. Based on these discussions, the panel decided that projections with F levels of $F_{SQ=0.93}$, $F_{1/2SQ=0.47}$, $F_{20\%}$ and $F_{0.1}$ should be included in the assessment.

Research Recommendations

- o Future assessments should explore alternate estimation techniques for the maturity ogive including the use of running averages or a cohort-type analysis.
- o Yield per recruit analysis in future assessments should be extended from age 10 in the current assessment to age 15.
- o Future assessments should attempt to incorporate recreational catch into the catch at age matrix and analysis. Current recreational landings data are inadequate due to the current creel census design and lack of information on capture location. Further work is needed to develop specific recommendations for the MRFSS about the level of biological sampling and interview coverage to obtain information of location of catch.
- o Non-age based assessment techniques (Delury) should be used to extend the estimates of stock biomass and F as early as survey data permit.
- o Data provided by the NEFSC summer survey should be reviewed to assess the utility for assessing year class strength and projecting recruitment.

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Table A1. Commercial landings (metric tons, live) of Atlantic cod the Gulf of Maine (NAFO Division 5Y), 1960 - 1993.[1]

	Gulf of Maine				
Year	USA	Canada	USSR	Other	Total
1960	3448	129	-	-	3577
1961	3216	18	-	-	3234
1962	2989	83	-	-	3072
1963	2595	3	133	-	2731
1964	3226	25	-	-	3251
1965	3780	148	-	-	3928
1966	4008	384	-	-	4392
1967	5676	297	-	-	5973
1968	6360	61	-	-	6421
1969	8157	59	-	268	8484
1970	7812	26	-	423	8261
1971	7380	119	-	163	7662
1972	6776	53	11	77	6917
1973	6069	68	-	9	6146
1974	7639	120	-	5	7764
1975	8903	86	-	26	9015
1976	10172	16	-	-	10188
1977	12426	-	-	-	12426
1978	12426	-	-	-	12426
1979	11680	-	-	-	11680
1980	13528	-	-	-	13528
1981	12534	-	-	-	12534
1982	13582	-	-	-	13582
1983	13981	-	-	-	13981
1984	10806	-	-	-	10806
1985	10693	-	-	-	10693
1986	9664	-	-	-	9664
1987	7527	-	-	-	7527
1988	7958	-	-	-	7958
1989	10397	-	-	-	10397
1990	15154	-	-	-	15154
1991	17781	-	-	-	17781
1992	10891	-	-	-	10891
1993*	8287	-	-	-	8287

[1] USA landings from NMFS, NEFC Detailed Weighout Files and Canvass data.

* Provisional

Table A2. Distribution of USA commercial landings (metric tons, live) of Atlantic cod from the Gulf of Maine (Area 5Y), by gear type, 1965 - 1993. The percentage of total USA commercial landings of Atlantic cod from the Gulf of Maine, by gear type, is also presented for each year. Data only reflect Gulf of Maine cod landings that could be identified by gear type.

	Landings (metric tons, live)						Percentage of Annual Landings					
Year	Otter Trawl	Sink Gill Net	Line Trawl	Handline	Other Gear	Total	Otter Trawl	Sink Gill Net	Line Trawl	Handline	Other Gear	Total
1965	2480	501	462	168	1	3612	68.7	13.9	12.8	4.6	-	100.0
1966	2549	830	308	150	4	3841	66.4	21.6	8.0	3.9	0.1	100.0
1967	4312	734	206	274	<1	5526	78.0	13.3	3.7	5.0	-	100.0
1968	4143	1377	213	339	4	6076	68.2	22.7	3.5	5.6	-	100.0
1969	6553	851	258	162	4	7828	83.7	10.9	3.3	2.1	-	100.0
1970	5967	951	407	178	9	7512	79.4	12.7	5.4	2.4	0.1	100.0
1971	5117	1043	927	98	8	7193	71.1	14.5	12.9	1.4	0.1	100.0
1972	4004	1492	1234	54	2	6786	59.0	22.0	18.2	0.8	-	100.0
1973	3542	1182	1305	23	9	6061	58.4	19.5	21.5	0.4	0.2	100.0
1974	5056	1412	904	36	17	7425	68.1	19.0	12.2	0.5	0.2	100.0
1975	6255	1480	920	12	8	8675	72.1	17.1	10.6	0.1	0.1	100.0
1976	6701	2511	621	4	41	9878	67.8	25.4	6.3	0.1	0.4	100.0
1977	8415	2872	534	6	166 [a]	11993	70.2	23.9	4.5	-	1.4	100.0
1978	7958	3438	393	10	91 [b]	11890	66.9	28.9	3.3	0.1	0.8	100.0
1979	7567	2900	334	19	167 [c]	10987	68.9	26.4	3.0	0.2	1.5	100.0
1980	8420	3733	251	48	61	12513	67.3	29.8	2.0	0.4	0.5	100.0
1981	7937	4102	276	23	45	12383	64.1	33.1	2.2	0.2	0.4	100.0
1982	9758	3453	188	46	34	13479	72.4	25.6	1.4	0.3	0.3	100.0
1983	9975	3744	77	4	67	13867	71.9	27.0	0.6	-	0.5	100.0
1984	6646	3985	22	3	69	10725	62.0	37.2	0.2	-	0.6	100.0
1985	7119	3090	55	6	326 [d]	10596	67.2	29.1	0.5	0.1	3.1	100.0
1986	6664	2692	56	12	180 [e]	9604	69.4	28.0	0.6	0.1	1.9	100.0
1987	4356	2994	70	13	68	7501	58.1	39.9	0.9	0.2	0.9	100.0
1988	4513	3308	68	27	22	7938	56.9	41.7	0.8	0.3	0.3	100.0
1989	6152	4000	72	36	119 [f]	10379	59.3	38.5	0.7	0.4	1.1	100.0
1990	10420	4343	126	20	186 [g]	15095	69.0	28.8	0.8	0.1	1.2	100.0
1991	13049	4158	212	59	266 [h]	17744	73.5	23.4	1.2	0.3	1.5	100.0
1992	7344	3081	359	94	14	10891	67.4	28.3	3.3	0.9	0.1	100.0
1993	4876	3130	236	16	29	8287	58.8	37.8	2.8	0.2	0.3	100.0

[a] Of 166 mt landed, 107 mt were by mid-water pair trawl and 42 mt were by drifiting gill nets.
[b] Of 91 mt landed, 56 mt were by Danish seine and 27 mt were by drifting gill nets.
[c] Of 167 mt landed, 199 mt were by drifting gill nets and 38 mt were by Danish seine.
[d] Of 326 mt landed, 268 mt were by longline and 37 mt were by Danish seine.
[e] Of 181 mt landed, 152 mt were by longline and 23 mt were by Danish seine.
[f] Of 199 mt landed, 75 mt were by longline and 27 mt were by Danish seine.
[g] Of 186 mt landed, 159 mt were by longline and 16 mt were by Danish seine.
[h] Of 266 mt landed, 245 mt were by longline and 9 mt were by Danish seine.

Table A3. Estimated number (000's) and weight (metric tons, live) of Atlantic cod caught by marine recreationalfishermen, in 1960, 1965, 1970, 1974, and 1979 - 1993.[1]

Year	All Regions		Gulf of Maine Stock		Recreational Catch	
	No. of Cod (000's)	Wt. of Cod (mt)	No. of Cod (000's)	Wt. of Cod (mt)	Mean Weight (kg)	Percent of Total Landings
1960	4791	14016	Not Estimated		-----	-----
1965	5032	13565	Not Estimated		-----	-----
1970	3844	16292	Not Estimated		-----	-----
1974	2901	12368	Not Estimated		-----	-----
1979	3091	4026	2698	3446	1.28	23
1980	2440	7331	2254	6860	3.04	34
1981	4845	9712	3240	5035	1.55	29
1982	3250	8244	1797	2948	1.64	18
1983	3747	7542	2054	2622	1.28	16
1984	2562	5080	1730	2674	1.55	20
1985	3674	7664	1676	3029	1.81	22
1986	1548	3510	1217	2418	1.99	20
1987	2063	3779	1596	2611	1.64	26
1988	2966	7327	1472	3043	2.07	28
1989	2463	6119	1925	4244	2.20	29
1990	2635	5144	1945	3448	1.77	19
1991	1854	3727	1410	2472	1.75	12
1992	721	1516	512	1009	1.97	8
1993	2282	4874	1392	2667	1.92	24

[1] From 1979-1993 Marine Recreational Fishery Statistics Survey expanded catch estimates.

Table A4. USA sampling of commercial Atlantic cod landings from the Gulf of Maine cod stock (NAFO Division 5Y), 1982 - 1993.

	Number of Samples				Number of Samples, by Market Category & Quarter															Annual Sampling Intensity			
	Length Samples		Age Samples		Scrod					Market					Large					No. of Tons Landed/Sample			
Year	No.	# Fish Measured	No.	# Fish Aged	Q1	Q2	Q3	Q4	Σ	Q1	Q2	Q3	Q4	Σ	Q1	Q2	Q3	Q4	Σ	Scd	Mkt	Lge	Σ
1982	48	3848	48	866	6	7	6	6	25	4	3	7	4	18	0	2	1	2	5	134	348	792	266
1983	71	5241	67	1348	14	10	10	4	38	4	10	6	2	22	1	3	5	2	11	106	294	318	197
1984	55	3925	55	1224	7	5	6	7	25	4	3	5	6	18	1	6	3	2	12	85	319	245	193
1985	69	5426	66	1546	5	6	7	5	23	8	6	7	4	25	7	5	3	6	21	95	229	132	155
1986	53	3970	51	1160	5	5	6	3	19	5	6	8	2	21	1	5	4	3	13	124	242	170	182
1987	43	3184	42	939	4	4	3	4	15	5	5	3	5	18	4	2	3	1	10	83	224	225	175
1988	34	2669	33	741	4	3	4	4	15	1	5	3	5	14	1	2	2	0	5	147	271	391	234
1989	32	2668	32	714	3	3	3	3	12	4	1	5	4	14	2	2	1	1	6	209	430	311	325
1990	39	2982	38	789	3	7	3	5	18	4	7	4	3	18	0	2	1	0	3	300	378	966	387
1991	56	4519	56	1152	2	10	4	3	19	5	11	11	3	30	0	3	3	1	7	250	313	519	318
1992	51	4086	51	1002	2	8	6	3	19	6	7	7	3	23	3	1	1	4	9	104	232	375	214
1993	23	1753	23	447	3	3	3	1	10	1	2	4	1	8	1	1	2	1	5	177	453	527	360

Source: 1978-1985 from Serchuk and Wigley (Woods Hole Lab. Ref 86-12); 1986-1993 from NEFSC files.

Table A5. Landings at age (thousands of fish; metric tons) and mean weight (kg) and mean length (cm) at age of total commercial landings of Atlantic cod from the Gulf of Maine stock (NAFO Division 5Y), 1982 - 1993.

	Age											
Year	1	2	3	4	5	6	7	8	9	10	11+	Total
					Total Commercial Landings in Numbers (000's) at Age							
1982	30	1380	1633	1143	633	69	91	61	41	4	33	5118
1983	-	866	2357	1058	638	422	47	61	23	9	15	5496
1984	4	446	1240	1500	437	194	74	19	15	11	17	3957
1985	-	407	1445	991	630	128	78	32	4	11	11	3737
1986	-	84	2164	813	250	177	39	24	20	4	8	3583
1987	2	216	595	1109	277	66	51	9	8	8	3	2344
1988	-	160	1443	953	406	43	9	17	1	2	1	3035
1989	-	337	1583	1454	449	81	35	6	3	5	7	3960
1990	-	205	3425	2064	430	157	27	30	10	15	17	6380
1991	-	344	934	4161	851	143	41	30	6	1	1	6512
1992	-	313	530	484	2018	202	62	7	12	3	-	3631
1993	-	76	1487	641	129	457	28	6	2	-	-	2825
					Total Commercial Landings in Weight (Tons) at Age							
1982	24	1595	2717	3160	3019	461	813	608	531	41	613	13582
1983	-	1009	3913	2619	2410	2518	271	643	227	102	269	13981
1984	3	516	2071	4080	1607	1145	603	186	193	152	250	10816
1985	-	513	2523	2816	2814	705	615	363	51	141	152	10693
1986	-	110	3976	2375	1153	1072	296	243	253	54	132	9664
1987	2	283	1001	3641	1340	451	455	88	116	110	40	7527
1988	-	203	2715	2311	2097	295	85	191	11	36	14	7958
1989	-	420	2811	4351	1737	325	323	67	43	87	163	10397
1990	-	219	5794	4687	1834	1200	290	354	153	214	350	15095
1991	-	388	1463	10455	3520	1045	399	369	93	32	17	17781
1992	-	480	1019	1313	6175	1011	594	88	161	49	-	10891
1993	-	99	2809	1611	561	2819	281	79	27	-	-	8286
					Total Commercial Landings Mean Weight (kg) at Age							
1982	0.801	1.156	1.664	2.764	4.770	6.739	8.944	9.931	12.922	10.618	18.456	2.654[a]
1983	-	1.164	1.660	2.475	3.778	5.962	5.808	10.522	10.089	10.898	17.813	2.544
1984	0.589	1.159	1.670	2.721	3.677	5.898	8.119	9.595	12.889	13.951	15.028	2.731
1985	-	1.260	1.746	2.840	4.466	5.525	7.901	11.218	11.420	13.386	14.523	2.861
1986	-	1.304	1.837	2.923	4.619	6.067	7.669	10.030	12.463	12.907	16.554	2.698
1987	1.028	1.313	1.684	3.283	4.831	6.824	8.878	10.023	13.752	14.738	14.596	3.212
1988	-	1.268	1.881	2.426	5.166	6.767	9.932	11.126	14.960	15.763	20.356	2.622
1989	-	1.247	1.776	2.993	3.864	4.872	9.267	11.938	14.806	18.196	21.521	2.626
1990	-	1.071	1.692	2.271	4.265	7.645	10.734	11.758	15.015	14.784	20.295	2.366
1991	-	1.130	1.568	2.512	4.136	7.309	9.642	12.322	15.547	24.328	21.885	2.731
1992	-	1.533	1.922	2.714	3.061	5.000	9.566	12.462	13.449	16.631	-	2.999
1993	-	1.293	1.889	2.513	4.356	6.174	9.999	13.869	17.544	-	-	2.933
					Total Commercial Landings Mean Length (cm) at Age							
1982	43.2	48.3	53.8	63.4	76.8	86.1	94.6	97.9	107.4	101.0	120.7	59.9[b]
1983	-	48.6	53.8	61.4	70.8	82.4	80.5	98.8	97.5	100.0	118.7	59.8
1984	39.0	48.4	54.1	63.4	69.7	81.8	91.5	96.7	106.9	109.6	112.0	61.6
1985	-	49.8	55.1	64.6	74.9	80.3	90.8	101.9	103.1	108.2	109.7	62.8
1986	-	50.3	55.9	65.0	75.4	82.6	89.9	98.7	105.8	107.5	116.2	61.6
1987	47.0	50.4	54.4	67.8	76.9	86.5	93.8	98.7	109.5	111.7	111.3	65.4
1988	-	50.1	56.4	61.1	78.7	86.4	98.6	102.3	113.0	114.8	125.0	61.4
1989	-	49.8	55.5	65.7	71.5	76.7	95.8	103.4	112.6	120.4	126.8	61.7
1990	-	47.5	54.8	60.0	73.7	90.0	100.9	104.0	111.8	112.6	124.6	59.2
1991	-	47.7	52.6	61.8	72.6	88.6	97.2	105.0	113.3	132.5	128.0	62.2
1992	-	53.1	56.6	62.9	65.6	77.0	97.3	106.1	109.1	117.0	-	64.3
1993	-	50.5	56.8	61.7	74.2	83.7	98.6	110.0	119.1	-	-	63.5

[a] Mean weight.
[b] Mean length.

Table A6. Mean weight at age (kg) at the beginning of the year (January 1) for Atlantic cod from the Gulf of Maine stock (NAFO Division 5Y), 1982 - 1993. Values derived from catch mean weight-at-data (mid-year) using procedures described by Rivard (1980).

	Age									
Year	1	2	3	4	5	6	7	8	9	10+ [a]
1982	0.791	0.965	1.364	2.364	(3.750)	(5.600)	(7.400)	9.853	(11.650)	16.000
1983	0.793	1.024	1.385	2.029	3.231	5.333	6.256	9.701	10.010	16.000
1984	0.761	1.021	1.394	2.125	3.017	4.720	6.957	(9.670)	11.646	16.000
1985	0.748	1.065	1.423	2.178	3.486	4.507	6.826	9.544	10.468	16.000
1986	0.745	1.083	1.521	2.259	3.622	5.205	6.509	8.902	11.824	16.000
1987	0.758	1.087	1.482	2.456	3.758	5.614	7.339	8.767	11.744	16.000
1988	0.765	1.068	1.572	2.021	4.118	5.718	8.233	9.939	12.245	16.000
1989	0.825	1.059	1.501	2.373	3.062	5.017	7.919	10.889	12.835	16.000
1990	0.803	0.982	1.453	2.008	3.573	5.435	7.232	10.438	13.388	16.000
1991	0.690	1.006	1.296	2.062	3.065	5.583	8.586	11.501	13.520	16.000
1992	0.751	1.175	1.474	2.063	2.773	4.548	8.362	10.962	12.875	16.000
1993	0.751	1.079	1.702	2.198	3.438	4.347	7.071	11.518	13.261	16.000
Mean Values										
90-93	0.749	1.061	1.481	2.083	3.212	4.978	7.813	11.105	13.261	16.000
82-93	0.765	1.051	1.464	2.178	3.408	5.136	7.391	10.140	12.123	16.000

[a] Mean weight-at-age values for 10+ set equal to mean (1982-1993) catch (mid-year) weight at age value for 10+.

( ) Values in parentheses are modified from calculated values.

Table A7. Total and USA commercial landings, USA catch-per-unit of effort indices (CPUE: all cod trips),and derived effort indices for Gulf of Maine cod, 1965 - 1993.

Year	Total Landings (mt)	USA Landings (mt)	USA CPUE Index (All Cod Trips)	Total Calculated Days Fished	USA Calculated Days Fished
1965	3928	3780	0.6954	5649	5436
1966	4392	4008	0.8510	5161	4710
1967	5973	5676	1.4096	4237	4027
1968	6421	6360	1.1273	5696	5642
1969	8484	8157	1.4241	5957	5728
1970	8261	7812	0.8871	9312	8806
1971	7662	7380	0.8815	8692	8372
1972	6917	6776	0.6800	10172	9965
1973	6146	6069	0.6382	9630	9510
1974	7764	7639	1.0207	7607	7484
1975	9015	8903	1.0220	8821	8711
1976	10188	10172	1.0842	9397	9382
1977	12426	12426	1.2094	10275	10275
1978	12426	12426	0.9712	12794	12794
1979	11680	11680	0.9361	12477	12477
1980	13528	13528	0.8346	16209	16209
1981	12534	12534	0.8561	14641	14641
1982	13582	13582	0.8395	16179	16179
1983	13981	13981	0.8466	16514	16514
1984	10806	10806	0.5410	19974	19974
1985	10693	10693	0.5219	20489	20489
1986	9664	9664	0.4630	20873	20873
1987	7527	7527	0.3056	24630	24630
1988	7958	7958	0.3498	22750	22750
1989	10397	10397	0.5561	18696	18696
1990	15154	15154	1.0279	14743	14743
1991	17781	17781	1.1054	16086	16086
1992	10891	10891	0.5470	19910	19910
1993	8287	8287	0.4327	19152	19152

Table A8. Gulf of Maine cod GLM effort standardization.

SAS General Linear Models Procedure

Dependent Variable: LNCPUEDF

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	10042.42776453	418.43449019	271.01	0.0001
Error	22417	34610.87206235	1.54395646		
Corrected Total	22441	44653.29982688			

R-Square	C.V.	Root MSE	LNCPUEDF Mean
0.224898	-116.8327	1.24256045	-1.06353847

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	10	4172.47634712	417.24763471	270.25	0.0001
AREA	4	213.43028101	53.35757025	34.56	0.0001
QTR	3	1091.33076950	363.77692317	235.61	0.0001
TONCLASS	4	2804.09441832	701.02360458	454.04	0.0001
DEPTHCD	3	1761.09594858	587.03198286	380.21	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	10	3864.47552921	386.44755292	250.30	0.0001
AREA	4	337.52113256	84.38028314	54.65	0.0001
QTR	3	1077.53586173	359.17862058	232.64	0.0001
TONCLASS	4	3365.93344569	841.48336142	545.02	0.0001
DEPTHCD	3	1761.09594858	587.03198286	380.21	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate	Retransformed Estimate
INTERCEPT		-0.966438423 B	-22.51	0.0001	0.04293803	
AREA	511	0.352862172 B	6.04	0.0001	0.05840734	1.425565
	512	0.093390087 B	2.64	0.0083	0.03535865	1.098576
	513	0.282590501 B	11.13	0.0001	0.02540134	1.326990
	515	-0.026414709 B	-0.84	0.4026	0.03155861	0.974416
	514	0.000000000 B	.	.	.	1.000000
QTR	1	-0.450275482 B	-17.99	0.0001	0.02503570	0.637652
	3	-0.555648751 B	-23.76	0.0001	0.02338944	0.573857
	4	-0.471084150 B	-20.69	0.0001	0.02276910	0.624487
	2	0.000000000 B	.	.	.	1.000000
TONCLASS	31	0.470024146 B	18.66	0.0001	0.02519506	1.600541
	32	0.854568967 B	33.24	0.0001	0.02571061	2.351138
	33	0.896470299 B	32.09	0.0001	0.02793882	2.451894
	41	1.301746565 B	43.24	0.0001	0.03010851	3.677377
	25	0.000000000 B	.	.	.	1.000000
DEPTHCD	1	0.593978838 B	18.13	0.0001	0.03275947	1.812153
	2	0.324741394 B	12.86	0.0001	0.02525790	1.384114
	4	-0.636948746 B	-24.01	0.0001	0.02652370	0.529090
	3	0.000000000 B	.	.	.	1.000000

Table A9. Nominal and standardized (GLM) Gulf of Maine cod landings (mt), effort (days fished) and landings per day fished (LPUE) for the otter trawl effort standardization fleet, 1982-1993.

Year	Landings (mt)	Nominal Effort	Nominal LPUE	Standardized Effort	Standardized LPUE
1982	3395	3158	1.075	4953	0.686
1983	3698	3791	0.975	5782	0.640
1984	2423	3798	0.638	5495	0.441
1985	3012	5294	0.569	8489	0.355
1986	2794	5568	0.502	8745	0.320
1987	1708	5100	0.335	7836	0.218
1988	2060	4753	0.433	7994	0.258
1989	2316	3524	0.657	6125	0.378
1990	4916	4053	1.213	7663	0.641
1991	5432	4737	1.147	8829	0.615
1992	2777	4978	0.558	8003	0.347
1993	2284	4727	0.483	6879	0.332

Table A10. Standardized stratified mean catch per tow in numbers and weight (kg) for Atlantic cod from NEFSC offshore spring and autumn research vessel bottom trawl surveys in the Gulf of Maine (Strata 26-30 and 36-40), 1963 - 1994. [a,b]

	Gulf of Maine [c]			
	Spring		Autumn	
Year	No/Tow	Wt/Tow	No/Tow	Wt/Tow
1963	-	-	5.92	17.9
1964	-	-	4.00	22.8
1965	-	-	4.49	12.0
1966	-	-	3.78	12.9
1967	-	-	2.56	9.2
1968	5.44	17.9	4.34	19.4
1969	3.25	13.2	2.76	15.4
1970	2.21	11.1	4.90	16.4
1971	1.43	7.0	4.37	16.5
1972	2.06	8.0	9.31	13.0
1973	7.54	18.8	4.46	8.7
1974	2.91	7.4	4.33	9.0
1975	2.51	6.0	6.15	8.6
1976	2.78	7.6	2.15	6.7
1977	3.88	8.5	3.08	10.2
1978	2.06	7.7	5.75	12.9
1979	4.27	9.5	3.49	17.5
1980	2.15	6.2	7.04	14.2
1981	4.86	10.8	2.42	8.1
1982	3.75	8.6	7.77	16.1
1983	3.91	10.5	4.22	8.8
1984	3.40	5.8	2.42	8.8
1985	2.52	7.7	2.92	8.5
1986	1.96	3.6	1.95	5.1
1987	1.68	3.0	2.98	3.4
1988	3.13	3.3	5.90	6.6
1989	2.26	2.5	4.65	4.6
1990	2.36	3.1	2.99	4.9
1991	2.39	2.9	1.25	2.8
1992	2.41	8.7	1.43	2.4
1993	2.50	5.9	1.23	1.0
1994	1.27	2.4	----	---

[a] During 1963-1984, BMV oval doors were used in the spring and autumn surveys; since 1985, Portugeuse polyvalent doors have been used in both surveys. Adjustments have been made to the 1963-1984 catch per tow data to standardize these data to polyvalent door equivalents. Conversion coefficients of 1.56(numbers) and 1.62 (weight) were used in this standardization (NEFC 1991).

[b] Spring surveys during 1973-1981 were accomplished with a '41 Yankee' trawl; in all other years, spring surveys were accomplished with a '36 Yankee' trawl. No adjustments have been made to the catch per tow data for these differences.

[c] In the Gulf of Maine, spring surveys during 1980-1982, 1989-1991 and 1994, and autumn surveys during 1977-1978, 1980, 1989-1991 and 1993 were accomplished with the R/V DELAWARE II; in all other years, the surveys were accomplished using the R/V ALBATROSS IV. Adjustments have been made to the R/V DELAWAREII catch per tow data to standardize these to R/V ALBETATROSS IV equivalents. Conversion coefficients 0.79 (number) and 0.67 (weight) were used in this standardization (NEFC 1991).

Table A11. Standardized [for both door and gear changes] stratified mean number per tow at age and standardized stratified mean weight (kg) per tow of Atlantic cod in NEFSC offshore spring and autumn research vessel bottom trawl surveys in the Gulf of Maine, 1963-1994. [a,b]

	Age Group											Totals						Standardized
Year	0	1	2	3	4	5	6	7	8	9	10+	0+	1+	2+	3+	4+	5+	Mean Wt (kg)/Tow
Spring [c,d,e]																		
1968	0.128	0.613	1.234	1.407	0.846	0.538	0.207	0.129	0.111	0.059	0.165	5.438	5.310	4.697	3.463	2.056	1.211	17.92
1969	0.000	0.000	0.036	0.307	0.880	0.807	0.633	0.256	0.144	0.089	0.101	3.253	3.253	3.253	3.217	2.909	2.030	13.20
1970	0.000	0.159	0.123	0.055	0.094	0.273	0.466	0.615	0.075	0.059	0.287	2.206	2.206	2.047	1.923	1.869	1.775	11.06
1971	0.000	0.025	0.142	0.109	0.292	0.048	0.083	0.300	0.206	0.154	0.072	1.431	1.431	1.406	1.264	1.154	0.863	6.98
1972	0.000	0.353	0.153	0.519	0.197	0.200	0.036	0.106	0.101	0.229	0.164	2.058	2.058	1.705	1.552	1.033	0.836	8.04
1973	0.000	0.034	4.249	0.906	0.619	0.349	0.195	0.095	0.223	0.251	0.612	7.535	7.535	7.500	3.251	2.345	1.725	18.79
1974	0.000	0.476	0.056	1.359	0.329	0.222	0.114	0.048	0.048	0.020	0.232	2.905	2.905	2.429	2.373	1.014	0.685	7.44
1975	0.006	0.094	0.699	0.106	1.065	0.259	0.111	0.005	0.005	0.019	0.144	2.512	2.505	2.412	1.713	1.607	0.541	6.03
1976	0.000	0.042	0.304	1.048	0.153	0.897	0.086	0.108	0.066	0.000	0.073	2.777	2.777	2.735	2.430	1.382	1.229	7.55
1977	0.000	0.025	0.298	0.521	1.994	0.109	0.791	0.006	0.101	0.000	0.037	3.883	3.883	3.858	3.560	3.039	1.045	8.54
1978	0.000	0.034	0.105	0.285	0.348	0.766	0.075	0.320	0.008	0.106	0.008	2.055	2.055	2.020	1.916	1.630	1.282	7.70
1979	0.044	0.535	1.630	0.212	0.499	0.401	0.685	0.059	0.142	0.012	0.053	4.273	4.229	3.694	2.064	1.852	1.353	9.49
1980	0.070	0.070	0.440	0.343	0.123	0.418	0.239	0.303	0.000	0.129	0.014	2.149	2.079	2.009	1.569	1.226	1.103	
6.18																		
1981	0.000	1.014	0.662	0.986	1.216	0.328	0.287	0.110	0.155	0.106	0.000	4.864	4.864	3.850	3.188	2.202	0.986	10.79
1982	0.015	0.336	1.019	0.516	0.694	0.864	0.117	0.108	0.000	0.042	0.039	3.751	3.737	3.400	2.381	1.865	1.171	8.62
1983	0.012	0.626	0.978	0.833	0.641	0.357	0.181	0.092	0.000	0.090	0.101	3.912	3.900	3.274	2.296	1.463	0.822	10.50
1984	0.000	0.151	1.033	1.147	0.741	0.190	0.053	0.058	0.030	0.000	0.000	3.402	3.402	3.251	2.218	1.072	0.331	5.83
1985	0.000	0.028	0.238	0.622	0.665	0.677	0.095	0.114	0.052	0.000	0.026	2.517	2.517	2.489	2.251	1.629	0.964	7.65
1986	0.000	0.417	0.330	0.647	0.387	0.074	0.046	0.027	0.011	0.000	0.018	1.957	1.957	1.540	1.210	0.563	0.176	3.60
1987	0.000	0.049	0.638	0.486	0.300	0.128	0.011	0.045	0.011	0.000	0.014	1.682	1.682	1.633	0.995	0.509	0.209	3.01
1988	0.029	0.663	1.053	0.633	0.355	0.217	0.087	0.063	0.000	0.027	0.000	3.127	3.098	2.435	1.382	0.749	0.394	3.30
1989	0.000	0.023	0.649	0.790	0.632	0.090	0.077	0.000	0.000	0.000	0.000	2.261	2.261	2.238	1.589	0.799	0.167	2.53
1990	0.000	0.000	0.190	1.327	0.627	0.167	0.032	0.018	0.000	0.000	0.000	2.362	2.362	2.362	2.172	0.845	0.217	3.08
1991	0.000	0.043	0.209	0.355	1.477	0.268	0.024	0.018	0.000	0.000	0.000	2.394	2.394	2.351	2.142	1.787	0.310	2.89
1992	0.000	0.050	0.230	0.240	0.280	1.310	0.220	0.070	0.000	0.010	0.000	2.410	2.410	2.360	2.130	1.890	1.610	8.66
1993	0.000	0.200	0.500	0.800	0.330	0.090	0.480	0.060	0.020	0.000	0.023	2.503	2.503	2.303	1.803	1.003	0.673	5.87
1994	0.000	0.031	0.284	0.389	0.208	0.120	0.051	0.126	0.027	0.020	0.018	1.273	1.273	1.243	0.958	0.570	0.362	2.43

[a] Strata 26-30 and 36-40.

[b] Catch per tow at age values for 1963-1969 obtained by applying combined 1970-1981 age-length keys to stratified mean catch per tow at length distributions from each survey.

[c] Spring surveys during 1973-1981 were accomplished with a '41 Yankee' trawl; in all other years, spring surveys were accomplished with a '36 Yankee' trawl. No adjustments have been made to the catch per tow data for these differences.

[d] During 1963-1984, BMV oval doors were used in the spring and autumn surveys; since 1985, Portugeuse polyvalent doors have been used in both surveys. Adjustments have been made to the 1963-1984 catch per tow data to standardize these data to polyvalent door equivalents. Conversion coefficients of 1.56 (numbers) and 1.62 (weight) were used in this standardization (NEFC 1991).

[e] In the Gulf of Maine, spring surveys during 1980-1982, 1989-1991 amd 1994, and autumn surveys during 1977-1978, 1980, 1989-1991 and 1993 were accomplished with the R/V DELAWARE II; in all other years, the surveys were accomplished using the R/V ALBATROSS IV. Adjustments have been made to the R/V DELAWARE II catch per tow data to standardize these to R/V ALBTATROSS IV equivalents. Conversion coefficients of 0.79 (numbers) and 0.67 (weight) were used in this standardization (NEFC 1991).

Table A11 (Continued). [a,b]

Year	Age Group 0	1	2	3	4	5	6	7	8	9	10+	Totals 0+	1+	2+	3+	4+	5+	Standardized Mean Wt (kg)/Tow
Autumn [d,e]																		
1963	0.050	0.649	1.349	1.253	0.849	0.579	0.537	0.300	0.183	0.095	0.075	5.917	5.867	5.218	3.869	2.616	1.767	17.95
1964	0.000	0.092	0.122	0.471	0.856	0.853	0.783	0.373	0.237	0.114	0.101	4.003	4.003	3.911	3.789	3.318	2.462	22.79
1965	0.002	0.850	0.880	0.824	0.750	0.496	0.374	0.170	0.080	0.044	0.025	4.494	4.493	3.643	2.763	1.939	1.189	12.00
1966	0.170	0.204	0.640	0.697	0.718	0.558	0.441	0.192	0.078	0.048	0.036	3.783	3.613	3.409	2.769	2.072	1.354	12.91
1967	0.012	0.129	0.215	0.574	0.671	0.384	0.268	0.162	0.070	0.041	0.034	2.562	2.549	2.420	2.204	1.630	0.959	9.23
1968	0.012	0.036	0.179	0.719	1.256	0.973	0.627	0.261	0.156	0.072	0.095	4.387	4.374	4.338	4.159	3.440	2.184	19.44
1969	0.016	0.059	0.123	0.354	0.630	0.552	0.466	0.220	0.145	0.129	0.062	2.758	2.742	2.683	2.560	2.206	1.576	15.37
1970	0.743	0.941	0.265	0.551	0.329	0.488	0.423	0.789	0.131	0.094	0.147	4.900	4.157	3.217	2.952	2.401	2.072	16.43
1971	1.346	0.178	0.239	0.211	0.597	0.460	0.434	0.254	0.318	0.200	0.128	4.365	3.019	2.841	2.602	2.391	1.794	16.52
1972	0.031	5.579	1.217	1.526	0.234	0.094	0.172	0.039	0.159	0.242	0.016	9.307	9.276	3.697	2.480	0.955	0.721	12.96
1973	0.636	0.328	2.173	0.139	0.507	0.212	0.078	0.028	0.051	0.168	0.136	4.457	3.820	3.493	1.320	1.181	0.674	8.73
1974	0.282	1.123	0.189	1.744	0.292	0.359	0.078	0.012	0.012	0.042	0.198	4.332	4.050	2.927	2.738	0.994	0.702	8.97
1975	0.047	0.147	3.067	0.134	2.356	0.254	0.109	0.017	0.003	0.003	0.012	6.150	6.103	5.956	2.889	2.755	0.399	8.62
1976	0.000	0.243	0.209	0.632	0.100	0.768	0.058	0.095	0.000	0.016	0.031	2.151	2.151	1.908	1.699	1.067	0.967	6.74
1977	0.000	0.022	0.359	0.550	1.155	0.152	0.593	0.038	0.097	0.022	0.096	3.083	3.083	3.061	2.703	2.153	0.998	10.22
1978	0.249	1.369	0.371	1.118	0.656	1.430	0.112	0.325	0.009	0.060	0.051	5.749	5.500	4.131	3.760	2.642	1.987	12.89
1979	0.005	0.368	0.594	0.162	0.836	0.392	0.782	0.051	0.215	0.000	0.083	3.488	3.483	3.115	2.521	2.359	1.523	17.54
1980	0.027	1.264	2.602	1.754	0.497	0.232	0.335	0.207	0.030	0.018	0.071	7.037	7.010	5.745	3.144	1.390	0.893	14.21
1981	0.012	0.619	0.382	0.549	0.474	0.089	0.119	0.037	0.108	0.000	0.028	2.418	2.406	1.786	1.404	0.855	0.381	8.05
1982	0.000	0.700	3.142	2.473	1.167	0.248	0.000	0.039	0.000	0.000	0.000	7.769	7.769	7.068	3.927	1.454	0.287	16.07
1983	0.045	1.660	0.977	0.852	0.139	0.264	0.197	0.000	0.000	0.000	0.090	4.223	4.178	2.518	1.541	0.690	0.551	8.81
1984	0.044	0.384	0.421	0.565	0.399	0.220	0.204	0.089	0.000	0.031	0.066	2.423	2.379	1.995	1.574	1.009	0.610	8.81
1985	0.266	0.378	0.910	0.763	0.209	0.218	0.074	0.000	0.034	0.021	0.049	2.922	2.656	2.278	1.368	0.605	0.396	8.49
1986	0.000	0.301	0.490	0.654	0.333	0.086	0.042	0.000	0.000	0.024	0.021	1.951	1.951	1.650	1.160	0.506	0.173	5.10
1987	0.138	0.599	1.324	0.600	0.257	0.061	0.000	0.000	0.000	0.000	0.000	2.979	2.841	2.242	0.918	0.318	0.061	3.41
1988	0.000	1.951	2.245	0.960	0.528	0.110	0.076	0.033	0.000	0.000	0.000	5.903	5.903	3.952	1.707	0.747	0.219	6.61
1989	0.000	0.416	2.391	1.356	0.294	0.174	0.014	0.000	0.000	0.009	0.000	4.653	4.653	4.238	1.847	0.491	0.197	4.58
1990	0.006	0.029	0.367	1.643	0.623	0.278	0.028	0.010	0.000	0.000	0.000	2.985	2.978	2.949	2.583	0.939	0.317	4.91
1991	0.008	0.142	0.142	0.221	0.632	0.079	0.000	0.024	0.000	0.000	0.000	1.248	1.240	1.098	0.956	0.735	0.103	2.78
1992	0.060	0.290	0.450	0.140	0.040	0.330	0.110	0.000	0.010	0.000	0.000	1.430	1.370	1.080	0.630	0.490	0.450	2.45
1993	0.040	0.198	0.569	0.363	0.032	0.000	0.032	0.000	0.000	0.000	0.000	1.232	1.193	0.995	0.427	0.063	0.032	1.00

[a] Spring and autumn: Strata 26-30 and 36-40.

[b] Catch per tow at age values for 1963-1969 obtained by applying combined 1970-1981 age-length keys to stratified mean catch per tow at length distributions from each survey.

[d] During 1963-1984, BMV oval doors were used in the spring and autumn surveys; since 1985, Portugeuse polyvalent doors have been used in both surveys. Adjustments have been made to the 1963-1984 catch per tow data to standardize these data to polyvalent door equivalents. Conversion coefficients of 1.56 (numbers) and 1.62 (weight) were used in this standardization (NEFC 1991).

[e] In the Gulf of Maine, spring surveys during 1980-1982, 1989-1991 and 1994, and autumn surveys during 1977-1978, 1980, 1989-1991 and 1993 were accomplished with the R/V DELAWARE II; in all other years, the surveys were accomplished using the R/V ALBATROSS IV. Adjustments have been made to the R/V DELAWARE II catch per tow data to standardize these to R/V ALBTATROSS IV equivalents. Conversion coefficients of 0.79 (numbers) and 0.67 (weight) were used in this standardization (NEFC 1991).

Table A12. Stratified mean catch per tow in numbers and weight (kg) of Atlantic cod in State of Massachusetts inshore spring and autumn bottom trawl surveys in territorial waters adjacent to the Gulf of Maine (Mass. Regions 4-5), 1978 - 1994.

Year	Age Group											Totals				Stratified Mean Weight (kg)
	0	1	2	3	4	5	6	7	8	9	10+	0+	1+	2+	3+	
						Gulf of Maine Area (Mass. Regions 4-5)[1]										
Spring																
1978	21.965	12.784	4.162	4.572	0.872	1.028	0.000	0.000	0.023	0.000	0.000	45.406	23.441	10.657	6.495	12.16
1979	56.393	36.630	2.581	1.533	4.659	1.995	0.183	0.000	0.000	0.000	0.069	104.043	47.650	11.020	8.439	20.53
1980	8.156	50.311	12.679	0.971	0.745	0.737	0.080	0.214	0.000	0.025	0.000	73.918	65.762	15.451	2.772	17.71
1981	19.753	24.794	23.884	3.122	1.279	0.041	0.146	0.022	0.022	0.000	0.000	73.063	53.310	28.516	4.632	21.79
1982	1.489	16.235	7.060	3.418	1.147	0.232	0.011	0.057	0.045	0.000	0.000	29.694	28.205	11.970	4.910	13.42
1983	0.453	27.703	18.572	5.331	0.501	1.221	0.142	0.022	0.000	0.000	0.000	53.945	53.492	25.789	7.217	19.77
1984	0.206	2.896	5.408	2.271	0.865	0.138	0.162	0.000	0.000	0.000	0.000	11.946	11.740	8.844	3.436	8.63
1985	0.793	2.711	3.822	2.794	0.692	0.000	0.000	0.000	0.000	0.000	0.000	10.812	10.019	7.308	3.486	6.42
1986	0.957	19.960	3.222	0.887	0.426	0.090	0.019	0.000	0.000	0.000	0.000	25.561	24.604	4.644	1.422	7.77
1987	0.659	8.590	6.997	2.268	0.257	0.147	0.048	0.000	0.000	0.087	0.000	19.053	18.394	9.804	2.807	9.59
1988	1.595	11.841	11.356	2.511	1.370	0.000	0.039	0.000	0.000	0.000	0.000	28.712	27.117	15.276	3.920	9.66
1989	0.157	20.679	25.260	6.580	0.458	0.106	0.124	0.000	0.000	0.000	0.000	53.364	53.207	32.528	7.268	18.26
1990	4.10	6.33	6.89	17.77	2.64	0.18	0.05	0.02	0.000	0.000	0.000	37.980	33.88	27.55	20.66	19.51
1991	0.32	5.88	3.56	2.54	5.03	0.36	0.000	0.000	0.000	0.000	0.000	17.69	17.37	11.49	7.93	11.37
1992	1.36	6.42	6.35	3.58	0.65	1.37	0.12	0.04	0.00	0.00	0.00	19.88	18.53	12.11	5.76	10.10
1993	69.03	3.40	7.76	3.60	1.45	0.05	0.30	0.00	0.00	0.00	0.00	85.59	16.56	13.16	5.40	7.63
1994	3.90	4.07	6.15	2.45	0.53	0.16	0.03	0.04	0.00	0.02	0.00	17.35	13.45	9.38	3.23	4.83
Autumn																
1978	151.533	2.082	0.000	0.120	0.140	0.318	0.000	0.080	0.000	0.000	0.000	154.273	2.740	0.658	0.658	3.02
1979	4.933	3.430	0.042	0.000	0.026	0.000	0.000	0.000	0.000	0.000	0.000	8.431	3.498	0.068	0.026	0.99
1980	5.680	8.834	0.052	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000	14.616	8.936	0.102	0.050	1.57
1981	2.018	5.652	7.290	0.729	0.000	0.000	0.000	0.000	0.000	0.000	0.000	15.689	13.671	8.019	0.729	6.65
1982	4.667	2.346	1.005	0.060	0.050	0.000	0.000	0.000	0.000	0.000	0.000	8.128	3.461	1.115	0.110	1.35
1983	1.308	0.651	0.100	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.072	0.764	0.113	0.013	0.18
1984	12.296	0.344	0.022	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	12.675	0.379	0.035	0.013	0.18
1985	2.832	0.419	0.018	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.279	0.447	0.028	0.010	0.09
1986	2.478	1.150	0.833	0.000	0.067	0.000	0.000	0.000	0.000	0.000	0.000	4.528	2.050	0.900	0.067	0.55
1987	389.584	2.386	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	391.990	2.406	0.020	0.000	0.45
1988	4.571	20.490	0.679	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	25.740	21.169	0.679	0.000	1.57
1989	2.971	2.700	0.350	0.210	0.185	0.000	0.000	0.000	0.000	0.000	0.000	6.416	3.445	0.745	0.395	1.27
1990	9.37	9.13	1.74	0.31	0.06	0.03	0.000	0.000	0.000	0.000	0.000	20.638	11.27	2.14	0.40	1.56
1991	4.65	4.20	0.81	0.03	0.05	0.01	0.00	0.00	0.00	0.00	0.00	9.74	5.09	0.89	0.08	0.80
1992	24.30	2.01	0.11	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	26.48	2.18	0.17	0.06	0.42
1993	49.92	3.32	0.61	0.33	0.00	0.00	0.01	0.00	0.00	0.00	0.00	54.21	4.29	0.97	0.36	1.97

[1] Massachusetts sampling strata 25-36.

Table A13. Summary statistics of the base, alternative, and final ADAPT VPA calibration for Gulf of Maine cod; terminal year 1993.

ADAPT Run Number 291 1994 10 13 13 54 32
COD: GULF OF MAINE STOCK
GMCOD94 - 8+ GROUP; ALL INDICES UNWEIGHTED, NO TIME TAPERED WEIGHTING

1994 N	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1993 F	Estimate
N 2	4.20334E3	1.27682E3	3.29203E0	0.30	F 2	0.02
N 3	3.48325E3	8.09347E2	4.30378E0	0.23	F 3	0.73
N 4	1.25882E3	3.42497E2	3.67541E0	0.27	F 4	1.21
N 5	2.45215E2	8.42669E1	2.90999E0	0.34	F 5	0.64
N 6	1.31386E2	5.02920E1	2.61247E0	0.38	F 6	0.92
					F 7	0.92
					F 8+	0.92

ADAPT Run Number 328 1994 10 17 17 36 35
COD: GULF OF MAINE STOCK
GMCOD94 - 8+ GROUP; NO COMMERCIAL INDICES; ELSE THE SAME AS RUN 291 IN WP 1.

1994 N	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1993 F	Estimate
N 2	4.18515E3	1.39773E3	2.99425E0	0.33	F 2	0.02
N 3	3.46780E3	8.86014E2	3.91393E0	0.26	F 3	0.76
N 4	1.17489E3	3.74733E2	3.13528E0	0.32	F 4	1.30
N 5	2.16457E2	9.15470E1	2.36444E0	0.42	F 5	0.61
N 6	1.38454E2	6.84113E1	2.02385E0	0.49	F 6	0.96
					F 7	0.96
					F 8+	0.96

ADAPT Run Number 329 1994 10 17 18 12 38
COD: GULF OF MAINE STOCK
GMCOD94 - 8+ GROUP; ALL INDICES AS IN RUN 291 PLUS #20 MASS FALL3
ALL MASS INDICES REVISED AS PER CADRIN NDSC WP 10/18/94

1994 N	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1993 F	Estimate
N 2	3.91102E3	1.32800E3	2.94505E0	0.34	F 2	0.02
N 3	3.86923E3	9.38559E2	4.12252E0	0.24	F 3	0.74
N 4	1.22424E3	3.66153E2	3.34352E0	0.30	F 4	1.15
N 5	2.69231E2	1.00742E2	2.67247E0	0.37	F 5	0.60
N 6	1.43170E2	5.97292E1	2.39699E0	0.42	F 6	0.87
					F 7	0.87
					F 8+	0.87

ADAPT Run Number 334 1994 10 18 11 13 11
COD: GULF OF MAINE STOCK
GMCOD94 - 7+ GROUP; ESTIMATE AGE 4 F FROM PR
NO EST OF AGE 5 N; ONLY FULLY RECR AGE 5 F ESTIMATED DIRECTLY

1994 N	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1993 F	Estimate
N 2	4.21563E3	1.29927E3	3.24462E0	0.31	F 2	0.02
N 3	3.49331E3	8.23544E2	4.24179E0	0.24	F 3	0.73
N 4	1.26180E3	3.48188E2	3.62391E0	0.28	F 4	0.96
N 6	7.18931E1	1.88437E1	3.81524E0	0.26	F 5	0.96
					F 6	0.96
					F 7+	0.96

ADAPT Run Number 332 1994 10 18 11 0 8
COD: GULF OF MAINE STOCK
GMCOD94 - 7+ GROUP; ELSE SAME AS RUN 291

1994 N	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.	1993 F	Estimate
N 2	4.20596E3	1.28877E3	3.26355E0	0.31	F 2	0.02
N 3	3.48446E3	8.16696E2	4.26653E0	0.23	F 3	0.73
N 4	1.25793E3	3.45296E2	3.64306E0	0.27	F 4	1.22
N 5	2.42140E2	8.41553E1	2.87730E0	0.35	F 5	0.63
N 6	1.31816E2	5.07636E1	2.59666E0	0.39	F 6	0.93
					F 7+	0.93

Table A14. Estimates of beginning year stock size (thousands of fish), instantaneous fishing mortality (F) and spawning stock biomass (tons) for Gulf of Maine cod derived from virtual population analysis (VPA) calibrated using the ADAPT procedure, 1982-1993.

STOCK NUMBERS (Jan 1) in thousands - GMCOD94

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	6129	5534	7742	4915	7413	9970	21715	3467	3168	5166	5301	5137	0
2	9108	5018	4531	6339	4024	6070	8163	17778	2838	2594	4230	4340	4206
3	4328	6208	3325	3306	4822	3219	4774	6538	14251	2138	1812	3180	3484
4	2666	2066	2950	1600	1399	1990	2097	2603	3921	8568	906	1004	1258
5	1661	1149	734	1058	413	410	625	855	815	1342	3250	304	242
6	166	787	363	206	296	112	85	145	293	279	329	835	132
7+	547	284	250	214	156	132	58	98	182	152	134	65	291
1+	24606	21046	19896	17638	18524	21902	37517	31484	25469	20239	15962	14864	----
2+	18477	15512	12154	12723	11110	11932	15802	28017	22301	15073	10661	9727	9613

FISHING MORTALITY - GMCOD94

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.18	0.21	0.12	0.07	0.02	0.04	0.02	0.02	0.08	0.16	0.09	0.02
3	0.54	0.54	0.53	0.66	0.69	0.23	0.41	0.31	0.31	0.66	0.39	0.73
4	0.64	0.83	0.83	1.15	1.03	0.96	0.70	0.96	0.87	0.77	0.89	1.22
5	0.55	0.95	1.07	1.07	1.10	1.37	1.26	0.87	0.87	1.21	1.16	0.63
6	0.61	0.90	0.89	1.16	1.08	1.05	0.82	0.96	0.89	0.84	1.13	0.93
7+	0.61	0.90	0.89	1.16	1.08	1.05	0.82	0.96	0.89	0.84	1.13	0.93
4+	0.59	0.89	0.95	1.11	1.07	1.17	0.98	0.91	0.87	0.99	1.03	0.93

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

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	328	297	399	142	214	292	642	111	221	310	346	336
2	2143	1247	1141	3096	2016	3043	4034	8713	638	591	1137	1083
3	3185	4634	2503	3871	6013	4219	6442	8559	10269	1297	1307	2503
4	4821	3105	4650	2781	2576	4029	3650	5089	5334	12174	1261	1410
5	6070	2972	1738	2983	1205	1184	2018	2189	2290	3059	6755	854
6	823	3496	1429	739	1246	511	409	598	1302	1282	1174	2948
7+	5407	2309	2127	1666	1290	1103	566	986	2083	1459	1140	593
1+	22776	18060	13987	15278	14558	14382	17761	26246	22138	20172	13120	9727
2+	22448	17763	13588	15136	14344	14090	17119	26135	21917	19862	12774	9391

PERCENT MATURE (females) - GMCOD94

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	7	7	7	4	4	4	4	4	9	9	9	9
2	26	26	26	48	48	48	48	48	24	24	24	24
3	61	61	61	95	95	95	95	95	54	54	54	54
4	88	88	88	100	100	100	100	100	81	81	81	81
5	97	97	97	100	100	100	100	100	94	94	94	94
6	100	100	100	100	100	100	100	100	98	98	98	98
7+	100	100	100	100	100	100	100	100	100	100	100	100

Table A15. Yield and spawning stock biomass per recruit estimates and input data for Gulf of Maine cod.

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

GULF OF MAINE COD (5Y) - 1993 UPDATED AVE WTS, FPAT AND MAT VECTORS

Proportion of F before spawning: .1667
Proportion of M before spawning: .1667
Natural Mortality is Constant at: .200
Initial age is: 1; Last age is: 10
Last age is a PLUS group;
Original age-specific PRs, Mats, and Mean Wts from file:
==> d:\assess\gmcod\yrcodgma.dat

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
1	.0000	1.0000	.0900	.500	.749
2	.0540	1.0000	.2400	1.257	1.061
3	.4020	1.0000	.5400	1.768	1.481
4	.8780	1.0000	.8100	2.503	2.083
5	1.0000	1.0000	.9400	3.955	3.212
6	1.0000	1.0000	1.0000	6.532	4.978
7	1.0000	1.0000	1.0000	9.985	7.813
8	1.0000	1.0000	1.0000	12.603	11.105
9	1.0000	1.0000	1.0000	14.670	13.261
10+	1.0000	1.0000	1.0000	16.000	16.000

Summary of Yield per Recruit Analysis for:
GULF OF MAINE COD (5Y) - 1993 UPDATED AVE WTS, FPAT AND MAT VECTORS

Slope of the Yield/Recruit Curve at F=0.00: --> 26.8128
F level at slope=1/10 of the above slope (F0.1): -----> .159
Yield/Recruit corresponding to F0.1: -----> 1.6809
F level to produce Maximum Yield/Recruit (Fmax): -----> .267
Yield/Recruit corresponding to Fmax: -----> 1.7956
F level at 20 % of Max Spawning Potential (F20): -----> .346
SSB/Recruit corresponding to F20: --------> 5.2772

Listing of Yield per Recruit Results for:
GULF OF MAINE COD (5Y) - 1993 UPDATED AVE WTS, FPAT AND MAT VECTORS

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.00	.00000	.00000	5.5167	29.3875	3.4286	26.3906	100.00
	.09	.18933	1.37647	4.5745	17.4141	2.4952	14.6126	55.37
F0.1	.16	.26508	1.68093	4.1987	13.2049	2.1254	10.5086	39.82
	.19	.28878	1.73859	4.0814	11.9872	2.0104	9.3278	35.35
Fmax	.27	.34401	1.79555	3.8086	9.3781	1.7444	6.8124	25.81
	.28	.35064	1.79486	3.7760	9.0888	1.7126	6.5352	24.76
F20%	.35	.38276	1.76866	3.6181	7.7705	1.5600	5.2772	20.00
	.37	.39319	1.75219	3.5669	7.3732	1.5108	4.9003	18.57
	.47	.42450	1.68135	3.4139	6.2801	1.3645	3.8702	14.66
	.56	.44866	1.60789	3.2963	5.5426	1.2533	3.1831	12.06
	.65	.46799	1.54067	3.2028	5.0214	1.1658	2.7031	10.24
	.74	.48390	1.48214	3.1262	4.6385	1.0948	2.3545	8.92
	.84	.49729	1.43222	3.0620	4.3476	1.0361	2.0928	7.93
	.93	.50876	1.39001	3.0073	4.1204	.9864	1.8906	7.16
	1.02	.51874	1.35438	2.9599	3.9383	.9439	1.7305	6.56
	1.12	.52754	1.32424	2.9183	3.7894	.9070	1.6009	6.07
	1.21	.53538	1.29865	2.8814	3.6652	.8745	1.4941	5.66
	1.30	.54242	1.27680	2.8484	3.5600	.8457	1.4046	5.32
	1.40	.54880	1.25803	2.8186	3.4696	.8200	1.3284	5.03
	1.49	.55463	1.24181	2.7915	3.3909	.7968	1.2629	4.79
	1.58	.55997	1.22770	2.7667	3.3217	.7757	1.2058	4.57
	1.67	.56491	1.21535	2.7438	3.2602	.7565	1.1555	4.38
	1.77	.56949	1.20448	2.7227	3.2051	.7389	1.1110	4.21
	1.86	.57376	1.19484	2.7031	3.1554	.7227	1.0711	4.06

Table A16. Stochastic stock biomass and catch projections, starting conditions and input data for Gulf of Maine cod:

Input for Projections:

Number of Years: 3; Initial Year: 1994; Final Year: 1996
Number of Ages : 6; Age at Recruitment: 2; Last Age: 7
Natural Mortality is assumed Constant over time at: .200
Proportion of F before spawning: .1667
Proportion of M before spawning: .1667
Last age is a PLUS group;

Age-specific Input data for Projection # 1

Age	Fish Mort Pattern	Nat Mort Pattern	Proportion Mature	Average Weights Catch	Average Weights Stock
2	.0530	1.0000	.2400	1.257	1.061
3	.4210	1.0000	.5400	1.768	1.481
4	.8740	1.0000	.8100	2.503	2.083
5	1.0000	1.0000	.9400	3.955	3.212
6	1.0000	1.0000	1.0000	6.532	4.978
7+	1.0000	1.0000	1.0000	12.000	11.000

Option	Basis		SSB(95)	Landings(95)	SSB(96)	Landings(96)	SSB(97)
A	$F_{0.1}$	0.16	8.2	1.5	12.2	2.2	16.6
B	$F_{20\%}$	0.35	8.0	3.1	10.4	3.9	12.4
C	$0.5(F_{93})$	0.47	7.9	4.0	9.4	4.7	10.4
D	$F(_{93})$	0.93	7.4	6.9	6.5	6.0	5.5

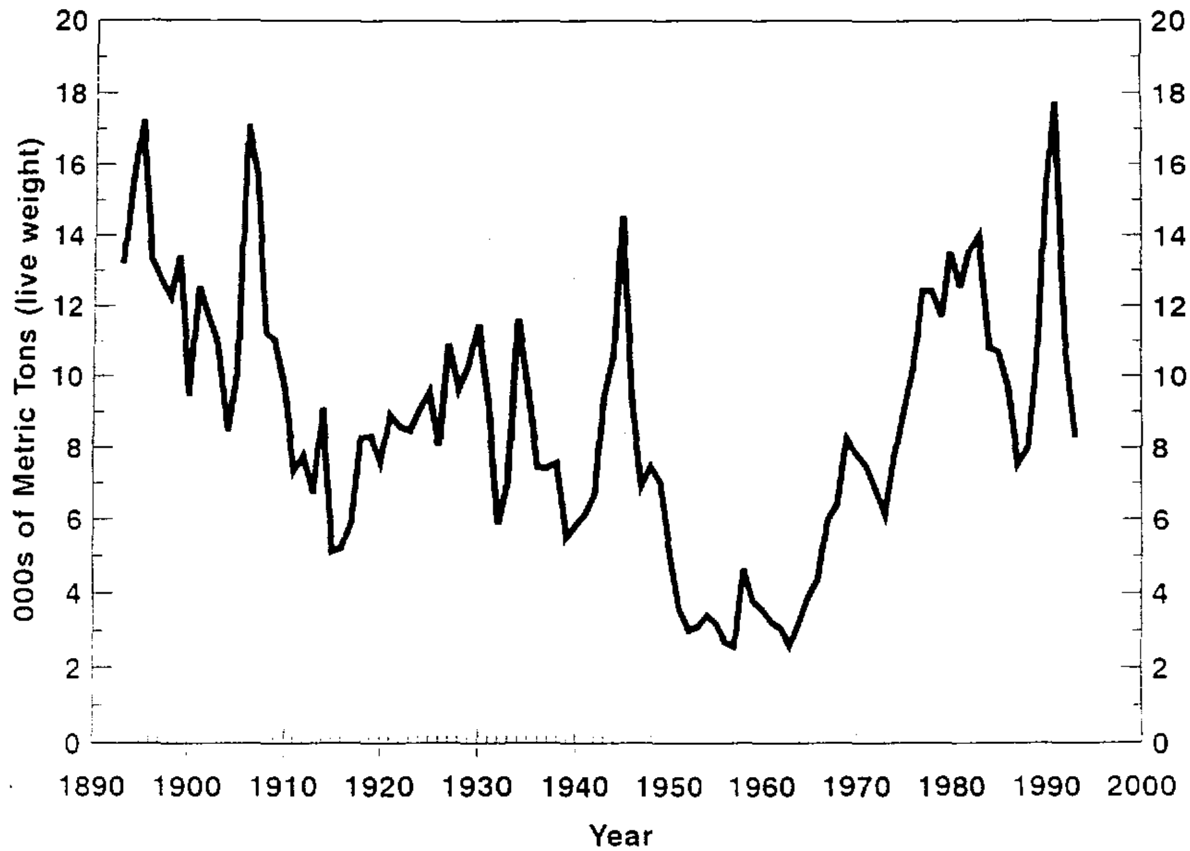


Figure A1. Total commercial landings of Gulf of Maine Cod (Division 5Y), 1893-1993.

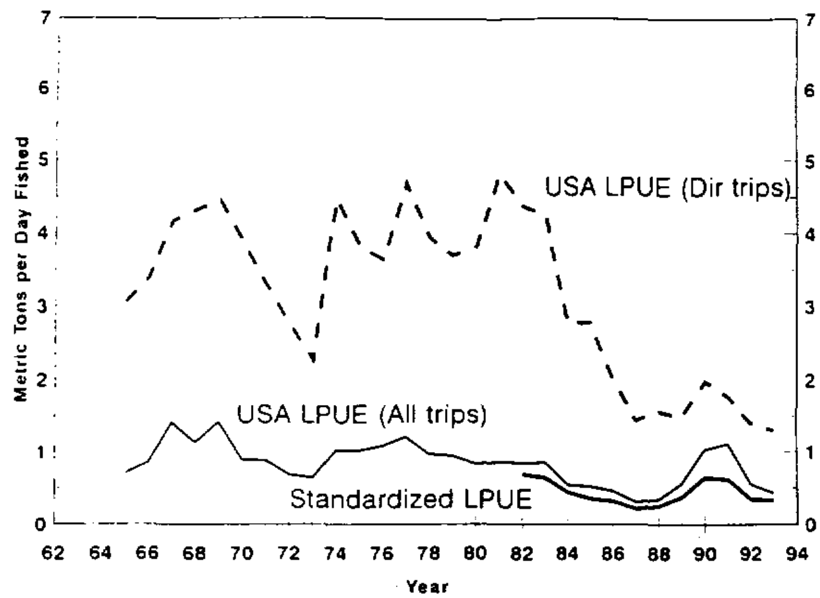


Figure A2. Trends in USA LPUE (landings per day fished) of Gulf of Maine cod. The 1965-1993 indices are based on all otter trawl trips landing cod (All trips) and on otter trawl trips in which cod constituted 50% or more of the trip landings by weight (Dir trips). A standard LPUE series from 1982-1993 based on a GLM incorporating year, tonnage class, area, quarter and depth is also included.

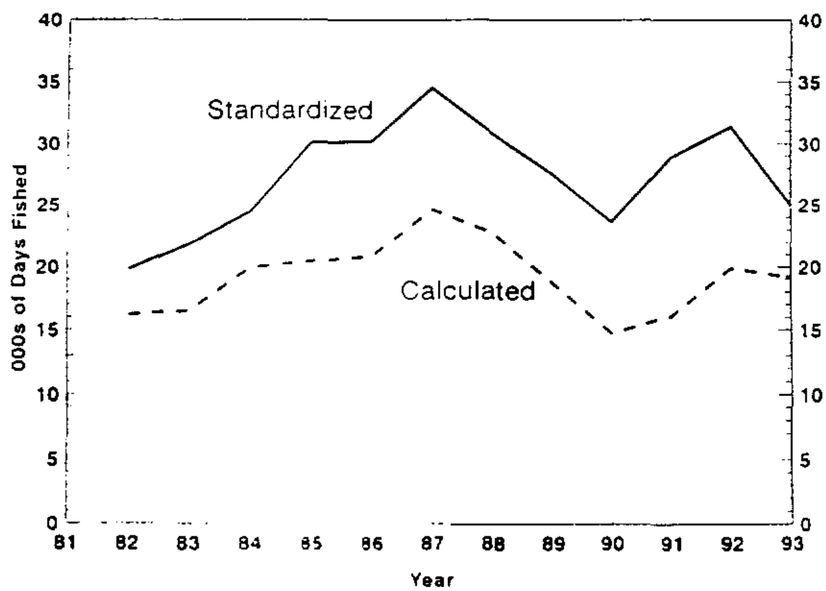


Figure A3. Trends in USA fishing effort (days fished) on Gulf of Maine coed, 1982-1993. Results are based on all otter trawl trips landing cod. A standardized effort series based on a GLM incorporating year, tonnage class, area, quarter and depth is also included.

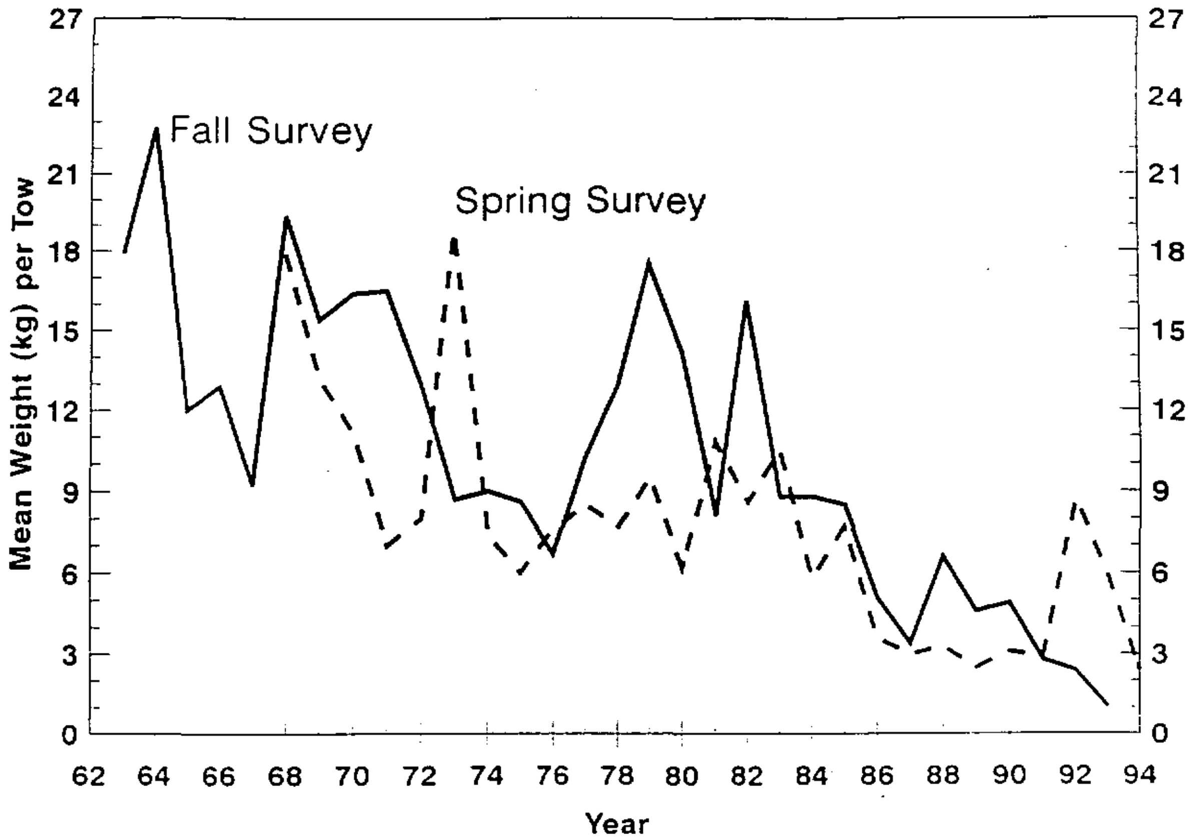


Figure A4. Standardized stratified mean catch (kg) per tow of Atlantic cod in NEFSC spring and autumn research vessel bottom trawl surveys in the Gulf of Maine, 1963-1994.

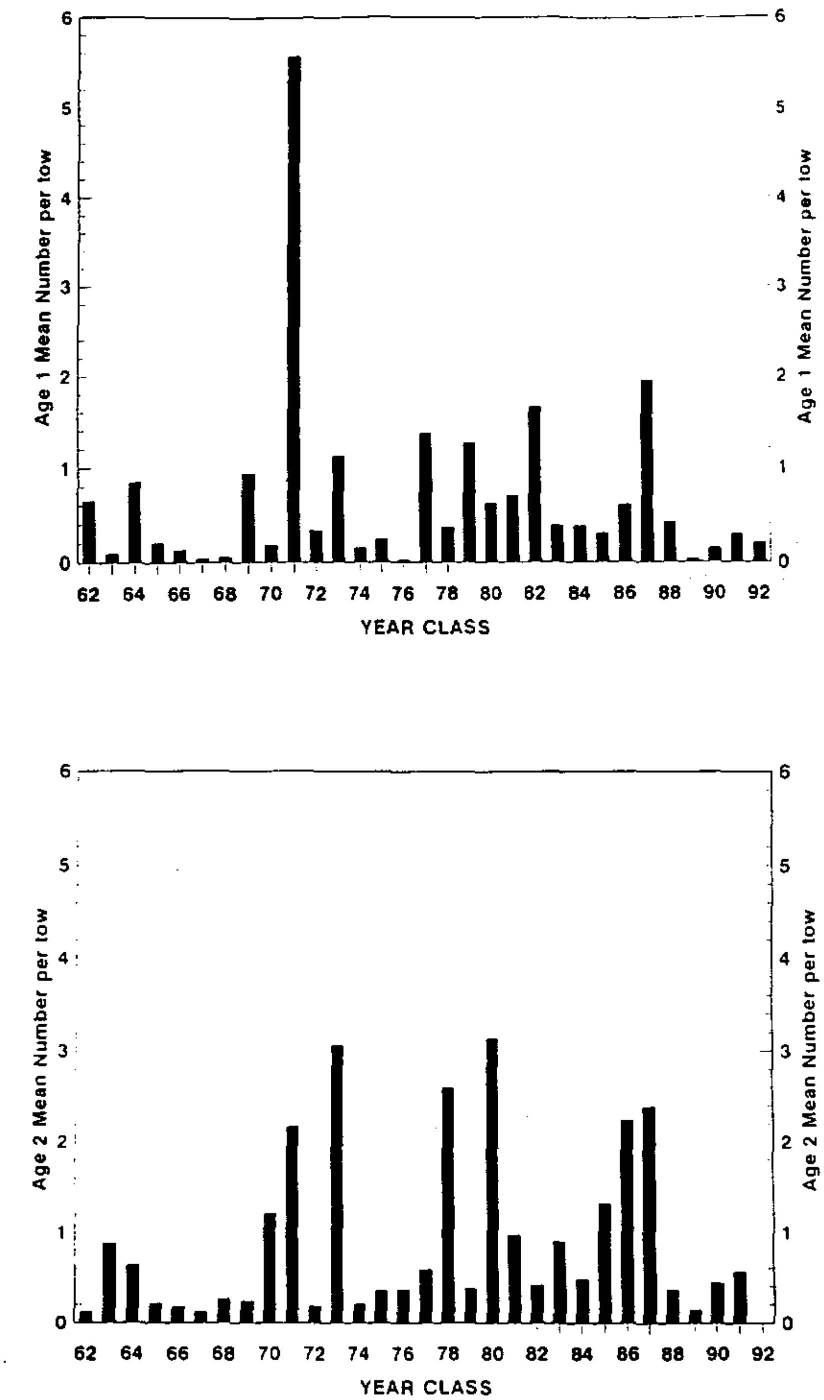


Figure A5. Relative year class strengths of Gulf of Maine cod at (top) age 1 and (bottom) age 2 based on standardized catch (number) per tow indices from NEFSC autumn research vessel bottom trawl surveys, 1963-1993.

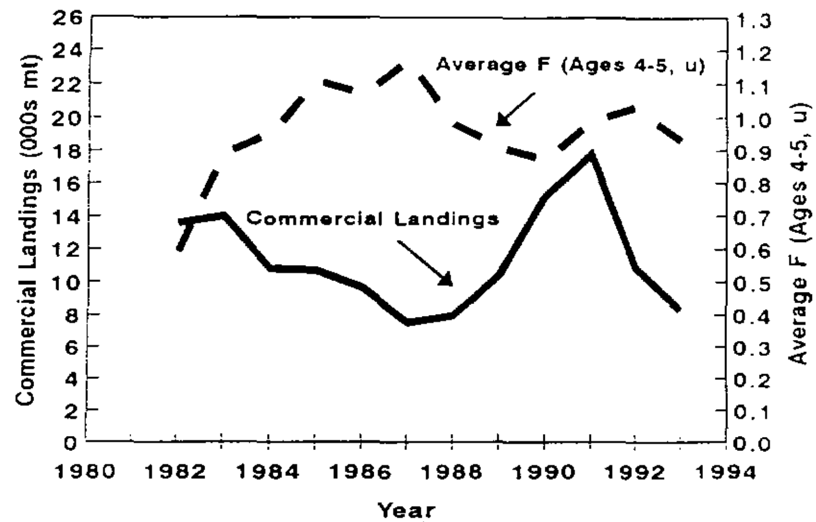


Figure A6. Trends in total commercial landings and fishing mortality for Gulf of Maine cod, 1982-1993.

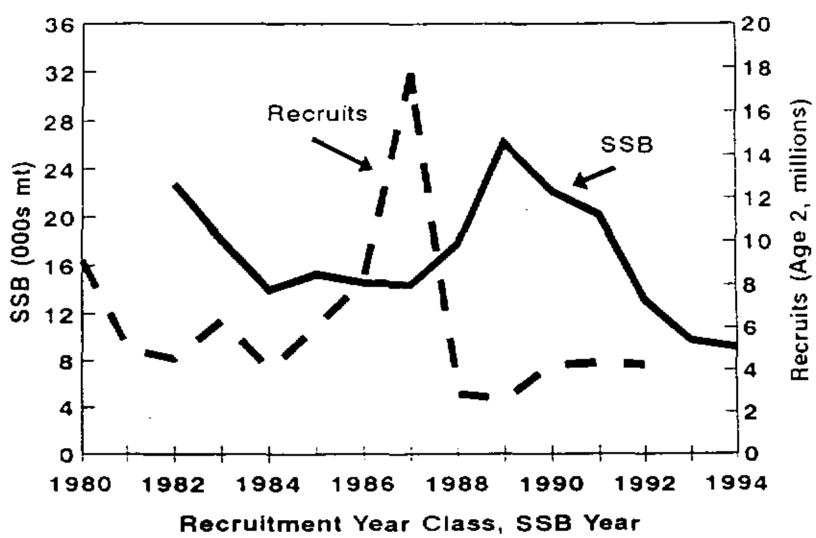


Figure A7. Trends in spawning stock biomass and recruitment for Gulf of Maine cod.

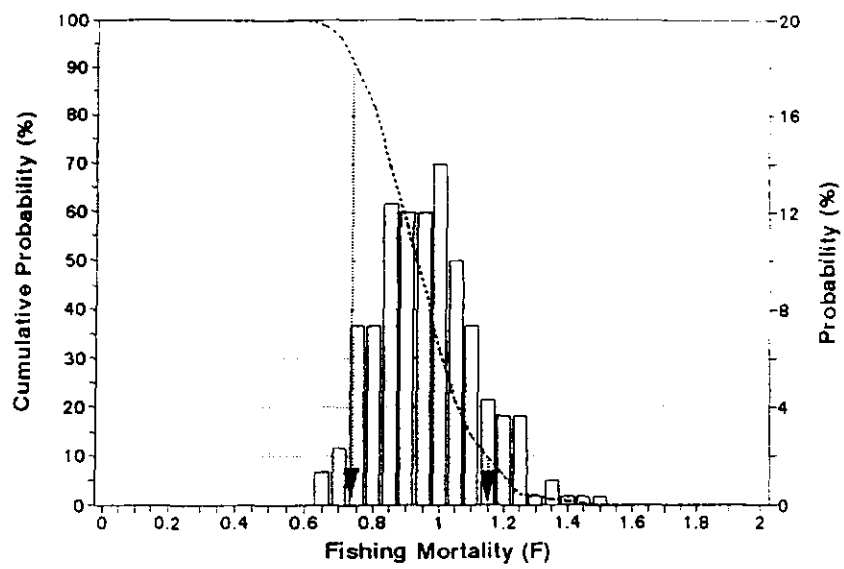


Figure A8. Precision of the estimates of the instantaneous rate of fishing mortality (F) on the fully recruited ages (Ages 4 +) in 1993 for Gulf of Maine cod. The vertical bars display both the range of the estimator and the probability of individual values within the range. The solid line gives the probability that F is greater than any selected value on the X-axis. The precision estimates were derived from 300 bootstrap replications of the final ADAPT VPA formulation.

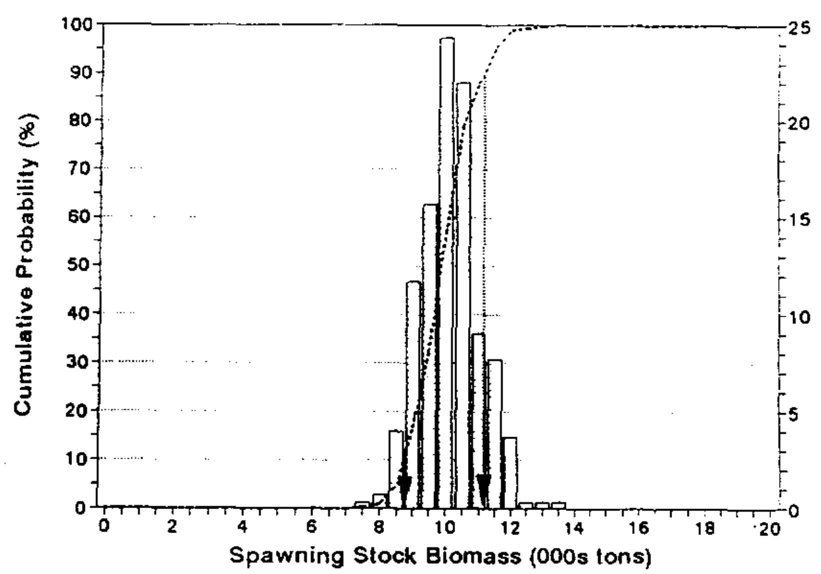


Figure A9. Precision of the estimates of spawning stock biomass (SSB) at the beginning of the spawning season (Mach 1) for Gulf of Maine cod, 1993. The vertical bars display both the range of the estimator and the probability of individual values within the range. The solid line gives the probability that SSB is less than any selected value on the X-axis. The precision estimates were derived from 300 bootstrap replications of the final ADAPT VPA formulation.

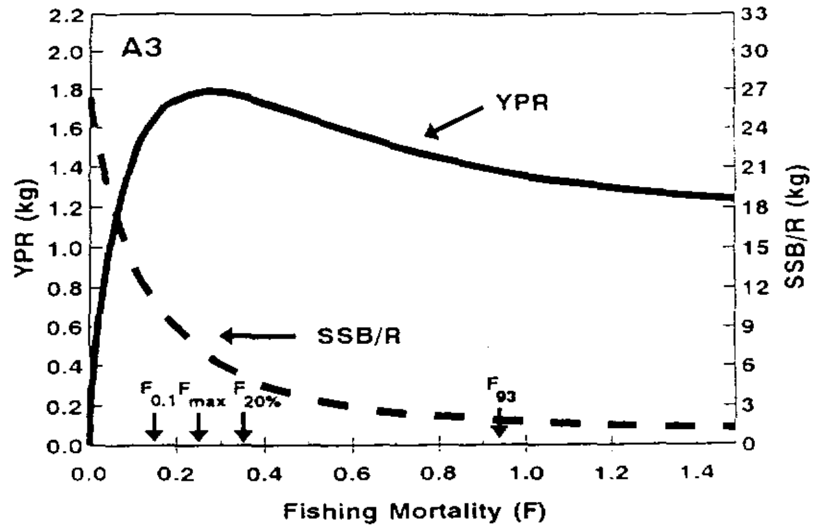


Figure A10. Yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) for Gulf of Maine cod.

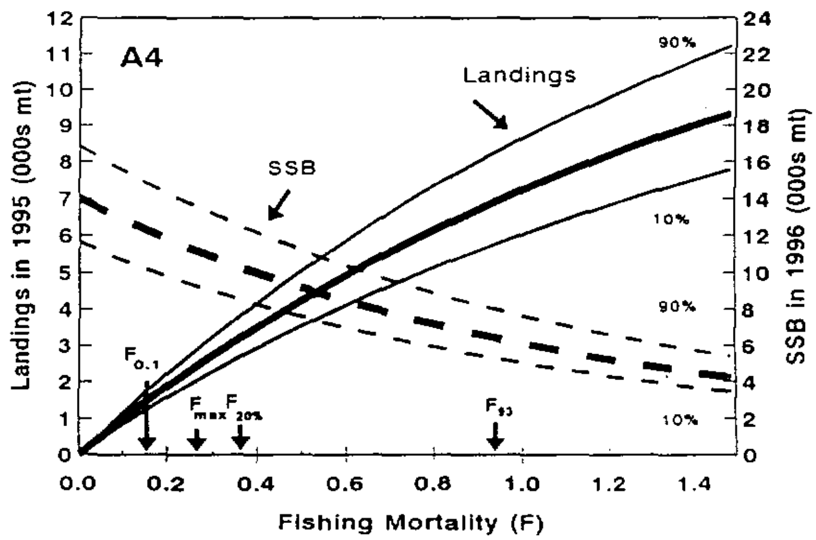
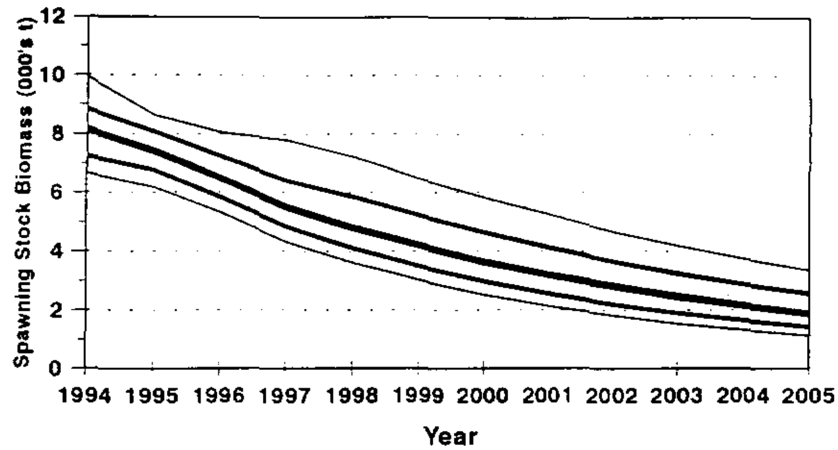
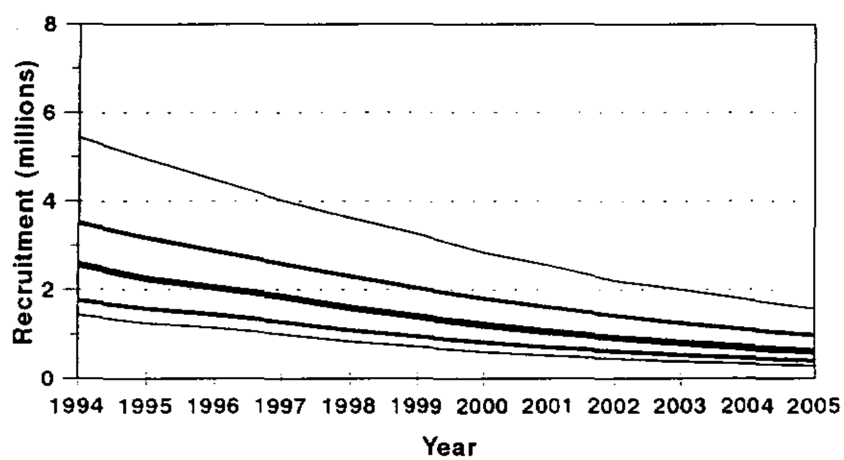


Figure A11. Predicted catches in 1995 and spawning stock biomasses in 1996 of Gulf of Maine cod over a range of fishing mortalities in 1995 from F=0 to F=1.6.

Medium Term Projections - SSB
Status quo F (=0.93)



Medium Term Projections - Recruitment
Status quo F (=0.93)



Medium Term Projections - Landings
Status quo F (=0.93)

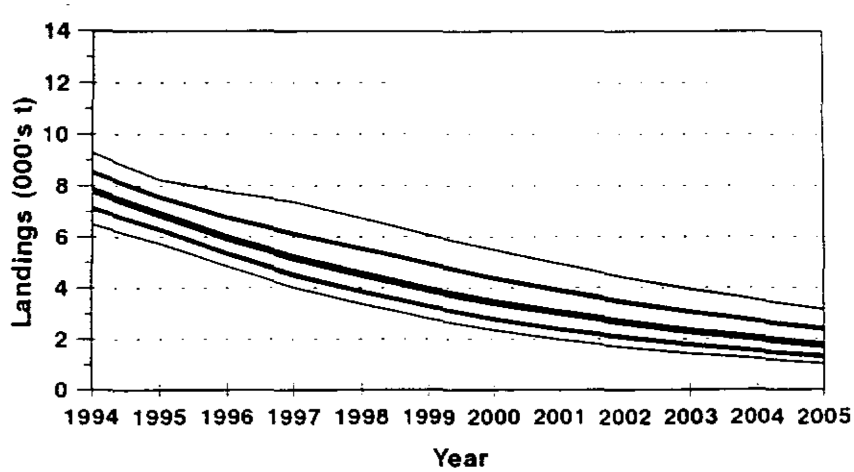
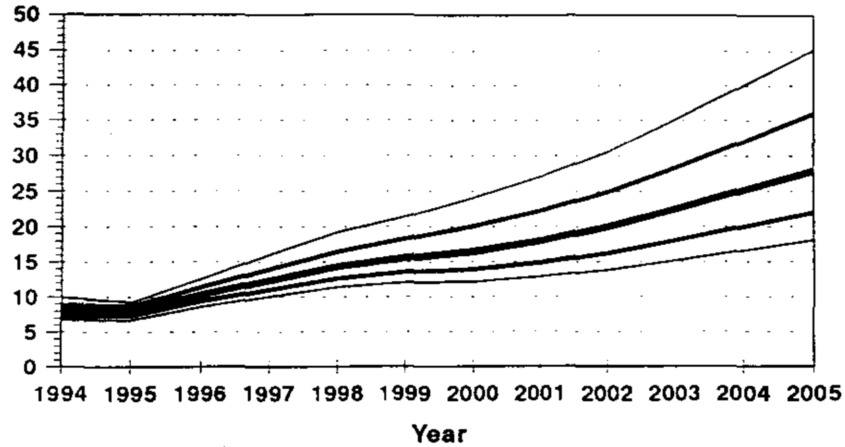
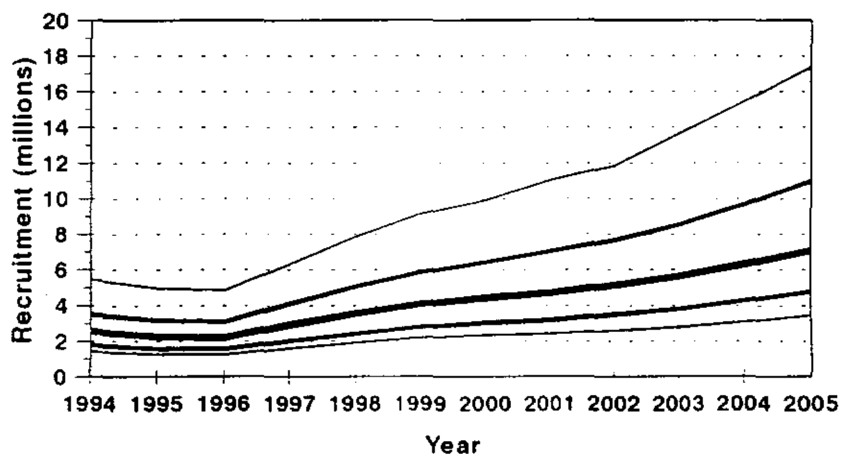


Figure A12.

Medium Term Projections - SSB
F20% (=0.35)



Medium Term Projections - Recruitment
F20% (=0.35)



Medium Term Projections - Landings
F20% (= 0.35)

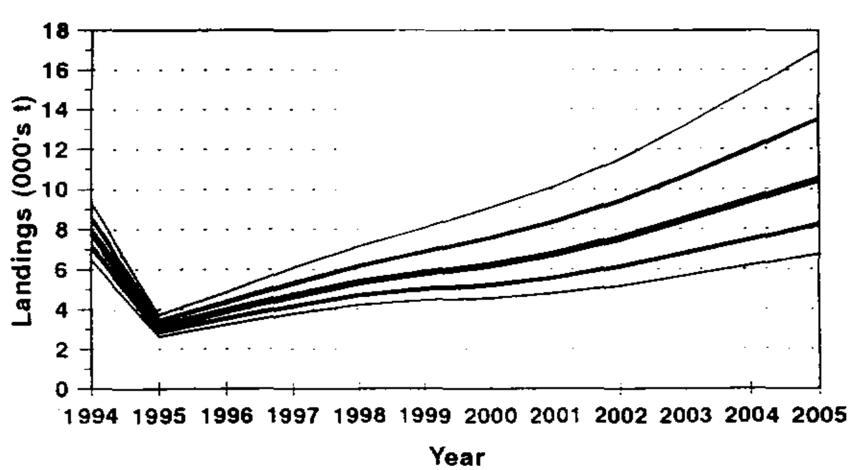


Figure A13.

B. GULF OF MAINE - GEORGES BANK WHITE HAKE

Terms of Reference

The following terms of reference were addressed:

a. Characterize current and historic length and age composition, abundance and catch of the population as data permit.

b. Provide current information of stock structure and biological parameters including growth and maturation and, if possible, conduct yield and spawning stock biomass per recruit analyses, and provide appropriate biological reference points.

c. Provide estimates of fishing mortality and MSY as data permit.

Introduction

White hake (*Urophycis tenuis*) is found from the Gulf of St Lawrence to North Carolina (Bigelow and Schroeder, 1953). Much confusion has arisen as to the complete distribution of this species because of its close resemblance to its congener, the red hake (*Urophycis chuss*). Both occupy much of the same habitat and have often been described together (Bigelow and Schroeder, 1953; Musick,1974; Markle et.al. 1980)

Landings of white hake have never been considered to be of great importance until the recent decline of the more desirable species of groundfish (i.e. cod and haddock). In 1993, white hake landings in the Gulf of Maine exceeded those for cod; the species which had previously contributed most to landings (NEFSC in press). This has led to some concern that the population of white hake may not be able to sustain such high landings and that, therefore, more information on the fishery was needed. This paper summarizes all current information on the white hake fishery and population structure and gives estimates of current fishing mortality rates and stock levels.

Stock Structure

Little is known about the stock structure of white hake. There have been studies aimed at determining whether more than one stock exists, but these tend to be confounded with the presence of red hake and also the timing and location of sampling.

Fahay and Able (1989) used several sources of data to resolve this problem. Evidence based on larvae collections suggests that two groups of white hake exist in the Gulf of Maine-Georges Bank-Scotian Shelf region, although their spatial definitions are unknown. The first group arises from a late winter-early spring spawn occurring in deep water on the continental slope from the northeast Gulf of St. Lawrence to Southern New England. The second group spawns in the relatively shallow waters of the Scotian Shelf. No larvae were found in the Gulf of Maine itself but the authors concluded that the Gulf of Maine population is supported by the two spawning events described above.

Lang et. al. (1994) presents evidence which supports the existence of a deep water spring spawning population that recruits to the estuaries in the Gulf of Maine. In this study, the earliest appearance of white hake were as pelagic juveniles occurring in deep, offshore areas. Larger fish (50-80 mm) were found later inshore as demersal juveniles. There was a northward progression of size and age as the season progressed from spring to summer. This study found no evidence of summer spawned fish recruiting to the Gulf of Maine estuaries but the timing of sampling may have missed these fish.

An age validation study conducted at NEFSC (Bohan and Burnett, unpubl. data) indicated that three growth patterns exist among Gulf of Maine-Southern New England white hake. The predominant pattern indicated a winter-spring spawn and accounted for over 90% of the samples. The second pattern indicated a later spawning period because the fish were smaller in size at age and the size of the nucleus of the otolith was much smaller than the predominant pattern. This growth pattern occurred in fish from strata 29, 30, and 36 which are the closest strata to the Scotian Shelf. The third growth pattern was found in a limited number of white hake caught on the southern slope of Georges Bank which had poorly defined annuli that made ageing impossible.

In light of the studies listed above, the subcommittee decided to treat the white hake found in US waters as one stock. Figure B1 shows the distribution of white hake from the NEFSC spring and autumn bottom trawl surveys. In the spring (during or just after spawning) white hake are located in deep water and are not found in inshore waters as often as in the autumn surveys. These fish may be spawning in deeper waters than the surveys encompass in the spring. Survey indices from various strata sets (Figure B2) show that the Gulf of Maine (Strata 26-30, 33-40) exhibited the same general trends as Georges Bank (Strata 13-25), while both differed from the Southern New England region (Strata 1-12). Therefore, the stock considered in this paper consists of landings from the Gulf of Maine and south (SA 464, 465, 511- 626) and the survey strata set used was the Gulf of Maine to Northern Georges Bank (21-30, 33-40) since this area accounted for over 90% of landings (see section on Commercial Landings).

The Fishery

Commercial Landings

Total landings of white hake gradually increased from 1,100 mt in 1967 to 8,300 mt in 1985 (Figure B3). Landings fluctuated around 5,000 to 6,000 mt during the late 1980's, but peaked sharply in 1992 at 9,500 mt. Landings declined slightly to 9,200 mt in 1993.

Landings of white hake by NAFO Subarea and country are shown in Table B1. The major country landing in Division 5Y (Gulf of Maine) has been the US with small amounts landed by Canada. NAFO Division 5Z (Georges Bank) has also been dominated by US landings, but in recent years, Canadian landings increased to 30% of the Georges Bank total. Subarea 6 landings are insignificant. Landings from other countries have been minor with the highest landings occurring in 1977.

The primary gear type landing white hake is the otter trawl (Table B2). Historically, line trawls have been important, but from 1980 to 1991, line trawls accounted for less than 2% of the total. In 1992 and 1993, however, line trawls increased in importance and represented 11% and 16% of the total landings, respectively. The sink gill net fishery historically accounted for less than 10% of the total landings but increased in the 1970s to between 20% and 40% of the total. Figure B4 shows the landings by gear type in the Gulf of Maine, Georges Bank and the Mid-Atlantic. The line trawl fishery was more active in the Gulf of Maine in the 1960s than in the other two areas. In the later part of the time series, the share taken by line trawl gear has increased in all areas. Otter trawl landings dominate in all areas whereas the sink gill net fishery occurs mostly in the Gulf of Maine.

The primary season for landing white hake is during the summer (Figure B5), with the highest percentage of landings occurring in the third quarter. Third quarter landings are highest in the Gulf of Maine, as they are in the total, since Gulf of Maine landings dominate the total. On Georges Bank, the landings appear evenly distributed among the four quarters. The Mid-Atlantic lands more white hake in the second quarter than in other periods.

Undertonnage vessels (less than 5 GRT) traditionally accounted for between 20 and 40% of US landings (Table B3) but have since become less important and, in 1993, represented less than three percent of the total. Tonnage classes 2 and 3 (5-50 GRT, 51-150 GRT, respectively) have accounted for the majority of the landings in the past with tonnage class 3 the most important contribution to landings over the last ten years. Tonnage class 4 boats have increased in importance and, in 1993, accounted for 36% of the total landings.

The increase in the landings of tonnage class 3 and 4 vessels is also seen in the shift of landings from inshore to offshore areas (Figures B6 and B7). Figures B6 and B7 show this shift occurring in the otter trawl and sink gill net fisheries, respectively. In Figure B6, the first panel (1983-1987) shows a concentration of high landings in the central Gulf of Maine. The second panel (1989-1993) shows a shift to the southeast and northeast. The southeastern shift is to the outer portion of SA 515 and to SA 522. The landings of sink gill net vessels (Figure B7) have shifted from inshore areas to the central portion of the Gulf of Maine.

The white hake fishery in the United States has traditionally been a bycatch fishery with the majority of trips (90%) landing < 20% white hake by weight of the total catch (Table B4). In the past few years, however, a slight shift has occurred whereby 20% of trips landing white hake land >20% white hake by weight. This apparent increase in directivity could arise from targeting of white hake, an increase in abundance of white hake, or a decline in the abundance of the groundfish caught with white hake. The most likely cause appears to be the decline in other groundfish.

Recreational Catches

The amount of recreational catches reported since 1979 have been insignificant (< 0.1 mt).

Discards

Discarding of white hake was qualitatively evaluated. Based on GIS plots of sea sampling data, discarding practices which may lead to potentially high levels of white hake discard mortality were observed in the sink gill net and otter trawl fisheries, particularly in the Gulf of Maine and Georges Bank. Preliminary assessment indicated that discard occurs at sizes generally smaller (<40 cm) than sizes kept and landed (>40 cm). The percentage of white hake landed by trip has increased over time, particularly during the most recent years, which may suggest that white hake normally discarded are being landed. Such changes in discarding patterns, if real, may have important consequences on the results from the analytical modeling. This is discussed in the appropriate sections below.

Sampling Intensity

White hake, since they are landed headed and gutted, have only recently been measured in the ports. A regression was developed to convert dorsal fin-caudal fin length to total length. This regression resulted in the development of a special measuring device to collect white hake length measurements in the ports. Unfortunately, age samples are still unavailable from the ports since otoliths are the structures used for ageing and are lost with the head.

Table B5 shows the summary of commercial length samples from the ports by market category. Since medium white hake were poorly sampled at the beginning of the sampling period and since they appeared to be no different from small white hake in length composition, small and medium white hake were pooled. The sampling intensity overall has been good, except in 1989, when only 13 samples were taken, resulting in one sample taken for every 349 mt landed.

Another source of samples of the commercial fishery is from the Domestic Sea Sampling Program. Length samples and age samples can be taken from both the kept and discarded portion of the white hake catch. Unfortunately, age structures have not been consistently taken from both portions from different gear types (Table B6). The sink gill net fishery kept portion of the catch is very well sampled, but the discards are hardly ever measured. The otter trawl fishery is more sparsely sampled and the portion of the catch sampled varies.

Length Composition

Commercial length composition during 1985-1993 was estimated by market category (pooling small and medium) from monthly length frequency samples, pooled on a semi-annual basis. Mean weights were obtained by applying the NEFSC survey length-weight equation (ln Weight (kg, live) = -12.58 + 3.2196 ln Length(cm)) to the semi-annual market category length frequencies. Mean weight values were then divided into market category landings to derive estimated numbers landed by market category. These numbers were then summed over market categories and half-years to produce the annual length compositions shown in Figure B8. In 1991 through 1993, there were enough length samples by gear to estimate numbers landed at length by otter trawls and sink gill nets. Figure B9 shows the length compositions by gear type. Otter trawls generally land smaller fish than sink gill nets.

Domestic Sea Sampling length composition was estimated by applying the NEFSC survey length-weight equation to the sampled length frequencies by catch disposition (kept or discarded). These mean weights were then divided into the total trip weights by catch disposition to derive estimated numbers landed for each sampled trip. The numbers have not been raised to the total catch of all the sea sampled trips because the sampling of the two groups was not in proportion to the totals caught in the sea sampled trips. Therefore, the length frequencies (Figures B10 and B11) are expressed as a percentage of the total for each group (i.e. kept at length/total kept and discard at length/total discard).

Stock Abundance and Biomass Indices

Commercial LPUE

United States commercial LPUE (landings-per-unit-effort in metric tons landed per day fished) indices for white hake were calculated for each tonnage class as given above from otter trawl trips that landed any white hake (Table B7).

Fishing effort was standardized by applying a five factor General Linear Model (year, quarter, area, tonnage class, and depth) to log LPUE data derived for all otter trawl trips taking white hake from 1975 through 1993 (Table B8). The model accounted for 32% of the total sum of squares. Total effort from each cell was multiplied by the product of the retransformed log coefficients for each factor (excluding year). The estimated standardized effort was then summed over all categories to give total annual estimates of standardized effort (Table B9). The trend of the standardized index follows the trend of the nominal LPUE index (Figure B12). Both peak in the late 1970s and are stable through the 1980s.

Research Vessel Abundance and Biomass Indices

The NEFSC Bottom trawl survey has been in existence since 1963 when the autumn survey was established. Offshore areas from the Gulf of Maine to Southern New England were sampled. Beginning in 1967, offshore areas in the Mid-Atlantic were sampled as well. The spring survey began in 1968. The surveys have been conducted with the same gear and vessel as much as possible. The strata set used for white hake is the Gulf of Maine to Northern Georges Bank (21-30, 33-40).

The spring and autumn stratified mean number per tow, weight per tow, and mean length are given in Table B10 and illustrated in Figure B13. Survey indices are highly variable, especially in the spring survey. The autumn weight per tow index was around 5 kg/tow in the early 1960s, increased during the 1970s to fluctuate around 12 kg/tow. Mean weight per tow in the autumn has fluctuated around 10 kg/tow since 1983. Number per tow in the autumn has shown more of a steady increase suggesting that the high weight per tow index in the 1970s consisted of large fish and the slightly lower biomass index in the 1980s is composed of smaller fish recruiting to the gear.

Length frequency histograms for the surveys are shown in Figure B14. These figures show the modal length at about 40 cm in almost all years. In the 1970s, there were more white hake over 100 cm and fewer fish under 20 cm than in the 1980s.

Stock Parameters

Mortality

Natural mortality (M) for most gadid stocks is assumed to be 0.2. Hoenig (1983) developed an empirical relationship between Z and longevity:

$$\ln Z = 1.46 - 1.01 \ln T_{max}$$

Assuming a maximum age of 20 years for white hake and 0 fishing mortality M is estimated as 0.2.

Estimates of instantaneous total mortality were derived from NEFSC spring survey data (Table B11) for three years of catch per tow at age data. Only these years were available at the present time. Age at full recruitment was assumed at age 2. Therefore, an estimate was derived by taking the natural logarithm of pooled age 2+ to pooled age 3+. The estimate of Z for the 1988-1989 period was 1.32. If age at full recruitment is assumed as age 1 then Z is 0.91. More years of age data are needed to determine which is more appropriate.

Maturity

Estimates of length at 50% maturity were taken from O'Brien et. al. (1990). The estimate for females is 35.1 cm and for males is 32.7 cm.

Growth

The growth rate of white hake was estimated by fitting the Von Bertalanffy growth equation to the age data from the 1987-1989 NEFSC spring surveys and the 1987 NEFSC autumn survey, sexes combined. Fish from the autumn were considered to be a half year older than their spring counterparts. The results of the analysis are shown in Figure B15. The estimate for L_{inf} was 125.8 cm and k was estimated as 0.153. These results seem driven by the female portion of the stock since Bohan and Burnett (unpublished data) estimated L_{inf} for females and males to be 144 and 69, respectively. No males have been found to be older than age 8 (Burnett et al, 1984).

Estimates of Stock Size and Fishing Mortality

DeLury Analysis

A modified Delury model was employed to derive estimates of mortality rates and stock sizes for white hake from 1985-1993. The model as formulated by Conser (1994) is

$$n_y = [\, n_{y-1} + \frac{r_{y-1}}{s_r} - q_n C_{y-1}]\, e^{-M e_y}$$

where:

r_{y-1}, n_{y-1} = survey indices of abundance for recruits and fully recruited fish in year-1
s_r = selectivity of the recruits relative to the fully recruited fish
q_n = catchability coefficient of fully recruited fish
C_{y-1} = catch in number during survey year-1
M = natural mortality
e_y = process error.

Estimates of n, r, and q were then obtained by minimizing the difference between the observed and the predicted values in a nonlinear least squares objective function (Conser 1994).

Indices of abundance and mean weight for recruits and fully recruited fish from the NEFSC autumn survey, and the commercial catch in weight and number were used to fit the model (Table B12). Recruits were defined as all white hake 29 to 43 cm and fully-recruited fish were defined as all fish greater than or equal to 44 cm. Natural mortality was set at 0.2 and selectivity of the recruits relative to the fully recruited fish in the NEFSC survey was set equal to 1.0. The partial recruitment of recruits over the year was assumed to be linear giving an average partial recruitment of recruits to the commercial fishery of 0.50. The process error residuals were weighted to be twice the measurement error.

The uncertainty associated with the estimated parameters was evaluated using a bootstrap procedure (Conser 1994). Standard errors, coefficients of variation, and percent bias of the nonlinear least square (NLLS) estimates were derived from 200 bootstrap iterations. All NLLS estimates were corrected for bias.

Results from the DeLury analysis are given in Table B13. Fishing mortality of fully-recruited fish varied without trend over the 1985-1993 period, ranging from 0.30 to 0.56. Fishing mortality peaked in 1988 at 0.56 but subsequently declined to a low of 0.34 the following year (Figure B16). Fishing mortality has increased in the last four years and is currently (1933) at 0.42. Stock biomass of fully-recruited fish was relatively stable over the 1985-1993 period fluctuating around 12,000 mt (Figure B17). Recruitment has also been stable since 1985, but increased slightly biomass. Estimates of stock biomass and catchability were obtained by minimization of a nonlinear least squares objective function (Conser 1994).

Annual biomass indices from the survey (Table B10) and the catch biomass as estimated by the DeLury model (Table B13) were used to fit the production model. Biomass indices were estimated from indices of abundance and mean weight of recruits and fully recruited fish in the NEFSC autumn survey from 1985-1993. The natural mortality estimate was 0.2, the virgin biomass index was set at 50,000 g and α^{1} 7. The stock resiliency parameter is generally bounded between 1 and 10 for marine species (Shepherd 1987). Marine mammals can be considered to be least resilient with an α' at about 1 and species that are highly resilient, perhaps with refugia for the brood stock, would have an α' of about 10. Given the life history pattern of white hake, α' was set at 7.

The uncertainty associated with the estimated parameters was evaluated using a bootstrap procedure (Conser 1994). Standard errors, coefficients of variation, and percent bias of the nonlinear least square (NLLS) estimates were derived from 200 bootstrap iterations. All NLLS estimates were corrected for bias.

Maximum sustainable yield (MSY) was estimated to be 7,700 mt, requiring stock biomass levels of 21,000 mt to produce this level of yield (i.e., B_{msy}) (Figure B14). Based on these results white hake is currently fished slightly above MSY and stock biomass is currently less than what is needed to support harvest at MSY levels.

Biological Reference Points

Yield and Spawning Stock Biomass Per Recruit

The current biological reference point for white hake is index-based; defined as the 25th percentile of a 3-three moving average of NEFSC autumn biomass indices. Yield-per-recruit, total stock biomass per recruit, and spawning stock biomass per recruit analyses were performed using the Thompson and Bell (1934) method to derive possible fishing mortality-based reference points.

Mean weights at age were derived from taking lengths-at-age from the Von Bertalanffy equation described above and applying the NEFSC survey length-weight equation described above. This most likely underestimates weight-at-age in the catch, at least for the first few age groups, since the fishery generally takes faster growing individuals. The maturity ogive was taken from O'Brien et. al. (1993). The partial recruitment vector was extrapolated assuming L_{50} at age 2 and full recruitment at age 4. This partial recruitment pattern takes into account more of the discards than the Modified DeLury and the Shepherd Production Models described above. Input data and results of the yield and SSB per recruit analyses are presented in Table B15 and are illustrated in Figure B19. The yield per recruit analyses indicate that $F_{0.1} = 0.13$, $F_{max} = 0.22$ and $F_{20\%} = 0.33$. These values are uncertain due to incomplete information on discarding of white hake, the weight-at-age in the catch, and the PR as noted above.

to 9.5 million fish in 1992 (Figure B17). Levels of recruitment in 1993 and 1994 appear to be approximately half that of 1992.

DeLury and bootstrapping procedures indicated two notable, related results: 1) heteroscedastic error variances (trends in residuals over time), particularly with regard to process error (Figure B18); and 2) particularly large bias in the estimates of partially- and fully-recruited fishing mortality rates (up to 20%). While the brevity of the time series may be a possible explanation for the trends in residuals, other more systemic factors may produce the observed results. These factors may include, but are not limited to: 1) exclusion of discards from the DeLury Difference equation as well as changes in the pattern of discarding and its effect on the assumed partial recruitment vector; and 2) temporal changes in the catchability of partially-recruited relative to the fully-recruited stock abundance indices. Estimates or statistical inferences from conditional bootstrapping implicitly assumes that the residual errors are independent and normally distributed, and thus departures from these assumptions such as those described above, will most likely lead to relatively large bias.

Surplus Production Analysis

A surplus production model was employed to derive estimates of catchability, maximum sustainable yield (MSY) for the stock, and annual estimates of exploitable biomass. The model was formulated by Conser (1994) as the difference in positive production due to recruitment and somatic growth and the negative production due to natural mortality.

$$P_y = \frac{aB_y}{1+\frac{B_y}{K}} - MB_y$$

where a is the parameter of the Beverton-Holt function, representing the maximum instantaneous rate of positive production, B_y is the exploited stock biomass at the beginning of year y, K is the parameter of the Beverton-Holt function representing the threshold stock biomass above which density dependent effects dominate, and M is the instantaneous rate of natural mortality. The model was reparameterized using

$a = (\alpha'+1)M$ and $K = B_{max} / \alpha'$

and the stock-production curve becomes

$$P_y = \alpha' M B_y \frac{1-\frac{B_y}{B_{max}}}{1+\alpha'\frac{B_y}{B_{max}}}$$

where α' is a unitless measure of the resilience of the stock and B_{max} is the exploitable virgin stock

Subcommittee Comments

The subcommittee noted uncertainty in stock structure and potential effects of mixing between the northern and southern stock components in strata 29 and 30 (which taken together are particularly large). Survey length frequency and age samples from these strata have become predominant in recent years. Northern stock (Gulf of St. Lawrence-Scotian Shelf) white hake growth is delayed due to later spawning so mixing with southern stock (Gulf of Maine) fish may result in smearing of the length frequencies over wider range for the first three years, at least until growth of northern hake catches up. Uncertainty in identification of small white hake was also noted by the subcommittee. White hake and red hake may be difficult to distinguish in the landings, and to a lesser extent in the survey. This may be more problematic in recent years since the proportions of landings of small and medium market categories have increased substantially. The subcommittee noted that increased landings of small and medium market sizes may possibly reflect changes in market preference for hake of the size traditionally discarded.

The subcommittee discussed the results of two General Linear Models used in effort standardization. One model included percentage of white hake landed as a factor in the model while the other did not. While the subcommittee agreed that inclusion of percent landings in the model as a factor was interesting and deserved investigation, there was no consensus on its interpretability as an explanatory effect of fleet performance.

Three different formulations involving fully recruited sizes used in the DeLury model were presented to the subcommittee. Discussion focused on which size range for use in the DeLury model best represented full recruitment to the fishery. Based on survey length frequencies it appeared that fish were fully available to the fishing grounds at about 40 cm. Landings and kept samples from the DSSP indicated that fish become fully selected by the gear at about 46 cm, but the subcommittee noted that accounting for discarding of smaller sizes would most likely lower the L50. The subcommittee discounted the L50 of 40 cm as too low and reached consensus that the DeLury run using the L50 of 43 cm as the best compromise. Overlap in upper 75th and lower 25 percentiles of F and N from the 43 cm and 46 cm runs, respectively, indicated reasonable agreement in those DeLury options. The subcommittee noted the following with regard to results of the DeLury model. (1) The discard component of the catch was not included in the catch component of the DeLury difference equation and underestimates of catch becomes subsumed into the process error. (2) The assumption of linear partial recruitment over the recruiting size range (29-43 cm) may not be realistic. Factors affecting this assumption discussed by the subcommittee included: variation in growth of fish through the recruiting sizes; changes in fishing patterns or relative exploitation of those sizes; and changes in recruitment patterns such as the relative timing of recruitment into the fishing grounds. The subcommittee indicated the need to better define the partial recruitment pattern.

Two options were presented with regard to alpha-prime parameter as input to the surplus production model to the subcommittee. Based on biological considerations, i.e. rapid growth, highly fecund, low L50 etc., the subcommittee agreed that alpha-prime would most likely be on the higher end of the range (> 7), but expressed uncertainty of greater stock resilience (alpha-prime = 9) due to lack of information on stock distribution and migration patterns that may provide evidence of refugia. Results from the surplus production model run with alpha-prime set at 7 were accepted and these indicated recent levels of stock biomass to be less than B_{msy}; B_{msy} at about 20,000 mt with average stock biomass over the 1985-92 period at about 14,000 mt. Under the more resilient stock scenario (alpha-prime = 9), B_{msy} was estimated to be in the range of current stock sizes. In either case, the results suggest signs of growth overfishing but not recruitment overfishing. Further, in reviewing results of yield per recruit analyses the subcommittee agreed that, although uncertain as to the actual value of F_{max}, average F over the 1985-92 period has been at or slightly greater than F_{max}, and concluded that the stock may be growth overfished. Thus, it was concluded that results from YPR and surplus production models were consistent.

The subcommittee noted the following from the surplus production model results, a residual pattern arising from relatively large under-estimates of beginning year exploitable stock biomass during the 1988-1990 period. The subcommittee suggested two possible reasons for such a large systematic process error (although the shortness of the time series is a contributing factor): 1) catch in those years is under-estimated-i.e. absence of large amounts of discarding in those years; 2) change in catchability of recruited component as defined in the DeLury model over those years. The subcommittee also noted that results from the surplus production model are dependent upon a relatively short time series as well as a narrow dynamic range in stock biomass estimates.

SARC Consensus Summary

The white hake assessment, previously index-based, was upgraded to a size-based analytical assessment. The SARC accepted the assessment results based on methods which employed a modified DeLury and surplus production analyses, providing current estimates of F and stock biomass, and absolute biomass-based biological reference points (MSY and B_{msy}). A preliminary yield per recruit analysis was also conducted providing fishing mortality-based reference points.

While accepted, the SARC expressed concern and caution with regard to some of the model assumptions, model output diagnostics, and the use of these preliminary biological reference points as alternative over-fishing definitions. A temporal pattern in the residual errors (heterogeneous error variances) from the DeLury model and relatively large bias in estimates of F and stock biomass was observed suggesting possible systemic problems (or assumption departures) associated with the analysis. Although it was recognized that the brevity of the time series may be a plausible explanation, several other factors were discussed: 1) exclusion of discards from the DeLury Difference equation as well as changes in the pattern of discarding and its effect on the assumed partial recruitment vector; and 2) temporal changes in the catchability of partially-recruited relative to the fully-recruited stock abundance indices (which are assumed constant through time). In addition, the SARC recognized that the alpha-prime parameter (a measure of stock resiliency) used in the surplus production model was uncertain for this stock. The choice of alpha-prime had an important influence on the position of stock biomass to B_{msy}. Biological considerations such as rapid growth, high fecundity, and the possible spatial separation of the spawning and fishing grounds may suggest a relatively high value for this parameter.

The SARC discussed the likely outcome of the above uncertainty on estimates of biological reference points derived from these models. The exclusion of discards (if large) from the DeLury difference equation as well as changing discarding patterns and catchability of partial- and fully-recruited biomass indices would under-estimate biomass, but agreement on the directionality of exploitable stock biomass relative to *Bmax* was not reached. In addition, such factors would most likely effect the assumed linearity of the partial recruitment vector used in yield per recruit analyses, and therefore the SARC agreed that fishing mortality-based reference points (e.g, F_{max}) are also uncertain. Despite uncertainty in these biological reference points, there was some measure of agreement between these and the current over-fishing definition based on NEFSC autumn biomass indices. The SARC agreed that biological reference points derived from the analytical models should be evaluated for alternative over-fishing definitions for this stock.

Sources of Uncertainty

- White and red hake are difficult to distinguish at smaller sizes in the landings. Therefore, there is some uncertainty what proportion of the white hake landings are actually red hake (or vise versa).

- Uncertainty in stock structure and possible mixing of northern stock (Gulf of St. Lawrence-Scotian Shelf) fish with southern stock (Gulf of Maine and south), particularly in strata 29 and 30.

- Canadian landings in area 4X (Scotian Shelf) were not used in the assessment.

- Discarding of white hake may be significant. Biomass and biomass reference points may be underestimated because they were not used in the analysis. The actual magnitude of discarding by size/age and any changes in discarding patterns would have impact on yield per recruit, DeLury and surplus production models.

- Uncertainty in the assumed linear partial recruitment pattern used in yield per recruit and DeLury analyses. This may be an unrealistic assumption since changes in many factors such as growth, fishing and discarding patterns, and timing of recruitment to the fishing grounds may alter the linearity of the PR.

- The alpha-prime parameter (or resiliency) used in the surplus production model is undefined for this stock. Biological considerations, i.e. rapid growth, highly fecund, etc., may suggest a relatively high value as might be expected for other groundfish.

- o Heteroscedastic error variances (trends in residuals over time) from DeLury results and relatively large bias in the estimates of partially- and fully-recruited fishing mortality rates (up to 20%) were of some concern in this assessment. While the brevity of the time series may be a possible explanation for the trends in residuals, other more systemic factors may produce these results, such as: 1) exclusion of discards from the DeLury Difference equation as well as changes in the pattern of discarding and its effect on the assumed partial recruitment vector; and 2) temporal changes in the catchability of partially-recruited relative to the fully-recruited stock abundance indices.

- o Uncertainty in the sensitivity of exclusion of discards and the changing discarding patterns on surplus production model results. Exclusion of the discarded portion of the catch from the DeLury difference equation would raise biomass estimates, but the directionality of exploitable stock biomass relative to B*max* is not clear.

Research Recommendations

- o Proportions of white and red hake species mix in landings should be estimated.

- o Investigate possible delineation of stocks of white hake distributed between the Scotian Shelf and Southern New England, and determine the extent of stock mixing that occurs. One avenue of research might include otolith exchange between US and Canada.

- o Canadian landings in area 4X (Scotian Shelf) should be incorporated into the assessment.

- o Investigate the temporal re-aggregation of landings to correspond to the autumn survey (Oct. 1-Sept. 30) to be used in the DeLury and surplus production models.

- o Length frequency samples by gear type should be obtained in the ports since a larger percentage of landings in the unclassified market category has occurred in more recent years.

- o Examine all available age data in the survey to complete the time series used in the assessment. Further, examine white hake age data collected in the DSSP to determine age composition of the catch.

- o Investigate the use of multiple tuning indices (i.e. NEFSC autumn and spring surveys) or a Bayesian approach in the DeLury model

- o Investigate further the applicability of percent landed as an explanatory factor in LPUE GLM.

- o Extend the time series in the surplus production model since catches are available over a longer time period than the 1985-1993 period used for calibrating with abundance indices. This may provide a greater dynamic range in biomass estimates for estimating the shape of the surplus production function.

- o Investigate the use of survey size composition and maturity at size for estimation of spawning stock biomass and conventional recruitment from the DeLury analysis. If possible, construct a stock-recruitment relationship.

- o Investigate other biological information, including stock-recruitment, to better define the alpha-prime parameter (or resiliency) used in the surplus production model.
- o Examine sensitivity of excluding discards from the DeLury difference equation as well as changing discarding patterns on surplus production model results.

- o Examine possible reasons for heteroscedastic error variances (trends in residuals over time) from DeLury results and resultant large bias in the estimates of partially- and fully-recruited fishing mortality rates. Possible factors to explore include: 1) exclusion of discards from the DeLury Difference equation as well as changes in the pattern of discarding and its effect on the assumed partial recruitment vector; and 2) temporal changes in the catchability of partially-recruited relative to the fully-recruited stock abundance indices.

- o Attempt to estimate the partial recruitment pattern by using NEFSC survey indices (deriving growth through partially-recruited size range) and mesh selection studies.

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Table B1. Total Landings (mt,live)[1] of white hake by country from the Gulf of Maine to Cape Hatteras (NAFO Subareas 5 and 6), 1964-1993.

	5Y[2]			5Z			6			Total			Total Subarea	Grand
	Canada	USA[3]	Other[4]	Canada	USA	Other[4]	Canada	USA	Other[4]	Canada	USA	Other	5	Total
1964	3	2129		26	772			4		29	2905	-	2930	2934
1965		2019			570			3		-	2593	-	2590	2593
1966		1127			408			2		-	1537	-	1535	1537
1967		797		16	312			<1		16	1109	-	1125	1125
1968	5	770		80	418			4		85	1193	-	1274	1278
1969	4	828		30	505	6		2		34	1335	6	1373	1375
1970	12	1201		34	590	222		5	58	46	1795	280	2058	2121
1971	18	1612		82	905	109		29	105	100	2546	214	2726	2860
1972	8	2146		32	764	159		14		40	2924	159	3109	3123
1973	17	2305		100	719	1		3	4	117	3027	5	3142	3149
1974	36	2868		196	768			3		232	3640	-	3869	3872
1975	17	2934		129	550			1		146	3485	-	3630	3631
1976		3378		195	539			3		195	3920	-	4112	4115
1977		4012		170	728	189		1	149	170	4740	338	5098	5248
1978	20	3843		135	837	1		4	28	155	4684	29	4836	4868
1979	102	2922		149	860	3		1	1	251	3782	4	4035	4037
1980	14	3382		291	982	1		2	1	305	4366	2	4670	4673
1981	21	4680		433	1233			4		454	5916	-	6366	6370
1982	352	5099		412	1070	1		4	1	764	6173	2	6934	6939
1983	441	5291		369	1111			2		810	6404	-	7212	7214
1984	479	5269		534	1467			8		1013	6744	-	7749	7757
1985	452	5901		501	1446			2		953	7349	-	8300	8302
1986	308	5055		648	1049			4		956	6107	-	7060	7063
1987		4402		555	1407			5		555	5814	-	6364	6369
1988		3171		534	1568			37		534	4776	-	5273	5310
1989		3471		583	1067			5		583	4543	-	5121	5126
1990		3804		547	1107			8		547	4920	-	5458	5467
1991		4309		552	1262			29		552	5600	-	6123	6152
1992		6335		1120	2058			45		1120	8438	-	9513	9558
1993	[5]	4432		1671	2997			32		1671	7461	-	9100	9132

[1]Canada and Other as reported to ICNAF/NAFO for 1964-1992. USA landings derived from NEFSC Weighout files.
[2]NK Landings for SA5 assigned to Subarea 5Y
[3]US 5Y landings include 464 and 465
[4]Includes Japan, Spain, and USSR.
[5]Canadian 5Y landings for 93 moved to 4X.

Table B2. US commercial landings (mt,live) of white hake by gear, 1964-1993. The annual percentage of total US commercial landings by gear type is also presented.

	Landings (mt,live)					Percentage of Annual Landings				
		Bottom	Sink				Bottom	Sink		
	Line	Otter	Gill	Other[1]						
Year	Trawl	Trawl	Net	Gear	Total	Trawl	Trawl	Net	Gear	Total
1964	1146	1772	99	8	3026	37.9	58.6	3.3	0.3	100.0
1965	1511	1124	64	4	2703	55.9	41.6	2.4	0.2	100.0
1966	703	793	99	5	1599	43.9	49.6	6.2	0.3	100.0
1967	325	858	67	4	1253	25.9	68.5	5.3	0.3	100.0
1968	265	875	115	3	1259	21.1	69.5	9.2	0.2	100.0
1969	228	1037	103	2	1370	16.7	75.7	7.5	0.1	100.0
1970	201	1508	129	4	1842	10.9	81.9	7.0	0.2	100.0
1971	532	1943	118	9	2602	20.4	74.7	4.5	0.3	100.0
1972	833	1766	383	11	2994	27.8	59.0	12.8	0.4	100.0
1973	816	1803	421	6	3046	26.8	59.2	13.8	0.2	100.0
1974	624	1845	1198	10	3677	17.0	50.2	32.6	0.3	100.0
1975	972	1336	1201	2	3510	27.7	38.1	34.2	0.0	100.0
1976	527	1597	1818	6	3948	13.3	40.5	46.0	0.2	100.0
1977	350	2319	2091	10	4769	7.3	48.6	43.8	0.2	100.0
1978	297	2160	2213	19	4689	6.3	46.1	47.2	0.4	100.0
1979	192	2016	1556	19	3782	5.1	53.3	41.1	0.5	100.0
1980	72	2587	1680	28	4366	1.6	59.3	38.5	0.6	100.0
1981	108	3423	2376	11	5917	1.8	57.8	40.2	0.2	100.0
1982	95	3861	2201	18	6174	1.5	62.5	35.6	0.3	100.0
1983	59	4868	1394	85	6406	0.9	76.0	21.8	1.3	100.0
1984	5	5152	1486	104	6747	0.1	76.4	22.0	1.5	100.0
1985	20	5514	1417	417	7368	0.3	74.8	19.2	5.7	100.0
1986	19	4699	1162	510	6390	0.3	73.5	18.2	8.0	100.0
1987	36	4805	910	73	5825	0.6	82.5	15.6	1.3	100.0
1988	40	3650	1007	83	4780	0.8	76.4	21.1	1.7	100.0
1989	15	2552	1892	89	4548	0.3	56.1	41.6	2.0	100.0
1990	78	3280	1508	55	4922	1.6	66.6	30.6	1.1	100.0
1991	249	3548	1614	189	5600	4.4	63.3	28.8	3.4	100.0
1992	948	5190	2261	40	8438	11.2	61.5	26.8	0.5	100.0
1993	1203	4653	1588	16	7461	16.1	62.4	21.3	0.2	100.0

[1] Includes handline, Scottish seine, drift gill net, scallop dredge, Danish seine, pound net, floating trap net, longline, midwater trawl, lobster pots, fish pots, purse seine, troll line, common seine, diving gear, set gill net, harpoon, rakes, and trammel net.

Table B3. US Landings (mt,live) of white hake by tonnage class[1], 1964-1993.

	Tonnage Class (TC)					Percentage of total				
Year	2	3	4	Others[2]	Total	2	3	4	Others[2]	Total
1964	450	1084	258	1234	3026	14.9	35.8	8.5	40.8	100.0
1965	312	590	228	1573	2703	11.5	21.8	8.4	58.2	100.0
1966	280	445	145	728	1599	17.5	27.9	9.1	45.6	100.0
1967	206	437	150	459	1253	16.5	34.9	12.0	36.6	100.0
1968	300	457	185	317	1259	23.8	36.3	14.7	25.2	100.0
1969	286	555	239	290	1370	20.9	40.5	17.4	21.2	100.0
1970	520	748	323	251	1842	28.2	40.6	17.5	13.6	100.0
1971	600	1114	367	521	2602	23.1	42.8	14.1	20.0	100.0
1972	738	1002	343	912	2995	24.6	33.5	11.4	30.5	100.0
1973	933	922	298	893	3046	30.6	30.3	9.8	29.3	100.0
1974	1339	907	347	1084	3676	36.4	24.7	9.4	29.5	100.0
1975	1304	609	271	1327	3510	37.1	17.3	7.7	37.8	100.0
1976	1587	845	299	1217	3948	40.2	21.4	7.6	30.8	100.0
1977	2363	1020	503	883	4769	49.5	21.4	10.5	18.5	100.0
1978	2161	1087	535	906	4689	46.1	23.2	11.4	19.3	100.0
1979	1687	1055	469	571	3782	44.6	27.9	12.4	15.1	100.0
1980	1809	1143	730	685	4366	41.4	26.2	16.7	15.7	100.0
1981	2346	1492	1348	731	5917	39.6	25.2	22.8	12.4	100.0
1982	2626	1828	1310	411	6174	42.5	29.6	21.2	6.7	100.0
1983	1964	2405	1798	240	6407	30.7	37.5	28.1	3.7	100.0
1984	1966	2746	1625	411	6748	29.1	40.7	24.1	6.1	100.0
1985	1882	2987	2199	299	7367	25.5	40.5	29.8	4.1	100.0
1986	1189	2512	2223	465	6389	18.6	39.3	34.8	7.3	100.0
1987	1078	2556	1876	315	5825	18.5	43.9	32.2	5.4	100.0
1988	1114	1755	1684	227	4780	23.3	36.7	35.2	4.7	100.0
1989	1535	1525	1193	295	4548	33.8	33.5	26.2	6.5	100.0
1990	1330	1727	1672	192	4921	27.0	35.1	34.0	3.9	100.0
1991	1749	1948	1636	268	5601	31.2	34.8	29.2	4.8	100.0
1992	2666	2933	2354	486	8439	31.6	34.8	27.9	5.8	100.0
1993	1995	2563	2704	199	7461	26.7	34.4	36.2	2.7	100.0

[1]TC2 = 5-50 GRT, TC3 = 51-150 GRT, TC4 = 151-500 GRT.
[2]Undertonnage vessels

Table B4. Summary of the landings (mt,live) and number of trips by percentage white hake of total landings. The percentage of each category is also given.

	<10%		10 - 20%		20 - 30%		30 - 40%		40 - 50%		50 - 60%		60 - 70%		70 - 80%		80 - 90%		90 - 100%		Total	
	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips
1975	1112	14380	755	2000	321	601	194	232	327	340	257	196	104	83	100	35	238	92	101	28	3510	17987
1976	1375	14822	678	2000	323	530	389	467	243	354	288	197	213	110	91	55	187	70	161	66	3948	18671
1977	1697	15979	871	2277	592	1042	454	689	424	447	418	308	157	77	60	21	18	12	78	11	4770	20863
1978	2061	16689	805	1938	433	810	383	370	234	148	232	154	146	76	232	50	99	38	6	23	4631	20296
1979	1826	19870	582	1531	294	419	288	317	377	389	200	162	131	80	58	44	24	17	1	1	3782	22830
1980	2184	22132	847	2249	483	1032	233	315	361	373	86	91	82	62	23	23	5	6	62	33	4366	26316
1981	1730	17319	1188	2271	665	887	473	487	298	232	336	297	428	289	553	247	226	103	18	8	5917	22140
1982	2056	18673	1162	2325	766	943	652	569	413	265	423	273	433	269	231	85	32	9	7	2	6174	23413
1983	1852	16888	1511	2589	1009	1158	729	553	521	276	393	166	279	141	60	12	10	3	42	11	6407	21797
1984	1549	15065	1708	2644	1279	1350	884	658	702	491	380	253	189	79	40	19	10	6	5	1	6747	20566
1985	1475	16562	1768	2597	1470	1095	1176	790	804	385	348	169	220	84	87	51	3	4	17	4	7368	21741
1986	1295	16574	1387	2273	1056	848	1066	647	610	225	316	137	251	98	207	66	55	4	147	8	6390	20880
1987	1140	19906	1366	2606	1155	1170	968	595	587	302	373	147	153	56	59	9	6	3	17	2	5825	24796
1988	710	15289	864	1628	893	1043	795	627	590	420	484	251	235	142	122	52	53	19	36	11	4780	19482
1989	621	13808	688	1603	682	857	644	739	694	695	479	326	320	177	202	58	143	28	74	12	4548	18303
1990	814	13286	844	1416	685	665	702	606	425	208	650	437	480	211	231	107	61	35	29	9	4922	16980
1991	958	13769	1072	1758	1020	1292	764	669	673	593	333	286	234	74	223	93	96	31	227	14	5600	18584
1992	722	13165	1057	1924	1408	1335	1433	946	1155	665	914	565	809	382	699	225	161	65	81	22	8438	19294
1993	602	11847	854	1524	1180	889	1309	727	1164	612	725	347	727	271	458	169	283	44	159	60	7461	16490

Percentage of total

	<10%		10 - 20%		20 - 30%		30 - 40%		40 - 50%		50 - 60%		60 - 70%		70 - 80%		80 - 90%		90 - 100%		Total	
	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips	mt	trips
1975	31.7	79.9	21.5	11.1	9.2	3.3	5.5	1.3	9.3	1.9	7.3	1.1	3.0	0.5	2.8	0.2	6.8	0.5	2.9	0.2	100.0	100.0
1976	34.8	79.4	17.2	10.7	8.2	2.8	9.9	2.5	6.2	1.9	7.3	1.1	5.4	0.6	2.3	0.3	4.7	0.4	4.1	0.4	100.0	100.0
1977	35.6	76.6	18.3	10.9	12.4	5.0	9.5	3.3	8.9	2.1	8.8	1.5	3.3	0.4	1.3	0.1	0.4	0.1	1.6	0.1	100.0	100.0
1978	44.5	82.2	17.4	9.5	9.3	4.0	8.3	1.8	5.1	0.7	5.0	0.8	3.1	0.4	5.0	0.2	2.1	0.2	0.1	0.1	100.0	100.0
1979	48.3	87.0	15.4	6.7	7.8	1.8	7.6	1.4	10.0	1.7	5.3	0.7	3.5	0.4	1.5	0.2	0.6	0.1	0.0	0.0	100.0	100.0
1980	50.0	84.1	19.4	8.5	11.1	3.9	5.3	1.2	8.3	1.4	2.0	0.3	1.9	0.2	0.5	0.1	0.1	0.0	1.4	0.1	100.0	100.0
1981	29.2	78.2	20.1	10.3	11.2	4.0	8.0	2.2	5.0	1.0	5.7	1.3	7.2	1.3	9.4	1.1	3.8	0.5	0.3	0.0	100.0	100.0
1982	33.3	79.8	18.8	9.9	12.4	4.0	10.6	2.4	6.7	1.1	6.8	1.2	7.0	1.1	3.7	0.4	0.5	0.0	0.1	0.0	100.0	100.0
1983	28.9	77.5	23.6	11.9	15.8	5.3	11.4	2.5	8.1	1.3	6.1	0.8	4.3	0.6	0.9	0.1	0.2	0.0	0.7	0.1	100.0	100.0
1984	23.0	73.3	25.3	12.9	19.0	6.6	13.1	3.2	10.4	2.4	5.6	1.2	2.8	0.4	0.6	0.1	0.2	0.0	0.1	0.0	100.0	100.0
1985	20.0	76.2	24.0	11.9	20.0	5.0	16.0	3.6	10.9	1.8	4.7	0.8	3.0	0.4	1.2	0.2	0.0	0.0	0.2	0.0	100.0	100.0
1986	20.3	79.4	21.7	10.9	16.5	4.1	16.7	3.1	9.5	1.1	4.9	0.7	3.9	0.5	3.2	0.3	0.9	0.0	2.3	0.0	100.0	100.0
1987	19.6	80.3	23.4	10.5	19.8	4.7	16.6	2.4	10.1	1.2	6.4	0.6	2.6	0.2	1.0	0.0	0.1	0.0	0.3	0.0	100.0	100.0
1988	14.8	78.5	18.1	8.4	18.7	5.4	16.6	3.2	12.3	2.2	10.1	1.3	4.9	0.7	2.6	0.3	1.1	0.1	0.7	0.1	100.0	100.0
1989	13.7	75.4	15.1	8.8	15.0	4.7	14.2	4.0	15.3	3.8	10.5	1.8	7.0	1.0	4.4	0.3	3.1	0.2	1.6	0.1	100.0	100.0
1990	16.5	78.2	17.2	8.3	13.9	3.9	14.3	3.6	8.6	1.2	13.2	2.6	9.8	1.2	4.7	0.6	1.2	0.2	0.6	0.1	100.0	100.0
1991	17.1	74.1	19.1	9.5	18.2	7.0	13.6	3.6	12.0	3.2	6.0	1.5	4.2	0.4	4.0	0.5	1.7	0.2	4.1	0.1	100.0	100.0
1992	8.6	68.2	12.5	10.0	16.7	6.9	17.0	4.9	13.7	3.4	10.8	2.9	9.6	2.0	8.3	1.2	1.9	0.3	1.0	0.1	100.0	100.0
1993	8.1	71.8	11.4	9.2	15.8	5.4	17.5	4.4	15.6	3.7	9.7	2.1	9.7	1.6	6.1	1.0	3.8	0.3	2.1	0.4	100.0	100.0

Table B5. Summary of US Commercial White Hake landings (mt), number of length samples (n), and number of fish measured (len) by market category and quarter from the Gulf of Maine to the Mid-Atlantic (SA 464,465 511-515,521-526,533-539,611-626) for all gear types, 1985-1993.

		small					medium					large					unclassified					All
Year		Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Total
1985	mt	129	162	235	167	694	63	78	181	124	446	237	433	1135	623	2428	367	737	1690	988	3782	7349
	N	2	4	3	-	9	-	-	-	-	-	-	5	5	3	13	-	1	3	1	5	27
	# fish	233	323	317	-	873	-	-	-	-	-	-	632	519	271	1422	-	101	293	104	498	2793
1986	mt	59	134	105	100	398	86	89	55	54	284	274	422	835	417	1948	455	752	1578	694	3478	6107
	N	1	2	3	1	7	1	2	-	2	5	1	3	1	1	6	2	2	3	1	8	26
	# fish	102	156	338	101	697	94	227	-	229	550	122	317	125	96	660	215	206	292	106	819	2726
1987	mt	98	300	641	576	1616	13	49	122	123	306	171	326	943	372	1813	262	482	1035	301	2080	5814
	N	-	2	4	5	11		2	1	1	4	-	1	6	3	10	2	1	1	1	5	30
	# fish	-	240	291	507	1038		203	91	109	403	-	111	518	236	865	218	140	112	125	595	2901
1988	mt	181	549	893	397	2020	26	82	262	120	489	136	330	695	325	1486	73	137	437	134	782	4776
	N	5	6	3	5	19	1	1	1	-	3	1	2	1	-	4	1	1	-	1	3	29
	# fish	558	764	240	478	2040	100	92	105	-	297	121	214	85	-	420	112	100	-	41	253	3010
1989	mt	148	221	404	358	1132	41	54	124	68	287	187	472	903	470	2032	33	190	774	96	1092	4542
	N	1	1	2	2	6	-	-	1	-	1	-	-	2	2	4	1	-	1	-	2	13
	# fish	91	94	213	195	593	-	-	103	-	103	-	-	206	204	410	100	-	106	-	206	1312
1990	mt	207	410	885	450	1953	43	108	303	171	625	167	298	596	320	1381	24	182	580	176	962	4920
	N	3	4	4	2	13	-	-	2	1	3	2	-	1	1	4	-	-	1	-	1	21
	# fish	309	408	399	151	1267	-	-	302	99	401	214	-	101	103	418	-	-	101	-	101	2187
1991	mt	150	366	1215	612	2342	88	160	381	129	758	126	241	533	338	1238	52	358	714	138	1262	5601
	N	1	5	8	4	18	2	1	1	1	5	4	1	1	4	10	-	2	1	-	3	36
	# fish	50	471	765	350	1636	204	100	102	100	506	375	99	96	433	1003	-	207	94	-	301	3446
1992	mt	424	626	1735	848	3633	102	202	765	358	1428	231	351	699	371	1651	60	280	1246	140	1726	8438
	N	4	4	8	3	19	1	4	3	3	11	2	2	3	-	7	1	-	2	-	3	40
	# fish	329	432	655	240	1656	80	388	266	317	1051	297	194	325	-	816	97	-	237	-	334	3857
1993	mt	331	502	453	214	1500	161	397	1117	461	2135	173	476	795	416	1860	94	463	975	433	1965	7461
	N	2	5	4	1	12	2	3	2	1	8	2	3	7	2	14	-	2	2	1	5	39
	# fish	150	504	275	50	979	184	309	196	95	784	199	262	676	175	1312	-	214	196	97	507	3582

Table B6. Summary of Domestic Sea Sampling number of length samples (n), number of trips, sampled (trips), number of fish measured (len), and number of age samples taken (age) by gear type, quarter, and catch disposition, 1989-1993.

	Sink Gill Net									
	Q1		Q2		Q3		Q4		Total	
	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc
1989 n	-	-	-	-	14	1	3	-	17	1
trips	-	-	-	-	12	1	2	-	14	1
len	-	-	-	-	416	2	50	-	466	2
age	-	-	-	-	3	-	3	-	6	-
1990 n	2	-	6	-	16	-	1	1	25	1
trips	1	-	5	-	7	-	1	1	14	1
len	2	-	204	-	1093	-	104	32	1403	32
age	2	-	28	-	76	-	-	-	106	-
1991 n	-	-	66	8	206	6	55	2	327	16
trips	-	-	21	1	68	5	21	2	110	8
len	-	-	2527	135	8636	26	1339	4	12502	165
age	-	-	155	49	297	12	57	4	509	65
1992 n	2	-	65	1	239	3	83	1	389	5
trips	1	-	33	1	132	3	49	1	215	5
len	2	-	1617	1	7560	3	880	1	10059	5
age	2	-	59	-	208	3	70	-	339	3
1993 n	7	-	45	1	141	4	116	6	309	11
trips	5	-	21	1	71	4	52	5	149	10
len	35	-	1241	1	3348	6	636	6	5260	13
age	5	-	25	1	164	-	15	3	209	4

	Otter Trawl									
	Q1		Q2		Q3		Q4		Total	
	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc
1989 n	1	3	6	16	4	47	-	5	11	71
trips	1	2	3	6	3	15	-	4	7	27
len	15	20	108	696	154	1578	-	157	277	2451
age	-	-	-	7	16	93	-	20	16	120
1990 n	3	2	4	1	1	2	-	4	8	9
trips	1	2	1	1	1	2	-	3	3	8
len	41	8	28	8	138	91	-	221	207	328
age	7	-	12	7	-	-	-	-	19	7
1991 n	1	-	-	1	11	2	3	1	15	4
trips	1	-	-	1	2	1	1	1	4	3
len	1	-	-	180	409	43	4	2	414	225
age	-	-	-	-	-	-	-	2	-	2
1992 n	6	-	1	-	1	1	1	-	9	1
trips	5	-	1	-	1	1	1	-	8	1
len	150	-	78	-	3	86	56	-	287	86
age	31	-	16	-	-	13	-	-	47	13
1993 n	12	-	23	10	3	1	25	1	63	12
trips	2	-	6	3	1	1	3	1	12	5
len	253	-	428	51	79	14	578	30	1338	95
age	2	-	-	21	15	-	2	-	19	21

Table B7. US Commercial landings (mt), days fished (df), and landings per day fished (mt/df) by vessel tonnage class, of white hake for otter trawl trips catching white hake, 1975-1993.

	Class 2			Class 3			Class 4			Totals		
	mt	df	mt/df	mt	df	mt/df	mt	df	mt/df	mt	df	mt/df[1]
ALL TRIPS												
1975	339	1970	0.17	582	2951	0.20	267	1257	0.21	1188	6178	0.19
1976	426	2256	0.19	834	2814	0.30	291	1272	0.23	1551	6342	0.25
1977	744	2572	0.29	986	3627	0.27	493	1307	0.38	2222	7506	0.30
1978	554	2876	0.19	1028	3969	0.26	530	1480	0.36	2112	8325	0.27
1979	527	3403	0.15	990	4581	0.22	467	1801	0.26	1983	9785	0.21
1980	675	3877	0.17	1088	5063	0.21	723	2380	0.30	2486	11320	0.23
1981	610	2718	0.22	1417	4896	0.29	1344	2790	0.48	3371	10404	0.35
1982	705	3415	0.21	1753	6413	0.27	1304	3771	0.35	3763	13599	0.29
1983	740	2964	0.25	2240	6391	0.35	1792	4362	0.41	4772	13717	0.36
1984	783	2895	0.27	2648	7645	0.35	1620	4623	0.35	5051	15163	0.34
1985	658	2398	0.27	2614	8716	0.30	2146	4923	0.44	5417	16037	0.35
1986	294	1796	0.16	1929	7975	0.24	2219	5459	0.41	4442	15230	0.32
1987	404	1933	0.21	2384	8504	0.28	1915	5448	0.35	4704	15885	0.30
1988	290	1517	0.19	1595	7018	0.23	1732	5156	0.34	3617	13691	0.28
1989	191	1340	0.14	1112	6168	0.18	1174	4516	0.26	2476	12024	0.22
1990	291	1614	0.18	1262	5965	0.21	1698	4533	0.37	3251	12112	0.29
1991	438	2242	0.20	1396	7413	0.19	1678	5088	0.33	3513	14743	0.26
1992	652	2584	0.25	2232	8731	0.26	2263	5532	0.41	5148	16847	0.32
1993	381	2116	0.18	1933	9199	0.21	2290	5031	0.46	4604	16346	0.33

[1]Total mt/df was derived by weighting individual tonnage class mt/df values by the percentage of total landings accounted for by each vessel class and summing over the three vessel class categories.

Table B8. White hake effort (days) standardization. Standard: Year = 75; Area = 515[1]; Qtr = 3; TC = 3[2]; Depth = 3[3].

GENERAL LINEAR MODEL

Dependent Variable :LNCPUEDF

Source	DF	Sum of Squares	Mean Square	F Value	PR > 1	R-Square	CV
Model	33	28901.4	875.8	875.80	0.0001	0.31789	-60.7
Error	40849	62013.7	1.5				
Corrected Total	40882	90915.0					

Source	DF	Type I SS	Mean Square	F Value	PR > F
Year	18	2288.3	127.1	83.74	0.0001
Area	7	16983.1	2426.2	1598.13	0.0001
Qtr	3	2857.6	952.5	627.44	0.0001
TC	2	2480.5	1240.2	816.96	0.0001
Depthcd	3	4291.9	1430.6	942.38	0.0001

Source	DF	Type III SS	Mean Square	F Value	PR > F
Year	18	3275.4	182.0	119.86	0.0001
Area	7	6014.6	859.2	565.98	0.0001
Qtr	3	3734.1	1244.7	819.90	0.0001
TC	2	1912.5	956.2	629.89	0.0001
Depthcd	3	4291.9	1430.6	942.38	0.0001

Parameter		Estimate	T for H_0 : Coefficient	Pr > |T| Parameter = 0	Std Error of Estimate	Re-Transformed Estimate
Intercept		-1.04707 B	-27.86	0.0001	0.037581	
Area	511	0.52850 B	10.33	0.0001	0.051146	1.696388
	512	0.52509 B	18.50	0.0001	0.028377	1.690606
	513	-0.39135 B	-17.15	0.0001	0.022818	0.676145
	514	-0.42839 B	-16.19	0.0001	0.026456	0.651552
	515	0.00000 B	-	-	-	1.000000
	522[1]	-0.44661 B	-22.79	0.0001	0.019598	0.639795
	525[2]	-1.35401 B	-40.41	0.0001	0.033506	0.258204
	530[3]	-1.24666 B	-36.70	0.0001	0.033971	0.287464
Quarter	1	-0.75242 B	-40.98	0.0001	0.018359	0.471223
	2	-0.56311 B	-33.37	0.0001	0.016874	0.569437
	3	0.00000 B	-	-	-	1.000000
	4	-0.07127 B	-4.32	0.0001	0.016496	0.931209
TC	2	-0.15654 B	-8.25	0.0001	0.018985	0.855100
	3	0.00000 B	-	-	-	1.000000
	4	0.49821 B	33.08	0.0001	0.015062	1.645776
Depthcd	1	-0.67720 B	-24.29	0.0001	0.027883	0.508037
	2	-0.53709 B	-32.50	0.0001	0.016527	0.584449
	3	0.00000 B	-	-	-	1.000000
	4[4]	0.54435 B	30.65	0.0001	0.017761	1.723495

[1]Includes 521,522,523(561).
[2]Includes 524(562) 525,526.
[3]Includes 537,538,539.
[4]Includes depthcd 4-7.

Table B9. Nominal and standardized white hake landings (mt), effort (days fished) and landings per day fished (LPUE) for the otter trawl fleet.

Year	Landings (mt)	Nominal Effort	Nominal LPUE	Standardized Effort	Standardized LPUE
1975	660	2698	0.245	1504	0.439
1976	737	2324	0.317	1355	0.544
1977	842	2616	0.322	1378	0.611
1978	896	2728	0.317	1596	0.562
1979	882	3682	0.239	2392	0.369
1980	1008	4276	0.236	3014	0.335
1981	1404	3817	0.368	3200	0.439
1982	1804	5483	0.329	5066	0.356
1983	2292	6196	0.370	5563	0.412
1984	2424	6772	0.358	6086	0.398
1985	3375	8713	0.387	8424	0.401
1986	2791	8284	0.337	8534	0.327
1987	2841	8849	0.321	7772	0.366
1988	2460	8188	0.300	6817	0.361
1989	1313	6267	0.209	4809	0.273
1990	1771	6435	0.275	5190	0.341
1991	1935	7055	0.274	5571	0.347
1992	2675	7988	0.335	6210	0.431
1993	2455	7849	0.313	6036	0.407

Table B10. Stratified mean catch per tow in numbers and weight (kg) for white hake from NEFSC offshore spring and autumn research vessel bottom trawl surveys (strata 21-30,33-40), 1963-1994[1,2,3].

Year	Spring No/Tow	Spring Wt/Tow	Spring Length	Autumn No/Tow	Autumn Wt/Tow	Autumn Length
1963				5.00	6.31	46.16
1964				1.77	4.14	56.31
1965				4.39	6.86	50.41
1966				6.79	7.67	45.12
1967				3.92	3.64	42.63
1968	1.60	1.74	44.08	4.24	4.54	44.93
1969	3.76	5.09	46.28	9.24	13.09	46.79
1970	5.84	11.86	52.95	8.05	12.82	51.32
1971	3.31	5.14	51.26	10.38	12.10	43.61
1972	10.18	12.66	47.32	12.52	13.10	45.23
1973	9.24	12.22	49.90	9.05	13.46	51.72
1974	8.08	13.99	55.03	5.35	11.00	54.47
1975	9.32	11.22	44.73	5.28	7.23	48.55
1976	9.98	17.01	52.74	6.04	10.56	54.66
1977	6.13	11.01	55.52	9.78	13.74	47.81
1978	3.22	6.14	51.84	7.87	12.54	50.21
1979	5.26	4.97	43.02	5.62	10.31	53.14
1980	10.38	13.96	49.70	10.86	16.66	48.83
1981	17.09	19.92	45.94	8.70	12.16	49.87
1982	6.06	8.91	51.00	1.96	2.11	46.75
1983	3.23	3.12	43.72	8.22	10.79	48.77
1984	2.75	4.17	51.42	5.32	8.23	51.94
1985	4.33	5.38	48.53	9.37	9.74	42.94
1986	8.24	5.61	39.97	14.42	11.56	41.92
1987	7.15	6.44	45.27	7.59	9.62	49.15
1988	4.52	3.69	41.87	8.12	9.88	46.08
1989	3.65	3.22	43.00	11.76	9.23	40.53
1990	11.11	18.37	53.29	13.09	10.58	41.49
1991	8.42	6.14	41.57	13.22	12.20	44.58
1992	7.59	7.11	45.09	10.16	11.24	47.75
1993	7.93	6.84	45.07	11.35	11.66	45.21
1994	4.59	3.17	40.13			

[1]During 1963-1984, BMV oval doors were used in the spring and autumn surveys; since 1985, Portuguese polyvalent doors have been used in both surveys. No adjustments were made because no significant difference was found between the two types of doors for white hake (NEFC 1991).

[2]Spring surveys during 1973-1981 were accomplished with a '41 Yankee' trawl; in all other years, spring surveys were accomplished with a '36 Yankee' trawl. No adjustments were made because no significant difference was found between the two types of trawls for white hake (Sissenwine and Bowman, 1987).

[3]During

Table B11. Stratified mean number per tow at age of white hake in the NEFSC bottom trawl spring and autumn surveys (Strata 21-30,33-40), 1982-1989, for the years available. Also shown at the bottom of the page are the plus groups used in deriving the estimates of instantaneous total mortality.

	Age Group															
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Total
Spring																
1982	0.00	1.04	2.63	0.63	1.06	0.26	0.05	0.07	0.04	0.00	0.00	0.01	0.01	0.00	0.00	5.80
1983	NOT AGED															
1984	NOT AGED															
1985	NOT AGED															
1986	NOT AGED															
1987	0.00	1.13	3.24	2.05	0.35	0.13	0.11	0.02	0.00	0.01	0.00	0.00	0.01	0.00	0.01	7.06
1988	0.00	1.77	1.26	1.02	0.22	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.37
1989	0.00	1.44	1.21	0.28	0.46	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.43
Autumn																
1982	0.13	0.74	0.41	0.08	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.41
1983	NOT AGED															
1984	NOT AGED															
1985	NOT AGED															
1986	NOT AGED															
1987	0.72	1.56	3.81	0.94	0.15	0.14	0.03	0.03	0.00	0.05	0.00	0.02	0.02	0.02	0.00	7.49

	AGE								LN (1+/2+)	LN(2+/3+)
Year	0+	1+	2+	3+	4+	5+	6+	Time Period	Z	Z
Spring										
1982	5.80	5.80	4.76	2.13	1.50	0.44	0.18			
1983										
1984										
1985										
1986										
1987	7.06	7.06	5.93	2.69	0.64	0.29	0.16	1987-1988	0.91	1.39
1988	4.37	4.37	2.60	1.34	0.32	0.10	0.01			
1989	3.43	3.43	1.99	0.78	0.50	0.04	0.02			
Autumn										
1982	1.41	1.28	0.54	0.13	0.05	0.00	0.00			
1983										
1984										
1985										
1986										
1987	7.49	6.77	5.21	1.40	0.46	0.31	0.17			

Table B12. Input parameters for the Modified-DeLury and the Shepherd Stock Production Models. Natural mortality was assumed to be 0.2. The selectivity of the recruits to the survey gear was assumed to be equal to that of the fully-recruited animals. Partial recruitment of the recruits was assumed linear for the year.

	Indices of Abundance		Mean Wt (g)		Index of	Total Catch	
	Recruits	Fully-Recruited	Recruits	Fully-Recruited	Exploited Biomass	Millions	1000 mt
1985	1.245	3.743	454.5	2032.4	7890.	3.496013	8.304
1986	2.824	4.051	374.0	2109.1	9071.9	2.349630	7.065
1987	7.538	5.046	459.3	1579.2	9699.7	2.832091	6.371
1988	2.116	5.016	424.3	1775.4	9354.4	4.004625	5.312
1989	4.178	3.506	431.0	2002.5	7921.1	2.201709	5.127
1990	4.214	4.367	429.9	1657.8	8145.6	3.357205	5.469
1991	5.458	5.370	398.5	1552.6	9425.0	4.110854	6.154
1992	6.545	5.760	425.1	1609.8	10663.8	5.631835	9.561
1993	3.162	6.574	427.5	1491.9	10483.5	5.296829	9.135
1994	3.577	6.112	404.1	1591.9			

Table B13. Results of the Modified-DeLury Model for white hake.

	Fishing Mortality			Stock Sizes (Millions)			Stock Biomass (000s MT)		
	Recruits	Fully-Recruited	Exploited	Recruits	Fully-Recruited	Exploited	Recruits	Fully-Recruited	Exploited
1985	0.1982	0.3965	0.3562	1.923	7.331	8.292	8.874	14.90	15.34
1986	0.1508	0.3016	0.2359	4.291	5.214	7.360	1.605	11.00	11.80
1987	0.2516	0.5032	0.3544	8.807	6.065	11.008	4.045	9.58	11.60
1988	0.2775	0.5550	0.4852	2.913	8.573	10.030	1.236	15.22	15.84
1989	0.1703	0.3406	0.2561	5.730	5.729	8.594	2.470	11.47	12.71
1990	0.1881	0.3761	0.2911	6.081	7.234	10.274	2.614	11.99	13.30
1991	0.2094	0.4188	0.3185	7.632	8.072	11.888	3.041	12.53	14.05
1992	0.2255	0.4510	0.3384	9.568	9.279	14.063	4.067	14.94	16.97
1993	0.2091	0.4182	0.3584	4.691	10.890	13.236	2.006	16.24	17.25
1994				5.327	8.716	11.380	2.153	13.88	14.95

Table B14. Results of the Surplus Production model (given in 000s mt).

YEAR	Biomass	Surplus Production
1985	13.56	7.256
1986	14.22	7.338
1987	14.98	7.436
1988	14.56	7.384
1989	13.49	7.239
1990	13.89	7.296
1991	15.65	7.482
1992	17.67	7.618
1993	16.75	7.583

B_{max}	80.460
B_{msy}	21.017
K	11.494
MSY	7.685
P_at_K	6.897

Table B15. The NEFC Yield and Stock Size per Recruit Program - PDBYPRC
PC Ver.1.2 [Method of Thompson and Bell (1934)] 1-Jan-1992
Run Date: 19-10-1994; Time: 12:51:34.50

WHITE HAKE
Proportion of F before spawning: .0000
Proportion of M before spawning: .0000
Natural Mortality is Constant at: .200
Initial age is: 1; 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
1	.2000	1.0000	.3300	.191	.191
2	.5000	1.0000	.7400	.642	.642
3	.7000	1.0000	.9400	1.385	1.385
4	1.0000	1.0000	.9900	2.375	2.375
5	1.0000	1.0000	1.0000	3.543	3.543
6	1.0000	1.0000	1.0000	4.818	4.818
7	1.0000	1.0000	1.0000	6.140	6.140
8	1.0000	1.0000	1.0000	7.457	7.457
9	1.0000	1.0000	1.0000	8.733	8.733
10	1.0000	1.0000	1.0000	9.941	9.941
11	1.0000	1.0000	1.0000	11.066	11.066
12	1.0000	1.0000	1.0000	12.099	12.099
13	1.0000	1.0000	1.0000	13.037	13.037
14	1.0000	1.0000	1.0000	13.880	13.880
15+	1.0000	1.0000	1.0000	14.634	14.634

Summary of Yield per Recruit Analysis for:
WHITE HAKE
Slope of the Yield/Recruit Curve at F=0.00: --> 20.5491
F level at slope=1/10 of the above slope (F0.1): -----> .132
Yield/Recruit corresponding to F0.1: -----> 1.0807
F level to produce Maximum Yield/Recruit (Fmax): -----> .220
Yield/Recruit corresponding to Fmax: -----> 1.1520
F level at 20 % of Max Spawning Potential (F20): -----> .328
SSB/Recruit corresponding to F20: --------> 4.6060

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.00	.00000	.00000	5.5167	23.3687	4.5881	23.0353	100.00
	.10	.25084	.98949	4.2684	12.1070	3.3474	11.7818	51.15
F0.1	.13	.30040	1.08072	4.0223	10.2525	3.1038	9.9299	43.11
	.20	.38008	1.14960	3.6275	7.5902	2.7139	7.2727	31.57
Fmax	.22	.39898	1.15200	3.5340	7.0207	2.6218	6.7046	29.11
	.30	.46038	1.12468	3.2309	5.3453	2.3242	5.0349	21.86
F20%	.33	.47803	1.10746	3.1439	4.9144	2.2392	4.6060	20.00
	.40	.51601	1.05762	2.9572	4.0651	2.0572	3.7615	16.33
	.50	.55737	.98594	2.7546	3.2608	1.8609	2.9635	12.86
	.60	.58968	.91972	2.5968	2.7178	1.7092	2.4265	10.53
	.70	.61586	.86107	2.4695	2.3305	1.5878	2.0448	8.88
	.80	.63766	.80976	2.3638	2.0420	1.4877	1.7615	7.65
	.90	.65622	.76488	2.2742	1.8195	1.4034	1.5440	6.70
	1.00	.67229	.72549	2.1969	1.6430	1.3312	1.3723	5.96
	1.10	.68641	.69071	2.1291	1.4997	1.2685	1.2335	5.35
	1.20	.69894	.65983	2.0692	1.3810	1.2133	1.1191	4.86
	1.30	.71019	.63224	2.0156	1.2812	1.1644	1.0234	4.44
	1.40	.72036	.60744	1.9672	1.1961	1.1205	.9421	4.09
	1.50	.72962	.58504	1.9233	1.1225	1.0809	.8723	3.79
	1.60	.73811	.56470	1.8832	1.0584	1.0449	.8117	3.52
	1.70	.74593	.54615	1.8464	1.0020	1.0121	.7586	3.29
	1.80	.75316	.52916	1.8124	.9519	.9821	.7118	3.09
	1.90	.75989	.51354	1.7809	.9072	.9543	.6702	2.91
	2.00	.76616	.49913	1.7516	.8670	.9287	.6330	2.75

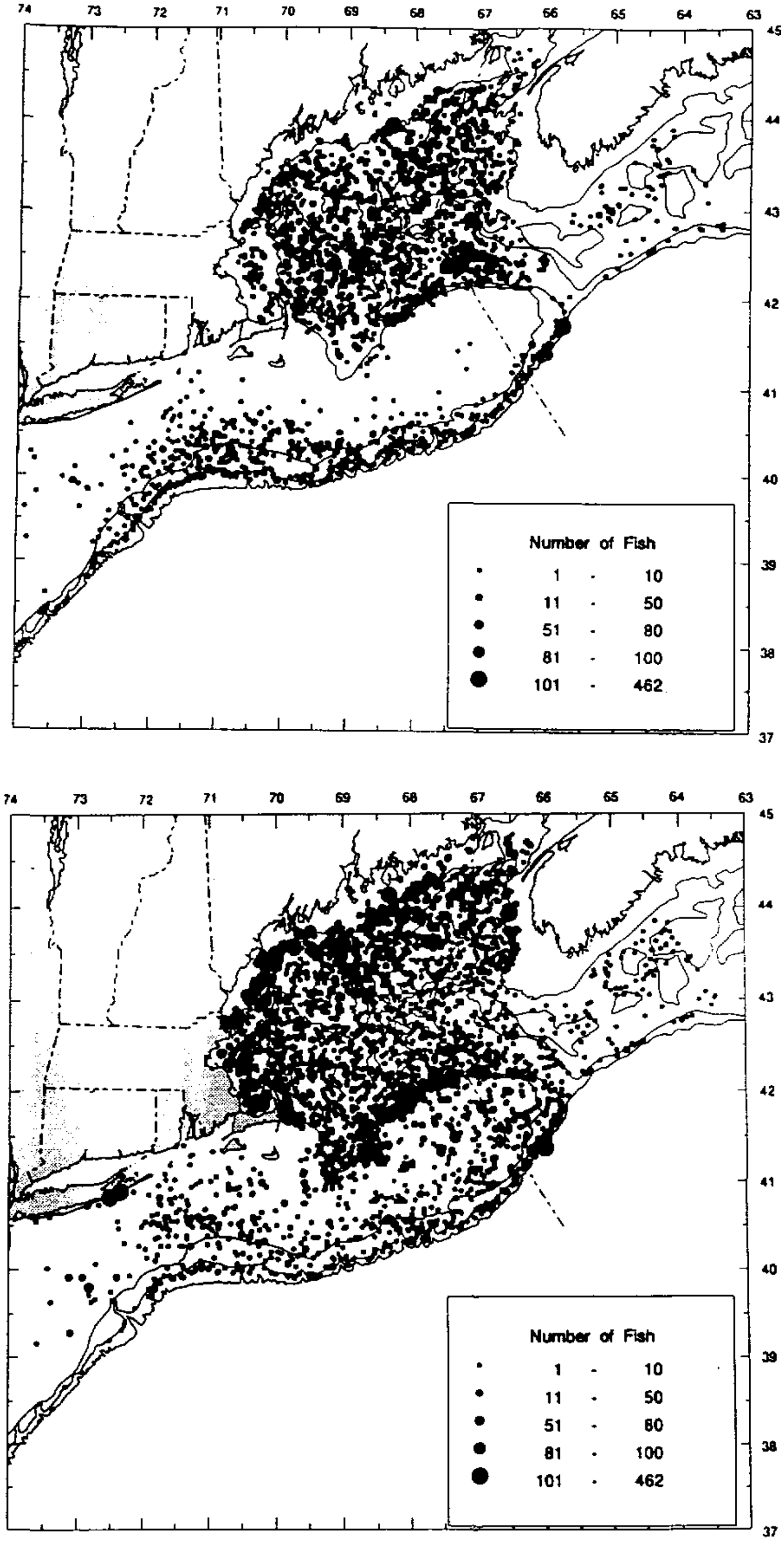

Figure B1. Distribution of white hake in the NEFSC spring (top), 1968-1994, and autumn (bottom), 1963-1993, surveys.

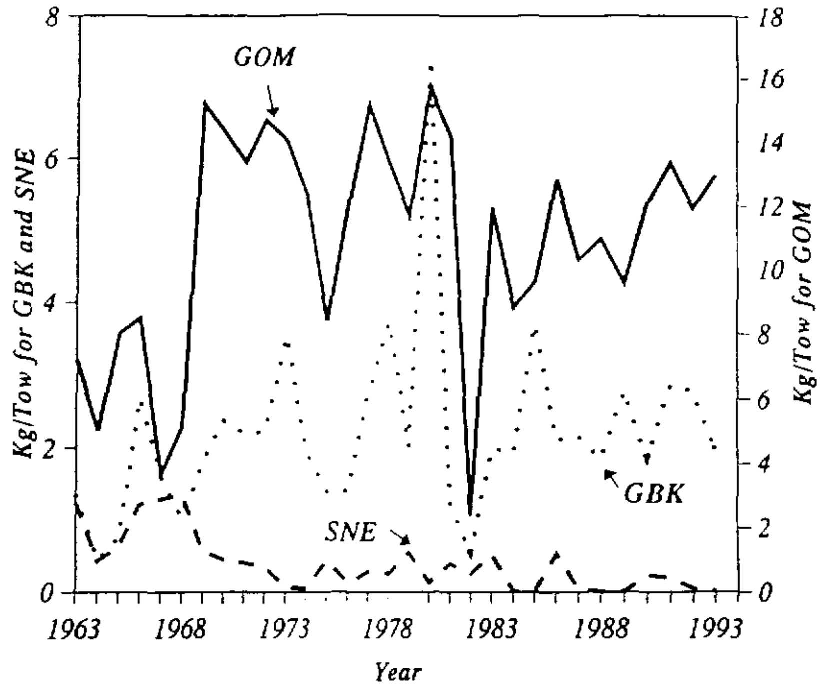

Figure B2. NEFSC Autumn Groundfish Survey indices from three regions: Gulf of Maine (Strata 26-30, 33-40), Georges Bank (Strata 13-25) and Southern New England (Strata 1-12), 1963-1993.

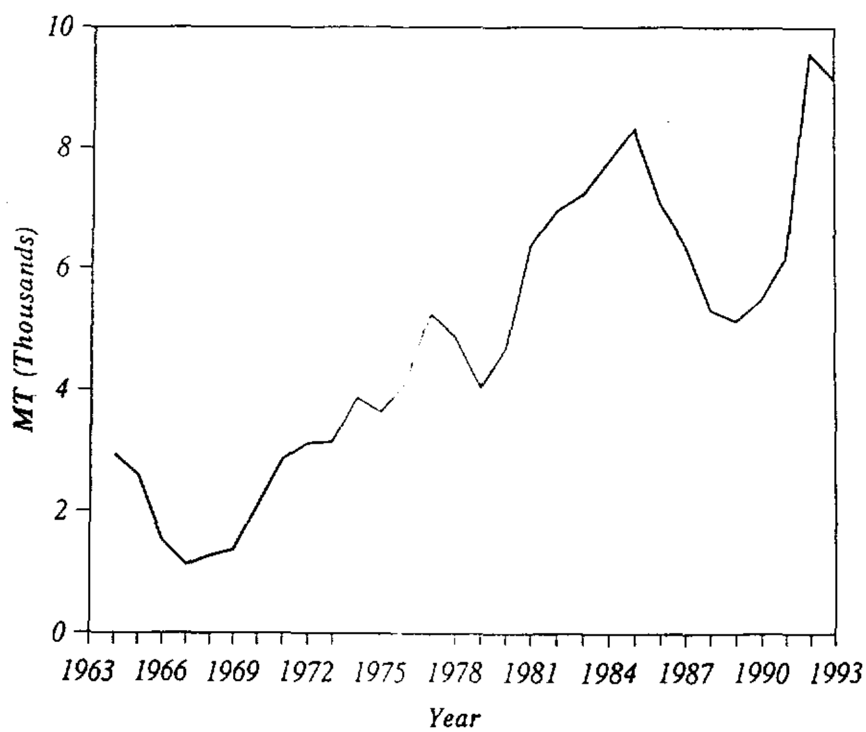

Figure B3. Total landings of white hake in the Gulf of Maine to Mid-Atlantic region, 1964-1993.

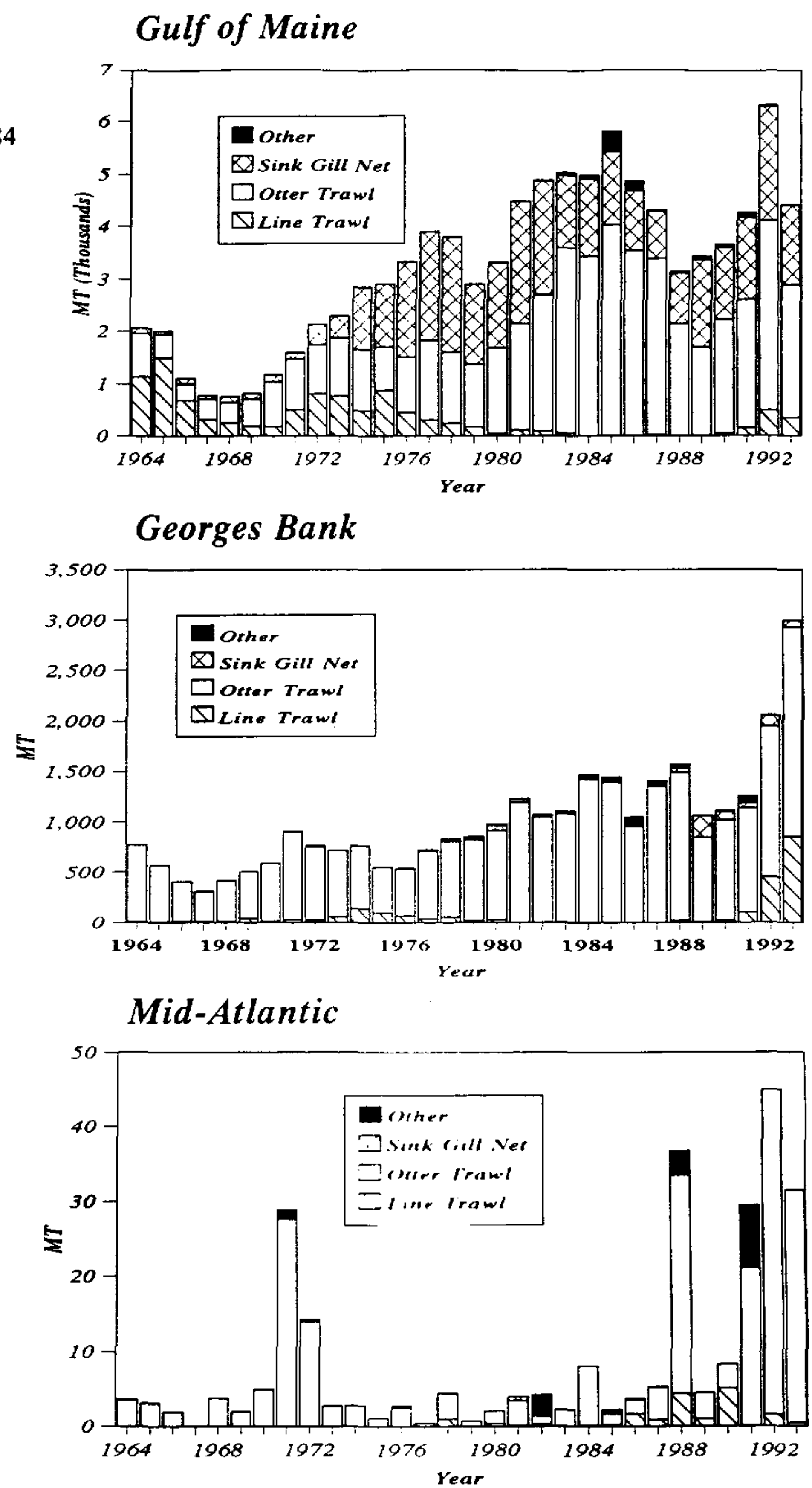

Figure B4. Landings of white hake by gear type in three areas: Gulf of Maine (SA 511-515, 464, 465), Georges Bank (SA 520-562), and the Mid-Atlantic (SA>611).

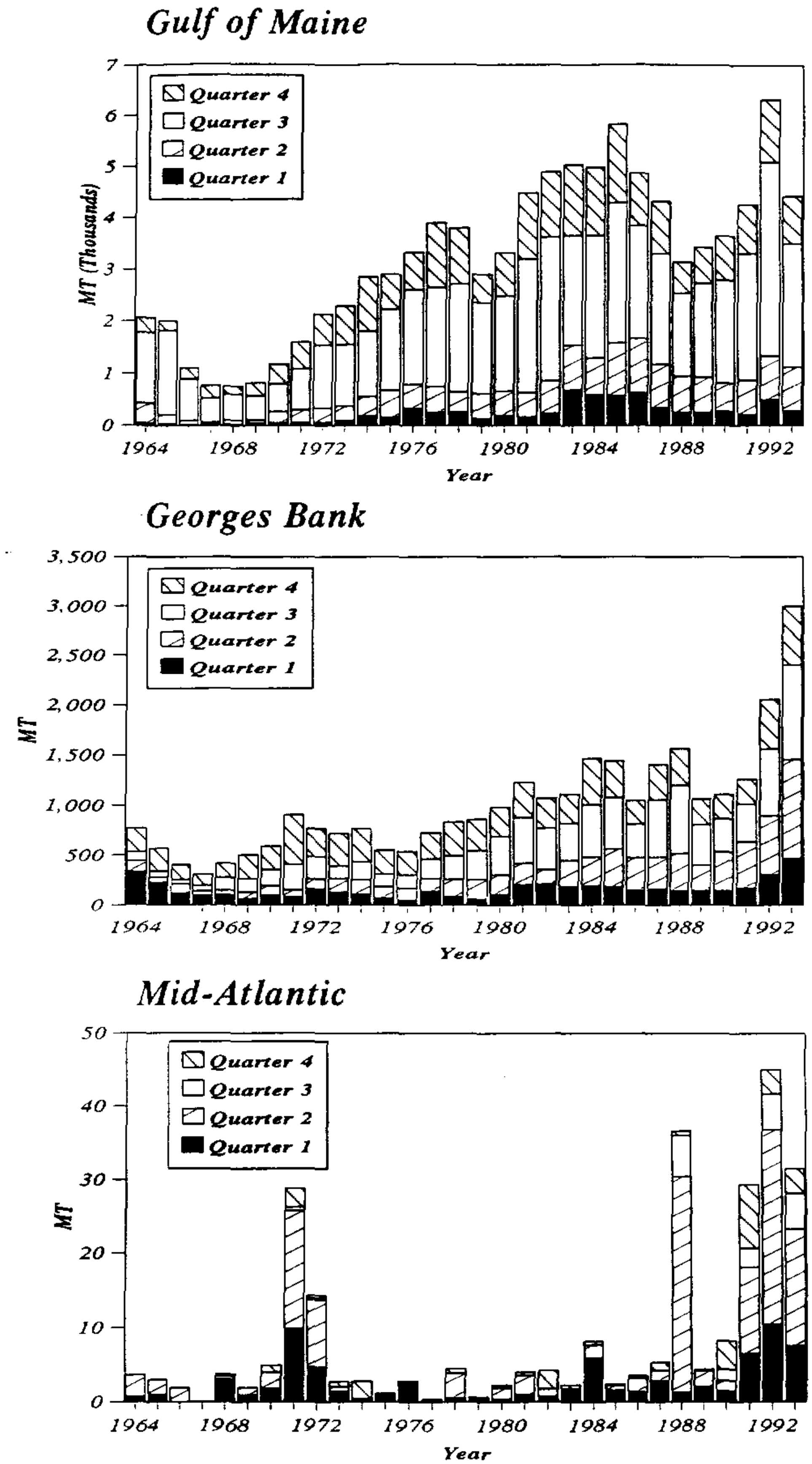

Figure B5. Landings of white hake by quarter in three areas: Gulf of Maine (SA 511-515, 464, 465), Georges Bank (SA 520-562), and the Mid-Atlantic (SA>=611).

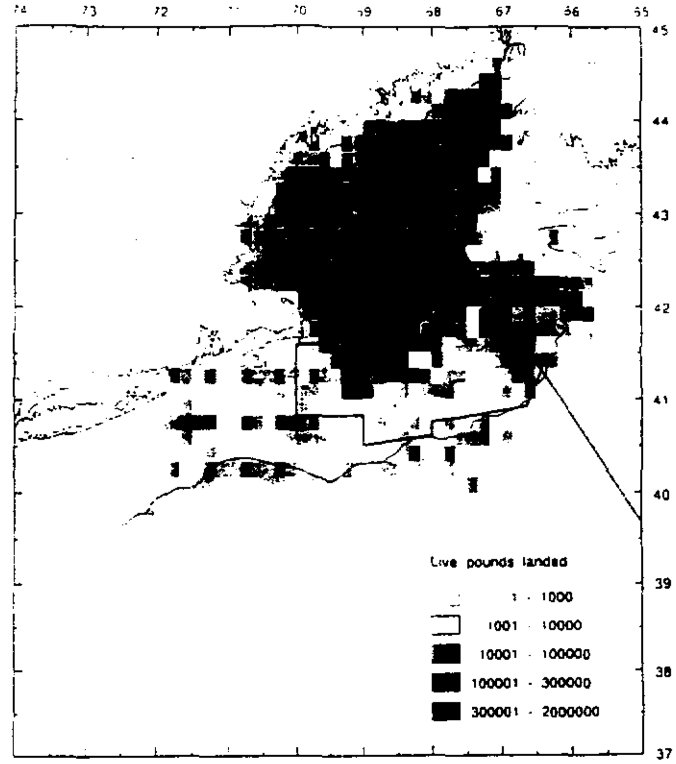

Figure B6a. Distribution of white hake landings in the otter trawl fishery during 1983-1987.

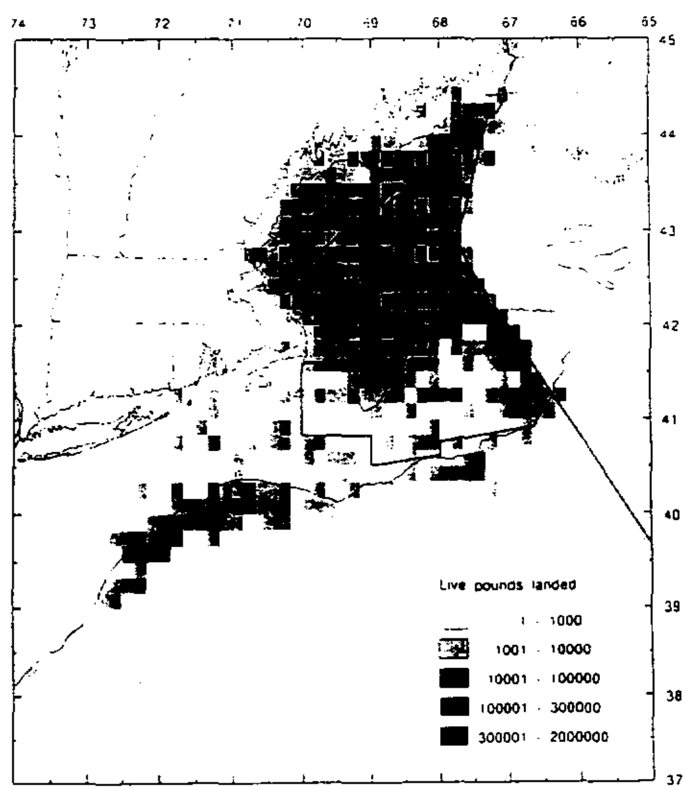

Figure B6b. Distribution of white hake landings in the otter trawl fishery during 1989-1993.

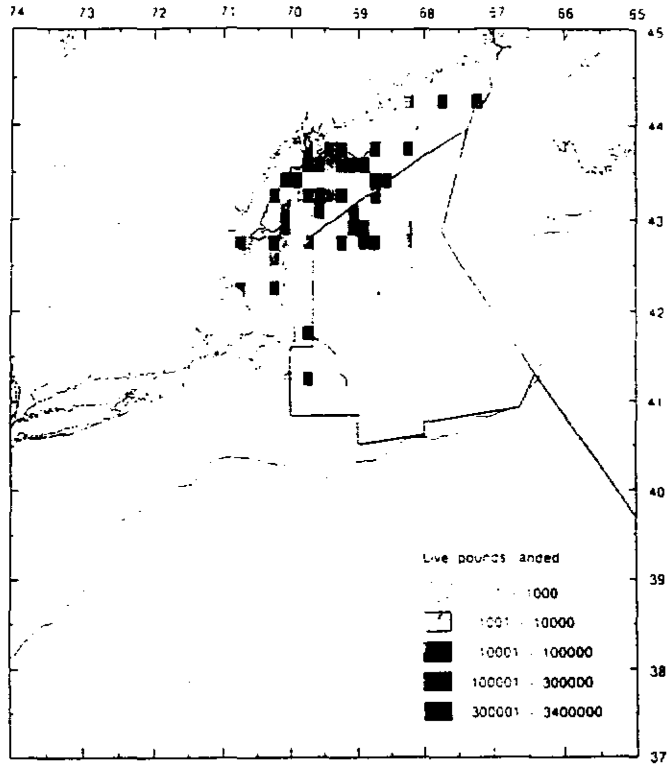

Figure B7a. Distribution of white hake landings in the sink gill net fishery during 1983-1987.

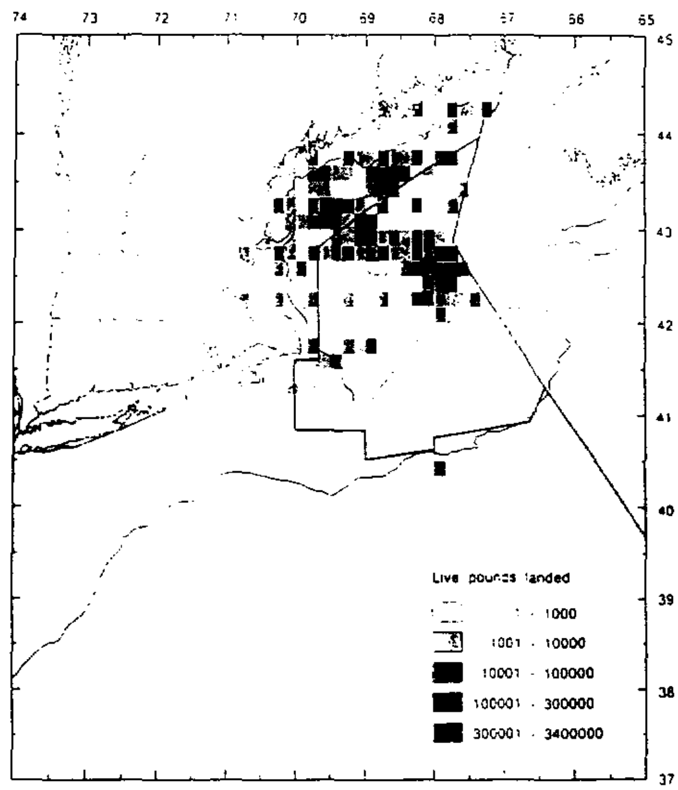

Figure B7b. Distribution of white hake landings in the sink gill net fishery during 1989-1993.

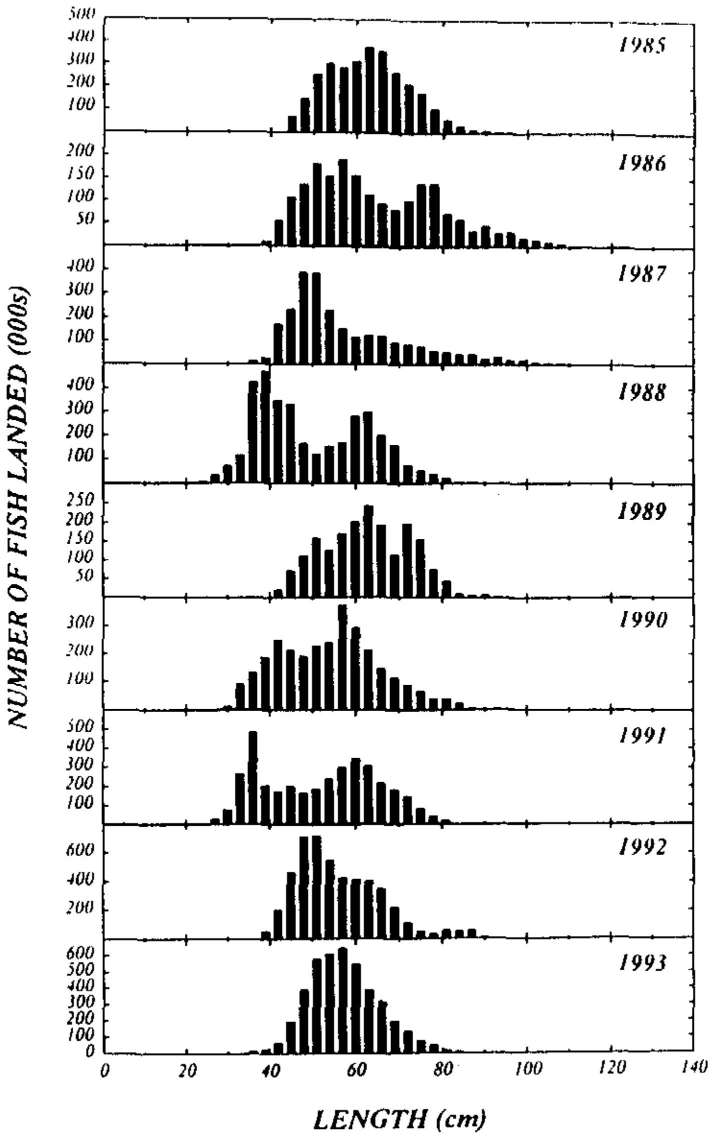

Figure B8. Commercial length for white hake for all gear types, 1985-1993

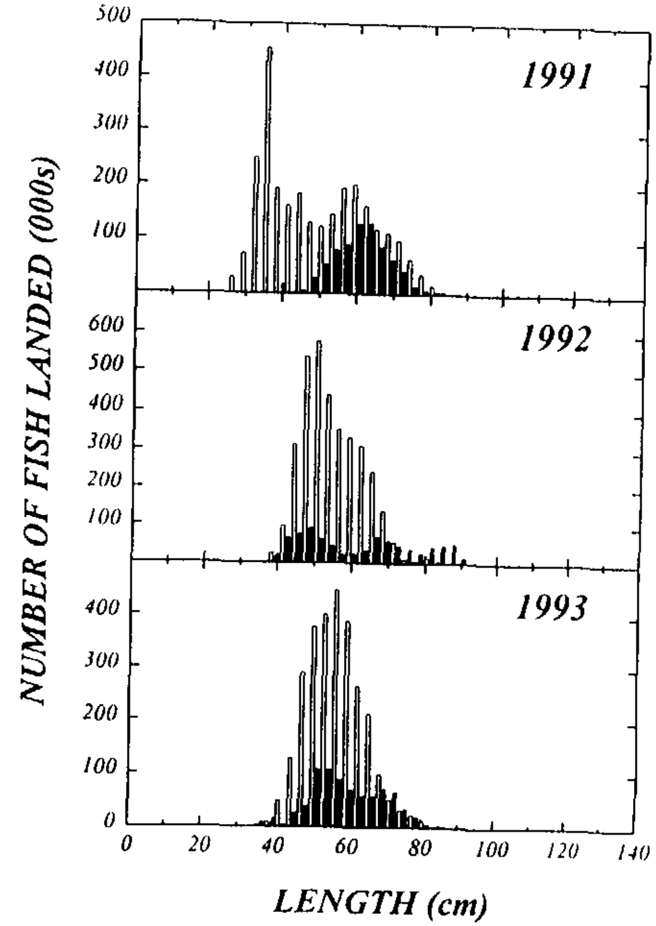

Figure B9. Commercial length frequencies by gear type, 1991-1993. The open bars represent otter trawls and the solid bars represent sink gill nets.

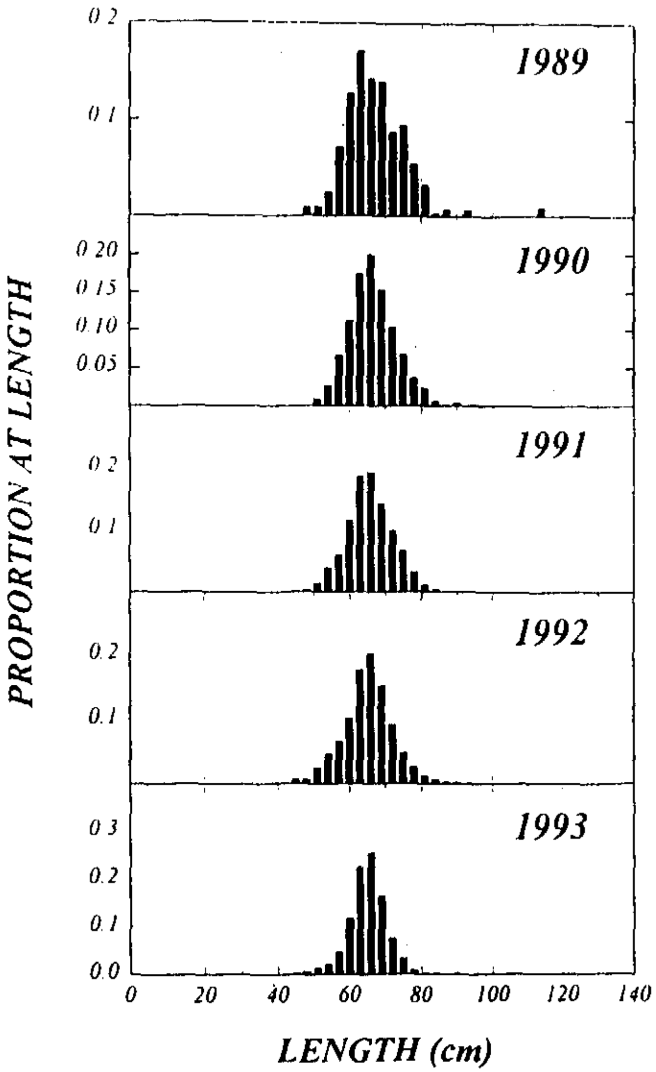

Figure B10. Length frequency composition of sea sampled sink gill net trips, 1989-1993.

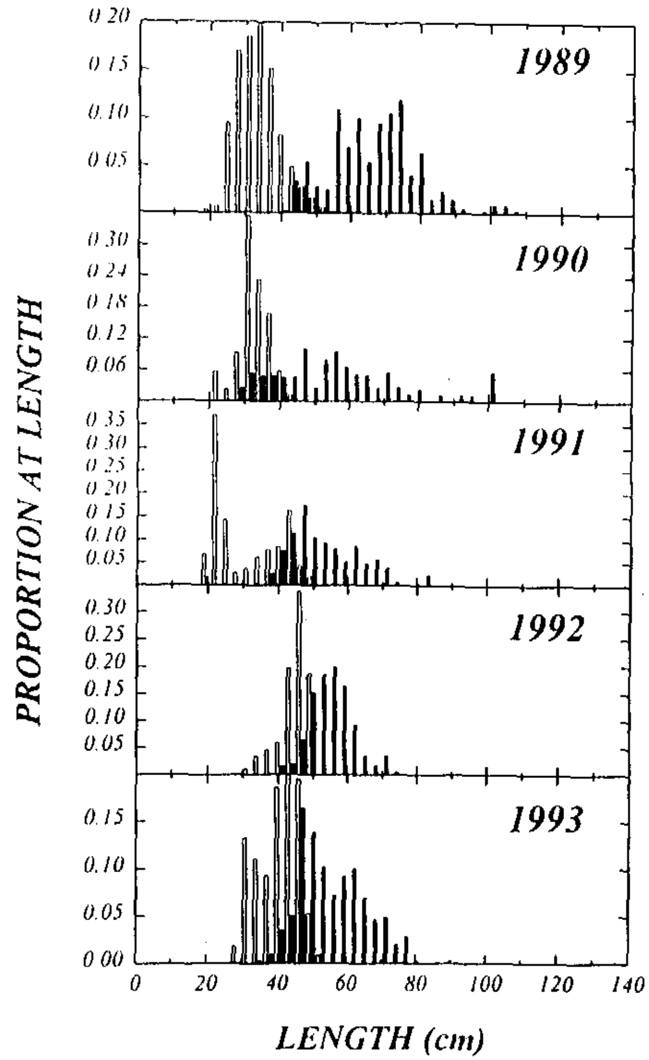

Figure B11. Length frequency composition of sea sampled otter trawl trips, 1989-1993. The open bars represent discards while the closed bars are the kept portion of the catch.

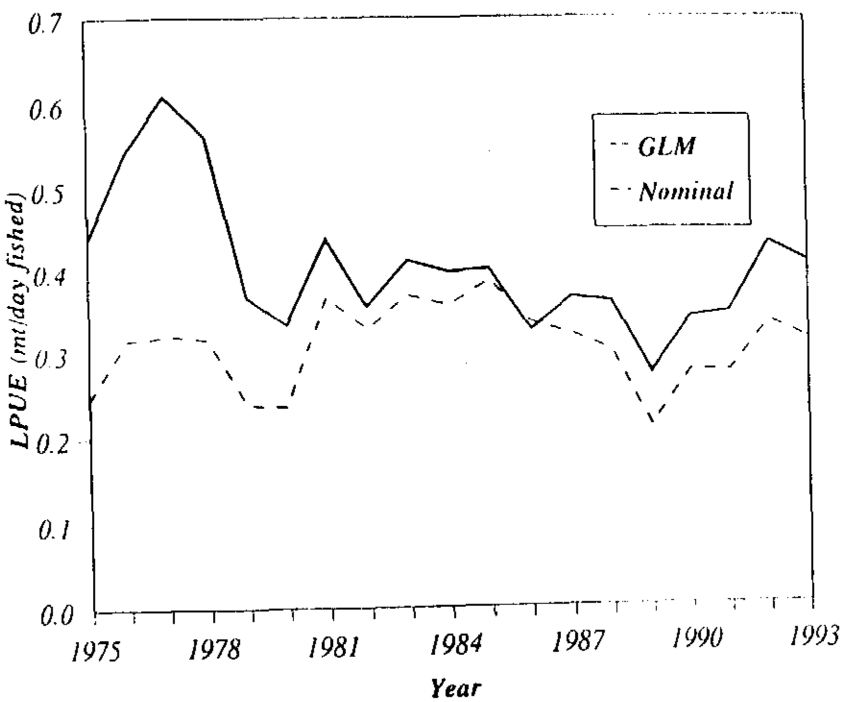

Figure B12. Nominal and standardized landings per day fished (LPUE) of white hake. LPUE was standardized with a general linear model whose factors were year, quarter, area, tonnage class, and depth.

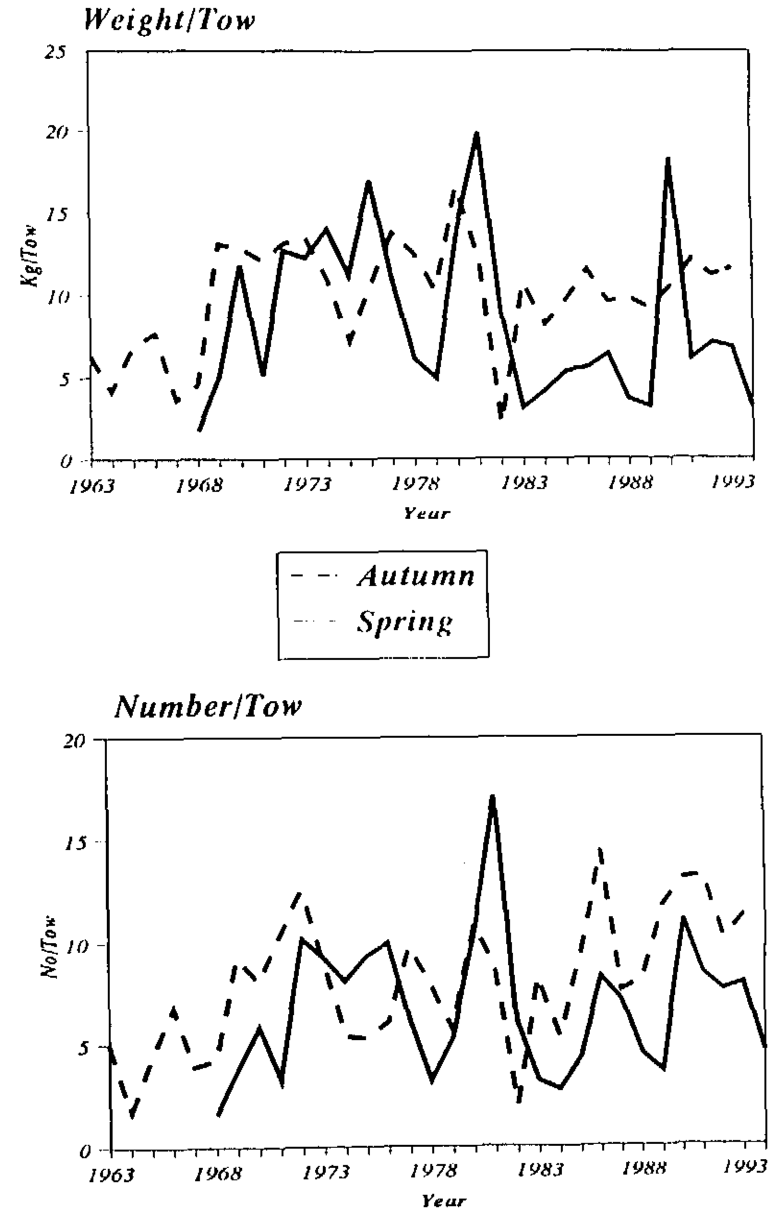

Figure B13. Indices of biomass and abundance from the NEFSC bottom trawl surveys from the Gulf of Maine to Northern Georges Bank (Strata 21-30, 33-40), 1963-1994.

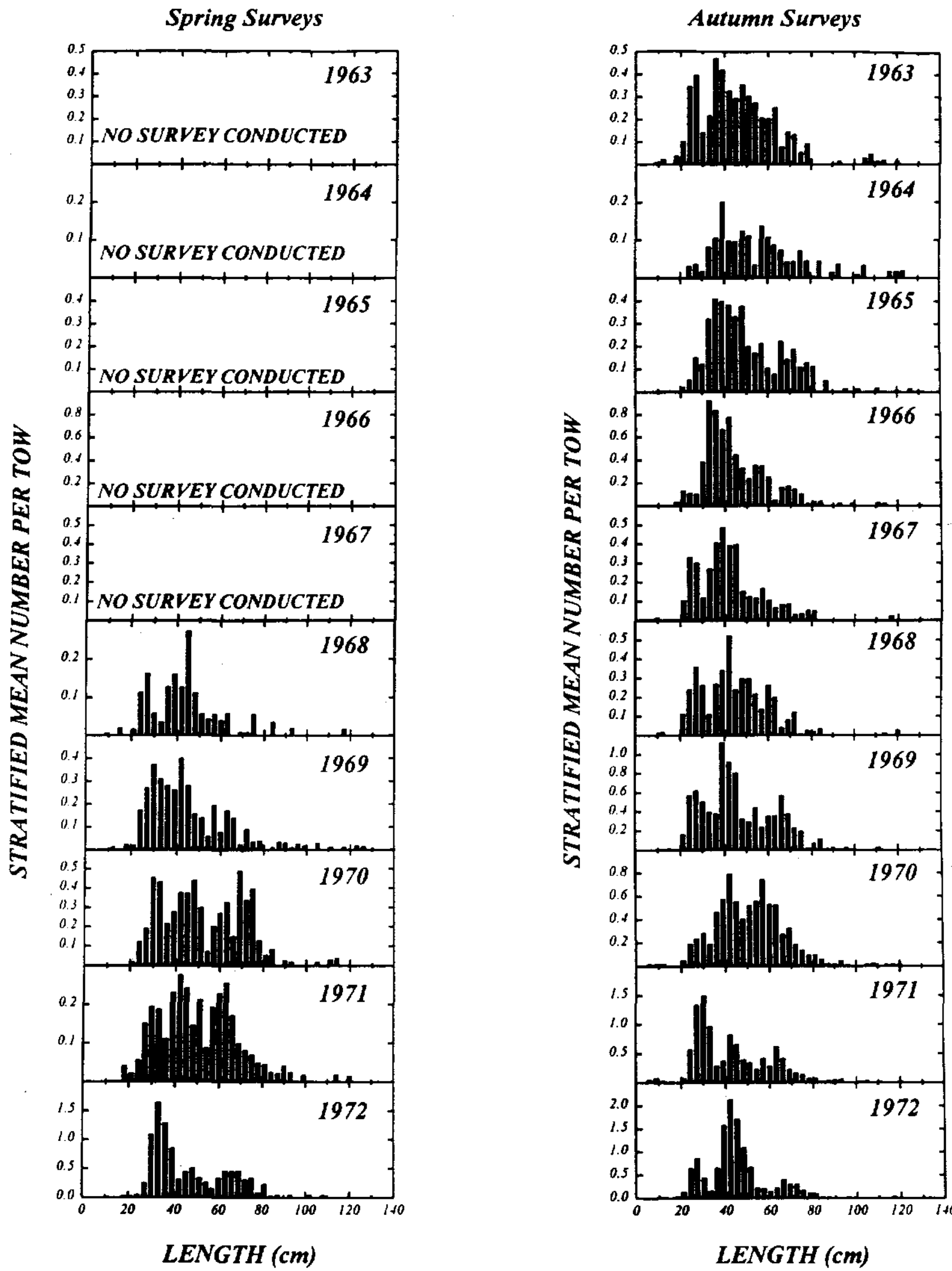

Figure B14. Length frequencies of white hake from the NEFSC bottom trawl surveys in the Gulf of Maine to Northern Georges Bank region, 1963-1994.

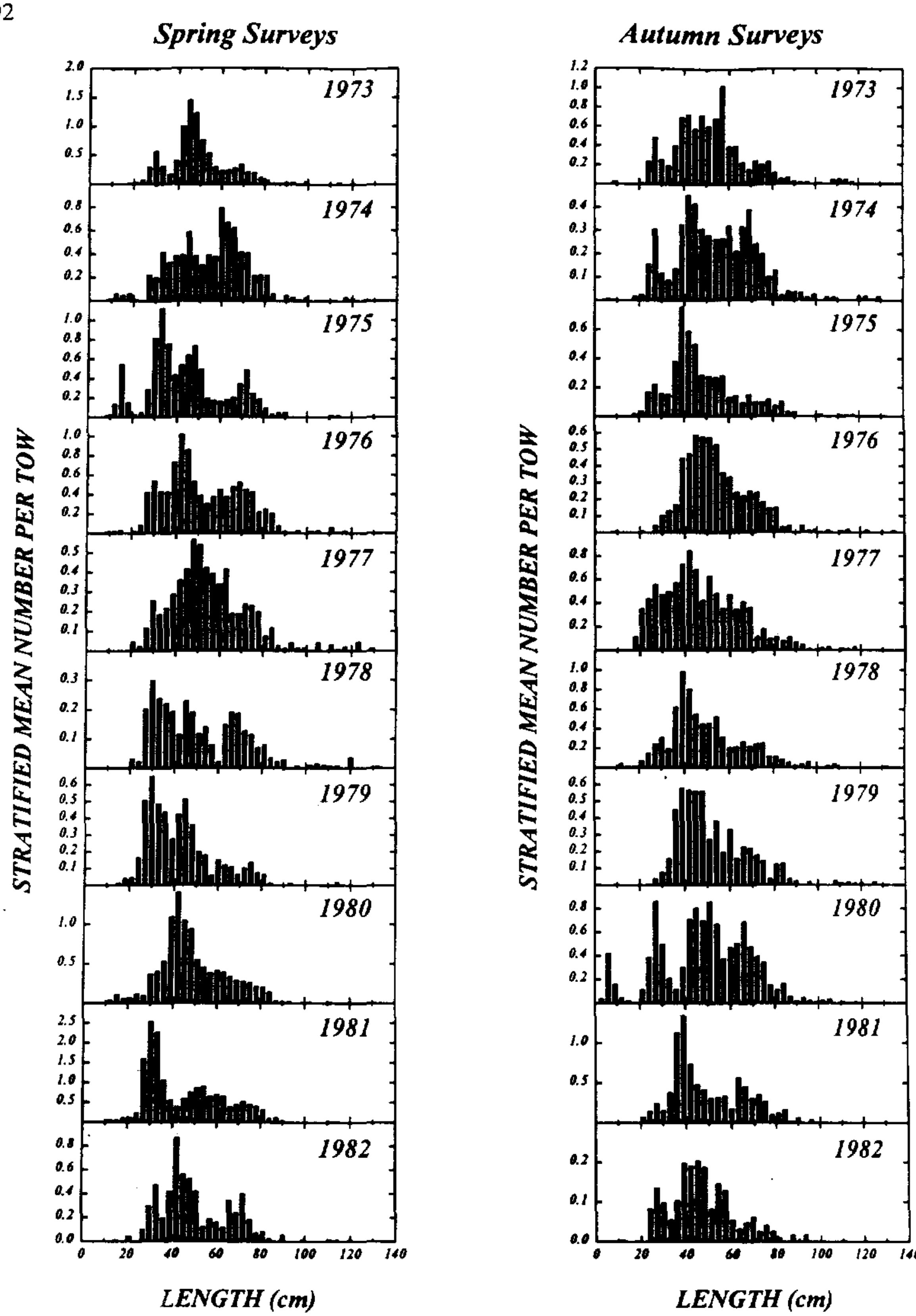

Figure B14. cont.

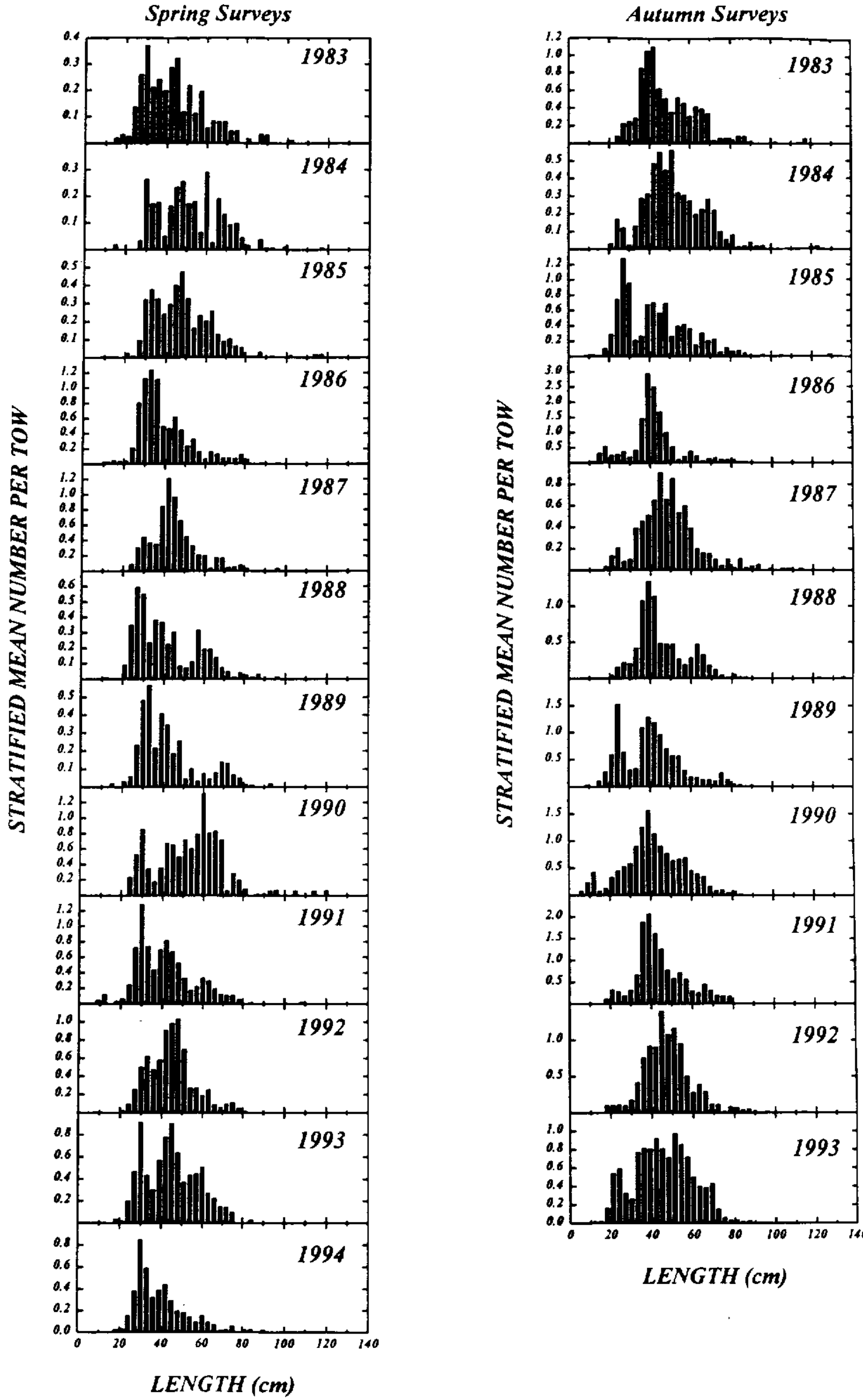

Figure B14. cont.

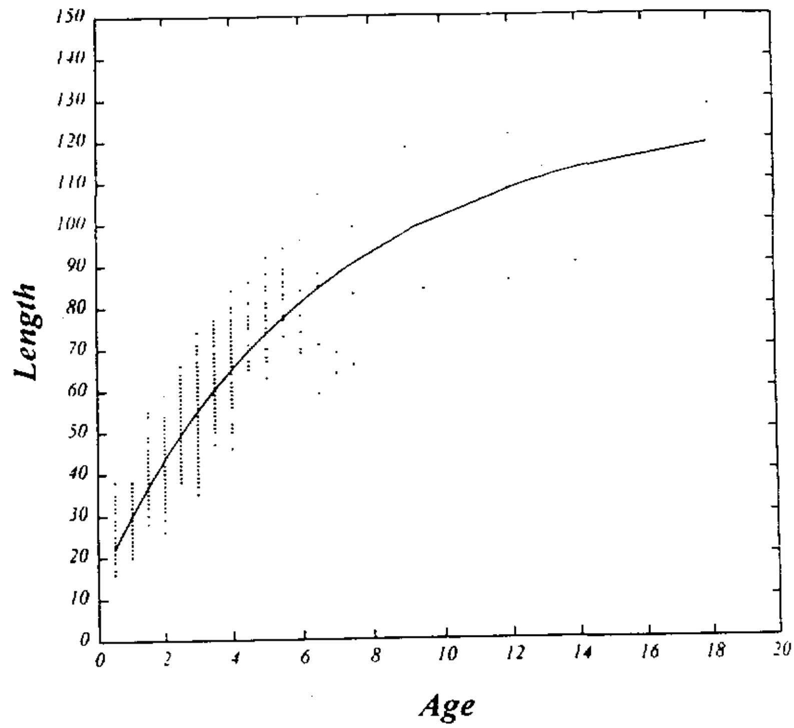

Figure B15. Von Bertalanffy Growth Curve for white hake, sexes combined.

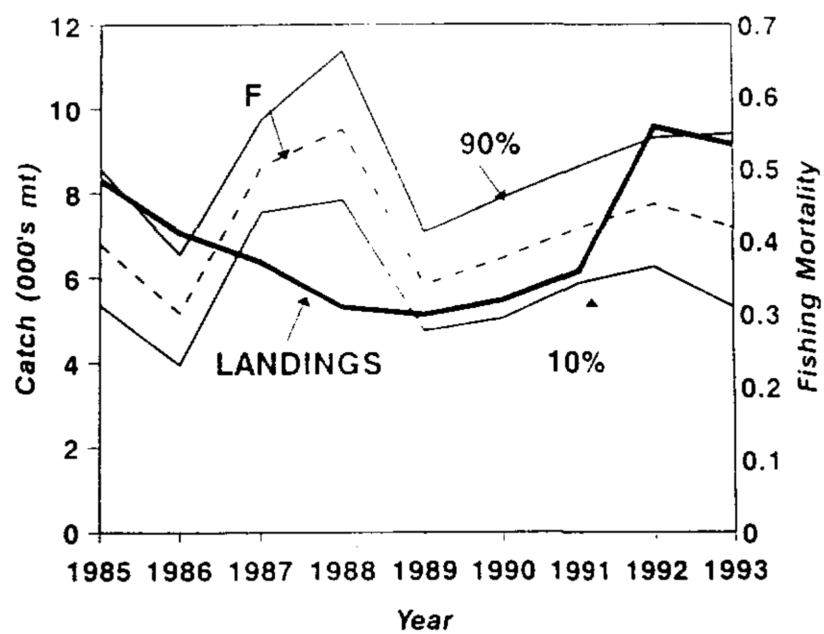

Figure B16. trends in commercial landings in numbers and fishing mortality estimated from the DeLury model. The 80% Confidence intervals for fishing mortality are also presented.

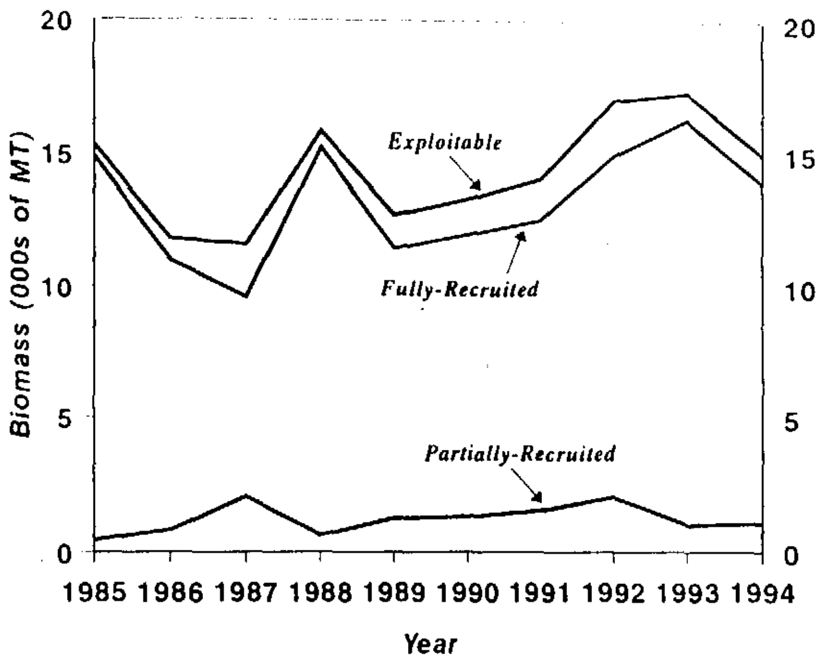

Figure B17. Trends in fully-recruited biomass and recruitment stock sizes from the DeLury model.

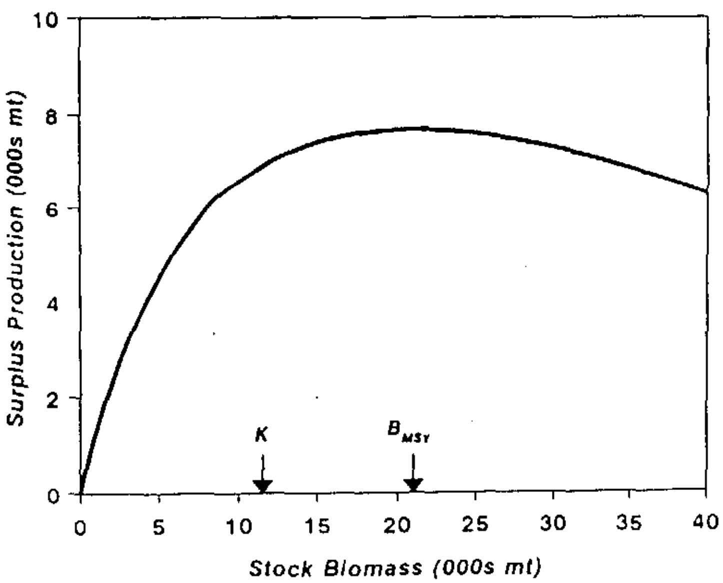

Figure B18. Surplus production curve showing surplus production values in relation to MSY and K.

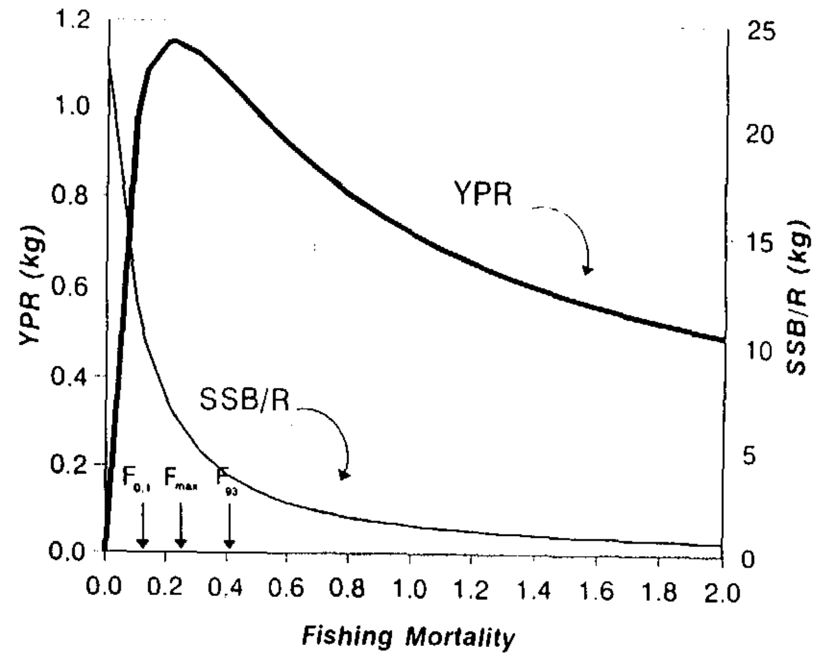

Figure B19. Yield and spawning Stock Biomass per Recruit of white hake.

C. SCUP

Terms of Reference

The following terms of reference were addressed:

a. Summarize landings, length composition, and available age/length data for the Cape Cod - Cape Hatteras stock of scup.

b. Summarize all available indices of stock abundance/biomass based on commercial and recreational CPUE and state and NEFSC survey catch per tow.

c. Attempt, if possible, to estimate the age composition (i.e., numbers at age) of recent scup landings.

d. Provide estimates of mortality using all available sources of data.

e. Review revised yield-per-recruit and spawning-stock-biomass-per-recruit analyses.

f. If possible conduct a full virtual population analysis (VPA).

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 in the winter. Sexual maturity occurs at age 2, with spawning occurring from May-August. Scup reach a maximum length of about 40 cm and a maximum age of about 20 years. Tagging studies have indicated the possibility of two stocks of scup, one in Southern New England and another extending south from New Jersey (Neville and Talbot, 1964; Cogswell, 1960, 1961; Hamer, 1970, 1979) . 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 and the Atlantic States Marine Fisheries Commission are in the process of developing a Fishery Management Plan for scup. The Council and Commission first considered development of a plan for scup as an amendment to the Summer Flounder FMP in January 1990. However, the development of a scup plan was delayed through a series of amendments to the Summer Flounder FMP and work on a separate Scup FMP was not resumed until 1993. The proposed 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 from 1930-1947 (Figure C1), averaged over 19,000 mt per year from 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 C1). Landings in 1993 were about 4,400 mt, 25% less than in 1992.

Distant water fleet landings (principally from the Southern New England area) were reported from 1963-1981 (Figure C1). Landings peaked at about 5,900 mt in 1963, averaged only about 1,100 mt per year from 1964-1975, and were only a few mt annually from 1976-1981.

Landings of scup in Rhode Island and New Jersey have accounted for about 65% of the total during 1979-1993, with Rhode Island averaging about 37% of the total and New Jersey about 28% 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 76% of the total catch during 1979-1993. The remainder of the commercial landings is taken by floating trap (13%), with paired 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 from 1989-1993 with between 29 and 91 otter trawl trips per year in which scup were landed or discarded (Table C2).

The intensity of length frequency sampling of discarded scup from sea sampling has declined in 1992-1993 relative to 1989-1991. A total of 7,359 lengths were obtained in 1989 compared to only 429 in 1993. 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 C2). In 1993, samples were collected from only 7 tows. Depending on how discard tonnage is estimated, this level of sampling corresponds to 100 lengths sampled per 330-500 mt in the past two years, less than the informal criterion of 100 lengths sampled per 200 mt. No age data are available from sea samples.

Analyses conducted for this assessment indicate that the NEFSC sea sampling data are currently inadequate to develop reliable estimates of discard at age in the commercial fishery. Initially, the effects on discard rates (mt of scup discarded per day fished) of year, quarter, fishery statistical area, fishery area (i.e., north and south of Delaware Bay), vessel tonnage class, and codend mesh size were evaluated based on analysis of variance. Effects of quarter and area were significant in various years, but no consistent pattern was observed. Rates of discard and landings per day fished were estimated by quarter-area combinations and then multiplied by total number of days fished observed from the NEFSC weighout data base to provide estimates of total landings and discard. Those landings estimates were significantly (>200% difference in all years) below those observed directly from the NEFSC weighout data base.

Alternative models were examined in which sea sampled trips were categorized into high or low landings levels, based on the distribution of landings rates observed in sea sampled and NEFSC weighout trips. Inspection of frequency distributions indicated that 70-85% of the sea sampled trips and 66-72% of the weighout trips landed less than 0.3 mt/day fished between 1989-1993; and 75-83% of the sea sampled trips and 68-75% of the weighout trips landed less than 0.3 mt per trip. When rates of discard and landings per day fished were calculated by landings level and half-year, the correspondence between estimates of total landings and landings observed from the weighout data base improved. An estimate based on a geometric mean provided only a 25-66% underestimate of annual landings relative to observed weighout levels, while estimates based on arithmetic means differed from observed levels by 10-142%. Estimates based on bias-corrected geometric means differed from observed levels by 2-214% depending on the year. Corresponding estimates of discards similarly varied widely from year to year, depending on the method of calculation.

Ratios of discards/landings by landings level 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 (Pelagic/Coastal Subcommittee, 1995). To reflect discards in components of the fishery not included in the weighout data base (general canvas and North Carolina), the estimate of discard (by half year) was raised by the ratio of total commercial landings (by half year) to weighout landings.

The poor correspondence between landings estimated from sea sampling and landings observed from the weighout data base may stem from at least three sources: 1) inadequate sampling of some components of the fishery (e.g., freezer trawlers, trips landing large quantities of scup; 2) highly variable behavior in fishery (e.g., landings and discard of scup driven by market conditions or landings or availability of other species); and 3) inappropriate model specification (e.g., estimation of scup discard as a function of scup landings rather than scup abundance or effort for or landings of squid or summer flounder).

Examples of estimated discard at age are given in Anon. (1995). For 1989-1993, the total weight (mt) of discard was estimated from the observed ratios of discard to landings, 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 from 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. In 1989-1990, discard was composed primarily of age 2 fish, followed by age 1 fish. In 1991, most discards were age 1, while in 1992, observed discards were dominated by age 2 fish. In 1993, discards were mainly ages 0 and 2, with the amount at age 0 being relatively high.

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 1979-1993. 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 1979-1993 ranged between 1,200 and 5,900 mt (Table C1) and averaged about 2,750 mt per year. The 1993 estimate was 1,341 mt, a 36% decrease from 1992. 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 (type B2) in weight during 1979-1993 ranged from 28 mt in 1979 to a high of 748 mt in 1986, while averaging about 280 mt per year (Table C3). The 1993 estimate was 188 mt, 50% less than in 1992. Mortality due to discarding in the recreational fishery has been reported to range from 0-15% (Howell and Simpson, 1985) and from 0-13.8% (Williams, pers. comm.). Howell and Simpson (1985) 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 rates in the recreational fishery between 5% and 15% appear reasonable. For this assessment, the Subcommittee assumed 15%. Estimates of the amount of discarded scup in the recreational fishery which suffered mortality varied between 4 and 112 mt and averaged 42 mt per year (Table C3).

Total Catch

Estimates of the total catch of scup during 1984-1993 are given in Table C3. These estimates include commercial and recreational landings and discards. The total catch during this period varied from a high of nearly 15,000 mt in 1986 to a low of about 7,200 mt in 1993. The total catch decreased by nearly 50% from 1992 (13,900 mt) to 1993.

During this 10-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 1979-1993 is summarized in Table C4, (for additional details see Pelagic/Coastal Subcommittee1994). In the commercial fishery, annual sampling intensity varied from 60-481 mt per 100 lengths. In nearly all years, the overall sampling exceeded the informal criterion of 100 lengths sampled per 200 mt.

In the recreational fishery, sampling intensity varied from 48-443 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.

Age Compositions

Numbers at age were estimated for 1984-1993 for the commercial landings (separately for Maine - Virginia, i.e., NEFSC weightout landings, and North Carolina), commercial discards, recreational landings, and recreational discards (Pelagic/Coastal Subcommittee, 1995). The combined numbers at age for the total catch are given in Table C5. 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. 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.

Mean weights at age for the commercial landings, commercial discards, recreational landings, and recreational discards for 1984-1993 are given in Pelagic/Coastal Subcommittee (1995), with the mean weights at age for the total catch given in Table C6.

Stock Abundance and Biomass Indices

Commercial LPUE

A general linear model (GLM) (SAS, 1985) of commercial landings per unit effort (LPUE) was used to develop a standardized index of scup abundance (Table C7). Landings of scup per day fished were calculated from interviewed trips where scup contributed at least 5% of the total landed weight of the trip, as recorded in the Northeast Region commercial weighout data base from 1973-1993. The GLM included effects of year, tonnage class, two-digit statistical area, and quarter, with tonnage class 4, area 63, quarter 4 in 1993 serving as the standard cell. The model explained 30% of the variance in observed LPUE over the period.

The LPUE indices for 1973-1993 (nominal and GLM values) are plotted in Figure C2 and indicate a steady downward trend from a peak in 1978 and an index fluctuating around the historic low since the late 1980s.

Research Vessel Survey Indices

NEFSC and state surveys

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. Details on the gear and methods employed in the respective state surveys are given in Pelagic/Coastal Subcommittee (1995).

Mean weight-per-tow indices for the NEFSC spring and autumn, Massachusetts spring, Rhode Island spring/autumn and Connecticut spring/autumn surveys time series are depicted in Figure C3. The catch-per-tow in numbers at age from these surveys (Pelagic/Coastal Subcommittee, 1995) were utilized as input in the tuning model for virtual population analysis.

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 of scup can influence the availability of scup and the effectiveness of the various surveys in providing 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. The Subcommittee examined 1) the average catch per tow in number at each age and 2) the average catch per tow in weight (ages combined) to determine if the indices exhibited comparable trends and patterns. Graphical (SPLOM plots) and statistical analyses (paired Spearman correlations) were used to examine these relationships. No strong positive relationships were observed using graphical methods. Spearman correlations indicated sporadic significant relationships, but these were not consistent between ages and no strong trends emerged. The Subcommittee agreed that the 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, the Subcommittee agreed to include all relevant indices in the ADAPT tuning model for estimating stock size and fishing mortality.

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).

Total Mortality

Instantaneous total mortality (Z) was estimated from available state and NEFSC survey catch-at-age data using the pooled cohort (age $3+_{t+1}$/age $2+_t$) method (Pelagic/Coastal Subcommittee, 1995). Estimates of fishing mortality (F) were obtained by subtracting M = 0.20. The Rhode Island autumn survey is dominated by age 0-1 fish, with few older fish. Mortality rates calculated from the autumn Rhode Island data reflect the low availability of age 2+ fish to the survey gear. Massachusetts spring survey mortality estimates range from F = 0.42 (31% exploitation) to F = 3.46 (92% exploitation). The NEFSC spring survey ranges from F = 0.83 (52% exploitation) to F = 5.15 (96% exploitation) and the NEFSC autumn survey fishing mortality estimates range from 1.04 (60% exploitation) to 3.06 (90% exploitation). The Connecticut spring/autumn survey-based fishing mortality estimates range from 0.73 (48% exploitation) to 3.25 (91% exploitation). Mean annual mortality estimates calculated excluding Rhode Island (due to low availability of age 2+ fish) are consistently over F = 1.0 (58% exploitation) and are as high as F = 2.4 (86% exploitation) in some years.

Although mortality estimates from the surveys are highly variable, annual means suggest that fishing mortality has been above F = 1.0 (58% exploitation) during the 1984-1992 time period.

Virtual Population Analysis

Tuning

Numbers at age on 1 January 1994 and corresponding fishing mortality (F) rates in 1993 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 age 6 and older. Stock sizes in 1994 were directly estimated for ages 1-4, with abundance of age 5 and 6+ calculated from F estimated for age 4 in 1993. Stock size at age 0 in 1994 could not be estimated because no 1994 survey indices of age 0 abundance were available. Initial partial recruitment patterns from separable virtual population analysis 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 spring-autumn survey, ages 0-4
6) CTDEP spring-autumn survey, ages 0-5
7) VIMS autumn survey, age 0
8) NEFSC winter trawl survey, ages 1-4

Spring and NEFSC winter survey indices at age were compared to stock sizes at age 1 in 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. Various sensitivity runs were made to examine the effect of excluding discards, excluding some of the survey indices, and employing certain analytical options (for details see Pelagic/Coastal Subcommittee, 1995). The Subcommittee inspected residual patterns and partial variances contributed by individual indices and eliminated the MADMF spring age 1, RIDFW age 2-4, NEFSC spring age 4, and NEFSC winter age 1-4 indices based on high partial variances, and CTDEP age 0 based on a trend in residual patterns. Because the Subcommittee felt that there was 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 in the final run ranged from 33-44% and increased to 82% for estimates of age 4 abundance. Approximate coefficients of variation for survey catchability coefficients ranged from 28-47%. Absolute values of correlation coefficients between estimated parameters were all less than 0.23, with nearly all below 0.15. No trends in standardized residuals were observed. Summary results are presented in Table C8.

The SARC examined two additional sensitivity runs to determine the effect of excluding discards, excluding additional survey indices, and including the commercial LPUE indices. The results were within the range of values from the various runs made by the Subcommittee and provided no basis for rejecting the results of the run submitted by the Subcommittee.

Exploitation pattern

The exploitation pattern has been variable from year to year, but full recruitment has occurred between ages 2-3 from 1989-1993, influenced by the magnitude of annual commercial discard-at-age patterns. An average exploitation pattern was calculated as the ratio of the geometric means (1989-1993) 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, 4% recruitment at age 0, 22% at age 1, and 91% at age 2. For the purposes of yield-per-recruit calculations and catch and stock biomass projections, full (100%) recruitment was assumed at ages 2 and older.

Fishing mortality

Fishing mortality (F) rates averaged over ages 2-5 were above 1.0 every year from 1984-1993, except in 1990 when F was 0.96 (Figure C4). Mean F peaked at 2.13 in 1988 and has fluctuated around 1.3 in the past three years.

Spawning stock biomass

Spawning stock biomass (SSB) has fluctuated widely between 1984-1993, but appears to have trended downward, with the 1992-1993 levels similar to the low levels observed in 1988-1989 (Figure C5). SSB in 1993, as estimated in this analysis, is at a record low for the 1984-1993 series.

Recruitment

Recruitment estimates are highly dependent on the estimates of commercial discards at age 0, but results of the current assessment indicate a downward trend from high levels of 140 million in 1984-1985 to a low of 60 million in 1989 (Figure C5). The 1991-1992 year classes are estimated to be below the 1984-1993 average (91 million, GM) at 67 million and 72 million, respectively, while the 1993 year class is estimated to be slightly higher than average, at 92 million.

The recruitment estimates should be interpreted with caution, as the sampling intensity providing the basis for the estimates of commercial discards contributing to this segment of the estimate is very low or non-existent.

Precision of F and SSB estimates

A comparison between catch biomass as calculated in the VPA and total catch (including reported commercial landings, estimated recreational landings, and estimated commercial and recreational discards) is presented in Table C9.

The precision of the 1993 F and SSB estimates from VPA was evaluated using bootstrap techniques (Ephron, 1982). Two hundred bootstrap iterations were produced, in which errors (differences between predicted and observed survey values) were resampled. Estimates of precision and bias are presented in Pelagic/Coastal Subcommittee (1995). Bootstrapped estimates of spawning stock biomass indicate a CV of 25%, with low bias (bootstrap mean estimate of spawning stock biomass of 4,794 mt compared with VPA estimate of 4,641 mt). A total of 90% of the bootstrapped estimates of spawning stock biomass were below 6,000 mt (Figure C6).

The bootstrap estimates of standard error associated with fishing mortality rates indicate low precision. Coefficients of variation for F estimates ranged from 43% at age 0, 29% at age 1, 24% at age 2, and 79% at ages 3 and older. There was an indication of a positive bias as high as 19% at ages 3 and older. The bootstrap mean estimate of 1.08 was lower than the point estimate from the VPA. There is almost no chance that F in 1993 was below 0.4 (Figure C7).

Biological Reference Points

Yield and Spawning Stock Biomass per Recruit

The Mid-Atlantic Fishery Management Council (MAFMC) and Atlantic States Marine Fisheries Commission (ASMFC) have jointly adopted an F_{max} overfishing definition. During the course of developing a Fishery Management Plan for scup, the ASMFC Scup/Black Sea Bass Technical Committee did some yield-per-recruit (Y/R) and spawning-stock-biomass-per-recruit (SSB/R) analyses under various combinations of codend mesh size and minimum fish lengths in both the recreational and commercial fisheries (see Pelagic/Coastal Subcommittee (1995).

The Subcommittee re-calculated Y/R and SSB/R using the Thompson and Bell (1934) model. Partial recruitment was estimated from the exploitation pattern observed from 1989-1993 (see above). Mean weights at age in the spawning stock and catch were estimated as weighted (by the fishery) arithmetic means of the 1989-1993 values for landings and discards. Proportion mature at age was estimated from NEFSC research vessel survey data (Almeida, pers. comm.). Natural mortality was assumed to be 0.20. The proportion of fishing mortality and natural mortality occurring before spawning was 0.417, equivalent to peak spawning at 1 June, with mortality uniform over the year. The analysis indicated that $F_{0.1}$ = 0.141, F_{max} = 0.236, and $F_{20\%}$ = 0.284, with yield including both landings and discard (Table C10). At F_{max}, about 24% of the maximum spawning potential (%MSP) is obtained, while at $F_{0.1}$, 39% MSP is obtained.

Projections of Catch and Stock Biomass

Catch and stock biomass projections were not made. The estimates of fishing mortality and stock size at age at the beginning of 1994, determined by VPA, were characterized by unacceptably low precision and were considered by the SARC to provide an unreliable basis for any forecasts. There was also no information on recruitment levels which might be expected in 1994 and subsequent years and on which any projections of catch and stock biomass would be heavily dependent. However, if both fishing mortality and recruitment remain at current levels, catch and SSB will remain near the record-low levels estimated for 1993.

Conclusions

The results of analyses presented in this report indicate that the scup stock is overexploited 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 VPA and survey catch curve analysis in excess of 1.0, declines in commercial LPUE indices to low levels in the late 1980s, and declining trends in spawning stock biomass as estimated by VPA. Current biomass levels are below the levels of landings observed in the 1950s. In spite of the uncertainty in the VPA results arising from uncertain quantities and age compositions of commercial discards, the estimated levels of fishing mortality are far in excess of the biological reference points, including F_{max}.

Research Recommendations

- Increased and more representative sea and port sampling of the various fisheries in which scup are caught (both as a targeted and non-targeted species) is needed to adequately characterize the length composition of both landings and discards. The current level of sampling, particularly of the discards, seriously impacts the ability to reliably assess this stock and provide forecasts of catch and stock biomass. Particular emphasis is placed on the need to obtain sea samples from freezer trawlers from which no samples have been collected in the past five years.

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

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

- The assumption by the Subcommittee of 100% commercial discard mortality is based on limited observations and is a point of some contention between scientists and fishermen. Studies to better characterize the mortality of scup in different gear types should be conducted to more accurately assess discard mortality.

- o Given the low number of age groups represented in the present catch-at-age matrix for scup as well as the uncertainty associated with the age compositions of catches, primarily the discarded portion, consideration should be given to the future use of non-age-based assessment methods (e.g., DeLury).

- o Commercial LPUE data should be investigated further as a possible tuning index for scup, including spatial variations and confounding effects.

- o In light of evidence indicating that scup biomass is currently at a record low level, investigations on the trophic relationships of scup should be conducted. Investigators from outside the NEFSC, including university investigators, may wish to conduct such research.

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Table C1. Landings (mt) of scup from Maine through North Carolina, 1979-1993.

Year	Commercial	Recreational	Total
1979	8,584	1,198	9,782
1980	8,424	3,109	11,533
1981	9,856	2,068	11,924
1982	8,703	3,100	11,803
1983	7,794	3,432	11,226
1984	7,769	1,434	9,203
1985	6,726	3,282	10,008
1986	6,918	5,908	12,826
1987	6,069	2,980	9,049
1988	5,728	2,414	8,142
1989	3,716	3,248	6,964
1990	4,317	2,007	6,324
1991	6,867	3,634	10,501
1992	5,980	2,110	8,090
1993[1]	4,438	1,341	5,779

[1]Provisional.

Table C2. Summary of sampling in the Northeast Region sea sampling program, 1989-1993. 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 (including general canvas and North Carolina landings) are reported in Table C7.

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	29
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

Table C3. Total catch (mt) of scup from Maine through North Carolina, 1984-1993.

Year	Commercial landings	Commercial discards[1]	Recreational landings	Recreational discards[2]	Total catch
1984	7,769	2,152[3]	1,434	37	11,392
1985	6,726	4,188[3]	3,282	67	14,263
1986	6,918	2,004[3]	5,908	112	14,942
1987	6,069	2,539[3]	2,980	42	11,630
1988	5,728	1,661[3]	2,414	34	9,837
1989	3,716	2,173	3,248	40	9,177
1990	4,317	3,877	2,007	50	10,251
1991	6,867	3,535	3,634	68	14,104
1992	5,980	5,749	2,110	57	13,896
1993	4,438	1,434	1,341	28	7,241

[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]Extrapolated from 1989-1993 data.

Table C4. Summary of the sampling intensity for scup in the commercial and recreational fisheries, 1979-1993.

	Commercial fishery				Recreational fishery			
Year	No. of samples	No. of lengths	Weighout landings (mt)	Sampling intensity (mt/100 lengths)	No. of samples	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

Table C5. Total catch at age (numbers in 000's) for scup from Cape Cod to North Carolina, 1984-1993.

	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11	Total
1984	123	17935	14415	8613	6303	1745	606	267	1	-	-	-	50009
1985	53241	22466	16692	10097	3256	643	907	308	10	-	-	-	107621
1986	587	6264	43806	7084	2429	711	282	513	13	-	-	-	61689
1987	251	11121	27400	13030	2541	490	525	47	18	-	-	17	55441
1988	1601	2745	20913	12561	3350	356	261	177	7	-	-	-	41971
1989	731	14449	22299	8747	1071	145	220	128	7	-	-	-	47796
1990	1041	12439	31505	10799	693	175	129	64	-	5	-	-	56850
1991	2196	24627	19669	16082	3277	146	228	92	-	2	-	-	66320
1992	38999	13622	39505	2713	2161	2182	174	62	-	3	-	-	99420
1993	5519	3525	20345	4908	1404	292	40	13	-	1	-	-	36047

Table C6. Total catch mean weight at age (kg) for scup from Cape Cod to North Carolina, 1984-1993.

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10	11
1984	0.037	0.117	0.169	0.288	0.365	0.450	0.781	1.050	1.545	-	-	-
1985	0.033	0.117	0.180	0.289	0.432	0.604	0.770	1.242	1.545	-	-	-
1986	0.049	0.105	0.199	0.357	0.629	0.667	1.036	1.252	1.573	-	-	-
1987	0.032	0.111	0.176	0.250	0.440	0.624	0.784	1.258	1.068	-	-	1.0007
1988	0.033	0.112	0.174	0.262	0.478	0.704	0.835	1.307	1.545	-	-	-
1989	0.037	0.084	0.147	0.275	0.431	0.673	0.718	1.175	1.545	-	-	-
1990	0.032	0.130	0.165	0.238	0.441	0.626	0.685	1.165	-	1.096	-	-
1991	0.056	0.130	0.201	0.277	0.393	0.696	0.775	0.862	-	1.096	-	-
1992	0.033	0.099	0.164	0.369	0.445	0.442	0.768	2.018	-	1.096	-	-
1993	0.028	0.124	0.198	0.304	0.485	0.657	0.833	1.330	-	1.096	-	-

Table C7. General Linear Model (GLM) of commercial weighout landings and effort. Data based on trips landings >5% scup, 1973-1993, to develop a standardized index of abundance. Variation in LPUE modelled as result of year (YR), vessel tonnage class (TC), two-digit statistical area (AR), and calendar quarter (QTR); main effects model, no interactions. Retransformed corrected YR parameter estimates are used as indices of stock biomass.

Dependent variable: Ln LPUE

Source	DF	SS	MSE	F	R_2
Model	29	9,595.5	330.5	165.3	0.30
Error	11,172	22,344.1	2.0		
Total	11,201	31,929.6			

Model SS

Variable	DF	Type III SS	F	PR>F
YR	20	1,332.5	33.31	0
TC	2	1,517.8	379.45	0
AR	4	920.7	115.09	0
QTR	3	1,058.6	176.43	0

Year	YR Coefficient	Standard error of estimate	Retransformed coefficient
1973	0.359	0.123	1.443
1974	0.383	0.105	1.475
1975	0.061	0.093	1.068
1976	0.252	0.101	1.293
1977	0.843	0.089	2.333
1978	0.991	0.091	2.677
1979	0.764	0.093	2.157
1980	0.662	0.092	1.947
1981	0.333	0.086	1.400
1982	0.746	0.078	2.114
1983	0.638	0.088	1.899
1984	0.567	0.087	1.769
1985	0.129	0.082	1.141
1986	0.110	0.080	1.120
1987	0.229	0.082	1.262
1988	0.105	0.085	1.115
1989	-0.237	0.091	0.792
1990	-0.192	0.087	0.828
1991	0.134	0.094	1.149
1992	-0.202	0.089	0.820
1993	0.000		1.000

Table C8. Results of virtual population analysis for scup, 1984-1994.

FISHING MORTALITY

■	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
0 ■	0.00	0.54	0.01	0.00	0.02	0.01	0.01	0.04	0.92	0.07
1 ■	0.40	0.25	0.11	0.24	0.05	0.19	0.33	0.35	0.34	0.18
2 ■	0.61	0.82	1.12	0.94	1.00	0.65	0.85	1.43	1.76	1.32
3 ■	0.94	1.28	1.07	1.39	2.09	2.16	0.79	1.79	0.77	1.32
4 ■	1.93	1.28	1.43	1.85	2.89	1.34	1.36	0.58	1.69	1.32
5 ■	1.23	1.34	1.19	1.53	2.55	2.25	0.82	1.35	1.03	1.32
6 ■	1.23	1.34	1.19	1.53	2.55	2.25	0.82	1.35	1.03	1.32

Avg F for ages 2-6

■	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
■	1.19	1.21	1.20	1.45	2.22	1.73	0.93	1.30	1.26	1.32

BACKCALCULATED PARTIAL RECRUITMENT

■	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
0 ■	0.00	0.40	0.01	0.00	0.01	0.01	0.01	0.02	0.52	0.05
1 ■	0.21	0.19	0.08	0.13	0.02	0.09	0.25	0.20	0.19	0.14
2 ■	0.32	0.61	0.78	0.51	0.35	0.29	0.63	0.80	1.00	1.00
3 ■	0.49	0.95	0.75	0.75	0.72	0.96	0.58	1.00	0.44	1.00
4 ■	1.00	0.96	1.00	1.00	1.00	0.59	1.00	0.33	0.96	1.00
5 ■	0.64	1.00	0.83	0.82	0.88	1.00	0.61	0.76	0.59	1.00
6 ■	0.64	1.00	0.83	0.82	0.88	1.00	0.61	0.76	0.59	1.00

STOCK NUMBERS (Jan 1) in thousands

■	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
0 ■	137651	141337	70051	80723	112113	60200	113003	66572	71690	92203	0
1 ■	60099	112588	67542	56822	65864	90342	48626	91577	52517	23407	70496
2 ■	34825	32977	71851	49631	36459	51441	60892	28556	52694	30672	15974
3 ■	15599	15469	11896	19190	15842	10927	21939	21347	5583	7396	6703
4 ■	8142	4978	3529	3330	3921	1605	1032	8191	2926	2116	1615
5 ■	2720	963	1130	691	427	179	345	218	3741	440	462
6 ■	1333	1794	1257	836	513	423	384	469	402	80	113
0+ ■	260371	310106	227256	211222	235138	215116	246220	216930	189552	156314	95363

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

■	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
0 ■	0	0	0	0	0	0	0	0	0	0
1 ■	684	1365	780	655	832	805	633	1182	519	309
2 ■	3147	2910	6184	4069	2879	3975	4867	2180	2858	2416
3 ■	2762	2390	2472	2449	1581	1112	3428	2556	1361	1180
4 ■	1220	1159	1125	622	518	364	238	2322	591	544
5 ■	673	306	422	210	96	43	141	79	988	153
6 ■	633	845	833	339	169	137	213	197	263	40
0+ ■	9120	8975	11815	8345	6074	6436	9519	8516	6581	4643

Table C9. Total catch (mt) (commercial and recreational landings and estimated discards) of scup compared with VPA estimates of total catch biomass (mt).

Year	Total catch	VPA calculated catch biomass	VPA:total catch ratio
1984	11,392	11,041	0.97
1985	14,263	13,387	0.94
1986	14,942	15,164	1.01
1987	11,630	11,466	0.99
1988	9,837	9,865	1.00
1989	9,177	7,949	0.87
1990	10,251	10,142	0.99
1991	14,104	13,655	0.97
1992	13,896	12,588	0.90
1993	7,241	7,187	0.99

Table C10. Results of yield per recruit and spawning stock biomass per recruit, scup.

Proportion of F before spawning: .4170
Proportion of M before spawning: .4170
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 Stock	Average Weights Catch
0	.0400	1.0000	.0000	.034	.034
1	.2200	1.0000	.1300	.113	.113
2	1.0000	1.0000	.7500	.172	.172
3	1.0000	1.0000	.9900	.276	.276
4	1.0000	1.0000	1.0000	.429	.429
5	1.0000	1.0000	1.0000	.498	.498
6	1.0000	1.0000	1.0000	.746	.746
7	1.0000	1.0000	1.0000	1.090	1.090
8	1.0000	1.0000	1.0000	1.242	1.242
9	1.0000	1.0000	1.0000	1.360	1.360
10	1.0000	1.0000	1.0000	1.449	1.449
11	1.0000	1.0000	1.0000	1.514	1.514
12	1.0000	1.0000	1.0000	1.561	1.561
13	1.0000	1.0000	1.0000	1.595	1.595
14	1.0000	1.0000	1.0000	1.619	1.619
15+	1.0000	1.0000	1.0000	1.636	1.636

Slope of the Yield/Recruit Curve at F=0.00: --> 2.5423
F level at slope=1/10 of the above slope (F0.1): -----> .139
Yield/Recruit corresponding to F0.1: -----> .1401
F level to produce Maximum Yield/Recruit (Fmax): -----> .236
Yield/Recruit corresponding to Fmax: -----> .1498
F level at 20 % of Max Spawning Potential (F20): -----> .284
SSB/Recruit corresponding to F20: --------> .5087

Listing of results by fishing mortality level (FMORT).
TOTCT=Total catch, TOTSTK=Total stock, SPNST=Spawning stock; N=numbers, W=weight

	FMORT	TOTCTHN	TOTCTHW	TOTSTKN	TOTSTKW	SPNSTKN	SPNSTKW	% MSP
	.000	.00000	.00000	5.5167	2.9100	3.3407	2.5439	100.00
	.100	.23741	.12584	4.3354	1.5603	2.1719	1.2505	49.16
F0.1	.139	.29219	.14015	4.0637	1.2931	1.9049	.9989	39.27
	.200	.35711	.14886	3.7424	1.0056	1.5908	.7313	28.75
Fmax	.236	.38691	.14982	3.5954	.8857	1.4478	.6209	24.41
F20%	.284	.41993	.14873	3.4328	.7626	1.2907	.5087	20.00
	.300	.42971	.14799	3.3847	.7283	1.2445	.4776	18.77
	.400	.47874	.14169	3.1447	.5713	1.0153	.3371	13.25
	.500	.51429	.13488	2.9717	.4742	.8528	.2519	9.90
	.600	.54141	.12881	2.8408	.4099	.7320	.1966	7.73
	.700	.56290	.12369	2.7377	.3648	.6387	.1586	6.24
	.800	.58043	.11943	2.6542	.3319	.5647	.1314	5.17
	.900	.59509	.11586	2.5849	.3068	.5046	.1111	4.37
	1.000	.60758	.11285	2.5262	.2872	.4550	.0956	3.76
	1.100	.61840	.11029	2.4757	.2714	.4133	.0833	3.28
	1.200	.62791	.10808	2.4316	.2585	.3778	.0735	2.89
	1.300	.63635	.10615	2.3926	.2476	.3472	.0655	2.57
	1.400	.64393	.10446	2.3578	.2384	.3207	.0588	2.31
	1.500	.65079	.10295	2.3263	.2305	.2974	.0532	2.09
	1.600	.65705	.10161	2.2977	.2235	.2769	.0484	1.90
	1.700	.66281	.10039	2.2715	.2174	.2586	.0443	1.74
	1.800	.66813	.09929	2.2473	.2119	.2423	.0407	1.60
	1.900	.67307	.09828	2.2249	.2070	.2276	.0376	1.48
	2.000	.67769	.09735	2.2040	.2026	.2143	.0348	1.37

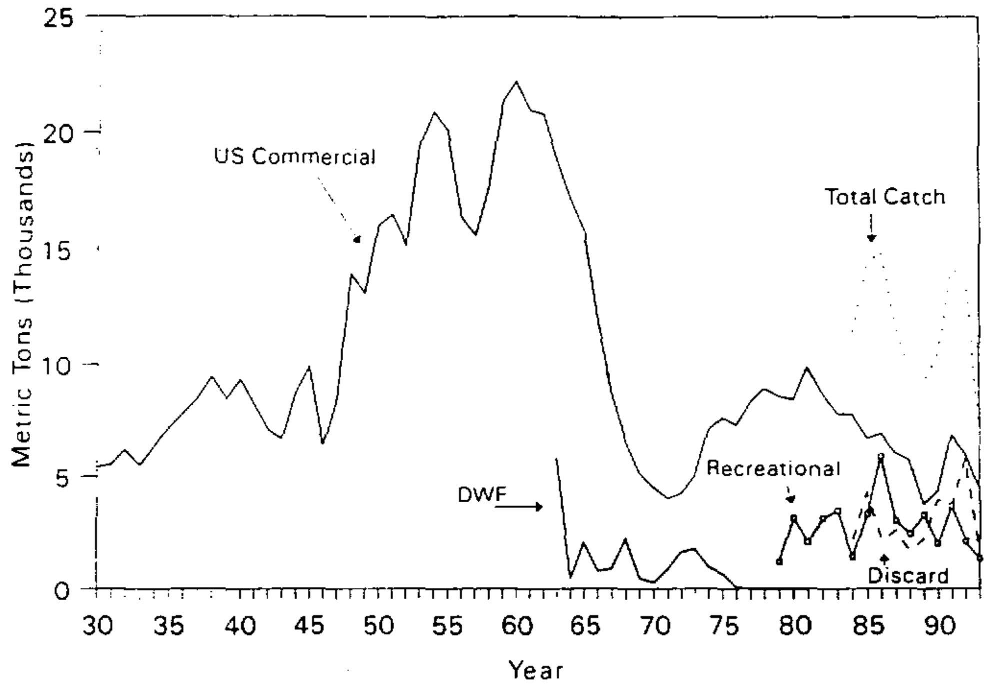

Figure C1. Total catch of scup from Maine through North Carolina, 1930-1933, including US commercial landings (does not include North Carolina prior to 1979), distant water fleet (DWF) landings, recreational landings, and commercial and recreational discard combined.

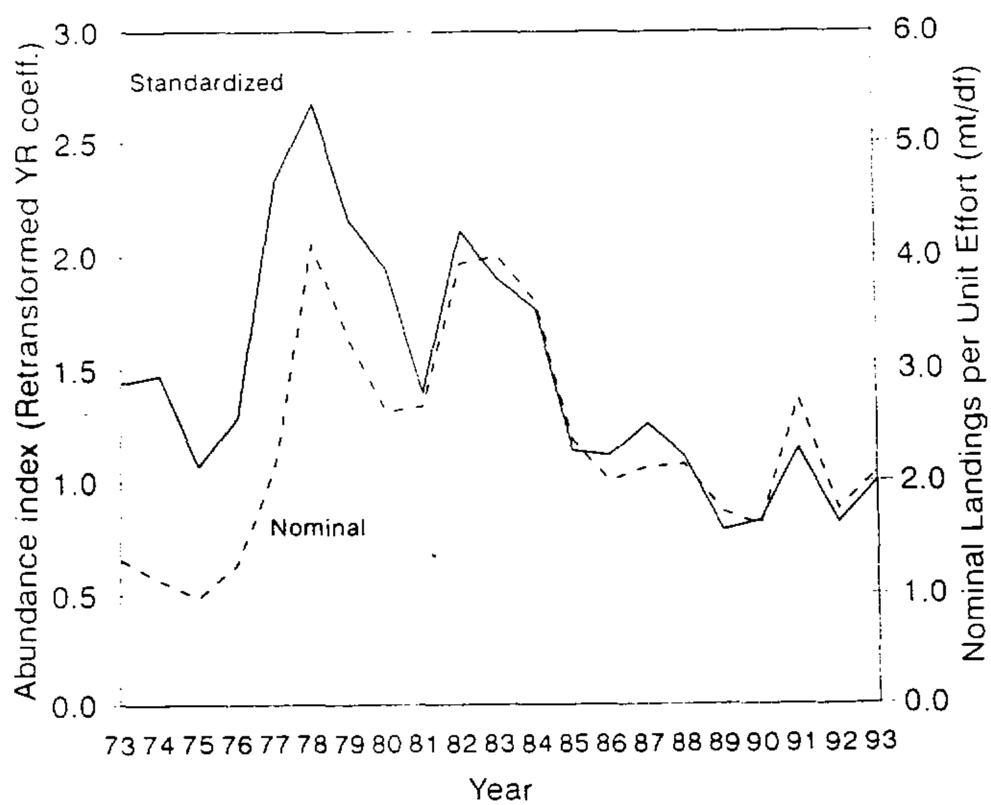

Figure C2. US commercial fishery LPUE indices (nominal and GLM estimates) for scup, 1973-1993. GLM values are retransformed corrected year parameter estimates derived from an analysis of weighout landings and effort data for trips with >5% scup landings.

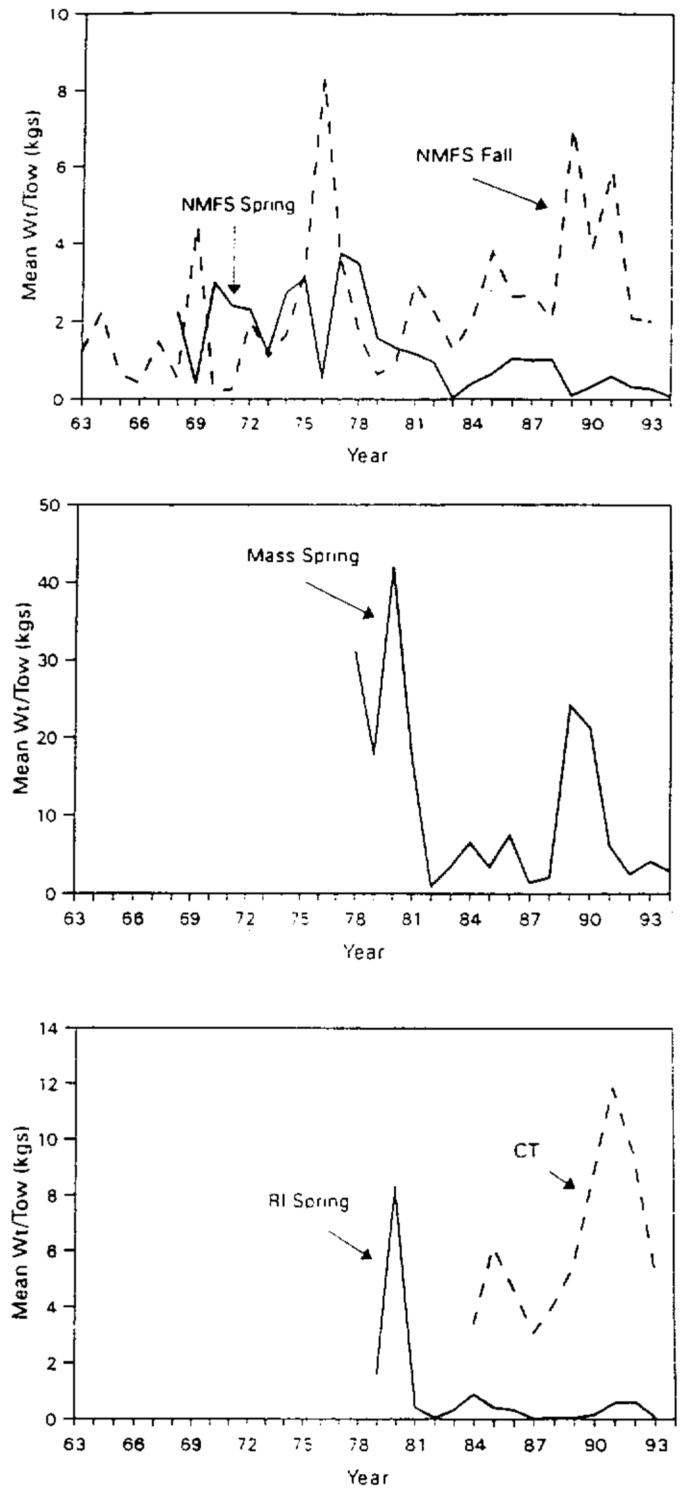

Figure C3. Mean weight-per-tow (kg) indices for scup from NEFSC spring and autumn, Massachusetts spring, Rhode Island spring, and Connecticut spring/autumn research vessel survey.

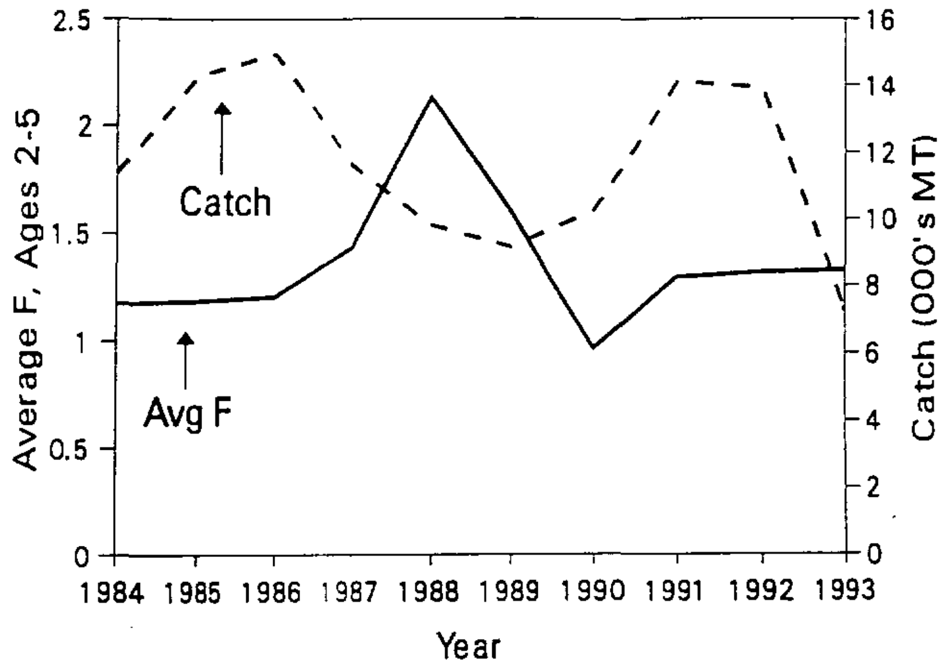

Figure C4. Estimates of mean F (ages 2-5) from VPA and total catch of scup, 1984-1993.

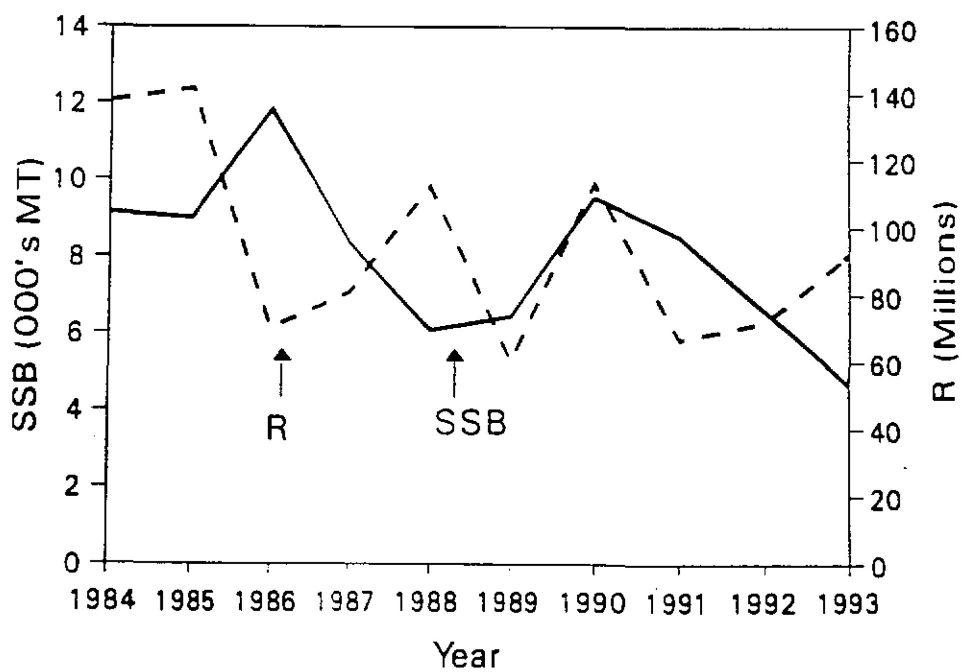

Figure C5. Estimates of recruitment at age 0 and spawning stock biomass (SSB) of scup from VPA, 1984-1993.

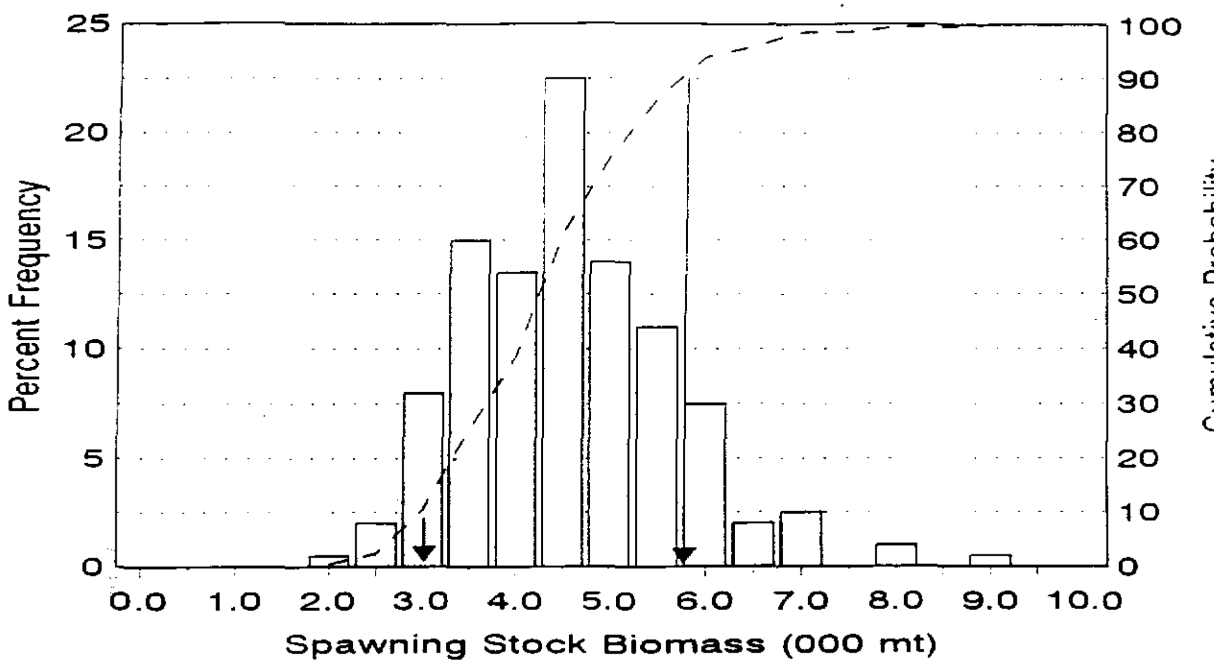

Figure C6. Precision of the estimates of spawning stock biomass (SSB) on June 1, 1993 (time of spawning) for scup. Vertical bars display the range of the bootstrap estimate and the probability of individual values in the range. The dashed line gives the probability that SSB is less than any value along the X axis.

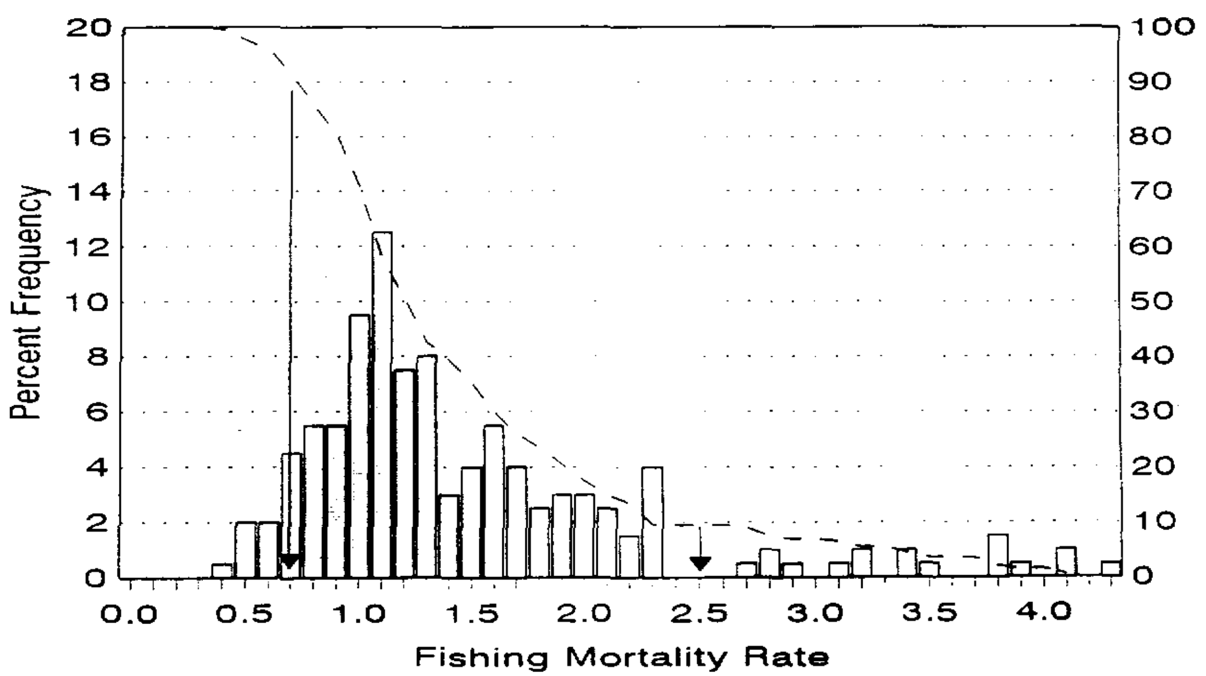

Figure C7. Precision of the estimates of fully recruited F (ages 2-5) in 1993 for scup. Vertical bars display the range of the bootstrap estimates and the probability of individual values in the range. The dashed line gives the probability that F is greater than any value along the X axis.

D. SURFCLAM

Terms of Reference

The following Terms of Reference were addressed:

a. Summarize trends in landings, size composition, areal distribution and LPUE for appropriate population units.

b. Summarize fishery-independent abundance indices, including NMFS research vessel data.

c. Provide estimates of current stock size, fishing mortality rates, and likely trends in abundance for a 10-year period under alternative quota levels.

Introduction

The Atlantic surfclam, *Spisula solidissima,* occurs both in state waters and the EEZ, along the Atlantic seaboard from Maine through North Carolina. Since 1977 EEZ populations have been regulated under provisions of the Surfclam-Ocean Quahog Fishery Management Plan, prepared by the Mid-Atlantic Fishery Management Council (MAFMC, 1993). Since 1978, an annual quota has been in effect . Quotas have risen from 13,880 mt in 1978-1981 to the present quota level of 21,976 mt (1000 mt of meats are equivalent to 129,706 bushels) (Table D1).

Increases in total allowable harvests followed from improved resource conditions, as a result of large year classes spawned in the late 1970s (Weinberg 1993). Available fishing time was restricted from 1977 to 1990, to slow the rate of catch, thereby ensuring that adequate clam supplies were available for processing throughout the year and to husband the large year classes. Prior to lifting of effort management restrictions, fishing time was limited to 6 hours per trip. Minimum size limits were reduced from 5.5 inches (14 cm, shell length) in 1981-1984 to 5.25 inches (13.3 cm) in 1985, and 5 inches (12.7 cm) in 1986-1989. Since 1989, the minimum size limit (4.75") has been suspended, owing to the relative dearth of small clams in the population and concentration by the fleet on larger clams. During the period 1981-1989 discards of small surfclams were significant. Survival of discarded clams has been estimated at about 50% (Haskin and Starypan, 1976).

Since 1991, the Atlantic surfclam fishery in the EEZ has been regulated under provisions of Amendment #8 to the FMP, which include an individual transferable quota (ITQ) management system. Under this system, restrictions on fishing time, vessel permit moratoriums and other measures were eliminated in favor of a system where shares of the annual quota were allocated to existing participants in the fishery. As a result of this change, the number of vessels participating in the fishery has declined substantially, and average fishing time per vessel has risen. The annual quota for surfclams in the EEZ is set in the autumn of each year.

The EEZ surfclam resource was last assessed in Autumn 1992, at SARC 15 (NEFSC 1993a; 1993b). At that time, the resource was considered to be fully exploited, with populations comprised primarily of relatively large adult clams (NEFSC 1993b). That assessment concluded that the Northern New Jersey assessment area (where 90% of EEZ landings were derived) would be depleted of surfclams in 6-7 years (by 1998-1999), assuming the fishery continued to derive most of the landings from there, and that annual catch quotas remained constant. Based on swept-area estimates of total biomass, the total Mid-Atlantic supply was estimated to be able to support 11-14 years of harvest at the current quota (NEFSC, 1993b).

Recommendations from the previous assessment called for the development of more sophisticated stock depletion models for surfclam, incorporating CPUE data, adjusted for discards, catch length frequency data, research vessel survey information, and ageing studies (NEFSC, 1993a). Additional comments by the MAFMC Scientific and Statistical Committee indicated the desirability of accounting for low-level annual recruitment (as is evident now) into calculations of the number of 'supply years' left, assuming various quota scenarios.

The previous assessment of the resource estimated fishing mortality rates, based on the decline in numbers-per-tow from R/V survey indices. Stock size was evaluated by expansion of area-swept biomass indices, also from surveys. This assessment addresses many of the research recommendations made at SARC 15, and specifically evaluates the terms of reference established by the SAW Steering Committee. A DeLury population estimator was developed to combine survey and commercial abundance indices and catches into an integrated assessment of stock size and harvest rates. Revised catch data include estimates of fishery discards from 1982-present. Commercial landings per unit of effort (LPUE) data were evaluated through the use of a general linear model, to adjust for areal and vessel size class differences in LPUE abundance indices. Year coefficients from these models were used in DeLury modeling studies.

Effort data contained in the logbook information are potentially biased low for some years in which very restrictive fishing times were enforced (e.g. 6 hours/trip). Accordingly, adjustment factors for these years were estimated and applied to GLM-based abundance measures. A research vessel survey of surfclam and ocean quahog populations was undertaken in the summer of 1994. Preliminary analyses of data from this survey indicated relatively high catch rates for both species, in most assessment areas, perhaps indicating a change in catchability of the species to the gear in 1994. The 1994 survey catch data were evaluated in the context of the integrated assessment model, incorporating all sources of information.

SARC-15 calculations of the numbers of years of surfclam supply at current quotas was based on a relatively simple model incorporating swept-area biomass estimates, two assumptions of natural mortality rate and included no estimates of recruitment. In this assessment a more sophisticated projection model utilizes a stochastic framework incorporating variability in starting biomass, natural mortality and recruitment. Other versions of the projection method evaluate the effects of an alternative constant fishing mortality rate policy on annual catches, and calculate maximum constant quota levels that would result in a 50% probability of taking the target catch in year 10 of the projection (e.g. 1995-2004).

Commercial Data

Commercial landings and effort data from 1982 to 1994 are from mandatory vessel logbooks. It is assumed throughout this assessment that one bushel of surfclams = 17 lbs = 7.711 kg. Parameters relating shell length to meat weight are from Serchuk and Murawski (1980), and are region specific. Vessel size class categories are: Class 1 (small, 1-50 GRT), Class 2 (medium, 51-104 GRT), and Class 3 (large, 105+ GRT). Commercial length frequencies and discards were estimated by region from port agent interviews. For estimating discards, only those interviews which had positive information on discards were used (i.e., blanks were ignored). When sufficient data were available, commercial length frequencies were estimated from a minimum of 30 randomly chosen trips (900 clams measured) per region/year.

Landings

Between 1965 and 1974, total landings rose from 20,000 to 44,000 mt of meats (Table D1, Figure D1). After 1974, total landings declined steadily to 16,000 mt in 1978. Major recruitment of surfclams in the Mid-Atlantic region from Delmarva through New Jersey (Figure D2) in the late 1970s resulted in increased landings throughout the early 1980s. Annual EEZ quotas have been set since 1978. Between 1983 and 1994, annual EEZ landings have been fairly constant, ranging from 20,000 - 25,000 mt. In the 1980's, approximately 75% of the landings were from the EEZ; the remainder were taken from state waters. In the 1990's, the percentage of landings from the EEZ has decreased slightly to approximately 70%. EEZ landings have typically been very close to the annual quota.

Since 1983, approximately 90-100% of the EEZ landings have been taken from the Middle Atlantic region (Table D2). In the period between 1986-1994, 74-91% of the Middle Atlantic landings came from Northern New Jersey, 5-16% came from Delmarva, and 0-10% came from Southern New Jersey (Table D3, Figure D3). This represents a shift away from the Delmarva region, which had been a major location for landing surfclams in the late 1970's and to a lesser degree in the early 1980's. The fishery is currently focused off the coast of New Jersey (Figure D4).

Discards

Discarding reached substantial levels in the early 1980s when clams of the 1978 cohort became large enough to be captured in commercial clam dredges. In 1982 for example, 33% of the total biomass caught from New Jersey was discarded (Table D4). To reduce discarding, the existing minimum size limit was reduced in stages from 140 mm in 1982 to 127 mm in 1985. Between 1986 and 1990, percent of catch discarded ranged from 3-25%. Minimum size regulations were suspended after 1989. Discarding percentage has been less than 5% of the total catch from 1991 to 1994.

Size Composition

Length frequency distributions for surfclams landed between 1982 and 1994 are shown for the New Jersey and Delmarva regions (Figures D5 and D6). Between 1982 and 1990, average size of clams landed from S. New England (approximately 150 mm - 160 mm) was greater than that from areas to the south (typically 120 mm - 140 mm) (Table D5). No data are available from S. New England after 1990. Mean length of clams landed from the Delmarva area has decreased steadily from 159 mm in 1982 to 109 mm in 1994. Mean length of clams landed from the New Jersey area has remained relatively steady throughout this period (140 - 145 mm), although the percentage of small clams (80 - 110 mm) taken has increased in 1993 and 1994.

Landings/Effort

Effort Trends

In the early 1980s, similar high annual efforts of 15,000 - 16000 hrs were taking place in Delmarva and N. New Jersey (Figure D7). Effort subsequently declined in Delmarva, but remained high in N. New Jersey.

Reported effort (hrs fishing) per trip has varied greatly between 1982 and 1994 (Table D6, Figures D8 and D9). This was the result of regulations which limited effort per trip to 12 hr from 1982-1984, and to 6 hr per trip from 1985-1990. In N. New Jersey, when these regulations were terminated average time reported fishing per trip increased dramatically to 8.6 hours in 1991, 9.9 hours in 1992, and 11.3 hrs in 1994. Like the N. New Jersey area, the 6-hr trip limit resulted in a mean effort per trip very close to 6 hr in the Delmarva region from 1985-1990. Unlike N. New Jersey, average reported effort per trip in Delmarva did not increase when the effort limit was removed. While the variance increased after 1990, mean reported effort per trip remained close to 6 hr. An additional contrast between regions is that number of surfclam trips in the Delmarva area has declined by one order of magnitude since 1983 (Table D6). In N. New Jersey number of clam trips increased from 1982 to 1988, and remained stable thereafter.

LPUE

Nominal Trends

In the Mid-Atlantic region, typically >80% of the annual surfclam catch is made by large (105+ GRT) vessels (Table D7). Focussing on performance of large vessels in the Mid-Atlantic, nominal landings per unit effort (LPUE) increased from 352 kg/hr in 1982 to 1845 kg/hr in 1986 (Figure D10). LPUE has declined since 1986, to its low value in 1994 of 822 kg/hr. The pattern of declining LPUE since 1986, described for the Mid-Atlantic, is also true for large vessels in the N. New Jersey area (Table D7, Figure D11). In the Delmarva area, LPUE of large vessels also declined from 1986 to 1992. Since 1993, N. New Jersey surfclam trips outnumber those made in the Delmarva area by about 4:1. While relatively few trips have been made in the Delmarva area recently, LPUE has increased from 1325 kg/hr in 1992 to 1732 kg/hr in 1994 (Table D7, Figure D11). In S. New Jersey, LPUE of large vessels increased until 1992, followed by a steep decline in 1993 and 1994 (Table D7). In 1993, the ten minute squares with the highest LPUEs are located off S. New Jersey and Delmarva.

Between 1986 and 1994, mean landings per trip in the N. New Jersey area have been relatively stable at approximately 9 mt (Table D8). The fact that nominal LPUE in that same area has declined from 1848 kg/hr in 1986 to 761 kg/hr in 1994 (41% of the 1986 rate) is consistent with the fact that average hrs per trip has increased substantially (Table D6).

General Linear Models

An analysis using General Linear Models (GLMs) was carried out, by region (Tables D9 and D10), using the natural log of LPUE to obtain a standardized abundance index from the commercial data. For N. New Jersey (NNJ), year and vessel tonclass were included as explanatory variables. For Delmarva (DMV), "subregion" was also included as an explanatory factor. "Subregions" were created by partitioning the DMV region into halves of approximately equal area.

GLM results from NNJ (Table D10) and DMV (Table D9) are most important because the fishery is active in these areas and NMFS research surveys have indicated that these areas contain the majority of the stock biomass. Bias corrected and backtransformed year coefficients for landings in weight per effort from the GLMs are listed in Table D11 and plotted in Figure D11. The standardized LPUEs follow the nominal LPUEs of large vessels rather closely. Examination of the standardized LPUE by region indicates a large decline since 1986 in NNJ, and a recent increase in DMV.

Standardized year coefficients, based on clam biomass, were converted to coefficients based on numbers of clams (Table D11) so that additional modelling could be carried out (see DeLury Model section). Conversion from weight to numbers involved division by the weight of an average clam landed from the specific region and year under consideration. The commercial length frequency distributions (Figures D5 and D6) and growth parameters relating shell length to meat weight (Serchuk and Murawski, 1980) were used.

Adjustment for Effort Reporting

Procedures to report fishing effort for surf clam vessels changed in late 1990 in response to revised regulations. As a result of the revised procedures, effort was more accurately reported in terms of actual hours fished during 1991-94 than during 1982-90. Even after standardization of LPUE with general linear modeling, estimates of standardized LPUE in the Northern New Jersey region exhibited an unexpected sharp discontinuity in 1990. Standardized LPUE in Northern New Jersey showed similar decreasing trends during 1986-90 and during 1991-94 that differed by a marked decrease in 1991 (Figure D11). In contrast, standardized LPUE for the Delmarva region exhibited no discontinuity between LPUE in 1990 and 1991. The change in reporting was considered to be a potentially important bias that would affect the utility of LPUE as a relative abundance index in the important Northern New Jersey region. This was examined in an initial run of the modified DeLury model for Northern New Jersey that used standardized LPUE as a relative abundance index. Residuals for the estimated catchability coefficients during 1991-94 indicated a systematic bias. As a result, an analysis to adjust the standardized LPUE series was performed.

The observed linearity patterns in standardized LPUE during 1986-90 and 1991-94 suggested that LPUE could be empirically modelled as a decreasing linear function of time. The change in effort reporting in late 1990 could be incorporated into this linear model through the addition of a conversion factor, denoted by c, that related a unit of effort during 1986-90 (E_{OLD}) to a unit of effort during 1991-94(E_{NEW}) as

$$E_{NEW} = c \cdot E_{OLD}.$$

Expressions for LPUE (details are given in Weinberg et al., 1995) during the 1986-90 and 1991-94 periods were used to compute least squares estimates of the conversion factor based on estimates of standardized LPUE during 1986-1994 (Table D12). The resulting estimate of c was significantly different from 1 and the model fit was considered to be adequate (R^2=0.998) for the purpose of determining a conversion factor. The conversion factor (c=0.745) was then applied to the observed LPUE during 1986-90 to give a consistent series of LPUE for 1986-1994. The 1986-1994 period represents a block of years when landings were stable (Table D3). This contrasts with the 1978-1985 period, when landings were relatively low. The effect of including 1985 in the LPUE series to estimate c was examined, and it was found that this produced a poorer fit to the data with large residuals for 1985 and 1986. In addition, the same model structure was considered for the standardized LPUE in the Delmarva region. In this case, the estimated conversion coefficient was not significantly different from 1 and no effort adjustment was used.

Research Survey Data

Description of Surveys

A series of 20 research vessel survey cruises have been conducted between 1965 and 1994 (Table D13) to evaluate the distribution, relative abundance and size composition of surf clam and ocean quahog populations in the Middle Atlantic, Southern New England and Georges Bank (Figure D2). Information from these surveys is used to predict relative year-class strength; and to evaluate the effects of fishery management measures. Assessments of both short- and long-term fishery productivity are based on comparing trends in survey abundance indices with fishery yields.

Assessment areas have been subdivided into strata which remain fixed through time (Figure D2). The surveys are performed using a stratified random sampling design, allocating a pre-determined number of tows to each stratum. Standardized sampling procedures used in these surveys are described in Murawski and Serchuk (1989). One tow is collected per station, and intended tow duration and speed are 5 minutes and 1.5 knots, respectively. Catch in meat weight per tow is computed by applying appropriate length-weight equations to numbers caught in each 10 mm size category. By averaging over all tows within a stratum, representative size frequency distributions per tow are computed by stratum. Representative size frequency distributions and mean number of clams per tow are also computed by region using as a weighting factor the area of each stratum within the region.

Survey data from 1982-1994 form a consistent series because those data were officially audited, tows that exceeded a specified level of gear damage were not included, non-random tows were not analyzed, and doppler distance was used to standardize every tow's catch to a common tow distance (0.15 n. mi).

For the 1994 survey only, all stations in five strata were sampled twice, first during Cruise Leg I with the tow point of the clam dredge in a novel position (4th hole from the front) and then repeated during Leg II using the gear in the "classical" position (3rd hole from the back). The purpose of this was to examine the sensitivity of the number of clams caught by the dredge to tow point location. Tow point location was found to not have a significant effect on number or size of surfclams caught by the dredge. All survey data reported in this assessment were collected with the clam dredge tow point set in the "classical" position.

Abundance Indices

Stratified mean number per tow from 1965-1994 are given by region in Table D14. The 1994 survey datum point stands out as a maximum for the 30-yr time series in the N. New Jersey region.

From 1982 to 1992 (Table D14), the total number of surfclams per tow declined by 36% in the N. New Jersey area. In the Delmarva area (Table D14) numbers per tow do not have a clear trend from 1982 to 1992, although the values from the 1989 and 1992 surveys were lower than those from the 1984 and 1986 surveys.

Size Frequency Distributions

Size frequency distributions are plotted by year/region in Figures D12 and D13 for the N. New Jersey and Delmarva regions.

While the 1994 survey caught an unusually high number of clams in N. New Jersey, the size structure of the catch consists primarily of large (120-150 mm long) clams. This size structure differs very little from that of the previous three surveys. One can not invoke a major recruitment event to explain the 1994 data because surfclams do not grow that fast. Studies of surfclam growth rate have shown that approximately 5-6 years are required to attain a shell length of 120 mm (Jones, Thompson, and Ambrose 1978; Serchuk and Murawski 1980). None of the surveys conducted between 1986 and 1992 produced evidence that a major recruitment event was taking place. This reasoning leads to the conclusion that capture efficiency of the clam dredge was higher during the 1994 survey in at least some areas.

Areal Distribution of Survey Catches

Clam abundance per tow data from the 1994 survey were partitioned into "recruits" (i.e., 105-120 mm) (Figure D14) and "fully recruited" (120+ mm) (Figure D15) size groups. Based on growth equations (Serchuk and Murawski, 1980), "recruits" are capable of growing into the fully recruited size in approximately 1 year. Fully recruited clams are clustered primarily in Delmarva's Stratum #9, along the coast of New Jersey (Strata #87-#89), and on Georges Bank. Recruits have a spatial distribution similar to that of the fully recruited surfclams.

In the S. Virginia/N. Carolina region, tows with high densities of recruits were not widespread (Figure D14). Rather, higher densities were restricted to the northern edge of Stratum #5 adjacent to the Delmarva region. Recruits were relatively abundant in Stratum #87 off of S. New Jersey and in Stratum #89 off of N. New Jersey (Figure D14).

Data from two recent surveys were combined to show the overall distribution of surfclams of all sizes along the east coast of the United States (Figure D16).

The percentage of surfclam biomass by region was computed from the 1994 survey data (Figure D17). The calculation was based on a standard tow distance of 0.15 n. mi. with an area of 0.0001233 sq. n. mi; the fraction of habitat suitable for surfclams was assumed to be the same in all strata; expansion of the biomass per tow to a regional biomass was based on the respective areas of strata within regions. The results suggest that NNJ has more surfclam biomass than other regions (33.8%). DMV and GBK each contain approximately 25% of the biomass. SNJ contains about 10% of the biomass. Other regions contain only minor amounts of surfclam biomass. This partitioning appears consistent with Figures D14 - D16.

Population Size and Fishing Mortality Estimation

Modified DeLury Model

Previous assessments of the surfclam resource relied on research vessel survey data exclusively to estimate total mortality rates (ln catch-per-tow in numbers regressed against year), and total stock size (swept-area minimum biomass approach). Estimates of total mortality from this approach are influenced greatly by the substantial variance associated with individual survey estimates (Weinberg, 1993). Likewise, total population size estimates from swept area measurements are influenced by regional and annual variations in survey catchability (q). Based on the recommendations of SAW 15, an integrated approach to the assessment of surfclam stocks was undertaken so as to combine commercial and survey abundance indices, along with annual catch data to estimate annual fishing mortality and stock sizes.

A brief description of the modified DeLury model (Conser and Idoine 1992; Conser 1994) used for surfclam assessments is provided below:

Because of the lack of a time-series of catch and abundance indices-at-age, these data are divided into two length (size) stanzas, defined as partially-recruited and fully-recruited. The size intervals are chosen so that on average, animals within the partial-recruit size interval will be expected to grow into the fully-recruited interval within the next year. Catch data (including discard estimates) are converted to numbers, via appropriate mean weights in the catch for the two size intervals. Abundance indices are similarly converted to numbers in each interval. A 'survey year' is defined as the period between successive annual abundance indices (survey or commercial).

Then:

R_y population size (in numbers) of the recruits at time of survey during calendar year y,

N_y population size (in numbers) of the fully-recruited group at time of survey during calendar survey year y,

C_y catch in numbers during calendar year y,

M instantaneous rate of natural mortality (yr^{-1}),

using the DeLury framework, the first order difference equation:

$$N_{y+1} = [N_y + R_y]e^{-M} - [c_y\, e^{[tc-ts-1]M}] \qquad (4.1.1)$$

ts point during the calendar year when the survey occurs,

tc point during the calendar year when the catch is taken,

and $0 \leq ts \leq tc < 1$,

relates the fully-recruited stock size at the time of survey year N_{y+1}, to fully-recruited stock size at time of survey the previous year, N_y, plus recruitment, R_y, minus catch, C_y, all discounted for natural mortality, M. The survey and/or commercial indices of abundance, n_y and r_y are related to absolute stock sizes by catchability coefficients:

$$n_y = q_n N_y \qquad (4.1.2)$$

$$r_y = q_r R_y \qquad (4.1.3)$$

Substituting equations 4.1.2 and 4.1.3 into 4.1.1 and introducing a process error term gives:

$$n_y = (n_{y-1} + r_{y-1}/s_{r,y-1})e^{-M+\varepsilon y} - q_n C_{y-1} e^{(tc-ts-1)M+\varepsilon y} \quad (4.1.4)$$

where $S_r = q_r/q_n$ is the selectivity of the recruits relative to the fully recruited group and ε_y is a normally distributed random variable with mean 0 and variance representing the process error.

The model is estimated using a non-linear least-squares procedure detailed in Conser (1994).

Population size at time of the survey in year y, N_y, is estimated by:

$$N_y = n_y/q_n \quad (4.1.5)$$

Recruitment in year y, R_y, is given by:

$$R_y = r_y/S_{ry}q_n \quad (4.1.6)$$

Total mortality rate, Z is then given by:

$$Z_{R+N,y} = \ln_e [N_y+R_y/N_{y+1}] \quad (4.1.7)$$

At present, the model can either be estimated with survey or commercial abundance indices, but not both simultaneously. Accordingly, several trial runs were undertaken with various abundance measures, and other assumptions. Final survey- and commercial-based DeLury models were combined in weighted deterministic and stochastic formats to give a 'blended' final DeLury result. This final result is weighted either by the inverse of the mean-square error resulting from the model fits, or by other Bayesian criteria. DeLury model fitting was undertaken only for the Northern New Jersey and Delmarva fishery areas (accounting for >90% of the landings), as data for the other fishery areas were insufficient for the purposes of this type of estimation procedure.

Input Data/Assumptions

Natural Mortality Rate

The instantaneous natural mortality rate (M) for surfclam is not known precisely, but has been assumed to be 0.05 (Fogarty and Murawski, 1986; Murawski and Serchuk, 1989). This level of M is consistent with survival of 5% of the population for 60 years, under conditions of no fishing. This value was used in all subsequent DeLury models, and M ranging uniformly from 0.02-0.08 was used in population projections.

Catch Numbers/Weights

Commercial catch (landings plus estimated discards) were converted from weights to numbers using average mean weights based on commercial size frequency sampling for the landings and survey size frequency data for discards. Based on the 1982-1994 commercial catch data (Figures

D5 and D6), 120 mm was selected as the size at which surfclams are fully recruited to the fishery. Size windows for the recruits were determined from age/length equations for each region (Serchuk and Murawski, 1980). For Northern New Jersey, recruits were defined as ranging from 105-120 mm in shell length; for Delmarva, the size window for recruits was 103-120 mm.

Survey Abundance Indices

Abundance indices were used from 7 surveys conducted between 1982 and 1994 (i.e. 1982, 1983, 1984, 1986, 1989, 1992, 1994). The model incorporated missing values in the estimation process. Indices were again grouped by size classes into recruits and fully-recruited animals. The sensitivity of various model results to inclusion of 1994 survey points was tested by projecting the survey indices and determining if the observed survey points fell within the confidence intervals of the projected indices.

Commercial Abundance Indices

Commercial abundance indices (LPUE in numbers) are assumed to represent fully-recruited animals only (Table D11). Accordingly, commercial-based DeLury runs incorporated recruit abundance indices from the corresponding surveys.

DeLury Population Estimation

Results from Survey-Based Runs

For both N. New Jersey and Delmarva, the "survey-only" runs resulted in generally larger CV's of parameter estimates, and lower fishing mortality rates than did the corresponding commercial runs. Because the 1994 survey values were so large, relative to the time series, several runs were made using the 1994 recruit index, then replacing the 1994 recruit index by the recent average recruit index (for N. New Jersey, an index of 13; for Delmarva an index of 26.6). Because of the dominating effect of the actual 1994 values on the fits for Northern New Jersey, replacing the indices with averages resulted in much improved model fits.

Results from Commercial-Based Runs

For the Northern New Jersey area, the fit was relatively good, producing relatively low CVs for parameter estimates. Initial trials for the Delmarva area, however, were dominated by a very low "fully recruited" commercial index value for 1994 (Table D11). This value was thought to be due to a few boats targeting concentrations of small clams below the cut-off length of 120 mm for fully-recruited animals (Figure D6). Accordingly, the 1994 index value was treated as a missing value.

Weighted Final Runs

Weighted final runs of the DeLury model blend "survey-based" and "commercial-based" data. The weighted final DeLury run for Northern New Jersey is summarized in Table D15 and Figures D18-D21. These analyses indicate that the stock size of fully-recruited animals peaked in 1986 at 800 million clams, and has since declined to about 600 million. The estimated fishing mortality rate on fully-recruited surfclams in 1993 was 0.23 (bias adjusted: 0.22), with F on recruits of 0.12. The weighted estimate of fishing mortality rate for both size classes is F=0.21. Fishing mortality on both sizes has risen steadily since 1984. The bias adjusted exploited biomass peaked in 1986 at 101 thousand mt, and has since declined to 78 thousand mt. Recruitment in 1982 and 1983 was 285 and 395 million animals, respectively. Recruitment has since declined to less than 200 million clams. Note that in Figure D21, the observed Northern New Jersey survey index for 1994 of 103.51 lies far outside the model calculated 90% confidence interval for the 1994 value. This suggests that the observed 1994 value is inconsistent with the rest of the time-series on which the model is based.

The weighted final DeLury run for Delmarva is summarized in Table D16 and Figures D22-D25. This model run is estimated with substantially more error than for Northern New Jersey. Stock size for fully-recruited animals peaked in 1989 at about 250 million clams, and has remained stable since then. Recruitment declined substantially since the early 1980s. Fishing mortality on fully-recruited animals is estimated to be 0.23, with an F of 0.12 on recruits, for a weighted average of 0.20. Note that the 1994 commercial index number of 2.41 was well below the model computed 90% confidence interval for that value (Figure D25).

Projections

Description of Projection Methods

The calculation of 'clam supply years' was undertaken to meet Term of Reference c. using a stochastic projection model. In particular, the number of supply years was defined as the number of years, beginning with 1995, for which the specified surf clam quota can be fully taken. The projections began in the year 1995, and continued until the surf clam population was commercially exhausted or until the year 2094 was reached.

A biomass model describes how exploitable biomass changes annually due to the effects of natural mortality, harvest, and recruitment. The basic model is

$$B(t+1) = \big(B(t) + R(t) - C(t)\big)\cdot e^{-M(t)}$$

where
B(t) is the exploitable biomass in year t,
R(t) is the amount of exploitable biomass that was produced during year t (recruitment),
C(t) is the amount of exploitable biomass that was landed during year t,
M(t) is the instantaneous natural mortality rate during year t.

The catch biomass was determined in a deterministic manner under a constant quota or a constant exploitation rate. There were three stochastic components to the surf clam projection model: the initial exploitable biomass, the annual level of recruitment, and the annual natural mortality rate.

The level of the initial exploitable biomass in 1995 was based upon the empirical distribution of the estimates of exploitable biomass in 1994 that were computed with the modified DeLury model (cf. previous section).

The annual level of recruitment was taken to follow a lognormal distribution. The annual level of natural mortality was taken to follow a uniform distribution centered at the best estimate of the surf clam instantaneous natural mortality rate.

Starting Conditions/Assumptions

Surf clam projections were made for two fishery areas: Northern New Jersey and Delmarva.

Northern New Jersey:

The initial exploitable biomasses in 1995 were taken from a set of 200 bootstrapped estimates of the exploitable biomass in 1994 less the projected catch of 16,285 mt during 1994. For each initial biomass, a total of 10 simulations were performed to generate a total of 2,000 population trajectories through time. The recruitment distribution was parameterized based upon the estimated recruitment in the years 1984, 1986, 1989, and 1992. Estimated recruitment for 1982 and 1983 was excluded because the values were considered to be strongly influenced by the extremely high recruitment of the 1977 year class. Maximum likelihood estimates of the log mean and variance parameters ξ and Φ were $\xi=8.849499$ and $\Phi=0.284837$. This led to a mean recruitment level of 7560 mt with a coefficient of variation (CV) of 28%. Natural mortality of surf clams was assumed to be uniformly distributed on the interval [0.02, 0.08]; the expected value of annual natural mortality was 0.05 as used in the estimation of the initial exploitable biomass. The constant catch quota projections were based upon the average landings from Northern New Jersey during 1992- 1994, 16,986 mt.

A total of 13 projections were performed for the Northern New Jersey region. Projection runs 1 through 3 were based on the estimated recruitment distribution and considered the effects of a constant quota of 16,986 mt, and +or -10% of this value. The fourth run was based on a constant exploitation rate (fraction of exploited biomass that was caught during the year) of 0.20 . Runs 5 through 7 examined the effects of having no recruitment with a constant quota of 16,986, 18,685, and 15,287 mt. Run 8 considered the effect of no recruitment with a constant exploitation rate of 0.20. Because the recruitment values generated with the estimated lognormal distribution did not vary greatly, it was thought that the CV might be too low. For this reason, another lognormal distribution with $\xi=8.849499$ and $\Phi=0.832555$ was used; this forced the CV of recruitment to be 100% and set the mean recruitment to 9,858 mt. Runs 9 through 11 examined the effects of using the more variable recruitment distribution with a constant quota of 16,986, 18,685, and 15,287 mt. Run 12 considered the effect of using the more variable recruitment distribution with a constant exploitation rate of 0.20. Run 13 was the result of an iterative process to compute the constant quota under which 50% of the projected populations would have 10 or more years of clam supply where recruitment followed the lognormal distribution with parameters ξ=8.849499 and Φ=0.284837.

Delmarva:

The initial exploitable biomasses in 1995 were taken from a set of 200 bootstrapped estimates of the exploitable biomass in 1994 less the projected catch of 2,770 mt during 1994. For each initial biomass, a total of 10 simulations were performed to generate a total of 2,000 population trajectories through time. The recruitment distribution was parameterized based upon the estimated recruitment in the years 1984, 1986, 1989, and 1992. Estimated recruitment for 1982 and 1983 was excluded because the values were considered to be strongly influenced by the extremely high recruitment of the 1978 year class. Maximum likelihood estimates of the parameters ξ and Φ were ξ=7.994964 and Φ=0.837629. This led to a mean recruitment level of 4212 mt with a CV of 101%. Natural mortality of surf clams was assumed to be uniformly distributed on the interval [0.02, 0.08]; the expected value of annual natural mortality was 0.05 as used in the estimation of the initial exploitable biomass. The constant catch quota projections were based upon the average landings from Delmarva during 1992-94, 2,470 mt.

A total of 9 projections were performed for the Delmarva surf clam fishery. Runs 14 - 16 were based on the estimated recruitment distribution and considered the effects of a constant quota of 2,470 mt, and + or -10% of this value. Runs 17 - 19 examined the effects of having no recruitment with a constant quota of 2,470, 2,717, and 2,223 mt. Because the recruitment values used to estimate the parameters of the lognormal distribution had a decreasing trend through time, it was thought that the average value of recruitment might be too high. For this reason, another lognormal distribution was estimated based on only the 1989 and 1992 recruitment values; this gave ξ=7.169963 and Φ=0.192682 and set the average value of recruitment to 1324 mt with a CV of 19%. Projection runs 20 - 22 examined the effects of using the recruitment distribution based on 1989 and 1992 with a constant quota of 2,470, 2,717, and 2,223 mt.

Two projection runs were performed to analyze the N. New Jersey and Delmarva regions together. Run 23 was based on the sum of the average annual catches from the two regions. It was also based on the sum of the recruitments from the two regions. Run 24 was used to calculate what constant annual quota could be taken for 10 years, with at least a 50% probability, assuming the same recruitment as in Run 23 for the two areas combined.

<u>Projection Results</u>

Projection results for the two areas are summarized in Table D17 and Figures D26-D34. For Northern New Jersey, catches assuming the 1992-1994 average (16,986 MT) and average recruitment can be sustained for about 4 years, after which there will be insufficient biomass to generate that level of catch. Average exploitation rates increase dramatically over the duration of the fishery (Figure D26). Under scenarios of ±10% of the average catch, supply years change by about 1 year. Under conditions of 0 recruitment, average supply years decline from 4.48 to 2.93.

Constant harvest rate policies result in declining catches to about 6,364 mt in year 10 under average recruitment, 1,057 mt in year 10 under 0 recruitment, and 8,258 mt in year 10 assuming higher and more variable recruitment. The quota that results in a 50% probability of sufficient resource to generate the constant catch for 10 years is 11,263 mt (66% of the 1992-1994 average).

For Delmarva, the current low catch (1992-1994 average = 2,470 mt) can be sustained for at least 100 years, assuming average recruitment. Increases of 10% in the catch have no effect on this result. Under the 0 recruitment option, there is sufficient supply for 6-7 years. With more realistic lower recruitment, average supply would last about 9-13 years (±10% of current catch).

For N. New Jersey and Delmarva considered simultaneously (Figure D34), current annual catches can be taken for about 7 years, assuming that recent levels of recruitment continue. The quota that results in a 50% probability of sufficient resource to generate the constant catch for 10 years is 16,385 mt (84% of the 1992-1994 average).

Thus, under the current allocation of catch by region and recent levels of recruitment, it is unlikely that current catches can be maintained for 10 years.

Yield Per Recruit (YPR)

Yield per recruit analyses were carried out for the N. New Jersey and Delmarva regions to compare estimates of current fishing mortality rates (F) with biological reference points, $F_{0.1}$ and F_{MAX}. The analysis was based on region-specific weight at age data (Serchuk and Murawski, 1980), M was assumed to be 0.05, and clams were assumed fully recruited at age 5. In the N. New Jersey region between 1986 and 1993, F's on fully recruited clams have ranged between 0.12 and 0.23. In the Delmarva region during the same period, F's on fully recruited clams have varied between 0.09 and 0.24. $F_{0.1} = 0.07$ and $F_{MAX} = 0.21$ for the New Jersey region, and $F_{0.1} = 0.08$ and $F_{MAX} = 0.24$ for the Delmarva region. Thus, current F's in both regions approximate F_{MAX}.

Conclusions

- Total population sizes of Mid-Atlantic surfclam peaked in the mid-1980s, and have since declined, in some cases substantially. Large year classes spawned in the late 1970s continue to dominate the populations.
- Continued recruitment to the exploited population has occurred in recent years as a result of slower growing individuals of the large year classes, and some new recruitment.
- Currently the majority of landings are derived from off Northern New Jersey, where exploited biomass in 1994 was about 78 thousand mt of meats. Under current levels of catch and recruitment, there is approximately 4 years of supply remaining in that region.

- o Landings off Delmarva currently account for about 14% of the Middle Atlantic catch (1992-1994 average catch of 2,470 mt). With an exploited biomass of 23 thousand mt, the current harvests could be taken for about 11 years, assuming a moderate decline from recent average recruitment.

- o Fishing mortality rates of Northern New Jersey and Delmarva surf clam populations are estimated to be about F=0.2. If the current quota levels and allocations by area are maintained, fishing mortality rates on these stocks will increase significantly over the next several years.

- o For N. New Jersey and Delmarva considered simultaneously, current annual catches can be taken for about 7 years, assuming that recent levels of recruitment continue. The quota that results in a 50% probability of sufficient resource to generate the constant catch for 10 years is 16,385 mt (84% of the 1992-1994 average).

Sources of Uncertainty

- o The catchability of surfclams in the 1994 NEFSC survey appeared to differ substantially from previous surveys. As a result, 1994 survey data were not used in tuning DeLury models or estimating clam biomass by region.

- o The length frequency distribution for the 1994 commercial catch off Delmarva is based on few samples. This distribution suggests a strong trend toward capture of smaller individuals in that region. It is not known if the shift to smaller animals off Delmarva represents a meaningful shift by the fishery or is the result of small sample size.

- o Data are lacking on the capture efficiency of the research survey clam dredge with respect clams 20-70 mm in length. As a result, the distribution and abundance of these smaller individuals is not well documented.

Research Recommendations

- o Improve and revise biological studies of growth rate, maturity, and meat yield by region/season. In particular, refine the size 'windows' used to estimate recruit abundance.

- o Extend backward the time series of survey and catch data used in DeLury models

- o Incorporate 10' square as a exploratory factor in the GLM

- o With Methods Working Group, develop MultiIndex Delury Model.

- o Further examine the need to adjust CPUE for effort reporting. Specifically, compare trip length with hours fished, and examine whether movement of individual Class 3 vessels between regions could account for differences in catch rate.

- o Genetic and other studies are necessary to better understand stock structure.

- o Examine factors affecting survey gear efficiency and consider clam size selectivity.

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Table D1. Total USA surf clam landings (metric tons of meats), total landings from the Exclusive Economic Zone (EEZ), landings from state waters, percent of total from the EEZ[1], and annual quotas .

Year	Total Landings	EEZ Landings	State Waters Landings	Percent of Total Landed[1] from EEZ	EEZ Quota
1965	19,998	14,968	5,029	75	-
1966	20,463	14,696	5,766	72	-
1967	18,168	11,204	6,964	55	-
1968	18,394	9,072	9,322	49	-
1969	22,487	7,212	15,275	32	-
1970	30,535	6,396	24,139	21	-
1971	23,829	22,704	1,126	95	-
1972	28,744	25,071	3,674	87	-
1973	37,362	32,921	4,441	88	-
1974	43,595	33,761	9,834	77	-
1975	39,442	20,080	19,362	51	-
1976	22,277	19,304	2,982	87	-
1977	23,149	19,490	3,660	84	-
1978	17,798	14,240	3,558	80	13,880
1979	15,836	13,186	2,650	83	13,880
1980	17,117	15,748	1,369	92	13,882
1981	20,910	16,947	3,964	81	13,882
1982	22,552	16,688	5,873	74	18,506
1983	25,373	20,485	4,887	81	18,892
1984	31,862	24,776	7,086	78	18,892
1985	32,894	23,691	9,204	72	21,205
1986	35,720	24,923	10,797	70	24,290
1987	27,553	22,147	5,406	80	24,290
1988	28,824	23,951	4,873	83	24,290
1989	30,424	22,335	8,089	73	25,184
1990	32,556	24,027	8,528	74	24,282
1991	30,037	20,638	9,399	69	21,976
1992	33,831	22,109	11,722	65	21,976
1993	33,527	21,961	11,565	66	21,976
1994[2]	-	19,777	-	-	21,976

[1] Landings through 1993 are from the U.S. Dept. of Commerce series "Fisheries of the United States".

[2] The 1994 landings were projected from data available in the s1032 database as of September 13, 1994.

Table D2. Total annual EEZ surf clam landings (metric tons) from principle harvesting regions[1], as reported in mandatory logbooks reported by each vessel.

Year	Middle Atlantic	Southern New England	Georges Bank	Total[4]
1983[2]	16,277	672	0	16,949
1984	17,769	339	2453	20,561
1985	16,913	389	1845	19,147
1986	19,646	1121	1813	22,580
1987	19,675	1138	905	21,718
1988	21,130	1510	738	23,378
1989	20,083	1359	433[5]	21,875
1990	22,934	998	7	23,939
1991	20,561	32	0	20,593
1992	21,680	5	0	21,685
1993	21,841	3	0	21,844
1994[3]	19,777	0	0	19,777

1 Regions are shown in Figure 2.1.1.2. The "Middle Atlantic" includes Southern Virginia/North Carolina through Long Island.

2 Landings data are from the s1032 logbook database.

3 Estimated from data available on September 13, 1994.

4 The "Regions Total" is slightly less than total EEZ landings (Table D1) because a small fraction of the trips could not be assigned to a region.

5 Fishery closed due to PSP contamination as of late summer, 1989.

Table D3. Annual EEZ surf clam landings and percent of landings from areas of the Mid-Atlantic region.

	Long Island		Northern New Jersey		Southern New Jersey		Delmarva		Southern Virginia North Carolina	
	mt	%	mt	%	mt	%	mt	%	mt	%
1978[1]	0	0	1348	31	53	1	2927	68	0	0
1979	0	0	1463	38	97	3	2268	59	0	0
1980	0	0	1692	41	132	3	2300	56	0	0
1981	0	0	6462	97	114	2	95	1	0	0
1982	49	0	7440	45	434	3	6777	41	1988	12
1983	212	1	5515	34	999	6	5772	35	3779	23
1984	6	0	8787	49	1776	10	5303	30	1897	11
1985	0	0	8427	50	1077	6	6636	39	772	5
1986	16	0	14703	75	1474	8	2604	13	849	4
1987	0	0	17238	88	749	4	1306	7	387	2
1988	0	0	19196	91	195	1	1147	5	591	3
1989	0	0	16415	82	90	0	3118	16	461	2
1990	0	0	16996	74	891	4	3546	15	1502	7
1991	15	0	17623	86	1289	6	1634	8	0	0
1992	61	0	18334	85	2064	10	1221	6	0	0
1993	62	0	16338	75	2023	9	3418	16	0	0
1994[2]	39	0	16285	82	682	3	2770	14	0	0

[1] Values from 1978-1982 are from the weighout database. Values from 1983-1994 are from the s1032 logbook data base.

[2] The 1994 values were projected from data available as of September 13, 1994.

Table D4. Annual EEZ surf clam discard estimates[1] (mt, meats), percent of total catch discarded[2] from areas of the Mid-Atlantic region, and minimum size limits (mm of shell length).

	Northern New Jersey		Southern New Jersey		Delmarva		Size
	mt	%	mt	%	mt	%	Limit
1982	3684	33.1	215	33.1	2295	25.3	140
1983	2122	27.8	385	27.8	2127	26.9	140
1984	2266	20.5	458	20.5	2015	27.5	133
1985	1938	18.7	248	18.7	1725	20.6	127
1986	2328	13.7	233	13.7	239	8.4	127
1987	1414	7.6	61	7.6	415	24.1	127
1988	1317	6.4	13	6.4	106	8.5	127
1989	1048	6.0	6	6.0	258	7.6	127
1990	1089	6.0	57	6.0	123	3.4	127
1991	495	2.7	36	2.7	5	0.3	-
1992	918	4.8	102	4.8	4	0.3	-
1993	0	0[3]	0	0[3]	0	0	-
1994	0	0[3]	0	0[3]	0	0[3]	-

1 Discard weight was calculated from the percent discard estimate and the reported weight of landings by area/year.

2 Percent discards were estimated from data in mandatory log reports, weighted by landings per trip. The discard rate was estimated for the New Jersey area, and is applied to both the North and South. Estimates for 1982-1986 are derived from quarterly data reported in Lab. Ref. Doc. 86-11.

3 Percent is assumed to be zero. No discards were reported on any interview sheet.

Table D5. Summary statistics on surf clam commercial length frequency data by year/area. Data were collected by port agents taking random samples from landings.

Area/Year	Mean Length (mm)[1]	Min L	Max L	Number of Measured Clams[2]
New Jersey				
1982[3]	140.5	75	205	7477
1983	142.5	75	205	11253
1984	142.1	45	195	12751
1985	140.4	55	195	7674
1986	136.3	105	175	5130
1987	134.4	95	185	900
1988	137.7	85	165	900
1989	139.9	105	175	919
1990	136.5	95	175	901
1991	143.0	93	188	2272
1992	141.1	64	186	1710
1993	139.8	80	170	928
1994	138.5	85	185	900
Delmarva				
1982	159.0	85	205	7756
1983	151.5	45	205	5923
1984	138.8	95	195	3066
1985	132.0	95	175	1832
1986	130.0	95	155	1260
1987	131.4	105	165	730
1988	136.0	115	165	420
1989	136.6	115	175	866
1990	139.1	95	175	892
1991	125.5	20	183	1080
1992	123.5	73	198	1170
1993	122.4	77	155	1392
1994	109.2	85	135	119
S. New England				
1982	153.7	135	175	30
1983	150.0	125	165	30
1984	147.9	115	175	90
1985	151.6	115	175	150
1986	161.0	125	195	330
1987	160.9	115	195	569
1988	154.3	105	185	810
1989	155.8	115	185	449
1990	164.1	135	185	209
1991	-[4]	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-

1 "Mean length" is the expected value from the length frequency distribution, using size classes of 1 cm. Length frequency distributions were derived by weighting trips by their respective landings.
2 Total number of clams used in this assessment. Typically, 30 clams are measured per trip. The minimum and maximum lengths of measured clams are reported.
3 Values from 1987-1990 and 1994 are from subsamples of the data. Subsamples contained data from 30 randomly selected trips, when available.
4 "-" = no data available.

Table D6. Summary statistics on fishing effort (hrs.) per surf clam trip by region from 1982-1994. N = number of trips.

Region/ YEAR	Mean	SD	N
Northern NJ			
1982	10.6	2.7	1409
1983	9.6	3.0	1629
1984	9.3	2.7	1628
1985	5.7	.9	1432
1986	5.7	.8	1619
1987	5.7	.8	2006
1988	5.7	.7	2288
1989	5.7	.8	2051
1990	6.0	1.5	1958
1991	8.6	3.5	1931
1992	9.9	4.2	2057
1993	9.8	3.9	1795
1994[1]	11.3	4.9	1158
Delmarva			
1982	11.2	2.2	1458
1983	11.2	2.5	1408
1984	10.7	2.5	769
1985	5.9	.8	688
1986	5.9	1.0	269
1987	5.8	.8	124
1988	5.9	.5	102
1989	5.8	.7	278
1990	6.2	1.7	337
1991	7.0	3.8	179
1992	5.0	2.5	160
1993	5.7	2.8	447
1994[1]	5.0	3.3	228

[1] 1994 data do not represent entire year.

Table D7. Comparison of Middle Atlantic surf clam landings per unit effort (LPUE, kilograms per hour fishing time) & percent of total catch taken by year. Statistics, as reported in mandatory logbook submissions, 1982-1994.

YEAR/Area	Vessel Class 1		Vessel Class 2		Vessel Class 3	
			LPUE	%	LPUE	%
Northern NJ						
1982	180	3	208	40	325	56
1983	222	6	353	68	372	26
1984	363	5	569	72	697	23
1985	591	5	979	57	1227	38
1986	739	3	1300	35	1848	61
1987	735	2	1206	35	1712	63
1988	725	2	1154	33	1699	64
1989	753	3	1170	35	1547	62
1990	729	2	1187	32	1566	66
1991	400	0	959	29	1063	71
1992	362	0	1018	22	851	77
1993	381	0	1118	20	904	79
1994	393	0	979	23	761	77
Southern NJ						
1982	92	8	226	39	269	54
1983	121	12	236	54	399	35
1984	246	10	438	31	595	59
1985	578	4	779	12	1216	84
1986	575	3	1020	17	1519	80
1987	331	0	1003	22	1604	78
1988	-	-	879	31	1437	69
1989	514	3	1001	47	1200	50
1990	227	0	1070	37	1237	62
1991	247	0	1454	39	1700	61
1992	-	-	1590	43	2007	57
1993	390	0	2238	54	1694	46
1994	343	1	1807	17	993	81
Delmarva						
1982	177	4	202	11	327	85
1983	293	6	234	15	408	80
1984	350	5	444	15	734	80
1985	690	3	1180	13	1844	84
1986	623	4	1068	13	1934	83
1987	481	3	729	3	2057	94
1988	532	2	1693	10	1959	88
1989	564	0	1401	13	1944	87
1990	-	-	1305	21	1687	79
1991	-	-	1008	20	1406	80
1992	-	-	1733	34	1325	66
1993	-	-	1360	44	1352	56
1994	-	-	1381	38	1732	62

Table D8. Average surfclam landings per trip, by region. N is number of trips. Units are kg of meats.

REGION=DMV

YEAR	N	KG Mean	KG SD
1982	1458	3325.2	1703.8
1983	1408	4053.4	2425.3
1984	769	6792.0	3652.9
1985	688	9616.2	4445.9
1986	269	9579.9	4803.9
1987	124	10309.6	5336.7
1988	102	10717.5	4918.5
1989	278	10652.2	3673.4
1990	337	9806.4	3561.8
1991	179	9128.2	3522.3
1992	160	7204.6	2171.7
1993	447	7616.0	2415.6
1994	228	7776.9	1853.6

REGION=NNJ

YEAR	N	KG Mean	KG SD
1982	1409	2733.0	1784.5
1983	1629	3313.5	1496.4
1984	1628	5341.8	2278.6
1985	1432	5858.8	2719.3
1986	1619	8795.0	4108.8
1987	2006	8295.0	3835.3
1988	2288	8165.8	3939.4
1989	2051	7746.9	3513.2
1990	1958	8414.4	3820.8
1991	1931	8815.8	3699.5
1992	2057	8721.5	3428.0
1993	1795	9088.4	3432.8
1994	1158	9003.9	3485.3

Table D9. Surfclam GLM of CPUE, 1982-1994. Factors are year, tonclass, sub-region. Standards are yr=1982, tonclass=3. Region is **DELMARVA.**

General Linear Models Procedure

Dependent Variable: L_LPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	4252.52191702	283.50146113	1001.24	0.0001
Error	6431	1820.93221326	0.28314915		
Corrected Total	6446	6073.45413027			

R-Square	C.V.	Root MSE	L_LPUE Mean
0.700182	8.248032	0.53211761	6.45144945

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	12	3949.00429188	329.08369099	1162.23	0.0001
SUBREG	1	13.07047765	13.07047765	46.16	0.0001
TONCL	2	290.44714749	145.22357374	512.89	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	12	3803.01112298	316.91759358	1119.26	0.0001
SUBREG	1	13.89660432	13.89660432	49.08	0.0001
TONCL	2	290.44714749	145.22357374	512.89	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		5.632667748 B	375.05	0.0001	0.01501861
YEAR	1983	0.159518464 B	7.40	0.0001	0.02154625
	1984	0.739303709 B	28.41	0.0001	0.02602497
	1985	1.642922232 B	59.48	0.0001	0.02762156
	1986	1.633340445 B	43.54	0.0001	0.03751599
	1987	1.650318411 B	32.36	0.0001	0.05099457
	1988	1.741920968 B	31.53	0.0001	0.05525327
	1989	1.816363298 B	51.77	0.0001	0.03508390
	1990	1.684283210 B	50.12	0.0001	0.03360677
	1991	1.624006653 B	38.22	0.0001	0.04249347
	1992	1.801032205 B	40.49	0.0001	0.04447689
	1993	1.779610984 B	60.74	0.0001	0.02929840
	1994	1.987781246 B	51.91	0.0001	0.03829221
	9999	0.000000000 B	.	.	.
SUBREG	2	0.120432885 B	7.01	0.0001	0.01719089
	99	0.000000000 B	.	.	.
TONCL	1	-0.695632331 B	-24.53	0.0001	0.02835548
	2	-0.380652133 B	-23.34	0.0001	0.01631172
	99	0.000000000 B	.	.	.

Table D10. Surfclam GLM of CPUE, 1982-1994. Factors are year, tonclass. Standards are yr=1982, tonclass=3. Region is **NORTHERN NEW JERSEY.**

------------------------------------ REGION=NNJ ------------------------------------

General Linear Models Procedure

Dependent Variable: L_LPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	6741.92289303	481.56592093	2174.65	0.0001
Error	22946	5081.27965085	0.22144512		
Corrected Total	22960	11823.20254388			

	R-Square	C.V.	Root MSE	L_LPUE Mean
	0.570228	6.951790	0.47057955	6.76918589

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	12	6232.66329614	519.38860801	2345.45	0.0001
TONCL	2	509.25959689	254.62979844	1149.86	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	12	5626.04140531	468.83678378	2117.17	0.0001
TONCL	2	509.25959689	254.62979844	1149.86	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		5.517296668 B	420.69	0.0001	0.01311499
YEAR	1983	0.471753356 B	27.48	0.0001	0.01716677
	1984	0.992149850 B	57.69	0.0001	0.01719712
	1985	1.478434006 B	83.66	0.0001	0.01767198
	1986	1.842834435 B	107.44	0.0001	0.01715224
	1987	1.772666116 B	108.24	0.0001	0.01637658
	1988	1.742205647 B	109.[illegible]	0.0001	0.01595510
	1989	1.705161349 B	104.59	0.0001	0.01630333
	1990	1.735369938 B	105.34	0.0001	0.01647394
	1991	1.466494076 B	88.[illegible]	0.0001	0.01656737
	1992	1.323439404 B	[illegible]	0.0001	0.01641269
	1993	1.384651243 B	[illegible]	0.0001	0.01690601
	1994	1.246704532 B	[illegible]	0.0001	0.01878628
	9999	0.000000000 B		.	.
TONCL	1	-0.682613010 B	[illegible]	0.0001	0.01548526
	2	-0.195083846 B	[illegible]	0.0001	0.00674496
	99	0.000000000 B		.	.

Table D11.
GLM Year Estimates

Species: Surfclam

Species	* Region	Year	EST (GLM)	MSE	EST+.5MSE	GLM EST Back Transformed	** wt/clm (gr)	wt/clm (kg)	*** GLM EST (in #'s)
SC	DMV	82	0.00	0.28	0.14	1.15	140	0.14	8.23
		83	0.16	0.28	0.30	1.35	124	0.12	10.90
		84	0.74	0.28	0.88	2.41	96	0.10	25.14
		85	1.64	0.28	1.78	5.96	83	0.08	71.77
		86	1.63	0.28	1.77	5.90	79	0.08	74.68
		87	1.65	0.28	1.79	6.00	82	0.08	73.18
		88	1.74	0.28	1.88	6.58	90	0.09	73.07
		89	1.82	0.28	1.96	7.08	91	0.09	77.85
		90	1.68	0.28	1.83	6.21	97	0.10	64.00
		91	1.62	0.28	1.77	5.84	74	0.07	78.99
		92	1.80	0.28	1.94	6.98	71	0.07	98.27
		93	1.78	0.28	1.92	6.83	68	0.07	100.43
		94	1.99	0.28	2.13	8.41	50	0.05	168.19
SC	NNJ	82	0.00	0.22	0.11	1.12	123	0.12	9.08
		83	0.47	0.22	0.58	1.79	124	0.12	14.44
		84	0.99	0.22	1.10	3.01	122	0.12	24.70
		85	1.48	0.22	1.59	4.90	118	0.12	41.52
		86	1.84	0.22	1.95	7.05	108	0.11	65.31
		87	1.77	0.22	1.88	6.58	105	0.11	62.63
		88	1.74	0.22	1.85	6.38	112	0.11	56.95
		89	1.71	0.22	1.82	6.15	117	0.12	52.53
		90	1.74	0.22	1.85	6.34	109	0.11	58.12
		91	1.47	0.22	1.58	4.84	124	0.12	39.04
		92	1.32	0.22	1.43	4.20	120	0.12	34.97
		93	1.38	0.22	1.50	4.46	119	0.12	37.49
		94	1.25	0.22	1.36	3.89	118	0.12	32.93

* = For each Region, the Standard Year in the GLM is 1982
** = based on commercial length frequency data
*** = final estimate is in numbers, the (Backtransformed EST / wt per clam (in kg))

Table D12. Summary of estimation results for the determination of the effort adjustment factor (c).

Non-Linear Least Squares Summary Statistics   Dependent Variable LPUE

Source	DF	Sum of Squares	Mean Square
Regression	3	22755.977479	7585.325826
Residual	6	49.480821	8.246804
Uncorrected Total	9	22805.458300	
(Corrected Total)	8	1297.280422	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B0	267.3059439	67.299255299	102.63047964	431.98140808
B1	-2.3658090	0.764337806	-4.23607755	-0.49554038
c	0.7447368	0.062700781	0.59131339	0.89816018

Asymptotic Correlation Matrix

Corr	B0	B1	c
B0	1	-0.999818144	0.8175706
B1	-0.999818144	1	-0.823706685
c	0.8175706	-0.823706685	1

Table D13. Summary of research vessel survey cruises used in the analysis of EEZ surf clam population dynamics, 1965-1994.

Research Vessel (cm)	Dates of Cruises	Dredge Knife Width (cm)	Time of Tow (minutes)	Number of Stations	Ring Size or[1] Bar Space
Undaunted	May 1965	76	5	375 (293)[2]	5.1
Undaunted	Oct 1965	76	5	217 (158)	5.1
Albatross IV	Aug 1966	76	5	240 (210)	5.1
Albatross IV	Jun 1969	76	5	278 (166)	5.1
Delaware II	Aug 1970	122	4	199 (133)	3.0
Delaware II	Jun 1974	76	5	241 (142)	5.1
Delaware II	Apr 1976	122	4	259 (133)	3.0
Delaware II	Jan 1977	122	4	244 (92)	3.0
Delaware II	Jan 1978	122	4	324 (192)	3.0
Delaware II	Dec 1978	122	4	163 (105)	2.5
Delaware II	Jan 1980	152	5	229 (156)	5.1
Delaware II	Aug 1980	152	5	231 (114)	5.1
Delaware II	Aug 1981	152	5	261 (119)	5.1
Delaware II	Aug 1982	152	5	272 (151)	5.1
Delaware II	Aug 1983	152	5	381 (169)	5.1
Delaware II	Jul 1984	152	5	448 (241)	5.1
Delaware II	Jun 1986	152	5	334 (296)	5.1
Delaware II	Jul 1989	152	5	340 (290)	5.1
Delaware II	Jun 1992	152	5	496 (388)	5.1
Delaware II	Jul 1994	152	5	538[3] (352)	5.1

[1]Portion of the dredge where the catch is retained.

[2]Number of stations located in surf clam assessment strata.

[3]Value is relatively large because additional samples were taken to examine the effect of gear configuration on catch per tow.

Table D14. Summary of research vessel survey abundance per tow data, by year, region and size class.

SURVEY YEAR	REGION					
	N. NEW JERSEY			DELMARVA		
	RECRUITS (105-119mm)	FULLY RECRUITED (120+mm)	ALL SIZES	RECRUITS (103-119mm)	FULLY RECRUITED (120+mm)	ALL SIZES
1965(A) *	--	--	38.1	--	--	27.68
1965(B)	--	--	35.7	--	--	28.02
1966	--	--	30.4	--	--	32.53
1969	--	--	34.3	--	--	26.26
1970	--	--	25.7	--	--	19.64
1974	--	--	21.4	--	--	36.66
1976	0.4	11.3	12.9	0.8	16.5	22.0
1977	0.3	1.1	2.5	0.5	9.1	11.4
1978(A)	0.3	0.7	2.1	0.6	7.6	11.6
1978(B)	1.7	1.5	45.0	1.1	6.5	622.3
1980(A)	4.2	4.1	20.3	1.8	8.5	43.9
1980(B)	19.3	8.9	34.3	3.8	7.4	31.1
1981	7.9	8.6	23.1	32.6	14.8	93.5
1982 **	24.9	47.3	96.2	60.1	18.9	125.0
1983	31.1	38.6	86.3	24.3	31.4	63.3
1984	10.0	45.8	71.5	31.9	35.9	229.0
1986	6.9	42.5	58.1	50.0	77.5	138.7
1989	6.9	47.0	61.1	12.0	32.2	49.5
1992	13.5	34.3	59.1	7.5	29.6	43.7
1994	27.2	105.9	176.5	39.2	63.9	141.4

* Values from 1965-1981 are from NEFSC Lab. Ref. Doc. 86-14 and from Murawski and Serchuk (1989). They are standardized to a 60-in wide dredge towed 5-min

** Values from 1982-1994 are standardized to a tow distance of 0.15 n. mi.

Table D15. DeLury model results for **Northern New Jersey** surfclam, based on a combination of survey and commercial-based runs.

DETERMINISTIC RESULTS

CALENDAR YEAR	STOCK SIZE ESTIMATES (millions at time of survey) RECRUITS	FULLY-RECRUITED	MORTALITY RATES (between surveys) Z on sizes 1+	F on size 1	F on sizes 2+
1982	285.356	271.660	0.29	0.16	0.33
1983	395.197	418.753	0.14	0.06	0.12
1984	135.780	702.317	0.09	0.02	0.05
1985	168.865	763.568	0.10	0.03	0.05
1986	92.377	848.958	0.19	0.07	0.14
1987	168.865	785.909	0.23	0.10	0.20
1988	168.865	764.071	0.24	0.10	0.21
1989	92.153	739.674	0.22	0.09	0.19
1990	168.865	671.828	0.27	0.12	0.25
1991	168.865	648.513	0.26	0.12	0.23
1992	178.372	637.012	0.28	0.13	0.26
1993	168.865	624.976	0.26	0.12	0.23
1994	175.007	618.296			

RECRUITS = SIZECLASS 1   FULLY-RECRUITED = SIZECLASS 2+

CALENDAR YEAR	---- BIOMASS ESTIMATES (at time of the survey) ---- (1000 mt) RECRUITS	FULLY-RECRUITED	TOTAL BIOMASS	EXPLOITED BIOMASS	CATCH BIOMASS DURING YEAR (1000 mt)
1982	18.150	29.141	47.290	38.216	9.282
1983	25.084	44.801	69.886	57.343	6.576
1984	8.710	77.692	86.402	82.047	9.920
1985	10.833	84.467	95.300	89.884	9.396
1986	5.927	101.553	107.480	104.517	15.867
1987	10.834	94.011	104.845	99.428	17.945
1988	10.834	91.399	102.233	96.816	19.855
1989	5.949	88.548	94.497	91.522	16.939
1990	10.901	80.426	91.327	85.876	17.541
1991	10.901	77.635	88.536	83.085	17.871
1992	11.526	80.312	91.838	86.075	18.793
1993	10.912	78.795	89.706	84.250	16.338
1994	11.174	77.670	88.844	83.257	

CALENDAR YEAR	---- 1000 Metric Tons ---- EXPLOITED BIOMASS	DELTA B	CATCH	SURPLUS PRODUCTION	PROD-BIOMASS RATIO
1982	38.216	19.128	9.282	28.410	0.8828
1983	57.343	24.703	6.576	31.279	0.5803
1984	82.047	7.837	9.920	17.757	0.2184
1985	89.884	14.633	9.396	24.029	0.2655
1986	104.517	-5.088	15.867	10.779	0.1013
1987	99.428	-2.612	17.945	15.333	0.1540
1988	96.816	-5.294	19.855	14.561	0.1529
1989	91.522	-5.646	16.939	11.293	0.1242
1990	85.876	-2.791	17.541	14.749	0.1783
1991	83.085	2.990	17.871	20.860	0.2626
1992	86.075	-1.825	18.793	16.968	0.2076
1993	84.250	-0.994	16.338	15.344	0.1932
1994	83.257				

Table D15. (continued).

STOCHASTIC **RESULTS** (with bao = 2; i.e., with bias corrected estimates)

BOOTSTRAP OUTPUT VARIABLE: R_0
Population size (in number) of the recruits at time of the survey

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	2.854E2	2.729E2	1.621E1	0.06
1983	3.952E2	3.562E2	1.847E1	0.05
1984	1.358E2	1.208E2	6.776E0	0.05
1985	1.689E2	1.543E2	5.463E0	0.03
1986	9.238E1	8.303E1	4.832E0	0.05
1987	1.689E2	1.543E2	5.463E0	0.03
1988	1.689E2	1.543E2	5.463E0	0.03
1989	9.215E1	8.361E1	4.424E0	0.05
1990	1.689E2	1.543E2	5.463E0	0.03
1991	1.689E2	1.543E2	5.463E0	0.03
1992	1.784E2	1.641E2	8.691E0	0.05
1993	1.689E2	1.543E2	5.463E0	0.03
1994	1.750E2	1.789E2	5.728E0	0.03

BOOTSTRAP OUTPUT VARIABLE: N_0
Popn size (in number) of fully-recruited animals at time of the survey

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	2.717E2	2.886E2	3.735E1	0.14
1983	4.188E2	4.051E2	3.640E1	0.09
1984	7.023E2	6.415E2	3.192E1	0.05
1985	7.636E2	7.260E2	3.071E1	0.04
1986	8.490E2	8.252E2	3.783E1	0.04
1987	7.859E2	7.733E2	4.439E1	0.06
1988	7.641E2	7.499E2	5.108E1	0.07
1989	7.397E2	7.315E2	5.837E1	0.08
1990	6.718E2	6.764E2	5.978E1	0.09
1991	6.485E2	6.460E2	6.299E1	0.10
1992	6.370E2	6.221E2	6.942E1	0.11
1993	6.250E2	6.021E2	7.064E1	0.11
1994	6.183E2	5.818E2	7.185E1	0.12

Table D15. (continued).

BOOTSTRAP OUTPUT VARIABLE: F_RN
Fishing mortality rate for all animals of recruitment size and larger (i.e., recruits plus the fully-recruited group during survey years

SURVEY YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	0.2381	0.2771	0.0221	0.09
1983	0.0949	0.1119	0.0177	0.19
1984	0.0432	0.0028	0.0146	0.34
1985	0.0476	0.0210	0.0243	0.51
1986	0.1356	0.1157	0.0183	0.13
1987	0.1791	0.1668	0.0208	0.12
1988	0.1882	0.1631	0.0289	0.15
1989	0.1740	0.1428	0.0250	0.14
1990	0.2197	0.2025	0.0317	0.14
1991	0.2074	0.1983	0.0396	0.19
1992	0.2252	0.2111	0.0335	0.15
1993	0.2067	0.2016	0.0348	0.17

BOOTSTRAP OUTPUT VARIABLE: F_N
Fishing mortality rate on the fully-recruited animals during survey yrs

SURVEY YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	0.3297	0.3804	0.0309	0.09
1983	0.1232	0.1437	0.0220	0.18
1984	0.0467	0.0024	0.0158	0.34
1985	0.0523	0.0228	0.0268	0.51
1986	0.1428	0.1215	0.0192	0.13
1987	0.1970	0.1826	0.0233	0.12
1988	0.2077	0.1788	0.0327	0.16
1989	0.1850	0.1509	0.0272	0.15
1990	0.2461	0.2239	0.0378	0.15
1991	0.2330	0.2196	0.0474	0.20
1992	0.2552	0.2353	0.0422	0.17
1993	0.2329	0.2232	0.0439	0.19

BOOTSTRAP OUTPUT VARIABLE: F_N_bar
Average fishing mortality rates on fully-recruited animals during survey years
1st Row: **F in 1993**
2nd Row: **Average F for 1992 1993**
3rd Row: **Average F for 1991 1992 1993**

SURVEY YEAR(S)	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1993 0	0.2329	0.2232	0.0439	0.19
1992 93	0.2441	0.2292	0.0420	0.17
1991 93	0.2404	0.2260	0.0432	0.18

Table D15. (continued).

BOOTSTRAP OUTPUT VARIABLE: B_R_0
Population biomass of the recruits at time of the survey
i.e. 50% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	1.815E1	1.736E1	1.031E0	0.06
1983	2.508E1	2.261E1	1.172E0	0.05
1984	8.710E0	7.747E0	4.347E-1	0.05
1985	1.083E1	9.900E0	3.504E-1	0.03
1986	5.927E0	5.327E0	3.100E-1	0.05
1987	1.083E1	9.901E0	3.505E-1	0.03
1988	1.083E1	9.901E0	3.505E-1	0.03
1989	5.949E0	5.398E0	2.856E-1	0.05
1990	1.090E1	9.962E0	3.526E-1	0.03
1991	1.090E1	9.962E0	3.526E-1	0.03
1992	1.153E1	1.060E1	5.616E-1	0.05
1993	1.091E1	9.972E0	3.530E-1	0.03
1994	1.117E1	1.142E1	3.657E-1	0.03

BOOTSTRAP OUTPUT VARIABLE: B_N_0
Population biomass of the fully-recruited animals at time of the survey
i.e. 50% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	2.914E1	3.096E1	4.006E0	0.14
1983	4.480E1	4.334E1	3.894E0	0.09
1984	7.769E1	7.096E1	3.531E0	0.05
1985	8.447E1	8.031E1	3.397E0	0.04
1986	1.016E2	9.871E1	4.525E0	0.04
1987	9.401E1	9.251E1	5.310E0	0.06
1988	9.140E1	8.970E1	6.111E0	0.07
1989	8.855E1	8.757E1	6.987E0	0.08
1990	8.043E1	8.098E1	7.156E0	0.09
1991	7.763E1	7.734E1	7.541E0	0.10
1992	8.031E1	7.844E1	8.752E0	0.11
1993	7.879E1	7.591E1	8.906E0	0.11
1994	7.767E1	7.308E1	9.026E0	0.12

BOOTSTRAP OUTPUT VARIABLE: B_RN_0_expl
Exploited biomass at time of the survey
i.e. 50% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	3.822E1	3.963E1	3.969E0	0.10
1983	5.734E1	5.465E1	3.785E0	0.07
1984	8.205E1	7.483E1	3.548E0	0.04
1985	8.988E1	8.526E1	3.503E0	0.04
1986	1.045E2	1.014E2	4.590E0	0.04
1987	9.943E1	9.746E1	5.412E0	0.05
1988	9.682E1	9.465E1	6.223E0	0.06
1989	9.152E1	9.027E1	7.057E0	0.08
1990	8.588E1	8.596E1	7.283E0	0.08
1991	8.309E1	8.232E1	7.680E0	0.09
1992	8.608E1	8.374E1	8.933E0	0.10
1993	8.425E1	8.090E1	9.059E0	0.11
1994	8.326E1	7.879E1	9.172E0	0.11

Table D16. DeLury model results for Delmarva surfclam, based on a combination of survey and commercial-based runs.

DETERMINISTIC RESULTS

CALENDAR YEAR	STOCK SIZE ESTIMATES (millions at time of survey) RECRUITS	FULLY-RECRUITED	MORTALITY RATES (between surveys) Z on sizes 1+	F on size 1	F on sizes 2+
1982	120.526	35.510	0.71	0.54	1.09
1983	86.253	78.182	0.49	0.30	0.60
1984	138.572	100.985	0.31	0.18	0.35
1985	67.665	178.633	0.49	0.26	0.51
1986	115.471	154.332	0.22	0.11	0.22
1987	67.665	217.282	0.17	0.07	0.13
1988	67.665	240.595	0.23	0.10	0.21
1989	29.873	249.170	0.26	0.11	0.23
1990	67.665	214.583	0.26	0.12	0.24
1991	67.665	216.468	0.22	0.10	0.20
1992	19.779	229.576	0.14	0.05	0.09
1993	67.665	217.337	0.25	0.12	0.23
1994	75.609	223.400	.		

RECRUITS = SIZECLASS 1 FULLY-RECRUITED = SIZECLASS 2+

---- BIOMASS ESTIMATES (at time of the survey) ----

CALENDAR YEAR	RECRUITS	FULLY-RECRUITED	TOTAL BIOMASS (1000 mt)	EXPLOITED BIOMASS	CATCH BIOMASS DURING YEAR (1000 mt)
1982	6.138	3.675	9.813	6.744	7.925
1983	4.694	7.558	12.252	9.905	6.836
1984	7.257	9.855	17.113	13.484	6.310
1985	3.544	17.433	20.977	19.205	7.498
1986	6.312	13.202	19.514	16.358	2.723
1987	3.699	18.587	22.286	20.436	1.513
1988	3.699	20.581	24.280	22.431	1.200
1989	1.576	23.103	24.679	23.891	3.247
1990	3.569	19.896	23.465	21.681	3.607
1991	3.569	20.071	23.640	21.856	1.636
1992	1.072	21.893	22.965	22.429	1.223
1993	3.666	20.726	24.392	22.559	3.418
1994	4.038	20.845	24.883	22.864	

CALENDAR YEAR	EXPLOITED BIOMASS (1000 Metric Tons)	DELTA B	CATCH	SURPLUS PRODUCTION	PROD-BIOMASS RATIO
1982	6.744	3.161	7.925	11.086	1.6824
1983	9.905	3.579	6.836	10.414	1.0960
1984	13.484	5.721	6.310	12.031	0.8933
1985	19.205	-2.847	7.498	4.651	0.2425
1986	16.358	4.078	2.723	6.802	0.4287
1987	20.436	1.994	1.513	3.508	0.1868
1988	22.431	1.460	1.200	2.661	0.1084
1989	23.891	-2.210	3.247	1.036	0.0588
1990	21.681	0.175	3.607	3.782	0.1927
1991	21.856	0.573	1.636	2.210	0.0974
1992	22.429	0.130	1.223	1.353	0.0664
1993	22.559	0.305	3.418	3.723	0.1724
1994	22.864				

Table D16. (continued).

STOCHASTIC RESULTS (with bao = 1)

BOOTSTRAP OUTPUT VARIABLE: R_0
Population size (in number) of the recruits at time of the survey

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	1.205E2	1.205E2	2.805E1	0.23
1983	8.625E1	8.625E1	3.068E1	0.36
1984	1.386E2	1.386E2	5.274E1	0.38
1985	6.766E1	6.766E1	8.020E0	0.12
1986	1.155E2	1.155E2	3.774E1	0.33
1987	6.766E1	6.766E1	8.020E0	0.12
1988	6.766E1	6.766E1	8.020E0	0.12
1989	2.987E1	2.987E1	1.089E1	0.36
1990	6.766E1	6.766E1	8.020E0	0.12
1991	6.766E1	6.766E1	8.020E0	0.12
1992	1.978E1	1.978E1	7.203E0	0.36
1993	6.766E1	6.766E1	8.020E0	0.12
1994	7.561E1	7.561E1	3.367E0	0.04

BOOTSTRAP OUTPUT VARIABLE: N_0
Popn size (in number) of fully-recruited animals at time of the survey

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	3.551E1	3.551E1	1.648E1	0.46
1983	7.818E1	7.818E1	2.879E1	0.37
1984	1.010E2	1.010E2	4.070E1	0.40
1985	1.786E2	1.786E2	6.100E1	0.34
1986	1.543E2	1.543E2	6.393E1	0.41
1987	2.173E2	2.173E2	7.610E1	0.35
1988	2.406E2	2.406E2	7.965E1	0.33
1989	2.492E2	2.492E2	8.047E1	0.32
1990	2.146E2	2.146E2	7.640E1	0.36
1991	2.165E2	2.165E2	7.821E1	0.36
1992	2.296E2	2.296E2	8.298E1	0.36
1993	2.173E2	2.173E2	8.280E1	0.38
1994	2.234E2	2.234E2	8.479E1	0.38

Table D16. (continued).

BOOTSTRAP OUTPUT VARIABLE: F_N
Fishing mortality rate on the fully-recruited animals during survey yrs

SURVEY YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	1.0854	1.0854	0.2729	0.25
1983	0.5994	0.5994	0.2128	0.35
1984	0.3531	0.3531	0.1026	0.29
1985	0.5104	0.5104	0.1754	0.34
1986	0.2197	0.2197	0.0704	0.32
1987	0.1337	0.1337	0.0437	0.33
1988	0.2053	0.2053	0.0580	0.28
1989	0.2264	0.2264	0.0519	0.23
1990	0.2450	0.2450	0.0671	0.27
1991	0.1997	0.1997	0.0700	0.35
1992	0.0934	0.0934	0.0352	0.38
1993	0.2319	0.2319	0.0897	0.39

BOOTSTRAP OUTPUT VARIABLE: F_N_bar
Average fishing mortality rates on fully-recruited animals during survey years
1st Row: F in 1993
2nd Row: Average F for 1992 1993
3rd Row: Average F for 1991 1992 1993

SURVEY YEAR(S)	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1993 0	0.2319	0.2319	0.0897	0.39
1992 93	0.1627	0.1627	0.0564	0.35
1991 93	0.1750	0.1750	0.0563	0.32

BOOTSTRAP OUTPUT VARIABLE: B_R_0
Population biomass of the recruits at time of the survey
i.e. 50% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	6.138E0	6.138E0	1.428E0	0.23
1983	4.694E0	4.694E0	1.670E0	0.36
1984	7.257E0	7.257E0	2.762E0	0.38
1985	3.544E0	3.544E0	4.200E-1	0.12
1986	6.312E0	6.312E0	2.063E0	0.33
1987	3.699E0	3.699E0	4.384E-1	0.12
1988	3.699E0	3.699E0	4.384E-1	0.12
1989	1.576E0	1.576E0	5.742E-1	0.36
1990	3.569E0	3.569E0	4.230E-1	0.12
1991	3.569E0	3.569E0	4.230E-1	0.12
1992	1.072E0	1.072E0	3.902E-1	0.36
1993	3.666E0	3.666E0	4.345E-1	0.12
1994	4.038E0	4.038E0	1.798E-1	0.04

Table D16. (continued).

BOOTSTRAP OUTPUT VARIABLE: B_N_0
Population biomass of the fully-recruited animals at time of the survey
i.e. 50% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	3.675E0	3.675E0	1.705E0	0.46
1983	7.558E0	7.558E0	2.784E0	0.37
1984	9.855E0	9.855E0	3.972E0	0.40
1985	1.743E1	1.743E1	5.953E0	0.34
1986	1.320E1	1.320E1	5.469E0	0.41
1987	1.859E1	1.859E1	6.510E0	0.35
1988	2.058E1	2.058E1	6.813E0	0.33
1989	2.310E1	2.310E1	7.461E0	0.32
1990	1.990E1	1.990E1	7.084E0	0.36
1991	2.007E1	2.007E1	7.252E0	0.36
1992	2.189E1	2.189E1	7.913E0	0.36
1993	2.073E1	2.073E1	7.896E0	0.38
1994	2.084E1	2.084E1	7.912E0	0.38

BOOTSTRAP OUTPUT VARIABLE: B_RN_0_expl
Exploited biomass at time of the survey
i.e. 50% into the calendar year

YEAR	NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1982	6.744E0	6.744E0	1.759E0	0.26
1983	9.905E0	9.905E0	2.942E0	0.30
1984	1.348E1	1.348E1	4.201E0	0.31
1985	1.921E1	1.921E1	6.073E0	0.32
1986	1.636E1	1.636E1	5.714E0	0.35
1987	2.044E1	2.044E1	6.668E0	0.33
1988	2.243E1	2.243E1	6.978E0	0.31
1989	2.389E1	2.389E1	7.510E0	0.31
1990	2.168E1	2.168E1	7.252E0	0.33
1991	2.186E1	2.186E1	7.419E0	0.34
1992	2.243E1	2.243E1	7.915E0	0.35
1993	2.256E1	2.256E1	8.065E0	0.36
1994	2.286E1	2.286E1	7.882E0	0.34

Table D17. Calculated 'supply years' of surfclams from the Northern New Jersey area (Runs 1-13), Delmarva area (Runs 14-22), and combined N. New Jersey/Delmarva area (Runs 23-24) under different quota options. Runs 4, 9 and 12 assume constant fishing mortality rates. Runs 13 and 24 give the results for a quota level that allows a 50% probability that the quota lasts 10 years, under the assumption that recent levels of recruitment continue.

Run Number	Quota Assumption	Level (MT)	Recuitment Mean, (CV)	---- Supply Years ---- Mean	Median	Max	Expl. 1995	Rate Max.
N. New Jersey								
1	Mean(92-94)	16,986	7,259(0.29)	4.48	4	8	0.28	0.73
2	Run 1+10%	18,685	7,259(0.29)	3.84	4	7	0.31	0.78
3	Run 1-10%	15,287	7,259(0.29)	5.35	5	9	0.25	0.89
4	Const. F	u=0.20	7,259(0.29)	(Avg. Landings Yr. 10 = 6364 MT)				
5	Mean(92-94)	16,986	0 (0)	2.93	3	4	0.28	0.83
6	Run 5+10%	18,685	0 (0)	2.69	3	4	0.31	0.84
7	Run 5-10%	15,287	0 (0)	3.32	3	5	0.25	0.89
8	Const. F	u=0.20	0 (0)	(Avg. Landings Yr. 10 = 1057 MT)				
9	Mean(92-94)	16,986	9,858(100)	5.67	5	22	0.28	0.70
10	Run 9+10%	18,685	9,858(100)	4.73	4	19	0.31	0.67
11	Run 9-10%	15,287	9,858(100)	7.10	6	29	0.25	0.94
12	Const. F	u=0.20	9,858(100)	(Avg. Landings Yr. 10 = 8,258 MT)				
13	Find Quota	11,263	7,259(0.29)	9.59	10	17	0.18	0.96
Delmarva								
14	Mean(92-94)	2,470	4,212(1.01)	98.61	100	100	0.15	0.15
15	Run 14+10%	2,717	4,212(1.01)	92.74	100	100	0.16	0.16
16	Run 14-10%	2,223	4,212(1.01)	99.77	100	100	0.13	0.13
17	Mean(92-94)	2,470	0 (0)	6.34	6	15	0.15	0.77
18	Run 17+10%	2,717	0 (0)	5.82	6	13	0.16	0.80
19	Run 17-10%	2,223	0 (0)	6.99	7	15	0.13	0.68
20	Mean(92-94)	2,470	1,324(0.19)	10.94	11	23	0.15	0.85
21	Run 20+10%	2,717	1,324(0.19)	9.42	9	21	0.16	0.72
22	Run 20-10%	2,223	1,324(0.19)	12.98	13	26	0.13	0.84
NNJ + DMV								
23	Mean(92-94)	19,465	11,471(0.55)	6.70	7	23	0.24	0.71
24	Find Quota	16,385	11,471(0.55)	9.81	10	28	0.20	0.74

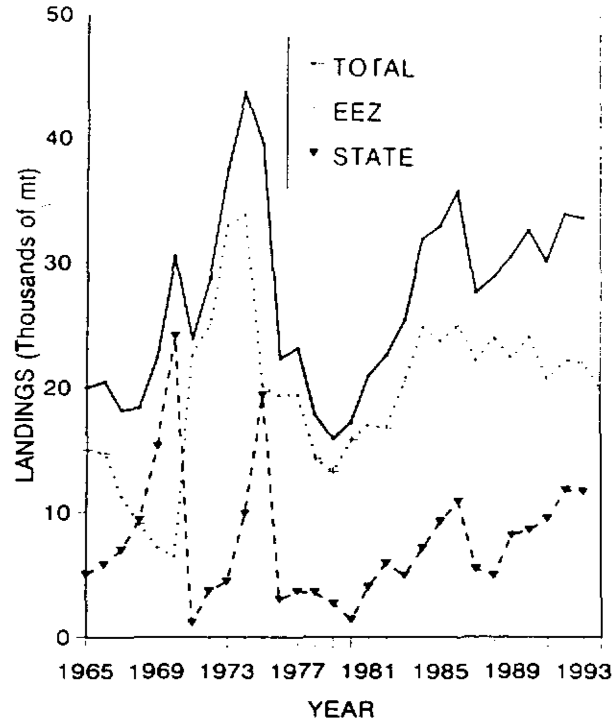

Figure D1. Landings of surfclams (thousands of mt of meats), 1965-1994. Data are for all areas (total). Exclusive Economic Zone (EEZ: 3-200 miles from the coast), and state (inshore) waters. EEZ landings for 1994 were estimated from logbook data available on 13 September 1994.

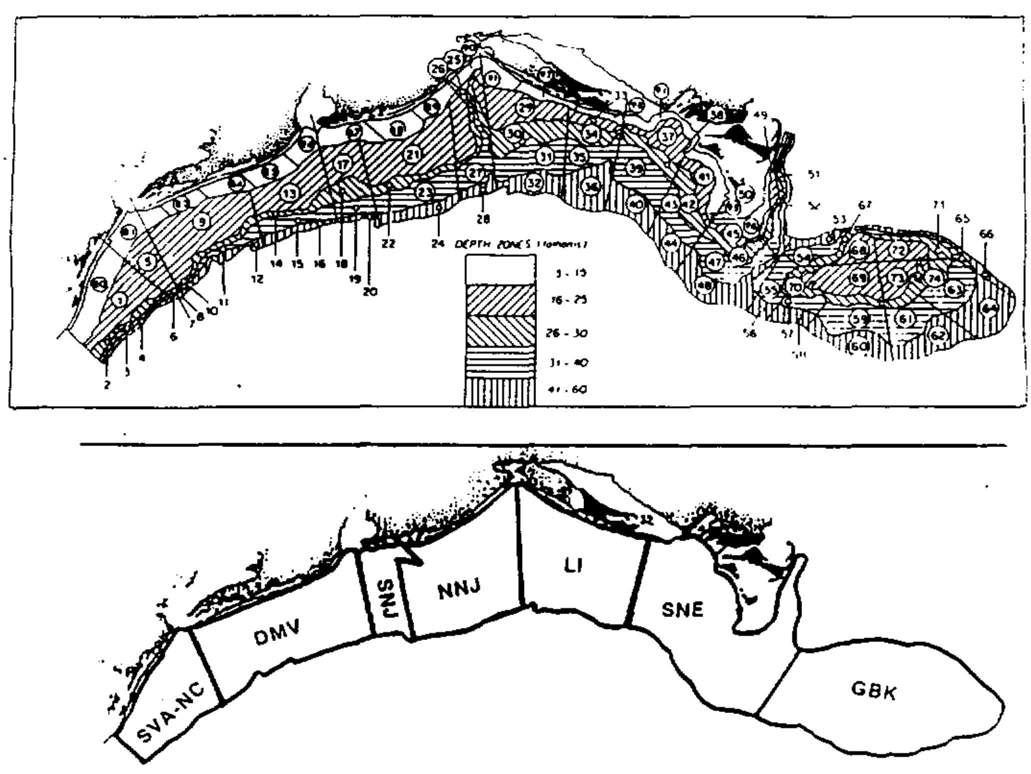

Figure D2. Survey Strata (sampling areas), National Marine Fisheries Service, Northeast Fisheries Science Center, Surfclam-Ocean Quahog Survey.

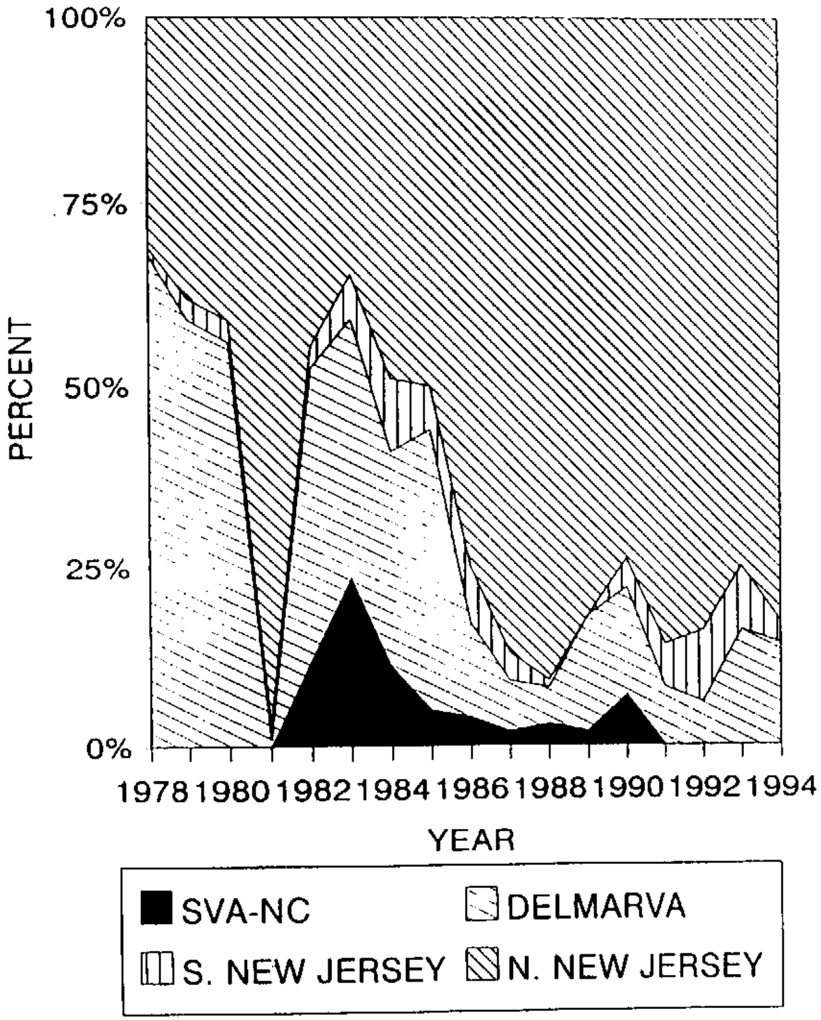

Figure D3. Proportion of surfclam landings in the Mid-Atlantic region, by area and year, 1978-1994. Landings for 1994 were estimated from logbook data available on 13 September 1994.

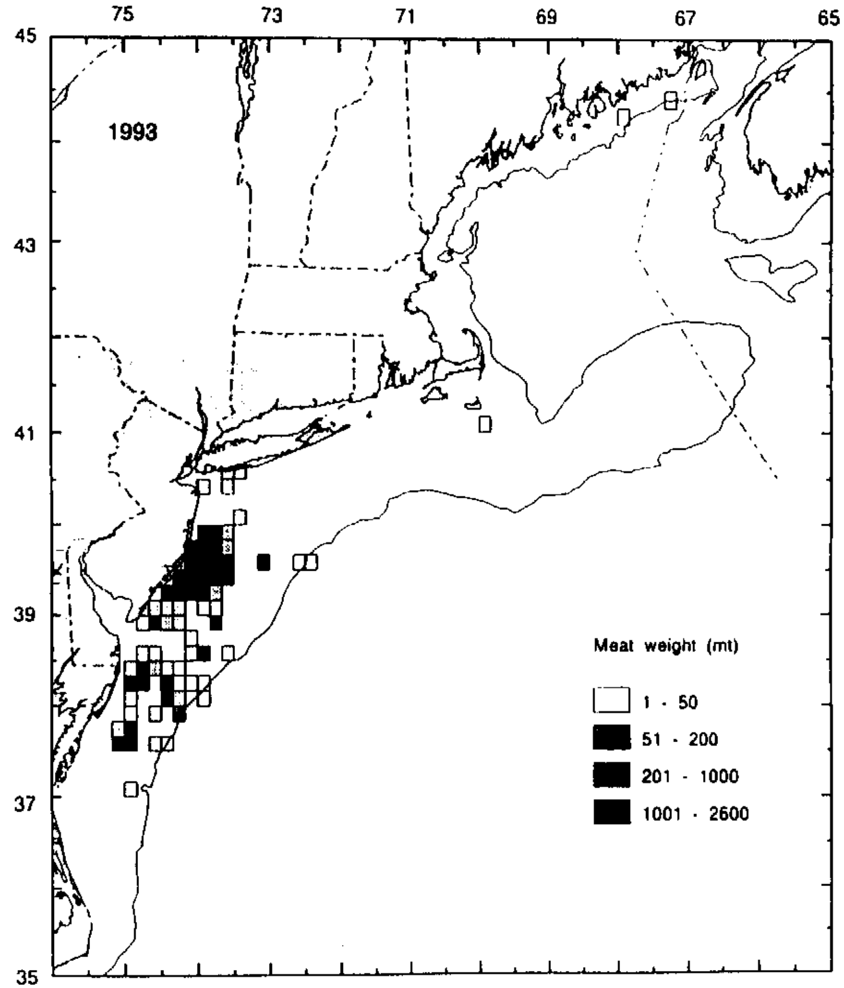

Figure D4. Distribution of surfclam landings, 1993.

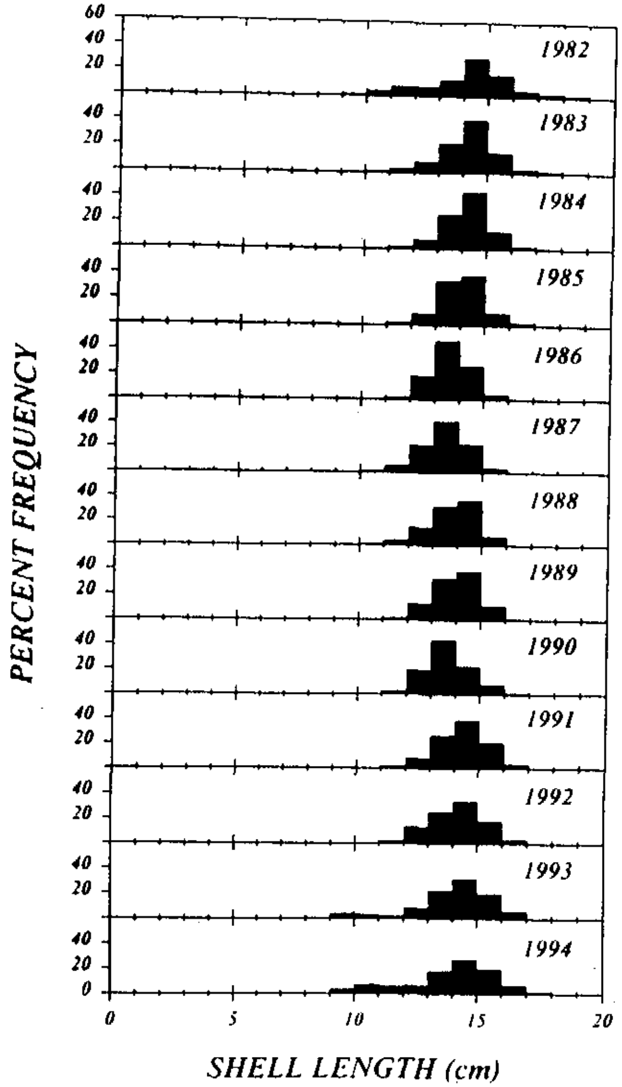

Figure D5. Commercial length frequency distributions (by percent) of surfclams harvested from the New Jersey area. Data are from port samples, 1982-1994.

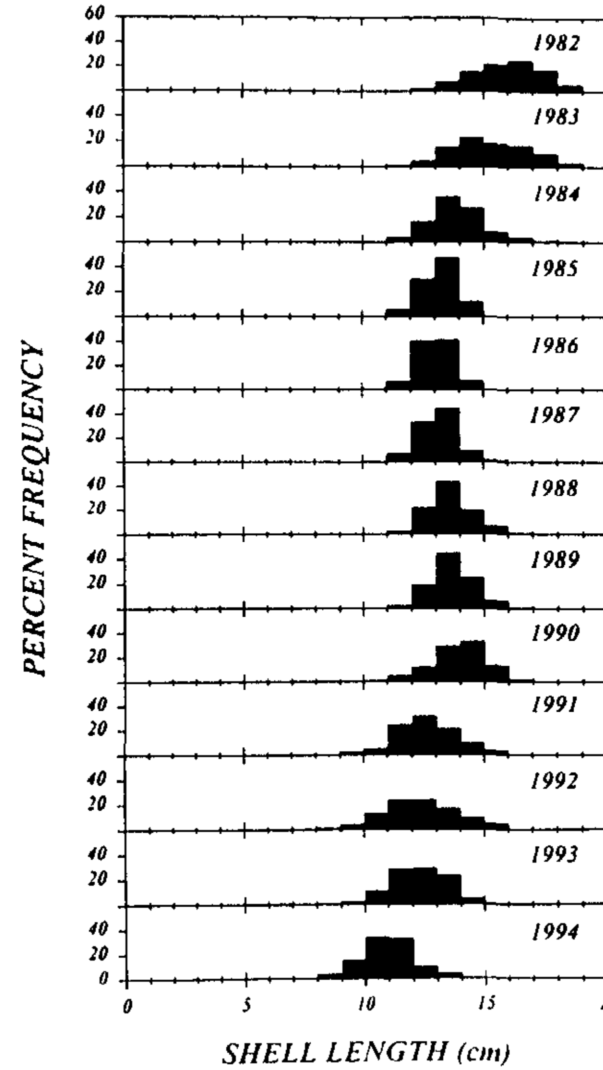

Figure D6. Commercial length frequency distributions (by percent) of surfclams harvested from the Delmarva area. Data are from port sample, 1982-1994.

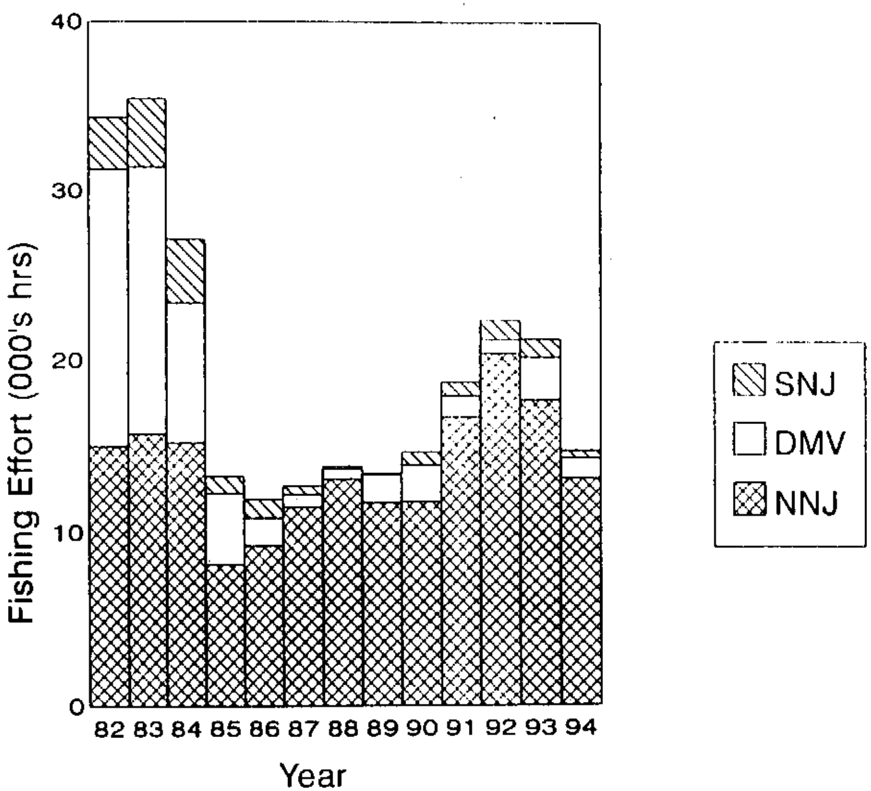

Figure D7. Total reported hours fishing during surfclam trips, by region year. 1994 data do not represent a full year.

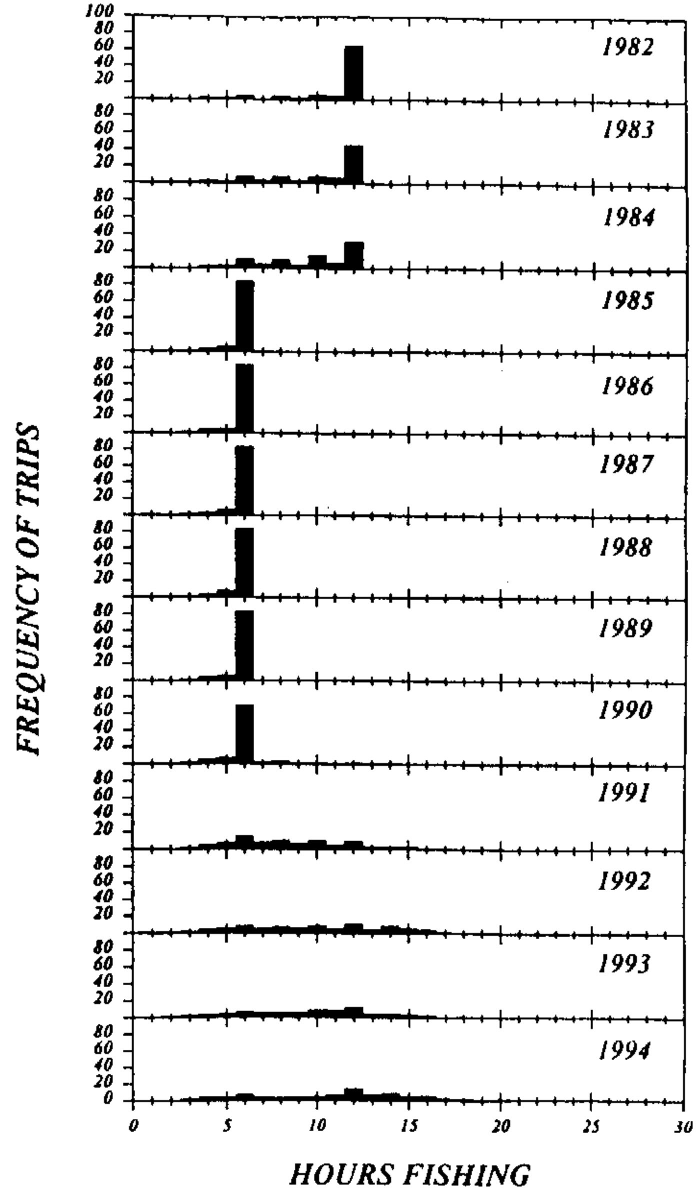

Figure D8. Frequency distribution of fishing effort per surfclam trip in the Northern New Jersey area.

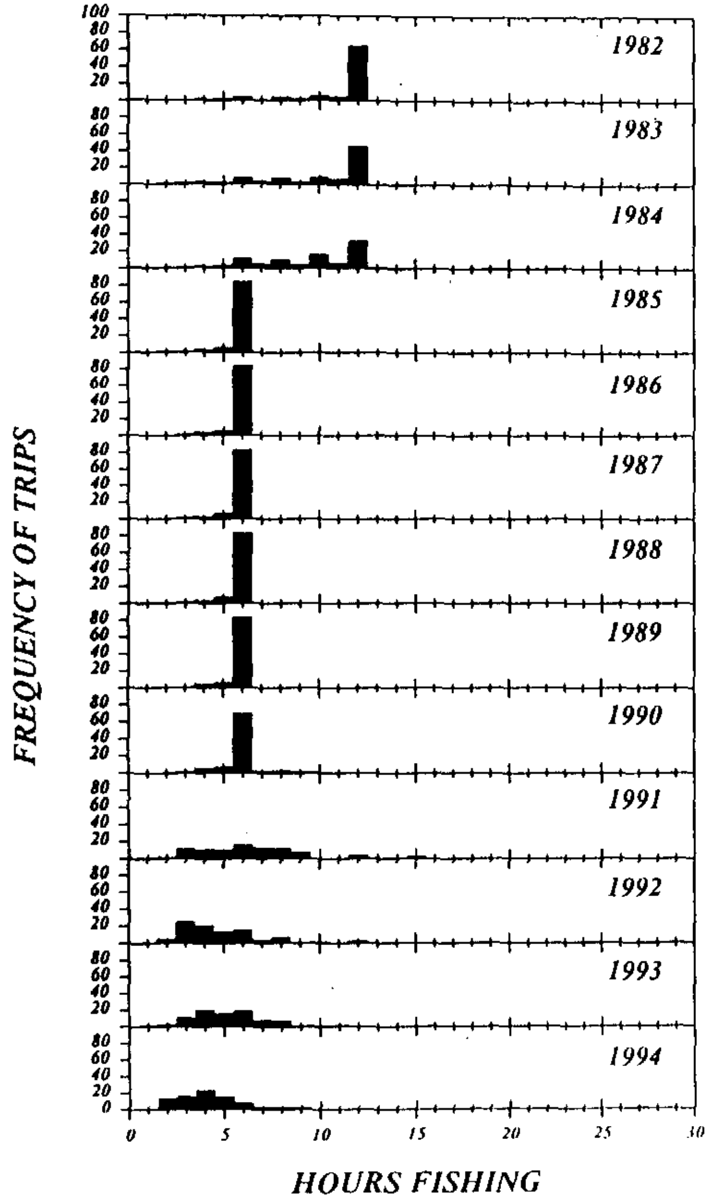

Figure D9. Frequency distribution of fishing effort per surfclam trip in the Delmarva area.

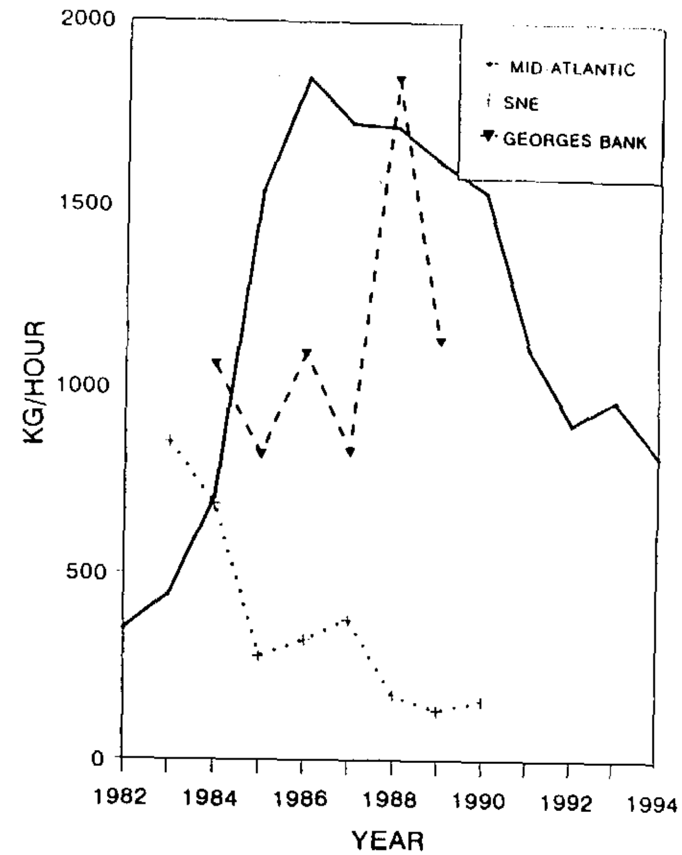

Figure D10. Landings per unit effort (kilograms per hour fished) of surfclams by Class 3 vessels (105 +GTR) by region, 1982-1994. Values were computed from logbook data.

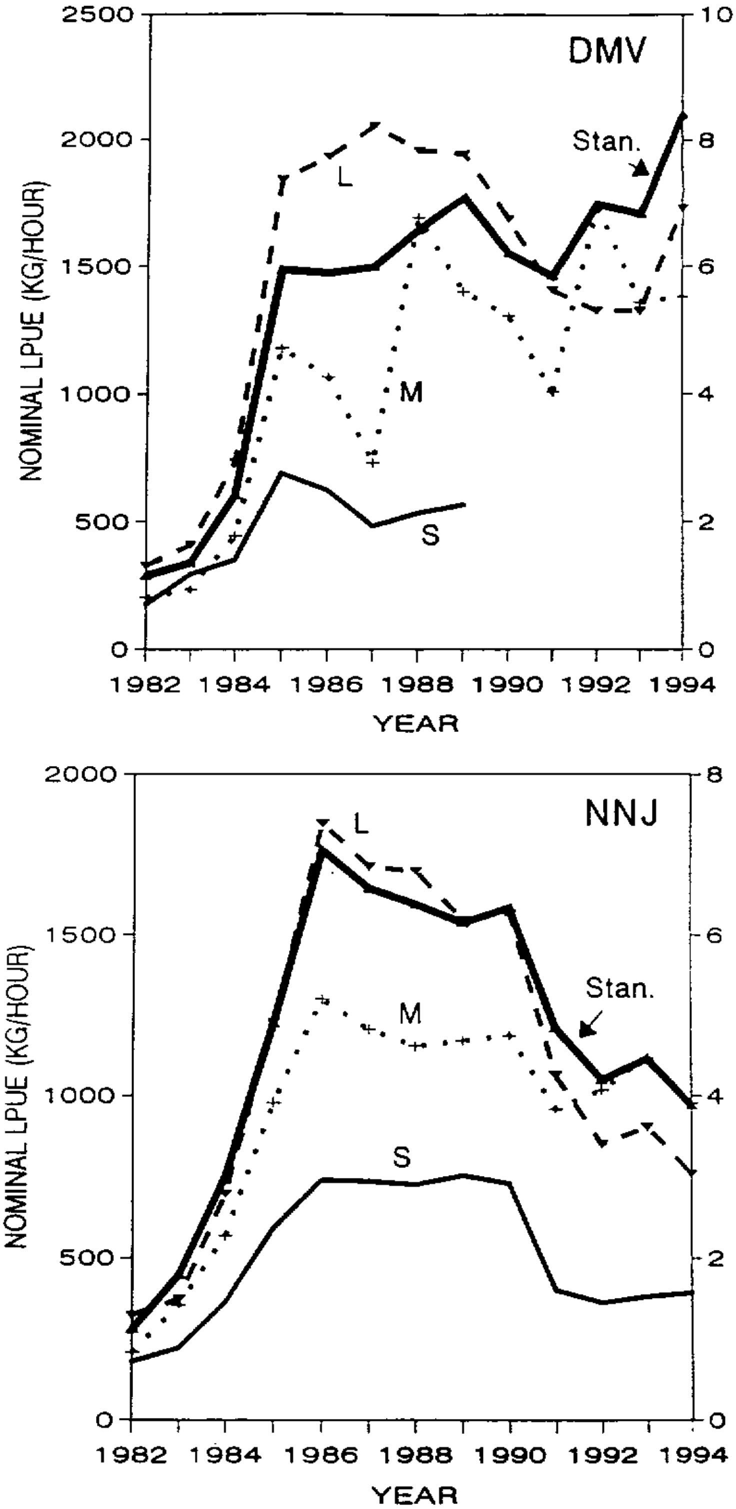

Figure D11. Nominal surfclam LPUEs by year for two regions (Delmarva and Northern New Jersey) and three vessel classes (small, medium, and large). Also shown are standardized LPUEs (Stan.) from GLM analyses.

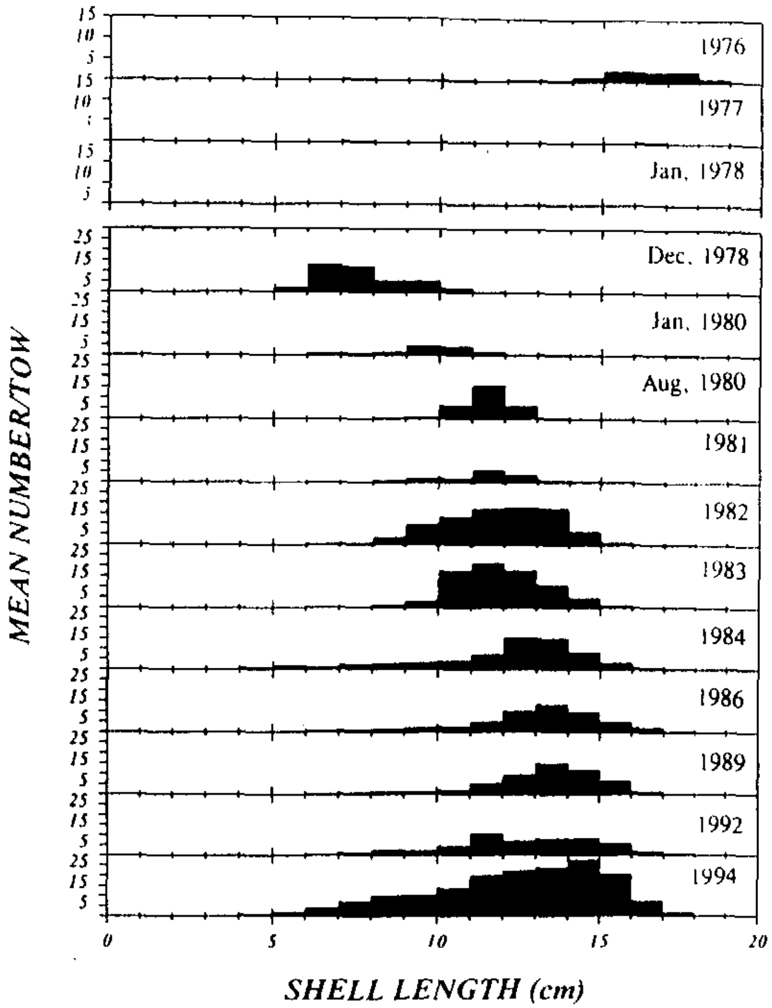

Figure D12. Stratified mean number of surfclams per tow at 1 cm length intervals in NMFS clam surveys of Northern New Jersey, 1976-1994. Pre-1982 data were standardized to a 5' wide blade towed for 5 min. Data from 1982-1994 were standardized to a tow distance of 0.15 n. mi. Note that the upper graphs (1976-Jan 1978) are plotted on a different scale because they represent few individuals.

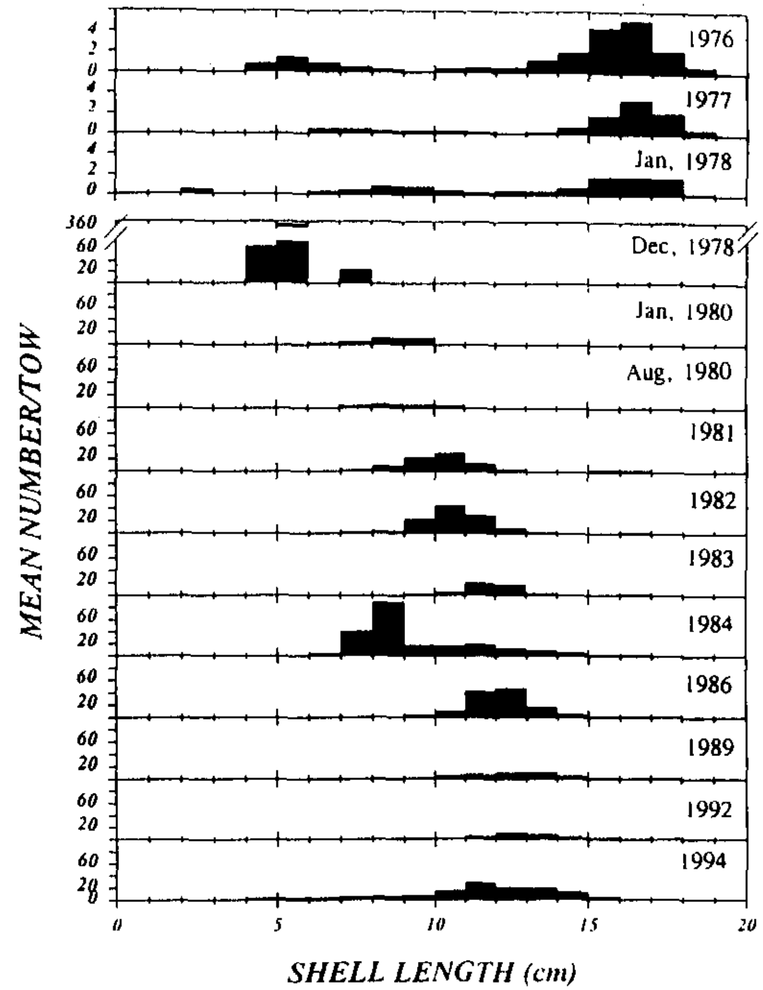

Figure D13. Stratified mean number of surfclams per tow at 1 cm length intervals in NMFS clam surveys off Delmarva. 1976-1994. Pre-1982 data were standardized to a 5' wide blade towed for 5 min. Data from 1982-1994 were standardized to a tow distance of 0.15 n. mi. Note that the upper graphs (1976-Jan 1978) are plotted on a different scale because they represent few individuals.

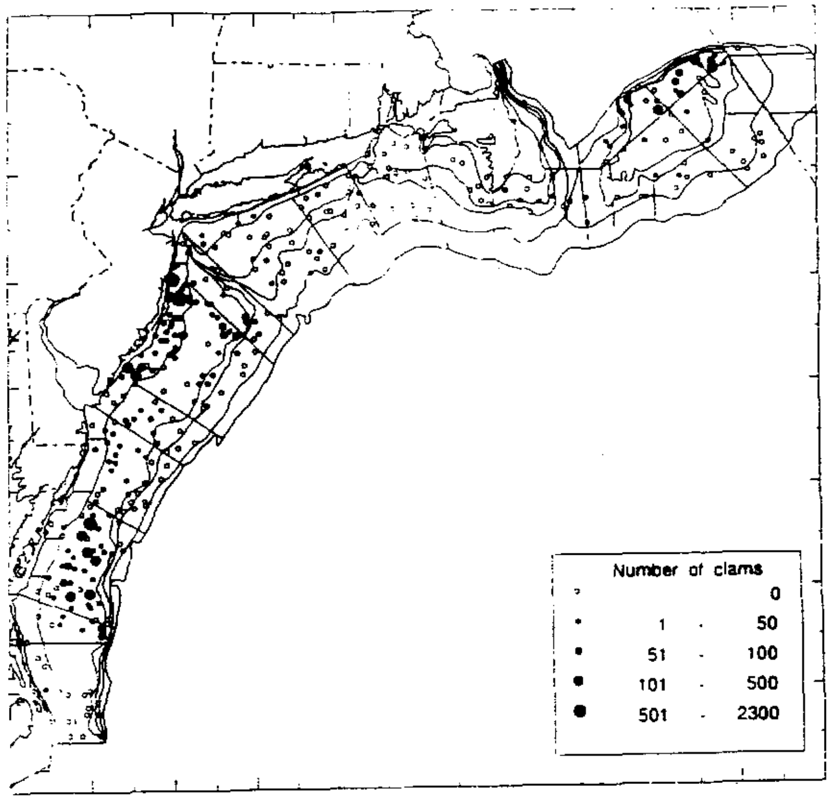

Figure D14. Recruit (105-120 mm) surfclam abundance per tow on the NEFSC clam survey, 1994.

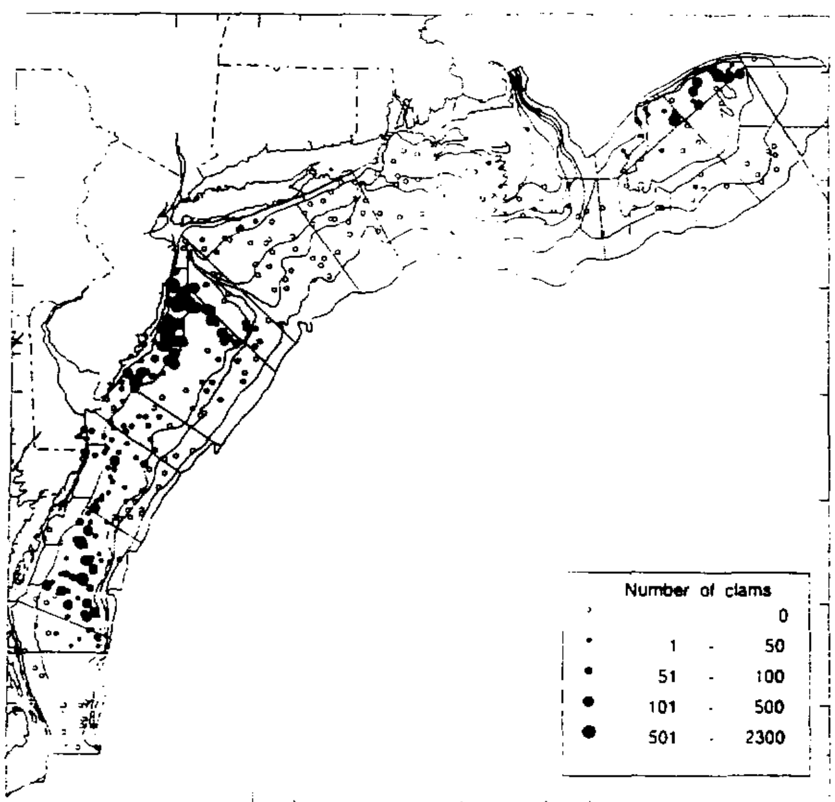

Figure D15. Distribution of surfclams >120 mm NEFSC clam survey, 1994.

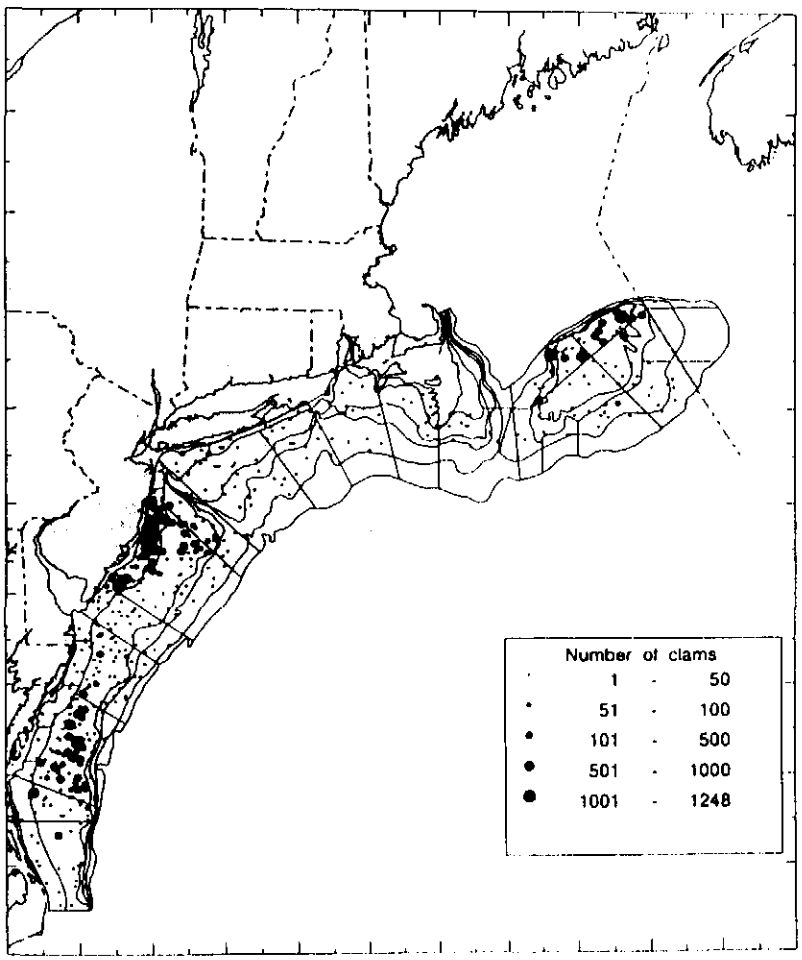

Figure D16. Surfclam abundance per tow based on the 1992 and 1994 NEFSC surveys.

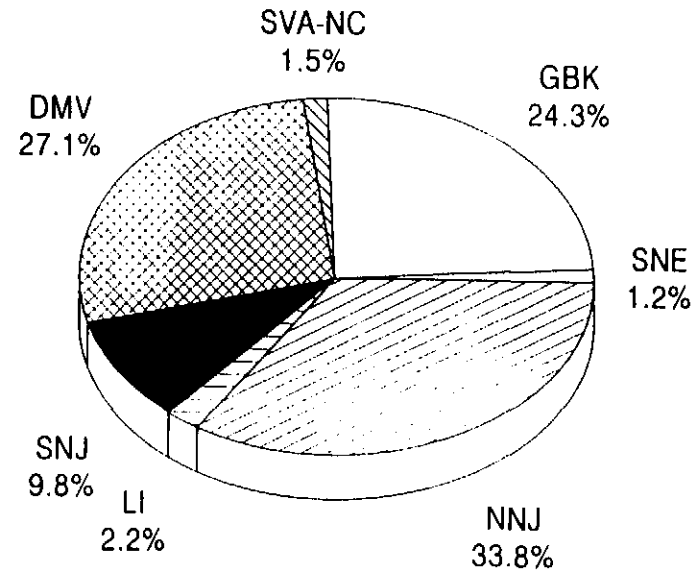

Figure D17. Relative distribution of surfclam biomass, based on the 1994 NEFSC research vessel survey data.

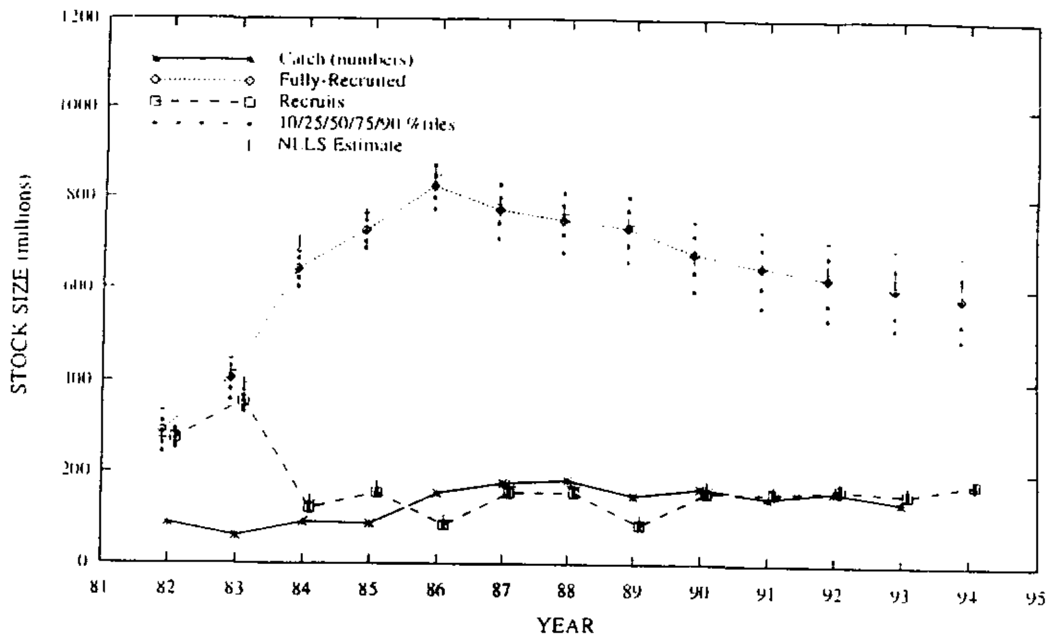

Figure D18. Calculated stock sizes (millions) for Northern New Jersey surfclam, 1982-1994. Results are given for two size groups (pre- and recruits), and the catch (in numbers) is given. Additional information is presented in Table D15.

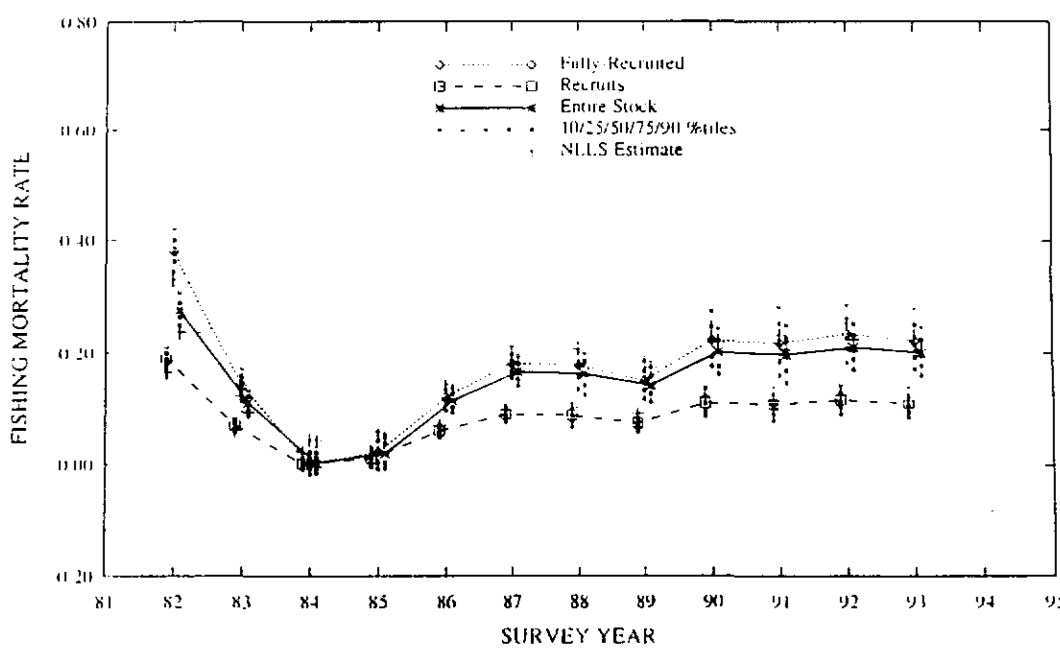

Figure D19. Calculated fishing mortality rates for Northern New Jersey surfclam, 1982-1994. Results are given for two size groups (pre- and recruits) and a weighted average is given. Additional information is presented in Table D15.

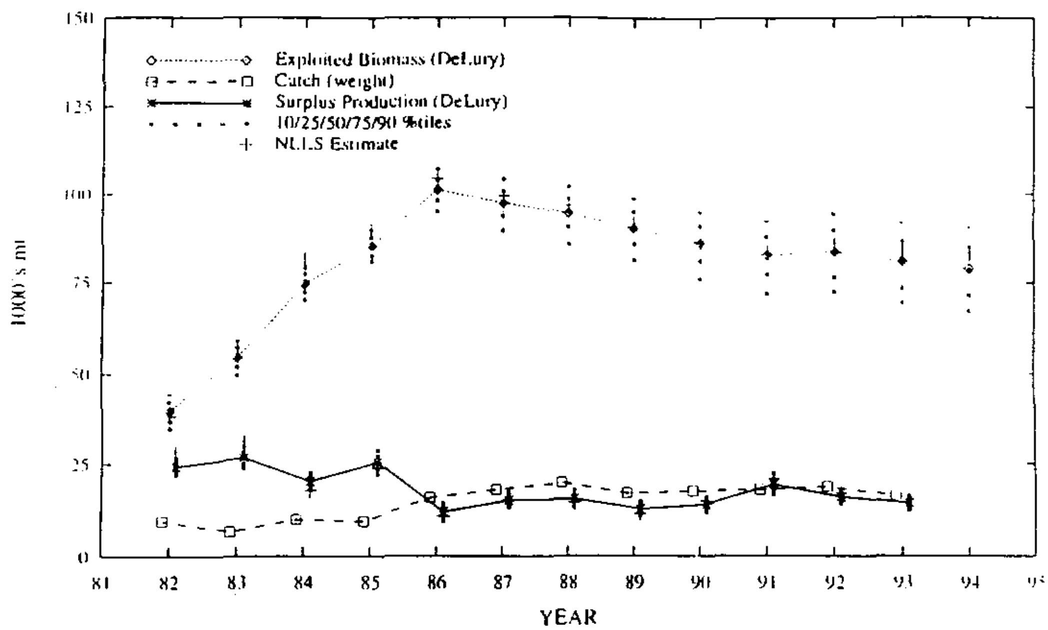

Figure D20. Calculated biomasses and surplus production for Northern New Jersey surfclam, 1982-1994. Additional information is presented in Table D15.

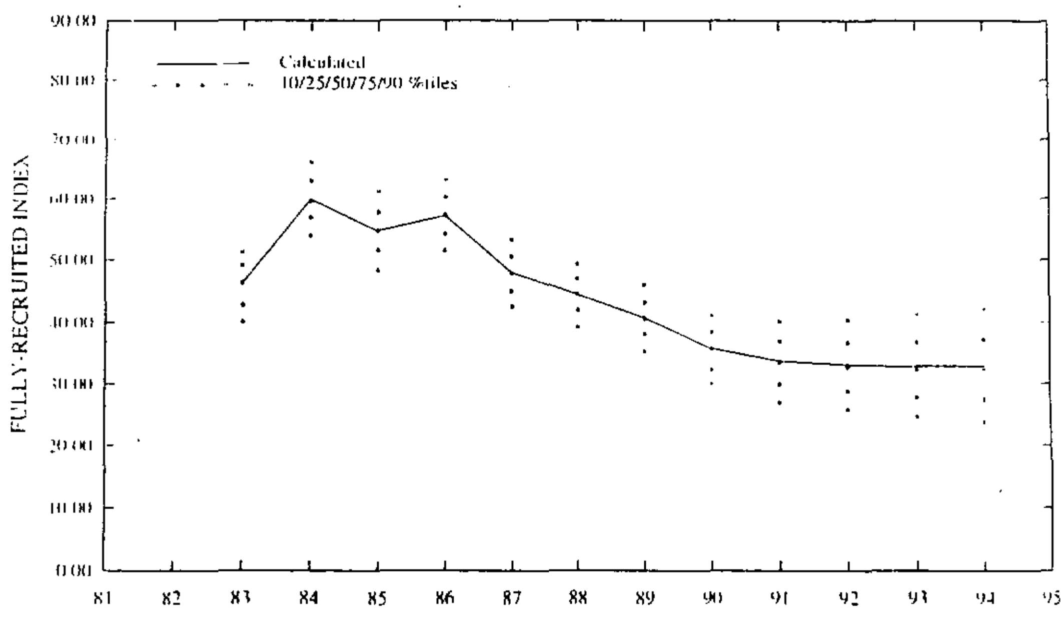

Figure D21. Calculated survey indices for fully-recruited sizes of Northern New Jersey surfclams, 1982-1994. Note that the actual 1994 survey point of 103.51 lies outside of the confidence intervals for the estimated index, based on a tuning run not including the index series. Additional information is presented in Table D15.

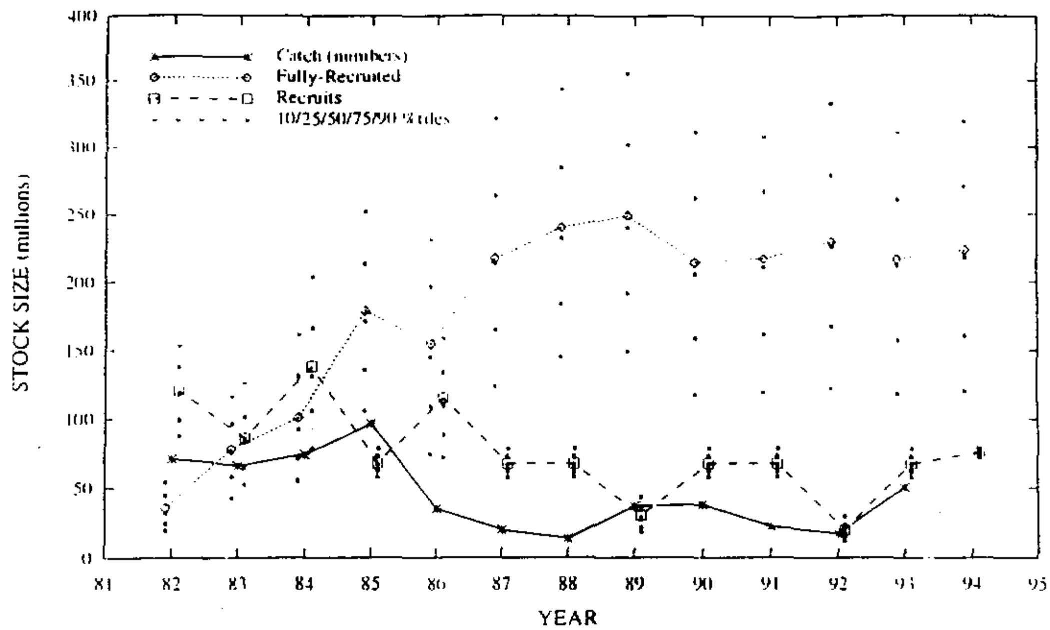

Figure D22. Calculated stock sizes (millions) for Delmarva surfclam, 1982-1994. Results are given for two size groups (pre- and recruits), and the catch (in numbers) is given. Additional information is presented in Table D16.

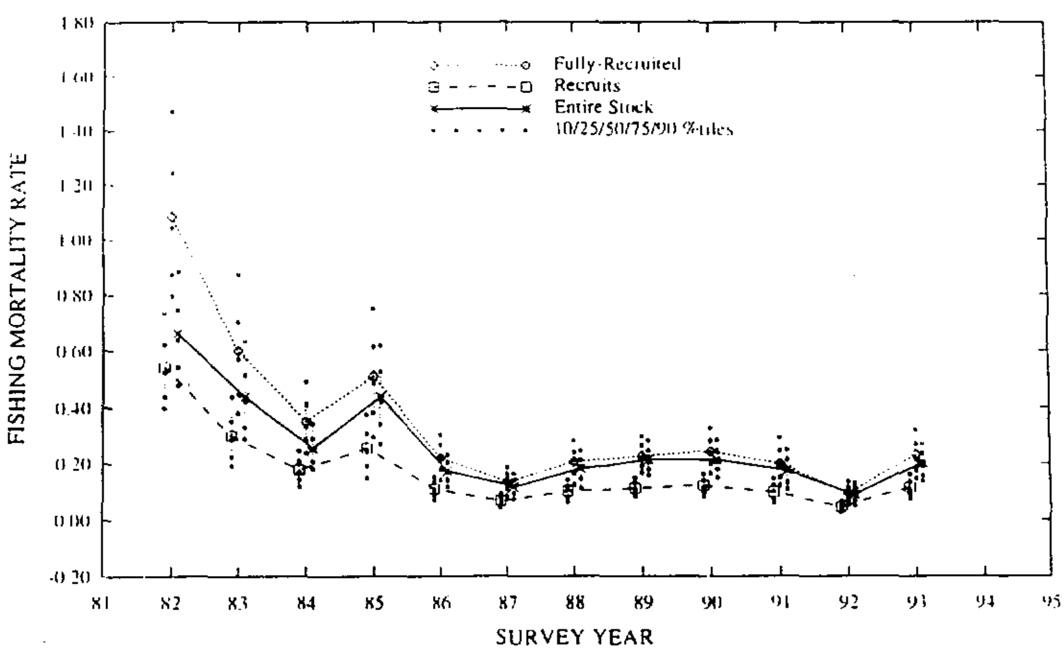

Figure D23. Calculated fishing mortality rates for Delmarva surfclam, 1982-1994. Results are given for two size groups (pre- and recruits) and a weighted average is given. Additional information is presented in Table D16.

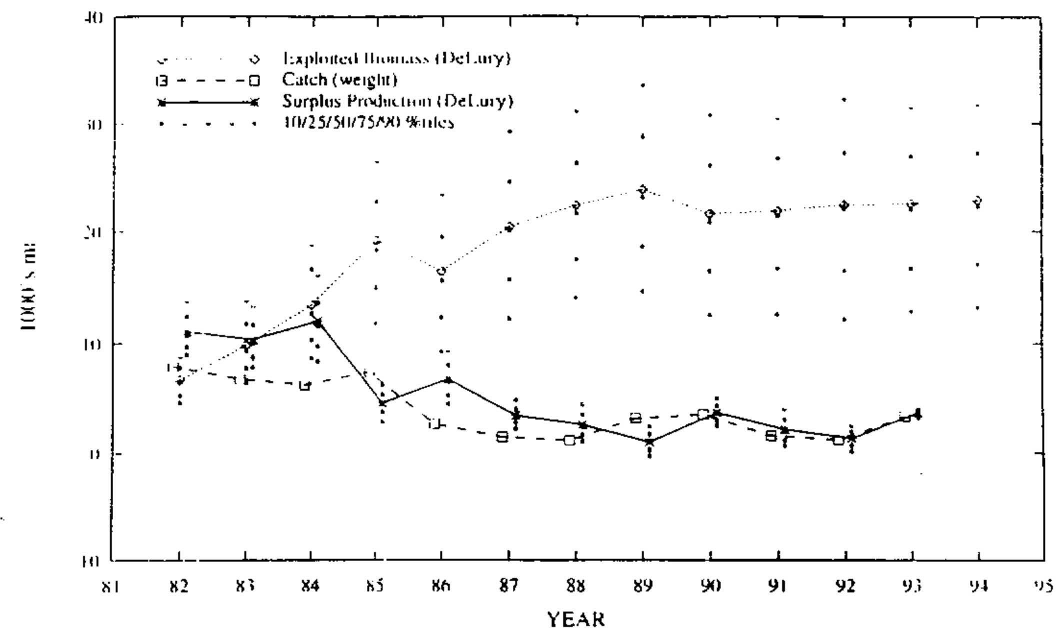

Figure D24. Calculated biomasses and surplus production for Delmarva surfclam, 1982-1994. Additional information is presented in Table D16.

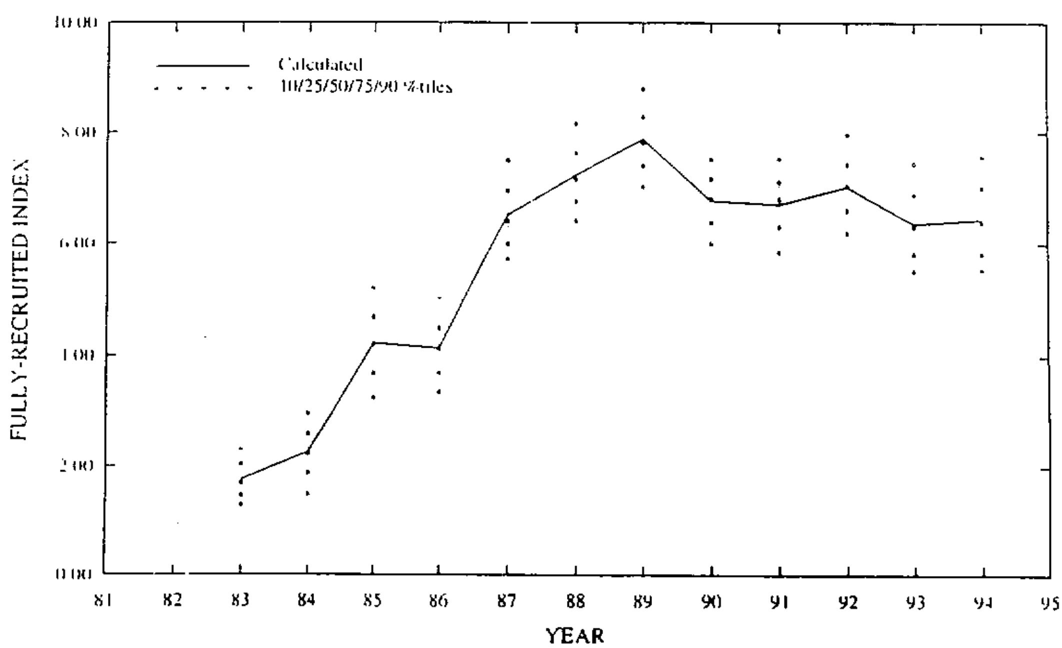

Figure D25. Calculated commercial indices for fully-recruited sizes of Delmarva surfclams, 1982-1994. Note that the actual 1994 commercial index point of 2.41 lies outside of the confidence intervals for the estimated index, based on a tuning run not including the index series. Additional information is presented in Table D16.

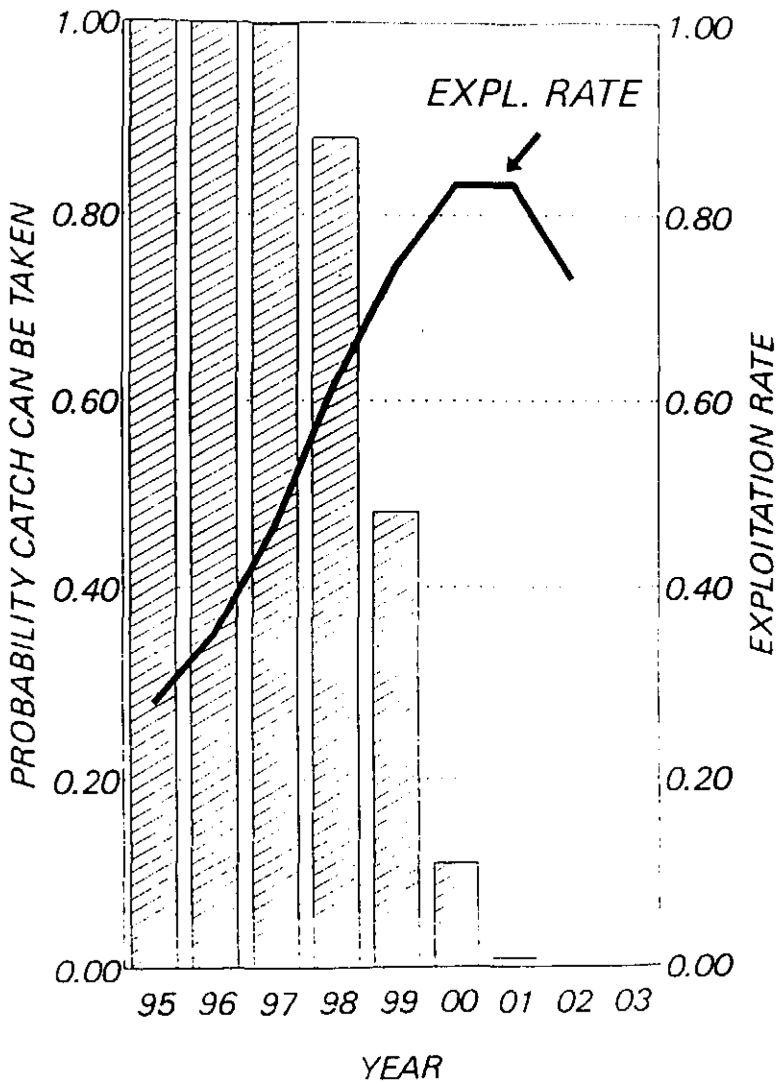

Figure D26. Calculation of 'supply years' of constant quotas for surfclam from Northern New Jersey. Results are from Run 1 described in Table D17. Data are the probability that the constant catch of 16,986 MT ('92-'94 average) can be taken, based on 2,000 stochastic simulation runs. Also plotted is the average annual exploitation rate corresponding to the catch. Average recruitment is 7,259 MT (cv=0.29)

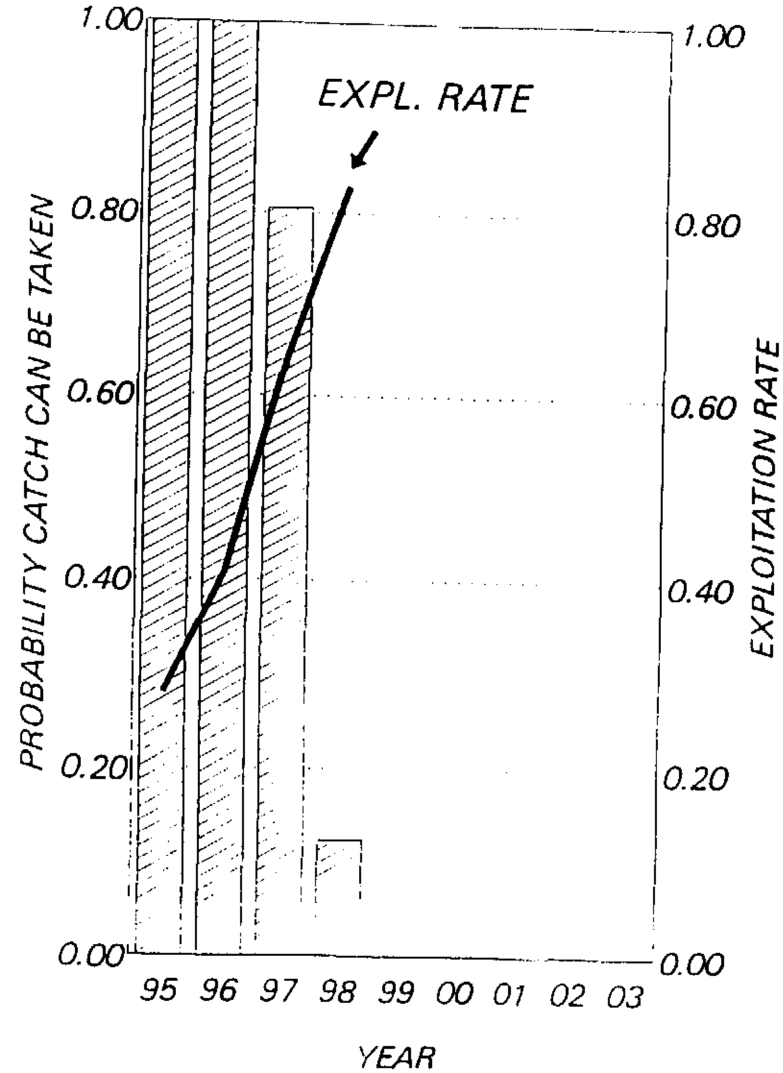

Figure D27. Calculation of 'supply years' of constant quotas for surfclam from Northern New Jersey. Results are from Run 5 described in Table D17. Data are the probability that the constant catch of 16,986 MT ('92-'94 average) can be taken, based on 2,000 stochastic simulation runs. Also plotted is the average annual exploitation rate corresponding to the catch. Recruitment is set to 0 (cv=0)

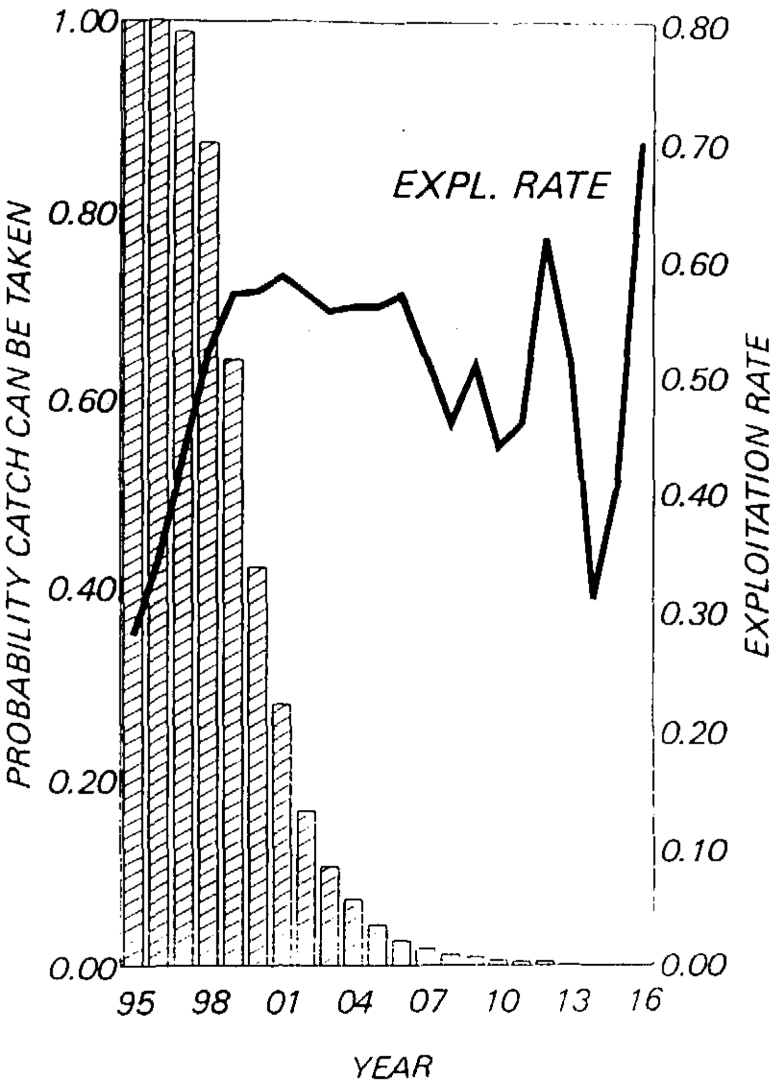

Figure D28. Calculation of 'supply years' of constant quotas for surfclam from Northern New Jersey. Results are from Run 9 described in Table D17. Data are the probability that the constant catch of 16,986 MT ('92-'94 average) can be taken, based on 2,000 stochastic simulation runs. Also plotted is the average annual exploitation rate corresponding to the catch. Recruitment is set to 9,858 MT (cv = 1.00).

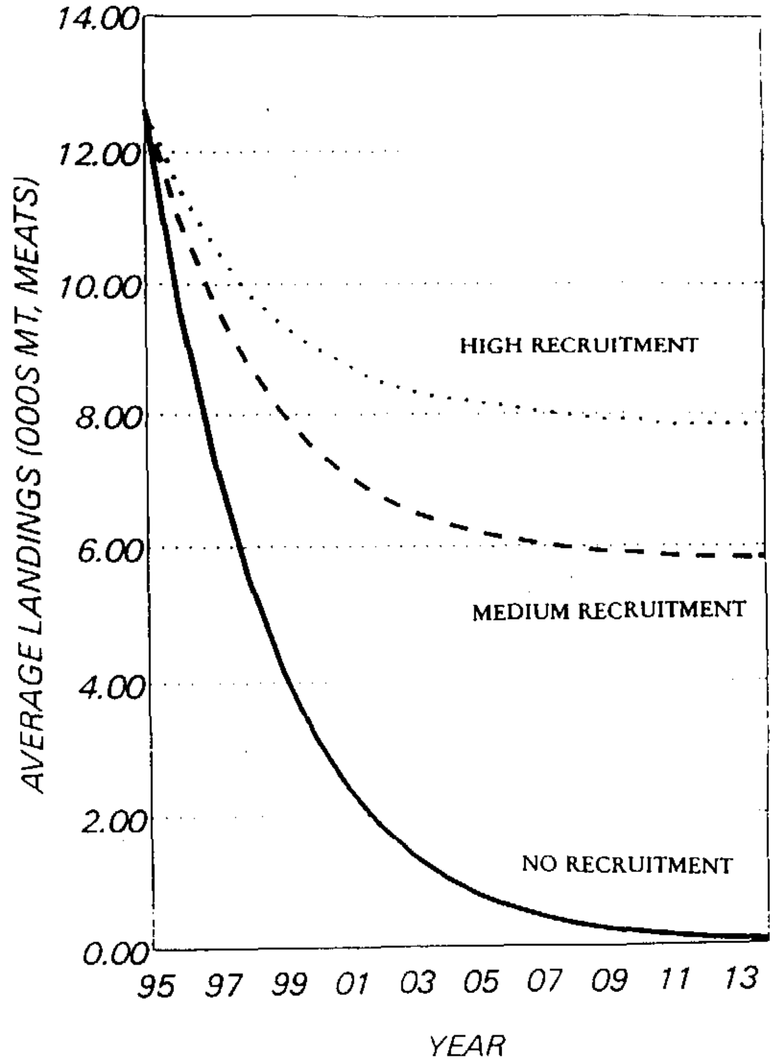

Figure D29. Calculation of average annual catch for surfclam from Northern New Jersey, assuming constant fishing mortality rates. Results are from Runs 4,8 and 12 described in Table D17. Recruitment is set to: (Run 4 = 7,259 MT [cv = 0.29]); (Run 8 = 0 MT [cv = 0.0]); (Run 12 = 9,858 MT [cv = 1.00]).

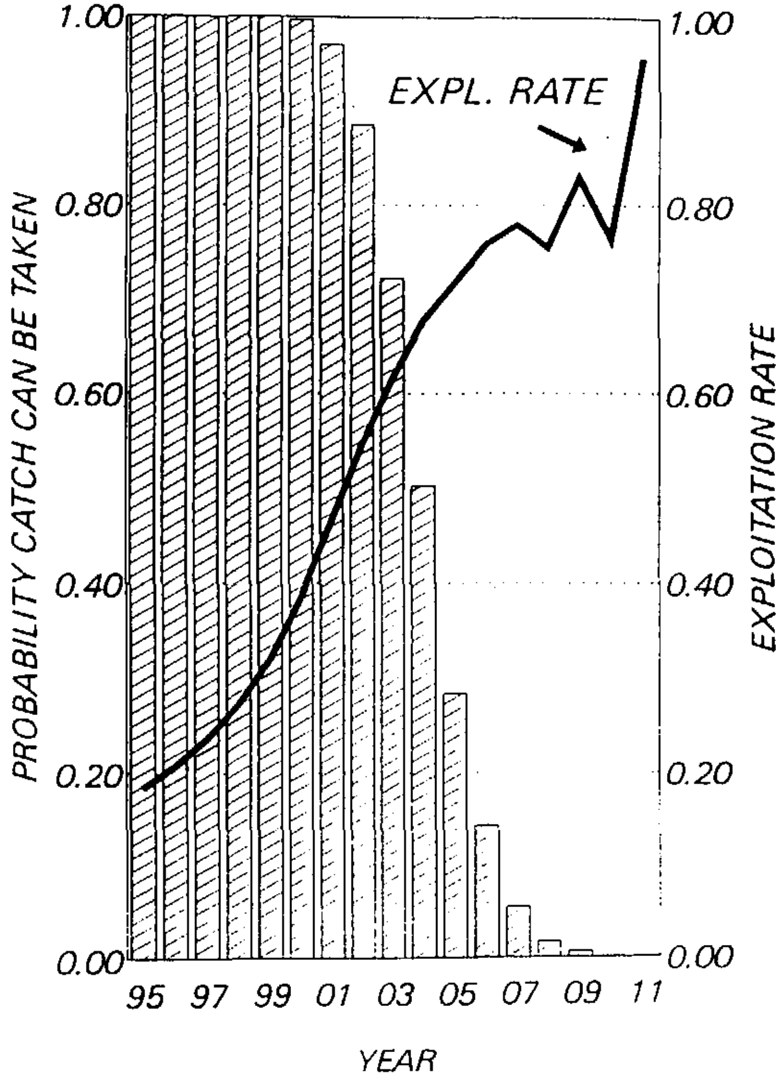

Figure D30. Calculation of 'supply years' of constant quotas for surfclam from Northern New Jersey. Results are from Run 13 described in Table D17. Data are the probability that the constant catch of 11,236 MT (level giving 50% probability of reaching year 10) can be taken, based on 2,000 stochastic simulation runs. Also plotted is the average annual exploitation rate corresponding to the catch. Recruitment is set to 7,259 MT (cv=0.29).

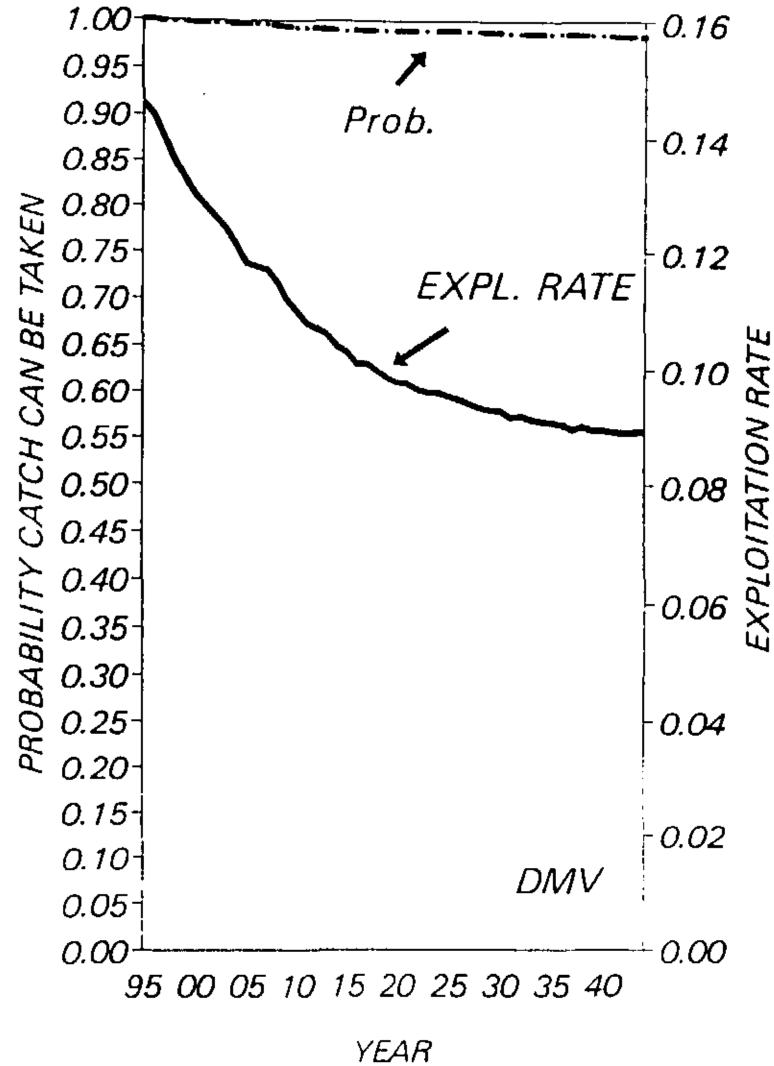

Figure D31. Calculation of 'supply years' of constant quotas for surfclam from Delmarva. Results are from Run 14 described in Table D17. Data are the probability that the constant catch of 2,470 MT ('92-'94 average) can be taken, based on 2,000 stochastic simulation runs. Also plotted is the average annual exploitation rate corresponding to the catch. Average recruitment is 4,212 MT (cv=1.01)

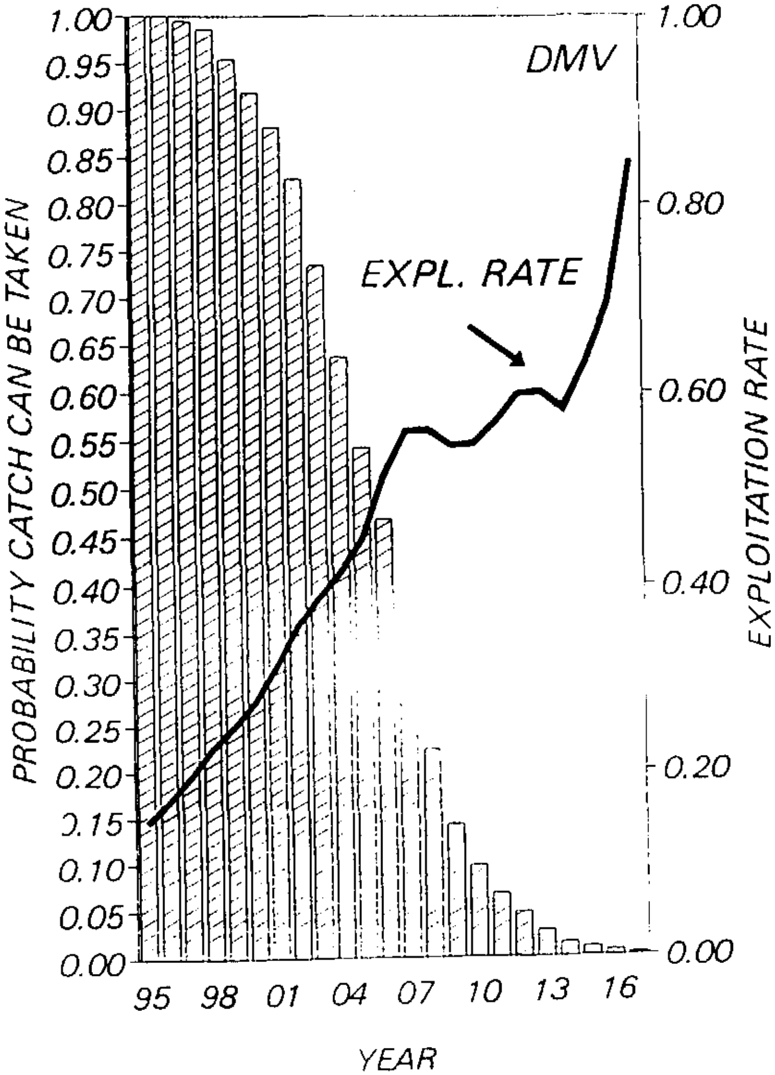

Figure D32. Calculation of 'supply years' of constant quotas for surfclam from Delmarva. Results are from Run 17 described in Table D17. Data are the probability that the constant catch of 2,470 MT ('92-'94 average) can be taken, based on 2,000 stochastic simulation runs. Also plotted is the average annual exploitation rate corresponding to the catch. Recruitment is set to 0 (cv=0).

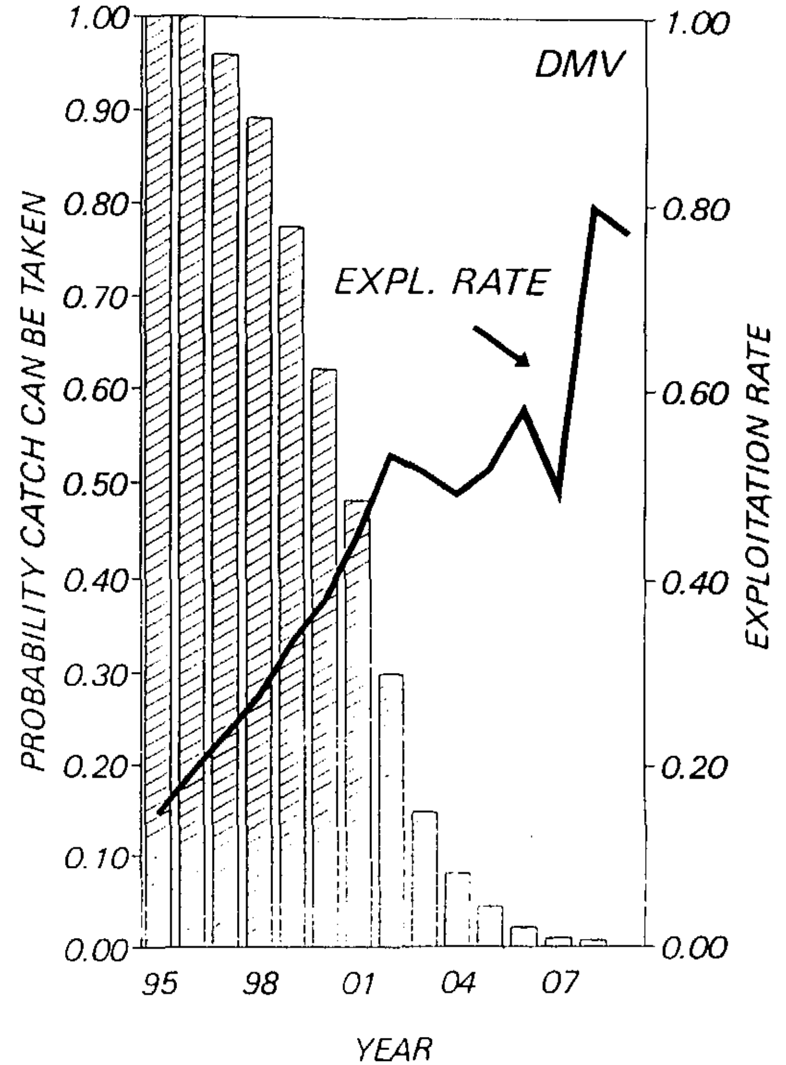

Figure D33. Calculation of 'supply years' of constant quotas for surfclam from Delmarva. Results are from Run 20 described in Table D17. Data are the probability that the constant catch of 2,470 MT ('92-'94 average) can be taken, based on 2,000 stochastic simulation runs. Also plotted is the average annual exploitation rate corresponding to the catch. Recruitment is set to 1,324 MT (cv=0.19).

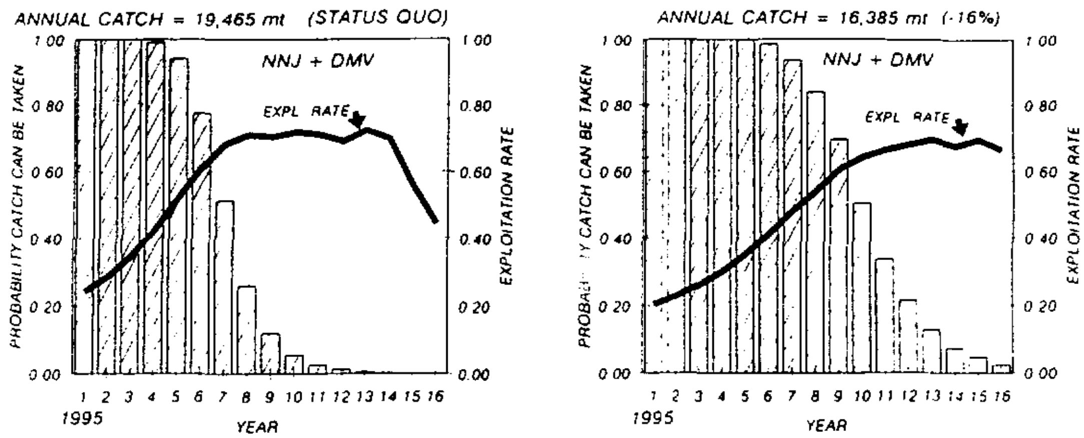

Figure D34 Calculation of 'supply years' of constant quotas for surfclams from Northern New Jersey and Delmarva. Results are from Runs 23 (left) and 24 (right) described in Table D17. Left panel shows the probability that the constant catch of 19,465 mt (1992-1994 average) can be taken, based on 2,000 stochastic simulation runs. Also plotted is the average annual exploitation rate corresponding to the catch. Average recruitment is 11,471 mt (cv=0.55). Right panel shows results for a reduced annual catch which would last for 10 years with a 50% probability.

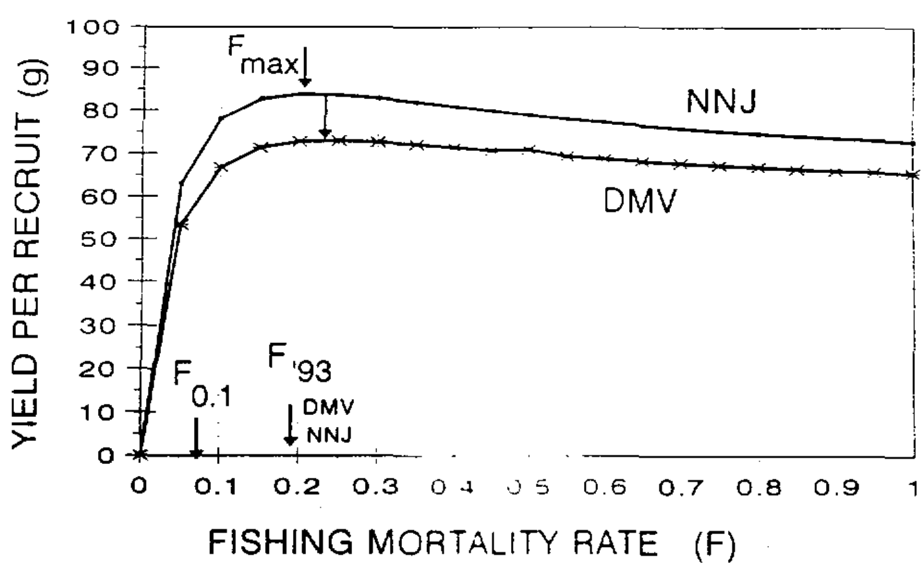

Figure D35. Yield per recruit analysis for surfclams from the Northern New Jersey and Delmarva regions.

E. OCEAN QUAHOG

Terms of Reference

The following terms of reference were addressed:

a. Summarize trends in landings, CPUE, size composition, and areal distribution for Middle Atlantic and Gulf of Maine exploitation areas,

b. Summarize fishery-independent abundance indices, including NMFS research vessel survey data,

c. Provide estimates of current stock size and fishing mortality, as data permit, and trends in abundance over a 30-year period, under alternative quota levels.

Introduction

The ocean quahog, *Arctica islandica*, is distributed in USA waters from the Canadian border to Cape Hatteras. South of Cape Cod, the species occurs primarily in EEZ waters, although some fishable concentrations occur in Rhode Island Sound, and in coastal waters off Massachusetts. In the Gulf of Maine, ocean quahogs occur both in state and EEZ waters. Two significant fisheries currently exist for ocean quahog, in the Middle Atlantic Bight, from Marthas Vineyard, Massachusetts to the Delmarva Peninsula, and in EEZ waters off eastern Maine. Since 1977 EEZ populations have been regulated under provisions of the Surfclam-Ocean Quahog FMP, prepared by the Mid-Atlantic Fishery Management Council (MAFM,C 1993). Two separate management regimes currently exist. Annual quotas, regulated through an Individual Transferable Quota (ITQ) system, apply to Mid-Atlantic waters. A separate experimental fishery area exists in the Gulf of Maine. Under provisions of the experimental fishery, no annual quota or other effort control regulations currently exist, although the fishery is strictly controlled and monitored for the incidence of paralytic shellfish poisoning (PSP). The ocean quahog resource on Georges Bank is currently closed to fishing due to the presence of PSP toxins in ocean quahog meats.

The Mid-Atlantic fishery quota rose from 13,608 mt (shucked meats) in 1978-1979 to a maximum of 27,215 mt in 1986-1988 (Table E1; Figure E1). Quotas have declined to 24,494 mt in recent years, although the annual quota has not been achieved since 1985. The areal distribution of the Mid-Atlantic fishery has shifted dramatically, since its beginning in 1976. Initially centered off Delmarva and Southern New Jersey, the focus of effort first shifted northward to the entire New Jersey coast, then to the Long Island coast. The Maine fishery continues in a relatively restricted area centered off Mt. Desert Island.

The ocean quahog resource was last assessed in Autumn 1992, at SARC 15 (NEFSC 1993a; 1993b). At that time the resource was considered to be at a high biomass level, and fully-exploited. It was noted that CPUE had fallen by 1/3 from 1986-1992, and that areas off Delmarva and New Jersey had experienced heavy cumulative exploitation and substantial decreases in biomass. Under prevailing harvest patterns, the Mid-Atlantic ocean quahog resource was projected to last for 13-17 years (NEFSC, 1993b).

Research recommendations resulting from the last assessment included analyses of the precision of survey and CPUE sampling data, and more experimental studies of factors influencing recruitment success. Recommendations also called for the development of more sophisticated stock depletion models for ocean quahog, to estimate stock size and exploitation rates.

The previous assessment of the resource estimated fishing mortality rates based on regressions of the decline in stock numbers over several successive research vessel surveys. This method resulted in estimates of total mortality rates of 0.03-0.04, but the regressions were poorly determined. Total stock size estimates in the last assessment were based on area-swept calculations from research vessel surveys. This assessment uses a different approach to estimate stock size and fishing mortality. Depletion estimators based on CPUE (in numbers) are derived for the Delmarva, New Jersey and Long Island sub-areas. These estimators are based on annual CPUE values derived from a general linear modeling approach, taking into account variations in the tonnage classes of vessels fishing, and sub-regions within each area.

The calculation of the numbers of years of ocean quahog supply remaining at current quotas is based on a more realistic stochastic projection method. Given the uncertainty in estimates of natural mortality, this variable is allowed to vary uniformly between bounding values. Also, uncertainty in starting stock biomass levels is accounted for. Results of these stochastic 'supply year' (e.g. number of years in which the quota can be fully taken) calculations include the probability that the quota can be taken in any one year, and the exploitation rates needed to take the target catch. Supply years calculations are presented separately for Delmarva, New Jersey and Long Island. Although analytical calculations for the Maine area are not undertaken, current trends in the fishery and stock are interpreted, based on CPUE and R/V survey data,

Biological Overview

The ocean quahog is among the longest-lived and slowest growing of marine bivalves world-wide. Growth studies conducted off New Jersey, Long Island, and on Georges Bank indicate that ages in excess of 100 are common, and longevity past 200 years is documented (Thompson et al., 1980; Murawski et al., 1982; Ropes and Pyoas, 1982; Ropes and Murawski 1983). Recent growth studies conducted off eastern Maine (Kraus et al. 1992) indicated a maximum age of 66, but substantially slower rates of growth than on Georges Bank or off Long Island. Shell length, particularly in older individuals, may not be well correlated with age. Shell thickness and weight, however, appear to be highly correlated with age (Ropes and Murawski, 1983).

In the Middle-Atlantic Bight, sexually mature individuals as small as 20 mm have been found, and all animals are mature by about 50 mm. Spawning occurs primarily in late summer and autumn, although the timing and duration of spawning can vary widely (Mann, 1982). Larval life span apparently varies with water temperature, and may last for 60 days or more in the wild (Lutz et al., 1982). Thus, although genetic studies have not been conducted, it is likely that quahogs in the Georges Bank-Mid-Atlantic region are components of a single population. The relationships between quahogs in the Gulf of Maine and those to the south are not known.

Animals less than about 50 mm are rare in Georges Bank-Middle Atlantic populations, based on research vessel survey data and commercial landings sampling. More of these sizes are available off eastern Maine, both due to stronger recent recruitment, and slower rates of growth that result in an accumulation of animals in the 50-60 mm size range there. Given the advanced age, but more rapid rates of growth in the Mid-Atlantic, it is possible that the current populations of relatively large animals represent the accumulated stock from relatively low but steady recruitment over long periods of time. Survey size compositions and limited ageing data do not show evidence for large single-cohort recruitment events, as with surfclams.

Commercial Data

Commercial landings data and estimates of landings per unit effort (LPUE) are from mandatory vessel logbooks. This database contains catch location and consistent fishing effort information from 1983 - 1994. Location information for 1982 is problematic, and the resulting allocation of trips to regions for 1982 is less accurate than for 1983 - 1994. Logbook data collected before 1980 are not currently available for analysis.

In previous assessments (e.g. NEFC, 1990; Murawski et al., 1990; NEFSC, 1993a), regions within the Mid-Atlantic were defined by LORAN chains. Resulting commercial regions did not conform precisely to the defined regions used for analysis of research survey data. Closer matching of survey and commercial regions was needed to use the proposed analytical models. Therefore, for the current assessment, ocean quahog trips for the 1982-1994 time series were assigned to newly defined regions which match closely the regions defined for survey data. All tables and figures have been updated in a manner consistent with the redefined commercial regions.

It is assumed throughout this assessment that one bushel of ocean quahogs = 10 lbs = 4.5359 kg. Region specific parameters relating shell length to meat weight are taken from Murawski and Serchuk (1979). Vessel size class categories are: Class 1 (small, 1-50 GRT), Class 2 (medium, 51-104 GRT), and Class 3 (large, 105+ GRT).

Landings

Between 1967 and 1975, total landings did not exceed 1000 mt (Table E1). Total landings rose rapidly after 1975, but have remained stable at approximately 20,000 - 23,000 mt per year from 1985 - 1994 (Table E1; Figure E1). Annual EEZ quotas have been set since 1978. EEZ landings have typically been below the annual quota by approximately 2,000 mt. Typically, 95% - 100% of the annual landings are harvested from the EEZ; the remainder is taken from state waters (Table E1).

Although over 95% of the landed ocean quahog biomass is harvested from the Mid-Atlantic region (Table E2), an important small-vessel fishery also exists off the coast off Maine. For the fishery as a whole, large vessels are responsible for taking 80 - 100% of the annual catch (Table E2).

The catch of ocean quahogs from the New Jersey (NJ) region (Figure E2) has ranged from 6,000 - 16,000 mt per year from 1978 - 1994 (Figure E3; Table E2). During this time interval, annual catch from the NJ region has typically been greater than that from either Delmarva (DMV) or Long Island (LI). However, annual catches from NJ have declined since 1990. Annual catches from DMV increased throughout the early 1980's, but like NJ, catches from DMV have declined in recent years (Figure E3). Until 1992, few ocean quahogs were caught from the LI region, but from 1992 - 1994 catches from the LI region have been as great as from the NJ region (Figure E2). The fishery has continued to move to the north and east, with significant catches taken in 1993 from areas directly south of Martha's Vineyard Massachusetts (Figure E4).

Ocean quahog catches from the coast of Maine are restricted to a narrow band within the 50 fathom line (Figure E4). Total catches from this area have ranged from 84 to 166 mt of meats per year since 1992 (Table E2).

Size Composition

Length frequency distributions for ocean quahogs landed between 1982 and 1994 are shown for the Delmarva, New Jersey, and Long Island regions (Figures E5-E7). The mean length of clams landed from each region has been very stable through time (Table E3). While the estimates for LI are based on small sample sizes, it appears that the average shell length of a clam landed from the NJ area is larger than that from LI by approximately 6 mm (Table E3). Ocean quahogs caught from LI and SNE have been of similar size.

Landings/Effort

Trends in reported hours fishing by region (Figure E8) are similar to trends described earlier for regional catches (Figure E3). Since 1992, effort in the LI region has increased greatly. Effort in the NJ region is variable, but still high. There is currently very little fishing effort in the DMV region.

Within a given year and region, 80 - 100% of the ocean quahog catch is made by large vessels (Table E2). Nominal CPUE for large vessels has been declining since the early 1980s in the NJ and DMV regions (Table E2). Since 1986, LPUE has dropped in DMV from 708 to 448 kg/hr (-37%) and in NJ from 631 to 346 kg/hr (-45%). LPUE for all areas (Figure E9) has declined over time, but the slope is not as steep (662 kg/hr in 1986, 472 kg/hr in 1994; -29%). This is due to migration of the fleet in the early 1990s to the Long Island region where clams had not been previously exploited in quantity. Thus, although CPUE has declined in the regions that have been exploited throughout the 1980s and 1990s, the fleet has managed to buffer the decline in overall

CPUE by exploiting new regions. While the trend is based on a very short time series, CPUE in the LI region has already started to decline from 870 kg/hr in 1992 to 611 kg/hr in 1994.

To examine trends in CPUE on a finer spatial scale, 8 ten minute squares (TNMS) were analyzed from across the Mid-Atlantic region (Figure E10; Table E4). Squares were selected if they had a long history of harvesting. They are likely to represent locations which had relatively high virgin biomass for their local area. In Table E4, TNMS's are ordered from south (left) to north (right). The maximum cumulative catch of 16,320 mt meat was taken from TNMS 377431 which is off the coast of Virginia. The catch from this square has been very low since 1990, indicating that it was harvested out and then abandoned. Every square has a similar pattern of decreasing CPUE as cumulative catch builds up over time. In some cases near the end of the time series CPUEs increase, but these correspond only to minor catches. These data are used in the calculation of "percent of resource remaining".

General Linear Models

A standardized abundance index from the commercial data was calculated using general linear modelling. Year, vessel tonclass and subregion were included as explanatory variables. "Subregions" were created by partitioning regions into halves of approximately equal area.

GLM results are presented in detail for DMV (Table E5), NJ (Table E6) and LI (Table E7). Bias corrected and backtransformed year coefficients for landings in weight per effort from the GLMs are listed in Table E8 and plotted in Figure E11. In general, the standardized CPUEs for NJ, DMV and LI follow the declining nominal LPUEs of large vessels rather closely.

Standardized year coefficients, based on clam biomass, were converted to coefficients based on numbers of clams (Table E8) so that additional modelling could be carried out. Conversion from weight to numbers involved division by the weight of an average clam landed from the specific region and year under consideration. The commercial length frequency distributions (Figures E5-E7) and growth parameters relating shell length to meat weight (Murawski and Serchuk, 1979) were used.

Research Survey Data

Description of Surveys

A series of 20 research vessel survey cruises have been conducted between 1965 and 1994 to evaluate the distribution, relative abundance and size composition of surf clam and ocean quahog populations in the Middle Atlantic, Southern New England and Georges Bank (Figure E2). NMFS also collected non-random samples from the coast of Maine in 1992 and 1994 to map the distribution of ocean quahogs and to examine population size frequency distributions. Because the size of ocean quahogs in the Maine region is small relative to the Mid-Atlantic, an additional liner was placed into the clam dredge, reducing the square openings from 5 cm to approximately 2.5 cm. Information from these surveys is used to predict relative year-class strength, and to evaluate the effects of fishery management measures. Assessments of both short- and long-term fishery productivity are based on comparing trends in survey abundance indices with fishery yields.

From Georges Bank (GBK) to S. Virginia/N. Carolina (SVA/NC), assessment areas have been subdivided into strata which remain fixed through time (Figure E2). The surveys are performed using a stratified random sampling design, allocating a pre-determined number of tows to each stratum. Standardized sampling procedures used in these surveys are described in Murawski and Serchuk (1989). One tow is collected per station, and intended tow duration and speed are 5 minutes and 1.5 knots, respectively. Catch in meat weight per tow is computed by applying appropriate length-weight equations to numbers caught in each 10 mm size category. By averaging over all tows within a stratum, representative size frequency distributions per tow are computed by stratum. Representative size frequency distributions and mean number of clams per tow are also computed by region using as a weighting factor the area of each stratum within the region.

Survey data from GBK to SVA/NC from 1982-1994 form a consistent series, tows that exceeded a specified level of gear damage were not included, nonrandom tows were not analyzed, and doppler distance was used to standardize every tow's catch to a common tow distance (1.5 n. mi.).

Abundance Indices and Size Composition

With the exception of samples from Maine, there is no evidence of either substantial recruitment by small clams or of growth by large ocean quahogs in any region (Figures E12-E16). By applying the age/length relationship given in Murawski et al. (1982) it is possible to assign approximate ages to clams collected in the 1994 survey. Most of the clams collected from New Jersey and Delmarva were 80-100 mm in shell length, which corresponds roughly to 44-120 years of age. Most of the clams collected from the LI and SNE regions were slightly smaller, 70-90 mm, and therefore younger, 27 - 70 years old. Detailed size composition data for New Jersey, Long Island and Georges Bank are given in Figure E16. These data, presented in mm size intervals, confirm the presence of a few small animals in the 30-50 mm range (approximate ages 6 to 12). Whether recruitment in these numbers is adequate to accumulate the standing stock of large animals at the observed age composition is speculative, but raises the possibility of a low-level but sustainable fishery. Simulation studies utilizing the observed frequency of these young animals and observations of accumulated stock are therefore recommended.

In the Maine area, the population consists of two modes. The larger group is centered between 50 and 54 mm shell length. Most clams in the smaller group measured 20-29 mm in July, 1992, and 30-39 mm in August, 1994. Work is currently in progress to section these shells and estimate age and growth. Based on the work of Kraus et al. (1992) the 50-54 mm long clams would be 35-43 years of age. The smaller group, 30-39 mm long, would be 15-20 years of age.

For the Delmarva area, the 1994 data did not produce unusually large numbers or weight per tow estimates. However, as with surfclam data, the catch of ocean quahogs in the New Jersey area was unexpectedly high. As with surfclams, this has to be the result of a gear efficiency change rather than a sudden increase in clam population size. Ocean quahog growth is extremely slow, and there was no evidence from previous surveys that a large cohort of recruits was entering the population. An unusually high 1994 survey catch was also taken in the Long Island, S. New England and Georges Bank regions. It is clear from Figures E12-E15 that the high 1994 catches occurred in several strata within the NJ and LI regions, but that fairly typical catches were made in 1994 in several strata within the DMV region.

Given the problems with the 1994 survey (see previous chapter for a more complete discussion), it is difficult to make any statements from the survey data about recent changes in population size in the Mid-Atlantic region.

Likewise, it would be inappropriate to use the 2 surveys from Maine to make inferences about changes in population size, because those samples were taken from nonrandom locations. The data are useful, however, for mapping the distribution of the population.

Areal Distribution of Survey Catches

Data from several surveys (1982-1992) were combined to show the overall distribution of ocean quahogs along the east coast of the United States (Figure E17). The distribution is continuous from Georges Bank to S. Virginia, and tends to occur in deeper water than for surfclams. Off the coast of Maine samples were collected from depths shallower than 50 fathoms (1 fathom is approximately 2 meters). Within this depth range, ocean quahogs appear to be restricted to a patch centered between 67° and 68° W. Tows were taken to the east and west of the patch to attempt to define its limits. The location of the patch, as defined by survey data, agrees well with the location of recent landings (Figure E4)

The percentage of ocean quahog biomass by region was computed from the 1994 survey data (Figure E18). The calculations were based on a standard tow distance of 0.15 n. mi. with an area of 0.0001233 sq. n. mi., the fraction of habitat suitable for surfclams is assumed to be the same in all strata, and expansion of the biomass per tow to a regional biomass is based on the respective areas of strata within regions. Based on the 1994 survey, the GBK, SNE and LI regions each contain about 26% of the biomass. NJ and Delmarva are estimated to have approximately 20% and 2% of the biomass, respectively.

Like the 1994 survey, estimates from the 1992 survey for (NJ + DMV) biomass were approximately 20% of the total biomass. The 1992 survey indicated that NJ had approximately twice the biomass of the DMV region, whereas the 1994 survey suggested a greater difference (10:1 ratio). The 1994 ratio should be interpreted with caution considering that, during the 1994 survey, the clam dredge made unusually large ocean quahog catches in the NJ region, but not in the DMV region.

Population Size and Fishing Mortality Estimation

Population estimates for ocean quahogs were developed using a modified version of the Leslie-DeLury model (see Ricker, 1975; Seber, 1973). The classic model was changed to allow for natural mortality following fishing. Ordinary least-squares regression techniques were then used to generate estimates of initial population size and catchability coefficients. LOWESS smoothing techniques were used to identify the period in which the critical assumption of constant catchability was satisfied. Natural mortality rates were derived by examining consistency between two estimates of the fraction of the initial population size remaining in 1994. The DeLury model was applied to entire regions (Delmarva, New Jersey, and Long Island) and selected ten minute squares within those regions. Finally, bootstrap techniques were used to approximate the sampling distribution of initial population size for stochastic projections.

Description of Depletion Estimators

The Leslie-DeLury model is one of a general class of closed population models in which initial population size is derived as function of relative catch rates and cumulative catch. Catch rates are expressed as catch per unit of sampling effort. The model was developed originally by Leslie and Davis (1939) and reformulated by DeLury (1947). Since the original paper by Leslie and Davis (1939), a number of minor adjustments have been proposed (see Braaten 1969 for a review). A major advance to model theory was proposed by Collie and Sissenwine (1983) who incorporated recruitment into the model and introduced the distinction between process and measurement error. Their work has been advanced further by Conser (1994) who has developed a general statistical framework for model application and associated software.

Depletion models have a number of well known statistical problems including unequal variances and lack of independence. Fieller (1942, see Seber, 1973) was one of the first to treat the variance of N(0) and Braaten(1969) reviewed the robustness of the estimators under a wide variety of assumptions regarding variation in catchability and effort. In addition, the estimates of q and M are highly correlated and therefore difficult to estimate independently (Collie and Sissenwine, 1983). In spite of their apparent simplicity, depletion models remain a fertile area for modern statistical research (Pollock, 1991).

If a Type 1 fishery (Ricker, 1975) is assumed, a general depletion model can be derived from first principles as follows. Assume that catch C(t) is removed at mid year and that natural mortality acts on the population equally before and after the fishery. The dynamics of the population N(t) can described by the simple difference equation:

$$N(t+1) = \left(N(t)\ e^{-\frac{M}{2}} - C(t) \right) e^{-\frac{M}{2}} \qquad (1)$$

where M is the natural mortality rate. If it is assumed that catch per unit effort (CPUE(t)) is proportional to population size then

$$CPUE\,(t) = q\;N(t) \qquad (2)$$

where q is known as the catchability coefficient. By substituting Eq. 2 into Eq. 1 the recursive solution can be shown to be (c.f. Brodziak and Rosenberg 1993):

$$e^{M(t+1)}\;CPUE\,(t+1) = q\;N(0) - q\;e^{\left(\frac{M}{2}\right)} \sum_{j=0}^{t} C(j)\;e^{j\,M} \qquad (3)$$

when M= 0, Eq. 3 reduces to

$$CPUE\,(t+1) = q\;N(0) - q \sum_{j=0}^{t} C(j) \qquad (4)$$

which is equivalent to the original depletion estimator of Leslie and Davis (1939). Eq. 3 is a simple linear equation $Y = \beta_0 + \beta_1 X$ where $\beta_0 = q\,N(0)$ and $\beta_1 = q$.

Braaten (1969) noted the overwhelming importance of variability in catchability q. The Subcommitee considered other statistical problems minor compared to potential changes in catchability. To that end ordinary least squares was used to estimate parameters for Eq. 3 and the Subcommittee focused on identifying time periods in which q appeared to be stable.

Input Data and Assumptions

Natual Mortallity Rate and Recruitment

Natural mortality must be assumed in Eq. 3 but the Subcommittee noted that this implications for reductions in population size from the Leslie-DeLury model should be consistent with predictions of the general model $N(t) = N(0)\,e^{-Zt}$. Since $N(t) = q^{-1}$ CPUE(t) then

$$\ln(CPUE\,(t)) = \ln(CPUE\,(0)) - Z\,t \qquad (5)$$

Thus the predictions of N(t)/N(0) from Eq. 3 and predicted CPUE(t)/CPUE(0) from Eq. 5 should be consistent. Moreover, an estimated average F can be derived from Eq. 3 as

$$\bar{F} = \frac{\sum_{j=1}^{t} C(j)/\hat{N}(j))}{t} \qquad (6)$$

Therefore M+F from Eq. 6 should approximate Z obtained from Eq. 5. Such consistency occurred generally within the range of M=0.01 to M=0.03 among regions. It was noted that this methodology does not address the high sampling correlation between q and Z but does provide a check for internal consistency. For the purposes of reporting results and stochastic projections a range of M=0.015 to 0.025 was selected.

The recruitment dynamics of ocean quahog are not well known. NEFSC surveys have not detected evidence of recruitment pulses and no trends in average weight of landed quahogs have been observed. Recruitment was assumed to be zero for modeling purposes in this assessment.

CPUE Numbers

Catch per unit effort in numbers was derived from the GLM standardized CPUE for weight (Table E8) by dividing the standardized index by the average weight of quahogs in the landings (Table E9). CPUE has varied markedly over time (Figures E19-E21) as a function of population depletion and reallocation of fishing effort among regions. In the early 1980's fishing effort was concentrated in the Delmarva Region (Figure E19). Delmarva catches peaked in 1988 but by then effort had already begun to shift to New Jersey. There, peak catches occurred between 1989 and 1991 (Figure E20). In the Long Island Region, effort by class 3 vessels increased ten-fold from 1991 to 1992 and landings increased more than seven times (Figure E21). These geographical changes could affect catchability (or Z); comparison of the trends in CPUE suggest consistent downward trends in New Jersey and Long Island since 1988. In the Delmarva region CPUE has decreased markedly but the 1990 and 1991 values seem lower than expected.

Estimation

Estimates of population abundance and total biomass were generated for Delmarva, New Jersey and Long Island Regions. Due to apparent changes in catchability, application of the Leslie-Delury model was restricted to 1988-94 for sub-regions and ten-minute squares.

Sub-regions

LOWESS smoothing of ln (CPUE) suggested two intervals during which average Z (or q) appeared invariant: 1983-1987 and 1988-1994. Total mortality rates for these periods are summarized in Table E10 and depicted in Figures E22-E24. Results suggest average total mortality rates of 0.064, 0.094 and 0.080 for Delmarva, New Jersey and Long Island respectively. Moreover, contemporary rates have increased markedly in New Jersey and Long Island as the fishery shifted geographically from south to north.

Population abundance estimates are summarized in Table E11 by region for alternative assumed levels of M. Nominal probability levels for the Leslie-DeLury model regressions were all statistically significant. For the range of assumed M (0.015-0.025) the projected average biomasses in 1994 prior to the fishery ranged from 74,000 to 88,000 mt in Delmarva, 133,000 to 151,000 mt in New Jersey, and 53,000 to 61,000 mt in Long Island. Catchability is over twice as high in the Long Island region as in Delmarva or New Jersey.

Bootstrap estimates of population size and depletion rates suggest that only 50 to 60% of the resource that existed in 1988 will remain after the 1994 fishery (Table E12). Median estimates from the bootstrap runs (Table E12) are nearly identical to the point estimates in Table E11. The sampling distributions of population sizes are asymmetrical and increase with the assumed level of M. The respective estimates of the fraction remaining are more symmetrical and relatively invariant with respect to the assumed level of M.

Depletion of the Long Island quahog populations appears to be occurring very rapidly (Figure E25). Note that the 1993 and 1994 cumulative catches have decreased adjusted CPUE by nearly half of its previous level in just two years.

Annual estimates of biomass and fishing mortality rates, based on the DeLury model, indicate that recent fishing mortality rates have declined off Delmarva and New Jersey, but have increased greatly off Long Island (Table E13). The current (1994) Fs are: Delmarva = 0.01; New Jersey = 0.05; Long Island = 0.18.

Ten Minute Squares

The Leslie-DeLury model was applied to selected 10-minute squares within each sub-region (Table E14). Results confirm the general trends for each sub-region although the statistical fits are less precise. Results further suggest that the observed patterns are scale invariant--population decline is evident in both small and large regions. Localized depletions may occur rapidly as indicated by the marked decline in abundance in TNMS 407356 after the 1994 fishery.

Projections

Description of Projection Methods

The calculation of 'quahog supply years' was undertaken to meet Term of Reference c. using a stochastic projection model. In particular, the number of supply years was defined as the number of years, beginning with 1995, for which the specified ocean quahog quota can be fully taken. The projections began in the year 1995, and continued until the ocean quahog population was consequently exhausted or until the year 2094 was reached.

Model

The basic model describes how exploitable biomass changes annually due to the effects of natural mortality and harvest. In contrast to surf clams, recruitment of ocean quahogs was considered to be negligible based on the longevity of quahogs (lifespan up to 220 years) and the lack of observable recruitment from recent decades. The basic model was

$$B(t+1) = \left(B(t) - C(t)\right)\cdot e^{-M(t)}$$

where
B(t) is the exploitable biomass in year t,
C(t) is the amount of exploitable biomass that was landed during year t,
M is the instantaneous natural mortality rate.

The catch biomass was set at a constant quota. There were two stochastic components to the ocean quahog projection model: the initial exploitable biomass and the annual natural mortality rate.

Stochastic Components

The modified Leslie-DeLury model was used to derive the sampling distribution for initial exploitable biomass based on a range of likely values of M. A total of 6 values of M (0.015, 0.017, 0.019, 0.021, 0.023, and 0.025) were used to represent uncertainty in the value of M. For each value of M, a total of 1000 bootstrap realizations of the regression model were generated by adding a randomly selected error term from the original model fit to the set of predicted values to give a total of 6000 possible initial conditions. Of these 6000 possible initial conditions, a total of 200 values were selected for use in the projections. This resulted in approximately 30 initial conditions for each value of M.

Let Y_i and X_i represent the original data set and Y_i^* represent the predicted value from the regression $Y_i^* = \beta_0 + \beta_1 X_i$. The residuals from this regression can be defined as $R_i = Y_i^* - Y_i$. Let k be a uniform random number that can assume integer values between 1 and n where n=number of observations. Bootstrap data set j, (j=1, ...1000) was generated as $Y_{B,i,j} = Y_i^* + R_{k,j}$. The bootstrap realization ($Y_{B,i,j}$, X_i) was then used to generate a population estimate for mid year 1994, say $N_{94,j}$. Initial conditions for the projections required this estimate to be decremented for natural mortality and the estimated catch for 1994 and converted to total biomass as follows:

$$B_{95,j} = \left(N_{94,j}\, e^{-M} - C_{94}\, e^{-\frac{M}{2}}\right) \overline{w_{94}}$$

where M is the instantaneous natural mortality rate and w_{94} is the average weight of a landed quahog in 1994.

For projection, the annual level of natural mortality was fixed to be the value of M that was used to generate the bootstrapped initial population size with the modified Leslie-DeLury model. In this way, the projections would not use values of M that were inconsistent with the initial estimate of population biomass.

The key outputs of the projections were descriptive statistics of the distribution of quahog supply years. Other outputs included descriptive statistics for the distribution of exploitable biomass and exploitation rate through time. Annual descriptive statistics were computed only for non-extinct populations.

Starting Conditions/Assumptions

One projection of ocean quahog landings was made for each of three fishery areas: Delmarva, New Jersey, and Long Island. Additionally, starting biomasses and catch quotas were combined for the three areas to provide a 'global' simulation. The latter simulation is probably more realistic than any of the area-based projections, since only a single resource-wide quota applies, and there are currently no restrictions on how much catch can be removed from any sub-area (except of course Georges Bank).

Delmarva

The initial exploitable biomasses in 1995 were taken from a set of 200 bootstrapped estimates of the population size in 1994 less the projected catch of 27.027 million quahogs in 1994 and using the corresponding value of M as described above. For each initial biomass and value of M, a total of 10 simulations were performed to generate a total of 2,000 population trajectories through time. The constant catch quota projection was based upon the average landings from Delmarva during 1992-1994; 1,790 mt.

New Jersey

The initial exploitable biomasses in 1995 were taken from a set of 200 bootstrapped estimates of the population size in 1994 less the projected catch of 177.949 million quahogs in 1994 and using the corresponding value of M as described above. For each initial biomass and value of M, a total of 10 simulations were performed to generate a total of 2,000 population trajectories through time. The constant catch quota projection was based upon the average landings from New Jersey during 1992-1994; 8,020 mt.

Long Island

The initial exploitable biomasses in 1995 were taken from a set of 200 bootstrapped estimates of the population size in 1994 less the projected catch of 361.379 million quahogs in 1994 using the corresponding value of M as described above. For each initial biomass and value of M, a total of 10 simulations were performed to generate a total of 2,000 population trajectories through time. The constant catch quota projection was based upon the average landings from Long Island during 1992-1994; 10,360 mt.

All Areas Combined

The initial exploitable biomasses were taken from the 200 bootstrap runs used for the individual areas. A total of 10 simulation runs were made for each initial condition, to provide a total of 2,000 projections for the 'supply years' calculation for the three areas combined. The constant catch quota projection was based upon the average total landings from Delmarva-Long Island during 1992-1994; 20,170 mt.

Results

Results of calculated 'supply years' for ocean quahog are given in Table E15 and Figures E26-E29. Under the starting assumptions of initial population size given by Leslie/DeLury population estimators, no substantial recruitment, and natural mortality rate varying between 0.015-0.025, regional supplies are projected to last between 4 and 32 years. Of particular concern is the situation in Long Island. Depletion estimators indicate a rapid decline in resource as calibrated by standardized LPUE indices. Exploitation rates in all areas rise rapidly. It should be noted that these calculations do not include biomass values for the Southern New England and Georges Bank resource areas which contain between 56 and 60% of the total resource, based on 1992 and 1994 resource surveys.

Yield Per Recruit

Revised yield per recruit calculations were performed for the Middle-Atlantic populations (Figure E30). These calculations used the shell length-age relations in Murawski et al. (1982), and the combined length-weight equation given in Murawski and Serchuk (1979). Knife-edge selection at age 17 (60.6 mm shell length) was assumed, given the dearth of animals smaller than this size in the populations. A constant M of 0.02 was assumed. Spawning stock biomass per recruit was not computed, since most quahogs mature well below the assumed age size at selection. Alternatively, calculations of total stock biomass per recruit (SB/R) provided a minimum estimate of life-time spawning biomass. F_{MAX} was calculated to be 0.065, $F_{0.1}$ was calculated to be 0.03. Based on current (1994) fishing mortality rates, the resource off Long Island is being fished at about 3 times F_{Max}, while New Jersey and Delmarva are fished below F_{MAX}.

Conclusions

- o Total landings of ocean quahog rose rapidly beginning in 1976, and have since leveled-off at about 24,000 mt of shucked meats per year. EEZ landings have not achieved the specified quota for the resource since 1986.

- o The fishery has shifted northward progressively since the mid 1970s. During the 1970s and early 1980s the fishery was centered off Delmarva and Southern New Jersey. During the late 1980s the fishery shifted northward to Northern New Jersey. Currently most landings of ocean quahogs are from an area off Long Island.

- o Relative resource abundance, as measured by standardized CPUE measures, has declined substantially in some fishery areas. For Delmarva, the 1994 population size is about 60% of the 1988 level; for New Jersey, 55%; and for Long Island, 50%.

- o Total instantaneous mortality rates for the period 1988-1994 were estimated via Leslie/DeLury regression techniques. Currently, total Z is estimated to be 0.06 off Delmarva, 0.09 off New Jersey and 0.08 off Long Island. The rate of natural mortality is not precisely known, but is thought to be from 0.01-0.03. Annual fishing mortality rates in 1994 for the three areas are: Delmarva = 0.01; New Jersey = 0.05; Long Island = 0.18.

- o Calculations of supply years remaining, given current quotas and catch distributions, were undertaken with a stochastic projection model. Based on these calculations, the median number of 'supply years' remaining in Delmarva = 32; New Jersey = 14; Long Island = 4. For the three areas combined, there is an estimated 11 year supply. Based on recent research survey information, these three regions contain about 40-60% of the entire ocean quahog resource.

Sources of Uncertainty

- o The catchability of ocean quahogs in the 1994 NEFSC survey appeared to differ substantially from previous surveys. As a result, the use of the 1994 data for estimation of swept-area population size was not undertaken.

- o The biological composition of the catches taken from the Long Island area is uncertain due to a lack of commercial sampling.

- o Recruitment dynamics of the ocean quahog population are not well known. Spatial relationships between spawning stock and recruitment have not been quantified. Projection results may be conservative because they are based on the assumption that recruitment is negligible.

- o Variation in size-at-age of ocean quahogs makes it difficult to assess population age structure and to detect recruitment.

- o Population size estimates for Delmarva, New Jersey and Long Island areas were based upon Leslie-DeLury calculations using commercial LPUE data. To the extent that resources in these areas are unfished (either being too deep, or in non-fished areas), these population size estimates will be minimum estimates. This factor may be particularly important off Long Island. Furthermore, for areas such as Southern New England and Georges Bank, where minimal EEZ fishing has occurred to date, no population size data are presented. The relative quantity of biomass in these areas can be estimated based on research vessel survey data, but such estimates assume a constant catchability of quahogs across all survey areas, a questionable assumption.

- o As yet, based on LPUE or research vessel survey data, there are insufficient data to estimate the size of the fishable resource off eastern Maine.

- o Catch curves and depletion models are sensitive to the time series analyzed. For example, using 1990-1994 Delmarva CPUE rather than 1988-1994, estimates of Z are significantly lower, and estimated supply years are greatly increased.

Research Recommendations

- o Evaluate whether regional differences in catchability from the Leslie-DeLury model can be used to calibrate swept-area estimates of population size for unfished areas from research surveys.

- o Conduct additional biological studies of maturity and growth for the development of biological reference points, particularly emphasizing shell length-thickness relationships.

- o Develop geostatistical estimates of population size, incorporating historical research vessel survey information.

- o Increase levels of biological sampling of the catch.

- o Conduct additional GLM studies to characterize the fine-scale spatial and temporal pattern of individual fishing vessels based on logbook data.

- o Evaluate implications of low recruitment for the sustainability of quahog yields.

- o Perform yield per recruit analyses for Gulf of Maine populations.

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Table E1. Annual landings of ocean quahog (metric tons, meats) from state waters and the Exclusive Economic Zone[1], and annual quotas.

Year	State Water	EEZ	Total[1]	Percent EEZ	EEZ Quota
1967	20	-	20	0	-
1968	102	-	102	0	-
1969	290	-	290	0	-
1970	792	-	792	0	-
1971	921	-	921	0	-
1972	634	-	634	0	-
1973	661	-	661	0	-
1974	365	-	365	0	-
1975	569	-	569	0	-
1976	656	1,854	2,510	74	-
1977	1,118	7,293	8,411	87	-
1978	1,218	9,197	10,415	88	13,608
1979	1,404	14,344	15,748	91	13,608
1980	1,458	13,885	15,343	90	15,876
1981	410	15,966	16,375	97	18,144
1982	207	15,572	15,779	99	18,144
1983	701	15,228	15,978	96	18,144
1984	1,200	16,401	17,602	93	18,144
1985	189[2]	23,566	23,755	99	19,958
1986	814	19,771	20,585	96	27,215
1987	569	22,226	22,795	98	27,215
1988	412	20,594	21,006	98	27,215
1989	184	22,996	23,145	99	23,587
1990	116	21,079	21,195	99	24,040
1991	40	22,246	22,287	100	24,040
1992	60	22,819	22,882	100	24,040
1993	1,297	22,133	23,430	94	24,494
1994[3]	-	19,554	-	-	24,494

[1] Landings through 1993 are from the U.S. Dept of Commerce series "Fisheries of the United States".

[2] Inshore landings from Maine coastal waters.

[3] The 1994 EEZ landings were estimated from data available in the s1032 database on September 13, 1994. Landings for 1994 came from N. Carolina- Long Island (94%), Southern New England (5%) and the coast of Maine (1%).

Table E2. Annual ocean quahog catch (thousands of metric tons), effort (thousands of hours fished), and CPUE data (kilograms per hour fished) for large regions in the Middle Atlantic Bight.

	Delmarva[1]				New Jersey				Long Island			
Year	Sum[2]	Catch[3]	Eff	CPUE[3]	SUM	Catch	Eff	CPUE	SUM	Catch	Eff	CPUE
1978[4]	1.29	-	-	-	6.35	-	-	-	.00	-	-	-
1979	5.45	-	-	-	6.03	-	-	-	.00	-	-	-
1980	2.28	-	-	-	7.74	-	-	-	.00	-	-	-
1981	0.60	-	-	-	8.77	-	-	-	.00	-	-	-
1982	4.35	6.82	9.4	721[5]	10.26	1.72	3.5	495	.00	0	0	-
1983	5.39	5.19	6.8	758	8.25	7.73	12.6	615	.02	.02	.1	420
1984	7.16	6.45	9.7	665	8.86	7.96	13.6	584	.00	0	0	-
1985	7.20	6.42	8.6	746	10.68	9.81	16.3	604	.04	.04	.1	462
1986	8.23	6.94	9.8	708	9.06	8.33	13.2	631	.40	.37	.3	1159
1987	10.54	9.53	13.7	694	9.07	8.10	13.7	592	1.18	1.18	.8	1454
1988	11.71	10.92	18.0	607	7.01	6.71	11.4	589	.64	.44	.5	964
1989	6.44	5.43	10.4	523	14.10	12.14	21.4	568	.60	.60	.8	759
1990	3.69	2.88	6.2	464	15.58	13.46	25.3	532	.74	.73	1.3	576
1991	4.84	3.97	10.0	397	14.57	12.64	27.0	469	1.67	.94	1.2	820
1992	2.38	1.92	4.5	426	6.94	5.38	13.5	397	11.94	10.53	12.1	870
1993	1.98	1.74	4.3	401	10.17	8.03	21.3	378	8.65	7.85	11.9	657
1994[6]	1.00	.98	2.2	448	6.94	5.90	17.0	346	10.48	8.75	14.2	611

	Southern New England				Total Southern Area				Maine			
Year	Sum	Catch	Eff	CPUE	SUM	Catch	Eff	CPUE	SUM	Catch	Eff	CPUE
1978	.07	-	-	-	7.72	-	-	-	-	-	-	-
1979	.00	-	-	-	11.48	-	-	-	-	-	-	-
1980	.15	-	-	-	10.16	-	-	-	-	-	-	-
1981	.05	-	-	-	9.42	-	-	-	-	-	-	-
1982	.00	-	-	-	14.61	-	-	-	-	-	-	-
1983	.63	.62	1.5	401	14.29	13.56	21.0	645	-	-	-	-
1984	.82	.82	2.5	327	16.85	15.24	25.9	589	-	-	-	-
1985	.69	.69	2.1	335	18.77	[illegible]	27.2	629	-	-	-	-
1986	.56	.56	1.1	494	18.25	16.21	24.5	662	-	-	-	-
1987	.70	.67	1.2	573	21.49	19.48	29.4	662	-	-	-	-
1988	.84	.68	1.2	553	20.25	16.80	31.1	603	-	-	-	-
1989	1.19	.91	2.1	438	22.34	19.10	34.7	551	-	-	-	-
1990	.93	.91	1.8	498	20.96	16.00	34.6	520	.004	-	-	-
1991	.86	.86	1.4	599	21.95	18.41	39.5	466	.166	.0749	8.2	9
1992	1.14	1.08	1.5	713	22.40	15.92	31.7	597	.112	.0513	6.1	8
1993	1.02	.93	1.3	706	21.82	18.55	38.9	477	.084	.0322	2.3	14
1994[5]	.97	.89	1.6	597	19.40	16.51	34.9	472	.109	.058	2.7	22

1 Regions correspond to those thown in Figure 2.1.1.2. "Total Southern Area" = Delmarva + New Jersey + Long Island + Southern New England + Georges Bank + S. Virginia/N. Carolina. It does not include Maine.

2 "Sum" is the sum of all landings by all vessel classes.

3 Except for Maine, "Catch" is catch by class 3 vessels, and this was used in the CPUE index. For Maine, "small" class 1 vessels were used. CPUE is based on trips where catch and effort were greater than zero.

4 Sums from 1978-1982 are based on the "WO" database. Sums from 1983-1994 as well as all catch, effort, and CPUE values are based on the s1032 database.

5 For 1982, regions were defined as in NEFSC LRD 89-08, by LORAN chain. This definition resulted in less precise allocation of landings to regions than that used for the 1983-1994 data.

6 Values for 1994 are estimated from data available on September 13, 1994.

Table E3. Summary statistics on ocean quahog commercial length frequency data by year/area. Data were collected by port agents taking random samples from catches.

Area/Year	Mean Length (mm)[1]	Min L	Max L	Number of Measured Clams[2]
Delmarva				
1982[3]	85.0	65	115	2611
1983	87.0	65	115	1716
1984	85.2	65	125	3116
1985	-[4]	-	-	-
1986	-	-	-	-
1987	90.2	65	115	900
1988	90.1	55	115	780
1989	89.3	75	115	899
1990	92.4	75	125	900
1991	91.4	35	117	3331
1992	92.9	66	118	1668
1993	91.6	64	115	850
1994	92.5	65	115	120
New Jersey				
1982	92.6	65	125	779
1983	93.9	75	115	1980
1984	-	-	-	-
1985	94.5	65	125	900
1986	94.5	75	125	870
1987	94.2	65	115	900
1988	92.6	65	115	933
1989	94.3	65	115	900
1990	95.5	55	115	870
1991	95.5	65	117	658
1992	90.4	77	108	90
1993	94.8	78	112	300
1994	96.9	85	115	90
Long Island				
1992	87.3	70	98	30
1993	-	-	-	-
1994	89.7	75	105	30
S. New England				
1988	89.1	65	105	150
1989	87.3	75	115	240
1990	91.8	75	105	120
1991	90.5	70	109	121
1992	86.4	70	105	150
1993	85.3	72	99	30
1994	-	-	-	-

1 "Mean length" is the expected value from the length frequency distribution, using size classes of 1 cm. Length frequency distributions were derived by weighting trips by their respective catches.

2 Total number of clams used in this assessment. Typically, 30 clams are measured per trip. The minimum and maximum lengths of measured clams are reported.

3 Values for 1982-1983 are from NEFSC LRD 83-25. Values from 1985-1990 and 1994 are from subsamples of the data. Subsamples contained data from 30 randomly selected trips, when available.

4 "-" = no data available. No data are available for Long Island before 1992 or S. New England before 1988.

Table E4. Cumulative annual ocean quahog catch and CPUE data for eight ten-minute squares in the Middle Atlantic Bight from Delmarva to Long Island from 1982-1994.

	Ten Minute Square Data															
	377422		377431		377441		387462		387463		407346		407356		407223	
Year	CUM[1]	CPUE[2]	CUM	CPUE	CUM	CPUE	CUM	CPUE	CUM	CPUE	CUM	CPUE	CUM	CPUE	CUM	CPUE
1982	3.14	-	0.44	-	0.05	-	0.00	-	0.00	-	0.00	-	0.00	-	0.00	-
1983	4.81	728	2.37	804	0.10	862	0.38	619	1.42	740	0.00	-	0.00	-	0.00	-
1984	5.81	627	4.54	647	1.21	799	1.42	633	3.43	668	0.00	-	0.00	-	0.00	-
1985	6.83	768	6.43	735	3.71	852	3.91	604	4.73	644	0.15	841	0.00	-	0.00	-
1986	8.78	675	8.57	735	4.81	732	5.12	593	5.30	642	0.99	999	0.05	859	0.00	-
1987	10.63	750	11.27	718	6.92	637	6.42	607	5.91	597	1.70	624	0.05	-	0.00	-
1988	12.36	610	14.04	664	9.56	578	7.32	538	6.96	536	2.90	806	0.05	-	0.00	-
1989	12.61	411	14.55	514	10.85	487	9.59	514	8.39	545	3.99	728	0.54	808	0.00	-
1990	12.88	399	15.20	451	11.42	562	11.27	479	9.81	522	4.88	676	1.00	936	0.16	366
1991	13.11	258	15.99	362	12.29	404	12.42	396	10.67	434	6.43	672	1.17	648	.90	971
1992	13.41	404	16.11	289	12.56	365	13.61	372	11.35	408	7.02	597	1.28	656	7.61	911
1993	13.41	-	16.17	346	12.67	496	14.20	295	11.90	340	7.54	547	1.39	516	10.16	685
1994	13.51	509	16.32	564	12.70	401	14.33	308	12.05	273	8.19	495	2.06	552	11.64	665

[1] Cumulative catch data (CUM) are thousands of metric tons of shucked meats collected by vessels of all sizes from 1982-1994.

[2] Catch per unit effort data (CPUE) are kg/hour fishing by class 3 (large) vessels.

Table E5. Ocean quahog GLM OF CPUE 1982-1994. Factors are year subreg tonclass Standards are: yr=1982, toncl=3(large). Sub-region is DELMARVA.

General Linear Models Procedure

Dependent Variable: L_LPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	561.63935987	37.44262399	243.23	0.0001
Error	12057	1856.07497724	0.15394169		
Corrected Total	12072	2417.71433710			

R-Square	C.V.	Root MSE	L_LPUE Mean
0.232302	6.174537	0.39235404	6.35438806

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	12	407.42973135	33.95247761	220.55	0.0001
SUBREG	1	22.47580097	22.47580097	146.00	0.0001
TONCL	2	131.73382754	65.86691377	427.87	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	12	314.88179195	26.24014933	170.46	0.0001
SUBREG	1	28.16176789	28.16176789	182.94	0.0001
TONCL	2	131.73382754	65.86691377	427.87	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		6.528481371 B	533.60	0.0001	0.01223468
YEAR	1983	-0.061609351 B	-3.14	0.0017	0.01959453
	1984	-0.169065207 B	-9.29	0.0001	0.01819314
	1985	-0.087408178 B	-4.75	0.0001	0.01838727
	1986	-0.137231097 B	-7.56	0.0001	0.01814542
	1987	-0.128059998 B	-7.41	0.0001	0.01729001
	1988	-0.215925221 B	-12.76	0.0001	0.01691955
	1989	-0.292550965 B	-16.29	0.0001	0.01795394
	1990	-0.455510800 B	-22.13	0.0001	0.02058695
	1991	-0.574248715 B	-30.67	0.0001	0.01872140
	1992	-0.482254173 B	-20.01	0.0001	0.02409897
	1993	-0.497428666 B	-19.93	0.0001	0.02496113
	1994	-0.528407092 B	-13.14	0.0001	0.04021582
	9999	0.000000000 B	.	.	.
SUBREG	2	0.122456619 B	13.53	0.0001	0.00905379
	99	0.000000000 B	.	.	.
TONCL	1	-1.124920662 B	-6.40	0.0001	0.17576594
	2	-0.294386972 B	-28.60	0.0001	0.01029500
	99	0.000000000 B	.	.	.

Table E6. Ocean quahog GLM OF CPUE 1982-1994. Factors are year subreg tonclass Standards are: yr=1982, toncl=3(large) , subreg=1. Sub-region is NEW JERSEY.

------------------------------------ REGION=NJ ------------------------------------

General Linear Models Procedure

Dependent Variable: L_LPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	635.16278027	42.34418535	260.77	0.0001
Error	20041	3254.28288407	0.16238126		
Corrected Total	20056	3889.44566433			

R-Square	C.V.	Root MSE	L_LPUE Mean
0.163304	6.491764	0.40296558	6.20733551

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	12	447.24162221	37.27013518	229.52	0.0001
SUBREG	1	170.14501754	170.14501754	1047.81	0.0001
TONCL	2	17.77614051	8.88807026	54.74	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	12	477.40321672	39.78360139	245.00	0.0001
SUBREG	1	165.09953200	165.09953200	1016.74	0.0001
TONCL	2	17.77614051	8.88807026	54.74	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		6.334125548 B	298.41	0.0001	0.02122633
YEAR	1983	0.247747469 B	11.08	0.0001	0.02235445
	1984	0.190935999 B	8.65	0.0001	0.02206079
	1985	0.208079882 B	9.56	0.0001	0.02176281
	1986	0.228713823 B	10.27	0.0001	0.02226454
	1987	0.198119414 B	8.81	0.0001	0.02248363
	1988	0.158343532 B	6.79	0.0001	0.02330661
	1989	0.171596384 B	7.97	0.0001	0.02153971
	1990	0.102913649 B	4.80	0.0001	0.02143721
	1991	-0.023292933 B	-1.08	0.2816	0.02163263
	1992	-0.091768682 B	-3.95	0.0001	0.02324442
	1993	-0.192925330 B	-8.72	0.0001	0.02212901
	1994	-0.326586459 B	-13.24	0.0001	0.02466092
	9999	0.000000000 B	.	.	.
SUBREG	2	-0.253100511 B	-31.89	0.0001	0.00793758
	99	0.000000000 B	.	.	.
TONCL	1	-0.876753020 B	-8.66	0.0001	0.10121038
	2	-0.052818422 B	-6.01	0.0001	0.00879272
	99	0.000000000 B	.	.	.

Table E7. Ocean quahog GLM OF CPUE 1982-1994. Factors are year subreg tonclass Standards are: yr=1982, toncl=3(large) , subreg=1. Sub-region is LONG ISLAND.

------------------------------------ REGION=LI ------------------------------------

General Linear Models Procedure

Dependent Variable: L_LPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	12	159.70553580	13.30879465	93.49	0.0001
Error	3847	547.65560152	0.14235914		
Corrected Total	3859	707.36113732			

R-Square	C.V.	Root MSE	L_LPUE Mean
0.225777	5.709254	0.37730510	6.60865882

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	10	131.08446527	13.10844653	92.08	0.0001
SUBREG	1	20.11453498	20.11453498	141.29	0.0001
TONCL	1	8.50653555	8.50653555	59.75	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	10	148.25725176	14.82572518	104.14	0.0001
SUBREG	1	17.56198123	17.56198123	123.36	0.0001
TONCL	1	8.50653555	8.50653555	59.75	0.0001

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		6.461855033 B	447.09	0.0001	0.01445311
YEAR	1983	-0.488700461 B	-2.58	0.0098	0.18920538
	1985	-0.164074718 B	-1.36	0.1734	0.12050426
	1986	0.615310995 B	11.15	0.0001	0.05519909
	1987	0.935312544 B	25.87	0.0001	0.03615417
	1988	0.467943744 B	10.32	0.0001	0.04535600
	1989	0.319871491 B	7.27	0.0001	0.04400940
	1990	0.248664746 B	5.53	0.0001	0.04496165
	1991	0.237944267 B	8.12	0.0001	0.02929961
	1992	0.261107303 B	15.46	0.0001	0.01688469
	1993	0.034221864 B	1.92	0.0543	0.01777884
	1994	0.000000000 B	.	.	.
SUBREG	2	-0.178985759 B	-11.11	0.0001	0.01611478
	99	0.000000000 B	.	.	.
TONCL	2	0.136291742 B	7.73	0.0001	0.01763136
	99	0.000000000 B	.	.	.

Table E8.
GLM Year Estimates Species: Ocean Quahog

Species	* Region	Year	EST (GLM)	MSE	EST+.5MSE	GLM EST Back Transformed	** wt/clm (gr)	wt/clm (kg)	*** GLM EST (in #'s)
OQ	DMV	82	0.00	0.15	0.08	1.08	29	0.03	37.24
		83	-0.06	0.15	0.02	1.02	31	0.03	32.76
		84	-0.17	0.15	-0.09	0.91	29	0.03	31.45
		85	-0.09	0.15	-0.01	0.99	34	0.03	29.11
		86	-0.14	0.15	-0.06	0.94	34	0.03	27.69
		87	-0.13	0.15	-0.05	0.95	34	0.03	27.95
		88	-0.22	0.15	-0.14	0.87	34	0.03	25.60
		89	-0.29	0.15	-0.22	0.81	33	0.03	24.43
		90	-0.46	0.15	-0.38	0.68	37	0.04	18.51
		91	-0.57	0.15	-0.50	0.61	35	0.04	17.38
		92	-0.48	0.15	-0.41	0.67	37	0.04	18.02
		93	-0.50	0.15	-0.42	0.66	36	0.04	18.24
		94	-0.53	0.15	-0.45	0.64	37	0.04	17.21
OQ	NJ	82	0.00	0.16	0.08	1.08	35	0.04	30.99
		83	0.25	0.16	0.33	1.39	36	0.04	38.60
		84	0.19	0.16	0.27	1.31	36	0.04	36.47
		85	0.21	0.16	0.29	1.34	36	0.04	37.10
		86	0.23	0.16	0.31	1.36	36	0.04	37.87
		87	0.20	0.16	0.28	1.32	36	0.04	36.73
		88	0.16	0.16	0.24	1.27	34	0.03	37.37
		89	0.17	0.16	0.25	1.29	36	0.04	35.77
		90	0.10	0.16	0.18	1.20	37	0.04	32.49
		91	-0.02	0.16	0.06	1.06	37	0.04	28.64
		92	-0.09	0.16	-0.01	0.99	32	0.03	30.92
		93	-0.19	0.16	-0.11	0.89	36	0.04	24.84
		94	-0.33	0.16	-0.25	0.78	39	0.04	20.06
OQ	LI	82	.	.					
		83	-0.49	0.14	-0.42	0.66	.	.	.
		84	.	.	.	.	.	.	.
		85	-0.16	0.14	-0.09	0.91	.	.	.
		86	0.62	0.14	0.69	1.99	.	.	.
		87	0.94	0.14	1.01	2.74	.	.	.
		88	0.47	0.14	0.54	1.71	.	.	.
		89	0.32	0.14	0.39	1.48	.	.	.
		90	0.25	0.14	0.32	1.38	.	.	.
		91	0.24	0.14	0.31	1.36	.	.	.
		92	0.26	0.14	0.33	1.39	27	0.03	51.64
		93	0.03	0.14	0.11	1.11	.	.	.
		94	0.00	0.14	0.07	1.07	29	0.03	37.03

* = For Delmarva and New Jersey, Standard year is 1982.
For Long Island the Standard year is 1994.
** = Clam weight is based on commercial length frequency data.
***= Final estimate is in numbers, the (Backtransformed EST / wt per clam (in kg))

Table E9. Summary of input data used to estimate population abundance of ocean quahog via the Leslie-DeLury model.

Region	Year	GLM Standardized Catch per Unit Effort		Catch		Average Wt
		(Weight)	(Numbers)	(000's mt)	(millions)	(kg)
Delmarva	83	1.01548	32.76	5.39	173.87	0.031
	84	0.91202	31.45	7.16	246.90	0.029
	85	0.98962	29.11	7.2	211.76	0.034
	86	0.94152	27.69	8.23	242.06	0.034
	87	0.95019	27.95	10.54	310.00	0.034
	88	0.87027	25.60	11.71	344.41	0.034
	89	0.80607	24.43	6.44	195.15	0.033
	90	0.68486	18.51	3.69	99.73	0.037
	91	0.60818	17.38	4.84	138.29	0.035
	92	0.66679	18.02	2.38	64.32	0.037
	93	0.65675	18.24	1.98	55.00	0.036
	94	0.63671	17.21	1	27.03	0.037
New Jersey	83	1.38949	38.60	8.25	229.17	0.036
	84	1.31275	36.47	8.86	246.11	0.036
	85	1.33545	37.10	10.68	296.67	0.036
	86	1.36329	37.87	9.06	251.67	0.036
	87	1.32222	36.73	9.07	251.94	0.036
	88	1.27066	37.37	7.01	206.18	0.034
	89	1.28761	35.77	14.1	391.67	0.036
	90	1.20214	32.49	15.58	421.08	0.037
	91	1.05961	28.64	14.57	393.78	0.037
	92	0.98948	30.92	6.94	216.88	0.032
	93	0.89428	24.84	10.17	282.50	0.036
	94	0.78239	20.06	6.94	177.95	0.039
Long Island	83	0.65868	24.39	0.02	0.74	0.027
	84	--	--	0.00	0.00	0.027
	85	0.91129	33.75	0.04	1.48	0.027
	86	1.98673	73.58	0.4	14.81	0.027
	87	2.73599	101.33	1.18	43.70	0.027
	88	1.7145	63.50	0.64	23.70	0.027
	89	1.47853	54.76	0.6	22.22	0.027
	90	1.37691	51.00	0.74	27.41	0.027
	91	1.36223	50.45	1.67	61.85	0.027
	92	1.39415	51.64	11.94	442.22	0.027
	93	1.11116	39.68	8.65	308.93	0.028
	94	1.07377	37.03	10.48	361.38	0.029

Table E10. Estimates of total mortality rate for ocean quahogs based on changes in $\log_e$ catch (number) per unit effort (thousands/hr) by region and period.

Region	Period	Instantaneous Total Mortality Rate		N	Coefficient of Determination R^2	Probability
		Estimate (yr^{-1})	Std Error			
Delmarva	1983-87	0.044	0.008	5	0.904	0.013
	1988-94	0.064	0.019	7	0.696	0.020
New Jersey	1983-87	0.006	0.008	5	0.175	0.483
	1988-94	0.094	0.016	7	0.881	0.002
Long Island	1983-87[a]	-0.370	0.082	4	0.910	0.046
	1988-94	0.080	0.014	7	0.870	0.002

[a]/ Limited data, total effort ranged from 0 to 800 hr; catches ranged from 200 to 1,180 mt.

Table E11. Region population abundance estimates of ocean quahogs derived from modified Leslie-DeLury model applied to CPUE and Catch in numbers for 1988 to 1994 (N=7). Average weight of landed quahogs used to compute biomass.

Region	Natural Mortality Rate	Catchability Coefficient	Coefficient of Determination	Predicted Population Abundance at mid year, prior to removal of Catch					
				1988			1994		
				Number	Ave. Wt	Biomass	Number	Ave. Wt	Biomass
	M (yr^{-1})	q (x 10^{-3})	R^2	(millions)	(kg)	(000's mt)	(millions)	(kg)	(000's mt)
DMV	0.015	8.22	0.74	3160	0.034	107.4	2006	0.037	74.2
	0.020	7.56	0.70	3366	0.034	114.4	2174	0.037	80.4
	0.025	6.89	0.65	3683	0.034	125.2	2378	0.037	88.0
NJ	0.015	6.64	0.83	5680	0.034	193.5	3400	0.039	132.6
	0.020	6.24	0.81	6067	0.034	206.3	3616	0.039	141.0
	0.025	5.84	0.79	6499	0.034	221.0	3864	0.039	150.7
LI	0.015	19.39	0.80	2931	0.027[A]	79.1	1824	0.029	52.9
	0.020	18.12	0.80	3162	0.027[A]	85.4	1961	0.029	56.9
	0.025	16.85	0.80	3427	0.027[A]	92.5	2116	0.029	61.4

[A]/ Mean weights from 1992 substituted here

Table E12 Approximate percentiles for regional population abundance estimates based on 1000 bootstrap regressions of modified Leslie-Delury model. Applied to CPUE and catch in numbers, 1988-1994. N=7

Region	Natural Mortality Rate M (yr^{-1})	Catchability (x 10^{-3})			Initial Population Size Jan 1, 1988 (millions)			Population Size in mid year 1994 prior to removal of catch (millions)			Percent of 1988 Population Remaining at end of 1994. Estimated 1994 catch removed. (millions)		
		0.25	0.50	0.75	0.25	0.50	0.75	0.25	0.50	0.75	0.25	0.50	0.75
DMV	0.015	6.8	8.1	9.4	2835	3190	3660	1720	2040	2462	59	62	66
	0.025	5.6	6.8	8.2	3238	3783	4506	1926	2384	2991	57	61	64
NJ	0.015	5.9	6.6	7.3	5333	5820	6429	3001	3440	3989	52	55	58
	0.025	5.2	5.9	6.6	6009	6682	7406	3315	3880	4487	51	54	57
LI	0.015	17.1	19.1	21.7	2698	3038	3349	1575	1881	2161	44	49	53
	0.025	14.8	16.7	19.3	3093	3534	3992	1762	2133	2517	44	49	53

Table E13. Computation of biomass levels for DMV, NJ and LI ocean quahog. Data are from DeLury calculations.

Assumed M= 0.02

Region	Year	Pred N	millions Pred N	kg ave Wt	mt pred Bio	annual F	ave F	Percent annual U
DMV	88	25.4497	3366.362	0.034	114.5	0.102		9.7
	89	22.4189	2965.463	0.033	97.9	0.066		6.4
q=	90	20.5433	2717.368	0.037	100.5	0.037		3.6
0.00756	91	19.4048	2566.772	0.035	89.8	0.054		5.3
	92	18.006	2381.746	0.037	88.1	0.027		2.7
	93	17.1776	2272.169	0.036	81.8	0.024		2.4
	94	16.4339	2173.796	0.037	80.4	0.012	0.046	1.2
NJ	88	37.866	6068.269	0.034	206.3	0.034		3.3
	89	35.8674	5747.981	0.036	206.9	0.068		6.6
q=	90	32.7848	5253.974	0.037	194.4	0.08		7.7
0.00624	91	29.5851	4741.202	0.037	175.4	0.083		8.0
	92	26.6142	4265.096	0.032	136.5	0.051		5.0
	93	24.7736	3970.128	0.036	142.9	0.071		6.9
	94	22.5719	3617.292	0.039	141.1	0.049	0.062286	4.8
LI	88	57.2909	3161.749	0.027	85.4	0.008		0.8
	89	55.7397	3076.142	0.027	83.1	0.007		0.7
q=	90	54.2452	2993.664	0.027	80.8	0.009		0.9
0.01812	91	52.6891	2907.787	0.027	78.5	0.021		2.1
	92	50.5583	2790.193	0.027	75.3	0.158		14.6
	93	41.7813	2305.811	0.028	64.6	0.134		12.5
	94	35.5219	1960.37	0.029	56.9	0.184	0.074429	16.8

Table E14. Population abundance estimates from modified Leslie-DeLury model for selected ten minute squares within Delmarva, New Jersey and Long Island Regions (1988-94). Natural mortality rate M, was set to 0.02 for all regressions. Percent remaining estimates use 1988 as baseline year.

Region	Ten Minute Square	Population Size (millions)		Percent Remaining at mid year 1994	Percent Remaining after Removal of 1994 Catch	Coefficient of Determination R^2
		1988	1994			
Delmarva	377422	149.0	60.3	40.5	38.2	0.35
	377441	640.8	417.9	65.2	64.4	0.49
	377431	357.5	1897.8	53.1	51.4	0.46
New Jersey	387463	429.4	226.3	52.7	51.3	0.78
	387462	549.5	285.9	52.0	50.9	0.91
	407346	564.8	350.3	62.0	58.5	0.75
Long Island	407356[A]	176.8	103.9	58.8	45.1	0.60
	407223[B]	1,105.2	689.5	62.4	57.2	0.98

[A]Estimate based on 1986-1994 data with no catches in 1987, 1988

[B] Estimate based on 1991-1994 data only

Table E15. Calculated 'supply years' of ocean quahogs from Delmarva, New Jersey and Long Island, under constant quotas equal to the 1992-1994 average landings.

Area	Quota Assumption	Level (MT)	Recruitment Mean, (CV)	---- Supply Years ---- Mean	Median	Max	Expl. 1995	Rate Max.
DMV	Mean(92-94)	1,790	0 (0)	32.5	32	57	0.02	0.56
NJ	Mean(92-94)	8,020	0 (0)	14.3	14	25	0.06	0.63
LI	Mean(92-94)	10,360	0 (0)	3.98	4	8	0.24	0.87
DMV+NJ+LI	Mean(92-94)	20,170	0 (0)	11.4	11	22	0.08	0.96

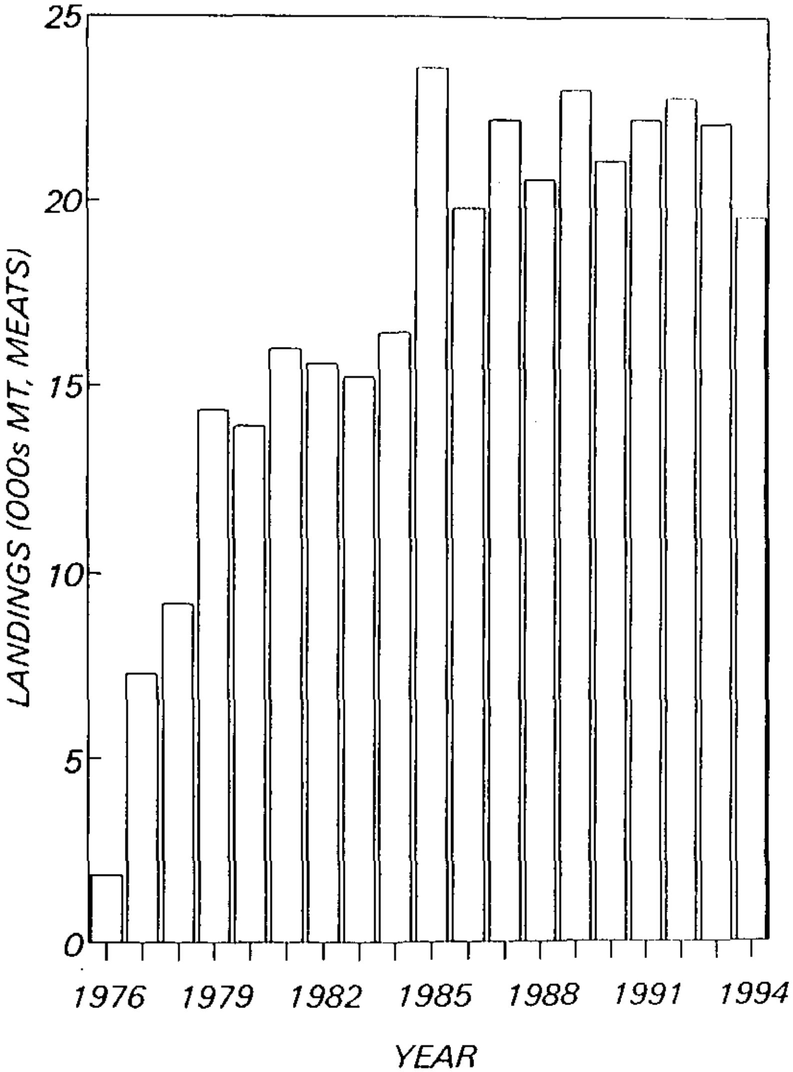

Figure E1. Landings of ocean quahogs from EEZ waters, 1976-1994. Landings for 1994 were estimated from logbook data through 3 September 1994.

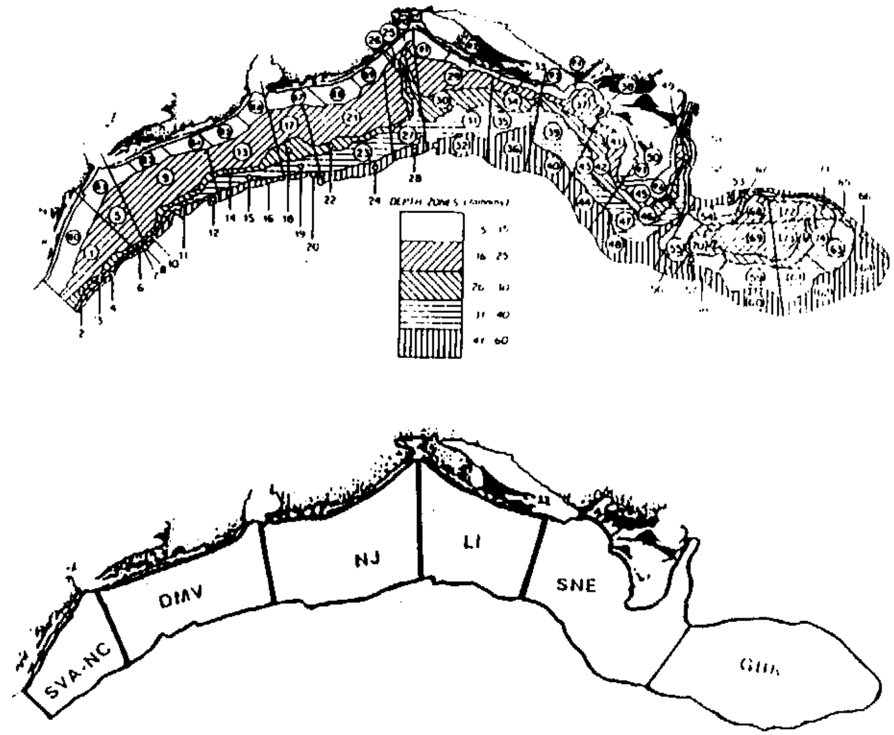

Figure E2. Survey strata (sampling areas) for NEFSC surfclam-ocean quahog surveys. Below are strata groups used to define assessment areas.

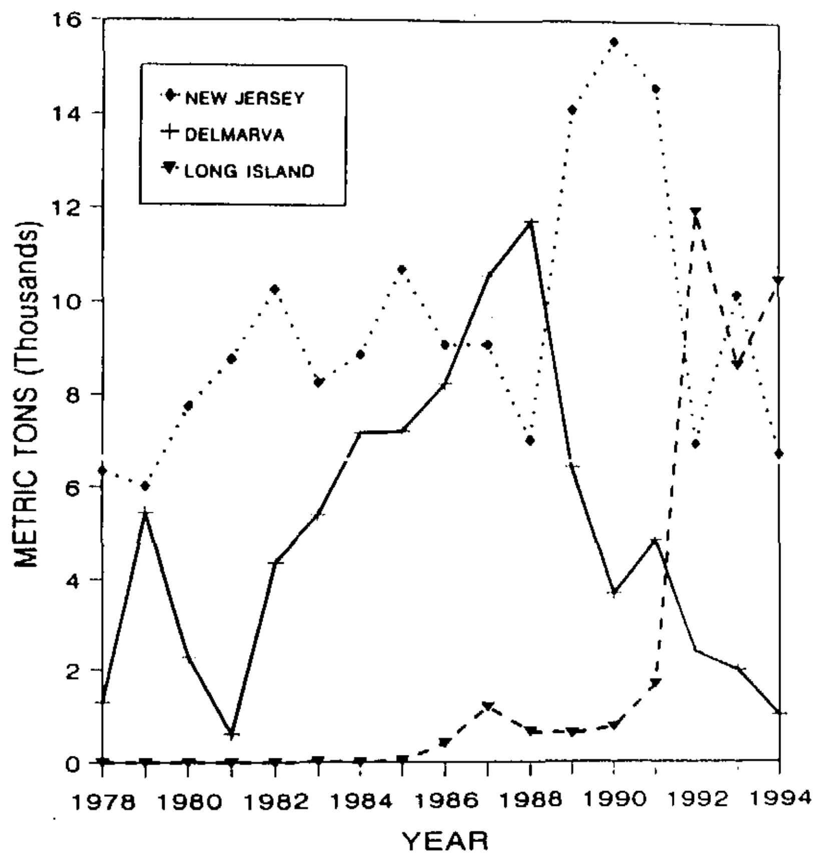

Figure E3. Annual ocean quahog landings (thousands of metric tons of meats) by assessment region, 1978-1994.

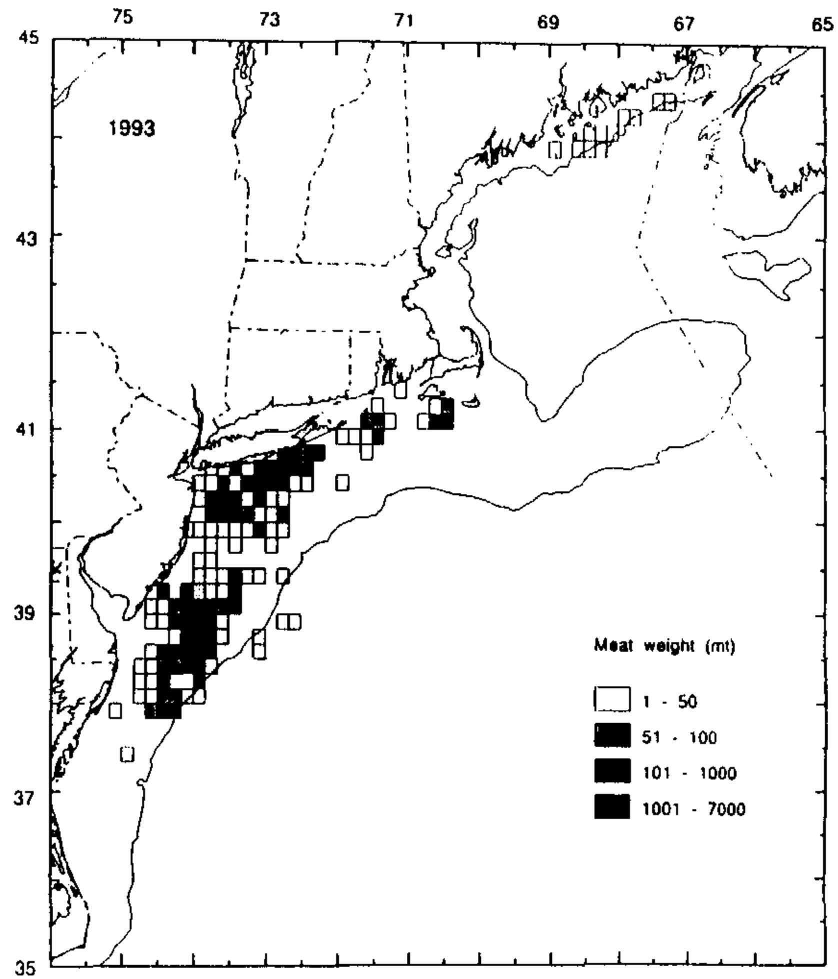

Figure E4. Distribution of ocean quahog landings by 10' square, 1993.

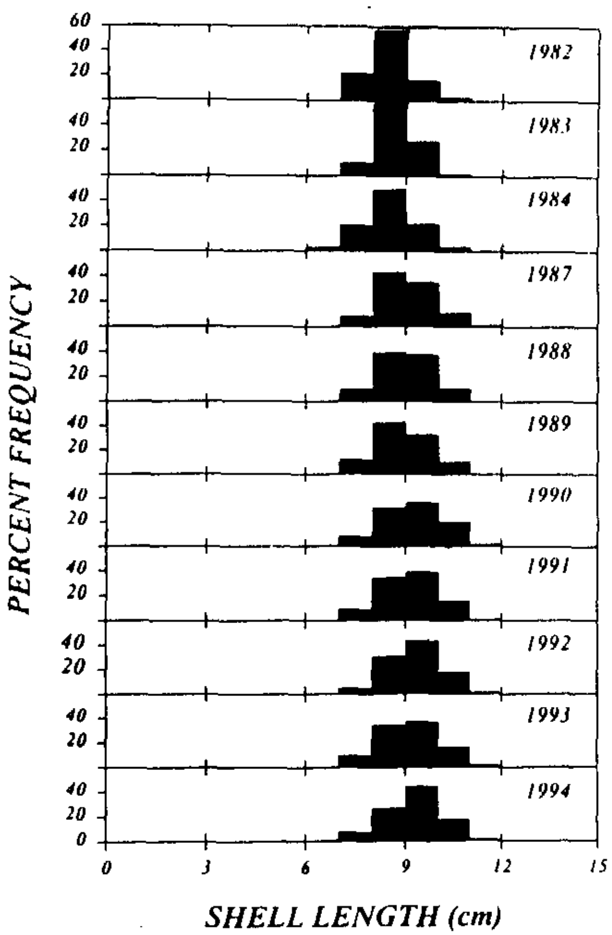

Figure E5. Commercial length frequency distributions (percent frequency) of ocean quahogs harvested from the Delmarva area. Data are from port samples, 1982-1994.

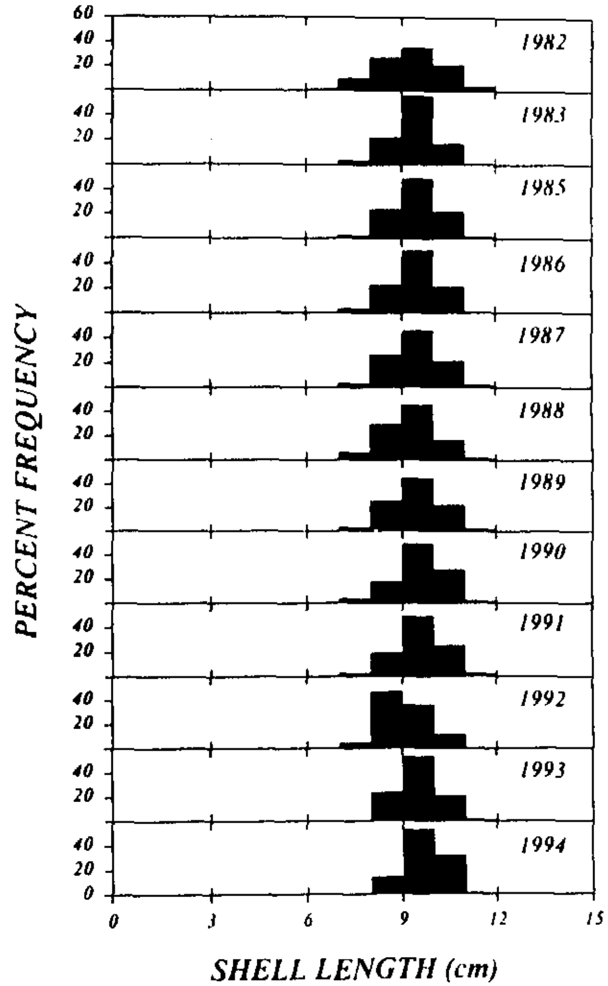

Figure E6. Commercial length frequency distributions (percent frequency) of ocean quahogs harvested from the New Jersey area. Data are from port samples, 1982-1994.

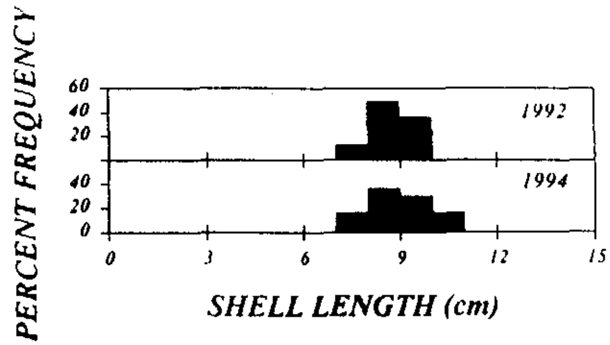

Figure E7. Commercial length frequency distributions (percent frequency) of ocean quahogs harvested from the Long Island area. Data are from port samples, 1992 and 1994.

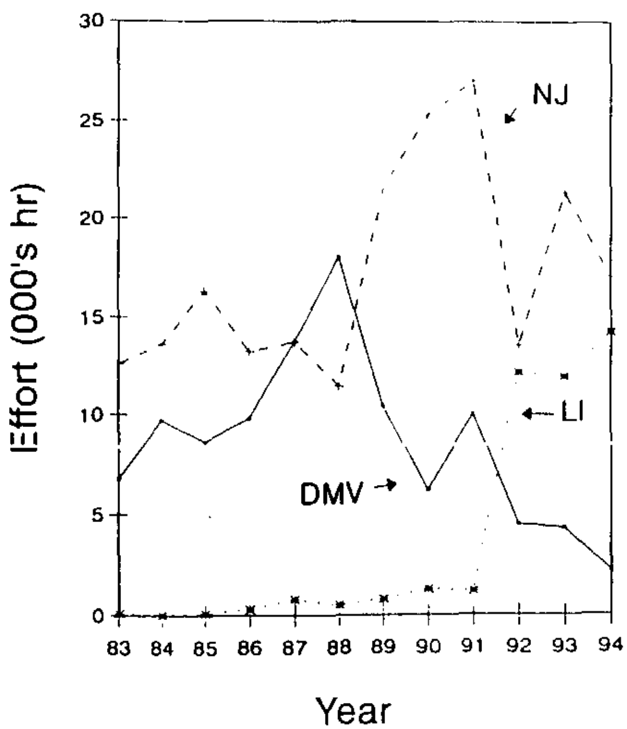

Figure E8. Annual fishing effort (thousands of hours), by class 3 vessels in the ocean quahog fishery, 1983-1994.

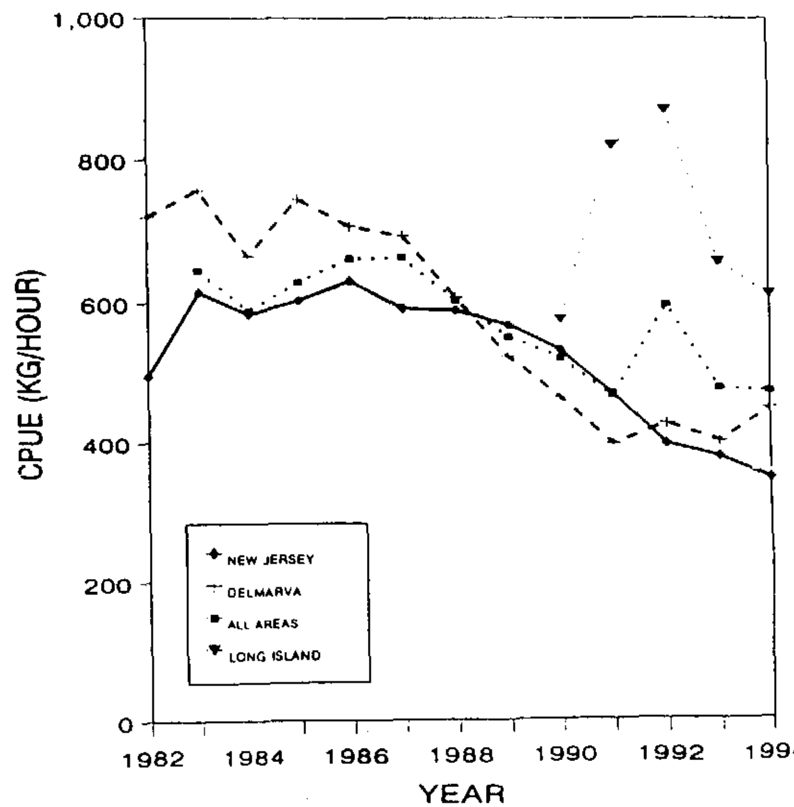

Figure E9. Catch per unit of effort of ocean quahogs (kg/hour fished) by class 3 vessels (105+ GRT), 1982-1994. Data derived from mandatory logbook submissions. "All areas" includes locations from Georges Bank through North Carolina. CPUE for Long Island for years where catch was less than 1.5 metric tons are not shown.

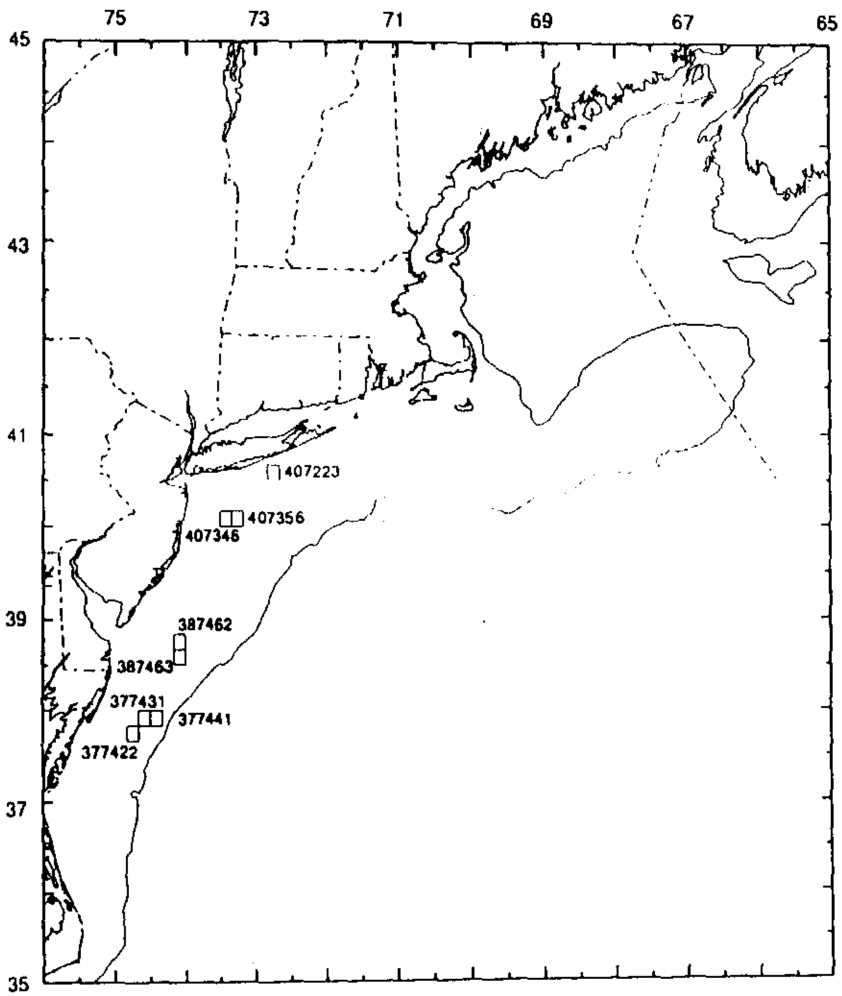

Figure E10. Locations of 10' squares used in fine-scale Leslie-DeLury depletion analyses.

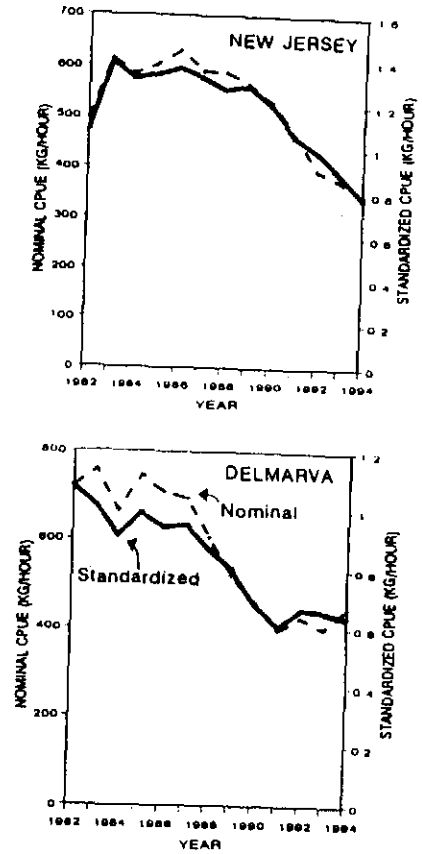

Figure E11. Nominal and GLM standardized catch per unit of effort by class 3 vessels fishing ocean quahogs off New Jersey and Delmarva.

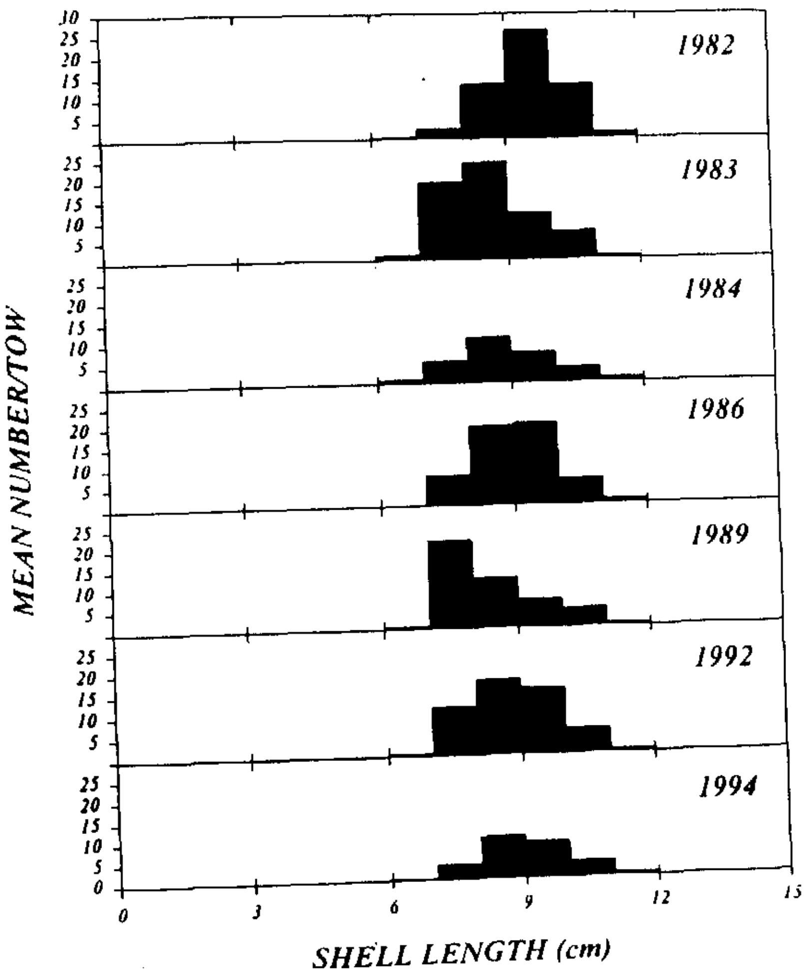

Figure E12. Length frequencies of ocean quahogs taken during hydraulic dredge surveys off Delmarva, 1982-1994. Data are stratified mean numbers per standardized survey tow.

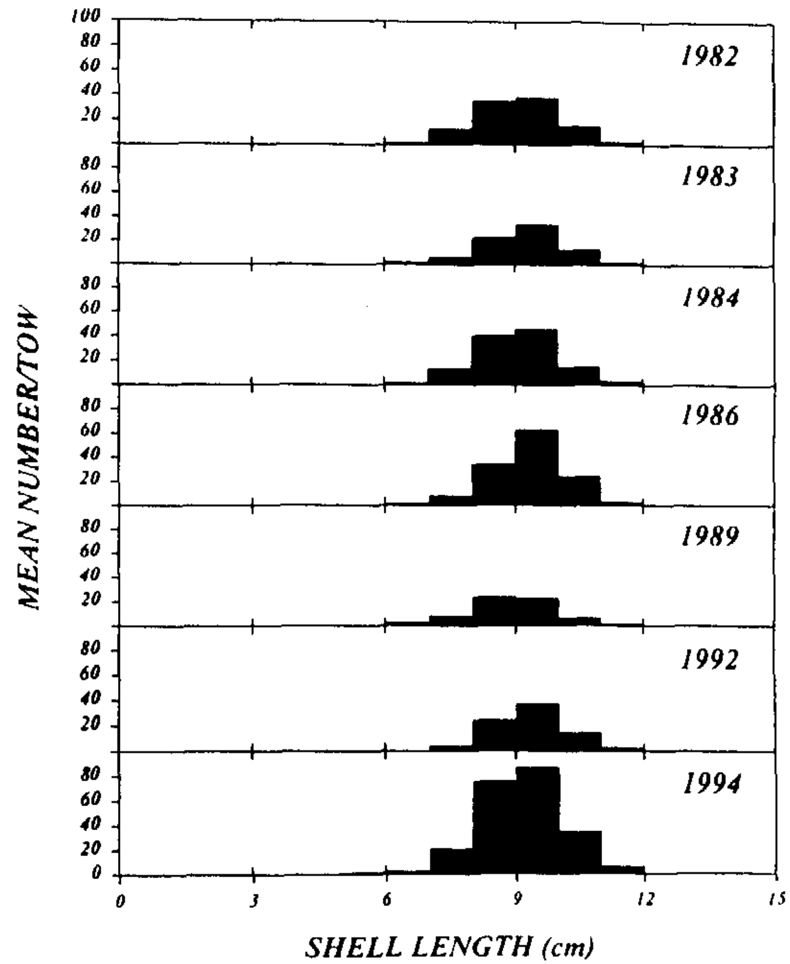

Figure E13. Length frequencies of ocean quahogs taken during hydraulic dredge surveys off New Jersey, 1982-1994. Data are stratified mean numbers per standardized survey tow.

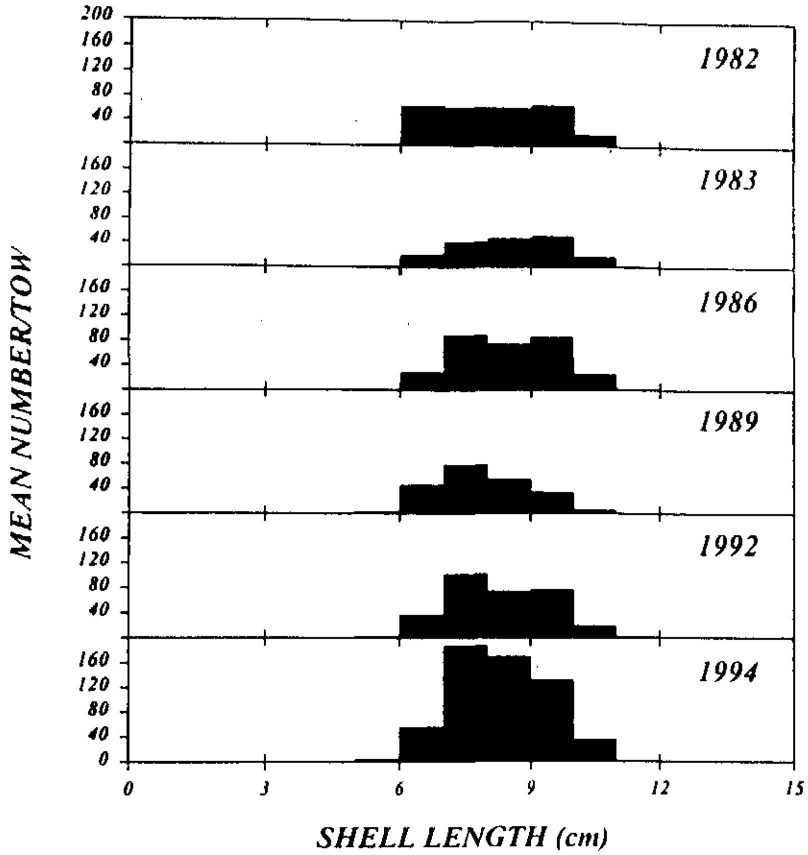

Figure E14. Length frequencies of ocean quahogs taken during hydraulic dredge surveys off Long Island, 1982-1994. Data are stratified mean numbers per standardized survey tow.

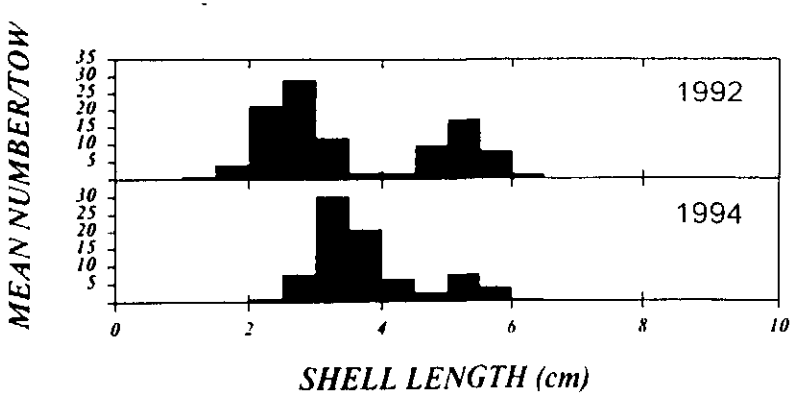

Figure E15. Length frequencies of ocean quahogs taken during hydraulic dredge surveys off Maine, 1992 and 1994. Data are mean numbers per standardized survey tow.

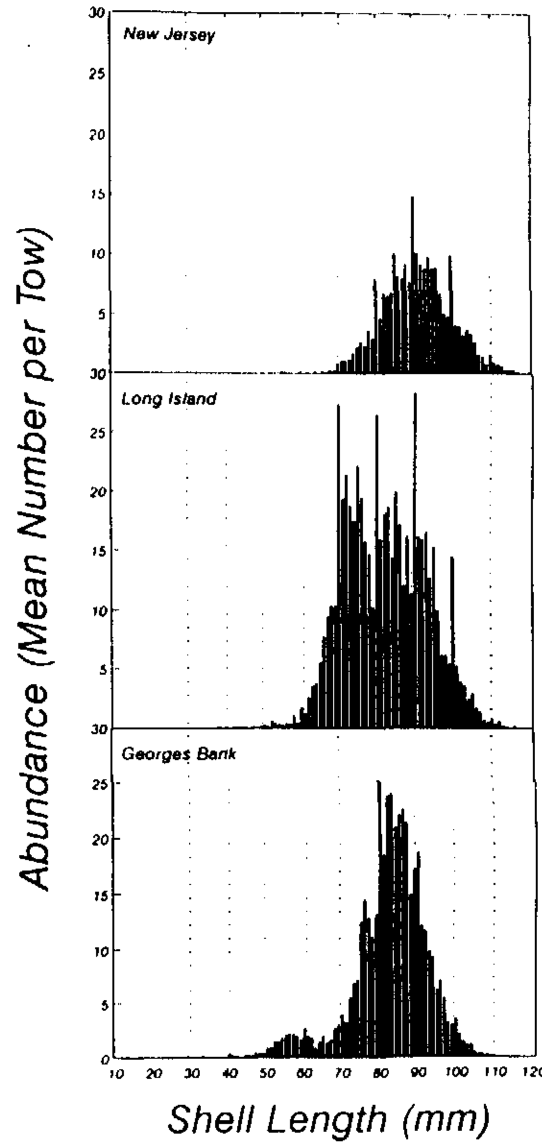

Figure E16. Length frequencies (in mm size groups) of ocean quahogs taken off New Jersey Long Island and Georges Bank during the 1994 NEFSC hydraulic dredge survey.

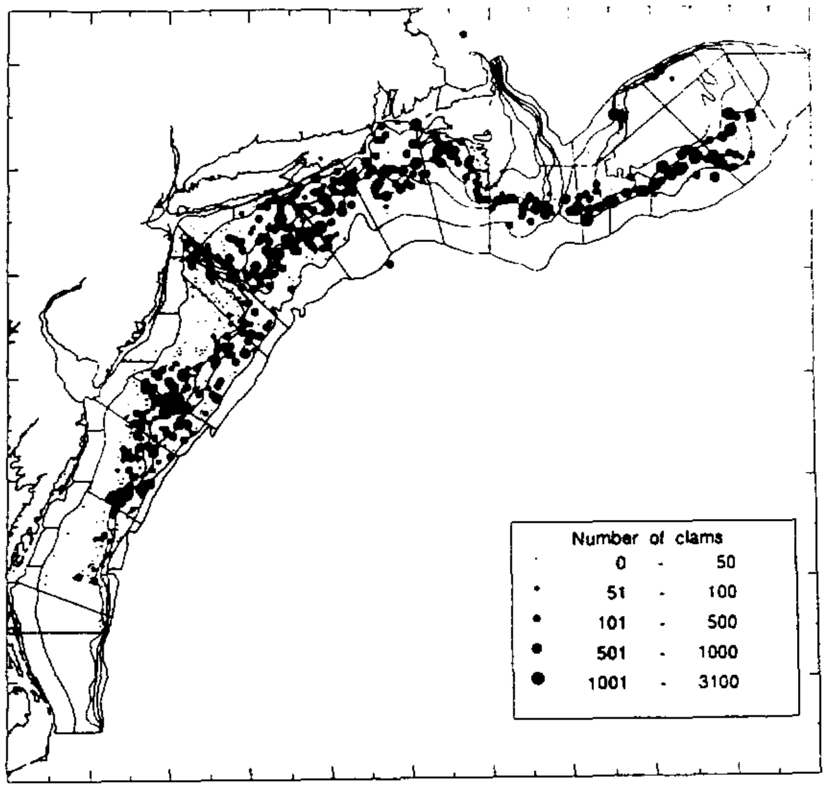

Figure E17. Distribution of ocean quahog catches in hydraulic dredge surveys, 1982-1992.

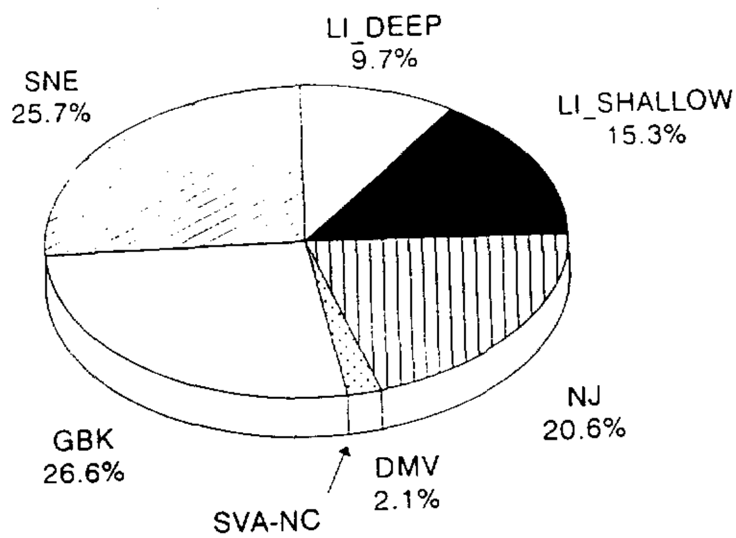

Figure E18. Relative distribution of ocean quahog biomass, based on the 1994 NEFSC research vessel survey.

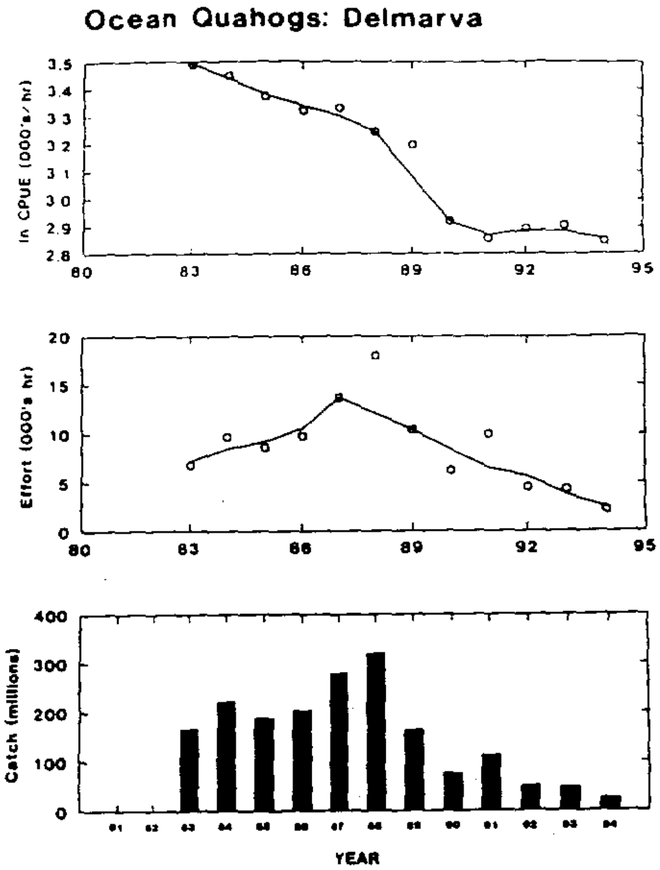

Figure E19. Trends in catch per unit effort (thousands / hr), effort (thousands of hr), and catch (millions) for ocean quahogs, 1983-1994, in the Delmarva Region. Solid lines in the upper and middle plots represent LOWESS smoothed estimates using a tension factor of 0.4.

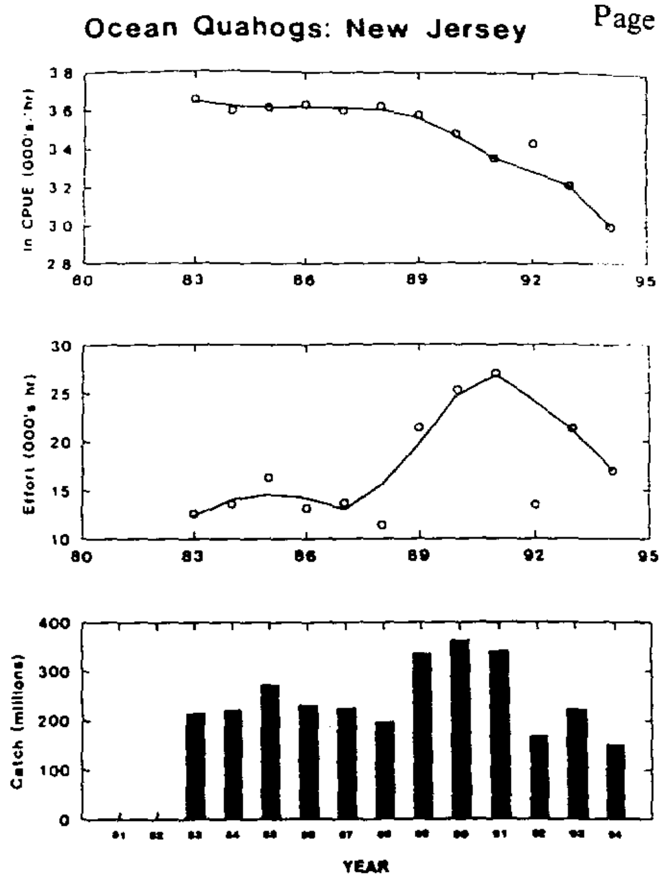

Figure E20. Trends in catch per unit effort (thousands / hr), effort (thousands of hr), and catch (millions) for ocean quahogs, 1983-1994, in the New Jersey Region. Solid lines in the upper and middle plots represent LOWESS smoothed estimates using a tension factor of 0.4.

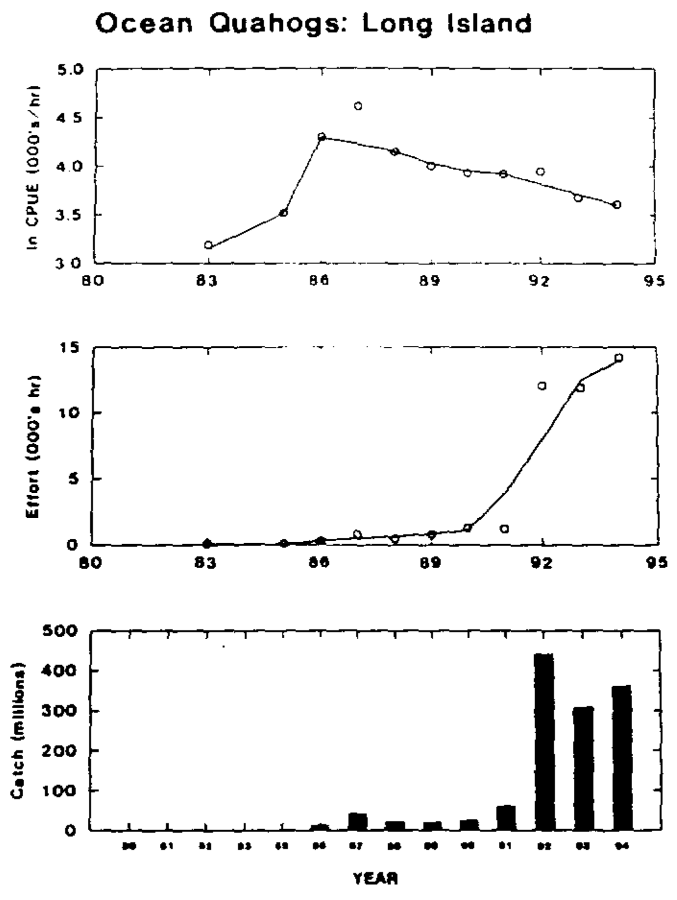

Figure E21. Trends in catch per unit effort (thousands / hr), effort (thousands of hr), and catch (millions) for ocean quahogs, 1983-1994, in the Long Island Region. Solid lines in the upper and middle plots represent LOWESS smoothed estimates using a tension factor of 0.4.

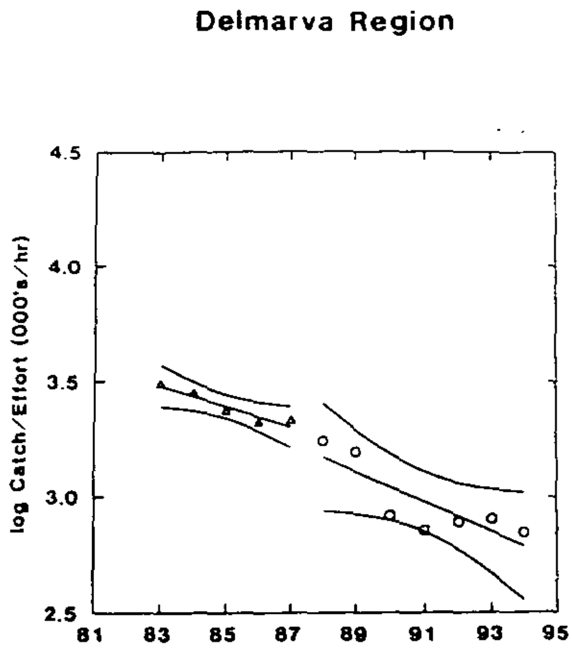

Figure E22. Regression of $\log_e$ of Catch per unit effort (thousands / hr) for ocean quahog for 1983-1987 and 1988-1994 in the Delmarva Region. Error bounds represent 95% confidence intervals on predicted value.

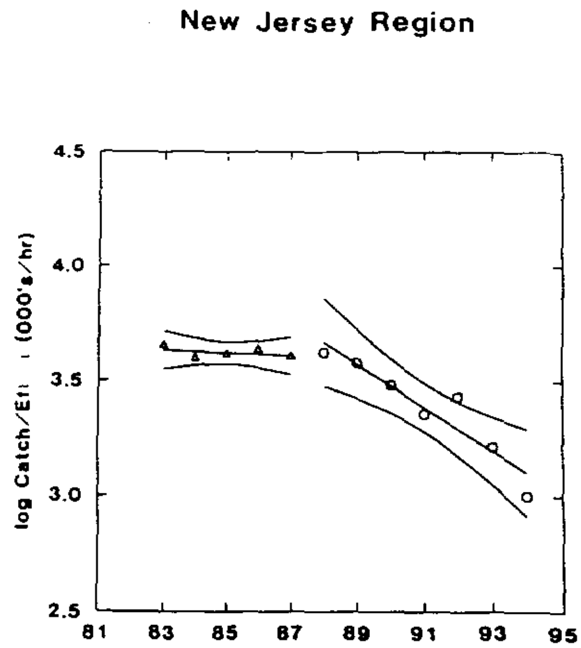

Figure E23. Regression of $\log_e$ of Catch per unit effort (thousands / hr) for ocean quahog for 1983-1987 and 1988-1994 in the New Jersey Region. Error bounds represent 95% confidence intervals on predicted value.

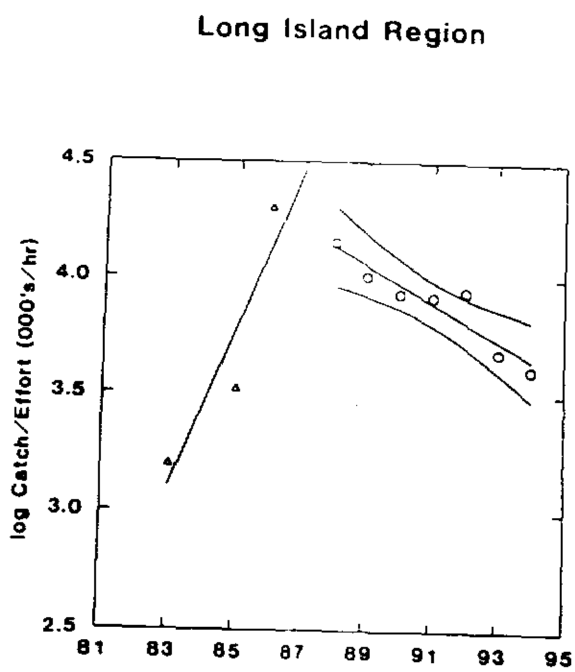

Figure E24. Regression of $\log_e$ of Catch per unit effort (thousands / hr) for ocean quahog for 1983-1987 and 1988-1994 in the Long Island Region. Error bounds represent 95% confidence intervals on predicted value.

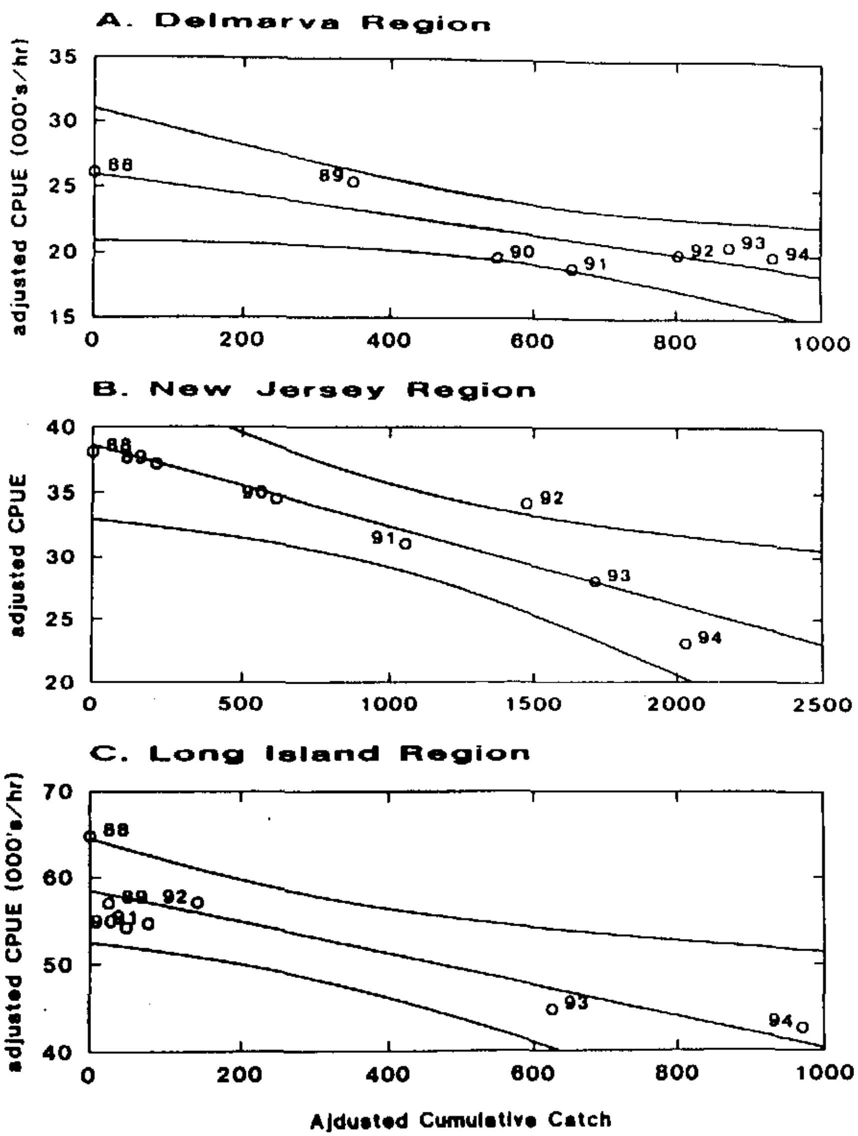

Figure E25. Modified Leslie-Delury regressions of adjusted CPUE vs adjusted cumulative catch for ocean quahogs in A) Delmarva, B) New Jersey, and C) Long Island Regions, 1988-1994. Adjustments to CPUE and catch are based on an assumed instantaneous natural mortality rate of 0.02 yr^{-1}.

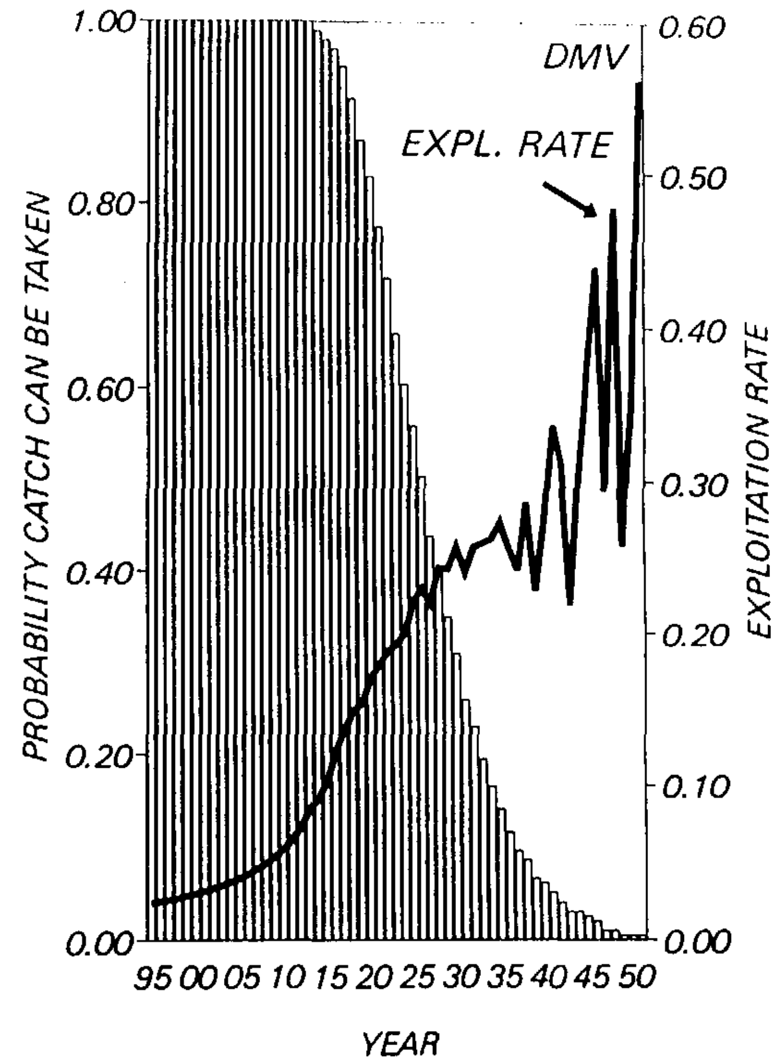

Figure E26. Calculation of 'supply years' of constant quotas for ocean quahogs from Delmarva. Data are the probability that the constant catch of 1,790 MT can be taken in any one year, and the annual exploitation rate corresponding to the catch. Results are based on 2,000 stochastic simulation runs.

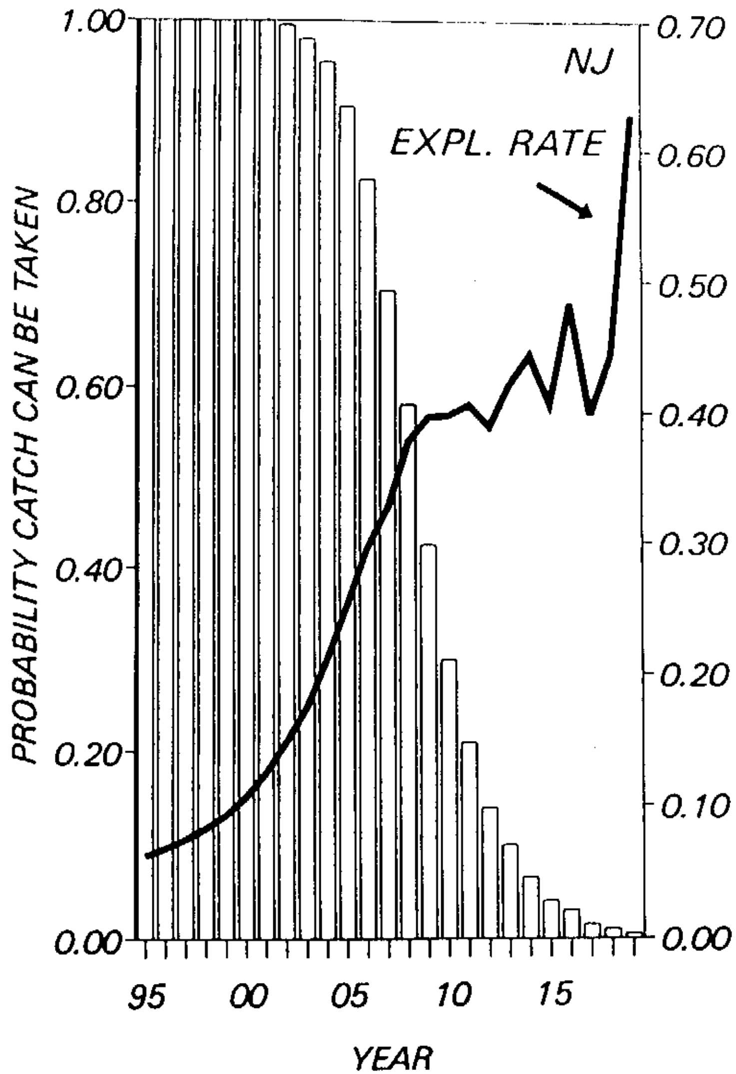

Figure E27. Calculation of 'supply years' of constant quotas for ocean quahogs from New Jersey. Data are the probability that the constant catch of 8,020 MT can be taken in any one year, and the annual exploitation rate corresponding to the catch. Results are based on 2,000 stochastic simulation runs.

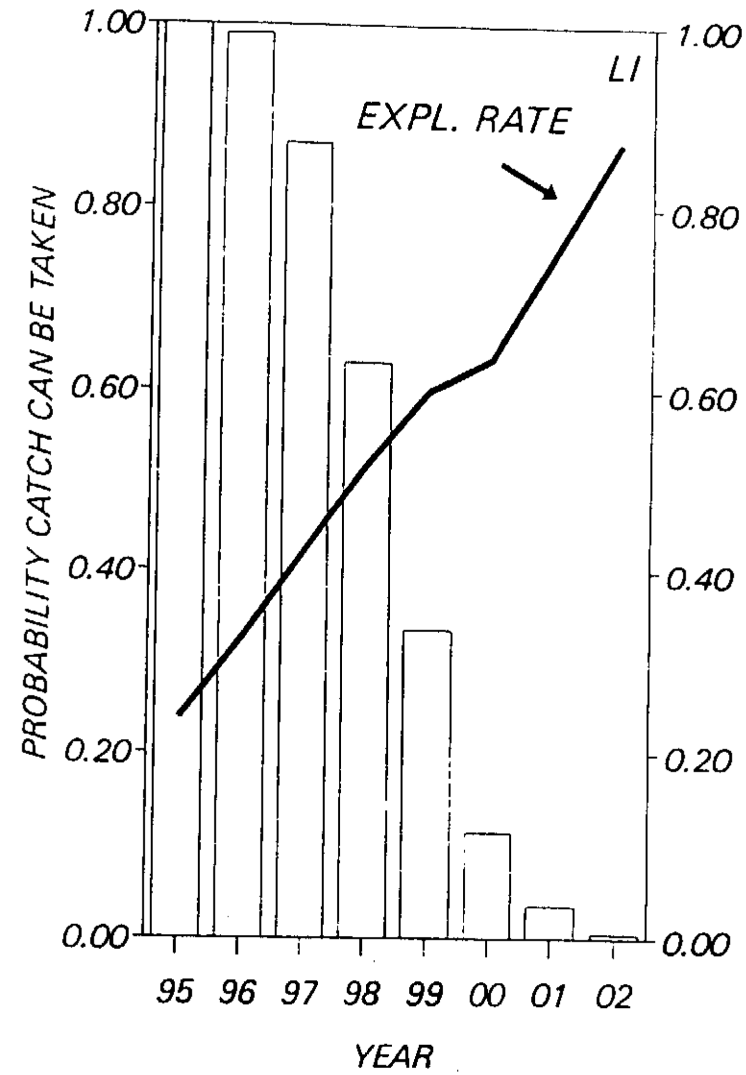

Figure E28. Calculation of 'supply years' of constant quotas for ocean quahogs from Long Island. Data are the probability that the constant catch of 10,360 MT can be taken in any one year, and the annual exploitation rate corresponding to the catch. Results are based on 2,000 stochastic simulation runs.

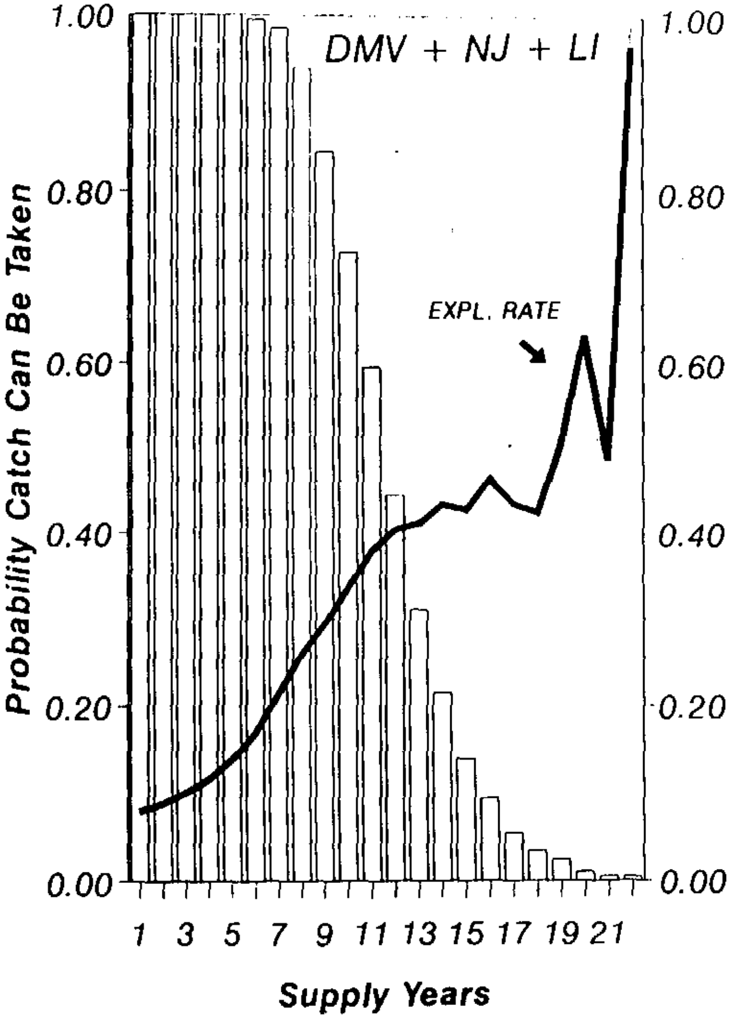

Figure E29. Calculation of 'supply years' of constant quotas for ocean quahogs from Delmarva, New Jersey and Long Island, combined. Data are the probability that the constant catch of 20,170 MT can be taken in any one year, and the annual exploitation rate corresponding to the catch. Results are based on 2,000 stochastic simulation runs.

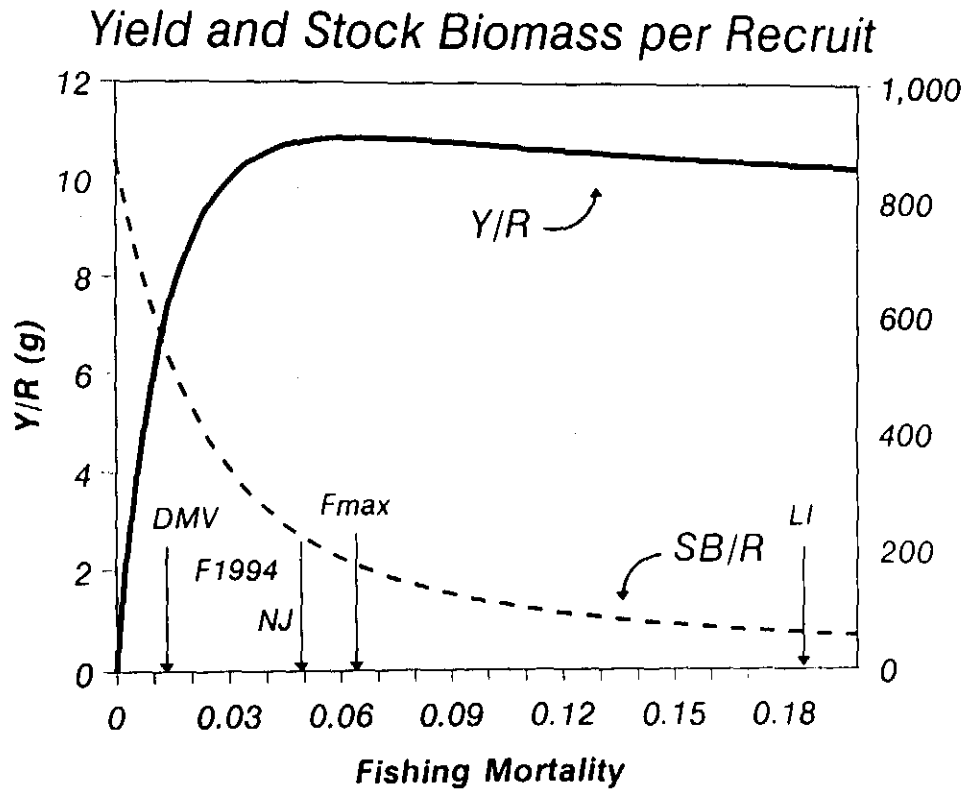

Figure E30. Yield and stock biomass per recruit for ocean quahog, based on growth parameters from off Long Island, New York. Current estimates of fishing mortality rates in three assessment areas are also given.

OTHER BUSINESS

Recurring Research Recommendations

Dr. Terry Smith indicated that agreed upon research recommendations that will appear in the "SARC Consensus Summary of Assessments" will be highlighted in discussions with the SAW Steering Committee. Some of these recommendations, however, are recurring and may require special action.

For discussion purposes, Dr. Smith distributed a memo in which he identified three 'over-arching' recommendations which were relevant to almost every stock assessed: 1) increased and more representative sea sampling of the fisheries in which the stocks being assessed are caught; 2) adequate port sampling to characterize the length composition of landings and to improve the basis of age sampling; and 3) additional consideration of non-age based assessment methods both as a primary assessment methodology and to judge the sensitivity or accuracy of age-based assessments. To deal with the fishery dependent sampling problems, Dr. Smith presented a proposal to form a SARC working group. The group would provide a status report at the next SARC meeting. The SARC agreed that there is a need for such a working group and that objectives related to adequacy of sampling, representativeness, sampling design, and the relationship of sampling, assessments, and management advice were appropriate.

The SAW/SARC Process

While discussing the SARC process, invited experts indicated that they were pleased to have participated as members of the SARC and noted the insertion of a "biology" or life-history dimension to be a positive aspect of the assessment review team.

It was suggested that the current SAW/SARC process has been in place long enough for an evaluation of the SARC model. A "rethinking", it was believed, is particularly appropriate at this time in connection with the change of chairmanship. Discussed was the formation of a group, possibly working by correspondence, which would provide a report [to the Steering Committee] through the SAW Chair. The group could begin its evaluation with subcommittee structure and responsibilities, address the size and quality of documentation, and suggest ways to improve the SARC sessions to make them as efficient as possible.

Suggestions for Future SAWs

Dr. Paul Rago indicated that future recurring problems may involve ecosystem level issues and the regulation practices in fisheries. Resolution of problems related to, for example, discard estimation and area or seasonal closures may require a broad base of expertise and interaction among a number species subcommittees in addition to the Assessment Methods Subcommittee. Dr. Rago presented a brief summary of a proposal to deal with such issues which may be folded into the discussions of the ad hoc group considering the SAW prosess. The proposal would reduce the emphasis on single species assessments and examine such issues as species interactions, fleet behavior, and conditions resulting from regulations such as area or seasonal closures; focus on problems germane to current assessments; and begin preparation for future assessments. The approach would be to address common problems among individual species by a broad base of experts including, experts on species, ecosystems, assessment methods, data bases, and regulations.

Noted was the usefulness of advice which would come forth from analytical and multispecies approaches. Future SARC sessions could benefit from an examination of food habits information, i.e., as predator and/or prey. In this regard, work on multispecies virtual papulation analyses, multivariate time series analyses, as well as several mechanistic multispecies analyses could be presented to the SARC.

One SARC member indicated that it may be worth while to inject some industry involvement into the SARC process. This could be achieved by holding meetings of industry representatives or industry 'advisors', before each SARC meeting. Such meetings would provide the opportunity to convey to the industry the species terms of reference, why things are done the way they are, and what is expected to be accomplished. In addition, such interaction would facilitate rapport with the industry as a whole and insight to the industry perspective.